



**Rossmoyne Senior High School**

**ATAR course examination, 2020**

**Question/Answer booklet**

## Physics Unit 3

Please place your student identification label in this box

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Student number:      In figures

In words

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### Time allowed for this paper

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

### Materials required/recommended for this paper

*To be provided by the supervisor*  
This Question/Answer booklet

Number of additional  
answer booklets used  
(if applicable)

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### *To be provided by the candidate*

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

Special items:      nil

### 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 material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Circle your classroom teacher**

Holyoake

Patterson

Shashikumar

Wallace

**Structure of this paper**

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Short response	11	11	50	54	30
Section Two Problem-solving	6	6	90	90	50
Section Three Comprehension	2	2	40	36	20
				<b>Total</b>	100

**Instructions to candidates**

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.
2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.
4. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

In calculations, give final answers to three significant figures and include appropriate units where applicable.

In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

## Section One: Short response

30 % (54 Marks)

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

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

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

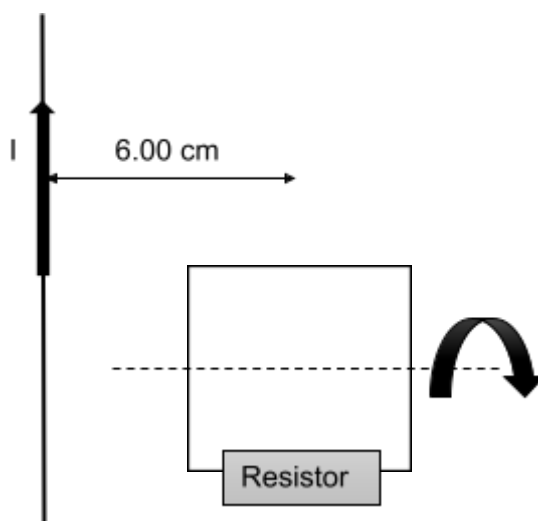
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

## Question 1

(5 marks)

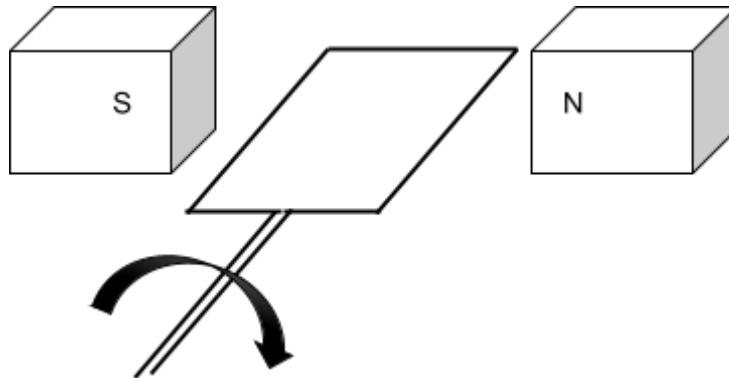
A single square wire loop of length 5.00 cm is placed near a long straight wire carrying a constant current of 15.4 A as shown in the diagram below. The center of the loop is located 6.00 cm away from the wire. The loop then rotates 90.0° uniformly along the axis shown with the resistor moving out of the page in a time of  $1.00 \times 10^{-2}$  s. Calculate the average magnitude of the induced EMF while the loop rotates. Provide your answer in  $\mu\text{V}$  in the space provided below.



$V =$  \_\_\_\_\_  $\mu\text{V}$

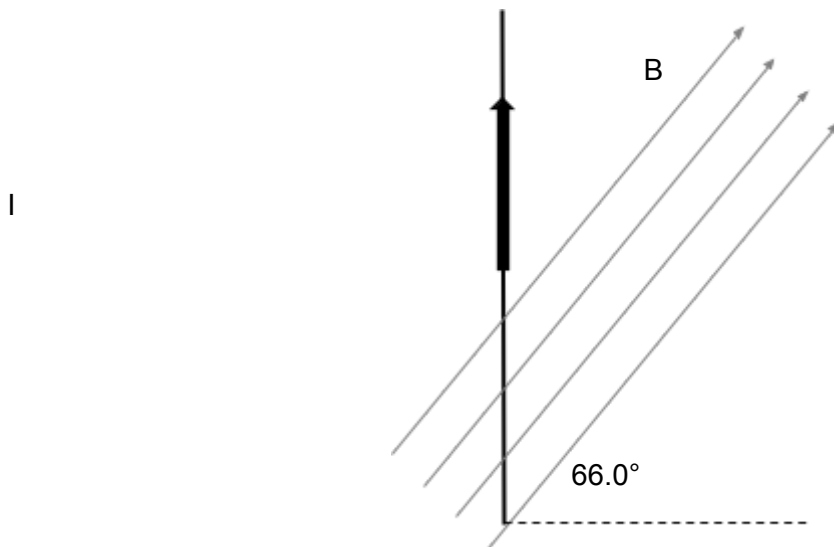
**Question 2****(4 marks)**

Consider the AC generator model below consisting of a  $0.0100 \text{ m}^2$  coil of 100 turns placed completely in a uniform magnetic field of  $0.150 \text{ T}$ . Calculate the magnitude of the  $V_{\text{RMS}}$  generated if the coil turns at a rate of  $30.0 \text{ Hz}$ .



**Question 3****(3 marks)**

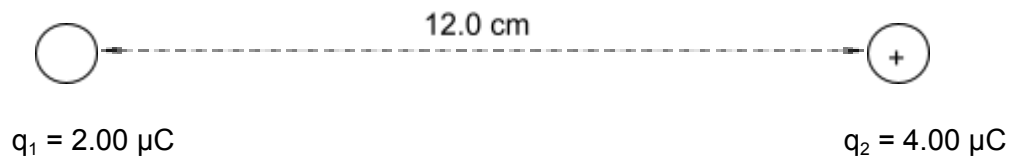
A conventional current of 30.0 A flows up a 5.00 m vertical power pole. The power pole is located in Perth where the magnetic field is  $5.50 \times 10^{-5}$  T North at  $66.0^\circ$  to the horizontal as shown in the diagram. Calculate the force acting on the power line due to the Earth's magnetic field.

**Question 4****(3 marks)**

Calculate the gravitational force of attraction the Moon exerts on the Earth

**Question 5****(5 marks)**

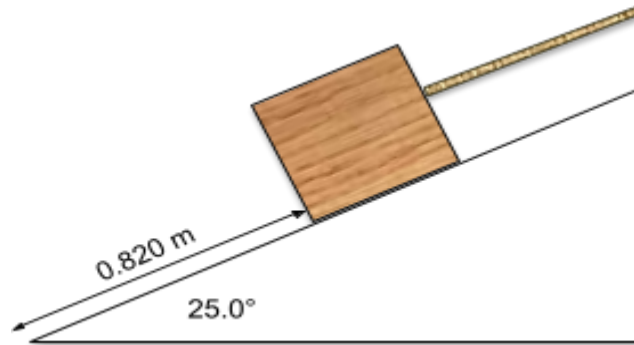
Two positive charges are 12.0 cm apart as shown. Calculate the distance from  $q_1$  where the net force on a test charge would be zero.



