CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12

ATAR PHYSICS

MID YEAR EXAMINATION 2016

PLACE STICKER HERE

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2		
3		
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

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	13	13	50	50	28%
Section Two: Problem-Solving	6	6	90	94	52%
Section Three: Comprehension	2	2	40	36	20%
				Total	180

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.

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YEAR 12
ATAR PHYSICS
MID YEAR EXAMINATION 2016

Section One: Short Response

This section has **thirteen (13)** questions. Answer **all** questions. Write your answers in the space provided.

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

Question 1 **(4 marks)**

A boy accidentally kicks a soccer ball along level ground at 2.00 ms^{-1} towards the edge of a small cliff that is 9.00 m high. Calculate the distance the soccer ball will land from the base of the vertical cliff face.

$s_v = u_v t + 1/2at^2$ 0.5

$9 = 0 + 4.9\ t^2$ 0.5

$t = 1.36$ s 1

$s_H = v_H \times t$ 0.5

$s_v = 2.00 \times 1.36$ 0.5

$s_v = 2.72$ m 1

Question 2 **(4 marks)**

A student determines the time for 10 revolutions of a 0.200 g mass, being whirled horizontally on the end of a nylon thread of 0.500 m length, is exactly 8.00 s. Calculate the centripetal acceleration of the mass.

$t = 8.0/10 \quad = 0.800$ s

$v = s/t \quad = 2\pi r/T$ 0.5

$= 6.28 \times 0.500/0.800$ 0.5 $= 3.93$ m/s 1

$a_c = v^2/r$ 0.5

$=3.93^2/0.5$ 0.5

$a_c = 30.9\ ms^{-2}$ towards centre of circle 1

Question 3 **(3 marks)**

Calculate the strength of the magnetic field a distance of 5.00 cm from a conducting wire that has a current of 3.50 A flowing through it.

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$ ①

$$B = \frac{1.26\times10^{-6}}{2\pi}\frac{3.50}{0.05}$$ ①

$$B = 1.40\times10^{-5}\,T$$ ①

Question 4 **(4 marks)**

A 10.0 m length of wire being used as an electric fence, is strung horizontally between two posts where the earth's magnetic field is 5.50μT at 66.0˚ above the horizontal.

Calculate the force experienced by the wire when a 3.00 A DC real current is turned on and flows east to west along the wire.

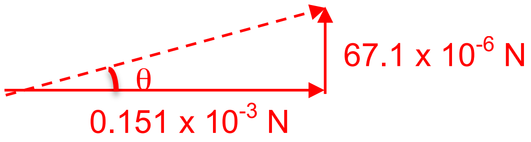
$$F = I\ell B$$ ①

$$F = (3)(10)(5.50\times10^{-6}\times\cos 66)$$

$=67.1 \times 10^{-6}$ N (0.5) up (0.5)

$$F = (3)(10)(5.50\times10^{-6}\times\sin 66)$$

$=0.151 \times 10^{-3}$ N (0.5) South (0.5)



$$F = \sqrt{(67.1\times10^{-6})^2 + (0.151\times10^{-3})^2}$$

$= 1.65 \times 10^{-4}$ N

$$\tan\theta = \frac{opp}{adj} = \frac{67.1\times10^{-6}}{0.151\times10^{-3}}$$

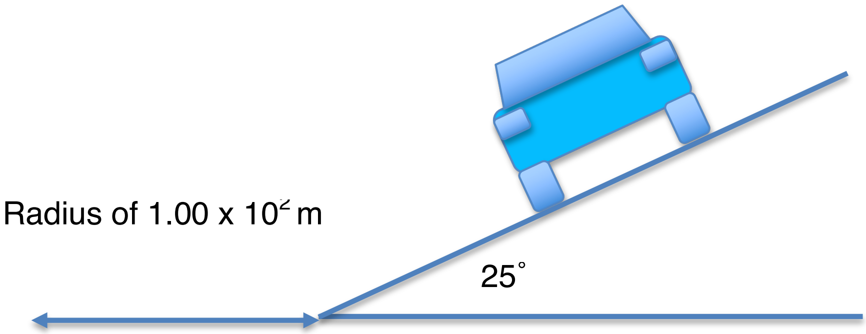
$= 24.0°$

F = 1.65×10^{-4} N, 24.0° above the horizontal in a southerly direction. ①

Appropriate justification required to obtain full marks.

Question 5 (4 marks)

A car of mass 1.00 x 10^3 kg is driving around a banked curve that has a radius of 1.00 x 10^2 m as shown in the diagram below.



Calculate the speed the car requires to negotiate the curve as shown, with no reliance on friction.

$$\Sigma F = ma$$ ①

$$\Sigma F_v = F_N cos\theta - mg = 0$$ (0.5)

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

$$\frac{F_N \sin\theta}{F_N \cos\theta} = \tan\theta = \frac{mv^2}{rmg}$$

$$\tan\theta = \frac{v^2}{rg}$$ (0.5)

$$v = \sqrt{rg}\tan\theta \qquad v = \sqrt{100 \times 9.8}\tan 25$$ (0.5)

$$v = 21.4\, ms^{-1}$$ ①

Question 6 (4 marks)

Calculate the force that exists between two protons that are separated by a distance of 1.25 x 10^{-7} m in a vacuum.

$$F = \frac{1}{4\pi\varepsilon_0} \times \frac{q_1 \times q_2}{r^2}$$ ①

$$F = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{(1.60 \times 10^{-19})^2}{(1.25 \times 10^{-7})^2}$$ ①

$$F = 1.47 \times 10^{-14} N$$ ① Repulsion ①

Question 7 **(5 marks)**

A 5.00 x 10^2 kg satellite orbits the Earth about the equator once every 90.0 minutes. Calculate the height of the satellite above the Earth's surface.

