# PHYSICS
# Year 12 - STAGE 3
# Trial WACE
# 2010

| | |
|---|---|
| Section A | |
| Section B | |
| Section C | |
| Total | |

| | |
|---|---|
| Name: | Solution |
| 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; Formula and Constants sheet

**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 Curriculum Council 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.

All calculations are to be set out in detail. Marks may be awarded for correct equations and clear setting out, even if you cannot complete the calculation. Express **numerical answers** to two (2) or three (3) significant figures and include units where appropriate. Express **estimates** to one (1) or two (2) significant figures, and state any assumptions clearly.

**Structure of this paper**

| Section | Number of Questions available | Number of questions to be attempted | Suggested working time | Marks Available | Percentage of Exam |
|---|---|---|---|---|---|
| A: Short Answers | 16 | 16 | 60 mins | 70 | 35 |
| B: Problem Solving | 7 | 7 | 80 mins | 90 | 45 |
| C: Comprehension & Interpretation | 2 | 2 | 40 mins | 40 | 20 |
| | | | Total | 200 | 100 |

INSTRUCTIONS TO CANDIDATES

- The rules of the conduct of Western Australian external examinations are detailed in the Year 12 Information Handbook 2010. Sitting this examination implies you agree to abide by these rules.
- Answer the questions according to the following instructions:
- Write your answers in the spaces provided beneath each question. The value of each question (out of 200) is shown following each question. You should note that the space made available for an answer is not necessarily an indication of the length of the answer. 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.
- Answers to questions involving calculations should be evaluated and given in decimal form. It is suggested that you quote all answers to three significant figures with the exception of questions for which estimates are required. Despite an incorrect final result, you may obtain marks for method and working, provided these are clearly and legibly set out.
- Questions containing specific instructions to **show working** should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at. Correct answers which do not show working will not be awarded full marks.
- Questions containing the instruction "ESTIMATE" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained.
- When descriptive answers are required, you should display your understanding of the context of a question.
- An answer which does not display an understanding of Physics principles will not attract marks.

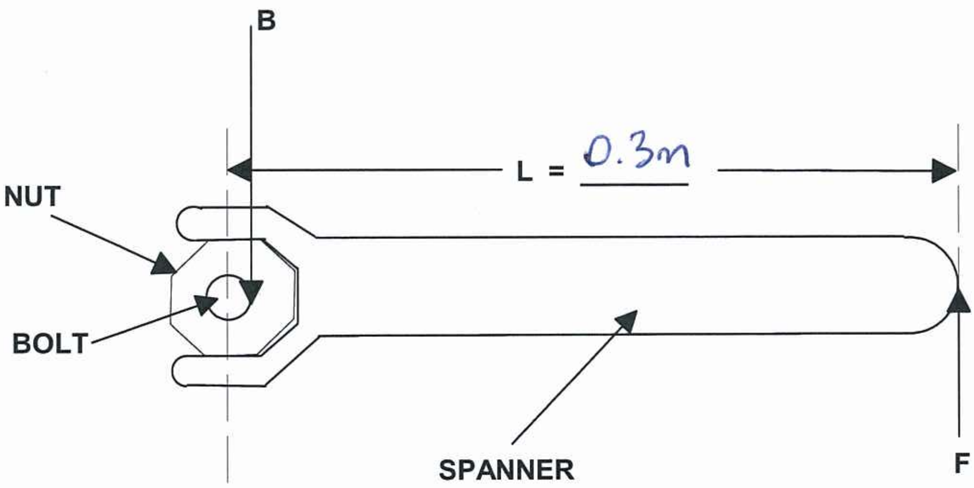
- The Physics: Formulae and Constants Sheet provided with this question paper may be used as required.

**Section A: Short Answers**
Marks allocated: 70 marks out of a total of 200 (35%)

**Attempt ALL 16 questions in this section.**
**Answers are to be written in the space below or next to each question.**

1 A nut on a bolt on a bicycle requires a torque of 6 N m to just loosen it.

(a) Label the diagram below and estimate realistic values for the length (L) and force (F) that would just supply enough torque to loosen the nut. (~~4~~ 3 marks)




PRODUCT = 6Nm. (1)

$\tau = F \times r$ (1)

$6 = F \times 0.3$

$F = \frac{6}{0.3} = 20N$ (1)

(b) ESTIMATE the binding force (B), between the nut and the bolt, which is just sufficient to stop the nut from coming loose. (~~2~~ 3 marks)

B = 1500 - 3000 N. (1)

Radius (bolt) = 2-4 mm

$= 3 \times 10^{-3}$ m

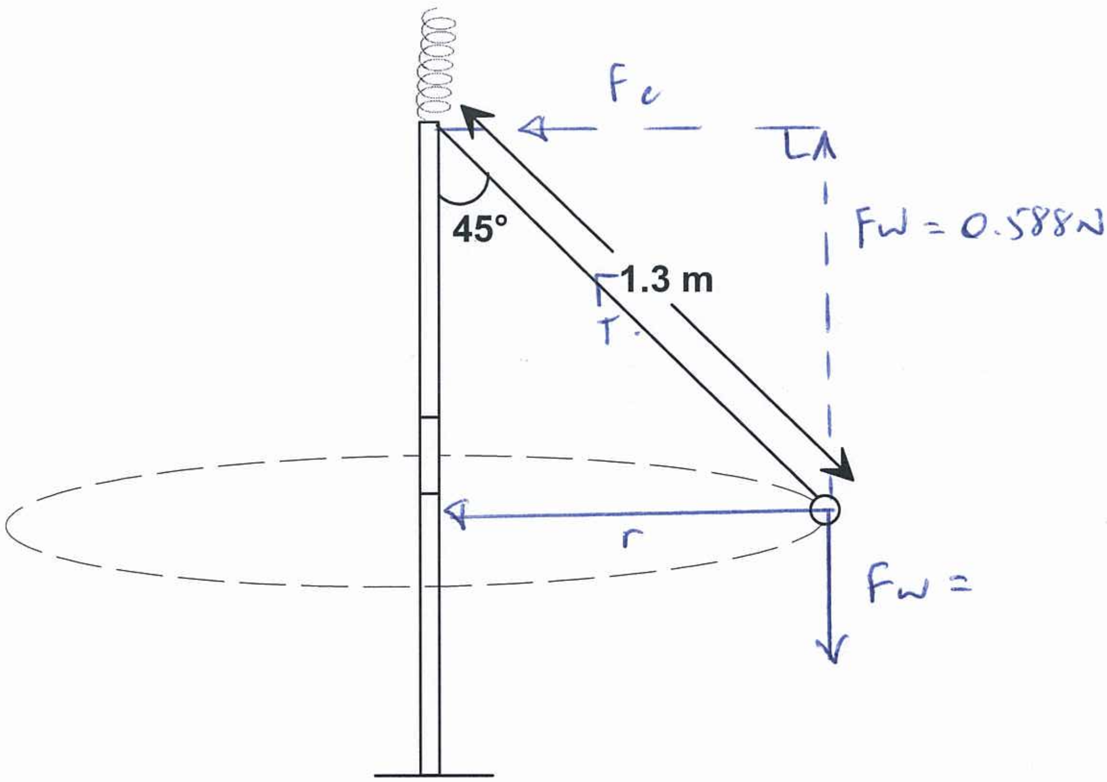
$\therefore \Sigma m = 6 = rF$

$= 3 \times 10^{-3} \times F$ (1)

$F = \frac{6}{3 \times 10^{-3}}$

$= 2000$ N. (1)

2 During a game of totem tennis a ball of mass 60.0 g swings freely in a horizontal circular path. The string is 1.30 m long and is at an angle of 45° to the vertical as shown in the diagram.




(a) Calculate the radius of the ball's circular path. (2 marks)

$\sin 45° = \frac{r}{1.3}$ (1)

$r = 1.3 \sin 45°$

$= \underline{0.92\,m}$. (1)

(b) Calculate the tension in the string AND the centripetal force experienced by the ball (3 marks)

$F_w = 60 \times 10^{-3} \times 9.8$

$= \underline{0.588N}$. (1)

$\tan 45° = \frac{0.588}{F_c}$

$F_c = \frac{0.588}{\tan 45}$

$= \underline{0.588N .\ t.c.}$ (1)

$\cos 45 = \frac{0.588}{T}$

$T = \frac{0.588}{\cos 45} = \underline{0.832N}$ (1)



$\therefore F_c = 0.588N$ (t.c). & $T = 0.832N$.

3 A 700.0 kg roller coaster car at the Royal Show starts 40.0 m above the ground, goes down a dip in the track and just manages to roll over the next hill which is 33.0 m above ground level.

