Mercedes College

Semester 1 Examination 2013

PHYSICS

Stage 3

Write your name here
MARKING ANSWERS
Teacher: SG PM

Time allowed for this paper

− 1 for units (max of 5)

Reading time before commencing work: ten minutes
Working time for paper: two and a half hours

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer Booklet
Formulae and Constants Sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course. Graphics calculators may **not** be used.

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.

MARKS SUMMARY

Section One (70 marks = 35%	Section Two (90 marks= 50%)	Section Three (20 marks= 15%)	Total Mark (180)	Final %

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	15	15	55	70	35
Section Two: Extended Answer	7	7	70	90	50
Section Three: Comprehension and Data Analysis	1	1	25	20	10
					100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2013.* Sitting this examination implies that you agree to abide by these rules.

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

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. 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.

5. The "Formula and Constants Sheet" may be used as required.

6. All final numerical answers should be expressed to **three** (3) significant figures and include the appropriate **units**.

Section One: Short Answer **[70 marks or 35% of total]**

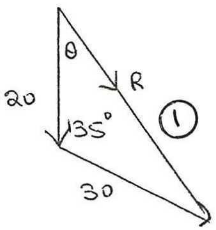
Write your answers in the spaces provided. Where appropriate show all working.

Question 1

A helicopter is flying at a constant height above the ground. The helicopter is carrying a crate suspended from a cable as shown.

The helicopter flies 20 km south. It then turns and travels south-east for a further 30 km.

(a) Determine the **magnitude** and **direction** of the resultant displacement of the helicopter. **[4 marks]**



$R^2 = 20^2 + 30^2 - 2 \times 20 \times 30 \cos 135$

$R^2 = 2.148 \times 10^3$

$\therefore R = 46.4$ km (1)

$\frac{\sin\theta}{30} = \frac{\sin 135}{46.4}$ so $\theta = 27.2°$ (1)

ie displacement = 46.4 km S 27.2° E (1)

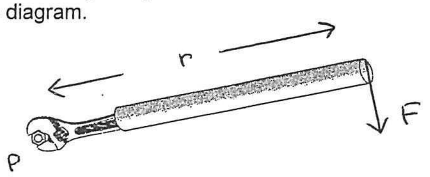
(b) The helicopter takes 15 minutes to complete the journey described above. What is the average **velocity** of the helicopter? Give your answer in units of ms^{-1}. **[2 marks]**

$v = \frac{s}{t} = \frac{46.4}{0.25} = 186\ kmh^{-1}$ (1) S 27.2° E

$= 51.6\ ms^{-1}$ S 27.2° E (1)

Question 2

A student is unable to loosen a nut by using a wrench. The student then attaches a pipe over the end of the wrench as shown in the diagram.



Using the principles of physics, explain why the student is now able to loosen the nut.

[3 marks]

The torque created $\tau = F \times r$ ①

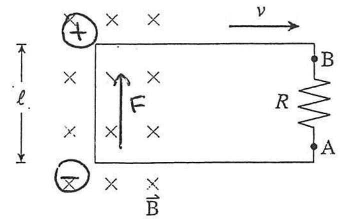
By increasing the distance from the pivot to the point where the force is applied will ① produce a larger torque ⇒ easier to loosen the nut ①

OR to produce a given torque, a smaller force (effort) will be required.

Question 3

The single rectangular loop of wire shown below is being pulled out of the 0.50 T magnetic field at a constant speed.

An EMF of 0.60 V is being generated and the length of the side "l" is 0.30 m.



What is the speed of the loop and what is the direction of the induced current through the resistor?

[4 marks]

induced EMF $= v . l . B$ ①

$v = \frac{0.60}{0.30 \times 0.50} = 4.00 \text{ ms}^{-1}$ ① ①

current will flow $B \rightarrow A$ ① (clockwise through loop)

(g) Use the **gradient** to calculate an experimental value of "g". Give the final answer to 3 significant figures.

[3 marks]

$$P^2 = \frac{4\pi^2 m_1 r}{g m_2} = \left(\frac{4\pi^2 m_1 r}{g}\right) \cdot \frac{1}{m_2}$$

ie gradient $\equiv \frac{4\pi^2 m_1 r}{g}$ ①

$$g = \frac{4\pi^2 m_1 r}{\text{gradient}} = \frac{4\pi^2 \times 0.012 \times 0.80}{4.00 \times 10^{-2}}$$ ①

$$= 9.48 \text{ ms}^{-2}$$

Range is $9.97 \longrightarrow 9.02$ ①

(h) Comment on the accuracy of the value obtained for "g".

[1 mark]

relatively close to the expected value of 9.80 ms^{-2} ①

End of Section Three

(d) To obtain a **straight line graph** it is necessary to plot P^2 against $1/m_2$.

Complete the following table.

m_2 (kg)	$1/m_2$ (kg^{-1})	Average period P (s)	P^2 (s^2)
0.020	50	1.40	1.96
0.040	25	1.05	1.10
0.060	16.7	0.79	0.624
0.080	12.5	0.74	0.548

(1) (1) (1)

[3 marks]

(e) Plot a graph to show P^2 versus $1/m_2$. **Use the graph paper provided.**

Show P^2 on the y-axis and $1/m_2$ on the x-axis. Draw a line of best fit.

[4 marks]

(1) axes (1) accuracy of plot

(1) scale (1) line of best fit

(f) Determine the gradient of the straight line obtained. Include the appropriate units.

[3 marks]

$$\text{gradient} = \frac{\text{Rise}}{\text{Run}} = \frac{1.00}{25} = 4.00 \times 10^{-2}$$ (1) (1)

$$\text{gradient} = \frac{\text{Rise}}{\text{Run}} = \frac{1.40}{35} = 4.00 \times 10^{-2}$$

gradient in range $3.80 \times 10^{-2} \longrightarrow 4.20 \times 10^{-2}$

units $s^2\,kg$ (1)

Question 4

The polar-orbiting satellite NOAA-N was launched in May 2006.

