METHODIST
LADIES'
COLLEGE

Methodist Ladies' College
Semester One Examination, 2016

Question/Answer Booklet

PHYSICS
ATAR Year 12

Student Name: SOLUTIONS

Teacher Name: W.R.B. and S.C.D.

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Formulae and Data Booklet

Number of additional answer booklets used (if applicable):	

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of total exam	Your mark
Section One: Short answer			50	54	30	
Section Two: Problem-solving			90	90	50	
Section Three: Comprehension			40	36	20	
				Total	100	

Instructions to candidates

1. The rules for the conduct of ATAR course examinations are detailed in the 2016 Year 12 Information Handbook. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to **three** significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and to follow any instruction that are specific to a particular questions.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the questions that you are continuing to answer at the top of the page.

6. The Formulae and Data Booklet is to be handed in with your Question/Answer Booklet.

SECTION ONE: Short Response **54 marks (30%)**

This section has **13** questions. Answer **all** questions. Write your answers in the spaces provided. Suggested working time for this section is **50 minutes.**

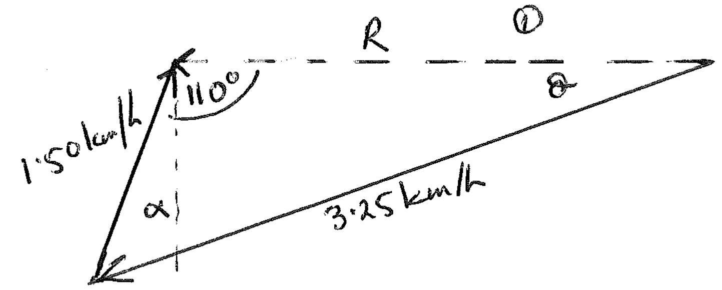
Question 1 **(5 marks)**

A swimmer in the Rottnest Channel Swim is able to swim at 3.25 km/hr through the water. She encounters a current flowing at 1.50 km/hr from a direction 20° west of south.

Given that she needs to swim due west to reach Rottnest, in which direction must she swim in order to have a resultant velocity due west and what is this resultant velocity?

(Draw a vector diagram as part of your answer)

Rottnest Channel Swim Association



Sine Rule $\frac{a}{\sin A} = \frac{b}{\sin B}$ ①

$\therefore \frac{\sin\theta}{1{\cdot}50} = \frac{\sin 110}{3{\cdot}25}$

$\therefore \sin\theta = \frac{1{\cdot}50}{3{\cdot}25}\sin 110^\circ$

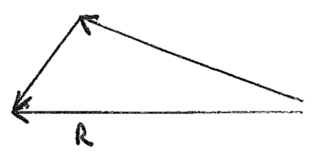
$= 0{\cdot}434$

$\theta = \sin^{-1}(0{\cdot}434)$

$= 25{\cdot}7^\circ$

She swims West 25·7° South

WRONG ANSWER



4 marks max
Getting current
wrong by 180°
$\theta = 25{\cdot}7°$
$R = 3{\cdot}44$

$\frac{R}{\sin\alpha} = \frac{3{\cdot}25}{\sin 110}$ $\therefore R = \frac{3{\cdot}25 \times \sin 44{\cdot}3^\circ}{\sin 110^\circ}$

Resultant Velocity = **2.42 km/h West**

Question 2 **(3 marks)**

The planet Neptune has a radius of 2.27×10^4 km and a mass that is about 17 times that of Earth. Calculate the magnitude of the gravitational field at the surface of the planet Neptune.

$g = \frac{GM}{r^2}$ ①

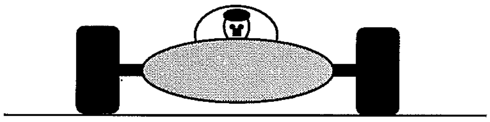
$g_{Neptune} = \frac{6{\cdot}67\times10^{-11} \times M_{Earth} \times 17}{(2{\cdot}27\times10^{7}\,m)^2}$ ①

$= 13{\cdot}1\ m\,s^{-2}$ (or $N\,kg^{-1}$) ①

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 3 **(4 marks)**

Fast racing cars are built like the one illustrated in the diagram.



What two features of this racing car design make it particularly stable?

Explain why these features make the car more stable.

Feature 1: Wide Base (1)

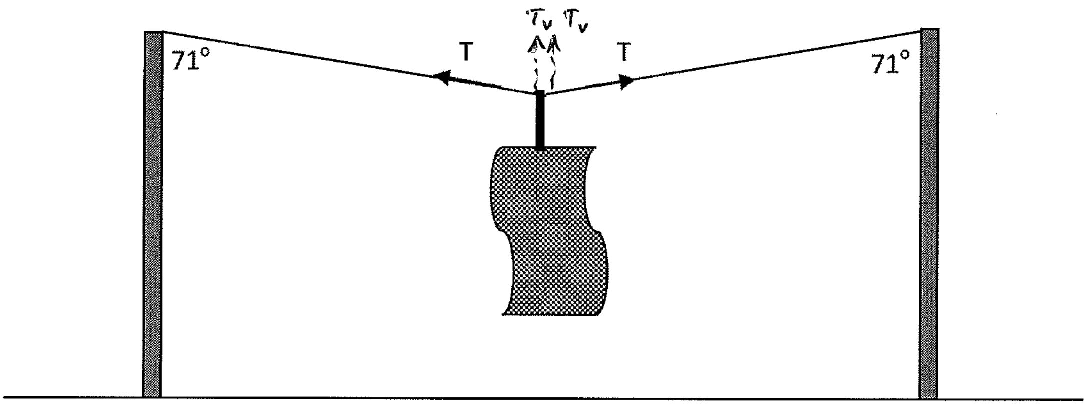
Feature 2: Low Centre of Mass (1)

Any 2 good points (2)

These features mean that a large force will be required to provide the torque to overcome that due to gravity. The wide base increases the distance that the weight force acts from the pivot hence increasing the counter torque needed to be overcome. The low centre of mass means the force acting to tip the car acts over a small distance thus requiring a bigger force. The angle needed to tip the car over also increases.

Question 4 **(4 marks)**

A wet beach towel of mass 0.850 kg is hung from a clothes hanger on a washing line so that the line makes an angle of 71° with each pole.



Calculate the tension T in the washing line

$$\Sigma F_V = 0 \quad (1)$$

$$\therefore \quad 2T_V = W_{TOWEL} \quad (1)$$

$$\therefore \quad 2T\cos 71^\circ = 0.850 \times 9.8 \quad (1)$$

$$\therefore \quad T = \frac{0.850 \times 9.8}{2\cos 71^\circ} = \underline{12.8\,N} \quad (1)$$

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 5 **(5 marks)**

A Perth taxi has a vertical aerial on the back of it with a height of 1.85 m. The taxi is driving westwards along the freeway at a speed of 90.0 km h^{-1} .

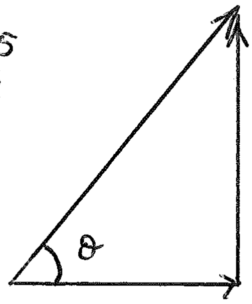
(<u>Useful data</u>: horizontal component of the Earth's field strength is 2.11 x 10^{-5} T and the vertical component of the Earth's field strength is 5.05 x 10^{-5} T)

(a) Draw a diagram of the Earth's magnetic field in Perth indicating the angle of dip and direction of North.

(2 marks)

$\tan\theta = \frac{5.05}{2.11}$

$\theta = 67°$



$B_V = 5.05 \times 10^{-5}$ T upwards

$\longrightarrow$ N

$B_H = 2.11 \times 10^{-5}$ T northwards

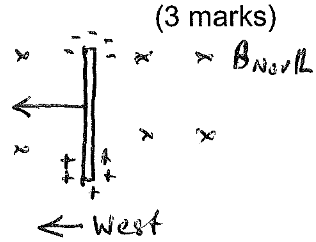
(b) What would be the voltage induced in the aerial and state which end, top or bottom, would be positive?

(3 marks)

$v = 90 \text{ km h}^{-1}$
$= 25 \text{ m s}^{-1}$

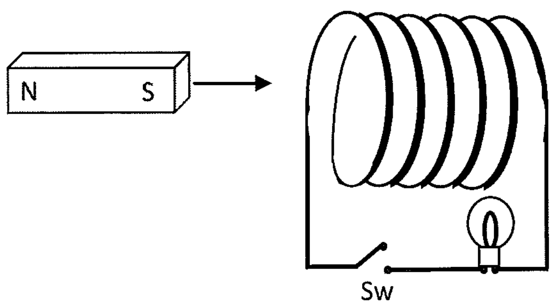
$\mathcal{E} = Blv$ ①
$= 2.11 \times 10^{-5} \times 1.85 \times 25$
$= 9.76 \times 10^{-4}$ V ①

bottom is positive ①



Question 6 **(4 marks)**

A magnet is pushed twice into the coil shown in the diagram. The first time it is pushed in the switch (Sw) is open, as shown and the second time the switch is closed. The force needed to push the magnet into the coil is different in both cases.



Explain why the two forces are different.

