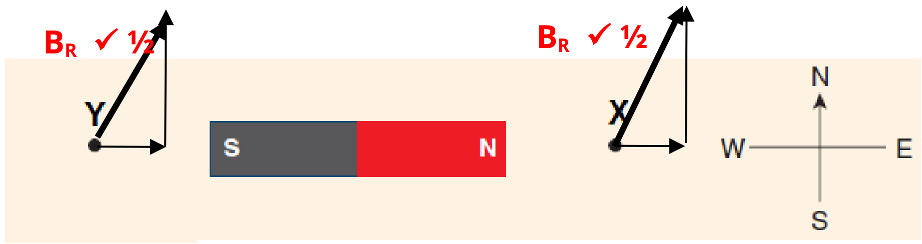
Day 2 Yr 12 Physics Soln. Vac. Tut. April 2017.

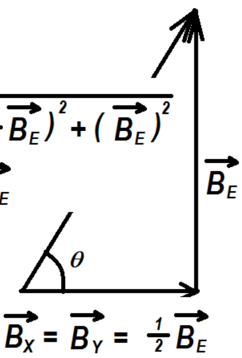
1. The diagram shows a bar magnet that has a field strength at the positions X and Y half that of the earth's magnetic field. Sketch the resultant magnetic field at positions X and Y. [3]



Briefly explain your sketches.

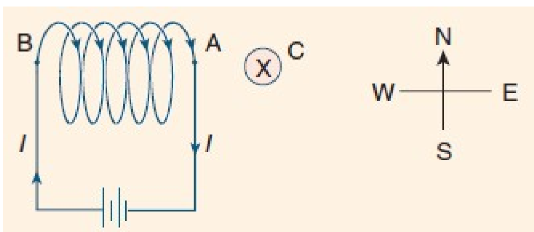
The Earth's magnetic field is $\vec{B}_E$ due North; at X or Y, the field strength is $\frac{1}{2}\vec{B}_E$ due East ∴ the resultant will be worked as shown on the right:

$$\vec{B}_R = \sqrt{\left(\tfrac{1}{2}\vec{B}_E\right)^2 + \left(\vec{B}_E\right)^2} = \tfrac{\sqrt{5}}{2}\vec{B}_E$$



$$\theta = \tan^{-1}\left(\tfrac{2}{1}\right) = 63.4^\circ$$

2. The diagram shows a current-carrying solenoid located next to a long, straight, current-carrying conductor C (perpendicular to page) that carries a current into the page.



(a) In what direction is the magnetic force on this conductor? [1]

South ✓

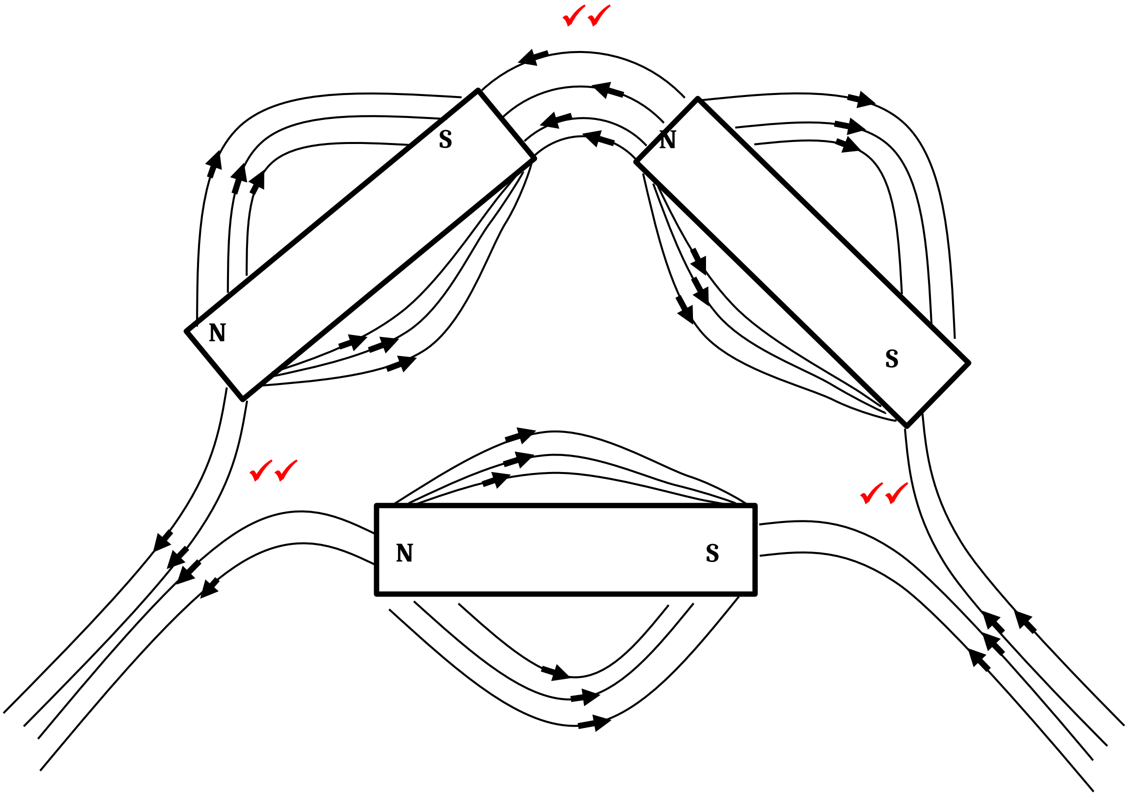
(b) The direction of the current in the solenoid is reversed and the current in it is halved. The current in conductor C is also reversed and the magnitude doubled. In what direction will be the force on conductor C? [1]

South ✓

(c) How will the magnitude of the force on conductor C in part (b) compare to what it was in part (a)? [1]

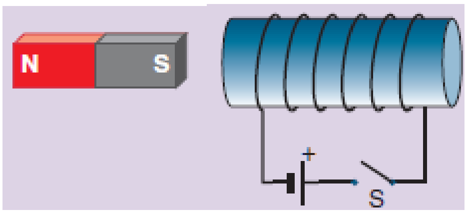
About the same ✓

3. Draw the magnetic field due to the arrangement of magnets shown. [6]



4.

An electromagnet with a soft iron core is set up as shown in the diagram below. A small bar magnet with its south end towards the electromagnet is placed to the left of it. The switch S is initially open.



The following questions refer to the force between the electromagnet and the bar magnet under different conditions.

a) Describe the force on the bar magnet while the switch remains open. [1]

There will be no force as the electromagnet is not magnetised. (Maybe a small attractive force as the magnet forces the domain in the soft iron piece to realign and be attracted to it.) ✓

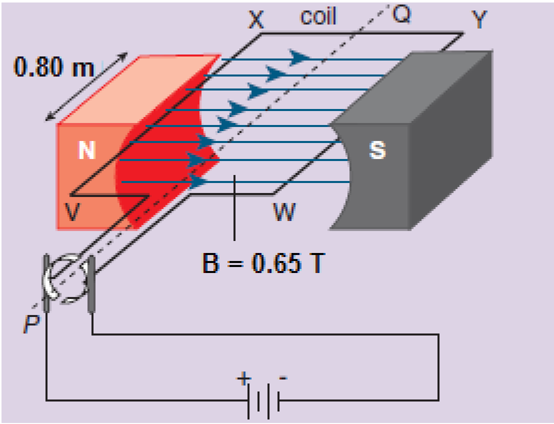
b) Describe the force on the bar magnet when the switch is closed and a heavy current flows. [2]

Repulsive force as the electromagnet produces a south pole directly opposite the south pole of the magnet. Like poles repel. ✓✓

c) The battery is removed and then replaced so that the current flows in the opposite direction. Describe the force on the bar magnet now. [2]

Attractive force as the electromagnet produces a north pole directly opposite the south pole of the magnet. Unlike poles attract. ✓✓

5. The following is a simplified diagram of a DC motor



(a) Briefly write down the functions of the following parts.

