Coloumb's law

$$F = \frac{k\, q_1 q_2}{r^2} \qquad k = 9 \times 10^9$$

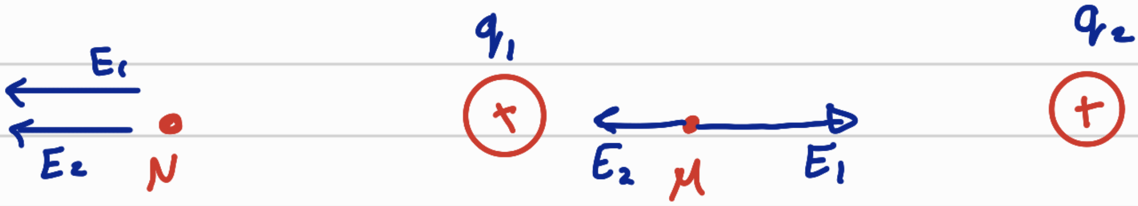
Electric Field

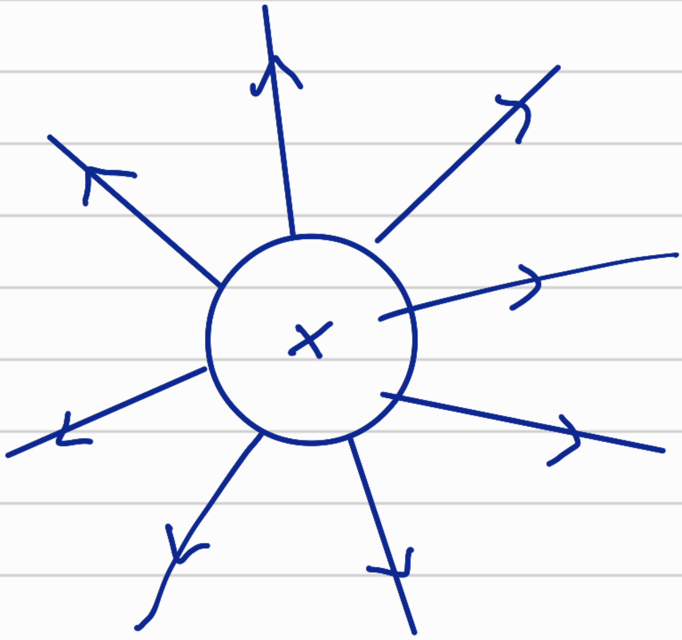
$$E = \frac{kq}{r^2}$$

E خارج من الشحنة الموجبة

E داخل للشحنة السالبة

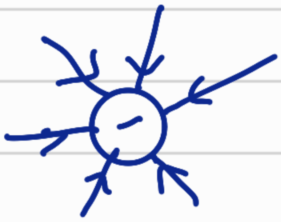
$$F = E q_0$$

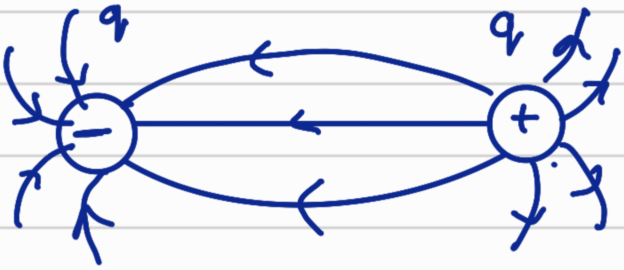


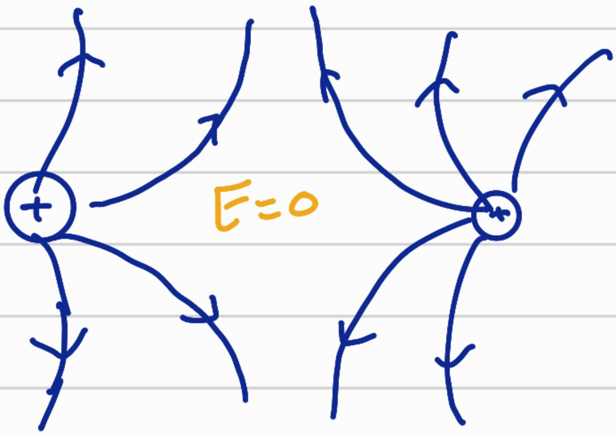


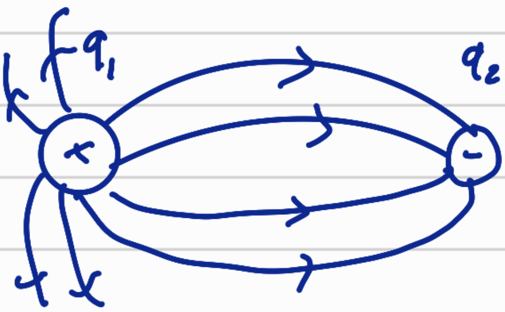
كثافه الخطوط تدل على مقدار الحقل

Nonuniform Electric









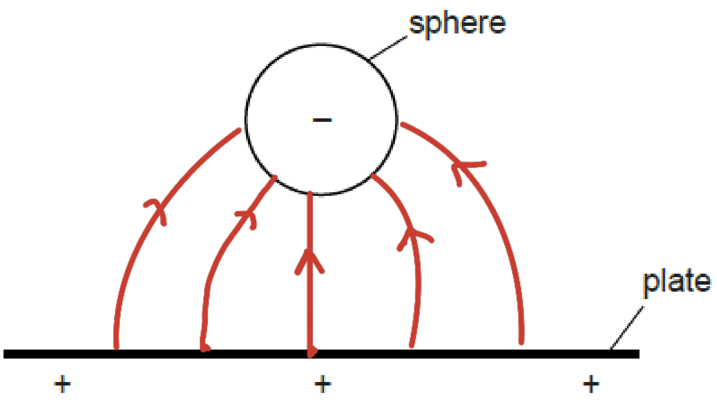
$q_1 = 2 q_2$

Uniform Electric

$E =$
500 N/C

Electric Fields Homework Sheet

Q1. (a) The figure below shows a negatively charged sphere close to a positively charged metal plate.

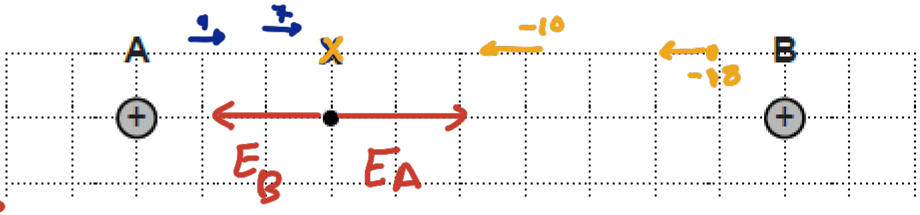


On the above figure draw **a minimum of five field lines** to show the electric field pattern between the plate and the sphere. **[2]**

نقطه التعادل دوما اقرب للشحنه الاقل

At point X $E_A = -E_B$

(b) The figure below shows two positively charged particles **A** and **B**.

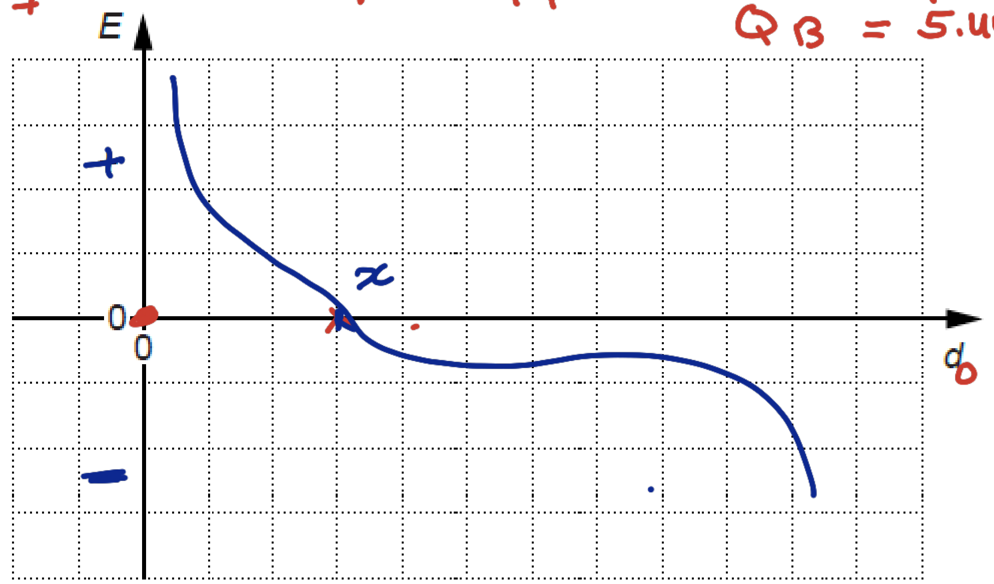


$E_A = E_B$

$\frac{kQ_A}{3^2} = \frac{kQ_B}{7^2} \Rightarrow \frac{Q_A}{9} = \frac{Q_B}{49}$

$Q_B = \frac{49}{9} Q_A$

$Q_B = 5.44\, Q_A$



At point **X**, the magnitude of the resultant electric field strength due to particles **A** and **B** is zero.

1- charge B is greater because its further away from B

