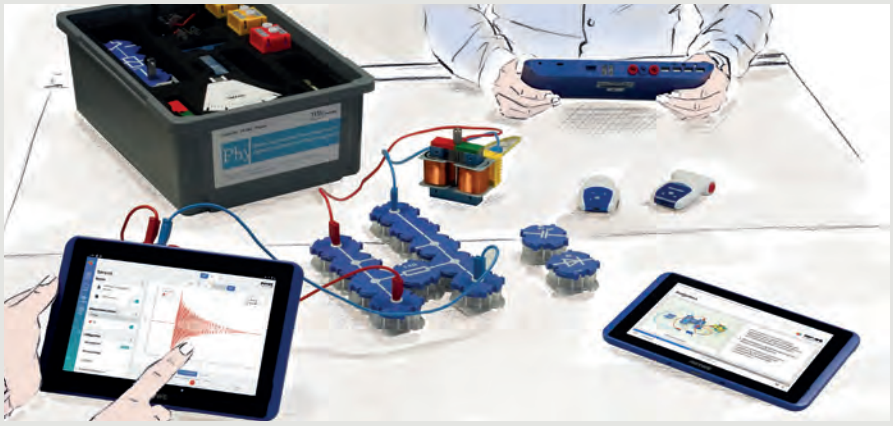
TESS | PHYWE

DEMO | PHYWE

PHYWE

excellence in science



PHYWE Solutions
for Schools and Universities

Digital Science Education | Student Experiments | Demonstration Experiments

Physics Phy | Chemistry Che | Biology Bio | Applied Sciences Sci

How to use
the catalogue pages

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

Item number

Experimental setup

QR code with direct link to the product on the PHYWE website

Pictograms for quick overview, e.g. PC is necessary for experiment

Title of the experiment

Benefits of the experiment

Related scientific topic

Description of main principle

Note e.g. top seller, new or only available from PHYWE

Tasks for students

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

- Sets and experiments with digital measurement via Cobra SMARTsense
- Sets and experiments which require a computer
- Training recommended
- Nobel price winner experiment
- Base set, required for supplementary sets
- Supplementary set requiring a base set
- Experiments with laser
- Experiments with radioactivity
- Further information about the experiment: QR codes to the PHYWE website and the interactive experiment on curricuLAB©.

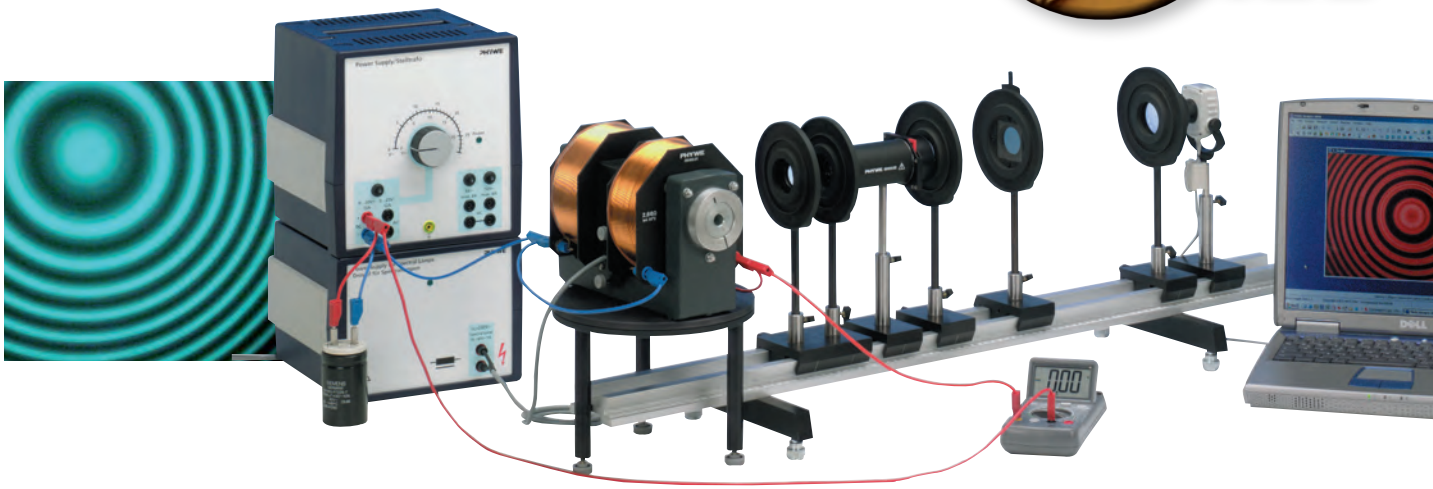
PHYWE Solutions

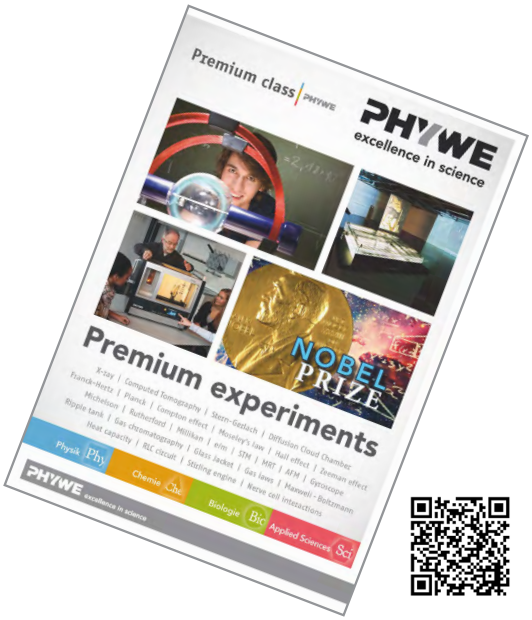
Website

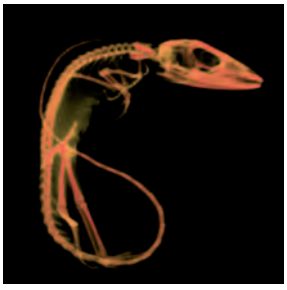
PHYWE supplies more than 50 Nobel Prize experiments

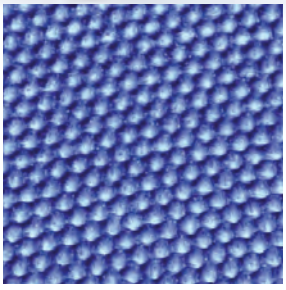
The Nobel Prize is awarded annually in the disciplines of physics, chemistry, physiology or medicine, literature and peace. For scientists and researchers, it is the highest award.

PHYWE supplies more than 50 Nobel Prize experiments. Some of them you can find in the TESS expert chapters. From Conrad Röntgen to Max Planck to Albert Einstein. Experiments in the footsteps of Nobel Prize winners. PHYWE makes Nobel Prize experiments understandable.









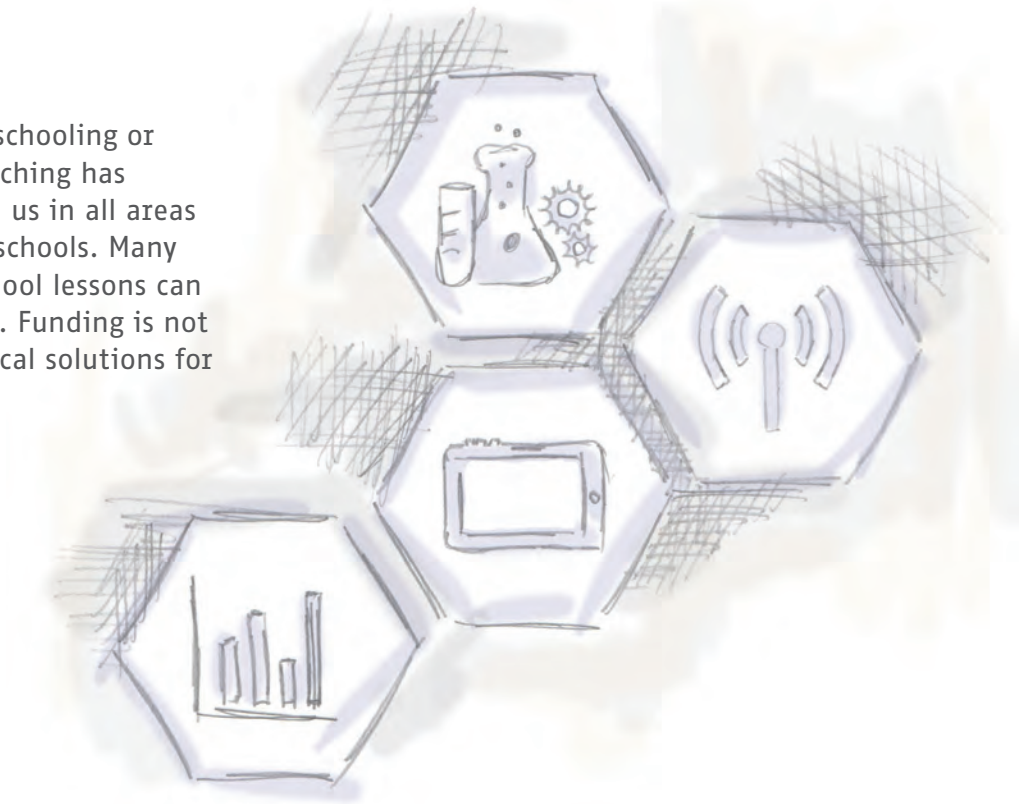
More information about the PHYWE Nobel Prize experiments can be found in the new brochure Premium experiments or in this catalogue. The PHYWE Nobel Prize experiments are identified with this icon.

2 Digital Science Education

Digital Science Education

The complete solution by PHYWE

Whether classroom teaching, homeschooling or teaching in nature – the way of teaching has changed. Digitalization has reached us in all areas of life, and this also applies to our schools. Many programs were initiated so that school lessons can be designed in a contemporary way. Funding is not enough, however – you need practical solutions for teaching science.



This is how **digital teaching** works today

At PHYWE, we have developed a concept for digital teaching that consists of four components:

Experiment sets

Sensors

Display unit

Software

With this well thought out solution that relates directly to your curriculum, you can design your school lesson simple, progressive and time-saving. Be state-of-the-art: Work with modern, high-performance hardware, supported by our specially developed software and combine this individually with our digital sensors and the tried and tested TESS sets.

Get to know our digital product portfolio now.

Classroom teaching

Face-to-face teaching rethought through the use of experiment sets that conform to the curriculum, state-of-the-art sensors, powerful display units, the most advanced measurement software and excellent teaching and learning platform.

Homeschooling

Homeschooling means digital teaching outside of school. In order for you to make this just as efficient and successful as your classroom teaching, you need an excellent teaching and learning platform, easy-to-use sensors, a powerful display unit and advanced measurement software.

Teaching in nature

Mobile teaching in the environment and in the field is very important, but it poses a number of challenges. Be perfectly prepared with specially coordinated experiment sets, mobile and durable measuring devices and display units, robust sensors and advanced measuring software.

Website

Cobra SMARTlink

Simple. Digital. Experiment.

Cobra SMARTlink is a state-of-the-art, high-performance 3-in-1 tablet:

- **Measuring device:** Start measuring directly with 7 integrated sensors and the pre-installed measurement software measureAPP, 4 USB-Ports for connection of additional sensors, microphone and GPS-sensor
- **Display unit:** A brilliant 10.1 "display offers sufficient space for all applications
- **Android tablet:** Access to more than 3 million apps in the Google Play Store

Especially recommended for student experiments as it can be used simple, good and reliably.

"Everything you need,
exactly what you want."

Start measuring directly with 7 integrated sensors and the pre-installed measurement software measureAPP:

- Acceleration
- Temperature (2x)
- Current
- Light
- UV
- Voltage
- Humidity

Enough power for all your applications.

A powerful 8-core processor with a clock rate of 2 GHz, 4 GB of RAM and a 64 GB SSD hard drive ensure that every-thing always runs smoothly.

On your marks, get set, go!

The pre-installed measureAPP offers more than 150 experimental descrip-tions for all subjects.

Evyerthing you need in perfect storage.

The accessories for the Cobra SMARTlink include 2 connection cables 4 mm (red, blue), 2 tempe-rature sensors type K, a USB type C charging cable with charging adap-ter and an easily under-standable manual. The sturdy packaging card-board including storage box enables a quick check for completeness.

In case you need a little more.

More than 40 Cobra SMARTsense sensors can be connected via Bluetooth and USB.

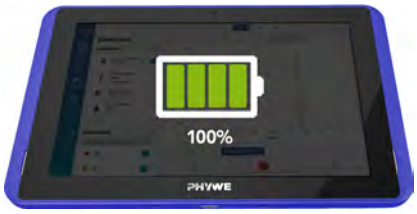
Everything in perfect view.

The brilliant 10.1 "full HD display offers sufficient space and a razor-sharp display.

Perfect for experimenting, but not only.

There are more than 3 million apps from the Google Play Store ready for use.

Battery for the whole day ... and more.



The large battery with 10.000 mAh en-sures use throughout the (school) day.

Cobra SMARTlink	Item no: 12999-99
Cobra SMARTlink – SMARTlink version for non-eu countries	Item no: 12999-99E

Website

Cobra SMARTsense

Simple. Intuitive. Measurement.

Perfect for student experiments

Cobra SMARTsense is the ideal solution for inexpensive digitalization of science teaching. The sensors connect wirelessly (Bluetooth) or wired (USB) directly to the student's digital end device (smartphone, tablet or desktop PC). Using the free and award-winning measureAPP measurement software for iOS, Android and Windows, measured values can be easily recorded and graphically displayed. If more evaluations are needed, the measureLAB measurement software for Windows and macOS can be used.

Switch on and start measuring.

Get started right away with any Bluetooth-enabled end device and the free measureAPP.

Totally happy.

Over 40 sensors with more than 70 measured quantities for all subjects.

A battery that never runs out of breath.

Intelligent and efficient power management for up to 50 teaching hours on one battery charge.

Something for everyone.

The free measureAPP provides perfect support and runs on all mobile platforms and end devices. For professionals, measureLAB is available.

If you can use a little more.

Up to 32,000 measured values per second guarantee precision and recordings with up to 17 measuring channels simultaneously are possible.

Connecting made easy.

Fast connection of sensors and data exchange via Bluetooth – for many sensors additionally possible via USB.

Accessories:		
	USB quick charger with 6 USB ports	Item number: 07934-99
	Button cell CR2032, 3V (2 pcs)	Item number: 07922-17
	measureAPP	Item number: 14581-61 for free

Website

Cobra SMARTsense

Simple. Intuitive. Measurement.

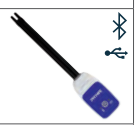
Phy Cobra SMARTsense Sensors for Physics

Sensor	Voltage	Current	Force & Acceleration	Temperature	Dual Photogate	Pressure	Acceleration	Motion	3-Axis Magnetic field
Image									
Measured value	Voltage	Current	Acceleration	Temperature	Time	Pressure	Acceleration	Distance	Magnetic flux
Measurement range	± 30 V	± 1 A *	± 50 N / ± 16 g	- 40…120 °C	0 … ∞ s	20…400 kPa	± 8 g	0,20…2 m	130 mT / 5 mT
Resolution	0,02 V	0,5 mA	30 mN / 0,01g	0,01 °C	0,01 ms	0,1 kPa	0,01 g	1 mm	0,1 mT / 0,001 mT
Sampling rate	1 kHz / 10 kHz	1 kHz / 10 kHz	1000 Hz	10 Hz	1000 Hz	500 Hz	100 Hz	20 Hz	20 Hz
Battery	Li-ion battery	Li-ion battery	Li-ion battery	CR2032	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery
Item number	12901-01	12902-01	12943-00	12903-00	12945-00	12905-01	12907-01	12908-01	12947-00

Che Cobra SMARTsense Sensors for Chemistry

Sensor	pH	Conductivity	Dropcounter	Colorimeter	Thermocouple	Nitrate Ion	Ammonium Ion	Chloride Ion	Calcium Ion
Image									
Measured value	pH	Conductivity	Drop count	Transmission Turbidity	Temperature	Nitrat-Concentration	Ammoniom-Concentration	Chloride-Concentration	Calcium-Concentration
Measurement range	0…14 pH	0…20.000 µS/cm 0…100 °C	0…∞ Imp	0…100 %, 0...3 abs, 0...400 NTU	-200...1.200 °C	0,6...6200 ppm	0,9...1800 ppm	1,8...3550 ppm	0,4...4000 ppm
Resolution	0,01 pH	8 µS/cm, 0,1 °C	30 Imp/s	0,1%, 0,01 abs	0,1 °C	2 ppm	0,5 ppm	1 ppm	1 ppm
Sampling rate	100 Hz	10 Hz	50 Hz	1 Hz	10 Hz	100 Hz	100 Hz	100 Hz	100 Hz
Battery	CR2032	CR2032	Li-ion battery	Li-ion battery	Li-ion battery	CR2032	CR2032	CR2032	CR2032
Item number	12921-00	12922-00	12923-00	12924-01	12938-01	12912-00	12913-00	12914-00	12915-00

Bio Cobra SMARTsense Sensors for Biology

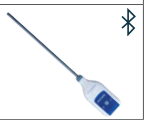
Sensor	Humidity	EKG	CO_2	Spirometer	Heart rate	Oxygene	Blood pressure	Skin resistance	Ethanol vapor
Image									
Measured value	Humidity	Voltage	CO_2-Concent-ration	Volume flow	Heare rate	CO_2-Concent-ration	Blood pressure	Skin resistance	Ethanol-Concentration
Measurement range	0…100 % rH	0…4,5 mV	0…100.000 ppm	± 10 l/s	30…200 bpm	0…20 mg/l 0…100 %	30…200 bpm	0…10 µS	0…3 %
Resolution	0,1 % rH	4,5 µV	2 ppm	0,01 l/s	1 bpm	0,01 mg/l, 0,1 %	1 bpm	0,01 µS	...
Sampling rate	10 Hz	1000 Hz	1 Hz	200 Hz	10 Hz	100 Hz	10 Hz	100 Hz	100 Hz
Battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery
Item number	12931-01	12934-01	12932-01	12936-01	12935-01	12933-01	12944-00	12942-00	12948-00

* Overcurrent protection

Phy Cobra SMARTsense Sensors for Physics

Light	Radioactivity	Surface Temperature	High Current	Rotary Motion	Energy	Sound	Wide Range Temperature	Photogate	Light & Color
									
Brightness	Radioactivity	Surface Temperature	Current	Angle	Current, Voltage Work	Sound level	Temperature	Time	Brightness UV RGB
0…128 klx	0...40000 #/min	- 25...125 °C	±10 A *	30 rps	± 30 V / ± 1 A	0,1..15 kHz /55..110dB	- 20...330 °C	0 … ∞ s	0 … 200 klx 0 … 400 W / m²
1 lx	1 #/min	0,1 °C	10 mA	0,125°	1 mV; 40 µA	0,1 dB	C = 0,01°C	0,01 ms	1 lx / 0,1 W / m².
10 Hz	10 Hz	10 Hz	1000 Hz	1000 Hz	100 Hz	10 Hz (Soundlevel); 32kHz (Soundsignal) at USB	10 Hz	1000 Hz	1 kHz / 1 Hz
Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery	CR2032	Li-ion battery	Li-ion battery
12906-01	12937-02	12917-01	12925-00	12918-01	12919-00	12939-00	12910-00	12909-00	12951-00

Che Cobra SMARTsense Sensors for Chemistry

Potassium Ion	Oxygen Reduction Potential (ORP)	Temperature	Methane	High Precision Temperature
				
Potassium-Concentration	Redoxpotential	Temperature	Methane-Concentration	Temperature
0,4...3900 ppm	-2000...2000 mV	- 40…120 °C	0…10000 ppm	- 50…150 °C
1 ppm	1 mV	0,01 °C	3 ppm	0,01 °C
100 Hz	100 Hz	10 Hz	100 Hz	10 Hz
CR2032	CR2032	CR2032	Li-ion battery	Li-ion battery
12916-00	12927-00	12903-00	12949-00	12950-00

Sci Cobra SMARTsense Sensors for Science

Sensor	Voltage	Current	Temperature
Image			
Measured value	Voltage	Current	Temperature
Measurement range	± 30 V	± 1 A *	- 40…120 °C
Resolution	0,02 V	0,5 mA	0,01 °C
Sampling rate	1 kHz / 10 kHz	1 kHz / 10 kHz	10 Hz
Battery	Li-ion battery	Li-ion battery	CR2032
Item number	12901-01	12902-01	12903-00

Bio Cobra SMARTsense Sensors for Biology

Weather station	pH	Conductivity	Methane
			
Wind speed, Pressure, Humidity, Temperature	pH	Conductivity	Methane-Concentration
2...50 km/h 45...110 kPa	0…14 pH	0…20.000 µS/cm 0…100 °C	0…10000 ppm
0,1 km/h, 0,01 kPa	0,01 pH	8 µS/cm, 0,1 °C	3 ppm
10 Hz	100 Hz	10 Hz	100 Hz
Li-ion battery	CR2032	CR2032	Li-ion battery
12946-00	12921-00	12922-00	12949-00

Sci Cobra SMARTsense Sensors for Science

Sensor	Force & Acceleration	Light	CO_2	Humidity
Image				
Measured value	Acceleration	Brightness	CO_2 Concentration	Humidity
Measurement range	± 50 N / ± 16 g	0…128 klx	0…100.000ppm	0…100 % rH
Resolution	30 mN / 0,01 g	1 lx	2 ppm	0,1 % rH
Sampling rate	1000 Hz	10 Hz	1 Hz	10 Hz
Battery	Li-ion battery	Li-ion battery	Li-ion battery	Li-ion battery
Item number	12943-00	12906-01	12932-01	12931-01

Website

SensorCases for Cobra SMARTlink / Cobra SMARTsense

Simple. Perfect. Storage.

The SensorCases are the smart solution for comfortable and mobile storage.

The sturdy sensor cases with 16-fold automatic charger, robust wheels and pull-out bare telescopic handle contain all equipment in a box with up to 56 Cobra SMARTsense sensors or 16 Cobra SMART- link in stable foams.

SensorCase Cobra SMARTlink, 8-fold	Item number: 12986-88	1 unit
SensorCase Cobra SMARTlink, 16-fold	Item number: 12987-88	1 unit

Phy

SensorCase Cobra SMARTsense, Physics, 16-fold	Item number: 12981-88	Set
consisting of		
Cobra SMARTsense – Voltage, ± 30 V (Bluetooth + USB)	Item number: 12901-01	16 units
Cobra SMARTsense – Current, ± 1 A (Bluetooth + USB)	Item number: 12902-01	16 units
Cobra SMARTsense – Temperature, -40 ... 120 °C	Item number: 12903-00	16 units
Cobra SMARTsense – Force and Acceleration	Item number: 12943-00	8 units

Che

SensorCase Cobra SMARTsense, Chemistry, 16-fold	Item number: 12982-88	Set
consisting of		
Cobra SMARTsense – Temperature, -40 ... 120 °C	Item number: 12903-00	16 units
Cobra SMARTsense – Thermocouple, -200 ... +1200 °C (Bluetooth + USB)	Item number: 12938-01	16 units
Cobra SMARTsense – pH, 0 ... 14 (Bluetooth)	Item number: 12921-00	16 units
Cobra SMARTsense – Dropcounter, 0 ... ∞	Item number: 12923-00	1 unit
SensorCase for Cobra SMARTsense	Item number: 12980-00	1 unit

Bio

SensorCase Cobra SMARTsense, Biology, 16-fold	Item number: 12983-88	Set
consisting of		
Cobra SMARTsense – Temperature, -40 ... 120 °C (Bluetooth)	Item number: 12903-00	16 units
Cobra SMARTsense – CO_2, ... 0 ... 100000 ppm (Bluetooth + USB)	Item number: 12932-01	8 units
Cobra SMARTsense – Heart Rate, 30 ... 200 bpm (Bluetooth + USB)	Item number: 12935-01	16 units
Cobra SMARTsense – EKG, 0 ...4,5 mV (Bluetooth)	Item number: 12934-00	8 units
SensorCase for Cobra SMARTsense	Item number: 12980-00	1 unit

Website

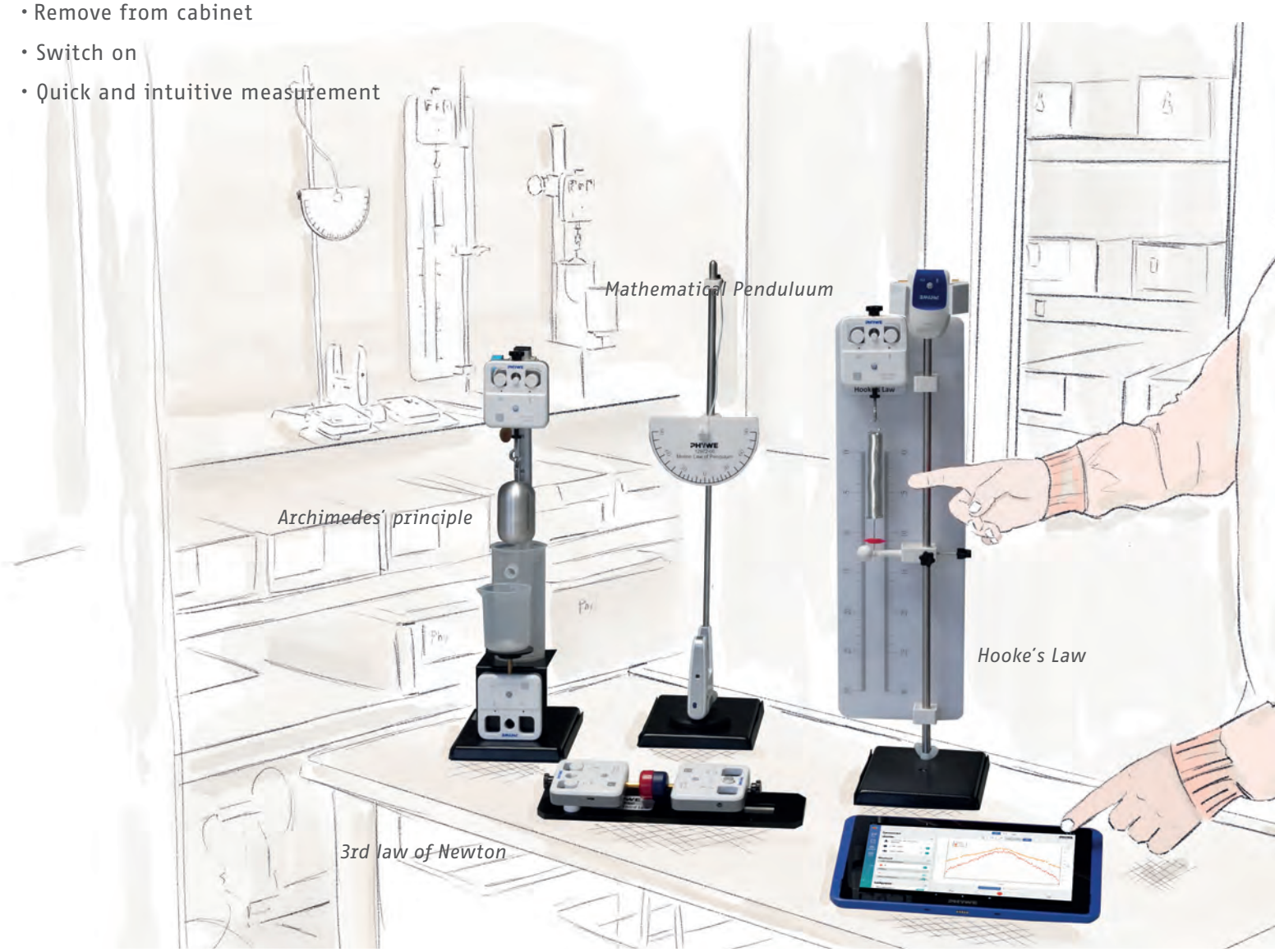
Cobra SMARTexperiments

Simple. Smart. Experiment.

Cobra SMARTexperiments contain all components and sensors necessary for measurement

- Remove from cabinet
- Switch on
- Quick and intuitive measurement

All-in-one-experiment – no lengthy setup, no interface necessary!



3rd law of Newton	Item number: 12973-00
Hooke's law	Item number: 12970-00
Mathematical pendulum	Item number: 12972-00
Archimedes' principle	Item number: 12971-00

USB quick charger with 6 USB ports	Item number: 07934-99
measureAPP	Item number: 14581-61

Cobra DigiCart

Simple. Complete. Dynamic.

Website

**The All-in-One System Cobra DigiCart –
the whole world of dynamics and kinetics in one set.**

- 8 experiments in Basic set and additional 4 experiments in Expert-Set
- 4 integrated sensors (Force-, Speed-, Acceleration- and Positionsensor)
- Communication via modern Bluetooth technology
- Powerful, longasting Lithium-ion batteries with automatic charge protection
- Simple charging via USB

Cobra DigiCart Basic Set	Item number: 12940-77
Cobra DigiCart Expert Set	Item number: 12940-88
Cobra DigiCart (blue)	Item number: 12940-01
Cobra DigiCart (white)	Item number: 12940-00
Cobra DigiCartApp	Item number: 14582-61

iOS

Website

curricuLAB®

Simple. Digital. Teaching.

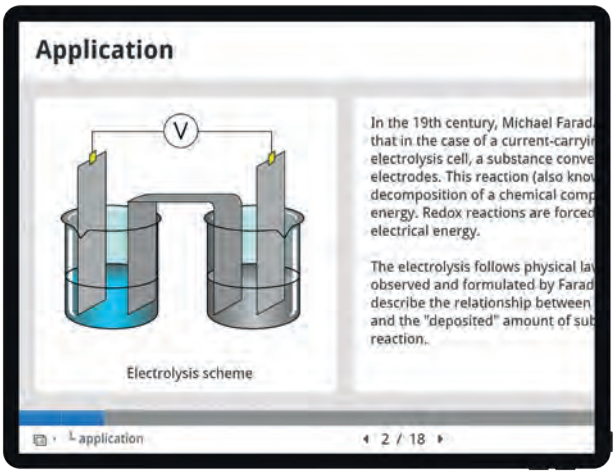
With the new teaching and learning platform curricuLAB® PHYWE offers a fast and uncomplicated entry into digital teaching. With more than 1800 curriculum-compliant contents for all topics (physics, chemistry, biology or nature and technology) and thousands of additional contents curricuLAB® is one of the biggest experiment data bases for the digital science lessons.

Awarded with the Comenius-EduMedia-Medal 2022 as a teaching and learning management system of outstanding pedagogical, content-related and design quality.

Comenius EduMedia Medaille 2022

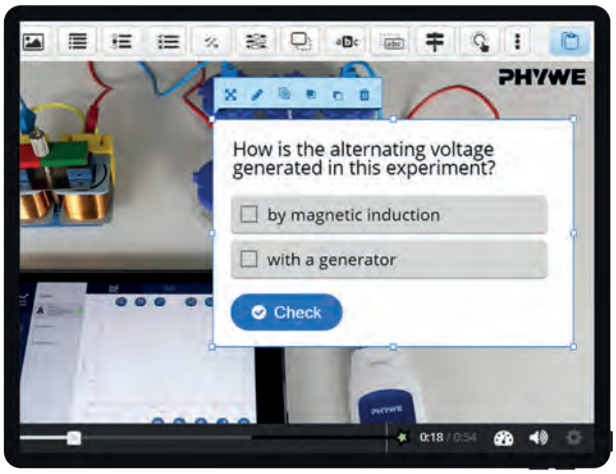
Learning content, that inspires.

Interactive and practical content motivates and makes you want more.



It could hardly be easier.

The intuitive editor makes every change a breeze.



Something for everyone.

More than 4000 didactical based and interactive teaching and learning contents.

**Would you like to test curricuLAB® without obligation?
Then get your free demo access in 2 minutes at www.curriculab.de.**

No limits to creativity.

Choose from more than 40 highly interactive content types to create your own content.

Share content quickly and easy.

Sharing of content using links or QR codes that comply with data protection regulations.

For all platforms and end devices.

curricuLAB® is platform-independent and runs on all Internet-capable end devices.

What our customers say:

Max Metelmann
Schloß-Gymnasium Benrath, Düsseldorf

"The new curricuLAB® combines classical, analogue experiments with digital innovations such as quiz questions and cloze texts in one document. This opens the doors for modern, digital and student-oriented teaching."

Peter Gromes
Comenius-Schule, Herborn

"curricuLAB® offers an excellent basis for student experiments in the classroom. A truly successful tool for the digital age."

Marija Vlaski
Adorno-Gymnasium, Frankfurt am Main

"With curricuLAB® we can easily prepare our learning content in a digital and modern way - for teaching and working at home. We can create the content in the student council and then quickly adapt it individually according to the personal ideas of our colleagues. For us this is a real workload reduction!"

curricuLAB® Single license	Item number: 14578-62
curricuLAB® School license	Item number: 14577-62

Website

measureAPP iOS

Simple. Mobile. Measurement.

PHYWE measureAPP is the app for simple and fast data logging in your digital science education. In combination with our Cobra SMARTsense sensors we offer you an intuitive, simple and modern overall solution that leaves nothing to be desired.

Awarded the Comenius-EduMedia-Seal 2022 as an educational medium which is outstanding in terms of pedagogy, content and design.

Comenius EduMedia Siegel 2022

So simple that it's almost too simple.

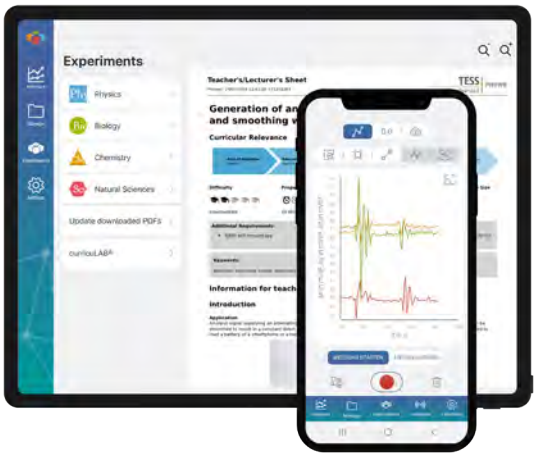
Quick and intuitive measuring (just 2 clicks for data recording).

Data exchange made easy.

Wireless data exchange and connection of Cobra SMARTsense sensors via bluetooth and USB.

Something for everyone.

Find and open more than 150 experiment descriptions directly in the app.



Your ideal companion.

Create individual notes, photos or videos to document the measurement results.

iOS

measureAPP	Item number: 14581-61

measureLAB

macOS

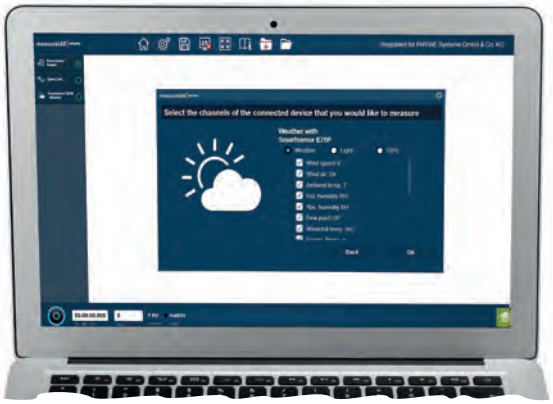
Simple. Precise. Measurement.

Website

The software measureLAB assists you and your students with analyzing your experiment data: No matter if it's a simple integral or a fully automatic equivalence point calculation, measureLAB is the measuring-software of your choice. And more than 150 preconfigured experiments reduce your preparation time to a minimum.

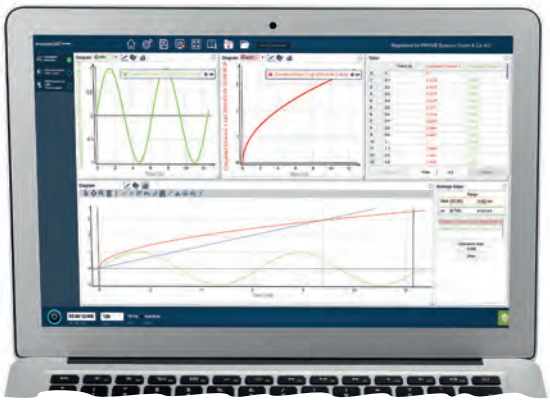
Easy connections.

Wireless data transfer via Bluetooth, WLAN or USB.



Professional measurements easy done.

Measurement speeds of up to 10 MHz, as well as extensive evaluation functions and data processing options.



Something for everyone.

Find and open more than 150 experiment descriptions directly in the software.

Cobra Xpert-Link:

The high-end system for demanding measurements at high speed.

macOS

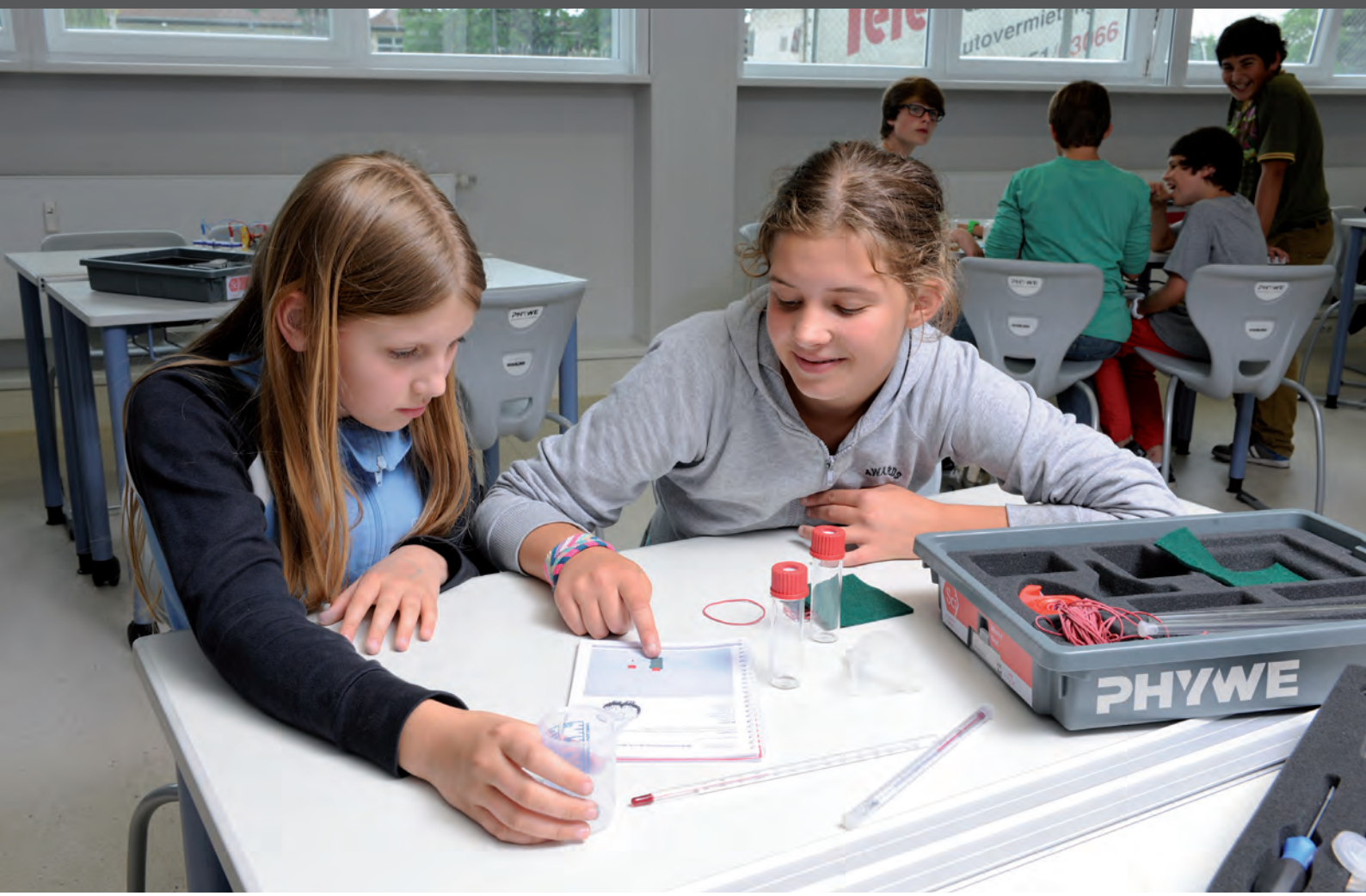
measureLAB multi user licence	Item number: 14580-61
Cobra Xpert-Link	Item number: 12625-99

Digital experiment sets

for students (TESS) and teachers (DEMO)

Our experiment sets for students offer a simple, safe and time-saving solution for experimenting in digital science education.

Our experiment sets for teachers are perfect for demonstration of experiments in digital science lessons.



3. TESS/DEMO advanced

Website

TESS: student experiments –
easy, safe, and time-saving experimentation

Easy

Space-saving and well-structured storage:
- robust and safe
- space-saving, stackable
- clear and quick check for completeness

Safe

Student-adapted equipment for safe experimentation:
- proven and reliable
- robust and versatile equipment
- quality made in Germany

Versatile

One system for all science subjects and inter-disciplinary classes:

Phy Bio Che Sci

Uniform

There is a matching Demo set for teacher experiments for every TESS student set:

TESS ⟷ Demo

The advantages of the PHYWE experiment descriptions at a glance

Student version with:

- precise formulation of the tasks
- complete lists of materials
- step-by-step set-up instructions
- ready-to-use tables for the experiment results
- questions and drawing templates for the evaluation
- notes on hazards and disposal

Teacher version additionally with:

- information concerning the learning goals and theoretical background
- measurement results and diagrams
- answers to the questions on the student sheets

Printed or in digital format:

- in digital format on the learning platform curricuLAB©
- various topic-based handbooks

Time-saving

Detailed, curriculum-compliant experiment descriptions for students and teachers (including solutions and additional information).

Modern

In numerous cases, the TESS experiments can also be performed with Cobra SMARTsense sensors.

Cobra SMART sense

Website

Teacher experiments – quick, clearly visible, and reliable

The curriculum-compliant teacher experiments have been created in line with the student experiments. They can be performed with or without digital sensors (Cobra SMARTsense).

Your advantages

Minimum preparation time

- complete sets and experiment set-ups
- matching experiment descriptions concerning the set-up, execution, and evaluation of the experiments

Clearly visible

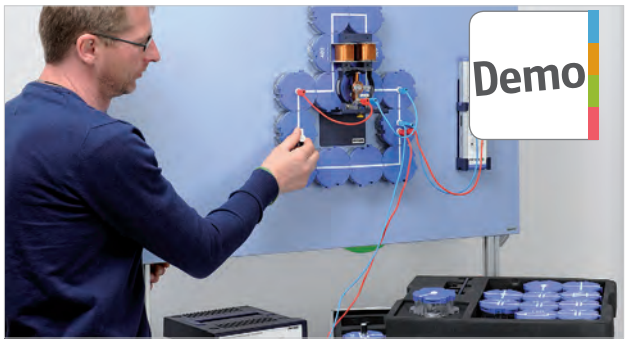
- optimised for demonstration: shifted from the horizontal to the vertical, uniform background, demonstration measuring instruments and display units

Reliable

- developed in cooperation with teachers and in compliance with the curricula
- extensively tested, robust, and durable

Corresponding concept: the same topics as in the student experiments, but with bigger set-ups

Small, horizontal set-up on the desk



Big, vertical set-up on the board

Expanding: the same topic, but with deeper context

Qualitative experiment: Melting point depression/boiling point elevation (P7152400)

Quantitative experiment: Determination of molar masses via a measurement of the boiling point elevation (ebullioscopy) (P1136000)

Storage container with rollers for TESS sets, for 8 trays with 15 cm height

15210-00

Function and Applications

Mobile storage container with rollers for up to 8 TESS boxes (tall form, h = 15 cm) or up to 16 TESS boxes (short form, h = 7,5 cm).

Benefits

- Easy, space-saving and open storage
- Mobile due to rollers, can be transported easily to other classrooms

Equipment and Technical Data

- Robust design
- Two sections with each 8 pairs of railings to store TESS sets
- Two side handles for comfortable transport
- Four wheels with rotation, two of them with brakes
- Dimensions (B x H x T) = 70 cm x 92 cm x 48 cm

Website

Storage container with rollers for TESS sets, for 18 trays with 15 cm height

15211-00

Function and Applications

Mobile storage container with rollers for up to 18 TESS boxes (tall form, h = 15 cm) or up to 36 TESS boxes (short form, h = 7,5 cm).

Benefits

- Easy, space-saving and open storage
- Mobile due to rollers, can be transported easily to other classrooms

Equipment and technical data

- Robust design
- Three sections with each 12 pairs of railings to store TESS sets
- Two side handles for comfortable transport
- Four wheels with rotation, two of them with brakes
- Dimensions (B x H x T) = 104 cm x 127 cm x 48 cm

Website

02150-00

PHYWE Demo Physics board with stand

Website

Function and Applications

Demo Physics board with stand.

Benefits

- Board 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

- Galvanised steel panels mounted in aluminium profile frames.
- The spacing between support bases can be adjusted in any desired way.
- Dimensions of the board: 600 mm – 1000 mm

Necessary equipment

- 2x G-clamp (Art. No. 02014-00)

15500-00

Moveable experimental table 90 x 75 cm, 30 mm table top with PP edge

Website

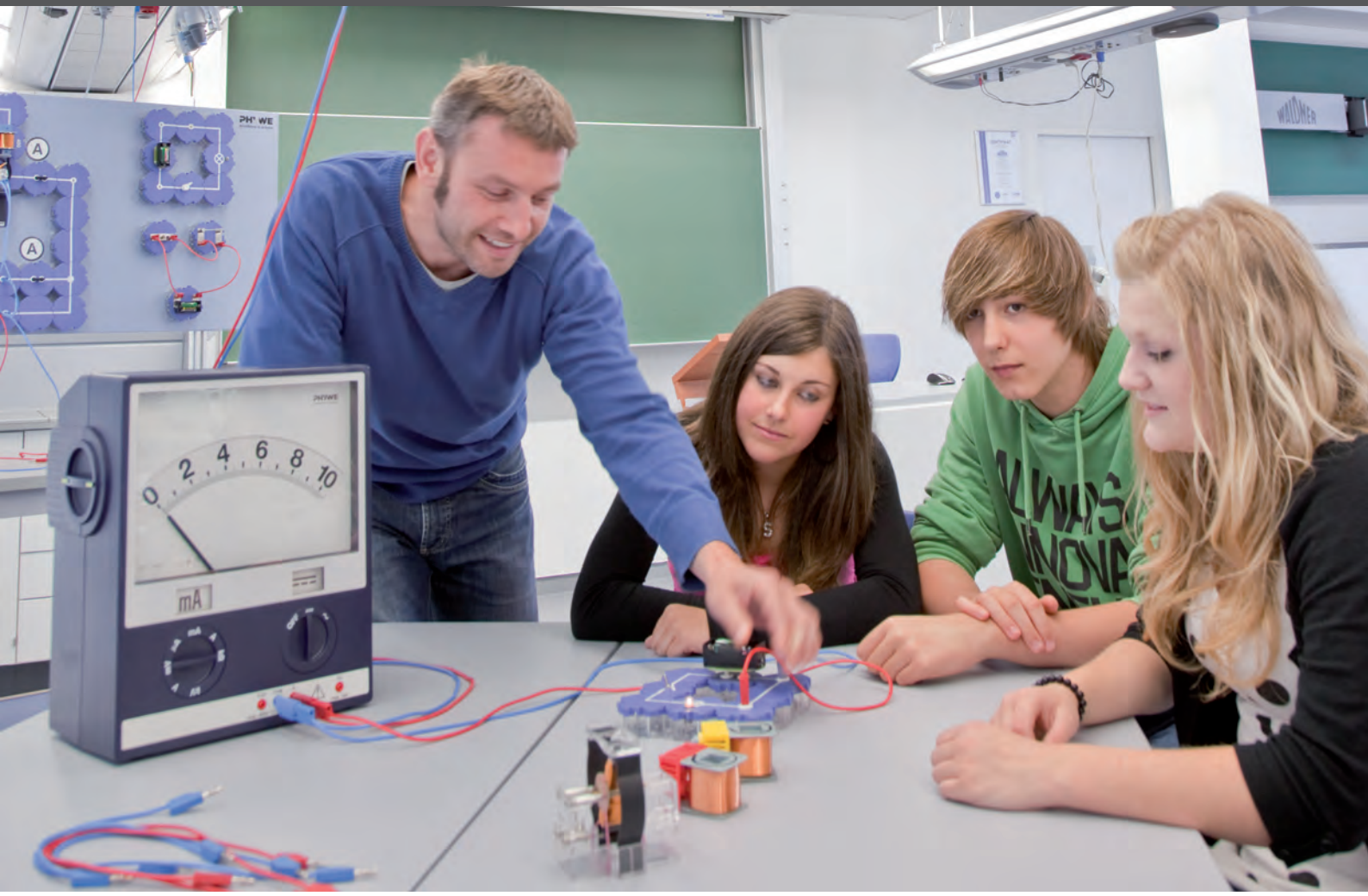
Function and Applications

Mobile experiment stand with shelf cabinet with 3 drawers to hold the DEMO advanced set in a case.

Equipment and Technical Data

Consisting of:

- Movable table
- Color: gray
- Square tube frame, four-legged
- Equipped with 4 wheels with rubber tires, 2 as certainable
- Table top: 30 mm thick, with peripheral PP edge
- Dimensions (mm): 900 x 750 x 900
- Shelf cabinet with three full extension
- Including 3-way electrical connector with cable winder and 4 m connecting cable
- Without storage boxes



TESS/DEMO advanced

3.2 Physics

Complete curriculum coverage in Physics –

Cover the requirements of modern natural science

International Reference Curriculum (School)

Topic \ Sets	Mechanics 1-3	Centripetal Force	Wave Phenomena	Acoustics 1-2	Heat 1-2	Renewable Energy 1-3	Electricity / Electronics 1-3
	TESS / Demo	Demo	Demo	TESS	TESS / Demo	TESS / Demo	TESS / Demo
MECHANICS							
Forces, simple machines	✓						
Mechanics of fluids and gases	✓						
Vibrations and waves	✓		✓				
Linear motion	✓						
Circular motion		✓					
ACOUSTICS							
Sound generation, propagation and perception				✓			
Vibrations and waves				✓			
THERMODYNAMICS							
Temperature measurement					✓		
Thermal expansion					✓		
Heat transfer and thermal insulation					✓		
Thermal energy					✓	✓	
Physical states					✓		
ENERGY							
Energy forms, conversion and conservation	✓				✓	✓	✓
Use and application of renewable energy						✓	
Energy storage						✓	
Wind, water, solar, geothermal, fuel cells						✓	✓
ELECTRICITY							
Circuits							✓
Electrical components							✓
Magnetism							
Electrostatics							
Electromagnetism							✓
Electrical energy and performance							✓
Electric field							
Electromagnetic induction							✓
Electromagnetic waves							
OPTICS							
Straight propagation of light							
Reflection and refraction							
Colours							
Interference and diffraction							
RADIOACTIVITY							
Natural radioactivity							
Types of radiation and their properties							
STRUCTURE OF MATTER							
X-ray physics							
Atomic and nuclear physics							
Movement of charged particles in EM fields							

education with the TESS and DEMO System

Electro-statics	Magnetism	Electric Motor / Generator	Electric Fields	Microwaves	Optics 1-3	Optics / Atomic Physics	Radio-activity	Structure of Matter
TESS	TESS	TESS	TESS	Demo	TESS / Demo	TESS	TESS / Demo	Demo
	✓	✓	✓			✓	✓	
						✓		
						✓		
	✓							
✓								
			✓					
		✓						
				✓				
					✓			
					✓			
					✓			
					✓	✓		
							✓	
							✓	
								✓
						✓		✓
								✓

25271-88D

Website

NEW

curricuLAB

Cobra SMART sense Basic

Student set Mechanics 1 digital, TESS advanced Physics

Function and Applications

Basic set allowing the performance of 32 experiments about the following topics:

- Physical quantities and characteristics (5 experiments)
- Forces (10 experiments)
- Elementary machines (9 experiments)
- Liquids and gases (2 experiments)
- Oscillations (6 experiments)

In 17 experiments, you can use the Cobra SMARTsense Sensor Force in combination with tablets (iOS and Android) and smartphones (Android) instead of the classic measuring device.

Benefits

- The equipment set consists of all necessary components for the experiments
- The ideal combination of classic experiments and digital data acquisition
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Real tripod material for a particularly stable and therefore safe construction

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment
- Cobra SMARTsense Force and Accelaration Sensor +/- 50 N / +/- 16 g

15272-88

Website

curricuLAB

+ Basic

Student set Mechanics 2, TESS advanced Physics

Function and Applications

Supplementary equipment set for TESS Basic Set Mechanics 1 (25271-88). Together with the Basic set, it is possible to performe 51 student experiments in total:

- Physical quantities and characteristics (6 experiments)
- Forces (16 experiments)
- Elementary machines (11 experiments)
- Liquids and gases (10 experiments)
- Ocillations (8 experiments)

Benefits

- The equipment set consists of all necessary components for the experiments
- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- Simple teaching and efficient learning thanks to the digital experiment descriptions included as a QR code

Student set Linear motion Dynamics digital, TESS advanced Physics

15283-88D

NEW

Website

curricuLAB

Function and Applications

Equipment set allowing the performance of 6 experiments about the following topics:

- Uniform and non-uniform motion (1 experiment)
- Laws of motion (1 Experiment)
- Newtons laws (2 Experiments)
- Conversion of engery (1 Experiment)
- Free fall (1 Experiment)

In all experiments, the Cobra SMARTsense Sensor Photogate is used instead of the classic measuring device in combination with tablets (iOS and Android) and smartphones (Android). In three experiments, the digital data acquisition also provides a further didactic added value.

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Particularly accurate and reproducible measurement results through the use of forked light barriers
- Particularly modern coverage of the curriculum theme „movement“ in the student experiment

Equipment and Technical Data

- The equipment set consists of all the necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment
- Cobra SMARTsense Photogate: Measuring range: 0 ... infinite s, resolution: 0.01 ms, sampling rate: 800 Hz
- Cobra SMARTsense Motion: Measuring Range: 0.2..2 m, resolution: 1 mm, sampling rate: 50 Hz

15510-88

DEMO advanced Physics Set Mechanics 1

Website

curricuLAB

Basic

Function and Applications

Equipment set allowing the performance of 24 experiments about the following topics:

- Forces (10 experiments)
- Simple Machines (9 experiments)
- Oscillation (3 experiments)
- Mechanical Forms of Energy (1 experiment)
- Mechanics of Liquids and Gases (1 experiment)

Benefits

- Demonstrative measurement of forces with large circular dynamometers with a fixing magnet and ball-bearing pulley with two cord grooves for two measuring ranges
- The experiments can be modified in next to no time
- Magneto-adhesive angular disc and measuring scale facilitate the measurements
- Coloured arrows enhancing observations and explanations
- Easy teaching by using the demo board for demonstration
- Magneto-adhesive components ensure easy handling and freedom of positioning
- Secure fastening using magnets with an adhesive force of at least 10 N
- 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 teacher experiments are delivered as PDF documents on a DVD
- Matched with international Curriculum: all topics are covered

15511-88

DEMO advanced Physics Supplementary Set Mechanics 2

Website

curricuLAB

Basic

Function and Applications

Supplementary equipment set for the DEMO Set Mechanics 1 (15510-88). In combination with the set Mechanics 1 another 19 demonstration experiments can be performed:

- Forces (5 experiments)
- Simple Machines (4 experiments)
- Mechanical Forms of Energy (1 experiment)
- Mechanics of Liquids and Gases (9 experiments)

Benefits

- Magneto-adhesive and flexible track with a reinforced front edge, which allows to set up completely unconventional track shapes for experiments on the law of conservation of energy
- Magneto-adhesive components ensure easy handling and freedom of positioning
- Secure fastening using magnets with an adhesive force of at least 10 N
- Easy marking of motions using colored arrows and points
- Liquid levels are easy to observe on the plain background
- The experiments can be modified in next to no time
- Complete equipment set in addition to Mechanics 1
- 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 teacher experiments are delivered as PDF documents on a DVD
- Matched with international Curriculum: all topics are covered

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

DEMO advanced Physics Set Linear Motion (Dynamics)

15514-88

Function and Applications

Equipment set allowing the performance of 13 demonstration experiments about the following topics:

- Uniform and uniformly accelerated and decelerated motion
- Newton's laws
- Potential and kinetic energy
- Momentum (elastic and inelastic collisions)

Benefits

- Extremely robust demonstration track with a length of 1.5 m included
- Sunken scale in the track with mm graduation
- Adjustable feet over the entire track length for a very simple alignment of the track on small tables
- Cart for demonstration tracks with low friction sapphire bearings
- No overloading due to elastic bearing of base plate
- Rolling on flat planes prevented as wheels are covered by overlapping side walls
- Multiple time measuring instrument with 4 measuring inputs and 1 trigger input and four 4-digit digital displays
- 6 different operating modes allow the timer unit to be adjusted to suit almost any experimental requirement: distance-time law for four tracks, measurement of speed at four positions, principles of collisions, measurement of the orbiting time of a rotary movement, the direct measurement of the duration of a complete swing of a mechanical pendulum and for short or long-term measurements with two 8-digit displays by connecting each of 2 timers (0000.0000 to 9999.9999 seconds)
- Matched with international Curriculum: all topics are covered
- Complete equipment set: simple execution of the experiments
- The equipment is stored in a robust aluminum case with removable lid

Website

curricuLAB

Software „Measure Dynamics", site licence

14440-62

Function and Applications

Software „measure Dynamics", automatic video analysis of movements. The measurement software „measureDynamics" provides an inexpensive way to analyze movements and display them in the shape of diagrams. All you need is a digital video camera, like webcams, camcorders or common digital cameras with movie function. A site licence is provided to install the software on every PC at the site and on all personal PCs of students and teaching personnel.

Benefits

- Automatic object recognition and tracing, including several filmed objects simultaneously, e.g. coupled pendulum, or movement of different body parts of the human body
- 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, PHYWE measureLAB, and other applications
- Video processing includes cutting, compression and other common features
- Software-guided modeling for didactical transfers (including homework)
- Demonstration experiments in the classroom or 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
- Compatible with all Windows versions from Windows 7

Website

25289-88

Student set Acoustics 1, TESS advanced Physics

Website

curricuLAB

Basic

Function and Applications

Equipment set allowing the performance of 14 experiments about the following topics:

- Generation, propagation and perception of sound (8 Experiments)
- Physical properties: Oscillations and waves (2 Experiments)
- Applications in the field of medicine, music, and everyday life (4 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- Multidisciplinary treatment of the subject acoustics: physics, biology and music
- More than 10 documented experiments, mainly software- based
- Powerful educational software for generation and analysis of acoustic signals

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment

15321-88

Student set Acoustics 2, TESS advanced Physics

Website

curricuLAB

Basic

Function and Applications

Supplementary equipment set for TESS set Acoustics 1 (15289-88). Together with the set Acoustics 1, it is possible to perform 22 student experiments in total:

- Generation, propagation and perception of sound
- Physical properties: Oscillations and waves
- Applications in the field of medicine, music, and everyday life

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Matched with international curriculum: all topics are covered
- Experimenting literature for pupils and teachers available: minimal preparation time
- Multidisciplinary treatment of the subject acoustics: physics, biology and music
- More than 20 documented experiments, mainly software- based
- Powerful educational software for generation and analysis of acoustic signals

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment

Student set Heat 1 digital, TESS advanced Physics

25274-88D

NEW

Website

curricuLAB

Basic

Cobra SMART sense

Function and Applications

Basic set allowing the performance of 21 experiments about the following topics:

- Thermal equilibrium and temperature measurement (3 experiments)
- Thermal expansion (4 experiments)
- Heat transfer (2 experiments)
- Thermal energy (4 experiments)
- Change of state (5 experiments)
- Solutions (3 experiments)

In 18 experiments, you can use the Cobra SMARTsense Sensor Temperature in combination with tablets (iOS and Android) and smartphones (Android) instead of the classic measuring device. In addition, the digital data acquisition provides further didactic added value in 6 experiments.

