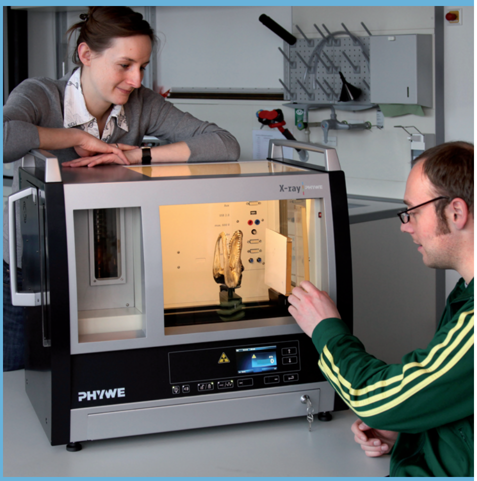
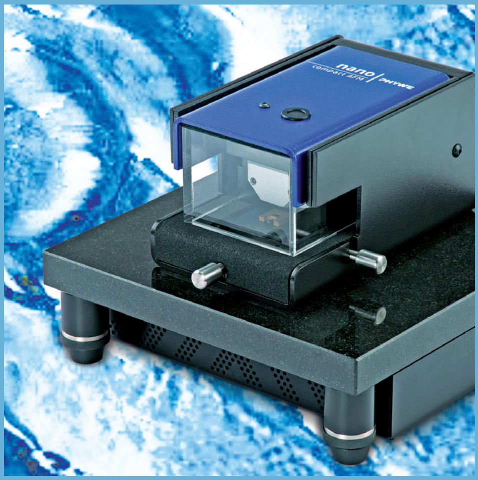
TESS expert PHYWE

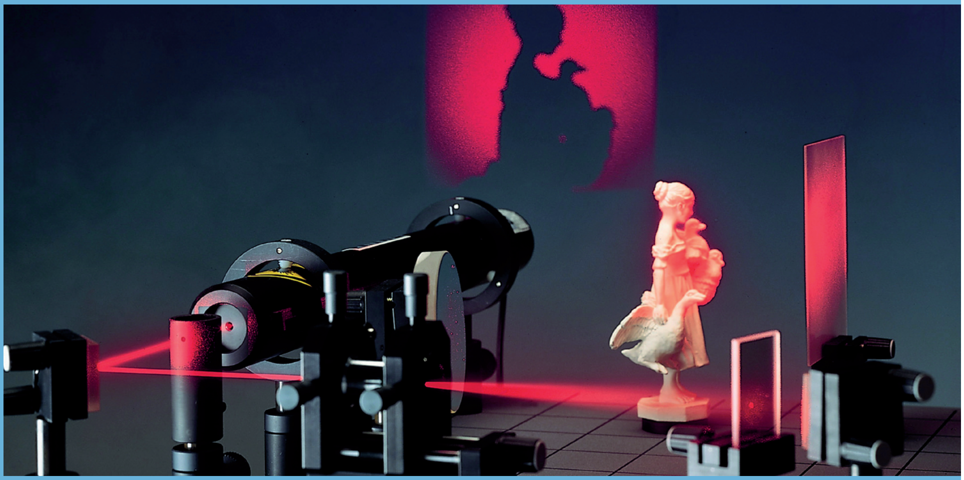
Demo expert PHYWE

Phy

OCT. 2013







Physics

University Experiments

Physics: Curricula Compliant Experiments –

for your educational needs

PHYWE™ experiments have been matched to the curricula of more than 30 selected universities worldwide. The interaction between PHYWE's experiments and the supporting content of experimental lectures and lab courses has led to the creation of a teaching package that is highly relevant to the taught curriculum worldwide.

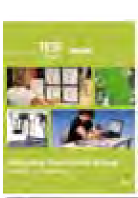
Physics

Bachelor of Science Course - Reference Example

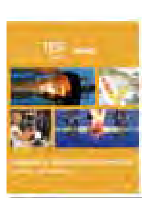
Content	1. Sem.	2. Sem.	3. Sem.	4. Sem.	5. Sem.	6. Sem.
Laboratory Experiments	Mechanics, Acoustics (Chapter 3, 4)	Thermo-dynamics (Chapter 5)	Electricity, Magnetism (Chapter 6)	Optics, Laser Physics-Photonics (Chapter 7, 15)	Quantum Physics, Solid State Physics (Chapter 8, 10)	X-ray Phsics, Nuclear Physics - Radioactivity, Particle Physics (Chapter 14, 12, 13)
Experimental Physics	Classical Experimental Pysics Lecture + Tutorial (Chapter 3, 4, 5, 6)		Structure of Matter, Nano Physics Lecture + Tutorial (Chapter 10, 11)		Atomic Physics, Molecule and Solid State Physics Lecture + Tutorial (Chapter 9, 10)	
Interdisciplinary Subject	Mathematics	Computational Physics		Measurement Technique (Chapter 3, 14)	Subsidiary and Elective Subjects	Subsidiary and Elective Subjects
Theoretical Courses	Classical theoretical Physics Lecture + Tutorial			Modern theoretical Physics Lecture + Tutorial		
Bachelor Thesis						Bachelor Thesis

100% of the experimental courses are covered by PHYWE experiments!

PHYWE Experiments available in this catalogue

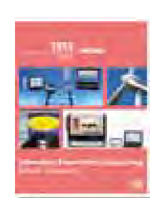


TESS expert and Demo expert Biology



TESS expert and Demo expert Chemistry

TESS expert and Demo expert Medicine



TESS expert and Demo expert Engineering and Geo Science

TESS & Demo expert Physics

A strong partner for more than 100 years –
Tradition ■ Partnership ■ Innovation ■ Quality

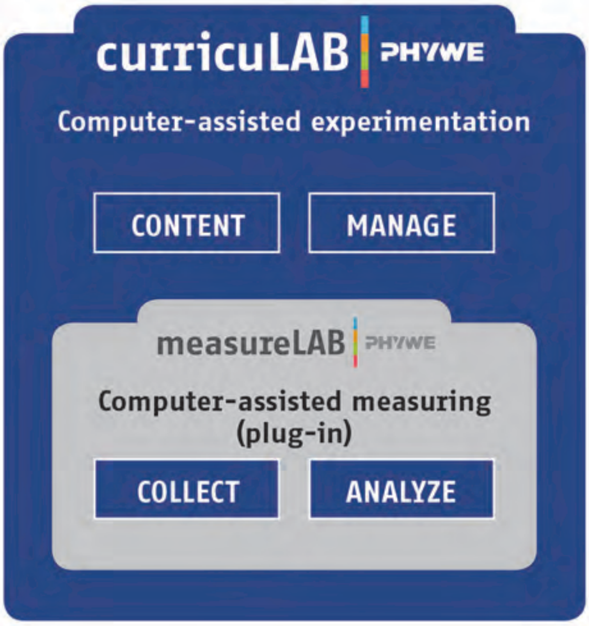
100 YEARS PHYWE excellence in science 1913 – 2013

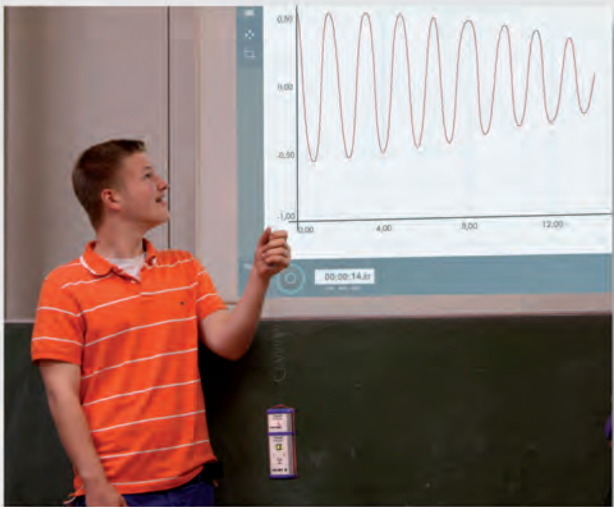
The teaching and learning platform curricuLAB™ – future experimentation without limits

curricuLAB is a powerful **teaching and learning platform** for science experiments. Apart from the provision of **learning contents**, it also enables the **acquisition of measurement values** in a didactic context and it **can be configured** based on your desires and requirements – experimentation without limits!

Features

- Independent of the user terminal – desktop PC, laptop, tablet, or smart-phone
- Independent of the operating system
- One platform for all PHYWE devices
- Location-independent and network integrated – access from wherever you are
- Interactive – image-assisted, editable instructions
- Report function – with interactive elements

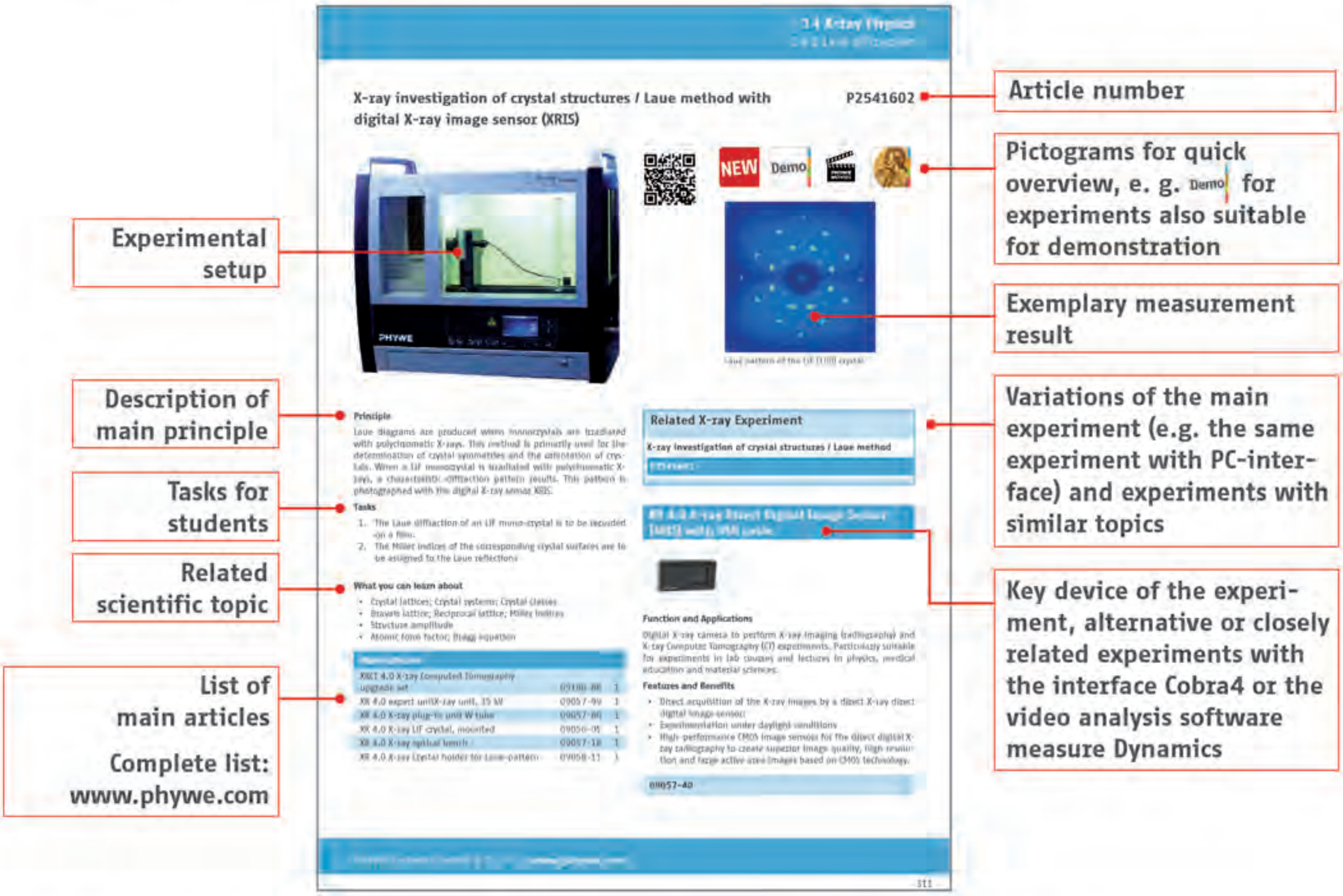




Connecting interactive teachware with hands-on experiments

How to use
the catalogue pages

The TESS and Demo expert catalogue is adapted to the PHYWE reference curriculum. PHYWE's experiments fit to the content of experimental lectures and lab courses of schools, colleges and universities. The description of each experiment offers you a lot of information:



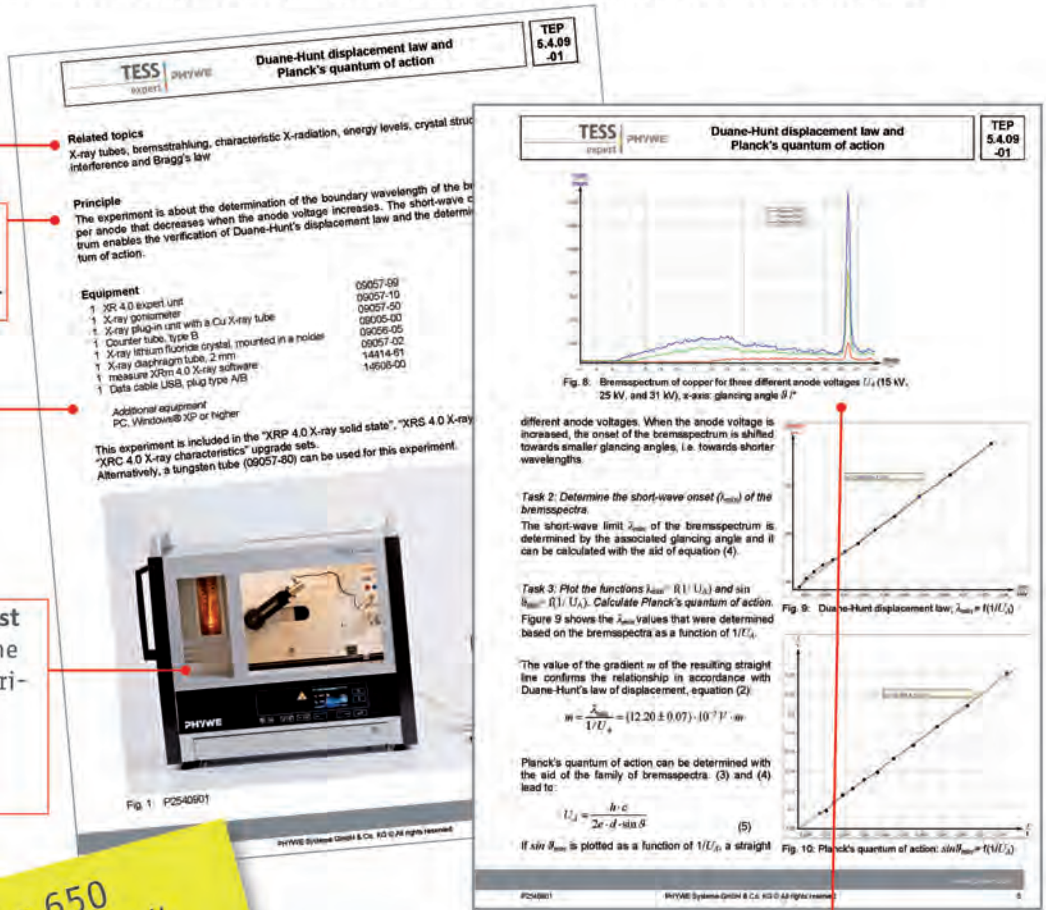
Pictograms for a quick overview of categories, related films or information:

- Cobra4 — Experiments with the computer based measuring system Cobra4
- Demo — Experiments suitable for demonstration
- Experiments with laser
- Experiments which have received a Nobel Prize
- m — Computer based measuring in addition to Cobra4
- Experiments with radioactivity
- PHYWE MOVIES — Product movie available. Click at www.phywe.com
- NEW — New and completely revised experiments
- Training recommended

How to use
the didactic literature

Extensive experimental literature is available for all our university level experiments.
Rely on the advantages of our TESS™ and Demo expert experiment descriptions:

- All experiments are uniformly built up
- Experiments cover the entire range of classical and modern physics
- Didactically adapted descriptions – enables direct preparation by the student
- Developed and proven by practitioners – comfortable and reliable performance
- Excellent measurement accuracy – results agree with theory
- Computer-assisted experiments – easy, rapid assessment of results
- Modular experimental set-up – multiple use of individual devices, cost effective and flexible



Related topics and **Principle and task** to introduce the subject.

Picture, Equipment list and instruction for the execution of the experiment guarantee easy conduction of the experiment.

More than 650 experiments described!

Theory and evaluation includes full theory of the experiment and shows graphical and numerical experimental results.

How to use
the table of contents

Use the curricula-based content on the next pages to find your topics and our corresponding experiments. The TESS™ and Demo expert catalogue is adapted to international university curricula making it easy for you to find experiments corresponding to your desired topic. On each page you find the detailed description of one of our university level experiments. More information including the complete experiment description is available on our website **www.phywe.com.**

Overview TESS expert

3 Mechanics — Curricular topic = main chapter of the catalogue

3.1 Measurement Techniques		
P2110100	Measurement of basic constants: length, weight and time	18
3.2 Motion in one Dimension		
P2130360	Newton's 2nd law / demonstration track with Cobra4	19
P2130380	Newton's 2nd law/ demonstration track with measure Dynamics	19
P2130301	Newton's 2nd law/ air track	19
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P2130760	Free fall with Cobra4	20
P2130780	Free fall with measure Dynamics	20
P2130701	Free fall with universal counter	20
P2130660	Impulse and momentum / demonstration track with Cobra4	21
3.3 Motion in two and three Dimensions		

Curricular subtopic = sub-chapter of the catalogue

Curricular fitting PHYWE experiments

Find the overview of all experiments fitting to the international Reference Curriculum on our hompage!

Click www.phywe.com

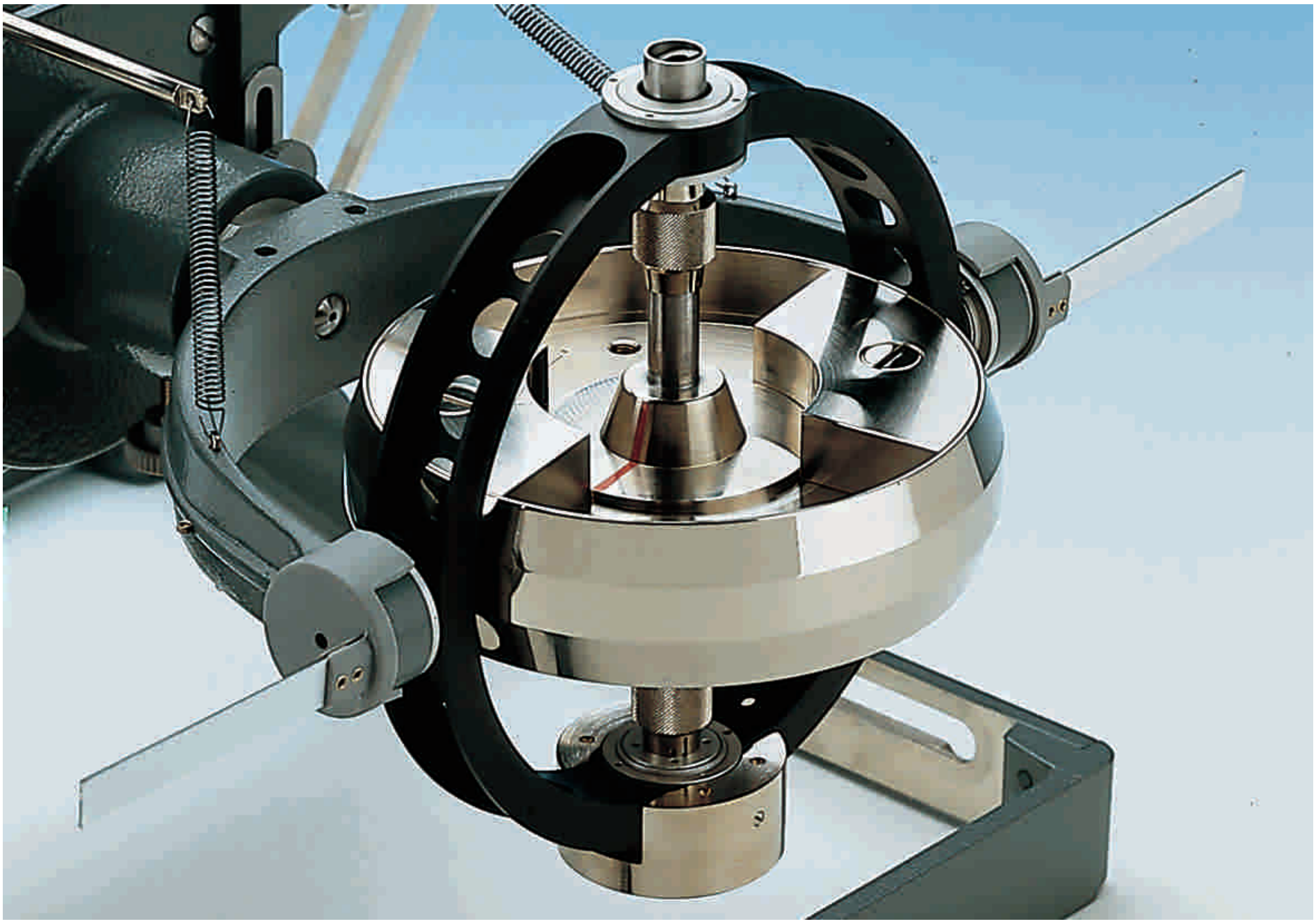
3 Mechanics

4 Oscillations and Mechanical Waves, Acoustics

11 Nano Physics

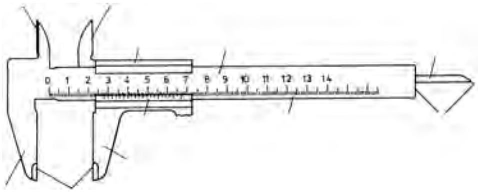
15 Laser Physics - Photonics

16 Further Demonstration Equipment



Mechanics

P2110100 Measurement of basic constants: length, weight and time



Vernier caliper

Principle

Caliper gauges, micrometers and spherometers are used for the accurate measurement of lengths, thicknesses, diameters and curvatures. A mechanical balance is used for weight determinations, a decade counter is used for accurate time measurements. Measuring procedures, accuracy of measurement and reading accuracy are demonstrated.

Tasks

1. Determination of the volume of tubes with the caliper gauge.
2. Determination of the thickness of wires, cubes and plates with the micrometer.
3. Determination of the thickness of plates and the radius of curvature of watch glasses with the spherometer.

What you can learn about

- Length; Diameter; Inside diameter thickness; Curvature; Vernier; Weight resolution; Time measurement

Main articles		
Universal Counter	13601-99	1
Spherometer	03017-00	1
Precision balance,2 pans,500g	44011-50	1
Set of precision weights,1mg-200g	44070-20	1
Light barrier, compact	11207-20	1
Micrometer	03012-00	1
Vernier caliper	03010-00	1

Universal Counter

NEW

Function and Applications

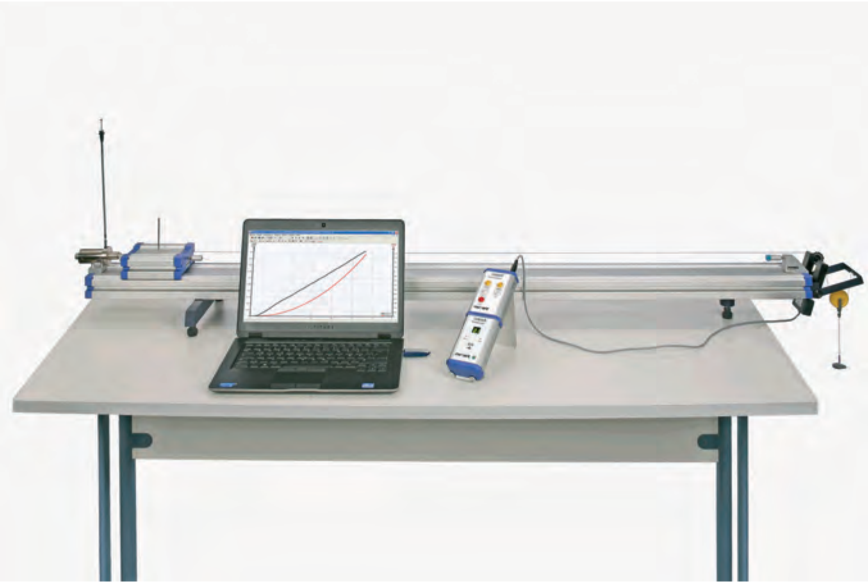
The universal counter is used for measuring time, frequency, pulse rates, pulse counting, periodic times, speeds and velocities.

Benefits

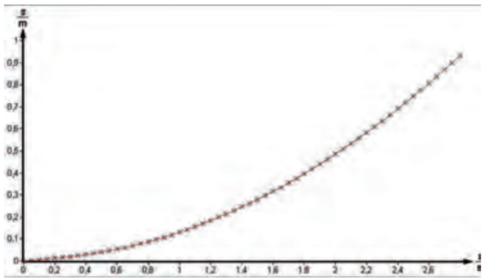
The device has all the qualities that are expected of a modern universal counter and is also equipped with a number of technical specifics of how it specifically arise from the requirements of science teaching practice. For the scientifically correct representation of each measurement is shown in principle with the associated unit. With the overflow of the display is automatically switched into the next area. Before the measurement starts it can be manually adjusted to a maximum of 6 decades defined range, eg to suppress is not physically meaningful digits on the display. A special jack for direct connection of a GM counter tube is available for radioactivity experiments. The required voltage can be changed manually to determine the characteristics of a counter tubes to.

13601-99

Newton's 2nd law / demonstration track with Cobra4 P2130360



NEW · Cobra4 · Demo



Path-time law.

Principle

According to Newton's 2nd law of motion for a mass point, the relationship between mass, acceleration and force are investigated.

Tasks

1. The distance-time law, the velocity time law and the relationship between mass, acceleration and force are determined.
2. The conservation of energy can be investigated.

What you can learn about

- Linear motion; Velocity; Acceleration; Conservation of energy

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Starter system for demonstration track	11309-00	1
Demonstration Track, Aluminium, 1.5 m	11305-00	1
Cart, low friction sapphire bearings	11306-00	1

Related Experiments

Newton's 2nd law/ air track

P2130301

Newton's 2nd law/ demonstration track

P2130305

Cobra4 experiment

Newton's 2nd law/ air track with Cobra4

P2130363

measure Dynamics experiment - available 2014

Newton's 2nd law/ demonstration track with measure Dynamics

P2130380

Cobra4 Wireless-Link

Function and Applications

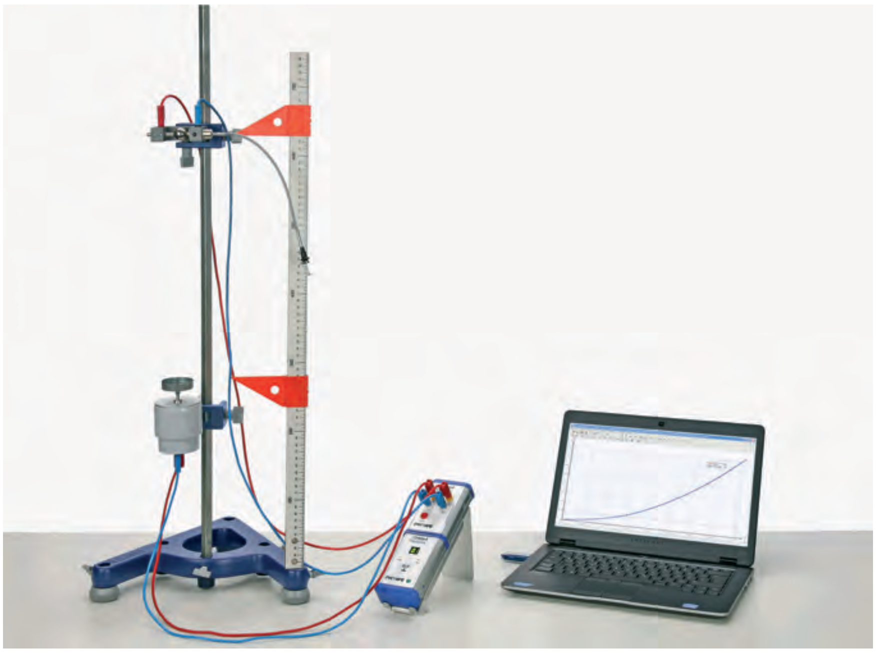
Interface module for the radio-based transmission of sensor measuring values in conjunction with the Cobra4 Wireless Manager.

Benefits

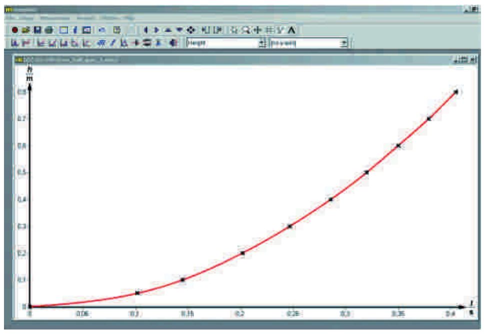
- All Cobra4 Sensor-Units can be quickly connected using a secure and reliable plug-in / lockable connection.
- All Cobra4 measuring sensors are automatically detected.
- The radio network with the Cobra4 Wireless-Manager is established automatically and is extremely stable.

12601-00

P2130760 Free fall with Cobra4



NEW Cobra4 Demo



Height of fall as a function of falling time.

Principle

The fall times t are measured for different heights of fall h. h is represented as the function of t or t^2, so the distance-time law of the free fall results as $h = 1/2 \cdot g \cdot t^2$. Then the measured values are taken to determine the acceleration due to gravity g.

Tasks

Determination of

1. distance time law for the free fall,
2. velocity-time law for the free fall,
3. precise measurement of the acceleration due to gravity for the free fall.

What you can learn about

- Linear motion due to constant acceleration
- Laws governing falling bodies
- Acceleration due to gravity

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Falling sphere apparatus	02502-88	1
Support base DEMO	02007-55	1
Plate holder	02062-00	1

Related Experiment

Free fall with universal counter

P2130701

measure Dynamics experiment - available 2014

Free fall with measure Dynamics

P2130780

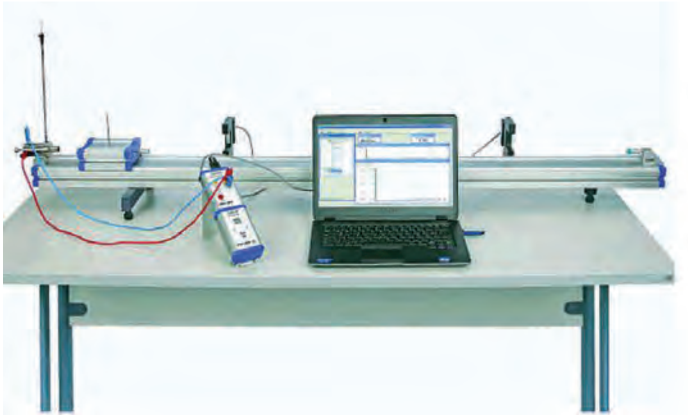
Cobra4 Sensor-Unit Timer/Counter

Function and Applications

Sensor-Unit of the Cobra4 family. Interface-module with timer and counter functionality for up to four light barriers, one measuring microphone, movement sensor, falling sphere apparatus or other devices with TTL compatible signals. Optionally an external trigger device can be used (switch, starter system for motion track, ...). The measured values of the sensor can be transmitted with the Cobra4 Wireless manager and the Cobra4 Wireless-Link by radio or with the USB-Link to the PC.

12651-00

Impulse and momentum / demonstration track with Cobra4 P2130660



Principle

An impulse is described as the change in momentum by a force applied upon a body for a small interval of time. The momentum is defined here as the product of force and time and is conserved if no friction loss occurs. This means that in a closed system of different bodies the latter can transfer or receive momentum, however the total momentum of the system remains temporally and quantitatively constant.

Task

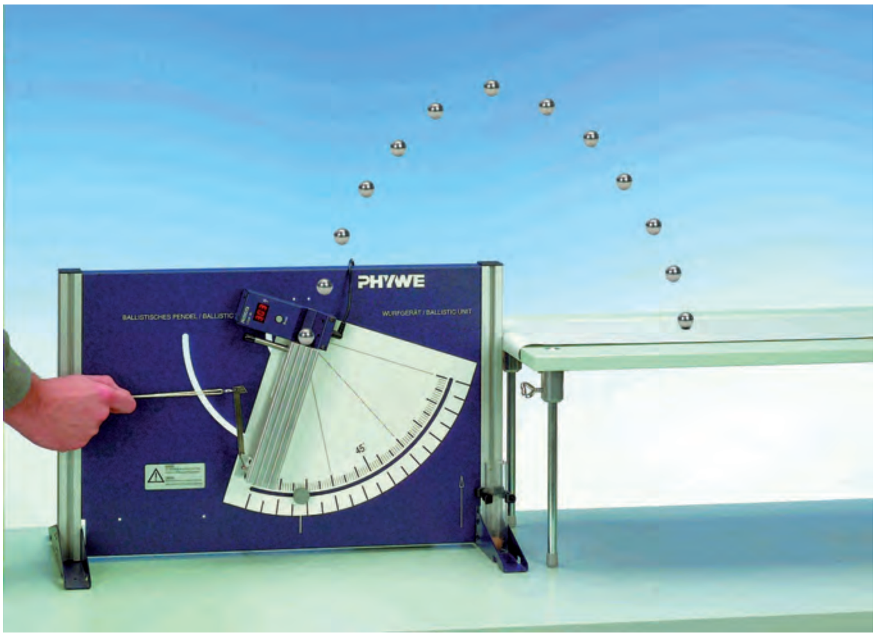
Determine the momentum p for different masses m.

What you can learn about

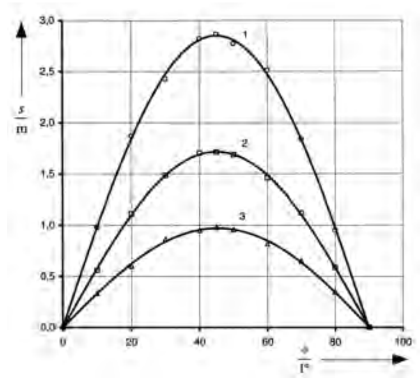
- Impulse
- Momentum
- Velocity
- Friction

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Starter system for demonstration track	11309-00	1
Demonstration Track, Aluminium, 1.5 m	11305-00	1
Cart, low friction sapphire bearings	11306-00	1

P2131100 Projectile motion



Demo



Maximum range as a function of the angle of inclination for different initial velocity v_0:

Curve 1 v_0 = 5.3 m/s
Curve 2 v_0 = 4.1 m/s
Curve 3 v_0 = 3.1 m/s

Principle

A steel ball is fired by a spring at different velocities and at different angles to the horizontal. The relationships between the range, the height of projection, the angle of inclination and the firing velocity are determined.

Tasks

1. To determine the range as a function of the angle of inclination.
2. To determine the maximum height of projection as a function of the angle of inclination.
3. To determine the (maximum) range as a function of the initial velocity.

What you can learn about

- Trajectory parabola
- Motion involving uniform acceleration
- Ballistics

Main articles		
Ballistic Unit	11229-10	1
Two-tier platform support	02076-03	1
Speed measuring attachment	11229-30	1
Power supply 5 VDC/2.4 A	13900-99	1
Barrel base PHYWE	02006-55	1
Meter scale, demo. l=1000mm	03001-00	1
Recording paper, 1 roll,25 m	11221-01	1

measure Dynamics experiment - available 2014

Projectile motion with measure Dynamics

P2131180

Ballistic Unit

Function and Applications

For demonstrating projectile motion and for quantitative investigation of the laws of projection, in particular for determining the range of a projectile as a function of the projectile angle and the initial velocity of the projectile.

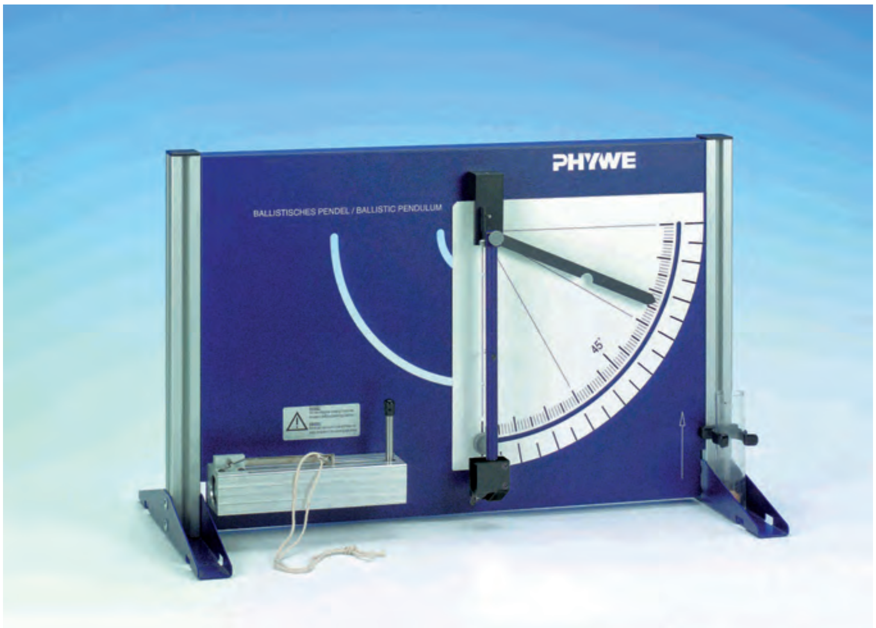
Benefits

- The catapult included in the extent of delivery can be used to:
- achieve reproducible projectile ranges up to 3 m (scatter of the projectile ranges approx. 1%)
- set a continuously variable projection angle between 0° and 90°- to select three projection speeds
- use two balls with different masses but with the same diameter

11229-10

Ballistic pendulum

P2131200



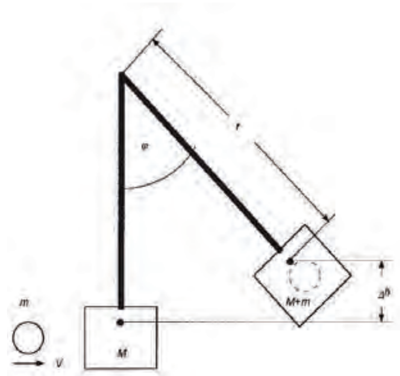


Diagram on the theory of the ballistic pendulum.

Principle

A classic method of determining the velocity of a projectile is to shoot the projectile into a resting mass which is large compared to the projectile's mass and hung as a pendulum. In the process, the projectile remains in the pendulum mass and oscillates with it. This is an inelastic collision in which the momentum remains unchanged. If the pendulum's mechanical data are known, one can infer the velocity of the pendulum's mass (including the projectile's mass) at the lowest point of the pendulum's oscillation from the amplitude of the pendulum's oscillation. The momentum of the two masses in this phase of the oscillation must thus be equal to the impulse of the projectile before it struck the pendulum. If one knows the masses of the pendulum and the projectile, one can calculate the projectile's velocity. In order to be able to use this measuring principle without danger, the following set-up is used here: A steel ball is shot at the mass of a pendulum with the aid of a spring catapult. The pendulum mass has a hollow space in which the steel ball is held. If, additionally, two light barriers and a time measuring device are available, an independent, direct measurement of the initial velocity of the ball can be made.

Tasks

1. Measurement of the oscillation amplitudes of the ballistic pendulum after capturing the steel ball for the three possible tension energies of the throwing device.
2. Calculation of the initial velocities of the ball from the measured oscillation amplitudes and the mechanical data of the pendulum is performed using the approximation formula (3).
3. Plotting of the velocity v of the steel ball as a function of the maximum deflection; (0.90°) of the pendulum according to formula (3), taking into consideration the special mechanical data of the experiment.
4. Determination of the correction factor for the utilised pendulum for the conversion of the velocities determined by using the approximation formula into the values obtained from the exact theory. Correction of the velocity values from Tasks 2.5. If the supplementary devices for the direct measurement of the initial velocity are available, measure the initial velocities corresponding to the three tension steps of the throwing device by performing 10 measurements each with subsequent mean value calculation. Plot the measured points in the diagram from Task 3. Give reasons for contingent systematic deviations from the theoretical curve.

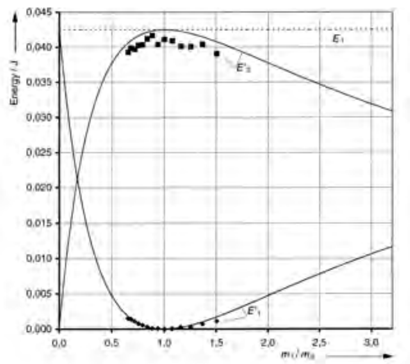
What you can learn about

- Potential and kinetic energy
- Rotational energy
- Moment of inertia
- Inelastic collision
- Principle of conservation of momentum
- Angular momentum
- Measurement of projectile velocities

Main articles		
Ballistic Unit	11229-10	1
Speed measuring attachment	11229-30	1
Ballistic Pendulum,f.Ballist.Unit	11229-20	1
Power supply 5 VDC/2.4 A	13900-99	1
Steel ball, d = 19 mm	02502-01	2

P2130560 Law of collision/ demonstration track with Cobra4

NEW Cobra4 Demo



Measuring parameters for velocity measurement.

Principle

The velocity of two carts, moving without friction on a demonstration track, are measured before and after collision, for both elastic and inelastic collision.

Tasks

- **Elastic collision**

1. A cart whose mass always remains unchanged collides with a second resting cart at a constant velocity. A measurement series, in which the velocities of the first cart before the collision and the velocities of both carts after it are to be measured, is conducted by varying mass of the resting carts.

- **Inelastic collision**

1. A cart, whose mass always remains unchanged, collides with a constant velocitiy with a second resting cart. A measurement series with different masses of the resting cart is performed: the velocities of the first cart before the collision and those of both carts, which have equal velocities, after it are to be measured.

What you can learn about

- Conservation of momentum; Conservation of energy
- Linear motion; Velocity; Elastic loss

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Starter system for demonstration track	11309-00	1
Demonstration Track, Aluminium, 1.5 m	11305-00	1
Cart, low friction sapphire bearings	11306-00	2

Related Experiments

Laws of collision / air track with 4-4 timer

P2130501

Laws of collision / demonstration track with 4-4 timer

P2130505

Cobra4 Experiments

Laws of collision / air track with Cobra4

P2130563

measure Dynamics experiment - available 2014

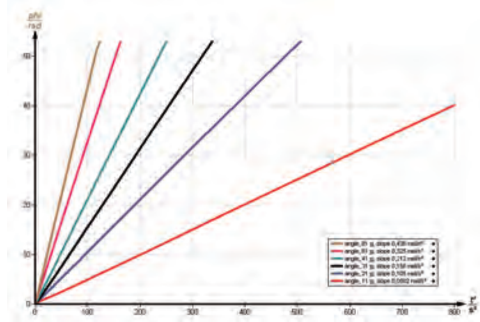
Laws of collision/ demonstration track with measure Dynamics

P2130580

Moment of inertia and angular acceleration with Cobra4 and a precision pivot bearing

P2131363

NEW Cobra 4 Demo



Angle vs. square of time for one turntable.

Principle

If a constant torque is applied to a body that rotates without friction around a fixed axis, the changing angle of rotation increases proportionally to the square of the time and the angular velocity proportional to the time.

Tasks

1. Measurement of the laws of angle and angular velocity according to time for an uniform rotation movement.
2. Measurement of the laws of angle and angular velocity according to time for an uniformly accelerated rotational movement.
3. Rotation angle; is proportional to the time *t* required for the rotation.

What you can learn about

- Angular velocity
- Rotation
- Moment
- Torque
- Moment of inertia
- Rotational energy

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Movement sensor with cable	12004-10	1
Precision pivot bearing	02419-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Inertia rod	02417-03	1
Turntable with angle scale	02417-02	1

Related Experiment

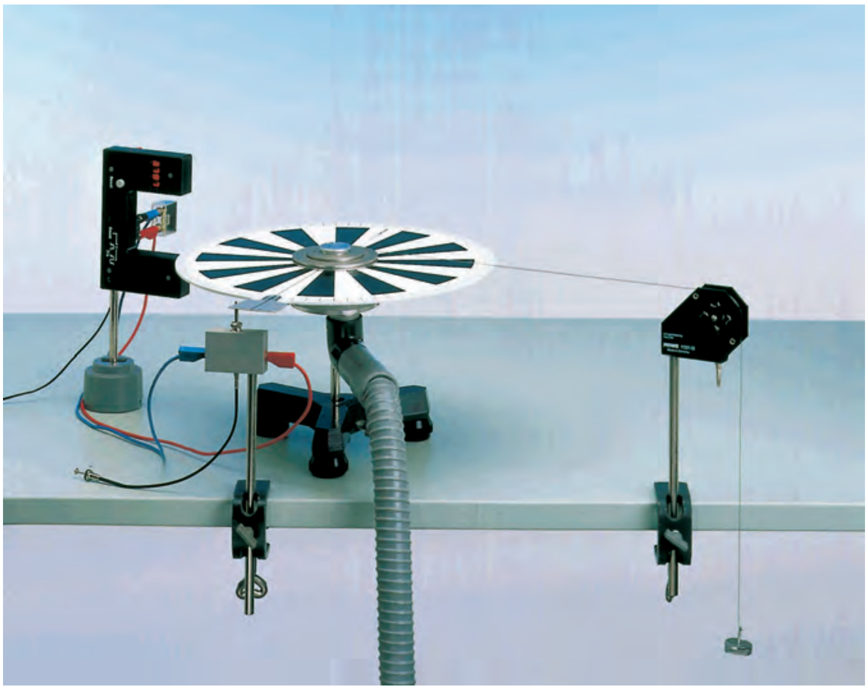
Moment of inertia and angular acceleration and with an air bearing

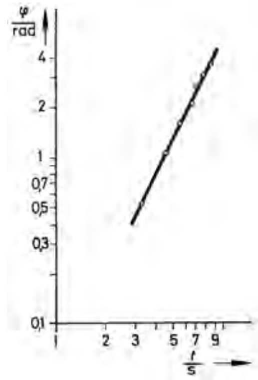
P2131301

Moment of inertia and angular acceleration with a precision pivot bearing

P2131305

P2131500 Moment and angular momentum





Angle of rotation as a function of time with uniformly accelerated rotary motion for m = 0.01 kg, r = 0.015 m.

Principle

The angle of rotation and angular velocity are measured as a function of time on a body which is pivoted so as to rotate without friction and which is acted on by a moment. The angular acceleration is determined as a function of the moment.

Tasks

With uniformly accelerated rotary motion, the following will be determined:

1. the angle of rotation as a function of time,
2. the angular velocity as a function of time,
3. the angular acceleration as a function of time,
4. the angular acceleration as a function of the lever arm.

What you can learn about

- Circular motion
- Angular velocity
- Angular acceleration
- Moment of inertia
- Newton's laws
- Rotation

Main articles		
Blower 230V/50Hz	13770-97	1
Air bearing	02417-01	1
Light barrier with counter	11207-30	1
Holding device w. cable release	02417-04	1
Turntable with angle scale	02417-02	1
Precision pulley	11201-02	1
Tripod base PHYWE	02002-55	1

Light barrier with counter

Function and Applications

With the function of an electronic time measuring and counting device.

Benefits

- 4 figure luminous display, selection switch for 4 operating modes
- RESET key
- BNC jack for exterior starting and/or stopping of time measurement
- TTL output to control peripheral devices
- Power supply connector (4 mm jacks)

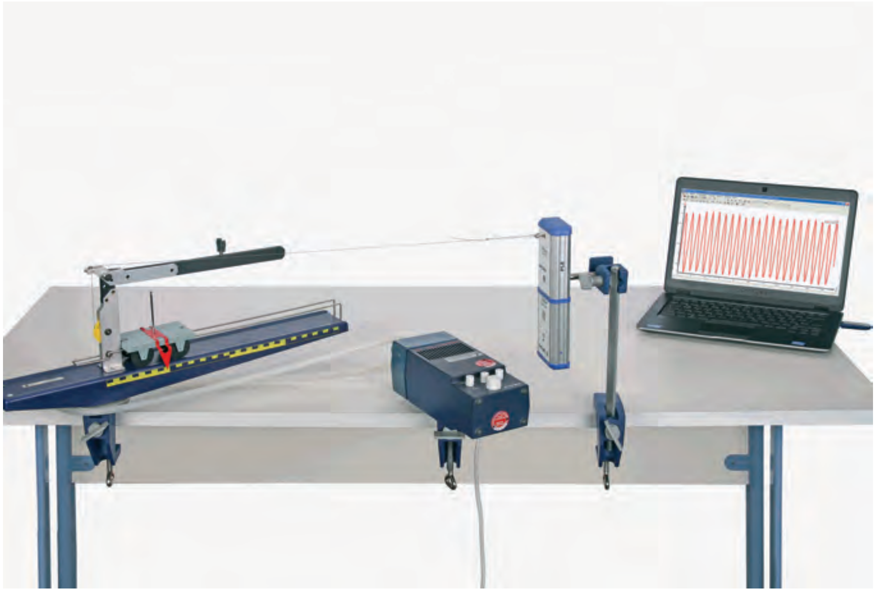
Equipment and technical data

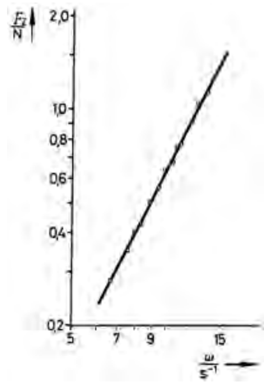
- Fork width: 70 mm
- Usable barrier depth: 65 mm
- Sensitivity adjustable
- LED-Display: 4 digits, 8 mm
- Time measurement: 0...9.999 s
- Counting: 0...9999
- Supply voltage: 5 V DC
- Max. working frequency: 25 kHz
- External dimensions (mm): 160 x 25 x 105 M6
- Threaded holes in casing: 7
- Stem included: 100 mm, M6 thread

11207-30

Centrifugal force with Cobra4

P2131660





Centrifugal force as a function of the angular velocity v.

Principle

A body with variable mass moves on a circular path with adjustable radius and variable angular velocity. The centrifugal force of the body will be measured as a function of these parameters.

Tasks

Determination of the centrifugal force as a function

1. of the mass,
2. of the angular velocity,
3. of the distance from the axis of rotation to the centre of gravity of the car.

What you can learn about

- Centrifugal force
- Centripetal force
- Rotary motion
- Angular velocity
- Apparent force

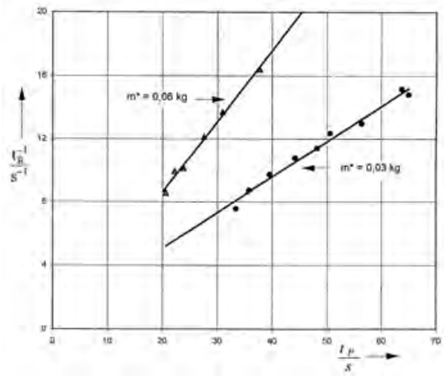
Main articles		
Cobra4 Wireless-Link	12601-00	1
Centrifugal force apparatus	11008-00	1
Cobra4 Sensor-Unit Force ± 4 N	12642-00	1
Software Cobra4 - multi-user licence	14550-61	1
Laboratory motor, 220 V AC	11030-93	1
Gearing 30/1, for 11030-93	11029-00	1
Bearing unit	02845-00	1

Related Experiment

Centrifugal force

P2131601

P2131900 Laws of gyroscopes/ 3-axis gyroscope



Determination of the momentum of inertia from the slope of straight line (tR)^-1 = f(tP).

Principle

The momentum of inertia of the gyroscope is investigated by measuring the angular acceleration caused by torques of different known values. In this experiment, two of the axes of the gyroscope are fixed. The relationship between the precession frequency and the gyro-frequency of the gyroscope with 3 free axes is examined for torques of different values applied to the axis of rotation. If the axis of rotation of the force free gyroscope is slightly displaced, a nutation is induced. The nutation frequency will be investigated as a function of gyro frequency.

Tasks

1. Determination of the momentum of inertia of the gyroscope by measurement of the angular acceleration.
2. Determination of the momentum of inertia by measurement of the gyro-frequency and precession frequency.
3. Investigation of the relationship between precession and gyro-frequency and its dependence from torque.
4. Investigation of the relationship between nutation frequency and gyro-frequency.

What you can learn about

- Momentum of inertia; Angular momentum
- Torque
- Precession; Nutation

Main articles

Gyroscope with 3 axes	02555-00	1
Light barrier with counter	11207-30	1
Additional gyro-disk w. c-weight	02556-00	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076-99	1

Gyroscope with 3 axes

Function and Applications

Demonstration and practical set for working up the gyroscope laws.

Benefits

The following relationships can be produced:

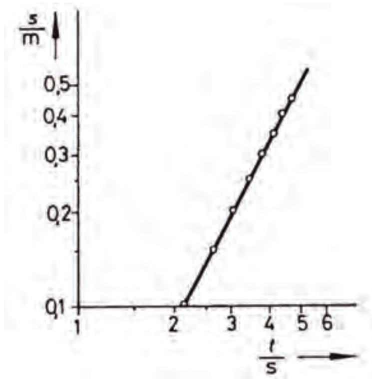
- Precession (influence of torque and rotational frequency)
- Nutation (influence of the speed of the disc on the nutational frequency)
- Measurement of the moment of inertia of the gyroscope disc from the angular acceleration for a known torque
- Investigation of the relationship between the duration of a precession rotation and the rotational frequency of the gyroscope disc, Investigation of the relationship between the precession frequency and the turning moment exerted on the gyroscope axis for constant rotational frequency of the disc
- Determination of the relationship between the rotational and nutational frequency of the gyroscope disc
- Gyroscope disc with double ball bearings, balanced and freely movable via 3 axes, which is wound up by hand with the aid of a thread
- Mounted on a metal stand, Sliding counterweight for calibrating the gyro disc

Equipment and technical data

- Disc diameter: 245 mm; Disc thickness: 25 mm
- Disc weight: approx. 1317 g; Counterweight: approx. 925 g

02555-00

Mechanical conservation of energy/ Maxwell's wheel P2131800



Distance travelled by the centre of gravity of the Maxwell disk as a function of time.

Principle

A disc, which can unroll with its axis on two cords, moves in the gravitational field. Potential energy, energy of translation and energy of rotation are converted into one another and are determined as a function of time.

Tasks

The moment of inertia of the Maxwell disc is determined. Using the Maxwell disc,

1. the potential energy,
2. the energy of translation,
3. the energy of rotation,

are determined as a function of time.

What you can learn about

- Maxwell disc
- Energy of translation; Energy of rotation
- Potential energy
- Moment of inertia
- Angular velocity; Angular acceleration
- Instantaneous velocity
- Gyroscope

Main articles		
Light barrier with counter	11207-30	1
Maxwell wheel	02425-00	1
Holding device w. cable release	02417-04	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076-99	1
Meter scale, demo. l=1000mm	03001-00	1
Capacitor 100 nF/250V, G1	39105-18	1

measure Dynamics experiment - available 2014

Mechanical conservation of energy/ Maxwell's wheel with measure Dynamics

P2131880

Maxwell wheel

Function and Applications

Apparatus for conversion of potential to kinetic energy and vice-versa (translation and rotation). Two aperatures at ends of axles keep wheel from running off its trajectory and are used, together with a light barrier, to measure translation velocity.

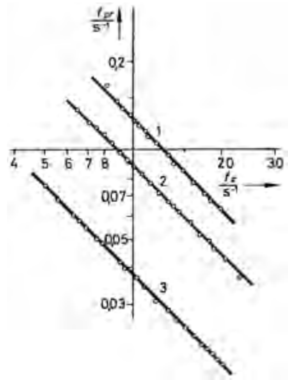
Equipment and technical data

- Metal wheel with support rod and adjustable suspension.
- Wheel diameter: 130 mm, Mass of wheel: 470g.
- Moment of inertia: 10 kg cm². Cord length: 800 mm, Diameter of shutter: 20 mm.

02425-00

P2132000 Laws of gyroscopes/ cardanic gyroscope

Demo



Precession frequency as a function of the gyro frequency for different additional masses.

Principle

If the axis of rotation of the force-free gyroscope is displaced slightly, a nutation is produced. The relationship between precession frequency or nutation frequency and gyro-frequency is examined for different moments of inertia. Additional weights are applied to a gyroscope mounted on gimbals, so causing a precession.

Tasks

1. To determine the precession frequency as a function of the torque and the angular velocity of the gyroscope.
2. To determine the nutational frequency as a function of the angular velocity and the moment of inertia.

What you can learn about

- Moment of inertia
- Torque
- Angular momentum
- Nutation
- Precession

Main articles		
Gyro,Magnus type, incl. Handb.	02550-00	1
Digital stroboscope	21809-93	1
Stopwatch, digital, 1/100 s	03071-01	1

Gyroscope, Magnus type, incl. handbook

Function and Applications

Gyro, Magnus type, universal gyro for demonstration and quantitative evaluation of gyro laws and their application.

Benefits

Rich accessories to demonstrate the following topics:

- symmetrical and asymmetrical elonged and flattened gyro
- force free, driven and captive gyro, navigational gyro compass

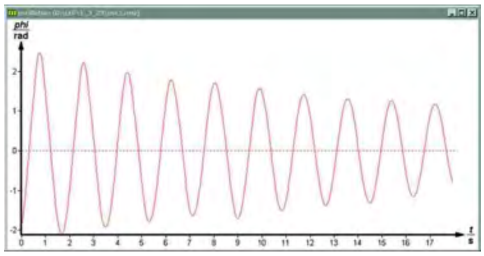
Equipment and technical data

- steel gyro disc with reinforced edge suspended in gimbols with bolt bearings, springs and clamps for restriction
- variation of moments of inertia by supplementary steel-weights
- Disk diameter: 128 mm, Storage box (mm): 355 x 380 x 385
- Including manual of 124 pages.

02550-00

Moments of inertia of different bodies/ Steiner's theorem with Cobra4

P2132860



Typical measuring result

Principle

The moment of inertia of a solid body depends on its mass distribution and the axis of rotation. Steiner's theorem elucidates this relationship.

Tasks

1. The moments of inertia of different bodies are determined by oscillation measurements.
2. Steiner's theorem is verified.

What you can learn about

- Rigid body
- Moment of inertia
- Centre of gravity
- Axis of rotation
- Torsional vibration
- Spring constant
- Angular restoring force

Main articles		
Angular oscillation apparatus	02415-88	1
Software Cobra4 - multi-user licence	14550-61	1
Movement sensor with cable	12004-10	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Cobra4 Wireless Manager	12600-00	1
Portable Balance, OHAUS CS2000	48917-93	1

Angular oscillation apparatus

Function and Application

Apparatus for the investigationof moment of inertia. for qualitative illustration of relationshipbetween mass distribution and moment of inertia, as well as for quantitative determination of moments of inertia of various models. In addition, the validity of the "Steiner law" can be varified experimentally.

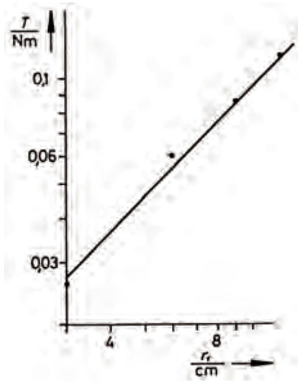
Benefits

Consists of:

- Rotation axis with spring,
- Metal- and Styrofoam disk,
- Full material and hollow cylinder
- Sphere and bar with adjustablemass pieces

02415-88

P2120100 Moments



Moment as a function of the distance between the origin of the coordinates and the point of action of the force.

Principle

Coplanar forces (weight, spring balance) act on the moments disc on either side of the pivot. In equilibrium, the moments are determined as a function of the magnitude and direction of the forces and of the reference point.

Tasks

1. Determination of the Moment as a function of the distance between the origin of the coordinates and the point of action of the force.
2. Determination of the Moment as a function of the angle between the force and the position vector to the point of action of the force.
3. Determination of the Moment as a function of the force.

What you can learn about

- Moments
- Couple
- Equilibrium
- Statics
- Lever
- Coplanar forces

Main articles		
Moments disk	02270-00	1
Tripod base PHYWE	02002-55	2
Spring Balance 1 N	03060-01	2
Barrel base PHYWE	02006-55	1
Bolt with pin	02052-00	1
Fish line, l. 100m	02090-00	1
Support rod PHYWE,square,l 400mm	02026-55	2

Moments disk

Function and Applications

Disk to investigate general equilibrium conditions of a body submitted to forces and supported at its centre of gravity so that it can rotate.

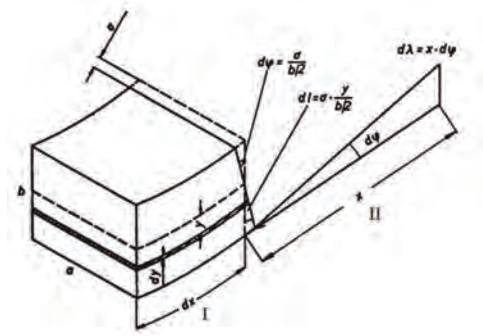
Equipment and technical data

- Metallic disk, white on both sides with a central hole for low friction support on rod with pin.
- One side with auxiliary circles with angular scales.
- Disk diameter: 270 mm.
- Number of holes: 64.
- Grid constant (mm): 30 x 30.

02270-00

Modulus of elasticity

P2120200



Deformation of a bar.

Principle

A flat bar is supported at two points. It is bent by the action of a force acting at its centre. The modulus of elasticity is determined from the bending and the geometric data of the bar.

Tasks

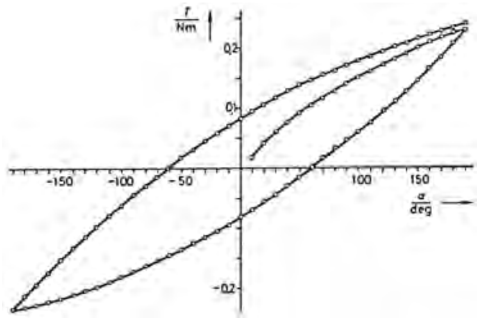
1. Determination of the characteristic curve of the dial gauge.
2. Determination of the bending of flatbars as a function of the force; at constant force: of the thickness, of the width and of the distance between the support points.
3. Determination of the modulus of elasticity of steel, aluminium and brass.

What you can learn about

- Young's modulus
- Modulus of elasticity
- Stress
- Deformation
- Poisson's ratio
- Hooke's law

Main articles		
Flat bars, set	17570-00	1
Dial gauge 10/0.01 mm	03013-00	1
Tripod base PHYWE	02002-55	2
Holder for dial gauge	03013-01	1
Knife-edge with stirrup	03015-00	1
Spring Balance 1 N	03060-01	1
Vernier caliper	03010-00	1

P2120300 Mechanical hysteresis



Mechanical hysteresis curve for the torsion of a copper rod of 2 mm diameter and 0.5 m long.

Principle

The relationship between torque and angle of rotation is determined when metal bars are twisted. The hysteresis curve is recorded.

Tasks

1. Record the hysteresis curve of steel and copper rods.
2. Record the stress-relaxation curve with various relaxation times of different materials.

What you can learn about

- Mechanical hysteresis
- Elasticity
- Plasticity
- Relaxation
- Torsion modulus
- Plastic flow
- Torque
- Hooke's law

Main articles

Torsion apparatus	02421-00	1
Spring Balance 1 N	03060-01	1
Spring balance 2,5 N	03060-02	1
Torsion rod, Al, l = 500 mm, d = 4 mm	02421-06	1
Torsion rod, Al, l = 500 mm, d = 3 mm	02421-05	1
Torsion rod, Cu, l = 500 mm, d = 2 mm	02421-08	1
Torsion rod, steel, l = 500 mm, d = 2 mm	02421-01	1

Torsion apparatus, complete

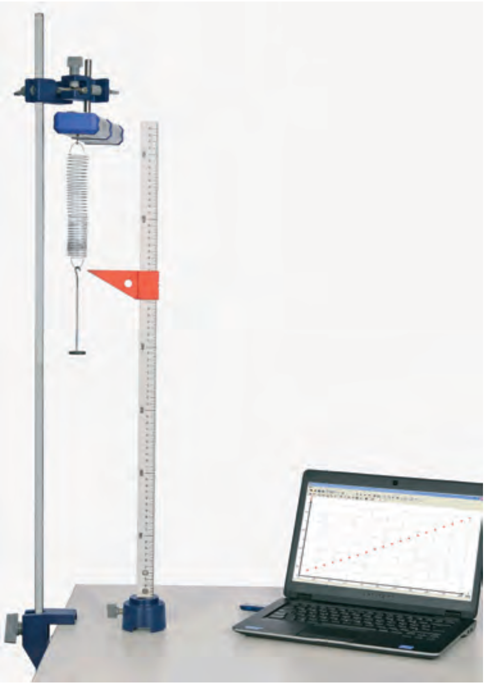
Function and Applications

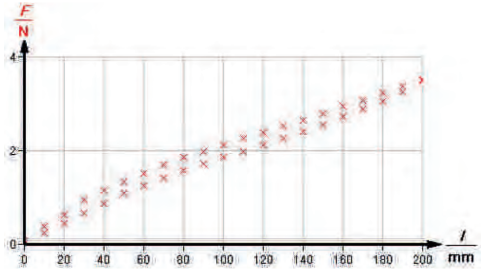
To investigate deformations due to torques. For demonstration of the combined effects of force and lever.

02421-88

Hooke's law with Cobra4

P2130160





Measurement of the elongation of a rubber band.

Principle

The validity of Hooke's Law is proven using various helical springs with different spring constants. In comparison, the behaviour of a stretched rubber band is examined, for which there is no proportionality between acting force and resulting extension.

Tasks

1. Measurement of the tensile force as a function of the path for three different helical springs and a rubber band.
2. Determination of the spring constant and evaluation of a hysteresis curve.
3. Verification of Hooke's law.

What you can learn about

- Spring constant
- Limit of elasticity
- Extension and compression

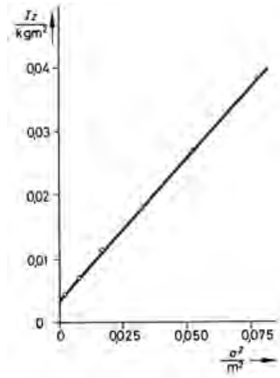
Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Force ± 4 N	12642-00	1
Cobra4 Wireless Manager	12600-00	1
Support base DEMO	02007-55	1
Scale, l = 750 mm, on rod	02200-00	1
Support rod PHYWE, square, l = 1000 mm	02028-55	1

Related Experiment

Hooke's law

P2130101

P2133100 Moments of inertia and torsional vibrations



Moment of inertia of two equal masses, of 0.214 kg each, as a function of the distance between them.

Principle

Various bodies perform torsional vibrations about axes through their centres of gravity. The vibration period is measured and the moment of inertia determined from this.

Tasks

The following will be determined:

1. The angular restoring moment of the spiral spring.
2. The moment of inertia a) of a disc, two cylinder, a sphere and a bar, b) of two point masses, as a function of the perpendicular distance to the axis of rotation. The centre of gravity lies in the axis of rotation.

What you can learn about

- Rigid body; Moment of inertia; Angular restoring moment
- Axis of rotation; Torsional vibration; Spring constant
- Moment of inertia of a sphere, a disc, a cylinder, a long bar and 2 point masses

Main articles		
Light barrier with counter	11207-30	1
Rotation axle	02415-01	1
Sphere	02415-02	1
Rod with movable masses	02415-06	1
Hollow cylinder	02415-04	1
Disk	02415-03	1
Solid cylinder	02415-05	1

Related Experiment

Moment of inertia / Steiner's theorem

P2132801

Light barrier with counter

Function and Applications

With the function of an electronic time measuring and counting device.

Benefits

- 4 figure luminous display, selection switch for 4 operating modes
- RESET key
- BNC jack for exterior starting and/or stopping of time measurement
- TTL output to control peripheral devices
- Power supply connector (4 mm jacks)

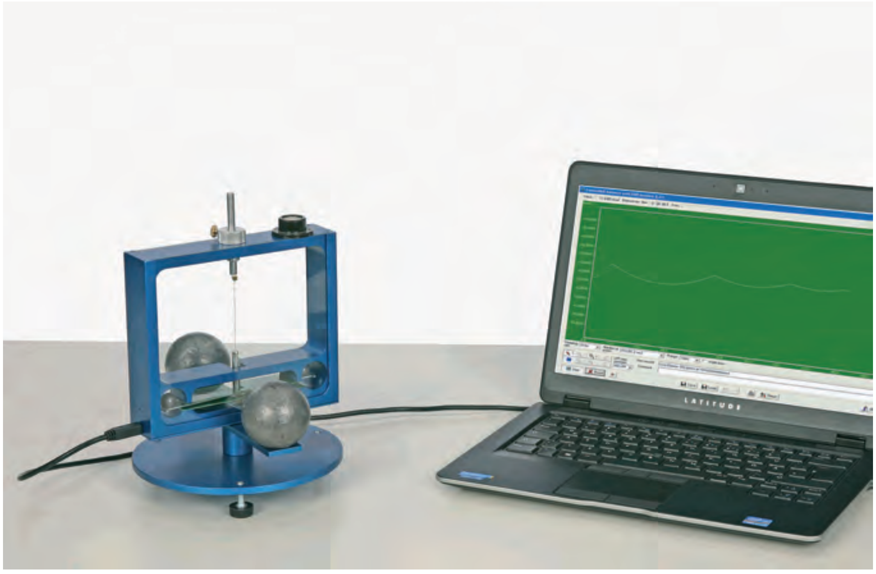
Equipment and technical data

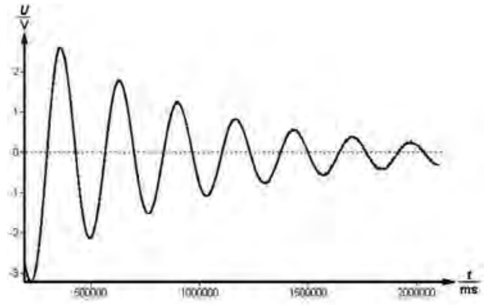
- Fork width: 70 mm
- Usable barrier depth: 65 mm
- Sensitivity adjustable
- LED-Display: 4 digits, 8 mm
- Time measurement: 0...9.999 s

11207-30

Determination of the gravitational constant / computerised Cavendish balance

P2130901





Output voltage of the free and damped oscillating Cavendish balance.

Principle

Two small lead spheres are positioned on a beam, which is freely suspended on a thin metal wire. At the beginning the large lead spheres are positioned symmetrically opposite to the small spheres in that way that the attractive forces are eliminated. There after, the large spheres are swung so that they are close to the small spheres. As a consequence of the gravitational attracting force the beam with the small spheres now moves in a new equilibrium position, where the attractive forces are equivalent to the force of the torsion of the wire. The gravitational constant can be determined from the new equilibrium position.

Tasks

1. Calibration of an angular detector.
2. Determination of the oscillation time of a free and damped oscillating torsion pendulum.
3. Determination of the gravitational constant.

What you can learn about

- Law of gravitation
- Free, damped, forced and torsional oscillations
- Moment of inertia of spheres and rods
- Steiner's theorem
- Shear modulus

Main articles		
Cavendish balance/computerized	02540-00	1
Circular level, d = 36 mm	02123-00	1

Cavendish balance/computerized

Function and Applications

For the demonstration of the mass attraction of two bodies and for the determination of the gravitational constant.

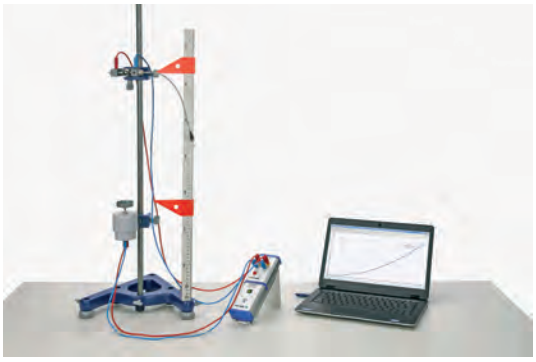
Benefits

- Complete and compact system with control unit, only a recording system (e.g. aninterface-system) or a multimeter is to be used to get 2%
- Accurate results in a single lab period
- Short oscillation periods of 2-4 minutes using a 25 µm diameter adjustable length tungsten wire
- No more optical lever jitters due to SDC-(Symmetric Differential CapacitiveControl) sensor technology

02540-00

Free fall with Cobra4

P2130760



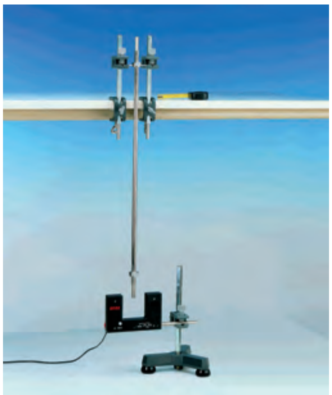
Principle

The fall times t are measured for different heights of fall h. h is represented as the function of t or t^2, so the distance-time law of the free fall results as $h = 1/2 \cdot g \cdot t^2$. Then the measured values are taken to determine the acceleration due to gravity g.

For more details refer to page 20.

Reversible pendulum

P2132200



Principle

By means of a reversible pendulum, terrestrial gravitational acceleration g may be determined from the period of oscillation of a physical pendulum, knowing neither the mass nor the moment of inertia of the latter.

For more details refer to www.phywe.com

Variable g pendulum with Cobra4

P2132360

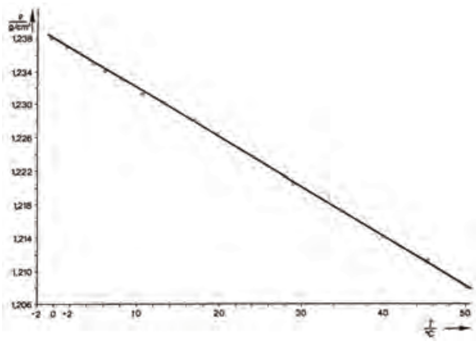
Principle

Earth's gravitational acceleration g is determined for different lengths of the pendulum by means of the oscillating period. If the oscillating plane of the pendulum is not parallel to the gravitational field of the earth, only one component of the gravitational force acts on the pendulum movement.

For more details refer to page 49.

Density of liquids

P2140100



Density of glycerol as a function of temperature.

Principle

The density of water and glycerol is determined as a function of temperature using the Mohr balance.

Task

The density of water and glycerol is measured in 1 to 2 °C steps over a temperature range from 0 to 20 °C, then in larger steps up to 50 °C.

What you can learn about

- Hydrogen bond
- Water anomaly
- Volume expansion
- Melting
- Evaporation
- Mohr balance

Main articles		
Westphal/ Mohr density balance	45016-00	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Cooling coil for thermostat Alpha A	08493-01	1
Glycerol 250 ml	30084-25	2
Water, distilled 5 l	31246-81	1

Westphal / Mohr density balance

Function and Applications

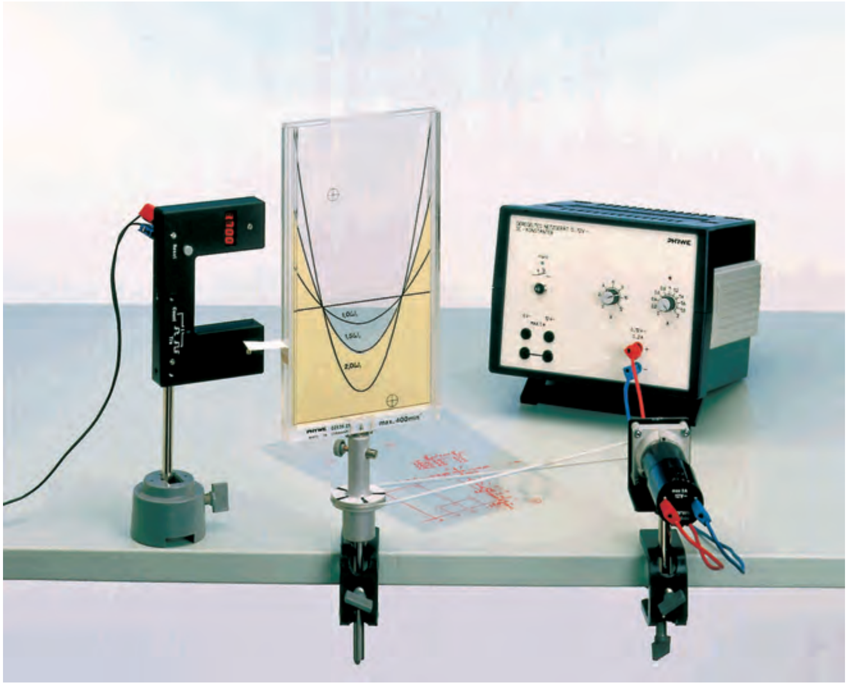
Precision balance with balance bar with unequal arm length for determination of densities of liquids and solid state bodies

Equipment and technical data

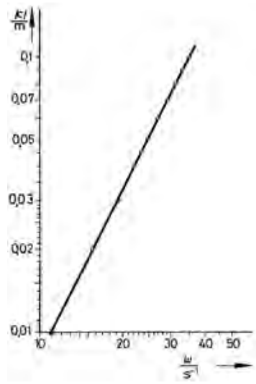
- the bearing of the balance bar consists of a low friction steel cutting edge, with height variable support rod
- balance bar equipped with 9 positions for counter weight pieces
- delivered in wooden storage box, counter weight pieces
- tweezers, Reimann`s bouyancy body with wire, thermometer
- glass cylinder, 100 ml, grid basket with hook for density determination of solid state bodies, beaker
- Weight range: 0...2 g/ccm, Sensitivity: 0.0001 g/ccm

45016-00

P2140200 Surface of rotating liquids



Demo



Location of the lowest point c of the liquid as a function of the angular velocity.

Principle

A vessel containing liquid is rotated about an axis. The liquid surface forms a paraboloid of rotation, the parameters of which will be determined as a function of the angular velocity.

Tasks

On the rotating liquid surface, the following are determined:

1. the shape,
2. the location of the lowest point as a function of the angular velocity,
3. the curvature.

What you can learn about

- Angular velocity
- Centrifugal force
- Rotary motion
- Paraboloid of rotation
- Equilibrium

Main articles		
Light barrier with counter	11207-30	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Rotating liquid cell	02536-01	1
Motor, with gearing, 12 VDC	11610-00	1
Bearing unit	02845-00	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076-99	1
Barrel base PHYWE	02006-55	1

Power supply 0-12 V DC/ 6 V, 12 V AC, 230 V

Function and Applications

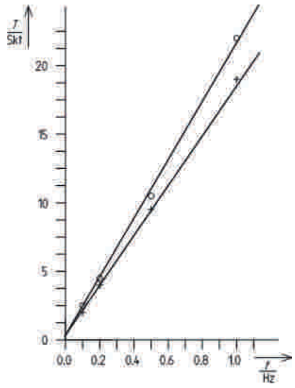
High quality power supply specially suitable for student experiments in electricity and electronics as well as for demonstration.

Equipment and technical data

- Stabilised
- Shortcircuit proof
- Output voltage: 1...12 V DC, 6 V / 12 V AC
- Rated current: DC 0...2 A / AC 5 A
- Ripple: max 1 mV
- Resistance: 1 mOhm
- Mains voltage: 230 V
- Housing dimensions: 194 x 140 x 130 mm

13505-93

Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer) P2140300



Moment of rotation as a function of the frequency for a Newtonian liquid glycerol (+), liquid paraffin (o).

Principle

The viscosity of liquids can be determined with a rotation viscometer, in which a motor with variable rotation speed drives a cylinder immersed in the liquid to be investigated with a spiral spring. The viscosity of the liquid generates a moment of rotation at the cylinder which can be measured with the aid of the torsion of the spiral spring and read on a scale.

Tasks

1. Determine the gradient of the rotational velocity as a function of the torsional shearing stress for two Newtonian liquids (glycerine, liquid paraffin).
2. Investigate the temperature dependence of the viscosity of Castor oil and glycerine.
3. Determine the flow curve for a non Newtonian liquid (chocolate).

What you can learn about

- Shear stress
- Velocity gradient
- Internal friction
- Viscosity
- Plasticity

Main articles		
Rotary viscometer, 15 - 2,000,000 mPas	18223-99	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Glycerol 250 ml	30084-25	2
Separator for magnetic bars	35680-03	1
Supp.rod stainl.st.,50cm,M10-thr.	02022-20	1

Rotary viscometer, 15 - 2,000,000 mPas

Function and Applications

Classic rotational viscometer for the viscosity determination according to ISO2555 ("Brookfield method") and many ASTM standards.

Benefits

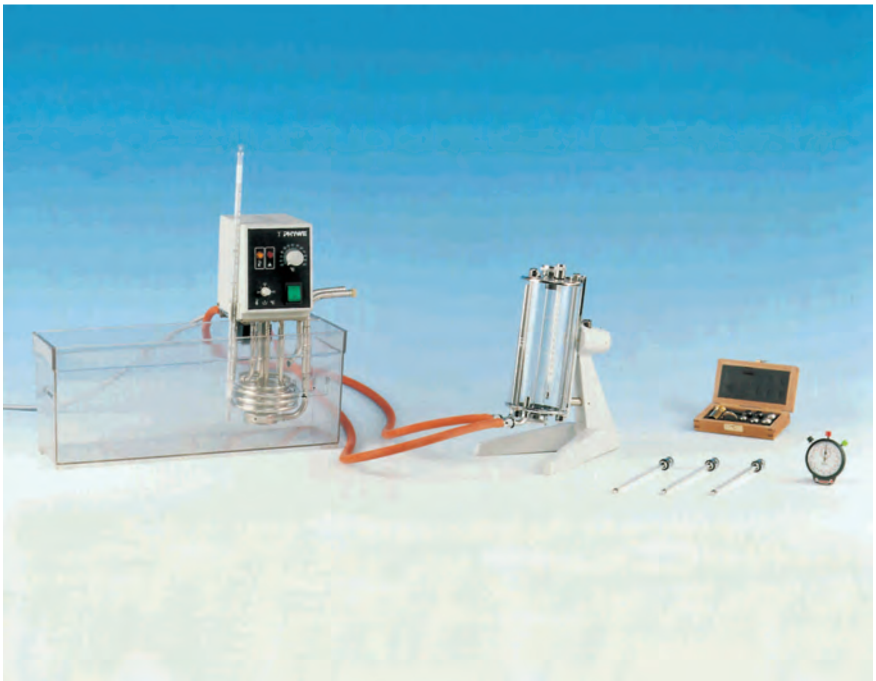
- The results are 100% compatible to the Brookfield method
- All results (viscosity, torque in %,speed, spindle) are displayed on the built-in display, multilanguage display: English, French, German, Spanish, Italian, Japanese, Portuguese, Dutch, Polish, Catalan
- Visual and acoustic signals at critical measuring conditions, Warning, if the device is used outside of the permissible measuring ranges, Digital speed control with "built-in"accuracy through stepping motor
- Touchless, optoelectronic torque measuring system with high accuracy and without wear

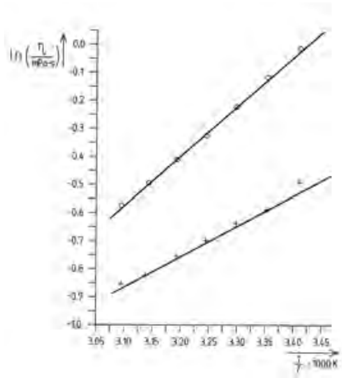
Equipment and technical data

- Viscosity range: 15 - 2,000,000 m Pas in 84 ranges (21 speeds and 4 spindles), Torque (rpm): 0.1/ 0.2/ 0.3/ 0.5/0.6/ 1/ 1.5/ 2/2.5/ 3/ 4/ 5/ 6/ 10/ 12/20/ 30/ 50/ 60/100/ 200

18223-99

P2140400 Viscosity measurement with the falling ball viscometer





Temperature dependence of the dynamic viscosity of water (o) and methanol (+), respectively.

Principle

Due to internal friction among their particles, liquids and gases have different viscosities. The viscosity, a function of the substance's structure and its temperature, can be experimentally determined, for example, by measuring the rate of fall of a ball in a tube filled with the liquid to be investigated.

Tasks

Measure the viscosity

1. of methanol-water mixtures of various composition at a constant temperature,
2. of water as a function of temperature and
3. of methanol as a function of temperature.

From the temperature dependence of the viscosity, calculate the energy barriers for the displace ability of water and methanol.

What you can learn about

- Liquid
- Newtonian liquid
- Stokes law
- Fluidity
- Dynamic and kinematic viscosity
- Viscosity measurements

Main articles		
Falling ball viscometer	18220-00	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Thermometer,24..+51C,for 18220-00	18220-02	1
Bath for thermostat, Makrolon	08487-02	1
External circulation set for thermostat	08493-02	1

Falling ball viscometer

Function and Applications

Falling ball viscometer.

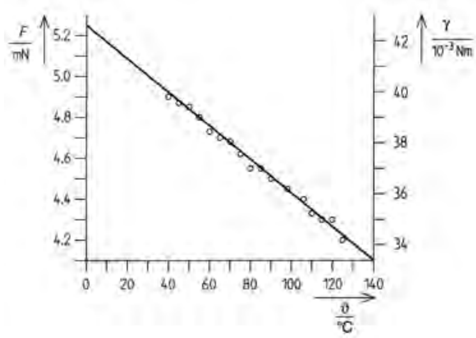
Equipment and technical data

- Thermometer
- Diameter of the fall tube: 15.95 mm
- Initiable fall times: 25...300 s
- Fall distance: 100 mm
- 6 balls

18220-00

Surface tension with the ring method (Du Nouy method) P2140500

Demo



Temperature dependency of surface tension of olive oil.

Principle

The force is measured on a ring shortly before a liquid film tears using a torsion meter. The surface tension is calculated from the diameter of the ring and the tear-off force.

Tasks

1. Determine the surface tension of olive oil as a function of temperature.
2. Determine the surface tension of water/methanol mixtures as functions of the mixture ratio.

What you can learn about

- Surface energy
- Interface
- Surface tension
- Adhesion
- Critical point
- Eötvös equation

Main articles		
Magnetic stirrer MR Hei-Standard	35750-93	1
Torsion dynamometer, 0.01 N	02416-00	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Surface tension measuring ring	17547-00	1
Retort stand, 210mm × 130mm, 500mm	37692-00	1
Ethyl alcohol, absolute 500 ml	30008-50	1
Water jet pump, plastic	02728-00	1

Torsion dynamometer, 0.01 N

Function and Applications

Torsion dynamometer to measure small forces or investigate electrostatic and magnetic interactions between bodies

Benefits

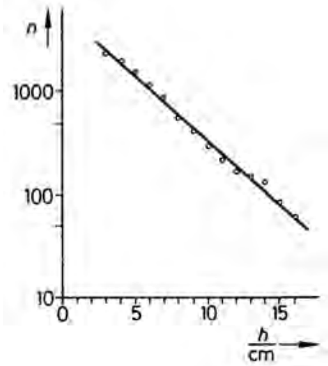
- force compensation, zero point adjustment
- eddy current damping element, front and side scales
- overloadprotection and a stem

Equipment and technical data

- Range front scale: 10 mN, Range side scale: ±3 mN
- Raw subdivision: 1 mN, Fine subdivision: 0,1 mN
- Maximum lever load: 0,2 N
- Scale diameter: 170 mm, Length of lever arm: 240 mm

02416-00

P2140700 Barometric height formula



Number of steel balls (m = 0.034 g), as a function of the height *h*, which pass through the volume element V in 30 seconds (vibrational frequency 50 Hz).

Principle

Glass or steel balls are accelerated by means of a vibrating plate, and thereby attain different velocities (temperature model). The particle density of the balls is measured as a function of the height and the vibrational frequency of the plate.

Tasks

Measurement of the particle density as a function of:

1. the height, at fixed frequency
2. the vibrational frequency of the exciting plate, at fixed height

What you can learn about

- Kinetic gas theory
- Pressure
- Equation of state
- Temperature
- Gas constant

Main articles		
Kinetic gas theory apparatus	09060-00	1
Digital stroboscope	21809-93	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Light barrier with counter	11207-30	1
Tripod base PHYWE	02002-55	2
Power supply 5 V DC/2.4 A with 4 mm plugs	11076-99	1
Stopwatch, digital, 1/100 s	03071-01	1

Power supply variable 15 VAC/ 12 VDC/ 5 A

Function and Applications

Standard heavy duty power supply unit for low voltage.

Supplies unit for continuously adjustable DC and AC voltages & 2 frequently required fixed voltages.

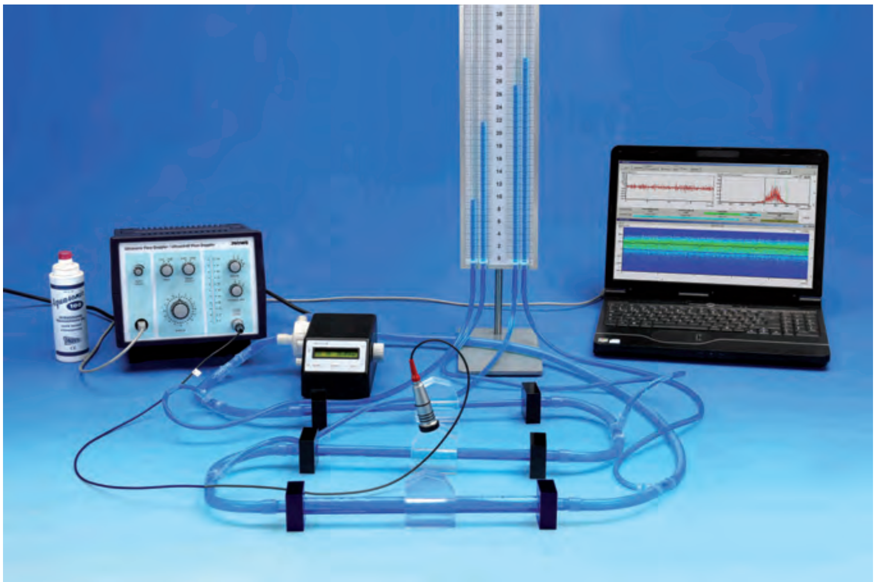
Equipment and technical data

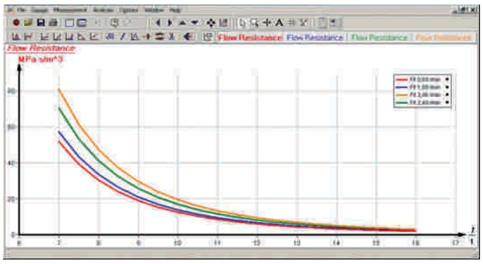
- AC output: 0...15 V/5 A
- DC output: 0...12 V/5 A
- Max. current (short term): 10 A
- Add. fixed voltages: 6 V AC/6 A12 V AC/6 A
- Max. current (short term): 10 A
- Max. power: 150 VA
- Fuses: one 6 A and two 10 A
- Supply voltage: 230 V AC
- dimensions (mm): 230 x 236 x 168

13530-93

Mechanics of flow

P5140100





The dependence of the resistance on the tube diameter.

Principle

The Doppler effect is used with ultrasonic waves to investigate the laws of stationary laminar flow, which underlie a many great technical applications. The liquid under investigation flows through a circuit of tubing. Particular aspects to be studied experimentally include the relationship between the speed of flow and the surface of the tubing (continuity condition) plus that between the resistance to the flow and the diameter of the tube (Hagen-Poiseuille law). By means of these two laws, the dynamic viscosity or fluidity can be derived using familiar geometry.

Tasks

1. Measure the average speed of 3 different flows using the ultrasonic Doppler sonograph with Doppler prisms. Determine the nature of the flow.
2. Measure the drop in pressure between the measuring points and determine the resistance to the flow.
3. Calculate viscosity and fluidity and compare with those for other liquids.

What you can learn about

- Ultrasonic Doppler effect
- Laminar and turbulent flow
- Continuity equation
- Bernoulli's equation
- Hagen-Poiseuille law
- Viscosity and fluidity

Main articles		
Basic set: Ultrasonic Doppler technique	13923-99	1
Extension Set: Mechanics of flow	13923-01	1

Related Experiment

Flow Measurement / Ultrasonic Doppler effect

P5142100

Basic set: Ultrasonic Doppler technique

Function and Applications

Kit containing instrument and accessories for general ultrasonic sonography experiences. The software displays the measured data from the ultrasonic doppler apparatus, basic instrument of this kit, in realtime on the computer screen. Modular and extendable with accessory kits for experimentations in the fields of hydraulics and medical diagnostics.

Benefits

- This kit forms a very didactic experimentation system beginning from the basics of sonography and can with accessory kits be extended for the use in specific applications as hydraulics and medical diagnostics (only for training purposes!)
- an experimentation manual is included

Equipment and technical data

- 1 x ultrasonic pulse Doppler apparatus, 1 x centrifugal pump
- 1 x ultrasonic gel, 1 x liquid for sonography (1l)
- 1 x ultrasonic probe 2 MHz, 1 x Doppler prisma 3/8
- 1 x Set of flexible tubes

13923-99

Software "Measure Dynamics", site-licence

Function and Application

Software "measure Dynamics", automatic video analysis of movements. The new measurement software "measure Dynamics" provides an inexpensive way to analyze movements and display them in the shape of diagrams. All you need is a digital video camera, whereby modern webcams, camcorders or common digital cameras with film mode function are completely sufficient. The campus licence permits the installation of the software on every PC at the campus and on all personal PCs of the students and teachers belonging to the campus!

Benefits

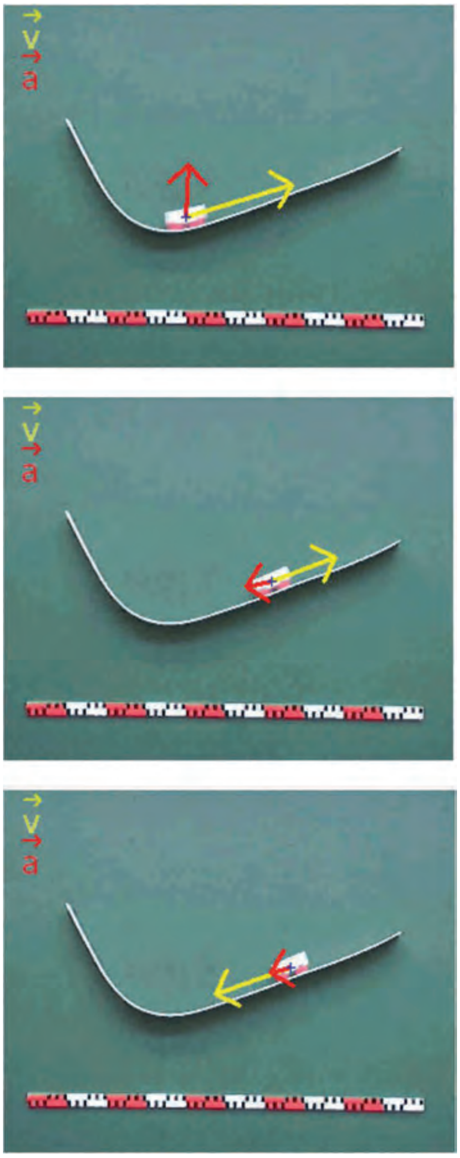
- Automatic object recognition and tracing, including several filmed objects simultaneously, e.g. coupled pendulum
- Dialogue-supported creation of trajectories as well as movement, velocity and acceleration diagrams
- Stroboscopic effect for motion sequences (visualization of the entire path of movement)
- Easy data transfer of all measured values to MS Excel®, PHYWE measure, and other applications
- Video processing inclusive of cutting, compression, etc.
- Software-guided modeling for didactical transfers (including-homework)

Possible Applications

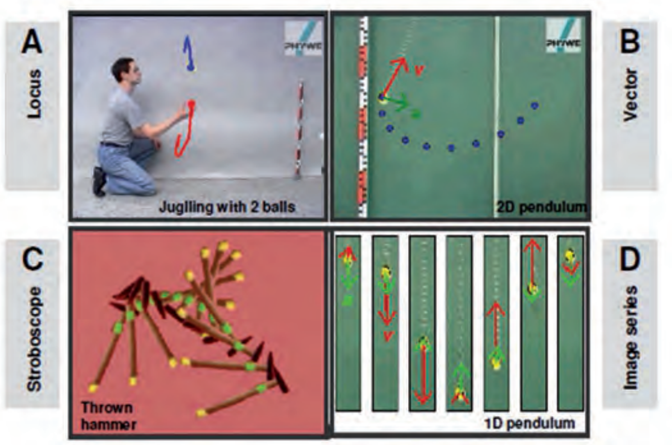
- Demonstration experiments in the lecture hall, for example, all types of one-dimensional and two-dimensional movements
- "Field studies", for example, display of motion sequences in shot-putting, basket-shooting in basketball, trampoline jumping, high-jump, and much more.

14440-62

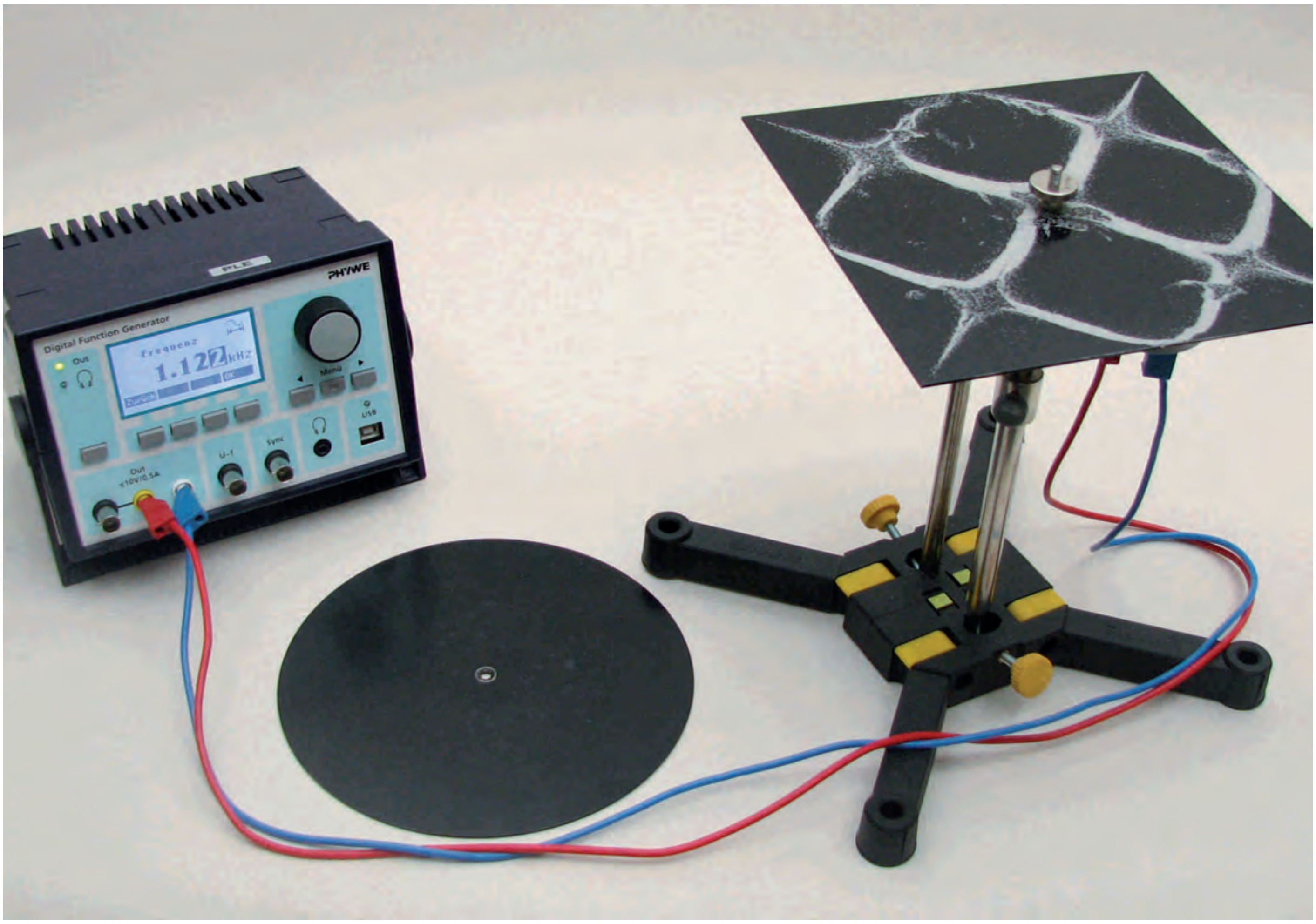
EduMedia Award for Didactical Software



Speed and acceleration of a car in a roller coaster.

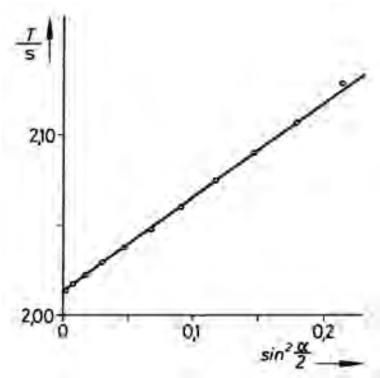


Possibilities in measure Dynamics for supporting the phenomenological recording of movements.



Oscillations and Mechanical Waves, Acoustics

P2132100 Mathematical pendulum



Period of the pendulum as a function of the angle of deflection.

Principle

A mass, considered as of point form, suspended on a thread and subjected to the force of gravity, is deflected from its position of rest. The period of the oscillation thus produced is measured as a function of the thread length and the angle of deflection.

Tasks

1. For small deflections, the oscillation period is determined as a function of the cord length.
2. The acceleration due to gravity is determined.
3. The oscillation period is determined as a function of the deflection.