$F_c = \frac{mv^2}{r}$ 0.5 $F_g = G\frac{m_1 m_2}{r^2}$ 0.5

$F_c = F_g$ 0.5 $v = \frac{2\pi r}{T}$ 0.5

$(r+h)^3 = \frac{GMT^2}{4\pi^2}$ 1

$(r+h)^3 = \frac{6.67\times 10^{-11}\times 5.97\times 10^{24}\times 5400^2}{4\times\pi^2}$ 0.5

$(r+h)^3 = \sqrt[3]{2.95 * 10^{20}}$

$(r+h) = 6.65\times 10^6 m$

$r = (6.65\times 10^6 - 6.38\times 10^6)$ 0.5

$r = 2.70\times 10^5 m$ 1

Question 8 **(3 marks)**

Protons experience a force of 1.50 x 10^{-14} N when they are fired at right angles into the magnetic field of a 3.13 x 10^{-1} T cyclotron. Determine the speed at which the proton enters the field.

$F = Bqv$

1

$v = \frac{1.50\times 10^{-14}}{3.13\times 10^{-1}\times 1.60\times 10^{-19}}$ 1

$v = 3.00\times 10^5\ ms^{-1}$ 1

Question 9 **(4 marks)**

A Formula 1 car of 702 kg mass, travels around a level circular curve with a radius of 300 m at a speed of 180 km per hour. Calculate the force provided by friction at the road surface.

$$F_c = F_f = \frac{m\,v^2}{r}$$ ①

$$F_f = \frac{702\,(\frac{180}{3.6})^2}{300}$$ ①

$$F_f = \frac{17550}{300}$$

$F_f = 58.5\,N$ ① towards the centre of the curve ①

-1 no direction specified

Question 10 **(4 marks)**

When a tennis ball is hit straight up into the air, its flight is affected by air resistance.

(a) Will the upward part of the flight take a longer, a shorter or the same time as the downward part of the flight? Circle the correct response below.

(1 mark)

Longer [✓ shorter] same time

(b) Explain your justification for the response selected.

(3 marks)

- Air resistance is proportional to speed of the projectile (also accept v^2).
- On the path up, the acceleration due to gravity and air resistance will be in the opposite direction to the velocity. The velocity of the ball will decrease at a greater rate than if no air resistance were present. (0.5)
- On the path down, the acceleration due to gravity is in the opposite direction to the air resistance. The ball will accelerate downwards, as it does, its velocity will increase – but so will the amount of air resistance. (0.5)
- The velocity on the path down will always be less than the velocity on the path up. Decrease in velocity will mean an increase in time taken on the path down.

Question 11 **(4 marks)**

A student makes a simple coil by looping an insulated wire 20 times around a glass that has a diameter of 10.0 cm. He then places it horizontally into a uniform vertical magnetic field 0f 0.200 T and connects the ends of the wire to a voltmeter.

Calculate the EMF generated when he withdraws the coil from the field in a time of 0.500 s.

$\phi = BA$ ①

$= 0.200 \times (\pi\ (0.10/2)^2 = 1.57 \times 10^{-3}$ ①

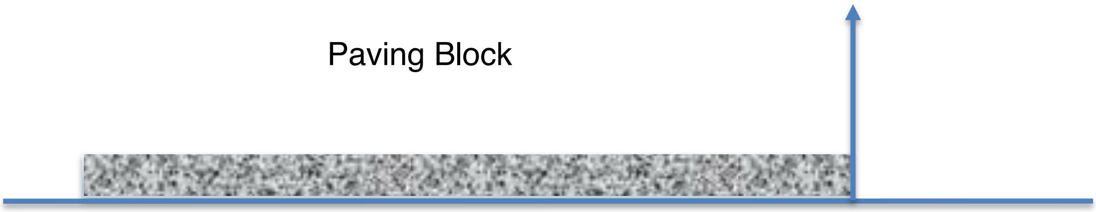
$$\varepsilon = \frac{-N(\phi_2 - \phi_1)}{\Delta t}$$ ①

$$\varepsilon = \frac{-20(1.57 \times 10^{-3} - 0)}{0.500}$$

$\varepsilon = 6.28 \times 10^{-2}\ V$ ①

Question 12 **(4 marks)**

A man wants to replace his old garden paving blocks and needs to raise each one by lifting at one end.



The uniform square blocks each have a mass of 18.0 kg and sides of length 85.0 cm. Calculate the minimum force necessary to rotate one of the paving blocks on one edge to lift it up from the ground.

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

Take pivot as LH edge of paver

$\tau_{cw} = (18.0 \times 9.8)\times\left(\frac{0.85}{2}\right)$ (1)

$\tau_{ccw} = (0.85)(F)$ (1)

$F = 88.2\ N$ Upwards

(0.5) (0.5)

Question 13 **(3 marks)**

A fireman is attempting to put a fire out in an apartment building using a fire hose that projects water at an initial speed of 30.0 ms^{-1}. Calculate the angle he must aim the fire hose to get water through a window 30.0 m above the ground from a distance of 50.0 m away, taking the water 2.91 s to reach the window.

$u_h = 30\cos\theta$

$s = u_h t$ (1)

$s = 30\cos\theta\ t$

$\cos\theta^{-1} = 30/2.91$ (1)

$\theta = 55.0^{\circ}$ (0.5) above the horizontal (0.5)

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:_______________________________________

Question 1 **(13 marks)**

In July 1969, the Apollo 11 mission involved the first landing of a manned space vehicle on another part of the Solar System. The Command Module orbited the Moon once every 119 minutes whilst the Lunar Module was on the Moon's surface. The Command Module's orbit was 1.10 x 10^2 km above the surface of the Moon.

(a) Calculate the circumference of the orbit of the Command Module.

(3 marks)

$C = 2\pi r$ ①

$C = 2\pi(1.74 \times 10^6 + 1.10 \times 10^5)$ ①

$C = 1.16 \times 10^7 m$ ①

(b) Calculate the magnitude of the orbital velocity of the Command Module.

(3 marks)

$$v = \frac{s}{t} = \frac{C}{t}$$

$$v = \frac{s}{t} = \frac{1.16 \times 10^7}{119 \times 60}$$ ①

$v = 1.62 \times 10^3\ ms^{-1}$ ①

(c) Use the data provided to calculate the mass of the Moon assuming the Command Module was in a circular orbit.