(i) State, with a reason, which of the two particles has the largest charge. **[3]**

2- the electric field is equal at point X

(ii) On the figure above sketch the graph of the variation of the resultant electric field, *E*, with distance, *d*, from particle **A**. **[4]**

Q2. (a) Electric fields are caused by
(i) point charges
(ii) two parallel plates with a potential difference across them.

Describe the difference between the electric field caused by a point charge and the electric field between two parallel plates. Your answer should include a diagram of each type of field and make reference to the electric field strength in both cases. **[5]**

(b) (i) The figure below shows two small spheres A and B separated by a distance of 20cm. Both spheres have the same charge of $+5.0 \times 10^{-7}$ C.

Q2. (a) Electric fields are caused by
(i) point charges
(ii) two parallel plates with a potential difference across them.

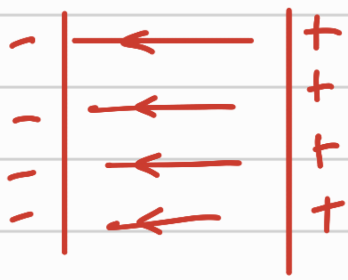
Describe the difference between the electric field caused by a point charge and the electric field between two parallel plates. Your answer should include a diagram of each type of field and make reference to the electric field strength in both cases. **[5]**

(b) (i) The figure below shows two small spheres A and B separated by a distance of 20cm. Both spheres have the same charge of $+5.0 \times 10^{-7}$ C.

