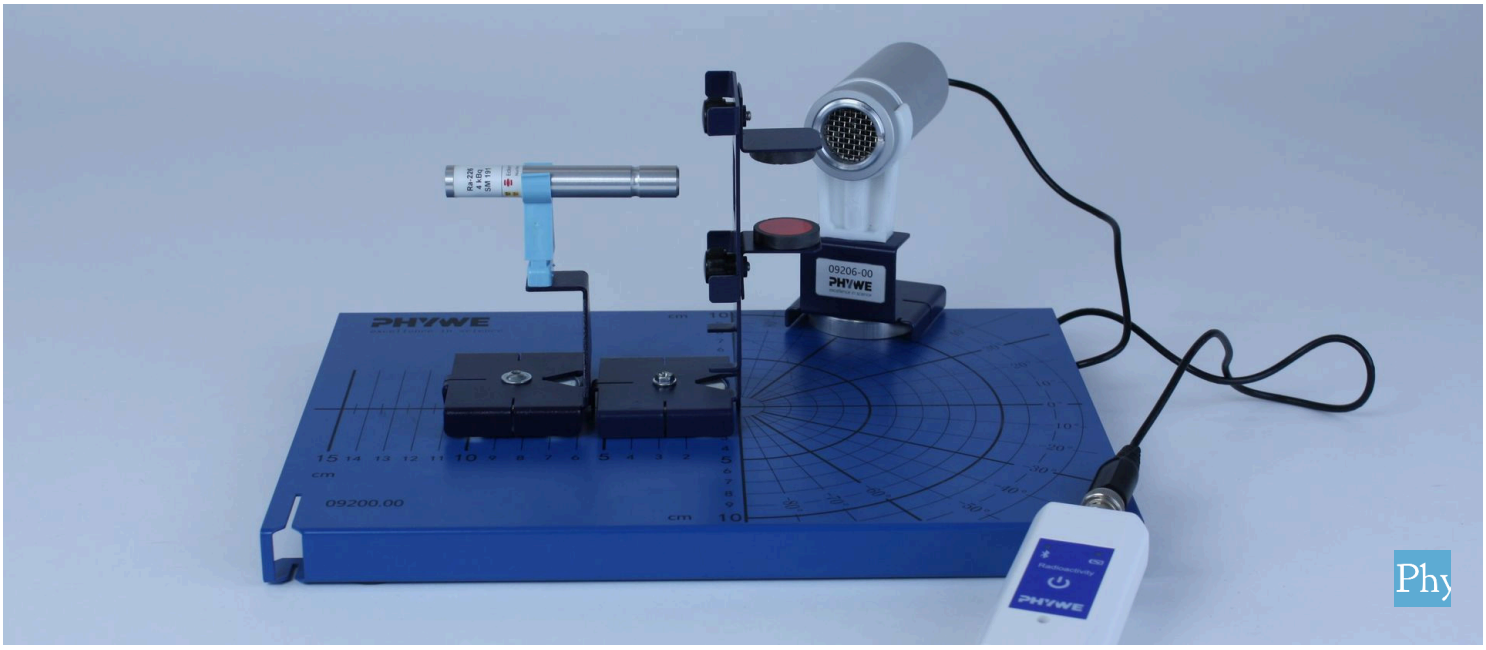
The deflection of beta radiation in a magnetic field with Cobra SMARTsense



Physics > Modern Physics > Radioactivity

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

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Teacher information

Application

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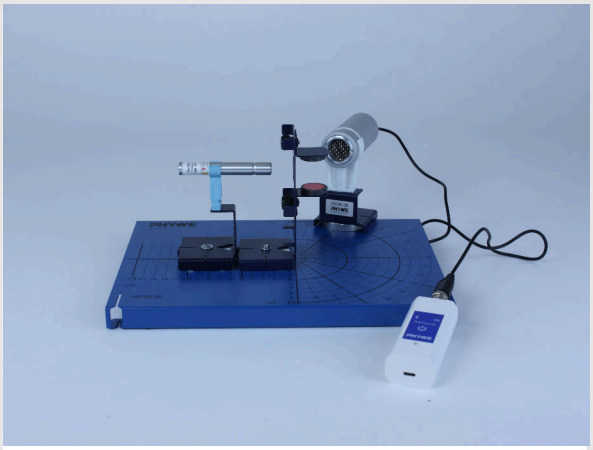

Shielding of radioactive radiation

The Lorenz force acts on β particles that move perpendicular to the field direction of a magnet. At constant speed and magnetic field strength, the β particles move in the field area on a circular path whose radius depends on their speed and the magnetic field strength.

