PHYSICS

YEAR 12

UNIT 3

Name: SOLUTIONS

Teacher: ___________________________

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet; ATAR Physics Formulae and Data Booklet

To be provided by the candidate:

- Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

- Special items: Calculators satisfying the conditions set by the SCSA for this subject.

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 answer	14	14	50	54	30
Section Two: Extended answer	6	6	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

3. 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.

4. You must be careful to confine your responses to the specific questions asked and follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. 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.
   - 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. Refer to the question(s) where you are continuing your work.

Section One: Short response **30% (54 marks)**

This section has **fourteen (14)** questions. Answer **all** questions. Write your answers in the space 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.

Spare pages are included at the end of this booklet. 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 that you are continuing to answer at the top of the page

Suggested working time for this section is 50 minutes.

Question 1

An aeroplane is being flown with its maximum horizontal speed of 400 kmh^{-1} at an altitude of 1500 m. A piece of the plane becomes dislodged and drops off it whilst it is in motion.

If air resistance can be ignored, calculate the velocity of this piece of the plane when it lands on the ground (in ms^{-1}).

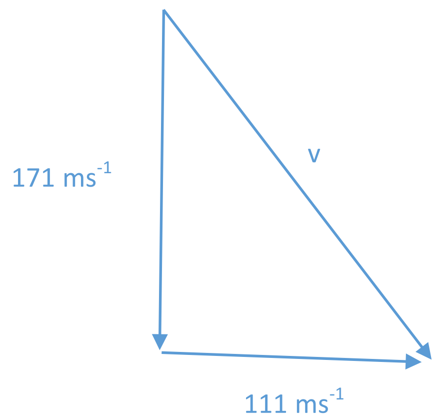
(4 marks)

$v^2 = u^2 + 2as; u = 0\ ms^{-1}, a = 9.80\ ms^{-2}, s = 1500m$

$v^2 = 0 + 2\ x\ 9.8\ x\ 1500$

$v_v = 171\ ms^{-1}$ **1 mark**

$u_h = \frac{400}{3.6} = 111\ ms^{-1}$ **1 mark**



$v^2 = 171^2 + 111^2$

$v = 204\ ms^{-1}$ **1 mark**

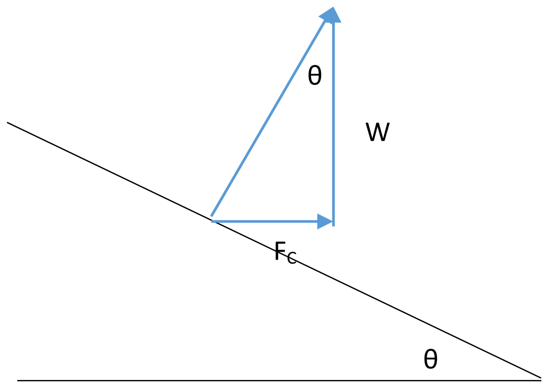
$\tan\theta = \frac{171}{111}; \theta = 57.0^o$ **1 mark**

SEE NEXT PAGE

Question 2

The banking of roads can help cars navigate high speed bends safely. Calculate the angle to the horizontal that a road should be inclined for a 1500 kg car to negotiate a horizontal circular path with a radius of 250 m at 110 kmh^{-1}.

(3 marks)



$$v = \frac{110}{3.6} = 30.6\ ms^{-1}$$

$$\tan\theta = \frac{F_c}{W} = \frac{mv^2}{r} \Big/ mg = \frac{v^2}{gr}$$ 1 mark

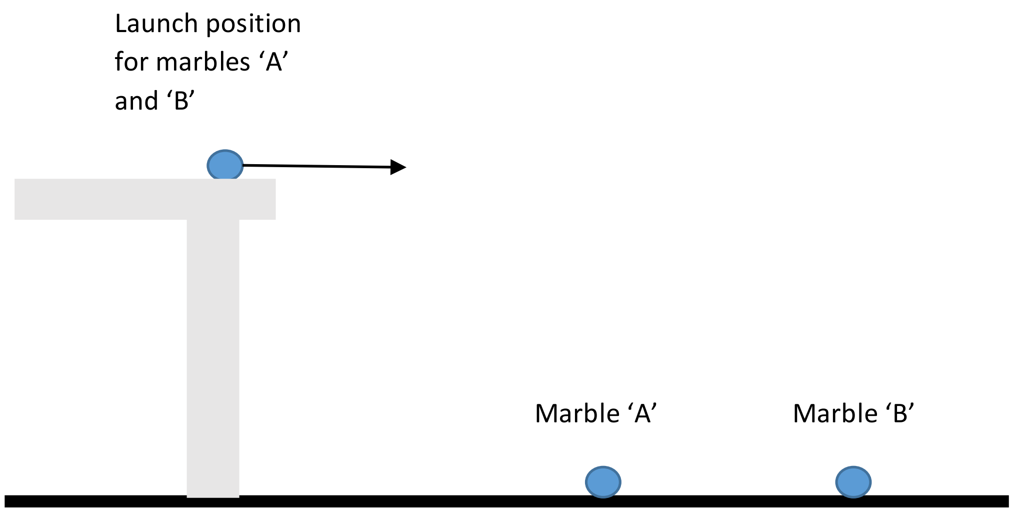
$$\therefore\ \tan\theta = 30.6^2 / (9.8 \times 250)$$ 1 mark

$$\theta = 20.9^o$$ 1 mark

Question 3

Two marbles ('A' and 'B') are rolled off a horizontal table separately and fall through the same vertical height to the floor below. Their landing positions are shown on the diagram below.

(4 marks)



Which one of the following statements correctly describes the motion of marbles 'A' and 'B'? Briefly explain the reasons for your choice in the space provided.

A 'B' hits the ground before 'A' because it is further from the launch site.

B 'B' has a larger launch velocity than 'A'.

C 'A' and 'B' hit the ground simultaneously with the same velocity.

D 'B' lands before 'A' due to its larger launch velocity.

ANSWER: **B** **1 mark**

EXPLANATION:

- **Both marbles have an initial vertical velocity of 0 ms^{-1}.** **1 mark**
- **Horizontal displacement for marble B is greater than horizontal displacement for marble A.** **1 mark**
- **∴ marble B's initial horizontal velocity is greater than marble A; hence, marble B's launch velocity is greater than marble A.** **1 mark**

Question 4

A baseball player is sprinting around second base after hitting the ball to the outfield. Essentially, the player is undertaking a circular path around the base at high speed.

Whilst doing this, the player appears to be leaning over towards the centre of his circular path. With the aid of a diagram, explain why he needs to do this.

(4 marks)

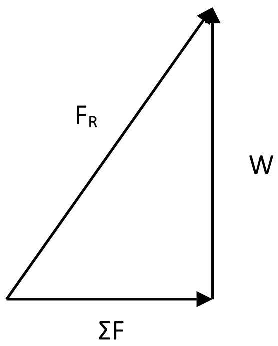
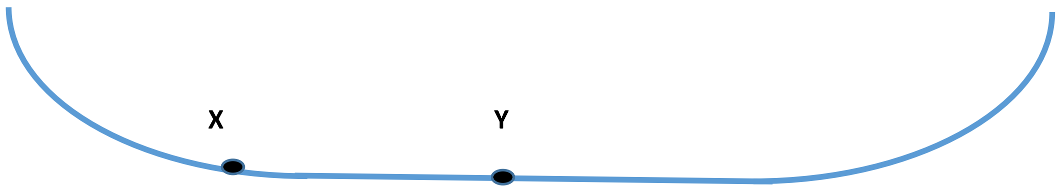


Diagram – 1 mark

- **Without leaning over, the player is unable to generate enough friction to create the centripetal force required.** **1 mark**
- **By leaning over, they are able to create a net horizontal force via friction towards the centre of their circular path.** **1 mark**
- **This larger frictional force is able to supply the large centripetal force required.** **1 mark**

Question 5

The diagram below shows the cross-sectional structure of a skateboard halfpipe. Two points ‘X’ and ‘Y’ are marked at two different positions on the halfpipe (‘X’ is at the bottom of the curved section of the halfpipe; ‘Y’ is on the flat section).



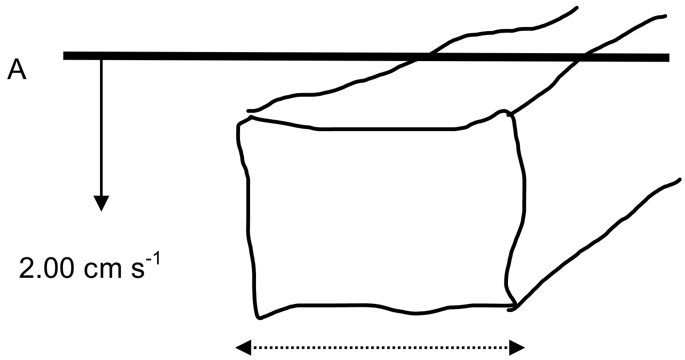
Compare the forces experienced by a skateboarder at these two positions. At which point is this force greatest? Assume the skateboarder’s speed is the same at both points. With reference to relevant formulae, explain your choice.