(a) Calculate the amount of energy the car has lost? (2 marks)

$E_p^{START} = mgh$
$= 40 \times 9.8 \times 700$
$= 2.74 \times 10^5$ J. ½

$E_p^{33} = mgh$
$= 700 \times 9.8 \times 33$
$= 2.26 \times 10^5$ J. ½

∴ ENERGY LOST $= (2.74 - 2.26) \times 10^5$
$= 4.8 \times 10^4$ J 1

(b) What has happened to this "lost" energy? (1 mark)

Converted to heat, sound 1

(c) Neglecting energy losses, what is the maximum height above the ground the roller coaster car can achieve as it negotiates successive hills and dips? Explain your answer. (2 marks)

40 m. 1
Max height provides the only source of energy & hence conservation of energy dictates this to be the max possible height. 1

4 A boy rides his skate board up a ramp with an initial speed of 7.00 $ms^{-1}$ but slows down with a constant deceleration of 2.00 $ms^{-2}$. He travels some distance up the ramp before coming to rest and rolls down again.
Ignoring friction, calculate:
(a) the distance the boy travels up the ramp before stopping (2 marks)

$u = 7.00 ms^{-1}$
$a = -2 ms^{-2}$
$s = ?$
$v = 0$

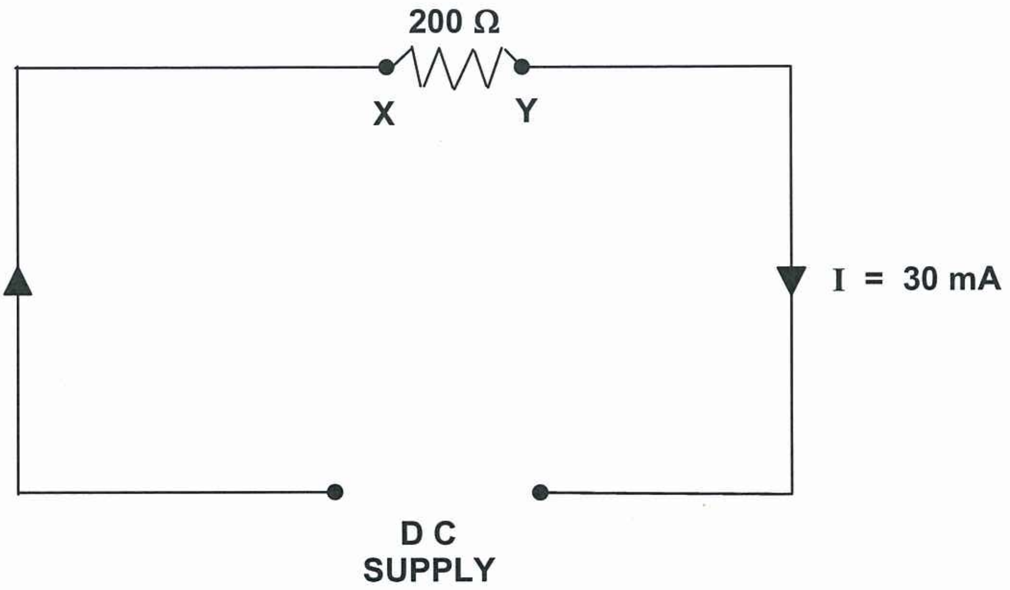
$v^2 = u^2 + 2as$
$s = \frac{v^2 - u^2}{2a} = \frac{0 - 7^2}{2 \times (-2)}$ 1
$= 12.3 m$. 1

(b) the time that it takes him to reach the highest point. (2 marks)

$t = ?$

$v = u + at$
$t = \frac{v - u}{a}$ 1
$= \frac{0 - 7}{-2}$
$= 3.5 s$. 1

5 A simple electrical circuit consisting of a DC voltage supply, and resistor is shown below. The resistor value is 200.0 Ω and the current is 30.0 mA in the direction shown.




(a) Calculate the potential difference across the resistor. (2 marks)

$R = 200\,\Omega$

$I = 30 \times 10^{-3}$ A

$V = IR$ (1)

$= 30 \times 10^{-3} \times 200$

$= 6.00$ V. (1)

(b) Which of the following statements about the potential difference across the resistor is true?

**A.** The potential at point **X** is higher than at point **Y**.
**B.** The potential at point **X** is the same as at point **Y.**
**C.** The potential at point **X** is lower than at point **Y.**

Statement A. (2) (2 marks)

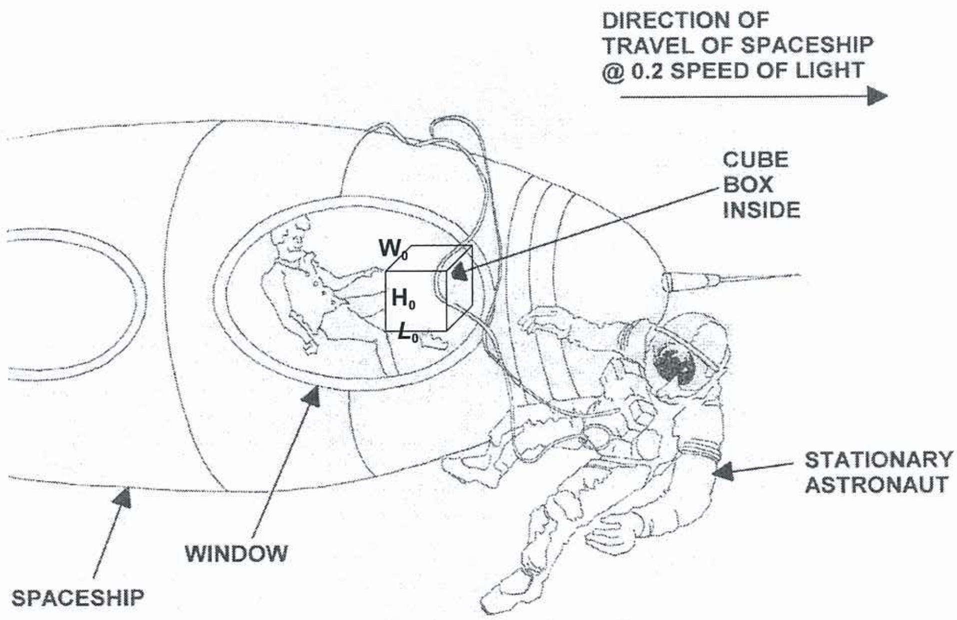
(c) Calculate the electrical energy dissipated in the 200.0 Ω resistor each second. (2 marks)

$P = VI = I^2R$ (1)

$= (30 \times 10^{-3})^2 \times 200$

$P = 0.18$ W (1)

6 A spaceship travelling at 20% of the speed of light (i.e. 0.2 x c) contains a cube shaped box.
An astronaut floating freely in space outside the spaceship views the box through a window as the spaceship passes and records its dimensions as L, W and H.
A passenger on the spaceship records the dimensions of the box as $L_o$, $W_o$ and $H_o$.




(a) Which of the following options best describes the dimensions of the box as observed by the astronaut outside the spaceship compared to the measurements made by the passenger?

**A.** $L<L_o$, $W<W_o$, $H=H_o$
**B.** $L>L_o$, $W=W_o$, $H=H_o$
**C.** $L<L_o$, $W=W_o$, $H=H_o$
**D.** $L<L_o$, $W<W_o$, $H<H_o$

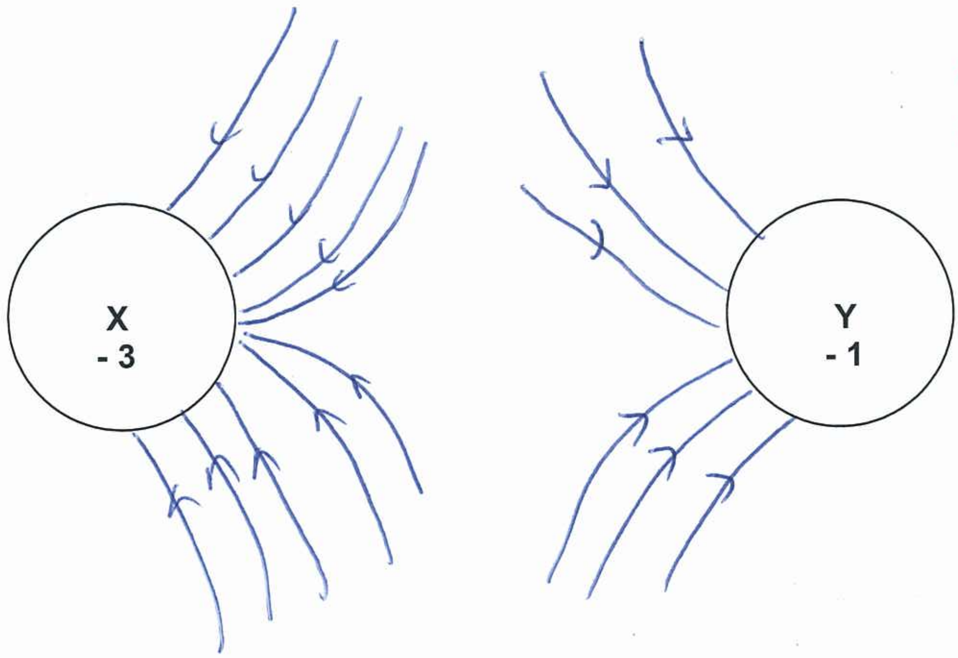
Answer C. 1 (1 mark)

(b) Explain why you selected your answer. (3 marks)

1

Object travelling at relatwistic speeds, its dimension will contract 1
Only the dimension in the same direction as motion will be contracted. 1

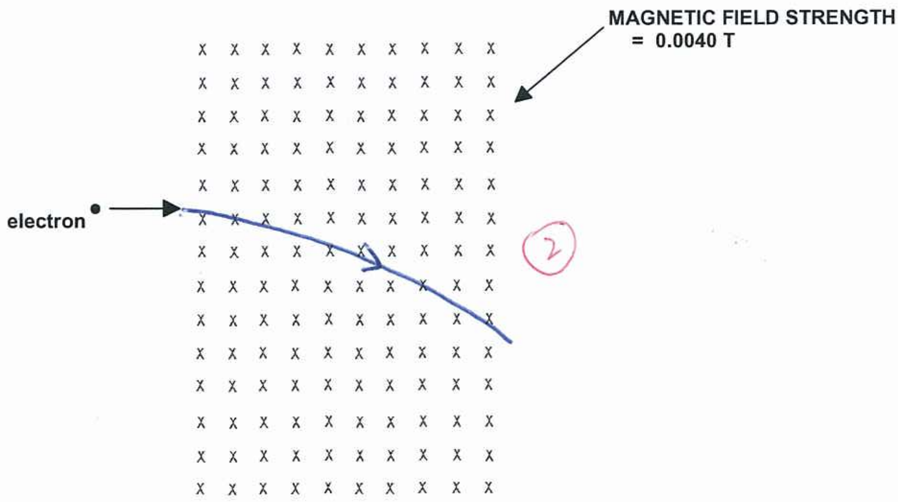
7 The diagram below shows two negatively charged particles. Particle X has a charge 3 times that of particle Y. On the diagram draw eight (8) electric field lines that best represent the field associated with the two particles. (3 marks)




direction ①
shape ①
? ①

−1 any error
• lines crossing
etc

8 An electron travelling horizontally at $1.5 \times 10^{6}$ m s$^{-1}$ enters a vertical uniform magnetic field of strength $4.00 \times 10^{-3}$T (into page).




