Section One: Short Response

CURRENTLY 66 marks 30% (54 marks)

This section has !!!!!! 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.

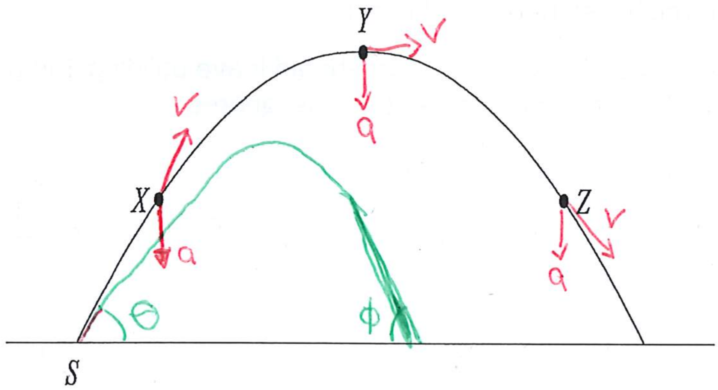
When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

Supplementary pages for the use of the planning / continuing your answer to a question have been provided at the end of this Questions/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continues – i.e. give the page number.

Suggested working time: 50 minutes

Question 1 **(5marks)**

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.



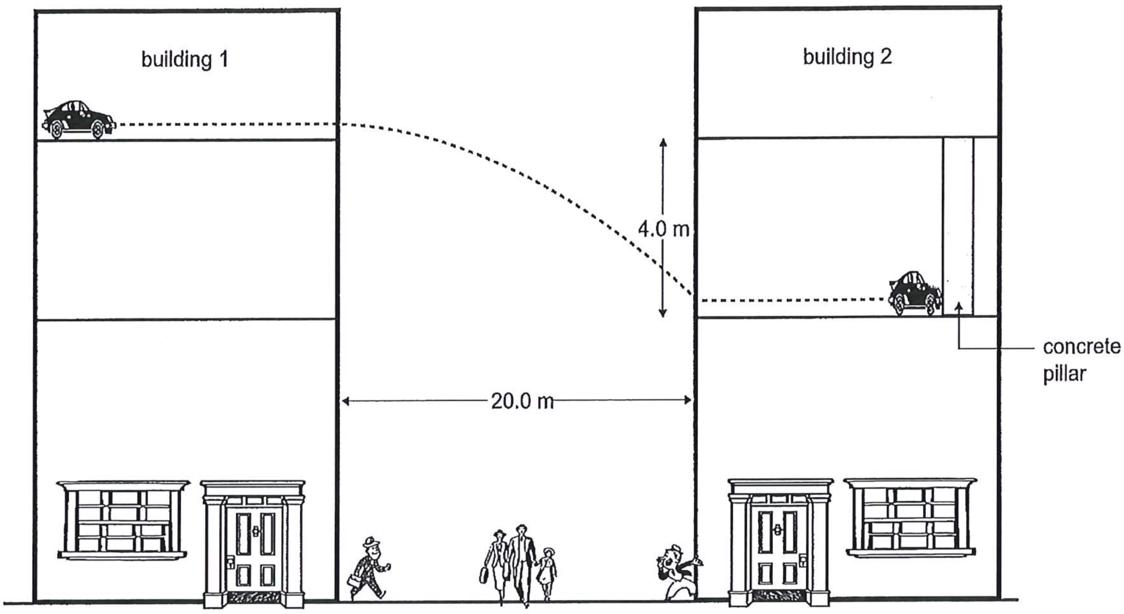
(a) Label each position, X, Y & Z, with an arrow that best represents the velocity and the acceleration of the ball, at that time. (3 marks) ½ each

(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. (2 marks)

- $\theta > \phi$
- not symmetrical
- s_H shorter, s_v smaller

these points seen on diagram

Question 2 ~~(4 marks)~~ 3marks



↓ +ve

In a movie, the stunt men drove their car across a horizontal car park in building 1 and landed it in the car park of building 2, landing one floor lower. Building 2 is 20.0 m from building 1, as shown in ~~Figure 3~~ above. The floor where the car lands in building 2 is 4.00 m below the floor from which it started in building 1.

Calculate the minimum speed at which the car should leave building 1 in order to land in the car park of building 2, if the effect of air resistance is ignored.

1 $u_v = 0$

$s_v = 4m$

$s_h = 20m$

$s_v = u_v t + \frac{1}{2} a t^2$

$4 = 0 + 4.9 t^2 \Rightarrow t = 0.90s$ 1

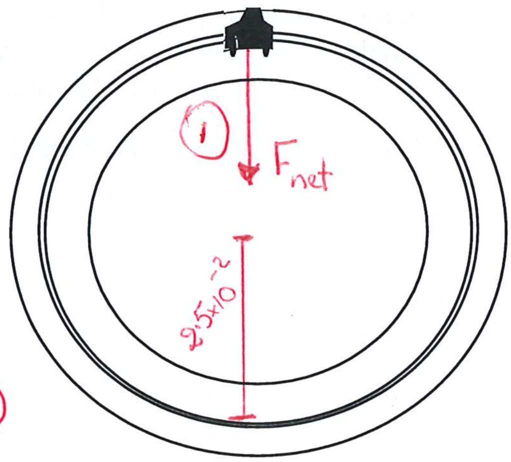
$s_h = u_h t + \frac{1}{2} a_h t^2$

$20 = u_h(0.9) + 0 \Rightarrow u_h = 22.13\ ms^{-1}$ 1

$u_{total} = \sqrt{u_h^2 + u_v^2}$ $\quad u_v = 0 \Rightarrow u_h = u_{total}$

Question3 **(4 marks)**

A toy slot car set has a circular track as shown in the diagram.



(a) On the diagram show the direction of the net (unbalanced) force acting on the slot car.

