MLC Semester 1 Physics Examination, 2010

Question/Answer Booklet

PHYSICS

Stage 3

Please place your student name in this box

Time allowed for this paper

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

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer Booklet
Formulae and 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

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 response	16	16	55	55	30%
Section Two: Problem-solving	8	8	100	95	53%
Section Three: Comprehension	2	2	25	30	17%
				180	100%

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

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

5. Spare pages are available on request. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Section One: Short response **30% (55 Marks)**

This section has **16** questions. Answer **all** questions. Write your answers in the space provided.

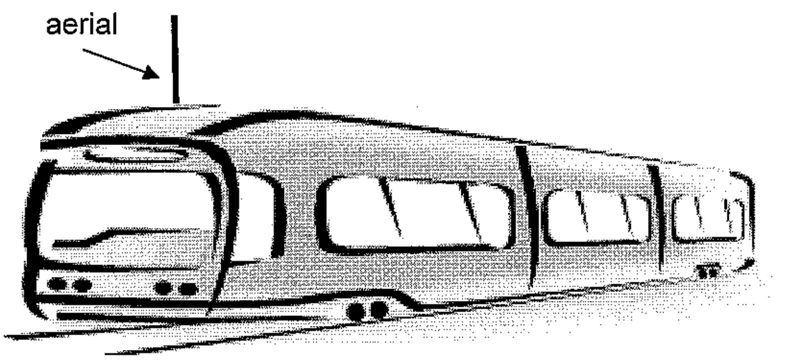
Spare pages are available on request. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 55 minutes.

Question 1 **(4 marks)**

A Perth student is investigating the emf induced along a metal rod moving in the Earth's magnetic field. The 3.00 m long rod (aerial) is clamped, vertically upright, to the top of a train and is electrically insulated from the train. The train is moving at 72.0 km h^{-1} west in a region where the horizontal component of the Earth's magnetic field has magnitude 5.00×10^{-5} T.



(a) Calculate the value of the induced emf in the train's aerial, showing your working. (3 marks)

$V = Bvl$

$= (5.00 \times 10^{-5})\left(\frac{72.0 \times 10^{3}}{3600}\right) 3.00$

$= 3.00 \times 10^{-3}$ V

(b) Which part of the aerial will develop a positive charge? Circle the correct answer. (1 mark)

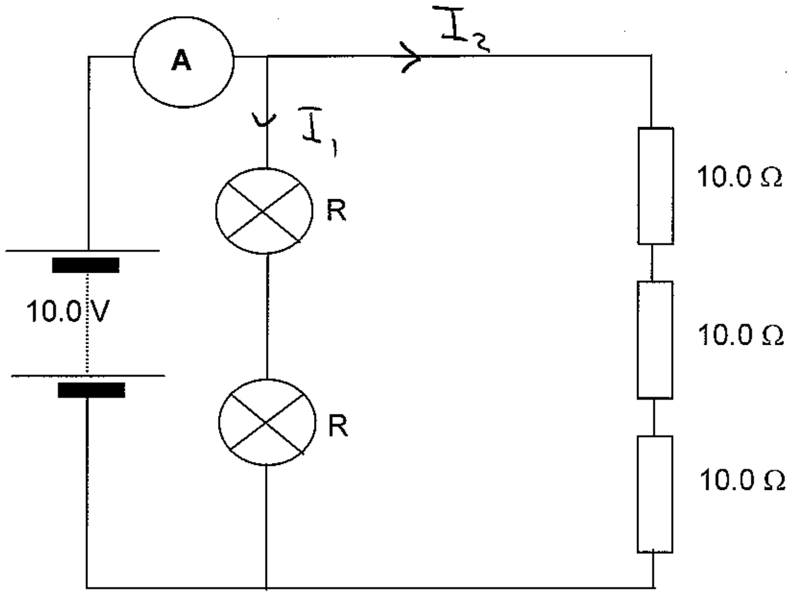
(i) top

(ii) bottom

(iii) there is not enough information supplied

Question 2 **(4 marks)**

In the circuit shown below the lamps are identical to each other. The ammeter reads 1.33 A.



Calculate the resistance of one lamp.

$$I_2 = \frac{V}{R} = \frac{10}{30} = 0.33$$

$$I_A = I_1 + I_2$$

$$\Rightarrow I_1 = 1.33 - 0.33$$

$$= 1A$$

$$V_R = 5.00V \Rightarrow$$

$$R_R = \frac{5.00}{1} = 5.0\Omega$$

Question 3 **(4 marks)**

A compact disc spins at 4000 revolutions per minute, and has a radius of 6.00×10^{-2} m. A dust particle of mass 1.00×10^{-4} kg rests on the outer edge of the disc. Calculate the frictional force required to prevent the dust particle from flying off the spinning disc.

$$f = \frac{4000}{60} = 66.67Hz$$

$$v = \frac{2\pi r}{T} = 2\pi r f$$

$T = 0.0149s$
$v = 25.13 m s^{-1}$

$$F = \frac{mv^2}{r} = \frac{m\,4\pi^2 r^2 f^2}{r}$$

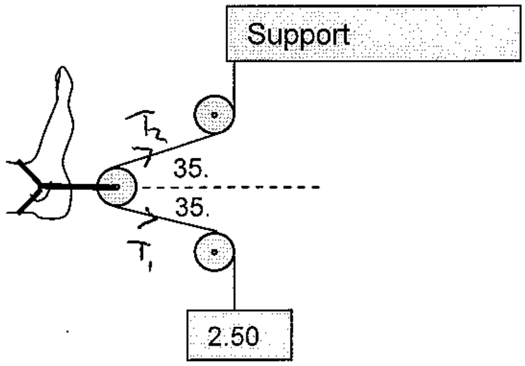
$$F = 4\pi^2 r m f^2$$

$$= (1\times10^{-4})(4)(\pi^2)(6.00\times10^{-2})66.67^2$$

$$= 1.05N \text{ towards centre}$$

Question 4 **(4 marks)**

A traction device uses three pulleys to apply a horizontal force to a patient's foot as shown in the figure opposite.
A single string goes around the three fixed pulleys. One end of the string is tied to a 2.50 kg load and the other end is tied to a rigid support.
The middle pulley is attached to the patient's ankle and pulls it as shown.



Calculate the force exerted on the patient's ankle.
Assume that the pulleys are frictionless.

$$F_{weight} = 2.50 \times 9.8$$

$$\Rightarrow T_1 = T_2 = 2.5 \times 9.8$$

$$T_{foot} = T_{1H} + T_{2H} = (2)(2.5)(9.8)\cos 35.0$$

$$= 40.1\text{ N left}$$

Question 5 **(4 marks)**

An aeronautical engineer is asked to launch a satellite such that it is in a synchronous orbit around Venus. Assuming Venus has a mass of 4.87×10^{24} kg, a radius of 6.05×10^{6} m and the length of a day on Venus is 2.10×10^{7} s calculate:

(a) The orbital radius of the satellite. (3 marks)

$$v = \frac{2\pi r}{T}$$

$$F_G = F_C$$

$$\frac{Gm_1m_2}{r^2} = \frac{m_1v^2}{r} \Rightarrow r = \frac{Gm}{v^2} = \frac{GmT^2}{4\pi^2r^2}$$

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}} = 1.54 \times 10^{9}\text{ m} \quad \sqrt[3]{\frac{(2.1\times10^{7})^2(6.67\times10^{-11})(4.37\times10^{24})}{4\pi^2}}$$

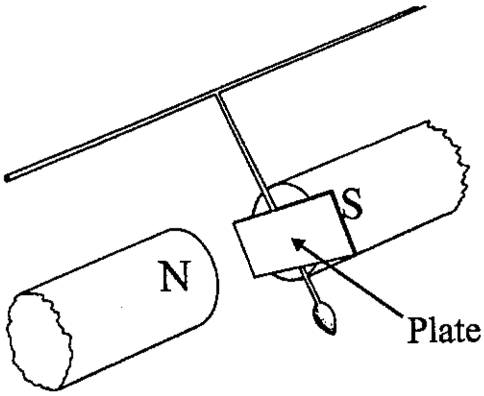
(b) Its orbital speed. (1 mark)

$$v = \frac{2\pi r}{T} = \frac{2\pi\ 1.54\times10^{9}}{(2.1\times10^{7})}$$

$$= 4.60\times10^{2}\text{ m s}^{-1}$$

Question 6 **(3 marks)**

An oscillating pendulum has an aluminium plate attached to it that passes between opposite magnetic poles as shown.

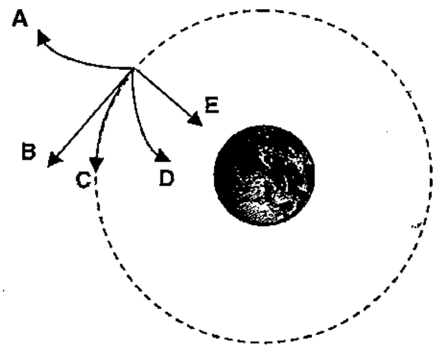


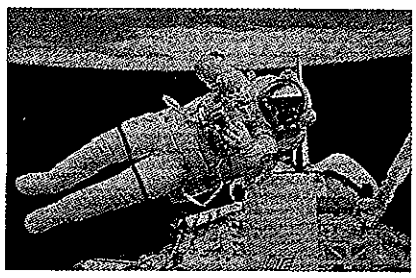
(a) Describe what would happen to the aluminium plate as it swings between the poles. (2 marks)

(b) How would your observations change if the aluminium plate is replaced with an identically-shaped iron plate? (1 mark)

Question 7 **(1 mark)**

While working on a satellite in orbit around the Earth an astronaut lets go of his specially designed wrench. Which of the options (A – E) best describes the path of the wrench the instant it slips free from the astronaut's grasp?

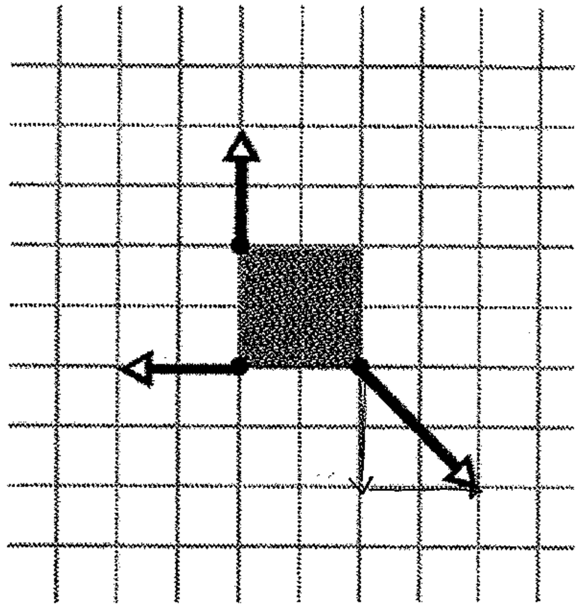




Answer: C

Question 8 **(3 marks)**

The figure shows an overhead view of a metal square lying on a frictionless floor. Three forces, which are drawn to scale, act at the corners of the square.



a. Is the square in translational equilibrium?
(1 mark)

YES

b. Is the square in rotational equilibrium?
(1 mark)

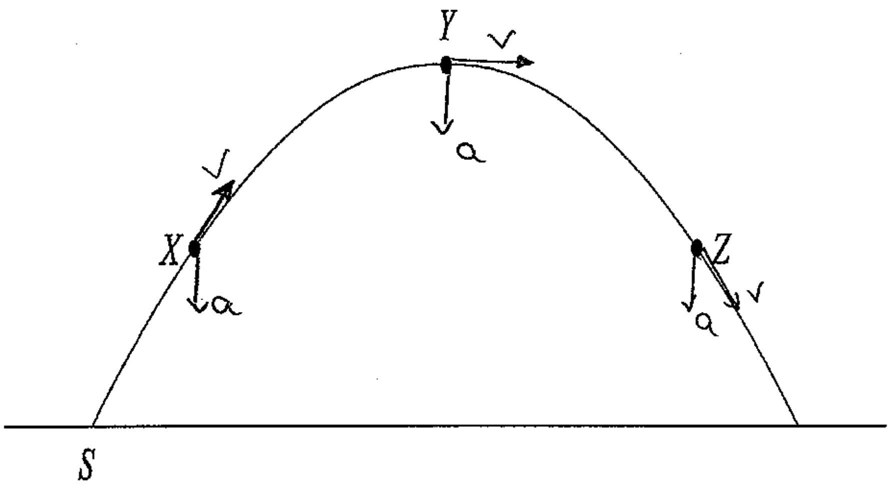
No

c. Is it possible for a fourth force to act on the fourth corner of the square such that the square is in static equilibrium? (1 marks)

No

Question 9 **(4 marks)**

A ball is thrown from *S* at an angle to the horizontal as shown in the diagram below. *X*, *Y*, and *Z* are different positions along the ball's trajectory.