(i) Field magnets [1]

These provide the external magnetic field that interacts with the field produced by the current through the coils. This interaction is what leads to the motion of the coils. ✓

(ii) Soft iron core [1]

This is the integral part of the armature. It intensifies the magnetic field through the coil by having its magnetic domains line up with the field of the external magnet. ✓

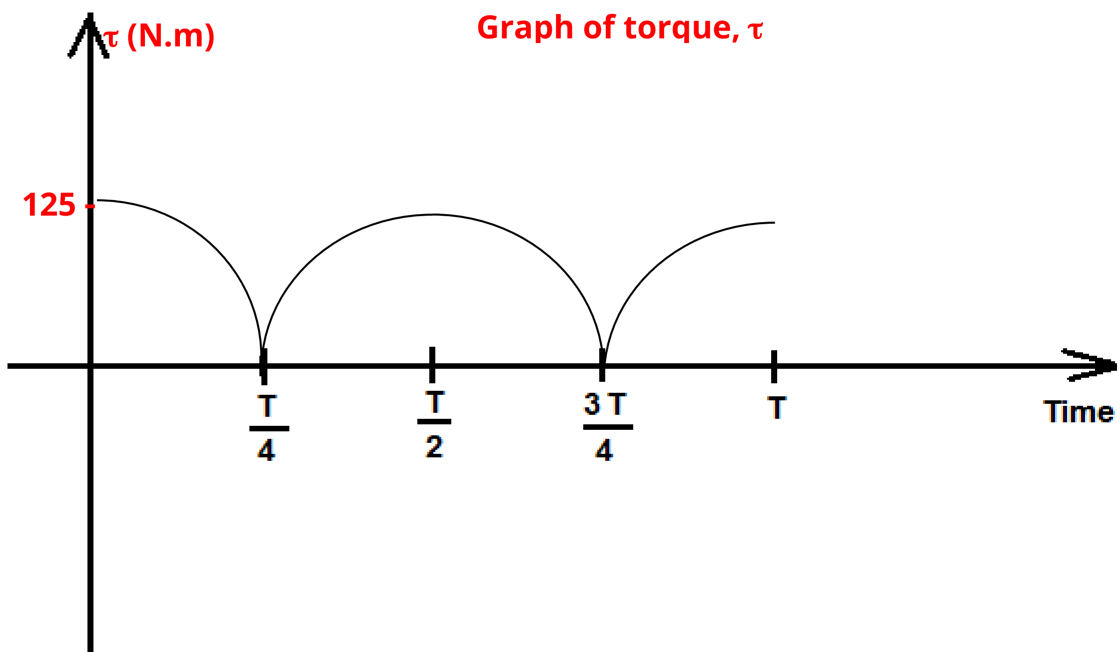
(iii) Split ring commutator [1]

These enable the current direction though the coil to be switched once every ½ circle. This ensures that the torque on the coil is always in the same sense making the coil spin continuously in one direction. ✓

(iv) Carbon brushes [1]

These are conductors that melt at very high temperatures that enable the current to be passed from stationary wires from the battery to rotating coils via rotating commutators on the axle. They prevent the entangling of wires as the coil rotates. ✓

b) Sketch a torque versus time graph for one complete rotation, using the shown position as zero time. [3]



(c) List four ways in which the DC motor could be modified so the maximum torque could increase. [2]

• More turns of wire on the coil; • Greater current through the coil; • Magnets with greater flux density
• Magnets shaped so the coil is perpendicular to the flux in more positions of the coil
• More coils and more commutator

(d) Motors can be used as generators if they are modified in a certain way. How could this motor be converted into a generator? [2]

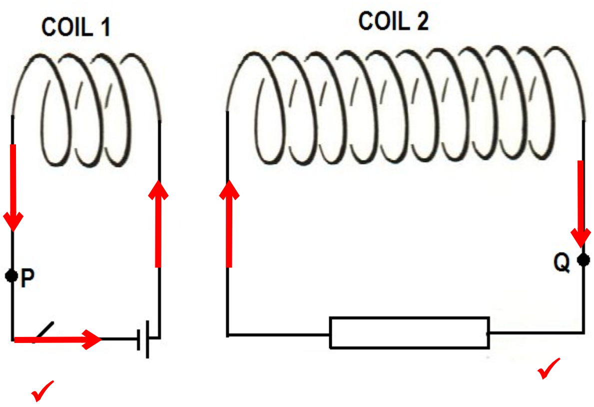
A source of rotation for the coil would need to be included and the split ring commutator would need to be replaced with slip rings. The battery needs to be removed of course. ✓✓

(e) If the motor was modified and converted into a generator, would the generator produce AC or DC current? Explain briefly. [1]

AC because the output of each half of coil is connected to one carbon brush due to the slip ring commutator. As the coil rotates in the magnetic field, the current in it varies in magnitude and direction, resulting in the AC output. ✓

6. **[3 marks]**

The diagram below shows 2 insulated wire coils.



(a) At the instant the switch is closed, a (conventional) current begins to flow in Coil 1. At the points P and Q, draw arrows to show the direction of the (conventional) current I_1 in the circuit for Coil 1 and the direction of the induced (convectional) current I_2 in the circuit for Coil 2. [2]

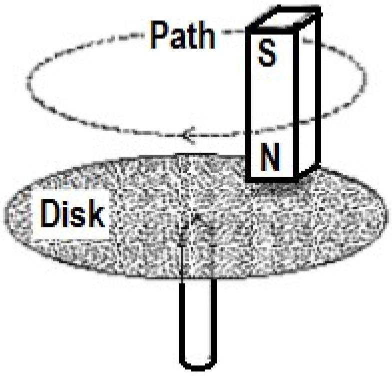
(b) If the switch remains closed, what happens to the current in Coil 2? Circle your choice of the options given below. [1]

✓

It Reverses It decreases to Zero It remains Unchanged

7. **[3 marks]**

A classroom physics demonstration apparatus consists of a non-magnetic disk balanced on a point support as shown in the diagram beside. The metal disk is initially stationary. A magnet is moved in a circular path just above the surface of the disk without touching it.



Will the disk:

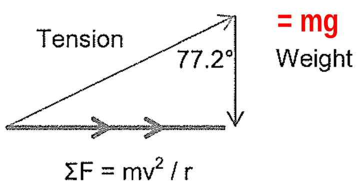
A. Remain stationary
B. Rotate in the same direction as the magnet
C. Rotate in the opposite direction of the magnet?

