SECTION A

A1. (a) any line (curve) through the origins;
straight-line; ***[2]***

(b) (i) a straight-line (drawn with ruler);
which is appropriate *i.e.* does not or would not go through the origin; ***[2]***
*Award **[0]** if points joined "dot to dot".*

(ii) data subjected to both types of error;
Can be implied in subsequent answer.
random since points are scattered above and below the line;
systematic since line does not/would not go through origin; ***[3]***
Accept answers that get this general idea across but do not accept answers that try to explain the source of the error without naming type of error.
*Award **[2 max]** for answers that confuse random with systematic but are otherwise correct. Award **[1 max]** for stating that there is only one type of error with correct explanation.*

(iii) use of "large triangle" for gradient (seen or implied);
Hypotenuse of triangle used should be at least half the distance between the first and the last point on the graph i.e. 5 cm.
to get gradient $= 0.59\times10^{-6} = 5.9\times10^{-7}$; ***[2]***
*Ignore any units. Award **[1 max]** for 0.59 without power of ten. Accept from 5.3 to* 6.5×10^{-7}.
*Award **[0]** if using a single point unless student's line goes through that point **and** the origin as well. Award **[0]** if using two data points as opposed to the gradient unless both data points are on candidate's line.*

(iv) use of Coulomb's law (seen or implied);
correct identification of gradient $= \mathrm{k}\, q_1 q_2 = \mathrm{k}\, q^2$;
$q^2 = 6.56\times10^{-17}\ \mathrm{C}^2$;
$q = 8.1\times10^{-9}\ \mathrm{C}$; ***[4]***
*Award **[3 max]** for a bald answer without any working. Award **[1 max]** if the candidate uses a point on the graph to calculate q.*

~~**A2.** (a) zero;~~ ~~*[1]*~~

~~(b) resultant vertical force from ropes $= (2.15 \times 10^3 - \text{weight}) = 237\text{ N}$;~~
~~equating their result to $2T \sin 50$;~~
~~*i.e.* $2T \sin 50 = 237$~~
~~calculation to give $T = 154.7\text{ N} \approx 150\text{ N}$;~~ ~~*[3]*~~
~~*Accept any value of tension from 130 N to 160 N. Award **[2]** for missing factor of 2 but otherwise correct i.e. 309 N.*~~

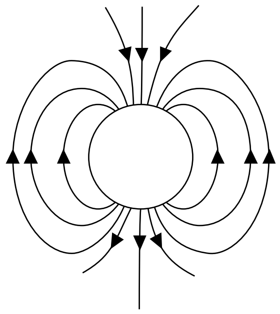
~~(c) correct substitution into $F = ma$;~~
~~to give $a = \dfrac{237}{1.95 \times 10^2} = 1.21\text{ m s}^{-2}$;~~ ~~*[2]*~~
~~*Watch for ECF.*~~
~~***N.B.** Depending on value of g answer will vary from 1.0(3) m s^{-2} to 1.2(3) m s^{-2} all of which are acceptable.*~~

~~(d) statement that air friction increases with increased speed seen/implied;~~
~~in 10 seconds friction goes from 0 N to 237 N / force increases from zero until it equals the net upward accelerating force;~~ *[2]*

A3. (a) force per unit charge;
exerted on a small positive test charge / small positive charge / positive point charge; *[2]*

(b) at least four radial lines evenly spaced around the sphere;
with arrows away from centre; *[2]*
*Award **[1 max]** if any lines inside sphere.*

A3. (a)

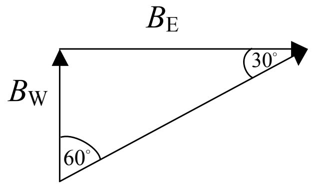


overall correct shape with no field lines touching;
direction of field; ***[2]***

(b) <u>bar</u> magnet / solenoid; ***[1]***
Do not accept just "magnet".

