Electric fields

Task and equipment

Information for teachers

Learning target

With this experiment the students will learn about the concepts of “equipotential lines” and “field lines“, using the example of a homogeneous electric field. At first, the students will locate five equipotential lines of the electric field. They then will elaborate the corresponding field line distribution in the evaluation part.

Previous knowledge

To be well prepared for the experiment, the students should know that a voltage is equivalent to the difference in electric potentials between two points of an electric field. What is more, they should be familiar with the fact that applying a voltage to two electrodes (anode, cathode) causes an electric field to build up. This electric field exerts an electric force on charged samples. From previous Mechanics lessons it should be known that displacing a sample perpendicular to a force, exerted on the sample, does not demand any work to be done.

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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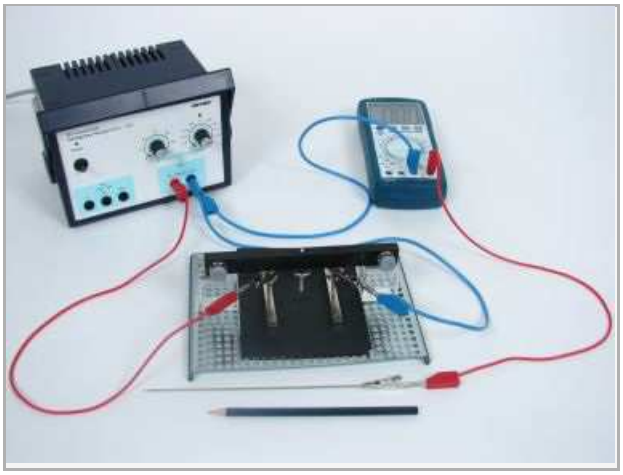
Task

How are equipotential lines and field lines distributed within electric fields?

Investigate the electric field, which is created by applying a voltage to two parallel rod electrodes:

1. Measure the distribution of the electric potential between the two electrodes and identify lines of equal potential (equipotential lines).
2. Determine the electric field pattern.



Student's Sheet

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Equipment

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

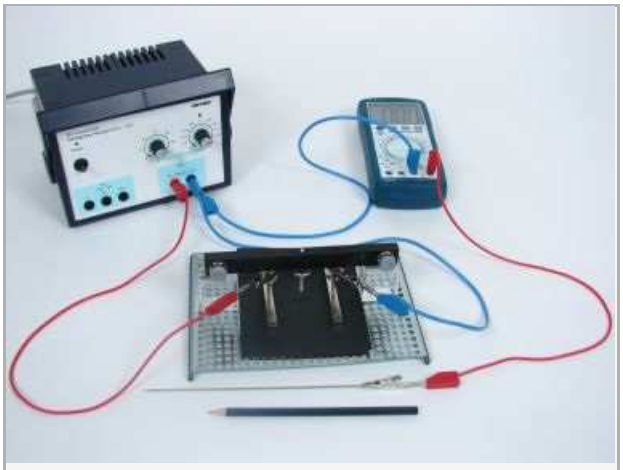

Fig. 1

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).

