Trinity College

Semester Two Practice Exam B

3AB PHYSICS

Name: Suggested SOLUTIONS C.A.

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.

Short Answers	Problem Solving	Comprehension and Interpretation	TOTAL	%
/70	/90	/40	/200	/100

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.

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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 min	70	35
B: Problem Solving	7	7	80 min	90	45
C: Comprehension and Interpretation	2	2	40 min	40	20
			Total	200	100

INSTRUCTIONS TO CANDIDATES

1 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.

2 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. Conversely, 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.

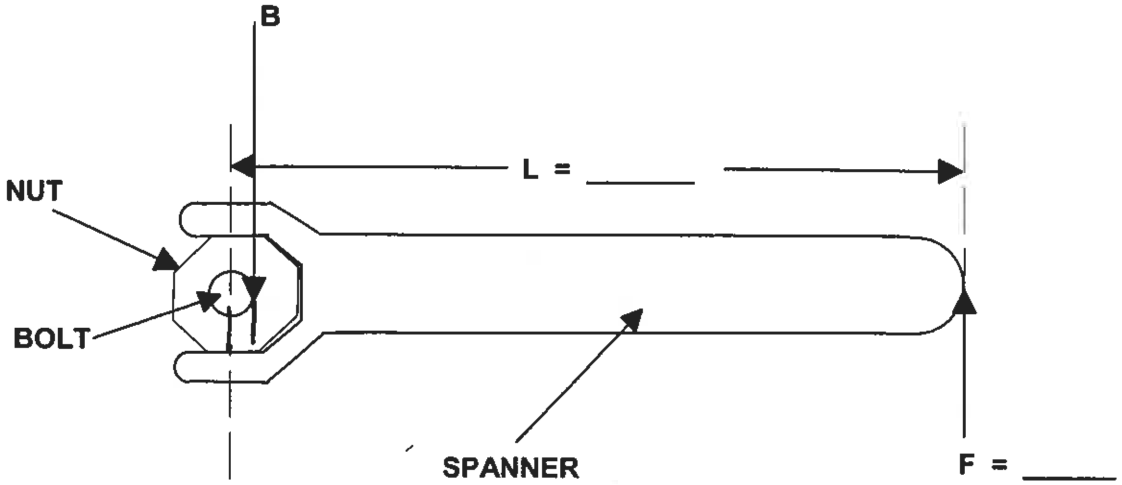
Section A: Short Answers

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, against a binding force, B which is due to rust, etc.

(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 marks)



$\tau_{ACW} = 6$ Nm. ✓1

Estimate ∴ $0.1\text{m} \leq L \leq 0.25\text{m}$ ✓1

$\tau = r.F$

∴ $60N \leq F \leq 24N$ ✓1

0.2m → 30N

0.25 → 24N.

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

B = ______________

[On diag: r_B = 4mm, L = 96mm]

$r_B \approx \frac{1}{24} L$

∴ $F_B \approx 24. F$ } ✓1m

∴ $1440N \leq B \leq 576N$ ✓1m

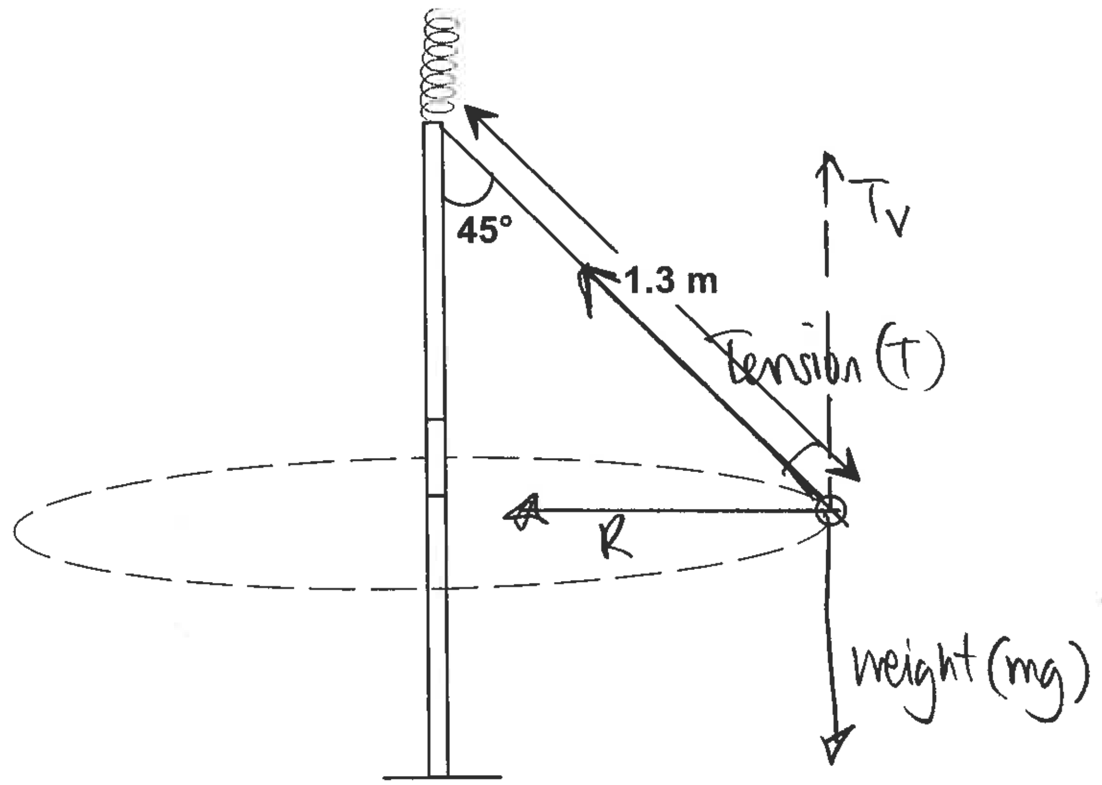
or abouts

No working ⇒ 0m

Some idea ⇒ 1m

reasonable values ⇒ 2m

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



(a) On the diagram above draw labelled vectors to show

(i) the tension force
(ii) the weight force
(iii) the total force (R)

acting on the tennis ball when it moves in the horizontal circle.. (2 marks)

(−1m each incorrect)

(b) Calculate the tension in the string (3 marks)

$T_V = mg = T\cos\theta$ ✓ 1

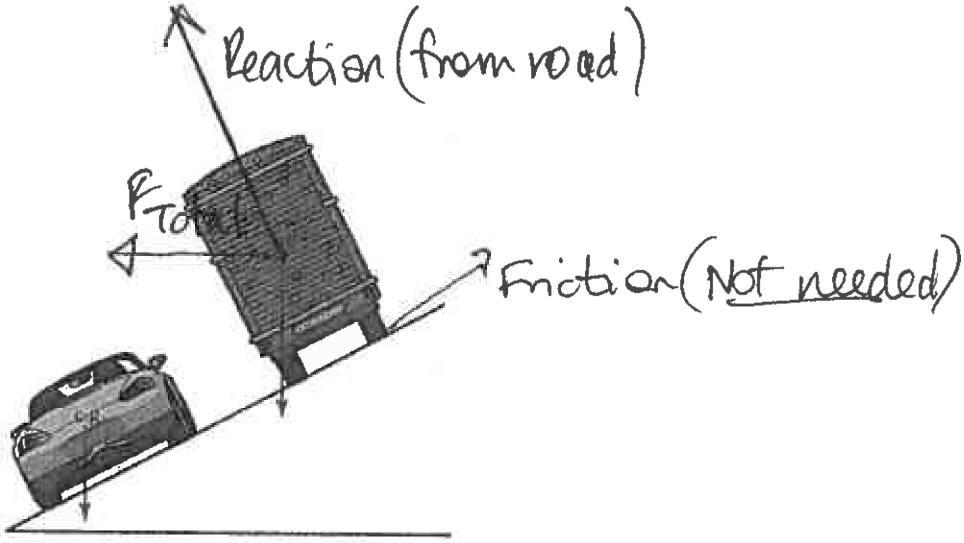
$T = mg/\cos 45$ [or sin 45° ✓]

$= \frac{0.06 . 9.8}{\cos 45}$ ✓ 1

[mg = 0.588 N]

$= 8.32 \times 10^{-1}$ N ✓ 1 (Along string)

3.



The diagram shows a car and a large truck travelling around a circular bend on a banked road. The truck is travelling at 65 kmh^{-1} and the banking angle is 28°. The banking angle is such that neither vehicle is relying on friction to negotiate the bend in the road.

(a) Use appropriate formulae to explain why the masses of the vehicles are not a consideration when choosing an appropriate banking angle. (2 marks)

- $\tan\theta = \frac{v^2}{rg}$ ✓ 1
- No mass, m in the formula, hence mass has no influence on the banking angle, θ. ✓ 1

(b) The force of gravity on the truck has already been indicated. Draw in all other forces, including the net force acting on the truck 1 each (2 marks)

(c) Find the radius of curvature of the curved road for the truck. (2 marks)

[$65\ kmh^{-1} \rightarrow 18.1\ ms^{-1}$]

$\tan 28° = \frac{(18.1)^2}{r \cdot 9.8}$ ✓ 1

$\therefore r = 6.28 \times 10^1$ m ✓ 1

4. A boy rides his skate board up a ramp with an initial speed of 7.00 m s^{-1} but slows down with a constant deceleration of 2.00 m s^{-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)

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

$\therefore s = \frac{v^2 - u^2}{2 \cdot a}$ ✓ 1

$= \frac{7^2}{2 \cdot -2} = 12.25$ m ✓ 1

OR

$s = ut + \frac{1}{2}at^2$

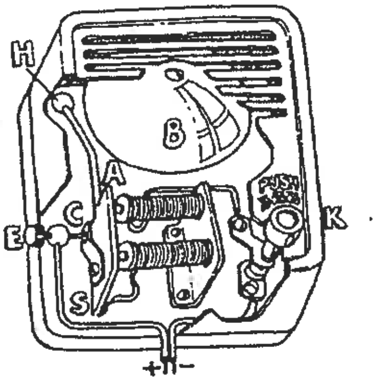
where $t = \frac{v-u}{a} = \frac{7}{2}$

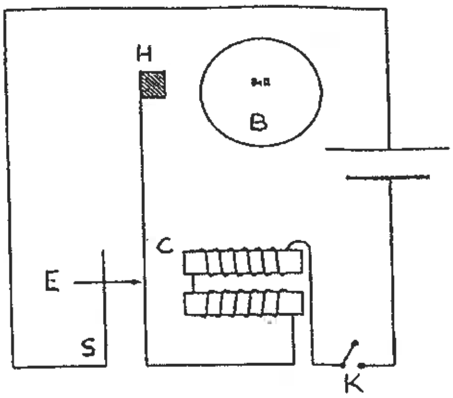
$= 3.5$ sec

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

$t = \frac{v-u}{a} = \frac{0.7}{2} = 3.5s$ | ok // $v = u + at$

5. The diagram below shows the internal structure and the circuit diagram of a doorbell.





(a) When the switch K is momentarily closed and then opened again, explain why the striker, H will hit the bell. (2 marks)

- current running through solenoid A,
- Electromagnet created.
- striker, C attracted due to mag. field/force

[NO current INDUCED in striker]

(b) As the striker moves toward the bell, the contact C is separated from the electrode E. After hitting the bell, and in the absence of an electric current, the striker springs away from the bell and returns to make contact with the electrode E.

