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PHYSICS EXPERIMENTS
November 2017

Frederiksen Physics Experiment Catalogue

November 2017

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Frederiksen Experiments

We are happy to present this collection of experiments for our customers!

Frederiksen Scientific has always had a clear focus on experiments. A large number of our product manuals include descriptions of different experiments – some in great detail, some only sketched. This variety can sometimes be challenging – but nevertheless, you can still find lots of inspiration in the product manuals.

The experiments described on the following pages have been given a *homogeneous framework* to enable teachers and lab technicians to quickly assess the objectives of the lab and the equipment needed.

The catalogue is not yet covering more than a fraction of any curriculum – please consider this as a work in progress. The number of titles will grow over time.

Each experiment is a union of two important parts: The **manual** and the **equipment list**. In the following section, each page contains a **description** of an experiment with the corresponding list of equipment. The lab manual for the experiment can be downloaded for free from our web site. One such manual is included as a sample at the end of this booklet.

The manuals are intended to be used by the students. Most of them also contains a small section with notes for the teacher – and the list of equipment is of course included in all of them. The majority of the manuals are 4-page documents and can therefore be printed in "folder format" if you have access to an A3 printer.

The experiments have been given unique numbers. If you want to order the complete equipment list for an experiment you can simply refer to its number. (This works for mail orders only. Experiment numbers are not available for web orders.) Items in a possible "Also required" section are not included.

We hope you will find this catalogue inspiring.

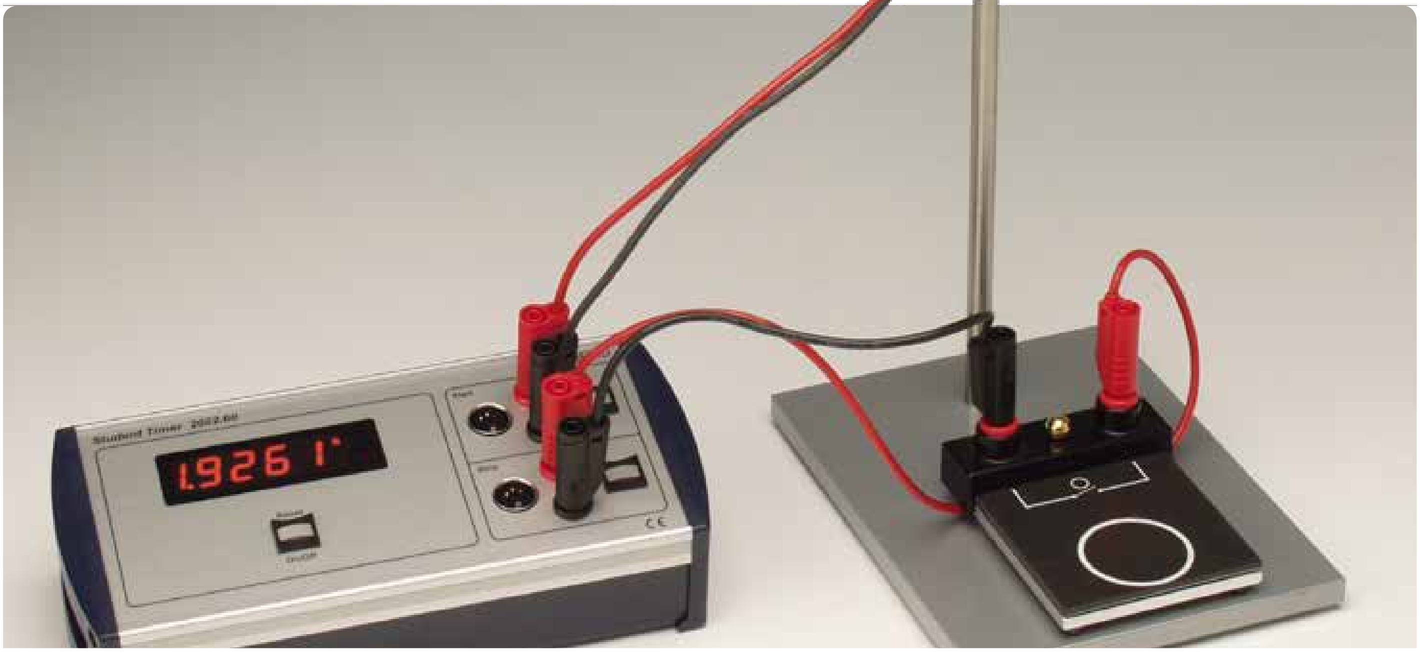

Width
1: 406.0us
2: chan off
Duty Cycle
1: 48.70%
2: chan off
Rise Time
1: 293.5us
2: chan off
DC

INDEX

EXPERIMENTS

Free fall – Measuring g

Experiment number: 134510-EN
Type: Student exercise
Topic: Kinematics
Suggested for: Grade 10+



Objective

Examining the laws of free fall; determining the acceleration of gravity.

Principle

A metal ball is held by a magnet and creates electric contact between the two connectors in the release device at the top.
When the magnet is suddenly removed the ball drops which starts the timer.

The ball hits the plate at the bottom which sends a stop pulse to the timer.

The path length of the free fall is measured by a ruler or a tape measure.

Equipment list

The *complete* list below may conveniently be referred to as item number **134510**.

Item No.	#	Note	Text
200280	1		Student timer
198010	1		Free Fall apparatus
000800	1		Retort stand rod 150 cm
002310	1		Square bosshead
000100	1		Retort stand base 2.0 kg
105750	1		Safety cable, silicone, 200 cm, black
105751	1		Safety cable, silicone, 200 cm, red
105740	1		Safety cable, silicone, 100 cm, black
105741	1		Safety cable, silicone, 100 cm, red

Also required

Tape measure 200 cm (like 140010).

Similar experiments:
135630-EN The Bessel pendulum (advanced)

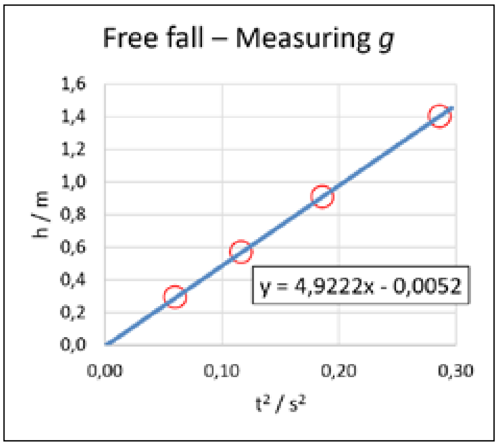
Sample results

The following table shows typical results. The values in the time column were averaged over three measurements.

h / cm	t / ms
29.2	245.54
56.9	341.57
91.0	431.41
140.4	534.97

The results are plotted with h as a function of t^2 and the slope is found. From this, the acceleration due to gravity can be found:

$$g = 2 \cdot 4.92 \, \frac{\mathrm{m}}{\mathrm{s}^2} = 9.84 \, \frac{\mathrm{m}}{\mathrm{s}^2}$$



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Speed of sound

Experiment number: 131410-EN
Type: Student exercise
Topic: Sound, kinematics, measurement techniques
Suggested for: Grade 9 – 10

Objective

Measuring the speed of sound in atmospheric air.

Principle

An electronic timer is started and stopped by the signal from two microphones placed with a certain distance between them. The sound source is placed so the sound passes the start microphone first and later reaches the stop microphone.

Equipment list

The *complete* list below may conveniently be referred to as item number **131410**.

Item No.	#	Note	Text
200280	1		Student timer
248600	2		Microphone
248601	2		Cable DIN-6 to modular
248200	1		Clapper board
000410	2		Retort stand foot, square

Also required

Ruler or tape measure (like 140510 or 140010).

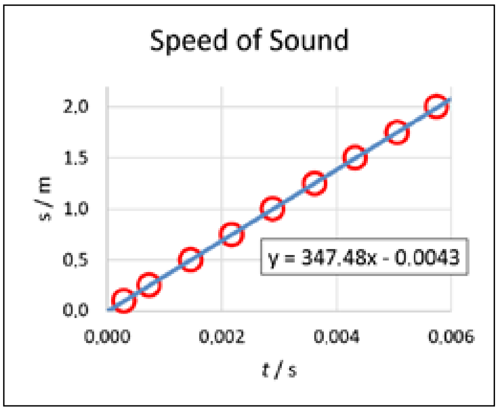
Similar experiments:
131415-EN Speed of sound with SpeedGate

Sample results

These results were obtained with a room temperature of 25.3 °C and a relative humidity of 60 %. In the lab manual you will find a simplified formula for the expected speed of sound, resulting (for these conditions) in a value of 347.4 m/s.

s / m	t / ms
0.10	0.29
0.25	0.73
0.50	1.46
0.75	2.17
1.00	2.89
1.25	3.62
1.50	4.33
1.75	5.06
2.00	5.75

When plotted, the measurements very closely fall on a straight line through (0,0) with a slope that gives the experimental result 347.5 m/s.



Speed of sound with SpeedGate

Experiment number: 131415-EN
Type: Student exercise
Topic: Sound, kinematics, measurement techniques
Suggested for: Grade 9 – 10

Objective

Measuring the speed of sound in atmospheric air.

Principle

An electronic stopwatch is started and stopped by the signals from two microphones which are placed with some distance between them. The source of the sound is positioned so that the sound first passes the start microphone and after that the stop microphone.

Equipment list

The *complete* list below may conveniently be referred to as item number **131415**.

Item No.	#	Note	Text
197570	1		SpeedGate (includes one 197571)
248600	2		Microphone
197571	1		Cable modular plugs crossed 2m
248200	1		Clapper board
000410	2		Retort stand foot, square

Also required

Ruler or tape measure (like 140510 or 140010).

Similar experiments:
131410-EN Speed of sound with Student Timer

This version of the experiment uses the versatile SpeedGate as an electronic stopwatch. Although primarily designed as a photogate, the built-in timer functions just as well with external signals.

This equipment option enables you to make more experiments within a limited budget.

Precision of results

You can expect exactly the same level of precision as when using for instance our 200280 Student Timer as the stopwatch – please refer to experiment 131410-EN for sample measurements.

Resonance in an air column

Experiment number: 132810-EN **Topic:** Waves, sound
Type: Student exercise **Suggested for:** Grade 10-12

Objective

Investigating standing waves in the air column in a closed-end (i.e. half-open) pipe.

Determining the speed of sound in air.

Principle

Resonance in the pipe happens at certain combinations of the frequency of the sound and the length of the air column. In this experiment we will vary one of these parameters at a time.

The results from the measurments will be matching pairs of frequencies and wavelengths – from these, the speed of sound can be found.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
132810A (option A: Student function generator)
132810B (option B: Function generator 250350).
(The photo shows option A)

Item No.	#	Note	Text	
250310	(1)	a	Student Funct. Generator	**Option A**
250350	(1)	a	Function Generator	**Option B**
247500	1		Kundt's tube (Plexiglas)	
250500	1		Loudspeaker on post	
248600	1		Microphone	
248601	1		Cable, modular plug to 6-pin DIN	
251560	1		Battery box	
386231	1	b	Multimeter DMM-8062	
000600	2		Stand base	
000850	2		Steel rod, 25 cm	
002310	2		Bosshead, square	
001800	2		Stand clamp, overlapping jaws	
000410	2		Stand base, square	
105720	1		Safety cable, silicone 50 cm, black	
105721	1		Safety cable, silicone 50 cm, red	
105740	1		Safety cable, silicone 100 cm, black	
105741	1		Safety cable, silicone 100 cm, red	

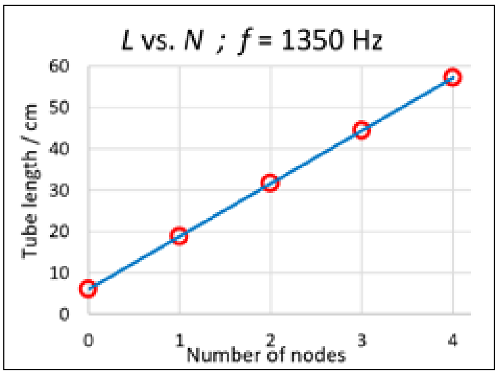
Notes
a) Select *one* option
b) ... or similar. Resolution: 0.1 mV AC

Also required

060000 Thermometer (or similar)
185000 Hygrometer (or similar) – **or** data from a nearby meteorological station.

Sample results

In one of the measurement series the length of the tube is varied while the frequency is fixed at 1.35 kHz. The lengths where resonance occurs are plotted as a function of the number of resonance nodes.



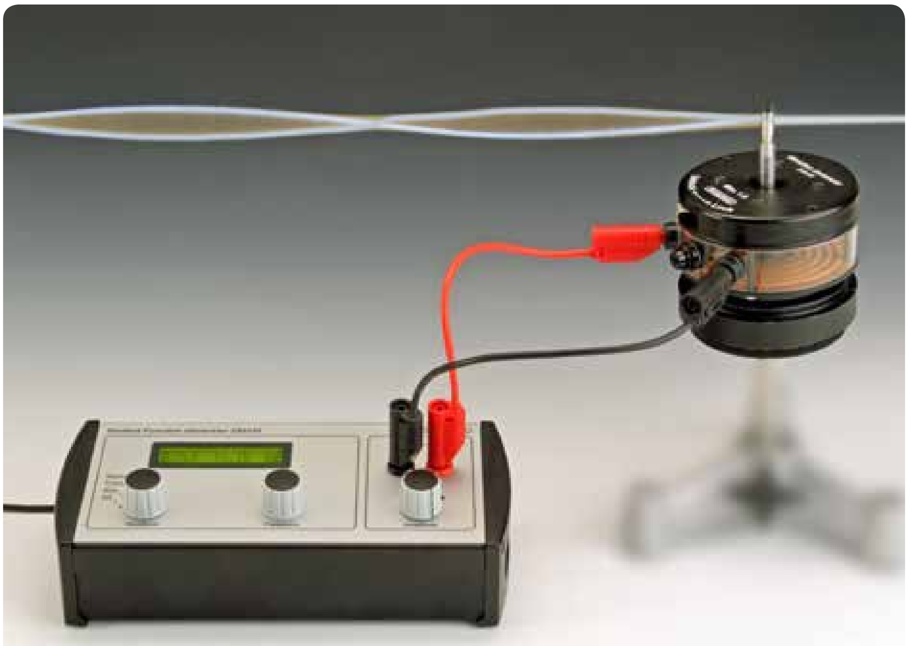
The graph shows how the data points fall precisely on a straight line. The slope of the line equals half of the wavelength. Combining this with the known frequency, the speed of sound can be found to be 345.6 m/s.

(This is 0.3 % off at 24°C and 65 % rel.hum.)

Similar experiments:
132860-EN Resonance – standing waves on a string

Resonance – standing waves on a string

Experiment number: 132860-EN **Topic:** Waves
Type: Student exercise **Suggested for:** Grade 10-12



Objective

A study of standing waves on a tight string, with a focus on the frequency of the harmonics.

The relationship between the frequency of the natural oscillations and the thickness and tension of the string is investigated.

The propagation velocity of the waves is determined.

Principle

A function generator connected to a vibrator emits a wave train along the string. The wave train is reflected at both ends of the string. At certain frequencies, strong standing waves are observed. The phenomenon is called resonance. At the resonance frequencies it is easy to determine the wavelength.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
132860A (option A: Student function generator)
132860B (option B: Function generator 250350).
(The photo shows option A)

Item No.	#	Note	Text	
250310	(1)	a	Student Funct. Generator	**Option A**
250350	(1)	a	Function Generator	**Option B**
218500	1		Electromagnetic vibrator	
208500	1		Pulley on rod	
103840	1		Dynamometer 5 N	
116600	1		Line, braided, 50 m	
799109	1		Mason cord, 120 m	
767022	1		Line, braided, 20 m	
000820	1		Retort stand rod, 75 cm	
000850	2		Retort stand rod, 25 cm	
001600	2		Table Clamp	
002310	2		Square boss head	
105720	1		Safety cable, silicone, 50 cm, black	
105721	1		Safety cable, silicone, 50 cm, red	

Notes
a) Select *one* option

Also required

102900 Digital scales 300 g / 0,01 g – or similar
140010 Tape measure 200 cm – or similar

Similar experiments:
132810-EN Resonance in an air column

Progression of the lab manual

The first section calls for only elementary math and a modest abstraction level.

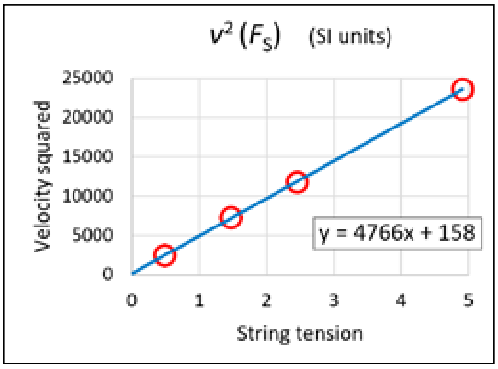
The following two sections are more demanding. The sample results below are from these.

Sample results

According to theory, the square of the propagation speed of waves on a string should be proportional to the string tension. The proportionality constant should be the reciprocal of the mass per unit length of the string.

The results shown in the graph was obtained with a line weighing 0.208 g/m.

The reciprocal of the slope 1/(4766 m/kg) gives 0.000210 kg/m or 0.210 g/m – a deviation of only 0.9 %.



Conservation of energy in the gravitational field

Experiment number: 134570-EN
Type: Student exercise
Topic: Mechanical energy
Suggested for: Grade 10-12

Objective

To examine the conservation of mechanical energy.

Principle

A weight (pendulum bob) swings as a pendulum in a thread.

When in the extreme positions of the swing, we can determine the vertical position of the weight and hence its potential energy.

In the lowest (centre) position, the weight passes a photogate. We can thereby determine the speed of the weight and calculate its kinetic energy.

Sample results

The diameter of the weight is measured to be 29.7 mm. This is the distance the weight must travel from breaking the light beam until letting it through again.