(c) (i) upwards
the direction of the compass needle is the resultant of two fields / *OWTTE*;
the field must be into the plane of the (exam) paper to produce a resultant field in the direction shown / *OWTTE*; ***[2]***
*Award **[1]** for "upwards because of the right hand rule" / OWTTE.*

(ii)



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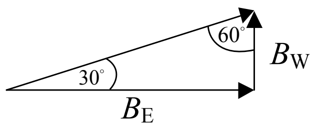


vector addition with correct values of two angles shown $30^\circ, 60^\circ$ ***or*** 90°;

from diagrams $B_E = B_W \times \tan 60$ ***or*** $B_E = \dfrac{B_W}{\tan 30}$; ***[2]***

(iii) $B_W = \dfrac{\mu_0 I}{2\pi r} = \dfrac{2\times10^{-7}\times4}{2\times10^{-2}} = 4.0\times10^{-5}\ \text{T}$;

$B_E = B_W \times \tan 60 = 6.9\times10^{-5}\ \text{T}$; ***[2]***

A3. (a) (i) **two** arrows directed towards the centre of the circular path, within $\pm 0.5\,\text{cm}$ of the centre. ***[1]***

(b) (i) negative by stating any rule for the direction of the magnetic force; ***[1]***

(ii) the work done is zero;
since the force is at all times normal to the velocity; ***[2]***

(c) a curved path starting at X and in the right direction i.e. counterclockwise;
circular path of radius $\frac{R}{2}$; ***[2]***
Allow diameter 3-4 cm and be generous with how round the circle is.

Part 2 Electrical conduction and the force on a conductor in a magnetic field

(a) (i) $\longleftarrow$; ***[1]***

(ii) the force on the electrons produced by the electric field causes them to accelerate along the direction of the rod;
however, they will (soon) collide with a lattice ion but after collision will again be accelerated (along the rod) before making another collision / *OWTTE*;
hence the electrons gain a drift/net velocity in the direction of the wire / in the (opposite) direction to the field even though they still have random velocities / *OWTTE*; ***[3]***

(b) (i) $\longleftarrow$; ***[1]***

(ii) $F = BIL = Ma$;
to give $a = \dfrac{BIL}{M}$; ***[2]***

(c) (i) let the body move a distance Δx in time Δt, then work one by F is $W = F\Delta x$;
therefore rate of working $=$ power $= P = \dfrac{F\Delta x}{\Delta t} = Fv$; ***[2]***
i.e. Look for expression for work done and identifying power as rate of working.

(ii) $P = BILv = EI$;
to give $v = \dfrac{E}{BL}$;
$v = \left(\dfrac{0.8}{0.60 \times 0.25}\right) = 5.3\,\text{m}\,\text{s}^{-1}$; ***[3]***

Part 2 Magnetic and electric fields

(a) (i) use of $qV = \frac{1}{2}mv^2$;
$1.6\times10^{-19}\times420 = \frac{1}{2}\times1.67\times10^{-27}\times v^2$
$v = 2.8\times10^5\ \text{m s}^{-1}$; ***[2]***

(ii) arc of circle / continuous curve within region ABCD <u>and</u> deflected upwards *i.e.* towards AB;
straight-line as tangent to arc beyond BC; ***[2]***

(iii) $F = 1.5\times10^{-2}\times1.6\times10^{-19}\times2.8\times10^5$;
$= 6.7\times10^{-16}\ \text{N}$; *(allow 6.8×10^{-16} N)* ***[2]***

(b) (i) force per unit positive charge;
on small test charge (placed at that point); ***[2]***

(ii) $6.7\times10^{-16} = 1.6\times10^{-19}\times E$;
$E = 4.2\times10^3\ \text{V m}^{-1}$; ***[2]***

(iii) undeviated / straight line (along original path);
reason *e.g.* forces in field <u>always</u> equal and opposite; ***[2]***

Part 2 Electricity and magnetism

(a) work done per unit charge in moving charge completely around the circuit / power supplied per unit current; ***[1]***

(b) (i) two sets of series resistors at 90 Ω each;
and these are in parallel for a total of 45 Ω;
plus the internal resistance in series for a grand total of 50 Ω; ***[3]***