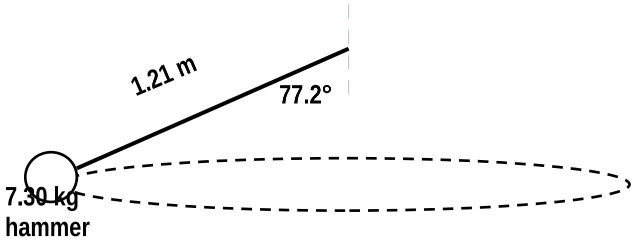
Answer: ____B____ ✓

State your reason(s) below:

The disk is a bulk conductor and so can have current flow in any direction. As the magnetic flux from the moving magnet cuts across the disk, eddy currents are induced in the disk. These eddy currents generate a magnetic field that interacts with those of the moving magnet creating a force that moves the disk in the same direction as the moving magnet. ✓✓

8. A student is investigating the physics of the hammer throw event at the London Olympics. A hammer of mass 7.30 kg is describing uniform circular motion at a constant height. The length of the hammer is 1.21 m and the wire makes an angle of 77.2° with the vertical. Calculate the time taken for the hammer to make one revolution. (5)





$m = 7.30$ kg $l = 1.21$ m $\theta = 77.2°$

$\sin\theta = r / 1.21$ so $r = 1.21 \times \sin 77.2 = 1.18$ m ✓

Vector diagram or other analysis of vector components ✓ ✓

$\tan 77.2 = mv^2 / r \div mg = v^2 / gr$

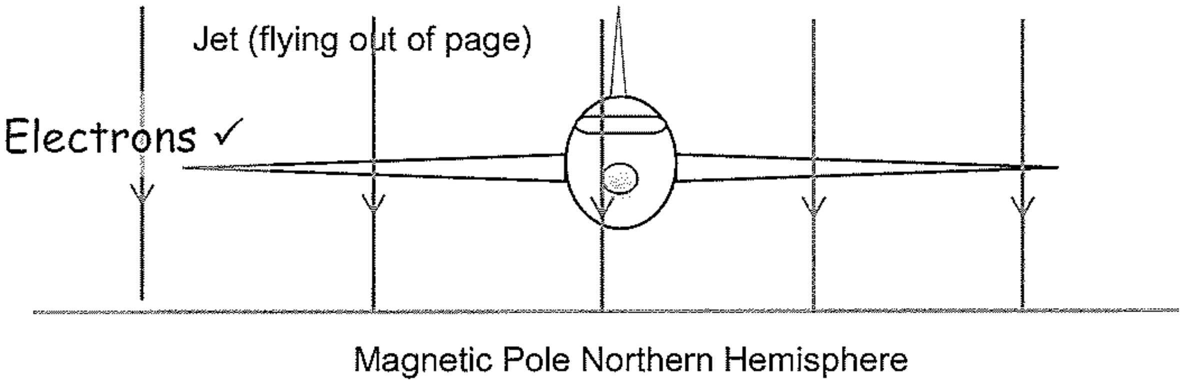
$v^2 = \tan 77.2 \times 9.8 \times 1.18 = 50.896$

$v = 7.13415$ ✓

$T = 2\pi r / v = 2\pi \times 1.18 / 7.13415 = 1.04$ s ✓

(Alternative methods that lead to correct answer acceptable)

9. A jet is flying directly over the magnetic pole in the Northern geographical hemisphere. The jet is flying at 858 km h^{-1}, it has a wingspan of 15.0 m and the Earth's magnetic flux density at this location is 57.8 μT.

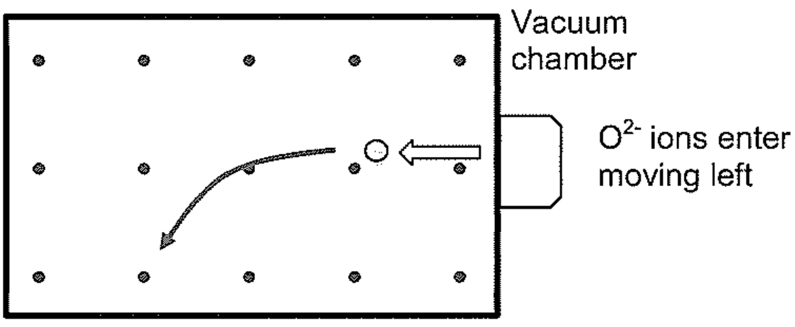


a) Draw the Earth's magnetic field at this location by using 5 lines. (1)
b) Indicate on the diagram where electrons will build up on the wingspan. (1)
c) Calculate the emf induced across the wingspan. (2)

$V = 858 / 3.6 = 238.33 \text{ m s}^{-1}$ $l = 15.0 \text{ m}$ $B = 57.8 \times 10^{-6} \text{ T}$

Emf = v.B.l
Emf = $238.33 \times 57.8 \times 10^{-6} \times 15.0$ ✓
Emf = 2.07×10^{-1} V ✓

10. Oxygen ions (O^{2-}) are injected into a vacuum chamber that contains a uniform magnetic field. For the cross section shown the magnetic flux is 2.88×10^{-4} Wb in an area 30.0 cm by 20.0 cm. The direction of the magnetic field is indicated and the ions enter at a speed of 2.76×10^{4} m s^{-1}.



a) In which direction will the ions be deflected? (Circle the correct response)

up the page   down the page   into the page   out of the page   (1)

b) Calculate the magnitude of force experienced by each ion. (3)

$\Phi = BA \quad \therefore B = \Phi / A = 2.88 \times 10^{-4} / (0.30 \times 0.20) = 0.00480$ T

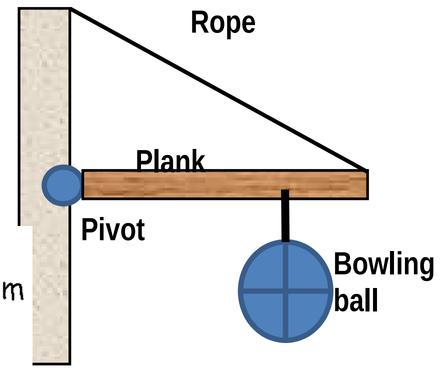
$q = 2 \times 1.60 \times 10^{-19}$ C $v = 2.76 \times 10^{4}$ m s^{-1} ✓

$F_{mag} = q.v.B$

$F_{mag} = 2 \times 1.60 \times 10^{-19} \times 2.76 \times 10^{4} \times 0.00480$ ✓

$F_{mag} = 4.24 \times 10^{-17}$ N ✓

11. A rigid wooden plank of mass 2.5 kg is attached to a wall by a pivot and is supported by a rope in tension. A 3.5 kg bowling ball is suspended from the plank. The diagram is to scale. **Estimate** the tension in the rope. Express your answer to an appropriate number of significant figures. (4)



Let length of plank = 1.00 m = lever arm to rope

lever arm to ball = 0.750 m   lever arm to plank CofM = 0.500 m

$\theta_{rope} = 30.0°$ ✓ (or other reasonable estimates)

$\theta_{plank} = \theta_{ball} = 90.0°$ moment = r.F.sin θ

$\Sigma acwm = \Sigma cwm$ about pivot

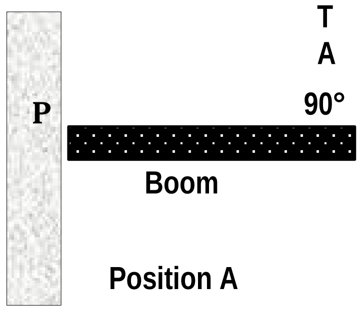
$r_{rope}.F_{tension}.\sin 30° = r_{ball}.F_{ball}.\sin 90° + r_{plank}.F_{plank}.\sin 90°$

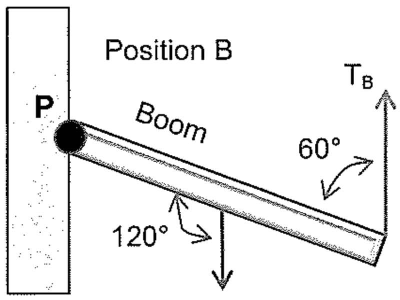
$1*F_{tension}*0.5 = 0.75*3.5*9.8 + 0.50*2.5*9.8$ ✓

$F_{tension} = 75.95$ ✓ = 76 N (appropriate sig figs ✓)

12. A rigid boom of mass m is free to rotate about a frictionless pivot P. The boom is held in static equilibrium by a rope that is in tension. The boom is held in two different positions where the tension in position A is T_A and the tension in position B is T_B. The positions are shown in the diagram below.

a) When comparing the magnitude of tension in each position, circle the best response:





$T_A = T_B$ $T_A > T_B$ $T_A < T_B$ Insufficient information for a response (1)

b) Clearly explain your choice. (3)

Let boom length = l

$\Sigma acwm = \Sigma cwm$ about pivot

Position A $0.5 \times l \times mg \times \sin 90 = l \times T_A \times \sin 90$ ✓