(4 marks)

- **Force at X › force at Y** **1 mark**
- **At Y, F_Y = weight = mg** **1 mark**
- **At X, at the bottom of the vertical circular path** **1 mark**
- $F_X = \frac{mv^2}{r} + mg$ **1 mark**

Question 6

An insulated copper wire is pulled downwards across the face of one of the poles of a bar magnet (as shown below). It is moved with an average velocity of 2.00 cm s^{-1} and the width of the bar magnet's face is 10.0 cm.



The end of the copper wire marked 'B' gains a net negative charge and the wire generates a small emf with an average value of 2.74 mV.

a) Using the information above, determine the polarity of the face of the bar magnet shown (North or South).

(1 mark)

NORTH **1 mark**

b) Estimate the strength of the bar magnet's magnetic field near its face.

(2 marks)

$emf = lvB, let\ l = 0.100\ m$

$2.74\ x\ 10^{-3} = 0.100\ x\ .0200\ x\ B$ **1 mark**

$B = 1.37\ V = 1.4\ V\ (2sf)$ **1 mark**

Question 7

A current-carrying straight conductor is placed in a magnetic field and experiences a magnetic force equal to 75% of the maximum value this force could be in this field. Calculate the size of the angle 'θ' between the conductor and the magnetic field. Show working.

(3 marks)

$F = IBl\ \sin\theta; maximum\ F\ occurs\ when\ \theta = 90^o;\ \therefore\ maximum\ F = IBl$ **1 mark**

$IBl\ \sin\theta = IBl\ x\ 0.75;\ \therefore\ \sin\theta = 0.75$ **1 mark**

$\therefore\ \theta = 48.6^o$ **1 mark**

Question 6

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

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

(4 marks)

$m = 25\ kg$

$r = \left(\frac{5}{2}\right) = 2.50\ m$

$T = 2\ s$

$F_{max} = 255\ N$

$v = \frac{2\pi r}{T} = \frac{(2 \times \pi \times 2.5)}{2} = 7.85\ ms^{-1}$ (1)

$F_c = \frac{mv^2}{r} = \frac{(25 \times 7.85^2)}{2.5} = 616\ N$ (1)

$616 > 255$ (1) ∴ Girl will be forced to let go. (1)

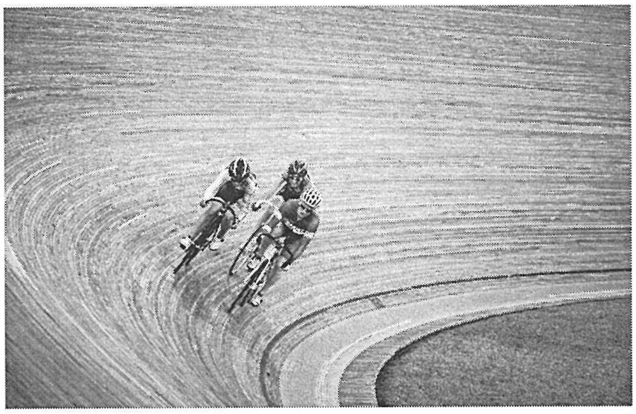
Question 7

A current-carrying straight conductor is placed in a magnetic field and experiences a magnetic force equal to 75% of the maximum value this force could be in this field. Calculate the size of the angle 'θ' between the conductor and the magnetic field. Show working.

(3 marks)

Question 8

A velodrome is an oval-shaped cycle track, parts of which are steeply banked. The riders in the picture are travelling at 14.8 ms^{-1} and the radius of curvature of the banked track is 32 m.



a) Why is the track banked at an angle?

(2 marks)

- reaction force exerted by track will have horizontal component - acting towards centre ①
- provides centripetal force, reducing dependence on friction. ①

b) If the bikes shown in the diagram have no tendency to slide up or down the slope, calculate the value of the banking angle θ.

(2 marks)

$$\tan\theta = \frac{v^2}{gr}$$

$$= \frac{14.8^2}{9.8 \times 32} = 0.694 \quad ①$$

$$\therefore \theta = 34.9° \quad ①$$

Question 9

A mass is suspended by a 90 cm long rope attached to a spring balance that initially reads 14.0 N as shown in **Diagram 1.**

The mass is pulled to one side and then released as shown in **Diagram 2**.

Diagram 1

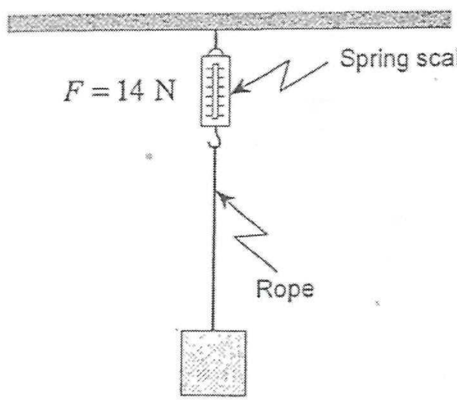
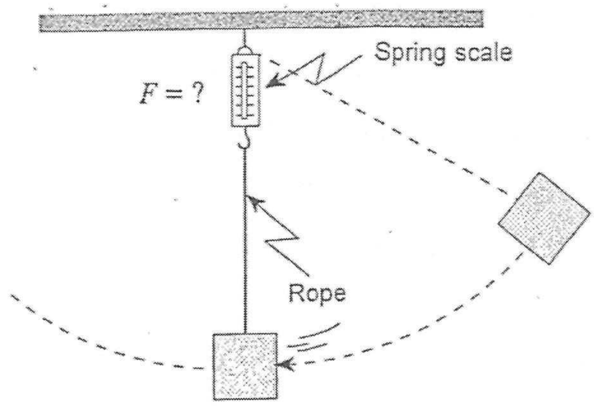


Diagram 2



As the mass passes through the vertical point it has a velocity of 2.45 ms^{-1}.

What is the reading on the spring balance at this instant?

(3 marks)

$W = mg$

$\therefore m = \frac{14}{9.8} = 1.43\ kg$ (1)

$F_c = R - W$

$\therefore R = F_c + W$

$= \frac{mv^2}{r} + mg$

$= \frac{1.43 \times 2.45^2}{0.90} + 14.0$ (1)

$= 23.5 N$ (1)

Question 10

The letters of the word PERTH, as shown, are to be carved from stone and mounted separately in the ground. The five letters are each going to be 1 m high, 0.75 m wide and 0.5 m deep (thick).

Give one letter which:

a) will be stable when stood upright E, R, T or H

b) will stand up, but is least stable T

c) will not stand upright without additional support P

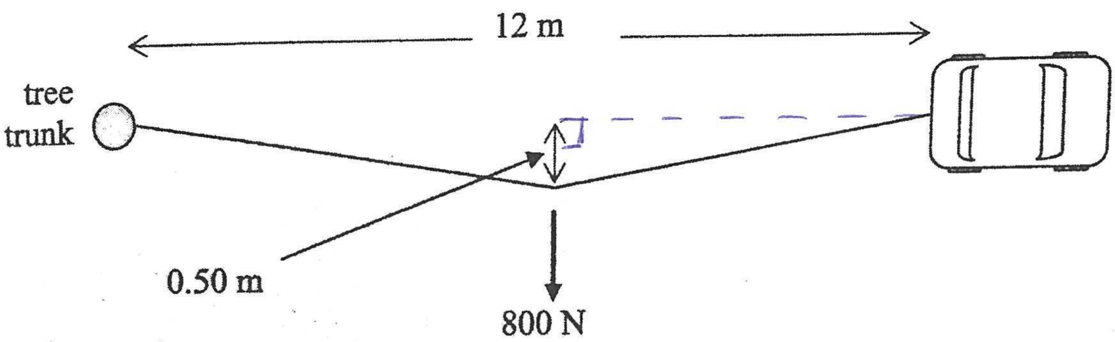
d) has its centre of gravity outside of the stone P (possibly R)

(4 marks)

Question 11

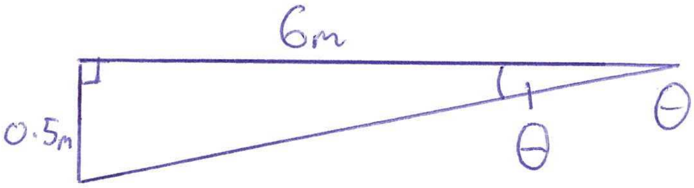
Hasib and Jane get there car stuck in sand. They tie a non-stretch rope to the car and pull together with a force of 800 N, but they are unable to move the car.

Hasib then notices a tree 12 metres behind the car. He ties the other end of the rope tightly around the tree trunk and then they pull the middle of the rope sideways a distance of 0.50 m with a force of 800 N.



What force does the rope now exert on the car?

