Electrostatic tip shape effect

Task and equipment

Information for teachers

Learning target

With this experiment the students will investigate how a lightning is created during a thunderstorm and why elevations from the earth such as skyscrapers have a higher risk of being struck. In the experiment the students will simulate the electric field between a thundercloud and the earth ground by two parallel rod electrodes. One of the electrodes contains a tip-shape electrode, which changes the homogeneous electric field the same way a skyscraper will change the field between thundercloud and earth ground.

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, they should know an electric field exerts a force F on a charged particle in every point of the field. According to Newton's second law ($F = m \cdot a$) this force causes the particle (mass m) to be accelerated by the acceleration a.

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 that this 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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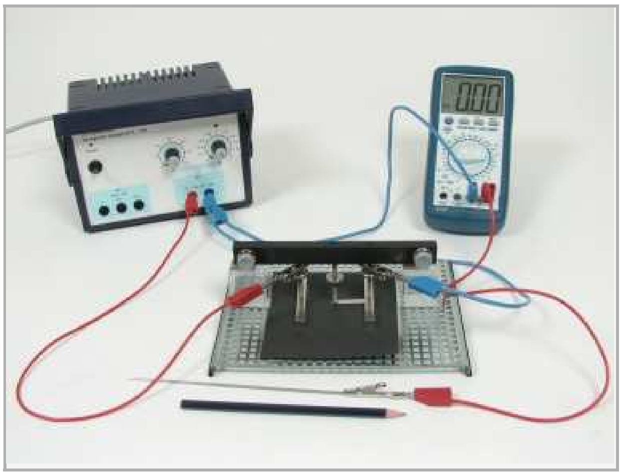
Task

Why are skyscrapers endangered to be struck by lightening?

A lightning forms a strong electric current, which is created, when in a medium (for example air) a large number of free charges is produced by strong electric fields. During a thunderstorm usually high elevations from earth (for example skyscrapers) are more often affected by lightning strokes. Investigate how the electric field between a thundercloud and the earth ground is distributed in the area next to a skyscraper. Consider the thundercloud and the ground as parallel electrodes. Simulating a high building one of the electrodes will be configured with a sharp elevation.

1. Measure the distribution of the potential within the electric field and derive the electric field pattern.
2. Observe how the electric field changes in the area of the tip electrode and transfer your observations to the situation of a thunderstorm.



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	Rod electrode		1
6	Rod electrode with slot for tip-shape electrode		1
7	Tip-shape electrode		1
8	Knitting needles, 20 pcs	06342-00	1
9	Alligator clips, bare, 10 pcs	07274-03	3
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	DMM with NiCr-Ni thermo couple	07122-00	1
13	Connecting cord, 32 A, 250 mm, red	07360-01	2
14	Connecting cord, 32 A, 250 mm, blue	07360-04	2
Additional material			
15	Soft pencil		1

Set-up and procedure

Set-up

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

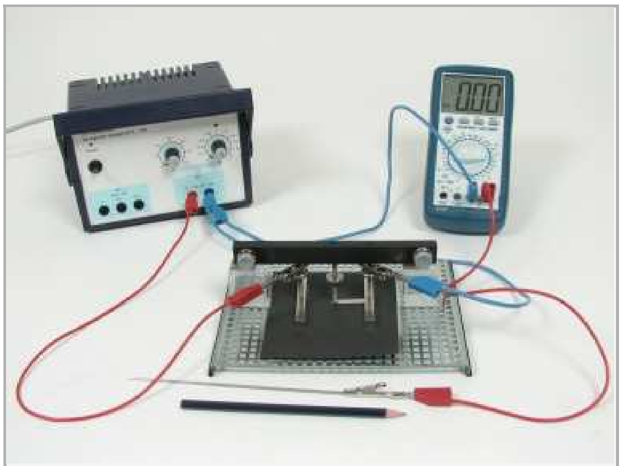


Abb. 1

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).