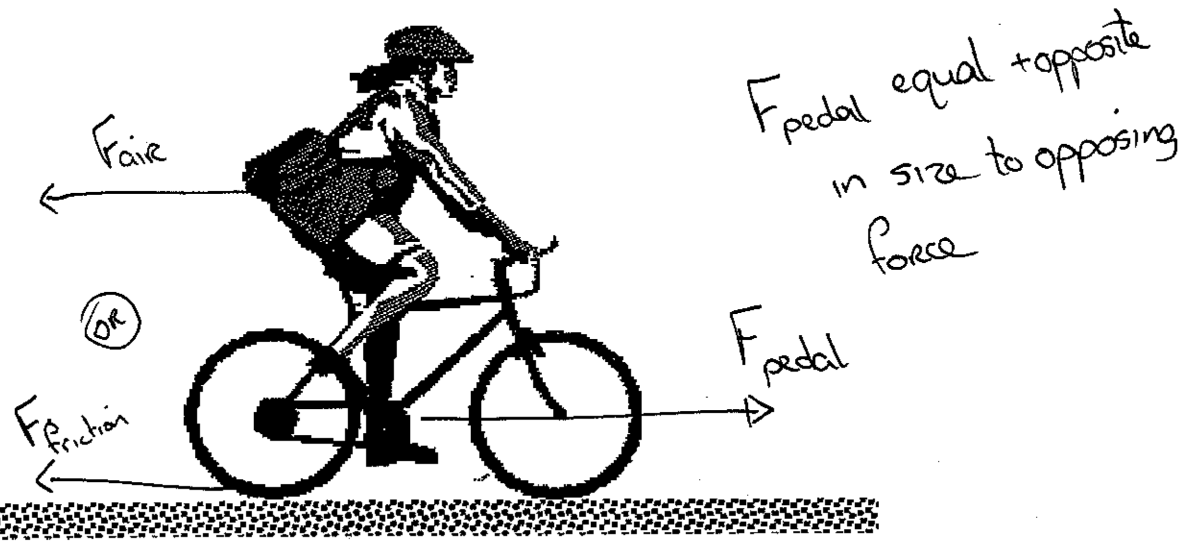
(a) Label each position, X, Y & Z, with an arrow that best represents the velocity and the acceleration of the ball, at that time.

(3 marks)

(b) This trajectory shown above assumes that the ball is not affected by air resistance. Draw the trajectory of the ball if air resistance is present.

(1 mark)

Question 10 **(4 marks)**

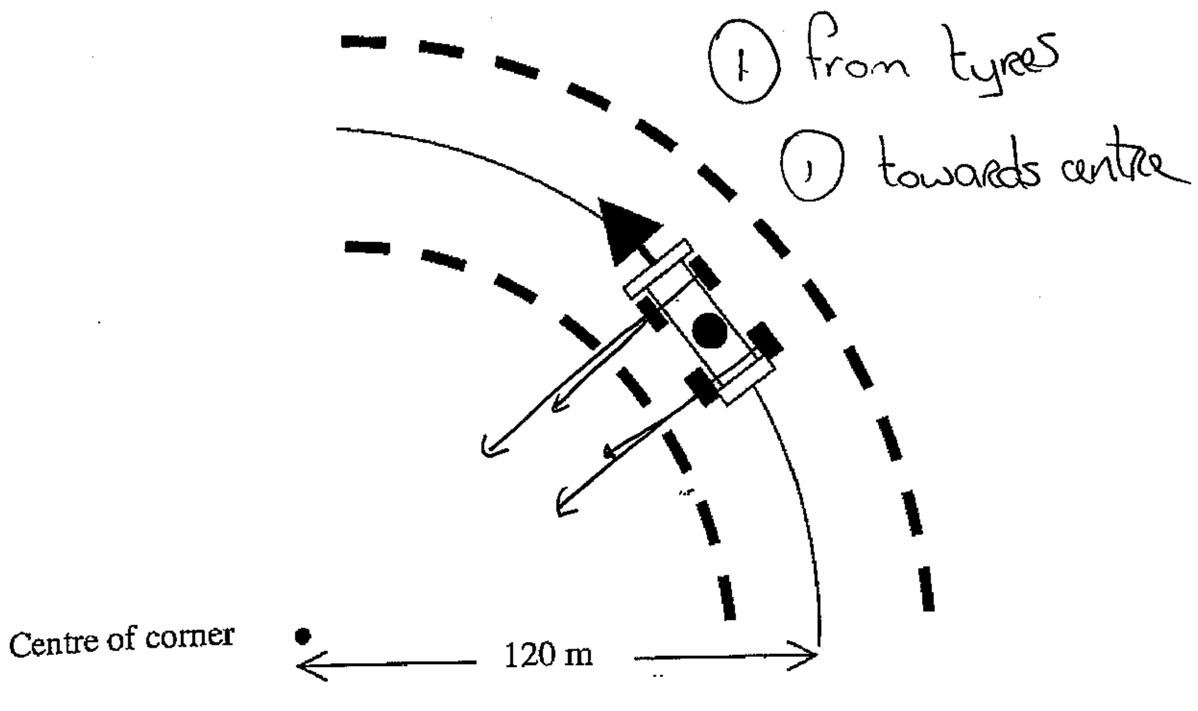


(a) On the diagram above indicate the forces acting horizontally on the cyclist and his bicycle when he is travelling at a constant speed while supplying a constant driving force.

(2 marks)

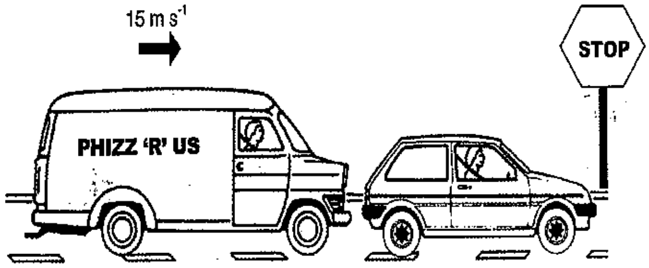
(b) In the diagram below a car is travelling around a corner. Clearly and accurately indicate the direction of the net horizontal component of the force exerted by the road on the car's tyres as the car travels around the corner.

(2 marks)



Question 11 **(5 marks)**

The diagram opposite shows a collision which is about to occur. The van has a mass of 2200kg and is travelling with a speed of 15m s^{-1} at the instant of the collision.
The car has a mass of 710kg and is stationary at a stop sign just prior to the collision. Both vehicles lock together after the collision.



(a) What is the velocity of the car immediately following the collision?

(3 marks)

$\sum P_{before} = \sum P_{after}$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$(2200)(15) + 0 = (2910)v \Rightarrow v = 11.3 \, m s^{-1}$ forward

$11 \, m s^{-1}$

(b) If the average frictional force acting on the car and van after the collision is 5000N, how far do the car and van move from their original positions before they come to rest?

(2 marks)

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

$F = ma = m\left(\frac{v^2 - u^2}{2s}\right) = \frac{mu^2}{2s}$

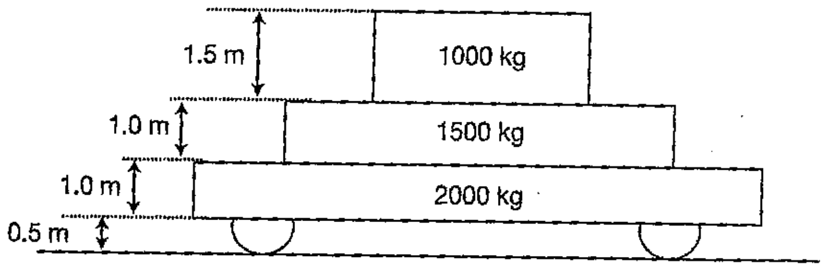
$a = 1.72 \, m s^{-2}$

$s = \frac{mu^2}{2F} = \frac{(2910)(11.3^2)}{(2)(5000)} = 37m$

Question 12 **(2 marks)**

Consider a 6.0m long,
2 tonne trolley cart loaded as shown in the diagram.

Calculate the height of the centre of mass of the loaded trolley above the ground. Ignore the mass of the wheels.

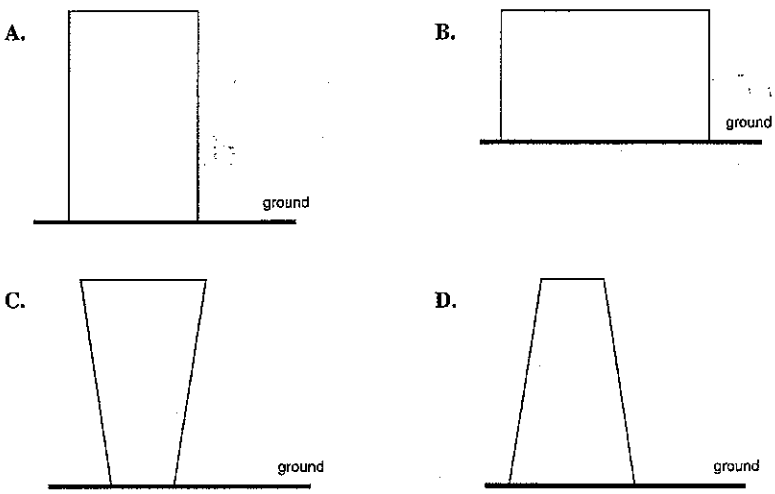


$x_{cm} = \frac{(2000)(1) + (1500)(2) + (1000)(3.25)}{4500}$

$= 1.8m$ above ground

Question 13 **(3 marks)**

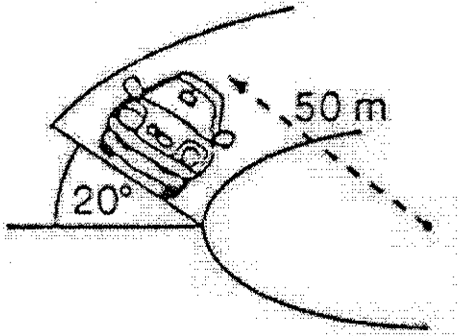
Which one of the following structures, made from a uniformly dense material is the least stable when placed on level ground? Justify your response.