A few measurements:

h_0 / m	h / m	Δt / ms	Δh / m	v / m/s	E_{pot} / J	E_{kin} / J	ΔE
0.213	0.310	21.71	0.097	1.368	0.0952	0.0936	-1.7%
0.213	0.301	22.78	0.088	1.304	0.0864	0.0850	-1.6%
0.213	0.414	15.13	0.201	1.963	0.1973	0.1928	-2.3%

The calculated energy loss is of course very sensitive to the measured diameter as well as the table value used for g, the acceleration due to gravity.

Equipment list

The *complete* list below may conveniently be referred to as item number **134570**.

Item No.	#	Note	Text
200280	1		Student timer
197550	1		Photogate
272502	1		Aluminium weight 100 g
105711	1		Safety cable, silicone 25cm, red
000850	1		Retort stand rod 25 cm
000830	1		Retort stand rod 50 cm
000800	1		Retort stand rod 150 cm
002310	3		Square bosshead
000100	2	a	Retort stand base 2.0 kg
116500	1		Extra strong thread

Notes

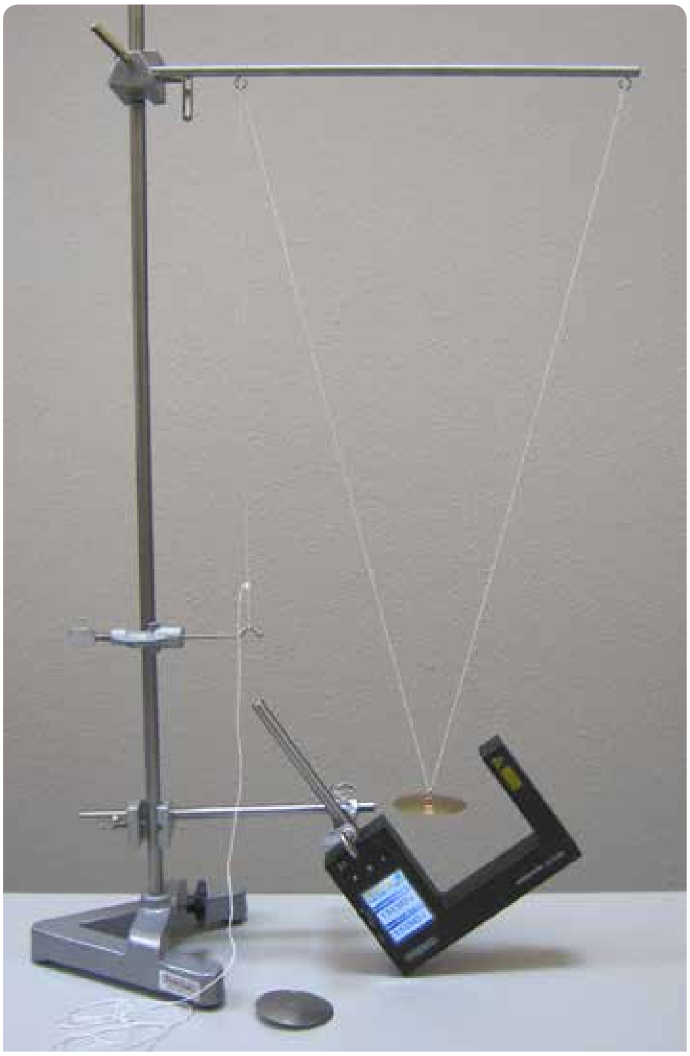
a) Photo shows one 000410 Retort stand foot, square instead of one of the 000100 bases.

Also required

Ruler or tape measure (like 140500 or 140010).
102961 Digital scales (200 g/0.1 g) – or similar.

Mathematical pendulum (with SpeedGate)

Experiment number: 135110-EN
Type: Student exercise
Topic: Mechanics
Suggested for: Grade 11-12



Objective

Establishing the formula for the oscillation period of a mathematical pendulum.

Principle

A mass of small extent, which oscillates in a light thread is a good approximation of a so-called *mathematical pendulum.* (Ideally, it is a point mass in a rigid, massless string with frictionless suspension - in vacuum.)

In order to check the formula for the oscillation period, the different parameters are varied – both some that are part of the formula, and others that should not have any influence. The two weights included have the same shape but different mass. The pendulum length and the amplitude of the oscillation can also be varied.

Sample results

One measurement series with varying length:

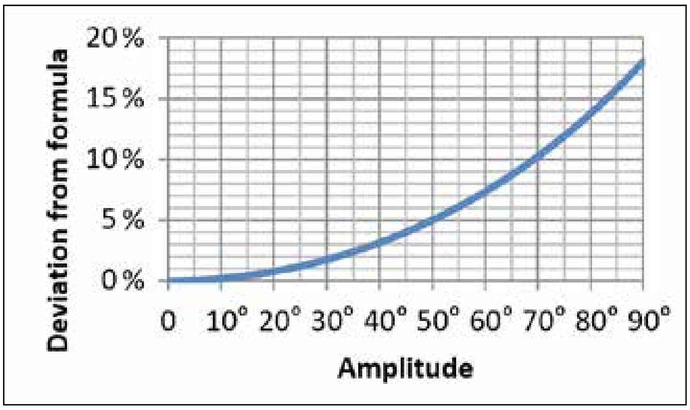
Measured		*Comp. w/ theory*	
L / m	**T / s**	**T_{theo} / s**	**devi.**
0.266	1.0270	1.0343	-0.71%
0.419	1.2950	1.2981	-0.24%
0.588	1.4960	1.5378	-2.72%
0.689	1,6603	1.6646	-0.26%
0.817	1.8121	1.8127	-0.03%

Based on a table value for g the theoretical oscillation periods were found from

$$T = 2\pi \cdot \sqrt{\frac{L}{g}}$$

The results show a fine agreement with theory.

(This formula for the period of the pendulum is only valid for small amplitudes – the graph shows how a more developed theory deviates from the simple formula.)



Equipment list

The *complete* list below may conveniently be referred to as item number **135110**.

Item No.	#	Note	Text
218210	1		Math. pendulum w. suspension
197570	1		SpeedGate
000100	1		Retort stand base, A-shaped, 2.0 kg
000800	1		Retort stand rod, 150 cm
000850	1		Retort stand rod, 25 cm
002310	2		Square boss head
002320	1		Boss head, swivel
002700	1		Stand clamp with hook

Also required

Ruler or tape measure (like 140500 or 140010).
102961 Digital scales (200 g/0.1 g) – or similar.

Physical pendulum

Experiment number: 135610-EN **Topic:** Mechanics, rigid bodies
Type: Student exercise **Suggested for:** Grade 12+

Objective

To study the *physical pendulum* – i.e. a composite, rigid body – comparing measured and calculated values of moments of inertia.

(Another name for physical pendulum is *compound pendulum.*)

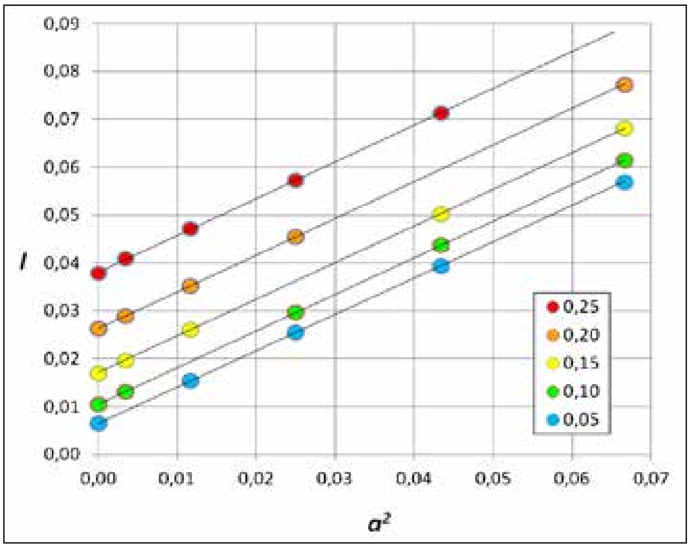
Principle

The moment of inertia is determined by measuring the period for the physical pendulum.
The emphasis is on symmetric mass distributions which places the pendulum's centre of mass in the centre of the pendulum. This simplifies the calculations.

The experiment can be extended to arbitrary mass distributions.

Sample results

The so-called *Steiner's theorem* is important when working with moments of inertia. The graphs shows the experimental results for symmetrical weight positions: The measured moments of inertia is plotted as a function of the distance between the centre of mass and the pivot (SI units).



According to Steiner's theorem, these points should lie on a straight line with the total mass of the pendulum as the slope. The parameter given in the box is the distance from the pendulum centre to the weights.

The experimental results show an excellent agreement with theory.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
135610A (option A: SpeedGate)
135610B (option B: Counter and photogate).

Item No.	#	Note	Text	
218100	1		Phys. pendulum / Bessel-pendulum	
001510	1		Clamp	
000820	(1)	b	Retort stand rod 75 cm	**Option A**
197570	(1)	b	SpeedGate	**Option A**
002310	(1)	b	Bosshead, square	**Option A**
200250	(1)	b	Electronic counter	**Option B**
197550	(1)	b	Photocell unit	**Option B**
000100	(1)	b	Retort stand base	**Option B**
000850	(1)	b	Retort stand rod 25 cm	**Option B**
002310	(2)	b	Bosshead, square	**Option B**

Notes
a) The same equipment list is used in Exp. 135630
b) Select *one* option

Also required

Tape measure (like 140010) or precision ruler.
102962 Digital scales (500 g/0.1 g) – or similar.

Similar experiments:
135630-EN The Bessel pendulum

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The Bessel pendulum

Experiment number: 135630-EN
Type: Student exercise
Topic: Mechanics, rigid bodies, precision measurements
Suggested for: Grade 12+

Objective

Determining the local acceleration due to gravity g with great precision.

Principle

The equipment is a model of a so-called **reversion pendulum**. The name refers to the pendulum's ability to be used upside down – there is a pivot at each end. The reversion pendulum is built with different distances from the pivots to the centre of mass, and is subsequently adjusted to have the same oscillation period for the two pivots.

From this, g can easily be calculated.

Expected precision

The equipment constitutes a *model* of the Bessel pendulum that shows the *principle* behind the device. Nevertheless, the achievable precision is not bad:

Using e.g. the SpeedGate and averaging over a sufficient number of periods, relative timing uncertainties reaches 10^{-5} i.e. 0.001 %. However, the value to use when calculating g has to be interpolated which increases the uncertainty by a factor of about 15. Still not too bad.

The other necessary measurement – the distance between the two pivots – is by far the dominant factor. The distance is around 417 mm and can hardly be measured better than within 0.5 mm. This corresponds to a relative uncertainty of about $1.2 \cdot 10^{-3}$ i.e. 0.12 %.

(The research grade Bessel pendulums used earlier was constructed to make it possible to measure this distance using interferometry.)

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
135610A (option A: SpeedGate)
135610B (option B: Counter and photogate).

Item No.	#	Note	Text	
218100	1		Phys. pendulum / Bessel-pendulum	
001510	1		Clamp	
000820	(1)	b	Retort stand rod 75 cm	**Option A**
197570	(1)	b	SpeedGate	**Option A**
002310	(1)	b	Bosshead, square	**Option A**
200250	(1)	b	Electronic counter	**Option B**
197550	(1)	b	Photocell unit	**Option B**
000100	(1)	b	Retort stand base	**Option B**
000850	(1)	b	Retort stand rod 25 cm	**Option B**
002310	(2)	b	Bosshead, square	**Option B**

Notes
a) The same equipment list is used in exp. 135610
b) Select *one* option

Similar experiments:
135610-EN Physical pendulum

Also required

Tape measure (like 140010) or precision ruler.

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Circular motion with conical pendulum

Experiment number: 135710-EN **Topic:** Mechanics, two-dimensional motion
Type: Student exercise **Suggested for:** Grade 12+

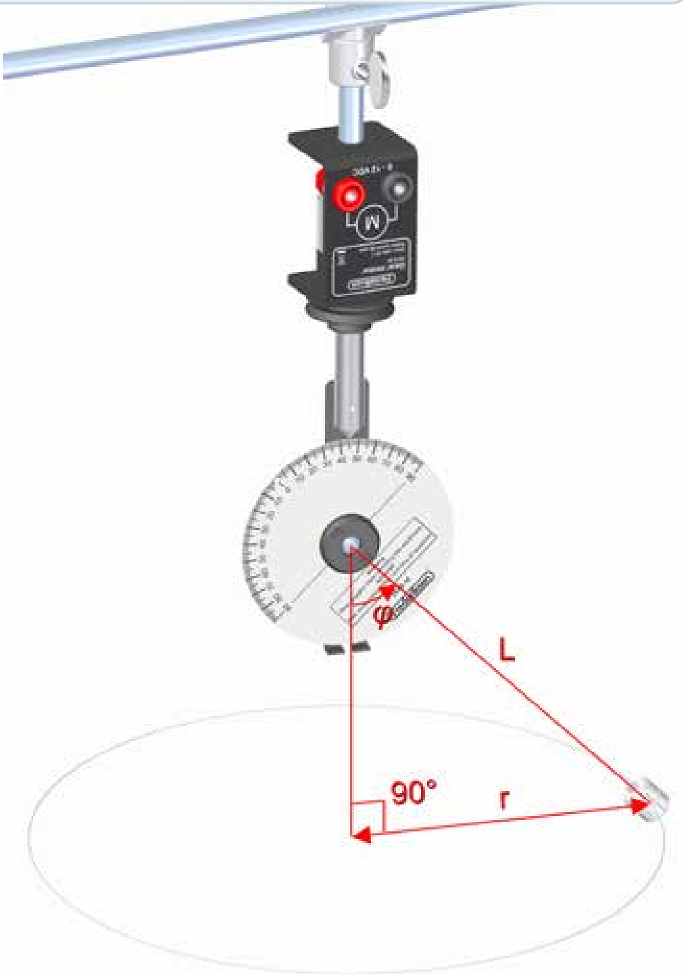
Objective

To investigate how the centripetal force depends on orbital radius and orbital period.

Principle

We use a conical pendulum in this experiment. The bob performs a circular motion under the under the influence of the tension of the string and the force of gravity. The angle between these two forces is read on the fly on the graduated scale on the conical pendulum.

The orbital period can be found with a stopwatch or with a photogate; the latter is to be preferred.



Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
135710A (option A: SpeedGate)
135710B (option B: Counter and photogate).

Item No.	#	Note	Text	
207010	1		Conical pendulum	
202550	1		Gear motor	
361600	1	b	Power supply 0-12 V, 3 A	
197570	(1)	c	SpeedGate	**Option A**
200250	(1)	c	Electronic counter	**Option B**
197550	(1)	c	Photocell unit	**Option B**
000800	1		Retort stand rod 150 cm	
000810	2		Retort stand rod 100 cm	
002310	4		Square Bosshead	
001600	2		Table clamp	
105750	1		Safety cable, silicone, 200 cm, black	
105751	1		Safety cable, silicone, 200 cm, red	

Notes
a) The same equipment is used in Exp. 135730
b) Alternative power supply: 364000
c) Select *one* option

Also required

Paperboard, scissors, ruler, digital scales

Similar experiments:
135730-EN Conical pendulum - mesuring *g*

Sample results

One of the measurement series keeps the orbital radius fixed while varying the length of the pendulum and hence the orbital period.

In the first line below, the radius r is calculated. In the next three lines, a value for φ is calculated (based on the fixed r value). The motor speed is adjusted to obtain this angle.

Measured			*Const.*	*Compared with theory*		
L / cm	φ / °	T / s	r / cm	$F_{c,meas}$ / mN	$F_{c,theo}$ / mN	devi.
16.9	61	0.5704	14.78	107.7	109.0	-1.3%
19.0	51	0.7052	14.78	73.9	71.3	3.6%
21.4	44	0.7772	14.78	57.0	58.7	-2.9%
25.0	36	0.9005	14.78	43.8	43.8	0.0%

The measured centripetal force is found from the mass of the pendulum bob and the relation:

$$F_c = m \cdot g \cdot \tan(\varphi)$$

- In agreement with theoretical values given by:

$$F_c = \frac{4\pi^2 \cdot m \cdot r}{T^2}$$

Conical pendulum – measuring g

Experiment number: 135730-EN
Type: Student exercise
Topic: Mechanics, two-dimensional motion
Suggested for: Grade 12+

Objective

To determine the acceleration due to gravity by means of a conical pendulum.

Principle

We use a conical pendulum in this experiment. The bob performs a circular motion under the influence of the tension of the string and the force of gravity. The angle between these two forces is read on the fly on the graduated scale on the conical pendulum.

The orbital period can be found with a stopwatch or with a photogate.

From the measured quantities, g can be calculated.

Sample results

It is possible to calculate g for each complete measurement like this:

Pendulum length: 231 mm
Angle: 61°
Period: 667.44 ms

$$g = \frac{4\pi^2 \cdot L \cdot \cos(\varphi)}{T^2} = \frac{4\pi^2 \cdot 0.231\ \mathrm{m} \cdot \cos(61°)}{(0.66744\ \mathrm{s})^2} = 9.92\ \mathrm{m/s^2}$$

After a series of measurements, an average value can be found.

The students are encouraged to consider other means of analysing the experimental data – like plotting $4\pi^2 \cdot L \cdot \cos(\varphi)$ as a function of T^2 for a data series with fixed L.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
135710A (option A: SpeedGate)
135710B (option B: Counter and photogate).

Item No.	#	Note	Text	
207010	1		Conical pendulum	
202550	1		Gear motor	
361600	1	b	Power supply 0-12 V, 3 A	
197570	(1)	c	SpeedGate	**Option A**
200250	(1)	c	Electronic counter	**Option B**
197550	(1)	c	Photocell unit	**Option B**
000800	1		Retort stand rod 150 cm	
000810	2		Retort stand rod 100 cm	
002310	4		Square Bosshead	
001600	2		Table clamp	
105750	1		Safety cable, silicone, 200 cm, black	
105751	1		Safety cable, silicone, 200 cm, red	

Notes
a) The same equipment is used in Exp. 135710
b) Alternative power supply: 364000
c) Select *one* option

Also required

Paperboard, scissors, ruler

Similar experiments:
135710-EN Circular motion with conical pendulum

Collisions on an air track

Experiment number: 134720-EN **Topic:** Mechanics, dynamics
Type: Student exercise **Suggested for:** Grade 11-12+

Objective

To investigate elastic and inelastic collisions between two carts on an air track. For both kinds of collisions, conservation of both momentum and energy are examined.