When the magnet is pushed into the coil it causes a change in magnetic flux through the coil and induces an emf.
with the switch open, no current flows around the coil ①
and little force is needed to push the magnet. ①
with the switch closed, the emf causes a current to flow in the coil ①, which by Lenz's Law will produce an opposing magnetic field which opposes the change in flux ①
so more force is needed to push the magnet.

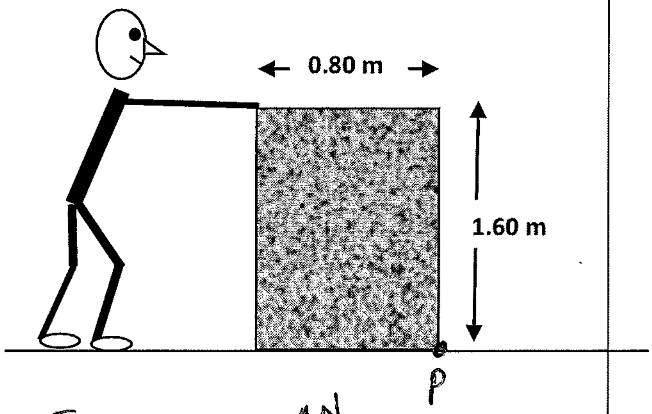
Question 7 **(4 marks)**

A man loading a truck wants to push a packing case over onto its side.

The case has a mass of 250 kg and dimensions of 0.800 m (base) and 1.60 m (height).

What minimum force must the man use if he is to tilt the case so the bottom end nearest to him rises off the ground?

(Assume a horizontal pushing force at the top and high friction at the bottom.)



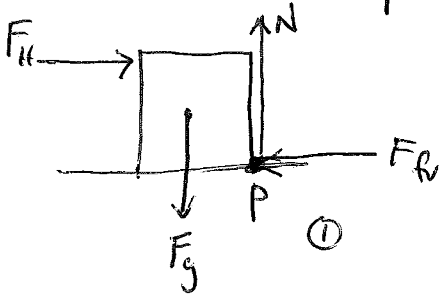
Take moments about P.

$\sum \tau_{cw} = \sum \tau_{acw}$ ①

$\therefore \quad F_H \times 1.60 = F_g \times 0.40$ ①

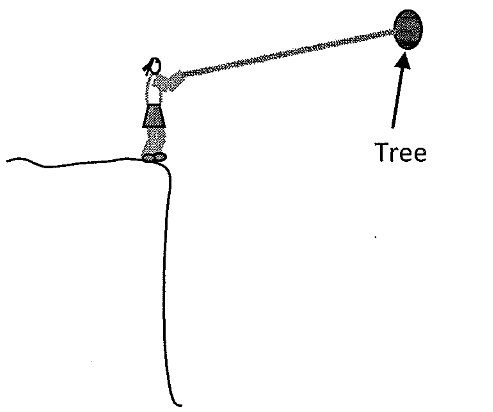
$\therefore \quad F_H = \dfrac{250 \times 9.8 \times 0.40}{1.60}$

$= \underline{612 \text{ N}}$ ①



Question 8 **(4 marks)**

Jane swings from a cliff on a vine rope of length 9.50 m. At the bottom of her swing she has a speed of 8.00 m s^{-1} and can just hold onto the rope. Jane has a mass of 65.0 kg.



(a) Calculate the centripetal force on Jane at the bottom. (2 marks)

① $F_c = \dfrac{mv^2}{r} = \dfrac{65 \times 8^2}{9.50} = \underline{438 \text{ N}}$ ①

(b) Calculate the tension in the rope (and Jane's arms) at the bottom of the swing. (2 marks)

$F_c = T - F_g$ ①

$\therefore \quad T = F_c + F_g$

$= 438 + 65 \times 9.8$

$= 1075 \text{ N}$

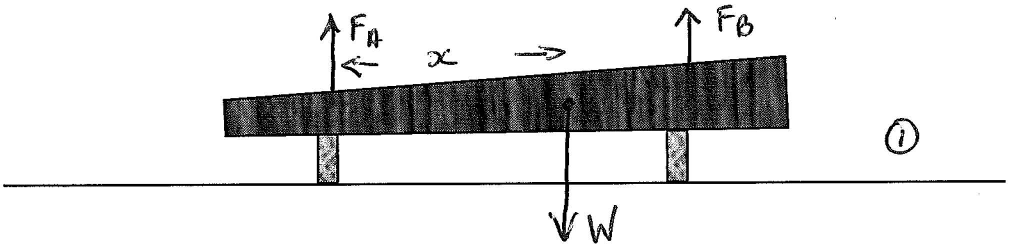
$\simeq \underline{1070 \text{ N}}$ ① (Has to hold ≃ 110 kg!)

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 9 **(4 marks)**

A 5.40 metre long log rests on two bricks, each placed 1.00 m from its ends. The brick at the left end provides an upward force of 620 N while the other brick provides an upward force of 715 N.

How far from the left end of the log is the centre of mass of the log?



Take moments about F_A

$\sum \tau_{cw} = \sum \tau_{acw}$ ①

$\therefore \quad W \times x = F_B \times 3.40$

$\therefore \quad x = \dfrac{715 \times 3.40}{1335}$

$= 1.82\ \text{m}$

$W = F_A + F_B$ ①

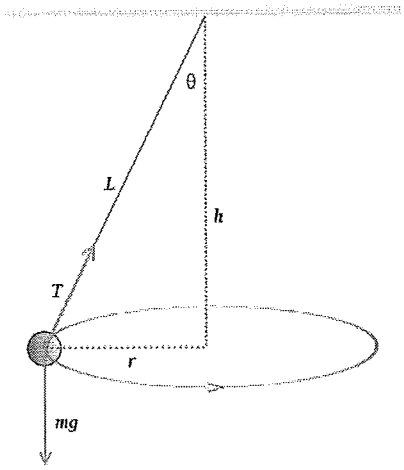
$= 620 + 715$

$= 1335\ \text{N}$

$\therefore$ Centre of mass is $\underline{2.82\ \text{m}}$ from L.H. end. ①

Question 10 **(5 marks)**

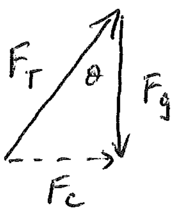
A conical pendulum has a period of 0.50 s and a radius of 50.0 cm. If the mass of the pendulum is 75.0 g then what is the tension in the string?



①

$F_c = \dfrac{mv^2}{r} = 0.075 \times \dfrac{4\pi^2 r}{T^2}$

sub $v = \dfrac{2\pi r}{T}$ ① $= 5.92\ \text{N}$ ①



$F_T^2 = F_c^2 + F_g^2$ ①

$\therefore \quad F_T = \sqrt{5.92^2 + (0.075 \times 9.8)^2}$

$= \sqrt{35.6}$

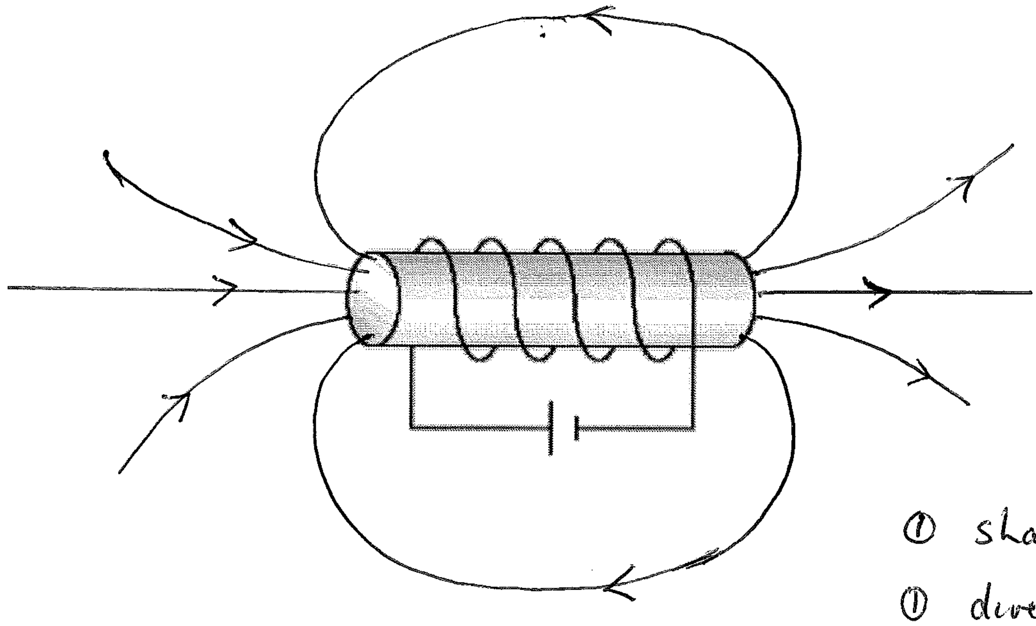
$= \underline{5.97\ \text{N}}$ ①

Question 11 **(4 marks)**

For each of the diagrams below draw field lines to illustrate the direction, strength and shape of the magnetic fields around the current carrying conductors.