(4 marks)

$$\frac{m_{module} v^2}{r} = \frac{G M_{moon} m_{module}}{r^2}$$ ①

so $M_{moon} = \frac{rv^2}{G}$ ①

$$M_{moon} = \frac{(1.85 \times 10^6 1.62 \times 10^3)^2}{6.67 \times 10^{-11}}$$ ①

$M_{moon} = 7.28 \times 10^{22}\ kg$ ①

No marks if value is taken directly from the formula and constants sheet

(d) At the end of its mission, the Lunar Module ascended from the Moon and docked with the Command Module. On docking, the combined mass was greater than just the Command Module, which had a mass of 9.98 x 10^3 kg. The docked craft remained at the same altitude above the Moon's surface as the docking procedure made no difference to the orbital speed of the increased mass of the joined spacecraft. Explain why the increased mass of the docked craft had no effect.

(3 marks)

•For a satellite (docked craft) orbiting a central mass (the Moon)

$$\frac{mv^2}{r^2} = \frac{G \times M \times m}{r^2}$$

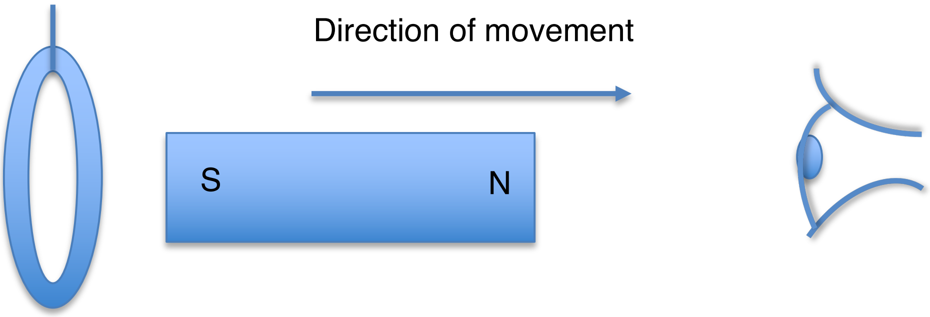
•The mass of the satellite (docked craft) cancels out as it is on both sides of the equation and rearranging the formula results in

$$v = \frac{\sqrt{G} \times M_{moon}}{(r_{moon} + altitude)^2}$$

• The orbital velocity is determined by the distance the docked craft are from the centre of mass of the moon (radius of Moon + altitude), and the Mass of the Moon and not the mass of the docked craft.

Question 2 **(7 marks)**

A bar magnet is pulled away from a circular metal ring that hangs freely from a vertical string, as shown in the diagram below.



(a) Determine the direction (clockwise or anticlockwise) of the induced current in the ring if you are looking towards the ring as shown.

(1 mark)

Anticlockwise

(b) State the type of magnetic pole (north or south) that would be set up on the side of the ring closest to the magnet.

(1 mark)

North pole

(c) Explain the formation and direction of the resulting current.

(5 marks)

- As the magnet is pulled away from the ring there is a reducing magnetic flux passing through the area of the ring
- According to Faradays Law this change in flux will generate an EMF and a resultant current will flow in the ring.
- The current flowing in a ring will generate its own magnetic field
- According to Lenz's law the direction of this current will produce a magnetic field that opposes the initial field that created it
- Thus the side closest to the magnet will establish a north pole to counteract the retreating south pole.

Question 3 **(18 marks)**

A baseball player hits a fly ball with a speed of 12.0 ms^{-1} at 60° to the horizontal, when the ball is hit initially 1.00 m above the ground. In the following disregard the effects of air resistance acting on the ball.

(a) Calculate the time it takes the ball to travel from its starting point to its maximum height.

(5 marks)

$u_v = u\ sin\theta$ ①

$u_v = 12.0\ sin60$ = 10.4 ms^{-1} upwards ①

$v = u + at$

$0 = 10.4 + (-9.8t)$ ①

$\frac{-10.4}{-9.8} = t$ ①

$t = 1.06\ s$ ①

(b) Calculate the time the ball is in the air before it hits the ground.

(4 marks)

$u_h = u\,cos\theta$

$u_h = u\,cos60$ = 6.00 ms^{-1} in direction of hit 1

$s = ut + \frac{1}{2}gt^2$ 1/2

$-1.00 = 10.4 \times t + (-\,4.9 \times t^2)$ = $(\,4.9 \times t^2) - 10.4t - 1 = 0$ 1/2

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{10.4 \pm \sqrt{(-10.4)^2 - 4\times4.9\times1.00}}{-9.8}$$ 1

t = 2.21 s 1

(c) Calculate the horizontal distance the baseball travelled at the point of hitting the ground.

(4 marks)

$s_h = u_h \times$ t 1

$s_h = 6.00 \times 2.21$ 1

$s_h = 13.3\,m$ 1

(d) Calculate the velocity of the ball just as it struck the ground.

(5 marks)

$v_v = u_v + at$

$v_v = -10.4 \ + (9.8 \times 2.21)$

$v_v = 11.3\ ms^{-1}$ ①

$v = \sqrt{}(11.3^2 + 6.00^2)$

$v = 12\ .8\ ms^{-1}$ ①

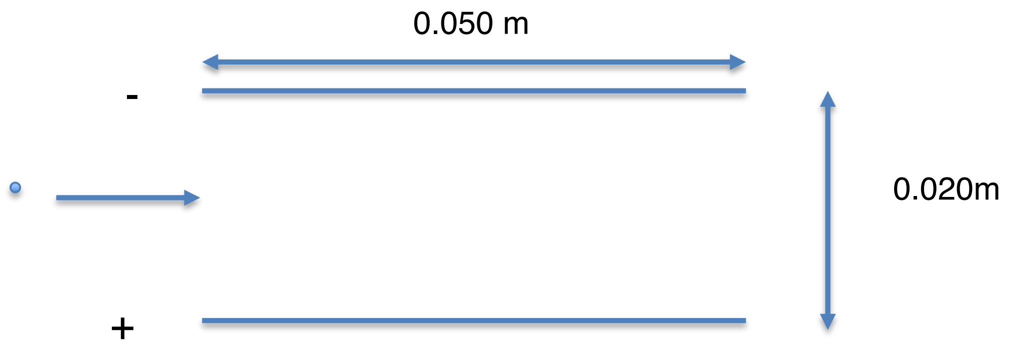
$\theta = tan^{-1}(\frac{11.3}{6.00}) =$ ①

$\theta = 62.0\ below\ the\ horizontal$

$v = 12\ .8\ ms^{-1}\ 62.0^{\circ}\ below\ the\ horizontal$ ①

Question 4 **(17 marks)**

A uniform electric field is set up between two parallel horizontal plates of length 0.050 m and a separation of 0.020 m in a vacuum. The potential difference between the plates is 10.0 V. An electron travelling at a velocity of 4.00 x 10^6 ms^{-1} parallel to the plates enters at a point midway between the plates as shown in the diagram below.