$T_A = 0.5 \times mg$ ✓

Position B $0.5 \times l \times mg \times \sin 60 = l \times T_B \times \sin 120$ (same method)

$T_B = 0.5 \times mg$ ✓

(Or acceptable alternative proof)

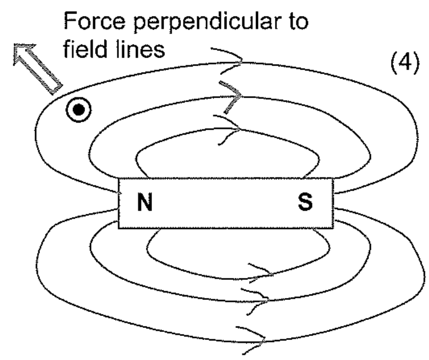
13. In the Physics course we assume that the flux linkage between the primary and secondary windings of a transformer is always 100% efficient. However, we recognise that the transformer itself may not be 100% efficient.

a) Describe two sources of inefficiency in a transformer. (2)

Eddy currents in the core of transformer leading to heating effects ✓
Heating effects in the wires of the transformer windings (I^2R losses) ✓
Or other acceptable sources.

b) Describe how these inefficiencies affect the electrical characteristics of a transformer. (1)

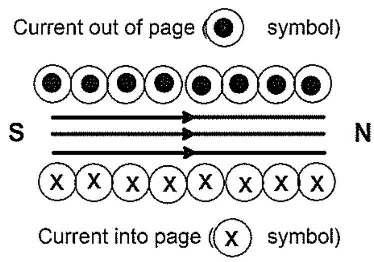
The ideal current on the output side is reduced. ✓
(P = IV so power on output side is reduced.)



(4)

c) Explain how the design of a transformer can be modified to minimise the effects of these inefficiencies. (2)

Eddy currents reduced by making core out of laminations t
flow ✓
Use of thicker (lower resistance) wires in the transformer
($\therefore I^2R$ losses reduced) ✓



14. The diagram at right shows a permanent magnet and a wire carrying current.

i. Sketch 6 lines to indicate the field of the magnet.
ii. Indicate on the diagram the direction of magnetic force acting on the wire

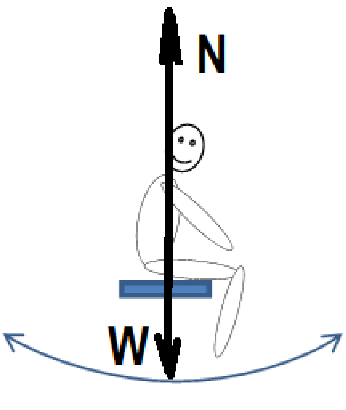
a) The second diagram at right shows the cross section of a powered solenoid. The magnetic polarity at each end of the solenoid is shown.
   i. Shown on the diagram, the direction of current that will establish this field.
   ii. Sketch 3 magnetic field lines within the solenoid core.

15. A person is sitting on a swing that is moving through the arc of a circle. It has reached the lowest point and is moving at maximum speed. Explain with reference to a vector diagram how the person's apparent weight is different compared to being at rest on the swing.

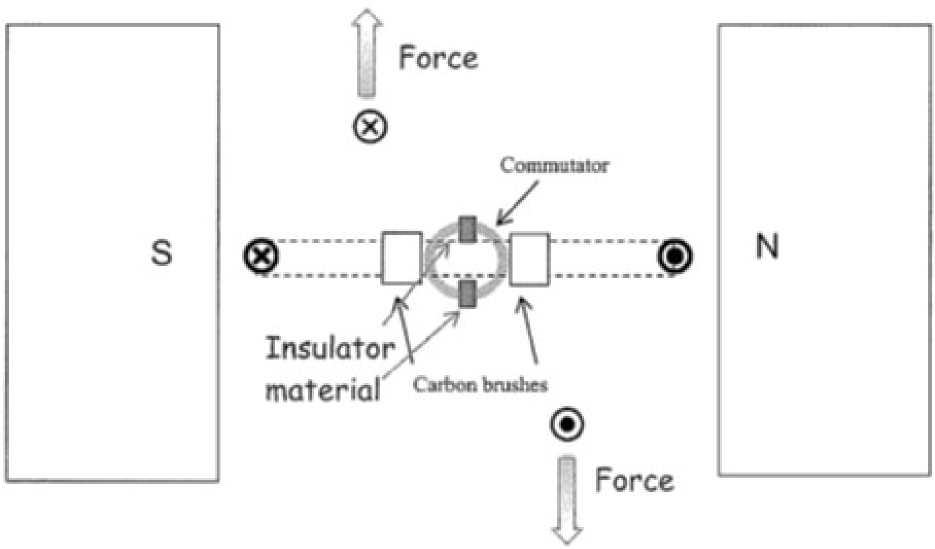
$\sum F = \frac{mv^2}{r}$

Sensation of weight from the normal reaction force ✓
Vector diagram ✓
The person is in circular motion so the net force acting on the person is the centripetal force directed to the centre of the circle. ✓

Considering all forces acting on the person
In a vector diagram $\Sigma F = mv^2/r = N + W$ and acts up (to centre) (4)
So the magnitude of N (normal reaction) acting up must be greater than magnitude of weight (mg) acting down ✓
(Or similar.)



16. The diagram shows the side view of a DC electric motor. A square coil is placed flat in the uniform magnetic field between the North and South magnetic poles. Current direction in the coil is shown on the sides adjacent to the magnetic poles. The commutator and carbon brushes are also shown.



a. In which direction will the coil turn from this start position? (1)

Clockwise ✓

b. On the diagram sketch and label the location/s of insulator materials on the commutator at this start position. (1)

c. Explain the function of the brush and commutator arrangement. (2)

An electrical connection that allows an external source of emf to feed current via fixed brushes into the rotating coil.

The arrangement breaks the connection every 180° to ensure that the current direction is switched.

d. Using the symbols and sketch on the above diagram the location of the coil after 60º of rotation from this start position. Put arrows on your symbols to indicate the direction of magnetic force acting on them. (2)

(as above - approximately 60° & direction up/down)

e. At this new position after 60º of rotation from the start position; state the torque value of the motor as a percentage of maximum torque. (2)

