



3AB PHYSICS

Semester Two Practice Exam A

Name: = SOLUTIONS

TIME ALLOWED FOR THIS PAPER:

Reading time before commencing work: Ten minutes

Working time for paper: Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the Supervisor

This Question/Answer Booklet.

Physics: Formulae and Constants Sheet (inside front cover of this Question/Answer Booklet).

To be provided by the candidate:

Standard Items: Pens, pencils, eraser or correction fluid, ruler.

Special Items: MATHOMAT and/or Mathaid, compass, protractor, set square and calculators satisfying the conditions set by the Curriculum Council.

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.

Short Answer	Problem Solving	Comprehension	TOTAL	%
/60	/100	/40	/200	/100

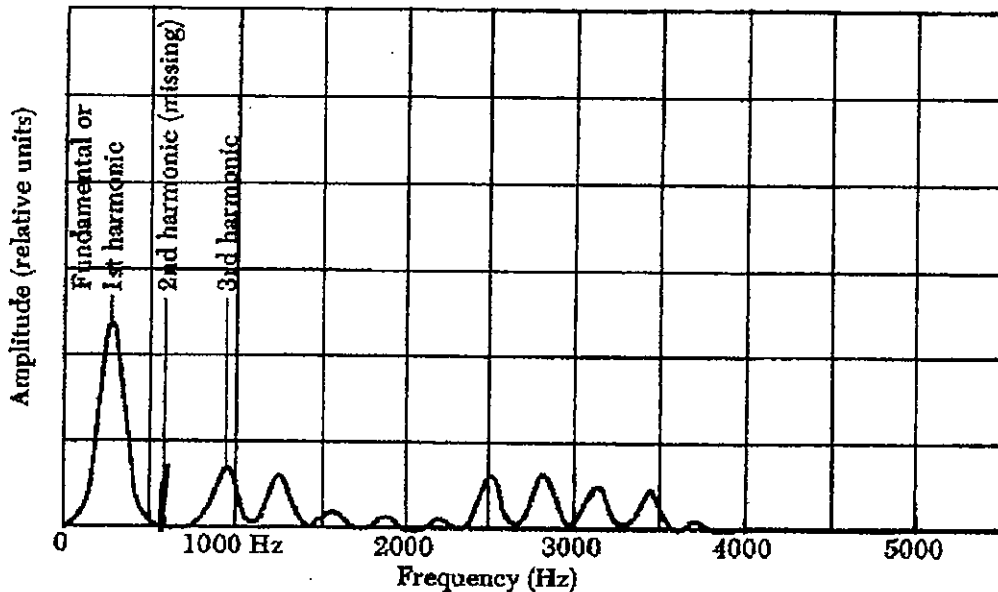
Section A: Short Answers

Marks allocated: 60 marks out of a total of 200 (30%)

Attempt ALL 15 questions in this section. Each question is worth 4 marks.

Answers are to be written in the space below or next to each question.

1. The graph below represents the sound spectrum produced by a musical instrument. Study the graph and answer the questions.



- (a) Circle which of the following type or types of instrument this one might be.

Open pipe

Closed pipe

String

(2 m)

- (b) Explain why you chose your answer to (a)

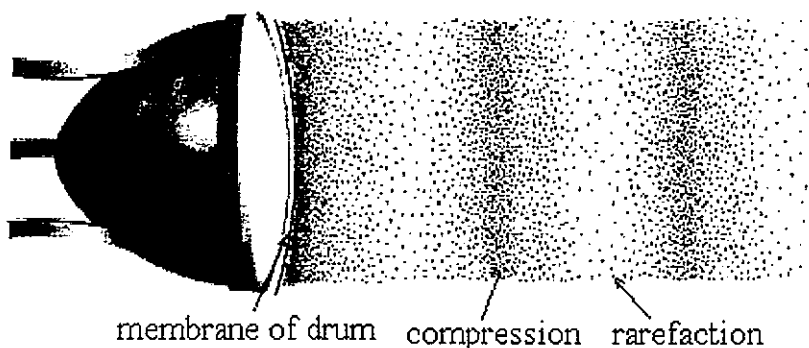
- Closed pipe only allows odd harmonics
so 2nd harmonic not possible

- If 2nd harmonic was present it
could be either open pipe or string.

(node required at closed end and antinode
at open end)

(2 m)

2. The diagram below shows how a longitudinal sound wave may be produced by a big drum. The diagram has been drawn one twentieth full size, that is, it has been drawn with a scale of 1:20.