What you can learn about

- Duration of oscillation
- Period
- Amplitude
- Harmonic oscillation

Main articles		
Light barrier with counter	11207-30	1
Tripod base PHYWE	02002-55	1
Power supply 5 V DC/2.4 A with 4 mm plugs	11076-99	1
Support rod PHYWE,square,l 1250mm	02029-55	1
Clamping pads on stem	02050-00	1
Meter scale, demo. l=1000mm	03001-00	1
Fish line, l. 100m	02090-00	1

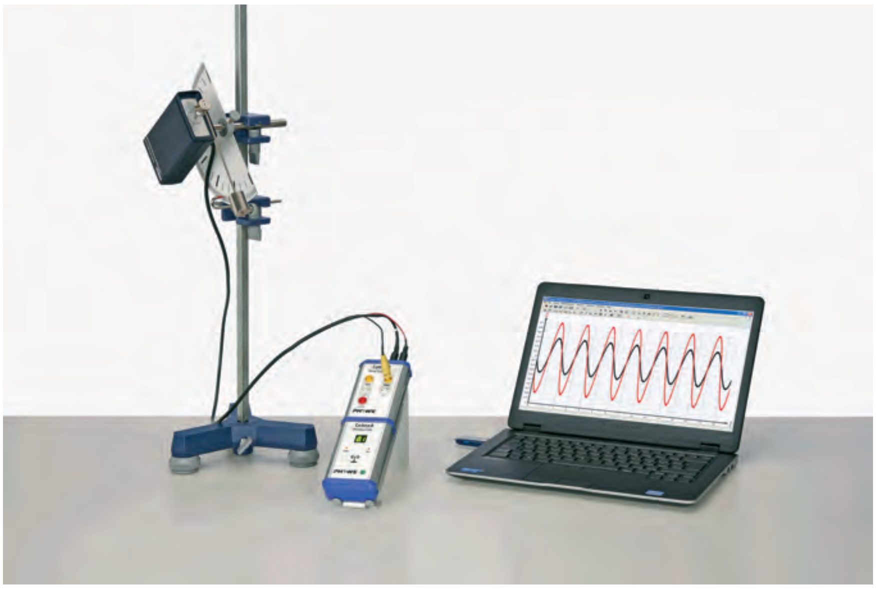
Related Experiment

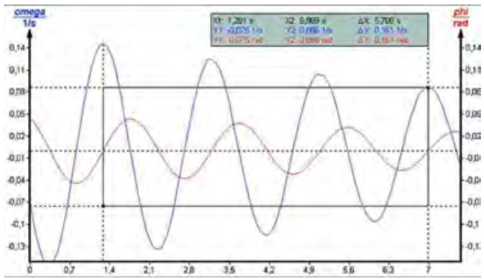
Reversible pendulum

P2132200

Variable g pendulum with Cobra4

P2132360





Typical measurement result

Principle

Earth's gravitational acceleration g is determined for different lengths of the pendulum by means of the oscillating period. If the oscillating plane of the pendulum is not parallel to the gravitational field of the earth, only one component of the gravitational force acts on the pendulum movement.

Tasks

1. Determination of the oscillation period of a thread pendulum as a function of the pendulum length.
2. Determination of g.
3. Determination of the gravitational acceleration as a function of the inclination of the pendulum force.

What you can learn about

- Oscillation period
- Harmonic oscillation
- Mathematical pendulum
- Physical pendulum
- Variable g-pendulum
- Decomposition of force
- Gravitational force

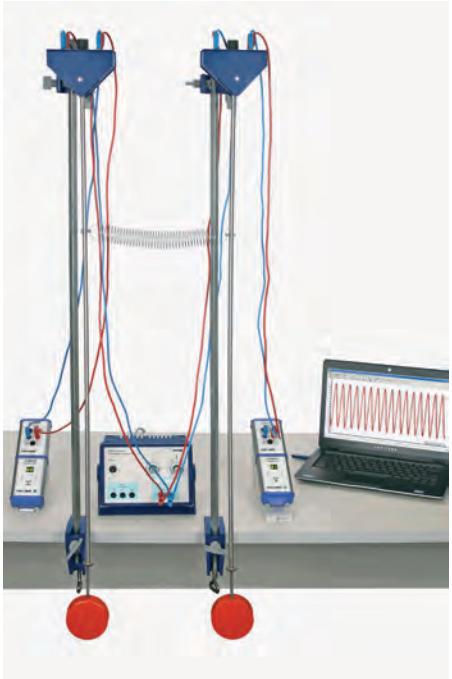
Main articles		
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Cobra4 Wireless Manager	12600-00	1
Movement sensor with cable	12004-10	1
Tripod base PHYWE	02002-55	1
Protractor scale with pointer	08218-00	1
Pendulum f. movement sensor	12004-11	1

Related Experiment

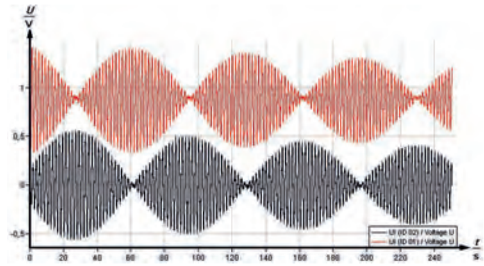
Variable g pendulum

P2132301

P2132560 Coupled pendula with Cobra4 (advanced version)



NEW Cobra4 Demo



Amplitude curves of the vibrations of coupled pendula in the beat case for three different coupling lengths l = 30 cm.

Principle

Two equal gravity pendula with a particular characteristic frequency are coupled by a "soft" spiral spring. The amplitudes of both pendula are recorded as a function of time for various vibrational modes and different coupling factors. The coupling factors are determined by different methods.

Tasks

1. To determine the spring constant of the coupling spring.
2. To determine and to adjust the characteristic frequencies of the uncoupled pendula.
3. To determine the coupling factors for various coupling-lengths using a) the apparatus constant, b) the angular frequencies for "inphase"and "in opposite phase" vibration, c) the angular frequencies of the beatmode.
4. To check the linear relation between the square of the coupling lengths and a) the particular frequencies of the beat mode, b) the square of the frequency for "inopposite phase" vibration.
5. To determine the pendulum's characteristic frequency from the vibrational modes with coupling and to compare this with the characteristic frequency of the uncoupled pendula.

What you can learn about

- Spiral spring
- Gravity pendulum
- Spring constant
- Torsional vibration
- Torque
- Beat
- Angular velocity
- Angular acceleration
- Characteristic frequency

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Pendulum with recorder connection	02816-00	2
Cobra4 Wireless-Link	12601-00	2
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Electricity	12644-00	2
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Bench clamp PHYWE	02010-00	2

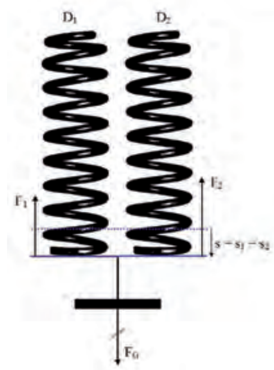
measure Dynamics experiment - available 2014

Coupled pendula with measure Dynamics

P2132580

Harmonic oscillations of spiral springs - Spring linked inparallel and series with Cobra4 P2132660


NEW Cobra4 Demo



Parallel connection of helical springs.

Principle

The spring constant D is determined for different experimental set-ups from the oscillation period and the suspended mass.

Tasks

1. Determination of the spring constant D for different springs.
2. Determination of the spring constant for springs linked in parallel.
3. Determination of the spring constant for springs linked in series.

What you can learn about

- Spring constant
- Hooke's law oscillations
- Limit of elasticity
- Parallel springs, Serial springs
- Use of an interface

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Force ± 4 N	12642-00	1
Cobra4 Wireless Manager	12600-00	1
Tripod base PHYWE	02002-55	1
Support rod PHYWE, square, l = 1000 mm	02028-55	1
Right angle clamp PHYWE	02040-55	1

Cobra4 Sensor-Unit Force ± 4 N

Function and Applications

The Cobra4 Sensor-Unit Force ± 4 N contains a bending beam (DMS technology), which converts the mechanical load into an electrical signal.

Benefits

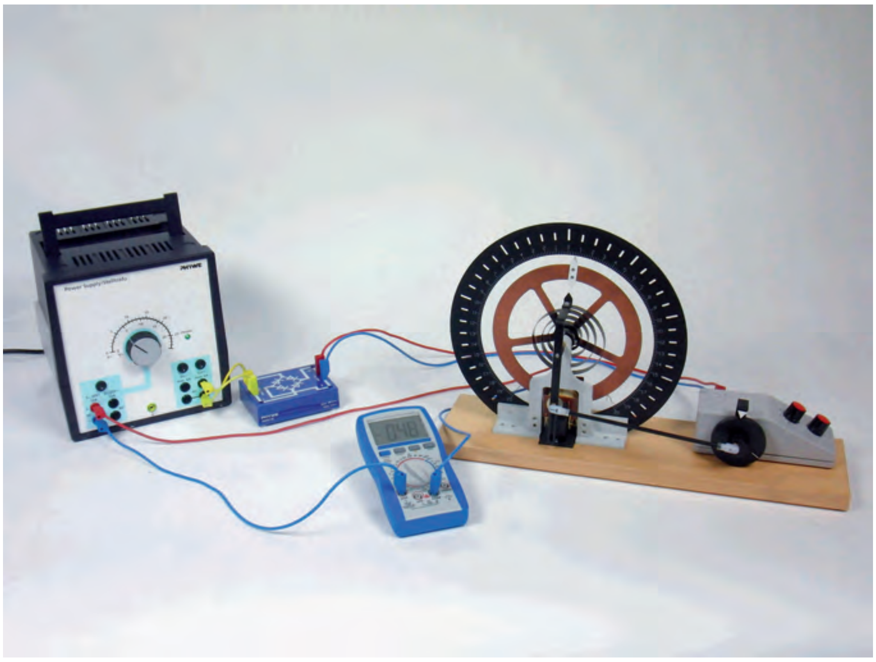
- Depending on the type of application, the force sensor can be connected to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link or the Cobra4USB-Link using a secure and reliable plug-in / lockable connection.
- On the top of the casing, a plate can be plugged in for measuring weights that are placed on it.
- On the bottom of the device, there is a hook on which weights may be hung.
- On the mechanically secure in take of the Cobra4 sensor unit, force from above or below is applied using a drop rod with a M6 thread.

Equipment and technical data

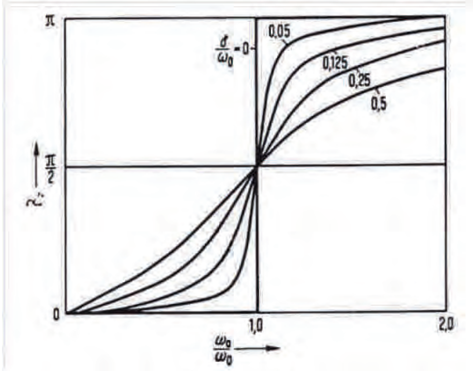
- 100 mm long rod with M6 thread
- weight plate, weight hook
- operating manual
- Measuring range: -4...+4 N
- Maximum sampling rate: 16 Hz
- Measuring accuracy: 0.2 mN
- Dimensions (L x B x H): 64 x 70 x 35 mm
- Weight: 100 g

12642-00

P2132701 Forced oscillations - Pohl's pendulum



Demo



Phase shifting of forced oscillation for different dampings.

Principle

If an oscillating system is allowed to swing freely it is observed that the decrease of successive maximum amplitudes is highly dependent on the damping. If the oscillating system is stimulated to swing by an external periodic torque, we observe that in the steady state the amplitude is a function of the frequency and the amplitude of the external periodic torque and of the damping.

Tasks

- **A. Free oscillation**

1. To determine the oscillating period and the characteristic frequency of the undamped case.
2. To determine the oscillating periods and the corresponding characteristic frequencies for different damping values. Successive, unidirectional maximum amplitudes are to be plotted as a function of time. The corresponding ratios of attenuation, the damping constants and the logarithmic decrements are to be calculated.
3. To realise the a periodic case and the creeping.

- **B. Forced oscillation**

1. The resonance curves are to be determined and to be represented graphically using the damping values of *A*.
2. The resonance frequencies are to be determined and are to be compared with the resonance frequency values found before hand.

What you can learn about

- Angular frequency; Characteristic frequency; Resonance frequency; Torsion pendulum; Torsional vibration; Torque and Restoring torque; Damped/ undamped free oscillation; Forced oscillation; Ratio of attenuation/ decrement; Damping constant; Logarithmic decrement; Aperiodic case; Creeping

Main articles		
Torsion pendulum after Pohl	11214-00	1
Variable transformer, 25 VAC/ 20 VDC, 12 A	13531-93	1
Bridge rectifier, 30V AC/1A DC	06031-10	1
Digital multimeter 2010	07128-00	1

Related Experiment

Forced oscillations - Pohl's pendulum with Cobra3

P2132711

Cobra4 Experiment - available 2014

Forced oscillations - Pohl's pendulum with Cobra4

P2132760

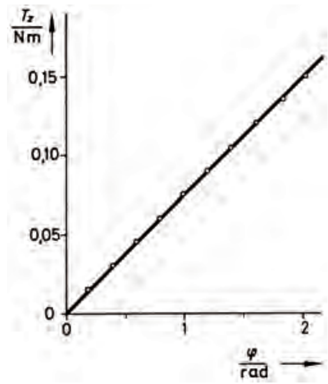
measure Dynamics experiment - available 2014

Forced oscillations - Pohl's pendulum with measure Dynamics

P2132780

Torsional vibrations and torsion modulus

P2133000



Torque and deflection of a torsion bar.

Principle

Bars of various materials will be exciting into torsional vibration. The relationship between the vibration period and the geometrical dimensions of the bars will be derived and the specific shear modulus for the material determined.

Tasks

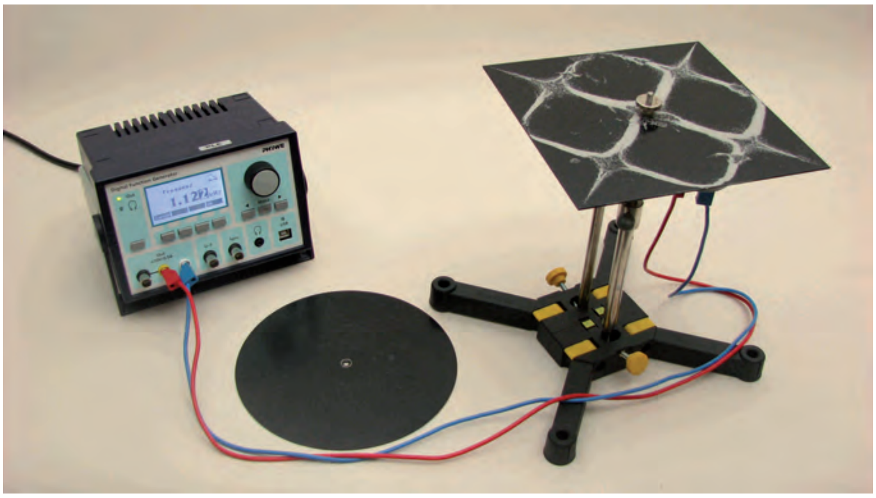
1. Static determination of the torsion modulus of a bar.
2. Determination of the moment of inertia of the rod and weights fixed to the bar, from the vibration period.
3. Determination of the dependence of the vibration period on the length and thickness of the bars.
4. Determination of the shear modulus of steel, copper, aluminium and brass.

What you can learn about

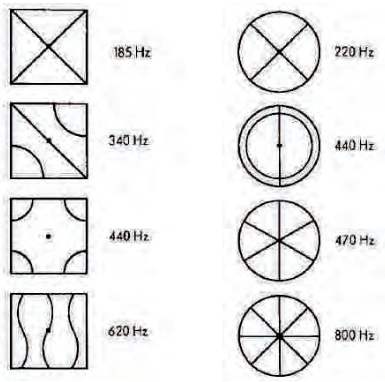
- Shear modulus
- Angular velocity
- Torque
- Moment of inertia
- Angular restoring torque
- G-modulus
- Modulus of elasticity

Main articles		
Torsion apparatus	02421-00	1
Spring Balance 1 N	03060-01	1
Spring balance 2,5 N	03060-02	1
Torsion rod, Al, l = 500 mm, d = 4 mm	02421-06	1
Torsion rod, Al, l = 500 mm, d = 3 mm	02421-05	1
Sliding weight	03929-00	2

P2150501 Chladni figures



NEW Cobra4 Demo



Some Chladni figures with corresponding frequencies.

Principle

Square and round metal plates are brought to vibrate through acoustic stimulations by a loudspeaker. When the driving frequency corresponds to a given eigen-frequency (natural vibration mode) of the plate, the nodal lines are made visible with sand. The sand is expelled from the vibrating regions of the plate and gathers in the lines because these are the only places where the amplitude of vibrations is close to zero.

Tasks

Determine the frequencies at which resonance occurs and drive the plate specifically at these frequencies.

What you can learn about

- Wave length
- Stationary waves
- Acoustic vibrations
- Two-dimensional standing waves
- Eigen-modes

Main articles		
Digital Function Generator, USB	13654-99	1
Loudspeaker / Sound head, 8 ohms	03524-01	1
Sound pattern plates	03478-00	1
Support base variable	02001-00	1
Stand tube	02060-00	1
Sea sand, purified 1000 g	30220-67	1
Boss head	02043-00	1

Digital Function Generator, USB, incl. Cobra4 Software

Function and Applications

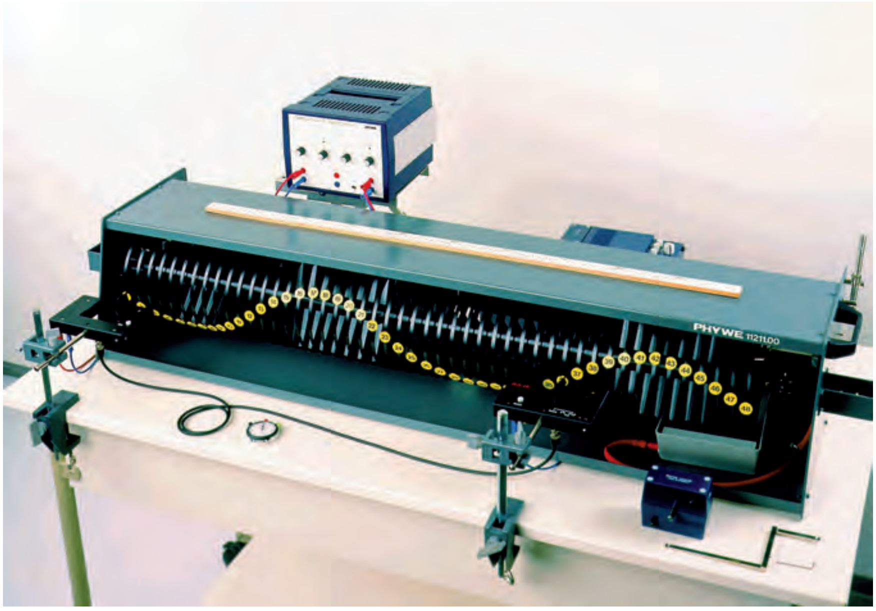
Digital signal generator for use as a programmable voltage source in practical or demonstration experiments, particularly in the disciplines of acoustics, electrical engineering and electronics

Benefits

- Can be used as universal stand-alone device or controlled via a USB interface
- Universally applicable thanks to broad, continually adjustable frequency range
- Usable as programmable voltage source via amplifier output
- Intuitive, menu-driven operation using control knob and function buttons, with help capability
- Illuminated monochrome graphic display for maximum visibility and readability
- Simple setting of voltage and frequency ramps in stand-alone mode
- Features V = f(f) output for easy reading of frequency in the form of a voltage - ideal for measuring circuit response to frequency ramps using an oscilloscope
- Low distortion and signal-to-noise ratio for brilliantly clear signals - ideal for acoustics/audio experiments

13654-99

Propagation of a periodically excited continuous transverse wave P2133200



Demo

$\frac{f_k}{\text{Hz}}$	k	$\frac{f_k}{k}$	λ
0.38	1	0.38	$2L/1$
0.74	2	0.37	$2L/2$
0.94	3	0.31	$2L/3$
1.43	4	0.36	$2L/4$

The resonance frequencies measured with increasing speed of rotation.

Principle

The periodicity of connected stationary oscillators is demonstrated on the example of a continuous, harmonic transverse wave generated by a wave machine. The number of oscillations carried out by different oscillators within a certain time is determined and the velocity of propagation is measured. A relation between frequency, wavelength and phase velocity is established. The formation of standing waves is demonstrated and studied.

Tasks

1. The frequency of the oscillators 1, 10, 20, 30 and 40 is to be determined with the electronic counter of the lightbarrier and the stopwatch for a particular frequency of excitation.
2. By means of a path-time measurement the phase velocity of a transverse wave is to be determined.
3. For three different frequencies the corresponding wavelengths are to be measured and it is to be shown that the product of frequency and wavelength is a constant.
4. The four lowest natural frequencies with two ends of the oscillator system fixed are to be detected.
5. The four lowest natural frequencies with one end of the oscillator system fixed and the other one free are to be detected.

What you can learn about

- Periodic motion
- Frequency
- Wavelength
- Phase velocity
- Standing waves
- Natural frequency
- Free and fixed end
- Damping of waves

Main articles

Wave machine	11211-00	1
Laboratory motor, 220 V AC	11030-93	1
Power supply -2op-, 2x15V/2A	13520-93	1
Gearing 30/1, for 11030.93	11029-00	1
Gearing 100/1, for 11030.93	11027-00	1
Light barrier with counter	11207-30	1
Light barrier, compact	11207-20	1

Power supply -2op-, 2x15V/2A

Function and Applications

Specially suited for electronics experiments.

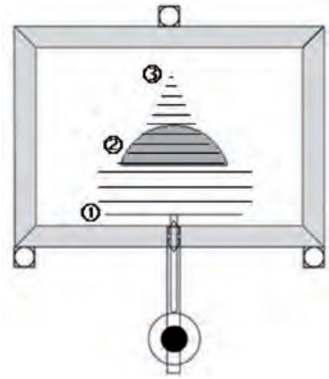
Equipment and technical data

- output voltage 2x0...15V
- nominal current 2A / 1A, current regulation 0...2A
- internal resistance <= 10m="" ohm="" li="">
- mains voltage 230V / 50...60Hz, power consumption 170 VA
- housing dimensions 230x236x168mm

-

13520-93

P2133400 Wave phenomena in a ripple tank



Examination of the behaviour of a concave lens with the ripple tank.

Principle

In the ripple tank water waves are generated by a vibration generator. Circular waves are then used to investigate the dependency of the vibration frequency on the wavelength. With the aid of plane waves the dependency of the velocity of the waves' propagation on the depth of the water can be determined. Moreover, the reflection of waves as well as the refraction of waves at a plate, a prism, a concave lens and at a convex lens can be clearly demonstrated. It is shown, that water waves are a proved method to demonstrate the behaviour of waves in general.

Tasks

1. Use the single dipper to generate circular waves. By using a ruler the wave length can be determined. The measurement is made for different frequencies.
2. The external wave generator is connected to the water ripple tank and circular waves are generated. By moving the external wave generator the Doppler Effect is investigated.
3. Plane waves are generated with the integrated wave generator. By using two barriers show the reflection of waves.
4. Use a plate to simulate a zone of lower water depth and measure the wave length before and above the plate.
5. Observe the refraction of water waves at several objects (plate, prism, concave and convex lens).

What you can learn about

- Generation of surface waves; Propagation of surface waves
- Dependency of wave velocity; Reflection of waves
- Refraction of waves;Concave, convex lenses; Mirrors

Main articles		
Ripple Tank with LED-light source, complete	11260-99	1
Demo set for ripple tank	11260-20	1
External vibration generator for ripple tank	11260-10	1
Software "Measure Dynamics", single user	14440-61	1

Ripple Tank with LED-light source, complete

Function and Applications

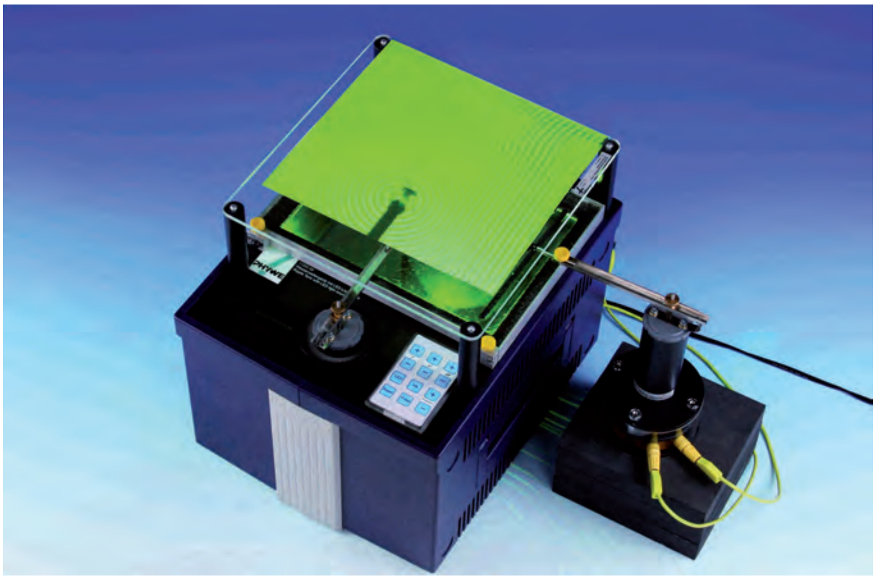
Just remove from the storage cupboard, fill with water and start! The Ripple tank provides a demonstration of the general properties of waves and wave propagation phenomena like reflection, dispersion, diffraction, interference, and Doppler-effect.

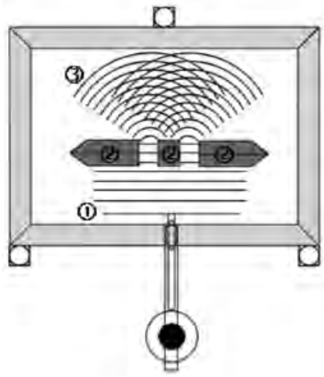
Benefits

- Very easy to operate compact unit for demonstration of wave characteristics such as reflection, dispersion, breakage, interference, diffraction and Doppler effect
- Reflection-free basin on adjustable feet
- 3-point adjustment
- Amplitude and frequency variable excitation dipper system
- Stroboscope for synchronous and "slow-motion" projection of waves
- Simultaneous LED display of: frequency, amplitude, phase shift and type of illumination

11260-99

Interference and diffraction of water waves with the ripple tank P2133500





Interference with the double slit.

Principle

A set of circular water waves is generated simultaneously and the resulting interference is observed. By increasing the number of interfering circular waves, Huygens' Principle can be verified.

With the aid of plane water waves, diffraction phenomena of waves at different obstacles (slit, edge, double-slit etc.) are investigated.

In a further experiment, the principle of "phased array antennas" can be demonstrated. To do so, two circular waves are generated to interfere and the resulting interference pattern on varying the phase of one of the circular waves with respect to the other one is observed.

Tasks

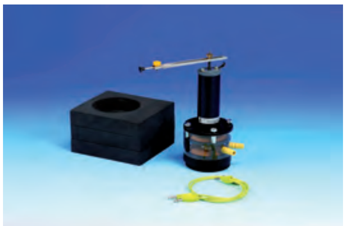
1. Use the comb to generate two circular waves and observe the resulting interference. Increase the number of interfering circular waves up to ten by using all teeth of the comb to demonstrate Huygens' Principle.
2. Generate plane water waves and use a barrier to demonstrate diffraction at an edge. Then, form a slit and observe diffraction behind the slit. Repeat this experiment for a double-slit.
3. By using the integrated wave generator as well as the external wave generator, generate two circular waves and observe the interference. Vary the phase of the external wave generator and observe the resulting interference pattern to understand the principle of "phased array antennas".

What you can learn about

- Diffraction of water waves
- Interference of waves
- Huygens' Principle
- Principle of "phased arrays antennas"
- Doppler effect

Main articles		
Ripple Tank with LED-light source, complete	11260-99	1
External vibration generator for ripple tank	11260-10	1

External vibration generator for ripple tank incl. stand



Function and applications

Optional accessory for ripple tank: second dipper for demonstrating interference patterns from waves that are not in phase.

Benefits

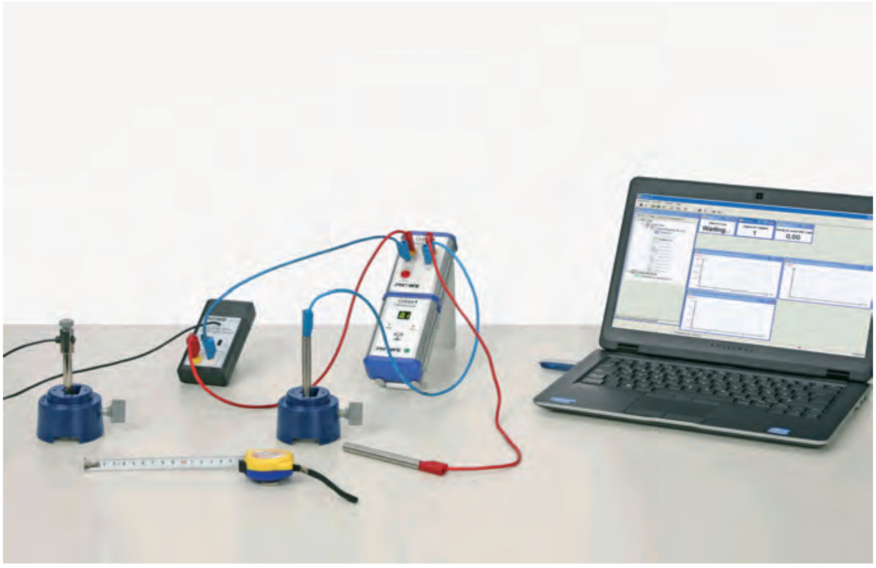
- Settings and power for this dipper come directly from the ripple tank
- No additional power supply needed
- Stand for the second dipper (padded foam base) is included in the set

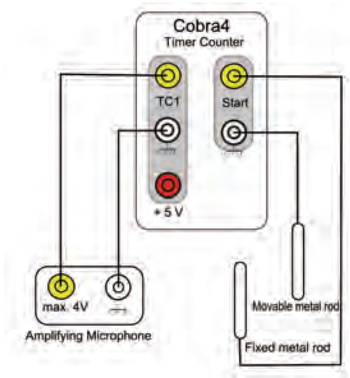
Equipment and technical data

- External vibration generator (dipper) for ripple tank on damped base

11260-10

P2153060 Measurement of the speed of sound in air with Cobra4





Circuit diagram.

Principle

The velocity of sound in air is determined by measurements of sound travel times.

Task

Determine the speed of sound in air.

What you can learn about

- Propagation of sound waves
- Velocity of sound
- Sound waves
- Sonic bang

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Timer/Counter	12651-00	1
Measuring microphone with amplifier	03543-00	1
Cobra4 Wireless Manager	12600-00	1
Barrel base PHYWE	02006-55	2
Support	09906-00	1

Related Experiments

Velocity of sound in air with Universal Counter

P2150305

Measurement of the speed of sound in various gases with Cobra4

P2153160

Measurement of the speed of sound in metal rods with Cobra4

P2153260

Measuring microphone with amplifier

Function and Applications

Electret capsule with 1.5 m long cable suitable for special investigations, e.g. point shaped plotting of soundfields.

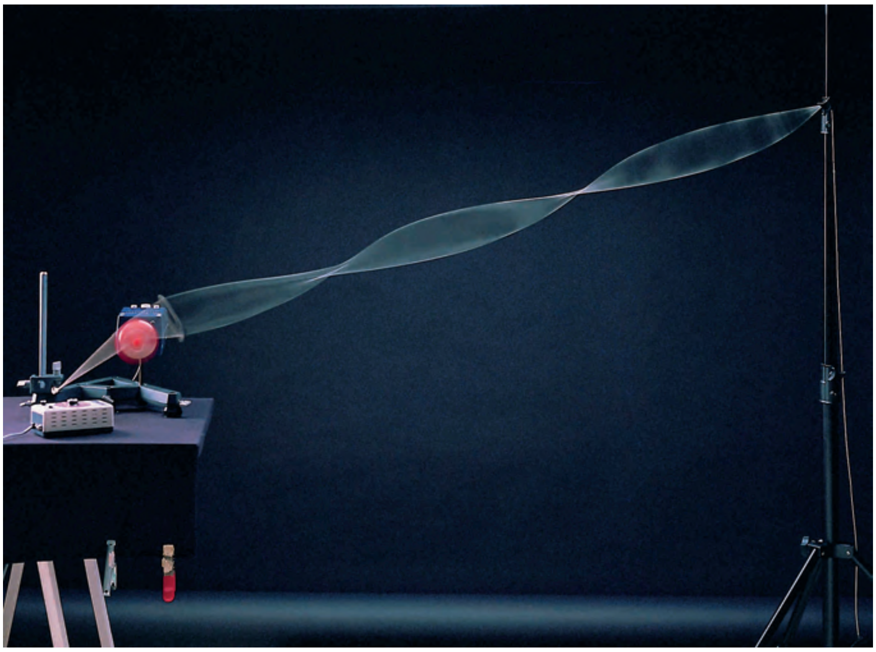
Equipment and technical data

- Frequency range 30 Hz ... 20 kHz
- Sensitivity 6.0 mV/Pa at 1 kHz
- Gain 0 ... 1000 in phase with sound signal
- Signal output 4V max. at 3 Ohm
- Dimensions: (mm) 120 x 25 x 60

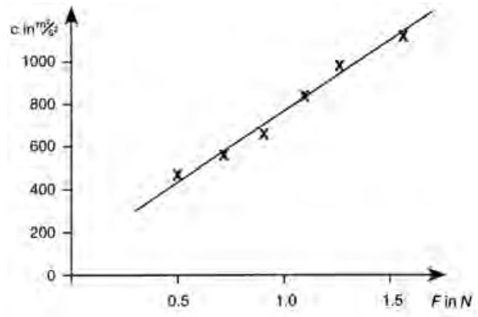
03543-00

Phase velocity of rope waves / waves of wires

P2133300



Demo



The square of phase velocity depending upon the force *F* applied on the rope.

Principle

A quadrangular rubber rope is inserted through the demonstration motor and a linear polarised fixed wave is generated. With the help of a stroboscope, the frequency and the wave length are determined. Then the phase velocity of ropewaves with a fixed tensile stress is ascertained. Subsequently, the mathematical relationship between the phase velocity of the rope and the tensile on the rope is examined.

Tasks

1. With constant tensile stress, the frequency f, which depends on the wavelength λ of the wave that propagates itself along the rope. The frequency is plotted as a function of $1/\lambda$. From this graph, the phase velocity c is determined.
2. The phase velocity c of the rope waves, which depends on the tensile stress on the rope is to be measured. The quadrant of the phase velocity is plotted as a function of tensile stress.

What you can learn about

- Wavelength
- Phase velocity
- Group velocity
- Wave equation
- Harmonic wave

Main articles

Laboratory motor, 220 V AC	11030-93	1
Digital stroboscope	21809-93	1
Gearing 10/1, for 11030.93	11028-00	1
Grooved wheel, after Hoffmann	02860-00	1
Spring balance 10 N	03060-03	1
Bench clamp PHYWE	02010-00	1

Laboratory motor, 220 V AC

Function and Applications

Laboratory motor fitted with noise suppression on stem, load independant rotation speed, electronically controlled.

Equipment and technical data:

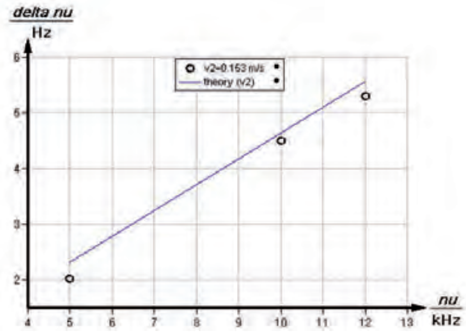
- Variable revolution: 0...9000 tpm
- Fixed revolution: 13000 tpm
- Clockwise and anticlockwise rotation.
- Maximum torque: 6 Ncm
- Maximum output power: 25 W
- Dimensions with stem (mm):190 x 180 x 85
- Stem length/diameter (mm): 110/10
- Support for additional gear box.

Accessories:

- spanner for pulley, allen key
- chuck for 6 mm and 10mm stems, Power: 220 V AC

11030-93

P2150405 Acoustic Doppler effect with universal counter



Comparison of the measured values with calculated values for a detector moving towards the emitter.

Principle

If an emitter of sound or a detector is set into motion relative to the medium of propagation, the frequency of the waves that are emitted or detected is shifted due to the Doppler effect.

Tasks

1. Measure the Doppler shift for varying frequencies and velocities for a moving sound emitter. Compare the measurements with the values predicted by theory and validate equation (4).
2. Measure the Doppler shift for varying frequencies and velocities for a moving detector. Compare the measurements with the values predicted by theory and validate equation (6).

Related Topics

- Wave propagation
- Doppler shift of frequency

Main articles		
Universal Counter	13601-99	1
Digital Function Generator, USB	13654-99	1
Car, motor driven	11061-00	1
Measuring microphone with amplifier	03543-00	1
Loudspeaker / Sound head, 8 ohms	03524-01	1
Light barrier, compact	11207-20	1
Track, l 900 mm	11606-00	1

Car, motor driven

Function and Applications

For the experimental investigation of uniform movements and introduction of the concept of speed.

Benefits

- Drive: integrated battery powered electric motor (with radio noise suppression).
- Sliding switch for continuous speed adjustment; forward and backward switches, 4-wheel drive
- Recess with clamping spring to attach holding bolt 03949.00
- Eccentric clamps to attach recording tape for recording timer 11607.00.

Equipment and technical data

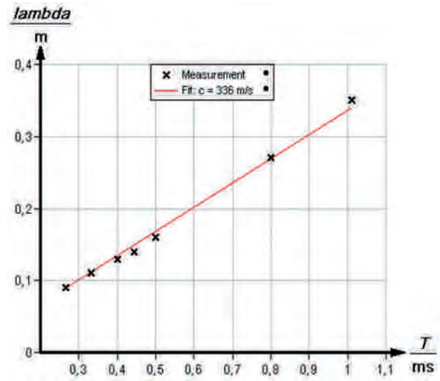
- Same chassis as measurement and experimenting car 11060.00.
- Dimensions without wheels (mm): 114×53×64.

11061-00

Velocity of sound using Kundt's tube and digital function generator

P2150605

NEW · Cobra 4 · Demo



Determination of the velocity of sound at a tube length of *l* = 615 mm.

Principle

Cork dust in a glass tube is set into tiniest motion by a sound wave. If the frequency of the sound wave matches the natural frequency of the volume in the glass tube, a standing wave will form. The corc dust then assembles in visible patterns that show the nodes of pressure and motion of the standing wave. From the length of the volume and the number of the nodes the velocity of sound in the tube can be calculated for each natural frequency.

Tasks

Determine the velocity of sound in air using Kundt's tube at different lengths of volume.

What you can learn about

- Longitudinal waves
- Sound velocity in gases
- Frequency; Natural frequency
- Wavelength; Stationary waves

Main articles		
LF amplifier, 220 V	13625-93	1
Digital Function Generator, USB	13654-99	1
Loudspeaker / Sound head, 8 ohms	03524-01	1
Tripod base PHYWE	02002-55	3
Kundt's apparatus	03475-88	1
Thermometer -10...+50 °C	38034-00	1
Screened cable, BNC, l 750 mm	07542-11	1

LF amplifier, 220 V

Function and Applications

For amplifying direct and alternating voltage up to 100 kHz. Can be used for induction experiments and for examining acoustic and electromagnetic fields. Signal output for the amplified measured signal.

Benefits

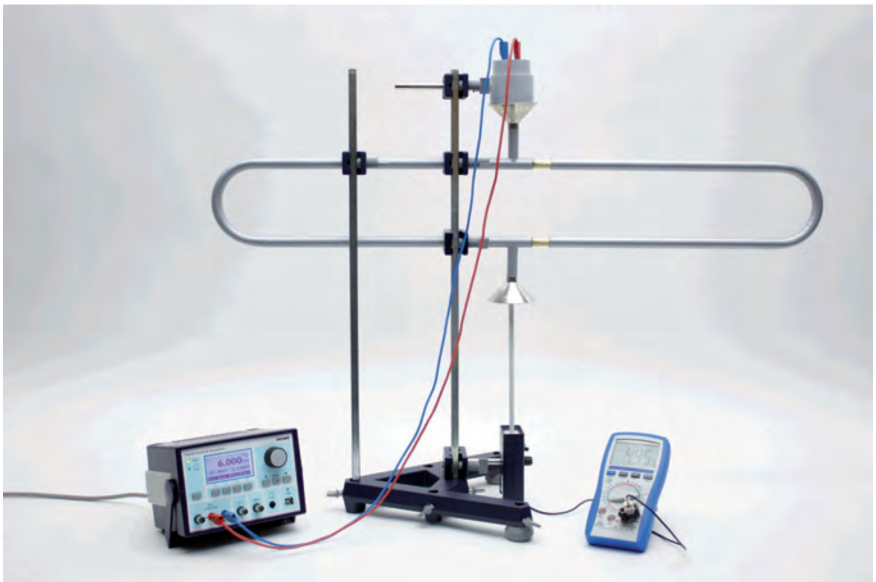
- Effective value output for display of the effective value of the signal output voltage.
- Power amplifier 12.5 W for weak acoustic frequency signals to control low resistance loudspeakers.
- For signals from frequency generators or computer interfaces.
- Amplification is continuously adjustable.

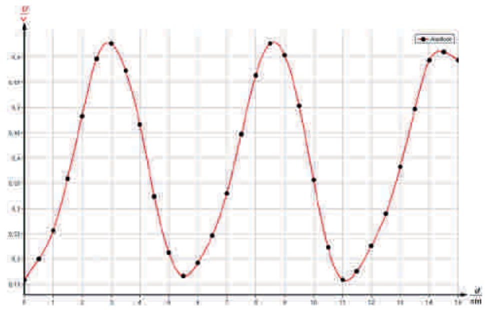
Equipment and technical data

- Ampl. factor: 0.1...10000, continuously adjustable
- Input impedance: 50 kOhm/ AC, 100 kOhm/ D
- Input voltage: -10 V...+10 V; Frequency range: 3.5 Hz....200 kHz,

13625-93

P2150702 Wavelengths and frequencies with a Quincke tube with digital function generator





Sample measurement at a frequency of f = 3000 Hz.

Principle

When a sound wave of a particular frequency is divided into two coherent components (like, for example, light waves in an interferometer experiment), and if the path of one of the component waves is altered, it is possible to calculate the wavelength of the sound wave and its frequency from the interference phenomena recorded with a microphone.

Tasks

1. Record the extension of a Quincke tube for given frequencies in the range 2000 Hz to 6000 Hz.
2. Calculate the frequencies from the wavelengths determined and compare them with the given

What you can learn about

- Transverse and longitudinal waves
- Wavelength
- Amplitude
- Frequency
- Phase shift
- Interference
- Velocity of sound in air
- Loudness
- Weber-Fechner law

Main articles		
Digital Function Generator, USB	13654-99	1
Interference tube, Quincke type	03482-00	1
Measuring microphone	03542-00	1
Loudspeaker / Sound head, 8 ohms	03524-01	1
Digital multimeter 2010	07128-00	1
Vernier calliper	03010-00	1
Support rod PHYWE,square, l 630mm	02027-55	2

Interference tube, Quincke type

Function and Applications

To determine sound wave lengths and frequencies through interference of sound waves in air.

Equipment and technical data

- Interference tube with three mounting clamps.
- Length: 300 mm.
- Scale with cm-division.
- Frequencies: 2...5 kHz.

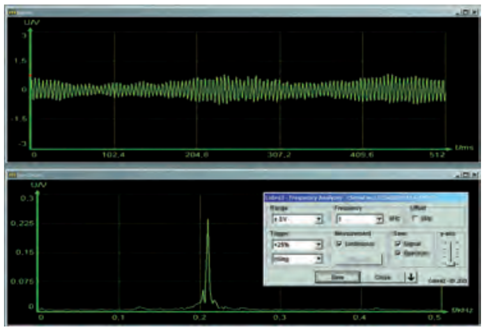
Accessories

- Sound head (03524-00).
- Measuring microphone (03542-00).

03482-00

Resonance frequencies of Helmholtz resonators with Cobra3 P2150811

Demo



Time signal, spectrum and parameter settings for measurements on the empty 1000 ml round-bottomed flask.

Principle

Acoustic cavity resonators posses a characteristic frequency which is determined by their geometrical form. In this case the resonator is excited to vibrations in its resonance frequency by background noise.

Task

Determination of different resonance frequencies of a resonator depending on the volume.

What you can learn about

- Cavity resonator
- Resonance frequency
- Acoustic resonant circuit

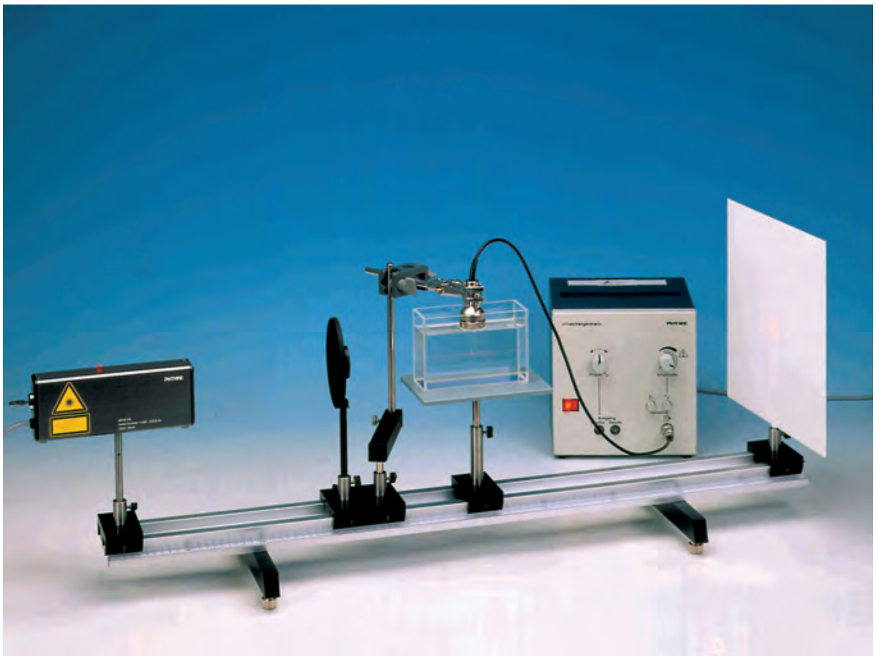
Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Measuring microphone with amplifier	03543-00	1
Tripod base PHYWE	02002-55	1
Software Cobra3 - Fourier analysis	14514-61	1
Power supply 12V / 2A	12151-99	1
Long-neck round-bott.flask 1000ml	36050-00	1
Glass tube,diam 12mm l 300 mm	45126-01	1

Cobra4 Experiment - available 2014

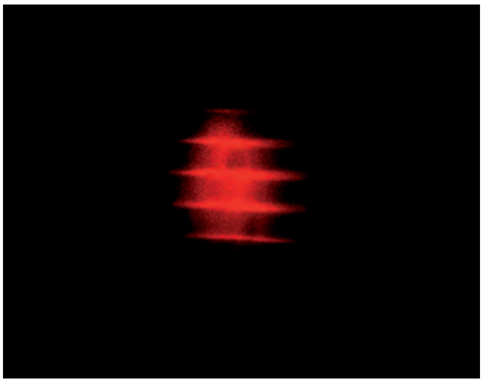
Resonance frequencies of Helmholtz resonators with Cobra4

P2150860

P2151000 Optical determination of the velocity of sound in liquids



Demo



Resulting diffraction pattern on the screen.

Principle

A stationary ultrasonic wave in a glass cell full of liquid is traversed by a divergent beam of light. The sound wave length can be determined from the central projection of the sound field on the basis of the refractive index which changes with the sound pressure.

Tasks

1. To determine the wavelength of sound in liquids.
2. From this calculate the sound velocity, from the structure of the centrally projected image.

What you can learn about

- Ultrasonics
- Sound velocity
- Frequency
- Wavelength
- Sound pressure
- Stationary waves

Main articles		
Ultrasonic generator	13920-99	1
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Glass cell, 150x55x100 mm	03504-00	1
Optical profile-bench, l 1000mm	08282-00	1
Screen, metal, 300 x 300 mm	08062-00	1
Swinging arm	08256-00	1
Slide mount for optical bench, h = 80 mm	08286-02	1

Ultrasonic generator

Function and Applications

Ultrasonic generator for sine- and pulse operation for experimentation with wave phenomena and run time measurements, for exemplatory technical applications e.g. ultrasonic welding.

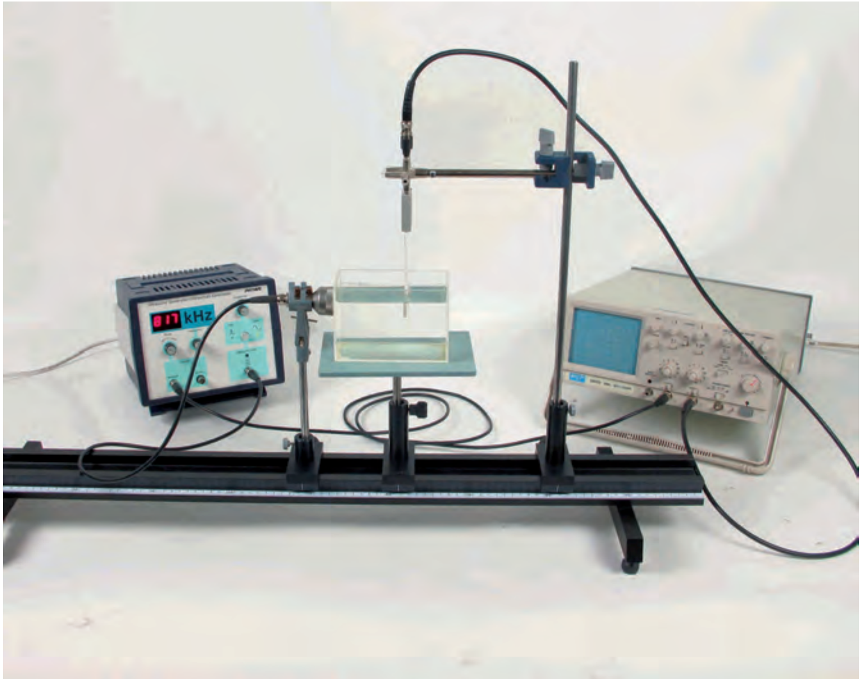
Equipment and technical data

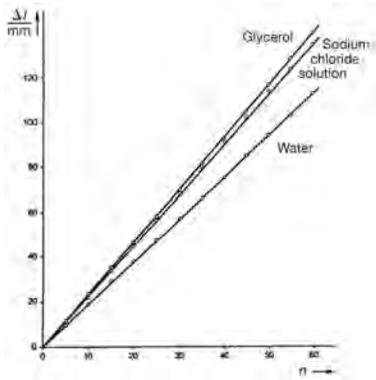
- With 3-digit LED for frequency and adjustable frequency for optimisation experiments and exactly determination of wave length under different experimental conditions.
- Monitor- and trigger-outputs with BNC sockets for phase determination with an oscilloscope.
- Robust plastic housing, Including: sealed sound head
- Frequency range (Sinus): 780...820 kHz
- Maximum sound output power: 16 W
- Puls repetition frequency: 500 Hz
- Puls duration: 3 µs, Supply voltage: 110...240 V AC
- Dimensions, H × W × D (mm): 170 × 232 × 260, Mass: 3.67 kg

13920-99

Phase and group velocity of ultrasound in liquids

P2151100





Detector displacement l as a function of the number n of wavelengths covered, for water, glycerol and sodium chloride solution (temperature = 25 °C).

Principle

The sound waves transmitted to a liquid by the ultrasonic generator are picked up by a piezoelectric ultrasonic pick-up and the signal from transmitter and receiver compared on an oscilloscope.

The wavelength is determined and the phase velocity calculated from the relative phase position of the signals.

The group velocity is determined from measurements of the sound pulse delay time.

Tasks

The signals from the ultrasonic generator and the ultrasonic pick-up are recorded on the oscilloscope.

1. To measure the relative phase position of the signal from the ultrasonic pick-up as a function of its distance from the ultrasonic generator (which is in the sine mode), and to determine the ultrasonic wavelength and the phase velocity when the frequency is known.
2. To determine the oscilloscope's coefficient of sweep with the aid of the ultrasonic frequency.
3. With the generator in the pulsed mode, to record the delay time of the sound pulses as a function of the distance between a generator and the pick-up, and to determine the group velocity.

What you can learn about

- Longitudinal waves
- Velocity of sound in liquids
- Wavelength
- Frequency
- Piezoelectric effect
- Piezoelectric ultrasonics transformer

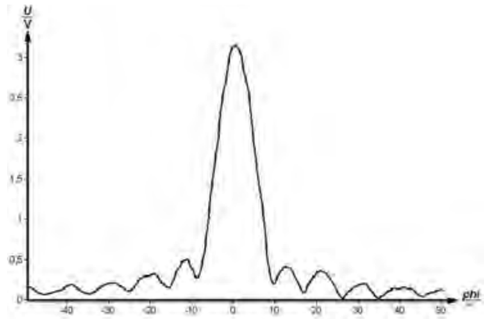
Main articles		
Ultrasonic generator	13920-99	1
Ultrasonic pickup	13920-00	1
30 MHz digital storage oscilloscope	11462-99	1
Glass cell, 150x55x100 mm	03504-00	1
Optical profile bench l = 60 cm	08283-00	1
Slide mount for optical bench, h = 80 mm	08286-02	1
Base for optical bench, adjustable	08284-00	2

Related Experiment

Temperature dependence of the velocity of ultrasound in liquids

P2151200

P2151515 Ultrasonic diffraction at different single and double slit systems



The angular distribution of the intensity of a plane ultrasonic wave diffracted at a slit.

Principle

A plane ultrasonic wave is subjected to diffraction at single slits of various widths and at various double slits. The intensity of the diffracted and interfering partial waves are automatically recorded using a motordriven, swivel ultrasound detector and a PC.

Tasks

1. Record the intensity of an ultrasonicwave diffracted by various single slits and double slits as a function of the diffraction angle.
2. Determine the angular positions of the maximum and minimum values and compare them with the theoretical values.

What you can learn about

- Huygens principle
- Longitudinal waves
- Interference
- Fraunhofer and Fresnel diffraction

Main articles		
Goniometer with reflecting mirror	13903-00	1
Goniometer Operation Unit	13903-99	1
Ultrasound operation unit	13900-00	1
Object holder for goniometer	13904-00	1
Ultrasonic transmitter	13901-00	1
Ultrasonic receiver on stem	13902-00	1
Diffraction objects f.ultrasonic	13905-00	1

Related Experiments

Ultrasonic diffraction at different multiple slit systems

P2151615

Diffraction of ultrasonic waves at a pin hole and a circular obstacle

P2151715

Goniometer Operation Unit

Function and Applications

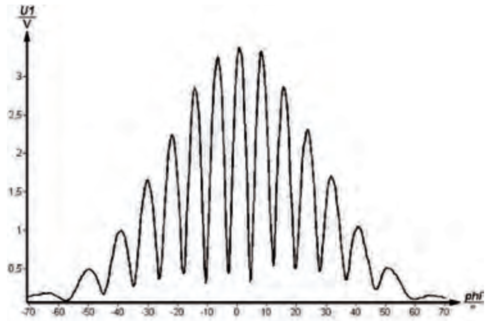
Microprocessor controlled operation unit for goniometer in failsafe housing to control the goniometer angle and recording of detector signals, with RS232 PC interface.

Benefits

- For manual, programmable and PC-operation.
- Red 7-segment LED to display goniometer angle, start/stop angle, angle velocity and angle stepwidth.
- Two up/down buttons, auto modestart button, quick-calibration button, step motor interface DIN socket, cable included.
- BNC-socket for input signal.
- 4 mm sockets for xy-recorder connection.
- Reproduction of measurements just by pressing one button.

13903-99

Interference by two identical ultrasonic transmitters P2151915



Angular distribution of the intensity of two interfering ultrasonic waves having the same phase, amplitude, frequency and direction of propagation.

Principle

Ultrasonic waves of the same frequency, amplitude and direction of propagation are generated by two sources of sound positioned parallel to each other. The sources can vibrate both in-phase and out-of phase. The angular distribution of the intensity of the waves, which interfere with each other, is automatically recorded using a motor-driven, swivel ultrasound detector and a PC.

Tasks

1. Determine the angular distribution of two sources of ultrasound vibrating in phase.
2. Determine the angular positions of the interference minima and compare the values found with those theoretically expected.
3. Repeat the measurements with the two sources of ultrasound vibrating out of-phase.

What you can learn about

- Huygens principle; Longitudinal waves; Interference

Main articles		
Goniometer with reflecting mirror	13903-00	1
Goniometer Operation Unit	13903-99	1
Ultrasound operation unit	13900-00	1
Ultrasonic transmitter	13901-00	2
Ultrasonic receiver on stem	13902-00	1
Power supply 5 VDC/2.4 A	13900-99	1
Software Goniometer	14523-61	1

Related Experiments

Stationary ultrasonic waves - determination of wavelength
P2151300

Absorption of ultrasound in air
P2151400

Ultrasonic diffraction at a Fresnel zone plate / structure of a Fresnel zone
P2151800

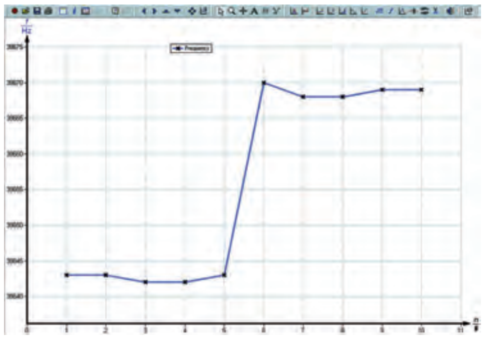
Interference of ultrasonic waves by a Lloyd mirror
P2152000

Determination of the ultrasonic velocity (sonar principle)
P2152115

Ultrasonic Michelson interferometer
P2152200

Ultrasonic diffraction by a straight edge
P2152300

P2152415 Ultrasonic Doppler effect with Cobra3



Doppler shift of frequency.

Principle

If a source of sound is in motion relative to its medium of propagation, the frequency of the waves that are emitted is displaced due to the Doppler effect.

Tasks

The frequency changes are measured and analysed for different relative velocities of source and observer.

What you can learn about

- Propagation of sound waves
- Superimposition of sound waves
- Doppler shift of frequency
- Longitudinal waves

Main articles

Cobra3 BASIC-UNIT, USB	12150-50	1
Ultrasound operation unit	13900-00	1
Car, motor driven	11061-00	1
Ultrasonic transmitter	13901-00	1
Ultrasonic receiver on stem	13902-00	1
Light barrier, compact	11207-20	1
Track, l 900 mm	11606-00	1

Cobra4 Experiment - available 2014

Ultrasonic Doppler effect with Cobra4

P2152460

Ultrasound operation unit

Function and Applications

Ultrasound operation unit.

Benefits

- Microprocessor controlled quartz-stabilised operation unit for ultrasonic transmitter and receiver.
- Adjustable output amplitude, 2 DIN sockets, one with 180° phaseshift, continuous and burst mode operation.
- 1 synchronous BNC output for delay time measurement.
- Input signal amplifier with 3 main amplifications and fine adjustment with one BNC-socket for oscilloscope and 4 mm sockets for XY-recorder.
- Overload warning LED allows adaption of ultrasound intensity to the experiment.
- Ideally suited for ultrasound experiments with large distances between transmitter and receiver, e.g. Doppler-effect with ultrasound.
- Fail-safe housing.

13900-00

Ultrasonic echography (A-Scan)

P5160200

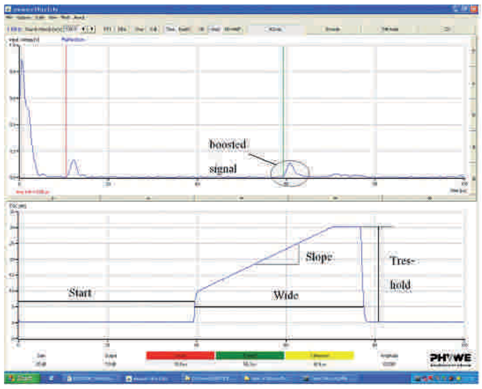


Illustration of the effects of the amplifier or booster settings on the diagram.

Principle

An ultrasonic wave transmitted in a sample will be reflected at discontinuities (defects, cracks). From the relationship between the time of flight of the reflected wave and the sound velocity, the distance between ultrasonic transducer and defects (reflector) can be calculated. Position and size of these defects can be determined by measuring in different directions.

Tasks

1. Measure the longest side of the block with the calliper and the time off light of ultrasound wave for this distance with the 2 MHz probe.
2. Calculate the sound velocity.
3. Measure the position and the size of the different defects of the test block with the calliper and the ultrasound echography method.

What you can learn about

- Propagation of ultrasonic waves
- Time of flight
- Echo amplitude
- Reflection coefficient
- A-scan
- Flaw detection
- Non destructive testing (NDT)
- Ultrasonic transceiver

Main articles		
Basic Set Ultrasonic echoscope	13921-99	1
Vernier calliper	03010-00	1

Related Experiments

Ultrasonic echography (B-Scan)

P5160300

Frequency dependence of resolution power

P5160700

Basic Set Ultrasonic echoscope

Function and Applications

With the ultrasonic echoscope the basics of ultrasound and its wave characteristics can be demonstrated. Terms like amplitude, frequency, sound velocity or Time Gain Control TGC will be explained.
The cylinder set can be used to vividly demonstrate reflection as well as sound velocity and frequency depending on attenuation in solid state materials.
The knowledge e.g. regarding sound velocity will be used to measure the test block.
The principles of image formation from A-scan to B-scan can be explained. With the different probes the frequency depending resolution can be evaluated.

13921-99

Velocity of ultrasound in solid state material

P5160100

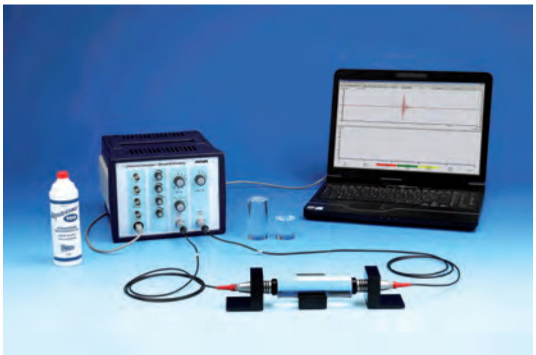
Principle

The velocity of sound in acrylics shall be determined by time of flight reflection technique with an ultrasonic echoscope. The measurements are done by reflection method, on three cylinders of different length. Two measurement series are carried out with ultrasonic probes of different frequencies.

For more details refer to page 221.

Attenuation of ultrasound in solid state materials

P5160800



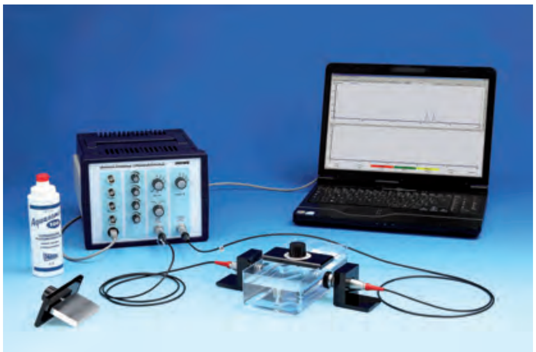
Principle

The damping of ultrasound in solid objects is determined for 2 (or optionally 3) different frequencies in the transmission mode. The resulting values are then compared to the corresponding literature values. In addition, the frequency dependence of the damping effect is analysed. Furthermore, the sound velocity in acrylic objects is determined for 2 (or optionally 3) different frequencies in the transmission mode.

For more details refer to page 222.

Shear waves in solid state materials

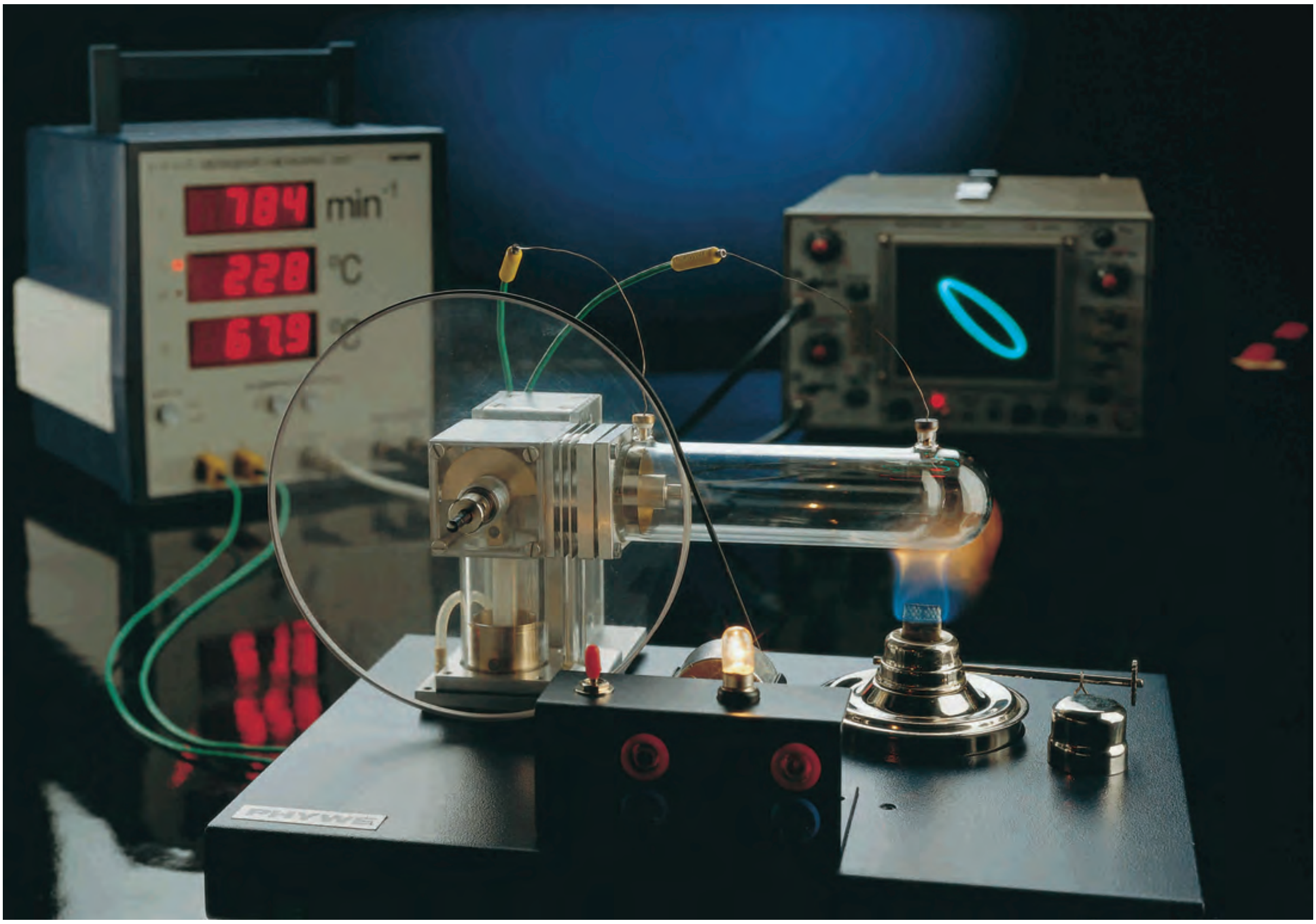
P5160900



Principle

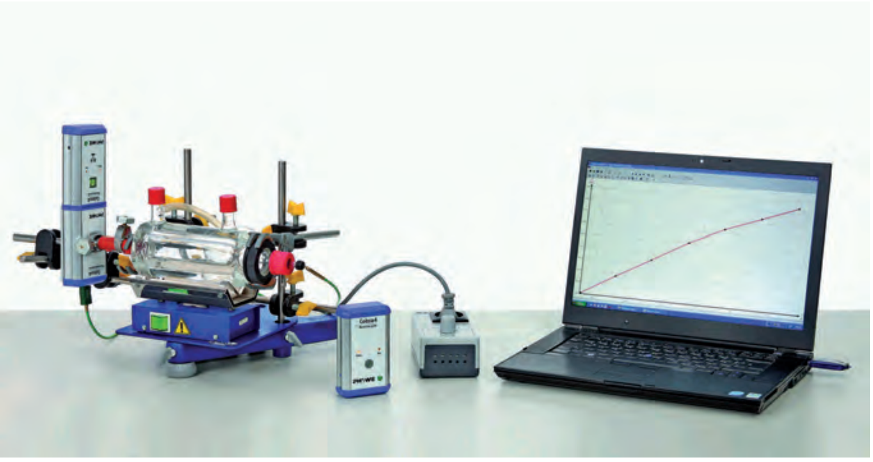
The aim of this experiment is to study the generation and propagation of ultrasound waves in solid objects. In addition, the additional generation of transverse wave modes (shear wave modes) resulting from an oblique angle of incidence should be identified and the sound velocities for the longitudinal and transverse component should be determined. The relationship between the coefficients of elasticity of the material and its sound velocities enables the determination of the magnitude of the coefficients.

For more details refer to page 223.



Thermodynamics

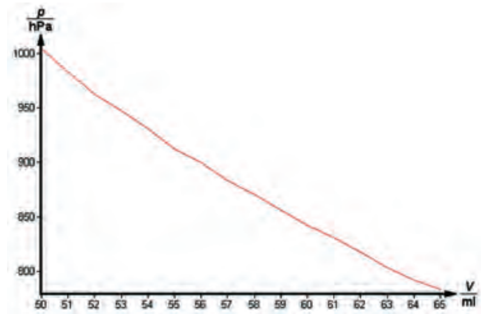
P2320160 Equation of state for ideal gases with Cobra4



NEW

Cobra4

Demo



Correlation between volume and pressure under isothermic conditions.

Principle

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the general equation of state. For achange of state under isochoric conditions this equation becomes Amontons'law. In this experiment it is investigated whether Amontons' law is valid for a constant amount of gas (air).

Tasks

- For a constant amount of gas (air) investigate the correlation of

1. Volume and pressure at constant temperature (Boyle and Mariotte's law)
2. Volume and temperature at constant pressure (Gay-Lussac's law)
3. Pressue and temperature at constant volume (Charles' (Amontons' law))

- From the relationships obtained calculate the universal gas constant as well as the coefficient of thermal expansion, the coefficient of thermal tension, and the coefficient of cubic compressibility.

What you can learn about

- Thermal tension coefficient
- General equation of state for ideal gases
- Universal gas constant
- Amontons' law

Main articles		
Set Gas laws with glass jacket & Cobra4	43020-00	1
Cobra4 Remote-Link	12602-00	1
Power regulator	32288-93	1

Cobra4 Experiments

Gay-Lussac's law with Cobra4

P3011160

Amontons' law with Cobra4

P3011260

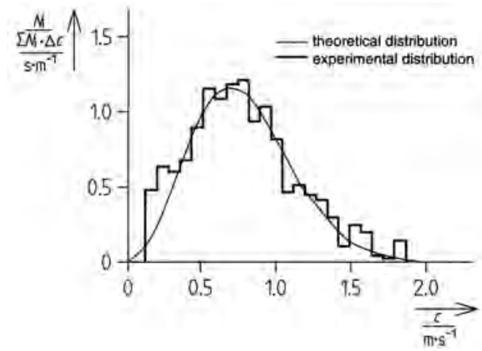
Boyle's law with Cobra4

P3011360

Maxwellian velocity distribution

P2320300

Demo



Experimental and theoretical velocity distribution in the model experiment.

Principle

By means of the model apparatus for kinetic theory of gases the motion of gas molecules is simulated and the velocities determined by registration of the throw distance of the glass balls. This velocity distribution is compared to the theoretical Maxwell-Boltzmann equation.

Tasks

1. Measure the velocity distribution of the "model gas".
2. Compare the result to theoretical behaviour as described by the Maxwell- Boltzmann distribution.
3. Discuss the results.

What you can learn about

- Kinetic theory of gases
- Temperature
- Gas- molecules
- Model kinetic energy
- Average velocity
- Velocity distribution

Main articles		
Kinetic gas theory apparatus	09060-00	1
Digital stroboscope	21809-93	1
Receiver with recording chamber	09061-00	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Tripod base PHYWE	02002-55	2
Stopwatch, digital, 1/100 s	03071-01	1
Glass beaker DURAN®, tall, 50 ml	36001-00	5

measure Dynamics experiment - available 2014

Maxwellian velocity distribution with measure Dynamics

P2320380

Power supply variable 15 VAC/ 12 VDC/ 5 A

Function and Applications

Standard heavy duty power supply unit for low voltage.

Supplies unit for continuously adjustable DC and AC voltages & 2 frequently required fixed voltages.

Equipment and technical data

- AC output: 0...15 V/5 A
- DC output: 0...12 V/5 A
- Max. current (short term): 10 A
- Add. fixed voltages: 6 V AC/6 A12 V AC/6 A
- Max. current (short term): 10 A
- Max. power: 150 VA
- Fuses: one 6 A and two 10 A
- Supply voltage: 230 V AC
- dimensions (mm): 230 x 236 x 168

13530-93

Vapour pressure of water at high temperature — P2340100

Principle

The high-pressure steam apparatus makes it possible to measure steam pressure in a temperature range of 100-250°C. This allows for investigations to be performed on real gases and vapours. Typical equilibrium states between gas and liquid phases can be set up. For this purpose, water is heated in a closed pressure chamber at constant volume. The heat of vaporisation is determined at various temperatures from the measurement of vapour pressure as a function of temperature.

For more details refer to page 93.

Vapour pressure of water below 100°C - molar heat of vaporisation — P2340200

Principle

The vapour pressure of water in the range of 40°C to 85°C is investigated. It is shown that the Clausius-Clapeyron equation describes the relation between temperature and pressure in an adequate manner. An average value for the heat of vaporization of water is determined.

For more details refer to page 94.

Barometric height formula — P2140700

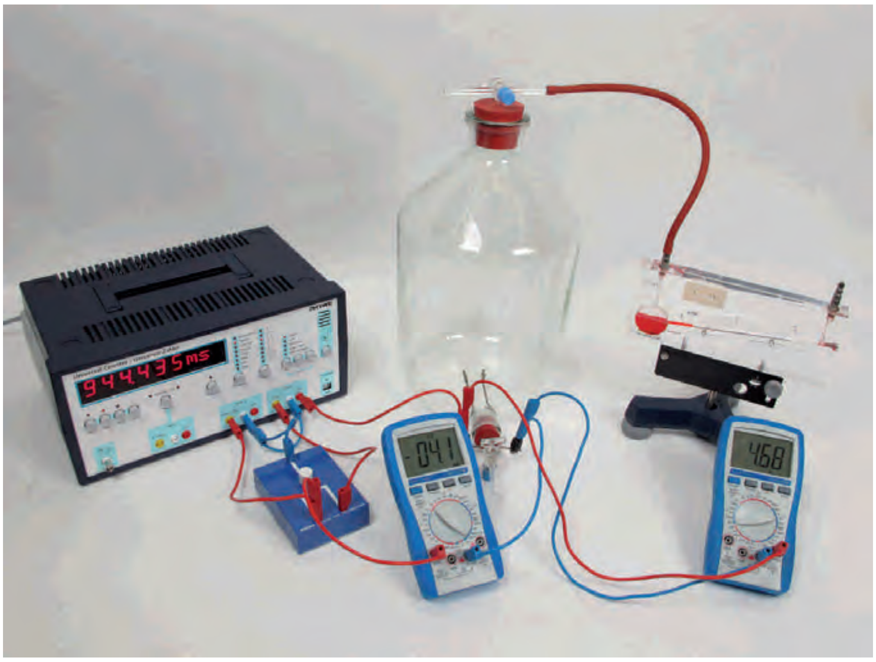
Principle

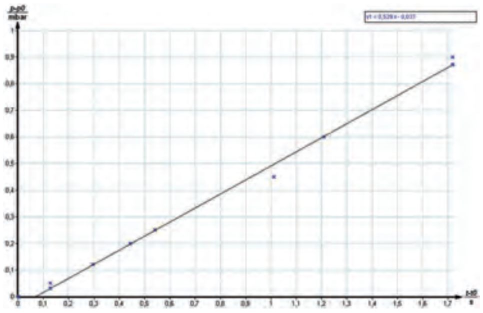
Glass or steel balls are accelerated by means of a vibrating plate, and thereby attain different velocities (temperature model). The particle density of the balls is measured as a function of the height and the vibrational frequency of the plate.

For more details refer to page 44.

Heat capacity of gases

P2320201





Pressure change p as a function of the heat-up time t. U = 4.59 V, I = 0.43 A.

Principle

Heat is added to a gas in a glass vessel by an electric heater which is switched on briefly. The temperature increase results in a pressure increase, which is measured with a manometer. Under isobaric conditions a temperature increase results in a volume dilatation, which can be read from a gas syringe. The molar heat capacities C_V and C_p are calculated from the pressure or volume change.

Task

Determine the molar heat capacities of air at constant volume C_V and at constant pressure C_p.

What you can learn about

- Equation of state for ideal gases
- First law of thermodynamics
- Universal gas constant
- Degree of freedom
- Mole volumes
- Isobars
- Isotherms
- Isochors and adiabatic changes of state

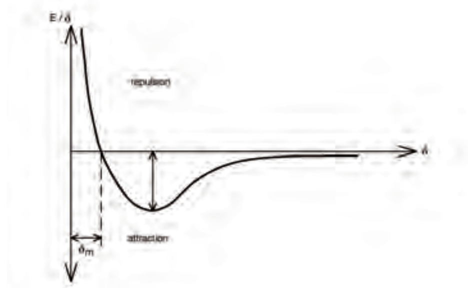
Main articles		
Universal Counter	13601-99	1
Precision manometer	03091-00	1
Weather station, wireless	04854-00	1
Mariotte flask, 10 l	02629-00	1
Tripod base PHYWE	02002-55	1
Digital multimeter 2010	07128-00	2
Two-way switch, single pole	06030-00	1

Cobra4 Experiment

Heat capacity of gases with Cobra4

P2320260

P2320400 Thermal equation of state and critical point



p-V-isotherms of ethane.

Principle

A substance which is gaseous under normal conditions is enclosed in a variable volume and the variation of pressure with the volume is recorded at different temperatures. The critical point is determined graphically from a plot of the isotherms.

Tasks

1. Measure a number of p-V isotherms of ethane.
2. Determine the critical point and the critical quantities of ethane.
3. Calculate the constants of the Van der Waals equation, the Boyle temperature, the radius of the molecules and the parameters of the interaction potential.

What you can learn about

- Ideal gases; Real gases
- Equations of state
- Van der Waals equation; Boyle temperature
- Critical point
- Interaction potential
- Molecule radius

Main articles

Critical point apparatus	04364-10	1
Rotary valve vacuum pump, one stage	02740-95	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Oil mist filter, DN 16 KF	02752-16	1
Secure bottle, 500 ml, 2 x Gl 18/8, 1 x 25/12	34170-01	1
Bath for thermostat, makrolon	08487-02	1
Adapter for vacuum pump	02657-00	1

Critical point apparatus

Function and Applications

Critical point apparatus with transparent compression chamber on three legged base, pressure measurement-, generation- and cooling system, two gas valves.

Equipment and technical data

- Temperature range: 0...55 °C
- Pressure range: 0...50 bar, 0.5 bar division
- Volume range: 0...4 ml, 0.05 ml division

04364-10

Adiabatic coefficient of gases – Flammersfeld oscillator

P2320500

Argon	χ =	1.62 ± 0.09
Nitrogen	χ =	1.39 ± 0.07
Carbon dioxide	χ =	1.28 ± 0.08
Air	χ =	1.38 ± 0.08

Sample results for the adiabatic coefficients. Experimental conditions: ten measurements, each of about n = 300 oscillations.

Principle

A mass oscillates on a volume of gas in a precision glass tube. The oscillationis maintained by leading escaping gas back into the system. The adiabatic coefficient of various gases is determined from the periodic time of the oscillation.

Tasks

Determine the adiabatic coefficient of air nitrogen and carbon dioxide (and also of argon, if available) from the periodic time of the oscillation T of the mass m on the volume V of gas.

What you can learn about

- Equation of adiabatic change of slate
- Polytropic equation
- Rüchardt's experiment
- Thermal capacity of gases

Main articles

Steel cylinder,CO2, 10l, full	41761-00	1
Steel cylinder,nitrogen,10l, full	41763-00	1
Light barrier with counter	11207-30	1
Gas oscillator, Flammersfeld	04368-00	1
Sliding weight balance, 101 g / 0.01 g	44012-01	1
Reducing valve for CO2 / He	33481-00	1
Reducing valve f.nitrogen	33483-00	1

Gas oscillator, Flammersfeld

Function and Applications

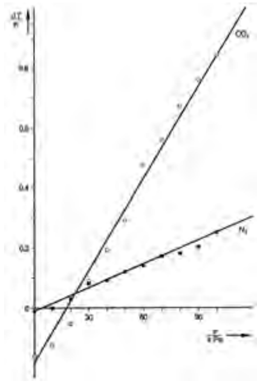
For determination of the adiabatic coefficient with Rüchardt's method.

Equipment and technical data

- Gas oscillator.
- Glass vessel capacity: 1 l.
- Precision tube diameter: 12 mm.
- Oscillating body.

04368-00

P2320600 Joule-Thomson effect



Temperature differences measured at various ram pressures.

Principle

A stream of gas is fed to a throttling point, where the gas (C02 or N2) undergoes adiabatic expansion. The differences in temperature established between the two sides of the throttle point are measured at various pressures and the Joule-Thomson coefficients of the gases in question are calculated.

Tasks

1. Determination of the Joule-Thomson coefficient of C02.
2. Determination of the Joule-Thomson coefficient of N2.

What you can learn about

- Real gas
- Intrinsic energy; Gay-Lussac theory
- Throttling
- Van der Waals equation; Van der Waals force
- Inverse Joule-Thomson effect
- Inversion temperature

Main articles		
Temperature meter digital, 4-2	13617-93	1
Joule-Thomson apparatus	04361-00	1
Steel cylinder,C02, 10l, full	41761-00	1
Steel cylinder,nitrogen,10l, full	41763-00	1
Gas-cylinder Trolley for 2 Cyl.	41790-20	1
Temp. probe, immersion type, Pt100	11759-01	2
Reducing valve for C02 / He	33481-00	1

Joule-Thomson apparatus

Function and Applications

Joule-Thompson apparatus.

Benefits

- Frame with pressure gauge and a spiral of coppercapillary tube.
- Plastic-coated glass tube with a throttle body and 2 measurement points for Pt-100-temperature sensor.

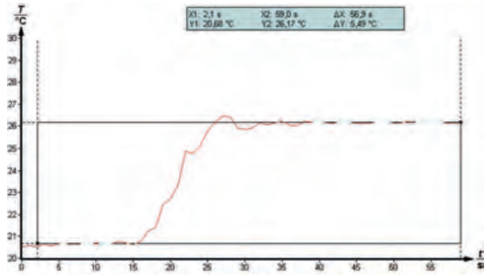
Equipment and technical data

- Pressure range 0 .. 0.1 MPa, Division 5 kPa
- Tube length / diameter. (Mm): 250/46
- Copper coil 37.5 m / 132 coils
- 1 m pressure hose, Hose clamps

04361-00

Heat capacity of metals with Cobra4

P2330160



Course of temperature in the calorimeter. For 180 g Iron (100 °C) and 200 g water (room-temperature).

Principle

Heated specimens are placed in a calorimeter filled with water at low temperature. The heat capacity of the specimen is determined from the rise in the temperature of the water.

Tasks

1. To determine the specific heat capacity of aluminium, iron and brass.
2. To verify Dulong Petit's law with the results of these experiments.

What you can learn about

- Mixture temperature
- Boiling point
- Dulong Petit's law
- Lattice vibration
- Internal energy
- Debye temperature

Main articles

Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
Compact Balance, 500 g / 0.1 g	49243-93	1
Support base DEMO	02007-55	1
Calorimeter vessel, 500 ml	04401-10	1

Related Experiment

Heat capacity of metals

P2330101

Calorimeter vessel, 500 ml

Function and Applications

E. g. for determining thermal conductivities of solid state bodies.

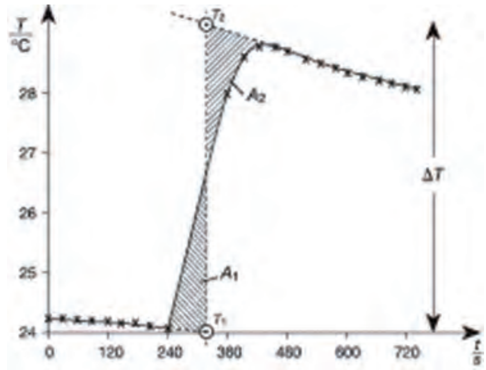
Equipment and technical data

- Aluminium vessels imbedded in plastic.
- Containers with Styrofoam thermal insulation.
- The calorimeter vessel with thermal conductivity connection sleeve has a cylindrical recess at the bottom which can receive a thermal conductivity rod.
- Dimensions: diameter: 130 mm, height: 120 mm.

04401-10

P2330200 Mechanical equivalent of heat

Demo



Temperature-time diagram for a measurement example.

Principle

In this experiment, a metal test body is rotated and heated by the friction due to a tensed band of synthetic material.The mechanical equivalent of heat for problem 1 is determined from the defined mechanical work and from the thermal energy increase deduced from the increase of temperature. Assuming the equivalence of mechanical work and heat, the specific thermal capacity of aluminium and brass is determined.

Tasks

1. Determination of the mechanical equivalent of heat.
2. Determination of the specific thermal capacity of aluminum and brass.

What you can learn about

- Mechanical equivalent of heat
- Mechanical work
- Thermal energy
- Thermal capacity
- First law of thermodynamics
- Specific thermal capacity

Main articles		
Mechanical equiv.of heat app.	04440-00	1
Friction cylinder CuZn, m 1.28 kg	04441-02	1
Spring balance 100 N	03060-04	1
Friction cylinder Al, m 0.39 kg	04441-03	1
Spring balance 10 N	03060-03	1
Bench clamp PHYWE	02010-00	1
Commercial weight, 2000 g	44096-78	1

Cobra4 Experiment - available 2014

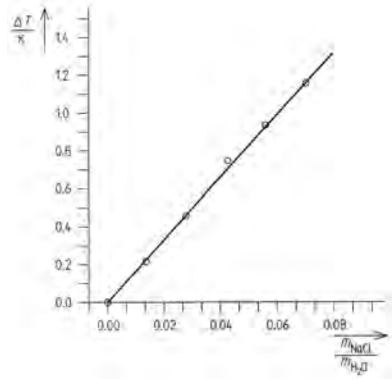
Mechanical equivalent of heat with Cobra4

P2330260

Boiling point elevation

P2340300

Demo



Example of a measurement: boiling point increase as function of concentration of table salt in an aqueous solution.

Principle

The boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

Exercises

1. Measure the increase in boiling point of water as a function of the concentration of table salt, urea and hydroquinone.
2. Investigate the relationship between the increase in boiling point and the number of particles.
3. Determine the molar mass of the solute from the relationship between the increase in boiling point and the concentration.

What you can learn about

- Raoult's law, Henry's law
- Ebullioscopic constants
- Chemical potential
- Gibbs-Helmholtz equation
- Concentration ratio
- Degree of dissociation

Main articles		
Temperature meter digital, 4-2	13617-93	1
Heating mantle f. roundbottom flask,250ml	49542-93	1
Apparatus for elevation of boiling point	36820-00	1
Power regulator	32288-93	1
Temp. probe, immersion type, Pt100	11759-01	1
Pellet press for calorimeter	04403-04	1

Temperature meter digital, 4-2

Function and Application

Modern, user-friendly designed instrument for measuring temperature and temperature differences at four different measuring points.

Benefits

- Two demonstrative 4 digit LED display (+ sign), with 20 mm high digits for presentation of the values measured at the selected measuring points.
- RS 232 interface for simultaneous display and evaluation of the measured values from all four measuring points with a computer.
- Recorder output can be switched for output of the measured values of one of the digital displays to a tY recorder.
- Measurements of temperature difference between two probes in any combination.
- Tare function (set 0.00) with a ten times better resolution in a wide range on each side of the newly set zero.
- Automatic compensation of probe differences with an adjust function.

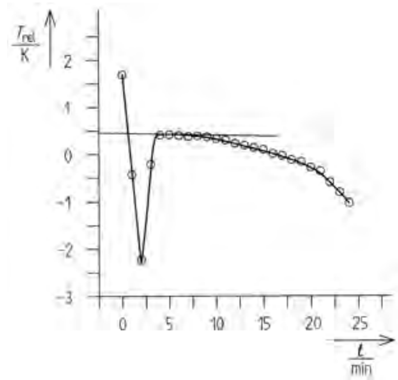
Equipment and technical data

- Measuring range: - 50 ... + 300°C, Resolution: up to 0.01°C, Probe type: Pt 100, Probe connection: 4 diode plug, 5 pin
- Interface: RS 232 C, 9600 Baud, Mains supply: 230 V / 50...60 Hz
- Casing dimensions (mm): 270 × 236 × 168

13617-93

P2340400 Freezing point depression

Demo



Cooling curve of water/table salt (NaCl) mixture.

Principle

The freezing point of a solution is lower than that of the pure solvent. The depression of the freezing point can be determined experimentally using a suitable apparatus (cryoscopy). If the cryoscopic constants of the solvent are known, the molecular mass of the dissolved substances can be determined.

Exercises

1. Determine the degree of freezing point depression after dissolving a strong electrolyte (NaCl) in water. By comparing the experimental value with the theoretical one predicted for this concentration, determine the number of ions into which the electrolyte dissociates.
2. Determine the apparent molar mass of a non-electrolyte (hydroquinone) from the value of freezing point depression.

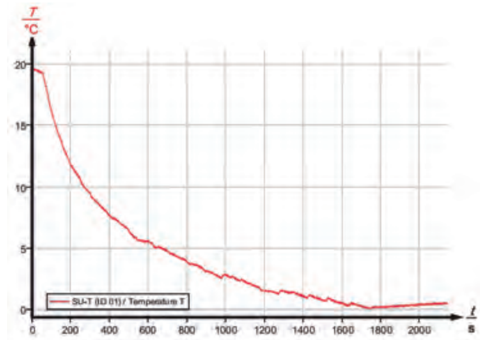
What you can learn about

- Raoult's law; Cryoscopic constants; Chemical potential
- Gibbs-Helmholtz equation; Concentration ratio; Degree of dissociation
- Van't Hoff factor; Cryoscopy

Main articles		
Temperature meter digital, 4-2	13617-93	1
Apparatus for freezing point depression	36821-00	1
Temp. probe, immersion type, Pt100	11759-01	2
Magnetic stirrer Mini / MST	47334-93	1
Retort stand, h 1000 mm	37695-00	1
Pellet press for calorimeter	04403-04	1

Cooling by evacuation

P2340660



Temperature curve of the water during pumping. The boiling temperature of water is dependent on the pressure of the air that burdens it.

Principle

When the air pressure above a watersurface is reduced, the water begins to boil at a certain temperature. The temperature of the water is hereby reduced and further evacuation can finally bring it to 0 °C and even lower.

Task

Determine the temperature curve of water during pumping.

What you can learn about

- Air pressure
- Kinetic gas theory
- Supercooling

Main articles		
Rotary valve vacuum pump, one stage	02740-95	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	1
Pump plate, complete	02668-88	1
Bell jar, with knob and sealing ring	02668-10	1
Manometer -1.0...0.6 bar	03105-00	1
Support base DEMO	02007-55	1

Cobra4 Wireless-Link

Function and Applications

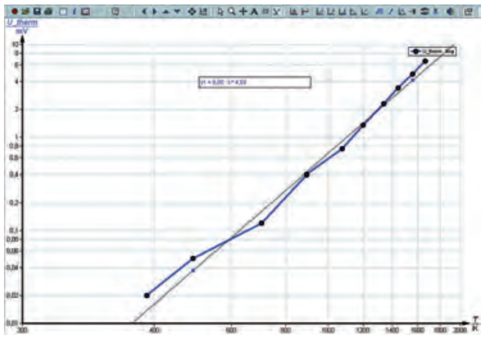
Interface module for the radio-based transmission of sensor measuring values in conjunction with the Cobra4 wireless manager.

Benefits

- All Cobra4 Sensor-Units can be quickly connected using a secure and reliable plug-in / lockable connection.
- All Cobra4 measuring sensors are easy to plug in and automatically detected. The radio network with the Cobra4Wireless Manager is established automatically and is extremely stable, as it uses its own radio protocol
- Up to 99 Cobra4 Wireless-Links can be connected to one Cobra4 Wireless-Manager, no more cable mess, thanks to radio measuring.With radio transmission, moving sensors offer completely new experimentation options, e.g. the measurement of acceleration of a student on a bicycle etc.
- The use of high performance batteries means that no external power supplyis required.

12601-00

P2350101 Stefan-Boltzmann's law of radiation with an amplifier



Thermoelectric e. m. f. of thermopile as a function of the filament's absolute temperature.

Principle

According to the Stefan-Boltzmann law, the energy emitted by a black body per unit area and unit time is proportional to the power of four of the absolute temperature of the body. Stefan-Boltzmann's law is also valid for a so-called "grey" body whose surface shows a wavelength independent absorption-coefficient of less than one. In the experiment, the "grey" body is represented by the filament of an incandescent lamp whose energy emission is investigated as a function of the temperature.

Tasks

1. To measure the resistance of the filament of the incandescent lamp at room temperature and to ascertain the filament's resistance R_0 at zero degrees centrigrade.
2. To measure the energy flux density of the lamp at different heating voltages. The corresponding heating currents read off for each heating voltage and the corresponding filament resistance calculated. Anticipating a temperature-dependency of the second order of the filament-resistance, the temperature can be calculated from the measured resistances.

What you can learn about

- Black body radiation
- Thermoelectric e. m. f.
- Temperature dependence of resistances
- Stefan-Boltzmann law

Main articles		
Thermopile, Moll type	08479-00	1
Universal measuring amplifier	13626-93	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Optical profile bench l = 60 cm	08283-00	1
Digital multimeter 2010	07128-00	3
Base for optical bench, adjustable	08284-00	2
Slide mount for optical bench, h = 30 mm	08286-01	2

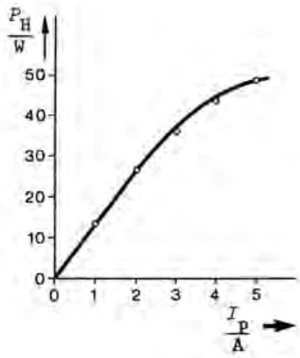
Related Experiment

Stefan-Boltzmann's law of radiation with Cobra3

P2350115

Peltier heat pump

P2410800



Pump cooling capacity as a function of the operating current.

Principle

The (cooling capacity) heating capacity and efficiency rating of a Peltier heat pump are determined under different operating conditions.

Tasks

1. To determine the cooling capacity Pc the pump as a function of the current and to calculate the efficiency rating hc at maximum output.
2. To determine the heating capacity Pw of the pump and its efficiency rating hw at constant current and constant temperature on the cold side.
3. To determine Pw, η w and Pc , ηc from the relationship between temperature and time on the hot and cold sides.
4. To investigate the temperature behaviour when the pump is used for cooling, with the hot side air-cooled.

What you can learn about

- Peltier effect; Heat pipe; Thermoelectric e. m. f.
- Peltier coefficient; Cooling capacity; Heating capacity
- Efficiency rating; Thomson coefficient; Seebeck coefficient
- Thomson equations; Heat conduction
- Convection; Forced cooling; Joule effect

Main articles		
Thermogenerator with 2 water baths	04366-00	1
Power supply, universal	13500-93	1
Rheostat, 33 Ohm , 3.1A	06112-02	1
Flow-through heat exchanger	04366-01	1
Air cooler	04366-02	1

Thermogenerator with 2 water baths

Function and Applications

To commute thermal energy into electrical energy directly and for operation as heat pump. Also been used to demonstrate the Seebeck effect and the Peltier effect.

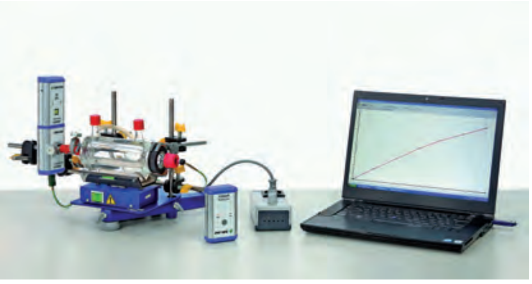
Equipment and technical data

- Generator block consisting of two nickel coated copper plates with hole for thermometer, between these, p- and n-conducting silicon thermocouples, connected thermally parallel and electrically in series.
- Two water containers with open sides, which are used as heat reservoirs, are screwed to the generator block. They can be exchanged for flowthrough heat exchanger or air cooler.
- Standard accessories: 2 open water containers (brass, nickel coated); 2 rubber gaskets; 2 clamping jaws and 4 knurled screws.
- Number of thermocouples: 142.
- Permanent operating temperature: approx. 100°C.
- Interior resistance: 2.8 Ohm.
- Operation as thermo generator: output voltage at T = 40°C: approx. 2 V; efficiency at T = 40°C: approx. 1%.
- Operation as heat pump: max. permanent current 6 A.
- Dimensions (mm): generator block: 24 × 80 × 126, water container 28 × 70 × 94.

04366-00

Equation of state for ideal gases with Cobra4

P2320160



NEW

Principle

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the general equation of state. For achange of state under isochoric conditions this equation becomes Amontons'law. In this experiment it is investigated whether Amontons' law is valid for a constant amount of gas (air).

For more details refer to page 72.

Thermal and electrical conductivity of metals

P2350200

Principle

The thermal conductivity of copper and aluminium is determined in a constant temperature gradient from the calorimetrically measured heat flow. The electrical conductivity of copper and aluminium is determined, and the Wiedmann-Franz law is tested.

For more details refer to page 95.

Solar ray collector

P2360100

Principle

The solar ray collector is illuminated with a halogen lamp of known light intensity. The heat energy absorbed by the collector can be calculated from the volume flow and the difference in the water temperatures at the inlet and outlet of the absorber, if the inlet temperature stays almost constant by releasing energy to a reservoir. The efficiency of the collector is determined from this. The measurement is made with various collector arrangements and at various absorber temperatures.

For more details refer to page 96.

Heat insulation / heat conduction with Cobra4

P2360360

Principle

A model house with replaceable side walls is used for determining the heat transition coefficients (k values) of various walls and windows and for establishing the heat conductivities of different materials. For this purpose the temperatures on the inside and outside of the walls are measured at a constant interior and outer air temperature (in the steady state). With a multilayer wall structure the temperature difference over a layer is proportional to the particular thermal transmission resistance. The thermal capacity of the wall material affects the wall temperatures during heating up and temporary exposure to solar radiation.

For more details refer to page 97.

Stirling engine with Cobra3

P2360415

Principle

The Stirling engine is submitted to a load by means of an adjustable torquemeter, or by a coupled generator. Rotation frequency and temperature changes of the Stirling engine are observed. Effective mechanical energy and power, as well as effective electrical power, are assessed as a function of rotation frequency. The amount of energy converted to work per cycle can be determined with the assistance of the pV diagram. The efficiency of the Stirling engine can be estimated.

For more details refer to page 89.

Semiconductor thermogenerator – Seebeck effect

P2410700

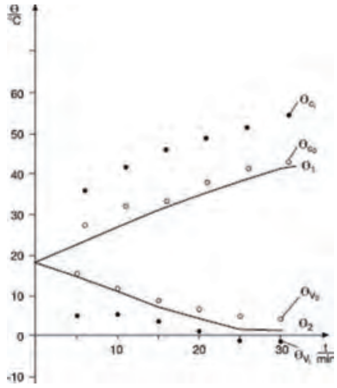
Principle

In a semi-conductor thermogenerator, the no-load voltage and the short-circuit current are measured as a function of the temperature difference. The internal resistance, the Seebeck coefficient and the efficiency are determined.

For more details refer to page 209.

P2360200 Electric compression heat pump

Demo



Temperatures at the inlet and outlet of the vaporiser V_i, V_0 and condenser C_i, C_0 as a function of the operating time; continuous curves: temperature in water reservoirs.

Principle

Pressures and temperatures in the circulation of the heat electrical compression heat pump are measured as a function of time when it is operated as a water-water heat pump.

The energy taken up and released is calculated from the heating and cooling of the two water baths.

When it is operated as an air-water heat pump, the coefficient of performance at different vaporiser temperatures is determined.

Tasks

1. Water heat pump: To measure pressure and temperature in the circuit and in the water reservoirs on the condenser side and the vaporiser side alternately. To calculate energy taken up and released, also the volume concentration in the circuit and the volumetric efficiency of the compressor.
2. Air-water heat pump: To measure vaporiser temperature and water bath temperature on the condenser side under different operating conditions on the vaporiser side,

- with stream of cold air
- with stream of hot air
- without blower.

If a power meter is available, the electric power consumed by the compressor can be determined with it and the coefficient of performance calculated.

What you can learn about

- Refrigerator; Compressor
- Restrictor valve; Cycle
- Vaporization; Condensation
- Vapour pressure; Vaporisation enthalpy

Main articles		
Heat pump, compressor principle	04370-88	1
Work and power meter	13715-93	1
Tripod base PHYWE	02002-55	1
Hot/cold air blower, 1800 W	04030-93	1

Work and power meter

Function and Applications

For AC and DC circuits

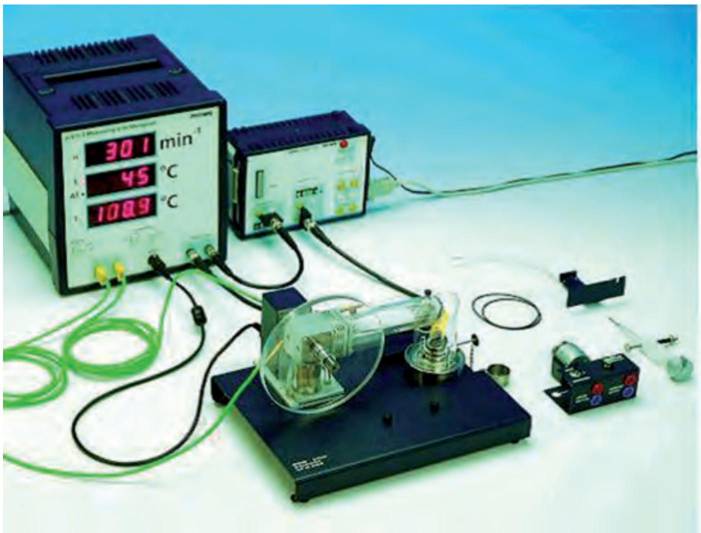
Equipment and technical data

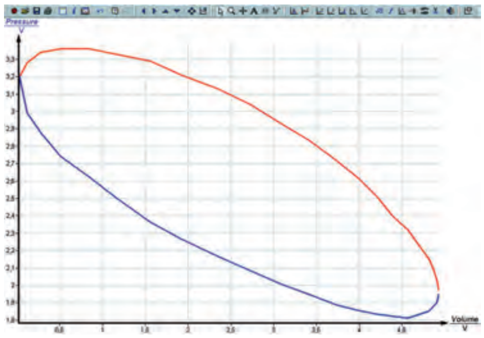
- Two 4-digit, 20 mm LED-displays
- Display 1 for real and apparent power,current, voltage, phase difference and freqency
- Display 2 for energy and time, Selector for serial display of all units
- LED-Status-display and automactic range selection
- Power: max. 2400 W, Resolution: max. 0.001 W
- Voltage: 0-30V AC/DC, 0-240, Veff- Current: 0...10A AC/DC
- Phasen difference: 0...+/- 90 degree, Frequency: 0...10000 Hz
- Energy: max. 9999 Wh or Ws, Resolution: max. 0.001 Ws
- Analog output for all units of disp. 1, Mains: 110/230V, 50/60Hz
- Shock-resistant plastic housing with carry handle and base

13715-93

Stirling engine with Cobra3

P2360415





Pressure as a function of Volume for the Stirling process.