Benefits

- The ideal combination of classic experiments and digital data acquisition
- Individual teaching structure possible: you can choose the instrument you want (classic or digital)

Student set Heat 2, TESS advanced Physics

15275-88

Website

curricuLAB

Basic

Function and Applications

Supplementary equipment set for TESS Basic Set Heat 1 (15274-88). Together with the Basic set it is possible to performe 34 student experiments in total:

- Thermal equilibrium and temperature measurement (4 experiments)
- Thermal expansion (6 experiments)
- Heat transfer (6 experiments)
- Thermal energy (8 experiments)
- Change of state (7 experiments)
- Solutions (3 experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered

DEMO advanced Physics Set Heat

15530-88

Website

curricuLAB

Function and Application

Equipment set allowing the performance of 15 experiments about the following topics:

- Thermal Expansion (6 experiments)
- Heat Transfer (4 experiments)
- Thermal Energy (3 experiments)
- States of Matter (2 experiments)

Benefits

- Optimised for demonstration experiments: Transformation from horizontal into vertical direction with the help of the Demo board
- Demonstrative display of the measured values on the digital large-scale display
- Secure fastening of burners and hot vessels
- Glass equipment, liquid levels and flowing liquids can be observed easily on the plain background
- Complete equipment set: Simple execution of the experiments
- The equipment is stored in a robust aluminum case with removable lid

25287-88D

Website

curricuLAB

Cobra SMART sense Basic

Student set Renewable energy 1, Basics & thermal energy, digital, TESS advanced Applied Sciences

Function and Applications

Basic set allowing the performance of 17 experiments about the following topics:

- Energy conversion (5 Experiments)
- Heat energy from solar energy (7 Experiments)
- Ambient Heat (5 Experiments)

Among other, everyday relevant topics such as global warming and thermal insulation are raised.

Benefits

- Complete equipment set for 17 experiments
- Covers energy conversion, heat energy from solar energy, ambient heat
- The equipment is stored in a rugged, stackable and compact box, allowing quick controlif set content is complete
- Matched with international curriculum: all topics are covered
- Covers major interdisciplinary and key technologies
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes
- Together with the two supplementary sets, more than 30 additional experiments can be carried out covering solar, wind, water energy and fuel cell technology

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Cobra SMARTsense Voltage, Current and Temperature included

25288-88

Website

curricuLAB

Basic

Student set Renewable energy 2, Solar / Water / Wind, TESS advanced Applied Sciences

Function and Applications

Supplementary equipment set for Renewable Energy Basic set (25287-88). Together with the Renewable Energy Basic set, it is possible to perform 43 student experiments in total:

- Electrical energy from solar energy (11 Experiments)
- Wind energy (8 Experiments)
- Water energy (4 Experiments)
- Parabolic trough power plant (3 Experiments)
- Energy conversion (5 Experiments)
- Heat energy from solar energy (7 Experiments)
- Ambient Heat (5 Experiments)

The experiments also include the recording of characteristic lines of the devices for generating electrical energy which are contained in the sets.

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Matched with international curriculum: all topics are covered
- Comprehensive treatment of all subjects of energy, its conversion and storage and the use of renewable energy sources in more than 40 experiments
- Quantitative treatment of additional relevant key technologies are possible
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Student set Renewable energy 3, Fuel cells, TESS advanced Applied Sciences

25286-88

Function and Applications

Supplementary equipment set for Renewable Energy Basic set (25287-88). Together with the Renewable Energy Basic set, it is possible to performe 26 student experiments in total:

- Hydrogen technology (9 Experiments)
- Energy conversion (5 Experiments)
- Heat energy from solar energy (7 Experiments)
- Ambient Heat (5 Experiments)

The experiments also include the reocrding of characteristic lines of the devices for generating electrical energy which are contained in the sets.

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Matched with international curriculum: all topics are covered
- Comprehensive treatment of all subjects of energy, its conversion and storage and the use of renewable energy sources in more than 20 experiments
- With this set quantitative treatment of additional relevant key technologies are possible
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Website

curricuLAB

Basic

DEMO advanced Applied Sciences Basic Set Renewable Energy, basics and thermal energy

15580-88

Function and Applications

Equipment set allowing the performance of 10 experiments about the following topics:

- Energy Conversion (4 experiments)
- Heat Energy from Solar Energy (3 experiments)
- Energy from Ambient Heat (3 experiments)

Benefits

- Treatment of major interdisciplinary and key technologies
- Rugged magnetically adhesive puzzle blocks featuring contrasted screen-printed electric symbol on top
- Wiring diagram of the experiments can be completely illustrated
- Safe electric contact is guaranteed by the use of a unique puzzle block system with corrosion-free gold plated contacts
- Corresponding students kits available (TESS advanced Renewable Energies): for flexible and competence-oriented science classes
- Expandable by Demo supplementary sets Renewable Energy Solar cells, Wind energy, Hydropower and Fuel cells
- Easy teaching by using the demo board for demonstration
- 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
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes
- Matched with international Curriculum: all topics are covered

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Website

curricuLAB

Basic

15581-88

Website

curricuLAB

Basic

DEMO advanced Renewable Energy supplementary set Solar cells, Wind energy, Hydropower

Function and Applications

Supplementary equipment set for the DEMO Basic Set Renewable Energy Basics and Thermal Energy. In combination with the set Basics and Thermal Energy another 17 demonstration experiments can be performed:

- Electrical Energy from Solar Energy (7 experiments)
- Wind Energy (5 experiments)
- Hydro power (3 experiments)
- Parabolic trough - Power station (2 experiments)

Benefits

- Demonstrative devices for experiments to photovoltaic, conversion of wind energy and hydropower into electrical energy
- Treatment of major interdisciplinary and key technologies
- Wiring diagram of the experiments can be completely illustrated
- Realistic design of the components
- Corresponding students kits available: for flexible and competence-oriented science classes
- Complete equipment set in addition to DEMO Basic Set Renewable Energy
- 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
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes
- Matched with international Curriculum: all topics are covered

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

15582-88

Website

curricuLAB

Basic

DEMO advanced Applied Sciences Renewable Energy supplementary set Fuel Cells

Function and Applications

Supplementary equipment set for the DEMO Basic Set Renewable Energy Basics and Thermal Energy. In combination with the set Basics and Thermal Energy another 7 demonstration experiments can be performed:

- Hydrogen technology (7 experiments)

Benefits

- For many qualitative and quantitative experiments on hydrogen technology, the source of useful energy is always the electric fuel cell. This kit contains essential building blocks for construction of a fuel cell
- The placement of fuel cell and electrolyzer onto the demo building blocks of the electric/electronic system allows a demonstrative and clear set-up on the board
- The quadruple PEM fuel cell can provide an output voltage of about 3.5 V and operate so larger bulbs and motors
- Electrolyzer with high gas production to provide the quadruple fuel cell
- Operation of the fuel cell also with air to represent realistic technology applications of H-technology, such as in automobiles or power supplies
- Corresponding students kits available: for flexible and competence-oriented science classes
- Complete equipment set in addition to DEMO Basic Set Renewable Energies
- The equipment is stored in a robust aluminum case with removable lid
- Foam insert for a quick control of completeness and secure transport
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes
- Matched with international Curriculum: all topics are covered

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Student set Electricity / Electronics 1 with Building Blocks, digital, TESS advanced Physics

25264-88D

Function and Applications

Basic set allowing the performance of 28 experiments about the following topics:

- Electric Circuits (8 Experiments)
- Electrical Resistance (8 Experiments)
- Electrical Work and Power (1 Experiment)
- Tranformation of Energy (1 Experiment)
- Electrochemistry (6 Experiments)
- Safe Working with Electrical Energy (2 Experiments)
- Sensors (2 Experiments)

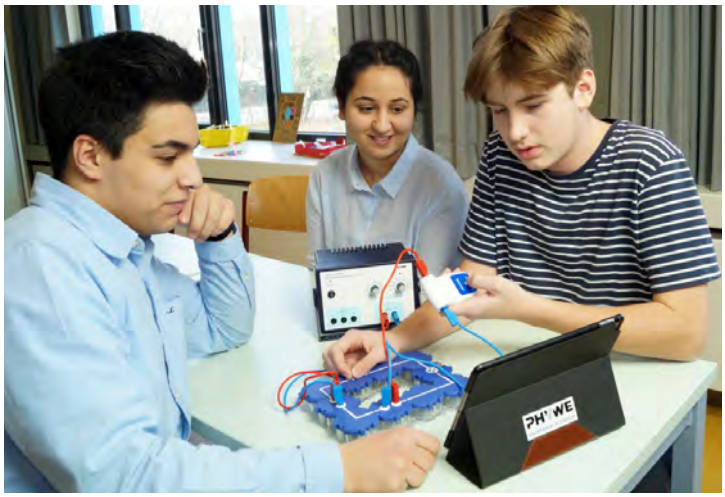
In 25 experiments, you can also use the Cobra SMARTsense Voltage and Current sensors in combination with tablets and smartphones instead of the classic measuring device. In addition, digtial data acquisition provides further didactic added value in experiments.

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- No additional cable connections between the different parts required - clearer and faster setup
- Secure contact through puzzle-like components
- Gold plated, corrosion resistant contacts
- Double learning success: Electrical circuit diagram visible on the top and right components on the underside
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Cobra SMARTsense Voltage and Current included



25266-88

Website

curricuLAB

Student set Electricity / Electronics 2 with Building Blocks, Electromagnetism and Induction

Function and Applications

Supplementary equipment set for Electric/Electrononics Building Block System Basic set 1. In combination with this set, another 18 student experiments can be performed:

- Electromagnetism (6 experiments)
- Electric motors (3 experiments)
- Induction (3 experiments)
- Transformers (2 experiments)
- Self-Induction (3 experiments)
- Safe Working with Electrical Energy (1 experiment)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- The circuits are assembled directly on student's desk and the safe electric contact is guaranteed by the use of a unique Building block system with corrosion-free gold plated contacts. No breadboard is required.
- Rugged -PUZZLE- blocks featuring contrasted screen-printed electric symbol on top
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Basic

25267-88

Website

curricuLAB

Student set Electricity/Electronics 3 with Building Blocks, Electronics, TESS advanced Physics

Function and Applications

Supplementary equipment set for Electric/Electrononics Building Block System Basic set 1. In combination with this set, another 23 student experiments can be performed:

- Capacitors (3 experiments)
- Diodes (11 experiments)
- Transistors (9 experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- The circuits are assembled directly on student's desk and the safe electric contact is guaranteed by the use of a unique puzzle block system with corrosion-free gold plated contacts. No breadboard is required.
- Rugged -PUZZLE- blocks featuring contrasted screen-printed electric symbol on top
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Basic

Student set Electromagnetism, digital, TESS advanced Physics

25269-88

NEW

Website

Cobra SMART sense

curricuLAB

Function and Applications

Basic set allowing the performance of 9 experiments about the following topics:

- Electromagnetic induction (1 experiment)
- Magnetic field of coils (6 experiments)
- Earth's magnetic field (1 experiment)
- Magnetic permeability (1 experiment)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international Curriculum: all topics are covered
- With the included Cobra SMARTsense 3-Axis Magnetic Field in combination with tablets and smartphones it is possible to acquire digital data
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Cobra SMARTsense 3-Axis Magnetic field included

More information on the scope of delivery is available on our website at **www.phywe.com**.

25230-88

Student set Magnetism, TESS advanced Physics

Website

curricuLAB

Function and Applications

Equipment set allowing the performance of 11 experiments about the following topics:

- Magnetic Interaction (3 Experiments)
- Magnetic Induction (3 Experiments)
- Magnetic Fields (5 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- The simple and didactically structured experiments offer fast set up and facilitate the students the entrance to the subject.
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

15240-88

Student set Electrostatics, TESS advanced Physics

Website

curricuLAB

Function and Applications

Equipment set allowing the performance of 16 experiments about the following topics:

- Contact electricity (2 Experiments)
- Electrostatic force (3 Experiments)
- Electrostatic induction (3 Experiments)
- Storing charge (4 Experiments)
- Insulators and conductors (4 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- The simple and didactically structured experiments offer fast set up and facilitate the students the entrance to the subject
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Student set Electric motor / Generator, digital, TESS advanced Physics

15221-88D

NEW

Website

curricuLAB

Cobra SMART sense

Function and Applications

Equipment set for 10 student experiments on the topics:

- Electromagnetism (1 Experiment)
- Energy forms, transformation and conservation (1 Experiment)
- Electric motor and generator (8 Experiments)

In 3 experiments, you can use the Cobra SMARTsense Voltage and Current sensors in combination with tablets and smartphones instead of the classic measuring device.

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to choose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Components in all mountable devices, clear base plate reduced to the necessary
- Matched plug-in system for quick setup and conversion. Few modules instead of many individual components
- Complete syllabus coverage: various DC and AC motors and generators and introductory experiments on electromagnetism and the conversion of electrical energy into kinetic energy incl. required accessories
- From the basics of electromagnetism to application in motors, generators and transformers

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Cobra SMARTsense Voltage and Current included

15250-88D

Website

NEW

curricuLAB

Cobra SMART sense

Student set Equipotential lines and electric fields, digital, TESS advanced Physics

Function and Applications

Set for measurement and recording of equipotential lines of different electrode configurations on electrically conducting paper. This set allows the performance of 5 student experiments about the following topics:

- Electric fields
- Electric field strength
- Inhomogeneous electric fields (dipole fields)
- The electric conductor as an equipotential surface
- Electrostatic tip-shape effect

In all 5 experiments, you can use the Cobra SMARTsense Sensor Voltage instead of the classic meter in combination with tablets and smartphones

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets / smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Direct measurement of potential with high resistance voltmeter
- Measuring points can be transferred (pressed through) onto a sheet of white paper during measurement
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Cobra SMARTsense Voltage included

15569-88

Website

curricuLAB

Basic

DEMO advanced Physics Electricity/Electronics Building Block System, basic set Electricity

Function and Applications

Equipment set allowing the performance of 30 experiments about the following topics:

- Electric Circuits (9 experiments)
- Electrical Resistance (9 experiments)
- Electric Power and Work (1 experiment)
- Transformation of Energy (1 experiment)
- Electrochemistry (6 experiments)
- Safe Working with Electricity (2 experiments)
- Sensors (2 experiments)

Benefits

- Experiments for qualitative and quantitative introduction to electricity
- Knowledge transfer of the elemental behaviour of numerous electrical components
- Circuit assemblies show their wiring diagram
- 100-percent compatibility between teacher and student building blocks
- Rugged magnetically adhesive puzzle-style building blocks with screen-printed electric symbols
- Building blocks are easy to remove and swap due to their gripper rims
- Safe electric contact is guaranteed by the use of a unique puzzle block system with corrosion-free gold plated contacts
- Complete equipment set for quick and easy set-up and performance of the experiments
- The equipment is stored in a robust aluminum case with removable lid

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

DEMO Electricity/Electronics Building Block System Electromagnetism and Induction

15571-88

Function and Applications

Supplementary equipment set for DEMO Set Electricity (15569-88). In combination with the set Electricity another 24 demonstration experiments can be performed:

- Transformation of Energy (1 experiment)
- Electromagnetism (6 experiments)
- Electric Motors (4 experiments)
- Induction (5 experiments)
- Transformers (3 experiments)
- Self-Induction (4 experiments)
- Safe Working with electricity (1 experiment)

Benefits

- Continuing experiments from the field of electricity to the topics electromagnetism and induction
- Instructional model engine with double-T armature, stator pole pieces and support surface for stator magnet
- Wiring diagram of the experiments can be completely illustrated
- Rugged magnetically adhesive puzzle blocks featuring contrasted screen-printed electric symbol on top
- The building blocks are easy to remove from experimental set-ups using the gripper rims
- Safe electric contact is guaranteed by the use of a unique puzzle block system with corrosion-free gold plated contacts
- Complete equipment set in addition to Electricity/Electronics 1
- The equipment is stored in a robust aluminum case with removable lid

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Website

curricuLAB

Basic

DEMO Electricity/Electronics Building Block System, supplementary set Electronics

15572-88

Function and Applications

Supplementary equipment set for DEMO Set Electricity (15569-88). In combination with the set Electricity another 27 demonstration experiments can be performed:

- Capacitor (3 experiments)
- Diode (11 experiments)
- Transistor (13 experiments)

Benefits

- Continuing experiments from the field of electricity to the topic electronics
- Provides insight into semiconductor technology and deep going comprehension of the functional principle of capacitor, diode and transistor
- 100-percent compatibility between teacher and student building blocks
- Wiring diagram of the experiments can be completely illustrated
- Rugged magnetically adhesive puzzle blocks featuring contrasted screen-printed electric symbol on top
- The building blocks are easy to remove from experimental set-ups using the gripper rims
- Safe electric contact is guaranteed by the use of a unique puzzle block system with corrosion-free gold plated contacts
- Complete equipment set in addition to Electricity/Electronics 1
- The equipment is stored in a robust aluminum case with removable lid
- Matched with international Curriculum: all topics are covered

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments

Website

curricuLAB

Basic

25573-88D

Website

NEW

curricuLAB

Cobra SMART sense Basic

DEMO advanced Physics Electromagnetism 1, digital

Function and Applications

Equipment set for performing at least 7 demonstration experiments on the topics:

- Engines (3 experiments)
- Induction (1 experiment)
- Generators (3 experiments)

In 6 experiments, you can use the Cobra SMARTsense Voltage, Current and High Current sensors in combination with tablets and smartphones instead of the classical measuring devices. In conjunction with DEMO advanced Physics Electromagnetism 2 (25574-88), five more experiments can be performed digitally.

Benefits

Didactically valuable build-up motor set

- 3 different rotors
- Shock-proof plastic housing with marked winding direction and safety sockets
- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to choose the measuring intrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with smartphones, tablets and desktop PCs
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment is stored in a robust aluminum case with a removable lid
- Cobra SMARTsense Voltage, Current and High Current included

25574-88

Website

NEW

curricuLAB

Basic

DEMO advanced Physics Electromagnetism 2

Function and Applications

Equipment set for performing at least 6 demonstration experiments on the topics:

- Induced voltage with electromagnets
- High-current transformer (melting nail)
- Eddy current damping in a magnetic field (Waltenhofen's pendulum)
- Rotary motion by eddy currents (AC meter)
- Thomson's ring experiment
- 1 Hz resonant circuit

In connection with the DEMO set for electromagnetism 1 (25573-88) at least 3 further experiments can be performed:

- Voltage transformer
- Current transformer
- High-voltage line

Benefits

- Minimal preparation time
- Impressive demonstration experiments
- Shock-proof plastic housing with marked winding direction and safety sockets
- The equipment is stored in a robust aluminum case with a removable lid
- Foam insert: quick control for completeness and safe transport
- Easy teaching and efficient learning through the digital experiment descriptions enclosed as QR codes

Equipment and Technical Data

- The equipment is stored in a robust aluminum case with a removable lid

Student set optics 1 including LED- / Laser lightsource

15278-88

Website

curricuLAB

Function and Applications

Basic set allowing the performance of 31 experiments about the following topics:

- Propagation of light (3 experiments)
- Mirrors (7 experiments)
- Refraction (9 experiments)
- Lenses (8 experiments)
- The human eye (4 experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- Student safe Laser- / LED- experimental lamp with key switch laser and akku.
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international Curriculum: all topics are covered
- Easy teaching and efficient learning

Equipment and Technical Data

- Including laser- /LED lamp
- Robust, stackable storage box with foam insert fitting to the contained equipment

More information on the scope of delivery is available on our website at **www.phywe.com**.

25276-88

Student set Optics 1 including light box, TESS beginner Sciences

Website

curricuLAB

Basic

Function and Applications

Basic set allowing the performance of 34 experiments about the following topics:

- Propagation of light (5 Experiments)
- Mirrors (7 Experiments)
- Refraction (10 Experiments)
- Lenses (8 Experiments)
- The human eye (4 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international Curriculum: all topics are covered
- Simple teaching and efficient learning thanks to the digital experiment descriptions included as a QR code

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments (including light box)

Student set Optics 2 digital, TESS advanced Physics

25277-88D

Function and Applications

Supplementary equipment set for Basic set Optics 1. Together with the Optics Basic set and optional equipment TESS Optics color mixing, it is possible to performe 70 student experiments in total:

- Propagation of light (11 Experiments)
- Mirrors (11 Experiments)
- Refraction (10 Experiments)
- Lenses (14 Experiments)
- Colours (6 Experiments)
- The human eye (5 Experiments)
- Optical equipment (9 Experiments)
- Wave optics (4 Experiments)

In two experiments you can use the Cobra SMARTsense Sensor Light instead of the classic measuring device in combination with tablets (iOS and Android) and smartphones (Android). In these experiments, the digital data acquisition also provides a further didactic added value.

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Multifunctional student lamp - All-in-one: It can be used for geometrical optic basics either on the table, color mixing or on the optical bench

Website

curricuLAB

Basic

Cobra SMART sense

Student set Optics 3, Wave optics, TESS advanced Physics

15280-88

Function and Applications

Supplementary equipment set for the sets Optics 1 and Optics 2. Together with the sets Optics 1 and 2, the optional equipment TESS Optics color mixing and the optional accessories for Optics 3, it is possible to performe 96 student experiments in total:

- Interference (4 Experiments)
- Diffraction from unidimensional objects (8 Experiments)
- Diffraction from two-dimensional objects (3 Experiments)
- Resolving power (3 Experiments)
- Qualitative experiments on polarisation (6 Experiments)
- Quantitative experiments on polarisation (2 Experiments)
- Propagation of light (11 Experiments)
- Mirrors (11 Experiments)
- Refraction (10 Experiments)
- Lenses (14 Experiments)
- Colours (6 Experiments)
- The human eye (5 Experiments)
- Optical equipment (9 Experiments)
- Wave optics (4 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- Through the use of a stable optical bench made of metal safe and exact experimental setups

Website

curricuLAB

Basic

15350-88D

Website

NEW

curricuLAB

Cobra SMART sense

Student set Optics / Atomic physics digital, TESS advanced Physics

Function and Applications

Equipment set allowing the performance of 17 experiments about the following topics:

- Spectroscopic analysis (2 Experiments)
- Diffraction on a grating (1 Experiment)
- Diffratction on everyday life's objects (2 Experiments)
- Absorption and fluorescence (3 Experiments)
- h-Determination with light emitting diodes (1 Experiment)
- Bandgap of semiconductors (1 Experiment)
- Investigation of solar cells and fotodiodes (2 Experiments)
- Electric and optical properties of LED (2 Experiments)
- Polarisation of light (3 Experiments)

In 10 experiments, you can use the Cobra SMARTsense sensors Current and Voltage in combination with tablets (iOS and Android) and smartphones (Android) instead of the classic measuring device.

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Matched with international curriculum
- Quantum and / or wave optics in student experiment
- Simple teaching and efficient learning thanks to the digital experiment descriptions included as a QR code

15550-88

Website

curricuLAB

DEMO advanced Physics Set Optics, incl. halogen lamp with magnetic base

Function and Applications

Equipment set allowing the performance of 60 experiments about the following topics:

- Propagation of Light (7 experiments)
- Mirrors (16 experiments)
- Refraction (10 experiments)
- Lenses (13 experiments)
- Colours (6 experiments)
- The human Eye (3 experiments)
- Optical Equipment (5 experiments)

Benefits

- Excellent complement to identical student experiments by directly comparable devices
- Light-intense halogen lamp
- Demonstrative models of lenses
- Minimum preparation time
- Easy teaching by using the demo board for demonstration
- 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 teacher experiments are delivered as PDF documents on a DVD
- Matched with international Curriculum: all topics are covered

DEMO advanced Physics set: Geometrical Optics on the optical bench

15560-88

Function and Applications:

This demo set contains the following 5 teacher experiments on geometric optics on the profile bank:

- Determination of the focal length of converging lenses
- Determination of the focal length of diverging lenses
- Creation of images using a condenser lens
- The pinhole camera
- The microscope

Benefits:

- All relevant DEMO experiments on geometric optics in one set
- Bright and focusable LED light
- Stable optical bench
- Easy set-up
- Convenient placement of all components in a sturdy aluminum case
- Foam insert for quick inspection

Website

curricuLAB

DEMO advanced Physics set: Diffraction and interference on the profile bench

15565-88

Function and Applications:

This demo set contains the following 7 teacher experiments on diffraction and interference on the profile bench:

- Diffraction at edge, gap, double slit, grid and pinhole
- Michelson interferometer
- Wavelength dependence of diffraction phenomena

Benefits:

- All relevant DEMO experiments on geometric optics in one set
- two diode lasers of different wavelengths (532 nm and 635 nm)
- Stable optical bench
- Easy construction
- convenient placement of all components in a sturdy aluminum case
- Foam insert for quick inspection for completeness

Website

curricuLAB

25261-88

Website

curricuLAB

Student set Radioactivity, digital, TESS advanced Physics

Function and Applications

Equipmentic set allowing the performance of 11 experiments about the following topics:

- Examination of naturally occurring radioactive substances (5 Experiments)
- Types of radiation and their characteristics (6 Experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Matched with international curriculum: all topics are covered
- Experiments on the fundamentals of radioactivity using only common available natural radioactive sources
- Special radioactive emitter only required for 4 advanced experiments
- Counter tube is an integral part of the set
- Measurements are made with the kit contained Cobra SMARTsense and directly transfered to smartphone, tablet computer or PC.

Equipment and Technical Data

- The equipment set consists of all necessary components to perform the basic experiments using a Bluetooth capable device (not included) like smartphone, tablet computer or PC
- Cobra SMARTsense Radioactivity

15590-88

Website

curricuLAB

DEMO advanced Physics set Radioactivity

Function and Applications

Equipment set allowing the performance of 15 experiments about the following topics:

- Detection of radioactive Radiation (1 experiment)
- Statistics of radioactive Processes (1 experiment)
- Natural Radioactivity (3 experiments)
- Characteristic Properties of radioactive Radiation (8 experiments)
- Application of radioactive Substances (2 experiments)

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 teacher 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
- The Geiger-Müller counter is attached to the top of the board where it is clearly visible
- Magneto-adhesive components for a simple and clear arrangement
- Student experiments can be carried out parallel to demonstration experiments due to identical holders

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

TESS/DEMO advanced

3.3 Chemistry

Complete curriculum coverage in Chemistry –
Cover the requirements of modern natural science

International Reference Curriculum (School)

Topic \ Sets	General Chemistry	Environment and Outdoors	Inorganic Chemistry	Acids, Bases Salts	Titration
	TESS	TESS	TESS	TESS	TESS / Demo
GENERAL CHEMISTRY					
Chemical and material properties	✓				
Mixture and seperation	✓				
State of matter, diffusion (kinetic particle theory)	✓		✓		
Fundamentals of chemical reactions (mass and energy turnover, ...)	✓				
Detection reaction, ion detection	✓		✓		
Chemical bond (polar, nonpolar, ionic, covalent)	✓			✓	
Periodicity and chemical properties	✓		✓		
Chemistry and environment		✓	✓		
INORGANIC CHEMISTRY					
Air and combustion		✓	✓		
Water	✓	✓	✓		
Metals and alloys			✓		
Non-metals, gases and semi-metals			✓		
Acids and bases, proton transitions			✓	✓	✓
Quantitative analysis: titrations					✓
Salts			✓	✓	
Redox reactions, electron transfer	✓		✓		
Special topics: firefighting, large-scale processes, explosives, ...			✓		
ORGANIC CHEMISTRY					
Basics of organics					
Hydrocarbons and petrochemistry					
Oxygenated organic compounds					
Polymer chemistry					
Food chemistry: fats, carbohydrates, amino acids / proteins, ...					
Aromatic hydrocarbons					
Special topics: detergents, medicines, fragrances / aromas, ...					
PHYSICAL CHEMISTRY					
Energy turnover in chemical reactions					
Gas laws					
Calorimetry, energetics of chemical reactions					
Kinetics of chemical reactions					
Electrochemistry - potentials, conductivity, electrolysis					
Chemical equilibria	✓				
Spectroscopy and photometry					

education with the TESS and DEMO System

Analytical Chemistry	Organic Chemistry	Polymer Chemistry	Food Chemistry	Gas laws, Thermochemistry Kinetics	Electrochemistry	Colorimetry
TESS	TESS	TESS	TESS	Demo	TESS	TESS
✓						
✓	✓					
✓						
✓						
					✓	
	✓					
	✓					
	✓					
		✓				
			✓			
	✓					
	✓					
				✓		
				✓		
				✓		
				✓		
					✓	
				✓		
						✓

25300-88D

Student set General Chemistry digital, TESS advanced Chemistry

Website

curricuLAB

Function and Applications

Basic equipment set allowing the performance of 25 experiments about the following topics:

- Properties of matter (5 Experiments)
- Mixtures (2 Experiments
- Mixture separation (4 Experiments)
- Chemical reactions (2 Experiments)
- Test reactions (3 Experiments)
- Particle model (4 Experiments)
- Chemical Bonds (5 Experiments)

In 3 experiments, you can use the Cobra SMARTsense Sensor Temperature instead of the classic measuring device in combination with tablets (iOS and Android) and smartphones (Android). In 1 experiment, the digital data acquisition also provides a further didactic added value.

Benefits

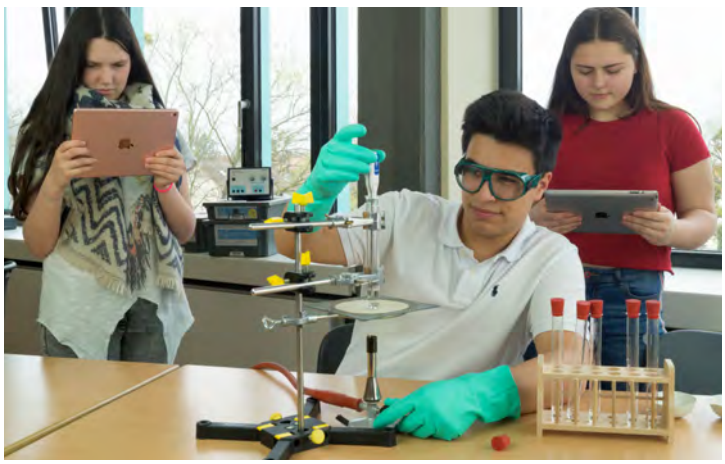
- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the identification and thus increases the motivation of the students
- Experimental literature available for students and teachers: Short preparation time
- Matched to education plans: all topics covered
- Set developed by pedagogues for general chemistry

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments; only one for the existing gas supply suitable burner must be purchased separately
- Robust, stackable storage box with a foam insert fitting to the contained equipment
- Cobra SMARTsense Temperature: Measuring range: -40 ... 120 ° C, resolution: 0.01 ° C, sampling rate: 10 Hz

Necessary accessories

- TESS advanced General Chemistry, necessary accessories for 1 group (13341-88)
- TESS advanced General Chemistry, consumables and chemicals for 10 groups (13300-10)



Student set Inorganic chemistry digital, TESS advanced Chemistry

25301-88D

Function and Applications

Equipment set allowing the performance of 35 experiments about the following topics:

- Metals (3 experiments)
- Air and other gases (12 experiments)
- Water - components of water and water purification (12 experiments)
- Building material (3 experiments)
- Fertilizer (4 experiments)
- Glas manufacture (1 experiment)

In 3 experiments, you can use the Cobra SMARTsense Sensor Temperature instead of the classic measuring device in combination with tablets (iOS and Android) and smartphones (Android).

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)

Student set Acids, Bases, Salts digital, TESS advanced Chemistry

25302-88D

Function and Applications

Equipment set allowing the performance of 31 experiments about the following topics:

- Acids (16 experiments)
- Alkalis (8 experiments)
- Salts (7 experiments)

In 6 experiments you can use the Cobra SMARTsense sensors Temperature and pH instead of the classic measuring device in combination with tablets (iOS and Android) and smartphones (Android).

Benefits

- The ideal combination of classic experiments (practical competence) and digital data acquisition (media competence)
- Individual teaching structure possible: you can decide to chose the measuring instrument you want (classic or digital)
- Future-proof: preparing today the transition to the digital school
- Perfectly matched to digital science lessons with tablets and smartphones
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)

Student set Titration and analytical chemistry, TESS advanced Chemistry

25303-88

Function and Applications

Experiment set to perform student experiments for titration and the analysis of ions. With this experiment set 14 experiments can be performed:

- Properties of acids and bases
- Acid-base titrations
- Determination of the pK value of an acid
- Analysis of cations by flame colouration
- Analysis of anions by flame colouration

Benefits

- Complete experiment set: experiments easy to perform
- Stable storage box: durable and stackable, facilitate fast control if content is complete
- Experiment guides available both for students and teachers: preparation time reduced to a minimum
- Curriculum-compliant: all topics are covered
- Developed by educators as an ideal introduction into titration and analytical chemistry

25304-88

Website

curricuLAB

Student set Organic chemistry, TESS advanced Chemistry

Function and Applications

Equipment set allowing the performance of 36 experiments about the following topics:

- Preliminary tests (7 experiments)
- Hydrocarbons (5 experiments)
- Petroleums (4 experiments)
- Alcohols (7 experiments)
- Carbonyl compounds (3 experiments)
- Carboxylic (alkane) acids (4 experiments)
- Esters (3 experiments)
- Soaps (3 experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time

25305-88

Website

curricuLAB

Student set Polymer Chemistry, TESS advanced Chemistry

Function and Applications

Equipment set allowing the performance of 18 experiments about the following topics:

- The polymer concept (2 experiments)
- Natural polymers (1 experiment)
- The initial identification of plastics (5 experiments)
- Preliminary experiments on the synthesis of plastics (1 experiment)
- The mechanism of the formation of plastics (5 experiments)
- Modification of plastics (1 experiment)
- Identification methods for plastics (2 experiments)
- The re-cycling of plastics (1 experiment)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time

25306-88

Website

curricuLAB

Student set Food chemistry, TESS advanced Chemistry

Function and Applications

Equipment set allowing the performance of 40 experiments about the following topics:

- Proteins (3 experiments)
- Fat (9 experiments)
- Beverage (3 experiments)
- Spices (1 experiment)
- Carbohydrate (12 experiments)
- Vitamines and minerals (1 experiment)
- Water (3 experiments)
- Additives (8 experiments)

Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time

Student set Electrochemistry, digital, TESS advanced Chemistry

25307-88D

NEW

TOPSELLLER

Website

curricuLAB

Cobra SMART sense

Function and Applications

Equipment set for carrying out 29 student experiments on the topics:

- Preliminary tests (4 experiments)
- Electrochemical cells and potentials (14 experiments)
- Protection against corrosion and energy storage (6 experiments)
- Electrolyisis and quantitative processes (5 experiments)

In 27 experiments, you can use the Cobra SMARTsense Voltage and Current sensors in combination with tablets (iOS and Android) and smartphones (Android) instead of the classic measuring device.

Benefits

- The ideal combination of classic experiments and digital data acquisition
- Individual teaching structure possible: you can decide on the instrument you want (classic or digital)
- Future-proof: Prepare the transition to the digital school today
- Perfectly matched to digital science lessons with tablets and smartphones
- Faster and higher learning success: The use of digital devices increases the motivation of the students
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international curriculum: all topics are covered
- Set developed by pedagogues for introduction into electrochemistry

Equipment and Technical Data

- The device set consists of all components necessary for the tests
- Cobra SMARTsense Voltage: Measuring range: +/- 30 V, resolution: 0.02 V, sampling rate: 800 Hz
- Cobra SMARTsense Current: Measuring range: +/- 1 A, resolution: 0.5 mA, sampling rateMotor, 2 V, with disc and marking point 11031-00

Necessary accessories

- TESS advanced Chemistry Electrochemical measurement set EC, necessary accessories for 1 group (13422-88)

Consumables

- TESS advanced Electrochemical measurement set EC, consumable and chemicals for 10 groups (30505-10)

Website

PHYWE Chemistry –
with the glass jacket apparatus

The glass jacket apparatus is a multi-purpose system and finds application in numerous different fields of chemistry. It is for example used to develop the gas laws, to determine molar masses, to measure combustion enthalpies and provides easy and well-arranged set-ups for steam distillation and gas chromatography.

Working with the glass jacket system is easy – especially because of the detailed experiment descriptions.

Your benefits

- Demonstrative and transparent
- Versatile modular system, easy to assemble
- Ideal for working with gases
- Uncomplicated, fast experiments
- Excellent results
- Can be stored completely assembled

TESS/DEMO advanced

3.4 Biology

Complete curriculum coverage in Biology –
Cover the requirements of modern natural science

International Reference Curriculum (School)

Topic \ Sets	Microscopy	General Biology	Plant Physiology and Biochemistry	Environment and Outdoors
	TESS	TESS	TESS / Demo	TESS
		Cobra SMART sense	Cobra SMART sense	Cobra SMART sense
CELLS AND MICROBIOLOGY				
Microscopy: basics and working techniques	✓			
Plant and animal cells	✓			
Specialized cells, tissues and organs	✓			
Seed plants, ferns, fungi	✓			
Vertebrates and other animals	✓			
Cell structure and transport	✓			
Cell organelles - electron microscopic, recognizable structures	✓			
Methods of cell research				
ANIMALS				
Vertebrates: mammals, birds, reptiles, amphibians and fish	✓	✓		
Invertebrates: insects and spiders	✓			
PLANTS				
Anatomy and physiology of seed plants, ferns	✓	✓		
Photosynthesis and cellular respiration		✓	✓	
Reproduction in flowering plants	✓	✓		
Germination and growth		✓		
ECOLOGY				
Structure and characteristics of ecosystems		✓		✓
Aquatic ecosystems: lake, river				✓
Land ecosystems, soil analysis		✓		
Importance / endangerment of ecosystems (prot. of species, sustainability, restoration)		✓		✓
THE HUMAN				
Anatomy: bones and skeleton, joints, muscles, internal organs	✓	✓		
Physiology: respiration, heart and blood circulation		✓		
SENSORY ORGANS				
Sense of light and sense of gravity		✓		
Hearing		✓		
Sense of taste and sense of smell		✓		
NUTRITION AND DIGESTION				
Nutrients		✓		
Digestion and excretion	✓	✓		
COMMUNICATION AND REGULATION				
Nervous system, neurobiology				
METABOLISM				
Photosynthesis and cellular respiration / dissimilation and assimilation			✓	
Material cycle: producers, consumers, destructors		✓	✓	
Enzymes			✓	
Cell metabolism, fermentation, citrate cycle, chemosynthesis, biotechnology			✓	
GENETICS				
Molecular genetics				
Genetic engineering				
BEHAVIOUR				
Behavior in humans and animals		✓		

education with the TESS and DEMO System

Biological Water Analysis	Soil Examination	Human Physiology and Electro-physiology	Neuro Simulator	Molecular Biology	Biotechnology
TESS	TESS	TESS	TESS / Demo	TESS	TESS / Demo
					✓
✓					
✓	✓				
✓					
	✓				
	✓				
		✓			
		✓			
		✓	✓		
					✓
					✓
				✓	
				✓	
		✓			

15290-88

Student set Microscopy, TESS advanced Biology

Website

curricuLAB

Function and Applications

Equipment set allowing the performance of 50 experiments about the following topics:

- Basics of microscopy (3 experiments)
- Work techniques (6 experiments)
- Preparation of reagents (1 experiment)
- Cell components (8 experiments)
- Seed plants (9 experiments)
- Vertibrates (8 experiments)
- Invertibrates (7 experiments)
- Other plants (1 experiment)
- Fungi (1 experiment)
- Protists (5 experiments)
- Procaryotes (1 experiment)

Benefits

- Set covers all microscopy topics of international curricula
- Complete equipment set, experiments easy to perform
- For a variety of topics in genetics, botany, zoology and anatomy
- Experiment guides for students and teachers optimized for minimal preparation time

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment

Necessary accessories

- A suitable microscope for student experiments
- A suitable balance, weighing capacity 120 g, readability 0.1 g
- A knife
- TESS advanced Biology Microscopy consumables for 10 groups

Student set General biology, TESS advanced Biology

25296-88

Website

curricuLAB

Function and Applications

Basic set allowing the performance of 41 experiments about the following topics:

- Bones, body heat and breathing (3 experiments)
- Plants (18 experiments)
- Nutrients and digestion (11 experiments)
- Soil survey (2 experiments)
- Senses (6 experiments)
- Reproduction (1 experiment)

Benefits

- For first-time experimenting in biology
- Complete equipment set: easy to perform experiments
- Experiments for all basic curriculum topics
- Provides all equipment required for basic biology labs

Equipment and Technical Data

- The equipment set consists of all necessary components for the experiments
- Robust, stackable storage box with a foam insert fitting to the contained equipment

Necessary accessories

- TESS advanced Biology set Biology necessary accessories for 1 group
- TESS advanced Biology set Biology consumables for 10 groups

12628-88D

Website

NEW

curricuLAB

Cobra SMART sense

Student set environment and outdoors digital, TESS advanced Biology

Function and Applications

The digital set allows you to use the latest measurement technology for your environmental and outdoor analysis and is very easy to use. In addition to classic parameters such as temperature, air pressure, brightness, relative humidity, pH, conductivity and water turbidity, the weather station allows you to make complete weather observations and even collect GPS data in the field. The Cobra SMARTlink can not only be used as an interface for the sensors, but also offers additional flexibility for group work with its built-in sensors.

Benefits

- Whether in the classroom, outdoors or on project days: in this robust aluminium case, you will always find the right device for carrying out fascinating experiments with student groups.
- Several student groups can work on and investigate interesting topics in parallel.
- Works with all iOS and Android devices with free app (measureAPP).
- Students can evaluate the data at home, as a homework assignment.
- Ideal for outdoors project days.

Equipment and Technical Data

- Robust aluminum case
- 1 x Cobra SMARTlink
- 1 x Cobra SMARTsense - Weatherstation (Bluetooth + USB)
- 1 x Cobra SMARTsense - Relative Humidity, 0 ... 100 %
- 1 x Cobra SMARTsense - pH, 0 ... 14
- 1 x Cobra SMARTsense - Conductivity, 0 ... 20000 µS/cm
- 1 x Cobra SMARTsense - Temperature, - 40 ... 120 °C
- 1 x Cobra SMARTsense - Absolute Pressure, 20...400 kPa
- 1 x Cobra SMARTsense - Light, 1 ... 128 kLX
- 1 x Cobra SMARTsense - Colorimeter for the measurement of turbidity, 0 ... 100 %
- 1 x pH electrode, plastic, gel-filled
- 1 x 100 red pH 4 buffer tablets
- 1 x 100 green pH 10 buffer tablets
- 5 x 20 ml calibration solution for conductivity electrode
- 2 x protective case for pH and conductivity electrodes
- 1 x 120 labels
- 4 x 100 ml square flange (HDPE)
- 2 x 250 ml PP laboratory beaker

12629-88

Website

Digital extension set ion measurement (N03, NH4, Cl, Ca, K)

Function and Applications

Set of 5 Cobra SMARTsense ion sensors for measuring nitrate, ammonium, chlorine, calcium and potassium in solutions, e.g. in soil solutions for determining the nutrient status or for ion measurements in chemistry classes.

Equipment and Technical Data

- Cobra SMARTsense Nitrate Ion: range: 0.6...6200 ppm, resolution: 2 ppm, sample rate: 10 Hz
- Cobra SMARTsense Ammonium Ion: range: 0.9...1800 ppm, resolution: 0,5 ppm, sample rate: 10 Hz
- Cobra SMARTsense Choride Ion: range: 1.8...3550 ppm, resolution: 1 ppm, sample rate: 10 Hz
- Cobra SMARTsense Calcium Ion: range: 0.4...4000 ppm, resolution: 1 ppm, sample rate: 10 Hz
- Cobra SMARTsense Potassium Ion: range: 0.4...3900 ppm, resolution: 1 ppm, sample rate: 10 Hz

Student set Soil examination, TESS advanced Biology

30836-88

Website

Function and Applications

Case with material for 6 work groups to investigate the 18 most important soil parameters: soil profile (soil horizons, soil type), mineral matter (stone content, fine earth content, soil texture), body of humus (humus content, humus type), water/ air (soil moisture, water capacity, water permeability rate, utilisable water capacity), soil structure (soil compaction, aggregate stability/ tilth), acidity (pH value, lime content), nutrients (nitrate content of soil, nitrate content of fruit and vegetables), soil life (soil animals).

Benefits

- Easy to perform analyses using rapid test indicator sticks.
- Problem-oriented investigative methods to determine soil acidification, lime requirement, nitrogen supply, soil compaction, etc.
- The case can be used by 6 works groups working in tandem.
- Includes detailed instruction manual

Equipment and Technical Data

Transport case made of metal with instruments and accessories:

- Soil compaction measurement probe
- Pans for picking up and measure samples
- Portable balance
- Trough, measuring tape, spring balance, brush
- Beaker with magnifying glass
- Snap-cap vials, laboratory beakers, rubber stopppers
- Glass tubes, dropping bottle, square bottles
- Wire gauze, flat plastic sacks
- Petri dishes, funnels, graduated cylinder
- Round filters
- Rapid test indicator sticks nitrate, nitrite, pH
- 65 page manual

Necessary accessories

TESS advanced Examination of soil consumables for 10 groups

30834-88

Website

Student set Biological water analysis, TESS advanced Biology

Function and Applications

Eco-Kit „Biological testing of water quality". The physical, chemical, and bacteriological examination procedures allow an assessment of the momentary water quality. As the variety of species in a body of water decreases with increasing pollution, and thus the composition of the organism societies changes, the biological determination of the water quality provides additional important indications on the water quality and allows conclusions to be drawn on the previous pollution. The species and frequency of indicator organisms at various degrees of pollution are thereby coupled to the water quality classes I to IV.

Benefits

- This kit enables 6 work groups to simultaneously carry out examinations of running and standing waters in the field.
- The enclosed manual containing tables and evaluation sheets for analysis allow assignment to the water quality classes I...IV.

Equipment and Technical Data

- Carrying case
- Screens
- Trays
- Dishes, large and small
- Tweezers
- Brushes
- Pipettes
- Magnifying glasses, large and small
- Petri dishes
- Dip net for catching aquatic organisms
- Caliper
- Rulers
- Snap lid jars
- Detailed and exhaustive manual in English language with theoretical and practical part with identification keys

30839-01

Website

Water analysis excursion case with filter photometer

Function and Applications

This excursion case enables students to actively participate in the measurement of water parameters in your immediate neighbourhood. Rapid chemical analyses provide meaningful results in a very short time. The colourimetric tests can be reproducibly and exactly evaluated by using the portable filter photometer.

Benefits

- Compact water laboratory for mobile use with photometer, reagents and accessories in a new robust case with a premium foamed plastic insert.
- Increased accuracy and reproducibility by photometric evaluation of colourimetric tests.
- Economic refill packs with up to 200 determinations per parameter.
- Turbidity measurement included.

Equipment and Technical Data

- Reagent case
- Photometer PF-12 incl. manual and 4 batteries with filters for the following wave lengths: 345 / 436 / 470 / 540 / 585 / 620 / 690 nm / turbidity (860 nm)
- Test kits: Ammonium, iron, nitrate, nitrite, phosphate, pH , carbonate hardness and total hardness
- Manual with test instructions for test kits
- 4 empty tubes, 1 funnel, 1 beaker 25 ml, 1 syringe 5 ml, 1 syringe 1 ml, 1 thermometer, 2 titration syringes with dropping tips, 2 titration test tubes

Student set Human and electrophysiology digital, TESS advanced Applied Sciences

15675-88D

Website

curricuLAB

Cobra SMART sense

Function and Applications

Heart rate, pulse, lung volume, body temperature and blood pressure are the core parameters of human and electrophysiology. With our set, you can vividly teach students the meaning of these terms. The set contains our Cobra SMARTsense sensors that are easy to operate and take measurements in real time.

Equipment set allowing the performance of 9 experiments about the following topics:

- Electrophysiology of the heart (3 experiments)
- Blood circulation (1 experiment)
- Skin temperature (1 experiment)
- Lung function, lung volume (3 experiments)
- Lung diseases (1 experiment)

Benefits

- For datalogging with mobile devices (iOS, Android, Windows).
- Complete equipment set, no further accessories required.
- Easy to operate (plug & measure), thus also suitable for all education levels.

Equipment and Technical Data

The equipment set consists of all necessary components for the experiments:

- Stable, stackable storage box with device-molded, molded foam insert
- Cobra SMARTsense ECG
- Cobra SMARTsense Pulse
- Cobra SMARTsense Temperature
- Cobra SMARTsense Spirometer
- Blood pressure measurement combination

15620-88D

Student set Biochemistry and Plant Physiology, TESS advanced Biology

Website

curricuLAB

Cobra SMART sense

Function and Applications

Set allowing the performance of 11 experiments about the following topics:

- Photosynthesis (2 methods)
- Transpiration of leaves
- Breathing (C02 and 02 measurement)
- Glycolysis (2 methods)
- Ionic permeability of the cell membrane
- Determination of the Michaelis constant
- Enzyme inhibition
- Substrate inhibition of enzymes
- Enzymatic activity of catalase

Benefits

- For both demonstration and student experiments
- Data acquisition with the free app „measureAPP“ for mobile devices (iOS, Android, Windows)
- Sharing and exporting of the data
- 11 standard experiments in one set
- Compact setup
- All components in one package

Equipment and Technical Data

- Cobra SMARTsense Temperature: Measuring range: -40 ... 120 °C, resolution: 0.01 °C, sampling rate: 10 Hz
- Cobra SMARTsense pH: Measuring range: -0 ... 14, resolution: 0.01, sampling rate: 10 Hz
- SMARTsense Conductivity: Measuring range: 0 ... 20,000 µS / cm, 0 ... 100 °C, resolution: 1 µS / cm, 0.1 °C, sampling rate: 10 Hz
- Cobra SMARTsense Light: Measuring range: 1 lx ... 128 klx, resolution: 0.1 lx, sampling rate: 10 Hz
- Cobra SMARTsense Pressure: Measuring range: 20 ... 400 kPa, resolution: 0.1 kPa, sampling rate: 800 Hz
- Cobra SMARTsense C02: Measuring range: 0 ... 100,000 ppm, resolution: 2 ppm, sampling rate: 1 Hz
- Cobra SMARTsense Oxygen: Measuring range: 0 ... 20 mg / l, resolution: 0.01 mg / l, sampling rate: 100 Hz
- Lamp socket with reflector, diameter 20 cm, and 120 W filament lamp
- Special glassware
- Special stand material for the experiment setups

Student set Genetics, TESS advanced Biology

15311-88

Website

curricuLAB

The world sensation at PHYWE - Simple genetics for everyone in a practical set!

Function and Applications

DNA analysis has never been so simple and clear. Our experimental set contains all the necessary equipment needed for experiments in genetics, including the sensational blueGel gel electrophoresis system and the practical 3-in-1 agarose tablets (agarose, TBE-salt and a fluorescent dye). In addition, the set contains a washable pipetting practice card, which saves time and material when training with the pipette. The 3-in-1 agarose tablets, together with the blueGel„¢ system, allows visualization of DNA separation while it is being performed! Latest LED technology makes UV light superfluous. The enclosed foldable darkroom allows filming and photographing with your own smart phone. Gel electrophoresis finally without high voltage; the 48V power supply unit for electrophoresis is included. The 3-in-1 agarose tablets contain agarose, TBE and a harmless fluorescent dye that makes DNA and RNA glow - just add water, boil it up, and you are done.

Benefits

- All necessary equipment for gel electrophoresis in one set, including the power supply for electrophoresis.
- Included are the blueGel gel electrophoresis system and the 3-in-1 agarose tablets, which together enable live observation through built-in LED.
- No harmful chemicals required.
- Microliter pipette (2 µl - 20 µl), matching tips and a pipetting practice card are also included.
- Minimum preparation time.

Equipment and Technical Data

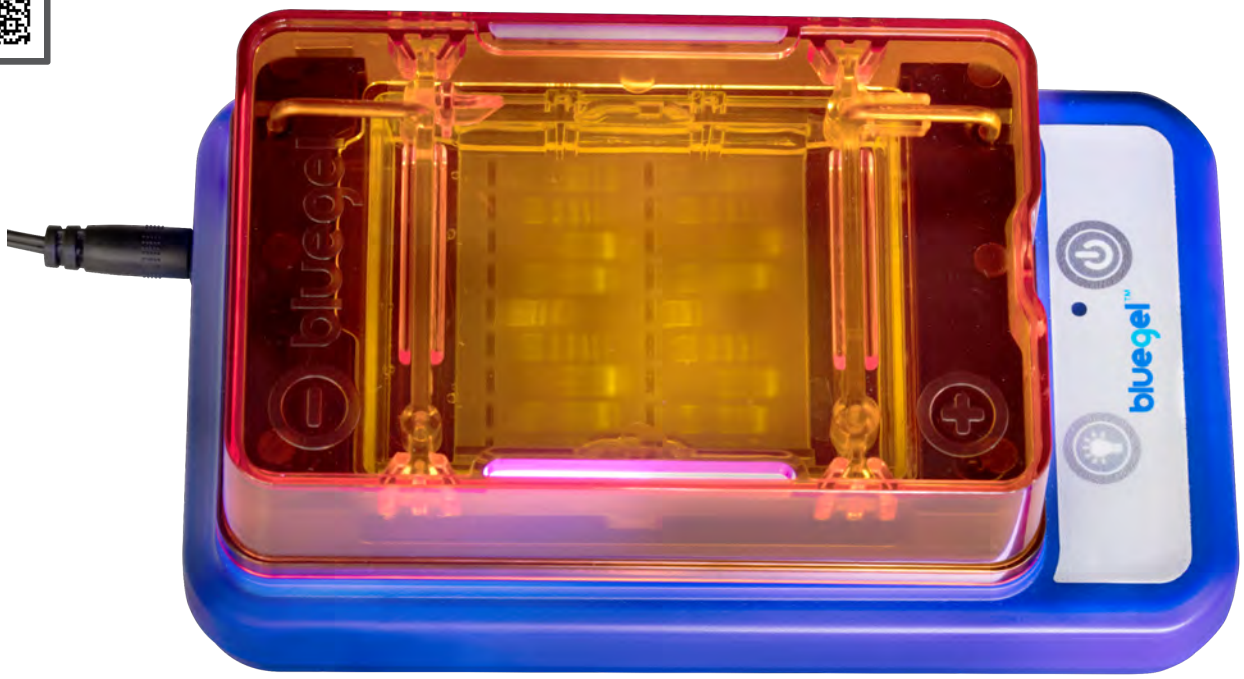
- The equipment set consists of all components necessary for the experiments; only the TBE electrophoresis buffer must be purchased separately.
- Stable, stackable storage boxes with unit-shaped foam insert
- Four kits available (to purchase separately): plasmid DNA, Lambda DNA, DNA fingerprinting, paternity test

More information on the scope of delivery is available on our website at **www.phywe.com**.

35016-99

blueGel gel - electrophoresis unit with integrated illuminator

Website



The world sensation at PHYWE - Simple genetics for everyone!

Function and Applications

DNA analysis has never been so simple and clear. The blueGel gel electrophoresis system allows the visualization of DNA separation while it is being performed. The latest LED technology makes UV light superfluous. The included foldable darkroom allows filming and photographing with your own smart phone. Gel electrophoresis finally without high voltage, the 48V power supply is included. Together with the 3-in-1 agarose tablets, DNA analysis can be performed safely and easily. The tablets contain agarose, TBE and a harmless fluorescent dye - simply add water, boil it up, and you are done.

Benefits

- Live observation by LED technology and use of a harmless fluorescent dye.
- Saving of material by analysis of 26 samples with one run of a 20 ml gel.
- Complete system: Running chamber with LED, power supply, buffer chamber, casting system and combs.
- Safe: Operating voltage of 48 V and with automatic power cut-off when the lid is removed.
- Robust and equipped with high-quality, wear-free electrodes.

Equipment and Technical Data

- Integrated blue light transilluminator
- For gels of the size 60 x 60 mm (about 20 ml)
- Platinum and stainless steel electrode
- Required buffer: 25 ml TBE
- Included accessories: darkening hood, 2 combs for 9 or 13 bags each, power supply unit, pump spray with microfibre cloth against fogged up covers, storage bag
- Mains voltage: 100-240 V, 50 - 60 Hz
- Operating voltage: 48 V
- Dimensions: 23 cm x 10 cm x 7 cm
- Weight: 350 g

miniPCR mini16 Thermocycler for 16 samples, PCR machine

35015-99

Website

Function and Application

We bring the Nobel Prize topic PCR (polymerase chain reaction) into your classroom. The Thermocycler miniPCR mini16 copies the genetic material (DNA) exactly as the big, expensive laboratory devices do. The miniPCR offers space for up to 16 samples and is very easy to use. The device is conveniently controlled and programmed via a free app on your smartphone or computer. The app is compatible with Windows, Mac, Android, Kindle, iPhones as well as iPads and is available in all app stores. The thermal cycler can be connected via Bluetooth. You do not need to keep the machine connected to your computer, tablet or smartphone to run the program.

Benefits

- Up to 16 samples can be analyzed in one run.
- Easy to operate, using the free app „miniPCR" for all operating systems.
- Covering all common PCR modes: classic endpoint PCR, linear gradients, heating block function and a completely free configurable mode.
- The transparent housing allows a view into the inner workings of the cycler.
- Optional operation by a powerbank allows the portable device to be used almost anywhere.

Equipment and Technical Data

- Space for 16 samples: 2 x 8 0.2 ml reaction vessels (single vessels or strips of 8)
- Heated lid
- Easy to use app for all common PCR modes
- Operation with common reagents
- Included accessories: power supply unit, USB cable, dust cover
- Dimensions and weight: 5 cm x 13 cm x 10 cm, about 500 g
- Mains supply: 90 - 246 V, 50-60 Hz, 65 W
- Optional operation via Li-Ion powerbank (not included)

Necessary accessories:

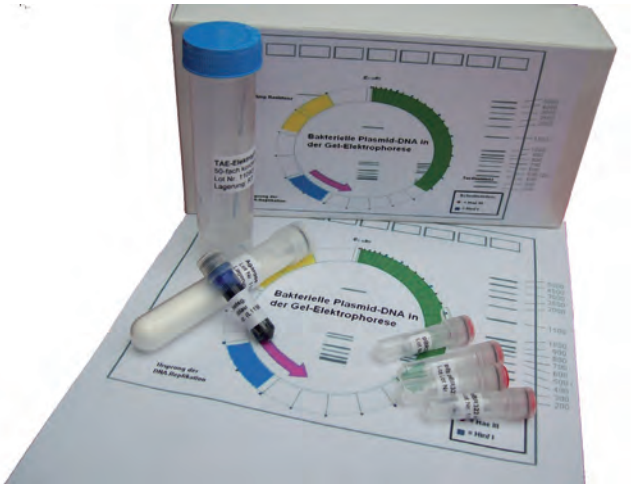
- Microliter pipette 2-20 µl
- Microliter pipette 20-200 µl
- Tips, plastic (PP), in box, 2-200 µl, yellow, 96 pieces
- PCR single tubes, 0.2 ml, domed lid, 1000 pieces
- Disposable reaction tubes 1.5 ml, 1000 pieces
- Stand for disposable reaction tubes
- Genetic Fingerprint kit for PCR

A complete set is also available with all necessary components (35015-88).

P8110500

Electrophoresis of Plasmid DNA

Website



Benefits

- Complete equipment set which also contains all required consumables
- Consumables can be purchased as a replacement kit
- Ready to use: DNA fragment samples are already predigested
- Easy to use: detailed experiment guide
- DNA samples can can be stored for a longer period at room temperature because they are lyophilized

Learning objectives

- Plasmid DNA
- Electrophoresis
- Restriction enzymes
- Restriction digestion
- Banding pattern

Principle

The most important work methods of molecular genetics are taught in this experiment. With the aid of agarose gel electrophoresis migration velocity and the cleavage pattern of plasmid DNA can be investigated.