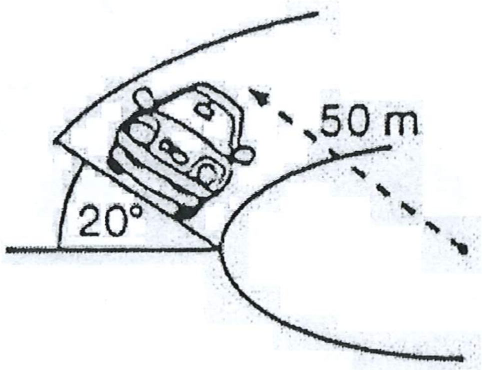
(b) The diagram is drawn one tenth full size. The mass of the slot car is 0.25 kg and the net force is 3.25 N, **estimate** the speed of the car.

$$F = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{(3.25)(2.5\times10^{-1})}{0.25}} \quad (1) \quad = 1.8\ ms^{-1}$$

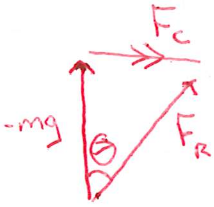
$r = 2.5\times10^{-2}$ on diagram $\Rightarrow 2.5\times10^{-1}$ m (1)

(1) must be no more than 2 sig fig (estimate!)

Question 4 **(~~3 or~~ 4marks)**



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



$F_{R\,Hor} = F_c$ (2) marks for showing derivation

$$\tan\theta = \frac{F_c}{mg} \Rightarrow F_c = mg\tan\theta$$

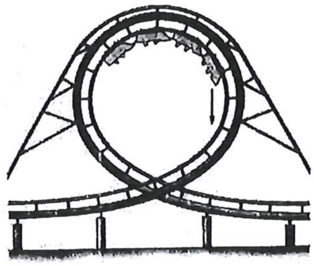
$$\frac{mv^2}{r} = mg\tan\theta$$

(1) $v = \sqrt{rg\tan\theta} = (50.0)(9.8)(\tan 20)$

$= 13.4\ ms^{-1}$ (1)

Question 5 **(4marks)**

A thrill seeker is persuaded to go on a "loop the loop" amusement ride similar to the one in the picture opposite. The loop has a diameter of 18.0 m and takes 4.70 s to complete one loop.



(a) Calculate the centripetal acceleration of a 40.0kg rider. (3 marks)

$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (9)}{(4.7)^2}$ (1)

$= 16 \text{ m s}^{-2}$ towards the centre
(1) (1)

(b) Is the centripetal acceleration for a 50.0kg rider the same, increased or decrease? (~~Briefly~~ Explain.) (1 mark)

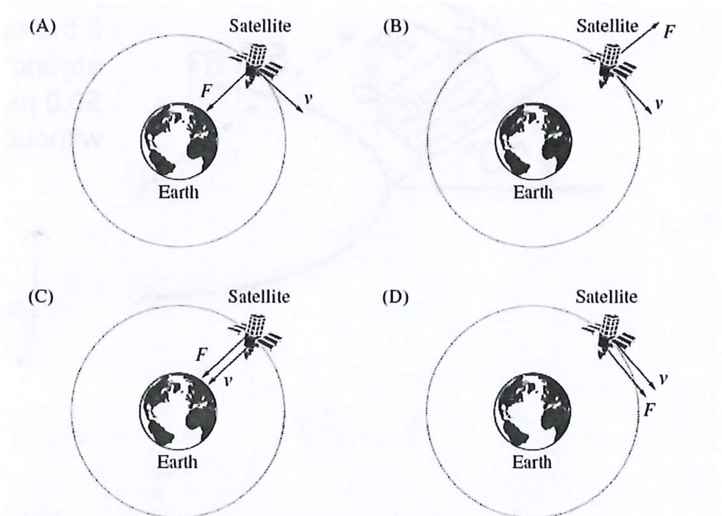
Same
(The formula $a_c = \frac{v^2}{r}$ does not include mass)

Question 6 4marks? ~~**(3marks)**~~

The diagrams show a communications satellite in orbit about the Earth.

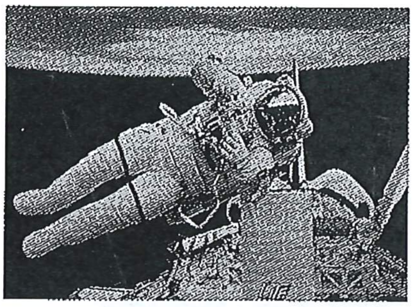
a) Which diagram correctly represents the net force: **F** acting on the satellite and the velocity: **v** of the satellite?
ANSWER: ___A___ (1)

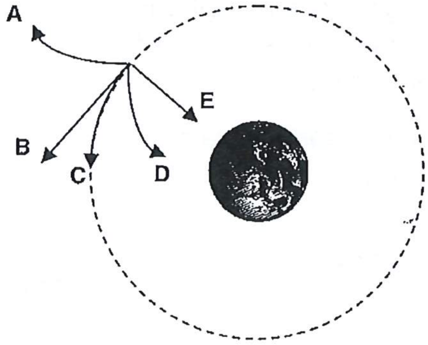
b) Explain why domestic satellite dishes for paytTV do not 'track' across the sky (i.e. they don't move) although the satellites that they receive their signals from are in constant motion



The satellites are in a geosynchronous orbit (1)
⇒ they have a period of 24 hours ⇒ they remain over (1)
the same geographical location on Earth (1)

Question 7 **(1 mark)**





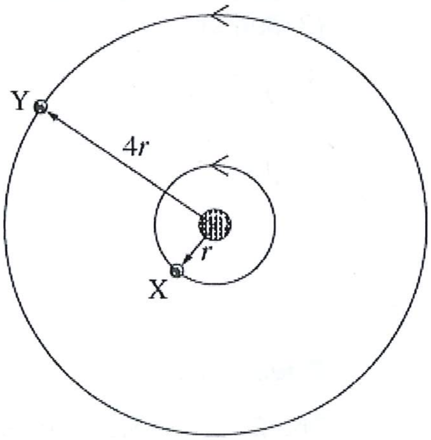
While working on a satellite in orbit around the Earth an astronaut lets go of his specially designed wrench.

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 **(9 marks)**

It has been discovered that a distant star has two planets orbiting it. One planet 'X' is a distance 'r' from the star where r = 6.54×10^8 m between the centre of masses. The second planet 'Y' is a distance '4r' from the star.