- (a) Use the scale diagram to measure the wavelength of the sound produced.

λ is compression to compression
measured 2.5 cm.

$$\therefore \text{Actual } \lambda = 20 \cdot 2.5 = \underline{0.50 \text{ m}} \quad (1 \text{ m})$$

- (b) Find the frequency of the "note" produced by the drum

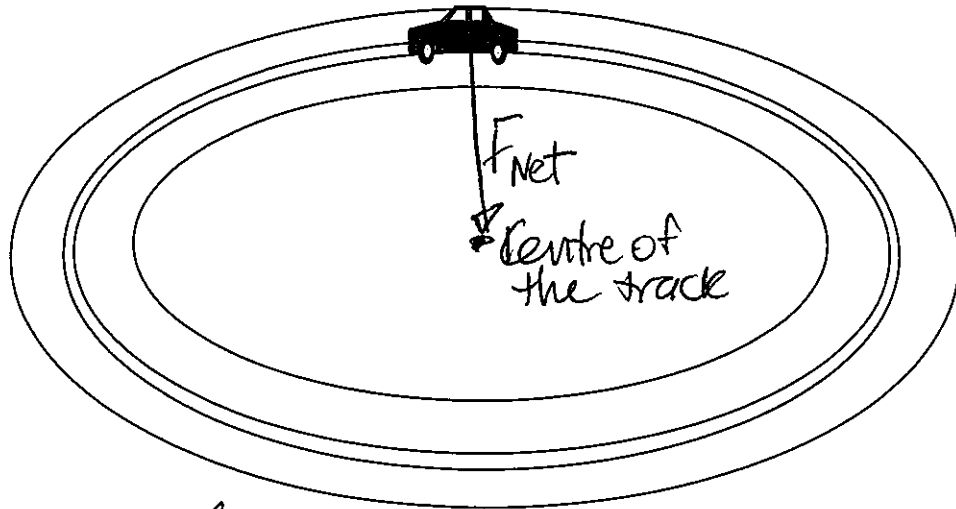
$$c = 346 \text{ m s}^{-1} \quad f = \frac{c}{\lambda} = \frac{346}{0.5} = \underline{692 \text{ Hz}} \quad (1 \text{ m})$$

- (c) How reasonable is your answer? Do you think that this is a likely frequency to come from such an instrument? Explain.

• Unlikely to come from such a drum (70 cm) across,
 $\approx 690 \text{ Hz}$ is fairly high frequency. For
 example many tuning forks are 256 Hz, 512 Hz etc.

(2 m)

3. A toy slot car set moves around a circular track as shown in the diagram below.



- (a) On the diagram draw and label a vector arrow to show the net force acting on the slot car.

(towards centre of circle)

(2 m)

- (b) The mass of the slot car is 0.25 kg, the diameter of the track is 110 cm and the net force is 3.25 N. Calculate the speed of the car.

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

ie $v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{3.25 \cdot 0.55}{0.25}}$ ✓

$$= \sqrt{7.15} = 2.67 \text{ ms}^{-1} \text{ ✓}$$

[If we use $r = 1.1 \rightarrow 3.88 \text{ ms}^{-1} \rightarrow 1 \text{ m}$]

(2 m)

4. A laser emits a red light of $\lambda = 720 \text{ nm}$. The area of the dot of light formed by the laser is 3 mm². The intensity of the beam is 10 Wm^{-2} . Stating any assumptions, calculate the number of photons emitted by the laser each second.