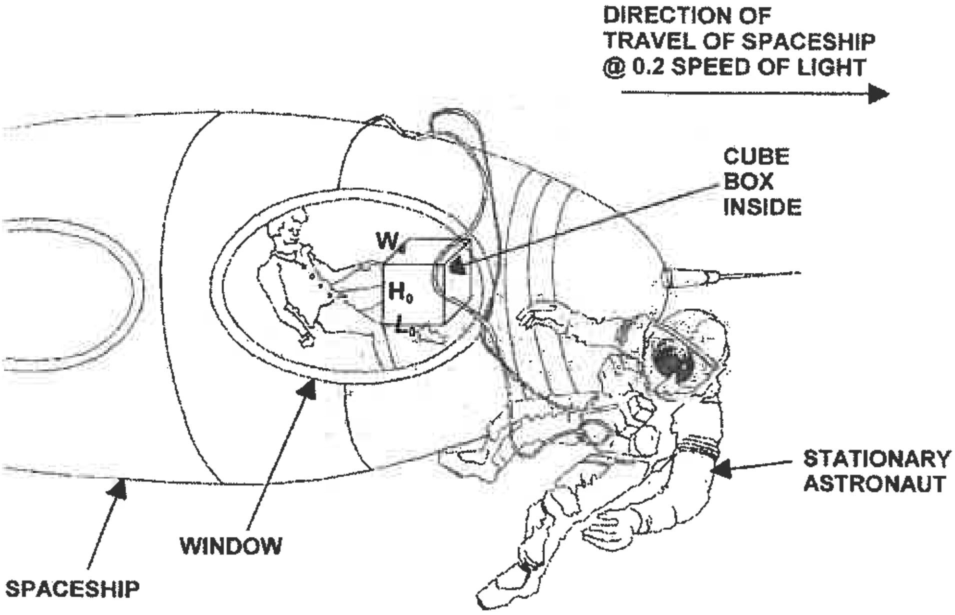
i) If the key switch remained closed, explain why the striker repeatedly hits the bell. (2 marks)

As striker moves, circuit is broken ∴ striker will spring back and make contact with electrode E.

ii) Describe two changes that could be made to the device to cause the bell to ring louder. (2 marks)

- Increase current
- № of coils in solenoid

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?

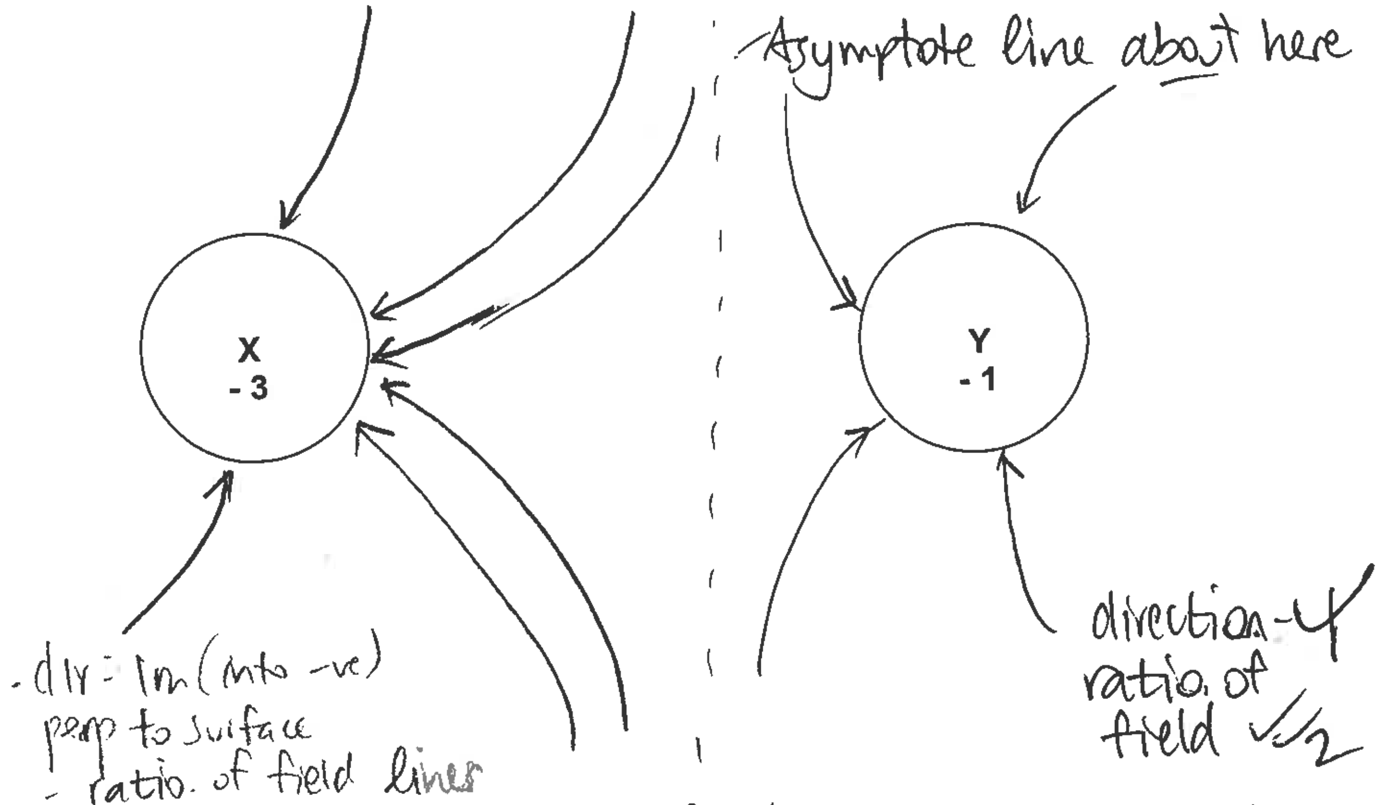
A. $L<L_o$, $W<W_o$, $H=H_o$
B. ~~$L>L_o$, $W=W_o$,~~ $H=H_o$
C. $L<L_o$, $W=W_o$, $H=H_o$
D. $L<L_o$, $W<W_o$, $H<H_o$

Answer C (1 mark)

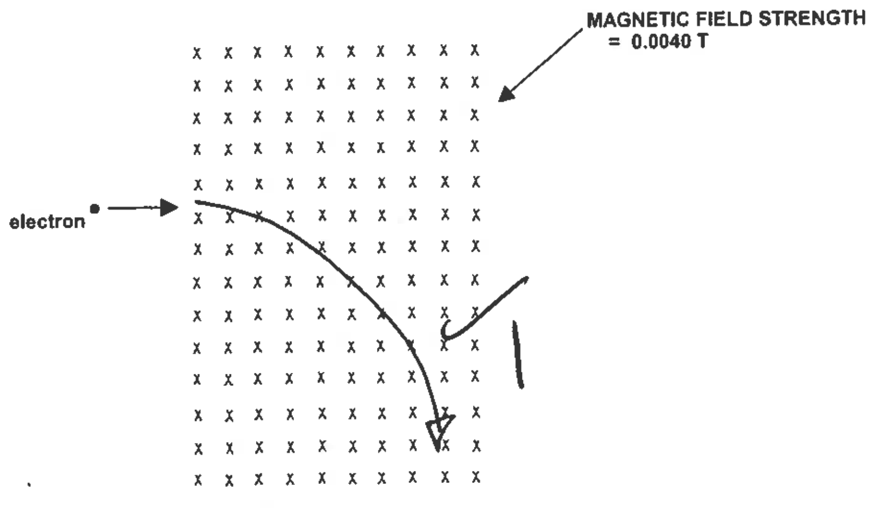
(b) Explain why you selected your answer. (3 marks)

If object travels at relativistic speeds, length in the direction of travel (as seen be a stationary observer) is shorter. other dimensions W and H remain unchanged. ✓ 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)



8. An electron travelling horizontally at 1.5×10^6 m s^{-1} enters a vertical uniform magnetic field of strength 0.0040 T.



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

$F = Bqv$ ✓ 1

$= 4 \times 10^{-3} \cdot 1.6 \times 10^{-19} \cdot 1.5 \times 10^{6}$

$= 9.6 \times 10^{-16}$ N ✓ 1

(b) On the diagram above draw a line to show the path of the electron as it travels in the magnetic field. (1 mark)

(directed downwards)

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)

$I = V/R = \frac{12}{10+20} = 0.4A$ ✓1

$P = I^2R = (0.4)^2 \cdot 30 = 4.8W$ ✓1 | OR $P = IV = 0.4 \cdot 12 = 4.8W$

(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)!

① $\frac{1}{R_T} = \frac{1}{20} + \frac{1}{10} = 3/20$ ∴ $R_T = 6.67\Omega$

② $I = V/R = \frac{12}{6.67} = 1.8A$

[if just add R's ⇒ 2m each]

③ $I_{10} = 1.2A$, $I_{20} = 0.6A$ ✓1.

