PHYWE

Student and Demonstration Experiments

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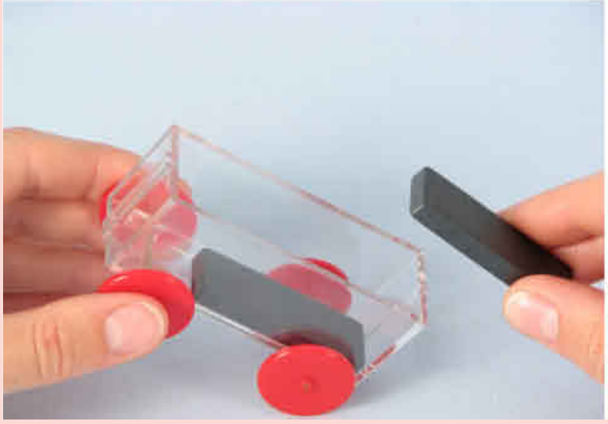
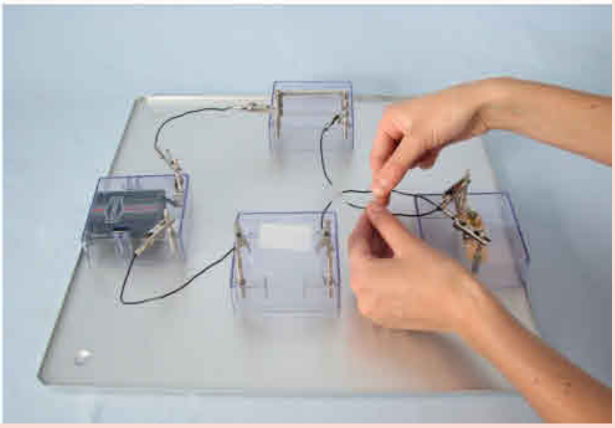
TESS beginner PHYWE

Current and Magnets





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TESS beginner Student and Demonstration experiments

Current and Magnets

Order No. 13246-02

PHYWE series of publications
TESS beginner Student and Demonstration experiments: Current and Magnets
Order No. 13246-02

Authors of experimental literature: Sabine Iwanek, Wiebke Kutzborski

1st edition

Contents

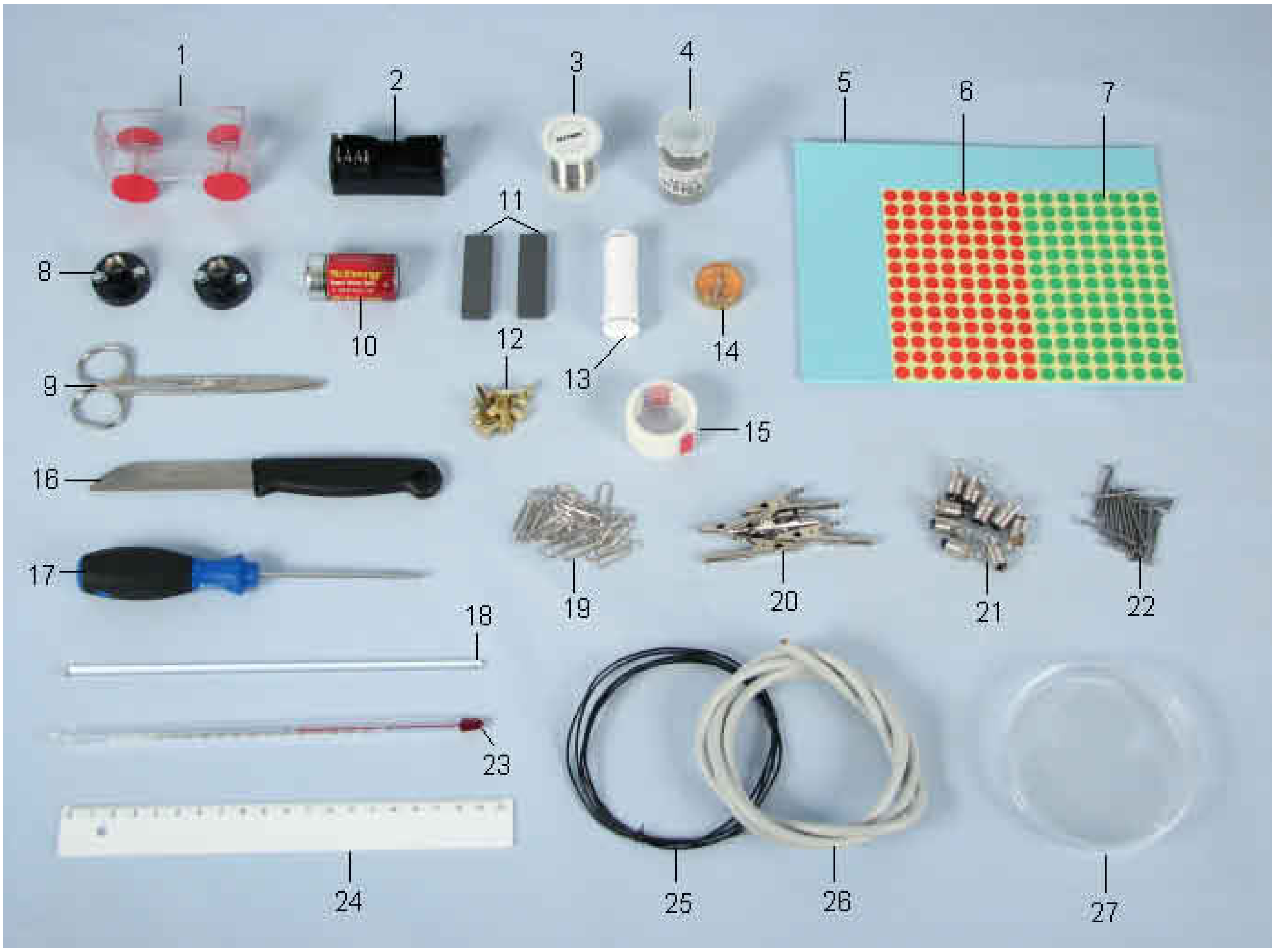
Student experiments:

Demonstration experiments:

Equipment and Storage

Student Set, Current and Magnets 13245-88

	Description	No.	Quantity
(1)	Car, plastic	11059-00	1
(2)	Battery holder (baby cell)	330792	1
(3)	Constantan wire	06100-00	1
(4)	Sprinkler w. iron powder	06305-10	1
(5)	Foam rubber, 20 x 15 cm	13231-11	1
(6)	Circular labels, red	06305-04	1
(7)	Circular labels, green	06305-05	1
(8)	Lamp holder E10, 2 pieces	06170-02	1
(9)	Scissors, straight, l=125mm	46970-00	1
(10)	Battery cell, 1.5 V, R14	07922-01	1
(11)	Bar magnet, l=50 mm	07819-00	1
(12)	Envelope clamps	13231-41	1
(13)	Silk thread	02412-00	1
(14)	Drawing compass	06350-03	1
(15)	Adhesive tape	170455	1
(16)	Knife, stainless	33476-00	1
(17)	Screwdriver, width 3mm	01612-00	1
(18)	Glass rod, l=200mm	40485-03	1
(19)	Paperclips	13231-30	1
(20)	Alligator clip w. term. screw	07274-10	1
(21)	Filament lamps 1.5V,10pcs	06150-03	1
(22)	Nails,	05505-10	1
(23)	Students thermometer	38005-02	1
(24)	Ruler, plastic, 200 mm	09937-01	1
(25)	Jumper wire, isolated	330790	1
(26)	Two-core electric wire	330791	1
(27)	Petri dish	64709-05	1



Demo-Set, Current and Magnets 13246-88

	Description	No.	Quantity
(1)	Flat battery, 4.5 V	07496-01	2
(2)	Iron wool 200 g	31999-20	1
(3)	Protective desk plate	39180-10	1
(4)	Crucible tongs, l=250mm	46964-00	1
(5)	Battery case, transparent	06030-22	2
(6)	Lamp holder, E10	06170-01	2
(7)	Knife switch, transparent	06034-06	1
(8)	Filament lamps 3.5V	06152-03	1
(9)	Connecting cord	07360-05	6
(10)	Connecting plug, 2 pcs.	07278-05	2
(11)	Lab thermometer	38056-00	1
(12)	Iron wire, d = 0.2 mm	06104-00	1
(13)	Constantan wire, d=0.2 mm	06100-00	1
(14)	Jumper wire, isolated	330790	1
(15)	Parchment disks	02672-00	1
(16)	Screwdriver, width 3mm	01612-00	1
(17)	Knife, stainless	33476-00	1
(18)	Scissors, l=140mm	64623-01	1
(19)	Bar magnet, l=150mm	06310-00	1
(20)	Copper electrode	45212-00	1
(21)	Zinc electrode	45214-00	1
(22)	Iron electrode	45216-00	1
(23)	Aluminium electrode	45217-00	1
(24)	Nickel electrode	45218-00	1
(25)	Pocket compass	06350-00	1
(26)	Sprinkler w. iron powder	06305-10	1
(27)	Iron wire, notched, 5 bars	326875	1

Storage tray

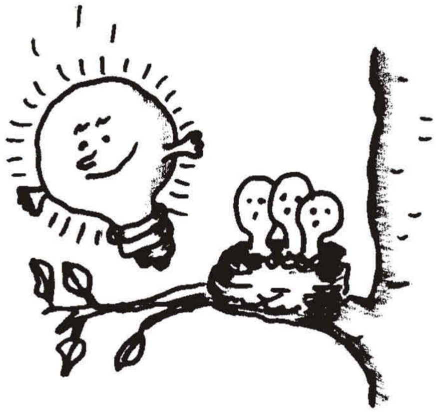
When can a filament lamp glow?

Task

Try to bring a filament lamp to glow.

Material

1 Filament lamp
1 Battery
1 Insulated wire
1 Pair of scissors
1 Knife
1 Ruler
Adhesive tape



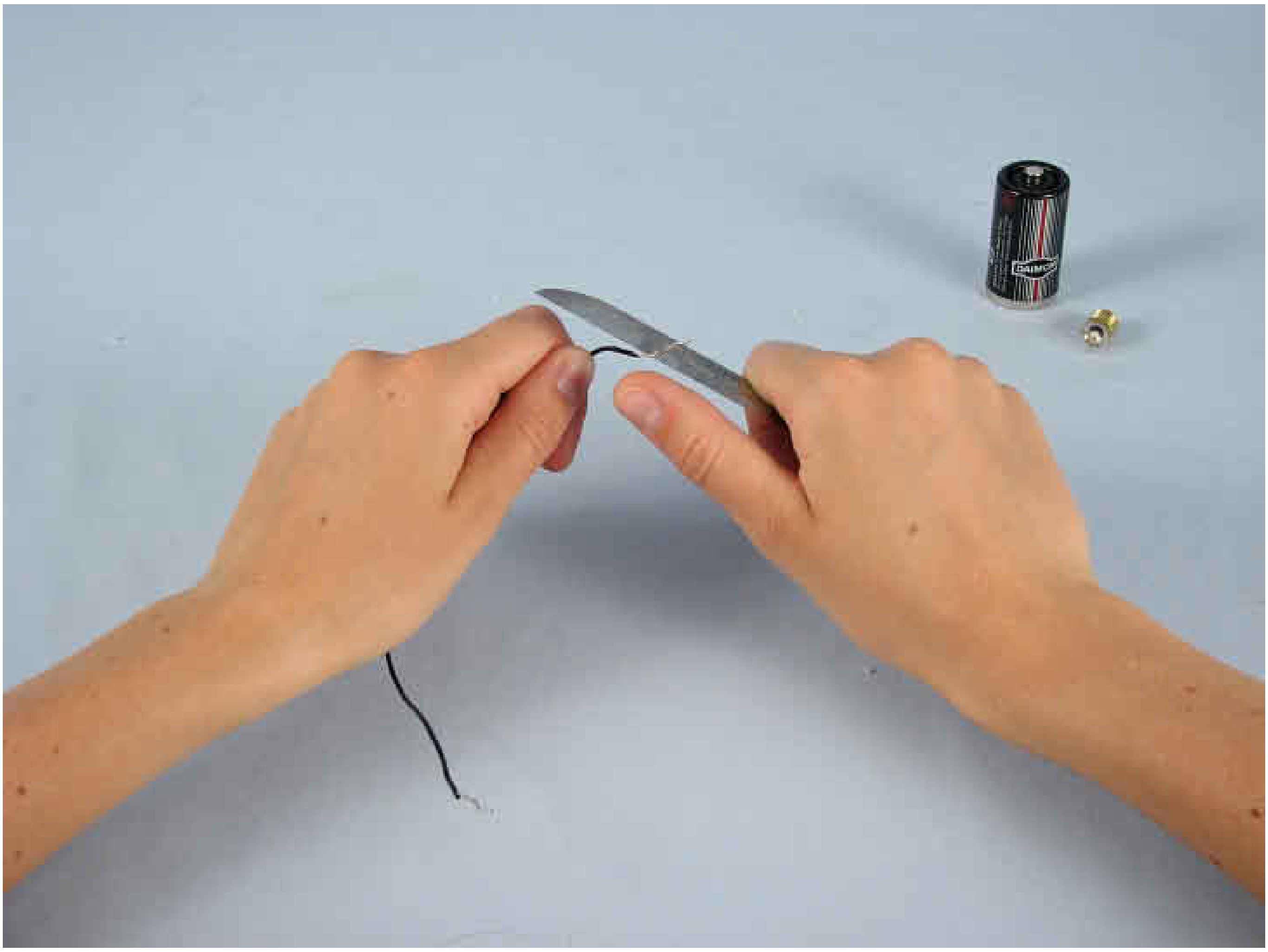


Fig. 1

Set-up and procedure

- Cut off two approximately 20 cm lengths from the insulated wire.
- Use the knife to carefully remove about 1 cm of the insulation material from each end of each length of wire.
- Use the lengths of wire and the battery to try to bring the filament lamp to light up.

Observations

1. How must the battery be connected to the filament lamp for it to glow?

   ....

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   ....

2. When doesn't the filament lamp glow?

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3. Make a sketch of how you connected the wire, battery and filament lamp.

Evaluation

1. What was the cause of the not lighting up and the lighting up of the filament lamp?

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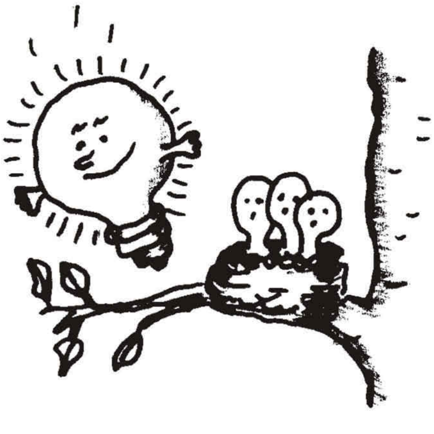
Room for notes



(When can a filament lamp glow?)