Q2 (a)

the electric field is not uniform because the field decreases with distance increase

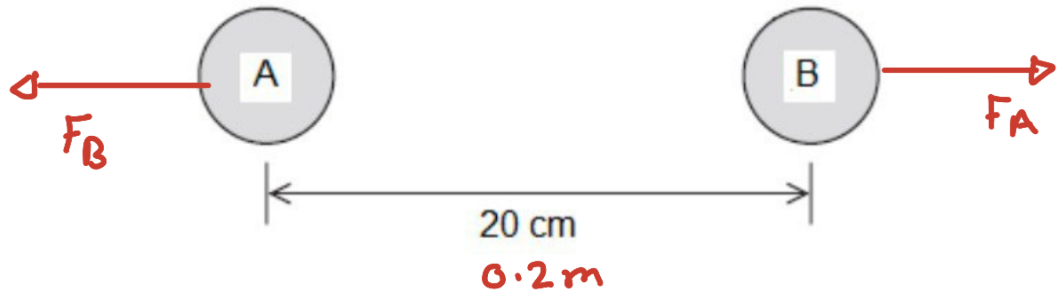
$$E = \frac{kq}{r^2}$$



Uniform Electric Field

the electric field is the same at all points

(b) (i) The figure below shows two small spheres A and B separated by a distance of 20cm. Both spheres have the same charge of $+5.0 \times 10^{-7}$ C.

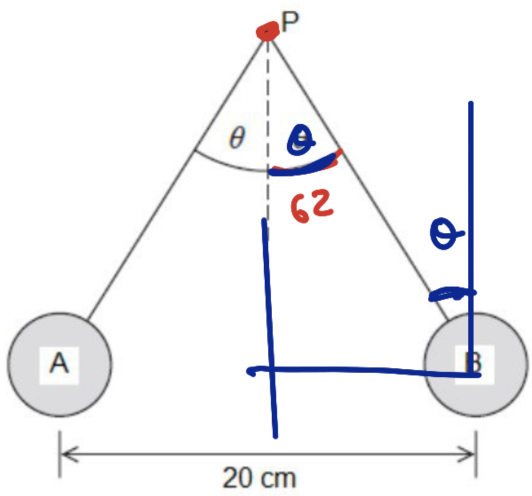


Determine the size of the electrostatic force acting on the spheres and draw an arrow on the figure to indicate the direction of the force on sphere A. **[3]**

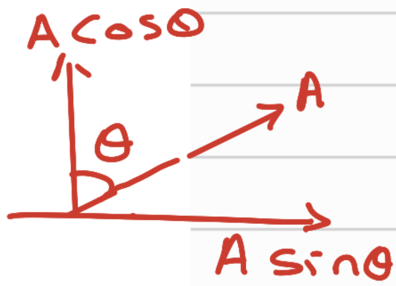
$$F = \frac{kQ_1Q_2}{r^2} = \frac{kQ^2}{r^2}$$

$$F = \frac{9\times10^9 \times 5\times10^{-7}}{(0.2)^2} = 0.056\ N$$

(ii) The spheres in part (b)(i) are now attached to non-conducting threads and suspended from a point P as is shown in the figure below.

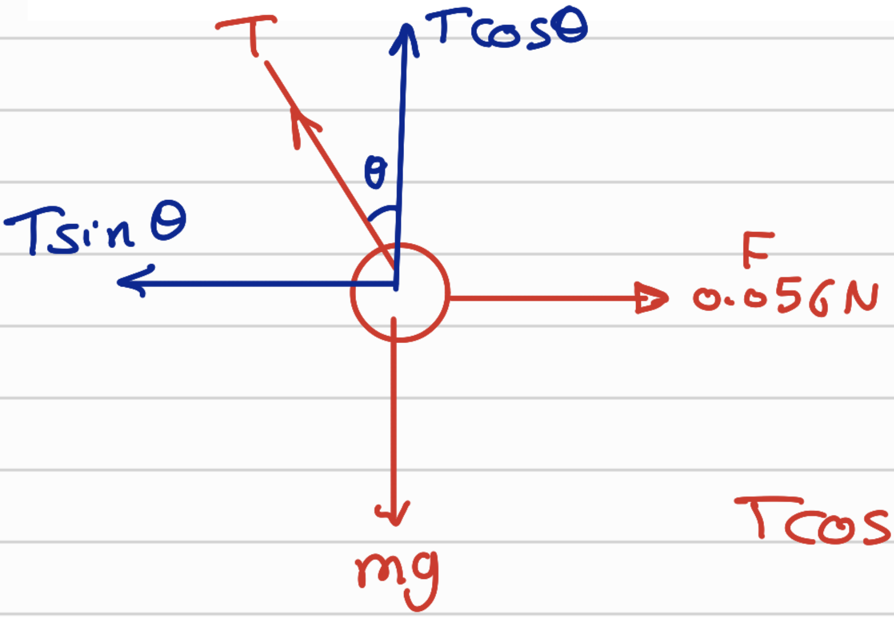


$F = 0.056\ N$



The spheres hang in equilibrium. Both spheres have the same charge of $+5.0 \times 10^{-7}$ C and the mass of each sphere is 3.0g.