Tasks

1. Casting agarose gels
2. Preparing samples for electrophoresis
3. Performing electrophoresis
4. Staining the samples and analyse the banding pattern

P8110700

Genetic fingerprinting

Website

Benefits

- Complete equipment set which also contains all required consumables
- Consumables can be purchased as a replacement kit
- Ready to use: DNA fragment samples are already predigested
- Easy to use: detailed experiment guide
- Lyopholized DNA samples for longer-term storage at room temperature

Learning objectives

- DNA fingerprinting
- Electrophoresis
- Banding pattern
- DNA profile
- Forensics
- PCR

Principle

This experiments allows to simulate the method of DNA fingerprinting and uses a DNA fingerprint to identify the offender in a hypothetical crime. After separation of a given DNA by using gel electrophoresis and staining the DNA samples the students can compare the pattern of fragments on the gel with other DNA samples and match the DNA to the offender.

Tasks

1. Casting agarose gels
2. Preparing samples for electrophoresis
3. Performing electrophoresis
4. Staining the samples and analysing the banding pattern

Also available:
Electrophoresis of Lambda DNA (P8110600) and Paternity test (P8110800)

4 TESS expert

Website

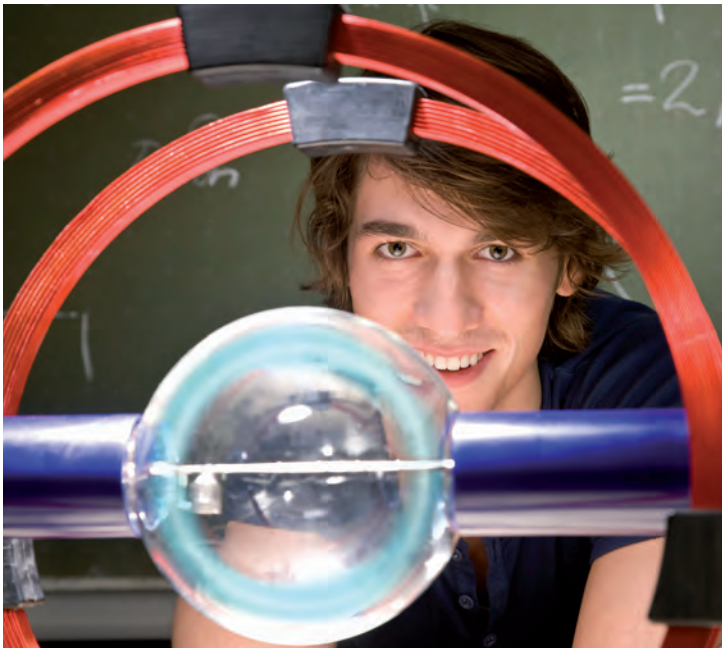
TESS expert from PHYWE –
experiments for higher education

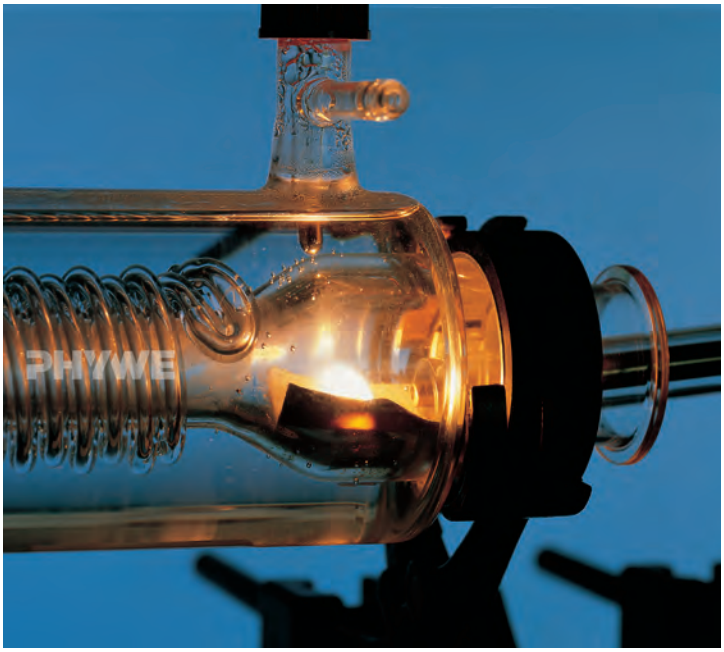
The curriculum-compliant student and teacher experiments from TESS expert are for Physics, Chemistry, Biology and Applied Sciences (laboratory) courses at universities, colleges of advanced technology, technical colleges and similar institutions and advanced courses in high schools. They are focused exclusively on higher education programs.

TESS expert contains more than

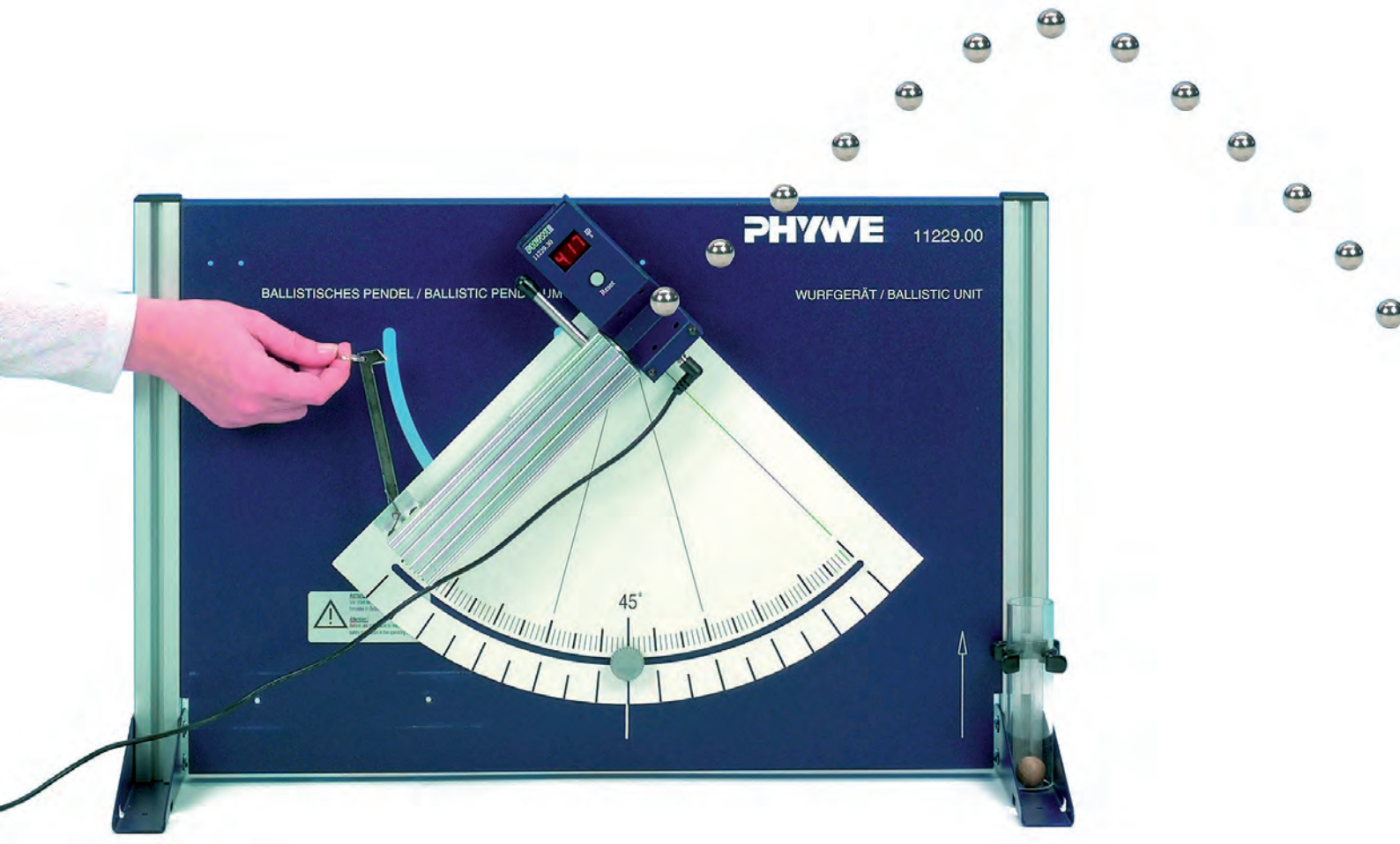
>300 experiments in Physics
>200 experiments in Chemistry
>100 experiments in Biology
>100 experiments in Applied Sciences.

Of these >700 experiments, we have selected the most important ones in the next chapters.





An overview of all university experiments can be found on our website at **www.phywe.com/experiments-sets/university-experiments/**.



TESS expert - Physics

4.2.1 Mechanics

P2110105

Basic measurement techniques

Website

curricuLAB

Benefits

- Foundation of every practical sciences lab course
- Aquire the skills to measure basic mechanical variables
- Realise the limits of measuring accuracy
- Combine different measurements to determine a quantity of interest
- Determine curvatures using the spherometer

Learning objectives

- Length
- Diameter
- Inside diameter thickness
- Curvature
- Vernier

Principle

Caliper gauges, micrometers and spherometers are used for the accurate measurement of lengths, thicknesses, diameters and curvatures. 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.

P2130702

Free Fall with timer 2-1

Website

curricuLAB

Benefits

- Gravitation scrutinized
- Find out how the velocity of a falling object increases
- Didactical demonstration of the falling distances
- Visualise the squared distance-time law
- Steady set-up
- All crucial parts directly engineered for this experiment

Learning objectives

- Linear motion due to constant acceleration
- Laws of falling bodies
- Gravitational acceleration

Principle

A sphere falls freely over certain distances. The falling time is measured and evaluated from diagrams. The acceleration due to gravity can be determined.

Tasks

1. To determine the functional relationship between height of fall and falling time.
2. To determine the acceleration due to gravity.

The conservation of momentum theorem with Cobra DigiCart

P6201000

Benefits

- Free measuring software DigiCartAPP for all mobile devices and all operating systems (Windows, Android, iOS).
- Especially understandable and didactically prepared experimental literature can be used in the DigiCartAPP.

Learning objectives

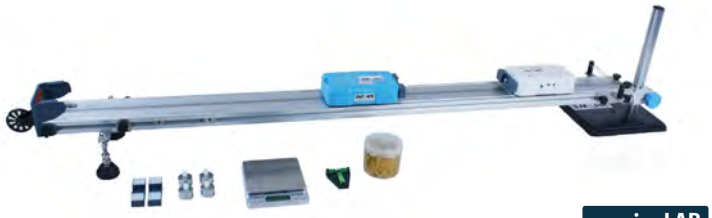
- Physical concept of impulse
- Energy conservation
- Elastic impact
- Inelastic impact

Principle

The momentum of a moving body is defined as the product of its mass and its velocity.

Newton's second law states that the change in momentum over time corresponds to the external force acting.

Website



curricuLAB

Newton's 2nd law/ demonstration track

P2130305

Benefits

- Accurate results due to measurements with low friction: cart with sapphire bearings
- Over the entire track length adjustable feet for a very simple alignment of the track even on small tables

Learning objectives

- Velocity
- Acceleration
- Force
- Acceleration of gravity

Principle

The distance-time law, the velocity time law, and the relationship between mass, acceleration and force are determined with the aid of the demonstration track rail for uniformly accelerated motion in a straight line.

Website

curricuLAB

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

P2130380

Benefits

- Accurate results due to measurements with low friction: cart with sapphire bearings
- Over the entire track length adjustable feet for a very simple alignment of the track even on small tables

Learning objectives

- Linear motion
- Velocity
- Acceleration
- Conservation of energy
- Kinetic energy
- Potential energy

Principle

A mass, which is connected to a cart via a silk thread, drops to the floor. The resulting motion of the cart will be recorded by way of a video camera and evaluated with the „measure Dynamics" software.

Website

curricuLAB

P2131100

Projectile motion

Website

curricuLAB

Benefits

- Classic method to determine a projectile's velocity
- Immediate evaluation with the integrated velocity measurement
- Magnetic mount of the different projectiles

Learning objectives

- Trajectory parabola
- Motion involving uniform acceleration
- Ballistics

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.

P2131200

Ballistic pendulum

Website

curricuLAB

Benefits

- Classic method to determine a projectile's velocity
- Immediate evaluation with the integrated velocity measurement
- Magnetic mount of the different projectiles

Learning objectives

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

Principle

A classic method of determining the velocity of a projectile is to shoot it into a resting mass hung as a pendulum. The projectile remains in the pendulum and swings with it. This is an inelastic collision in which the momentum remains unchanged. The velocity of the pendulum's mass (including the projectile's mass) at the lowest point of the pendulum can be derived from the amplitude of the pendulum's oscillation. Additionally to the set-up, two light barriers and a time measuring device are available for an independent, direct measurement of the initial velocity of the ball.

Tasks

Measure the amplitude of the pendulum for three different initial velocities of the shot ball.

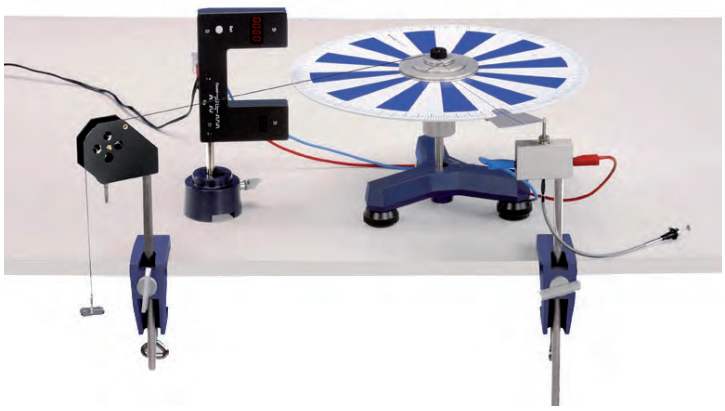
Moment of inertia and angular acceleration with a precision pivot bearing

P2131305

Website

Benefits
- Long runtime
- Nearly friction-less movement due to precision bearing and precision pulley
- Steady set-up prevents interferences

Learning objectives
- Angular velocity
- Rotary motion
- Moment
- Moment of inertia of a disc
- Moment of inertia of a bar
- Moment of inertia of a mass point



Principle

A moment acts on a body which can be rotated about a bearing without friction. The moment of inertia is determined from the angular acceleration.

Tasks

From the angular acceleration, the moment of inertia is determined as a function of the mass and the distance from the axis of rotation

1. of a disc
2. of a bar
3. of a mass point

curricuLAB

Moment of inertia and angular acceleration with Cobra SMARTsense and a precision pivot bearing

P2131367

Website

Benefits
- Long runtime
- Nearly friction-less movement due to precision bearing
- Steady set-up prevents interferences
- Data logging reveals instantaneous results during measurement

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

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

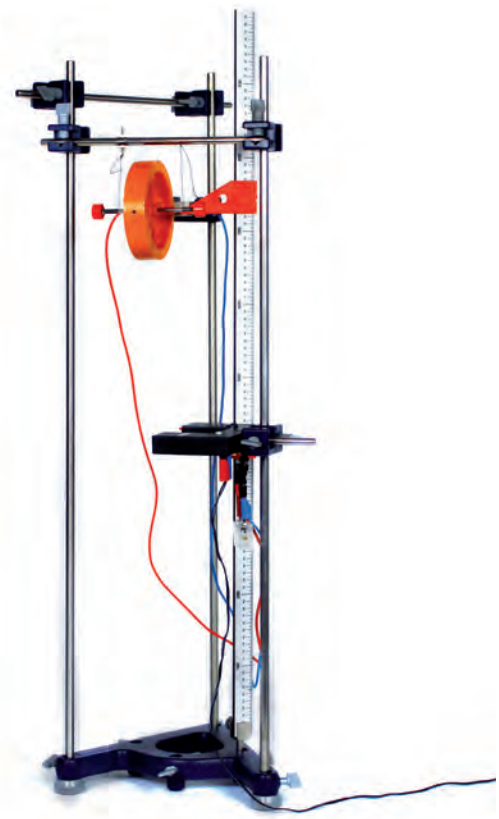
1. Measurement of the laws of angle and angular velocity according to time for a uniform rotation movement.
2. Measurement of the laws of angle and angular velocity according to time for a uniformly accelerated rotational movement.
3. Rotation angle; is proportional to the time *t* required for the rotation.

curricuLAB

P2131800

Website

curricuLAB



Mechanical conservation of energy/ Maxwell's wheel

Benefits

- High and sturdy set-up
- Expressive demonstration of energy conversion
- Convert potential energy in energy of rotation, energy of translation, and vice versa

Learning objectives

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

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.

P2131900

Website

curricuLAB

Laws of gyroscopes/ 3-axis gyroscope

Benefits

- Long-lasting motion due to low friction
- Slow rotation allows a comfortable measurement
- Quickly establish equilibrium with the easy to adjust counter weight
- Adjust the torque by adding additional weights

Learning objectives

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

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.

Moments of inertia and torsional vibrations with Cobra SMARTsense

P2133167

Website

Benefits

- Angular oscillation apparaturs includes five different body shapes for in-depth experimenting
- High-precision movement sensor
- Very robust and durable setup

Learning objectives

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

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.

curricuLAB

Cobra SMART sense

Centripetal force/centrifugal force with Cobra SMARTsense

P6000667

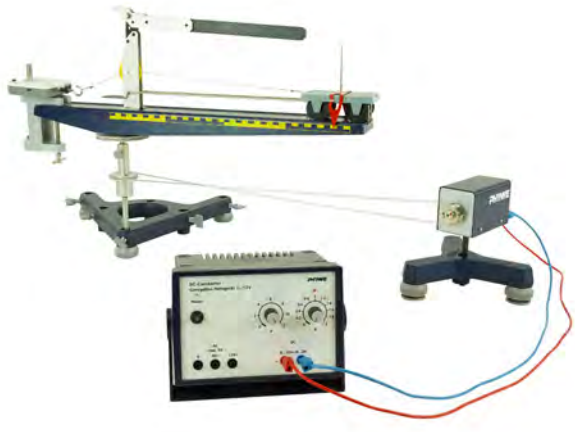
Website

Benefits

- Wireless connection with Cobra4 Wireless/USB-Link enables accurate data logging
- Automatic sensor identification and loadable pre-settings with the software measureLAB
- High precision allows to determine the rotational frequency

Learning objectives

- Torque and rotary moments in general
- Centripatal force
- Angular acceleration



Principle

The examination of the dependencies of the centripetal force is a classic experiment of mechanics. Here and in experiments with rotational movements in general radio transmission offers many advantages. Conventional set-ups of experiments to measure the centripetal force mostly measure the force through a cord to stationary measuring units outside. If a spring scale is used to measure the values, greater speed also increases the radius of the path due to the increasing elongation of the spring. Therefore, the examination of the centripetal force with altered radii or angular speeds while setting the other quantity to a fixed value is rather complicated to perform. The Cobra4 Sensor-Unit Force with elongation measurement strips simplifies this experiment. Radio transmission additionally simplifies the set-up of this experiment.

curricuLAB

Cobra SMART sense

12970-00

Cobra SMARTexperiment - Hooke's Law

Website

Cobra SMART sense

Benefits

- All-in-one experiment - no lengthy setup, no interface necessary
- Includes all components and sensors necessary for measurement
- Stable tripod material
- Free measurement software measureAPP

Learning objectives

- Effect of force on elastic bodies like springs
- Spring constant
- Hooke's law

Principle

Hooke's law: The elastic deformation is proportional to the load applied.

Equipment and Technical Data

- Included sensors: 1 Cobra SMARTsense Force & Acceleration
- 1 Cobra SMARTsense Motion

P2130101

Hooke's law

Website

curricuLAB

Benefits

- The law that governs the elongation of springs
- Determine the magnitude that describes the main characteristics of a spring
- Discover the main difference in the behaviour of springs and rubber bands

Learning objectives

- Hooke's law
- Spring constant
- Limit of elasticity
- Elastic hysteresis
- Elastic after-effect

Principle

The validity of Hooke's law is determined for two helical springs with different spring constants. The elongation of the helical spring, which depends on the deforming force, is studied by means of the weights of masses. For comparison, a rubber band, for which no proportionality exists between the exerted force and the resulting elongation, is submitted to the same forces.

Tasks

1. Determining the spring constants of helical springs.
2. Study of the elongation of a rubberband.

Moments

P2120100

Benefits
- Understand the relation and the difference between moments and force.
- Smart designed equipment that makes measurements clear and easy.

Learning objectives
- Moments
- Coupling
- Equilibrium
- Statics
- Lever
- Coplanar forces

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

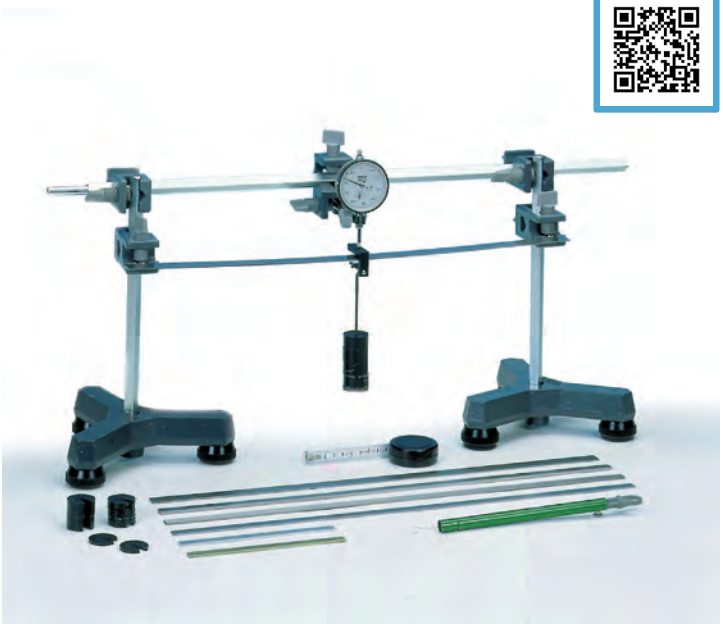
1. Determination of the moment as a function of the distance between the origin of the coordinates and the point of action of the force.
2. Determination of the moment as a function of the angle between the force and the position vector to the point of action of the force.
3. Determination of the moment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

Modulus of elasticity

P2120200

Benefits
- Find out the parameters that give a bar stability
- Measure the difference of elasticity in various metals with different lengths
- Learn how to determine forces with a dial gauge

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



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 dialgauge.
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.

P2120300

Mechanical hysteresis

Website

curricuLAB

Benefits

- Beyond Hooke's law
- Hysteresis - mostly known from the field of magnetism - can be experienced in mechanics
- Learn the meaning of the words stress, relaxation and equilibrium in a physics context

Learning objectives

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

Principle

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

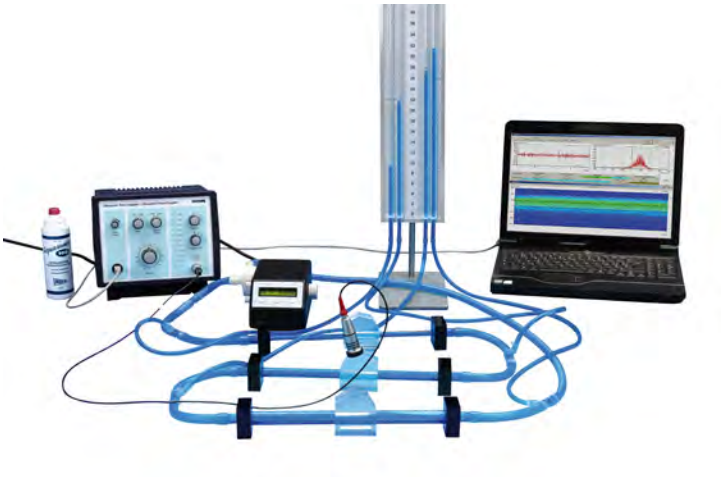
Tasks

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

P5140100

Mechanics of flow

Website



curricuLAB

Benefits

- Excellent introductory experiment for medical students to teach principles of flow
- Experiment setup can be varied and be used for other experiments
- Compact experiment setup
- Results can be read off easily from a scale

Learning objectives

- Ultrasonic Doppler effect
- Steady, laminar and turbulent flow
- Continuity equation
- Bernoulli's equation
- Hagen-Poiseuille law
- Flow velocity and flow resistance (static and dynamic)
- Pressure, pressure scales
- Viscosity and fluidity
- Ultrasonic flow measurements

Principle

The ultrasonic Doppler effect is used for studying the laws of steadily and laminarly flowing liquids in a tube circuit, which form the basis of numerous technical applications. The experiment focuses particularly on the relationship between the flow velocity and the cross-sectional tube area (continuity condition) as well as on the relationship between the flow resistance and the tube diameter (Hagen-Poiseuille law). If the geometry is known, both relationships can be used to determine the dynamic viscosity or fluidity.

Tasks

1. Determine the mean and maximum Doppler frequency shift for different speeds and diameters.
2. Calculate the mean flow velocity in accordance with the Doppler law

Density of liquids

P2140100

Website

Benefits
- Mohr density balance enables high-precision measurements
- Interdisciplinary use also in applied sciences or physical chemistry

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

Principle

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

Tasks

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.

curricuLAB

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

P2140300

Website

Benefits
- Classic experiment to determine the viscosity of a huge variety of fluids
- Watch all results directly on the built-in multilanguage display
- Use several spindles that come with a storage rack
- Wearless torque measuring system with high accuracy

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

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.

curricuLAB

P2140400

Website

curricuLAB

Viscosity measurement with the falling ball viscometer

Benefits

- Viscosity measurement for two fluids and any mix ratio
- Viscosity measurement for different temperatures possible
- Angle of falling ball viscometer can be changed
- Interdisciplinary use also in applied sciences or physical chemistry

Learning objectives

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

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.

P2140500

Website

curricuLAB

Surface tension with the ring method (Du Nouy method)

Benefits

- High sensitivity measurement possible thanks to ring method
- Analogue set-up that can also be used as a demo experiment in the lecture hall
- Torsion dynamometer used can measure very small forces and is therefore suitable to measure other electrostatic and magnetic interactions between bodies

Learning objectives

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

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.

Surface tension of liquids

P2140501

Benefits

- High sensitivity measurement possible thanks to ring method
- Analogue set-up that can also be used as a demo experiment in the lecture hall
- Interdisciplinary use also in applied sciences or physical chemistry

Learning objectives

- Wetting and non-wetting liquids
- Capillarity

Principle

The cohesive forces in a liquid generate tension on its surface, the so-called surface tension. A metal ring that is plunged into a liquid is withdrawn from the liquid. At a certain tensile force, the liquid film will be disrupted from the ring. Based on the tensile force and ring diameter, the surface tension of a liquid can be calculated

Website

curricuLAB

Cobra SMARTexperiment - Archimedes' principle

12971-00

Benefits

- All-in-one experiment - no lengthy setup, no interface necessary
- Includes all components and sensors necessary for measurement
- Stable tripod material
- Free measurement software measureAPP
  1. In three steps to the result: remove from the cupboard
  2. insert sensor and switch on
  3. fast and intuitive measurement

Learning objectives

- The buoyancy force of a body in a medium is equal to the weight force of the medium displaced by the body

Principle

The Archimedes' principle: The static buoyancy of a body in a medium is as great as the weight of the medium displaced by the body.

Equipment and Technical Data

- Included sensors: 2 Cobra SMARTsense Force & Acceleration (12943-00)

Website

Website

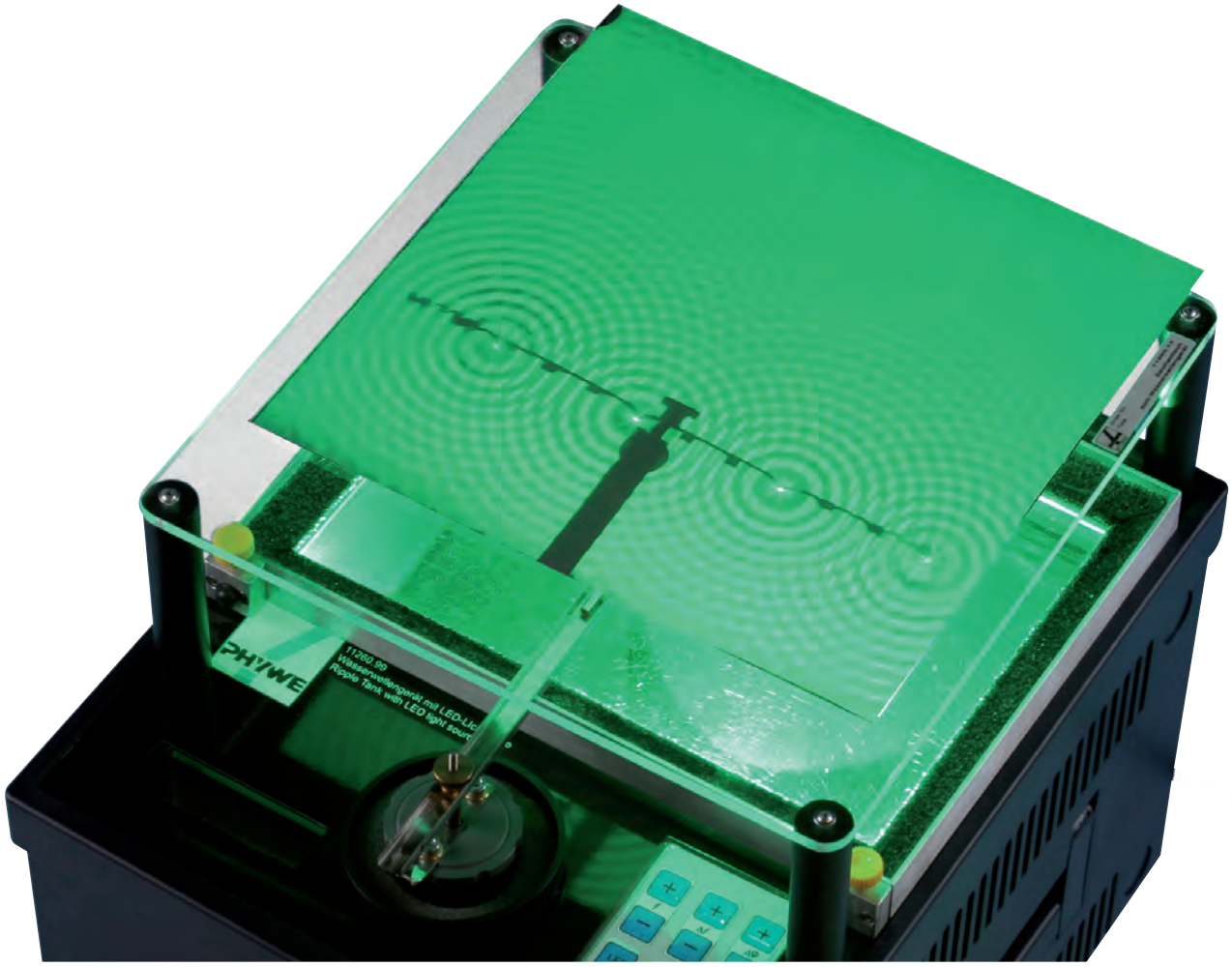
Cobra SMARTexperiments –
All experiments on our website.

*You need more information? All experiments can be found on our website at **www.phywe.com** or send an email to **info@phywe.com**.*

Cobra SMARTexperiments contain all components and sensors necessary for measurement

All-in-one-experiment – no lengthy setup, no interface necessary!

- Remove from cabinet
- Switch on
- Quick and intuitive measurement



TESS expert - Physics

4.2.2 Oscillations, Waves & Acoustics

P2132100

Mathematical pendulum

Website

curricuLAB

Benefits

- Quick and easy set-up
- Automatically measure the oscillation period using the light barrier

Learning objectives

- Duration of oscillation
- Period
- Amplitude
- Harmonic oscillation

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.

12972-00

Cobra SMARTexperiment - Mathematical Pendulum

Website

Cobra SMART sense

Benefits

- All-in-one experiment - no lengthy setup, no interface necessary
- Includes all components and sensors necessary for measurement
- Stable tripod material
- Free measurement software measureAPP

Learning objectives

- Physical pendulum
- Harmonic oscillation
- Oscillation period

Principle

The mathematical pendulum: The oscillation period of the harmonic oscillation depends on the length of the pendulum but not on the attached mass.

Equipment and Technical Data

- Included sensors: 1 Cobra SMARTsense Photogate A

Reversible pendulum

P2132200

Benefits
- Quick and easy set-up
- Determine the gravitational constant g immediately without knowledge of mass or moment of inertia
- Automatically measure the oscillation period using the light barrier

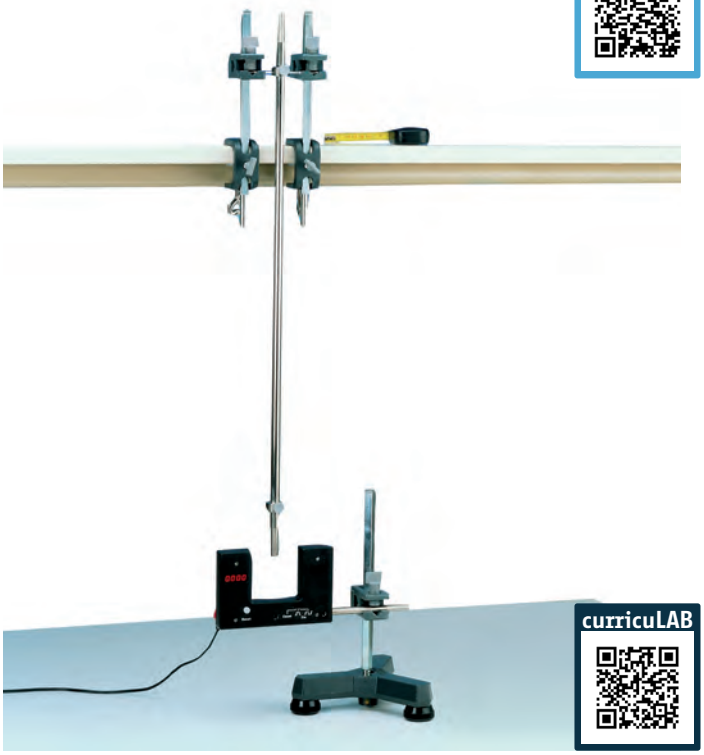
Learning objectives
- Physical pendulum
- Moment of inertia
- Steiner's law
- Reduced length of pendulum
- Reversible pendulum
- Terrestrial gravitational acceleration

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.

Tasks

1. Measurement of the period for different axes of rotation.
2. Determination of terrestrial gravitational acceleration*g*.



Website

curricuLAB

Variable g pendulum

P2132301

Benefits
- Quick and easy set-up
- Determine the gravitational constant g immediately without knowledge of mass or moment of inertia
- Automatically measure the oscillation period using the light barrier
- Simulate the pendulum oscillation as it would behave on the moon

Learning objectives
- Oscillation period
- Harmonic oscillation
- Mathematical pendulum
- Physical pendulum
- Decomposition of force
- Moment of inertia

Principle

Investigate the oscillation behaviour of a pendulum (rod pendulum) by varying the magnitude of the components of the acceleration of gravity which are decisive for the oscillation period. The pendulum that is to be used is constructed in such a manner that its oscillation plane can be progressively rotated from a vertical orientation to a horizontal one. The angle F, by which the oscillation plane deviates from its normal vertical position, can be read from a scale.

Tasks

1. Measurement of the oscillation period of the pendulum as a function of the angle of inclination F of the oscillation plane for two different pendulum lengths.
2. Graphical analysis of the measured correlations and acomparison with the theoretical curves, which have been standardised with the measured value at F= 0.

Website

curricuLAB

P2132667

Website

curricuLAB

Cobra SMART sense

Harmonic oscillations of spiral springs with CobraSMARTsense

Benefits

- Large and sturdy set-up suitable for demonstration and lab courses as well
- Data logging reveals instantaneous results during measurement

Learning objectives

- Spring constant
- Hooke's law oscillations
- Limit of elasticity
- Parallel springs
- Serial 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 differentsprings.
2. Determination of the spring constant for springs linked inparallel.
3. Determination of the spring constant for springs linked inseries.

P2132567

Website

curricuLAB

Cobra SMART sense

Coupled pendula with Cobra SMARTsense expert version

Benefits

- Large and sturdy set-up suitable for demonstration and lab courses as well
- Live data-logging system to measure the oscillations of both pendula at once

Learning objectives

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

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 "in phase" and „in opposite phase" vibration, c) the angular frequencies of the beatmode.

Forced oscillations - Pohl's pendulum

P2132705

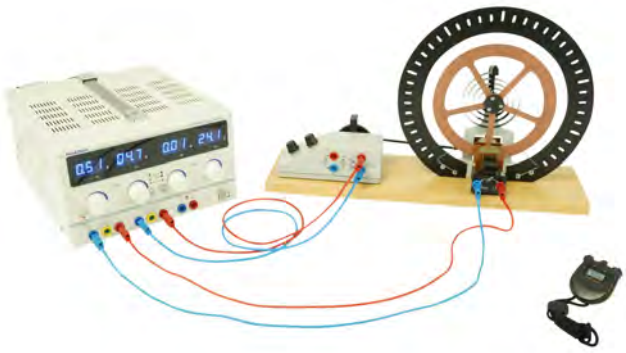
Website

Benefits

- Long-lasting oscillation due to ball bearings
- Damping via abrasion-resistant eddy current brake
- Simple illustration of the elementary principle of forced oscillations
- Suitable for demonstration and student experiments as well
- Designed for large and clear shadow projection while experimenting

Learning objectives

- 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



curricuLAB

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. The characteristic frequencies of the free oscillation as well as the resonance curves of the forced oscillation for different damping values are to be determined

Torsional vibrations and torsion modulus

P2133000

Website

Benefits

- The use of eight different rods out of different material and with several diameters increase the understanding of all correlations
- Simple experimental set-up with immediate and clear results
- Extremely solid construction

Learning objectives

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

curricuLAB

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.

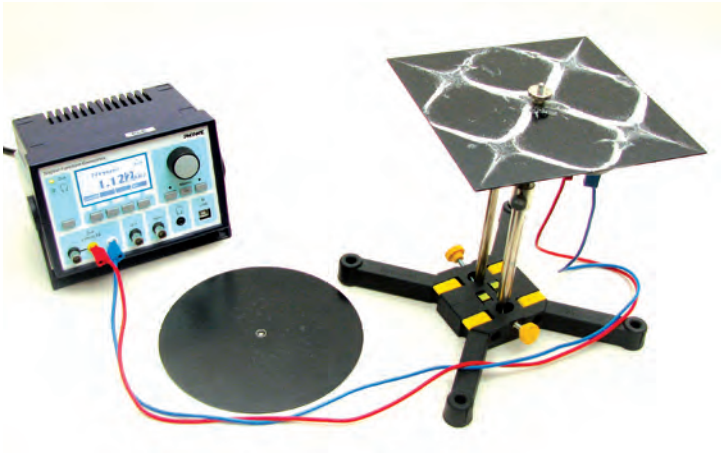
Tasks

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.

P2150501

Chladni figures

Website



curricuLAB

Benefits

- Experiment set-up particularly suitable to visualize resonance
- Use digital function generator for quick frequency-tuning in other experiments

Learning objectives

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

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

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

P2133210

Propagation of a periodically excited continuous transverse wave

Website

curricuLAB

Benefits

- Large and very illustrative way to watch the propagation of waves including damping, coupling, standing waves and many more
- Slow propagation speed allows an excellent observation
- Easy fixation of wave images at any time

Learning objectives

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

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.

Interference and diffraction of water waves with the Ripple Tank

P2133500

Website

Benefits

- See and understand the laws that govern wave phenomena
- Just add water - compact device offers fast and easy setup
- Bright green LED offers qualities even for a demonstration experiment

Learning objectives

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

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.

curricuLAB

Phase velocity of standing waves with Cobra SMARTsense

P2133669

Website

Benefits

- Very illustrative way to watch the propagation of waves including damping, couping, standing waves and many more
- Slow propagation speed allows an excellent observation in particular with a stroboscope

Learning objectives

- Wavelength
- Phase Speed
- Group speed
- Wave equation
- Harmonic

Principle

A linearly polarized standing transverse wave is generated on a rubber band with a square cross-section by means of a vibration generator. The wavelength is determined as a function of the excitation frequency. Then the phase velocity of the cable wave is changed by changing the tensile stress. The relationship between the phase velocity of the rope and the tension on the rope is investigated. With the help of a stroboscope the standing wave can be displayed even more impressively.

Tasks

1. At constant tensile stress the frequency f depends on the wavelength λ of the wave propagating on the rope. The frequency is calculated as a function of 1 / λ. From this diagram the phase velocity c can be determined.
2. The phase velocity c of the rope wave is to be measured. The phase velocity is displayed as a function of the tensile stress

Cobra SMART sense

curricuLAB

P2150305

Velocity of sound in air with Universal Counter

Website

curricuLAB

Benefits

- Perfect as demonstration and student experiment
- Easy setup and fast procedure
- Easy entry into the topic of error calculation possible

Learning objectives

- Wave propagation
- Longitudinal wave
- Air pressure variation
- Sound wave
- Impulse of sound

Principle

The velocity of sound in air is determined by measurement of sound travel times across known distances.

Tasks

Determine the sound velocity in air for different distances between sound source and microphone.

P2153067

Velocity of sound in air with Cobra SMARTsense

Website

curricuLAB

Benefits

- Simple set-up and procedure
- Easy entry into the topic of error calculation possible
- Simplified implementation: all pre-settings already prepared

Learning objectives

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

Principle

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

Tasks

Determine the speed of sound in air.

Acoustic Doppler effect with universal counter

P2150405

Benefits
- Easy frequency setting thanks to digital function generator
- Intuitive measuring instrument
- Results well reproducible because of the motor-driven car

Website

Learning objectives
- Wave propagation
- Doppler shift of frequency

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.
2. Measure the Doppler shift for varying frequencies and velocities for a moving detector. Compare the measurements with the values predicted by theory.

curricuLAB

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

P2150605

Benefits
- Two experiments in one: determination of the sound velocity and determination of the wavelength of standing waves
- Easy frequency setting thanks to digital function generator

Website

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

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 cork 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.

curricuLAB

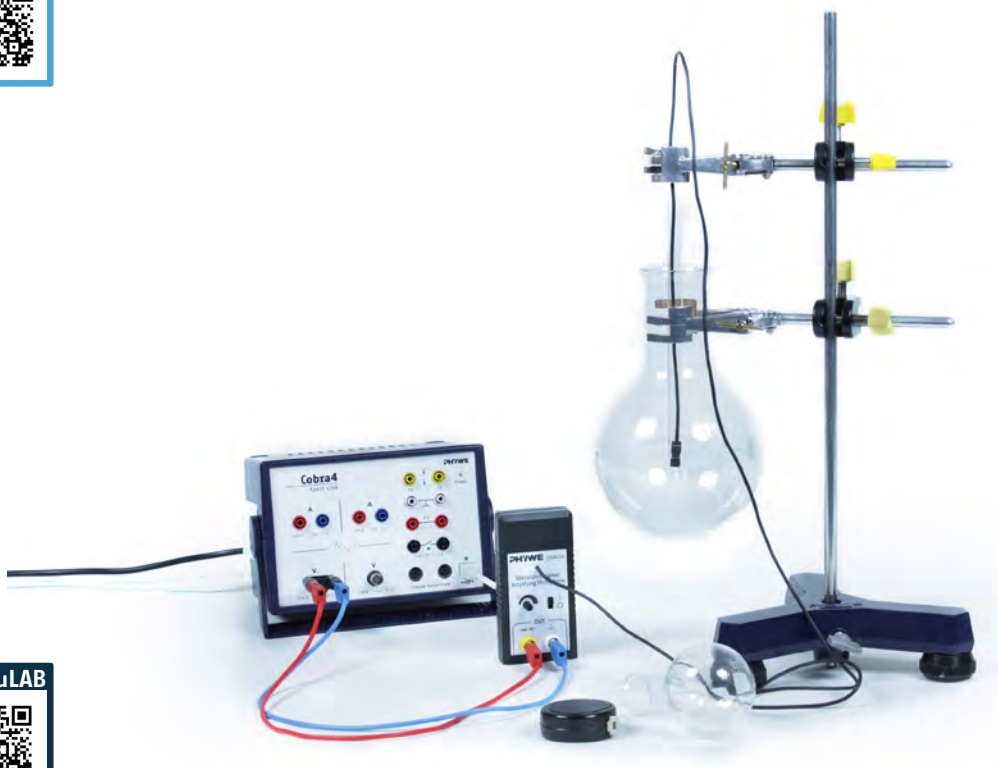
P2150864

Resonance frequencies of Helmholtz resonators with Cobra Xpert-Link

NEW

Website

curricuLAB



Benefits

- Measure the resonance frequencies without additional excitation by using only the ambient noise
- Immediate observation of both, the sound wave signal and the resonance frequencies using FFT
- Measure live while changing the body volume and thus the resonance frequency
- Simplified implementation: all pre-settings already prepared

Learning objectives

- Cavity resonator
- Resonance frequency
- Acoustic resonant circuit

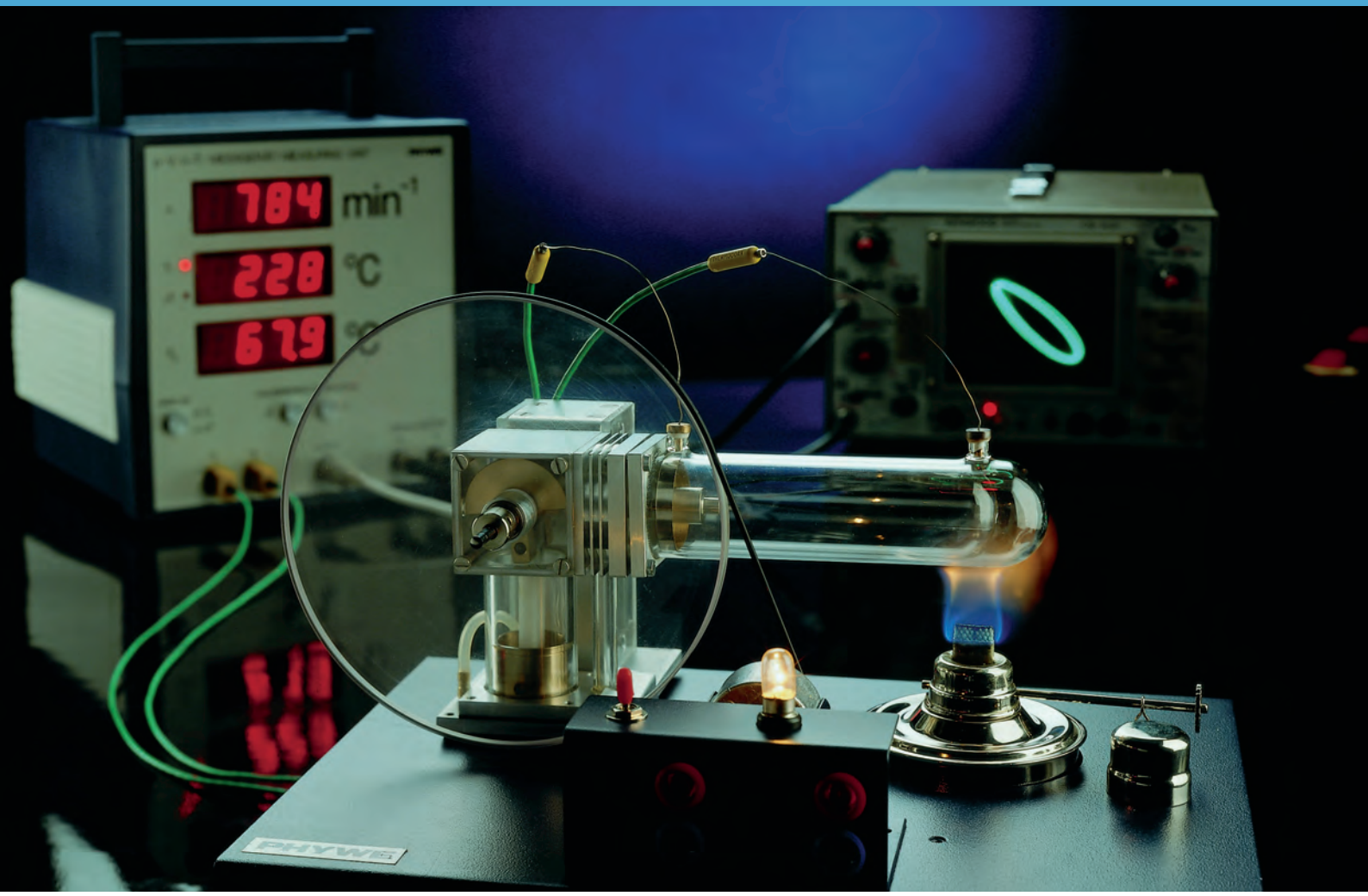
Principle

Acoustic cavity resonators possess 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.

Tasks

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

More information on the scope of delivery is available on our website at **www.phywe.com**.



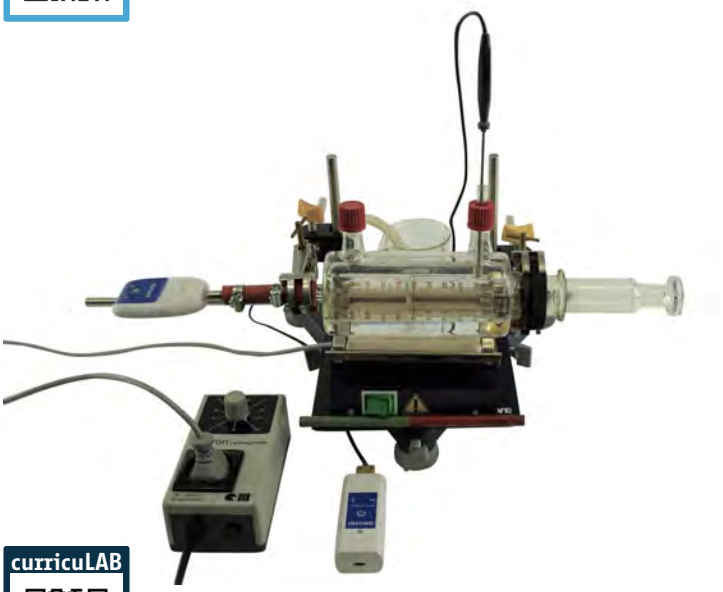
TESS expert - Physics

4.2.3 Thermodynamics

P2320167

Equation of state for ideal gases (gas laws: Gay-Lussac, Amontons, Boyle)

Website



curricuLAB

Cobra SMART sense

Benefits

- Unique system: All gas laws can be measured with the same setup
- Very compact setup, can be stored in the shelf and is always ready to use
- Very demonstrative: Volume is read directly at the gas syringe, temperature and pressure are measured with sensors in real-time

Learning objectives

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

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 a change 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

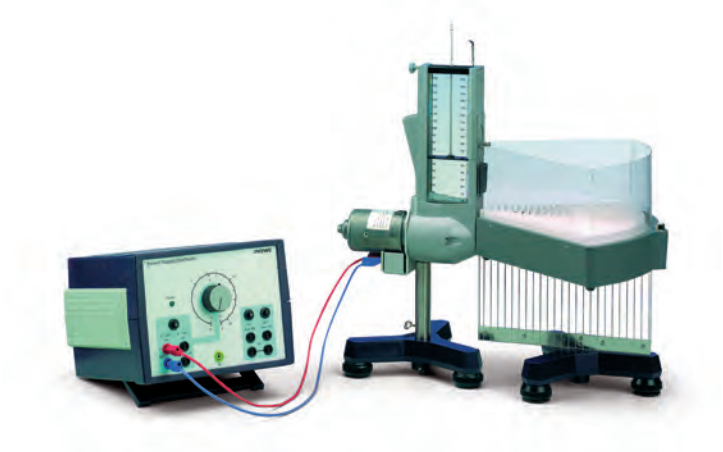
- For a constant amount of gas (air) investigate the correlation of

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))

P2320300

Maxwellian velocity distribution

Website



curricuLAB

Benefits

- For both demonstration and student experiments
- Unique experiment to quantitatively study kinetic gas theory
- Visualization of the Maxwell Boltzmann distribution

Learning objectives

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

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.

Heat capacity of gases with Cobra SMARTsense

P2320267

Website

Benefits

- Determination of c_p and c_v
- For both demonstration and student experiments
- Suitable for many different gases
- Simplified implementation: all pre-settings already prepared

Learning objectives

- Equation of state for ideal gases
- 1st law of thermodynamics
- Universal gas constant
- Degree of freedom
- Mole volumes
- Isobars
- Isotherms
- Isochors and adiabatic changes of state

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 are calculated from the pressure or volume change.

Tasks

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

curricuLAB

Cobra SMART sense

Adiabatic coefficient of gases - Flammersfeld oscillator

P2320500

Website

Benefits

- Suitable for many different gases
- Compact, easily transportable setup

Learning objectives

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

Principle

A mass oscillates on a volume of gas in a precision glass tube. The oscillations 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 from the periodic time of the oscillation T of the mass m on the volume V of gas.

curricuLAB

P2320600

Joule-Thomson effect

Website

Benefits

- For both demonstration and student experiments
- Affordable set-up

Learning objectives

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

Principle

A stream of gas is fed to a throttling point, where the gas (CO_2 or N_2) 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 arecalculated.

Tasks

1. Determination of the Joule-Thomson coefficient of CO_2.
2. Determination of the Joule-Thomson coefficient of N_2.

P2330167

Heat capacity of metals with Cobra SMARTsense

Website

curricuLAB

Cobra SMART sense

Benefits

- Flexible experimenting thanks to wireless data transmission
- Data acquisition with tablets possible
- Simplified implementation: all pre-settings already prepared

Learning objectives

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

Mechanical equivalent of heat

P2330200

Benefits

- Elegant set-up to measure conversion of mechanical energy in thermal energy
- Perfect as demonstration experiment and very suitable as an introductory student experiment

Learning objectives

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

Website

curricuLAB

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.

Stefan-Boltzmann's law of radiation with Cobra Xpert-Link

P2350164

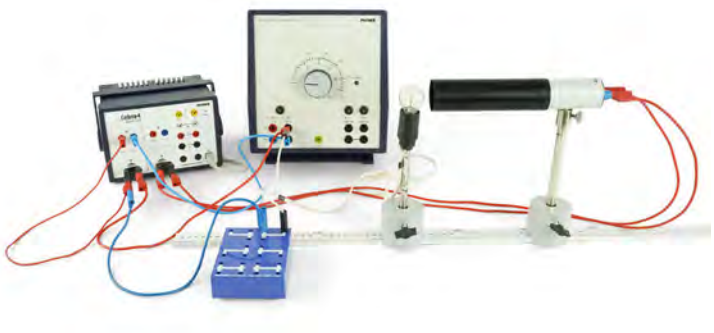
NEW

Benefits

- Simplified implementation: all pre-settings already prepared
- Intuitive, touch-optimized software
- Recording of all required measured values via one device
- Cost savings: No need for an additional measuring amplifier

Learning objectives

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



Website

curricuLAB

Principle

According of Stefan-Boltzmann's law, the energy emitted by a black body per unit area and unit time is proportional to the power „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.

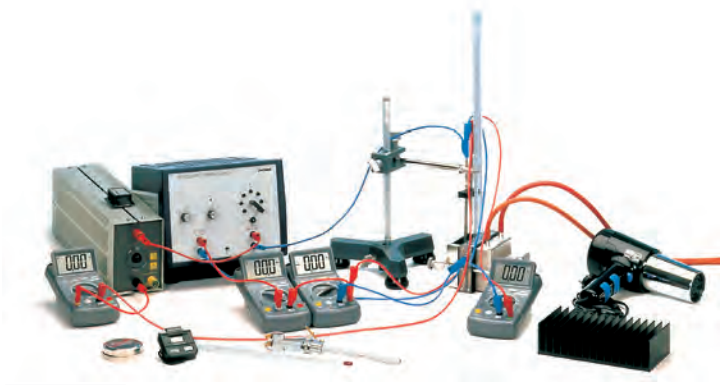
Tasks

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.

P2410800

Peltier heat pump

Website



curricuLAB

Benefits

- Open design allows to fully understand function and applications
- Individual instruments for distinct functions (no „black box“)
- Key products of the experiment setup can also be used for investigating the Seebeck effect

Learning objectives

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

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 P_c of the pump as a function of the current and to calculate the efficiency rating h_c at maximum output.
2. To determine the heating capacity P_w of the pump and its efficiency rating h_w at constant current and constant temperature on the cold side.
3. To determine P_w, $\dot{I}_w$ and P_c , $\dot{I}_c$ 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.

Electric compression heat pump

P2360201

Benefits
- Different operating modes possible
- For both demonstration and student experiments
- Simple set-up

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

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.

Stirling engine digital set up

P2360467

Benefits
- Demonstration of the complete Carnot process
- Reverse Carnot process possible as well using the motor/generator unit
- All important parts are clearly visible, making their functions transparent
- Measurement device displays all relevant parameters (p, V, rpm, T)

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

Principle

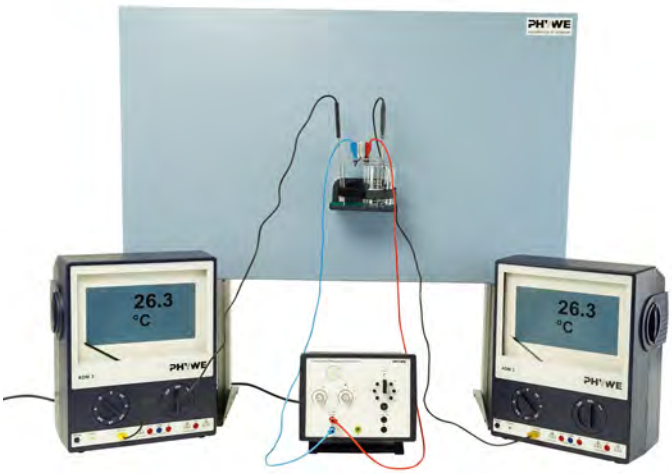
The Stirling engine is submitted to a load by means of an adjustable torquemeter, or by a coupled generator. Rotation frequency and temperature changes of the Stirling engine are observed. Effective mechanical energy and power, as well as effective electrical power, are assessed as a function of rotation 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.

P9507300

Website



Model test for the use of ambient heat with the Peltier heat pump with ADM3

Benefits

- Part of a system solution - easily expandable for further experiments
- Simple teaching by using the demo board physics
- Clear test execution by using ADM3 multimeters

Learning objectives

- Learn how a thermocouple works.
- Influence of a „water reservoir" on the functioning of the thermocouple.

Principle

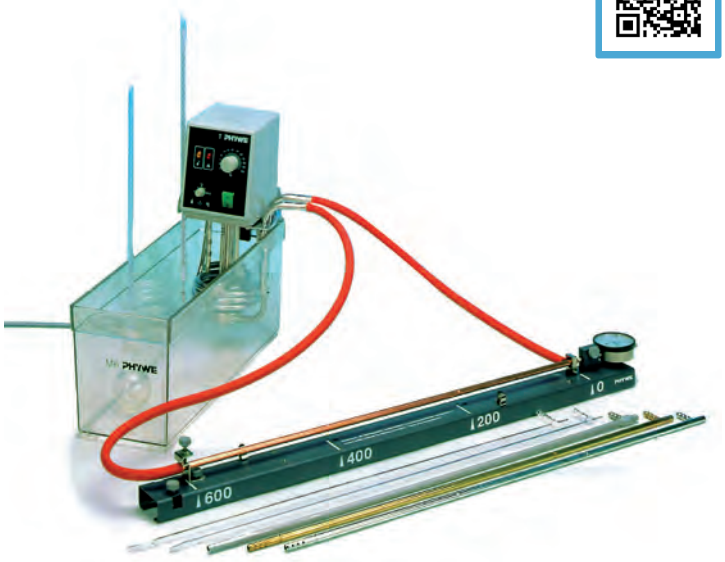
When a direct current flows through a Peltier element, a temperature difference is created: one side heats up, the other side cools down. The temperature of the warm side influences the temperature of the cold side and vice versa. If the warm side is kept at a constant temperature by a large storage tank, e.g. water, the cold side cools down more than without a storage tank. In this experiment temperatures are measured during operation of the thermogenerator without and with „water storage tank" on the warm side as a function of time.