②

(a) Calculate the force that the electron experiences. (2 marks)

$B = 4 \times 10^{-3}$ T
$v = 1.5 \times 10^{6}$ m s$^{-1}$
$q = 1.6 \times 10^{-19}$ C

$F = qBv$ ①
$= 1.6 \times 10^{-19} \times 4 \times 10^{-3} \times 1.5 \times 10^{6}$
$= 9.6 \times 10^{-16}$ N ①

(b) On the diagram above draw a line to show the path of the electron as it travels in the magnetic field. (2 marks)

9 Students construct a model electric heater in the laboratory using two lengths of nichrome wire as heating elements. The two wires have resistances of 10.0 Ω and 20.0 Ω respectively.

(a) Calculate the current that would flow through each wire and the power that will be produced by the model heater if they are connected in **series** with each other and a 12 V battery is used to complete the circuit. (2 marks)

$R_T = 30\,\Omega$
$V = 12V$

$I_T = \frac{V_T}{R_T} = \frac{12}{30} = 0.4\ A.$ 1

$P = I^2R = 0.4^2 \times 30 = 4.8\ W.$ 1

(b) If the two lengths of nichrome wire were then connected in **parallel** with the 12 V battery, calculate the current that would flow through each wire and the total power produced. (2 marks)

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$
$= \frac{1}{10} + \frac{1}{20}$

$R_T = 6.67\,\Omega.$ 1/2

$I_T = \frac{V_T}{R_T} = \frac{12}{6.67}$
$= 1.8A$ 1/2

$I_{10} = \frac{V}{R} = \frac{12}{10} = 1.2A$

$I_{20} = \frac{V}{R} = \frac{12}{20} = 0.6A.$

$P = I^2R$
$= 1.8^2 \times 6.67 = 21.6\ W.$ 1

10 Towards the end of the 20th century scientists suggested that quarks were the basic building blocks of protons and neutrons. Quarks have the following properties:

- They have mass.
- They can have electromagnetic charges of +1/3, +2/3, -1/3, and -2/3
- They have colour charge.
- They have spin.

(a) If a proton is made up of 3 quarks, what are the charges on each quark? (2 marks)

$+\frac{2}{3}, +\frac{2}{3}, -\frac{1}{3}$ Right/Wrong.

(b) Explain your answer. (1 mark)

charge on a proton is +1 ∴ sum must equal +1.

(c) If a neutron is made up of 3 quarks, what are the charges on each quark? (2 marks)

$+\frac{2}{3}, -\frac{1}{3}, -\frac{1}{3}$ Right, wrong

(d) Explain your answer. (1 mark)

charge must be 0.

11 According to the theory of special relativity, some properties are dependent on the frame of reference in which they are observed. If an observer is observing the events listed in column 1, indicate in column 2 if the event is:
Always the same or
May sometimes be different (3 marks)

| Column 1 | Column 2 |
|---|---|
| The **distance** between two given events | sometimes different (1) |
| The **time interval** between two given events | sometimes different (1) |
| The **mass** of an electron measured at rest | same (1) |

12 American astronomer Edwin Hubble was able to calculate the speed at which galaxies were receding from their redshift. He used the formula $V_{galaxy} = \Delta\lambda/\lambda \times c$

Where: $V_{galaxy}$ is the speed of the observed galaxy (m $s^{-1}$)
$\Delta\lambda$ is the change in wavelength (m)
$\lambda$ is the normal wavelength (m)
c is the speed of light (m $s^{-1}$)

Using this redshift formula, calculate the recession speed of the NGC 4889 galaxy if the wavelength of a spectral line of ionised calcium measured in the laboratory is 393.3 nm but has a wavelength of 401.8 nm when observed in light from the galaxy. (3 marks)

$\Delta\lambda = 401.8 - 393.3$
$= 8.5 \times 10^{-9}$ m (1)

$V = \frac{\Delta\lambda}{\lambda} \times c$
$= \frac{8.5 \times 10^{-9}}{393.3 \times 10^{-9}} \times 3 \times 10^{8}$
$V = 6.49 \times 10^{6}$ m$s^{-1}$. (2)

13 Aircraft flying through the Earth's magnetic field are subject to an induced EMF across the wings.

(a) At which places on Earth will the aircraft experience the maximum induced EMF? (1 mark)

NORTH & SOUTH POLES.

(b) If the maximum magnitude of the Earth's magnetic field is 5.00 x $10^{-5}$ T, calculate the magnitude of the EMF that would be induced across the wings of a Boeing 747 flying at its maximum speed. A Boeing 747 wing span is about 60 m and its maximum speed is about 900 km $h^{-1}$. (2 marks)

$V = 900$ km$h^{-1}$
$= 250$ m$s^{-1}$

$\mathcal{E} = Bvl$ (1)
$= 5.0 \times 10^{-5} \times 250 \times 60$
$= 7.5 \times 10^{-1}$ V (1)

(c) Would it be realistic for the induced EMF produced in this way to be used to power appliances on board the aircraft? Justify your answer. (2 marks)

NO. 1
1. V too low 1
2. Second conductor required ?

14 A synchrotron produces hard X-rays that travel along a beam line and impact on a sample of crystalline material. ESTIMATE the energy of these hard X-rays in keV. (3 marks)

$f \sim 10^{20}$ Hz 1

$E_p = hf$ 1
$= 6.63\times10^{-34} \times 10^{20}$
$= 6.63\times10^{-14}$ J.
$= 4.14\times10^{5}$ eV
$= 4.14\times10^{2}$ keV. 1

$-\frac{1}{2}$ not in keV

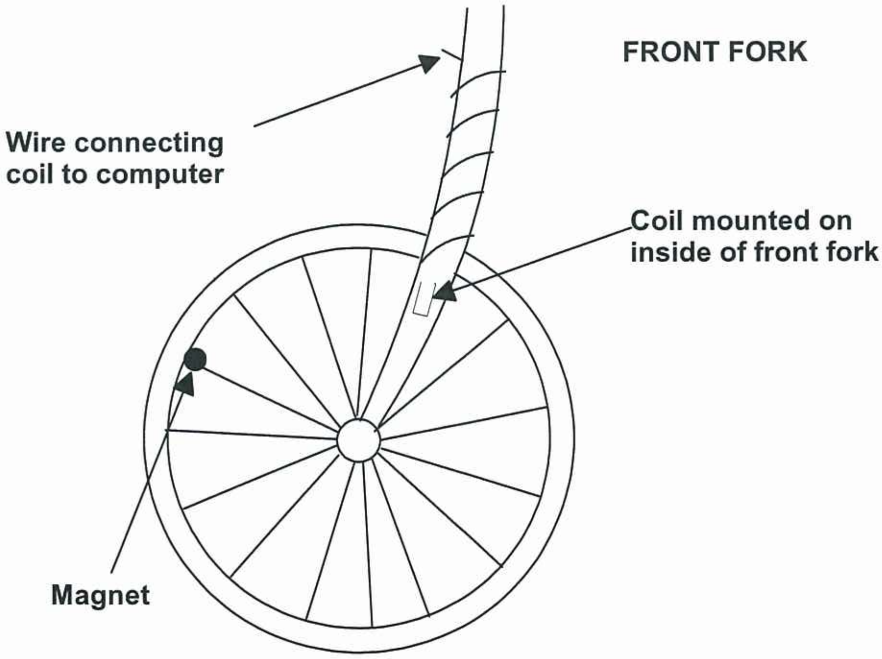
15 Global positioning systems (GPS) are used to measure distances on Earth. To provide accurate and reliable information, clocks on GPS satellites must be accurate to within 20 to 30 nanoseconds per day. ***General Relativity*** theories indicate that clocks on GPS satellites will run faster than clocks on the Earth (because of gravitational effects) by about 446 picoseconds per second. If this error were not taken into account, calculate the distance error per second the GPS radio signal would produce?

(3 marks)

$t = 446\times10^{-12}$ s $\frac{1}{2}$
$c = 3\times10^{8}$ ms$^{-1}$

$V = \frac{s}{t}$ $\frac{1}{2}$
$s = vt$
$= 3\times10^{8} \times 446\times10^{-12}$
$= 1.34\times10^{-1}$ m.
$= 13.4$ cm. 2

16 Small computers mounted on bicycles measure the speed and distance a rider has achieved on a ride. A permanent magnet is attached to a spoke in the front wheel and a coil is mounted on the front fork of the bicycle. A wire connects the coil to a small computer on the handlebars which provides a read out of the bicycle's speed and distance. When the computer is first used the rider programs into it the circumference of the wheel. The diagram below shows the arrangement.




(a) Briefly describe in terms of electromagnetic induction how the bicycle's speed is measured. (4 marks)

Magnet on spoke passes coil & induces a pulse
Time difference between pulses, given radius is known
will produce velocity of bike.

1 1 1 1

(b) Is it necessary to mount the magnet on the circumference of the wheel, as shown in the diagram, for the system to function properly?
Explain your answer. (2 marks)

No. Any radius is suitable.

1 1

## Section B: Extended Answers

### Marks allocated: 90 marks out of a total of 200 (45%)

This section has seven questions. Attempt all questions.

(12 marks)

1 A satellite provides information about the receding glaciers on the Earth's surface. It has a mass of 395 kg and is in a circular orbit of radius 1.45 x 10[4] km. By orbiting for 12 days it can map most of the Earth's glaciers.