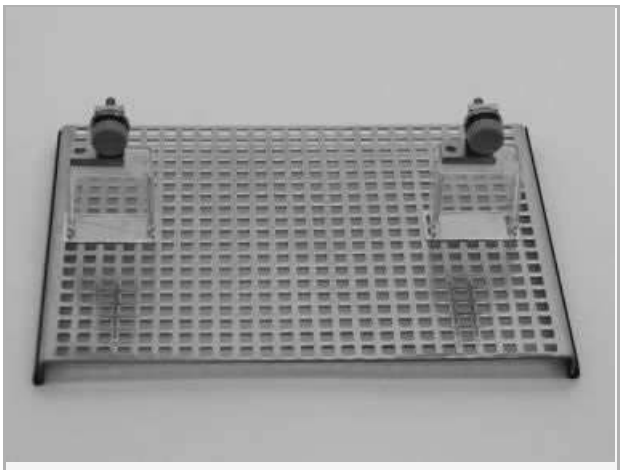

Fig. 2

- 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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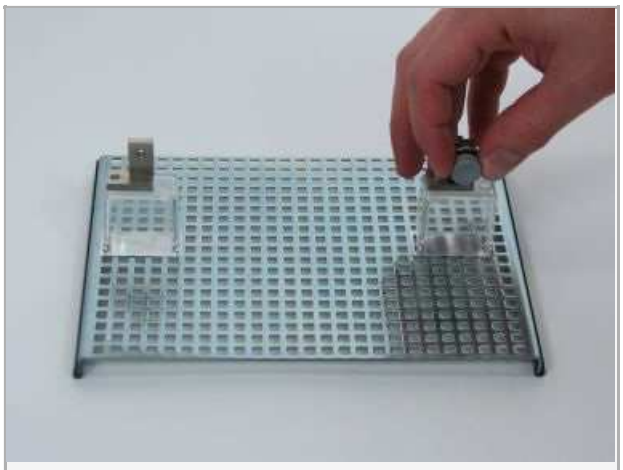

Fig. 3

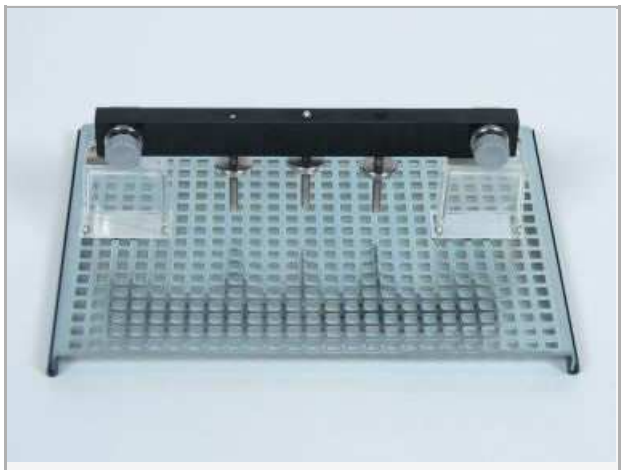

Fig. 4

- 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).

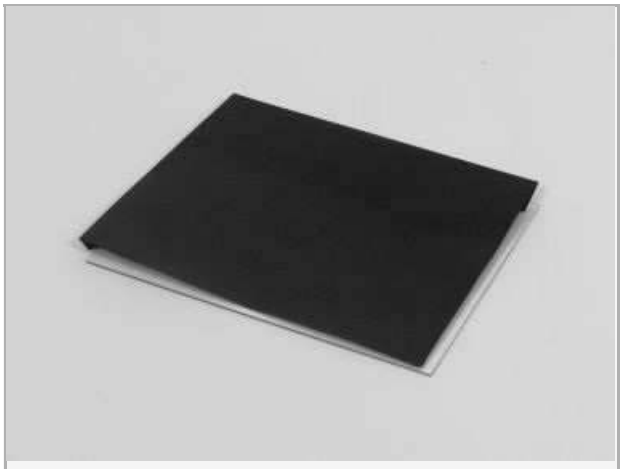

Fig. 5

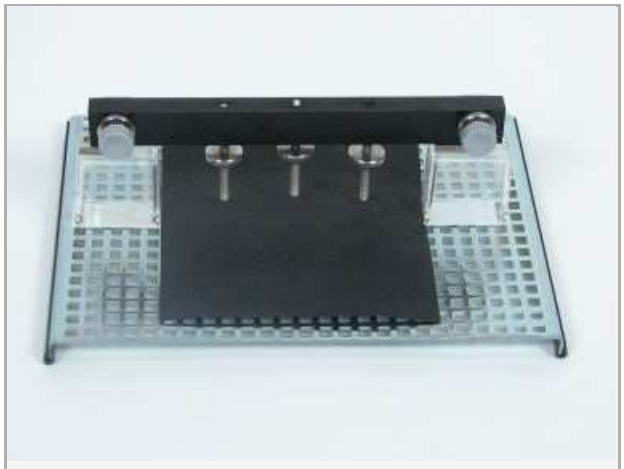

Fig. 6

- 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).

