Investigating equipotentials and electric fields

Advanced Higher Physics requires knowledge of electric field patterns around single point charges, a system of charges and in a uniform electric field. This practical enables students to become familiar with the relationship between electric field lines and lines of equipotential. The equipotential surfaces around a point charge and between two parallel plates are marked out. The potential gradient and hence the electric field strength between a set of parallel plates can then be found as can the relationship between the electric potential and distance from a point charge. It is very straightforward, requires little apparatus and is safe. It is a simple practical exercise that will enhance understanding.

Investigating the equipotential surfaces between two parallel plates

The apparatus required is a multimeter, a 1.5 V cell, some graph paper, a black conductive bag [1] cut into a strip approximately 5 cm x 10 cm, and a set square. Set up the apparatus as shown in Figure 1.

Connect one bulldog clip to the negative terminal of the cell. Connect the negative terminal of the multimeter to the negative terminal of the cell. The negative terminal is 0 V.

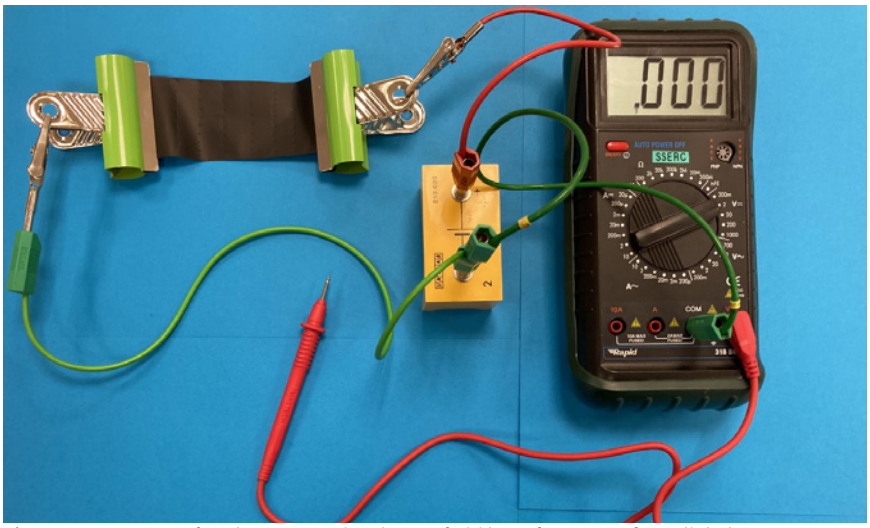

Figure 1 - Apparatus for plotting out the electric field lines for a pair of parallel plates.

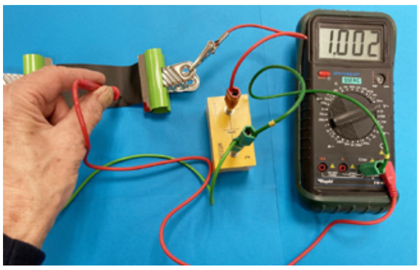
Figure 2


Figure 3 - The lines of equipotential are drawn out by the parallel lines of dots made by the probe making out points at the same potential.

Connect the positive terminal of the cell to the other bulldog clip. Connect the positive terminal of the multimeter to a flying lead. Set the multimeter to read 2 V maximum and switch on. Take the flying lead and 1 cm from the 0 V bulldog clip, note the reading on the voltmeter and mark the position by pressing down on the black polythene, see Figure 2.

Record the position of 4 more points having the same potential as the initial point. Move the flying lead to 2 cm from the bulldog clip and note the reading. As before record the position of 4 more points with the same potential. Repeat up to 8 cm. The results are shown in Figure 3.

The lines are clearly parallel to the edge of the bulldog clips. Students could sketch out the equipotential lines and add the electric field lines, after reminding them no work is done when moving over an equipotential surface. The electric field lines must therefore be at 90° to the lines of equipotential. This is an excellent formative assessment exercise. It checks basic understanding of the concepts associated with electric field lines and equipotential surfaces. A graph can be plotted of the potential difference against distance from the 0 V bulldog clip, see Figure 4.

