Conductive and non-conductive materials (Item No.: P6101300)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Natural Sciences	Age 11-14	Nature and technology	Electric and magnetic devices in daily use	Conductive and non-conductive materials

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	30 Minutes	2 Students

Additional Requirements:

- Distilled water
- Common salt
- Sugar
- Spoon
- Agitator rod

Experiment Variations:

- Digital measurement data recording with a tablet PC and Cobra4 sensor

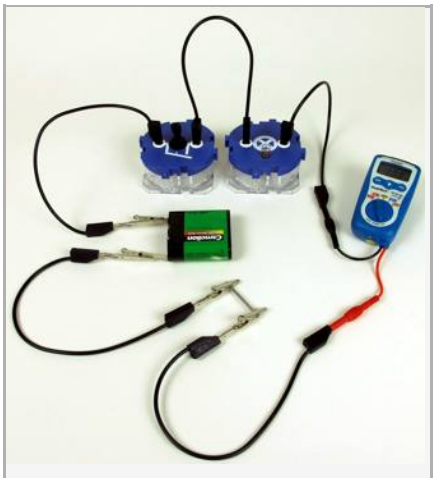
Keywords:

Conductor, non-conductor, material property, electrical conductivity, solid, liquid, electric circuit, metals, non-metals, electrolyte

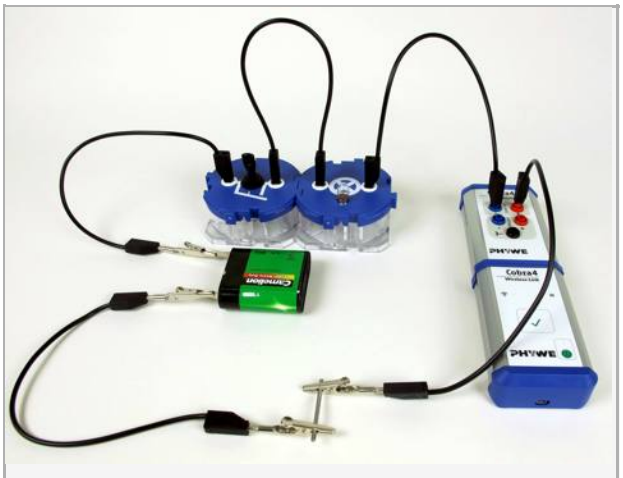
Information for the teacher

Educational objective and competences

During this experiment, the students will examine various solids and liquids in terms of their electric conductivity. They will notice that some materials conduct electricity while others do not. They will conclude that electric conductivity depends on the material. In addition, they will learn that non-conducting liquids can become conductive when specific substances are dissolved in these liquids.



Standard experiment set-up



Experiment set-up for measurements with a tablet PC

Competences

Process-related competences:

K: Knowledge gain
C: Communication
A: Assessment

The students can...

K 01 – name aspects which may have an influence and distinguish between significant and insignificant ones.
K02 – develop problem-related questions and formulate hypotheses.
K04 – prepare simple circuit diagrams to support their reasoning.
K05 – use specialised knowledge, which they have already acquired, for solving problems.
K06 – execute simple experiments independently based on written instructions.
K08 – recognise technical concepts in examples from everyday life.
K09 – plan, execute and document simple experiments by themselves.
K11 – identify trends, structures and relationships in acquired data.
K12 – make assumptions about connections and causes.

C01 – reproduce acquired knowledge and use technical terms in a correct and systematic manner.
C02 – describe the technical connections and relationships in everyday language.
C03 – acquire measurement data and extract them from age-appropriate representations.
C05 – present their results with the aid of specified media.
C06 – express and accept criticism.
C07 – work in groups on their own initiative.
C08 – create drawings and circuit diagrams.
C09 – read age-appropriate, relevant texts and relay the content thereof.

A01 – appraise their own results based on a comparison with other groups.
A02 – recognise the role of scientific phenomena in their everyday life.
A03 – evaluate arguments, take up a position and substantiate their point of view.
A04 – follow the safety instructions and identify environmental aspects and explain their purpose/significance.
A06 – explain the areas of application in which scientific knowledge is of importance.
A07 – identify and state close connections with other subjects.
A08 – distinguish between the desired and undesired characteristics for the application of scientific effects.