Observation

1. One wire must be held at each battery terminal. One of these wires must touch the threaded base of the lamp and the other the tip contact at the bottom of the lamp.
2. The lamp doesn't glow when the two contact positions of it are not connected one to each of the battery terminals. A single connection to the battery is not sufficient to cause the filament lamp to glow.

Evaluation

1. The lamp can only light up when the battery supplies it with current. When this is the case, current flows through the filament and causes it to glow. Current can only flow, however, when it can flow in an uninterrupted circulation, a so-called circuit. This is why the lamp needs not only a connection to the battery, but also a connection back to it. Current then flows from the battery and into a contact position on the lamp, for example the small tip contact in the middle of the lamp base. From here it flows through a connecting wire to the filament and back to the battery through the threaded metal base.

Room for notes

How does a technically flawless circuit look?

Task

Use the materials provided to make up a functional and stable circuit.

Material

1 Filament lamp
1 Lamp holder
1 Battery holder
1 Battery
1 Insulated wire
1 Ruler
1 Knife
1 Pair of scissors
1 Screwdriver
4 Alligator clips with clamping screw

Fig. 1

Set-up and procedure

- Cut off two approximately 20 cm lengths from the insulated wire.
- Use the knife to carefully remove about 1 cm of the insulation material from each end of each length of wire. If you have carried out experiment S1, then you can use the lengths of wire you prepared then.
- Construct a circuit which brings the lamp to light up and consists of the filament lamp, lamp holder, battery, battery holder, wire and alligator clips.

Observations

1. Make a sketch of how you have connected the various components.

Evaluation

1. What is the advantage of this circuit over the one which you set up in experiment S1?

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2. What could be added to this circuit to make it even better?

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(How does a technically flawless circuit look?)

Evaluation

1. In this circuit the filament lamp and the battery are firmly connected to each other and have a stable contact.
2. It would be even better, for example, with a switch with which the lamp could be switched on and off.

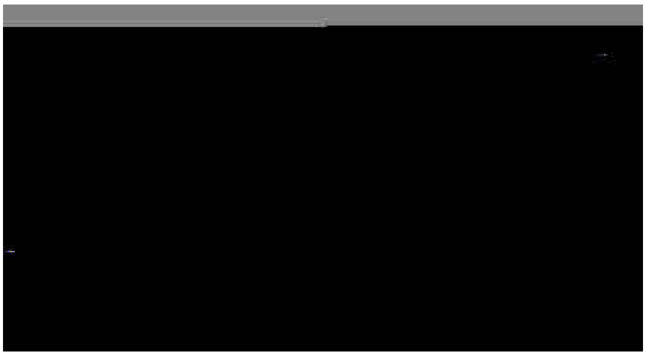
Room for notes

How does a light switch function?

Task

Install various switches in a circuit.

Material



1 Filament lamp
1 Lamp holder
1 Battery holder
1 Battery
1 Insulated wire
2 Nails
5 Alligator clips with clamping screw
1 Padded envelope clip
1 Pack of paper clips
1 Screwdriver
1 Pair of scissors
1 Knife
1 Ruler

Storage Box

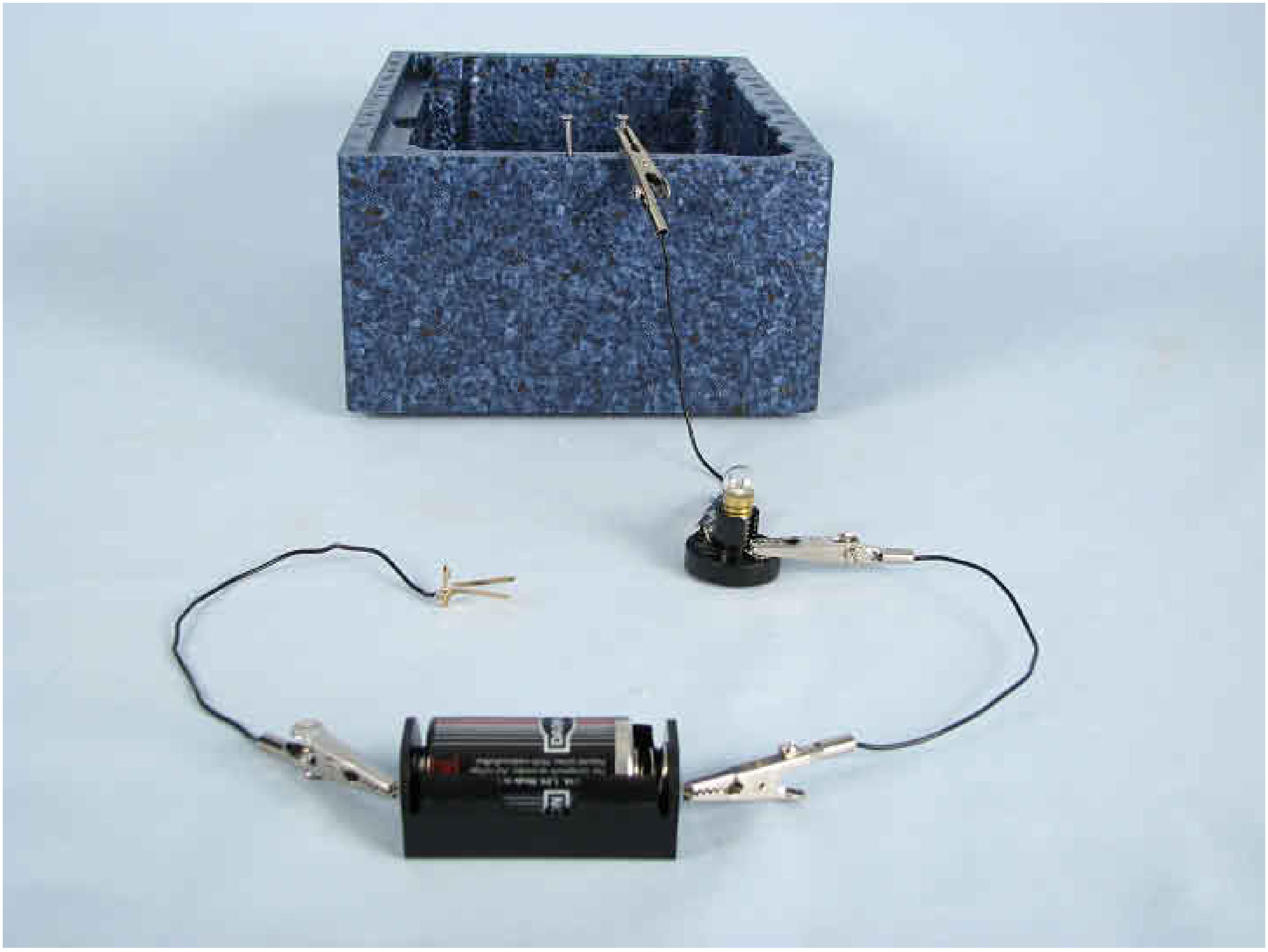


Fig. 1

Set-up and procedure

- You need your perfect circuit from experiment S2 for this experiment.
- Cut off a further 20 cm long piece from the insulated wire and use the knife to carefully remove about 1 cm of the insulation from each end of this piece.
- Fit an alligator clip to one end of the wire and wrap the other wire end around the head of a padded envelope clip.
- Take one of the wires off of the battery in your perfect circuit and replace it with your new piece of wire, clamping it firmly to the battery by means of the alligator clip.
- You now have two free wire ends: one with a padded envelope clip and one with a crocodile clip. The switch is to be inserted between these.
- Stick two nails about 1 cm apart in the storage box at the position where you want to have your switch.
- Firmly pinch the crocodile clip to one of the nails.
- Clamp the padded envelope clip so to the second nail that you can move it back and forth and can now make a connection to the second nail to switch the lamp on and off!
- Think of further possible switches, such as one which functions like a bell-button or one made up of paper clips.

Observations

1. Draw the switch which you have thought up yourself and explain how it works.

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Evaluation

1. Do you know of any other types of switches used on technical equipment or at home?

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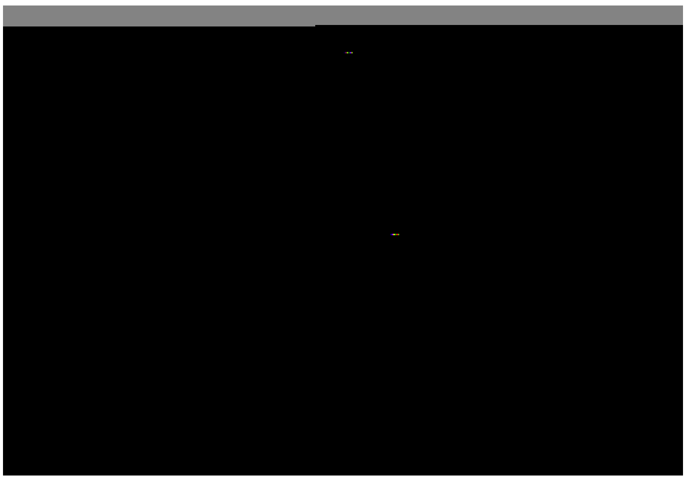
Room for notes



(How does a light switch function?)

Evaluation

1. Change-over switch: The light can be switched on or off at several points in a room.
   Sensor switch: Switches the heating of a kettle off when the water boils.
   Multi-contact switch on a cooker: Regulates on, off and temperature.
   Switch with time relay: Switches staircase lighting off after a set time.
   Timer: Controls the night heating connection, for example.
   Switch for car interior lighting: Is switched when the car door is opened and closed (possibly delayed).
   Fan switch: Controls the heating and blowing.

Room for notes

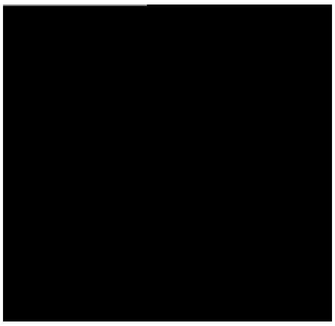
Why are electrical appliances connected to a socket with a single cable?

Task

Examine the thick gray cable and use it to connect a filament lamp to a battery.

Material

1 Filament lamp
1 Ruler
1 Lamp holder
1 Knife
1 Screwdriver
1 Pair of scissors
1 Battery holder
1 Battery
1 Gray (two-wire) cable
4 Alligator clips with clamping screw



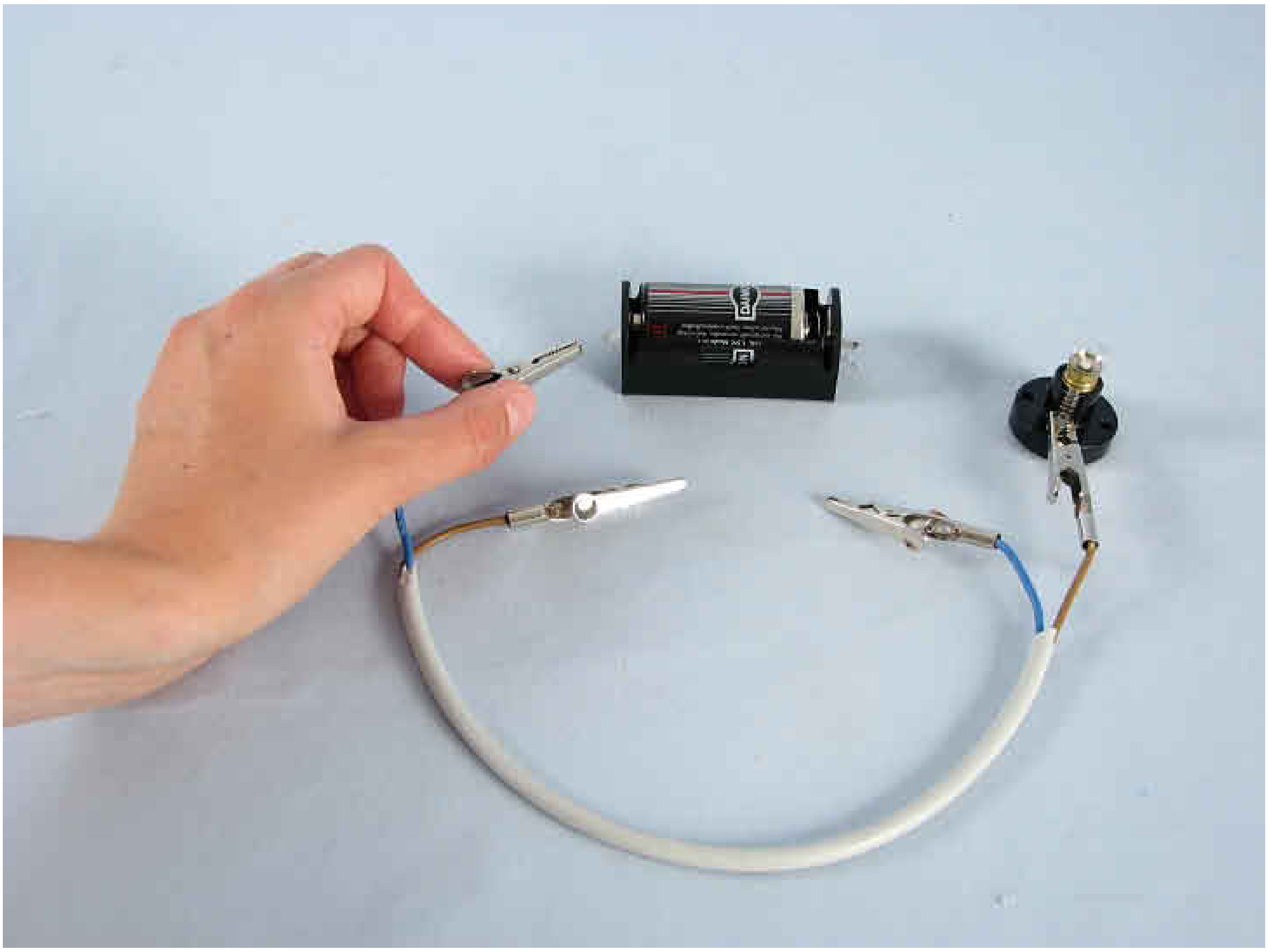


Fig. 1

Set-up and procedure

- Cut a 20 cm length off from the gray cable.
- Look at the cut. What can you see there?
- Use the knife to first remove about 5 cm of the gray plastic insulation from each end so that the cable inside is exposed.
- Again use the knife to peel about 2 cm of insulation material off of each of the four inside cable ends. Take care not to be pricked by the thin wires.
- Fasten alligator clips to each of the four ends.
- Connect the piece of cable which has been prepared to the filament lamp and the battery.

Observations

1. Describe the gray cable. How does it differ from that which you have up to now used in your experiments?

Evaluation

1. Why is electrical equipment usually connected to the electric mains with only one cable instead of the two cables which you have used in the previous experiments?

(Why are electrical appliances connected to a socket with a single cable?)

Preparation

The removal of the insulation material from the cable takes some time and requires a certain amount of skill. At least 15 minutes should be planned for this. A danger of injury is associated with the use of a knife and by the thin strand wires. The students should be appropriately warned on this.