Torque = r.F.sinθ

θ for torque calculation = 30° / 150° ✓

∴ sin θ = 0.5 and torque = 50% of maximum ✓

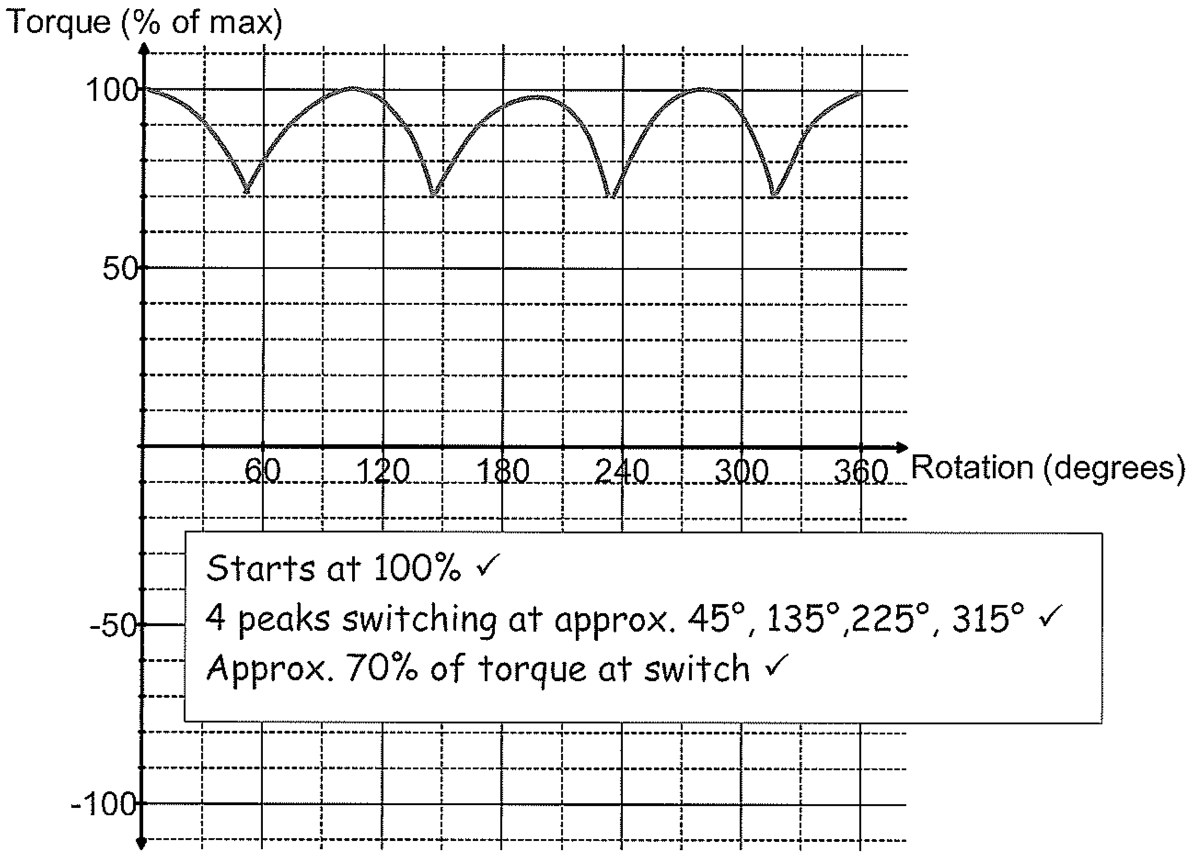
f. A single 90.0 mm length of wire adjacent to a magnetic pole experiences a 0.0240 N force when a current of 6.20 A is present. Calculate the magnetic flux density between the poles. (2)

$F = B.I.l$

$B = F / (I.l) = 0.024 / (6.20 \times 0.090)$ ✓

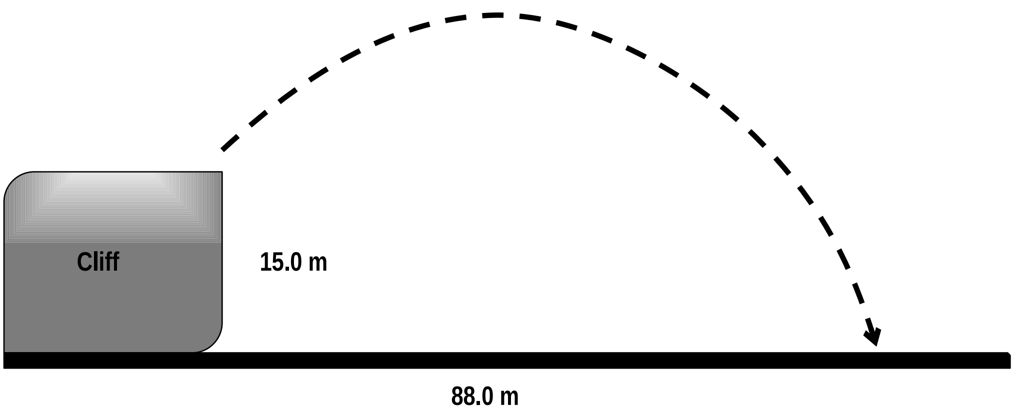
$B = 4.30 \times 10^{-2}$ T ✓

g. The motor is later modified to have two sets of evenly spaced coils and a commutator with four segments. On the axes below, sketch the shape of the torque output curve for one revolution from the start position shown. (3)



Starts at 100% ✓
4 peaks switching at approx. 45°, 135°,225°, 315° ✓
Approx. 70% of torque at switch ✓

17. A physics student observes a stone of mass 350 g being catapulted from the top of a cliff. The launch position at the top of the cliff is 15.0 m above ground level and it takes the stone a time of 5.00 seconds to reach the ground. The stone lands 88.0 m in front of the launch position. You may ignore air resistance for the calculations.



a) Calculate the vertical component of the velocity when the stone is launched. (3)

In the vertical let up = positive;
then at landing point $s = -15.0$ m, $t = 5.00$ s, u = ? □
Using $s = ut + \frac{1}{2}at^2$,
$-15 = (u \times 5) + (-4.9) \times 5^2$ □
$u = +21.5$ m.s^{-1} (positive = up) □

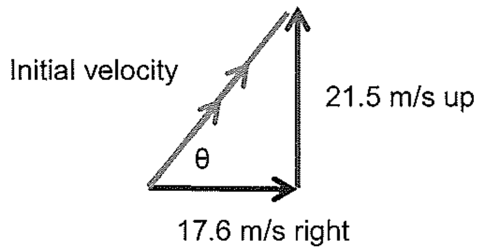
b) Considering the kinetic energy of the stone along its flight path. Circle the best response for the following statement. The kinetic energy of the stone at maximum height is:

Maximum   50% of maximum   Zero   ***minimum***

Equal to all other positions (1)

c) Calculate the initial velocity of the stone, referring to the angle of elevation above the horizontal for direction. (4)

In the horizontal; $s_{range} = 88.0$ m, $t_{flight} = 5.00$ s □,
$v_h = s_{range}/t_{flight} = 88.0 \quad 5 = 17.6$ m.s^{-1} to the right □
Considering a velocity vector diagram (see right)
$u = \sqrt{(21.5^2 + 17.6^2)} = 27.8$ m.s^{-1} □
$\theta = \tan^{-1}(21.5/17.6) = 50.7^o$ □



d) Calculate the kinetic energy of the 350 g stone just before it hits the ground. (3)

18.
oles.

Considering the conservation of mechanical energy

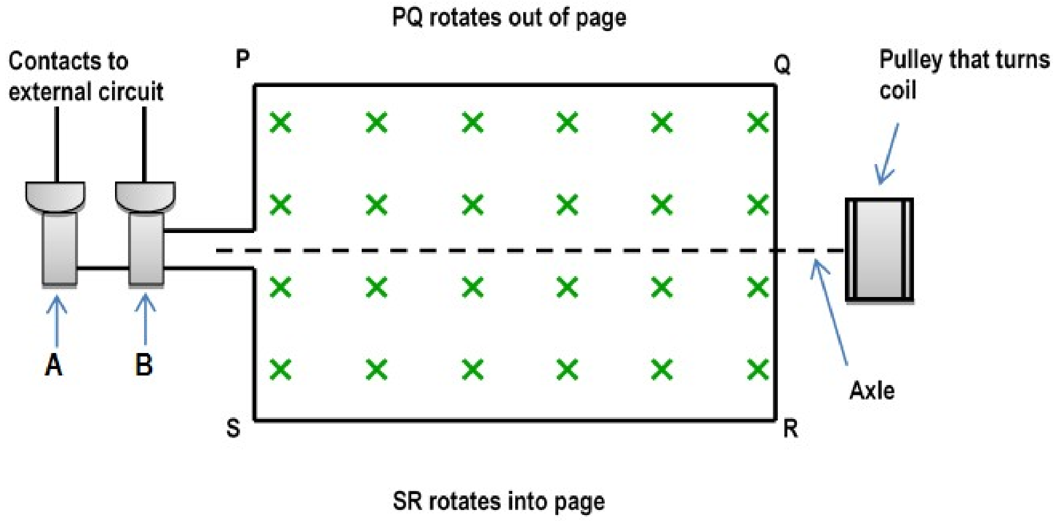
Total Mechanical Energy = constant at any height.