Main articles		
Meter for Stirling engine, pVnT	04371-97	1
Stirling engine transparent	04372-00	1
Cobra3 BASIC-UNIT, USB	12150-50	1
Sensor unit pVn for Stirling engine	04371-00	1
Torque meter	04372-02	1
Motor/ generator unit	04372-01	1
Thermocouple NiCr-Ni, -50..1100°C	13615-01	2

Related Experiment

Stirling engine with an oscilloscope

P2360401

Cobra4 Experiment - available 2014

Stirling engine with Cobra4

P2360460

Principle

The Stirling engine is submitted to a load by means of an adjustable torquemeter, or by a coupled generator. Rotation frequency and temperature changes of the Stirling engine are observed.

Effective mechanical energy and power, as well as effective electrical power, are assessed as a function of rotation frequency.

The amount of energy converted to work per cycle can be determined with the assistance of the pV diagram. The efficiency of the Stirling engine can be estimated.

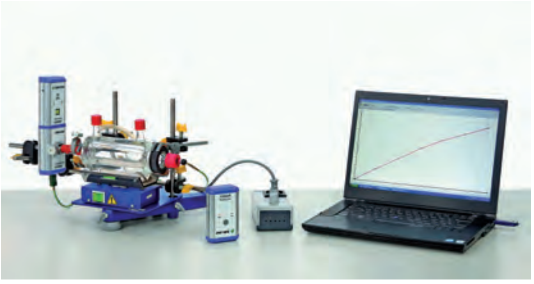
Tasks

1. Determination of the burner's thermal efficiency
2. Calibration of the sensor unit.
3. Calculation of the total energy produced by the engine through determination of the cycle area on the oscilloscope screen, using transparent paper and coordinate paper.
4. Assessment of the mechanical work per revolution, and calculation of the mechanical power output as a function of the rotation frequency, with the assistance of the torque meter.
5. Assessment of the electric power output as a function of the rotation frequency.
6. Efficiency assessment.

What you can learn about

- First and second law of thermodynamics
- Reversible cycles
- Isochoric and isothermal changes
- Gas jaws
- Efficiency
- Stirling engine
- Conversion of heat
- Thermal pump

Equation of state for ideal gases with Cobra4 P2320160



Principle

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the general equation of state. For achange of state under isochoric conditions this equation becomes Amontons'law. In this experiment it is investigated whether Amontons' law is valid for a constant amount of gas (air).

For more details refer to page 72.

Thermal equation of state and critical point P2320400

Principle

A substance which is gaseous under normal conditions is enclosed in a variable volume and the variation of pressure with the volume is recorded at different temperatures. The critical point is determined graphically from a plot of the isotherms.

For more details refer to page 76.

Adiabatic coefficient of gases - Flammersfeld oscillator P2320500

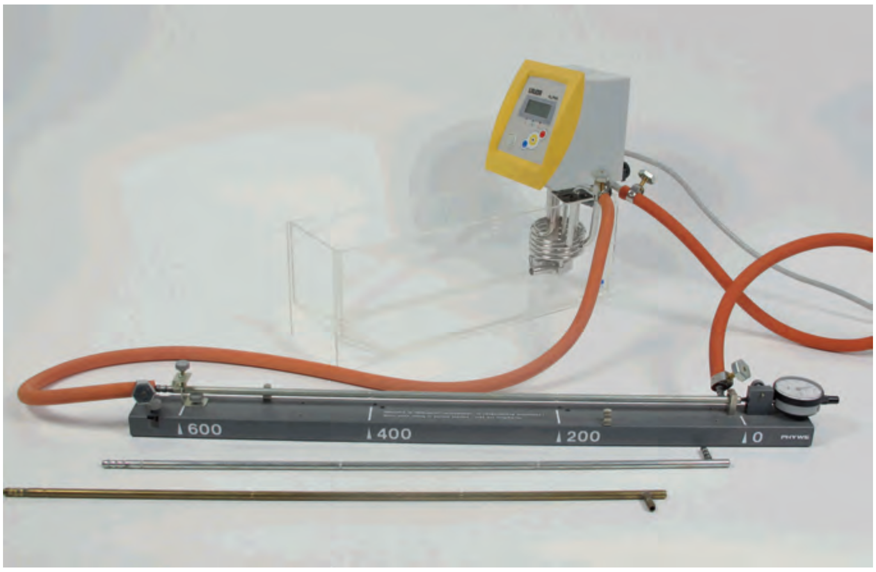
Principle

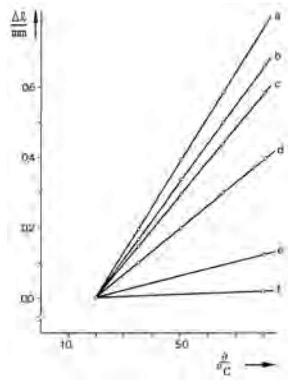
A mass oscillates on a volume of gas in a precision glass tube. The oscillationis maintained by leading escaping gas back into the system. The adiabatic coefficient of various gases is determined from the periodic time of the oscillation.

For more details refer to page 77.

Thermal expansion in solids

P2310200





Relationship between length and temperature for a) aluminium, b) brass, c) copper, d) steel, e) duran glass, f) quartz glass (lo = 600 mm).

Prinicple

The linear expansion of various materials is determined as a function of temperature

Tasks

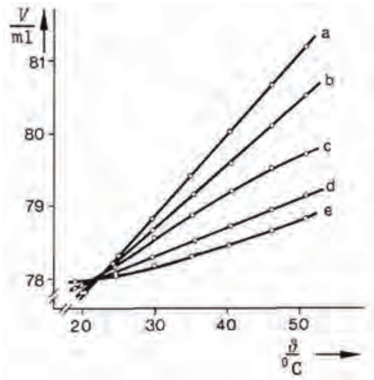
1. Determine the linear expansion of brass, iron, copper, aluminum, Duran glass and quartz glass as a function of temperature using a dilatometer.
2. Investigate the relationship between change in length and overall length in the case of aluminum.

What you can learn about

- Linear expansion
- Volume expansion of liquids
- Thermal capacity
- Lattice potential
- Equilibrium spacing
- Grüneisen equation

Main articles		
Immersion thermostat Alpha A, 230 V	08493-93	1
Dilatometer with clock gauge	04233-00	1
Bath for thermostat, makrolon	08487-02	1
Tube, quartz for 04231-01	04231-07	1
Aluminium tube for 04231-01	04231-06	1
External circulation set f. thermostat Alpha A	08493-02	1
Copper tube for 04231-01	04231-05	1

P2310300 Thermal expansion in liquids



Relationship between volume V and temperature T of: a) ethyl acetate, b) methylated spirit, c) olive oil, d) glycerol and e) water.

Prinicple

The volume expansion of liquids is determined as a function of temperature.

Tasks

Determine the volume expansion of n-heptane (C7H16), olive oil and water as a function of temperature, using the pycnometer.

What you can learn about

- Linear expansion
- Volume expansion of liquids
- Thermal capacity
- Lattice potential
- Equilibrium spacing
- Grüneisen equation

Main articles

Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, Makrolon	08487-02	1
Measuring tube,l.300mm,IGJ19/26	03024-00	2
Glycerol 250 ml	30084-25	1
Ethyl acetate 250 ml	30075-25	1
Olive oil,pure 100 ml	30177-10	1
Flask,flat bottom, 100ml,IGJ19/26	35811-01	2

Immersion thermostat Alpha A, 230 V

Function and Applications

Immersion circulator with simple,reliable options for obtaining consistent results. Compact unit can be combined with any existing baths up to 25 mm wallthickness.

Benefits

- Wide temperature range to meet application needs. Digital settings for simple operation. Strong pump for high temperature conformity. To be used with water as heat transfer liquid. Screw clamp for bath walls up to 25 mm. Robust design using high grade stainless steel and temperature resistant polymer. Wear-free; integrated overload protection

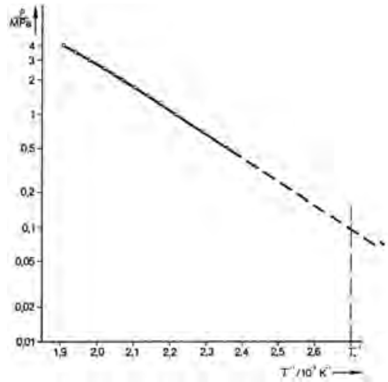
Equipment and technical data

- Heater capacity: 1.5 kW; Temperature accuracy: ± 0.05 K;Working temperature range: 25 to 85°C; With additional cooling: -25 to 85°C. Power supply: 230 V; 50-60 Hz; Dimensions (WxDxH): 125 x 125 x 300 mm

08493-93

Vapour pressure of water at high temperature

P2340100



Natural logarithm of vapour pressure *p* as a function of the reciprocal of the temperature (1/T): *Tb* = boiling point at normal pressure.

Principle

The high-pressure steam apparatus makes it possible to measure steam pressure in a temperature range of 100-250°C. This allows for investigations to be performed on real gases and vapours. Typical equilibrium states between gas and liquid phases can be set up. For this purpose, water is heated in a closed pressure chamber at constant volume. The heat of vaporisation is determined at various temperatures from the measurement of vapour pressure as a function of temperature.

Exercises

1. Measure the vapour pressure of water as a function of temperature.
2. Calculate the heat of vaporisation at various temperatures from the values measured.
3. Determine boiling point at normal pressure by extrapolation.

What you can learn about

- Boiling point
- Heat of vaporisation
- Clausius-Clapeyron equation
- Van't Hoff law; Carnot cycle

Main articles		
High pressure vapour unit	02622-10	1
Heating apparatus for glass jacket system	32246-93	1
Tripod base PHYWE	02002-55	1
Heat conductive paste,50 g	03747-00	1
Boss head	02043-00	1
Lab thermometer,-10..+250C	38065-00	1

Heating apparatus for glass jacket system

Function and Applications

Hot plate. For a uniform and hence material protecting heating of cylindrical bodies or devices made of metal, ceramic or glass.

Equipment and technical data

- power requirement 500 W max.
- surface temperature 500 °C
- mains supply: 230 V, 50...60 Hz
- dimensions (mm): 160 x 95 x 90 mm
- Items suitable for heating: minimum length: 130 mm, diameter: 36...100 mm

Accessories

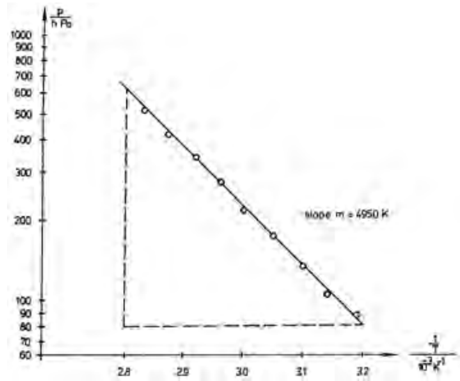
Recommended accessorie to regulate the temperature:

- power controller (32288-93)

32246-93

P2340200 Vapour pressure of water below 100°C - molar heat of vaporisation

Demo



Semilogarithmic representation of vapour pressure p as a function of 1/T.

Principle

The vapour pressure of water in the range of 40 °C to 85 °C is investigated. It is shown that the Clausius-Clapeyron equation describes the relation between temperature and pressure in an adequate manner. An average value for the heat of vaporisation of water is determined.

Tasks

1. About 250 ml of demineralised water are allowed to boil for about 10 minutes to eliminate all traces of dissolved gas. The water is then cooled down to room temperature.
2. The 3-neck round flask is filled about three-quarters full with gas-free water and heated. At 35 °C the space above the water within the round flask is evacuated. Further heating causes an increase in pressure p and temperature T of water within the round flask. p and T are read in steps of 5 °C up to a maximum of T = 85 °C.

What you can learn about

- Pressure; Temperature
- Volume; Vaporisation
- Vapour pressure
- Clausius-Clapeyron equation

Main articles		
Rotary Vane pump, one stage, 115 V / 230 V	02740-95	1
Magnetic stirrer	35731-93	1
Manometer -1.0...0.6 bar	03105-00	1
Oil mist filter, DN 16 KF	02752-16	1
Round flask,100ml,3-n.,GL25/2GL18	35677-15	1

Magnetic stirrer with connection for electronic contact-thermometer, 10 ltr., 230 V

Function and Application

Magnetic stirrer

Benefits

- because of a pressure moulded aluminium housing which is coated with an electrostatically applied powder the stirrer is excellent corrosion resistant, hotplate made from an aluminiumsilicon alloy (AlSi 12) for good heat-transfer, two seperate switchs with LEDs for heating and stirring

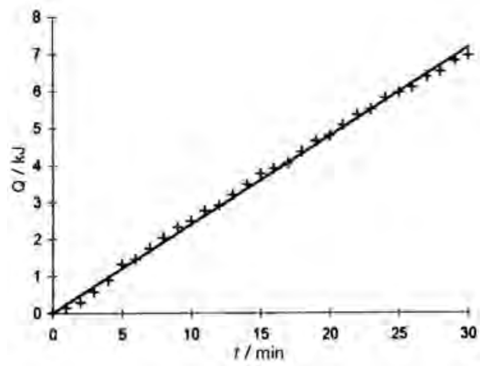
Equipment and technical data

- max. stirring capacity: 10 ltr., speed-range: 50 ... 1250 rpm
- heating power: 600 W, hotplate diameter: 145 mm, hotplate temperature:regulated 50 ... 325°C, setting accuracy: +/- 3°C, connection for an electroniccontact-thermometer: DIN 5-pins 270°, over-heating protection: 350°C, M-10 threateded support rod connection integrated in the housing
- voltage: 230 V, frequency: 50...60 Hz, weight: 2,8 kg

35731-93

Thermal and electrical conductivity of metals

P2350200



Heat of surroundings over time.

Principle

The thermal conductivity of copper and aluminium is determined in a constant temperature gradient from the calorimetrically measured heat flow.

The electrical conductivity of copper and aluminium is determined, and the Wiedmann-Franz law is tested.

Tasks

1. Determine the heat capacity of the calorimeter in a mixture experiment as a preliminary test.
2. Measure the calefaction of water at a temperature of 0°C in a calorimeter due to the action of the ambient temperature as a function of time.
3. To begin with, establish a constant temperature gradient in a metal rod with the use of two heat reservoirs (boiling water and ice water) After removing the pieces of ice, measure the calefaction of the cold water as a function of time and determine the thermal conductivity of the metal rod.
4. Determine the electrical conductivity of copper and aluminium by recording a current-voltage characteristic line.
5. Test of the Wiedmann-Franz law.

What you can learn about

- Electrical conductivity
- Wiedmann-Franz law
- Lorenz number
- Diffusion
- Temperature gradient
- Heat transport
- Specific heat
- Four-point measurement

Main articles		
Temperature meter digital, 4-2	13617-93	1
Universal measuring amplifier	13626-93	1
Multitap transformer, 14 VAC/ 12 VDC, 5 A	13533-93	1
Surface temperature probe PT100	11759-02	2
Rheostat, 10 Ohm , 5.7A	06110-02	1
Heat conductivity rod, Cu	04518-11	1
Magnetic stirrer Mini / MST	47334-93	1

P2360100 Solar ray collector

Demo

No.	Glass plate	Light	Cold air	$\frac{\vartheta_{in}}{°C}$	$\frac{\vartheta_{out}-\vartheta_{in}}{K}$	$\frac{\eta}{\%}$
1.1	+*	–	–	≈ 5	2.5	15
1.2	–*	–	–	≈ 5	5.0	29
2.1	+	+	–	≈ 20	11.0	64
2.2	–	+	–	≈ 20	12.5	73
3.1	+	+	–	≈ 50	8.0	47
3.2	–	+	+	≈ 50	8.0	47
3.3	+	+	–	≈ 50	6.0	35
3.4	–	+	+	≈ 50	3.0	17

Water temperatures and collector efficiency under various experimental conditions, m = 100 cm^3/min, qi = 1 kW/m^2, A = 0 • 12 m^2.

Principle

The solar ray collector is illuminated with a halogen lamp of known light intensity. The heat energy absorbed by the collector can be calculated from the volume flow and the difference in the water temperatures at the inlet and outlet of the absorber, if the inlet temperature stays almost constant by releasing energy to a reservoir. The efficiency of the collector is determined from this. The measurement is made with various collector arrangements and at various absorber temperatures.

Tasks

To determine the efficiency of the solar ray collector under various experimental conditions.

- Absorption of energy from the environment (20 °C) without illumination by sun or halogen lamp, water temperature at the absorber inlet Te ; 5 °C.

1. Absorber with insulation and glassplate (complete collector).
2. Absorber alone (energy ceiling).

- Illumination with halogen lamp. Water temperature Te; 20 °C.

1. Complete collector.
2. Collector without glass plate.

- Illumination with halogen lamp. Water temperature Te; 50 °C.

1. Complete collector.
2. Complete collector, cold jet of air impinges.
3. Collector without glass plate.
4. Collector without glass plate, cold jet of air impinges.

What you can learn about

- Absorption; Heat radiation; Greenhouse effect
- Convection; Conduction of heat; Collector equations
- Efficiency; Energy ceiling

Main articles

Solar ray collector	06753-00	1
Circulating pump w.flowmeter	06754-01	1
Halogen lamp 1000 W	08125-93	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Heat exchanger	06755-00	1
Solar collector stand, teaching aid	06757-00	1
Tripod base PHYWE	02002-55	2

Solar ray collector

Function and Applications

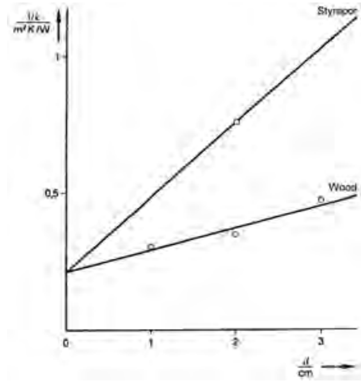
Compact unit for study of all collector functions.

Equipment and technical data

- Flat collector to heat water through absorption of radiation energy or thermal energy from environment.
- Black stainless steel absorbers with 2 temperature measurement points at inlet and outlet.
- Metal mirrored back wall and front glass cover removable.
- Collector frame with angular scale and fastening screw to adjust illuminating angle.
- Absorber dimensions (mm): 300 x 400.
- Absorber volume: approx. 50 ml.
- Insulation: 20 mm polyurethane foam.
- Dimensions (mm): 480 x 520 x 60.

06753-00

Heat insulation / heat conduction with Cobra4 P2360360



Heat transition resistance 1/*k* as a function of the wall thickness *d*.

Principle

A model house with replaceable side walls is used for determining the heat transition coefficients (k values) of various walls and windows and for establishing the heat conductivities of different materials. For this purpose the temperatures on the inside and outside of the walls are measured at a constant interior and outer air temperature (in the steady state).

With a multilayer wall structure the temperature difference over a layer is proportional to the particular thermal transmission resistance. The thermal capacity of the wall material affects the wall temperatures during heating up and temporary exposure to solar radiation.

Tasks

1. Measurement and interpretation of water temperatures during the heating up and during temporary external illumination of the walls.
2. Determination of the heat conductivities of wood and Styropor.
3. Determination of the k values of ordinary glass and insulating glass windows and of wooden walls of different thicknesses, and of walls with wood, Styropor or cavity layers.

What you can learn about

- Heat transition; Heat transfer; Heat conductivity
- Thermal radiation
- Hothouse effect
- Thermal capacity
- Temperature amplitude attenuation

Main articles		
High insulation house	04507-93	1
Thermal regulation for high insulation house	04506-93	1
Cobra4 Mobile-Link set	12620-55	2
Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	2
Ceramic lamp socket E27	06751-01	1
Tripod base PHYWE	02002-55	1
Fast Charging System for up to 4 MeH Accumulators	07930-99	1

High insulation house

Function and Applications

Device for quantitative experiments with thermal insulation.

Equipment and technical data

- The high insulation house consists of a thermally insulated base rack with removable lid, measuring walls, exterior insulation and heating.
- Basic rack: ground insulated through a 5 cm thick Styrofoam plate.
- Side walls with square apertures (210 mm × 210 mm);.
- The measuring walls are set in from the inside and pressed by two screws against the aperture gasket.
- Each of the exterior walls carry a profile and a small eccentric plate to hold supplementary insulating material.
- Every angle pillar has a hole to introduce temperature probes.
- The hole is sealed off with foam material.

04507-93

Cooling by evacuation

P2340660

Principle

When the air pressure above a watersurface is reduced, the water begins to boil at a certain temperature. The temperature of the water is hereby reduced and further evacuation can finally bring it to 0 °C and even lower.

For more details refer to page 83.

Adiabatic coefficient of gases – Flammersfeld oscillator

P2320500

Principle

A mass oscillates on a volume of gas in a precision glass tube. The oscillationis maintained by leading escaping gas back into the system. The adiabatic coefficient of various gases is determined from the periodic time of the oscillation.

For more details refer to page 77.

Heat capacity of metals with Cobra4 P2330160

NEW

Principle

Heated specimens are placed in a calorimeter filled with water at low temperature. The heat capacity of the specimen is determined from the rise in the temperature of the water.

For more details refer to page 79.

Boiling point elevation P2340300

Principle

The boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

For more details refer to page 81.

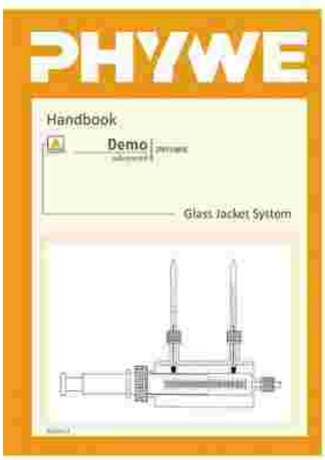
Freezing point depression P2340400

Principle

The freezing point of a solution is lower than that of the pure solvent. The depression of the freezing point can be determined experimentally using a suitable apparatus (cryoscopy). If the cryoscopic constants of the solvent are known, the molecular mass of the dissolved substances can be determined.

For more details refer to page 82.

Handbook Glass Jacket System



Article no. 01196-12

Description

Comprehensive set of 17 experiments using the glass jacket set for various uses.

Topics

- Gas laws
- Gas reactions
- Determining molecular mass
- Calorimetry
- Gas chromatography
- Distillation of steam

This system consists of a glass jacket, special inserts and accessories. It was mainly developed for experiments with gases and can be used at school for teaching physics, chemistry and biology.

- Demonstrative and transparent
- Versatile and easily assembled
- Water bath for accurate measurements

This documentation contains the following experiments:

Gay-Lussac's law
P1222900

Charles's (Amontons') law
P1223000

The Boyle-Mariotte law
P1223100

The gas laws of Boyle-Mariotte, Gay-Lussac and Charles(Amontons)
P1223200

Determination of molar masses with the vapour density method
P1223301

Gay-Lussac's law of volumes
P1223351

Law of integer ratio of volumes
P1223400

Gay-Lussac's law of volumes
P1223551

Avogadro's law
P1223651

The empirical formula of methane, ethane and propane
P1223751

Determination of the heat of formation of water
P1223800

Determination of the heat of formation of CO2 and CO and Hess's law
P1223900

Determination of the heating values of solid and gaseous fuels in a horizontal calorimeter
P1224051

Determination of the calorific value of food stuffs
P1224100

Determination of the heating values of liquids in a vertical calorimeter
P1224251

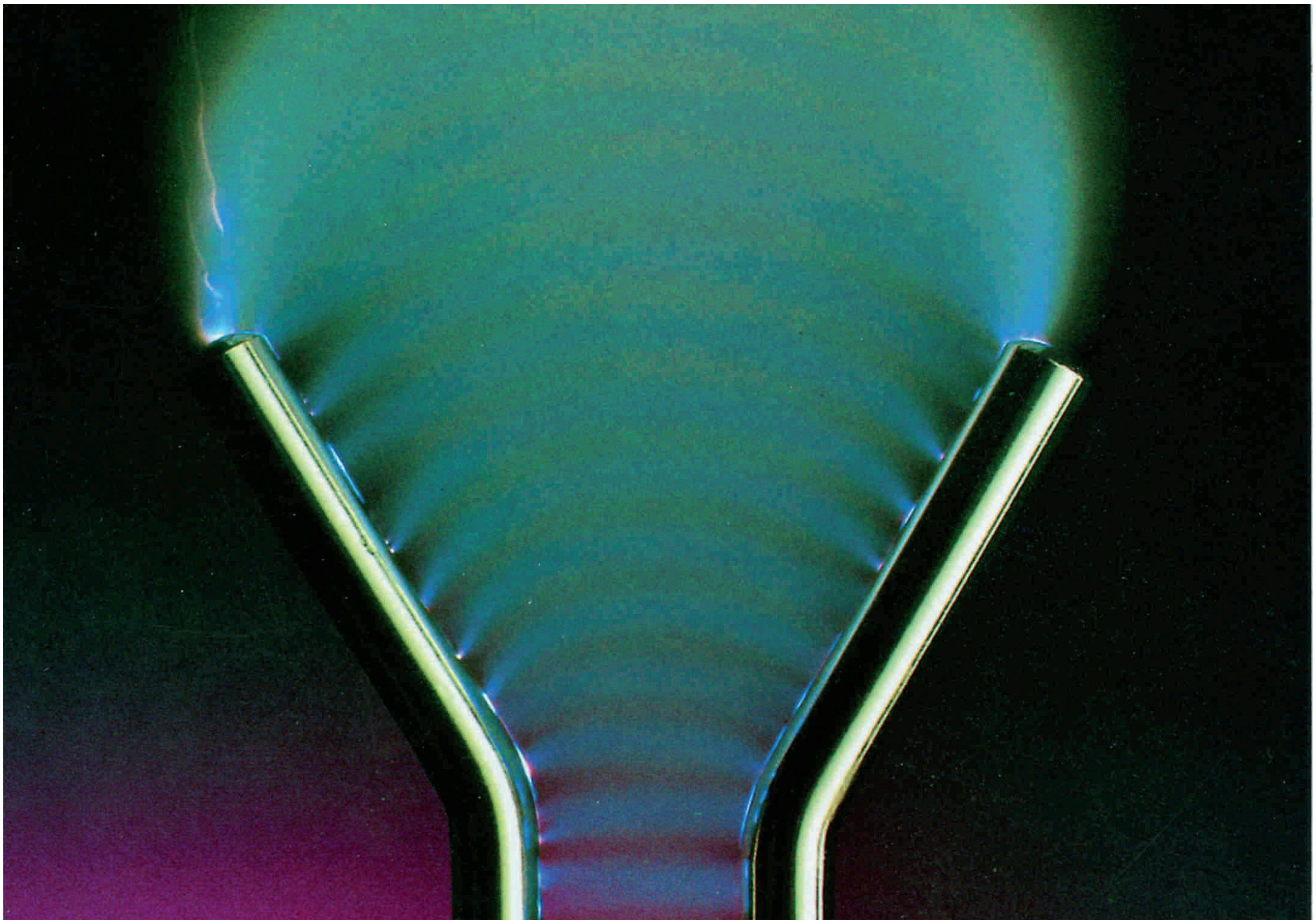
Determination of the heating value of fuel oil and of the calorific value of olive oil
P1224300

Chromatographic separation processes: gas chromatography
P1224451

Steam distillation
P1224551

01196-12

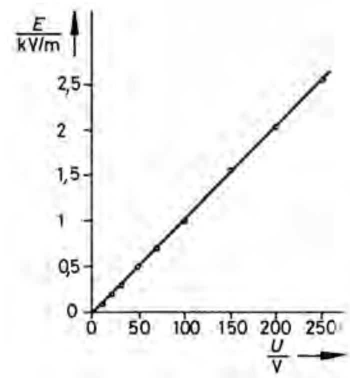
Steam distillation - P1224551



Electricity and Magnetism

P2420100 Electric fields and potentials in the plate capacitor

Demo



Electric field strength as a function of the plate voltage.

Principle

A uniform electric field E _ is produced between the charged plates of a plate capacitor. The strength of the field is determined with the electric field strength meter, as a function of the plate spacing d and the voltage U. The potentialø within the field is measured with a potential measuring probe.

Tasks

1. The relationship between voltage and electric field strength is investigated, with constant plate spacing.
2. The relationship between electric field strength and plate spacing is investigated, with constant voltage.
3. In the plate capacitor, the potential is measured with a probe, as a function of position.

What you can learn about

- Capacitor; Electric field
- Potential; Voltage; Equipotential lines

Main articles		
Electric field meter	11500-10	1
Power supply, 0...600 VDC	13672-93	1
Optical profile bench l = 60 cm	08283-00	1
Plate capacitor, 283x283 mm	06233-02	2
Capacitor plate w.hole d 55 mm	11500-01	1
Potential probe	11501-00	1
High-value resistor, 10 MOhm	07160-00	1

Electric field meter

Function and Applications

For measurement of static electricfields without losses and with the correct sign as well as for electrostatic measurement of voltages in those cases in which normal static voltmeters are not sensitive enough.

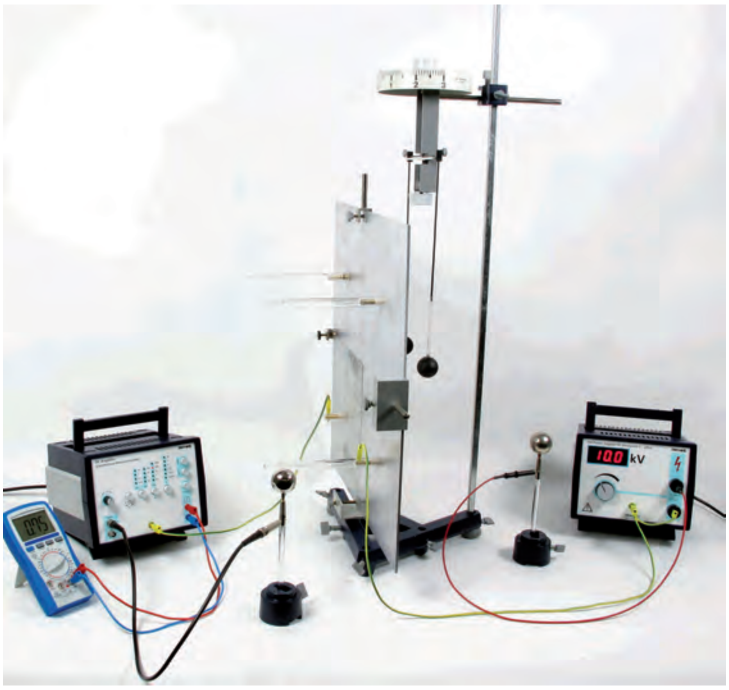
Equipment and technical data

- Steel sheet casing on a rod
- push-button key for measuring range selection
- rotating knob for electric zero adjustment
- two pair of 4 mm sockets to connect power supply and measuring instrument
- gold plated measuring head with gold plated winged wheel
- voltage measuring attachment gold plated with two 4 mm sockets to connect voltage which is to be measured
- Every earth and zero potential freesmoothed direct voltage between 14 and 18 V is suited as an electric energy supply (e.g. from universal power supply 13500-93)
- Data output (9-pin Sub-D jack) for connection to the serial interface (RS 232) of a computer via the special cable supplied
- Accessory (not included): Software Electric Field Meter 14406-61.

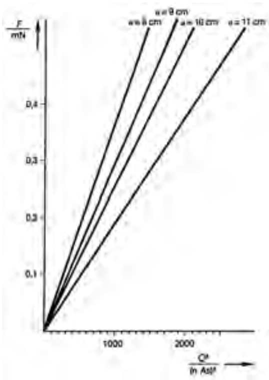
11500-10

Coulomb's law / image charge

P2420401



Demo



Relationship between electrostatic force F and the square of the charge Q for various distances (a) between ball and plate.

Principle

A small electrically charged ball is positioned at a certain distance in front of a metal plate lying at earth potential. The surface charge on the plate due to electrostatic induction together with the charged ball forms an electricfield analogous to that which exists between two oppositely charged point charges. The electrostatic force acting on the ball can be measured with a sensitive torsion dynamometer.

Tasks

1. Establishment of the relation between the active force and the charge on the ball.
2. Establishment of the relation between force and distance, ball to metal plate.
3. Determination of the electric constant.

What you can learn about

- Electric field; Electric field strength
- Electric flux; Electrostatic induction
- Electric constant; Surface charge density
- Dielectric displacement; Electrostatic potential

Main articles		
DC measuring amplifier	13620-93	1
Power supply, high voltage, 0-25 kV	13671-93	1
Torsion dynamometer, 0.01 N	02416-00	1
Support base DEMO	02007-55	1
Plate capacitor, 283x283 mm	06233-02	4
Conductor spheres, w. suspension	02416-01	2
Digital multimeter 2010	07128-00	1

DC measuring amplifier

Function and Applications

Versatile measuring amplifier for measurement of very small direct currents, electrical charges and for quasi-static measurements of DC voltages.

Equipment and technical data

- 8 current measurement ranges with very low voltage drop
- 6 voltage measurement ranges with extremely high input resistance, 5 charge measurement ranges
- Analogue output for connection of demonstration measurement instruments/ pen recorders, button for reversing output voltage
- Selection of measurement modes using push-button
- Diode indicators for active measurement range
- Zero point adjustment, discharge button, range selection buttons

Current measurement

- Measurement range: 0.01 nA...0.1 mA in 8 decade ranges, Voltage drop: 1 mV

Voltage measurement

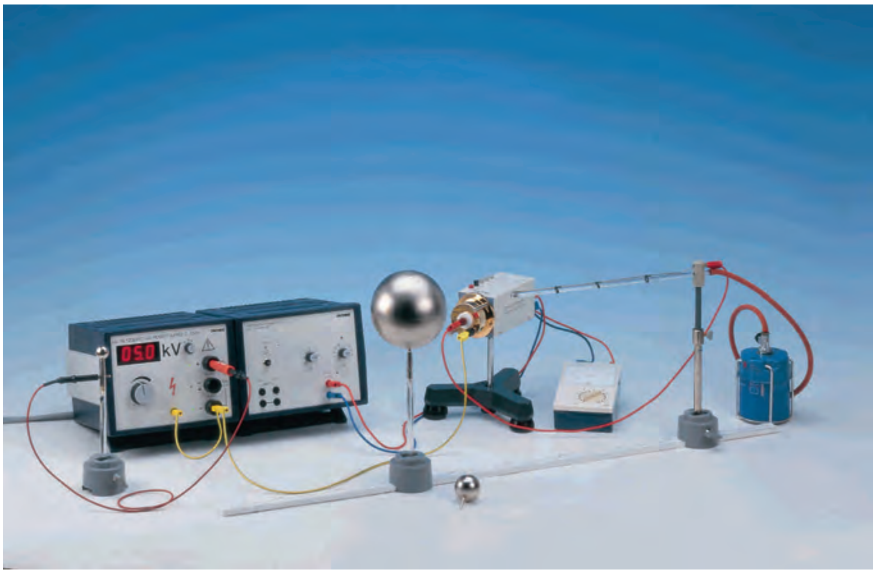
- Measurement range: 0.1 mV...10 V in 6 decade ranges
- Input resistance: 10 gOhm

Charge measurement

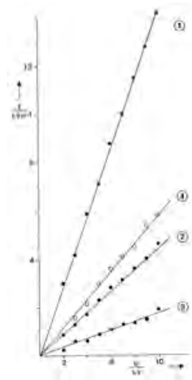
- Measurement range: 0.1 nAs...0.001 mAs in 5 decade ranges
- Accuracy: 3%, Input: BNC socket, Overload protection: 250 V

13620-93

P2420500 Coulomb potential and Coulomb field of metal spheres



Demo



Field strenght as a function of voltage. Graphs 1-3: sphere with 2R = 12 cm; r1 = 25 cm, r2 = 50 cm, r3 = 75 cm; graph 4: sphere with 2R = 4 cm; r1 = 25 cm.

Principle

Conducting spheres with different diameters are charged electrically. The static potentials and the accompanying electric field intensities are determined by means of an electric field meter with a potential measuring probe, as a function of position and voltage.

Tasks

1. For a conducting sphere of diameter 2R = 12 cm, electrostatic potential is determined as a function of voltage at a constant distance from the surface of the sphere.
2. For the conducting spheres of diameters 2R = 12 cm and 2R = 4 cm, electrostatic potential at constant voltage is determined as a function of the distance from the surface of the sphere.
3. For both conducting spheres, electricfield strength is determined as a function of charging voltage at three different distances from the surface of the sphere.
4. For the conducting sphere of diameter 2R = 12 cm, electric field strength is determined as a function of the distance from the surface of the sphere at constant charging voltage.

What you can learn about

- Electric field; Field intensity
- Electric flow; Electric charge
- Gaussian rule
- Surface charge density
- Induction; Induction constant
- Capacitance
- Gradient
- Image charge
- Electrostatic potential
- Potential difference

Main articles		
Electric field meter	11500-10	1
High voltage supply unit, 0-10 kV	13670-93	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Conductor ball, d 120mm	06238-00	1
Multi-range meter, analogue	07028-01	1
Potential probe	11501-00	1
Capacitor plate w.hole d 55 mm	11500-01	1

Elementary charge and Millikan experiment

P2510100

Principle

Charged oil droplets subjected to an electric field and to gravity between the plates of a capacitor are accelerated by application of a voltage. The elementary charge is determined from the velocities in the direction of gravity and in the opposite direction.

For more details refer to page 182.

Electron spin resonance

P2511200

Principle

With electron spin resonance (ESR) spectroscopy compounds having unpaired electrons can be studied. The physical background of ESR is similar to that of nuclear magnetic resonance (NMR), but with this technique electron spins are excited instead of spins of atomic nuclei. The g-factor of a DPPH (Di-phenylpikrylhydrazyl) and the halfwidth of the absorption line are determined, using the ESR apparatus.

For more details refer to pages 192, 206.

High voltage supply unit, 0-10 kV

13670-93

Function and Applications

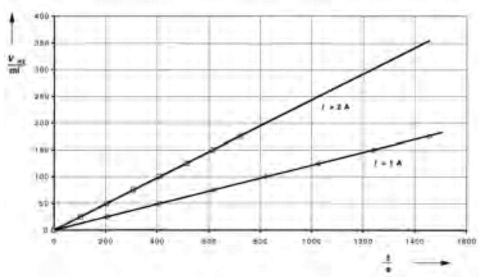
For electrostatic experiments and for operation of spectral and gas discharge tubes.

Equipment and technical data

- It supplies 3 continuously variable DC voltages isolated from earth and ground. Two of the voltages are connected in series 0-5 kV DC = total of 0 -10 kV DC. Selectable positive and negative polarity.
- 3-figure LED display.Outputs short-circuit proof. Special safety sockets.
- Internal resistance: approx.5 MOhm.

For more details refer to page 199.

P2411100 Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser



Volume of the hydrogen generated by the PEM electrolyser as a function of time at different current I.

Principle

In a PEM electrolyser, the electrolyte consists of a proton-conducting membrane and water (PEM = Proton-Exchange-Membrane). When an electric voltage is applied, hydrogen and oxygen are formed. The PEM fuel cell generates electrical energy from hydrogen and oxygen. The electrical properties of the electrolyser and the fuel cell are investigated by recording a current-voltage characteristic line. To determine the efficiency, the gases are stored in small gasometers in order to be able to measure the quantities of the gases generated or consumed.

Tasks

1. Recording the characteristic line of the PEM electrolyser.
2. Recording the characteristic line of the PEM fuel cell.
3. Determination of the efficiency of the PEM electrolysis unit.
4. Determination of the efficiency of the PEM fuel cell.

What you can learn about

- Electrolysis
- Electrode polarisation
- Decomposition voltage
- Galvanic elements
- Faraday's law

Main articles		
Power supply, universal	13500-93	1
PEM electrolyser	06748-00	1
Cobra4 Mobile-Link set	12620-55	1
PEM fuel cell	06747-00	1
Cobra4 Sensor-Unit Weather	12670-00	1
Gas bar	40466-00	1
Digital multimeter 2010	07128-00	2

Cobra4 Sensor-Unit Weather: Humidity, Air pressure, Temperature, Light intensity, Altitude

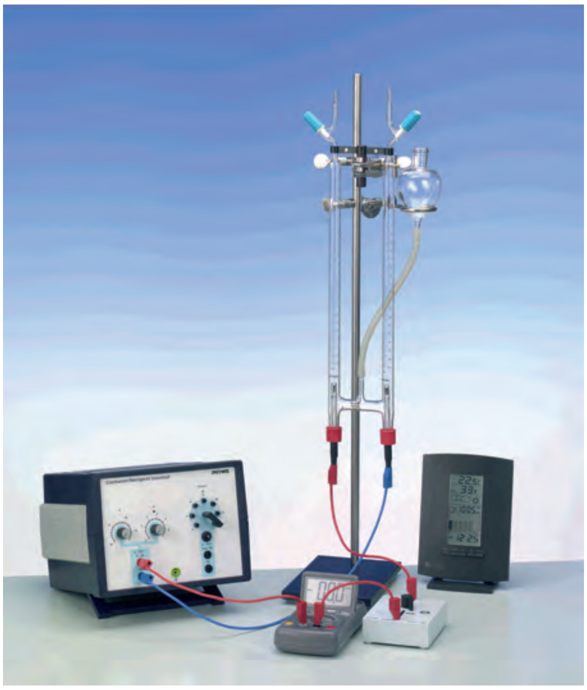
Function and Applications

Depending on application type, the Cobra4 Sensor-Unit Weather can be connected to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 USB-Link oder the Cobra4 Junior-Link using a secure and reliable plug-in/ lockable connection.

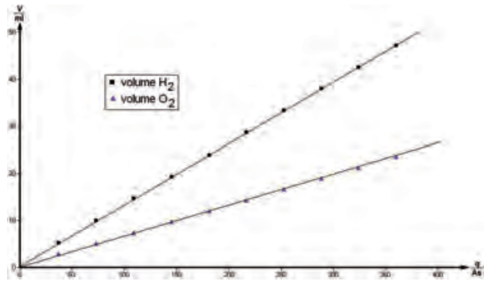
12670-00

Faraday's law

P2411200



Demo



Correlations between the transferred charge and the evolved volumes of hydrogen and oxygen in the electrolysis of diluted sulphuric acid (T = 296.05 K and p = 100.4 kPa).

Principle

The correlation between the amounts of substances transformed in the electrode reaction and the applied charge (amount of electricity) is described by Faraday's law. Faraday 's constant, which appears as a proportionality factor, can be determined experimentally from this dependence.

Task

Determine Faraday's constant from the dependence of the volumes of hydrogen and oxygen evolved on the applied charge in the hydrolysis of diluted sulphuric acid.

What you can learn about

- Electrolysis
- Coulometry
- Charge
- Amount of substance
- Faraday's law
- Faraday's constant
- Avogadro's number
- General equation of state for ideal gases

Main articles		
Power supply, universal	13500-93	1
Electrolysis apparatus-Hofmann	44518-00	1
Weather monitor, 6 lines LCD	87997-10	1
Digital multimeter 2010	07128-00	1
On/off switch	06034-01	1
Retort stand, h 750 mm	37694-00	1
Platin.electrode in prot.tube,8mm	45206-00	2

Power supply, universal

Function and Applications

Versatile heavy duty power supply which can also be used as a constant current supply in schools, laboratories or workshops.

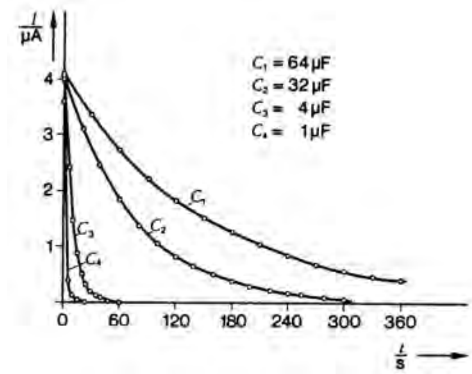
Equipment and technical data

- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V
- Adjustable current limit between 0...5 A
- LED display for constant current operation
- Permantely short-circuit proof & protected against exterior voltages
- Alternative voltage output:
- Multitap transformer 2...15 V, outputs galvanically separated from main grid
- Full load capacity (5 A), even if direct current is supplied simultaneously
- Short-circuit protection through overcurrent circuit breaker
- All output voltages available at 4 mm safety plug sockets.

13500-93

P2420201 Charging curve of a capacitor / charging and discharging of a capacitor

Demo



Course of current with time at different capacitance values; voltage and resistance are constant (U = 9 V, R = 2.2 M).

Principle

A capacitor is charged by way of a resistor. The current is measured as a function of time and the effects of capacitance, resistance and the voltage applied are determined.

Tasks

- To measure the charging current over time:

1. using different capacitance values C, with constant voltage U and constant resistance R
2. using different resistance values (C and U constant)
3. using different voltages (R and C constant).

- To determine the equation representing the current when a capacitor is being charged, from the values measured.

What you can learn about

- Charging
- Discharging
- Time constant
- Exponential function
- Half life

Main articles		
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Capacitor,2x30 micro-F	06219-32	1
DMM, auto range, NiCr-Ni thermocouple	07123-00	1
Two-way switch, single pole	06030-00	1
Connection box	06030-23	2
Capacitor 1 microF/ 100V, G2	39113-01	1
Capacitor 4,7microF/ 100V, G2	39113-03	1

Cobra4 Experiment - available 2014

Switch-on behaviour of a capacitor and an inductivity with cobra4

P2420260

Power supply 0-12 V DC/ 6 V, 12 V AC, 230 V

Function and Applications

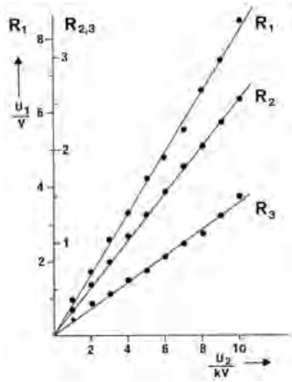
High quality power supply specially suitable for student experiments in electricity and electronics as well as for demonstration.

Equipment and technical data

- Stabilised, Shortcircuit proof
- Output voltage: 1...12 V DC, 6 V / 12 V AC
- Rated current: DC 0...2 A / AC 5 A
- Ripple: max 1 mV
- Resistance: 1 mOhm
- Mains voltage: 230 V
- Housing dimensions: 194 x 140 x 130 mm

13505-93

Capacitance of metal spheres and of a spherical capacitor P2420300



U_1 (measured voltage) as a function of U_2 (charging voltage) measured on conducting spheres with three different diameters.

Principle

Metal spheres with different radii and a spherical capacitor are charged by means of a variable voltage. The induced charges are determined with a measuring amplifier. The corresponding capacitances are deduced from voltage and charge values.

Tasks

1. Determination of the capacitance of three metal spheres with different diameters.
2. Determination of the capacitance of a spherical capacitor.
3. Determination of the diameters of each test body and calculation of their capacitance values.

What you can learn about

- Voltage; Potential; Charge; Electric field
- Electrostatic induction; Electrostatic induction constant
- Capacitance; Capacitor; Dielectrics

Main articles		
High voltage supply unit, 0-10 kV	13670-93	1
Universal measuring amplifier	13626-93	1
Conductor ball, d 120mm	06238-00	1
Hemispheres,Cavendish type	06273-00	1
Multi-range meter, analogue	07028-01	1
High-value resistor, 10 MOhm	07160-00	1
Digital multimeter 2010	07128-00	1

Wimshurst machine

Function and Applications

Historical device for generation of highvoltage to carry out many impressive electrostatic experiments.

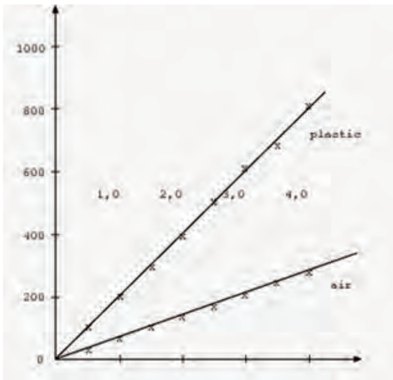
Equipment and technical data:

- Manually driven plastic discs and adjustable spark gap connected in parallel to two integrated Leiden bottles (high voltage capacitors)
- Diameter of disc: 30 cm
- Voltage: max. 160 kV
- Length spark gap: ca. 60 mm
- Dimensions (mm): 360 x 190 x 450

07616-00

P2420600 Dielectric constant of different materials

Demo



Electrostatic charge Q of a plate capacitor as a function of the applied voltage U_C, with and without dielectric (plastic) between the plates (d = 0.98 cm).

Principle

The electric constant is determined by measuring the charge of a plate capacitor to which a voltage is applied. The dielectric constant is determined in the same way, with plastic or glass filling the space between the plates.

Tasks

1. The relation between charge Q and voltage U is to be measured using a plate capacitor.
2. The electric constant is to be determined from the relation measured under point 1.
3. The charge of a plate capacitor is to be measured as a function of the inverse of the distance between the plates, under constant voltage.
4. The relation between charge Q and voltage U is to be measured by means of a plate capacitor, between the plates of which different solid dielectric media are introduced. The corresponding dielectric constants are determined by comparison with measurements performed with air between the capacitor plates.

What you can learn about

- Maxwell's equations
- Electric constant
- Capacitance of a plate capacitor
- Real charges; Free charges
- Dielectric displacement
- Dielectric polarisation; Dielectric constant

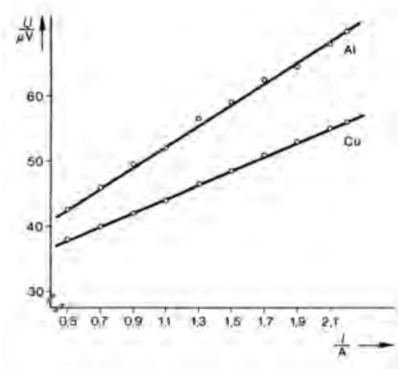
Main articles		
High voltage supply unit, 0-10 kV	13670-93	1
Plate capacitor, d 260mm	06220-00	1
Universal measuring amplifier	13626-93	1
Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1
Plastic plate 283 x 283 mm	06233-01	1
High-value resistor, 10 MOhm	07160-00	1
Glass plates f.current conductors	06406-00	1

Related Experiment

Electric fields and potentials in the plate capacitor

P2420100

4 Point Method / Measurement of low resistances / Ohm's Law P2410101



Current/voltage characteristics of a copper rod and an aluminium rod.

Principle

The resistances of various DC conductors are determined by recording the current / voltage characteristic. The resistivity of metal rods and the contact resistance of connecting cords are calculated.

Tasks

1. To plot the current / voltage characteristics of metal rods (copper and aluminium) and to calculate their resistivity.
2. To determine the resistance of various connecting cords by plotting their current / voltage characteristics and calculating the contact resistances.

What you can learn about

- Ohm's law
- Resistivity
- Contact resistance
- Conductivity
- Four-wire method of measurement

Main articles

Universal measuring amplifier	13626-93	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Heat conductivity rod, Cu	04518-11	1
Heat conductivity rod, Al	04518-12	1
Digital multimeter 2010	07128-00	2
Connection box	06030-23	1

Universal measuring amplifier

Function and Applications

Universal measuring amplifier for amplification of AC and DC voltages. Suitable for practical exercises.

Equipment and technical data

input impedance:

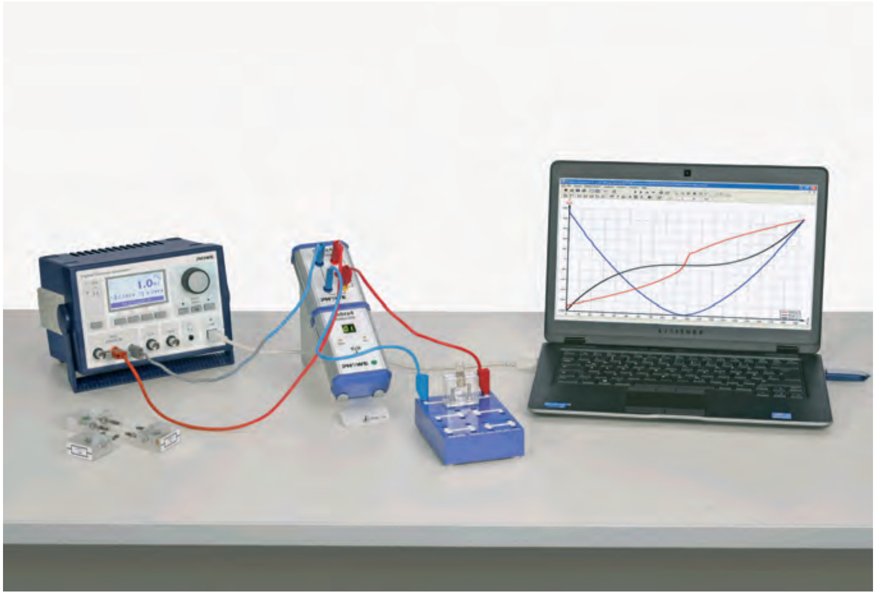
electrometer: > 10 (13) Ohm

low drift: 10 kOhm,input voltage: -10 to + 10 V,output voltage: -10 to + 10 V

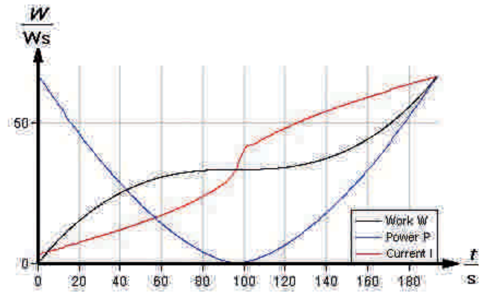
frequency ranges: V=1 0...100 kHz, V=10 0... 75 kHz, V=10(2) 0... 10 kHz, V=10(3) 0... 6 kHz, V=10(4) 0...2.5 kHz, V=10(5) 0... 2 kHz, mains voltage: 230 V AC, dimensions: 194 x 140 x 126 mm

13626-93

P2410160 Ohm's law with Cobra4



NEW Cobra4 Demo



Current, Power and Work of an incandescent bulb.

Principle

The relation between voltage and current is measured for different resistors. The resistance is the derivative of the voltage with respect to current and is measured in dependance on current. In case of an incandescent lamp the temperature rise with higher current leads to a considerable higher resistance.

Tasks

1. Measure the voltage-current characteristic of an incandescent bulb and it's power and the work dissipated.
2. Measure the resistance of several resistors in dependancy of the current strength.

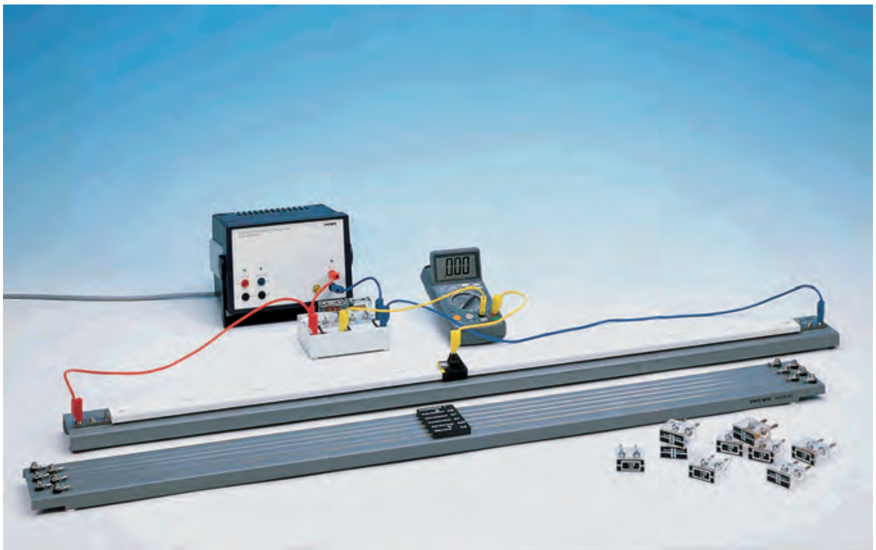
What you can learn about

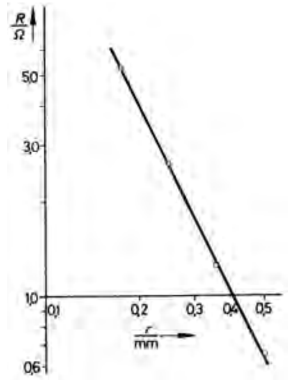
- Ohm's law
- Resistivity
- Contact resistance
- Conductivity
- Power and Work

Main articles		
Digital Function Generator, USB	13654-99	1
Cobra4 Sensor-Unit Energy	12656-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Connection box	06030-23	1
resistor 220 Ohm, 1W, G1	39104-64	1
resistor 330 Ohm, 1W, G1	39104-13	1

Wheatstone bridge

P2410200





Resistance of a conductor wire as a function of its radius r.

Principle

The Wheatstone bridge circuit is used to determine unknown resistances. The total resistance of resistors connected in parallel and in series is measured.

Tasks

1. Determination of unknown resistances. Determination of the total resistance
2. of resistors in series and of resistors in parallel.
3. Determination of the resistance of a wire as a function of its cross-section.

What you can learn about

- Kirchhoff's laws
- Conductor
- Circuit
- Voltage
- Resistance
- Parallel connection
- Series connection

Main articles		
Power supply, 5V/ 1A, +/-15 V	13502-93	1
Slide wire meas. bridge, simple	07182-00	1
Resistance board, metal	06108-00	1
Digital multimeter 2010	07128-00	1
Connection box	06030-23	1
Resistor 1 Ohm 2%, 2W, G1	06055-10	1
Resistor 2 Ohm 2%, 2W, G1	06055-20	1

Related Experiment

Kirchhoff's laws

P2410500

Cobra4 Experiments

Kirchhoff's laws with Cobra4

P2410560

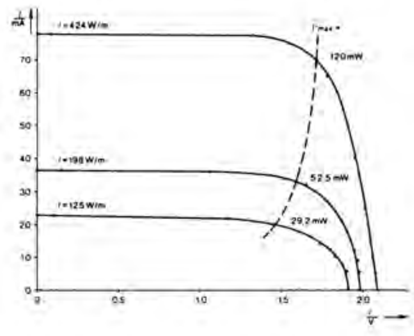
In Cooperation with:

mint.loc
Wege zur MINT Berufsorientierung
Niedersächsische Landesschulbehörde

Project of:

Lower Saxony Education Office, Germany

P2410901 Characteristic curves of a solar cell



Current-voltage characteristic at different light intensities J.

Principle

The current-voltage characteristics of a solar cell are measured at different light intensities, the distance between the light source and the solar cell being varied. The dependence of no-load voltage and short-circuit current on temperature is determined.

Tasks

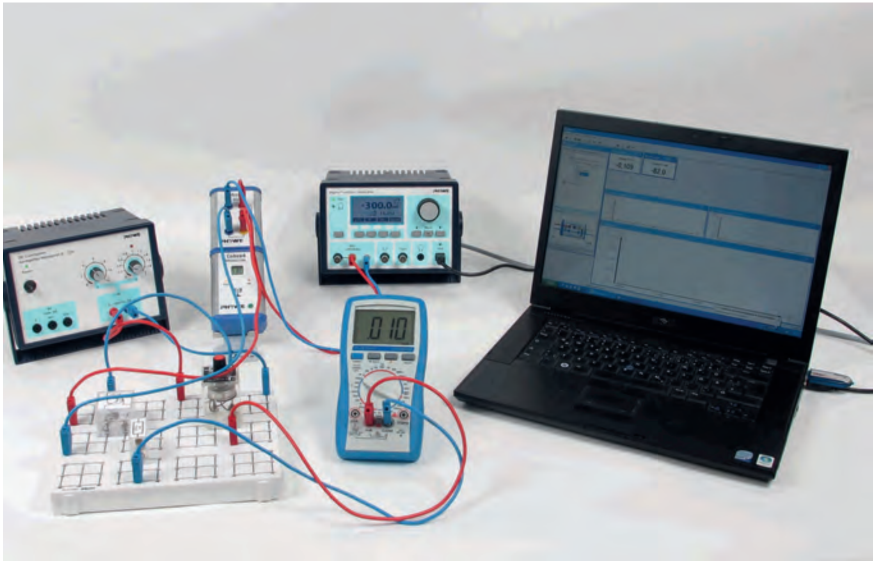
1. To determine the light intensity with the thermopile at various distances from the light source.
2. To measure the short-circuit current and no-load voltage at various distances from the light source.
3. To estimate the dependence of no-load voltage, and short-circuit current on temperature.
4. To plot the current-voltage characteristic at different light intensities.
5. To plot the current-votlage characteristic under different operating conditions: cooling the equipment with a blower, no cooling, shining the light through a glass plate.
6. To determine the characteristic curve when illuminated by sunlight.

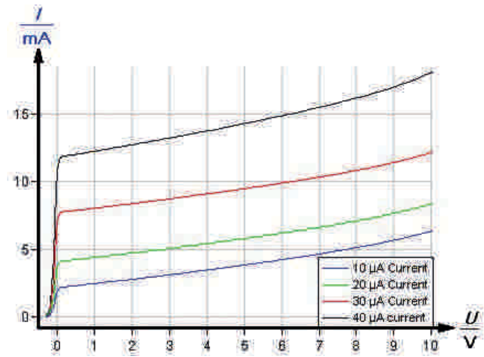
What you can learn about

- Semiconductor
- p-n junction
- Energy-band diagram
- Fermi characteristic energy level
- Diffusion potential
- Internal resistance
- Efficiency
- Photo-conductive effect
- Acceptors; Donors
- Valence band; Conduction band

Main articles		
Thermopile, Moll type	08479-00	1
Universal measuring amplifier	13626-93	1
Rheostat, 330 Ohm , 1.0A	06116-02	1
Solar battery, 4 cells, 2.5 x 5 cm	06752-04	1
Ceramic lamp socket E27	06751-01	1
Tripod base PHYWE	02002-55	2
Hot/cold air blower, 1800 W	04030-93	1

Characteristic curves of semiconductors with Cobra4 P2410960





Collector current/voltage characteristic of BC337 transistor.

Principle

The current-voltage characteristic of a semiconducting diode is measured.
The collector current in dependency on the emitter-collector voltage is measured for different values of base current strength through a NPN transistor.

Tasks

1. To investigate the dependence of the current strength flowing through a semi-conducting diode.
2. To determine the variations of the collector current with the collector voltage for varios values of the base current intensity.

What you can learn about

- Semiconductor; p-n junction
- Energy-band diagram; Acceptors
- Donors; Valence band
- Conduction band
- Transistor
- Operating point

Main articles		
Digital Function Generator, USB	13654-99	1
Cobra4 Sensor-Unit Energy	12656-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Plug-in board,4mm plugs	06033-00	1
DMM with NiCr-Ni thermo couple	07122-00	1

Digital Function Generator, USB, incl. Cobra4 Software

Function and Applications

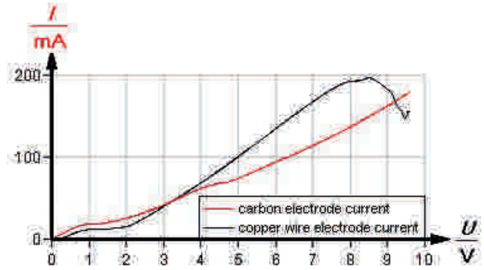
Digital signal generator for use as a programmable voltage source in practical or demonstration experiments, particularly in the disciplines of acoustics, electrical engineering and electronics.

Benefits

- Can be used as universal stand-alone device or controlled via a USB interface
- Universally applicable thanks to broad, continually adjustable frequency range
- Usable as programmable voltage source via amplifier output
- Intuitive, menu-driven operation using control knob and function buttons, with help capability
- Illuminated monochrome graphic display for maximum visibility and readability
- Simple setting of voltage and frequency ramps in stand-alone mode
- Features V = f(f) output for easy reading of frequency in the form of a voltage - ideal for measuring circuit response to frequency ramps using an oscilloscope
- Low distortion and signal-to-noise ratio for brilliantly clear signals - ideal for acoustics/audio experiments

13654-99

P2411360 Second order conductors - Electrolysis with Cobra4



Current/voltage characteristics of an aqueous copper sulphate solution conducted with graphite electrodes and copper wires.

Principle

In this experiment a copper (II) sulphate solution is to be electrolysed using two different materials - graphite electrodes and copper wires. During the electrolyses the current/voltage curves are recorded.

Task

Measure the correlation between voltage and current on second order conductors (copper (II) sulphate solution) using two different materials - graphite electrodes and copper wires.

What you can learn about

- Electrolysis
- Electrode polarisation
- Conductivity
- Ohm's law

Main articles		
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Digital Function Generator, USB	13654-99	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Electricity	12644-00	1
Tripod base PHYWE	02002-55	1
Holder for two electrodes	45284-01	1

TESS Electrochemical measurement set

Function and applications

Material to equip school groups for deriving electrochemical fundamentals in an 8-10 hour practical session. All the equipment is contained on a tray with clearly organised compartments.

30505-88

Semiconductor thermogenerator - Seebeck effect P2410700

Principle

In a semi-conductor thermogenerator, the no-load voltage and the short-circuit current are measured as a function of the temperature difference. The internal resistance, the Seebeck coefficient and the efficiency are determined.

For more details refer to page 209.

Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser P2411100

Principle

In a PEM electrolyser, the electrolyte consists of a proton-conducting membrane and water (PEM = Proton- Exchange-Membrane). When an electric voltage is applied, hydrogen and oxygen are formed. The PEM fuel cell generates electrical energy from hydrogen and oxygen. The electrical properties of the electrolyser and the fuel cell are investigated by recording a current-voltage characteristic line. To determine the efficiency, the gases are stored in small gasometers in order to be able to measure the quantities of the gases generated or consumed.

For more details refer to page 106.

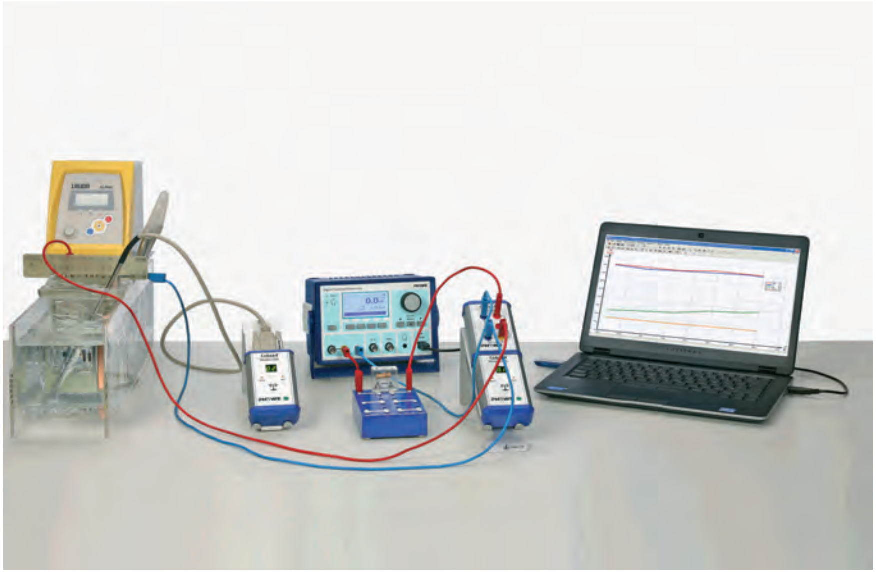
Charging curve of a capacitor / charging and discharging of a capacitor P2420201

Principle

A capacitor is charged by way of a resistor. The current is measured as a function of time and the effects of capacitance, resistance and the voltage applied are determined.

For more details refer to page 108.

P2410460 Temperature dependence of different resistors and diodes with Cobra4



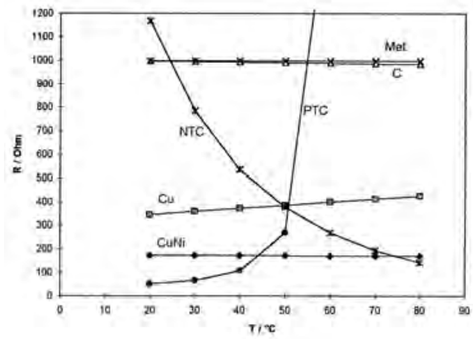


Diagram of resistances.

Principle

The temperature dependence of an electrical parameter (e.g. resistance, conducting-state voltage, blocking voltage) of different components is determined. To do this, the immersion probe set is immersed in a water bath and the resistance is measured at regular temperature intervals.

Tasks

1. Measurement of the temperature dependence of the resistance of different electrical components.
2. Measurement of the temperature dependence of the conducting state voltage of semiconducting diodes.
3. Measurement of the temperature dependence of the voltage in the Zener and the avalanche effects.

What you can learn about

- Carbon film resistor
- Metallic film resistor
- PTC
- NTC
- Z diode
- Avalanche effect
- Zener effect
- Charge carrier generation
- Free path
- Mathie's rule

Main articles		
Immersion thermostat Alpha A, 230 V	08493-93	1
Software Cobra4 - multi-user licence	14550-61	1
Immersion probes for determining ct	07163-00	1
Cobra4 Sensor-Unit Energy	12656-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Temperature	12640-00	1

Related Experiment

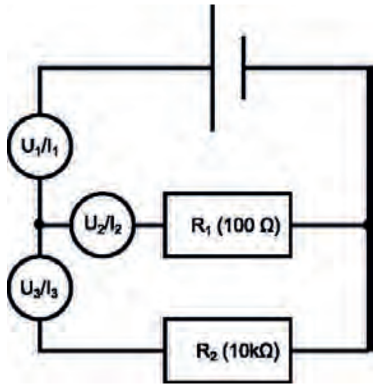
Temperature dependence of different resistors and diodes with a multimeter

P2410401

Kirchhoff's laws with Cobra4

P2410560

NEW Cobra4 Demo



Schematic circuit for the Wheatstone bridge.

Principle

First Kirchhoff's laws are verified by measuring current, voltage and resistance in series and parallel circuits. The Wheatstone bridge circuit is used to determine unknown resistances more precisely.

Tasks

1. Verify Kirchhoff's laws by measuring current and voltage for series and parallel connected resistors for each resistor as well as the total values. From these measurements calculate the partial and total resistances.
2. Determine unknown resistances by the use of the Wheatstone bridge circuit.

What you can learn about

- Kirchhoff's laws
- Induction law
- Maxwell equations
- Current
- Voltage
- Resistance
- Parallel connection
- Series connection
- Potentiometer

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Sensor-Unit Energy	12656-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Connection box	06030-23	1
resistor 220 Ohm, 1W, G1	39104-64	1

Related Experiment

Kirchhoff's laws

P2410500

Wheatstone bridge

P2410200

Power supply 0...12 V DC/ 6 V, 12 V AC,230V

Function and Applications

High quality power supply specially suitable for student experiments in electricity and electronics as well as for demonstration.

Equipment and technical data

- Stabilised, Shortcircuit proof, Output voltage: 1...12 V DC, 6 V / 12 V AC, Rated current: DC 0...2 A / AC 5 A
- Ripple: max 1 mV, Resistance: 1 mOhm, Mains voltage: 230 V
- Housing dimensions: 194 x 140 x 130 mm

13505-93

4 Point Method / Measurement of low resistances Ohm's Law

P2410101

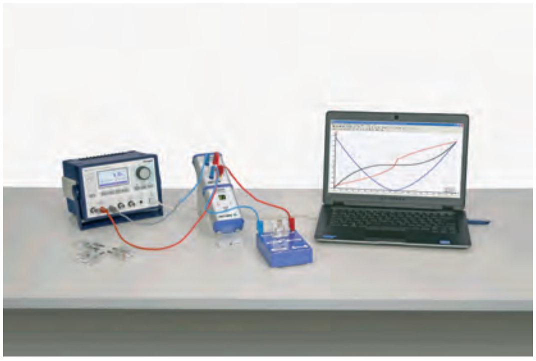
Principle

The resistances of various DC conductors are determined by recording the current / voltage characteristic. The resistivity of metal rods and the contact resistance of connecting cords are calculated.

For more details refer to page 111.

Ohm's law with Cobra4

P2410160



NEW

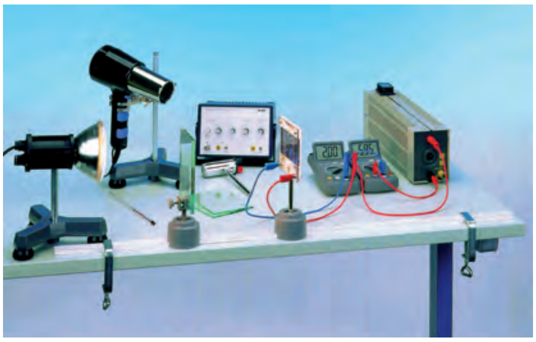
Principle

The relation between voltage and current is measured for different resistors. The resistance is the derivative of the voltage with respect to current and is measured in dependance on current. In case of an incandescent lamp the temperature rise with higher current leads to a considerable higher resistance.

For more details refer to page 112.

Characteristic curves of a solar cell

P2410901



Principle

The current-voltage characteristics of a solar cell are measured at different light intensities, the distance between the light source and the solar cell being varied. The dependence of no-load voltage and short-circuit current on temperature is determined.

For more details refer to page 114.

Characteristic curves of semiconductors with Cobra4 — P2410960

NEW

Principle

The current-voltage characteristic of a semiconducting diode is measured.
The collector current in dependency on the emitter-collector voltage is measured for different values of base current strength through a NPN transistor.

For more details refer to page 115.

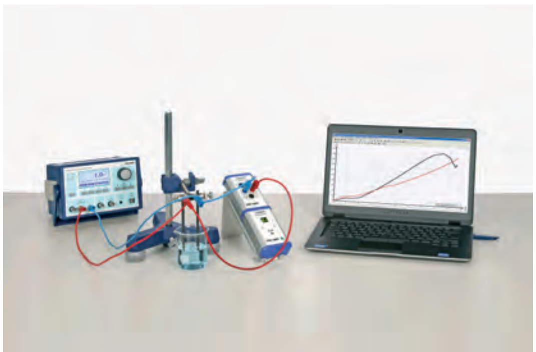
Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser — P2411100

Principle

In a PEM electrolyser, the electrolyte consists of a proton-conducting membrane and water (PEM = Proton- Exchange-Membrane). When an electric voltage is applied, hydrogen and oxygen are formed. The PEM fuel cell generates electrical energy from hydrogen and oxygen. The electrical properties of the electrolyser and the fuel cell are investigated by recording a current-voltage characteristic line. To determine the efficiency, the gases are stored in small gasometers in order to be able to measure the quantities of the gases generated or consumed.

For more details refer to page 106.

Second order conductors - Electrolysis with Cobra4 — P2411360



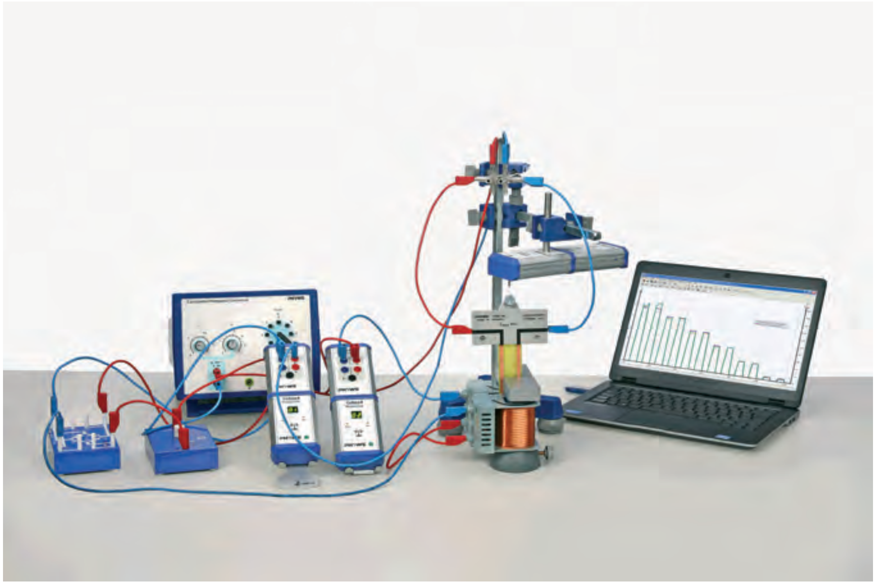
NEW

Principle

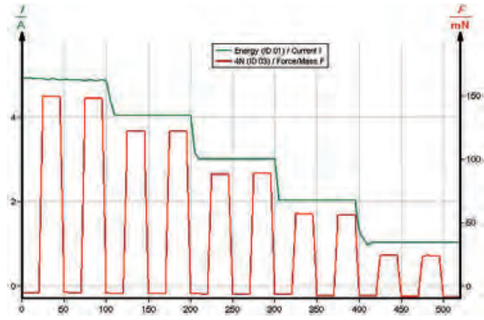
In this experiment a copper (II) sulphate solution is to be electrolysed using two different materials - graphite electrodes and copper wires. During the electrolyses the current/voltage curves are recorded.

For more details refer to page 116.

P2410660 Current balance / Force acting on a current-carrying conductor with Cobra4



NEW Cobra4 Demo



Lorentz force F as a function of the current I_L in the conductor loop.

Principle

The force acting on a current-carrying conductor loop in a uniform magnetic field (Lorentz force) is measured with a balance. Conductor loops of various sizes are suspended in turn from the balance, and the Lorentz force is determined as a function of the current and magnetic induction. The uniform magnetic field is generated by an electromagnet. The magnetic induction can be varied with the coil current.

Tasks

1. The direction of the force is to be determined as a function of the current and the direction of the magnetic field.
2. The force F is to be measured, as a function of the current I_L in the conductor loop, with a constant magnetic induction B and for conductor loops of various sizes. The magnetic induction is to be calculated.
3. The force F is to be measured, as a function of the coil current I_M, for a conductor loop. In the range being considered, the magnetic induction B is, with sufficient accuray, proportional to the coil current I_M.

What you can learn about

- Uniform magnetic field
- Magnetic induction (formerly magnetic-flux densitiy)
- Lorentz force
- Moving charges
- Current

Main articles

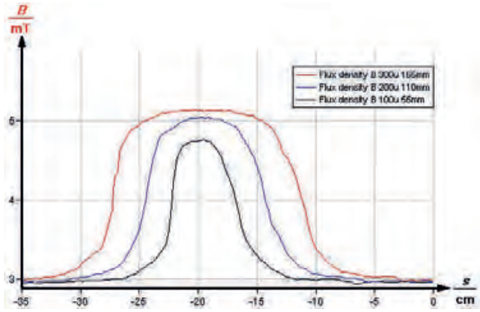
Power supply, universal	13500-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	3
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Force ± 4 N	12642-00	1
Cobra4 Sensor-Unit Electricity, Current ± 6 A / Voltage ± 30	12644-00	2
Coil, 300 turns	06513-01	2

Related Experiment

Current balance/ force acting on a current-carrying conductor with an amperemeter

P2410601

Magnetic field of single coils / Biot-Savart's law with Cobra4 P2430260



Curve of magnetic flux density (measured values) for coils with a constant density of turns n/l, coils radius r = 20 mm, lengths l_1 = 53 mm, l_2 = 105 mm and l_3 = 160 mm.

Principle

The magnetic field along the axis of wire loops and coils of different dimensions is measured with a teslameter (Hall probe). The relationship between the maximum field strength and the dimensions is investigated and a comparison is made between the measured and the theoretical effects of position.

Tasks

1. To measure the magnetic flux density in the middle of various wire loops with the Hall probe and to investigate itsdependence on the radius and number of turns.
2. To determine the magnetic field constant.
3. To measure the magnetic flux density along the axis of long coils and compare it with theoretical values.

What you can learn about

- Wire loop
- Biot-Savart's law
- Hall effect
- Magnetic field
- Induction
- Magnetic flux density

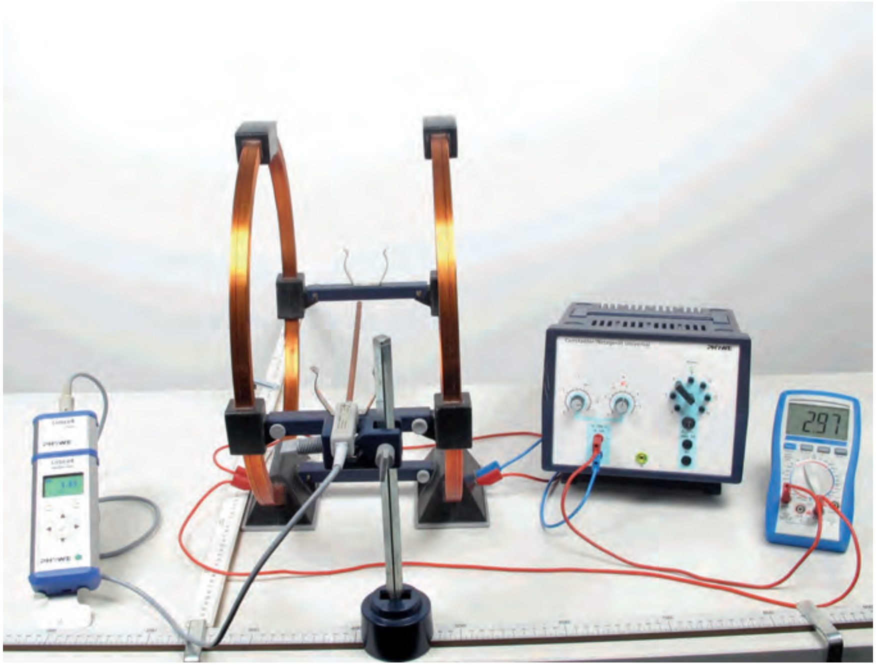
Main articles		
Cobra4 Wireless-Link	12601-00	2
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor Tesla	12652-00	1
Cobra4 Sensor-Unit Electricity	12644-00	1
Software Cobra4 - multi-user licence	14550-61	1
Power supply, universal	13500-93	1
Hall probe, axial	13610-01	1

Related Experiment

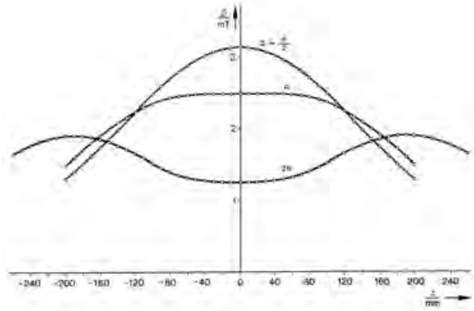
Magnetic field of single coils/ Biot-Savart's law with a teslameter

P2430201

P2430362 Magnetic field of paired coils in a Helmholtz arrangement with Cobra4



NEW



B (r = 0; r is the distance perpendicular to the axis of the coils) as a function of z (z is the distance from the center of the coils in the direction of the axis of the coils) with the parameter.

Principle

The spatial distribution of the field strength between a pair of coils in the Helmholtz arrangement is measured. The spacing at which a uniform magnetic field is produced is investigated and the superposition of the two individual fields to form the combined field of the pair of coils is demonstrated.

Tasks

1. To measure the magnetic flux density along the z-axis of the flat coils when the distance between them alpha = R (R = radius of the coils) and when it is larger and smaller than this.
2. To measure the spatial distribution of the magnetic flux density when the distance between coils alpha = R, using the rotational symmetry of the set-up: a) measurement of the axial component B_z; b) measurement of radial component B_r.
3. To measure the radial components B'_r and B''_r of the two individual coils in the plane midway between them and to demonstrate the overlapping of the two fields at $B_r = 0$.

What you can learn about

- Maxwell's equations
- Wire loop
- Flat coils
- Biot-Savart's law
- Hall effect

Main articles		
Cobra4 Mobile-Link set	12620-55	1
Cobra4 Sensor Tesla	12652-00	1
Helmholtz coils, one pair	06960-00	1
Power supply, universal	13500-93	1
Hall probe, axial	13610-01	1
Digital multimeter 2010	07128-00	1
Barrel base PHYWE	02006-55	1

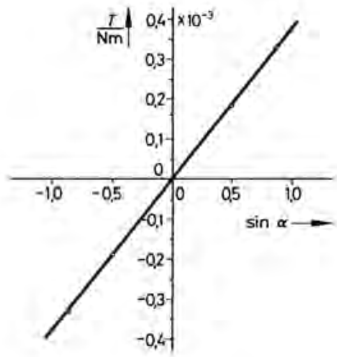
Related Experiment

Magnetic field of paired coils in a Helmholtz arrangement with a teslameter

P2430301

Magnetic moment in the magnetic field

P2430400



Torque due to a magnetic moment in a uniform magnetic field as a function of the angle between the magnetic field and magnetic moment.

Principle

A conductor loop carrying a current in an uniform magnetic field experiences a torque. This is determined as a function of the radius, of the number of turns and the current in the conductor loop and of the strength of the external field.

Tasks

Determination of the torque due to a magnetic moment in a uniform magnetic field, as a function

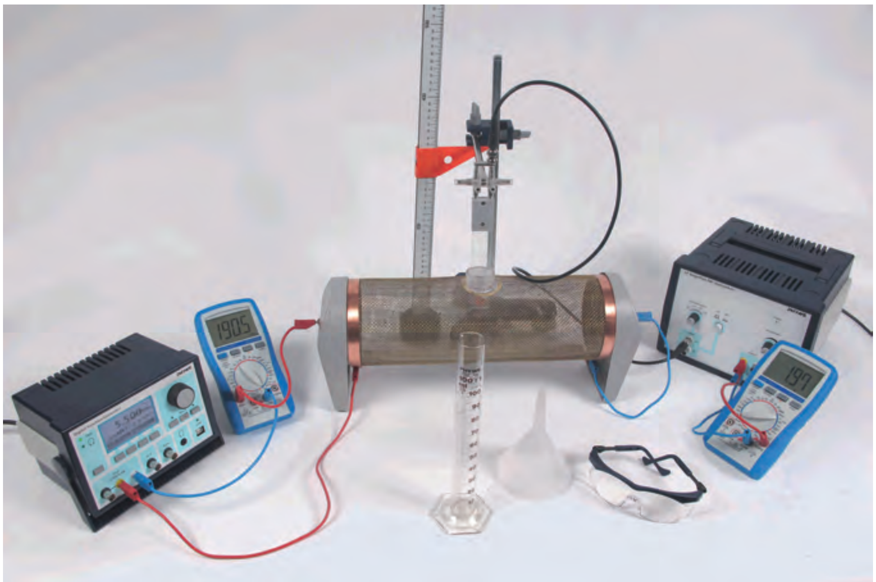
1. of the strength of the magneticfield,
2. of the angle between the magnetic field in the magnetic moment
3. of the strength of the magnetic moment.

What you can learn about

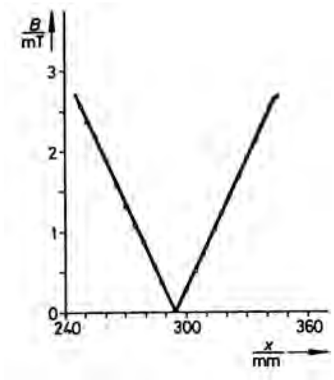
- Torque
- Magnetic flux
- Uniform magnetic field
- Helmholtz coils

Main articles		
Helmholtz coils, one pair	06960-00	1
Power supply, universal	13500-93	1
Torsion dynamometer, 0.01 N	02416-00	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Conductors, circular, set	06404-00	1
Coil holder for 02416.00	02416-02	1
Digital multimeter 2010	07128-00	2

P2430605 Magnetic field inside a conductor with digital function generator



NEW Cobra4 Demo



The linear relationship between current density and magnetic field is obvious.

Principle

A current is passed through an electrolyte producing a magnetic field. This magnetic field inside the conductor is measured as function of position and current by determining the induction voltage.

Tasks

Determine the magnetic field inside the conductor as a function of

1. the current in the conductor and verify the linear relationship.
2. the distance from the middle axis of the conductor and determine the position where the field inside the conductor vanishes.

Related Topics

- Maxwell's equations
- Magnetic flux
- Induction
- Current density
- Field strength
- Electrolyte

Main articles		
LF amplifier, 220 V	13625-93	1
Digital Function Generator, USB	13654-99	1
Hollow cylinder, PLEXIGLAS	11003-10	1
Search coil, straight	11004-00	1
Tripod base PHYWE	02002-55	1
Digital multimeter 2010	07128-00	2
Glass beaker, short, 5000 ml	36272-00	1

Digital Function Generator, USB, incl. Cobra4 Software

NEW

Function and Applications

Digital signal generator for use as a programmable voltage source in practical or demonstration experiments, particularly in the disciplines of acoustics, electrical engineering and electronics.

Benefits

- Can be used as universal stand-alone device or controlled via a USB interface
- Universally applicable thanks to broad, continually adjustable frequency range
- Usable as programmable voltage source via amplifier output
- Intuitive, menu-driven operation using control knob and function buttons, with help capability
- Illuminated monochrome graphic display for maximum visibility and readability
- Simple setting of voltage and frequency ramps in stand-alone mode
- Features V = f(f) output for easy reading of frequency in the form of a voltage - ideal for measuring circuit response to frequency ramps using an oscilloscope
- Low distortion and signal-to-noise ratio for brilliantly clear signals - ideal for acoustics/audio experiments

13654-99

Determination of the earth's magnetic field

P2430100

Principle

A constant magnetic field, its magnitude and direction known, is superimposed on the unknown earth magnetic field. The earth-magnetic field can then be calculated from the magnitude and direction of the resulting flux density.

For more details refer to page 129.

Magnetic field outside a straight conductor

P2430500

Principle

A current which flows through one or two neighbouring straight conductors produces a magnetic field around them. The dependences of these magnetic fields on the distance from the conductor and on the current are determined.

For more details refer to page 130.

Linear Levitation Track, length: 70 cm

11330-00

Function and Applications

A magnetic levitation system uses magnetic fields to levitate and accelerate a vehicle along a track. Similar systems are in use today as high-speed trains and some of the newer, radical-ride roller coasters. The PHYWE Levitation Tracks use the power of a solar cell panel to propel the PHYWE Solar Cart with the help of a linear motor. Thereby, the Solar Cart hovers above the magnetic track.

For more details refer to www.phywe.com

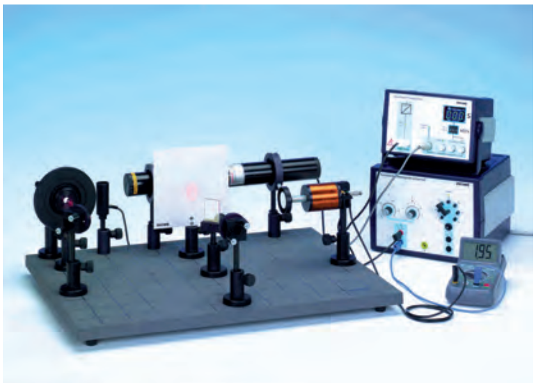
Ferromagnetic hysteresis with Cobra4 — P2430760

Principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores can be compared.

For more details refer to page 145.

Magnetostriction with the Michelson interferometer — P2430800

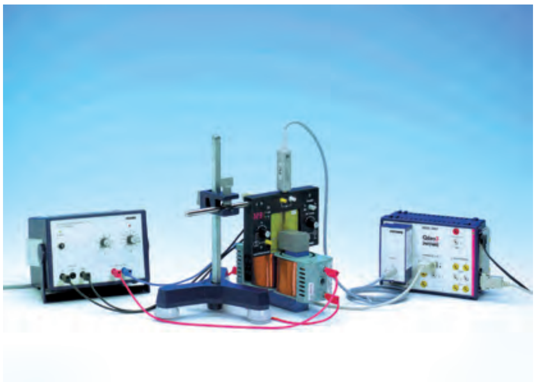


Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

For more details refer to pages 146, 208.

Hall effect in p-germanium with Cobra3 — P2530111

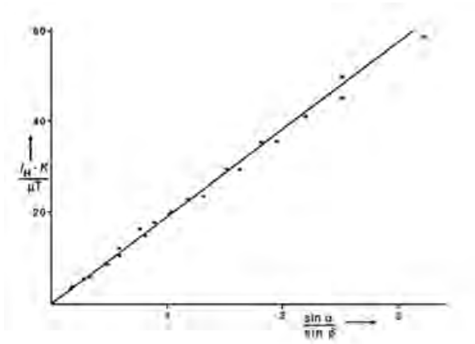


Principle

The resistivity and Hall voltage of a rectangular germanium sample are measured as a function of temperature and magnetic field. The band spacing, the specific conductivity, the type of charge carrier and the mobility of the charge carriers are determined from the measurements.

For more details refer to page 212.

Determination of the earth's magnetic field P2430100



Linear function to determine the horizontal component hBE of the magnetic flux density of the earth-magnetic field.

Principle

A constant magnetic field, its magnitude and direction known, is superimposed on the unknown earth magnetic field. The earth-magnetic field can then be calculated from the magnitude and direction of the resulting flux density.

Tasks

1. The magnetic flux of a pair of Helmholtz coils is to be determined and plotted graphically as a function of the coil current. The Helmholtz system calibration factor is calculated from the slope of the line.
2. The horizontal component of the earth-magnetic field is determined through superimposition of the Helmholtz field.
3. The angle of inclination must be determined in order to calculate the vertical component of the earth-magnetic field.

What you can learn about

- Magnetic inclination and declination
- Isoclinic lines; Isogenic lines
- Inclinometer; Magnetic flow density; Helmholtz coils

Main articles		
Teslameter, digital	13610-93	1
Helmholtz coils, one pair	06960-00	1
Power supply, universal	13500-93	1
Magnetometer	06355-00	1
Hall probe, axial	13610-01	1
Rheostat, 100 Ohm , 1.8A	06114-02	1
Digital multimeter 2010	07128-00	1

Helmholtz coils, one pair

Function and Applications

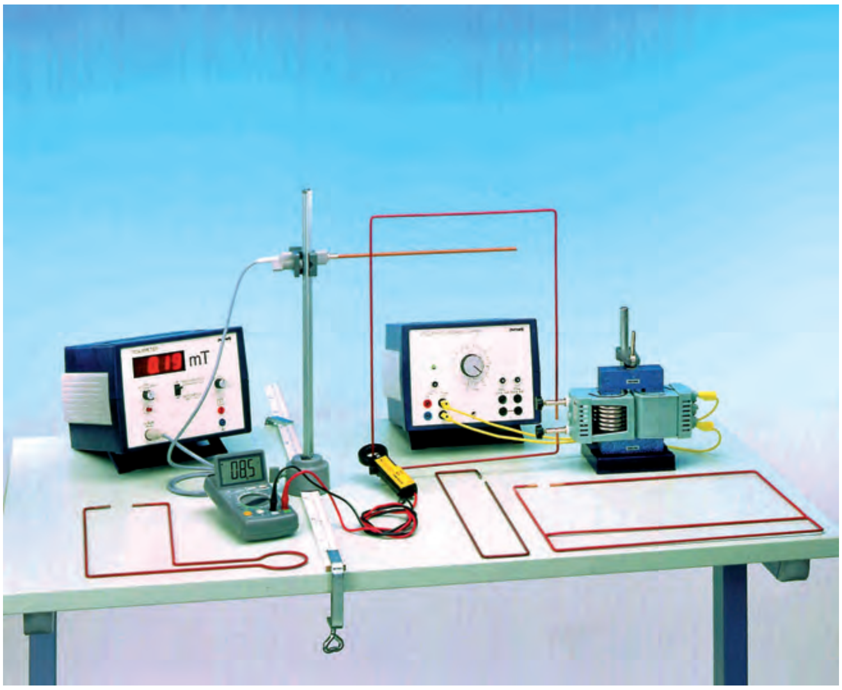
Helmholtz coils, one pair to generate a homogeneous magnetic field. Especially with narrowbeam tube for e/m determination.

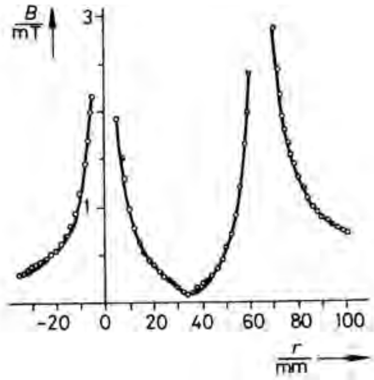
Equipment and technical data

- Two identical coils each on standbase with numbered 4mm sockets
- Removable busbars with holder for narrow beam tube
- Coils can be used indivdually and at any distance.
- Coil diameter: 400 mm, Number of windings: each coil 154
- Coil resistance: 2.1 Ohm
- Max. current per coil: 5 A, Max. flux density (5A): 3.5 mT

06960-00

P2430500 Magnetic field outside a straight conductor





Magnetic field component By of two parallel conductors on the x-axis as a function of the distance from one conductor, if the current in both conductors is in the same direction.

Principle

A current which flows through one or two neighbouring straight conductors produces a magnetic field around them. The dependences of these magnetic fields on the distance from the conductor and on the current are determined.

Tasks

Determination of the magnetic field

1. of a straight conductor as a function of the current,
2. of a straight conductor as a function of the distance from the conductor,
3. of two parallel conductors, in which the current is flowing in the same direction, as a function of the distance from one conductor on the line joining the two conductors,
4. of two parallel conductors, in which the current is flowing in opposite directions, as a function of the distance from one conductor on the line joining the two conductors.

What you can learn about

- Maxwell's equations
- Magnetic flux
- Induction
- Superimposition of magnetic fields

Main articles		
Teslameter, digital	13610-93	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Hall probe, axial	13610-01	1
Coil, 140 turns, 6 tappings	06526-01	1
Current conductors,set of 4	06400-00	1
Current transformer/Clamp Ammeter adaptor	07091-10	1

Teslameter, digital

Function and Applications

For the measurement of magnetic DC and AC fields.

Equipment and technical data:

- Teslameter with 3 1/2 digit LED display, 20 mm high.
- 3 measuring ranges 20 - 200 - 1000 m
- T fsd - , sensitivity 10 micro T.
- For alternating and direct fields calibrated analog output.

13610-93

Magnetic field of single coils/ Biot-Savart's law with Cobra4 P2430260

NEW

Principle

The magnetic field along the axis of wire loops and coils of different dimensions is measured with a teslameter (Hall probe). The relationship between the maximum field strength and the dimensions is investigated and a comparison is made between the measured and the theoretical effects of position.

For more details refer to page 123.

Magnetic field of paired coils in a Helmholtz arrangement with Cobra4 P2430362

NEW

Principle

The spatial distribution of the field strength between a pair of coils in the Helmholtz arrangement is measured. The spacing at which a uniform magnetic field is produced is investigated and the superposition of the two individual fields to form the combined field of the pair of coils is demonstrated.

For more details refer to page 124.

Ferromagnetic hysteresis with Cobra4 P2430760

NEW

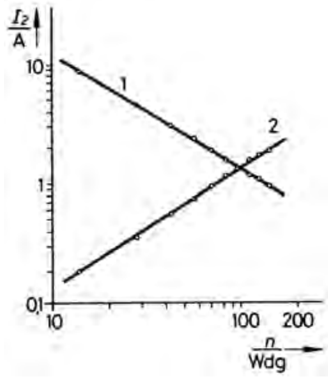
Principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores can be compared.

For more details refer to page 145.

P2440100 Transformer

Demo



Secondary short-circuit current of the transformer as a function 1. of the number of turns in the secondary coil, 2. of the number of turns in the primary coil.

Principle

An alternating voltage is applied to one of two coils (primary coil) which are located on a common iron core. The voltage induced in the second coil (secondary coil) and the current flowing in it are investigated as functions of the number of turns in the coils and of the current flowing in the primary coil.

Tasks

- The secondary voltage on the open circuited transformer is determined as a function

1. of the number of turns in the primary coil,
2. of the number of turns in the secondary coil,
3. of the primary voltage.

- The short-circuit current on the secondary side is determined as a function

1. of the number of turns in the primary coil,
2. of the number of turns in the secondary coil,
3. of the primary current.

- With the transformer loaded, the primary current is determined as a function

1. of the secondary current,
2. of the number of turns in the secondary coil,
3. of the number of turns in the primary coil.

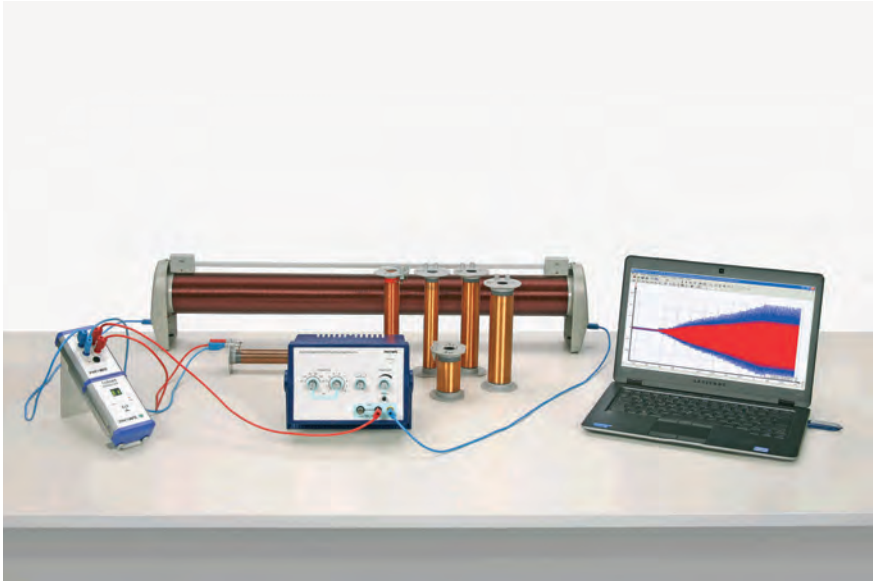
What you can learn about

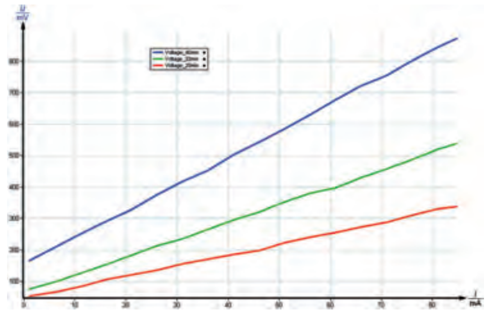
- Induction
- Magnetic flux
- Loaded transformer
- Unloaded transformer
- Coil

Main articles		
Multitap transformer, 14 VAC/ 12 VDC, 5 A	13533-93	1
Coil, 140 turns, 6 tappings	06526-01	2
Rheostat, 10 Ohm , 5.7A	06110-02	1
Clamping device	06506-00	1
Iron core, U-shaped, laminated	06501-00	1
Two-way switch, double pole	06032-00	1
DMM with NiCr-Ni thermo couple	07122-00	3

Magnetic Induction with Cobra4

P2440260





Induced voltage as a function of current for different coils.