(a) A solenoid

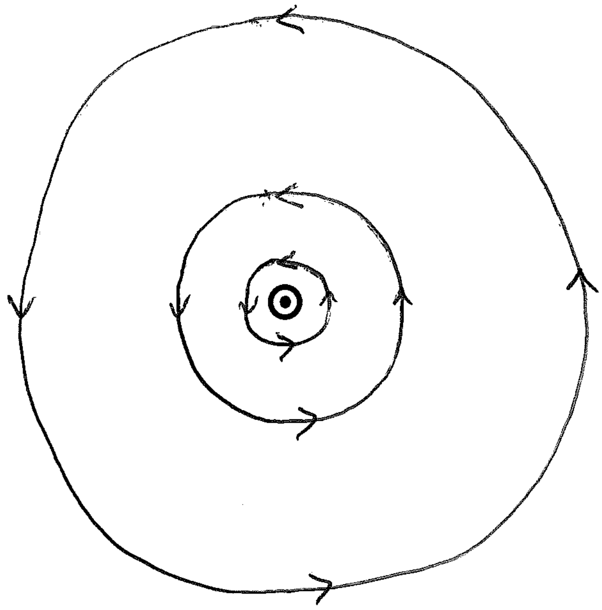
(2marks)



① shape
① direction

(b) A long wire carrying current out of the page

(2marks)

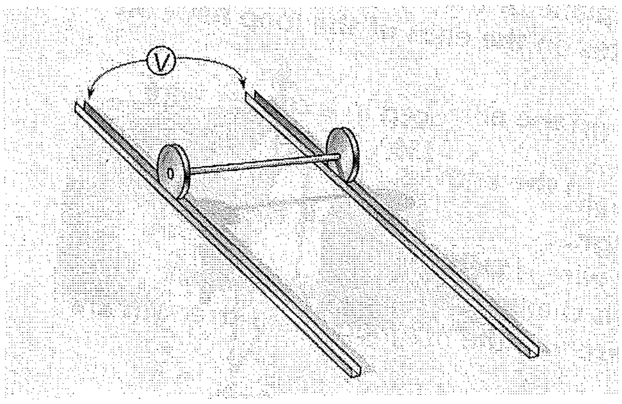


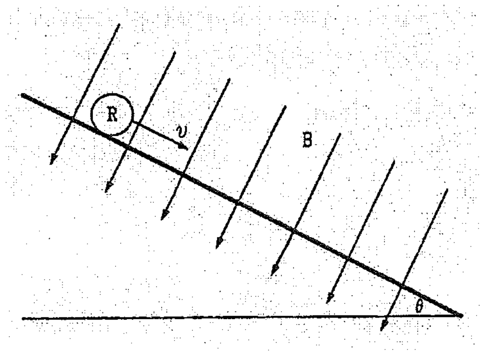
① shape
① direction

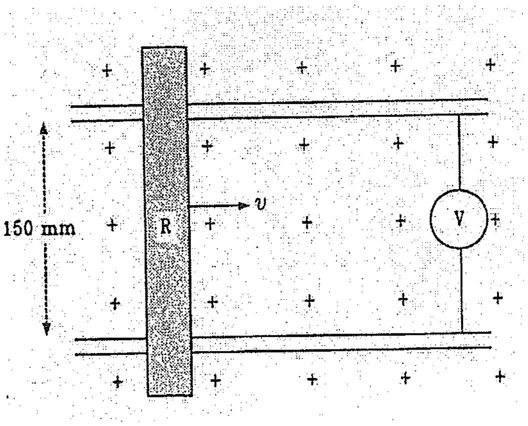
Question 12 **(4 marks)**

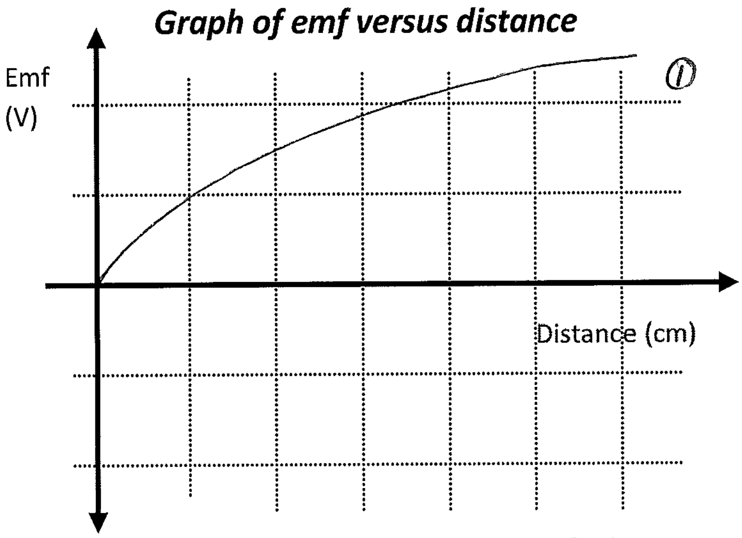
A pair of metal wheels connected to an axle, roll along a sloping section of metal rails as shown:

The axle is 15.0 cm long and there is a magnetic field strength of 5.50×10^{-2} T perpendicular to the plane of the track.









(a) Use the axes above to **sketch** a graph of emf versus distance from the point of release. (You must consider the relationship between emf and distance.) (2 marks)

$v^2 = u^2 + 2as$ but $\mathcal{E} = B\ell v$ $u = 0$

$\therefore \mathcal{E} = \frac{(2as)^{\frac{1}{2}}}{B\ell}$ $\therefore \underline{\mathcal{E} \propto \sqrt{s}}$ ①

(b) At a particular instant, the axle is moving down the rails at a speed of 8.25 m s^{-1}. Determine the voltage generated across the rails. (2 marks)

$\mathcal{E} = B\ell v$ ①

$= 5.50 \times 10^{-2} \times 15 \times 10^{-2} \times 8.25$

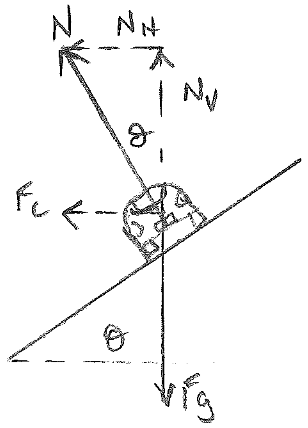
$= 0.0681$ V ①

Question 13 **(4 marks)**

An engineer wants to design the banking for a curved section of road in the Victorian mountains that is often covered in ice.

Calculate the banking angle that will allow a car to go round the bend safely on ice, without the need for friction from the tyres. You must draw a free body diagram showing all forces acting on the car for the banked curve situation.

Use the following data: Mass of car = 1200 kg, Radius of curve = 80 m,
Maximum speed of car = 72 km h^{-1}.



① $F_c = N_H \quad F_g = N_V$

$\tan\theta = \frac{F_c}{F_g} = \frac{\frac{mv^2}{r}}{mg} = \frac{v^2}{rg}$ ①

$\therefore \tan\theta = \frac{20^2}{80 \times 9.8} = 0.510$ ①

$\therefore \theta = \tan^{-1}(0.510)$
$= 27.0°$

$V_c = 72 \text{ km h}^{-1}$
$= 20 \text{ m s}^{-1}$

End of Section One

SECTION TWO: Problem-solving

90 marks (50%)

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the questions that you are continuing to answer at the top of the page.

Suggested working time: 90 minutes

Question 14 **(13 marks)**

(a) During netball practice a ball is thrown horizontally to a teammate 2.50 m away with a velocity of 9.00 m s^{-1}. If the ball is thrown from a point 1.50 m above the ground, how far above ground level would the ball be when her teammate catches it? (Ignore air resistance)

(4 marks)

$u_H = 9.00\ m\,s^{-1}$

$h = 1.50\ m$

$S_H = 2.50\ m$

$S_H = u_H t$ ①

$\therefore t = \frac{S_H}{u_H} = \frac{2.50}{9.00} = 0.278\ s$

$S_V = u_V t + \frac{1}{2} a_V t^2$ ① ↓ +ve

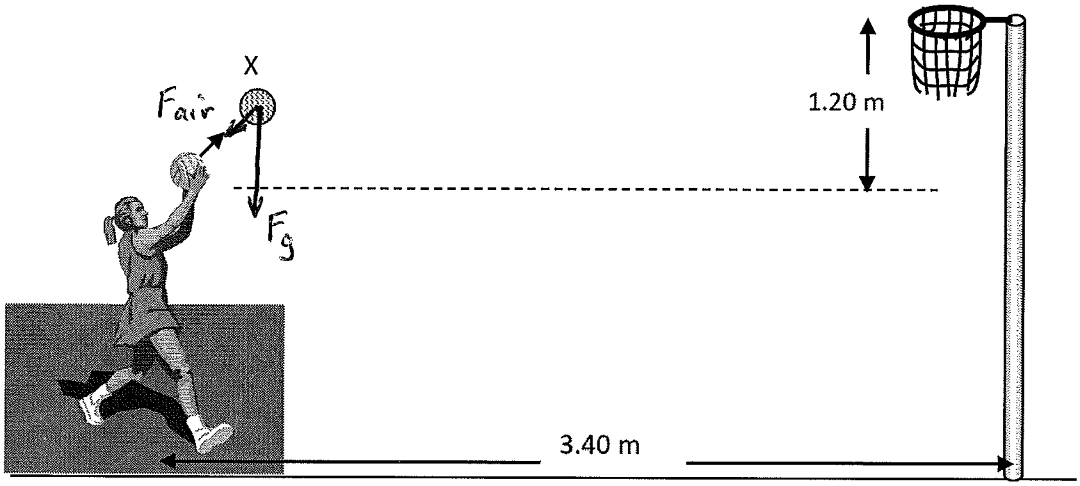
$\therefore S_V = 0 + \frac{1}{2} \times 9.8 \times (0.278)^2$