④ $P = I^2R = 1.8^2 \cdot 6.67 = 21.6W$ ✓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:

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

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

(2 marks)

$+2/3, +2/3, -1/3$.

(b) Explain your answer.

(1 mark)

Charge on proton = 1 ∴ Σ quark charges = 1 !

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

(2 marks)

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

(d) Explain your answer.

(1 mark)

again: Σ quark charges = 0 (neutron)

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
The **time interval** between two given events	Sometimes different
The **mass** of an electron measured at rest	The same

1m each

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)
λ 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)

$V = \Delta\lambda/\lambda \cdot c$

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

$\therefore V = 8.5 \times 10^{-9} / 393.3 \times 10^{-9} \cdot 3 \times 10^{8}$ ✓ 1

$= 6.48 \times 10^{6}\ ms^{-1}$ ✓ 1

[If use $\lambda = 401.8$ nm $\Rightarrow$ 2m]
[$\Rightarrow V = 6.35 \times 10^{6}\ ms^{-1}$]

[If use 401.8nm $\Rightarrow$ 2m]

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)

· when B field is strongest / mag field lines are closest together

⇒ At the N or S POLES

(b) If the maximum magnitude of the Earth's magnetic field is 5.00×10^{-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 900 km h^{-1}. (2 marks)

Assume l, v + B are mutually perpendicular

then $EMF = B.l.v$

$= 5\times10^{-5} . 60 . 250$

$= 0.75 V$

(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

· 0.75V is too small. (Even calculator uses $V_c \geq 1.5V$) Any good reason.

· unreliable voltage (depends on B, and v)

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)

Hard X-rays ⇒ high Energy.

· From F+C sheet $f \approx 10^{20}$ Hz ✓ 1 ($\lambda \approx 10^{-12}$ m)

or 10^{19} Hz

$\therefore E = hf$

$= 6.63\times10^{-34} . 10^{20}$

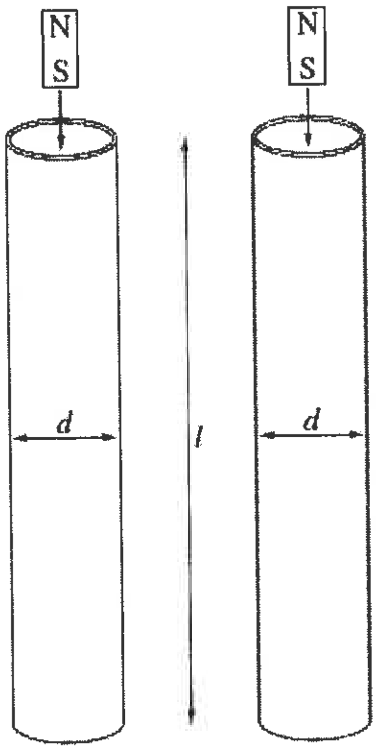
$= 6.63\times10^{-14}$ J } ✓ 1

E $= 6.63\times10^{-14} / 1.6\times10^{-16}$ in keV

$= 4.1\times10^{2}$ keV ✓ 1

[If E in J ⇒ 2m]

15. In a student experiment, a bar magnet is dropped through a long plastic tube of length L and diameter, d. The time taken for the magnet to hit the floor is recorded.



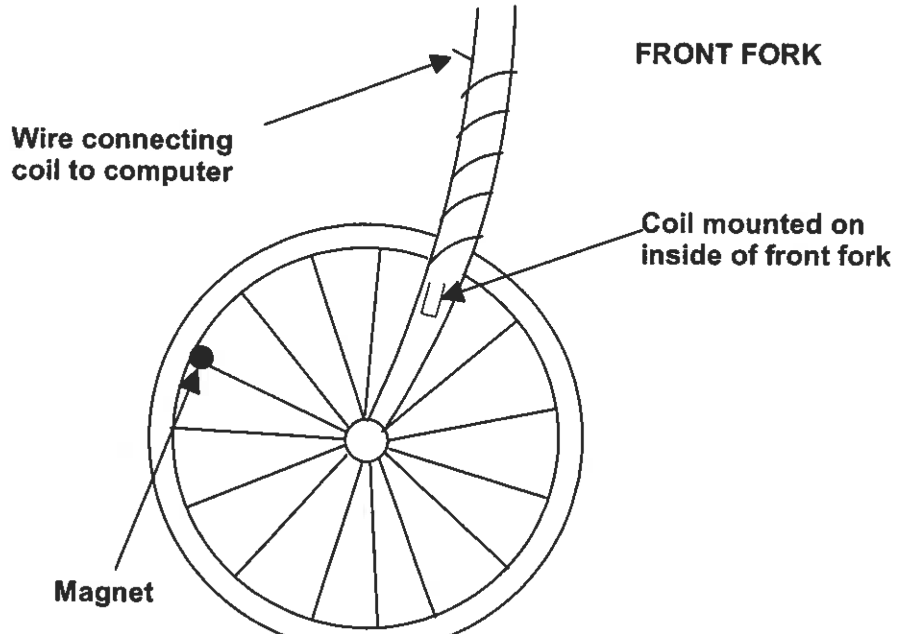
The experiment is repeated using a copper tube of the same length and diameter.

The experiment is repeated using s copper tube of the same length and diameter and the students noticed a difference in the time, t taken.
How will the times differ? Account for the difference using physics principles.

(3 marks)

- Time for copper > Time for plastic ✓ 1
- As magnet falls thru Cu pipe, eddy currents are generated in the pipe (due to changing/moving B field) ✓ 1
- These currents OPPOSE the movement of the magnet (Lenz's Law) ✓ 1

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)

[If emf/level ⇒ 2m]

- Each time magnet passes coil, a small pulse of current is INDUCED ✓
- time interval between pulses is calculated
- Computer uses $V = \frac{s}{t} = \frac{\text{circumference}}{T}$ to calculate V. ✓/2

(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 – Time for each revolution/pulse of induced current won't change if you change distance from axle.

[However, less error is produced if distance from axle ↑]

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)

$r = 1.45 \times 10^7$ m

$m_s = 395$ kg

$v^2 = \frac{G m_e}{r}$ ✓ 1 [as $g = \frac{Gm}{r^2}$ and $g = \frac{v^2}{r}$]

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

$v^2 = 27.506 \times 10^6$

$v = 5.2 \times 10^3$ ms^{-1} ✓ 1

[If $v = 87.8$ ms^{-1} ⇒ 1m]

(b) At what **altitude** above the Earth's surface is the satellite orbiting? (3 marks) Easy!

Alt = $r - r_e$ ✓ 1

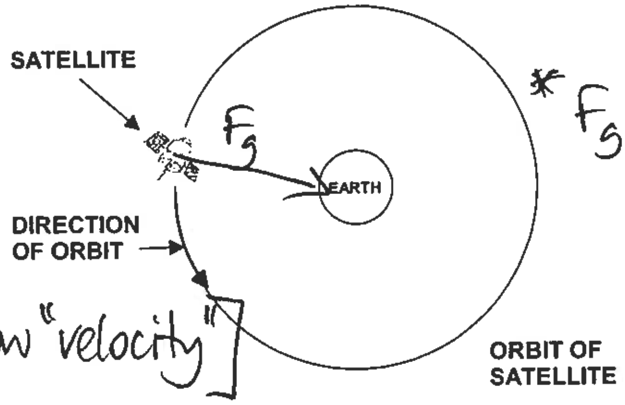
$= 1.45 \times 10^7 - 6.37 \times 10^6$ ✓ 1

$= 8.13 \times 10^6$ m ✓ 1

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

Gravity (between Earth + satellite) provides F_c. ✓✓ 2

(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)



* $F_g = F_c$

[−1m if show "velocity"]

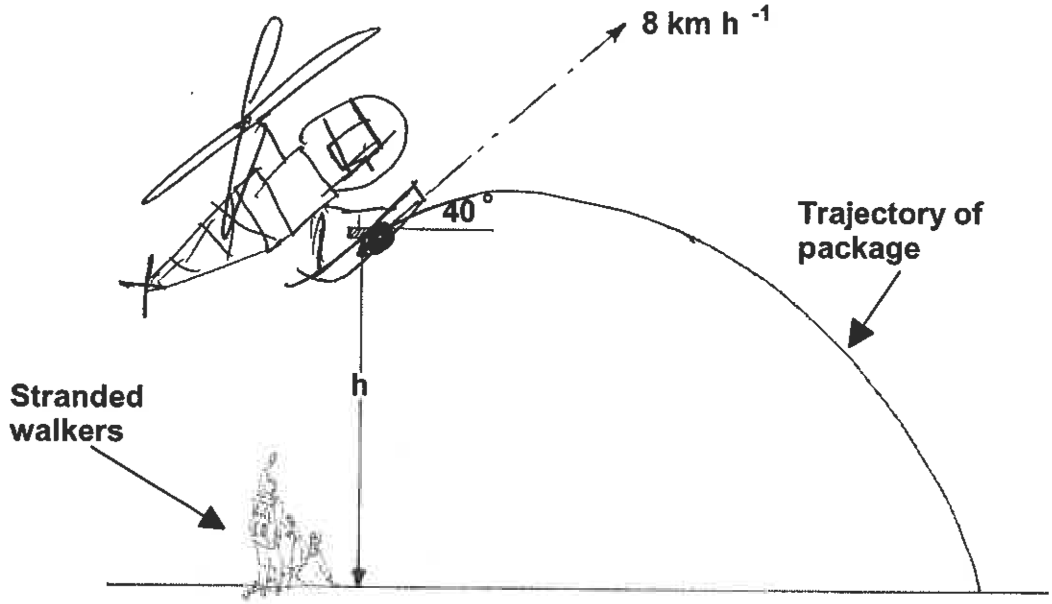
(e) Would you expect this satellite to be in a geostationary orbit about the Earth? Explain your answer. (2 marks)

NO - If it's used to observe receding Glaciers then POLAR orbit is better.