(4 marks)



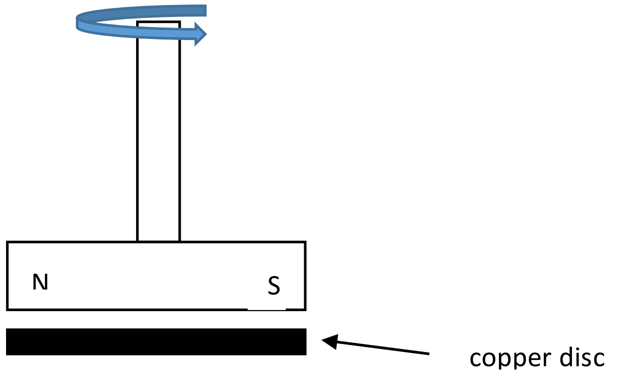
$\theta = \tan^{-1}\left(\frac{0.5}{6}\right) = 4.76°$ ① ①

$\tan 4.76 = \frac{800}{x}$ ①

$x = 961\text{ N}$ to left of page. ①

Question 8

A car speedometer utilises magnetic properties in its operation. Essentially, its main components consist of a rotating bar magnet adjacent to a round, copper disc (see the diagram below).



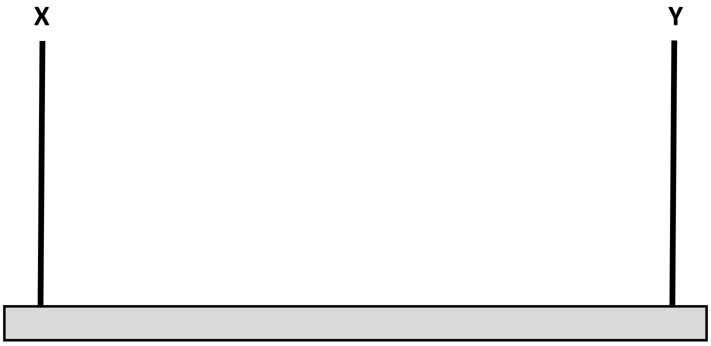
As the bar magnet rotates in the manner shown, the copper disc follow it by rotating in the same direction. Explain why.

(4 marks)

- **The rotating bar magnet causes a ΔΦ across the surface of the copper disc.** **1 mark**
- **∴ eddy currents are induced on the surface of the copper disc.** **1 mark**
- **The direction of the eddy currents opposes the motion of the rotating bar magnet (Lenz's Law).** **1 mark**
- **Hence, the copper disc rotates with the bar magnet to oppose the ΔΦ it experiences.** **1 mark**

Question 11

A uniform, 35.0 kg horizontal platform is supported by two vertical steel cables 'X' and 'Y' situated 10.0 m apart as shown. A person with a mass of 85.0 kg stands 3.00 m from 'X'.



With the person in the position stated, calculate the tension in cables 'X' and 'Y'.

(4 marks)

$Take\ moments\ around\ 'X';\ \Sigma M = 0;\ \Sigma M_C = \Sigma M_A$ **1 mark**

$(85\ x\ 9.8\ x\ 3) + (35\ x\ 9.8\ x\ 5) = F_Y\ x\ 10$ **1 mark**

$\therefore\ F_Y = 421\ N\ up$ **1 mark**

$\Sigma F = 0;\ \Sigma F_{UP} = \Sigma F_{DOWN};\ \therefore\ F_X = (85\ x\ 9.8) + (35\ x\ 9.8) - 421 = 755\ N\ up$ **1 mark**

Question 12

a) Calculate the magnetic field strength at a distance of 20.0 cm from a long straight conductor carrying a current of 550 mA. The experiment is performed in air.

(2 marks)

$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{4\pi\ x\ 10^{-7}}{2\pi}\ x\ \frac{550\ x\ 10^{-3}}{0.20}$ **1 mark**

$\therefore B = 5.5\ x\ 10^{-7}\ T$ **1 mark**

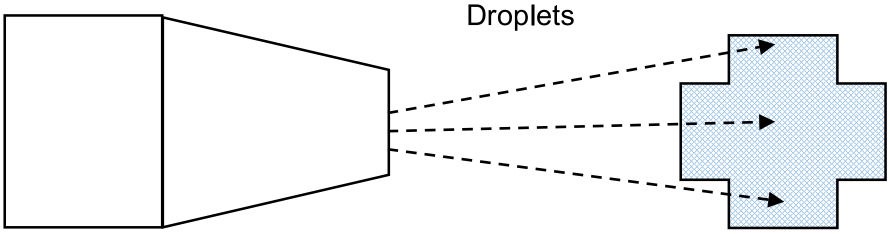
b) The Magnetic Constant, μ_0, is also known as "the magnetic permeability of free space". The magnetic permeability of water is slightly lower than the value for free space. If the experiment in part a) was conducted in water, explain how that would change the result calculated in air.

(2 marks)

- **Magnetic field strength (B) is directly proportional to permeability of medium (μ).** **1 mark**
- **μ for water is less than μ for free space; hence, B will be less in water medium if all else remains the same.** **1 mark**

Question 14

In an electrostatic spray painting system, droplets of paint are ejected from a positively charged spray gun to the object to be painted, which is negatively charged.



The magnitude of the charge on each droplet is 2.0 x 10^{-10} C and, on average, they have a diameter of about 150 μm.

a) State whether electrons were added to or removed from the droplets of paint by the spray gun.

(1 mark)

REMOVED **1 mark**

b) Calculate the electrostatic force acting between adjacent droplets if they are virtually touching each other.

(3 marks)

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

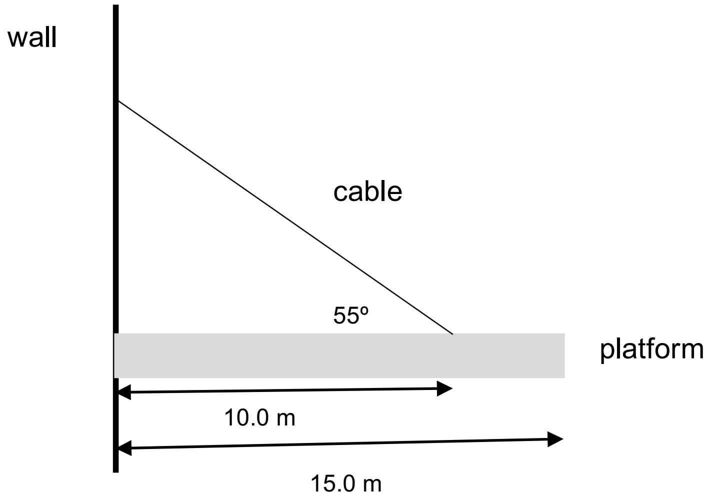
$= \frac{1}{4\pi\ x\ 8.85\ x\ 10^{-12}}\ x\ \frac{2\ x\ 10^{-10}\ x\ 2\ x\ 10^{-10}}{(150\ x\ 10^{-6})^2}$ **1 mark**

$= 1.60\ x\ 10^{-2}\ N\ repulsion$ **1 mark**

End of Section One

Question 16 **(16 marks)**

A nature lookout consists of an elevated concrete walkway high above the ground. A uniform platform has been constructed so people can walk out over a gorge and view it. The entire platform structure is shown in the figure below.



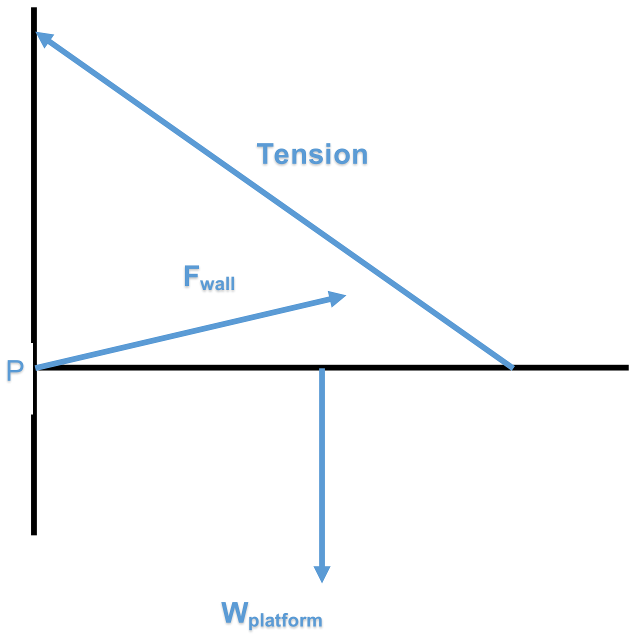
The platform is designed to support a load of 8.5 tonnes and is 15 m long. A single steel cable supports the platform, attached 10.0 m from the end at 55º as shown in the figure. The platform has a mass of 0.7 tonnes.

The platform is uniform and it can be assumed that – when it is acting - the 8.5 tonne maximum load acts half-way along its length.

The steel cable shown has a maximum tensile strength of 1.5 x 10^5 N.

a) Draw a free-body diagram showing all of the forces acting on the platform when in it is an unloaded state as drawn above. Label the forces appropriately.

(3 marks)



- **Three forces are shown** **1 mark**
- **Forces labelled correctly** **1 mark**
- **No forces are missing; no unnecessary forces are shown** **1 mark**

b) Show that with the maximum load acting through the platform's midpoint, the cable will be able to support the platform. Support your answer with calculations.