Thermal expansion in solids and liquids

P2310100

Benefits
- Two experiments in one

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



Principle

The volume expansion of liquids and the linear expansion of various materials is determined as a function of temperature.

Tasks

1. To determine the volume expansion of ethyl acetate,methylated spirit, olive oil, glycerol and water as a function of temperature, using the pycnometer.
2. To determine the linear expansion of brass, iron, copper, aluminium, duran glass and quartz glass as a function of temperature using a dilatometer.
3. To investigate the relationship between change in length and overall length in the case of aluminium.

Vapour pressure of water at high temperature

P2340100

Benefits
- No open flame in the setup - Reduction of thermal hazard
- No gas burner required - Easy to operate and no consumption of consumables

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

Principle

The high-pressure steam apparatus makes it possible to measures team 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.

Tasks

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.

P2340200

Website

curricuLAB

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

Benefits

- Compact, easily transportable setup
- For both demonstration and student experiments
- No gas burner required - Easy to operate and no consumption of consumables
- No open flame in the setup - Reduction of thermal hazard

Learning objectives

- Pressure
- Temperature
- Volume
- Vaporization
- Vapour pressure
- Clausius-Clapeyron equation

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.

P2350201

Website

curricuLAB

Thermal conductivity of metals

Benefits

- Easy to set temperature gradient
- Compact, easily transportable setup

Learning objectives

- Thermal conductivity
- Diffusion
- Temperature gradient
- Heat transport
- Specific heat

Principle

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

Tasks

1. Determine the heat capacity of the calorimeter in a mixture experiment as a preliminary test. 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.
2. 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.

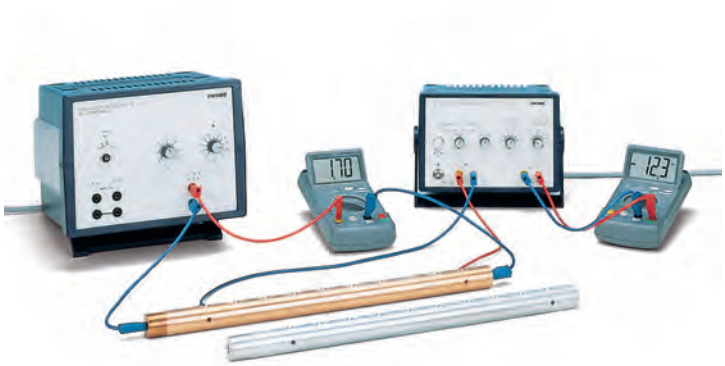
Electrical conductivity of metals

P2350205

Benefits
- Easy and precise measurement of the electrical conductivity
- Compact, easily transportable setup

Website

Learning objectives
- Electrical conductivity
- Resistivity
- Wiedmann-Franz law
- Lorenz number
- Four-point measurement



Principle

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

Tasks

1. Determine the electrical conductivity of copper and aluminium by recording a current-voltage characteristic line.
2. Test of the Wiedmann-Franz law.

curricuLAB

Solar ray collector

P2360100

Benefits
- Complete solution to study all aspects of thermal energy using a solar ray collector
- Covers one of the most important and highly visible technologies in renewable energy

Website

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

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

1. To determine the efficiency of the solar ray collector under various experimental conditions.
2. Absorption of energy from the environment (20 °C) without illumination by sun or halogen lamp, water temperature at the absorber inlet T e; 5 °C.

curricuLAB

P2340667

Cooling by evacuation with Cobra SMARTsense

Website

curricuLAB

Cobra SMART sense

Benefits
- Data logging via tablet possible.
- For both demonstration and student experiments

Learning objectives
- Air pressure
- Kinetic gas theory
- Supercooling

Principle

When the air pressure above a water surface 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.

Tasks

Determine the temperature curve of water during pumping.

P2350400

Emittance of hot bodies (Leslie cube)

Website

curricuLAB

Benefits
- Simple set-up
- Affordable experiment
- For both demonstration and student experiments

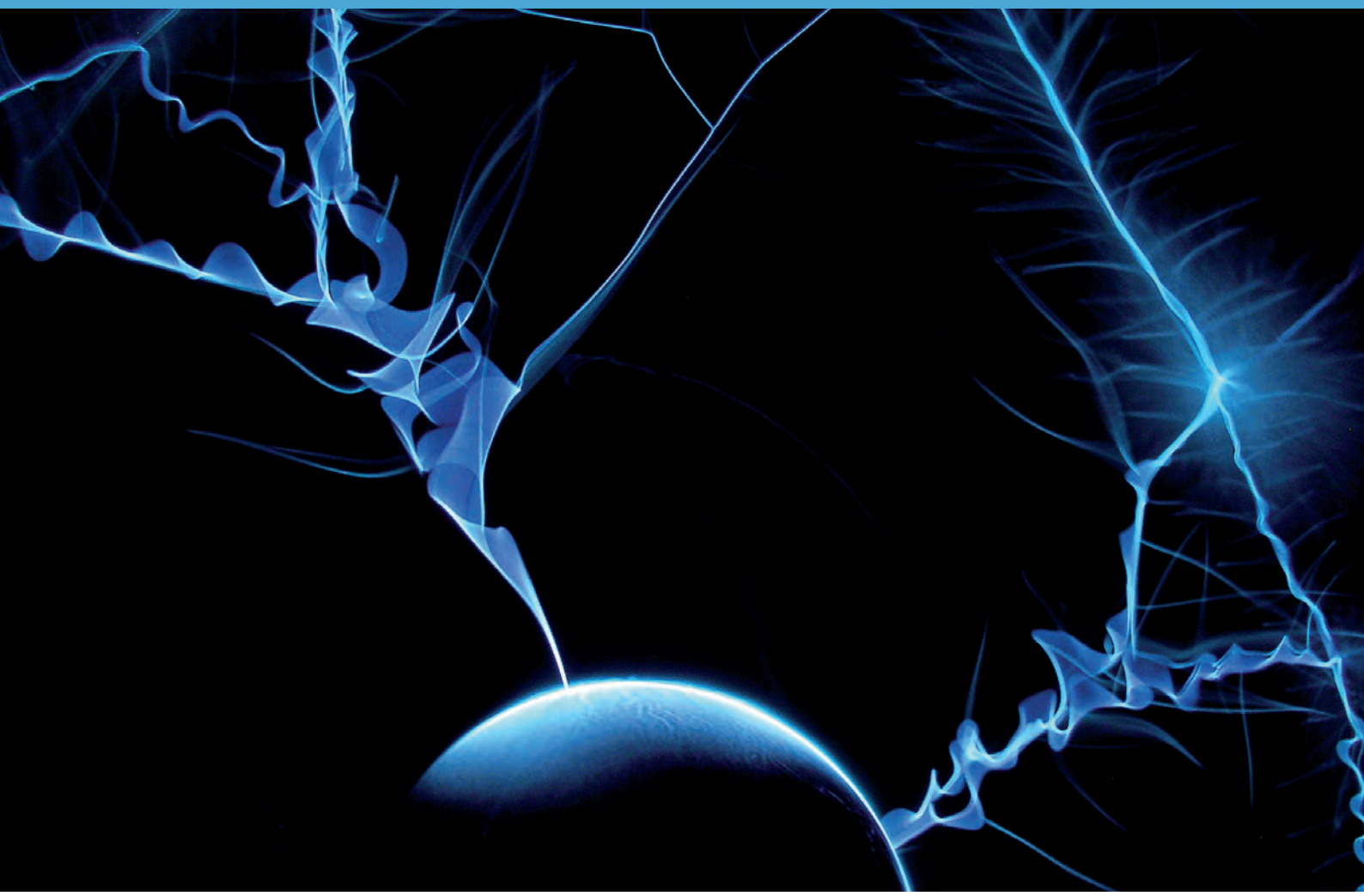
Learning objectives
- Thermal radiation and emittance
- Kirchhoff's law of thermal radiation
- Leslie's cube
- Black and grey body

Principle

Thermal radiation can be measured at all surfaces as long as their temperature differs from that of the surrounding. Therefore it applies that the hotter an object is, the more radiation it emits. Also the surface colour influences the behaviour: dark surfaces emit more thermal radiation than light ones. An example for application of this effect is a heat sink which is often coated with a black layer to emit more thermal radiation.

Tasks

1. Measurement of the room temperature T_0 (in Kelvin) before starting the experiment.
2. Determination and comparison of the emittance for all four sides of the Leslie cube at a constant high temperature. Therefore, the thermal radiation of a cube filled with boiling water is measured with a Moll-type thermopile.
3. Determination and comparison of the emittance for all four sides of the Leslie cube depending on the temperature.

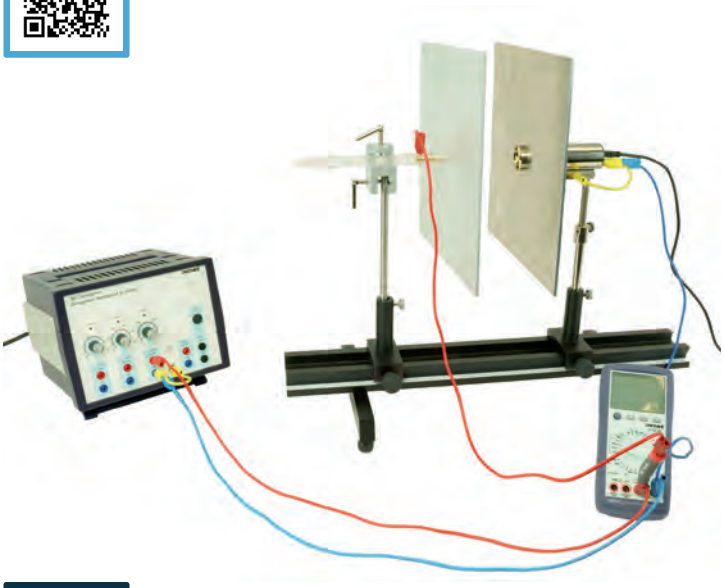


TESS expert - Physics

4.2.4 Electricity & Magnetism

P2420105

Website



curricuLAB

Electric fields and potentials in the plate capacitor

Benefits

- Loss-less measurement of electric field strength
- High-sensitive electric field meter also suitable for electrostatic measurement of voltages

Learning objectives

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

Principle

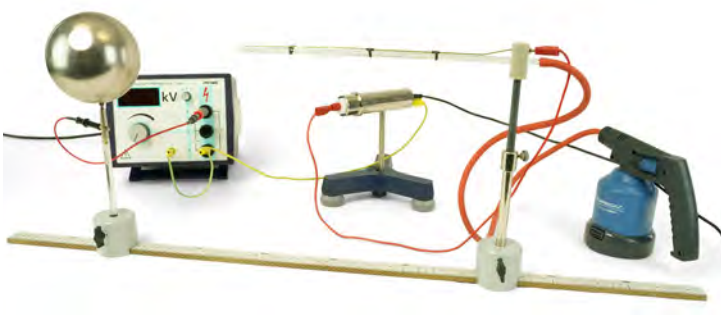
A uniform electric field E is produced between the charged plates of a plate capacitor. The strength of the field is computer-assisted determined with the electric field strength meter, as a function of the plate spacing *d* and the voltage *U*. The potential Ã¸ within the field is measured with a potential 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.

P2420505

Website



curricuLAB

Coulomb potential and Coulomb field of metal spheres

Benefits

- Supplies non-hazardous high voltage
- Loss-less measurement of electric field strength
- High-sensitive electric field meter also suitable for electrostatic measurement of voltages

Learning objectives

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

Principle

Conducting spheres with different diameters are charged electrically. The static potentials and the accompanying electric field intensities are computer-assisted 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, electrostatic potential is determined as a function of voltage at a constant distance.
2. For the conducting spheres, electrostatic potential at constant voltage is determined as a function of the distance.
3. For both conducting spheres, electricfield strength is determined as a function of charging voltage at three different distances.
4. For the conducting sphere, electric field strength is determined as a function of the distance at constant charging voltage.

Coulomb's law/ image charge

P2420405

Benefits

- Experimental visualisation of a fundamental principle of electrodynamics
- Supplies non-hazardous high voltage
- Very sensitive measurement of the acting force

Learning objectives

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

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 electric field 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.

Website

curricuLAB

Wimshurst influence machine

07616-00

Function and Applications

Historical device for generation of high voltage 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: max. 60 mm at low air humidity
- Dimensions (mm): 360 x 190 x 450

Website

Van-de-Graaff generator, 230V/50Hz

07645-97

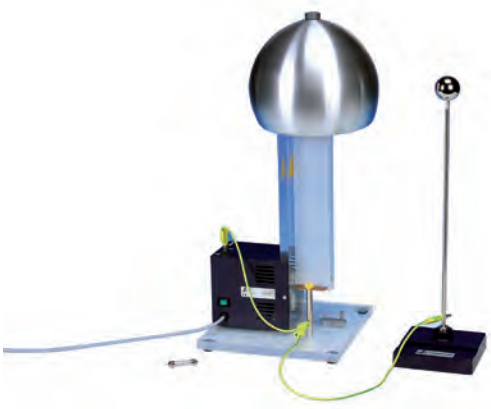
Function and Applications

Compact unit for production of high direct voltage.

Equipment and Technical Data

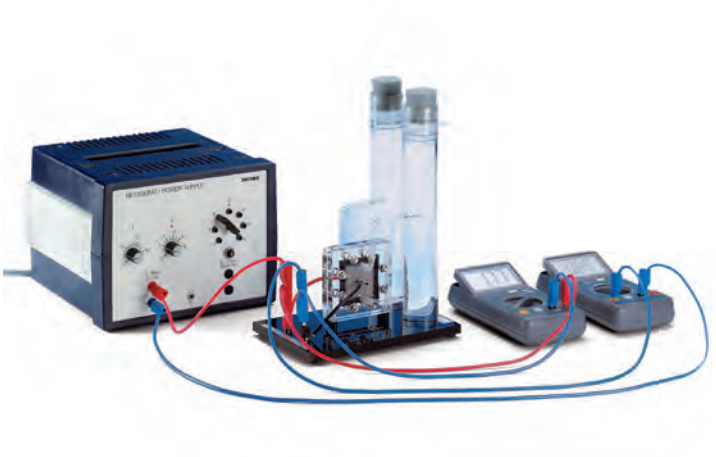
- With integrated motor for mains operation and additional crank for manual operation
- Removable conducting sphere with 4mm bushes and diameter of 210 mm
- Output voltage max. 150...200 kV
- Mains voltage 230 V
- Height: approx. 58 cm
- Incl. conducting sphere (d = 80 mm) on stem with insulating base, neontube and 50 cm connecting cord

Website



P2411101

Website



curricuLAB

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

Benefits

- Quantitive determination of all relevant parameters
- Production of hydrogen and oxygen which can then be quantified
- Storage of the produced gases in a „gas bar" for reuse

Learning objectives

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

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.

P2420201

Website

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

Benefits

- Simple and very clear set-up: only few components required
- Further experiments in electricity and electronics can be performed with the equipment

Learning objectives

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

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

1. To measure the charging current over time:
   I. Using different capacitance values C, with constant voltage U and constant resistance R
   II. Using different resistance values (C and U constant)
   III. Using different voltages (R and C constant).
2. To determine the equation representing the current when a capacitor is being charged, from the values measured.

Charging curve of a capacitor and switch-on behaviour of an inductance with Cobra Xpert-Link

P2420264

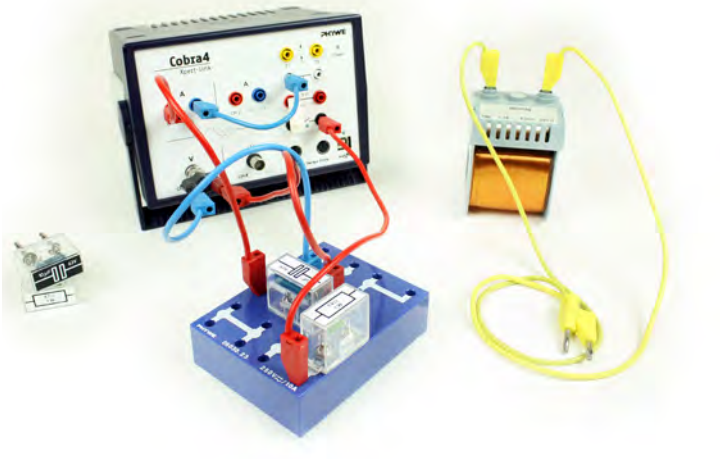
Website

Benefits

- Simple and very clear set-up: only few components required
- Cost savings: Xpert-Link provides all subsidiary functions
- Simplified implementation: all pre-settings already prepared
- Further experiments in electricity and electronics can be performed with the equipment

Learning objectives

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



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

1. To measure the charging current over time:
   I. Using different capacitance values C, with constant voltage U and constant resistance R
   II. Using different resistance values (C and U constant)
   III. Using different voltages (R and C constant)
2. To determine the equation representing the current when a capacitor is being charged, from the values measured.

curricuLAB

Capacitance of metal spheres and of a spherical capacitor

P2420300

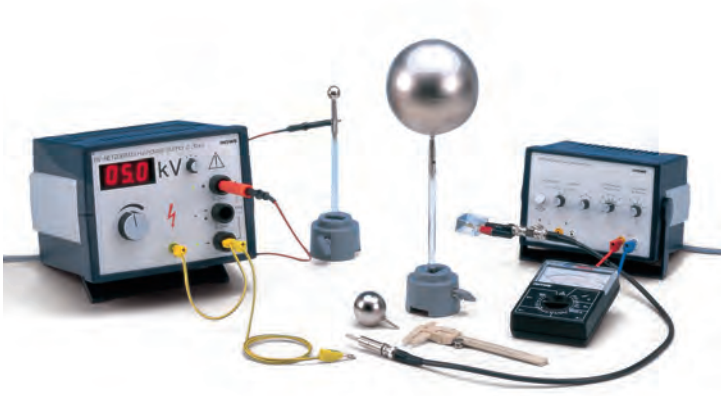
Website

Benefits

- Supplies non-hazardous high voltage
- Several conductive spheres included
- Clever investment: The included universal measuring amplifier can also be used for other applications

Learning objectives

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



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.

curricuLAB

P2420600

Dielectric constant of different materials

Website

curricuLAB

Benefits

- Supplies non-hazardous high voltage
- Easy experimental set-up due to clear and compact design
- Clever investment: The included universal measuring amplifier can also be used for other applications

Learning objectives

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

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.

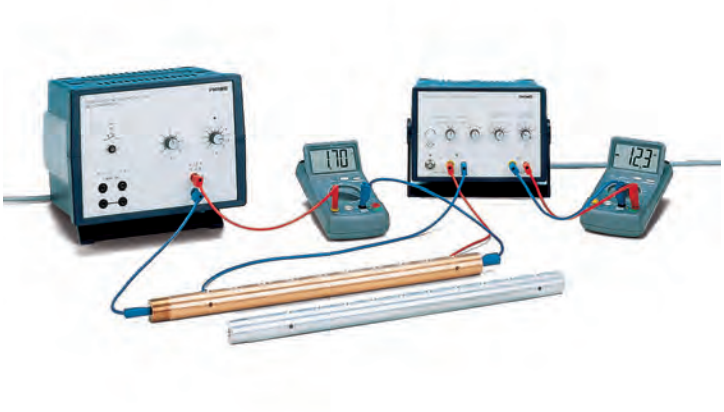
Tasks

1. The relation between charge Q and voltage U is to be measured using a plate capacitor determining the electric constant.
2. The charge of a plate capacitor is measured as a function of the inverse distance between the plates, under constant voltage.
3. 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.

P2410101

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

Website



curricuLAB

Benefits

- Measurement at two different metals possible
- Conductivity rods can be used both for electrical and thermal conductivity experiments
- Measurement amplifier can be used for both AC and DC measurements and amplifies up to 10,000 times

Learning objectives

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

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.

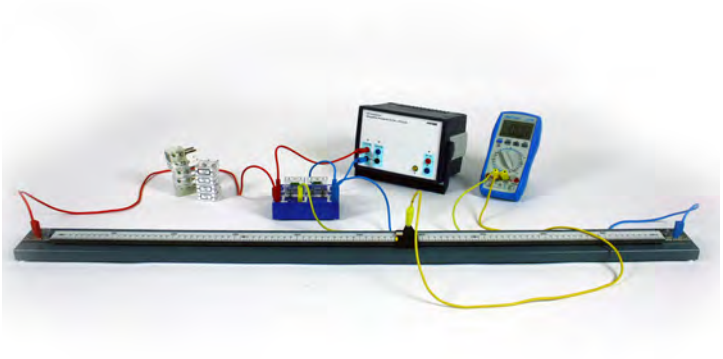
Wheatstone bridge

P2410200

Website

Benefits
- Highly precise and reproducible measurements possible
- Many different measurement variations possible
- Also suitable for measurement of low resistances

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



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.
2. Determination of the total resistance of resistors in series and of resistors in parallel.

curricuLAB

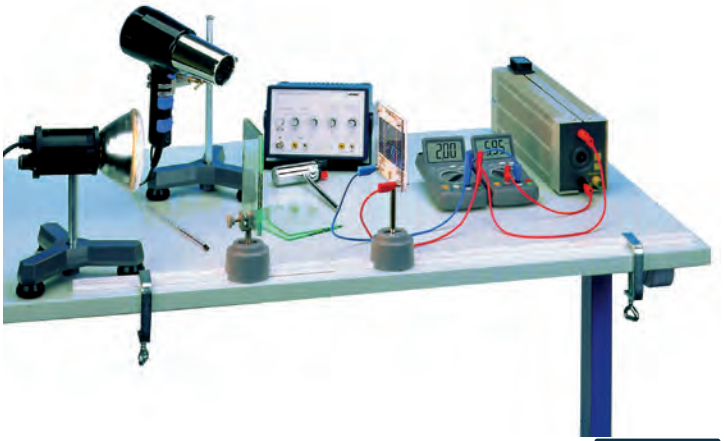
Characteristic curves of a solar cell

P2410901

Website

Benefits
- Set-up allows quantitative measurement which also takes light intensity into account
- Set-up allows to avoid but also to measure temperature effect quantitatively
- Determine relationship between short-circuit and light intensity

Learning objectives
- Semiconductor
- p-n junction
- Energy-band diagram
- Fermi characteristic energy level
- Diffusion potential
- Efficiency
- Photo-conductive effect
- Valence band
- Conduction band



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 and temperatures.
3. To plot the current-voltage characteristic at various operating conditions: different light intensities, cooling the equipment with a blower, no cooling, shining the light through a glass plate, sunlight illumination.

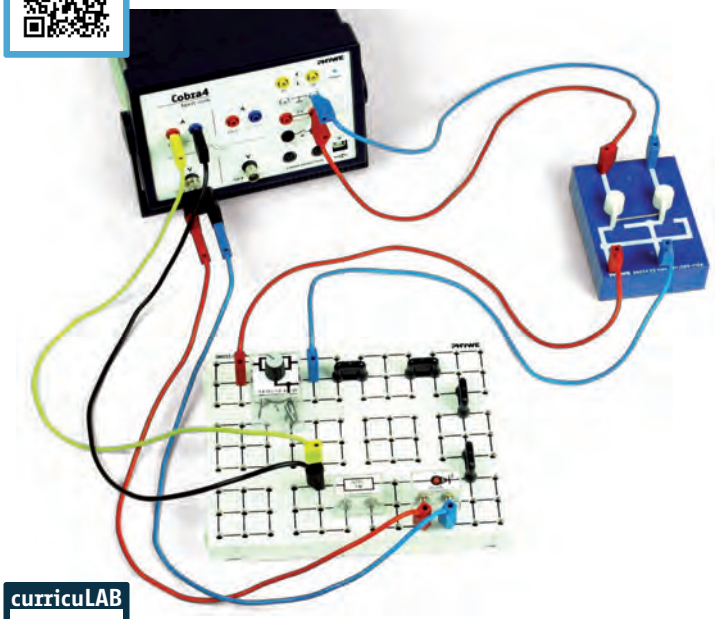
curricuLAB

P2410964

Characteristic curves of semiconductors with Cobra Xpert-Link

Website

NEW



curricuLAB

Benefits

- Get to know the behaviour of several types of semiconductors
- Measure voltage and current simultaneously on four channels
- Simplified implementation: all pre-settings already prepared
- Further experiments in electricity and electronics can be performed with the equipment

Learning objectives

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

Principle

Determine the current strength flowing through a semi-conducting diode. Determine the collector current with the collector voltage for various values of the base current intensity.

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.

P2410401

Temperature dependence of different resistors and diodes

Website

curricuLAB

Benefits

- One setup to measure both electrical components and semiconducting diodes, as well as the blocking voltage
- All immersion probes are mounted on one convenient heat-resistant circuit board for easy handling

Learning objectives

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

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.

Kirchhoff's laws

P2410500

Benefits

- Setup to measure both Kirchhoff's laws and to determine unknown resistances
- Components can also be used for other basic and advanced electricity experiments

Learning objectives

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

Principle

Kirchhoff's laws are verified by measuring current, voltage and resistance in series and parallel circuits. In addition, 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.

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

P2410601

Benefits

- The use of a mechanic balance is especially suitable for a vivid demonstration of the Lorentz force
- Four different wire loops included: Clearer and deeper understanding of all correlations leads to an enhanced learning success

Learning objectives

- Uniform magnetic field
- Magnetic induction
- Lorentz force
- Moving charges
- Current

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. Determination of the direction of the force.
2. Determination of the force as a function of the current in the conductor loop and the coil current.

P2430201

Website

curricuLAB

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

Benefits

- Simple setup which allows an easy measurement of the magnetic flux density depending on different parameters
- No calibration needed, Teslameter is calibrated up to 1 T

Learning objectives

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

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 its dependence 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.

P2430301

Website

curricuLAB

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

Benefits

- Particularly homogeneous magnetic field and high flux density due to large Helmholtz coil diameter
- Helmholtz coils suitable for multiple other elementary experiments

Learning objectives

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

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 depending on the distance between them.
2. To measure the spatial distribution of the magnetic flux density when the distance between coils alpha = R
3. To measure the radial components of the two individual coils and demonstrate the overlapping of the two fields.

Magnetic moment in the magnetic field

P2430400

Benefits
- Particularly homogeneous magnetic field and high flux density due to large Helmholtz coil diameter
- Torsion dynamometer offers highly precise measurements

Website

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

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

1. Determination of the torque due to a magnetic moment in a uniform magnetic field, as a function
   I. of the strength of the magnetic field,
   II. of the angle between the magnetic field in the magnetic moment
   III. of the strength of the magnetic moment.

curricuLAB

Determination of the earth's magnetic field

P2430100

Benefits
- Particularly homogeneous magnetic field and high flux density due to large Helmholtz coil diameter
- Setup with precalibrated teslameter does not require additional magnets and coils for calibration

Website

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

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

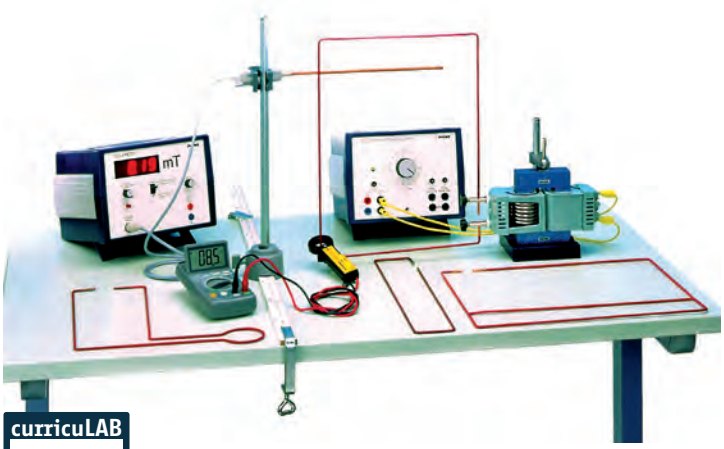
1. The magnetic flux of a pair of Helmholtz coils is to be determined and plotted graphically as a function of the coil current. The Helmholtz system calibration factor is calculated from the slope.
2. The horizontal component of the earth-magnetic field is determined through superimposition of the Helmholtz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

curricuLAB

P2430500

Magnetic field outside a straight conductor

Website



curricuLAB

Benefits

- Four different current conductors allow the observation of the magnetic field in different configurations
- Experimental setup allows the visualization of the Maxwell Equations
- No extra calibration needed, Teslameter is calibrated up to 1 T

Learning objectives

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

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

1. Determination of the magnetic field
   I. of a straight conductor as a function of the current,
   II. of a straight conductor as a function of the distance from it,
   III. of two parallel conductors, in which the current is flowing in the same or opposite direction, as a function of the distance from it.

P2430767

Ferromagnetic hysteresis with Cobra SMARTsense

Website

curricuLAB

Cobra SMART sense

Benefits

- Simple experimental setup and intuitive handling of the software: Better results in less time
- Added value due to the use of datalogging: Direct visualisation of the learning objective

Learning objectives

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

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 $\hat{I}$– 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.

Tasks

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

Ferromagnetism, paramagnetism and diamagnetism

P2430900

Website

Benefits
- Compact system to study the types of magnetism
- Robust setup

Learning objectives
- Ferromagnetism
- Paramagnetism
- Diagmagnetism
- Magnetic field intensity

Principle

The aim of this experiment is to study the behaviour of nickel, tungsten, and bismuth rods in a strong, inhomogeneous magnetic field. This field is formed, for example, between cone-shaped pole pieces that sit on a permanent magnet.

The rods are suspended horizontally on a long and very thin silk thread so that they can move freely.

Tasks

1. Study the behaviour of nickel, tungsten, and bismuth rods in a strong, inhomogeneous magnetic field.

curricuLAB

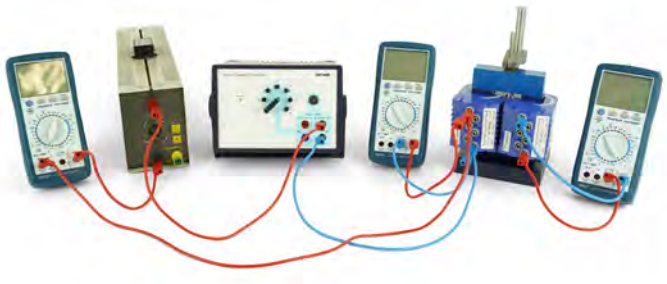
Transformer

P2440101

Website

Benefits
- Coils with several tappings for various combinations of winding numbers between primary and secondary coil
- Quick, easy, and neat set-up

Learning objectives
- Induction
- Magnetic flux
- Loaded transformer
- Unloaded transformer
- 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

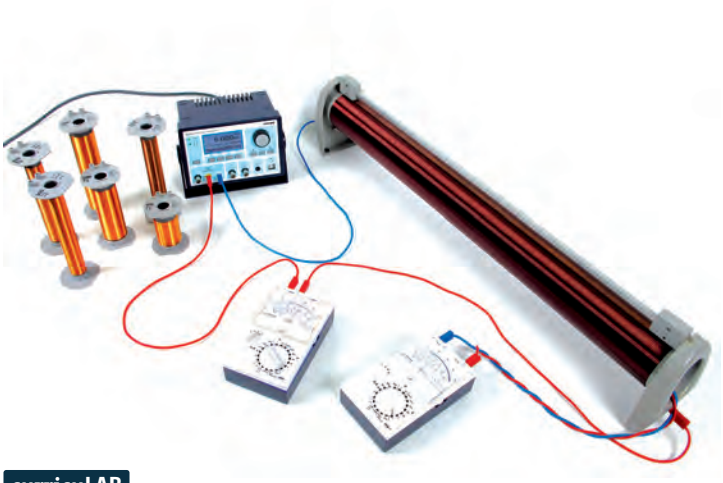
1. The secondary voltage on the open circuited transformer and the short-circuit on the secondary side is determined as a function of the number of coils in the primary / secondary coil and the primary voltage.
2. With the transformer loaded, the primary current ist determined as a function of the the secondary current and the number of turns in the secondary / primary coil.

curricuLAB

P2440201

Magnetic induction

Website



curricuLAB

Benefits

- Huge field coil for homogenous magnetic field
- On-the-fly switching of the numerous induction coils
- Easy frequency setting thanks to digital function generator

Learning objectives

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

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 off requency, number of turns, diameter and field strength.

Tasks

1. Determination of the induction voltage as a function
   I. of the strength of the magnetic field,
   II. of the frequency of the magnetic field,
   III. of the number of turns of the induction coil,
   IV. of the cross-section of the induction coil.

P2440301

Inductance of solenoids

Website

curricuLAB

Benefits

- Quick, easy, and neat set-up
- On-the-fly switching of the numerous induction coils for quick and easy experimenting
- Easy frequency setting thanks to digital function generator

Learning objectives

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

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.

Tasks

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

RLC circuit with Cobra Xpert-Link

P2440664

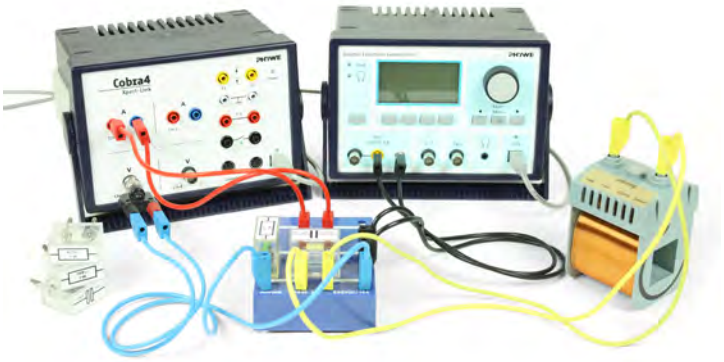
Website

Benefits

- Voltage and current can be measured directly and simultaneously
- Root mean square value displayed in real-time
- Impedance will be computed in real-time
- Fast and easy experimenting simply by switching components
- Cost savings: oscilloscope functions integrated into the datalogging solution

Learning objectives

- Periodic oscillations
- Damped oscillations
- Kirchhoff's laws
- Series-tuned circuit
- Parallel-tuned circuit
- Capacitance
- Inductance
- Impedance
- Phase shift
- Q-factor
- Bandwidth



Principle

In an RLC circuit, energy is exchanged periodically between a capacitor and a coil. When the electric field of the capacitor decreases by discharge over the coil, a magnetic field is established in the coil. As soon as the capacitor is completely depleted, the current flow through the coil vanishes. The magnetic field decreases again and the capacitor is charged, again.

Tasks

1. Measure the voltage drop over the LC component and the current through the circuit of a series-tuned and a parallel-tuned RLC circuit and determine the resonance frequencies.
2. Determine the impedance of the various RLC circuits.
3. Determine the bandwidth and the Q-factor from the resonance curves of the respective RLC circuit.

curricuLAB

Rectifier circuits

P2440700

Website

Benefits

- Get to know several types of rectifier circuits
- Suitable for vocational classes

Learning objectives

- Half- and Full-wave rectifier
- Graetz rectifier
- Diode and Zener diode
- Avalanche effect
- Charging capacitor
- Internal resistance
- Smoothing factor
- Ripple voltage
- Voltage stabilisation/ doubling

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

1. Using the half-wave and bridge rectifier:
   I. To display the output voltage.
   II. To measure the diode current as a function of the output current.
   III. To measure the ripple component of the output voltage as a function of the output current.
   IV. To measure the ripple as a function of the capacitance.
   V. To measure the output voltage as a function of the input voltage.
2. To measure the current through one diode as a function of the output current
3. To measure the ripple of the output voltage as a function of the output current

curricuLAB

P2440964

Website

curricuLAB

High-pass and low-pass filters with Cobra Xpert-Link

Benefits

- Cost savings: No need for an additional power supply
- Simplified implementation: all pre-settings already prepared
- The software controls all devices simultaneously
- Further experiments in electricity and electronics can be performed with the equipment

Learning objectives

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

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

1. Determination of the ratio of output voltage to input voltage with the RC/CR network, RL/LR network, CL/LC network, Two CR networks connected in series
2. Determination of the phase displacement with the RC/CR network
3. Determination of the phase displacement with two CR networks connected in series.

P2441005

Website

curricuLAB

RLC measuring bridge

Benefits

- Quickly obtain experiment results using the Wheatstone bridge
- Easy to tune by aural measurement relying on the sensitivity of the human ear
- Save time while switching the numerous coils, resistance and capacities on-the-fly

Learning objectives

- Wheatstone bridge
- Inductive and capacitive reactance
- Ohmic resistance
- Impedance
- Kirchhoff's laws

Principle

Ohmic resistances, inductances and capacitances are determined in a Wheatstone bridge circuit operated on AC. Balancing is done aurally through headphones, using the high sensitivity of the human ear.

Tasks

1. Determination of
   I. Ohmic resistances
   II. Inductances
   III. Capacitances with the Wheatstone bridge, using bridge balancing

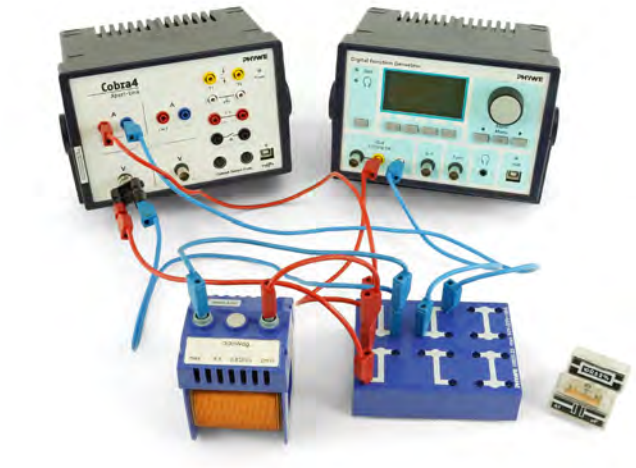
Resistance, phase shift and power in AC circuits with digital function generator

P2441164

Website

Benefits

- Quick set-up
- Investigate the influence of electrical components in an AC circuit.
- Analysis of the electric circuit parameters with the Cobra Xpert-Link.



Learning objectives

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

Principle

Series circuits containing self-inductances or capacitances and ohmic resistances are investigated as a function of frequency.

Real power or Apparent power and phase delay can be determined by measurement with the Cobra Xpert-Link.

Tasks

1. Series circuit of self-inductance / capacitor and resistor
   I. Investigation of impedance and phase shift as a function of frequency
   II. Investigation of the relation between real power and current intensity
   III. Determination of self-inductance / capacitance and ohmic resistance

curricuLAB

Induced voltage pulse and Faraday's law of induction with Cobra4 Xpert-Link

P2441264

NEW

Website

Benefits

- Simplified implementation: all pre-settings already prepared
- Fast and easy experimenting
- Coil with several tappings for quick change of winding numbers
- Investigate the influence of different falling velocities with high frequency / resolution measurements

Learning objectives

- Induced pulse
- Faraday's law of induction
- Maxwell's equations
- Magnetic flux
- Magnetic flux density
- Magnetic field lines

Principle

A permanent magnet drops through a coil with different velocities. The change in the magnetic flux generates an induced voltage pulse. It is shown that the total induced voltage during the entire fall is constant and therefore independent of the velocity.

Tasks

1. Observation of the induced voltage pulse during the fall of the magnet through the coil
2. Observation of the induced voltage for an inverted magnet polarisation
3. Evaluation of the influence of the number of windings on the induced voltage
4. Evaluation of the influence of the fall height on the induced voltage

P2460203

Polarization of Microwaves

Website

curricuLAB

Benefits

- Convenient all-in-one set
- With the same set, all aspects of microwave physics can be studied quantitatively: polarization, reflection, transmission, refraction, propagation, diffraction, interference, inverse square law, standing waves, conservation of energy in reflection and transmission

Learning objectives

- Microwaves
- Electromagnetic waves
- Transverse waves
- Polarization
- Malus law

Principle

Electromagnetic waves impact on a grating whose permeability depends on the rotation plane of the wave.

Tasks

1. The intensity of microwave radiation behind the grating is measured as a function of the angle.

P2460303

Reflection, Transmission and Refraction of Microwaves

Website

curricuLAB

Benefits

- Convenient all-in-one set
- With the same set, all aspects of microwave physics can be studied quantitatively: polarization, reflection, transmission, refraction, propagation, diffraction, interference, inverse square law, standing waves, conservation of energy in reflection and transmission

Learning objectives

- Microwaves
- Electromagnetic waves
- Reflection
- Transmission
- Refraction
- Absorption

Principle

When electromagnetic waves encounter an obstacle, phenomena like reflection, transmission and refraction occur. In the present experiment these phenomena are verified and described by means of microwaves.

Tasks

1. Reflection, absorption and refraction are illustrated using various materials and the law of reflection is verified (angle of incidence = angle of reflection).

TESS expert - Physics

4.2.5 Light & Optics

P2210101

Measuring the velocity of light

Website

curricuLAB

Benefits

- Determine yourself what the „speed of light" actually is
- Find out how the velocity of light differs in material
- The size of a table top suffice

Learning objectives

- Refractive index
- Wavelength
- Frequency
- Phase
- Modulation
- Electric field constant
- Magnetic field constant

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.

P2240267

Photometric law of distance - inverse square law

Website

curricuLAB

Cobra SMART sense

Benefits

- Find out how exactly it becomes darker with increasing distance from a light source
- Get results fast and reproducible with a data-logging system
- Analize results easily and compare them to theory using a computer

Learning objectives

- Luminous flux
- Quantity of light
- Luminous intensity
- Illuminance
- Luminance

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.

Lambert's law of radiation on optical base plate

P2240410

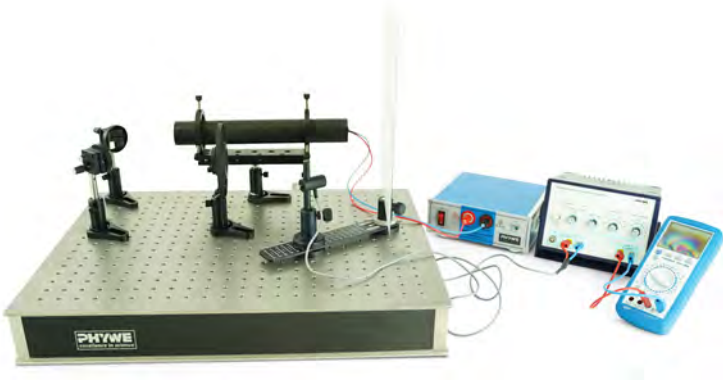
Website

Benefits

- Study the light intensity that a sheet of paper is diffusely reflecting
- Learn about the different physical units associated with light
- Very versatile optical base plate

Learning objectives

- Luminous flux
- Light quantity
- Light intensity
- Illuminance
- Luminance



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.

curricuLAB

Fibre-optics compact spectrophotometer

35630-00

Website

Function and Applications

The compact spectrometer is a specially developed compact instrument for science education. It is easy to use and its accompanying software provides diverse possibilities for visualizing, measuring, comparing and evaluating spectroscopic data. For the measurement of optical spectra the included cuvettes simply have to be inserted into the spectrometer. By means of the included optical fiber cuvette adapter it is for example also possible to measure external light sources. The internal fixed grid decomposes the light spectrally. The spectrum is recorded by means of a CCD array, so that the complete spectrum is recorded in one go, which makes it possible to reliably detect even rapid changes in a spectrum. The software is especially designed for this spectrometer and can be downloaded for free. The power supply is provided through four AA batteries (not included).

Benefits

- Compact All-in-one device for rapid measurements of full spectral range
- No separate light source required
- The optical fibre cuvette adapter allows for flexible recording of external light sources
- Measurement of emission and absorption spectra throughout the whole visible spectral range and parts of IR and UV

curricuLAB

P2210201

Laws of lenses and optical instruments

Website

curricuLAB

Benefits

- Understand a basic optical component: the lens
- Learn how common optical instruments work
- Geometric optics in a nutshell

Learning objectives

- Law of lenses
- Magnification
- Focal length
- Object distance
- Telescope
- Microscope
- Path of a ray
- Convex lens
- Concave lens
- Real image
- Virtual image

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).

P2210305

Dispersion and resolving power of a grating spectroscope

Website

Benefits

- Understand fundamentals of spectroscopy
- Compact setup
- Precise and reproducible results

Learning objectives

- Maxwell relationship
- Dispersion
- Polarisability
- Refractive index
- Prism
- Rowland grating, Diffraction grating
- Spectrometer
- Goniometer
- Constructive and destructive interference
- Interference and diffraction on edge, slit, and grating
- Spectral resolving power

Principle

The diffracted light from a periodic line grating is observed with a goniometer. The diffraction angles of spectral lines in different orders of diffraction are measured for the spectral lines from a Hg spectral lamp. By using gratings with different grating constants the angular spectral dispersion in dependence on grating constant is determined.

The effect of the total number of grating lines taking part in the diffraction is observed by reducing the beam width with an adjustable slit and the diffraction on that slit is taken into account. The spectral resolving power of a grating with given grating constant and useful beam width is observed and compared with theoretical considerations.

Interference experiment

P2220101

Benefits
- Observe that light plus light can result in darkness
- Understand how to make use of the interference effect
- A laser as lightsource allows clear observation
- Digital data aquisition

Learning objectives
- Wavelength
- Phase
- Fresnel biprism
- Fresnel mirror
- Virtual light source

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.

Newton's rings with interference filters and Digital Array Camera

P2220201

Benefits
- The color of soap bubbles is based on it: interference in thin films
- Use interference optics to determine most subtle differences
- Elaborate filters make quantitative measurements possible

Learning objectives
- Coherent light
- Phase relationship
- Path difference
- Interference in thin films
- Newton's ring apparatus

Principle

In a Newton's rings apparatus, monochromatic light interferes in the thin film of air between the slightly convex lens and a plane glass plate. The wavelengths are determined from the radii of the interference rings.

Tasks

Using the Newton's rings apparatus, to measure the diameter of the rings at different wavelengths and:

1. to determine the wavelengths for a given radius of curvature of the lens
2. to determine the radius of curvature at given wavelengths.

P2220401

Fresnel's zone plate

Website

curricuLAB

Benefits

- Find out that optical lenses can be completely different from what you are used to
- Interference is used to produce effects commonly achieved with diffraction
- The use of a laser lightsource provides clear results

Learning objectives

- Huygens Fresnel principle
- Fresnel and Fraunhofer diffraction
- Interference
- Coherence
- Fresnel's zone construction
- Zone plates

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.

P2220501

Michelson interferometer

Website

curricuLAB

Benefits

- Discover the essence of the Physics Nobel Prize of 1907
- Lead to experimental findings that only special relativity theory could explain
- Pre-setup of the critical components makes for short preparation time
- Digital data aquisition

Learning objectives

- Interference
- Wavelength
- Refractive index
- Velocity of light
- Phase
- Virtual light source

Principle

In the Michelson arrangement interference will occur by the use of 2 mirrors. The wavelength is determined by displacing one mirror using the micrometer screw.

Tasks

Determination of the wavelength of the light of the used laser.

Coherence and width of spectral lines with the Michelson interferometer

P2220601

Website

Benefits

- Study the quantity that allows light to be used in interference experiments
- Analyze different spectral lines of a mercury lamp
- Make practical use of a Michelson interferometer to characterize light

Learning objectives

- Fraunhofer and Fresnel diffraction
- Interference
- Spatial and time coherence
- Coherence conditions
- Coherence length for non punctual light sources
- Coherence time
- Spectral lines
- Broadening of lines due to Doppler effect and pressure broadening
- Michelson interferometer
- Magnification

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.

curricuLAB

Michelson interferometer - High Resolution

P2220910

Website

Benefits

- Learn about the measurement principle with which gravitational waves can be observed
- Assemble your own interferometer using individual optical components
- Find out that even lasers have limited coherence length

Learning objectives

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source

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 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 laser light.
3. The contrast function K is qualitatively recorded in order to determine the coherence length with it.

P2221210

Website

Fabry-Perot interferometer - optical resonator modes

Benefits

- Study a fundamental component of lasers
- Fascinating patterns emerge in a surprisingly symmetric setup
- Learn about a widely used type of interferometer

Learning objectives

- Interference
- Wavelength
- Diffraction index
- Speed of light
- Phase
- Virtual light source
- Two-beam interferometer

Principle

Two mirrors are assembled to form a Fabry-Perot 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.

Tasks

1. Construction of a Fabry-Perot interferometer using separate optical components.
2. The interferometer is used to observe different resonator modes within the interferometer.

P2230201

Website

curricuLAB

Diffraction of light at a slit and an edge

Benefits

- Learn that the transition region from light to shadow is not a sharp line, but a diffraction pattern
- You can make use of diffraction patterns to determine properties of the objects causing them
- Simple setup with very few components

Learning objectives

- Intensity
- Fresnel integrals
- Fraunhofer diffraction

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.

Diffraction intensity of multiple slits and grids

P2230401

Website

Benefits

- Understand what makes an optical grid work, by approaching it via „multiple slits“
- The coherent light of a laser gives the possibility of easy observation
- Clear correlation of measurement results to the underlying theory

Learning objectives

- Law of Huygens principle
- Law of Interference
- Law of Fraunhofer and Fresnel diffraction
- Law of Coherence
- Law of Laser

Principle

Multiple slits which all have the same width and the same distance among each other, as well as transmission grids with different grid constants, are submitted to laser light. The corresponding diffraction patterns are measured according to their position and intensity, by means of a photo diode which can be shifted.

Tasks

1. The position of the first intensity minimum due to a single slit is determined, and the value is used to calculate the width of the slit.
2. The intensity distribution of the diffraction patterns of a threefold, fourfold and even a fivefold slit, where the slits all have the same widths and the same distance among each other, is to be determined.

Diffraction at a slit and Heisenberg's uncertainty principle

P2230101

Website

Benefits

- Quantum mechanical versus wave theory viewpoints are discussed observing light transversing a slit
- A measured diffraction pattern can be explained by quite different theories
- The famous „uncertainty principle“ can be confirmed in this setup

Learning objectives

- Diffraction
- Diffraction uncertainty
- Kirchhoff's diffraction formula
- Measurement accuracy
- Uncertainty of location
- Uncertainty of momentum
- Wave-particle dualism
- De Broglie relationship

Principle

The distribution of intensity in the Fraunhofer diffraction pattern of a slit and at an edge is measured. The results are evaluated both from the wave pattern view point, by comparison with Kirchhoff's diffraction formula, and from the quantum mechanics standpoint to confirm Heisenberg's uncertainty principle.

Tasks

1. To measure the intensity distribution of the Fraunhofer diffraction pattern of a single slit (e. g. 0.1 mm) and an edge. The heights of the maxima and the positions of the maxima and minima are calculated according to Kirchhoff's diffraction formula and compared with the measured values.
2. To calculate the uncertainty of momentum.

P2250101

Polarisation through quarter-wave plates

Website

curricuLAB

Benefits

- The principles Polaroid glasses work on
- Discover ways to modify certain attributes of light
- Make the electric vector go round and round

Learning objectives

- Plane
- Circularly and elliptically polarised light
- Polariser
- Analyzer
- Plane of polarisation
- Double refraction
- Optic axis
- Ordinary and extraordinary ray

Principle

Monochromatic light falls on a mica plate perpendicular to its optic axis. At the appropriate plate thickness (lambda/4, or quarter-wave plate) there is a 90° phase shift between the ordinary and the extraordinary ray when the light emerges from the crystal. The polarisation of the emergent light is investigated at different angles between the optic axis of the lambda/4 plate and the direction of polarisation of the incident light.

Tasks

1. To measure the intensity of plane polarised light as a function of the position of the analyser.
2. To measure the light intensity behind the analyser as a function of the angle between the optic axis of the lambda/4 plate and that of the analyser.
3. To perform experiment 2. with two lambda/4 plates one behind the other.

P2250200

Polarimetry

Website

curricuLAB

Benefits

- Even transparent fluids can change the properties of light passing them
- Find out how fast one type of sugar changes into another one
- Use optical methods, involving the plane of polarisation, to observe chemical processes

Learning objectives

- Half-shade principle
- Optical rotatory power
- Optical activity
- Saccharimetry
- Specific rotation
- Reaction rate
- Weber-Fechner law

Principle

The rotation of the plane of polarisation through a sugar solution measured with a half-shade polarimeter and the reaction rate constant for the inversion of cane sugar determined.

Tasks

1. To determine the specific rotation of cane sugar (sucrose) and lactose by measuring the rotation of various solutions of known concentration.
2. To determine the reaction rate constant when cane sugar is transformed into invert sugar.

Fresnel's law - theory of reflection with optical plate

P2250310

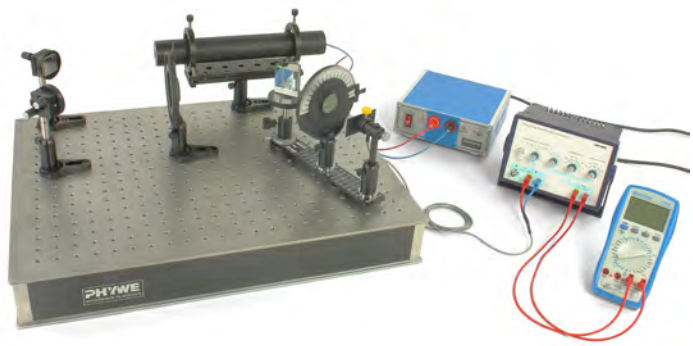
Website

Benefits

- See that reflection at a glass surface changes some properties of light
- Find out that at special angles, light can be completely polarized upon reflection
- Very versatile optical base plate

Learning objectives

- Electromagnetic theory of light
- Reflection coefficient
- Reflection factor
- Brewster's law
- Law of refraction
- Polarization
- Polarization level



Principle

Plane-polarized light is reflected at a glass surface. Both the rotation of the plane of polarization and the intensity of the reflected light are to be determined and compared with Fresnel's formulare 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.

curricuLAB

Malus' law

P2250401

Website

Benefits

- The principle that Polaroid glasses work on
- Introductory yet quantitative experiment to polarization
- Straightforward simple setup

Learning objectives

- Electric theory of light
- Polarisation
- Polariser
- Analyser
- Brewster's law
- Malus' law

Principle

Linear polarised light passes through a polarisation filter. Transmitted light intensity is determined as a function of the angular position of the polarisation filter.

Tasks

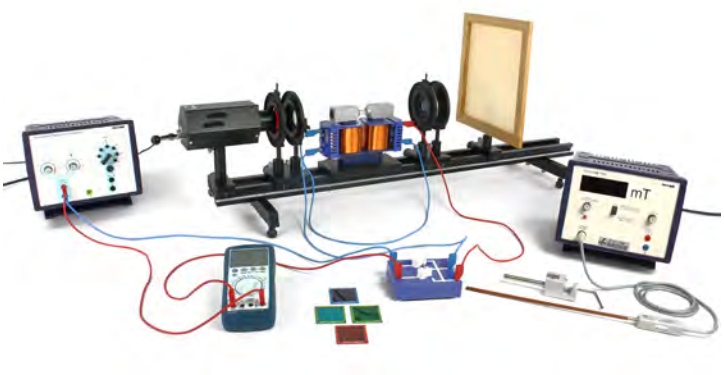
1. The plane of polarisation of a linear polarised laser beam is to be determined.
2. The intensity of the light transmitted by the polarisation filter is to be determined as a function of the angular position of the filter.
3. Malus' law must be verified.

curricuLAB

P2260101

Faraday effect

Website



curricuLAB

Benefits

- Experience that magnetic fields can influence light by changing its polarization properties
- Learn how wavelength and the optical medium influence the effect of the magnetic field
- Discover a bridge between the fields of optics and electromagnetism

Learning objectives

- Electromagnetic field interaction
- Electron oscillation
- Electromagnetism
- Polarization
- Verdet's constant
- Hall effect

Principle

The angle of rotation of the polarization- plane of plane polarised light through a flint glass rod is found to be a linear function of the product of the mean flux-densitiy and the length of the optical medium. The factor of proportionally, called Verdet's constant, is investigated as a function of the wavelength and the optical medium.

Tasks

1. To determine the magnetic flux-densitiy between the pole pieces using the axial Hall probe of the teslameter for different coil currents. The mean flux-density is calculated by numerical integration and the ratio maximum flux-density over mean flux-density established.
2. To measure the maximum flux- density as a function of the coil current and to establish the relationship between mean flux-density and coil current anticipating that the ratio found under 1. remains constant.
3. To determine the angle of rotation as a function of the mean flux-density using different colour filters. To calculate the corresponding Verdet's constant in each case.
4. To evaluate Verdet's constant as a function of the wavelength.

More information on the scope of delivery is available on our website at **www.phywe.com**.

Helium Neon laser, basic set

P2260701

Website

Benefits

- Set up and run a laser, that is by now classic, from its constituting elements
- Get a feel for the delicate adjustments necessary to achieve lasing conditions
- Dicover the way many parameters can influence the output of this gas laser

Learning objectives

- Spontaneous and stimulated light emission
- Inversion
- Collision of second type
- Gas discharge tube
- Resonator cavity
- Transverse and longitudinal resonator modes
- Brewster angle

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.

Tasks

1. Set up the He-Ne laser. Adjust the resonator mirrors by use of the pilot laser (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.

curricuLAB

Nd:YAG laser

P2260900

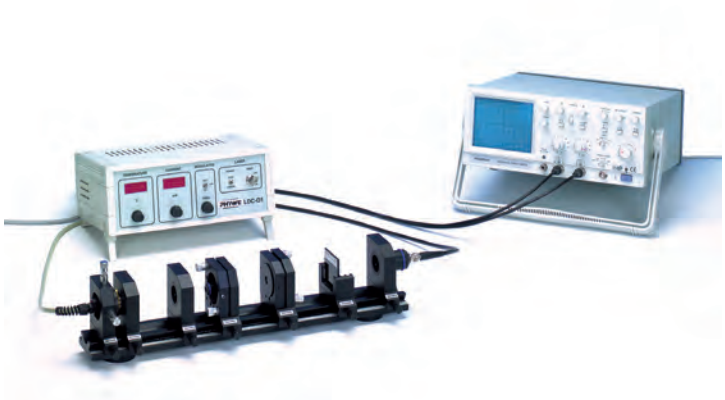
Website

Benefits

- Experience the physics of modern solid state lasers
- Get to the point where you turn invisible IR-light into a bright green light
- Find out about the type of relationships that govern different conversion steps

Learning objectives

- Optical pumping
- Spontaneous emission
- Induced emission
- Inversion
- Relaxation
- Optical resonator
- Resonator modes
- Polarization
- Frequency doubling



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.

curricuLAB

P2261000

Fibre optics

Website

curricuLAB

Benefits

- Telecommunication and computer networking rely heavily on these techniques
- Convince yourself of the advantages and see the basic working principles of optical fiber applications
- See by your own measurements that even light takes some time to travel through a fiber

Learning objectives

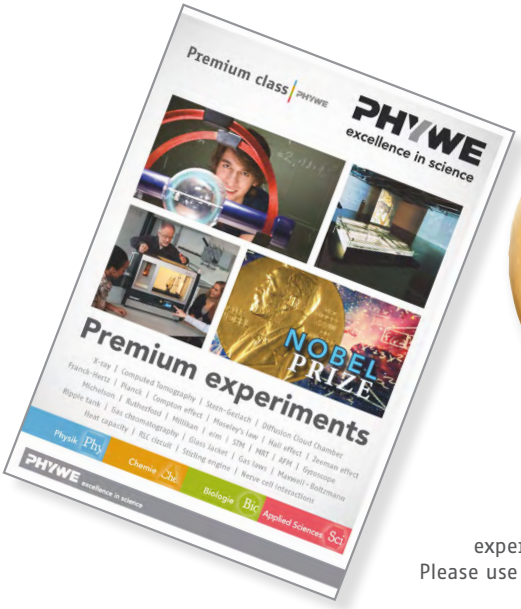
- Total reflection
- Diode laser
- Gaussian beam
- Monomode and multimode fibre
- Numerical aperture
- Transverse and longitudinal modes
- Transit time
- Threshold energy
- Slope efficiency
- Velocity of light

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.