[Also: T ≠ 24hrs. T = 17420 sec = 4.84hrs.]

(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° 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. (3 marks)

$t = 2.5 s$.

$V_v = V_0 \sin 40$

$= 1.43 ms^{-1} \uparrow$ ✓1

↑ +ve

$s = ut + \frac{1}{2}gt^2$ ✓1

$= (1.43 . 2.5) - 4.9 . (2.5)^2$ ✓1

$= -27.1 m$ ✓1

(or 27.1 m ↓)

(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. (3 marks)

$U_v = 1.43 ms^{-1} \uparrow$

In 2.5 sec, helicopter will continue to rise. $S_H = U_v . 2.5$

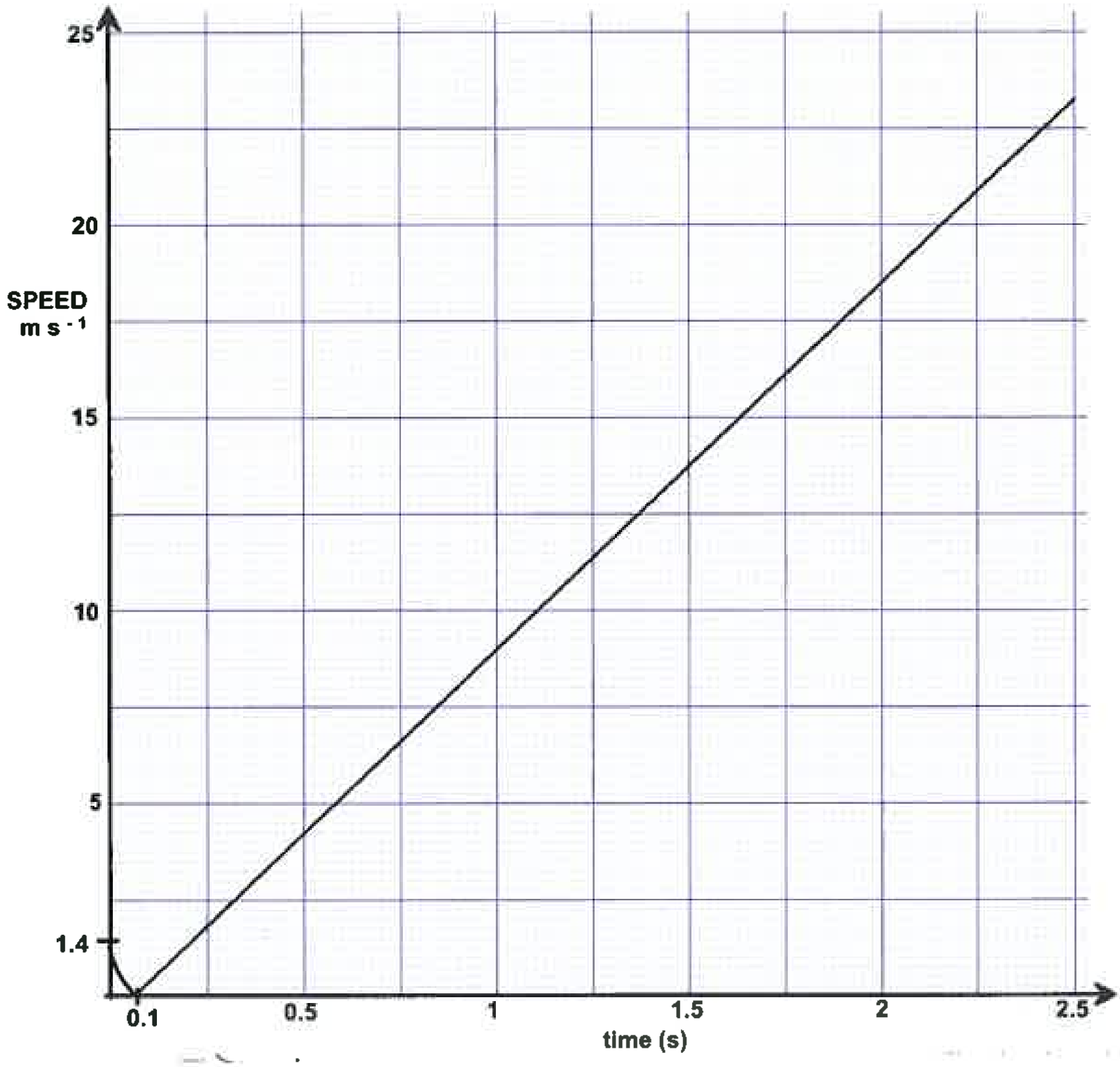
$= 3.57 m \uparrow$ ✓1

∴ Total dist $= 27.1 + 3.57$

$= 30.67 m \uparrow$ ✓✓2

Distance is only vertical as $U_{H (Heli)} = U_{H (package)}$ ✓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. (4 marks)



• Title: ✓ 1 m
• Shape/plot: 2m ✓✓
• Axes/scale: 1 m ✓

* Key points on graph: (0, 1.4)
(0.1, 0)
(2.5, -23)

(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)

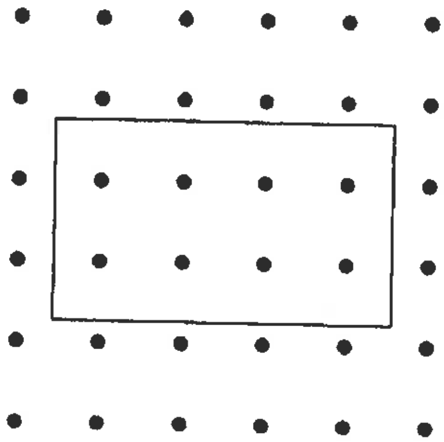
Further away - Horizontal component of helicopter is greater now (8 kmh⁻¹) hence in displacement increases. (2.22 ms⁻¹)

[Notes: ToF will be reduced, so std may state "closer" - but will need reason]

(14 marks)

3.

(a) The diagram below shows a confined magnetic field with a rectangular wire coil in the plane of the page.



State the direction of the induced current in the coil as clockwise or anti-clockwise (if there is one) as it is moved:

(2 marks)

i. to the left None

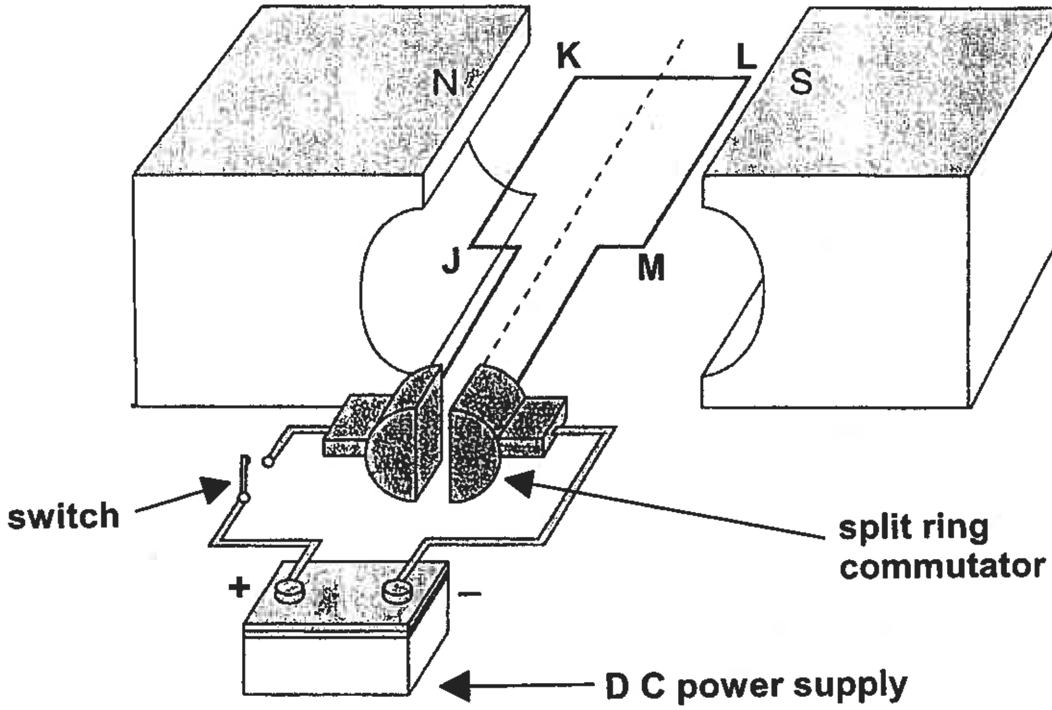
ii. b) to the right None

✓ 1m ea

(Assume that despite movement, it is still contained within the B field)

3. cont...

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

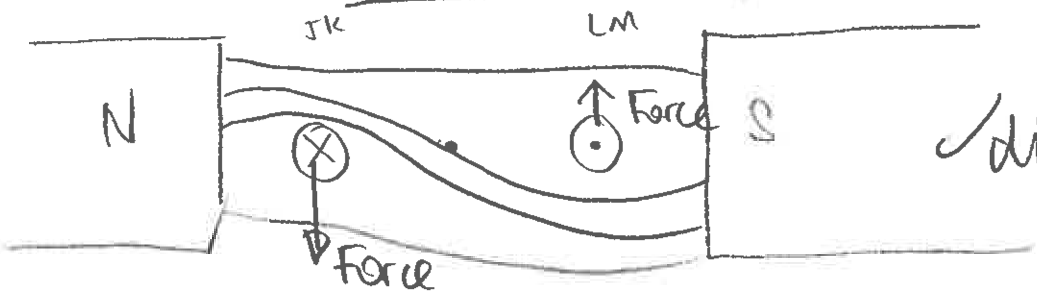


(b) In which direction, clockwise or anticlockwise will the motor rotate when the switch is closed? (1 mark)

ACW.