Principle

The air track enables virtually frictionless motion in one dimension. This ensures that the only forces acting parallel with the track are the mutual influence between the two carts. The carts can therefore be considered an isolated system.

The two carts are launched towards each other with different speeds. The masses of the carts are also varied.

The speeds of the carts are measured by two SpeedGates that can display the speed when passed. SpeedGate remembers the previous measurement and fits perfectly with collision experiments where the cart typically passes the photogate once on its way to the collision and once on its way back.

Equipment list

The *complete* list below may conveniently be referred to as item number **134720**.

Item No.	#	Note	Text
195050	1		Air track w/ accessories
197070	1		Air blower
197570	2		SpeedGate
195055	2		Mounting bracket for SpeedGate

Also required

102962 Digital scales (500 g/0.1 g) – or similar

Sample results

Raw data from one collision:

Masses

m_1 = 310.8 g
m_2 = 312.1 g

Velocities before collision

u_1 = 0.333 m/s
u_2 = -0.418 m/s

Velocities after collision

v_1 = -0.425 m/s
v_2 = 0.316 m/s

From this we calculate total momenta and kinetic energies before and after the collision. For the sake of assessing the result we also find the numerically largest of the two momenta before the collision:

Momenta

$p_{\text{tot, before}}$ = -0.0270 kg·m/s
$p_{\text{tot, after}}$ = -0.0335 kg·m/s
$|p|_{\text{max, before}}$ = 0.1321 kg·m/s

Energies

$E_{\text{kin, before}}$ = 44.5 mJ
$E_{\text{kin, after}}$ = 43.7 mJ

In any collision, the total momentum is expected to be conserved. To compare the experimental results with theory, students are asked to find the deviation as a percentage of the largest incoming momentum.

In this example, we get less than 5 % difference.

The energy loss can also be found. In this example it amounts to about 2 %. This means that we have an (almost) elastic collision.

Newton's second law

Experiment number: 134710-EN
Type: Student exercise
Topic: Mechanics
Suggested for: Grade 11-12+

Objective

An experimental demonstration of Newton's second law.

Principle

A cart (glider) on a horizontal air track accelerates using a thread, a pulley, and a weight influenced by gravity. The mass of the weight and the cart are weighed.

At two different positions, photogates measure the speed of the cart as well as the time interval spent between the two photogates. The actual acceleration of the cart is calculated from these measurements.

Newton's second law leads to a theoretical value of the acceleration which is compared to the measured one.

Equipment list

The *complete* list below may conveniently be referred to as item number **134710**.

Item No.	#	Note	Text
195050	1		Air track (incl. accessories)
197070	1		Air blower
197570	2		SpeedGate
195055	2		Mounting bracket for 197570
116500	1		Extra strong thread

Also required

102900 Digital scales (300 g/0.01 g) – or similar

Sample results

The table shows the results from one of a range of measurements.

The cart weighs 205.89 g and is pulled by a 10.74 g weight.

Speeds measured by the SpeedGates are 0.362 m/s, resp. 0.903 m/s, and the time spent between the SpeedGates is 1.13383 s.

The latter is corrected for finite measurement intervals and from these figures, the experimentally determined acceleration a_{meas} can be found.

This actual acceleration is compared to the theoretical acceleration, predicted by Newton's second law:

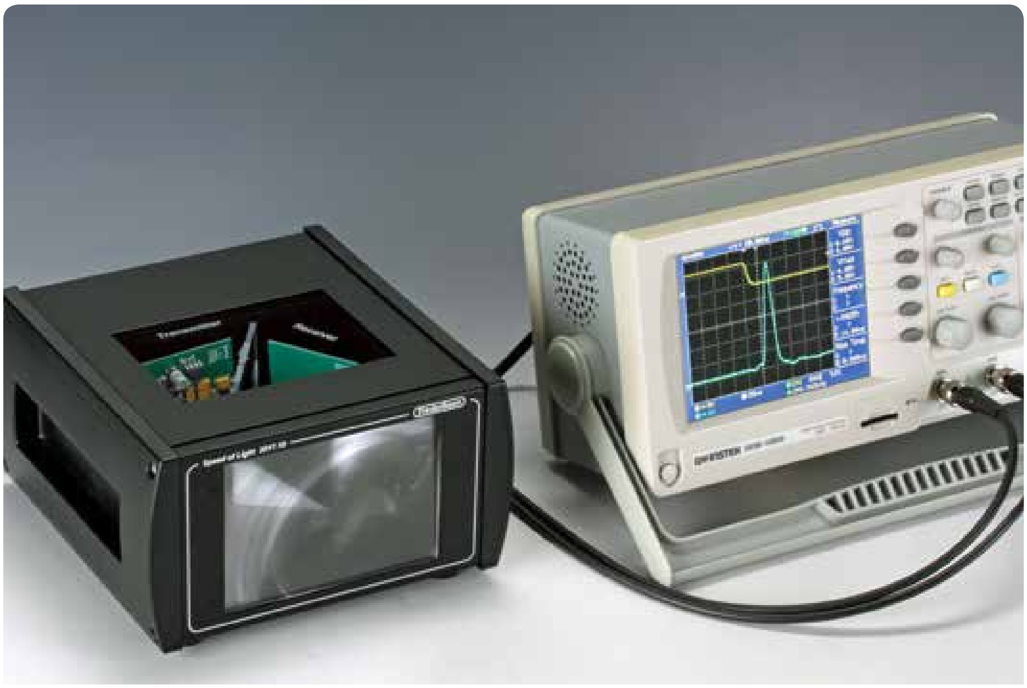
The force of gravity on the pulling weight is calculated. This force acts on the combined mass of the cart, the weight itself and the equivalent mass of the pulley, leading to the theoretical value a_{theo}.

In this example, the measured and the theoretical accelerations are very close – actually more than twice this deviation is still acceptable, given the experimental uncertainties involved.

m_C = 0.20589 kg							
m_w kg	v_A m/s	v_B m/s	t_{AB} s	t_{corr} s	a_{meas} m/s²	a_{theo} m/s²	dev. %
0.01074	0.362	0.903	1.13383	1.11728	0.4842	0.4813	0.6%

The speed of light

Experiment number:	133890-EN	**Topic:**	Light, kinematics, fundamental constants
Type:	Student exercise	**Suggested for:**	Grade 9-10+



Trivially easy alignment

The reflector board included with 201710 has a surface that shows retroflection – i.e. it sends incoming light back in the same direction it came from.

This makes it much easier to direct the light back into the apparatus than if e.g. a mirror was used.

The alignment is so non-critical that a demo version of the experiment can be made by walking back and forth with the reflector in your hand.

Sample results

The 'scope screens below correspond to a distance to the reflector of 0 m (fig. A) and almost 10 m (fig. B). The red trace is a synchronization signal, the yellow trace is the sensor output.

Objective

To measure the speed of light in atmospheric air.

Principle

We measure time of flight and distance travelled by the light – from which the speed can be calculated immediately

The equipment emits very short flashes of light. The light hits a reflector and returns to the apparatus where a sensor converts the flash into an electric pulse. Using an oscilloscope, we measure the delay of the light resulting from its trip back and forth.

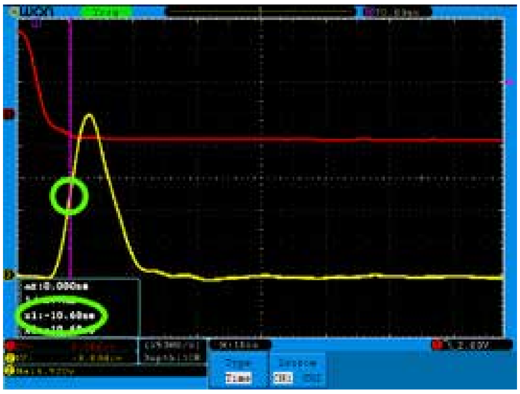


fig. A

The bottom screen shows directly the time of flight of the light pulses (in this case 63.6 ns).

Precision turns out to be close to the pixel-resolution of the oscilloscope screen.

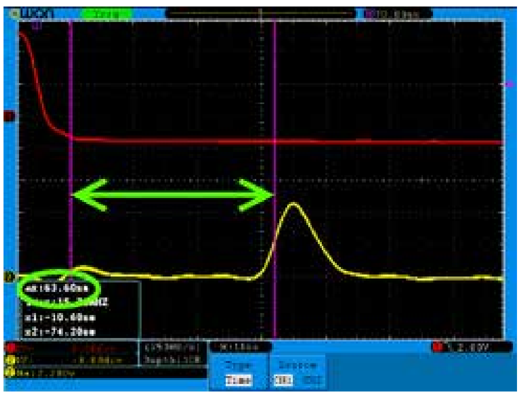


fig. B

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
133890A (option A: Bench oscilloscope 400150)
133890B (option B: PC oscilloscope 400100).
(Photo shows an older oscilloscope.)

Item No.	#	Note	Text	
201710	1		The speed of light	
400100	(1)	a	Digital oscilloscope, 60 MHz	**Option A**
400150	(1)	a	PC oscilloscope, 60 MHz	**Option B**

Notes
a) Select *one* option

Also required

Tape measure (140010 or similar) or long ruler.

Setting up the oscilloscope

It doesn't take an expert to complete this lab.

For each of the two recommended oscilloscopes, the lab manual includes an appendix with a detailed walk-through of the setup.

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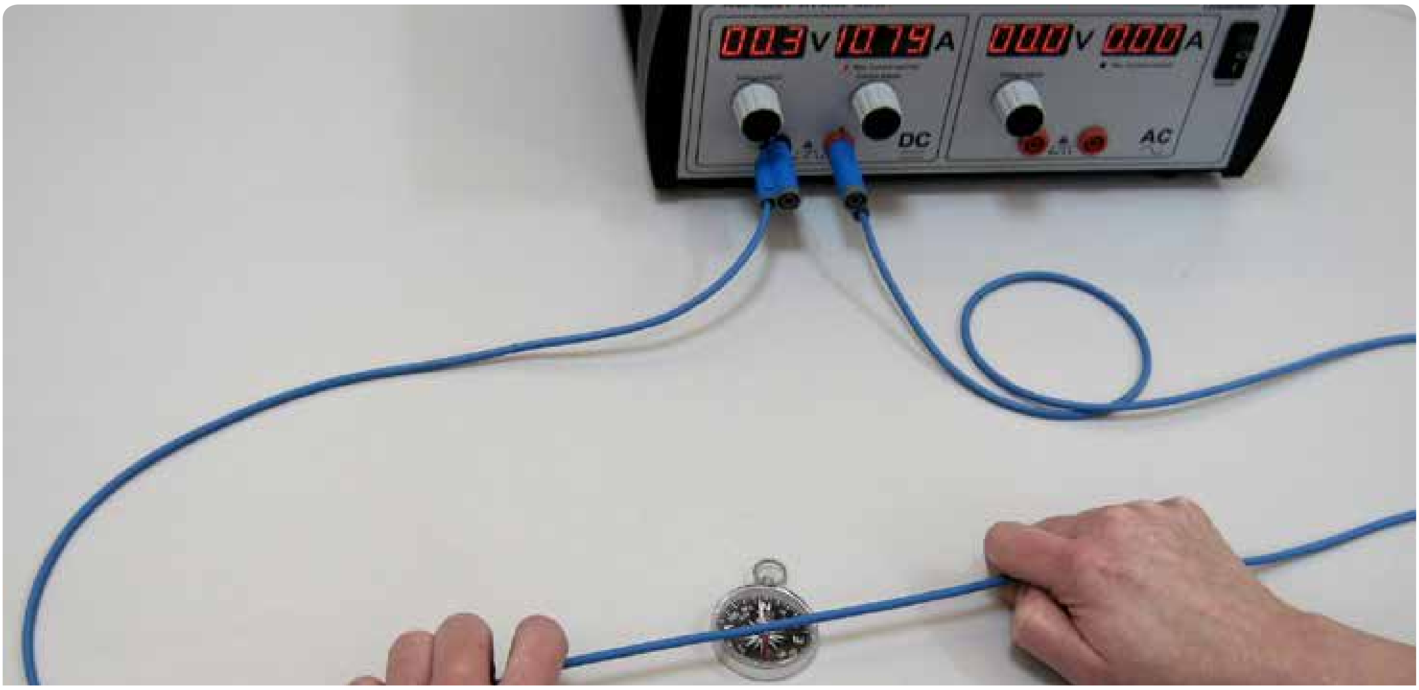
H.C. Oersted's experiment

Experiment number:	137110-EN	**Topic:**	Electromagnetism
Type:	Student exercise	**Suggested for:**	Grade 8, 9, (10)



Objective

We will examine the magnetic field around a current-carrying wire. The observations are compared to an easy to remember rule of thumb.

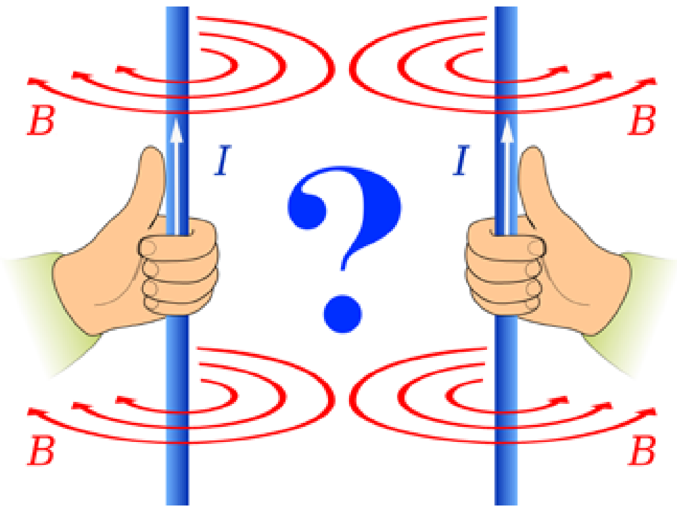
Principle

The direction of the magnetic field at a given position can be found by a small compass. The north pole of the compass needle points in the direction of the field.

In this experiment we examine the magnetic field below and above a horizontal wire (Oersted's classical experiment) as well as around a vertical wire.

Student challenge

This experiment is meant to form part of the introduction to electromagnetism. The fundamental rules are therefore yet to be established. The following challenge is part of the lab manual:



Grip rule – which hand?

The current is called I. The direction of the current is shown with the white arrow. The magnetic field is called B, its direction is shown with red arrows.

Only one side of the figure can be correct!

Equipment list

The *complete* list below may conveniently be referred to as item number: **137110**

Item No.	#	Note	Text
340505	1		Pocket Compass with ring Ø40 mm
364000	1	a	Power supply
105753	1		Safety cables, silicone, 200 cm, blue

Notes

a) This power supply features a variable current limiter. (The wire in the experiment is actually a short circuit!)

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Magnetic force on a conductor

Experiment number:	137230-EN	**Topic:**	Electromagnetism
Type:	Student exercise	**Suggested for:**	Grade 9-10+

Objective

To examine the force on a current carrying conductor in a magnetic field.

To confirm the theoretical expression for the force (Laplace's force, Lorentz force).

Principle

We use the magnetic field from a permanent magnet placed on digital scales.

The size of the force on the magnet is equal to the force on the conductor and has the opposite direction (action = reaction).

Reading of the scales can therefore be used to find the force on the conductor.

Equipment list

The *complete* list below may conveniently be referred to as item number: **137230**

Item No.	#	Note	Text
456500	1		Current balance
364000	1	a	Power supply
105720	1		Safety cable 50 cm, sort
105721	1		Safety cable 50 cm, red
000100	1		Stand base
000850	1		Retort stand rods, 25 cm

Notes
a) This power supply features a variable current limiter.
(The conductor in the current balance is actually a short circuit!)

Also required

Ruler or calliper gauge
102964 Kern scales 200 g / 0,01 g – or similar

Similar experiments:
137240-EN Laplace's force law
(Same topic – more advanced version)

Sample results

Varying the current through one of the conductors shows a nice, linear relationship as seen below. (*fig. A*)

The conductors are on printed circuit boards that are easily swapped to vary the length.

The graph below (*fig. B*) shows the magnetic force as a function of the length of the conductor.

The number of magnets in the holder can be varied as well. The corresponding graph (not shown) displays a slight saturation effect when adding the last couple of magnets.

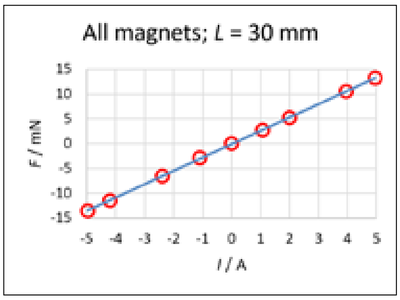


fig. A

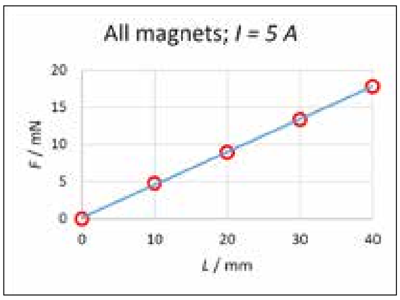


fig. B

Laplace's force law

Experiment number: 137240-EN **Topic:** Electromagnetism
Type: Student exercise **Suggested for:** Grade 11-12+

Objective

To examine the force on a current carrying conductor in a magnetic field including the angle dependency.

To confirm the theoretical expression for the force (Laplace's force, Lorentz force).

