ELECTRIC FIELDS

Multiple-choice questions

Question 1

From $F = \frac{kQ_1Q_2}{d^2}$ we get that the force varies as $\frac{1}{d^2}$. So to decrease the force to $\frac{1}{3}$ of the original $\frac{1}{r^2} = \frac{1}{3}$

$\therefore r^2 = 3$

$\therefore r_{new} = \sqrt{3}\, d$

∴ B (ANS)

Question 2

From $F = \frac{kqq}{d^2}$ we get that the new force is given by $F_{new} = \frac{k(2q)(3q)}{d^2}$

$\therefore F_{new} = 6F$

∴ A (ANS)

Question 3

The field is given by the direction of the force on a +ve charge. The field between parallel plates is modelled as uniform. Therefore the field is always to the right

∴ A (ANS)

Question 4

Work is done on the charge to move it from B to C, therefore, its potential energy will increase. The negative charge is repelled by the negative plate, so it has work done on it to move it towards this plate.

∴ A (ANS)

Question 5

The force is given by F = Eq. As the field is uniform (see above), the force will remain constant.

∴ D (ANS)

Question 6

The force is given by F = Eq. As the field is uniform (see above), the direction and magnitude of the force will remain constant. The force will repel the positive charge from the positive plate.

∴ C (ANS)

Question 7

The field is given by the direction of the force on a +ve charge. The field between parallel plates is modelled as uniform.
The magnitude of the field is given by

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

$\therefore E = \frac{225}{0.15}$

$\therefore E = 1\,500\ \text{V m}^{-1}$

∴ A (ANS)

Question 8

The force is given by F = Eq

$\therefore F = 1500 \times 3.2 \times 10^{-19}$

$\therefore F = 4.8 \times 10^{-16}\ \text{N}$

The field will exert a force on the alpha particle to the right. (repelled by the +ve plate).

∴ C (ANS)

Question 9

Use $a = \frac{F}{m}$

$\therefore a = \frac{4.8 \times 10^{-16}}{6.6 \times 10^{-27}}$

$\therefore a = 7.27 \times 10^{10}$

∴ B (ANS)

Question 10

The stationary alpha particle will be repelled by the positive plate, so it will accelerate towards the negative plate. This means that its speed will increase uniformly.
The change in energy is given by the work done, which is F × d

$\therefore WD = 4.8 \times 10^{-16} \times 0.15$

$\therefore WD = 7.2 \times 10^{-17}\ \text{J}$

∴ C (ANS)

Question 11

$\Delta KE = qV.$

$\therefore \frac{1}{2}mv^2 = 1.6 \times 10^{-19} \times 50 \times 10^3$

$\therefore \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 8.0 \times 10^{-15}$

$\therefore v^2 = 1.7 \times 10^{15}$

$\therefore v = 1.3 \times 10^8\ \text{m s}^{-1}$

∴ C (ANS)

Question 12 (2017 Question 2 89%)

Use F = Eq to be the electrical force on the oil drop.

∴ F = Eq

∴ $F = 10^4 \times 9.6 \times 10^{-19}$

∴ $F = 9.6 \times 10^{-15}$ N

∴ B (ANS)

Question 13 (2017 Question 3 84%)

Use $E = \frac{V}{d}$, where E = 1 000 N C^{-1} and $d = 5.0 \times 10^{-3}$ m.

∴ V = E × d

∴ $V = 1\,000 \times 5.0 \times 10^{-3}$

∴ V = 5 V

∴ A (ANS)

Extended questions

Question 14a

There are two forces acting on the oil drop, its weight and a force due to the electric field.
As it is suspended, these must be in equal and opposite directions. Therefore the electric force must be acting up.
The charge needs to be negative.

Question 14b

Use mg = Eq

∴ $m \times 9.8 = 10\,000 \times 3.2 \times 10^{-12}$

∴ $m = 3.3 \times 10^{-9}$ kg

Question 14c

The electric field between the two plates is modelled as uniform. Therefore the drop will stay suspended, as the weight remains constant, so the downward force remains balanced by the upward force. Xu is correct and Amy is incorrect.

Question 14d

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

∴ $10\,000 = \frac{V}{0.02}$

∴ V = 200 V (ANS)

Question 15a

The field from the 2 nC charge is to the right, as is the field from the -8 nC charge.

