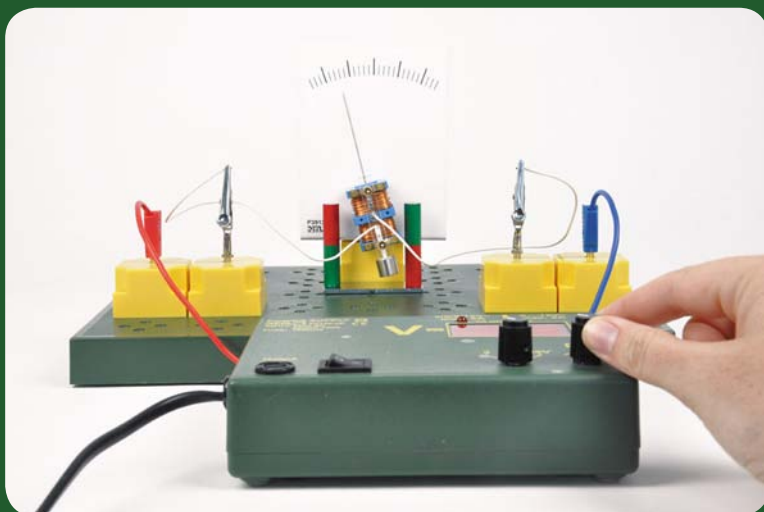


Student Experiments

Manual

ELECTRODYNAMICS

P9160-4T



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- EMS 3.2 Current flow and deflection of a current-carrying conductor in a magnetic field ("right-hand rule")
- EMS 3.3 Coil in a magnetic field (rotating-coil device)

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- EMS 4.1 Simple DC motor
- EMS 4.2 Series motor
- EMS 4.3 Shunt-wound motor
- EMS 4.4 DC generator - external pole generator

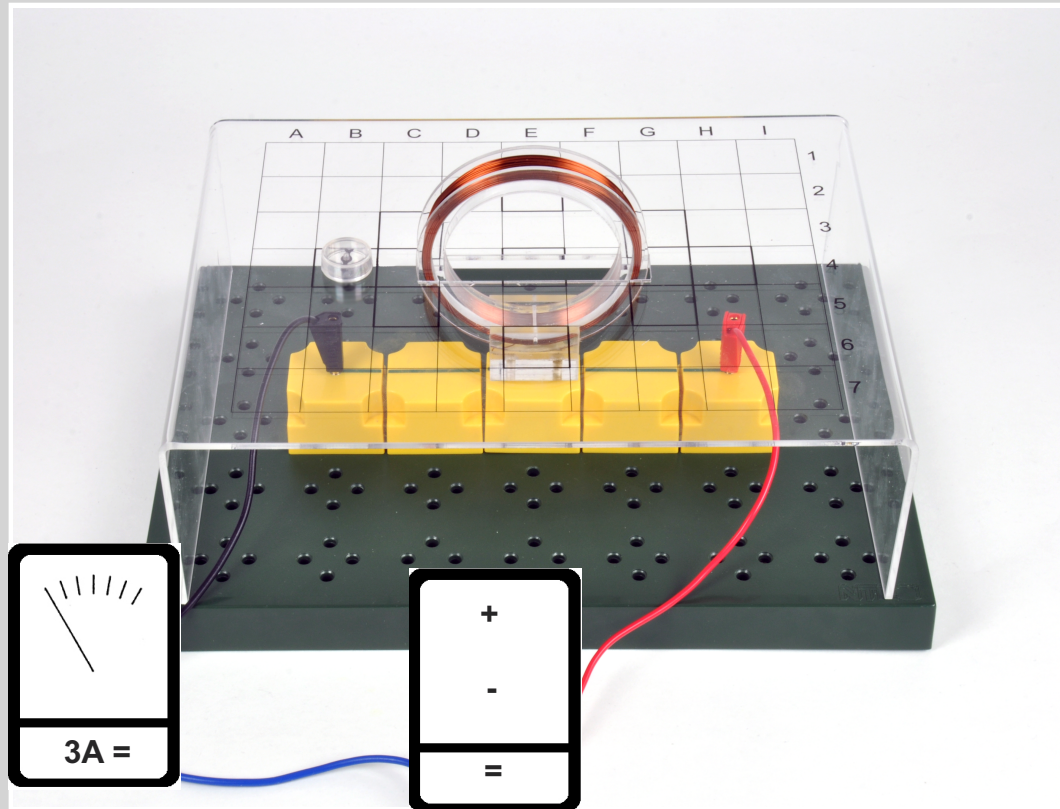
THE MAGNETIC FIELD AND ITS FIELD LINES AROUND A POWERED COIL

EMS 1.1

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

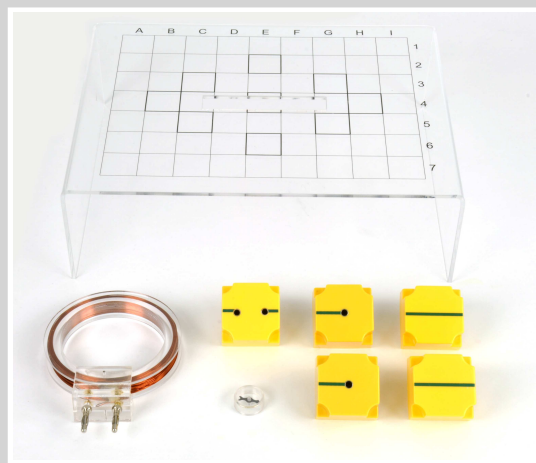


Material:

- 1x Plug-in panel, small
- 1x Grid plate
- 1x Connection lead ,25 cm, black
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 2x PIB connector
- 2x PIB wire, straight
- 1x PIB wire interrupted, with sockets
- 1x Induction coil
- 1x Drawing compass

Additionally required:

- 1x Power source
- 1x Meter



THE MAGNETIC FIELD AND ITS FIELD LINES AROUND A POWERED COIL

EMS 1.1

The magnetic field around a powered coil is to be determined by means of a drawing compass

Experiment:



Arrangement according to the illustration.

The building blocks are fixed at the plug-in panel according to the illustration. The coil is fixed at the "PIB wire, interrupted, with sockets". The grid plate is added to the plug-in panel in such way that the coil protrudes through the provided opening.

The power supply is connected and the power is turned on. The power is adjusted in such way that there is 1 A in the power circle. (Consider the right polarization)

The compass is placed at the separate fields of the grid plate one after the other and the direction of the magnetic needle is marked on the enclosed grid sheet. This process is repeated for each field of the grid. Optional only the fat edged fields could be tested. But for a more beautiful picture of the field lines it is recommended to investigate all the fields of the grid plate.

Now the magnetic field vectors can be seen. These field vectors can be combined to magnetic field lines. If you remember the magnetic field lines of a bar magnet the drawing becomes easier.