**Question 6****(8 marks)**

A box of mass  $15.0\text{ kg}$  sits  $0.820\text{ m}$  up an incline of  $25.0^\circ$  as shown in the diagram. A rope parallel to the incline keeps the box at rest.

- (a) Calculate the tension of the rope (ignoring any static friction).

**(3 marks)**

The rope is then cut and the box is allowed to slide down the incline. It is measured to take  $0.800$  seconds to travel  $0.820\text{ m}$  down the incline.

- (b) Calculate the frictional force that acts on the box parallel to the incline to oppose the motion.

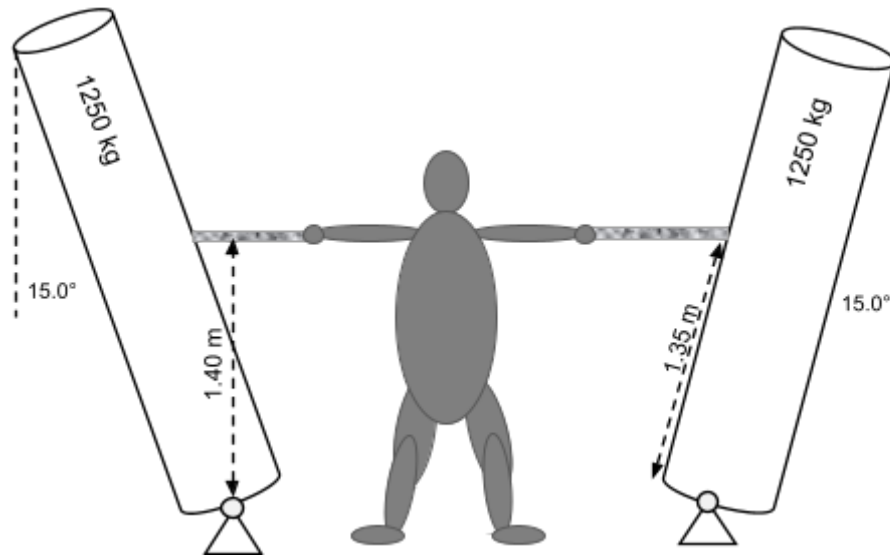
**(5 marks)**



## Question 7

(4 marks)

The World Strongman “Hercules Hold” involves a person holding on to two large pillars for as long as possible. In the diagram below, two 1250 kg pillars are held stationary in a frictionless hinge at an angle of  $15.0^\circ$  by two horizontal steel chains inserted 1.35 m from the base. The pillars are of uniform mass and 3.20 m tall. Calculate the tension in each of the steel cables.



See next page



## Question 8

(6 marks)

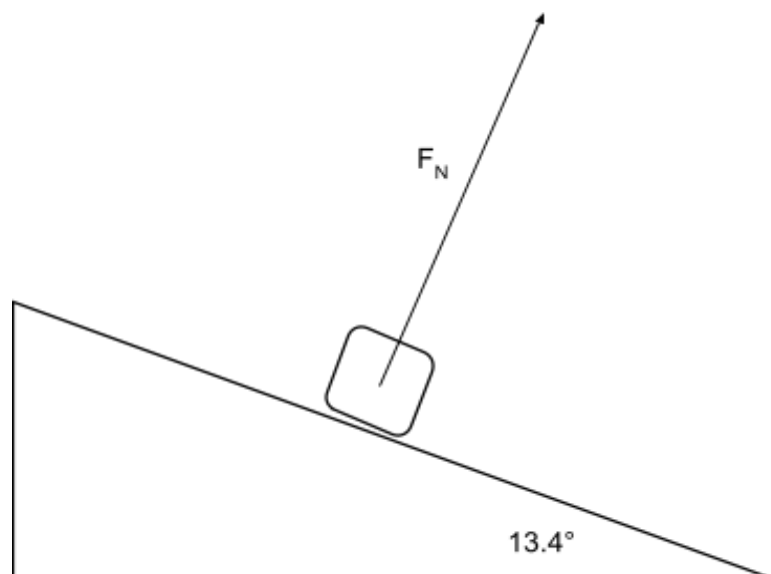
By banking the curves of racetracks it is possible for vehicles to turn in a horizontal circle **without relying on friction**. For a car of mass  $1.70 \times 10^3$  kg, the angle of banking is set at  $13.4^\circ$  above the horizontal. The curve has a radius of 171 m and the car drives at a speed to maintain its height.

- (a) Calculate the 'ideal speed' that the car can travel at without relying on friction. (4 marks)

Obviously, cars can travel faster and slower than this 'ideal speed' when travelling around banked curves.

- (b) On the diagram below, draw a vector diagram showing all the forces **including friction ( $F_f$ )** that must act on the car in order for it to travel in horizontal circular motion when moving faster than the ideal speed. The net force may be drawn as a dashed line and the normal force is already drawn for you.

(2 marks)

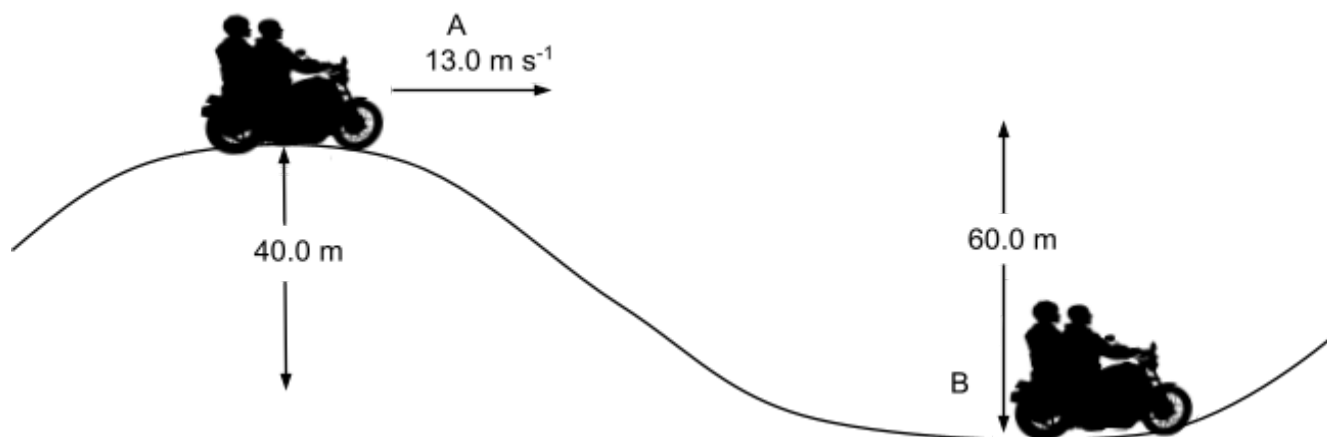


See next page

## Question 9

(8 marks)

A motorcycle and riders of combined mass of 355 kg is travelling over the undulating road as shown in the diagram below. The radius of curvature at points A and B are shown.