$= 0.378\ m$ ①

$\therefore h_2 = 1.50 - 0.378$

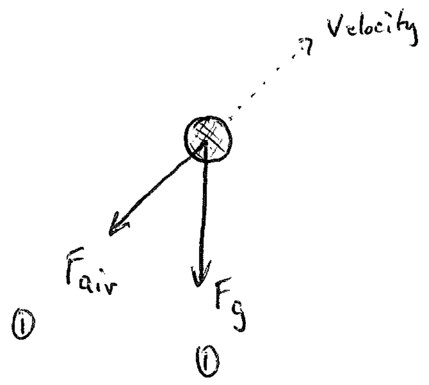
$= \underline{1.12\ m}$ ①

(b) During a game a netball player shoots in an attempt to put her team in the lead. The ball travels from her hands through the hoop and without touching the ring lands on the floor.



(a) Draw and label all the forces on the ball at point X, just after it has been thrown.

(2 marks)



F_{air} = air resistance force

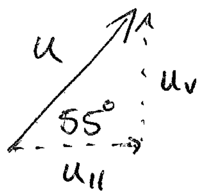
F_g = weight force.

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) The diagram above shows the ball being thrown at an angle of 55.0° above the horizontal towards the basket 3.40 m in front of the player and 1.20 m above her.

If the ball goes into the basket on its way down, at what speed did the ball leave the thrower's hands? (Ignore air resistance)

(5 marks)



$u_V = u\sin\theta$ (1)

$u_H = u\cos\theta$

$\theta = 55°$

$S_V = 1.20\text{m}$

$S_H = 3.40\text{m}$

$S_H = u_H t$ (1)

$\therefore t = \frac{S_H}{u_H} = \frac{S_H}{u\cos\theta}$

$S_V = u_V t + \frac{1}{2}a_V t^2$ (1) ↑ +ve

$\therefore S_V = u_V\left(\frac{S_H}{u\cos\theta}\right) - 4.9\left(\frac{S_H}{u\cos\theta}\right)^2$

$\therefore S_V = S_H\tan\theta - \frac{4.9\ S_H^2}{u^2\cos^2\theta}$

$\therefore 1.20 = 3.40\tan 55° - \frac{4.9\times(3.4)^2}{u^2\cos^2 55°}$ (1)

$\therefore \frac{4.9\times 3.4^2}{u^2\cos^2 55°} = 3.40\tan 55° - 1.20 = 3.66$ (1)

$\therefore u^2 = \frac{4.9\times 3.4^2}{\cos^2 55°\times 3.66} = 47.1 \quad \therefore u = \underline{6.86\text{ms}^{-1}}$

(d) The standard mass of a netball for competitions is 450 g but one of the opposing team has another type of netball that is the same size but has a larger mass of 600 g. If both balls are thrown horizontally at exactly the same speed the 600 g ball travels further. Explain why this is?

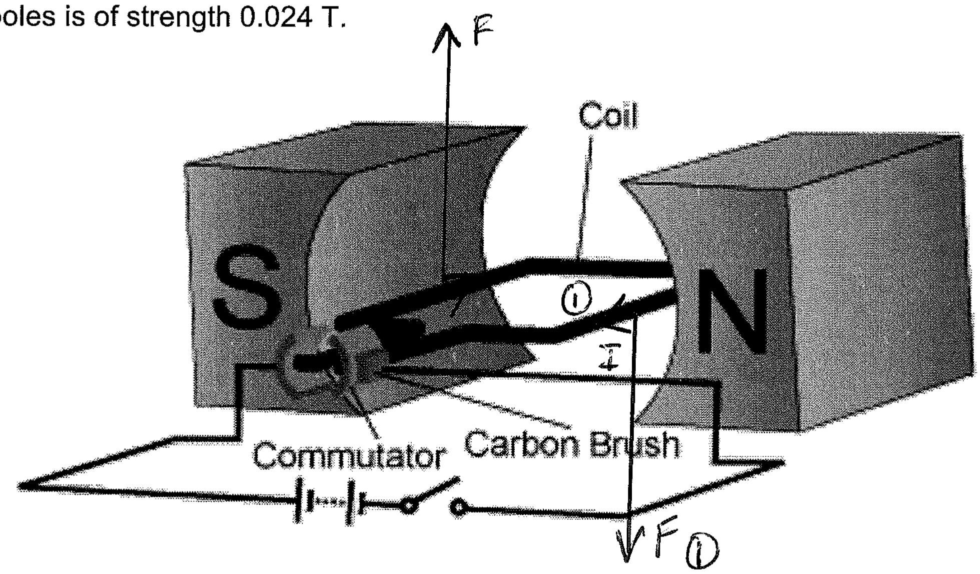
(2 marks)

Air resistance depends on shape, surface area and velocity and none of these are changing so the air resistance on both balls is the same. (1)

The heavier ball has more inertia (mass) and so will decelerate more slowly, $a = F/m$, and so will travel farther. (1)

Question 15 **(10 marks)**

A DC electric motor is shown in the diagram below. The coil has 250 turns of wire and is a rectangle with sides of length 8.00 cm and width of 5.00 cm. The magnetic field in the region between the magnetic poles is of strength 0.024 T.



Direct Current Motor

(a) Use arrows in the diagram above to show the direction of current flow around the coil and the direction of the magnetic forces acting on the sides of the coil when the switch is closed.

See Diagram ① Correct right hand palm rule. (2 marks)

① correct current direction

(b) When the switch is closed a current of 9.50 A initially flows through the coil. Calculate the size of the magnetic force on each side of the coil, and the size of the torque acting on the coil, when the switch is first closed.

(4 marks)

$F = NBIl$ ①

$= 250 \times 0.024 \times 9.50 \times 8.00 \times 10^{-2}$ ①

$= 4.56\ N$

$\tau = BAIN$ ① or $\tau = 2rF$

$= 0.024 \times 8.00 \times 10^{-2} \times 5.00 \times 10^{-2} \times 9.50 \times 250$

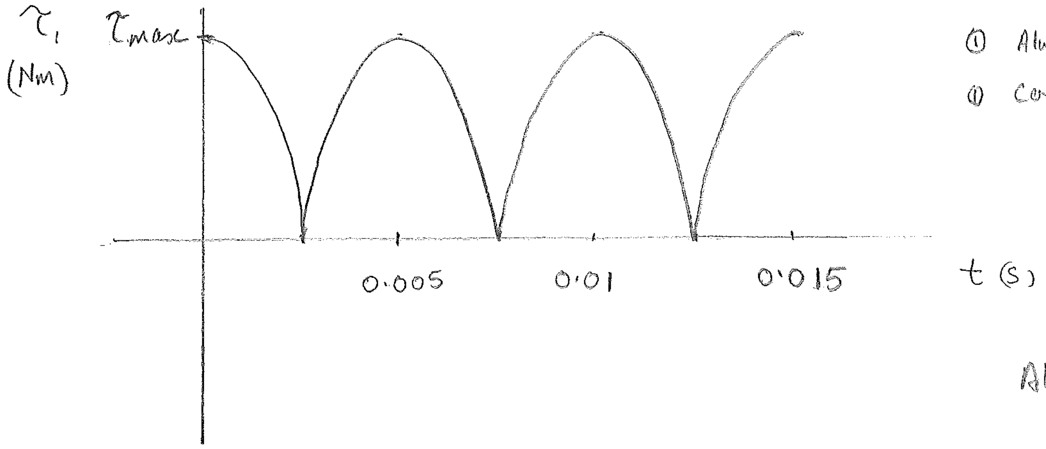
$= 4.56N \times 5 \times 10^{-2} m$

$= 0.228\ Nm$ ①

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) Sketch a graph of torque versus time when the motor is spinning at 100 Hz.
Put a scale on each axis and briefly explain why the motor increases in speed but eventually reaches a top speed.

(4 marks)



① Always positive/shape
① Correct scales

Allow flatter steeper curve due to curved magnets.