At this position TME = KE + GPE = $\frac{1}{2}$ mv^2 + mgh
identifies variables✓
TME = ($\frac{1}{2}$ × 0.35 × 772.01) + (0.35 × 9.8 × 15) ✓
TME = 186.55 J ✓

At end of flight GPE = zero ∴ TME is all kinetic
Kinetic energy just before stone hits ground = 187 J ✓

Alternatively in vertical v = u + at = 21.5 + (-9.8*5) = -27.5 ✓ ✓
in horizontal v = 17.6 final v^2 = 27.5^2 + 17.6^2 = 1066.01 ✓
KE = $\frac{1}{2}$ m v^2 = 0.5*0.35*1066.01 = 187 J ✓

- The uniform magnetic field of flux density 0.0386 T is indicated.
- The dimensions of the coil are: PQ = SR = 7.00 cm and PS = QR = 5.00 cm
- The coil rotates about the axle as indicated when a torque is applied to the pulley.
- The coil has 400 turns of wire and is rotated at 750 revolutions per minute (rpm).



a) Identify components A and B shown on the diagram, explain their function and explain why they are used rather than a commutator. (3)

The **slip rings** ✓provide a constant electrical contact between the rotating coil which is a source of emf and the external circuit that is powered by the generator. ✓

An emf output alternating between positive and negative is required, so a commutator is not used as it would keep the output all positive (or all negative) ✓ (NB not DC voltage)

b) Mark on the diagram the direction of current along PQ and SR as the coil rotates from the position shown and explain briefly how you arrived at your answer. (2)

As per diagram P to Q and R to S ✓

By Lenz's law as the coil rotates from a position of maximum flux contained flux is being lost. Current will be induced to flow in such a way that its flux will replace the loss.✓

Or by right hand palm rule. Positive charge in PQ moving down in the field experiences a push to the right. ✓

c) Calculate the

magnitude of the average induced emf from the AC generator by considering one quarter of a rotation from the position shown. (4)

$N = 400 \quad \Phi_2 = 0$

$\Phi_1 = B.A = 0.0386 \times 0.07 \times 0.05 = 1.351 \times 10^{-4}$ Wb ✓

$f = 750 / 60 = 12.5$ Hz $\quad T = 1 / f = 1/12.5 = 0.08$ s

Time for $\frac{1}{4}$ turn = 0.08 / 4 = 0.02 s ✓

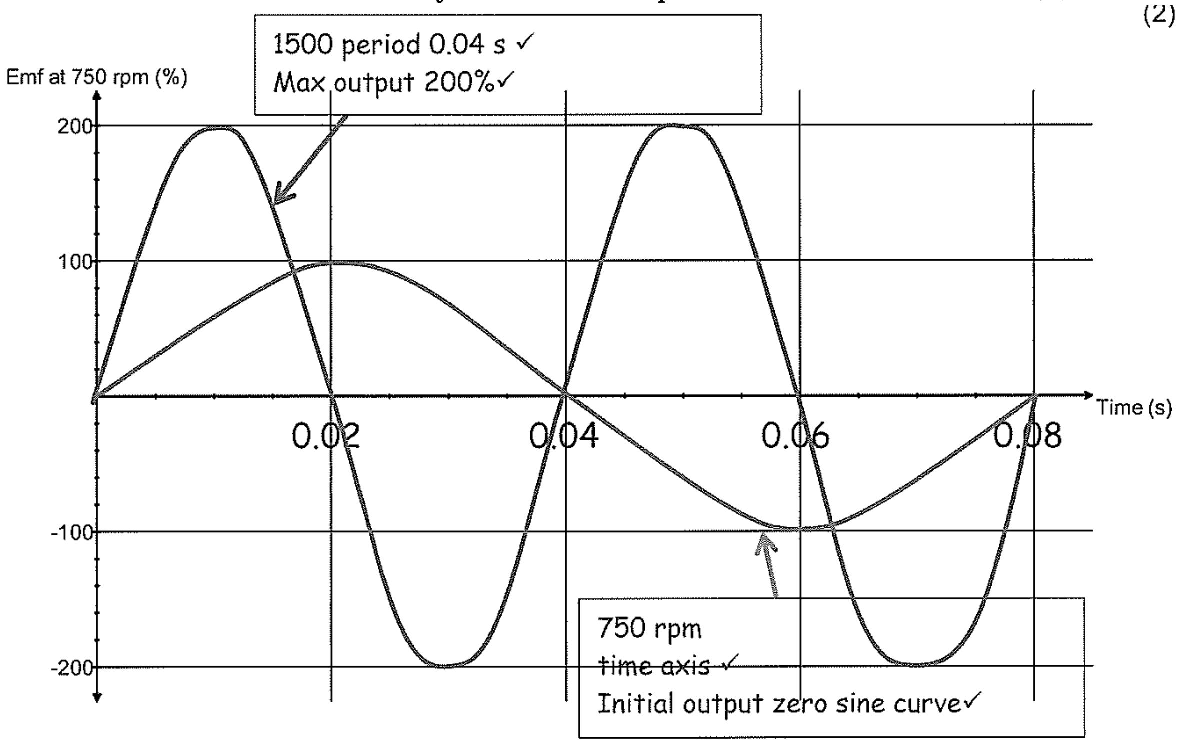
$$emf = -N\frac{\phi_2 - \phi_1}{t}$$

$$emf = -400\frac{0 - 1.351\times10^{-4}}{0.02} \quad ✓$$

emf = 2.70 V ✓

d) On the axes shown below, sketch the shape of the emf output for this generator as it rotates one full turn from the initial position shown. Put in a suitable numerical time scale on the time axis and label your curve '750 rpm'. (2)

(2)



e) Sketch a second shape of the emf output for a rate of rotation of 1500 rpm and label this curve '1500 rpm'. (2)

19. The orbit of Venus lies between the Earth's orbit and the Sun. The radius of Venus is 6.05×10^6 m. The Magellan spacecraft was launched by NASA in 1995 for the purpose of radar mapping Venus. At one stage Magellan was put into a circular orbit of Venus at an altitude of 346 km. It took Magellan 94 minutes to complete this orbit. Magellan had a mass of 1035 kg.

a) Calculate the centripetal acceleration of the Magellan satellite in this orbit. (3)

Orbital radius = $6.05 \times 10^6 + 346 \times 10^3 = 6.396 \times 10^6$ m
Orbital period = $94 \times 60 = 5640$ s

$v = 2\pi r / T = (2\pi \times 6.396 \times 10^6) / 5640 = 7125.4$ m/s ✓

$a_{centripetal} = v^2 / r = 7125.4^2 / 6.396 \times 10^6$ ✓

$a_{centripetal} = 7.93798 = 7.94$ m s^{-2} towards Venus ✓

(Alternatively $a = 4\pi^2 r / T^2$)

b) Calculate the mass of the planet Venus using the satellite data provided. (3)

$a_{centripetal} = 7.93798$ m s^{-2}
Orbital radius = $6.05 \times 10^6 + 346 \times 10^3 = 6.396 \times 10^6$ m
Orbital period = $94 \times 60 = 5640$ s

$a_{centripetal} = v^2 / r$ = gravitational field strength = GM / r^2
$7.93798 = G M / (6.396 \times 10^6)^2$ ✓
$M = (7.93798 \times (6.396 \times 10^6)^2)/(6.67 \times 10^{-11})$ ✓
$M = 4.87 \times 10^{24}$ kg ✓

Alternatively
derive $r^3 = (G.M.T^2)/ 4\pi^2$
$M = (r^3 \times 4\pi^2) / (6.67 \times 10^{-11} \times T^2)$

c) If the Magellan spacecraft was double the mass in this orbit explain how its orbital period would be affected. (2)