Principle

A magnetic field of variable frequency and varying strength is produced in a long coil. The voltages induced across thin coils which are pushed into the long coil are determined as a function of frequency, number of turns, diameter and field strength.

Tasks

- Determination of the induction voltage as a function

1. of the strength of the magneticfield,
2. of the frequency of the magneticfield,
3. of the number of turns of the induction coil,
4. of the cross-section of the induction coil.

What you can learn about

- Maxwell's equations
- Electrical eddy field
- Magnetic field of coils
- Coil
- Magnetic flux
- Induced voltage

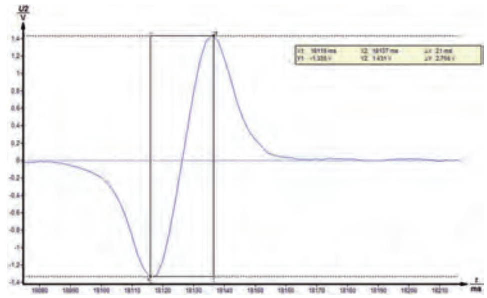
Main articles		
Digital Function Generator, USB, incl. Cobra4 Software	13654-99	1
Field coil, 750 mm, 485 turns/m	11001-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor-Unit Electricity, Current ± 6 A / Voltage ± 30	12644-00	1
Induction coil,300 turns,dia.32mm	11006-02	1
Induction coil,100 turns,dia.40mm	11006-05	1

Related Experiment

Magnetic induction

P2440201

P2441211 Induction impulse



Measured induction voltage USS versus time. Additionally the evaluation of the peak-to-peak voltage USS = 2.766 V is shown.

Principle

A permanent magnet falls with different velocities through a coil. The change in the magnetic flux Φ generates an induced voltage impulse. The induced voltage impulse USS is recorded with a computer interface system. Depending on the polarity of the permanent magnet the induced voltage impulse is negative or positive.

Tasks

1. Measurement of the induced voltage impulse USS and the falling magnet's velocity.
2. Evaluation of the induced voltage impulse USS as a function of the magnet's velocity.
3. Calculation of the magnetic flux induced by the falling magnet as a function of the magnet's velocity.

What you can learn about

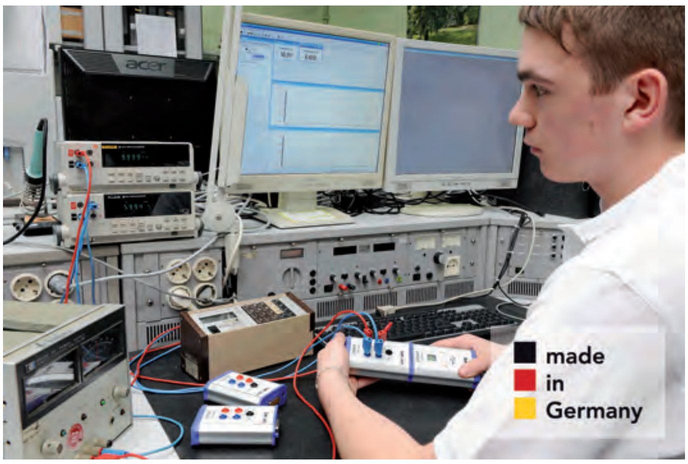
- Law of induction
- Magnetic flux
- Maxwell's equations

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Light barrier, compact	11207-20	1
Coil, 600 turns, short	06522-01	1
Tripod base PHYWE	02002-55	1
Software Cobra3 Universal recorder	14504-61	1
Power supply 12V / 2A	12151-99	1
Coil holder	06528-00	1

Cobra4 Experiment - available 2014

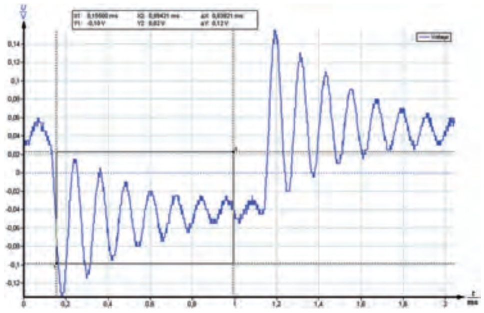
Induction impulse with Cobra4

P2441260



Inductance of solenoids with Cobra3

P2440311



Inductance per turn as a function of the length of the coil at constant radius.

Principle

A square wave voltage of low frequency is applied to oscillatory circuits comprising coils and capacitors to produce free, damped oscillations. The values of inductance are calculated from the natural frequencies measured, the capacitance being known.

Tasks

- To connect coils of different dimensions (length, radius, number of turns) with a known capacitance C to form an oscillatory circuit.
- From the measurements of the natural frequencies, to calculate the inductances of the coils and determine the relationships between:

1. inductance and number of turns
2. inductance and length
3. inductance and radius.

What you can learn about

- Lenz's law
- Self-inductance
- Solenoids
- Transformer
- Oscillatory circuit
- Resonance
- Damped oscillation
- Logarithmic decrement
- Q factor

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Measuring module function generator	12111-00	1
Coil, 1200 turns	06515-01	1
Induction coil,300 turns,dia.40mm	11006-01	1
Induction coil,300 turns,dia.32mm	11006-02	1

Related Experiment

Inductance of solenoids

P2440301

Cobra4 Experiment - available 2014

Inductance of solenoids with Cobra4

P2440360

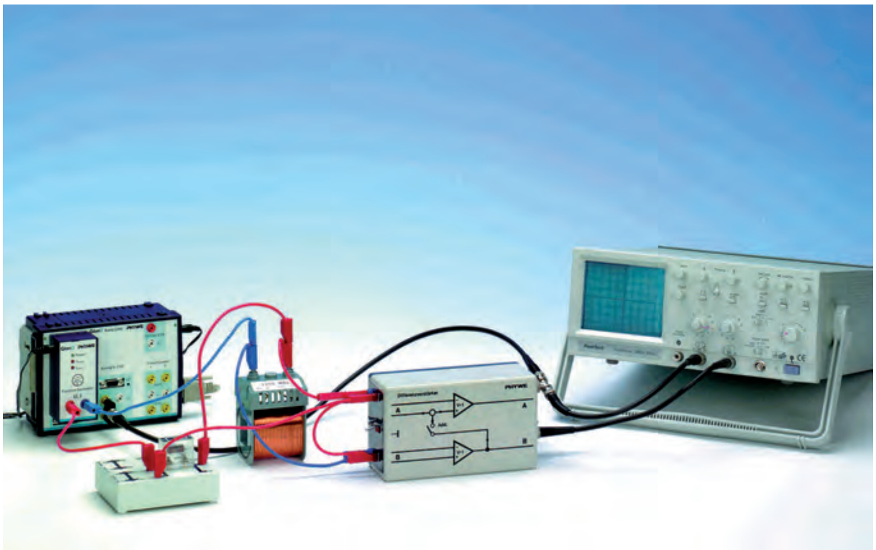
Induction coil,300 turns,dia.40mm

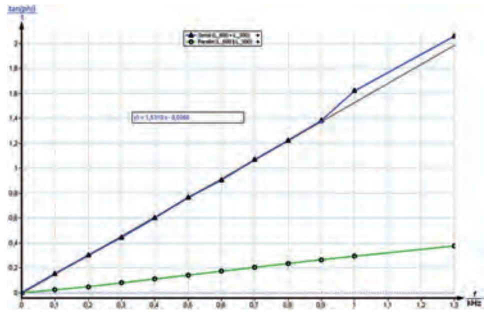
Function and Applications

To investigate electromagnetic induction together with field coil (11001-00) and the constitution of magnetic fields within long coils.

11006-01

P2440411 Coil in the AC circuit with Cobra3 and the FG module





Tangent of the current-voltage phase displacement as a function of the frequency used for calculation of the total inductance of coils connected in parallel and in series.

Principle

The coil is connected in a circuit with a voltage source of variable frequency. The impedance and phase displacements are determined as functions of frequency. Parallel and series impedances are measured.

Tasks

1. Determination of the impedance of a coil as a function of frequency.
2. Determination of the inductance of the coil.
3. Determination of the phase displacement between the terminal voltage and total current as a function of the frequency in the circuit.
4. Determination of the total impedance of coils connected in parallel and in series.

What you can learn about

- Inductance; Kirchhoff's laws
- Maxwell's equations
- a.c. impedance; phase displacement

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Measuring module function generator	12111-00	1
Software Cobra3 PowerGraph	14525-61	1
Coil, 300 turns	06513-01	1
Coil, 600 turns	06514-01	1
Power supply 12V / 2A	12151-99	1
Connection box	06030-23	1

Related Experiment

Coil in the AC circuit

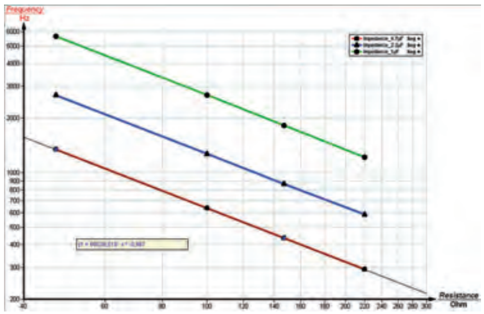
P2440401

Cobra4 Experiment - available 2014

Coil in the AC circuit with Cobra4

P2440460

Capacitor in the AC circuit with Cobra3 and the FG module P2440515



Impedance of various capacitors as a function of the frequency.

Principle

A capacitor is connected in a circuit with a variable-frequency voltage source. The impedance and phase displacement are determined as a function of frequency and of capacitance. Parallel and series impedances are measured.

Tasks

1. Determination of the impedance of a capacitor as a function of frequency.
2. Determination of the phase displacement between the terminal voltage and total current as a function of the frequency in the circuit.
3. Determination of the total impedance of capacitors connected in parallel and in series.

What you can learn about

- Capacitance; Kirchhoff's laws
- Maxwell's equations
- a.c. impedance; Phase displacement

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Measuring module function generator	12111-00	1
Software Cobra3 PowerGraph	14525-61	1
Power supply 12V / 2A	12151-99	2
Connection box	06030-23	1
Capacitor 1 microF/ 100V, G2	39113-01	1
Capacitor 2,2microF/ 100V, G2	39113-02	1

Related Experiment

Capacitor in the AC circuit

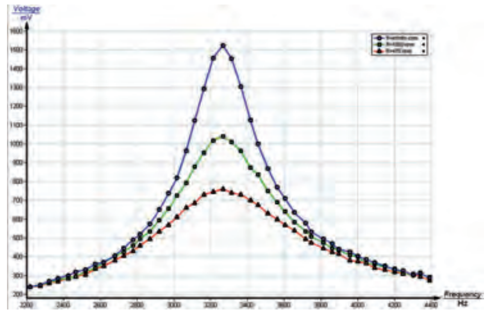
P2440501

Cobra4 Experiment - available 2014

Capacitor in the AC circuit with Cobra4

P2440560

P2440611 RLC circuit with Cobra3 and the FG module



Total voltage as a function of frequency in the parallel tuned circuit. Curves recorded for different resistors (top down): R =∞ Ω, 1000 Ω, 470 Ω.

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Measuring module function generator	12111-00	1
Software Cobra3 PowerGraph	14525-61	1
Coil, 3600 turns, tapped	06516-01	1
Software Cobra3 Universal recorder	14504-61	1
Power supply 12V / 2A	12151-99	2
Connection box	06030-23	1

Principle

The current and voltage of parallel and series-tuned circuits are investigated as a function of frequency.

Q-factor and band-width are determined.

Tasks

Determination of the frequency performance of a

- Series-tuned circuit for

1. voltage resonance without damping resistor,
2. current resonance without damping resistor,
3. current resonance with damping resistor.

- parallel-tuned circuit for

1. current resonance without parallel resistor,
2. voltage resonance without parallel resistor
3. voltage resonance with parallel resistor.

What you can learn about

- Series-tuned circuit
- Parallel-tuned circuit
- Resistance
- Capacitance
- Inductance
- Capacitor
- Coil
- Phase displacement
- Q factor
- Band-width
- Loss resistance
- Damping

Related Experiment

RLC circuit

P2440601

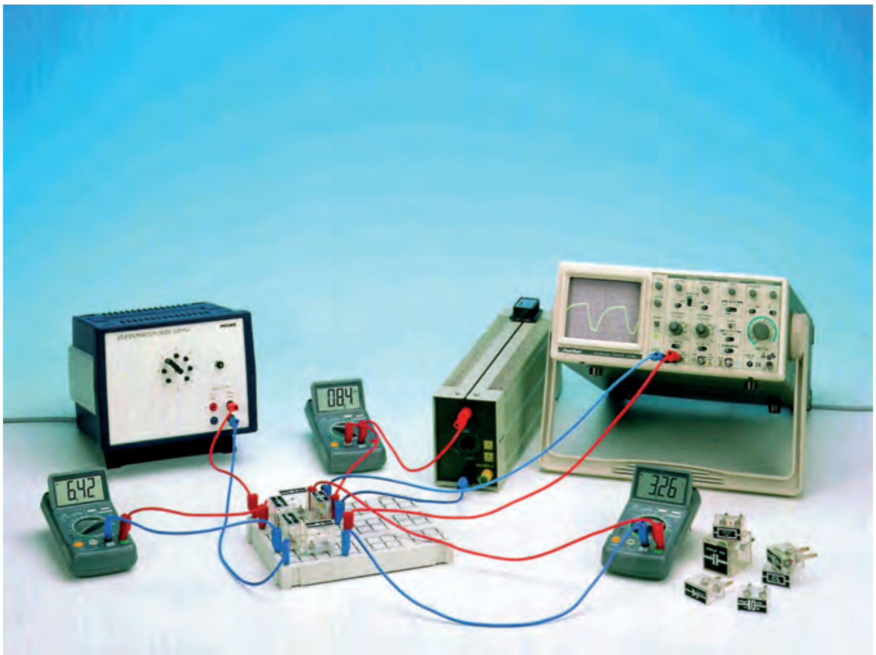
Cobra4 Experiment - available 2014

RLC circuit with Cobra4

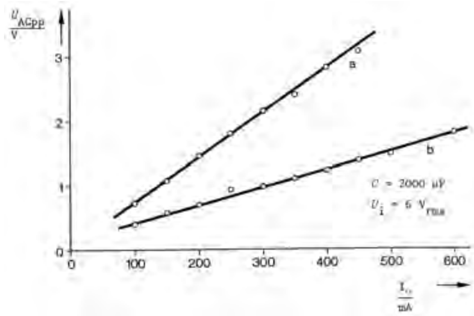
P2440660

Rectifier circuits

P2440700



Demo



Ripple of the output voltage as a function of the charging current: a) half-wave rectifier, b) bridge rectifier.

Principle

The ripple of the output voltage of various rectifier circuits is measured as a function of the load current strength and the charging capacitance. The characteristics of a voltage stabilizer and of a multiplier are investigated.

Tasks

- Using the half-wave rectifier:

1. To display the output voltage (without charging capacitor) on the oscilloscope.
2. To measure the diode current I_D as a function of the output current strength I_0 (with the charging capacitor).
3. To measure the ripple component U_{ACpp} of the output voltage as a function of the output current (C = constant).
4. To measure the ripple as a function of the capacitance (I_0 = constant).
5. To measure the output voltage U_0 as a function of the input voltage U_i (I_0 = 0).

- Using the bridge rectifier:

1. To display the output voltage (without charging capacitor) on the oscilloscope.
2. To measure the current through one diode, I_D, as a function of the output current I_0 (with the charging capacitor).
3. To measure the ripple of the output voltage as a function of the output current (C = constant).
4. To measure the ripple as a function of the capacitance (I_0 = constant).
5. To measure the output voltage as a function of the input voltage.

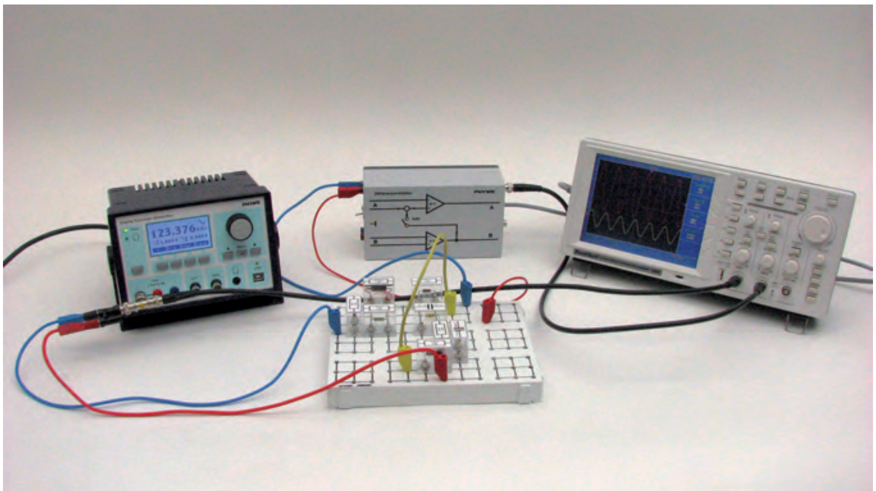
- To measure the voltage at the charging capacitor, U_c, and the output voltage of a stabilised voltage source as a function of the input voltage U_i.
- To measure the output voltage of a voltage multiplier circuit as a function of the input voltage.

What you can learn about

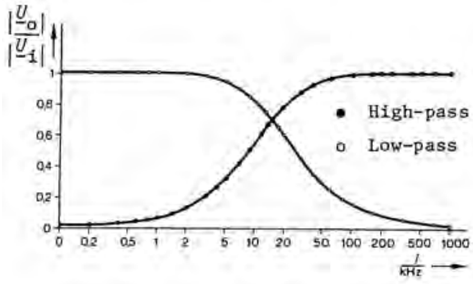
- Half-wave rectifier
- Full-wave rectifier
- Graetz rectifier
- Diode and Zener diode
- Avalanche effect
- Charging capacitor
- Ripple
- r.m.s. value
- Internal resistance
- Smoothing factor
- Ripple voltage
- Voltage stabilisation
- Voltage doubling

Main articles		
30 MHz digital storage oscilloscope	11462-99	1
Multitap transformer, 14 VAC/ 12 VDC, 5 A	13533-93	1
Rheostat, 330 Ohm , 1.0A	06116-02	1
Plug-in board,4mm plugs	06033-00	1
Digital multimeter 2010	07128-00	3
Electrolyte capacitor 2000 µF/35V, G2	39113-08	1
Capacitor,electr.1mF/35V,G1	06049-09	1

P2440801 RC filters



NEW · Cobra4 · Demo



Example of a measured frequency response of the high- and low-pass filters.

Principle

Resistor-Capacitor (RC) circuits serve as filters for frequencies. The frequency response of the most commonly used RC filters is recorded by point-by-point measurements as well as the frequency sweep method, and displayed on the oscilloscope. The results are plotted and verified using the measure analysis software.

Tasks:

1. Record the frequency response of the output voltage of

- a high-pass filter
- a low-pass filter
- a band-pass filter
- a Wien-Robinson bridge
- a parallel-T filter, point by point and to display the sweep on the oscilloscope. Investigate the step response of
- a differentiating network
- an integrating network.

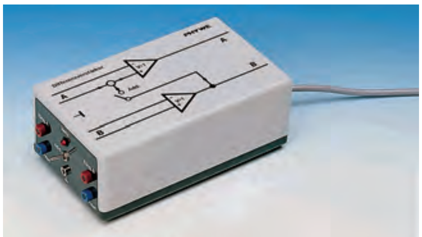
2. Analyse and verify the measurements using the measure analysis software.

What you can learn about

- High-pass; Low-pass
- Wien-Robinson bridge; Parallel-T filters
- Differentiating network; Integrating network
- Step response; Square wave; Transfer function

Main articles		
Digital Function Generator, USB	13654-99	1
30 MHz digital storage oscilloscope	11462-99	1
Difference amplifier	11444-93	1
Plug-in board,4mm plugs	06033-00	1
Resistor 500 Ohm 5%, 1W, G1	06057-50	1
Capacitor 10nF/ 250V, G1	39105-14	4
Screened cable, BNC, l 1500 mm	07542-12	2

Difference amplifier



Function and Applications

For the simultaneous potential-free measurement of two voltages when connected to the inputs of a two channel oscilloscope.

Benefits

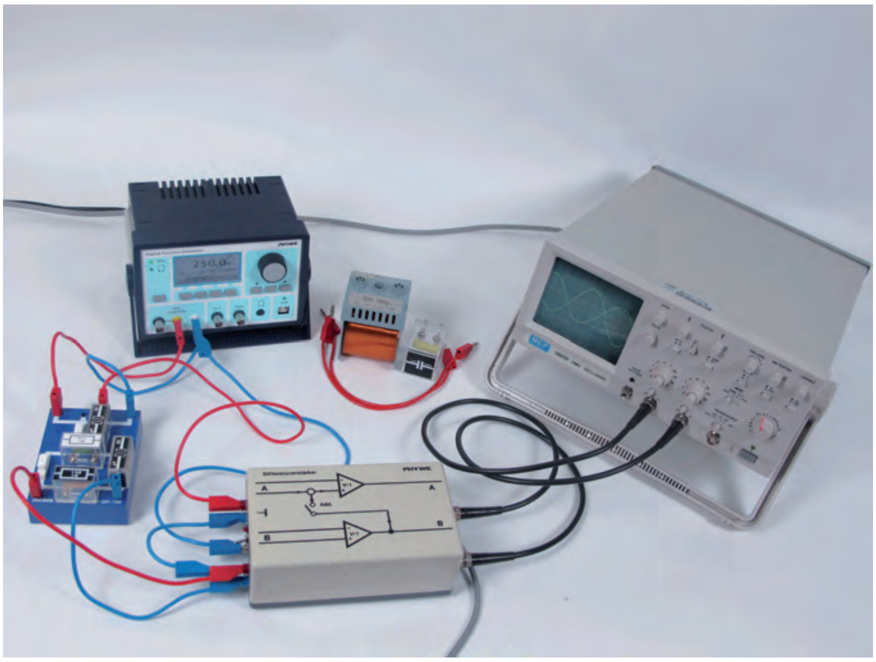
- The high resistance difference inputs can be connected to any point of a circuit, without influencing the electrical behaviour of the circuit.
- Allows demonstration of the phase shift between voltage and current in alternating current circuits.
- Enables characteristics to be presented in the xy operation mode of an oscilloscope.
- Input voltages can be added.

Equipment and technical data

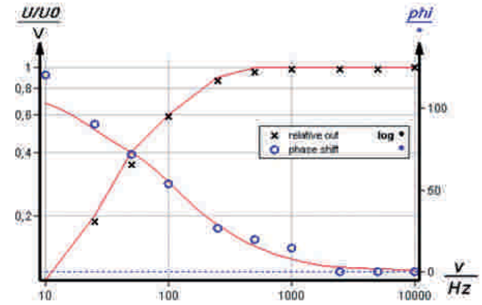
- amplification 1 ± 3%, frequency range for UE 20 Vss 0. 15 kHz, for UE 6 Vss 0.70 kHz, for UE 2 Vss 0.100 kHz
- inputs A and B: connection 4-mm-pair of sockets
- impedance 1 M_/10 pF, overload capacity mains voltage proof
- outputs A and B: connection BNC-sockets;
- internal resistance 100 Ohm, external resistance 10 kOhm
- overload capacity short-circuit proof, mains supply 230 V, 50.60Hz
- casing dimensions (mm) 190×110×60

11444-93

High-pass and low-pass filters with digital function generator P2440905



NEW Cobra4 Demo



Voltage ratio (left axis) and phase displacement (right axis) of the double CR network as a function of frequency with $R_1=50\ \Omega$, $R_2=1\ k\Omega$ and $C_1=25\ \mu F$, $C_2=50\ \mu F$.

Principle

A coil, a capacitor, an ohmic resistance and combinations of these components are investigated for their filter characteristics as a function of frequency. The phase displacement of the filters is determined also as a function of frequency.

Tasks

Determination of the ratio of output voltage to input voltage with the

1. RC/CR network,
2. RL/LR network,
3. CL/LC network,
4. Two CR networks connected in series
5. Determination of the phase displacement with the RC/CR network.
6. Determination of the phase displacement with two CR networks connected in series.

What you can learn about

- Circuit; Resistance
- Capacitance; Inductance
- Capacitor; Coil
- Phase displacement
- Filter
- Kirchhoff's laws
- Bode diagram

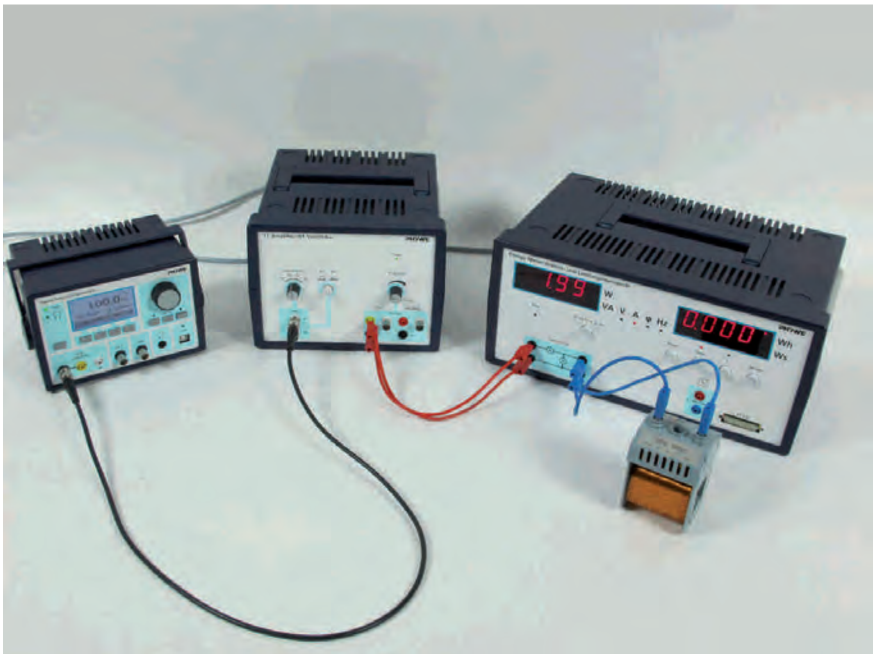
Main articles		
Universal Counter	13601-99	1
Oscilloscope, 30 MHz, 2 channels	11459-95	1
Function generator, 0.1 Hz - 100 KHz	13652-93	1
Difference amplifier	11444-93	1
Coil, 300 turns	06513-01	1
Connection box	06030-23	2
Capacitor 1 microF/ 100V, G2	39113-01	1

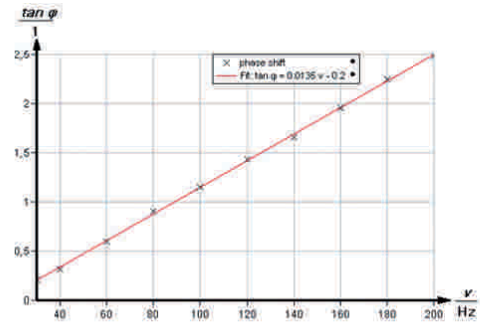
Related Experiment

High-pass and low-pass filters with the FG module

P2440915

P2441101 Resistance, phase shift and power in AC circuits with digital function generator





Self-inductance and resistor in series: tan *phi* as a function of *ν*.

Principle

Series circuits containing self-inductances or capacitances and ohmic resistances are investigated as a function of frequency. Measuring the electrical magnitudes with a work or power measurement instrument, real power or apparent power can be displayed directly.

Tasks

Series circuit of self-inductance and resistor (real coil)

- Investigation of impedance and phase shift as a function of frequency
- Investigation of the relation between real power and current intensity
- Determination of self-inductance and ohmic resistance

Series circuit of capacitor and resistor

- Investigation of impedance and phase shift as a function of frequency
- Investigation of the relation between real power and current intensity
- Determination of capacitance and ohmic resistance

What you can learn about

- Impedance; Phase shift; Phasor diagram
- Capacitance; Self-inductance

Main articles

Work and power meter	13715-93	1
LF amplifier, 220 V	13625-93	1
Digital Function Generator, USB	13654-99	1
Coil, 300 turns	06513-01	1
Connection box	06030-23	1

Work and power meter

Function and Applications

For AC and DC circuits

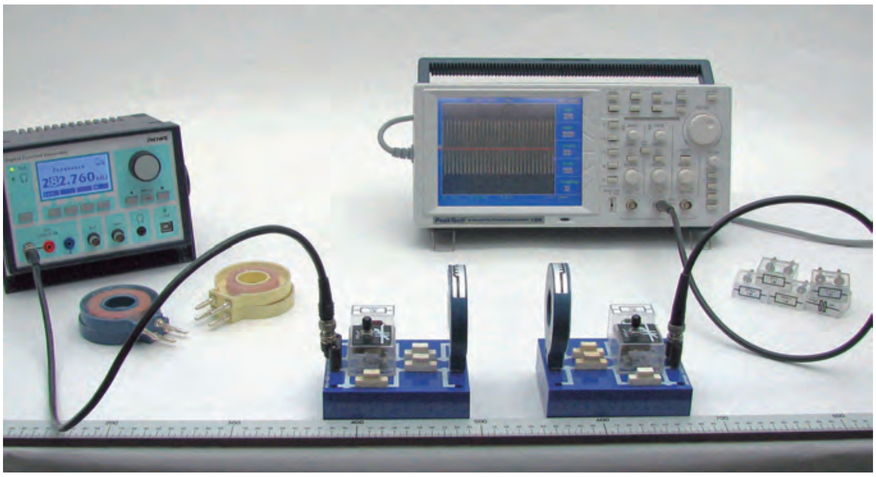
Equipment and technical data

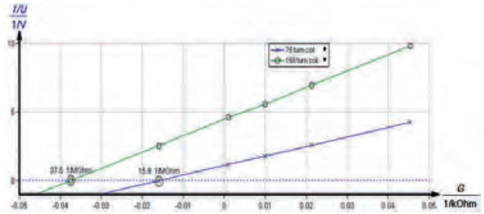
- Two 4-digit, 20 mm LED-displays
- Display 1 for real and apparent power,current, voltage, phase difference and freqency
- Display 2 for energy and time, Selector for serial display of all units
- LED-Status-display and automactic range selection
- Power: max. 2400 W, Resolution: max. 0.001 W
- Voltage: 0-30V AC/DC, 0-240, Veff- Current: 0...10A AC/DC
- Phasen difference: 0...+/- 90 degree
- Frequency: 0...10000 Hz, Energy: max. 9999 Wh or Ws
- Resolution: max. 0.001 Ws, Analog output for all units of disp. 1
- Mains: 110/230V, 50/60Hz
- Shock-resistant plastic housing with carry handle and base

13715-93

Coupled resonant circuits

P2450201





Reciprocal resonance voltage as a function of the additional conductance, used to determine Gp.1. HF coil, 75 turns; 2. 150-turn coil.

Principle

The Q factor of oscillating circuits is determined from the band width and by the Pauli method. In inductively coupled circuits (band-pass filters) the coupling factor is determined as a function of the coil spacing.

Tasks

1. Determine the dissipation factor t and k and the quality factor Q from the band width of oscillating circuits.
2. Determine the dissipation factor and Q factor of oscillating circuits from the resonant frequency , the capacitance Ctot and the parallel conductance Gp by the Pauli method.
3. Determine the coupling factor k and the band width of a band-pass filter as a function of the coil spacing s.
4. Analyse and verify the measurements using the measure analysis software.

What you can learn about

- Resonance
- Q factor
- Dissipation factor
- Bandwidth
- Critical or optimum coupling
- Characteristic impedance
- Pauli method
- Parallel conductance
- Band-pass filter
- Sweep

Main articles

Digital Function Generator, USB	13654-99	1
30 MHz digital storage oscilloscope	11462-99	1
HF-coil, 35 turns, 75 micro-H	06915-00	2
HF-coil, 50 turns,150 micro-H	06916-00	2
HF-coil, 75 turns,350 micro-H	06917-00	2
Coil, 150 turns, short	06520-01	1
Variable capacitor, 500 pF, G2	06049-10	2

Digital Function Generator, USB, incl. Cobra4 Software

Function and Applications

Digital signal generator for use as a programmable voltage source in practical or demonstration experiments, particularly in the disciplines of acoustics, electrical engineering and electronics

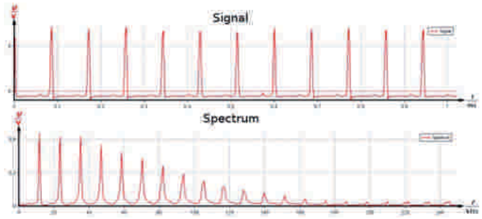
Benefits

- Can be used as universal stand-alone device or controlled via a USB interface
- Universally applicable thanks to broad, continually adjustable frequency range
- Usable as programmable voltage source via amplifier output
- Intuitive, menu-driven operation using control knob and function buttons, with help capability
- Illuminated monochrome graphic display for maximum visibility and readability
- Simple setting of voltage and frequency ramps in stand-alone mode
- Features V = f(f) output for easy reading of frequency in the form of a voltage - ideal for measuring circuit response to frequency ramps using an oscilloscope

13654-99

P2450301 Forced oscillations of a nonlinear electrical series resonant circuit - chaotic oscillation

NEW Cobra4 Demo



Voltage tapped off the diode at Uss=9V. The circuit is oscillating chaotically.

Principle

A sinusoidal voltage is applied to a non-linear circuit with a silicon diode functioning as voltage-independent capacity. The oscillating circuit, i.e. the occurrence of chaotic oscillatory behavior with increasing amplitude is studied.

Tasks

1. Study the oscillatory behavior of the non-linear circuit for an exciting signal with amplitudes between 0.1 and 15 V at frequency of 35 kHz.
2. Investigate the oscillatory image and the Fourier spectrum as functions of the excitation amplitude. Show that period multiples and regions of chaotic oscillatory amplitude occur with increasing amplitude.

Related Topics

- Oscillating circuit; Forced oscillation; Diode
- Period multiples; Fourier spectrum; Chaotic oscillation

Main articles		
Digital Function Generator, USB	13654-99	1
Cobra3 BASIC-UNIT, USB	12150-50	1
30 MHz digital storage oscilloscope	11462-99	1
Coil, 1200 turns	06515-01	1
Software Cobra3 - Fourier analysis	14514-61	1
Power supply 12V / 2A	12151-99	1
Connection box	06030-23	1

Power frequency generator, 10 Hz - 1 MHz

Function and Applications

Sinus and rectangular signal generator with signal and power output for optimal adaptation to different experimental circuits.

Benfits

- Large frequency range, frequencies can be continuously adjusted to five decade areas
- Output for sinus and regtangular signals, Power output for sinus

Equipment and technical data

- Demonstative frequency display with 4 digit LED display
- Supplementary headphone and loudspeaker connector jack

Signal output:

- Max. output voltage Upp: approx. 6 V, Power: 1 W
- Nominal final resistor: 4 Ohm
- Distortion factor: < 1% (typically < 0.2%)

Power output:

- Max. output voltage Upp: approx. 18 V
- Power: 10 W, Nominal final resistor: 4 Ohm
- Distortion factor: < 1% (typically < 0.3%)

Input:

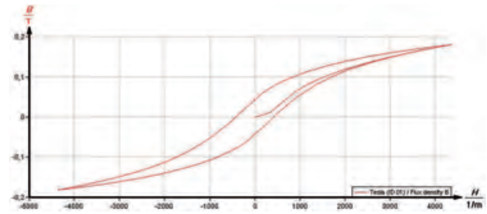
- Input voltage range: Up = 0...1V, Electric strength: Up < 30V
- Input resistance: 50 kOhm, Required power: max. 70 VA
- Dimensions (mm): 370 x 236 x 168

13650-93

Ferromagnetic hysteresis with Cobra4

P2430760

NEW Cobra4 Demo



Hysteresis for a massive iron core.

Principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores can be compared.

Task

Record the hysteresis curve for a massive iron core and for a laminated one.

What you can learn about

- Induction
- Magnetic flux
- Coil
- Magnetic field strength
- Magnetic field of coils
- Remanence
- Coercive field strength

Main articles		
Power supply, universal	13500-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Wireless Manager	12600-00	1
Cobra4 Sensor Tesla	12652-00	1
Cobra4 Sensor-Unit Electricity	12644-00	1
Hall probe, tangential, protection cap	13610-02	1

Related Experiment

Ferromagnetism, paramagnetism and diamagnetism

P2430900

Cobra4 Sensor Tesla, magnetic field strength, resolution max. ±0.01 mT

Cobra4

Function and Applications

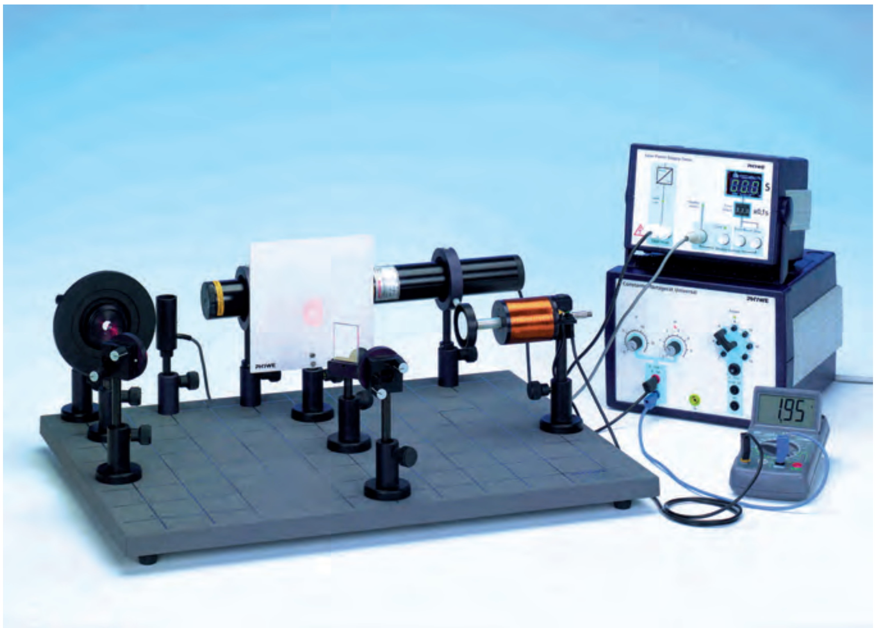
Sensor out of the Cobra4 family to measure the magnetic field strength in DC and AC fields. This sensor is suitable for the connection of the Hall probes.

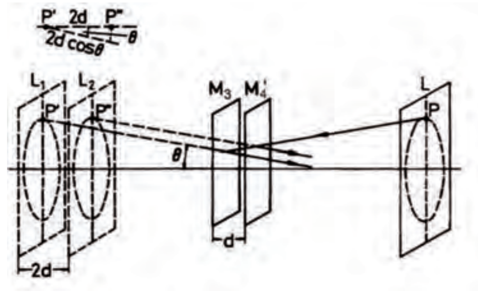
Benefits

- Connection of two different Hall probes possible: tangential and axial
- Exceptionally good resolution
- Measurement of the earth's magnetic field possible
- The unit can be connected to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 USB-Link or the Cobra4 Junior-Link using a secure and reliable plug-in/lockable connection.

12652-00

P2430800 Magnetostriction with the Michelson interferometer





Formation of circular interference fringes.

Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

Tasks

1. Construction of a Michelson interferometer using separate optical components.
2. Testing various ferromagnetic materials (iron and nickel) as well as a non-ferromagnetic material (copper), with regard to their magnetostrictive properties.

What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Ferromagnetic material
- Weiss molecular magnetic fields
- Spin-orbit coupling

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Power supply, universal	13500-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Rods for magnetostriction,set	08733-01	1
Adjusting support 35 x 35 mm	08711-00	3

Power supply for laser head 5 mW

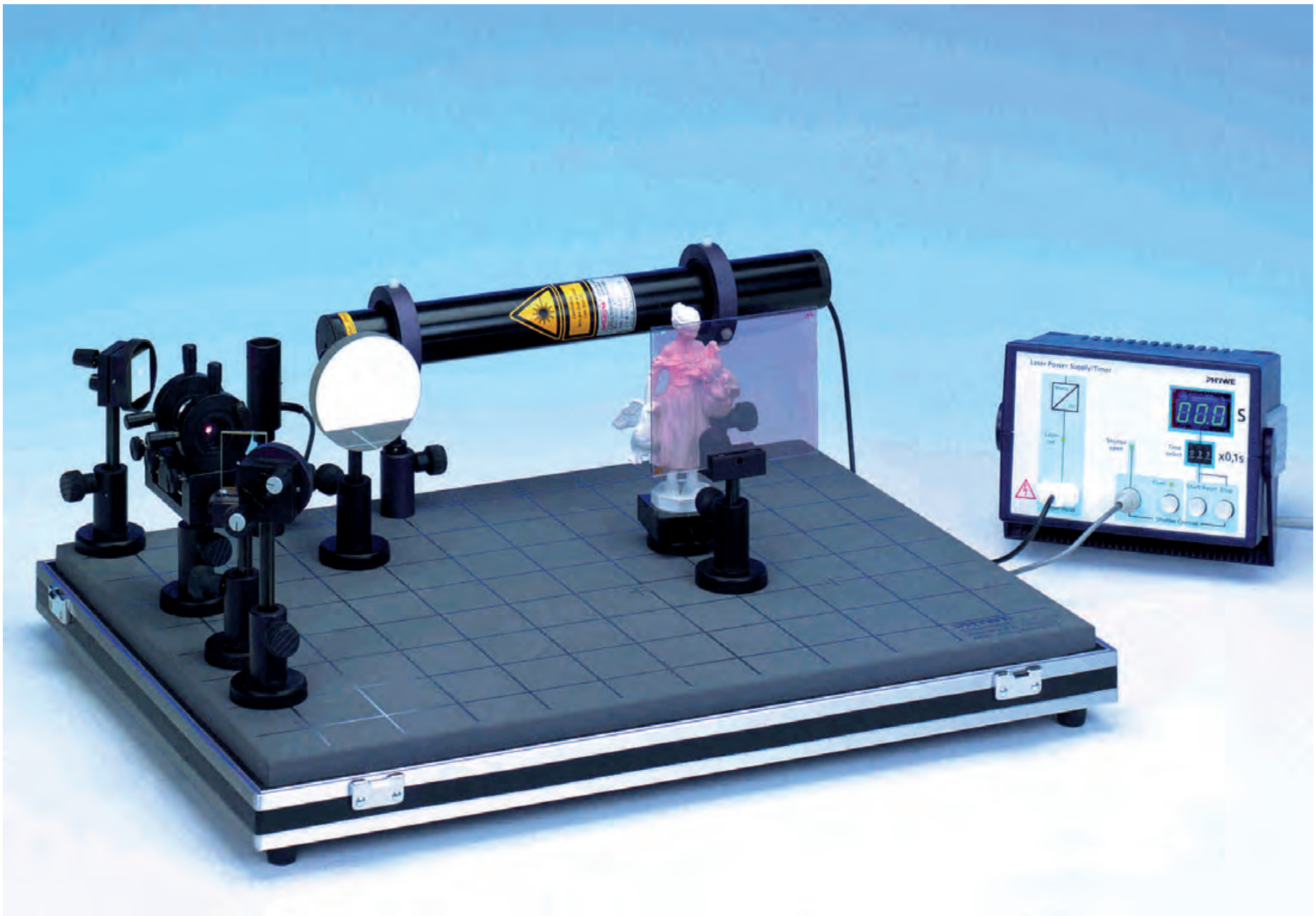
Function and Applications

High voltage power supply for lasers, e. g. the 5 mW laser (08701-00).

Equipment and technical data

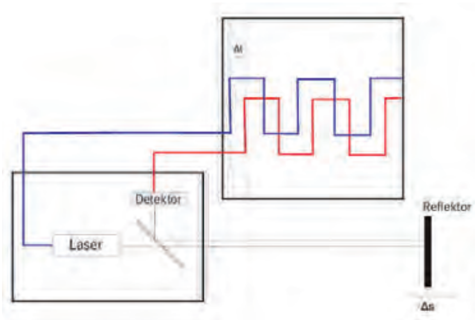
- With programmable timer for selection of exposure time of holograms between 0.1 ... 99 s.
- With a controllable shutter.
- Digital display for preset shutter times as well as those which have already occured.
- Shutter control via time select, new start, stop and shutter open (permanent open).
- Dimensions of plastic housing (mm): 184 x 140 x 130.
- Incl. shutter with fixed connection cord with unit plug on holding rod.
- Rod diameter: 10 mm.

08702-93



Light and Optics

P2210101 Measuring the velocity of light



Principle of measurement.

Principle

The intensity of the light is modulated and the phase relationship of the transmitter and receiver signal compared. The velocity of light is calculated from the relationship between the changes in the phase and the light path.

Tasks

1. To determine the velocity of light in air.
2. To determine the velocity of light in water and synthetic resin and to calculate the refractive indices.

What you can learn about

- Refractive index
- Wavelength
- Frequency
- Phase
- Modulation
- Electric field constant
- Magnetic field constant

Main articles		
Speed of Light Meter Set	11226-88	1
30 MHz digital storage oscilloscope	11462-99	1

Speed of Light Meter Set

Function and Applications

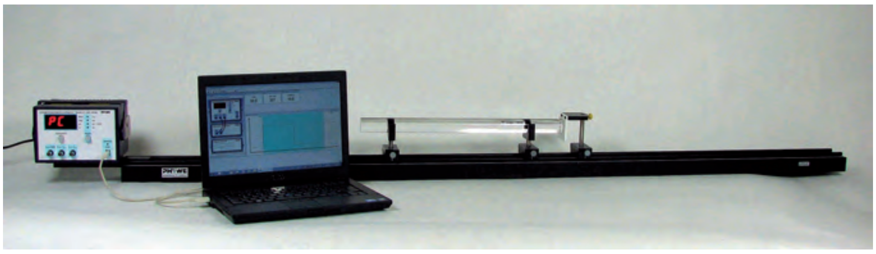
The complete set to measure the light velocity in air, transparent liquids and solids.

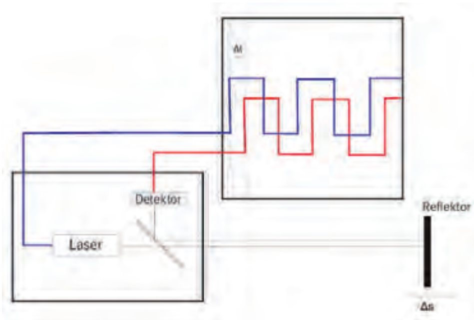
Equipment and technical data

Consists of 1x Light velocity measuring apparatus, 1 x Retroreflector with stem, 1x Power supply 12 V/ 2 A, 1x Slide mount for optical bench, 1x Optical bench, l = 1800 mm, 1 x Holder for speed of light measuring instrument, 1 x Acrylic glass cylinder with a holder, 1 x Tubular cell with a holder

11226-88

Measuring the velocity of light using the software measure P2210111





Principle of measurement.

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The intensity of the light is modulatedand the phase relationship of the transmitter and receiver signal compared. Thevelocity of light is calculated from therelationship between the changes in thephase and the light path.

Tasks

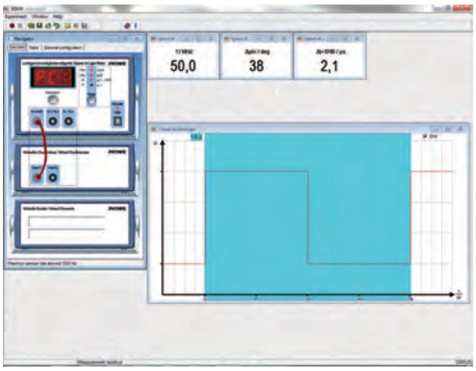
1. To determine the velocity of light inair.
2. To determine the velocity of light inwater and synthetic resin and to calculate the refractive indices.

What you can learn about

- Refractive index
- Wavelength
- Frequency
- Phase
- Modulation
- Electric field constant
- Magnetic field constant

Main articles		
Speed of Light Meter Set	11226-88	1
Data cable USB, plug type A/B, 1.8 m	14608-00	1

Software Speed of Light Meter



The Software for the Speed of Light Meter belongs to the "measure-software" family. This software is charactarisedby easy and intuitive features and is very user friendly.

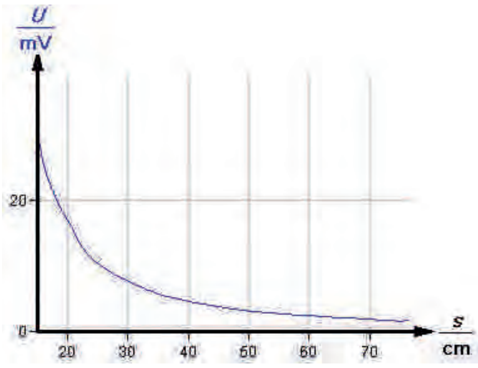
With this software all measured quantities from the Speed of Light Meter can be recorded and graphically displayed. Especially the optical distance measurement lends itself to be recorded via software.

This way the dynamics of motion (swinging pendulum, moving cart etc.) can be recorded continuosly (1000Hz) without interfering mechanically with the process.

14411-61

P2240260 Photometric law of distance with Cobra4

NEW · Cobra4 · Demo



Luminous intensity as a function of the square of the reciprocal of the distance (lamp - diode).

Principle

The luminous intensity emitted by a punctual source is determined as a function of distance.

Tasks

1. The luminous intensity emitted by a punctual source is determined as a function of distance from the source.
2. The photometric law of distance is verified by plotting illuminance as a function of the reciprocal value of the square of the distance.

What you can learn about

- Luminous flux; Quantity of light
- Luminous intensity; Illuminance
- Luminance

Main articles		
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Sensor-Unit Energy	12656-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Wireless Manager	12600-00	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Cobra4 Sensor-Unit Motion	12649-00	1
Screen, metal, 300 x 300 mm	08062-00	1

Related Experiment

Photometric inverse-square law

P2240201

Cobra4 Sensor-Unit Motion

Function and Applications

The Cobra4 Sensor-Unit motion measures path, velocity and acceleration of an object moving in one dimension, e.g. a cart on a demonstration track. The measurement is performed via an ultrasound sensor.

Benefits

- Contact-free measurement of path, velocity and acceleration
- Direct display and calculation of the measured values
- The movement of different objects can be analyzed, e.g. carts on a demonstration track, students in the classroom, bouncing balls etc.

12649-00

Lambert's law of radiation on optical base plate

P2240405

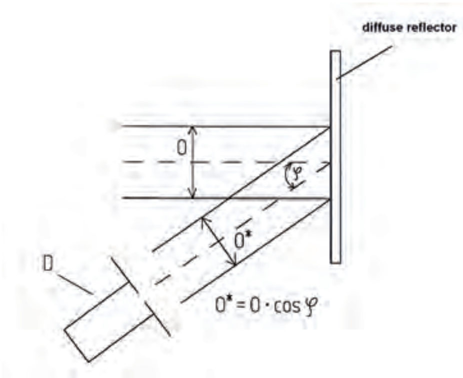


Diagram of the principle of measurements with the used magnitudes (with O^* as apparent magnitude of surface O).

Principle

Visible light impinges on a diffusely reflecting surface. The luminance of this surface is determined as a function of the angle of observation.

Tasks

1. The luminous flux emitted reflected by a diffusely reflecting surface is to be determined as a function of the angle of observation.
2. Lambert's law (cos-law) is to be verified using the graph of the measurement values.

What you can learn about

- Luminous flux
- Light quantity
- Light intensity
- Illuminance
- Luminance

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Rot. guide rail w. angular scale	08717-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1

Laser, He-Ne, 0.2/1.0 mW, 230 V AC

Function and Applications

Linearly polarised light source, very short design.

Benefits

- Welded glass tube assures a very long lifetime > 18 000 operating hours
- Key switch and integrated greyfilter to reduce radiation power to 0.2 mW. Screw-in release to activate the grey filter.
- Anodised aluminium casing with integrated mains power supply,screw in holding stem, signal light and required warnings printed on both sides.Fixed mains connecting cable 140 cm.

Equipment and technical data

- Wavelength 632.8 nm, optical output power without filter 1.0 mW, with filter 0.2 mW
- beam diameter 0.5 mm, beam divergence < 2 mrad.
- minimum polarisation500:1, max drift over 8 hours ± 2.5%
- oscillating mode TEM00, lifetime > 18000 h
- power requirements 35 VA, connectingvoltage 230 V, 50.60 Hz.

08180-93

Dispersion and resolving power of a prism and a grating spectroscope P2210300

Principle

The refractive indices of liquids, crown glass and flint glass are determined as a function of the wave length by refraction of light through the prism at minimum deviation. The resolving power of the glass prisms is determined from the dispersion curve.

For more details refer to page 155.

Interference of light P2220100

Principle

By dividing up the wave-front of a beam of light at the Fresnel mirror and the Fresnel biprism, interference is produced. The wavelength is determined from the interference patterns.

For more details refer to page 156.

Diffraction of light through a double slit or by a grid with optical base plate P2230405

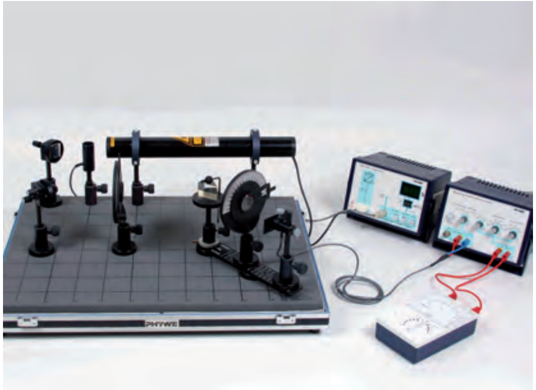
Principle

The coherent monochromatic light of a laser is directed to a diaphragm with a varying number of slits. The resulting interference patterns are studied using a photoelement.

For more details refer to page 168.

Fresnel's law – theory of reflection

P2250305



Principle

Plane-polarized light is reflected at a glas surface. Both the rotation of the plane of polarization and the intensity of the reflected light are to be determined and compared with Frewsnel's formulae for reflection.

For more details refer to page 175.

Fibre optics

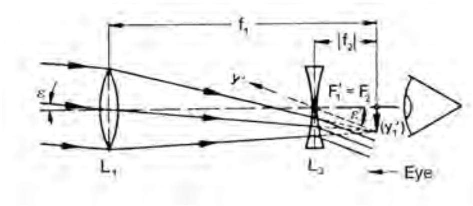
P2261000

Principle

The beam of a laser diode is treated in a way that it can be coupled into a monomode fibre. The problems related to coupling the beam into the fibre are evaluated and verified. In consequence a low frequency signal is transmitted through the fibre. The numerical aperture of the fibre is recorded. The transit time of light through the fibre is measured and the velocity of light within the fibre is determined. Finally the measurement of the relative output power of the diode laser as a function of the supply current leads to the characteristics of the diode laser such as "threshold energy" and "slope efficiency".

For more details refer to page 299.

P2210200 Law of lenses and optical instruments



Path of a ray in Galileo telescope.

Principle

The focal lengths of unknown lenses are determined by measuring the distances of image and object and by Bessel's method. Simple optical instruments are then constructed with these lenses.

Tasks

1. To determine the focal length of two unknown convex lenses by measuring the distances of image and object.
2. To determine the focal length of a convex lens and of a combination of a convex and a concave lens using Bessel's method.
3. To construct the following optical instruments:
   a) Slide projector; image scale to be determined
   b) Microscope; magnification to be determined
   c) Kepler-type telescope
   d) Galileo's telescope (opera glasses).

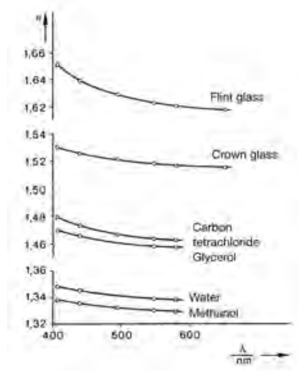
What you can learn about

- Law of lenses
- Magnification
- Focal length
- Object distance
- Telescope
- Microscope
- Path of a ray
- Convex lens
- Concave lens
- Real image
- Virtual image

Main articles		
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Optical profile-bench, l 1000mm	08282-00	1
Diaphragm holder	08040-00	2
Experiment lamp 5, with stem	11601-10	1
Condenser holder	08015-00	1
Double condenser, f 60 mm	08137-00	1
Screen, translucent, 250x250 mm	08064-00	1

Dispersion and resolving power of a prism and a grating spectroscope

P2210300



Dispersion curves of various substances.

Principle

The refractive indices of liquids, crown glass and flint glass are determined as a function of the wave length by refraction of light through the prism at minimum deviation. The resolving power of the glass prisms is determined from the dispersion curve.

Tasks

1. To adjust the spectrometer-goniometer.
2. To determine the refractive index of various liquids in a hollow prisms.
3. To determine the refractive index of various glass prism.
4. To determine the wavelengths of the mercury spectral lines.
5. To demonstrate the relationship between refractive index and wavelength (dispersion curve).
6. To calculate the resolving power of the glass prisms from the slope of the dispersion curves.
7. Determination of the grating constant of a Rowland grating based on the diffraction angle (up to the third order) of the high intensity spectral lines of mercury.
8. Determination of the angular dispersion of a grating.
9. Determination of the resolving power required to separate the different Hg-lines. Comparison with theory.

What you can learn about

- Maxwell relationship
- Dispersion
- Polarisability
- Refractive index
- Prism
- Rowland grating
- Spectrometer
- Goniometer

Main articles		
Spectrometer/goniom. w. vernier	35635-02	1
Power supply for spectral lamps	13662-97	1
Spectral lamp Hg 100, pico 9 base	08120-14	1
Hollow prism	08240-00	1
Lamp holder,pico 9,f.spectr.lamps	08119-00	1
Diffraction grating, 600 lines/mm	08546-00	1

Spectrometer/goniom. w. vernier

Function and Applications

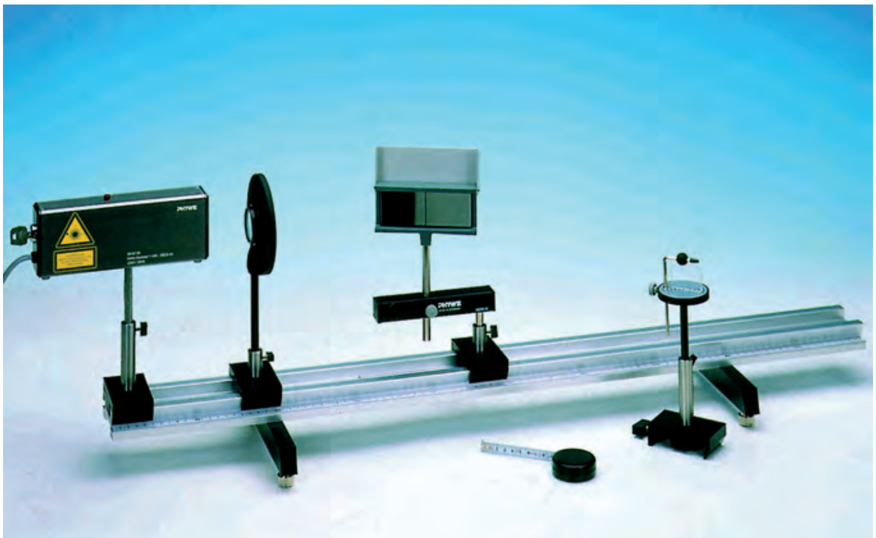
Spectrometer/ goniometer with double vernier.

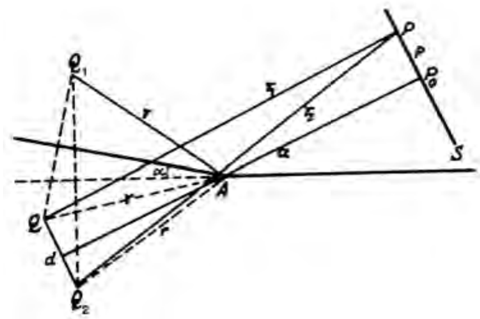
Equipment and technical data

- With magnifying glasses
- 60° glass prism
- Illumination device and telescope

35635-02

P2220100 Interference of light





Geometrical arrangement, using the Fresnel mirror.

Principle

By dividing up the wave-front of a beam of light at the Fresnel mirror and the Fresnel biprism, interference is produced. The wavelength is determined from the interference patterns.

Tasks

Determination of the wavelength of light by interference

1. with Fresnel mirror,
2. with Fresnel biprism.

What you can learn about

- Wavelength
- Phase
- Fresnel biprism
- Fresnel mirror
- Virtual light source

Main articles		
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Fresnel mirror	08560-00	1
Optical profile-bench, l 1000mm	08282-00	1
Fresnel biprism	08556-00	1
Lens, mounted, f +300 mm,achrom.	08025-01	1
Prism table with holder	08254-00	1
Swinging arm	08256-00	1

Laser, He-Ne, 1.0 mW, 230 V AC

Function and Applications

Linearly polarised light source, very short design.

Benefits

- Welded glass tube assures a very long lifetime > 18 000 operating hours.
- Anodised aluminium casing with integrated mains power supply.
- Fixed mains connecting cable 140 cm.

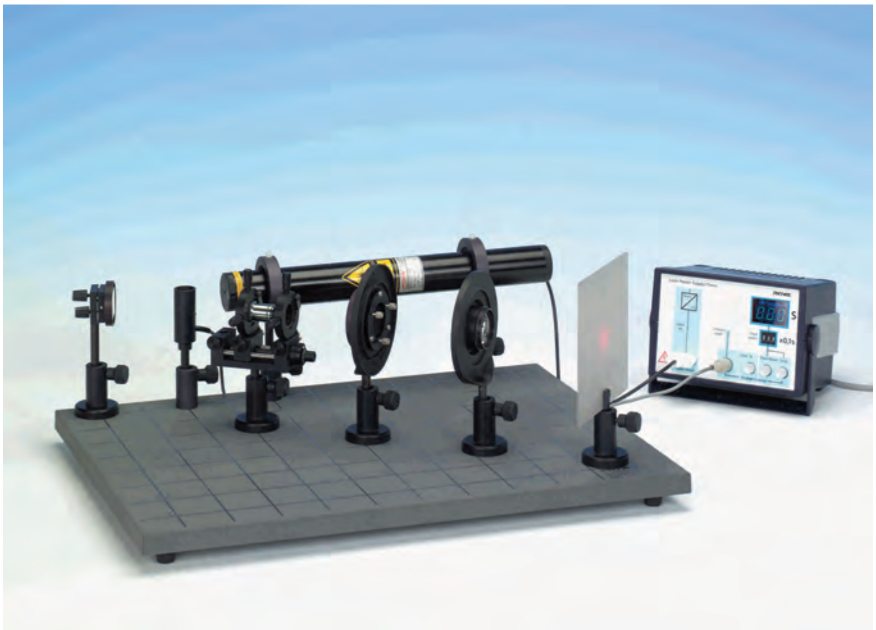
Equipment and technical data

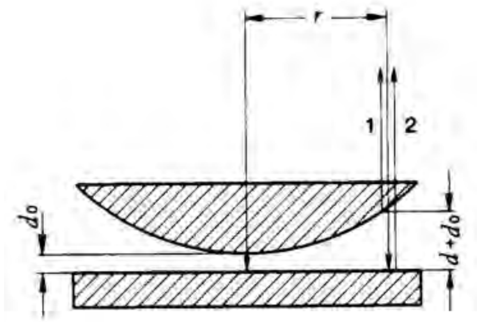
- Wavelength 632.8 nm, Optical output power 1.0 mW
- Beam diameter 0.5 mm, Beam divergence < 2 mrad.
- Minimum polarisation 500:1, Max drift over 8 hours ± 2.5%
- Oscillating mode TEM00, Lifetime > 18000 h
- Power requirements 35 VA, Connecting voltage 230 V, 50.60 Hz.

08181-93

Newton's rings with optical base plate

P2220205





Generation of Newton's rings.

Principle

The air wedge formed between slightly convex lens and a plane glass plate (Newton's colour glass) is used to cause interference of monochromatic light. The wavelength is determined from the radii of the interference rings.

Tasks

The diameters of interference rings produced by Newton's colour glass are measured and these are used to:

1. Determine the wavelength for a given radius of curvature of the lens.
2. Determine the radius of curvature for a given wavelength.

What you can learn about

- Coherent light
- Phase relation
- Path difference
- Interference at thin layers
- Newton's colour glass

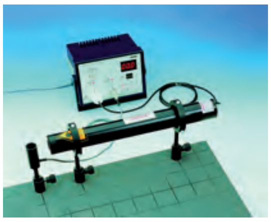
Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Newton colourglass f.opt.b. pl.	08730-02	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

Related Experiment

Newton's rings with interference filters

P2220200

He/Ne Laser, 5mW with holder



Function and Applications

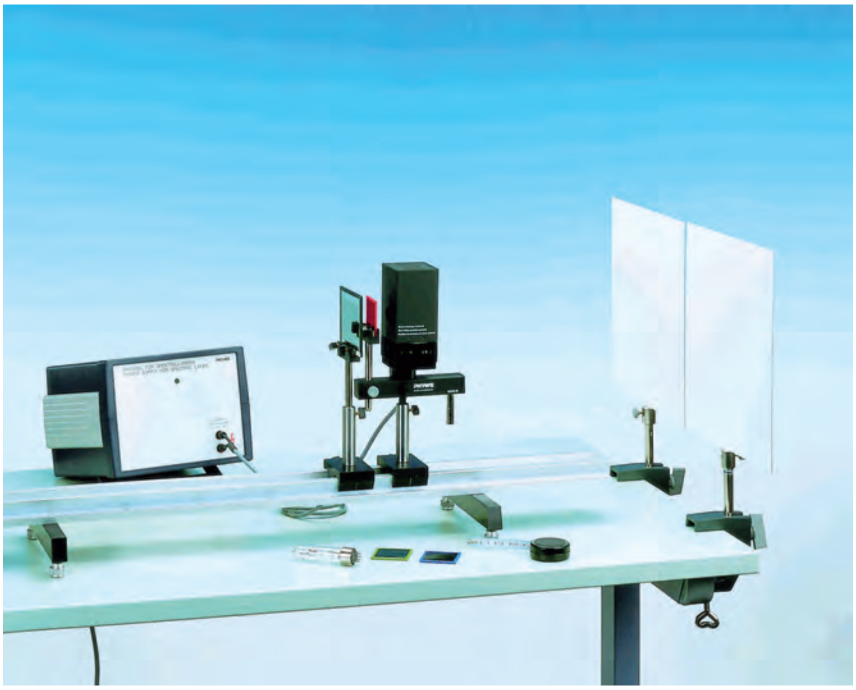
He/Ne laser with fixed connection cable with HV jack for laser power pack.

Equipment and technical data

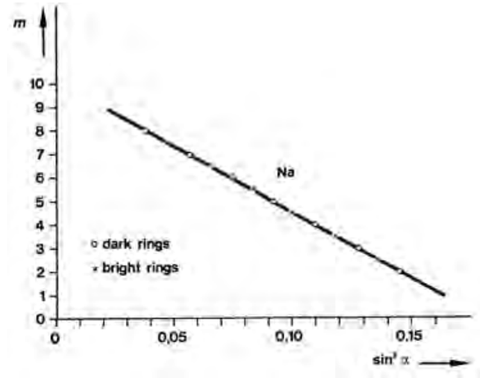
- Wave length 632.8 nm
- Modes TEM00
- Degree of polarisation 1:500
- Beam diameter 0.81 mm
- Beam divergence 1 mrad
- Max. power drift max. 2.5%/ 8 h
- Service life ca. 15000 h
- Coaxial cylinder casing Ø = 44.2mm, l = 400 mm

08701-00

P2220300 Interference at a mica plate according to Pohl



Demo



Interference order m as a function of $\sin^2$ a for Na-light.

Principle

Monochromatic light falls on a plane parallel mica plate. The light rays, reflected at the front surface as well as at the rear surface, will interfere to form a pattern of concentric rings. The radii of the rings depend on the geometry of the experimental setup, the thickness of the mica plate and the wavelength of the light.

Tasks

The experiment will be performed with the light of a Na-lamp and with the light of different wavelengths of a Hg-vapour tube.

1. The thickness of the mica plate is determined from the radii of the interference rings and the wavelength of the Na-lamp.
2. The different wavelengths of the Hg-vapour tube are determined from the radii of the interference rings and the thickness of the mica plate.

What you can learn about

- Interference of equal inclination
- Interference of thin layers
- Plane parallel plate
- Refraction
- Reflection
- Optical path difference

Main articles

Power supply for spectral lamps	13662-97	1
Spectral lamp Na, pico 9 base	08120-07	1
Spectral lamp Hg 100, pico 9 base	08120-14	1
Mica plate	08558-00	1
Optical profile bench l = 60 cm	08283-00	1
Lamp holder,pico 9,f.spectr.lamps	08119-00	1

Power supply for spectral lamps

Function and Applications

Power supply for spectral lamps with Pico9 socket and nominal current 1A.

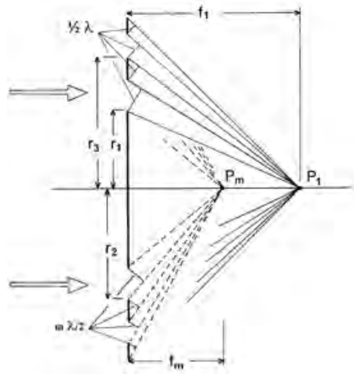
Equipment and technical data:

- voltage without load 230V
- burning voltage 15...60V
- power supply voltage 230V/50Hz
- Dimensions 230x236x168

13662-97

Structure of a Fresnel zone / zone plate

P2220400



Geometry of the zone plate.

Principle

A zone plate is illuminated with parallel laser light. The focal points of several orders of the zone plate are projected on a ground glass screen.

Tasks

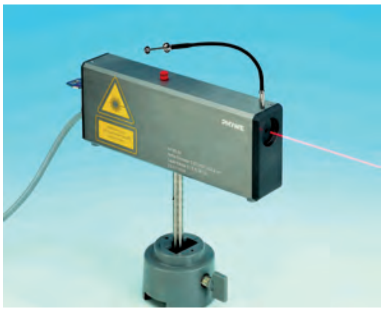
1. The laser beam must be widened so that the zone plate is well illuminated. It must be assured that the laser lightbeam runs parallel over several meters.
2. The focal points of several orders of the zone plate are projected on a ground glass screen. The focal lengths to be determined are plotted against the reciprocal value of their order.
3. The radii of the zone plate are calculated.

What you can learn about

- Huygens Fresnel principle
- Fresnel and Fraunhofer diffraction
- Interference; Coherence
- Fresnel's zone construction; Zone plates

Main articles		
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Fresnel zone plate	08577-03	1
Optical profile-bench, l 1000mm	08282-00	1
Object holder, 5x5 cm	08041-00	2
Base for optical bench, adjustable	08284-00	2
Slide mount for optical bench, h = 30 mm	08286-01	7
Lens holder	08012-00	4

Laser, He-Ne, 1.0 mW, 230 V AC



Function and Applications

Linearly polarised light source, very short design.

Benefits

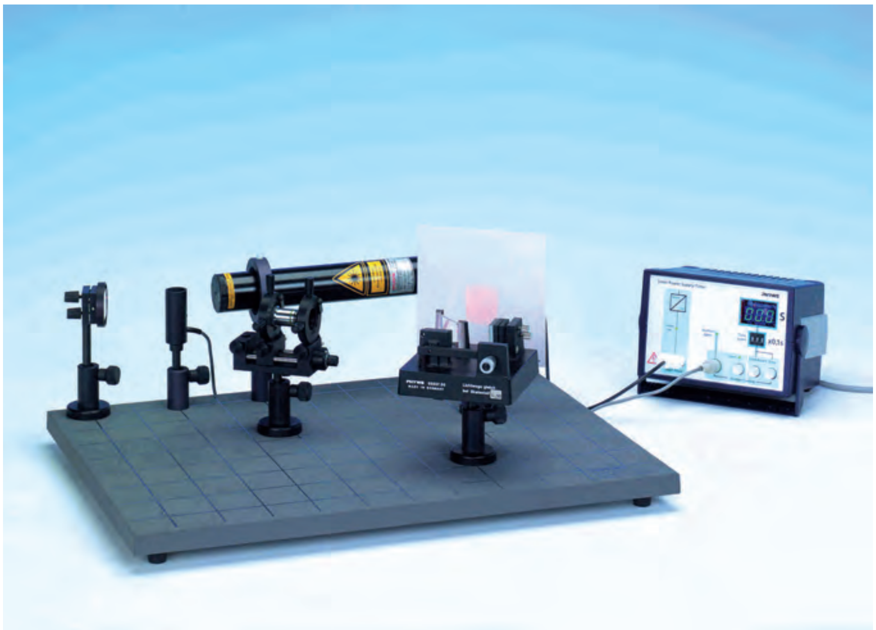
- Welded glass tube assures a very long lifetime > 18 000 operating hours.
- Anodised aluminium casing with integrated mains power supply.
- Fixed mains connecting cable 140 cm.

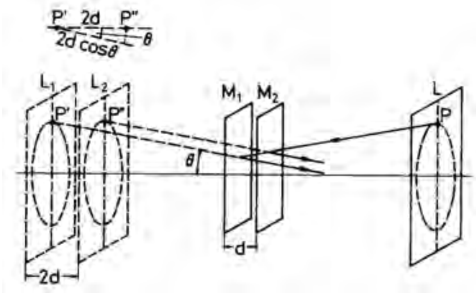
Equipment and technical data

- Wavelength 632.8 nm, Optical output power 1.0 mW
- Beam diameter 0.5 mm, Beam divergence < 2 mrad.
- Minimum polarisation 500:1, Max drift over 8 hours ± 2.5%
- Oscillating mode TEM00, Lifetime > 18000 h
- Power requirements 35 VA, Connecting voltage 230 V, 50.60 Hz.

08181-93

P2220505 Michelson interferometer with optical base plate





Formation of interference rings.

Principle

In a Michelson interferometer, a lightbeam is split into two partial beams by a semi transparent glass plate (amplitude splitting). These beams are reflected by two mirrors and brought to interference after they passed through the glass plate a second time.

Task

The wavelength of the used laserlight is determined through the observation of the change in the interference pattern upon changing the length of one of the interferometer arms.

What you can learn about

- Interference
- Wavelength
- Refraction index
- Light velocity
- Phase
- Virtual light source
- Coherence

Main articles		
Michelson interferometer	08557-00	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

Related Experiment

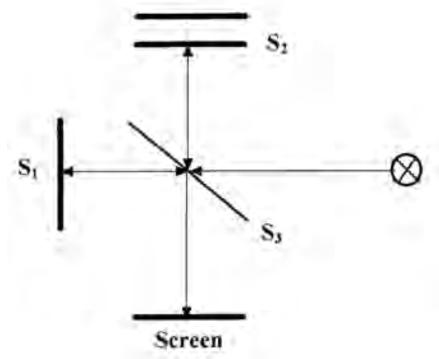
Michelson interferometer

P2220500

Albert A. Michelson
1907, Nobel Prize in Physics

Coherence and width of spectral lines with the Michelson interferometer

P2220600



Beam path in Michelson's interferometer.

Principle

The wavelengths and the corresponding lengths of coherence of the green spectral lines of an extreme high pressure Hg vapour lamp are determined by means of a Michelson interferometer.

Different double slit combinations are illuminated to verify the coherence conditions of non punctual light sources.

An illuminated auxiliary adjustable slit acts as a non punctual light source.

Tasks

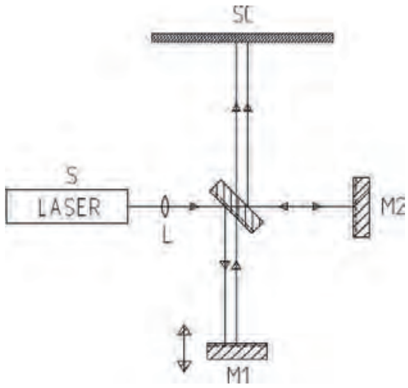
1. Determination of the wavelength of the green Hg spectral line as well as of its coherence length.
2. The values determined in 1. are used to calculate the coherence time and the half width value of the spectral line.
3. Verification of the coherence condition for non punctual light sources.

What you can learn about

- Fraunhofer and Fresnel diffraction
- Interference
- Spatial and time coherence
- Coherence conditions
- Coherence length for non punctual light sources
- Coherence time
- Spectral lines (shape and half width value)
- Broadening of lines due to Doppler effect and pressure broadening
- Michelson interferometer
- Magnification

Main articles		
Michelson interferometer	08557-00	1
Lamp,f.50W Hg high press. lamp	08144-00	1
Power supply 230 V/ 50 Hz for 50 W-Hg-lamp	13661-97	1
Optical profile-bench, l 1000mm	08282-00	1
Object holder, 5x5 cm	08041-00	1
Iris diaphragm	08045-00	1
Swinging arm	08256-00	1

P2220705 Refraction index of CO2 with the Michelson interferometer



Michelson's setup for interference.

Principle

Light is caused to interfere by means of a beam splitter and two mirrors according to Michelson's set up. Substituting the air in a measurement cuvette located in one of the interferometer arms by CO_2 gas allows to determine the index of refraction of CO_2.

Task

A Michelson Interferometer is set up and adjusted so that interference rings can be observed. CO_2 gas is filled into a measurement cuvette that was filled before with air. From changes in the interference pattern the difference of the refraction index between air and CO_2 is determined.

What you can learn about

- Interference
- Wavelength
- Index of refraction
- Light velocity
- Phase
- Virtual light source
- Coherence

Main articles		
Michelson interferometer	08557-00	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

Related Experiment

Refraction index of air and CO2 with the Michelson interferometer

P2220700

Michelson interferometer

Function and Application

To measure light wavelengths and refractivity of liquids and gases.

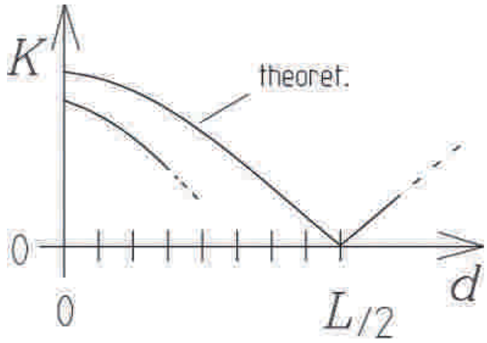
Equipment and technical data

- Metalbase-plate 120 x 120 mm with removable holding stem and with adjustable surface mirrors 30 x30 mm
- Two polarising filters and micrometer
- Fine shoots to the tilt adjustment of fixed mirror
- Bracket for additional required cell for investigation of gases

08557-00

Michelson interferometer - High Resolution

P2220900



Experimentally determined contrast function in comparison to the theoretical contrast function K of a 2-mode laser.

Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alterationin the interference pattern is observed and the wave length of the laser light determined.

Tasks

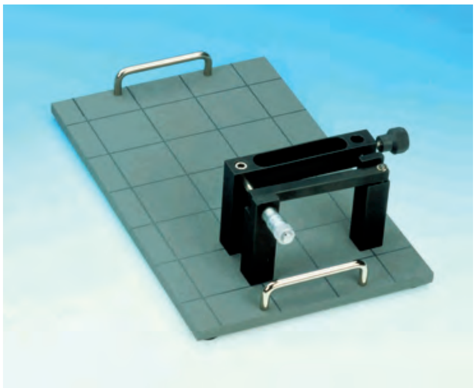
1. Construction of a Michelson interferometer using separate components.
2. The interferometer is used to determine the wavelength of the laserlight.
3. The contrast function K is qualitatively recorded in order to determine the coherence length with it.

What you can learn about

- Interference; Wavelength
- Diffraction index
- Speed of light; Phase
- Virtual light source

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Optical base plate with rubberfeet	08700-00	1
Photoelement f. opt. base plt.	08734-00	1
Beam splitter 1/1,non polarizing	08741-00	1
Adjusting support 35 x 35 mm	08711-00	4

Interferometer w. prec.drive



Function and Applications

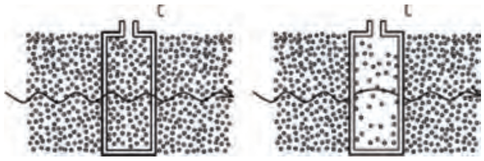
For precise and reproducible linear shift of optical components e.g. in interferometer set ups.

Equipment and technical data

- Suppression of tilting effects due to traverse construction.
- Wavelength adjustment through lever device with micrometer screw.
- Stiff steel base plate with NEXTEL®-Plastic coating.
- Set up on base plate.
- Shift path: max. 0.25 mm.
- Resolution: 500 nm.
- Dimensions (mm): 320 × 200 × 14.
- Mass: 5 kg.

08715-00

P2221100 Refraction index of air with the Mach-Zehnder interferometer with optical base plate



Schematic representation of the cell with normal pressure (a) and nearly absolute vacuum (b).

Principle

Light is brought to interference by two mirrors and two beam splitters in the Mach-Zehnder arrangement. By changing the pressure in a measuring cell located in the beam path, one can deduce the refraction index of air.

Tasks

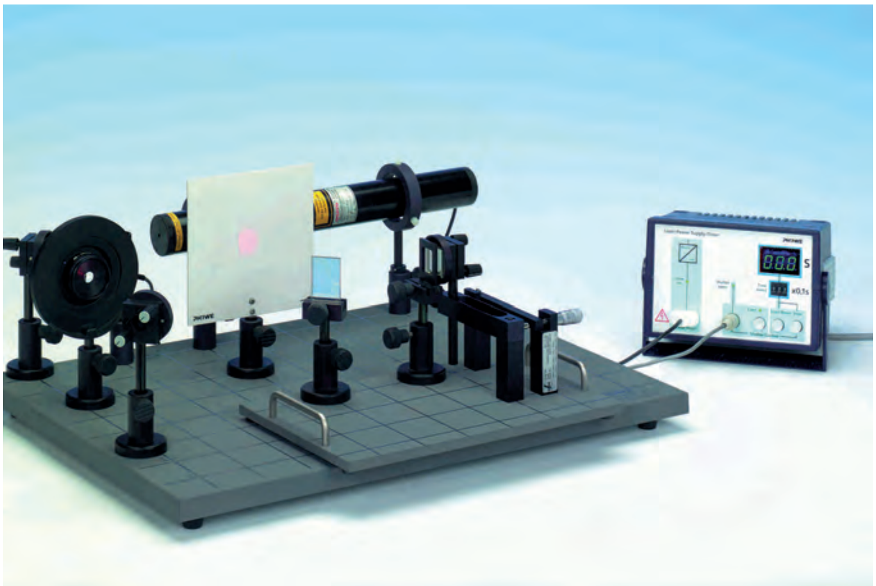
1. Construction of a Mach-Zehnder interferometer using individual optical components.
2. Measurement of the refraction index n of air by lowering the air pressure in a measuring cell.

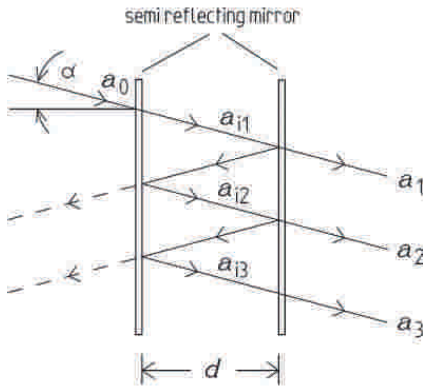
What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1
Beam splitter 1/1,non polarizing	08741-00	2

Fabry-Perot interferometer - determination of the wavelength of laser light P2221205





Multibeam interferometer after Fabry and Perot. Illustration of the principle for deriving the individual amplitudes.

Principle

Two mirrors are assembled to form a Fabry-Perot interferometer. Using them, the multibeam interference of a laser's light beam is investigated. By moving one of the mirrors, the change in the interference pattern is studied and the wavelength of the laser's light determined.

Tasks

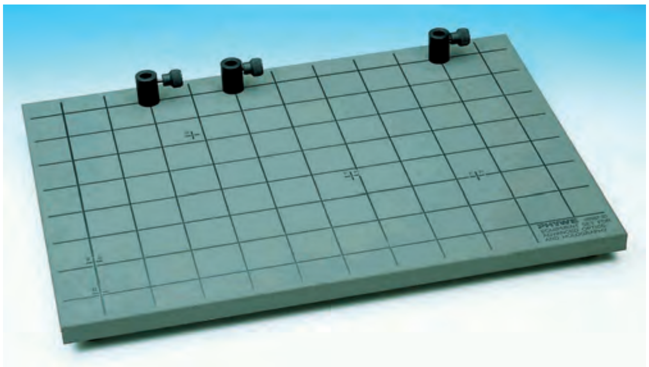
1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to determine the wavelength of the laser light.

What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Beam splitter T=30,R=70, w.holder	08741-01	1
Optical base plate with rubberfeet	08700-00	1
Beam splitter 1/1,non polarizing	08741-00	1
Adjusting support 35 x 35 mm	08711-00	3

Optical base plate with rubberfeet



Function and Applications

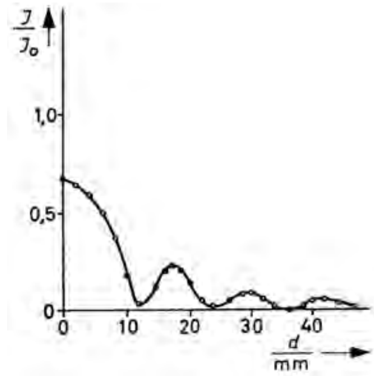
For setting up magnetically adhering optical components.

Equipment and technical data

- Rigid and vibration-damped working base made of steel plate.
- With corrosion protection, NEXTEL® plastic coating and imprinted grid (5×5) cm.
- Three fixed adapter sleeves for laser and laser shutter.
- With rubber feet for non-slip working.
- Base plate size (mm): 590 × 430 × 24
- Mass: 7 kg

08700-00

P2230205 Diffraction of light at a slit and at an edge



Intensity distribution for diffraction through a slit as a function of the location along a straight line running parallel to the plane of the slit, normalised according to intensity I_0 without slit.

Principle

Monochromatic light is incident on a slit or an edge. The intensity distribution of the diffraction pattern is determined.

Tasks

1. Measurement of the width of a given slit.
2. Measurement of the intensity distribution of the diffraction pattern of the slit and of the edge.

What you can learn about

- Intensity
- Fresnel integrals
- Fraunhofer diffraction

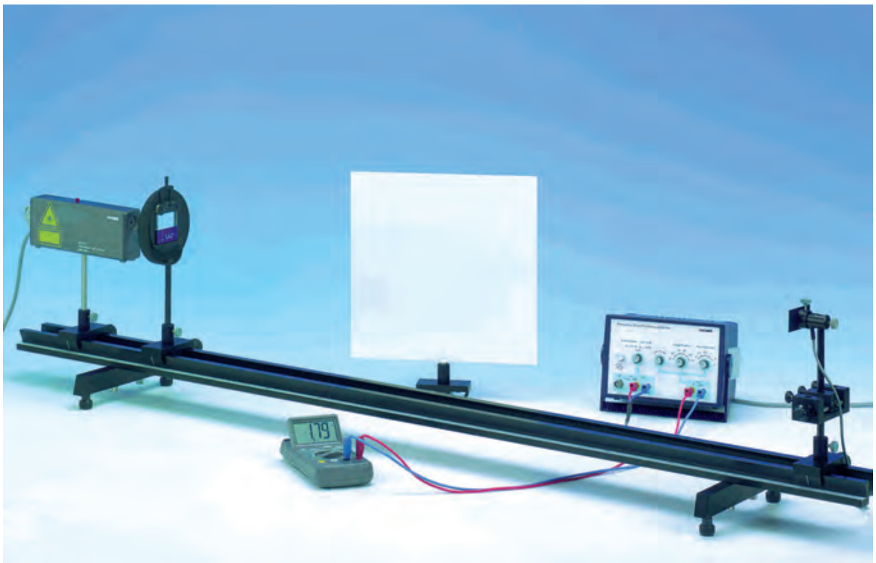
Main articles		
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
Slit, adjust. f. opt. base plt.	08727-00	1
Photoelement f. opt. base plt.	08734-00	1
Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1

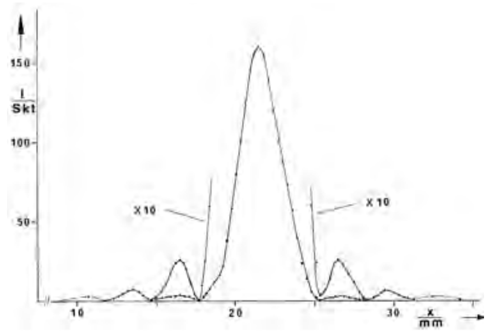
Related Experiment

Diffraction of light at a slit and an edge

P2230200

Intensity of diffractions due to pin hole diaphragms and circular obstacles P2230300





Diffracted intensity I vs position x of the photodiode, using a diaphragm with D1 = 0.25 mm.

Principle

Pin hole diaphragms and circular obstacles are illuminated with laser light. The resulting intensity distributions due to diffraction are measured by means of a photo diode.

Tasks

1. The complete intensity distribution of the diffraction pattern of a pin hole diaphragm (D1 = 0.25 mm) is determined by means of a sliding photo diode. The diffraction peak intensities are compared with the theoretical values. The diameter of the pin hole diaphragm is determined from the diffraction angles of peaks and minima.
2. The positions and intensities of minima and peaks of a second pin hole diaphragm (D2 = 0.5 mm) are determined. The diffraction peak intensities are compared with the theoretical values. The diameter of the pin hole diaphragm is determined.
3. The positions of minima and peaks of the diffraction patterns of two complementary circular obstacles (D*1 = 0.25 mm and (D*2 = 0.5 mm) are determined. Results are discussed in terms of Babinet's Theorem.

What you can learn about

- Huygens principle
- Interference
- Fraunhofer and Fresnel diffraction
- Fresnel's zone construction
- Coherence
- Laser
- Airy disk
- Airy ring- Poisson's spot
- Babinet's theorem
- Bessel function
- Resolution of optical instruments

Main articles		
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Si-Photodetector with Amplifier	08735-00	1
Screen, with diffracting elements	08577-02	1
Sliding device, horizontal	08713-00	1
Control Unit for Si-Photodetector	08735-99	1
Optical profile-bench, l 1500mm	08281-00	1
Object holder, 5x5 cm	08041-00	1

Si-Photodetector with Amplifier

Function and Applications

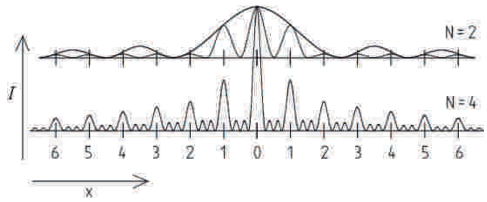
Silicon diode with high signal-to-noise ratio for photometric measurements where there is a high degree of interference.

Equipment and technical data

- Movable holder for diode on round mounting rod with lens for incoming light
- Removable slot filter
- 1.5/m lead with diode plug for connecting to the required control unit
- Spectral range 390 nm...1150 nm
- Maximum sensitivity 900 nm
- Voltage when dark 0.75 mV
- Sensitivity (900 nm) 860 mV/μW/cm²
- Band width 65 kHz
- Slot filter d= 0.3 mm
- Mounting rod l=110 mm, diam.=10 mm

08735-00

P2230405 Diffraction of light through a double slit or by a grid with optical base plate



Qualitative intensity distribution of diffraction through 2 and 4 slits, the distance x being normalised to *l*s. The intensity distribution of the simple slit has been represented with exaggerated height to give a clearer view.

Principle

The coherent monochromatic light of a laser is directed to a diaphragm with a varying number of slits. The resulting interference patterns are studied using a photoelement.

Tasks

- The intensity distribution of diffraction patterns formed by multiple slits is mesasured using a photoelement.
- The dependence of this distribution from the slit widths, the number of slits and the grid constant is investigated.
- The obtained curves are compared to the theoretical values.

What you can learn about

- Fraunhofer diffraction; Huygens' principle; Interference; Coherence

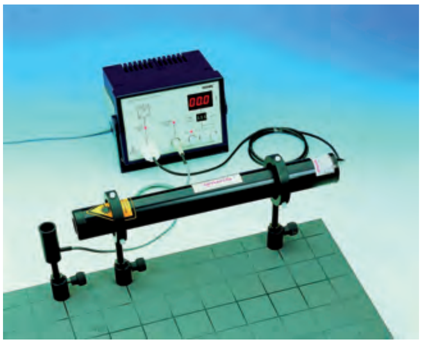
Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1

Related Experiment

Diffraction intensity due to multiple slits and grids

P2230400

He/Ne Laser, 5mW with holder



Function and Applications

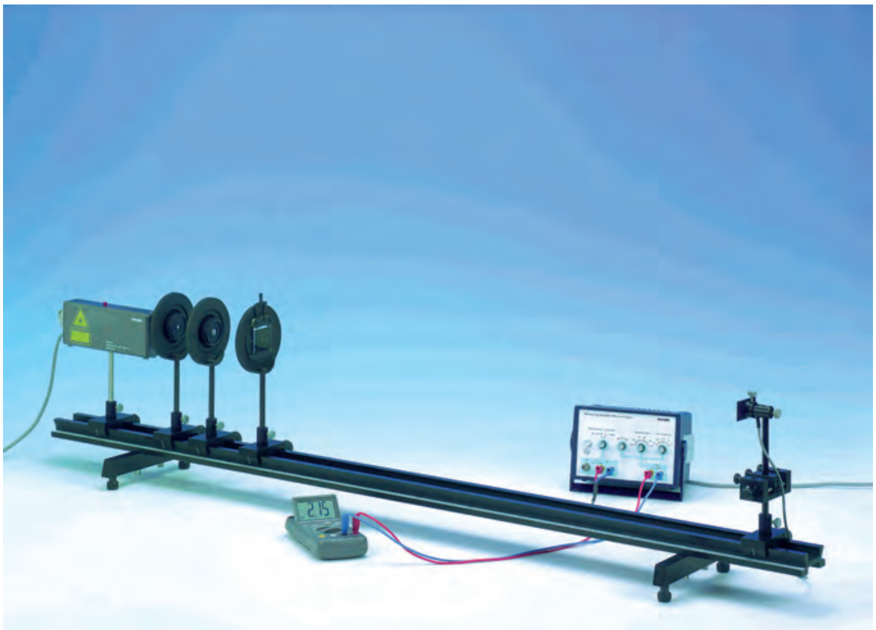
He/Ne laser with fixed connection cable with HV jack for laser power pack.

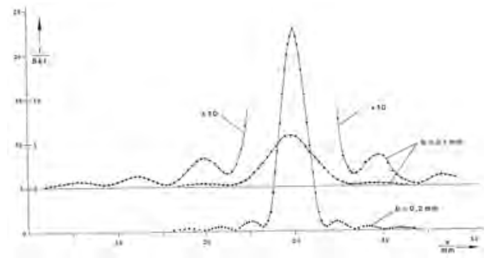
Equipment and technical data

- Wave length 632.8 nm
- Modes TEM00
- Degree of polarisation 1:500
- Beam diameter 0.81 mm
- Beam divergence 1 mrad
- Max. power drift max. 2.5%/ 8 h
- Service life ca. 15000 h
- Coaxial cylinder casing Ø = 44.2mm, l = 400 mm
- Incl. 2 holders with three-point bearing and 2 setting collars

08701-00

Diffraction intensity at slit and double slit systems P2230500





Diffraction intensity I as a function of location x for the single slit b1 = 0.1 mm and b2 = 0.2 mm. The x axis of the graph for b1 = 0.1 mm is shifted upwards. The intensity of the areas next to the central peak is represented enlarged by a factor of 10. (Distance between slit and photodiode L = 107 cm; = 632.8 nm).

Principle

Slit and double slit systems are illuminated with laser light. The corresponding diffraction patterns are measured by means of a photodiode which can be shifted, as a function of location and intensity.

Tasks

1. Determination of the intensity distribution of the diffraction patterns due to two slits of different widths.The corresponding width of the slit is determined by means of the relative positions of intensity values of the extremes. Furthermore, intensity relations of the peaks are evaluated.
2. Determination of location and intensity of the extreme values of the diffraction patterns due to two double slits with the same widths, but different distances between the slits. Widths of slits and distances between the slits must be determined as well as the intensity relations of the peaks.

What you can learn about

- Huygens principle; Interference; Fraunhofer and Fresnel diffraction; Coherence; Laser

Main articles		
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Si-Photodetector with Amplifier	08735-00	1
Sliding device, horizontal	08713-00	1
Control Unit for Si-Photodetector	08735-99	1
Optical profile-bench, l 1500mm	08281-00	1
Object holder, 5x5 cm	08041-00	1
Digital multimeter 2010	07128-00	1

Si-Photodetector with Amplifier

Function and Applications

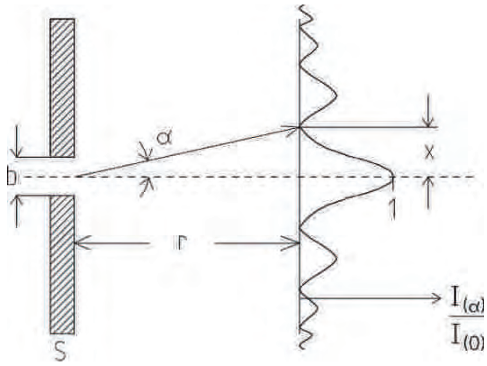
Silicon diode with high signal-to-noise ratio for photometric measurements where there is a high degree of interference.

Equipment and technical data

- Movable holder for diode on round mounting rod with lens for incoming light, Removable slot filter
- 1.5/m lead with diode plug for connecting to the required control unit, Spectral range 390 nm...1150 nm, Maximum sensitivity 900 nm
- Voltage when dark 0.75 mV, Sensitivity (900 nm) 860 mV/μW/cm², Band width 65 kHz, Slot filter d= 0.3 mm, Mounting rod l=110 mm, diam.=10 mm

08735-00

P2230605 Diffraction intensity at a slit and at a wire - Babinet's theorem



Principle of set up for diffraction through a slit and qualitative distribution on intensities in the detector plane LD.

Principle

Babinet's Principle states that the diffraction pattern for an aperture is the same as the pattern for anopaque object of the same shape illuminated in the same manner. That is the pattern produced by a diffracting opening of arbitrary shape is the same as a conjugate of the opening would produce.

Task

Babinet's theorem is verifid by the diffraction pattern of monochromaticlight directed through a slit and anopaque stripe complementary to the latter. The experiment is also performed with a circular aperture and anopaque obstacle conjugate to this opening.

What you can learn about

- Fraunhofer interference
- Huygens' principle
- Multiple beam interference
- Babinet's theorem
- Coherence

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Screen, with diffracting elements	08577-02	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
Photoelement f. opt. base plt.	08734-00	1

Related Experiment

Diffraction intensity at a slit and at a wire - Babinet's theorem

P2230600

Related Article

Function and Applications

Universal measuring amplifier for amplification of AC and DC voltages. Suitable for practical exercises.

Equipment and technical data

input impedance:

Electrometer: > 10 (13) Ohm

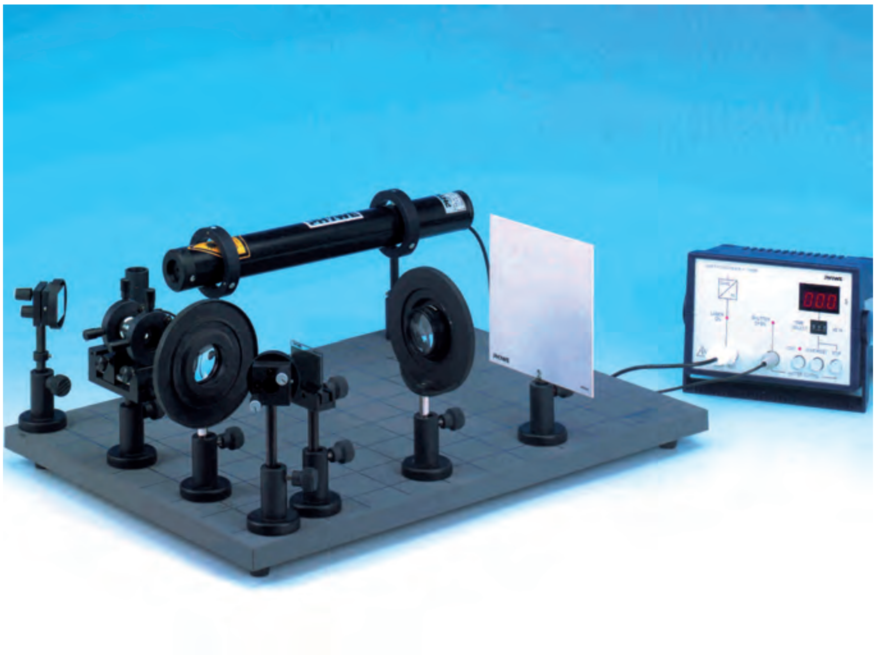
Low drift: 10 kOhm

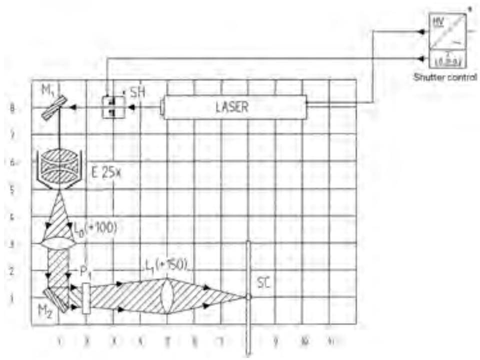
- input voltage: -10 to + 10 V
- output voltage: -10 to + 10 V

Universal measuring amplifier
13626-93

Fourier optics – 2f arrangement

P2261100





Experimental setup for the fundamental principles of Fourier optic (2f setup).