For parts (a) to (c) assume there are no gravitational effects.

(a) Using the data provided, calculate the force on the electron due to the electric field.

(5 marks)

$E = \frac{V}{d}$ ①

$E = \frac{10.0}{0.02}$

$E = 500\, Vm^{-1}$ ①

$F = Eq$ ①

$F = 500 \times 1.6\times10^{-19}$ ①

$F = 8.00 \times10^{-17} N\ towards\ the\ posative\ plate$ ①

-1 if no direction given

(b) Calculate the time taken for the electron to emerge from the plates at the other end.

(3 marks)

$s = v \times t$ ①

$t = \frac{s}{v}$

$t = \frac{s}{v} = \frac{5.00 \times 10^{-2}}{4.00 \times 10^{6}}$ ①

$t = 1.25 \times 10^{-8}\, s$ ①

(c) Calculate the distance the electron is from the positive plate as it emerges from the electric field.

(5 marks)

$s = \frac{1}{2}\, a\, t^2 \; where \; a = \frac{F}{m}$ ①

$s = \frac{1}{2} \times \frac{F}{m} \times t^2$

$s = \frac{8.00 \times 10^{-17} \times (1.25 \times 10^{-8})^{2}}{(2 \times 9.11 \times 10^{-31})}$ ①

$s = 6.86 \times 10^{-3} m$ ①

Distance from top plate (+) = (0.02/2) - 6.86 x 10^{-3} ①

Distance from top plate (+) = 3.14 x 10^{-3} m ①

(d) A dust particle with a mass of 1.00 x 10^{-12} kg enters the field shown in the same way to that of the electron. The dust particle travels through the field without any deviation to its path. Determine the charge on the dust particle.

(3 marks)

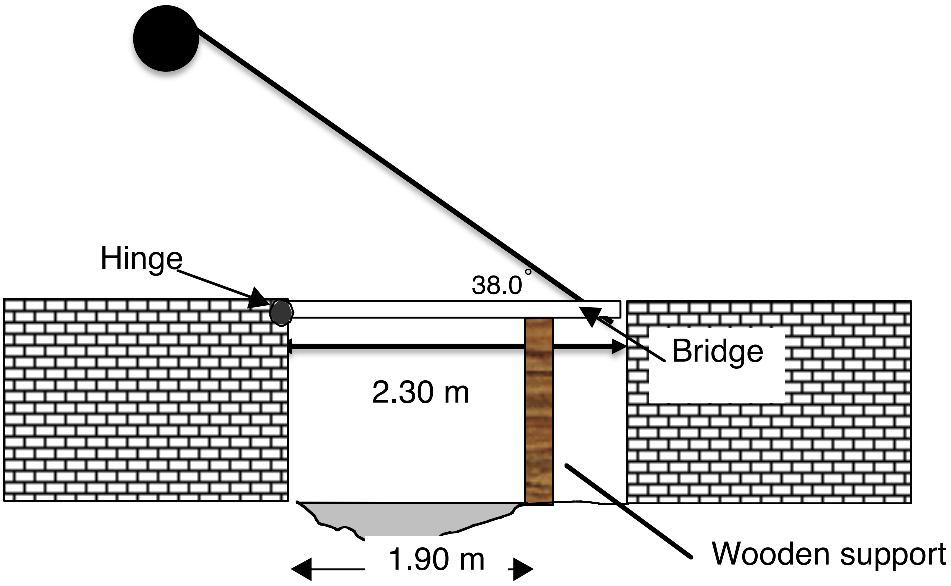
$mg = Eq$ ①

$q = \frac{9.8 \times 1.00 \times 10^{-12}}{500}$ ①

$q = +1.96 \times 10^{-14} C$ ①

Question 5 **(19 marks)**

A cantilever bridge 2.30 m long has been constructed leading from a funfair over a small stream in such a way that it can be raised by two ropes. The 150 kg bridge is held by a hinge at the left-hand side and rests on a wooden support 1.90 m from the same end. The bridge can be raised by the **two** ropes connected to the right hand end of the bridge making an angle of 38.0° to the horizontal as shown in the diagram below.



(a) The wooden support can provide a maximum force of 3.86 kN before it collapses. Calculate the maximum mass that can be placed at the centre of the bridge before the support collapses.

(5 marks)

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

$\Sigma\tau_{cw} = (1470 + mg) \times 1.15 = 1.90 \times 3.86 \times 10^3$ ①

$(1470 + mg) = \frac{1.90 \times 3.86 \times 10^3}{1.15}$ ①

$mg = 7334 - 1470$

$mg = 4.91\ kN$ ①

m = (4.91 x 10^3) /9.8 = 5.01x10^2 kg ①

(b) Calculate the tension in each rope just as the bridge is raised without any additional mass on the bridge.

(4 marks)

Take torque about the hinge

$\Sigma\tau_{cw} = \Sigma\tau_{acw}$ (1/2)

$\Sigma\tau_{cw} = 150 \times 9.8 \times 1.15 = 2.30 \times 2T\sin 38$ ①

$2\text{Tsin}38 = \dfrac{1470 \times 1.15}{2.30}$ ①

$\text{T} = \dfrac{1691}{2.3 \times 2\sin 38}$ (1/2)

$\text{T} = 597\ \text{N in each rope}$ ①

(c) Explain what will happen to the tension in the rope as the cantilever bridge is being raised higher.