Observation

1. The cable has a plastic outer insulation. There are two wires inside of it which are also insulated. They do not contain single wires but are made up of a bundle of numerous thin wires.

   Such wire bundles are called strands.

Evaluation

1. Cables which are used to connect electrical appliances to a socket contain two cables which serve to make a closed circuit and a third one, a protective earth conductor, for earth contact at the socket. The corresponding plugs have a metal contact at the side and are called plugs with earth contact or safety plugs.

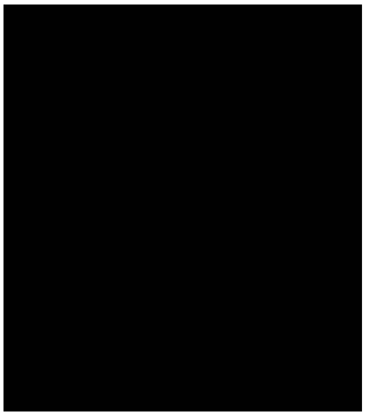
Room for notes

How can electric current be used for heating?

Task

Measure the temperature of a current-carrying wire with a thermometer.

Material



1 Battery holder
1 Battery
2 Alligator clips with clamping screw
1 Screwdriver
1 Roll of constantan wire
1 Thermometer
1 Pair of scissors
1 Ruler
Adhesive tape

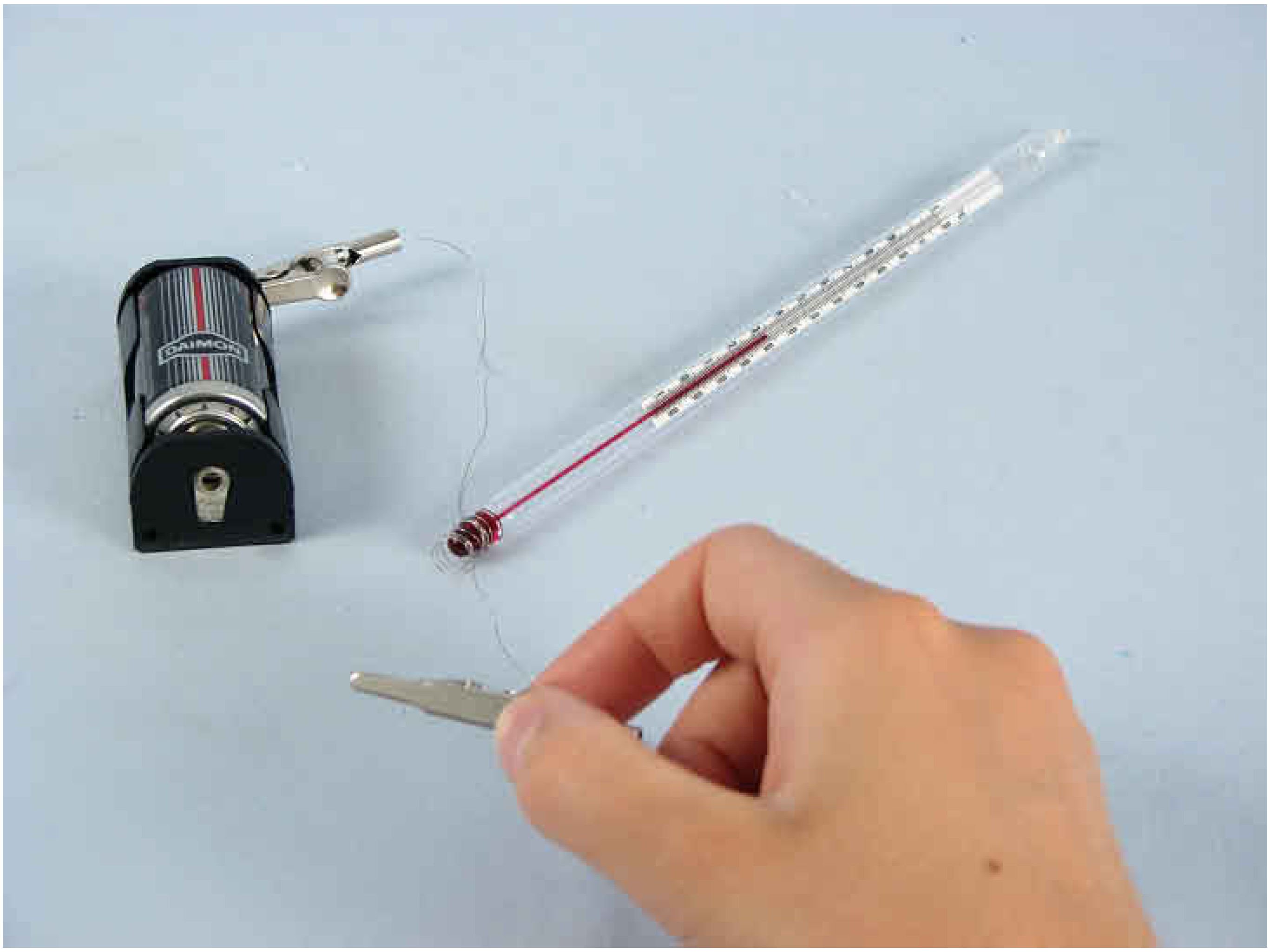


Fig. 1

Set-up and procedure

- Cut a 50 cm long piece of wire from the roll.
- Place the battery in the battery holder and take care that + and – are at the correct ends.
- Attach alligator clips to the two ends of the piece of wire.
- Wind the wire around the lower part of the thermometer which contains a red thermometer liquid to make about ten turns of it. The remaining two wire end lengths with attached alligator clips should now each be about 15 cm long.
- You can use a piece of adhesive tape to fix the wire windings to the thermometer so that they do not unwind.
- Read the temperature shown by the thermometer and write it down
- Now firmly clamp the two alligator clips to the battery holder.
- Keep a watch on the temperature scale of the thermometer.
- Wait about two minutes, then write down the temperature it shows and take the alligator clips off of the battery holder.

Observations

1. Temperature at the start:

   ....

2. Temperature at the end:

   ....

Evaluation

1. What could happen to a current-carrying wire?

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   ....

2. Explain how a toaster functions.

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   ....

   ....

3. Do you know of any other electrical appliances which create heat?

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   ....

   ....

[redacted]

(How can electric current be used for heating?)

Observation

1. Temperature at the start: e.g. 25 °C
2. Temperature at the end: e.g. 32 °C

Evaluation

1. A wire in an electric circuit could heat up.
   Wires which become hot are called heating wires.
2. A toaster has heating wires, between which is space for a slice of bread. As soon as bread is inserted, current is switched on and flows through the heating wires. The wires get so hot that they become red-hot and so toast the bread. The flow of current is interrupted when the slice of bread is catapulted out.
3. Immersion heater. Cooker hotplate. Oven. Soldering iron. Heating pad. Iron. Fan. Coffee machine.

Room for notes

Can electric current flow through everything?

Task

Test various materials to determine which ones allow a current to flow through them.

Material

1 Battery holder
1 Battery
1 Knife
1 Nail
6 Alligator clips with clamping screw
1 Insulated wire
1 Pair of scissors
1 Ruler
1 Paper clip
1 Screwdriver

[redacted]

Examples of objects made of various materials which could be clamped between the two alligator clips:
A scrap of cloth, a pencil, a shard of glass, coins, jewellery, a spoon, a belt buckle, a piece of chalk, a knitting needle or a piece of paper.

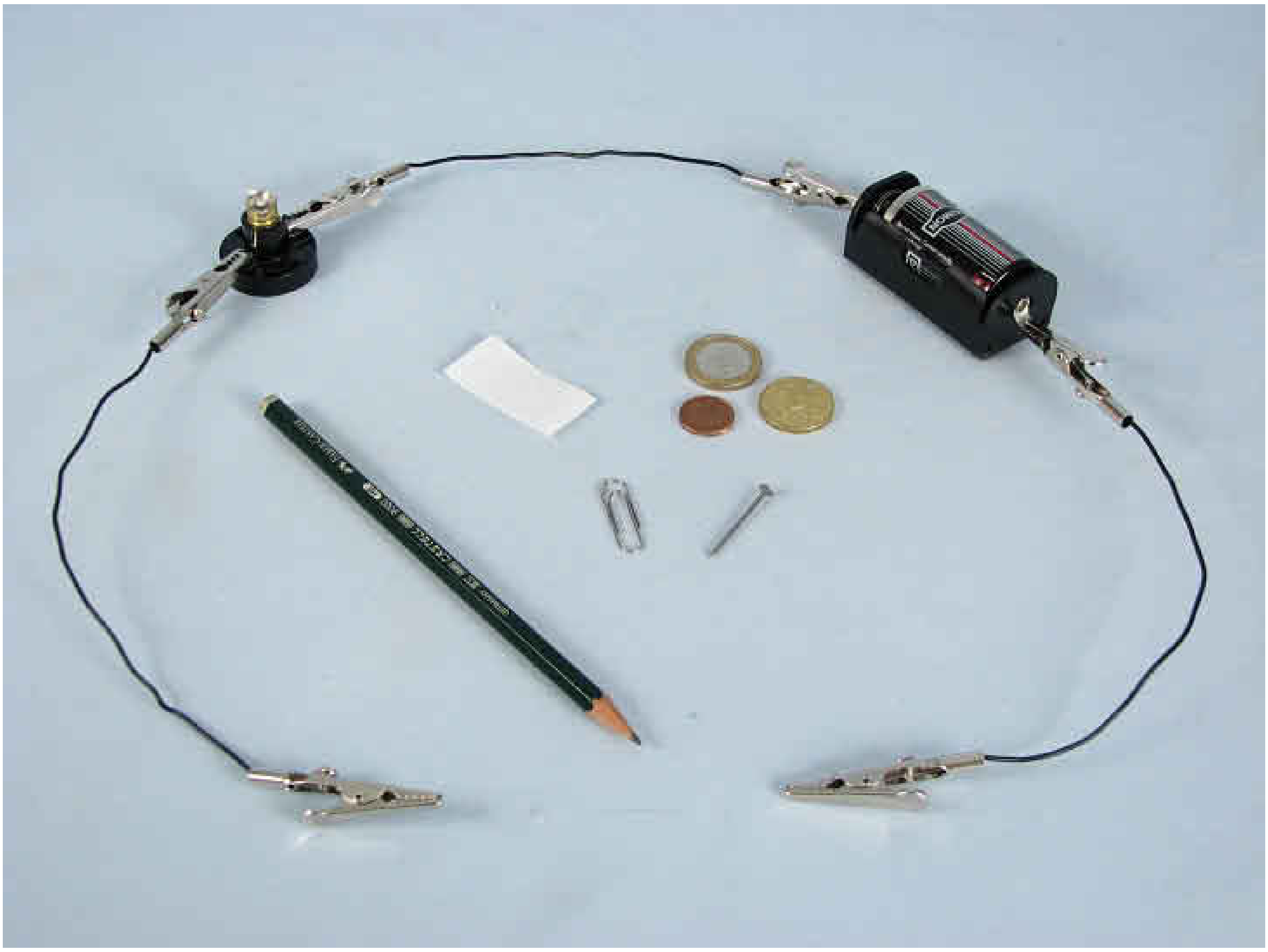

Fig. 1

Set-up and procedure

- Construct a circuit with which you can test how good various objects can conduct electric current.
- Place the battery in the battery holder and take care that + and – are at the right ends.
- Screw the filament lamp in the lamp holder.
- Cut off three pieces, each about 15 cm long, from the insulated wire and use the knife to bare 1 cm at each of the six wire ends.
- Fix alligator clips to the ends of the wires.
- Connect the lamp to the battery.
- You now still have two free wire ends with alligator clips between which you can clamp test objects.
- Test what happens when you connect the various test objects in your circuit.

Observations

1. What happens when you connect your test objects in the circuit?

Test object	What happens?

Evaluation

1. How can you recognize if a test object conducts electric current or not?

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   ....

2. Which materials conduct electric current and which do not?

   ....

   ....

   ....

(Can electric current flow through everything?)

Observation

1.

Test object	What happens?
Iron nail	Lamp lights up
Plastic ruler	Lamp does not light up
Paper clip	Lamp lights up
Constantan wire	Lamp lights up
Scrap of cloth	Lamp does not light up
Shard of glass	Lamp does not light up
Belt buckle	Lamp lights up
Chalk	Lamp does not light up
1 Euro coin	Lamp lights up

Evaluation

1. The lamp in the test circuit lights up.
2. Conductors: Metals
   Non-conductors: Plastic, glass, wood, paper, cloth, chalk

Room for notes

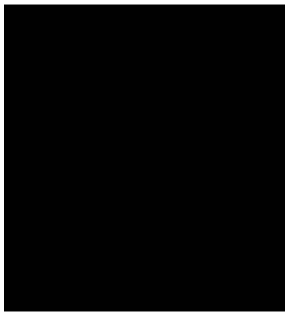
How can two lamps be connected to one battery?

Task

Find a possibility to connect two lamps to a battery so that both lamps light up.