$$n^{\circ} \text{ photons} = \frac{E_{\text{total}}}{E_{\text{photon}}}$$

$$\text{time} = 1 \text{ sec}$$

$$3 \text{ mm}^2 = 3 \times 10^{-6} \text{ m}^2$$

$$E_{\text{photon}} = \frac{hc}{\lambda}$$

$$E_{\text{total}} = P \cdot t$$

$$= A \cdot I \cdot t$$

$$= (3 \times 10^{-6}) \cdot 10 \cdot 1$$

$$= 3 \times 10^{-5} \text{ J (per sec)}$$

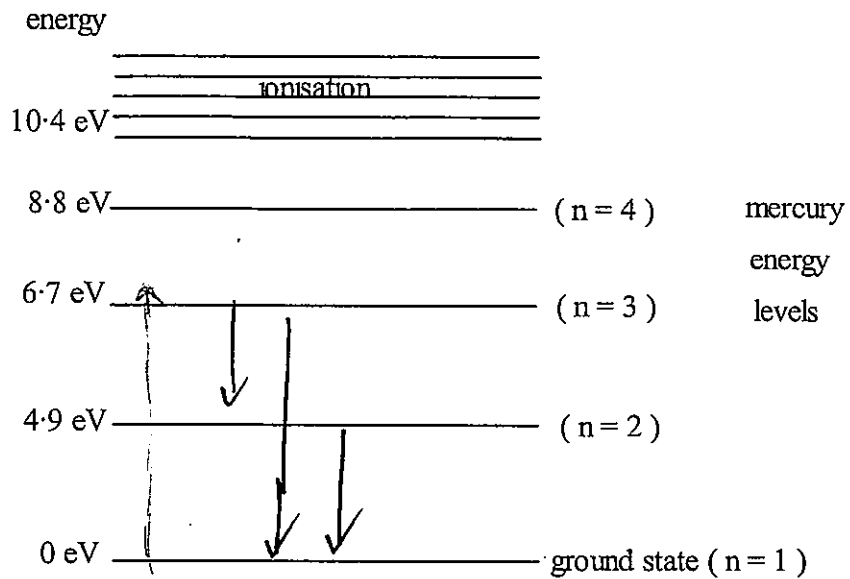
[OR: $E = hf$; $f = 4.17 \times 10^{14}$]

$$= \frac{6.63 \times 10^{-34} \cdot 3 \times 10^8}{720 \times 10^{-9}}$$

$$= 2.76 \times 10^{-19} \text{ J ✓}$$

$$\therefore n^{\circ} \text{ photons} = \frac{3 \times 10^{-5}}{2.76 \times 10^{-19}} = 1.085 \times 10^{14} \text{ photons ✓}$$

5. Below is a diagram showing the energy levels in the mercury atom.



If a beam of **electrons** with energy of 7.0 eV are incident upon the mercury gas in a low pressure discharge tube, a number of things could happen.

(a) Calculate all possible energies (in eV) of the **emergent** electrons.

Transition:	ΔE (eV)	E of Emergent e^-
$E_1 \rightarrow E_2$	4.9	2.1 eV
$E_1 \rightarrow E_3$	6.7	0.3 eV
(no interaction)	0.	7.0 eV

*show working!!

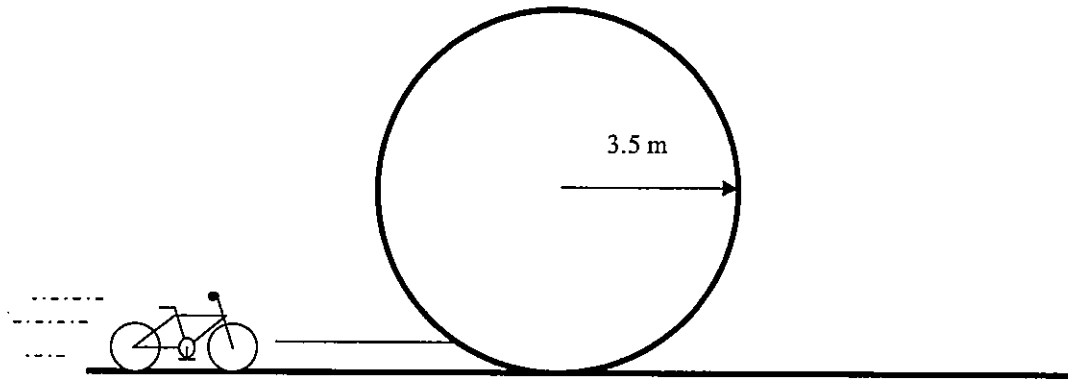
(2 m)

(b) What are all of the possible energies (in eV) of the photons produced by the electron transitions in excited atoms of this element as these electrons return to the ground state?