Content-related competences:

S: Specialised knowledge

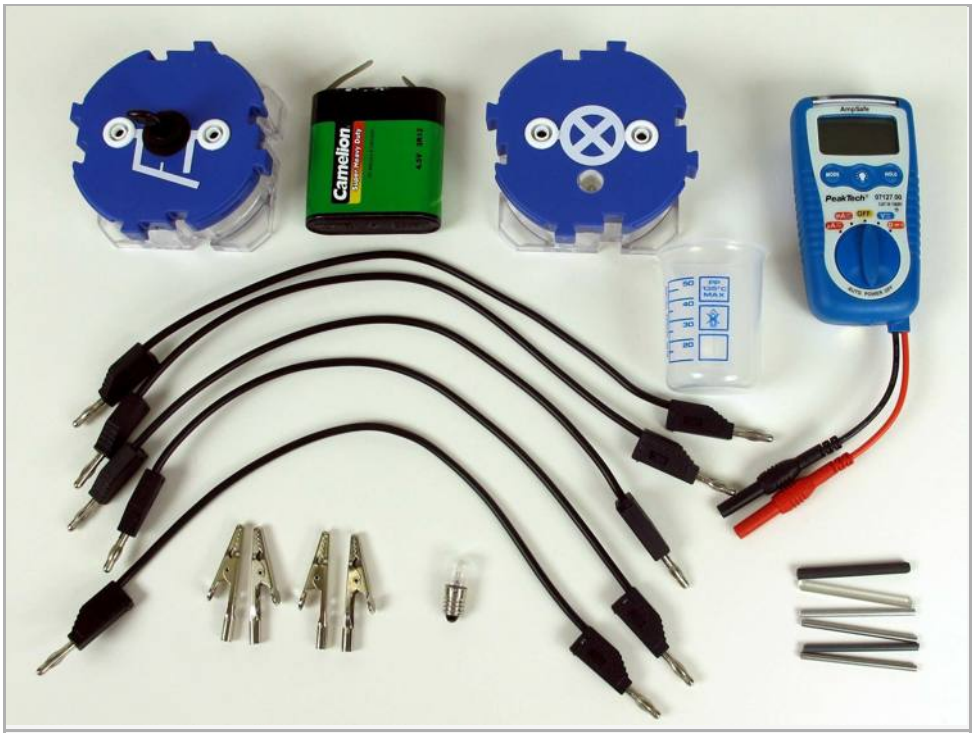
The students can...

S 06 – describe simple electric circuits.
S09 – identify and name various materials as conductors and non-conductors.
S10 – follow the relevant rules of conduct to prevent hazards caused by electricity.
S12 – identify and name the relevant effects of the electric current (heat, light, etc.).
S16 – set up simple "machines" and "devices".
S22 – describe and identify materials/substances based on their typical properties.
S23 – classify materials and substances based on common properties and justify this classification.
S24 – identify material properties under guidance and with the help of suitable measurement methods and devices.
S29 – identify and name substances based on their composition and classify them as pure substances/mixtures, metals/non-metals, elements/compounds, etc.

Equipment

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Position No.	Material	Order No.	Quantity
1	Flat battery, 4.5 V	07496-01	1
2	On/off switch	09390-07	1
3	Lamp holder, E10, with sockets	09390-06	1
4	Lamp 4 V/0.04 A, E 10	06154-00	1
5	Alligator clips, bare, 10 pcs	07274-03	(4)
6	Connecting cord, 32 A, 250 mm, black	07360-05	5
7	Conductors/non-conductors, l = 50 mm	06107-01	1
8	Beaker, low form, PP, 50ml	46273-01	1
9	Digital multimeter for pupils, AmpSafe, electronic overload protection	07127-00	1
Additionally required:			
10	Water, distilled 5 l	31246-81	1
11	Sodium chloride, 250 g	30155-25	1
12	D (+)-Sucrose, 100 g	30210-10	1
13	Spoon, stainless steel, l = 210 mm	40874-00	1
14	Glass rod, boro 3.3, l = 300mm, d = 9 mm	40485-07	1