Material

2 Filament lamps
2 Lamp holder
1 Pair of scissors
1 Insulated wire
8 Alligator clips with clamping screw
1 Battery holder
1 Battery
1 Knife
1 Ruler
1 Screwdriver



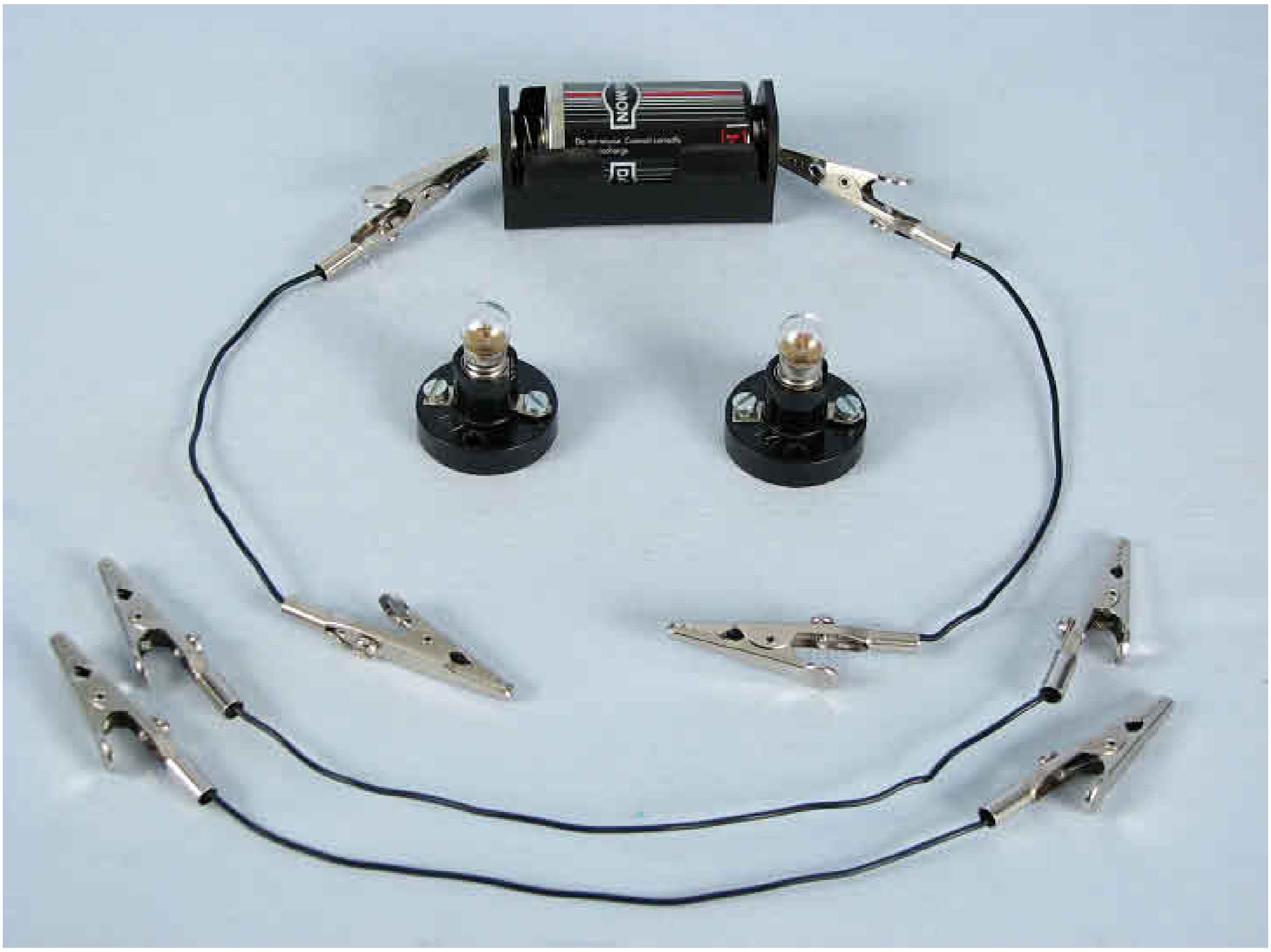


Fig. 1

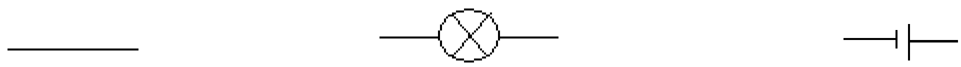
Set-up and procedure

- Cut four approximately 20 cm long lengths off from the insulated wire.
- Bare 1 cm of the ends and attach alligator clips.
- Now construct a circuit in which both lamps light up (Shush! Insider tip: There are three possibilities).

Observations

1. Make drawings of all the possibilities that you can think of. If you want to make a circuit diagram like an expert, use the following symbols for a:

conducting wire | lamp | battery



2. Do the lamps light up as bright as a single lamp which is connected to the battery?

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Evaluation

1. Electricians use the technical terms “series connection” and “parallel connection” for the various ways in which two filament lamps can be connected to one battery.
   Which term belongs to which circuit? Write the terms in on your drawings.

2. Which type of circuit is used for chains of electric Christmas tree candles?

   ....

   ....

3. Which type of circuit allows several electrical appliances to be connected to one multiple outlet strip?

   ....

   ....

Room for notes

[redacted]

(How can two lamps be connected to one battery?)

Observation

1. Only the circuit symbols for filament lamp, conducting wire and battery are introduced here as these correspond to the parts used in the experiment. For a correct circuit diagram, each branching of a wire must be shown by a dot.
2. When the lamps are connected one behind the other (in series) they give a weaker light, but when each is connected to the battery with its own circuit (in parallel) each lights up as brightly as one lamp alone.

Evaluation

2. A series connection is mostly used. The light chain can then be switched off by turning just one of the candles.
3. A parallel circuit.

Room for notes

Which materials find a magnet attractive?

[redacted]

Task

Test which test objects are attracted by a magnet.

Material

2 Magnets, 50 mm
1 Pair of scissors
1 Adhesive tape
1 Pack of paper clips

Cover of the storage box
Various coins
A collection of small metallic and non-metallic objects
Sandpaper

Fig. 1

Set-up and procedure

- Stick the two magnets horizontally to the upper side of the storage box cover so that they are approximately at the middle of it and there is a gap of about 3 cm between them.
- Lean the cover against the storage box and allow various coins and small objects to slide down the cover from above the gap.
- Note which objects pass through the gap and which do not.
- Vigorously rub the edge of a 1 cent coin with sandpaper for a time. What is to be seen?

Observations

1.

Objects which slide through the gap	Objects which are held back

2. What did you notice after you had sandpapered the 1 cent coin?

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Evaluation

1. Which materials are the magnetically attracted objects made of?

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(Which materials find a magnet attractive?)

Material

The small collection of metallic and non-metallic objects required for this experiment can easily be assembled from what is held in pockets and satchels.

Observation

1.

Objects which slide through the gap	Objects which are held back
1 and 2 euro coins	1, 2 and 5 cent coins
10, 20 and 50 cent coins	Paper clips
Rubber	Iron nail
Paper ball	Padded envelope clip
Glass marbles	Needle
Plastic objects	Screws
Stones	Metal nuts

2. A silver core came to light under the copper-coloured surface.

Evaluation

1. The objects which were attracted were those made of iron (and some of the less well known metals copper and nickel) and which contained iron. None of the other materials, which includes other metals, were magnetically attracted.
   The 1 cent coin has an iron core below the copper surface.

   Brief information on coins:
   Genuine 1, 2 and 5 cent coins are made of copper-coated steel and are highly magnetic.
   10, 20 and 50 cent coins consist of so-called “Nordic gold”, a copper-zinc-aluminium-tin alloy. They are not magnetic.
   1 and 2 euro coins have a nickel-brass exterior or a nickel-copper ring, underneath which there are two layers of nickel-copper (or nickel-brass) with a layer of nickel between them. Brass is an alloy of copper and zinc. 1 and 2 euro coins are only slightly magnetic.

Room for notes

Where is the greatest magnetic force?

Task

Examine how strong a magnet is and where it has the greatest force.

Material

1 Magnet, 50 mm
1 Nail
1 Pack of paper clips

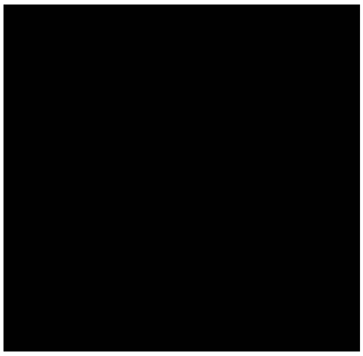

Fig. 1

Set-up and procedure

- Shake the paper clips out of the package onto the table and try to collect as many as possible of them with the magnet. Who collects the most?
- Hold the head of the nail at various parts of the magnet and test where it is attracted. Repeat this procedure using a paper clip.

Observations

1. How many paper clips could you pick up with the magnet?

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2. Where were most of the paper clips hanging?

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3. At which positions was the nail attracted and at which the paper clip?

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Evaluation

1. Where did the magnetic force have the most strength?

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(Where is the greatest magnetic force?)

Observation

1. 40 paper clips were held by the magnet.
2. More paper clips were hanging from the two ends of the magnet and less from the middle of it.
3. An attempt to have the nail held at the middle of the magnet was unsuccessful. When it was moved towards the ends, however, it remained hung on.
   The paper clip was slightly attracted by the middle of the magnet, but far more by the ends of the magnet.

Evaluation

1. The force of a magnet is particularly strong at its ends. Only a small attractive force was detectable in the middle.

Room for notes

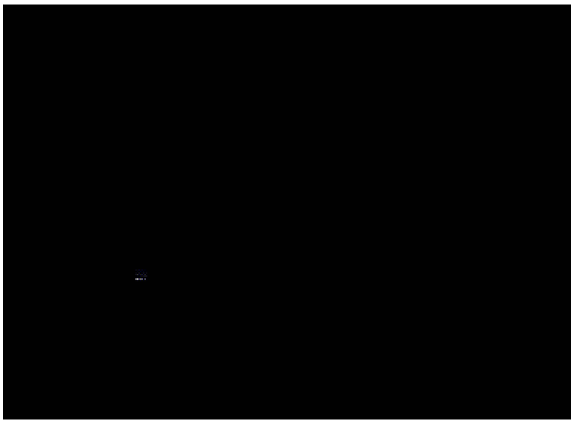
How far does magnetic force reach?

Task

Determine over which distance a magnetic force can make itself felt.

Material

1 Magnet, 50 mm
1 Ruler
1 Roll of thread
1 Pack of paper clips
1 Pair of scissors



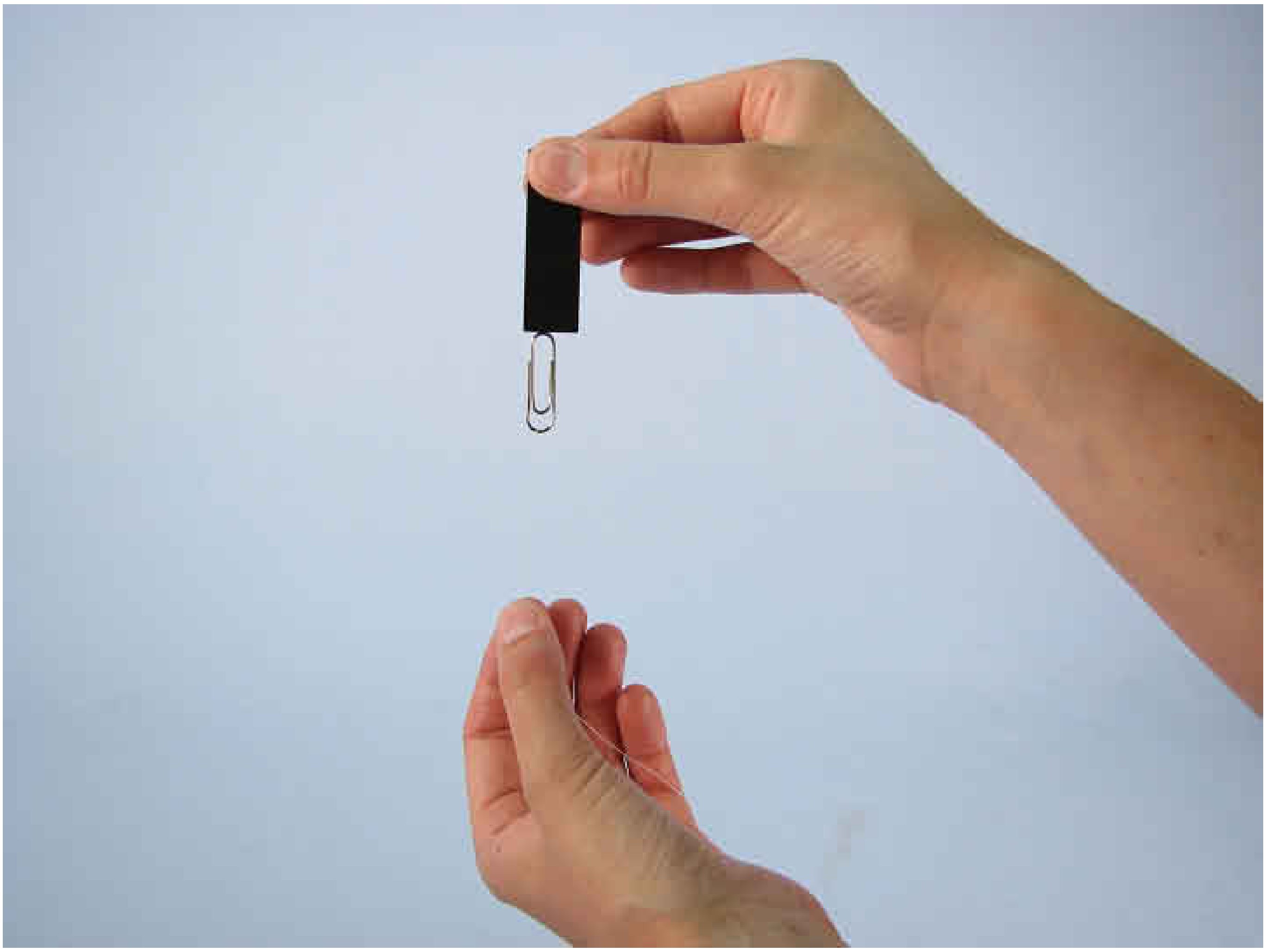


Fig. 1

Set-up and procedure

- Cut off an approximately 20 cm length of thread and tie it to one end of a paper clip.
- Hold the magnet vertically with the ends up and down and hang the paper clip on the magnet with the thread hanging down.
- Now carefully pull on the thread. What happens?
- Place the ruler on the table in front of you and position the magnet with one end at the zero mark.
- Push a paper clip along the ruler towards the magnet and read off the distance at which the paper clip is attracted by the magnet.
- Again hold the magnet vertically and let a classmate hold a sheet of paper under it. Try to hang a paper clip from the paper. Repeat this procedure, replacing the sheet of paper by various other objects of different thicknesses.
- Hang a paper clip on the vertically-held magnet. Hold another paper clip at the bottom of the first one. Make the chain of hanging paper clips as long as possible.

Observations

1. What happens when you carefully take the paper clip off of the magnet?

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2. From which distance is the paper clip attracted by the magnet?

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3. What happens when various other objects are held between the magnet and the paper clip?

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4. How many paper clips were in the chain that you made?

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Evaluation

1. Why does one not have to hold a paper clip directly at a magnet to be able to show the effect that the magnet has?

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Room for notes

(How far does magnetic force reach?)

Observation

1. The paper clip stays standing in the air. It only falls down when it has been drawn about 1 cm away from the magnet.
2. With the magnet lying on the table, the paper clip is attracted to it from an approximately 2 cm distance away.
3. The effect of the magnet could be detected through several sheets of paper. The magnetic force could also be detected through other materials, such as not very thick pieces of plastic, glass and wood.
4. A chain of 3 to 4 paper clips could be hung on the magnet.

Evaluation

1. According to the magnetic strength of a magnet, the magnetic force makes itself felt over a greater or smaller distance, even through substances other than air. This is because of the so-called magnetic field which surrounds the magnet.
   The magnetic effect can cause objects made of iron to also become magnets. They can then attract other ones themselves, as was the case in the chain of paper clips.
   Hanging objects from the middle of the magnet does not work, they must be moved to the ends to remain hanging. The paper clip was slightly attracted by the middle of the magnet, but much more strongly by the ends of it.

Room for notes

Which shape does a magnetic field have?

Task

To make magnetic fields of various arrangements of magnets, nail and paper clips visible.