Transition	ΔE (photon E)
$E_3 \rightarrow E_1$	6.7 eV
$E_3 \rightarrow E_2$	1.8 eV
$E_2 \rightarrow E_1$	4.9 eV
-1m each incorrect	

(2 m)

6. A cyclist is dared by a friend to execute a loop the loop maneuver on a track specially designed for the purpose. The radius of the loop is 3.5 metres. At what minimum speed must the cyclist maintain whilst in the loop to execute the maneuver successfully, and not lose contact with the track?



$$\begin{aligned} \text{Reaction force} = \text{zero} &\Rightarrow \frac{mv^2}{r} = mg \checkmark \\ v &= \sqrt{r \cdot g} \checkmark \\ &= \sqrt{3.5 \cdot 9.8} \checkmark \\ &= \sqrt{34.3} \checkmark \\ &= \underline{5.86 \text{ ms}^{-1}} \checkmark \end{aligned}$$

7. A solar storm may eventuate when the sun emits protons and helium nuclei. In a recent such storm, these particles hit the Earth's atmosphere with a velocity of $1.2 \times 10^6 \text{ m s}^{-1}$. Calculate the radius of the path of a proton in such a storm as it passes directly above the Earth's magnetic North Pole where it is moving parallel to the Earth's surface at a point where the magnetic field has a flux density of $5.8 \times 10^{-5} \text{ T}$.

$$\begin{aligned} v &= 1.2 \times 10^6 \text{ ms}^{-1} & \frac{mv^2}{r} &= Bqv \checkmark \\ \text{proton} & & \text{ie } r &= \frac{mv}{Bq} \checkmark \\ \vec{B} &= 5.8 \times 10^{-5} \text{ T} & &= \frac{1.67 \times 10^{-27} \cdot 1.2 \times 10^6}{5.8 \times 10^{-5} \cdot 1.6 \times 10^{-19}} \checkmark \\ M_{\text{proton}} &= 1.67 \times 10^{-27} \text{ kg} & &= 2.159 \times 10^2 \text{ m} \\ q &= 1.6 \times 10^{-19} \text{ C} & &= \underline{216 \text{ m}} \checkmark \\ \text{Assume } \perp \text{ to } \vec{B} & & & \end{aligned}$$

8. To test the value of the gravitational force of Triton, one of Neptune's moons, a space probe is sent from earth and it settles on Triton's surface. Inside the space probe is a 10.0 kg mass suspended on a spring balance, which is calibrated in newtons.

Data: mass of Triton = 2.14×10^{23} kg
 radius of triton = 1.35×10^6 m
 mass of space probe = 2.00×10^3 kg

What is the reading on the spring balance in Newtons? = weight force

$$\text{OR } g = \frac{GM}{r^2}$$

$$= 7.83 \text{ ms}^{-2}$$

$$W = mg$$

$$= 10 \cdot 7.83$$

$$= \underline{78.3 \text{ N}}$$

$$F = \frac{GM_r m_r}{r_T^2}$$

$$= \frac{6.67 \times 10^{-34} \cdot 2.14 \times 10^{23} \cdot 10}{(1.35 \times 10^6)^2}$$

$$= \underline{78.3 \text{ N}}$$

[If $7.83 \text{ N} \Rightarrow 2 \text{ m}$]

9. A uniform, horizontal beam is supported by a cable as shown in the diagram. The beam is attached to the wall by a hinge. Its mass is 20.0 kg and its length is 1.00 m. A 10.0 kg load hangs from the end of the beam. Calculate the magnitude of the tension in the cable.

$$\text{Vertically: } \Sigma F_V = 0 \checkmark$$

$$\therefore T_V = T \cos 50^\circ = W_B + W_L$$

$$\therefore T = \frac{196 + 98}{\cos 50^\circ} \checkmark$$

$$= \frac{294}{\cos 50^\circ}$$

$$= \underline{457.38 \text{ N}} \text{ Along wire.} \checkmark$$

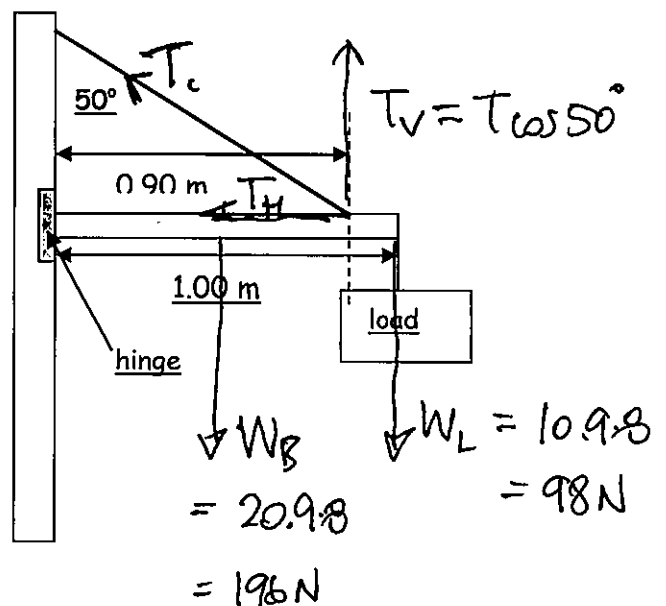
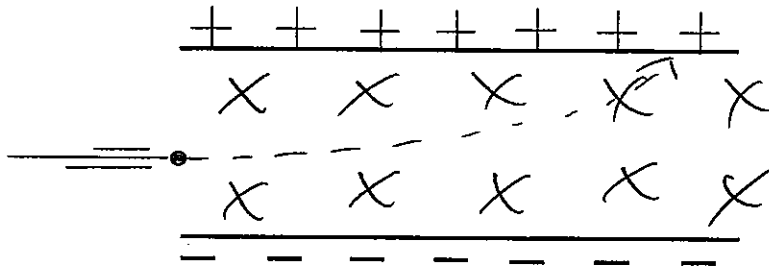