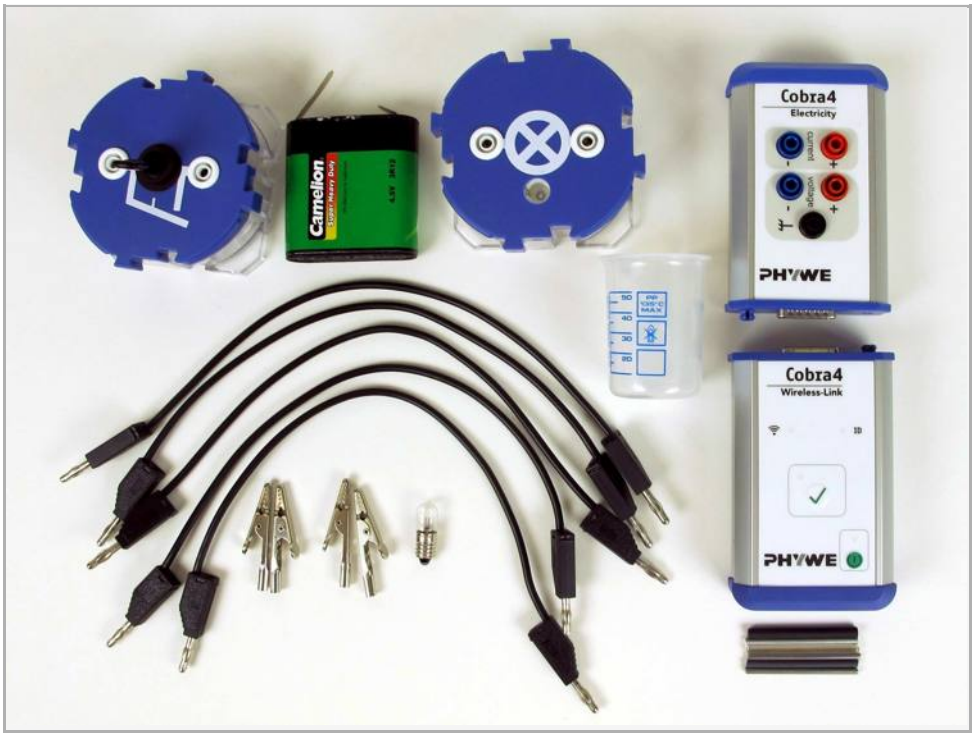
Additional material for measurements with a tablet PC

In order to perform the experiment with digital measurement data recording via a tablet PC, the following additional material is required.

The digital multimeter is not required for this variant.

Position No.	Material	Order No.	Quantity
1	Cobra4 Wireless/USB-Link	12601-09	1
2	Cobra4 Sensor-Unit Electricity, Strom/Spannung ±6 A, ±30 V	12644-00	1
3	Apple iPad		1
4	PHYWE measure App		1

Download on the App Store



Safety information

For this experiment, the general notes and instructions concerning safe experimentation in science classes apply.

Didactic notes

Procedure

- The students should already know how a simple electric circuit with a series connection works.
- In general, the students know already that metals conduct electricity. In this experiment, they will learn that there are non-metal materials that also conduct electricity.
- The students cannot directly see which materials are included in the "Conductors and non-conductors" set. Go through the materials before the experiment so that the materials can be named correctly in the experiment report. The materials include stainless steel (twice), PVC (plastic), aluminium, coal and glass.
- The lamp in the electric circuit is used to limit the current in the case of solid materials and also to indicate whether current is flowing or not. Due to the relatively short length and large diameter of the "wires" that are used for the experiment, the current intensities do not differ greatly from one another when the conducting materials are examined. The aim of the experiment is simply to see whether a specific material conducts electricity or not.
- Since a battery is used for the experiment, the set-up does not present any electrical hazards. However, we still recommend using the ON/OFF switch, since the students may not be able to determine when electricity is dangerous. Make sure that the students always interrupt the electric circuit when they change the set-up of the experiment.

Tablet PC option

In addition to the classic variant, you can also let the students perform the experiment with the Cobra4 equipment and tablet PCs. The digital measurement data recording method enables the students to quickly acquire the measurement data, understand them more readily and to evaluate them in a particularly comfortable way.

- Remove the multimeter from the set-up and replace it with the Sensor-Unit Electricity connected to the Cobra4 Wireless/USB-Link. The students perform the same measurements with the Sensor-Unit and evaluate the digital measurement values. If the students save their measurement values for each material, they can retrieve the exact values after the execution of the experiment and use them for the questions in the experiment report.
- Due to the constant current intensity of the experiment, we recommend using the digital display option and not the diagram representation of the app.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Conductive and non-conductive materials (Item No.: P6101300)

Standard experiment

Introduction

Maybe you have already touched an electric fence and have experienced a (painful) electric shock. Electric fences are usually supplied with current from a battery which is connected to the fence via an electric cable.

