PROSPERITY ACADEMY

A2 PHYSCIS 9702

Crash Course

RUHAB IQBAL

ELECTRIC FIELDS

COMPLETE NOTES

0331 - 2863334

ruhab.prosperityacademics
@gmail.com

Electric Fields:- A region or space where a charge experiences a force.

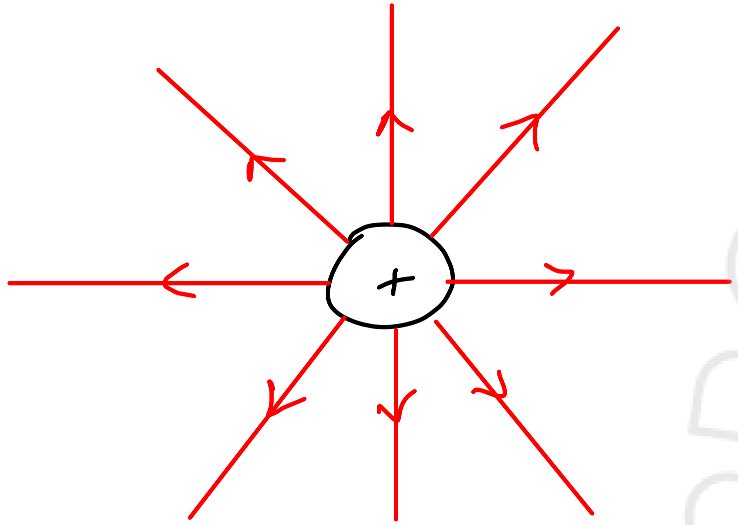
Electric field lines:- Hypothetical lines of forces that depict the force acting on a unit charge.

Unit charge:- +1 C ⊕

Charge:- Property of matter that causes it to experience a force in an electric field

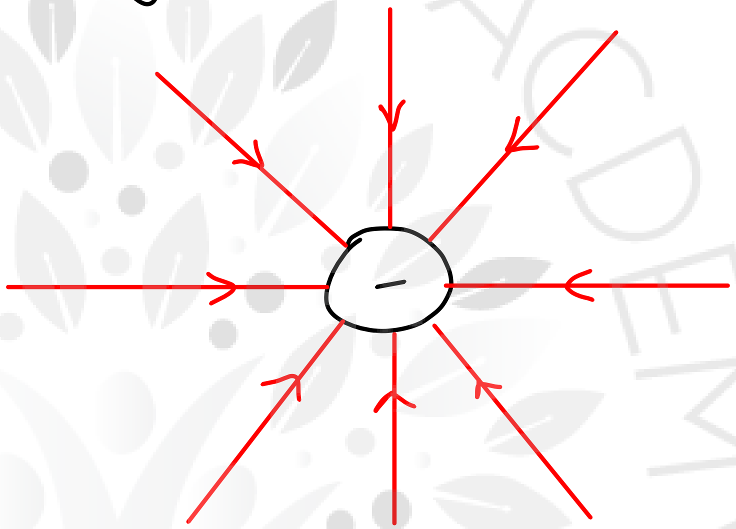
- Charges can be positive or negative.
- like charges repel, unlike charges attract

Positive charge:-



positive point charge
Repulsive

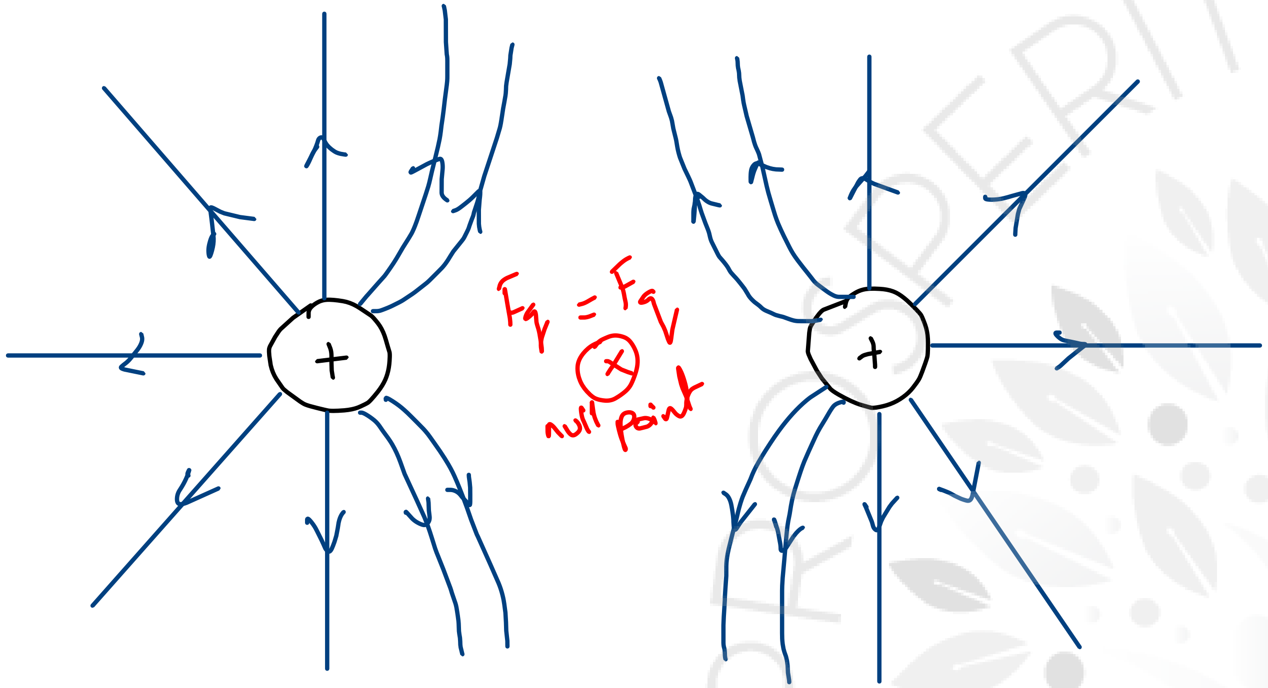
Negative charge:-

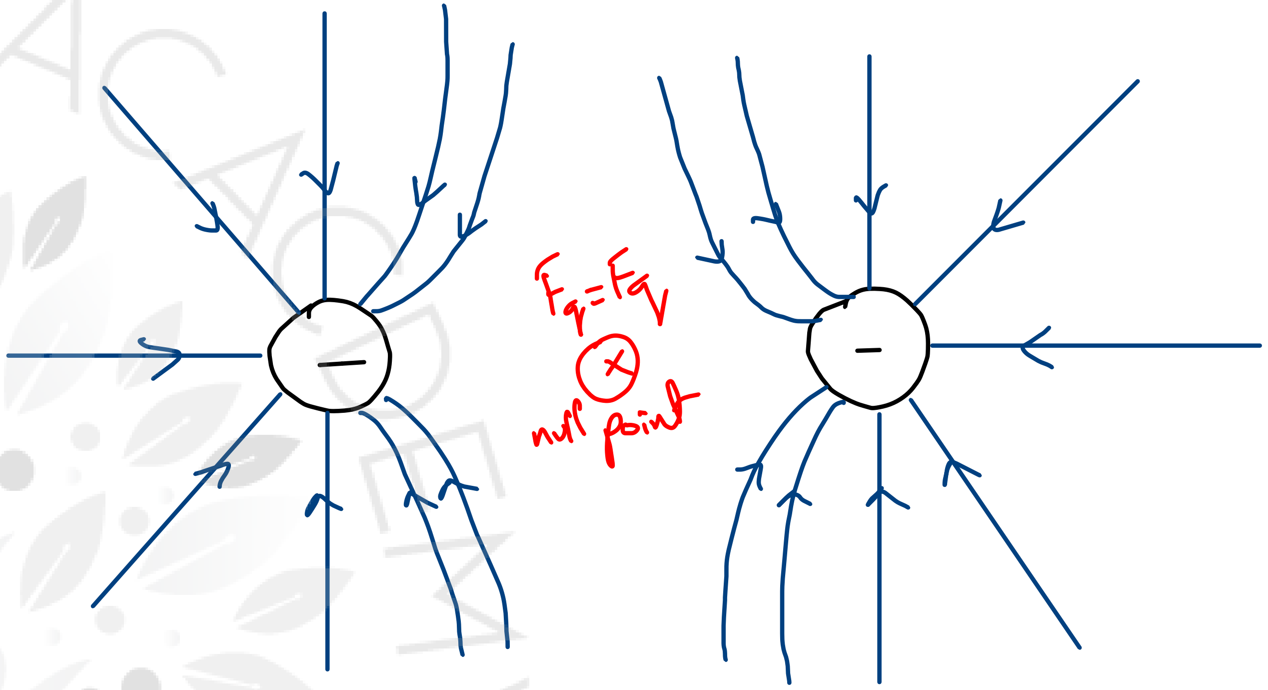


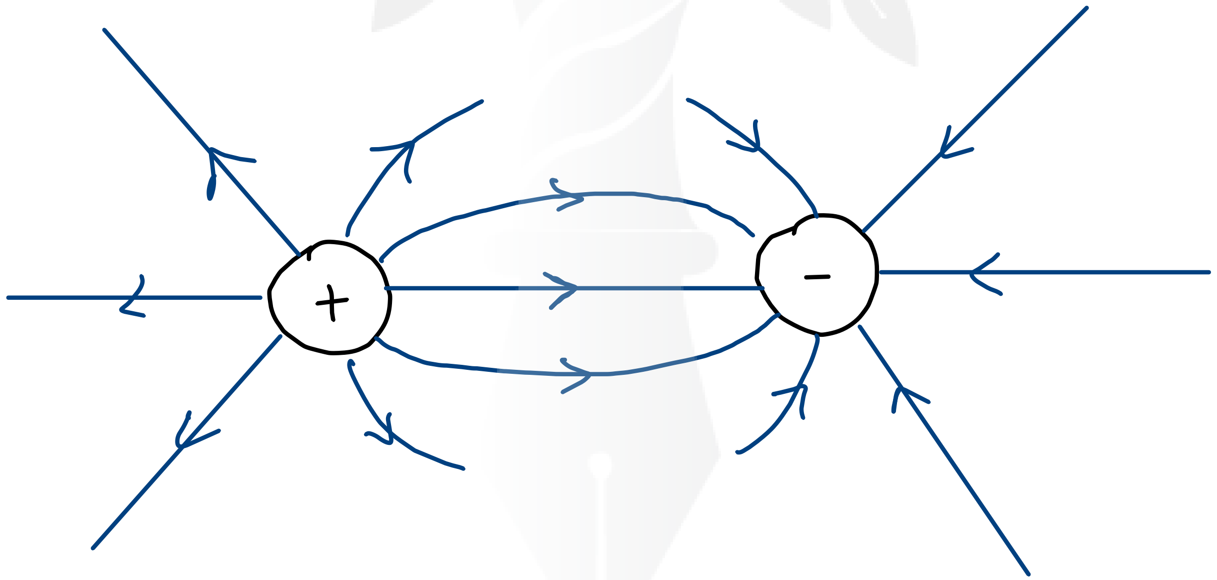
Negative point charge
Attractive

Point charge:- The complete charge is assumed to be concentrated at the centre

Electric field lines are always $+ \longrightarrow -$


+
+
Fq = Fq
null point


−
−
Fq=Fq
null point


+
−

To show a stronger field, draw field lines closer together

Electric field strength:- Force experienced per unit charge for a charge placed in an electric field.

$$E = \frac{F_q}{q} = \frac{\frac{KQ\cancel{q}}{r^2}}{\cancel{q}} = \frac{KQ}{r^2}$$

Coulomb's law:- The electric force experienced between 2 charges is directly proportional to the product of the charges but inversely proportional to the square of the distances between their centres

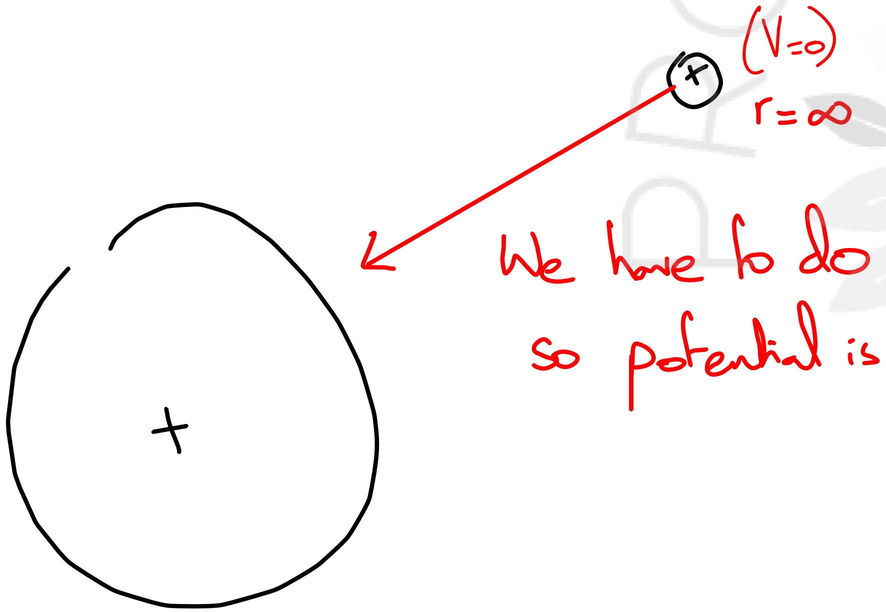
$$F_q \propto \frac{Qq}{r^2} \Rightarrow F_q = \frac{KQq}{r^2} \Rightarrow F_q = \frac{Qq}{4\pi\varepsilon_0 r^2}$$

9×10^9

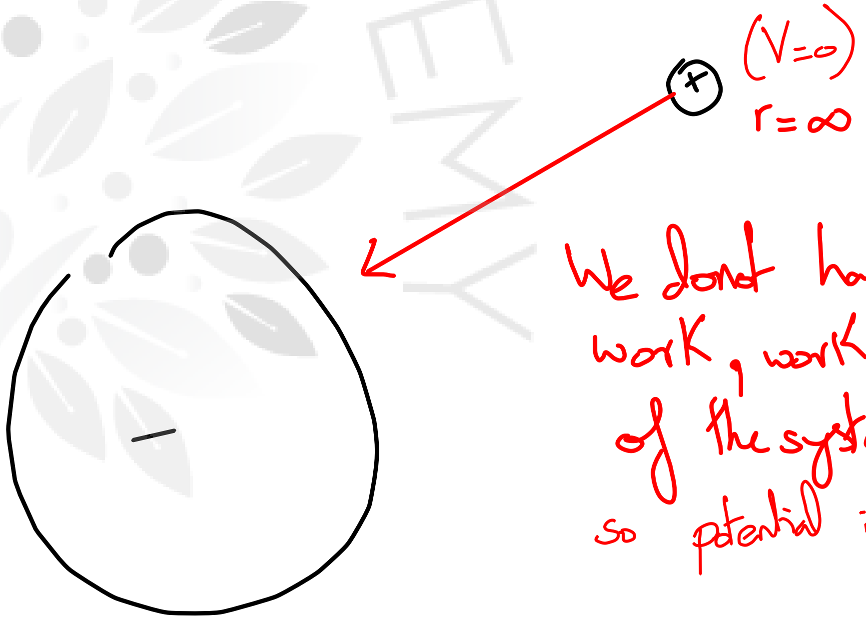
don't write this as the formula (this is for you)

write this, if the examiner asks

Electric Potential (V) :- Work done per unit charge in bringing that charge from infinity to a point within an electric field.



We have to do work so potential is positive



We dont have to do work, work gets out of the system by itself so potential is negative

$$V = \frac{W}{q} = \frac{F_q \times s}{q} = \frac{\frac{KQ\cancel{q}}{r^{\cancel{2}}} \times \cancel{r}}{\cancel{q}} = \frac{KQ}{r}$$

Electric Potential Energy:-

$$V = \frac{W}{q} \Rightarrow W = Vq$$

$$E.p.e = \frac{KQq}{r}$$

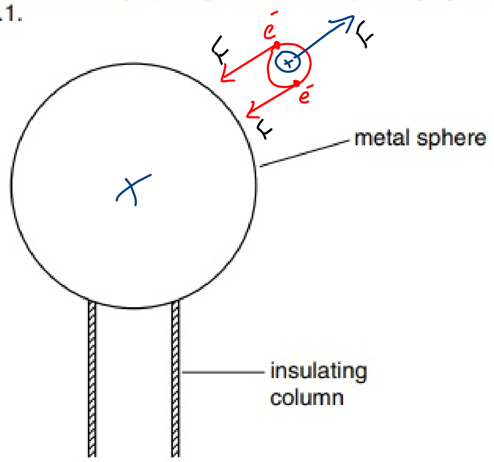
$$\Delta E.p.e = \Delta V \times q$$

$$(V_f - V_i) \times q$$

$$\left(\frac{KQ}{r_f} - \frac{KQ}{r_i}\right) \times q$$

$$KQq\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$$

4 In a particular experiment, a high voltage is created by charging an isolated metal sphere, as illustrated in Fig. 4.1.



ion :- disbalance of +ve & -ve charges

Fig. 4.1

The sphere has diameter 42 cm and any charge on its surface may be considered as if it were concentrated at its centre.

The air surrounding the sphere loses its insulating properties, causing a spark, when the electric field exceeds 20 kV cm^{-1}.

(a) By reference to an atom in the air, suggest the mechanism by which the electric field causes the air to become conducting.

