Electric field strength

Task and equipment

Information for teachers

Learning target

With this experiment the students will observe how a homogeneous electric field between two rod electrodes changes when the voltage between the electrodes is altered. The students will make conclusions based on the distribution of equipotential lines. They will draw the electric field pattern for two voltage configurations and elaborate the concept of the electric field strength.

Previous knowledge

To be well prepared for the experiment, the students should be familiar with the concepts of equipotential lines and field lines. They should know that a voltage is equivalent to the difference in electric potentials between two points of an electric field, and that applying a voltage to two electrodes causes an electric field to build up. What is more, in previous Mechanics lessons the relationships of work, force and distance should have been dealt with.

Notes on the procedure

- If you put manifold paper and white paper between the carbon paper and the polycarbonate plate, you will be able to push the points of measurement through onto the white paper with the knitting needle. This way the carbon paper can be used multiple times.
- For a symmetric field distribution the electrodes need to be in good contact with the plane of resistance (the carbon paper). Thus check prior to the measurement of the field if the electrodes are pressed equally firmly onto the carbon paper. You should also create a conducting layer of graphite between the electrodes and the carbon paper using a soft pencil.
- The digital multimeter (DMM), which is used to measure the voltage, needs to have a high inner resistance (> 10 MΩ). Lacking this high resistance, there will be an electric current in the measuring circuit on the carbon paper between the cathode (0 V) and the knitting needle. This current will change the electric field on the carbon paper and the measurement of the electric potential will be distorted.

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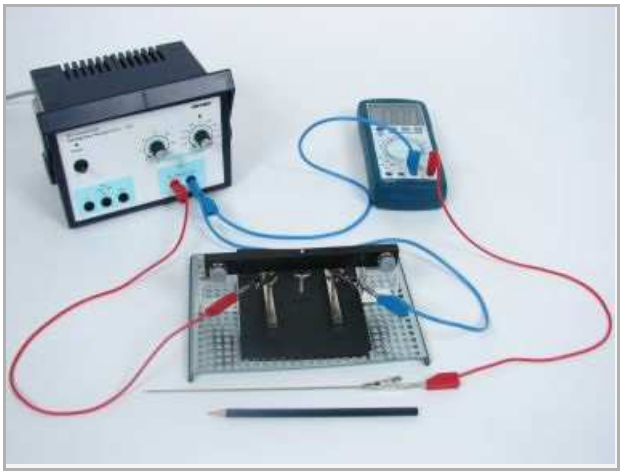
Task

What are the characteristics of homogeneous electric fields?

Investigate what happens to the homogeneous electric field between two parallel rod electrodes, when the voltage, applied to the electrodes, is changed.

1. First of all, determine the distribution of equipotential lines within the electric field between the two electrodes for two different voltages.
2. Derive the concept of the electric field strength and observe how this quantity is affected by a change in voltage.



Student's Sheet

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Equipment

Position No.	Material	Order No.	Quantity
1	DMM with NiCr-Ni thermo couple	07122-00	1
2	Mounting plate r, 16cmx21cm	13002-00	1
3	Universal holder, block R	13024-13	2
4	Polycarbonate plate, 136x112x1 mm	13027-05	1
5	Set of electrodes with holder for set equipotential lines	13027-24	1
6	Rod electrode	13027-24	1
7	Rod electrode with slot for tip-shape electrode	13027-24	1
8	Knitting needles, 20 pcs	06342-00	1
9	Alligator clips, bare, 10 pcs	07274-03	1
10	Carbon paper f.Equipot.30 sheets	13027-29	1
11	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
12	Connecting cord, 32 A, 250 mm, red	07360-01	2
13	Connecting cord, 32 A, 250 mm, blue	07360-04	2
Additional material			
14	Soft pencil		1

Set-up and procedure

Set-up

To get an impression of the experimental set-up, please view Fig. 1.