If you touch this cable, you do not get an electric shock although electric current flows through this cable just like through the electric fence. How can this phenomenon be explained?

Application

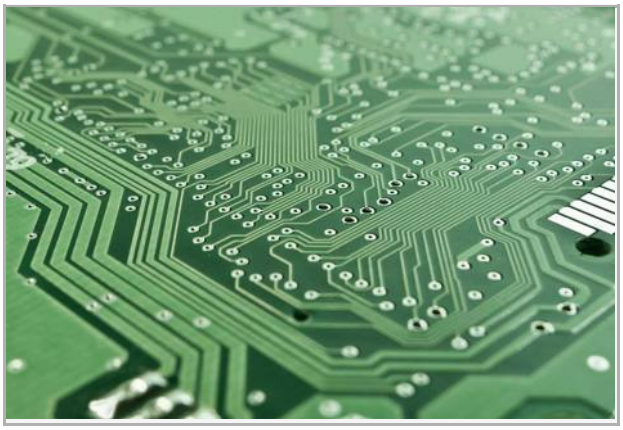
The electric cable between the battery and fence is usually covered with plastic with the actual metal conductor inside. The inside of the cable transfers the current to the electric fence, while the plastic cover does not conduct any current. This is why you do not get an electric shock when you touch the cable.

Materials that conduct electricity are called conductors. On the other hand, materials that do not conduct electricity are called non-conductors or insulators.

Conductors and non-conductors play an important role in our everyday life:

- Conductors are used to let electric current flow. They are often covered by non-conductors in order to prevent hazards to people.

- The printed circuit board in a smartphone or computer has numerous conductive tracks that are separated from one another by non-conducting layers. This prevents interference between the various circuits.



- Not only solid materials can conduct electricity. There are also liquids or substances dissolved in water that can do this. Substances or materials that do not usually conduct electricity can become conductors when they are moist!

Task

During this experiment, you will examine the electric conductivity of several materials and substances to find out which of them conduct electricity.

You know already that electric current can only flow within a closed electric circuit. Integrate different materials into an electric circuit and see whether a lamp in the circuit illuminates and whether current flows.

1. Set the electric circuit up and integrate different rods.
2. Integrate a beaker into the electric circuit and fill it with several different liquids.

Experiment set-up

Assumption

Which materials conduct electricity?

Initial question

Before the experiment, contemplate which materials are likely to conduct electricity.

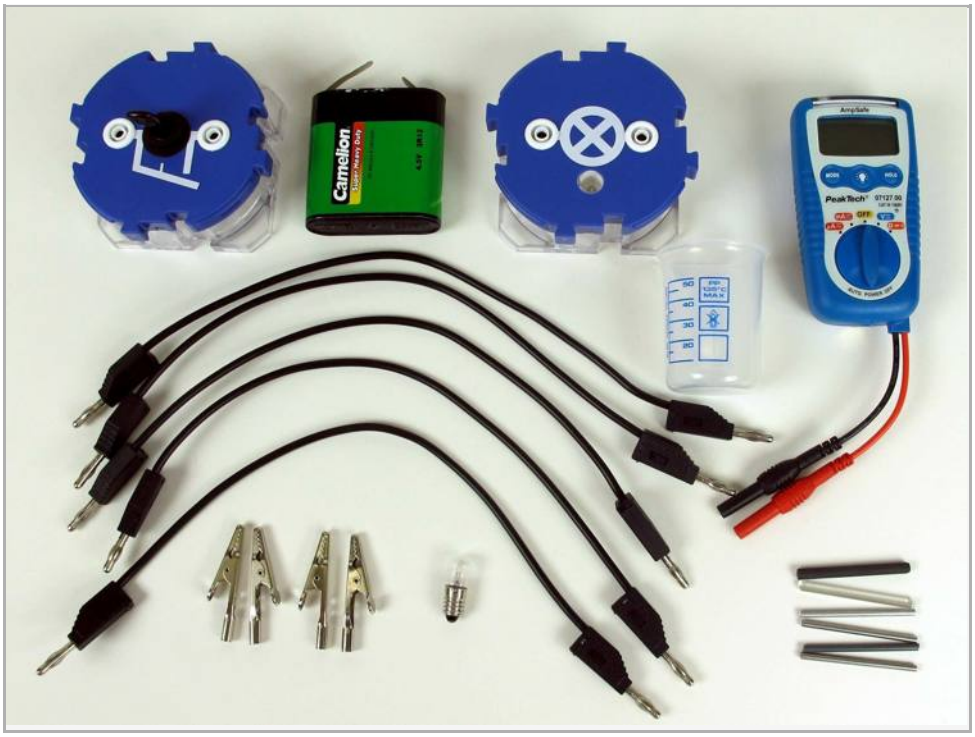
- [ ] Stainless steel
- [ ] Plastic
- [ ] Aluminium
- [ ] Coal
- [ ] Glass
- [ ] Common salt
- [ ] Sugar
- [ ] Distilled water
- [ ] Salt water
- [ ] Sugar water