- (a) Calculate the force that the motorcycle exerts on the road at point A. (4 marks)

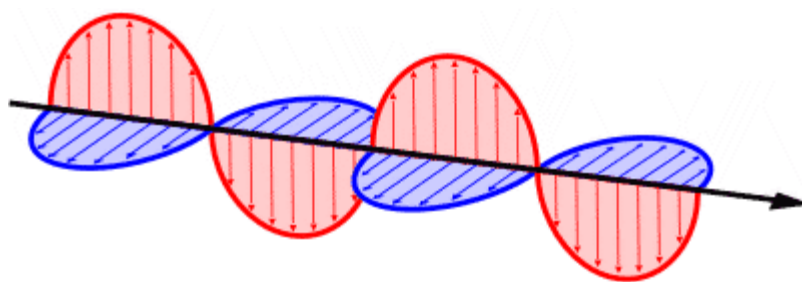
- (b) If the occupants of the motorcycle feel 1.35 times heavier (than their regular weight) at point B, calculate the speed the motorcycle is travelling at point B. (4 marks)

**Question 10****(5 marks)**

A power station generates electric power at a rate of  $2.00 \times 10^2$  MW. The power is transmitted along a 40.0 km long transmission line to a transformer at voltage of 220 kV. The line has a resistance rating of  $0.150 \, \Omega \, \text{km}^{-1}$ . Calculate the voltage delivered to the primary coil of the transformer at the end of this transmission line. Show working.

**Question 11****(3 marks)**

The diagram below models an electromagnetic wave.



Describe the relationship between the plane of the oscillating fields and direction of propagation (velocity) of the wave. Label the diagram to assist with your description.

**End of Section One****See next page**

**Section Two: Problem-solving****50 % (88 Marks)**

This section has **six** questions. Answer **all** questions. Write your answers in the spaces provided.

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

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

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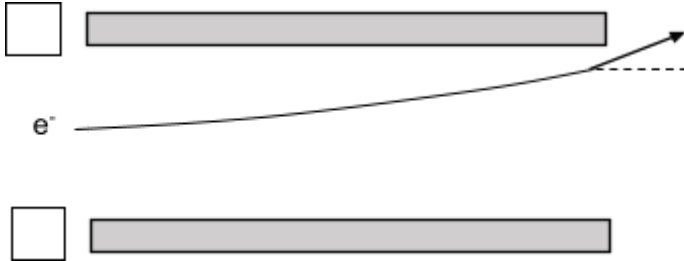
Suggested working time: 90 minutes.

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## Question 12

(13 marks)

An electron is accelerated from rest by a potential difference of 1.50 kV. The electron then enters the space between two horizontal plates. The electron's velocity is initially parallel with the plates. The plates are 16.0 cm long and 20.0 cm apart. The path the electron takes while in the space between the plates is shown below.



- (a) In the boxes to the left of the plates, state the charge that plates must have in order to deflect the electron. (1 mark)
- (b) On the diagram, draw the electric field produced by the horizontal plates only. (1 mark)
- (c) Calculate the speed of the electron as it enters the horizontal plates. (3 marks)
- (d) Calculate the acceleration of the electron while it is within the horizontal plates. (3 marks)

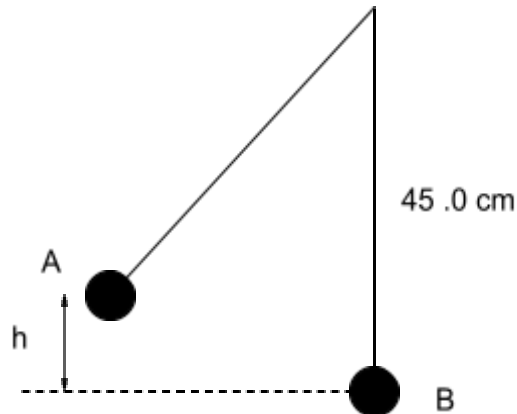
- (e) Calculate the angle to the horizontal that the electron will be travelling at as it leaves the field.  
(If you could not complete part (c), use a speed of  $2.00 \times 10^7 \text{ m s}^{-1}$ ). (5 marks)



## Question 13

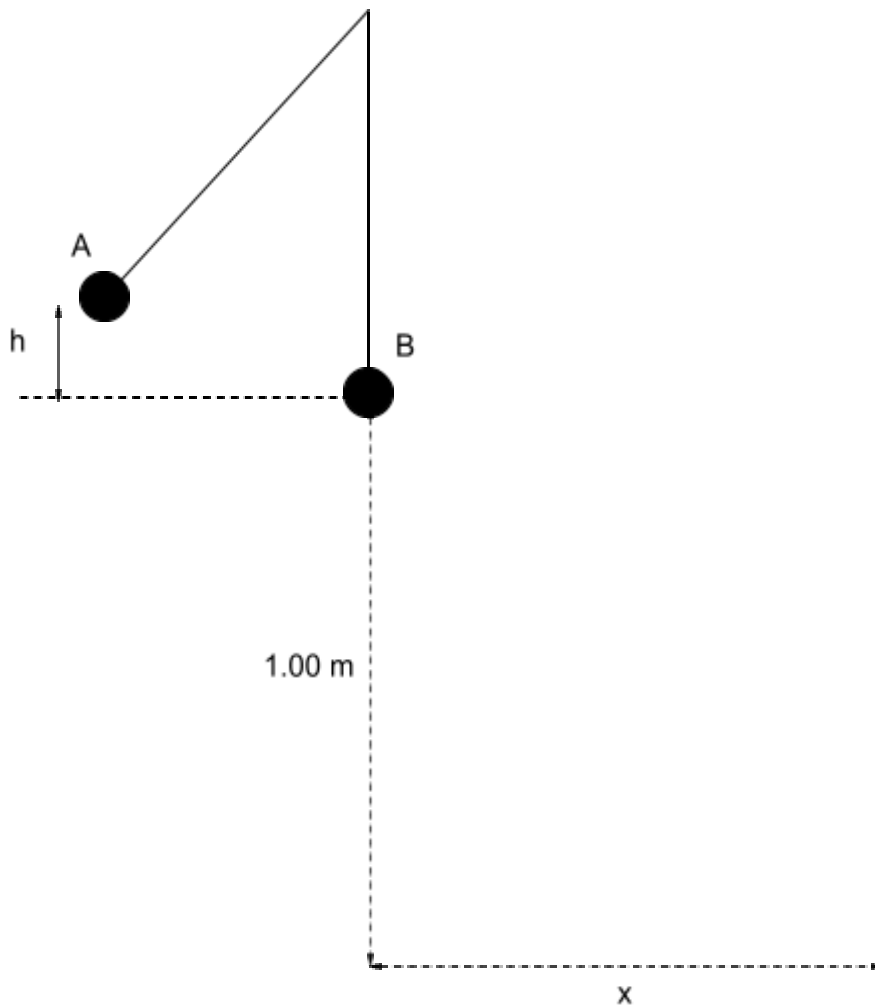
(16 marks)