Equipment list

The *complete* list below may conveniently be referred to as item number: **137240**

Item No.	#	Note	Text
456500	1		Current balance
456510	1	a	Current balance, angle dependent
364000	1	b	Power supply
105720	1		Safety cable 50 cm, sort
105721	1		Safety cable 50 cm, red
000100	1		Stand base
000850	1		Retort stand rods, 25 cm

Notes
a) Accessory for 456500 – not a stand-alone unit.
b) This power supply features a variable current limiter.
(The conductor in the current balance is actually a short circuit!)

Also required

Ruler or calliper gauge
102964 Kern scales 200 g / 0,01 g – or similar

Similar experiments:
137230-EN Magnetic force on a conductor
(Same topic – but at a more elementary level)

Principle

We use the field from a permanent magnet placed on digital scales.

According to Newton's 3rd law, the force on the magnet and the force on the conductor are of equal size, but of opposite directions.

Reading the scales can therefore be used to find the force on the conductor.

Sample results

The raw results (*fig. A*) looks promisingly like a sine wave. In a more thorough analysis, a possible angle offset $\Delta\theta$ is introduced (turns out to be 1.7° in this sample result) – resulting in an excellent agreement with theory (*fig. B*).

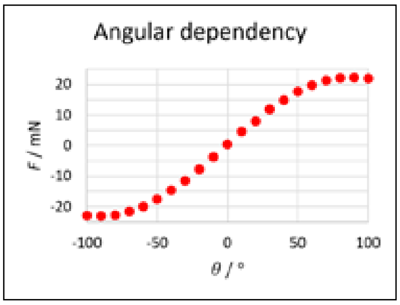


fig. A

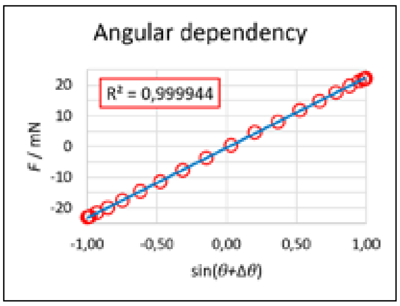
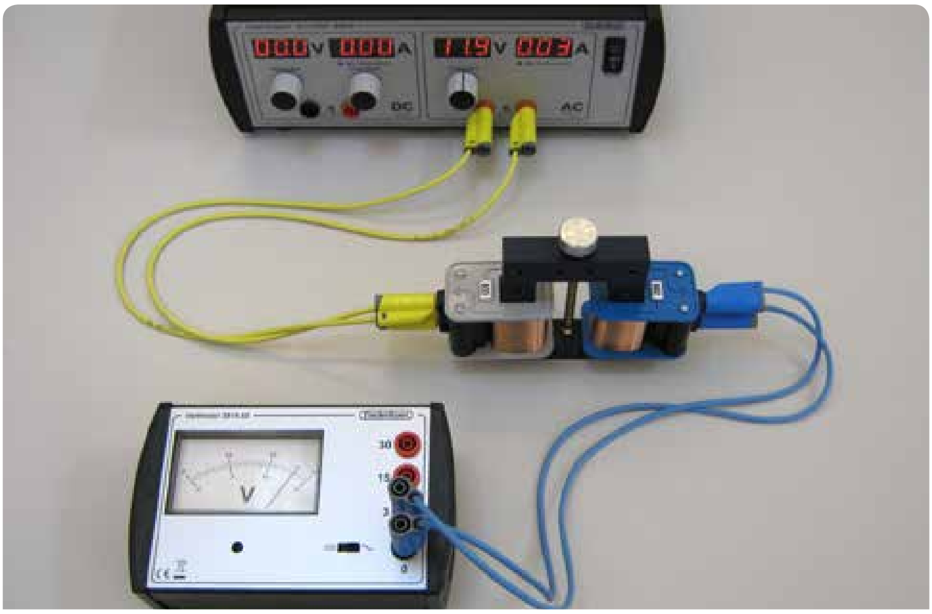


fig. B

The transformer

Experiment number: 137710-EN
Type: Student exercise
Topic: Magnetism and induction
Suggested for: Grade 9-10



Objective

We will examine a transformer built from individual coils and a UI core.

The results are compared to the theory for the ideal transformer.

Principle

With the interchangeable coils, the transformer is easy to build with many different winding combinations.

The primary voltage is measured on the built-in voltmeter in the power supply.*
The secondary voltage is measured by an external voltmeter.

*) A power supply without a voltmeter can also be used. Instructions are included in the manual.

Equipment list

The *complete* list below may conveniently be referred to as item number **137710**.

Item No.	#	Note	Text
463000	1		UI core
462510	1		Coil, 200 turns
462520	2		Coil, 400 turns
462525	1		Coil, 800 turns
381560	1		Voltmeter
364000	1	a	Power supply
105722	2		Safety cable, silicone, 50 cm yellow
105723	2		Safety cable, silicone, 50 cm blue

Notes
a) Others may be used (see details in lab manual).

Similar experiments:
136210-EN Rectifier circuits

Sample results

Given		*Measured*		*Compared with theory*		
N_p	N_s	U_p / V	U_s / V	N_s / N_p	U_s / V	devi.
200	400	5.9	10.57	2	11.8	-10.4%
200	800	6.0	21.30	4	24.0	-11.2%
800	400	12.5	5.52	0.5	6.25	-11.7%
800	200	12.7	2.82	0.25	3.175	-11.1%

Sample results showing a rather consistent deviation from the theoretical “ideal” transformer.

The deviation represents magnetic flux that escapes the secondary coil.

Download the **Lab Manual** for this experiment (4 pages PDF) from **www.frederiksen.eu**

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Rectifier circuits

Experiment number: 136210-EN | **Topic:** AC circuits, electricity
Type: Student exercise | **Suggested for:** Grade 9-10

Objective

We investigate how a diode and a bridge rectifier converts the alternating voltage to a direct voltage.
We also see how a capacitor can be used to smoothen the pulsating direct current.

The rectifier circuit constitutes a very simple "power supply". In this lab exercise we will use a resistor as "a device to be powered".

Principle

Normally, the rectifier circuit is placed after a transformer that converts the AC mains voltage from the wall socket to a lower voltage.
In order to be able to follow the variations in voltage and current, we don't use 50 Hz (or 60 Hz) AC voltage here but instead a function generator adjusted to e.g. 0.1 Hz

With such a "slow motion" AC voltage, the variations can be observed with analog (needle) meters.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
136210A (option A: Student function generator)
136210B (option B: Function generator 250350).
The photo shows Option B.

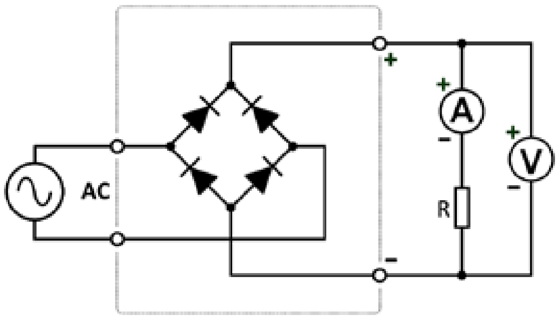
Item No.	#	Note	Text	
381560	1		Voltmeter	
381570	1		Ammeter	
434000	1		Rectifier diode	
434500	1		Bridge rectifier	
420548	1		Resistor, 470 Ω, 1%, 10 W	
430070	1		Electrolytic capacitor 15000 µF 25 V	
250310	(1)	a	Student func. generator	**Option A**
250350	(1)	a	Function generator	**Option B**
105720	3		Safety cable, silicone, 50 cm, black	
105721	3		Safety cable, silicone, 50 cm, red	
105722	2		Safety cable, silicone, 50 cm, yellow	
105723	1		Safety cable, silicone, 50 cm, blue	

Notes
a) Select *one* option

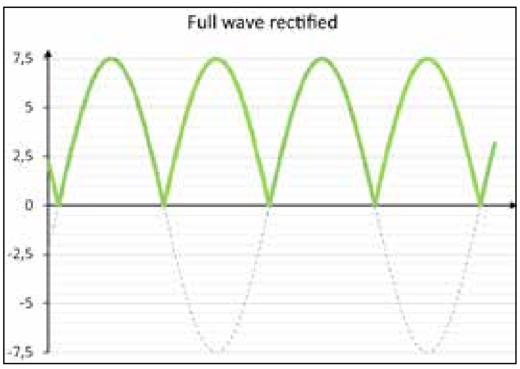
Similar experiments:
137710-EN The transformer

Idea behind the lab manual

The students will build the circuits given in schematics form like the one below:



The "text book" graphs for the voltage versus time are given for each circuit and the students are challenged to draw the real behaviour as they experience it.



Behaviour of an "ideal rectifier bridge".

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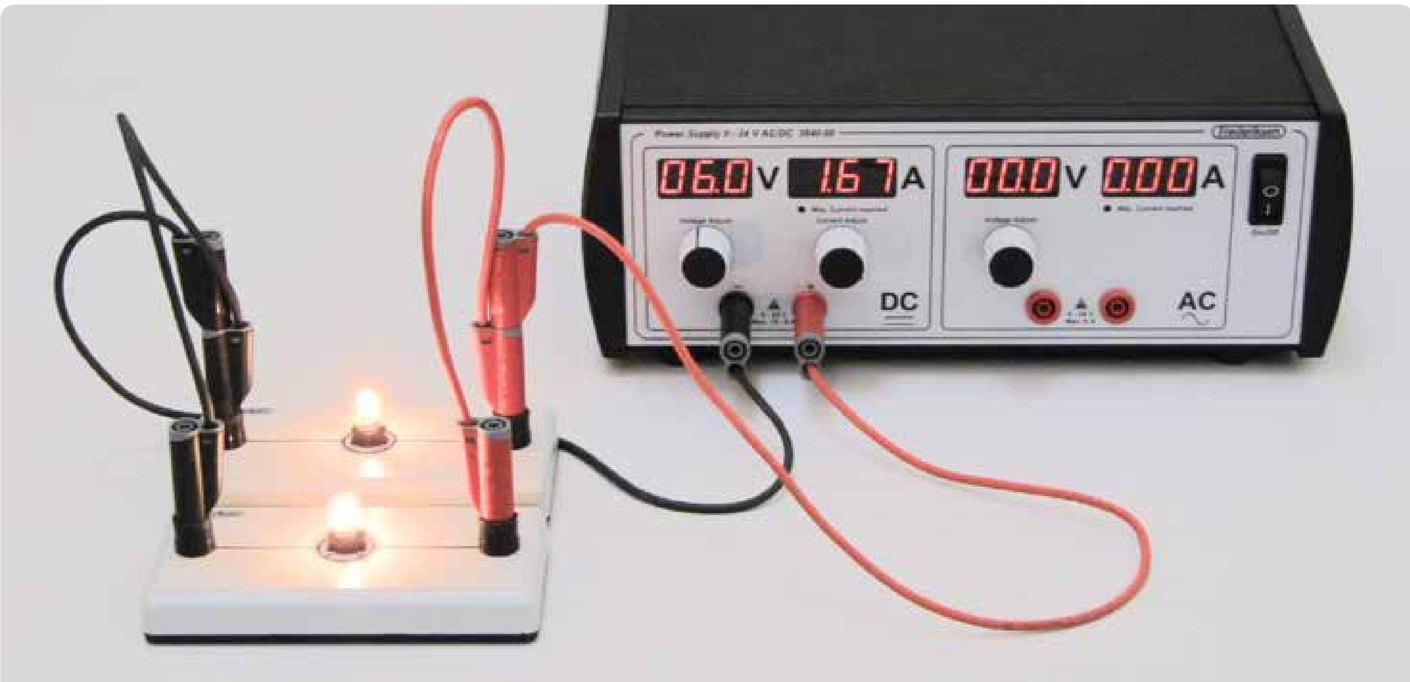
Bulbs in series and parallel connection

Experiment number: 136010-EN | **Topic:** Electricity
Type: Student exercise | **Suggested for:** Grade 7-8



Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
136010A (opt. A: Power supply w/ built-in meters)
136010B (opt. B: Power supply + external meters)
The photo shows Option A.

Item No.	#	Note	Text	
412000	2		Lamp socket E10, 2 connectors	
425040	1	a	Light bulb 6 V, 1 A (pack of ten)	
364000	(1)	b	Power supply 0-24 V	**Option A**
361600	(1)	b	Power supply 0-12 V	**Option B**
381560	(1)	b	Voltmeter	**Option B**
381570	(1)	b	Ammeter	**Option B**
105710	1		Safety cable 25cm, black	
105711	1		Safety cable 25cm, red	
105720	1		Safety cable 50 cm, black	
105721	(1)	b	Safety cable 50 cm, red	**Option A**
105721	(3)	b	Safety cable 50 cm, red	**Option B**
105740	(1)	b	Safety cable 100 cm, black	**Option B**

Notes
a) Two bulbs are used out of a pack of ten
b) Select *one* option

Also required

"Post-It" (Small format) or similar for labelling

Similar experiments:
136030 Resistors in series and parallel circuits

Objective

To examine voltage and current in circuits with simple combinations of bulbs (incandescent lamps).

Principle

For one bulb alone – and for series and parallel connections of two bulbs – we find the voltage and current needed to make the bulbs light up normally.

The simplest setup uses a power supply with built-in voltmeter and ammeter.

(Other types of power supply may be used if two separate instruments are added as detailed in the lab manual – option B in the equipment list.)

Idea behind the lab manual

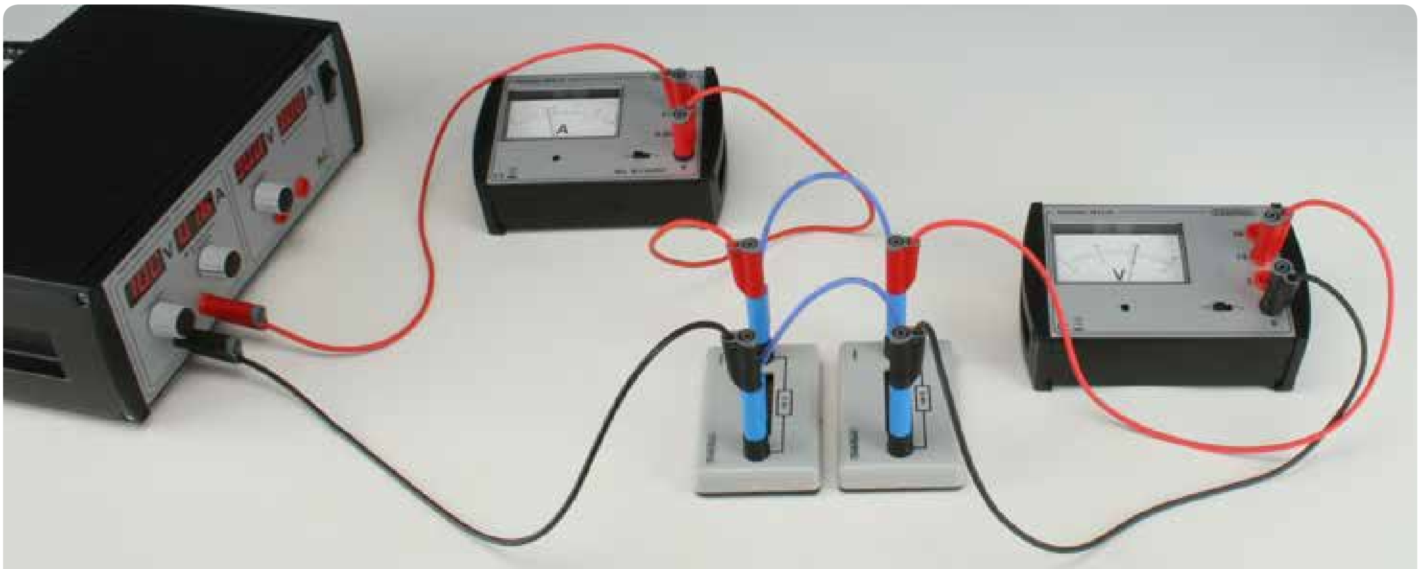
This is intended to be an introductory experiment. The students are lead step by step through the challenge.

During this lab, three circuits will be built. None of them are drawn as schematics – they are only presented as simple and clear photographs.

Afterwards, the students are asked to formulate rules for voltages and currents in parallel and series connections of identical bulbs – compared to one single bulb.

Resistors in series and parallel circuits

Experiment number: 136030-EN **Topic:** Electricity
Type: Student exercise **Suggested for:** Grade 7-9



Objective

To investigate the behaviour of current, voltage and resistance in series and parallel circuits with two resistors.

The formulae for the total resistance in these two cases are validated.

Principle

Current and voltage are measured with two analog instruments. The resistance is found using Ohm's law – both for the two resistors individually and for the series and parallel circuits.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
136030A (opt. A: 24 V Power supply - recommended)
136030B (opt. B: 12 V Power supply)
The photo shows Option A.

Item No.	#	Note	Text	
381560	1		Voltmeter	
381570	1		Ammeter	
420541	1		Resistor 100 Ω, 1 %, 10 W	
420546	1		Resistor 150 Ω, 1 %, 10 W	
364000	(1)	a	Power supply 0-24 V	**Option A**
361600	(1)	a	Power supply 0-12 V	**Option B**
105720	2		Safety cable 50 cm, black	
105721	3		Safety cable 50 cm, red	
105713	2		Safety cable 25 cm, blue	

Notes
a) Select *one* option

Similar experiments:
136010 Bulbs in series and parallel connection

Sample results

Component values and measurement parameters has been tailored to make reading of analog meters as easy as possible.

The results cited in this paragraph were obtained by an experienced experimenter, hence the extra (interpolated) decimals in some of the numbers.

The individual resistors were spot on the nominal values according to these data:

	Mesured			Expected
	U / V	I / A	R / Ω	R / Ω
R_1	15.0	0.150	100	100
R_2	15.0	0.100	150	150

For the series connection, the measured resistance was off by 1.1 %:

Mesured				Expected
	U / V	I / A	R / Ω	R / Ω
Series	12.0	0.0475	252.6	250

The parallel connection was off by only -0.4 %:

	Mesured			Expected
	U / V	I / A	R / Ω	R / Ω
Parallel	15.0	0.251	59.8	60

From this and previous data obtained at 15 V, the students can comment on the accordance with Kirchhoff's current law.