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com

Equipment and procedure



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13	Spoon, stainless steel, l = 210 mm	40874-00	1
14	Glass rod, boro 3.3, l = 300mm, d = 9 mm	40485-07	1

Set-up

Set the experiment up as shown in Figure 1.

Fig. 1

Before you connect the battery, ensure that the ON/OFF switch is set to off. To do so, set the lever to the OFF position as shown in Fig. 2

This is to ensure that current will not flow through the electric circuit. Turn the switch on only for the measurement and switch if off again immediately afterwards.

Do not change the set-up of the experiment unless the ON/OFF switch is set to off!

Fig. 2: Switch in the OFF position

Set the electric circuit up in the following order:

Battery – ON/OFF switch – lamp holder – ammeter – conductor and non-conductor (start with a rod of your choice) – battery

Use cables to connect the components.

- You can connect the cables directly to the blue components and also to the ammeter.
- Connect a crocodile clip to each of the battery terminals and to the ends of the rods. You can then connect the cables to the clips.

Insert the lamp into the lamp holder.

Procedure

Switch the ammeter on for the measurement. To do so, set the selector switch to mA. Press the "Mode" button until "DC" is displayed on the screen.

1. Examine the behaviour of the rods of the "Conductors and non-conductors" set. Start with the rod that you have integrated in the electric circuit as described under "Set-up".

   Turn the ON/OFF switch on. The electric circuit is now closed.

   Observe the lamp and measure the current with the measuring instrument.

   Turn the ON/OFF switch off again.

   Remove the rod from the electric circuit and integrate the next rod.

   Repeat the measurement with all of the rods from the set. Ensure that the switch is always off when you change the rods.

   Enter your observations into the table of the experiment report.

2. Now, remove the last rod. Instead, clamp the cables to the rim of the beaker as shown in Fig. 3.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Fig. 3

Fill the beaker completely with common salt.

Turn the ON/OFF switch on. The electric circuit is now closed.

Observe the lamp and measure the current with the measuring instrument.

Turn the ON/OFF switch off again.

Remove the common salt completely from the beaker.

Repeat the measurement with sugar and remove the sugar after the measurement.

Fill distilled water into the beaker until it touches both crocodile clips.

Turn the ON/OFF switch on. The electric circuit is now closed.

Observe the lamp and measure the current with the measuring instrument.

Turn the ON/OFF switch off again.

Enter your observations into the table of the experiment report.

---

3. Add a teaspoon of salt to the distilled water in the beaker. Stir the water with the agitator rod so that the salt dissolves until it can no longer be seen.

   Turn the ON/OFF switch on. The electric circuit is now closed.

   Observe the lamp and measure the current with the measuring instrument.

   Turn the ON/OFF switch off again.

   Empty the beaker and rinse it.

   Fill it once again with distilled water and add a teaspoon of sugar. Dissolve the sugar and repeat the measurement.

   Note down your observations in the experiment report.

Switch the ammeter off by turning the selector switch to OFF.

Evaluation

During the experiment, you have observed a lamp in the electric circuit and an ammeter indicating the flow of current in order to find out whether different types of material conduct electricity.

Go to the experiment report and answer the questions about the experiment.