(5 marks)

- As the bridge is raised the angle between the ropes and the end of the cantilever bridge increases.
- The distance between the hinge and the centre of mass of the bridge also decreases.
- The combination of this reduces the tension in the ropes.

(d) Calculate the force provided by the hinge when the angle between the bridge and each rope is 38.0° just as the bridge is being raised.

(5 marks)

$\mathbf{T\ from\ part\ (b) = 597\ N, so\ 2T = 1194\ N}$

$\boldsymbol{\Sigma F_H = 2T\cos 38}$ $\boldsymbol{\Sigma F_H = 941\ N}$ ①

$\boldsymbol{\Sigma F_V = (2T\sin 38) + (150 \times 9.8) + F_V}$ ①

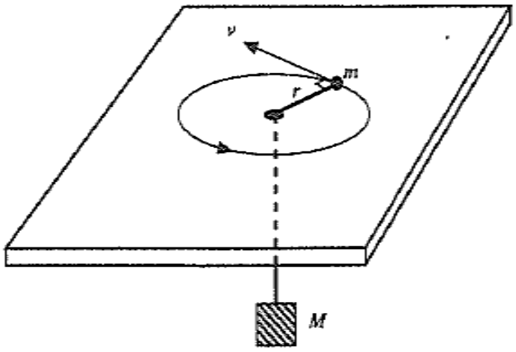
$\boldsymbol{\Sigma F_V = 735\ up + 1470\ down + F_R = 0}$ $\boldsymbol{F_R = 735\ N\ up}$ ①

$\boldsymbol{\Sigma F_{Hinge} = \sqrt{}(735^2 + 941^2)}$ $\boldsymbol{Tan\theta^{-1} = \frac{1417}{128} = 38.0^\circ}$ ①

$\boldsymbol{\Sigma F_{Hinge} = 1.19 \times 10^3\ N\ @\ 38.0^\circ\ above\ the\ horizontal}$ ①

Question 6 **(20 marks)**

A mass *m,* attached to one end of a string, moves in a circle of radius *r,* on a frictionless tabletop. The other end of the string passes through a hole in the table and is attached to another mass *M*, which hangs below the table as shown in the diagram below. (Ignore the friction that may occur between the string and the hole in the table). Once set in motion, the mass *m* continues to move in uniform circular motion with a constant speed *v*.



(a) Show that the radius of the circle is related to the masses and the period of rotation by; $r = \frac{T^2 Mg}{4\pi^2 m}$.

(3 marks)

$F_c = F_g = \frac{mv^2}{r} =$ where $v = \frac{2\pi r}{T}$ ①

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

$F_c = Mg = \frac{m \times (\frac{2\pi r}{T})^2}{r}$ $F_c = Mg = \frac{m 4\pi^2}{r}$ ① $r = \frac{T^2 Mg}{4\pi^2 m}$

In an experiment, the mass *m* is set in motion with different values of *r* and *v*, resulting in uniform circular motion, with the period *T* being measured. The results of the experiment are shown in the following table.

r (m)	*T* (s)	T^2 (s^2)
0.10	0.45	0.20
0.20	0.65	0.42
0.30	0.78	0.61
0.40	0.88	0.77
0.50	0.99	0.98

(b) Process the data such that you are able to plot a graph of *r* v T^2.

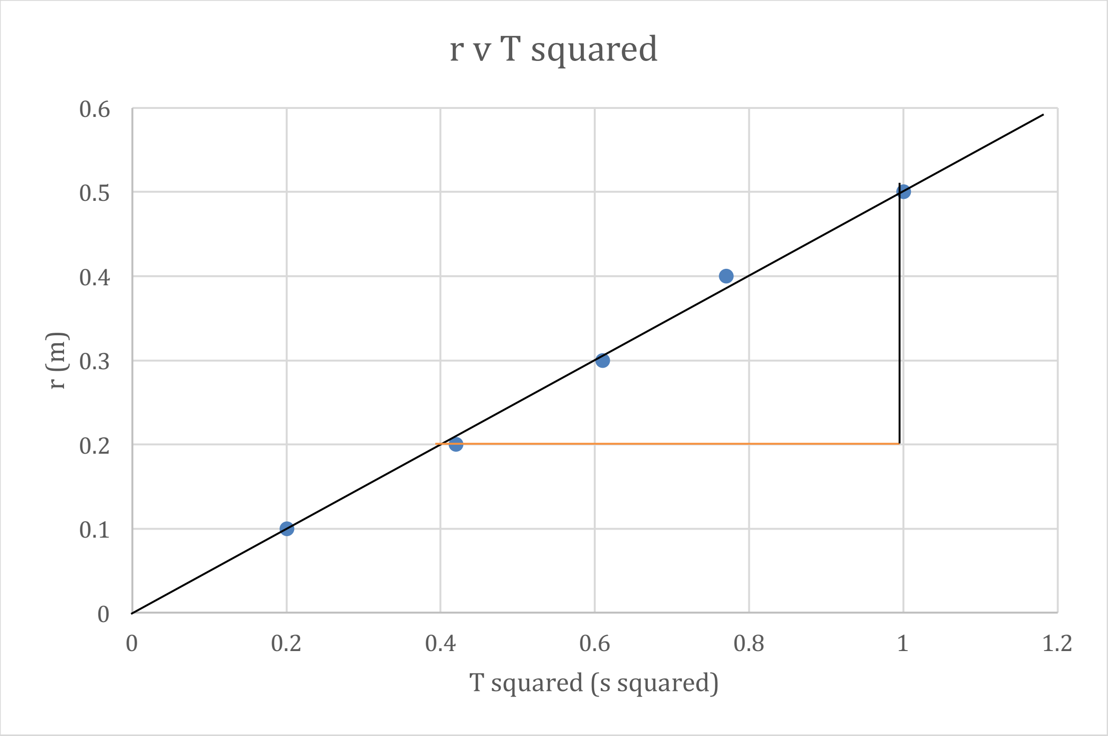
(4 marks)

Title 1 mark
Unit 1 mark
Correct values 1
Sig Figures (2 sig fig) 1

(c) Construct a graph of *r* v T^2 on the graph paper provided.