* The electric field will cause opposing forces on the nucleus and the electrons. In this process, the electrons are stripped/pulled off the nucleus turning the particles into ions and therefore air becomes conducting .... [3]

(b) Calculate, for the charged sphere when a spark is about to occur,

(i) the charge on the sphere,

$$\frac{20\times10^{3}\times(21\times10^{-2})^{2}}{10^{-2}\times(9\times10^{9})} = Q$$

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

$$\frac{20\,\text{kV}\times10^{3}}{\text{cm}\times10^{-2}} = \frac{(9\times10^{9})\,Q}{\left(\frac{42}{2}\times10^{-2}\right)^{2}} = 9.8\times10^{-6}\ \text{C}$$

charge = ... 9.8×10^{-6} .... C [3]

(ii) its potential.

$$V = \frac{KQ}{r} \Rightarrow \frac{(9\times10^{9})(9.8\times10^{-6})}{(21\times10^{-2})}$$

$$V = 420\,000$$

potential = ... 420 000 .... V [2]

(c) Under certain conditions, a spark sometimes occurs before the potential reaches that calculated in **(b)(ii)**. Suggest a reason for this.

Maybe the air is humid

.... [1]

Charge is lost by:-

- Air is humid
- Sphere is not smooth
- Heat

s17 qp41 q5

5 An α-particle is travelling in a vacuum towards the centre of a gold nucleus, as illustrated in Fig. 5.1.

Fig. 5.1

The gold nucleus has charge 79e.
The gold nucleus and the α-particle may be assumed to behave as point charges.
At a large distance from the gold nucleus, the α-particle has energy 7.7×10^{-13} J.

$r=\infty$ / $V=0$

(a) The α-particle does not collide with the gold nucleus. Show that the radius of the gold nucleus must be less than 4.7×10^{-14} m.

$$\Delta K.E = \Delta E.p.e = \Delta V\times q = (V_f - V_i)\times q$$

$$7.7\times10^{-13} = \frac{KQq}{r}$$

$$7.7\times10^{-13} = \frac{(9\times10^{9})(79\times1.6\times10^{-19})(2\times1.6\times10^{-19})}{r}$$

$$r = 4.728\times10^{-14} \simeq 4.7\times10^{-14}$$

[3]

(b) Determine the acceleration of the α-particle for a separation of 4.7×10^{-14} m between the centres of the gold nucleus and of the α-particle.

$$F_q = ma$$

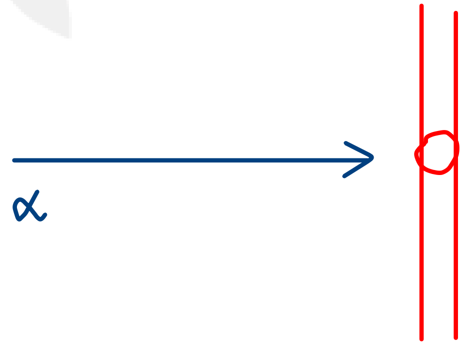
$$\frac{KQq}{r^2} = m\times a$$

$$a = \frac{(9\times10^{9})(79\times1.6\times10^{-19})(2\times1.6\times10^{-19})}{(4.7\times10^{-14})^2\times(4\times1.66\times10^{-27})} = 2.5\times10^{27}$$

acceleration = 2.5×10^{27} m s^{-2} [3]

(c) In an α-particle scattering experiment, the beam of α-particles is incident on a very thin gold foil.
Suggest why the gold foil must be very thin.

So that the interaction of the alpha particle can be studied with a single gold nucleus and its atomic structure can be deduced. [1]



5 Two small solid metal spheres A and B have equal radii and are in a vacuum. Their centres are 15 cm apart.
Sphere A has charge +3.0 pC and sphere B has charge +12 pC. The arrangement is illustrated in Fig. 5.1.

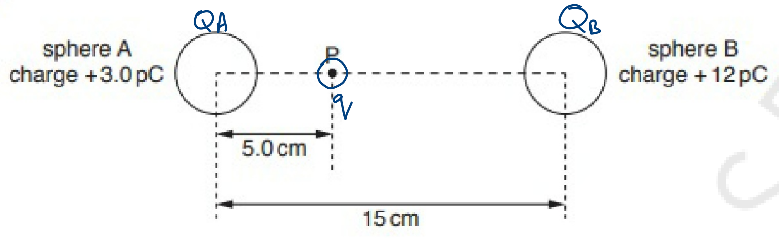


Fig. 5.1

Point P lies on the line joining the centres of the spheres and is a distance of 5.0 cm from the centre of sphere A.

(a) Suggest why the electric field strength in both spheres is zero.

Both spheres are of metal and thus charges can flow in them. The charges are therefore able to align themselves in such a way that inside of the sphere, the net force is zero [2]

(b) Show that the electric field strength is zero at point P. Explain your working.

$$F_A = F_B$$

$$\frac{\cancel{K} Q_A \cancel{q}}{r_A^2} = \frac{\cancel{K} Q_B \cancel{q}}{r_B^2}$$

$$\frac{(3\times10^{-12})}{(5\times10^{-2})^2} = \frac{(12\times10^{-12})}{(10\times10^{-2})^2}$$

$$\frac{\cancel{3}\times\cancel{10^{-12}}}{\cancel{25}\times\cancel{10^{-4}}} = \frac{\cancel{12}\times\cancel{10^{-12}}}{\cancel{100}\times\cancel{10^{-4}}}$$

$$1 = 1$$

$\boxed{\text{Shown}}$

[3]

(c) Calculate the electric potential at point P.

$$V = \frac{KQ_A}{r_A} + \frac{KQ_B}{r_B}$$

$$= \frac{(9\times10^{9})(3\times10^{-12})}{(5\times10^{-2})} + \frac{(9\times10^{9})(12\times10^{-12})}{(10\times10^{-2})}$$

electric potential = 1.62 V [2]

(d) A silver-107 nucleus ($^{107}_{47}Ag$) has speed v when it is a long distance from point P.

$V=0$
$r=\infty$

Use your answer in **(c)** to calculate the minimum value of speed v such that the nucleus can reach point P.

$$\Delta E.P.E = \Delta K.E$$

$$(V_f - V_i)\times q = \frac{1}{2}mv^2$$

$$\sqrt{\frac{2\times(1.62-0)\times(47\times1.6\times10^{-19})}{107\times(1.66\times10^{-27})}} = \sqrt{v^2}$$

$$11712.11 = v$$
$$1.2\times10^{4}$$

speed = 1.2×10^{4} ms^{-1} [3]

[Total: 10]

4 **(a)** Explain what is meant by the *potential energy* of a body.

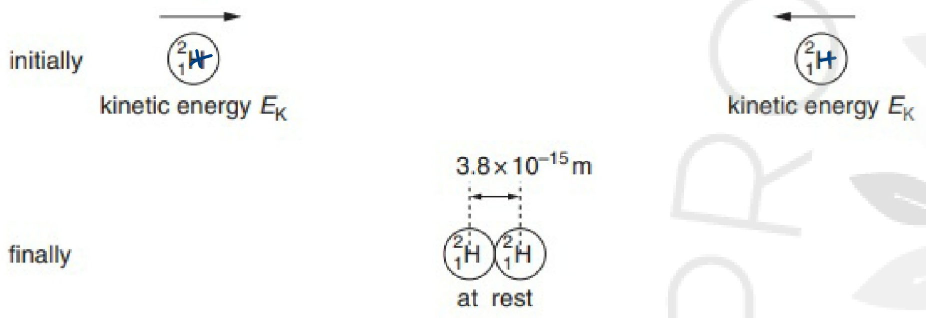
Energy that an object possesses by virtue of it's state or position.

.... [2]

(b) Two deuterium ($^2_1$H) nuclei each have initial kinetic energy E_K and are initially separated by a large distance. $r = \infty$ $\phi = 0$, $V = 0$

The nuclei may be considered to be spheres of diameter 3.8×10^{-15} m with their masses and charges concentrated at their centres.

The nuclei move from their initial positions to their final position of just touching, as illustrated in Fig. 4.1.



(i) For the two nuclei approaching each other, calculate the total change in

1. gravitational potential energy,

$$\Delta G.P.E = \Delta\phi \times m = (\phi_f - \phi_i) \times m$$

$$\frac{-GMm}{r_f}$$

$$\frac{-(6.67\times10^{-11})(2\times1.67\times10^{-27})^2}{3.8\times10^{-15}} \quad (-ve)$$

energy = 1.93×10^{-49} J [3]

2. electric potential energy.

$$\Delta E.p.e = \Delta V \times q = (V_f - V_i) \times q$$

$$E.p.e = \frac{KQq}{r} = \frac{(9\times10^9)(1.6\times10^{-19})^2}{3.8\times10^{-15}}$$

energy = 6.06×10^{-14} J [3]

(ii) Use your answers in **(i)** to show that the initial kinetic energy E_K of each nucleus is 0.19 MeV.

$E_{input} = E_{output}$

$2E_K + \Delta G.P.E = \Delta E.p.e$

$2E_K + 1.93\times10^{-49} = 6.06\times10^{-14}$

$E_K = \frac{6.06\times10^{-14} - 1.93\times10^{-49}}{2} = 3.03\times10^{-14}$ J

$1\text{eV} = 1.6\times10^{-19}$ J

$1\text{MeV} = 1.6\times10^{-19}\times10^{6} = 1.6\times10^{-13}$

1.6×10^{-13} : 1 MeV

3.03×10^{-14} J : x MeV

$x = \frac{3.03\times10^{-14}}{1.6\times10^{-13}}$

$x = 0.189$

$x = 0.19$ MeV [2]

(iii) The two nuclei may rebound from each other. Suggest one other effect that could happen to the two nuclei if the initial kinetic energy of each nucleus is greater than that calculated in **(ii)**.

fusion will occur

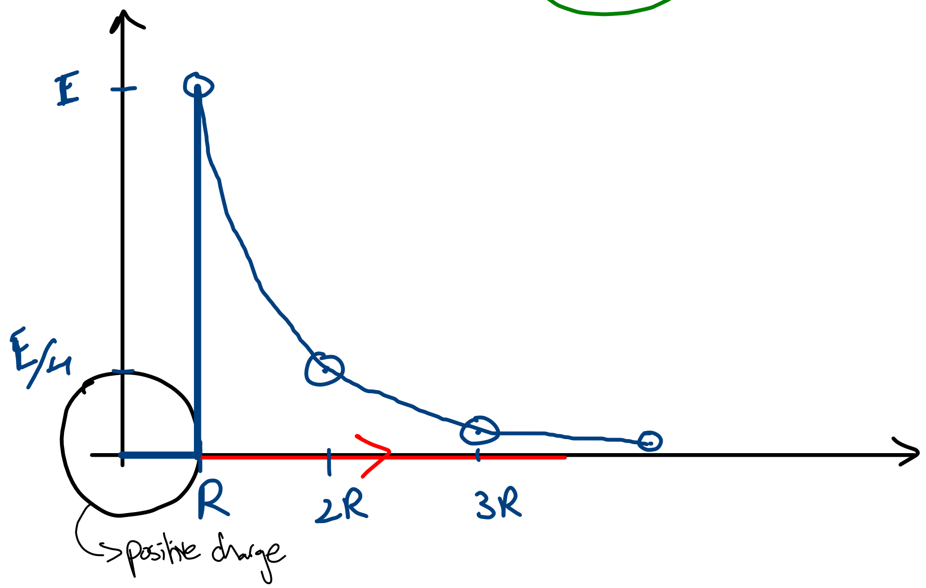
.... [1]

Electric field strength:-

The force experienced per unit charge by a charge placed in an electric field.

Vector, measured in Vm^{-1} or NC^{-1}.

$$E = \frac{F}{q} = \frac{\frac{KQ\cancel{q}}{r^2}}{\cancel{q}} = \frac{KQ}{r^2}$$



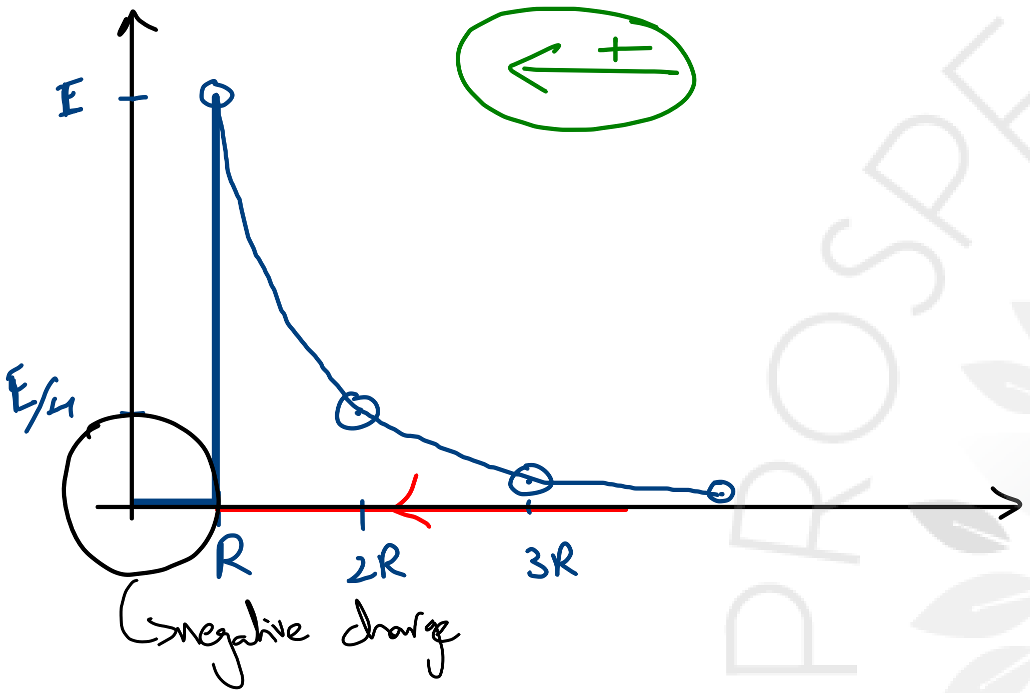
$$E = \frac{\overbrace{KQ}^{\text{const}}}{r^2} \Rightarrow E \propto \frac{1}{r^2}$$

$$E_1 r_1^2 = E_2 r_2^2$$

$$ER^2 = E_2(2R)^2 \qquad ER^2 = E_3(3R)^2$$

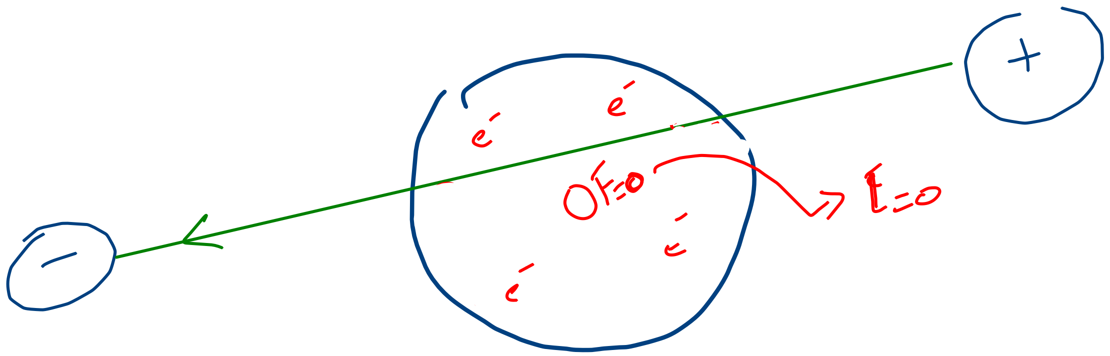
$$E\cancel{R^2} = E_2\, 4\cancel{R^2} \qquad E\cancel{R^2} = E_3\, 9\cancel{R^2}$$