>>

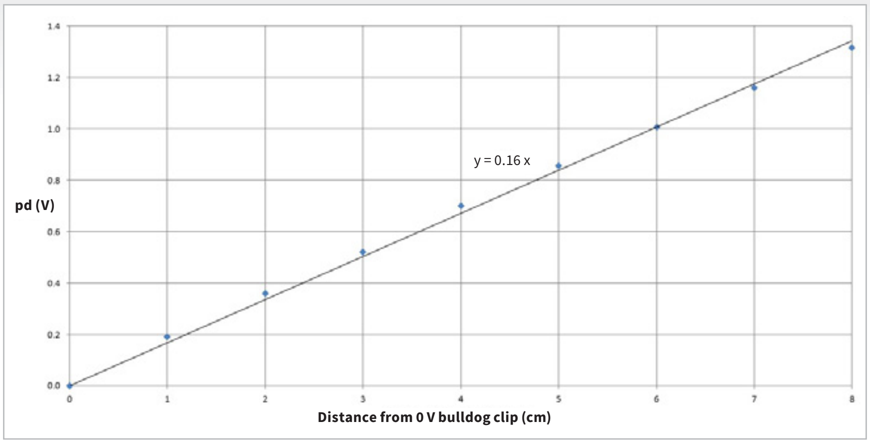

Figure 4

This gives a straight-line graph showing V α d. Students could be asked what the gradient of the graph gives. Again, this is good reinforcement of basic knowledge since the electric field strength between a pair of parallel plates is equal to the potential gradient V/d, the gradient of the graph.

The equipotential lines around a point charge

If circular symmetry is required, an embroidery hoop or a Petri dish can be used to give this. The apparatus required is shown in Figure 5.

Draw round the Petri dish. Cut out a circle with a radius about 2 cm larger than that of the Petri dish. Stick double sided sticky tape to the side of the petri dish. Cut two strips of aluminium foil, one the width of the Petri dish and one twice the width of the Petri dish and both at least 4 cm longer than its circumference. Stick the strip of aluminium that is the width of the Petri Dish to the sides of the Petri dish so each end of the foil can be made into a connecting wire, see Figure 6. Place the Petri dish on top of the circular piece of conducting material. Centre the Petri dish so the centre of the circle of conducting material is over the centre of the Petri dish, see Figure 7. To keep the conductive material in place stick small pieces, 5 mm square, of double-sided sticky tape to the aluminium foil. Stick the conducting material to these points. Take the wider second strip of aluminium foil and place it round the Petri dish as before so there is a connecting wire. Hold this piece of aluminium in place using an elastic band. Fold the extra width over the elastic band. This gives electrical connection to both sides of the conducting material (Figure 8). If an embroidery hoop is used, each hoop needs to be covered with aluminium foil and the foil needs to be longer than the hoop to enable a good electrical connection to be made as with the Petri dish. The circle of conductive material is then stretched between the hoops and the top hoop is then tightened to hold the material taut. >>