More information about the PHYWE Nobel Prize experiments can be found in the brochure Premium experiments. Please use the QR code or take a look on **www.phywe.com/cataloques**.

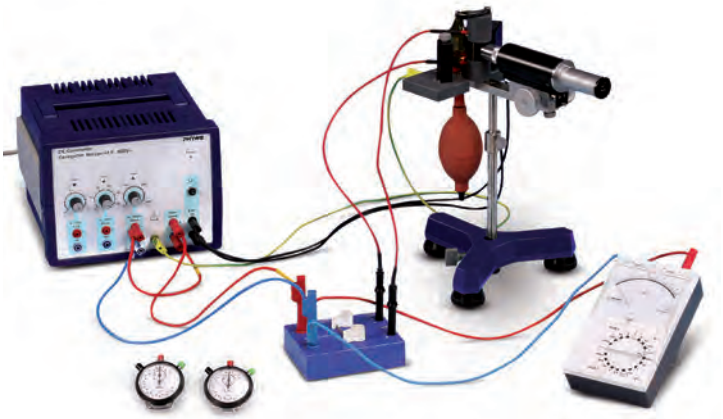
TESS expert - Physics

4.2.6 Modern Physics

P2510100

Elementary charge and Millikan experiment

Website



curricuLAB

Benefits

- Fascination Nobel Prize (Millikan 1923)
- Exact determination of the elementary electric charge
- Compact set-up

Learning objectives

- Electric field
- Viscosity
- Stokes' law
- Droplet method
- Electron charge

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.

P2510200

Specific charge of the electron- e/m

Website

curricuLAB

Benefits

- Neon-filled narrow beam tube for perfect visibility of the electron beam
- High-precise and easy to perform measurements with the built-in fluorescent ladder construction
- Suitable for demonstration and lab courses as well
- Large Helmholtz coils to generate a large volume homogeneous magnetic field. Can be used in a lot of different experiments
- The observation chamber allows to perform the experiment in spite of daylight

Learning objectives

- Cathode rays
- Lorentz force
- Electron in crossed fields
- Electron mass
- Electron charge

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.

Tasks

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.

Franck-Hertz experiment with a Hg-tube

P2510311

Benefits
- Experience the essence of the Nobel Price: Franck, Hertz (1925)
- Classical Version with Mercury (Hg)
- One operating unit for 2 experiments (Hg, Ar)
- Precise determination of electron excitation energy of Hg
- Direct connection to computer, no extra interface necessary

Learning objectives
- Energy quantum
- Electron collision
- Excitation energy

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.

Website

curricuLAB

Franck-Hertz experiment with a Ar-tube

P2510320

Benefits
- Fascinating Nobel Prize experiment (Franck-Hertz 1925)
- Suitable for demonstration and lab courses as well
- Compact argon tube in sturdy casing - ready to use due to short heat-up time
- Control unit compatible to Ar and Hg tube
- Easy-to-use software for control, data acquisition and evaluation

Learning objectives
- Energy quantum
- Quantum leap
- Electron collision
- Excitation energy

Principle

Electrons are accelerated in a tube filled with argon vapour. The excitation energy of argon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

Tasks

1. To record the counter current strength *I* in a Franck-Hertz tube as a function of the anode voltage *U*.
2. To determine the excitation energy *E* from the positions of the current strength minima or maxima by difference formation.

Website

curricuLAB

P2510402

Website

curricuLAB

Planck's „quantum of action" and photoelectric effect (line separation by interference filters)

Benefits

- Experience the essence of the Nobel Prize: Planck (1918)
- Planck's „quantum of action" the most important proof in quantum physics measured directly within few hours with the photocell
- Modular setup with the photocell and interference filters
- Easy determination of h
- No darkroom required

Learning objectives

- External photoelectric effect
- Work function
- Absorption
- Photon energy
- Anode
- Cathode

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.

P2510510

Website

curricuLAB

Planck's „quantum of action" and external photoelectric effect

Benefits

- Experience the essence of the Nobel Prize: Planck (1918)
- Using the photocell Planck's „quantum of action" can be measured within few hours
- Modular setup with photocell on an optical bench an a different grating to produce monochromatic light
- Easy Determination of h

Learning objectives

- Photon energy
- Photon absorption
- External photo effect
- Work function
- Photocell
- Quantum theory
- Plancks constant
- Grating spectrometer

Principle

White light from a filament lamp is filtered by a grating spectrometer and illuminates a photocell. The maximum energy of the ejected electrons depends only on the frequency of the incident light, and is independent of its intensity. This law appears to be in contradiction with the electromagnetic wave theory of the light, but it becomes understandable in the frame of the corpuscular theory of light. The stopping voltage U at different light frequencies is determined by the I /U characteristics of the photocell and plotted over the corresponding light frequency f . Plancks quantum of action is then determined from this graph.

Quantum eraser with the Mach-Zehnder interferometer

P2220810

Website

Benefits

- Realise that part of the information a photon carries can be erased
- Discuss the wave particle duality of photons by interpreting the experimental outcome from different points of view
- Mach-Zehnder setup allows to follow very clearly the different path of the photons

Learning objectives

- Wave-particle duality
- Wave interference
- Quantum mechanics

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.

Stern-Gerlach experiment

P2511101

Website

Benefits

- Experience the essence of the Nobel Prize: Gerlach (1943)
- First proof of the quantization of the spatial orientation of the angular momentum
- A beam of neutral potassium atoms are deflected in a non homogeneous magnetic field and can even be measured precisely

curricuLAB

Learning objectives

- Magnetic moment
- Bohr magneton
- Directional quantization
- g-factor
- Electron spin
- Atomic beam
- Maxwellian velocity distribution
- Two-wire field

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 non-homogeneity of the field applies a force at right angles to the direction of their motion. The potassium atoms 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.

P2511007

Zeeman effect with a variable magnetic system

Website

curricuLAB

Benefits

- Experience the essence of the Nobel prize: Zeeman (1902)
- Normal and anomalous Zeeman effect with one setup
- Permanent magnet where the variable distance between the 2 pole-shoes creates the magnetic field
- High precision Fabry-Perot interferometer necessary for good results
- Image analysis by specific PC capture and analysis software

Learning objectives

- Bohr's atomic model
- Quantisation of energy levels
- Electron spin
- Bohr's magneton
- Interference of electromagnetic waves
- Fabry-Perot interferometer

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 508,6nm, green light) is investigated using a Fabry-Perot interferometer. The evaluation of the results leads to a fairly precise value for Bohr's magneton.

P2511301

Electron diffraction

Website

curricuLAB

Benefits

- Experience the essence of the Nobel Prize: de Broglie (1929)
- Impressive visualization of a Nobel Prize experiment with various changeable parameters
- Simple setup
- Easy determination of the interplanar spacing of graphite
- Perfect demonstration of wave-particle duality

Learning objectives

- Bragg reflection
- Debye-Scherrer method
- Lattice planes
- Graphite structure
- Material waves
- De Broglie equation

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.

Fundamental principles of Nuclear Magnetic Resonance (NMR)

P5942100

Website

Benefits

- Complete, easy to install and affordable MRT education system
- One system to cover all aspects from NMR basics to sophisticated 2D and 3D imaging sequences
- Detailed experiment guides included with the system
- Learning results guaranteed thanks to easy to manage course steps
- Can be set up at any location in the student lab

Learning objectives

- 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
- Signal-to-noise ratio

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. 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 in other experiments which can be performed with the same system without requiring any additional components.

curricuLAB

Compton effect

P2524415

Website

Benefits

- Experience the essence of the Nobel Prize: Compton (1927)
- Nobel Prize experiment can be performed by students within some hours
- Impressive second proof of the wave-particle dualism
- Use of a gamma detector in combination with a high precision power supply guarantees good and reproducible results

Learning objectives

- Corpuscle
- Scattering
- Compton wavelength
- g-quanta
- de Broglie wavelength
- Klein-Nishina formula

Principle

When photons are scattered on electrons, their momentum and energy gets changed. 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.

curricuLAB

P2510605

Website

Fine structure: one and two electron spectra

Benefits
- Wavelength determination of optical spectra with high precision
- Simple setup
- Reading of a nonius

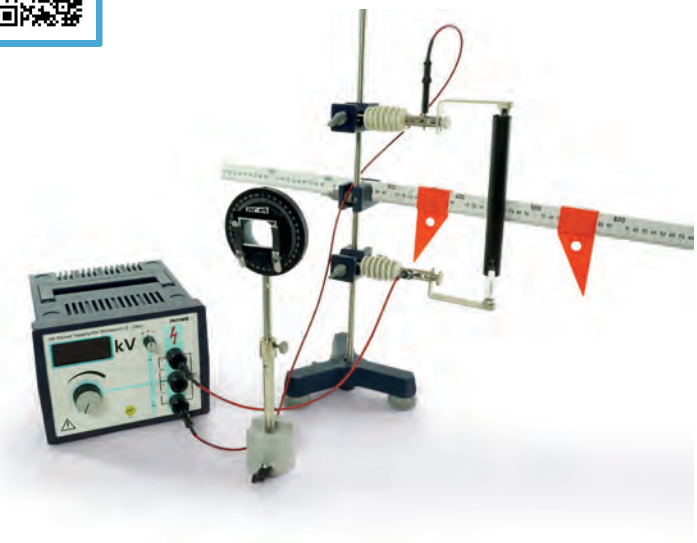
Learning objectives
- Grating and prism spectrometer
- Energy level
- Excitation energy
- Selection rules for optical transitions
- Electron spin
- Orbital angular momentum
- Spin magnetic moment
- Orbital magnetic moment
- Spin-orbit interaction
- Multiplicity

Principle

To determine the wavelength, a spectrometer-goniometer is used. It consists of a dispersive element, which deflects light through an angle depending on the wavelength, and a goniometer to determine the angle of deflection of the light beam. As dispersive elements a grating and a flint prism are used. In case of single electron spectra the spin-orbit coupling produces doublet spectra. For measuring the splitting of the sodium 2P -levels the in nm-range, double lines from transitions involving these levels are observed with a dispersion grating. For the two electron spectra the transition from LS- to jj-coupling occurring from lighter to heavier elements is of importance, causing „forbidden" lines to appear with the heavier elements having larger atomic number Z.

P2510710

Website



curricuLAB

Balmer series / Determination of Rydberg's constant

Benefits
- Simple setup for high ranking experiments
- Fundamental Rydberg's constant determined within an hour
- HV power supply with high safety standards makes experimentation safe

Learning objectives
- 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

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.

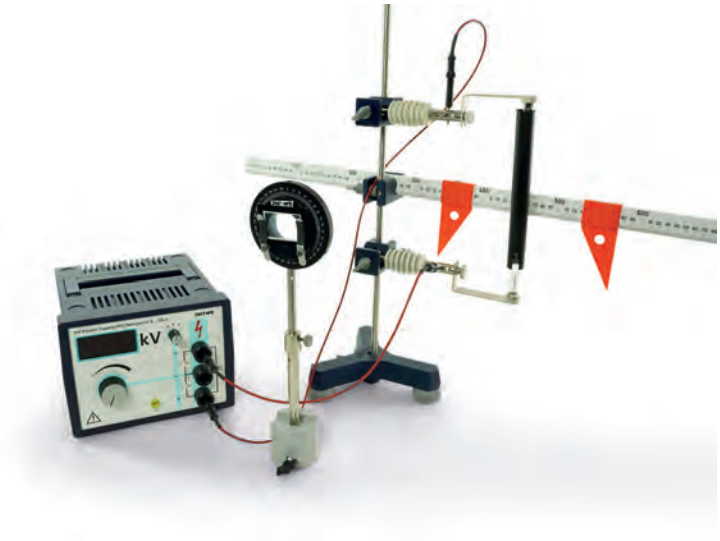
Atomic spectra of two-electron system: He, Hg

P2510810

Website

Benefits

- Spectral lines of various elements can be determined with high precision
- Simple setup for high ranking experiments
- HV power supply with high safety standards makes experimentation safe



Learning objectives

- Parahelium
- Orthohelium
- Exchange energy
- Spin
- Angular momentum
- Spinorbit interaction
- Singlet and triplet series
- Multiplicity
- Rydberg series
- Selection rules
- Forbidden transition
- Metastable state
- Energy level
- Excitation energy

Principle

The spectral lines of He and Hg are examined by means of a diffraction grating. The wavelengths of the lines are determined from the geometrical arrangement and the diffraction grating constants.

Tasks

1. Determination of the wavelengths of the most intense spectral lines of He.
2. Determination of the wavelengths of the most intense spectral lines of Hg.

More information about the PHYWE Nobel Prize experiments can be found in the brochure Premium experiments. Please use the QR code or take a look on **www.phywe.com/cataloques**.

P2530402

Band gap of germanium

Website

curricuLAB

Benefits

- Hall effect unit to control all parameters (temperature, voltage) and supports intrinsic , p- and n-type Ge crystals
- Can also be used to study Hall effect in p and n-type Ge

Learning objectives

- Semiconductor
- Band theory
- Forbidden band
- Intrinsic conduction
- Extrinsic conduction
- Impurity depletion
- Valence band
- Conduction band

Principle

The conductivity of a germanium test sample is measured as a function of temperature. The energy gap is determined from the measured values.

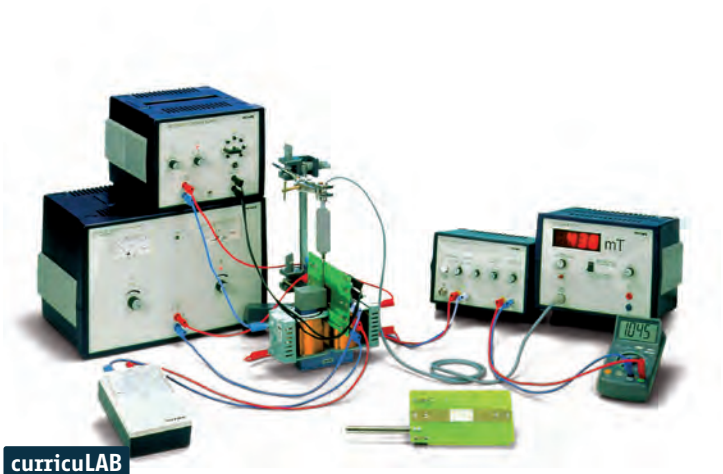
Tasks

1. The current and voltage are to be measured across a germanium test-sample 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.

P2530300

Hall effect in metals

Website



curricuLAB

Benefits

- Hall effect in metals for different metal foils
- High current power supply guarantees the precise results
- Clear setup where all important parts are visible
- Setup transformator to produce a high magnetic field, measured by a teslameter (included)

Learning objectives

- Normal Hall effect
- Anomalous Hall effect
- Charge carriers
- Hall mobility
- Electrons
- Defect electrons

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

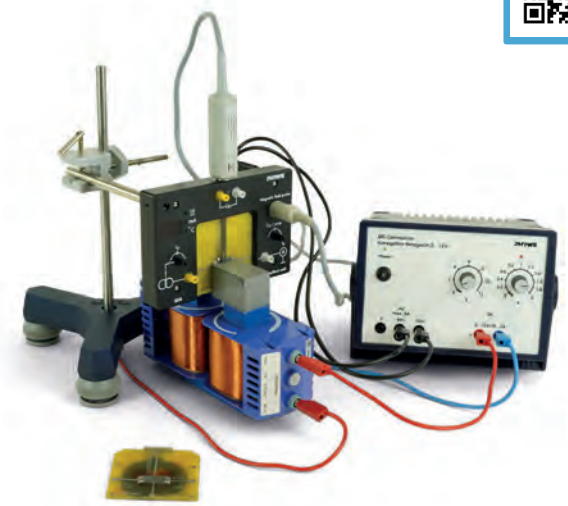
1. The Hall voltage is measured in thin copper and zinc foils.
2. The Hall coefficient is determined from measurements of the current and the magnetic induction.
3. The temperature dependence of the Hall voltage is investigated on the copper sample.

Hall effect in n- and p-germanium

P2530116

Website

Benefits
- Hall effect unit to control temperature, voltage, and supports intrinsic, p- and n-type Ge crystals
- Version with PC control and data acquisition
- Direct connection to PC via USB connection
- No extra interface necessary



Learning objectives
- Semiconductor
- Band theory
- Forbidden zone
- Intrinsic conductivity
- Extrinsic conductivity
- Valence band
- Conduction band
- Lorentz force
- Magnetic resistance
- Mobility
- Conductivity

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

1. 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).
2. The voltage across the sample is measured at room temperature and constant control current as a function of the magnetic induction B.
3. The voltage across the sample is measured at constant control current as a function of the temperature.

curricuLAB

Semiconductor thermogenerator - Seebeck effect

P2410700

Website

Benefits
- Open design allows to fully understand function and applications
- Individual instruments for distinct functions (no „black box“)
- Key products of the experiment setup can also be used for investigating the Peltier effect

Learning objectives
- Seebeck effect (thermoelectric effect)
- Thermoelectric e.m.f.
- Efficiency
- Peltier coefficient
- Thomson coefficient
- Seebeck coefficient
- Direct energy conversion
- Thomson equations

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 U_0 and short-circuit current I_s 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.

curricuLAB

P2538000

Basic methods in imaging of micro and nano-structures with AFM (Atomic Force Microscopy)

Website

curricuLAB

Benefits

- Investigation in static and dynamic mode
- Modification of numerous parameters to optimize image quality
- Perform experiment with different samples
- Excellent price-performance ratio
- Custom-designed for use in teaching labs

Learning objectives

- Atomic Force Microscopy (AFM)
- Lennard-Jones potential
- Imaging of nano structures
- Static Force Mode
- Dynamic Force Mode
- Feedback loop
- Force
- Vibrational amplitude

Software included. Computer not provided.

Principle

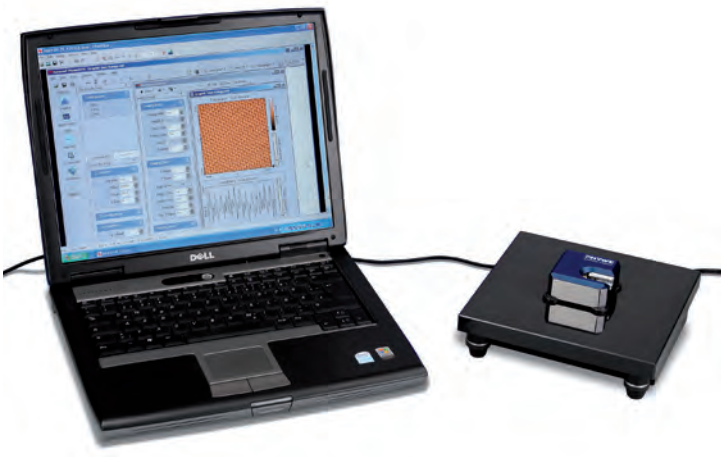
Approaching a sharp silicon tip mounted on a cantilever to a sample surface leads to an atomic scale interaction. The result is a bend of the cantilever which is detected by a laser. In static mode the resulting deflection is used to investigate the topography of the sample surface line by line using 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. Their effect on the imaging quality is investigated for different nano structured samples.

P2532000

Atomic Resolution of the graphite surface by STM (Scanning Tunneling Microscope)

Website

TOPSELLLER



curricuLAB

Benefits

- Observe atoms within minutes
- Custom-designed for use in teaching labs
- Microscope consists of one compact, portable instrument, no additional instruments required
- Vibration-isolated for better and reproducible results

Learning objectives

- Tunneling effect
- Hexagonal structures
- Scanning Tunneling Microscopy
- Imaging on the sub nanometer scale
- Piezo-electric devices
- Local Density Of States (LDOS)
- Constant-Height-Mode
- Constant-Current-Mode

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.

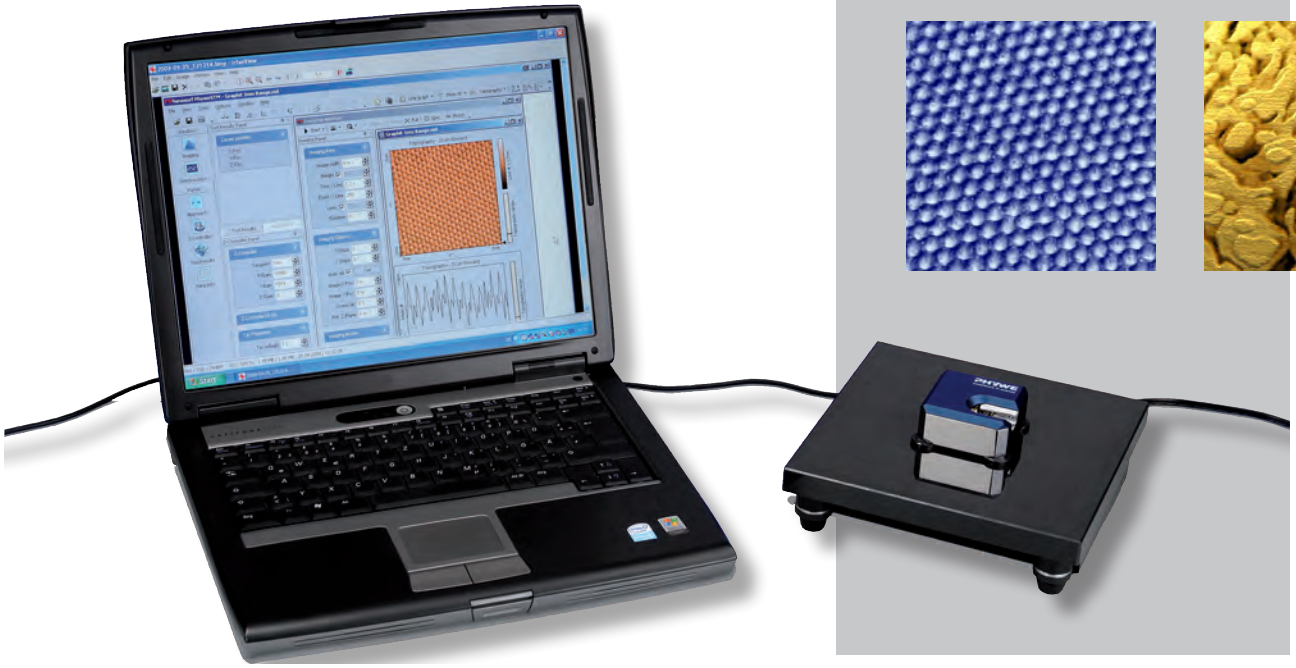
Tasks

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.

Scanning-Tunneling-Microscope

Your entry into the nanoscale world

Website



Fascinating Experiments in the field of quantum mechanics, solid state physics, material sciences and nanotechnology

Since the developement of the Scanning Tunneling Microscope (STM) by Gerd Binning and Heinrich Rohrer in 1981 and the nobel prize for physics in 1986 the STM is one of the most used device in the fields of surface sciences and nano sciences. It provides a direct and affordable access to the nanoscopic world and enables the investigation of effects and characteristics at atomic and molecular scale

The Compact-STM from PHYWE is designed for quick and reliable measurements by experts and novices alike. It is characterized by a compact design with integrated controll-unit and vibrational damping. Together with the easy handling and the included well-engineered software measureNano the PHYWE STM is a ideal devices for scientific classes, science centers, lectures, lab courses and research to convey the fascination of nanoscale world as well as applications of nanotechnology.

Features

Experiments in the fields of nano technology, quantum mechanics, solid state physics, material sciences

Compact measuring USB device with integrated control-unit and vibration damping

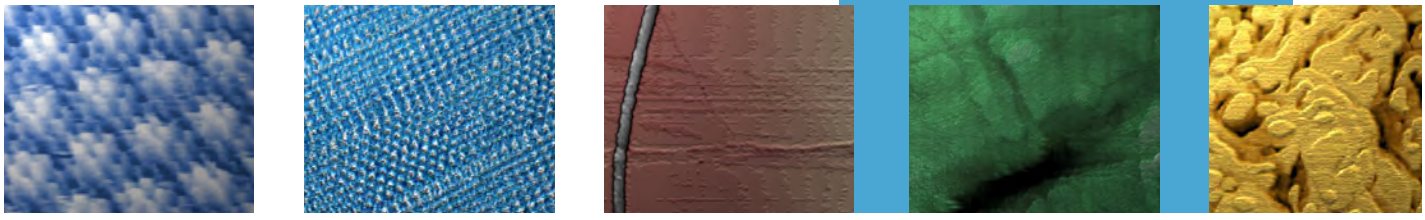
Imaging and spectroscopy of conducting samples at atomic scale

including measureNano, a well-engineered software for measuring, analyzing and visualization

Complete set, incl. HOPG- and Gold-Sample, Tools and Consumables

Easiest and most affordable method for a direct access into the nano world

Unpacking, Swicht-on, Measuring – in 15 min to atomic resolution



P2520102

Half-life and radioactive equilibrium

Website

curricuLAB

Benefits

- Experience the essence of the Nobel Prize: M. Curie, P. Curie and Becquerel (1903)
- Isotope generator produces sufficient radioactive particles 1/2 life law
- Versatile GM counter can be used in many other experiments

Learning objectives

- Parent substance
- Daughter substance
- Rate of decay
- Disintegration or decay constant
- Counting rate
- Half life
- Disintegration product

Principle

The half-life of a Ba-137 m daughter substance eluted (washed) out of a Cs-137 isotope generator is measured directly and is also determined from the increase in activity after elution.

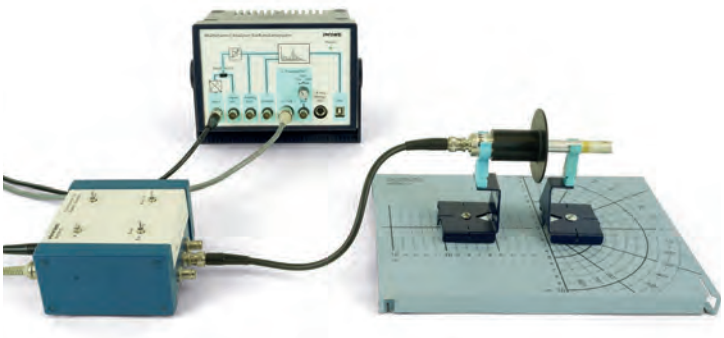
Tasks

1. To measure the activity of the isotope generator as a function of time immediately after elution.
2. To measure the activity of a freshly eluted solution of Ba-137 m as a function of time.

P2522015

Alpha energies of different sources with MCA

Website



curricuLAB

Benefits

- Experience the essence of the Nobel Prizes: Rutherford (1908)
- The combination of multichannel analyzer (MCA), preamplifier and alphadetector leads to precise results
- No vacuum required
- MCA and preamplifier can be used in many other experiments

Learning objectives

- 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

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.

Rutherford experiment with MCA

P2522115

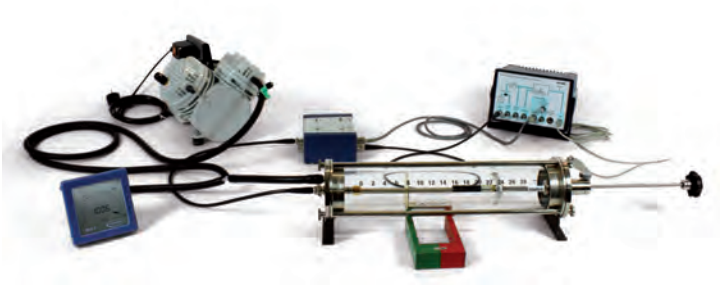
Website

Benefits

- Experience the essence of the Nobel Prizes: Rutherford (1908)
- Gold and Aluminium foil included
- The combination of multi channel analyzer (MCA), preamplifier and alpha detector leads to precise results
- Transparent glass container with perfect visibility of the whole setup and good vacuum conditions, used in several experiments

Learning objectives

- Scattering
- Angle of scattering
- Impact parameter
- Central force
- Coulomb field
- Coulomb forces
- Rutherford atomic model
- Identity of atomic number and charge on the nucleus



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.

curricuLAB

Fine structure of the alpha spectrum of Am-241 with MCA/ alpha spectroscopy

P2522215

Website

Benefits

- Alpha spectroscopy of the fine structure of alpha emitting Americium to understand the technique within a practical course
- The combination of multichannel analyzer (MCA), preamplifier and alpha detector leads to precise results.
- Transparent glass container with perfect visibility of the whole setup and good vacuum conditions, used in several experiments.

Learning objectives

- 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

Principle

The alpha-spectrum of an open 241-Am-emitter is measured with a semiconductor a-detector. In connection with a multi channel analyzer the main parts of the spectrum are investigated.

Tasks

1. The spectrum of an uncovered 241-Am-emitter is recorded with the multi channel analyzer. The energies of the two peaks preceding the principal peak are 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.

curricuLAB

P2524101

Website

curricuLAB

Inverse-square law and absorption of gamma or beta rays with the Geiger-Müller counter

Benefits

- Basic experiment in nuclear physics
- Showing two fundamental laws: Inverse square law and absorption
- Classical version with GM Counter for better understanding

Learning objectives

- Radioactive radiation
- β-decay
- Conservation of parity
- Antineutrino
- g- quants
- Half-value thickness
- Absorption coefficient
- Term diagram
- Pair formation
- Compton effect
- Photoelectric effect

Principle

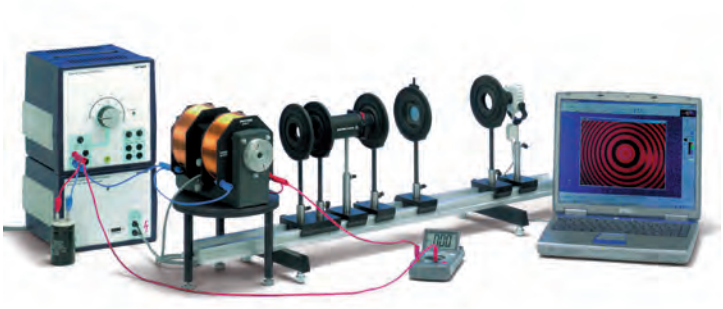
The inverse square law of distance is demonstrated with the gamma radiation from a 60-Co preparation, the half-value thickness and absorption coefficient of various materials determined with the narrow beam system and the corresponding mass attenuation coefficient calculated.

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.

P2511005

Website



curricuLAB

Zeeman effect with electromagnet

Benefits

- Experience the essence of the Nobel Prize: Zeeman (1902)
- Normal and anomalous Zeeman effect with one setup
- Electromagnet secures a fine variation of the necessary magnetic field to be calculated or measured
- High precision Fabry-Perot interferometer necessary for good results

Learning objectives

- Bohr's atomic model
- Quantisation of energy levels
- Electron spin
- Bohr's magneton
- Interference of electromagnetic waves
- Fabry-Perot interferometer

Software included. Computer not provided.

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 508,6nm, green light) is investigated using a Fabry-Perot interferometer. The evaluation of the results leads to a fairly precise value for Bohr's magneton.

Visualisation of radioactive particles/ diffusion cloud chamber

P2520400

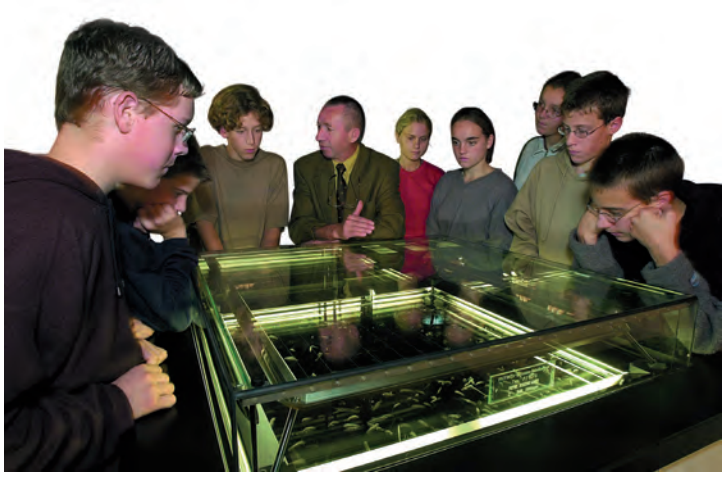
Website

Benefits

- Experience the essence of the Nobel prize: CTR Wilson (1927)
- Only instrument to visualize natural backround and cosmic radiation
- Can discriminate between different types of radiations (alpha, beta, gamma, mesons and myons)
- Qualitative and quantitative experiments described

Learning objectives

- α, β, γ -particles
- β-deflection
- Ionising particles
- Mesons
- Cosmic radiation
- Radioactive decay
- Decay series
- Particle velocity
- Lorentz force



curricuLAB

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.

X-ray fluorescence and Moseley's law

P2524715

Website

Benefits

- A high ranking nuclear physics experiment can be performed by students within some hours
- The combination of multichannel analyzer (MCA), gamma detector and high precision HV power supply leads to precise results
- Fundamental Rydberg's constant and Mosley's law are easily determined

Learning objectives

- Binding energy
- Photoelectric eftect
- Shell structure of electron shells
- Characteristic X-ray radiation
- g-spectrometry
- X-ray spectral analysis

curricuLAB

Principle

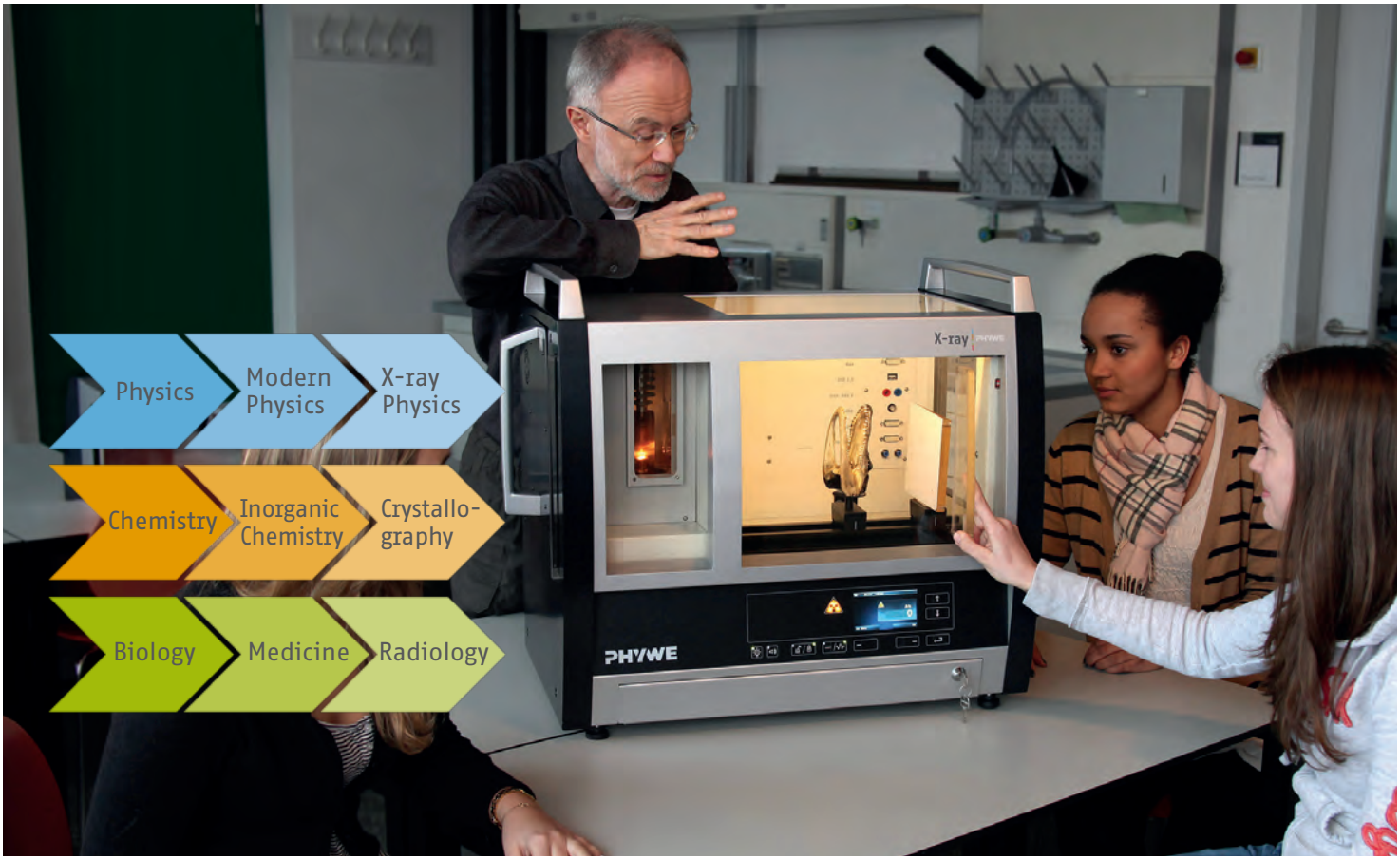
The irradiation of iodine, barium (sulfat), silver and tin with soft gamma-radiations gives rise to Ka radiations characteristics of these elements. The X-ray spectra are recorded with a gamma spectrometer consisting of a scintillation counter, a pulse height analyser and a recorder. After calibration 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 Cs-137 emitter (32 keV) and the gamma-line of 241 Am at 59.6 keV.
2. Recording of the X-ray fluorescence spectra (Ka-lines) of different elements and determination of the corresponding energies.

Website

XR4 X-ray system –
The smart solution for X-ray experiments



Fascinating X-ray experiments with unique solutions

Discover the perfect combination of innovative technology and highest safety standards with approved PHYWE quality and a modern design.

The PHYWE XR4 X-ray system can be used in all fields of education: schools, colleges and universities by using the solution that fits to your experiment in natural sciences, medicine, material sciences or geo sciences.

Leading in quality, technology, innovation and design ... all from a single partner!

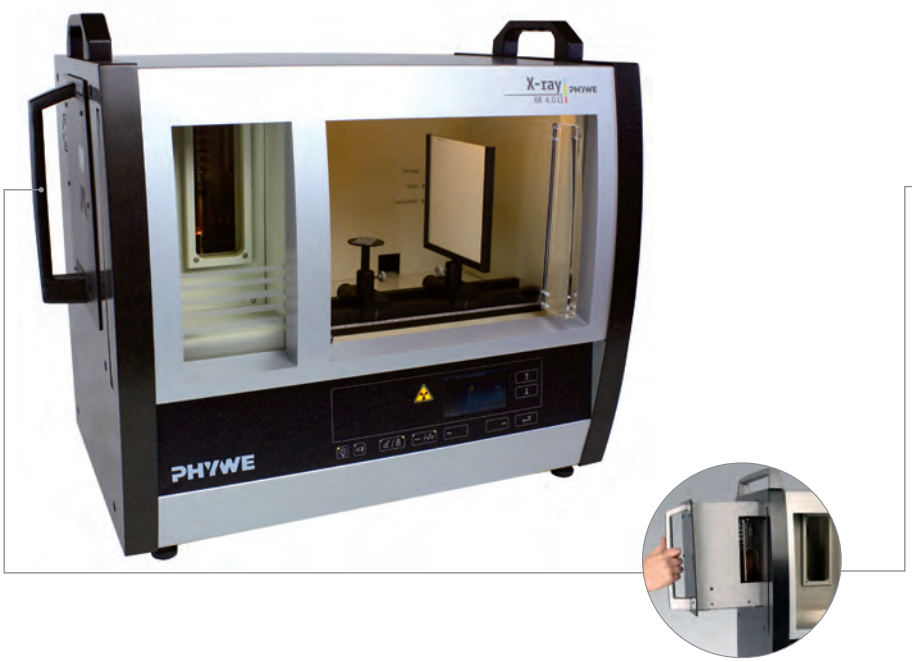
Benefits:

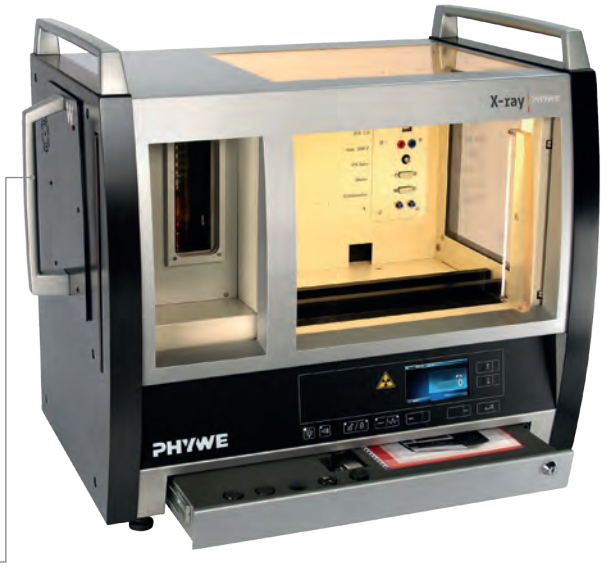
- Modular system of your choice
- Fitting to your needs
- Hands-on equipment
- Applicable for all fields of natural science

Physics Phy | Chemistry Che | Biology Bio

This is your individual X-ray solution!

Choose your desired X-ray unit, select at least one x-ray tube and any extension set to perform up to 59 experiments.





XR4 LI unit

Item no. 09056-99

Features:

- Unique tube Xchange technology
- XXL chamber
- Touch panel
- TFT Display

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)

XR4 expert unit

Item no. 09057-99

Additional benefits:

- 3 view optical access
- Storage drawer
- Applicable for research experiments

Select at least one x-ray tube

XR4 X-ray
Plug-in Cu tube

Item no. 09057-51

Default tube for most x-ray experiments

XR4 X-ray
Plug-in Mo tube

Item no. 09057-61

Used for x-ray characterisation and material analysis

XR4 X-ray
Plug-in Fe tube

Item no. 09057-71

Used for experiments with high energy x-rays

XR4 X-ray
Plug-in W tube

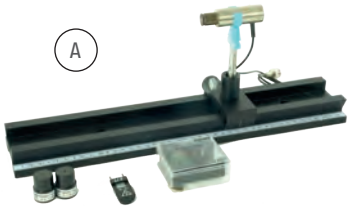
Item no. 09057-81

Used for x-ray characterisation, radiography, and dosimetry

Select any desired application

Extension sets

for all fields of X-ray sciences



	Extension sets	Necessary accessories	Core components	Application examples	Experiments
(A)	**XR4 X-ray solid-state physics** Item no. 09125-88	• Goniometer (H) 09057-10	• GM counter tube • LiF / KBr single crystals • Absorption set	• Diffractometry • X-ray spectroscopy • Bragg reflection / bremsstrahlung • Characteristic lines	5 experiments
(B)	**XR4 X-ray characteristics** Item no. 09135-88	• Goniometer (H) 09057-10	• 3 X-ray tubes (Cu, Fe, Mo) • GM counter tube, • LiF / KBr single crystals	• Radiation spectra of the anode • Moseley law • Rydberg constant • Duane-Hunt law	14 experiments
(C)	**XR4 X-ray structural analysis** Item no. 09145-88	• Goniometer (H) 09057-10	• GM counter tube, • LiF / KBr / NaCl single crystals • Crystal holder • Powder samples	• Structure investigations • Laue patterns • Debye-Scherrer images • Powder diffractometry	17 experiments
(D)	**XR4 X-ray material** Item no. 09165-88	• Goniometer (H) 09057-10	• X-ray energy detector • Multi-channel analyzer • Sample sets	• X-ray fluorescence spectroscopy • Non-destructive testing (NDT) • Compton effect • Energy-dispersive experiments	13 experiments
(E)	**XR4 X-ray imaging** Item no. 09155-88		• Digital SLR camera • Radiographic object • Model loader • Implant model	• X-ray imaging • Radiography • Radiology	4 experiments
(F)	**XR4 X-ray dosimetry** Item no. 09175-88		• Parallel-plate capacitor • Power supply unit 600 V • DC current amplifier • Camera	• Dosimetry • Degradation • Damage • Ionization of air	3 experiments
(G)	**XR4 X-ray computed tomography** Item no. 09185-88		• Direct, digital X-ray image sensor • Rotation unit, vertical rotation • Measure Tomography software package	• 3-dimensional reconstruction • Cross sections • Direct, digital image capture	3 experiments

Discover the fundamental principles of Computed Tomography (CT)

PHYWE XR4 X-ray Computed Tomography upgrade setgrade set

Upgrade set as an extension of the XR4 expert unit. Shows the fundamental principles of computed tomography (CT) used in medical and industrial applications. Ease of use and speed make the Computed Tomography set particularly suitable for laboratory experiments and lectures in physics, medicine and material sciences.

The set covers the following experiments and topics:
- X-ray imaging of biological and technical samples
- Non-destructive testing (NDT)
- Digital image processing for the generation of three-dimensional images of an object
- Digital images of Laue patterns
- Complete CT scan and recontraction in less than 10 min

Software included. Computer not provided.

XR4 X-ray Computed Tomography upgrade set Item no. 09185-88	Scope of supply	YouTube

PHYWE XR4 CT accessories pro

9 experiments related to physical aspects, i.e.:
- Resolution and detail detectability
- X-ray attenuation and contrast
- Optimization of CT scan
- Beam hardening and measuring artefacts
- Hounsfield units and Laue diffraction

XR4 CT accessories pro Item no. 09057-44	Scope of supply

P2540105

Characteristic X-rays of copper

Website

curricuLAB

Benefits

- Experience the essence of the Nobel Prizes: Röntgen (1901), W.H. Bragg, W.L. Bragg, (1914)
- Application of Bragg's law
- Ganiometer with 2 independent or coupled (2:1) axis for sample and detector

Learning objectives

- Bremsstrahlung
- Characteristic radiation
- Energy levels
- Crystal structures
- Lattice constant
- Absorption
- Absorption edges
- Interference
- Order of diffraction

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 analyzer.
2. Step 1 is to be repeated using the KBr monocrystal as analyzer.
3. Calculate the energy values of the characteristic copper lines and compare them with the energy differences of the copper energy terms.

P2541805

X-ray dosimetry

Website

curricuLAB

Benefits

- Experience the essence of the Nobel Prizes: Röntgen (1901), W.H. Bragg, W.L. Bragg, (1914)
- X-ray unit with newest technology to fulfill German safety regulations for student experiments
- Large unbreakable lead enforced acrylic glass windows according to DIN safety regulations

Learning objectives

- X-rays
- Absorption inverse square law
- Ionizing energy
- Energy dose
- Equivalent dose and ion dose and their rates
- Q factor
- Local ion dose rate
- Dosimeter

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

Qualitative X-ray fluorescence spectroscopy of metals - Moseley's law

P2544505

Website

Benefits

- Experience the essence of the Nobel Prize: Röntgen (1901)
- X-ray fluorescence analysis (XRF) of different alloys
- Other alloys are also possible
- X-ray energy detector (XRED) with multichannel analyzer (MCA) guarantess high counting rates without warm-up time

Learning objectives

- Bremsstrahlung
- Characteristic X-radiation
- Absorption of X-rays
- Bohr's atom model
- Energy levels
- Moseley's law
- Rydberg frequency
- Screening constant
- Semiconductor energy detectors
- Multichannel analysers

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 α- and K β-lines.

curricuLAB

Principles of CT scan

P2550505

Website

Benefits

- Experience the essence of the Nobel Prize: Röntgen (1901)
- Introduction to the basics of the medical application of X-rays
- X-ray unit with newest technology to fulfill German safety regulations for student experiments
- Large unbreakable lead enforced acrylic glass windows according to DIN safety regulations

Learning objectives

- Detector calibration
- Saturation
- CT acquisition
- CT reconstruction

Principle

X-ray computed tomography consists of using X-rays that are converted to a digital signal by a detector and computational algorithms to calculate virtual sections through an object without the need to physically cut them. With this data it is possible to generate 3D representations of the sample under investigation. Both from the external as from the interior of the sample.

Tasks

1. Perform a CT scan
2. Define the reconstruction parameters
3. Investigate the reconstructed volume

curricuLAB

1895 Wilhelm C. Roentgen discovers X-radiation – PHYWE turns it into an experience!

In the 21st century, this discovery has formed the basis for scientific, medical and technical teaching and for research at schools, universities and institutes worldwide.

Roentgen received the first Nobel prize in 1901 for his discovery.

The fascination of X-rays

With the PHYWE X-ray XR 4.0 the physics of X-rays can be utilized in a broad range of fields of education at universities, colleges and schools. Extension sets of the XR 4.0 product family permit custom applications in physics, chemistry, biology, medicine, material sciences and geo sciences.

The XR 4.0 is unique as it provides an abundance of uses with an excellent price/performance ratio. Apart from its modern and innovative design the XR 4.0 excels at professional technology, a patent-pending safety system, innovative software solutions, intuitive graphical user interface as well as extensive accessories packages – **Quality Made in Germany!**

The PHYWE XR 4.0 expert unit was developed in cooperation with:

GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

XLAB
Göttinger Experimentallabor für junge Leute e.V.

Part of the curriculum: topic - subtopic	Field of application	Phy	Che	Bio	Sci Med	Sci Geo	Sci Eng
Modern Physics - Atomic Physics Modern Physics - X-ray Physics	Characteristic spectra	x					
Modern Physics - Atomic Physics Modern Physics - X-ray Physics	Bremsspectrum	x					
Modern Physics - Molecular & Solid State Physics	Solid-state physics	x					
Modern Physics - X-ray Physics Inorganic Chemistry - Solid State Chemistry & Crystallography	X-ray diffraction	x	x				
Inorganic Chemistry - Solid State Chemistry & Crystallography Geo Sciences - X-ray analysis Material Sciences - X-ray Structural Analysis	Structural analysis		x			x	
Modern Physics - X-ray Physics Spectroscopy - X-ray Fluorescence Analysis Material Sciences - X-ray Fluorescence Analysis Geo Sciences - X-ray analysis	X-ray spectroscopy	x				x	x
Geo Sciences - X-ray analysis	Rock analysis					x	
Material Sciences - X-ray Structural Analysis Material Sciences - X-ray Fluorescence Analysis	Material analysis		x				x
Non-destructive Testing - X-ray Methods	Non-Destructive Testing (NDT)						x
Medicine/Biology - Radiology Non-destructive Testing - X-ray Methods	X-ray diagnostics				x		x
Medicine/Biology - Radiology Nuclear Medicine - X-ray Dosimetry	Dosimetry			x	x		
Medicine/Biology - Radiology	Radiology / Radiography			x	x		
Medicine/Biology - Radiology Non-destructive Testing - X-ray Methods	Computed tomography	x		x	x		x

TESS expert - Chemistry

4.3.1 General Chemistry

P3010401

Determination of molar mass using the ideal gas law

Website

curricuLAB

Benefits

- Examination of many different gases possible
- Illustrative experimental setup

Learning objectives

- Molar mass and relative molar mass
- Properties of gases
- Ideal and ordinary gases
- Equations of state

Principle

All gases may be considered, to a first approximation, to obey the ideal gas equation which relates the pressure *p*, volume *V*, temperature *T* and amount ofsubstance *n* of a gas. The amount of gas *n* is expressed as the number of moles and is equal to *m* /*M* where *m* is the mass of gas present and *M* is the mass of one mole of the gas. The volume occupied by a known mass of gas is to be measured at a given temperature and pressure, so that the ideal gas equation can beused to estimate the molar mass of the gas.

Tasks

Determine the molar masses of the gases helium, nitrogen, carbon dioxide and methane.

P3010501

Determination of the molar mass of a liquid

Website

curricuLAB

Benefits

- For both demonstration and student experiments
- Simple procedure - fast results
- Glass jacket system easily expandable

Learning objectives

- Ideal and ordinary gases
- Equations of state for ideal gases
- Gas volumetry
- Determination of molar masses according to the vapour density method (Victor Meyer)

Principle

The molar mass of a liquid is to be determined by evaporating a liquid at constant temperature and pressure, and measuring the volume of vapour formed using a calibrated gas syringe.

Tasks

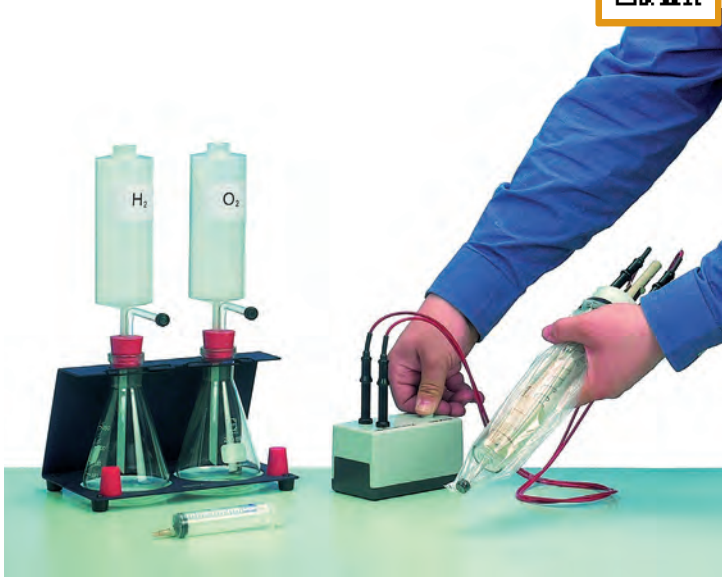
1. Determine the molar masses of diethyl ether and methanol.
2. Discuss the results in terms of the real and ideal behaviour of vapours.

Gay-Lussac's law of volumes

P3022100

Benefits
- Simple, transparent experimental setup
- Practical gas bar for storing the gases

Website



Learning objectives
- Gay-Lussac's law of gaseous combustion
- Hydrogen/oxygen reaction

Principle

Gay-Lussac's law of volumes states that gases always react with one another in certain fixed ratios of their volume.

This experiment mixes hydrogen and oxygen in the plunger eudiometer in different ratios where the mixtures react explosively. All of these gas mixtures can be ignited within a very short period of time, demonstrating that hydrogen and oxygen always react with one another in a volumetric ratio of 2 to 1.

Tasks

Examine the volume relationship in the hydrogen/oxygen reaction using a plunger eudiometer.

Solubility diagram of two partially miscible liquids

P3030501

Benefits
- Good and reproducible results due to temperature control in the experiment.

Website

Learning objectives
- Binary system
- Miscibility gap
- Mixed phase
- Coexisting phase
- Raoult's law
- Critical dissolution temperature

Principle

A number of different mixtures of phenol and water are prepared and heated until complete miscibility is achieved. As the mixtures cool, two-phase systems form at certain temperatures which are recognisable by the appearance of turbidity. Plotting separation temperatures against compositions of the mixtures gives the separation curve.

Tasks

1. Plot the separation curve of the phenol / water binary system and prepare a temperature / mass fraction diagram.
2. Determine the critical separation point.

curricuLAB

P3030601

Miscibility gap in a ternary system

Website

curricuLAB

Benefits

- Good and reproducible results due to temperature control in the experiment.
- Stable and safe construction due to solid stand material

Learning objectives

- Three component system
- Miscibility gap
- Phase diagram
- Triangular diagram
- Gibb's phase law

Principle

A number of completely miscible two component mixtures are prepared to investigate the three component acetic acid / chloroform / water system. These mixtures are titrated with the third component until a two phase system is formed which causes turbidity. The phase diagram for the three component system is plotted in a triangular diagram.

Tasks

1. Titrate nine different acetic acid / chloroform mixtures with water until a two phase system is formed in each case.
2. Titrate six acetic acid / water mixtures with chloroform until phase separation is observed.
3. Plot the results of the titrations, expressed as molar fractions, in a triangular diagram.

P3021900

Determination of molar masses via a measurement of the boiling point elevation (ebullioscopy)

Website

curricuLAB

Benefits

- Compact, easily transportable setup
- Experimentation made easy by intuitive operation
- For both demonstration and student experiments

Learning objectives

- Molar mass
- Boiling point elevation
- Ebullioscopy
- Ebullioscopic constant

Principle

Didactic setup to train and demonstrate the determination of molar masses by way of a measurement of the boiling point elevation. The boiling point elevation of aqueous solutions of different substances is determined using. The ebullioscopic constant of water is calculated from the experimental results.

Tasks

1. Determine the boiling point elevation of aqueous solutions of different substances.
2. Calculate the ebullioscopic constant of water from the experimental results.

Condensation of gases through an increase of pressure and through cooling

P3011400

Website

curricuLAB

Benefits

- Compact setup
- Perfect as demonstration and student experiment
- Beautiful illustration of the phase transition from gaseous to liquid

Learning objectives

- Condensation
- Gas laws

Principle

Gases are condensing when they are cooled and at high pressure. In this experiment butane is condensed by cooling it to ca. -15 °C. In the second part of the experiment butane is condensed by compressing it.

Tasks

1. Condense butane by cooling it under its boiling point of -0.4 °C.
2. Condense butane at high pressure.

P3030701

Distribution equilibrium

Website

Benefits

- Modern, easy-to-use photospectrometer

Learning objectives

- Principles of thermodynamics
- Partial molar free enthalpy (chemical potential)
- Equilibrium between phases
- Distribution and extraction
- Nernst distribution equation
- Lambert-Beer law
- Photometry

Principle

At constant temperature and under constant pressure, a dissolved substance distributes itself between two immiscible liquids in a constant concentration ratio. This ratio is equal to the partition coefficient (distribution coefficient) of the substance examined in the given two-phase system.

Tasks

1. Measure the extinction of various concentrated solutions of *trans*-azobenzene in acetonitrile at constant wavelength. Subsequently determine the equilibrium concentrations (extinctions) of *trans*-azobenzene in the system *n*-heptane /acetonitrile after single and repeated distribution at constant temperature.

P3031101

Dissociation constants

Website

curricuLAB

Benefits

- Modern spectrophotometer with display
- Spectrophotometer can be used for many other applications
- Detailed operating instructions

Learning objectives

- True and potential electrolytes
- Strong and weak acids
- Law of mass action
- Dissociation constants and pKa values
- Henderson-Hasselbalch-Equation
- UV-vis spectrometry
- Lambert-Beer's Law
- Photometry

Principle

The coloured indicator thymol blue is a weak acid that is partially dissociated in aqueous solution, whereby non-ionized and ionized forms show absorption maximums at different wavelengths in the visible range. Photometric measurements in the visible spectral range can therefore be used to advantage to determine the position of the Ka and pKa values of the indicator which characterize dissociation equilibrium.

Tasks

1. Experimentally determine the extinction (absorbance) of an aqueous solution of thymol blue (thymolsulphonephthalein) in dilute HCl.
2. Calculate the dissociation constant (indicator constant) Ka from the measurement results.

Solubility product with Cobra SMARTsense

P3030867

Website

Benefits

- Good and reproducible results due to temperature control in the experiment.
- The use of the compact Cobra SMARTsense is space-saving.

Learning objectives

- Solubility
- Dissociation
- Electrolytic conductance
- Activity

Principle

The solubility of poorly soluble salts is expressed as the solubility product, i.e. the product of the concentration of cations and anions in the solution which are in equilibrium with the solid salt. These concentrations can be determined via conductivity measurements.

Tasks

1. Measure the conductivities of saturated aqueous solutions of the salts calcium fluoride and calcium carbonate at 25 °C.
2. With the aid of tabulated ionic conductivities, calculate the solubility products of the salts from their conductivities.

Cobra SMART sense

curricuLAB

Complex formation equilibrium / equilibrium constant

P3031001

Website

Benefits

- Stable and safe construction due to solid stand material
- High quality glassware for good results

Learning objectives

- Complex formation
- Chemical equilibrium
- Equilibrium constant

Principle

Many metals, in particular transition elements, can form complexes with charged or neutral ligands. Complex formation reactions are equilibrium reactions. The stability of these complexes is described by the complex formation constant.