Use $E = \frac{kQ}{d^2}$ for both charges and add as vectors.

$$E = \frac{9.0\times10^9\times2\times10^{-9}}{(0.06)^2} + \frac{9.0\times10^9\times8\times10^{-9}}{(0.06)^2}$$

∴ E = 5 000 + 20 000

∴ E = 25 000 V m^{-1} (ANS)

Question 15b

The field is to the right

Question 15c

To the left of the 2 nC charge the field from the 2 nC charge will be to the left and the field from the 8 nC charge will be to the right. For them to cancel out, they need to have the same magnitude.
The field from the 8 nC charge will be four times as strong as the field from the 2 nC charge.
This means the 8 nC charge needs to be twice as far away. (The field drops off as $\frac{1}{r^2}$) so the point will be 12 cm to the left of the 2 nC charge. Therefore the distance from the 8 nC charge is 24 cm, and the distance from the 2 nC charge is 12 cm.
Check with arithmetic.

$$E_2 = \frac{9.0\times10^9\times2\times10^{-9}}{(0.12)^2}$$

E_2 = 1 250 V m^{-1}

$$E_8 = \frac{9.0\times10^9\times8\times10^{-9}}{(0.24)^2}$$

E_2 = 1 250 V m^{-1}

Question 15d

If the two charges were the same, then moving them together would require work, so they would have greater potential energy. Since the two charges are opposite, (and they attract each other) moving them closer together will result in a **decrease** in the combined potential energy.

Question 16a

Use ΔKE = qV.

∴ $\frac{1}{2}mv^2 = 1.6 \times 10^{-19} \times 2.5 \times 10^3$

∴ $\frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 4.0 \times 10^{-16}$

$\therefore v^2 = 8.8 \times 10^{14}$
$\therefore v = 3.0 \times 10^7$ m s^{-1} (ANS)

Question 16b

Use $E = \frac{V}{d}$
$\therefore E = \frac{2500}{0.04}$
$\therefore V = 6.25 \times 10^4$ V m^{-1} (ANS)

Question 16c

Use $v^2 - u^2 = 2ax$
where $u = 0$, $x = 0.04$ m
$\therefore 8.8 \times 10^{14} - 0 = 2 \times a \times 0.04$
$\therefore a = 1.1 \times 10^{16}$ m s^{-2} (ANS)

An alternative method is to use F = ma = Eq
$\therefore a = \frac{Eq}{m}$
$\therefore a = \frac{6.25 \times 10^4 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}$
$\therefore a = 1.1 \times 10^{16}$ m s^{-2} (ANS)

Question 16d

The work done (change in KE) is given by qV. Therefore, the changes will not affect the final KE (speed) of the electrons. Increasing the distance will decrease the electric field, so the acceleration (hence the force) will be smaller but over a longer distance.

Question 17a

Use ΔKE = qV.
$\therefore \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = 1.6 \times 10^{-19} \times V$
$\therefore \frac{1}{2} \times 9.1 \times 10^{-31} \times (1.0 \times 10^7)^2 - \frac{1}{2} \times 9.1 \times 10^{-31} \times (5.0 \times 10^6)^2 = 1.6 \times 10^{-19} \times V$
$\therefore 4.55 \times 10^{-17} - 1.14 \times 10^{-17} = 1.6 \times 10^{-19} \times V$
$\therefore$ 213 V (ANS)

Question 17b

Use $E = \frac{V}{d}$
$\therefore E = \frac{213}{0.0015}$
$\therefore E = 1.42 \times 10^5$ V m^{-1} (ANS)

Question 18a

Use ΔKE = qV and then $E = \frac{V}{d}$ or link the two together to get ΔKE = qEd
$\therefore 15 = 3.2 \times 10^{-5} \times E \times 1.2 \times 10^{-2}$
$\therefore 15 = 3.84 \times 10^{-7} \times E$
$\therefore E = 3.9 \times 10^7$ V m^{-1} (ANS)

Question 18b

Use ΔKE = qV to get
$15 = 3.2 \times 10^{-5} \times V$
$\therefore V = 4.69 \times 10^5$ V (ANS)

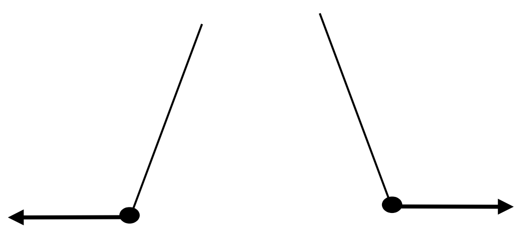
Question 19a

To counter the weight, the electric force needs to be upwards. If the field is downwards, then this is the direction of the force on a positive charge. Therefore, the oil drop must have a **negative** charge as the electric force on it is up.
∴ excess electrons (ANS)