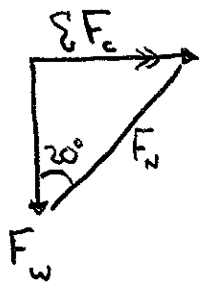


- C
- Narrow base
- High COM

Question 14 **(4 marks)**

A new van is being test driven to determine how it performs when driven on slippery, banked surfaces. If the van has a mass of 1.20 tonne and it is driven around a 20.0° banked curve, which has a radius of 50.0 m, calculate the maximum speed of the van without slipping as it drives around the curve.





$$\cos 20 = \frac{F_c}{F_N}$$

$$F_N = \frac{mv^2}{r\cos 20}$$

$$\sin 20° = \frac{mg}{F_N}$$

$$F_N = \frac{mg}{\sin 20}$$

$$\frac{\cancel{m}v^2}{r\cos 20} = \frac{\cancel{m}g}{\sin 20}$$

$$v^2 = \frac{rg}{\tan 20}$$

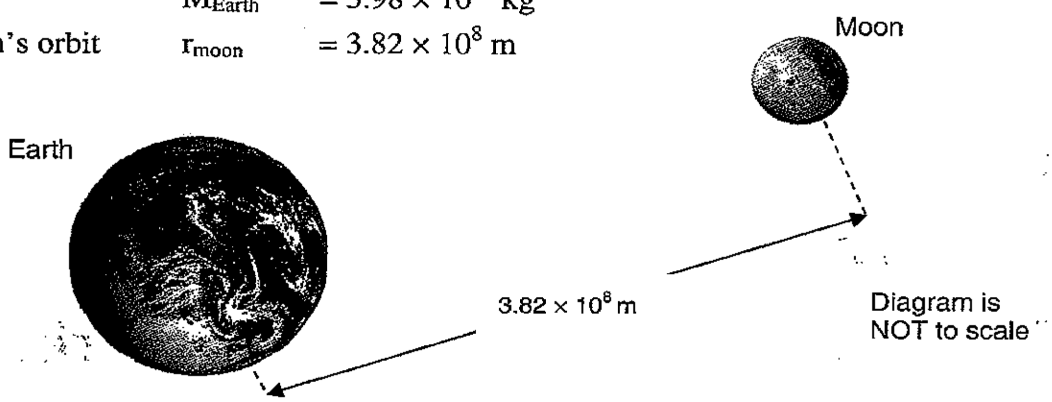
$$\tan 20° = \frac{F_c}{F_w} = \frac{\frac{mv^2}{r}}{mg} = \frac{v^2}{rg}$$

$$v = \sqrt{rg\tan\theta} = \sqrt{(50)(1.2\times10^3)\tan 20°}$$

$$= 13.4\ m\,s^{-1}$$

Question 15 **(4 marks)**

Mass of Earth	M_{Earth}	$= 5.98 \times 10^{24}$ kg
Radius of Moon's orbit	r_{moon}	$= 3.82 \times 10^{8}$ m



(a) What is the strength of the Earth's gravitational field at the Moon's location?

(2 marks)

$$g = \frac{Gm}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})}{(3.82\times10^{8})^2}$$

$$= 2.73\times10^{-3}\ \text{N kg}^{-1}$$

(b) What is the speed of the Moon around the Earth?

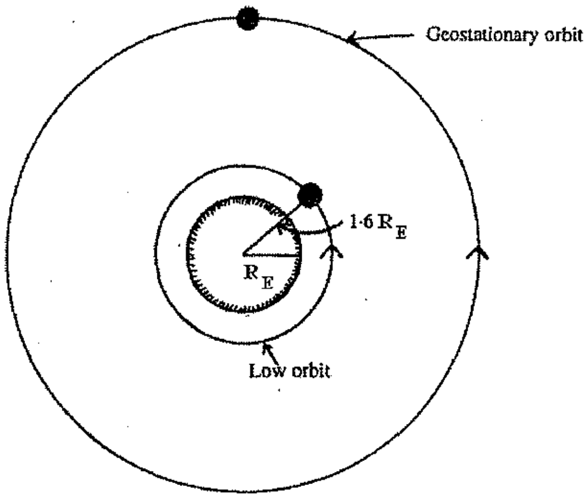
(2 marks)

$$a = g = \frac{v^2}{r} \Rightarrow v = \sqrt{gr}$$

$$= \sqrt{(2.73\times10^{-3})(3.82\times10^{8})} = 1.02\times10^{3}\ \text{m s}^{-1}$$

Question 16 **(2 marks)**

In the process of setting an "Aussat" satellite into a geosynchronous or geostationary orbit, it is initially launched into a low orbit of radius 1.6 R_E, where R_E is the radius of the Earth. In this orbit its period is 3 hours.



Calculate the gravitational field strength of the Earth's field at this low orbit.

$$g = \frac{Gm}{r^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})}{[(1.6)(6.37\times10^{6})]^2}$$

$$= 3.8\ \text{N kg}^{-1}$$

End of Section One

Section Two: Problem-solving **53% (95 Marks)**

This section has **eight (8)** questions. You must answer **all** questions. Write your answers in the space provided.

Spare pages are included available on request. They can be used for planning your responses and/or as additional space if required to continue an answer.

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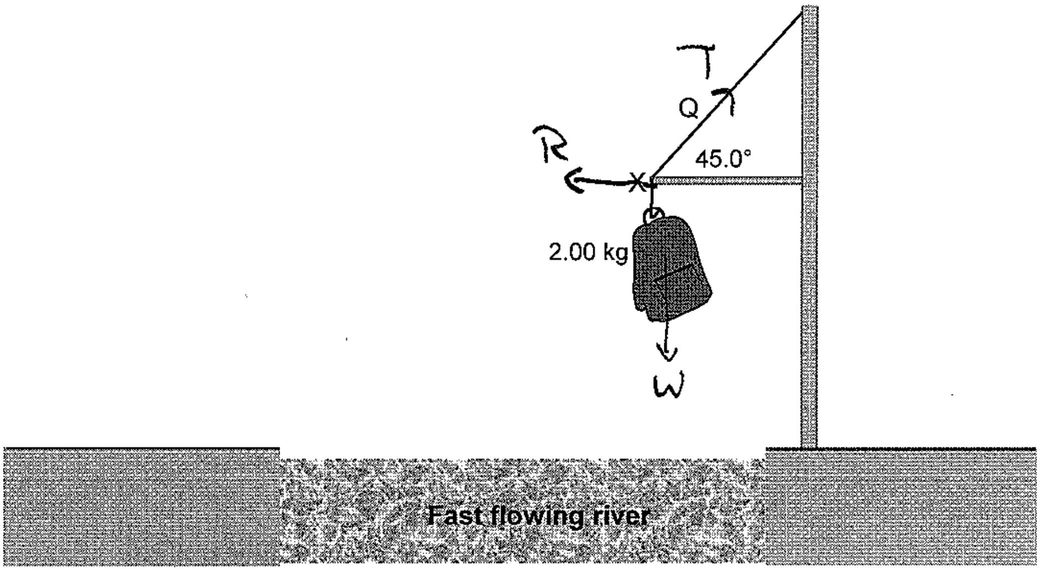
Suggested working time for this section is 95 minutes.

Question 17 **(12 marks)**

A survival course requires trainees to retrieve a ration pack of mass 2.00 kg suspended from a rope above a fast flowing river, as shown in the diagram below.



(a) Determine the net force acting on the suspended pack. (1 mark)

$F_{net} = 0N$

(b) On the diagram, draw vectors to represent the forces acting at point X. Ignore any frictional forces that might act at X. (3 marks)

(c) Calculate the tension in the rope at the point marked Q. (3 marks)

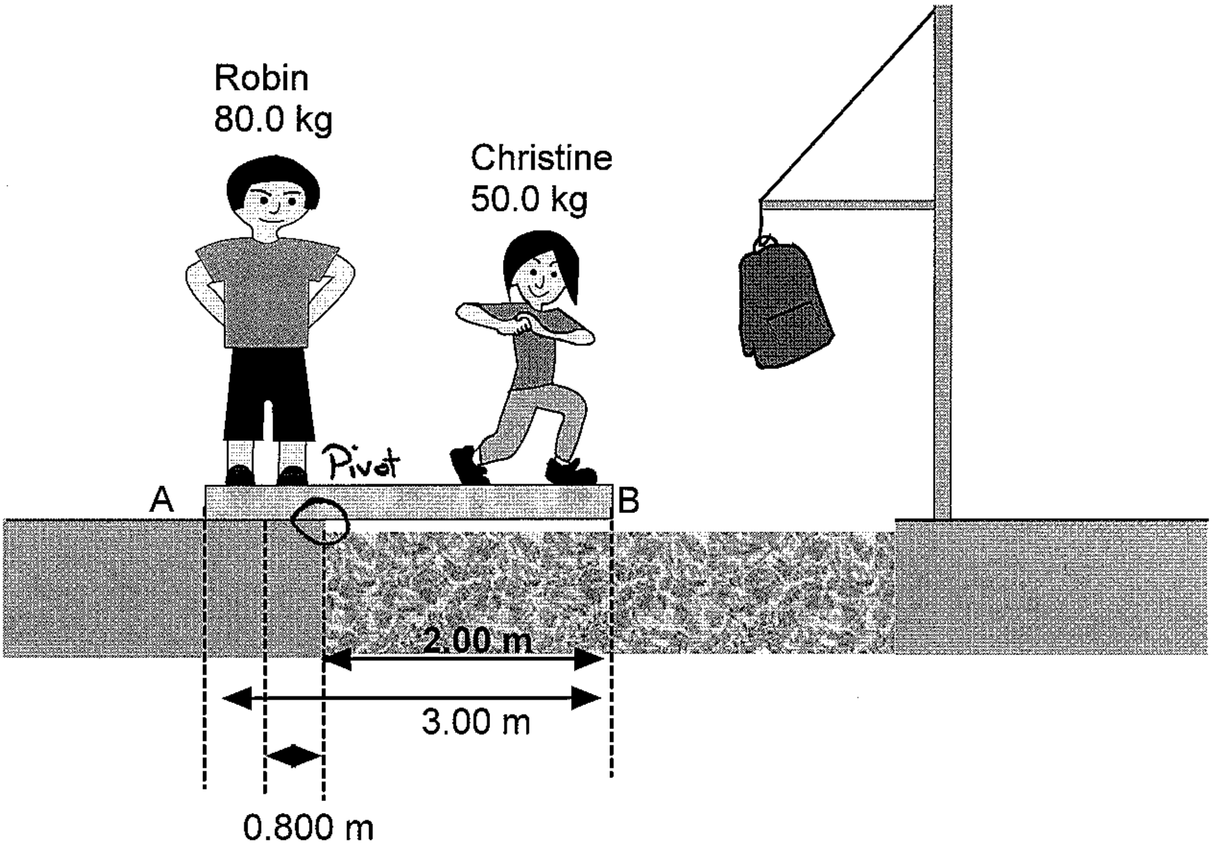
$\Sigma F_v = T_v + W = 0$

$T_v = (9.8)(2.0) = 19.6$

$T = \frac{T_v}{\sin 45} = \frac{(9.8)(2.00)}{\sin 45} = 27.7\,N$

along wire

(d) Robin, a trainee whose mass is 80.0 kg, is unable to reach the hanging mass. Robin suggests to a friend, Christine, that they could use a 3.00 m long uniform plank of mass 12.0 kg as shown below.



Robin stands so that his centre of mass is 0.200 m from end A of the plank. With Robin holding down one end, the plank extends over the river bank by 2.00 m. Christine, of mass 50.0 kg, walks out along the plank toward end B.

