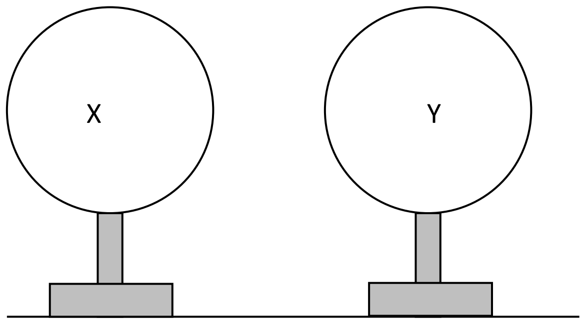
Problem of the week

Electric fields (SL&HL)

(a) The figure shows two identical conducting spheres X and Y on insulated supports. X has charge +4.0 nC and Y a charge –12 nC. The spheres are allowed to touch and are then separated again.



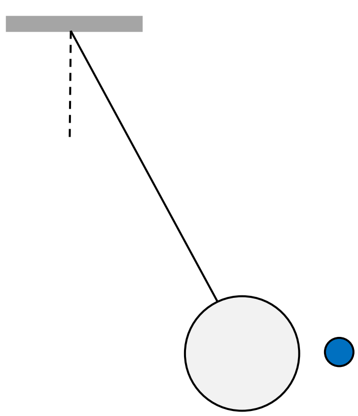
(i) State and explain the charge on each sphere after they are separated.

(ii) Describe the transfer of charge from one sphere to the other.

(iii) Discuss how the answer to (i) would change, if at all, if the spheres were grounded while they touched.

(b) An oil drop has charge 3e, where e is the elementary charge. The oil drop splits into two identical smaller oil drops. State and explain the possible values of the charge on each of the smaller drops given that both are charged.

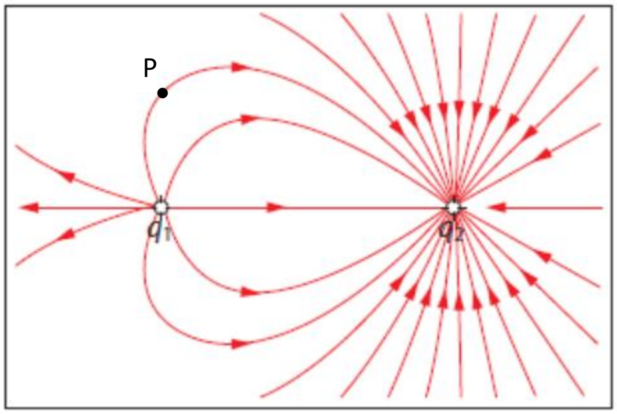
(c) A neutral conducting sphere hangs at the end of an insulated string. A point positive charge placed near the sphere attracts the sphere as shown.



(i) Explain why there is an attractive electric force between the sphere and the point charge.

(ii) The positive point charge is replaced by a negative point charge of the same magnitude. State and explain what will happen now.

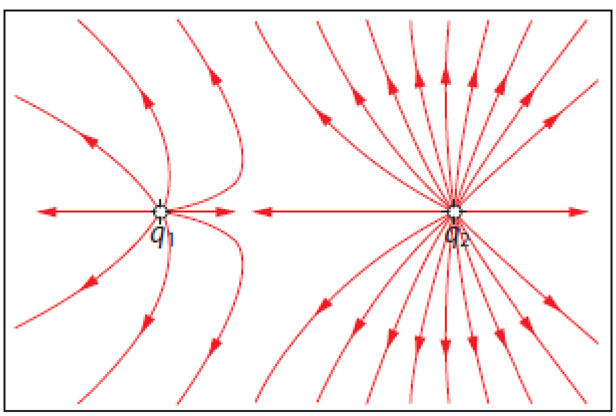
(d) The diagram shows electric field lines for two, point charges q_1 and q_2.



(i) State the sign of q_1 and the sign of q_2.

(ii) A negatively charged point particle is placed at point P. Draw, on the diagram, an arrow to represent the resultant electric force experienced by this particle.

(e) The diagram shows electric field lines for two other point charges q_1 and q_2.