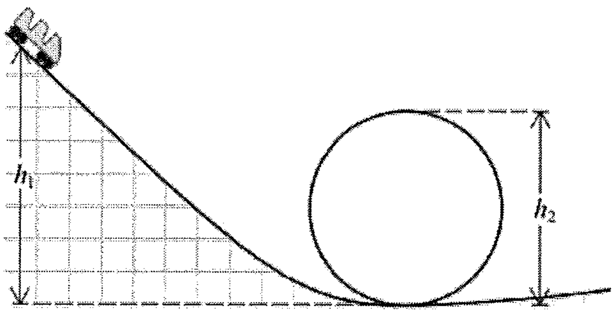
The torque provides a turning force which accelerates the coil speeding it up. ①
As the motor turns the coil is a conductor moving in a magnetic field so creates an emf against the applied current reducing this until it reaches a point where all the forces balance and so remains at a constant speed. ①

OR Lenz's law states that a moving conductor will produce a flux to oppose the change (motion) that causes it when moving through a magnetic field which results in a velocity where all the forces balance. ①

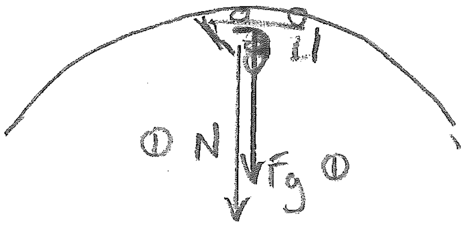
DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 16 **(10 marks)**

A roller coaster carriage passes upside down through a vertical loop of **radius** 6.00 m. The speed of the carriage at the top of the loop is 36.0 km hr^{-1}. A 55.0 kg girl sits in the carriage.



(a) Draw a sketch showing the forces acting on the girl as the carriage passes through the top of the loop. (2 marks)



(b) Calculate the resultant force on the girl as the carriage passes through the top of the loop. (2 marks)

$V = 36.0 \text{ km h}^{-1}$
$= 10 \text{ m s}^{-1}$

$$F_{net} = F_c = \frac{mv^2}{r} \quad ①$$
$$= \frac{55 \times 10^2}{6}$$
$$= 917 \text{ N} \quad ①$$

(c) Calculate the magnitude of the reaction force of the seat on the girl as the carriage passes through the top of the loop.

(3 marks)

$F_c = N + F_g$ ①

$\therefore N = F_c - F_g$

$= 917 - 55 \times 9.8$ ①

$= \underline{378 \text{ N}}$ ①

(d) At what minimum speed can the carriage pass through the top of the loop so that the girl would momentarily feel weightless?

(3 marks)

At Minimum Speed $F_c = F_g$ as $N = 0$ ①

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

$\therefore v = \sqrt{rg}$ ①

$= \sqrt{6 \times 9.8}$

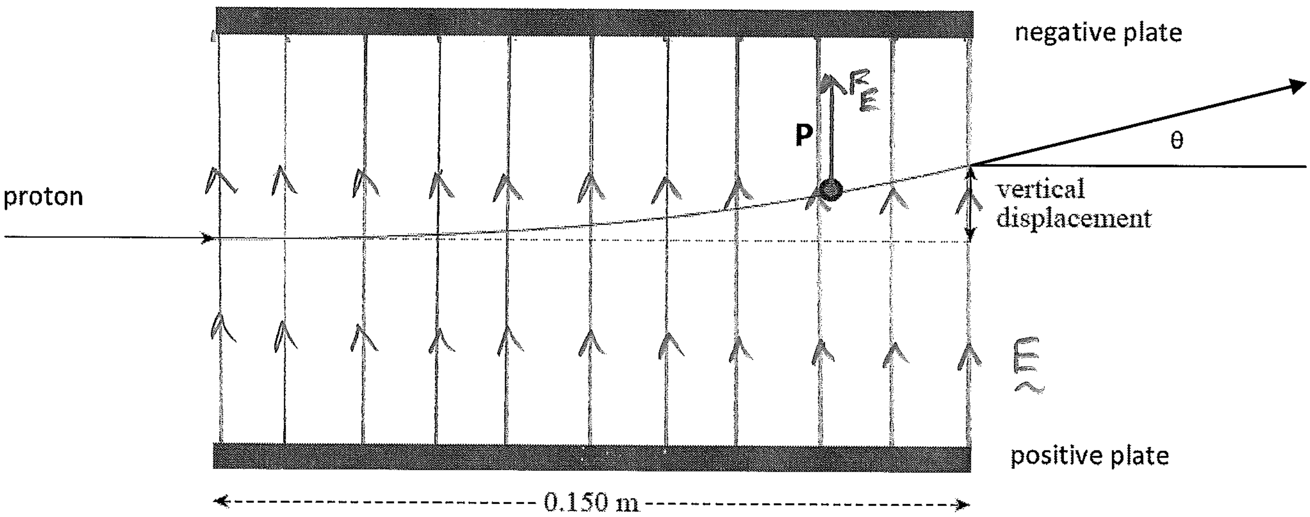
$= \underline{7.67} \text{ m s}^{-1}$ ①

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 17 **(18 marks)**

A proton is fired horizontally into a uniform electric field in the vacuum between two oppositely charged parallel conducting plates, as shown in the diagram below. The proton enters the field halfway between the plates, with a speed of 1.25×10^6 m s^{-1}. The plates are 0.120 m long, and the uniform electric field has a magnitude of 5.00×10^4 V m^{-1}.

Ignore end effects and the effect of gravity



[*This diagram is not drawn to scale.*]

use either 0.120 m or 0.150 m.

(a) (i) Draw the electric field between the plates and indicate the direction of the force on the proton at point P. (3 marks)

E = uniform, parallel lines ①, correct direction ①, Force shown ①

(ii) If the distance between the plates is 8.00 cm then what is the potential difference, V_p, between the plates? (2 marks)

$$E = \frac{V}{d} \quad ①$$

$$\therefore 5.00 \times 10^4 \text{ Vm}^{-1} = \frac{V_p}{8.00 \times 10^{-2} \text{ m}}$$

$$\therefore V_p = 5 \times 10^4 \times 8 \times 10^{-2} = 4000 \text{ V} \quad ①$$

(b) How long does the proton spend between the parallel plates? (2 marks)

Can use 0.150 m

$\therefore t = 120$ ns

$$u_H = \frac{s}{t} \quad ①$$

$$\therefore t = \frac{s}{u_H} = \frac{0.120 \text{ m}}{1.25 \times 10^6 \text{ ms}^{-1}} = 9.6 \times 10^{-8} \text{ s} \quad ①$$

$$= 96 \text{ ns}$$

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) Show that the magnitude of the vertical acceleration, a, of the proton in the region between the plates is 4.79×10^{12} m s^{-2}.

(2 marks)

$F = ma$ ① $\quad E = \frac{F}{q} \therefore F = Eq$

$\therefore a = \frac{F}{m} = \frac{Eq}{m} = \frac{5\times10^{4}\times1.6\times10^{-19}}{1.67\times10^{-27}}$ ①

$= \underline{4.79\times10^{12}\ ms^{-2}}$

(d) What is the final vertical velocity and displacement of the proton on leaving the parallel plates?

(4 marks)

$V = u + at$ ①

$\therefore V_V = u_V + at$

$= 0 + 4.79\times10^{12}\times9.6\times10^{-8}$

$= \underline{4.60\times10^{5}\ ms^{-1}}$ ①

$S_V = u_V t + \frac{1}{2}a_V t^2$ ①

$= 0 + \frac{1}{2}\times4.79\times10^{12}\times(9.6\times10^{-8})^2$

$= 0.0221$ m

$= \underline{2.21\text{ cm}}$ ①

if use $t = 1.20$ ns

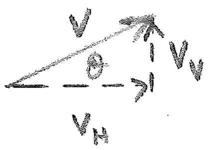
$V_V = \underline{5.75\times10^{5}\ m/s}$

$S_V = 0.0345$ m

$= \underline{3.45\text{ cm}}$

(e) Hence at what angle does it leave the plates?

(2 marks)



$\tan\theta = \frac{V_V}{V_H} = \frac{4.60\times10^{5}}{1.25\times10^{6}} = 0.368$ ① $\quad (0.460)$

$\therefore \theta = \tan^{-1}(0.368) = \underline{20.2^{\circ}}$ ① $\quad (24.7^{\circ})$

(f) If the proton was initially accelerated to its horizontal velocity by vertical parallel plates with a potential difference of V_v then what potential difference, V_v, was needed?