A 50.0 g mass is connected to 45.0 cm long piece of string which is fixed at one end. Hence, it is able to act as a pendulum. The string has a breaking tension of 0.700 N. The mass is raised to a height 'h' (point A) and released. At point B, the string is vertical and just reaches its breaking tension of 0.700 N – hence, it snaps. This situation is illustrated in the diagram below.



- a) Given that string only just reaches its breaking tension of 0.700 N at point B, calculate the instantaneous speed of the 50.0g mass at this point. Show working. (5 marks)
- b) Hence, calculate the height (h) at which the mass was released. [If you were unable to calculate an answer for part a), use a speed of  $1.40 \text{ ms}^{-1}$  at point B] (4 marks)

The string snaps at point B; hence, the 50.0g mass becomes a projectile. For the questions that follow the diagram below, assume air resistance is negligible.



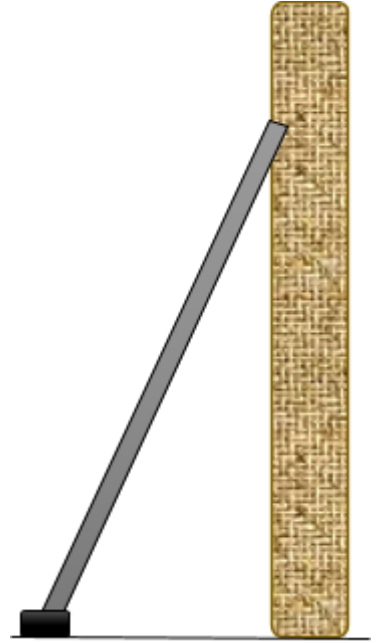
- c) On the diagram above, draw a vector representing the instantaneous velocity of the 50.0 g mass at B. Label this vector with the magnitude of this velocity. (2 marks)
- d) Calculate the value of 'x' - the horizontal range of the projectile. Show all working. (5 marks)

**Question 14****(16 marks)**

A 4.00 m long 10.0 kg ladder of uniform mass is resting against frictionless wall such that the reaction force acting on the ladder from the wall is perpendicular to the wall. The foot of the ladder is 1.70 m away from the wall.

- (a) Calculate the Reaction Force at the wall.

(5 marks)



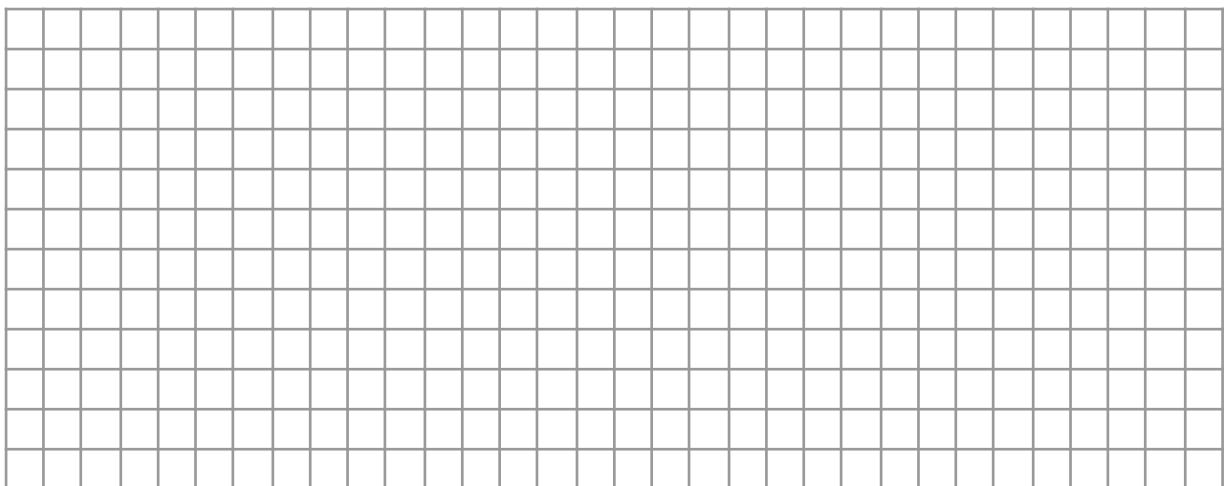
- b) Calculate the magnitude and direction of the total reaction force from the ground. This total reaction is the sum of Friction and Normal Force acting at this point.

(4 marks)

An 80.0 kg worker begins climbing the ladder. Suppose the maximum frictional force that the feet of the ladder can provide is  $2.00 \times 10^2$  N.

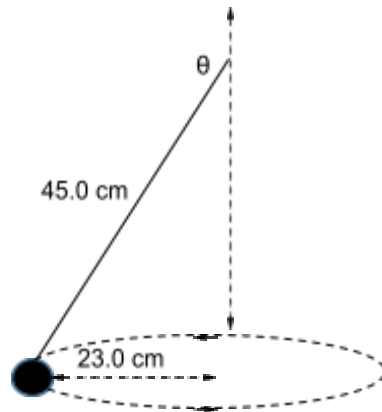
- (c) Calculate the maximum distance along the ladder from the base that the worker could stand before the ladder begins to slip. (4 marks)

- (d) On the graph below, sketch on the y axis the value of the frictional force, as a function of the distance on the x axis. Indicate where the worker would be along the ladder before it slipped. Identify this point at which the ladder will slip in your sketch. A spare graph is provided on the end of this Question/Answer booklet. (3 marks)



**Question 15****(16 marks)**

During a Physics experiment investigating horizontal circular motion, a student is swinging a 150 g mass in a horizontal circle of radius 23.0 cm. the mass is attached to a string that is 45.0 cm in length.



