The electric conductor as an equipotential surface

Task and equipment

Information for teachers

Learning Target

With this experiment the students will investigate how the electric field between two circular electrodes changes when an electric conductor (rod electrode) is inserted into the field. The experiment demonstrates that an electric conductor always forms an equipotential surface of an electric field due to shifting of charges. The field lines run perpendicular to its surface.

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.

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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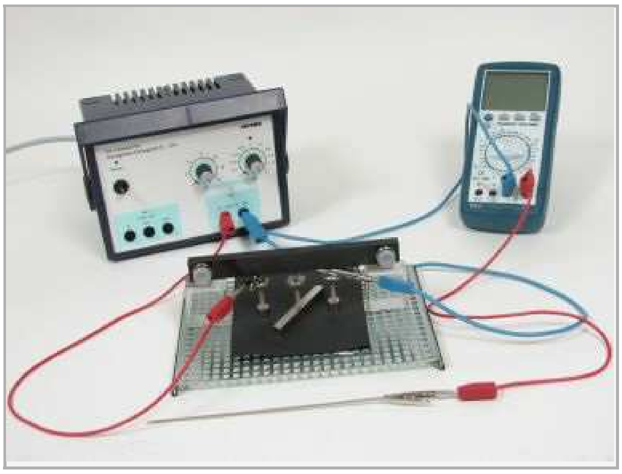
Task

How does an electric conductor impact an electric field?

Investigate how the electric field between two circular electrodes will change, when an electric conductor (here: a rod electrode) is inserted into the field:

1. Determine the electric potential of a conductor within an electric field.
2. Measure the distribution of electric potential in the electric field between the two electrodes, particularly in the area close to the conductor.
3. Derive the electric field pattern.



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
	Set of electrodes with holder for set equipotential lines	13027-24	1
	needed out of it:		
4	Electrode holder		1
5	Circular electrodes		1
6	Rod 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.

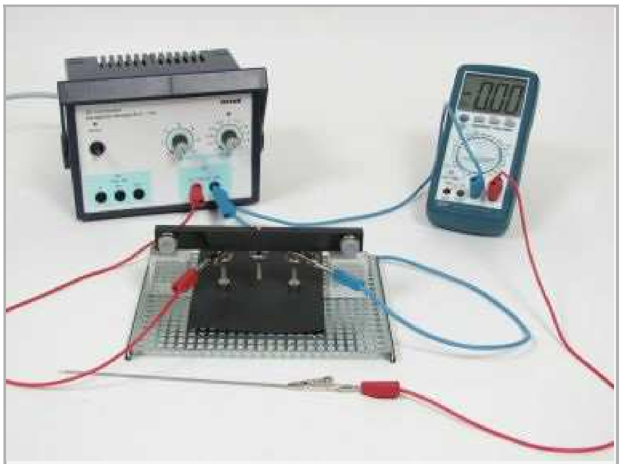


Fig. 1

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).