Material

2 Magnets, 50 mm
1 Iron powder sprinkler
1 Pack of paper clips
1 Nail

1 Sheet of white A4 paper
Cover of the storage box

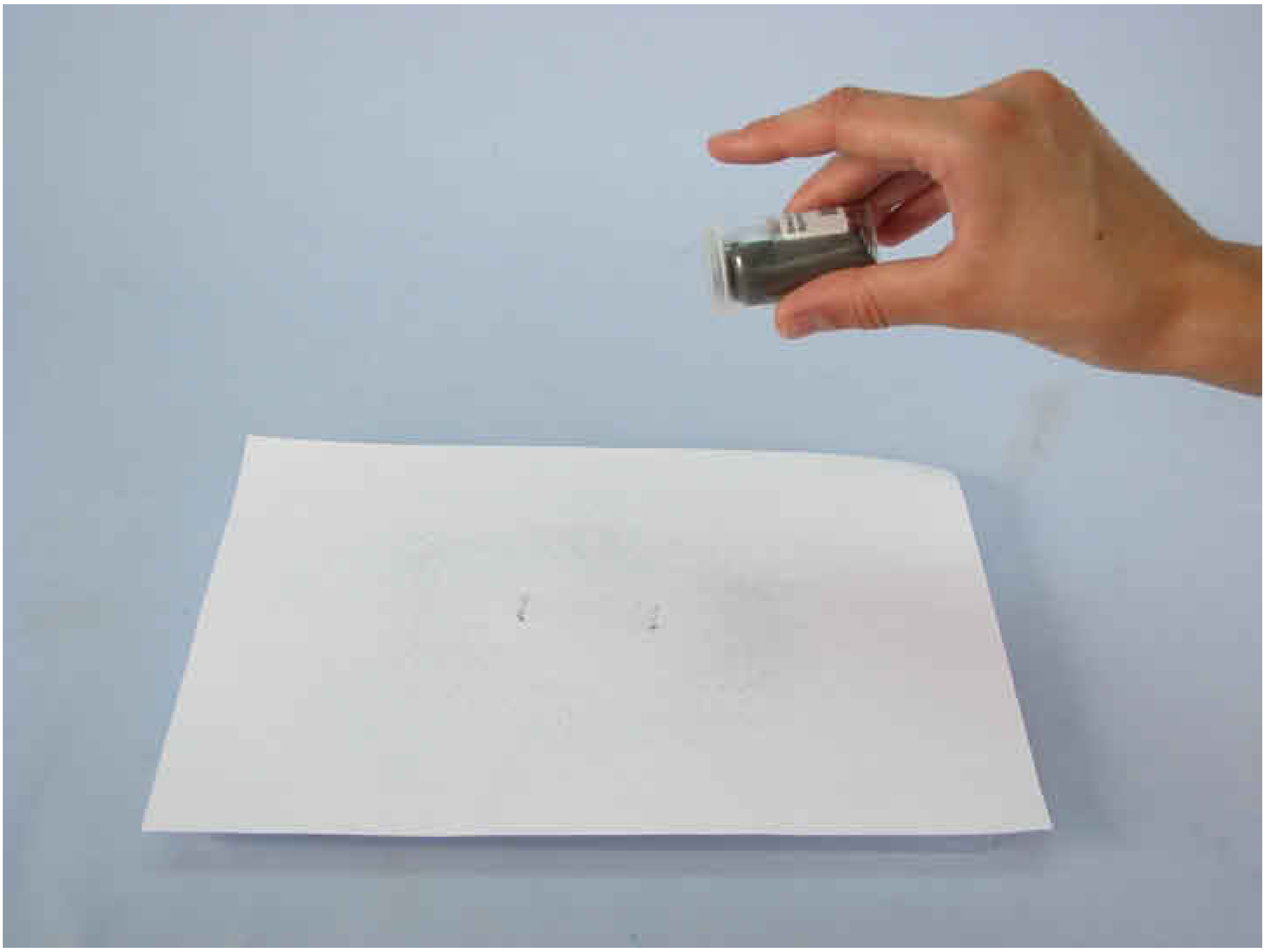

Fig. 1

Set-up and procedure

- Lay a magnet in the hollow of the storage box cover and cover it with the sheet of A4 paper.
- Replace the closed lid of the iron powder container by the lid with holes and sprinkle a thin even layer of iron powder over the paper.
- Knock carefully at the side of the sheet of paper. What happens?
- Take the paper off but ensure that none of the powder gets lost.
- Now lay the second magnet in the cover and turn the magnets so that the ends of them are about 3-4 cm away from each other and attract each other.
- Cover them with the iron powder covered sheet of paper and again knock lightly against the side so that the powder can align itself.
- Repeat this procedure with one of the two magnets turned round so that they repel each other. Should the iron powder covering no longer be distributed sufficiently even on the paper, fill it back into the sprinkler and re-make the required paper covering as previously.
- Take the two magnets away and place the iron nail in the cover. Observe how the iron powder now arranges itself.
- Put a magnet back in so that it attracts the nail. Which pattern is now formed?

Observations

1. Draw each pattern which was formed by the iron powder for:
   1. One magnet. 2. Two magnets which attracted each other. 3. Two magnets which repelled each other. 4. An iron nail. 5. A nail which was attracted by a magnet.

2. What do you notice when you compare the iron powder pattern with a magnet with the pattern without a magnet?

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Evaluation

1. What do the iron powder patterns show you?

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Room for notes

(Which shape does a magnetic field have?)

Observation

2. The iron nail alone does not make any iron powder pattern. As soon as it is attracted by the magnet, however, the contours of it are recognizable in the powder.

Evaluation

1. The iron powder patterns show how the lines of the magnetic field are arranged.
   They are denser at the magnetic poles, in other words, there where the force of the magnet is greatest, than in the middle section. The lines between two magnets which attracted each other touch each other, whereas those between two magnets which repelled each other bend away from each other.
   An iron nail alone has no magnetic field, but when it is subject to attraction to a magnet, then magnetic field lines are formed around it.

Room for notes

Which force influences a magnet?

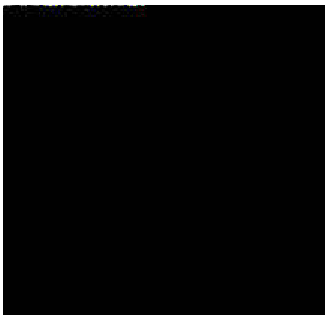
Task

Determine if a freely movable magnet orients itself in any particular direction.

Material

2 Magnets, 50 mm
1 Compass
1 Glass rod
1 Roll of thread
1 Petri dish / plastic dish
1 Sheet of sponge rubber
1 Pair of scissors
1 Ruler
2 Marking points, red
2 Marking points, green

Pen
Storage box
Water
Sheet of white A4 paper



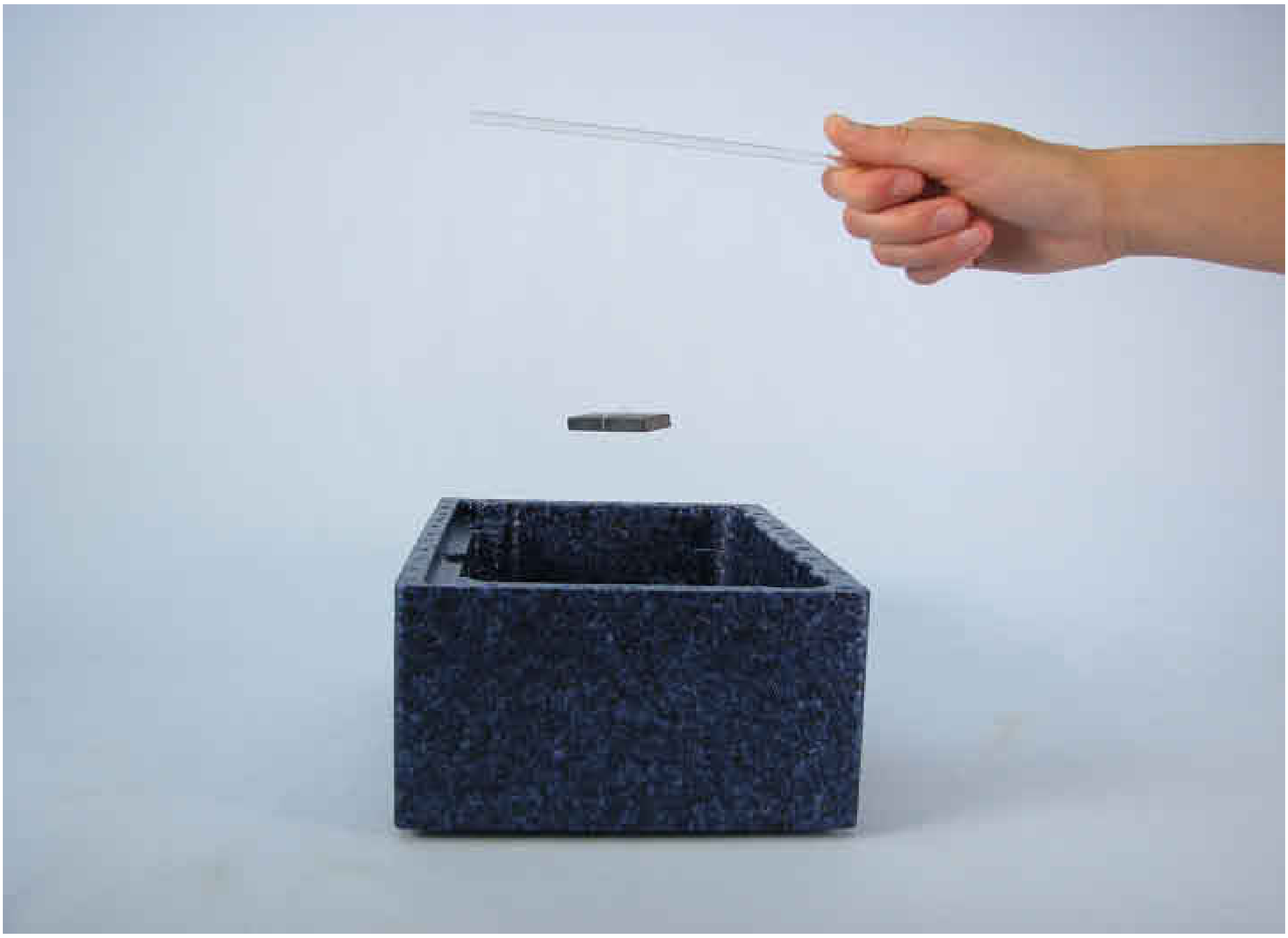


Fig. 1

Set-up and procedure

- Take all of the parts which are in the storage box out of it.
- Lay the glass rod over the empty compartment in the box.
- Tie the thread firmly to a magnet and hang the magnet so at the glass rod that it can freely dangle.
- Wait until the magnet no longer swings back and forth. Pay attention to the direction in which it points, then turn it a little away from this direction. What happens?
- Lay the bottom of the plastic dish on the sheet of rubber sponge. Use the dish bottom as template to draw a circle around it with the ball-point pen and then cut the disk out. Tip: You can save rubber sponge by drawing the circle as near to the edge of it as possible.
- Cut the disk to be a little bit smaller. To do this, make several dot marks, each about half a centimetre from the disk edge, and cut along them.
- Fill the plastic dish with water and let the circular rubber sponge float on it.
- Very carefully lay a magnet across the middle of the disk.
- Turn the magnet with disk a little and observe what happens.
- Look at the direction in which the compass needle points. Turn the compass. What do you now realize?
- Construct a model of the earth's magnetic field: Lay the magnet on the sheet of A4 paper and put the plastic dish (which you have previously dried) over it.
- Scatter iron powder over the dish and the paper as thinly and evenly as possible. Look at the pattern.

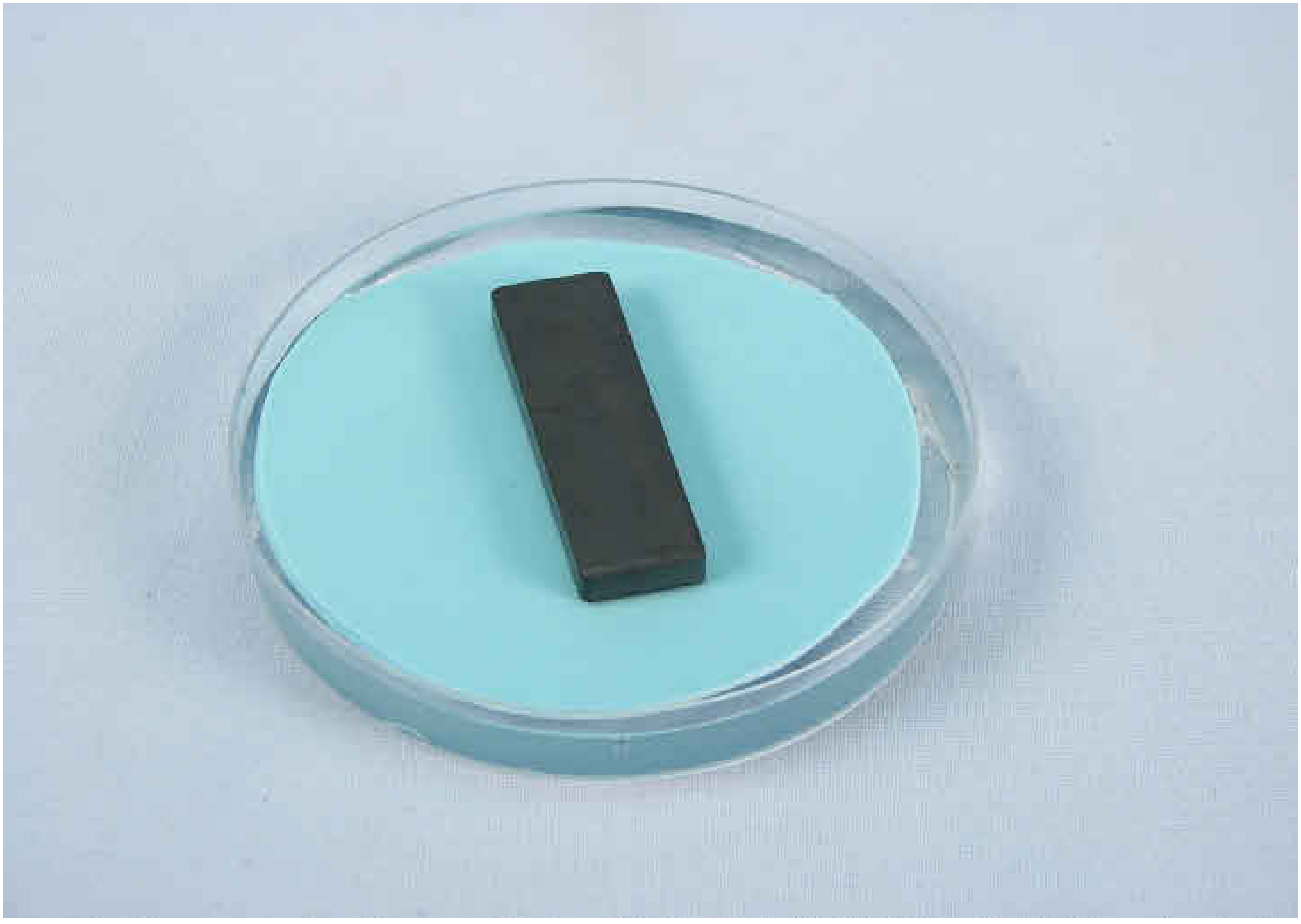


Fig. 2

Observations

1. What happened when you turn the magnet somewhat away from the position at which it was hanging still?

....