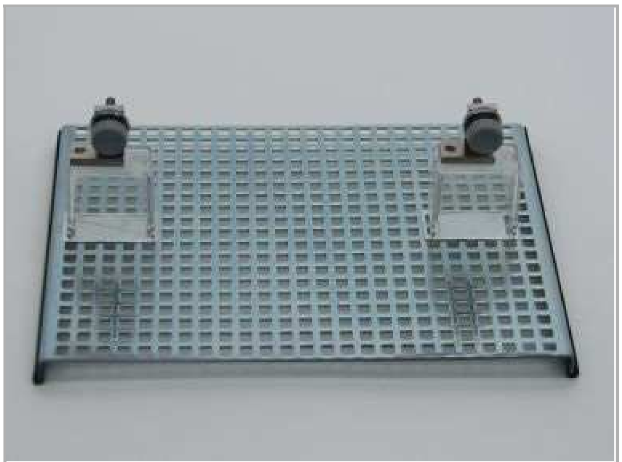


Fig. 2

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

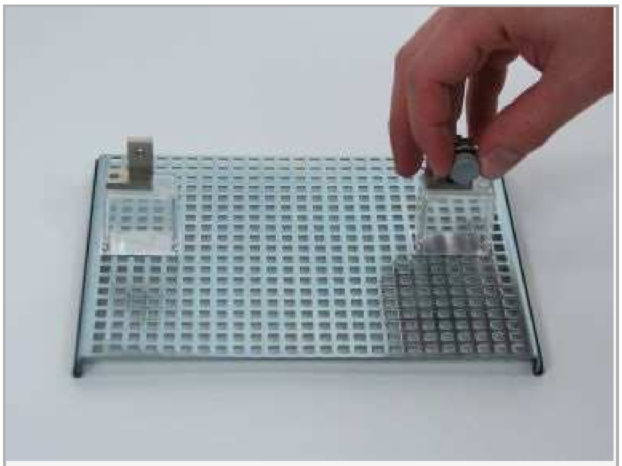


Fig. 3

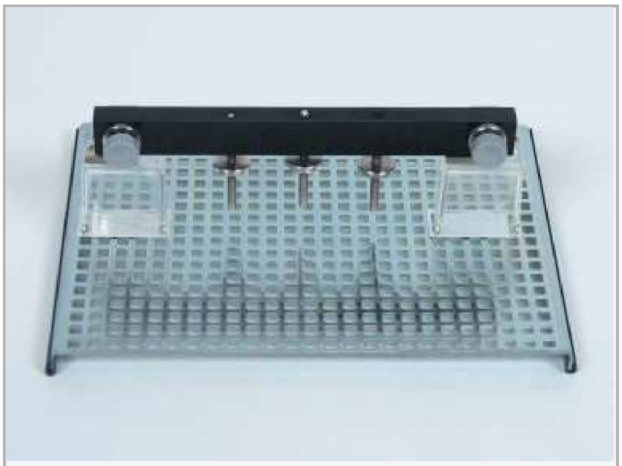


Fig. 4

- 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

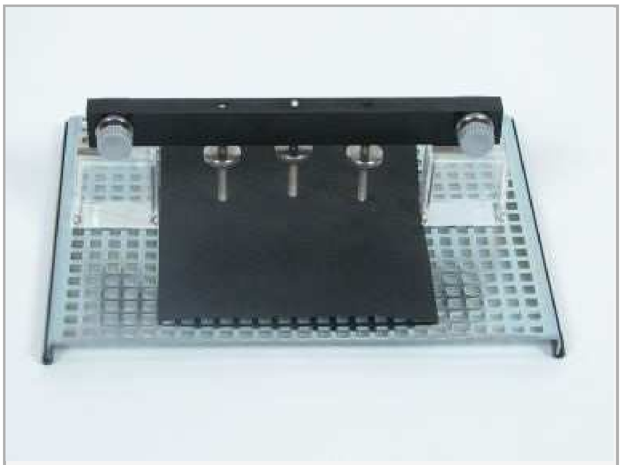


Fig. 6

- Place the rod electrodes below the outer knurled screws. Turn the slot on one of the electrodes towards the second electrode and insert the tip-shape electrode (Fig. 7-8). By tightening all three knurled screws, press the rod electrodes as well as the tip-shape electrode 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.