Robert-Bosch-Breite 10
D - 37079 Göttingen
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Experiment (with a tablet PC)

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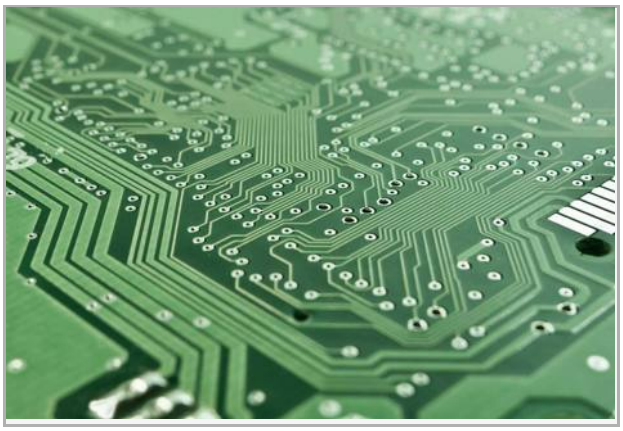

- Not only solid materials can conduct electricity. There are also liquids or substances dissolved in water that can do this. Substances or materials that do not usually conduct electricity can become conductors when they are moist!

Task

During this experiment, you will examine the electric conductivity of several materials and substances to find out which of them conduct electricity.

You know already that electric current can only flow within a closed electric circuit. Integrate different materials into an electric circuit and see whether a lamp in the circuit illuminates and whether current flows.

1. Set the electric circuit up and integrate different rods.
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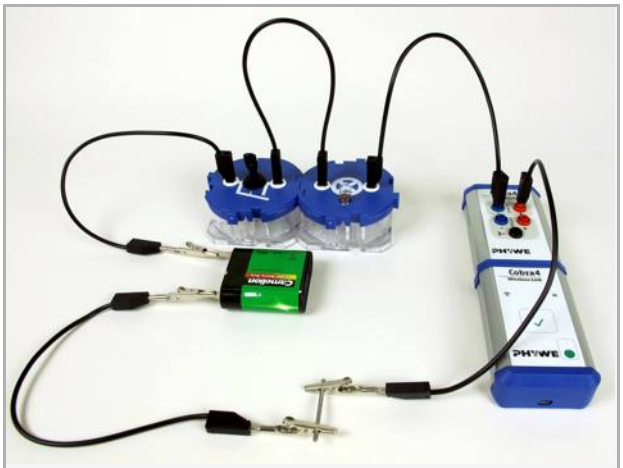


Experiment set-up

Assumption

Which materials conduct electricity?

Initial question

Before the experiment, contemplate which materials are likely to conduct electricity.

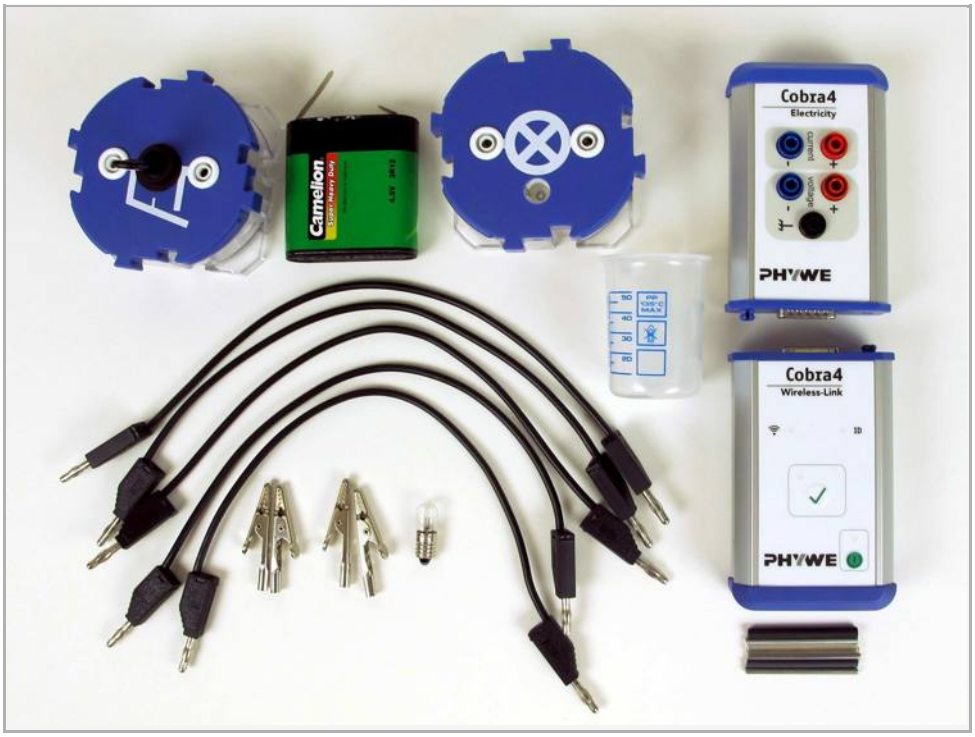
- [ ] Stainless steel
- [ ] Plastic
- [ ] Aluminium
- [ ] Coal
- [ ] Glass
- [ ] Common salt
- [ ] Sugar
- [ ] Distilled water
- [ ] Salt water
- [ ] Sugar water