The satellite is now orbiting in a circular orbit above the Earth's surface at an altitude of 870 km.

(a) What is the orbital speed of the satellite? **[2 marks]**

$$r = 6.38 \times 10^{6} + 870 \times 10^{3} = 7.25 \times 10^{6}\ \text{m}$$

$$v^2 = \frac{GM_e}{r} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{7.25 \times 10^{6}} = 5.492 \times 10^{7}$$ (1)

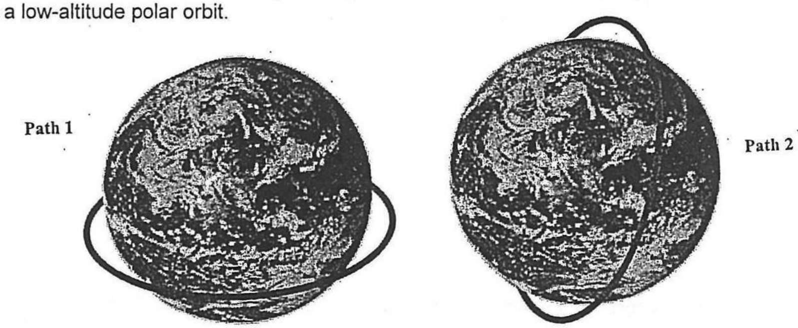
$$\therefore v = 7.41 \times 10^{3}\ \text{m s}^{-1}$$ (1)

(b) Calculate the magnitude of the acceleration due to gravity at the satellite's altitude? **[2 marks]**

$$g = \frac{GM_e}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(7.25 \times 10^{6})^2}$$ (1)

$$= 7.58\ \text{m s}^{-2}$$ (1)

The diagram below shows two circular paths around the Earth. Path 1 is not a possible satellite orbit. Path 2 is a low-altitude polar orbit.



(c) Explain why Path 1 is **not** a possible satellite orbit.

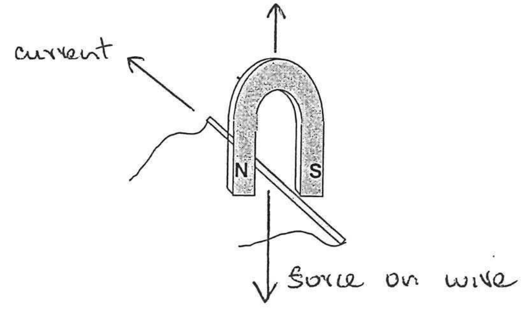
All satellites must orbit around the centre of the earth — the gravitational force exerted by the earth on the satellite provides the centripetal force needed to keep the satellite in a stable orbit. (1) (1)

[2 marks]

Question 5

A strong horseshow magnet of mass 264 g is placed over a metal rod which has a mass of 35.5 g.

Thin wires are connected to the ends of the rod and a current of 225 A is passed through.



The **magnet** just begins to lift upwards.

(a) Assume that the magnetic field between the poles is 4.00 cm wide. Calculate the strength of the magnetic field. **[3 marks]**

$F_m = W$

$ILB = mg$ ①

$B = \frac{mg}{IL} = \frac{0.264 \times 9.8}{225 \times 0.04}$ ①

ie $B = \underline{0.287\ T}$ ①

(b) What is the direction of the conventional current flowing in the wire? Show your answer on the diagram. **[1 mark]**

into the page ①

or right to left as on diagram

	Trial 1	Trial 2	Trial 3	Average
mass m_2 (kg)	Period P (s)	Period P (s)	Period P (s)	Period P (s)
0.020	1.40	1.38	1.42	1.40
0.040	1.05	1.06	1.04	1.05
0.060	0.79	0.80	0.79	0.79
0.080	0.73	0.75	0.75	0.74

②

(a) Which two important variables were controlled in this investigation? **[2 marks]**

1st variable	Same radius ① same mass m_1
2nd variable	Same surface (= Same friction) ①

(b) Is it appropriate to include the values of the period **P** from all three trials when finding the average period **P**? Explain your answer. **[2 marks]**

Yes – the results of the trials ① for each mass m_2 are very consistent ① ie there are no <u>outliers</u> in the data

(c) Determine the average period **P**. Write the values in the last column of the data table. **[2 marks]**

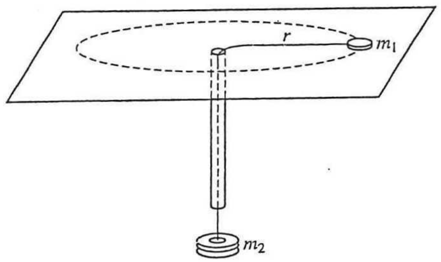
Section Three: Comprehension and Interpretation [20 marks or 15 % of total]

This section has one (1) question which must be answered in the spaces provided.

Question 23

Read the following information very carefully and then answer the questions which follow.

ESTIMATION of GRAVITATIONAL ACCELERATION



An experiment is performed using the apparatus above. A small disk of mass m_1 on a frictionless table is attached to one end of a string. The string passes through a hole in the table and an attached narrow, vertical plastic tube. An object of mass m_2 is hung at the other end of the string.

A student holding the tube makes the disk rotate in a circle of constant radius **r**, while another student measures the period **P**.

The relationship between these variables is given below:

$$P^2 = \frac{4\pi^2 m_1 r}{g m_2}$$

(Where g = acceleration due to gravity)

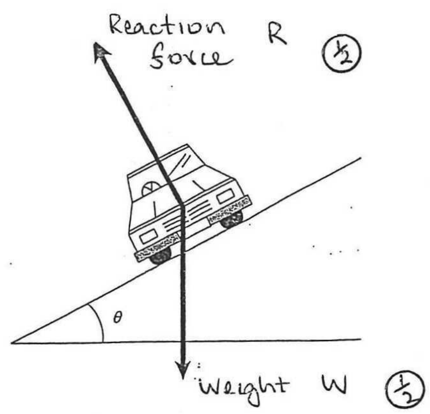
The procedure is repeated, and the period **P** is determined for four different values of m_2, where m_1 = 0.012 kg and **r** = 0.80 m.