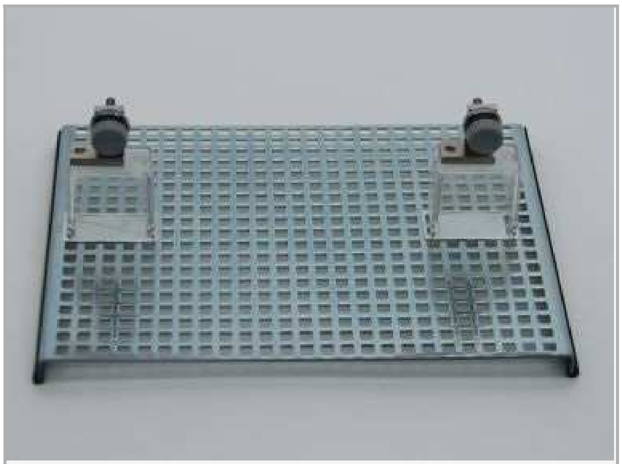


Fig. 2

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

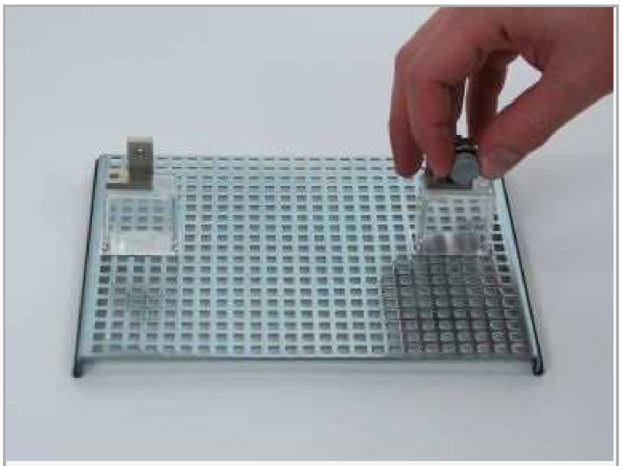


Fig. 3

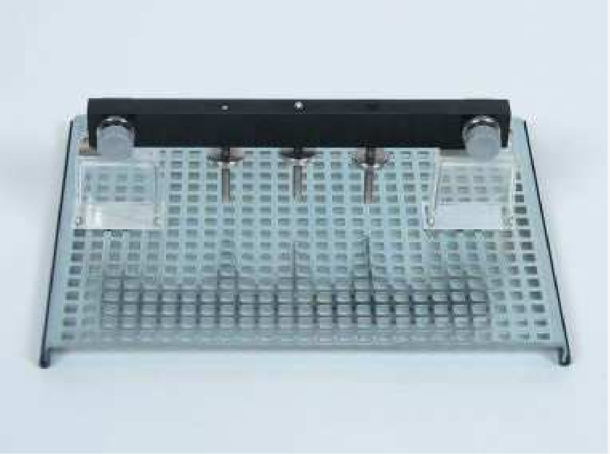


Fig. 4

- 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 circular electrodes below the outer knurled screws. By tightening the knurled screws, press both electrodes equally firmly onto the underlying plate (Fig. 7).

Fig. 7

- Draw the profiles of the electrodes on the carbon paper, loosen the knurled screws slightly and remove the carbon paper again (Fig. 8).
- Accurately fill the marked areas with a soft pencil (Fig. 9). 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.

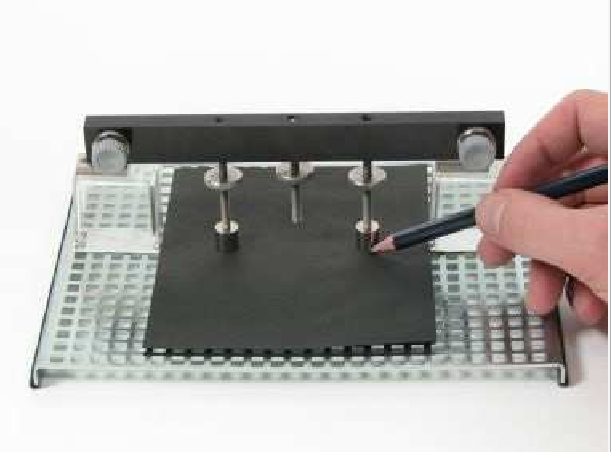


Fig. 8

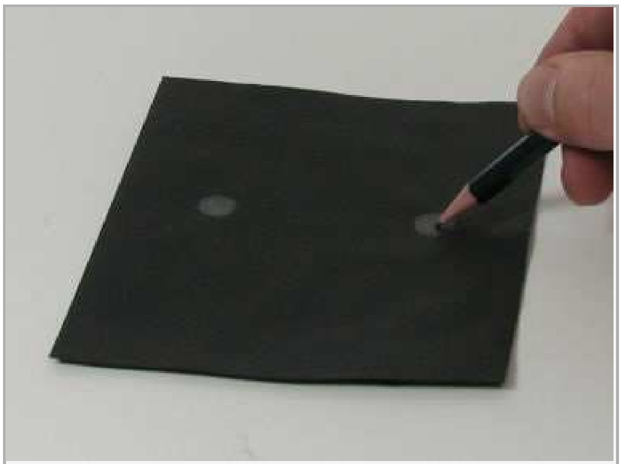


Fig. 9

- 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).
- Connect both electrodes to the outputs of the power supply (Fig. 11).
- Connect the digital multimeter (DMM) to one output (0 V) of the power supply as well as with the knitting needle (Fig. 10-11). 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.