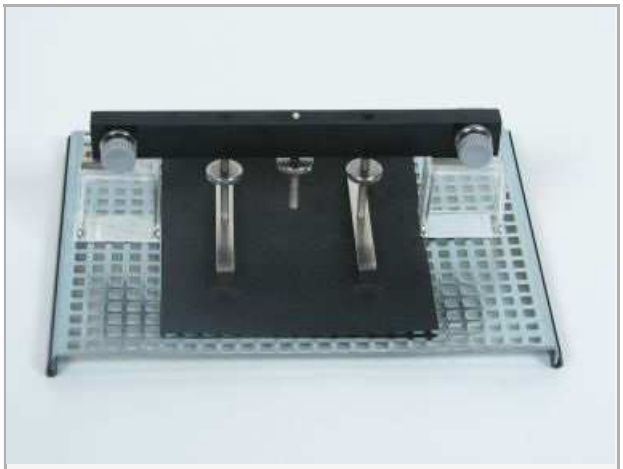

Fig. 7

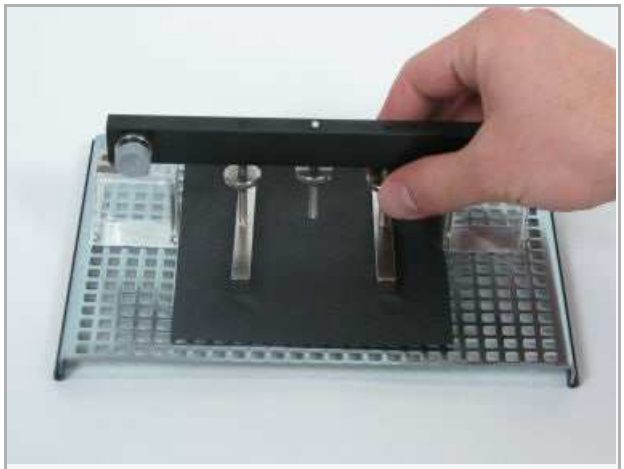

Fig. 8

- 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.

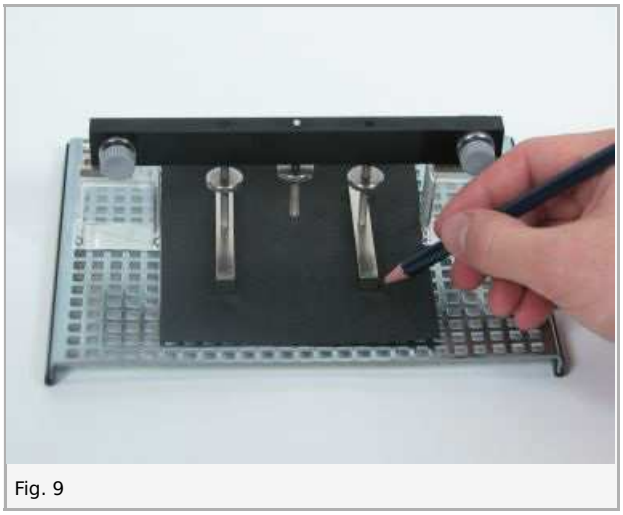

Fig. 9

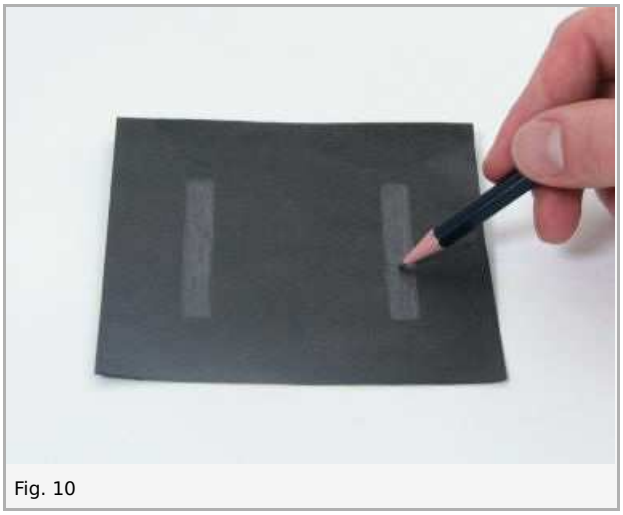

Fig. 10

- 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).