Three trials were performed for each value of m_2 used.

The data obtained is tabulated below.

Question 6

The diagram below shows a car moving around a curved bend in a road. The surface of the road is banked at an angle θ to the horizontal.



(a) **Label** each of the forces represented by the black arrows.

[1 mark]

(b) Explain the advantage in "banking" the surface of the road.

[3 marks]

As the car moves around the curve in the road a centripetal force ($F_c = \frac{mv^2}{r}$) will be required. (1)
On a flat surface, this centripetal force can only be provided by the sideways frictional force between the tyres & road surface — this force is variable dependin on the road conditions etc. (1)
By banking the road at an angle θ the reaction force will have a horizontal component ($R\cos\theta$) acting (1) towards the centre of the curve — this force can now provide the required centripetal force.

Question 7

Patients are normally asked to remove metallic objects before being MRI scanned.

A patient in a scanner is still wearing a ring of radius 7.5 mm. The magnetic field in the scanner is 0.52 T.

(a) How much magnetic flux passes through the area of the ring when the ring is held perpendicular to the magnetic field direction?

$A = \pi r^2 = \pi (7.5 \times 10^{-3})^2 = 1.77 \times 10^{-4}\ m^2$ (1)

$\phi = BA = 0.52 \times 1.77 \times 10^{-4}$

$= 9.19 \times 10^{-5}$ Wb (1)

[2 marks]

(b) The magnetic field of the scanner is reduced to zero in 0.085 seconds. Calculate the EMF that can be induced in the ring.

$\Delta\phi = \phi_2 - \phi_1 = 0 - 9.19 \times 10^{-5} = -9.19 \times 10^{-5}$

$EMF = \frac{-N\Delta\phi}{\Delta t} = \frac{-1(-9.19 \times 10^{-5})}{0.085}$ (1)

$= +1.08 \times 10^{-3}$ V (1)

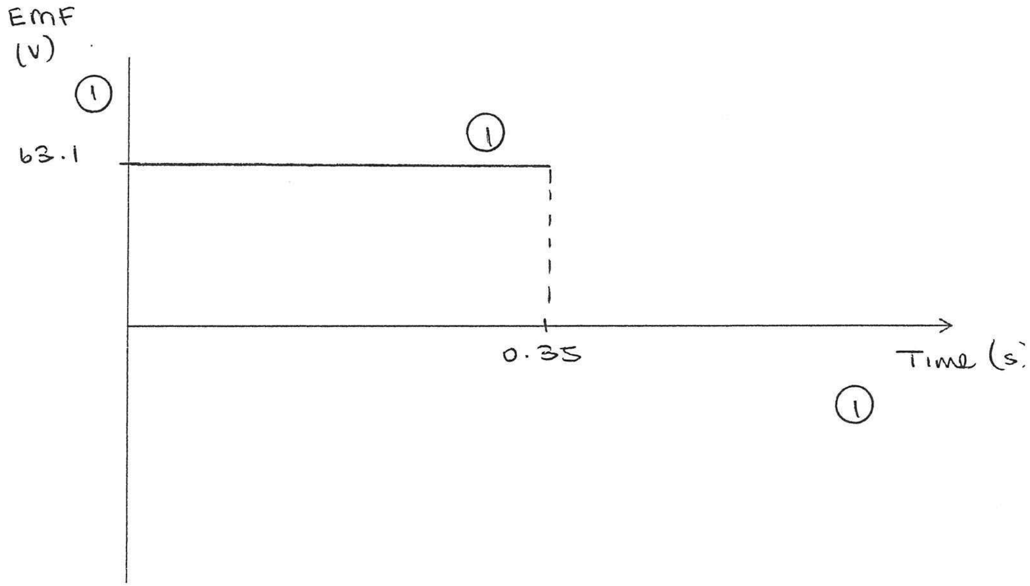
[2 marks]

(c) A ring with a different radius would have a different EMF. State **TWO** other ways in which the EMF in the ring would be **halved**.

1st way	double the time taken (1)
2nd way	halve the strength of the magnetic field (1)

[2 marks]

c) If the magnetic field changes at a **uniform** rate, sketch a graph to show how the EMF induced in the coil varies with time during the 0.35 second time interval.

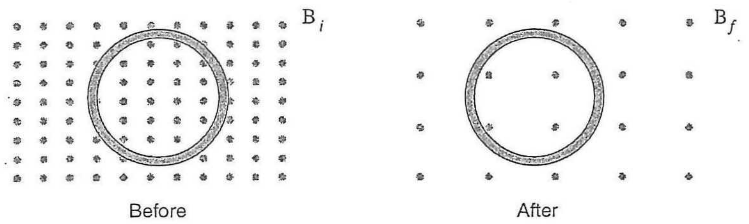


[3 marks]

End of Section Two

Question 22 [Total = 9 marks]

The "Before" diagram shows a coil at one instant in a changing magnetic field. The "After" diagram shows the same coil at a slightly later time.



a) Has the magnetic field strength increased or decreased during this time? Explain the reason for your answer.

The flux lines are further apart ①
→ strength of field has decreased ①

[2 marks]

b) Use the information in the following table to calculate the EMF induced in the coil.

Coil radius = 0.15 m
Number of turns = 250
Initial field B_i = 1.50 T
Final field B_f = 0.25 T
Time taken = 0.35 seconds

[4 marks]

$A = \pi r^2 = \pi \times 0.15^2 = 7.07 \times 10^{-2}\ m^2$ ①

$\phi_1 = BA = 1.50 \times 7.07 \times 10^{-2} = 0.106\ Wb$ ①

$\phi_2 = BA = 0.25 \times 7.07 \times 10^{-2} = 0.0177\ Wb$

$\therefore \Delta\phi = \phi_2 - \phi_1 = -0.0883\ Wb$

$EMF = -\frac{N\Delta\phi}{\Delta t} = -\frac{250(-0.0883)}{0.35}$ ①

$= +63.1\ V$ ①

Question 8

A girl of mass 25.0 kg is hanging on to a rail on a carousel (roundabout) of diameter 5.00 m. The carousel takes exactly 2.00 seconds to spin around once. The girl can hold on to the rail with a maximum force of 255 N.