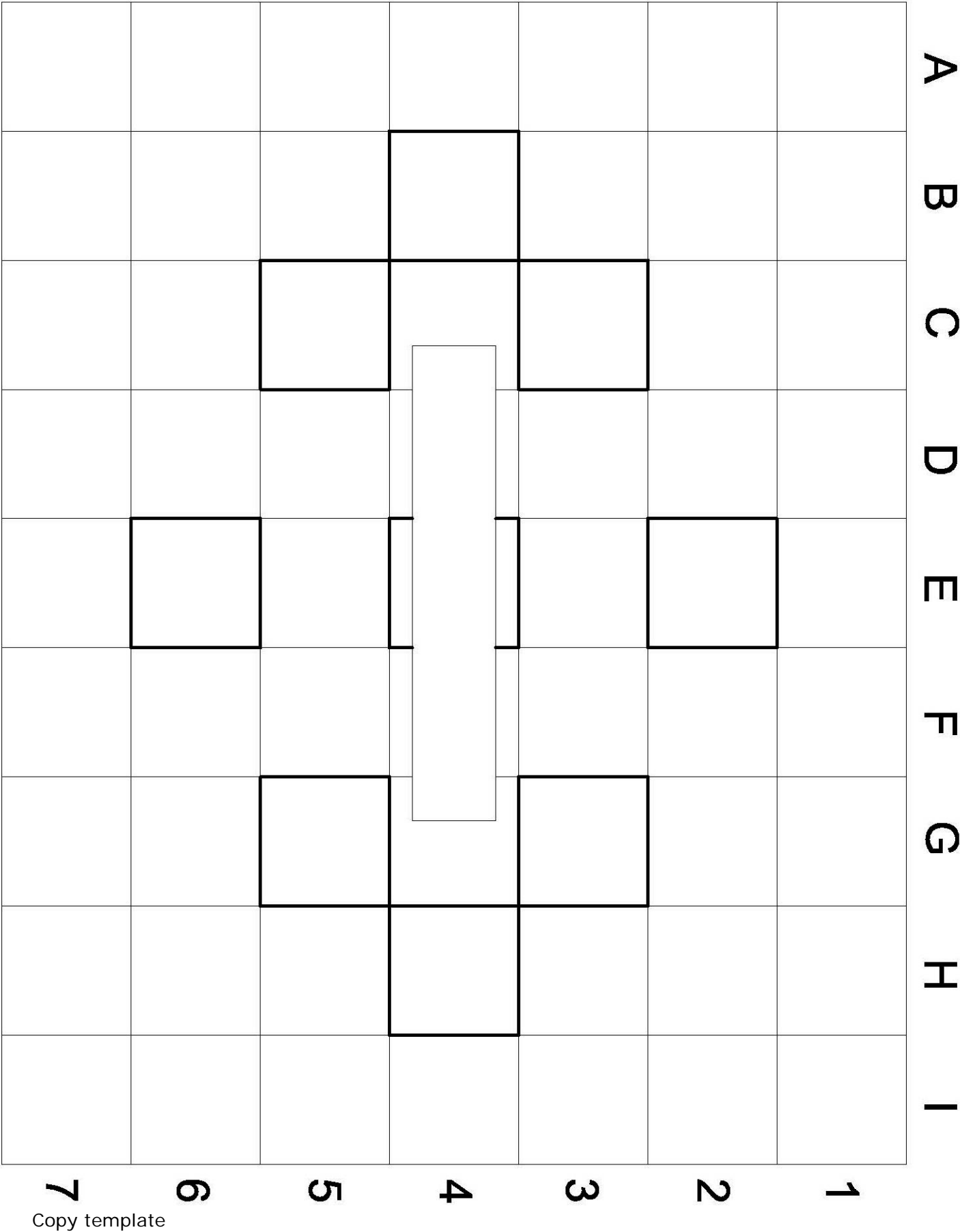


Conclusion:

The magnetic field is built up by means of the power which flows through the coil. This magnetic field varies the compass needle from its original position. Circular field lines arise around the thigh of the induction coil.

THE MAGNETIC FIELD AND ITS
FIELD LINES AROUND A POWERED
COIL

EMS 1.1



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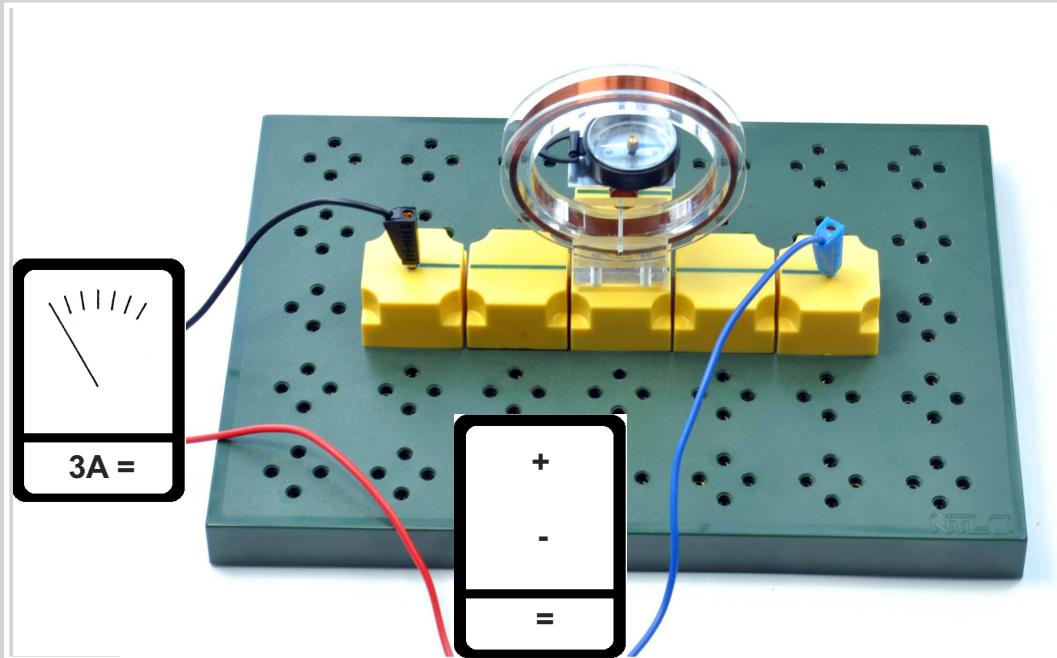
THE INFLUENCE OF THE COIL CURRENT ON THE DIRECTION OF THE MAGNETIC FIELD

EMS 1.2

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

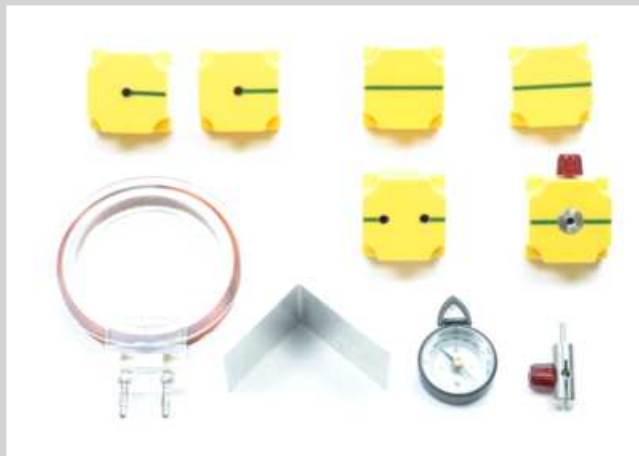


Material:

- 1x Plug-in panel, small
- 1x Connection lead, 25 cm, black
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 2x PIB connector
- 2x PIB wire, straight
- 1x PIB with adapter bush
- 1x PIB wire interrupted, with sockets
- 1x Holder with slit and hole
- 1x Holder for pocket compass
- 1x Induction coil
- 1x Pocket compass

Additionally required:

- 1x Power source
- 1x Meter



THE INFLUENCE OF THE COIL CURRENT ON THE DIRECTION OF THE MAGNETIC FIELD

EMS 1.2

The flow direction of the current is to be determined.

Experiment:

Arrangement according to the illustration.

The plug-in blocks are fixed on the plug-in panel according to the illustration. The induction coil is fixed at the "PIB wire, interrupted, with sockets". The holder for pocket compass is mounted on the "PIB with adapter bush" The PIB is fixed on the plug-in panel in such way that the pocket compass is in the same height as the coil.

Power is sent again with 1 A through the coil. The compass is placed in the middle of the holder for the pocket compasses. What happens to the compass needle if you reverse the poles of the power supply?

The magnetic field direction is easily investigated by means of the "right-hand rule" (also called screw-rule): If you put the fingers of the right hand around the wire in such way that the thumb shows in the power direction, the fingers bend in the direction of the magnetic field around the wire. (To remember: the magnetic field direction is the direction in which the north pole of the magnetic needle shows.)

Screw-rule: The rotation of a dextrorotatory screw in direction of the current is the magnetic field direction.

Now a rule is formulated, which defines, from which pole the electric current in a coil starts: If the power floats clockwise, the power emanates from the South Pole. If the power floats anticlockwise, the power emanates from the North Pole. Is this the conventional power direction or the direction of the electron flow?



Conclusion:

When the current direction is reversed the magnetic field is also reversed.

If you know the power direction in the coil, you can determine the direction of the magnetic field by means of the "right-hand rule" or the "screw-rule"