Likewise, the students are asked to reflect on the voltage drops over the individual resistors in the series circuit, compared to the voltage drop over both – this time without mentioning what to expect.

	Measured
	U / V
Series	12.0
R_1	4.9
R_2	7.3

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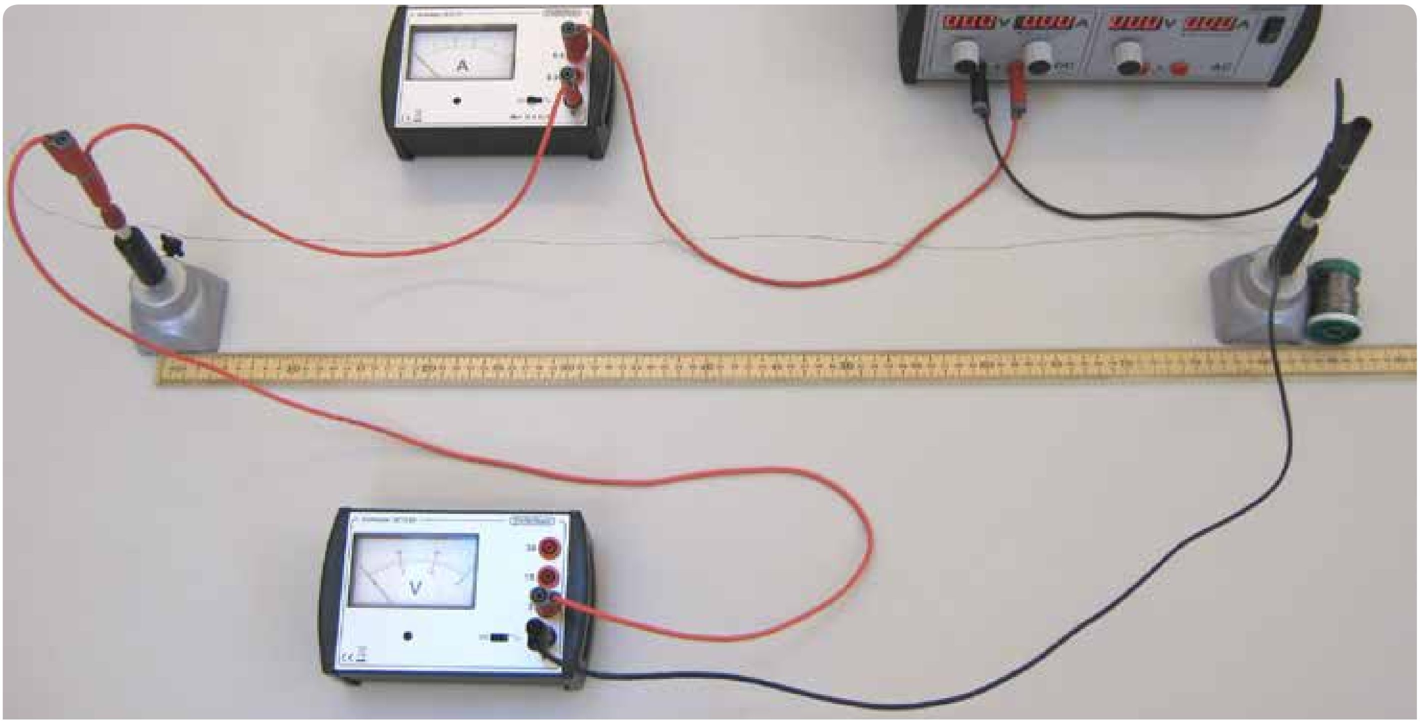
Ohm's law

Experiment number: 136050-EN **Topic:** Electricity
Type: Student exercise **Suggested for:** Grade 7-10



Equipment list

The *complete* list below may conveniently be referred to as item number **136050**.

Item No.	#	Note	Text
381570	1		Ammeter
381560	1		Voltmeter
115520	1		Kanthal wire 0.50 mm
425040	1	a	Bulb, 6 V, 1 A
412000	1		Lamp socket with 2 connectors, E10
361600	1	b	Power supply 0-12 V, 3 A
435030	1		Terminal posts, insulated (pair)
000410	2		Retort stand base, square
105720	1		Safety cable, silicone, black, 50 cm
105721	2		Safety cable, silicone, red, 50 cm
105740	1		Safety cable, silicone, black, 100 cm
105741	1		Safety cable, silicone, red, 100 cm

Notes
a) Box of ten (only one bulb is used)
b) Alternative power supply: 364000. The photo shows this model

Also required

Ruler or tape measure (like 140510 or 140010).

Similar experiments:
136060-EN Resistance in metal wires

Objective

Examining the relationship between voltage and current for a metal wire.

Principle

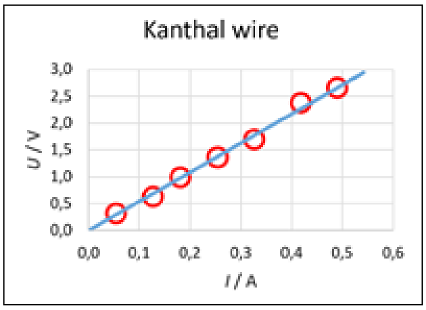
A length of Kanthal wire is extended between two terminal posts in order to measure the current through the wire and the voltage across it.
For comparison, the same measurements are carried out for a small light bulb.

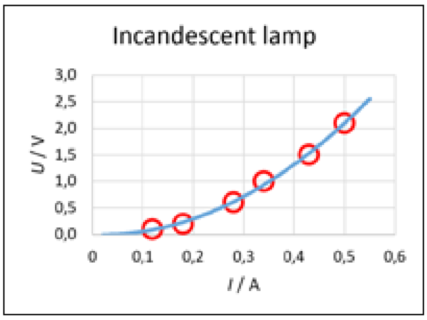
The results are analysed graphically and compared with Ohm's law.

Sample results

Sample graphs for U(I) for a metal wire and an incandescent light bulb are shown here.

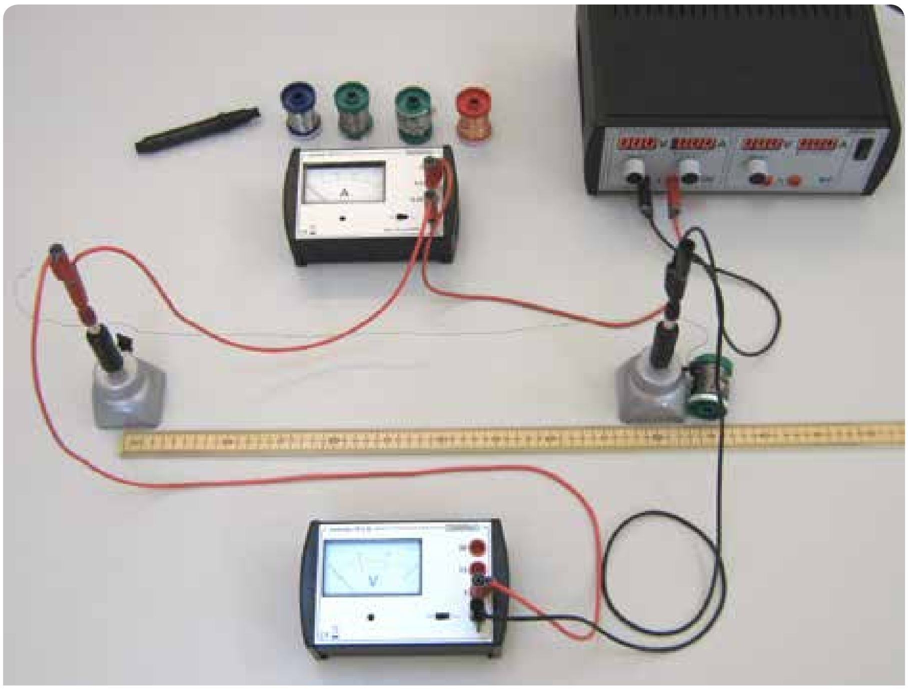
The students are asked which of the two objects (if any) comply with Ohm's law.





Resistance in metal wires

Experiment number: 136060-EN **Topic:** Electricity
Type: Student exercise **Suggested for:** Grade 7-10



Objective

To investigate how the resistance in a metal wire depends on the material, the length and diameter.

Principle

Different metal wires are stretched between two terminal posts. The current through the wire and the voltage across it are measured.

The resistance of the wire is found using Ohm's law.

Equipment list

The *complete* list below may conveniently be referred to as item number **136060**.

Item No.	#	Note	Text
381570	1		Ammeter
381560	1		Voltmeter
113520	1		Copper wire un-insol. 0.50 mm
114520	1		Constantan wire 0.50 mm
115510	1		Kanthal wire 0.25 mm
115520	1		Kanthal wire 0.50 mm
115530	1		Kanthal wire 1.00 mm
116000	1		Iron wire 0.5 mm
364000	1	a	Power supply
435030	1		Terminal posts, set of two
000410	2		Retort stand base, square
105720	1		Safety cable, silicone, black, 50 cm
105721	2		Safety cable, silicone, red 50 cm
105740	1		Safety cable, silicone, black 100 cm
105741	1		Safety cable, silicone, red 100 cm

Notes
a) Up to 5 A is needed in this experiment.

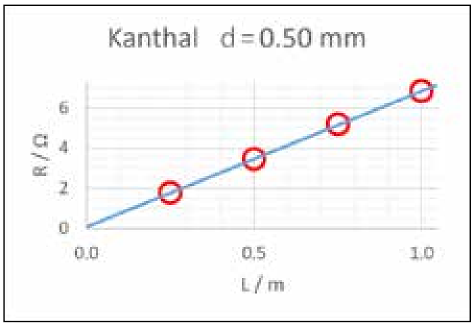
Also required

Ruler or tape measure (like 140510 or 140010).

Similar experiments:
136050-EN Ohm's law

Sample results

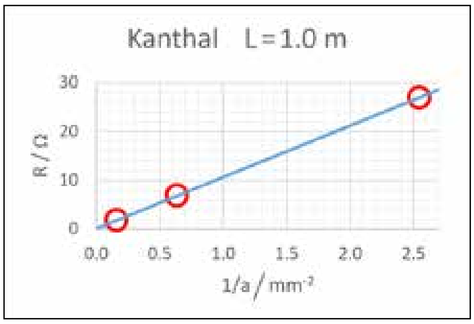
In one of the measurement series, resistance is measured as a function of the length of the wire. The following graph shows the results.



Students are expected to formulate this relationship in qualitative terms only. If the teacher deems it fitting for a particular class, the concepts of direct and inverse proportionality can be used.

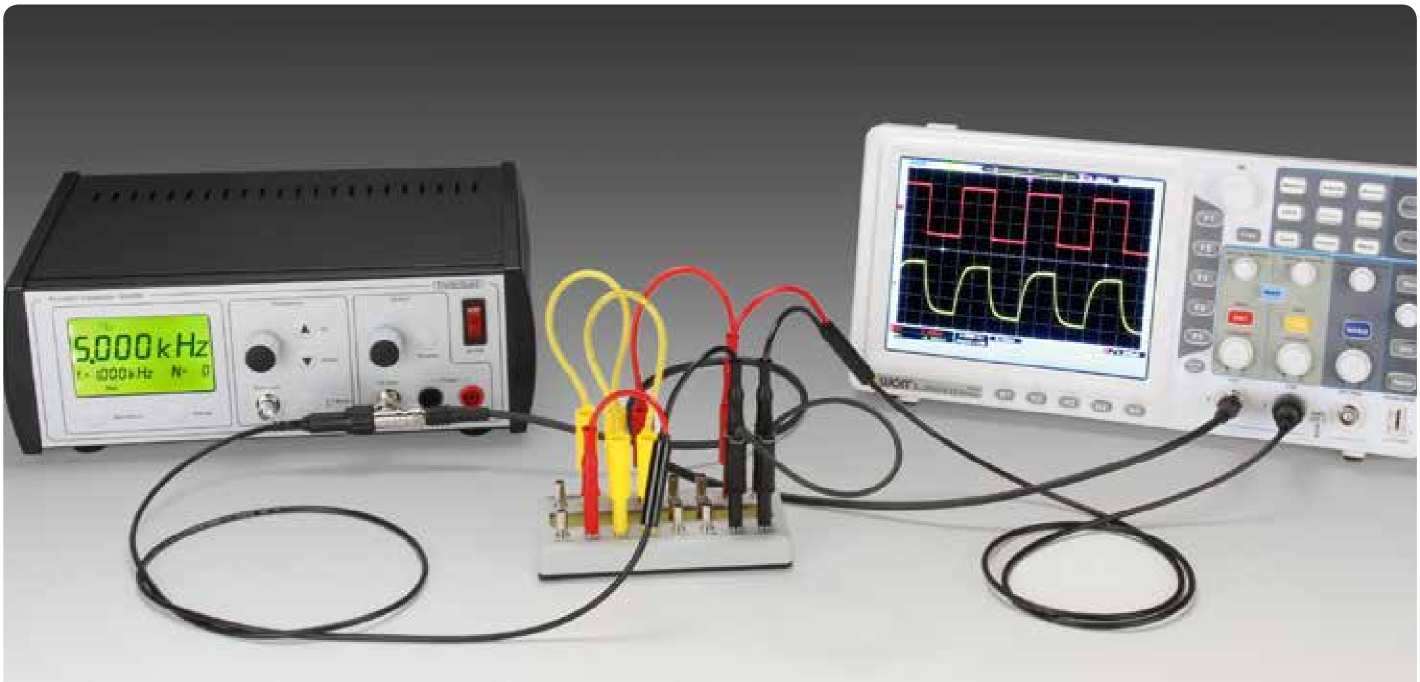
The next graph shows inverse proportionality between resistance and the cross-section area of the wire.

– As can be seen, the rugged analog meters are excellent for this experiment.



RC Low-pass filters

Experiment number:	136310-EN	**Topic:**	AC circuits / electronics
Type:	Student exercise	**Suggested for:**	Grade 12+



Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
136310A (option A: Stand-alone oscilloscope)
136310B (option B: PC oscilloscope).
The photo shows Option A.

Item No.	#	Note	Text	
420600	1		LCR-circuit	
250350	1		Function generator	
400150	(1)	b	Oscilloscope, digital 60 MHz	**Opt. A**
400100	(1)	b	Oscilloscope 60 MHz PC-USB	**Opt. B**
110002	2		Cable, BNC to two safety plugs	
111100	1		BNC T adapter	
110025	1		Coaxial cable, BNC, 50 Ohm	
105710	1	c	Safety cable, silicone, 25 cm, black	
105711	2	c	Safety cable, silicone, 25 cm, red	
105712	2	c	Safety cable, silicone, 25 cm, yellow	
105713	2	c	Safety cable, silicone, 25 cm, blue	

Notes
a) Exp. 136310, -20, -30, -40 and -50 all use the same equipment.
b) Select *one* option.
c) Cables sufficient for all 5 experiments.

Objective

The behaviour of simple RC low-pass filters is investigated by measuring frequency response and step response.

Principle

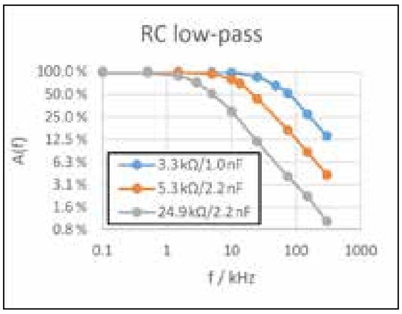
Frequency response: The amplitude of a sine wave signal is measured before and after passing the filter. The ratio between the two amplitudes is plotted with a logarithmic frequency axis.

Step response: A square wave signal is used as input and the output is studied on an oscilloscope.

Sample results (freq. response)

The graphs show the measured frequency responses for three different RC low-pass filters.

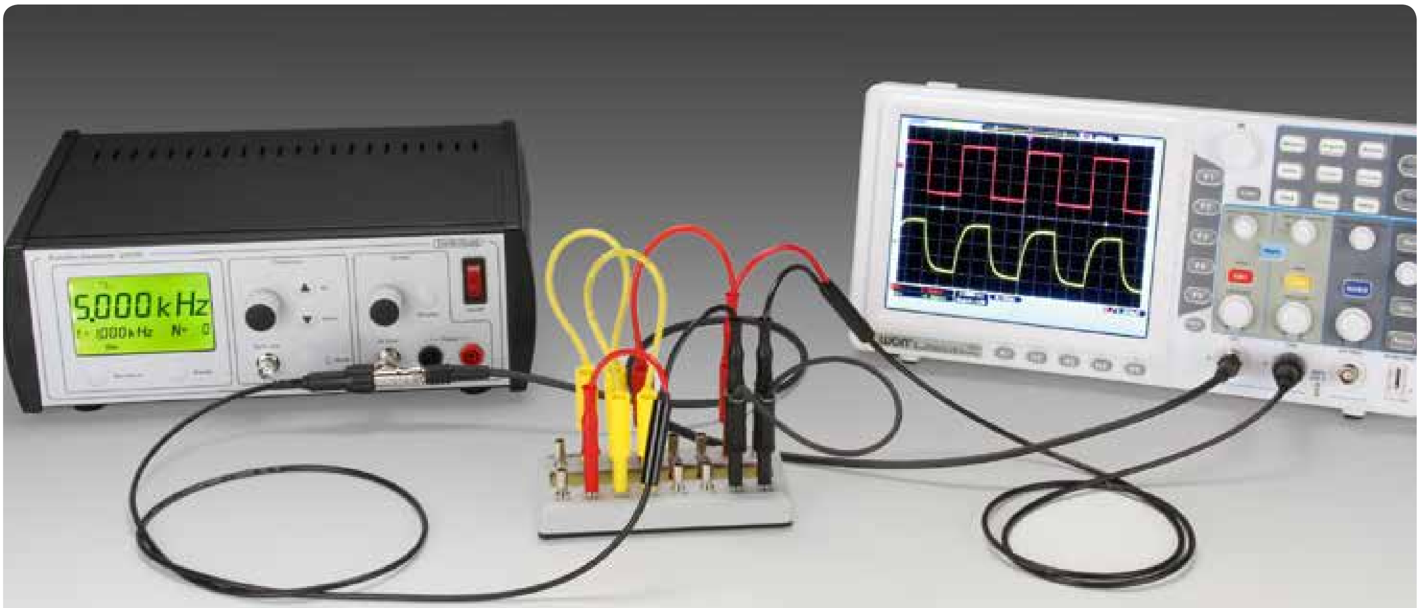
Both axes are logarithmic. It is easy to see that the response curves run parallel for high frequencies.