(c) Explain your answer to 3(b) by drawing a simple diagram to show the resultant forces and magnetic field, as viewed in the diagram. (2 marks)

SIDE VIEW



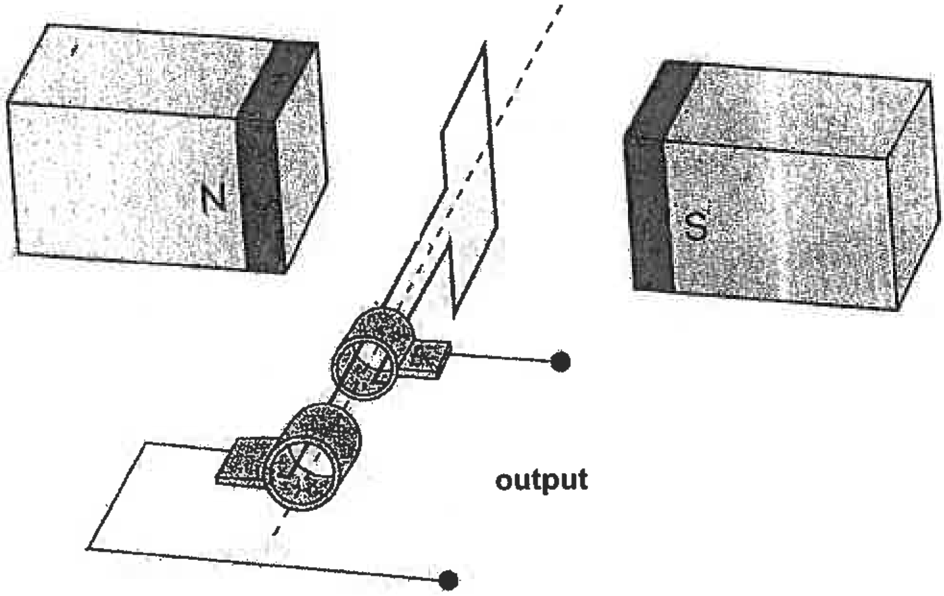
✓ dig 1.

• B field is distorted [B from coil and NS magnet interact] producing torsion in B field

• resulting Torque is ACW ✓ reason 1.

OR// R.H palm rule for charges in B field.

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 2.5×10^{-4} Wb.



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

$\phi = B.A$

$B = \phi/A = \frac{2.5 \times 10^{-4}}{(0.15 . 0.2)}$ ✓1 ✓1

$= 8.33 \times 10^{-3}$ T ✓1

If use N ⇒ ⊖m

(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)

$EMF = -N . \frac{\Delta \phi}{\Delta t}$ ✓1

[OR: EMF = 4.BANF (F = 0.06 sec)]

$= \frac{1200 . 2.5 \times 10^{-4}}{0.015}$ ✓1

$= 20$ V ✓1 (2.0×10^{1} V)

[If V = 10V ⇒ 1m]

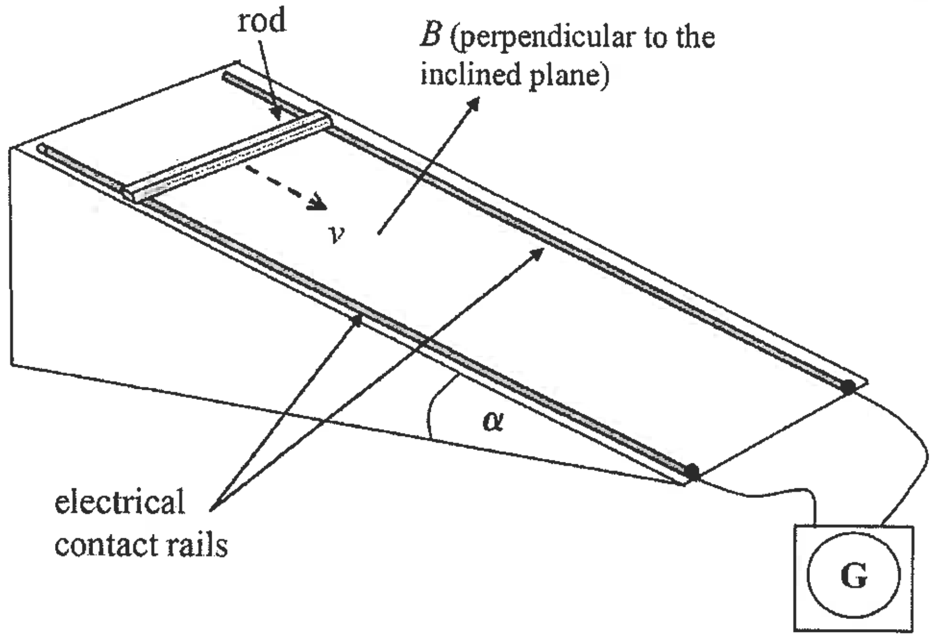
(f) List 3 ways you could modify the alternator to increase the magnitude of the emf. (3 marks)

- spin faster (more E. in)
- Increase No of coils
- Increase $\bar{B}$.
- Increase Area of Coil

1m each any 3x

(15 marks)

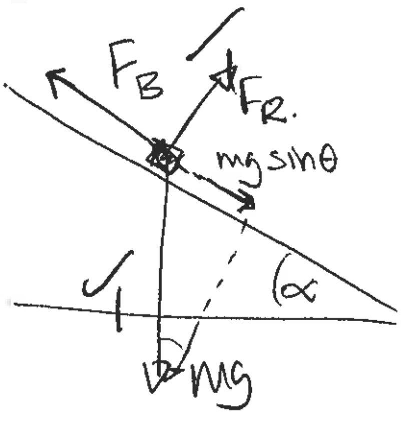
4 Below is a diagram of a "sliding wire" apparatus. As the copper rod slides down on the electrical contacts a current is induced. The induced current results in a force that opposes the motion of the copper rod.



The rod initially accelerates down the slope, but soon achieves a constant velocity as the magnetic force opposes the force responsible for the acceleration, thus achieving terminal velocity.

a) Draw a diagram to illustrate the forces acting on the sliding rod.

(2 marks)



-1m each x

b) Derive an expression for the terminal velocity, v_t .

(3 marks)

At terminal velocity v_t, $\Sigma F_{\parallel} = 0$ ✓1

$\therefore Bqv = mg\sin\theta$ ✓1

$\therefore v = \dfrac{mg\sin\theta}{Bq}$ ✓1

c) Terminal velocity was found to change as the angle of the slope changed. The table below contains some collected data. Complete the table.

Angle (α)	Terminal velocity speed ($cm.s^{-1}$)	Terminal velocity speed ($m.s^{-1}$)	Sin (α)
20	0.56	5.6×10^{-3}	0.342
25	0.71	7.1×10^{-3}	0.423
30	0.83	8.3×10^{-3}	0.5
35	0.93	9.3×10^{-3}	0.574
40	1.05	1.05×10^{-2}	0.643
45	1.19	1.19×10^{-2}	0.707
50	1.27	1.27×10^{-2}	0.766
55	1.40	1.40×10^{-2}	0.819
60	1.44	1.44×10^{-2}	0.866
65	1.50	1.50×10^{-2}	0.906
70	1.56	1.56×10^{-2}	0.940

✓1 ✓1

2 (2 marks)

d) Plot V_t against sin (α) to obtain a straight line. Determine the gradient of the line.

(Plot the graph over the page, and show your calculation of the gradient here.)

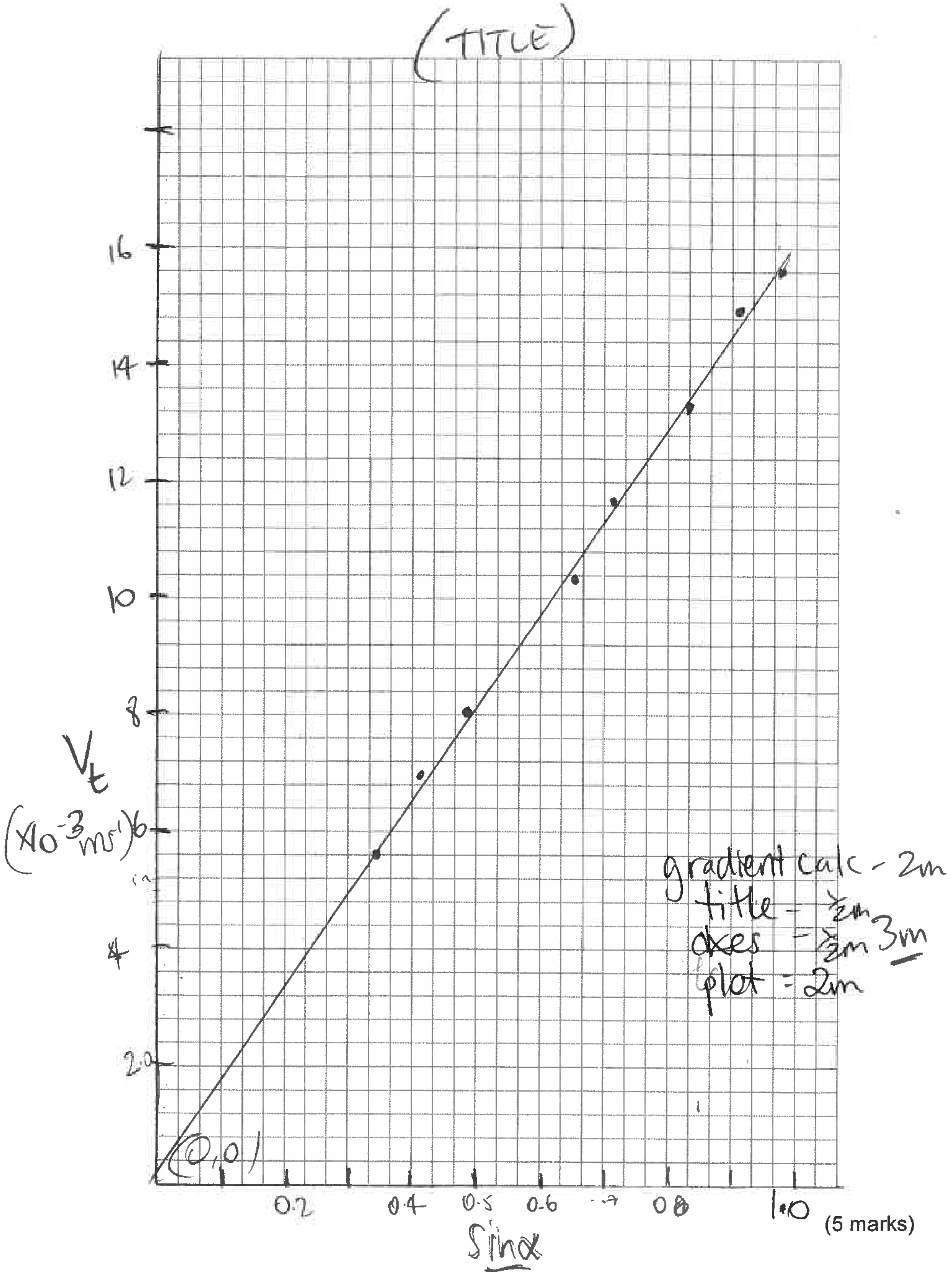
$$m = \frac{\Delta Y}{\Delta x}$$

$$= \frac{\Delta V_t}{\Delta \sin\alpha}$$

$$= \frac{1 \times 10^{-2}}{5.98 \times 10^{-1}}$$

$$= 1.67 \times 10^{-2} \ (ms^{-1})$$

2m


(TITLE)
16
14
12
10
8
6
4
2.0
V_t (x10^-3 ms^-1)
(0,0)
0.2
0.4
0.5
0.6
0.8
1.0
Sinα
gradient calc - 2m
title - ½m
axes - ½m
plot = 2m
3m