Principle

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 2 f configuration.

Task

Investigation of the Fourier transform by a convex lens for different diffraction objects in a 2 f setup.

What you can learn about

- Fourier transform
- Lenses
- Fraunhofer diffraction
- Index of refraction
- Huygens' principle

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Screen, with diffracting elements	08577-02	1
Sliding device, horizontal	08713-00	1
Optical base plate with rubberfeet	08700-00	1
xy shifting device	08714-00	2
Pin hole 30 micron	08743-00	1

Related Experiment

Fourier optics – 4f arrangement – filtering and reconstruction

P2261200

Quantum eraser

P2220800

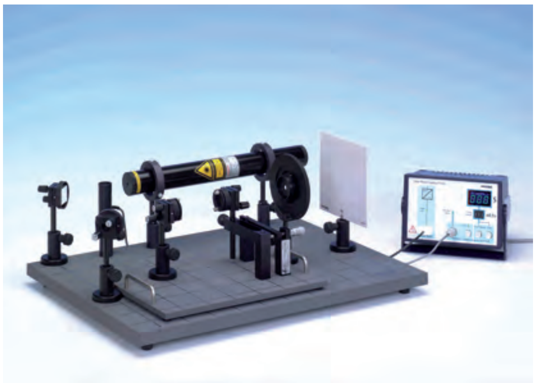
Principle

A Mach-Zehnder-interferometer is illuminated with a laser beam. Circular interference fringes appear on the screens behind the interferometer. If polarisation filters with opposite polarisation planes are placed in the two interferometer paths the interference patterns disappear. Placing another polariser before one of the screens causes the pattern to reappear. Electromagnetic radiation can be described both in terms of propagating waves, as well as particles (photons). The experiment illustrates this duality by showing how interference patterns can be explained on the basis of both classical wave mechanics and quantum physics.

For more details refer to pages 180, 300.

Fabry-Perot interferometer - optical resonator modes

P2221206



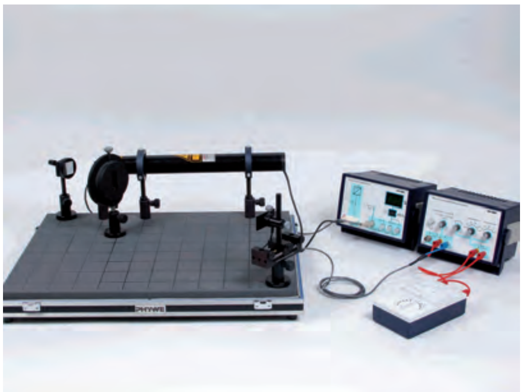
Principle

Two mirrors are assembled to form aFabry-Pert Interferometer. Using them, the multibeam interference of a laser's light beam is investigated. On moving one of the mirrors, the change in the intensity distribution of the interference pattern is studied. This is a qualitative experiment, to study the shape of different laser-modes and compare it with some photos given in this description.

For more details refer to page 293.

Diffraction at a slit and Heisenberg's uncertainty principle

P2230105

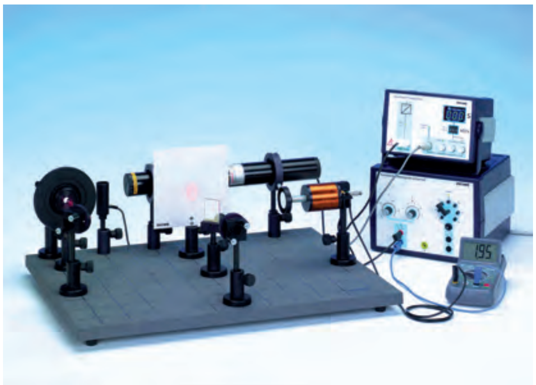


Principle

The intensity distribution in the Fraunhofer diffraction pattern of a slit is measured. Measurement results are evaluated both in the wave representation through comparison with Kirchhoff's diffraction fromula and in the photon representation, in order to verify Heisenberg's uncertainty principle.

For more details refer to page 181.

Magnetostriction with the Michelson interferometer — P2430800



Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample and the change in the interference pattern is observed.

For more details refer to pages 146, 208.

Examination of the structure of NaCl monocrystals with different orientations — P2541301

NEW

Principle

The spectra of the X-rays that are reflected with various different orientations by NaCl monocrystals are analysed. The associated interplanar spacings are determined based on the Bragg angles of the characteristic lines.

For more details refer to pages 214, 289.

X-ray investigation of crystal structures / Laue method — P2541601

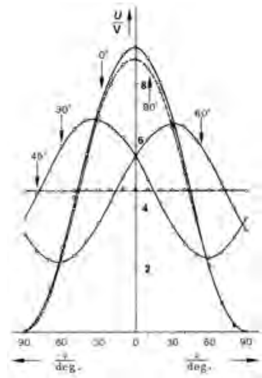
NEW

Principle

Laue diagrams are produced when monocrystals are irradiated with polychromatic X-rays. This method is primarily used for the determination of crystal symmetries and the orientation of crystals. When a LiF monocrystal is irradiated with polychromatic X-rays, a characteristic diffraction pattern results. This pat-tern is photographed and then evaluated.

For more details refer to pages 216, 277.

P2250105 Polarisation through quarter-wave plates



Intensity distribution of polarised light for different angles of the /4 plate, as a function of the analyser position.

Principle

Monochromatic light impinges on amica plate, perpenicularly to its optical axis. If the thickness of the plate is adequate (lambda/4 plate), a phase shift of 90° occurs between the ordinary and the extraordinary beam when the latter leaves the crystal. The polarisation of exiting light is examined for different angles between the optical axis of the lambda/4 plate and the direction of polarisation of incident light.

Tasks

1. Measurement of the intensity of linearly polarised light as a function of the analyser's position (Malus' law).
2. Measurement of the light intensity behind the analyser as a function of the angle between the optical axis of the lambda/4 plate and the analyser.
3. Carrying out experiment (2) with two succesive lambda/4 plates.

What you can learn about

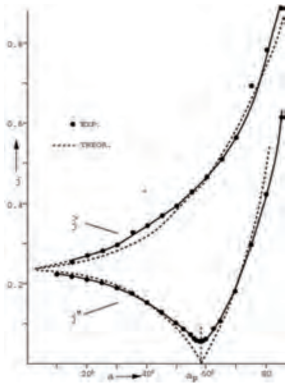
- Linearly, circularly an elliptically polarised light
- Polarizer
- Analyser
- Malus' law
- Plane of polarisation
- Double refraction
- Optical axis
- Ordinary and extraordinary beam

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	2
Polarizing filter f.opt.base pl.	08730-00	2

Fresnel's law - theory of reflection

P2250305

Demo



Measurement results.

Principle

Plane-polarized light is reflected at a glas surface. Both the rotation of the plane of polarization and the intensity of the reflected light are to be determined and compared with Frewsnel's formulae for reflection.

Tasks

1. The reflection coefficients for light polarized perpendicular and parallel to the plane of incidence are to be determined as a function of the angle of incidence and plotted graphically.
2. The refractive index of the flint glass prism is to be found.
3. The reflection coefficients are to be calculated using Fresnel's formulae and compared with the measured curves.
4. The reflection factor for the flint glass prism is to be calculated.
5. The rotation of the polarization plane for plane polarized light when reflected is to be determined as a function of the angle of incidence and presented graphically. It is then to be compared with values calculated using Fresnel's formulae.

What you can learn about

- Electromagnetic theory of light
- Reflection coefficient, Reflection factor
- Brewster's law
- Law of refraction
- Polarization, Polarization level

Main articles		
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Prism, 60 degrees, h.36.4mm,flint	08237-00	1
Rot. guide rail w. angular scale	08717-00	1
Photoelement f. opt. base plt.	08734-00	1
Polarizing filter f.opt.base pl.	08730-00	2

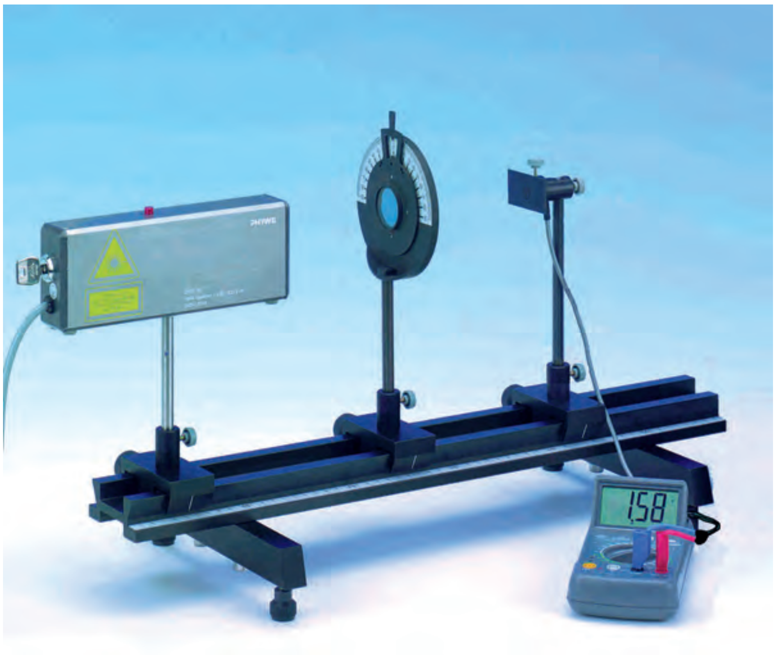
Universal measuring amplifier

Function and Applications

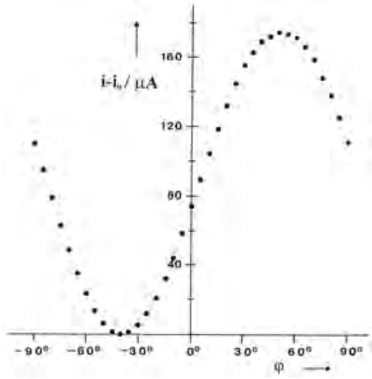
Universal measuring amplifier for amplification of AC and DC voltages. Suitable for practical exercises.

13626-93

P2250400 Malus' law



Demo



Corrected photo cell current as a function of the angular position of the polarization plane of the analyzer.

Principle

Linear polarised light passes through a polarization filter. Transmitted light intensity is determined as a function of the angular position of the polarisation filter.

Tasks

1. The plane of polarisation of a linear polarised laser beam is to be determined.
2. The intensity of the light transmitted by the polarisation filter is to be determined as a function of the angular position of the filter.
3. Malus' law must be verified.

What you can learn about

- Electric theory of light
- Polarisation
- Polariser
- Analyser
- Brewster's law
- Malus' law

Main articles		
Laser, He-Ne, 1.0 mW, 230 V AC	08181-93	1
Photoelement f. opt. base plt.	08734-00	1
Optical profile bench l = 60 cm	08283-00	1
Polarising filter,on stem	08610-00	1
DMM, auto range, NiCr-Ni thermocouple	07123-00	1
Slide mount for optical bench, h = 30 mm	08286-01	3
Base for optical bench, adjustable	08284-00	2

Optical profile bench l = 60 cm

Function and Applications

Profile bench with bore holes on the rear side for mounting adjustable bases. In connection with turning knuckle (08285-00) usable to elbow or extend optical benches.

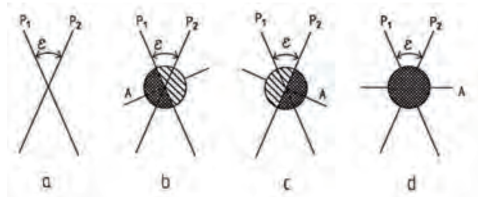
Equipment and technical data

- Width: 81 mm.
- Height: 32 mm.
- Length: 600 mm.

08283-00

Polarimetry with optical base plate

P2250505



Working principle of the half shadow polarimeter.

Principle

Optically active substances cause very slight rotations of the light polarisation plan, which the method of crossed polarisation filters is not strong enough to measure. With this method, the direction of polarisation of the analyser is perpendicular to that of the polarizer. If an optically active substance is placed between them, the polarisation direction of the analyser must be corrected by the corresponding angle of rotation of the plane of polarisation in order to obtain an intensity minimum again. A stronger adjustment possibility for the determination of the angle is given with the half shadow polarimeter, used in this experiment to measure the angle of rotation of the plane of polarisation caused by glucose-water solutions of different concentrations.

Task

Determine the angle of rotation for sugar solutions of different concentrations.

What you can learn about

- Lippich polariser
- Malus' law

Main articles		
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Optical base plate with rubberfeet	08700-00	0
Pol.filter halfshade f.opt.b.pl.	08730-01	1
Polarizing filter f.opt.base pl.	08730-00	2
Adjusting support 35 x 35 mm	08711-00	1
Surface mirror 30 x 30 mm	08711-01	1
Holder,dir.vis. prism,opt.b.pl.	08726-00	1

Laser, He-Ne, 0.2/1.0 mW, 230 V AC

Function and Applications

Linearly polarised light source, very short design.

Benefits

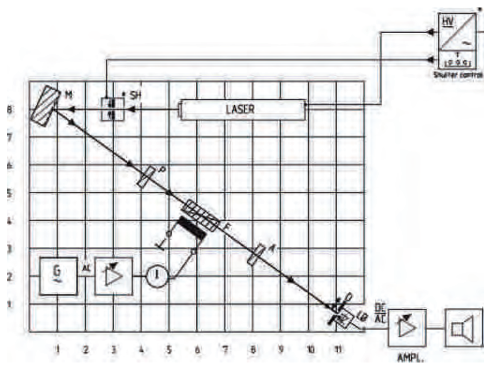
- Welded glass tube assures a very long lifetime > 18 000 operating hours, Key switch and integrated greyfilter to reduce radiation power to 0.2 mW. Screw-in release to activate the grey filter.
- Anodised aluminium casing with integrated mains power supply,screw in holding stem, signal light and required warnings printed on both sides.Fixed mains connecting cable 140 cm.

Equipment and technical data

- Wavelength 632.8 nm, optical output power without filter 1.0 mW, with filter 0.2 mW
- beam diameter 0.5 mm, beam divergence < 2 mrad.
- minimum polarisation500:1, max drift over 8 hours ± 2.5%
- oscillating mode TEM00, lifetime > 18000 h
- power requirements 35 VA, connectingvoltage 230 V, 50.60 Hz

08180-93

P2260106 Faraday effect with optical base plate



Experimental set up.

Principle

When the Faraday Effect was discovered in 1845 it was the first experiment that elucidated the relation of light and electromagnetism. If linearly polarized light passes through a region with magnetic field the angle of rotation of the plane of polarisation is altered. This alteration appears to be a linear function of both the average magnetic flow density and the distance that the wave covers in the magnetic field. The factor of proportionality is a mediumspecific constant and is called Verdet's constant.

Task

Investigate the Faraday effect qualitatively through observation of the electro optical modulation of the polarised laser light with frequencies in the acoustic range.

What you can learn about

- Interaction of electromagneticfields
- Electromagnetism
- Polarisation
- Verdet's constant
- Malus' law
- Electronic oscillation

Main articles		
Digital Function Generator, USB	13654-99	1
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Loudspeaker,8 Ohm/5 kOhm	13765-00	1
Photoelement f. opt. base plt.	08734-00	1

Related Experiment

Faraday effect

P2260100

Faraday modulator f.opt.base pl.

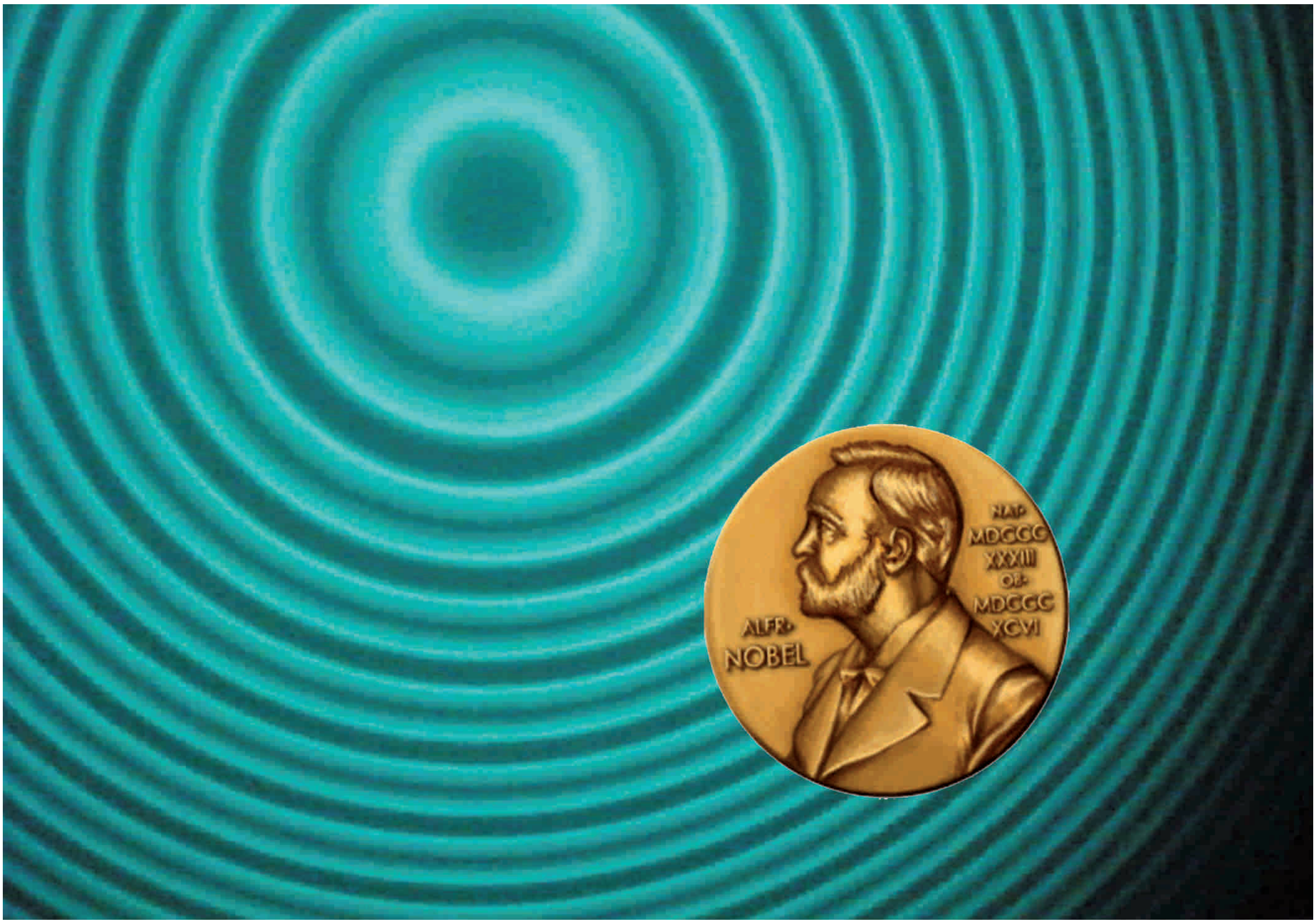
Function and Applications

Copper coil on temperature-stable aluminium winder with insert for holdingglass rods (SF58) for Faraday effect.

Equipment and technical data

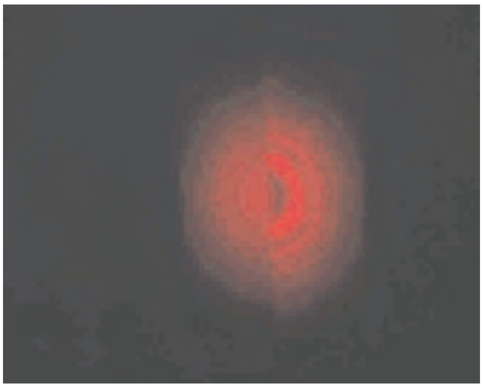
- With round stem, clamp screws and fixed connection cable = 1m with 4-mm jacks
- Number of windings 1200
- Inductivity 6.3 mH
- Ohm's resistance 4 Ω
- Internal diameter 14 mm
- Max. current 5 A (1 min)

08733-00



Quantum Physics

P2220800 Quantum eraser



Pattern seen on the screen when blocking half of the beam.

Principle

A Mach-Zehnder-interferometer is illuminated with a laser beam. Circular interference fringes appear on the screens behind the interferometer. If polarisation filters with opposite polarisation planes are placed in the two interferometer paths the interference patterns disappear. Placing another polariser before one of the screens causes the pattern to reappear. Electromagnetic radiation can be described both in terms of propagating waves, as well as particles (photons). The experiment illustrates this duality by showing how interference patterns can be explained on the basis of both classical wave mechanics and quantum physics.

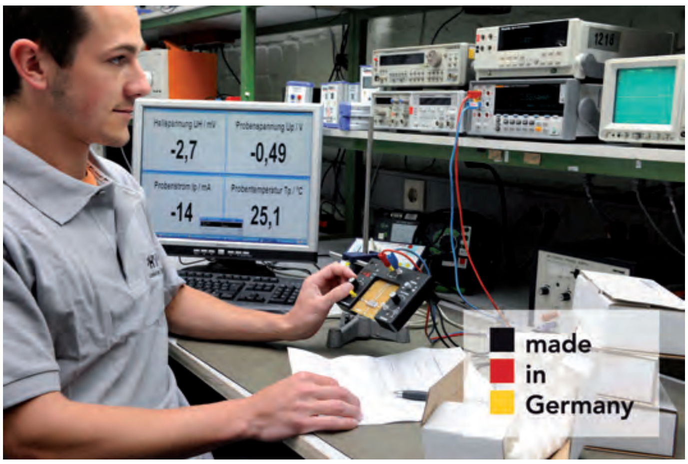
Tasks

1. Set up the experiment and observe the interference pattern on the screen.
2. Change the polarisation of the beams with the PF1 and PF2 polarisers and observe the influence on the interference pattern.
3. Use the third polariser PF3 to cancel the polarisation of the light in the two beams and observe the reappearance of the interference pattern.

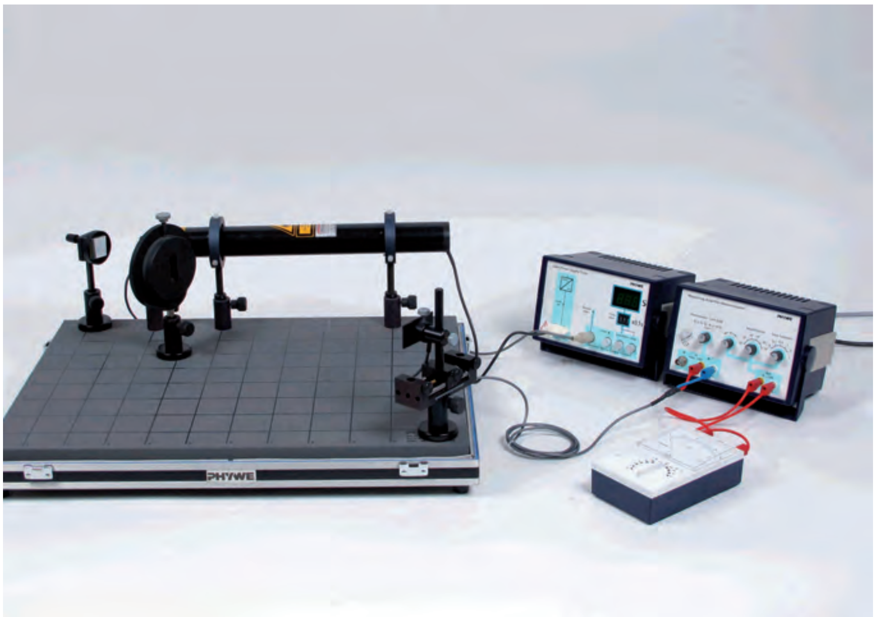
What you can learn about

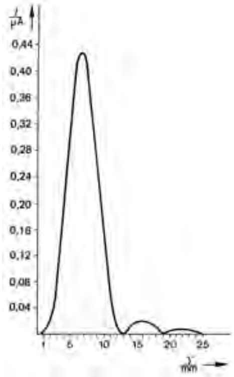
- Wave-particle duality
- Wave interference
- Quantum mechanics

Main articles		
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Optical base plate in covering case	08700-01	1
Diaphragm holder for optical base plate	08724-00	1
Polarizing filter for optical base plate	08730-00	3
Polarization specimen, mica	08664-00	1
Beam splitter 1/1,non polarizing	08741-00	2
Surface mirror 30 x 30 mm	08711-01	4



Diffraction at a slit and Heisenberg's uncertainty principle — P2230105





Intensity distribution of the diffraction pattern of a 0.05 mm wide slit, at a distance of 490 mm.

Principle

The intensity distribution in the Fraunhofer diffraction pattern of a slit is measured. Measurement results are evaluated both in the wave representation through comparison with Kirchhoff's diffraction fromula and in the photon representation, in order to verify Heisenberg's uncertainty principle.

Tasks

1. The intensity distribution of the Fraunhofer diffraction pattern due to a simple slit is measured. The amplitudes of the peaks and of the minima are calculated according to Kirchhoff's diffraction formula and compared to measured values.
2. Momentum uncertainty is calculated with the assistance of the diffraction patterns of simple slits of different widths, and Heisenberg's uncertainty relation is verified.

What you can learn about

- Diffraction; Sharpness
- Kirchhoff's diffraction
- Formula; Measurement precision
- Local uncertainty; Impulse uncertainty
- Wave-matter duality; De Broglie's relation

Main articles		
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
Photoelement f. opt. base plt.	08734-00	1
Diaphragm holder f.opt.base plt.	08724-00	1
Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1

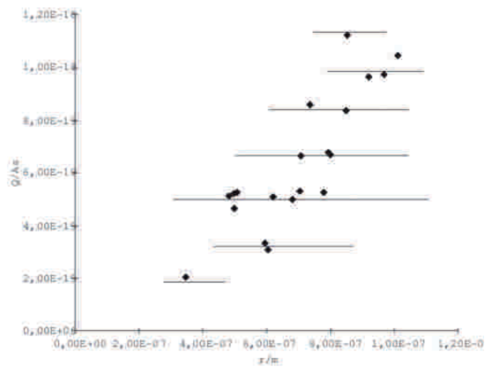
Related Experiment

Diffraction at a slit and Heisenberg's uncertainty principle

P2230100

Werner Heisenberg
1932, Nobel Prize in Physics

P2510100 Elementary charge and Millikan experiment



Measurements on various droplets for determining the elementary charge by the Millikan method.

Principle

Charged oil droplets subjected to an electric field and to gravity between the plates of a capacitor are accelerated by application of a voltage. The elementary charge is determined from the velocities in the direction of gravity and in the opposite direction.

Tasks

1. Measurement of the rise and fall times of oil droplets with various charges at different voltages.
2. Determination of the radii and the charge of the droplets.

What you can learn about

- Electric field
- Viscosity
- Stokes' law
- Droplet method
- Electron charge

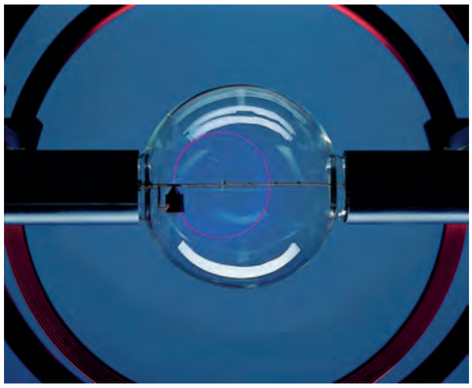
Main articles		
Millikan apparatus	09070-00	1
Power supply, 0...600 VDC	13672-93	1
Multi-range meter w.overl.prot.	07021-01	1
Polarity Switch for Millikan Apparatus	06034-07	1
Tripod base PHYWE	02002-55	1
Stop watch, interruption type	03076-01	2
Stand tube	02060-00	1

Robert A. Millikan

1923, Nobel Prize in Physics

Specific charge of the electron e/m

P2510200



Detail of experimental setup.

Principle

Electrons are accelerated in an electric field and enter a magnetic field at right angles to the direction of motion. The specific charge of the electron is determined from the accelerating voltage, the magnetic field strength and the radius of the electron orbit.

Task

Determination of the specific charge of the electron (e/m_0) from the path of an electron beam in crossed electric and magnetic fields of variable strength.

What you can learn about

- Cathode rays
- Lorentz force
- Electron in crossed fields
- Electron mass
- Electron charge

Main articles		
Narrow beam tube	06959-00	1
Helmholtz coils, one pair	06960-00	1
Power supply, 0...600 VDC	13672-93	1
Power supply, universal	13500-93	1
e/m - Observation Chamber	06959-01	1
Digital multimeter 2010	07128-00	2

In Cooperation with:

National University of Science and Technology "MISIS" in Moscow, Russia

e/m - Observation chamber

Function and Applications

Observation chamber for covering the e/m experiment (Helmholtz coils and narrow beam tube).

Benefits

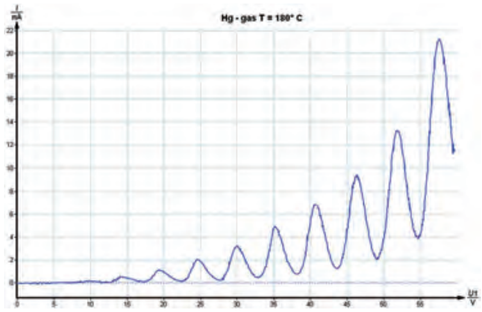
- parallax-free measuring of turning radii of electrons
- measuring of any turning radii of electrons, operation under normal lightning conditions, protection of the narrow beam tube due to less intensities required

Equipment and Technical data

- Covering box out of hard paper with observation window and connection openings; Dimensions LxWxH (mm): 550x310x470; Mirror with scale

06959-01

P2510311 Franck-Hertz experiment with a Hg-tube



Example of a Franck-Hertz curve for Hg-gas at T = 180 °C.

Principle

Electrons are accelerated in a tube filled with mercury vapour. The excitation energy of mercury is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

Tasks

1. Record the countercurrent strength I in a Franck-Hertz tube as a function of the anode voltage U.
2. Determine the excitation energy E from the positions of the current strength minima or maxima by difference formation.

What you can learn about

- Energy quantum
- Electron collision
- Excitation energy

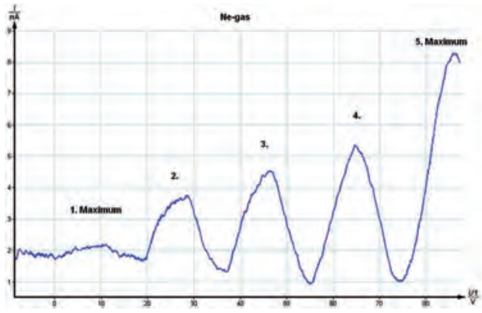
Main articles		
Franck-Hertz control unit	09105-99	1
Franck-Hertz Hg-tube on plate	09105-10	1
Franck-Hertz oven for Hg-tube	09105-93	1
Thermocouple NiCr-Ni, sheathed	13615-01	1
Connecting cord for Franck-Hertz Hg-tube	09105-30	1
Software Measure Franck-Hertz experiment	14522-61	1
Screened cable, BNC, l 750 mm	07542-11	1

James Franck
1925, Nobel Prize in Physics

Gustav Hertz
1925, Nobel Prize in Physics

Franck-Hertz experiment with a Ne-tube

P2510315



Example of a Franck-Hertz curve for Ne-gas.

Principle

Electrons are accelerated in a tube filled with neon vapour. The excitation energy of neon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

Tasks

1. Record the counter current strength I in a Franck-Hertz tube as a function of the anode voltage U.
2. Determine the excitation energy E from the positions of the current strength minima or maxima by difference formation.

What you can learn about

- Energy quantum
- Quantum leap
- Electron collision
- Excitation energy

Main articles		
Franck-Hertz control unit	09105-99	1
Franck-Hertz Ne-tube w. housing	09105-40	1
Connect.cord f.Franck-H. Ne-tube	09105-50	1
Software Measure Franck-Hertz experiment	14522-61	1
Screened cable, BNC, l 750 mm	07542-11	1
Data cable, plug/ socket, 9 pole	14602-00	1

Franck-Hertz control unit

Function and Applications

Compact operating unit for Franck-Hertz-experiment to be used with Hg- and Ne-tubes. In 1913/14 James Franck and Gustav Hertz approved Bohr's model of atoms with this experiment (Nobel Prize: 1925).

Benefits

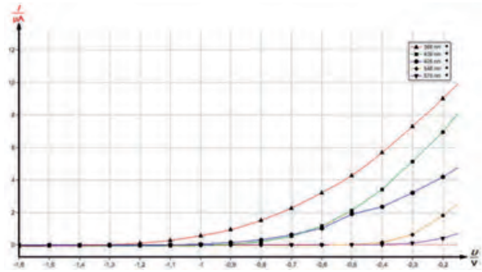
- Automatic detection of tube type and automatic limitation of tube parameter.
- Examination by direct reading of displayed values, xyt-recorder, oscilloscope or PC.
- From the recorded anode current as a function of acceleration voltage the excitation energy of the atoms can be determined.

Equipment and technical data

- Heating voltage (const.):6.5 ± 0,5 V, Acceleration voltage: 0...99 V, Counter voltage: 0...12 V, Emission voltage: 0...6 V
- Heater voltage: 0...10 V, Resolution (all voltages): 0,1 V
- Heater current: 400 mA, Heater temperature: 0...999°C
- Anode current: 0...50 nA, Output 4 mm-sockets:
- Acceleration voltage: 0...10 V(10 V ~ 100 V)
- Voltage ß anode current: 0...10 V(10 V ~ 50 nA)
- Data output: RS232 SubD-socket, Display: 20 mm 7-segment LED
- 4 operation modes: manually,automatic ramp, saw tooth (oscilloscope) and PC-control.
- Power control for heater with safety socket (600 W) and type K socket for thermocouples.
- Socket for 5-pole connection cable for Hg/Ne-tube.

09105-99

P2510402 Planck's "quantum of action" and photoelectric effect(line separation by interference filters)



Photoelectric current intensity I as a function of the bias voltage at different frequencies of the irradiated light.

Principle

A photocell is illuminated with monochromatic light of different wavelengths from a filament lamp with interference filters. The maximum energy of the ejected electrons in the photo-cell depends only on the frequency of the incident light, and is independent of its intensity. The stopping voltage Uo at different light frequencies is determined by the U/I caracteristics of the photocell and plotted over the corresponding light frequency f. Planck's quantum of action or Planck's constant (h) is determined from this graph .

Task

To determine Planck's quantum of action from the photoelectric voltages measured at different wave lengths

What you can learn about

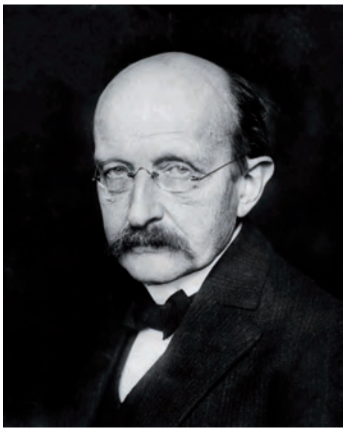
- External photoelectric effect
- Work function
- Absorption
- Photon energy
- Anode
- Cathode

Main articles		
Interference filters, set of 3	08461-00	1
Interference filters, set of 2	08463-00	1
Universal measuring amplifier	13626-93	1
Photocell for h-determination, with housing	06779-00	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Rheostat, 100 Ohm , 1.8A	06114-02	1
Experiment lamp 5	11601-00	1

Related Experiment

Planck's "quantum of action" and extern photoelectric effec effect (line separation by a diffraction grating)

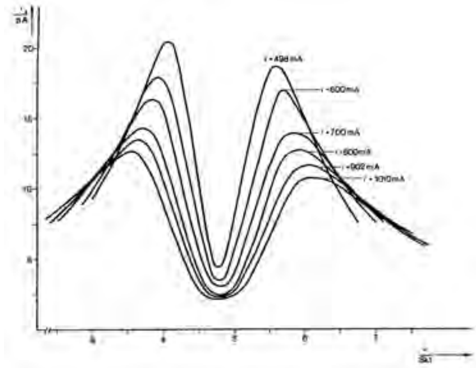
P2510502



Max Planck

1918, Nobel Prize in Physics

Stern-Gerlach experiment with a step motor and interface P2511111



Ionization current as a function of position (u) of detector with large excitation currents in the magnetic analyser.

Principle

A beam of potassium atoms generated in a hot furnace travels along a specific path in a magnetic two-wire field. Because of the magnetic moment of the potassium atoms, the nonhomogeneity of the field applies a force at right angles to the direction of their motion. The potassiumatoms are thereby deflected from their path. By measuring the density of the beam of particles in a plane of detection lying behind the magnetic field, it is possible to draw conclusions as to the magnitude and direction of the magnetic moment of the potassium atoms.

Tasks

1. Recording the distribution of the particle beam density in the detectionplane in the absence of the effective magnetic field.
2. Fitting a curve consisting of a straight line, a parabola, and another straight line, to the experimentally determined special distribution of the particle beam density.
3. Determining the dependence of the particle beam density in the detection plane with different values of the non-homogeneity of the effective magnetic field.
4. Investigating the positions of the maxima of the particle beam density as a function of the non-homogeneity of the magnetic field.

What you can learn about

- Magnetic moment
- Bohr magneton
- Directional quantisation
- g-factor
- Electron spin; Atomic beam
- Maxwellian velocity distribution
- Two-wire field

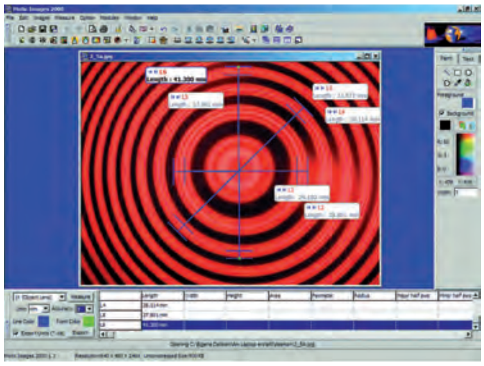
Main articles		
Stern-Gerlach apparatus	09054-88	1
High vacuum pump assembly,compact	09059-99	1
Step motor Stern-Gerlach appartus	09054-06	1
Electromagnet w/o pole shoes	06480-01	1
DC measuring amplifier	13620-93	1
Step motor unit	08087-99	1
Matching transformer	09054-04	1

Related Experiment

Stern-Gerlach experiment

P2511101

P2511001 Zeeman effect with an electromagnet



Screenshot of software used to measure the diameters of the interference rings as captured by the CCD-Camera.

Principle

The "Zeeman effect" is the splitting up of the spectral lines of atoms within a magnetic field. The simplest is the splitting up of one spectral line intothree components called the "normal Zeeman effect". In this experiment thenormal Zeeman effect as well as theanomalous Zeeman effect are studiedusing a cadmium spectral lamp as aspecimen. The cadmium lamp is submitted to different magnetic flux densitiesand the splitting up of the cadmiumlines (normal Zeeman effect 643.8 nm,red light; anomalous Zeeman effect 508.6 nm, green light) is investigated using aFabry-Perot interferometer. The evaluation of the results leads to a fairlyprecise value for Bohr's magneton.

Tasks

1. Using the Fabry-Perot interferometerand a selfmade telescope the splitting up of the central line into different lines is measured in wave numbers as afunction of the magnetic flux density.
2. From the results of point 1. a valuefor Bohr's magneton is evaluated.
3. The light emitted within the direction of the magnetic field is qualitatively investigated.

What you can learn about

- Bohr's atomic model
- Quantisation of energy levels
- Electron spin
- Bohr's magneton
- Interference of electromagnetic waves
- Fabry-Perot interferometer

Main articles		
Fabry-Perot interferometer	09050-03	1
Electromagnet w/o pole shoes	06480-01	1
Cadmium lamp for Zeeman effect	09050-20	1
Variable transformer, 25 VAC/ 20 VDC, 12 A	13531-93	1
Power supply for spectral lamps	13662-97	1
Rot.table for heavy loads	02077-00	1
Pole pieces, drilled, conical	06480-03	1

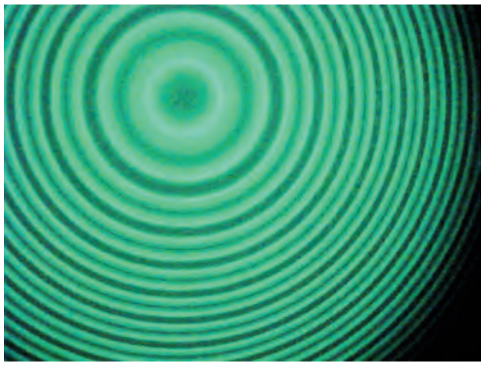
Related Experiment

Zeeman effect with a CCD camera including the measurement software

P2511005

Zeeman effect with a variable magnetic system

P2511006



Interference rings with the anomalous Zeeman effect.

Principle

The "Zeeman effect" is the splitting up of the spectral lines of atoms within a magnetic field. The simplest is the splitting up of one spectral line into three components called the "normal Zeeman effect". In this experiment the normal Zeeman effect as well as the anomalous Zeeman effect are studied using a cadmium spectral lamp as a specimen. The cadmium lamp is submitted to different magnetic flux densities and the splitting up of the cadmium lines (normal Zeeman effect 643.8 nm, red light; anomalous Zeeman effect 508.6 nm, green light) is investigated using a Fabry-Perot interferometer. The evaluation of the results leads to a fairly precise value for Bohr's magneton.

Tasks

1. Using the Fabry-Perot interferometer and a selfmade telescope the splitting up of the central line into different lines is measured in wave numbers as a function of the magnetic flux density.
2. From the results of point 1. a value for Bohr's magneton is evaluated.
3. The light emitted within the direction of the magnetic field is qualitatively investigated.

What you can learn about

- Bohr's atomic model; Quantisation of energy levels; Electron spin; Bohr's magneton; Interference of electromagnetic waves; Fabry-Perot interferometer

Main articles		
Fabry-Perot interferometer	09050-03	1
Magnetic System, variable	06327-00	1
Cadmium lamp for Zeeman effect	09050-20	1
Power supply for spectral lamps	13662-97	1
Sliding device, horizontal	08713-00	1
Optical profile-bench, l 1000mm	08282-00	1

Related Experiment

Zeeman effect with a variable magnetic system and a CCD camera including the measurement software

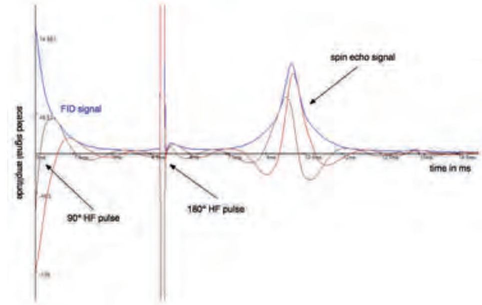
P2511007

Pieter Zeeman

1902, Nobel Prize in Physics

P5942100 Fundamental principles of Nuclear Magnetic Resonance (NMR)

NEW m Demo



Spin echo signal of an oil sample occuring 10 ms (echo time) after a 90° HF pulse (FID signal is shown). To generate the echo signal a 180° HF pulse has to be switched after half the echo time.

Principle

The fundamental principles concerning the phenomenon of nuclear magnetic resonance (NMR) are demonstrated. Experiments are executed with a MRT training device giving the opportunity to investigate some small probes in the sample chamber. Device control is done with the provided software. Investigations comprise the tuning of the system frequency to the Larmor frequency, the determination of the flip angle of the magnetisation vector, the effects of the substance quantity, the influence of particular magnetic field inhomogeneities, the measurement of a spin echo signal and an averaging procedure to maximise the signal-to-noise ratio. The adjustment of all parameters in these experiments are inevitable to obtain an adequate MR image.

Tasks

1. Tuning of the system frequency to the Larmor frequency.
2. Setting of the HF (High Frequency) pulse duration to determine the flip angle of the magnetisation vector.
3. Effects of the substance quantity on the FID signal (Free Induction Decay) amplitude.
4. Minimising magnetic field inhomogeneities via a superimposed magnetic field (shim).
5. Retrieving a relaxated FID signal via a spin echo flipping nuclear spins by 180°.
6. Improving the signal-to-noise ratio (SNR) of the FID signal.

What cou can learn about

- Nuclear spins; Atomic nuclei with a magnetic moment
- Precession of nuclear spins; Magnetisation
- Resonance condition, MR frequency
- MR flip angle; FID signal (Free Induction Decay); Spin echo
- Relaxation times (T1: longitudinal magnetisation, T2: transverse magnetisation)
- Signal-to-noise ratio

Main articles		
Compact MRT	09500-99	1

Related Experiments

Relaxation times in Nuclear Magnetic Resonance
P5942200

Spatial encoding in Nuclear Magnetic Resonance
P5942300

Magnetic Resonance Imaging (MRI) I
P5942400

Magnetic Resonance Imaging (MRI) II
P5942500

Compact MRT

Function and Applications

The systems gives you the unique opportunity of offering training at a real MRT machine directly on site. This is the only way to provide for realistic and practice-oriented nuclear magnetic resonance (NMR) training for all fields of science and medicine. The training software makes it easy for the users to experience all aspects of magnetic resonance tomography. The special option to influence experiments on runtime and to directly visualize the results gives users an unprecedented learning experience. In addition to parameters accessible only through MRT, as for example the tuning of the system frequency to the Larmor frequency or the specification of relaxation times, high-resolution tomographic MR images can be produced. Image artifacts found in clinical MRT can be examined directly in a simple process.
The system differs from other magnetic resonance tomographs only in the sample size and the fact that it is portable. However, in order to generate a fairly homogeneous magnetic field the sample chamber has to be comparatively small. The MRT compact set consists of the control unit, the magnet unit, and the training software and is optimized for education and training purposes. In addition to carrying out fundamental and basic experiments on MR technology, students can generate, export and analyze numerous images with all relevant contrasts in a high spatial resolution.

Benefits

- easy to connect and immediately operative (USB 2.0)
- new and numerous education experience
  - training at a real MRT in compact format with clinically relevant measuring procedures; high resolution MR imaging (2D, 3D)
  - live visualization of data; realtime control of experimental parameters
- realistic and practice-oriented training for all fields of science and medicine
  - T1/T2 measurements; all MR parameters accessible
  - experiment is selected from a clearly structured menu
  - measure a multitude of samples with a diameter up to one centimeter
  - software perfectly adapts to the operation for study purposes
  - suitable for a wide range of experiments, from basic understanding of magnetic resonance to complex imaging
- literature tailored precisely to the experiments (available with the set "compact magnetic resonance tomograph": 4 TESS experimental units
- possibility to select courses in which only the relevant parameters necessary for the findings are adjusted

Equipment and technical Data

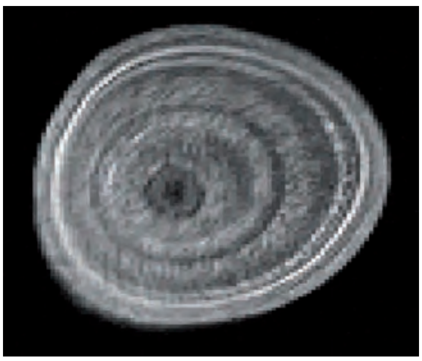
The system includes the following components:

- Control unit:
  - gradient amplifier and transmitter and receiver unit
  - PC connection: USB-B; Connection of the imaging unit (gradient): RJ45; Connection of the receiver/transmitter unit: BNC; Power supply: 12 V DC, 2 A; Power supply unit (external): 100-240 VAC, 50/60 Hz, 2 A
  - Dimensions (length x width x height):27 cm x 9.5 cm x 14 cm; Weight: 2.3 kg
- Magnet unit:
  - high-end gradient system for 2D and 3D images; System frequency: 22 MHz
  - Field intensity: 500 mT; Field homogenity: < 100 ppm
  - Sample diameter: max. 10 mm
  - Connection of the imaging unit (gradient): RJ45
  - Connection of the receiver/transmitter unit BNC
  - Dimensions (length x width x height): 27 cm x 25 cm x 14 cm; Weight: 17.5 kg
- Training Software:
  - Languages: German/English (other languages on request)
  - Product license: Training version; Data formats: DICOM, JPEG, CSV, TXT; Media types: USB stick
- Sample set
  - 5 different samples (water and oil samples each of with 5 and 10 mm diameter, sample with a particular structure)
  - 1 empty sample tube, 10 mm
  - Sturdy carrying case for safe transport
  - USB stick incl. training software, comprehensive descriptions of the experiments, detailed theoretical background, structured implementation plan, exercises, analyses with many figures clearly arranged (possibility to extend the basic set), operating manuals

Accessories

- Computer (min. processor 1.6 GHz) with Windows XP (32-Bit)/Vista (32-Bit)/7, USB 2.0 interface, min. 1 GB RAM, min. of 1 GB hard-disk space, 1024 x 758 graphics card (min. 256 MB, compatible with DirectX 9.0), 16-bit color resolution or better
- Soundbox for realistic background noise to connect the experiments with everyday experiences

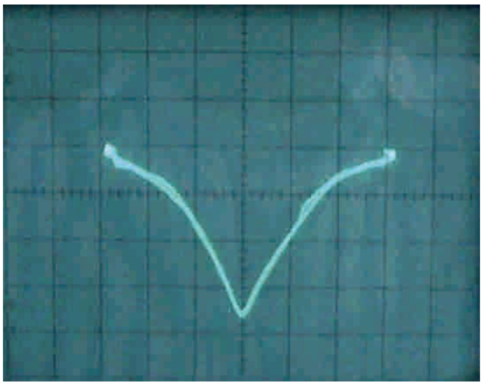
09500-99



Cross-sectional image of a branch

P2511200 Electron spin resonance

Demo



Resonance signal on the oscilloscope.

Principle

With electron spin resonance (ESR) spectroscopy compounds having unpaired electrons can be studied. The physical background of ESR is similar to that of nuclear magnetic resonance (NMR), but with this technique electron spins are excited instead of spins of atomic nuclei. The g-factor of a DPPH (Diphenylpikrylhydrazyl) specimen and the halfwidth of the absorption line are determined, using the ESR apparatus.

Tasks

1. Determine the g-factor (Landé-factor) of the DPPH (Diphenylpicrylhydrazyl) specimen.
2. Determine the FWHM (Full Width at Half Maximum) of the absorption line.

What you can learn about

- Zeeman effect
- Energy quantum
- Quantum number
- Resonance
- g-factor
- Landé factor

Main articles		
ESR power supply	09050-93	1
ESR resonator with field coils	09050-00	1
Teslameter, digital	13610-93	1
Power supply, universal	13500-93	1
Oscilloscope, 30 MHz, 2 channels	11459-95	1
Hall probe, tangential, protection cap	13610-02	1
DMM, auto range, NiCr-Ni thermocouple	07123-00	1

ESR resonator with field coils

Function and Apllications

ESR resonator

Benefits

- with field coilshigh quality oscillating circuit, tuneable within the 146 MHz Range.
- Two Helmholtz coils, BNC Socket, test specimen.

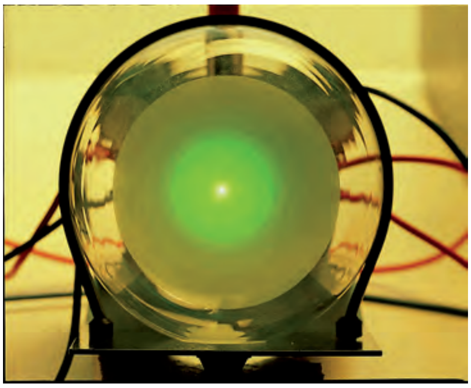
Equipment and technical data

- Diphenylpicrylhydrazyl sample 1 g, Resonatorfrequency approx. 146 MHz
- Resonator performance approx. 1000, Coil radius (Helmholz coils) 5.4 cm, Turns: 250

09050-00

Electron diffraction

P2511300



Interference rings of graphite on a fluorescent screen.

Principle

Fast electrons are diffracted from a polycrystalline layer of graphite: interference rings appear on a fluorescent screen. The interplanar spacing in graphite is determined from the diameter of the rings and the accelerating voltage.

Tasks

1. To measure the diameter of the two smallest diffraction rings at different anode voltages.
2. To calculate the wavelength of the electrons from the anode voltages.
3. To determine the interplanar spacing of graphite from the relationship between the radius of the diffraction rings and the wavelength.

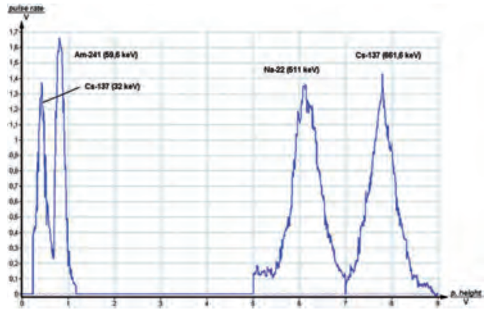
What you can learn about

- Bragg reflection
- Debye-Scherrer method
- Lattice planes
- Graphite structure
- Material waves
- De Broglie equation

Main articles		
Electron diffraction tube	06721-00	1
High voltage supply unit, 0-10 kV	13670-93	1
Power supply, 0...600 VDC	13672-93	1
High-value resistor, 10 MOhm	07160-00	1
Connecting cord, 30 kV, 500 mm	07366-00	1
Vernier caliper, plastic	03011-00	1

Louis de Broglie
1929, Nobel Prize in Physics

P2524415 Compton effect with the multichannel analyser



Energy of known peaks as a function of the pulse height.

Principle

The energy of scattered gamma-radiation is measured as a function of the angle of scatter. The Compton wavelength is determined from the measured values.

Tasks

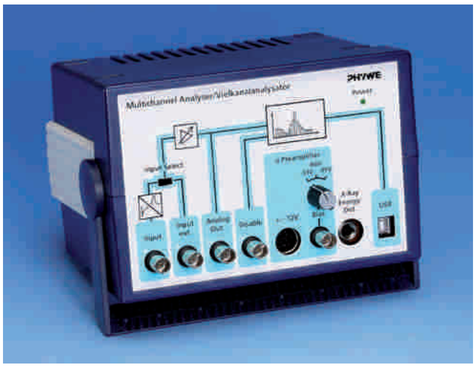
1. Calibrate the measuring set-up with the aid of a Cs-137 calibrating source (37 kBq) and a Na-22 source (74 kBq).
2. Measure the energy of the Cs-137 661.6 keV peaks scattered at different angles and calculate the Compton wavelength from the readings taken.

What you can learn about

- Corpuscle
- Scattering
- Compton wavelength
- g-quanta
- de Broglie wavelength
- Klein-Nishina formula

Main articles		
Gamma detector	09101-00	1
Radioactive source Cs-137, 18.5 MBq	09096-20	1
Multi channel analyser	13727-99	1
Radioactive source Cs-137, 37 kBq	09096-01	1
Screening cylinder for gamma detector	09101-11	1
Radioactive source Am-241, 370 kBq	09090-11	1
Operating unit for gamma detector	09101-93	1

Multichannel analyser



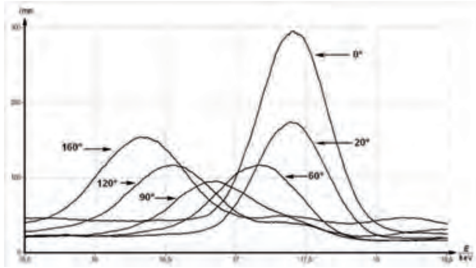
Function and applications

The multichannel analyser is for analysing voltage pulses which are proportional to energy and for determining pulse rates and intensities in conjunction with an X-ray detector, alpha detector or gamma detector. The analogue pulses from the detector are shaped by the analyser, digitised and summed per channel according to pulse height. This results in a frequency distribution of detected pulses dependent on the energy of the radiation.

13727-99

Compton effect - energy-dispersive direct measurement

P2546001



Molybdenum-Kα-Line of various scattering angles theta.

Principle

Photons of the molybdenum K-alpha X-ray line are scattered at the quasi-free electrons of an acrylic glass cuboid. The energy of the scattered photons is determined in an angle-dependent manner with the aid of a swivelling semiconductor detector and a multi-channel analyser.

Tasks

1. Energy calibration of the multi-channel analyser with the aid of the two characteristic molybdenum X-ray lines.
2. Energy determination of the photons of the Mo-line that are scattered through an acrylic glass element as a function of the scattering angle.
3. Comparison of the measured energy values of the lines of scatter with the calculated energy values.
4. Calculation of the Compton wavelength of electrons and a comparison of this value with the corresponding value of the 90° scattering.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Compton scattering
- Compton wavelength
- Conservation of energy and momentum
- Rest mass and rest energy of the electron
- Relativistic electron mass and energy
- Semiconductor detector
- Multi-channel analyser

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
Multi channel analyser	13727-99	1

Related Experiment

Compton scattering of X-rays

P2541701

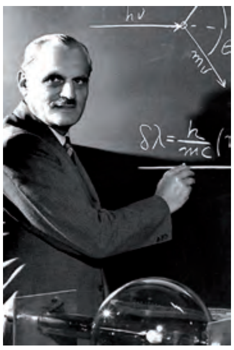
Best fitting XR 4.0 sets for this experiment:

XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

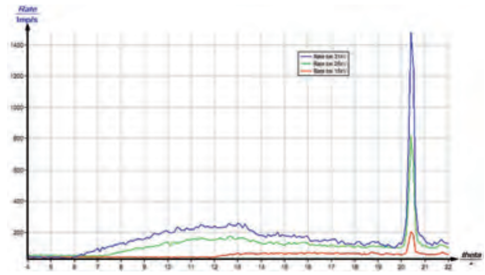
09160-88



Arthur H. Compton

1927, Nobel Prize in Physics

P2540901 Duane-Hunt displacement law and Planck's "quantum of action"



Bremsspectrum of copper for three different anode voltages U (15 kV, 15 kV, and 31 kV), x-axis: glancing angle theta /°.

Principle

X-ray spectra are recorded as a function of the anode voltage. The short wavelength limit of the bremsspectrum is used to determine the agreement with the Duane-Hunt displacement law, and to determine Planck's "quantum of action".

Tasks

1. Record the intensity of the X-rays emitted by the copper anode at various anode voltages as a function of the Bragg angle using an LiF monocrystal.
2. Determine the short wavelength limit (= maximum energy) of the bremsspectrum for the spectra obtained in (1).
3. Use the results to verify the Duane-Hunt displacement law, and to determine Planck's "quantum of action".

What you can learn about

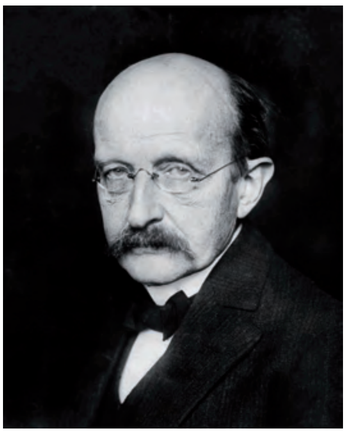
- X-ray tube
- Bremsstrahlung
- Characteristic X-ray radiation
- Energy levels
- Crystal structures
- Lattice constant
- Interference
- Bragg equation

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray Diaphragm tube d = 2 mm	09057-02	1

Best fitting XR 4.0 sets for this experiment:

XRE 4.0 X-ray expert set
09110-88

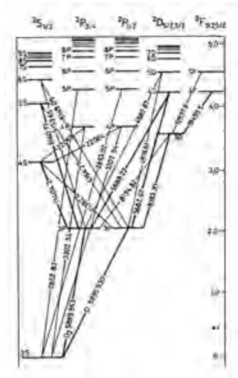
XRP 4.0 X-ray Solid state physics upgrade set
09120-88



Max Planck
1918, Nobel Prize in Physics

Atomic Physics

P2510600 Fine structure: one and two electron spectra



Spectrum of sodium.

Principle

The well-known spectral lines of He are used for calibrating the diffraction spectrometer.

The wave-lengths of the spectral lines of Na, Hg, Cd and Zn are determined using the spectrometer.

Tasks

1. Calibration of the spectrometer using the He spectrum and the determination of the constant of the grating.
2. Determination of the spectrum of Na.
3. Determination of the fine structure splitting.
4. Determination of the most intense spectral lines of Hg, Cd and Zn.

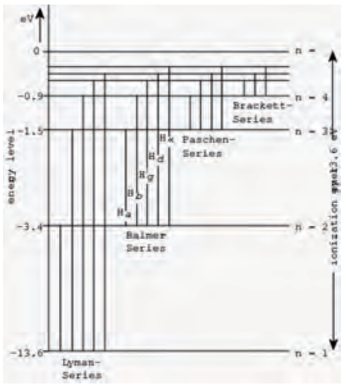
What you can learn about

- Diffraction spectrometer
- Spin
- Angular momentum
- Spin-orbital angular momentum interaction
- Multiplicity
- Energy level
- Excitation energy
- Selection rules
- Doublets
- Parahelium
- Orthohelium
- Exchange energy
- Angular momentum
- Singlet and triplet series
- Selection rules
- Forbidden transitions

Main articles		
Spectrometer/goniom. w. vernier	35635-02	1
Spectral lamp He, pico 9 base	08120-03	1
Power supply for spectral lamps	13662-97	1
Spectral lamp Na, pico 9 base	08120-07	1
Spectral lamp Hg 100, pico 9 base	08120-14	1
Spectral lamp Zn, pico 9 base	08120-11	1
Spectral lamp Cd, pico 9 base	08120-01	1

Balmer series/ determination of Rydberg's constant P2510700

Demo



Energy level diagram of the H atom.

Principle

The spectral lines of hydrogen and mercury are examined by means of a diffraction grating. The known spectral lines of Hg are used to determine the grating constant. The wave lengths of the visible lines of the Balmer series of H are measured.

Tasks

1. Determination of the diffraction grating constant by means of the Hg spectrum.
2. Determination of the visible lines of the Balmer series in the H spectrum, of Rydberg's constant and of the energy levels.

What you can learn about

- Diffraction image of a diffraction grating
- Visible spectral range; Single electron atom
- Atomic model according to Bohr
- Lyman-, Paschen-, Brackett and Pfund series
- Energy level; Planck's constant; Binding energy

Main articles		
High voltage supply unit, 0-10 kV	13670-93	1
Object holder, 5x5 cm	08041-00	1
Spectrum tube, hydrogen	06665-00	1
Spectrum tube, mercury	06664-00	1
Diffraction grating, 600 lines/mm	08546-00	1
Tripod base PHYWE	02002-55	1
Insulating support	06020-00	2

Related Experiment

Atomic spectra of two-electron system: He, Hg

P2510800

High voltage supply unit, 0-10 kV

Function and Applications

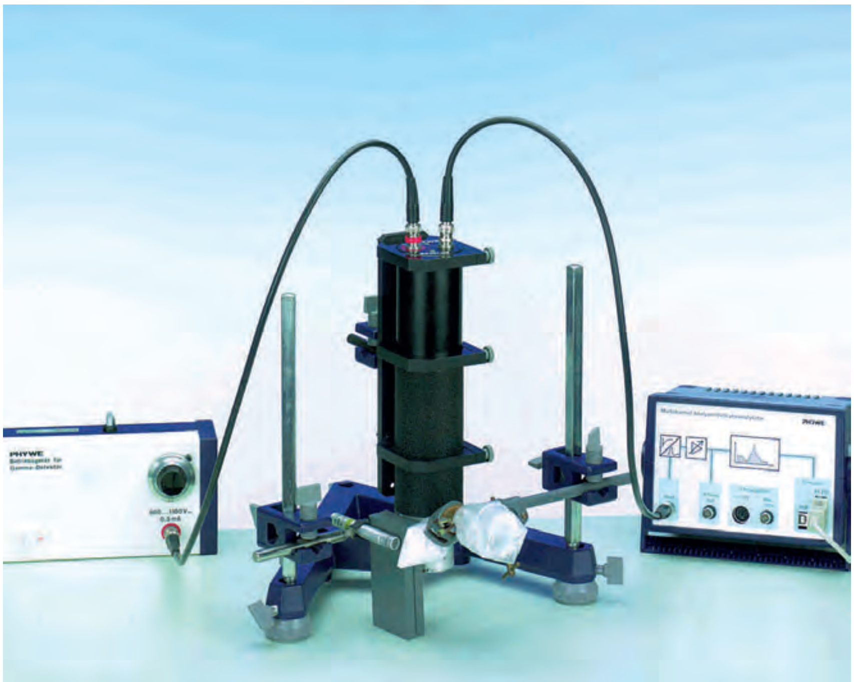
For electrostatic experiments and for operation of spectral & gas discharge tubes.

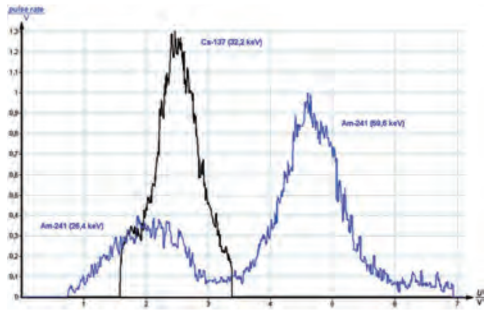
Equipment and technical data

- 3 continuously variable DC voltages isolated from earth and ground.
- Total of 0 -10 kV DC.
- 3-figure LED display.

13670-93

P2524715 X-ray fluorescence and Moseley's law with the multi channel analyser





Calibration lines of ^{137}Cs and ^{241}Am.

Main articles		
Gamma detector	09101-00	1
Multichannel analyser	13727-99	1
Radioactive source Cs-137, 37 kBq	09096-01	1
Radioactive source Am-241, 370 kBq	09090-11	1
Operating unit for gamma detector	09101-93	1
Absorption material, lead	09029-01	1
Support base DEMO	02007-55	1

Principle

The irradiation of strontinum (sulphate), cadmium, indium, iodine and barium (chloride) with soft gamma-radiations gives rise to Ka radiations characteristics of these elements.

The X-rayspectra are recorded with a gamma spectrometer consisting of a scintillation counter, a pulse height analyser and a recorder.

After calibration of the spectrometer, the Rydberg constant is determined from the energies of the X-ray lines, using Moseley's law.

Tasks

1. Calibration of the gamma-spectrometer in the low energy range, using the Ba-resonance line 137Cs emitter (32 keV) and the gamma-line of 241Am at 59.6 keV.
2. Recording of the X-ray fluorescence spectra (Ka-lines) of different elements and determination of the corresponding energies.
3. Plotting of the measured X-ray energies according to Moseley's law against (Z-1)2 and determination of the Rydberg constant R; from the slope of the resulting lines.

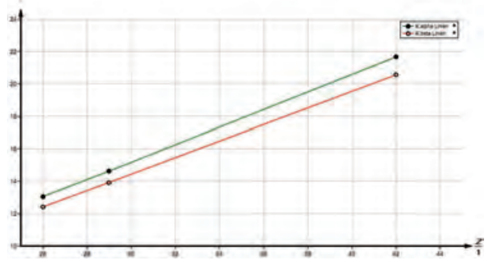
What you can learn about

- Binding energy
- Photoelectric effect
- Shell structure of electron shells
- Characteristic X-ray radiation
- g-spectrometry
- X-ray spectral analysis

Characteristic X-ray lines of different anode materials / Moseley's law

P2541001

NEW



Moseley lines; Curve a: transition n2 →n1 (Kα line), Curve b: transition n3 →n1 (Kβ line).

Principle

Moseley's law describes the relationship between the energy of the Ka lines of characteristic X-ray spectra and the atomic number. In this experiment, the characteristic X-ray lines of various different anode materials are determined in order to verify Moseley's law.

Tasks

1. Record the X-ray spectra of the three X-ray tubes.
2. Determine the wavelengths and frequencies of the characteristic X-ray lines based on the Bragg angles of the lines.
3. Create the Moseley lines and determine the Rydberg constant and screening constant.

What you can learn about

- Characteristic X-radiation; Bohr model; Energy levels
- Binding energy; Moseley's law; Screening constant

Main articles

XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray Plug-in Fe tube	09057-70	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1

Best fitting XR 4.0 sets

XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

XR 4.0 X-ray goniometer

NEW

Function and Applications

Goniometer with two independent stepper motors for the precise angular positioning of a sample and detector.

Benefits

- Self-calibrating goniometer

Plug & measure:

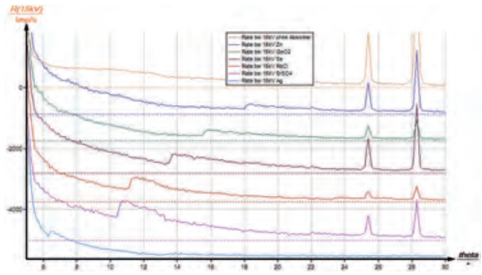
- Automatic identification of the goniometer
- Goniometer block with two independent stepper motors for rotating the sample holder and the detector either separately or coupled in a 2:1 ratio
- The detector holder with a slit diaphragm holder for absorption foils can be moved in order to change the angular resolution
- Includes a light barrier system for limiting the permissible swivelling range and, thereby, for protecting the detectors
- Intuitive operation directly at the unit or via a PC

Equipment and technical data

- Angular increment: 0.1°...10°, Rate: 0.5...100 s/increment
- Sample rotation range: 0...360°, Detector rotation range: -10°...+170°

09057-10

P2541201 K and L absorption edges of X-rays / Moseley's law and the Rydberg constant



X-ray spectra of copper without any absorber (top curve) and with the absorption edges of various elements.

Principle

Samples of various elements of different atomic numbers are irradiated with X-rays of a known spectral distribution. The energy of the transmitted intensities is analyzed using a monocrystal analyzer. Subsequently, the Rydberg constant and the screening constants are calculated from the energy of the absorption edges.

Tasks

1. Record the intensity of the X-rays emitted from the copper anode as a function of the Bragg angle using a LiF monocrystal as analyzer. Determine the *K* absorption edges of different absorber materials.
2. Calculate the Rydberg constant and the screening constants from the energy values of the *K* absorption edges.
3. Find the *L* absorption edges of different absorber materials.
4. Calculate the Rydberg constant from the energy values of the *L* absorption edges.

What you can learn about

- X-ray Bremsstrahlung; Characteristic radiation; Bragg equation; Bohr's atomic model; Atomic energy level scheme; Moseley's law; Rydberg constant; Screening constant

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray Chemical set for edge absorption	09056-04	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

XR 4.0 X-ray Plug-in Cu tube

NEW

Function and Applications

Factory adjusted copper tube in sheet steel housing ready for use in connection with XR 4.0 expert unit. Housing with plugs to accept the tubes operating quantities from the basic unit.
With handle, mechanical lock and two switching pins,which only operate correspondingly security microswitches of the basic unit when the plug-in module is correcly inserted.

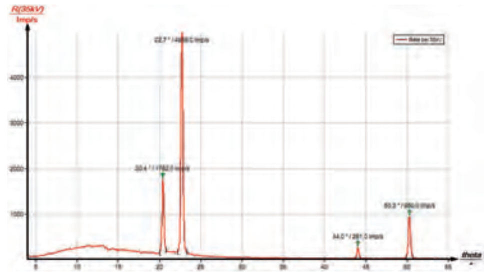
Benefits

- Quick-change technology for four different X-ray tubes (W, Cu, Mo, and Fe), adjustment free
- Complete protection against touching hot part

09057-50

Characteristic X-rays of copper

P2540101



Intensity of the X-radiation of copper as a function of the glancing angle theta; analyser crystal: LiF.

Principle

Spectra of X-rays from a copper anode are analyzed using different monocrystals and the results plotted graphically. The energies of the characteristic lines are then determined from the positions of the glancing angles for the various orders of diffraction.

Tasks

1. Record the intensity of the X-rays emitted by the copper anode as a function of the Bragg angle using a LiF monocrystal as analyser.
2. Step 1 is to be repeated using the KBr monocrystal as analyser.
3. Calculate the energy values of the characteristic copper lines and compare them with the energy differences of the copper energy terms.

What you can learn about

- Bremsstrahlung
- Characteristic radiation
- Energy levels
- Crystal structures
- Lattice constant
- Absorption
- Absorption edges
- Interference
- Order of diffraction

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1

Related Experiments

Characteristic X-rays of molybdenum
P2540201

Characteristic X-rays of iron
P2540301

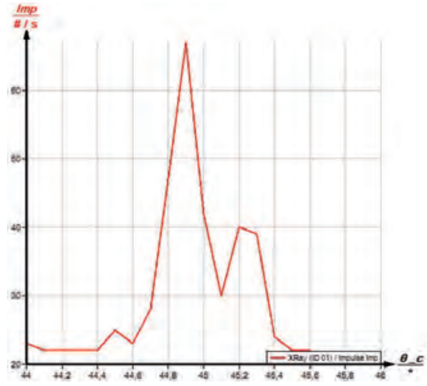
Characteristic X-rays of tungsten
P2542801

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set
09110-88

XRC 4.0 X-ray characteristics upgrade set
09130-88

P2540701 K alpha double splitting of molybdenum X-rays / fine structure



Splitting of the Kα1 and Kα2 lines of molybdenum (n = 4)

Principle

The polychromatic molybdenum X-ray spectrum is analyzed by means of a monocrystal. The energy of the characteristic lines is determined from the positions of the glancing angles at various orders of diffraction. The separation of the K a doublet in higher order diffraction is examined.

Tasks

1. Record the intensity of the X-rays emitted by the molybdenum anode as a function of the Bragg angle using a LiF monocrystal as analyzer.
2. Determine the wavelengths and ratio of the intensities of the two K a lines in high order diffraction and compare your results with the theoretical predictions.

What you can learn about

- Characteristic X-ray radiation; Energy levels
- Selection rules; Bragg equation; Energy term symbols

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray Diaphragm tube d = 1 mm	09057-01	1

Related Experiment

K alpha doublet splitting of iron X-rays / fine structure

P2540801

Best fitting XR 4.0 sets for this experiment:

XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

Geiger-Mueller counter tube, type B

Function and Applications

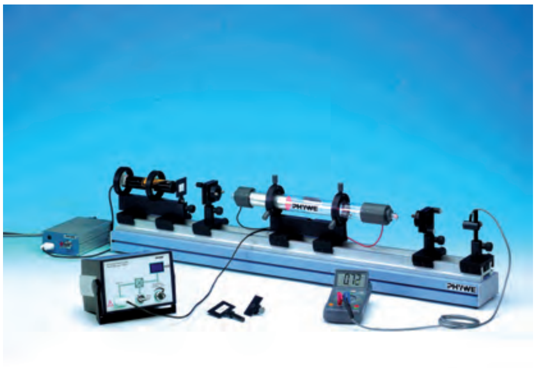
Self recovering Halogenid countertube for detection of Alpha-, Beta- und Gamma-radiation.

Benefits

mounted in metal cylinder with fixed 500 mm long BNC-cable, Including protection cap for countertube

09005-00

Helium neon laser, basic set — P2260701



Principle

The difference between spontaneous and stimulated emission of light is demonstrated. The beam propagation within the resonator cavity of a He- Ne laser and its divergence are determined, its stability criterion is checked and the relative output power of the laser is measured as a function of the tube's position inside the resonator and of the tube current. The following items can be realized with advanced set 08656.02. By means of a birefringent tuner and a Littrow prism different wavelengths can be selected and quantitatively determined if a monochromator is available. Finally you can demonstrate the existence of longitudinal modes and the gain profile of the He-Ne laser provided an analysing Fabry Perot system is at your disposal.

For more details refer to page 296.

Optical pumping — P2260800

Principle

The visible light of a semiconductor diode laser is used to excite the neodymium atoms within a Nd-YAG (NeodymiumYttrium Aluminium Garnet) rod. The power output of the semiconductor diode laser is first recorded as a function of the injection current. The fluorescent spectrum of the Nd-YAG rod is then determined and the maon absorption lines of the Nd-atoms are verified. Conclusively, the mean life-time of the4F3/2-level of the Nd-atoms is measured in approximation.

For more details refer to page 297.

Zeeman effect with an electromagnet — P2511001

Principle

The "Zeeman effect" is the splitting up of the spectral lines of atoms within a magnetic field. The simplest is the splitting up of one spectral line intothree components called the "normal Zeeman effect". In this experiment thenormal Zeeman effect as well as theanomalous Zeeman effect are studiedusing a cadmium spectral lamp as aspecimen. The cadmium lamp is submitted to different magnetic flux densitiesand the splitting up of the cadmiumlines (normal Zeeman effect 643.8 nm,red light; anomalous Zeeman effect 508.6 nm, green light) is investigated using aFabry-Perot interferometer. The evaluation of the results leads to a fairlyprecise value for Bohr's magneton.

For more details refer to page 188.

Stern-Gerlach experiment with a step motor and interface P2511111

Principle

A beam of potassium atoms generated in a hot furnace travels along a specific path in a magnetic two-wire field. Because of the magnetic moment of the potassium atoms, the nonhomogeneity of the field appliesa force at right angles to the directionof their motion. The potassiumatoms are thereby deflected from their path. By measuring the density of the beam of particles in a plane of detection lying behind the magnetic field, it is possible to draw conclusions as to the magnitude and direction of the magnetic moment of the potassium atoms.

For more details refer to page 187.

Electron spin resonance P2511200

Principle

With electron spin resonance (ESR) spectroscopy compounds having unpaired electrons can be studied. The physical background of ESR is similar to that of nuclear magnetic resonance (NMR), but with this technique electron spins are excited instead of spins of atomic nuclei. The g-factor of a DPPH (Di-phenylpikrylhydrazyl) and the halfwidth of the absorption line are determined, using the ESR apparatus.

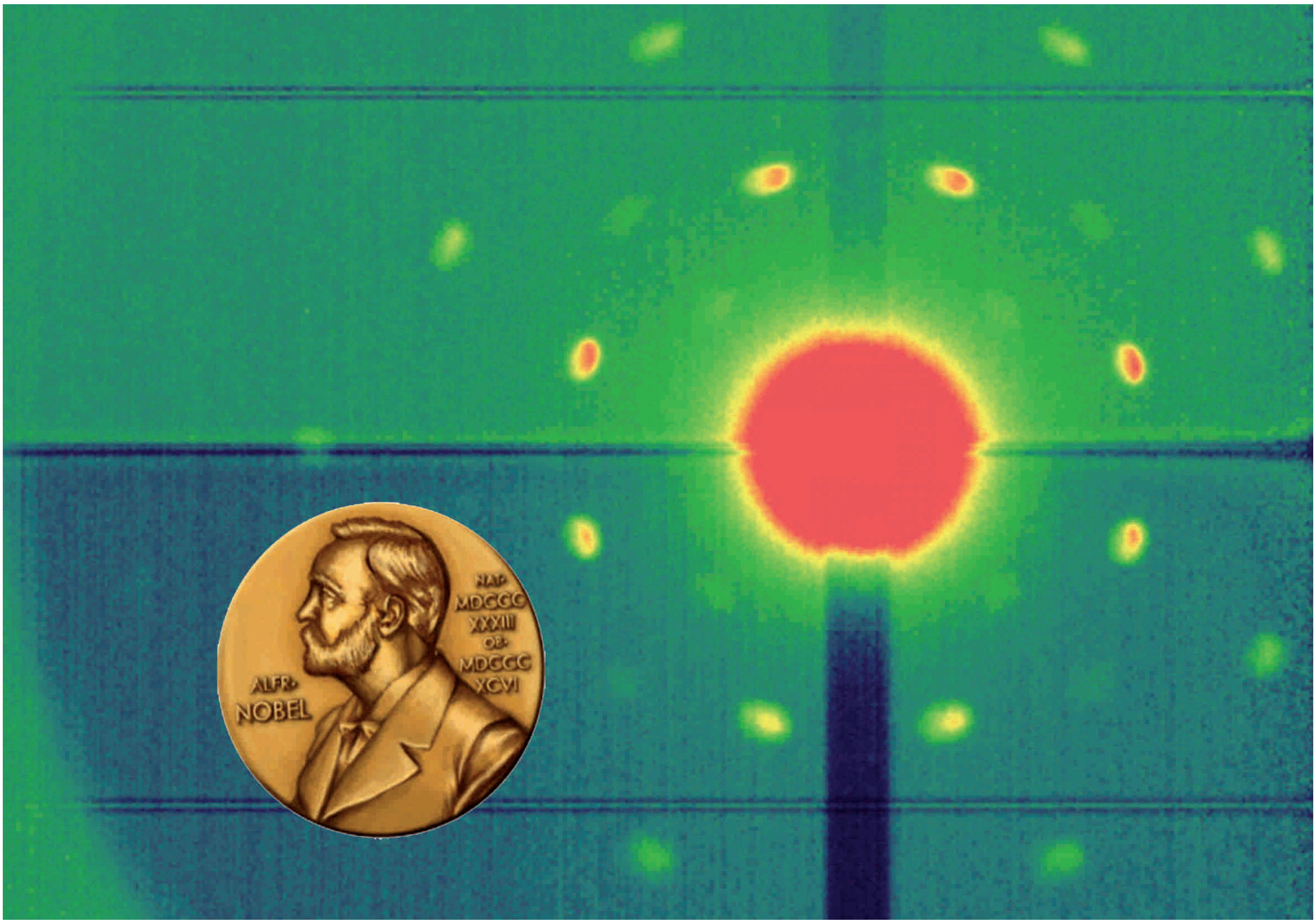
For more details refer to page 192.

Rutherford experiment with MCA P2522115

Principle

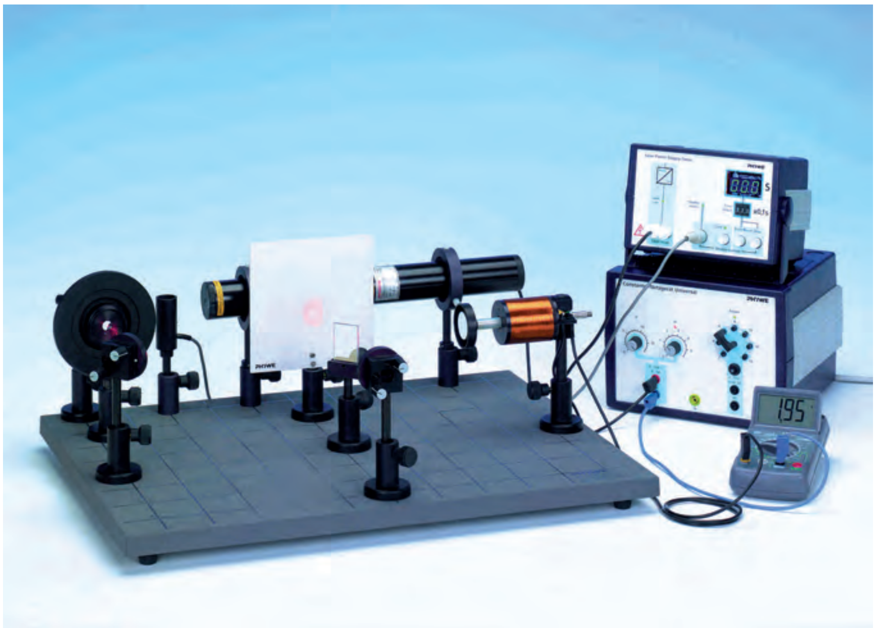
The relationship between the angle of scattering and the rate of scattering of alpha-particles by gold foil is examined with a semiconductor detector. This detector has a detection probability of 1for alpha-particles and virtually no zero effect, so that the number of pulses agrees exactly with the number of alpha-particles striking the detector. In order to obtain maximum possible counting rates, a measurement geometry is used which dates back to Chadwick. It is also possible in this case to shift the foil and source in an axial direction (thus deviating from Chadwick's original apparatus), so that the angle of scattering can be varied over a wide range.

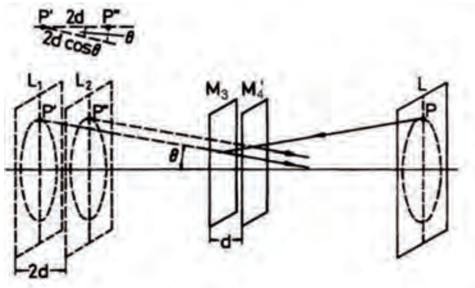
For more details refer to page 243.



Molecule and Solid State Physics

P2430800 Magnetostriction with the Michelson interferometer





Formation of circular interference fringes.

Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

Tasks

1. Construction of a Michelson interferometer using separate optical components.
2. Testing various ferromagnetic materials (iron and nickel) as well as a non-ferromagnetic material (copper), with regard to their magnetostrictive properties.

What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Ferromagnetic material
- Weiss molecular magnetic fields
- Spin-orbit coupling

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Power supply, universal	13500-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Rods for magnetostriction,set	08733-01	1
Adjusting support 35 x 35 mm	08711-00	3

Power supply for laser head 5 mW

Function and Applications

High voltage power supply for lasers, e. g. the 5 mW laser (08701-00).

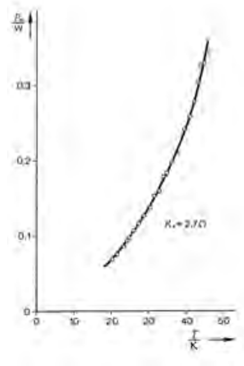
Equipment and technical data

- With programmable timer for selection of exposure time of holograms between 0.1 ... 99 s.
- With a controllable shutter.
- Digital display for preset shutter times as well as those which have already occured.
- Shutter control via time select, new start, stop and shutter open (permanent open).
- Dimensions of plastic housing (mm): 184 x 140 x 130.
- Incl. shutter with fixed connection cord with unit plug on holding rod.
- Rod diameter: 10 mm.

08702-93

Semiconductor thermogenerator - Seebeck effect

P2410700



Electrical power generated as a function of the temperature difference.

Principle

In a semi-conductor thermogenerator, the no-load voltage and the short-circuit current are measured as a function of the temperature difference. The internal resistance, the Seebeck coefficient and the efficiency are determined.

Tasks

1. To measure no-load voltage Uo and short-circuit current Is at different temperature differences and to determine the Seebeck coefficient.
2. To measure current and voltage at a constant temperature difference but with different load resistors, and to determine the internal resistance Ri from the measured values.
3. To determine the efficiency of energy conversion, from the quantity of heat consumed and the electrical energy produced per unit time.

What you can learn about

- Seebeck effect (thermoelectric effect); Thermoelectric e.m.f.
- Efficiency; Peltier coefficient; Thomson coefficient
- Seebeck coefficient; Direct energy conversion; Thomson equations

Main articles		
Thermogenerator with 2 water baths	04366-00	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Rheostat, 33 Ohm , 3.1A	06112-02	1
Voltmeter,0.3-300VDC,10-300VAC /	07035-00	1
Bath for thermostat, Makrolon	08487-02	1
Ammeter 1/5 A DC	07038-00	1
Flow-through heat exchanger	04366-01	2

Thermogenerator with 2 water baths

Function and Applications

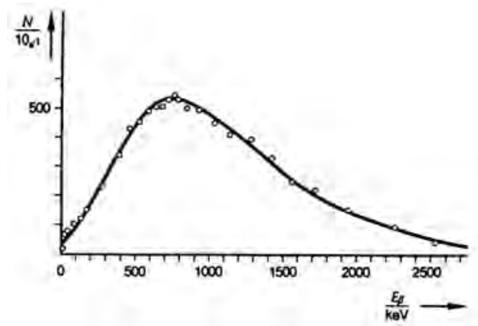
To commute thermal energy into electrical energy directly and for operation as heat pump. Also been used to demonstrate the Seebeck effect and the Peltier effect.

Equipment and technical data

- Generator block consisting of two nickel coated copper plates with hole for thermometer, between these, p- and n-conducting silicon thermocouples, connected thermally parallel and electrically in series. Two water containers with open sides, which are used as heat reservoirs, are screwed to the generator block. They can be exchanged for flowthrough heat exchanger or air cooler.
- Number of thermocouples: 142. Permanent operating temperature: approx. 100°C. Interior resistance: 2.8 Ohm.
- Operation as thermo generator: output voltage at T = 40°C: approx. 2 V; efficiency at T = 40°C: approx. 1%.
- Operation as heat pump: max. permanent current 6 A.

04366-00

P2523200 Beta spectroscopy



Beta-spectrum of ^{90}Sr.

Principle

The radiation of β-unstable atomic nuclei is selected on the basis of its pulses in a magnetic transverse field, using a diaphragm system. The relationship between coil current and particle energy is determined for calibration of the spectrometer and the decay energy of the β-transition is obtained in each case from the β^--spectra.

Tasks

1. Energy calibration of the magnetic spectrometer.
2. Measurement of the β-spectra of ^{90}Sr and ^{20}Na.
3. Determination of the decay energy of the two isotopes.

What you can learn about

- β^--decay
- β^+-decay
- Electron capture
- Neutrino
- Positron
- Decay diagram
- Decay energy
- Resting energy
- Relativistic Lorentz equation

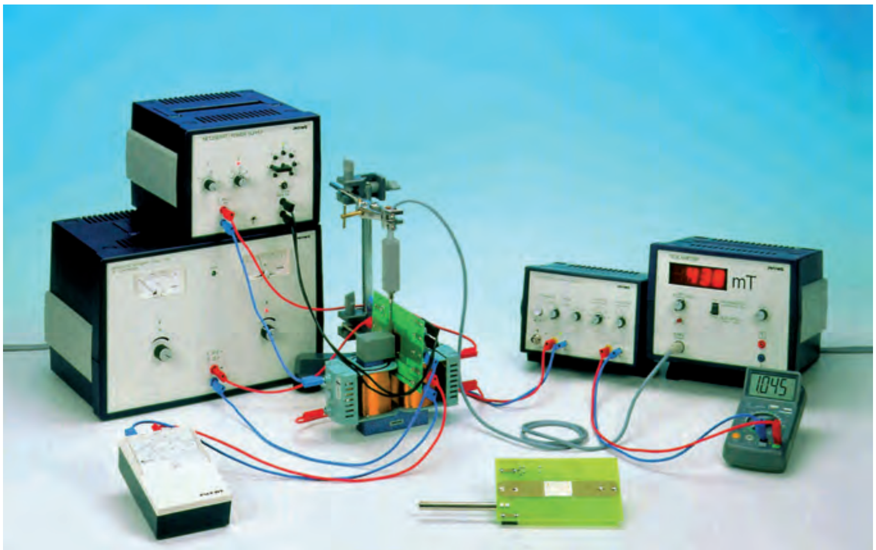
Main articles		
Teslameter, digital	13610-93	1
Power supply, universal	13500-93	1
Radioactive source Na-22, 74 kBq	09047-52	1
Radioactive source Sr-90, 74 kBq	09047-53	1
Geiger-Müller-Counter	13606-99	1
Beta-spectroscope	09104-00	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1

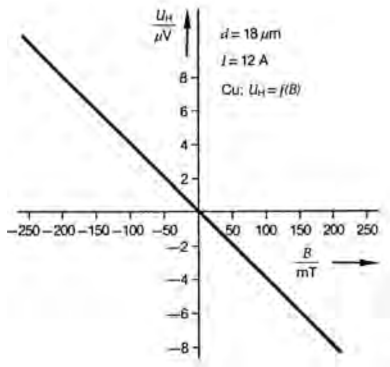
Carl David Anderson

1936, Nobel Prize in Physics

Hall effect in metals

P2530300





Hall voltage as a function of magnetic induction B, using a copper sample.

Principle

The Hall effect in thin zinc and copper foils is studied and the Hall coefficient determined. The effect of temperature on the Hall voltage is investigated.

Tasks

1. The Hall voltage is measured in thin copper and zinc foils.
2. The Hall coefficient is determined from measurements of the current and the magnetic induction.
3. The temperature dependence of the Hall voltage is investigated on the copper sample.

What you can learn about

- Normal Hall effect
- Anomalous Hall effect
- Charge carriers
- Hall mobility
- Electrons
- Defect electrons

Main articles		
Power supply 0-30VDC/20A,stabil	13536-93	1
Teslameter, digital	13610-93	1
Universal measuring amplifier	13626-93	1
Power supply, universal	13500-93	1
Hall effect, Cu, carrier board	11803-00	1
Hall effect, zinc, carrier board	11804-01	1
Hall probe, tangential, protection cap	13610-02	1

Power supply 0-30VDC/20A,stabilised

Function and Applications

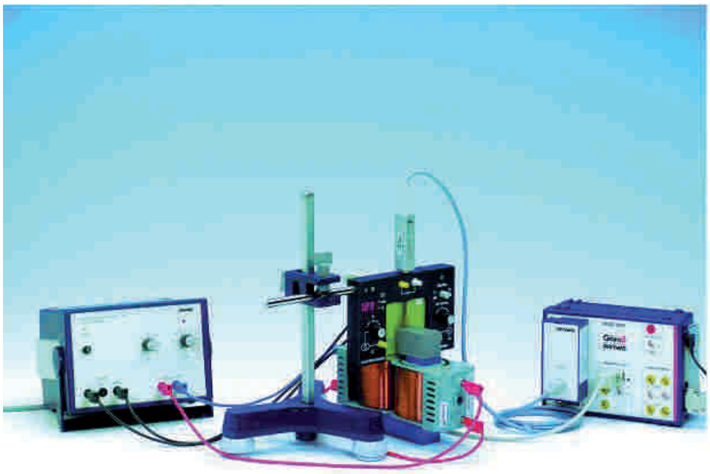
Heavy duty power supply with stabilised output voltage, low residual ripple and with constant current operation.

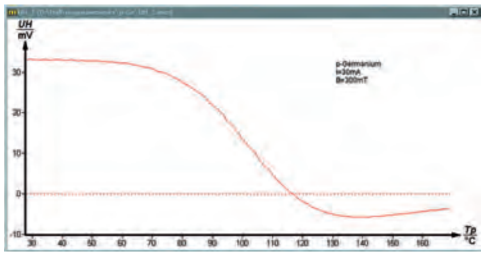
Equipment and technical data

Two moving coil instruments for simultaneous display of voltage and current. LED display of constant voltage and current operation. Output voltage: 0...30 VDC Nominal current: 0.2...20 A Residual ripples: 30 mV Required power: 900 V AInterior resistance: 40 mOhm Output is earth and mains-free, 4mm safety bushes. Power supply voltage: 230 V Impact resistant, stackable plastic housing with carrying handle and fold-away stand. Dimensions: 370 x 236 x 234 mm

13536-93

P2530111 Hall effect in p-germanium with Cobra3





Hall voltage as a function of temperature.

Principle

The resistivity and Hall voltage of a rectangular germanium sample are measured as a function of temperature and magnetic field. The band spacing, the specific conductivity, the type of charge carrier and the mobility of the charge carriers are determined from the measurements.

Tasks

The Hall voltage is measured at room temperature and constant magnetic field as a function of the control current and plotted on a graph (measurement without compensation for defect voltage). The voltage across the sample is measured at room temperature and constant control current as a function of the magnetic induction B. The Hall voltage U_H is measured as a function of the magnetic induction B, at room temperature.

What you can learn about

- Semiconductor; Band theory; Forbidden zone; Intrinsic conductivity; Extrinsic conductivity; Valence band; Conduction band; Lorentz force; Magnetic resistance; Mobility; Conductivity; Band spacing; Hall coefficient

Main articles		
Cobra3 BASIC-UNIT, USB	12150-50	1
Hall effect module	11801-00	1
Hall effect,p-Ge,carrier board	11805-01	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Measuring module, Tesla	12109-00	1
Hall probe, tangential, protection cap	13610-02	1
Coil, 600 turns	06514-01	2

Related Experiments

Hall effect in p-germanium (with the teslameter)
P2530101

Hall effect in n-germanium (with the teslameter)
P2530201

Hall effect in n-germanium with Cobra3
P2530211

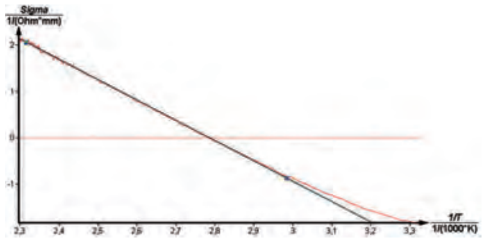
Cobra4 Experiments - available 2014

Hall effect in p-germanium with Cobra4
P2530160

Hall effect in n-germanium with Cobra4
P2530260

Band gap of germanium

P2530401



Regression of the conductivity versus the reciprocal of the absolute temperature.

Principle

The conductivity of a germanium test piece is measured as a function of temperature. The energy gap is determined from the measured values.

Tasks

1. The current and voltage are to be measured across a germanium test-piece as a function of temperature.
2. From the measurements, the conductivity s is to be calculated and plotted against the reciprocal of the temperature T. A linear plot is obtained, from whose slope the energy gap of germanium can be determined.

What you can learn about

- Semiconductor
- Band theory
- Forbidden band
- Intrinsic conduction
- Extrinsic conduction
- Impurity depletion
- Valence band
- Conduction band

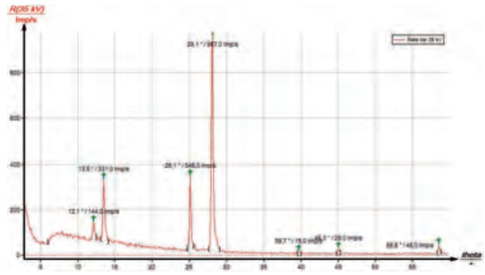
Main articles		
Hall effect module	11801-00	1
Intrins.conduct.Ge,carrier board	11807-01	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1
Tripod base PHYWE	02002-55	1
Digital multimeter 2010	07128-00	2
Support rod PHYWE,square,l 250mm	02025-55	1
Right angle clamp PHYWE	02040-55	1

Related Experiment

Band gap of germanium with Cobra3

P2530411

P2541301 Examination of the structure of NaCl monocrystals with different orientations



Intensity of the X-ray spectrum of copper as a function of the glancing angle theta: NaCl monocrystals with [111] crystal orientation as Bragg analyser.

Principle

The spectra of the X-rays that are reflected with various different orientations by NaCl monocrystals are analysed. The associated interplanar spacings are determined based on the Bragg angles of the characteristic lines.

Tasks

1. Determine the intensity of the X-rays that are reflected by the NaCl monocrystals with the orientations [100], [110] and [111] as a function of the Bragg angle.
2. Assign the reflections to the corresponding lattice planes that are given by way of their respective Miller indices.
3. Determine the lattice constant and calculate the interplanar spacing.
4. Determine the mass of a cell and the number of atoms in the cell.

What you can learn about

- Characteristic X-radiation; Energy levels; Crystal structures; Reciprocal lattices; Miller indices; Atomic form factor; Structure factor; Bragg scattering

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray NaCl-monocrystals, set of 3	09058-01	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller Counter tube, type B	09005-00	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRS 4.0 X-ray structural analysis upgrade set

09140-88

XR 4.0 Software measure X-ray

Function and Applications

Software package of the "measure" series for controlling the XR 4.0 Expert Unit (X-ray unit). XR 4.0 measure X-ray consists of a module for device control and measurement data recording and a module for measurement data processing (main program).

Benefits

Plug & measure

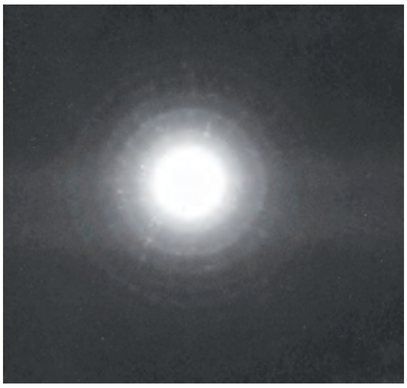
- Automatic identification of the connected devices of the XR 4.0 series, Loading of predefined settings
- Working directly without the need for specialist knowledge
- Intuitive user concept considerably simplifies the operation.

14414-61

X-ray investigation of cubic crystal structures / Debye- Scherrer powder method

P2541401

NEW



Debye-Scherrer pattern of a powdered sample of NaCl. Thickness of the sample: 0.4 mm. Exposure time: 2.5 h. Mo X-ray tube: U_a = 35 kV; I_a = 1 mA.

Principle

When polycrystalline samples are irradiated with X-rays a characteristic diffraction pattern results. These Debye-Scherrer reflections are photographed and then evaluated.

Tasks

1. Debye-Scherrer photographs are to be taken of powdered samples of sodium chloride and caesium chloride.
2. The Debye-Scherrer rings are to be evaluated and assigned to the corresponding lattice planes.
3. The lattice constants of the sample materials are to be determined.
4. The number of atoms in the unit cells of each sample are to be determined.

What you can learn about

- Crystal lattices; Crystal systems; Reciprocal lattice; Miller indices; Structure amplitude; Atomic form factor; Bragg scattering

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray film holder	09057-08	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray films, wet chemical,100 pieces, 100 × 100 mm²	09058-23	1
XR 4.0 X-ray Diaphragm tube d = 1 mm	09057-01	1
Slide mount for optical bench, h = 30 mm	08286-01	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRS 4.0 X-ray structural analysis upgrade set

09140-88

XR 4.0 Software measure LabVIEW (TM) driver V. 1.2

NEW

Function and application

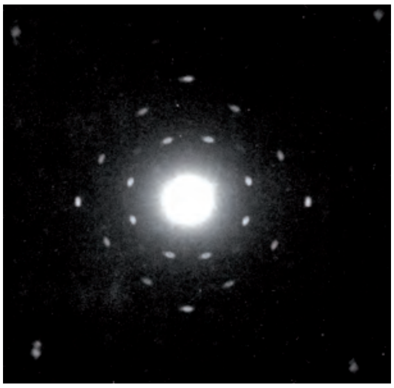
Software driver package of the "measure" series for developing a control software of XR 4.0 expert Unit (X-ray unit) under LabVIEW ™ (National Instruments).

Benefits

- The package includes all neccessary drivers for the control of all functions of PHYWE's X-ray unit XR 4.0 expert unit; Four sample applications are included; The numerous possibilities of control and visualisation with LabView (™ National Instruments) can be used immediately.

14414-62

P2541601 X-ray investigation of crystal structures / Laue method



Laue pattern of the LiF (100) crystal.

Principle

Laue diagrams are produced when monocrystals are irradiated with polychromatic X-rays. This method is primarily used for the determination of crystal symmetries and the orientation of crystals. When a LiF monocrystal is irradiated with polychromatic X-rays, a characteristic diffraction pattern results. This pattern is photographed and then evaluated.