By considering the forces acting on the spheres, calculate the tension in the thread and the angle θ. **[5]**



(2) لحساب T نعوض في اي معادلة

$$T = \frac{F}{\sin\theta} = \frac{0.056}{\sin 62.3}$$

$$T = 0.063$$

$$T\cos\theta = mg \quad \text{---- (1)}$$

$$T\sin\theta = F \quad \text{--- (2)}$$

eq (2) ÷ eq (1)

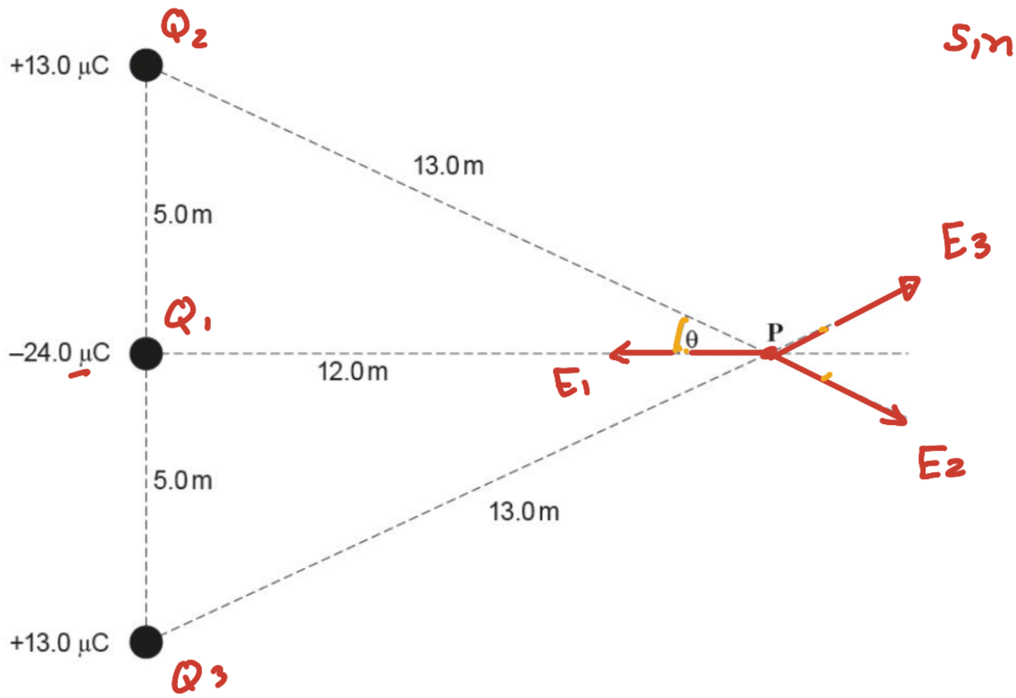
$$\frac{\cancel{T}\sin\theta}{\cancel{T}\cos\theta} = \frac{F}{mg} \qquad \tan\theta = \frac{F}{mg}$$

(1) $$\theta = \tan^{-1}\left(\frac{F}{mg}\right) = \tan^{-1}\left(\frac{0.056}{3\times10^{-3}\times9.8}\right) = 62.3^{\circ}$$

$\cos\theta = \frac{\text{المجاور}}{\text{الوتر}} = \frac{12}{13}$

$\sin\theta = \frac{\text{المقابل}}{\text{الوتر}} = \frac{5}{13}$

Q3. Three charges are arranged as shown in the figure below.



$k = 9\times10^{9}$

$k = \frac{1}{4\pi\varepsilon_0}$

$k = \frac{1}{4\pi(8.85\times10^{-12})}$

$= 8.99\times10^{9}$

$\simeq 9\times10^{9}$

(a) **Draw three arrows at P** to represent the electric fields due to each of the three charges. **[2]**

(b) Calculate the electric field strength at P due to the **-24.0 μC charge**. **[3]**

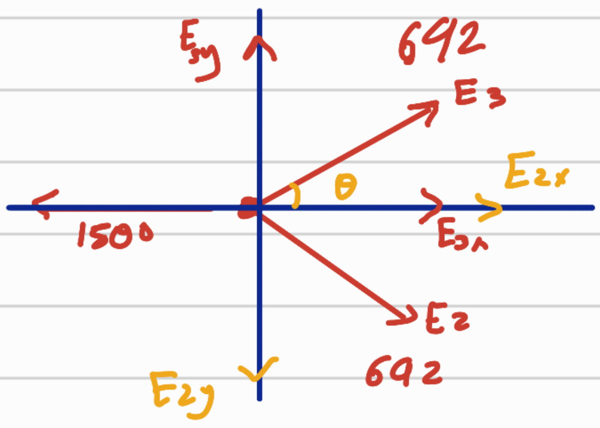
(c) Calculate the **total (resultant)** electric field strength at **P** due to all three charges. **[5]**

(d) Show that the total electric potential at **P**, due to all three charges, is zero. **[3]**

b) $E = \frac{kQ}{r^2}$

$E_1 = \frac{kQ_1}{r_1^2} = \frac{9\times10^{9}\times{}^{-}24\times10^{-6}}{(12)^2} = {}^{-}1500\ N/C$

