



**Methodist Ladies' College
Semester One Examination, 2016**

Question/Answer Booklet

**PHYSICS
ATAR Year 12**

Student Name: _____

Teacher Name: _____

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.

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

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

- 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.
- 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.
- 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)

**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.

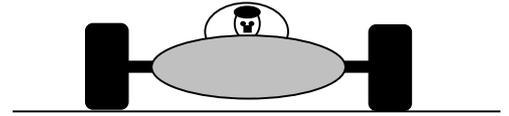
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Question 3

(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.

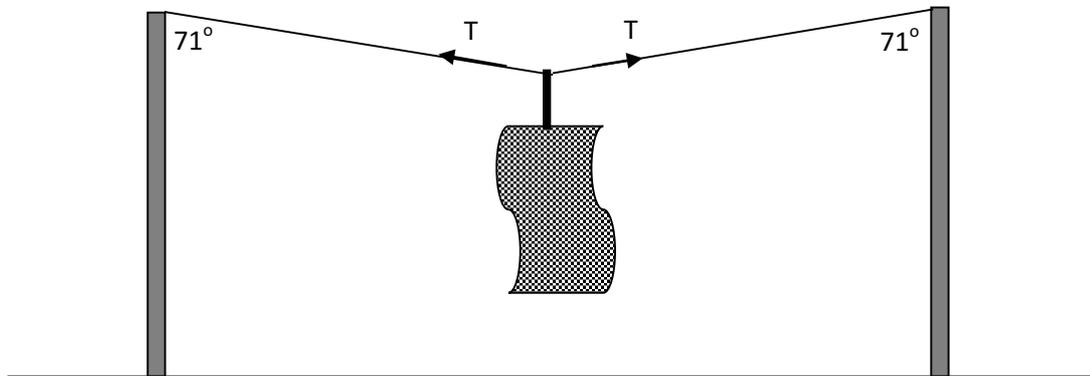
Feature 1: _____

Feature 2: _____

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

See next page

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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} .

(Useful data: horizontal component of the Earth's field strength is $2.11 \times 10^{-5} \text{ T}$ and the vertical component of the Earth's field strength is $5.05 \times 10^{-5} \text{ T}$)

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

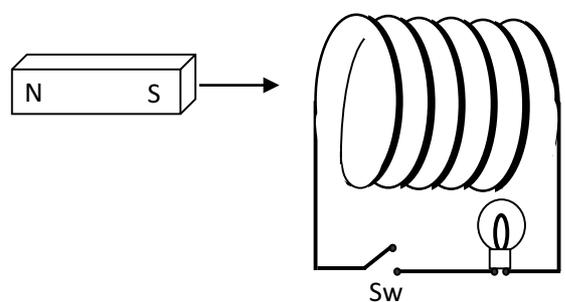
(2 marks)

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

(3 marks)**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.



See next page

Question 7

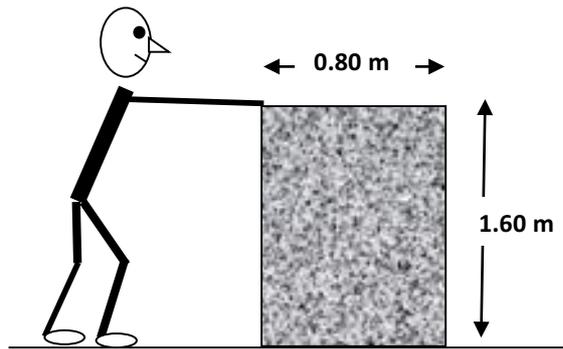
(4 marks)

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.)

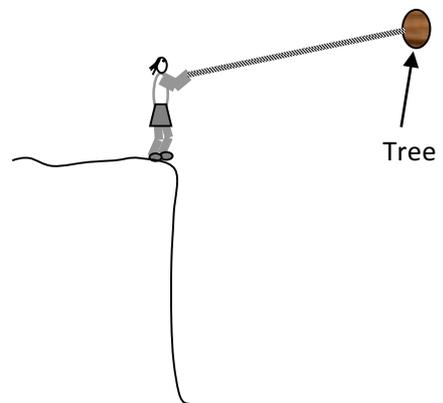


Question 8

(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)



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

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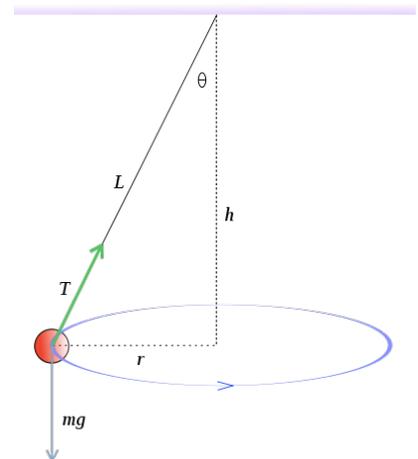
Question 9**(4 marks)**

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?