(5 marks)

(

e) Use the gradient to determine the magnitude of the magnetic field strength (B)

(3 marks)

$M = 1.67\times10^{-2} = \frac{mg}{Bq}$

As $V_t = \frac{mg}{Bq} \sin\alpha$ $(c=0)$

y ... x

$\therefore 1.67\times10^{-2} = \frac{mg}{Bq}$

* Use $q = 1.6\times10^{-19}$C
M = Melectron

$B = \frac{M_e g}{M \cdot q_e}$

$= \frac{9.11\times10^{-31} \cdot 9.8}{1.67\times10^{-2} \cdot 1.6\times10^{-19}}$

$= 3.341\times10^{-9}$ T

(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)

$E = \frac{hc}{\lambda}$

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

OR//
- 431.1×10^{-9} m ⇒ 4.61×10^{-19} J
- 486.1×10^{-9} m ⇒ 4.09×10^{-19} J
- and 656.3 nm ⇒ 3.03×10^{-19} J

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

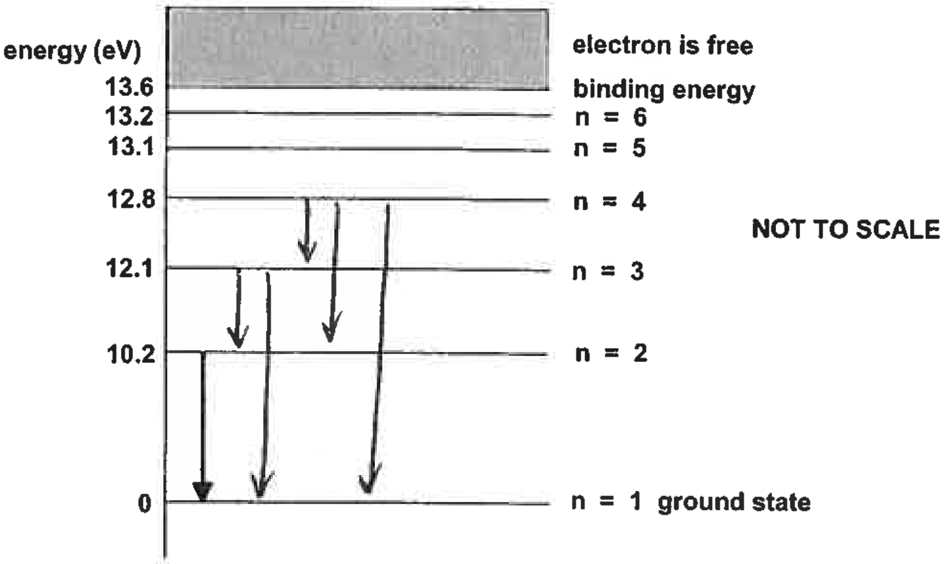
(1 mark)

$f_{486.1} = 3\times10^{8} / 486.1\times10^{-9} = 6.17\times10^{14}$ Hz

⇒ Infra-red

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

4 ⇒ 2
4 → 1
4 → 3
3 → 1
3 → 2
2 → 1



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

$E = 13.6\ eV$ ✓

$\therefore E = 13.6 \cdot 1.6\times10^{-19}\ J.eV^{-1}$ ✓1

$= \underline{2.18\times10^{-18}\ J}$ ✓1

(d) Draw arrows on the diagram to show all the possible energy transitions that may occur when an electron is in n=4. (one transition is already shown). (3 marks)

6 lines overall.

4 → 2, 4 → 1, 4 → 3 ½m each

3 → 1, 3 → 2

2 → 1

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. ½

✓1

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

(2 marks)

· Spectral absorption lines
· Absorbed by gases in · sun's atmosphere
· earth's atmosphere

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

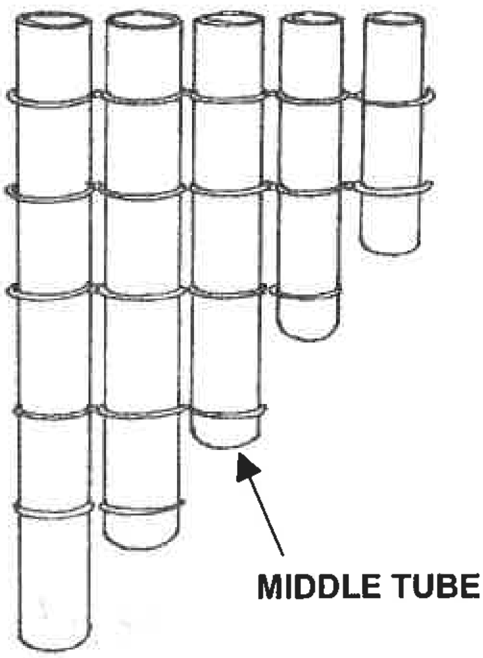
(2 marks)

NO: Light isn't passing thru gases that will absorb certain frequencies. → no dark lines.

(14 marks)

6 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 open 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: If $v = f.\lambda$

and $\lambda_f \propto l$

then $l \propto 1/f$

(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)

$l = v/2f$ ✓1

$= \frac{346}{2 \cdot 440}$ ✓1 $= 0.392$ m

[If $l = 0.786$ m ⇒ 1m]

(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 - different, it's now acting as a closed tube ✓1

now $\lambda_{f_1} = 4l$

or $f_1 = \frac{v}{4l}$ ✓1

$f = \frac{nv}{4l}$

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

(2 marks)

$f_{closed} = \frac{1}{2} \cdot f_{open}$

$= \frac{440}{2} = 220$ Hz OK

$f = \frac{v}{4l}$ ($\lambda = 4l$)

(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)

• frequency won't change, as length doesn't.

• but, due to $\phi \uparrow$, more air is moving now, hence VOLUME ↑ ✓1

(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.

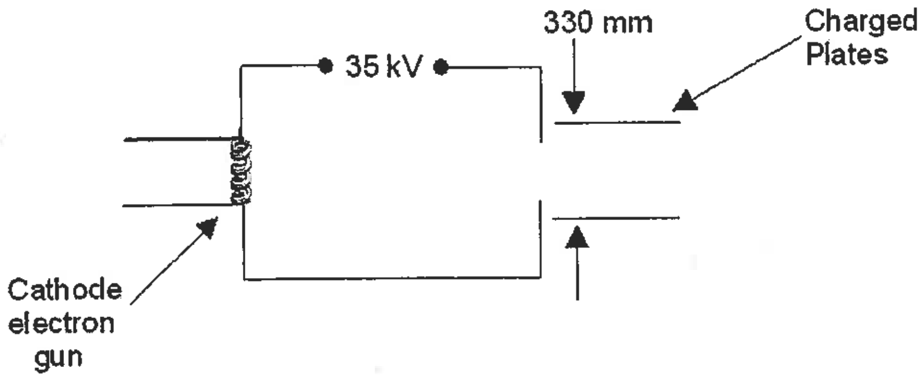
(3 marks)

• Two waves moving in same medium, + freque[ncy], same amplitudes, opposite directions,

✓✓✓/3

(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)

$E = V/d$ ✓1

$= 35\times10^{3}/0.330$ ✓1

$= 1.06\times10^{5}$ (NC^{-1} OR Vm^{-1}) ✓1

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

$KE = V.q = \frac{1}{2}mv^{2}$ ✓1 [$E = Vq = 5.6\times10^{-15}$ J]

$\therefore v = \sqrt{2E/m}$

$= \sqrt{\frac{2 . 35\times10^{3} . 1.6\times10^{-19}}{9.11\times10^{-31}}}$ ✓1 $= 1.11\times10^{8}$ ms^{-1} ✓1

$\approx (1/3\, c)$

(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)

$F_B = Bqv = \frac{mv^2}{r}$ ∴

$\therefore r = \frac{mv}{Bq}$ ✓1

$= \frac{9.11\times10^{-31} . 1.11\times10^{8}}{0.300 . 1.6\times10^{-19}}$ ✓1 $= 2.1$ mm ✓1

Section C: Comprehension and Interpretation

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.