Calculate how far Christine can safely walk along the plank. (5 marks)

$$\sum \tau_{cw} = \sum \tau_{acw}$$ (1)

$$\tau_{christine} + \tau_{plank} = \tau_{Robin}$$ (2)

$$(50.0)(9.8)(r_c) + (12.0)(9.8)(0.5) = (0.8)(80.0)(9.8)$$

$r_c = 1.16$ m from pivot (2)

OR

(reference the distance

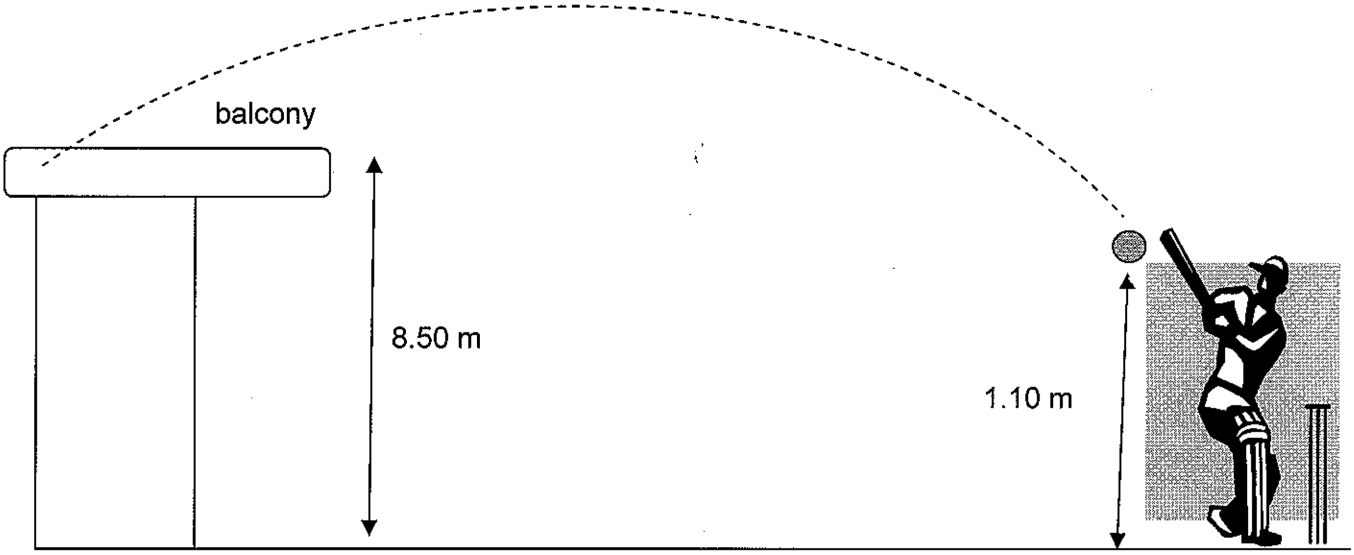
0.84 from B

OR

2.16 from A

Question 18 **(15 marks)**

During a cricket match a cricket ball is hit with an initial velocity of 45.0 m s^{-1} at an angle of 30.0° to the horizontal from a height of 1.10 m above the ground. It lands in the spectators' balcony which is 8.50 m above the ground.



(Diagram not to scale)

(a) Calculate the horizontal and vertical components of the cricket ball's initial velocity. (2 marks)

$u_H = 45.0 \cos 30 = 39.0 \text{ m s}^{-1}$ left

$u_V = 45.0 \sin 30 = 22.5 \text{ m s}^{-1}$ up

(b) Determine the final vertical displacement of the ball. (1 mark)

$8.50 - 1.10 = 7.4$ m up

(c) Calculate the vertical component of velocity of the ball when it lands in the spectators' balcony having followed the trajectory shown in the diagram above. (3 marks)

↑ +ve
↓ −ve

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

$v^2 = 22.5^2 + (2)(-9.8)(7.4)$

$v = -19.0 \text{ m s}^{-1}$

down

(d) Calculate the time of flight of the ball. (3 marks)

$$v_v = u_v + at$$

$$-19 = 22 - 9.8t$$

$$t = \frac{22+19}{9.8} = 4.23s$$

(e) Calculate the horizontal distance between the batsman and the point where the ball landed on the spectators' balcony. (2 marks)

If you are unable to complete (d) use value of 4.10 s for time of flight for this question.

$$s_H = u_H t$$

$$= (39.0)(4.23) = 1.65 \times 10^2 m \text{ left}$$

(f) Calculate the maximum height the ball achieved relative to the ground. (4 marks)

$$V_v = 0 m s^{-1}$$

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

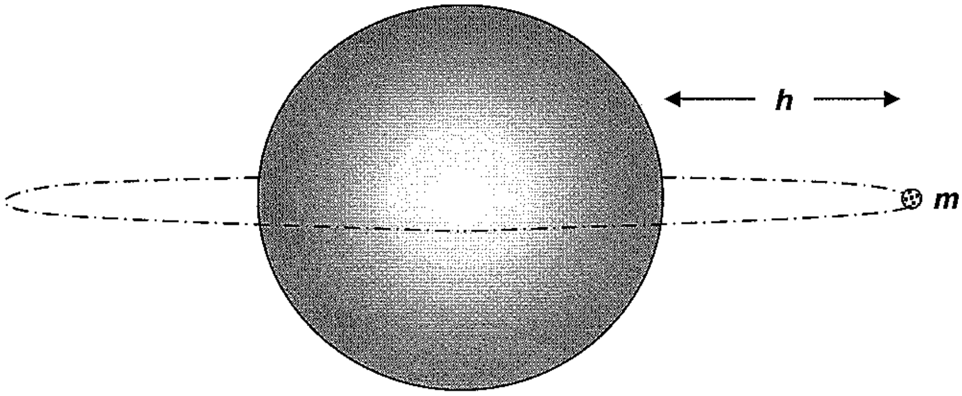
$$0 = (22.5)^2 - (2)(9.8)(s)$$

$$s = 25.8m$$

$$25.8 + 1.1 = 26.9m$$

Question 19 **(9 marks)**

A satellite of mass ***m*** follows a circular orbit around the Earth, at constant speed and at an altitude ***h*** above the Earth's surface as shown below.



(a) Determine the orbital period of the satellite if it appears stationary above a fixed point on the Earth's equator. (1 mark)

24 hours $= 24 \times 60 \times 60 = 8.64 \times 10^4$ s

(b) Calculate the height ***h*** of the satellite above the surface of the Earth. (5 marks)

$$F_c = F_G$$

$$\frac{\cancel{m}v^2}{r} = \frac{G\cancel{m}M}{r^2} \qquad v = \frac{2\pi r}{T}$$

$$\frac{4\pi^2 r^2}{T^2 r} = \frac{GM}{r^2}$$

$$r^3 = \frac{GMT^2}{4\pi^2} = \frac{(6.67\times10^{-11})(5.98\times10^{24})(8.64\times10^4)^2}{4\pi^2}$$

$$r = 4.22\times10^7 \text{ m}$$

height above Earth $= 4.22\times10^7 - 6.37\times10^6$

$= 3.58 \times 10^7$ m

(c) If the mass of the satellite is doubled, how will this affect its orbital radius? Justify your response. (2 marks)

• No difference

• Orbital radius depends on mass of body being orbited

• As shown in eqn $r^3 = \frac{GMT^2}{4\pi^2}$ where M = mass of Earth

(d) Name one use or application of geostationary satellites. (1 mark)

• Communication

• TV

Question 20 **(10 marks)**

In 1920, Edwin Hubble discovered that most galaxies are moving away from the Earth, suggesting that the Universe is expanding. Hubble also found that the further away a galaxy is, the faster it is moving. The speed at which the galaxy is moving is called its 'Speed of Recession'. The following data together with the associated errors were recorded by Hubble in the 1940s using an optical telescope. A light year is the distance travelled by a photon of light in one year.

Object name	Speed of recession ($\times 10^4$ km s^{-1})	Distance ($\times 10^6$ light years)
Virgo	0.2 ± 0.1	10.2
Corona Borealis	2.4 ± 0.2	400
Hydra	6.2 ± 0.3	1100
Kip	4.8 ± 0.2	900

(a) Graph these data on the graph paper opposite, including error bars. Plot speed of recession (*y*-axis) against distance (*x*-axis) and draw a line of best fit. (4 marks)

Labels Errors bars

Units LOBF going through all error bars

(b) Use the graph to predict the speed of recession of a galaxy that is 710 × 10^6 light years from Earth. Clearly show working on graph. Give answers in SI units. (1 marks)

$4 \times 10^7 \text{ m s}^{-1}$

Shown on graph

(c) Hubble's Law can be stated as

$$v_{galaxy} = (H_o)(distance)$$

H_o = Hubble's constant.
v_{galaxy} = speed of recession
distance = distance to the galaxy in light years

Use your graph to calculate a value for H_o. Show all working. Leave units for distance in light-years (Ly)

(3 marks)

Gradient : $\frac{4\times10^7}{710\times10^6} = 0.056 \text{ m s}^{-1} \text{ Ly}^{-1}$

(1) use graph
(1) units
(1) value

$5.6\times10^{-2} \text{ m s}^{-1} \text{ Ly}^{-1}$
$5.6\times10^{-5} \text{ km s}^{-1} \text{ Ly}^{-1}$

$v_{galaxy} = H_o \text{ distance}$
$\uparrow \quad \uparrow \quad \uparrow$
$y = m x$

(d) Calculate the distance travelled by light in one year (1 mark)