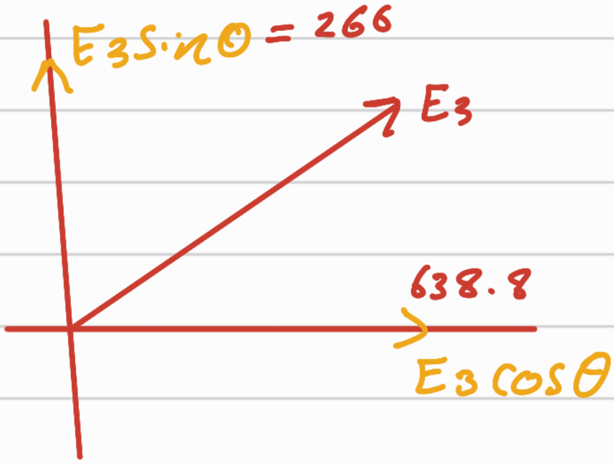
c)



$E_2 = \frac{kQ_2}{r_2^2} = \frac{9\times10^{9}\times13\times10^{-6}}{13^2}$

$= 692\ N/C$

$E_3 = 692\ N/C$

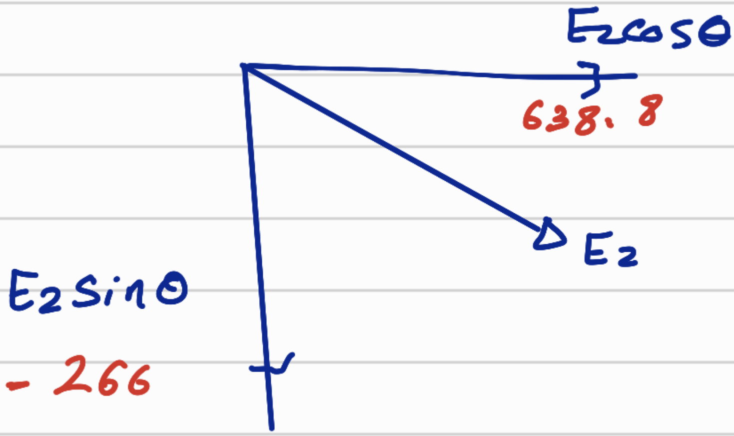


$E_{3x} = E_3 \cos\theta$

$= 692 \times \frac{12}{13} = 638.8$

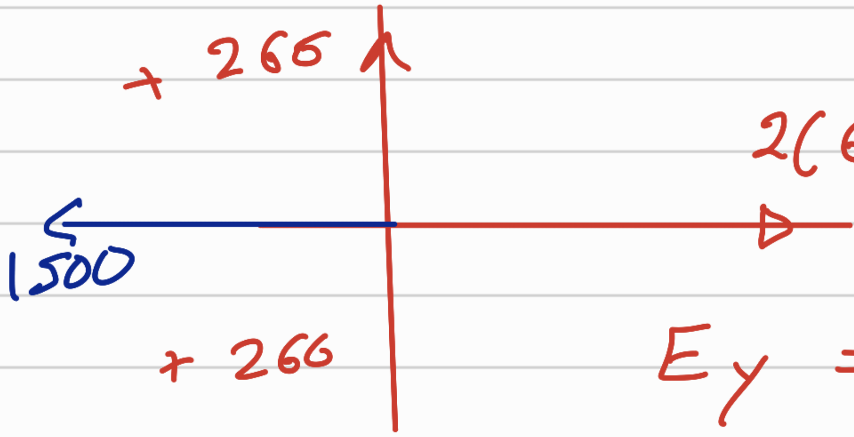
$E_{3y} = E_3 \sin\theta$

$692 \times \frac{5}{13} = 266$



$E_{2x} = E_2 \cos\theta = 638.8$

$E_{2y} = E_2 \sin\theta = -266$



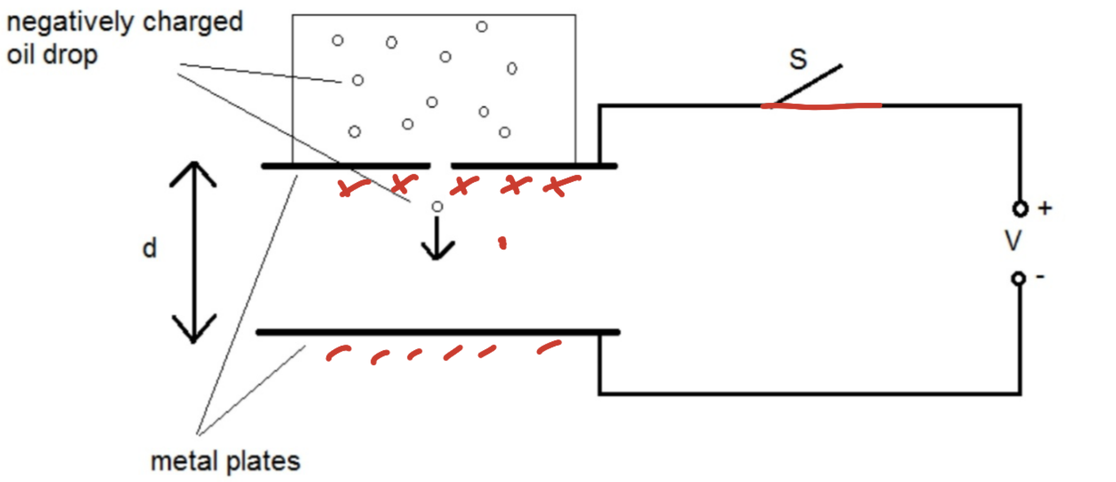
$2(638.8) = 1277$

$E_y = 0$

$E_{total} = 1277 - 1500 = 223\ N/C$

to the left

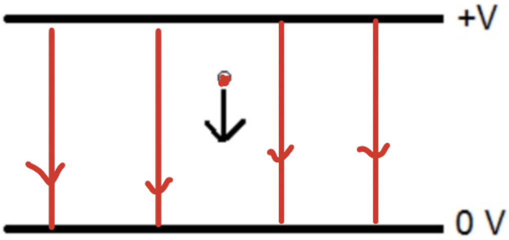
Q4. The figure below shows an experiment where negatively charged oil drops fall between two metal plates.



The distance between the two metal plates is d. When the switch S is closed a potential difference, V, is applied to across the plates and causes an electric field to be set up between the plates.

(a) The figure below shows a simplified diagram of the two plates with an oil drop falling between them. On the figure, draw lines to show the electric field between the plates. **[2]**

(a) The figure below shows a simplified diagram of the two plates with an oil drop falling between them. On the figure, draw lines to show the electric field between the plates. **[2]**



$F = EQ$

$E = \frac{V}{d} = \frac{\text{فرق الجهد}}{\text{المسافة}}$

(b) The value of the potential difference, V, is increased slowly. When V reaches a particular value the negatively charged oil drop stops falling and remains stationary between the plates. Explain why this happens. **[2]**