(4 marks)

$Take\ moments\ about\ P;\ \Sigma M = 0;\ \Sigma M_c = \Sigma M_A$ **1 mark**

$(8500 + 700) x\ 9.8\ x\ 7.5 = (T\ \sin 55^o)\ x\ 10.0$ **1 mark**

$\therefore T = 8.25\ x\ 10^4\ N$ **1 mark**

$T < 1.5\ x\ 10^5\ N, \therefore cable\ does\ not\ break$ **1 mark**

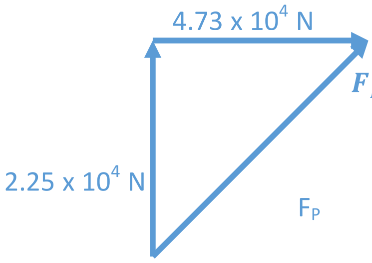
c) Hence, calculate the magnitude of the force that the wall exerts on the platform. [Hint – if you could not calculate an answer for part a), use a value of 9.0 x 10^4 N for the tension in the cable]

(4 marks)

$\Sigma F = 0;\ \Sigma F_{UP} = \Sigma F_{DOWN};\ F_P = (8500 + 700) x\ 9.8 - 8.25\ x\ 10^4\ \sin 55^o = 2.25\ x\ 10^4\ N\ up$

1 mark

$\Sigma F_{LEFT} = \Sigma F_{RIGHT;} \therefore F_P = 8.24\ x\ 10^{-4}\ \cos 55^o = 4.73\ x\ 10^4\ N\ right$ **1 mark**



${F_P}^2 = (2.25\ x\ 10^4)^2 + (4.73\ x\ 10^4)^2;\ F_P = 5.24\ x\ 10^4\ N$ **2 marks**

d) If the maximum load of 8.5 tonnes is gradually moved towards the end of the platform, describe what happens the magnitude and direction of the force you calculated in part c).

(2 marks)

- **As load moves to the end of the platform, ΣM_C increases, hence, tension in cable increases.**

  1 mark

- **Hence, force at wall will increase to balance this increase in tension.**

  1 mark

e) If the maximum load continues to move towards the end of the platform, the cable will eventually exceed its load limit and snap. Calculate how far towards the edge of the platform the load can move until the load limit on the wire is exceeded.

(3 marks)

$(700\ x\ 9.8\ x\ 7.5) + (8500\ x\ 9.8\ x\ r) = 1.5\ x\ 10^{-5}\ x\ \sin 55^{o}\ x\ 10.0$ **1 mark**

$r = 14.1\ m$ **1 mark**

$r\ < 15\ m, \therefore\ cable\ WILL\ snap$ **1 mark**

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

This section has **six (6)** questions. You must answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. 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 that you are continuing to answer at the top of the page.

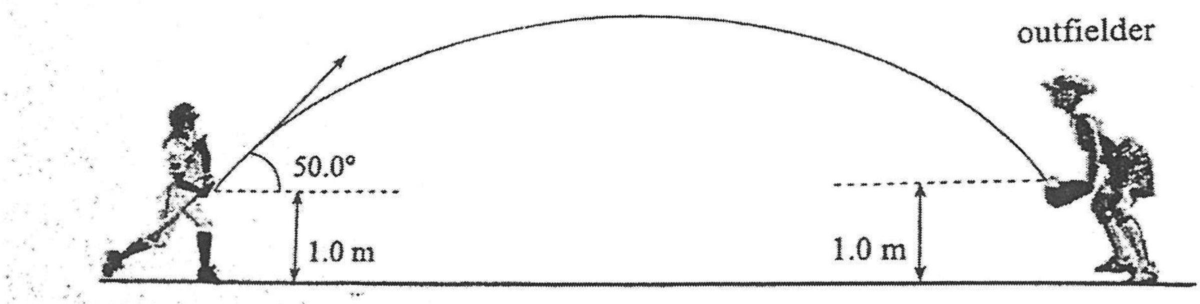
Suggested working time for this section is 90 minutes.

Question 16 **(14 marks)**

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

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

Ignore the effects of air resistance.



[This diagram is not drawn to scale.]

a) Calculate the time it takes to reach the outfielder. (3 marks)

$u_v = 19.5 \sin 50 = 14.9 ms^{-1}$ (1)

$t = \frac{2u_v}{g} = \frac{2(14.9)}{9.8} = 3.04 s$ (1) (1)

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

$v_h = 19.5 \cos 50 = 12.5 ms^{-1}$ (1)

$R = v_h t = 12.5 \times 3.04$ (1) $= 38.1 m$ (1)

SEE NEXT PAGE

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

(3 marks)

$h = \frac{u_v^2}{2g} = \frac{14.9^2}{19.6} = 11.3m$ above release point ①

$+ 1m$ ①

$= 12.3m$ above the ground. ①

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

↓ towards centre of Earth

①

(1 mark)

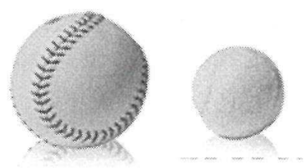
e) Does the ball have an acceleration of zero at the highest point of trajectory? Explain.

(2 marks)

① No.

① Unbalanced force due to gravity ∴ acceleration.

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

Softball  Tennis ball

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

(2 marks)

- Size - softball is bigger, will experience more air-resistance
- Texture - tennis ball is fuzzy, softball is smooth ∴ t.b. more resistance.
- Mass - momentum is proportional to mass, softball is heavier, ∴ less affected by air resistance.

① Naming difference ① Describing effect

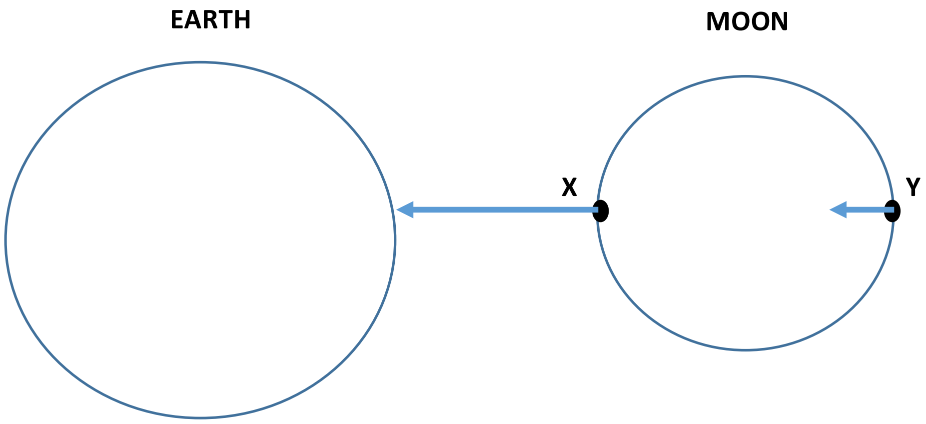
Question 17 **(17 marks)**

In astrophysics, the 'Roche Limit' or 'Roche Radius' is the distance within which a celestial body (eg – the Moon) - which is held together by its own gravity - will disintegrate due to a second celestial body (eg – the Earth) exerting a 'tidal force' on the first that exceeds the gravitational force holding it together.

Inside the Roche Limit or Roche Radius, bodies break up into particles and dust and typically form rings (eg – like those around Saturn); outside of it, bodies tend to form almost perfect spherical shapes.

a) The diagram below shows the Moon in orbit around the Earth. Consider the two points shown: 'X' and 'Y'. On the diagram, draw vectors showing the magnitude and direction of the Earth's gravitational field acting on these points on the Moon.

(4 marks)



Size of the earth is bigger than the moon **1 mark**

Two arrows pointing towards the Earth's centre of mass **1 mark**

Direction of both arrows is the same **1 mark**

$F_X > F_Y$ **1 mark**

b) The 'Roche Radius' for the Moon orbiting around the Earth is 9492 km. The Moon's orbital radius around the Earth is 384 399 km. Hence, the Moon does not disintegrate at this distance – the tidal forces are not large enough. In terms of the gravitational forces due to the Earth acting on different sides of the Moon, explain why it not only doesn't disintegrate at this distance. Diagrams may help your explanation.

(4 marks)

- **Outside Roche Limit, the difference between the forces on either side of the Moon (ie – at X and Y) is insignificant.** **1 mark**
- **Hence, the nett tidal force acting on the Moon is virtually zero.** **1 mark**
- **Therefore, the gravitational attraction of the Moon's matter towards its centre of mass far exceeds the tidal forces acting on the Moon.** **2 marks**

The Moon disintegrates within the Roche Limit, an orbital radius of 9492 km.

c) Use the data supplied in your Formulae and Data Sheet to calculate the Earth's gravitational field strength at position 'X' (g_x) and position 'Y' (g_y).