Will the girl be able to hang on, or will she be forced to let go of the rail? Justify your answer with an appropriate calculation.

[4 marks]

$v = \frac{2\pi r}{T} = \frac{2\pi \times 2.50}{2} = 7.86\ ms^{-1}$ ①

$F_c = \frac{mv^2}{r} =$ ① $\frac{25 \times 7.86^2}{2.5} = 617\ N$ ①

Since maximum force $F_c > 225\ N$, she will need to let go. ①

Question 9

Susan states that there is no force due to gravity acting on the International Space Station (ISS). She says this must be so as she has seen television footage showing astronauts and equipment floating around in the spacecraft.

Rose states that this is a common misconception for orbiting spacecraft, such as the ISS.

Using the principles of physics, help Rose convince Susan that there **must** be a force due to gravity acting on the ISS.

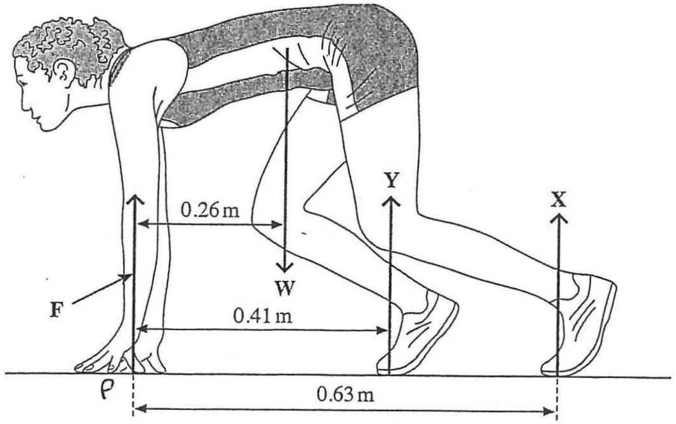
[3 marks]

The satellite is still within the Earth's gravitational field. The gravitational force provides the centripetal force required for the ISS to maintain a stable orbit around the Earth ③

ie there must be a force due to gravity acting on the ISS.

Question 10

A sprinter is shown before a race, stationary in the "set" position, as shown in the diagram below. Force **F** is the resultant force on the sprinter's finger tips. The reaction force, **Y**, on her forward foot is 180 N and her weight, **W,** is 520 N. **X** is the reaction force on her back foot.



a) By taking moments about her finger tips, calculate the force on her back foot (**X**).

[3 marks]

Taking moments about P

$\Sigma cw = \Sigma ACW$ (1)

$W \times 0.26 = (Y \times 0.41) + (X \times 0.63)$

$520 \times 0.26 = (180 \times 0.41) + 0.63X$ (1)

$135.2 = 73.8 + 0.63X$

ie $X = \frac{61.4}{0.63} = \underline{97.5 \text{ N}}$ (1)

b) Hence, calculate the magnitude of force **F**.

[3 marks]

$F_{up} = F_{down}$ (1)

$F + 180 + 97.5 = 520$ (1)

ie $F = 520 - 180 - 97.5$

$\therefore F = \underline{243 \text{ N}}$ (1)

(c) By taking moments about a suitable point, calculate the **tension** in the supporting cable.

[5 marks]

Taking moments about X

$\Sigma cw = \Sigma ACW$ (1)

$(W_1 \times 10) + (W_2 \times 17.5) = (T \sin 26.6) \cdot 35$

$(45 \times 10^3 \times 9.8 \times 10) + (440 \times 10^3 \times 9.8 \times 17.5) = (T \sin 26.6)\ 3$: (1)

$4.41 \times 10^6 + 7.546 \times 10^7 = (T \sin 26.6)\ 35$

$7.987 \times 10^7 = (T \sin 26.6)\ 35$ (1)

$T = \frac{7.987 \times 10^7}{\sin 26.6 \times 35}$ (1)

Tension $= 5.10 \times 10^6$ N (1)

(d) What happens to the tension in the cable as the truck moves further to the **right** along the platform? Explain your answer.

[3 marks]

To remain in equilibrium
$\Sigma cw = \Sigma ACW$

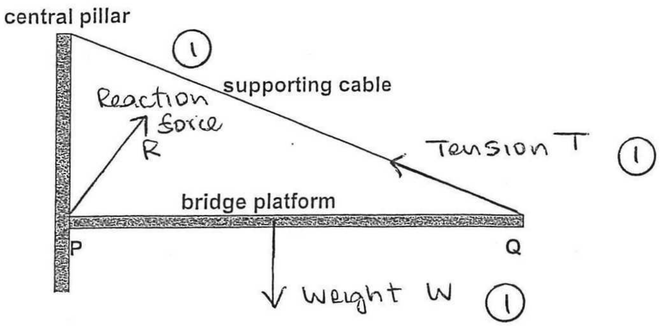
When the truck moves to right the cw torque will <u>increase</u> (larger "r") (1)

$\Rightarrow$ the ACW torque must also <u>increase</u> (1)

Since ϕ & distance to the pivot are the <u>same</u>, then the tension will <u>increase</u>. (1)

Question 21 [Total marks = 13]

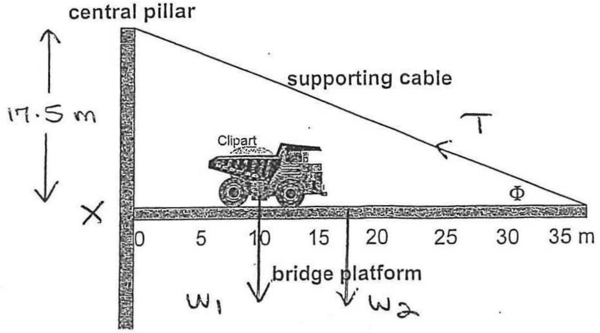
A particular structure consists of a concrete platform **PQ** attached to a central pillar by means of a very strong cable as shown in the diagram below.