$$E_2 = \frac{E}{4} \qquad E_3 = \frac{E}{9}$$



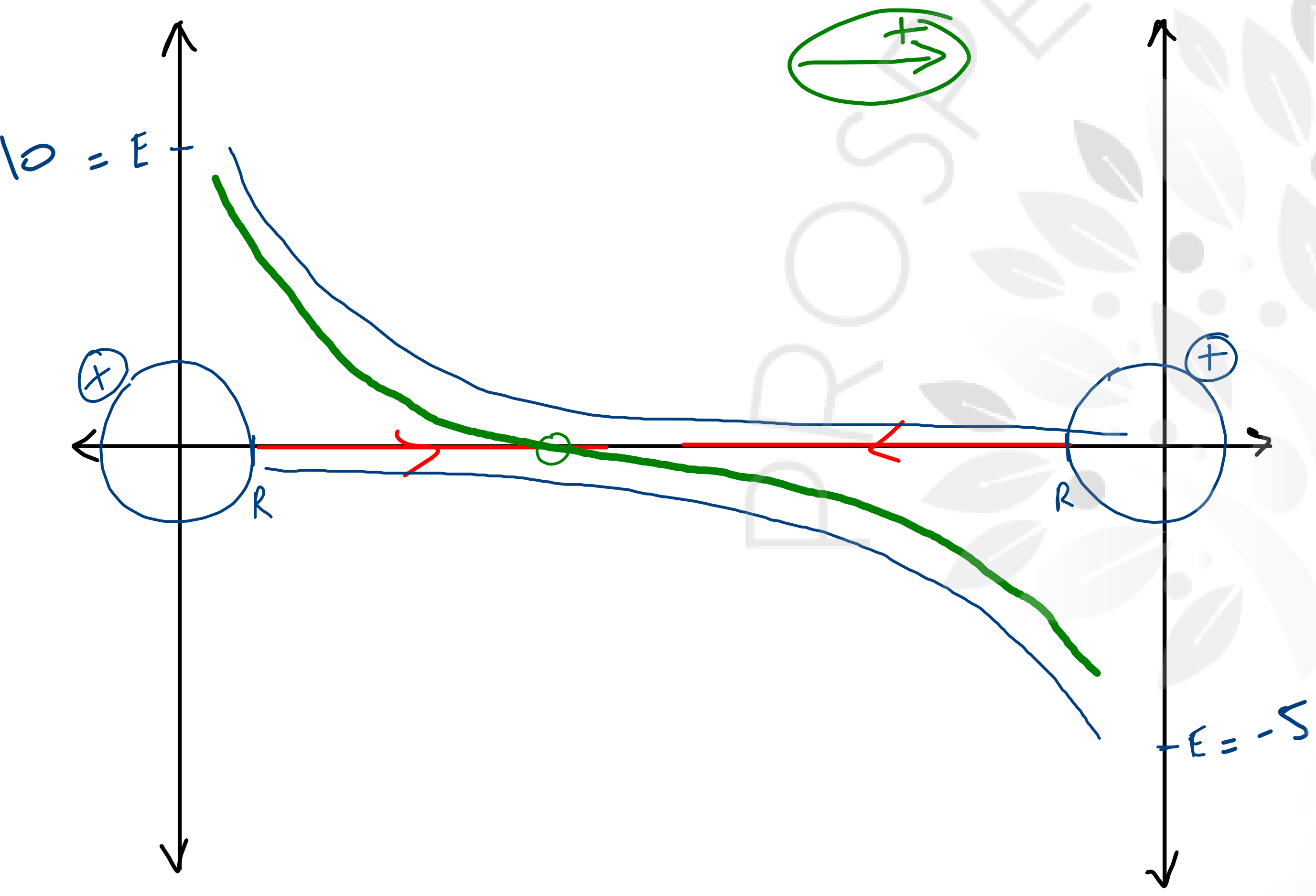
A2 course:-

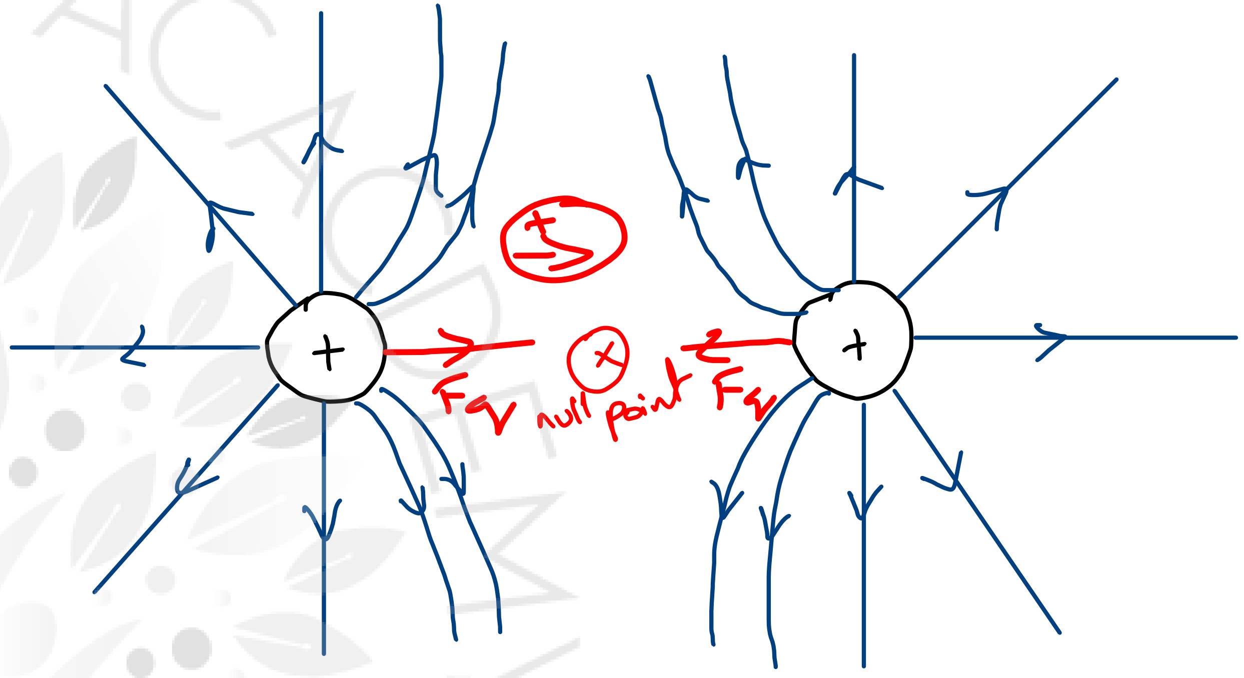
Point charges are mostly metal spheres $\Rightarrow$ Electric field strength inside is zero



As electrons are free to move, they align themselves in such a manner that $E=0$ inside a metal sphere (Basically all the electrons flow to the surface of the conductor an hence $E=0$ inside conductor)

Between 2 positive charges:-

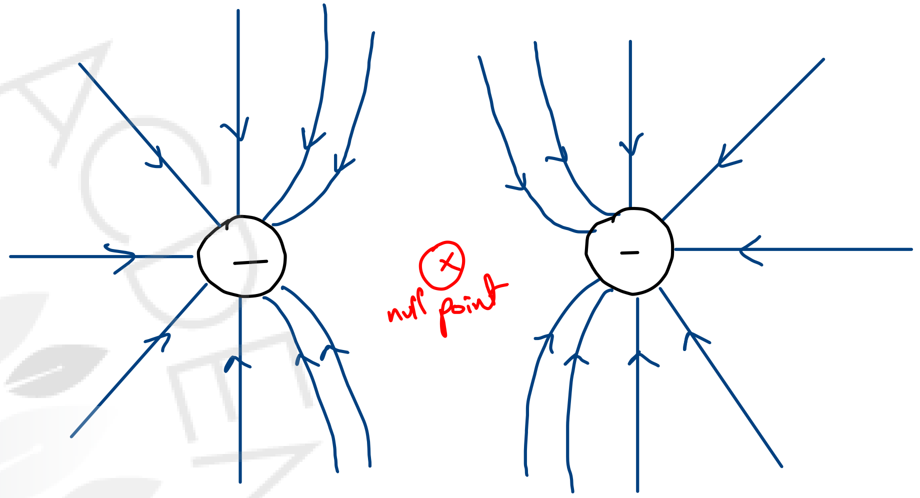




How to tell which charge is greater?

- The charge from which the null point is farther away is the greater charge
- If the charges have equal radii, then look at initial value of Electric field strength

Between 2 negative charges:-

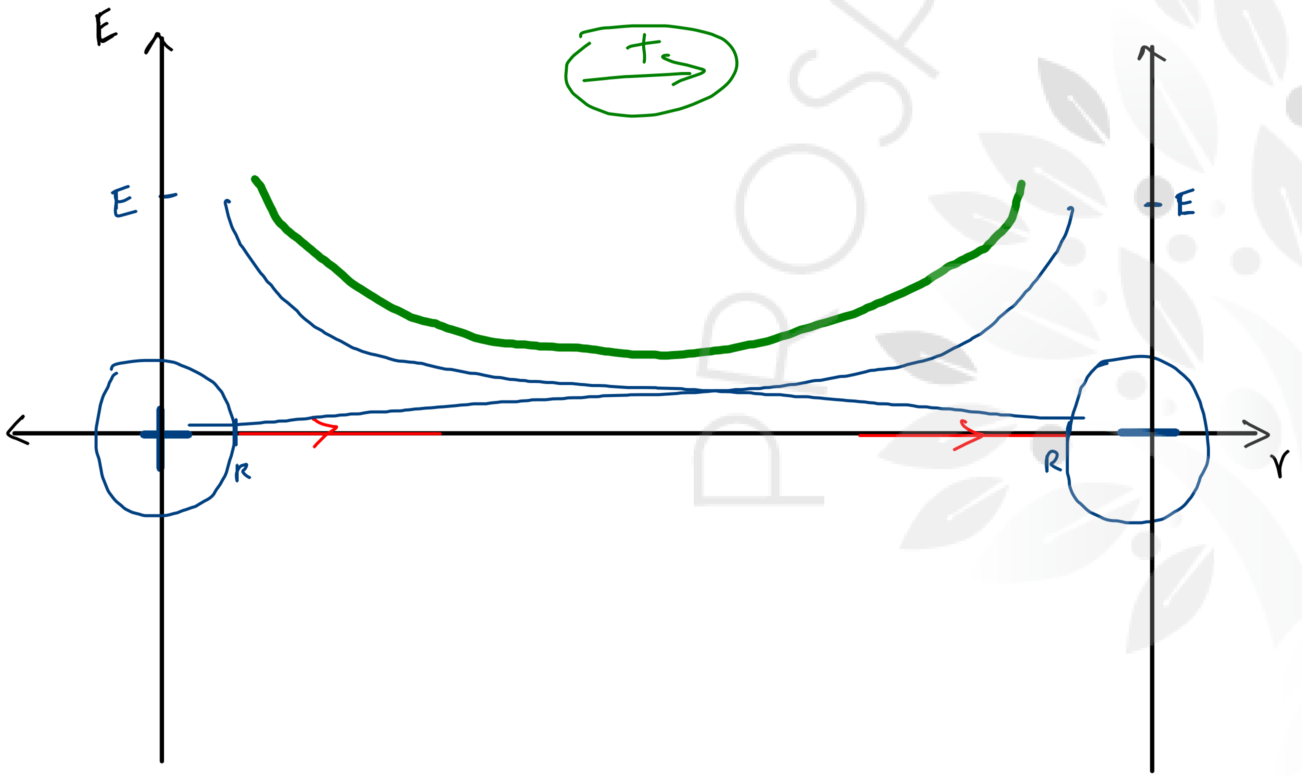


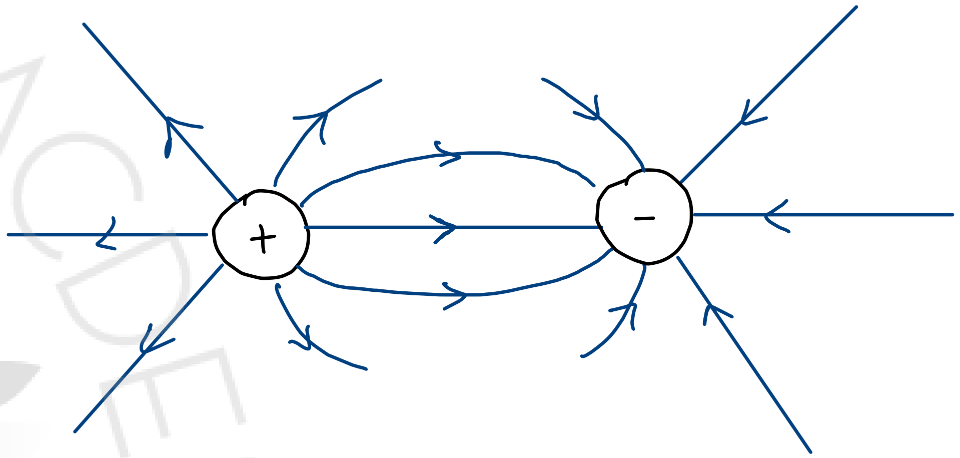
How to tell which charge is greater?

- The charge from which the null point is farther away is the greater charge

- If the charges have equal radii, then look at initial value of Electric field strength

Between a positive and a negative charge:-





Q. How to tell unlike and like charges?

- For like, there will be null point (E=0)
- For unlike, there will be no null point (E=0)

How to tell which charge is greater?

- If the charges have equal radii, then look at initial value of Electric field strength

Q. How to tell equal charges?

- For like, the null point is exactly at center
- For unlike, the graph will be symmetrical.

3 Two charged points A and B are separated by a distance of 6.0 cm, as shown in Fig. 3.1.

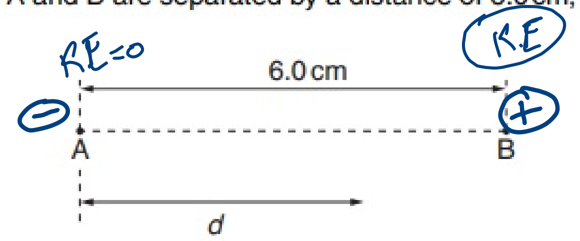
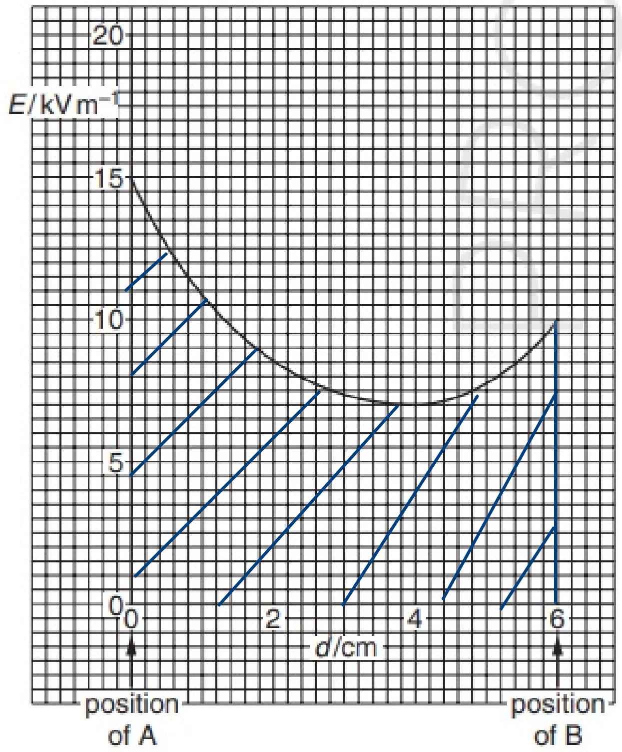


Fig. 3.1

The variation with distance d from A of the electric field strength E along the line AB is shown in Fig. 3.2.



Unlike

Fig. 3.2

An electron is emitted with negligible speed from A and travels along AB.

(a) State the relation between electric field strength E and potential V.

Electric field strength the negative rate of change of potential with respect to distance $\left(E = \frac{-dV}{dx}\right)$ [2]

(b) The area below the line of the graph of Fig. 3.2 represents the potential difference between A and B.

Use Fig. 3.2 to determine the potential difference between A and B.

potential difference = 530 V [4]

(c) Use your answer to **(b)** to calculate the speed of the electron as it reaches point B.

$\Delta K.E = \Delta E.p.e$

$K.E_f - K.E_i = \Delta V \times q$

$\frac{1}{2}mv^2 - 0 = 530 \times (1.6 \times 10^{-19})$

$\sqrt{v^2} = \sqrt{\frac{530 \times (1.6 \times 10^{-19}) \times 2}{9.1 \times 10^{-31}}} = 13651872.63$

speed = 1.37×10^7 m s^{-1} [2]

(d) (i) Use Fig. 3.2 to determine the value of d at which the electron has maximum acceleration.

d = 0 cm [1]

(ii) Without any further calculation, describe the variation with distance d of the acceleration of the electron.

acceleration decreases to a minimum at 4 cm and then increases [2]

$E = \frac{F}{q}$

$E = \frac{ma}{q}$

$\frac{Eq}{m} = a$

$\hookrightarrow$ const

$E \propto a$

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 6.1.

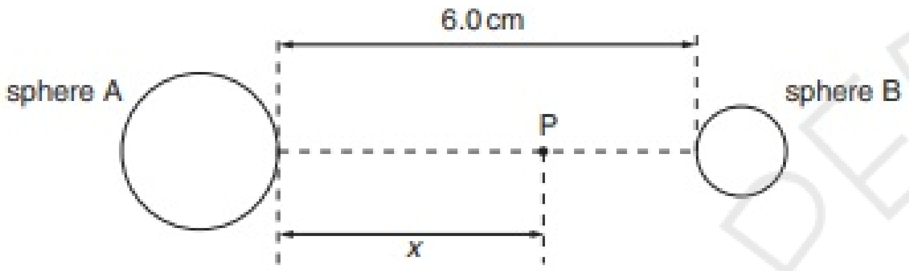
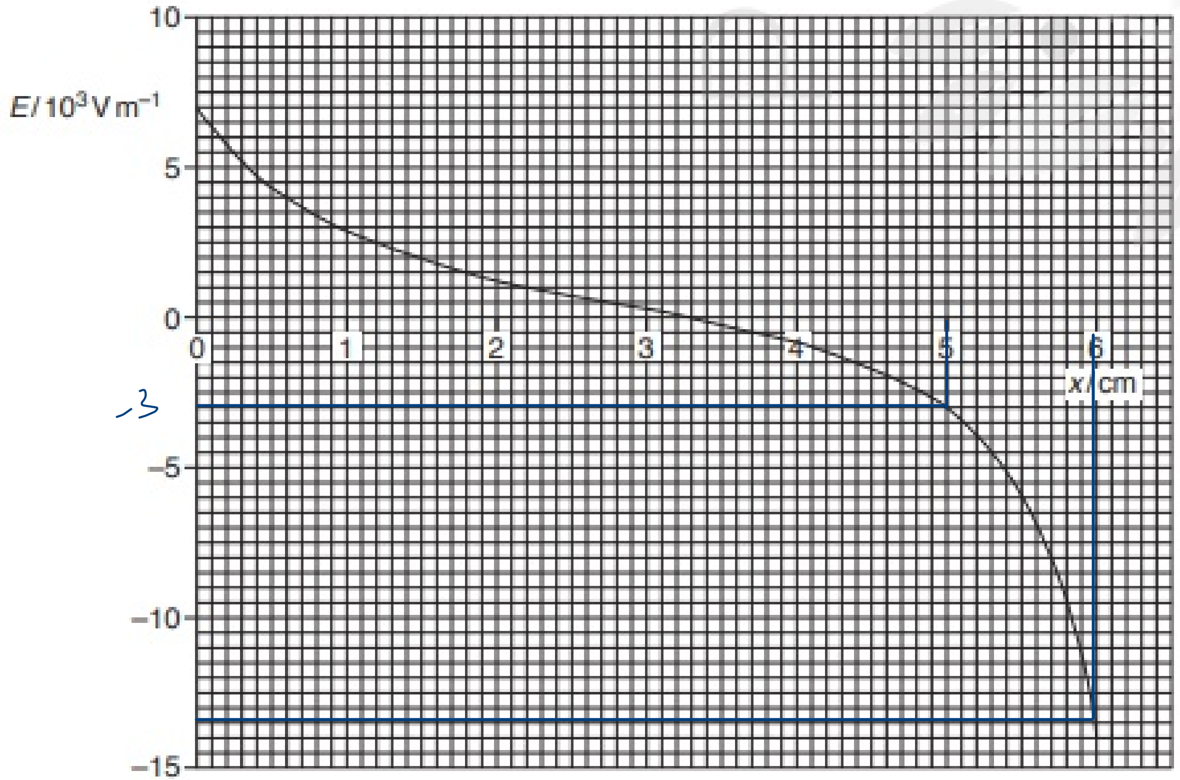


Fig. 6.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance *x* fror the surface of sphere A.