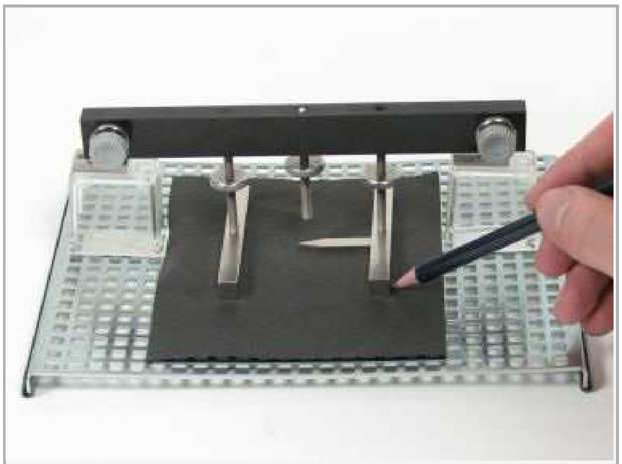


Fig. 9

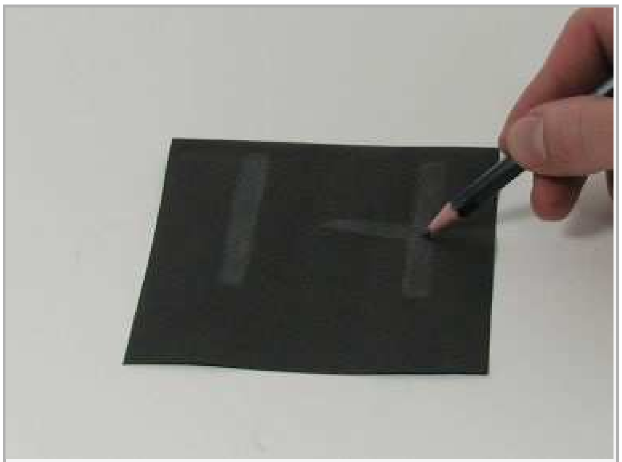


Fig. 10

- 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. 8).
- Connect both electrodes to the outputs of the power supply (Fig. 12). The electrode, which contains the tip-shape electrode, should be connected to the negative output (0 V)
- Connect the digital multimeter (DMM) to one output (0 V) of the power supply as well as with the knitting needle (Fig. 11-12). 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.

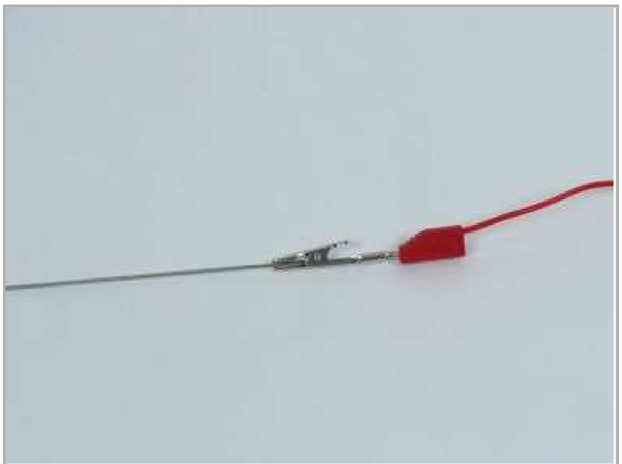


Fig. 11

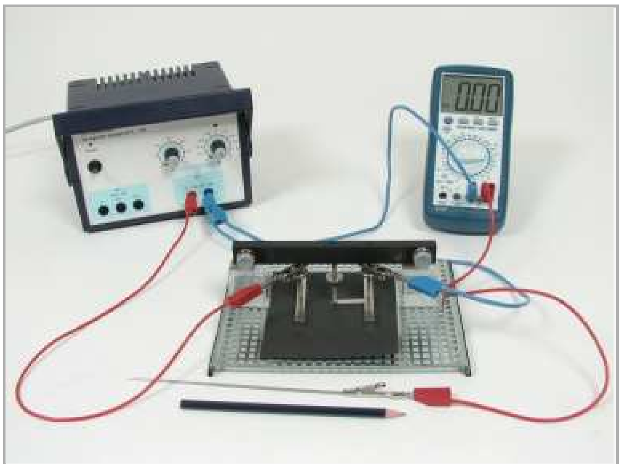


Fig. 12

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. 13-14). If necessary, adjust the DC output of the power supply.