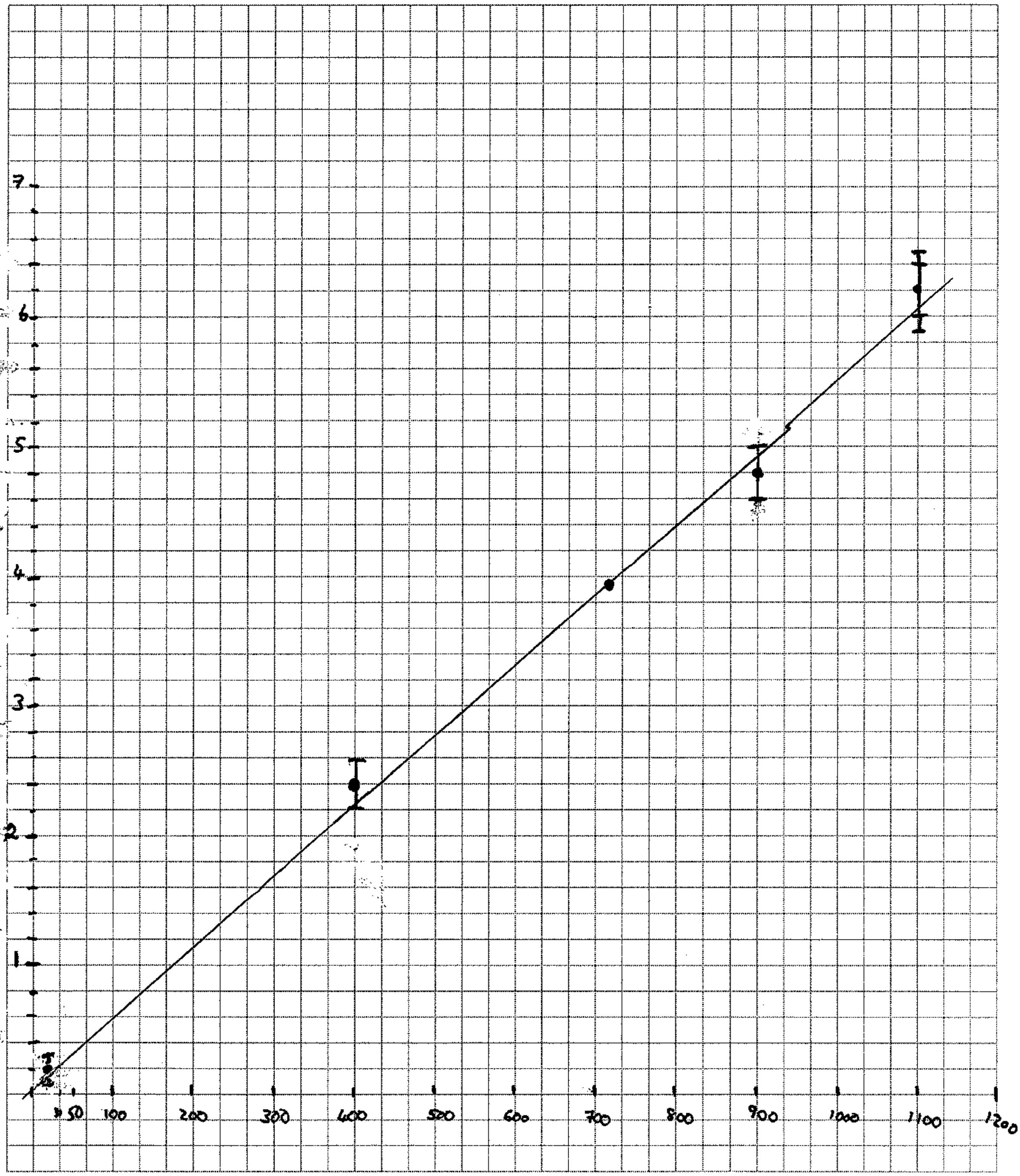
$v = \frac{s}{t} \Rightarrow s = (3\times10^8)(365\times24\times60\times60)$
$= 9.46\times10^{15} \text{ m}$

(e) Use the information calculated in (c) and (d) to express Hubble's constant in SI units.

(1 mark)

$$\frac{0.056}{9.46\times10^{15}} = 5.91\times10^{-18}\ \frac{m\,s^{-1}}{m}$$

$$= 5.91\times10^{-18}\ s^{-1}$$



• Units • Labels • Axis

Question 21 **(14 marks)**

(a) Two physics students take a ride on a roller coaster. During part of the ride they are travelling on a horizontal section at 35.0km h^{-1} due south. They enter a bend of radius 12.5m and finish up travelling at the same speed but in a westerly direction.

$9.7\ m s^{-1}$ (1)

a. Calculate the magnitude of their acceleration as they travel around the bend

(2 marks)

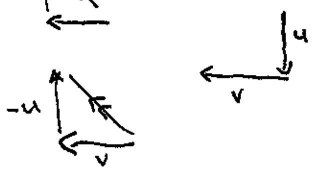
$$a = \frac{v^2}{r} = \left(\frac{35\times10^3}{3600}\right)^2 \cdot \frac{1}{12.5} = 7.6\ m s^{-2}$$

(1)

b. What is the direction of the acceleration when they are half way through the bend?

(1 mark)

North west



(b) A wooden horse and a wooden elephant are fixed to a merry-go-around platform. Each travels in a horizontal circular path at constant speed. The horse has a mass of 75kg and is travelling in a circle of radius 2.0m. The elephant has a mass of 150kg and travels in a circle of radius 6.0m. Calculate the following fractions:

a. $\dfrac{\text{Frequency of revolution of the elephant}}{\text{Frequency of revolution of the horse}}$ 1 : 1

(1 mark)

b. $\dfrac{\text{Speed of the elephant}}{\text{Speed of the horse}}$ $v = \dfrac{2\pi r}{T} = 2\pi r f$

(2 marks)

$$\frac{v_E}{v_H} = \frac{2\pi r f_E}{2\pi r f_H} = \frac{r_E}{r_H} = \frac{6}{2} = \frac{3}{1}$$

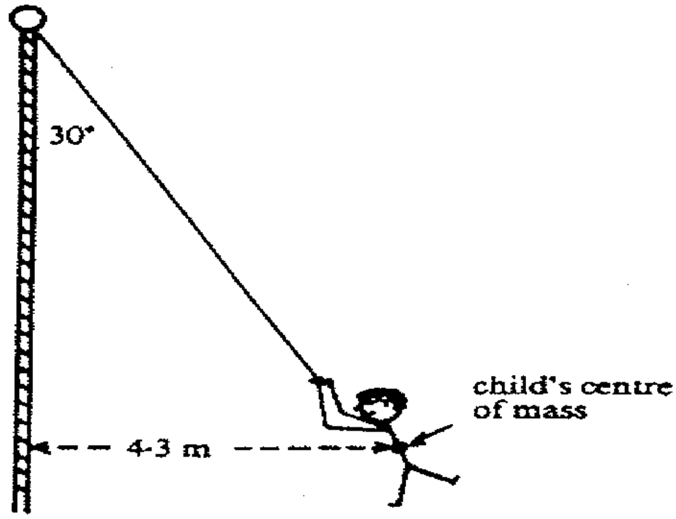
c. $\dfrac{\text{Net force on the elephant}}{\text{Net force on the horse}}$

(3 marks)

$$\frac{F_E}{F_H} = \frac{m_E V_E^2}{r_E} \cdot \frac{r_H}{m_H V_H^2} = \frac{m_E}{m_H} \cdot \frac{r_H}{r_E} \cdot \left(\frac{3}{1}\right)^2$$

$$= \frac{150}{75} \cdot \frac{2}{6} \cdot \frac{9}{1} = \frac{6}{1}$$

(c) A child is swinging on a maypole in a playground as shown in the diagram opposite. When the child – of mass 40kg – is moving at a constant speed of 5.0m s^{-1}the rope makes an angle of 30.0 degrees to the central pole. The centre of mass of the child moves in a horizontal circle of radius 4.30m.



a. Calculate the net force acting on the child

(2 marks)

$$F_{net} = F_H = \frac{mv^2}{r} = \frac{(40)(5^2)}{4\cdot3} = 2\cdot3\times10^2 N$$

towards centre

b. Calculate the tension in the rope. Assume that the mass of the rope itself is negligible.

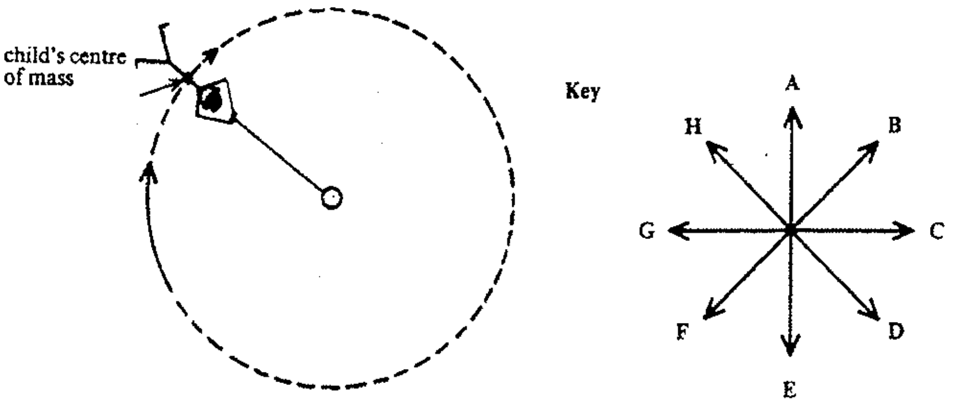
392 (2 marks)

$$\sum F_v = T_v + W = 0 \Rightarrow T_v = (40)(9\cdot8)$$

$$T_v = T\cos 30 \Rightarrow T = \frac{(40)(9\cdot8)}{\cos 30} = 4\cdot5\times10^2 N \text{ along rope}$$

c. If the child lets go of the rope when at the position shown in the figure below, in what direction (as viewed from above) will the child initially move? Use the key below to indicate your answer.

(1 marks)



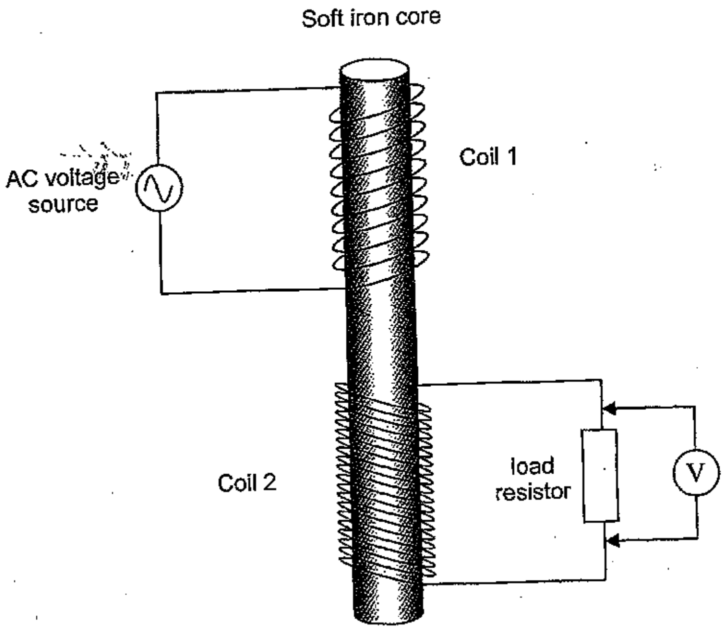
(as seen from above)

Answer: B

Question 22 **(13 marks)**

A student is investigating the operation of a transformer she has built using some wire coils and a soft iron rod. The diagram opposite shows her experimental set up.

Coil 1 has 10 loops and Coil 2 has 20 loops. The AC voltage source supplies 20V into Coil 1.



a. Calculate the reading on the voltmeter across the load in Coil 2.

(2 marks)

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow V_2 = 40V$$

b. What major assumption have you made in this calculation?

(1 mark)

- Power is conserved
- Energy is conserved
- $\frac{\Delta\phi}{t}$ is same in both part of core

c. What is the purpose of the soft iron core in this experiment?

(2 marks)

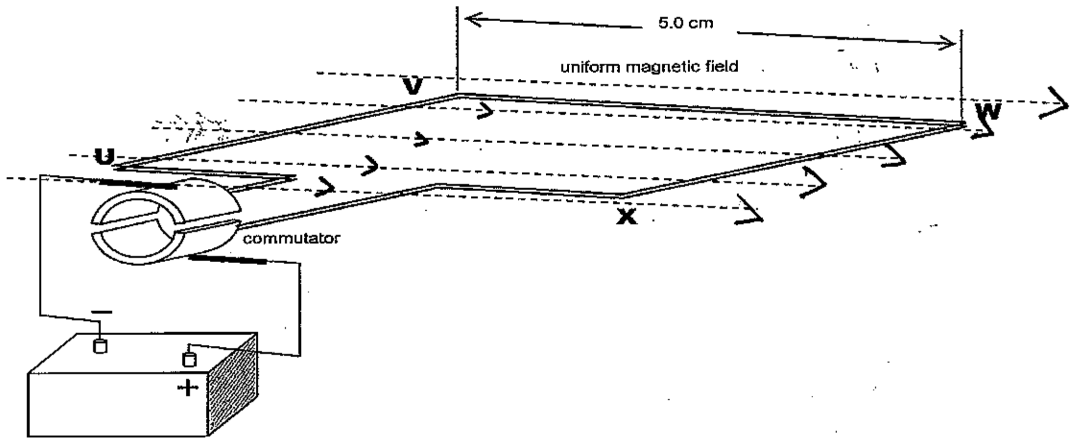
Provides flux linkage

d. In a further experiment the input voltage from the power supply is altered and the voltage across the load resistor is now measured to be 50V. The load resistor is 560Ω What power is being consumed by the load resistor?