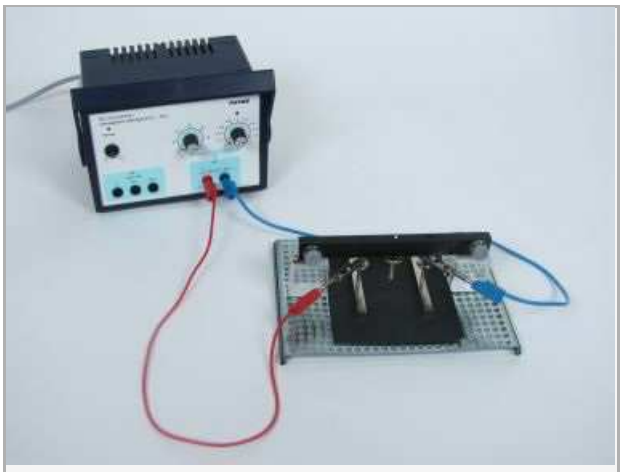

Fig. 11

- 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.

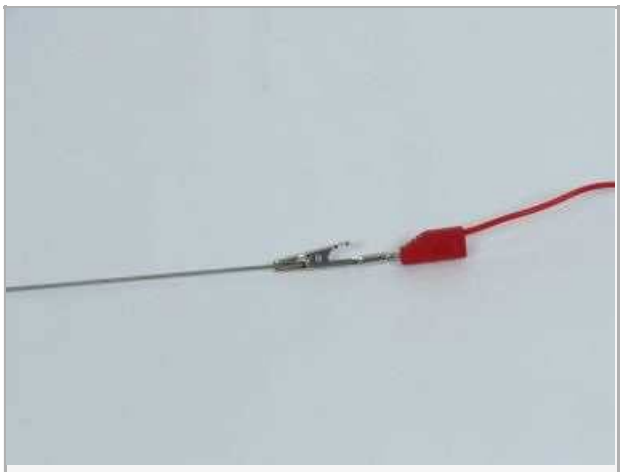

Fig. 12

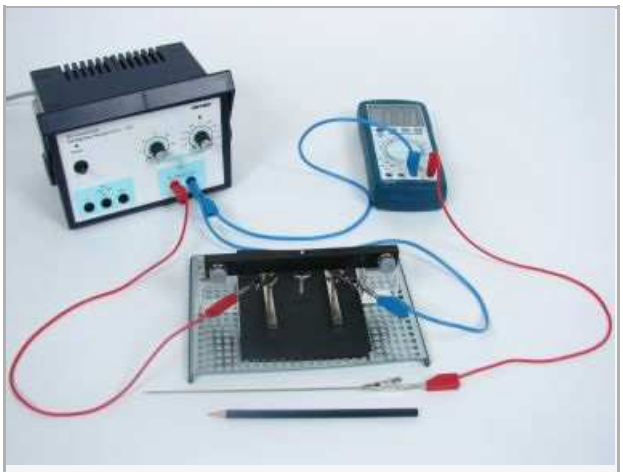

Fig. 13

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.