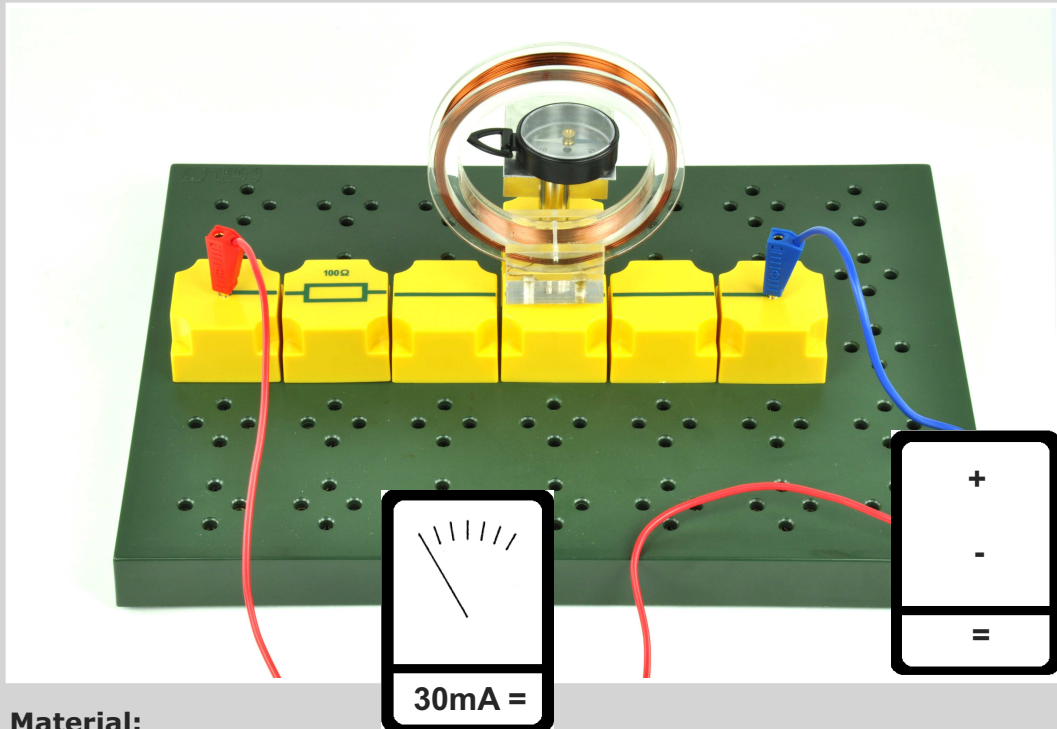
RELATION BETWEEN AMPERAGE AND THE TANGENT OF THE DEFLECTION ANGLE

EMS 1.3

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

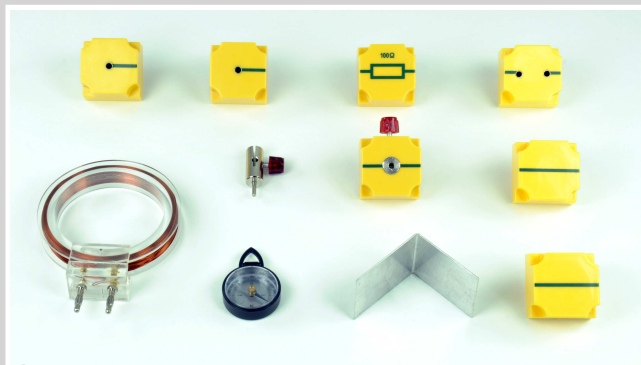


Material:

- 1x Plug-in panel, small
- 1x Connection lead, 50 cm, red
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 2x PIB connector
- 2x PIB wire, straight
- 1x PIB wire interrupted, with sockets
- 1x PIB with adapter bush
- 1x PIB resistor 100 Ω
- 1x Holder with slit and hole
- 1x Holder for pocket compass
- 1x Induction coil
- 1x Pocket compass

Additionally required:

- 1x Power source
- 1x Meter



RELATION BETWEEN AMPERAGE AND THE TANGENT OF THE DEFLECTION ANGLE

EMS 1.3

It is to be determined if the tangent of the deflection angle to the earth's magnetic field (results of the strength of the magnetic field of the coil) grows proportional to the power strength.

Experiment:



Arrangement according to the illustration.

The plug-in blocks are placed at the plug-in plane according to the illustration. The induction coil is fixed on the "PIB wire, interrupted, with sockets". The holder for pocket compass is fixed on the "PIB with adapter bush". The plug-in block is fixed on the plug-in plane in such way that the compass is at the same height as the coil.

A resistor with $100\ \Omega$ is placed in the electrical circuit to handle small amperages easier.

The compass is placed right in the middle of the coil. The arrangement is aligned in such way that the coil is aligned exactly in the north – south direction. The compass is turned in such way that the north pole of the magnetic needle points exactly to the north (0°).

The voltage is set at zero and like in the experiments before connected with the ammeter. The ammeter is set at the 30 mA range

After the aligning of the coil and the compass is controlled again, the power is increased very carefully until the needed deflection angle is reached. The accompanying amperage is noticed.

Which correlation can be established between the tangent of the deflection angle and the compass needle? (Results out of the diagram on the next page)



Conclusion:

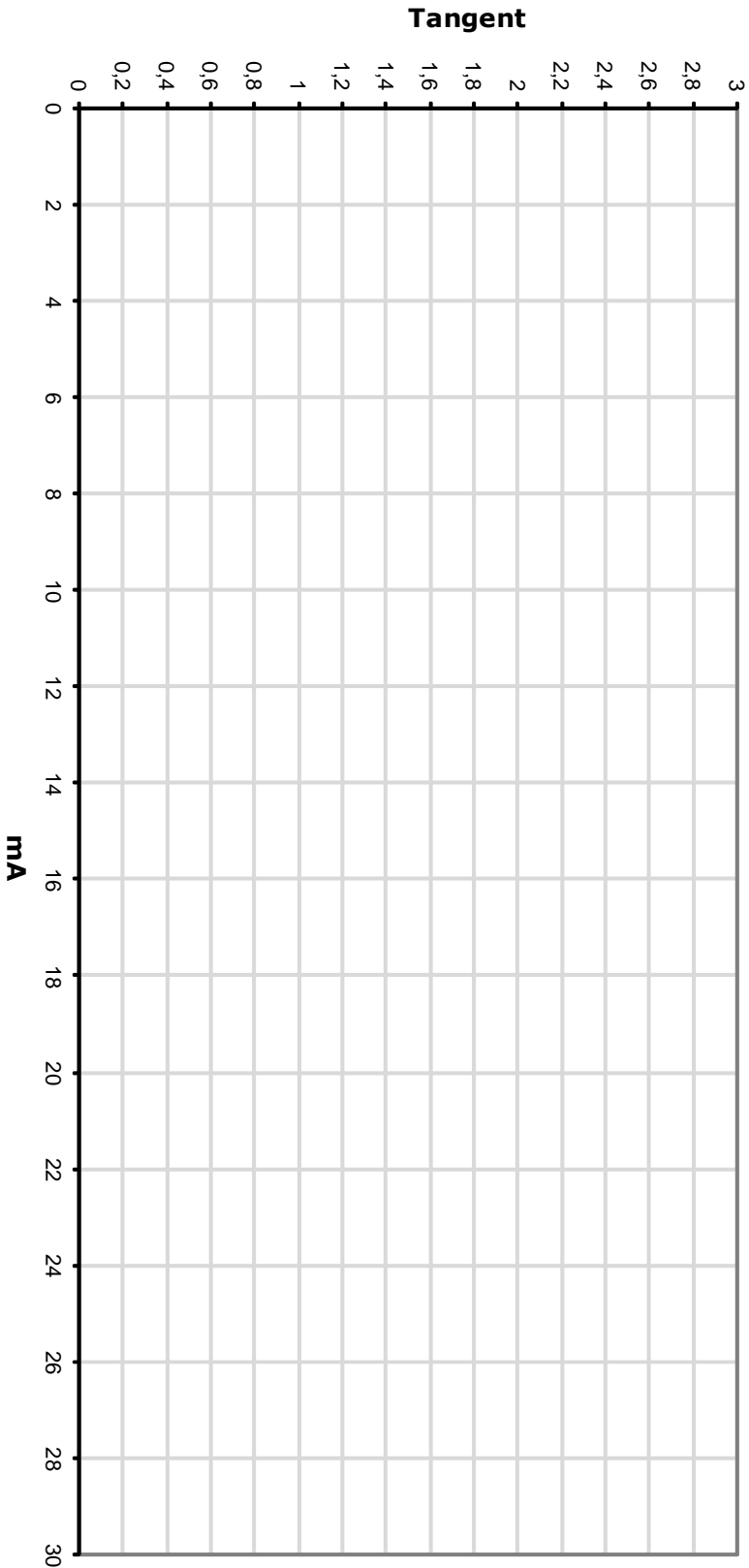
The tangent of the deflection angle grows proportional to the amperage.

RELATION BETWEEN AMPERAGE AND THE TANGENT OF THE DEFLECTION ANGLE

EMS 1.3

Deflection angle [°]	10	20	30	40	50	60	70
Amperage [mA]							
Tangent of the deflection angle							

Tangent of the deflection angle as a function of the associated amperage



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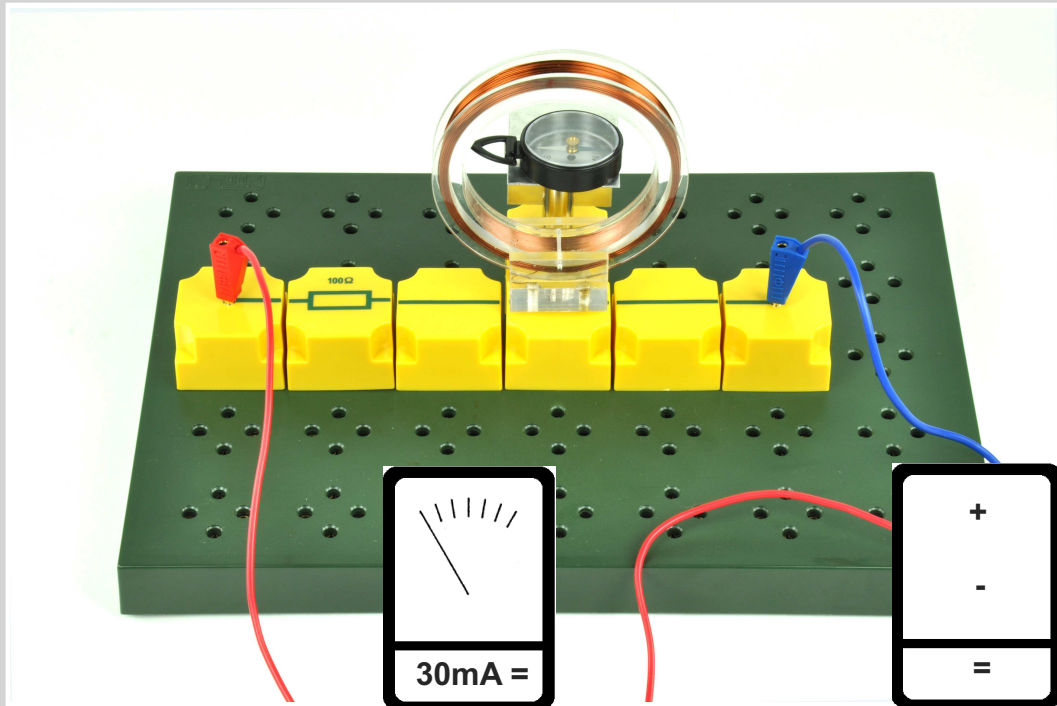
DETERMINING THE MAGNETIC FIELD FORCE OF A COIL AND DEFINING THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELDS VECTORS