(a) Calculate the orbital speed of the satellite. (3 marks)

$F_c = F_g$

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

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

$= \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{1.45 \times 10^{7}}$ 1

$v = 5.25 \times 10^{3}\ m s^{-1}$ 1

(b) At what **altitude** above the Earth is the satellite orbiting? (3 marks)

ALTITUDE $= r_o - r_e$ 1

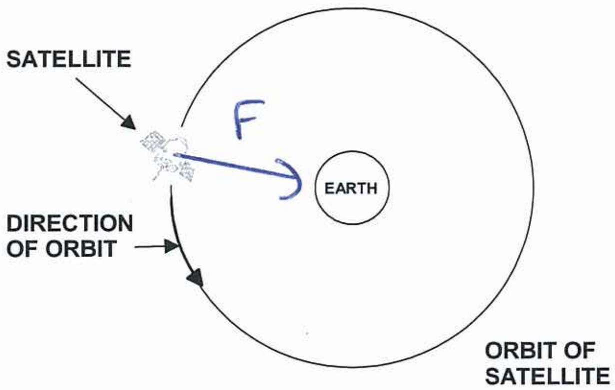
$= 1.45 \times 10^{7} - 6.37 \times 10^{6}$ 1

$= 8.13 \times 10^{6}$ m. 1

(c) List the force(s) that keep the satellite in its stable circular orbit. (2 marks)

gravitational force. R/W

(d) On the diagram below draw one or more **labelled** arrows to show the direction of the force(s) on the satellite as it orbits the Earth. (2 marks)

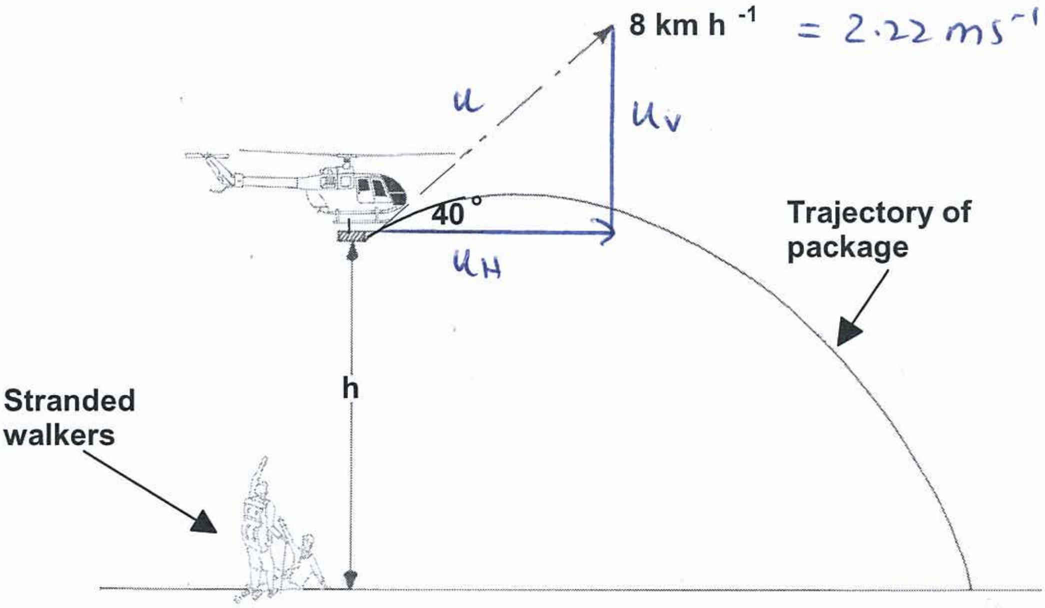



(e) Would you expect this satellite to be in a geostationary orbit about the Earth? Explain your answer. (2 marks)

NO. 1 Geostationary satellites must remain above the same point on the Earth's surface. 1

(12 marks)

2 A helicopter is required to drop emergency equipment to a group of walkers stranded in rugged bushland. A package is released from the helicopter at altitude (h) directly above the group. The helicopter is moving with a velocity of 8 km h$^{-1}$ at an angle of 40$^\circ$ above the horizontal when the package is released. The package lands on the ground 2.5 s after being released.




(a) Calculate the value of h. (4 marks)

$u_H = u\cos 40$
$= 1.70\ ms^{-1}$ (1)

$u_v = u\sin 40^\circ$
$= 1.43\ ms^{-1}$. (1)

$u_v = -1.43\ ms^{-1}$
$s = h$
$t = 2.5\ s$
$g = +9.8\ ms^{-2}$

$s = ut + \frac{1}{2}gt^2$ ↓+
$= -1.43 \times 2.5 + \frac{1}{2} \times 9.8 \times 2.5^2$
$h = 27.1\ m$. (2)

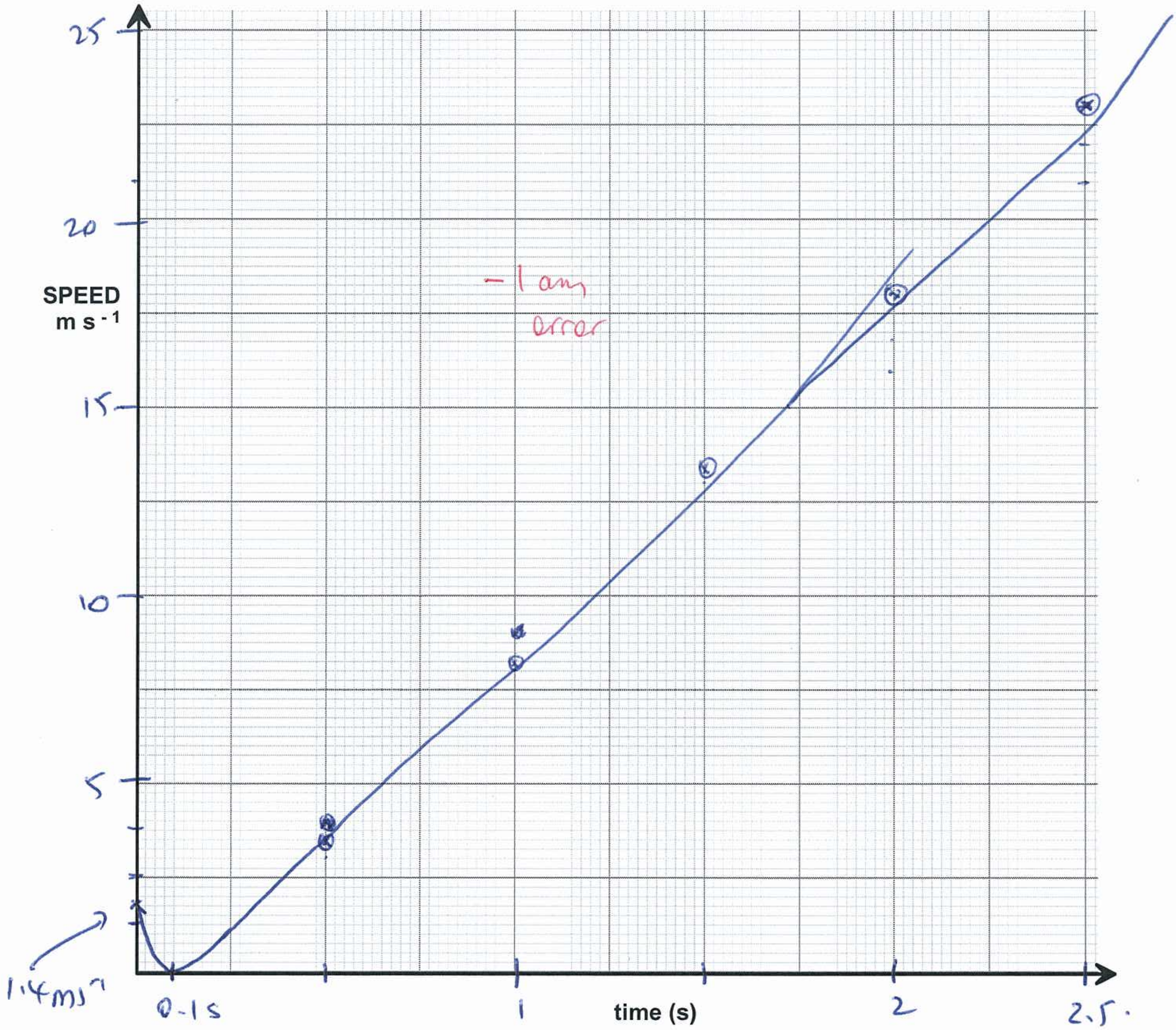
(b) If the helicopter continues to fly with its initial velocity, calculate the distance between the helicopter and the package at the instant the package hits the ground. (4 marks)

Package lands directly below helicopter (27.1 m) (1)
But helicopter has been climbing in that time (2.5 s). (1)
∴ in 2.5 s it has climbed –

$v = \frac{s}{t}$
$s = vt$
$= 1.43 \times 2.5$
$= 3.58\ m$ (1)

∴ dist $= 27.1 + 3.58$
$= 30.7\ m$. (1)

(c) On the axes below draw a graph that best represents the vertical speed of the package as a function of time. Include actual values on the axes. Show calculations that determine significant points on the graph. (2 marks)




$V(\text{at } 2.5s) = u + at$

$= -1.4 + 9.8 \times 2.5$

$= \underline{23.1}\ ms^{-1}$ (down).