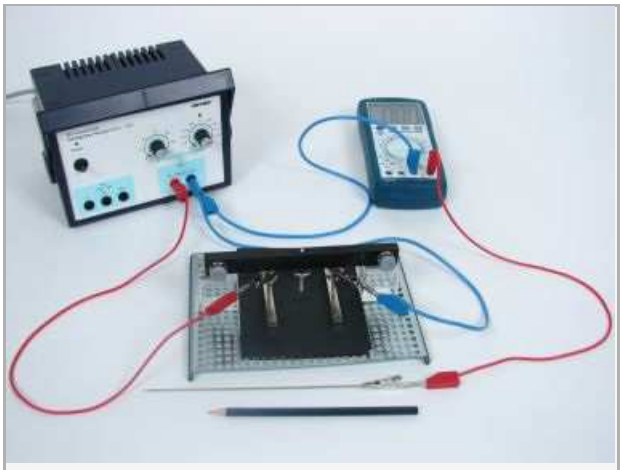

Fig. 1

Setting up the experiment, follow this procedure:

- Put the two universal holders onto the mounting plate, with the polycarbonate plate fitting just inbetween (Fig. 2).

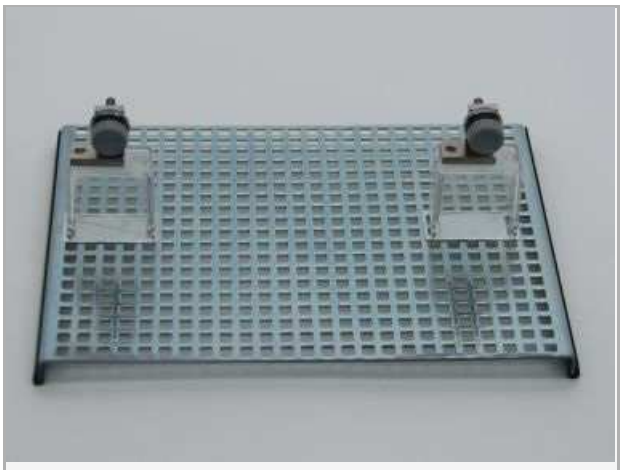

Fig. 2

- Completely loosen the knurled screws on both holders and use them to fix the electrode holder onto the universal holders (Fig. 3-4).

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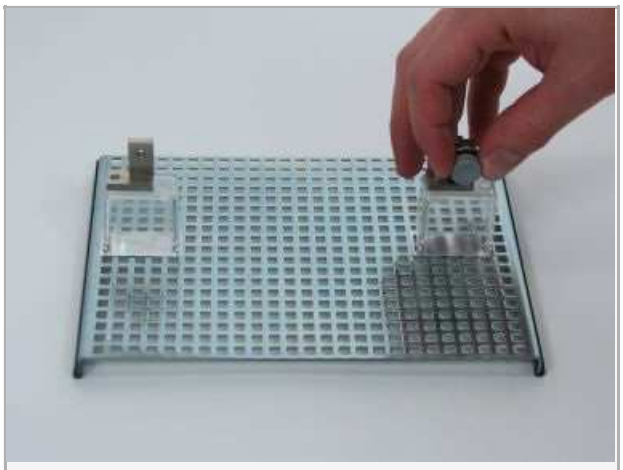

Fig. 3

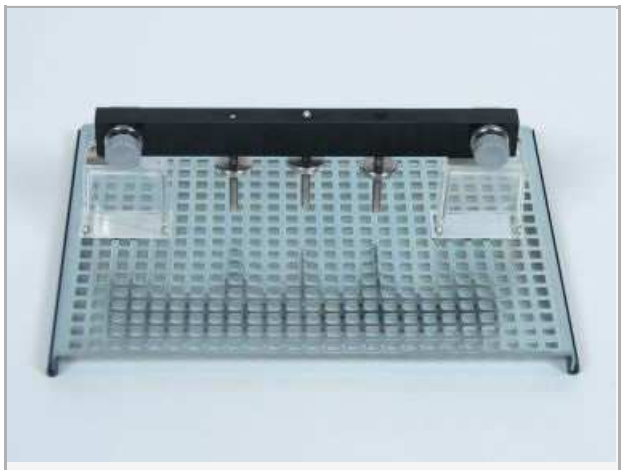

Fig. 4

- Cut a sheet of carbon paper, with a size of 130 mm x 100 mm, and put in on top of the polycarbonate plate (Fig. 5-6).