The variation with distance *x* of the electric field strength *E* at point P is shown in Fig. 6.2.



(i) Use Fig. 6.2 to explain whether the two spheres have charges of the same, or opposite, sign.

Same as their exists a null point (E=0) in the graph

[2]

(ii) A proton is at point P where $x = 5.0$ cm.
Use data from Fig. 6.2 to determine the acceleration of the proton.

$E = -2.5 \times 10^3$

$\frac{F}{q} = -2.5 \times 10^3$

$\frac{ma}{q} = -2.5 \times 10^3$

$a = \frac{(3 \times 10^3)(1.6 \times 10^{-19})}{(1.66 \times 10^{-27})}$

$a = -2.9 \times 10^{11}$

acceleration = 2.9×10^{11} m s^{-2} [3]

P : m = 1u
c = +1 e

$* \; E = \frac{F}{q}$

$E = \frac{ma}{q}$

$\boxed{\frac{Eq}{m} = a}$

(c) Use data from Fig. 6.2 to state the value of *x* at which the rate of change of electric potential is maximum. Give the reason for the value you have chosen.

x = 6cm as the rate of change of potential is electric field strength. As electric field strength is a vector quantity, the sign only tells us about the direction.

[2]

[Total: 9]

4 Two small charged metal spheres A and B are situated in a vacuum. The distance between the centres of the spheres is 12.0 cm, as shown in Fig. 4.1.

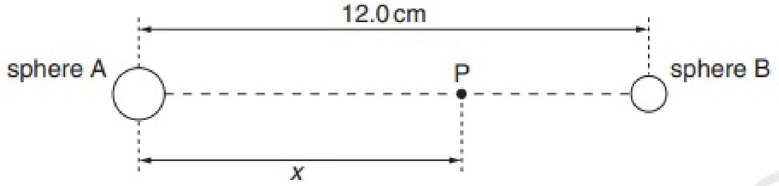
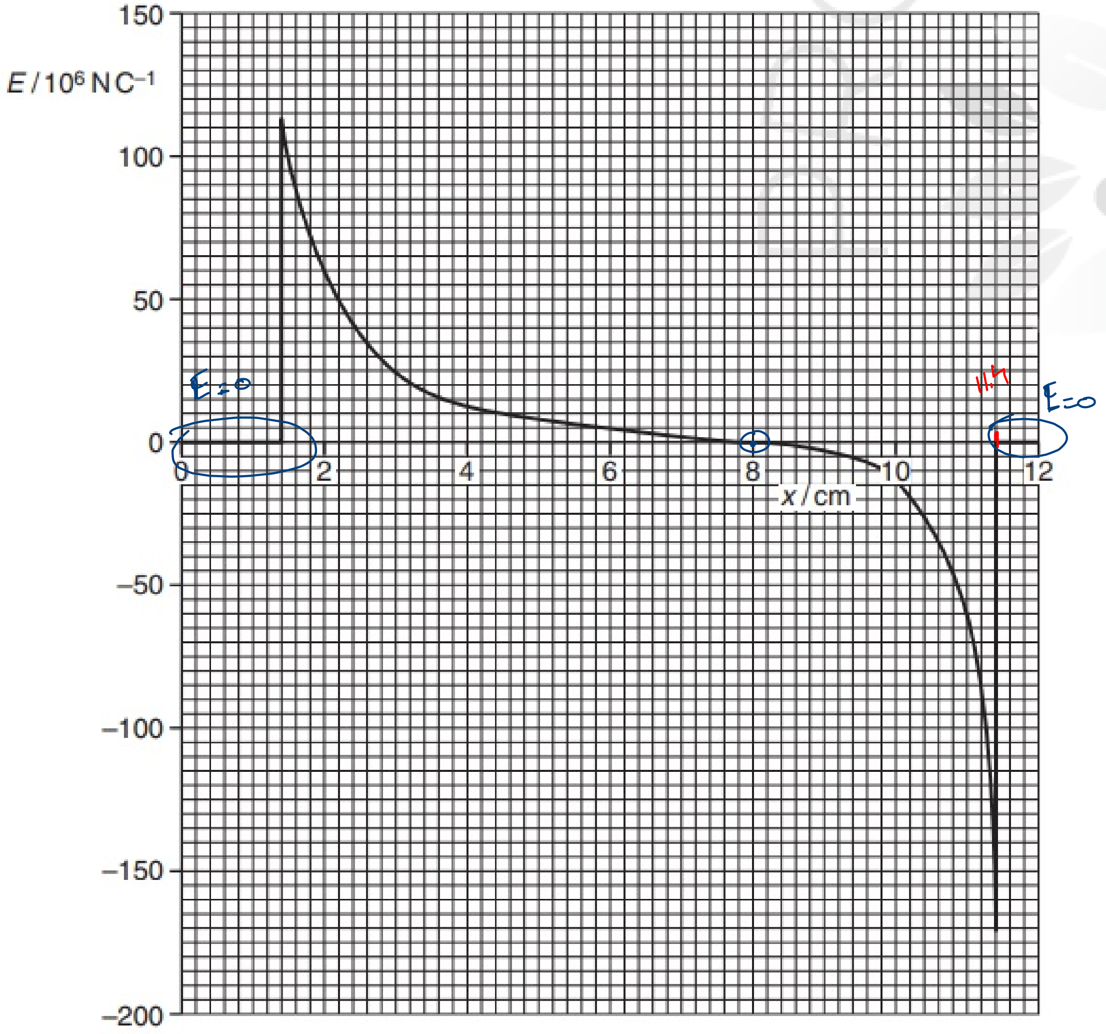


Fig. 4.1 (not to scale)

The charge on each sphere may be assumed to be a point charge at the centre of the sphere.
Point P is a movable point that lies on the line joining the centres of the spheres and is distance x from the centre of sphere A.
The variation with distance x of the electric field strength E at point P is shown in Fig. 4.2.



(a) State the evidence provided by Fig. 4.2 for the statements that

(i) the spheres are conductors,

Electric field strength is zero inside of charge. .... [1]

(ii) the charges on the spheres are either both positive or both negative.

- Existence of a null point (E = 0) in the graph.
- As electric field strength is a vector quantity, we see the direction of the electric field strength flips. .... [2]

(b) (i) State the relation between electric field strength E and potential gradient at a point.

$E = \frac{dV}{dr}$ .... [1]

(ii) Use Fig. 4.2 to state and explain the distance x at which the rate of change of potential with distance is

E

1. maximum,

Max at 11.4, as Electric field strength is rate of change of potential with distance and it is a vector quantity .... [2]

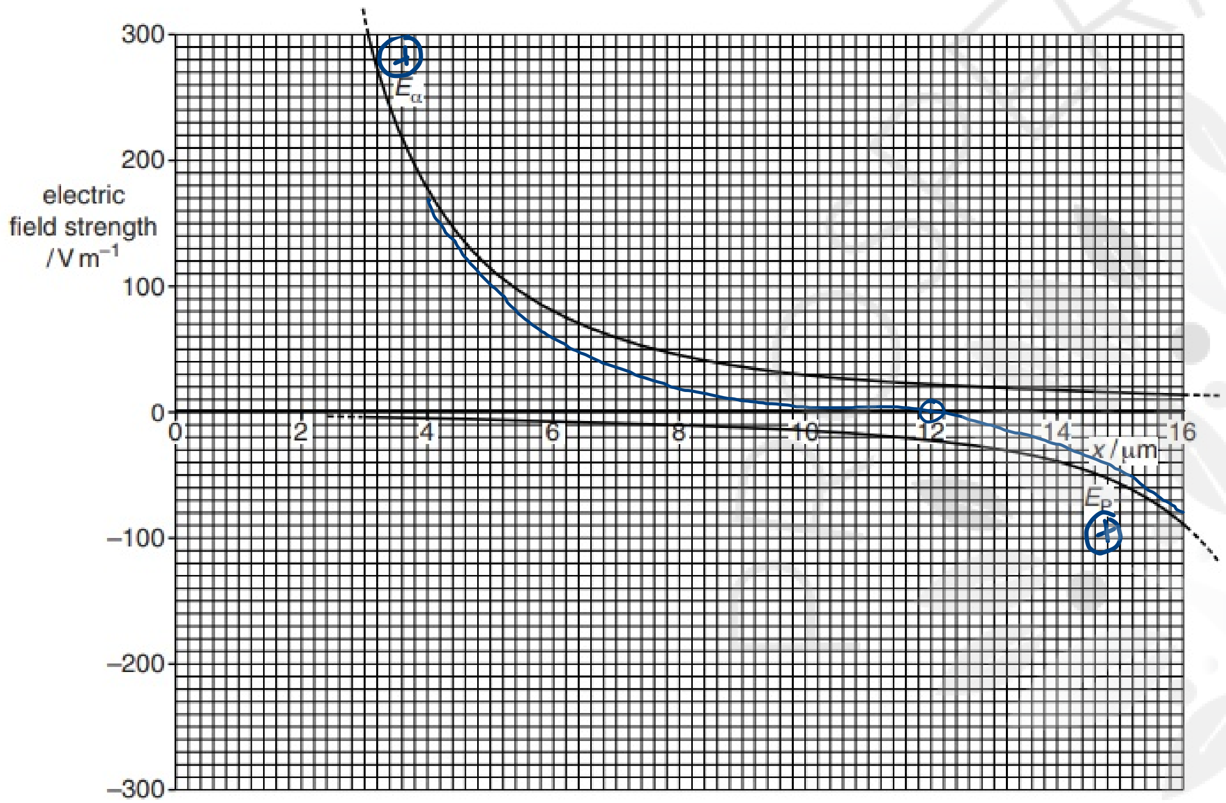
2. minimum.

at 8 cm as E = 0. .... [2]

Vectors :-

+ve -> direction <- -ve

(ii) A point P is distance x from the α-particle along the line joining the α-particle to the proton (see Fig. 4.1). The variation with distance x of the electric field strength E_α due to the α-particle alone is shown in Fig. 4.2.



The variation with distance x of the electric field strength E_P due to the proton alone is also shown in Fig. 4.2.

1. Explain why the two separate electric fields have opposite signs.

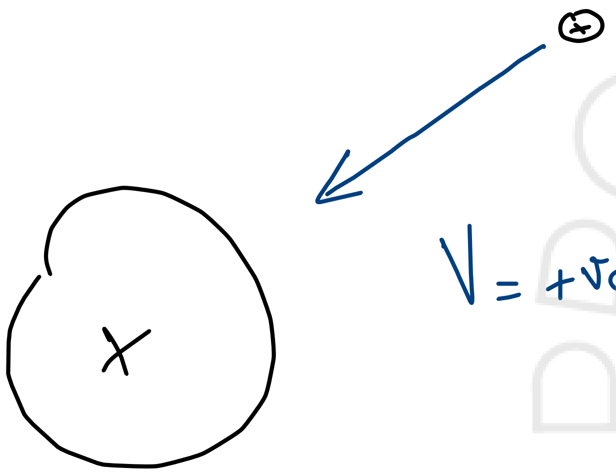
The electric field strength is a vector quantity.
The fields of both charges point opposite
directions [2]

2. On Fig. 4.2, sketch the variation with x of the combined electric field due to the α-particle and the proton for values of x from 4 μm to 16 μm. [3]

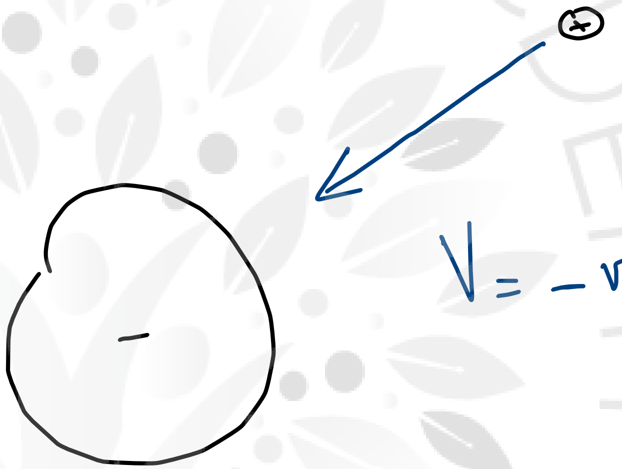
Electric potential (V) :-

Work done per unit charge in bringing that charge from infinity to a point within an electric field.

Scalar measured in volts



$V = +ve$

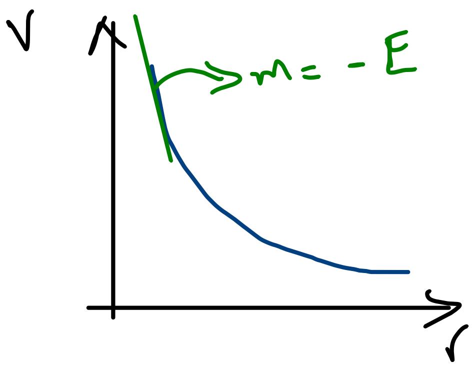


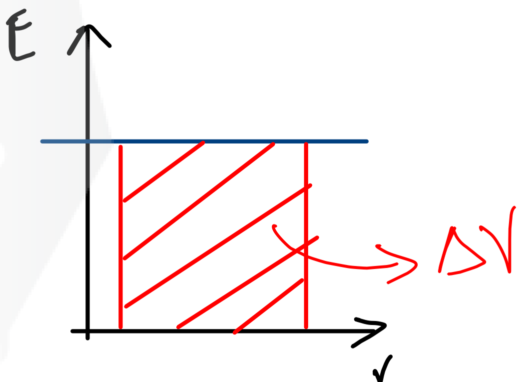
$V = -ve$

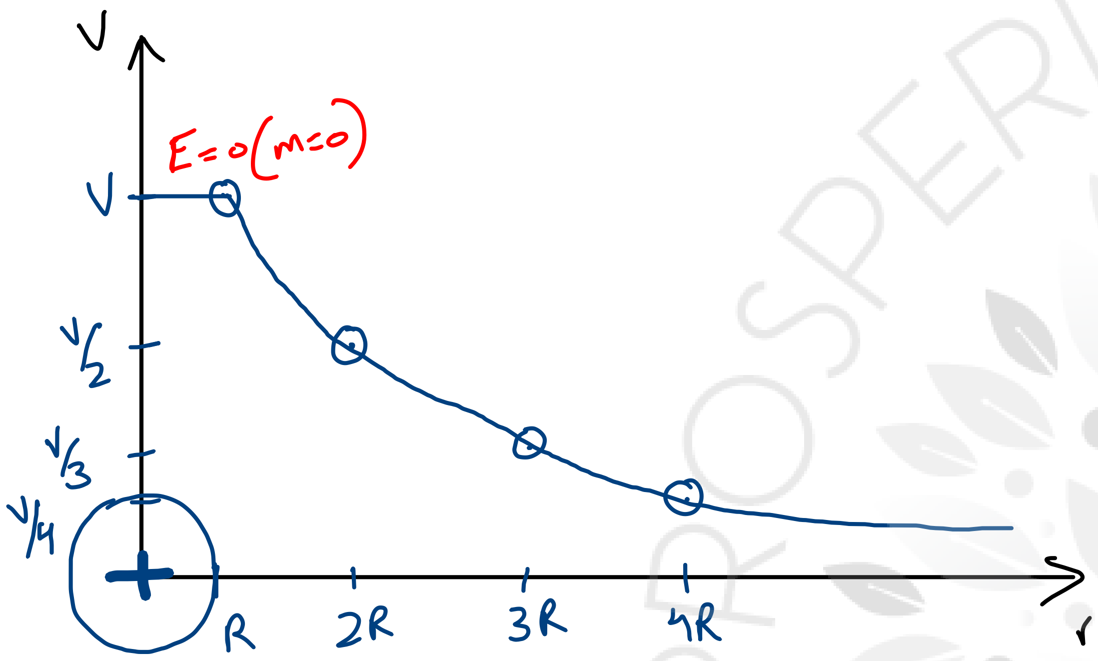
$$V = \frac{W}{q} = \frac{F_q \times r}{q} = \frac{\frac{KQ\cancel{q}}{r^{\cancel{2}}} \times \cancel{r}}{\cancel{q}} = \frac{KQ}{r}$$