$V(\text{at } 1.5s) = u + at$

$= -1.4 + 9.8 \times 1.5$

$= \underline{13.3\ ms^{-1}}$

$V(\text{at } 2.0s) = u + at$

$= -1.4 \times 9.8 \times 2$

$= \underline{18.2m}$ (down)

$V(\text{at } 1.0) = u + at$

$= \underline{8.4\ ms^{-1}}$

$V(\text{at } 0.5) = -1.4 + 9.8 \times 0.5$

$= \underline{3.5\ ms^{-1}}$

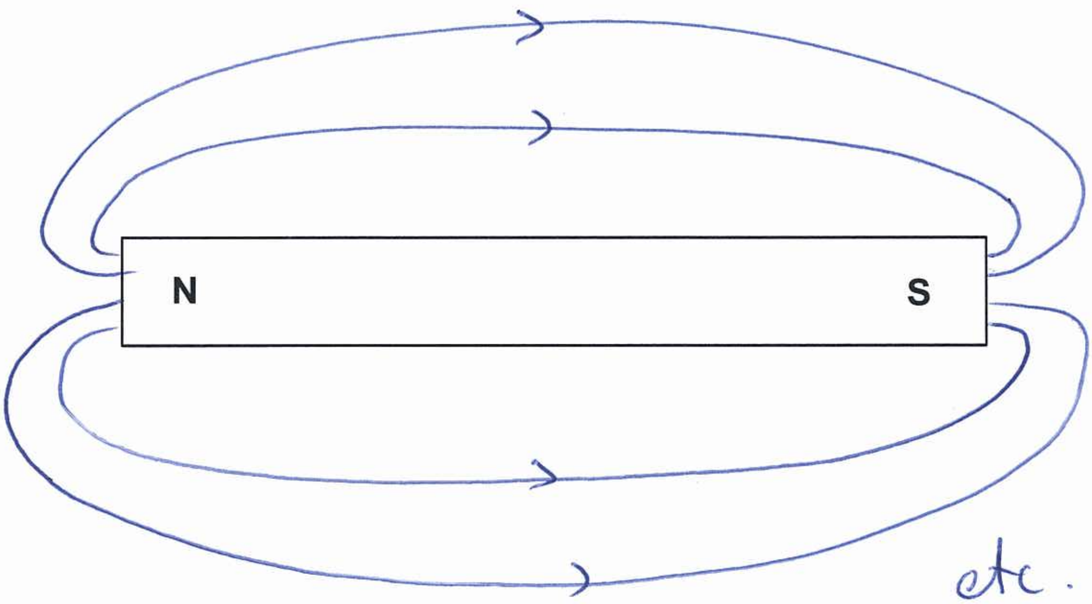
(d) If the helicopter was travelling **horizontally** at the same speed (8 km $h^{-1}$) and height (h) when it released the package, would you expect the package to land closer or further away from the group? Explain your answer. (2 marks)

FURTHER. (1) $V_H$ is greater & hence will travel further horizontally in 2.5 s. (1)

(14 marks)

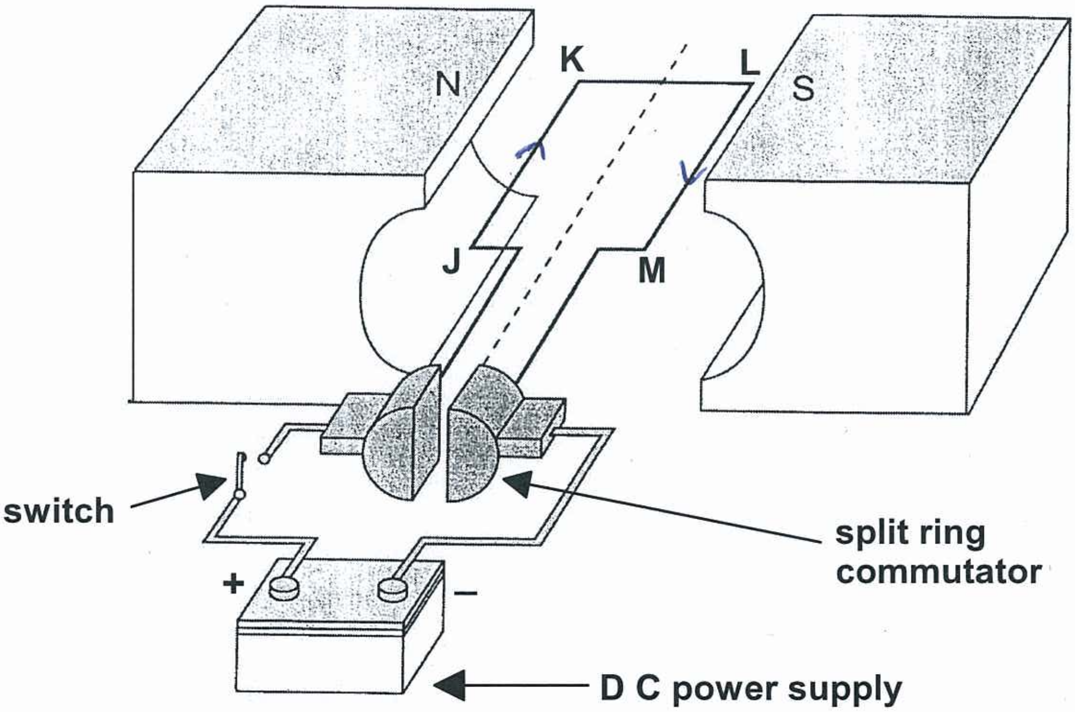
3 (a) The figure below shows a bar magnet. Draw eight (8) separate magnetic field lines around the magnet to represent the field produced by the magnet. (2 marks)

(1) shape
(1) direction




etc.

The figure below represents a DC motor whose coil is initially stationary.



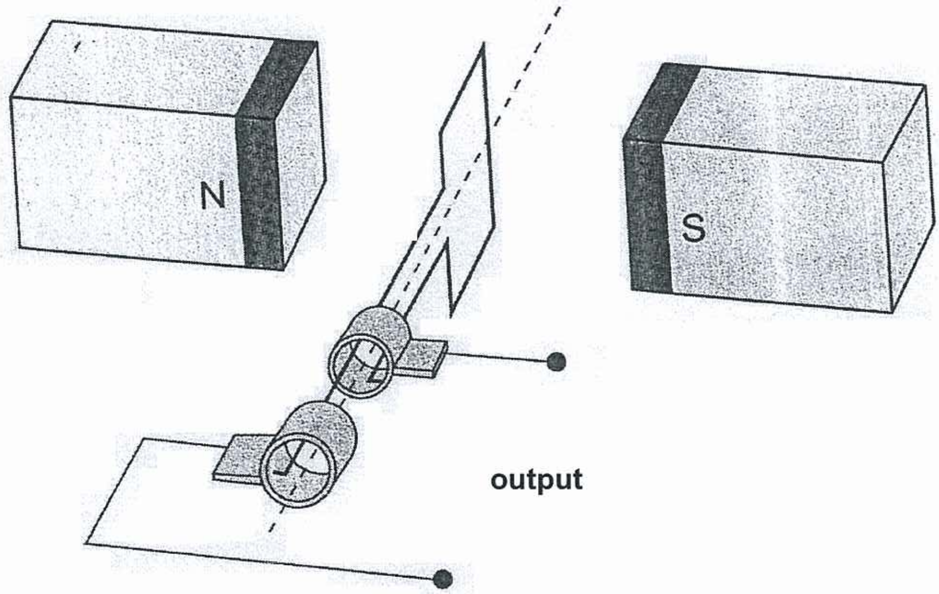

(b) In which direction, clockwise or anticlockwise will the motor rotate when the switch is closed? (1 mark)

ANTICLOCKWISE. 1

(c) Explain your answer to 3(b). (2 marks)

Using RH rule JK moves down, LM up 1
hence causing rotation in an anticlockwise direction. 1

The figure below represents an alternator consisting of a rectangular coil with sides of 0.15 m x 0.20 m and 1200 turns, rotating in a magnetic uniform field. The magnetic flux through the coil in the position shown is 2.5 x $10^{-4}$ Wb.




(d) Calculate the magnitude of the magnetic field strength. (3 marks)

$A = 0.15 \times 0.2$
$= 3.0 \times 10^{-2} m^2$ (1)

$B = \frac{\phi}{A} = \frac{2.5 \times 10^{-4}}{3 \times 10^{-2}}$ (1)
$= \underline{8.33 \times 10^{-3} T}$ (1)

(e) If the coil rotates half a revolution from its starting position in 0.03 s, calculate the magnitude of the average induced emf in the coil in this time. (3 marks)

$\therefore t_{1/4} = \frac{0.03}{2}$
$= 1.5 \times 10^{-2} s$ (1)

$\mathcal{E} = -N \frac{\Delta \phi}{\Delta t}$ (1)
$= -1200 \times \frac{2.5 \times 10^{-4}}{1.5 \times 10^{-2}}$
$= 20.0 V$ (1)

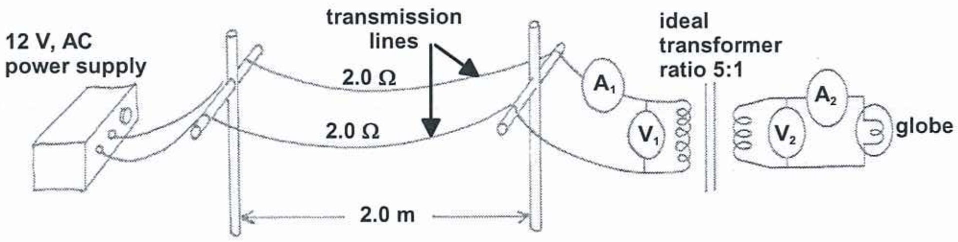
(f) How could you modify the alternator to increase the magnitude of the emf? (3 marks)

↑ # coils
↑ B
↑ V
↑ AREA.

3 x 1each

(15 marks)

4 A teacher set up a model to demonstrate how electricity is distributed using a power supply, transmission wires, meters and a transformer. A diagram of the model is shown below. Resistance in the wires connecting the **power supply, transformer and globe** to the transmission lines can be ignored.




The transformer is ideal (100% efficient) and the ratio of primary to secondary windings is 5:1.

(a) If the current through ammeter $A_1$ is 0.5 A, calculate the following:

(i) The reading on ammeter $A_2$ (2 marks)

$\frac{V_s}{V_p} = \frac{N_s}{N_p}$ (1) $V_{IN} I_{IN} = V_{OUT} I_{OUT}$ $5 \times 0.5 = 1 \times I_{OUT}$ $I = 2.5A$ (1)

(ii) The reading on voltmeter $V_1$ (2marks)

$V_1 = V_T - IR$ (1)
$= 12 - 0.5 \times 4$
$= 10V.$ (1)

(iii) The reading on voltmeter $V_2$ (2 marks)

$V_s = \frac{N_s}{N_p} \times V_p = \frac{1}{5} \times 10$ (1)
$= 2.0V.$ (1)

(b) Calculate the power delivered at the globe? (2 marks)

$P = VI$ (1)
$= 2 \times 2.5$
$= 5.0 W.$ (1)

(c) If the AC power supply is replaced by a 12V battery, what will be observed at the globe? (1 mark)

WILL NOT FUNCTION.