Similar experiments:
136320-EN RC high-pass filters
136350-EN LCR Low-pass filters

RC high-pass filters

Experiment number: 136320-EN **Topic:** AC circuits / electronics
Type: Student exercise **Suggested for:** Grade 12+



Objective

The behaviour of simple RC high-pass filters is investigated by measuring frequency response and step response.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
136310A (option A: Stand-alone oscilloscope)
136310B (option B: PC oscilloscope).
The photo shows Option A.

Item No.	#	Note	Text	
420600	1		LCR-circuit	
250350	1		Function generator	
400150	(1)	b	Oscilloscope, digital 60 MHz	**Opt. A**
400100	(1)	b	Oscilloscope 60 MHz PC-USB	**Opt. B**
110002	2		Cable, BNC to two safety plugs	
111100	1		BNC T adapter	
110025	1		Coaxial cable, BNC, 50 Ohm	
105710	1	c	Safety cable, silicone, 25 cm, black	
105711	2	c	Safety cable, silicone, 25 cm, red	
105712	2	c	Safety cable, silicone, 25 cm, yellow	
105713	2	c	Safety cable, silicone, 25 cm, blue	

Notes
a) Exp. 136310, -20, -30, -40 and -50 all use the same equipment.
b) Select *one* option.
c) Cables sufficient for all 5 experiments.

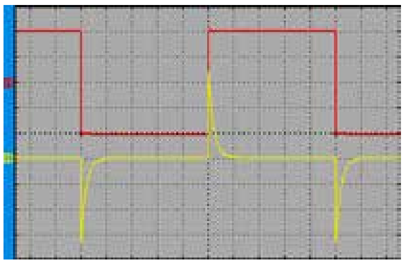
Similar experiments:
136210-EN RC low-pass filters

Principle

Frequency response: The amplitude of a sine wave signal is measured before and after passing the filter. The ratio between the two amplitudes is plotted with a logarithmic frequency axis.

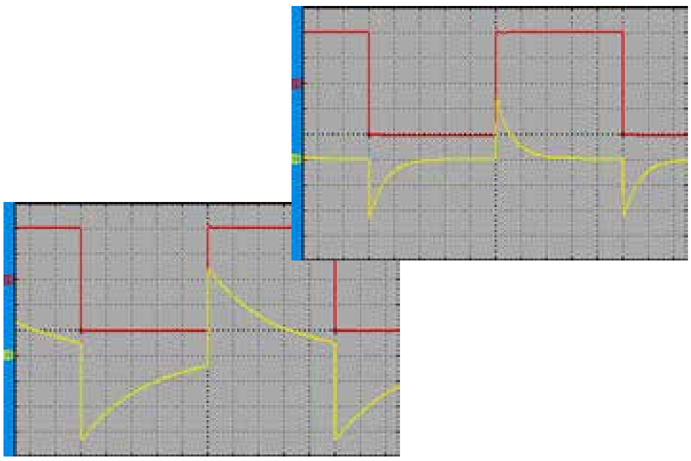
Step response: A square wave signal is used as input and the output is studied on an oscilloscope.

Sample results (step response)



The step response reveals a lot of information in a glance. The oscilloscope screen dump shows how a square wave (red) is shaped after passing the filter (yellow).

If all components and cables were ideal, the size of the jumps on the two curves should have the same height. In reality, the output (yellow) only jumps about 80 % of the ideal value. This simply reflects the fact that no real filter has an infinite bandwidth.

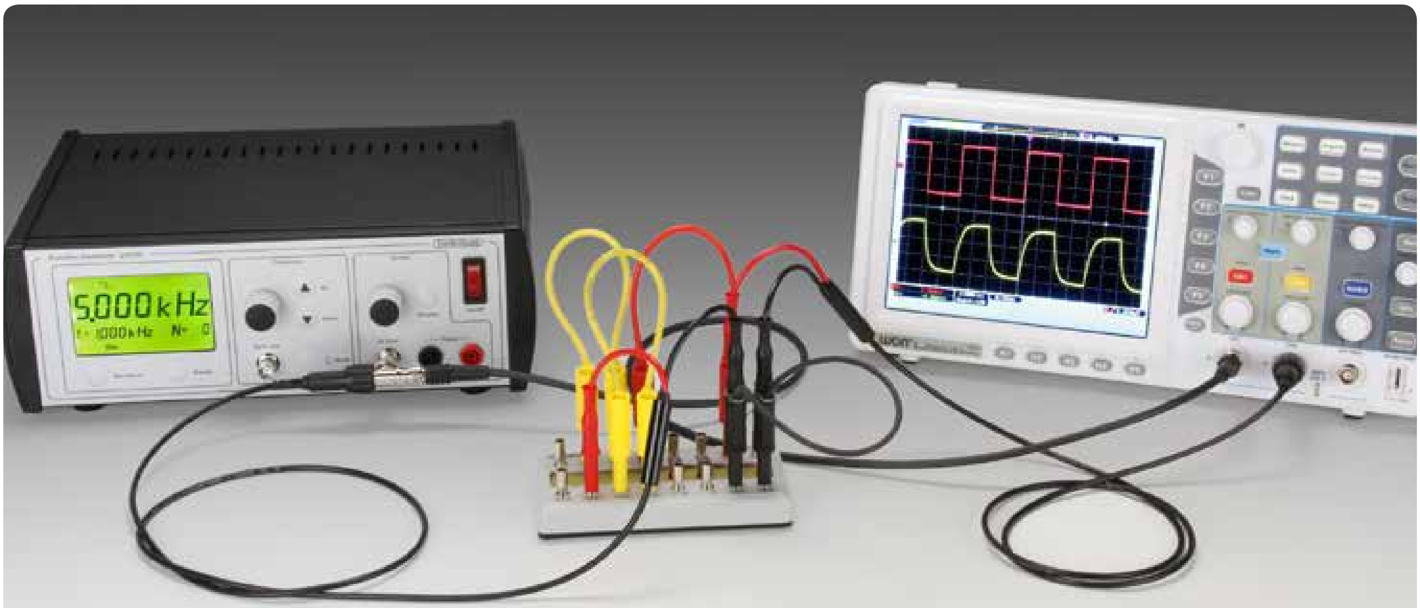


Changing the cut-off frequency also changes the step response.

Frederiksen®
Passion for science

Resonant circuits – measuring inductance

Experiment number: 136330-EN **Topic:** AC circuits / electronics
Type: Student exercise **Suggested for:** Grade 12+



Objective

By measuring resonance frequencies, coil inductance can be calculated. We work with two single coils, as well as series and parallel connections.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
136310A (option A: Stand-alone oscilloscope)
136310B (option B: PC oscilloscope).
The photo shows Option A.

Item No.	#	Note	Text	
420600	1		LCR-circuit	
250350	1		Function generator	
400150	(1)	b	Oscilloscope, digital 60 MHz	**Opt. A**
400100	(1)	b	Oscilloscope 60 MHz PC-USB	**Opt. B**
110002	2		Cable, BNC to two safety plugs	
111100	1		BNC T adapter	
110025	1		Coaxial cable, BNC, 50 Ohm	
105710	1	c	Safety cable, silicone, 25 cm, black	
105711	2	c	Safety cable, silicone, 25 cm, red	
105712	2	c	Safety cable, silicone, 25 cm, yellow	
105713	2	c	Safety cable, silicone, 25 cm, blue	

Notes
a) Exp. 136310, -20, -30, -40 and -50 all use the same equipment.
b) Select *one* option.
c) Cables sufficient for all 5 experiments.

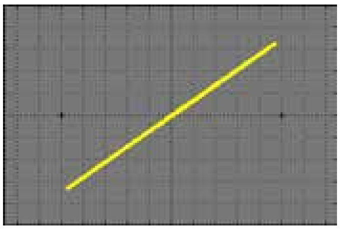
Similar experiments:
136340-EN LCR band-pass and band-stop filters

Principle

The (phase) resonance frequency is determined by using the oscilloscope in XY mode.

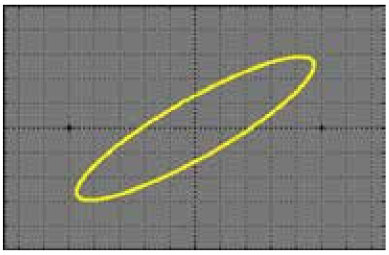
Sample results

Adjusting the frequency for 0° phase difference yields this oscilloscope image at 48.80 kHz:

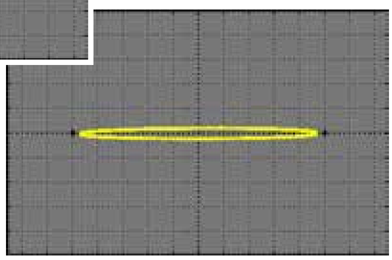


(This means that the inductance of the coil used here can be found to be 4.8 mH ± 1 %)
The method is very sensitive – detuning the frequency to 50.00 kHz opens up the phase ellipsis as seen on the lower left image.

Far away from the resonance frequency, the output signal is smaller (lower right image).



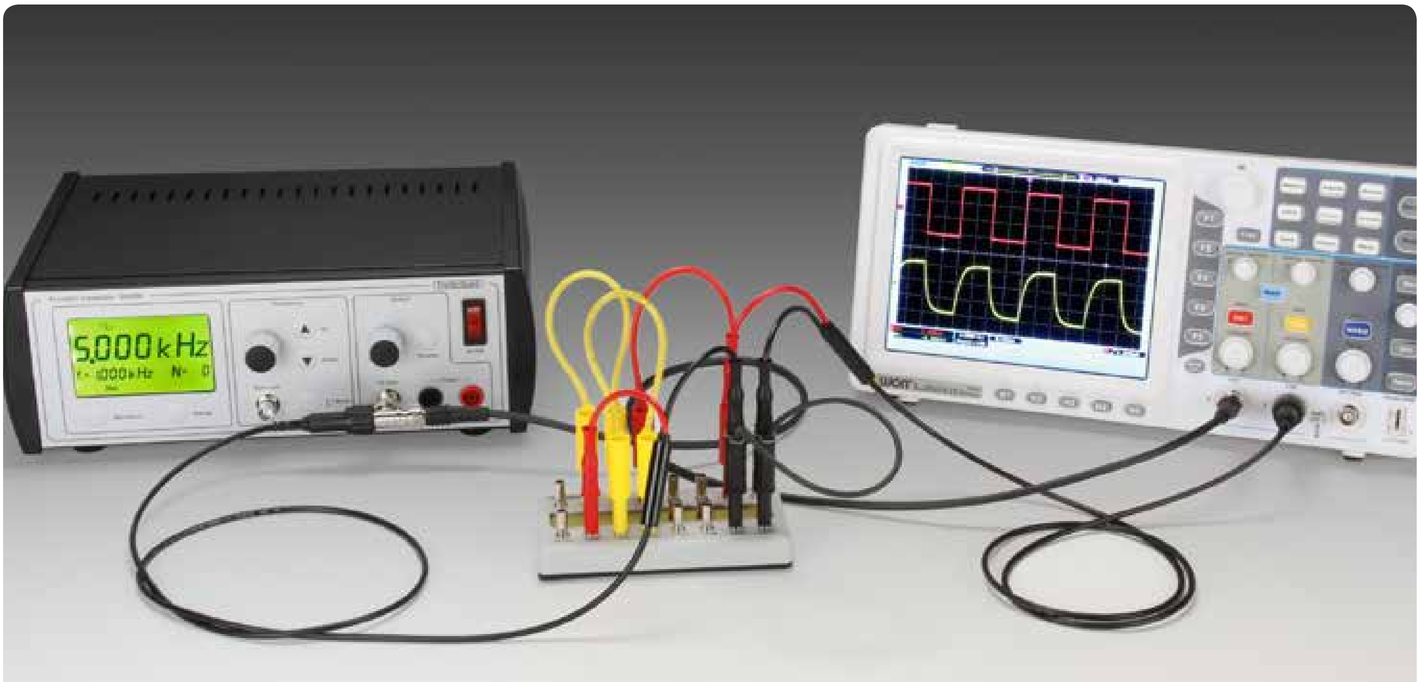
Not quite f_0



Far from f_0 (25 kHz)

LCR band-pass and band-stop filters

Experiment number: 136340-EN **Topic:** AC circuits / electronics
Type: Student exercise **Suggested for:** Grade 12+



Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
136310A (option A: Stand-alone oscilloscope)
136310B (option B: PC oscilloscope).
The photo shows Option A.

Item No.	#	Note	Text	
420600	1		LCR-circuit	
250350	1		Function generator	
400150	(1)	b	Oscilloscope, digital 60 MHz	**Opt. A**
400100	(1)	b	Oscilloscope 60 MHz PC-USB	**Opt. B**
110002	2		Cable, BNC to two safety plugs	
111100	1		BNC T adapter	
110025	1		Coaxial cable, BNC, 50 Ohm	
105710	1	c	Safety cable, silicone, 25 cm, black	
105711	2	c	Safety cable, silicone, 25 cm, red	
105712	2	c	Safety cable, silicone, 25 cm, yellow	
105713	2	c	Safety cable, silicone, 25 cm, blue	

Notes
a) Exp. 136310, -20, -30, -40 and -50 all use the same equipment.
b) Select *one* option.
c) Cables sufficient for all 5 experiments.

Similar experiments:
136330-EN Resonant circuits
136350-EN LCR Low-pass filters

Objective

The behaviour of LCR band-pass and band-stop filters are studied by measuring of frequency response.

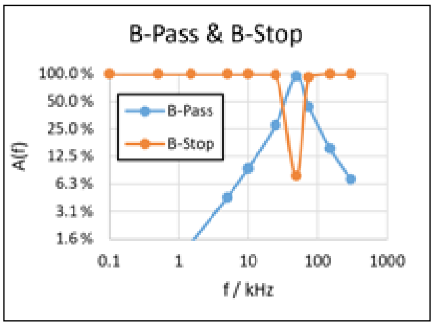
Principle

The centre frequency (or phase resonance frequency) is determined by using the oscilloscope in XY mode.

Frequency response: The amplitude of a sine wave signal is measured before and after passing the filter. The ratio of the signal amplitudes are plotted in a logarithmic coordinate system.

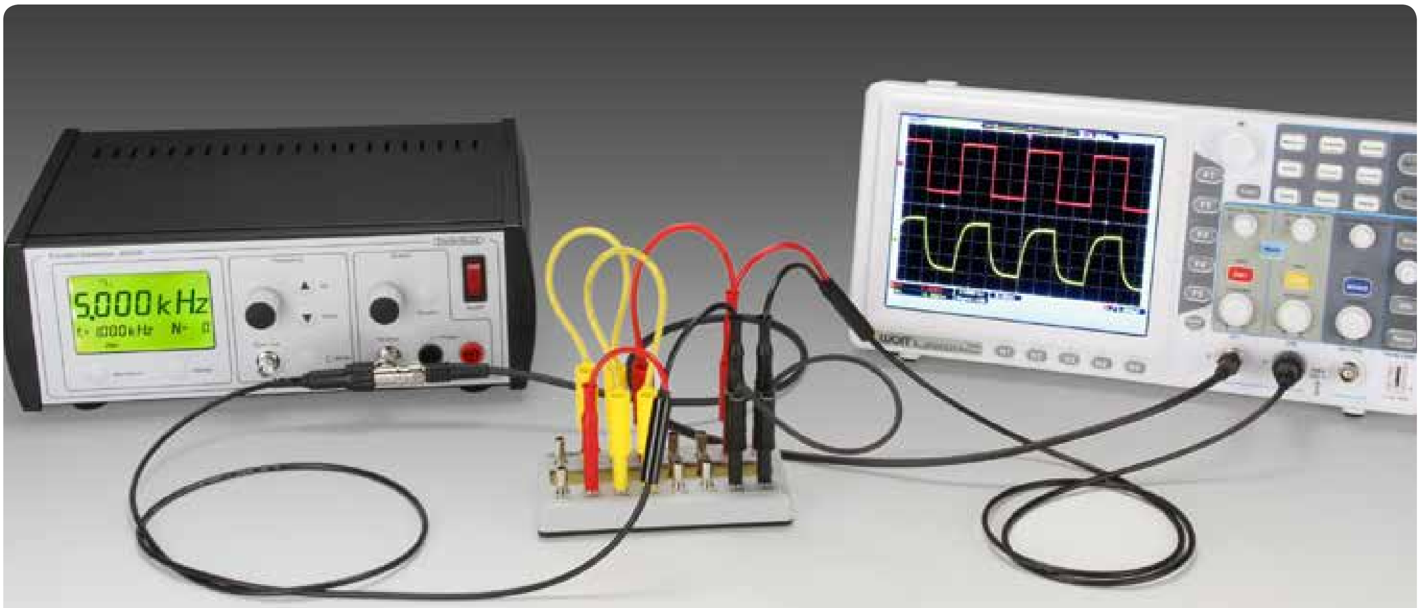
Sample results

Frequency response of two filters. Both axes are logarithmic.



LCR Low-pass filters

Experiment number: 136350-EN
Type: Student exercise
Topic: AC circuits / electronics
Suggested for: Grade 12+



Objective

The behaviour of LCR low-pass filters are studied by measuring the frequency response and step response.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
136310A (option A: Stand-alone oscilloscope)
136310B (option B: PC oscilloscope).
The photo shows Option A.