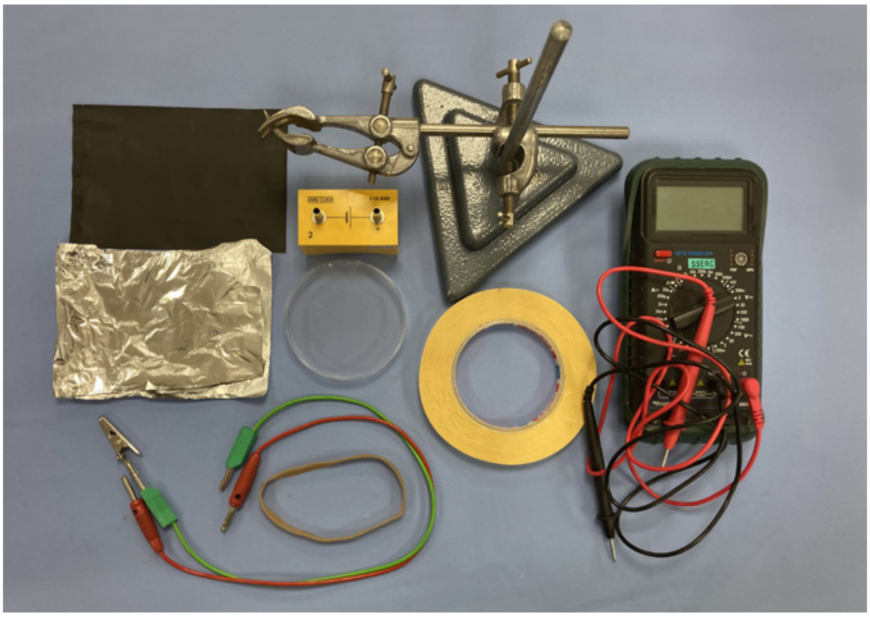
Figure 5


Figure 6

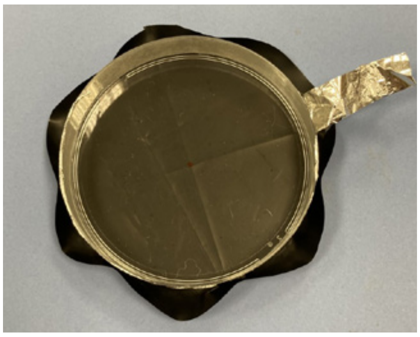
Figure 7

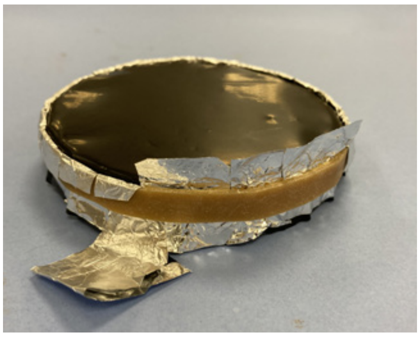
Figure 8

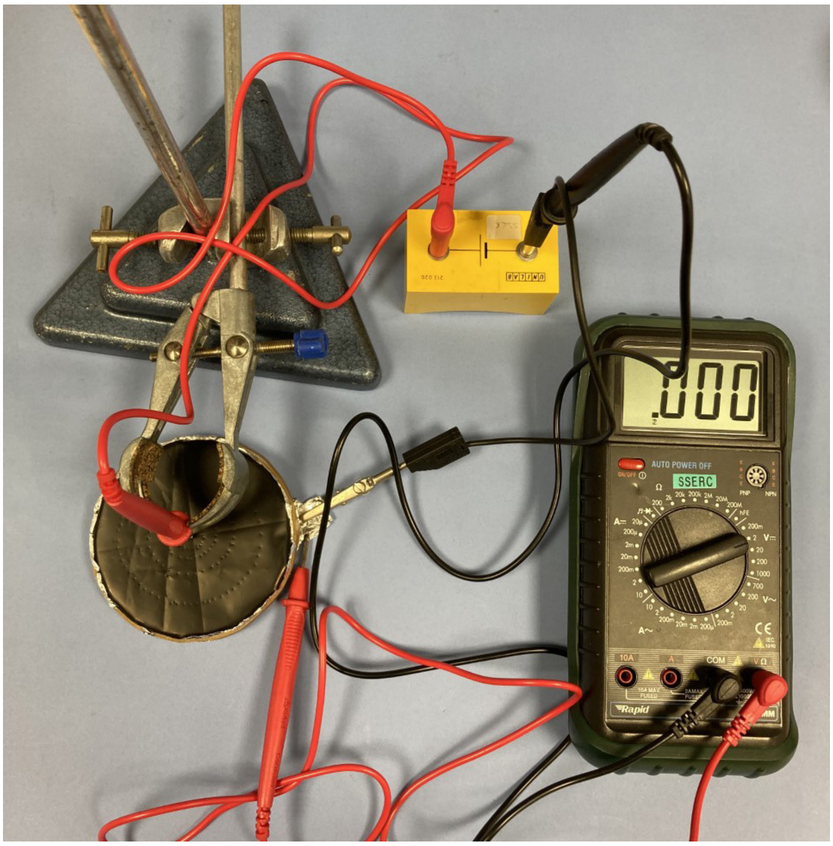

Figure 9

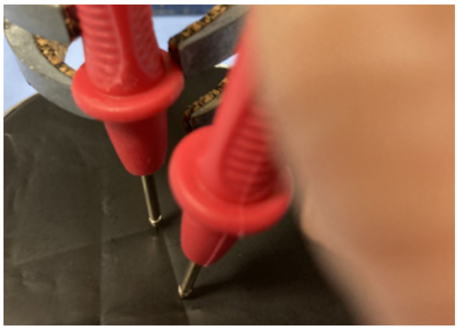

Figure 10

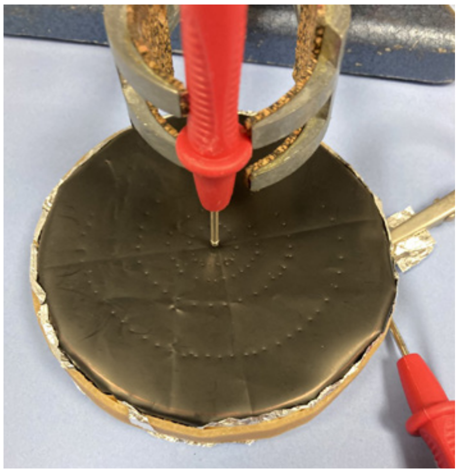

Figure 11

Set up the apparatus as shown in Figure 9. Take the positive probe and record points equipotential for a value of 0.7 V if using a 1.5 V cell. Repeat for values of 0.5 V, 0.3 V, 0.1 V. Then do just a few points for 0.6 V, 0.4 V and 0.2 V. The resulting equipotential lines are drawn out by the dots. The lines of equipotential are concentric circles (Figure 10).

