CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12

PHYSICS STAGE 3

MID YEAR EXAMINATION 2014

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1		
2		
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Total		/ 180 = %

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

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 exam
Section One: Short Answers	14	14	50	54	30%
Section Two: Problem-Solving	6	6	90	90	50%
Section Three: Comprehension	2	2	40	36	20%
				Total	100

Instructions to candidates

1. Write your answers in this Question/Answer Booklet

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

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

4. The Formulae and Data booklet is **not** handed in with your Question/Answer Booklet.

YEAR 12
PHYSICS STAGE 3
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Section One: Short Response

This section has **fourteen (14)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **50 minutes**.

Question 1 **(3 marks)**

When a meteor is at a distance of twice the Earth's radius from the surface of the Earth, calculate the magnitude of its acceleration due to gravity.

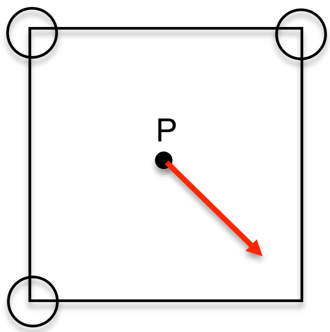
$$g = G\frac{M}{r^2} \quad (1)$$

$$= (6.67\times10^{-11})\frac{(5.97\times10^{24})}{(3\times6.38\times10^{6})^2} \quad (1)$$

$$= 1.09\ ms^{-2} \quad (1)$$

Question 2 **(1 mark)**

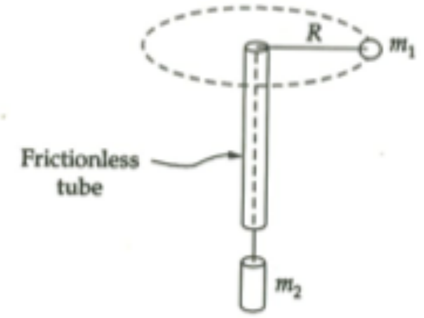
A square has equal positive charges at three of its corners, as shown in the diagram below. Sketch (on the diagram below) the direction of the electric field at point P.



Arrow must be pointing in the direction a positive test charge would travel – through the bottom right hand corner.

Question 3 **(4 marks)**

A ball of mass 5.00 kg (m_1) is connected to another mass of 6.00 kg (m_2) by a string, as shown in the diagram below. If the ball is whirled at a constant speed in a horizontal circle of radius 0.800 m, calculate the kinetic energy of the ball.



$F_c = m_1 g$ (0.5)

$= (6)(9.8)$ (0.5)

$F_c = \frac{mv^2}{r}$ (0.5)

$E_k = \frac{1}{2}mv^2$ (0.5)

$mv^2 = rF_c$

$= (0.8)(6)(9.8)$

$= 47.0$ (1)

$E_k = (0.5)(47.0)$

$= 23.5\ J$ (1)

Question 4 **(3 marks)**

A uniform magnetic field of 0.500 T is directed perpendicular to the plane of a square coil of side 10.0 cm. The coil has 300 turns. Calculate the magnetic flux through the coil.

$\Phi = BA$ (1)

$= (0.5)(0.1^2)$ (1)

$= 5.00 \times 10^{-3}\ Wb$ (1)

-0.5 marks for using the 300 turns.

Question 5 **(6 marks)**

An electron is released from rest in a uniform electric field of strength 1.25×10^3 NC^{-1}.

(a) Calculate the magnitude of the acceleration of the electron

(4 marks)

$E = \frac{F}{q}$ (0.5)

$F = (1.25 \times 10^3)(1.6 \times 10^{-19})$ (0.5)

$= 2.00 \times 10^{-16}\ N$ (1)

$F = ma$ (0.5)

$2.00 \times 10^{-16} = (9.11 \times 10^{-31})(a)$ (0.5)

$a = 2.20 \times 10^{14}\ ms^{-2}$ (1)

(b) Calculate the speed of the electron after 20.0 ns.

(2 marks)

$v = u + at$ (0.5)

$= 0 + (2.20 \times 10^{14})(20 \times 10^{-9})$ (0.5)

$= 4.40 \times 10^6\ ms^{-1}$ (1)

Question 6 **(3 marks)**

A car moves in a horizontal circle with a radius of 10.0 m. The tangential velocity of the car is 30.0 ms^{-1}. Calculate the acceleration of the car.

$a_c = \frac{v^2}{r}$ (1)

$= \frac{30^2}{10}$ (1)

$= 90.0\ ms^{-2}$ *towards the centre of the circle*

(0.5) (0.5)

Question 7 **(6 marks)**

A 10.0 m long uniform plank, of mass 15.0 kg, is supported at each end by vertical cables. A boy of unknown mass sits on the plank between the cables. The tension in the left cable is 400 N and in the right cable, 300 N. Use the principles of static equilibrium to calculate;

(a) The mass of the boy

(3 marks)

$\Sigma F = 0$ (1)

$F_L + F_R - m_p g - m_b g = 0$

$400 + 300 - (15)(9.8) - (m_b)(9.8) = 0$ (1)

$m_b = 56.4\ kg$ (1)

(b) The distance the boy is sitting from the left end of the plank.

(3 marks)

Take left end as pivot

(0.5) $\Sigma\tau = 0 \quad \tau = rF$ (0.5)

$\Sigma\tau_{cw} = (5)(15 \times 9.8) + (x)(56.4 \times 9.8)$ (0.5)

$\Sigma\tau_{ccw} = (10)(300)$ (0.5)

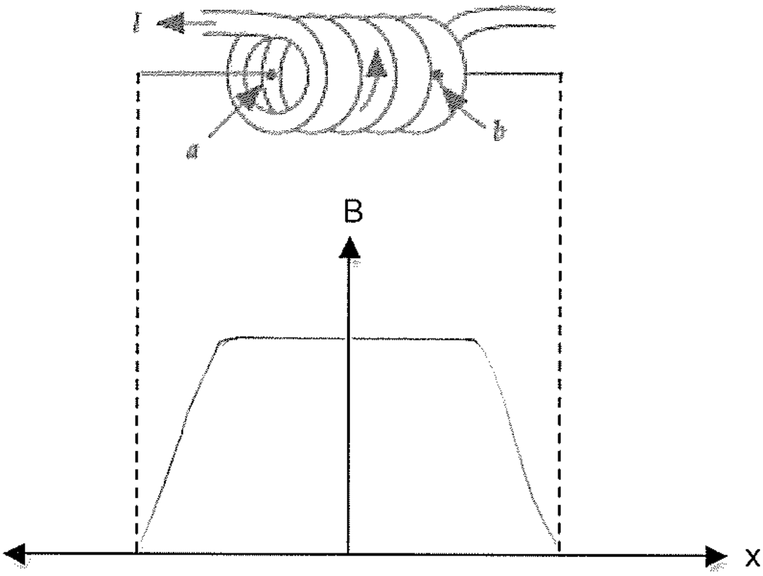
$735 + 552.72x = 3000$

$4.10\ m$ *from the left end*

(1)

Question 8 **(3 marks)**

A solenoid coil is shown below. On the axes below, sketch a graph to show the variation in the strength of the magnetic field along the length of the wire (i.e between the dashed lines) and indicate which end (a or b) is the North Pole.