Diagram \checkmark .

10. The diagram below shows electrons moving at a speed of $5.00 \times 10^6 \text{ ms}^{-1}$ and travelling between the charged plates of a TV tube.



- a) Show on the diagram the trajectory the electrons will experience due to the electric field between the plates.
(towards +ve plate) (1 m)
- b) A magnetic field of strength 6.00 mT is employed to cause the electrons to now travel undeflected through the region where the electric field exists. Show on the diagram the direction of such a magnetic field.
(into the page) (1 m)
- c) If the electric field is then switched off and the magnetic field remains, calculate the radius of curvature of the electrons. (Assume they emit no electromagnetic energy as they are deflected)

$$r = \frac{mv}{Bq} = \frac{9.11 \times 10^{-31} \cdot 5 \times 10^6}{6 \times 10^{-3} \cdot 1.6 \times 10^{-19}}$$

$$= \underline{4.75 \times 10^{-3} \text{ m}}$$

(2 m)

11. What is the ratio of the time taken for an object to fall 1.5 m on the surface of the earth as opposed to the time taken for an object to fall 1.5 m on the surface of the moon? (Note: ignore air resistance in both situations)

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

$$u=0, \Rightarrow s = \frac{1}{2}gt^2$$

$$\therefore t \propto \frac{1}{\sqrt{g}}$$

$$\therefore \text{EARTH} : \text{MOON}$$

$$\frac{1}{\sqrt{9.8}} : \frac{1}{\sqrt{1.62}}$$

$$0.319 : 0.785$$

$$\therefore 1 : 2.46$$

OR $0.404 : 1$

OR: EARTH MOON

$$s = ut + \frac{1}{2}gt$$

$$1.5 = 4.9t^2$$

$$t = 0.553 \text{ s}$$

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

$$1.5 = \frac{1}{2} \cdot 1.62 \cdot t^2$$

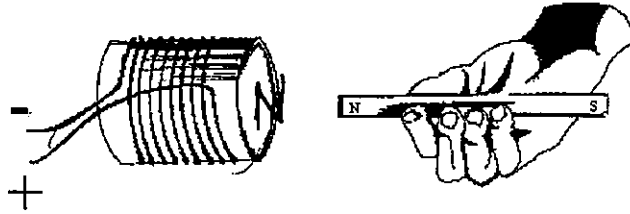
$$t = 1.36 \text{ s}$$

$$\therefore \text{ratio} = 0.553 : 1.36$$

OR $2 : 5$
 $1 : 2.5$

[*need to simplify - 1 : x
or x : 1.]

12. A student holds on to a strong bar magnet and pushes it to the left, into a current carrying coil as shown in the diagram.



- (a) What is the direction of the force the student feels as the magnet enters the coil?

opposing his motion, to the RIGHT.

(2 m)

- (b) Explain your answer to (a).

Current in coil: N pole created by this is at right end of the coil, closest to magnet. This N pole will oppose the motion of the bar magnet.

[Due to LENZ'S law $\Rightarrow \underline{0_m}$]

(2 m)

13. The 1950's film classic "Shane" shows a small boy shouting to a cowboy as the cowboy rides off towards some mountains. Apart from the original shout, the boy hears two echoes off the mountains.

- (a) What would cause there to be two echoes?

Two reflecting surfaces, at different distances from the boy.