Item No.	#	Note	Text	
420600	1		LCR-circuit	
250350	1		Function generator	
400150	(1)	b	Oscilloscope, digital 60 MHz	**Opt. A**
400100	(1)	b	Oscilloscope 60 MHz PC-USB	**Opt. B**
110002	2		Cable, BNC to two safety plugs	
111100	1		BNC T adapter	
110025	1		Coaxial cable, BNC, 50 Ohm	
105710	1	c	Safety cable, silicone, 25 cm, black	
105711	2	c	Safety cable, silicone, 25 cm, red	
105712	2	c	Safety cable, silicone, 25 cm, yellow	
105713	2	c	Safety cable, silicone, 25 cm, blue	

Notes
a) Exp. 136310, -20, -30, -40 and -50 all use the same equipment.
b) Select *one* option.
c) Cables sufficient for all 5 experiments.

Similar experiments:
136310-EN RC low-pass filters
136340-EN LCR band-pass and band-stop filters

Principle

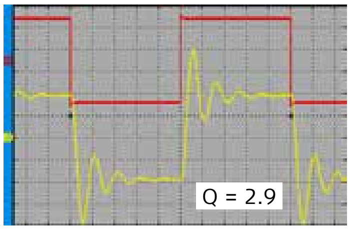
The cut-off frequency (or phase resonance frequency) is determined by using the oscilloscope in XY mode.

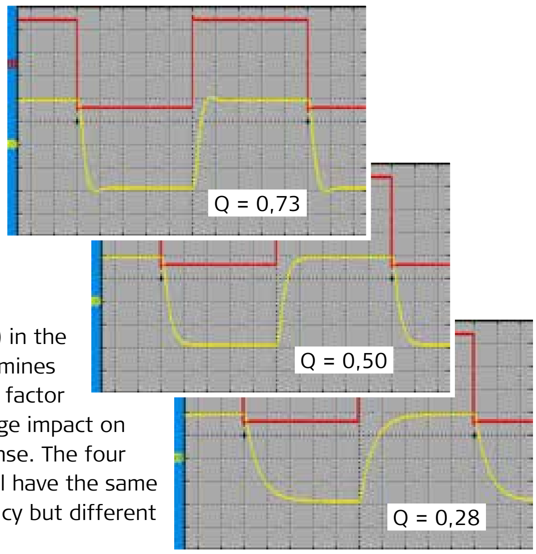
Frequency response: The amplitude of a sine wave signal is measured before and after passing the filter. The ratio of the signal amplitudes are plotted in a logarithmic coordinate system.

Step response: A square wave signal is used as input and the output is studied on an oscilloscope.

Sample results (step responses)

The oscilloscope images show how a square wave (red) is shaped after passing the filter (yellow).





The resistor (R) in the LCR filter determines the so-called Q factor which has a large impact on the step response. The four filters shown all have the same cut-off frequency but different Q factors.

Download the **Lab Manual** for this experiment (5 pages PDF) from **www.frederiksen.eu**

A note on radioactive sources and related equipment

In the following nuclear physics experiments, radioactive sources are used.

Regulations

As the sale and use of radioactive substances are regulated by national authorities, our customers are encouraged to familiarize themselves with the regulations that apply to the specific area and educational institution in question.

Frederiksen Scientific cannot provide radioactive sources unless we receive documentation that the customer and the end user are entitled to handling and using such sources.

Radioactive sources from Frederiksen Scientific

We provide the so-called "Risø" type of radio-active sources, recognizable by the M12 thread and the acrylic handles:

510010 Alpha (Am-241)
510020 Beta (Sr/Y-90)
510030 Gamma (Cs-137)
510035 Co-60 (double gamma decay)

The first three of these are also available as a set (item No. 510000) including a common container.

Please refer to our web site for details.

Other radioactive sources

Two other types of radioactive sources are widely used:

Disc-shaped (Ø 25 mm) sources

Cylindrical (Ø 12 mm) sources

Equipment related to radioactive sources

Some items in our program for nuclear physics are specifically designed to accommodate Risø sources – in the following designated "option A".

In order to allow the use of our equipment with the two other source designs, special versions of the hardware have been designed. These will be marked "option B" (for disc sources), resp. "option C" (for cylindrical sources) in the following pages.

Shipment

Radioactive sources may need to be shipped separately from other ordered equipment.

Alpha, beta and gamma radioactivity

Experiment number: 138410-EN **Topic:** Radioactivity
Type: Student exercise **Suggested for:** Grade 9-10+

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
138410A (option A: For Risø sources)
138410B (option B: For disc sources).
138410C (option C: For cylindrical sources).
The photo shows Option A.

Item No.	#	Note	Text
514100	(1)	a	Experiment bench, f. Risø sources, including absorbers **Option A**
514120	(1)	a	Experiment bench, f. disc sources, including absorbers **Option B**
514110	(1)	a	Exp. bench, f. cylindrical sources, including absorbers **Option C**
512515	1		GM tube with BNC plug
513610	1		GM counter

Notes
a) Please select *one* option. Regarding the three types of sources mentioned, please see p. 33.

Also required

Set of sources: Alpha (Am-241), Beta (Sr/Y-90) and Gamma (Cs-137). Please see p. 33 for details.
Paper (normal copier paper, 80 g/m²)

Similar experiments:
138430-EN Alpha particles, the spark detector

Objective

To investigate the radiation from the three sources concerning the ability to penetrate matter.

To observe the natural background radiation and that radiation arrives at irregular intervals.

Principle

For each source, counts are accumulated in 10-seconds intervals. (The distance to the sources is so small that absorption in the air is negligible.)

Sample results

The table below shows data from one of the measurements:
Beta particles are counted with a fixed distance between source and Geiger tube.

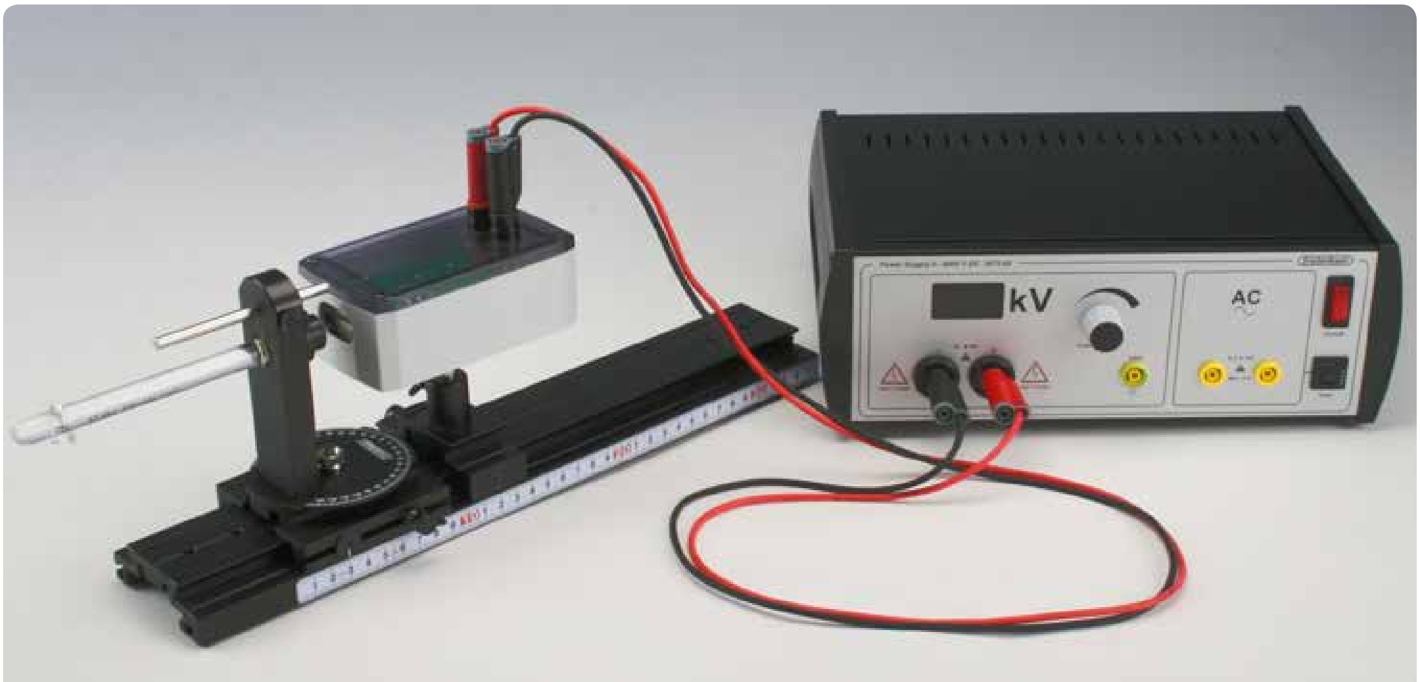
Different absorbers are inserted in front of the Geiger tube.

Source:	Beta, Risø 1979			
Period:	10 s			
Absorber:	(none)	paper	aluminium	lead
Counts:	4433	4117	1215	5
Corrected:	4431	4115	1213	3
% left:	**100%**	92.87%	27.37%	0.07%

With similar measurements on the other two types of sources, the students can formulate a qualitative description of their differences.

Alpha particles, the spark detector

Experiment number: 138430-EN **Topic:** Radioactivity
Type: Student exercise **Suggested for:** Grade 9-10+



Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
138430A (option A: For Risø sources)
138430B (option B: For disc sources).
138430C (option C: For cylindrical sources).
The photo shows Option A.

Item No.	#	Note	Text
514100	(1)	a	Experiment bench, f. Risø sources, including absorbers **Option A**
514120	(1)	a	Experiment bench, f. disc sources, including absorbers **Option B**
514110	(1)	a	Exp. bench, f. cylindrical sources, including absorbers **Option C**
512110	1		Spark detector
367060	1		High voltage supply (0-6 kV)
105740	1		Safety cable 100 cm, black
105741	1		Safety cable 100 cm, red
118530	1		Aluminium foil, 20 m roll
118540	1		Cling film, 60 m roll

Notes
a) Please select *one* option. Regarding the three types of sources mentioned, please see p. 33

Also required

Am-241 source. Please see p. 33 for details.
Paper (normal copier paper, 80 g/m²)

Similar experiments:
136410-EN Alpha, beta and gamma radioactivity

Objective

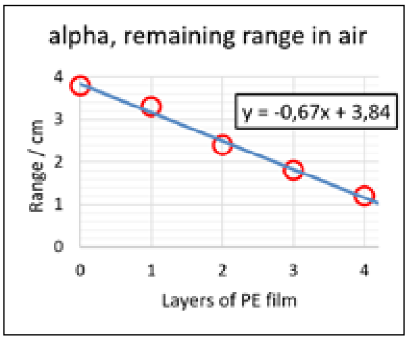
In this experiment we study the alpha radiation from a radioactive source. We will investigate what it takes to stop the radiation and we will find the range of alpha particles in air.

Principle

The spark detector has two electrodes carrying a high voltage – just below the threshold for spontaneous sparking. When an alpha particle pass through the air between the electrodes, some of the air molecules are ionized. The ions and the free electrons will trigger a spark.

Different materials can be placed between the source and the detector and the distance can be varied.

Sample results



The graph shows how the range in air is reduced when a number of cling film layers are inserted in front of the detector. One layer of this particular film reduces the range with 6.7 mm.

This can be compared with the thickness of the foil as declared on the package or even better with a measured thickness.

It turns out that the plastic foil in this case is equivalent to an air layer about 900 times thicker. (This ratio is not far from that between the density of the two materials.)

The beta spectrum (simple version)

Experiment number: 138530-EN **Topic:** Radioactivity
Type: Student exercise **Suggested for:** Grade (9)-10-11

Objective

To investigate the energy distribution of beta radiation. An approximate value of the maximum energy of the beta radiation is to be found.

Principle

The radiation is collimated by a plastic aperture. After that, it passes an area with a strong magnetic field from a pair of permanent magnets. In the magnetic field the trajectory of the beta particles is circular with a radius that depends on the velocity of the particles.

The deflection angle is read on the apparatus and is converted into kinetic energy with the help of a graph.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
138530A (option A: For Risø sources)
138530B (option B: For disc sources).
138530C (option C: For cylindrical sources).
The photo shows Option A.

Item No.	#	Note	Text
514105	(1)	b	Deflection of beta particles (for Risø source) **Option A**
514125	(1)	b	Deflection of beta particles (for disk source) **Option B**
514135	(1)	b	Deflection of beta particles (for cylindrical source) **Option C**
513610	1		Geiger counter
512515	1		Geiger-Müller tube with BNC-plug
514102	1		Rail for experiment bench, 40 cm
294610	1		Saddle with Ø10mm hole
330850	1		Bar magnets, pair

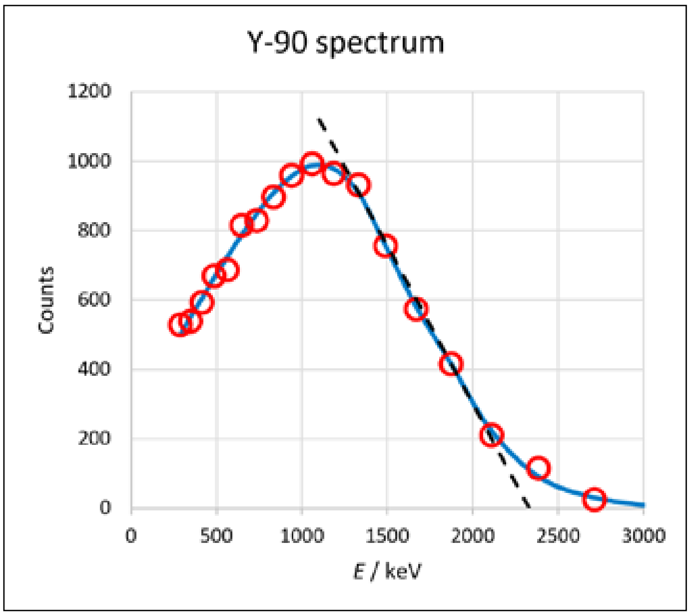
Notes
a) Almost identical equipment list is used in 138550-EN
b) Please select *one* option. Regarding the three source types mentioned, please see p. 33

Also required

Sr/Y-90 beta source. Please see p. 33 for details.

Sample results

This (simple) version of the experiment requires only the most elementary math skills. As a result, the spectrum will be slightly distorted – but will nevertheless show the important features of a continuous spectrum. The maximum beta energy found is remarkably close to the table value.



More advanced students should go for the alternative version, 138550-EN.

Similar experiments:
138550-EN The beta spectrum (advanced version)

The beta spectrum (advanced version)

Experiment number: 138550-EN **Topic:** Radioactivity
Type: Student exercise **Suggested for:** Grade 12+

Objective

To investigate the energy distribution of beta radiation. The maximum energy of the radiation is found. The experimental and the theoretical spectrum are plotted and compared.

Principle

The radiation is collimated by a plastic aperture. After that, it passes an area with a strong magnetic field from a pair of permanent magnets. In the magnetic field the trajectory of the beta particles is circular with a radius that depends on the velocity of the particles.
The deflection angle is read on the apparatus and is converted into kinetic energy with the help of a graph.

Equipment list [a]

The *complete* list below may conveniently be referred to as one of the following item numbers:
138550A (option A: For Risø sources)
138550B (option B: For disc sources).
138550C (option C: For cylindrical sources).
The photo shows Option A.

Item No.	#	Note	Text
514105	(1)	b	Deflection of beta particles (for Risø source) **Option A**
514125	(1)	b	Deflection of beta particles (for disk source) **Option B**
514135	(1)	b	Deflection of beta particles (for cylindrical source) **Option C**
513610	1		Geiger counter
512515	1		Geiger-Müller tube with BNC-plug
514102	1		Rail for experiment bench, 40 cm
294610	1		Saddle with Ø10mm hole
330850	1		Bar magnets, pair
406050	(1)	c	Teslameter

Notes
a) Identical equipment list is used in 138530-EN
 – except for 406050
b) Please select *one* option. Regarding the three source types mentioned, please see p. 33
c) May be omitted if optimum precision is not required
 – in this case: order 138530 instead.

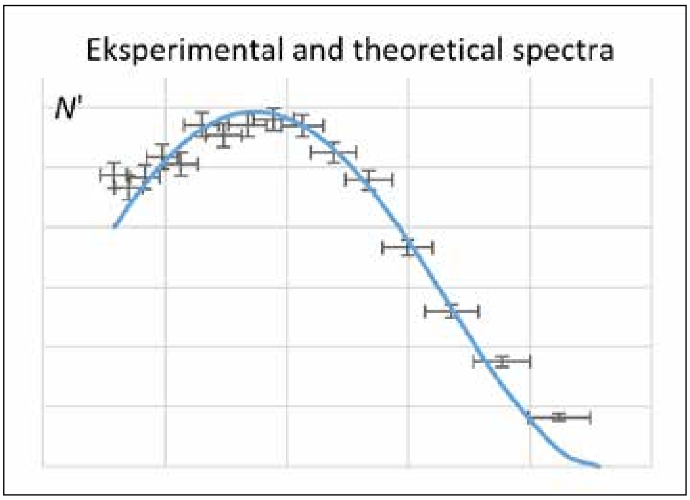
Also required

Sr/Y-90 beta source. Please see p. 33 for details.

Similar experiments:
138530-EN The beta spectrum (simple version)

Sample results

First, a Kurie plot is drawn to find the maximum beta energy. Next, this energy is used in Fermi's expression for the theoretical shape of the spectrum. The experimental and theoretical spectra are drawn.



Calculus and more advanced spreadsheet skills (for graph drawing) is used in this experiment.

Gamma Spectroscopy, the Cs-137 source

Experiment number: 138810-EN **Topic:** Nuclear physics
Type: Student exercise **Suggested for:** Grade 11-12+

Objective

In this exercise, the gamma spectrum from a Cs-137 source is studied.
This is also an introduction to the gamma spec-trometer and its accompanying software.

Principle

A *gamma spectrometer* consists of a *detector* (that registers the gamma quanta and responds with electric pulses, proportional to the energy) and a *multichannel analyser* (that measures the size of the electric signal and counts the number of gamma quanta).