Tasks

Determine the number of ligands of the silver amine complex with a precipitation titration from a silver salt solution.

curricuLAB

12982-88

SensorCase Cobra SMARTsense chemistry, 16-fold

Website

NEW

Cobra SMART sense

Function and Applications

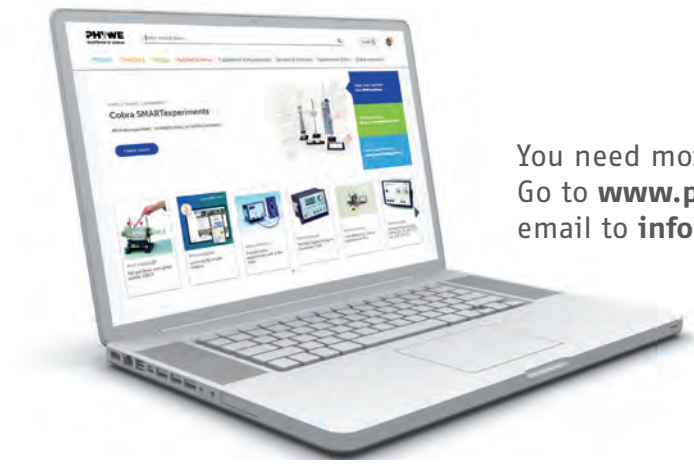
All equipment in the box is attuned to chemistry lessons with students. The case can be easily transported thanks to the integrated trolley system. Up to 16 Cobra SMARTsense sensors can be charged simultaneously via USB in the suitcase.

Scope of Delivery:

- 16 x Cobra SMARTsense pH (Art.Nr. 12921-00)
- 16 x Cobra SMARTsense Thermocouple (Art.Nr. 12938-01)
- 16 x Cobra SMARTsense Temperature (Art.Nr. 12903-01)
- 1 x Cobra SMARTsense Dropcounter (Art.Nr. 12923-00)

USB charging wire for Cobra SMARTsense sensors, power cable for the case and other accessories and consumables

Measurement software PHYWE measureAPP for all operating systems (iOS, Android and Windows 10) can be downloaded free of charge from the respective APP store.



You need more information?
Go to **www.phywe.com** or send an email to **info@phywe.com**.

TESS expert - Chemistry

4.3.2 Anorganic Chemistry

P3031900

Sublimation and solubility of iodine

Website

curricuLAB

Benefits

- Stable and safe setup due to solid stand material
- Secure connection of the items by GL screw joint system

Learning objectives

- Sublimation
- Resublimation
- Solubility
- Iodine

Principle

Iodine, whose melting point is at 113.5 °C, evaporates clearly below this temperature. It passes from the solid state directly to the gaseous state. This process is known as sublimation.

When iodine vapour cools down, solid crystals form, again without a liquid transitional phase. This process is known as resublimation.

Tasks

1. Show sublimation and resublimation of iodine.
2. Investigate the solubility of iodine in oxygen-containing and oxygen-free solvents.

P3110600

Redox reactions between metals and metal oxides (thermite process)

Website

curricuLAB

Benefits

- Impressive experiment to the thermite process
- Precise weighting information ensures successful execution

Learning objectives

- Redox reaction
- Thermite process
- Metals
- Welding of iron
- Aluminothermics
- Iron
- Aluminium

Principle

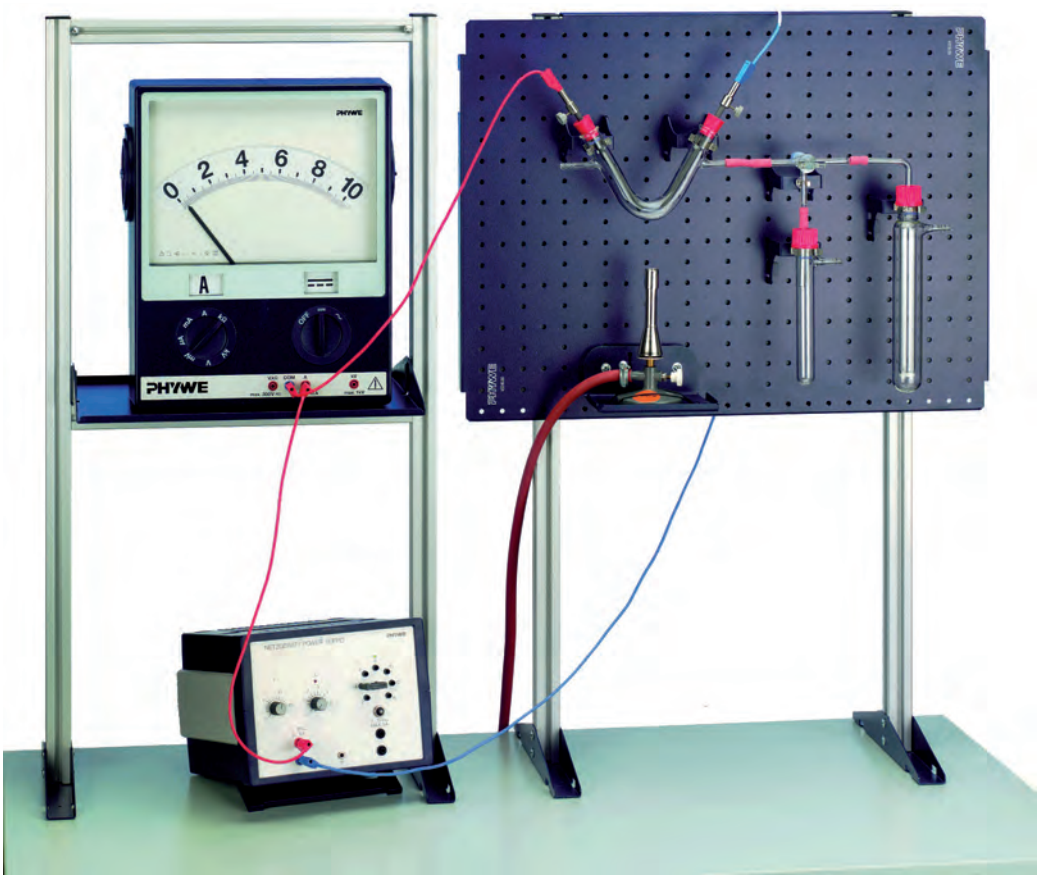
The experiments described here are highly suitable for demonstrating the different affinity of various metals in view of oxygen. The less noble a metal is the higher its affinity to oxygen and the more thermal energy is released during its oxidation. The technical importance of the thermite process for the welding of iron parts is that it is relatively easy to produce large amounts of liquid iron and, thereby, to fill wider weld grooves. This is why this process is mainly used for welding thick steel beams, rail tracks, and machine parts.

Tasks

1. Reduction of copper oxide with iron.
2. Reduction of iron oxide with aluminium (thermite process, alumino-thermics).

Molten-salt electrolysis

P1310500



Website

curricuLAB

Benefits

- Easy and fast experiment set-up
- Impressive demonstration how to produce alkali metals like sodium

Learning objectives

- Electrolysis
- Fused-salt electrolysis
- Preparation of Chlorine and sodium

Principle

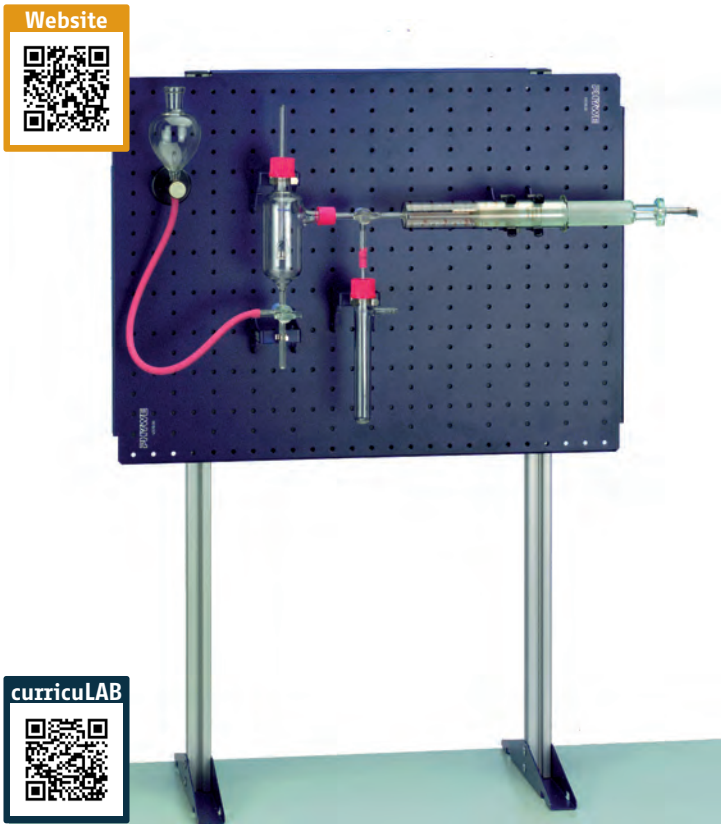
The electrolysis of molten sodium chloride to obtain chlorine and sodium, which can be used to produce sodium hydroxide, is an important industrial-scale process. The experiment is a simple demonstration of the important steps in this process. Due to the high melting point of sodium chloride, lead chloride (with a lower melting point) is used as starting material in the model experiment (instead of sodium chloride)

Tasks

Demonstration the electrolysis of molten sodium chloride to obtain chlorine and sodium.

P1309462

Determination of the molar masses of metals



Benefits

- Accurate determination of molar mass by application of the ideal gas law´
- Simple implementation and fast measurement results

Learning objectives

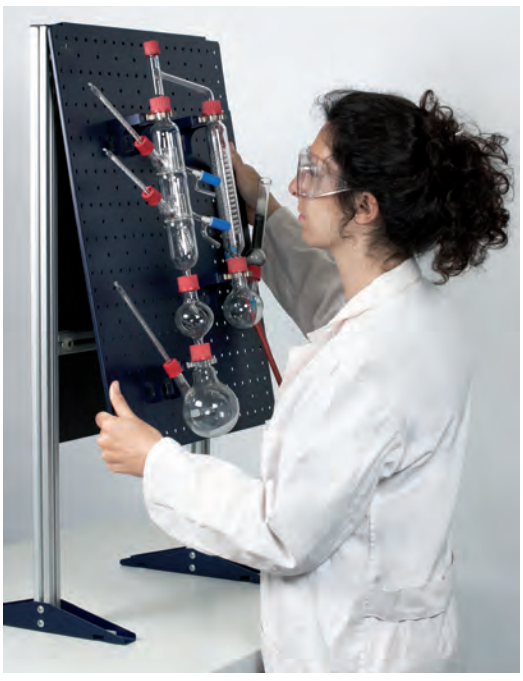
- Molar mass
- Molar volume
- Ideal gas laws
- Valency of metals

Principle

A piece of metal is weighed and placed in the insert of the reaction cylinder, whereafter an acid is added to the cylinder through the three-way valve until it is about half full. The metal is made to react with the acid by lowering the insert. The gas syringe connected to the reaction cylinder is used to collect the hydrogen which is generated. The mass of the metal and the volume of the hydrogen generated are used to calculate the desired molar mass. The reaction can also be used to determine the valency of the metal.

Tasks

Determine the molar mass of zinc.



TESS expert - Chemistry

4.3.3 Analytical Chemistry

P3050201

Website

curricuLAB

Reaction rate and activation energy of the acid hydrolysis of ethyl acetate

Benefits

- Thermostat for precise temperature control
- Stable and safe construction due to solid stand material

Learning objectives

- Reaction rate
- Reaction rate constant
- Rate law for first and second order reactions
- Reactions with pseudo order
- Arrhenius equation
- Activation energy

Principle

In acid solution, ethyl acetate is hydrolysed to equivalent quantities of ethanol and acetic acid according to a pseudo-first order rate law. The alkalimetric determination of the acetic acid formed enables conclusi-ons to be drawn on the temporal concentration of ester.

Tasks

1. Determine the reaction rate constant for the acidolysis of ethyl acetate at two (or more) temperatures.
2. Calculate the activation energy of the reaction from the temperature dependence of the measured rate constants.

P3062201

Website

curricuLAB

Electrogravimetric determination of copper

Benefits

- High quality platinum electrode for precise results
- Optimized test procedure by heating

Learning objectives

- Quantitative analysis
- Gravimetry
- Electrolysis
- Overpotential
- Electrode polarisation

Principle

Electrogravimetry is an important analytical method for the quantita-tive determination or separation of species in solution. The technique involves the quantitative electrolytic deposition of an element, usually a metal, on a suitable electrode in weighable form.

Tasks

Perform an accurate electrogravimetric determination of the amount of copper in a given sample solution.

Absorption of light (UV-VIS spectroscopy)

P3070101

Benefits
- Modern spectrophotometer with display
- Spectrophotometer can be used for many other applications
- Detailed operating instructions

Website

Learning objectives
- Absorption of light
- Electron excitation
- Influence of solvents
- Solvatochromic, hypsochromic and bathochromic shifts
- Lambert-Beer Law
- Decadic molar extinction coefficient

Principle

The structures of molecules are not changed by their chemical environment in the gas phase. In contrast to this, on transition to the condensed phase, in dilute solution, the solvent changes the binding state of the dissolved substance. One of the way this influence makes itself shown is in the electron spectrum (solvatochromatic shift).

Tasks

1. Plot UV-VIS absorption spectra of methyl orange.
2. Determine the type of electron transition that causes these bands (by the decadic molar extinction coefficients).
3. Plot the wavelengths of the absorption maxima in the visible range against the dielectric constants of the various solvents.

Column chromatography - separation of leaf pigments

P3120300

Benefits
- Optimised for demonstration experiments: Transformation from horizontal into vertical direction
- Practical water jet pump for easy generation of the required negative pressure
- Didactic introduction to a basic separation process

Website

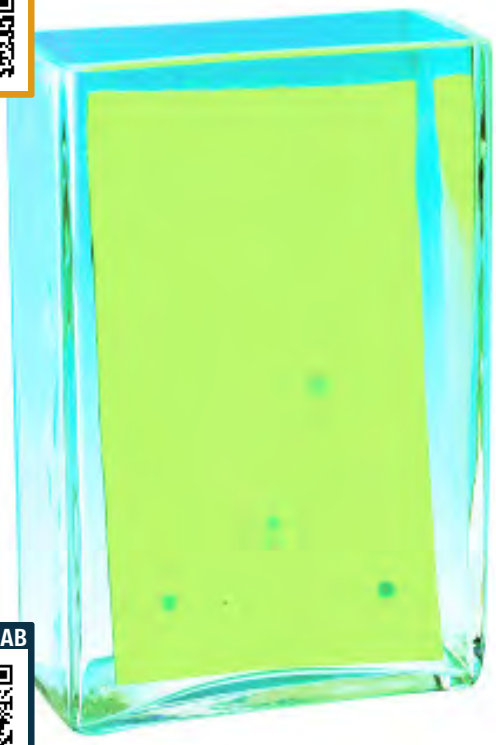
Learning objectives
- Chlorophyll
- Column chromatography
- Leaf pigments
- Xanthophyll

Principle

In this investigation, a uniformly green raw extract of fresh leaves is first separated into different fractions by means of column chromatography. To do so, the extract is added to a column filled with starch and drawn through the column under slightly reduced pressure (to increase the flow rate of the mobile phase) with ligroin as the eluent. A separation occurs in a clearly recognisable, broad, yellow area and in a narrow, green band. This means that the xanthophylls (yellow) are separated from the chlorophylls (green). If the vacuum is reduced during the separation, the separation is much better, but then separation also takes considerably longer. Each of these paration fractions can be collected individually and characterised by recording their absorption spectra, if necessary, or examined for fluorescence by radiation with UV light.

P3120400

Website



curricuLAB

Chromatographic separation processes: thin layer chromatography (TLC)

Benefits

- Didactic introduction to a basic separation process

Learning objectives

- Thin-layer chromatography
- Separation procedure
- Adsorbent material
- Stationary phase
- Mobile phase
- Capillary action

Principle

Chromatographic separation processes are very important for analytical chemistry. Their relatively simple technique and the possibility to separate even the smallest portions of mixtures explain the rapid development of these processes. There are numerous variations of this method.

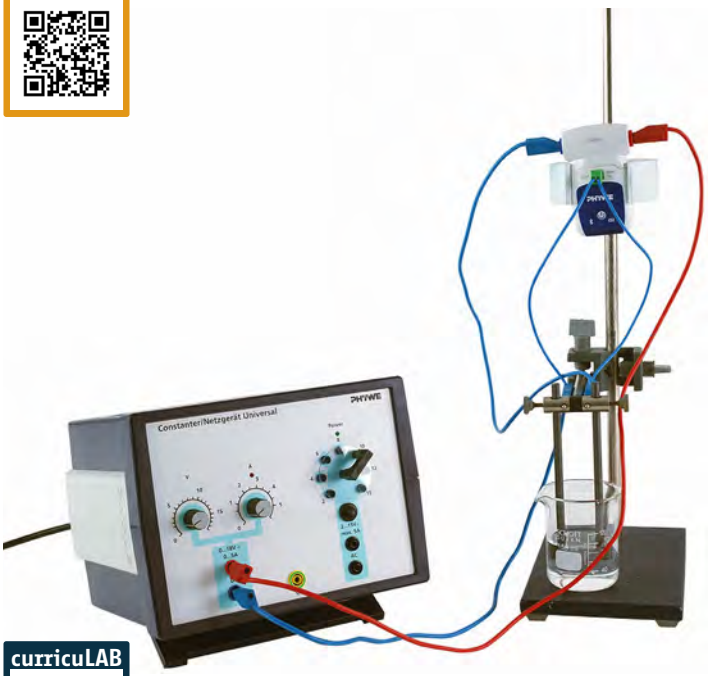
As a result, the optimum chromatographic separation method can be found for nearly every separation task. The method that is described here can be used to demonstrate the fundamental principles and possibilities of this method with relatively simple means.

Tasks

Separate a dye mixture by thin-layer chromatography.

P3061867

Website



curricuLAB

Cobra SMART sense

Electrode kinetics: The hydrogen overpotential of metals with Cobra SMARTsense

Benefits

- Simultaneous measurement of current and voltage
- Simplified implementation: all pre-settings already prepared

Learning objectives

- Electrode kinetics
- Polarisation
- Overpotential
- Irreversible processes
- The electrode-electrolyte interface
- Voltammetry and current-potential curves
- Relevance to electrolysis
- Fuel cells
- Corrosion
- Polarography

Principle

If the oxidation and reduction steps of an electrode reaction are rapid (high exchange current densities) then the passage of charge across the electrode-solution interface will barely displace the reaction equilibrium. Such an electrode is said to benon-polarisable in the sense that its potential, for small currents, is stable and equal to the equilibrium electrode potential. If, on the other hand, reaction equilibrium is established only slowly due to the kinetic inhibition of a step involved in the electrode reaction, then the electrode is said to be polarisable. To induce the reaction to proceed in a given direction the kinetic inhibition of the reaction must be overcome by applying a high overpotential. Electrode polarisation and the presence of overpotentials are important concepts in understanding electrode processes.

Titration curves and buffering capacity with Cobra SMARTsense

P3061667

Website

Benefits

- Drop counter optimizes the experimental procedure
- Simplified implementation: all pre-settings already prepared
- Extensive automation of the experiment allows concentration on the learning objectives

Learning objectives

- Strong and weak electrolytes
- Hydrolysis
- Dissociation of water
- Amphoteric electrolytes
- Isoelectric point
- Law of mass action
- Indicators
- Glass electrode
- Activity coefficient
- Buffering capacity
- Henderson-Hasselbalch equation

Principle

pH values can be measured with the aid of electrochemical measurements and proton-sensitive electrodes (e.g. glass electrodes). By combining a glass electrode with a reference electrode in one housing, a single-rod glass electrode, which is appropriate for acid-base titrations, is created. The titration curves allow an exact determination of the equivalence point in titrations of strong and weak acids and bases.

Tasks

1. Determine the titration curves of different neutralisation reactions.
2. Determine the titration curve of an ampholyte (glycine).
3. Determine the buffering capacity of various aqueous acetic acid/ sodium acetate mixtures at different total concentrations.

curricuLAB

Cobra SMART sense

Dissociation equilibrium with Cobra SMARTsense

P3030967

Website

Benefits

- Simplified implementation: all pre-settings already prepared
- Drop counter optimizes the experimental procedure

Learning objectives

- True and potential electrolytes
- Strong and weak acids
- Law of mass action
- Henderson-Hasselbalch equation
- Dissociation constant and pKa value
- Substituent effects
- Potentiometry

Principle

Carboxylic acids are potential electrolytes which exist in a weakly dissociated condition in aqueous solutions. The location of the dissociation equilibrium is quantitatively described by the Ka or pKa value which can be determined with potentiometric measurements.

Tasks

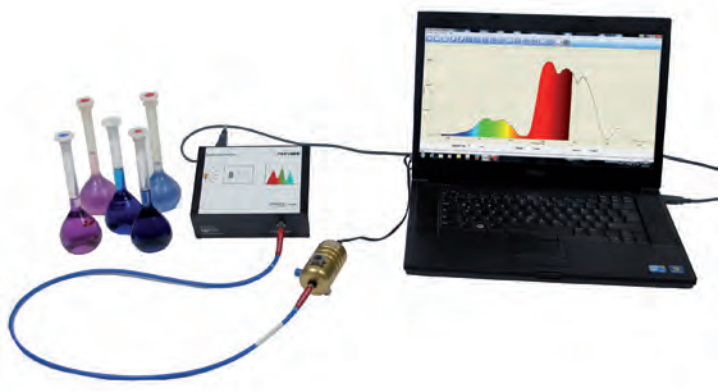
1. Measure the alteration of the pH value during a titration of approximately 0.1 molar aqueous solutions of formic acid, acetic acid, monochloroacetic acid, propionic acid, butyric acid and lactic acid with a 0.1 molar sodium hydroxide solution at constant temperature using Cobra SMARTsense-system.
2. From the neutralisation curves read the pKa values of the acids and compare them.

curricuLAB

Cobra SMART sense

P3070501

Website



curricuLAB

Multicomponent analysis with spectrophotometry (mixed colour photometry)

Benefits

- Experimental procedure without dangerous chemicals
- Modern, easy-to-use photospectrometer
- Simple evaluation by supplied software

Learning objectives

- Photometry
- UV-VIS spectrometry
- Lambert-Beer's law
- Dyes
- Absorption of light

Principle

In solutions containing different-coloured substances the concentrations of the dyes can be anlysed by spectrometry without prior separation of the substances.

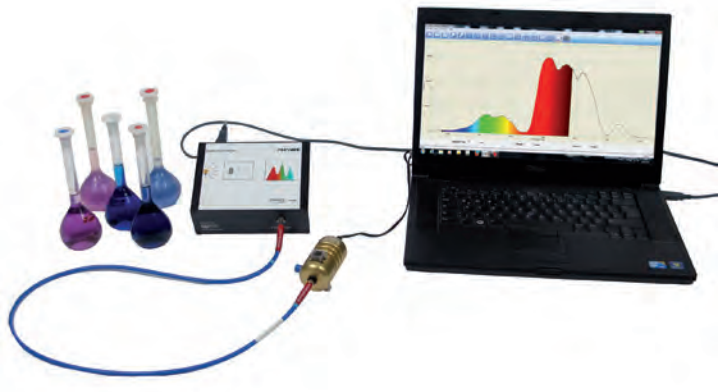
Using the integrated software the spectra of the pure dye solutions and mixtures thereof will be recorded. Calibration curves for each substances enable us to determine the quantity of that substance in the solution.

Tasks

In a mixed solution containing fuchsine acid and patent blue V, the proporion of fuchsine acid is to be determined.

P3070601

Website



Reaction kinetics with spectrophotometry

Benefits

- Modern, easy-to-use photospectrometer
- Simple evaluation by integrated software

Learning objectives

- Reaction kinetics
- First order reaction
- Photometry
- Reaction rate

Principle

The organic dye crystal violet is decolorised in an alkaline medium. This reaction takes place according to a velocity-time law, hence it is a reaction of the first order.

Using the integrated software, the change in concentration of the dye can be traced by measuring the extinction at the wavelength of the absorption maximum. The computer program plots the kinetic data in graphical form.

Tasks

The order of reaction during decolorisation of crystal violet is to be determined.

TESS expert - Chemistry

4.3.4 Organic Chemistry

P3120200

Quantitative determination of fat / Soxhlet extraction

Website

curricuLAB

Benefits

- Controlled and safe heating via heating mantle and power regulator
- Secure connection of the items by GL screw joint system

Learning objectives

- Soxhlet apparatus
- Fat extraction
- Food chemistry
- Food analysis

Principle

The discussion of healthy nutrition focuses on the fat content of foodstuffs. For this reason, it is important to know the exact fat content of individual foodstuffs. The experiment shown here presents a method for the quantitative determination of the fat content of foodstuffs by extraction using a Soxhlet apparatus. This small size of this Soxhlet extractor makes it possible to extract small quantities using extremely small amounts of solvent.

Tasks

Calculate the fat content of a sausage using soxhlet extraction.

P3110800

Cracking of hydrocarbons

Website

curricuLAB

Benefits

- Secure connection of the items by GL screw joint system
- Stable and safe setup due to solid stand material

Learning objectives

- Cracking
- Hydrocarbons
- Catalyst

Principle

Under the influence of energy, e.g. heat, light, and electric discharge, all chemical compounds can be broken down into smaller fractions. The reaction can continue up to the elements themselves. In general, low-volatile crude oil components are disintegrated as of approximately 400 °C. The presence of a catalyst lowers the activation energy of this cracking reaction so that the decomposition products are formed already at lower temperatures. Saturated carbohydrates are then transformed into smaller saturated and unsaturated molecules. Cycloalkanes are dehydrated to aromatic compounds, straight-chain molecules to branched-chain molecules, and branched-chain molecules to cyclic molecules.

Tasks

Investigate the cracking of hydrocarbons using a modelexperiment.

Haloalkanes: Wurtz reaction - lithium organyls

P3101100

Benefits
- Didactically demonstrative laboratory gasometer
- Secure connection of the items by GL screw joint system

Learning objectives
- Alkali-organyls
- Lithium organyls
- Wurtz synthesis
- Organometallic compounds

Principle

Unlike the other alkali-organyls, lithium organyls - with the exception of methyllithium - show a stronger covalent behaviour. They dissolve rather well in organic solvents, such as diethylether, tetrahydrofuran, and alkanes, and they are relatively stable in these solvents.

Wurtz synthesis was developed in 1854 for the preparation of higher alkanes based on haloalkanes. Alkyl iodides react the easiest. The reaction can be controlled best with lithium, since the other alkali metals react much more violently. Wurtz synthesis is often a side reaction that occurs during organometallic conversions.

Tasks

Investigate the reaction of ethyl iodide with lithium and the following reaction of ethyllithium with ethyl iodide.

Website

curricuLAB

Toluene: Bromination in the nucleus

P3101300

Benefits
- Secure connection of the items by GL screw joint system
- Stable and safe setup due to solid stand material

Learning objectives
- Bromine
- Toluene
- Lewis acid
- Bromination
- Distillation

Principle

Bromine is polarised and, thereby, activated by zinc chloride as a Lewis acid. It can attach itself in an ionic manner to the toluene nucleus via several complex intermediate stages. Following a dehydrobromination, bromotoluene is formed, i.e. the product of bromination in the nucleus.

In the absence of a catalyst and under the influence of light, however, side-chain bromination takes place via radical intermediate stages. The reaction can be controlled in a targeted manner by varying the reaction conditions.

Tasks

1. Brominate toluene using bromine.
2. Change the reaction conditions to optimize your results.
3. Distillate the resulting mixture.

Website

curricuLAB

P3101500

Preparation of p-toluenesulfonic acid

Website

curricuLAB

Benefits

- Controlled and safe heating via heating mantle and power regulator
- Secure connection of the items by GL screw joint system

Learning objectives

- Electrophilic aromatic substitution
- Sulphonation is a reversible reaction
- Azeotropic distillation

Principle

This experiment examins the formation of p-tolune-sulfonic acid. The sulfonation of toluene with concentrated sulfuric acid is an electrophilic aromatic substitution. This means, the sulphonation of toluene is an electrophilic substitution at the aromatic compound. The sulphonating reagents can be the free sulphur trioxide or the HSO3+ cation, which is present in the concentrated sulphuric acid in equilibrium. Unlike most other electrophilic substitutions, sulphonation is a reversible reaction. If water is present at higher temperatures, hydrolysis is mostly successful. In order to displace the equilibrium towards the desired product, the generated water must be bound or removed from the reaction mixture by way of azeotropic distillation

Tasks

- Prepare p-Toluenesulphonic acid from toluene and concentrated sulphuric acid.

P3101600

Cannizzaro reaction and reaction of benzaldehyde with ethylene glycol

Website

curricuLAB

Benefits

- Experiment including Abbe refractometer
- Controlled and safe heating via heating mantle and power regulator
- Secure connection of the items by GL screw joint system

Learning objectives

- Cannizzaro reaction
- Benzaldehyde
- Acetals
- Distillation
- Micro distillation

Principle

In the first part of the experiment, benzaldehyde disproportionates under the effect of alkalis to alcohol-solublebenzyl alcohol and water-soluble benzoic acid that precipitates when the aqueous solution is acidified. In the second part, benzaldehyde reacts with ethylene glycol to form a cyclic acetal. This ethylene acetal is resistant against basic and oxidising reagents. In an acid medium, it once again splits up into its original products. It is because of these characteristics that cyclic acetals are used for blocking the carbonyl function in preparative, organic chemistry.

Tasks

1. Show the Cannizzaro reaction of benzaldehyde under basic conditions.
2. Prepare benzaldehyde ethylene acetal from benzaldehyde with ethylene glycol.

Fractional distillation with the bubble tray column with CobraSMARTsense

P3031667

Benefits

- Simplified implementation: all pre-settings already prepared
- Didactic gas chromatograph included
- Glass jacket system easily expandable
- Simultaneous temperature measurement at four points

Learning objectives

- Bubble tray column
- Rectification
- Continuous and discontinuous distillation
- Vapour pressure
- Vaporisation
- Condensation
- Raoult's law

Website

curricuLAB

Cobra SMART sense

Principle

In countercurrent distillation (rectification) using a column, the rising vapour can enter into interactions with the condensate. In this manner, a fractional distillation, i.e. a distillation in several steps for the separation of substances with similar boiling points, can be performed in a single apparatus. If bubble tray columns are used condensate can be removed from the individual bubble trays.

Tasks

1. Investigate the mode of operation of a fractionating tower on a two-stage bubble tray column. Distil a mixture of three n-alcanes first with total reflux and then without any reflux.
2. Subsequently, examine and compare the initial mixture, the sump product, the head products and the condensates of both trays.

Kinetics of the inversion of saccharose

P3050301

Benefits

- Easy entry into polarimetry
- Combination of methodological skills and theoretical knowledge

Website

Learning objectives

- Reaction rate
- First order reaction
- Polarimetry
- Optical rotation

curricuLAB

Principle

The inversion reaction of saccharose, which is catalysed by protons, produces invert sugar, which is a mixture of glucose and fructose. The reaction is accompanied by a change in the optical rotation of the system. Glucose rotates the polarisation plane of linearly polarised light to the right, while inverted sugar rotates it to the left. A half-shade polarimeter is used for the measurement of the change in the angle of rotation of polarised light during the inversion reaction of saccharose over time.

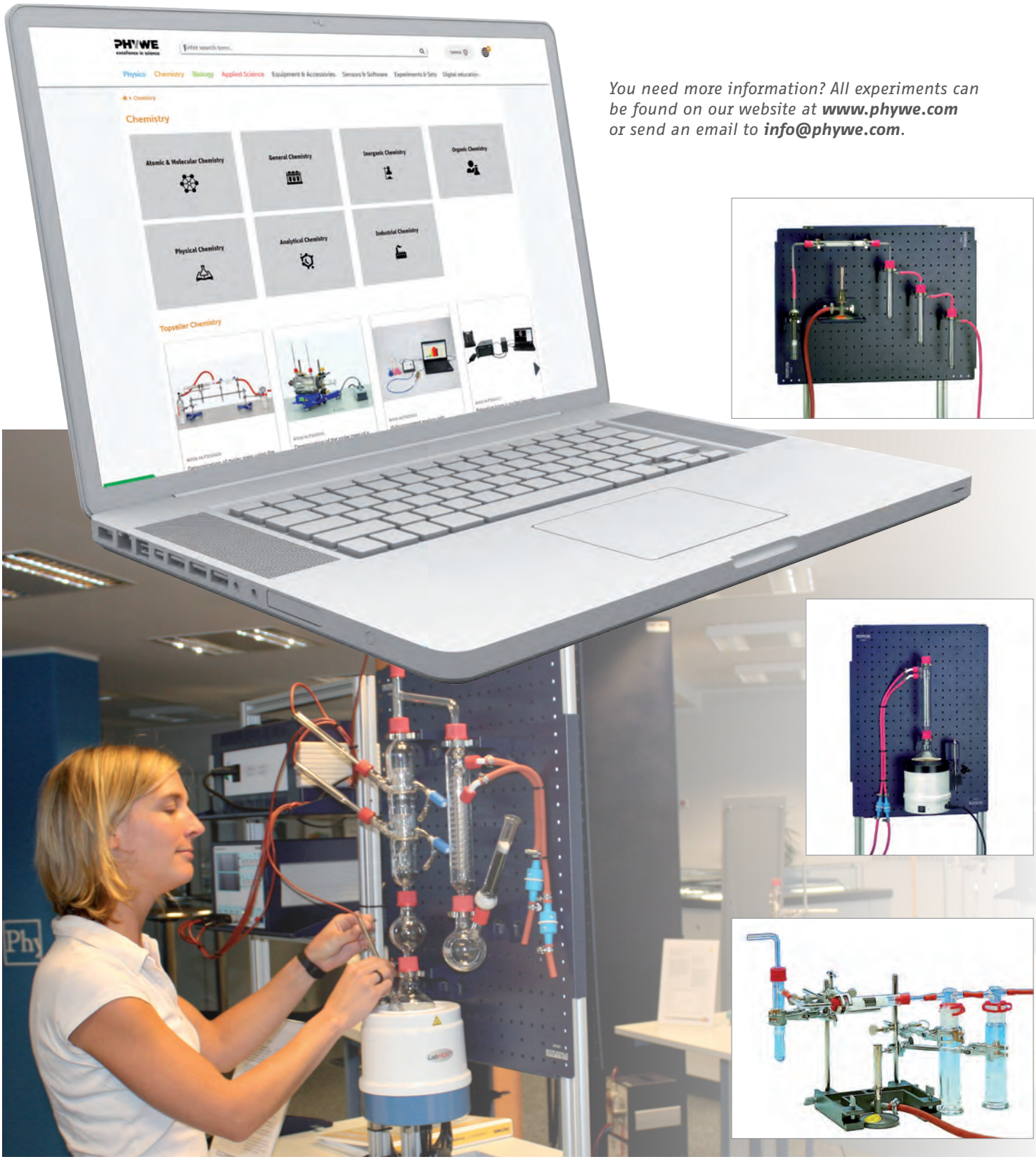
Tasks

1. Determine the specific rotation of saccharose and lactose by measuring the rotation angle of solutions of various concentrations.
2. Determine the rate constant of the inversion of saccharose.

Website

PHYWE Chemistry –
All experiments on our website

*You need more information? All experiments can be found on our website at **www.phywe.com** or send an email to **info@phywe.com**.*

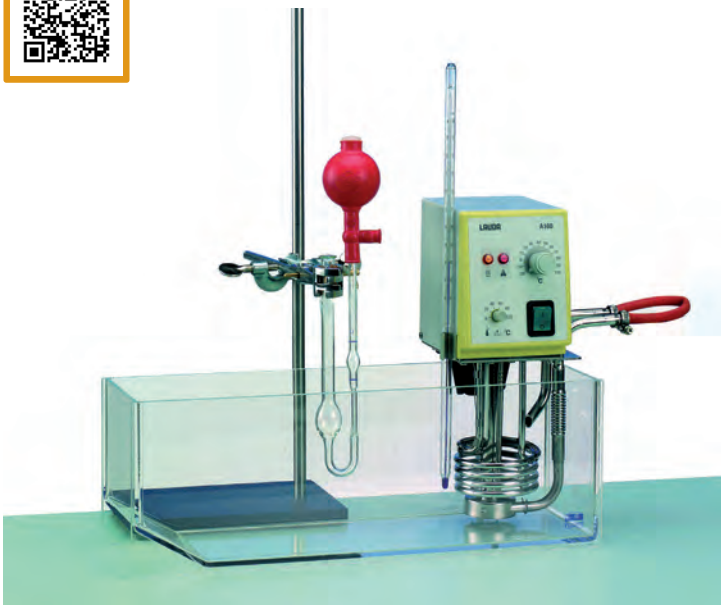


TESS expert - Chemistry

4.3.5 Physical Chemistry

P3010601

Website



Determining the molecular weight of a polymer from intrinsic viscosity measurements

Benefits

- Determination of an important parameter of rheology
- For both demonstration and student experiments

Learning objectives

- Viscosity of liquids
- Ostwald capillary viscometer
- Poiseuilles's equation
- Macromolecules
- Mass average and number average molecular weights
- The Mark-Houwink equation
- Alternative techniques e.g. osmosis
- Sedimentation (ultracentrifuge methods)
- Light scattering

Principle

The viscosity of a liquid is effectively determined by the strength of the intermolecular attractive forces. In the case of solutions, the viscosity of the solvent can alter significantly depending on the type and concentration of the solute. Due to their size, macromolecules have a very considerable impact on the viscosity of the solvent. Viscosity measurements can be used to estimate the mean molecular mass of a macromolecule if something is known about its conformation.

Tasks

1. Use a thermostatted capillary viscometer to measure the viscosities of solutions of polystyrene in toluene over a range of five polymer concentrations.
2. Determine the instrinsic viscosity and from that estimate the molecular weight (relative molecular mass) of the polymer in this solution.

P3020501

Website

Partial molar volumes

Benefits

- An illustrative fundamental experiment in thermodynamics
- Visualising the difference between ideal and real behavior

Learning objectives

- Principles of thermodynamics
- Ideal and non-ideal behaviour of gases and liquids
- Volume contraction
- Molar and partial molar quantities

Principle

Due to intermolecular interactions, the total volume measured when two real liquids (e.g. ethanol and water) are mixed deviates from the total volume calculated from the individual volumes of the two liquids (volume contraction). To describe this non-ideal behaviour in the mixing phase, one defines partial molar quantities which are dependent on the composition of the system. The values of these can be experimentally determined.

Tasks

1. Measure the densities of different ethanol-water mixtures of specified composition at 20 °C with pycnometers.
2. Calculate the real volumes and the mean molar mixing volumes of the investigated ethanol-water mixtures and also the partial molar volumes of each liquid for selected compositions.

Determination of the heat of formation of water

P3021501

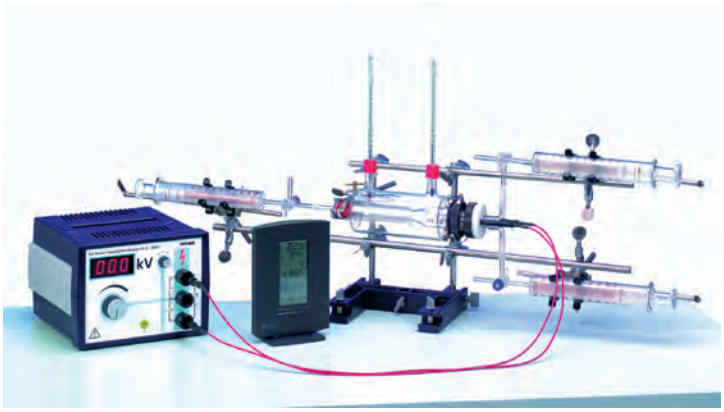
Website

Benefits

- Direct determination of standard enthalpy of formation
- Part of a system solution - glass jacket system easily expandable

Learning objectives

- First law of thermodynamics
- Thermochemistry
- Calorimetry
- Enthalpy of formation
- Enthalpy of reaction



Principle

Standard molar enthalpies of formation $\Delta_B H^{\Phi}$ are important compiled thermodynamics tabulation quantities for calculating standard enthalpies of reaction for any arbitrary reaction. They are defined as the heat of reaction occurring in the direct formation of one mole of the pertinent pure substance from the stable pure elements at constant-pressure. For spontaneous and quantitative formation reactions, e.g. the conversion of hydrogen and oxygen to water, standard enthalpies of formation can be measured directly using calorimetry.

Tasks

Determine the enthalpy of formation of water by burning 100 mlH_2 in a closed glass jacket calorimeter.

curricuLAB

Steam distillation

P3031251

Website

Benefits

- No separate steam generator necessary
- Only one heat source needed

Learning objectives

- Distillation
- Steam distillation
- Etheral oils
- Flavour

Principle

An elegant and simple apparatus for carrying out water vapour distillations: the advantage of this arrangement is that it eliminates the need for a separate vapour generator, making it possible to operate with a single heat source (other set-ups require two). The vapour is generated in the outer chamber and then passes through the inner chamber. Due to the structural arrangement, the inner chamber is heated directly by the vapour generated in the outer chamber. This also eliminates the possibility of overheating the substances being extracted.

Tasks

Extract ethereal oils from parts of plants e g. orange peel and cloves using steam distillation.

curricuLAB

P3040801

Adsorption isotherms

Website

Benefits

- High quality glassware for good results
- Stable and safe construction due to solid stand material

Learning objectives

- Adsorbent and adsorbate
- Henry Freundlich and Langmuir adsorption isotherms
- Volumetry

Principle

In general, the term adsorption is used to describe the attachment of gases or dissolved substances to the surface of a solid or liquid. At constant temperature, the quantity of adsorbed substances is a function of the type of system investigated and the partial pressure and / or concentration of the substance concerned. The correlation is described by a number of adsorption isotherms. The rivalidity is to be investigated experimentally.

Tasks

1. Determine the residual equilibrium concentrations of citric acid of differing initial concentrations.
2. Determine which of the adsorption isotherms is valid for the given system.

P3030401

Boiling point diagram of a binary mixture

Website

Benefits

- Important basic experiment for distillation
- Excellent for the introduction of refractometry

Learning objectives

- Fundamentals of distillation
- Equilibrium diagram
- Chemical potential
- Activity coefficient
- Raoult's law

Principle

A boiling point diagram shows the boiling points of a binary mixture as a function of the vapour / liquid equilibrium of the mixture at constant pressure. The boiling points of various mixtures of methanol and chloroform are measured and the composition of the liquid phases are determined using refractometry and a calibration curve.

Tasks

1. Determine the refractive indices of the pure components and about 10 different mixtures of known composition.
2. Plot the boiling point diagram of the binary mixtures of methanol and chloroform.

Boiling point elevation - Raoult's law

P3021001

Benefits

- Simple presentation and execution by temperature meter 4-2
- Simultaneous display of current temperature and temperature difference
- Compact, easily transportable setup

Learning objectives

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

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.

Tasks

1. Measure the increase in the 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 pellets.
3. Determine the molar mass of the solute from the relationship between the increase in boiling point and the concentration.

Freezing point depression

P3021101

Benefits

- All relevant measured variables at a glance
- Experimentation made easy by intuitive operation
- With detailed experiment guide

Learning objectives

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

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 cryoscopy constants of the solvent are known, the molecular mass of the substance dissolved can be determined.

Tasks

1. Determine the size of freezing point depression after dissolving a strong electrolyte (NaCl) in water.
2. Determine the number of ions into which the electrolyte dissociates.
3. Determine the molar mass of a non-electrolyte (hydroquinone) from the value of freezing point depression.

P3111000

Avogadro's law

Website

curricuLAB

Benefits

- Safe and controlled test procedure by slow eudiometer
- Practical gas bar for storing the gases
- Special heater for glass jacket for optimal temperature control

Learning objectives

- Avogadro's law
- Gas laws
- Carbon monoxide
- Hydrogen
- Chlorine
- Oxygen

Principle

In 1811, Avogadro stated his hypothesis that under the same conditions of pressure and temperature, equal volumes of all gases contain equal numbers of components (molecules, atoms). He derived this from the uniformity of the behaviour of (ideal) gases on increases in temperature and pressure (see the Gas Laws) and the Law of Volumes. When Avogadro's supposition is correct, then 6 parts by volume of CO and 3 parts by volume of O_2 must form 6 parts by volume of CO_2 when pressure and temperature are the same before and after the reaction. Similarly, at a temperature a little above 100°C, a gas mixture containing 6 parts by volume of H_2 and 3 parts by volume of O_2 must give 6 parts by volume of steam, and a mixture containing 5 parts by volume of H_2 and 5 parts by volume of Cl_2 must give 10 parts by volume of HCl.

P3060967

Nernst equation with Cobra SMARTsense

Website

curricuLAB

Cobra SMART sense

Benefits

- Relevant both for chemists and for physicists
- Essential introductory experiment for studying battery technology

Learning objectives

- Electrode potentials and their concentration dependence
- Redox electrodes
- Electrochemical cells

Principle

The Nernst equation states how the electrical potential of an electrode in contact with an ionic solution depends on the concentrations (more precisely, activities) of these ions. The equation can be verified experimentally by using an electrochemical cell consisting of an inert indicator electrode coupled to a suitable reference electrode (here in the form of an ORP combination electrode).

Tasks

Measure the potential of a platinum electrode with our ORP electrode immersed in solutions of known concentrations of the iron(II) and iron(III) complex ions [Fe(CN)6]4 - and [Fe(CN)6]3-.

Conductivity of strong and weak electrolytes with Cobra SMARTsense

P3060667

Website

curricuLAB

Cobra SMART sense

Benefits

- With detailed experiment guide
- Simplified implementation: all pre-settings already prepared
- Easy evaluation via software

Learning objectives

- Kohlrausch's law
- Equivalent conductivity
- Temperature-dependence of conductivity
- Ostwald's dilution law

Principle

It is possible to differentiate between strong and weak electrolytes by measuring their electrical conductance. Strong electrolytes follow Kohlrausch's law, whereas weak electrolytes are described by Ostwald's dilution law. The examination of the concentration dependence of the conductivity allows the molar conductivities of infinitely diluted electrolytes to be determined, and facilitates the calculation of degree of dissociation and the dissociation constants of weak electrolytes.

Tasks

1. Determine the concentration dependence of the electrical conductivity of potassium chloride and acetic acid solutions.
2. Calculate the molar conductivity and determine the molar conductivity at infinite dilution by extrapolation.

More information about our Cobra SMARTsense sensors are available on our website at
www.phywe.com/sensors-software/cobra-smartsense/

43011-88

Digital set calorimetry with the glass jacket for 3 experiments

Website

NEW

Cobra SMART sense

Function and Applications

Whether demonstrating Hess's law or determining calorific values of solids, gases or solid substances. Everything is possible with this set: easily and safely!

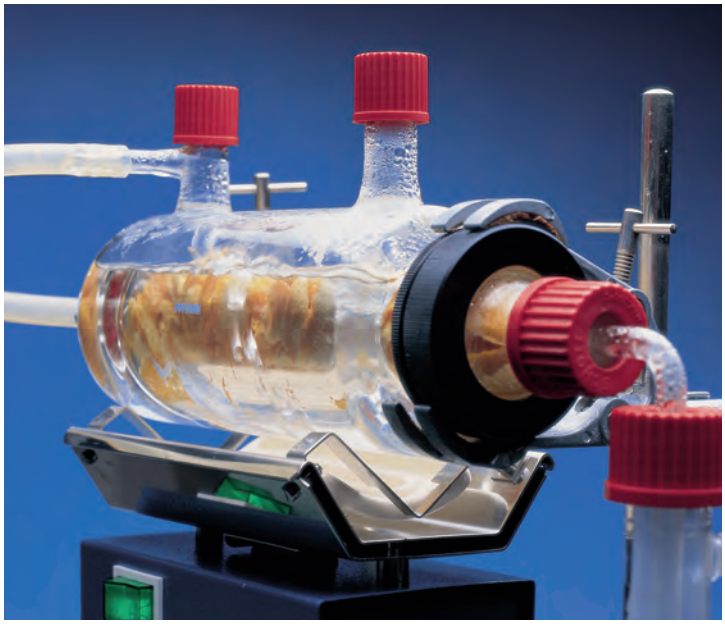
The core component is the PHYWE glass jacket with its calorimeter insert and gas combustion lance. The glass jacket protects the teacher or student from possible injury hazards, but also the special glass parts from the experimenter, so you can enjoy working with the quality items for a long time. Combined with the Cobra SMARTsense sensors, the glassware provides a real-time record of any temperature change.

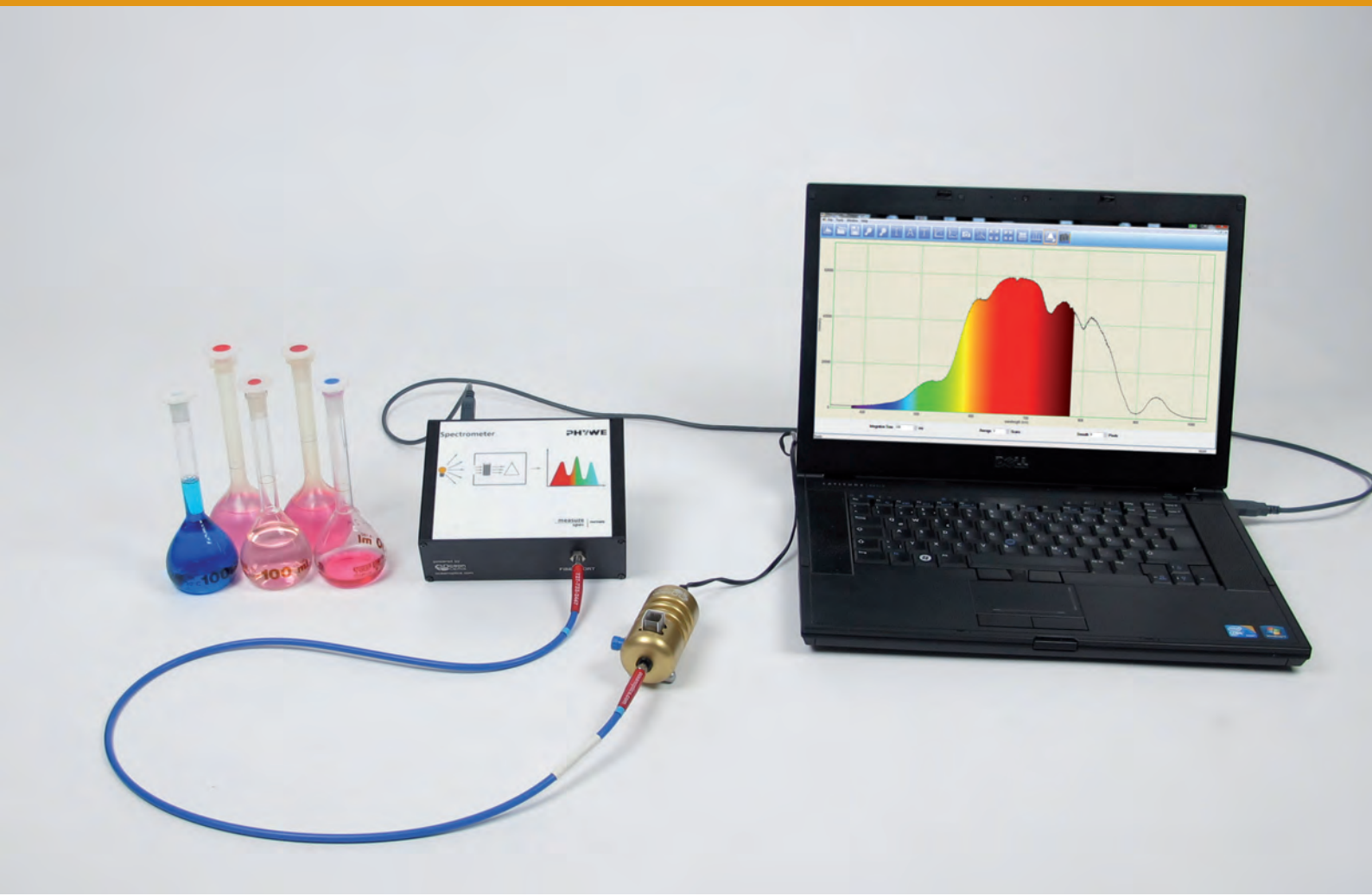
Benefits

- All components for 3 experiments in one convenient set:
  1.) Hess's law
  2.) Determing calorific values of solids and gases
  3.) Determing calorific values of solid substances
- Real-time data acquisition through state-of-the-art data loggers
- Safe experiments due to the glass jacket system
- Easy to set up
- High quality components
- No black box: the pupils and students can observe all processes

Equipment and Technical Data

- The equipment set consists of all components necessary for the experiments
- The consumables are available in a separate set
- 2x Cobra SMARTsense - Thermocouple (Bluetooth + USB): measuring range: -200°C ... 1200°C; resolution: 0.4°C; sampling rate: 10 Hz
- The matching immersion probes (13615-05) are part of the scope of delivery





TESS expert - Chemistry

4.3.6 Spectroscopy

P2544705

Qualitative X-ray fluorescence analysis of powder samples

Website

curricuLAB

Benefits

- High resolution energy detector
- Direct energy measurements by multichannel analyser
- Multipurpose x-ray unit

Learning objectives

- Bremsstrahlung
- Characteristic X-radiation
- Energy levels
- Fluorescent yield
- Semiconductor energy detectors
- Multichannel analyse

Principle

Various powder 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 multichannel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined. The elements of the samples are identified by comparing the line energies with the corresponding table values.

Tasks

1. Calibrate the semiconductor energy detector with the aid of the characteristic radiation of the tungsten X-ray tube.
2. Record the fluorescence spectra that are produced by the samples.
3. Determine the energy values of the corresponding fluorescence lines and compare the experimental energy values with the corresponding table values in order to identify the powder components.

PHYWE Compact magnetic resonance tomograph (MRT)

09500-99

Website

Function and Applications

Fully functional Magnetic Resonance Tomograph (MRT) for teaching purposes, covering all aspects from the basic principles of Nuclear Magnetic Resonance (NMR) to the high-resolution 2D and 3D MR imaging (MRI). It provides a comprehensive education experience by training with clinically relevant measuring procedures, high resolution MR imaging (2D, 3D), live visualisation of data, realtime control of experimental parameters, determination of Larmor frequency, T1/T2 measurements, all MR parameters accessible, measurement of a multitude of samples with a diameter of up to one centimeter, software-driven didactical approach and suitable for a wide range of experiments.

Benefits

- Complete, easy to install and affordable MRT education system
- One system to cover all aspects from NMR basics to sophisticated 2D and 3D imaging sequences
- Detailed experiment guides included
- Learning results guaranteed thanks to easy to manage course steps
- Can be set up at any location in the student lab
- Experience the realistic sound of the different MR sequences

Equipment and Technical Data

The system includes the following components:

- Control unit:
- Gradient amplifier, transmitter and receiver unit
- Power supply: 12 V DC, 2 A
- Power supply unit (external): 100-240 VAC, 50/60 Hz, 2 A

Electron spin resonance

P2511201

Website

Benefits

- Easy and fast experiment setup

Learning objectives

- Zeeman effect
- Energy quantum
- Quantum number
- Resonance
- g-factor
- Landé factor

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 half-width of the absorption line are determined, using the ESR apparatus.

Tasks

1. Determine the g-factor (Landé-factor) of the DPPH (Diphenylpicryl-hydrazyl) specimen.
2. Determine the FWHM (Full Width at Half Maximum) of the absorption line.

curricuLAB

35620-00

Fibre-optics spectrophotometer

Website

Function and Applications

The spectrometer Pro LED is a specially developed instrument for science education. It is easy to use and its intuitive integrated software provides a unique environment for visualizing, measuring, comparing and evaluating spectroscopic data. A glass fiber mount is available to keep your hands free during the experiments. The light to be examined is coupled via the optical fiber to the spectrometer, where it is directed to a fixed grid and thus spectrally decomposed. The spectrum is recorded by means of a CCD array, so that the complete spectrum is recorded in one go, which makes it possible to reliably detect even rapid changes in a spectrum. The integrated software in the device requires no installation and can be used immediately after connecting the spectrometer via USB interface with the PC. Power is supplied via a separate 12V power supply, which is included in the delivery.

Benefits

- Robust metal case
- Rapid measurements of full spectral range
- Flexible introduction of light to be investigated by means of an optical fibre
- 12 V power supply for the spectrometer and the light source included
- Measurement of emission and absorption spectra throughout the whole visible spectral range and parts of IR and UV
- Integrated measurement software doesn't require an installation

Equipment and Technical Data

Spectrometer

- Dimensions (mm): 133 x 120 x 60
- Mass: 950 g
- Structure: Metal case

P7110169

Lambert-Beer's law and photometry of copper sulfate solutions with Cobra SMARTsense

Website

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions.
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones.

Learning objectives

- Lambert-Beer´s Law
- Principle of photometry

Principle

There is a correlation between the absorption of monochromatic light radiated through a liquid sample and the concentration of the sample. This relationship is represented by Lambert-Beer's law. In this experiment the correlation between absorption (or transmission) and concentration of the measured solution is investigated. The validity of Lambert-Beer's law is also proven.

Tasks

The students prepare a copper sulfate stock solution with known concentration. Using the copper sulfate stock solution, different (diluted) copper sulfate solutions are prepared and the relationship between concentration and absorption is investigated. Afterwards the concentration of another copper sulfate solution is to be determined.

Spectrophotometer WPA S800+, 325...1100 nm

35603-99

Website

Function and Applications

This visible diode array spectrophotometer has been designed to meet the routine spectroscopy needs of customers requiring a small, light-weight instrument that is easy to use. This photometer is ideal for use in educational, biotech or industrial establishments.

Benefits

- Measures absorbance, % transmission, absorbance ratio and concentration
- Large backlit LCD graphical display enables wavelength scans, kinetic assays (including slope calculation) and standard curves to be viewed
- Delivered with „PVC", a PC utility software package, providing the user with the means to capture, print and store data from the instrument on to a PC
- Cell holder accepts standard 10 mm pathlength glass or plastic cuvettes
- Splashproof touch-sensitive keyboard
- Measuring methods: absorbance; transmission; kinetical tests (absorbance and time-curves)

Equipment and Technical Data

- Optical system: single beam device with diode array
- Lamp source: tungsten
- Wavelength range: 325...1100 nm
- Wavelength accuracy: ± 2 nm
- Bandwidth: <7 nm
- Absorbance range: -0.300...2.500 Abs
- Photometric reproducibility: <0.002 Abs at 0 Abs and 500 nm
- Photometric accuracy:±0.01 Abs at 1 Abs
- Cell holder for standard cuvettes with outside dimension: 12 mm x 12 mm
- Dimension (cm): 33 x 23 x 13

UV-VIS spectrophotometer T70 with monitor 190 - 1100 nm

35658-99

Website

Function and Applications

T70 UV/VIS Double Beam Spectrophotometer with a wavelength range of 190 - 1100nm and a Fixed Bandpass. The system is supplied with an 8 cell (10mm x 10mm) motorised cell changer.

Benefits

- Special functions available when connected to a computer
- High degree of automation requiring minimal key depressions to start analysis
- Supplied with a motorised 8-cell changer and pre-aligned Tungsten and Deuterium lamps

Equipment and Technical Data

- Optical system: Split beam ratio
- Scan speed: Selectable
- Wavelength range: 190 - 1100 nm
- Wavelength accuracy: +/- 0.3 nm
- Spectral bandwidth: 2 nm
- Photometric modes: Transmittance, absorbance, energy concentration
- Standard functionality: Photometric, quantitative, spectrum and DNA measurements
- Cell holder: Automatic 8 cell changer
- Detector: Silicon photo diode
- Light sources: Tungsten halogen and deuterium arc lamps
- Display: Digital LCD display
- Scope of delivery: 1 x UV/VIS spectrophotometer for the measurement range 190 to 1100 nm
- 2 x 10 mm quartz cells
- 1 x Spare tungsten halogen lamp
- 1 x Black block (for dark current)

12924-01

Website

Cobra SMARTsense - Colorimeter, 0 ... 100 % (Bluetooth + USB)

Simple. Intuitive. Measurement.