PART A- The Doppler Effect

Para 1

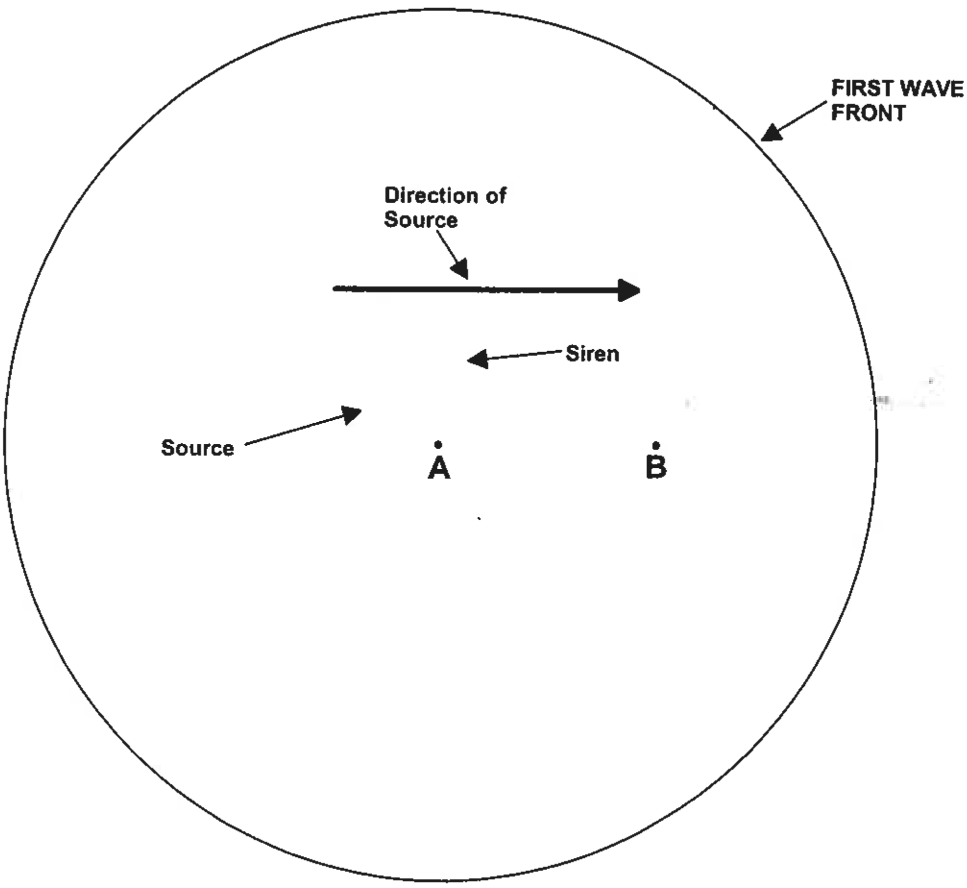
When a source of waves, whether light, sound or any other, is moving towards an observer, the wavelength detected by the observer will appear to be different to the actual wavelength emitted by the source. This is because each wave is emitted a little closer to the observer than the previous one and 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 λ.



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

i. Upon what property of sound waves does pitch depend? (1 mark)

frequency of sound

2 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)

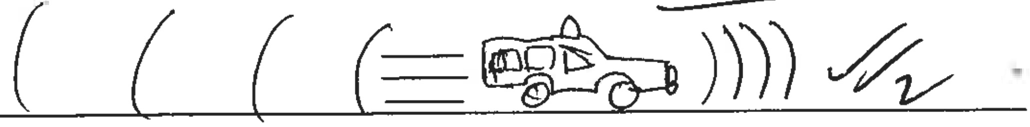
* λ's equal

Diagram A

Ambulance stationary

λ's different

Diagram B



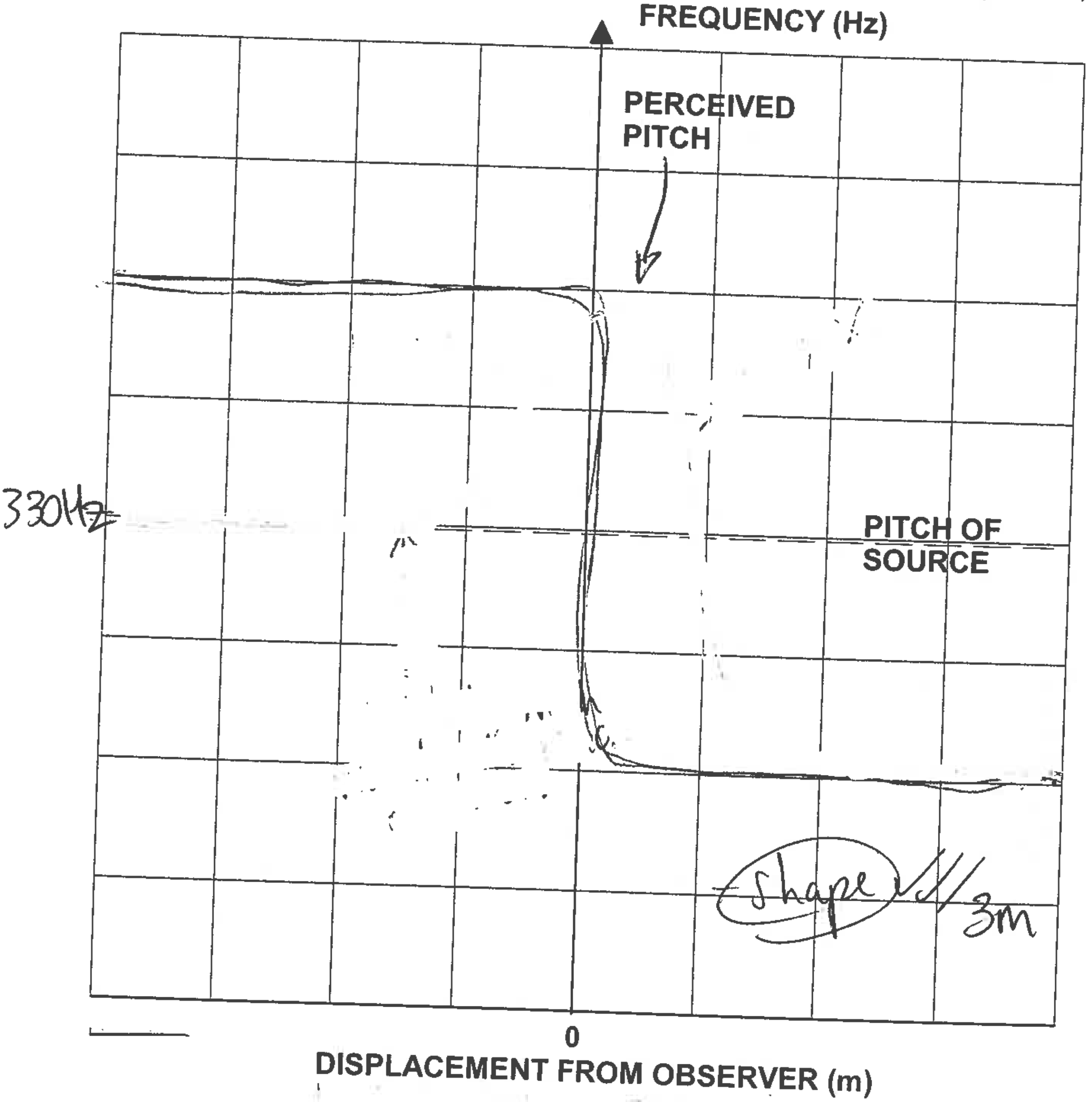
Ambulance travelling at high speed

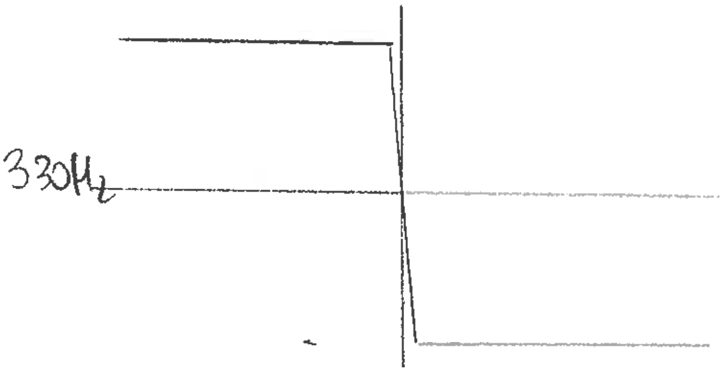
3 Does the actual pitch of a sound emitted by the ambulance, change as it approaches and passes an observer? Explain your answer. (2 marks)

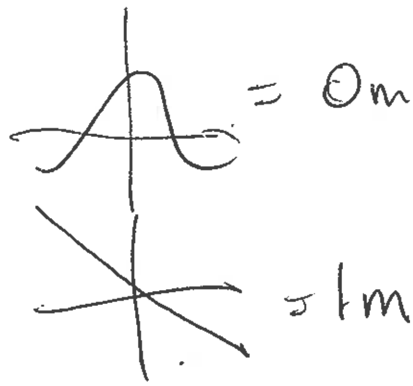
NO - actual pitch remains constant. it's the observed freq of the sound, to an observer that will change.

4 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. No valu[illegible]

(3 marks)







5 Write a mathematical formula using **λ, T** and **v** that could be used to calculate the wavelength of the wave fronts described in paragraph 3. (1 mark)

$\lambda = v/f$, $T = \frac{1}{f}$ $\therefore$ $\lambda = v.T$ ✓1

(same as dist = vel. time)

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

distance = $u.T$ ✓1

7 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)

$s = vT - (uT)$
$= T(v - u)$ ✓1

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

$s = vT + (uT)$
$= T(v + u)$ ✓1

8 (para 5) What is the meaning of the term "redshift"? (2 marks)

Movement of light source (Galaxy, star etc) AWAY from observer causes a shift in the observed frequency of light to the red end of spectrum (ie Decreased freq/increased λ) ✓1 ✓1

9 (para 5) What is the meaning of the term "blueshift"? (2 marks)

·observed frequency of light from a source moving TOWARDS ✓1 observer is shifted to blue end of spectrum. (ie Frequency ↑, λ ↓) ✓1

10 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. ✓1 Movement of the source RELATIVE to the observer is what matters.

✓1 reason

(Freq ↑ as observer moves towards source, and Freq ↓ as observer moves away)

PART B - Model Rocket

A group of students built and used a model rocket to investigate force and motion. The rocket had a total mass of 250.0 g and was powered by a stiff spring which could be compressed by 25.0 cm. A parachute inside the rocket was programmed to open after the rocket had reached its maximum height. The diagrams below show how the rocket was launched and how the parachute deployed for the descent.