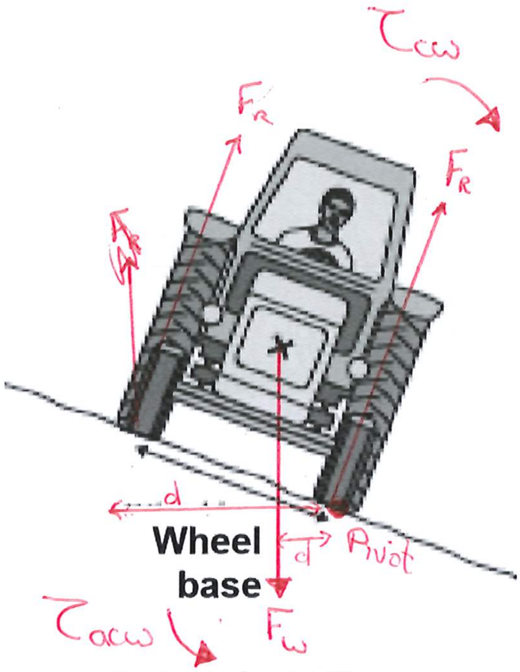


(a) If the time for planet X to orbit the star is 1.5 Earth years, calculate the mass of the host star. (5 marks)

(b) Determine the orbital period of planet Y in Earth years. (How many Earth years does it take planet Y to orbit the star?) (4 marks)

Question 9 **(4 marks)**

Tractors are often used on sloping fields so stability is important in their design. On the diagram the centre of **'X'** marks the centre of mass of the tractor.



a) Using force and torque diagrams, clearly explain why the tractor has not toppled over. (2 marks)

① com (F_w) is within the wheel base

① F_w provides an ACW moment to counteract the CW moment due to F_{R1}

b) State how the design of the tractor could be modified to increase the tractor's stability. (2 marks)

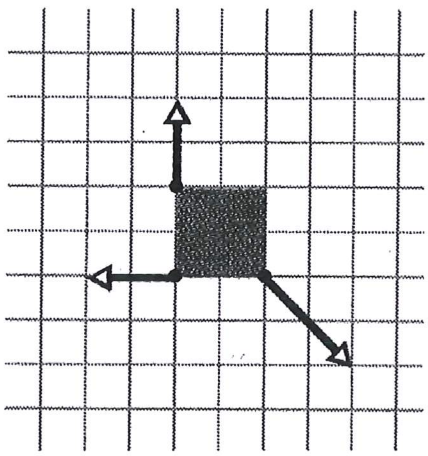
① Lower com

① Increase width of base

could make into 4

Question 10 **(3 marks)**

The figure shows an overhead view (birds-eye view) of a metal square lying flat on a frictionless floor. Three forces, which are drawn to scale, act at the corners of the square. Circle the correct answer.



a. Is the square in translational equilibrium?

YES NO (1 mark)

b. Is the square in rotational equilibrium?

YES NO (1 mark)

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?

YES NO (1 mark)

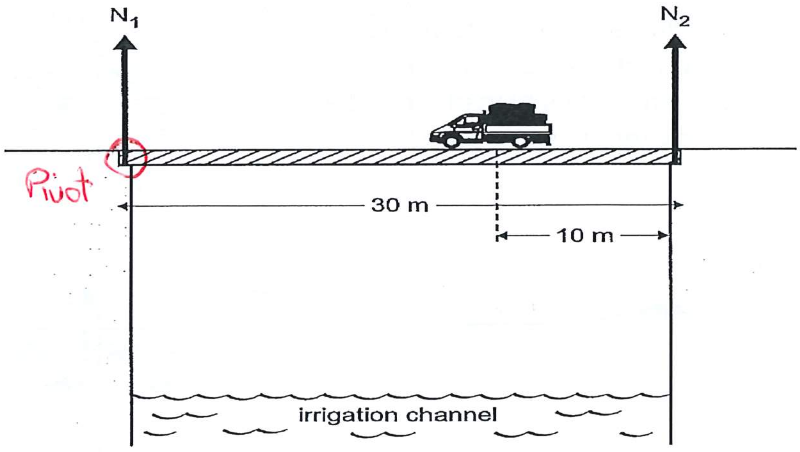
Explain (If you add a force to bring it into rotational equilibrium it will no longer be in translational equilibrium

Question 11 **(4 marks)**

The bridge in the diagram can be considered as a uniform concrete beam of length 30.0 m and mass 20.0 tonnes.

A heavily loaded small truck of mass 6.00 tonnes is pictured crossing the bridge.

Calculate the magnitude of each of the normal contact forces N1 (F_{n1}) and N2 (F_{n2})at each end of the bridge when the centre of mass of the truck is 10.0 m from one end.



(1) $\sum \tau = 0$ (OR) $\sum \tau_{cwm} = \sum \tau_{acwm}$

(1) $\tau_{truck} + \tau_{bridge} = \tau_{n2}$

$20 \times 9.8 \times 6 \times 10^3 + (20 \times 10^3)(9.8)(15) = (F_{n2})(30)$

$F_{n2} = 1.37 \times 10^5 N$ up

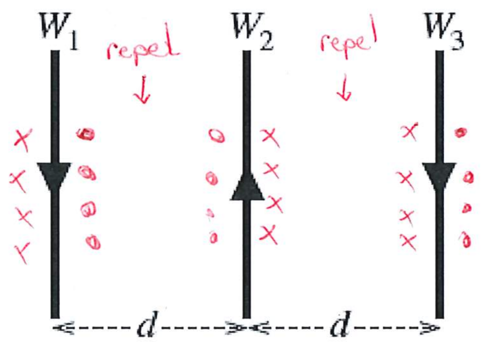
(1) $\sum F = 0 \Rightarrow \underset{down}{F_{w\,truck}} + \underset{down}{F_{w\,bridge}} + \underset{up}{F_{N1}} + \underset{up}{F_{N2}} = 0$

(1) $F_{N1} = (20 \times 10^3 \times 9.8) + (6 \times 10^3)(9.8) - 1.37 \times 10^5 = 1.18 \times 10^5 N$

Question 12 **(1 mark)**

Three identical wires W1, W2 and W3 are positions as shown. Each carries a current of the same magnitude in the direction indicted.