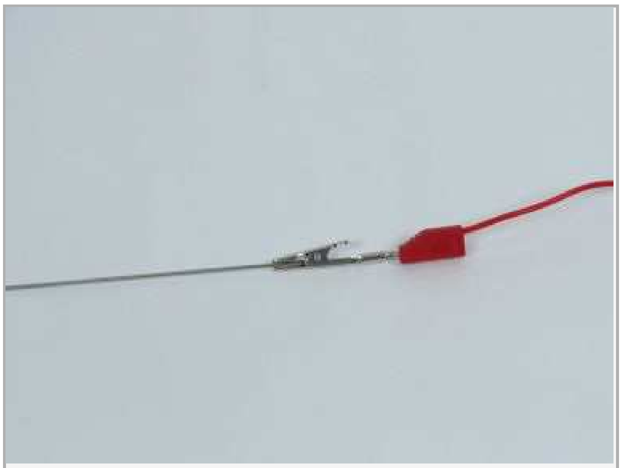


Fig. 10

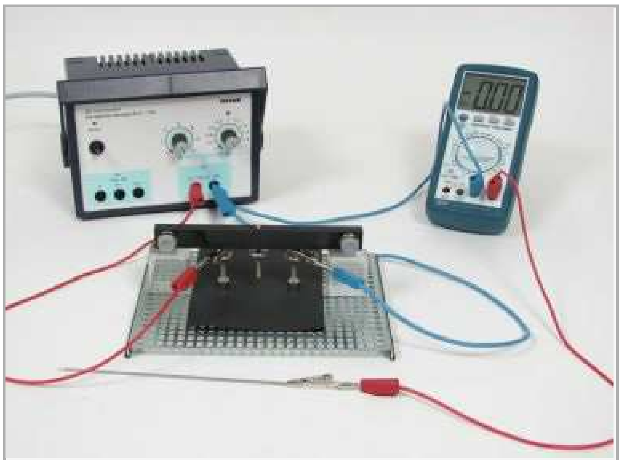


Fig. 11

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. 12-13). If necessary, adjust the DC output of the power supply.

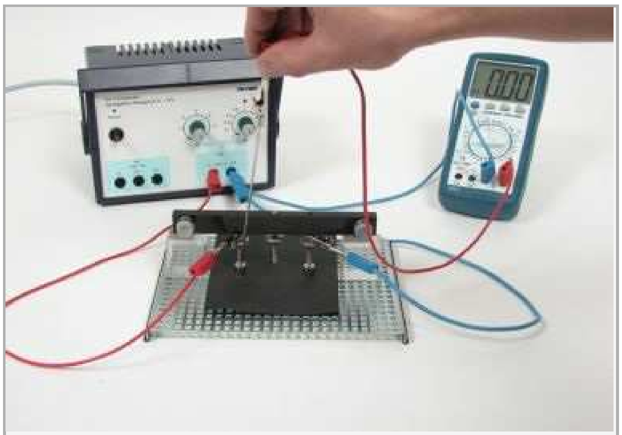


Fig. 12

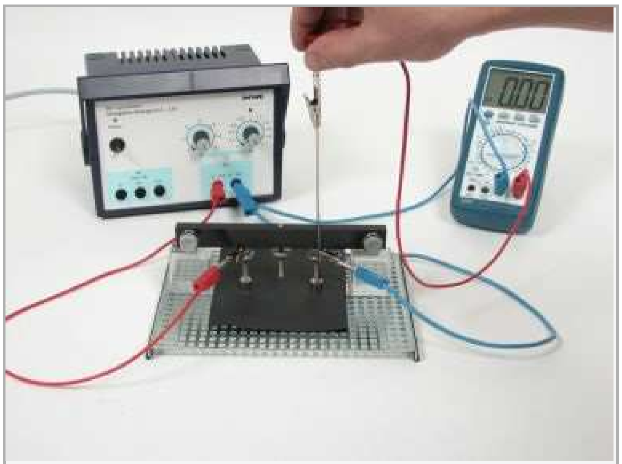


Fig. 13

- Fix the rod electrode below the middle knurled screw, with the rod positioned along the axis of symmetry between the two circular electrodes (Fig. 14). In this experiment the rod electrode serves as an electric conducting surface within the electric field of the circular electrodes.
- Mark the position of the rod electrode on the carbon paper, encircling it with the pencil (Fig. 15).