EMS 2.1

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

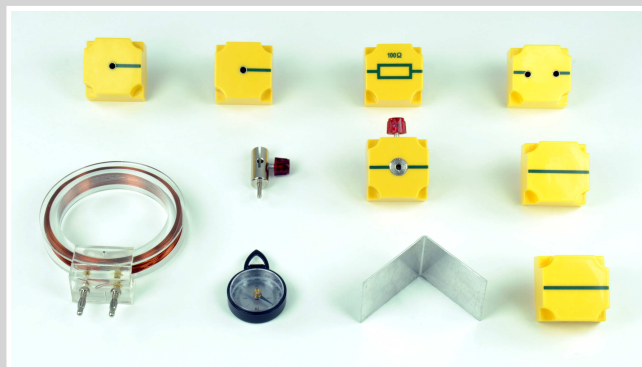


Material:

- 1x Plug-in panel, small
- 1x Connection lead, 50 cm, red
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 2x PIB connector
- 2x PIB wire, straight
- 1x PIB wire interrupted, with sockets
- 1x PIB with adapter bush
- 1x PIB resistor 100 Ω
- 1x Holder with slit and hole
- 1x Holder for pocket compass
- 1x Induction coil
- 1x Pocket compass

Additionally required:

- 1x Power source
- 1x Meter



DETERMINING THE MAGNETIC FIELD FORCE OF A COIL AND DEFINING THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

EMS 2.1

Theory:

The coil's field strength grows with the amperage **I** and the windings **n** and decreases with the diameter **d** of the coil. For coils with a small length applies therefore the formula: $H = n \cdot I / d$

Which unit belongs to the magnetic field strength according to the formula?

For the magnetic flux density (Induction) **B**: $B = \mu_0 \cdot H$
(Mostly used instead of the magnetic field strength)

$\mu_0 = 4\pi \cdot 10^{-7} \text{ N/A}^2$ or with reshaped unit: $4\pi \cdot 10^{-7} \text{ Vs/Am}$.

Experiment:



Arrangement according to the illustration.

The plug-in blocks are placed on the plug-in plane according to the illustration. The holder for pocket compass is mounted on the "PIB with adapter bush". The block is fixed on the plane in such way that the compass is at the same level as the coil.

- The compass is positioned as exact as possible horizontally in the inside of the coil. The arrangement is turned in such way that the compass needle is aligned parallel to the coil. Now the compass is turned until the needle points exactly to north (0°)
- The electrical circuit is connected to the power supply and the voltage is increased until the deflection angle of 30° is reached. By using a 100 Ω- resistor the amperage can be controlled easier.
- This adjustment has to be repeated a few times to verify the result. The amperages are noticed on the enclosed sheet.
- After the power source is returned to zero, the amperage which is needed to deflect the compass needle by 45° is to be investigated.
- The experiment is repeated for a deflection angle of 60°.

The determined results are noticed in the table on the enclosed sheet.

Tasks:

- The magnetic field strength at the inside of a coil of very small length with $n = 144$ turns and a diameter $d = 0,085 \text{ m}$ for the measured amperages (in Ampere) is to be determined.
- For deflections of 30° - 45° and 60° the size of the horizontal component is to be calculated.
- From the horizontal component and the assumed inclination angle of 60° the flux density **B** of the earth's magnetic field is to be calculated. (The flux density at the northern latitude of 50° is about $4,8 \cdot 10^{-5} \text{ T}$)

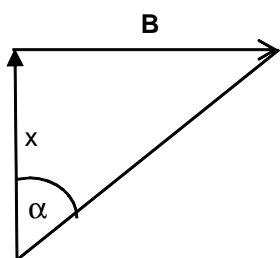
DETERMINING THE MAGNETIC FIELD FORCE OF A COIL AND DEFINING THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

EMS 2.1

Disclosures: turns (n)= 144
field constant (μ_0)= 1,25664E-06
diameter (d)= 0,085 m

deflection angle [α]	30	45	60	[°]
.....	[A]
measured	[A]
amperages	[A]
.....	[A]
average value=	[A]
coil's field strength (H)=	[A/m]
flux density (B)=	[T]

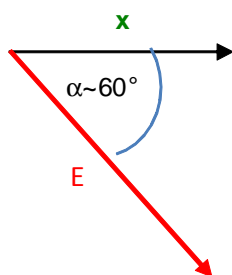
calculation of the horizontal component (x)



$$x = \frac{B}{\tan(\alpha)}$$

x= [T]

calculation of the earth's magnetic field (E)



$$E = \frac{x}{\cos(\alpha)}$$

E= [T]

Value for 50° northern latitude: **4,80E-05 [T]**

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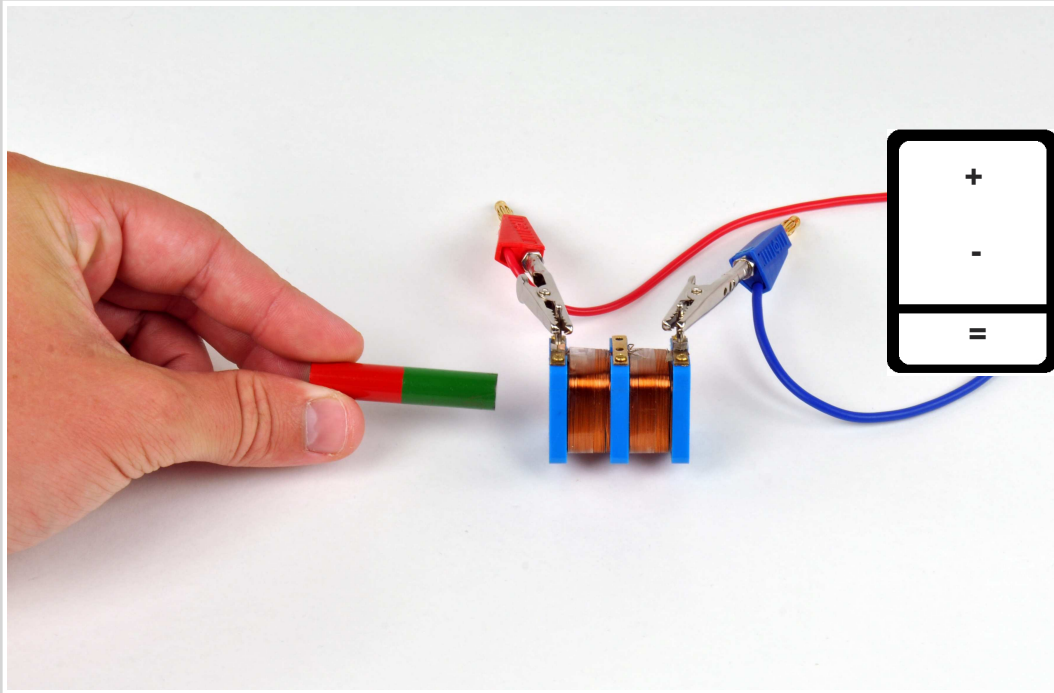
THE BASIS FOR ELECTRIC MOTOR AND GENERATOR AS AN INTERACTION

EMS 3.1

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

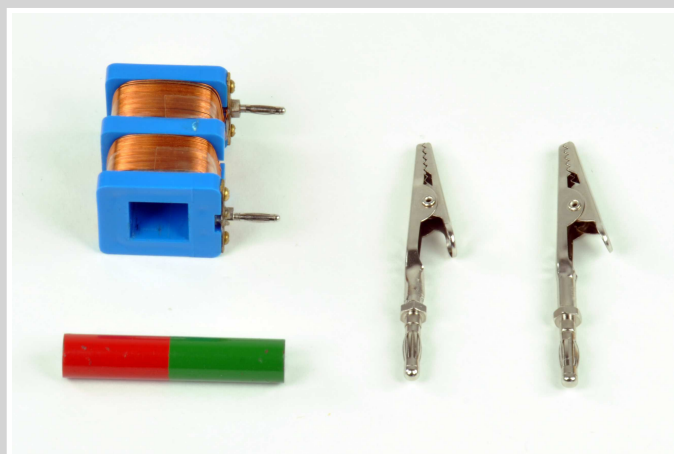


Material:

- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 1x Bar magnet
- 1x Moving coil with hole, blue
- 2x Crocodile clip with plug

Zusätzlich erforderlich:

- 1x Power source
- 1x Meter



THE BASICS FOR ELECTRIC MOTOR AND GENERATOR AS AN INTERACTION

EMS 3.1

Interactions:

No force without counterforce, no action without the same interaction. This rule, which is very frequent in the mechanics, applies always, also for all other forces and its counterforce.