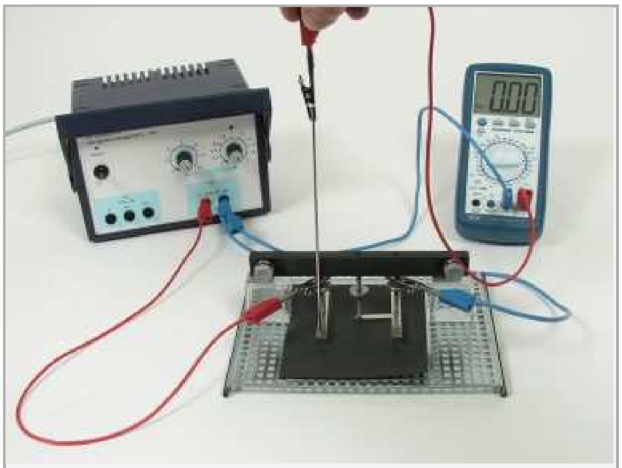


Fig. 13

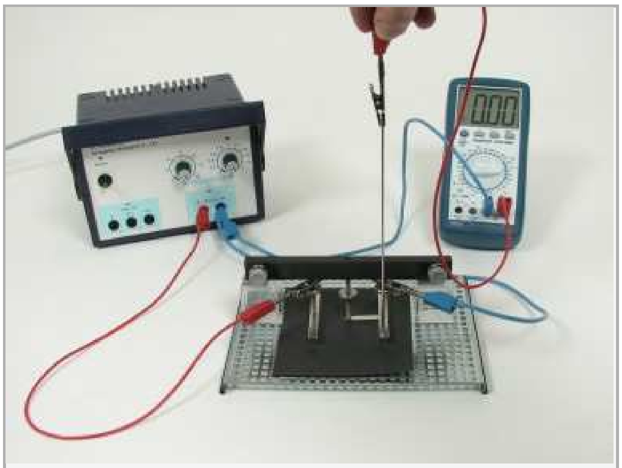


Fig. 14

- 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. 15). Start with a value of 1 V and continue in steps of 1 V. Mark eight points for each value.

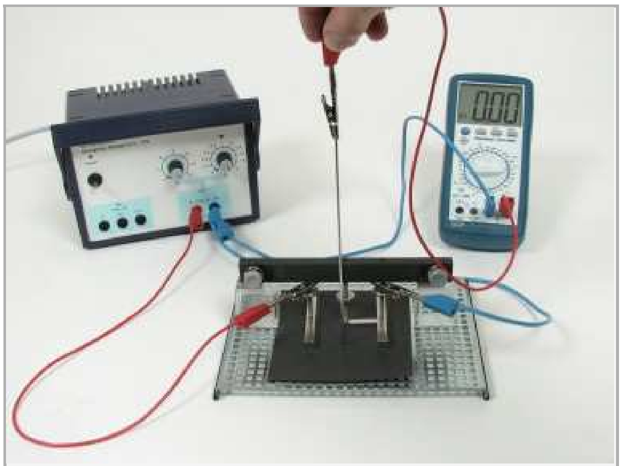


Fig. 15

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

Report: Electrostatic tip shape effect

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

Draw fifteen field lines of the electric field. Think about why these lines should start from the anode (10 V) at equal distance.

Evaluation - Question 2

What is the electric potential of the tip-shape electrode?

Evaluation - Question 3

How does the electric field pattern at the tip-shape electrode differ from the pattern at the rod electrodes?

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Evaluation - Question 4

what does the field pattern tell about the electric field strength in the area close to the tip-shape electrode?

Evaluation - Question 5

The conditions during a thunderstorm are more extreme. If the ground of the earth has an electric potential of about 0 V, the thundercloud will have a potential in the order of 10 MV. The high differences in electric potential create strong electric field strengths. How does the electric field impact the free charges in the air?

Evaluation - Question 6

A lightning demands a large number of free charges. These charges collide with air molecules. During the collision they are decelerated and transfer kinetic energy to the colliding molecule. If the charge transfers a sufficient amount of energy to the molecule, additional charges can be dissolved from the molecule. Can you now explain why it is most likely that large numbers of charges, and thus lightning strokes, are created at high elevations, such as skyscrapers?