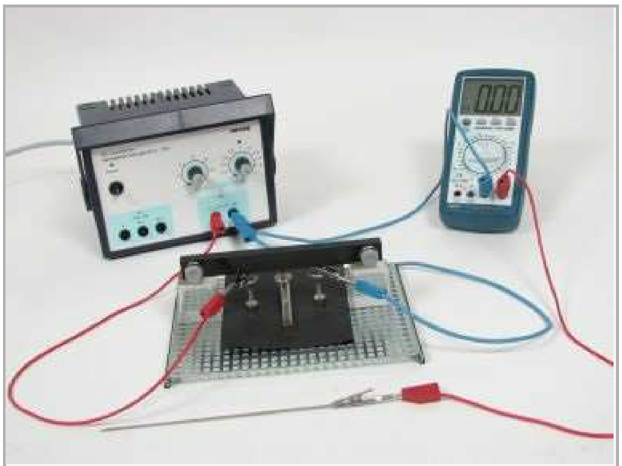


Fig. 14

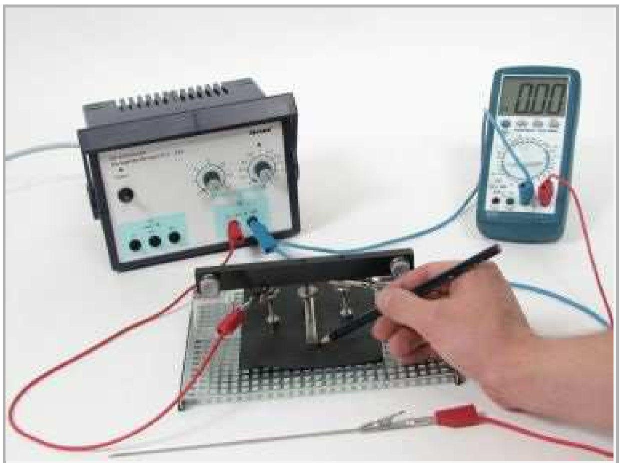


Fig. 15

- Scan the rod electrode with the knitting needle and measure its electric potential in different points on the surface (Fig. 16).

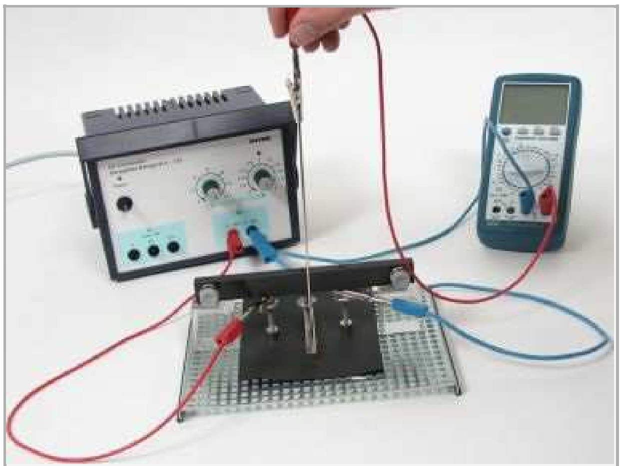


Fig. 16

- Rotate the rod electrode by an angle of about 45 degrees with respect to the starting position (Fig. 17). Repeat the measurement of the electric potential along the surface of the rod (Fig. 18).