Perfect for student experiments.

Function and Applications

Cobra SMARTsense is the ideal solution for inexpensive digitalization of science teaching. The sensors connect wirelessly (Bluetooth) or wired (USB) directly to the student's digital end device (smartphone, tablet or desktop PC). Using the free and award-winning measureAPP measurement software for iOS, Android and Windows, measured values can be easily recorded and graphically displayed.

Use the colorimeter sensor to measure the transmittance or absorbance of samples at different wavelengths. In addition, turbidity, for example of water samples, can also be determined directly in this way.

Benefits

- **Simplicity** - Get started right away with the Bluetooth-enabled end device and the free measureAPP
- **Completeness** - Over 40 sensors with more than 70 measured quantities for all subjects
- **Endurance** - Intelligent and efficient power management for up to 50 hours on one battery charge
- **Variety** - The free measureAPP provides perfect support and runs on all mobile platforms and end devices. For professionals, measureLAB is available.
- **Performance** - Up to 32,000 measured values per second guarantee precision and recordings with up to 17 measuring channels simulaneously are possible.
- **Connectivity** - Fast connection of sensors and data exchange via Bluetooth - for many sensors additionally possible via USB.

35630-00

Website

curricuLAB

Fibre-optics compact spectrophotometer

Function and Applications

The compact spectrometer is a specially developed compact instrument for science education. It is easy to use and its accompanying software provides diverse possibilities for visualizing, measuring, comparing and evaluating spectroscopic data. For the measurement of optical spectra the included cuvettes simply have to be inserted into the spectrometer. By means of the included optical fiber cuvette adapter it is for example also possible to measure external light sources. The internal fixed grid decomposes the light spectrally. The spectrum is recorded by means of a CCD array, so that the complete spectrum is recorded in one go, which makes it possible to reliably detect even rapid changes in a spectrum. The software is especially designed for this spectrometer and can be downloaded for free. The power supply is provided through four AA batteries (not included).

Benefits

- Compact All-in-one device for rapid measurements of full spectral range
- No separate light source required
- The optical fibre cuvette adapter allows for flexible recording of external light sources
- Measurement of emission and absorption spectra throughout the whole visible spectral range and parts of IR and UV

TESS expert - Chemistry

4.3.7 Industrial Chemistry

P3110400

Website

curricuLAB

Sulphur trioxide - the sulphuric acid contact process

Benefits

- Stable and safe setup due to solid stand material
- Secure connection of the items by GL screw joint system

Learning objectives

- Sulphur trioxide
- Sulphuric acid
- Contact process
- Oxidation
- Redox reaction

Principle

The contact process is currently used in the chemical industry to produce sulphuric acid in the high concentrations needed for industrial processes. In this model experiment, platinum-palladium-aluminium-oxide beads are employed as a catalyst for the reaction.

Tasks

1. Oxidise sulphur dioxide to sulphur trioxide.
2. Use the sulphur trioxide to produce sulphuric acid.

P3110500

Website

curricuLAB

Preparation of iron from oxidic ores (blast furnace process)

Benefits

- Illustrative presentation of the blast furnace process
- Secure connection of the items by GL screw joint system

Learning objectives

- Iron
- Blast furnace process
- Slug
- Production of iron
- Reduction
- Oxidation

Principle

This is a model experiment to show the industrial blast furnace process to produce iron from iron(III) oxide. During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

Tasks

1. Investigate the reduction fo iron(III) oxide to Iron(II) oxide.
2. Show the blast furnace process in a model experiment.

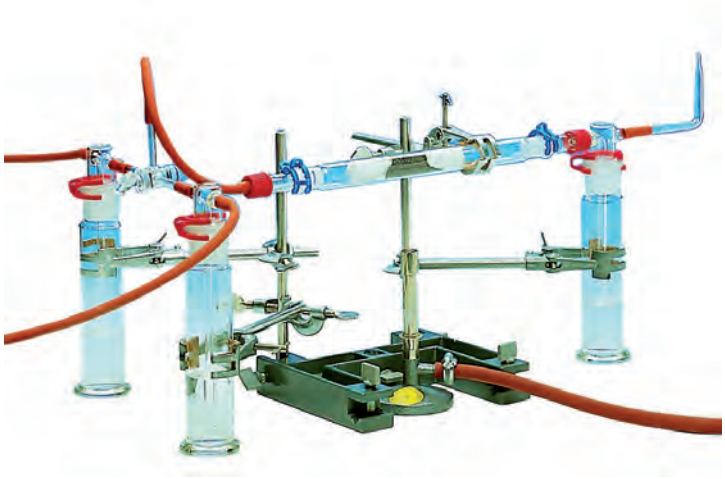
Ammonia preparation from the elements (Haber-Bosch process)

P3110200

Website

Benefits

- Representation of an important industrial process on a small scale
- Secure connection of the items by GL screw joint system
- Stable and safe setup due to solid stand material



Learning objectives

- Ammonia preparation from the elements
- Haber-Bosch process
- Ammonia
- Redox reaction

Principle

The Haber-Bosch process was the first large-scale technical method for producing nitrogen compounds based on the nitrogen in the air. The formation of ammonia benefits from a falling temperature and rising pressure since it is an exothermic reaction that is accompanied by a decrease in volume. At room temperature, however, the reaction rate would be so small that it could not be measured. In addition, current catalysts are only effective at higher temperatures (approximately 400-500 °C). If these temperatures are used at normal pressure, the ammonia yield is approximately 0.1% by volume. Technical processes, in which the pressure is increased in a continuous process, yield approximately 11% (establishment of equilibrium at 200 bar: 17.6% of ammonia).

Tasks

Demonstrate the principle of the Haber-Bosch process.

curricuLAB

Combustion of ammonia to produce nitrogen dioxide - Ostwald process

P3110300

Website

Benefits

- Introduction to the Ostwald process
- Practical water jet pump for easy generation of the required negative pressure
- Stable and safe setup due to solid stand material

Learning objectives

- Ostwald process
- Ammonia
- Nitrogen dioxide
- Nitrogen monoxide
- Nitric acid

Principle

In the presence of a suitable catalyst and while giving off heat, ammonia-air mixtures burn and form nitrogen monoxide and water. Nitrogen monoxide reacts immediately with the excess oxygen, thereby forming nitrogen dioxide.At higher temperatures, nitrogen monoxide is decomposed into nitrogen and oxygen. In the presence of water and oxygen, nitrogen dioxide forms nitric acid. On a large industrial scale, the combustion of ammonia with atmospheric oxygen is performed under contact with platinum (Ostwald process).

Tasks

Burn an ammonia-air mixture in the presence of a catalyst (platinum-palladium-aluminium-oxide beads) and prove the resulting nitrogen oxide.

curricuLAB

P1308969

Website

curricuLAB

Distillation - determination of the alcohol content of wine

Benefits

- Stable and safe setup on demonstration board
- Illustrative presentation of the distillation process including digital datalogging

Learning objectives

- Ethanol
- Distillation

Principle

If the alcohol content of a wine is determined directly with an alcohol meter (hydrometer), the resulting alcohol content reading is approximately 0% by volume. This is due to the composition of the wine. The effect of the alcohol on the density is cancelled out by other components such as sugars, acids, essential oils, etc..

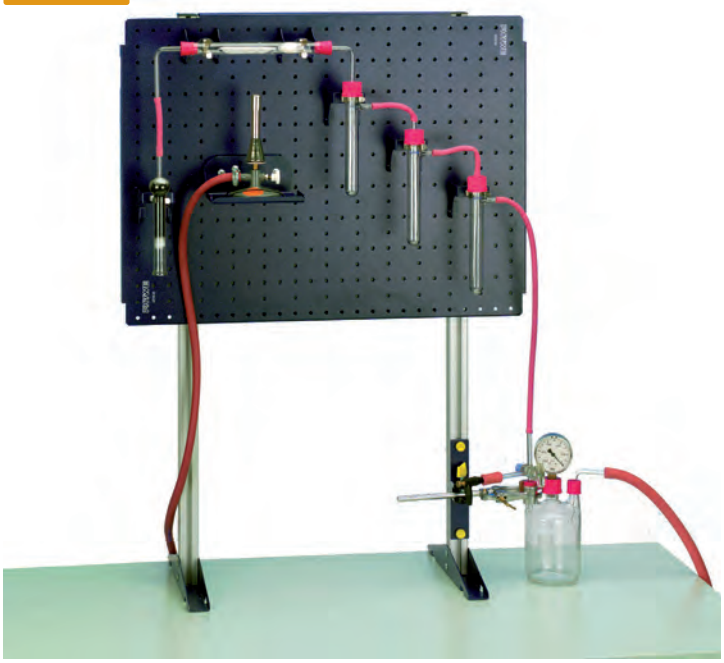
For this reason, in order to determine alcohol content by density, the alcohol must be separated out by means of distillation prior to the determination. This corresponds to the official method which currently applies for measuring alcohol in wines. First the wine is titrated to neutrality against bromothymol blue. After transfer to the distillation apparatus, two thirds of this wine sample is distilled off into the receiver flask. Subsequently the distillate is filled back up to the original volume again. Now the density is measured with a pycnometer or hydrometer.

Tasks

Distillate a sample of wine to determine the content of ethanol.

P1310000

Website



Model experiment on the desulphurisation of flue gas

Benefits

- Stable and safe experiment setup
- Illustrative Introduction to Desulphurisation

Learning objectives

- Environmental hazard due to sulfur dioxide
- Functioning of a flue gas desulphurisation plant

Principle

German coal contains an average of one tonne of sulphur per 100 tons of coal. The combustion of this 100 tons of coal „produces“ about two tonnes of sulphur dioxide. In comparison a large 700 megawatt power plant which burns about 200 tons of coal per hour produces about 100 tons of sulphur dioxide per day. Due to the environmental hazard of sulphur dioxide these flue gases have to be desulphurised. This experiment shows a simple demonstration of the chemical processes of flue gas desulphurisation like in power plants today.

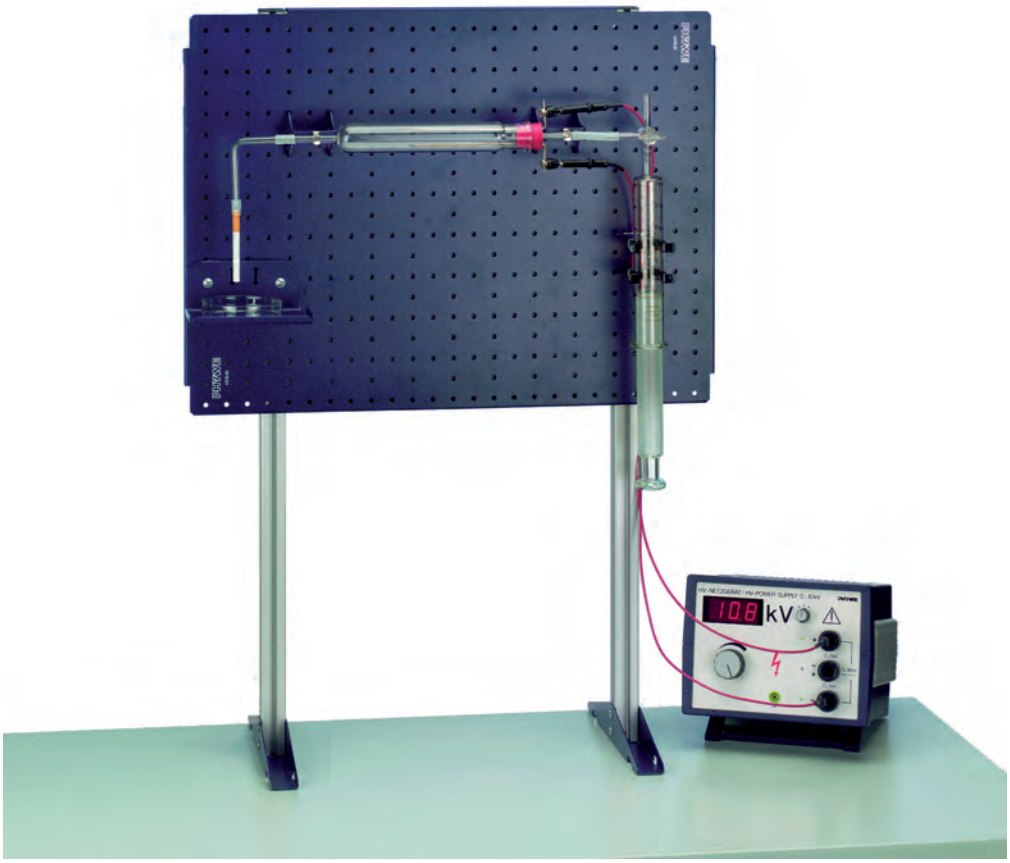
Tasks

Clean flue gas using limestone and describe the underlying chemical process.

Electrostatic flue gas cleaning

P1309200

Website



Benefits

- Easy experiment set-up and safe experiment performance
- Demonstration with cigarette smoke - no additional chemical substance is necessary

Learning objectives

- Introduction to gas purification systems
- Effect of an electrostatic filter for the separation process
- How an electrostatic flue gas cleaning works

Principle

Smoke consists of particles of solid substances suspended in gas. Fog is made up of suspended droplets. In cigarette smoke, as in many industrial processes, smoke and fog are frequently present together. The removal of particles contained in gases - predominately waste gases - is increasingly gaining in importance, both in everyday life and industrially, because frequently the particles and the substances absorbed on them are toxic. Well known examples are adsorbed polycyclic aromatics on soot particles in diesel exhaust, and dioxins, heavy metals and radioactive elements in waste gases from power stations and waste incinerators.

The experimental set-up used here also enables constituents of cigarette smoke to be semi-quantitatively deposited even in quite large amounts, so that they can be extracted with light petrol and be examined.

Tasks

Clean cigarette smoke using high voltage.

P3031501

Rectification - the number of theoretical trays in a distillation column

Website

curricuLAB

Benefits

- Complete insight into all running processes, because all components have an evacuated, but not silvered isolating-coat
- Simple withdrawel of samples through 2 column intermediate pieces
- High separation efficiency through 2 large packed columns
- Secure, because the high-efficiency condensor of the column head also condense high-volatile liquids
- Simple adjustment of the reflux ratios through onehand-controlled column head

Learning objectives

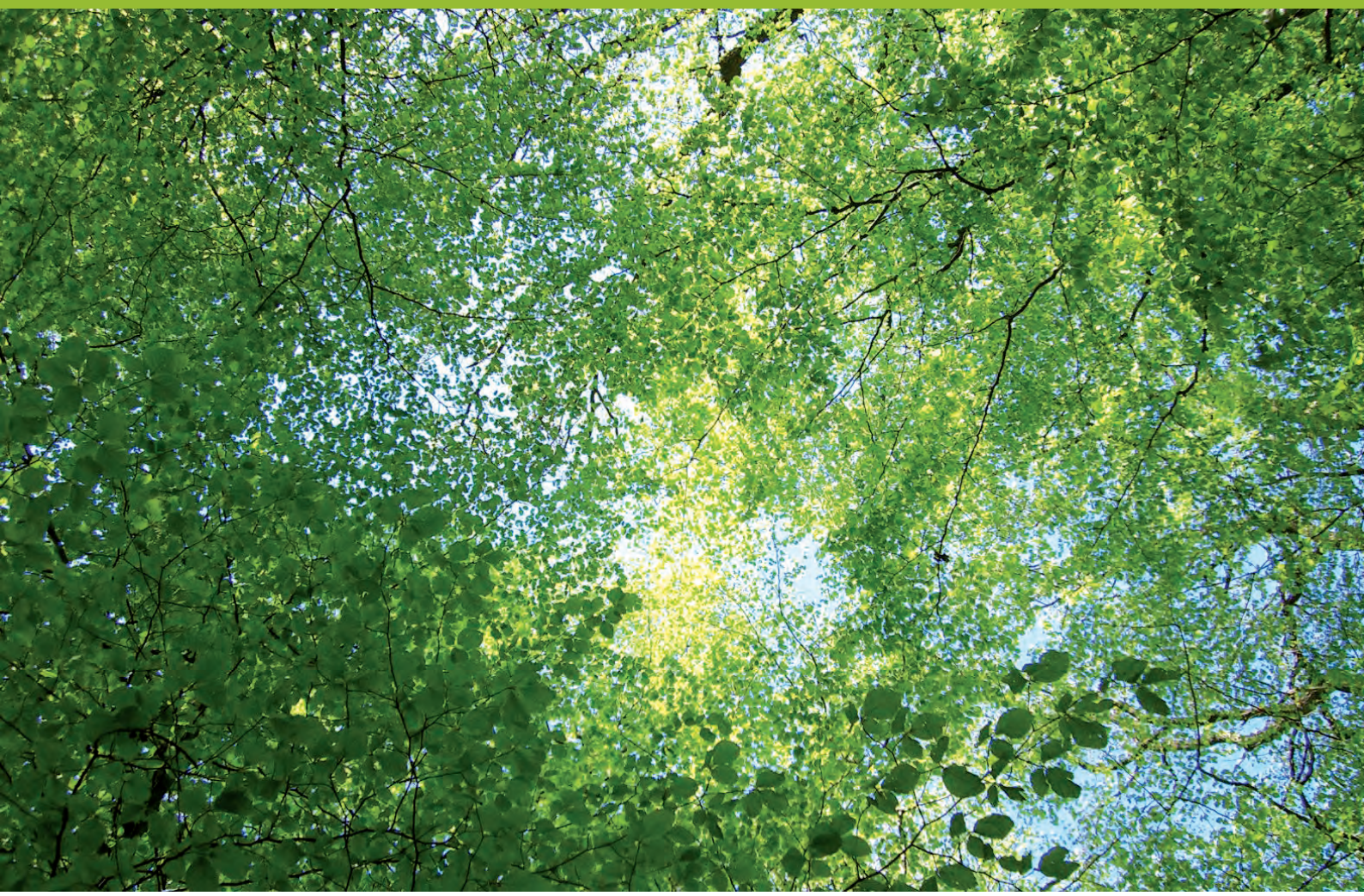
- Bubble tray column
- Rectification
- Raoult's law
- Henry's / Dalton's law
- Boiling-point diagram
- Reflux ratio

Principle

The separation power of a rectification (fractionating) column can be determined using an appropriate binary mixture whose equilibrium composition is measured in the distillation flask and in the domed glass head of the distillation apparatus. The number of theoretical trays can be numerically or graphically obtained from the measured values.

Tasks

1. Prepare 10 mixtures of methyl cyclohexane and *n*-heptane with substance ratios (mole fractions) from 0 to 1 and with step width of approximately 0.1. To record a calibration curve, determine the refractive indices of the mixtures and plot them against the mole fractions.
2. Distill a mixture of methyl cyclohexane and *n*-heptanein a recti-fication column with total reflux until an equilibrium has been established. Determine the composition of the condensate and the number of theoretical trays in the column for a through put of 500 and 1000 ml/h.



TESS expert - Biology

4.4.1 Botany, Plant Physiology & Ecology

P4110269

Website

curricuLAB

Photosynthesis (measurement of oxygen pressure) with Cobra SMARTsense

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Learning objectives

- Photosynthesis
- Intensity and color of light
- Pressure measurement

Principle

Representation of the photosynthesis performance of a plant by measuring the increase in oxygen pressure in white and green light or in the dark.

Tasks

- Comparison of oxygen pressure increase during photosynthesis under white light, green light and without light
- Discussion of the reasons for the differences in the rise of the printing curve

Cobra SMART sense

P4110669

Website

curricuLAB

Photosynthesis and cellular respiration in plants with Cobra SMARTsense

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Compact, easily transportable experimental set-up
- Suitable for demo experiments and lab courses

Learning objectives

- Photosynthesis
- Cellular respiration
- Oxygen
- Carbon dioxide
- Carbon cycle

Principle

This experiment shows that oxygen is produced during photosynthesis when the plant is exposed to light, while oxygen is consumed in the dark by the cellular respiration of the plant.

Tasks

1. Determination of oxygen formation during photosynthesis
2. Determination of oxygen consumption during cellular respiration

Cobra SMART sense

Transpiration of leaves with Cobra SMARTsense

P4110369

Website

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Compact, easily transportable experimental set-up
- Suitable both as demo experiment and lab course experiment

Learning objectives

- Transpiration
- Water and nutrient transport
- Wind effect
- Temperature influence
- Humidity influence
- Influence of the different leaf types

Principle

The transpiration of the plants serves to transport water and nutrients from the roots to the leaves. In the experiment, the pressure drop is measured which is caused by the water release of the leaves into the environment and which ensures the necessary flow of water from the soil.

Tasks

1. Measurement of transpiration under different environmental conditions and creation of pressure curves
2. Discussion of the differences between the different pressure curves

Cobra SMART sense

Osmosis - dependence of the osmotic pressure on the concentration

P1135700

Website

Benefits

- Quantitative determination of the osmosis processes
- Multiple measurement points permit detailed analysis
- Scalable experiment: number of measurement points can be varied

Learning objectives

- Osmosis
- Osmotic pressure
- Concentration

Principle

Osmosis describes the phenomenon that solvent molecules move through a partially permeable membrane into a region of higher solute concentration. Thus, the concentration of solute is equalized on both sides. The experimental set-up consists of seven chambers that are filled with solutions of sugar with different concentrations. The liquid column in the capillaries is determined and the dependence of the osmotic pressure on the concentration can easily be shown.

Tasks

1. Investigate the phenomenom of osmosis in a simple model experiment.
2. Determine the dependence of osmotic pressure on concentration of dissolved molecules.

P4100969

Analysis of plant pigments with Cobra SMARTsense

Website

curricuLAB

Cobra SMART sense

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Compact, easily transportable experimental set-up
- Suitable for demo experiments and lab course experiments

Learning objectives

- Diversity of plant pigments
- Detection with a colorimeter

Principle

Not only flowers of plants but also their fruits and leaves are dyed due to pigments. In this experiment, the different pigments of flowers and leaves are investigated. This experiment is performed with a colorimeter. This device sends light of a certain wavelength through a solution and measures by how much the intensity has decreased after passing through the solution.

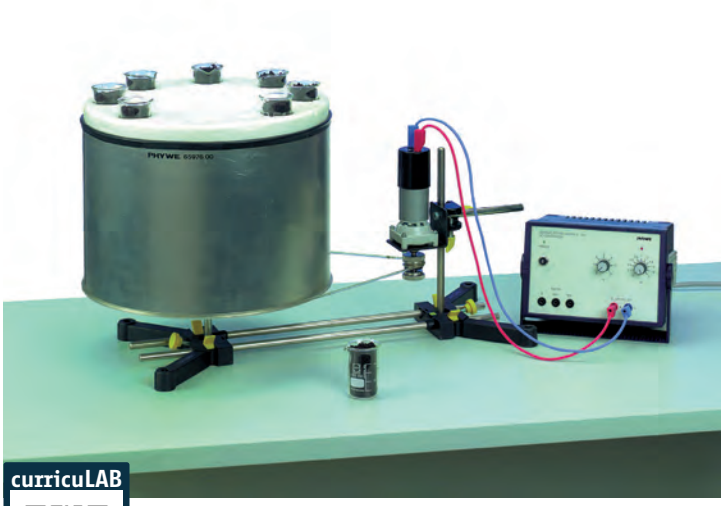
Tasks

1. Extraction of various plant dyes and measurement of their absorption with a colorimeter
2. Extraction of dyes from different plants

P4050200

The effect of gravity and centrifugal force on plants

Website



curricuLAB

Benefits

- Quantitative determination of gravity effects on plant growth

Learning objectives

- Positive geotropism of roots
- Negative geotropism of shoots
- Centrifugal force and rotational speed
- Statoliths
- Geotropism

Principle

The main shoot of a plant generally follows a perpendicular direction away from the centre of gravity of the earth (negative geotropism), whereas the main root grows towards the centre of gravity (positive geotropism). If however the plant is placed on a rotating horizontal disk, this will alter the direction of growth of the shoot and of the root.

Tasks

1. Measure the alignment of shoots and roots under the effect of centrifugal forces which are less than, equal to or greater than gravity
2. Raise sunflower seedlings in small beakers in a rotating drum
3. Set different centrifugal forces by changing the speed of rotation of the drum motor.

Glycolysis (temperature measurement) with Cobra SMARTsense

P4110569

Website

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Learning objectives

- Glycolysis
- Yeast fermentation of sugar
- Temperature measurement
- Breathing energy

Principle

Investigation of the temperature increase during the fermentation of sugar by yeast cells. The experiment allows to address metabolic processes such as glycolysis, fermentation, aerobic and anaerobic respiration and the pasteurization effect.

Tasks

1. Illustration of the temperature increase as a result of the fermentation of sugar by yeast
2. Comparison of temperature curves of samples with and without yeast

curricuLAB

Cobra SMART sense

Glycolysis (pressure measurement) with Cobra SMARTsense

P4110469

Website

Benefits

- Especially understandable and didactically prepared experiment guide (reference to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Learning objectives

- Glycolysis
- Yeast fermentation of sugar
- C02 pressure measurement
- Influence of temperature and pH

Principle

Detection of glycolysis by measuring the C02 production under different experimental conditions (temperature, pH).

Tasks

1. Detection of glycolysis by measuring the C02 production
2. Examination of the influence of temperature and pH on metabolic activity

curricuLAB

Cobra SMART sense

12628-89D

Student set Environment and outdoors digital, TESS advanced Biology

Website

curricuLAB

Cobra SMART sense

Complete set for ecological measurements

Function and Applications

The digital set allows you to use the latest measurement technology for your environmental and outdoor analysis and is very easy to use. In addition to classic parameters such as temperature, air pressure, brightness, relative humidity, pH, conductivity and water turbidity, the weather station allows you to make complete weather observations and even collect GPS data in the field. The Cobra SMARTlink can not only be used as an interface for the sensors, but also offers additional flexibility for group work with its built-in sensors.

Benefits

- Whether in the classroom, outdoors or on project days: in this robust aluminium case, you will always find the right device for carrying out fascinating experiments with school groups.
- Several student groups can work on and investigate interesting topics in parallel.
- Works with all iOS and Android devices
- Download free app from Apple App Store or Google PlayStore
- Students can evaluate the data at home, as a homework assignment.
- This device is also ideal for use e.g. in the context of a school hiking day: here, a topographic profile can easily be produced with the weather sensor. In geography lessons, the data can be evaluated and interpreted together. If the height is then set against the temperature, humidity relative to the path, or temperature relative to the time of day, great discoveries can be made, which are both practical and fun.

Equipment and Technical Data

- Robust aluminium case
- 1 x Cobra SMARTlink
- 1 x Cobra SMARTsense - Weatherstation (Bluetooth + USB)
- 1 x Cobra SMARTsense - Relative Humidity, 0 ... 100 %
- 1 x Cobra SMARTsense - pH, 0 ... 14
- 1 x Cobra SMARTsense - Conductivity, 0 ... 20000 µS/cm
- 1 x Cobra SMARTsense - Temperature, - 40 ... 120 °C
- 1 x Cobra SMARTsense - Absolute Pressure, 20...400 kPa
- 1 x Cobra SMARTsense - Light, 1 ... 128 kLX
- 1 x Cobra SMARTsense - Colorimeter for the measurement of turbidity, 0 ... 100 %
- 1 x pH electrode, plastic, gel-filled
- 1 x 100 red pH 4 buffer tablets
- 1 x 100 green pH 10 buffer tablets
- 5 x 20 ml calibration solution for conductivity electrode
- 2 x protective case for pH and conductivity electrodes
- 1 x 120 labels
- 4 x 100 ml square flange (HDPE)
- 2 x 250 ml PP laboratory beaker

Creating an ecosystem with Cobra SMARTsense

P1523969

Website

curricuLAB

Cobra SMART sense

Benefits

- Development of an independent ecosystem in the classroom
- Evolution can be observed through the transparent chambers
- Changes in measurement parameters can be recorded and documented through the Cobra SMARTsense sensors

Learning objectives

- Interaction of ecosystems
- Influence of the changes in one ecosystem on others

Principle

Different environmental environments are created in the three chambers, which are interconnected. This is a long-term experiment that can be continuously monitored and measurements can be taken.

Tasks

1. The students create different environments in the three chambers.
2. In a second work step, the students observe the ecosystem they have created and measure various, relevant environmental factors.
3. In a third work step, the students change some factors in their ecosystem (light, temperature, ...) and observe the changes that occur as a result.

More information about our Cobra SMARTsense sensors are available on our website at
www.phywe.com/sensors-software/cobra-smartsense/

Website

PHYWE Biology –
All experiments on our website

*You need more information? All experiments can be found on our website at **www.phywe.com** or send an email to **info@phywe.com**.*

TESS expert - Biology

4.4.2 Zoology

P4060200

Preferential temperature in insects

Benefits

- Precise measurement possible with 12 different temperature zones
- Allows to set up a wide temperature range
- In the ring-shaped measurement setup the animals can migrate in both directions at each measurement point
- Experimental setup can also be used for plant growth experiments

Learning objectives

- Temperature optimum
- Poikilothermic animals
- Thermotaxis
- Phototaxis
- Thigmotaxis
- Torpor
- Environmental requirements
- Geographical seperation

Principle

The temperature requirements of animals with regard to their environment differ widely: they vary from temperatures just below 0°C for arctic and antarctic animals to temperatures of around 50°C for desert animals and animals from hot springs. Within these limits many species prefer one range: the preferential temperature. Using their thermoreceptors the animals recognize the temperature which suits them, gather in an area at the corresponding temperature (thermotaxis) and thus show their preferred temperature.

Tasks

1. Test the temperature demands of different poikilothermic animal species
2. Produce a temperature gradient between approximately 45°C and 10°C using a ring-shaped temperature organ
3. Record the positions of the individual animals

P4090100

Volumetric measurement of breathing in small animals

Benefits

- Complete experiment setup for temperature-controlled spirometry
- Setup permits quantitative determination of the 02/C02 metabolism

Learning objectives

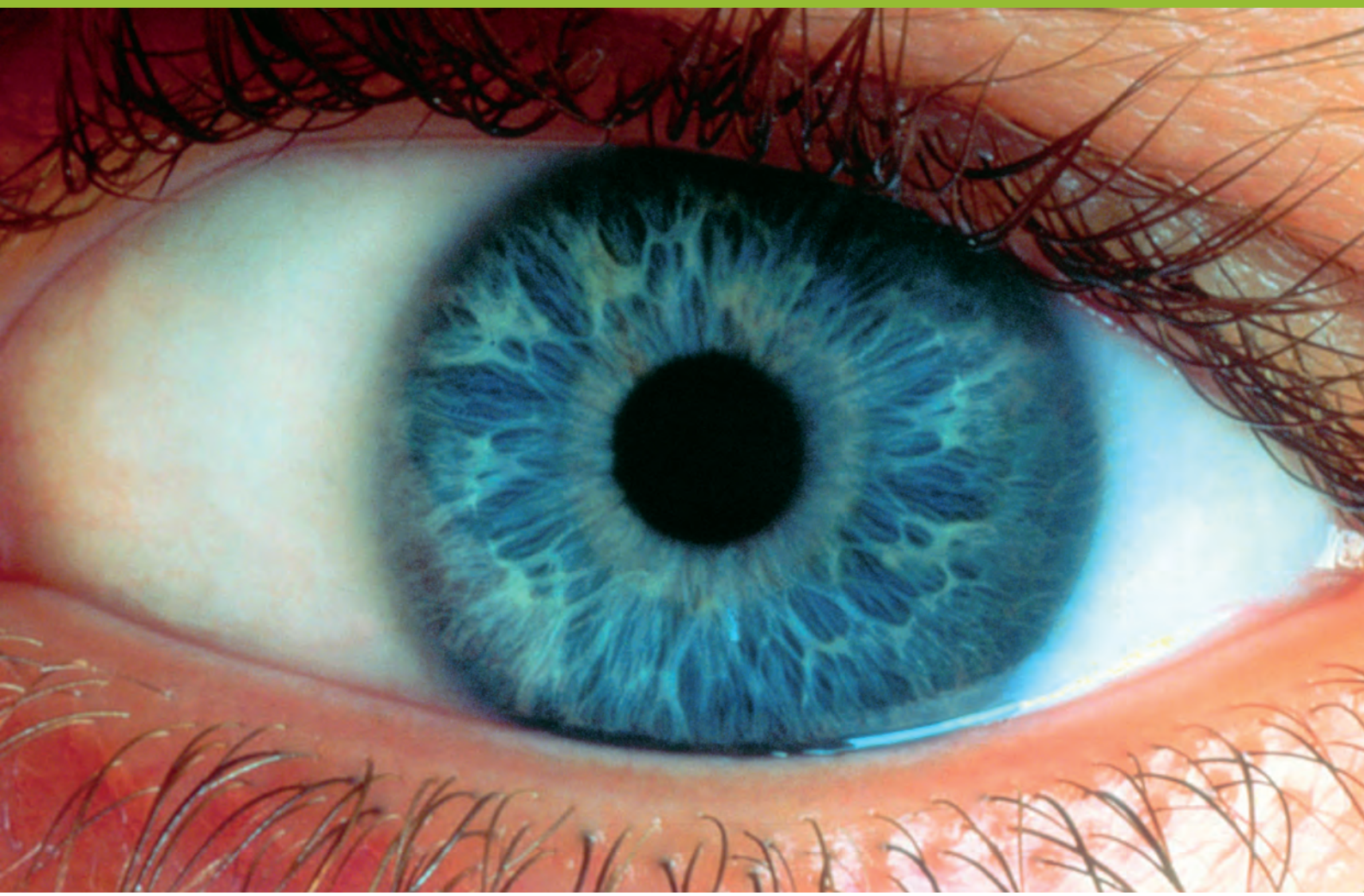
- Oxygen consumption
- Volumetric measurement
- Respirometer
- Carbon dioxide consumption
- Compensation vessel
- Q10 value

Principle

The measurement of breathing processes, i.e. determination of the consumption of oxygen or release of carbon dioxide is carried out volumetrically. For this purpose an invertebrate animal is enclosed in a temperature-controlled spirometer. The exhaled carbon dioxide is absorbed by concentrated potassium hydroxide solution.

Tasks

1. Measure the oxygen consumption of insects in relation to ambient temperature and body weight.



TESS expert - Biology

4.4.3 Physiology

15675-88D

Student set Human and electrophysiology digital, TESS advanced Applied Sciences

Website

curricuLAB

Function and Applications

Heart rate, pulse, lung volume, body temperature and blood pressure are the core parameters of human and electrophysiology. With our set, you can vividly teach students the meaning of these terms. The set contains our Cobra SMARTsense sensors that are easy to operate and take measurements in real time.

Equipment set allowing the performance of 9 experiments about the following topics:

- Electrophysiology of the heart (3 experiments)
- Blood circulation (1 experiments)
- Skin temperature (1 experiment)
- Lung function, lung volume (3 experiments)
- Lung diseases (1 experiment)

Benefits

- For datalogging with mobile devices (iOS, Android, Windows).
- Complete equipment set, no further accessories required.
- Easy to operate (plug & measure), thus also suitable for all education levels.

Equipment and Technical Data

The equipment set consists of all necessary components for the experiments:

- Stable, stackable storage box with device-molded, molded foam insert
- Cobra SMARTsense ECG
- Cobra SMARTsense Pulse
- Cobra SMARTsense Temperature
- Cobra SMARTsense Spirometer
- Blood pressure measurement combination

Determination of the human visual field

P4070200

Website

Benefits

- Perimeter design semidiagnostic, therefore appropriate for medical education

Learning objectives

- Perimeter
- Visual field (for white, blue, red, green)
- Field of view
- Blind spot
- Scotoma
- Rods and cones

Principle

The part of the surroundings perceived with an unmoved eye is called the visual field. In contrast, the field of view is that part of the surroundings perceived by the eyes when allowed to move freely but without moving the head. Depending on the uneven distribution of rods and cones in the retina (only cones in the centre and only rods at the periphery, with mixed rods and cones in between), the size of the visual field varies with the colour of the test object. The extent of the visual fields of both eyes and the position of the blind spot are determined with the aid of a perimeter.

Tasks

1. Determination of the visual field of the right and left eye for white, blue, red and green
2. Detection of any visual field deficiency (scotoma)
3. Location of the blind spot (site of optic nerve emergence)

Time resolving capability of the human eye

P4070300

Website

Benefits

- Perimeter design semidiagnostic, therefore appropriate for medical education

Learning objectives

- Perimeter
- Time-related resolving power
- Flicker fusion frequency
- Light/dark-adapted eye

Principle

As excitation of the light-perceptive cells of the retina always takes a little longer than the light stimulus, only a limited number of stimuli per unit of time can be processed (time-related resolving power of the eye). If a light source is switched on and off periodically in increasingly rapid sequence the eye at first perceives the individual flashes, then the appearance of flicker occurs and finally the impression of a continuous light (fusion of the flicker).

Tasks

1. Determine the flashing frequency of an LED at which the impression of a continuous light just occurs
2. Change the direction of incidence of the light using a perimeter
3. Determine the flicker fusion threshold of the left and right eye in relation to the direction of incidence of light stimulus and the state of adaptation of the eyes.

P4040101

Website

curricuLAB

Human merging frequency and upper hearing threshold

Benefits

- Exciting experiment for all age groups
- Simple experiment setup consisting of a versatile function generator and headphones
- Can be used to perform a medical survey of different age groups

Learning objectives

- Acoustic hearing thresholds
- Merging frequency
- Hearing range
- Sine wave generator
- Medical survey

Principle

The hearing range depends greatly on age. While tones above the upper acoustic threshold are not perceived at all, individual sounds under the lower hearing threshold are perceived as a continuous deep tone (merging).

Tasks

1. Determine the merging frequency and upper acoustic threshold of test subjects of various ages.
2. Stimulate the ear with tones at the lower and upper acoustic threshold using a sine wave generator and headphones.

P4120269

Website

Cobra SMARTsense

Ionic permeability of the cell membrane with Cobra SMARTsense

Benefits

- Especially understandable and didactically prepared description of the experiment (relevance to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Learning objectives

- Ion permeability
- Omotic processes
- Cell membrane

Principle

The cell membrane regulates the transport of nutrients and water into the cell and of waste products and water out of the cell. This can be done passively, e.g. due to osmotic processes, or actively. In this experiment the selective permeability of an artificial membrane (dialysis tube) for H^+ and OH^- ions will be investigated.

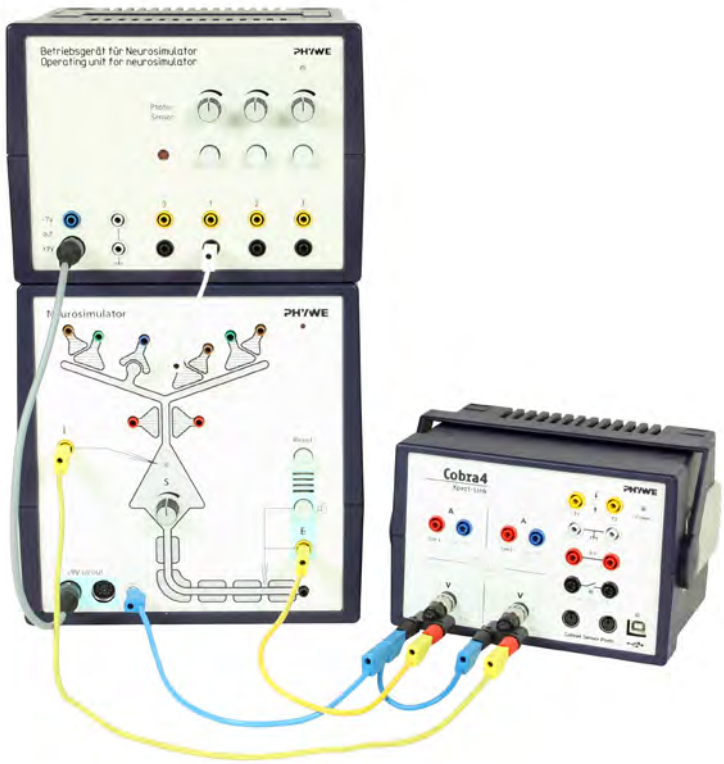
Tasks

Exploring the selective permeability of an artificial membrane (dialysis tube) for H^+ and OH^- ions.

The nerve cell with Cobra Xpert-Link

P4010764

Website



Benefits

- Experience processes in the nerve cell „hands-on"
- Make all properties of a nerve cell easy to understand - action potential, membrane potential, functions of synapses (e.g. synaptic learning and forgetting)
- Use as a demonstration system without a computer as well
- Scale up easily to perform further experiments like nerve cell interactions (e.g. conditioned reflex) and neural networks (e.g. short-term memory)

Principle

Interactive learning and teaching system with one neurosimulator for experiments about the nerve cell.

Tasks

Use the nerve function model to study the following aspects of a nerve cell: membrane potential, action potential, the different types of synapses

Learning objectives

- Comparison between low and high threshold and stimulus levels, membrane time constant and low pass filtering, excitatory synapse, depolarisation, temporal summation, spatial summation, synaptic amplification by terminal branches, effect of decreasing stimulus, Hebbian synapse, synaptic learning and forgetting, inhibitory synapse, hyperpolarization, spacial inhibitory-excitatory summation, veto synapse

P4010864

Nerve cell interactions with Cobra Xpert-Link

Website

Benefits

- Experience processes in the nerve cell and between nerve cells „hands-on“
- Make all properties of a nerve cell easy to understand - action potential, membrane potential, functions of synapses (e.g. synaptic learning and forgetting)

Learning objectives

- Lateral inhibition, contrast improvement, nerve cell interaction, conditioned reflex, Renshaw inhibition, motoneuron.

Principle

Interactive learning and teaching system with two neurosimulators for experiments covering nerve cells and nerve cell interactions.

Tasks

Motoneuron signals with recurrent inhibition by Renshaw cell, motoneuron signals without recurrent inhibition, functional characteristics of Renshaw inhibition, lateral inhibition, contrast improvement, conditioned reflex, reversed stimulus succession does not bring about a conditioned reflex.

P4010964

Neural networks with Cobra Xpert-Link

Website

curricuLAB

Benefits

- Experience processes in the nerve cell, between nerve cells and in neural networks „hands-on“
- Make all properties of a nerve cell easy to understand - action potential, membrane potential, functions of synapses (e.g. synaptic learning and forgetting)

Learning objectives

- When using three nerve cells: neuronal oscillator, rotating excitation, cerebral cortex and sensoric learning, triad.
- When using four nerve cells: unilateral inhibition, self-calibration of paired sensory channels, nerve cell interaction, neural network, ganglion cell, axon, interneuron.

Principle

Interactive learning and teaching system with three and four neurosimulators for experiments covering nerve cells, nerve cell interactions and neural networks.

Tasks

- When using three nerve cells: transient (phasic) responses: focus on visual sense, body clock, short-term memory, special anatomical circuits: cerebral cortex and sensoric learning, functional characteristic of a triad.
- When using four nerve cells: direction selectivity by unilateral inhibition, self-calibration of paired sensory channels.

TESS expert - Biology

4.4.4 Biochemistry

P4120369

Website

Cobra SMART sense

Determination of the Michaelis constant with CobraSMARTsense

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Principle

Conductivity measurements can be used to determine the rates of urea hydrolysis by the enzyme urease at different substrate concentrations from which the Michaelis constant can be determined.

P4120469

Website

Cobra SMART sense

Substrate inhibition of enzymes with Cobra SMARTsense

Principle

Conductivity measurements can be used to determine the rates of urea hydrolysis by the enzyme urease at different substrate concentrations.

Tasks

Measurement of conductivity and determination of the rate of urea hydrolysis by the enzyme urease at different substrate concentrations

P4120569

Website

Cobra SMART sense

Enzyme inhibition (poisoning of enzymes) with Cobra SMARTsense

Principle

With conductivity measurements, the rate of urea hydrolysis by the enzyme urease can be determined.

Tasks

- Determination of the rate of urea hydrolysis by measuring the conductivity
- Poisoning of the enzyme by addition of a suitable inhibitor

P4120169

Website

Cobra SMART sense

Determination of the isoelectric point of various amino acids with Cobra SMARTsense

Benefits

- Especially understandable and didactically prepared description of the experiment (reference to everyday life etc.) including protocol questions
- Future-oriented teaching: Integration into digital science lessons with tablets or smartphones

Principle

In this experiment the amino acids glycine, proline, phenylalanine and serine are examined by means of pH-value titration.

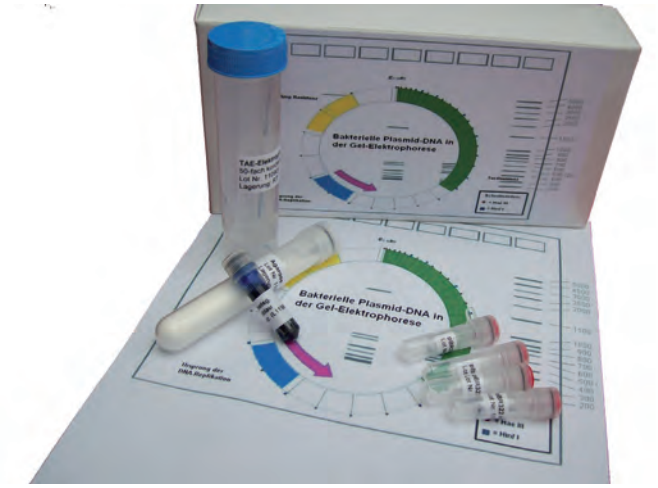
TESS expert - Biology

4.4.5 Molecular Genetics

P8110500

Electrophoresis of Plasmid DNA

Website



Benefits
- Complete equipment set which also contains all required consumables
- Consumables can be purchased as a replacement kit
- Ready to use: DNA fragment samples are already predigested
- Easy to use: detailed experiment guide
- DNA samples can can be stored for a longer period at room temperature because they are lyophilized

Learning objectives
- Plasmid DNA
- Electrophoresis
- Restriction enzymes
- Restriction digestion
- Banding pattern

Principle

The most important work methods of molecular genetics are taught in this experiment. With the aid of agarose gel electrophoresis migration velocity and the cleavage pattern of plasmid DNA can be investigated.

For use with the student set Genetics (page71).

P8110700

Genetic fingerprinting

Website

Benefits
- Complete equipment set which also contains all required consumables
- Consumables can be purchased as a replacement kit
- Ready to use: DNA fragment samples are already predigested
- Easy to use: detailed experiment guide
- Lyopholized DNA samples for longer-term storage at room temperature

Learning objectives
- DNA fingerprinting
- Electrophoresis
- Banding pattern
- DNA profile
- Forensics
- PCR

Principle

This experiments allows to simulate the method of DNA fingerprinting and uses a DNA fingerprint to identify the offender in a hypothetical crime. After separation of a given DNA by using gel electrophoresis and staining the DNA samples the students can compare the pattern of fragments on the gel with other DNA samples and match the DNA to the offender.

For use with the student set Genetics (page71).

Electrophoresis of Lambda DNA

P8110600

Principle

The most important work methods of molecular genetics are taught in this experiment. With the aid of agarose gel electrophoresis migration velocity and the cleavage pattern of lambda DNA can be investigated.

Website

Also available for use with the student set Genetics.

Paternity test

P8110800

Principle

This experiment allows to study the genetic method of paternity analysis, as it is used today. This experiment includes various DNA samples which are separated according to their size by using electrophoresis. DNA samples of different individuals are prepared for gel electrophoresis which is then performed in order to compare and analyze kinship between different humans.

Website

Also available for use with the student set Genetics.

Student set Genetics, TESS advanced Biology

15311-88

The world sensation at PHYWE - Simple genetics for everyone in a practical set!

Function and Applications

DNA analysis has never been so simple and clear. Our experimental set contains all the necessary equipment needed for experiments in genetics, including the sensational blueGel gel electrophoresis system and the practical 3-in-1 agarose tablets (agarose, TBE-salt and a fluorescent dye). In addition, the set contains a washable pipetting practice card, which saves time and material when training with the pipette. The 3-in-1 agarose tablets, together with the blueGel„¢ system, allows visualization of DNA separation while it is being performed! Latest LED technology makes UV light superfluous. The enclosed foldable darkroom allows filming and photographing with your own smart phone. Gel electrophoresis finally without high voltage; the 48V power supply unit for electrophoresis is included. The 3-in-1 agarose tablets contain agarose, TBE and a harmless fluorescent dye that makes DNA and RNA glow - just add water, boil it up, and you are done.

Website

For further information see detailed product description on page 71.

curricuLAB

35015-99

Website

miniPCR mini16 Thermocycler for 16 samples, PCR machine

Function and Application

We bring the Nobel Prize topic PCR (polymerase chain reaction) into your classroom. The Thermocycler miniPCR mini16 copies the genetic material (DNA) exactly as the big, expensive laboratory devices do. The miniPCR offers space for up to 16 samples and is very easy to use. The device is conveniently controlled and programmed via a free app on your smartphone or computer. The app is compatible with Windows, Mac, Android, Kindle, iPhones as well as iPads and is available in all app stores. The thermal cycler can be connected via Bluetooth. You do not need to keep the machine connected to your computer, tablet or smartphone to run the program.

Benefits

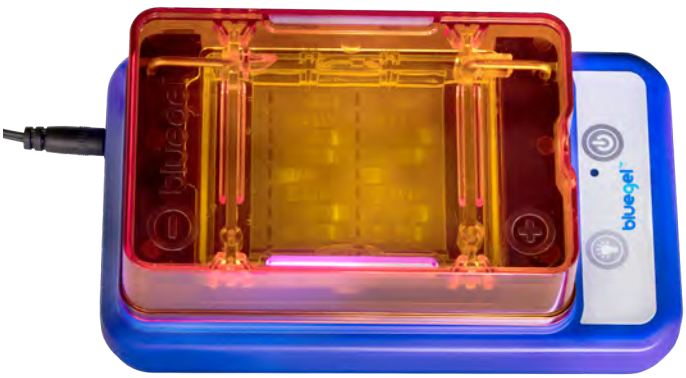
- Up to 16 samples can be analyzed in one run.
- Easy to operate, using the free app „miniPCR" for all operating systems.
- Covering all common PCR modes: classic endpoint PCR, linear gradients, heating block function and a completely free configurable mode.
- The transparent housing allows a view into the inner workings of the cycler.
- Optional operation by a powerbank allows the portable device to be used almost anywhere.

Equipment and Technical Data

- Space for 16 samples: 2 x 8 0.2 ml reaction vessels (single vessels or strips of 8)
- Heated lid
- Easy to use app for all common PCR modes
- Operation with common reagents
- Included accessories: power supply unit, USB cable, dust cover
- Dimensions and weight: 5 cm x 13 cm x 10 cm, about 500 g
- Mains supply: 90 - 246 V, 50-60 Hz, 65 W
- Optional operation via Li-Ion powerbank (not included)

35016-99

Website



blueGel gel - electrophoresis unit with integrated illuminator

The world sensation at PHYWE - Simple genetics for everyone!

Function and Applications

DNA analysis has never been so simple and clear. The blueGel gel electrophoresis system allows the visualization of DNA separation while it is being performed. The latest LED technology makes UV light superfluous. The included foldable darkroom allows filming and photographing with your own smart phone. Gel electrophoresis finally without high voltage, the 48V power supply is included. Together with the 3-in-1 agarose tablets, DNA analysis can be performed safely and easily. The tablets contain agarose, TBE and a harmless fluorescent dye - simply add water, boil it up, and you are done.

Benefits

- Live observation by LED technology and use of a harmless fluorescent dye.
- Saving of material by analysis of 26 samples with one run of a 20 ml gel.
- Complete system: Running chamber with LED, power supply, buffer chamber, casting system and combs.
- Safe: Operating voltage of 48 V and with automatic power cut-off when the lid is removed.
- Robust and equipped with high-quality, wear-free electrodes.

Equipment and Technical Data

- Integrated blue light transilluminator
- For gels of the size 60 x 60 mm (about 20 ml)
- Platinum and stainless steel electrode
- Required buffer: 25 ml TBE or TAE (TBE recommended)
- Included accessories: darkening hood, 2 combs for 9 or 13 bags each, power supply unit, pump spray with microfibre cloth against fogged up covers, storage bag

TESS expert - Biology

4.4.6 Microbiology

P4140100

Fundamental microbiological working methods

Website

curricuLAB

Benefits

- Experiment covers the basics of microbiology technics
- Equipment of this experiment can also be used to perform more advanced experiments

Learning objectives

- Basics of microbiological work techniques
- Disinfection
- Nutrient agar
- Sterility
- Sterilisation
- Moulds
- Yeast
- Bacteria
- Inoculation

Principle

In order to prevent nutrient media and cultures from being contaminated with microorganisms that adhere to the working equipment, the equipment, nutrient media, and nutrient solutions must be sterilised. Petri dishes filled with a solidified nutrient medium are called plates in the specialised language of microbiologists. The nutrient medium is poured into the dishes either from test tubes, with one test tube holding the required quantity of ready-made medium for one Petri dish, or from Erlenmeyer flasks if a large number of plates needs to be prepared at the same time.

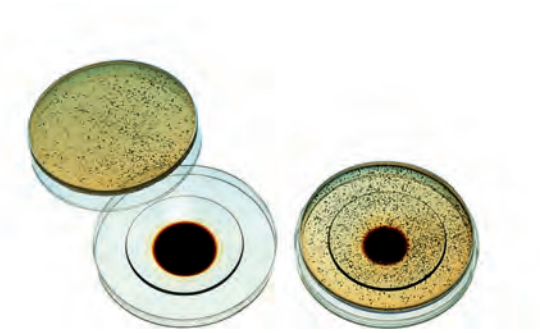
Tasks

1. Sterilisation of equipment
2. Preparation of standard nutrient agar for bacteria
3. Preparation of standard nutrient agar for moulds and yeasts
4. Preparation of a standard nutrient solution for bacteria
5. Preparation of slant agar tubes
6. Inoculation of microorganisms

P4100900

Microbial decomposition of mineral oil

Website



Learning objectives

- Contamination with mineral oil
- Degradation of mineral oil using biological agents
- Mineral oil-degrading microorganisms

Principle

Some microorganisms living in soil and water are capable of utilizing mineral oil compounds as carbon and energy sources. They break down these compounds to produce carbon dioxide and water, thereby decomposing mineral oil. Particularly mycobacteria, corynebacteria and proactomycetes are able to decompose mineral oil.

Tasks

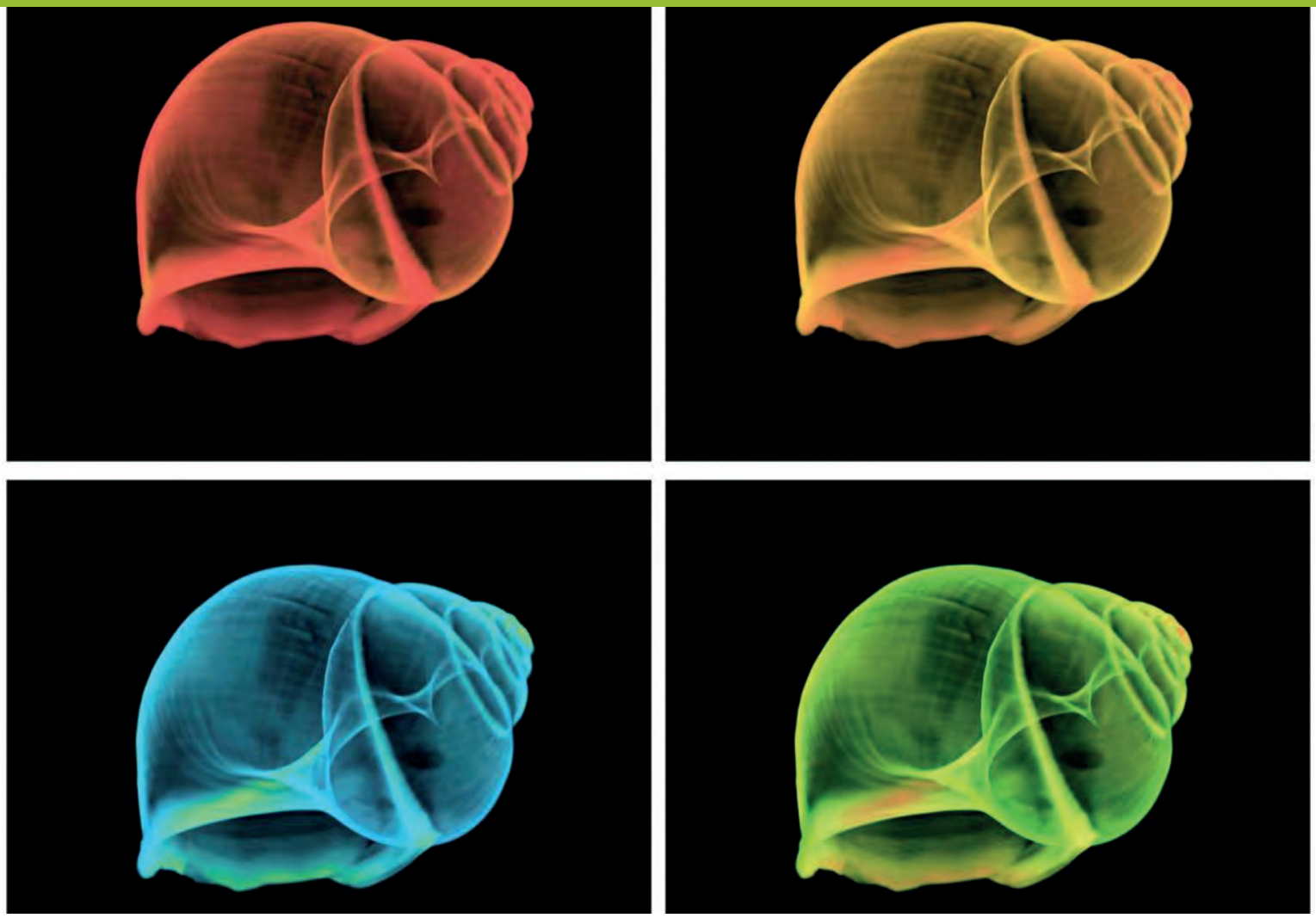
- Verify the presence of mineral oil-degrading microorganism in any type of soil samples

P4140200

Evidence of the spread of bacteria

Website

Also available: Evidence of the spread of bacteria (P4140200).