2 marks – graph -0.5 for any deviations in shape in each of the 4 sections.

1 mark – a is north pole

Question 9 **(4 marks)**

A boy travelling on a bicycle a 10.0 ms^{-1} on a horizontal road stops pedalling as he starts up a hill inclined at 3.00° to the horizontal. If friction can be ignored, calculate how far up the hill he travels before stopping.

$$\Sigma F = ma$$
$$\Sigma F = mg\sin\theta = ma \quad (0.5)$$
$$a = g\sin\theta$$
$$= (9.8)(\sin 3) \quad (0.5)$$
$$= 0.513\ ms^{-2} \quad (1)$$

$$v^2 = u^2 + 2as \quad (0.5)$$
$$0 = 10^2 + (2)(-0.513)(s) \quad (0.5)$$
$$s = 97.5\ m \quad (1)$$

Question 10 **(4 marks)**

Artificial satellites such as communications and GPS satellites are familiar in contemporary life.

(a) Which statement about the orbit of satellites is correct? Circle your chosen answer.

(1 mark)

(i) The higher the altitude of the orbit, the faster the satellite travels

(ii) The higher the altitude of the orbit, the slower the satellite travels

(iii) The height of the altitude of an orbit has no effect on the speed of a satellite

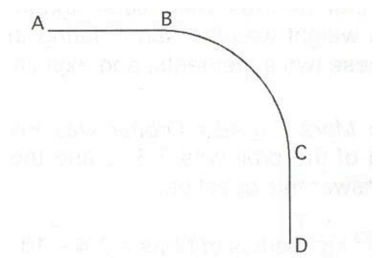
(b) Explain your reasoning below.

(3 marks)

- As the satellite moves further from the Earth, the total energy stays the same
- But the potential energy increases, therefore the kinetic energy decreases.
- Speed of the satellite decreases.

Question 11 **(4 marks)**

A cyclist of mass 60.0 kg is travelling along the path shown in the diagram below. The cyclist rides at a constant speed of 10.0 ms^{-1} throughout the path. State between which two points the cyclist would be accelerating. Explain your reasoning.



- B and C
- Between B and C the direction of the cyclists path is changing.
- Acceleration is a change in velocity which can be change in speed or change in direction of the motion (or both).
- As the speed is not changing at any point, acceleration can only occur where the direction is changing.

Question 12 **(4 marks)**

A 5.00 m tall vertical lightning conductor in Perth is hit by a bolt of lightning. This sends an electron current of 1.00 x 10^4 A travelling downwards in the conductor. If the Earth's Magnetic field is 5.50 x 10^{-5} T at 66° to the horizontal in Perth, determine the force exerted on the lightning conductor.

$$F = I\ell B$$ (1)

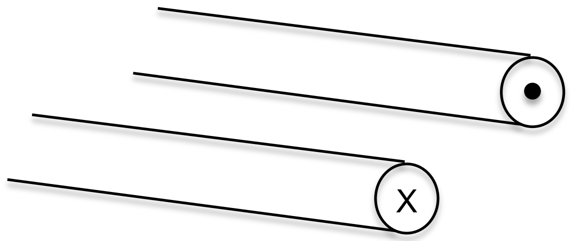
$$= (1.00\times10^{4})(5.00)(5.50\times10^{-5}\cos 66)$$ (1)

$$= 1.12\ N \quad West$$

(1) (1)

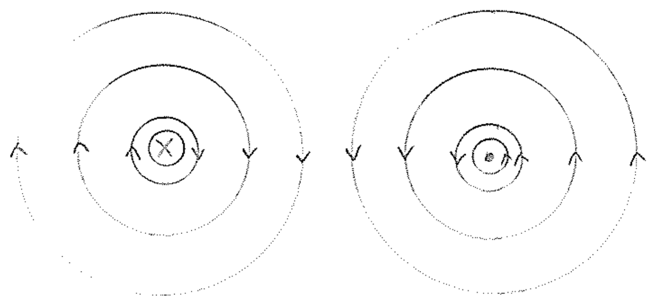
Question 13 **(4 marks)**

Two wires lying in the plane of the page carry equal currents in opposite directions, as shown in the diagram below.



(a) Sketch a diagram below to show the magnetic field around and between the wires.

(3 marks)



- 1 mark - correct directions
- 1 mark - concentric circles
- 1 mark - increasing difference in diameter

(b) At a point midway between the wires which of the options below best describes the magnetic field? Circle your chosen answer.

(1 mark)

(i) zero
(ii) directed into the page
(iii) directed out of the page

Question 14 **(5 marks)**

A cosmic ray electron moves at 7.50 x 10^6 ms^{-1} perpendicular to the Earth's magnetic field at an altitude where the field strength is 1.00 x 10^{-5} T. Calculate the radius of the circular path the electron will follow.

$$F_c = F_B$$ (1)

(0.5) $$\frac{mv^2}{r} = qvB$$ (0.5)

$$r = \frac{mv}{qB}$$

$$r = \frac{mv}{qB}$$ (1)

$$= \frac{(9.11\times10^{-31})(7.50\times10^{6})}{(1.6\times10^{-19})(1.00\times10^{-5})}$$ (1)

$$= 4.27\ m$$ (1)

End of Section One

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Section Two: Problem-Solving

This section has **six (6)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **90 minutes**.