The multichannel analyser contains a large array of *channels*, i.e. counters, each corresponding to a small energy interval. For each registered quantum, the analyser determines the corresponding counter and increments it by one. After sufficiently long time, the result can be plotted as a so-called *spectrum*: A graph showing the frequencies as a function of the gamma energy.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
138810A (option A: For Risø sources)
138810B (option B: For disc sources).
138810C (option C: For cylindrical sources).
The photo shows Option A.

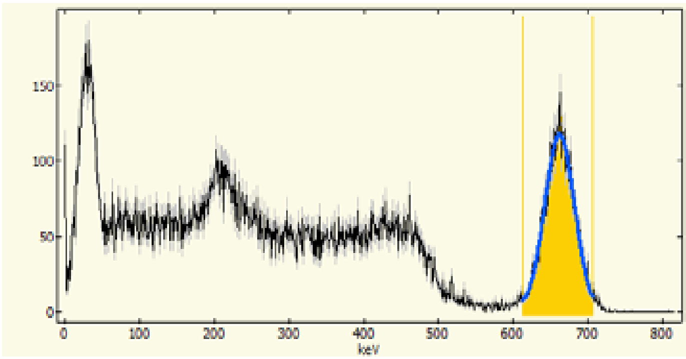
Item No.	#	Note	Text
518000	1		Multichannel analyser w/ software
518500	1		Scintillation detector for 518000
514180	(1)	a	Source holder for mounting bench, simple, Risø source **Option A**
514185	(1)	a	Source holder for mounting bench, simple, disc source **Option B**
514187	(1)	a	Source holder for mounting bench, simple, cylindrical source **Option C**
514102	1		Rail for experiment bench, 40 cm
294610	1		Saddle with Ø 10 mm hole
514010	2		Absorber plate, lead, 1.2 mm

Notes
Please select *one* option. Regarding the three source types mentioned, please see p. 33.

Also required

Cs-137 source. (Please see p. 34 for details)
PC (with USB and Windows 7, 8 or 10)

Sample results



The spectrum from a Cs-137 source (including barium X-rays) after only 60 seconds.

Extended manual

Filling 8 pages, the lab manual contains a step-by-step introductory course for the basic use of the multichannel analyser. Time requirements will depend on the level of the students – one hour is unlikely to be sufficient.

Similar experiments:
138850-EN Compton scattering

Compton scattering

Experiment number:	138850-EN	**Topic:**	Nuclear physics
Type:	Student exercise	**Suggested for:**	Grade 11-12+

Objective

Demonstrating the energy loss of gamma quanta by Compton scattering.
Verification of the theoretical expression for the energy of the scattered gamma quanta.

Principle

The equipment makes it possible to study Compton scattering by two angles: 60° and 90°. For each angle a couple of aluminium shells are used, whose geometry ensures that only gamma quanta that are scattered in precisely the desired angle, hits the detector.

Most of the direct radiation is absorbed by a lead absorber, placed directly between source and detector.

The energy of the gamma quanta is measured by a small scintillation detector and a multichannel analyser.

Equipment list

The *complete* list below may conveniently be referred to as one of the following item numbers:
138850A (option A: For Risø sources)
138850B (option B: For disc sources).
138850C (option C: For cylindrical sources).
The photo shows Option A.

Item No.	#	Note	Text
518000	1		Multichannel analyser w/ software
518500	1		Scintillation detector for 518000
519000	1		Compton scattering kit
514180	(1)	a	Source holder for mounting bench, simple, Risø source **Option A**
514185	(1)	a	Source holder for mounting bench, simple, disc source **Option B**
514187	(1)	a	Source holder for mounting bench, simple, cylindrical source **Option C**
514102	1		Rail for experiment bench, 40 cm
294610	2		Saddle with Ø 10 mm hole

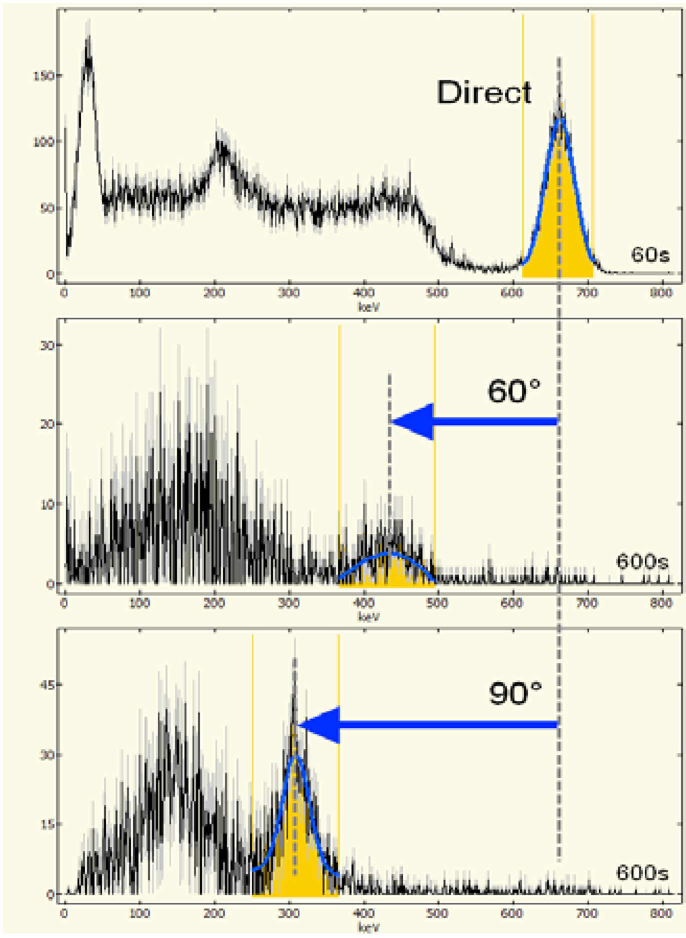
Notes
a) Please select *one* option. You will find an overview of source types on p. 33.

Also required

Cs-137 source. Please see p. 33 for details
PC (with USB and Windows 7, 8 or 10)

Similar experiments:
138810-EN Gamma spectroscopy, Cs-137

Sample results



The sample spectra show the displacement of the photo peak when the gamma quanta are scattered through an angle of 60°, resp. 90°.

The software can fit a Gaussian curve to the data to obtain the precise position of the peaks.

Lab Manual Sample

The following pages contain the manual for Ohm's law to illustrate a typical example.

All the manuals can be downloaded for free from our web site www.frederiksen.eu

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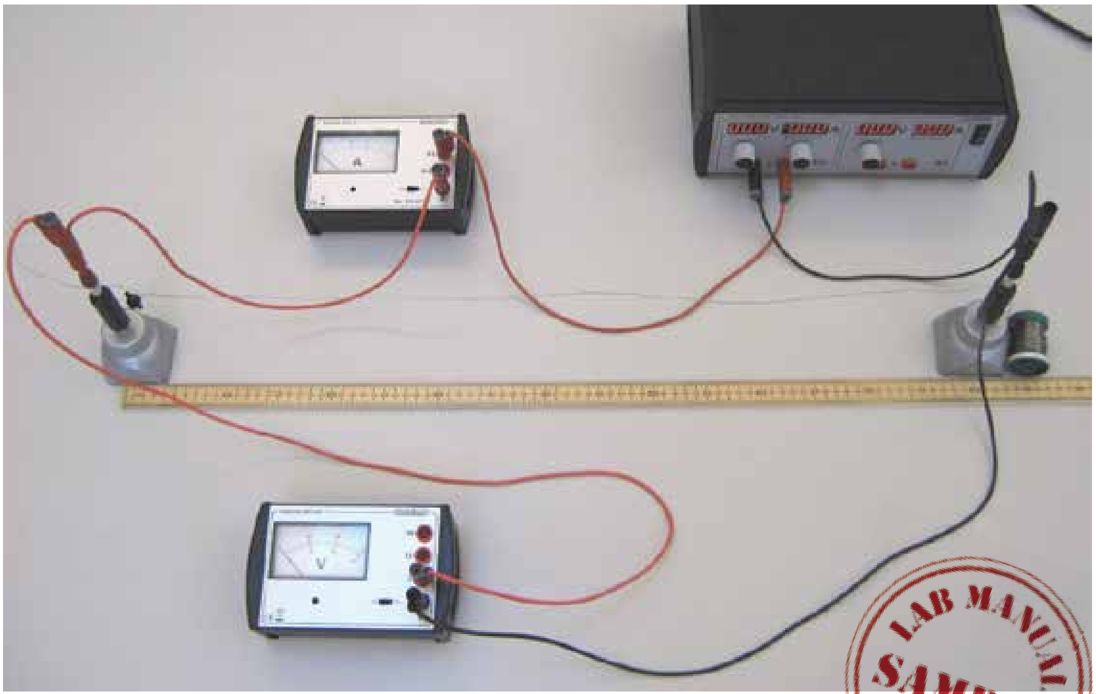
Ohm's law

Number	136050-EN	*Topic*	Electricity				
Version	2017-02-14 / HS	*Type*	Student exercise	*Suggested for*	grade 7-10	*p.*	1/4



Objective
Examining the relationship between voltage and current for a metal wire.

Principle
A length of Kanthal wire is extended between two terminal posts in order to measure the current through the wire and the voltage across it.
For comparison, the same measurements are carried out for a small incandescent lamp.

The results are analysed graphically and compared with Ohm's law.

Equipment
(Detailed equipment list on last page)

Power supply
Volt- and ammeters

Kanthal wire 0.50 mm
Bulb, 6 V / 1 A

Socket for light bulb
Stand material
Lab leads
Ruler, 1 m

Using multimeters
Instead of Frederiksen's analog instruments, you can use digital multimeters. Hints for use:

As an ammeter
We will need a current of up to 0.5 A. The safest is to use the high current input of the meter. Look at the sockets: If there is a separate socket marked "10 A" – this is the one to use together with the "Com" socket.

As a voltmeter
If the multimeters hasn't auto-ranging, pick a range that is capable of measuring 3 V.
If the meter has both a "mV" and a "V" socket, use "V" together with the "Com" socket.

Procedure

The wire can be re-used many times. Don’t cut it, unless explicitly instructed to do so. Instead, just let the coil stand next to the experiment and re-wind the wire afterwards.

Fasten the wire thoroughly to the terminal posts with approximately 80 cm between the posts when the wire is tight.
Don’t waste time on adjusting the length but measure the actual length accurately and write it down.

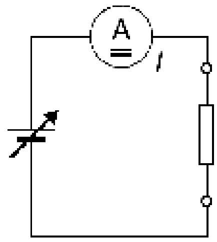
If the power supply has a current limiter, the measurements can be carried out with this turned fully up, with only the voltage adjusted. Turn the voltage down to 0 V while setting up.

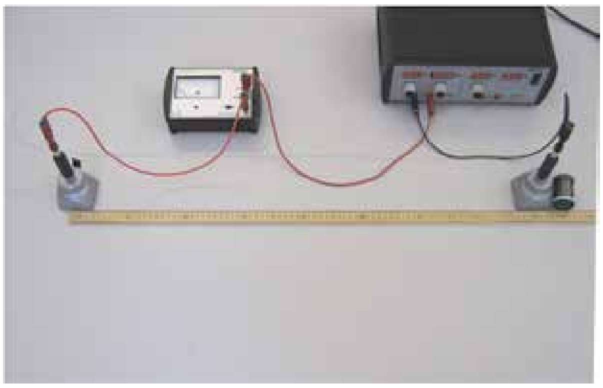
When you connect the volt- and ammeters, proceed systematically:

1. First, establish a circuit for the **current** to follow
2. Next, connect the voltmeter between the points where the **voltage** is to be measured.

In this experiment, all measurements can be done with voltmeter range 3 V and ammeter range 0.5 A. Both voltage nor current must be kept below these limits.

The instruments are set to DC measurements.





1 First, establish a circuit for the current …

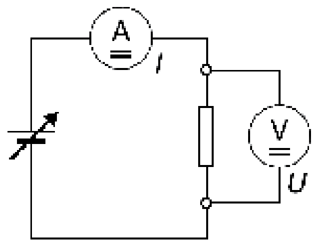
Make a table for the result as shown below.

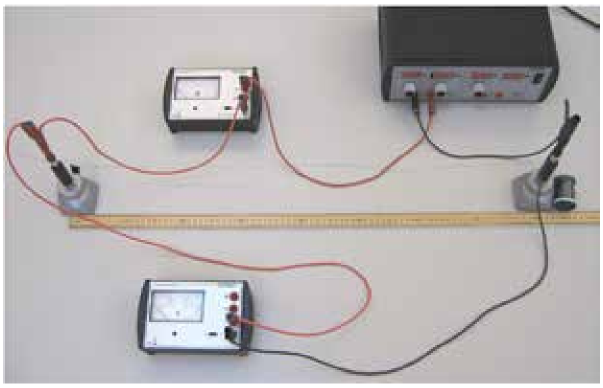
When ready, turn up the voltage slightly. Both instruments should respond now. Continue carefully until you reach either 3 V or 0.5 A.
Now you know the maximum values – write them down.

Now, you must plan and carry out a series of measurements – 7 to 10 all in all – with the voltage stepping up more or less evenly from 0 V to the maximum value.

For each measurement, write down both voltage and current in the table.

Now replace the wire and terminal posts with the 6 V / 1 A bulb in a socket. Repeat the entire measurement series. The lowest voltages are important here - try to hit about 0.1 V in one of the measurements.





2 … then add the voltmeter.

Table for results

Make a table like the one below:

Measured		Calculated
U	*I*	*R*
V	A	Ω

Theory

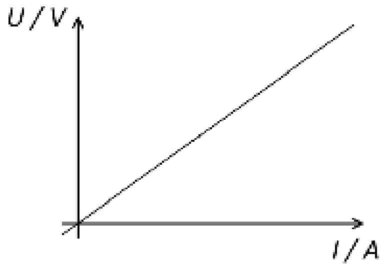
The voltage U across an electric component often varies in step with the current I through it. U is said to be proportional to I, and the relationship is expressed mathematically as:

$$U = R \cdot I$$

Here R is a constant, called the *components resistance*.
Thus, in this experiment we find the *resistance of this length of wire*. When you enter U in V and I in A, R will come out with the unit Ω (read: “ohm”).

This formula is known as *Ohm’s law*.

A graph with I along the 1st axis and U along the 2nd axis results in a straight line through (0,0).



Even if this relationship between current and voltage often is valid, it is absolutely not universally true.

If U and I are known, R can be found:

$$R = \frac{U}{I}$$

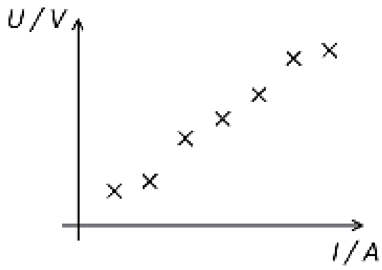
If Ohm’s law holds true for a given component, the value of R is a constant – and vice versa.

Even if Ohm’s law does *not* apply, you can of course insert measured values of U and I to calculate R – but in that case it would not be correct to speak about a resistance.

Calculations

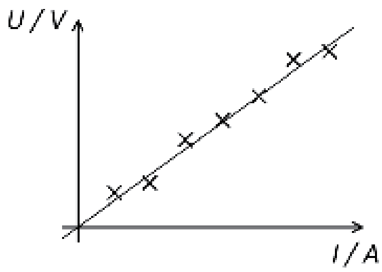
Draw a graph of the results for the Kanthal wire. It can be done in a spreadsheet or on paper:

The units on the axes should let 2 cm correspond to 0.1 A (1st axis) resp. 5 cm correspond to 1 V (2nd axis).



Plot the measurement points – mark them with small crosses – the points must ***not*** be connected by lines.

When all result have been plotted, try to draw a straight line through (0,0), lying as close as possible to all the measured points.
(A *transparent* ruler will be a great advantage.)



Calculate R for all measuring points in the table.

Similarly, plot the points for the light bulb in a spreadsheet or on paper. – Is it possible again to fit the points with a straight line through (0,0) ?

Discussion and evaluation

We must always take into account that measured values have uncertainties, meaning that small deviations from theory are acceptable!

We are interested to know if the metal wire obeys Ohm’s law. That can be decided in two ways:

- Do the points roughly lie on a straight line?
- Has R approximately a constant value?

Do the two methods give the same answer?

Does the metal wire comply with Ohm’s law? Does the light bulb? (Justify your answers.)

Teacher's notes

Concepts used

Voltage
Current
Resistance

Mathematical skills

Graph drawing
Evaluation of a simple formula

About the equipment

The instruments 381560 and 381570 are overload protected. They will also tolerate wrong polarity although only positive values can be read.

It will eventually be possible to read the current on a built-in ammeter in the power supply – if you want to avoid an external meter.
On the other hand, from a pedagogical perspective, it will be undesirable to use a built-in *voltmeter*. It will not in this context cause real problems for the measurement, but the students should get used to connect the voltmeter directly across the component in question.

Detailed equipment list

Specifically for this experiment

381570	Ammeter	
381560	Voltmeter	
115520	Kanthal wire 0.50 mm	
425040	Bulb 6 V / 1 A (box with 10)	
412000	Lamp socket E10, 2 connectors	

Standard lab equipment

361600	Power supply (Alternative power supply: 364000. The photo on p. 1 shows this model)	
435030	Terminal posts, insulated (pair)	
000410	Retort stand base, square	(2 pcs.)
105720	Safety cable, silicone, 50 cm, black	
105721	Safety cable, silicone, 50 cm, red	(2 pcs.)
105740	Safety cable, silicone, 100 cm, black	
105741	Safety cable, silicone, 100 cm, red	
140510	Ruler, 100 cm	

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We know that not everybody is meant to be a scientist. But we believe that everybody has the right to learn. And learning is encouraged through dedicated teachers and great teaching conditions.

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At Frederiksen, we like to do more than simply supply goods. Many of the products also include extras such as instructions or other support material, prepared by us or members of our network. One important aspect of our service is our employees, with their scientific backgrounds, who are always ready to help and answer your question.


S. Frederiksen

Passion for science

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