(5 marks)

Title 1
Axes labelled correctly with units 1
Linear Scale 1
Correct Data points 1
Line of best fit 1



(d) Determine the gradient of your graph.

(4 marks)

$$gradient = \frac{y_2 - y_2}{x_2 - x_1}$$

$$gradient = \frac{0.50 - 0.20}{1.0 - 0.40} = 0.50\ ms^{-2}$$

Triangle on graph 1 mark
Calculation of gradient 1 mark
Value 1 mark
Unit 1 mark

(e) Use the gradient of the graph to determine the ratio of M/m of the hanging mass to the rotating mass.

(4 marks)

$From\ r = \frac{MgT^2}{m\ 4\pi^2}$

$\frac{r}{T^2} = gradient = \frac{Mg}{m\ 4\pi^2}$ ①

$0.50\ ms^{-2} = \frac{Mg}{m\ 4\pi^2}$ ①

$0.50\ ms^{-2} \times \frac{4\pi^2}{g} = \frac{M}{m}$ ①

$\frac{M}{m} = 2.0$ ①

End of Section Two

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Section Three: Comprehension

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

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

NAME:______________________________________

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Question 1 (19 marks)

Suspension Systems

The suspension system of a car affects both the driver's control of the car and the comfort of the occupants. An important job of the suspension system is to prevent your car from shaking itself to pieces, its main function, however, is to keep the tyres in contact with the road surface.

In its simplest form the suspension system consists of two basic components.

1. Springs – these support the weight of the vehicle and move the body of the car up and over bumps in the road.
2. Shock Absorbers – these dampen the vertical motion of the springs, preventing the car from bouncing up and down.

Spring systems take two main forms, coil springs and torsion bars.

Most modern cars have coil springs. A coil spring is simply a spiral of steel rod, as shown in figure 1 below. The spring is stretched or compressed by the vertical movement of the wheels.

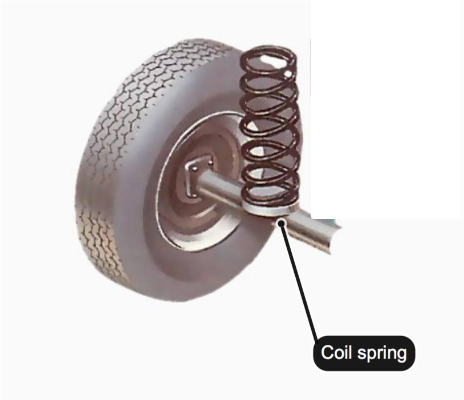


Figure 1 – coil spring attached to the wheel axle.

As the car moves over a bump, the spring is compressed. As the car moves down through a dip, the spring is stretched. This keeps the body of the car reasonably level and the wheels in contact with the road.

The spring rate (k) is a ratio used to measure how resistant a spring is to being compressed or stretched. The greater the spring rate, the greater the restoring force the spring will provide.

$$F = kx$$

where; F is the restoring force provided by the spring
k is the spring rate
x is the distance the spring is deflected (compressed or stretched) from its equilibrium position

If we have a stationary car which is loaded with fuel, oil and driver, ideally we want equal weights on each spring.

(a) For a 1200 kg car with coil spring suspension (k = 123 Nmm^{-1}) calculate the compression of each spring when the car is stationary.

(4 marks)

$W = mg$

$W = 1200 \times 9.8$

$= 11760\ N$ ①

$\frac{11760}{4} = 2940\ N$ ①

$F = kx$

$2940 = (123)(x)$ ①

$x = 23.9\ mm$ ①

Error in value of k accepted 23.9m

Trucks that carry heavy loads typically have springs with large values of k.

(b) Explain why trucks carrying heavy loads require coil springs with a large value of k.

(3 marks)

- Large value of k means there is a large restoring force for a small change in the length of the spring.
- The truck and load will have a large mass and therefore large inertia.
- A large force will be required to move the body of the truck to keep it level.

'Bottoming out' occurs when the spring reaches its maximum compression and the body of the vehicle scrapes the wheel axel.

(c) When is a vehicle is most likely to bottom out? Circle your response.

(1 mark)

Going Over a Bump On a Flat Road [✓ Going through a Dip]

(d) Explain, with the aid of a diagram, your reasoning for your answer in part (c).

(3 marks)

- When going through a dip, the force acting on the springs will be equal to the weight force plus the centripetal force causing the acceleration through the dip.
- The springs will be compressed the most at this point.
- Suitable diagram showing the sum of the forces

(e) A 5000 kg truck passes over a bump in the road of radius 20.4 m at 32.0 kmh^{-1}. Calculate the magnitude of the force exerted on the springs of the truck as it passes it over the bump.

(3 marks)

$$\sum F = ma$$

$$\sum F = F_N - mg = -ma_c$$ ①

$$F_N = mg - ma_c$$

$$a_c = \frac{v^2}{r} = \frac{(\frac{32.0}{3.6})^2}{20.4}$$ ①

$$= (5000)(9.8) - (5000)(3.87)$$

= 49000N – 19350N= 29650 N

= 2.97 x 10^4 N ①

1 mark paid if value of F_c was correct

A torsion bar is a length of steel with splined ends (splines are ridges or teeth), as shown in figure 2. Splines prevent the bars from turning in their sockets (the hole the bar fits into).

Figure 2 – Splines on the end of torsion bars.

One splined end of the torsion bar is fixed to a lever arm that forms part of the suspension, as shown in figure 3. The torsion bar rotates as the lever arm moves up and down. The other splined end of the torsion bar is fixed to the frame of the car, as shown in figure 3.

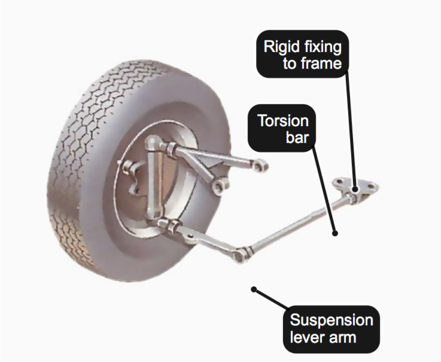


Figure 3 – Torsion bar connections.