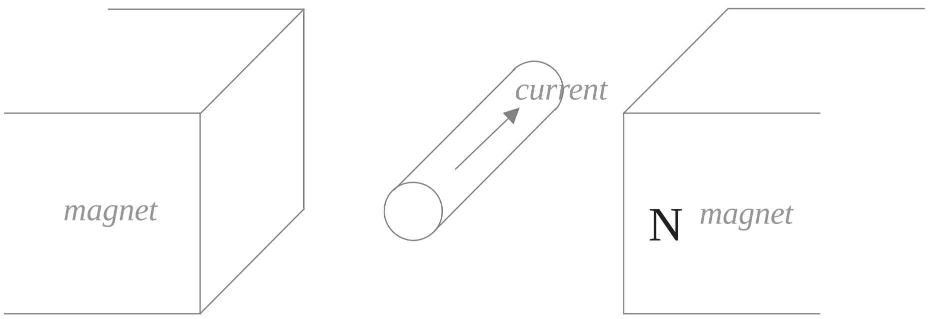
(ii) total current is $I = \left(\frac{12}{50}\right) = 0.24\,\text{A}$; ***[1]***
Watch for ECF if answer for resistance is wrong.

(iii) $P_{\text{total}} = EI$;
$= (12 \times 0.24) = 2.9\,\text{W}$; ***[2]***
Watch for ECF if answer for current is wrong.

(iv) across $30\,\Omega$ voltage drops by 3.60 V (so potential at X is 3.60 V);
across $60\,\Omega$ voltage drops by 7.20 V (so potential at Y is 7.20 V);
so potential difference between X and Y is (negative) 3.6 V; ***[3]***

(c) in the original circuit there is no current between X and Y / the resistance between X and Y is infinite;
introducing a real voltmeter changes the total resistance of the circuit / allows current between X and Y / the resistance between X and Y is no longer infinite; ***[2]***

(d) (i)



because the magnetic force on the rod must be vertically upward and the law for the magnetic force requires field directed to the left, hence right pole is N; ***[1]***

(ii) $0.20 \times I \times 0.80 = 4.0$;
and so $I = 25\,\text{A}$; ***[2]***

(iii) at Y;
the magnetic fields of the wire and of the magnet add; ***[2]***
*Award **[0]** for a correct answer with no explanation or with an incorrect explanation.*
Watch for ECF in case they got the polarity of the magnets wrong earlier in which case the answer is X.

B1. Part 2 Force fields

(a) (i) *at A*: constant;
at B: decreasing; ***[2]***

(ii) field line gives the direction of the force (on mass or charge);
if lines touched (or crossed), particle would move in two directions at the same time and this is impossible; ***[2]***

(b) (i) must be a force normal to direction of motion / some reference to circular motion;
so field is magnetic; { *Do not award if there is no reasoning or reasoning is fallacious or misleading.* ***[2]***

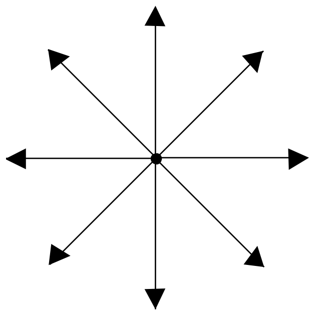
(ii) particles are oppositely charged; ***[1]***

(iii) $r = \frac{mv}{Bq}$;
speed is decreasing / particle losing energy;
hence radius is decreasing; { *Do not award if there is no reasoning or reasoning is fallacious or misleading.* ***[3]***

B3. Fields and electric charge associated with atoms

(a) the force per unit charge;
exerted on a small positive charge / positive test charge / positive point charge; ***[2]***

(b) (i)



at least 6 symmetric radial lines as shown <u>touching the proton</u>;
correct direction; ***[2]***

(ii) use of $E = k\frac{q}{r^2}$

$E = \frac{9.0\times10^{9}\times1.6\times10^{-19}}{25\times10^{-22}}$;

$= 5.8\times10^{11}\,\text{N C}^{-1}$; ***[2]***

Award full marks for bald correct answer.

(c) (i) use of $F = qE$

$F = 1.6\times10^{-19}\times5.8\times10^{11}$;

$= 9.3\times10^{-8}\,\text{N}$ ***[1]***

Allow use of force law.

(ii) recognize that $F = \frac{mv^2}{r}$;

$\frac{1}{2}mv^2 = \frac{1}{2}Fr$;

$= \frac{1}{2}\times9.3\times10^{-8}\times5.0\times10^{-11}$;

$= 2.3\times10^{-18}\ \text{J}$ ***[3]***

(iii) kinetic energy $= \frac{2.3\times10^{-18}}{1.6\times10^{-19}} = 14\ \text{eV}$;

PE = Total – KE;

= –28 (eV); ***[3]***