(2 m)

- (b) If the first echo was heard by the boy 2.5 s after the original shout, ESTIMATE how far it is from the boy to the reflecting surface.

$$\text{time to surface} = 1.25 \text{ sec}$$

$$\therefore s = v \cdot t$$

$$= 346 \cdot 1.25$$

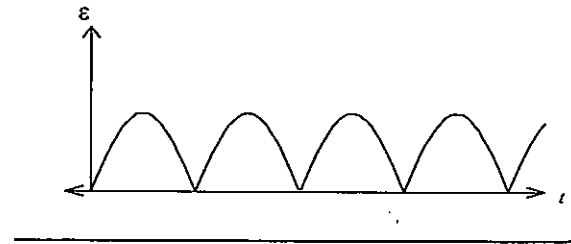
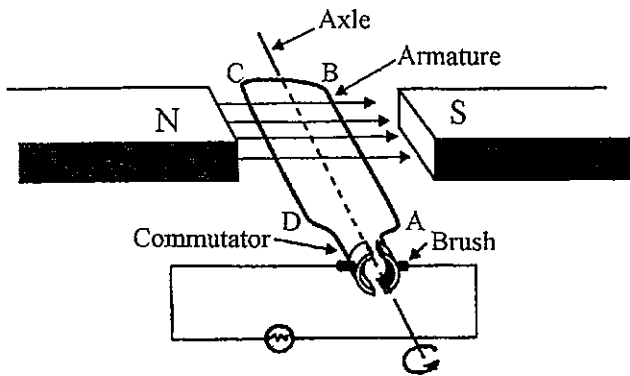
$$= 432.5 \text{ m}$$

(2 m)

$$\left[\text{If case } t = 2.5 \text{ s, } s = 865 \text{ m} \Rightarrow \underline{1 \text{ m}} \right]$$

$$\therefore \underline{4.33 \times 10^2 \text{ m}}$$

14. The diagram shows the arrangement of components, and an emf -v- time graph produced when the coil turns between the magnets.

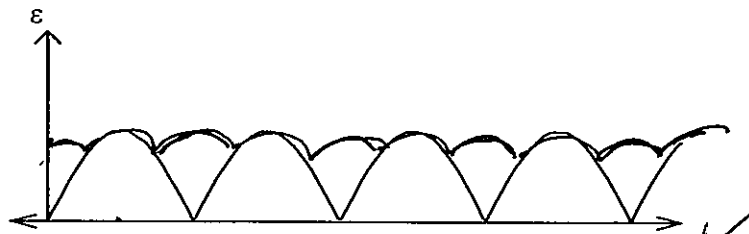


(a) Is the output shown on the graph AC or DC? Explain your answer.

DC ✓ - Although varying, the EMF is always in ONE DIRECTION. ✓ (no negative on graph)
 OR Using split-ring commutator ✓.

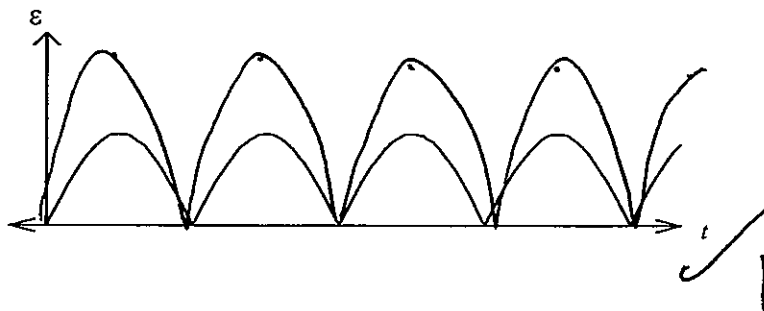
(b) By adding or changing the graphs and axes below, indicate what the output of the generator would be if: (2 m)

(i) another identical coil was placed on the same armature at right angles to the original coil.



(resultant of 2 sine waves 90° out of phase)