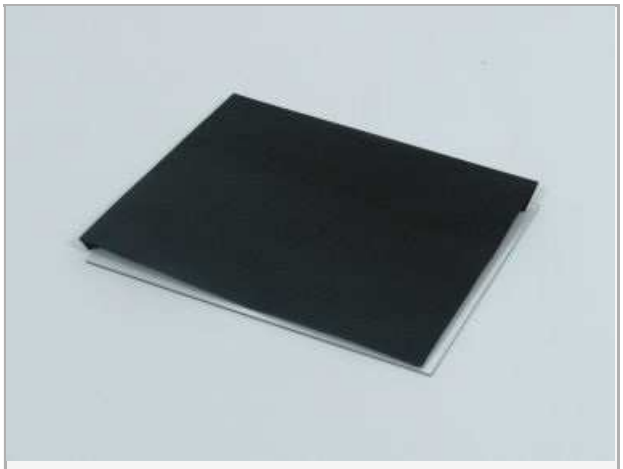

Fig. 5

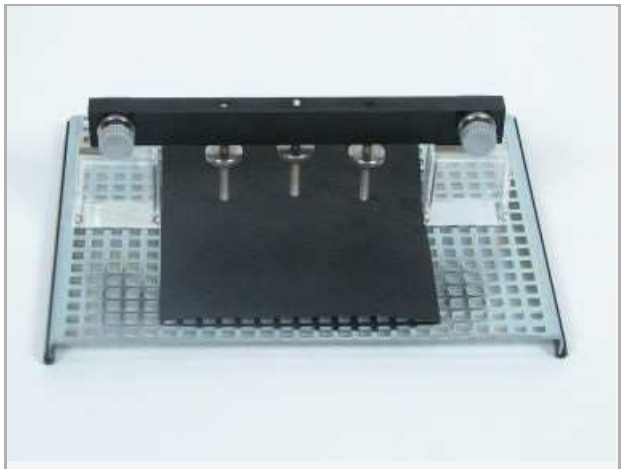

Fig. 6

- Place the two rod electrodes below the outer knurled screws, with the electrodes parallel to each other. One of the electrodes shows a slot. Turn this electrode so that the slot is facing away from the second electrode (Fig. 7). By tightening the knurled screws press both electrodes equally firmly onto the underlying plate (Fig. 8).