(a) The structure is in equilibrium even though there are **three** forces acting on it. **Draw** and **label** these three forces on the diagram.

[3 marks]

The diagram below shows a heavy truck moving along the platform. The distances (in metres) from the central pillar are shown on the diagram. The centre of mass of the truck is at the 10.0 m and the platform extends 35.0 m from the pillar, the top of which is 17.5 m above the platform. The platform is uniform and has a mass of 440 tonnes and the truck has a mass of 45.0 tonne.



(b) Calculate the value of the angle ϕ.

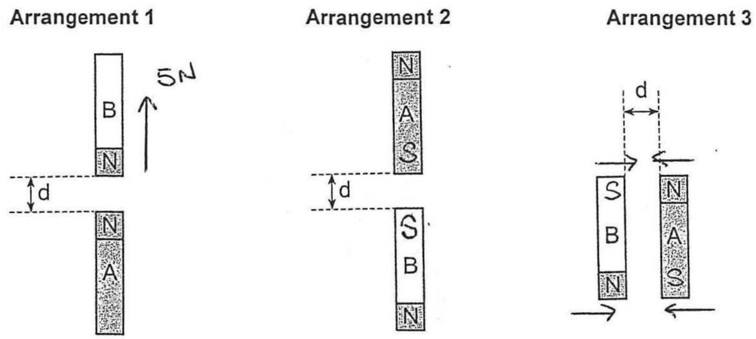
[2 marks]

$\tan \phi = \frac{17.5}{35}$ (1)

so $\phi = 26.6^{\circ}$ (1)

Question 11

Two similar bar magnets (**A** and **B**) are arranged in a number of different ways as shown in the diagrams below. In each case the distance **d** is identical.



In **Arrangement 1**, Magnet **B** experiences a repulsive force of 5 N upwards.

(a) In Arrangement 1, what is the magnitude and direction of the magnetic force experienced by Magnet **A**?

[1 mark]

5 N downwards (1)

(b) What is the magnitude and direction of the magnetic force on Magnet **B** when it is below Magnet **A** as in **Arrangement 2**?

[1 mark]

5 N downwards (1)

(c) When Magnet **B** is to the left of Magnet **A**, as in **Arrangement 3**, will the magnetic force be attractive, repulsive or zero? If non-zero, do you expect it to be greater than or less than 5N? Give your reasoning.

[2 marks]

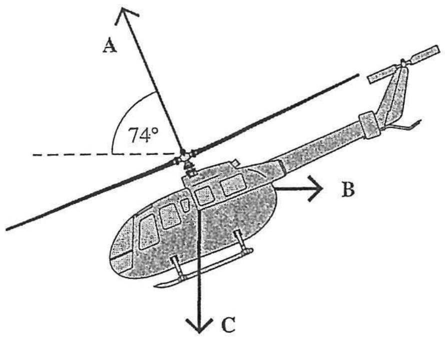
magnetic force will be attractive (1)

total force = 5 + 5 = 10 N

ie greater (1)

Question 12

The helicopter shown in the diagram below is moving horizontally through still air. The lift force from the helicopter's blades is labeled **A**.



a) Name the two forces **B** and **C** that also act on the helicopter.

B	air resistance drag ①	C	weight ①

[2 marks]

b) If the helicopter is moving with a constant velocity, what is the net force acting on it? Why?

[1 mark]

constant velocity $\Rightarrow a = 0$

$\therefore$ the net force must be zero ①

c) The lift force, **A**, is 9.5 x 10³ N and acts at an angle of 74° to the horizontal. Calculate the **weight** of the helicopter.

[3 marks]

vertical component of lift = weight ①

$A \sin 74 = mg = W$ ①

ie $W = 9.5 \times 10^3 \times \sin 74$

$= 9.13 \times 10^3$ N ①

b) Determine the **vertical component** of the Earth's magnetic field near Albert Park. Include the direction.

[3 marks]

$B_v = B_e \cdot \sin\theta$ ①

$= 60 \times 10^{-6} \times \sin 67$ ①

$= 5.52 \times 10^{-5}$ T upwards ①

(or $55.2\ \mu T$)

c) Calculate the EMF which would be generated between the tips of the wing on the racing car.

[3 marks]

$EMF = v \cdot l \cdot B$ ①

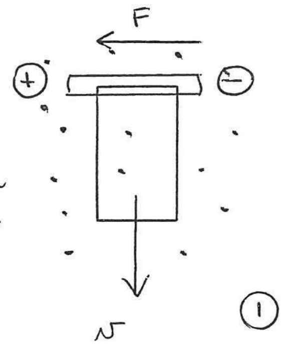
$= \frac{228}{3.6} \times 2.2 \times 5.52 \times 10^{-5}$ ①

$= 7.69 \times 10^{-3}$ V ①

d) Which end of the wing (**as viewed by the driver**) would be **positive**? Explain how you determined your answer.

[3 marks]

Plan view



magnetic field out of page ①

①

Using RH rule $\Rightarrow$ the right tip of the wing will be positive ①

(f) Calculate the period at which the Ferris wheel must rotate if Bonnie experience "weightlessness".

[3 marks]

$R = 0$ (1)

so $v^2 = gr = 9.80 \times 17.5$

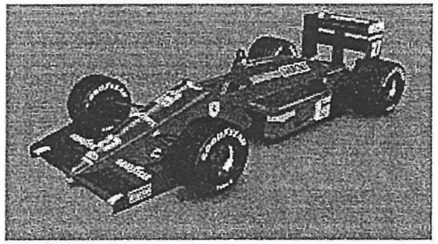
$\Rightarrow v = 13.09 \text{ ms}^{-1}$ (1)

$\therefore T = \frac{2\pi r}{v} = \frac{2\pi \times 17.5}{13.09} = 8.40 \text{ sec}$ (1)

Question 20 [Total = 11 marks]

Formula 1 racing cars have a wing above the rear wheels that causes a downwards force to aid traction. The wings are often made of graphite, a form of carbon that is a conductor.