(2 marks)

$$P = \frac{V^2}{R} = \frac{50^2}{560} = 4.46W$$

The student then dismantles a small DC motor to observe how it operates. A simplified diagram of the motor is shown below. In this model the single square loop is attached to a commutator and allowed to rotate freely in a uniform magnetic field. The loop is a square of side length 5.0cm. A current of 50mA is supplied from the battery to the square loop.



e. The side of the loop XW experiences a force vertically down when the loop is oriented as shown in the diagram. On the diagram place arrows on the magnetic field lines (the dashed lines) indicating the direction of the magnetic field.

(1 mark)

f. The side of the loop XW experiences a force of 2.00x 10^{-4}N down. Calculate the magnitude of the strength of the magnetic field.

(1 marks)

$F = IlBn \Rightarrow B = \frac{F}{Iln} = \frac{2.00\times10^{-4}}{(50\times10^{-3})(5\times10^{-2})(1)}$

$= 0.08T$

$8\times10^{-2}T$

g. Calculate the total torque on the loop when it is in this position

(2 marks)

$\tau = 2F.r = (\underbrace{2}_{2})(\underbrace{2.5\times10^{-2}}_{r})(\underbrace{2.00\times10^{-4}}_{F})$

$= 1.0\times10^{-5}$ Nm cw

h. It is often preferable to use electromagnets in place of permanent magnets when building DC motors. List two specific reasons why electromagnets are preferable to permanent magnets.

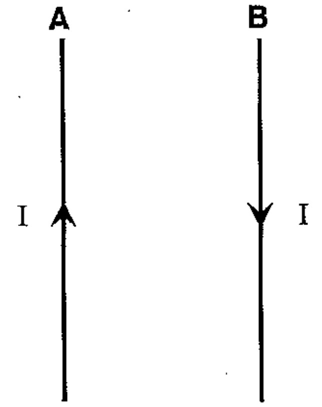
(2 marks)

- Don't lose magnetic properties – while sometimes permanent magnets do
- Can adjust B by adjusting I → easier to control
- More compact

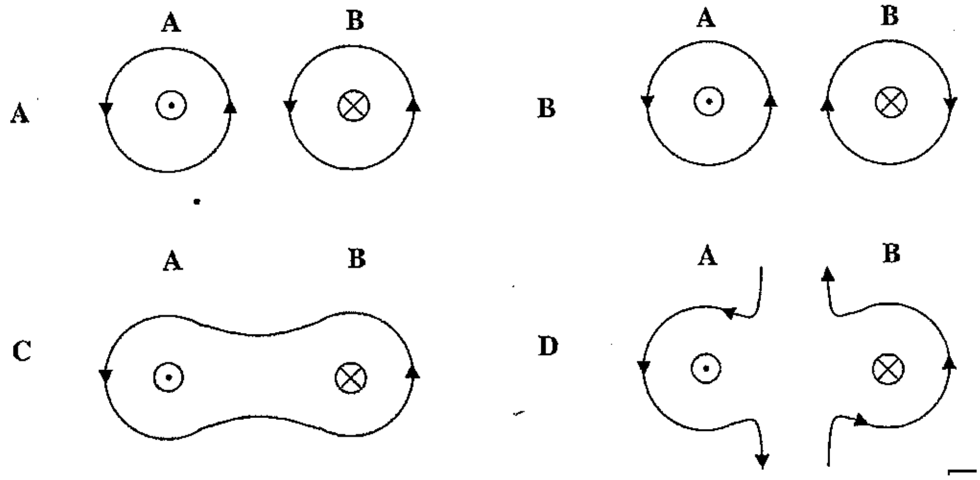
- something sensible

Question 23 **(11 marks)**

The diagram shows two wires A and B.



(a) Which diagram best indicates the shape and direction of the magnetic field about these current carrying wires?



Answer: B

(2 marks)

(b) Which of the following best indicates the direction of the magnetic force on wire B due to the currents flowing in the two wires?

A	Up	**B**	Down	**C**	To the right	**D**	Zero
E	Into the page	**F**	Out of the Page	**G**	To the left		

Answer: C

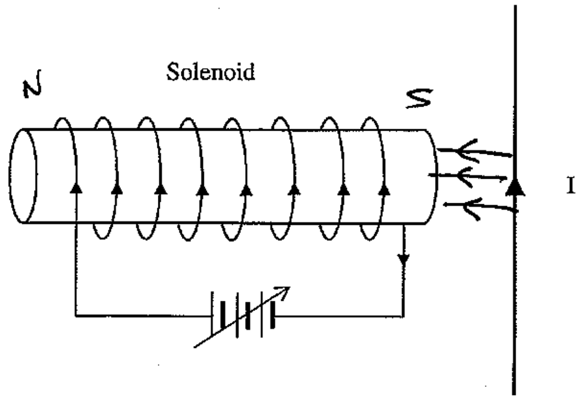
(2 marks)

B

C

(c) The diagram below shows a solenoid made by winding a current carrying conductor around a cardboard cylinder. The direction of the current in the solenoid is indicated by the arrows. A wire carrying a current I in the direction indicated by the arrow, is shown at the right hand end of the solenoid.

What is the direction of the magnetic force on this wire?



Answer: Out of page

(2 marks)

(d) Annotate the two diagrams below by drawing in the magnetic field lines

(2 marks)

Diagram 1

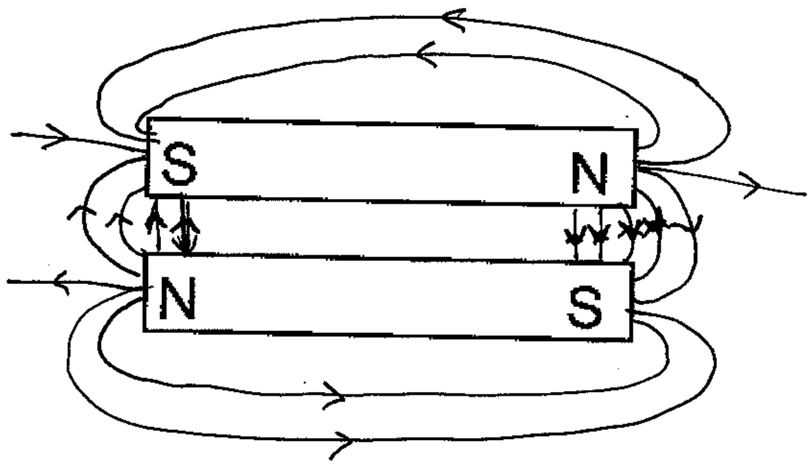
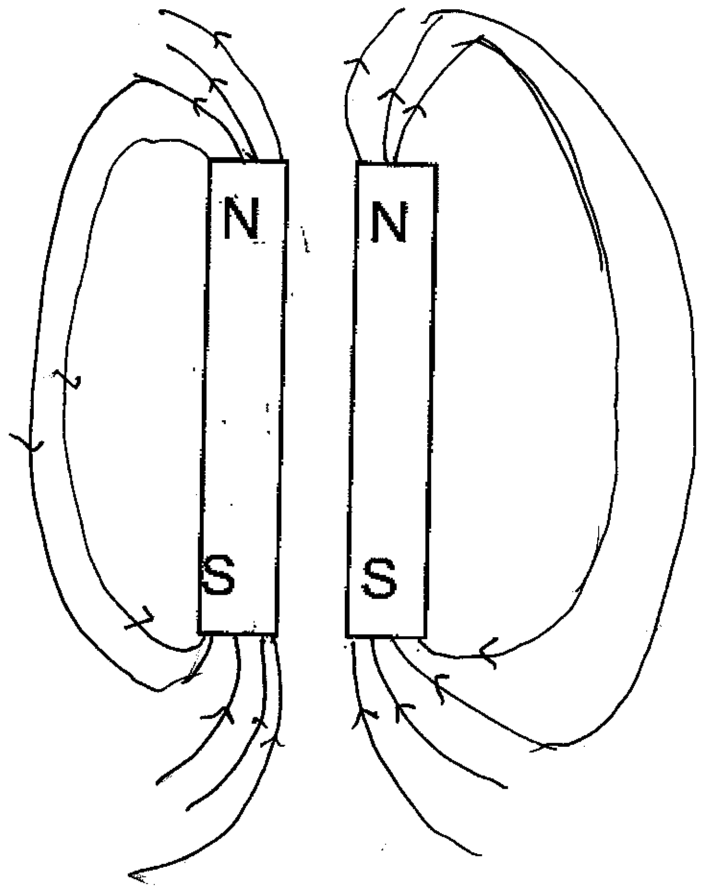


Diagram 2

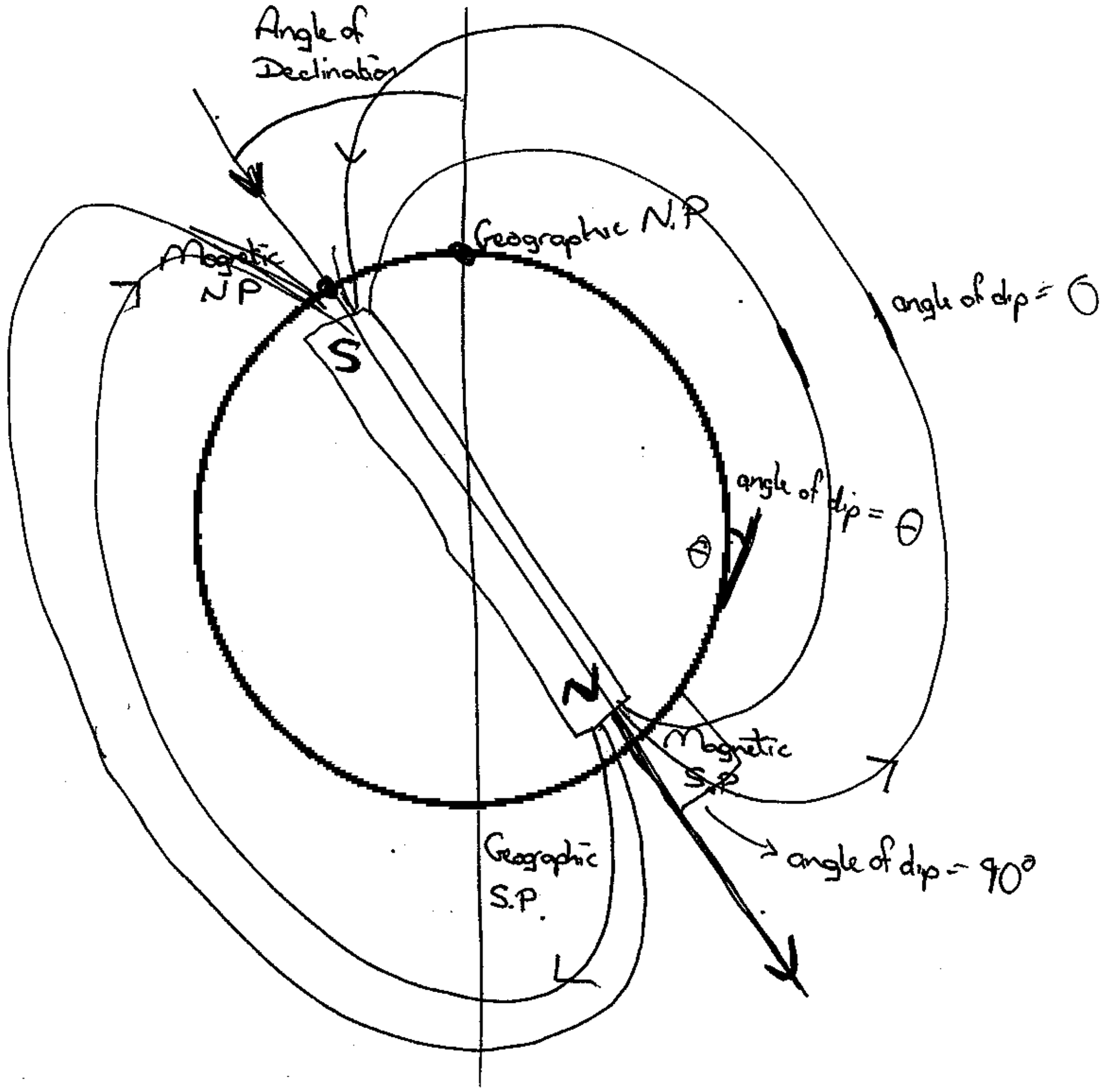


B, C, out of page

(e) Annotate the diagram below, by drawing in the Earth's magnetic field. Ensure that the following features are included and clearly labelled:

a. Magnetic north and south pole
b. Geographic north and south pole
c. Angle of declination
d. Angle of dip
e. Sufficient magnetic field lines to show the shape of the magnetic field.