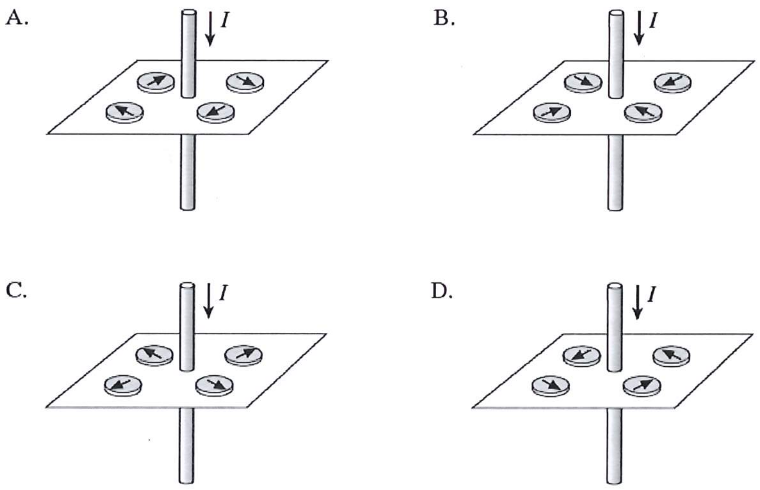
What is the magnitude and direction of the resultant force on W2? Circle the correct answer (A, B, C, D)



	Magnitude	*Direction*
(A)	Zero	None
(B)	Non zero	To the left
(C)	Non zero	To the right
(D)	Non zero	Out of the page

Question 13 **(1mark)**

Which of the following diagrams best shows the orientation for a set of four compasses placed around a current-carrying wire?

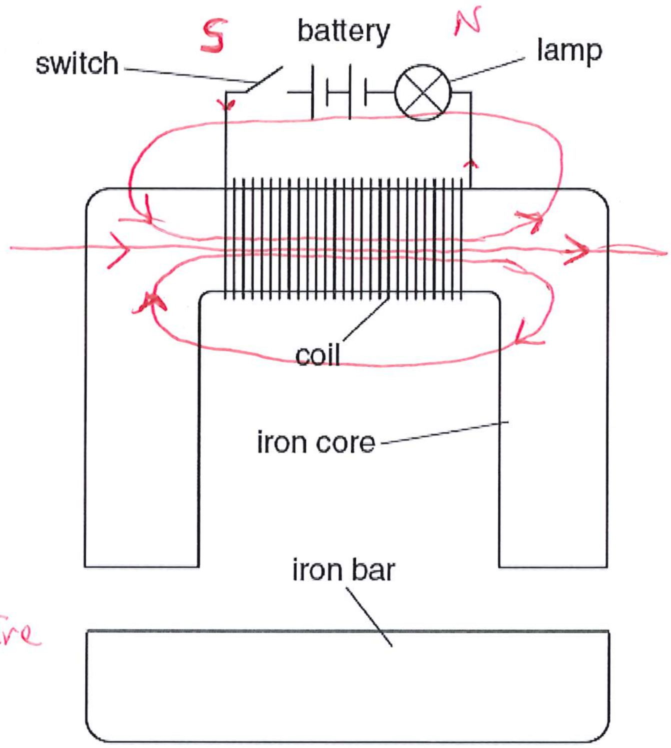


Answer: A

Question 14 **(4marks)**

This question is about using an electromagnet to lift a heavy load.

The figure shows a coil of insulated wire wrapped around the centre of an iron core. An iron bar is pulled up to the core when the switch is closed. The lamp glows when there is current in the coil.



(a) On the diagram, sketch **two** complete loops of flux produced by the coil when the switch is closed. (2 marks) (1) direction

(1) goes through centre

(b) Use ideas of magnetic flux to explain why the iron bar is pulled up to the iron core when the switch is closed. (2 marks)

(1) The coil creates a magnetic field

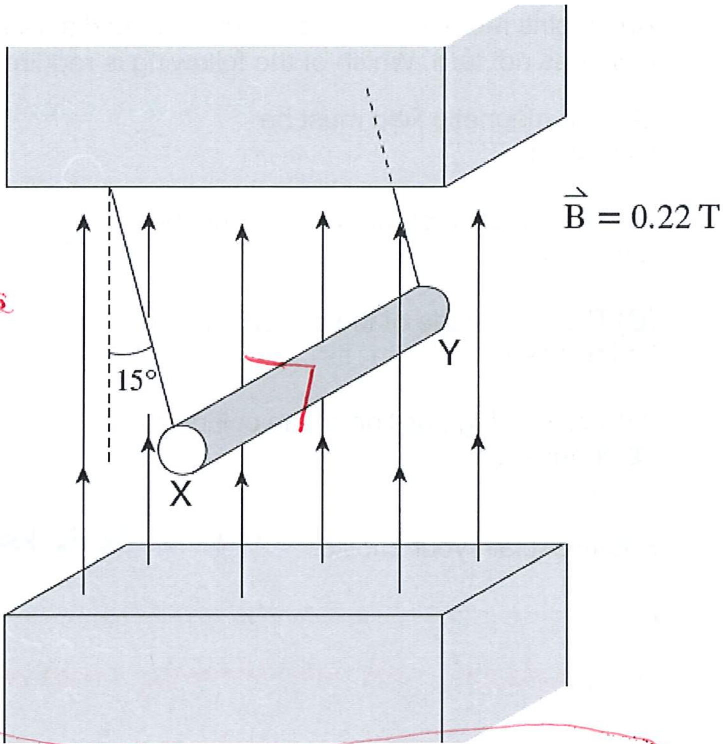
(1) This induces ~~magnetic field~~ magnetism in the iron core which attracts the iron bar upwards

Question 15 **(4marks)**

An 18.0 cm long metal rod of mass 35.0 g is suspended from the ceiling with a light wire of negligible mass. A uniform 0.220 T magnetic field is directed vertically upward.

When there is a current in the rod it swings outward 15.0° to the vertical as shown in ~~Figure 6.~~ the figure opposite

Calculate the magnitude and direction of the current in the rod.



(2)

$F_B = I.l.B =$

$\tan 15° = \frac{F_B}{mg} \Rightarrow F_B = (35.0 \times 9.8 \times 10^{-3})(\tan 15°) = 0.092\,N$

$F_B = IlB \Rightarrow I = \frac{0.092}{(18 \times 10^{-2})(0.220)} = 2.32\,A$ (1)

(1) Dirn X to Y

Answer 2.32 A into page / X to Y

Question 16 **(2 marks)** → 3 marks?

A beta particle travels at a speed of 3.90×10^3 km h^{-1} while following a circular path of radius 0.0200 m perpendicular to a magnetic field. Calculate the strength of the magnetic field. Show all working.