(5 marks)

$g_x = \frac{Gm}{r^2} = \frac{6.67\ x\ 10^{-11}\ x\ 5.97\ x\ 10^{24}}{(3.84\ x\ 10^8 - 1.74\ x\ 10^6)^2}$ **2 marks**

$= 0.00273\ ms^{-2}$ **1 mark**

$g_y = \frac{Gm}{r^2} = \frac{6.67\ x\ 10^{-11}\ x\ 5.98\ x\ 10^{24}}{(3.84\ x\ 10^8 + 1.74\ x\ 10^6)^2}$ **1 mark**

$= 0.00268\ ms^{-2}$ **1 mark**

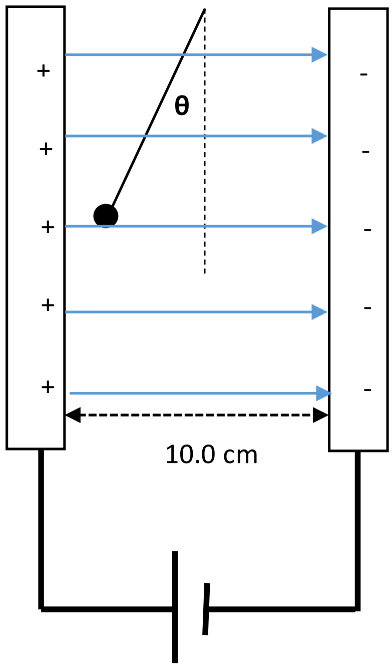
d) For a variety of reasons, astrophysicists have calculated two Roche Limit values for the Moon with the Earth as its second celestial object – the value in part b), which assumes the Moon is a rigid, solid body; and another value assuming that it has the density of a liquid. This value is much larger – 34 638 km. Explain why the 'liquid' value is much larger than the 'rigid body' value.

(4 marks)

- **The forces of attraction between the particles in a liquid are far less than in a solid. 1 mark**
- **Hence, the net tidal force required to disintegrate a Moon made of liquid would be much less than for a solid Moon. 1 mark**
- **Gravitational field strength is inversely proportional to the square of the distance between two bodies. 1 mark**
- **∴The minimum force required for disintegration can be achieved at a much greater distance from the Moon. 1 mark**

Question 18 **(11 marks)**

A small charged object of mass 0.500 mg is suspended from a 25.0 cm long piece of string made of insulating material. The charge on the object is 25.0 nC.



a) On the diagram above, draw the electric field between the charged plates.

(2 marks)

- **Direction of field** **1 mark**
- **Uniform shape** **1 mark**

b) Is the object positively or negatively charged? Explain your choice (2 marks)

- **Negative charge** **1 mark**
- **Attracted to positively charged plate and/or repelled by negatively charged plate**

  1 mark

c) Calculate the electric field strength between the two charged plates.

(2 marks)

$E = \frac{V}{d}; \therefore E = \frac{500}{0.10}$ **1 mark**

$E = 5000\ Vm^{-1}$ **1 mark**

d) Hence, calculate the electrostatic force acting on the charged object [if you could not calculate an answer to part a), use E = 5500 Vm^{-1}].

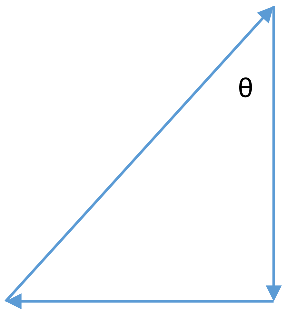
(2 marks)

$E = \frac{F}{q}; F = Eq = 5000\ x\ 25\ x\ 10^{-9}$ **1 mark**

$\therefore F = 1.25\ x\ 10^{-4}\ N$ **1 mark**

e) Calculate the size of the angle 'θ'. Show all working. [If you could not calculate an answer for part (d), use F_E = 1.4 x 10^{-4} N].

(3 marks)



W = mg

= 0.5 x 10^{-6} x 9.8

= 4.9 x 10^{-6} N

- **Weight calculation** **1 mark**

F_E = 1.25 x 10^{-4} N

$\tan\theta = \frac{1.25\ x\ 10^{-4}}{4.9\ x\ 10^{-6}}$ **1 mark**

$\theta = 87.8^o$ **1 mark**

Question 20 **(15 marks)**

Our Sun is a medium sized star that is part of a spiral galaxy called the Milky Way. Like all spiral galaxies, the stars in the Milky Way rotate around a galactic centre.

Our Sun's orbit is virtually circular with a radius of about 2.5 x 10^{20} m (about 26000 light years); its average orbital speed is about 2.2 x 10^{5} ms^{-1}.

a) Calculate the orbital period of the Sun around the galactic centre of the Milky Way (in years).

(4 marks)

$v = \frac{2\pi r}{T}$; $\therefore T = \frac{2\pi r}{v}$ **1 mark**

$T = \frac{2\pi \, x \, 2.5 \, x \, 10^{20}}{2.2 \, x \, 10^{5}}$ **1 mark**

$\therefore T = 7.14 \, x \, 10^{15} \, s$ **1 mark**

$= 2.26 \, x \, 10^{8} \, years$ **1 mark**

b) Calculate the gravitational field strength due to the Milky Way galaxy at the Sun's distance from the galactic centre.

(3 marks)

$g = a_c = \frac{v^2}{r}$ **1 mark**

$\therefore g = \frac{(2.2 \, x \, 10^{5})^2}{2.5 \, x \, 10^{20}}$ **1 mark**

$= 1.94 \, x \, 10^{-10} \, Nkg^{-1}$ **1 mark**

c) The circular orbit of the Sun around the galactic centre of the Milky Way is due to the gravitational force of attraction between the Sun's and Milky Way's centres of mass. Use the data provided and answers calculated thus far to show that the mass of our galaxy inside our Sun's orbit must be about 1.8 x 10^{41} kg. [If you could not calculate an answer to part a), use 7 x 10^{15} s; if you could not calculate an answer to part b), use 1.9 x 10^{-10} Nkg^{-1}]

(3 marks)

$g = \frac{Gm}{r^2}$ **1 mark**

$1.94 \, x \, 10^{-10} = \frac{6.67 \, x \, 10^{-11} \, x \, m}{(2.5 \, x \, 10^{20})^2}$ **1 mark**

$\therefore m = 1.81 \, x \, 10^{41} \, kg$ **1 mark**

d) If the mass of our Sun can be considered to be an average mass for the stars in our galaxy, estimate how many stars there must be inside our Sun's orbit in the Milky Way. Show working.

(2 marks)

$Number\ of\ stars = \frac{1.81\ x\ 10^{41}}{1.99\ x\ 10^{30}}$ **1 mark**

$= 9.12\ x\ 10^{10}$ **1 mark**

e) The mass of the Milky Way inside our Sun's orbit is about 1.8 x 10^{41} kg – which is about 10^{11} times the mass of our Sun. However, when scientists estimate the mass of the **visible matter** inside the Sun's orbit it only comes to about 10^{10} times the mass of our Sun.

i) What does this imply about the types of matter in our Galaxy? (2 marks)

- **Implies that a significant amount of matter in the Milky Way galaxy is NOT visible.**

  1 mark

- **Even though it is invisible, this matter still exerts gravitational force on other matter in the universe.** **1 mark**

ii) If the mass of our galaxy was only 10^{10} times the mass of our Sun, describe one (1) effect this would have on our Sun's motion.

(1 mark)

- **If mass was only 10^{10} times the mass of our Sun, then the following changes would occur to the Sun's orbit:**

  Decrease in orbital velocity; increase in orbital period. **1 mark**

End of Section 2

Question 20 **(15 marks)**

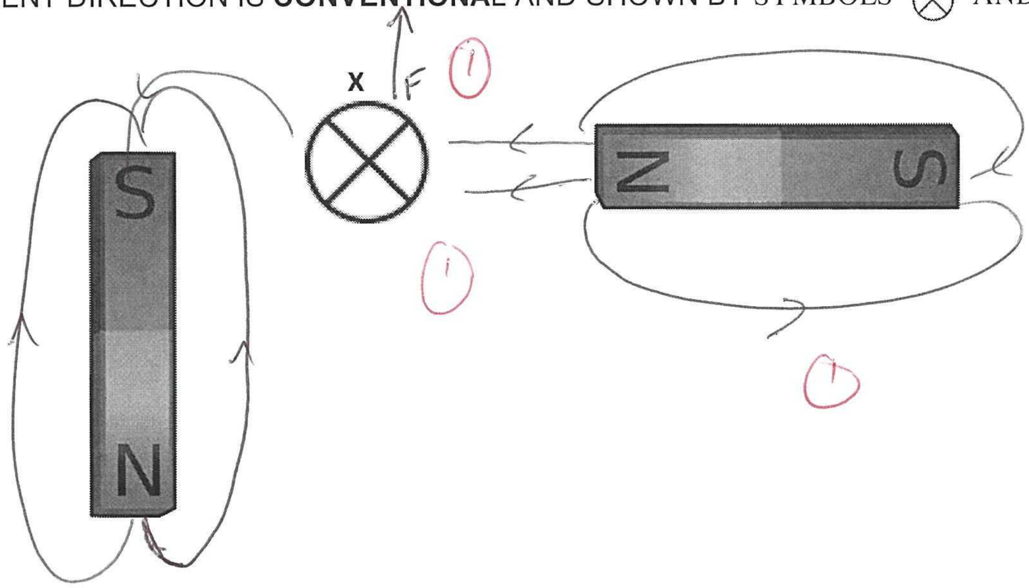
For each of the diagrams below:

i) draw the magnetic field lines produced; (2 marks each)