**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?



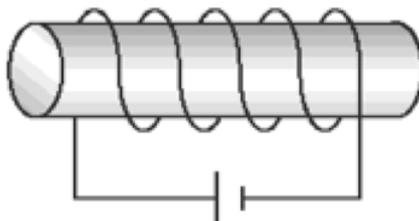
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Question 11**(4 marks)**

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)



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

(2marks)



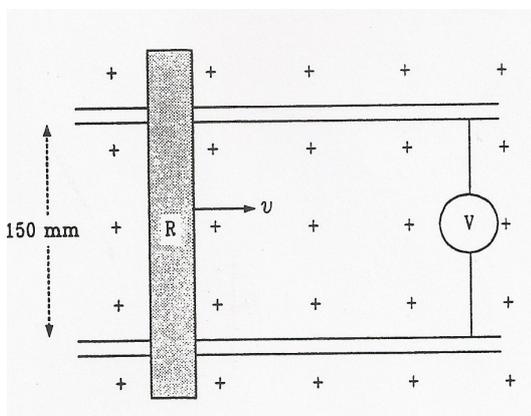
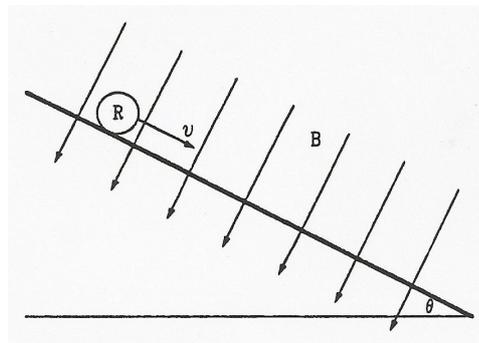
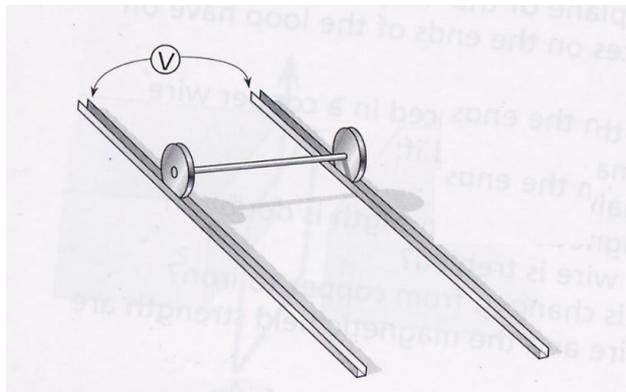
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Question 12

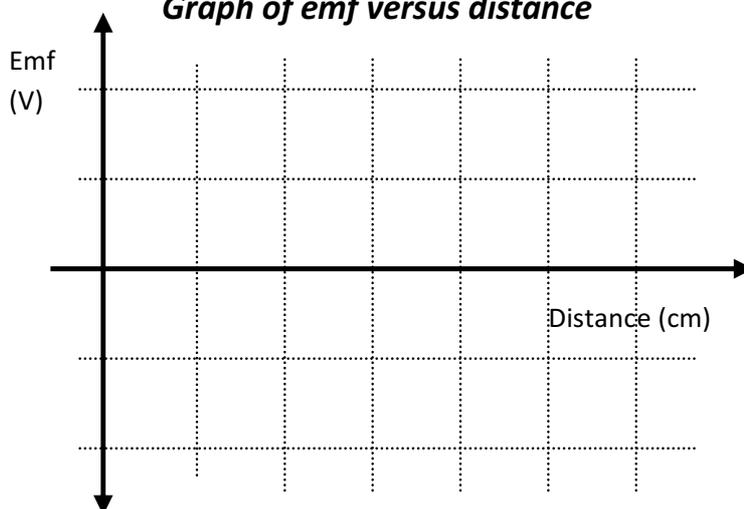
(4 marks)

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.



Graph of emf versus distance



- (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)

- (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)

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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.

End of Section One

See next page

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.

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Suggested working time: 90 minutes