$$* \quad E = \frac{-dV}{dr}$$

$$E \times \Delta r = -\Delta V$$







$$V = \frac{\overbrace{KQ}^{const}}{r} \Rightarrow V \propto \frac{1}{r}$$

$$V_1 r_1 = V_2 r_2$$

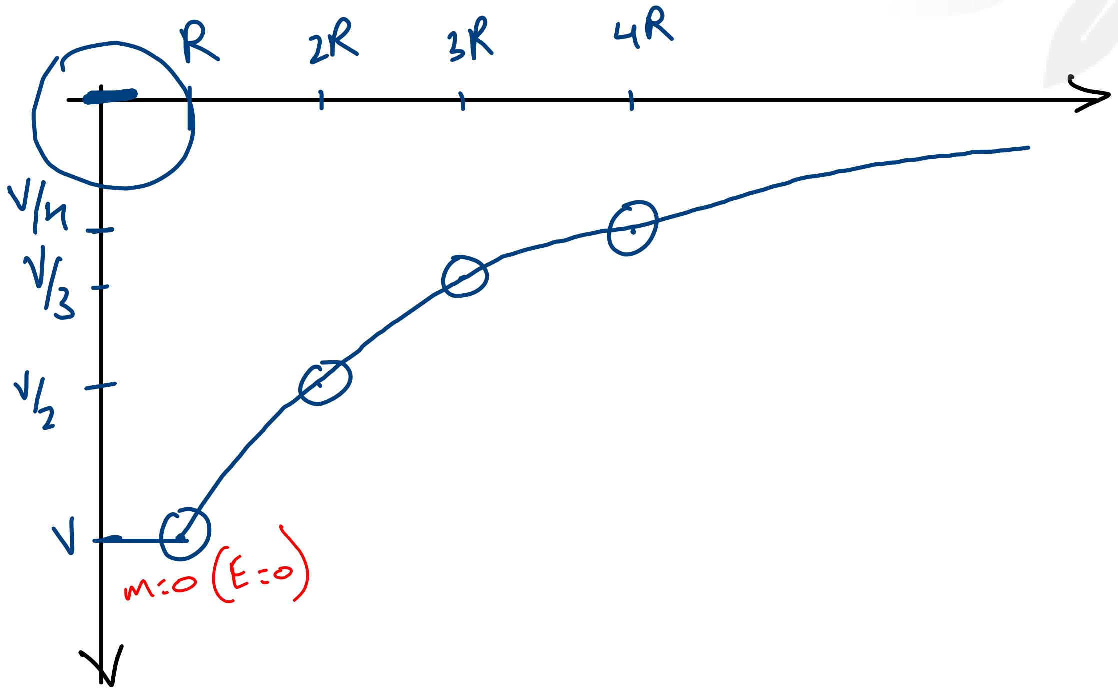
$$V\cancel{R} = V_2 \, 2\cancel{R}$$

$$V_2 = \frac{V}{2}$$

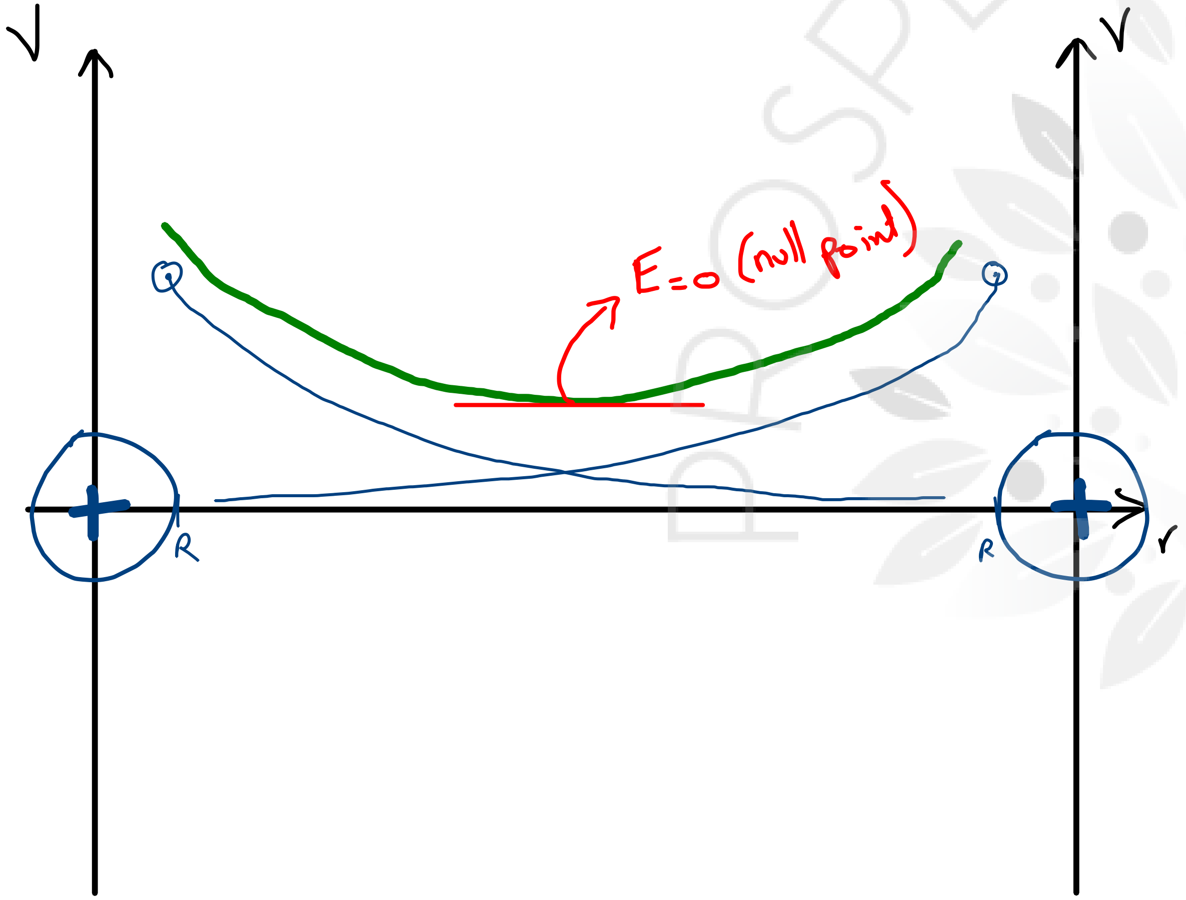
$$V_1 r_1 = V_3 r_3$$

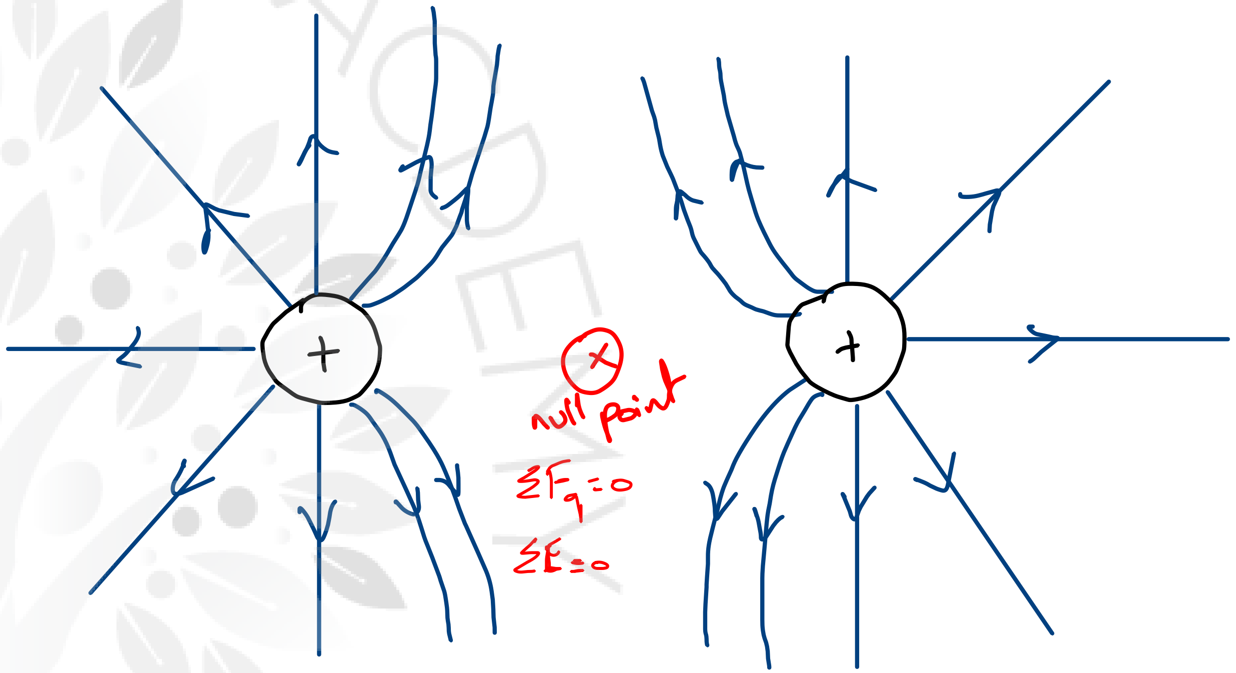
$$V\cancel{R} = V_3 (3\cancel{R})$$

$$V_3 = \frac{V}{3}$$



Between 2 positive charges :-



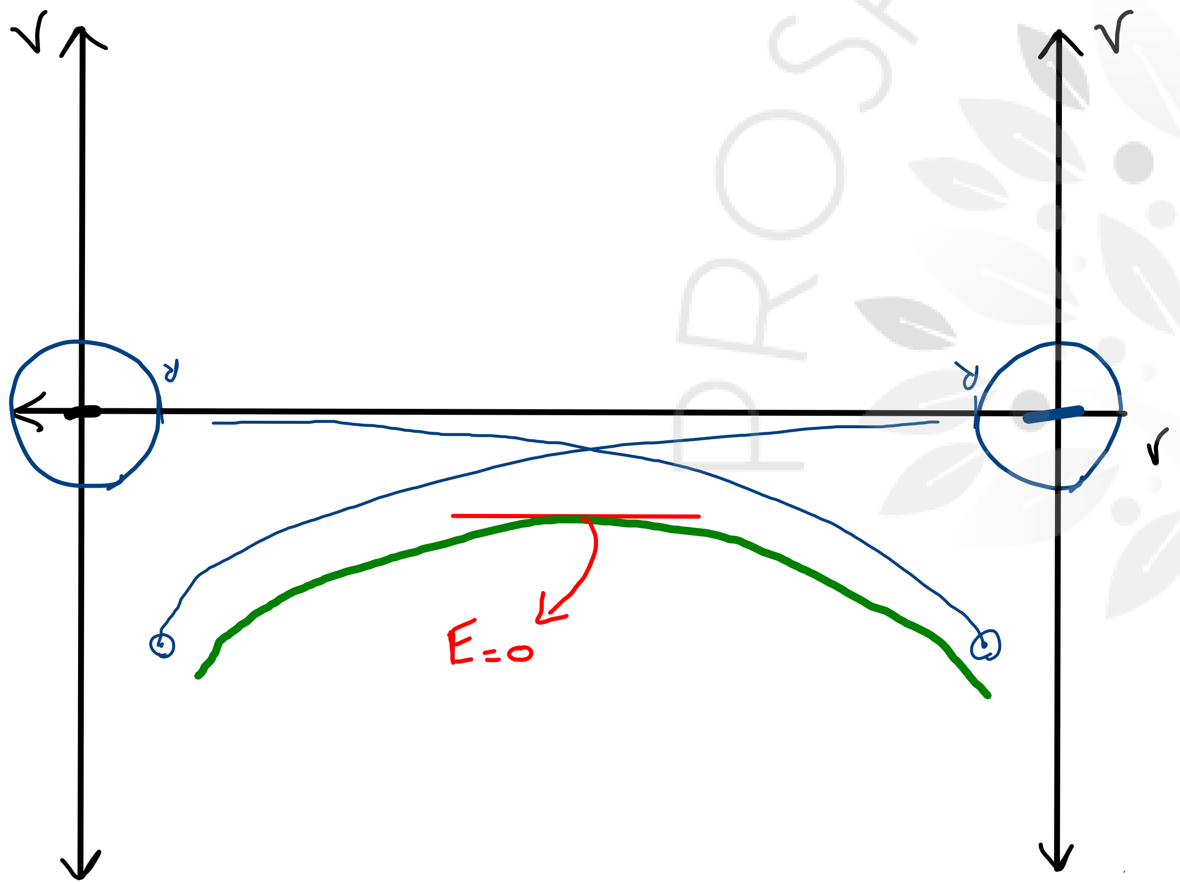


Q. Which charge is greater?

① The charge from which null point is farther is greater

② If charges have equal radii, look at initial values for voltage (Electric potential)

Between 2 negative charges :-

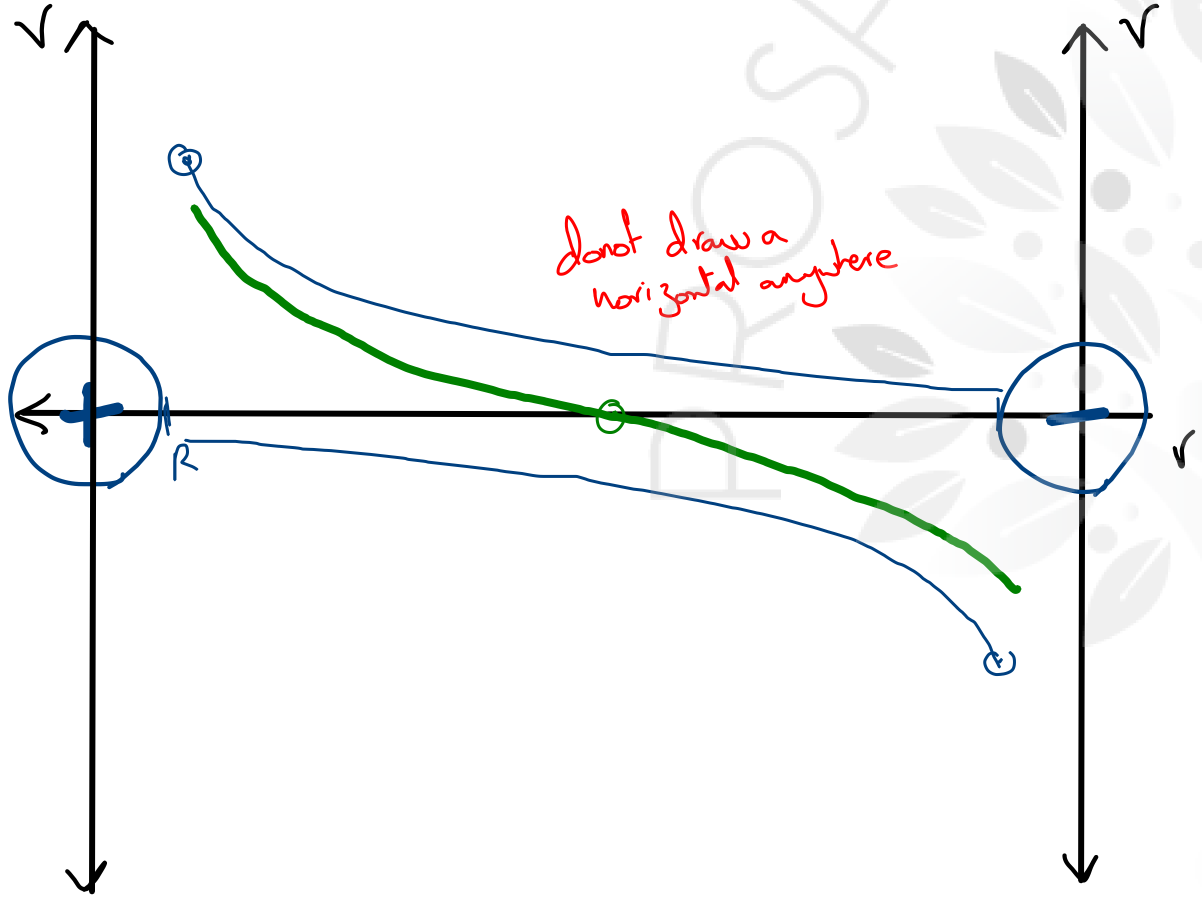


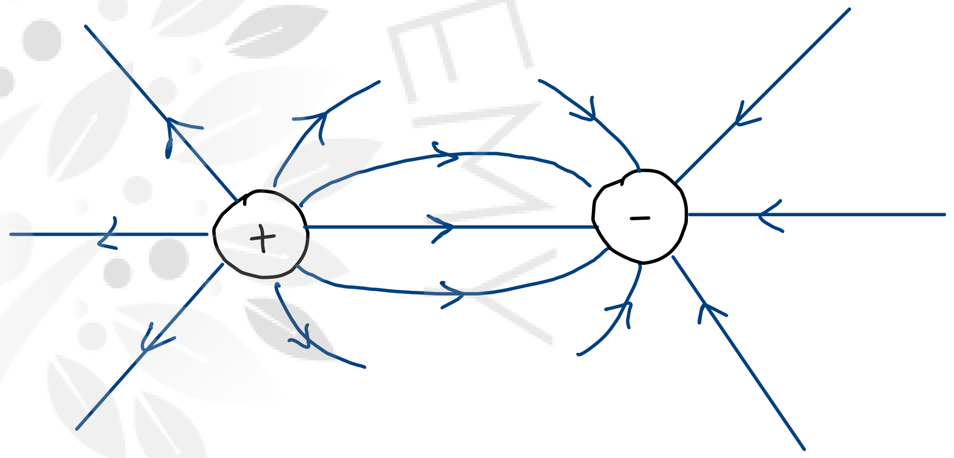
Q. Which charge is greater?

① The charge from which null point is farther is greater

② If charges have equal radii, look at initial values for voltage (Electric potential)

Between a positive and a negative charge:-





Q. Which charge is greater?

① If charges have equal radii, look at initial values for voltage (Electric potential)

Q. How to tell unlike and like charges?

For like, there will be a null point
For unlike, there will be no null point.

3 (a) Define *electric potential* at a point.

It is the work done per unit charge in bringing that charge from infinity to a point within an electric field.