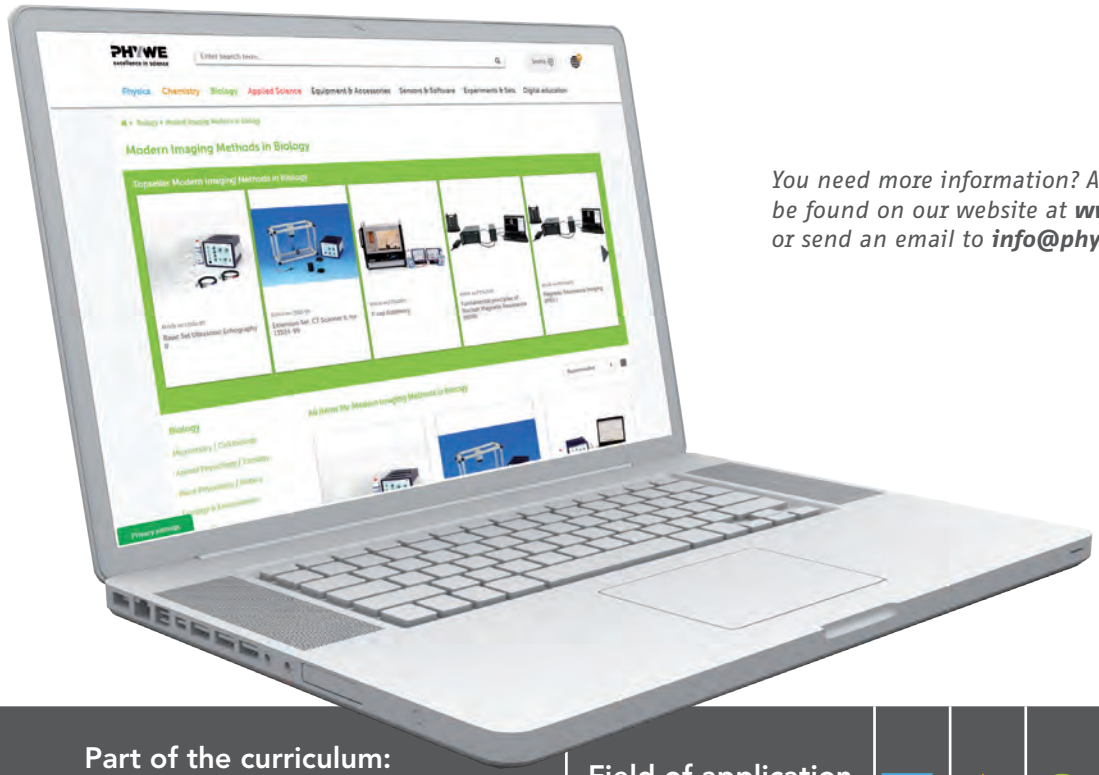


TESS expert - Biology

4.4.7 Imaging

Website

X-ray experiments for Biology –
All experiments on our website



*You need more information? All experiments can be found on our website at **www.phywe.com** or send an email to **info@phywe.com**.*

Part of the curriculum: topic - subtopic	Field of application	Phy	Che	Bio	Sci Med	Sci Geo	Sci Eng
Modern Physics - Atomic Physics Modern Physics - X-ray Physics	Characteristic spectra	x					
Modern Physics - Atomic Physics Modern Physics - X-ray Physics	Bremsspectrum	x					
Modern Physics - Molecular & Solid State Physics	Solid-state physics	x					
Modern Physics - X-ray Physics Inorganic Chemistry - Solid State Chemistry & Crystallography	X-ray diffraction	x	x				
Inorganic Chemistry - Solid State Chemistry & Crystallography Geo Sciences - X-ray analysis Material Sciences - X-ray Structural Analysis	Structural analysis		x			x	
Modern Physics - X-ray Physics Spectroscopy - X-ray Fluorescence Analysis Material Sciences - X-ray Fluorescence Analysis Geo Sciences - X-ray analysis	X-ray spectroscopy	x				x	x
Geo Sciences - X-ray analysis	Rock analysis					x	
Material Sciences - X-ray Structural Analysis Material Sciences - X-ray Fluorescence Analysis	Material analysis		x				x
Non-destructive Testing - X-ray Methods	Non-Destructive Testing (NDT)						x
Medicine/Biology - Radiology Non-destructive Testing - X-ray Methods	X-ray diagnostics				x		x
Medicine/Biology - Radiology Nuclear Medicine - X-ray Dosimetry	Dosimetry			x	x		
Medicine/Biology - Radiology	Radiology / Radiography			x	x		
Medicine/Biology - Radiology Non-destructive Testing - X-ray Methods	Computed tomography	x		x	x		x

Computed tomography

P2550105

Website

curricuLAB

Benefits

- Very fast, direct image capture
- Easy to understand linear procedure does not require training, instant results
- Integrates smoothly with software used in medical diagnostics to use additional CT software features
- All objects can be captured since object is inserted gravity-independently

Learning objectives

- Beam hardening
- Artefacts
- Algorithms

(Software for Windows included. Requires computer with graphica board.)

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.

P2541805

X-ray dosimetry

Website

curricuLAB

Benefits

- Experience the essence of the Nobel Prizes: Röntgen (1901), W.H. Bragg, W.L. Bragg, (1914)
- This experiment can alternatively also be performed with a copper, molybdenum or iron X-ray tube

Learning objectives

- X-rays
- Absorption inverse square law
- Ionizing energy
- Energy dose
- Equivalent dose and ion dose and their rates
- Q factor
- Local ion dose rate
- Dosimeter

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. Determine the distance between the aperture and the radiation source at maximum anode voltage and current.
2. Measure the ion current at maximum anode voltage as a function of the capacitor voltage. Determine the ion dose rate and the energy dose rate from the saturation current values.

P2541905

Contrast medium experiment with a blood vessel model

Website

curricuLAB

Benefits

- Effective demonstration of how a contrast medium can be visualized with X-rays)
- Excellent entry-level experiment for medical students

Learning objectives

- X-ray radiation
- Bremsstrahlung
- Characteristic radiation
- Law of absorption
- Mass absorption coefficient
- Contrast medium

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.

Ultrasonic echography (A-Scan) P5160200

Website

Benefits
- Exciting experiment to teach the basics of ultrasound imaging (echography)
- Diversified experiment with several measurement methods
- With the same setup B-scans can be performed
- Experiment setup can be upgraded for additional experiments in medical imaging and for echoscopy applications in material sciences

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

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 caliper 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 caliper and the ultrasound echography method.

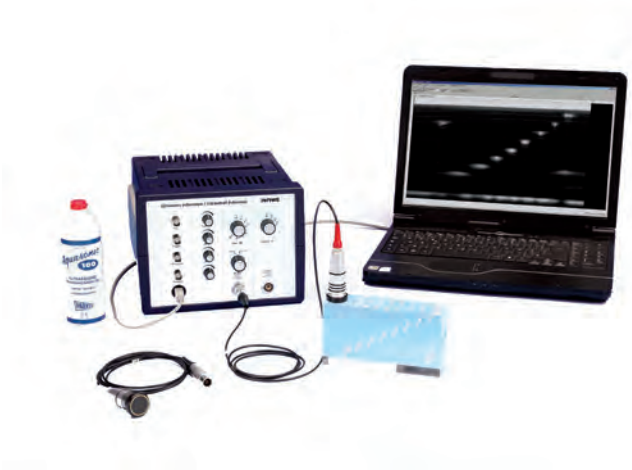
curricuLAB

Ultrasonic echography (B-Scan) P5160300

Website

Benefits
- Exciting experiment to teach the basics of ultrasound imaging (echography)
- Diversified experiment with several measurement methods
- With the same setup A-scans can be performed
- Experiment setup can be upgraded for additional experiments in medical imaging and for echoscopy applications in material sciences

Learning objectives
- Sound velocity
- Reflection coefficient
- Ultrasonic echography
- A-scan
- B-scan
- Greyscale display
- Resolution
- Zone of focus
- Image artefacts



Principle

The fundamental principles concerning the generation of ultrasonic B-scan images (brightness representation of the reflection amplitudes) are demonstrated with the aid of a simple test object. The experiment is executed with an ultrasonic echoscope in the pulse echo mode and the object is scanned manually. Then, the image quality and the most important image defects will be assessed.

Tasks

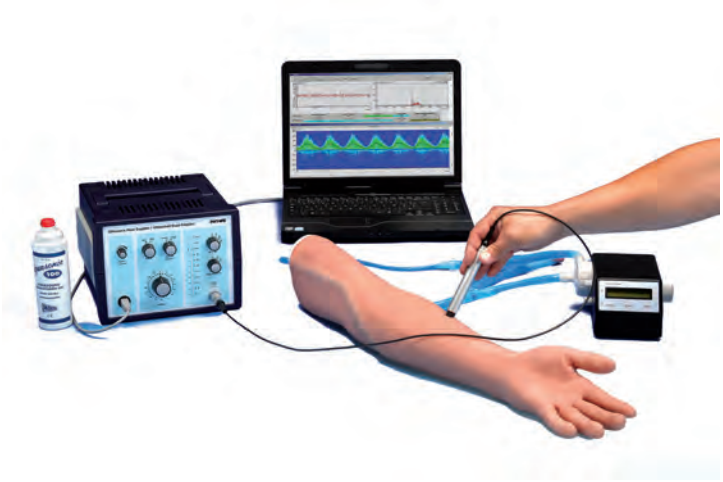
1. Measure the 3 edge lengths of the test block with a vernier caliper and determine the time of flight of the sound for the various edge lengths of the test block with the aid of the measurement software.
2. Calculate the sound velocity of the test block material and switch the measurement software (A-scan mode) to depth measurement.

curricuLAB

P5950100

Doppler sonography

Website



Benefits

- Ideal experiment for medical students to learn the principles of Doppler sonography
- True to life with an arm model with blood vessels and stenosis
- Experiment components can also be used for other experiments relevant for medical students

Learning objectives

- Venous flow
- Arterial flow
- Stenosis
- Blood flow velocity tracings
- Frequency shift
- Doppler effect
- Doppler angle
- Doppler sonography
- Colour Doppler
- Continuity equation

Principle

This set-up shows how blood flow studies are performed using Doppler ultrasound (Doppler sonograph). On a realistic arm dummy, the differences between continuous (venous) and pulsating (arterial) flow are shown as well as the difference in flow through a normal blood vessel and a stenosis.

Tasks

1. Analyse blood flow and search positive and negative flow components. Explain the differences.
2. Locate the built-in stenosis and compare the spectral distribution upstream and downstream of the stenosis.
3. Examine and compare the three pulse modes of the pump.

P5950300

Ultrasonic investigation with breast dummy

Website

Benefits

- Ideal experiment for medical students in the preclinical phase: true-to-life breast cancer examinaton using a breast model
- The echoscope used in the experiment can also be used for other medically relevant experiments like A-scan, B-scan and ultrasound tomography

Learning objectives

- Breast sonography
- Tumour size
- Benign Tumour
- Ultrasound imaging procedures
- Ultrasound echography
- A-mode
- B-mode

Principle

This experiment shows a typical application of ultrasound in medical diagnostics. A benign tumour on a realistic breast dummy is which has to be diagnosed, localized and measured with an ultrasound cross-section imaging method.

Tasks

- Examine the breast dummy and search for any pathological changes. Try to characterize them as accurately as possible (size, location, mobility, strength of the change).
- Produce an ultrasonic B-scan image of the breast dummy, especially in the regions of interest. Based on the ultrasound image, estimate the location and magnitude of the tumour.

Magnetic Resonance Imaging (MRI) I

P5942400

Benefits

- Complete, easy to install and affordable MRT education system
- One system to cover all aspects from NMR basics to sophisticated 2D and 3D imaging sequences
- Detailed experiment guides included with the system
- Learning results guaranteed thanks to easy to manage course steps

Website

Learning objectives

- Nuclear spins
- Precession of nuclear spins
- Resonance condition, MR frequency
- MR flip angle
- FID signal (Free Induction Decay)
- Magnetic gradient fields
- Spatial encoding (frequency coding, phase coding)
- Spin echo, gradient echo
- Fast-Fourier-Transformation (FFT)
- T1/T2 relaxation times
- De-/Rephasing

Principle

The basic principles of 2D MR imaging are demonstrated with two methods relying on two different gradient techniques. Experiments are executed with a MRT training device giving the opportunity to investigate some small probes in the sample chamber.

Tasks

1. Using the frequency and phase gradient techniques to generate a spin echo signal which can be used for 2D image reconstruction (Spin Echo 2D).
2. Using the frequency and phase gradient techniques to generate a gradient echo signal which can be used for 2D image reconstruction (Flash 2D).

curricuLAB

Magnetic Resonance Imaging (MRI) II

P5942500

Website

Learning objectives

- Nuclear spins
- Resonance condition
- MR frequency
- FID signal (Free Induction Decay)
- Magnetic gradient fields
- Spatial encoding (frequency encoding, phase encoding)
- Slice selection
- Spin echo
- Fast-Fourier-Transformation (FFT)
- T1/T2 relaxation times
- 2D and 3D magnetic resonance imaging

Principle

The aim of these experiments is to show how the spin echo technique can be used to generate 2D MR images of a slice of a well-defined thickness, orientation, and size (Localized Spin Echo 2D). These parameters determine the so-called „field of view" (FOV) of the MR image. We will introduce a method that enables the recording of 3D MR images (Spin Echo 3D). For this purpose, an additional phase encoding will be performed in the third dimension. Both methods include the automatic calibration of the system frequency with regard to the Larmor frequency. As a result, the MR image is more stable over several averaging steps.

Tasks

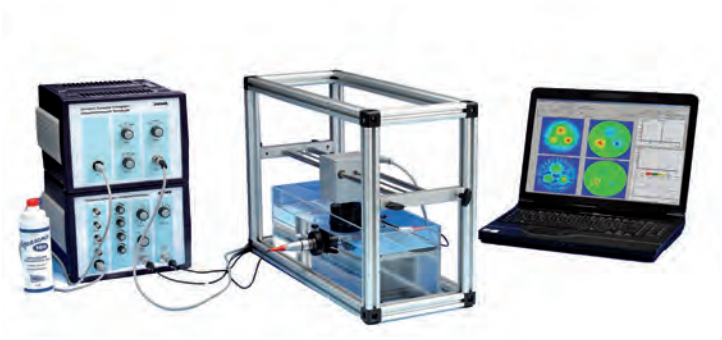
1. Generation of 2D MR images with explicit slice selection (Localized Spin Echo 2D).
2. Generation of 3D MR images (Spin Echo 3D).

curricuLAB

P5161200

Ultrasonic computed tomography

Website



curricuLAB

Benefits

- Ideal system for education: affordable compared to industrial system to demonstrate ultrasound-CT in a very comprehensible way
- With the same system mechanical scanning of an object can be performed, e.g. to create a B-scan image

Learning objectives

- Ultrasonic echography (A-scan)
- Tomography
- Resolution

Principle

This experiment explains the fundamental principles of image formation with a CT algorithm. A test object is used to create an attenuation tomogram and a time-of-flight tomogram followed by a discussion of the respective differences.

Tasks

1. Creation of several attenuation and time-of-flight tomograms
2. Variation of the device parameters
3. Discussion of the differences

P2538000

Basic methods in imaging of micro and nano-structures with AFM (Atomic Force Microscopy)

Website

curricuLAB

Benefits

- Investigation in static and dynamic mode
- Modification of numerous parameters to optimize image quality
- Perform experiment with different samples
- Excellent price-performance ratio
- Custom-designed for use in teaching labs

Learning objectives

- Atomic Force Microscopy (AFM)
- Lennard-Jones potential
- Imaging of nano structures
- Static Force Mode
- Dynamic Force Mode
- Feedback loop
- Force
- Vibrational amplitude

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. Their effect on the imaging quality is investigated for different nano structured samples.

Tasks

1. Learn how to 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 different samples (microstructures, carbon nano tubes, skin cross-section, bacteria, CD stamper, chip structure, glass beads) by optimizing the parameters respectively.

5 Lab Equipment & Accessories

Website

The PHYWE power supplies – all specifications at a glance

Properties	Standard power supplies		
			
Item name	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	PHYWE Power supply, universal, analog display DC: 0...18 V, 0...5 A / AC: 2/4/6/8/10/12/15 V, 5 A	PHYWE Variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A
Item number	13506-93	13503-93	13542-93
SPECIFICATIONS			
Direct current (DC):	0...12 V / 0...2 A, max. 24 W, ripple max. 1 mVss	0...18 V, 0...5 A, continuously adjustable	0...20 V /12 A
Alternate current (AC):	6 V / 12 V, 5 A	2/4/6/8/10/12/15 V, 5 A	0...25 V /12 A; 6 V and 12 V for 6 A each
Outputs simultaneously loadable:	yes	yes	yes
Short circuit-proof:	yes	yes	yes
Display:	no	yes	yes
Output voltage smoothened:	yes	yes	no
Power consumption:	68 VA	295 VA	375 VA
Dimensions (mm):	206 x 130 x 160	230 x 236 x 168	230 x 236 x 168
Weight (kg):	3.2	7.9	8.5
SPECIAL FEATURES			
	■ Fuse: Thermal fuse (no spare fuse required) ■ Outputs overload/short-circuit overload/short-circuit fixed, externally voltage-proof, earth/ground-free ■ Current limitation adjustable ■ Ideal for student experiments!	■ Versatile, powerful power supply unit for DC and AC ■ Also available as constant current source ■ Outputs galvanically isolated	■ Continuously adjustable DC and AC ■ 2 fixed voltages

High-voltage power supplies			Regulated and special power supplies	
				
PHYWE Power supply, regulated DC: 0...12 V, 0.5 A; 0...650 V, 50 mA / AC: 6.3 V, 2 A	PHYWE high precision power supply 1.5 kV DC	PHYWE High voltage power supply with digital display, 10 kV DC: 0... ± 10 kV, 2 mA	PHYWE power supply, variable DC: 12 V, 5 A / AC: 15 V, 5 A	PHYWE Multitap transformer DC: 2/4/6/8/10/12 V, 5 A / AC: 2/4/6/8/10/12/14 V, 5 A
13672-93	09107-99	13673-93	13540-93	13533-93
Output 1: 0...12 V, 0.5 A Output 2: 0...50 V, 50 mA Outputs 3/4: 300 V/0...300 V, 50 mA	100 ... 1500 V / max. 1 mA	3 continuously adjustable DC voltages: 0..+5 kV; 0..-5 kV; 0...+/- 10 kV; 2 mA	0 ... 12 V / 5 A	2/4/6/8/10/12 V, 5 A
6.3 V, 2 A	-	-	0...15 V, 5 A 6 V, 6 A 12 V, 6 A	2/4/6/8/10/12/14 V, 5 A
yes	only 1 output	yes	yes	yes
yes	yes	yes	yes	yes
no	yes	yes	no	no
yes	yes	yes	no	no
100 VA	12 VA	20 VA	ca. 190 VA	80 VA
230 x 250 x 168	206 x 130 x 160	230 x 250 x 168	230 x 236 x 168	230 x 236 x 168
5.8	1.25	5.5	7.5	3.3
■ Power supply unit with 5 output voltages ■ Especially suitable for tube experiments, filament beam tube and Franck-Hertz-experiment	■ Voltage fluctuation < 0.2% ■ 4-digit digital display ■ MHV socket for high voltage output ■ Continuous, reproducible voltage adjustment	■ Universally applicable high-voltage source ■ For all electrostatic experiments, experiments on radioactivity, for operating special tubes, gas discharge tubes	■ Continuously adjustable direct and alternating voltages ■ 2 fixed voltages	■ For direct and alternating voltages ■ Adjustable in 2 Volt steps

13506-93

Website

TOPSELLLER

PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A

Function and Applications

High-quality power supply specially for simultaneous supply with direct and alternating current, suitable for student experiments in electricity and electronics as well as for demonstration.

Benefits

- No replacement fuses required.
- Safe isolation and safety transformer make this power supply unit particularly suitable for student experiments for all ages.
- Ideal for measurements together with Cobra SMARTsense Voltage.

Equipment and Technical Data

- Controlled constant current source with adjustable current limiting: 0 ... 12 V; 0 ... 2 A /max. 24 W
- Residual ripple: max. 1 mVss
- AC voltage: 6 V/12 V also possible in series connection
- Alternating current: 5 A /max. 60 VA
- Outputs overload proof and short-circuit-proof, external voltage-proof, earth- and ground-free
- 4 mm safety sockets
- Thermal fuse (no replacement fuse necessary)
- Power consumption: 70 VA
- Mains voltage: 230 V~
- Shock-resistant, stackable plastic housing with carrying handle and stand
- Dimensions (mm): 194 x 140 x 130
- Weight: 3.2 kg

13503-93

Website

PHYWE Power supply, universal, analog display DC: 18 V, 5 A / AC: 15 V, 5 A

Function and Applications

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

Benefits

- For both alternating and direct current
- With analog display
- Permanently short circuit-proof

Equipment and Technical Data

- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V
- With an analog display with the measuring ranges 0...18 V and 0...5 A as well as a change-over switch for voltage and current measurement
- Stabilised, regulated DC output voltage, continuously adjustable from 0...18 V
- Current limitation adjustable from 0...5 A
- Ripple: < 5 mV
- Permanently short-circuit proof, external voltage protected
- LED for constant current operation
- AC voltage: step transformer 2...15 V, outputs galvanically isolated from the mains supply
- Voltage adjustment at socket ring around central socket with captive plug-in switch
- Full load capacity (5 A), even with simultaneous DC current draw
- Short-circuit protection by overcurrent circuit breaker
- Automatic fuse: 10 A
- All outputs earth and ground-free
- 4 mm safety sockets
- Power consumption: 295 VA

PHYWE Variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A

13542-93

Function and Applications

Standard heavy-duty power supply unit for low voltage. Supplies continously adjustable DC and AC voltages & 2 frequently requiredfixed voltages.

Equipment and Technical Data

- AC output: ca. 0.2...25 V/12 A
- DC output: ca.0.2...20 V/12 A
- Max. current (short-term): 13 A
- Additional fixed voltages: 6 V AC/6 A12 V AC/6 A
- Max. current (short-term): 10 A
- Max. power: 375 VA
- Displays: 2 digital meters for current and voltage

Website

PHYWE Power supply, regulated DC: 0...12 V, 0,5 A; 0...650 V, 50 mA / AC: 6,3 V, 2 A

13672-93

TOPSELLLER

Function and Applications

Power supply with 5 output voltages especially designed for experiments with tubes, fine beams and conducting the Frank-Hertz experiment.

Equipment and Technical Data

- Output 1: 0...12 V-/0.5 A
- Stability: < 0.1 %
- Residual ripple: < 5 mV
- Output 2: 0...50 V-/50 mA
- Stability: < 0.01 %
- Residual ripple: < 5 mV
- Outputs 3/4: 300 V-/0...300 V-/50 mA
- Stability: < 0.01 %

Website

PHYWE High precision power supply 1.5 kV DC

09107-99

Function and Applications

Highly stabilized high voltage DC power supply for photomultipliers and gamma detectors.

Equipment and Technical Data

- Output voltage up to 1.500 V DC
- Stabilization: better than 0.1 %
- Output current: max. 1 mA
- MHV socket for output
- Input voltage: 100 - 220 V AC, 50/60 Hz
- Dimensions: 206 x 130 x 160 mm
- Weight: 1.4 kg

Website

PHYWE Multitap transformer DC: 2/4/6/8/10/12 V, 5 A / AC: 2/4/6/8/10/12/14 V, 5 A

13533-93

Function and Applications

Power supply unit for low voltage supplies DC and AC voltages in 2 V steps.

Equipment and Technical Data

- Galvanic isolation for all outputs, free-of-ground
- Selection of voltage output via one side fixed 4 mm bridge plug
- AC output: 2/4/6/8/10/12/14 V/5 A
- DC output: 2/4/6/8/10/12 V/5 A
- Max. current (short term): 10 A
- Max. power: 75 VA
- Supply voltage: 230 V AC
- Dimensions (mm): 230 x 236 x 168
- Weight: 3 kg

Website

13673-93

Website

TOPSELLLER

PHYWE High voltage power supply with digital display, 10 kV DC: 0... ± 10 kV, 2 mA

Function and Applications

Universally applicable high-voltage source, suitable for all electrostatic experiments and experiments on radioactivity, as well as for operating special tubes and other gas discharge tubes. When operating gas discharge tubes, the burning voltage must be checked on the built-in digital display. For reasons of radiation protection, this voltage must not exceed 5 kV.

Benefits

- Voltages are provided as + or - polarity, thus particularly suitable for electrostatic experiments with both types of charge carriers.
- Earth socket enables any output to be earthed if required; a symmetrical voltage with respect to earth is also possible.
- Gas discharge tubes can be operated without a series resistor.
- Special safety sockets reliably protect the user from unpleasant radio flashovers.

Equipment and Technical Data

- Supply of 3 continuously variable DC voltages isolated from earth and ground.
- Two of the voltages 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
- Modern plastic housing, impact resistant, easy to service, light stackable with retractable carrying handle and stand
- Internal resistance: approx. 5 MOhm
- Ripple: < 6 %
- Short circuit current: max. 2 mA
- Dimensions: 230 x 236 x 168 mm
- Weight: 5.5 kg

13540-93

Website

PHYWE power supply, variable DC: 12 V, 5 A / AC: 15 V, 5 A

Function and Applications

Standard heavy-duty power supply unit for low voltage. For continuously adjustable DC and AC voltages and 2 frequently required fixed voltages.

Benefits

- For measurements with high currents and/or variable AC voltage

Equipment and Technical Data

- AC voltages: 0 ... 15 V / 5 A; 6 V /6 A
- DC voltage: 0 ... 12 V / 5 A
- Short-term: 0 ... 12 V- / 15 V~ /6 A
- Short-term: 6/12 V~ /10 A
- 3 automatic circuit breakers 6A /10A /10A
- Outputs earth and ground free, external voltage protected
- 4 mm safety sockets
- Mains switch / mains indicator lamp
- Shockproof, stackable plastic housing with carrying handle and stand
- Primary fused
- DC voltage generation by inverter
- Mains voltage: 230 V~
- Dimensions (mm): 230 x 236 x 168
- Weight: 7.5 kg

PHYWE Digital Function Generator, USB

13654-99

TOPSELLLER

Website

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
- Includes software for Windows and MacOS

Equipment and Technical Data

- Frequency range: 0.1 Hz...0.9999 Mhz in steps of 0.1 Hz
- Signal forms: sine, triangle, square, frequency ramp, voltage ramp
- Monochrome graphic display: 128 x 64 pixels
- USB 2.0 port
- Settings via buttons and knob or software-assisted via USB
- Software measureLAB for Windows and MacOS

PHYWE Power supply 230 V/ 50 Hz for 50 W-Hg-lamp

13661-97

Website

Function and applications

For operating the lamp in experiments using a 50-W high-pressure mercury lamp.

Equipment and Technical Data

- Includes starter with thermal overload protection, mains indicator light and special safety plug socket for connection of lamp
- Mains voltage: 230 V/50 Hz
- Impact resistant plastic case with carrying handle and stand
- Dimensions (mm): 230 x 236 x 168
- For operation of high pressure mercury vapor lamp, 50 W, 08144-00

PHYWE Power supply for spectral lamps, 230 VAC/50 Hz

13662-97

Website

Function and Applications

Power supply for spectral lamps with Pico 9 socket and nominal current 1A.

Equipment and Technical Data

- Voltage without load 230V
- Burning voltage 15...60V
- Supply voltage 230V/50Hz
- Dimensions (mm): 230 x 236 x 168

Website

PHYWE multimeters
for science education

Analog multimeter for beginners of electrical measuring (07021-11)

Ideal for first-time users and virtually indestructible (07127-00)

Universal multimeter for I, U, R, C, f and T (07122-00)

Item no.	07021-11	07127-00 („AmpSafe“)	07122-00
Display (analog/digital)	analog	digital	digital
Measurement (manual/automatic)	manual	automatic	manual
Measurement parameters and ranges			
DC voltage	0…3/15/60/150/600 V	0…600 V	0…0,2/2/20/200/600 V
AC voltage	0…15/60/150/600 V	0…600 V	0…2/20/200/600 V
DC current	0…100µA/10 mA/500 mA/10 A	0…200 mA	0…2/20/200 mA/10 A
AC current	0…10 mA/500 mA/10 A	0…200 mA	0…2/200 mA /10 A
Resistance	0…200 Ω/2/20/200 kΩ/2 MΩ	0…20 MΩ	0…200 Ω/2/20/200 kΩ/2/20 MΩ
Capacitance	-	-	0…2/20/200 nF/2/200 µF
Frequency	-	-	0…20 kHz
Temperature	-	-	-20°C…760°C
Special feature	mirror scale overload protection	flashlight electronic overload protection	-
Overvoltage category	CAT III 600V	CAT III 600V	CAT III 600V

Cover all requirements from grade 5 up to university level:

Ideal as a classroom set (Item no. MULTIMETER-SET):

Multimeters
for science education

Website

(07021-12)

(07029-12)

(07023-12)

(07024-12)

(07025-12)

Item no.	07021-12	07029-12	07123-12	07124-12	07125-12
Display (analog/digital)	analog	digital	digital	digital	digital
Measurement (manual/automatic)	manual	manual	automatic	manual	manual
Measurement parameters and ranges					
DC voltage	0…0,1 V…500 V	0…200 mV…1000 V	0…400 mV…1000 V	0…200 mV…600 V	0…200 mV…1000 V
AC voltage	0…10 V…500 V	0…200 mV…750 V	0…400 mV…750 V	0…200 V…600 V	0…2 V…750 V
DC current	0…50 µA…10 A	0…2 mA…20 A	0…400 µA…10 A	0…20 µA…10 A	0…20 µA…20 A
AC current	-	0…2 mA…20 A	0…400 µA…10 A	-	0…20 µA…20 A
Resistance	0…2kΩ…20MΩ	0…200Ω…2000MΩ	0…400Ω…40MΩ	0…200Ω…20MΩ	0…200Ω…20MΩ
Capacitance	-	0…20 nF…200 µF	0…10 nF…100 mF	-	0…2 nF…20 mF
Inductance	-	0…2 mH…20 H	-	-	-
Frequency	-	0…2 kHz… 10 MHz	0…100 Hz…30 MHz	-	-
Temperature	-	-20°C…1000°C	-20°C…1000°C	-	-
TRMS	-	-	yes	-	yes
Special feature	mirror scale	-	-	-	-
Overvoltage category	CAT III 600V	CAT IV 600V	CAT III 600V	CAT III 600V	CAT II 1000V, CAT III 600V

13840-00

PHYWE Demo Multimeter ADM 3: current, voltage, resistance, temperature

Website

TOPSELLLER

Function and Applications

The universal demonstration measurement device for measurements of current, voltage, resistance, and temperature. It is a battery-powered electronic analog measuring instrument with measuring amplifier and 9 selectable scales for 75 measuring ranges. All values can be displayed as digital values as well.

Benefits

- The universal demo measuring device for natural science education
- Analog and digital multimeter in one device
- Display of current, voltage, resistance and temperature
- Direct temperature measurement for NiCr-Ni probes
- 12 V scale matching the supply voltage of many common experiments
- 75 measuring ranges with fast switching scales by the press of a button
- Large high-contrast illuminated screen readable throughout the room
- Convenient for teachers with control elements and an additional display on the back panel
- Electronic overload protection for all measuring ranges
- Continuous operation of up to 10 h due to high-capacity battery
- Power-saving stand-by mode after approx. 60 min.
- Extra-safe for operation by students
- Firmware update support

Equipment and Technical Data

- 9 scales for 75 measuring ranges
- Direct/alternating voltage: 1mV...10kV
- Direct/alternating current: 1µA...10A
- Resistance: 0...10MΩ
- Temperature: -200°C...1200°C (also in °F and K)
- Input impedance: 10MΩ / 1Ω
- Accuracy: ±1,5 % of upper range value
- Frequency range: 2Hz...100kHz
- Battery run-time: approx. 10 h
- Display: 10 inch, illuminated
- Digit size: digital display: 2.7 cm, analog display: 1.5 cm
- Shock-resistant plastic case with retractable handle
- Display of measurement values via step motor driven needle
- Digital large-scale display of external sensor values
- Back panel with secondary display
- USB interface for firmware updates
- Extensive overload protection
- Includes external power supply
- Dimensions: 385€¯mm x 329€¯mm x 190€¯mm
- Weight: 5 kg

PHYWE Universal Counter

13601-99

Function and Applications

Measurement device for applications in mechanics and radioactivity. Measures time, frequency, pulse rates, pulse counting, periodic times, speeds and velocities.

Equipment and Technical Data

- Operating temperature range 5...40°C
- Relative humidity <80%
- Digital display:
  - Measurement reading LED 6-digit, 7-segment, 20 mm
  - Units LED 3-digit, 5x7 dot matrix
  - Units ms, s, Hz, kHz, MHz, I / s, RPM, Imp, V, m / s

Website

PHYWE Timer 4-4

13604-99

Function and Applications

Measures up to 4 times simultaneously. Multiple time measuring instrument for a variety of applications in teaching, wherever times are to be accurately measured. The timer unit has four 4 digit displays. The starting and stopping of the four built-in independent timers is actuated by the opening or closing of electrical circuits, or by means of light barriers or other TTL signal sources (e.g. a microphone).

Equipment and Technical Data

- Four 4-digit LED displays
- Digit height: 9 mm
- Number of timers: 4
- Measuring range: 0.000...9.999 s or 0000.0000...9999.9999 s

Website

PHYWE Timer 2-1

13607-99

Function and Applications

The chronometer Timer 2-1 has a 4-digit digital display and has been specially designed for use in student experiments and demonstrative teacher experiments.

Equipment and Technical Data

- Operating temperature range: 5...40°C
- Relative humidity: < 80%
- Control: (Start/ Stop) by electricalcircuits (contact closure/ contact opening or level ACC to TTL-Norm)
- Digital display: 4-Digit LED display, digit height 19 mm
- Time measurement: Measuring range 0.000...9.999 s

Website

PHYWE Teslameter, digital

13610-93

Function and Applications

For the measurement of magnetic DC and AC fields.

Equipment and Technical Data

- Especially useful for measuring AC fields
- Teslameter with 3 1/2 digit LED display, 20 mm high
- 3 measuring ranges: 20 - 200 - 2000 mT
- Sensitivity: 10 microT
- For alternating and direct fields
- Calibrated (up to 1T)
- Analog output

Website

13621-00

PHYWE Electrometer amplifier

Website

Function and Applications

Operational amplifier with high resistance input for quasi-static voltage measurement respectively charge measurement in fail-safe-plastic housing.

Equipment and Technical Data

- Power supply via 4 mm sockets or wall power supply with hole socket
- Gain/amplification: 1.0
- Input resistance: > 10000 GOhm
- Input current: < 0.5 pA
- Input capacitance: < 50 pF
- Input voltage:
- Amplifier (socket 1): ± 10 V-

13625-93

PHYWE LF amplifier, 220 V

Website

Function and Applications

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

Equipment and Technical Data

- Amplification 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,
- Accuracy of amplification factor: < 5% amplification factor
- Output voltage: 10 Veff
- Nominal final res.: 8 Ohm signal output, 1 kOhm RMS output

13626-93

PHYWE Universal measuring amplifier

Website

Function and Applications

Universal measuring amplifier for amplification of AC and DC voltages. Suitable for lab courses.

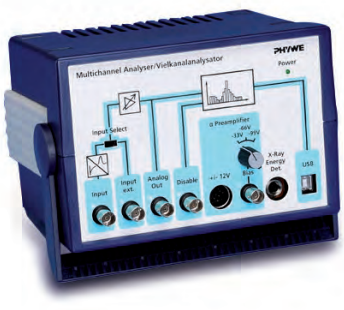
Equipment and Technical Data

- Input impedance of electrometer: > 10 (13) Ohm
- Low drift: 10 kOhm
- Input voltage: -10 to + 10 V
- Output voltage: -10 to + 10 V
- Six frequency ranges: V=1: 0...22 kHz, V=10: 0... 22 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

13727-99

PHYWE Multichannel Analyser (MCA)

Website



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

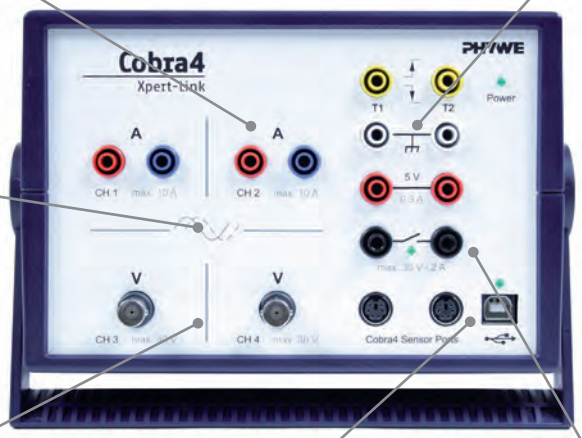
- Analog output for observing heights of the pulse spectrum on an oscilloscope
- A USB output for connecting to a computer

Cobra Xpert-Link, Demo-Interface – professional data collection in one system

Website

Two channels for current measurement
- channels galvanically isolated
- 1 mA...10 A, 2 MHz
- ideal for the implementation of experiments which require 2 measurement channels, e.g . in induction experiments

Oscilloscope function
- the Cobra Xpert-Link completely replaces an oscilloscope
- measurement of voltages, currents, phase shifts and TrueRMS possible



Connectors
- up to 2 light barriers or other devices with trigger input function (TTL level) can be controlled at the same time
- for power supply of light barriers via separate jacks with 5 V / max. 2 A –
- ideal for experiments which require several light barriers, e.g. Newton's laws

Two channels for voltage measurement
- channels galvanically isolated
- 10 µV ... 30 V, 10 MHz
- ideal for the implementation of experiments which require 2 measurement channels
- TrueRMS

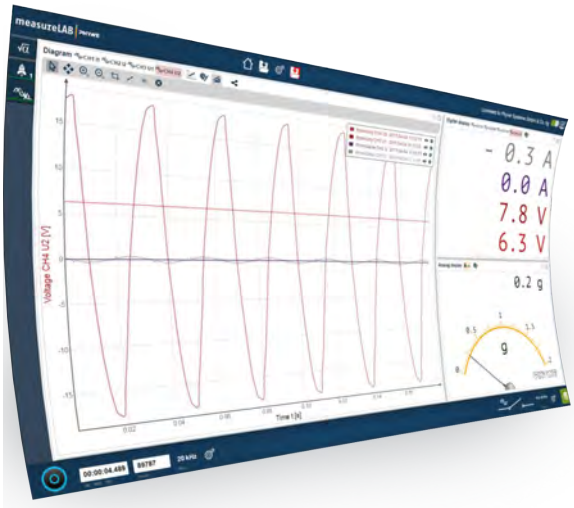
USB port
- USB connection to computer

Controllable relay
- relays can be easily and securely controlled via software
- max 30 V / 2 A
- ideal for experiments such as free fall

Cobra Xpert-Link & measureLAB - high-performance data collection and analysis

Benefits

- Operating system-independent, therefore future-proof: Windows and macOS
- Experiments are preconfigured in software: reduces preparation time
- Software oscilloscope
- Automatic identification of all Cobra4 interfaces and sensors
- Datasharing for demonstration experiments: Transfer of measurement data from teacher computer (measureLAB) to student tablet (free measureAPP for iOS and Android in the App Stores)
- Remote operation mode: students can use their own computers in the teaching lab



Website

Student microscopes
for schools

MIC-111A
Monocular model

MIC-126A
Binocular model

PHYWE MIC-100 series

Advantages

- Monocular and binocular models
- With rechargeable batteries for all models
- Strong and durable LED illumination
- Models with slide clamps for beginners and mechanical stage for advanced students

PHYWE MIC-100 series

Technical specifications

- Head: Monocular and binocular 30° inclined
- Eyepieces WF10x/18 mm, high eye point
- Eyepieces of the monocular models secured by screw
- Nosepiece for 4 objectives with click stops
- Achromatic objectives: 4x, 10x, 40x (S), 60x (S), 100x (S, oil) depending on model
- Condensor: Abbe N.A. 1.25 with iris diaphragm
- Models with mechanical stage: area: 140 x 130 cm, movement range: 78 x 30 mm
- Illumination: 3 W LED (color temperature: 5000 K), adjustable
- Integrated power supply 100...240 V, 50/60 Hz
- Rechargeable battery for off-grid operation
- Includes dust cover
- Dimensions: 35 cm x 21 cm x 23 cm (H x W x L)
- Weight: 5.5 kg

Model / Item no.	Monocular	Binocular	4/10/S40x objectives	S60x objectives	S100x objectives (oil)	Mechanical stage	Rechargeable battery
MIC-110A	▪		▪				▪
MIC-111A	▪		▪			▪	▪
MIC-116A	▪		▪	▪		▪	▪
MIC-119A	▪		▪		▪	▪	▪
MIC-121A		▪	▪			▪	▪
MIC-126A		▪	▪	▪		▪	▪
MIC-129A		▪	▪		▪	▪	▪
MIC-60X	Objective 60x (S), N.A. 0.85, achromatic, for MIC-100 series						
MIC-100X	Objective 100x (S), N.A. 1.25, achromatic, for MIC-100 series						

High-performance microscopes
for teachers, universities and labs

Website

MIC-321
Binocular model

PHYWE MIC-200 / MIC-300 series

Advantages

- For applications in biology and applied sciences, medicine and industry
- Binocular and trinocular models with 1000x magnification
- Two different model lines with high-grade resp. top-grade components

PHYWE MIC-200 und MIC-300 series

Technical specifications

- Siedentopf viewing head, inclined 30°, 360° rotatable, interpupillary distance: MIC-200: 48-75 mm, MIC-300: 50-75 mm, +/-5 diopter adjustment
- WF10x Plan eyepieces with high eye point
- UCIS Infinity independent achromatic optical system
- Quintuple nosepiece with infinity achromatic (MIC-200) resp. infinity plan achromatic (MIC-300) 4x, 10x, 40x(S) and 100x(S) objectives
- Abbe condenser N.A. 1.25 with iris diaphragm, phase-contrast slide holder, handwheel lift, condenser bracket with condenser center adjustment
- Mechanical stage:
  - MIC-200: size 141 x 131 mm, moving range 78 x 53 mm
  - MIC-300: size 185 x 177 mm, moving range 75 x 50 mm
- Low position coaxial coarse and fine focus mechanism with markings on the fine focus knobs
- Integrated power supply 100...240 V, 50/60 Hz
- The trinocular models include a C-mount adapter (1x)
- Includes dust cover
- Dimensions and Weight:
  - MIC-200: 39 cm x 23 cm x 28 cm, 8.6 kg
  - MIC-300: 41 cm x 25 cm x 28 cm, 12.5 kg

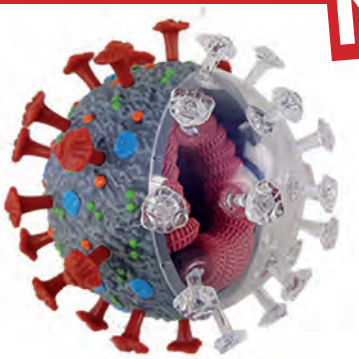
MIC-231
Trinocular model

Model / Item no.	Binocular	Trinocular	WF eyepieces	Achromatic objectives	Plan acromatic objectives	Mechanical stage	Rechargeable battery	Illumination
MIC-222	▪		10x/18mm	▪		▪	▪	3W LED
MIC-231		▪	10x/18mm	▪		▪		3W LED
MIC-321	▪		10x/20mm		▪	Rackless		Exchangeable 3W LED and 6V 30W halogen lamp
MIC-331		▪	10x/20mm		▪	Rackless		Exchangeable 3W LED and 6V 30W halogen lamp

Website

Biological models
for science education

NEW



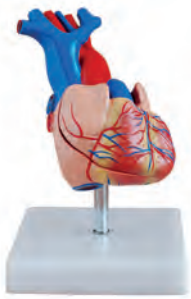
PHYWE Coronavirus (SARS-CoV-2), model

MOD-CORONAVIRUS

PHYWE Eye model, 6 times enlarged, 7 parts

MOD-EYE

PHYWE Human heart model, 2 parts



MOD-HEART

PHYWE Skeleton, 170 cm

MOD-SKELETON

PHYWE Human skull model

MOD-SKULL

PHYWE Brain model, 8 parts

MOD-BRAIN

PHYWE Dental care model (28 teeth)

MOD-TEETH

PHYWE Ear model, 5 times enlarged, 4 parts

MOD-EAR

PHYWE Skull with cervical spine, model

MOD-SKULLSPINE

PHYWE Vertebral column with pelvis and femur heads, model

MOD-VERTEBRA

PHYWE Mini torso, sexless, 18 parts, 42 cm, model

MOD-MINITORSO

PHYWE Mini skeleton, 85 cm

MOD-MINISKELETON

NEW

PHYWE Bacterium, modell

MOD-BACTERIUM

NEW

PHYWE AIDS-Virus, modell

MOD-AIDSVIRUS

PHYWE Mitosis and meiosis, set of 2 models

MOD-GENETICS

PHYWE Animal cell model

MOD-ANIMALCELL

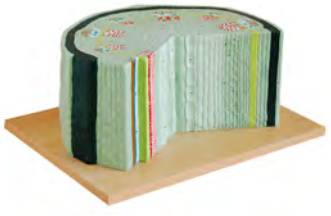
PHYWE Leaf structure, model

MOD-LEAF

PHYWE Monocot stem structure, model

MOD-MONOCOT

PHYWE Dicot stem structure, model



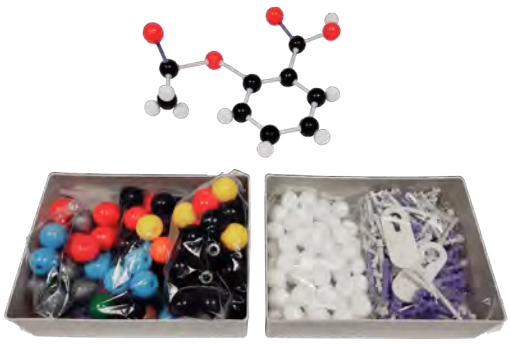
MOD-DICOT

Website

PHYWE molecular model construction sets
for science education

Student molecular model construction set, inorganic and organic chemistry (39832-01)

Student molecular model construction set, organic chemistry (39833-01)



Molecular model construction set, student/demo (39830-01)

Molecular model construction set, basic, demo (39829-01)

Molecular model construction set, extension set, demo (39829-02)

User	Student	Student	Student / Demo	Demo	Demo
Topic	Inorganic / Organic	Organic	Inorganic / Organic	Basic set	Extension set Inorganic / Organic
Item no.	39832-01	39833-01	39830-01	39829-01	39829-02
Ball sizes (mm)	17 / 23	17 / 23	23 / 30	30 / 40 / 50	30 / 40 / 50
Number of balls	52	50	179	66	114
Number of connectors	37	64	290	104	150
Orbitals	3	-	-	-	-
Removal tool	-	yes	yes	-	-

6 About PHYWE

Website

Traditional yet modern – more than 100 years of quality

Those who know nothing must believe everything.

Marie von Ebner-Eschenbach

With a more than 100-year tradition of excellence, PHYWE Systeme GmbH & Co. KG stands for technical acumen, 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 teaching of the natural sciences.

The product range comprises scientific equipment, experiments and solution systems along with modern computer-assisted measurements and wireless data logging systems and digital sensors, experiment guides and software in the areas of physics, chemistry, biology, medicine, material sciences and earth sciences. 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 specific needs!

made
in
Germany

measureLAB | PHYWE

measureAPP | PHYWE

curricuLAB® | PHYWE

Website

Service at PHYWE – individual and reliable

By choosing a PHYWE product, at the same time you decide in favour of a comprehensive service. We support you with our multi-level service concept. Rely on our strengths: rugged and long-lasting products made in Germany, customized for your needs.

Delivery & Installation

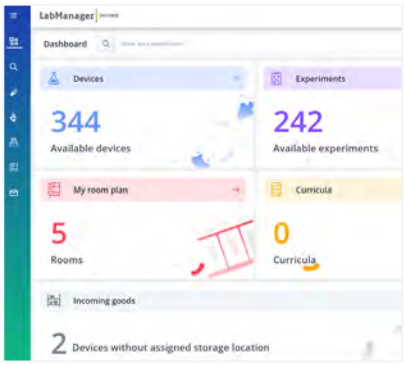
Save time:

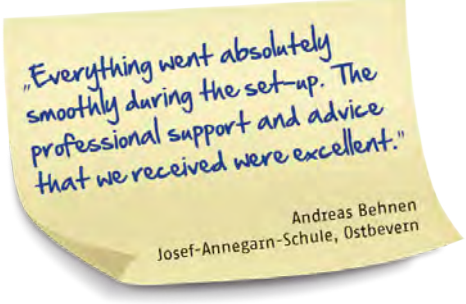
- Installation and setup of hard- and software
- Fast, on-time delivery
- Service for unpacking
- Check for completeness
- Training (on location or at PHYWE)

Order & Overview

Keep track:

- Best control over your equipment with the digital LabManager
- Browser-based access from every device
- Contact us for more information:
  E-mail: labmanager@phywe.de





made in Germany

Training

Use efficiently:

- Training of how to set up and operate instruments and experiments, explanation of device-specific tips and tricks
- Training for maintenance and handling
- On site or online training – we provide whatever fits best to our customers´ needs

Hotline & Maintenance

Receive answers:

- Problem solving by our experts
- Repair of defective devices
- Provision of spare parts
- Repair service / spare parts
- Hotline service – write an e-mail or call our experts:

E-mail: hotline@phywe.de
Phone: +49 (0) 551 604-196

Services

	Article No.
Installation, setup and functional test of the supplied material at your location.	
Installation and setup of equipment	**03333-06**
Organisation and inventory management platform - online and browser-based, accessible from any device.	
LabManager	**14594-62**
With examples and application exercises, our experts show you how easy digital teaching can be.	
Online Training - Digital Teaching	**03333-09**
Interactive online training, best suited for support with individual experiments, as the perfect addition to offers and for recapitulating specific topics.	
Customized Online Training	**03333-21**
Hands-on training of PHYWE equipment, technology and handling with the available products and experiments. Information on equipment-specific characteristics at your location.	
Training on-site	**03333-02**
Topic-related training courses of PHYWE equipment. Technology, handling and didactical use of equipment and experiments in the PHYWE information center in Göttingen, Germany.	
Training at Phywe site	**03333-03**

General notes on safety –
for safe experimentation

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.

You can find our General Terms and Conditions (GTC) on our website at https://www.phywe.com/general-terms-and-conditions/.

Or simply scan the QR code.

Website

7 Indices

Numerical Index by Item Number

02

03

07

09

12

13

M0

MU

P1

P2

P3

P4

P5

P6

Item No.	Item Name / Experiment Title	Page
P6000667	Centripetal force/centrifugal force with Cobra SMARTsense	83
P6201000	The conservation of momentum theorem with Cobra DigiCart	79

P7

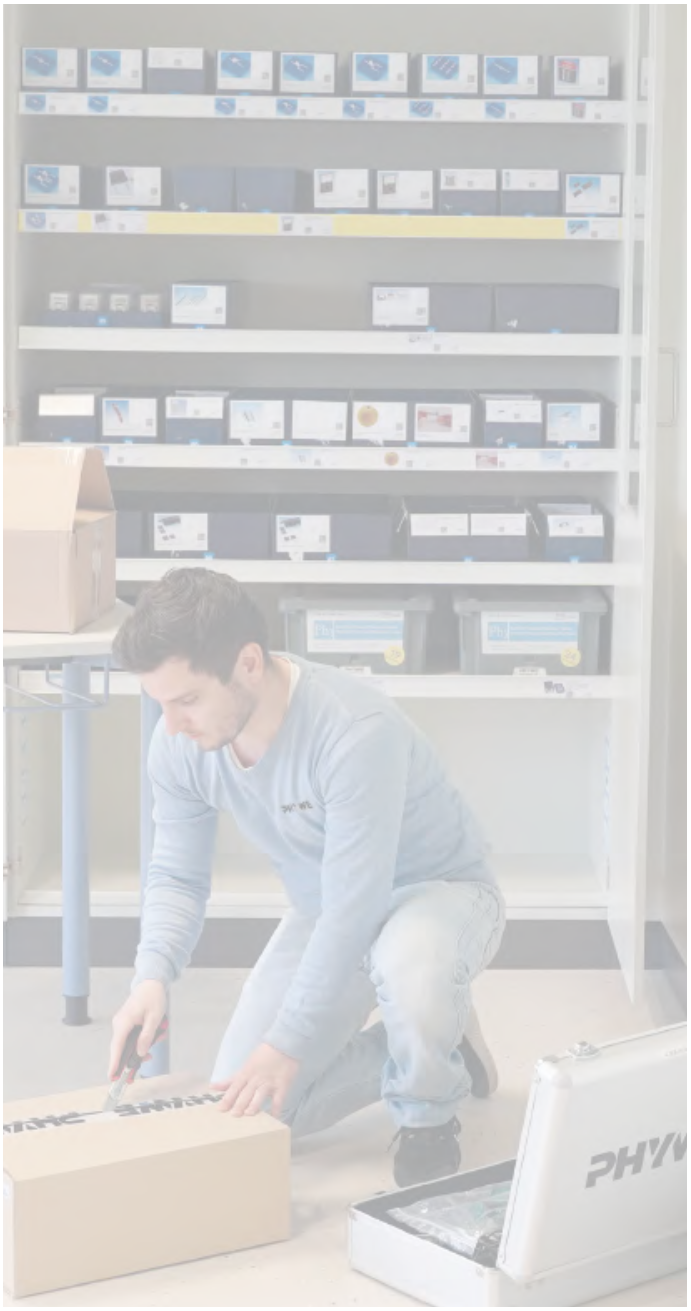
Item No.	Item Name / Experiment Title	Page
P7110169	Lambert-Beer's law and photometry of copper sulfate solutions with Cobra SMARTsense	204

P8

Item No.	Item Name / Experiment Title	Page
P8110500	Electrophoresis of Plasmid DNA	232, 74
P8110600	Electrophoresis of Lambda DNA	233
P8110700	Genetic fingerprinting	232, 74
P8110800	Paternity test	233

P9

Item No.	Item Name / Experiment Title	Page
P9507300	Model test for the use of ambient heat with the Peltier heat pump with ADM3	108



Alphabetical Index by Item Name

4

Item Name / Experiment Title	Page
4 Point Method / Measurement of low resistances / Ohm's Law	118

A

Item Name / Experiment Title	Page
Absorption of light (UV-VIS spectroscopy)	183
Acoustic Doppler effect with universal counter	99
Adiabatic coefficient of gases - Flammersfeld oscillator	103
Adsorption isotherms	198
Alpha energies of different sources with MCA	158
Ammonia preparation from the elements (Haber-Bosch process)	209
Analog multimeter, 500V AC/DC, 10A AC, 20MΩ	253
Analysis of plant pigments with Cobra SMARTsense	216
Atomic Resolution of the graphite surface by STM (Scanning Tunneling Microscope)	156
Atomic spectra of two-electron system: He, Hg	153
Avogadro's law	200

B

Item Name / Experiment Title	Page
Ballistic pendulum	80
Balmer series / Determination of Rydberg's constant	152
Band gap of germanium	154
Basic measurement techniques	78
Basic methods in imaging of micro and nanostructures with AFM (Atomic Force Microscopy)	156, 244
blueGel gel - electrophoresis unit with inbuilt illuminator	234, 72
Boiling point diagram of a binary mixture	198
Boiling point elevation - Raoult's law	199

C

Item Name / Experiment Title	Page
Cannizzaro reaction and reaction of benzaldehyde with ethylene glycol	190
Capacitance of metal spheres and of a spherical capacitor	117
Centripetal force/centrifugal force with Cobra SMARTsense	83
Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser	116
Characteristic curves of a solar cell	119
Characteristic curves of semiconductors with Cobra Xpert-Link	120
Characteristic X-rays of copper	166
Charging curve of a capacitor / charging and discharging of a capacitor	116
Charging curve of a capacitor and switch-on behaviour of an inductance with Cobra Xpert-Link	117
Chladni figures	96
Chromatographic separation processes: thin layer chromatography (TLC)	184
Cobra DigiCart (blue)	15
Cobra DigiCart (white)	15
Cobra DigiCart Basic Set	15
Cobra DigiCart Expert Set	15
Cobra DigiCartAPP	15
Cobra SMARTexperiment - 3rd law of Newton	14
Cobra SMARTexperiment - Archimedes' principle	89
Cobra SMARTexperiment - Hooke's Law	84
Cobra SMARTexperiment - Mathematical Pendulum	92
Cobra SMARTlink	6
Cobra SMARTlink	7
Cobra SMARTsense 3-Axis Magnetic field - Sensor for measuring the magnetic field in 3 axes	10
Cobra SMARTsense Absolute Pressure - Sensor for measuring the absolute pressure	10
Cobra SMARTsense Acceleration (3-axis) - Sensor for measuring acceleration in 3 axes	10
Cobra SMARTsense Ammonium Ion - Sensor with ion-selective electrode for ammonium	10
Cobra SMARTsense Blood Pressure - Sensor for measuring blood pressure	10
Cobra SMARTsense Calcium Ion - Sensor with ion-selective electrode for calcium	10
Cobra SMARTsense Cloride Ion (Bluetooth) - Sensor with ion-selective electrode for chloride	10
Cobra SMARTsense CO2 - Sensor for measuring the carbon dioxide content	10
Cobra SMARTsense Colorimeter - Sensor for measuring colours and turbidity	10, 206
Cobra SMARTsense Conductivity - Sensor for measuring conductivity in liquids	10
Cobra SMARTsense Current - Sensor for measuring electrical current	10

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

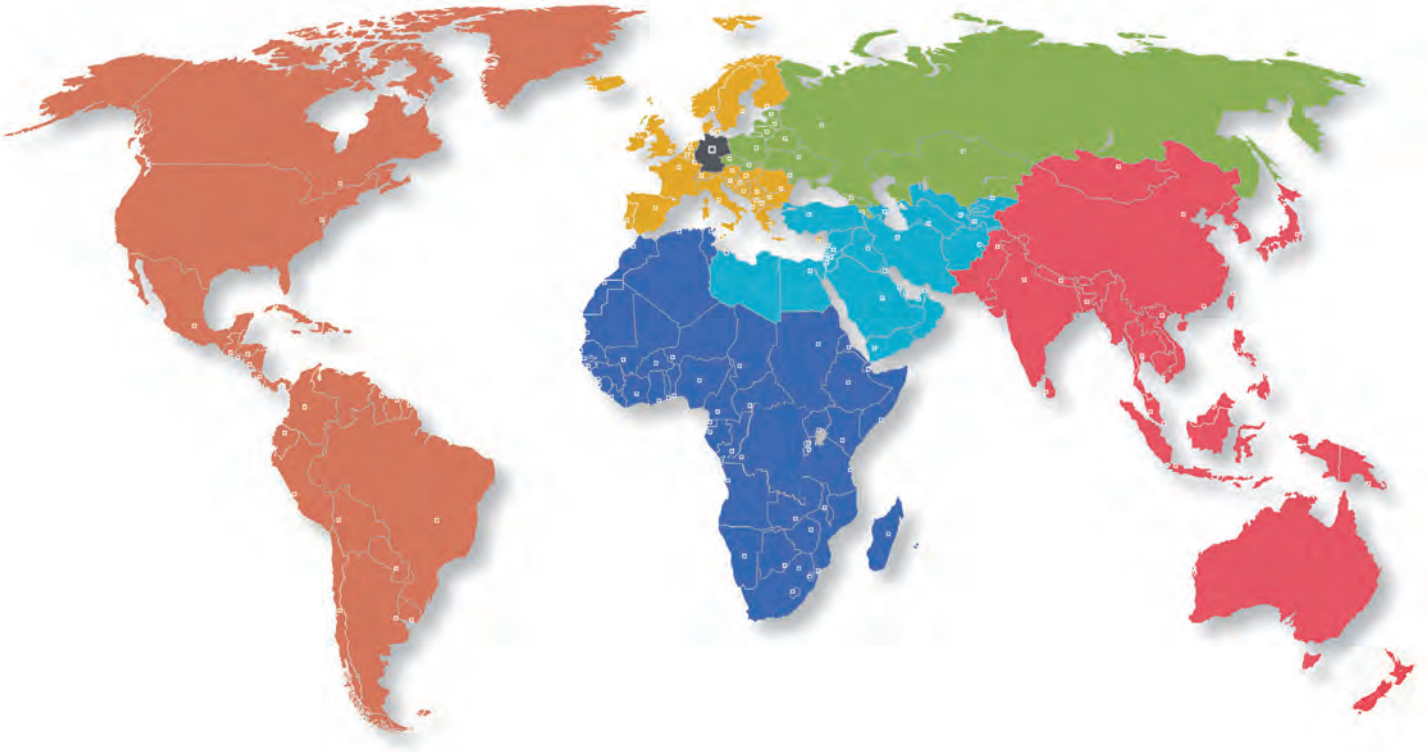
W

X

Z

Global network

Your partner is never far away!



For general enquiries please use the contact form on our website at ***www.phywe.com/contact/*** *or send an email to* ***enquiry@phywe.de****.*

For regional enquiries and personal contact go on our website at ***www.phywe.com/contact/****, select your region by clicking and use the contact form to your Area Sales Manager.*

Website

Worldclass solutions
for better education:
www.phywe.com

PHYWE
excellence in science

PHYWE Systeme GmbH & Co. KG
Robert-Bosch-Breite 10
37079 Göttingen / Germany

Phone +49 (0) 551 604 - 0
Fax +49 (0) 551 604 - 115

info@phywe.com
www.phywe.com

Our international Sales Partner

00220-02