NAME:_______________________________________

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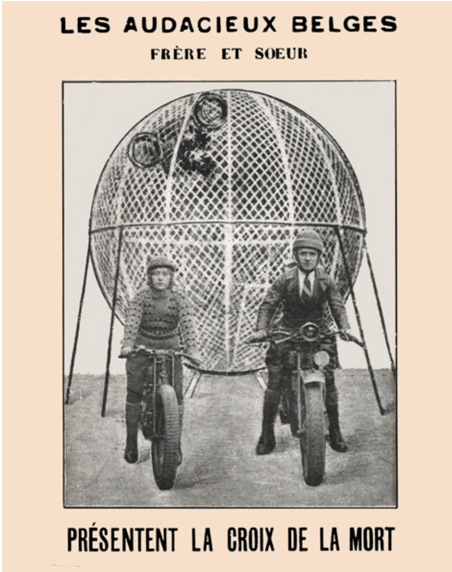
Question 1 **(13 marks)**

The 'Globe of Death' is a circus and carnival stunt where performers ride motorcycles in a mesh sphere (sometimes simultaneously). The riders can loop vertically as well as horizontally.



In a particular stunt after gaining sufficient speed, a stuntman travels in a vertical circle with a radius of 13.0 m. The stuntman has a mass of 70.0 kg and his motorcycle a mass of 40.0 kg.

(a) Calculate the minimum speed he must have at the top of the circle if the tyres are not to lose contact with the sphere.

(4 marks)

$$\Sigma F = ma$$

$$\Sigma F = -F_N - mg = -\frac{mv^2}{r}$$ (1)

$$Minimum\ speed\ at\ F_N = 0$$ (0.5)

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

$$v = \sqrt{rg}$$ (0.5)

$$= \sqrt{(13)(9.8)}$$ (1)

$$= 11.3\ ms^{-1}$$ (1)

At the bottom of the circle, his speed is twice that of (a).

(b) Calculate the normal force exerted on the rider/motorcycle system. If you could not calculate a value for (a) use 13.5 ms^{-1}

(4 marks)

$$\Sigma F = ma$$

$$\Sigma F = F_N - mg = \frac{mv^2}{r}$$ (1)

$$F_N = mg + \frac{mv^2}{r}$$

$$= (110)(9.8) + \frac{(110)(22.6^2)}{13}$$ (1)

$$= 5.40\ kN\ towards\ the\ centre\ of\ the\ loop\ (up)$$

(1) (1)

(c) Calculate how many times greater than his 'regular' normal force this is (i.e. how many 'g's is he experiencing).

(2 marks)

$$W = mg$$ (0.5)

$$= (110)(9.8)$$

$$= 1078$$ (0.5)

$$\frac{5400}{1079} = 5.00$$

(0.5) (0.5)

Humans cannot safely withstand large g-forces. In rollercoasters the problem of large g-forces is often solved by making the loop with a smaller radius at the top and a larger radius at the bottom, as shown in the diagram below.

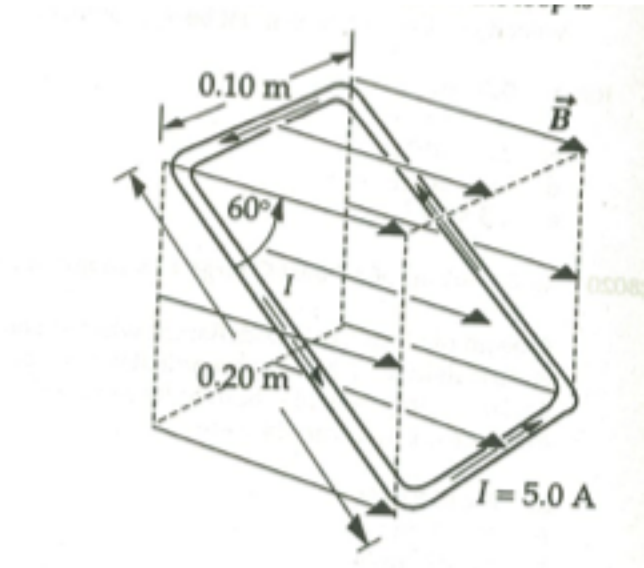
(d) Explain how having a larger radius at the bottom of a loop would help in reducing the g-forces on the rider. You may make reference to or re-write equations you have derived in previous parts of the questions without needing to re-derive them.

(3 marks)

- At the bottom $F_N = mg + \frac{mv^2}{r}$
- F_N needs to be equal and opposite to mg and provide the centripetal force required to maintain the circular path.
- By increasing the radius, the centripetal force required decreases (F_c = mv and less normal force is required.

Question 2 **(17 marks)**

A rectangular loop of wire (0.100 m x 0.200 m) carries a direct current of 5.00 A in a counter-clockwise direction. The loop is oriented, as shown below, in a magnetic field of 1.50 T.



(a) Calculate the force acting on the upper 0.100 m side of the loop. (4 marks)

$F = I\ell B$ (1)

$= (5)(0.1)(1.5)$ (1)

$= 0.750\ N\ Up$

(1) (1)

(b) Calculate the magnitude of the force acting on the 0.200 m side of the loop closest in the diagram. Any formulae used in (a) and re-used in (b) do not need to be restated. (3 marks)

$F = I\ell B$ (1)

$= (5)(0.2)(1.5\sin 60)$ (1)

$= 1.30\ N$ (1)

The loop of wire is now rotated so that its plane is parallel to the magnetic field. A rod is run through the centre of the loop, parallel to the short (0.100 m) sides.

(c) Calculate the net torque on the loop when it is in this position.

(4 marks)

$$\tau = rF \quad (0.5)$$
$$= \frac{0.2}{2} \times 0.750 \quad (0.5)$$
$$= 0.075 \quad (0.5)$$
$$total\ torque = 2 \times 0.075 \quad (0.5)$$
$$= 0.150\ Nm\ Clockwise$$

(1) (1)

(d) As the loop rotates will the torque on the loop remain constant? Explain your reasoning.

(3 marks)

- No
- The angle between F and B will not change (90°) but as the loop rotates the angle between the force and radius will increase.
- As $\tau = rF\sin\theta$ as the angle increases, the torque will decrease as r and F are constant.

(e) What additional device would be required in this setup to ensure the loop continues to rotate in one direction

(1 mark)

- Split-ring commutator

(f) Explain how the device you named in (e) enables the loop keep rotating in one direction.

(2 marks)

- The split-ring commutator changes the direction of the current once every half a cycle.
- This ensures the torque is always in the same direction.

Question 3 **(13 marks)**

A basketball player is fouled and knocked to the floor during a layup and is awarded two free throws.

The free throw line is located 4.14 m from the centre of the basket, which is 3.05 m above the ground.

In his first attempt, the basketballer shoots the ball at an angle of 35.0° above the horizontal and with a speed of 4.88 ms^{-1}. The ball is released 1.83 m above the floor.