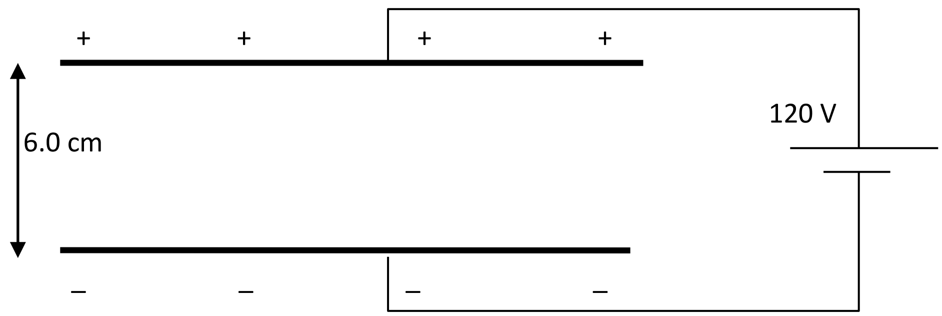
(i) Explain the feature of the diagram that shows that the magnitude of q_2 is greater than that of q_1.

(ii) State another feature that shows that the magnitude of the electric field is decreasing as we move away from the charges.

(iii) By making measurements on the diagram estimate that the ratio of the magnitudes of the charges is $\frac{q_2}{q_1} \approx 5$ to 1 s.f.

(iv) The distance between the charges is 8.0 cm. A point charge q_3 is placed on the mid-point of the line joining q_1 and q_2. Calculate the magnitude and direction of the resultant electric force on q_3 given that $q_1 = q_3 = 3.0\text{ nC}$ and $q_2 = 15\text{ nC}$.

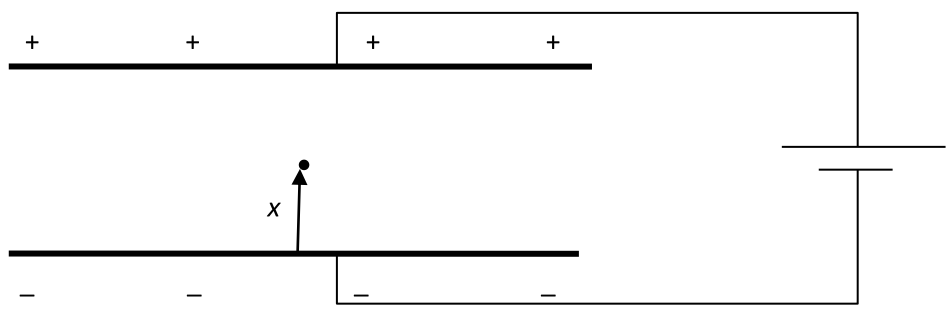
(f) Two long parallel plates are oppositely charged. The potential difference between the plates is 120 V. The separation of the plates is 6.0 cm.



(i) Draw the electric field lines for this arrangement.

(ii) Determine the electric field between the plates.

(iii) A point particle of charge +3.0 μC is placed at a distance *x* from the lower plate.



Draw, on the axes below, a graph to show the variation of the electric force *F* on the point charge with distance *x*.

Answers

(a)

(i) The total charge is –8.0 nC. By charge conservation this is also the total charge after separation. By symmetry two spheres have the same charge and so –4.0 nC each.

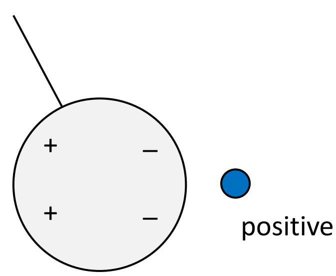
(ii) Negative 8 nC of charge moved from the negative sphere onto the positive sphere.

(iii) The spheres would discharge leaving each neutral.

(b) By charge conservation the total charge on the two droplets would be 3e. But charge is quantized in units of e, so the only possibility is e and 2e.

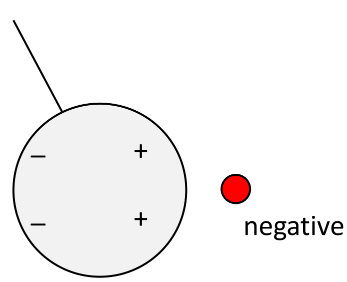
(c)

(i) The positive point charge attracts electrons closer to the right side of the sphere leaving a positive charge on the left side.