Like a magnet attracts a piece of iron he is also attracted by the iron piece. Like a current-carrying coil attracts magnets also the magnets apply force to the current-carrying coil = Basic principle for the electric motor.

Even if the coil can't move there is an interaction. A changing magnetic field, by means of e.g. a bar magnet, is reacting to the coil current = Induction, basic principle for the generator.

Experiment:



1. The coil is connected to the power source by means of crocodile clips with plug and voltage is built up. The coil is put horizontal on the table. Now the bar magnet is put in front or inside the coil opening. Turn the power on and off. Now you can see that if the coil is better anchored, the magnet will be attracted or repelled by the coil. If the magnet is better anchored, the coil will be attracted or repelled.
2. The coil is connected to a meter and a small range for direct current is set. A bar magnet is moved fast into and out of the coil. You can also try to shake the coil with the bar magnet inside. If you look at the meter you can see that voltage is induced into the coil.



Conclusion:

Magnetic fields exert forces on currents (Basis for electric motors)

Changing magnetic fields can cause currents (Basis for generators)

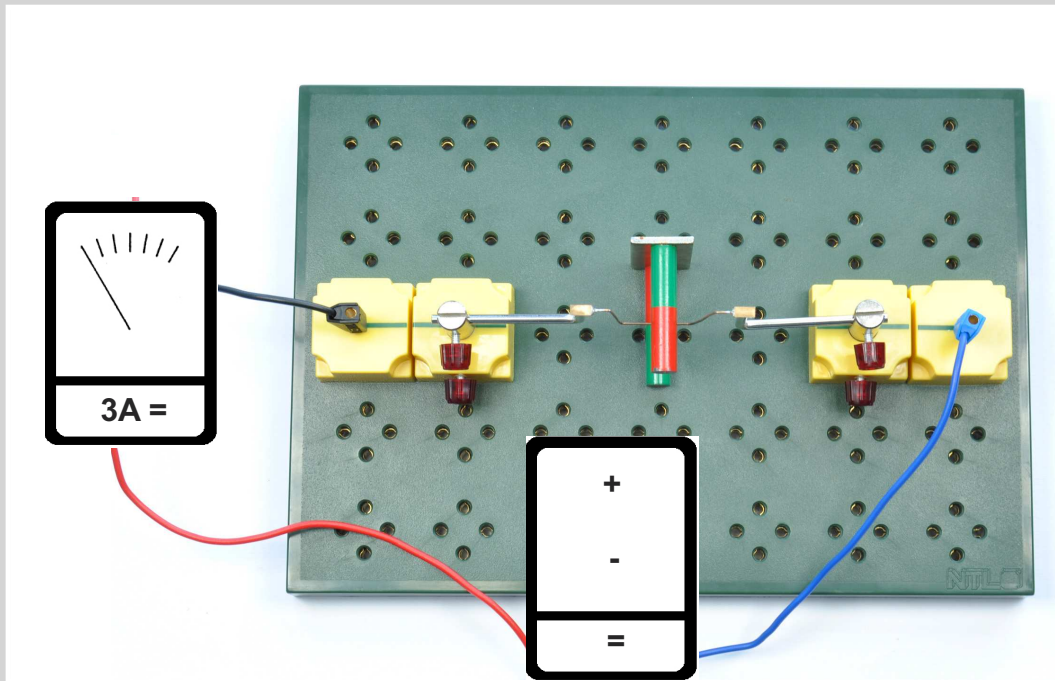
CURRENT FLOW AND DEFLECTION OF A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

EMS 3.2

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

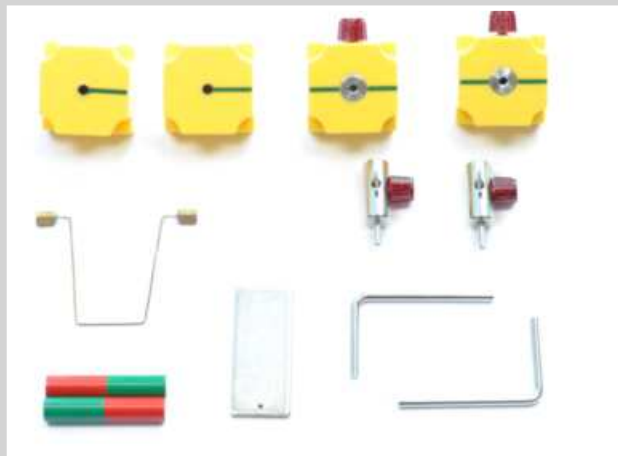


Material:

- 1x Plug-in panel, small
- 1x Connecting lead, 25 cm, black
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 2x PIB connector
- 2x PIB with adapter bush
- 2x Holder with slit and hole
- 1x Pole plate
- 2x Bar magnet
- 1x Electromagnetic swing
- 2x Electrode, right-angled

Additionally required:

- 1x Power source
- 1x Meter



CURRENT FLOW AND DEFLECTION OF A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

EMS 3.2

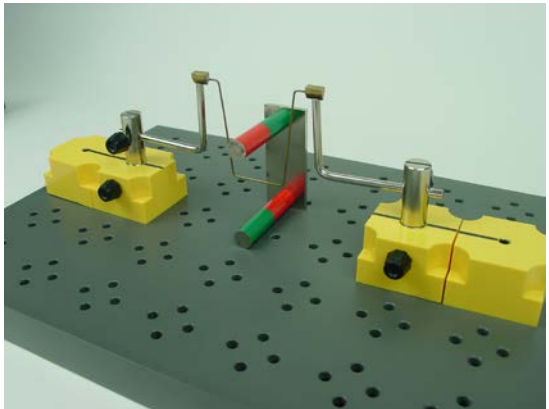
Experimental target:

The evidence of the force effect between a magnetic field and a current-carrying conductor. (In this case a half turn).

Learning the right-hand rule.

Experiments:



1. Arrangement according to the illustration. The two rectangular bent electrodes have incisions on one side. On this side the electromagnetic swing is to be set on.
 2. A u-magnet is made out of the two bar magnets and a pole plate. In this way a
 3. A strong magnetic field is produced between the two thighs of the u-magnet. The magnets are placed in such way that the North Pole is located above and the South Pole beneath.
- 
4. After the power source is set at zero it is connected to the electricity circle. An ampere meter is connected and the 3 A range is set. The voltage is increased slowly until a nameable deflection is seen. The amperage should be about 1 A. After that experiment the power source should be turned off.
 5. The experiment is to be repeated with amperages of $\frac{1}{2}$, $\frac{1}{4}$ A of the experiment before.
 6. A not really intense current is to be set in the electricity circle. The right hand is held in such way that the thumb, the pointer and the middle finger build three orthogonal standing axes. The thumb is to point in the current direction. The pointer is to point in the direction of the magnetic field lines. The middle fingers points in the direction of the force which acts at the conductor. Now the u- magnet is turned in such way that the South Pole is located above and the North Pole beneath. At this situation the deflecting force is to be investigated by means of the three- finger- rule. Also with reversed current direction the force direction can be determined.
 7. Again a sufficiently intense current is set to gain a nameable deflection of the conductor. The u-magnet is now turned in such way that the magnetic field lines run parallel to the horizontal electromagnetic swing. Notice the effect.

CURRENT FLOW AND DEFLECTION OF A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

EMS 3.2

Questions:



It is to be considered if the following statements are true:

1. There is force effect on a conductor in a magnetic field.
2. When a current- carrying conductor is in a magnetic field, there is a force effect on the electrical current.
3. The force on a current- carrying conductor in a magnetic field is at greatest when the conductor stands vertically to the magnetic field.

Which relation can be seen between the amperage and the force which deflects the conductor?

Answers:

1. This statement is not correct, because a magnetic field only effects on ferromagnetic materials and moved electrical loads.
2. This statement is not true because the force effect of a magnetic field to a current-carrying conductor is depending on the angle of the current direction and the magnetic field. If the angle is 0° there is no force.
3. This statement is true. The force depends on the sinus of the angle between the conductor and the magnetic field. The greatest force occurs at an angle of 90° .



Conclusion:

The force at the conductor is proportional to the amperage in the conductor.