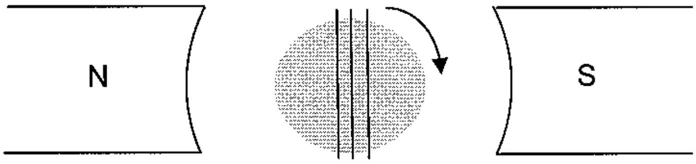
(3 marks)

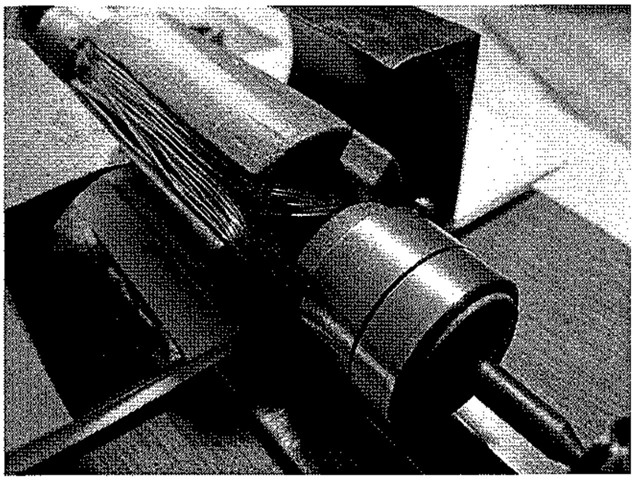


Question 24 **(11 marks)**

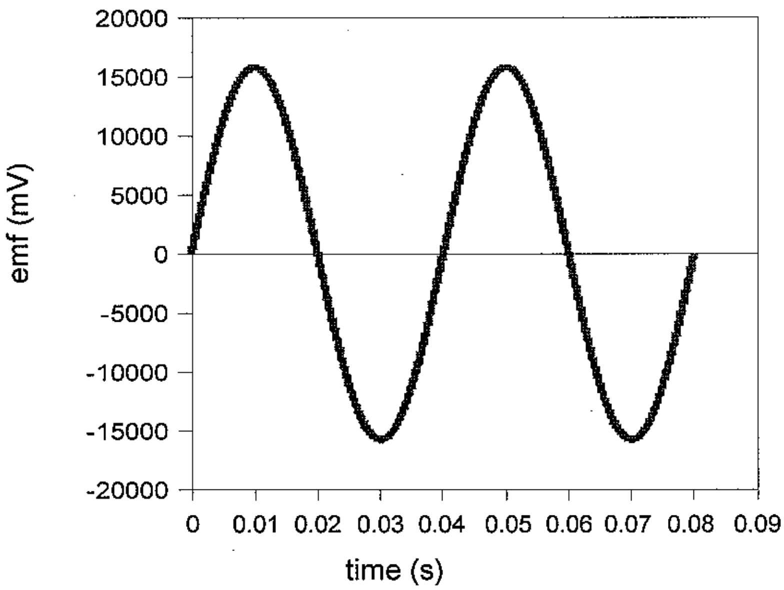
A student is conducting an experiment to investigate the properties of generators. She rotates a coil in a magnetic field as shown and, using a computer data-logger, generates a graph of the output emf from the coil versus time. The experimental arrangement and her graph of the output emf are shown below.

Experimental arrangement (diagram and photograph):





Graph of the emf generated versus time:



(a) Explain why an emf is generated in the coil. (3 marks)

• Relative change between mag field and a conductor

• Faraday's Law : an emf is induced in the conductor (coil)

Some credit for . electrons experience of force
· change in mag flux

(b) Explain why the graph of the output voltage takes the form (shape) shown. (2 marks)

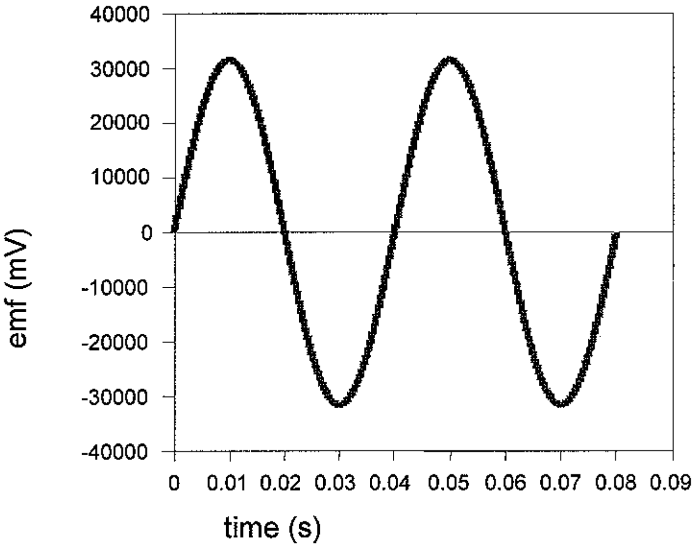
• Rate of change of flux isn't constant – it varies with the rotation ⇒ voltage also varies

(c) To increase the output from the generator, the coil can be wound on a material that becomes magnetic in the presence of a magnetic field but loses its magnetism when the field is removed. Explain why it is better to use this type of material rather than a material that can become a permanent magnet. (2 marks)

• It will increase the strength of the mag field (⇒ increases induced voltage)

• It isn't ferromagnetic ⇒ the poles of the N S magnet of the rotor aren't attracted to it ⇒ it doesn't slow down the rotor spin

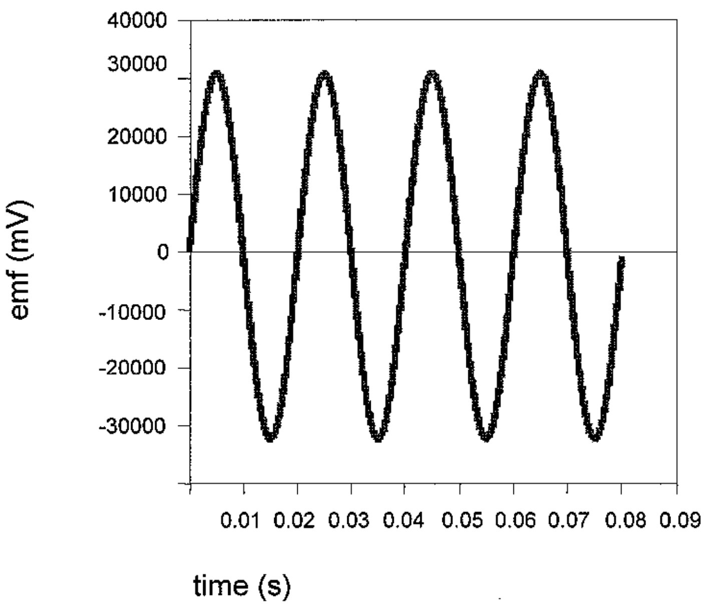
(d) The student then makes some changes to her experiment and produces the two graphs of output emf versus time as shown below. For each graph, describe one change she could make to her original equipment to produce the output emf shown. (4 marks)



Modification the student made: Double B OR

Double N OR

Double A



Modification the student made: Double frequency of rotation

End of Section Two

Section Three: Comprehension and Data Analysis **17% (30 Marks)**

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided.

Spare pages are available on request. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 40 minutes.

Question 25 **(12 marks)**

Black Holes

Anything on the surface of a large body (for example a planet) is affected by the gravitational field surrounding that body and to escape from the surface an object must move very quickly. The force of gravity will slow such an object but providing it is moving fast enough it can escape, that is, move sufficiently far away from the large body that the gravitational pull never manages to slow the escaping object's velocity to zero.

The minimum velocity needed to leave a surface is called the escape velocity and the equation used to calculate it is

$$v = \sqrt{\frac{2GM_E}{r_E}}$$

Imagine all the matter of the Sun, a ball of gas (mainly hydrogen and helium) with radius 6.96×10^8 m, squeezed together, so that it has a radius of only 2420 km. The Sun would now be a 'white dwarf' and its gases would have become a mixture of atomic nuclei and loose electrons.

Compressing the Sun even more would cause the electrons to fuse into the nuclei leaving nothing but neutrons. The Sun would be a 'neutron star' with a radius of 7250 m. The escape velocity of a neutron star is 1.93×10^8 m s^{-1}. It is hard to imagine anything being able to achieve such huge velocities but light would be able to escape since it travels at 3×10^8 m s^{-1}.

If the Sun continued to shrink past the neutron star stage the escape velocity would increase, eventually, to the speed of light. Then nothing, not even light, would be able to escape from the Sun's surface. Anything can fall into such an object, but nothing can escape. It is a 'black hole'.

The critical radius at which a neutron star becomes a black hole is given by the formula

$$r = \frac{2GM}{c^2}$$

In fact our Sun is too small to become a black hole. Stars more massive than the Sun explode before they begin to collapse, losing some of their mass. If the amount of mass remaining after such an explosion is more than 3.2 times the mass of our Sun, the collapsing star will become a black hole.

Black holes are difficult to detect. They neither emit nor reflect light, are very small and are very long distances from our own planet. The only way we can detect a black hole is to watch out for something falling into it. In general, objects falling toward black holes emit X-rays. If a black hole has a lot of matter falling into it there will be lots of X-rays emitted – enough for astronomers to detect.

The first black hole to be detected was Cygnus X-1. Initially, an X-ray source detected in the constellation Cygnus was found to be close (in astronomical terms) to the star HD-226868, a giant star 30 times more massive than the Sun. HD-226868 is one component of a binary star system. These two stars orbit their centre of mass every 5.6 days. The X-rays come from the other star, named Cygnus X-1.

The motion of HD-226868 shows that Cygnus X-1 is 5 to 8 times the mass of our Sun. A normal star of this mass should be visible with an optical telescope at that distance. However, no optical telescope has ever detected a star in the spot where the X-rays come from. Since Cygnus X-1 has at least 5 times more mass than the Sun, it is too massive to be anything other than a black hole.