- a) Draw a vector diagram showing the forces acting on the mass and the net force that results. (3 marks)

- b) Use the dimensions of the string and the radius of the path to perform a calculation that shows that the value of ' $\theta$ ' is about  $30^\circ$ . (3 marks)

- c) Hence, calculate the tension in the string.  
[If you could not calculate a value for ' $\theta$ ', use  $30^\circ$ ]

(4 marks)

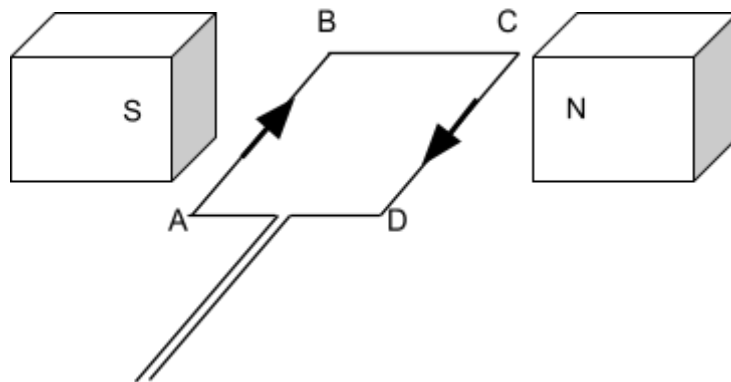
- d) Calculate the period (T) of revolution for the mass.

(6 marks)

## Question 16

(12 marks)

The following diagram represents a single coil associated with a DC electric motor which is completely enclosed in an external uniform magnetic field. The motor has a split ring commutator (not shown). The arrows on the coil represent the direction of the conventional current flow in the coil.



Coil dimensions:  
 $AB = CD = 0.400 \text{ m}$   
 $BC = AD = 0.300 \text{ m}$

- (a) Indicate on the diagram the direction of the force on side AB. (1 mark)
- (b) If the magnetic field has strength of  $0.550 \text{ T}$  and  $2.00 \text{ A}$  flows in the circuit, calculate the magnitude of force on side length AB. (2 marks)
- (c) Calculate the maximum torque produced by the coil. (3 marks)

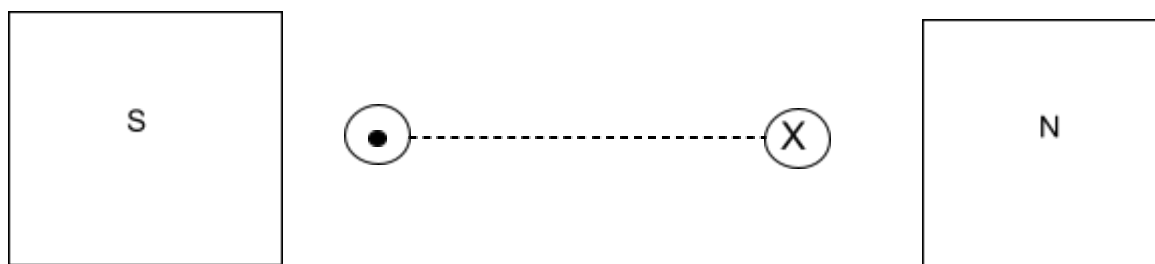
- (d) On the axis provided, sketch and label the force produced on the side AB as it is rotated through 360 degrees from the orientation shown in the diagram. (2 marks)



- (e) On the axis below, sketch and label the torque produced on side AB as it is rotated through 360 degrees from the orientation shown. (2 marks)



- (f) Sketch the net magnetic field produced by the magnets and the coil in the cross section below. Provide at least five field lines to demonstrate the net field. A spare diagram is provided on the end of this Question/Answer booklet. (2 marks)

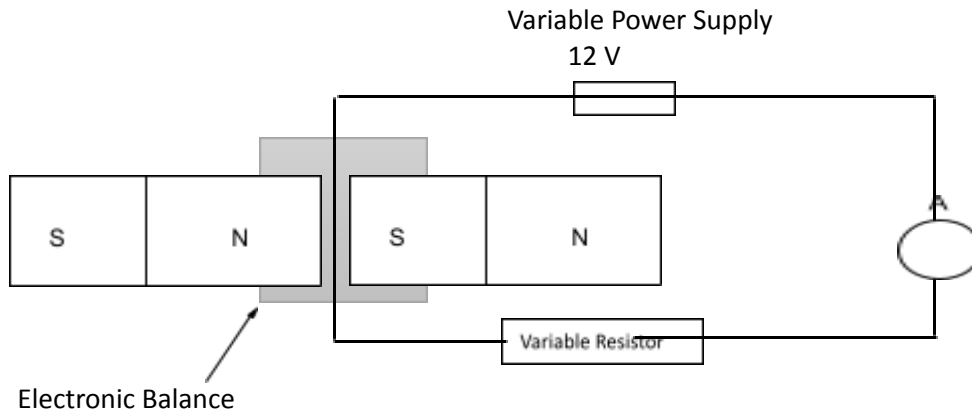




## Question 17

(18 marks)

The diagram below shows the equipment set up (top-down view) to determine the magnetic flux density between the poles of two strong magnets. A wire is placed on a plastic electric balance between the two magnets. The wire is in series with the Power Supply, Ammeter and Variable Resistor.



When a current ( $I$ ) passes through the coil, a downward force  $F_B$  will register on the electronic balance (displayed as mass in grams). By varying the current, the magnetic force varies proportionately.

- (a) On the circuit above, draw the direction of the conventional current in order to register a downward force. (1 mark)