$a_{centripetal} = v^2 / r$ = gravitational field strength = GM / r^2

It can be shown that $v_{satellite} = \sqrt{(G M / r)}$ where M is the mass of the host planet. ✓

Therefore, the mass of the satellite has no effect on the period. ✓

d) There is a location between the Earth and the Sun where the net gravitational field strength due to the Earth and the Sun is zero. Calculate the distance from Earth to this location. (3)

Earth-Sun distance = 1.50 $\times 10^{11}$ m;
Let distance from Earth to this location be x, then distance Sun to this location = (1.50 $\times 10^{11}$ -x) m ✓
Magnitude of gravitational field strength is equal at this location

$$\frac{GM_{Sun}}{r_{Sun}^{2}}=\frac{GM_{Earth}}{r_{Earth}^{2}} ✓ \therefore \frac{M_{Sun}}{M_{Earth}}=\frac{r_{Sun}^{2}}{r_{Earth}^{2}}=\frac{\left(1.5\,10^{11}-x\right)^{2}}{x^{2}}=\frac{1.99\,10^{30}}{5.97\,10^{24}}$$

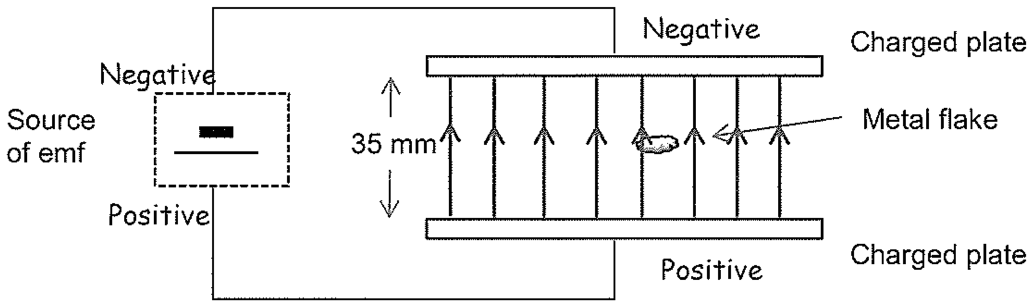
$$\frac{1.5\,10^{11}-x}{x}=\sqrt{\frac{1.99\,10^{30}}{5.97\,10^{24}}}=577.350 \quad ✓$$

$$578.350\,x=1.5\,10^{11};\; x=2.60\,10^{8}\,m \quad ✓$$

20. An uncharged flake of metal is stripped of 9.57 million electrons and fed into the space between two horizontal plates set 35.0 mm apart. The plates are charged by a source of emf that establishes an electric field strength of 6.40×10^{4} N C^{-1} in the space. The metal flake is seen to rise up in the space between the plates.

a) Indicate on the diagram the polarity of the source of emf, the charge polarity on each plate and sketch at least five field lines for the uniform electric field. (2)

Polarities ✓ Field Lines ✓



b) Calculate the magnitude of the potential difference across the parallel plates (2)

E = 6.40 $\times 10^{4}$ N.C^{-1} (V.m^{-1}); d = 0.035 m
E = V/d
V = E $\times$ d = 6.40 $\times 10^{4}$ $\times$ 0.035 = 2240 V ✓✓

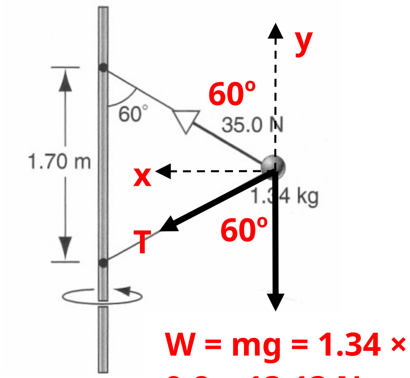
c) Calculate the magnitude of the electric force acting on the metal flake. (2)

q = 9.57 $\times 10^{6}$ $\times$ 1.60 $\times 10^{-19}$ = 1.53 $\times 10^{-12}$ C ✓
E = F/q; $\therefore$ F = E/q

$F = 6.40 \times 10^{4} \times 1.53 \times 10^{-12}$

$F = 9.80 \times 10^{-8}\ N$

21. A 1.34-kg ball is attached to a rigid vertical rod by means of two massless strings each 1.70 m long. The strings are attached to the rod at points 1.70 m apart. The system is rotating about the axis of the rod, both strings being taut and forming an equilateral triangle with the rod, as shown in the figure. The tension in the upper string is 35.0 N. Calculate the tension in the lower string, the net force on the ball and the speed of the ball at the instant shown.



W = mg = 1.34 × 9.8 = 13.13 N

For vertical force equilibrium:

$$\sum F_y = 0$$

$$35\cos 60\ T\cos 60\ 13.13 = 0$$

$$T\cos 60 = 35\cos 60\ 13.13 = 4.368 \checkmark\checkmark$$

$$T = \frac{4.368}{\cos 60} = 8.736\ N\ 8.74\ N$$

The net force on the ball is the centripetal force

$$Net\ Force = F_{net} = \sum F_x = 35\sin 60 + T\sin 60¿\ 35\sin 60 + 8.736\sin 60 = 37.87648706\ N\ 37.9\ N \checkmark$$

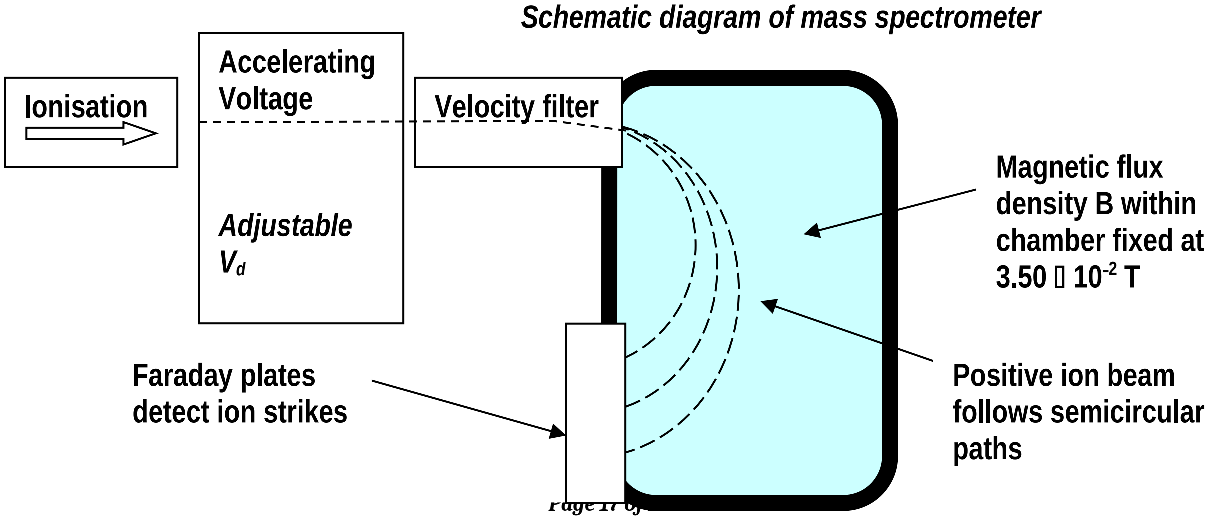
$$Using\ F_{net} = \frac{m v^2}{r}\ v = \sqrt{\frac{r \times F_{net}}{m}} = \sqrt{\frac{1.7\sin 60 \times 37.87648706}{1.34}} = 6.45\ m.s^{1} \checkmark\checkmark$$

22. **Using a mass spectrometer for a crime scene investigation.**

Australian Federal Police have isolated an element found at a crime scene. They think the element may be sodium or potassium so have asked the forensic laboratory to run tests on the element to identify it. The laboratory is able to ionise the element to give it a single positive charge. They then accelerate the ions through a potential difference (V_d) and by use of a velocity filter are able to send ions that have reached their maximum kinetic energy into a mass spectrometer. When the ions enter the mass spectrometer they are acted on by a uniform magnetic field and follow a semi -circular path.