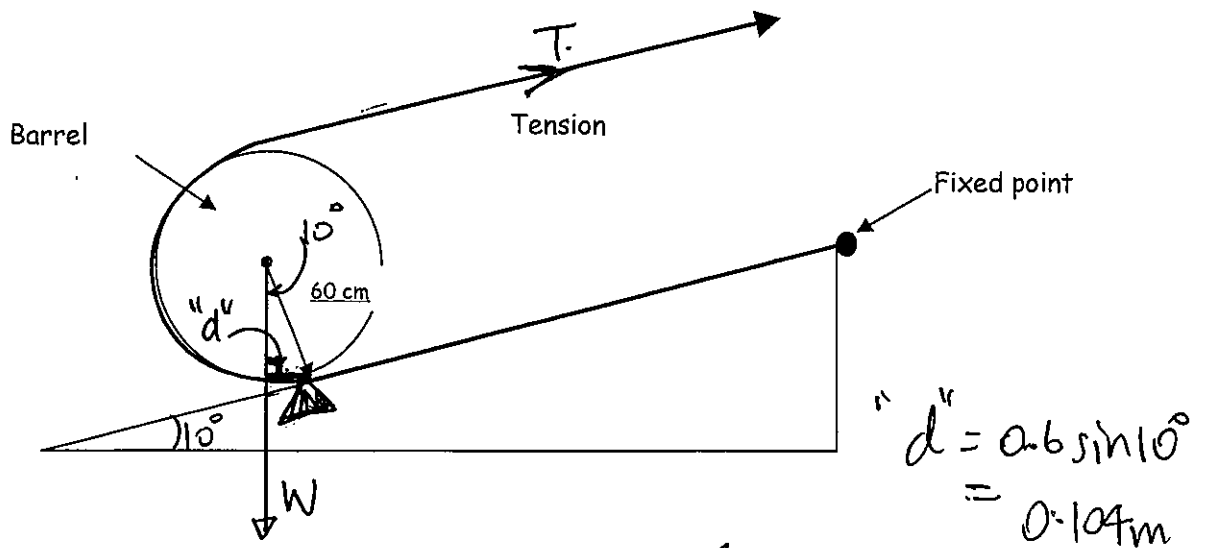
(ii) more turns were placed on the original single coil.



Greater MAX EMF.

(2 m)

15. A barrel is pulled up a ramp at a constant velocity using a piece of rope as shown in the diagram below. The barrel is at an angle of 10° to the horizontal. The barrel has a mass of 30 kg and a radius of 60 cm. What is the tension in the rope?



$$\sum \tau_{cm} = \sum \tau_{cm} \checkmark$$

$$T \cdot 1.2 = mg \cdot 0.6 \sin 10^\circ$$

$$T = \frac{(30 \cdot 9.8) \cdot 0.6 \sin 10^\circ}{1.2} \cdot 2$$

$$= 25.526 \text{ N}$$

$$mg = 294 \text{ N}$$

$$T = 25.5$$

$$(2.55 \times 10^1 \text{ N}) \text{ (along rope)}$$

$$\left[\begin{array}{l} \text{If use } 0.6 \tan 10^\circ \Rightarrow T = 25.9 \text{ N} \Rightarrow 3m \\ \text{or } 0.6 \cos 10^\circ \Rightarrow T = 1447 \text{ N} \Rightarrow 3m \end{array} \right]$$

$$\left[\text{If just } \sum F = 0, F = 51.1 \text{ N} \Rightarrow 0m \right]$$

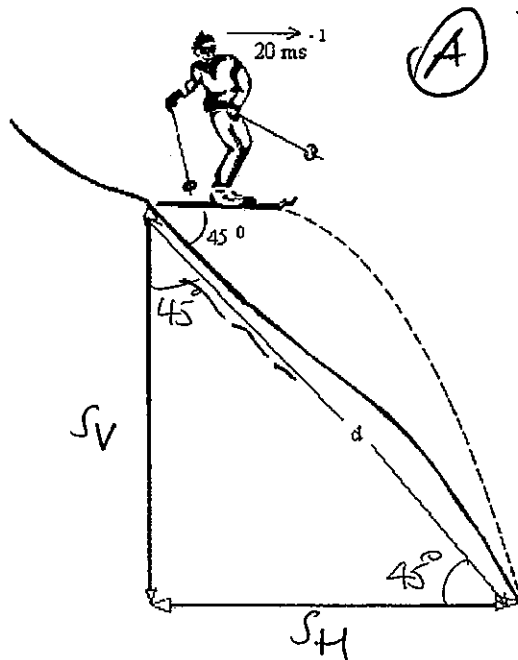
Section B: Problem Solving

Marks allotted: 100 marks out of a total of 200 (50%)

This section contains 7 questions. You are to answer all questions in the space provided.

1. (14 marks)

A ski jumper competing in the 1998 winter Olympics travels down a slope and leaves the ski track moving in the horizontal direction with a speed of 20 m s^{-1} . The landing incline below the take off point slopes downwards at an average 45° below the horizontal.