(d) Explain your answer to (4c) in terms of the operation of the transformer. (2 marks)

Transformer requires AC (1) to provide a $\Delta B$ in order to function. (1)

(e) If the resistance in the transmission wires was INCREASED then how would the power produced by the globe be affected? Explain your answer. (2 marks)

Increased Resistance so more energy would be lost in transmission. Therefore rate of energy delivered to globe would be reduced. 1 1

(f) In the real world electric power is distributed over large distances at high voltages. Explain why. (2 marks)

In order to reduce power loss. 1

1/2 Given $P_{loss} = I^2R$, then I must be reduced where possible. Hence, given $P = VI$ if $I\downarrow$ then $V\uparrow$ in order to maintain the same power. 1/2

(14 marks)

5 The emission spectra from excited hydrogen gas contain three distinct lines of wavelength 431.1 nm, 486.1 nm and 656.3 nm respectively.

(a) Perform as many calculations as necessary to demonstrate that the radiation with the shortest wavelength of those detected, has the largest energy. (2 marks)

As $E \propto \frac{1}{\lambda}$

highest energy = lowest $\lambda$

= 431.1nm 1

$E_p = hf = \frac{hc}{\lambda}$

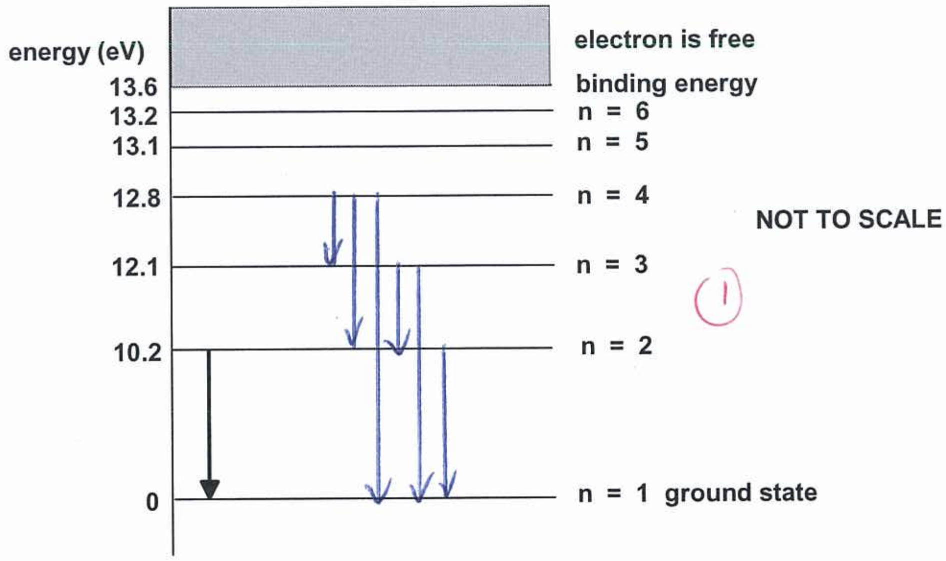
$= 6.63\times10^{-34} \times \frac{3\times10^8}{431.1\times10^{-9}}$

$= 4.61\times10^{-19}$ J. 1

(b) In which region of the electromagnetic spectrum do the three spectral lines appear? (1 mark)

VISIBLE.

The diagram below is an energy level diagram for the hydrogen atom. Use the diagram to answer questions (c) and (d) below.




(c) Calculate the amount of energy, in joules required to ionise an electron from the ground state. (3 marks)

$E = 13.6\,eV$ (1) $= 13.6 \times 1.6 \times 10^{-19}$

$= 2.18 \times 10^{-18}\,J$. (2)

$\therefore E > 2.18 \times 10^{-18}\,J$.

(d) How many different photons may result from the hydrogen atom when a GROUND STATE electron/s makes a transition to n = 4. (one transition is already shown).

(3 marks)

6. (2)

The emission spectrum of light from the sun is continuous with colours ranging from red to violet. Some black lines can be seen amongst the coloured spectrum.

(e) What is the name given to this type of spectrum? (1 mark)

Line absorption spectrum. (1)

(f) Explain why these dark lines are present in the spectrum from the sun.

(2 marks)

white light leaves Suns core & travels through solar atmosphere causing some photons to be absorbed by gases & hence removed from spectrum transmitted. 1

1

(g) Would you expect to see similar black lines on a continuous emission spectrum produced by light from an incandescent globe? Explain your answer.

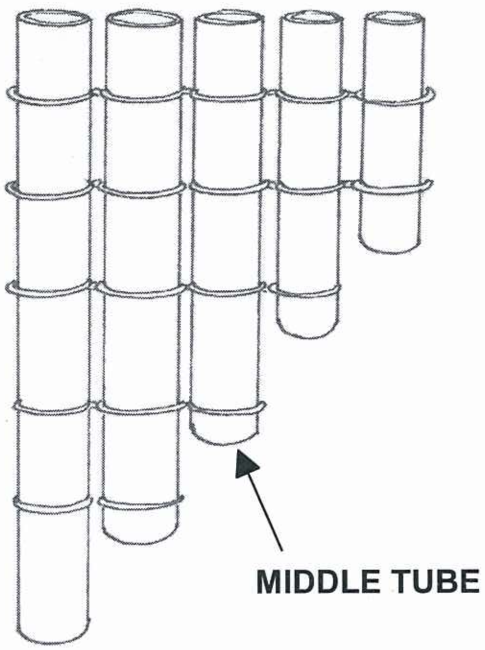
(2 marks)

NO. 1 No atmosphere (gases) present to absorb photons. 1

(14 marks)

5 A crude musical instrument can be made by tying several lengths of hollow metal tube together as shown in the diagram below. When a performer gently blows across the tops of the tubes, musical notes are produced.

For all parts of this question assume the performer blows with the same strength.



(a) If all the tubes are of equal diameter, which tube would you expect to produce the note with the highest fundamental frequency? Explain your answer.

(2 marks)

Shortest tube. 1

Shorter $\lambda$ to fit tube to cause standing wave

$\therefore$ highest f. 1

(b) If the fundamental resonant frequency of the middle tube is 440 Hz and the speed of sound in the tube is 346 m s$^{-1}$, calculate the length of the tube.

(2 marks)

$V = 346 ms^{-1}$

$f = 440 Hz$

$\lambda = ?$

$V = \lambda f$

$\lambda = \frac{V}{f}$

$= 0.786 m$ 1

$\therefore l = \frac{\lambda}{2} = 39.3 cm$

$= 0.393 m$. 1

(c) If the performer blocked the bottom end of the middle tube would you expect it to produce the same fundamental note as the open tube? Explain your answer.

(3 marks)

NO. 1 By blocking the tube it is now a closed pipe 1 & will resonate ($f_f$) at $\frac{\lambda}{4}$ not $\frac{\lambda}{2}$ 1

(d) Determine the fundamental frequency of the note produced by the middle tube when it is closed at one end.

(2 marks)

$l = 0.393 m$

$l = \frac{\lambda}{4}$

$\lambda = 4l$

$= 4 \times 0.393$

$= 1.57 m$ 1

$\therefore V = \lambda f$

$f = \frac{V}{\lambda} = \frac{346}{1.57}$

$= 220 Hz$ 1

(e) If the diameter of all the tubes was increased, but the lengths remained the same, how would this affect the characteristics of the notes played?

(2 marks)

f - same

Intensity is lower

Duration of sound is lower

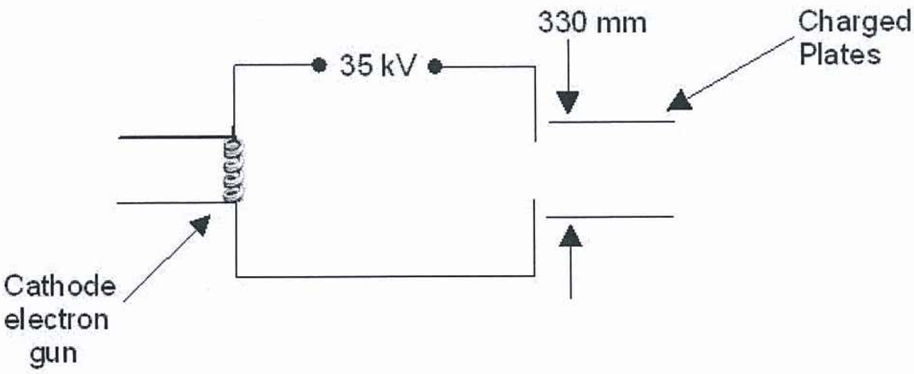
any two

(f) The instrument relies upon standing waves being set up in the tubes. State the conditions that need to exist for standing waves to be produced in an air column.

(3 marks)

2 waves 1 travelling in opposite direction 1 interfering such as to produce fixed points of 1 nodes & antinodes.

(9 marks)
7 An apparatus used for identifying minerals in mining samples involves releasing electrons from a cathode electron gun and accelerating them across a potential difference and through a pair of parallel charged plates and then impacting with the sample. The electrons are accelerated through a potential of 35 kV, and through a distance of 330 mm between the charged plates.