(a) Calculate the maximum height, above the ground, reached by the basketball.

(4 marks)

$$v^2 = u^2 + 2as \quad (1)$$

$$0 = (4.88\sin 35)^2 + (2)(-9.8)(s) \quad (0.5)$$

$$s = 0.400\ m \quad (1)$$

$$0.400 + 1.83 = 2.23\ m \quad (1)$$

(0.5)

(b) Calculate the distance along the floor from the free throw line to where the basketball lands.

(6 marks)

$$s = ut + \frac{1}{2}at^2 \quad (1)$$

$$-1.83 = (4.88\sin 35)(t) + \frac{1}{2}(-9.8)(t^2) \quad (0.5)$$

$$4.9t^2 - 2.799t - 1.83 - 0$$

$$\frac{-b \pm \sqrt{b^2 - (4)(a)(c)}}{2a} \quad (1)$$

$$\frac{-2.799 \pm \sqrt{2.799^2 - (4)(4.9)(-1.83)}}{(2)(4.9)}$$

$$t = 0.960\ s \quad (1)$$

$$s = tv \quad (1)$$

$$= (0.96)(4.88\cos 35) \quad (0.5)$$

$$= 3.84\ m \quad (1)$$

In the second free throw, the player again shoots the basketball at an angle of 35.0° above the horizontal from 1.83 m above the floor. This time however, the ball passes through the centre of the basket.

(c) If it takes 0.585 s for the ball to reach the top (centre) of the basket, calculate the initial speed the player gave the ball to enable it to reach the basket.

(3 marks)

$s = tv$ (0.5)

$4.14 = (0.585)(v_h)$ (0.5)

$v_h = 7.08\ ms^{-1}$ (0.5)

$$v = \frac{v_h}{\cos 35}$$

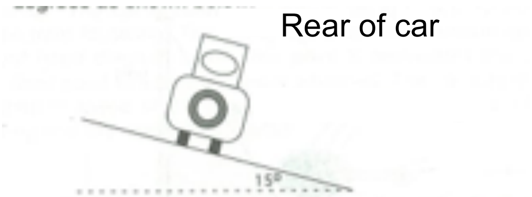
$$= \frac{7.08}{\cos 35}$$ (0.5)

$$= 8.64\ ms^{-1}$$ (1)

Question 4 **(15 marks)**

Train tracks and high speed roads are often banked to assist motorists and train drivers safely take corners. A view from behind a car on the corner of a high speed road, banked at 15.0° is shown below. The corner has a radius of 167 m.

Rear of car



(a) Explain why banked curves are used to assist motorists safely take corners on high speed roads.

(4 marks)

- As a car's speed increases, the amount of centripetal force required to maintain the circular path increases (Fc = mv^2/r).
- This force is supplied by friction on a flat road.
- On a banked curve the centripetal force is provided by the horizontal component of the normal force
- Less friction (even zero friction) is required to maintain the circular path in.

(b) Calculate the speed at which the curve in the diagram above can be taken if no friction is required to maintain the circular path.

(5 marks)

$$\Sigma F = ma$$ (0.5)

$$\Sigma F_V = F_N \cos\theta = mg$$ (0.5)

$$\Sigma F_H = F_N \sin\theta = \frac{mv^2}{r}$$ (0.5)

$$\frac{mg}{\cos\theta} = \frac{mv^2}{r\sin\theta}$$ (1)

$$\frac{\sin\theta}{\cos\theta} = \frac{v^2}{rg}$$

$$\tan = \frac{v^2}{rg}$$ (1)

$$\tan\theta = \frac{v^2}{rg}$$

$$\tan 15 = \frac{v^2}{(167)(9.8)}$$ (0.5)

$$v = 20.9\ ms^{-1}$$ (1)

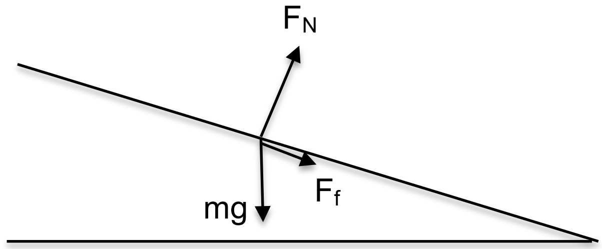
(c) If a car moving around this corner is travelling faster than the speed calculated in (b) how will the radius of the car's path change. Explain your reasoning.

(3 marks)

- The radius of the path will increase.
- Travelling faster, the centripetal force required to maintain the circular path will increase as Fc =mv^2/r
- As the horizontal component of the normal force cannot change, the radius will increase to keep the ratio the same to provide the same centripetal force

(d) If the banked curve is not a smooth slope, draw a labelled free body diagram below to show the forces acting on the car when it is travelling faster than the speed calculated in (b).

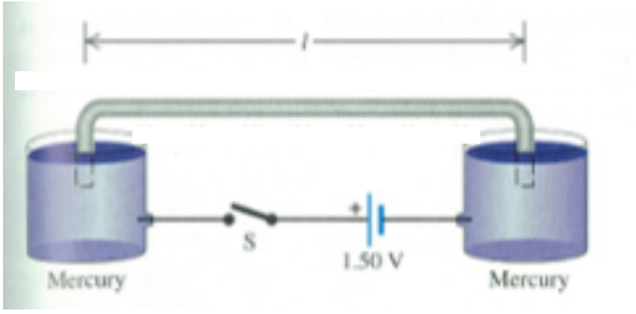
(3 marks)



Question 5 **(16 marks)**

An insulated wire of mass 5.40 x 10^{-5} kg is bent into the shape of a 'U' so that the horizontal part has a length of 15.0 cm.

The bent ends of the wire are partially immersed in two pools of mercury with 2.50 cm of each end below the mercury surface, as shown in the diagram below.



The entire structure is in a region containing a uniform 6.50 mT magnetic field.

When the switch is closed the wire jumps 35.0 cm into the air (above its original position)

(a) State what direction must the magnetic field be for the wire to jump upwards.

(1 mark)

- Into the page

(b) Calculate the initial speed of the wire as it leaves the mercury.

(3 marks)

$v^2 = u^2 + 2as$ (1)

$0 = u^2 + (2)(-9.8)(0.35)$ (1)

$u = 2.62\ ms^{-1}$ (1)

(c) Calculate the acceleration of the wire while it is still in contact with the mercury. If you could not calculate an answer for (a) use 3.42 ms^{-1}.