Tasks

1. The Laue diffraction of an LiF mono-crystal is to be recorded on a film.
2. The Miller indices of the corresponding crystal surfaces are to be assigned to the Laue reflections.

What you can learn about

- Crystal lattices
- Crystal systems
- Crystal classes
- Bravais lattice
- Reciprocal lattice
- Miller indices
- Structure amplitude
- Atomic form factor
- The Bragg equation

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray Lithium fluoride crystal, mounted	09056-05	1
XR 4.0 X-ray film holder	09057-08	1
XR 4.0 X-ray films, wet chemical,100 pieces, 100 × 100 mm²	09058-23	1
XR 4.0 X-ray Crystal holder for Laue-pattern	09058-11	1

Related X-ray Experiments

X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method

P2541501

X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)

P2541602

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

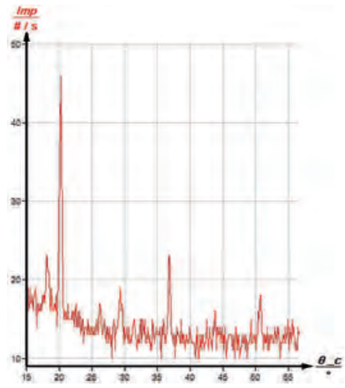
XRS 4.0 X-ray structural analysis upgrade set

09140-88

Max von Laue
1914, Nobel Prize in Physics

Debye-Scherrer diffraction patterns of powder samples with three cubic Bravais lattices (Bragg-Brentano-geometry)

P2542101



Bragg-Cu-Kα and Cu-Kβ-lines of Mo.

Principle

Polycrystalline powder samples, which crystallize in the three cubic Bravais types are irradiated with the radiation from a Roentgen tube with a copper anode. A swivelling Geiger-Mueller counter tube detects the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. Their evaluation gives the assignment of the Bragg lines to the individual lattice planes, their spacings as well as the lattice constants of the samples, and so also the corresponding Bravais lattice type.

Tasks

1. Record the intensity of the Cu X-rays back scattered by the four cubic crystal powder samples with various Bravais lattice types as a function of the scattering angle.
2. Calculate the lattice plane spacings appropriate to the angular positions of the individual Bragg lines.
3. Assign the Bragg reflections to the respective lattice planes. Determine the lattice constants of the samples and their Bravais lattice types.
4. Determine the number of atoms in the unit cell.

What you can learn about

- Crystal lattices and systems; Bravais-lattice; Reciprocal lattice
- Miller indices; Structure factor; Atomic scattering factor
- Bragg scattering; Characteristic X-rays; Monochromatization of X-rays; Bragg-Brentano Geometry

Main articles		
XR 4.0 expert unit X-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
Geiger-Mueller counter tube, type B	09005-00	1

Related Experiments

Debye-Scherrer diffractions pattern of powder samples with a diamond structure (according to Bragg-Brentano)

P2542201

Debye-Scherrer diffraction patterns of powder samples with a hexagonal lattice structure

P2542301

Debye-Scherrer diffraction patterns of powder samples with a tetragonal lattice structure

P2542401

Debye-Scherrer diffraction patterns with a cubic powder sample

P2542501

Best fitting XR 4.0 sets:

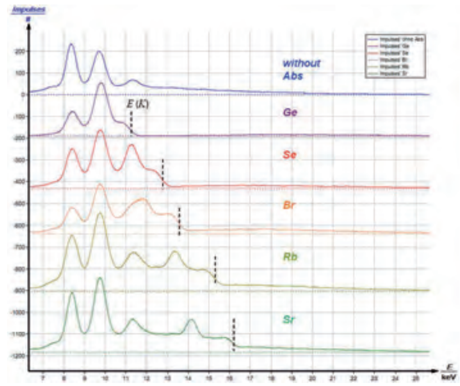
XRE 4.0 X-ray expert set

09110-88

XRS 4.0 X-ray structural analysis upgrade set

09140-88

P2546101 Energy-dispersive measurements of K- and L-absorption edges



X-ray spectra with the K-absorption edges.

Principle

Thin powder samples are subjected to polychromatic X-rays. The energy of the radiation that passes through the samples is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding absorption edges is determined and the resulting Moseley diagrams are used to determine the Rydberg frequency, the screening constant and the principal quantum numbers.

Tasks

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the calibration sample.
2. Recording of the energy spectra of the polychromatic X-rays that pass through the powder samples.
3. Determination of the energy of the corresponding *K*- and *L*-absorption edges.
4. Determination of the Rydberg frequency, screening constants, and principal quantum numbers with the aid of the resulting Moseley diagrams.

What you can learn about

- Bremsstrahlung; Characteristic X-radiation; Absorption of X-rays; Bohr's atom model; Energy levels; Moseley's law; Rydberg frequency; Screening constant; Semiconductor energydetectors; Multichannel analysers

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Chemical set for edge absorption	09056-04	1
XR 4.0 X-ray specimen set metals for X-ray fluorescence, set of 7	09058-31	1
Multi channel analyser	13727-99	1

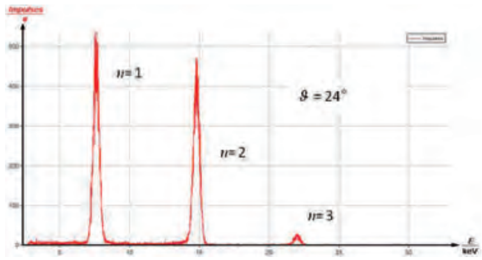
Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set
09110-88

XRM 4.0 X-ray material analysis upgrade set
09160-88

Karl Manne Georg Siegbahn
1924, Nobel Prize in Physics

Determination of the lattice constants of a monocrystal P2546201



Bragg reflexes with an increasing order of diffraction at theta = 24°.

Principle

Polychromatic X-rays impinge on a monocrystal under various glancing angles. The rays are reflected by the lattice planes of the monocrystal. An energy detector is only used to measure those radiation parts that interfere constructively. The lattice constant of the crystal is determined with the aid of the various orders of diffraction and the energy of the reflected rays.

Tasks

1. Energy determination of the X-rays that are reflected at the lattice planes of the LiF-crystal for various glancing angles or diffraction orders.
2. Calculation of the lattice constant of the LiF-crystal based on the glancing ngles and associated energy values.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Crystal structures
- Bravais lattice
- Reciprocal lattices
- Miller indices
- Bragg scattering
- Interference
- Semiconductor detectors
- Multichannel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Multi channel analyser	13727-99	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

XR 4.0 X-ray energy detector (XRED)

Function and Applications

With the new X-ray energy detector you can directly determine the energies of single x-ray quanta.

Benefits

In connection with the multi-channel analyser (MCA) you can characterise the complete x-ray energy spectrum of the analysed material., Characteristic x-ray lines for all elements of the PSE included in the software., Directly mountable on the goniometer of the x-ray unit, without loss of functionality of the goniometer, Directly connectable to MCA (USB) without any additional interface on, Green Operation-LED

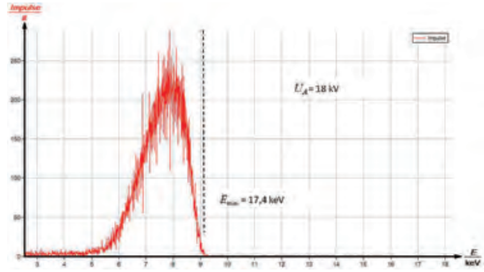
Typical application laboratory experiments in universities and high schools:

Characterisation of X-rays of different anode materials (Cu, Fe, Mo), Fluorescence analysis of pure materials and alloys

09058-30

P2546301 Duane-Hunt displacement law

NEW



W-X-ray spectrum with accelerating voltages of a: Ua = 9 kV.

Principle

X-ray spectra of an X-ray tube are measured in an energy dispersive manner with a semiconductor detector and with various anode voltages. Duane and Hunt's law of displacement is verified with the aid of the maximum energy of the bremsspectrum.

Tasks

1. Recording of the X-ray spectrum that is emitted by the copper anode for various anode voltages Ua.
2. Calculation of the minimum wavelength of the photons based on the maximum energy of the bremsspectrums.
3. Graphical representation of the relationship between the anode voltage and the minimum wavelength of the bremsspectrum.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Photo energy
- Semiconductor detectors
- Multichannel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Multi channel analyser	13727-99	1
measure Software multi channel analyser	14452-61	1
XR 4.0 XRED cable 50 cm	09058-32	1

Best fitting XR 4.0 sets for this experiment:

XRE 4.0 X-ray expert set

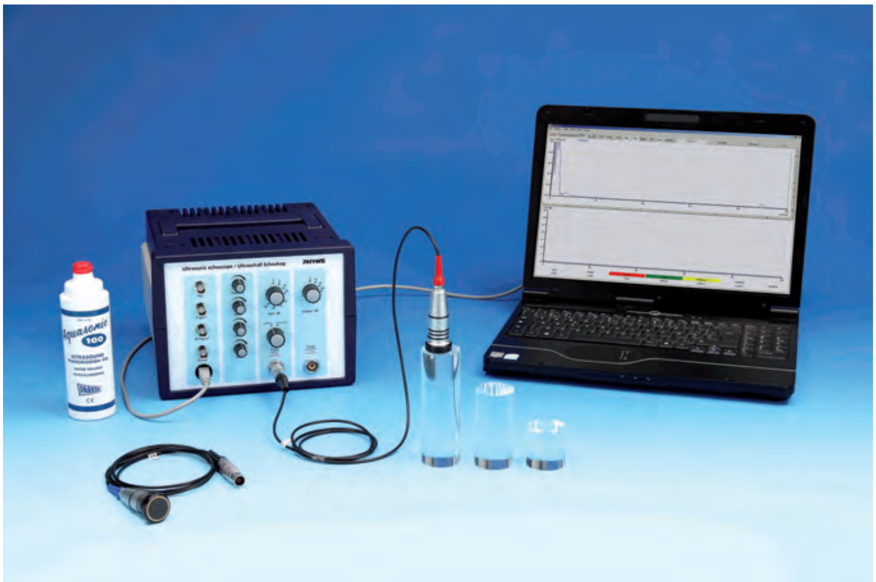
09110-88

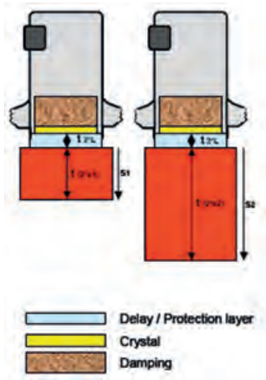
XRC 4.0 X-ray characteristics upgrade set

09130-88

Velocity of ultrasound in solid state material

P5160100





UT probe layout.

Principle

The velocity of sound in acrylics shall be determined by time of flight reflection technique with an ultrasonic echoscope. The measurements are done by reflection method, on three cylinders of different length. Two measurement series are carried out with ultrasonic probes of different frequencies.

Tasks

1. Measure the length of the three cylinders with the calliper.
2. Determine the time of flight of the ultrasonic reflection pulses for the three cylinders and the two ultrasonic probes.
3. Calculate the sound velocities, probe delays and use the two mean values obtained to calculate the cylinder length.

What you can learn about

- Sound velocity
- Propagation of ultrasonic waves
- Time of flight
- Ultrasonic echography
- Thickness measurement
- Probe delay

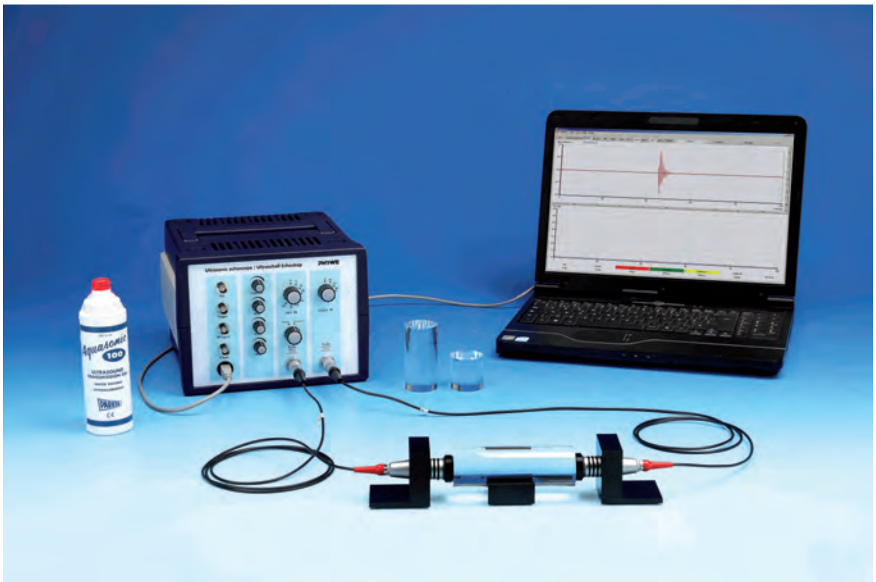
Main articles		
Basic Set Ultrasonic echoscope	13921-99	1
Vernier calliper stainless steel 0-160 mm, 1/10	03010-00	1

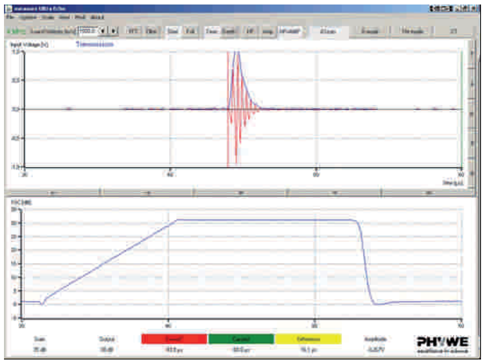
Basic Set Ultrasonic echoscope

- The Ultrasonic echoscope is a highly sensitive ultrasonic measuring device designed to connect to a personal computer or simply to an oscilloscope
- The supplied software enables an extensive signal processing (RF-signal, amplitude signal, B-scan, M-mode, spectral analysis).
- The ultrasonic probes are connected by robust snap-in plugs. The probe frequency is recognised automatically by the measuring device.
- By adjusting the power transmission and gain the ultrasonic signal can be tuned to nearly every arbitrary object of investigation.
- The loss of intensity of the ultrasonic signal from deeper layers of investigation is balanced by a time-dependent amplification (TGC time-gain control).
- Threshold, start and end point or slope can be chosen freely.
- Important signals (trigger, TGC , RF signal and amplitude signal) are available at BNC outlets.

13921-99

P5160800 Attenuation of ultrasound in solid state materials





4 MHz probes, cylinder with approx. 120 mm, time-of-flight measurement with zoom on.

Principle

The damping of ultrasound in solid objects is determined for 2 (or optionally 3) different frequencies in the transmission mode. The resulting values are then compared to the corresponding literature values. In addition, the frequency dependence of the damping effect is analysed. Furthermore, the sound velocity in acrylic objects is determined for 2 (or optionally 3) different frequencies in the transmission mode.

Tasks

1. Measure the lengths of the three cylinders with the calliper.
2. Determine the amplitudes and times of flight of the ultrasonic transmission pulses for the three cylinders and the two (or three) ultrasonic probes.
3. Calculate the attenuation and sound velocity values.

What you can learn about

- Propagation of ultrasonic waves
- Time of flight
- Sound velocity
- Damping of ultrasonic waves (scattering, reflection, absorption)
- Transmission coefficient

Main articles		
Basic Set Ultrasonic echoscope	13921-99	1
Extension set: Shear waves	13921-03	1
Ultrasonic probe 2 MHz	13921-05	1
Vernier calliper, plastic	03011-00	1

Ultrasonic probe 2 MHz

Function and Applications

The 2 MHz probes are suitable for largerange use. Due to the higher frequency the axial and lateral resolution is better compared to the 1 MHz probes. On the other hand the damping of 2 MHz sound waves in most materials is not too large, so that they can be used for medium range investigations. The 2 MHz probes are suitable for measurements at medical objects and as ultrasound Doppler-probes.

Benefits

- The ultrasonic probes are designed to produce high sound intensities and short sound pulses. It makes them particularly suitable for pulse-echo mode.
- All probesare sealed in a robust metal housing andare water proof at the sensor surface.
- The probes are delivered with a specialplug for automatic probe recognition.

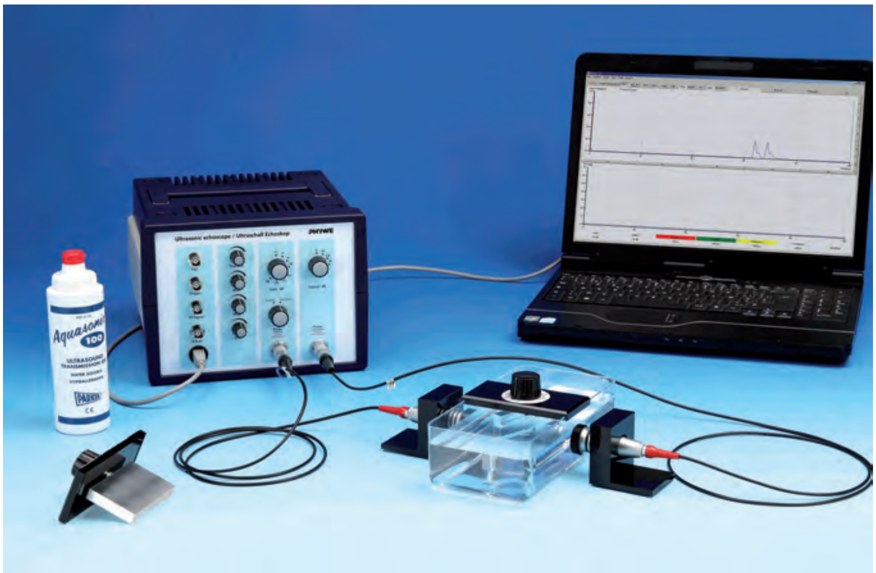
Equipment and technical data

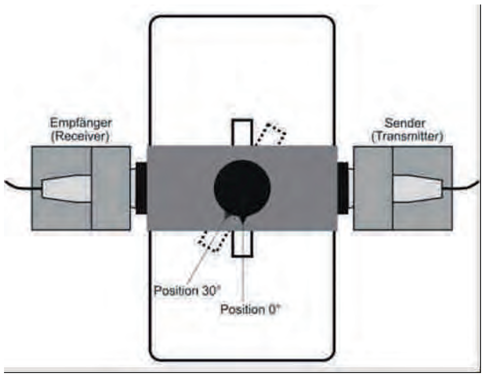
- Sound impedance adaptation to water / acrylic
- Size: L = 70 mm, D = 27 mm, Cable length: 1 m, Frequency: 2 MHz

13921-05

Shear waves in solid state materials

P5160900





Schematic set-up with an indication of the angular positions.

Principle

The aim of this experiment is to study the generation and propagation of ultrasound waves in solid objects. In addition, the additional generation of transverse wave modes (shear wave modes) resulting from an oblique angle of incidence should be identified and the sound velocities for the longitudinal and transverse component should be determined. The relationship between the coefficients of elasticity of the material and its sound velocities enables the determination of the magnitude of the coefficients.

Tasks

1. Determine the sound amplitude of an ultrasound wave passing through an acrylic glass plate (transmission measurement) as a function of the angle of incidence for the longitudinal and transverse component.
2. Use the measurement curves to determine the longitudinal sound velocity in acrylic glass based on the angle of the total reflection, and the transverse sound velocity based on the amplitude maximums and the angle of the total reflection.
3. Determine the sound amplitude of an ultrasound wave passing through an aluminium plate (transmission measurement) as a function of the angle of incidence for the longitudinal and transverse component.
4. Use the measurement curves to determine the longitudinal sound velocity in aluminium, based on the angle of the total reflection, and the transverse sound velocity based on the angle of the amplitude maximums and the angle of the total reflection.
5. Based on the transverse and longitudinal sound velocities, calculate the coefficient of elasticity for acrylic glass and aluminium.

What you can learn about

- Ultrasonic transmission measurement; Propagation of ultrasound waves; Ultrasound wave modes; Shear waves

Main articles		
Basic Set Ultrasonic echoscope	13921-99	1
Extension set: Shear waves	13921-03	1
Vernier calliper stainless steel 0-160 mm, 1/10	03010-00	1
Ruler, plastic, 200 mm	09937-01	1

Basic Set Ultrasonic echoscope

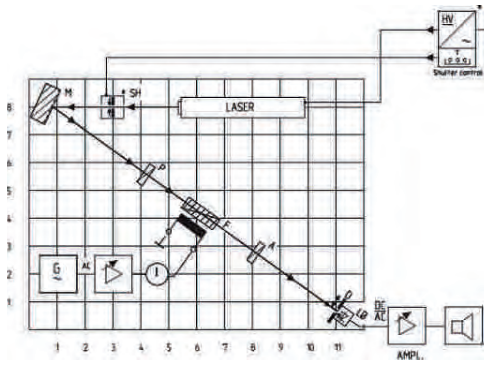
Function and Applications

With the ultrasonic echoscope the basics of ultrasound and its wave characteristics can be demonstrated. Terms like amplitude, frequency, sound velocity or Time Gain Control TGC will be explained. The cylinder set can be used to vividly demonstrate reflection as well as sound velocity and frequency depending on attenuation in solid state materials. The knowledge e.g. regarding sound velocity will be used to measure the test block.
The principles of image formation from A-scan to B-scan can be explained. With the different probes the frequency depending resolution can be evaluated.

13921-99

P2260106 Faraday effect with optical base plate

Cobra4 Demo



Experimental set up.

Principle

When the Faraday effect was discovered in 1845 it was the first experiment that elucidated the relation of light and electromagnetism. If linearly polarised light passes through a region with magnetic field the angle of rotation of the plane of polarisation is altered. This alteration appears to be a linear function of both the average magnetic flow density and the distance that the wave covers in the magnetic field. The factor of proportionality is a medium specific constant and is called Verdet's constant.

Task

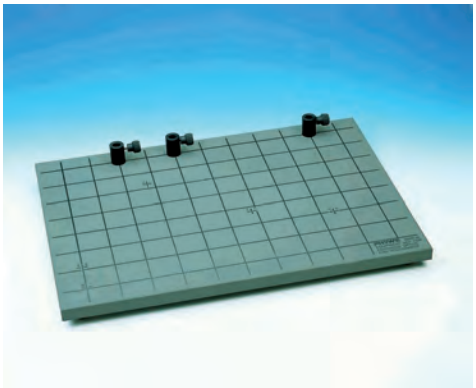
Investigate the Faraday effect qualitatively through observation of the electro optical modulation of the polarised laser light with frequencies in the acoustic range.

What you can learn about

- Interaction of electromagnetic fields
- Electro magnetism
- Polarisation
- Verdet's constant
- Malus' law
- Electronic oscillation

Main articles		
Digital Function Generator, USB	13654-99	1
Laser, He-Ne, 0.2/1.0 mW, 230 V AC	08180-93	1
Universal measuring amplifier	13626-93	1
Optical base plate with rubberfeet	08700-00	1
Faraday modulator f.opt.base pl.	08733-00	1
Loudspeaker,8 Ohm/5 kOhm	13765-00	1
Photoelement f. opt. base plt.	08734-00	1

Optical base plate with rubberfeet



Function and Applications

For setting up magnetically adhering optical components.

Equipment and technical data

- Rigid and vibration-damped working base made of steel plate.
- With corrosion protection, NEXTEL® plastic coating and imprinted grid (5×5) cm.
- Three fixed adapter sleeves for laser and laser shutter.
- With rubber feet for non-slip working.
- Base plate size (mm): 590 × 430 × 24.
- Mass: 7 kg

08700-00

Modulus of elasticity

P2120200

Principle

A flat bar is supported at two points. It is bent by the action of a force acting at its centre. The modulus of elasticity is determined from the bending and the geometric data of the bar.

For more details refer to page 33.

Mechanical hysteresis

P2120300

Principle

The relationship between torque and angle of rotation is determined when metal bars are twisted. The hysteresis curve is recorded.

For more details refer to page 34.

Hooke's law with Cobra4

P2130160

NEW

Principle

The validity of Hooke's Law is proven using various helical springs with different spring constants. In comparison, the behaviour of a stretched rubber band is examined, for which there is no proportionality between acting force and resulting extension.

For more details refer to page 35.

Nd:YAG laser

P2260900

Principle

The rate equation model for an optically pumped four-level laser system is determined. As lasing medium, a Nd:YAG (Neodymium-Yttrium Aluminium Garnet) rod has been selected which is pumped by means of a semiconductor diode laser. The IR-power output of the Nd:YAG laser is measured as a function of the optical power input and the slope efficiency as well as the threshold power are determined. Finally, a KTP-crystal is inserted into the laser cavity and frequency doubling is demonstrated. The quadratic relationship between the power of the fundamental wave and the beam power for the second harmonic is then evident.

For more details refer to page 298.

Peltier heat pump

P2410800

Principle

The (cooling capacity) heating capacity and efficiency rating of a Peltier heat pump are determined under different operating conditions.

For more details refer to page 85.

Characteristic curves of a solar cell

P2410901

Principle

The current-voltage characteristics of a solar cell are measured at different light intensities, the distance between the light source and the solar cell being varied. The dependence of no-load voltage and short-circuit current on temperature is determined.

For more details refer to page 114.

Characteristic curves of semiconductors with Cobra4 — P2410960

Principle

The current-voltage characteristic of a semiconducting diode is measured.
The collector current in dependency on the emitter-collector voltage is measured for different values of base current strength through a NPN transistor.

For more details refer to page 115.

Dielectric constant of different materials — P2420600

Principle

The electric constant is determined by measuring the charge of a plate capacitor to which a voltage is applied. The dielectric constant is determined in the same way, with plastic or glass filling the space between the plates.

For more details refer to page 110.

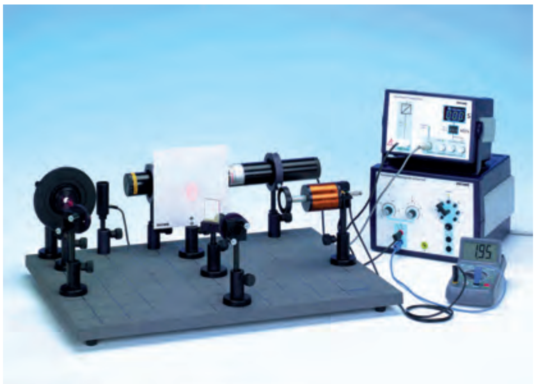
Ferromagnetic hysteresis with Cobra4 — P2430760

Principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores can be compared.

For more details refer to page 145.

Magnetostriction with the Michelson interferometer P2430800



Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

For more details refer to pages 146, 208.

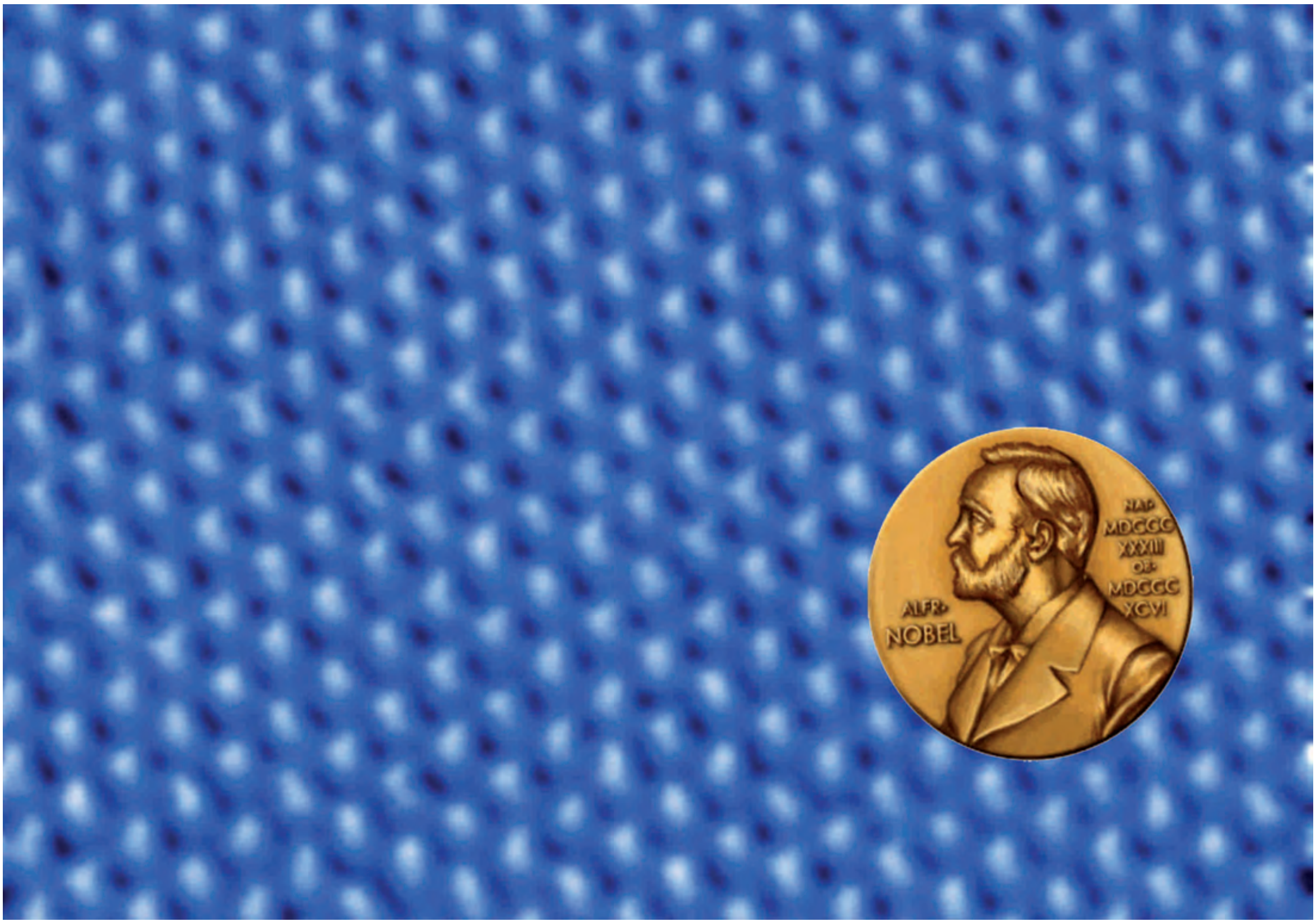
Atomic Resolution of the graphite surface by STM (Scanning Tunneling Microscope) P2532000

NEW

Principle

Approaching a very sharp metal tip to an electrically conductive sample by applying a electrical field leads to a current between tip and sample without any mechanical contact. This so-called tunneling current is used to investigate the electronic topography on the sub nanometer scale of a fresh prepared graphite (HOPG) surface. By scanning the tip line-by-line across the surface graphite atoms and the hexagonal structure are imaged.

For more details refer to page 236.



Nano Physics

Compact-Atomic Force Microscope (AFM)

Function and Applications

Compact and easy to use atomic force microscope to visualize and image structures on the micro and nano meter scale. Developed for educational purposes in practical lab course and pre-research labs in physics, chemistry, life sciences and material sciences. Also suitable to determine material characteristics (e.g. stiffness, magnetization, charging, material and phase contrast) and for manipulation (e.g. lithography).

Benefits

- Out-of-the-box device with integrated damping plate and control unit underneath
- Complete set, incl. sample set, cantilever, tools and consumables
- Tip scanner AFM for standard cantilever
- Easy and safe cantilever exchange and use: Flip mechanism with automatic laser switch off
- No laser alignement, mechanical stopper for longer lifetime of cantilevers
- Digital top view camera for easy positioning and side view lens for easy and fast approach
- Portable and compact: Transportable, easy to install with a small footprint
- Easy to use: Ideal for nanotechnology education, preparing students for their work on high-level research devices, and outreach

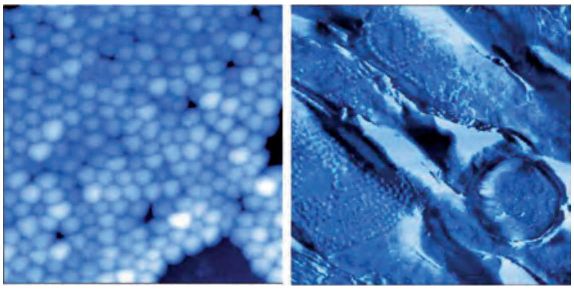
Equipment and technical Data

- Scan head with integrated control-unit on vibration-isolated experimentation board: 21 cm x 21 cm x 18 cm, USB 2.0 interface, 16 bit DA converter (XYZ), 16 bit AD converter (7 channels)
- Max scanning speed 60 ms/line, up to 2048x2048 data points
- Scan type (tip scanner): Linear low voltage electro magnetic
- Scan Range: 70 µm (1.1 nm resolution)
- Z-range: 14 µm (1.1 nm resolution); Z noise level (RMS): 0.6 / 0.5 nm (static / dynamic); Automatic approach: vertical, range 4.5 mm
- Sample: max. 13 mm in diameter, horizontal mount, LED illumination; Micrometer translation stage xy: min. +/- 5 mm
- Cantilever Aligment: automatic adjustment, alignment grooves from various suppliers; Camera system for top view: USB digital color, 3.1 M pixels
- Modes of operation: Static Force, Dynamic Force, Force Distance Spectroscopy, Amplitude Distance Spectroscopy
- Other modes (MFM, AFM, Phase contrast, lithography and advanced spectroscopy modes)
- Available with upgrade options material and spectroscopy and manipulation
- User expandability (scripting) available (upgrade option); Set of 10 cantilever, 6 samples, toolset
- Software for measuring, manipulation, analysing and visualisation, Hhandbook and Quick Installation Guide

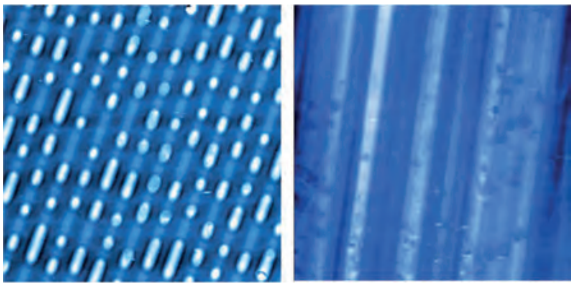
Accessories

- Material upgrade (Art. 09701-00): Additional Operating Modes (Phase Contrast, EFM, MFM, Force Modulation, Spreading Resistance), set of samples and cantilevers
- Spectroscopy and Manipulation upgrade (Art. 09702-00): Additional Operating Modes (Advanced Spectroscopy, Lithography (scratching, oxidation), Manipulation (oxidation, cutting and moving/pushing of nanoparticles)), User expandability (Visual basic, LabView, etc.), set of cantilevers and samples
- Side View Camera System (available 2013), other samples

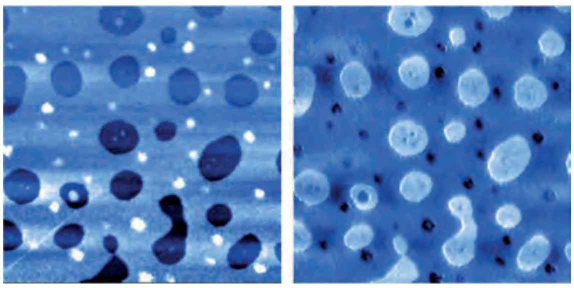
09700-99



Staphylococcus Spec., 10 µm and skin cross-section, 60 µm.



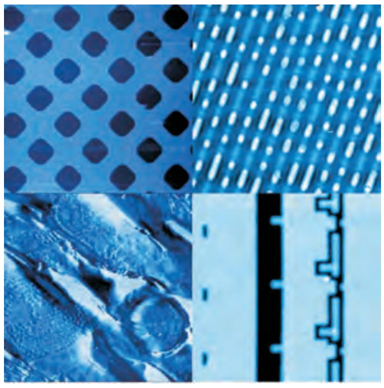
CD stamper, 20 µm and aluminum foil, 60 µm.



PS/PMMA films: Topography and phase contrast, 3 µm.

Basic methods in imaging of micro and nanostructures with atomic force microscopy (AFM)

P2538000



Topography of microstructure (50 µm), CD stamper (20 µm), skin cross-section (60 µm), and SCA chip structure (40 µm) FLTR.

Principle

Approaching a sharp silicon tip mounted on a cantilever to a sample surface leads to an atomic scale interaction. The result is a bend of the cantilever which is detected by a laser. In static mode the resulting deflection is used to investigate the topography of the sample surface line-by-line using a feedback loop. In dynamic mode the cantilever is oscillated at fixed frequency resulting in a damped amplitude near the surface. The measurement parameters (setpoint, feedback gain,...) play a crucial role for image quality. The dependence on the imaging quality is investigated for different nano structured samples.

Tasks

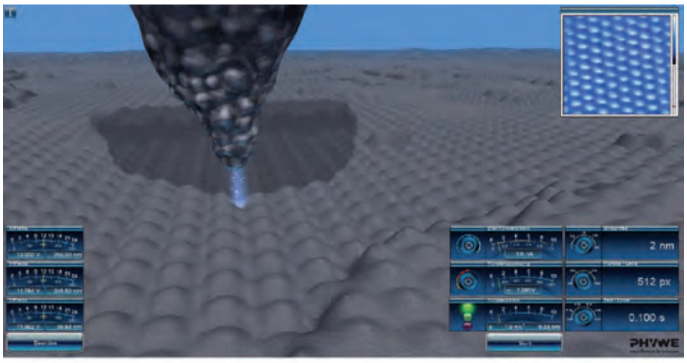
1. Set-up the microscope and start up the software. Mount a cantilever (with tip) and approach the tip towards a sample.
2. Investigate the influence of the scanning parameters on the imaging quality and performance, e.g. PID gain, setpoint (force), vibrational amplitude, and scanning speed. Use both static and dynamic force mode.
3. Image 7 different samples (microstructures, carbon nano tubes, skin cross-section, bacteria, CD stamper, chip structure, glass beads) by optimizing the parameters respectively.

What you can learn about

- Atomic Force Microscopy (AFM)
- Lennard-Jones potential
- Imaging of nano structures
- Static Force Mode; Dynamic Force Mode
- Feedback loop; Force
- Vibrational amplitude

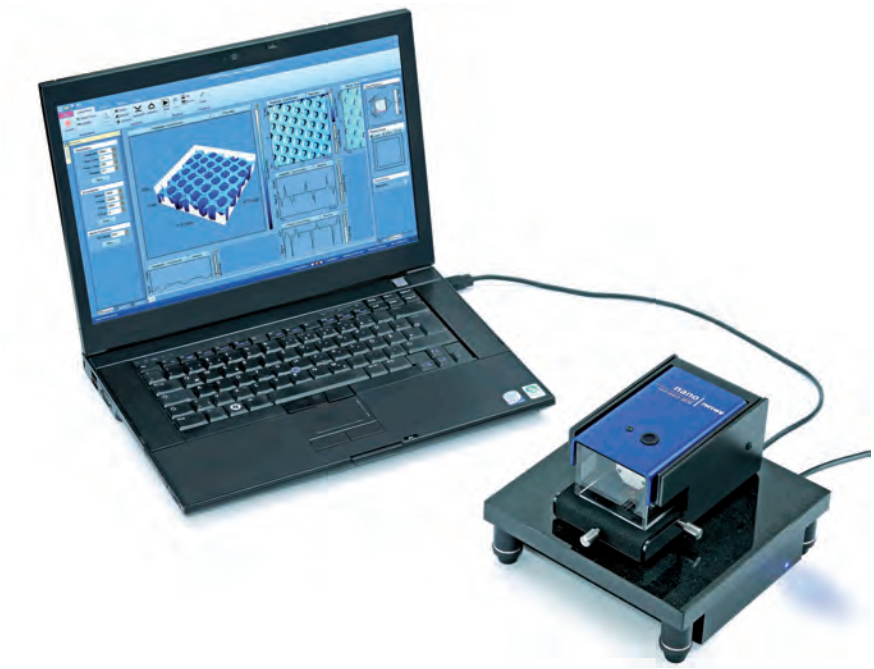
Main articles		
Compact AFM, Atomic Force Microscope	09700-99	1

Interactive nano simulation



Prior to the student's hands on experimentation, the interactive nano simulation enables the student to visualize and controll all relevant nano properties of the STM within an attractive multimedia environment. While 'playing' with the properties and fictive parameters the students gain a much deeper understanding of the main physical principles the STM imaging provides. The simulation is part of the packages **compact AFM** (09700-99) and **compact STM** (09600-99).

P2538100 Basic methods in force spectroscopy to investigate material characteristics with atomic force microscopy (AFM)



NEW · m · Demo

Sample (position)	Slope [mV/nm]	Slope [N/m]
Microstructure (terrace, 1)	0.972	0.200
Microstructure (pit, 2)	0.972	0.200
Carbon nanotube (tube, 3)	0.935	0.192
Carbon nanotube (background, 4)	0.873	0.180
Blood cells (red, 5)	0.941	0.194
Blood cells (white, 6)	0.932	0.192
Blood cells (granulocytes, 7)	0.945	0.194
Human Hair (8)	0.912	0.186

Slopes of the Force-Distance-Curves for different materials showing different stiffnesses of the samples.

Principle

Approaching a sharp silicon tip mounted on a cantilever to a sample surface leads to atomic scale interaction caused by different kind of forces between tip and sample. The result is a bend of the cantilever which is detected by a laser. In force-distance spectroscopy the deflection is used to investigate the stiffness of the sample by applying a force to the tip, indenting the sample. In amplitude-distance spectroscopy the cantilever is oscillated at fixed frequency resulting in a damped amplitude near the surface. The damping as a function of tip-sample distance gives information about the derivative of the force between tip and sample and therefore the stiffness of the underlying material.

Tasks

1. Set up the microscope and start up the software. Mount a cantilever and prepare a sample and approach the tip towards the sample. Take an AFM image of the sample and select different positions for force spectroscopy.
2. Use Force-Distance-Spectroscopy to reveal the system's deflection sensitivity for calibration purposes.
3. Use Force-Distance Spectroscopy to investigate different samples with repect to their mechanical stiffness.
4. Use Amplitude-Distance Spectroscopy mode to investigate the samples mechanical behavior and compare the results with Force-Distance measurements.

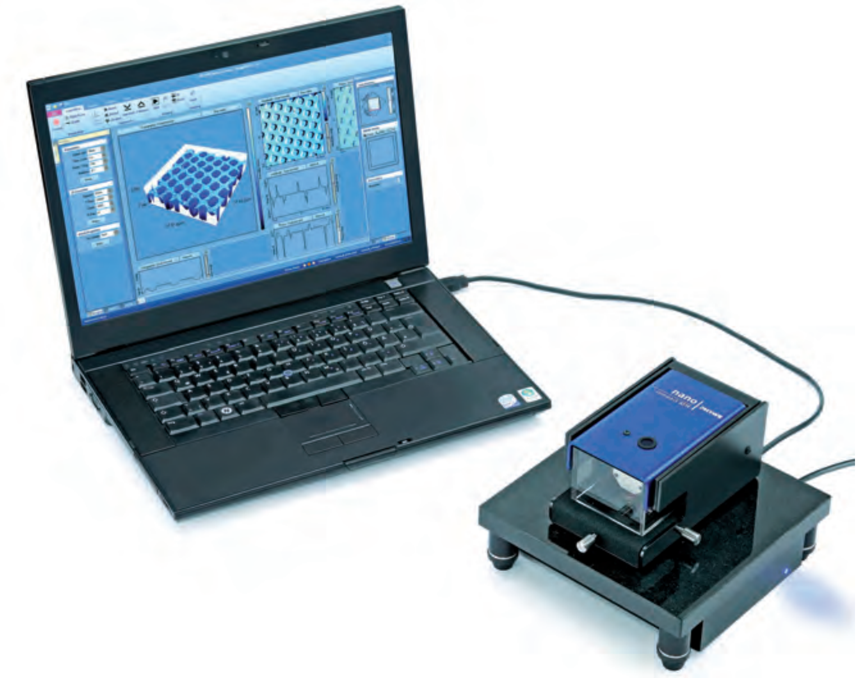
What you can learn about

- Atomic Force Microscopy (AFM)
- Atomic Force Spectroscopy
- Lennard-Jones potential
- Static force mode
- Dynamic force mode
- Mechanical force
- Stiffness
- Force-distance measurements
- Amplitude-distance measurements
- Nano mechanics

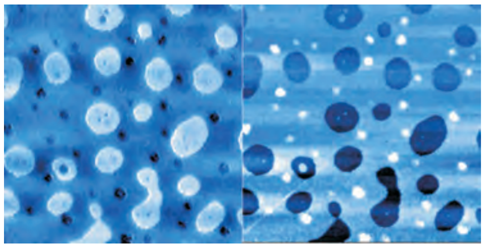
Main articles		
Compact AFM, Atomic Force Microscope	09700-99	1
Sample support, 10 pcs, for Compact Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM)	09619-00	1
Cover glasses 18x18 mm, 50 pcs.	64685-00	1

Phase Imaging Mode - Material contrast on the nanoscale withatomic force microscopy (AFM)

P2538200



NEW m Demo



PS/PMMA films: Topography (left, 2.6 µm) and phase contrast image (right, 2.6 µm) at same location. The difference in material hardness visible in the phase contrast image clearly shows growth and wetting behaviour of material mixtures.

Principle

Dynamic Atomic Force Microscopy is used to image different heterogeneous sample surfaces at a sub micrometer scale. Additionally the phase shift between the driving signal of the cantilever and the cantilever itself is recorded. The phase shift is connected with the energy dissipation involved in the contact between the tip and the sample, which depends on a number of factors, including such features as viscoelasticity and adhesion. These dependencies lead to a material specific contrast (phase contrast) in phase shift images. A collection of samples are investigated with respect to their phase contrast. This method is one of the most commonly used techniques for mechanical and composition characterisation of heterogeneous sample surfaces, e.g. polymers.

Tasks

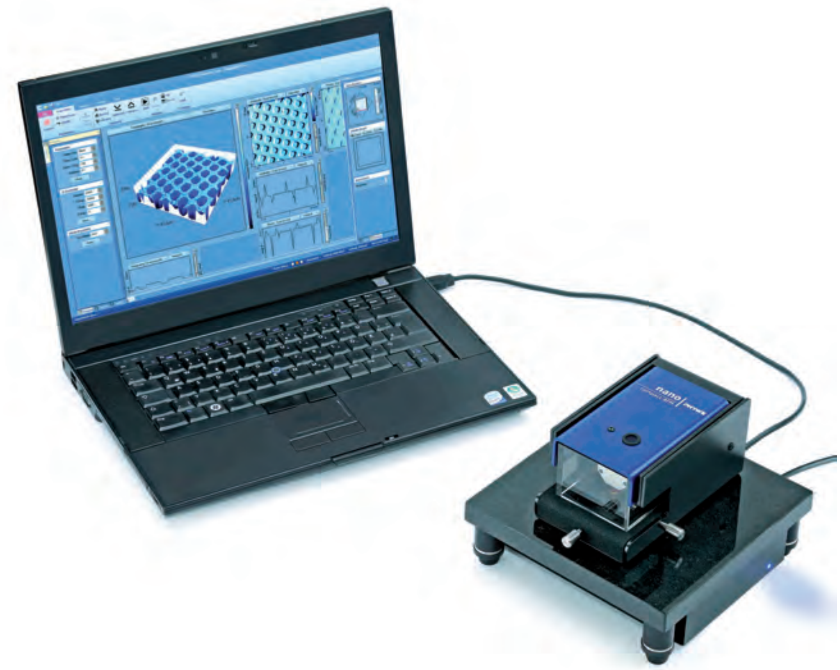
1. Set-up the microscope, prepare sample and tip, and approach the tip to the sample in phase imaging mode. Optimise the parameters with respect to the imaging quality.
2. Investigate different heterogeneous sample surface with phase contrast imaging.
3. Compare and interpret the results.

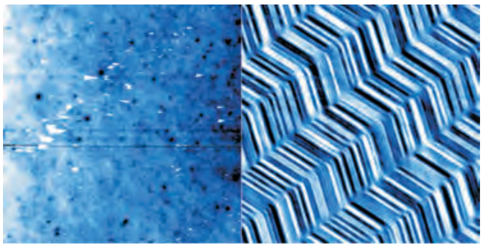
What you can learn about

- Atomic Force Microscopy
- Dynamic mode
- Vibration ampliude
- Phase shift
- Phase contrast imaging
- Material contrast
- Polymers

Main articles		
Compact AFM, Atomic Force Microscope	09700-99	1
Material upgrade, for compact atomic force microscope	09701-00	1

P2538500 Investigate in magnetic micro and nano structures by Magnetic Force Microscopy (MFM)




Digital Data Storage (DAT) tape: Topography (left, 50 µm) and phase contrast image (right, 50 µm) at same location. The phase contrast image contains the magnetic information and shows a stripe-like structure with a mean feature size of 3 µm (one bit).

Principle

Magnet interaction between the tip and sample is used to image magnetic structures with Atomic Force Microscopy (AFM). The principle of magnetic force microscopy can be shown scanning an backup tape (DAT). For this a magnetic tip is used and is magnetized with an ultra-magnet along a certain direction to be sensitive on different direction of magnetic field lines. After imaging the topography in contact mode the cantilever is retracted a few 10 nm. At this distance magnetic force dominates the interaction between cantilever and tape. Scanning the same area it leads to stripe-like structures showing the magnetisation of the tape. Also magnetic structures for data storage on floppy disks (ZIP or others) or hard disk down to a structure size of a few ten nanometer can be imaged and analysed.

Tasks

1. Set-up the microscope, magnetise the magnetic coated tip along a certain direction and approach the tip to the sample in phase imaging mode. Take a topography image.
2. Retract the tip a few 10 nm to do a MFM measurement for different distances. Magnetize the tip to another direction and compare and interpret the results.
3. Image the magnetic structures of different samples, e.g. floppy disk, ZIP floppy disk, and hard disk.

What you can learn about

- Magnetic forces
- Magnetic Force Microscopy (MFM)
- Imaging of magnetic nano structures
- Nano magnetics
- Magnetic data storage
- Phase contrast imaging
- Vibration amplitude
- Resonance shift

Main articles		
Compact AFM, Atomic Force Microscope	09700-99	1
Material upgrade, for compact atomic force microscope	09701-00	1

Related Experiment

Imaging of biological and medical micro and nanostructure with atomic force microscopy (AFM)

P2538400

Compact STM, Scanning Tunneling Microscope

Function and Applications

Easy to use scanning tunneling microscope to image conducting surfaces and to investigate effects and characteristics on atomic and molecular scale. A variety of experiments in the fields of Material Sciences, Solid State Physics/Chemistry, Nanotechnology and Quantum Mechanics can be performed. For example: micro- and nano morphology of surfaces, nano structures, imaging of atoms and molecules, conductivity, tunneling effect, charge density waves, single molecule contacts, and nanostructuring by self organisation (self assembled monolayers).

Benefits

- Out-of-the-box-device incl. all necessary accessories for a prompt entry into the world of atoms and molecules.
- Portable and compact: transportable, easy to install with a small footprint.
- Single device for more stable measurements.
- Quick atomic resolution on a normal table. No need for expensive vibration isolation.
- Easy to use: Ideal for nanotechnology education, preparing students for their work on high-level research devices, and outreach.
- Accessible sample stage and scanning tip: Quick exchange of tip and sample.
- Low operating voltage: Safe for all users.
- Interactive learning package: Quick and easy start in the operation, measuring modes and physical background of scanning tunneling microscopy and spectroscopy

Equipment and technical data

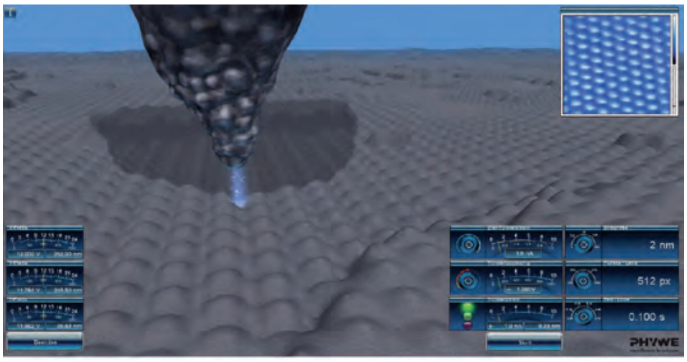
- Scan head with integrated control-unit on vibration-isolated experimentation board:
  - Maximum scan range (XY) 500 nm x 500 nm
  - Maximum Z-range 200 nm
  - Resolution in XY better than 8 pm
  - Resolution in Z better than 4 pm
  - Current 0.1-100 nA in 25 pA steps
  - Tip voltage +/-10 V in 5 mV steps
  - Dimensions 21 cm x 21 cm x 10 cm
  - Constant-Current Mode
  - Constant-Height Mode
  - Current-Voltage Spectroscopy
  - Current-Distant Spectroscopy
  - Control-Unit with USB socket, 16-Bit
  - DA converter for all three dimensions, up to 7 measurement channels, and maximum scanning speed of 60 ms/line
- Scan head cover with magnifying lense: 10 x
- Toolset for preparing and mounting tunneling tips: side-cutter, tong and tweezers
- Pt-Ir wire for tunneling tips: length 30 cm, diameter 0.25 mm
- Sample kit: Graphite (HOPG), Gold (111) films, and 4 spare sample supports
- Power supply (100-240 V, 50/60 Hz)
- USB cable: length 3 m
- Aluminium case (44 cm x 32 cm x 14 cm)
- Software for measuring, analysing and visualisation (one, two, and three dimensions)
- Interactive learning software for the working princple, measuring modes in imaging and spectroscopy, and the physical background of scanning tunneling microscopy and spectroscopy
- Handbook incl. short description of starting experiments with HOPG and gold films
- Quick Installation Guide
- Weight (incl. case) 6.7 kg

Accessories

- Computer with Windows 2000/XP/Vista/7, USB interface, 256MB RAM, 1024x758 graphics card, 16-bit colour resolution or better
- other samples
- electrical conductive adhesive for mounting own samples
- ethanol and cloth for cleaning

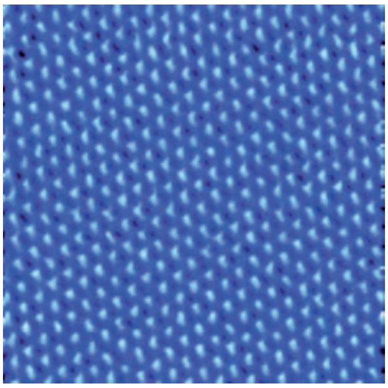
09600-99

Interactive nano simulation



Prior to the student's hands on experimentation, the interactive nano simulation enables the student to visualize and controll all relevant nano properties of the STM within an attractive multimedia environment. While 'playing' with the properties and fictive parameters the students gain a much deeper understanding of the main physical principles the STM imaging provides. The simulation is part of the packages **compact AFM** (09700-99) and **compact STM** (09600-99).

P2532000 Atomic Resolution of the graphite surface by STM (Scanning Tunneling Microscope)



Atomic resolved image of the graphite surface (5 nm x 5 nm).

Principle

Approaching a very sharp metal tip to an electrically conductive sample by applying a electrical field leads to a current between tip and sample without any mechanical contact.

This so-called tunneling current is used to investigate the electronic topography on the sub nanometer scale of a fresh prepared graphite (HOPG) surface.

By scanning the tip line-by-line across the surface graphite atoms and the hexagonal structure are imaged.

Tasks

1. Prepare a Pt-Ir tip and the graphite (HOPG) sample and approach the tip to the sample.
2. Investigate the topography of clean terraces and the step height between neighboring terraces in constant-current mode.
3. Image the arrangement of graphite atoms on a clean terrace by optimize tunneling and scanning parameters. Interpret the structure by analyzing angles and distances between atoms and atomic rows and by using the 2D and 3D graphite model.
4. Measure and compare images in the constant-height and constant-current mode.

What you can learn about

- Tunneling effect
- Hexagonal Structures
- Scanning Tunneling Microscopy (STM)
- Imaging on the sub nanometer scale
- Piezo-electric devices
- Local Density Of States (LDOS)
- Constant-Height
- Constant-Current-Mode

Main articles		
Compact Scanning Tunneling Microscope	09600-99	1
Crystal lattice kit: graphite	39840-00	1
Graphite model, 2D	09620-00	1

Related Experiments

Investigate in surface atomic structures and defects of different samples by STM

P2532500

Self-assembled molecular networks of arachin acid by STM

P2534000

Quantum Mechanics by STM - Tunneling Effect and Charge Density Waves

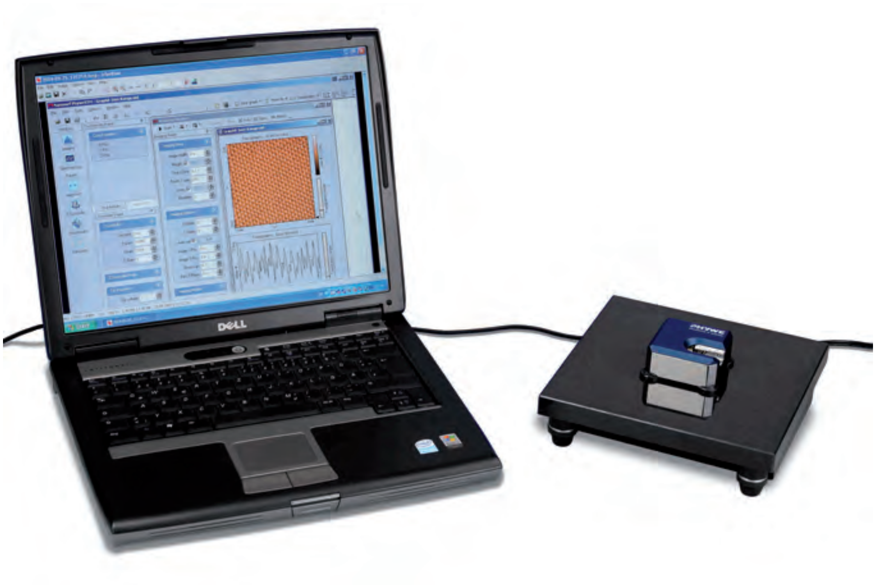
P2535000

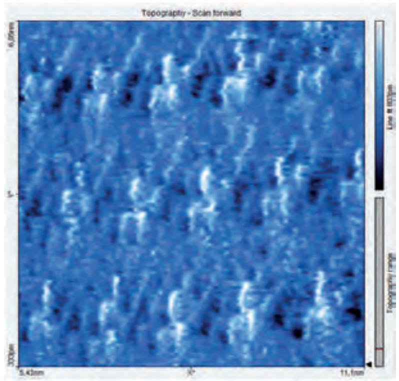
Investigation of carbon nano structures by STM and STS

P2536000

Quantum Mechanics by STM - Tunneling Effect and Charge Density Waves

P2535000





Charge density waves on T_aS_2.

Principle

In addition to the tunneling effect measured by tunneling spectroscopy another quantum mechanical effect the charge density waves are investigated for different samples. Charge density waves are modulated electron waves due to static and periodic lattice distortion and therefore mappable with scanning tunneling microscopy. The lattice distortion is caused by a lowering of the total energy of the system due to a Peierl's transisiton (Nesting of Fermi surfaces).

Tasks

1. Preparation of Pt/Ir tunneling tips and HOPG surface and approaching.
2. Current-Distance-Spectroscopy at HOPG and Gold and evaluation of the tunneling effect.
3. Imaging and characterization of charge density waves at different substrates and interpretation with regards to the band structure.
4. Investigating charge density waves at different voltages and interpretation of the imaged states (filled and empty).

What you can learn about

- Scanning Tunneling Microscopy and Spectroscopy
- Tunneling Effect; Local Density of States; Peierl's Theorem, Peierl's Transition
- Charge Density Waves; Commensurability; Incommensorability
- Transition Metal Chalcogenide; Band Structure

Main articles		
Compact Scanning Tunneling Microscope	09600-99	1
TaSe2 on sample support, for STM	09611-00	1
TaS2 on sample support, for STM	09612-00	1
WSe2 on sample support, for STM	09610-00	1

Related Experiment

Roughness and nanomorhology of different metal samples by STM

P2537000

Set samples nanomorphology, for Compact Scanning Tunneling Microscope (STM)

Function and Applications

Universal samples set to investigate the surface morphology of metals at the nanometer scale using the Compact Scanning Tunneling Microscope (09600-99).

Benefits

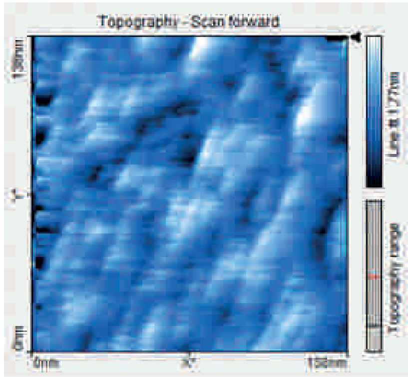
- Complete set to investigate different production and treatment conditions of different metal surface (polishing, etching, coining, rolling, tempering, annealing, ...), Suitable for preparation of indivdual samples due to included metal foils, samples supports, conductive glue, cutter and sample storage box, Clear and save storage of samples due to included samples storage box

Equipment and technical data

- 7 metal foils (gold, silver, tantalum, tin, aluminum) for more than 10 samples of each, coined sample, cutter, samples supports (10 pcs), conductive glue, storage box, table of content, quick introduction guide

09613-00

P2533500 Nanoscale electrical characteristics of different samples by STS



Topography of MoS2.

Principle

The tunneling current between a very sharp metal tip and an electrically conductive sample is used to investigate the current-voltage characteristics at a nanoscopic scale. The bandstructure of gold, graphite (HOPG) and MoS2 are investigated.

Tasks

1. Prepare a Pt-Ir tip and the sample surfaces. Approaching the tip towards the sample.
2. Investigate the topography of the gold, HOPG and MoS2 sample in constant-current mode.
3. Switch to spectroscopy mode. Measure and compare images recorded on the different materials in Tip-voltage mode (I-U spectroscopy).
4. Interpret the results regarding to the bandstructure.

What you can learn about

- Tunneling effect
- Scanning Tunneling Microscopy (STM)
- Scanning Tunneling Spectroscopy (STS)
- Local Density of States (LDOS)
- Band structure
- Band Gap
- k-Space
- Brioullin Zone
- Metal, Semi Metal, Semi Conductor

Main articles		
Compact Scanning Tunneling Microscope	09600-99	1
MoS2 on sample support, for STM	09608-00	1

Related Experiment

Nanoscale workfunction measurements by scanning tunneling spectroscopy

P2533000

Compact STM, Scanning Tunneling Microscope

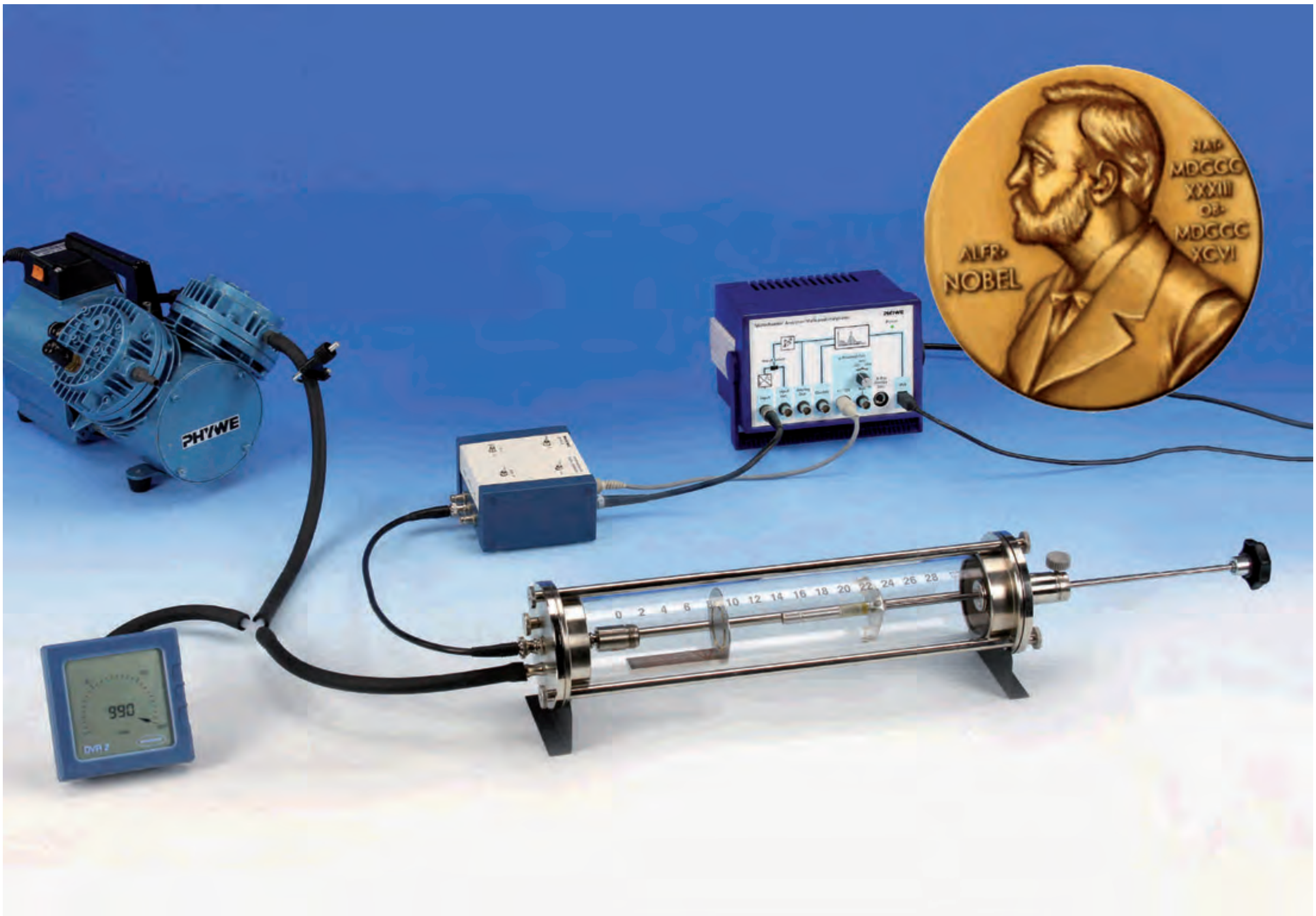
Function and Applications

Easy to use scanning tunneling microscope to image conducting surfaces and to investigate effects and characteritics on atomic and molecular scale. A variety of experiments in the fields of Material Sciences, Solid State Physics/Chemistry, Nanotechnology and Quantum Mechanics can be performed. For example: micro- and nano morphology of surfaces, nano structures, imaging of atoms and molecules, conductivity, tunneling effect, charge density waves, single molecule contacts, and nanostructuring by self organisation (self assembled monolayers).

Benefits

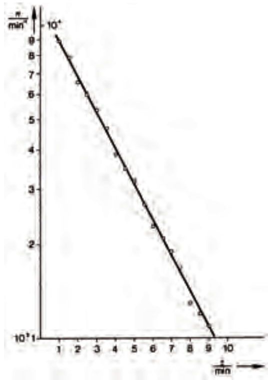
- Out-of-the-box-device incl. all necessary accessories for a prompt entry into the world of atoms and molecules
- Portable and compact: transportable, easy to install with a small footprint
- Quick atomic resolution on a normal table. No need for expensive vibration isolation
- Easy to use: Ideal for nanotechnology education, preparing students for their work on high-level research devices, and outreach

09600-99



Nuclear Physics - Radioactivity

P2520101 Half-life and radioactive equilibrium



Logarithmic plot of the counting rate of the eluted daughter substance as a function of time.

Principle

The half-life of a Ba-137 m daughter substance eluted (washed) out of a Ca-137 isotope generator is measured directly and is also determined from the increase in activity after elution.

Tasks

1. To record the counting rate as a function of the counter tube voltage (counter tube characteristic) when the isotope generator activity is constant (radioactive equilibrium).
2. To measure the activity of the isotope generator as a function of time immediately after elution.

What you can learn about

- Parent substance, Daughter substance, Rate of decay
- Disintegration or decay constant, Counting rate, Half life
- Disintegration product

Main articles		
Isotope generator Cs-137, 370 kBq	09047-60	1
Pulse rate meter	13622-93	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1
Digital multimeter 2010	07128-00	1
Base plate for radioactivity	09200-00	1
Plate holder on fixing magnet	09203-00	1
Counter tube holder on fix.magn.	09201-00	1

Related Experiment

Half-life and radioactive equilibrium with Cobra3

P2520111

Cobra4 Experiment

Half-life and radioactive equilibrium with Cobra4

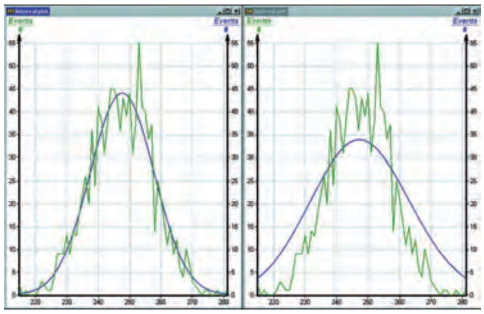
P2520160

Marie Curie

1903, Nobel Prize in Physics

Poisson's and Gaussian distribution of radioactive decay with Cobra4 (Influence of the dead time of the counter tube)

P2520360



Pulse rate distribution for high pulse rate (248 pulses/s) with an adapted Gaussian curve (left window) and a Poisson's curve (right window).

Principle

1) The aim of this experiment is to show that the number of pulses counted during identical time intervals by a counter tube which bears a fixed distance to along-lived radiation emitter correspond to a Poisson´s distribution. A special characteristic of the Poisson´s distribution can be observed in the case of a small number of counts n < 20: The distribution is unsymmetrical, i. e. the maximum can be found among smaller numbers of pulses than the mean value. In order to show this unsymmetry the experiment is carried out with a short counting period and a sufficiently large gap between the emitter and the counter tube so that the average number of pulses counted becomes sufficiently small.

2) Not only the Poisson's distribution, but also the Guassian distribution which is always symmetrical is very suitable to approximate the pulse distribution measured by means of a long-lived radiation emitter and a counter tube arranged with a constant gap between each other.A premise for this is a sufficiently high number of pulses and a large sampling size. The purpose of the following experiment is to confirm these facts and to show that the statistical pulse distribution can even be approximated by a Guassian distribution, when (due to the dead time of the counter tube) counting errors occur leading to a distribution which deviates from the Poisson's distribution.

3) If the dead time of the counter tube is no longer small with regard to the average time interval between the counter tube pulses, the fluctuation of the pulses is smaller than in the case of a Poisson's distribution.

What you can learn about

- Poisson's distribution; Gaussian distribution; Standard deviation
- Expected value of pulse rate; Different symmetries of distributions; Dead time
- Recovering time and resolution time of a counter tube

Main articles		
Radioactive source Am-241, 370 kBq	09090-11	1
Software Cobra4 - multi-user licence	14550-61	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Radioactivity	12665-00	1
Cobra4 Wireless Manager	12600-00	1
Base plate for radioactivity	09200-00	1

Cobra4 Sensor-Unit Radioactivity

Function and Applications

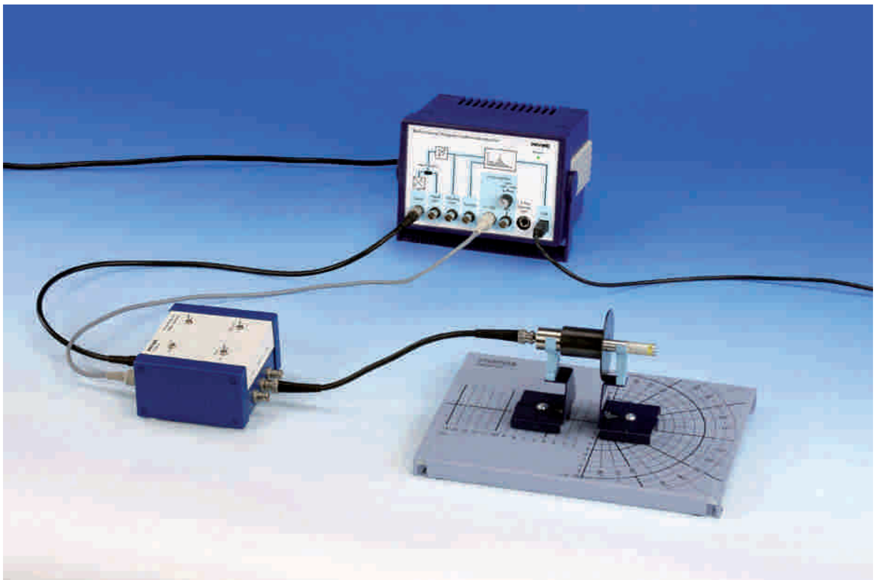
The Cobra4 Sensor-Unit Radioactivity allows the measurement of radioactive radiation (alpha, beta and gamma) with the aid of a Geiger-Mueller counter tube. The Sensor-Unit also supplies the counter tube with the necessary supply voltage and is controlled by a micro-controller.

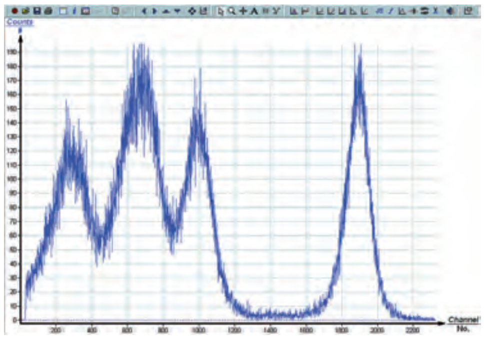
Benefits

- It can be fitted with 3 different counter tubes
- Variable counter tube voltage to investigate the characteristics of the counter tube
- Integrated speaker for acoustic signal of the counted pulses
- The unit can be connected to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 Junior-Link or the Cobra4 USB-Link using a secure and reliable plug-in / lockable connection

12665-00

P2522015 Alpha energies of different sources with MCA





Alpha-spectrum of the 226Ra.

Principle

An alpha-spectrometer, consisting of a photodetector, a preamplifier, a pulse height analyser and a recording device for registration of the spectra is calibrated by means of an open alpha-emitter of known alpha energy (^{241}Am). The energy spectrum of a radium source which is in equilibrium with its decay products, is recorded and evaluated. The alpha-energies found in this way are allocated to the corresponding nuclides of the radium decay series.

Tasks

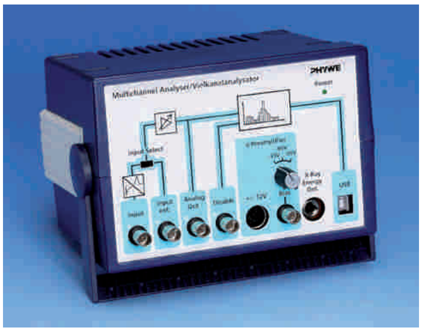
1. The Alpha-spectrum of the ^{226}Ra is recorded with multichannel analyzer.
2. The calibration spectrum of the open ^{241}Am alpha-emitter is recorded at the same settings.
3. The alpha-energies corresponding to the individual peaks of the alphaspectrum of the radium are calculated and compared to the values in the literature.

What you can learn about

- Decay series; Radioactive equilibrium
- Isotopic properties
- Decay energy
- Particle energy
- Potential well model of the atomic nucleus
- Tunnel effect
- Geiger-Nuttal law
- Semiconductor
- Barrier layer

Main articles		
Multi channel analyser	13727-99	1
Radioactive source Am-241, 3.7 kBq	09090-03	1
Radioactive source Ra-226, max. 4 kBq	09041-00	1
Pre-amplifier f.alpha detector	09100-10	1
Alpha and Photodetector	09099-00	1

Multichannel analyser



Function and Applications

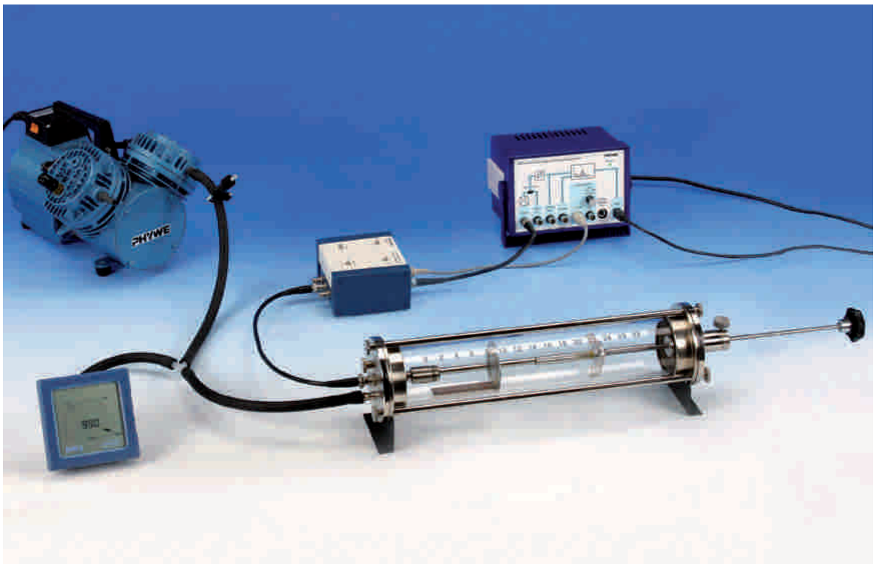
The multichannel analyser is for analysing voltage pulses which are proportional to energy and for determining pulse rates and intensities in conjunction with an X-ray detector, alpha detector or gamma detector. The analogue pulses from the detector are shaped by the analyser, digitised and summed per channel according to pulse height.

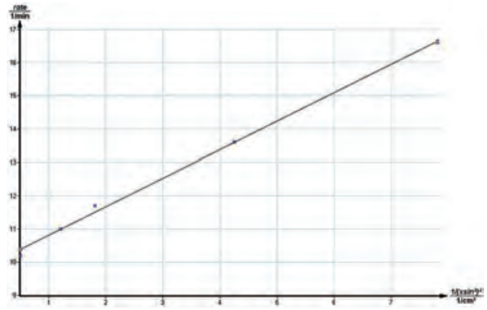
This results in a frequency distribution of detected pulses dependent on the energy of the radiation.

13727-99

Rutherford experiment with MCA

P2522115





Counting rate for gold as a function of 1 .

Principle

The relationship between the angle of scattering and the rate of scattering of alpha-particles by gold foil is examined with a semiconductor detector. This detector has a detection probability of 1 for alpha-particles and virtually no zero effect, so that the number of pulses agrees exactly with the number of alpha-particles striking the detector. In order to obtain maximum possible counting rates, a measurement geometry is used which dates back to Chadwick. It is also possible in this case to shift the foil and source in an axial direction (thus deviating from Chadwick's original apparatus), so that the angle of scattering can be varied over a wide range. In addition to the annular diaphragm with gold foil, a second diaphragm with aluminium foil is provided in order to study the influence of the scattering material on the scattering rate.

Tasks

1. The particle rates are measured at different angles of scattering between about 20° and 90°. The measurements are compared with the particle rates calculated by means of the Rutherford theory for the measurement geometry used.
2. The particle rates are measured in the case of scattering by aluminium and gold with identical angles of scattering in each case. The ratio of the two particle rates is compared with the particle rate calculated from Rutherford's scattering equation.

What you can learn about

- Scattering
- Angle of scattering
- Impact parameter
- Central force
- Coulomb field
- Coulomb forces
- Rutherford atomic model
- Identity of atomic number and charge on the nucleus

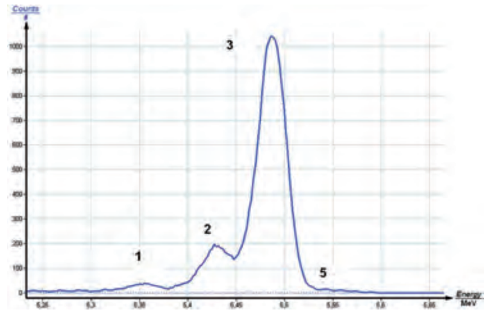
Main articles

Alpha detector	09100-00	1
Multi channel analyser	13727-99	1
Container f.nuclear phys.expts.	09103-00	1
Radioactive source Am-241, 370 kBq	09090-11	1
Pre-amplifier f.alpha detector	09100-10	1

Ernest Rutherford

1908, Nobel Prize in Physics

P2522215 Fine structure of the alpha spectrum of Am-241 with MCA / alpha spectroscopy



Measured alpha-spectrum of ^{241}Am.

Principle

The alpha-spectrum of an open ^{241}Am-emitter is measured with a semiconductor a-detector, maximum use being made in this case of the resolution capacity of the pulse height analyzer. Use is made for this purpose of the "Zoom" function, which is an additional amplification stage having in the effect that only that proportion of the pulses exceeding the threshold voltage of 5 V undergoes further processing. The pulse peaks above this threshold are amplified 5 times and restricted to a maximum of 10 V.

Tasks

1. The spectrum of an open ^{241}Am-emitter is recorded with the xyt recorder at the maximum resolution capacity of the measurement layout, using automatic window movement. The energy of the two peaks preceding the principal peak is calculated. The principal peak, corresponding to a particle energy of 5.486 MeV, is used for calibration purposes.
2. The resolution capacity of the measurement layout is measured from the half-life width of the principal peak.

What you can learn about

- Energy level diagram (decay diagram)
- Transition probability
- Excited nuclear states
- γ-emission
- Connection between the fine structure of the α-spectrum and the accompanying γ-spectrum

Main articles		
Multichannel analyser	13727-99	1
Container for nuclear physics exp.	09103-00	1
Radioactive source Am-241, 3.7 kBq	09090-03	1
Diaphragm pump, two stage, 220V	08163-93	1
Vacuum gauge DVR 2, 1 ... 1000 hPa	34171-00	1

Container for nuclear physics exp.

Function and Applications

Container for nuclear physical experiments.

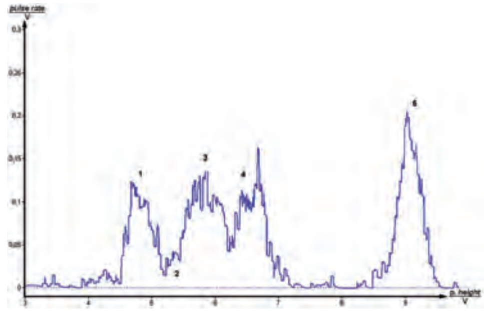
Equipment and technical data

- Cylindrical glasstube, 75 mm diam., 400 mm long, with a printed on scale 0 to 28 cm and metal flanges at its end.
- Removable by knurled head screws.
- One flange with vacuum tight centrally fitted bearing for a.push-rod for radioactive source adaption.
- Second flange with adaptors for vacuum system and detector.

09103-00

Study of the alpha energies of Ra-226 with MCA

P2522315



^{226}Ra pulse rate dependence of pulse height.

Principle

An alpha-spectrometer, consisting of a silicon surface barrier layer detector, a preamplifier, a pulse height analyser and a recording device for registration of the spectra is calibrated by means of an open alpha-emitter of known alpha-energy (^{241}Am). The energy spectrum of a radium source which is in equilibrium with its decay products, is recorded and evaluated. The alpha-energies found in this way are allocated to the corresponding nuclides of the radium decay series.

Tasks

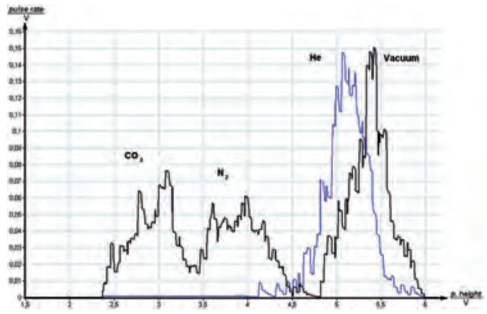
1. The alpha-spectrum of the ^{226}Ra is recorded, the settings of the pulse analyzer (amplification) and recorder (x and y input sensitivity) being selected so as to make best possible use of the recording width.
2. The calibration spectrum of the open ^{241}Am-emitter is recorded at the same settings.
3. The alpha-energies corresponding to the individual peaks of the alpha spectrum of the radium are calculated and, on the assumption of a constant energy loss in the source covering, the alpha-active nuclides of the radium decay series corresponding to the individual peaks are determined on the basis of the values in the literature.

What you can learn about

- Decay series
- Radioactive equilibrium
- Isotopic properties
- Decay energy
- Particle energy
- Potential well model of the atomic nucleus
- Tunnel effect
- Geiger-Nuttal law
- Semiconductor
- Barrier layer

Main articles		
Multichannel analyser	13727-99	1
Container for nuclear physics exp.	09103-00	1
Radioactive source Am-241, 3.7 kBq	09090-03	1
Diaphragm pump, two stage, 220V	08163-93	1
Radioactive source Ra-226, max. 4 kBq	09041-00	1
Vacuum gauge DVR 2, 1 ... 1000 hPa	34171-00	1
Pre-amplifier f.alpha detector	09100-10	1

P2522415 Energy loss of alpha particles in gases with MCA



Influence of the type of gas on the energy loss of alpha particles.

Principle

A study is made of the connection between the energy E of alpha-particles and the path x travelled by them in air at standard pressure.

The measurements recorded enable the differencial energy loss dE/dx to be calculated as a function of x.

Tasks

1. The spectrum of a covered 241Am source is measured at a fixed distance s as a function of the pressure p. The distance s is selected in such a way as to correspond to the maximum range at the highest pressure measurable with the manometer used. The energy corresponding to the central points of the individual spectra are determined (after calibration of the measurement layout with an open 241Am-emitter, see 3.) and plotted as a function of the distance x converted to a 1013 hPa basis. Using this function, the differential energy loss (dE/dx) is then calculated as a function of x and again plotted on the graph.
2. The spectrum of the source used in 1.is measured initially under the same geometric conditions under vacuum and subsequently with the vessel filled with helium, nitrogen or carbon dioxide, in each case under identical pressures. The different energy loss values are compared with the electron concentration in the particular gas.
3. The mean energy with which the alpha-particles leave the covered americium source is determined by calibration against the open americium emitter (E = 5.485 MeV). (This value is required for the evaluation in 1.)

What you can learn about

- Range; Range dispersion
- Mean free path length
- Mean ionization energy of gas atoms
- Mean energy loss of a-particles per collision
- Differencial energy loss; Bethe formula

Main articles		
Multichannel analyser	13727-99	1
Container for nuclear physics exp.	09103-00	1
Radioactive source Am-241, 3.7 kBq	09090-03	1
Radioactive source Am-241, 370 kBq	09090-11	1
Diaphragm pump, two stage, 220V	08163-93	1
Vacuum gauge DVR 2, 1 ... 1000 hPa	34171-00	1
Pre-amplifier f.alpha detector	09100-10	1

Diaphragm pump, two stage, 220V

Function and Applications

Diaphragm pump, two stage.

Benefits

- Maintenance-free, insensitve towards condensates, quiet, lightweight and easy to use because motor and compressor are together in one unit.
- It has a carryinghandle, overpressure valve 1.5 bar, toggle switch, working condenser and light metal casing.

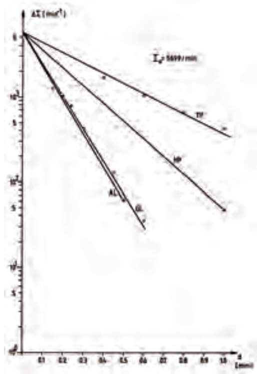
Equipment and technical data

- Aspirating power 30 l/min, Final pressure 13 mbar
- Pump head: Al, Valves: stainless steel
- Membrane and seals: CR (polychloroprene)
- Dimensions 323 x 250 x 222 mm
- Power supply voltage 230 V AC

08163-93

Electron absorption

P2523100



Counting rate I as a function of absorber thickness.

Principle

The attenuation of an electron particle stream passing through a material layer depends both on the thickness of the layer and on the mass coverage, resp. the "mass per unit area". It will be shown that the particle flux consisting of electrons of a particular energy distribution decreases with the "mass per unit area". As electron source, a radioactive sample of ^{90}Sr is used.

Tasks

1. The beta-counting rates are measured as a function of the absorber thickness using different absorbing materials such as aluminium (AL), glass (GL), hard paper (HP) and typing paper (TP).
2. The attenuation coefficients are evaluated for the four absorbing materials and plotted as a function of the density.

What you can learn about

- Density
- Counter tube
- Radioactive decay
- Attenuation coefficient
- Mass coverage

Main articles		
Radioactive source Sr-90, 74 kBq	09047-53	1
Geiger-Müller-Counter	13606-99	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1
Absorption plates f. beta-rays	09024-00	1
Base plate for radioactivity	09200-00	1
Supports f. base 09200.00, 2 pcs	09200-01	1
Plate holder on fixing magnet	09203-00	1

Geiger-Müller-Counter

Function and Applications

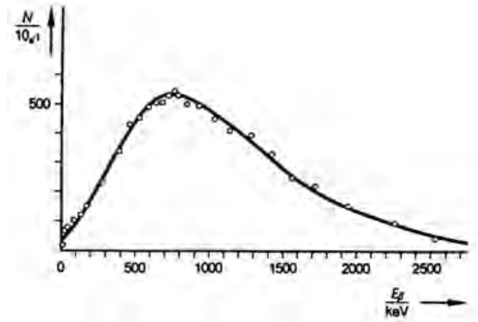
Demonstration and student use unit in connection with Geiger Müller counting tubes for experiments on radioactivity.

Equipment and technical data

- 4-digit LED display, 20mm high.4 standard measurement times 1/10/60/100 s, Automatic measurement sequence with memory 10 s
- Freely selectable measuring time, BNC-socket for counting tube 500V
- 4-mm-bushes for event counting with TTL signals, Mains 100-230 V/50-60 Hz, Shock proof casing with carrying handle
- Dimensions 190 x 140 x 130 mm

13606-99

P2523200 Beta spectroscopy



Beta-spectrum of ^{90}Sr.

Principle

The radiation of β-unstable atomic nuclei is selected on the basis of its pulses in a magnetic transverse field, using a diaphragm system. The relationship between coil current and particle energy is determined for calibration of the spectrometer and the decay energy of the β-transition is obtained in each case from the β^--spectra.

Tasks

1. Energy calibration of the magnetic spectrometer.
2. Measurement of the β-spectra of ^{90}Sr and ^{20}Na.
3. Determination of the decay energy of the two isotopes.

What you can learn about

- β^--decay
- β^+-decay
- Electron capture
- Neutrino
- Positron
- Decay diagram
- Decay energy
- Resting energy
- Relativistic Lorentz equation

Main articles		
Teslameter, digital	13610-93	1
Power supply, universal	13500-93	1
Radioactive source Na-22, 74 kBq	09047-52	1
Radioactive source Sr-90, 74 kBq	09047-53	1
Geiger-Müller-Counter	13606-99	1
Beta-spectroscope	09104-00	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1

Beta-spectroscope

Function and Applications

Beta spectroscope.

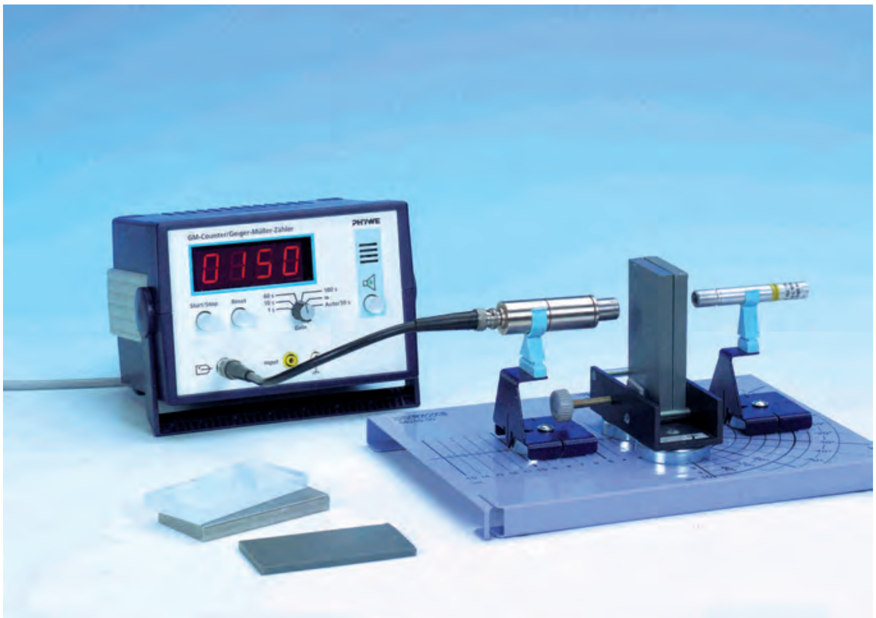
Equipment and technical data

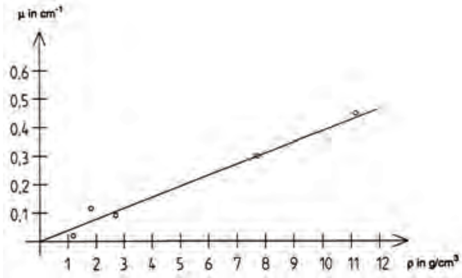
- Cylindrical chamber with base plate with diaphragm system.
- Top plate removable.
- Lateral bore-holes for radioactive source and flux-meter probe.
- Diameter: 90 mm.
- Height: 20 mm.

09104-00

Inverse-square law and absorption of gamma or beta rays with the Geiger-Müller counter

P2524101





Attenuation coefficient of different materials as a function of the material density (from left to right: Plexiglas®, concrete, aluminium, iron, lead).

Principle

The inverse square law of distance is demonstrated with the gamma radiation from a 60Co preparation, the half-value thickness and absorption coefficient of various materials determined with the narrow beam system and the corresponding mass attenuation coefficient calculated.

Tasks

1. To measure the impulse counting rate as a function of the distance between the source and the counter tube.
2. To determine the half-value thickness d1/2 and the absorption coefficient of a number of materials by measuring the impulse counting rate as a function of the thickness of the irradiated material. Lead, iron, aluminium, concrete and Plexiglas are used as absorbers.
3. To calculate the mass attenuation coefficient from the measured values.

What you can learn about

- Radioactive radiation; Beta-decay; Conservation of parity
- Antineutrino; Gamma quanta; Half-value thickness
- Absorption coefficient; Term diagram; Pair formation
- Compton effect; Photoelectric effect
- Conservation of angular momentum; Forbidden transition
- Weak interaction; Dead time

Main articles		
Radioactive sources, set	09047-50	1
Geiger-Müller-Counter	13606-99	1
Geiger-Mueller Counter tube, type A, BNC	09025-11	1
Absorption material, lead	09029-01	1
Absorption plates f. beta-rays	09024-00	1
Absorption material, concrete	09029-05	1

Radioactive sources, set

Function and Applications

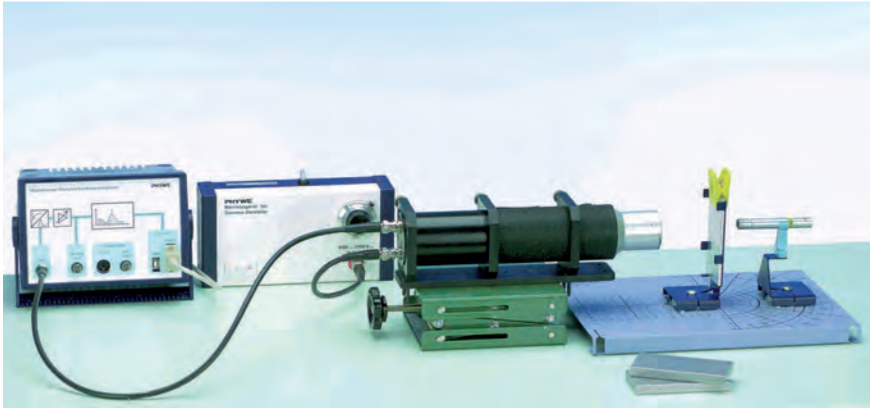
Set of 4 encapsulated radionuclides, radiation sources with storage container.

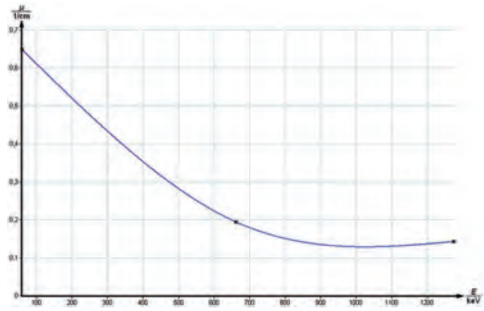
Equipment and technical data

- valid handling licence necessary
- notifiable to your supervisory authority
- Alpha Am-241, Hwz: 433 a
- Beta(+) Na- 22, Hwz: 2,6 a
- Beta(-) Sr- 90, Hwz: 28,5 a
- Gamma Co- 60, Hwz: 5,3 a
- Activity each source: 74 kBq

09047-50

P2524215 Energy dependence of the gamma absorption coefficient with MCA / Gamma spectroscopy





Total gamma-absorption coefficient as a function of the energy.

Principle

The intensity of gamma-radiation decreases when it passes through solid matter. The attenuation can be the result of Compton scattering, the photo effect or the pair production. An absorption coefficient can be attributed to each of the three phenomena. These absorption coefficients, as well as the total absorption, are highly energy-dependent. The energy dependence of the total absorption coefficient for aluminium in the range below 1.3 MeV is verified.

Tasks

1. For each of the emitting isotopes ^{22}Na, ^{137}Cs and ^{241}Am the gamma-spectrum is traced and a threshold energy, E, just below the photo-peak in the high energy range determined.
2. Using the scintillation counter in conjunction with the pulse height analyser as a monochromator, the gamma-intensity is measured as a function of the thickness of different aluminium layers.The three gamma- emitting isotopes are used successively as the source, assuming that the energy of the emitted gamma-radiation is known.

What you can learn about

- Compton scattering
- Photo effect
- Pair production
- Absorption coefficient
- Radioactive decay
- g-spectroscopy

Main articles		
Gamma detector	09101-00	1
Multi channel analyser	13727-99	1
Radioactive source Cs-137, 37 kBq	09096-01	1
Radioactive source Am-241, 370 kBq	09090-11	1
Operating unit for gamma detector	09101-93	1
Radioactive source Na-22, 74 kBq	09047-52	1
measure Software multi channel analyser	14452-61	1

Gamma detector

Function and Applications

To detect gamma, beta and x-rays. Large volume thallium doped NaI-crystal in light-tight capsule, with photomultiplier with mu-metal shielding mounted in holder with rod.

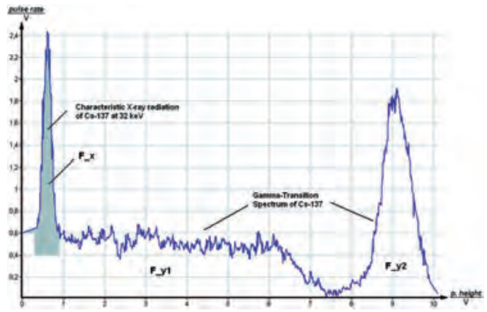
Equipment and technical data:

- Crystal: NaI (Ta).
- Crystal dimensions (mm): 38 x 50.8.
- Thickness of Al envelope: 0.4 mm.
- Operation voltage: 600..1100 V.

09101-00

Internal conversion in 137m Ba with MCA

P2524515



Gamma-spectrum of ^{137}Cs.

Principle

The radiation emitted during the decay of the ^{137}Cs isotope is measured with a scintillation detector and the energyspectrum determined with a pulse height analyzer. The spectrum contains fractions due to a gamma-transition and fractions originating from a characteristic X-ray radiation. The areas of the fractions in question are determined and the conversion factor obtained from them.

Tasks

1. Measurement of the g-spectrum of ^{137}Cs using a scintillation detector.
2. Determination of the conversion factor of the ^{137}mBa excited nucleus.

What you can learn about

- g-radiation; Nuclear transitions
- Transition probability
- Duration; Metastable states
- Isotopic spin quantum numbers
- Rules governing selection
- Multipole radiation; Isomeric nuclei
- Photonuclear reaction; Conversion electron
- Characteristic X-ray radiation
- Scintillation detectors

Main articles

Gamma detector	09101-00	1
Multi channel analyser	13727-99	1
Radioactive source Cs-137, 37 kBq	09096-01	1
Operating unit for gamma detector	09101-93	1
measure Software multi channel analyser	14452-61	1

Multi channel analyser

Function and applications

The multichannel analyser is for analysing voltage pulses which are proportional to energy and for determining pulse rates and intensities in conjunction with an X-ray detector, alpha detector or gamma detector. The analogue pulses from the detector are shaped by the analyser, digitised and summed per channel according to pulse height. This results in a frequency distribution of detected pulses dependent on the energy of the radiation.

Equipment and technical data

The multi channel analyser has an offset function for enhancing the energy resolution.
It possesses the following features:

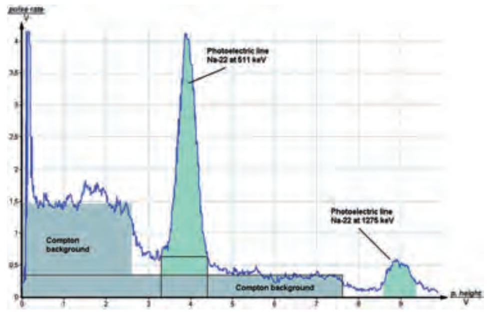
- Analogue output for observing heights of the pulse spectrum on an oscilloscope,
- A USB output for connecting to a computer,
- Integrated power supply for alpha detector pre-amp (909100.00),
- Integrated power supply for X-ray energy detector.
- Includes 1.5-m mains lead, USB cable type A/B
- Multi-channel analyser software (required)
- Resolution (per spectrum): up to 4096 channels (12 bit)
- Memory: unlimited
- Lag time: 60 µs
- Coincidence window: 1 µs
- Analogue input: negative pulse impedance: 3.3 kilohms, 150 pF

Accessories

Multi-channel analyser software (required)

13727-99

P2524615 Photonuclear cross-section / Compton scattering cross-section with MCA



Gamma-spectrum of ^{22}Na.

Principle

The radiation of ^{137}Cs and ^{22}Na is measured with a scintillation detector and the energy spectrum determined with a multi channel analyser. The fractions of the spectra caused by Compton scattering and those caused by the photoelectric effect are determined on the basis of their areas. The results are used for determining the ratio of the effective cross-sections and examining its energy dependence.

Tasks

1. Measurement of the g-spectra of ^{22}Na and ^{137}Cs, using a scintillation detector.
2. Determination of the ratio of the specific effective cross-sections due to the Compton effect and the photoelectric effect in photons having energy values of 511, 662 and 1275 keV.