(c) The oil drop has mass, m, and charge Q. It stops falling when V = 5500 V. The distance, d, between the two metal plates is 3.5 cm. Show that the magnitude of $\frac{Q}{m}$ for this oil drop is about 60 µC kg^{-1}. **[3]**

b) the net force act on the oil drop is equal zero (balanced)
gravity = Electric field (Force)

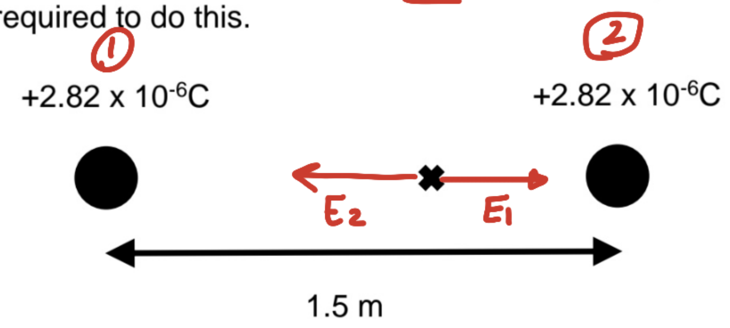
c) $mg = EQ$ $\quad$ $mg = \frac{V}{d} Q$

$$\frac{Q}{m} = \frac{gd}{V} = \frac{9.8 \times 3.5 \times 10^{-2}}{5500} = 62 \times 10^{-6} \text{ kg/C}$$

Q5. A small sphere has a charge of +2.82 x 10^{-6}C

(a) How many electrons have been removed from the sphere? **[2]**

(b) (i) A small identical sphere also has a charge of +2.82 x 10^{-6}C. It is brought from a distant point to a distance 1.5m from the first sphere. Determine the work required to do this. **[2]**



(ii) Determine the magnitude of the electric field strength at the point **x** that is 0.8m from the left-hand side sphere and state the direction of the field. **[4]**

$e = 1.6 \times 10^{-19} C$

a) $Q = ne$

$n = \frac{Q}{e} = \frac{2.82 \times 10^{-6}}{1.6 \times 10^{-19}} = 1.76 \times 10^{13}$ electron

b) $W = \Delta U = \frac{k Q_1 Q_2}{r}$

+ + 1.5

$W = \frac{9 \times 10^{9} \times (2.82 \times 10^{-6})^2}{1.5} = 0.0477 J$

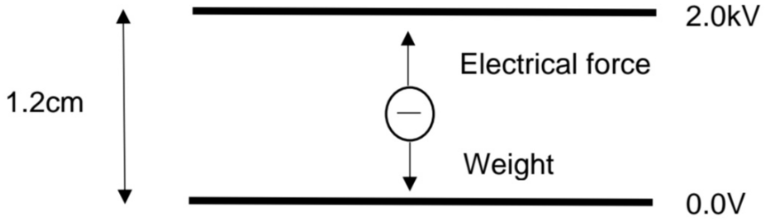
c) $E_1 = \frac{kQ_1}{r_1^2} = \frac{9 \times 10^{9} \times 2.82 \times 10^{-6}}{0.8^2} = 39656$ N/C
Right

$E_2 = \frac{k Q_2}{r_2^2} = \frac{9 \times 10^{9} \times 2.82 \times 10^{-6}}{0.7^2} = 51796$ N/C
left

$E = E_2 - E_1 = 12140$ N/C
left

$F = EQ = \frac{V}{d}Q$

(c) A negatively charged oil drop is held stationary between two horizontal plates. The potential difference between the plates is 2.0kV. The figure below shows the forces acting on the charged oil drop.