$v = \frac{3.90 \times 10^3}{3.6} = 1.083 \times 10^3\,m\,s^{-1}$

(1)

$r = \frac{mv}{qB} \Rightarrow B = \frac{mv}{qr} = \frac{(9.11 \times 10^{-31})(1.083 \times 10^3)}{(1.6 \times 10^{-19})(0.0200)} = 3.08 \times 10^{-7}\,T$

$m = 9.11 \times 10^{-31}$ kg

$q = 1.6 \times 10^{-19}$ C

(1)

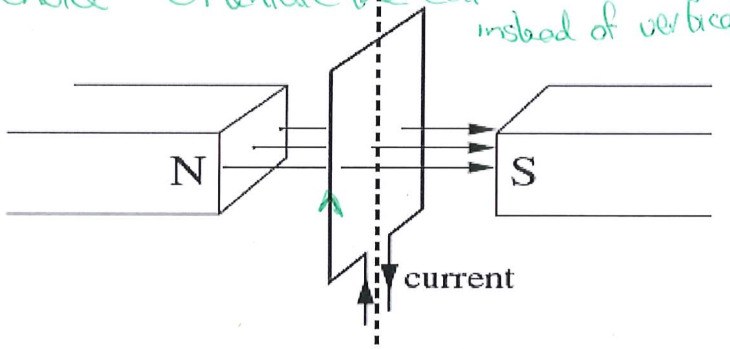
$v =$

Answer: 3.08×10^{-7} T

Question 17 **(3 marks)**

An electric motor is set up as shown in the diagram below. When the current is supplied the coil does not turn. Which of the following is required for the coil to start turning?

Give the choice "Orientate the coil horizontally instead of vertically



(A) The magnetic field must be increased.

(B) The direction of the current must be reversed.

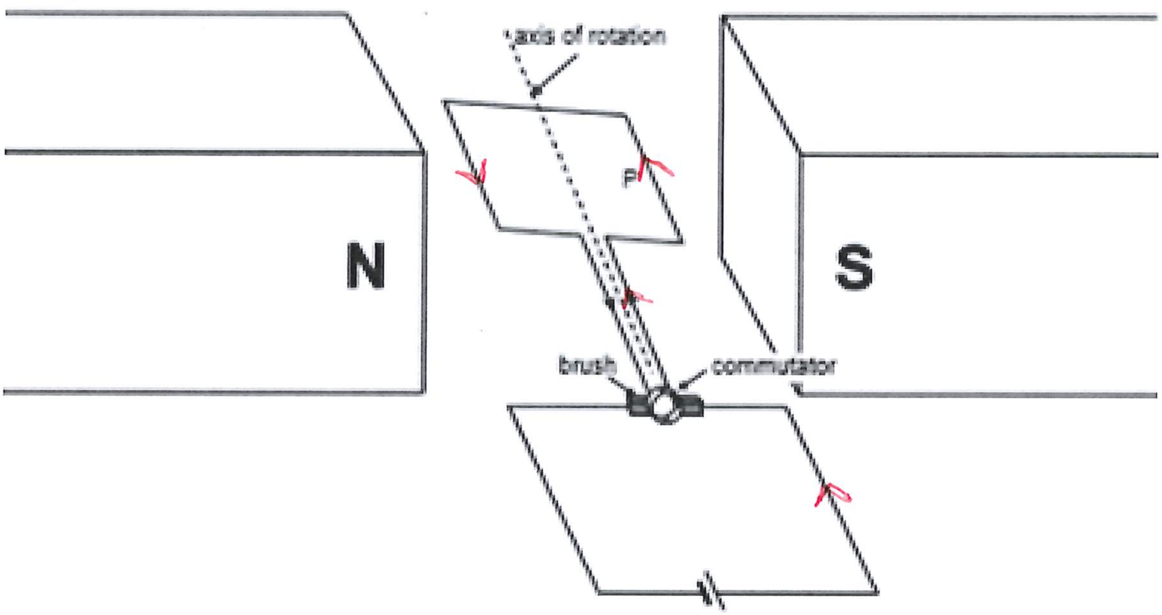
(C) The magnitude of the current must be increased.

(D) The starting position of the coil must be changed.

Briefly explain your ~~choice~~. what needs to be changed to allow the coil to start turning

- Orientate coil horizontally instead of vertically
- In current posn, coil experiences a force into the page ⇒ no torque experienced
- If orientated horizontally it experiences downward force ⇒ CW torque

Question 18 (6 marks)



The circuit of a simple DC motor is shown in the figure below. It consists of a current-carrying coil of 50 turns as the armature. The coil is square with sides of 5.0cm. The coil is square with sides of 5.0cm. The coil is in a uniform magnetic field of strength 0.005T. A current of 3.0A flows through the coil in the direction shown in the diagram.

(a) Calculate the magnitude of the force on side P of the coil. (2marks)

$F = nIlB$

$= (50)(3.0)(5 \times 10^{-2})(0.005)$

$= 0.0375\ N$

(b) When the coil is in the position shown in the diagram, which of the directions (A, B, C or D) best indicates the direction of the force exerted on side P? (1 mark)

(c) The ends of the coil are connected to a split-ring commutator, so that the coil is free to rotate. Explain why the split-ring commutator is fundamental to the operation of the DC electric motor. (3marks)

Section Three: Comprehension (Should be 36 marks – currently 40 marks)

20% (36 Marks)

This section has **two (2)** 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, unless specifically instructed to calculate the correct significant figures. 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 the use of planning / continuing your answer to a question have been 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: **40 minutes**

Question !!!! (Currently 20 marks) Could be more generous with marks – it's a long Q

(18 marks)

Neutron star collisions create huge magnetic spikes

The strongest magnetic fields known in the Universe are produced when a pair of extremely dense and compact stars merge. The first computational model has been devised of such an event that takes magnetism into account. The model begins with two cold neutron stars in a circular orbit around each other, and both with masses 1.4 times that of the Sun. Comparative masses can be seen in Table 1.

When their orbits decay and the two stars collide, they merge to form a single object incredibly quickly - within about 2 milliseconds. Spiral arms then form off the central object and, at the point of intersection; instability causes the two stars' magnetic fields to curl into vortex rolls.

Previous work had suggested that merged neutron star remnants might collapse under their own weight to produce black holes before being able to produce a big magnetic spike. But the collapse is estimated to take at least 100 milliseconds, and the new data suggests an extremely short timescale for the amplification of the merged object's magnetic field, showing the spike should occur in reality.