Because the bar is unable to rotate in the sockets, the bar has to twist as the suspension lever arm moves up or down, as shown in figure 4 below.

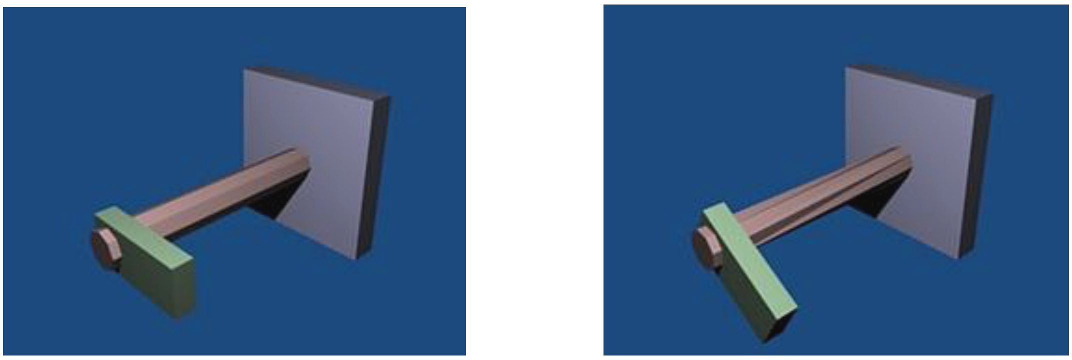


Figure 4 – A torsion bar undergoing twisting.

The steel bar's resistance to twisting provides a 'springing' effect which is the same as seen in the coil spring system. Torsion bars are used in all Formula 1 cars and many 4WDs.

A certain amount of twist must be permanently applied to the torsion bar to maintain the car's ride height.

(f) Explain why this is so.

(1 mark)

- The torsion bar needs to support the vehicles weight

(g) 4WDs often have their torsion bars over-twisted to raise the base of the car. State and explain the effect that over-twisting would have on the safety of the car when travelling around corners.

(4 marks)

- Reduces the amount of twisting the torsion bar can do
- Which limits its ability to keep the same vehicle height
- Reduces the ability of the torsion bars to maintain tyre/road contact.
- Friction from the tyres is required to maintain a circular path when turning a corner.

Question 2 **(17 marks)**

Electrical Propulsion

There are many methods of providing the necessary force to move vehicles or craft from one place to another. The most common form of propulsion we would all be aware of is the use of the chemical potential energy contained in fossil fuels as the means of moving vehicles using a combustion engine. The combustion engine converts the chemical potential energy into the kinetic energy that moves vehicles from place to place.

We are also probably aware that some propulsion systems utilise electricity to move vehicles such as trains and trams. More recently there have been efforts to produce commercial electric vehicles. Electric powered trams have been around for many years and were commonly in use in the nineteenth and early twentieth centuries. For various reasons they went out of favour and the tracks and the wiring to deliver the electricity were removed. In parts of the world, they have become quite common again, to address concerns raised about the pollution that results from a reliance on the combustion engine.

Many well known companies are now developing systems using less conventional forms of engines that run on electrical energy. This energy may come from converting sunlight directly into electrical energy using solar cells, or from plugging directly into mains supply to store electrical energy in banks of batteries built into the vehicle. Some propulsion systems have a combination of engines and are known as hybrids, that usually contain a fossil fuel burning engine, supplemented by an electric engine.

Figure 1 a typical Melbourne tram

Mass transport systems using electricity are quite common. Trains and trams are connected to an electrical grid that supplies voltage and a current (usually DC) to propel the vehicle using a motor. This is the basic form of electromagnetic propulsion (EMP), the principle of accelerating an object by the utilisation of a flowing electric current and interaction of magnetic fields. The electric current is used to either create an opposing magnetic field or to charge a fluid, which can then be repelled.

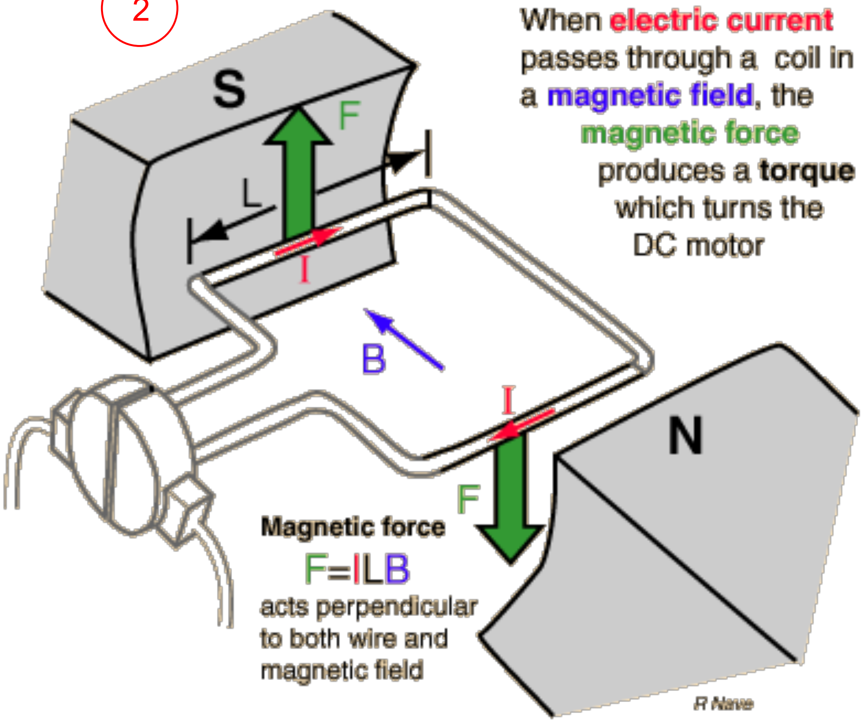
When current flows through a conductor in an external magnetic field, interaction between magnetic fields, can provide the necessary force to rotate the driving wheels.