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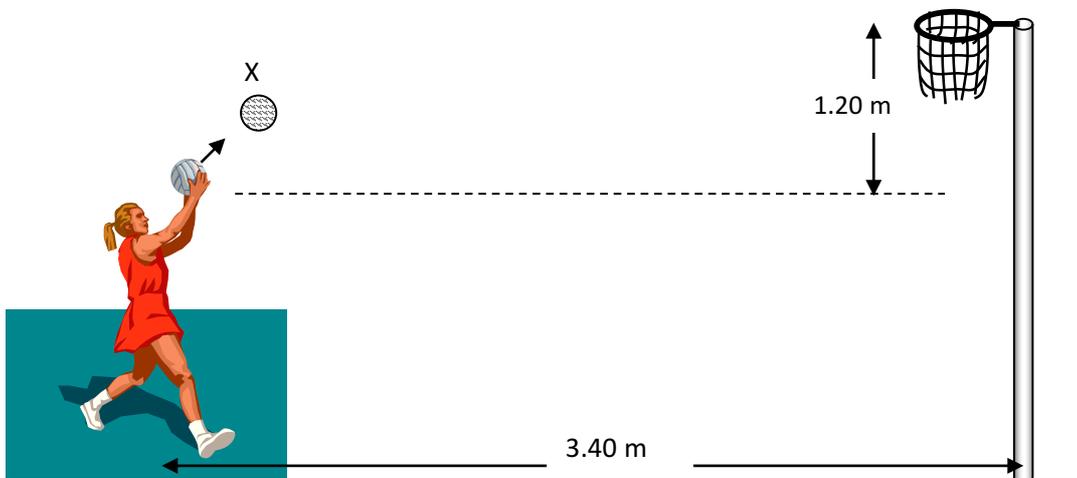
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Question 14

(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)

- (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)

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- (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)

- (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)

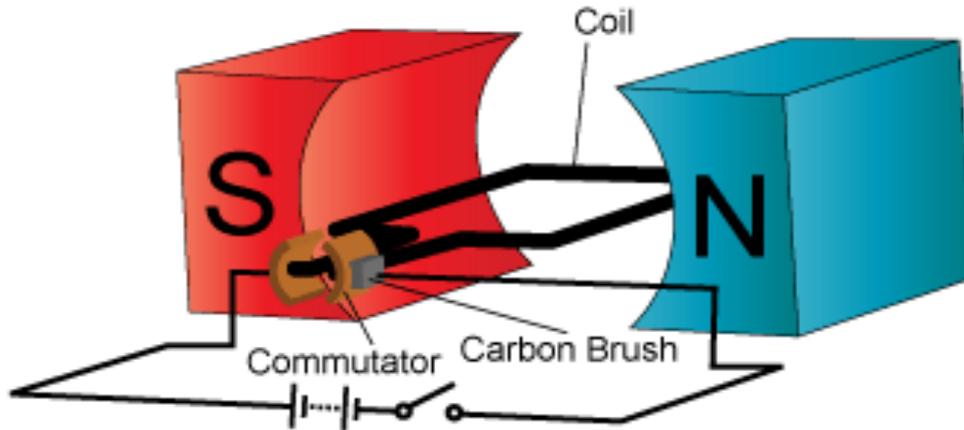
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Question 15

(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. (2 marks)

- (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)

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- (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)

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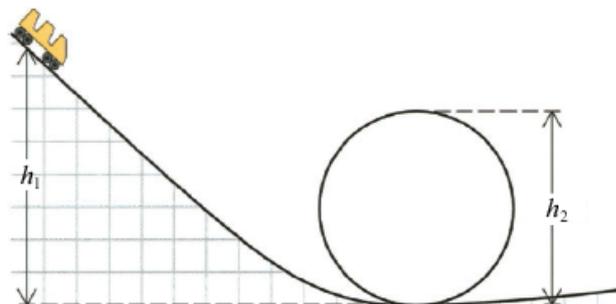
Question 16

(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)

- (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)

- (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)

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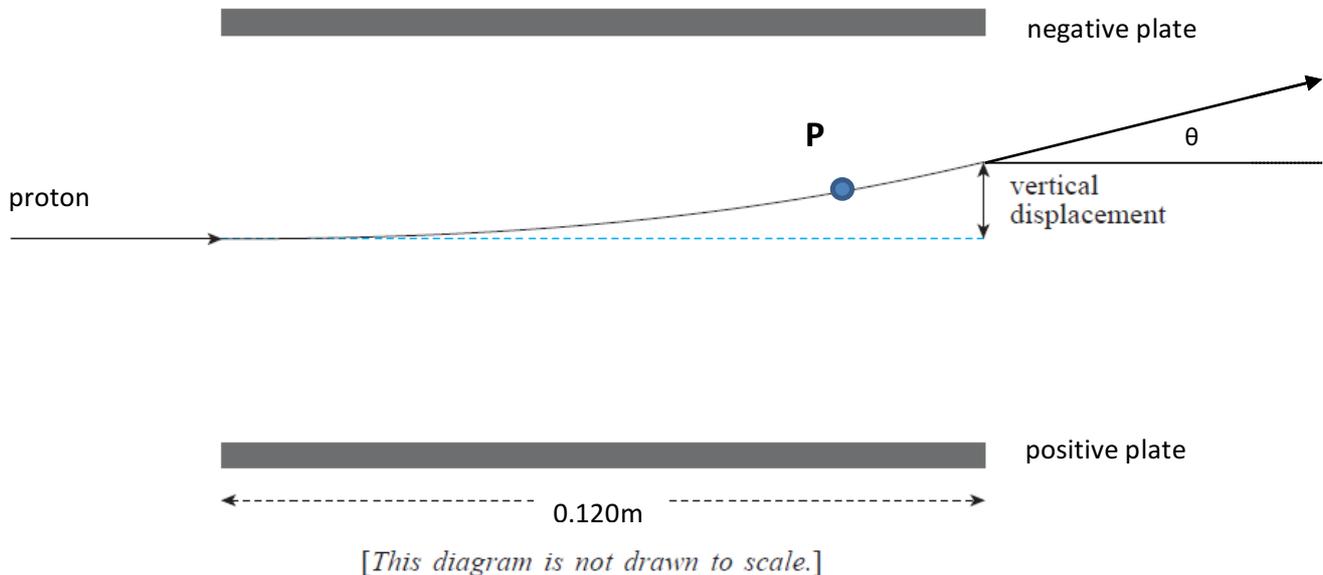
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Question 17