Table 1: Comparative masses of known entities in the Universe.

object	mass	radius
the sun	1.99×10^{30} kg	696,000 km
white dwarf star	0.5 to 1.4	5000 km
neutron star	1.4 to 3	10 km
stellar black hole	more than 3 solar masses	$2Gm/c^2$
super massive black	$> 10^6$ solar masses	$2Gm/c^2$
the known universe	10^{53} kg	13.7×10^9 light years

(Table adapted from http://hypertextbook.com/physics/matter/density/)

(a) Neutron stars are the remnants of huge stars that have exploded as supernovae. The neutron star mentioned in Paragraph 1 has a radius that is only of the order of 10 km. Such a dense object has very high gravitational field strength at its surface.

(i) For a spherical star of average density ρ, the magnitude of g at its surface is given by:

Tell them $\rho = \frac{mass}{volume}$ and volume $= \frac{4}{3}\pi r^3$?

$$g = 4/3\ G\ \pi\ r\ \rho$$

3 marks?

where G is the universal gravitational constant

Use this expression to show that the units of g are N kg^{-1}. **(2 marks)**

Units for G = $N\,m^2\,kg^{-2}$

Units for density = $\frac{mass}{volume}$: $kg\,m^{-3}$ 1

Units for g : = $\underbrace{N m^2 kg^{-2}}_{G}\ \underbrace{m}_{r}\ \underbrace{kg\,m^{-3}}_{\rho}$ 1

$= N\,kg^{-1}$ 1

(ii) Using the above formula and Table 1, **ESTIMATE** the gravitational field strength at the surface of the neutron star. **(5 marks)**

more space

1 $\frac{4}{3}\pi r^3$

$\rho_{largest} = \frac{mass}{volume} = \cancel{\frac{3(1.99\times10^{30})}{(4)(\pi)(696000\times10^3)^3}} =$

$\frac{mass}{volume}$ $\frac{(1.99\times10^{30})(3)}{(4/3)(\pi)(10\times10^3)^3} = 1.425\times10^{18}\ kg\ m^{-3}$ 1

$\rho_{smallest}$ $\frac{(1.99\times10^{30})(1.4)}{4/3\ \pi\ (10\times10^3)^3} = 6.65\times10^{17}\ kg\ m^{-3}$

1 either biggest, smallest or average

$g_{biggest} = \frac{4}{3} G\pi r\rho = (\frac{4}{3})(6.67\times10^{-11})(10\times10^3)(1.425\times10^{18})$ 1 $= 3.98\times10^{12}\ N\,kg^{-1}$

$g_{smallest}$ $= 1.86\times10^{12}\ N\,kg^{-1}$

g_{ave} $= 2.9\times10^{12}\ N\,kg^{-1}$ 1

(b) A remarkable property of neutron stars is that they spin about their axes at a very great rate. The radiation from these stars is observed as regular pulses. This gives rise to the name 'pulsars'. This particular neutron star of radius 10.0 km rotates 50.0 times every second. → 50Hz

(i) Show that the speed of a point on the equator of the star is about one percent of the speed of light. Hint: Find value on data sheet? **(2 marks)**

$v = \frac{2\pi r}{T} = 2\pi r f = 2\pi(10\times10^3)(50) = 3.14\times10^6\,ms^{-1}$ 1

do they know this yet

$c = 3.00\times10^8\,ms^{-1} \Rightarrow 1\%$ of $c = 3.00\times10^6\,ms^{-1}$ 1

Less space

Less space

(ii) Calculate the centripetal acceleration at a point on the equator of the star. **(3 marks)**

$a = \frac{v^2}{r} = \frac{(3.14\times10^6)^2}{10\times10^3} = 9.86\times10^8\,ms^{-2}$ towards centre

1 1 1

(c) Currently, the space probe, Cassini, is between Jupiter and Saturn. Cassini's mission is to deliver a probe to one of Saturn's moons, Titan, and then orbit Saturn collecting data. An ill-informed reporter stated that "the contents of the ship would experience weightlessness, while Cassini was in orbit around Saturn."

Using physics principles explain why the reporter is incorrect. **(2 marks)**

1 • Weightlessness can only occur if $g = 0 \Rightarrow mg = 0$

1 • Cassini experiences the gravitational field due to Saturn $\Rightarrow g \neq 0$

amongst other things

Accept similar/sensible statements

→ Weightlessness only occurs in deep space

Below is astronomical data that you may find useful when answering the following question.

mass of Cassini = 2.20 x 10^3 kg	diameter of Saturn = 1.21 x 10^8 m
mass of Jupiter = 1.90 x 10^{27} kg	Saturn day = 10.7 Earth hours
mass of Saturn = 5.70 x 10^{26} kg	

(d) Calculate the magnitude of the total gravitational field strength experienced by Cassini when it is 3.90 x 10^{11} m from Saturn. **(2 marks)**

$$g = \frac{GM}{r^2} = \frac{(6.67\times10^{-11})(5.70\times10^{26})}{\left(3.90\times10^{11} + \frac{1.21\times10^{8}}{2}\right)^2}$$

1 radius

1 everything else

$$= 2.5\times10^{-7}\ N\,kg^{-1}$$

(e) The Earth has multiple satellites orbiting it at any point in time. The centripetal force required to keep the satellites in orbit is provided by the Earth's gravitational field. Use this fact to derive an expression for the orbital radius, r, for the satellite, let:

G, the gravitational force constant
r, the radius of orbit of the satellite
v, the speed of the satellite in its orbit
M_E, the mass of the Earth
M_S, the mass of the satellite

(2 marks)

$F_c = F_G$ 1

$\frac{m_s v^2}{r} = \frac{G m_s m_E}{r^2}$

$r = \frac{G m_E}{v^2}$ 1

must be specific about m_E and m_S

(f) A telecommunications satellite needs to be placed at a certain height above the surface of the Earth, at the equator, so that it remains in geosynchronous orbit. Calculate the orbital radius of the satellite.

(2marks)

3 marks?