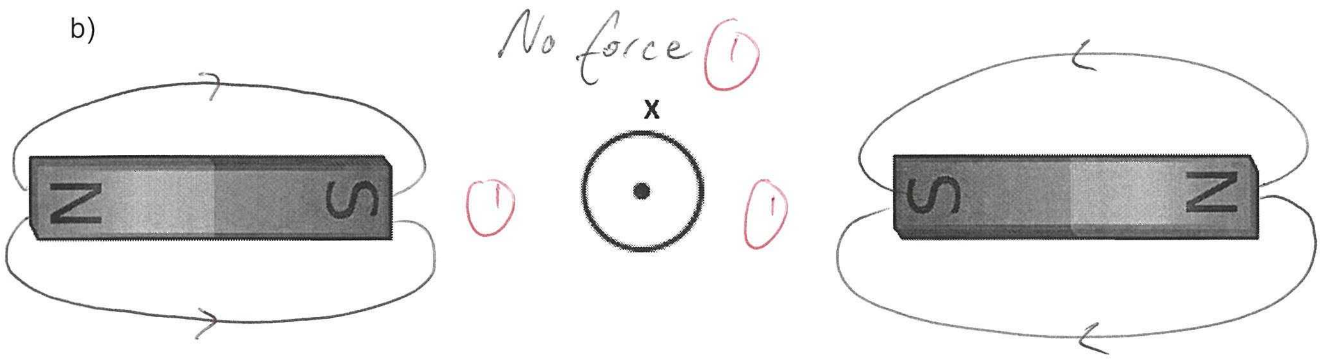
ii) show the force on the current carrying conductor labelled X. (1 mark each)

CURRENT DIRECTION IS **CONVENTIONAL** AND SHOWN BY SYMBOLS ⊗ AND ⊙ .

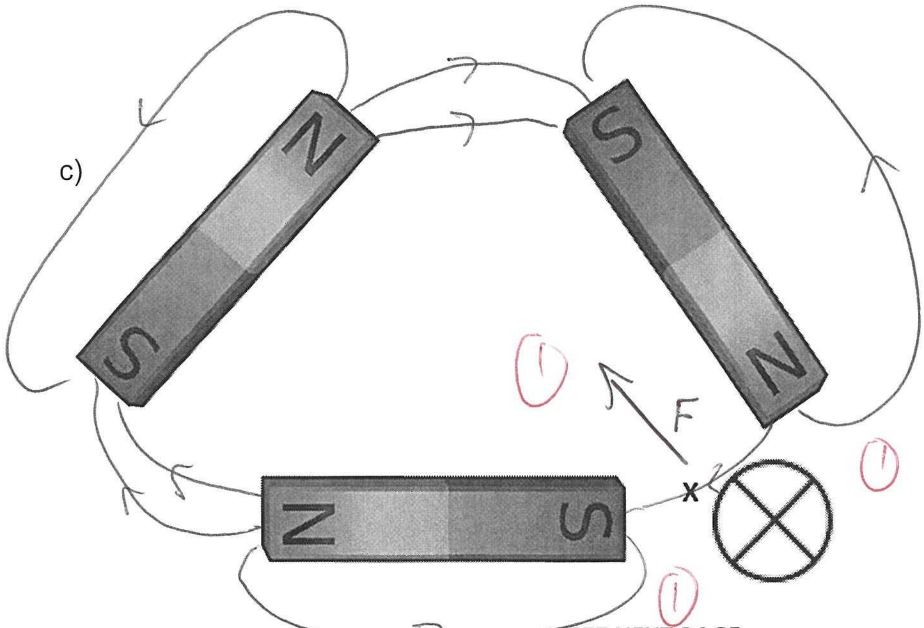
a)



b)

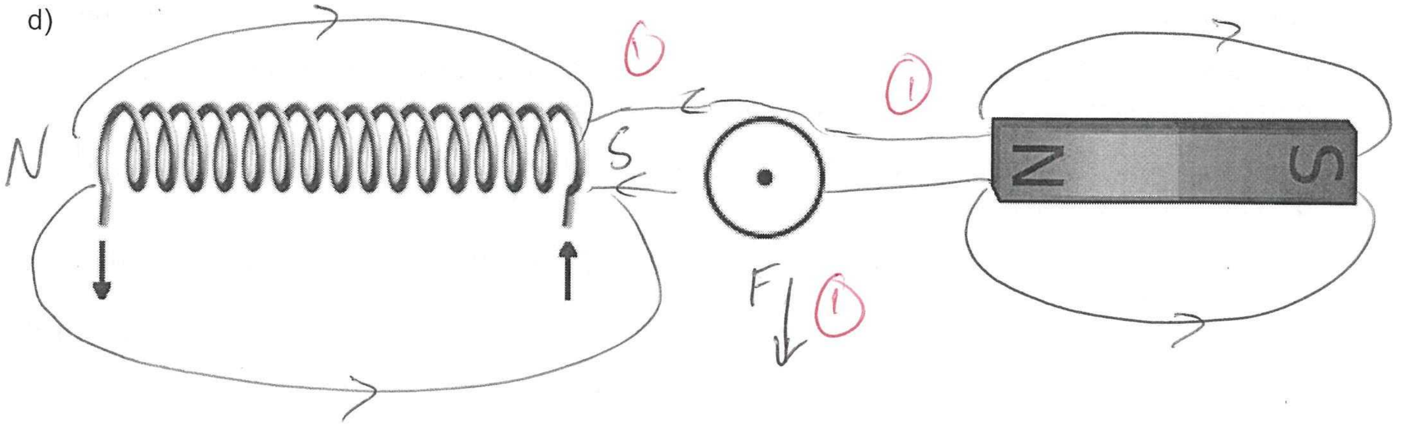


c)

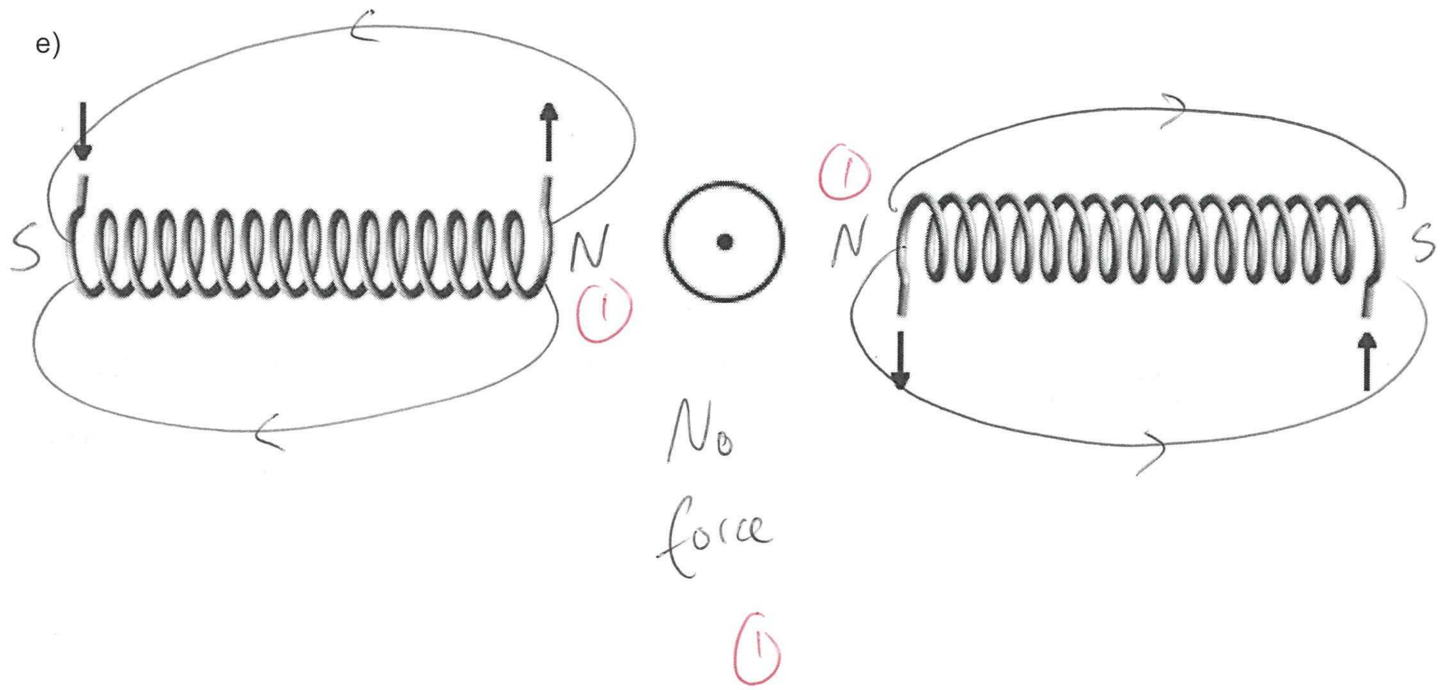


SEE NEXT PAGE

d)



e)



Section Three: Comprehension and Data Analysis **20% (36 Marks)**

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

Spare pages are included at the end of this booklet. 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 that you are continuing to answer at the top of the page.