(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 $1.25 \times 10^6 \text{ m s}^{-1}$. The plates are 0.120 m long, and the uniform electric field has a magnitude of $5.00 \times 10^4 \text{ V m}^{-1}$.

Ignore end effects and the effect of gravity



- (a) (i) Draw the electric field between the plates and indicate the direction of the force on the proton at point P. (3 marks)
- (ii) If the distance between the plates is 8.00 cm then what is the potential difference, V_p , between the plates? (2 marks)

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

See next page

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- (c) Show that the magnitude of the vertical acceleration, a , of the proton in the region between the plates is $4.79 \times 10^{12} \text{ m s}^{-2}$.
(2 marks)
- (d) What is the final vertical velocity and displacement of the proton on leaving the parallel plates?
(4 marks)
- (e) Hence at what angle does it leave the plates?
(2 marks)
- (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)

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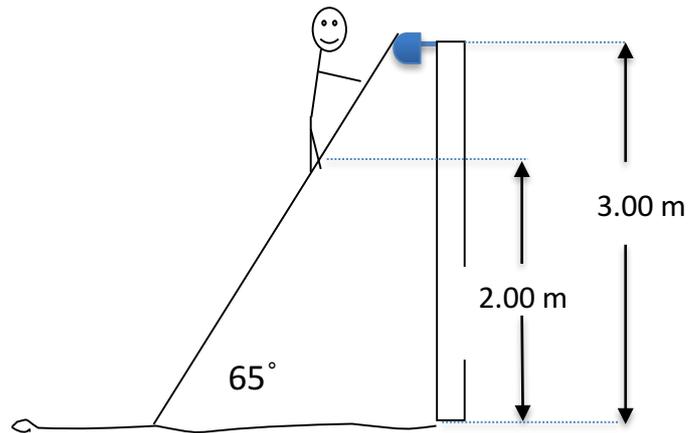
Question 18

(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 woman painter of mass 75.0 kg climbs the ladder so that she is 2.00 m above the ground then:

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

(2 marks)



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

(4 marks)

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

(4 marks)

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

(3 marks)

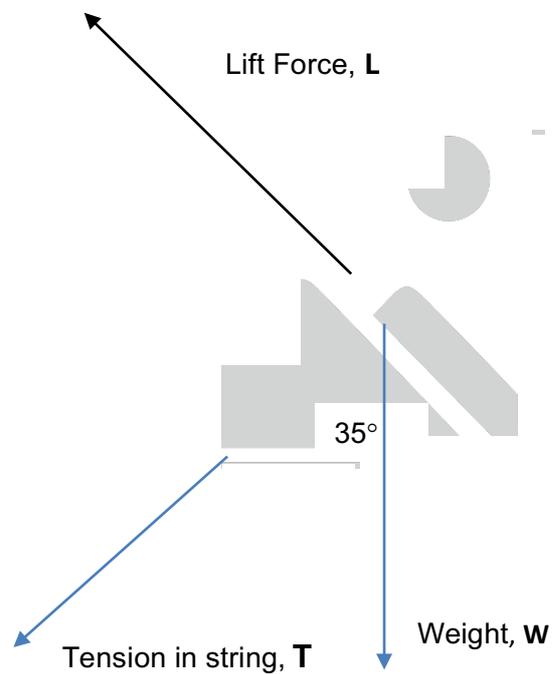
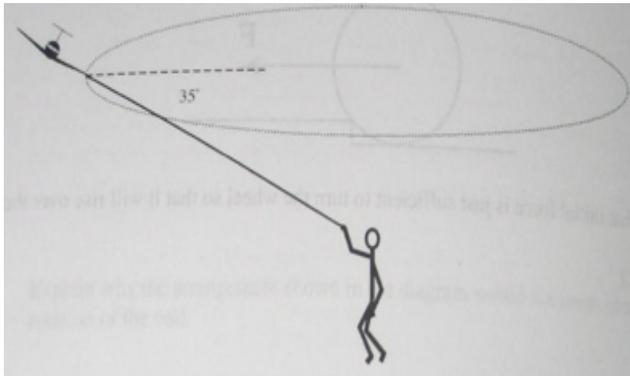
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Question 19