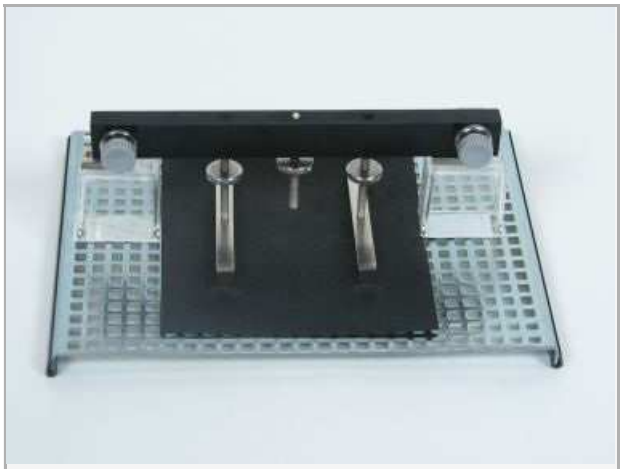

Fig. 7

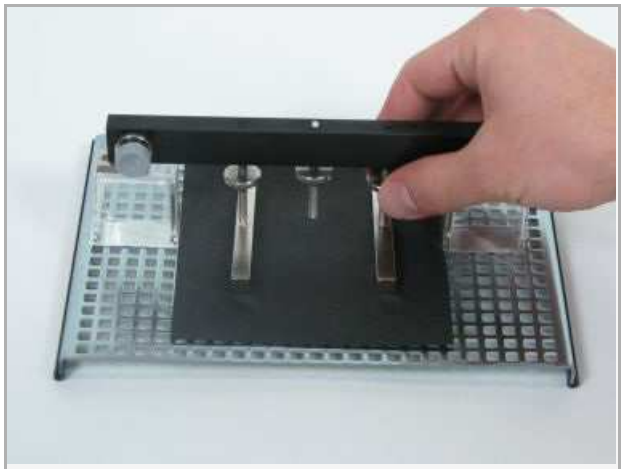

Fig. 8

- Draw the profiles of the electrodes on the carbon paper, loosen the knurled screws slightly and remove the carbon paper again (Fig. 9).
- Accurately fill the marked areas with a soft pencil (Fig. 10). The graphite of the pencil creates better contact between the

electrodes and the carbon paper so that, when applying a voltage to the electrodes, an electric field can be measured within the conducting carbon paper.

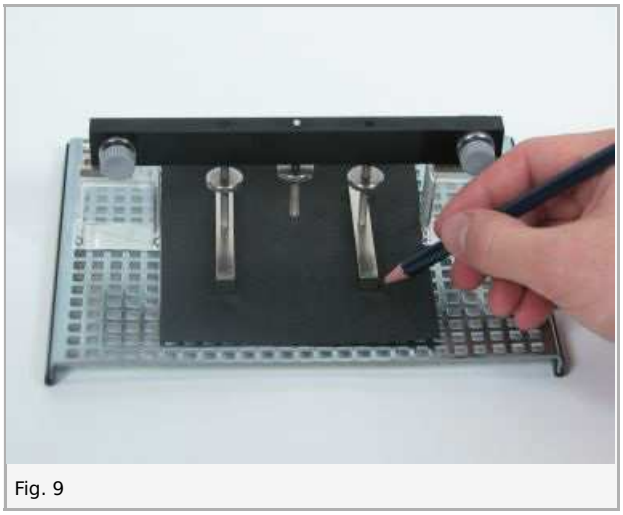

Fig. 9

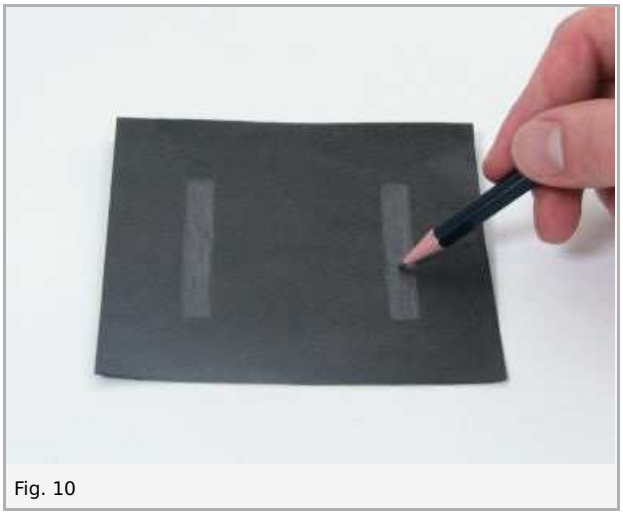

Fig. 10

- Put the carbon paper back into its original position, place the electrodes onto the marked areas and tighten them with the knurled screws on the carbon paper (Fig. 7-8).
- Connect both electrodes to the outputs of the power supply (Fig. 11).