[2]

(b) Two point charges A and B are separated by a distance of 20 nm in a vacuum, as illustrated in Fig. 3.1.

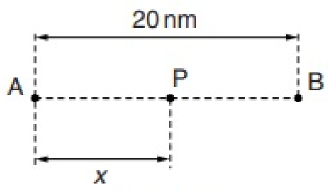
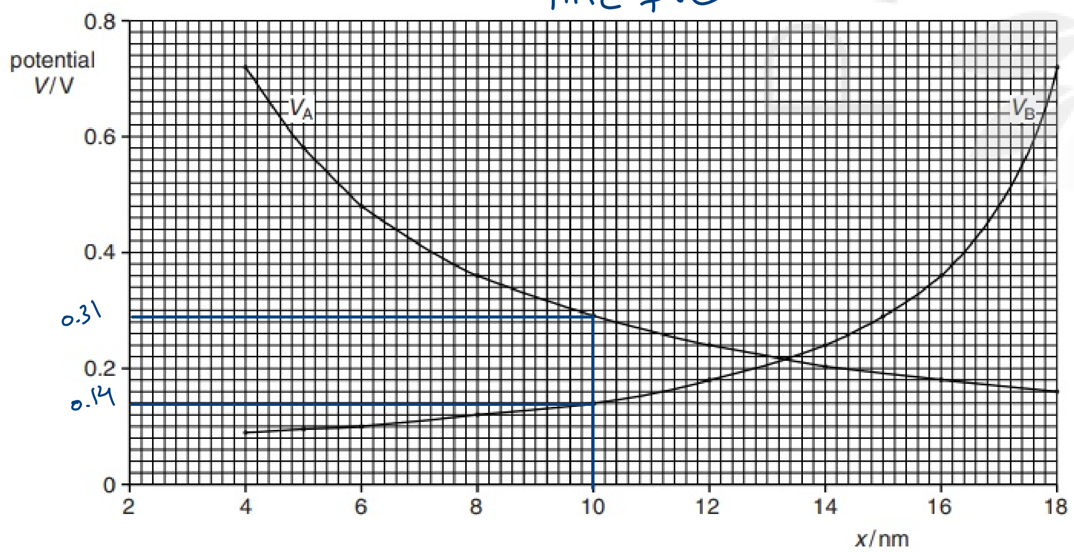


Fig. 3.1

A point P is a distance x from A along the line AB.
The variation with distance x of the electric potential V_A due to charge A alone is shown in Fig. 3.2.

like +ve



The variation with distance x of the electric potential V_B due to charge B alone is also shown in Fig. 3.2.

(i) State and explain whether the charges A and B are of the same, or opposite, sign.

They are of the same sign as both potentials are always positive

[2]

(ii) By reference to Fig. 3.2, state how the combined electric potential due to both charges may be determined.

Sum individual potentials at all points

[1]

(iii) Without any calculation, use Fig. 3.2 to estimate the distance x at which the combined electric potential of the two charges is a minimum.

$x =$ 10–13 nm [1]

↳ write one value

(iv) The point P is a distance $x = 10$ nm from A.
An α-particle has kinetic energy E_K when at infinity. $V_i = 0$

Use Fig. 3.2 to determine the minimum value of E_K such that the α-particle may travel from infinity to point P.

α: $m = 4u$
$q = +2e$

$E_K = \Delta E.p.e$

$E_K = \Delta V \times q \Rightarrow (V_f - V_i) \times q$

$E_K = (0.31 + 0.14 - 0) \times 2(1.6 \times 10^{-19})$
$= 1.44 \times 10^{-19}$

$E_K =$ 1.4×10^{-19} J [3]

7 **(a)** State what is meant by *electric potential* at a point.

It is the work done per unit charge in bringing that charge from infinity to a point within an electric field

.... [2]

(b) The centres of two charged metal spheres A and B are separated by a distance of 44.0 cm, as shown in Fig. 7.1.

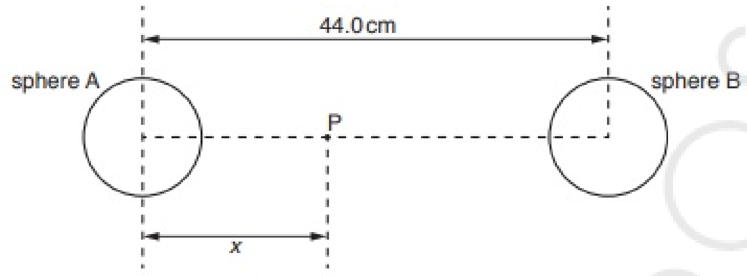
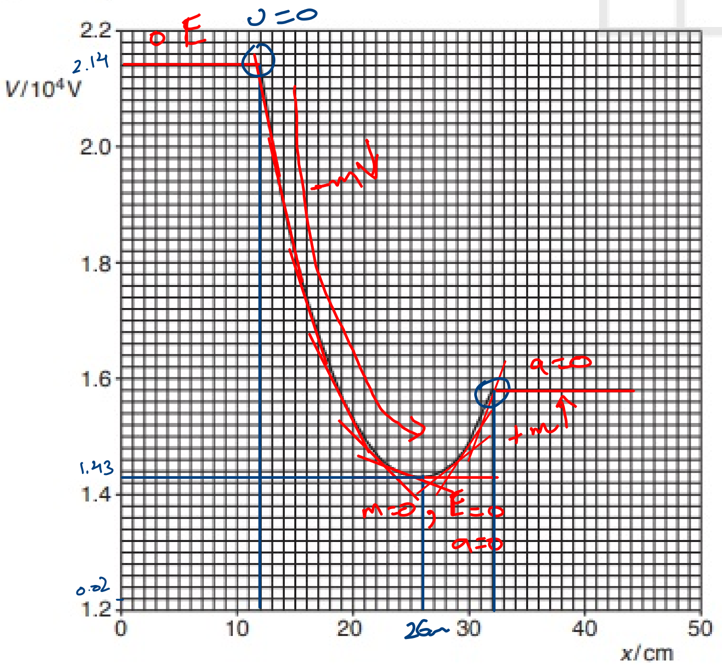


Fig. 7.1 (not to scale)

A moveable point P lies on the line joining the centres of the two spheres. Point P is a distance x from the centre of sphere A. The variation with distance x of the electric potential V at point P is shown in Fig. 7.2.



$$E = \frac{-dV}{dr}$$

(i) Use Fig. 7.2 to state and explain whether the two spheres have charges of the same, or opposite, sign.

Same sign as there exists a null point in the graph (gradient = 0)

.... [1]

(ii) A positively-charged particle is at rest on the surface of sphere A.

The particle moves freely from the surface of sphere A to the surface of sphere B.

1. Describe qualitatively the variation, if any, with distance x of the speed of the particle as it

moves from x = 12 cm to x = 25 cm speed increases at a decreasing rate

passes through x = 26 cm speed is maximum as acceleration = 0

moves from x = 27 cm to x = 31 cm speed decreases at an increasing rate

reaches x = 32 cm speed is still decreasing but will become constant

.... [4]

2. The particle has charge 3.2×10^{-19} C and mass 6.6×10^{-27} kg.

Calculate the maximum speed of the particle.

$$\Delta E.p.e = \Delta K.E$$

$$\Delta V \times q = \frac{1}{2} m v^2$$

$$[(2.14 - 1.43) \times 10^4] \times 3.2 \times 10^{-19} = \frac{1}{2}(6.6 \times 10^{-27}) v^2$$

$$\sqrt{\frac{2 \times 0.71 \times 10^4 \times 3.2 \times 10^{-19}}{6.6 \times 10^{-27}}} = \sqrt{v^2} = 8.297 \times 10^5$$

speed = 8.3×10^5 m s^{-1} [2]

[Total: 9]

$$E = \frac{F}{q} = \frac{ma}{q}$$

$$a = \frac{Eq}{m}$$

$$a \propto E$$

$F \propto \frac{dE_p}{dr}$

4 (a) Define *electric potential* at a point.

It is the work done per unit charge in bringing that charge from infinity to a point within an electric field.

.... [2]

(b) Two small spherical charged particles P and Q may be assumed to be point charges located at their centres. The particles are in a vacuum.

Particle P is fixed in position. Particle Q is moved along the line joining the two charges, as illustrated in Fig. 4.1.

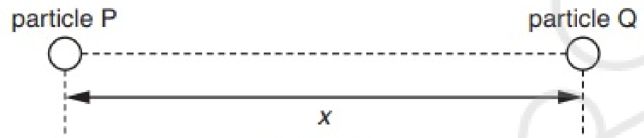
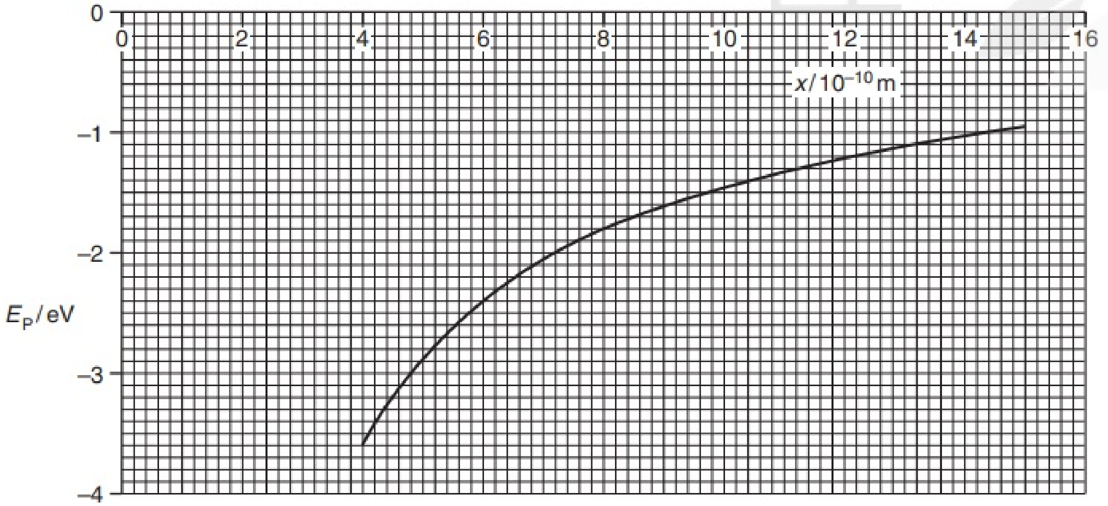


Fig. 4.1

The variation with separation x of the electric potential energy E_P of particle Q is shown in Fig. 4.2.



(i) State how the magnitude of the electric field strength is related to potential gradient.

magnitude of electric field strength = potential gradient

.... [1]

(ii) Use your answer in **(i)** to show that the force on particle Q is proportional to the gradient of the curve of Fig. 4.2.

See working on right

.... [2]

*

$E \propto \frac{dV}{dr} \qquad V = \frac{W}{q}$

$\frac{F}{q} \propto \frac{d\left(\frac{W}{q}\right)}{dr} \rightarrow \text{const}$

$\frac{F}{\cancel{q}} \propto \frac{1}{\cancel{q}}\left(\frac{dW}{dr}\right)$

$F \propto \frac{dW}{dr}$

(c) The magnitude of the charge on each of the particles P and Q is 1.6×10^{-19} C. Calculate the separation of the particles at the point where particle Q has electric potential energy equal to –5.1 eV.

$E.p.e = \frac{KQq}{r} \Rightarrow (5.1 \times \cancel{1.6 \times 10^{-19}}) = \frac{(9 \times 10^9)(1.6 \times 10^{-19})^{\cancel{2}}}{r}$

$r = \frac{(9 \times 10^9)(1.6 \times 10^{-19})}{5.1}$

separation = 2.8×10^{-10} m [4]

(d) By reference to Fig. 4.2, state and explain

(i) whether the two charges have the same, or opposite, sign,

opposite sign as work got out

.... [2]

(ii) the effect, if any, on the shape of the graph of doubling the charge on particle P.

The graph will get steeper as doubling the charge will double the electrical potential energy

.... [2]

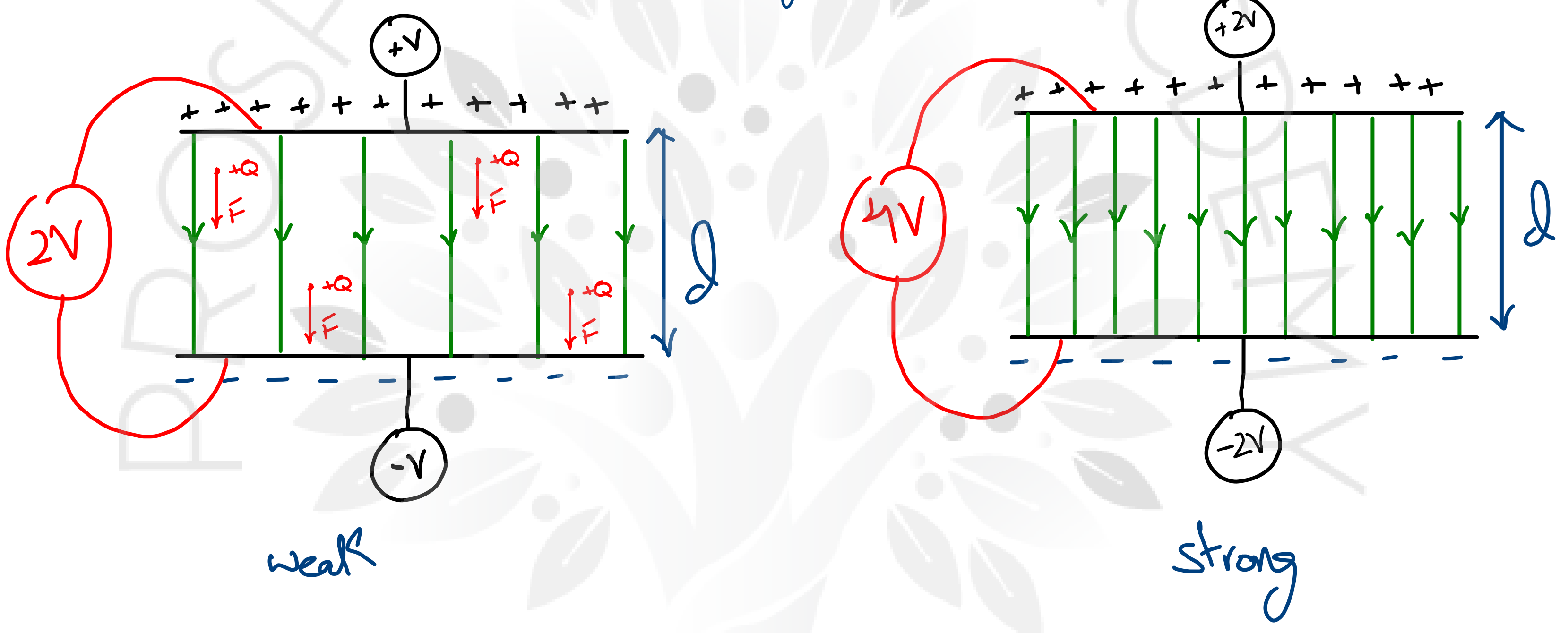
$E.p.e = \overbrace{\frac{Kq}{r}}^{\text{const}} \times Q$

$2\,E.p.e \propto 2Q$

Uniform Electric Field:-

The force experienced per unit charge is a constant throughout this region/space.

$$\frac{F_q}{q} = E = \text{const}$$



$$E = \frac{F_q}{q} \qquad V = \frac{W}{q} \qquad W = F_q \times s$$

$$Vq = W \qquad Vq = F_q \times s$$

$$E = \frac{V\cancel{q}}{s} \times \frac{1}{\cancel{q}} \qquad F_q = \frac{Vq}{s}$$

$$\boxed{E = \frac{V}{d}}$$

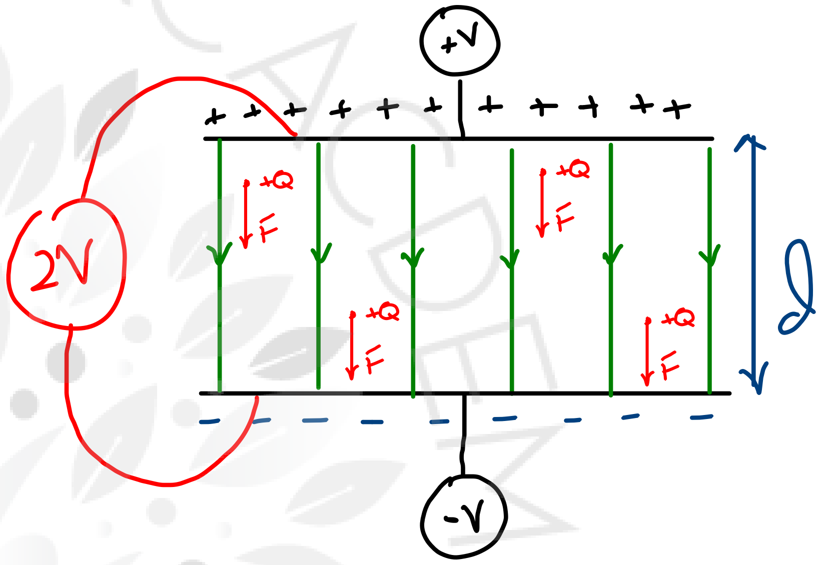
this only applies to a uniform electric field.