What you can learn about

- g-radiation
- Interaction with material
- Photoelectric effect
- Compton effect
- Pair formation
- Detection probability
- Scintillation detectors

Main articles		
Gamma detector	09101-00	1
Multi channel analyser	13727-99	1
Radioactive source Cs-137, 37 kBq	09096-01	1
Operating unit for gamma detector	09101-93	1
Radioactive source Na-22, 74 kBq	09047-52	1
measure Software multi channel analyser	14452-61	1

Operating unit for gamma detector

Function and Applications

Operating unit for gamma-detector.

Benefits

- Highly stabilized DC voltage continuously adjustable by 10 range potentiometer.

Equipment and technical data

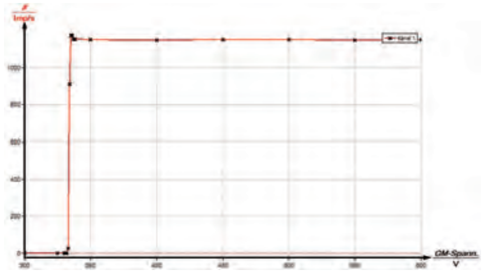
- Output / MHV socket: 600 - 1100 V DC.
- Stabilization: better than 0.1 %.
- Input voltage: 220 V AC.
- Dimensions (mm): 115 x 65 x 225.

09101-93

Counter tube characteristics

P2540010

NEW



Pulse rate as a function of the counter tube voltage.

Principle

The counter tube uses the ionising effect of high-energy radiation in order to measure the intensity of the radiation. The counter tube characteristics describe its working range, i.e. the voltage range in which it reliably counts the incoming particles.

Task

Determine the counter tube characteristics of the type B counter tube that is used.

What you can learn about

- Geiger-Mueller counter tube
- Quenching gas
- Characteristics
- Ionising radiation

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Geiger-Mueller Counter tube, type B	09005-00	1

Best fitting XR 4.0 sets for this experiment:

XRE 4.0 X-ray expert set

09110-88

XRP 4.0 X-ray Solid state physics upgrade set

09120-88

Geiger-Mueller counter tube, type B

Function and Applications

Self recovering Halogenid countertube for detection of Alpha-, Beta- und Gamma-radiation with Mica window.

09005-00

Geiger-Mueller Counter tube, 45 mm

NEW

Purpose and description

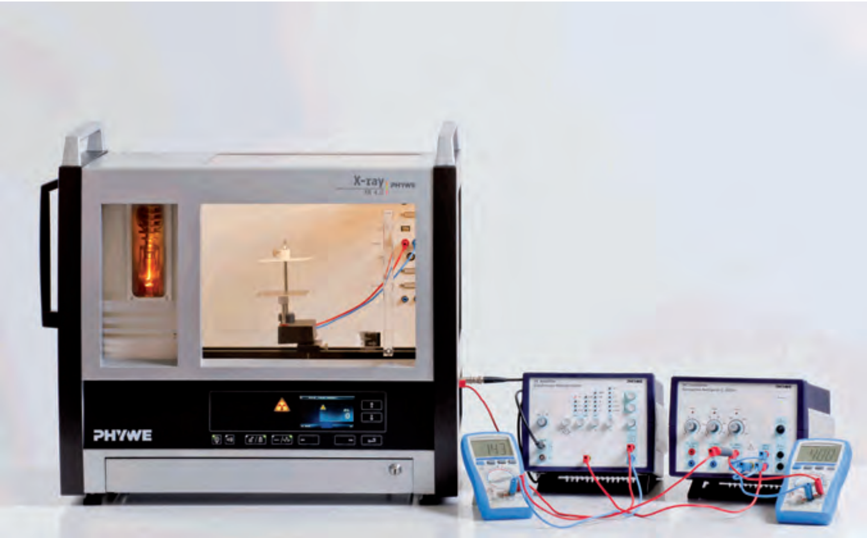
The Geiger-Mueller Counter tube, 45 mm is a self-extinguishing halogen counting tube for the detection of alpha, beta and gamma radiation. A long plateau (approx. 425...650V) with only a slight slope renders the selection of the operating point uncritical. The actual counting tube, which is mounted in a metal cylinder with a permanent BNC connecting cable, has a thinwalled metal sheath that is permeable to alpha radiation.

Benefits

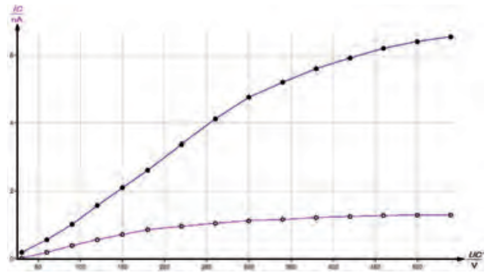
- Highly sensitive counting tube
- Useful to investigate weakly radioactive sources
- Even natural radioactive sources can be investigated.

09007-00

P2541801 X-ray dosimetry



NEW



Ionisation current I_C as a function of the capacitor voltage U_C for different diaphragm tubes.

Principle

Dosimetry, as a subspecialty of medical physics, deals with the determination and calculation of dose rates, which is also of great importance in view of the radiation protection directives. This experiment demonstrates the principle of measurement and it explains the various units of absorbed dose, equivalent dose, and absorbed dose rate. Inside a plate capacitor, an air volume is irradiated with X-rays. The resulting ion current is used to determine the dosimetric data.

Tasks

1. Using the two different diaphragm tubes and the fluorescent screen, the given distance between the aperture and the radiation source at maximum anode voltage and current is to be determined.
2. The ion current at maximum anode voltage is to be measured and graphically recorded as a function of the capacitor voltage by using two different beam limiting apertures. The ion dose rate and the energy dose rate are to be determined from the saturation current values.
3. Using the d = 5 mm aperture, the ion current is to be determined and graphically recorded at various anode currents but with maximum anode and capacitor voltages.
4. The ion current is to be measured and graphically recorded as a function of the capacitor voltage at different anode voltages and the corresponding saturation currents plotted graphically.

What you can learn about

- X-rays; Absorption inverse square law
- Ionizing energy; Energy dose
- Equivalent dose and ion dose and their Rates
- ρ factor; Local ion dose rate; Dosimeter

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray fluorescent screen	09057-26	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray Capacitor plates f.x-ray-unit	09058-05	1
DC measuring amplifier	13620-93	1
Power supply, 0...600 VDC	13672-93	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRD 4.0 X-ray dosimetry upgrade set

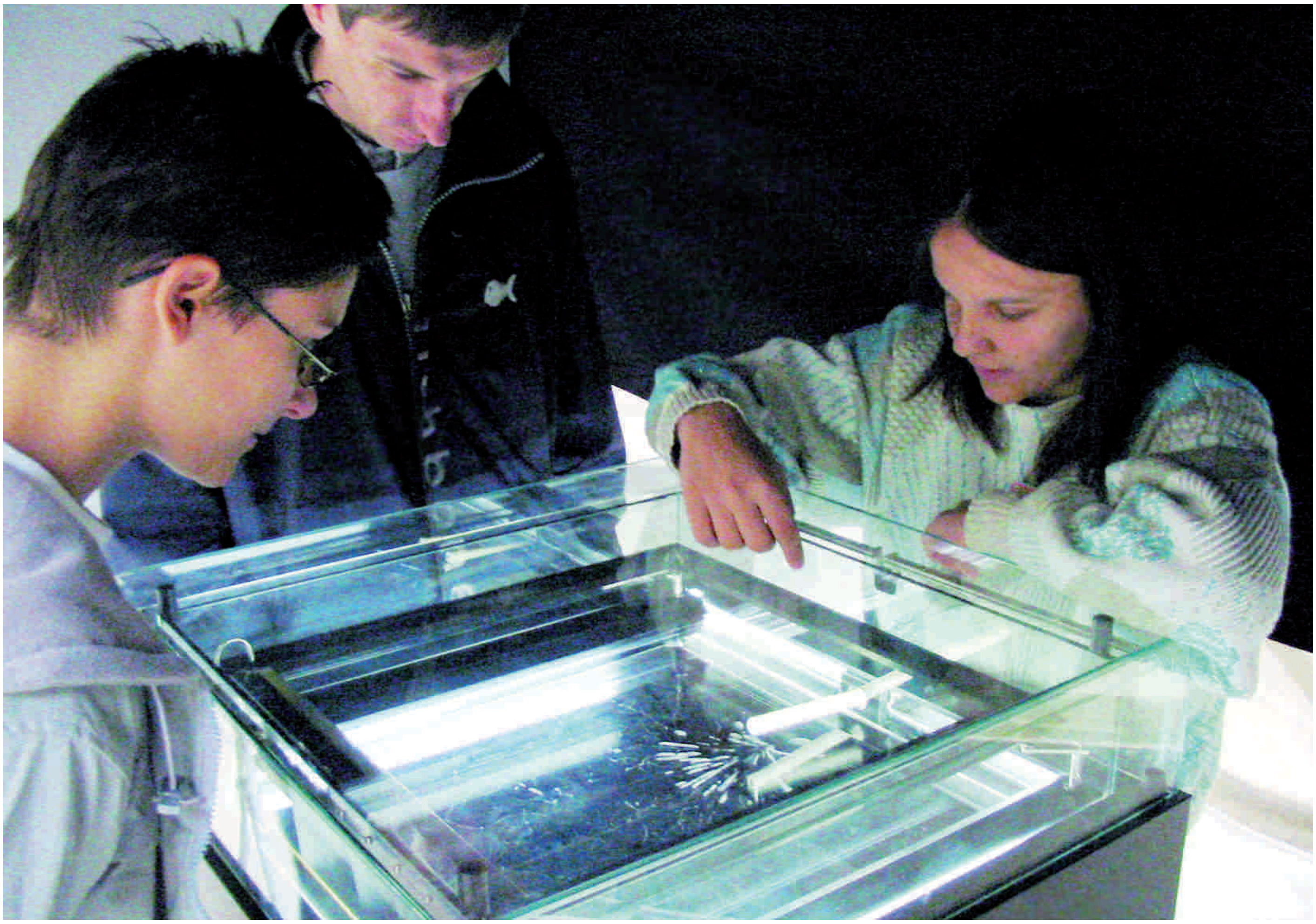
09170-88

DC measuring amplifier

Function and Applications

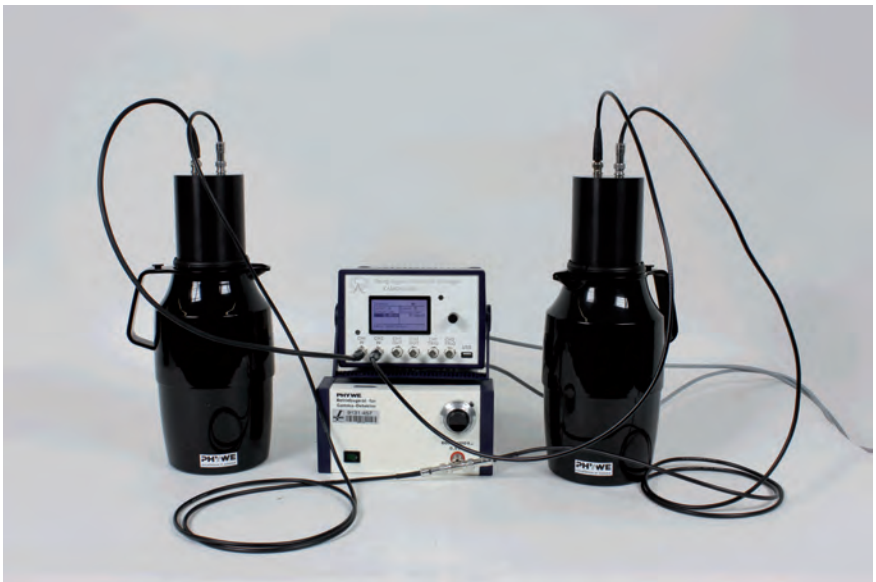
Versatile measuring amplifier for measurement of very small direct currents, electrical charges and for quasi-static measurements of DC voltages.

13620-93

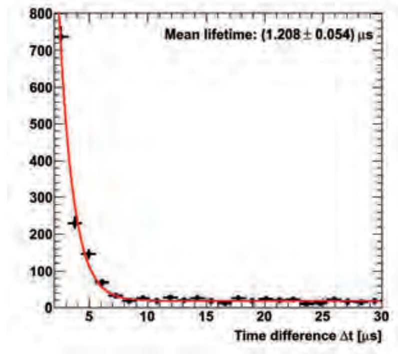


Particle Physics

P2520800 Cosmic Muon Lifetime measurement - Kamiocan -



NEW m Demo



Muon lifetime.

Principle

Muon is an elementary particle similar to the electron, with unitary negative electric charge and aspin of 1/2. Muons, electrons, and neutrinos are classified as a leptons. Most naturally occurring muons on earth are created by cosmic rays, which consist mostly of protons, arriving from space at very high energy. The measurement of cosmic muons lifetime without using unpopular radioactive sources in a clear experimental setup is realized in cooperation with the University of Göttingen and Netzwerk Teilchenwelt (www.teilchenwelt.de) and named "Kamiokanne" according to the Kamiokande experiment in Japan.

Tasks

1. Calibration
2. Muon rate determination
3. Muon lifetime mesurement
4. Coincidence, angular distribution

What you can learn about

- Cosmic Myons
- Cherenkov radiation
- Cosmic radiation
- Electromagnetic cascade
- Hadronic cascade
- Muonic cascade
- PMT

Main articles		
Cosmic Myon Counter complete experiment set- Kamiocan	09049-88	1

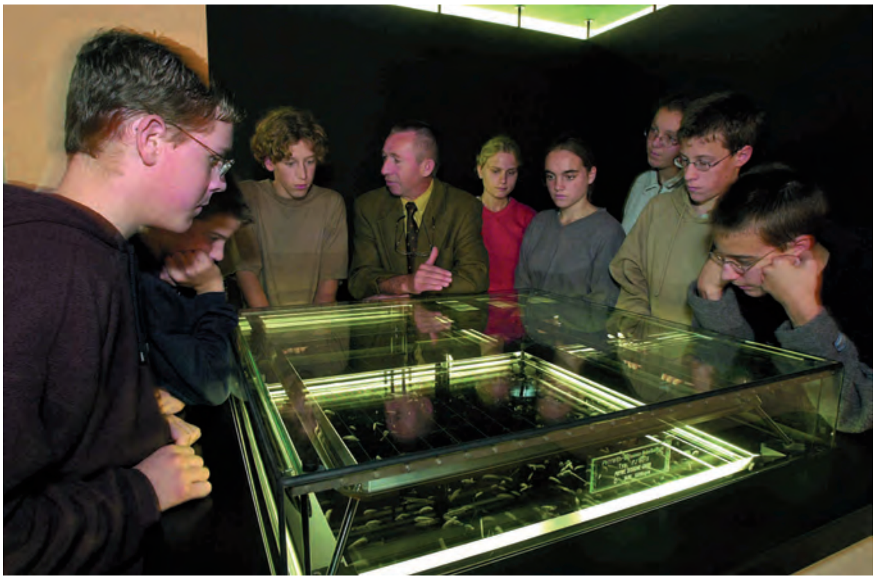
In Cooperation with:

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Masatoshi Koshiba

2002, Nobel Prize in Physics

Visualisation of radioactive particles / diffusion cloud chamber P2520400



Particles visible in the diffusion cloud chamber.

Principle

Radioactivity is a subject in our society which has been playing an important role throughout politics, economy and media for many years now.

The fact that this radiation cannot be seen or felt by the human being and that the effects of this radiation are still not fully explored yet, causes emotions like no other scientific subject before.

The high-performance diffusion cloud chamber serves for making the tracks of cosmic and terrestrial radiation visible so that a wide range of natural radiation types can be identified.

Furthermore, the diffusion cloud chamber offers the opportunity to carry out physical experiments with the aid of artificial radiation sources.

Tasks

1. Determination of the amount of background radiation
2. Visualisation of alpha, beta, gamma-particles and mesons
3. Visualisation of the Thorium (Radon) decay
4. Deflection of beta-particles in a magnetic field

What you can learn about

- α,β,γ -particles
- β-deflection
- Ionising particles
- Mesons
- Cosmic radiation
- Radioactive decay
- Decay series
- Particle velocity
- Lorentz force

Main articles		
Diffusion cloud chamber, 45 x 45 cm PJ45	09046-93	1
Radioactive source Sr-90, 74 kBq	09047-53	1
Accessory set for Beta deflection	09043-52	1
Support base DEMO	02007-55	1
Object holder, 5x5 cm	08041-00	1
Swinging arm	08256-00	1
Stand tube	02060-00	1

C.T.R. Wilson

1927, Nobel Prize in Physics

Diffusion cloud chamber, 45 x 45 cm PJ45, 230 V

Function and Applications

Continuously working large diffusion cloud chamber on pedestal; handles on side help to transport the instrument.

Equipment and technical data

- Dimensions: Height: 60 cm; Width: 64 cm; Depth: 64 cm
- Active observation surface: (45 × 45) cm
- Weight: approx. 80 kg
- Power input: approx. 0.9 kVA
- Power supply: 230 V; 50/60 Hz

09046-93

Diffusion cloud chamber 80 x 80 cm, PJ 80, 230 V

Function and Applications

Continuously working large diffusion cloud chamber on box; the instrument can be set up by itself.

Benefits

- The large diffusion cloud chamber with an 80 x 80 cm active observation surface are hermetically closed units.
- They each consist of a pedestal for the chamber on top of which lies the observation chamber.
- The chamber's pedestal holds the refrigerating unit, power supply, a tank for alcohol, a pump for alcohol and a timer.
- On top of the pedestal, the observation chamber is installed.
- The top and the sides of the observation chamber are made of glass.
- Underneath the upper sheet of glass, thin heating wires are installed, which heat up this part of the chamber and thus keep the chamber from misting over.
- These wires simultaneously serve as high-voltage mesh to gather up ions.

Equipment and technical data

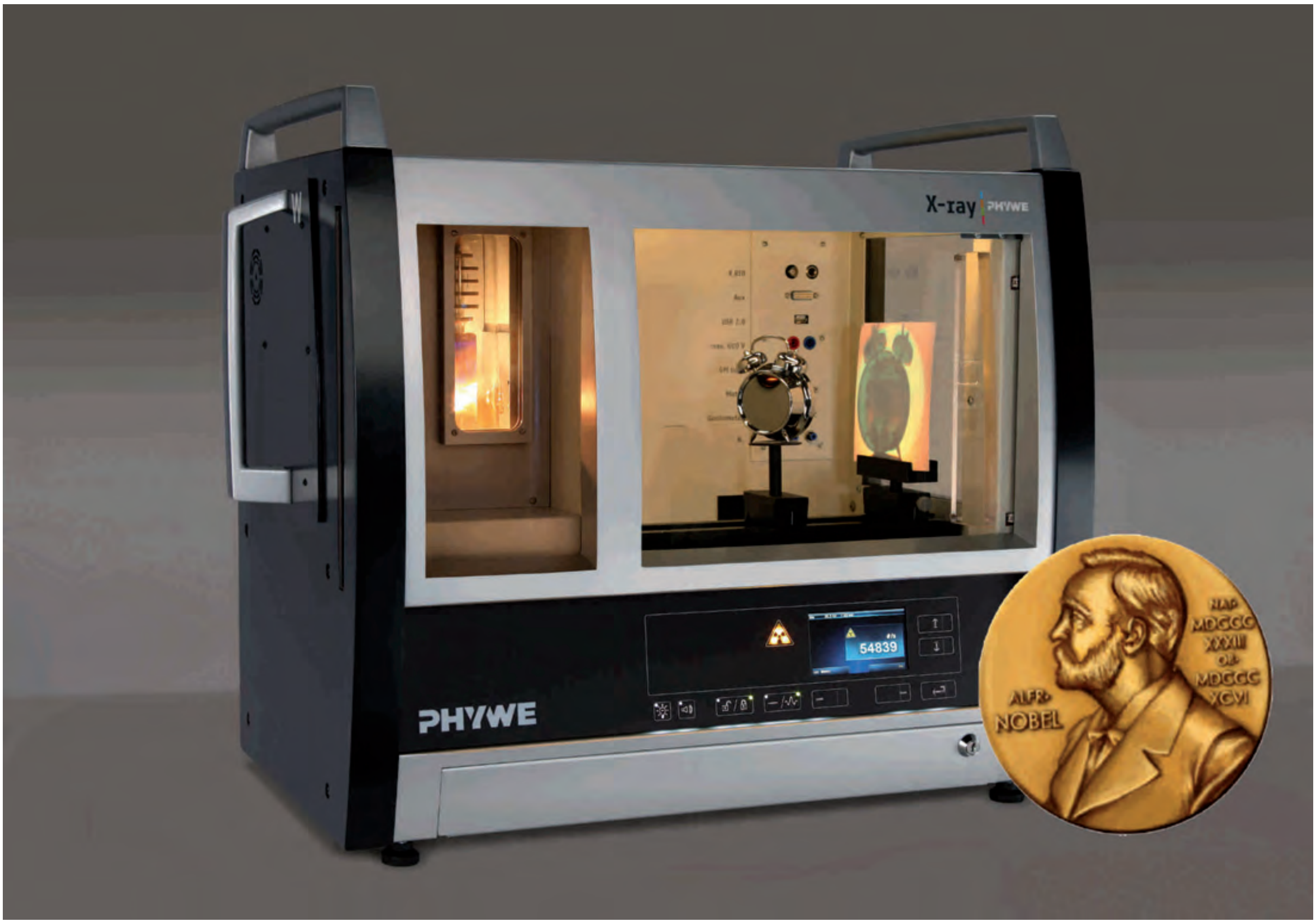
- Dimensions: Height: 126 cm; Width: 128 cm; Depth: 128 cm
- Height of pedestal: 10 cm
- Active observation surface: (80 × 80) cm
- Weight: approx. 450 kg
- Power input: approx. 2.0 kVA

09043-93

Training recommended Service PHYWE

For this experiment we recommend a seminar on equipment technology, handling and information of equipment-specific characteristics on site.

03333-02



X-ray Physics

XRE 4.0 expert set –
Details at a glance

XXL Chamber

- Large space for large experiments
- Temperature-controlled, internally-ventilated experimentation space

Experience the perfect synthesis of innovative technology, highest level of safety, well-proven PHYWE quality and modern design. Extensive performance characteristics and ideas make working with the PHYWE XR 4.0 a special experience.
We have presented some device highlights for you here.

Tube XChange Technology

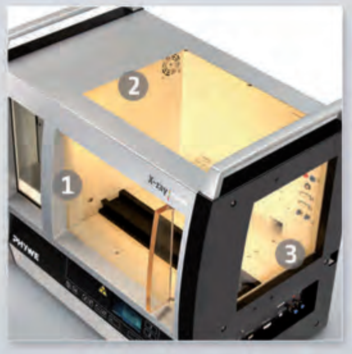
- Self-adjusting X-ray tubes with quick-change technology
- Contact protection against hot parts
- 4 anode materials for specific experiments (W, Mo, Cu, Fe)

Touch Panel

- Simultaneous control, manually and by computer
- Interactive, intuitive handling
- Self-explanatory icons for fast operation

3View – Insight provides a transparent view

- Exceptional observability of the experimentation space
- Extra-large window front on 3 sides (Diagonals: : 18"/18"/14", 46cm/46cm/36cm)



X-ray XR 4.0 PHYWE

Optical bench with riders

- Radiography experiments
- simple, precise positioning of optical components

S-Lock – new PHYWE Safety interlock

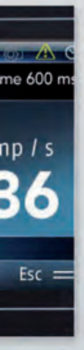
- Electrical and mechanical safety lock
- Prevents door opening with switched on X-radiation
- thus offers the highest possible safety
- patend pending

Goniometer (not pictured)

- Self-calibrating
- Collision protected
- Easy, safe handling

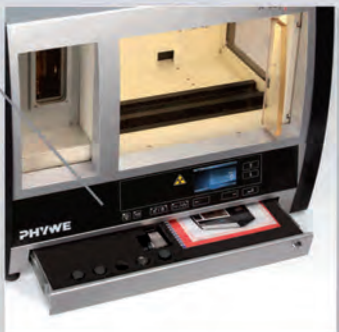
MultiLINK

- Connection field internal and external
- USB 2.0, N_2, BNC, XRED, Aux, etc.
- No annoying „cable-laying“
- In addition, extra-large cable conduit



High-resolution TFT backlit display

- diagonal 4,3“
- 480 x 272 Pixel
- 16 Bit, 65.536 colors
- with LED lighting
- Optimal, dynamic representation of all important device parameters and measured values



Safekeeping drawer

- All accessories are kept safely and always ready at hand
- Lockable

XR 4.0 expert unit –
Sets for all applications

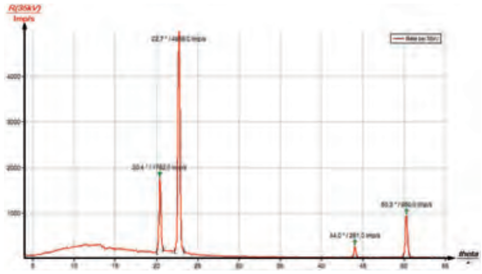
Basic set	Core components (incl. further Accessories)	Areas of application	Application examples
XRE 4.0 expert set Art. No. 09110-88 (Basic set)	▪ XR 4.0 expert unit (X-ray device); ▪ Tungsten tube (W), ▪ XR measure 4.0 X-ray software, ▪ optical bank ▪ TESS expert manual ▪ fluorescent screen ▪ USB cable, mains cable + adaptor	Phy Che Bio Med Geo Eng	▪ Basics & applications of X-radiation ▪ Radiographic experiments ▪ Radiology

Extend the basic set with the respective extension set according to area of application

Extension sets (optional)	Core components (incl. further accessories)	Areas of application	Application examples
XRP 4.0 solid-state physics Art. No. 09120-88	▪ Goniometer, GM counter tube, ▪ LiF / KBr single crystal ▪ absorption set	Phy	▪ Diffractometry ▪ X-ray spectroscopy ▪ Bragg-reflection / Bremsspectrum ▪ Characteristic lines
XRC 4.0 characterization Art. No. 09130-88	▪ 3 X-ray tubes (Cu, Fe, Mo) ▪ Goniometer, GM counter tube, ▪ LiF / KBr single crystal	Phy	▪ Radiation spectrums of the anode ▪ Moseley law ▪ Rydberg constant ▪ Duane-Hunt law
XRS 4.0 structure analysis Art. No. 09140-88	▪ Goniometer, GM counter tube, ▪ LiF / KBr / NaCl single crystal ▪ Crystal holder ▪ powder samples	Phy Che Geo Eng	▪ Structure investigations ▪ Laue patterns ▪ Debye-Scherrer recordings ▪ X-ray analysis
XRM 4.0 material analysis Art. No. 09160-88	▪ Goniometer ▪ X-ray energy detector ▪ Multi-channel analyzer ▪ Sample sets	Phy Che Geo Eng	▪ X-ray fluorescence spectroscopy ▪ Non-destructive testing (NDT) ▪ Compton Effect ▪ Energy-dispersive experiments
XRI 4.0 radio photo-graphy Art.-Nr. 09150-88	▪ Camera ▪ Radiographic object ▪ Model loader ▪ Implant model	Bio Med Geo	▪ Basics for the X-ray image provision ▪ Radiography ▪ Radiology ▪ Non-destructive testing (NDT)
XRD 4.0 dosimetry and radiation damage Art. No. 09170-88	▪ Parallel-plate capacitor ▪ Power supply unit 600 V ▪ DC current amplifier ▪ Camera	Phy Bio Med	▪ Dosimetry ▪ Degradation ▪ Damage ▪ Ionization of air
XRCT 4.0 computer tomo-graphy Art. No. 09180-88	▪ Direct, digital X-ray image sensor ▪ Rotation unit, vertical rotation ▪ measure Tomography software package	Phy Bio Med Eng	▪ 3-dimensional reconstruction ▪ Sectional drawings in respective position ▪ Direct, digital image provision
XRW 4.0 wireless demonstration Art. No. 09115-88	▪ Digital display panel ▪ Cobra4 Display-Connect ▪ Transmitter and receiver, etc.	Phy Che Bio Med Geo Eng	▪ Demonstration experiments (operation without computers) ▪ Placard-style representation of the measured values and parameters

Characteristic X-rays of copper

P2540101



Intensity of the X-radiation of copper as a function of the glancing angle theta; analyser crystal: LiF.

Principle

Spectra of X-rays from a copper anode are analyzed using different monocrystals and the results plotted graphically. The energies of the characteristic lines are then determined from the positions of the glancing angles for the various orders of diffraction.

Tasks

1. Record the intensity of the X-rays emitted by the copper anode as a function of the Bragg angle using a LiF or KBr monocrystal as analyzer.
2. Calculate the energy values of the characteristic copper lines and compare them with the energy differences of the copper energy terms.

What you can learn about

- Bremsstrahlung; Characteristic radiation; Energy levels; Crystal structures; Lattice constant; Absorption; Absorption edges

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

Related X-ray Experiments

Characteristic X-rays of molybdenum

P2540201

Characteristic X-rays of iron

P2540301

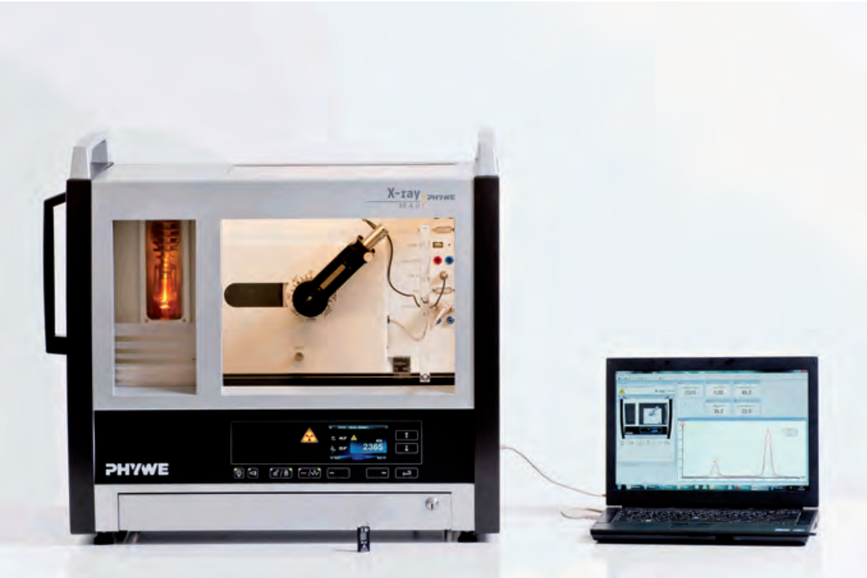
Characteristic X-rays of tungsten

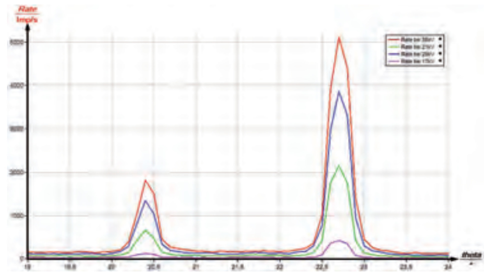
P2542801

Wilhelm Conrad Röntgen

1901, Nobel Prize in Physics

P2540401 The intensity of characteristic X-rays as a function of the anode current and anode voltage





X-ray spectrum at different anode voltages.

Principle

The polychromatic X-radiation from a copper anode is analyzed using a LiF monocrystal according to Bragg. Varying the anode current and anode voltage influences the intensity of the characteristic K_a and K_b radiation.

Tasks

1. Record the intensity spectrum of polychromatic radiation from a X-ray tube with the help of a LiF monocrystal.
2. Determine the intensities of the characteristic K_a and K_b radiations as a function of both, the anode current and the anode voltage, and plot them graphically.
3. Compare the results of the measurement with the theoretical intensity formula.

What you can learn about

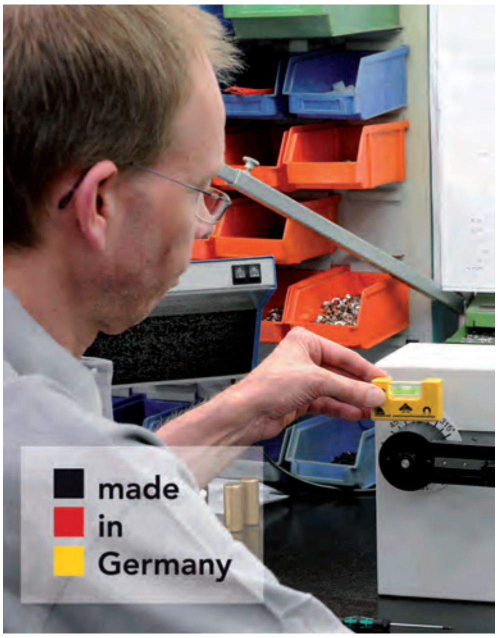
- Characteristic X-ray radiation
- Energy level
- Bragg equation
- Intensity of characteristic X-rays

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray Diaphragm tube d = 2 mm	09057-02	1

Best fitting XR 4.0 sets:

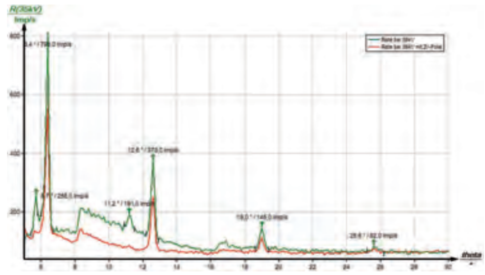
XRE 4.0 X-ray expert set
09110-88

XRC 4.0 X-ray characteristics upgrade set
09130-88



Monochromatisation of molybdenum X-rays

P2540501



X-ray spectrum of molybdenum with a KBr crystal as the analyser; green: without filter, red: with a zirconium Kβ filter.

Principle

The X-rays that are generated by an X-ray tube are polychromatic. Numerous experiments (e.g. Debye-Scherrer experiments concerning crystal structures), however, require monochromatic X-radiation, which can be generated by filtering the X-rays with monocrystals or with the aid of metal foils.

Tasks

1. Record the intensity of the X-rays emitted by the molybdenum anode as a function of the Bragg angle, using a LiF monocrystal as analyzer. The energy values of the characteristic molybdenum lines are to be calculated.
2. Use the LiF monocrystal to filter out a characteristic line and record the appertaining monochromatization graphically
3. Record the intensity of the X-rays emitted by the molybdenum anode as a function of the Bragg angle, using a LiF monocrystal as analyzer and a zirconium filter.

What you can learn about

- Bremsstrahlung
- Characteristic radiation
- Energy levels
- Absorption
- Absorption edges
- Interference
- Diffraction
- Bragg scattering

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 potassium bromide (KBr) crystal	09056-01	1

Related X-ray Experiment

Monochromatisation of copper X-rays

P2540601

Best fitting XR 4.0 sets:

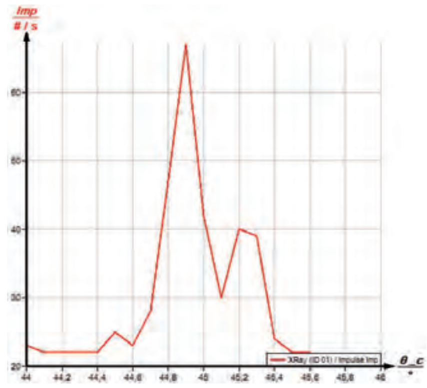
XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

P2540701 K alpha double splitting of molybdenum X-rays / fine structure



Splitting of the Kα1 and Kα2 lines of molybdenum (n = 4)

Principle

The polychromatic molybdenum X-ray spectrum is analyzed by means of a monocrystal. The energy of the characteristic lines is determined from the positions of the glancing angles at various orders of diffraction. The separation of the K a doublet in higher order diffraction is examined.

Tasks

1. Record the intensity of the X-rays emitted by the molybdenum anode as a function of the Bragg angle using a LiF monocrystal as analyzer.
2. Determine the wavelengths and ratio of the intensities of the two K a lines in high order diffraction and compare your results with the theoretical predictions.

What you can learn about

- Characteristic X-ray radiation
- Energy levels
- Selection rules
- Bragg equation
- Energy term symbols

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 Software measure X-ray	14414-61	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray Diaphragm tube d = 1 mm	09057-01	1
Geiger-Mueller counter tube, type B	09005-00	1

Related Experiments

K alpha doublet splitting of iron X-rays / fine structure
P2540801

Duane-Hunt displacement law and Planck's "quantum of action"
P2540901

Characteristic X-ray lines of different anode materials / Moseley's law
P2541001

Counter tube characteristics
P2540010

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set
09110-88

XRC 4.0 X-ray characteristics upgrade set
09130-88

Radiographic examination of objects

P2540020

Radiography of a digital alarm clock.

Principle

An X-ray tube produces X-rays that cause a fluorescent screen to emit light. Objects that are located between the X-ray source and the fluorescent screen will be irradiated so that their inner structure becomes visible. If one varies the anode current and voltage, the change in intensity can be observed in a qualitative manner on the fluorescent screen.

Tasks

1. X-ray an object and observe the result on the fluorescent screen.
2. Vary the anode current and voltage and observe the result on the fluorescent screen.

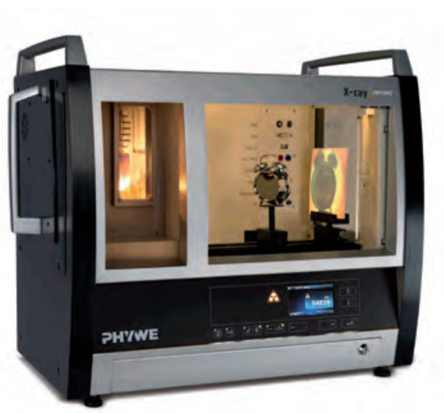
What you can learn about

- X-ray tube
- Absorption of X-rays
- Radiography
- Fluorescence

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray fluorescent screen	09057-26	1
XR 4.0 X-ray optical bench	09057-18	1
Slide mount for optical bench, h = 30 mm	08286-01	2

XR 4.0 expert unit

NEW



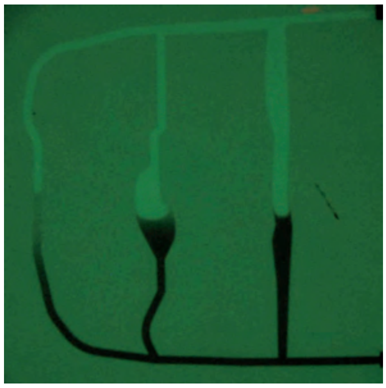
Function and Applications

School/full-protection device with X-ray tube quick-change technology for fluoroscopy and X-ray imaging, ionisation and dosimetry experiments, Laue and Debye-Scherrer images, X-ray spectroscopy, Bragg reflection, bremsspectrum/characteristic lines of various different anode materials, Moseley's law, determination of Planck's constant and Rydberg constant, Duane Hunt's law, material-thickness- and energy-dependent absorption, K and Ledges, contrast medium experiments, Compton scattering, and X-ray diffractometry.

09057-99

P2541901 Contrast medium experiment with a blood vessel model

NEW Demo



Blood vessel model with the contrast medium half filled.

Principle

When a blood vessel model is irradiated with X-rays, the blood vessels themselves are not visible at first. It is only after the injection of a contrast medium that the blood vessels become visible.

Tasks

1. Inject a 50% potassium iodide solution into the blood vessel model.
2. Observe the fluorescent screen of the X-ray basic unit to follow the course taken by the injected solution in the blood vessel model.

What you can learn about

- X-ray radiation
- Bremsstrahlung
- Characteristic radiation
- Law of absorption
- Mass absorption coefficient
- Contrast medium

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray fluorescent screen	09057-26	1
XR 4.0 X-ray Blood vess.model f.contrast fluid	09058-06	1
XR 4.0 X-ray optical bench	09057-18	1
Slide mount for optical bench, h = 30 mm	08286-01	2
Potassium iodide 50 g	30104-05	1

XR 4.0 Mobile X-ray Lab

NEW Demo

Function and Applications

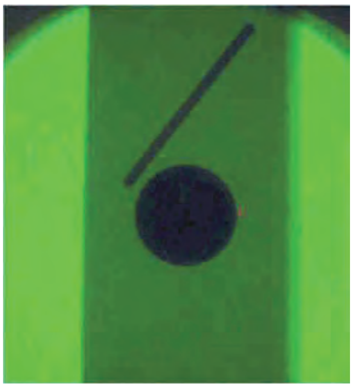
Teaching and performing experiments with the mobile X-ray lab. The mobile X-ray lab saves valuable time by making the set-up and dismantling of experiments in the classroom or lecture hall redundant. All of the important parts, such as X-ray tubes, goniometer, or multi-channel analyser, can be stored safely in the lockable cabinet. Prepare your experiments unhurriedly ahead of time before pushing them into the room at time of the lecture. Cluttered set-ups and tangled cables are a thing of the past: The most important connectors are located on the desktop. The screen is fixed in place on the desktop in a permanent manner in order to protect it against damage and theft. The extra-large castors easily surmount any edges or bumps. Any type of room can be instantly transformed into an X-ray science lab!

09057-48

Determination of length and position of an object which can not be seen

P2542001

NEW Demo



Pictures of the implant model projection in the y,z-plane.

Principle

This experiment provides training in determining the length and position of an object based on an X-ray image. A metal pin that is embedded in a wooden block is used as the model. This experiment is also an excellent preparatory exercise for demonstrating the principle of computed tomography.

Tasks

1. Record a bi-planar radiogram of two perpendicular planes of a metal pin which cannot be seen.
2. Determine the true length of the pin by taking into account the magnification factor which results from the divergence of the X-rays.
3. Determine the spatial position of the pin.

What you can learn about

- X-ray radiation
- Bremsstrahlung
- Characteristic radiation
- Law of absorption
- Mass absorption coefficient
- Stereographic projection

Main articles

XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray fluorescent screen	09057-26	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray slide for external optical bench	09057-29	1
XR 4.0 X-ray Implant model	09058-07	1
XR 4.0 X-ray Adapter for digital camera 1/4""	09057-15	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRI 4.0 X-ray imaging upgrade set

09150-88

XR 4.0 X-ray Implant model f.x-ray photography

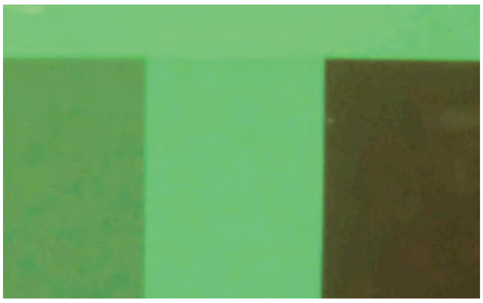
Function and Applications

For use with XR 4.0 X-ray expert unit kV to determine the length and spatial position of a non visible metal pin which is enclosed in a block of wood.

09058-07

P2540030 Qualitative examination of the absorption of X-rays

NEW Demo



From left to right: aluminium, cardboard, iron (all of them: d=1 mm).

Principle

X-rays penetrate objects that are impenetrable for visible light. The absorption depends on the thickness and type of the material. This dependence is demonstrated in a qualitative manner on a fluorescent screen with the aid of various different absorption specimens.

Tasks

1. Observe the transmission of X-rays as a function of the material thickness.
2. Determine how the atomic number of the elements in a material affects the transmission of X-rays.

What you can learn about

- X-ray tube; Absorption of X-rays
- Atomic number; Fluorescence; Lambert-Beer

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray fluorescent screen	09057-26	1
XR 4.0 X-ray optical bench	09057-18	1
Slide mount for optical bench, h = 30 mm	08286-01	2
Table with stem	09824-00	1

Best fitting XR 4.0 set:

XRE 4.0 X-ray expert set

09110-88

XR 4.0 X-ray plug-in unit W tube

Function and Applications

Factory adjusted tungsten tube in sheet steel housing ready for use in connection with XR 4.0 expert unit. Housing with plugs to accept the tubes operating quantities from the basic unit. With handle, mechanical lock and two switching pins, which only operate correspondingly security microswitches of the basic unit when the plug-in module is correcly inserted.

Benefits

Tube XChange Technology:

- Quick-change technology for four different X-ray tubes (W, Cu, Mo, and Fe), adjustment free; Complete protection against touching hot parts

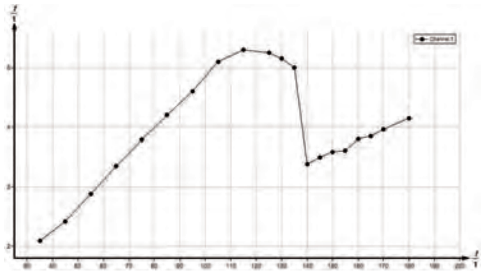
Equipment and technical data

- Anode angle 19°, Max. operation datas 1 mA/35 kV
- Test voltage 50 kV, Mass 4.3 kg
- Dimensions (26.7 x 18.8 x 20.3) cm; Incl. dust protection cover.

09057-80

Absorption of X-rays

P2541101



Absorption edge of copper; UA = 25 kV; λK = 138 pm.

Principle

The polychromatic X-radiation that is emitted by an X-ray tube is filtered in terms of its energy with the aid of a monocrystal.

The resulting monochromatic radiation is used as the primary radiation source for examining the absorption behaviour of various metal foils of different thicknesses.

Tasks

1. Determine the attenuation of the X-radiation by aluminium and zinc foils of different thicknesses and at two different wavelengths of the primary radiation.
2. Determine the mass absorption coefficient μ/ρ for aluminium, zinc, and tin absorbers of constant thickness as a function of the wavelength of the primary radiation. Prove the validity of $\mu/\rho = f(\lambda^3)$ in a graphical manner.
3. Determine the absorption coefficients μ for copper and nickel as a function of the wavelength of the primary radiation. Determine the energy values of the corresponding K shells based on the graphical representation. Prove the validity of $\mu/\rho = f(\lambda^3)$.

What you can learn about

- Bremsstrahlung; Characteristic radiation
- Bragg scattering; Law of absorption
- Mass absorption coefficient; Absorption edge
- Half value thickness; Photoelectric effect
- Compton scattering; Pair production

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller Counter tube, type B	09005-00	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRP 4.0 X-ray Solid state physics upgrade set

09120-88

XR 4.0 X-ray goniometer

Function and Applications

Goniometer with two independent stepper motors for the precise angular positioning of a sample and detector.

Benefits

- Self-calibrating goniometer

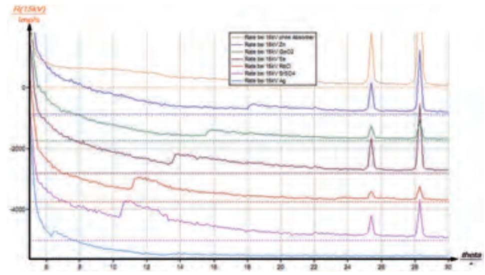
Plug & measure:

- Automatic identification of the goniometer
- Goniometer block with two independent stepper motors for rotating the sample holder and the detector either separately or coupled in a 2:1 ratio
- The detector holder with a slit diaphragm holder for absorption foils can be moved in order to change the angular resolution
- Includes a light barrier system for limiting the permissible swivelling range and, thereby, for protecting the detectors
- Intuitive operation directly at the unit or via a PC

09057-10

P2541201 K and L absorption edges of X-rays / Moseley's law and the Rydberg constant

NEW



X-ray spectra of copper without any absorber (top curve) and with the absorption edges of various elements.

Principle

Samples of various elements of different atomic numbers are irradiated with X-rays of a known spectral distribution. The energy of the transmitted intensities is analyzed using a monocrystal analyzer. Subsequently, the Rydberg constant and the screening constants are calculated from the energy of the absorption edges.

Tasks

1. Record the intensity of the X-rays emitted from the copper anode as a function of the Bragg angle using an LiF monocrystal as analyzer. Determine the K absorption edges of different absorber materials.
2. Calculate the Rydberg constant and the screening constants from the energy values of the K absorption edges.
3. Find the L absorption edges of different absorber materials.
4. Calculate the Rydberg constant from the energy values of the L absorption edges.

What you can learn about

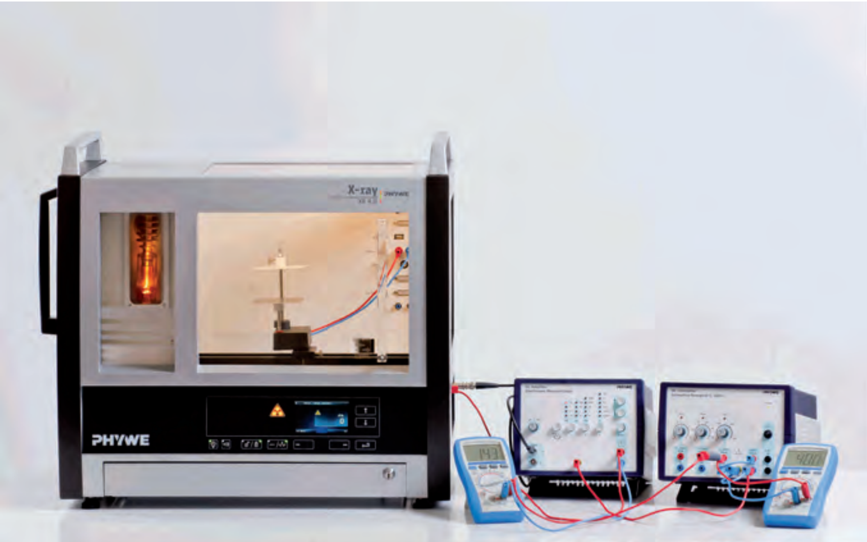
- X-ray Bremsstrahlung
- Characteristic radiation
- Bragg equation
- Bohr's atomic model; Atomic energy level scheme
- Moseley's law
- Rydberg constant; Screening constant

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller Counter tube, type B	09005-00	1
XR 4.0 X-ray Chemical set for edge absorption	09056-04	1
XR 4.0 X-ray Lithium fluoride crystal	09056-05	1

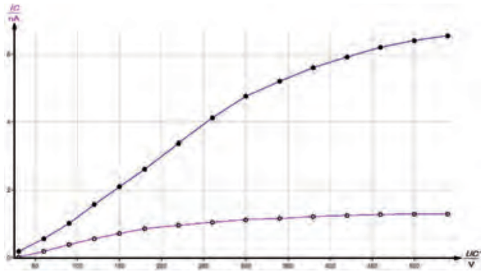
Best fitting XR 4.0 sets:
XRE 4.0 X-ray expert set
09110-88
XRC 4.0 X-ray characteristics upgrade set
09130-88

X-ray dosimetry

P2541801



NEW



Ionisation current Ic as a function of the capacitor voltage Uc for diffrent diaphragm tubes.

Principle

Dosimetry, as a subspecialty of medical physics, deals with the determination and calculation of dose rates, which is also of great importance in view of the radiation protection directives. This experiment demonstrates the principle of measurement and it explains the various units of absorbed dose, equivalent dose, and absorbed dose rate. Inside a plate capacitor, an air volume is irradiated with X-rays. The resulting ion current is used to determine the dosimetric data.

Tasks

1. Using the two different diaphragm tubes and the fluorescent screen, the given distance between the aperture and the radiation source at maximum anode voltage and current is to be determined.
2. The ion current at maximum anode voltage is to be measured and graphically recorded as a function of the capacitor voltage by using two different beam limiting apertures. The ion dose rate and the energy dose rate are to be determined from the saturation current values.
3. Using the d = 5 mm aperture, the ion current is to be determined and graphically recorded at various anode currents but with maximum anode and capacitor voltages.
4. The ion current is to be measured and graphically recorded as a function of the capacitor voltage at different anode voltages and the corresponding saturation currents plotted graphically.

What you can learn about

- X-rays
- Absorption inverse square law
- Ionizing energy
- Energy dose
- Equivalent dose and ion dose and their rates
- ϱ factor
- Local ion dose rate
- Dosimeter

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
DC measuring amplifier	13620-93	1
Power supply, 0...600 VDC	13672-93	1
XR 4.0 X-ray Capacitor plates f.x-ray-unit	09058-05	1

Related X-ray Experiment:

Ionizing effect of X-radiation

P2540040

Best fitting XR 4.0 sets:

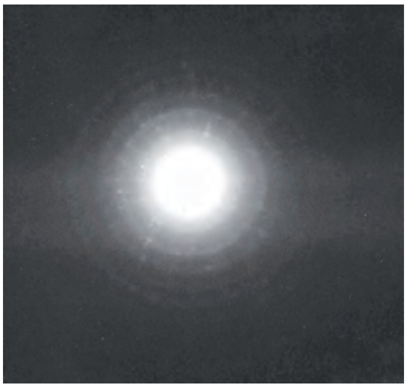
XRE 4.0 X-ray expert set

09110-88

XRD 4.0 X-ray dosimetry upgrade set

09170-88

P2541401 X-ray investigation of cubic crystal structures / Debye- Scherrer powder method



Debye-Scherrer pattern of a powdered sample of NaCl. Thickness of the sample: 0.4 mm. Exposure time: 2.5 h. Mo X-ray tube: U_a = 35 kV; I_a = 1 mA.

Principle

When polycrystalline samples are irradiated with X-rays a characteristic diffraction pattern results. These Debye-Scherrer reflections are photographed and then evaluated.

Tasks

1. Debye-Scherrer photographs are to be taken of powdered samples of sodium chloride and caesium chloride.
2. The Debye-Scherrer rings are to be evaluated and assigned to the corresponding lattice planes.
3. The lattice constants of the sample materials are to be determined.
4. The number of atoms in the unit cells of each sample are to be determined.

What you can learn about

- Crystal lattices
- Crystal systems
- Reciprocal lattice
- Miller indices
- Structure amplitude
- Atomic form factor
- Bragg scattering

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray film holder	09057-08	1
XR 4.0 X-ray optical bench	09057-18	1

Related X-ray Experiment

X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method

P2541501

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

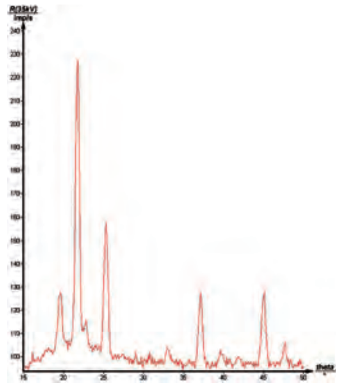
09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

Diffraction measurements to determine the intensity of Debye-Scherrer reflexes using a cubic powder sample

P2542601



Debye-Scherrer pattern of a copper powder sample.

Principle

A polycrystalline, cubic face-centered crystallizing powder sample is irradiated with the radiation from a Roentgen tube with a copper anode. A Geiger-Mueller counter tube is automatically swivelled to detect the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagram is automatically recorded. The intensities of the individual reflex lines are determined and compared with those theoretically expected. In addition, the evaluation allows the Bragg reflexes to be assigned to the individual lattice planes, and both their spacing and the corresponding Bravais lattice type to be determined.

Tasks

1. Record the intensity of the Cu X-rays back scattered by a cubic crystallizing copper powder sample as a function of the scattering angle.
2. Calculate the lattice plane spacings from the angle positions of the individual Bragg lines.
3. Assign the Bragg reflexes to the respective lattice planes. Calculate the lattice constant of the substance and the Bravais lattice type.
4. Determine the intensity of the individual reflex lines and compare them with the theoretically expected intensities.
5. Determine the number of atoms in the unit cell.

What you can learn about

- Crystal lattices and systems
- Bravais-lattice
- Reciprocal lattice
- Miller indices
- Structure factor
- Atomic scattering factor
- Lorentz-polarization factor
- Multiplicity factor
- Debye-Waller factor
- Absorption factor

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
Geiger-Mueller Counter tube, type B	09005-00	1
XR 4.0 X-ray Lithium fluoride crystal	09056-05	1
XR 4.0 X-ray Univ. crystal holder	09058-02	1
XR 4.0 X-ray holder for powder probes	09058-09	1

Related X-ray Experiments

Debye-Scherrer diffraction patterns of powder samples with three cubic Bravais lattices (Bragg-Brentano-geometry)

P2542101

Debye-Scherrer diffractions pattern of powder samples with a diamond structure (according to Bragg-Brentano)

P2542201

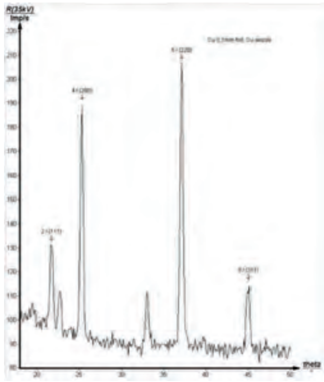
Debye-Scherrer diffraction patterns of powder samples with a hexagonal lattice structure

P2542301

Debye-Scherrer diffraction patterns of powder samples with a tetragonal lattice structure

P2542401

P2542701 Debye-Scherrer diffraction measurements for the examination of the texture of rolled sheets



Debye-Scherrer diagram of a rolled copper sheet.

Principle

A polycrystalline, cubic face-centered crystallizing copper powder sample and a thin copper sheet are separately irradiated with the radiation from a Roentgen tube with a copper anode. A Geiger-Mueller counter tube is automatically swivelled to detect the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. The evaluation allows the Bragg reflexes to be assigned to the individual lattice planes. In contrast to the powder sample, the rolled thin sheet gives a spectrum showing an alignment of the crystallites (rolled texture), that is made even more complete by heating the sheet.

Tasks

1. Record the intensity of the Cu X-rays back scattered by a cubic crystallizing copper powder sample as a function of the scattering angle.
2. Assign the Bragg reflexes to the individual lattice planes.
3. Record the Bragg spectrum of a thin sheet of copper.
4. Repeat the measurements made in Task 3 after the sheet of copper has been subjected to annealing.

What you can learn about

- Crystal lattices; Crystal systems
- Bravais-lattice
- Reciprocal lattice
- Miller indices
- Structure factor
- Atomic scattering factor
- Bragg scattering
- Characteristic X-rays
- Monochromatization of X-rays
- Fiber textures
- Sheet textures
- Annealing texture
- Recrystallization

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 Software measure X-ray	14414-61	1

Related X-ray Experiment

Counter tube characteristics

P2540010

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

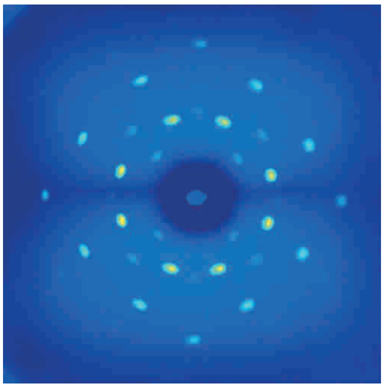
09110-88

XRS 4.0 X-ray structural analysis upgrade set

09140-88

X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)

P2541602



Laue pattern of the LiF (100) crystal.

Principle

Laue diagrams are produced when monocrystals are irradiated with polychromatic X-rays. This method is primarily used for the determination of crystal symmetries and the orientation of crystals. When a LiF monocrystal is irradiated with polychromatic X-rays, a characteristic diffraction pattern results. This pattern is photographed with the digital X-ray sensor XRIS.

Tasks

1. The Laue diffraction of an LiF mono-crystal is to be recorded on a film.
2. The Miller indices of the corresponding crystal surfaces are to be assigned to the Laue reflections

What you can learn about

- Crystal lattices; Crystal systems; Crystal classes
- Bravais lattice; Reciprocal lattice; Miller indices
- Structure amplitude
- Atomic form factor; Bragg equation

Main articles		
XRCT 4.0 X-ray Computed Tomography upgrade set	09180-88	1
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray Crystal holder for Laue-pattern	09058-11	1

Related X-ray Experiment

X-ray investigation of crystal structures / Laue method

P2541601

XR 4.0 X-ray Direct Digital Image Sensor (XRIS) with USB cable

Function and Applications

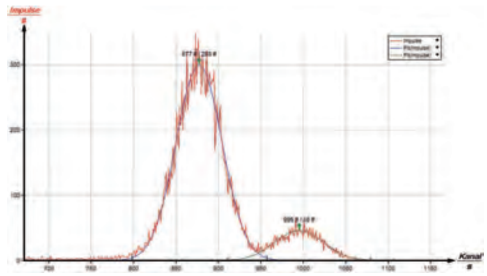
Digital X-ray camera to perform X-ray imaging (radiography) and X-ray Computer Tomography (CT) experiments. Particularly suitable for experiments in lab courses and lectures in physics, medical education and material sciences.

Features and Benefits

- Direct acquisition of the X-ray images by a direct X-ray direct digital image sensor:
- Experimentation under daylight conditions
- High-performance CMOS image sensors for the direct digital X-ray radiography to create superior image quality, high resolution and large active area images based on CMOS technology.

09057-40

P2544001 X-ray energy spectroscopy - calibration of the X-ray energy detector



Fluorescence lines of zinc with a fitted normal distribution.

Principle

Various metal samples are subjected to polychromatic X-rays. The resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The maxima of intensity of the corresponding characteristic X-ray lines are determined. The predefined energy values of the characteristic lines and channels of the multi-channel analyser that must be assigned in turn result in a calibration of the semiconductor energy detector.

Tasks

1. Record the spectra of the fluorescence radiation that is generated by the metal samples.
2. Determine the channel numbers of the maxima intensity of the characteristic lines of the corresponding fluorescence radiation.
3. Represent the predefined line energies as a function of the channel numbers graphically for two gain factors of the multi-channel analyser.

What you can learn about

- Bremsstrahlung; Characteristic X-radiation; Energy levels; Fluorescence radiation
- Conduction processes in semiconductors; Doping of semiconductors; Pin-diodes; Semiconductor energy detectors; Multichannel analysers

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray specimen set metals for X-ray fluorescence, set of 7	09058-31	1
Multichannel analyser	13727-99	1

XR 4.0 X-ray energy detector (XRED)

Function and Applications

With the new X-ray energy detector you can directly determine the energies of single x-ray quanta.

Benefits

- In connection with the multichannel analyser (MCA) you can characterise the complete x-ray energy spectrum of the analysed material.
- Characteristic x-ray lines for all elements of the PSE included in the software.
- Directly mountable on the goniometer of the x-ray unit, without loss of functionality of the goniometer.
- Directly connectable to MCA (USB) without any additional interface on.
- Green Operation-LED.
- Parallel observation of the signals in the oscilloscope (optional).

09058-30

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

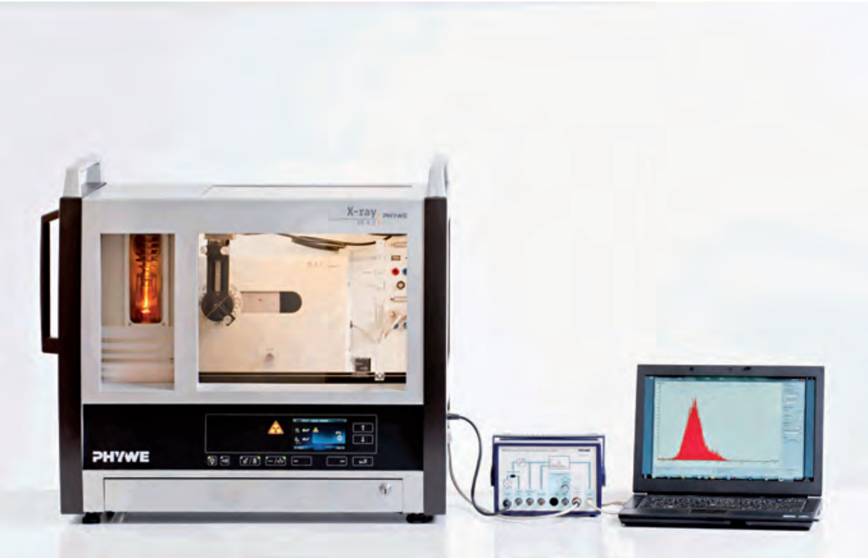
09110-88

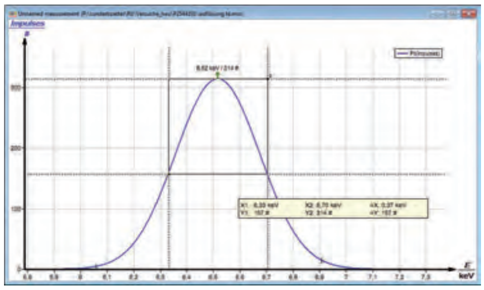
XRM 4.0 X-ray material analysis upgrade set

09160-88

Energy resolution of the X-ray energy detector

P2544101





Normal distribution of the iron Kα-lines for determining the line energy and the full width at half maximum (the original measurement curve is hidden).

Principle

Various metal samples are subjected to polychromatic X-rays. The resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser.

The energy of the characteristic X-ray lines and their full widths at half maximum are determined.

In addition, the dependence of the full widths at half maximum and the shift of the line centroid as a function of the counting rate are examined.

Tasks

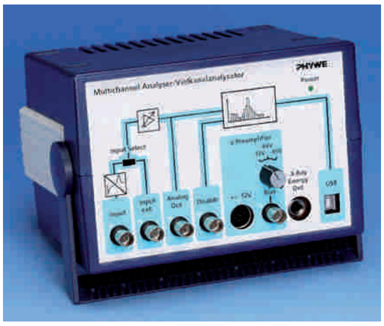
1. Calibration of the semiconductor detector with the aid of the characteristic radiation of the molybdenum X-ray tube.
2. Recording of the spectra of the fluorescence radiation that is generated by the metal samples.
3. Determination of the energy levels and full widths at half maximum of the characteristic lines and their graphical representation.
4. Determination and graphical representation of the full widths at half maximum as a function of the counting rate, with the Kalpha line of zircon used as an example.
5. Determination and graphical representation of the shift of the line centroid as a function of the counting rate, with the Kalpha line of zircon used as an example.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Fluorescence radiation
- Conduction processes in semiconductors
- Doping of semiconductors
- Pin-diodes
- Resolution and resolving power
- Semiconductor energy
- Multi-channel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray Specimen set metals for X-ray fluorescence, set of 7	09058-31	1
Multi channel analyser	13727-99	1

Multichannel analyser

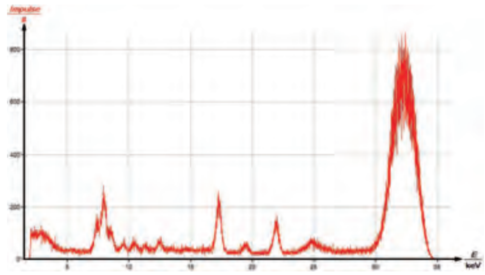


Function and applications

The multichannel analyser is for analysing voltage pulses which are proportional to energy and for determining pulse rates and intensities in conjunction with an X-ray detector, alpha detector or gamma detector. The analogue pulses from the detector are shaped by the analyser, digitised and summed per channel according to pulse height. This results in a frequency distribution of detected pulses dependent on the energy of the radiation.

13727-99

P2544201 Inherent fluorescence radiation of the X-ray energy detector



Characteristic fluorescence spectrum of the detector components (energy of the primary radiation E_0 = 32.5 keV).

Principle

Fluorescence radiation of the elements of a sample can cause fluorescence radiation inside the detector and its housing if the energy is sufficiently high.

As a result, the spectrum may include lines that are not caused by the sample. For the detection of potential additional lines, the detector is subjected to monochromatic X-radiation with the aid of a monocrystal.

For comparison, the fluorescence spectra of pure metal samples are measured.

Tasks

1. Calibrate the semiconductor energy detector with the aid of the characteristic fluorescence radiation of the calibration sample.
2. Irradiate the X-ray energy detector with monoenergetic X-rays that are produced by the Bragg reflection on an LiF monocrystal. Measure the resulting fluorescence spectrum.
3. Determine of the energy of the spectrum lines.

What you can learn about

- Bremsstrahlung; Characteristic X-radiation; Fluorescence radiation
- Fluorescent yield; Interference of X-rays; Crystal structures
- Bragg's law; Compton scattering; Escape peaks
- Semiconductor energy detectors; Multi-channel analysers

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray goniometer	09057-10	1
Multichannel analyser	13727-99	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

XR 4.0 Software measure LabVIEW (TM) driver V. 1.2

Function and Applications

Software driver package of the "measure" series for developing a control software of XR 4.0 expert Unit (X-ray unit) under LabVIEW ™ (National Instruments).

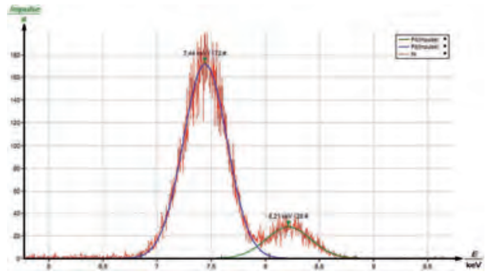
Benefits

- The package includes all neccessary drivers for the control of all functions of PHYWE's X-ray unit XR 4.0 expert unit.
- Four sample applications are included.
- The numerous possibilities of control and visualisation with LabView (™ National Instruments) can be used immediately.

14414-62

Qualitative X-ray fluorescence spectroscopy of metals – Moseley's law

P2544501



Fluorescence spectra of nickel.

Principle

Various metal samples are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi-channel analyser. The energy of the corresponding characteristic X-ray lines is determined, and the resulting Moseley diagram is used to determine the Rydberg frequency and the screening constants.

Tasks

1. Calibrate the semiconductor energy detector with the aid of the characteristic radiation of the tungsten X-ray tube.
2. Record the spectra of the fluorescence radiation that are generated by the metal samples.
3. Determine the energy values of the corresponding characteristic $K\alpha$- and $K\beta$-lines.
4. Determine the Rydberg frequency and screening constants with the aid of the resulting Moseley diagrams.

What you can learn about

- Bremsstrahlung; Characteristic X-radiation
- Absorption of X-rays; Bohr's atom model; Energy levels
- Moseley's law; Rydberg frequency; Screening constant
- Semiconductor energy detectors; Multi-channel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Multi channel analyser	13727-99	1
XR 4.0 X-ray Specimen set metals for X-ray fluorescence, set of 7	09058-31	1
measure Software multi channel analyser	14452-61	1

Related Experiments

Qualitative X-ray fluorescence analysis of alloyed materials

P2544601

Qualitative X-ray fluorescence analysis of powder samples

P2544701

Qualitative X-ray fluorescence analysis of solutions

P2544801

Qualitative X-ray fluorescence analysis of ore samples

P2544901

Best fitting XR 4.0 sets:

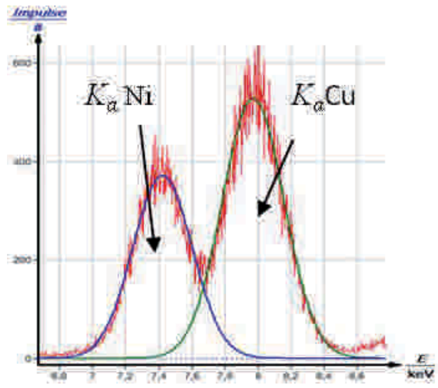
XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

P2545001 Quantitative X-ray fluorescence analysis of alloyed materials



Fluorescence spectrum of constantan, Kα-lines.

Principle

Various alloyed materials are subjected to polychromatic X-rays.

The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multichannel analyser.

The energy of the corresponding characteristic X-ray fluorescence lines is determined.

In order to determine the concentration of the alloy constituents, the intensity of their respective fluorescence signals is compared to that of the pure elements.

Tasks

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the tungsten X-ray tube.
2. Recording of the fluorescence spectra that are produced by the alloyed samples.
3. Recording of the fluorescence spectra that are produced by the pure metals.
4. Determination of the energy values of the corresponding fluorescence lines.
5. Calculation of the concentration levels of the alloy constituents.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Fluorescent yield
- Auger effect
- Coherent and incoherent photon scattering
- Absorption of X-rays
- Edge absorption
- Matrix effects
- Semiconductor energy detectors
- Multichannel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Multi channel analyser	13727-99	1
XR 4.0 X-ray Specimen set metals for fluorescence, set of 4	09058-34	1
XR 4.0 X-ray Specimen set metals for X-ray fluorescence, set of 7	09058-31	1

Related Experiment

Quantitative X-ray fluorescence analysis of solutions

P2545101

Best fitting XR 4.0 sets:

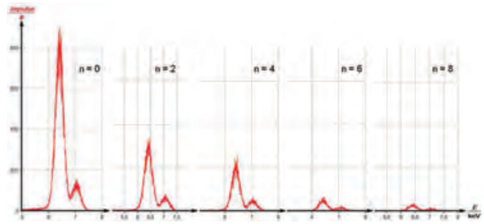
XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

X-ray fluorescence spectroscopy – layer thickness determination P2545201



Fe-fluorescence lines as a function of the number n of the pieces of aluminium foils placed on the substrate.

Principle

X-ray fluorescence analysis (XRF) is suitable for the non-contact and non-destructive thickness measurement of thin layers as well as for determining their chemical composition. For this type of measurement, the X-ray source and detector are located on the same side of the sample. When the layer on the substrate is subjected to X-rays, the radiation will penetrate the layer, if it is sufficiently thin, to a certain extent, depending on the thickness, and in turn cause characteristic fluorescence radiation in the material of the underlying substrate. On its way to the detector, this fluorescence radiation will be attenuated by absorption at the layer. The thickness of the layer can be determined based on the intensity attenuation of the fluorescence radiation of the substrate material.

Tasks

1. Calibrate the semiconductor energy detector.
2. Measure fluorescence spectrum of the iron substrate with different numbers n of pieces of aluminium foil with the same thickness placed on the substrate (including $n = 0$). Determine the intensity of the Fe-K_α fluorescence line.
3. Plot the intensity of the Fe-K_α fluorescence line as a function of the number of pieces of aluminium foil placed on the substrate in linear and semilogarithmic way.
4. Determine the intensity of the Fe-K_α fluorescence line for various numbers of pieces of aluminium foil that are fastened in front of the outlet of the tube of the energy detector.
5. Calculate the thickness of the aluminium foil.
6. Execute tasks 2 to 4 for copper foil on molybdenum or zinc substrate.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Fluorescent yield
- Auger effect
- Coherent and incoherent photon scattering
- Law of absorption
- Mass attenuation coefficient
- Saturation thickness
- Matrix effects
- Semiconductor
- Energy detectors
- Multi-channel analysers

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray Specimen set metals for X-ray fluorescence, set of 7	09058-31	1
XR 4.0 X-ray Specimen set metals for fluorescence, set of 4	09058-34	1
XR 4.0 XRED cable 50 cm	09058-32	1

Best fitting XR 4.0 sets:

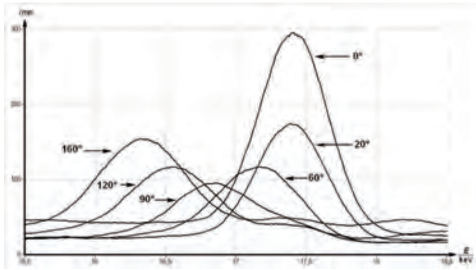
XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

P2546001 Compton effect - energy-dispersive direct measurement



Molybdenum-Kα-Line of various scattering angles theta.

Principle

Photons of the molybdenum Kα X-ray line are scattered at the quasi-free electrons of an acrylic glass cuboid. The energy of the scattered photons is determined in an angle-dependent manner with the aid of a swivelling semiconductor detector and a multi-channel analyser.

Tasks

1. Energy calibration of the multi-channel analyser with the aid of the two characteristic molybdenum X-ray lines Kα and Kβ
2. Energy determination of the photons of the Mo Kα-line that are scattered through an acrylic glass element as a function of the scattering angle.
3. Comparison of the measured energy values of the lines of scatter with the calculated energy values.
4. Calculation of the Compton wavelength of electrons and a comparison of this value with the corresponding value of the 90° scattering.

What you can learn about

- Bremsstrahlung
- Characteristic X-radiation
- Compton scattering
- Compton wavelength
- Conservation of energy and momentum
- Rest mass and rest energy of the electron
- Relativistic electron mass and energy
- Semiconductor detector
- Multichannel analyser

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 XRED cable 50 cm	09058-32	1
Multichannel analyser	13727-99	1
measure Software multi channel analyser	14452-61	1

Related Experiment

Compton scattering of X-rays

P2541701

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRM 4.0 X-ray material analysis upgrade set

09160-88

Energy-dispersive measurements of K- and L-absorption edges

P2546101

Principle

Thin powder samples are subjected to polychromatic X-rays. The energy of the radiation that passes through the samples is analysed with the aid of a semiconductor detector and a multichannel analyser. The energy of the corresponding absorption edges is determined, and the resulting Moseley diagrams are used to determine the Rydberg frequency, the screening constant, and the principal quantum numbers.

For more details refer to page 218.

Determination of the lattice constants of a monocrystal

P2546201

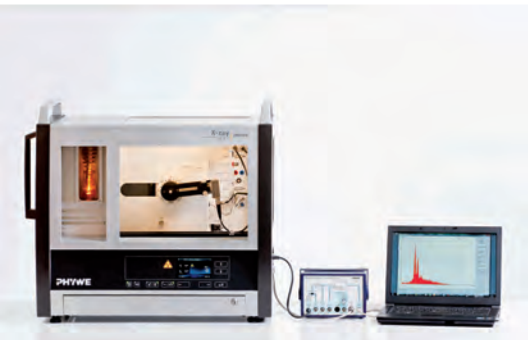
Principle

Polychromatic X-rays impinge on a monocrystal under various glancing angles. The rays are reflected by the lattice planes of the monocrystal. An energy detector is only used to measure those radiation parts that interfere constructively. The lattice constant of the crystal is determined with the aid of the various orders of diffraction and the energy of the reflected rays.

For more details refer to page 219.

Duane-Hunt displacement law

P2546301

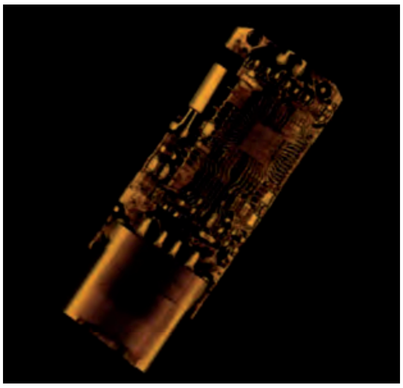


Principle

X-ray spectra of an X-ray tube are measured in an energy dispersive manner with a semiconductor detector and with various anode voltages. Duane and Hunt's law of displacement is verified with the aid of the maximum energy of the bremsspectrum.

For more details refer to page 220.

P2550100 Computed tomography



CT of an USB flash drive (movie).

Principle

The CT principle is demonstrated with the aid of simple objects. In the case of very simple targets, only a few images need to be taken in order to achieve a good result. The more complicated the objects are, the more images are necessary in order to show all the details. In addition, special samples are used to demonstrate how artefacts are generated and what causes beam hardening.

Tasks

1. Record a CT scan of the simple objects. While doing so, vary the number of steps.
2. Record a CT scan of the metal samples and analyse the result in view of beam hardening.

Related topics

- Beam hardening
- Artefacts
- Algorithms

Main articles		
XRCT 4.0 X-ray Computed Tomography upgrade set	09180-88	1
XRE 4.0 X-ray expert set	09110-88	1

Related X-ray Experiment

X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)

P2541602

Best fitting XR 4.0 sets:

XRE 4.0 X-ray expert set

09110-88

XRC 4.0 X-ray characteristics upgrade set

09130-88

EduMedia Award for Didactical Software

Allan M. Cormack (left)
Sir Godfrey Newbold Hounsfield (right)
1979, Nobel Prize in Medicine

XR 4.0 X-ray Direct Digital Image Sensor (XRIS) with USB cable

NEW

Function and Applications

Digital X-ray camera to perform X-ray imaging (radiography), and X-ray Computer Tomography (CT) experiments. Particularly suitable for experiments in lab courses and lectures in physics, medical education and material sciences.

Benefits

- Direct aquisition of the X-ray images by a direct X-ray direct digital image sensor: Experimentation under daylight conditions
- High-performance CMOS image sensors for the direct digital X-ray radiography to create superior image quality, high resolution, and large active area images based on CMOS technology.

Equipment and technical data

- Active area 5 x 5 cm^2,Resolution 48 µm,Image depth 12 bit
- USB 2.0 interface

The includes the XRIS camera and USB-cable to connect it to the PC.

09057-40

XR 4.0 X-ray CT Z-rotation stage (XRStage)

NEW

Function and Applications

Rotating tabel to position samples e.g. for the CT application.

Benefits

- Z-axis rotation of the sample to be analysed: Movement of the sample is not influenced by gravitational effects, rigid bodies of flexible size can be analysed on a simple way.

Equipment and technical data

- Angle resolution < 1 degree,Motorised
- plug&measure interface, stepper motor with 4200 steps/360°

09057-42

XR 4.0 Software measure CT

NEW

Function and application

Software package of the "measure" series for controlling the digital X-ray sensor XRIS and the X-ray unit XR 4.0. The data can be exported in all of the established formats and then evaluated with the aid of professional software. This ensures a smooth transition from training to professional application.

Advantages and features

Plug & measure:

- The intuitive user concept considerably simplifies the operation of the complex devices and puts the experiment into the focus of attention.
- Automatic identification of the connected devices of the XR 4.0 series. Working directly without the need for specialist knowledge.

Double Control:

- Simultaneous operation of the XR 4.0 X-ray unit via manual control or via a computer.

Reference experiments:

- The comprehensive collection of reference experiments and projects simplifies the selection of suitable experiments and can be used as a template for own experiment scripts/laboratory handbooks.

Clear structure:

- The software is clearly divided into the 4 basic steps: "Parameters", "CT scan", "Reconstruction", and "3D view". As a result, even beginners can easily familiarise themselves with the topic.
- Visualisation of the devices:
  In the first steps, numerous parameters must be set, e.g. the anode current and voltage. In order to facilitate these steps, the corresponding devices are displayed as virtual devices.

CT scan with live reconstruction:

- Sectional images are reconstructed during the scanning process. While at the beginning of the measurement hardly anything can be discerned, the contours become increasingly clear over time.
  Reconstruction as an independent step:
- Reconstruction is the most important process step in computed tomography. Again, numerous parameters play an important role during this step. They can be changed in their own screen and their effect can be observed directly in an example image.

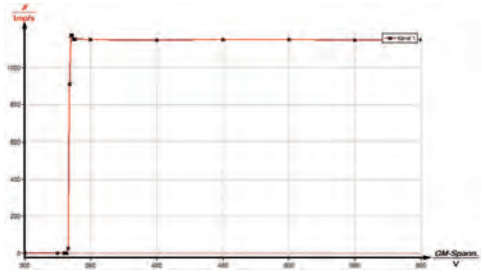
x,y,z-viewer and 3D view

- This area shows the results of the reconstruction process. The data can now be evaluated with professional software that the students will encounter in their future daily work. The data can be exported in all of the established formats.

14421-61

P2540010 Counter tube characteristics

NEW



Pulse rate as a function of the counter tube voltage.

Principle

The counter tube uses the ionising effect of high-energy radiation in order to measure the intensity of the radiation. The counter tube characteristics describe its working range, i.e. the voltage range in which it reliably counts the incoming particles.

Task

Determine the counter tube characteristics of the type B counter tube that is used.

What you can learn about

- Geiger-Mueller counter tube; Quenching gas; Characteristics; Ionising radiation

Main articles		
XR 4.0 expert unitX-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray Diaphragm tube d = 1 mm	09057-01	1
Geiger-Mueller counter tube, type B	09005-00	1
Counter tube holder on fix.magn.	09201-00	1

Best fitting XR 4.0 sets:

XRP 4.0 X-ray Solid state physics upgrade set

09120-88

XRE 4.0 X-ray expert set

09110-88

Geiger-Mueller counter tube, type B

Function and Applications

Self recovering Halogenid countertube for detection of Alpha- ,Beta- und Gamma-radiation.

Benefits

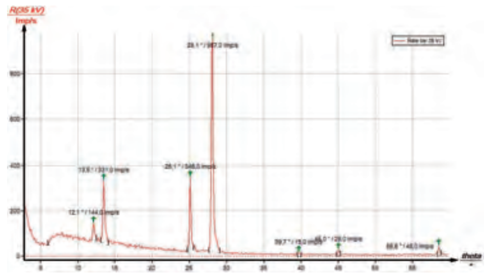
- mounted in metal cylinder with fixed 500 mm long BNC-cable
- Including protection cap for countertube

Equipment and technical data

- Mica window; Density of Mica window:2...3 mg/cm²
- Operation voltage: 500 V
- Plateau length: 200 V; Plateau slope: 0,04%/V
- Death time: approx. 100 µs
- Zero rate: approx. 15 Pulse/min
- Diameter of housing: 22 mm
- Diameter of counter tube: 15 mm
- Counter tube length: 76 mm; Mass: 103 g

09005-00

Examination of the structure of NaCl monocrystals with different orientations — P2541301



Intensity of the X-ray spectrum of copper as a function of the glancing angle theta: NaCl monocrystals with [111] crystal orientation as Bragg analyser.

Principle

The spectra of the X-rays that are reflected with various different orientations by NaCl monocrystals are analysed. The associated interplanar spacings are determined based on the Bragg angles of the characteristic lines.

Tasks

1. Determine the intensity of the X-rays that are reflected by the NaCl monocrystals with the orientations [100], [110], and [111] as a function of the Bragg angle.
2. Assign the reflections to the corresponding lattice planes that are given by way of their respective Miller indices.
3. Determine the lattice constant and calculate the interplanar spacing.
4. Determine the mass of a cell and the number of atoms in the cell.

What you can learn about

- Characteristic X-radiation
- Energy levels; Crystal structures
- Reciprocal lattices
- Miller indices
- Atomic form factor
- structure factor
- Bragg scattering

Main articles		
XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray NaCl-monocrystals, set of 3	09058-01	1
XR 4.0 Software measure X-ray	14414-61	1
XR 4.0 X-ray Univ. crystal holder f.x-ray-unit	09058-02	1
XR 4.0 X-ray Diaphragm tube d = 2 mm	09057-02	1

XR 4.0 X-ray goniometer

Function and Applications

Goniometer with two independent stepper motors for the precise angular positioning of a sample and detector.

Benefits

Self-calibrating goniometer
Plug & measure:

- Automatic identification of the goniometer
- Goniometer block with two independent stepper motors for rotating the sample holder and the detector either separately or coupled in a 2:1 ratio
- The detector holder with a slit diaphragm holder for absorption foils can be moved in order to change the angular resolution
- Includes a light barrier system for limiting the permissible swivelling range and, thereby, for protecting the detectors
- Intuitive operation directly at the unit or via a PC

Equipment and technical data

- Angular increment: 0.1°...10°; Rate: 0.5...100 s/increment
- Sample rotation range: 0...360°
- Detector rotation range: -10°...+170°
- Dimensions (cm): 35 x 30 x 20; Mass (kg): 5

09057-10

TESS expert Physics Handbook X-Ray Experiments

47 experiments with X-rays and their use in physics, chemistry, biology, medicine, material science, and geology.

Description

Comprehensive collection of reference experiments concerning the fundamental principles and use of X-rays in physics, chemistry, biology, medicine, material science and geology with the XR 4.0 X-ray unit platform as a pool of ideas concerning the potential areas of application in demonstration and laboratory experiments. A clear matrix simplifies the orientation in terms of scientific fields and topics.

Topics

Characteristic X-radiation / atomic structure / quantum physics and chemistry, X-ray absorption, Compton scattering, Dosimetry, Crystal structures/structural analysis with X-rays/Debye-Scherrer experiments (counting tube goniometer), Transirradiation experiments/non-destructive testing

Features

Experiment descriptions with clearly structured learning objectives, fundamental principles, photo of the set-up, equipment list, tasks, illustrated instructions concerning the set-up and procedure, theory and evaluation with example results plus important notes concerning the operation and safety of the equipment. This simplifies the orientation and execution as well as the selection of the experiment parts for personalised laboratory experiments. The information provided is so comprehensive that no other background information is required. , For every experiment, the software package "XRM 4.0 measure X-ray" includes presettings for the easy and direct execution of the experiment at the push of a button as well as numerous example measurements., Experiment matrix for quick orientation, Operating instructions concerning the components of the XR 4.0 platform including detailed information, DIN A4 format, spiral-bound, colour print, 377 pages

01200-02

TESS expert Handbook Computed Tomography (XRCT 4.0)

10 detailed experiments with x-rays and computed tomography.

Description

Comprehensive collection of reference experiments concerning the fundamental principles and use of X-rays and computed tomography in physics, medicine, and material science with the XR 4.0 X-ray unit platform and the XRCT 4.0 Computed tomogrphy upgtrade set as a pool of ideas concerning the potential areas of application in demonstration and laboratory experiments. A clear matrix simplifies the orientation in terms of scientific fields and topics.

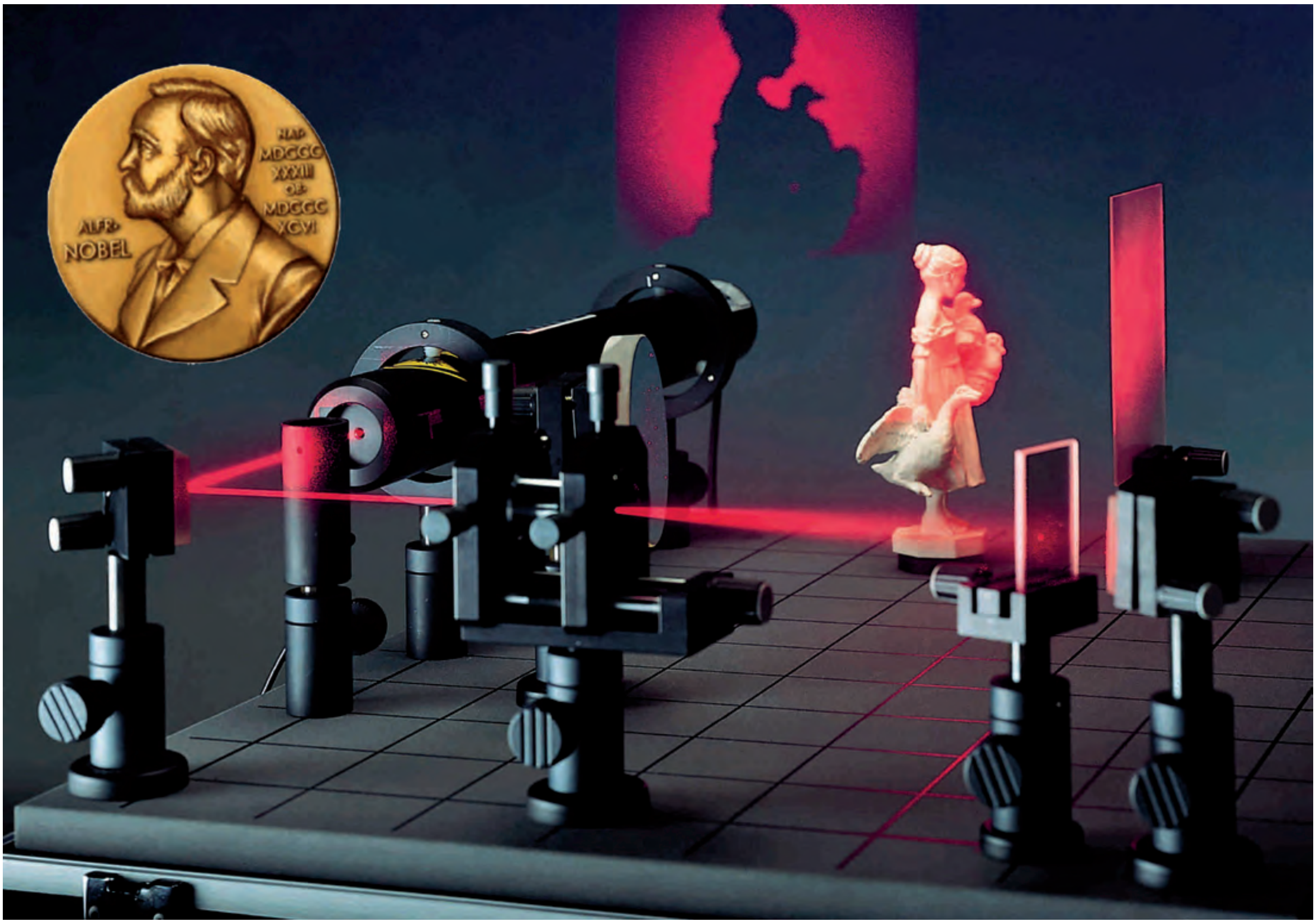
Topics

Fundamental principles
The detailed and target-group-specific experiment descriptions and instructions cover the following topics, among others: reconstruction of 3D images from two-dimensional images, effects of filters, cause of artefacts, and limits of the method., Medicine
In order to prepare students of medicine optimally for their professional practice, standard samples with different core themes are offered. E.g. use of the Hounsfield scale, diagnostics with the aid of computed tomography is supported., Materials science/engineering
Computed tomography is widely used in engineering and materials science applications, in particular in the field of NDT.

Features

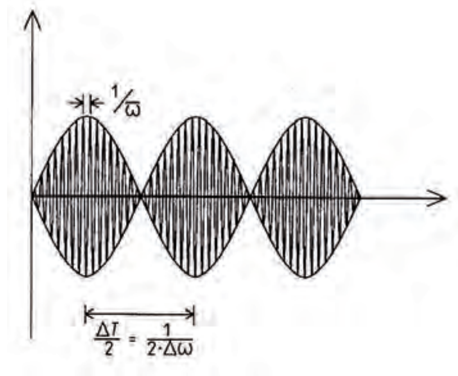
Experiment descriptions with clearly structured learning objectives, fundamental principles, photo of the set-up, equipment list, tasks, illustrated instructions concerning the set-up and procedure, theory and evaluation with example results plus important notes concerning the operation and safety of the equipment. This simplifies the orientation and execution as well as the selection of the experiment parts for personalised laboratory experiments. The information provided is so comprehensive that no other background information is required. , For every experiment, the software package "XRCT 4.0 measure CT" includes presettings for the easy and direct execution of the experiment at the push of a button as well as numerous example measurements., DIN A4 format, spiral-bound, colour print, 130 pages

01205-02



Laser Physics - Photonics

P2221000 Doppler effect with the Michelson interferometer



Resulting difference signal during interferometric measurement.

Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alteration in the interference pattern is observed and the modulatione frequency is measured using the Doppler effect.

Tasks

1. Construction of a Michelson interferometer using seperate components.
2. Measurement of the Doppler effectvia uniform displacement of one ofthe mirrors.

What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Temporal coherence
- Special relativity theroy
- Lorentz transformation

Main articles		
Recorder, tY, 2 channel	11415-95	1
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Interferometerplate w prec.drive	08715-00	1
Optical base plate with rubberfeet	08700-00	1
Light barrier with counter	11207-30	1
Power supply 0...12 V DC/ 6 V, 12 V AC, 230 V	13505-93	1

Light barrier with counter

Function and Applications

With the function of an electronic time measuring and counting device.

Benefits

- 4 figureluminous display, selection switch for 4 operating modes
- RESET key, BNC jack for exterior starting and/ or stopping of time measurement, TTL output to control peripheral devices
- power supply connector (4 mm jacks)

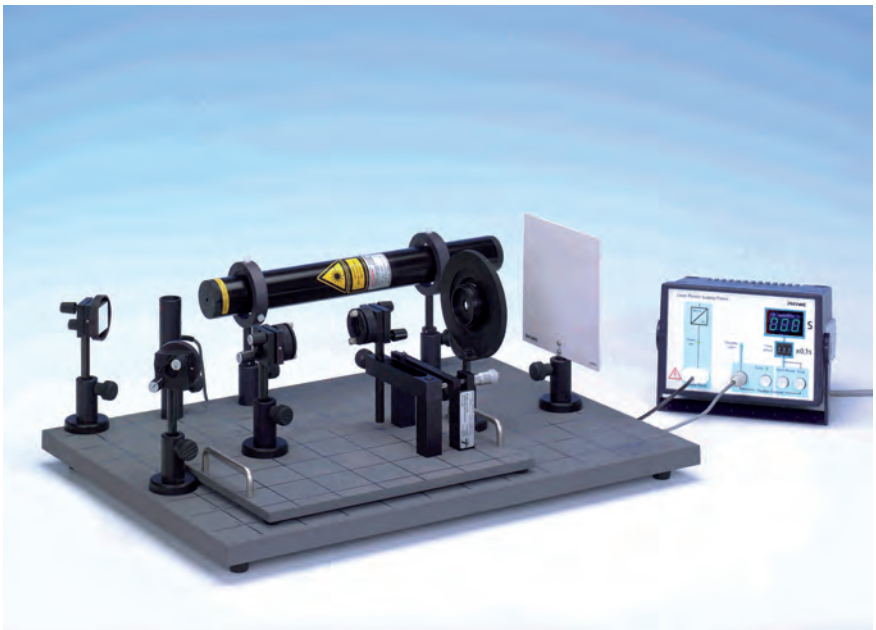
Equipment and technical data

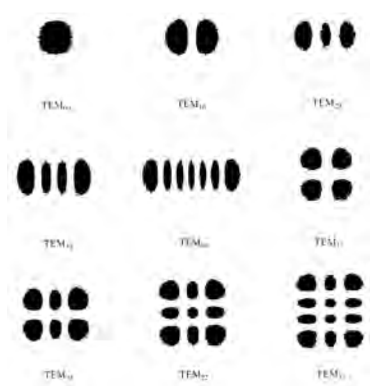
- Fork width: 70 mm, Usable barrier depth: 65 mm
- Sensitivity adjustable, LED-Display: 4digits, 8 mm
- Time measurement: 0...9,999 s, Counting: 0...9999
- Supply voltage: 5 V DC, Max. working frequency: 25 kHz
- External dimensions (mm): 160 x 25 x 105M6
- Threaded holes in casing: 7, Stem included: 100 mm, M6 thread

11207-30

Fabry-Perot interferometer - optical resonator modes

P2221206





Intensity distribution of the Hermitian-Gaussian resonator modes.

Principle

Two mirrors are assembled to form a Fabry-Pert Interferometer. Using them, the multibeam interference of a laser's light beam is investigated. On moving one of the mirrors, the change in the intensity distribution of the interference pattern is studied. This is a qualitative experiment, to study the shape of different lasermodes and compare it with some photos given in this desciption.

Tasks

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometeris used to observe different resonator modeswithin the interferometer.

What you can learn about

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Two-beam interferometer

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Concave mirror OC;r=1.4m,T=1.7%	08711-03	1
Interferometerplate w prec.drive	08715-00	1
Plane mirror HR>99%,mounted	08711-02	1
Optical base plate with rubberfeet	08700-00	1
Adjusting support 35 x 35 mm	08711-00	4

Power supply for laser head 5 mW

Function and Applications

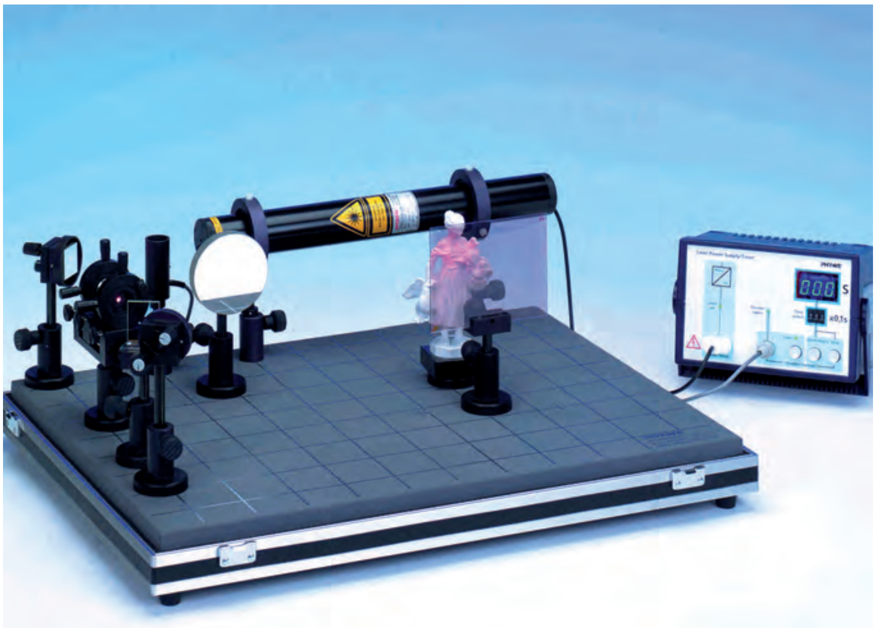
High voltage power supply for lasers, e. g. the 5 mW laser (08701-00).

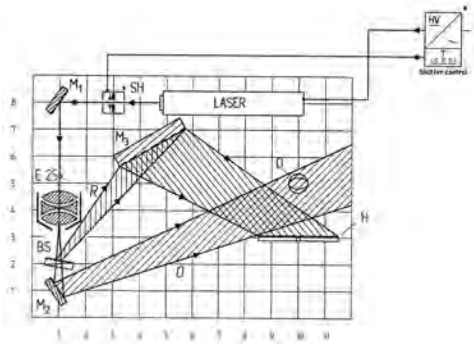
Equipment and technical data

- With programmable timer for selection of exposure time of holograms between 0.1 ... 99 s.
- With a controllable shutter.
- Digital display for preset shutter times as well as those which have already occured.
- Shutter control via time select, new start, stop and shutter open (permanent open).
- Dimensions of plastic housing (mm): 184 x 140 x 130.
- Incl. shutter with fixed connection cord with unit plug on holding rod.
- Rod diameter: 10 mm.

08702-93

P2260300 Recording and reconstruction of holograms with optical base plate





Setup for recording and reconstruction of a transmission hologram.

Principle

In contrast to normal photography a hologram can store information about the three-dimensionality of an object. To capture the three-dimensionality of an object, the film stores not only the amplitude but also the phase of the light rays. To achieve this, a coherent light beam (laser light) is split into an object and a reference beam by being passed through a beam splitter. These beams interfere in the plane of the holographic film. The hologram is reconstructed with the reference beam which was also used to record the hologram.

Tasks

1. Record a laser light hologram and process it to get a phase hologram. Reconstruct it by verifying the virtual and the real image.
2. Record a white light reflectionhologram and process it to get a phase hologram. Laminate it for reconstruction by a white light source.