(3 marks)

$$v^2 = u^2 + 2as \quad (1)$$

$$2.62^2 = 0^2 + (2)(a)(0.025) \quad (1)$$

$$a = 137\ ms^{-2} \quad up$$

(0.5) (0.5)

(d) Calculate the magnitude of the force on the wire.

(3 marks)

$$F = ma \quad (1)$$

$$= (5.40 \times 10^{-5})(137) \quad (1)$$

$$= 7.40 \times 10^{-3} N \quad (1)$$

(e) Calculate the current flowing through the wire.

(3 marks)

$$F = I\ell B \quad (1)$$

$$7.40 \times 10^{-3} = (I)(0.15)(6.50 \times 10^{-3}) \quad (1)$$

$$I = 7.59\ A \quad (1)$$

(f) Calculate the resistance of the wire (assume the resistance in all other parts of the circuit is negligible).

(3 marks)

$V = IR$ (1)

$1.5 = (7.59)(R)$ (1)

$R = 0.198\ \Omega$ (1)

Question 6 **(16 marks)**

A drawbridge is a bridge that can be raised to allow tall boats to pass underneath it. The bridge span can be split into two halves and each half lifted separately as shown in Figure 1 below or it can be raised as a single span, as shown in Figure 2.

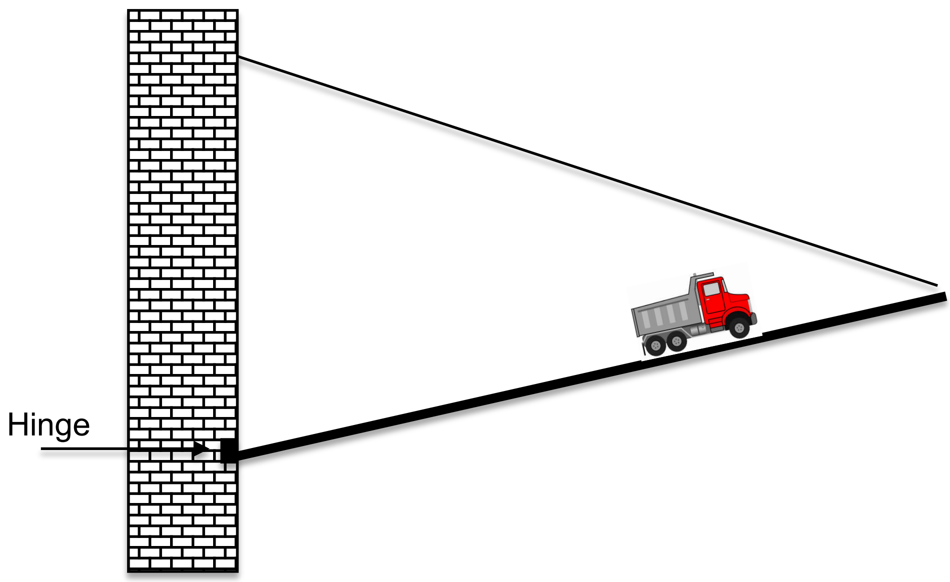
Figure 1 – Drawbridge, span raised as two halves.

Figure 2 – Drawbridge span raised as one.

A truck drives onto a uniform drawbridge that spans 40.0 m and has a mass of 12.0×10^3 kg. The drawbridge is designed so that the entire span is raised together (as in Figure 2).

The truck driver not realising the bridge is about to be raised, stops his truck, of mass 30 000 kg, three-quarters of the way across the span in a safety lane.

The bridge can be raised to an angle of 30.0° above the horizontal, as shown in the diagram below, (at this point the angle between the bridge and the cable is 70.0° and the angle between the horizontal and the cable is 30.0°).



(a) Calculate the magnitude of the tension in the cable when the drawbridge is held in this position.

(3 marks)

$$\Sigma\tau = 0 \;(0.5)\quad \tau = rF \;(0.5)$$

$$\Sigma\tau_{cw} = (20)(12.0\times10^3\times9.8)(\sin 60) + (30)(30000\times9.8)(\sin 60) \;(0.5)$$

$$\Sigma\tau_{ccw} = (40)(T)(\sin 70) \;(0.5)$$

$$2036892 + 7638344 = 37.59T$$

$$T = 257\ kN \;(1)$$

(b) Calculate the force that the hinge of the drawbridge exerts on the span.

(6 marks)

$$\Sigma F = 0 \;(1)$$

$$\Sigma F_V = T\sin 40 + F_{wallv} - m_{bridge}g - m_{truck}g = 0 \;(0.5)$$

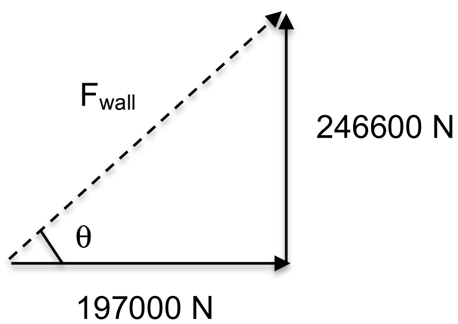
$$\Sigma F_H = F_{wallH} - T\cos 40 = 0 \;(0.5)$$

$$F_{wallv} = -(257\times10^3)(\sin 40) + (12.0\times10^3\times9.8) + (30000\times9.8)$$

$$= 246400N \;(0.5)$$

$$F_{wallH} = (257\times10^3)(\cos 40)$$

$$= 197000\ N \;(0.5)$$



$$F_{wall} = \sqrt{(246600^2 + 197000^2} \;(0.5)$$

$$= 3.16\times10^3\ N$$

$$\tan\theta = \frac{opp}{adj} = \frac{246600}{197000} \;(0.5)$$

$$\theta = 51.3^\circ$$

F_{wall} = 3.16 kN at 51.3° above the horizontal (to the right) (2)

'Phew' says the truck driver, 'I am glad that I stopped so far from the hinge. If I was closer to the hinge, the cable might not have been able to provide enough tension to hold the bridge span up'.

(c) Is the truck driver correct in his statements about the situation? Explain your reasoning.

(4 marks)

- No
- The bridge span is held up when it is in static equilibrium i.e
- As the bridge moves further away from the hinge, the radius increases, so by t=rfsin0, the t cw increases.
- Tccw must also increase but as theta and r cannot change, T would increase

(d) If the friction between the tyres and the drawbridge is 238 kN calculate the angle to which the drawbridge could be raised before the truck starts to slip.