(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. (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)

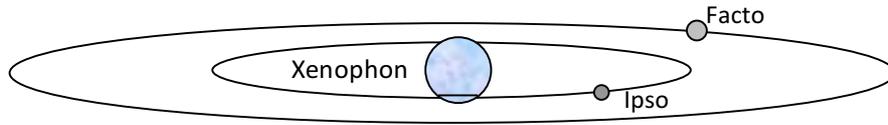
- (c) If the tension in the nylon line is 22.5 N and the lift force perpendicular to the wings of the model aeroplane is 35.0 N then what is the mass of the plane?
(3 marks)
- (d) If the maximum tension needed to break the nylon line is 80.0 N and the string remains at an angle of 35.0° then what lift force would be required to break the string for an aeroplane of mass 2.00 kg?
(2 marks)
- (e) For the situation described above in (d) determine the maximum speed that the model plane could go around a horizontal radius of 15.0 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)

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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)

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

(c) Calculate the mass of the star Xenophon.

(4 marks)

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

(3 marks)

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End of Section Two

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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.

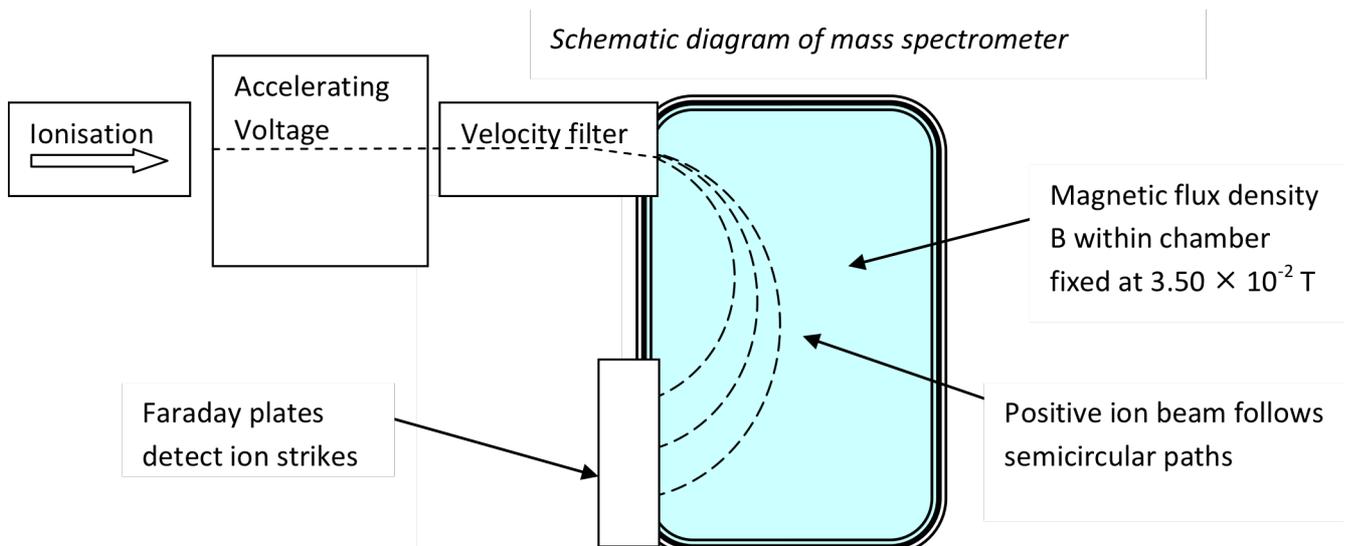
Question 21 Experimental Analysis and Interpretation

(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.



See next page

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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 $\pm 5\%$ and radius squared with an uncertainty $\pm 10\%$.

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	
600	0.490 ± 0.025	
800	0.530 ± 0.053	
1000	0.620 ± 0.027	
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:

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

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 $r = \frac{m \cdot v}{q \cdot B}$ 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:

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

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

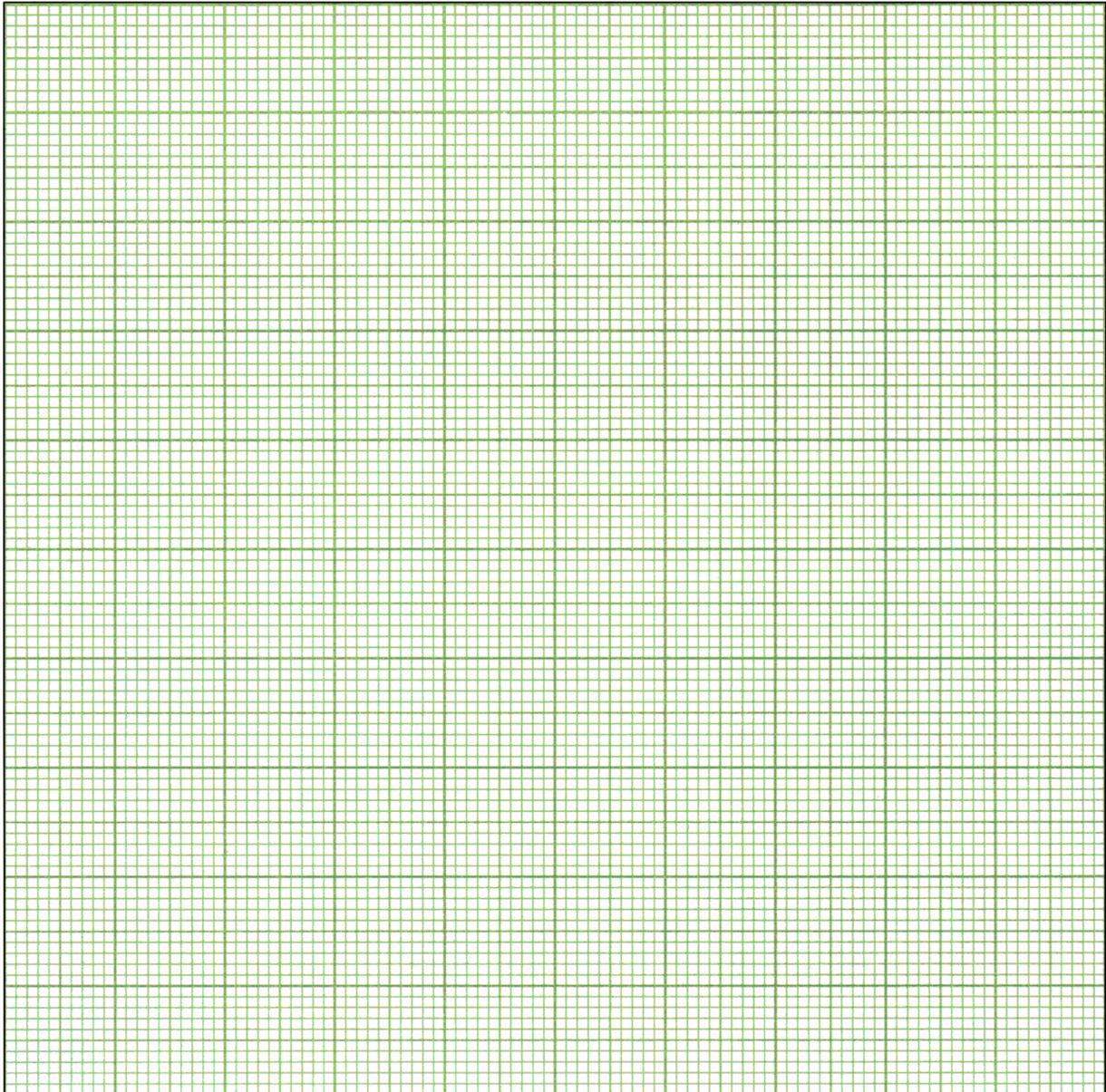
- (b) Complete the table by filling in the values of radius squared r^2 with the appropriate uncertainty range. Two values have been done for you.

(3marks)

- (c) Plot the graph of 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)

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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.

See next page

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

(3 marks)

- (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 4.00×10^{-4})

(4 marks)

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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, mv^2/r , is provided by the force of gravity between the satellite (m) and the earth (M), which is 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:

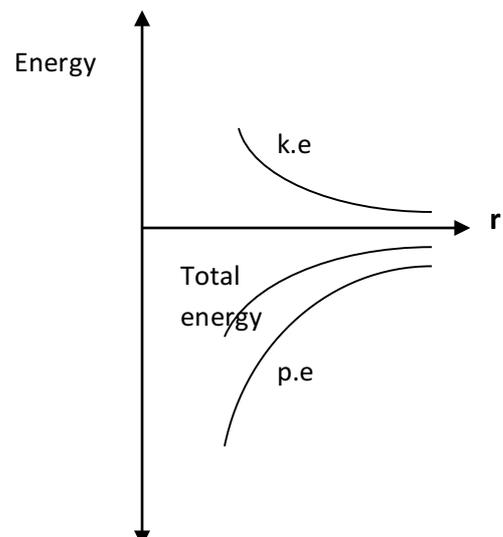
$$GMm/r$$

we have seen that this equals mv^2 , and this is twice the k.e. ($\frac{1}{2}mv^2$).

We can put the transaction into the form of an equation:

$$\text{loss in gravitational p.e.} = \text{gain in k.e.} + \text{energy lost to dust}$$

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.