(a) Calculate the strength of the electric field between the charged plates. (3 marks)

$E = \frac{V}{d} = \frac{35\times10^{3}}{330\times10^{-3}}$ ①

$= 1.06\times10^{5}\ Vm^{-1}$ ②

(b) Calculate the magnitude of the velocity of the electrons as they exit the electron gun assembly. (3 marks)

$E_K = 35keV$

$= 35\times10^{3}\times1.6\times10^{-19}$

$= 5.6\times10^{-15}J$ ①

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

$v = \sqrt{\frac{2E_K}{m}}$

$V = \sqrt{\left(\frac{2\times5.6\times10^{-15}}{9.11\times10^{-31}}\right)}$

$V = 1.11\times10^{8}ms^{-1}$ ②

(c) After leaving the electron gun assembly, the electrons travel through a uniform magnetic field which is perpendicular to their direction of motion. If the magnetic field strength is 0.300T, through what radius will the electrons be deviated? (3 marks)

$V = 1.11\times10^{8}ms^{-1}$

$B = 0.3T$

$m = 9.11\times10^{-31}kg$

$q = 1.6\times10^{-19}C$

$r = \frac{mv}{qB}$ ① $= \frac{9.11\times10^{-31}\times1.11\times10^{8}}{1.6\times10^{-19}\times0.3}$

$= 2.1\times10^{-3}m$ ②

$\therefore r = 2.1mm.$

***Section C: Comprehension and Data Analysis***
***Marks allocated: 40 marks out of a total of 200 (20%)***

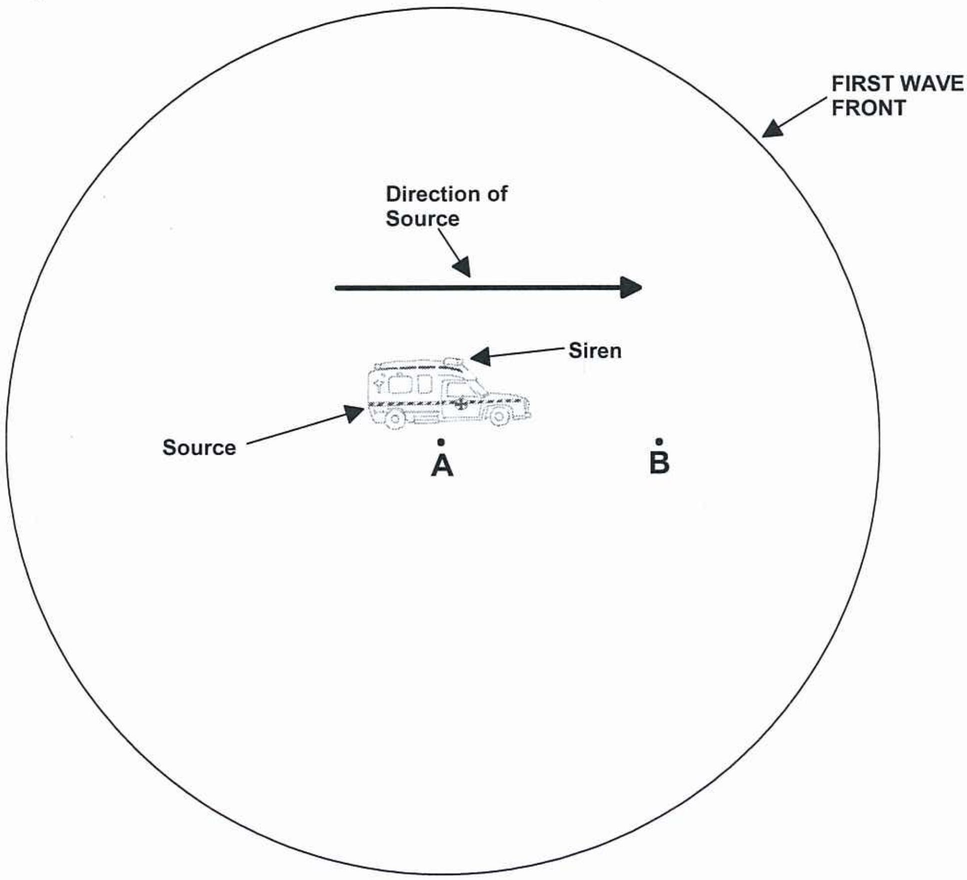
***This section contains two questions. Attempt both questions.***
***Write your answers to both questions in the spaces provided.***

## Question 1 The Doppler Effect

Para 1
When a source of waves, whether light, sound or any other, is moving towards an observer, the wavelength detected by the observer will appear to be different to the actual wavelength emitted by the source. This is because each wave is emitted a little closer to the observer than the previous one and is not so far behind the previous wave as it would be if the source was stationary. The reverse is the case if the source is moving away from the observer.

Para 2
In the particular case of sound waves, a stationary observer hears a change in the pitch of a sound that is being emitted by a moving source. For instance if a speeding ambulance emitted a high pitched sound, then as it approached the observer he would hear a variation in pitch. As the ambulance passed and sped away the observer would also hear a change in pitch.

Para 3
The diagram below shows a source of sound moving to the right with a speed of **u.** The outer circle represents a sound wave front, which was emitted when the source was at position A. The period of this wave front is **T**, the velocity is **v** and wavelength is $\lambda$.



Para 4
When the source has moved to position B, a second wave front is emitted. This now means that the distance between the wave fronts in the forward direction and those in the reverse direction are different. These distances are the wavelengths as perceived by observers to the front and rear, respectively.

Para 5
When light waves are emitted by moving sources such as galaxies, astronomers are interested in the apparent change in wavelength $\Delta\lambda$. The wavelength change is known as redshift or blueshift depending on whether the source is moving away from or towards the observer.
Questions

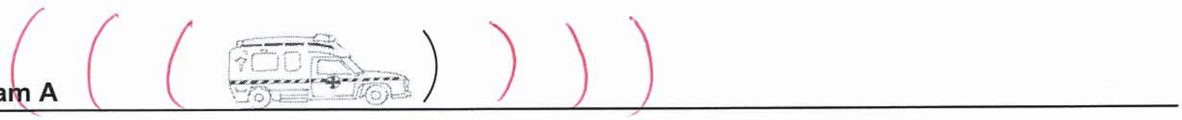
(a) Upon what property of sound waves does pitch depend? [1 mark]

frequency.

(b) In the diagrams below, the ambulance's siren is emitting a **constant** frequency. Complete the diagrams by drawing wave fronts to the front and rear of the ambulance. Note that in diagram A, the ambulance is stationary and in diagram B it is travelling to the right at high speed.

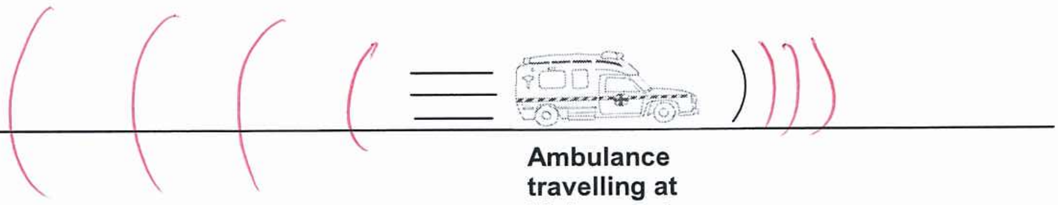
[4 marks]

**Diagram A**



**Ambulance stationary**

**Diagram B**



**Ambulance travelling at high speed**

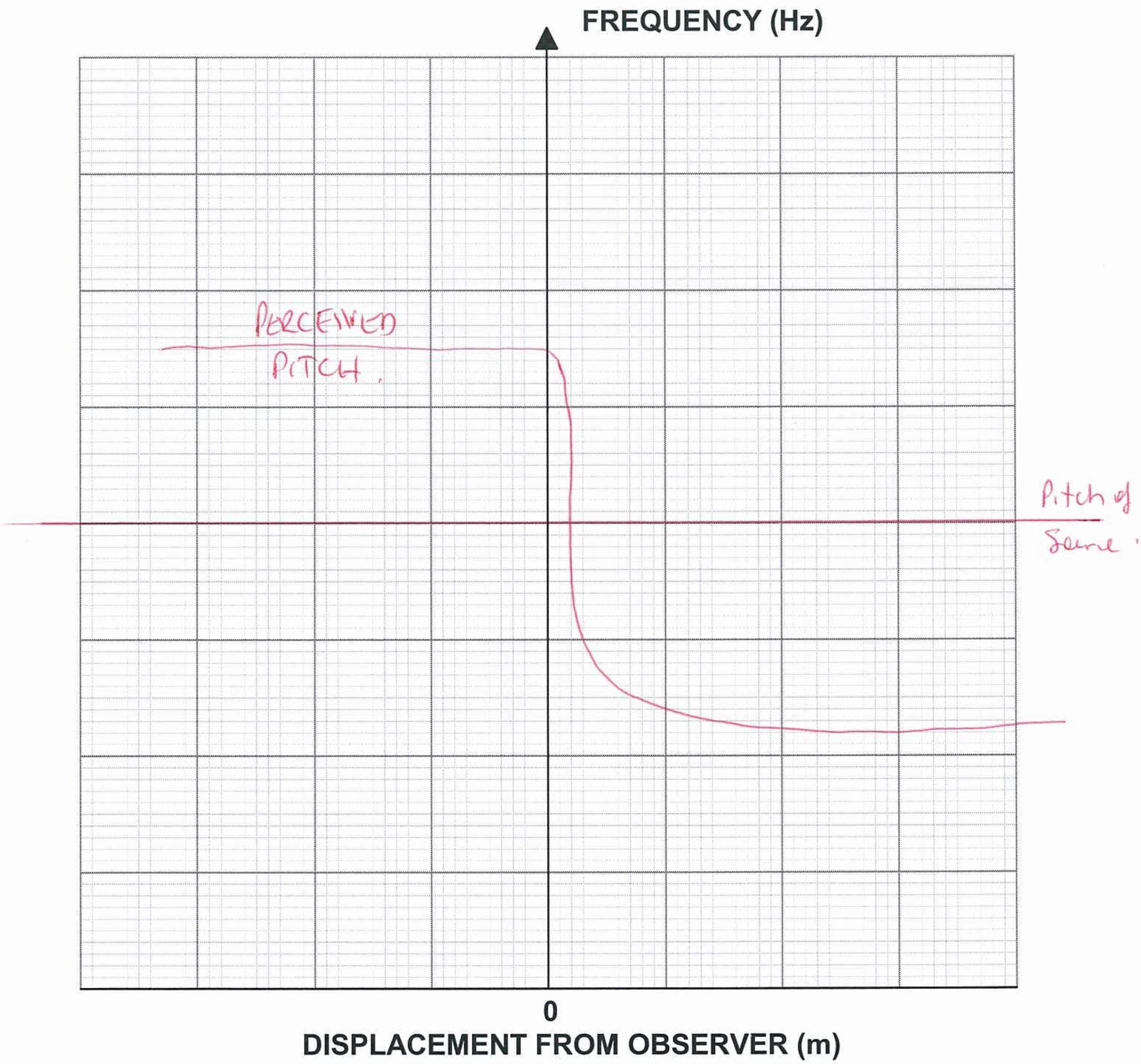
(c) Does the actual pitch of a sound emitted by the ambulance, change as it approaches and passes an observer? Explain your answer.