(3 marks)

$$\Sigma F = ma$$

$$\Sigma F = mg\sin\theta - F_f = 0$$ (1)

$$(30000 \times 9.8)(\sin\theta) - 238 \times 10^3 = 0$$ (1)

$$\theta = 54.0^\circ$$ (1)

End of Section Two

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YEAR 12
PHYSICS STAGE 3
MID YEAR EXAMINATION 2014

Section Three: Comprehension

This section has **two (2)** question. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **40 minutes**.

NAME:______________________________________

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Question 1 **(16 marks)**

Planetary Formation and Magnetic Fields

The four inner planets, in our solar system, see Figure 1, are known as terrestrial planets because they resemble the Earth (in Latin, *terra*). They all have hard, rocky surfaces with mountains, craters, valleys and volcanoes and you could stand on the surface of any one of them - although you would need a protective spacesuit on Mercury, Venus or Mars!

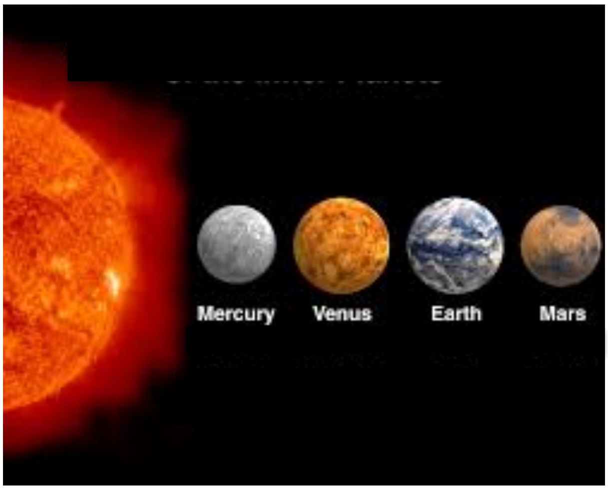


Figure 1 – The Sun and the four inner planets

Formation of the Terrestrial Planets

Processes in the Big Bang and within ancient stars produced the ingredients to make our solar system. But given these ingredients, how did the Sun and planets form?

A key piece of evidence about the origin of the solar system is that all the planets orbit the Sun in the same direction and in nearly the same plane. This suggested that our entire solar system formed from a vast, rotating cloud of hydrogen gas and interstellar dust called a molecular cloud.

Each part of the molecular cloud exerted a gravitational attraction on the other parts and their mutual gravitational pulls tended to make the molecular cloud contract. As it contracted, the greatest concentration of matter occurred at the centre of the cloud forming a dense region called the protosun. The remainder of the cloud formed a swirling disk called a solar nebula, see Figure 2.

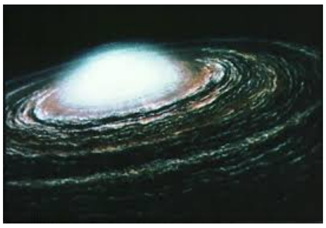


Figure 2 – An artisist impression of a protosun and solar nebula

The density of material in the solar nebula was low, as was the pressure of the nebula's gas. If the pressure is sufficiently low, a substance cannot remain in the liquid state, but must end up as a solid or a gas. As the solar nebula underwent contraction to form the protosun, the protosun was more luminous (brighter) than our present day Sun and it heated the inner part of the solar nebula to more than 2000 K. At these temperatures substances such as water, methane and ammonia became gases while rock-forming substances became solid. Of these materials, iron, silicon, magnesium and sulfur were particularly abundant, followed closely by aluminium, calcium and nickel.

Small chunks would have formed in the inner part of the solar nebula from collisions between neighbouring dust grains. Initially electric forces held them together. Over a few million years, these chunks coalesced (combined) into roughly 10^9 asteroid-like objects called planetesimals with diameters over 1 km or so. The gravitational attraction between the planetesimals caused them to collide and to coalesce into larger objects called protoplanets, which were roughly the size and mass of our Moon. This accumulation of material to form larger and larger objects is called accretion. During the final stage, these Moon sized protoplanets collided to form the terrestrial planets.

(a) Explain why it would not have been possible for the (orbiting) planets to form if the molecular cloud and later the solar nebula had not been rotating.

(2 marks)

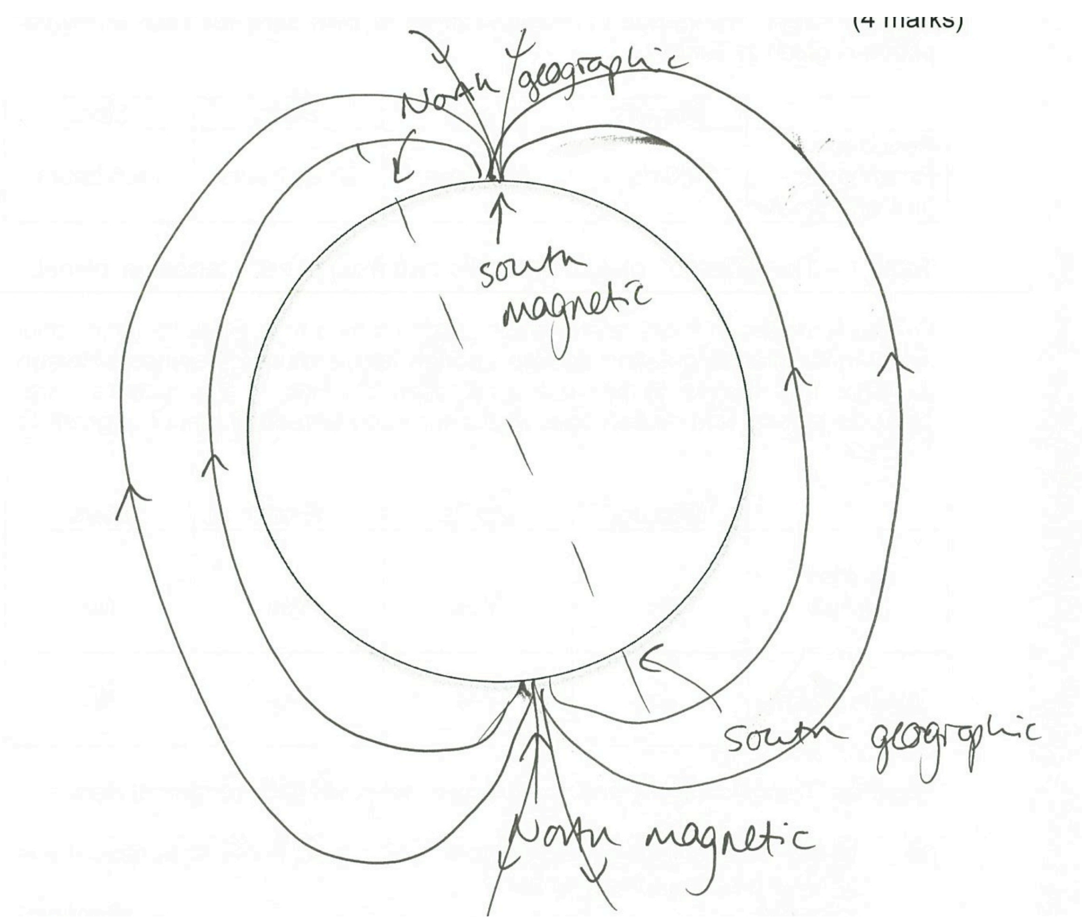
- With the molecular cloud and solar nebula rotating the velocity of the planets is perpendicular to the gravitational force between the planets and the protosun and protoplanets, which leads to circular motion
- If the molecular cloud and solar nebula were not rotating, the gravitational force would just pull the protoplanets into the protosun.