....

....

2. What did you observe when you slightly turned the rubber sponge plus magnet?

....

....

....

3. What did you realize as you watched the freely hanging magnet, the floating magnet and the compass needle?

....

....

....

Evaluation

1. In which direction does a compass needle point?

....

....

2. Why do the compass needle and the magnet turn to a particular direction?

....

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....

3. Draw the earth model and the pattern which the iron powder made. Label the north and south poles. Draw a compass in and consider in which direction the compass needle must point.
How do the earth‘s magnetic field lines run?

....

....

....

4. Label the north poles of the magnets with red markers and the south poles with green markers. To do this, you must know where north and south are. (Tip: The sun rises in the east, travels across the south and sets in the west. It is never to be seen in the north.) When the magnets have been prepared, you can use then in the next experiment, which is experiment 13.

(Which force influences a magnet?)

Observation

1. The magnet swung back to its rest position.
2. The disk turned so that the magnet again pointed in the same direction as before.
3. All three pointed in the same direction.

Evaluation

1. The compass needle points in the north-south direction.
2. The compass needle is also a magnet. Magnets align themselves according to the earth’s magnetic field.
3. They run from north to south.

Room for notes

Do two magnets attract or repel each other?

Task

Test the behaviour of two magnets to each other.

Material

2 Magnets, 50 mm
1 Compass
2 Marking points, red
2 Marking points, green
1 Ruler
1 Nail
1 Cart

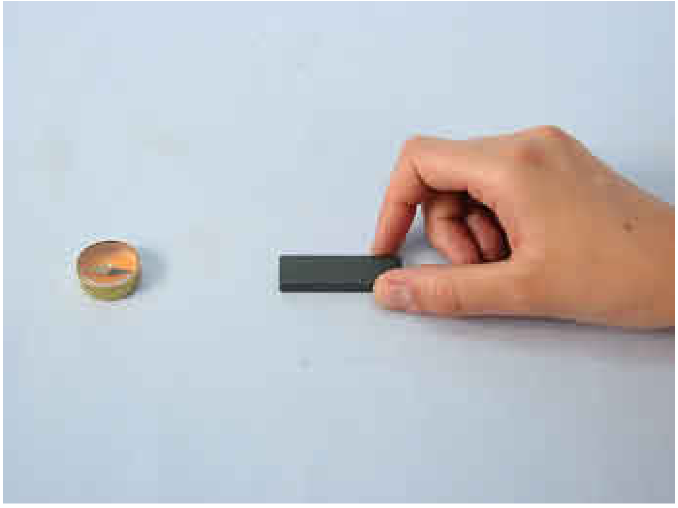


Fig. 1

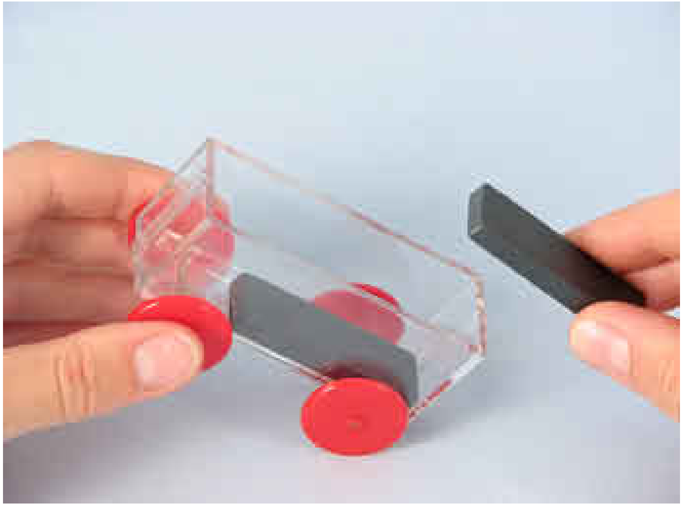


Fig. 2

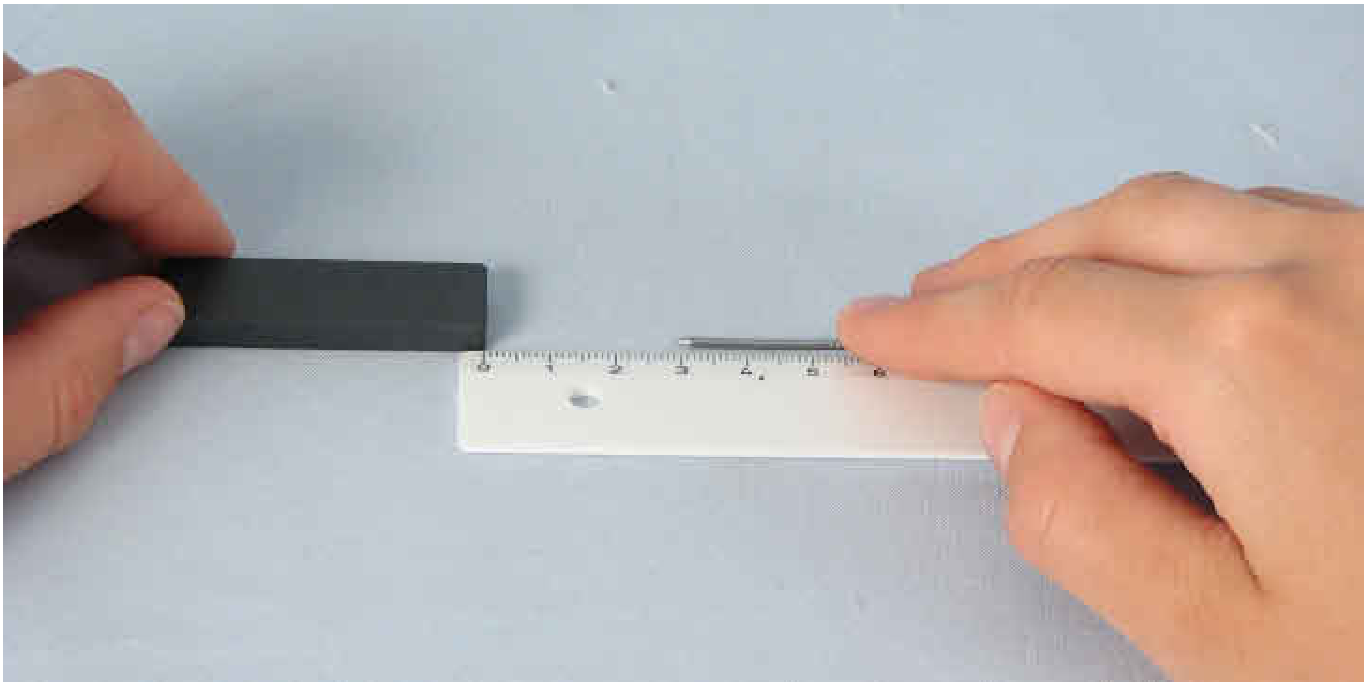


Fig. 3

Set-up and procedure

- The magnets must have had marker points stuck on them before the start of this experiment. To do this, bring one end of one of them near the coloured side of the compass needle (Fig. 1). When the north pole of the compass stays directed towards the magnet, then this end is the south pole of the magnet. Stick a green marker on it. When the compass needle turns so that the south pole of it is facing the magnet, the end facing the compass is the north pole of the magnet. Stick a red marker on it. Repeat this procedure with the other magnet.
- Lay one of the marked magnets in the small cart.
- Hold the second magnet a short distance away from the cart at the front of it, at the back of it, to the side of it and above it.
- Turn the magnet around and repeat the above step. What do you observe?
- Bring the magnet in the cart to slide to one corner. Take the second magnet and try to bring it to be suspended over the other one (Fig.2). (Tip: This can be more easily achieved when you first hold the cart at a slight incline.)
- Lay the ruler in front of you on the table and the magnet with one end at the zero mark.
- Push the nail tip-first along the ruler towards the magnet from the other direction (Fig.3). Read and record the distance at which the nail is subject to attraction.
- Now lay the second magnet over the first one so that the red pole lies over the green pole and re-peat this experiment.
- Turn the upper magnet round so that the like poles are facing each other. You must press them firmly together to manage this! Again record the distance.

Observations

1. What did you observe as you held the magnet near to the cart at various positions? What happened when you turned the magnet around?

 ....

 ....

 ....

2. What did you have to do to bring the magnet to become suspended?

 ....

 ....

3.

Arrangement	Distance
1 Magnet	
2 Magnets with unlike poles against each other	
2 Magnets with like poles against each other	

Evaluation

1. Make a rule on how two magnets behave towards each other:

 Like poles ....

 ....

 Unlike poles ....

 ....

2. Are two magnets stronger than one? Explain your answer.

 ....

 ....

 ....

 ....

 ....

Room for notes

(Do two magnets attract or repel each other?)

Observation

1. The cart started to move. When the magnet was turned around, the cart moved in the reverse direction.
2. The poles with the same coloured markers must lie on top of each other.
3.

Arrangement	Distance
1 Magnet	1 cm
2 Magnets with unlike poles against each other	0.5 cm
2 Magnets with like poles against each other	2 cm

Evaluation

1. Like poles repel each other.
   Unlike poles attract each other.
2. Two magnets are not always stronger than one, as this depends on which of their poles are directed towards the attracted object. When the same pole of each is directed towards the object, then the attractive force is greater then with only one of them. When unlike poles are directed towards it, however, then the attractive force is weaker than that of one of them alone.

Room for notes

Can you make a magnet out of a nail?

Task

Test the behaviour of two magnets to each other.

Material

1 Magnet, 50 mm
1 Petri dish / plastic dish
2 Small nails
1 Pair of scissors
1 Ruler

Sheet of paper
Pencil
Water

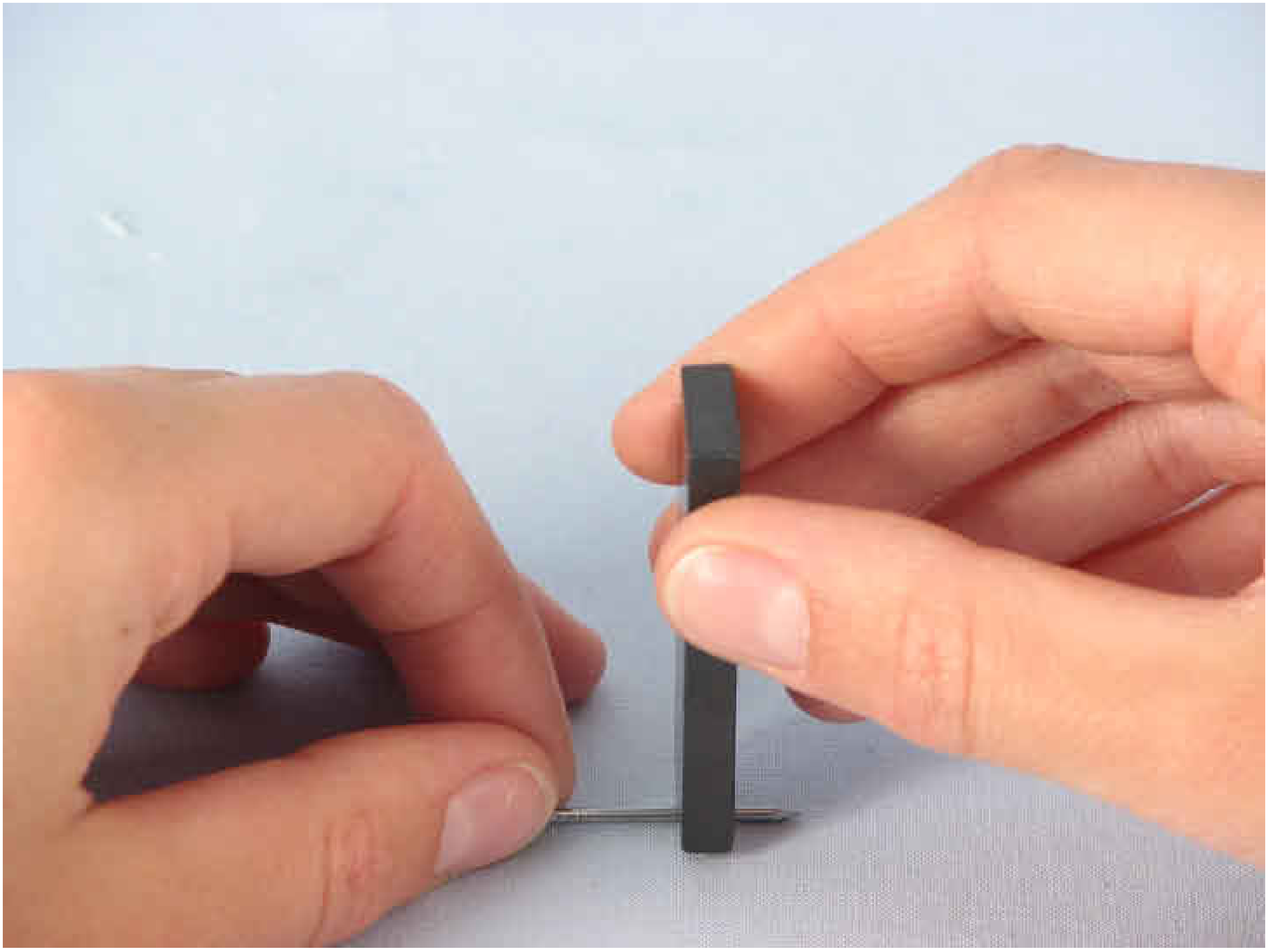


Fig. 1

Set-up and procedure

- Cut a 10 cm by 8 cm square out from the paper and fold a small boat from it.
- Stick the nail through the sail. This is made easier when you first scratch the position on the sail a little with the scissors.
- Fill the plastic dish with water and put the boat on the water.
- Push it a little to see if it turns in any one certain direction.
- Take the paper boat out of the water before it is completely wet through and withdraw the nail from the sail.
- Hold the nail against the second nail to see if there is any attraction.
- Magnetization starts now: Stroke the nail from the middle to the tip about 20 times with one pole of the magnet but, while doing this, hold the magnet somewhat above the nail each time you bring it back to the middle.
- Again stick the nail through the sail, let the boat float and observe in which direction it sails.
- Withdraw the nail from the sail and again hold it against the second nail.
- Now de-magnetize the nail: Draw the magnet along the whole length of the nail, from the head to the tip and back again. First do this with the magnet very close to the nail, then always a little further and further away from it. Repeat this procedure several times.
- Test if de-magnetization was successful.

