

TAP 409-1: Potential and field strength in a uniform electric field

A flame provides a small number of ions, allowing a conductor to acquire the same potential as the place where you put it. So the flame probe provides a convenient way of measuring the potential at a point in an electric field. Here you can look at the variation in potential difference within a uniform field, between two parallel metal plates.

You will need:

- ✓ demonstration digital multimeter
- ✓ EHT power supply 0–5 kV dc
- ✓ pair of large aluminium plates
- ✓ clip component holder
- ✓ 10 M Ω resistor (in addition to that in the EHT supply)
- ✓ 4 mm leads
- ✓ two slotted bases
- ✓ metre rule
- ✓ flame probe
- ✓ retort stand, boss and clamp
- ✓ gas supply
- ✓ calibration coil (optional)



Wire carefully, EHT voltages

School EHT supplies have an output limited to 5 mA or less which makes them safe. In this experiment, very low currents are sufficient so the extra resistor (e.g. 50 M Ω) can be included in the circuit as it is built into the supply.

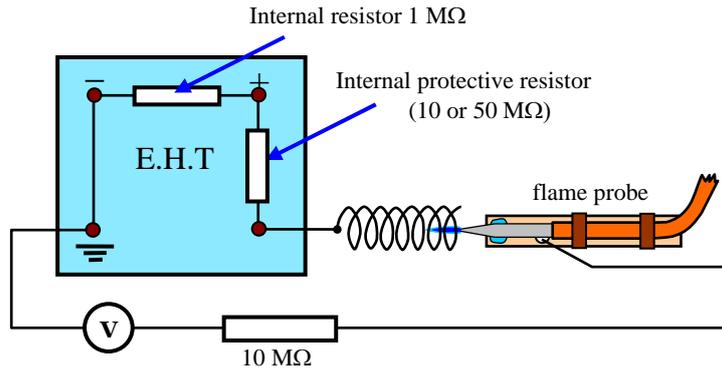
Note the high voltage on the capacitor plate, the naked flame on the flame probe and the sharp point on the hypodermic needle.

TAP 409-2: Flame probe construction

Checking and calibrating the flame probe

Before you can measure how the potential difference changes as you move between the plates, check the action of the flame probe.

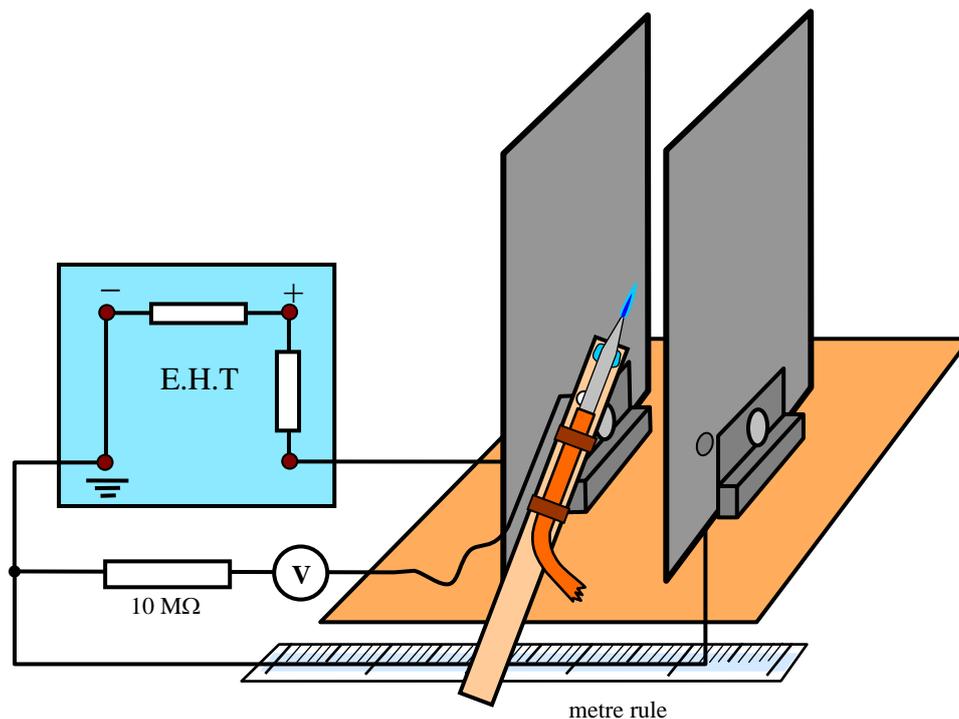
Everywhere inside the copper coil is at the same potential above 0 V. You can see that the flame probe measures the potential difference above ground in this space by altering the output pd on the EHT power supply.



You can use this arrangement to calibrate the flame probe, matching the numbers on the EHT power supply to the numbers appearing on the multimeter. Note that the multimeter is only measuring a fraction of the pd, as it forms part of a potential divider.

Measuring potential differences

You are now in a position to measure how the potential difference changes at different locations within a uniform electric field.



Explore the region between the plates by taking readings of potential at various distances from the plates (between the plates). At a given distance, you can take a few readings of potential by moving the flame probe parallel to the plates.

You should find that:

- 1) The graph of potential difference against distance from the earthed plate is a straight line through the origin.
- 2) The potential gradient ($= -$ the electric field) is constant.
- 3) The equipotentials are parallel to the plates, i.e. they are at right angles to the electric field.

Practical advice

The probe is a device that uses a small flame as source of ions, to allow a fine conductor to reach a steady pd, determined by the potential of the surrounding electric field at that point.

The probe is made from a fine tube (e.g. a hypodermic needle) through which there is a slow flow of gas to maintain a flame. An insulated wire provides the route from the point of the flame to a voltmeter. A Hoffman clip on the gas supply tubing enables the pressure to be adjusted until a small flame (2 to 3 mm long) is obtained at the tip. (Hint: Start with the clip open so that the gas flows relatively freely and be patient before trying to light the gas; it takes some time to clear the air out of the tubing. Before lighting the gas, reduce the flow, as too high a pressure blows the flame away.)

Further details of the construction of the flame probe are given in Teacher and technician notes.

The two aluminium plates have to be mounted vertically about 20 cm apart, on an insulator (most bench tops are fine, but on a wooden bench it is best to insulate the non-earthed plate by placing a polystyrene sheet between the plate and bench). One plate is connected to the positive terminal of the EHT power supply and the other to the earthed negative terminal. When the connections have been made, turn the supply on and touch each plate with the (unlit) needle of the flame probe to check that the multimeter indicates the expected potential differences.

Place the flame probe half-way between the plates somewhere near a line joining the centre of the two plates. You may also find it clearest to have the hypodermic needle pointing straight up.

The voltmeter should read about half the potential of the positive plate. If you move the flame probe parallel to the plates, you will notice that the voltmeter reading does not change. You are following an equipotential. Other equipotentials can be found at different distances from the plates. In all positions, you should find that moving parallel to the metal plates does not alter the potential.

Return the flame probe to a position close to the centre of the negative plate and fix a ruler to the bench so that you can measure the distance of the probe along a line joining the plates. By taking measurements of the potential at points along this line, you will be able to plot a graph of the potential against distance from the earthed plate.



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Note the high voltage on the capacitor plate, the naked flame on the flame probe and the sharp point on the hypodermic needle.

Technician note

Details of the flame probe construction are given in

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External reference

This activity is taken from Advancing Physics chapter 16, 30D