As the protoplanets grew, they were heated by the violent impacts of planetesimals as well as the decay of radioactive elements such as uranium, which caused melting. This meant the terrestrial planets began their existence as spheres of at least partially molten rock. Material was free to move within these molten spheres, so the denser iron-rich minerals sank to the centre of the planets while the less dense silicon rich materials floated to the surface. In this way the terrestrial planets developed dense iron cores.

All four terrestrial planets have magnetic fields of differing strengths.

(b) On the diagram below sketch a diagram showing the magnetic field structure of the Earth. Include the location of the geographic and magnetic North and South poles.

(4 marks)



1 mark – shape
1 mark – tilt of axis
2 marks – correct labels for North and South geographic and magnetic poles.

Planets do not have giant bar magnets in their cores to produce their magnetic fields but most have electrically conductive liquids in their planetary interiors.

(c) Explain how an electrically conductive liquid could be produced in a planetary interior.

(2 marks)

- As the particles of molten rock move past one another They are charged by friction.
- Losing or gaining electrons and becoming electrically conductive.

The electrically conductive liquid in a planet's interior can be made to swirl about if the planet is conducting quickly enough. The faster a planet rotates, the stronger the associated magnetic field. This is called the magnetic dynamo effect. The period of rotation (about its own axis) for each terrestrial planet is given in Table 1.

	Mercury	Venus	Earth	Mars
Period of Rotation (in Earth time)	58.8 days	243 days	23.93 hours	24.6 hours

Table 1 – The period of rotation (about its own axis) of each terrestrial planet.

For the terrestrial planets, plate tectonics also play a role. Plate tectonics cool the planet's mantle creating a large enough temperature difference between the core and mantle to produce convection currents in the metallic core. Tectonic activity and molten core status for each terrestrial planet is given in Table 2.

	Mercury	Venus	Earth	Mars
Tectonic Activity	No	Yes	Yes	No
Molten Core	Yes	Yes	Yes	No

Table 2 – Tectonic activity and molten core status for each terrestrial planet

(d) State the two effects/phenomena you would expect a planet to have if it is to have a strong magnetic field.

(2 marks)

- A short period of rotation
- A molten core and tectonic activity

(e) Based only on the information in Table 1, which planet would you expect to have the smallest magnetic field? Explain your reasoning.
(3 marks)

- Venus
- Venus has the longest period of rotation
- Therefore the magnetic dynamo effect will be smallest and magnetic field will be weaker.

(f) Based only on the information in Table 2, which planet would you expect to have the smallest magnetic field? Explain your reasoning
(3 marks)

- Mars
- No molten core and no tectonic activity
- Mars has no convection currents, so there is no electrical current and no magnetic field (which would be associated with the electrical current).

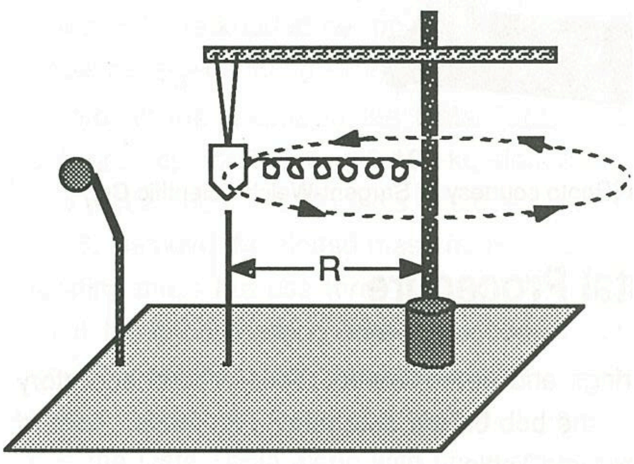
Question 2 **(20 marks)**

A group of students use a hand-operated centripetal force apparatus to verify that the centripetal force acting on a mass *m* moving in a circle of radius *r* at constant speed *v* is given by equation ①;

$$F = \frac{mv^2}{r} \quad - ①$$

To verify this relationship they took measurements to determine the value of F_C.

The hand-operated centripetal force apparatus, as shown in the diagram below, has a bob with a pointed tip at the bottom, which is suspended from a horizontal rotating bar. The bob also has a spring hooked between the side of the bob and the central rotating shaft.



For a given mass of the bob and a particular spring, the bob will rotate at a set radius for only one particular rotational period (T). The pointer is set to a pre-chosen radius *r* and then the system is rotated (by twirling the rotating shaft between the thumb and first finger). The bob will pass over the position of the pointer at the pre-chosen radius for only **one** particular rotation period.

(a) State what is providing the centripetal force in this experiment. (1 mark)

- The tension in the spring

When the rotation rate was achieved the total time for 25 complete revolutions was measured.

The students were only given one spring and radius but were able to vary the mass of the bob by placing slotted masses onto the top of the bob.

Measurements made by the students are given below:

Mass of bob = 4.20 x 10^2 g

Mass of each slotted mass = 50.0 g

Radius = 15.02 cm (measured with a ruler with 1 mm intervals)

Rotating Mass	T(s) for 25 revolutions Trial 1	T(s) for 25 revolutions Trial 2	T(s) for 25 revolutions Trial 3	T(s) for 25 revolutions Average	T(s) for 1 revolution average
Bob	25.21	25.14	25.22	25.19	1.01
Bob + 1 mass	28.67	28.63	28.61	28.64	1.15
Bob + 2 masses	28.05	28.10	28.01	28.05	1.12
Bob + 3 masses	29.36	29.32	29.35	29.34	1.17
Bob + 4 masses	30.62	30.61	30.72	30.65	1.23

(b) Explain why the students recorded the period for a number of revolutions rather than just one?