$r^3 = \frac{G m_E T^2}{4\pi^2}$

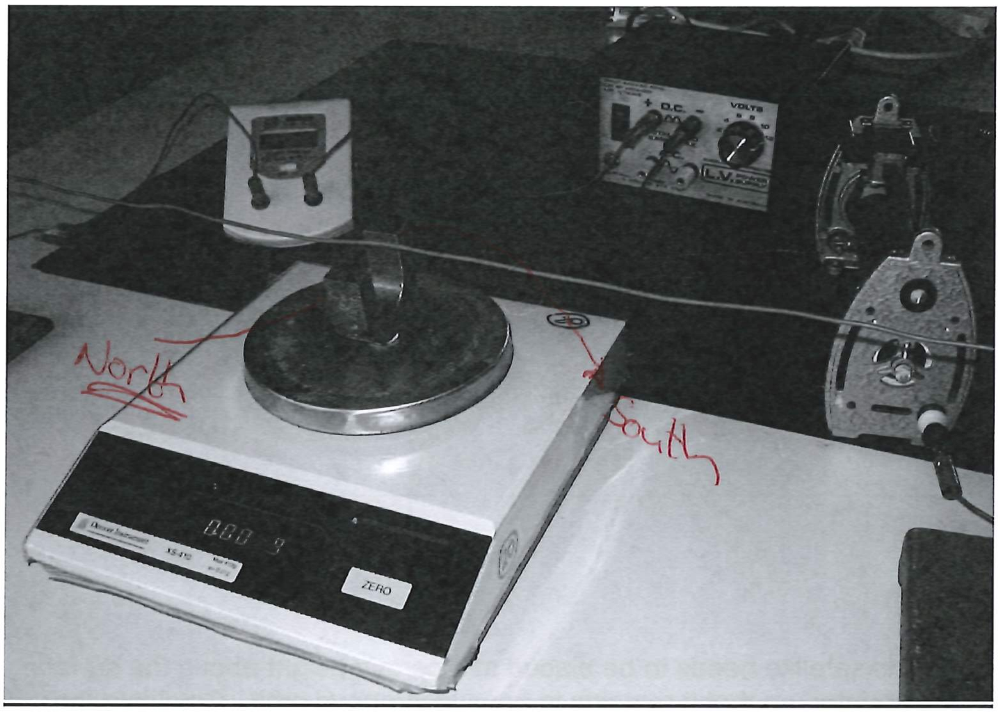
$r = \sqrt[3]{\frac{(6.67\times10^{-11})(5.98\times10^{24})(24\times60\times60)^2}{4\pi^2}}$ 1 1 1

$= 4.23\times10^{7}$ m

Question !!!!! Currently 20 marks – should be 18marks

(20 marks)

Determining the Magnetic Field Strength (B) of a Horse-shoe Magnet



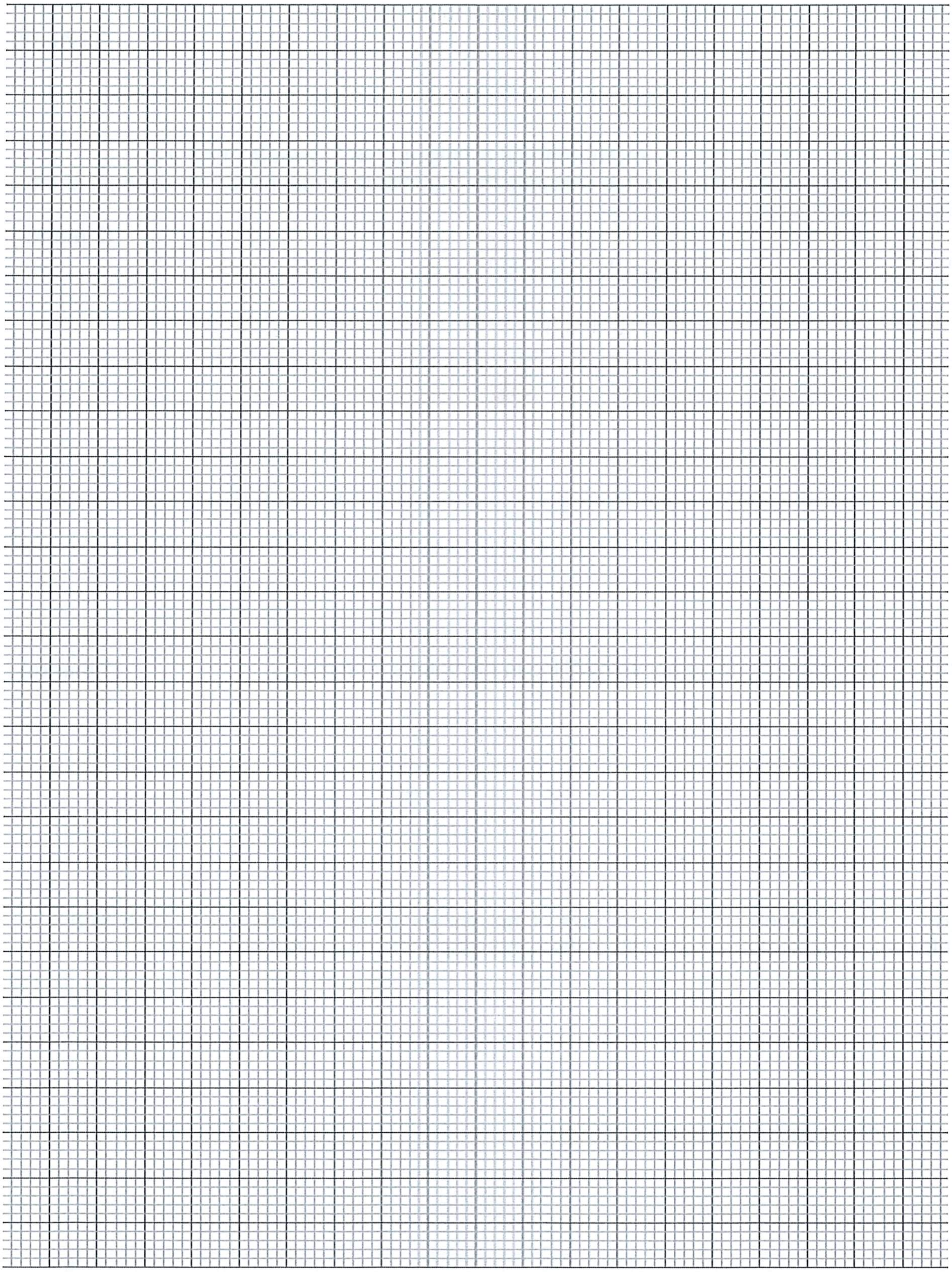
Students performed an experiment to calculate the magnetic field strength (B) of a horse-shoe magnet.

The equipment was set up as shown in the diagram: The horse-shoe magnet was placed on the mass balance and the mass balance was tared. (Set to read 0g) The current carrying conductor was stretched tightly and clamped in place such that it was unable to move. The dimensions of the horse-shoe magnet are shown in photograph 2.

The current through the conductor was varied and the reading on the mass balance noted. The results are displayed in the table below.