Since the β particles have a continuous energy spectrum, they are deflected to different degrees by a magnetic field. This makes it possible to determine the proportions of the different energy values experimentally, for example by evaluating the count rates Z determined for given path radii as a function of the magnetic flux density B.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other teacher information (1/3)

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Prior knowledge

As previous knowledge, the students should have mastered terms such as counting rate, zero rate and the use of the Geiger-Müller counter. In addition, the different types of radiation should be known or worked out with the help of this experiment. Furthermore, the magnetic field, the resulting forces in a magnetic field and moving charges in the magnetic field should be known.

Scientific principle

An angular scale is used to investigate the deflection of beta rays in the magnetic field.

Other teacher information (2/3)

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Learning objective

In this experiment, various findings can be conveyed:

- β rays consist of electrically charged particles because they are deflected by a magnet.
- Since the direction of deflection is opposite to the direction expected according to the three-finger rule, β particles have a negative charge.
- The stronger the magnetic field, the greater the deflection. If the field direction is changed, the deflection also occurs in the opposite direction.
- The β particles have different energy values because they are deflected to different degrees.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other teacher information (3/3)

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Tasks

The students investigate the deflection of beta rays in the magnetic field by moving the Geiger-Müller counter tube on the angular scale of the mounting plate and detecting the pulse rate.

Safety instructions (1/3)

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In this experiment, satisfactory results can only be achieved if the design and implementation are carried out with care. Particular attention should be paid to the following conditions:

- The magnetic field should be located at the centre of the angle division.
- The exit opening of the radiation source should be located in front of the magnetic poles.
- The distance between the radiation source and the counter tube window must not change under any circumstances when the counter tube is moved on the angle scale, as this would lead to strong deviations in the count rates. In order to also avoid a displacement of the counter tube in the counter tube holder, the position of the counter tube in the holder should be marked.
- The counter tube axis is radial if both marks of the counter tube holder point to the same angle mark.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
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Safety instructions (2/3)

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In this experiment, satisfactory results can only be achieved if the design and implementation are carried out with care. Particular attention should be paid to the following conditions:

- With the suggested measuring time of 60 s, 19 minutes are required for a series of measurements. If this time is not available, a shorter measurement time of 10 seconds can also be selected; however, due to the higher statistical uncertainty, 3 measurements should then be carried out for each angle setting and the average values evaluated.
- It is recommended to carry out this test with the Geiger-Müller counter tube, type B (order no. 09005-00). The Geiger-Müller counter tube, 45 mm (order no. 09007-00) detects a very large angular range due to its large diameter, so that a satisfactory result cannot be achieved.

Safety instructions (3/3)

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- The general instructions for safe experimentation in science lessons apply to this experiment.
- The activity of the radiation source used is quite low at 3 kBq, but the source should only be removed from the storage container for the duration of the experiment.
- The generally applicable rules for handling radioactive preparations according to the Radiation Protection Ordinance must be observed.

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Student Information

Motivation

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Particle tracks detected in a cloud chamber show curved paths for some particles

In cloud chambers energetic particles of many types can be visually detected. In addition to high-energy cosmic rays, radioactive particle tracks can also be seen. In a magnetic field many of these tracks are curved and do not show straight-line behaviour.

In this experiment we want to investigate the behaviour of beta particles in a magnetic field.

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Tasks

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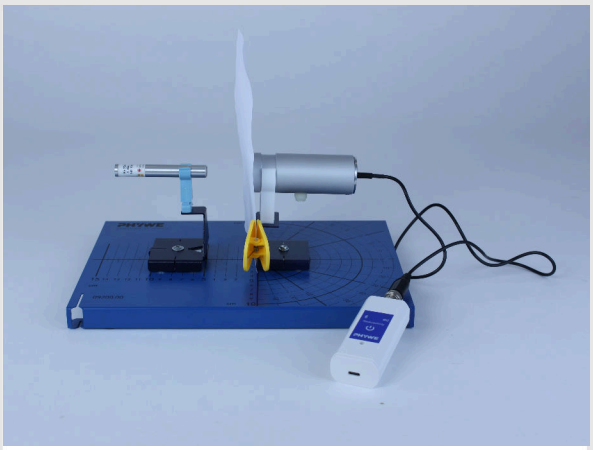

Experimental set-up with a sheet of paper in the beam path

- Record the pulse rate of a α emitter for different ranges first in the air and then with a sheet of paper in the beam path
- Compare the measurement series and conclude on the range of α particles.
- Explain what determines the range in the air.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense- Radioactivity (Bluetooth + USB)	12937-01	1
2	Base plate for radioactivity	09200-00	1
3	Counter tube holder on fixating magnet	09201-00	1
4	Source holder on fixing magnet	09202-00	1
5	Plate holder on fixing magnet	09203-00	1
6	Defl.magnets f. plate holder,2pcs	09203-02	1
7	Radioactive source Ra-226, max. 4 kBq	09041-00	1
8	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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37079 Göttingen
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Fax: 0551 604 - 107
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Set-up (1/4)