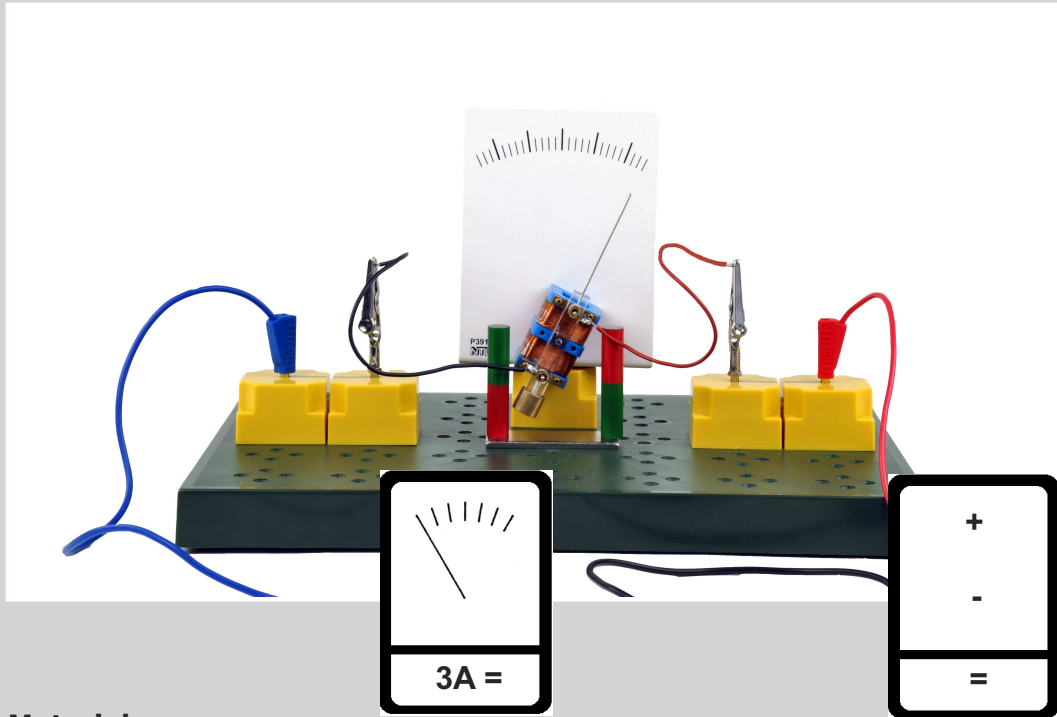
COIL IN A MAGNETIC FIELD (ROTATING-COIL DEVICE)

EMS 3.3

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

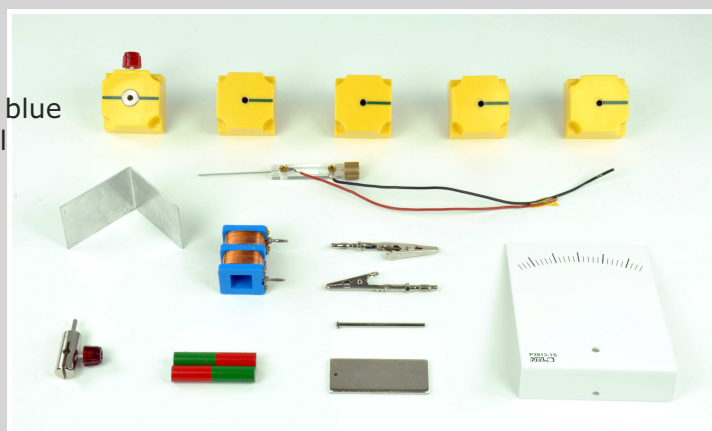


Material:

- 1x Plug-in panel, small
- 1x Connection lead, 25 cm, black
- 1x Connecting lead, 75 cm, red
- 1x Connecting lead, 75 cm, blue
- 4x PIB connector
- 1x PIB with adapter bush
- 1x Holder with slit and hole
- 2x Crocodile clip with plug
- 1x Pole plate
- 2x Bar magnet
- 1x Axis for moving coil
- 1x Moving coil with hole, blue
- 1x Pointer for moving coil
- 1x Scale for moving coil

Additionally required:

- 1x Power source
- 1x Meter



COIL IN A MAGNETIC FIELD (ROTATING-COIL DEVICE)

EMS 3.3

Experimental target:

The interaction between a current-carrying coil and a magnetic field is to be investigated.

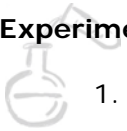
Theory:

The effect of a magnetic field on a current-carrying conductor multiplies if this conductor runs in turns. As the field has an effect on each single turn the forces are summing up according to the turns.

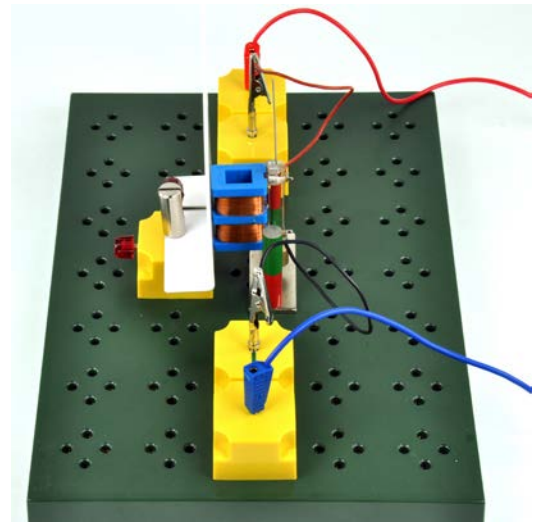
The both opposite sides of the rectangular conductor are flown through by opposite currents. Is this conductor located in a magnetic field, there are opposite forces at the opposite located conductor parts which run parallel to the magnetic field. This force couple causes a rotation of the conductor.

This effect is used in: meters with rotatable coils, speakers and electric motors.

Experiments:



1. Arrangement according to the illustration. The axis for moving coil is put through the moving coil with hole at the side with the two contacts. The pointer for moving coil is mounted. After that the axis for moving coil is put through the scale for moving coil and fixed by means of the holder with slit and hole. This holder is fixed on the plug-in plane by means of the "PIB with adapter bush". The connection wires are fixed with crocodile clips with plug. The bar magnets are formed to an u-magnet by means of a pole plate. The u-magnet is placed in such way that the coil is between the two thighs. The power supply is to be connected to the electricity circle and the voltage is to be slowly increased.



2. This experiment is to be repeated with reversed poles of the coil current.
3. Instead of the power supply a sensitive meter is connected. Note the meter when you move the coil in the magnetic field.

Questions:

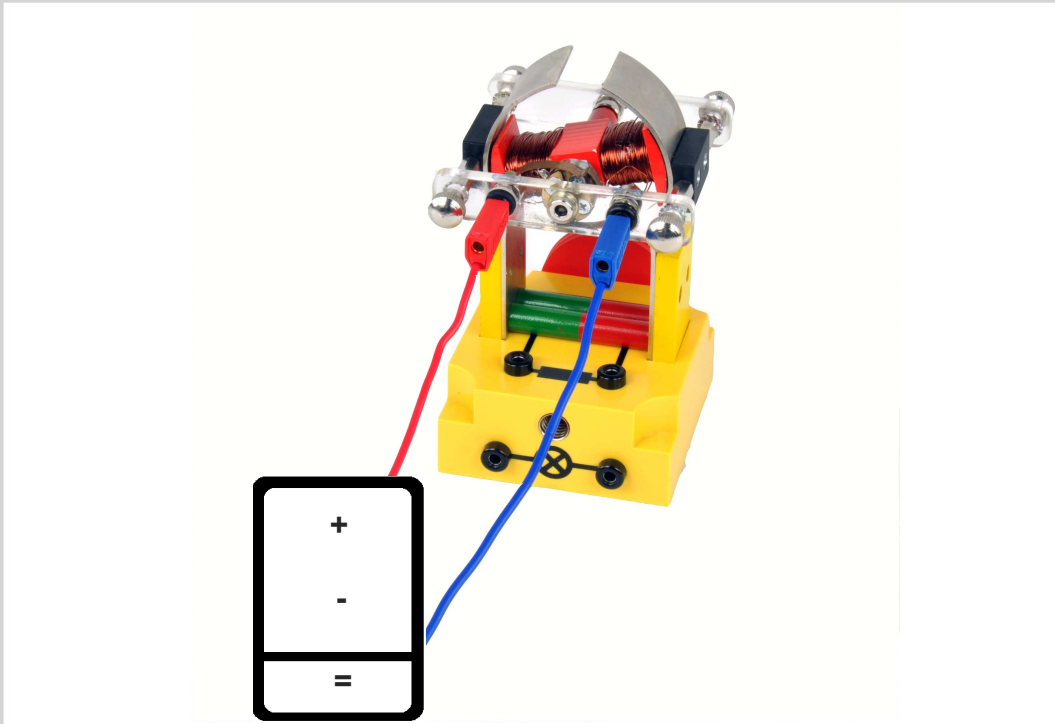


1. Why does the deflection angle of the coil increases when the current which is flowing through the coil is increased?
2. Changes the direction of rotation by reversing the poles of the magnetic field?
3. Changes the direction of rotation by reversing the poles of the power source?
4. Could this instrument also be used in an AC electricity circle?
5. How can the induction effect be increased?