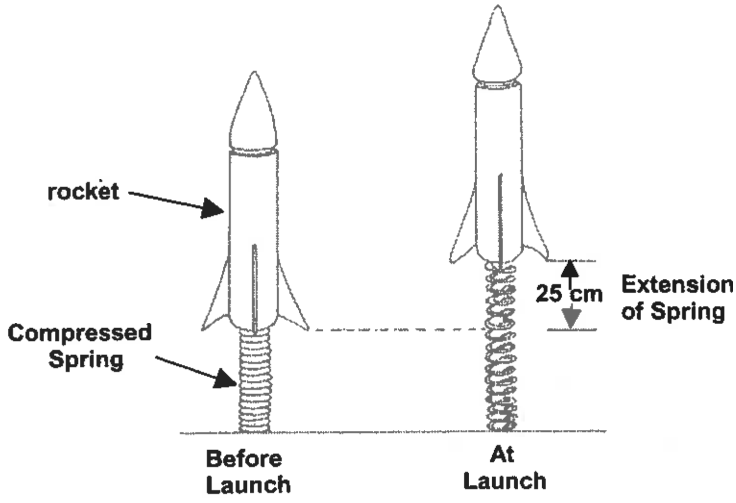


Figure 1 - Launch

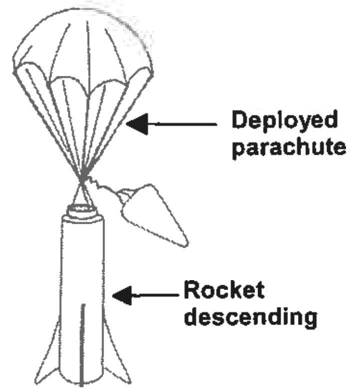
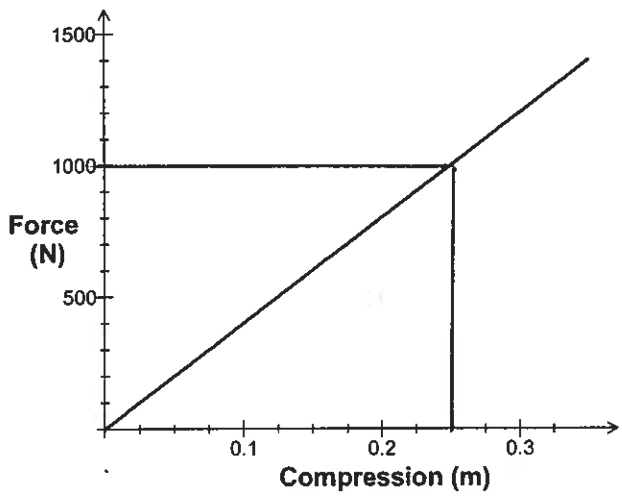


Figure 2 - Parachute

When it is launched, the rocket leaves the spring and the spring returns to its original length. The compression in the spring provides the force necessary to launch the rocket and is given by F = k x where F is the force in newtons, k is the proportionality constant and x is the extension or compression of the spring in metres.
The graph in figure 3 shows the force – compression characteristic of the spring.



1 Use the above graph to calculate the amount of energy stored in the compressed spring. (2 marks)

Area under curve = Energy stored
$W = F . S$
$= \frac{1}{2}(1000 . 0.25)$
$= 125 \text{ J}$ ✓1

($W = \int F . S$) ✓1

[250J ⇒ 1m]

2. Calculate the rocket's speed as it leaves the spring. (2 marks)

PE = KE

ie 125J = $\frac{1}{2}mv^2$ ✓1

m = 250g

$v = \sqrt{\frac{2E}{m}} = \sqrt{\left(\frac{2 \cdot 125}{0.25}\right)}$

= 31.6 ms⁻¹ ✓1

[If use E = 250J, v = 44.7 ms⁻¹ ⇒ 2m]

3. How much momentum does the rocket have as it leaves the spring? (2 marks)

p = m.v

= 0.25 . 31.6 ✓1

= 7.9 kg ms⁻¹ ✓1

↑ +ve

[If use E = 250J, p = 11.2 kg ms⁻¹ ⇒ 2m]

4. What force(s) act on the rocket immediately after it leaves the spring? (2 marks)

- Air resistance ↓
- Gravity/weight ↓

✓1 each

5 If the rocket took 2.90 s to reach its maximum vertical height, calculate the uniform deceleration of the rocket. (2 marks)

t = 2.9s

u = 31.6ms⁻¹

v = 0

Using 1st ½ of flight (release to top)

v = u + at

ie $a = \frac{v-u}{t} = \frac{0 - 31.6}{2.9}$ ✓1

= −10.9ms⁻² ✓1

[If u = 44.7, a = 15.4ms⁻² ⇒ 2m]

6 Neglecting air resistance, calculate the maximum height the rocket could reach. (2 marks)

~~a = −10.9ms⁻²~~

g = −9.8ms⁻²

v = 0 ms⁻¹

u = 31.6ms⁻¹

$v^2 = u^2 + 2gs$

ie: $s = \frac{v^2 - u^2}{2g} = \frac{0 - (31.6)^2}{9.8 \cdot 2}$ ✓1

= 50.95m ↑ ✓1

[If use t = 2.9 ⇒ 1m]

[If use a = 10.9 ⇒ 1m]

7 In fact the rocket DID experience air resistance. Is the value for the uniform deceleration calculated in Question 5 consistent with the rocket experiencing air resistance? Explain your answer. (2 marks)

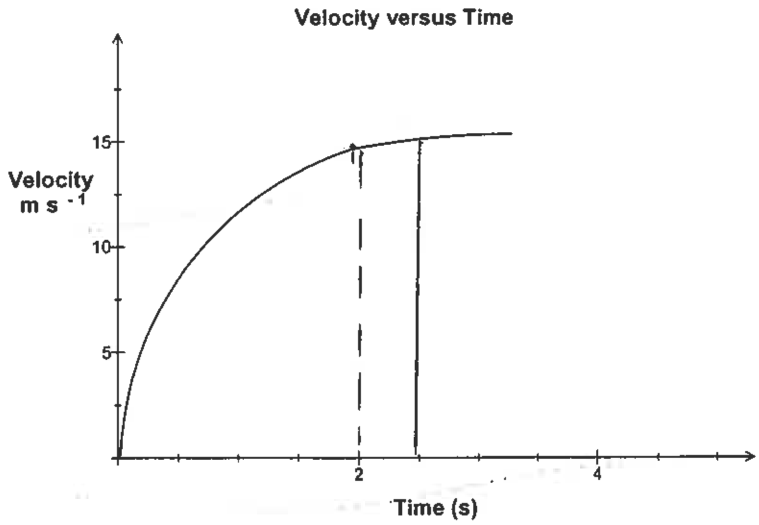
- Yes. Air resistance would increase decelleration above $9.8 ms^{-2}$ by adding an additional retarding force.
- If no air resist. accel = $-9.8 ms^{-2}$ reason ✓ 1

8 Using the group's results and your previous calculations, calculate the average retarding force due to air resistance on the rocket. (2 marks)

$F_{AR} = m.a$
$= 0.25(a_{AR} - a_g)$
$= 0.25(10.9 - 9.8)$ ✓ 1
$= 0.275 N$ ✓
(If $a_{AR} = 15.4 \Rightarrow F_{ae} = 1.4N \Rightarrow 2m$

Upon reaching its maximum height, the rocket begins to fall vertically to the ground. Soon after the start of its descent, the parachute opens and the rocket slowly returns to the ground.

A velocity – time graph of the descent is shown below.

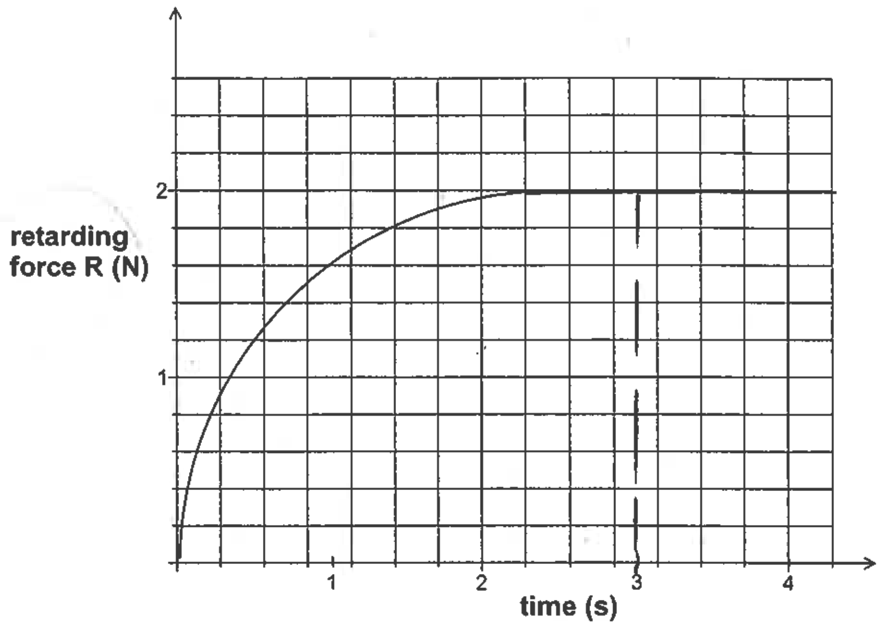


9 Use the graph to estimate the time it took for the parachute to open. Explain your answer. (2 marks)

2 sec (or 3 sec) ✓ 1

reason ✓ 1
Until that time, $\Delta v/\Delta t$ changes at a fairly steady rate. At t = 2sec, graph shows a sudden change in "change in gradient" or 'deceleration)

As it descends, the air resistance on the rocket, is small compared to the retarding force of the parachute. The graph below shows how the combined rocket /parachute retarding force varies with time as they fall.



10 Use the graph to determine the acceleration of the rocket 3 s after it begins its descent. (2 marks)

At t = 3.0 sec R(N) = 2N

$\therefore a = F/m$

$= +2/0.25$

$= 8 ms^{-2}$ ↑ (as movement is down) ✓1

Total Accel'n is $1.8 ms^{-2}$ ↓ ✓1

END OF EXAMINATION