[2 marks]

Actual pitch remains constant. 1
Higher or lower pitch heard by observer is a function of the source moving not the source itself. 1

(d) A stationary observer hears the siren of an emergency vehicle as it approaches, passes and travels onwards. The siren is emitting a sound of constant pitch of 330 Hz. On the grid below, sketch a graph to show the variation in frequency as experienced by the observer as the vehicle approaches, passes and travels onwards.

(3 marks)



(e) Write a mathematical formula which includes **λ, T** and **v** that could be used to calculate the wavelength of the wave front described in paragraph 3. [1 mark]

$V = \lambda f$ $\quad V = \lambda \times \frac{1}{T}$

$f = \frac{1}{T}$ $\quad V = \frac{\lambda}{T}$ $\quad \lambda = VT$. 1

(f) In terms of **u** and **T** how far has the source moved between emitting the first and second wave fronts? [1 mark]

distance = ut 1

(g) Write a mathematical expression involving **v**, **u** and **T** that represent the following:

(i) The distance between wave fronts in the forward direction. [1 mark]

$VT - uT$ 1

(ii) The distance between wave fronts in the backward direction. [1 mark]

$VT + uT$. 1

(h) (para 5) What is the meaning of the term "redshift"? [2 marks]

Redshift is used to identify the movement of galaxies 1
by measuring the Δ λ of light between actual λ and observed λ
If body moves away from Earth then λ ↑ & is red shifted.
1

(i) (para 5) What is the meaning of the term "blueshift"? 1 [2 marks]

Blue shift is used to identify the movement of galaxies
by measuring the Δ λ of light between actual λ & observed λ
If body moves towards the Earth, then λ ↓ & is blueshifted.
1

(j) If an observer travelled at speed towards a stationary siren that was emitting a single frequency, would he experience the Doppler Effect? Explain your answer. [2 marks]

Yes. As he travels towards the source
1 the λ would be experienced in shorter 1
intervals hence pitch would increase.

Question 2 (20 marks) **The Australian Synchrotron**

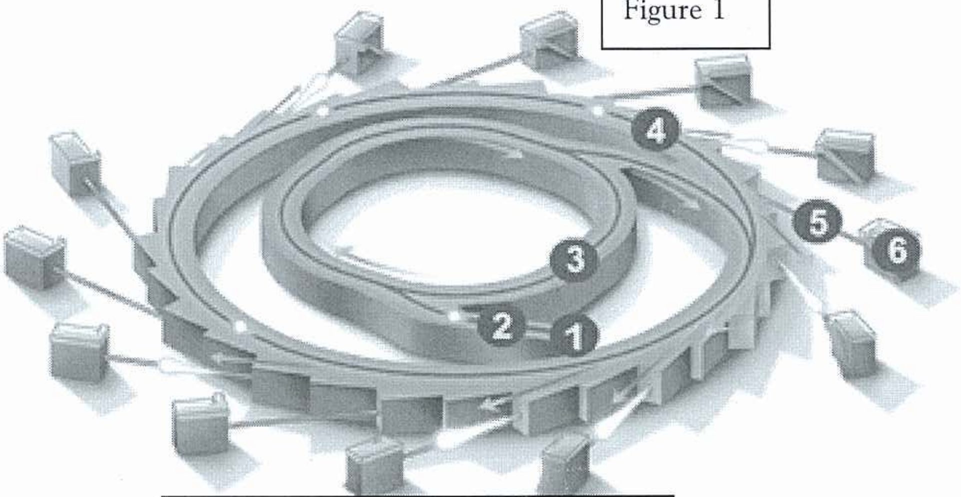



Figure 1

1. electron gun
2. linac
3. booster ring
4. storage ring
5. beamline
6. end station

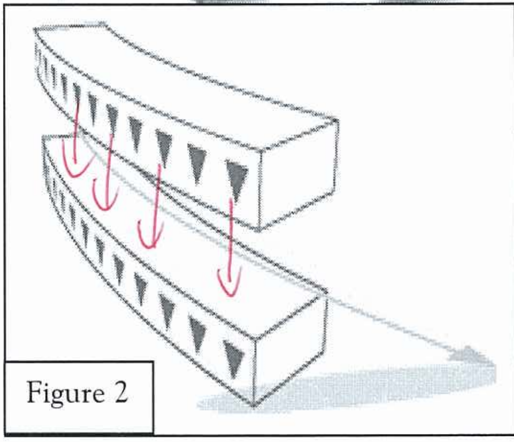


Figure 2

*Illustration of a bending magnet. At each deflection of the electron path a beam of light is produced. The effect is similar to the sweeping of a search light.*

Synchrotron light is the electromagnetic radiation emitted when electrons, moving at velocities close to the speed of light, are forced to change direction under the action of a magnetic field. The electromagnetic radiation is emitted in a narrow cone in the forward direction, at a tangent to the electron's orbit.

Synchrotron light is unique in its intensity and brilliance and it can be generated across the range of the electromagnetic spectrum: from infrared to x-rays.

How is synchrotron light created?

Beamline specifications:
Source: 1.9 tesla wiggler magnet
Available energy range 4->50 keV in 16 m diameter storage ring
Beam size at sample (horizontal x vertical) is 0.5 mm (h) x 0.2 mm (v)
Photon flux at sample > $5 \times 10^{12}$ photons / second

**Features**

- phase-contrast and analyser based x-ray imaging, which allows much greater contrast from weakly absorbing materials such as soft tissue than is possible using conventional methods
- two and three-dimensional imaging at high resolution
- lower tissue doses than conventional x-ray methods, making longitudinal studies (serial imaging) possible
- tuneable beam energy, which enables the imaging of specific elements with very high sensitivity

**Examples**

- Studies of lung function and development are assisting the development of better asthma treatments and improved clinical practice options for neonatal care
- Measurements of bone density and porosity, enhanced mammography techniques, and studies of nerve cell regrowth to assist the development of biopolymers to treat spinal injuries
- The contrast mechanisms used to visualise soft tissues can also be used to study structures inside plants, and are of particular interest for investigating drought- and salt-tolerant plants to develop more efficient crops for Australian conditions

The observation that normal tissue has remarkable resistance to cell death when irradiated with very thin X-ray beams has led to the development of microbeam radiation therapy (MRT). Dr Peter Rogers and colleagues from the Monash Medical Centre and Monash Centre for Synchrotron Science have found that normal tissue tolerates doses up to100 times greater than those permitted in treatments using conventional methods, and that entire tumours are destroyed when only 10 per cent of their volume has been irradiated. These beams can be captured and focussed to a specific wavelength appropriate for a particular technique.

<u>Questions.</u>

a) Draw in the direction of the magnetic field lines in Figure (2) above.

[2 marks]

b) Assuming that the electrons are accelerated to close to the speed of light, show that this would take them about 1.4 million times around outer storage ring in one second. However, in the *frame of reference* of an electron in the ring, it would appear that they had travelled round many more times than this is the same time. Explain this in terms of Einstein's Special Theory of relativity.

$t = 1$ second

$r = 8m$

$\therefore C = 2\pi r$
$= 50.3m$ 1

$\therefore$ in one second (assuming c)

$V = c = \frac{s}{t}$

$s = 3\times10^8 m$ 1

$\therefore$ #cycles $= \sim 6\times10^6$ orbits 1

Faster it moves, the slower time passes in the moving frame of reference & hence the shorter distance appears 1

[3 marks]

c) Why is synchrotron radiation preferable to normal x- or γ-ray therapy in the treatment of cancers?

Better contrast in internal images (1)

Thinner beams with higher intensity without destroying healthy cells. (1)

[2 marks]

d) One of the features of synchrotron radiation is that the location of specific elements can be accurately located within the body. Give an example where this ability could be valuable for use in Forensic Science.

eg Poisoning - toxic elements can be shown to be present in the body.

(2)

[2 marks]

e) By equating the 50 keV electrical energy given by the Linac with the kinetic energy, calculate a value for the velocity of the electrons emerging from it and hence the centripetal force acting on them.

$E_K = 50\text{ keV} = (50 \times 10^3 \times 1.6 \times 10^{-19})\text{ J} = \underline{8.0 \times 10^{-15}}\text{ J}$. (1)

$E_K = 8 \times 10^{-15} = \frac{1}{2}mv^2$

$v^2 = \frac{2 \times 8 \times 10^{-15}}{9.11 \times 10^{-31}}$

$v = \underline{1.33 \times 10^8\text{ ms}^{-1}}$ (1)

[3 marks]

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

$= \frac{9.11 \times 10^{-31} \times (1.33 \times 10^8)^2}{8}$

$= \underline{2.00 \times 10^{-15}\text{ N}}$. (1)

f) The final energy of photons colliding with the target sample is around $4 \times 10^{-14}$ J. What would the wavelength of the emerging electromagnetic waves be?

$$E_p = hf = \frac{hc}{\lambda} \quad (1)$$

$$\lambda = \frac{hc}{E_p} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{4\times10^{-14}}$$

$$= 4.97\times10^{-12}\ \text{m}. \quad (2)$$

[3 marks]

g) From the beam size data given, calculate a value for the power absorbed per square metre when $5 \times 10^{12}$ photons strike the target per second.

Energy per second $= 5\times10^{12} \times 4\times10^{-14} = 0.2\ \text{W}$ (1)

AREA of TARGET $= 0.5\times10^{-3} \times 0.2\times10^{-3}$
$= 1\times10^{-7}\ \text{m}^2$ (1)

$\therefore$ Power (per m²) $= \dfrac{0.2\ \text{W}}{1\times10^{-7}\ \text{m}^2}$

$= 2.0\times10^{6}\ \text{W m}^{-2}$ (1)

[3 marks]

**END OF EXAMINATION**