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The Cobra SMARTsense and measureAPP are required to measure radioactivity. The app can be downloaded free of charge from the App Store - QR codes see below. Check whether Bluetooth is activated on your device (tablet, smartphone).

iOS

Android

Windows

Set-up (2/4)

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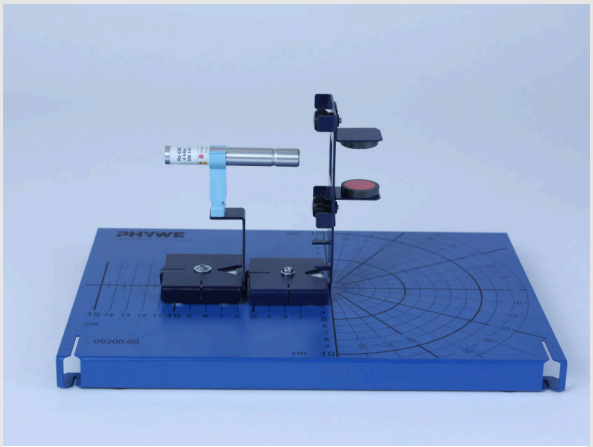

Structure with installed specimen holder and deflecting magnet

- Attach the deflector magnets to the plate holder using the knurled screws. The distance between the magnets should be 2 cm.
- Place the plate holder on the mounting plate. The center of the deflecting magnets should be exactly above the center of the angle scale.
- Clamp the specimen in the specimen holder and place the specimen holder on the mounting surface. Move the holder until the beam exit opening is exactly above the front edge of the specimen.

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Set-up (3/4)

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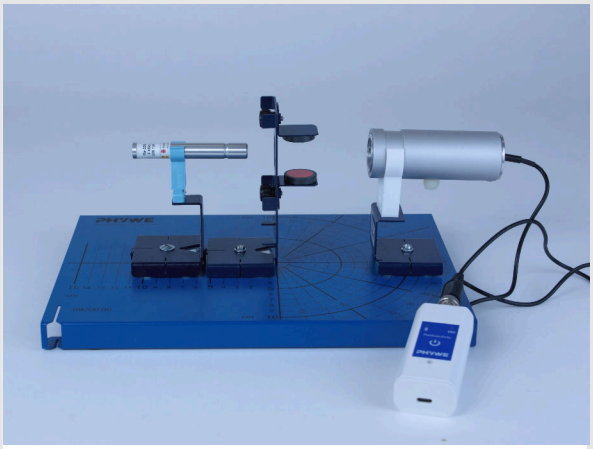

Test setup without absorber material in the beam path

- Clamp the Geiger-Müller counter tube into the counter tube holder, place it on the mounting plate so that the edge of the counter tube holder points to the intersection of the 0° angle division and the arc of a circle with radius r = 5 cm.
- Connect the Geiger-Müller counter tube to the sensor unit.

Set-up (4/4)

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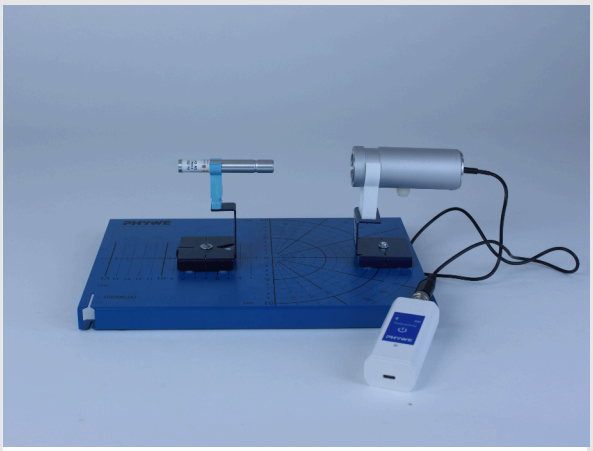

Test setup without deflecting magnets in the beam path

- Now remove the plate holder from the mounting plate without moving the radiation source.
- Connect the sensor to the PHYWE Measure app on the tablet by pressing the Bluetooth button for 3 seconds. Then the radioactivity sensor can be selected in the app.