What you can learn about

- Object beam; Reference beam; Real and virtual image
- Phase holograms; Amplitude holograms; Interference
- Diffraction; Coherence; Developing of film

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Optical base plate in exp.case	08700-01	1
Surface mirror,large, d=80 mm	08712-00	1
Holographic plates, 25 pieces	08746-00	1
Sliding device, horizontal	08713-00	1
Darkroom equipment for holography, 230 V	08747-88	1

Related Experiments

Transfer hologram from a master hologram

P2260305

Holography - Real time procedure (bending of a plate)

P2260306

Advanced Optics, Holography package incl. manual, 230 V

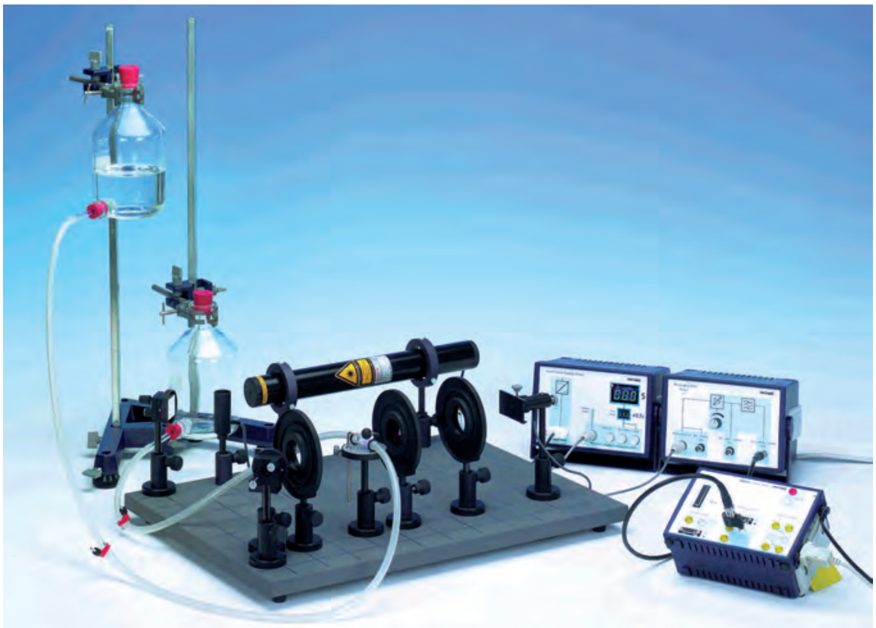
Function and Applications

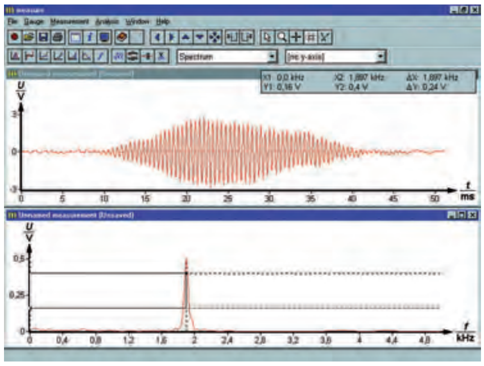
A complete set to perform the following experiments using the experimental system "Advanced Optics" incl. handbook "Holography" with 11 described experiments: white light holography, transmission holography, transfer a hologram from a masterhologram.

With the aid of a base plate and magnetic adhering holders, which can be positioned jolt-free, 1- and 2-dimensional setups can be quickly and reliably realised. By folding the lightpaths experiments with larger focal distances can be carried out on the working base.

08700-55

LDA - laser Doppler anemometry with optical base plate P2260511





Measurement of the signal spectrum with a signal peak

Principle

Small particles in a current pass through the LDA measuring volume and scatter the light whose frequency is shifted by the Doppler effect due to the particle movement. The frequency change of the scattered light is detected and converted into a particle or flow velocity.

Task

Measurement of the light-frequency change of individual light beams which are reflected by moving particles.

What you can learn about

- Interference
- Doppler effect
- Scattering of light by small particles (Mie scattering)
- High- and low-pass filters
- Sampling theorem
- Spectral power density
- Turbulence

Main articles		
He/Ne Laser, 5mW with holder	08701-00	1
Power supply for laser head 5 mW	08702-93	1
Cobra3 BASIC-UNIT, USB	12150-50	1
Si-Photodetector with Amplifier	08735-00	1
Optical base plate with rubberfeet	08700-00	1
Sliding device, horizontal	08713-00	1
LDA-Accessory-Set	08740-00	1

Control Unit for Si-Photodetector

Function and Applications

Amplifier for silicon photodetector

Equipment and technical data

- 3 BNC outputs:
  Output 1 (monitor output), gain 1, bandwidth for DC ... 60 kHz
  Output 2 , gain 1 ... 100, band width for AC 10 Hz ... 60 kHz
  Output 3 (filter output), gain 1 ... 100, band width for AC 200 Hz ...10 kHz
- Input: 5-pole diode socket for silicon photodetector
- Connections +9 V ... +12 V, Power consumption 1 W
- Impact-resistant plastic case (194 x 140 x 130) mm with carrying handle, Includes 110-V/240-V power supply

08735-99

Si-Photodetector with Amplifier

Function and Applications

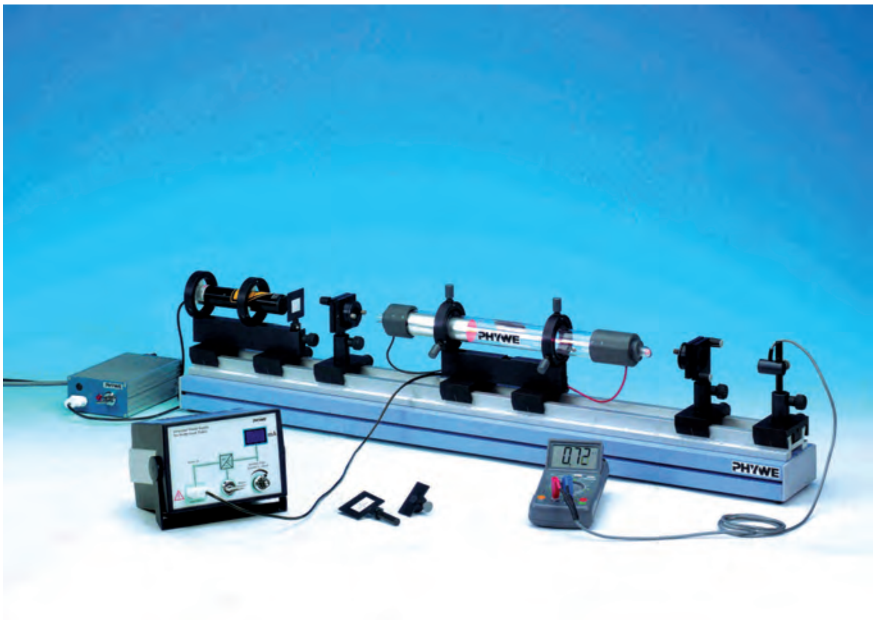
Silicon diode with high signal-to-noise ratio for photometric measurements where there is a high degree of interference.

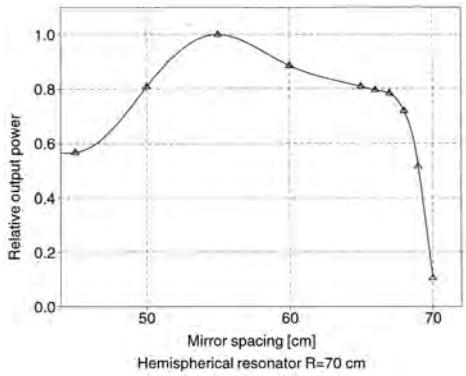
Equipment and technical data

- Movable holder for diode on round mounting rod with lens for incoming light, Removable slot filter, 1.5/m lead with diode plug for connecting to the required control unit.

08735-00

P2260701 Helium neon laser, basic set





Relative output power as a function of mirror spacing.

Principle

The difference between spontaneous and stimulated emission of light is demonstrated. The beam propagation within the resonator cavity of a He- Ne laser and its divergence are determined, its stability criterion is checked and the relative output power of the laser is measured as a function of the tube's position inside the resonator and of the tube current. The following items can be realized with advanced set 08656.02. By means of a birefringent tuner and a Littrow prism different wavelengths can be selected and quantitatively determined if a monochromator is available. Finally you can demonstrate the existence of longitudinal modes and the gain profile of the He-Ne laser provided an analysing Fabry Perot system is at your disposal.

Tasks

1. Set up the He-Ne laser. Adjust the resonator mirrors by use of the pilotlaser. (left mirror: VIS, HR, plane; right mirror: VIS, HR, R = 700 mm)
2. Check on the stability condition of a hemispherical resonator.
3. Measure the integral relative output power as a function of the laser tube's position within the hemispherical resonator.
4. Measure the beam diameter within the hemispherical resonator right and left of the laser tube.
5. Determine the divergence of the laser beam.
6. Measure the integral relative output power as a function of the tube current.

What you can learn about

- Spontaneous and stimulated light emission; Inversion
- Collision of second type; Gas discharge tube; Resonator cavity
- Transverse and longitudinal resonator modes
- Birefringence; Brewster angle
- Littrow prism; Fabry Perot Etalon

Main articles

Exp.Set-Helium-Neon Laser	08656-93	1
Sliding device, horizontal	08713-00	1
Protection glasses HeNe-laser	08581-10	1
Photoelement f. opt. base plt.	08734-00	1
Cleaning set for laser	08582-00	1
DMM, auto range, NiCr-Ni thermocouple	07123-00	1
Diffraction grating, 600 lines/mm	08546-00	1

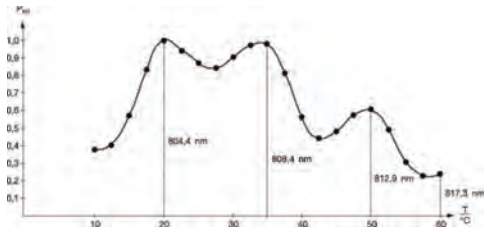
Related Experiment

Helium neon laser, advanced set

P2260705

Optical pumping

P2260800



Relative fluorescent power of the Nd-YAG rod as a function of the diode temperature (wavelength) for I = 450 mA.

Principle

The visible light of a semiconductor diode laser is used to excite the neodymium atoms within a Nd-YAG (NeodymiumYttrium Aluminium Garnet) rod.

The power output of the semiconductor diode laser is first recorded as a function of the injection current.

The fluorescent spectrum of the Nd-YAG rod is then determined and the maon absorption lines of the Nd-atoms are verified.

Conclusively, the mean life-time of the4F3/2-level of the Nd-atoms is measured in approximation.

Tasks

1. To determine the power output of the semiconductor diode laser as a function of the injection current.
2. To trace the fluorescent spectrum of the Nd-YAG rod pumped by the diode laser and to verify the main absorption lines of neodymium.
3. To measure the mean life-time of the 4F3/2-level of the Nd-atoms.
4. For further applications see experiment 2.6.09 "Nd-YAG laser" (P2260900).

What you can learn about

- Spontaneous emission
- Induced emission
- Mean lifetime of a metastable state
- Relaxation
- Inversion
- Diode laser

Main articles		
Basic set optical pumping	08590-93	1
Sensor f. measurem. of beam power	08595-00	1
30 MHz digital storage oscilloscope with colour display, 2 x BNC cables l =75 cm incl.	11462-99	1
Protection glasses for Nd:Yag laser	08581-20	1
Digital multimeter 2010	07128-00	1
Screened cable, BNC, l 750 mm	07542-11	3

Basic set optical pumping

Function and applications

The light from a lasersiode is used to excite neodymium atoms in a Nd:YAG crystal.

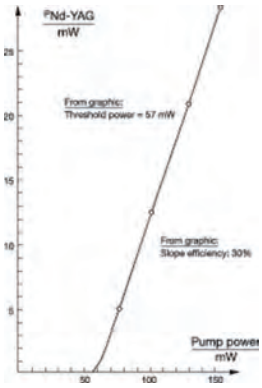
Benefits

- The power emitted by the laser diode can be measured as a function of the supply current.
- The fluorescence spectrum of the Nd:YAG crystal is analysed and the main absorption lines of the Nd-Atoms are verified.
- Finally the half-life of the 4F3/2-level is estimated.
- With only a small number of additional components it is possible to build a Nd:YAG laser with this system.

08590-93

P2260900 Nd:YAG laser

Demo



Nd-YAG laser power output as a function of the pump power = 808.4 nm.

Principle

The rate equation model for an optically pumped four-level laser system is determined. As lasing medium, a Nd:YAG (Neodymium-Yttrium Aluminium Garnet) rod has been selected which is pumped by means of a semiconductor diode laser.

The IR-power output of the Nd:YAG laser is measured as a function of the optical power input and the slope efficiency as well as the threshold power are determined.

Finally, a KTP-crystal is inserted into the laser cavity and frequency doubling is demonstrated. The quadratic relationship between the power of the fundamental wave and the beam power for the second harmonic is then evident.

Tasks

1. Set up the Nd:YAG laser and optimise its power output.
2. The IR-power output of the Nd:YAG laser is to be measured as a function of the pump power. The slope efficiency and the threshold power are to be determined.
3. Verify the quadratic relationship between the power of the fundamental wave, with lambda = 1064 nm, and the beam power of the second harmonic with lambda = 532 nm.

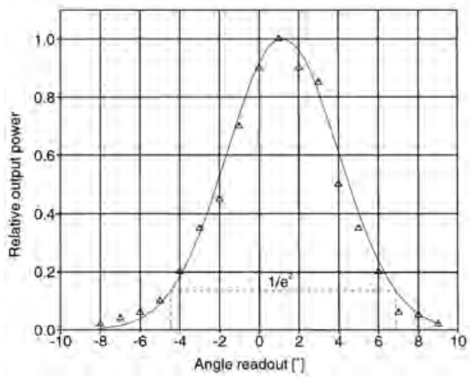
What you can learn about

- Optical pumping
- Spontaneous emission
- Induced emission
- Inversion
- Relaxation
- Optical resonator
- Resonator modes
- Polarization
- Frequency doubling

Main articles		
Basic set optical pumping	08590-93	1
Frequ. doubling crystal in holder	08593-00	1
Nd-YAG laser cavity mirror/holder	08591-01	1
Laser cav.mirror frequ. doubling	08591-02	1
Sensor f. measurem. of beam power	08595-00	1
30 MHz digital storage oscilloscope	11462-99	1
Protection glasses for Nd:Yag laser	08581-20	1

Fibre optics

P2261000



Relative output power at the fibre end versus angle readout.

Principle

The beam of a laser diode is treated in a way that it can be coupled into a monomode fibre. The problems related to coupling the beam into the fibre are evaluated and verified. In consequence a low frequency signal is transmitted through the fibre. The numerical aperture of the fibre is recorded. The transit time of light through the fibre is measured and the velocity of light within the fibre is determined. Finally the measurement of the relative output power of the diode laser as a function of the supply current leads to the characteristics of the diode laser such as "threshold energy" and "slope efficiency".

Tasks

1. Couple the laser beam into the fibre and adjust the setting-up in a way that a maximum of output power is achieved at the exit of the fibre.
2. Demonstrate the transmission of a LF-signal through the fibre.
3. Measure the numerical aperture of the fibre.
4. Measure the transit time of light through the fibre and determine the velocity of light within the fibre.
5. Determine the relative output power of the diode laser as a function of the supply current.

What you can learn about

- Total reflection; Diode laser
- Gaussian beam
- Monomode and multimode fibre
- Numerical aperture
- Transverse and longitudinal modes
- Transit time; Threshold energy
- Slope efficiency; Velocity of light

Main articles		
Experimental set Fibre optics	08662-93	1
Digital Storage Oszilloscope 200 MHz	11453-99	1
Screened cable, BNC, l 750 mm	07542-11	2

Charles K. Kao

2009, Nobel Prize in Physics

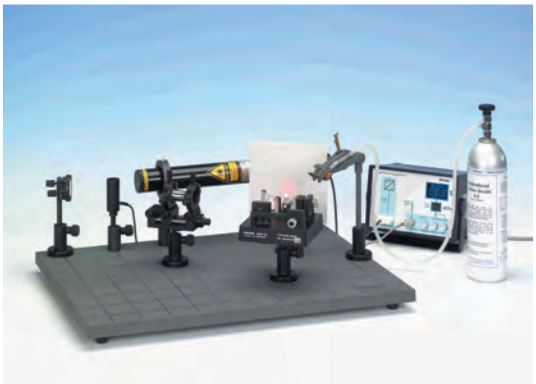
Coherence and width of spectral lines with the Michelson interferometer P2220600

Principle

The wavelengths and the corresponding lengths of coherence of the green spectral lines of an extreme high pressure Hg vapour lamp are determined by means of a Michelson interferometer. Different double slit combinations are illuminated to verify the coherence conditions of non punctual light sources. An illuminated auxiliary adjustable slit acts as a non punctual light source.

For more details refer to page 161.

Refraction index of CO2 with the Michelson interferometer P2220705



Principle

Light is caused to interfere by means of a beam splitter and two mirrors according to Michelson's set up. Substituting the air in a measurement cuvette located in one of the interferometer arms by CO_2 gas allows to determine the index of refraction of CO_2.

For more details refer to page 162.

Quantum eraser P2220800

Principle

A Mach-Zehnder-interferometer is illuminated with a laser beam. Circular interference fringes appear on the screens behind the interferometer. If polarisation filters with opposite polarisation planes are placed in the two interferometer paths the interference patterns disappear. Placing another polariser before one of the screens causes the pattern to reappear. Electromagnetic radiation can be described both in terms of propagating waves, as well as particles (photons). The experiment illustrates this duality by showing how interference patterns can be explained on the basis of both classical wave mechanics and quantum physics.

For more details refer to page 180.

Michelson interferometer - High Resolution P2220900

Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. While moving one of the mirrors, the alterationin the interference pattern is observed and the wave length of the laser light determined.

For more details refer to page 163.

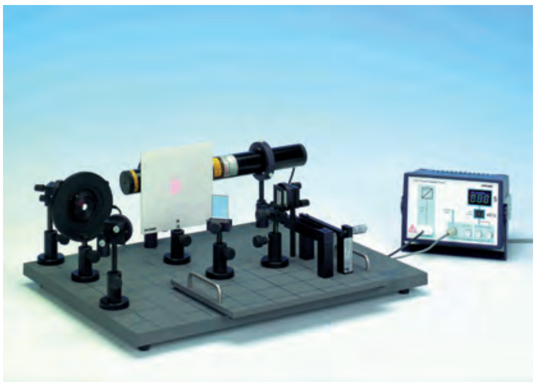
Refraction index of air with the Mach-Zehnder interferometer with optical base plate P2221100

Principle

Light is brought to interference by two mirrors and two beam splitters in the Mach-Zehnder arrangement. By changing the pressure in a measuring cell located in the beam path, one can deduce the refraction index of air.

For more details refer to page 164.

Fabry-Perot interferometer - determination of the wavelength of laser light P2221205



Principle

Two mirrors are assembled to form a Fabry-Perot interferometer. Using them, the multibeam interference of a laser's light beam is investigated. By moving one of the mirrors, the change in the interference pattern is studied and the wavelength of the laser's light determined.

For more details refer to page 165.

Polarisation through quarter-wave plates

P2250105

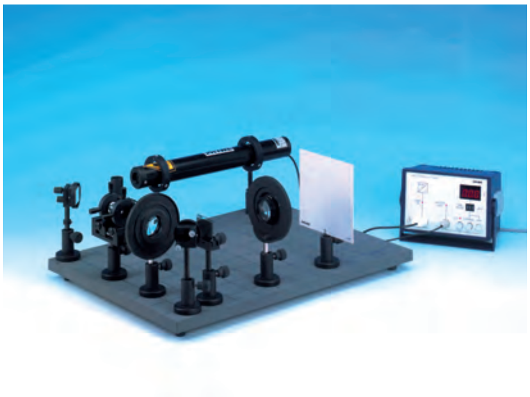
Principle

Monochromatic light impinges on amica plate, perpenicularly to its optical axis. If the thickness of the plate is adequate (lambda/4 plate), a phase shift of 90° occurs between the ordinary and the extraordinary beam when the latter leaves the crystal.The polarisation of exiting light is examined for different angles between the optical axis of the lambda/4 plate and the direction of polarisation of incident light.

For more details refer to page 174.

Fourier optics – 2f arrangement

P2261100



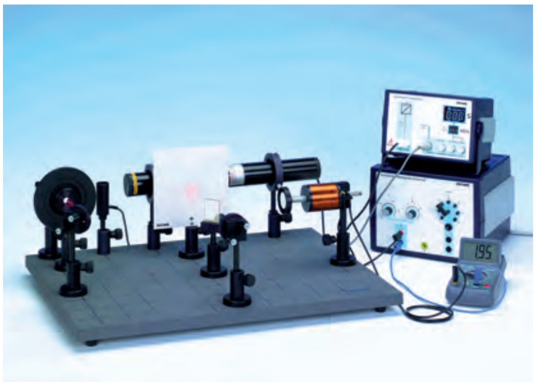
Principle

The electric field distribution of light in a specific plane (object plane) is Fourier transformed into the 2 f configuration.

For more details refer to page 171.

Magnetostriction with the Michelson interferometer

P2430800



Principle

With the aid of two mirrors in a Michelson arrangement, light is brought to interference. Due to the magnetostrictive effect, one of the mirrors is shifted by variation in the magnetic field applied to a sample, and the change in the interference pattern is observed.

For more details refer to pages 146, 208.

Further Demonstration Equipment

Demo Sets Physics and Applied Sciences

Benefits

- complete equipment set: simple execution of the experiments
- the equipment is stored in a robust aluminum case with removable lid
- foam insert for a quick control of completeness and secure transport of the set
- experimenting literature for all demonstration experiments are delivered as PDF documents on a DVD
- matched with international Curriculum: all topics are covered
- easy teaching by using the demo board for demonstration

Equipment and technical data

- the equipment set consists of all necessary components for the experiments
- robust storage case with foam insert fitting to the contained equipment

Demo Set Physics Mechanics 1	**15510-88**
Demo Set Physics Mechanics 2	**15511-88**
Demo Set Physics Thermodynamics	**15530-88**
Demo Set Physics Optics	**15550-88**
Demo Set Physics Electricity/Electronics, Electricity	**15570-88**
Demo Set Physics Electricity/Electronics, Electromagnetism and Induction	**15571-88**
Demo Set Physics Electricity/Electronics, Electronics	**15572-88**
Demo Set Applied Sciences Renewable Energy, Basics and Thermal Energy	**15580-88**
Demo Set Applied Sciences Renewable Energy Solar cells, Wind energy, Hydropower	**15581-88**
Demo Set Applied Sciences Renewable Energy, Fuel Cells	**15582-88**
Demo Set Physics Radioactivity	**15590-88**

Magnetic Demonstration Boards

Benefits

- Boards to be used on both sides, one side plain, the other side for optics experiments covered with a white plastic coating with grid lines.

Equipment and technical data

- Dimensions of the boards (mm): 600 × 1000 / 450 × 600

Demo board with stand	**02150-00**
Demo board with stand, small	**02149-00**

Manuals Magnetic Demonstration Board

Description

Instructions for experiments using the magnetic demonstration boards:

- Mechanics 49 experiments
- Heat 15 experiments
- Electricity 96 experiments
- Optics 60 experiments
- Radioactivity 19 experiments
- Renewable Energy 34 experiments

Manual Magnet Board Mechanics, 1	**01152-02**
Manual Magnet Board Mechanics, 2	**01153-02**
Manual Magnet Board Heat	**01154-02**
Manual Magnet Board Electricity	**01005-02**
Manual Magnet Board Optics	**01151-02**
Manual Magnet Board Radioactivity	**01156-02**
Manual Magnet Board Renewable Energy	**01157-02**

Clear explanation.
Demonstrations system for teaching

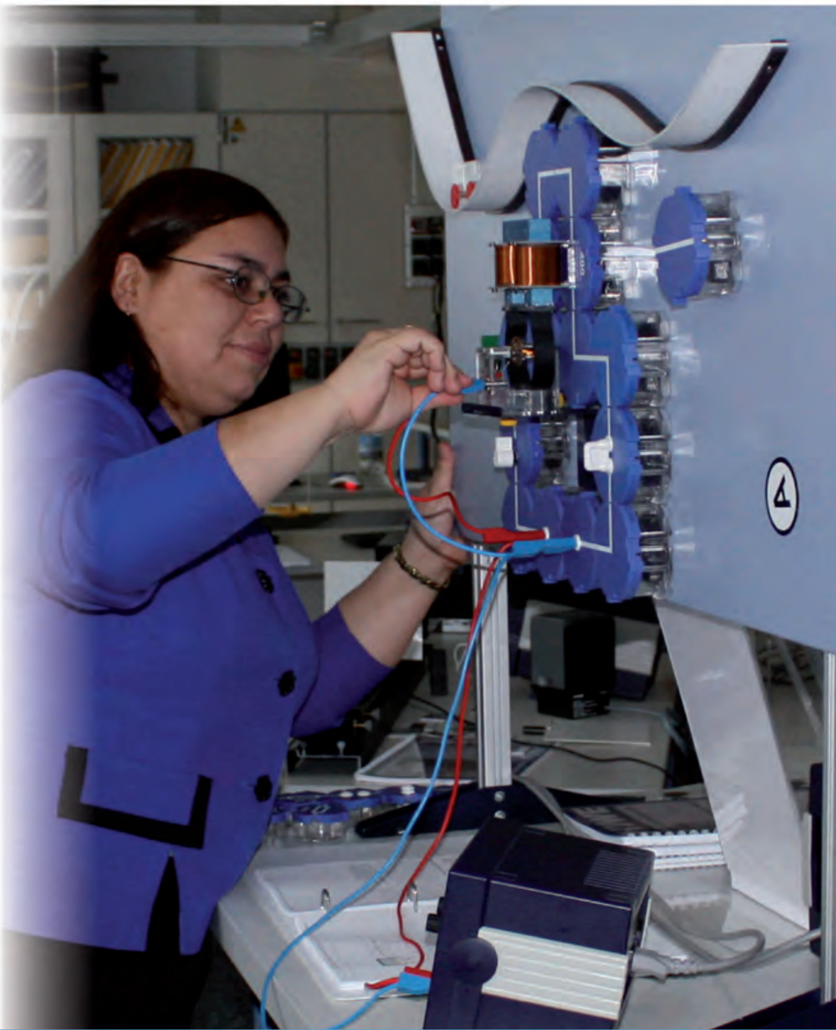
Demo | PHYWE

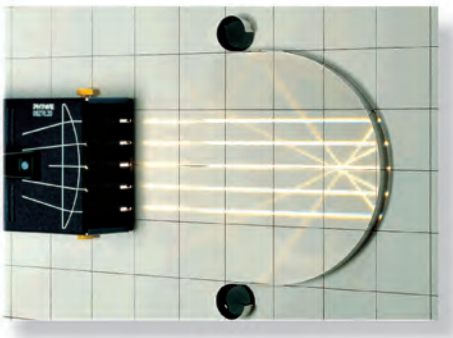
Additional to our TESS expert experiments, there are also our demonstration sets for teachers and lecturers. The innovative system opens up new dimensions for science classes and lecture halls. The particularly useful double-board system shifts the experiments from the horizontal to the vertical and convinces with unlimited possible set-ups, flexible positioning, and ease of installation.

The basis of these experiments is an extensive collection comprising the experiment literature, equipment collection, and storage system.

Your advantages at a glance

- Minimum preparation time
- Clearly visible demonstration experiments
- Easy set-up and trouble-free changing of experiments
- Customised to your needs





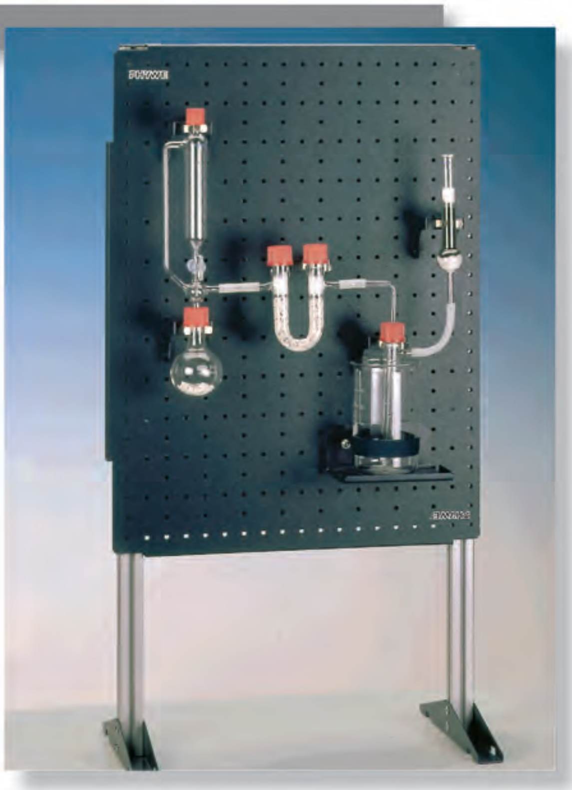
Two board systems
one idea in common

Demo PHYWE

Physics board system

- double-sided board for all physical fields: one-colour coated side, optics side with a white film and grid pattern
- quick positioning and modification of the experiment set-ups by way of magnetic holders

Chemistry board system



- frame with a hole matrix plate for the secure fastening of equipment with special holders with hooks or with magnetic holders
- easy exchange of hole matrix plates with complete experiment set-ups

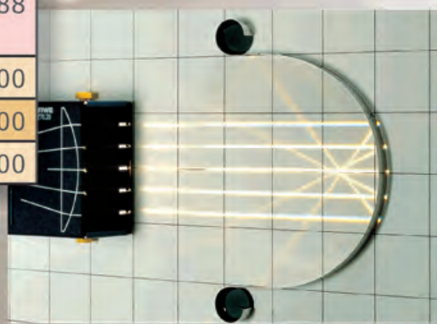
One idea in common

- vertical, clear set-up
- flexible positioning
- easy installation
- minimum preparation time

All of the Demo sets at a glance

Demo PHYWE

Demo sets	
Demo set physics mechanics on the magnetic board MT1, basic set	15510-88
Demo set physics mechanics on the magnetic board MT2, supplementary set	15511-88
Demo set physics thermodynamics on the magnetic board WT, complete set	15530-88
Demo set physics optics on the magnetic board OT, complete set	15550-88
Demo set physics radioactivity on the magnetic board RT, complete set	15590-88
Demo set physics electricity/electronics on the magnetic board ET-BS, basic set	15570-88
Demo set physics electricity/electronics on the magnetic board ET-IND, supplementary set electromagnetism and induction	15571-88
Demo set physics electricity/electronics on the magnetic board ET-TRO, supplementary set electronics	15572-88
Demo set applied sciences renewable energy ENT-BS, basic set	15580-88
Demo set applied sciences renewable energy ENT-SW, supplementary set solar, water, wind	15581-88
Demo applied sciences renewable energy ENT-FC, supplementary set fuel cell technology	15582-88
Cobra4 wireless, extension set for renewable energy: electrical parameters, temperature	12608-88
Complete experiments, chemistry/biotechnology, basic set	45560-00
Complete experiments, chemistry/biotechnology, comfort set	45561-00
Complete experiments, chemistry/biotechnology, holder set	45562-00



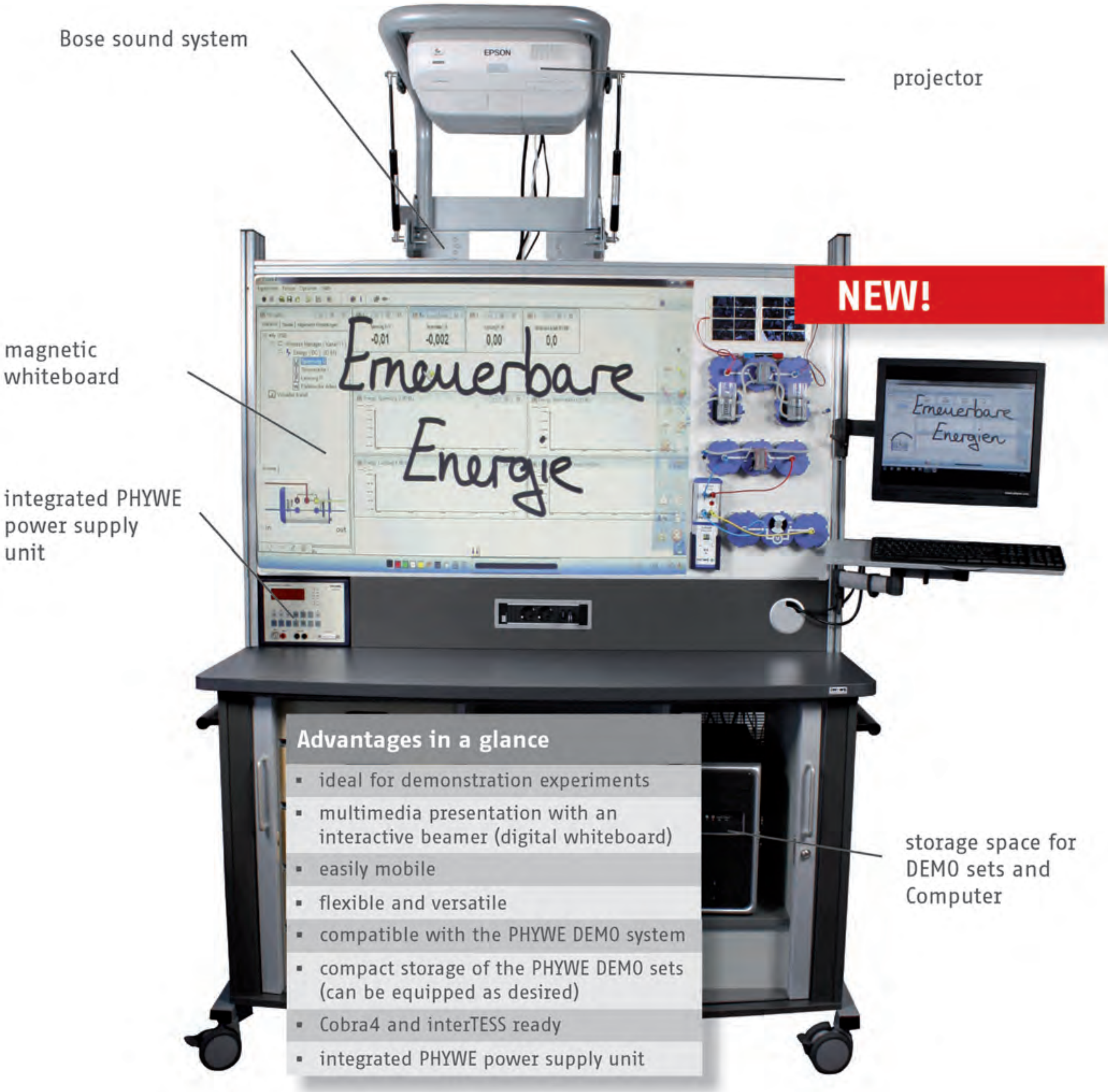
Further information available just one click away – www.phywe.com

WEB@ PHYWE

Multimedia Demo Lab

Demo | PHYWE

Demonstration experiments in every room



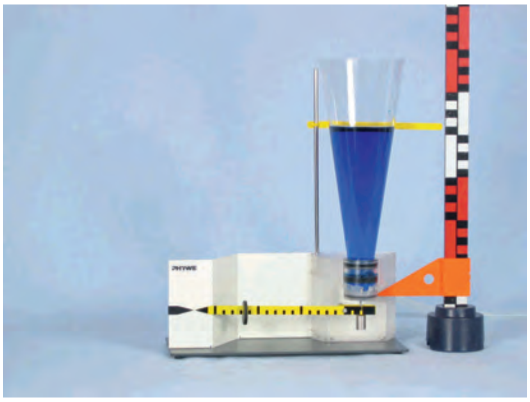
Advantages in a glance

- ideal for demonstration experiments
- multimedia presentation with an interactive beamer (digital whiteboard)
- easily mobile
- flexible and versatile
- compatible with the PHYWE DEMO system
- compact storage of the PHYWE DEMO sets (can be equipped as desired)
- Cobra4 and interTESS ready
- integrated PHYWE power supply unit

NEW: The Mobile Demo Lab. **Transform any room into a science laboratory**	**02190-93**

Hydrostatic pressure measurement

P1423200



Principle

Hydrostatic pressure in a fluid depends only on the height and not on the shape of the container.

Different containers can be placed on the Pascal's vase apparatus. In each case, the pressure on the bottom is transferred to a pointer.

For more details refer to www.phywe.com

Emmission capacity of hot bodies (Leslie cube)

P0454351

Principle

Each object emits heat radiation. Its intensity depends on the temperature of the object and its surface properties.
For a given temperature, emission of heat radiation for an object with higher absorption factor is higher than for one of lower absorption factor.
Emitted radiation of a cube of constant temperature is measured. The sides of the cube have different surface properties. To measure heat radiation, a thermopile and a measuring amplifier is used.

For more details refer to www.phywe.com

Barkhausen effect, Weiss domains

P0613800

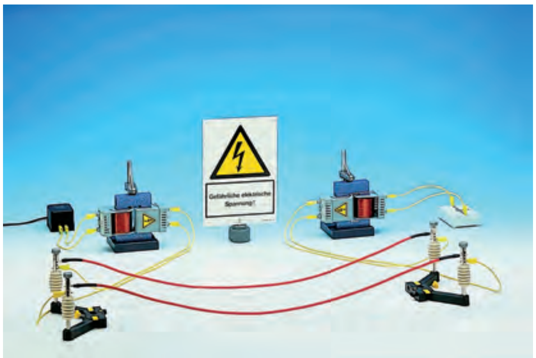
Principle

When a sample of iron or nickel is gradually magnetised, the stronger magnetism is not assumed throughout the volume of the metal all at once. Specific areas (Weiss domains) spontaneously change alignments at various times. Every time an alignment changes, a voltage is induced, which can be detected using a loudspeaker or an oscilloscope.

For more details refer to www.phywe.com

Model of a high voltage long distance line

P0506300



Demo

Principle

When electrical energy is transmitted over long distances, it is unavoidable that there will be losses due to resistance in the lines. Using transformer stations and high-voltage transmission lines can drastically reduce such losses. To model such lines, two wires of 1 m in length and total resistance of 100 ohms are connected to a 6-V/0.5-A light bulb and an AC voltage of 6 V is transmitted along them. Under these circumstances the lamp does not light. However, if two step transformers are set-up as transformer stations to increase the voltage in the simulated transmission lines to 1000 V and then convert it back down to 6 V immediately before the lamp, the lamp will light up with its normal brightness.

For more details refer to www.phywe.com

The forces between the primary and secondary coils (Thomson's ring)

P0506200

Demo

Principle

This experiment demonstrates the force on a closed conductor in which current is being induced. Using DC in the primary coil, there is a pulse as the power is turned on and the coil is forced away. Using AC, the coil hovers over the primary coil.

For more details refer to www.phywe.com

Waltenhofen Pendulum

P1298500

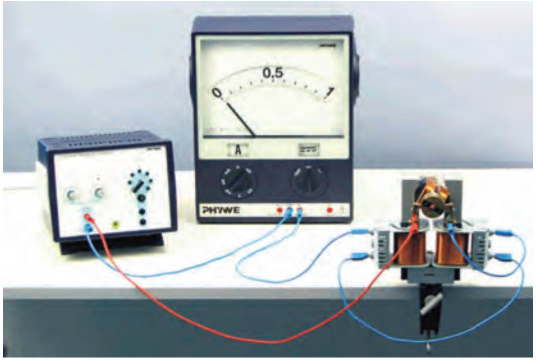
Demo

Principle

When a massive body made of conductive material moves through a magnetic field, eddy currents are induced. According to Lenz's law, the body is then subjected to a force which is opposed to the cause of the eddy currents, i.e. the motion of the pendulum. The braking action increases with the strength of the magnetic field. If slits are cut into the body, this reduces the generation of the eddy currents.

For more details refer to www.phywe.com

The series motor (with the demonstration generator system) P1433402



Demo

Principle

An electromotor can also be operated with an electromagnet as a field magnet. If armature coils and field coils are connected in series, then this is called a series-wound motor. The properties of this motor are studied by observing the direction of rotation and measuring the electric current.

For more details refer to www.phywe.com

Subjective colour mixing with the colour wheel P0872500

Demo

Principle

If a circular disc separated into various differently coloured sectors is rotated by a motor so fast that the eye can no longer distinguish the colours, a mixed colour is then perceived. By varying the composition and size of the sectors, it is possible to give the impression of any colour at all. The colour triangle can be used to predict what the perceived colour will be.

For more details refer to www.phywe.com

Natrium resonance fluorescence P0642600

Demo

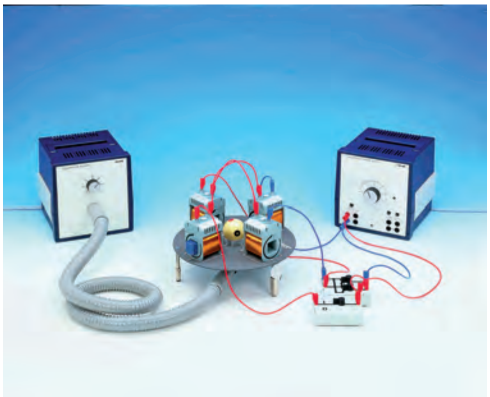
Principle

Resonance fluorescence is demonstrated by illuminating a sodium vapour with white visible light. The emitted light is spectrally analyzed and shows the emission spectrum of sodium. Therefore the same atomic levels are involved in both absorption and emission.

For more details refer to www.phywe.com

Model experiment NMR / ESR

P2511205



Demo

Principle
Model experiment for electron spin resonance for clear demonstration of interaction between the magnetic moment of the electron spin with a superimposed direct or alternating magnetic field.

For more details refer to www.phywe.com

Absorption spectra

P2511500

Demo

Principle

Electron shells of metal atoms in the gas phase can be elevated to an excited state by light. If light is passed through the metal vapour, various lines will be absent from its spectrum afterwards. These lines correspond to the energy levels of those electrons in the metal vapour which have been excited by the light. Spectra such as this are called absorption spectra. This experiment investigates absorption spectra of the following metals: strontium, barium, calcium, sodium, lithium, potassium, platinum, cobalt and magnesium.

For more details refer to www.phywe.com

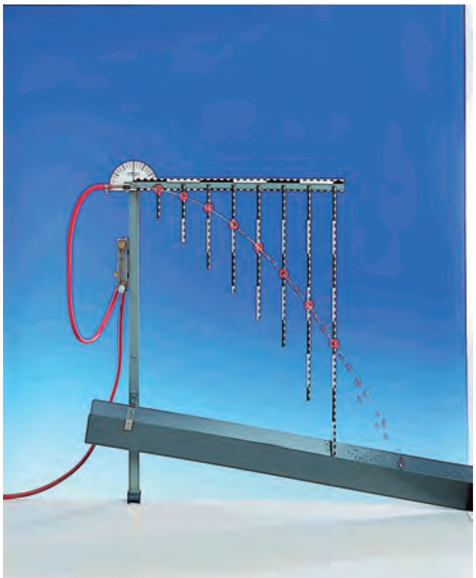
Inclined plane, with roller

Function and Applications

Practical compact device to demonstrate the investigation of the forces which keep a body in equilibrium on an inclined plane including a Roller as device under test for experiments with the inclinied plane .

11301-88

Water projection apparatus

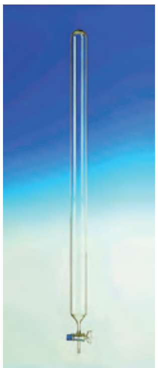


Function and applications

To demonstrate thrusting movements and for quantitative investigations of ballistic trajectories. Excellent didactic teaching device; the whole trajectory is constantly visible and can be continuously measured, due to the fact that the projectile is a water jet. Thrustangle and initial velocity can be varied continuously.

02515-00

Free-fall tube



Function and Applications

To verify that all bodies fall with the same velocity in a gravitational field if no interfering forces are present (air ascending force, air resistance).

Equipment and technical data

- Glass tube with falling bodies.
- Glass valve with olive handle for vacuum tube.
- Falling bodies: lead plate and feather.
- Length: approx. 100 cm.
- Diameter: 50 mm

02500-00

Rocket model

Function and Applications

To demonstrate the rocket principle.

Operating possibilities:

- Flight on an extended light cord: propulsion by means of carbon dioxide cartridges.
- To measure thrust forces (recoil force): propulsion by means of carbondioxide cartridges, measurement of thrust force by means of a dynamometer.
- Free flight: propulsion by means of a water jet. For this, the rocket is partly filled with water and clamped to its launching pad. An overpressure is generated inside the rocket with a special air pump, so that the water is pressed with high speed out of the nozzle.

02671-00

Prandtl's rotatable disk

Function and Applications

To demonstrate conservation of angular momentum.

02571-00

Bicycle wheel gyro

Function and Applications

Demonstration gyroscope consisting of a wheel with two handle bars and rope pulley for accelleration. To be used for demonstration of conservation of angular momentum with turntable after Prandtl.

Equipment and technical data

- The rim of the wheel is equipped with iron mass pieces for achieving higher angular moments.
- Indcluding a rope and a pan with fixation for mounting one end of the axis on a table for acceleration of gyroscope.
- Diameter: 500 mm.
- Length of axis: 500 mm.
- Mass: 2390 g.

02565-00

Magdeburg hemispheres

Function and Applications

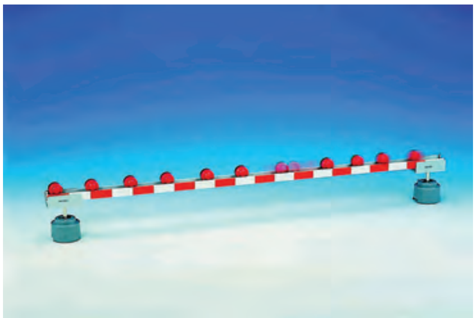
To demonstrate the effect of atmospheric pressure according to the historic experiment performed by Guericke.

Equipment and technical data

- Two nickel coated steel sheet hemispheres with polished edges.
- On handle each.
- One hemisphere with cock and hose olive.
- Holding force: approx. 750 N.
- Diameter of polished edges: 100 mm.
- Olive diameter: 10 mm.

02675-00

Magnetic rollers apparatus



Function and Applications

A multitude of physical phenomena can be represented:-

- longitudinal waves,
- elastic collisions,
- reflections,
- conservation of momentum,
- propagation of a pressure perturbation in a gas,
- barometric altitude formula, etc.

Accessories

- Standard accessories: 12 magnetic rollers (11065-01)

11065-00

Pin shearing apparatus

Demo

Function and Applications

To demonstrate forces exerted by a firmly tensed solid body on its support through cooling down contraction.

Equipment and technical data

- U-shaped tension support on rod, with steel tube and tensing wedge.
- Standard accessories: Cast iron pins, 10 pieces (04222.00).
- Material: cast iron.
- Length: 100 mm.
- Diameter: 9 mm.

04220-00

Ball and ring

Demo

Function and Applications

To demonstrate the dilatation of solid bodies. The ball only fits exactly trough the hole in the support when it is cold.

04212-01

Conductometer, Ingenhouß type

Demo

Function and Applications

To demonstrate different thermal conductivities of different materials. Aluminium vessel with lid and heat protection ring. Six thermally insulated rods arefixed to the lid. The rods are covered with temperature indicator tape which changes from orange to red at about + 40°C.

Equipment and technical data

- Rod materials aluminium, zinc, wood, copper, steel, brass.
- Changing temperature of the indicator approx. 40°C.

04517-00

Leslie radiation cube

Demo

Function and Applications

To investigate the thermal radiation of a body as a function of temperature and surface constitution.

Equipment and technical data

- Hollow brass cube with removable lid to be filled with hot water.
- With four different lateral surfaces: polished metal, dull metal, white enamel, black enamel.
- Lid with two orifices (d = 10 mm) for thermometer and stirrer.

Accessories

- Stirrer (04555-01).

04555-00

Parabolic mirrors,1 pair

Function and Applications

To demonstrate the focusing of radiation.

Equipment and technical data

- One mirror contains a luminous point, the other a match holder.
- The light source and the holder can be moved along the axis.
- The set consists of: parabolic mirror with holder (2×); amp socket BA 20 d on a rod; filament lamp 12 V / 50 W BA 20 d; match holder.

04540-00

Hope's apparatus

Function and Applications

To observe the maximum density of water at 4°C.

Equipment and technical data

Standing metal cylinder surrounded in the middle by a container which can take a coling mixture. 2 sleeves at the upper and lower ends of the cylinder to introduce thermometers or temperature probes. Cooling contaciner has a flow out for smelting water.

04270-00

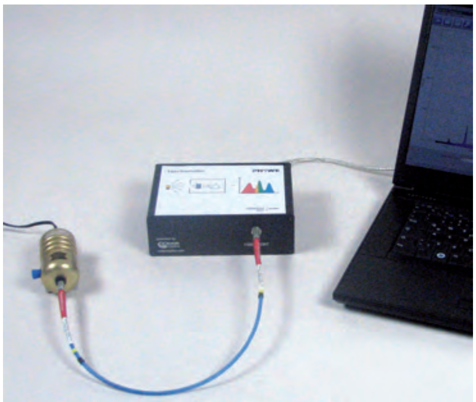
Gas liquefier

Function and Applications

Gas liquifier, for demonstrating isothermal condensation and evaporation due to changes in pressure and volume.

08173-00

Measurespec spectrometer with cuvette holder and light source

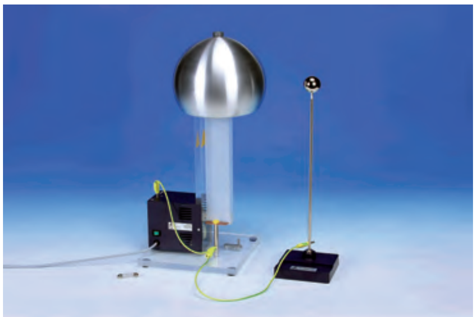


Function and Applications

This set consisting of a Measurespec spectrometer (35610-00) and a cuvette holder and light source for the Measurespec (35610-99) makes it possible to record both emission and absorption spectra. The light to be investigated is guided by optical fibres to a grid fixed inside the spectrometer, which disperses it into its spectral colours. The spectrum is recorded with the aid of a CCD array, which records the entire spectrum at once, making it possible to reliably record rapid changes in the spectrum itself. The spectra can be displayed and stored by means of the supplied software with its versatile functionality. The spectrometer is connected to a PC via a USB port, which also suffices to supply power to the spectrometer, so that no additional supply is needed. The cuvette holder holds standard cuvettes measuring 1 cm x 1 cm. The built-in light source makes it possible to record absorption spectra for solutions. The rapid measuring rate of the spectrometer even allows the speed of reactions involving changes in colour to be measured (reaction kinetics).

35610-88

Van-de-Graaff generator, 230V/50Hz



Demo

Function and Applications

Compact unit for production of high direct voltage.

Equipment and technical data:

- With integrated motor for mains operation and additional crank for manual operation
- removable conducting sphere with 4mm bushesand diameter of 210 mm
- Output voltage max. 150...200 kV
- Mains voltage 230 V
- Height: approx. 58 cm
- incl. conducting sphere (d=80mm) on stem with insulating base
- neontube and 50cm connecting cord

07645-97

Wimshurst machine

Demo

Function and Applications

Historical device for generation of highvoltage to carry out many impressive electrostatic experiments.

Equipment and technical data:

- Manually driven plastic discs and adjustable spark gap connected in parallel to two integrated Leiden bottles (high voltage capacitors)
- Diameter of disc: 30 cm
- Voltage: max. 160 kV
- Length spark gap: ca. 60 mm
- Dimensions (mm): 360 x 190 x 450

07616-00

Set of electrostatics apparatus

Demo

Function and Applications

In connection with Van de Graff generator or Wimshurst machine for impressive and illustrative demonstration of electrostatic phenomena.

Equipment and technical data

- Universal support base with 16 additional components such as for example wheel with pointed spokes, pith ball double pendulum, bell support, lightning board, friction rod and bunch of paper.

07644-00

Electroscope, Kolbe type, Electrometer

Demo

Function and Applications

High sensitivity, particularly suited for friction electricity experiments as well as for use with ionisation chamber (07158-88) to indicate direct and alternating voltages.

Equipment and technical data

- Pointer on needle bearing, can be stopped at zero position.
- Metallic casing; Glass front and backside to allow projection.
- Cellon scale.
- Connecting head with longitudinal and cross hole for 4 mm plug pin.
- 4 mm socket for earthing of casing.
- Voltage: up to approx. 1500 V-

07120-00

Hemispheres,Cavendish type

Function and Applications

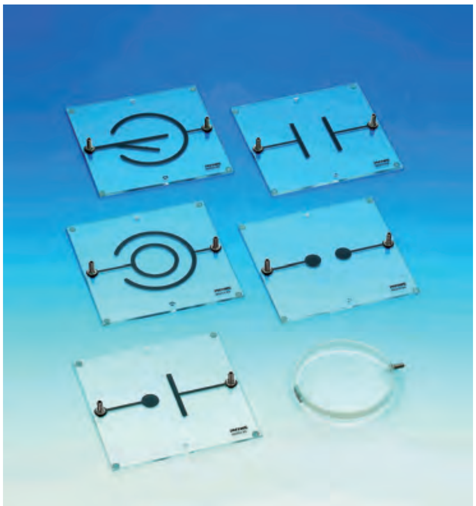
To investigate electrostatic induction and to determine the quantitative relation between electric field intensity and amount of induced charge, as well as to set up a spherical capacitor together with conducting spheres.

Equipment and technical data

- Two nickel coated brass hemispheres, each fixed to an insulating holding rod.
- Sphere diameter: 120 mm.

06273-00

Electrostat.field plotting set



Function and applications

To demonstrate how electric field lines run between electrodes of different shapes, without wetting the electrodes. The diverse electrode configurations are fixed in the form of rub proof thin conducting layers on Plexiglas plates. The representation of the field lines is obtained by means of grains of semolinain a light path cell laid onto the corresponding Plexiglas plate and previously filled 1 to 2 mm deep with castor oil.

06251-88

Electromagn.field lines,projection model

Function and applications

To represent the magnetic field of conductors through which a current flows with iron filings on an overhead projector. Three transparent plastic plates which stand on their bent down edges; due to the sunken observation surface, no iron filings can fall down.

06401-00

Magnetic-field tracer, 3-dimens.

Fuhction and Applications

For spatial visualisation of the field generated by a rod shaped magnet.

Equipment and technical data

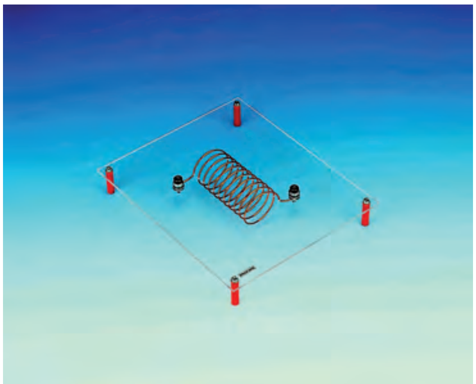
- Rectangular Plexiglas block with central hole for magnets
- Filled with high viscosity special liquid and iron filings.
- When the magnet is introduced, the iron filings uniformly distributed in the liquid orient themselves floating along the magnetic fieldlines.
- A contained gas bubble assures uniform distribution of the iron filings when the device is shaken.
- Hole diameter: 14 mm.

Accessories

- Additionally one need a magnet d = 8 mm, l = 60 mm (06317-00).

06403-00

Coil on Plexiglas panel



Function and Applications

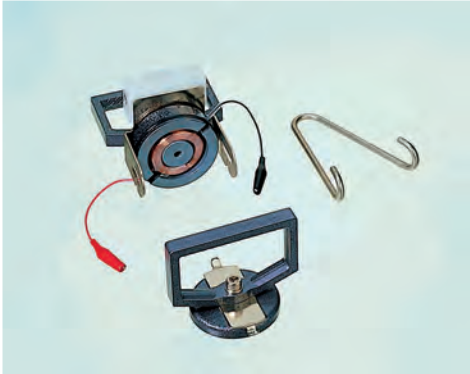
To project the magnetic field inside a coil, represented through iron filings, with an overhead projector.

Equipment and technical data

- Coil on aPLEXIGLAS® plate with 2 connecting sockets.
- Number of turns 10.
- Length of turns: 90 mm.
- Turn diameter: 50 mm.
- Dimensions of plate (mm): 245 × 205.

06409-00

Electromagnetic-force apparatus



Function and Applications

Plunger electromagnet to demonstrate electromagnetic forces.

Equipment and technical data

- Both pole pieces have handles, so that two persons can try to overcome the electromagnetic force generated by a 1.5 V single cell battery.
- Two holding shackles securely take up the forces released when the parts come apart.
- Holding force: approx. 600 N.

06481-00

Multimeter ADM2, demo., analogue

Function and Applications

Electronic analogue multimeter for measuring direct and alternating voltage and current, and for measuring resistance.

Benefits

- Eight demonstrative scales with a total of 66 measuring ranges.
- Measures direct or alternating current from 1 mikroA to 10 A.
- Measures direct or alternating voltage from 1 mV to 10 kV.
- Measures resistance up to 1 MOhm.
- Scale with zero in the middle with automatic middle positioning of pointer.
- Automatic switch-off of battery after approx. 50 min.
- Operatable and readable also from the back. Extensive overload protection in all measuring ranges.
- Eliminates the need for fuses and cutouts.

13820-01

Linear Levitation Track, length: 70 cm

Function and Applications

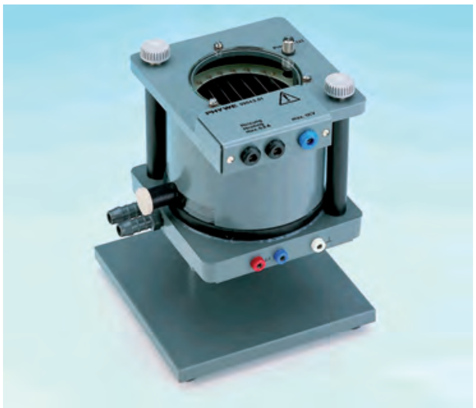
A magnetic levitation system uses magnetic fields to levitate and accelerate a vehicle along a track. Similar systems are in use today as high-speed trains and some of the newer, radical-ride roller coasters. The PHYWE Levitation Tracks use the power of a solar cell panel to propel the PHYWE Solar Cart with the help of a linear motor. Thereby, the Solar Cart hovers above the magnetic track.

Equipment and technical data

- Linear levitation track with a length of approximately 70 cm, built on 2 pillars, with transparent guide and bumpers
- 2 stylish halogen lamps integrated in the track for propulsion of the solar cart
- 2 carts (1 x solar cart and 1 x graphite cart for manual demonstration)

11330-00

Cloud chamber w.peltier cooling



Function and Applications

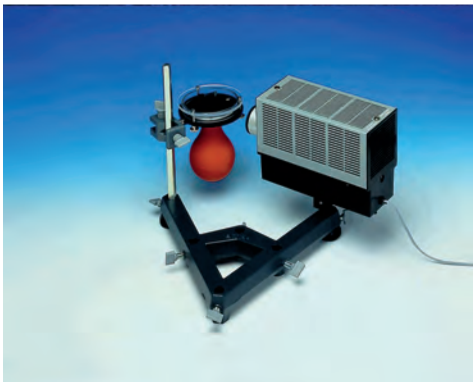
Continuous function cloud chamber with electric cooling (Peltier elements).

Benefits

- Continuous function allows to observe the paths of, beta^{-}-, beta^{+}-, alpha-particles, as well as those of the secondary electrons of gamma-radiation and altitude radiation.
- Furthermore, collision and decay processes distributed statistically in time can be observed too.
- The introduction of a provided permanent magnet allows to separate beta^{+}- and beta^{-}-particles due to the different radii of curvature of their paths.

09043-01

Cloud chamber,w/o source Ra



Function and Applications

Compact unit to make the paths of alpha particles visible.

Equipment and technical data

- The cylindrical chamber with lateral holding stem and rubber ball for compression and expansion is filled with a water / alcohol mixture.
- Swivelling shackle allows placement of absorption foil in front of source orifice.

09044-30

Diffusion cloud chamber 80 x 80 cm, PJ 80, 230 V

Function and Applications

Continuously working large diffusion cloud chamber on box; the instrument can be set up by itself.

Benefits

- The large diffusion cloud chamber with an 80 x 80 cm active observation surface are hermetically closed units.
- They each consist of a pedestal for the chamber on top of which lies the observation chamber.
- The chamber's pedestal holds the refrigerating unit, power supply, a tank for alcohol, a pump for alcohol and a timer.
- On top of the pedestal, the observation chamber is installed.
- The top and the sides of the observation chamber are made of glass.
- Underneath the upper sheet of glass, thin heating wires are installed, which heat up this part of the chamber and thus keep the chamber from misting over.
- These wires simultaneously serve as high-voltage mesh to gather up ions.

09043-93

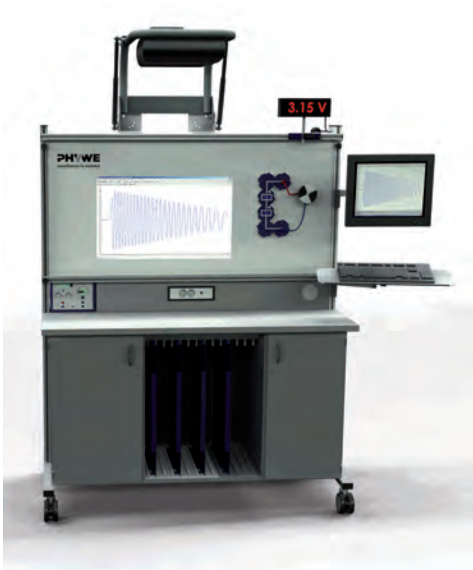
Diffusion cloud chamber, 45 x 45 cm PJ45

Function and Applications

Continuously working large diffusion cloud chamber on pedestal; handles on side help to transport the instrument. Active observation surface 45 x 45 cm.

09046-93

Mobile Demo Lab for demonstration experiments with a magnetic board



Function and Applications

This complete mobile system is designed for teaching natural sciences and is ideally suitable for demonstration experiments. All equipment for the experiments can be organized in 4 storage boxes for a quick and easy set-up. Everything belonging to modern teaching methods is incorporated into this new mobile teacher system. The vertical board allows writing with a pen and beamer projection, set-up of experiments with magnetic holders. Beamer, teacher desk and laboratory bench are included. It is ideal for all teaching environments and its modular design guarantees flexibility and adaptability for all of your purposes.

Benefits

- flexibly usage in different rooms: no need for a fixed installation of presentation equipment in the rooms
- the system combines techniques of the modern multi media presentation methods and modern demonstration experimentation with thousand fold used robust mobile desks
- preparation can be done in the seperate preparation room before the lesson starts
- minimum preparation time for lessons
- ideal for PC based experimentation by using of the Cobra4 interface system
- fast and flexible positioning and modification of the experiment set-ups using magnetic holders
- easy assembly and clearly visible vertical set-up ot the experiments

Equipment and technical data

- magnetic adhesive board; dimensions: 68 cm x 142 cm
- for vertical set-up of experiments and as a projection screen
- interactive projector, mounted above the board in a hinged manner
- free space under the board for a low-voltage power supply
- 2 easily accessible power sockets and 2 USB ports
- electric power connection with help of a 10 m long cable, self coiling
- USB connection mounted on top of the board for Cobra4 Wireless manager
- turnable arm mounted on the side of the board for a monitor
- turnable arm with tray mounted on the side of the board for a keyboard
- the PHYWE digital large-scale display can be easily attached on top of the board (power supply pre-installed)
- adapter for easy mounting of the PHYWE DEMO track (11305-00)

02190-93

Mobile Science Cart

Function and Applications

The Mobile Science Cart offers all functions to run science teaching classes via integrated access to water, gas, electricity and computer technology.
Cabinets with lockable doors are designed to store PHYWE student science sets (TESS), or teacher science sets (DEMO).
The acid resistant work surface is robust, so chemistry experiments may be conducted safely.

Equipment and technical data

- Fully mobile science teaching cabinet
- Integrated access to water, gas, electricity and computer
- Access to vacuum by water jet pump
- Fully lockable
- Storage adapted to all 50 TESS students science sets / 10 DEMO teacher science sets
- Acid resistant work surface
- Dimensions: 1420 x 690 x 1060 mm (W x D x H)
- Weight: 45 kg

02195-93

XR 4.0 Mobile X-ray Lab

NEW Demo

Function and Applications

Teaching and performing experiments with the mobile X-ray lab. The mobile X-ray lab saves valuable time by making the set-up and dismantling of experiments in the classroom or lecture hall redundant. All of the important parts, such as X-ray tubes, goniometer, or multi-channel analyser, can be stored safely in the lockable cabinet. Prepare your experiments unhurriedly ahead of time before pushing them into the room at time of the lecture. Cluttered set-ups and tangled cables are a thing of the past: The most important connectors are located on the desktop. The screen is fixed in place on the desktop in a permanent manner in order to protect it against damage and theft. The extra-large castors easily surmount any edges or bumps. Any type of room can be instantly transformed into an X-ray science lab!

Benefits

- Ideal for experiments in the classroom or lecture hall
  - Preparation of the experiment outside the classroom or lecture hall and easy to move
- Firm set-up of the X-ray unit
- Room for all of the accessories: protected against shock and dust
- Connectors such as USB, VGA, and HDMI integrated in the desktop
- Space-saving: PC stored in the lockable cabinet

Equipment and technical data

- Storage compartments for four X-ray tubes, goniometer, etc.
- Recesses in the desktop ensure the firm set-up of the XR 4.0
- Integrated power supply connection with distribution outlets at the back, on the desktop, and in the PC compartment
- Connectors on the desktop: 4 x USB, 1 x HDMI, 1 x triple power socket, 1 x VGA for connecting a beamer or monitor
- Dimensions: 1400 x 1500 x 800mm (W x H x D); Weight: 117kg
- Three layers of melamine-faced high-quality chipboard
- Plastic shutters with groove-mounted runners; lockable handle
- 4 castors with a diameter of 75 mm, two of them with brakes

XR 4.0, accessories, PC, and screen not included

09057-48

Moveable experimental table 75, 40 mm table top with PP edge

Demo

Function and Applications

Moveable experimental table.

Equipment and technical data

consisting of :

- Experimental table 75 75
- Oval ducted rack
- Colour: dove blue
- 4 castors, 2 lockable
- 1 shelf
- Tabletop: 40 mm thick, Synthetic material, perl; with PP-edge, grey
- Dimensions (mm): 750 x 600 x 908

Moveable experimental table 75, 40 mm table top with PP edge
54080-00

Moveable experimental table 75, 40 mm table top with PP edgeand with intermediate bottom
54080-01

Moveable experimental table 75, 40 mm table top with PP edgeintermediate bottom and socket board
54080-03

About PHYWE

Traditional yet modern
100 years of quality

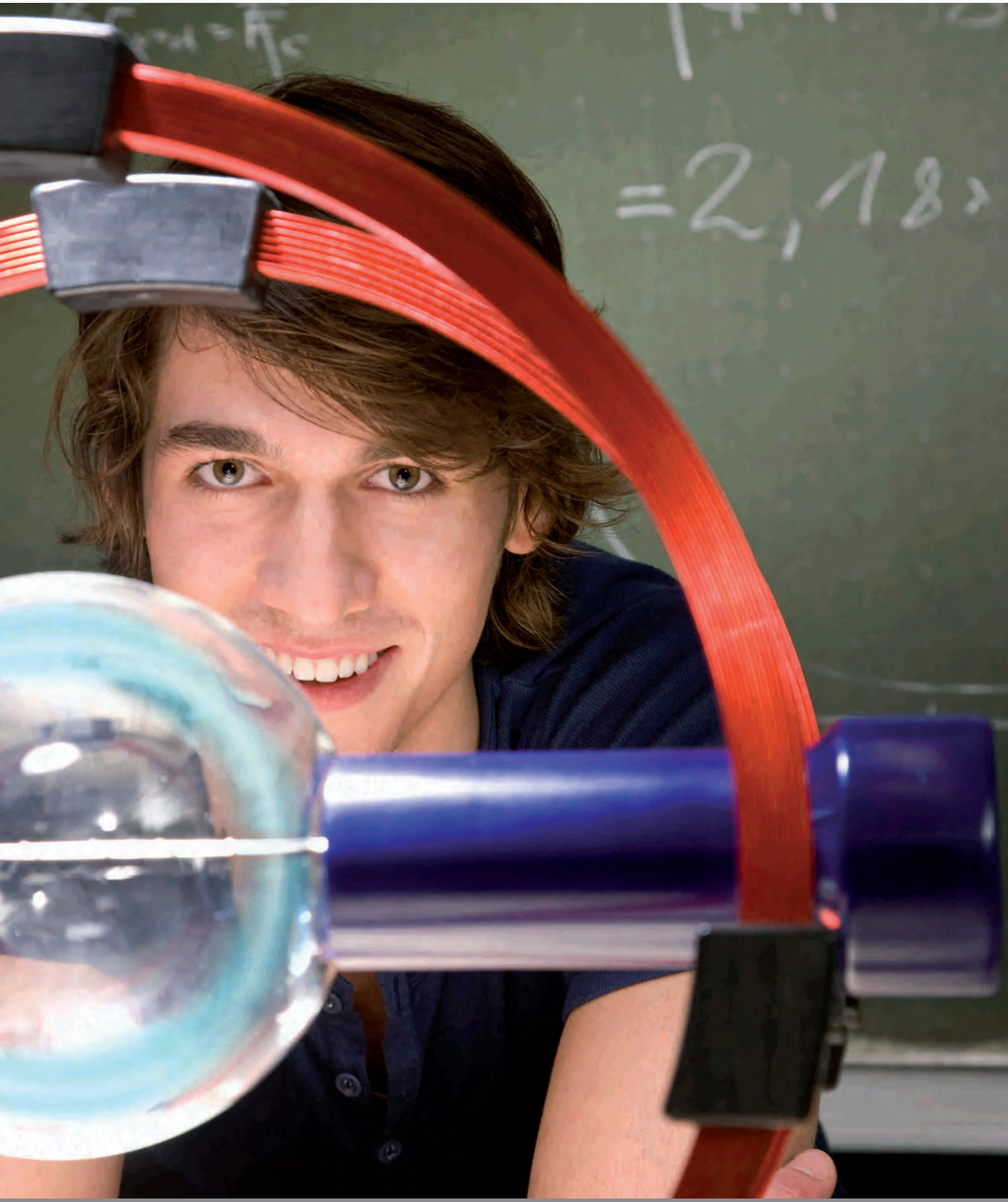
Those who know nothing must believe everything.

Marie von Ebner-Eschenbach

With a 100-year tradition of excellence, PHYWE Systeme GmbH & Co. KG stands for technical capability, innovation, quality and customer satisfaction. As a leading supplier of premium quality teaching and learning materials, PHYWE is one of the world's largest providers of system solutions for the instruction of the natural sciences.
The product range comprises scientific equipment, experiments and solution systems along with modern blended learning systems, literature and software for the areas of physics, chemistry, biology, medicine, material science and earth science. A broad spectrum of services such as training programmes, installation and comprehensive consulting services completes the portfolio.

PHYWE solutions can be individually adapted to the specific curricula in each country and provide ideal coverage for the full spectrum of performance specifications and requirements. Ask us to prepare a customised equipment offering to suit your special needs!

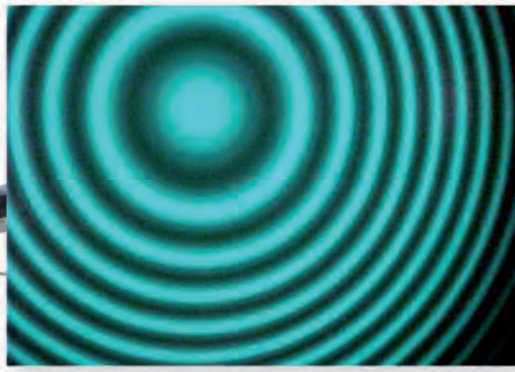
made in Germany



PHYWE supplies more than
50 Nobel Prize awarded experiments

The Nobel Prize is awarded annually in the disciplines of physics, chemistry, physiology or medicine, literature and peace. For scientists and researchers, it is the highest award.

PHYWE supplies more than 50 Nobel Prize awarded experiments. From Conrad Röntgen to Max Planck or Albert Einstein. Experiments in the footsteps of Nobel Prize winners. PHYWE made Nobel Prize experiments understandable.



Nobel Prize awarded experiments

1900 ...

1901 - Wilhelm Conrad Röntgen
1901 - Jacobus Henricus van 't Hoff
1902 - Hendrik A. Lorentz, Pieter Zeeman
1903 - Henri Becquerel, Pierre Curie, Marie Curie
1907 - Albert A. Michelson
1908 - Ernest Rutherford

1910 ...

1914 - Max von Laue
1915 - W.H. Bragg, W.L. Bragg
1918 - Max Planck
1918 - Fritz Haber

1920 ...

1921 - Albert Einstein
1922 - Niels Bohr
1923 - Robert A. Millikan
1924 - Manne Siegbahn
1924 - Willem Einthoven
1925 - James Franck, Gustav Hertz
1927 - Arthur H. Compton
1927 - C.T.R. Wilson
1929 - Louis de Broglie

1930 ...

1930 - Karl Landsteiner
1931 - Carl Bosch
1932 - Werner Heisenberg
1936 - Victor F. Hess,
Carl D. Anderson

1940 ...

1943 - Otto Stern
1945 - Wolfgang Pauli
1948 - Arne Tiselius

1950 until today

1954 - Max Born, Walther Bothe
1971 - Dennis Gabor
1986 - Heinrich Rohrer, Gerd Binnig
2009 - Charles K. Kao

The PHYWE Nobel Prize experiments are signed with this icon.

Computer assisted measurement –
for your science experiments

Cobra4 PHYWE

With computer-assisted experiments from PHYWE you rely on a system that perfectly matches the demands of modern scientific education. Approximately 50% of the total number of TESS and Demo expert experiments are computer-based. PHYWE offers the unique Cobra4™ system with completely new experimentation possibilities. Be inspired by more than 300 described experiments with Cobra4™.

The corresponding software "measure" stands for simple and reliable data recording, analysis and further processing – and it is available in 24 languages. Get more information about our Cobra4™ program in the brochure "Experiments with Cobra4"

Benefits

- wireless measurements – comfortable and modern
- more than 30 sensors for more than 50 measurands
- time-saving: settings can be saved
- fully automatic sensor identification
- up to 99 sensors can be addressed simultaneously
- can be used as a hand-held measuring instrument

View our Cobra4 catalogue online

The Cobra4 interfaces

Wireless-Link + Wireless Manager + Remote-Link
for wireless measurements

USB-Link
for high data rates

Mobile-Link*
for stand-alone measurements
*registered utility model

Xpert-Link
for special high-performance applications

The Cobra4™ system
combine interfaces and sensors

Cobra4 PHYWE

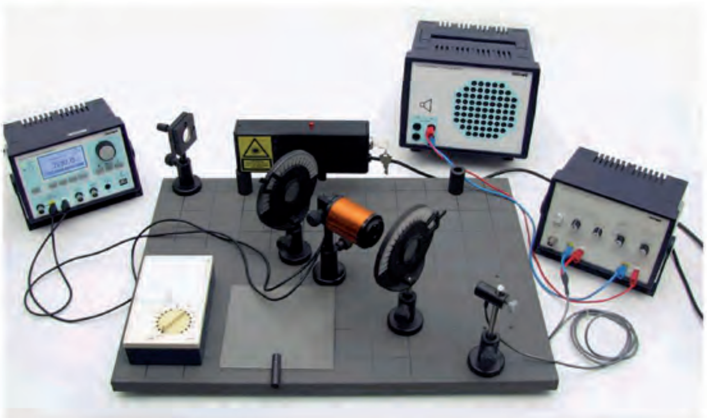
The Cobra4 system provides over 30 different sensors.

Digital function generator –
universal and intuitive

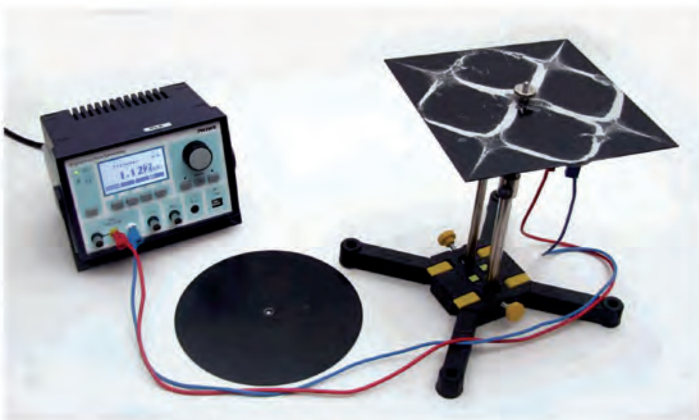
Cobra4
compatible

Features

- Universal, programmable voltage source with a bandwidth of 1 MHz and an output current of 1 A
- Can be used with Cobra4 or as a stand-alone device
- Intuitive operation via function keys and a rotary control knob
- Illuminated display for optimum visibility
- Low distortion factor and high signal-to-noise ratio for brilliant signals, especially for acoustics
- U = U(f) output for a particularly easy pick-up of the frequency – ideal for analysing circuits with frequency ramps
- Part of more than 30 TESS and Demo experiments



Faraday effect (P2260106)



Chladni's figures (P2150702)

New devices –
for the Cobra4 family

Cobra4 PHYWE

Cobra4™ Sensors

Sound level
(12669-00)

Skin resistance
(12677-00)

Oxygen
(12676-00)

Forceplate
(12661-00)

Colorimeter
(12634-00)

	Sound level	Skin resistance	Oxygen	Forceplate	Colorimeter
Measuring range:	35...94 dBA/dBC 75...130 dBA/dBC	0 to 10 µS	0 to 30% by volume (air) 0...20 mg/l, 0...200 % (liquid)	-2 to 5 kN	4 wavelengths (LEDs), transmission 0 to 100%
Resolution:	0,1 dB	0,01 µS	0...20 mg/l, 0...200 %	0,5 N	0,01 %T
Max. sampling rate:	100 Hz	100 Hz	100 Hz	100 Hz	10 Hz

Cobra4™ Xpert-Link

Cobra4 Xpert-Link PHYWE

The high-performance USB interface for high-precision measurements and universal use.

Features

- 4 integrated channels (2x current, 2x voltage), electrically isolated
- True RMS converter for all channels, AC and DC functions
- High resolution: up to 10 µV, up to 2 µA
- High sampling rates: > 1 MHz for current channels and
  > 5 MHz for voltage channels
- 2 trigger in and 1 trigger out (programmable control relais)
- 2 Cobra4 sensors can be connected

PHYWE – your partner for turn-key projects

YOU have a vision – WE have the solution

Labs and classrooms for all science disciplines with complete fulfilment by PHYWE. Support by experienced project managers.

From your drawing...

Consultancy

From your vision of the future we provide a step by step tangible project.

Project definition

Complete projects according to your curricula topics including:

- Solution for science experiments
- Solution for infrastructure & furniture
- Services, e.g. training

Delivery & Installation

Your PHYWE equipment:

- Unpacking
- Inventory
- Installation of hardware
- Installation of software

...to the running lab

Training

Hotline & Maintenance

Your staff is the key:
- Training of operation
- Training of maintenance and handling

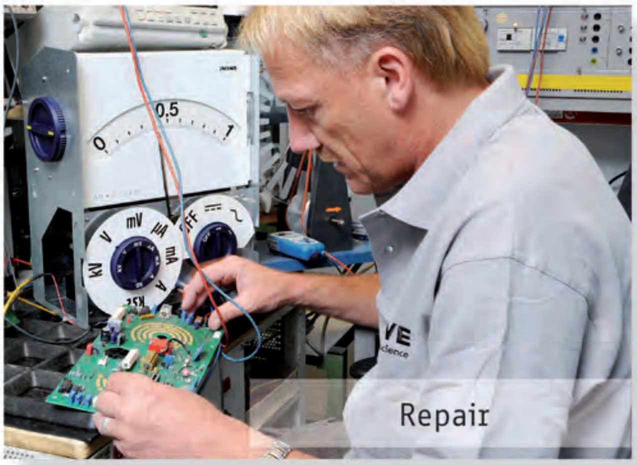
Your partner for decades:
- Inquiries of application
- Spare parts

made
in
Germany

Service at PHYWE – Professional care from A to Z

Service | PHYWE

Installation



Repair

Training

Technical hotline

Individual Service for individual needs

By choosing a PHYWE product you decide for a comprehensive service at the same time. We support you with our multi-level service concept. From planning through to installation and up to our extensive after sales service. Rely on our strengths: rugged and long-lasting products made in Germany, customized for your needs.

We offer

- ☑ Installation and training
- ☑ Seminars at PHYWE or on-site
- ☑ Repair & spare parts delivery
- ☑ Technical hotline

Service PHYWE

PHYWE Service team

„…very friendly, flexible and helpful staff. Everything is well organized." Uwe Löding, Head of the collection (Natural sciences) at the Felix-Klein-Gymnasium, Goettingen/Germany

You can reach the service team by

Phone	+49 (0) 551 604-196*
Fax	+49 (0) 551 604-106
E-Mail	service@phywe.de

* on weekdays 8 am – 4 pm (German local time)

Services

On-site placement service - inventory taking, per day:
We organize and inventory your collection.

On-site placement service	03333-10

On-site placement service - project settlement, per day:
We control the supply and put them away in cabinets and organization systems.

On-site placement service	03333-05

On-site installation, per day:
We install your equipment and do a function test at your site.

On-site installation	03333-06

On-site training, per day
We train the handling of equipment and experiments at your site.

On-site training	03333-02

Training & Presentation, per day at Phywe site:
We train the handling of equipment and experiments at PHYWE site.

Training & Presentation at Phywe site	03333-03

Cooperations –
Reliable partner for education

There's a way to do
it better – find it.

Thomas Edison

The share of ideas and transfer of knowledge between academia and PHYWE is one of our major attempts in R&D. Our network is spread out worldwide and comprises cooperation projects, research assignments, and the education of expert staff.

Some breathtaking novelties of our new XR 4.0 plattform are one by one the result of fruitful cooperation in this regard - thank you!

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFT UND KUNST
HILDESHEIM/HOLZMINDEN/GÖTTINGEN
FACULTY OF NATURAL SCIENCES AND TECHNOLOGY
HAWK

XLAB
Göttinger Experimentallabor
für junge Leute e.V.

General notes on safety

Notes on safety

The regulations for dealing with electrical devices, lasers, radioactive materials and hazardous materials are not uniform worldwide. Before any experimentation, it is essential that you become familiar with the national and local laws, directives and ordinances regarding the handling of these appliances and materials, as well as their storage and transport.

You can refer as an example to our notes on safety, which correspond to the high German and EU standards. The laws in the respective country are binding, however.

1.) Experiments using electrical energy

The utilisation of the electrically operated devices (mains power supply) that are offered herein is only allowed in science rooms of educational institutions, schools, universities, and laboratories, but NOT in residential areas.

Experiments at school usually use non-hazardous extra-low voltages (< 25 V~/< 60 V-). The following safety notes provide information about the existing legal regulations. In addition, they include rules of conduct for the responsible teacher for the execution of experiments with hazardous voltage levels.

When performing experiments with electrical energy, it must be absolutely sure that the persons involved in the experiment cannot come into contact with hazardous voltage. The professional (teacher) who supervises/conducts the experiment is responsible for this.

In the "Safety requirements for electrical equipment for measurement, control, and laboratory use" (DIN EN 61010-1, VDE 0411 part 1) of the European Union, non-hazardous voltage is defined as voltage < 33 V~ or < 70 V- or, in the case of higher voltage, with a limited current of 0.5 mA~ and 2 mA- maximum.

Other restrictions for schools providing general education have been decreed by the standing conference of the minister of education and cultural affairs of Federal Republic of Germany in the "Directives concerning safety during lessons" (GUV-SI 8070) with reference to the standard VDE 0105 part 12 ("Operation of power installations - Particular requirements for experiments with electrical energy in lecture rooms"). In these directives, the voltage limits for students up to the German class level 10 (age approximately 16 years) have been fixed at 25 V~ and 60 V- maximum.

Professionals (usually teachers) and students of class levels higher than level 10 may work with hazardous voltages in exceptional cases, if the teaching objective cannot be reached with non-hazardous voltage. In this case, the teacher must be present during the experiment.

The following rules and regulations should be observed:

1. **Electrical safety**
   (DIN EN 61010-1, VDE 0105 part 12, GUV-SI-8070)

Prior to the first experiments of students, trainees, or apprentices with electrical energy in a laboratory or classroom, the students, trainees, and apprentices must be informed in detail about the hazards of the electrical current and about the applicable safety instructions.

Prior to using the electrical devices, they must be checked for signs of damage! Do not use the device if it is damaged!

The operating instructions of the equipment that is used for the experiment must be followed!

Do not use hazardous voltages (> 25 V~ and > 60 V-) in student experiments!

The professional must re-check the experiment set-up (circuit) prior to the start of the experiment and inform the user of any potential hazards!

Modifications of the experiment set-up (set-up, conversion, and take-down) must only be performed when the set-up is completely disconnected from the power supply and when all poles of the supply voltage are switched off!

If measurements or adjustments are unavoidable during an experiment with hazardous voltage, work only with one hand and hold the other behind the back or put it in a pocket!

Ensure that there is a sufficient number of emergency OFF switches in the laboratory.

Use only 4-mm safety cables that are protected against accidental contact (e.g. PHYWE ref. no. 07336-01) when performing experiments with hazardous voltages!

After the completion of the experiment, it should be taken into consideration that component parts, such as capacitors, may supply hazardous voltage even some time after the equipment has been switched off!

Experiments with set-up transformers require special safety measures. Even if the primary side of the transformer is supplied with extra-low voltage (< 25 V~), very high hazardous voltages may be generated on the secondary side by the transformation, e.g. if the coils get mixed up!

If demonstration experiments are performed with hazardous voltages, the teacher or lecturer must ensure a sufficient safety distance from the students. In addition, these kinds of experiments must be marked with the danger sign "High voltage!" (PHYWE ref. no. 06543-00)!

Experiments that are directly supplied with mains power must not be performed unless a residual current circuit breaker (< 30 mA), e.g. a safety plug/socket assembly (PHYWE ref. no. 17051-93) or a variable isolating transformer (PHYWE ref. no. 13535-93), has been installed before the set-up. Do not plug the 4-mm connecting cables directly into the earthing contact socket outlet (SCHUKO socket)!

If power supply units (e.g. power supply unit for students, PHYWE ref. no. 13505-93) are used that do not produce hazardous voltages (extra-low voltages < 25 V~ and < 60 V-), simple, unprotected 4-mm connecting cables and other non-insulated components may also be used for student experiments.

2. **EMC (electromagnetic compatibility)**
   (Technical recommendation concerning the application of the EMC Act on electrical teaching equipment, Reg TP 322 TE01)

Experiment set-ups for the demonstration of physical processes must only be used in science rooms at schools, universities, and other educational institutions!

The teacher (expert) who sets up and performs the experiments is responsible for the compliance with the requirements for the EMC Act on the electromagnetic compatibility of equipment! The experiment set-ups do not require a CE mark or declaration of conformity, but the teacher as an expert must take all the necessary measures in order to avoid interferences in the environment!

Possible EMC measures:

- Ensure shielding and equipotential bonding!
- Keep a sufficiently large distance from sensitive equipment!
- Use short connecting cables (in order to reduce RF emission)!
- Floor coverings that my lead to static charges should be avoided and the body should be discharged prior to touching any sensitive experiment equipment!
- RF emitters, e.g. mobile phones, should be not be used in close vicinity of the experiment set-up!
- Critical experiment set-up and devices (e.g. Van de Graaf generator, Ruhkorff induction coil, transmitter), which can cause interferences even at a distance of several 100 metres should be switched on as briefly as possible.

2.) Experiments using lasers

In general, the "Directives concerning safety during lessons" (GUV-SI 8070) are applied at schools. In accordance with these directives, the following points must be observed when working with lasers:

1. Only lasers of class 1, 1 M, 2, and 2 M1 in accordance with DIN EN 60 825 may be used at schools.
2. Lasers of class 1 M, 2, and 2 M must be kept under lock and key.
3. Prior to setting up and performing experiments with lasers of class 1 M, 2, and 2 M, the students who observe or are involved in the experiment must be informed as to the risk to the eyes that is caused by the laser light. These lasers must only be used under the supervision of the teacher.
4. The area in which experiments with lasers of class 1 M, 2, and 2 M are performed must be marked with laser warning signs during the operation of the laser. This laser area of experiment set-ups must be secured against accidental access by some form of delimitation.
5. The set-up and performance of experiments with lasers of class 1 M, 2, and 2 M must ensure that looking into the direct laser beam or into the reflected beam is avoided, e.g. with the aid of some kind of screening. If lasers of class 1 M and 2 M are used, the beam cross-section must not be reduced, i.e. these lasers must not be used

in combination with converging components (e.g. magnifying glasses).

6. The use of laser devices of class 3 B or 4 in other educational institutions (universities etc.) must be reported to the responsible accident insurer and to the responsible occupational safety and health authority prior to the first start-up of the lasers.

For the use of laser systems of class 3 B or 4, a competent person must be appointed the laser safety officer in writing.

Additional information concerning the use of lasers can be found in the documents of the German Social Accident Insurance "GUV-V B – Laser radiation" and "GUV-I 832 – Use of laser systems". These documents are mainly based on the EU standard "DIN EN 60825-1 – Safety of laser products".

3.) Handling of radioactive products

In Germany, the handling of radioactive substances is controlled by the German Radiation Protection Ordinance (Strahlenschutzverordnung, StrlSchV). The legal bases of this ordinance are articles 25 to 27 combined with appendix V of the ordinance dated 20 July 2001, last amended by article 2 of the law of 02/08/2008. Substances within the exemption limits (see Appendix V of the German Radiation Protection Ordinance (StrlSchV) for the exemption limits) can be supplied to schools without any conditions. If the exemption limits are exceeded, the school will need a special handling permit issued by the responsible supervisory authority prior to purchasing the substances.

If several substances within the exemption limits are owned and/or purchased, the sum formula that is stated in the German Radiation Protection Ordinance must be observed.

Radioactive substances must be protected against unauthorised persons, which is why they must be stored in a theft-proof manner. In addition, the handling regulations of the German Radiation Protection Ordinance must be observed. Substances that have become unusable must be handed over directly to the responsible collection centre or to a disposal company.

4.) Safety instruction for handling hazardous materials

Before any experimentation with hazardous materials, it is essential that you become familiar with the national and local directives and ordinances concerning the handling of hazardous materials, their storage and transport. The basic principle is that all hazardous materials must be dealt with cautiously and carefully. It is of course required that, in case of experiments, neither the students nor the teachers be exposed to any unnecessary dangers to health. The instructions of the safety data sheets for the individual materials, in the most current version in each case, are to be considered, as well as the accident-prevention specifications and the respective workplace-related operating instructions. The waste disposal of used hazardous materials must be implemented according to recognized methods. The local specifications for the proper removal of chemical residues are to be considered in this case.

General Terms and Conditions (GTC)

of PHYWE Systeme GmbH & Co. KG

§ 1 Application of Conditions

1. These General Terms and Conditions (hereinafter referred to as GTC) shall apply for all goods, services and offers of PHYWE Systeme GmbH & Co.KG (hereinafter referred to as PHYWE) for its customers (hereinafter referred to as Customer). They shall apply equally for all future business between the contract parties without requiring a repeated reference. General Terms and Conditions of the Customer shall apply only if expressly approved by PHYWE in writing.
2. All deviating agreements between PHYWE and the Customer shall be set down in writing; a waiver of the written form does not have any effect on the agreement's validity. In the event of such an agreement these GTC shall be of lesser importance and shall supplement the agreement.
3. PHYWE reserves all rights to PHYWE operational and offer documents. If no order is placed, all documents shall be returned immediately of the Customer's own accord. All information in them and from other transactions shall be treated as strictly confidential.
4. All offers, samples and test products as well as their technical data and descriptions in the respective product information and promotional materials on the PHYWE website are for information only and are not binding. They do not represent a warranty of quality or application.
5. Insofar as PHYWE considers it necessary for the completion of its performances, PHYWE is authorized to exchange job-related data with assistants or trading partners. If the Customer does not desire such an information exchange, the Customer may object to it in writing at any time.

§ 2 Offer and Contract Conclusion

PHYWE's offers are not binding. PHYWE reserves an acceptance period of two weeks from receipt at PHYWE regarding the Customer's binding orders. Verbal statements of acceptance (by phone) and all Customer orders shall be confirmed by PHYWE in writing or by telex; a waiver of the confirmation does not affect the effectiveness of verbal statements of acceptance and orders (by telephone).

§ 3 Prices

1. The prices given in the PHYWE price list or the PHYWE order confirmation, exclusive of the relevant applicable value-added tax in the respective country, shall be binding. Additional goods and services are charged separately.
2. The prices are "ex work PHYWE" and include PHYWE standard packaging. Special packaging or other requests from the Customer, such as packaging in certain lots, are charged separately. Deviating provisions may be agreed between PHYWE and the Customer or by PHYWE for a region or a country in writing from time to time.

§ 4 Delivery and Performance Terms

1. Delivery dates or terms that may be agreed upon, both binding and unbinding, shall be set down in writing. Non-binding delivery terms may be exceeded by up to 8 weeks by PHYWE; only after expiration of this term we shall fall into arrears by reminder of the Customer. Delivery terms shall start as of contract conclusion and acceptance of payment details by PHYWE. In the event that changes to the contract are agreed upon, it is subsequently required to agree on a new delivery date at the same time. Claims for damages or recourse of the Customer towards PHYWE shall be excluded in any case.
2. In the event of delivery and performance delays due to force majeure, natural disasters as well as due to labour disputes, traffic or operation disturbances, lack of material through no fault of their own and similar reasons on PHYWE and its suppliers' part, the Customer is not entitled to withdraw from the contract or to assert claims towards PHYWE. The Customer is entitled to withdraw from the contract if the aforementioned reasons cause an extension of the delivery date by more than four months. PHYWE is entitled equally to withdraw from the contract. Claims for damages or recourse of the Customer towards PHYWE shall be excluded in any case.
3. PHYWE is entitled to make partial deliveries and partial performances at any time unless the deliveries and performances are to be made fully and completely in accordance with the contractual arrangements.
4. PHYWE's compliance with delivery and performance obligations requires the Customer's timely and proper compliance with its obligations.
5. If the Customer falls into arrears, PHYWE is entitled to demand reimbursement of the additional expenses it had to make for the unsuccessful offer and storage and maintenance of the owed object; with commencement of default of acceptance the risk of incidental deterioration and accidental loss is transferred to the Customer.

§ 5 Export Business

PHYWE is entitled to withdraw from the contract regarding delivery of such products (partial withdrawal) that require approval of the federal ministry for economics and export control, the Federal Institute for Medicaments and Medical Products or a similar governmental institution for their export from Germany or their import in their country of destination pursuant to legal provisions in the event that the approval is not issued or probably may not be obtained until the agreed delivery date. PHYWE shall immediately advise the Customer of this and possibly reimburse a compensation for the part of the performance affected by the withdrawal.

§ 6 Shipping and Transfer of Risk

1. Place of performance is Göttingen. The delivery condition is "ex works PHYWE". Other agreements must be made in writing.
2. The Customer may request PHYWE to ship the goods. It shall bear the costs and risk for it. In the case of a forwarding order the risk is transferred to the Customer as soon as the shipment had been handed over to the person executing the transport. If PHYWE is able to ship the goods at the time determined by contract and the shipment is delayed at the Customer's request the risk is transferred to the Customer at notice of readiness for shipment.
3. At the Customer's request shipments shall be insured in its name and on its account.

§ 7 Claims for Defects/Guarantee

1. PHYWE is working pursuant to the guarantee claims typical in Germany and the EU. If a PHYWE product shows any other defect already present at delivery, the Purchaser shall advise it immediately and provide evidence. In such an event PHYWE shall repair the defect or deliver a product free of defects (supplementary performance) pursuant to legal provisions. PHYWE shall bear the expenses required for the purposes of supplementary performance, including but not limited to transport, labour and material cost. Additional expenses caused by the sold product being brought to a place other as the domicile or the branch office of the Customer shall not be borne by PHYWE.
2. Insignificant or commercial deviations of the delivered goods in size, shape and colour being in the material's nature do not establish claims for defects by the Customer. Article 377 German Commercial Code applies.
3. PHYWE reserves the right to changes to the PHYWE products required for technical or other reasons not affecting usability and not reducing the service's value and for technical improvements. They do not establish claims for defects, abatement or withdrawal from the transaction by the Customer.
4. If PHYWE's operation or maintenance instructions are not adhered to, changes to the products are made, parts are exchanged or consumables not complying with the original specifications are used, the Customer may not assert claims for defects if the Customer does not refute a substantiated claim to the effect that it was only one of those circumstances that had caused the defect.
5. The Customer must immediately inform customer service management/PHYWE's technical hotline of visible defects in writing, however, the latest within one week after receiving and/or accepting the

delivered goods. Defects that can not be discovered within this period even with careful examination shall be communicated and proven to PHYWE in writing immediately upon discovery.

6. Claims for defects for regular wear and tear are excluded.
7. Only the immediate Customer is entitled to claims for defects towards PHYWE and may not transfer them to third parties.
8. Claims for defects fall under the statute of limitations after 12 months as of delivery of the goods under contracts with the Customer. Retaining payments by the Customer is only admissible if the proportion of the occurred defect is appropriate.

§ 8 Repairs

If the Customer is not entitled to claims for defects pursuant to § 7 or if the statutory period of limitation pursuant to § 7.8 is expired and PHYWE and the Customer agree on a repair of the products § 7.8 applies equally to the limitation of a defect of the repair.

§ 9 Reservation of Title

1. PHYWE reserves title to the goods until fulfilment of all claims from the business relation for whatever legal reason including the claims arising in the future or conditional claims. If the realisable value of existing securities (goods subject to reservation of title pursuant no. 3 below and transferred accounts receivable pursuant no. 5 below) exceeds the secured claims by more than 10 % in total PHYWE is obliged insofar to release securities at the seller's discretion at the Customer's request.
2. Joint ownership rights arising from combination or mixing are deemed goods subject to reservation of title. PHYWE has an appropriate right to the reservation of title on these goods as well.
3. The Customer is entitled to process and sell the goods subject to reservation of title in the course of normal business unless it falls into arrears. Pledging or protective conveyance is inadmissible. By way of security the customer shall immediately transfer to PHYWE all claims (including any outstanding balance claims from the current accounts) arising from the resale or another legal reason (insurance, inadmissible action) in connection with the goods subject to reservation of title to their full extent. PHYWE shall give it the revocable authorization to collect the claims transferred to PHYWE for its account in its own name. This authorization for collection may only be withdrawn if the Customer does not properly fulfil its payment obligations.
4. In the event that the Customer behaves contrary to the contract – including but not limited to falling into arrears – PHYWE is entitled to take back the goods subject to reservation of title after expiration of an appropriate additional respite or demand the transfer of the Customer's claims for return towards third parties as the case may be. PHYWE taking back the goods subject to reservation of title does not constitute a withdrawal from the contract unless PHYWE has expressly stated such withdrawal.

§ 10 Payment

1. All payments exceeding the credit limit of the Customer with PHYWE confirmed by PHYWE in writing shall be made for payment in advance or confirmed with an irrevocable letter of credit from a large European bank accepted by PHYWE or an equivalent bank guarantee.
2. Within or above credit limit invoices shall be payable without deducting a cash discount or other discounts with PHYWE receiving the payment within 20 days as of contract conclusion and receipt of the invoice or an equivalent payment listing by the Customer.
3. In the event of orders with a purchase price surpassing € 25,000.00 the Customer shall make an advance payment of 40% of the purchase price for PHYWE products and 60% of the purchase price for third party products. The advance payment is due on contract conclusion and receipt of an invoice or equivalent payment listing.
4. A payment is only deemed made when PHYWE has the amount at its disposal. In case of cheques the payment is only deemed made when the cheque has been cashed.
5. The Customer shall fall into arrears 3 days after maturity of the claim by PHYWE and receipt of an invoice or delivery without it requiring a written reminder. If the Customer falls into arrears PHYWE is entitled to demand interest of 8% above the relevant basic interest rate of the European Central Bank at the respective point in time. PHYWE may submit evidence of a greater damage
6. If PHYWE becomes aware of circumstances calling the Customer's financial standing into question, including but not limited to not cashing its cheque or stopping its payments, or if PHYWE becomes aware of other circumstances calling the Customer's financial standing in question, PHYWE is entitled to call the complete outstanding debts even if it had accepted cheques.
7. The Customer is only entitled to set off its debts if the counterclaims have been established as final and absolute or are undisputed. The same shall apply for the right of retention pursuant to article 273 German Civil Code, the commercial right of retention pursuant to article 369 German Civil Code and the right of refusal of services pursuant to article 320 German Civil Code.

§ 11 Copyright Infringements

1. PHYWE shall exempt the Customer and its customers from claims arising from infringements of copyrights, trade marks or patents unless the design of a delivery object had been made by the Customer. PHYWE's exemption obligations shall be limited to the amount of the predictable damage. An additional requirement for exemption is that in case of a legal dispute (article 72 German Code of Civil Procedure) the Customer informs PHYWE of the dispute and that the alleged legal infringement may be ascribed to the construction of PHYWE's delivery items without combination or use with other products.
2. Optionally PHYWE has the right to free itself from the obligations assumed in clause 1 by either

a) obtaining the required licences regarding the alleged infringed patents, or

b) providing the Customer with a changed delivery item or part of it that rectifies the infringement reproach concerning the delivery item by exchanging it for the infringing delivery items or their parts unless the changed delivery item (or parts of it) falls behind the original performance regarding the usability and/or its value.

§ 12 Liability

1. PHYWE shall be liable for breaches of contractual and non-contractual obligations, including but not limited to impossibility, delay and unlawful acts, only in cases of malicious intent and gross negligence – of its executive employees as well – limited to damages foreseeable at contract conclusion.
2. Claims for damages of material defects shall fall under the statute of limitation after 12 months as of delivery of the goods – with exception of personal injury or wilful or grossly negligent breaches of duty. The limitation of legal regress claims remains unaffected. The relevant legal provisions apply for claims for damages on account of other legal reasons.

§ 13 Applicable law, jurisdiction, partial invalidity

1. In addition to these provisions German law with exemption of the provisions of the UN Convention on Contracts for the International Sale of Goods dated 11/04/1980 (CISG) applies.
2. Place of jurisdiction is Göttingen
3. If a provision in these General Terms and Conditions or a provision under other agreements is or becomes ineffective the validity of all other provisions or agreements shall remain unaffected.

General Terms and Conditions of PHYWE Systeme GmbH & Co. KG, last updated on 01/08/2010

After announcement of new General Terms and Conditions all previous General Terms and Conditions loose their validity.

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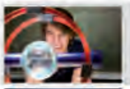
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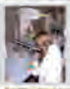
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