(a) Calculate the escape velocity from the Earth. (3 marks)

$$v = \sqrt{\frac{2Gm}{r_E}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{6.37 \times 10^{6}}}$$

$$v = 1.12 \times 10^{4}\ m\,s^{-1}$$

(b) Describe how the strength of the gravitational field changes as you move further away from a planet. (2 marks)

$$g \propto \frac{1}{r^2} \qquad g = \frac{Gm}{r^2}$$

Inverse square relationship

Twice distance $\rightarrow \frac{1}{4} g$

(d) Calculate the radius of a black hole having the same mass as the Sun.

(2 marks)

$$r = \frac{2GM}{c^2} = \frac{2(6.67\times10^{-11})\times(1.99\times10^{30})}{(3\times10^{8})^2}$$

$$= 2.95\times10^{3}\,m$$

(e) Using the radius from part (d), calculate the density of the black hole. Assume that the black hole is spherical and that its density is given by mass divided by volume. The volume of a sphere is given by

$$V = \frac{4\pi r^3}{3}$$

(2 marks)

$$V = \frac{4\pi r^3}{3} = \frac{4\pi(2.95\times10^{3})^3}{3} = 1.08\times10^{11}\,m^3$$

$$\text{Density} = \frac{m}{V} = \frac{1.99\times10^{30}}{1.08\times10^{11}} = 1.85\times10^{19}\,kg\,m^{-3}$$

units

(f) Is the centre of mass of the binary star system closer to Cygnus X-1 or to HD-226868?. Justify your answer.

(3 marks)

- HD $\simeq$ 30 times more massive than our sun
- Cygnus $\simeq$ 5→8 times more massive

HD > Cygnus ⇒ COM closer to HD

Question 26 **(18 marks)**

In an experiment, a group of students place a rectangular shaped conducting wire (a, b, c, d) carrying a current of 5.0 A inside the solenoid as shown in the figure below.
The distance from a to b and from c to d is 5.7 cm.
The distance from b to c is 3.3 cm.
The segment abcd is completely immersed in the magnetic field as shown.
The magnetic field strength in the solenoid is 3.5×10^{-2}T.

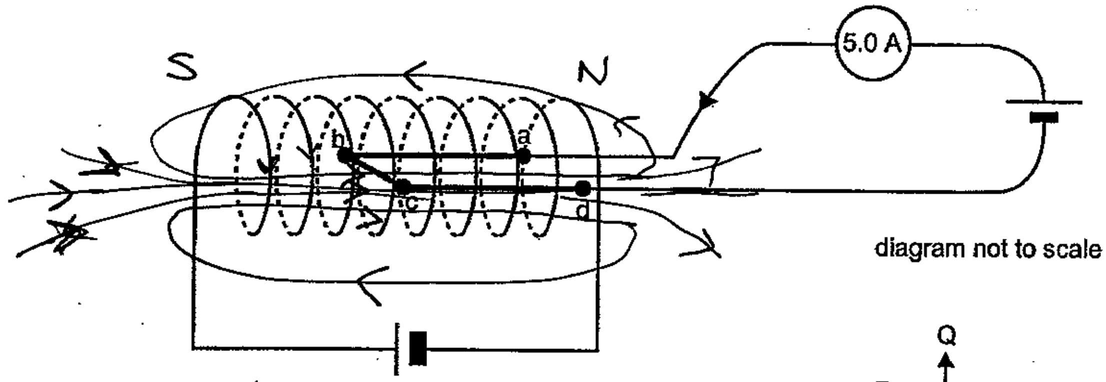


Figure 2a

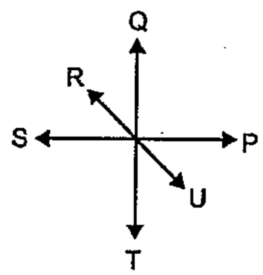


Figure 2b

a. Calculate the force on the section of wire |cd|. Use the key PQRSTU in Figure 2b to indicate direction. If there is no direction, write 'none'.

(2 marks)

NONE

$F_{CD} = 0N$

b. Calculate the force on the section of wire |bc|. Use the key PQRSTU in Figure 2b to indicate direction. If there is no direction, write 'none'.

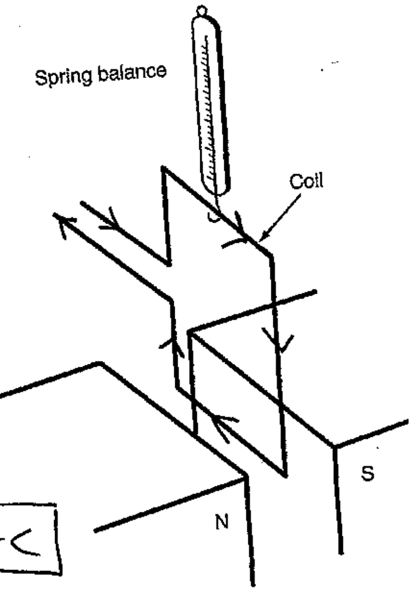
(2 marks)

$F = IlB$

$= (5)(3.3 \times 10^{-2})(3.5 \times 10^{-2}) = 5.8 \times 10^{-3}$ N

$\boxed{Q}$

In a different experiment a group of students set up a 2500-turn rectangular coil of wire and suspend it from a spring balance so that its lower side (6cm in length) lies between the poles of a magnet as shown in the diagram.



They passed various currents through the coil and recorded the reading on the spring balance. Their results are shown.

Current in Coil (A)	Reading on balance (N)
0	3.7
1	3.8
2	3.9
3	4.0
4	4.1
5	4.2

$\boxed{F_{total} = F_B + F_{weight}}$

In Sec C $\boxed{y = mx + c}$

$\boxed{\text{V. important}}$

a. Determine in which direction the current must be flowing through the coil to get the results shown. Indicate the direction of current flow on the diagram.

(1 mark)

b. Graph the results

(4 marks)

Labels Axis Units LOBF

c. Analyse the graph to find the quantities listed below. Show all working.

i. Mass of the coil

(1 mark)

$$F_{total} = F_{mg} + F_B$$
$$= mg + IlB$$

Intercept
When $I = 0$, $mg = 3.7\,N \Rightarrow m = 0.378\,kg$

ii. Strength of the magnetic field

(2marks)

$$F_{total} = I\,\underbrace{lB_n}_{} + mg$$
$$y = x \quad m \quad + \quad c$$

very few people had the 'c' value

$$\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1} = lB_n \Rightarrow B = \frac{\cancel{\text{gradient}}\ 0.1}{(2500)(6\times10^{-2})} =$$

$$\text{gradient} = \frac{3.95 - 3.85}{2.5 - 1.5} = \frac{0.1}{1} = 0.1$$

$\boxed{6.6\times10^{-4}\,T}$

iii. Reading on the spring balance if 10A was flowing through the coil

(1 marks)

$$F = (10)(0.1) + 3.7 = 4.7\,N$$

$$y = x \cdot m + c$$

iv. Reading on the spring balance if 4A was flowing in the opposite direction through the coil.

(2 marks)

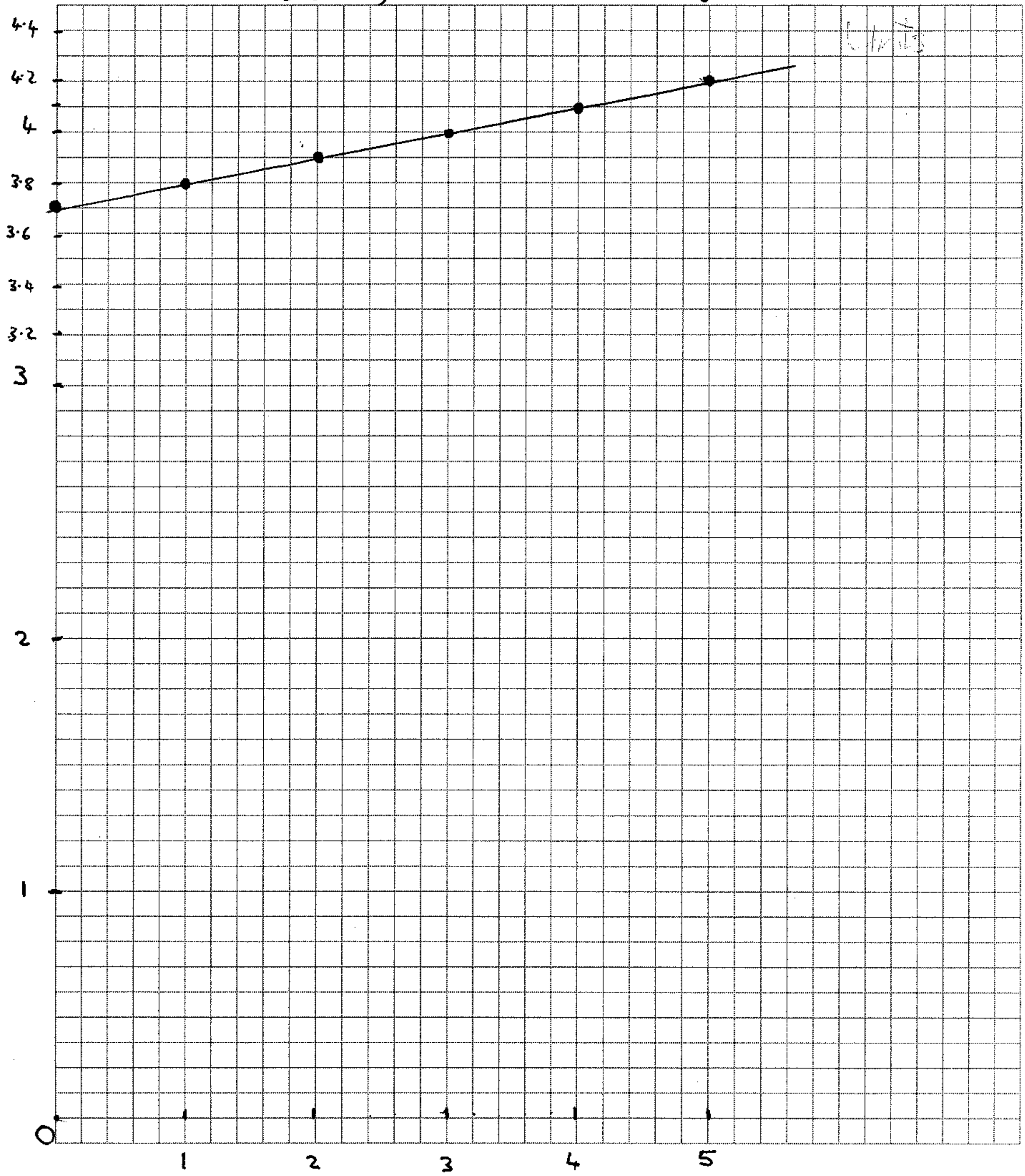
~~[illegible]~~

~~In opposite direction ⇒ 3.7 − 0.4 = 3.3 N~~

$y = mx + c$

$= (0.1)(-4) + 3.7 = 3.3\,N$

Axis
Labels
Units



d. Identify three factors which have been controlled in this experiment

(1 mark)

- Magnetic field
- Size / Length of wire in field
- Spring balance
- Environmental conditions : temperature, air pressure

e. Suggest two specific ways the original experiment could be improved to give more precise results.

(2 marks)

- Multiple readings + average ← must mention this because it is a serious omission not to!!
- More precise measuring instrument than spring balance

→ Note to self: Analog Galvanometer (v) Digital Ammeter

Dear Students! Remind ~~Ask~~ me to explain this to you, please!!

End of Exam