Equipmernt and procedure

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com



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8	Beaker, low form, PP, 50ml	46273-01	1
9	Cobra4 Wireless/USB-Link	12601-09	1
10	Cobra4 Sensor-Unit Electricity, current ± 6A / voltage ± 30V	12644-00	1
11	Apple iPad		1
12	PHYWE measure App		1
Additionally required:			
13	Water, distilled 5 l	31246-81	1
14	Sodium chloride, 250 g	30155-25	1
15	D (+)-Sucrose, 100 g	30210-10	1
16	Spoon, stainless steel, l = 210 mm	40874-00	1
17	Glass rod, boro 3.3, l = 300mm, d = 9 mm	40485-07	1

Set-up

Set the experiment up as shown in Figure 1.

Robert-Bosch-Breite 10
D - 37079 Göttingen
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Fax: +49 551 604 - 107
info@phywe.de
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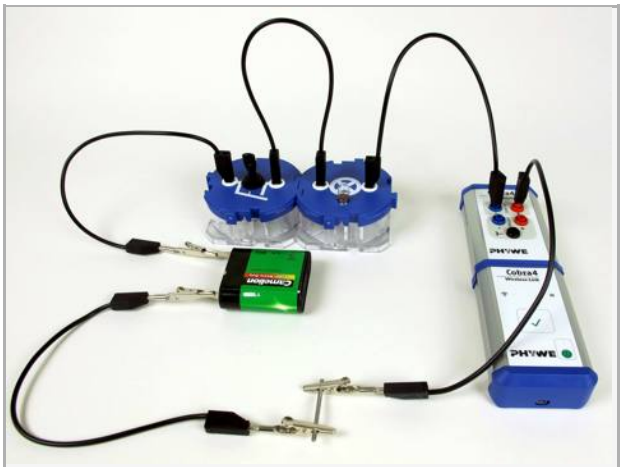

Fig. 1

Before you connect the battery, ensure that the ON/OFF switch is set to off. To do so, set the lever to the OFF position as shown in Fig. 2

This is to ensure that current will not flow through the electric circuit. Turn the switch on only for the measurement and switch if off again immediately afterwards.

Do not change the set-up of the experiment unless the ON/OFF switch is set to off!

Fig. 2: Switch in the OFF position

Set the electric circuit up in the following order:

Battery - ON/OFF switch – lamp holder – ammeter - conductor and non-conductor (start with a rod of your choice) - battery

Use cables to connect the components.

- You can connect the cables directly to the blue components and also to the ammeter.
- Connect a crocodile clip to each of the battery terminals and to the ends of the rods. You can then connect the cables to the clips.

Insert the lamp into the lamp holder.

Procedure

Connect the ''Wireless/USB-Link" and the sensor and switch the device on.

Connect your tablet PC with the "Wireless/USB-Link" and open the "measure" app .

Select the connected sensor.

Open the digital display and select the channel "Current I".

1. Examine the behaviour of the rods of the "Conductors and non-conductors" set. Start with the rod that you have integrated in the electric circuit as described under "Set-up".

   Turn the ON/OFF switch on. The electric circuit is now closed.

   Observe the lamp and measure the current with the measuring instrument.

   Turn the ON/OFF switch off again.

   Remove the rod from the electric circuit and integrate the next rod.

   Repeat the measurement with all of the rods from the set. Ensure that the switch is always off when you change the rods.

   Enter your observations into the table of the experiment report.

2. Now, remove the last rod. Instead, clamp the cables to the rim of the beaker as shown in Fig. 3.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com

Fig. 3

Fill the beaker completely with common salt.

Turn the ON/OFF switch on. The electric circuit is now closed.

Observe the lamp and measure the current with the measuring instrument.

Turn the ON/OFF switch off again.

Remove the common salt completely from the beaker.