Suggested working time for this section is 40 minutes.

Question 21 **(18 marks)**

"How do gravitational slingshots work?"

By Fraser Cain (From Universe Today Astronomy and News, http://www.universetoday.com/113488/how-do-gravitational-slingshots-work/)

Have you ever heard that spacecraft can speed themselves up by performing gravitational slingshot maneuvers? What's involved to get yourself going faster across the Solar System.

Let's say you want to go back in time and prevent Kirk from dying on the Enterprise B.

You could use a slingshot maneuver. You'd want to be careful that you don't accidentally create an alternate reality future where the Earth has been assimilated by the Borg, because Kirk wasn't in the Nexus to meet up with Professor Picard and Sir Iandalf Magnetopants, while they having the best time ever gallivanting around New York City.

sigh Ah, man. I really love those guys. What was I saying? Oh right. One of the best ways to increase the speed of a spacecraft is with a gravitational slingshot, also known as a gravity assist.

There are times that fantasy has bled out too far into the hive mind, and people confuse a made up thing with an actual thing because of quirky similarities, nomenclature and possibly just a lack of understanding.

So, before we go any further a "gravitational slingshot" is a gravity assist that will speed up an actual spacecraft, "slingshot maneuver" is made up bananas nonsense. For example, when Voyager was sent out into the Solar System, it used gravitational slingshots past Jupiter and Saturn to increase its velocity enough to escape the Sun's gravity.

So how do gravitational assists work? You probably know this involves flying your spacecraft dangerously close to a massive planet. But how does this help speed you up? Sure, as the spacecraft flies towards the planet, it speeds up. But then, as it flies away, it slows down again. Sort of like a skateboarder in a half pipe.

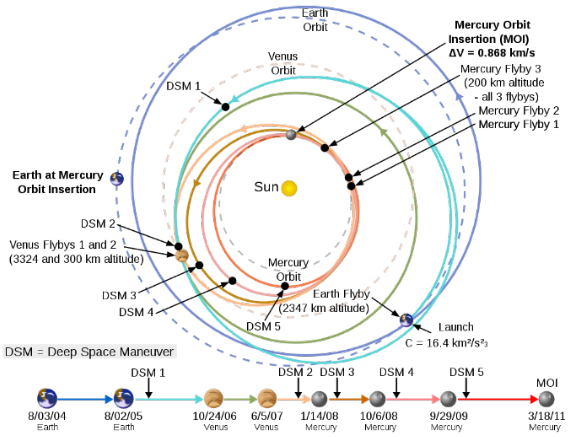
This process nets out to zero, with no overall increase in velocity as your spacecraft falls into and out of the gravity well. So how do they do it? Here's the trick. Each planet has an orbital speed travelling around the Sun.

As the spacecraft approaches the planet, its gravity pulls the much lighter spacecraft so that it catches up with the planet in orbit. It's the orbital momentum from the planet which gives the spacecraft a tremendous speed boost. The closer it can fly, the more momentum it receives, and the faster it flies away from the encounter.

To kick the velocity even higher, the spacecraft can fire its rockets during the closest approach, and the high speed encounter will multiply the effect of the rockets. This speed boost comes with a cost. It's still a transfer of momentum. The planet loses a tiny bit of orbital velocity.

If you did enough gravitational slingshots, such as several zillion zillion slingshots, you'd eventually cause the planet to crash into the Sun. You can use gravitational slingshots to decelerate by doing the whole thing backwards. You approach the planet in the opposite direction that it's orbiting the Sun. The transfer of momentum will slow down the spacecraft a significant amount, and speed up the planet an infinitesimal amount.

NASA's MESSENGER spacecraft made 2 Earth flybys, 2 Venus flybys and 3 Mercury flybys before it was going slowly enough to make an orbital insertion around Mercury. Ulysses, the solar probe launched in 1990, used gravity assists to totally change its trajectory into a polar orbit above and below the Sun. And Cassini used flybys of Venus, Earth and Jupiter to reach Saturn with an efficient flight path.



Nature sure is trying to make it easy for us. Gravitational slingshots are an elegant way to slow down spacecraft, tweak their orbits into directions you could never reach any other way, or accelerate to incredible speeds.

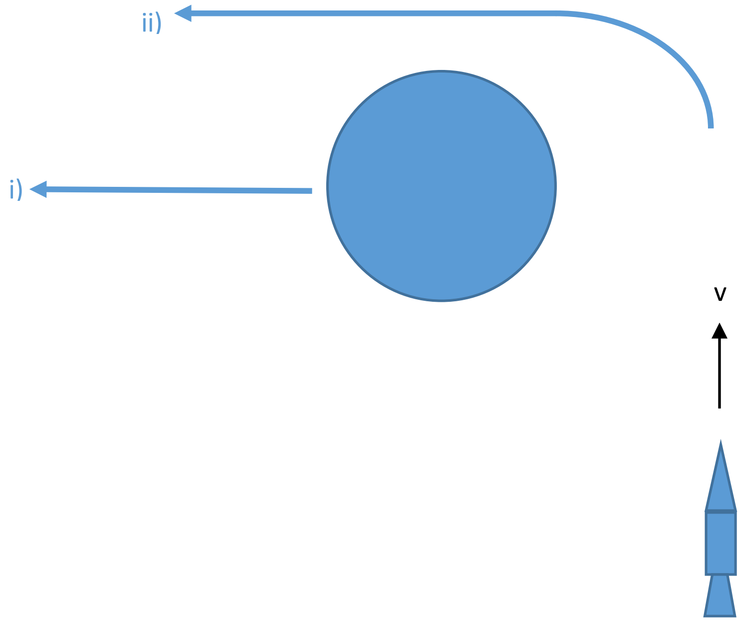
It's a brilliant dance using orbital mechanics to aid in our exploration of the cosmos. It's a shining example of the genius and the ingenuity of the minds who are helping to push humanity further out into the stars.

a) "Voyager was sent out into the Solar System, it used gravitational slingshots past Jupiter and Saturn to increase its velocity enough to escape the Sun's gravity."

Voyager (which is not under any external sources of power from engines, thrusters, etc.) needed a minimum speed to escape the Sun's gravity. In terms of the Sun's gravitational force, explain. (4 marks)

- **Any object trying to 'escape' the Sun will have to overcome its gravitational attraction. 1 mark**
- **Due to this gravitational attraction, objects trying to travel away from the Sun will decelerate (ie – speed will decrease). 1 mark**
- **If the object's speed reduces to zero, the object will fall back towards the Sun. 1 mark**
- **If the object's initial speed is large enough, gravity will not be able to reduce it to zero – object will escape. 1 mark**

b) The diagram below is incomplete. It shows a spacecraft approaching a planet which it is planning to use for a gravitational slingshot. Its velocity direction (v) as it approaches the planet is also shown with an arrow.



i) On the diagram, indicate with an arrow the direction of the planet's motion around the sun.

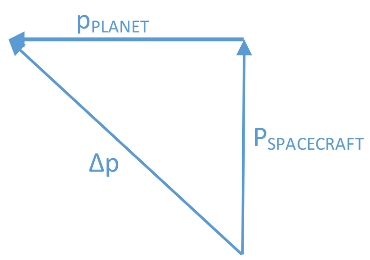
(1 mark)

- **See diagram – arrow points left 1 mark**

ii) On the same diagram you used in part i), draw the path that the spacecraft would take as it passed by the planet. Again, provide a brief explanation for your choice. A vector diagram may aid your explanation.

(5 marks)

- **See diagram – arrow anticlockwise 1 mark**



- **Vector for 'p' of spacecraft 1 mark**
- **Vector for 'p' of planet 1 mark**
- **Vector for resultant 'p' 1 mark**

- **Some momentum from the planet is transferred to the spacecraft, speeding it up.**

1 mark

c) The gravitational slingshot maneuver involves flying a spacecraft dangerously close to a massive planet. In August 2011, NASA's Juno mission to Jupiter was launched (it is now in orbit around Jupiter). As part of this mission, Juno used the Earth to complete a gravitational slingshot. In completing this maneuver, Juno came to within 560 km of the Earth's surface. If Juno has a mass of 1593 kg, calculate the gravitational force of attraction acting on Juno at this point.

(4 marks)

$$F_g = \frac{Gm_1m_2}{r^2}$$ **1 mark**

$$= \frac{6.67 \, x \, 10^{-11} \, x \, 5.98 \, x \, 10^{24} \, x \, 1593}{(560 \, x \, 10^3 + 6.37 \, x \, 10^6)^2}$$ **2 marks**

$$= 13230 \, N$$ **1 mark**

d) It's possible that if a spacecraft like Juno performs enough 'gravitational slingshot' maneuvers around a planet like Earth that it could cause the planet to move closer to the Sun and possibly spiral into it. Explain using any Physics concepts you have learned.