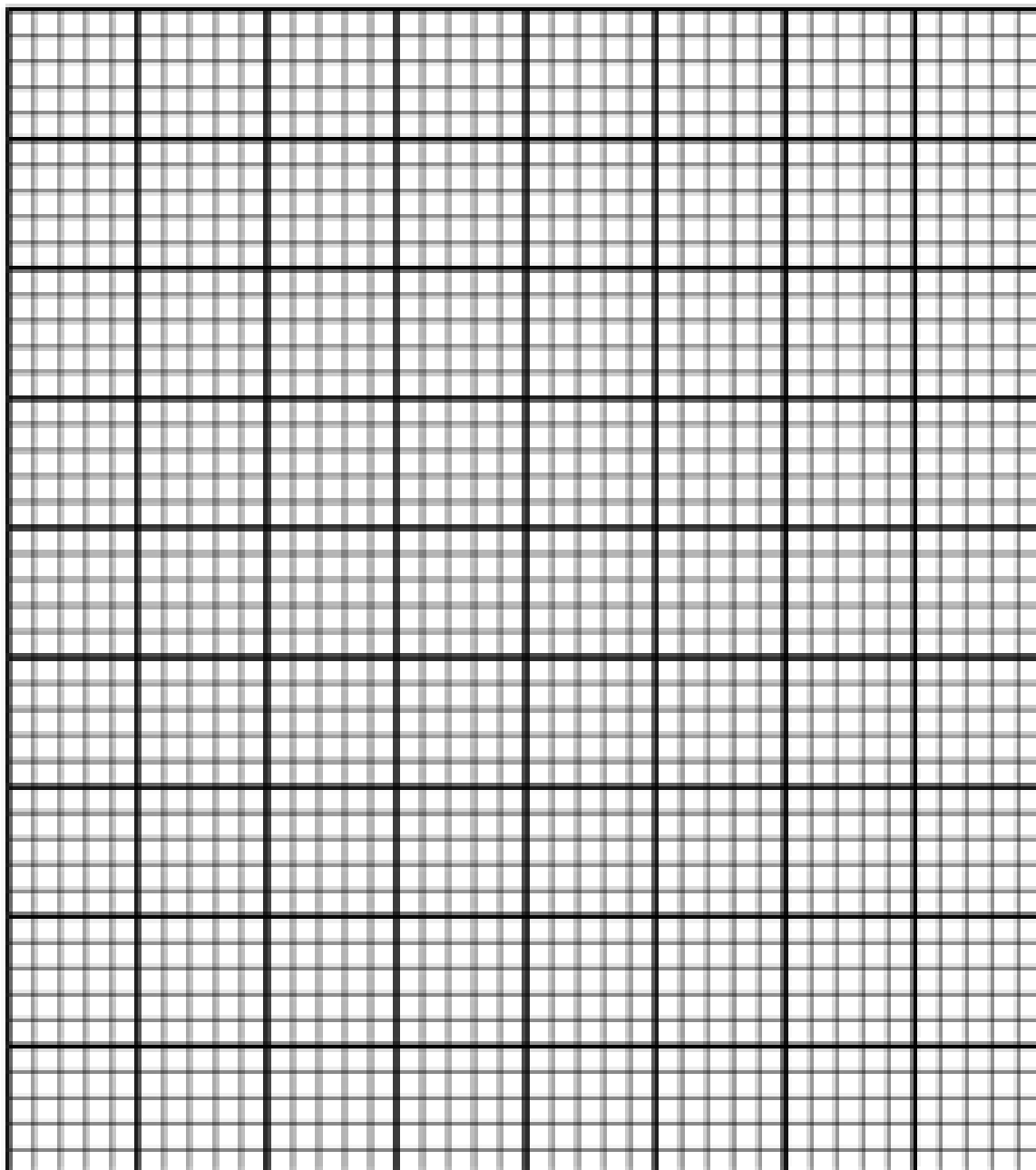
The data is collected and presented in the table below. The scales were determined to have an absolute uncertainty of  $\pm 0.2$  g. The length of the wire within the field was estimated to be 2.0 cm.

Current (A)	Mass ( $\pm 0.2$ g)	Magnetic Force ( $\times 10^{-2}$ N)
0.00	zero (no reading)	
1.37	0.5	
1.87	0.7	
2.55	0.9	
5.37	1.8	
8.29	2.8	
11.45	4.0	

- (b) Convert the reading of mass to weight and, hence, complete the final column in the table, including an absolute uncertainty for each reading. (2 marks)

- (c) On the graph, plot **Magnetic Force vs Current** including error bars. A spare grid is provided on the end of this Question/Answer booklet. If you need to use it, cross out this attempt and clearly indicate that you have redrawn it on the spare page.

(5 marks)



- (d) Determine the gradient of the graph.

(3 marks)

**Question 17 continued.**

- (e) Use the gradient to determine the magnetic flux density between the two magnets. (3 marks)

Suppose the wire was now tilted at an angle of  $30.0^\circ$  to the vertical (as shown in the views below).



- (f) Using your determined value for the magnetic flux density in part (e), calculate the magnetic force acting on the wire if a conventional current of  $10.0\text{ A}$  flows through the wire. (if you could not complete part (e), use  $B = 0.15\text{ T}$ ). (4 marks)

**End of Section Two**

**See next page**

## Section Three: Comprehension

20 % (34 Marks)

This section has **two** questions. You must answer **both** questions. Write your answers in the spaces provided.

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

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

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Suggested working time: 30 minutes.

## Question 18

(18 marks)

**Sun-synchronous orbits (SSO)**

Satellites in polar orbits travel around Earth from north to south rather than from west to east, passing roughly over Earth's poles. Satellites in a polar orbit do not have to pass the North and South Pole precisely; even a deviation within 20 degrees from a 90 degree inclination is still classed as a polar orbit. Polar orbits are also often low Earth orbits, with satellites at altitudes between 200 to 1000 km.

Venus is an almost perfectly spherical planet. Satellites in orbit around Venus maintain a constant orientation of their orbital plane with respect to distant stars. Figure 1 shows this, with the angle  $\theta$  between the orbital plane and the distant stars remaining constant throughout the Venus year.

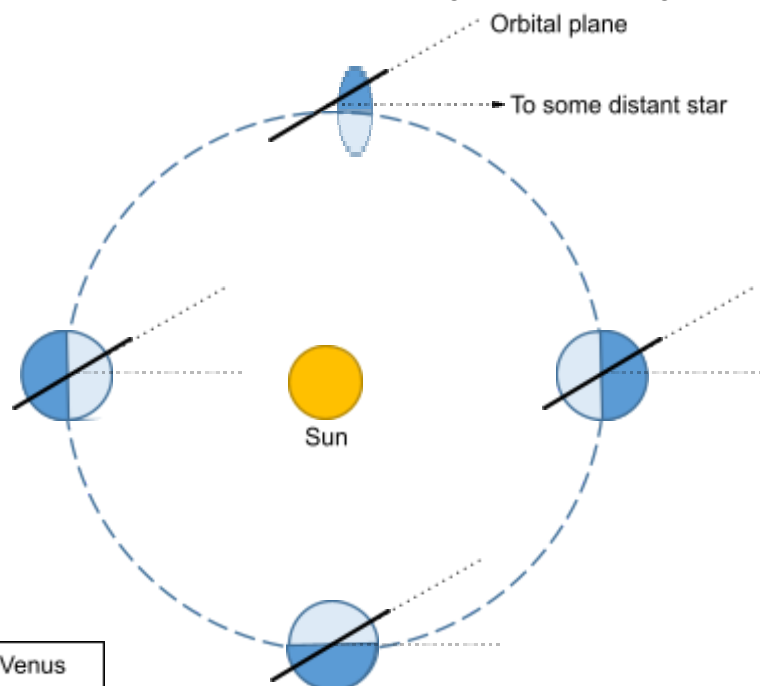
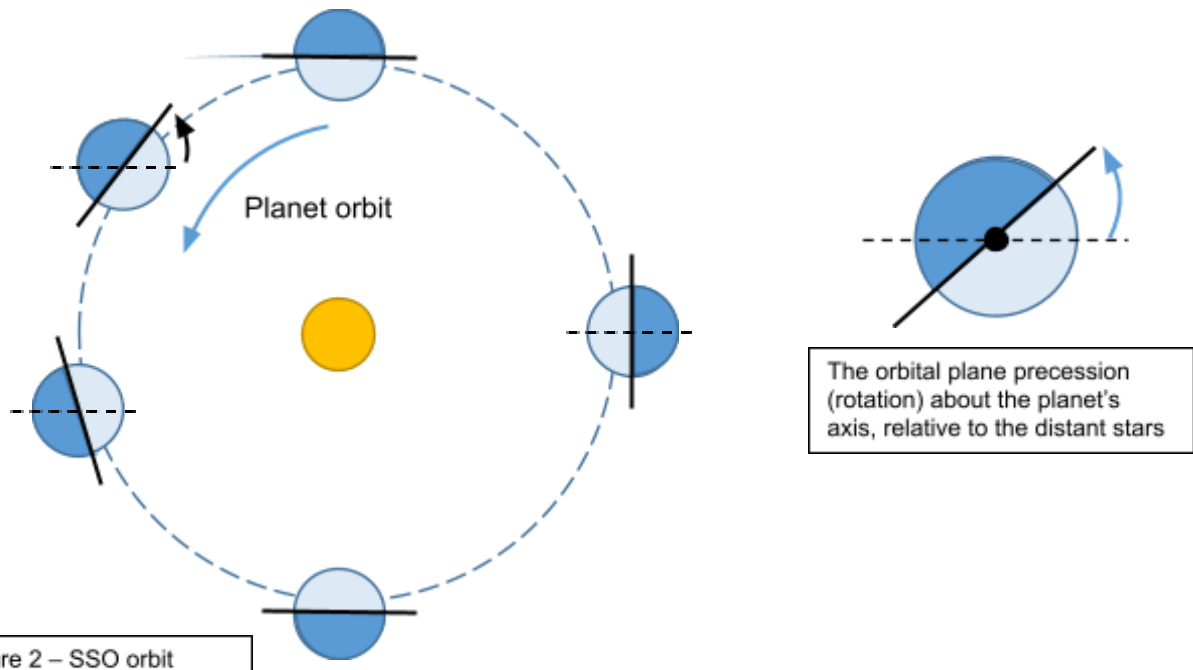