Question 19b

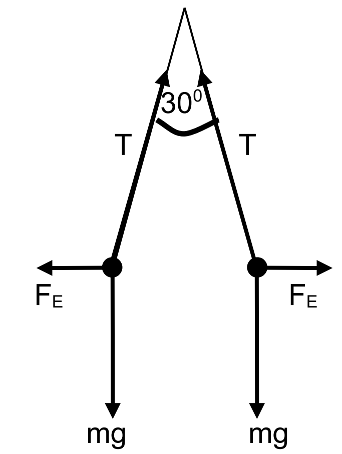
Equate mg = Eq
Let q = n × e
The mass is identified as 1.6 µg, which can be written as 1.6×10^{-6} g.
$\therefore 1.6 \times 10^{-9}$ kg.
$1.6 \times 10^{-9} \times 9.8 = 1.0 \times 10^{12} \times n \times 1.6 \times 10^{-19}$
∴ n = 0.098.
This is an impossible answer, as it must be a whole number of electrons.

Question 20a

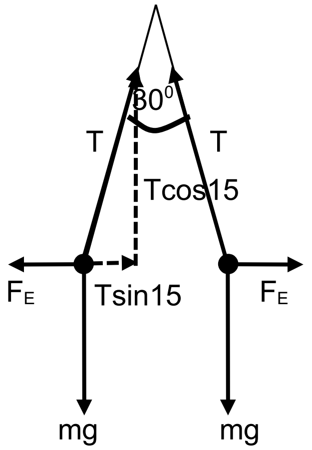


The two electrostatic forces repel each other to force the particles apart.

Question 20b



Just considering the left-hand side for all the forces to be balanced, T needs to be resolved into two components, one vertical and the other horizontal.



Considering the vertical components, we get that Tcos15 = mg

$\therefore$ T cos15 = $0.5 \times 10^{-3} \times 9.8$

$\therefore$ T = 5.1×10^{-3} N (ANS)

Question 20c

Equating the horizontal component gives that

F_E = T sin15.

Question 21a

KE = $\frac{1}{2}mv^2$

= $\frac{1}{2} \times 9.1 \times 10^{-31} \times (5.0 \times 10^6)^2$

= 1.1375×10^{-17} J

To convert from J to eV you need to divide by 1.6×10^{-19}.

$\therefore 1.1375 \times 10^{-17} \div 1.6 \times 10^{-19}$

= 71 eV (ANS)

Question 21b

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

$\therefore$ E = $\frac{5000}{0.0025}$

$\therefore$ E = 2.0×10^6

The direction of the field is up, as it is the given by the direction on a small +ve charge

$\therefore$ E = 2.0×10^6 V m^{-1} Up (ANS)

Question 21c

Use F = ma = Eq

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

$\therefore$ a = $\frac{2.0\times10^6\times1.6\times10^{-19}}{9.1\times10^{-31}}$

$\therefore$ a = 3.5×10^{17} m s^{-2} (ANS)

Question 21d

The only forces acting on the electron are in the vertical direction. There is the force due to the electric field, which is down on an electron, and the weight.

The acceleration due to the weight is 9.8 m s^{-2}, and the acceleration due to the electric field is 3.5×10^{17} m s^{-2}.

This will be vertically down.

Question 22a (2016 Question 2, 58%)

Use Wd = ΔKE = qV

where ΔKE = $\frac{1}{2}mv^2$

= $\frac{1}{2} \times 9.1 \times 10^{-31} \times (8.0 \times 10^7)^2$

= 2.912×10^{-15}

Use ΔKE = qV to get

$2.912 \times 10^{-15} = 1.6 \times 10^{-19} \times V$

$\therefore$ V = 18 200 V

$\therefore$ 12.2 kV (ANS)

Question 22b (2016 Question 3, 82%)

The force from the magnetic field is given by

F = Bqv, this must give rise to

circular motion where F = $\frac{mv^2}{r}$

$\therefore \frac{mv^2}{r} = Bqv$

$\therefore r = \frac{mv}{Bq}$

$\therefore r = \frac{9.1\times10^{-31}\times8.0\times10^{7}}{4.0\times10^{-4}\times1.6\times10^{-19}}$

$\therefore r = 11.375 \times 10^{-1}$

$\therefore r = 1.1$ m (ANS)

Question 22c (2016 Question 4, 81%)

The force from the magnetic field is given by

F = Bqv

$\therefore F = 4.0 \times 10^{-4} \times 1.6 \times 10^{-19} \times 8.0 \times 10^{7}$

$\therefore F = 5.12 \times 10^{-15}$ N (ANS)

Question 23 (2017 Question 2a 84%)

Use f = $k\frac{q_1q_2}{r^2}$

$\therefore f = 9.0 \times 10^{9} \times \frac{(1.6\times10^{-19})^2}{(53\times10^{-12})^2}$

$\therefore f = 8.2 \times 10^{-8}$ N

To get full marks, you needed to show the first two lines of this answer.