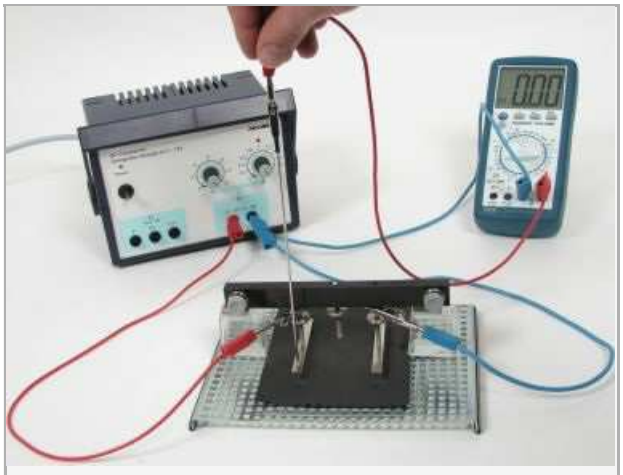

Fig. 14

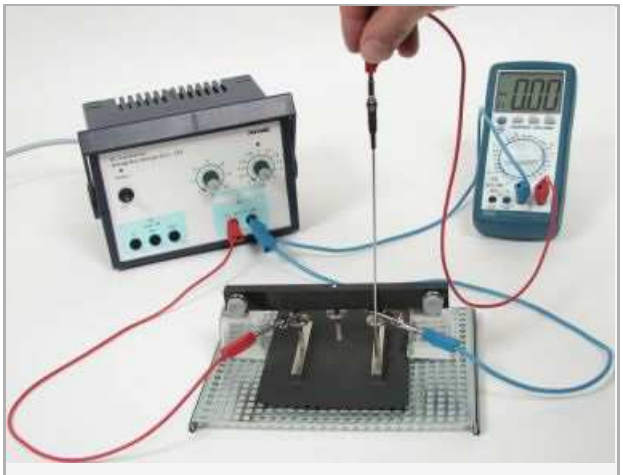

Fig. 15

- Find points on the carbon paper, which have the same electric potential (Fig. 16). For this purpose scan the carbon paper with the tip of the knitting needle and mark the points as small circles with a pencil. Start with a value of 1 V and continue in steps of 2 V. Mark eight points for each value.

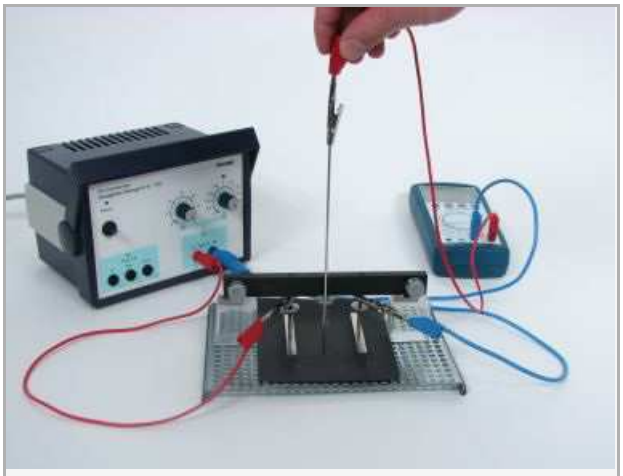

Fig. 16

- After completing the measurement, loosen the screws and remove the carbon paper.

Report: Electric fields

Result - Sketch

Use a pencil and connect the points of equal electric potential to lines. These lines are referred to as equipotential lines. Label each equipotential line by its electric potential.

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Evaluation - Question 1

What are the electric potentials of the two electrodes?

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Evaluation - Question 2

Why is no work done when a charged sample is moved along an equipotential line?

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Evaluation - Question 3

If a charged sample is placed into the electric field between two electrodes, an electric force will be exerted on it. Why is the direction of this force perpendicular to any equipotential line?

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Evaluation - Question 4

If you examine pairs of equipotential lines with the same difference in potential, what can you say about the distances of these lines?

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Evaluation - Question 5

What do the distances of the equipotential lines tell about the magnitude and the direction of the electric force?

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Evaluation - Question 6

Assume that a positively charged sample is put at the centre of the anode (10 V). Use a pencil to draw the line, along which the sample is displaced by the electric force from the anode towards the cathode (0 V). These lines are referred to as field lines.

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Evaluation - Question 7

If the magnitude of the electric force is equally large in all points of an electric field (this type of field is referred to as homogeneous), this will be pointed out, according to the concept of field lines, by drawing all field lines at equal distance. Draw four more field lines, all of them from the anode towards the cathode.

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