Required Kit:

P9901-4D Electricity 1

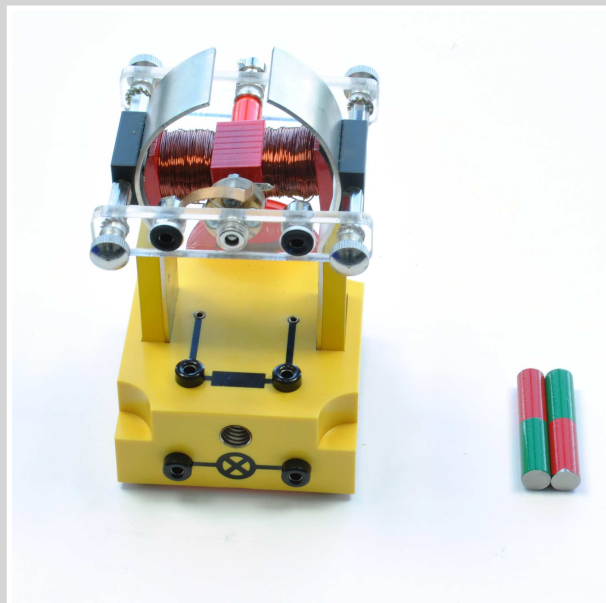
P9902-5T Electrodynamics

**Material:**

- 1x Connection lead, 50 cm, red
- 1x Connecting lead, 50 cm, blue
- 1x Motor/generator model
- 2x Bar magnet

Additionally required:

- 1x Power source
- 1x Meter



Experimental target:

Understanding of the functioning of a DC motor.

Setup:

Two bar magnets are jammed between the two pole plates. A red connection lead is stuck into the bush "A1". A blue connection lead is stuck into the bush "A2".

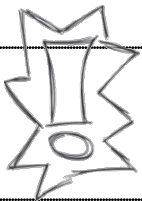
The commutator can be turned a little by means of loosen the small screw. The motor is running well when the interruption points of the commutator stand vertical to the anchor.

The two straps to the crank should be removed, to facilitate the rotation of the motor.

Experiment:

Direct current (lower than 10 V) is applied on the blue and red connecting lead (the polarity results in the direction of rotation) and the rotation of the rotor is investigated. If required fire up the anchor. The two straps can be attached again to load the motor a bit more.

The voltage is measured in loaded and unloaded situation by means of a voltmeter.



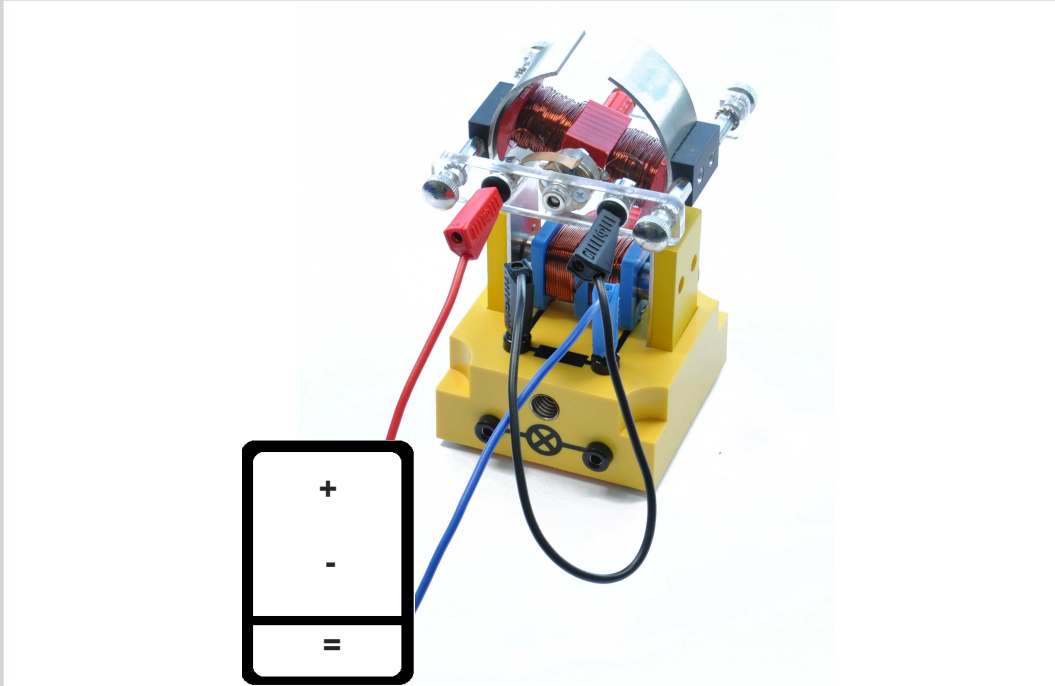
Note:

The motor can be used as a generator right after this experiment. (EMS 4.4)
Electricity causes movement → movement causes electricity.

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

**Material:**

1x Connection lead, 25 cm, black

1x Connection lead, 50 cm, red

1x Connecting lead, 50 cm, blue

1x Motor/generator model

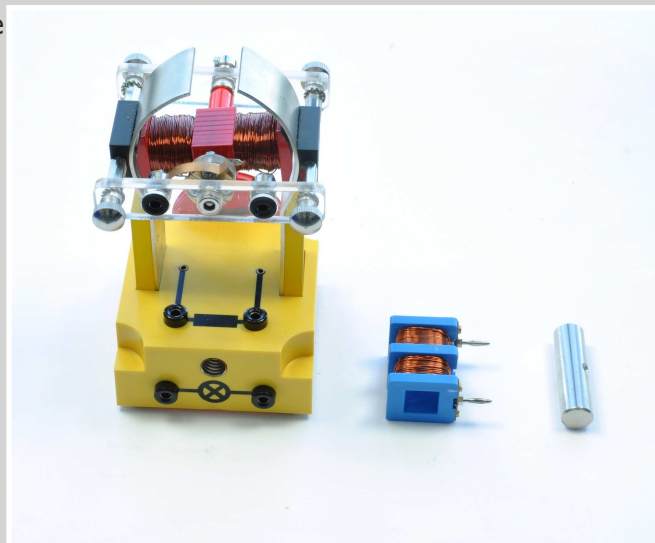
1x Moving coil with hole, blue

1x Iron core solid

Additionally required:

1x Power source

1x Meter



Experimental target:

Understanding of the function of a series motor.

Setup:

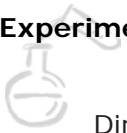
The iron core solid is put in the moving coil with hole. This moving coil with hole is inserted in the bushes "B". (The rotor has to stand horizontal to insert the moving coil). The bushes "A2/S2" (or "A2/S1" for other direction of rotation) are connected by means of a black connecting lead.

A red connecting lead is plugged in the bush "A1"

A blue connecting lead is plugged in the bush "S1" (or "S2" for other direction of rotation)

The commutator can be rotated a little by means of loosen the tiny screw in the ring. The motor is running well when the interruption points of the commutator stand vertical to the anchor. The two straps to the crank should be removed, to facilitate the rotation of the motor.

Experiment:



Direct current is applied on the red and blue connecting lead and the rotation of the rotator is investigated. If required fire up the anchor.

The drive belt can be attached at the crank again to load up the motor a little more.



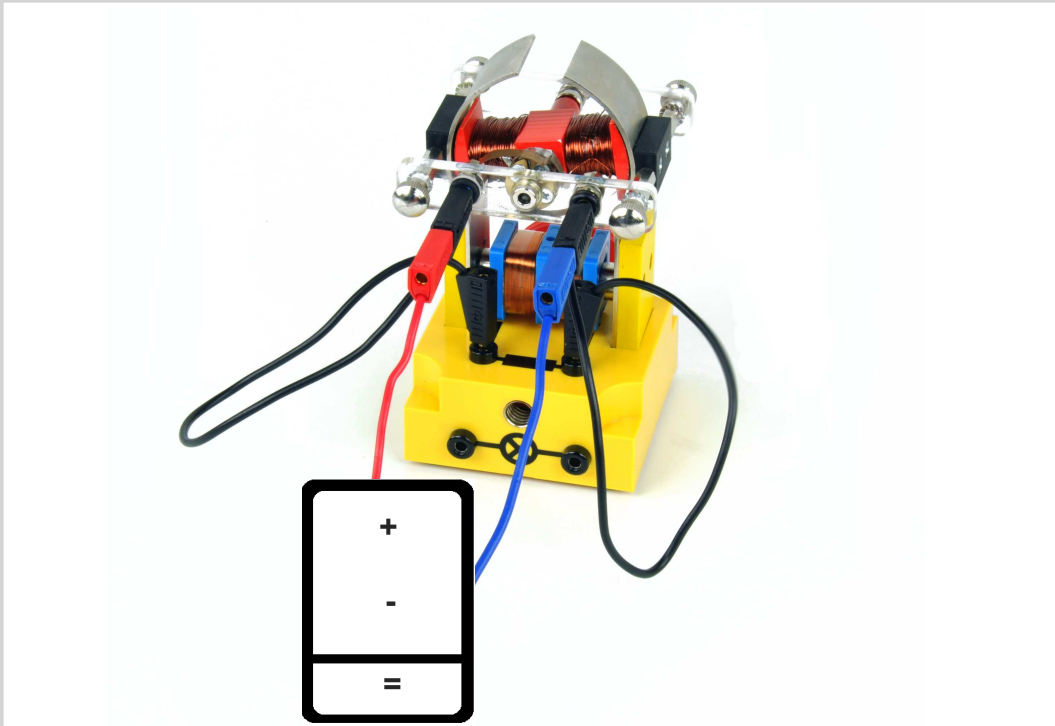
Note:

The series motor (rotor- and field winding are connected in series) can be used in contrast to the simple direct current motor also with alternative current. The direction of the current changes in the rotor- and field winding at the same time. To start up the motor with alternating current a higher voltage is required because the AC resistance of the coil is larger than the DC resistance.