(4 marks)

- **A slingshot maneuver involves a transfer of momentum from the planet to the spacecraft. 1 mark**
- **The spacecraft gains momentum from the planet. 1 mark**
- **As the spacecraft gains momentum, its speed increases; as the planet loses momentum, it loses speed. 1 mark**
- **As the planet loses speed, its orbital radius decreases. 1 mark**

Question 23 **(18 marks)**

Using Mass Spectrometry to Identify Drug Cheats in Sport

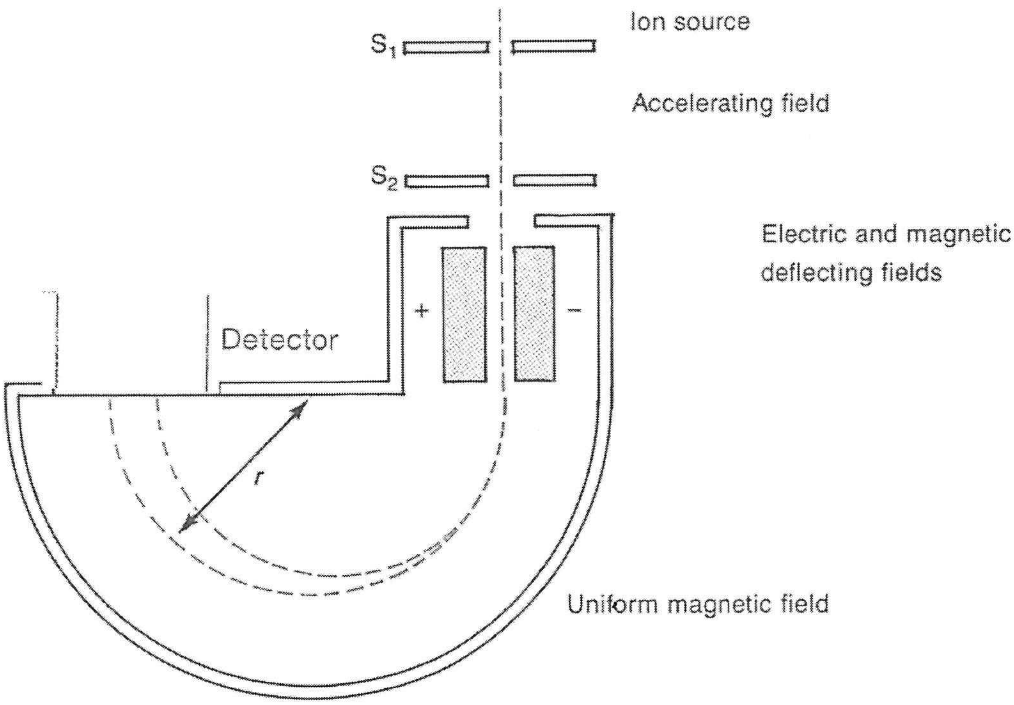
Many sporting organizations are faced with the real prospect that many of their athletes use a variety of performance enhancing drugs. To discourage such activities the authorities conduct regular random drug tests. This involves taking urine or a blood samples from the athlete and subjecting the sample to analysis.

One of the favoured methods of analyzing the sample is to use a technique known as mass spectrometry or MS for short. The samples taken from the athletes are broken down into very tiny parts within a vapour. The vapour is then ionized into charged particles (known as "ions") and then accelerated to a high speed by a powerful electric field.

After accelerating to high speeds, the ions enter a chamber where there is a uniform magnetic field. The ions experience a force due to the magnetic field and move in a curved path towards a detector. The images created on the detector are unique for the various charged fragments and hence they act like a "fingerprint" for the various substances involved.

By comparing the image obtained from the MS machine with the many known images for the banned substances it is possible to identify the presence of an illicit substance in the sample taken from the athlete. In this case, authorities will say that the athlete has returned a "positive test result" and punitive action may result.

The diagram below shows the principle of a mass spectrometer.



a) Why must the molecules in the vapour be ionized before entering the mass spectrometer?

(2 marks)

• provides charge difference

∴ force from electric field for acceleration.

(1) (1)

or, deflection occurs due to magnetic field

b) What is the direction of the magnetic field if the beam of charged particles is to bend in the direction shown in the diagram?

(2 marks)

• perpendicularly out of page

(1) (1)

c) The magnetic field provides the centripetal force that causes the charged particles to follow a curved path within the magnetic field.

Prove that the following relationship is correct.

$$\frac{m}{q} = \frac{Br}{v}$$

(3 marks)

$F_c = \frac{mv^2}{r}$ $F = qvB$

(1)

$\therefore\ qvB = \frac{mv^2}{r}$

(1)

$qB = \frac{mv}{r}$ $\therefore\ \frac{m}{q} = \frac{Br}{v}$ (1)

d) A particular ion (X) has a charge of +1 and a relative mass of 23. Another ion (Y) has a charge of +1 and a relative mass of 39. Both ions move at the same velocity in the same magnetic field. Determine the ratio of the radii (***r**Y* **:** ***r**X*) of the curved paths taken by these ions.

(3 marks)

$r = \frac{mv}{qB}$

$\therefore r_X = \frac{23v}{1B}$ $\quad r_Y = \frac{39v}{1B}$ (1)

as $V_X = V_Y$ and $B_X = B_Y$ (1)

$r_Y : r_X = 39:23$ (1)

e) Ions with a mass of 6.80 x 10-27 kg are accelerated through the electric field section of the mass spectrometer and emerge with kinetic energy of 4.24 eV. What is the velocity of these ions?

(3 marks)

$E_K = \frac{1}{2}mv^2$

$4.24eV =$ ~~8.06×10^{-19} J~~

$\times 1.6 \times 10^{-19}$ (1)

6.78×10^{-19}

$\therefore V = \sqrt{\frac{2E_K}{m}}$ (1)

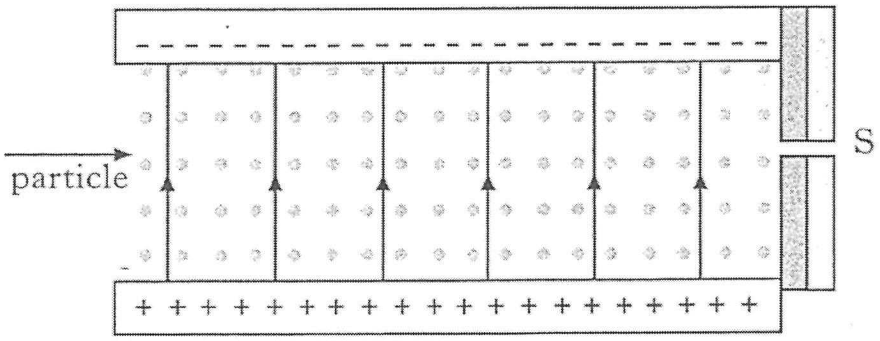
~~$= \sqrt{\frac{(2 \times 8.06 \times 10^{-19})}{6.8 \times 10^{-27}}} = 1.54 \times 10^4 ms^{-1}$~~

$= \sqrt{\frac{(2 \times 6.78 \times 10^{-19})}{6.8 \times 10^{-27}}} = 1.41 \times 10^4 ms^{-1}$

(1)

To ensure that all ions that enter the magnetic field chamber of the mass spectrometer have the same velocity it is necessary to first pass the mixture of ions through a device known as a "velocity selector". This device consists of a pair of crossed fields - that is, a magnetic field and an electric field that are at right angles to each other. These two fields are arranged in such a way that ions which have a specific velocity will pass through the region of the crossed fields without any deflection.

This is shown in the diagram below.



f) If the ions from part e) are passed through crossed fields without deflection and the magnetic field used has a strength of 1.365 T, what is the strength of the electric field used?

[If you were unable to determine an answer to part e] above, use a speed of 1.50 x 10^4 ms^{-1} in this question]

(3 marks)

$F = Eq \qquad F = qvB$

$\therefore Eq = qvB \Rightarrow E = vB$ (1) (1)

$= 1.91 \times 10^4 \times 1.365$ or $= 1.5 \times 10^4 \times 1.365$

$= 1.93 \times 10^4 \, NC^{-1}$ (1) $= 2.05 \times 10^4 \, NC^{-1}$

g) The electric field used in the crossed fields is provided by a set of parallel oppositely charged plates that are separated by a distance of 8.00 mm. Calculate the magnitude of the potential difference between the plates.

(2 marks)

$E = \frac{V}{d}$

$\therefore V = Ed = 1.93 \times 10^4 \times 8 \times 10^{-3}$ or $= 2.05 \times 10^4 \times 8 \times 10^{-3}$

$= 1.54 \times 10^2 \, V$ $= 1.64 \times 10^2 \, V$

End of Section 3

End of Section 3

Additional working space

Additional working space

Additional working space

Additional working space

SEE NEXT PAGE

Additional graph if required.

End of examination