See next page

(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)

- (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)

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- (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)

- (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)

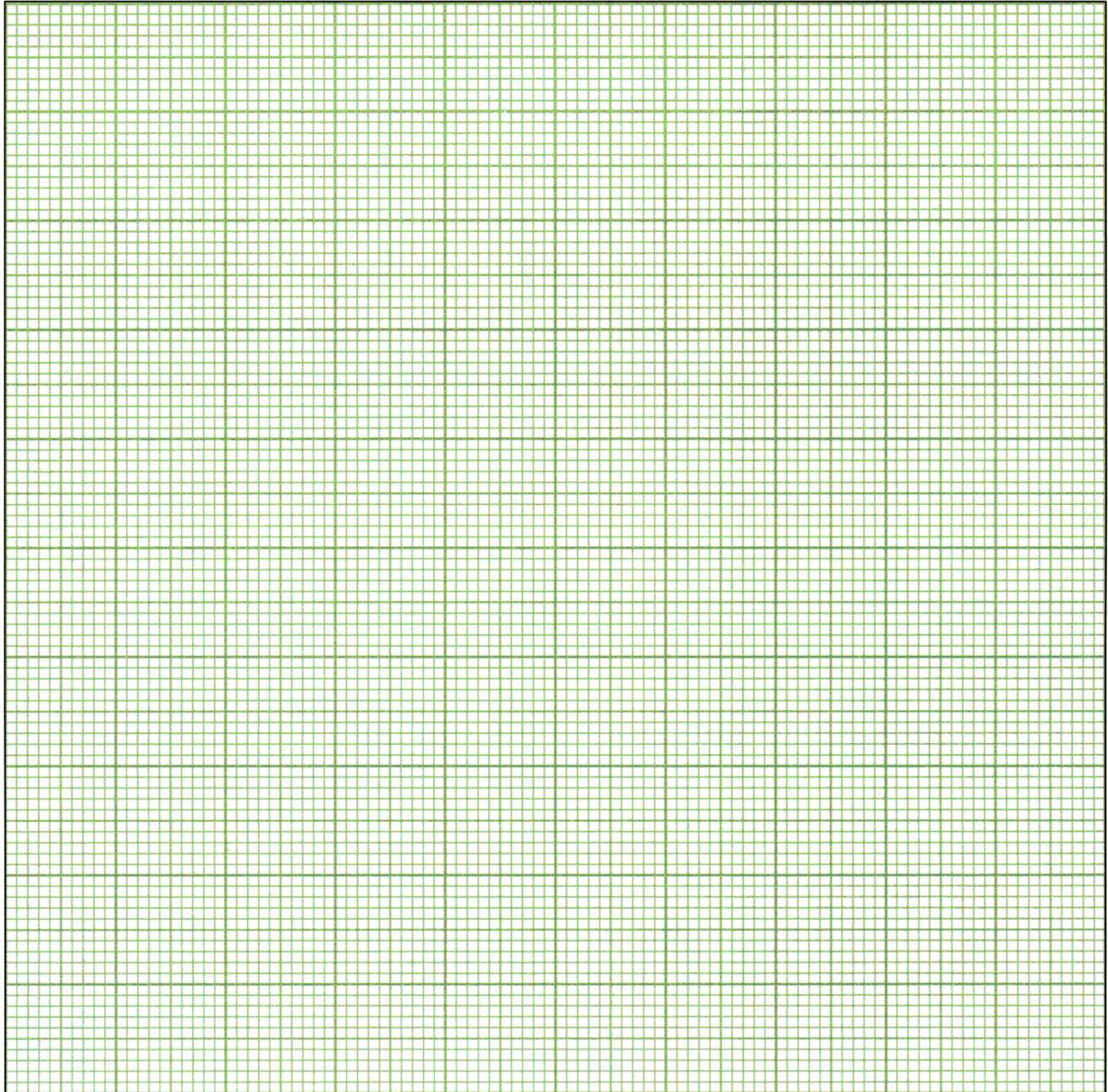
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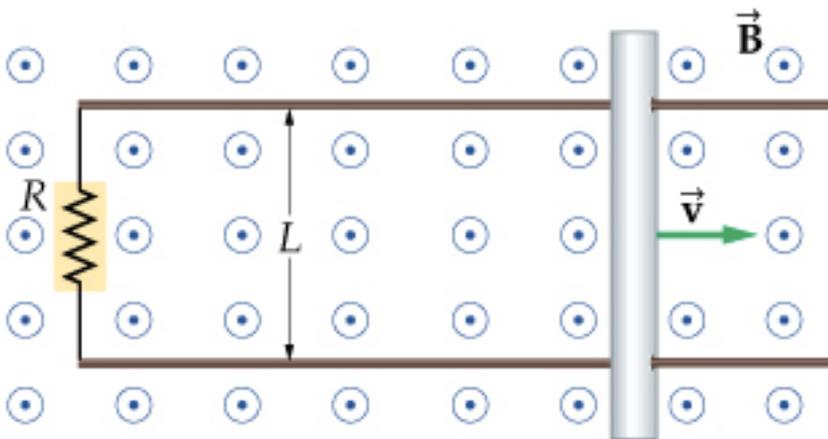
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Spare Questions