(3 marks)

$\Delta E_k = W = qV$ ①

$\therefore \frac{1}{2}mv^2 = qV \quad$ assume $u \simeq 0$

$\therefore V = \frac{\frac{1}{2}mv^2}{q}$ ① $= \frac{0.5\times1.67\times10^{-27}\times(1.25\times10^{6})^2}{1.6\times10^{-19}}$

$= \underline{8150\text{ V}}$ ①

Question 18 **(13 marks)**

A uniform ladder of mass 25.0 kg rests against a smooth curved gutter such that the force exerted on the ladder is perpendicular to the ladder and the top of the ladder is 3.00 m vertically above the ground. The ladder makes an angle of 65.0° to the ground and the gutter is 3.00 m vertically above the ground. If a painter climbs the ladder so that they are 2.00 m above the ground then:

of mass 75 kg

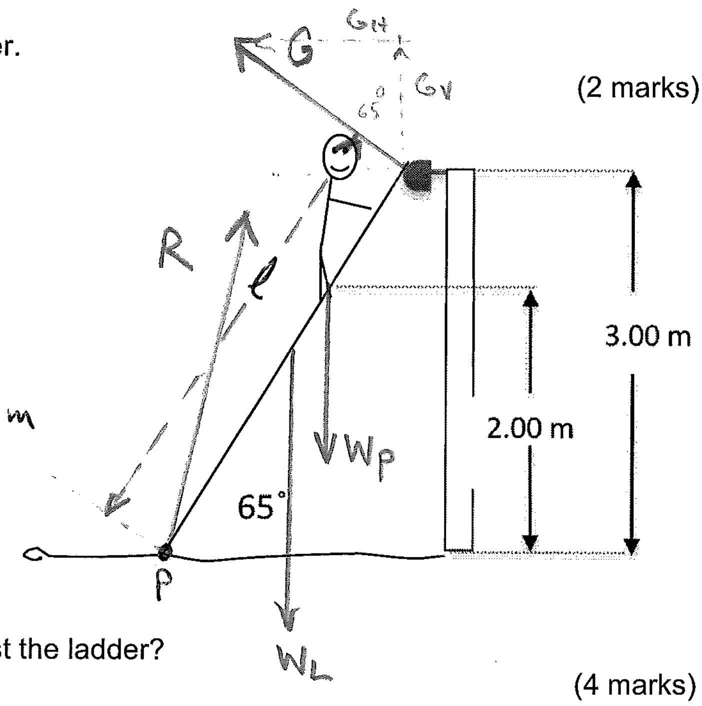
(a) Draw in all the forces acting on the ladder. (2 marks)

3 correct (1)

4 correct (2)

$\sin 65^\circ = \frac{3}{l}$

$\therefore l = \frac{3}{\sin 65^\circ} = 3.31\text{ m}$ (1)



(b) What force does the gutter exert against the ladder? (4 marks)

Take moments about P   Calculate l = (1)

$\Sigma \tau_{acw} = \Sigma \tau_{cw}$ (1)

$\therefore G \times l = W_L \times \frac{1.50}{\sin 65^\circ} \sin 25^\circ + W_p \times \frac{2}{\sin 65^\circ} \sin 25^\circ$ (1)

$\therefore G = \frac{25 \times 9.8 \times 1.5 \sin 25 + 75 \times 9.8 \times 2 \sin 25^\circ}{3.31 (\sin 65)}$

$= \underline{259\text{ N}}$ (1)

If take force horizontally

then $G \times 3 = W_L \times \frac{1.50}{\sin 66^\circ} \sin 25^\circ + W_p \times \frac{2}{\sin 65^\circ} \sin 25^\circ$

$\therefore G = 286\text{ N}$

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) What force does the ground exert on the ladder?

(4 marks)

$\Sigma F_V = 0$

$\therefore \quad R_V + G_V = W_L + W_P$

$\therefore \quad R_V = (25+75) \times 9.8 - 259 \sin 25^\circ$

$= 980 - 109$

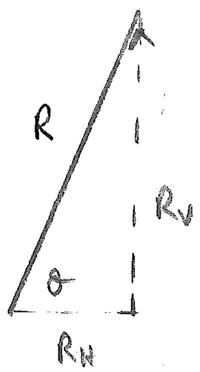
$= 871\,N$ ①

$\Sigma F_H = 0$

$\therefore \quad R_H = G_H = G \cos 25^\circ$

$= 259 \cos 25^\circ$

$= 235\,N$ ①



$R = \sqrt{R_V^2 + R_H^2}$

$= \sqrt{871^2 + 235^2}$

$= 902\,N$ ①

$\tan\theta = \frac{R_V}{R_H} = \frac{871}{235} = 3.71$

$\therefore \theta = \tan^{-1}(3.71) = 74.9^\circ$ ①

$\therefore R = 902\,N$ @ 74.9° above ground towards gutter.

(d) Explain why the ladder is more likely to slip at its base as the ~~woman~~ painter climbs higher.

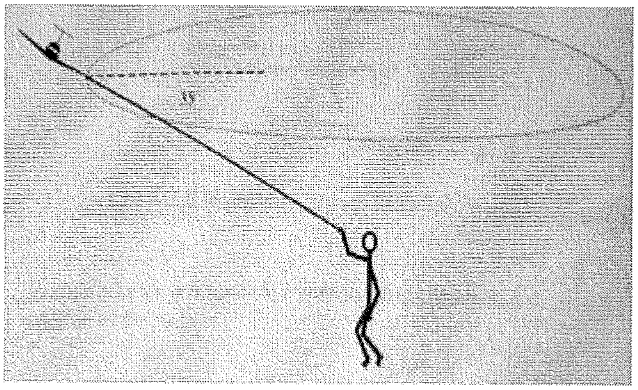
(3 marks)

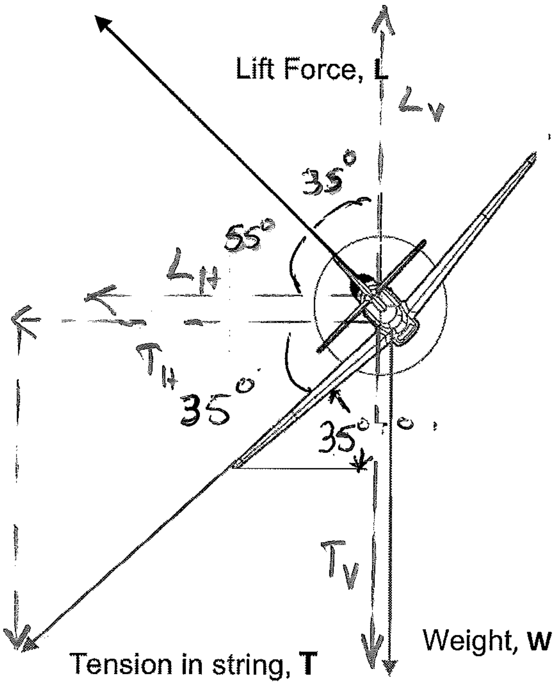
As the woman climbs the ladder the clockwise torque will increase ① and therefore require a greater anticlockwise torque from the gutter. This will result in the ground needing to apply a larger horizontal force to oppose that of the gutter. ① If this force cannot be provided by friction the ladder will slip. ①

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 19 **(13 marks)**

The diagram below shows a person holding a model aeroplane in horizontal circular motion by a nylon line, which is at an angle, **θ**, of 35° to the horizontal.





The forces acting on the aeroplane are shown in more detail on the right hand diagram after the plane rotates through 180°.

(a) On the diagram above, draw vectors to show the horizontal components (L_H) & (T_H) and the vertical components (L_V) & (T_V) of the lift force (L) and tension force (T) respectively acting on the model plane moving with uniform horizontal circular motion.

① each pair (2 marks)

(b) Show that the magnitude of the vertical component (L_V) of the lift force is given by:

$$L_V = mg + T\sin\theta \, .$$

(2 marks)

$T_V = T\sin\theta = T\sin 35°$ opposite side

Weight $= mg$

$\Sigma F_V = 0$ as the plane stays horizontal ①

$\therefore \quad W + T_V = L_V$ ①

$\therefore \quad L_V = mg + T\sin\theta$

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) If the tension in the nylon line is 22.5 N and the lift force perpendicular to the wings of the model aeroplane is 35.0 N then what is the mass of the plane?

(3 marks)

$$L_V = L\cos 35^\circ \quad (1)$$

$$\therefore \quad L\cos 35^\circ = mg + T\sin 35^\circ$$

$$\therefore \quad m = \frac{L\cos 35^\circ - T\sin 35^\circ}{g} \quad (1)$$

$$= \frac{35.0\cos 35^\circ - 22.5\sin 35^\circ}{9.8} = \frac{(28.7 - 12.9)}{9.8}$$

$$= 1.61\ \text{kg}$$

(d) If the maximum tension needed to break the nylon line is 80.0 N and the string remains at an angle of 35.0° then what lift force would be required to break the string for an aeroplane of mass 2.00 kg?

$T_{max} = 80\ \text{N} \qquad L = ?$

(2 marks)

$$L_V = mg + T\sin\theta$$

$$= 2\times 9.8 + 80\sin 35$$

$$= 65.5\ \text{N} \quad (1)$$

$$\therefore \quad L\cos 35^\circ = 65.5\ \text{N}$$

$$\therefore \quad L = 65.5/\cos 35^\circ = 79.9\ \text{N} \quad (1)$$

(e) For the situation described above in (d) determine the maximum speed that the model plane could go around a horizontal radius of 150 m. (Use a lift force of 80 N if no answer from (d) above.)

Hint: Write an expression for the centripetal force in terms of components of the other forces.

(4 marks)

$$F_c = L_H + T_H \quad (1)$$

$$= 79.9\sin 35^\circ + 80\cos 35^\circ$$

$$= 45.9\ \text{N} + 65.5\ \text{N}$$

$$= 111\ \text{N} \quad (1)$$

$$F_c = \frac{mv^2}{r} \quad (1)$$

$$\therefore \quad 111 = \frac{2\times v^2}{150}$$

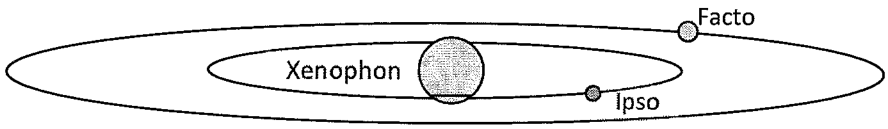
$$\therefore \quad v = \left(\frac{150\times 111}{2}\right)^{\frac{1}{2}} = 28.9\ \text{m s}^{-1} \quad (1)$$

See next page

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 20 **(13 marks)**

Two planets Ipso and Facto rotate in different orbits about a distant star Xenophon.