The lines for regular intervals of potential get more widely spaced, showing the relationship between potential and distance from a point charge is not linear (Figure 11). Plotting a graph of voltage against distance from the source gives a curve, see Figure 12. A curve fit for a power can be tried using Excel. To one significant figure this gives $V \alpha d^{-1}$, as expected. As before the electric field lines can be drawn. This gives the electric field around a point charge.

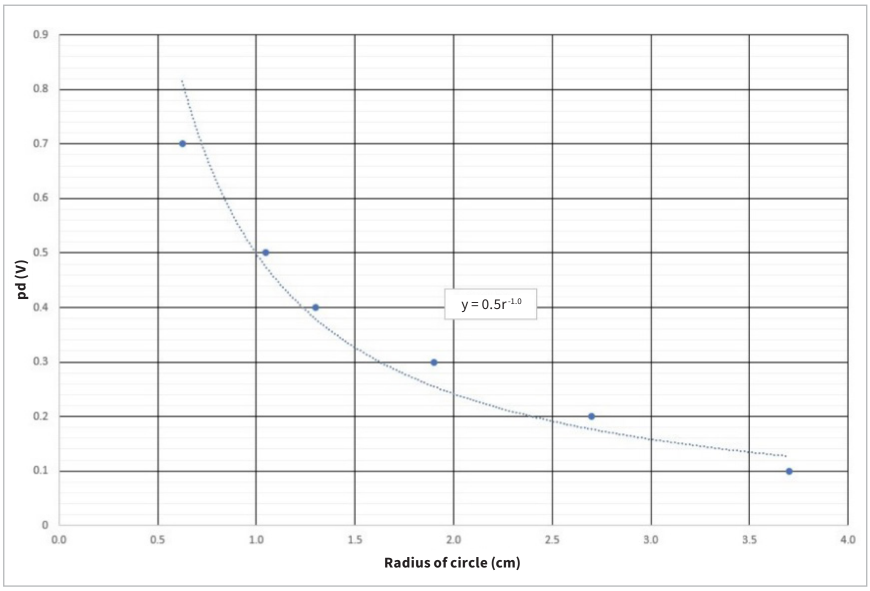

Figure 12

Reference

[1] Conductive bags are available from https://uk.farnell.com/multicomp/006-0003f/conductive-bag-101-6mm-x-152-4mm/dp/1687804