Repeat the measurement with sugar and remove the sugar after the measurement.

Fill distilled water into the beaker until it touches both crocodile clips.

Turn the ON/OFF switch on. The electric circuit is now closed.

Observe the lamp and measure the current with the measuring instrument.

Turn the ON/OFF switch off again.

Enter your observations into the table of the experiment report.

---

3. Add a teaspoon of salt to the distilled water in the beaker. Stir the water with the agitator rod so that the salt dissolves until it can no longer be seen.

   Turn the ON/OFF switch on. The electric circuit is now closed.

   Observe the lamp and measure the current with the measuring instrument.

   Turn the ON/OFF switch off again.

   Empty the beaker and rinse it.

   Fill it once again with distilled water and add a teaspoon of sugar. Dissolve the sugar and repeat the measurement.

   Note down your observations in the experiment report.

Evaluation

During the experiment, you have observed a lamp in the electric circuit and an ammeter indicating the flow of current in order to find out whether different types of material conduct electricity.

Go to the experiment report and answer the questions about the experiment.

Robert-Bosch-Breite 10
D - 37079 Göttingen
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Fax: +49 551 604 - 107
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Report: Conducting and non-conducting materials

Observation - table

Enter your observations into the table.

With which materials does the lamp illuminate? What does the ammeter indicate?

	Does the lamp illuminate?		Current (mA)	
Stainless steel	yes	1	39	1 ±2
Plastic	no	1	0	1 ±1
Aluminium	yes	1	39	1 ±2
Glass	no	1	0	1 ±1
Coal	yes	1	39	1 ±2
Common salt	no	1	0	1 ±1
Sugar	no	1	0	1 ±1
Water (distilled)	no	1	0	1 ±1
Salt water	yes	1	39	1 ±2
Sugar water	no	1	0	1 ±1

Observation - question 1

Does the lamp always illuminate when you connect one of the rods into the electric circuit?

No, the lamp illuminates only when a metallic rod (stainless steel or aluminium) or the coal rod is connected in the electric circuit.

It does not illuminate with the other rods (glass, plastic).

Observation - question 2

Compare your measurements. What did the ammeter indicate when the lamp was illuminated?

What does that mean?

When the lamp is illuminated, the measuring instrument always indicates a current of approximately 40 mA.

This means that, in this case, current flows through the entire electric circuit.

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
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Observation - question 3

You already know that metals conduct electricity.

However, are all non-metals non-conductors?

No, there are in fact non-metals that conduct electricity as well.

During the experiments, you have noticed that coal, for example, also conducts electricity.

Observation - question 4

You have examined the electric conductivity of salt water and sugar water.

What did you notice? Were you surprised by what you observed?

Neither salt nor sugar or distilled water alone conducts electricity.

Salt water, however, conducts electricity! However, the same is not true for all substances that can be dissolved in water.

Sugar water, for example, does not conduct electricity!

This is due to the properties of the solutions which seem to differ from one another.

Evaluation - question 1

Name several good electric conductors:

Stainless steel

Aluminium

Iron

Copper

Lead

Gold

Silver

Brass

Metals

Coal

Salt water

Acids

Bases

Robert-Bosch-Breite 10
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Tel: +49 551 604 - 0
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Evaluation - question 2

Name good insulators (non-conductors):

Glass

Polymer

Plastic

Glass

Wood

Porcelain

Air

Gases

Evaluation - question 3

Materials with which the lamp illuminates are called conductors.

Materials with which the lamp does not illuminate are called non-conductors,insulators.

Evaluation - question 4

Apply the knowledge that you have acquired during the experiment.

Which parts of the electric circuit are conductors? You should not touch them in a closed electric circuit!

- [x] Terminal of the battery
- [ ] Plastic parts of the cablesl
- [ ] Switches
- [x] Crocodile clips
- [x] Aluminium rod
- [ ] Glass rod
- [ ] Plastic beaker
- [ ] Ammeter

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D - 37079 Göttingen

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Initial question (repeated)

Before the experiment, you have contemplated which materials are likely to conduct electricity. Was your assumption correct?

After you have completed your observations, once again select those materials that conduct electricity:

- [x] Stainless steel
- [ ] Plastic
- [x] Aluminium
- [x] Coal
- [ ] Glass
- [ ] Common salt
- [ ] Sugar
- [ ] Distilled water
- [x] Salt water
- [ ] Sugar water

Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com