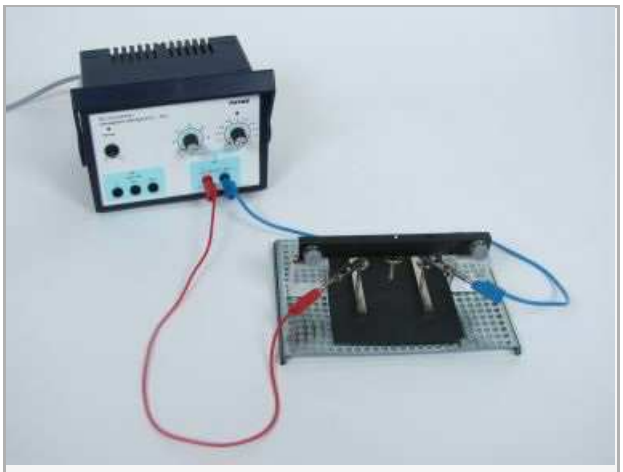

Fig. 11

- Connect the digital multimeter (DMM) to one output (0 V) of the power supply as well as with the knitting needle (Fig. 12-13). If the carbon paper contains an electric field and the knitting needle touches the carbon paper, the DMM will measure the voltage between the point of contact and the connected output of the power supply. If this output has 0 V, the measured voltage will be equivalent to the electric potential in the point of contact. Note: A voltage is always equivalent to a difference of electric potentials between two points.

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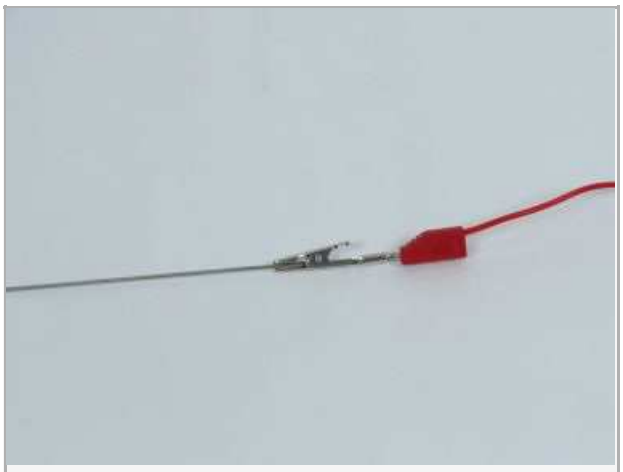

Fig. 12

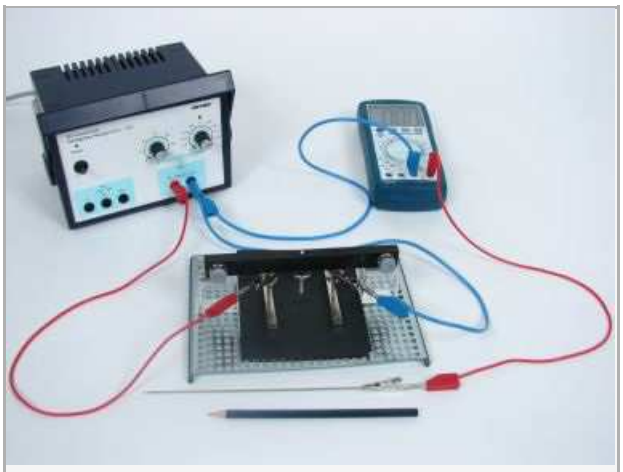

Fig. 13

Procedure

- Switch on the power supply and set its output to 10 V(DC). Attach the tip of the knitting needle to each of the two electrodes and check whether the electrodes have electric potentials of 0 V and 10 V respectively (Fig. 14-15). If necessary, adjust the DC output of the power supply.