(a) Explain with the aid of a diagram, how a DC motor produces a force to turn an axle connected to driving wheels.

(4 marks)

A suitable diagram showing direction of magnetic field, coil with current and force

②



When electric current passes through a coil in a magnetic field, the magnetic force produces a torque which turns the DC motor ①

①

Magnetic force $F=ILB$ acts perpendicular to both wire and magnetic field

(b) Trams are designed to go in a forward direction. It is also possible to get a tram to go in a reverse using the same driving motors. Describe what must occur for this to happen.

(1 mark)

The direction of the current through the motor needs to be reversed

Melbourne trams presently operate on 600 V using a high current. When starting the current can be around 163 A. Depending on the size and model of tram, it could could use up to 4 motors to move the tram.

(c) Calculate the initial torque provided by a single DC motor that has a coil with 250 turns of radius 0.010 m, and uses a magnetic field strength of 1.50 T when moving off from a stationary position.

(4 marks)

$\tau = Fr = BIlr$ $\tau = NBIA$ ①

$\tau = 250 \times 1.50 \times 163 \times \pi 0.01^2$ ②

$\tau = 19.2\ Nm$ ①

If incorrect area used maximum possible mark awarded was 2

(d) State two elements of the design of an ideal DC motor that would be used to propel a tram, and explain how each element **increases the efficiency** of the motor.

(4 marks)

Any suitable answer with explanation on how it affects efficiency
To increase the torque in a motor
•an increased field strength is used by including a soft iron core, or using a better or stronger magnet
• a radial magnet is used to maximize force acting on coil for longer
• or using a more efficient electromagnet to replace a radial magnet
• increase the area of the coil to increase torque
• use a brushless motor to reduce arcing

Using a split ring commutator was not an acceptable answer.

The term electromagnetic propulsion (EMP) can be described by its individual components: electromagnetic - using electricity to create a magnetic field (electromagnetism) and propulsion - the process of propelling something. One key difference between EMP and propulsion achieved by electric motors is that the electrical energy used for EMP is not used to produce rotational energy for motion; though both use magnetic fields and a flowing electrical current.

More recent applications of electromagnetic propulsion include maglev or magnetic levitation trains, magneto hydrodynamic drives for ships and submarines, military railguns and ion thrusters for low orbit satellites.

Magneto Hydrodynamic Propulsion (MHP) has the potential to be a useful invention because of its pollution free energy, noiseless operation and unique design for propelling ships and submarines using the force of electromagnetism. The system enables an interaction between electrically charged salt water and a magnetic field to propel a ship forward using a special type of engine known as a magneto hydrodynamic engine (MHD engine).

Craft propelled by these engines consist of a chamber in the hull known as a Thruster Tube. The Japanese built prototype named Yamato 1, had two Thruster Tubes, one either side of the central hull, with each containing 6 identical propulsion chambers surrounded by cooled superconducting magnets. The steps for this type of propulsion are quite simple as shown in Figure 2. A magnetic field directed upwards is created in sea water by the superconducting magnets fixed to the hull. When an electric current is sent through sea water at right angles to the magnetic field created, an electromagnetic force acts on the sea water in a direction perpendicular to both the direction of the magnetic field and that of the electric current. A propulsion force is attained as shown in Figure 2.

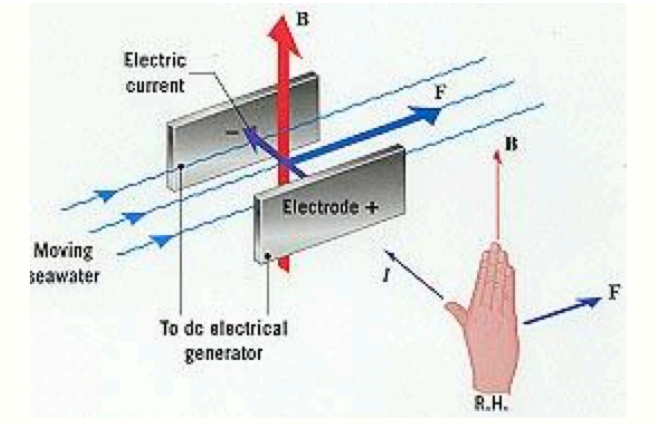


Figure 2 Force acting due to MHD Engine

Salt water continually enters the front of the thruster tubes due to the pressure differences created by the accelerated water being thrust out the rear of the tubes. Figure 3 below shows a simplified view of a MHD propelled craft

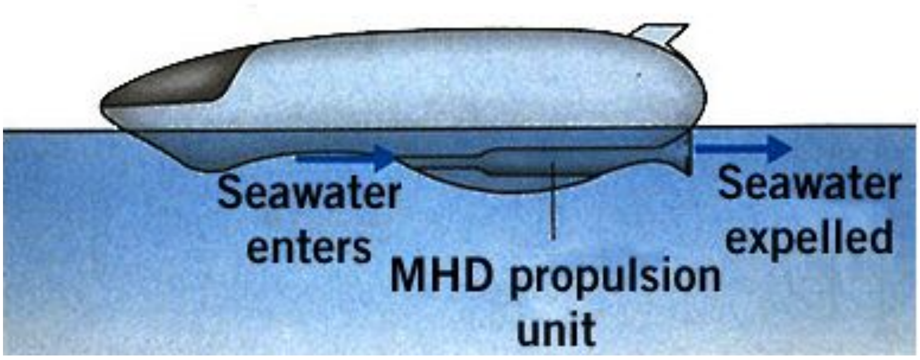


Figure 3 showing the basic design of a MHD propelled craft

(e) Calculate the maximum force that would act on a constant volume of water within a 5.40 m long propulsion unit when a current of 8.00×10^2 A is used in conjunction with a 2.50 T magnetic field.

(4 marks)

$F = BIL$ ①

$F = 2.50 \times 800 \times 5.40$ ①

$F = 1.08 \times 10^4 N$ ① backwards ①

End of Section Three
End of Examination