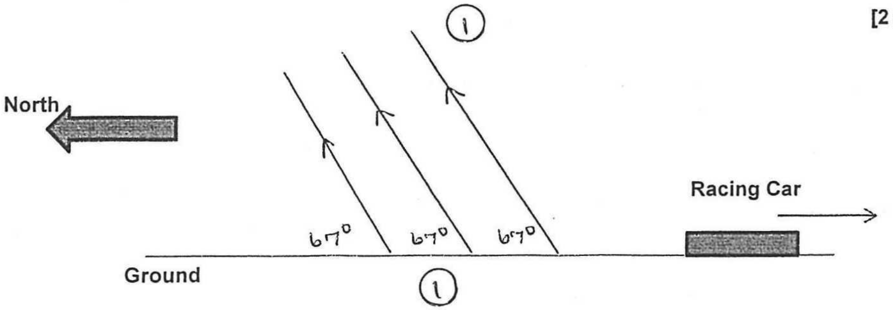
A car with a 2.2 m wing is travelling south at 228 kmh^{-1}. Assume that the wing is electrically insulated from the rest of the car.



Albert Park in Melbourne is the site of Australia's F1 race; the Earth's magnetic field here has strength of 60 μT and an angle of dip of 67°.

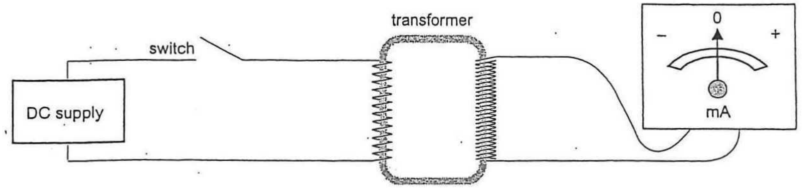
a) On the diagram below, show the flux lines of the Earth's magnetic field in the region of the car.

[2 marks]



Question 13

A transformer as shown in the diagram below is being tested. The primary coil is connected to a battery and switch. The switch is initially open and no current is flowing in the primary coil. An ammeter is connected to the secondary coil and initially shows no deflection. When the switch is **first** closed, the ammeter needle is deflected to the right and then returns to its initial position of no deflection.



(a) Explain why the ammeter deflects when the switch is closed and then returns to the un-deflected position.

Closing the switch — current in the primary coil will increase from 0 to a constant value (1) over a brief interval of time ⇒ the magnetic field around the primary coil will be increasing during this time & so there will be a change (1) in magnetic flux (ΔØ) & so a current will be induced in the primary coil.
Hold the switch down, the is no change in flux (1) (ΔØ) & no EMF will be induced in the secondary coil ⇒ ammeter will read zero.

[3 marks]

(b) The switch, which has been closed for a short time, is now returned to the open position and remains open. Which one of the following **best** describes what happens to the reading of the ammeter?

[1 mark]

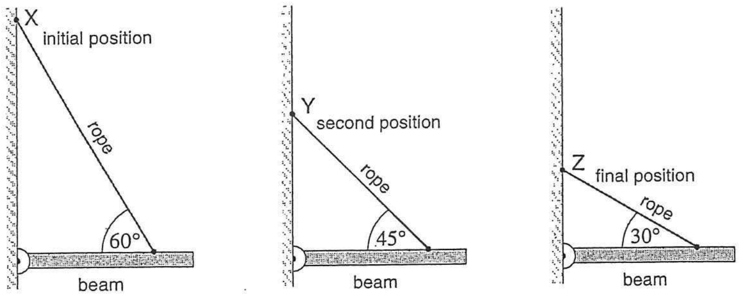
A	It deflects to the left and stays in this position
B	It deflects to the right and stays in this position
C	It deflects to the left and returns to the middle position
D	It deflects to the right and returns to the middle position
E	It does not change

C (1)

Question 14

A horizontal beam is held in position by a rope as shown.

The connection point on the wall is moved from location X to location Y to location Z. Assume the length of the rope is adjusted to keep the beam in a horizontal position in each situation.



Which of the following best describes what happens to the tension? Write the **letter** corresponding to your answer in the box.

A: Tension increases

B: Tension decreases

C: Tension remains the same

D: Tension increases then decreases.

A

(2)

Justify your answer. **[4 marks]**

The cw torque created by the weight of the beam remains constant (1)

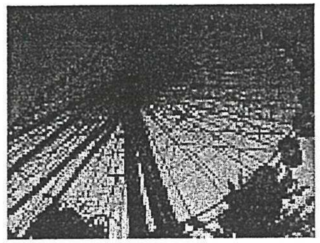
⇒ the ACW torque created by the rope must also remain constant

ACW torque $= (T\sin\theta).d$ ← constant

$T = \frac{\text{torque}}{d\sin\theta} \propto \frac{1}{\sin\theta}$ (1)

∴ as $\sin\theta$ decreases, the tension will increase

Another familiar ride at the amusement park is the Ferris wheel.



The wheel shown in the photograph moves in a **vertical** circle with a radius of 17.5 m and with a constant speed of 9.05 ms^{-1}.

(c) How long does it take the wheel to complete one full rotation? **[2 marks]**

$v = \frac{2\pi r}{T}$ so $T = \frac{2\pi r}{v}$ (1)

$T = \frac{2\pi \times 17.5}{9.05} = 12.2$ seconds (1)

Bonnie, a passenger on the Ferris wheel has a mass of 57.3 kg.