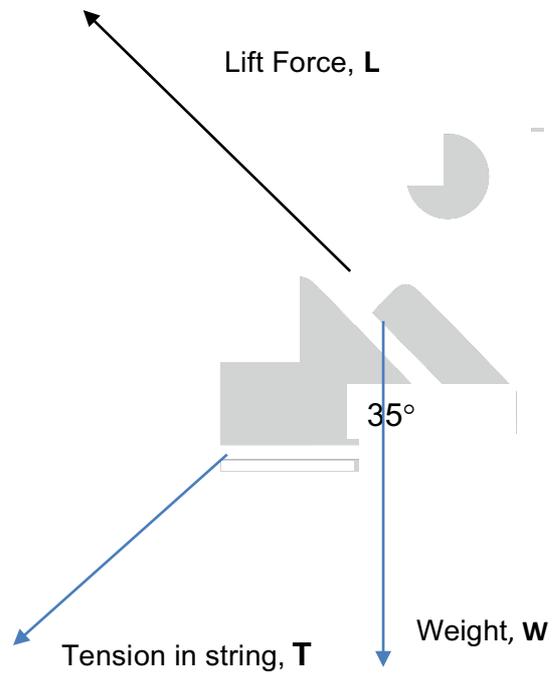
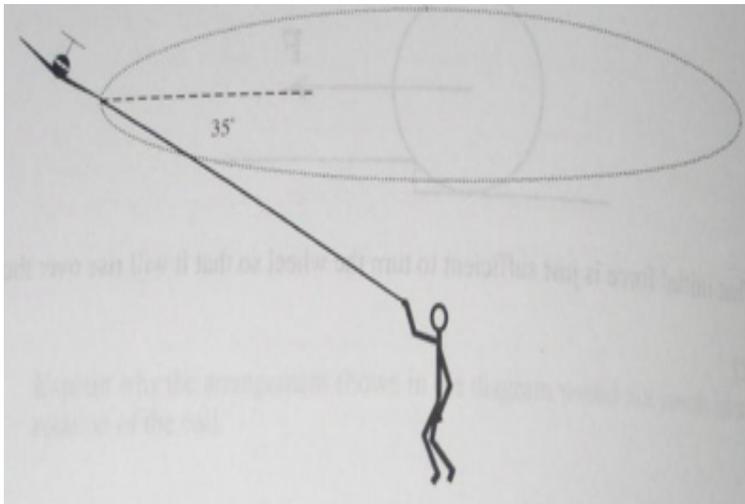
Section A



Question 19

(14 marks)

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



The Forces are shown in more detail on the left 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 component (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. (2 marks)

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

$$L_v = mg + T \sin \theta .$$

(3 marks)

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- (c) If the tension in the rope 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)

- (d) If the maximum tension needed to break the string was 80.0N 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 2.00kg?
(2 marks)

- (e) For the situation described above in (d) determine the maximum speed that the model plane could go around a horizontal radius of 150m. (Use a lift force of 80N if no answer from (d) above.)
Hint: write an expression for the centripetal force in terms of components of the other forces.
(4 marks)

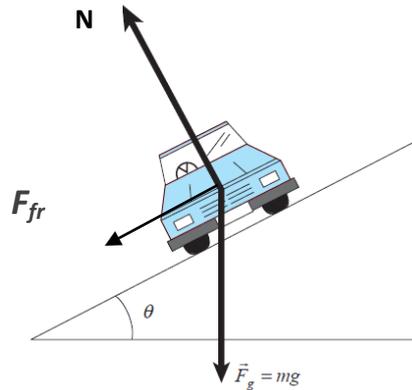
Question 19

(14 marks)

(a) The movement of a car in a circular path on a flat horizontal road relies on the friction between the road and the tyres to provide the centripetal acceleration. One component of the normal force on a car moving with uniform circular motion round a banked curve is directed towards the centre of the circle, thus reducing the reliance on friction.

- (i) On the diagram below, draw vectors to show the horizontal components (N_H) & (F_{frH}) and the vertical component (N_V) & (F_{frV}) of the normal force (N) and friction force (F_{fr}) respectively acting on a car moving with uniform circular motion round a banked curve.

(2 marks)



[This diagram is not drawn to scale.]

- (ii) Show that the magnitude of the vertical component (N_V) of the normal force is given by

$$N_V = mg + F_{fr} \sin\theta .$$

(3 marks)

- (iii) For a banking angle of 20.0° and a car of mass 1200kg with a maximum friction force of 7000N acting determine the magnitude of the Normal force, N .

(2 marks)

- (b) For the situation described above determine the maximum speed that the vehicle could go around the banked curve with a radius of 150m.

(4 marks)

- (c) Explain why the friction force required gets less as the banking angle increases and yet the maximum speed with which the vehicle can negotiate the bend increases.

(3 marks)

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