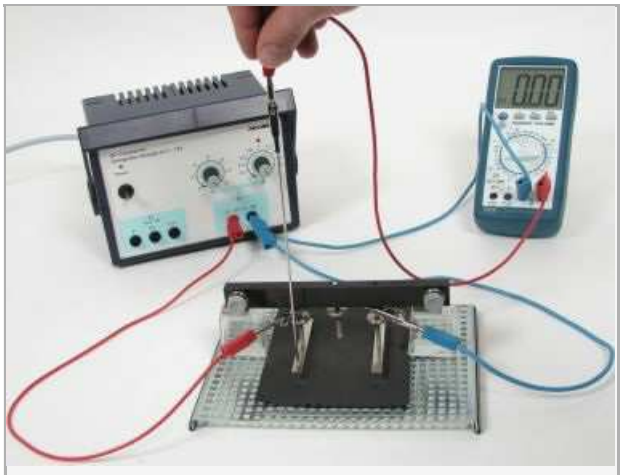

Fig. 14

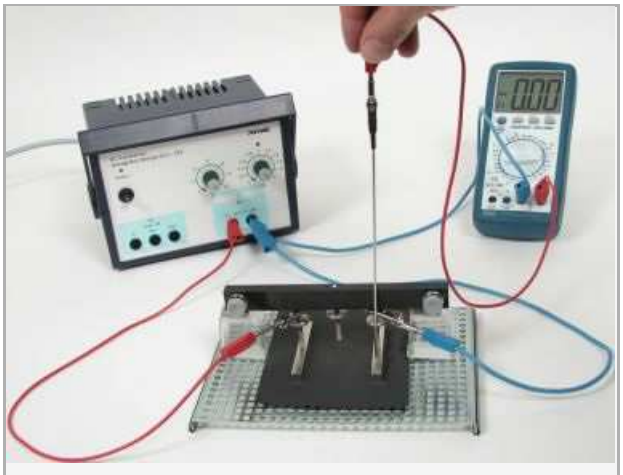

Fig. 15

- Find points on the carbon paper, which have the same electric potential. For this purpose scan the carbon paper with the tip of the knitting needle and mark the points with a pencil (Fig. 16). Scan for values of 1 V, 3 V and 5 V. Mark eight points for each value.

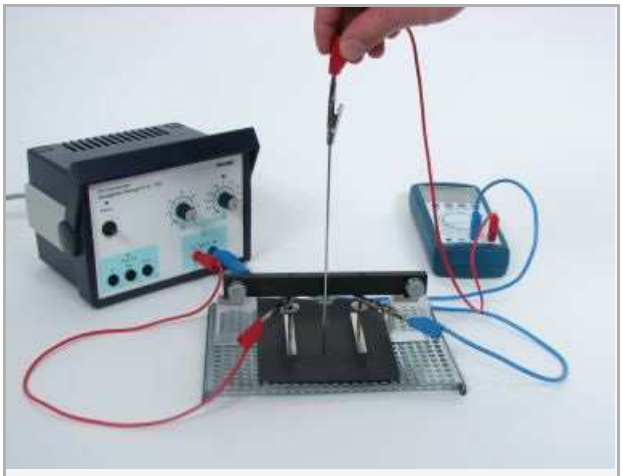

Fig. 16

- Adjust the DC output of the power supply to 5 V and check once more whether the electrodes have potentials of 0 V and 5 V respectively (Fig. 14-15).
- For electric potentials of 1 V and 3 V find eight points each on the carbon paper and mark these points with the pencil, too (Fig. 16). Instead of circles use small crosses.
- After completing the measurement, loosen the screws and remove the carbon paper.

Report: Electric field strength

Result - Sketch

Use a pencil and connect the points of equal electric potential as equipotential lines. Label each line by its electric potential. For the marked circles draw straight lines, for the marked crosses use dashed lines.

Evaluation - Question 1

What happens to the equipotential lines when the voltage is halved?

Evaluation - Question 2

A homogeneous electric field is characterized by the electric force being constant in all points of the field. Explain whether the two plotted fields are homogeneous or inhomogeneous.

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Evaluation - Question 3

For the first field (10 V voltage) draw seven field lines from the anode towards the cathode.

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Evaluation - Question 4

How much work is done by the electric field when a positively charged sample is displaced by the electric force F_e for a distance d?

Evaluation - Question 5

What is the voltage between any two points of the equipotential lines at 1 V and 3 V?

Evaluation - Question 6

The voltage U between two points A and B of an electric field is defined by the work, which has to be done by the field per charge q of a positively charged sample in order to displace the sample from A to B. Motivate why in the case of a displacement for a distance d by the force F_e the relation $U = F_e \cdot d / q$ is valid.

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Evaluation - Question 7

The quantity $E = F_e / q$ is referred to as electric field strength. For both fields (10 V and 5 V voltage) look at the distances of the equipotential lines at 1 V and 3 V. How does the electric field strength change when the voltage between the electrodes is halved?

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Evaluation - Question 8

For the first field you have already drawn seven field lines. Consider how many field lines you will have to draw for the second field if the density of field lines determines the magnitude of the electric field strength. Draw these field lines as dashed lines.

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