Technicians conduct a series of tests and measure the radius of circular motion for different values of potential difference used to accelerate the charged ions.

Schematic diagram of mass spectrometer



The table below shows the results obtained when the magnetic flux density B in the mass spectrometer was fixed at 3.50×10^{-2} T. Measurements of radius have been expressed with an uncertainty of ±5% and radius squared with an uncertainty ±10%.

Potential difference V_d (volts)	Radius of circular path (metres)	Radius squared (metres squared)
200	0.270 ± 0.014	0.073 ± 0.007
400	0.370 ± 0.019	**0.137 ±0.014**
600	0.490 ± 0.025	**0.240 ±0.024**
800	0.530 ± 0.053	**0.281 ±0.028**
1000	0.620 ± 0.027	**0.384 ±0.038**
1200	0.670 ± 0.034	0.449 ± 0.045

Mass of a potassium K^+ ion = 6.49×10^{-26} kg
Mass of sodium Na^+ ion = 3.82×10^{-26} kg

It can be shown that the radius ***r*** of circular motion for an ion of mass ***m*** and charge ***q***, entering the mass spectrometer at speed ***v*** and being deflected by a magnetic field of flux density ***B*** is as follows: $r=$¿

$$r=\frac{m.v}{q.B}$$

Answer the following questions

a) Use the equation $r=\frac{m.v}{q.B}$ and other equations on the formulae and constant sheet that link the kinetic energy in (joules) attained by a mass of charge **q** (coulombs) in a potential difference $\mathbf{V_d}$ (volts) and derive the following expression:

(3)

$$r^2=\frac{2.m}{q.B^2}.V_d$$

$$r=\frac{m.v}{q.B} \qquad r^2=\frac{m^2.v^2}{q^2.B^2} \checkmark$$

For a charge of mass m, $work\ done = \Delta KE = V.q$

If accelerated from rest, $\frac{1}{2}mv^2 = V_d.q$ so, $V_d=\frac{mv^2}{2q}$ ✓

$$r^2=\frac{m^2.v^2}{q^2.B^2}=\frac{2m.}{q.B^2}\times\frac{mv^2}{2q}=\frac{2.m}{q.B^2}.V_d \checkmark$$

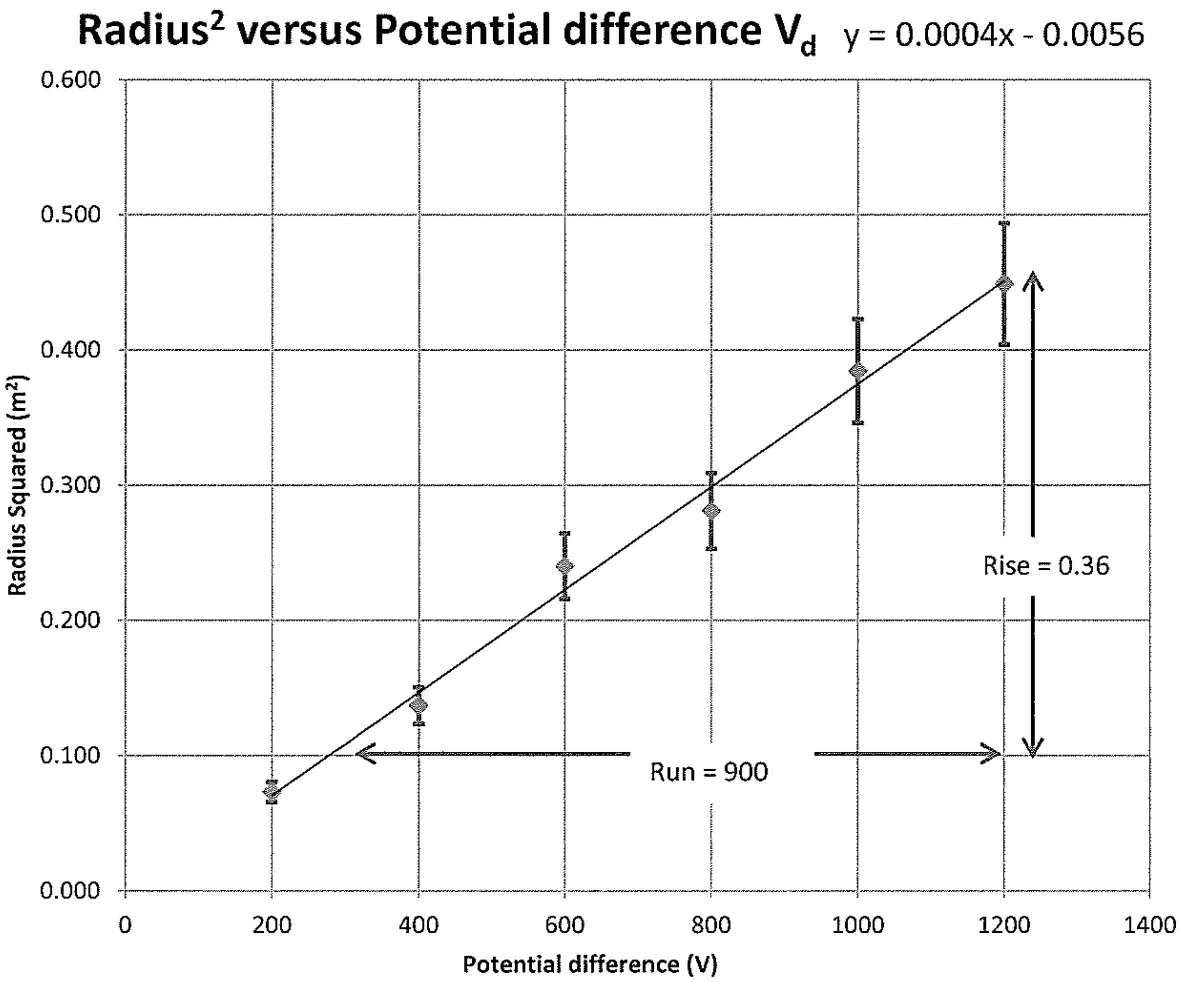
The equation follows the format y = **mx + c** for values of r2 plotted against Vd

b) Complete the table by filling in the values of radius squared $\mathbf{r^2}$ with the appropriate uncertainty range. Two values have been done for you.

(3)

Values ✓ significant figures ✓ uncertainty format ✓

c) Plot the graph of r^2 (vertical axis) versus **Potential difference V_d** (horizontal axis) on the graph paper next to the table. Include error bars and a line of best fit. (5)



Calculate the gradient of your line of best fit from your graph showing all working. (3)

Rise and Run taken from line of best fit on a big triangle ✓ ✓

Gradient = rise / run = 0.36 / 900 = 4.00×10^{-4} $m^2\ V^{-1}$ ✓

Axes labelled, Axes units labelled ✓

Line of best fit ✓

Error bars ✓

d) Use the value of the gradient that you obtained to calculate the mass of the charged ions. (If you could not obtain a gradient use the numerical value 4.00×10^{-4}) (3)

Gradient = $4.00 \times 10^{-4} = \frac{2.m}{q.B^2}$ ✓

$$m = \frac{4.00 \times 10^{-4} \times q \times B^2}{2}$$

$$m = \frac{4.00 \times 10^{-4} \times 1.60 \times 10^{-19} \times (3.50 \times 10^{-2})^2}{2}$$

✓

m = 3.92×10^{-26} kg ✓

e) Based on the results you have calculated, what is the identity of the charged ion?

(1)

The closest match is sodium ✓