Data regarding this planetary system are show in the table below.

Planet	Mass (kg)	Radius of planet (m)	Orbital radius (m)	Length of day (s)	Orbital period (s)
Ipso	1.4×10^{26}	6.0×10^{6}	4.3×10^{11}	2.1×10^{5}	5.2×10^{6}
Facto	2.2×10^{27}	8.1×10^{6}	6.5×10^{11}	3.5×10^{5}	

(a) Calculate the value of the gravitational acceleration at the surface of the planet Ipso. (3 marks)

$$g_{Ipso} = \frac{GM}{r^2} \quad (1)$$

$$= \frac{6.67\times10^{-11} \times 1.4\times10^{26}}{(6.0\times10^{6})^2} \quad (1)$$

$$= 259 \text{ m s}^{-2} \quad (1)$$

(b) Calculate the maximum force that Ipso can exert on Facto during their orbits. (3 marks)

$$F = \frac{G M_1 M_2}{r^2} \quad (1)$$

$$d_{min} = 6.5\times10^{11} - 4.3\times10^{11}$$
$$= 2.2\times10^{11} \text{ m} \quad (1)$$

$$= \frac{6.67\times10^{-11} \times 1.4\times10^{26} \times 2.2\times10^{27}}{(2.2\times10^{11})^2}$$

$$= 4.24\times10^{20} \text{ N} \quad (1)$$

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) Calculate the mass of the star Xenophon.

(4 marks)

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2} \quad ①$$

Ipso $$\frac{(4.3\times10^{11})^3}{(5.2\times10^6)^2} = \frac{6.67\times10^{-11}\times M_{XENO}}{4\pi^2} \quad ①$$

$$\therefore \quad M_{XENO} = \frac{4\pi^2\times(4.3\times10^{11})^3}{6.67\times10^{-11}(5.2\times10^6)^2} \quad ①$$

$$= 1.74\times10^{33}\ \text{kg} \quad ①$$

(d) Find the orbital period of Facto around Xenophon missing in the table.

(3 marks)

$$\frac{R_1^3}{T_1^2} = \frac{R_2^3}{T_2^2} \quad ①$$

$$\therefore \quad \frac{(4.3\times10^{11})^3}{(5.2\times10^6)^2} = \frac{(6.5\times10^{11})^3}{T_{Facto}^2}$$

$$\therefore \quad T_{Facto} = \left(\frac{(6.5\times10^{11})^3}{(4.3\times10^{11})^3}\times(5.2\times10^6)^2\right)^{\frac{1}{2}} \quad ①$$

$$= 9.66\times10^6\ \text{s} \quad ①$$

End of Section Two

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

THIS PAGE HAS BEEN LEFT INTENTIONALLY BLANK

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Section Three: Comprehension and data analysis. **20% (36 marks)**

This section contains **two (2)** questions. You should answer **both** questions and show full working. Unless otherwise indicated, all answers should be evaluated to 3 significant figures.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

Write your answers in the spaces provided.

Suggested working time: 40 minutes.

Read each passage carefully and answer all of the questions at the end of each passage. You are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and /or numerical results should be included as appropriate.

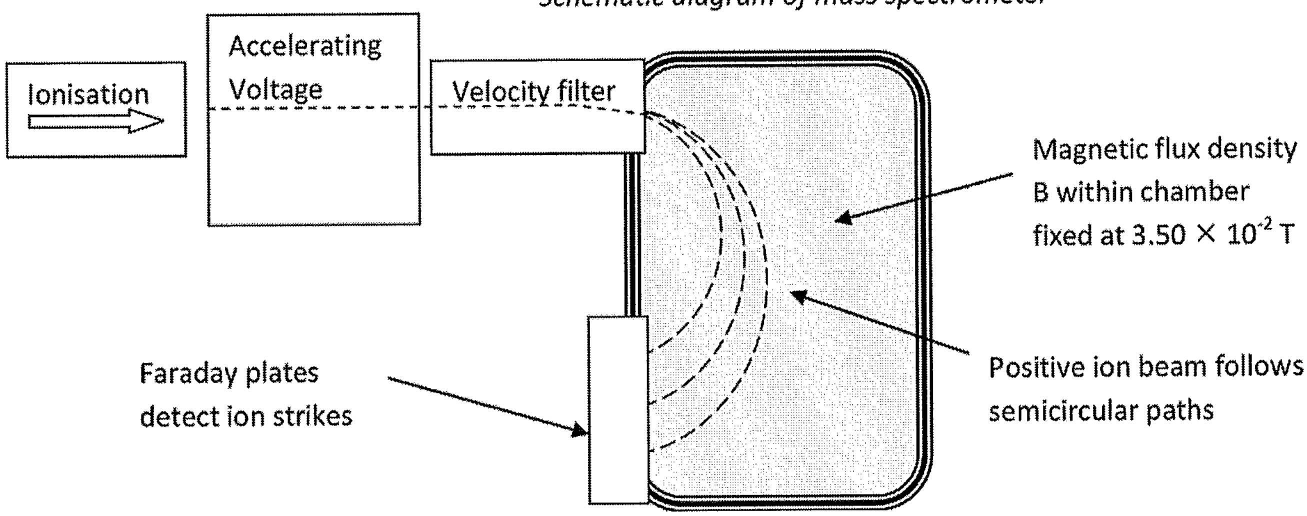
Question 21 **Experimental Analysis and Interpretation** **(18 marks)**

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 x 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

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:

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

Use the following known data to answer the following questions:

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

(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, **m**, of charge **q** (coulombs) in a potential difference **V_d** (volts) to derive the following expression:

$$r^2 = \frac{2.m}{q.B^2}.V_d$$ (3 marks)

$\Delta E_k = W = qV \quad \therefore \frac{1}{2}mv^2 = qV_d$ ①

$\therefore v^2 = \frac{2qV_d}{m}$

but $r^2 = \frac{m^2v^2}{q^2B^2}$ ①

sub for $v^2 \Rightarrow r^2 = \frac{m^{\cancel{2}}\left(\frac{2\cancel{q}V_d}{\cancel{m}}\right)}{q^{\cancel{2}}B^2}$ ①

$\therefore r^2 = \frac{2mV_d}{qB^2}$ Q.E.D

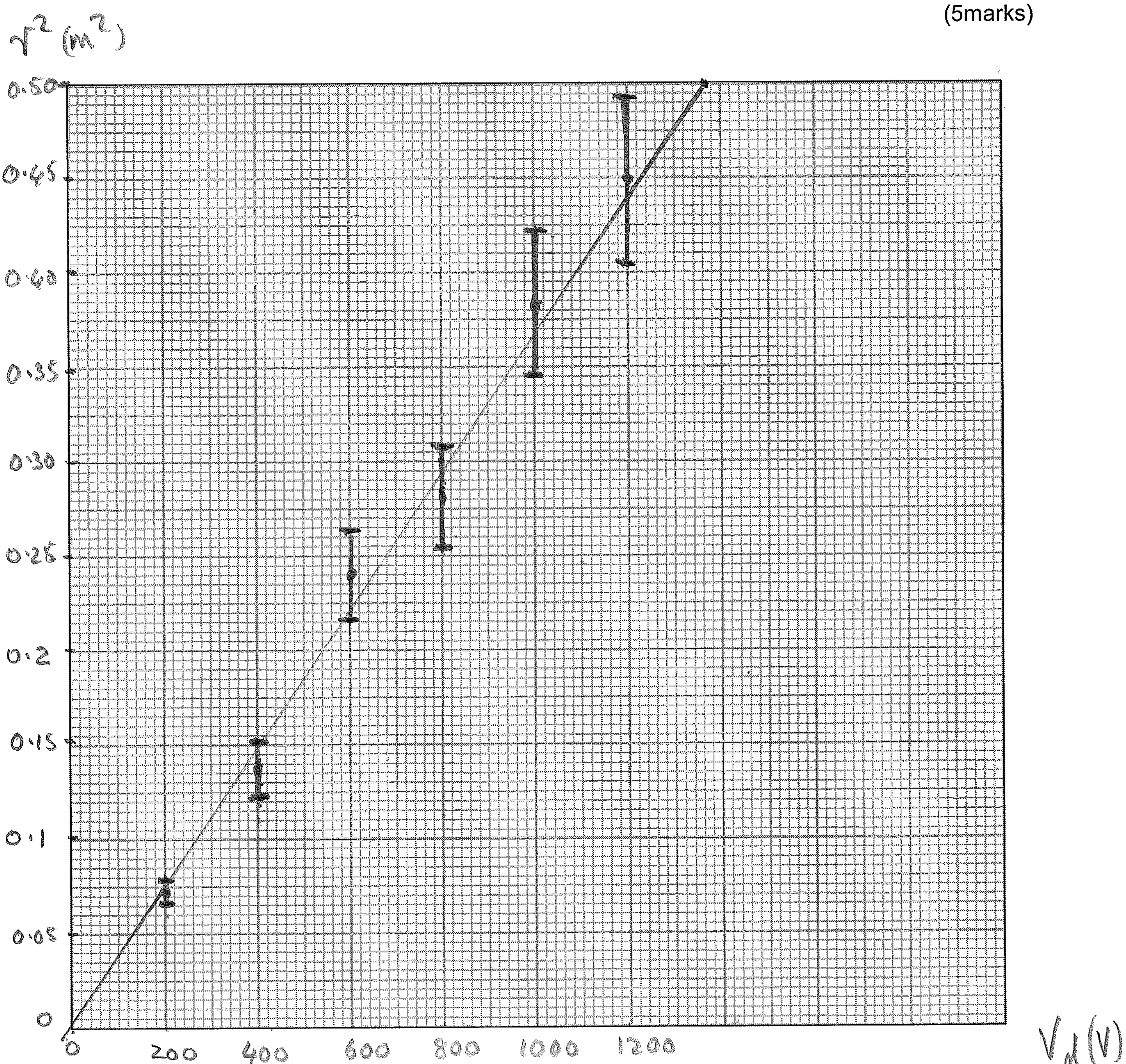
The equation follows the format **y = mx + c** for values of r^2 plotted against V_d

(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.