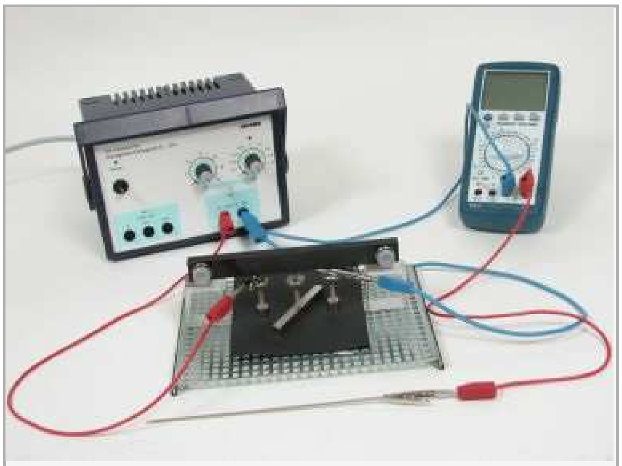


Fig. 17

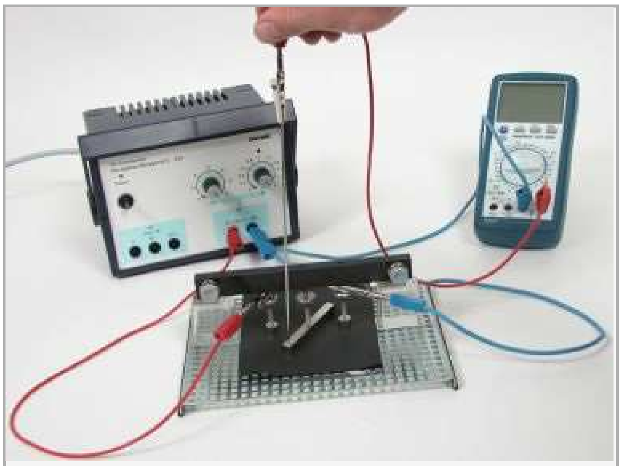


Fig. 18

- 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 as small circles with a pencil (Fig. 19). Start with a value of 1 V and continue in steps of 1 V. Mark eight points for each value.

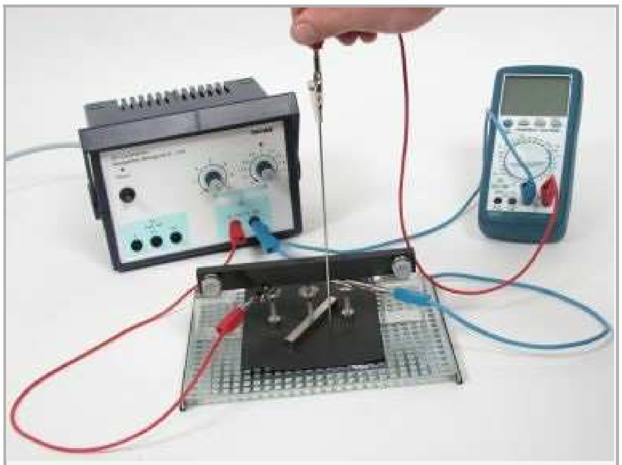


Fig. 19

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

Report: The electric conductor as an equipotential surface

Result - Sketch

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

Evaluation - Question 1

Which electric potential does the electric conductor (rod electrode) have before rotation?

Evaluation - Question 2

How does the rotation of the conductor affect its electric potential?

Evaluation - Question 3

Is there an electric field inside the conductor?

Evaluation - Question 4

The electric conductivity of a material is due to free charges. If no voltage is applied to the circular electrodes, there will be no electric field inside the conductor. Once a voltage is applied, the conductor will be penetrated by the electric field of the circular electrodes. How will this electric field affect free negative charges, and what will happen to the field?

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Evaluation - Question 5

Draw five field lines of the electric field, which would build up between the circular electrodes if no additional conductor was present inside the field. Ignore the conductor and the already plotted equipotential lines. Draw the field lines as dashed lines from the anode (10 V) to the cathode. Think about why these lines should start from the anode at equal distance.

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Evaluation - Question 6

Now consider that the actual field lines are confined to run perpendicular to the plotted equipotential lines. Draw the actual distribution of field lines.

Evaluation - Question 7

why do the field lines have to run perpendicular to the conductor surface?