(2 marks)

- There is random error in the reaction time in pressing the stopwatch.
- By recording the period for 25 revolutions, and then calculating the period for one revolution the effect of the random error is reduced (by a factor of 25).

(c) Process the data in the table above to give the average time for one revolution. You may use both columns, but do not have to.

(2 marks)

-0.5 marks for each incorrect column labels and units (up to 1 mark)
-0.5 mark for each incorrect sig figs (up to 1 mark)
-0.5 marks for each incorrect value (up to 1 mark

(d) Given that $v = \frac{2\pi r}{T}$, rewrite equation ①, showing any intermediary steps, to give a formula for F_c in terms of mass of the bob, radius of the bob's path and the period of revolution of the bob (i.e m, r and T).

(2 marks)

$$F_c = \frac{mv^2}{r} \qquad v = \frac{2\pi r}{T}$$

$$F_c = \frac{m(\frac{2\pi r}{T})^2}{r} \quad ①$$

$$F_c = \frac{4\pi^2 mr}{T^2} \quad ①$$

(e) Process the data in the table from the previous page so that you are able to plot a graph of 'T^2 vs m'.

(2 marks)

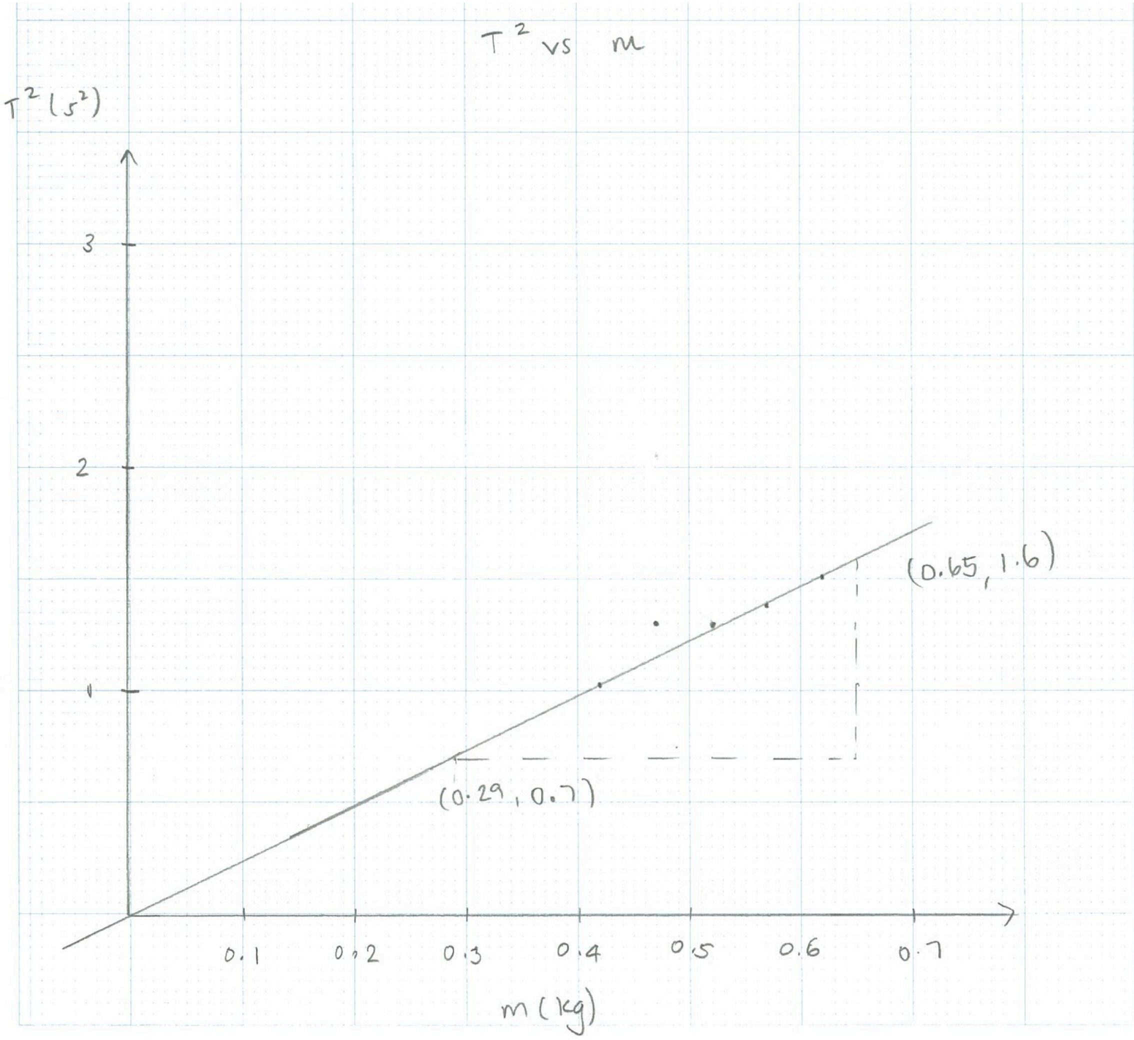
T^2 (s^2)	m (kg)
1.02	0.420
1.32	0.470
1.25	0.520
1.37	0.570
1.51	0.620

-0.5 marks for each incorrect column labels and units (up to 1 mark)
-0.5 marks for each incorrect sig figs (up to 1 mark)
-0.5 marks for each incorrect value (up to 1 mark)

(f) Plot a graph of ‘T^2 vs m’ on the graph paper provided.

(5 marks)

Title – 1 mark
Axes labels and units – 1 mark
Linear scale – 1 mark (-0.5 mark for no axes or no arrows on axes)
Correct points plotted – 1 mark
Line of best fit – 1 mark



(g) Calculate the gradient of your graph.

(3 marks)

triangle – 1 mark

$$gradient = \frac{1.6 - 0.7}{0.65 - 0.29}$$

$$= 2.50\ s^2 kg^{-1}$$

(h) Use the gradient of your graph to determine the value of F_c.

(3 marks)

$$gradient = \frac{T^2}{m} = \frac{4\pi^2 r}{F_c}$$

$$F_c = \frac{(4\pi^2)(0.1502)}{2.50}$$

$$= 2.37\ N$$

End of Section Three

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