The oil drop has a mass of 2.8 x 10^{-14}kg and the distance between the plates is 1.2cm.

(i) Show that the **size** of the charge on the oil drop is about 1.6 x 10^{-18}C. **[3]**

(ii) Calculate the number of electrons causing the charge on the oil drop. **[1]**

Electric force = weight

$$\frac{\Delta V}{d} Q = mg$$

$$Q = \frac{mgd}{\Delta V} = \frac{2.8\times10^{-14}\times9.8\times1.2\times10^{-2}}{2\times10^{3}}$$

$$= 1.646\times10^{-18}\,C$$

b) $Q = ne$ $\quad n = \frac{Q}{e}$

$$n = \frac{1.646\times10^{-18}}{1.6\times10^{-19}} = 10.28$$

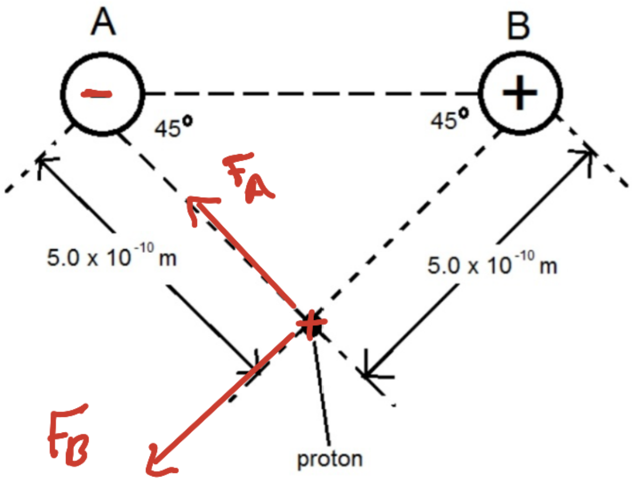
$\approx$ 10 electrons

Q6. (a) State **Coulomb's law**. **[2]**

$F \propto \frac{Q_1 Q_2}{r^2}$

force betwee two point charges is directly proportional to the product of the two charges and inversely to the square of the distance between them

(b) The picture below shows two ions, A and B, with opposite charges and a proton. The charge on ion A is -3.2×10^{-19}C while the charge on ion B is 3.2×10^{-19}C. The proton is at a distance of 5.0×10^{-10}m from both ions and at an angle of 45° to the line joining the centres of ions A and B.



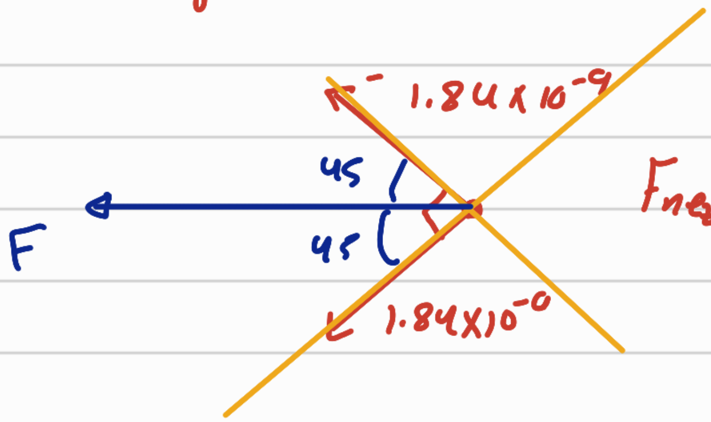
(i) Show that the force, F, acting on the proton from ion B is 1.8×10^{-9} N. **[2]**

(ii) Calculate the size of the resultant force experienced by the proton. **[3]**

$$F_B = \frac{k Q_B Q_p}{r^2} = \frac{9 \times 10^9 \times 3.2 \times 10^{-19} \times 1.6 \times 10^{-19}}{(5 \times 10^{-10})^2}$$