Figure 1 – Satellite of Venus

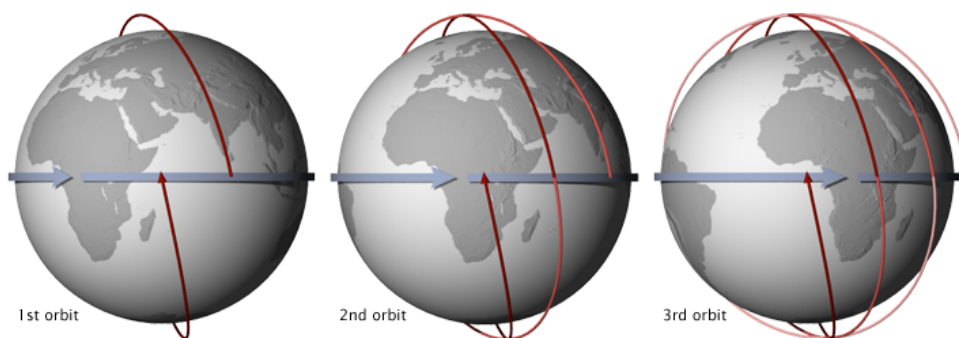
Most planets are not perfectly spherical. The Earth bulges at the Equator due to its rotation about its axis. The bulge of mass causes disturbances to the orbit of its satellites, causing orbital planes to rotate around the Earth's rotational axis. The rotation of an orbital plane is called a 'precession' of the orbit. A special type of orbit precession is shown in Figure 2.



The special feature of this orbit is that the precession is in synch with the planet's revolution around the Sun. The Earth revolves  $360^\circ$  around the Sun in a year. When a satellite's orbital plane also precesses  $360^\circ$  in a year, this is referred to as a Sun-synchronous orbit (SSO). A SSO has the unique feature that it can pass over places on Earth at the same local time each day. For example, passing over Perth, Western Australia at 7:00 am, every day.

This serves a number of applications; for example, it means the satellite can monitor an area by taking a series of images of a certain place across many days, weeks, months, or even years. Each image is taken under the same lighting conditions. Scientists use image series like these to investigate how weather patterns emerge, to help predict weather or storms; when monitoring emergencies like forest fires or flooding; or to accumulate data on long-term problems like deforestation or rising sea levels.

Often, satellites in SSO are synchronised so that they are in constant dawn or dusk (as shown in Figure 2) – this is because by constantly riding a sunset or sunrise, they will never have the Sun at an angle where the Earth shadows them. A satellite in a Sun-synchronous orbit would usually be at an altitude of between 600 to 800 km, completing several revolutions in an Earth day.



See next page

To achieve a SSO requires an orbital inclination (the angle between the orbital plane and the equator) that causes an orbital precession of  $360^\circ$  a year. Factors such as the equatorial radius, the amount of bulge, the eccentricity of the orbit all play a part. For a circular orbit around the Earth, these factors can be simplified to the following relationship:

$$\cos \cos i = - \left( \frac{r}{1.235 \times 10^7} \right)^{\frac{7}{2}}$$

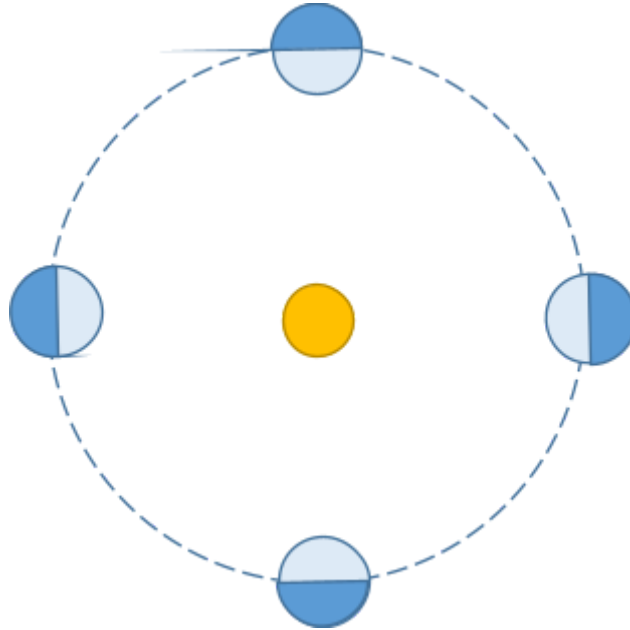
- $i$  is the angle of inclination (degrees)
- $r$  is the orbital distance (m)

(a) By referring to physical principles, explain why most planets have a bulge at their equator.  
(4 marks)

(b) Calculate the rate of precession of a SSO in degrees per day.  
(2 marks)

(c) Show via calculation that a typical SSO satellite of Earth orbits several times a day.  
(4 marks)