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Procedure (1/3)

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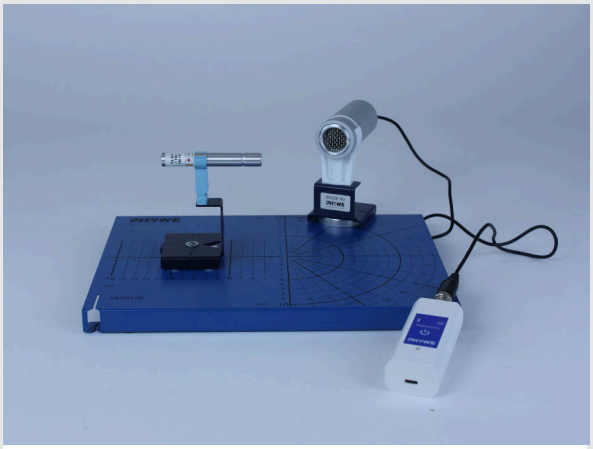

Experimental setup with detector in -90° position

- Note the first measured value in the table in the protocol. Move the counter tube holder to the 10° division of the angle scale; the distance between the counter tube and the radiation source must not change!
- Repeat the measurements for the angle values +90° and -90° in 10° steps.

Procedure (2/3)

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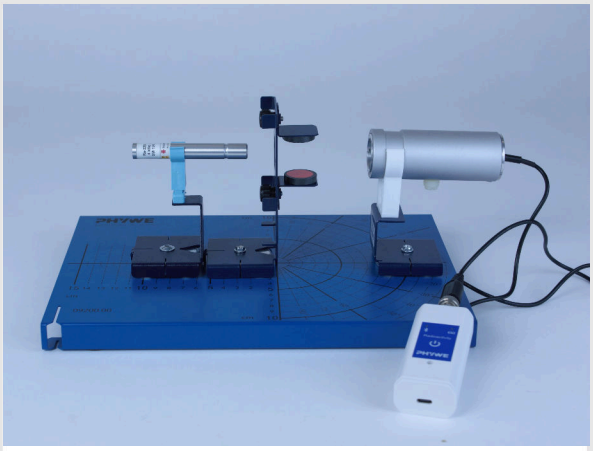

Experimental setup with deflecting magnets and detector in 0° position

- Carefully place the plate holder with the deflecting magnets on the mounting plate so that the magnets are above the center of the angle scale. Be careful not to move the radiation source and the counter tube.
- Now determine the count rates for all previous angle values under the influence of the deflecting magnet; enter these measured values in the table in the protocol as well.

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37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Procedure (3/3)

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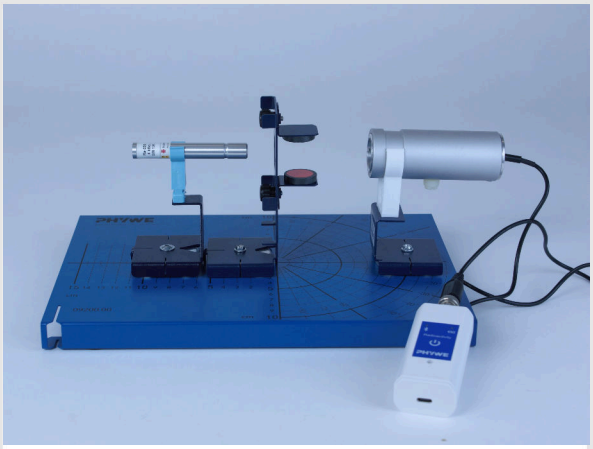

Experimental setup with deflecting magnets and detector in 0° position

- Repeat the measurement series after the position of the two magnets in the plate holder has been changed.
- Repeat the measurement series with a smaller distance between the deflecting magnets.
- Put the radiation source back into the storage container.

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Report

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Observation (1/2)

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Note the measured values for the measurement without and with installed magnets.

Angle	-90°	-80°	-70°	-60°	-50°	-40°	-30°	-20°	-10°
Z without magnet									
Z with magnet									

Angle	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Z without magnet										
Z with magnet										

Observation (2/2)

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Note down the measured values for measurements with exchanged magnets and with reduced magnet distance.

Angle	-90°	-80°	-70°	-60°	-50°	-40°	-30°	-20°	-10°
Z exchanged									
Z reduc.dist.									

Angle	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Z exchanged										
Z reduc.dist.										

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Task 1

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Where is the highest pulse rate measured without magnet?

- In the negative range of the angle scale.
- Approximately at 0°.
- In positive range of the angle scale

Check

What happens when you put a magnetic field in the path of the beam?

- It has no effect on the radiation.
- Radiation is absorbed.
- The radiation is deflected.

Check

Task 2

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What happens when you change the magnets?

- The deflection is increasing.
- The deflection remains the same.
- The deflection direction changes.

Check

What happens if the distance between the magnets is reduced?

- It has no effect on the radiation.
- The deflection becomes smaller.
- The deflection is increasing.

Check

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37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

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Slide	Score/Total
Slide 23: Multiple tasks	0/2
Slide 24: Multiple tasks	0/2

Total amount 0/4

Solutions | Repeat | Exporting text

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37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
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