Fig. 2

Observations

1. How did the sailing direction of the boat change after you magnetized the nail?

   Before magnetization ....

   ....

   After magnetization ....

   ....

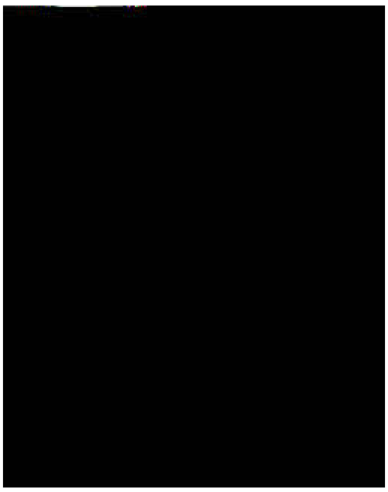
2. What did you observe after you had demagnetized the nail?

   ....

   ....

   ....

   ....



Evaluation

1. Decide for each statement whether it is valid (yes) or not valid (no) for the particular parts.

	Iron nail	Magnetized iron nail	Magnet
Has a north pole and a south pole.			
Attracts an iron nail.			
Is attracted by a magnet.			
Can be magnetized or demagnetized.			
Can be used as a com-pass needle.			
Does not direct itself to the earth's magnetic field.			

(Can you make a magnet out of a nail?)

Preparation

To be sure that the nails to be used are not magnetized, they should be subjected to demagnetization as described in the student experiment prior to the experiment. As alternative, an alternating voltage of 10 V can be applied to a coil with 1600 winds (07830-01) by a power supply (13505-93) and the voltage then be slowly but continually reduced to 0 V.

Observation

1. Before magnetization the boat did not move in any particular direction.
   After magnetization the boat turned to the north-south direction.
2. The nail is no longer directed north-south and does not attract the other nail.

Evaluation

1.

	Iron nail	Magnetized iron nail	Magnet
Has a north pole and a south pole.	no	yes	yes
Attracts an iron nail.	no	yes	yes
Is attracted by a magnet.	yes	yes	yes
Can be magnetized or demagnetized.	yes	yes	no
Can be used as a compass needle.	no	yes	yes
Does not direct itself to the earth’s magnetic field.	yes	no	no

Room for notes

This experiment impressively demonstrates the thermal effect of electric current. We suggest that you carry this demonstration after student experiment S5, as otherwise it gives the result of that experiment away in advance.

A conductor is heated by a flow of current to an extent which is dependent on its resistance. Copper only heats up a little because it has a low resistance, whereas iron, chromium and nickel wires heat up more. The thinner a wire, the higher the resistance of it and so the hotter it gets when current flows through it. A pad of steel wool held at the two poles of a battery becomes so hot that it burns.

Material

1	Flat-type battery	07496-01
1	Pad of iron wool	31999-20
1	Protective desk plate	39180-10
1	Crucible tongs	46964-00

Fig. 1

Set up and procedure

- Lay the battery flat on the protective underlay.
- Use the crucible tongs to grip the pad of steel wire and first hold it against one pole, then against the other pole and finally against both metal terminals simultaneously.

Observations

When the pad was only held against the one or the other pole, no action of an electric current could be seen. When it was held against both poles simultaneously, however, the steel wire first started to glow and then to burn. It was a darker colour afterwards and did not ignite when it was again held against both terminals of the battery.

Evaluation

Current cannot flow when only one of the poles of the battery is touched by the steel wool. When contact is made with both poles, the flow of current through the thin wire of the steel wool heated the wire so much that it glowed and burned to iron oxide, which did not conduct current.

When a flow of current strongly heats up conducting wires there could be a danger of fire.

A short-circuit which results from bare wires come into contact in a circuit could be the cause of this. The current hereby by-passes the consumer with the greatest electrical resistance so that far more current now flows through the wiring which leads to the short-circuit position and so heats it up.

Too large a number of current consumers can also cause wires to be overheated: The strength of the current is increased when several consumers are switched in parallel in a circuit. The increased current strength causes an increase in the temperature of the conducting wires.

A fuse cut-out consists of a thin wire which is held in a fireproof covering. Overloading of the circuit brings the thin wire to melt so that a further flow of current is prevented.

Material

1	Flat battery, 4.5 V	07496-01
2	Battery case, transparent	06030-22
2	Filament lamps 3.5V	06152-03
2	Lamp holder, E10	06170-01
1	Constantan wire, d=0.2 mm	06100-00
6	Connecting cord	07360-05
4	Connecting plug, 2 pcs.	07278-05
1	Iron wire, d = 0.2 mm	06104-00
1	Scissors, l=140mm	64623-01
1	Knife, stainless	33476-00
1	Screwdriver, width 3mm	01612-00
1	Parchment disks	02672-00
1	Jumper wire, isolated	330790
1	Lab thermometer	38056-00
1	Protective desk plate	39180-10

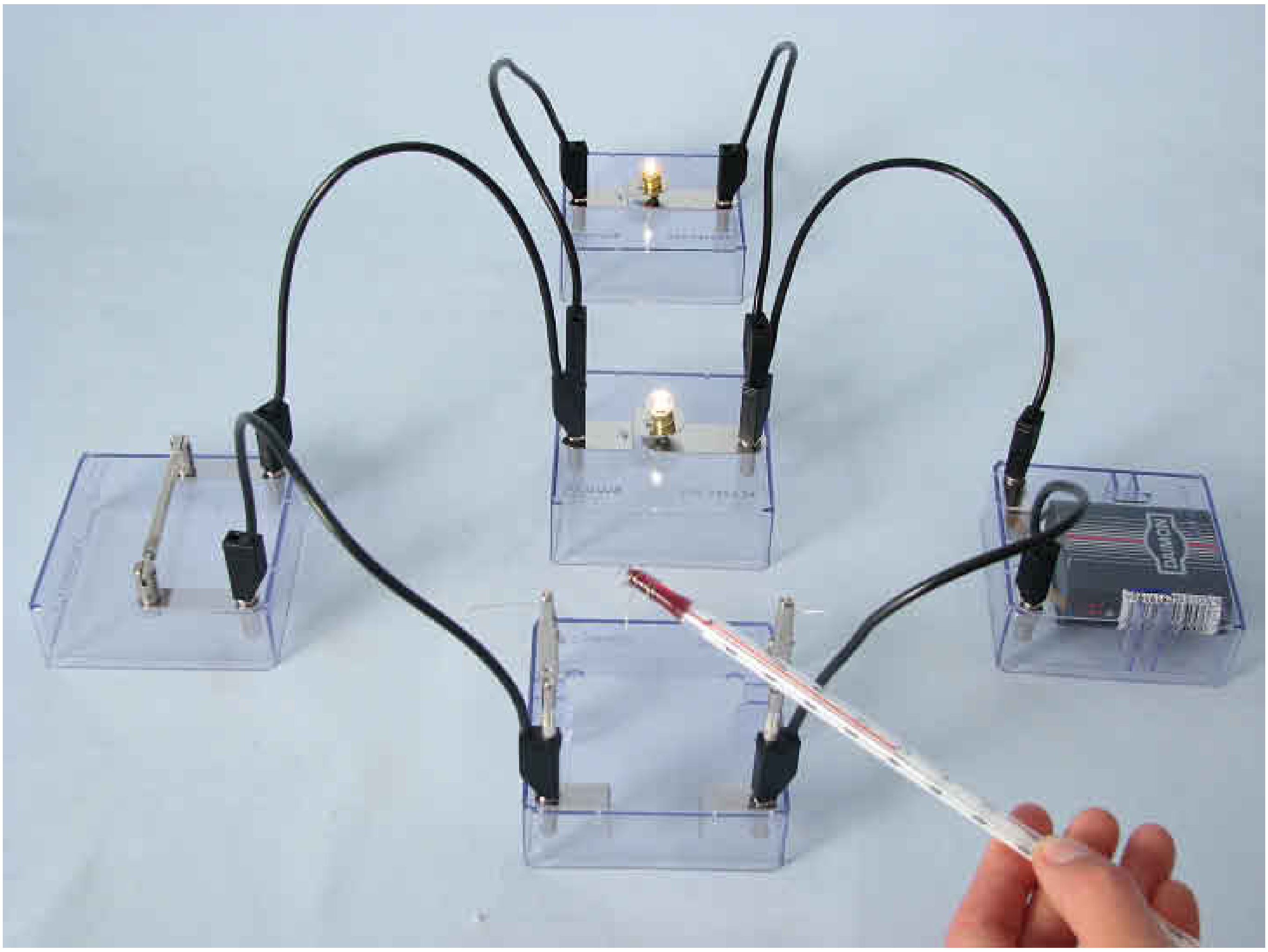


Fig. 1

Set up and procedure

The more current consumers, the stronger the flow of current

- Set up a circuit consisting of a battery in a battery box, the lever switch, a plate with metal contacts and a lamp holder with lamp. The switch must first be open.
- Wind an approximately 20 cm long length of constantan wire tight around the liquid reservoir of the thermometer so that roughly 2 cm end lengths of wire are left protruding out. With the switch still open, connect the coil between the metal contacts.
- Hold the thermometer in the looped wire and read the temperature (Fig. 1).
- Now close the switch and follow the change in the temperature over the next three minutes.
- Open the switch and wait until the initial temperature has again been reached.
- Now connect a second lamp holder with lamp in parallel in the circuit.
- Close the switch and repeat the above procedure.

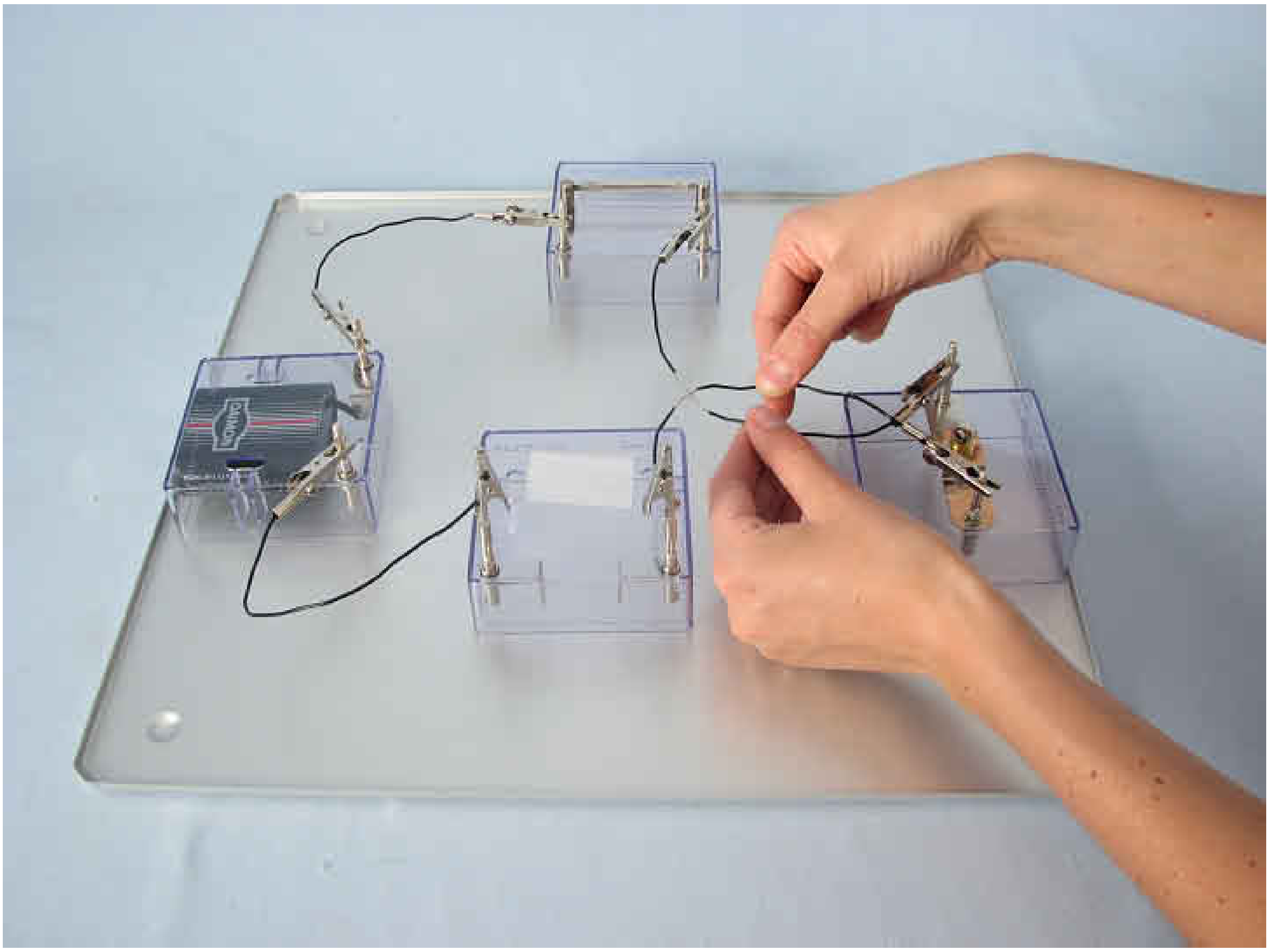


Fig. 2

Short-circuit

- Take two approximately 30 cm long lengths of insulated wire and remove a roughly 3 cm length of the insulation from the middle section of each of them. Connect connecting plugs to the ends of these lengths of wire.
- Set up a circuit on the protective underlay which consists of a battery in a battery box, the lever switch, the plate with metal contacts and a lamp holder with lamp, whereby the two lengths of wire prepared to have bare middle parts are to be used to make the connections to the lamp. The lever switch should first be open.
- Connect a piece of constantan wire between the metal contacts.
- Hang a small, folded piece of vellum paper over the constantan wire (Fig. 2).
- Close the lever switch.
- Now briefly bring the bare parts of the two prepared connecting wires together.

Fuse cut-out protection

- With the switch open, replace the constantan wire In the circuit set-up for demonstrating a short-circuit by a length of iron wire.
- Now close the switch and again briefly bring the bare parts of the two prepared connecting wires together (Fig. 3).