$$= 1.84 \times 10^{-9} N$$

$$F_A = \frac{kQ_A Q_p}{r^2} = -1.84 \times 10^{-9}\ N$$

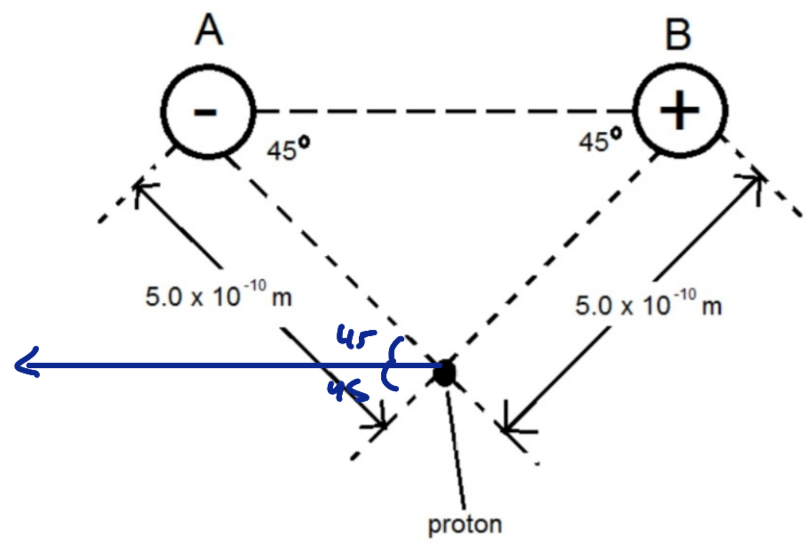


$$F_{net} = \sqrt{(1.84)^2 + (1.84)^2} \times 10^{-9}$$

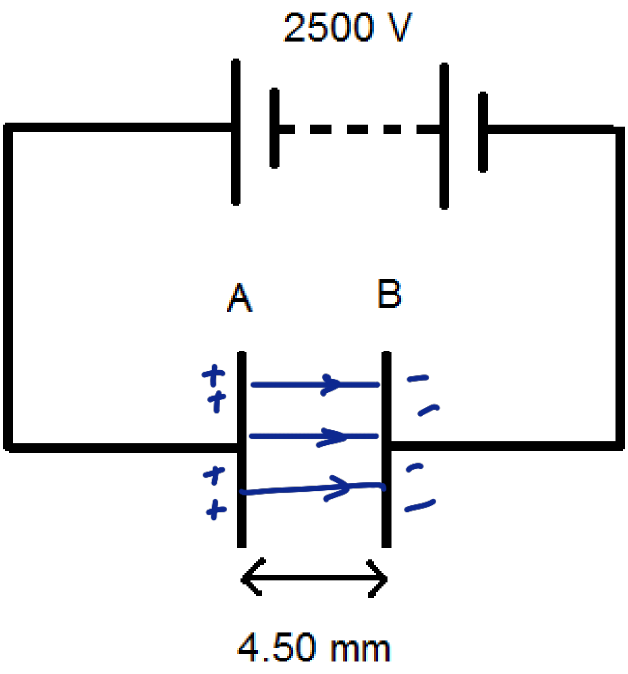
$$= 2.6 \times 10^{-9}\ N$$

$$\theta = \tan^{-1}\left(\frac{1.84 \times 10^{-9}}{1.84 \times 10^{-9}}\right) = 45^{\circ}$$

(iii) On the picture below draw an arrow to show the direction of the resultant force acting on the proton.



Q7. A student studying electric field places two parallel plates, A and B, a distance 4.50mm apart and connects them to a high voltage supply as is shown in the picture below. There is a vacuum between the plates.



(a) On the picture above sketch the electric field lines between the two plates clearly showing the direction of the field. **[2]**

(b) Electrons are accelerated from plate B to plate A.

(i) Calculate the force on an electron. **[3]**

(ii) Calculate the gain in kinetic energy of an electron as it travels from B to A. **[2]**

$\Delta K = W = Fd$

$= 8.88 \times 10^{-14} \times 4.5 \times 10^{-3} = 4 \times 10^{-16}\ J$

(iii) Find the time it takes for an electron to travel from B to A. Assume the electron starts from rest at plate B. **[3]**

(c) The separation between the plates is now doubled but the potential difference is unchanged. The student states that the gain in kinetic energy of an electron that starts at rest and travels from B to A will be unchanged. Show that the student is correct. **[3]**

$$\Delta K = W = F\ d$$

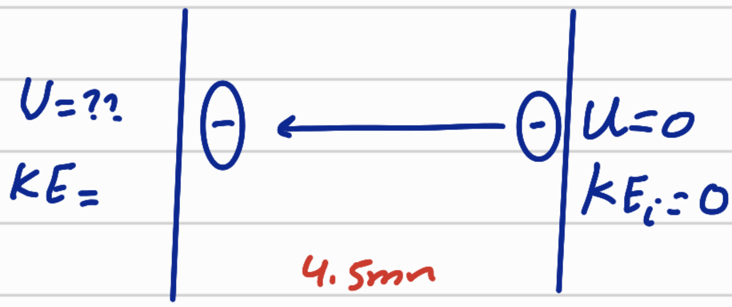
$$= \frac{VQ}{\cancel{2}d}\ \cancel{2}d$$

when the distance is doubled the force is halfed $\left(F = \frac{VQ}{d}\right)$ the the work stays the same

a) $F = EQ = \frac{V}{d}Q = \frac{2500}{4.5\times10^{-3}}\left({}^{-}1.6\times10^{-19}\right)$

$= {}^{-}8.88 \times 10^{-14}\ N$

$F = ma$ $\quad a = \frac{F}{m} = \frac{8.88\times10^{-14}}{9.11\times10^{-31}} = 9.757\times10^{16}\ m/s$ left



b) final velocity

$v^2 = \cancelto{zero}{u^2} + 2a\Delta x$

$v = \sqrt{2a\,\Delta x} = \sqrt{2\times9.757\times10^{16}\times4.5\times10^{-3}}$

$v = 29.6\times10^{6}\ m/s$

$\Delta KE = KE_f - KE_i =$

$= \frac{1}{2}mv^2 - \cancelto{zero}{\frac{1}{2}mu^2}$

$= \frac{1}{2}(9.11\times10^{-31})\times(29.6\times10^{6})^2$

$= \quad = 4 \times10^{-16}\ J$

iii)

$$v = \overset{\text{zero}}{\cancel{u}} + at$$

$$t = \frac{v}{a} = \frac{29.6 \times 10^{6}}{9.757 \times 10^{16}}$$

$$= 3.03 \times 10^{-10} \text{ s}$$