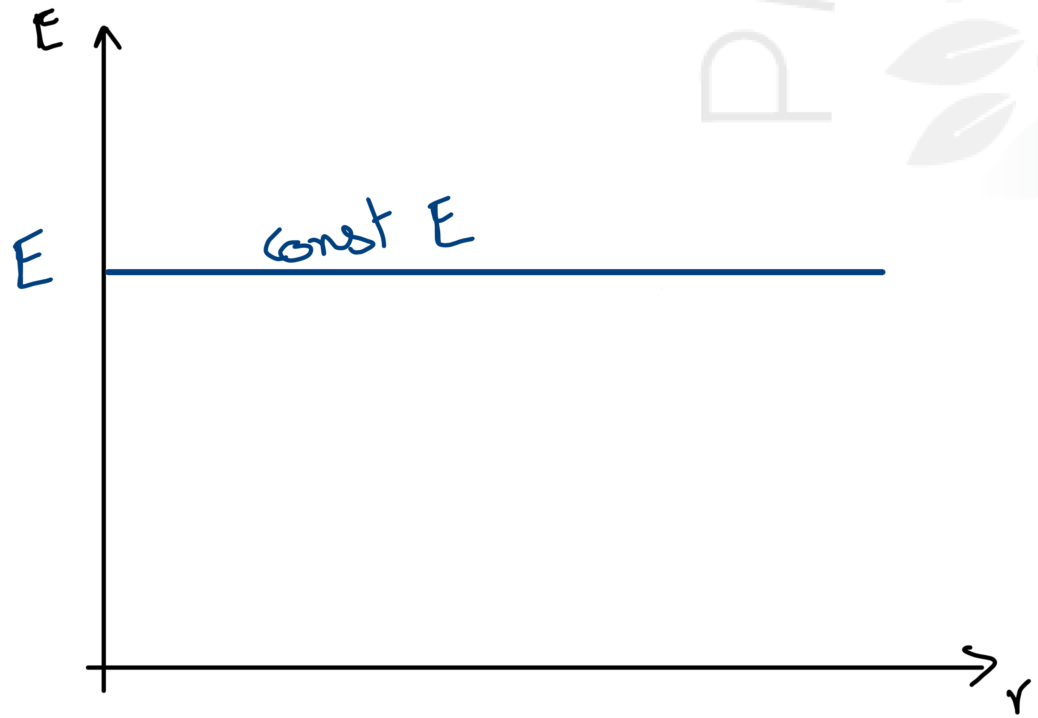
$$\frac{F}{q} = E = \frac{V}{d}$$

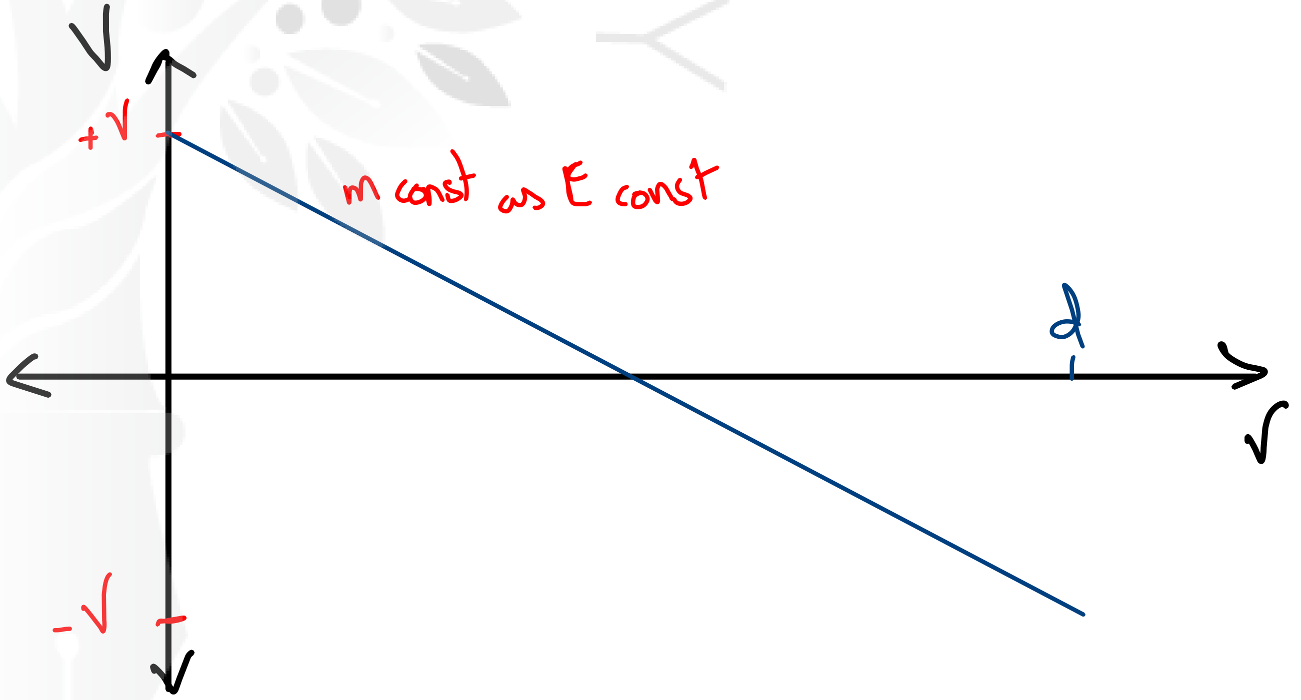
$*$ $F = \frac{Vq}{d}$

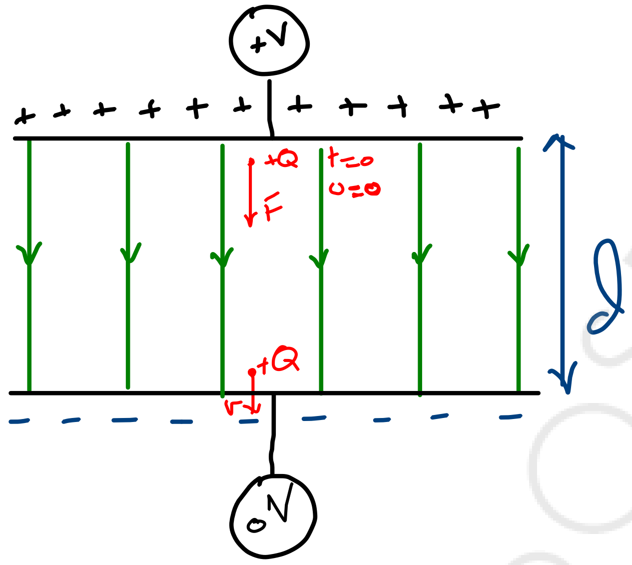
$*$ $m \times a = \frac{Vq}{d}$

$a = \frac{Vq}{md}$









$$V = \frac{W}{q} \Rightarrow W = Vq = \frac{1}{2}mv^2$$

$$\frac{2Vq}{m} = v^2$$

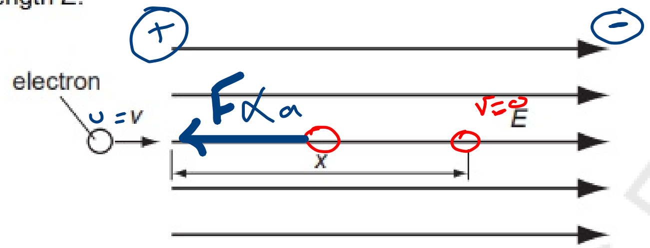
Work done is independant of distance

How to make a uniform electric field?

1) Take 2 metal plates and place them at a distance parallel to each other

2) Charge them oppositely. This is most easily done by creating a potential difference between the plates

29 The diagram shows an electron, with charge e, mass m, and velocity v, entering a uniform electric field of strength E.



E const

$E = \frac{F_{const}}{q}$

$F = ma \Rightarrow a$ const

The direction of the field and the electron's motion are both horizontal and to the right.

Which expression gives the distance x through which the electron travels before it stops momentarily?

A $x = \frac{mv}{E}$ **B** $x = \frac{mv}{Ee}$ **C** $x = \frac{mv^2}{2E}$ **D** $x = \frac{mv^2}{2Ee}$

③ $v^2 = u^2 + 2as$

$0^2 = v^2 + 2ax$

$0^2 = v^2 + 2\left(\frac{-Ee}{m}\right)x$

$\cancel{-}v^2 = \cancel{-}\frac{2Ee}{m} \times x$

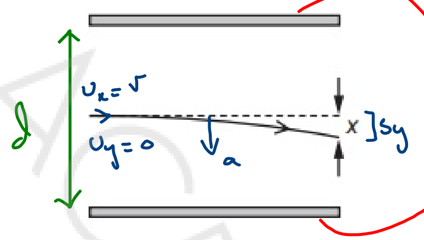
$\frac{mv^2}{2Ee} = x$

$E = \frac{F}{q} = \frac{ma}{q}$

$E = \frac{ma}{e}$

$a = -\frac{Ee}{m}$

32 The path of an electron with initial speed v in the uniform electric field between two parallel plates is shown.



The vertical deflection x is measured at the right-hand edge of the plates.

The distance between the plates is halved. The potential difference between the plates remains the same.

What will be the new deflection of the electron with the same initial speed v?

A x **B** $\sqrt{2}x$ **C** $2x$ **D** $4x$

① Vertically

$s_y = u_y t + \frac{1}{2}a_y t^2$

$x = 0 + \frac{1}{2}\left(\frac{Vq}{md}\right)t^2$

$x = \frac{Vq}{2md}t^2$

$E = \frac{V}{d} = \frac{F}{q}$

$\frac{Vq}{d} = m \times a$

$a_1 = \frac{Vq}{md}$ $a_2 = \frac{Vq}{m\,d/2}$

$a_2 = \frac{2Vq}{md}$

② Vertically

$s_y = u_y t + \frac{1}{2}at^2$

$x_2 = 0 + \frac{1}{\cancel{2}}\left(\frac{\cancel{2}Vq}{md}\right)t^2$

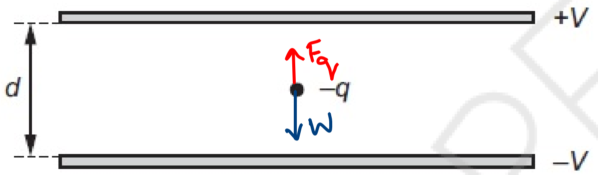
$x_2 = \frac{2}{2}\frac{Vq}{md}t^2 \rightarrow x$

$\Rightarrow x_2 = 2x$

An oil droplet has charge –q and is situated between two horizontal metal plates as shown in the diagram.

$E = \frac{V}{d} = \frac{F}{q}$

$F_q = \frac{2Vq}{d} \Leftarrow \frac{2V}{d} = \frac{F}{q}$



2V

$+V - (-V)$

$+V + V$

$2V$

The separation of the plates is d. The droplet is observed to be stationary when the upper plate is at potential +V and the lower plate is at potential –V.

Equilibiom

$\Sigma F = 0$

For this to occur, what is the weight of the droplet?

$F_q = W$

$W = \frac{2Vq}{d}$

A $\frac{Vq}{d}$ B $\frac{2Vq}{d}$ C $\frac{Vd}{q}$ D $\frac{2Vd}{q}$

6 (a) (i) Define *electric potential* at a point.

It is the work done per unit charge in bringing that charge from infinity to a point within an electric field.

[2]

(ii) State the relationship between electric potential and electric field strength at a point.

Electric field strength is the negative rate change of potential with respect to distance

[2]

(b) Two parallel metal plates A and B are situated a distance 1.2 cm apart in a vacuum, as shown in Fig. 6.1.

7/7

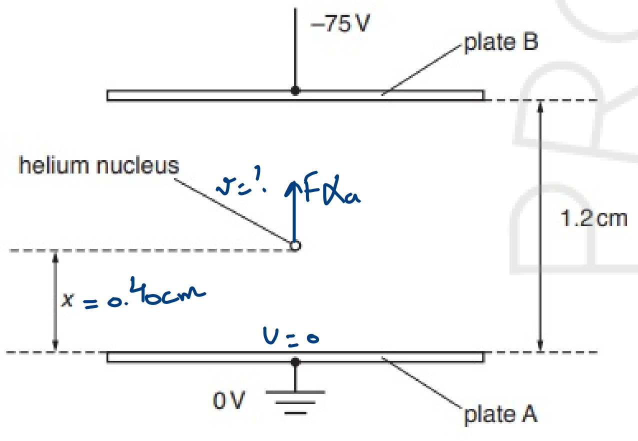


Fig. 6.1

Plate A is earthed and plate B is at a potential of –75 V.

A helium nucleus is situated between the plates, a distance *x* from plate A.

Initially, the helium nucleus is at rest on plate A where *x* = 0.

(i) The helium nucleus is free to move between the plates. By considering energy changes of the helium nucleus, explain why the speed at which it reaches plate B is independent of the separation of the plates.

$V = \frac{W}{q} \Rightarrow W = Vq \Rightarrow K.E = E.p.e \Rightarrow \frac{1}{2}mv^2 = Vq$

so we can v is not dependent on distance. $v = \sqrt{\frac{2Vq}{m}}$

[2]

(ii) As the helium nucleus (^4_2He) moves from plate A towards plate B, its distance *x* from plate A increases.

Calculate the speed of the nucleus after it has moved a distance *x* = 0.40 cm from plate A.

③ $v^2 = u^2 + 2as$

$v^2 = 0^2 + 2(3.01\times10^{11})(0.40\times10^{-2})$

$v = 49071$

$v = 4.9\times10^4$

$E = \frac{V}{d} = \frac{F}{q} \Rightarrow F = \frac{Vq}{d}$

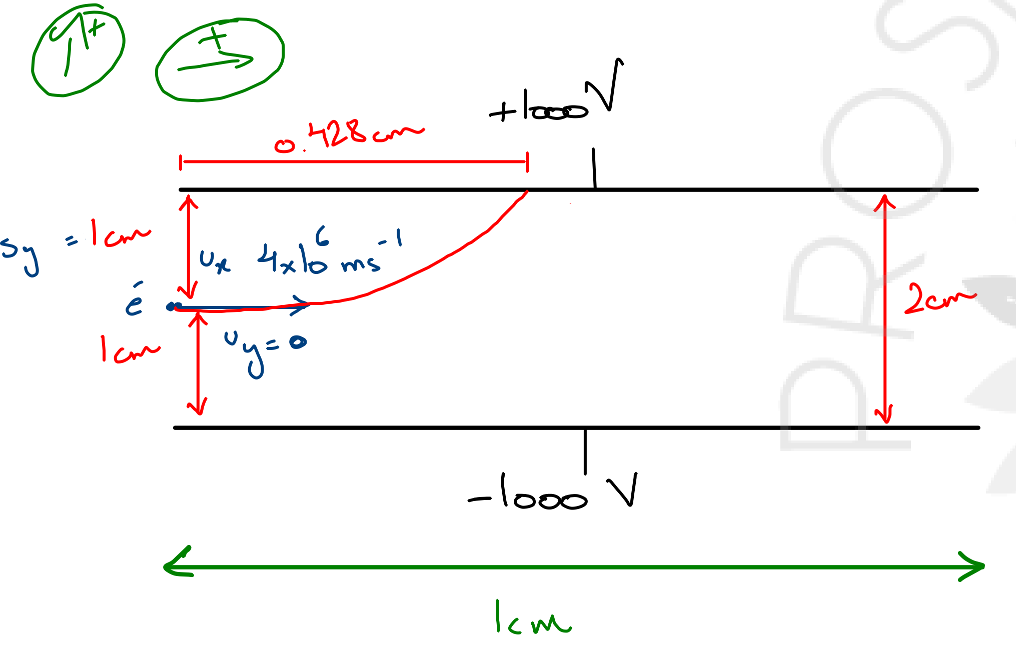
$a = \frac{Vq}{md}$

$3.01\times10^{11} = a = \frac{(75)(2\times1.6\times10^{-19})}{4(1.66\times10^{-27})(1.2\times10^{-2})}$

speed = 4.9×10^4 m s^{-1} [3]

[Total: 9]

An electron with initial speed $u = 4.0 \times 10^{6}\ ms^{-1}$ enters a uniform electric field made using 2 plates with a separation of 2 cm as shown. The potential of the top plate is 1000 V and the potential of the bottom plate is -1000 V and they are held in a horizontal plane. If the length of each plate is 1 cm, and assuming a negligible air resistance, will the electron emerge from the field?