Current (A)	Change in Mass Δm (g)	Force (N) mg
0	0	0
1.0	0.18	~~1.76~~ 1·8
2.0	0.33	~~3.23~~ 3·2
3.0	0.53	5·2
4.0	0.76	7·4
5.0	0.97	9·5

↑ 2 sig fig



(a) The direction of conventional current in the photograph above is left to right. Annotate the north and south pole of the magnet on the photograph above.

(1 mark)

North nearest
South furthest

(b) Explain using relevant **mathematical relationships / formulae** how this experimental setup can be used to calculate the magnitude of magnetic field strength of the horse-shoe magnet.

(2 marks)

- Conductor experiences a force – magnitude of force = $F = ILB$

I and F varied, L measured

$\Rightarrow B$ calculated

(c) Complete the table above by filling in the values for force. **(1 marks)**

50%

(d) The photograph is 10% the size of the real equipment. Use the photograph, and this information to measure the length of the conductor in the magnetic field

$L =$

Length of conductor in magnetic field = ___________________

(e) Use the mathematical relationship you've described in part (b), and the information you calculated in (c) to **draw a graph** which will allow you to calculate the magnetic field strength. Don't include error-bars.

(4 marks)

1 Accurate plotting
1 LOBF
1 Axis correct way round
1 Units, Labels

(f) **Use the graph** to calculate the magnetic field strength of the horse shoe magnet. Clearly show all working.

(4 marks)

$$F = I \, l \, B \quad (1) \text{ (or equivalent)}$$

$$\underset{y}{\uparrow} = \underset{x}{\uparrow} \quad \underset{m}{\uparrow}$$

$m = \frac{y_2 - y_1}{x_2 - x_1}$ (1) shown on graph (1) correct units

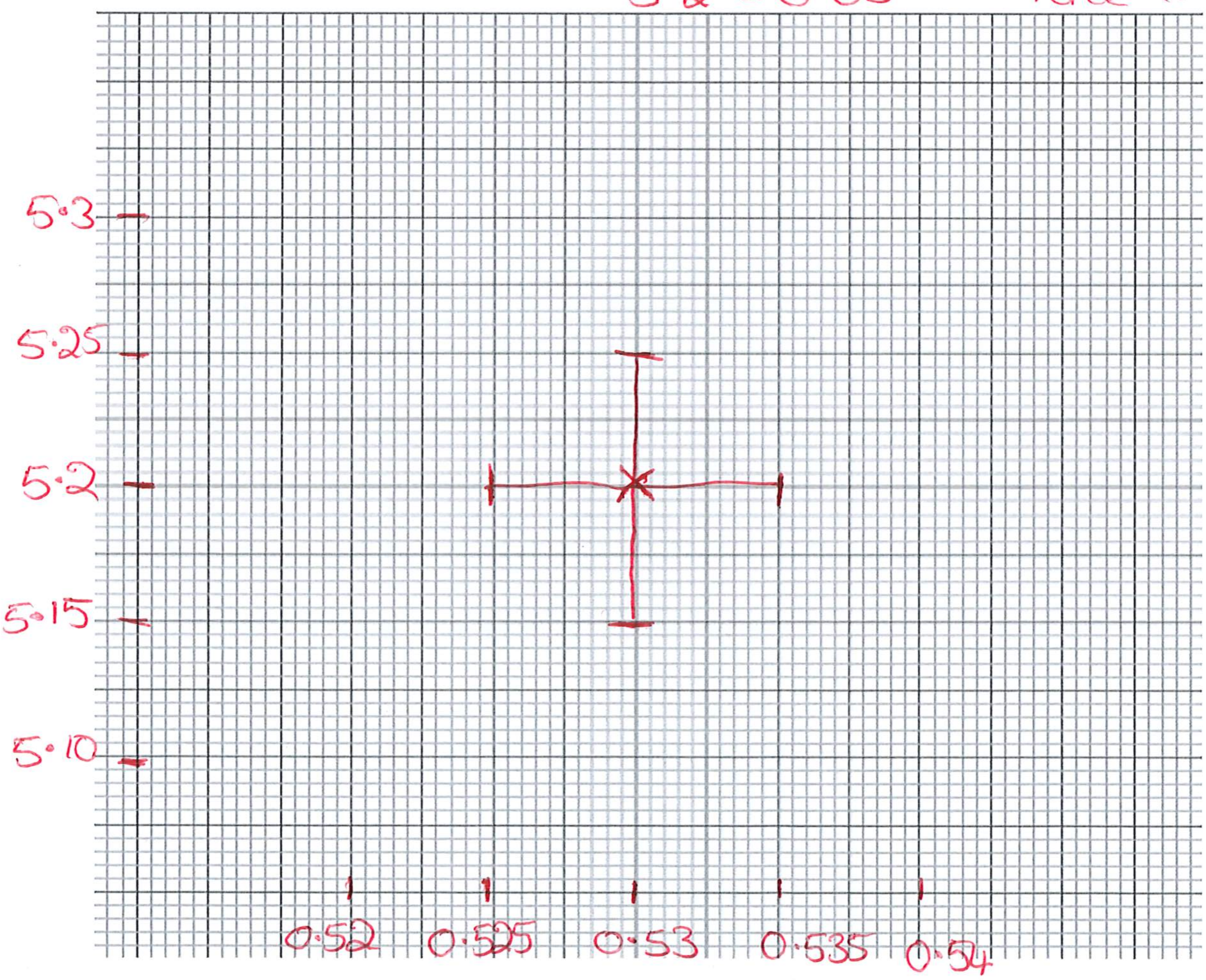
(1) $\Rightarrow B =$

(g) Error bars should be included for all points on your graph. However, as they are very small they are difficult to display accurately at graph scale. For the **fourth data point only** (Balance reading = 0.53g; Current = 3.0A), display the error bar associated with **this point only** by drawing a magnified version of this point in the graph paper below. **(2 marks)**

Put (g) after (h)

0.53 ± 0.005

5.2 ± 0.05 ← Force (ok if mass plotted)



Current

Put h before g

(h) For the fourth data point only (Balance reading = 0.53g; Current = 3.0A), calculate the value for magnetic field strength and its associated uncertainty. **(4 marks)**

Acknowledgements

Question !!!!!!! New Scientist, March 2006 by Kimm Groshong ; Journal Reference: *Science* (DOI: 10.1126/science.1125201)