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics

**Material:**

2x Connection lead, 25 cm, black

1x Connection lead, 50 cm, red

1x Connecting lead, 50 cm, blue

1x Motor/generator model

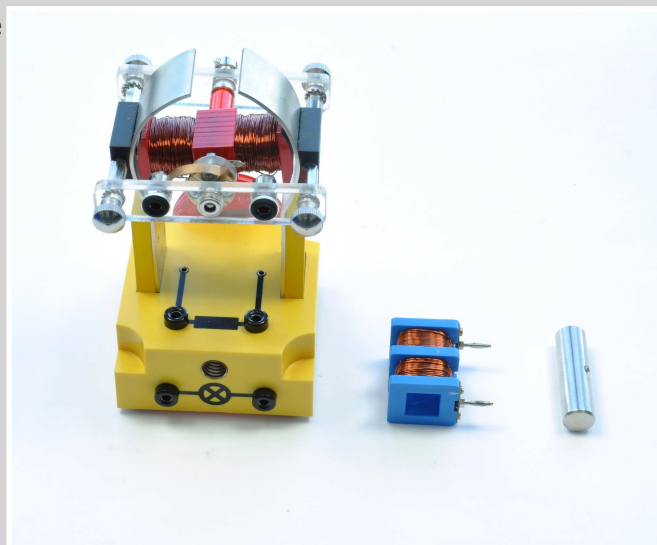
1x Moving coil with hole, blue

1x Iron core solid

Additionally required:

1x Power source

1x Meter



Experimental target:

The tuning of external and internal anchor field.

Setup:

The iron core solid is put in the moving coil with hole. This moving coil with hole is inserted in the bushes "B". (The rotor has to stand horizontal to insert the moving coil). The bushes "A2/S2" and "A1/S1" are connected by means of two black connecting leads according to the illustration. Now the series circuit of the field winding and the resistance wire is completed. The current of the anchor winding (internal field) flows parallel to the field coil with the upstream resistance wire (external field).

A red connecting lead is plugged in the bush "A1"

A blue connecting lead is plugged in the bush "A2"

Experiment:



Direct current is applied on the blue and red connecting lead. If required fire up the anchor. Now the voltage can be increased until at least 10 Volts. If the tuning of the fields is correct the motor will run fast and steady.



Note:

The resistor in series to the field winding is necessary to match up the strength of the external and internal magnetic field. If one magnetic field predominates clearly the anchor will orientate only according to this magnetic field and there will be no rotation of the rotor.

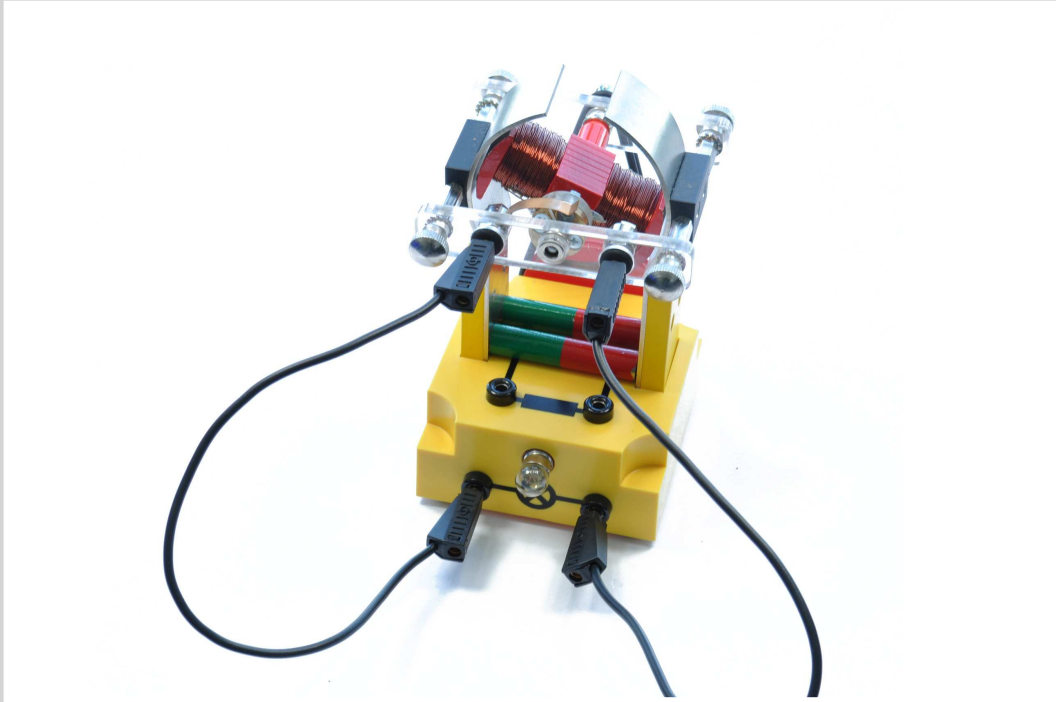
DC GENERATOR - EXTERNAL POLE GENERATOR

EMS 4.4

Required Kit:

P9901-4D Electricity 1

P9902-5T Electrodynamics



Material:

2x Connection lead, 25 cm, black

1x Connection lead, 75 cm, red

1x Connecting lead, 75 cm, blue

1x Motor/generator model

2x Bar magnet

1x Moving coil with hole, blue

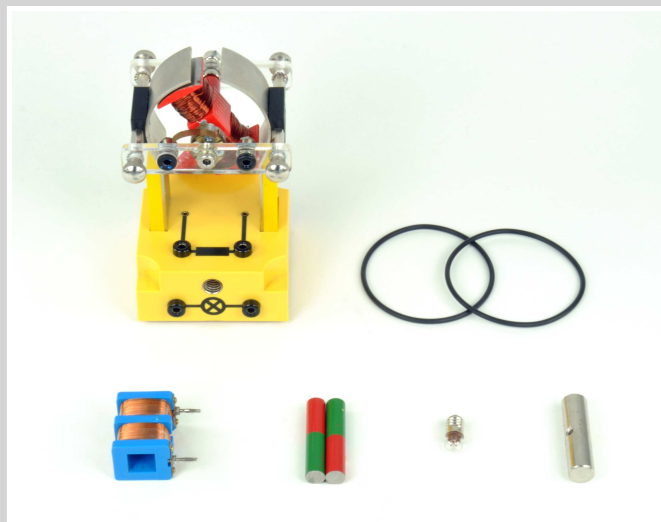
1x Iron core solid

1x Light bulb, 2,5 V/70 mA

Additionally required:

1x Power source

1x Meter



DC GENERATOR – EXTERNAL POLE GENERATOR

EMS 4.4

Experimental target:

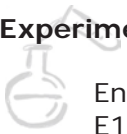
Become acquainted with a generator of which the external magnetic field is constant. (External magnet poles)

Setup:

The setup is exactly the same as by the simple DC motor. The bar magnets are fixed again between the pole plates of the motor/generator model.

The bushes of the anchor winding ("A1", "A2") are connected to the bushes of the lamp socket ("L1", "L2") A sensitive lamp is screwed in the socket. The drive belt is pulled over the drive pulley and the anchor axis.

Experiment:



Enable the drive belt to rotate and notice the lightning of the glow lamp (2,5 V; 70mA E10)

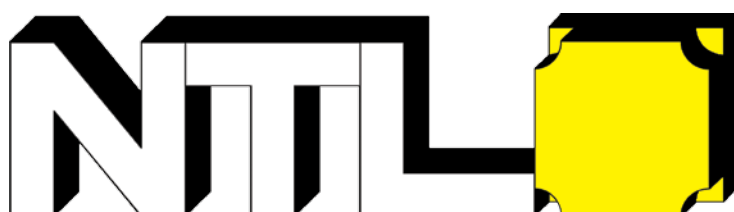
1. The voltage with and without the glowing lamp is to be measured.
(with lamp about 2,2 V; without lamp about 2,5 V)
2. The amperage through the lamp with slow rotation is to be measured.
(about 50 mA)

Next the two bar magnets are replaced by the moving coil with hole. The iron core solid is inserted in the coil and the coil is plugged in the bushes "B" of the motor/generator model. A voltage of about 10 V is applied on the coil. Now the voltage is measured again with and without the glowing lamp. (with lamp about 1,5 V; without lamp about 2,5 V)



Conclusion:

Because of the changing of the tapped end of the anchor winding at every half turn a pulsating direct current is produced.



Student Experiments

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