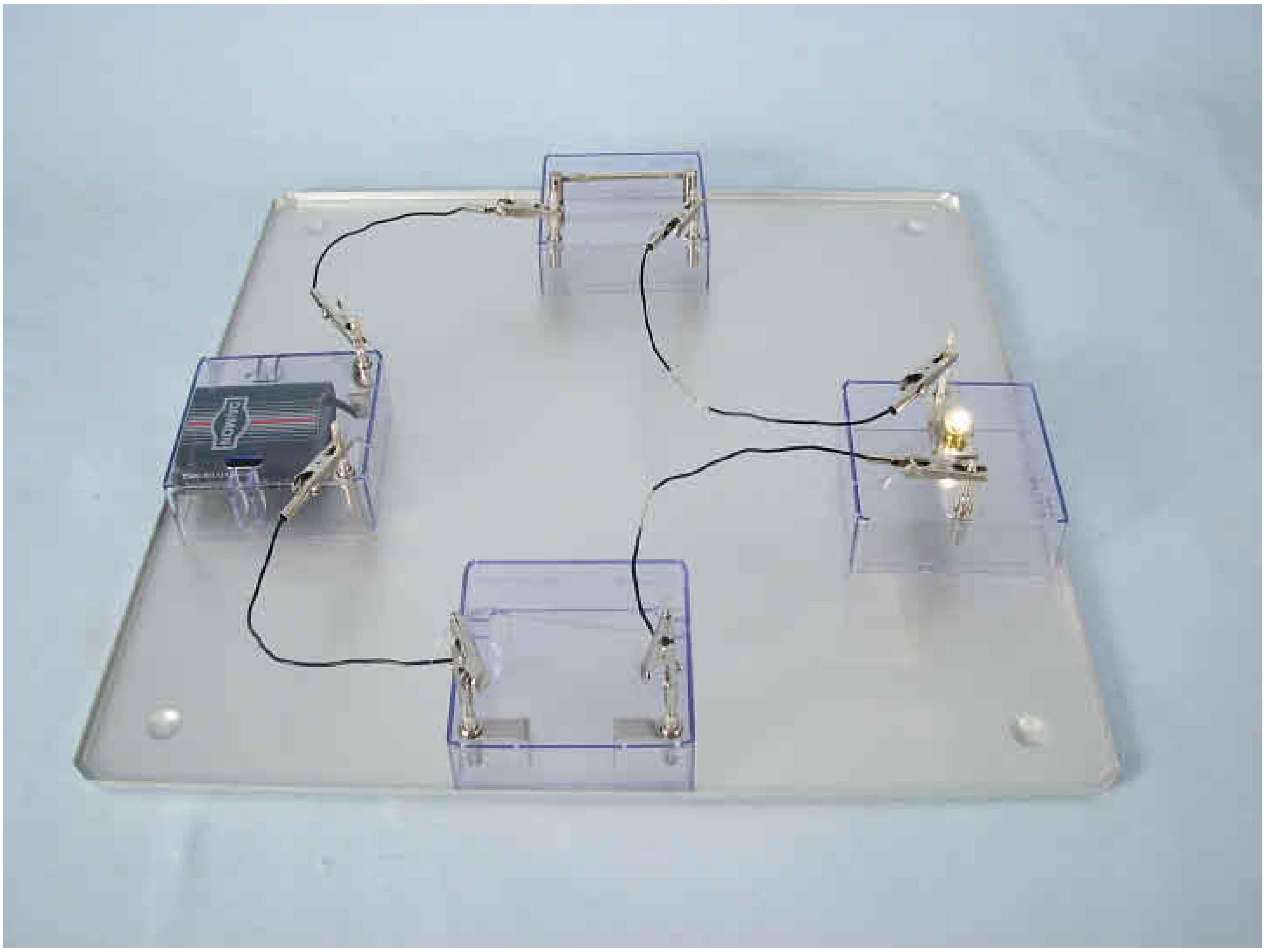


Fig. 3

Observations

The more current consumers, the stronger the flow of current

The temperature increased by 1 – 2 °C with one filament lamp and by 3 – 4 °C with two filament lamps.

Short-circuit

The lamp lit up when the switch was closed. When the two bare wires were brought together, the lamp went out, the wire glowed and the vellum paper burnt.

Fuse cut-out protection

The lamp lit up when the switch was closed. When the two bare wires were brought together, the lamp went out and the wire melted.

Evaluation

The more current consumers, the stronger the flow of current

The more current which flows through a wire, the more it heats up. When the second lamp is also connected, more current flows through the wire and the current strength increases. The greater the current strength in a wire, the higher the temperature of the wire.

Short-circuit

A short-circuit was caused by the touching of the two bare wires. Current no longer flowed through the lamp, as this had the highest resistance in the circuit, but took the shorter way across the part where the two bare wires touched each other. The lessened resistance caused a stronger current to flow and this made the wire so hot that it glowed.

Fuse cut-out protection

The iron wire acted as a fuse cut-out. It melted when the electric wiring was overloaded and so cut off the flow of current.

When the students have already carried out experiment S8 and have so found out that not all metals are attracted by a magnet, this experiment can be used as follow-up to determine which metals this applies to.

Metals which are attracted by magnets are called ferromagnets. They have regions in their grid structure in which elementary magnetic moments are arranged in parallel. Only iron, nickel and cobalt have ferromagnetic properties at room temperature. Some metals from the lanthanide series have them at very low temperatures.

Material

1	Bar magnet, l=150mm	06310-00
1	Copper electrode	45212-00
1	Zinc electrode	45214-00
1	Iron electrode	45216-00
1	Aluminium electrode	45217-00
1	Nickel electrode	45218-00

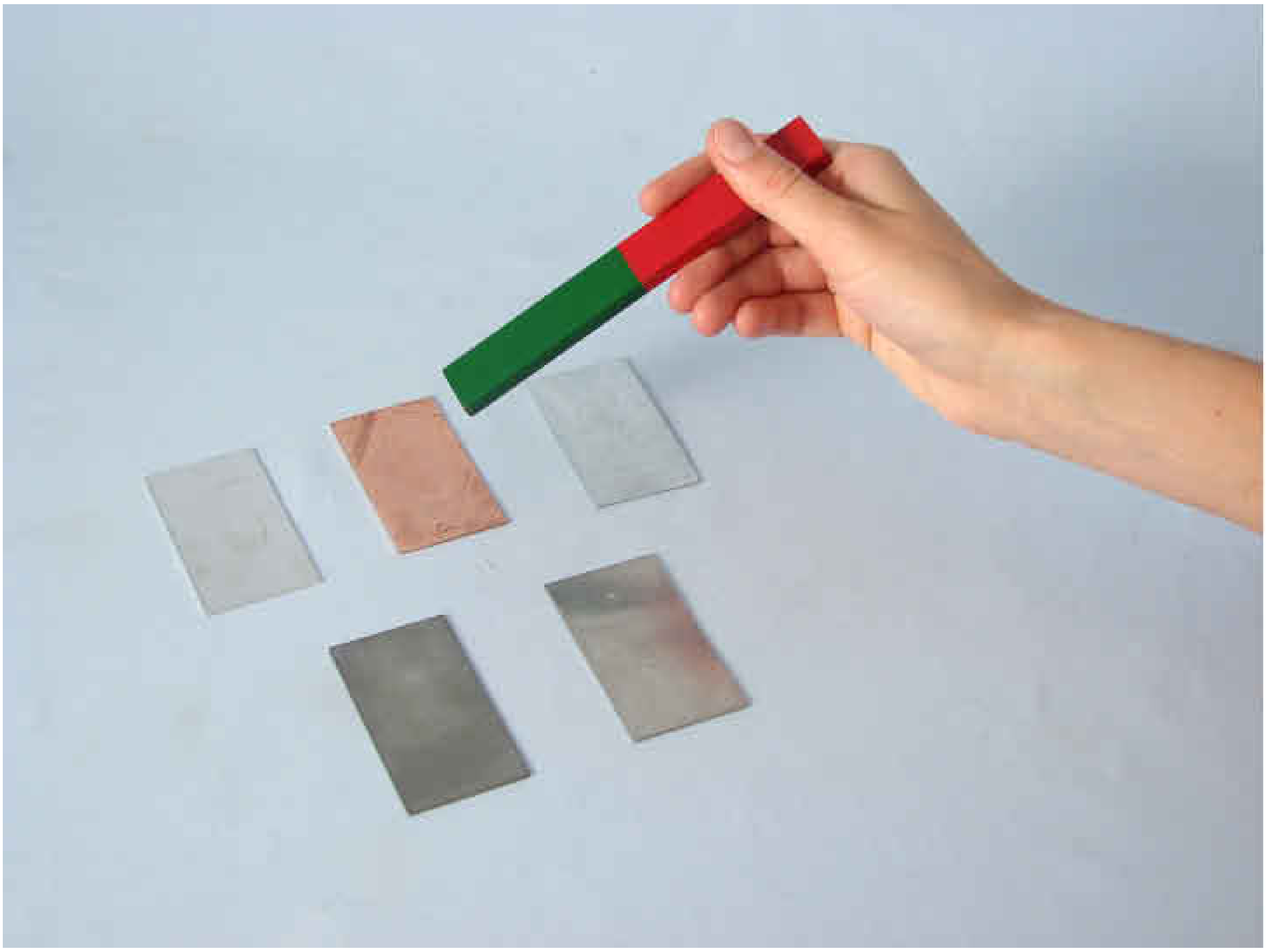


Fig. 1

Set up and procedure

- Examine and compare the plates of metal. Make assumptions on which are magnetic and which are not.
- Use the magnet to successively determine which metals it attracts.

Observations

Only iron and nickel are attracted by the magnet. Copper, tin and aluminium are not attracted.

Evaluation

Magnets only attract the metals iron, nickel and cobalt.
Iron is important in steel production. Steel is an alloy of iron and various other elements which are mixed in it to bring about wanted characteristics.
Nickel has a silvery white shine and is used in coins and as coating for other metals because of its permanence.
Cobalt, a sample of which is included in the set, is a very hard metal with a bluish gray colour. It is used in steel to give alloys improved abrasion resistance.
Because of their special property, the three ferromagnetic metals are put to use everywhere where electromagnetism is technically applied, such as in generators, transformers and electric motors.

Iron is a ferromagnetic metal. There are regions in it in which the smallest magnetic units, the iron atoms, are arranged in parallel. These regions are not uniformly oriented in non-magnetic iron. The action of a permanent magnet is required to align them so that iron also becomes a magnet with a north pole and a south pole. This alignment can be broken up again, for example, by means of a permanent magnet or a strong blow. When a magnet is divided into smaller pieces, each piece is a complete magnet with a north pole and a south pole, as this property is inherent in the elementary magnets.

Material

1	Bar magnet, l=150mm	06310-00
1	Pocket compass	06350-00
1	Sprinkler w. iron powder	06305-10
1	Iron wire, notched, 5 bars	326875

1 Sheet of white A4 paper

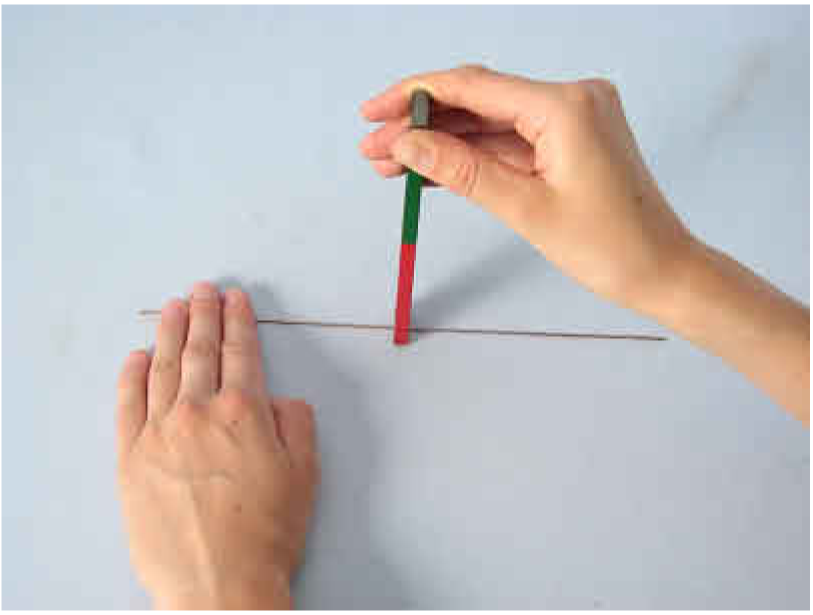


Fig. 1

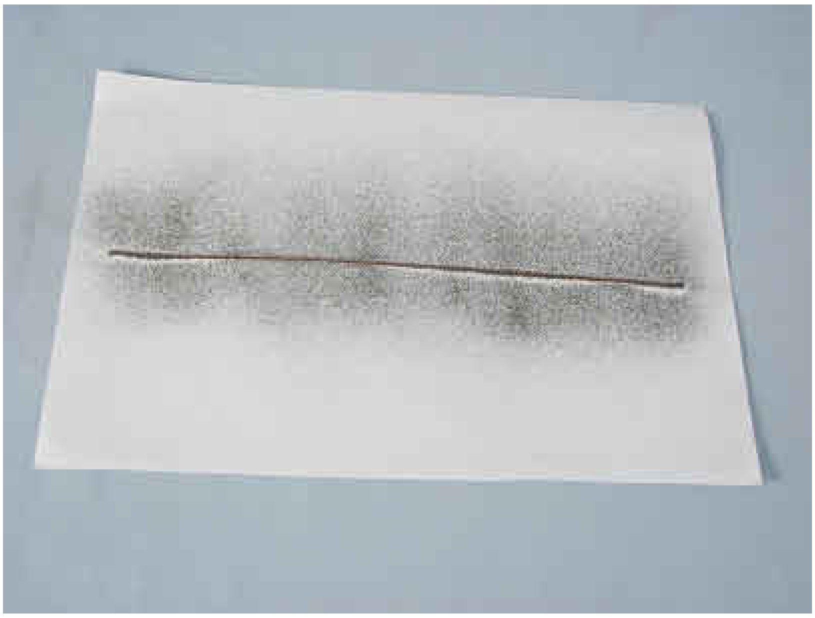


Fig. 2

Set up and procedure

- The notched iron wire must be non-magnetic at the start of the experiment. To remove residual magnetism, move a magnet over the whole length of the wire, first in one direction, then in the other direction, while you keep bringing it a little further away from the wire. You can alternatively insert the wire in a coil with 1600 turns (article no. 07830-01) and then use a power supply (article no. 13505-93) to apply a 10 V alternating voltage and slowly but continually reduce this to 0 V.
- First test the magnetic properties of the wire by placing it on a sheet of paper and scattering iron oxide powder over it.
- Now carry out the following procedure about 20 times.
- Stroke the wire with the magnet, starting with the magnet in the middle of the wire and drawing it to one end, then lift the magnet up a short distance above the wire when you bring it back to the middle of the wire.
- Again test the magnetic properties of the wire using iron oxide powder.
- Break the wire apart in the middle. Test each part with iron oxide powder.
- Break off another part and test the magnetic behaviour of it.

Observations

The demagnetized wire does not attract iron oxide powder. After the magnetizing procedure, powder hangs onto each end of the wire. When the magnetized wire is broken into two parts, powder is attracted to the ends of each part. This is also the case when a further part is broken off.

Evaluation

After having been stroked by the magnet, the notched iron wire has itself become a magnet with a north pole and a south pole. When it is broken into parts, each part is also a complete magnet with north and south poles.

One could theoretically keep on breaking parts up and still always have smaller and smaller complete magnets with north and south poles. In this case, however, the magnetic force of smaller magnets would soon be too weak to show magnetic properties with the iron oxide powder test. This is why the wire is only breaking it twice is recommended here.