(d) What reaction force does she experience when she is at the **highest point** of the Ferris wheel's circular path? **[3 marks]**

$R = mg - \frac{mv^2}{r}$ (1)

$= (57.3 \times 9.8) - \frac{57.3 \times 9.05^2}{17.5}$ (1)

∴ $R = 2.93 \times 10^2$ N upwards (1)

If the Ferris wheel rotates fast enough then Bonnie may experience "**weightlessness**" as she passes through certain parts of the ride.

(e) What is meant by the term "weightlessness" and where on the ride will she experience it? Why? **[3 marks]**

"weightlessness" — sensation of not (1) experiencing any reaction force on the body

At top of ride $R = mg - \frac{mv^2}{r}$

(1) so if $mg = \frac{mv^2}{r}$ then $R = 0$ (1)

Question 19 [Total marks = 16]

The photograph below shows a roller coaster ride at an amusement park. The roller coaster wagons can move along the track safely as long as high velocities are maintained.

The track shown in the photograph is circular in shape and has a **diameter** of 32.6 m.

(a) What is the **minimum** speed that the roller coaster must have in order to remain on the track at the highest point of the vertical track?

[2 marks]

at top $F_c = W$

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

$v^2 = gr = 9.80 \times 16.3 = 159.7$

$\therefore v_c = \underline{12.6\ ms^{-1}}$ (1)

One of the passengers on the roller coaster, Carla, has a mass of 49.4 kg.

(b) What reaction force does she experience when the roller coaster is moving at the **lowest point** of the track with a speed of 18.3 ms^{-1}?

[3 marks]

$R = \frac{mv^2}{r} + mg$ (1)

$= \frac{49.4 \times 18.3^2}{16.3} + (9.8 \times 49.4)$ (1)

$\therefore R = \underline{1.50 \times 10^3\ N}$ (1)

Question 15

A step-up transformer is used to convert a voltage of 1.50 x 10^4 V to a higher voltage of 3.00 x 10^5 V.

The primary coil has 2000 turns. Assume the transformer is 100 % efficient.

a) How many turns are in the secondary coil?

[2 marks]

$\frac{N_S}{N_P} = \frac{V_S}{V_P}$

$\therefore N_S = \frac{V_S}{V_P} \times N_P = \frac{3.00 \times 10^5}{1.50 \times 10^4} \times 2000$ (1)

$= \underline{40,000\ \text{turns}}$ (1)

b) The power supplied to the primary coil is 6.5 MW. What is the size of the current in the secondary coil?

[2 marks]

Since transformer is 100% efficient

$P_S = 6.5\ MW$

ie $6.5 \times 10^6 = V_S . I_S = 3.00 \times 10^5 \times I_S$ (1)

$\Rightarrow I_S = \frac{6.5 \times 10^6}{3.00 \times 10^5} = \underline{21.7\ A}$ (1)

c) Which coil wires should be **thicker** – the primary, or secondary? Explain why.

[2 marks]

(1) The primary coil will carry the larger current → the potential for a significant loss of energy due to resistive heating (I^2R) will be greater. (1)

Thicker wires have <u>less</u> resistance ⇒ wires in the primary coil should be <u>thicker</u>.

End of Section One

Section Two: **Problem Solving** **[90 marks or 50 % of total]**

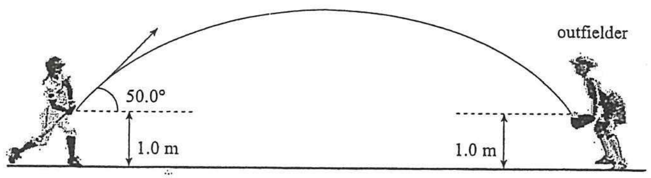
Answer all SEVEN (7) questions in the spaces provided.

Question 16 (Total marks = 14)

A softball is hit at an angle from a point 1.0 m above the ground. The softball has an initial velocity of 19.5 ms^{-1} at an angle of 50° above the horizontal, as shown in the diagram below.

The ball is caught by an outfielder as it returns to a height of 1.0 m above the ground.

Ignore the effects of air resistance.



[This diagram is not drawn to scale.]

$v_H = v\cos\theta = 19.5\cos 50 = 12.53\ ms^{-1}$ (1)

$v_V = v\sin\theta = 19.5\sin 50 = 14.94\ ms^{-1}$

(a) Calculate the time the ball takes to reach the outfielder. **[3 marks]**

vertical motion

$u = 14.94$
$a = -9.8$
$s = 0$

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

$0 = 14.98 - 4.9t^2$

ie $t = \frac{14.94}{4.9}$ (1) $= 3.05$ sec (1)

(b) How far from the batter is the outfielder when she catches the ball? **[3 marks]**

distance ≡ range

$= v_H \cdot t$ (1)

$= 12.53 \times 3.05$

(1) $= 38.2$ m (1)

The orbit of Jupiter is known to be elliptical rather than circular. At Jupiter's closest point, it is 4.95 AU from the Sun and at its most distant point it is 5.46 AU from the Sun.

(c) Calculate the gravitational force of attraction between Jupiter and the Sun when Jupiter is **most** distant from the Sun. **[4 marks]**

$R = 5.46 \times 1.50 \times 10^{11} = 8.19 \times 10^{11}$ m (1)

$F = \frac{G m_S \cdot m_J}{R^2}$ (1)

$= \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 318 \times 5.97 \times 10^{24}}{(8.19 \times 10^{11})^2}$ (1)

ie force $= 3.76 \times 10^{23}$ N (1)

(d) Calculate the centripetal acceleration experienced by Jupiter in its orbit when it is **most distant** from the Sun. **[3 marks]**

$F = m_J \cdot a_c$

ie $a_c = \frac{F}{m_J} = \frac{3.76 \times 10^{23}}{318 \times 5.97 \times 10^{24}}$ (1)

(1) $= 1.98 \times 10^{-4}\ ms^{-2}$ (1)

or $a_c = g = \frac{G m_J}{R^2} \longrightarrow a_c = 1.98 \times 10^{-4}\ ms^{-2}$

Question 18 [Total marks = 13]

The planet Jupiter orbits the Sun with a period of 4333 days. It has a mass 318 times that of the Earth and a diameter 11.2 times larger than the diameter of the Earth.