Correct sig fig's ① correct r^2 ① correct tolerance ① (3marks)

(c) Plot the graph of $\mathbf{r^2}$ (vertical axis) versus **potential difference, V_d**, (horizontal axis) on the graph paper provided. Include error bars and a line of best fit.

(5marks)



If you need to make a second attempt, spare graph paper is at the end of this question. Indicate clearly if you have used the second graph and cancel the working on the first graph.

units, labels ① line of best fit ①
pts plotted correctly ① tolerances ②

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(d) Calculate a value for the gradient of the graph, in the correct units, showing how you obtained this value. (3 marks)

$$\text{gradient} = \frac{0.50 - 0.00}{1360 - 0} \ \frac{m^2}{V} \quad (1)$$

$$= 3.67 \times 10^{-4} \ m^2 V^{-1} \quad (1) \quad (1)$$

(e) Use the value of the gradient that you obtained to determine the identity of the charged ion. (If you could not obtain a gradient use the numerical value 4.00 x 10^{-4}) (4 marks)

$$\text{gradient} = \frac{r^2}{Vd} = \frac{2m}{qB^2} \quad (1)$$

$$\therefore \quad 3.67 \times 10^{-4} = \frac{2m}{qB^2} \quad (1)$$

$$\therefore \quad m = \frac{3.67 \times 10^{-4} \times qB^2}{2} \quad (1)$$

$$= \frac{3.67 \times 10^{-4} \times 1.6 \times 10^{-19} \times (3.50 \times 10^{-2})^2}{2}$$

$$= 3.60 \times 10^{-26} \ \text{kg}$$

This will be a sodium ion (1)

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 22 **EARTH SATELLITES** **(18 marks)**

(Paragraph 1)
Satellites that are used to relay television programs and telephone messages stay in a stable orbit for many years. They have to be replaced when their batteries run down or when they can no longer be recharged by their photocells. The satellite must be put into orbit with exactly the right speed to match its height above the earth or, more correctly, its distance to the centre of the Earth. In the stable situation the centripetal force needed to stay in a circular orbit, $\mathbf{mv^2/r}$, is provided by the force of gravity between the satellite (**m**) and the earth (**M**), which is $\mathbf{GMm/r^2}$. Cancelling gives us

$$v^2 = GM/r$$

We see that the smaller the radius **r**, the faster the satellite must travel.

(Paragraph 2)
We now come to the point of the whole business. Suppose that an Earth satellite is in a stable orbit, circling the Earth and losing very little kinetic energy until it meets a cloud of dust. This will slow the satellite and it will fall into a lower orbit. But in the lower orbit, it has to go faster. How can slowing it down increase its speed? This is called the **'satellite paradox'**.

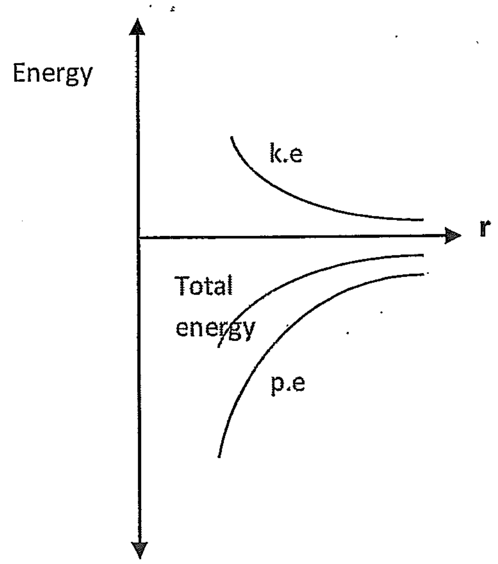
(Paragraph 3)
The answer is, of course, found from the law of conservation of energy. When the satellite falls into the lower orbit, it is nearer the Earth and so has lost gravitational p.e. (or, as in the diagram, it has less negative p.e.). In fact we can show that the loss in p.e. is twice the gain in k.e. So when the satellite drops down into a lower orbit it has lost energy and this is a more stable orbit.
The amount of **gravitational p.e.** is given by:

$$GMm/r$$

we have seen that this equals $\mathbf{mv^2}$, and this is twice the k.e. ($\frac{1}{2}\mathbf{mv^2}$).
We can put the transaction into the form of an equation:

loss in gravitational p.e. = gain in k.e. + energy lost to dust

The sketch graphs here show the gravitational p.e., which is negative but rises continuously with radius because work must be done to lift the satellite from the surface of the Earth (or, more correctly, from the centre of the Earth). The k.e. must be always positive, because the velocity is squared. The total energy is still negative because the value of the p.e is twice that of the k.e.



(Paragraph 4)
The same thing happens to an electron circling the nucleus of an atom. In this case, it does not encounter dust but it can change into a higher or lower orbit with the absorption or emission of a photon. In this case it trades electrical p.e. for the increased k.e. in the lower orbit and the energy is converted into light energy as a photon. Alternatively, when the atom is excited by heat or by receiving light energy of exactly the correct amount, the electron can jump into a higher orbit which is stable.

(a) When working out the speeds and periods of satellites, why is the mass of the satellite not a factor ?

(4 marks)

The speed of a satellite is determined by stating that its centripetal force is provided by the gravitational attraction of the Earth, so

$$F_c = F_g \longrightarrow \frac{\cancel{m}v^2}{\cancel{r}} = \frac{GM_e\cancel{m}}{r^{\cancel{2}}} \longrightarrow v = \sqrt{\frac{GM_e}{r}}$$

① ①

and $T = \frac{2\pi r}{v}$

Hence the mass of the satellite cancels from each side of the equation and is not a factor in v or T ②

(b) What is the 'satellite paradox' and what would happen to a satellite that was lifted up to a certain height and then given a horizontal velocity too great for that height?

(4 marks)

The satellite paradox is that if a satellite speeds up / slows down it will change orbits such that its final speed in the new orbit is slower / faster (i.e. the opposite of the initial change in speed)

A satellite at a certain height with a horizontal velocity too great for that height would have too much total energy, so would move to a higher orbit ① matching its total energy, in which its horizontal velocity would be reduced ①

2

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) In paragraph 4 it makes an analogy between electrons orbiting a nucleus and satellites orbiting the Earth. Write an energy equation for an electron orbiting a nucleus similar to that given in paragraph 3 for a satellite. Why is the total energy always negative?

(4 marks)

2

loss in electrical PE = gain in KE + energy converted into a photon

The total energy is always negative because the value of the PE, which is negative, is twice that of the KE, which is positive 2

(d) One of the very latest American 'spy' satellites is the Teal Ruby. It is in a circular orbit at a height of 740 km above sea level. Calculate the work done in putting this satellite into its stable orbit if its mass is approximately 1000 kg.

(6 marks)

Work done putting satellite into orbit is

W = increase in KE + increase in PE 1

$$\Delta KE = \frac{1}{2} m v^2 = \frac{1}{2} m \left(\frac{GM}{r}\right)$$

$$= \frac{1}{2}(1000\ \text{kg})\left(\frac{6.67\times10^{-11}\times5.97\times10^{24}}{6.38\times10^{6}+7.40\times10^{5}}\right) \quad 1$$

$$= 2.80\times10^{10}\ \text{J} \quad 1$$

$$\Delta PE = \frac{GMm}{R_E} - \frac{GMm}{r} \quad 1$$

$$= 6.67\times10^{-11}\times5.97\times10^{24}\times1000\left(\frac{1}{6.38\times10^{6}} - \frac{1}{7.12\times10^{6}}\right)$$

$$= 6.49\times10^{9}\ \text{J} \quad 1$$

End of Section Three - End of Questions

$\therefore W = \Delta KE + \Delta PE = \underline{3.45\times10^{10}\ \text{J}}$ 1

End of paper

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Additional Working Space

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Extra Copy of Graph Paper