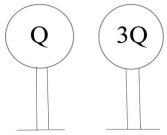
State Examination Commission – Physics Higher Level, 2011

Question 9

a) State Coulomb's law. (6)
Two identical spherical conductors on insulated stands are placed a certain distance apart. One conductor is given a charge Q while the other conductor is given a charge 3Q and they experience a force of repulsion *F*. The two conductors are then touched off each other and returned to their original positions.
What is the new force, in terms of *F*, between the spherical conductors. (18)



b) Draw a labelled diagram of an electroscope.
Why should the frame of an electroscope be earthed?
Describe how to charge an electroscope by induction. (15)

c) How does a full-body metal-foil suit protects an operator when working on high voltage power lines?
Describe an experiment to investigate the principle by which the operator is protected. (17)

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What is the new force, in terms of *F*, between the spherical conductors.

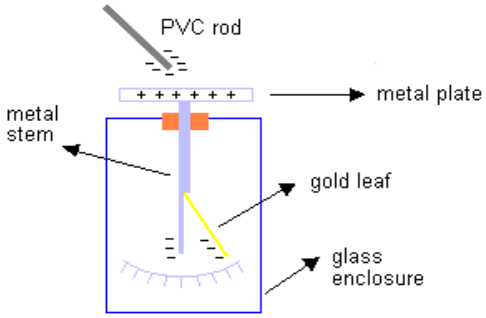
$$F = \frac{1}{(4\pi\epsilon_0)}\frac{Qx3Q}{r^2} = \frac{1}{(4\pi\epsilon_0)}\frac{3Q^2}{r^2}$$

$$F' = \frac{1}{(4\pi\epsilon_0)}\frac{2Qx2Q}{r^2} = \frac{1}{(4\pi\epsilon_0)}\frac{4Q^2}{r^2} = \frac{4}{3}\frac{1}{(4\pi\epsilon_0)}\frac{3Q^2}{r^2} = \frac{4}{3}F$$

or, more simply

$$F \propto 3Q^2$$
$$F' \propto 4Q^2$$
$$\frac{F'}{F} = \frac{4Q^2}{3Q^2} = \frac{4}{3}$$
$$F' = \frac{4}{3}F$$

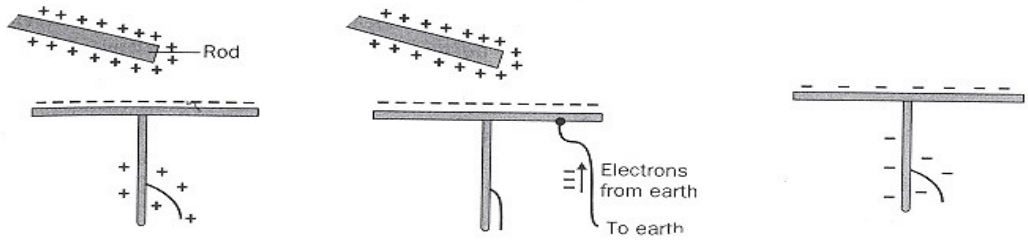
b) Draw a labelled diagram of an electroscope.



Why should the frame of an electroscope be earthed?

If you earth the electroscope case, the electroscope measures potential in experiments. Without earthing, the quantity it is measuring is charge. This is related to p.d. (by its capacitance C, i.e. V = Q/C), but it isn't the same as p.d. because the capacitance can vary a lot – even during an experiment. Capacitance depends on the position of the electroscope, people nearby and so on.

Describe how to charge an electroscope by induction. (15)



Hold a positive rod near the cap and the leaf rises. Earth the cap and electrons flow onto the leaf from the earth causing the leaves to fall. Remove the rod and the negative charges on the cap spread to leaves causing them to rise. Electroscope is now negatively charged.

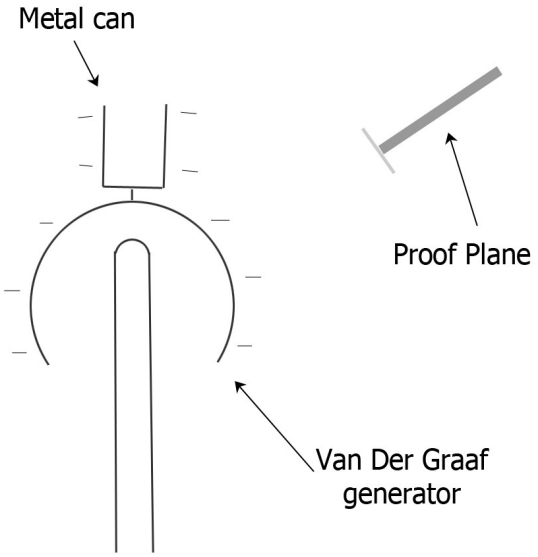
c) How does a full-body metal-foil suit protects an operator when working on high voltage power lines?

Because excess charge always resides on the surface of a conductor (metal suit), causing the electric field inside to be zero, and hence the conductor shields anything within it from external electric fields.

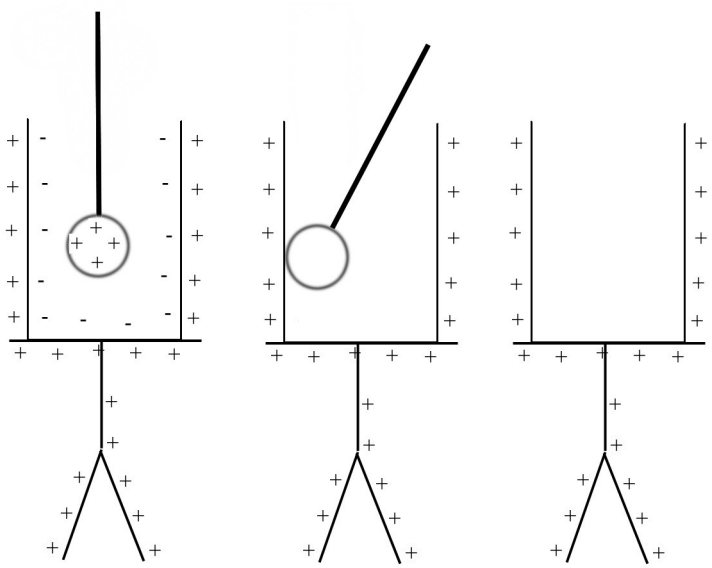
Describe an experiment to investigate the principle by which the operator is protected. (17)

Attached a small metal can to the top of a Van der Graaf generator and charge it up. Take a proof plane (a metal disc with an insulating handle) , touch it against the outside of the can, and then brush it against the cap of an electroscope. The leaves will part showing that the proof plane had picked up charge from the outside of the can.

Repeat for the inside of the can. The leaves will not part on the electroscope. There is no charge inside the can.



Alternatively,



If a positively charged sphere is lowered into an uncharged metal cup sitting on top of an electroscope, there is an equal but opposite charge induced on the inside of the cup, leaving the outer surface with a positive charge and causing the leaves to part. If the sphere is removed the leaves collapse and the cup is uncharged. If, however, the ball touches the inside of the cup, the induced charge on the inside of the cup flows onto it, and exactly neutralizes it. The leaves remain open and do not move, even after the sphere is removed, showing there is no redistribution of the positive charge on its outer surface .