This results in an attractive force between the point charge and the negative surplus on the right and a repulsive force with the positive surplus on the left. But the negative charge is closer so the resultant force is attractive.

(ii) The negative charge pushes electrons in the sphere away and so the force is still attractive. The situation is:

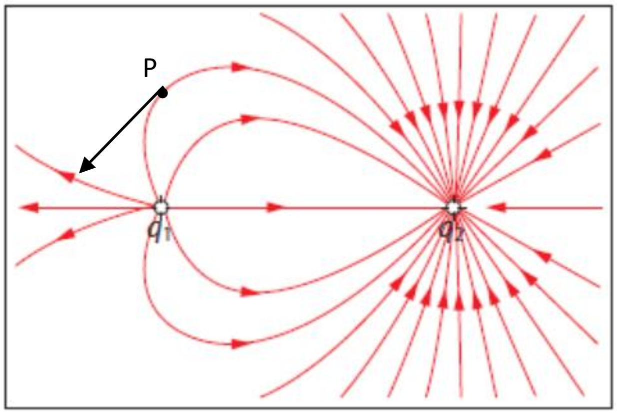


The negative charge pushes electrons in the sphere away and so the force is still attractive.

(d)

(i) q_1 is positive (arrows out of charge) and q_2 is negative.

(ii) Tangent to field line opposite to arrow.



(e)

(i) The resultant electric field strength is zero closer to q_1.

(ii) The density of the lines is decreasing.

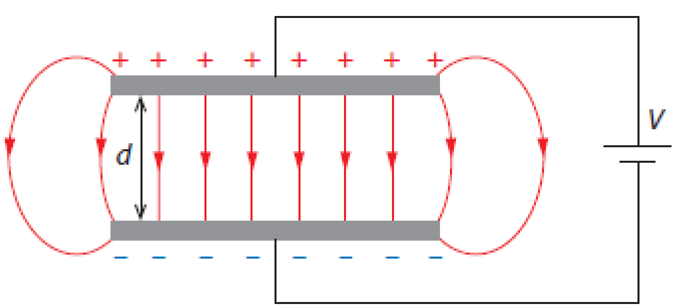
(iii) The net field is zero at a point a distance 2.4 cm from q_1 and 5.6 cm from q_2. Hence $k\frac{q_1}{2.5^2}=k\frac{q_2}{5.6^2}\Rightarrow\frac{q_2}{q_1}=\frac{5.6^2}{2.5^2}=5.02\approx 5$. (Measurements in cm may differ depending on your magnification; it is the ratio that counts.)

(iv) The resultant force is directed to the left.

$$F_{net}=8.99\times10^9\times\frac{15\times10^{-9}\times3.0\times10^{-9}}{0.04^2}-8.99\times10^9\times\frac{3.0\times10^{-9}\times3.0\times10^{-9}}{0.04^2}\approx 2.0\times10^{-4}\text{ N}.$$

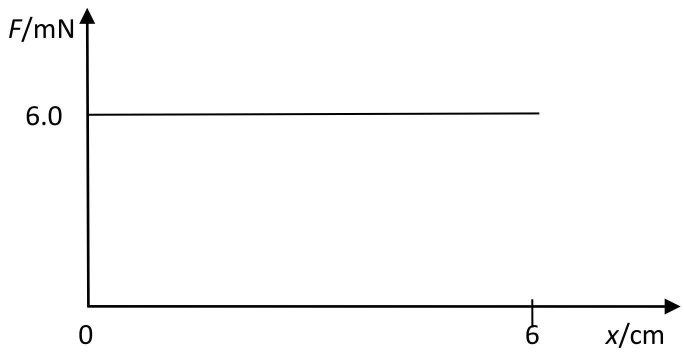
(f)

(i)



(ii) $E=\frac{V}{d}=\frac{120}{6.0\times10^{-2}}=2.0\times10^3\text{ N C}^{-1}$.

(iii)


F/mN
6.0
0
6
x/cm