The electron will not emerge ☹

Solve vertically:-

(2) $s_y = u_y t + \frac{1}{2} a_y t^2$

$$(1\times10^{-2}) = 0 + \frac{1}{2}(1.758\times10^{16})(t^2)$$

$$t = 1.07\times10^{-9}\ s$$

$$E = \frac{V}{d} = \frac{F}{q}$$

$$a = \frac{Vq}{md}$$

$$V = 1000 - (-1000)$$
$$V = 2000V$$

$$a = \frac{2000 \times (1.6\times10^{-19})}{(9.1\times10^{-31})\ (2\times10^{-2})}$$

$$a = 1.758\times10^{16}$$

Solve horizontally

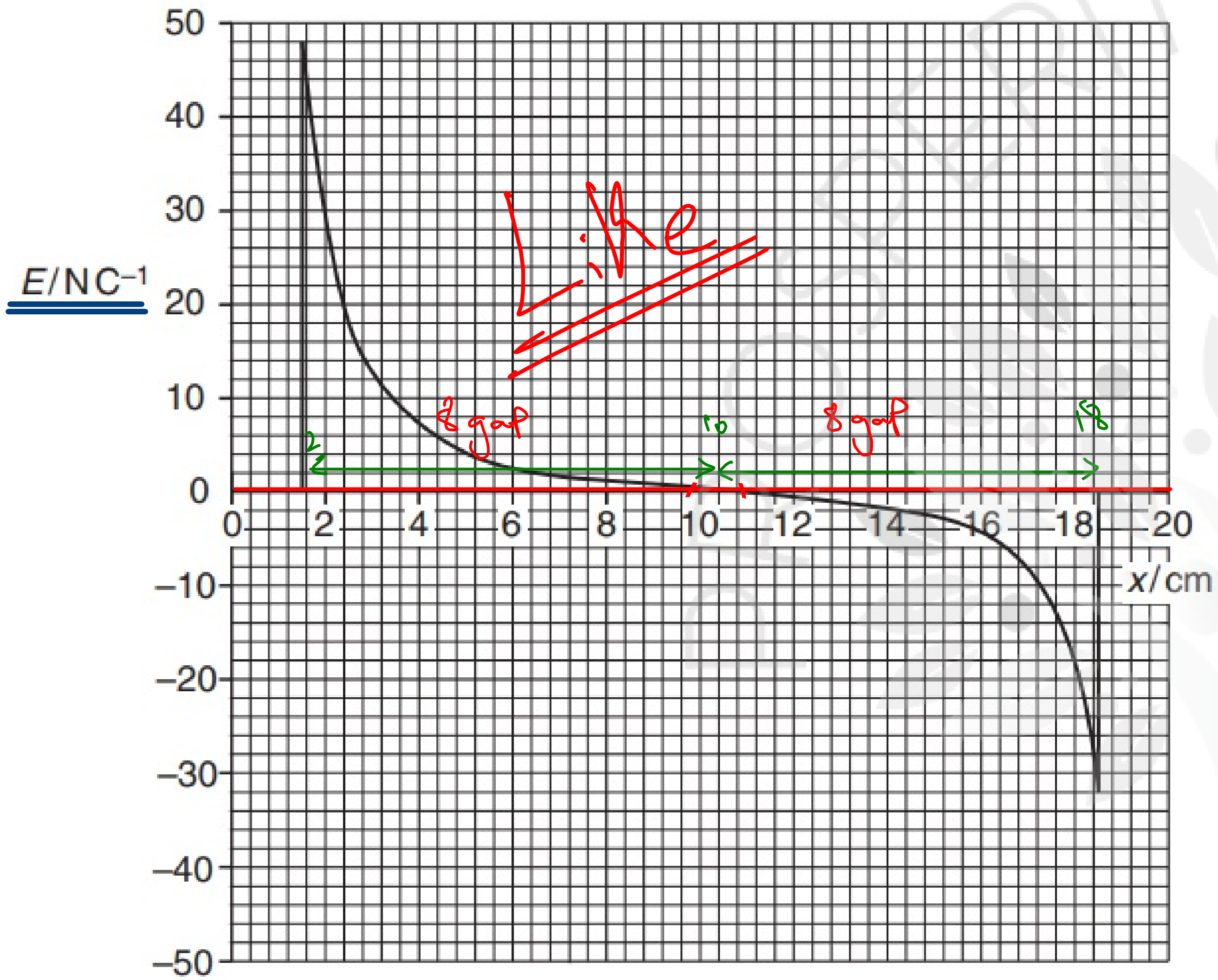
$s = ut + \frac{1}{2} at^2$

$s_x = u_x t$

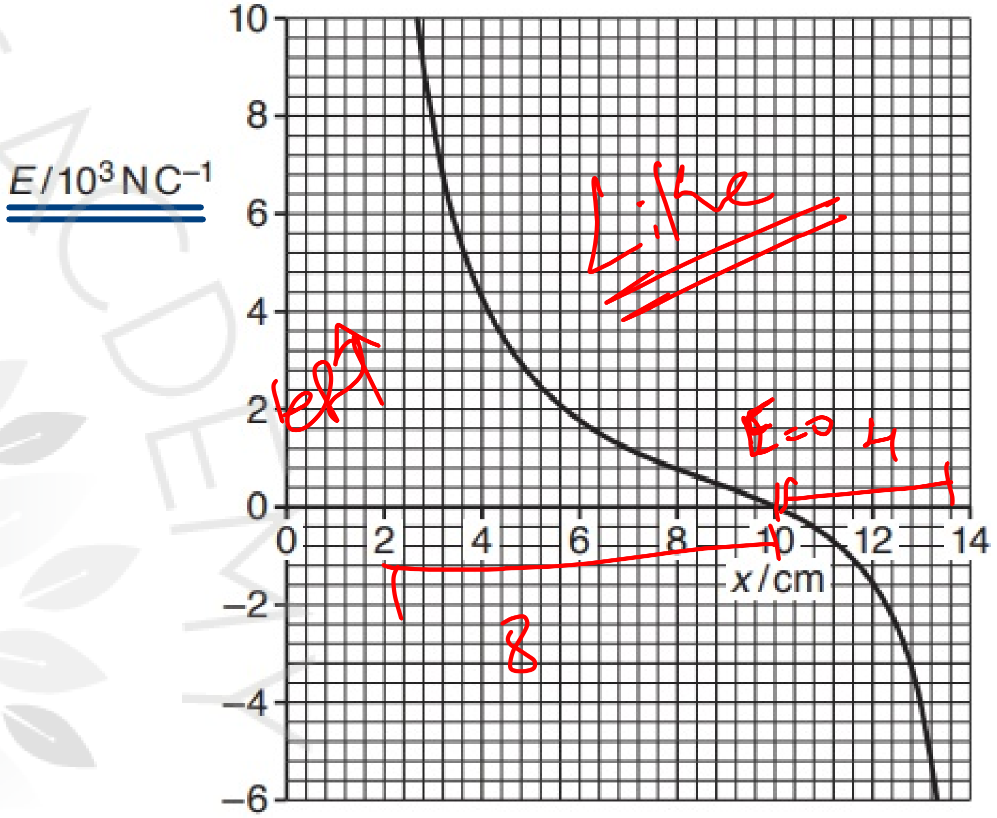
$s_x = 4\times10^{6} \times 1.07\times10^{-9}$

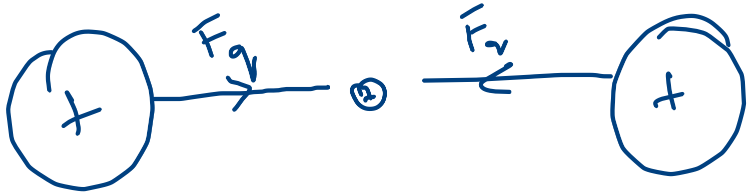
$s_x = 4.28\times10^{-3}\ m$

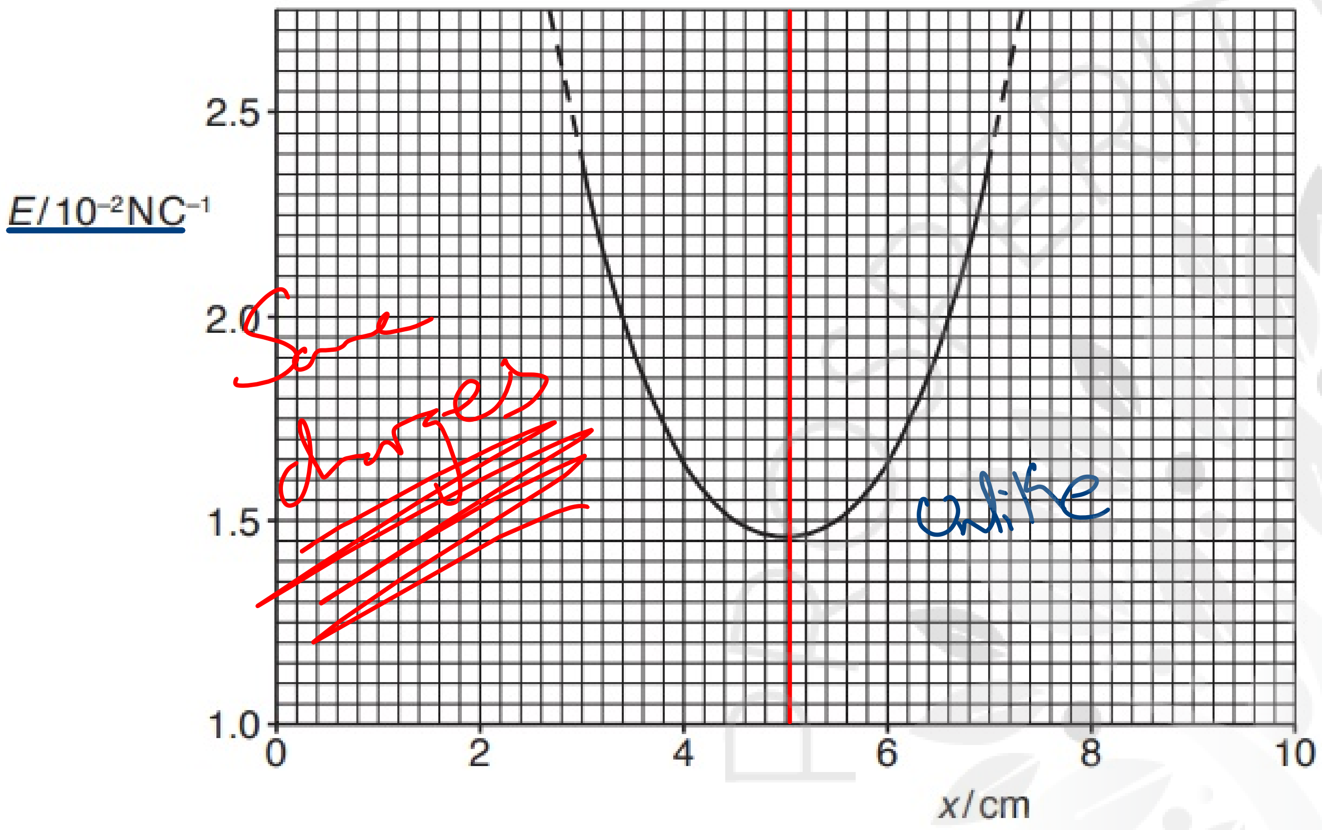
$s_x = 0.428\times10^{-2}\ m = 0.428cm$



like
E = 0
unlike
E ≠ 0







E / 10⁻² N C⁻¹
2.5
2.0
1.5
1.0
0
2
4
6
8
10
x / cm
Same charges
Unlike

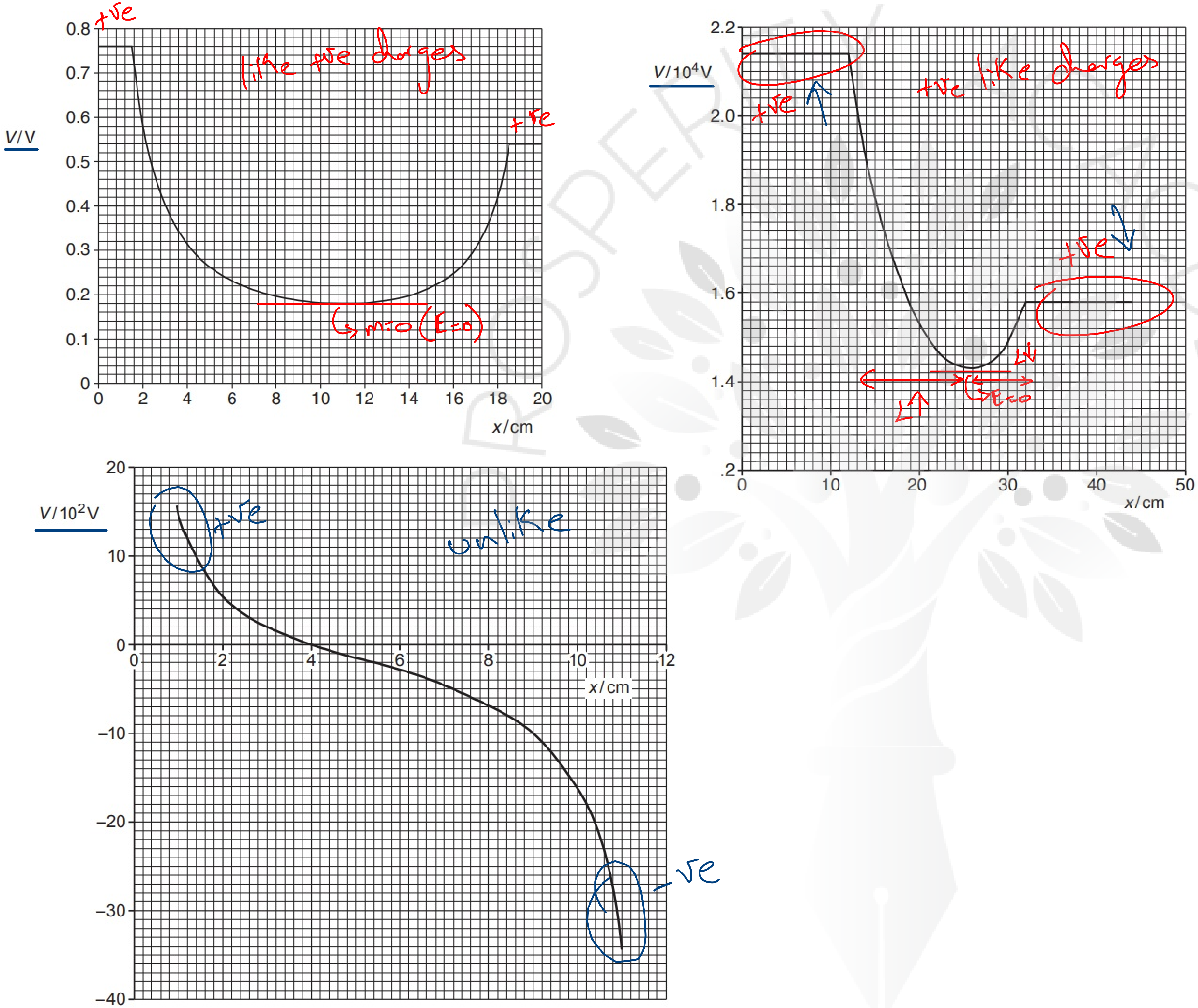
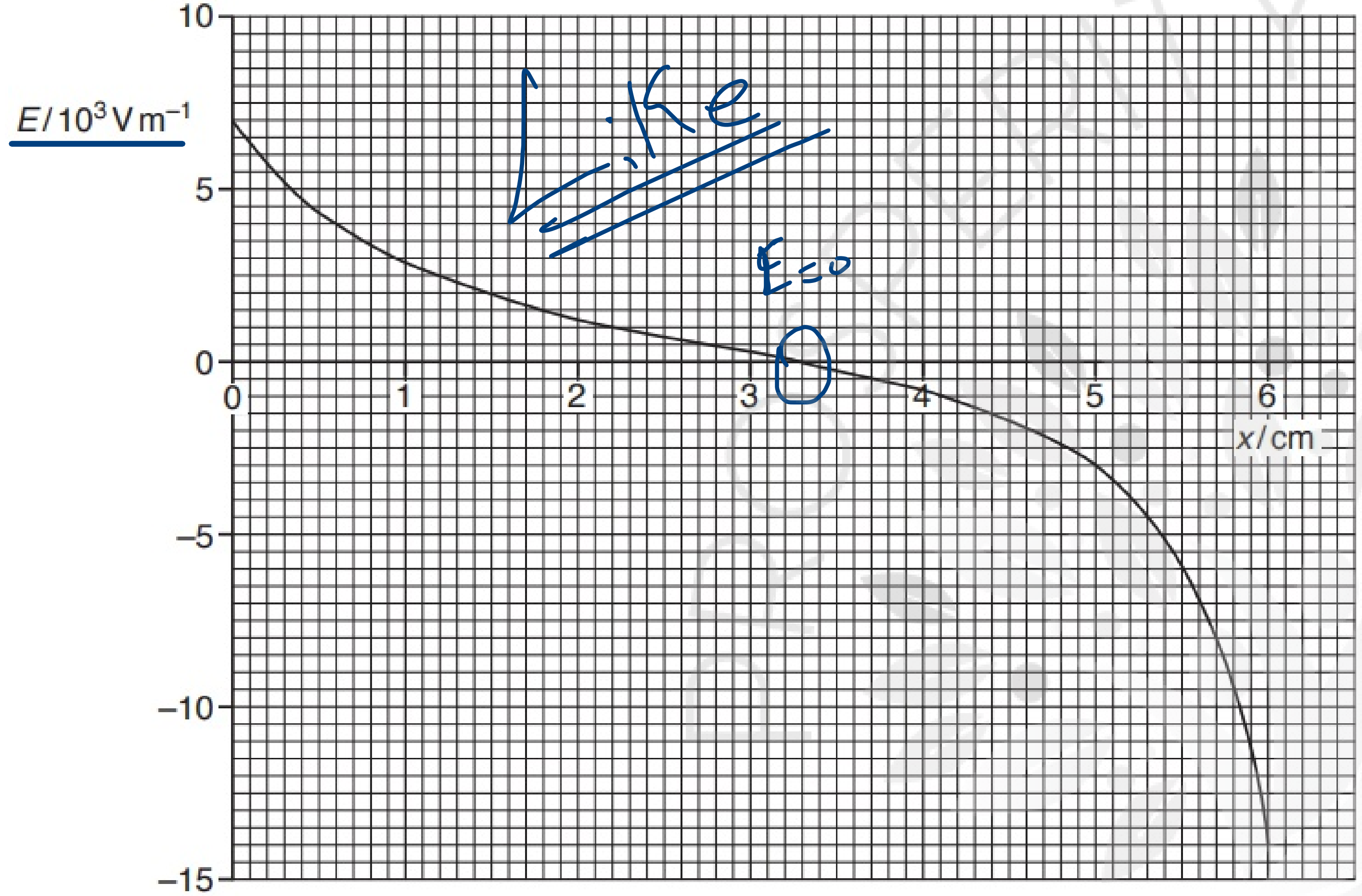


Fig. 5.2

$V = \frac{KQ}{r}$


E / 10^3 V m^-1
10
5
0
–5
–10
–15
0
1
2
3
4
5
6
x / cm
Like
E=0