(a) Calculate the period of Jupiter's orbit in **seconds**.

[2 marks]

Period $T = 4333 \times 24 \times 60 \times 60$ (1)

$= 3.74 \times 10^{8}$ sec (1)

(b) Assuming Jupiter has a circular orbit with a radius of 5.2 AU (astronomical unit), calculate the speed of Jupiter as it orbits the Sun.

Note: 1 AU = distance from the Earth to the Sun

[4 marks]

$R = 5.2 \times 1.50 \times 10^{11} = 7.80 \times 10^{11}$ m (1)

$v^2 = \frac{GM_s}{R}$

$= \frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30}}{7.80 \times 10^{11}}$ (1)

$v^2 = 1.70 \times 10^{8}$ (1)

so $v = 1.30 \times 10^{4}$ ms^{-1} (1)

or $v = \frac{2\pi r}{T} \rightarrow v = 1.31 \times 10^{4}$ ms^{-1}

(c) Calculate the maximum height **above the ground** reached by the ball as it travels to the outfielder.

[3 marks]

vertical motion

$u = 14.94$

$v = 0$

$a = -9.8$

$v^2 = u^2 + 2as$

$0 = 14.94^2 - 19.6\,s$

ie $s = \frac{14.94^2}{19.6} = 11.4$ m (1)

$\therefore$ maximum height above ground $= 11.4 + 1.0$ (1)

$= 12.4$ m (1)

(d) What is the direction of the **net force** acting on the ball at the highest point of the trajectory?

[1 mark]

vertically downwards (1)

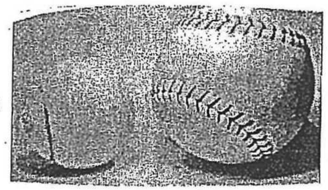
(e) Does the ball have an acceleration of zero at the highest point of the trajectory? Explain.

[2 mark]

(1) No — the ball still experiences a downwards acceleration of 9.8 ms^{-2} due to gravity (1)

(f) A tennis ball is now hit at the same height and with the same initial velocity as the softball in part (a). The two balls are shown in the photograph below.

tennis ball



softball

State **one** difference between the balls and describe how it affects the force of air resistance.

tennis ball has a rougher surface texture → increased air resistance (2)

also surface area

or mass

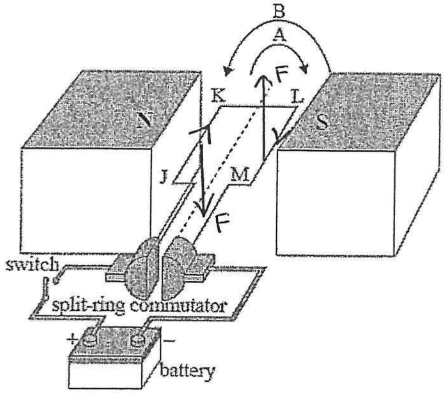
[2 marks]

Question 17 [Total marks = 14]

The diagram below shows a small DC electric motor, powered by a battery through a split-ring commutator.

The rectangular coil has sides **KJ** and **LM** of length 70.0 cm, and sides **KL** and **JM** of length 40.0 cm. The coil contains 4 turns of insulated wire.

With a current of 15.0 A passing through the coil, a maximum torque of 0.600 Nm was achieved.



a) Does the coil rotate in the direction shown as **A** or in the direction shown as **B** (see diagram)? Explain how you decided. **[2 marks]**

Using RH rule to find the direction of the force acting on JK (1)

ie force is upwards ⇒ coil will rotate ACW (1) (B)

b) Calculate the magnitude and direction of the maximum force acting on side **KJ** of the coil.

[Remember: Torque $\tau = 2\,(F \times r)$] **[3 marks]**

$\tau = 2 \times F \times r$

$0.600 = 2 \times F \times 0.20$ (1)

ie $F = \dfrac{0.600}{2 \times 0.20} = 1.50$ N (1)

(1)

downwards

c) Hence, calculate the strength of the magnetic field between the poles of the magnet. **[4 marks]**

$F = N(ILB)$ (1)

ie $1.50 = 4 \times 15 \times 0.70 \times B$ (1)

$\therefore B = \dfrac{1.50}{4 \times 15 \times 0.70}$ (1)

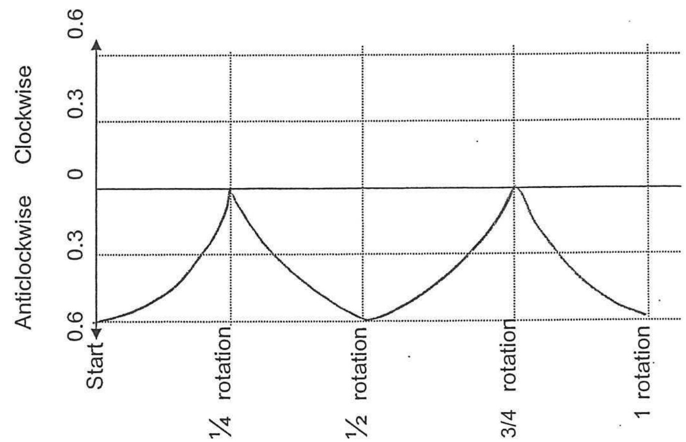
$= 3.57 \times 10^{-2}$ T (1)

d) Why is the **split-ring commutator** an essential part of a DC electric motor? **[2 marks]**

The commutator will reverse the direction of current flow in the armature every ½-rotation (1)

⇒ the forces acting on the sides of the coil will cause it to rotate continuously in the same direction (1)

e) Sketch a graph showing the magnitude and direction of the torque produced during one complete rotation of the coil. **Assume the coil starts perpendicular to the magnetic field.** **[3 marks]**



(1) start

(1) shap

(1) Belo