- (d) The article describes a SSO that is in constant dawn/dusk. Another type of SSO alternates between noon and midnight. Draw in the orbit of a noon/midnight SSO at each position of Earth in the diagram below. (2 marks)



- (e) Use the relationship given in the article for the following questions:

- i. Calculate the orbital inclination for a SSO around Earth at an orbital distance of  $7.27 \times 10^6$  m. (2 marks)
- ii. Hence, describe whether this SSO would be classified as a polar orbit. (2 marks)
- iii. Determine the theoretical maximum orbital distance for a SSO around Earth. (2 marks)

## Question 19

(18 marks)

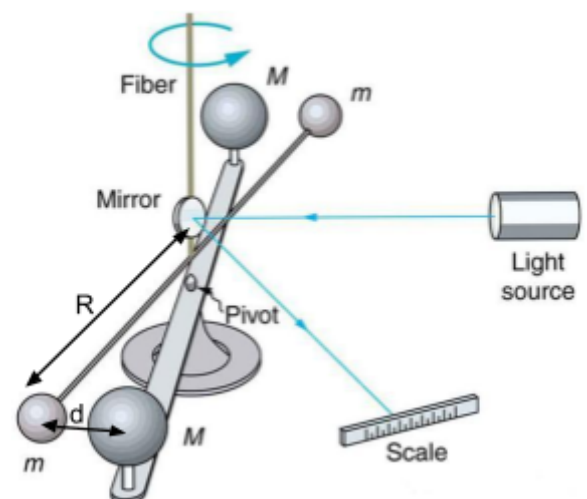
## The Cavendish Experiment

The Cavendish Experiment was conducted from 1797 to 1799 by British Scientist Henry Cavendish and was the first experiment to yield accurate values for the Newtonian constant of gravitation “G”. Cavendish was famously heard remarking that he had “weighed the mass of the Earth” and it garnered much attention and admiration from the scientific community of the time. Sir Isaac Newton had died some 70 years earlier and was only able show that the force of gravitational attraction was proportional to:

$$F_G \propto \frac{m}{r^2}$$

He also knew that the mass of the Earth was also in direct proportionality to the gravitational force that the Earth exerted on a given mass but there existed a constant of proportionality (the Newtonian constant of gravitation) that would provide a direct conversion into the units of force ( $N = \text{kgms}^{-2}$ ). There were many estimates conducted to try and determine the mass of the Earth but these values were wildly varied and unreliable for Newton to advance his theories of universal gravitation any further.

Cavendish’s apparatus shown in the diagram below. Attracted by gravitational force to the large identical lead spheres, a light horizontal rod with two small identical lead spheres at its ends rotated until the torque from gravitational force equaled to the elastic restoring force from the thin torsion fiber. The experiment was so sensitive, that slightest fluctuations of air currents in the room would send the apparatus wobbling uncontrollably, so Cavendish was required to take his measurements of the deflection of the torsion fiber outside the room using a telescope and a beam of light reflected onto a precise scale.



Consider an apparatus with the following values:

$$M = 101.5 \text{ kg}$$

$$m = 1.20 \text{ kg}$$

$$R = 1.20 \text{ m}$$

$$\tau_{\text{Total}} = 1.23 \times 10^{-5} \text{ Nm}$$

$$d = 0.400 \text{ m}$$

$$\text{Angle between } R \text{ and } d = 90.0^\circ$$



- (a) Using the total torque on the rod provided, calculate the magnitude of the force produced on either end of the rod. (3 marks)
- (b) Using the force from (a) and the values provided, calculate a magnitude for the Newtonian constant of gravitation "G". (If you could not complete (a), use  $F = 5.25 \times 10^{-6} \text{ N}$ ) (3 marks)
- (c) Calculate the percentage error of the experimentally determined value to the accepted value. (2 marks)

- (d) Show, by rearranging Newton's law of universal gravitation, the S.I. units of the Newtonian constant of gravitation "G". (3 marks)

The cavendish experiment was such a sensitive apparatus that the steel spheres needed to be electrically grounded prior to the measurements being made as the slightest net charge on either sphere (caused by the movement of the air across the spheres) could introduced a Coulombic force. Suppose both large spheres accumulate a +10.0 nanocoulomb charge and both small spheres accumulate a -10.0 nanocoulomb charge. This causes the distance 'd' the masses m and M are separated to become 0.330 m

- (e) Calculate the new total torque produced with the addition of the Coulombic force. (5 marks)

- (f) State and explain the effect that the charge accumulation would have on the experimental value of the Newtonian constant of gravitation “G” if the scientists were not aware of the net charge accumulation. (2 marks)

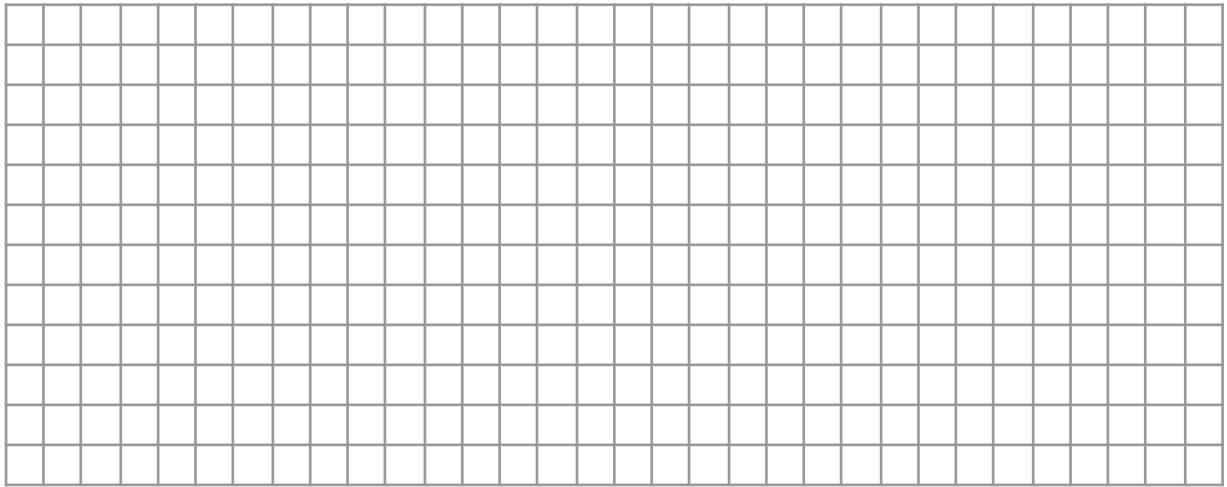
**End of questions**

**See next page**

Supplementary page

Question number: \_\_\_\_\_

Spare Graph Q 15 (e)



Spare diagram Q18 (f)



Spare grid Q19(c)