(A) OR! $S_V = -4.9t^2$
 $S_H = 20t$
 $\therefore \text{As } S_V = S_H$
 $4.9t^2 = 20t$
 SOLVER $\rightarrow t$
 $t = 4.08 \text{ sec}$
 $S_V = S_H = 20 \cdot 4.08$
 $= 81.63 \text{ m}$

(a) If the skier lands on the slope, and air resistance is ignored, calculate the skier's displacement (d) down the slope.

(B) $S_V = d \sin 45$
 $S_H = \frac{S_V}{\tan 45}$
 $= d \sin 45$

Horizontally: $S_H = V_H \cdot t$
 ie. $t = \frac{d \cdot \sin 45}{20}$ (1) $\checkmark \checkmark$

Vertically: $S_V = ut + \frac{1}{2}gt^2$
 $d \cdot \sin 45 = -4.9t^2$ (2) $\checkmark \checkmark$

Sub (1) into (2) $\rightarrow d \cdot \sin 45 = -4.9 \left(\frac{d \cdot \sin 45}{20} \right)^2 \checkmark \checkmark$

SOLVER: $d = 115.45 \text{ m}$ \checkmark

OR $S_V = -4.9t^2$ (1) and $S_V = \frac{S_H}{\tan 45}$ (2)

where $t = \frac{S_H}{20}$ $\therefore 4.9 \left(\frac{S_H^2}{400} \right) = \frac{S_H}{\tan 45}$

and: $d = \sqrt{S_H^2 + S_V^2} = 115.45 \text{ m}$

(8 m)

(b) How long is the skier in the air before landing?

$$\begin{aligned}
 t &= \frac{115.45 \cos 45^\circ}{20} \\
 &= \frac{81.6357}{20} \\
 &= \underline{4.08 \text{ sec}}
 \end{aligned}$$

$$\begin{aligned}
 \text{OR } t &= \frac{S_H}{20} \\
 &= \frac{81.63}{20} \\
 &= \underline{4.08 \text{ sec}}
 \end{aligned}$$

$$\begin{aligned}
 \text{OR } S &= \frac{1}{2}gt^2 \quad (u=0) \\
 -81.63 &= -4.9t^2 \\
 t &= \underline{4.08 \text{ sec}} \quad (3 \text{ m})
 \end{aligned}$$

(c) What is the vertical component of velocity just before the instant the skier lands?

$$\begin{aligned}
 v^2 &= u^2 + 2gs \\
 &= 0 + -19.6 \cdot (115.45 \cos 45^\circ) \\
 &= \underline{40 \text{ ms}^{-1}} \text{ downward}
 \end{aligned}$$

[no direction $\Rightarrow -\hat{z} \text{ m}$]

$$\begin{aligned}
 \text{OR: } v &= u + gt \\
 &= -9.8 \cdot 4.08 \\
 &= \underline{40 \text{ ms}^{-1}} \downarrow
 \end{aligned}$$

(3 m)

$$\left[\text{if use } v = \frac{s}{t} \Rightarrow \underline{0 \text{ m}} \right]$$

2. (14 marks)

Alicia investigates the shortest length of a closed pipe which will resonate to a note of a given frequency. She uses a very long cylindrical metal pipe filled with water so that the water level in the pipe can be controlled. She uses a small speaker connected to a signal generator to provide the sound, enabling her to determine the period of the note used. Her physics textbook tells her that the relationship between the period of the note (T) and the shortest resonating length (L) is given by:

$$T = 4(L + E)/v$$

where v is the speed of sound in the gas in the pipe (in this case air at 25°C) and E is the "end correction" for the pipe ($L+E$ = effective length).

Alicia records her data in the table as shown below.

Period (T) (ms)	Length (L) (cm)
0.588	2.29
0.741	3.61
1.00	5.85
1.18	7.41
2.27	16.8
3.12	24.2
3.91	31.0
5.56	45.2

- (a) On the grid on the next page, plot a suitable graph to show the relationship between period (T) and the shortest resonant length (L).

if x-axis = period
y-axis = length \Rightarrow max 3m (5m)

- (b) From your graph, determine the speed of sound in air.

• Gradient = $\frac{\Delta T}{\Delta L}$ (Assume T (y-axis), L (x-axis))

$$= \frac{(5.56 - 0.588) \times 10^{-3}}{(45.2 - 2.29) \times 10^{-2}}$$

$$= \frac{4.972 \times 10^{-2}}{42.91 \times 10^{-2}} = 0.011587$$

(OR, use LOBF regression from calculator) (3m)

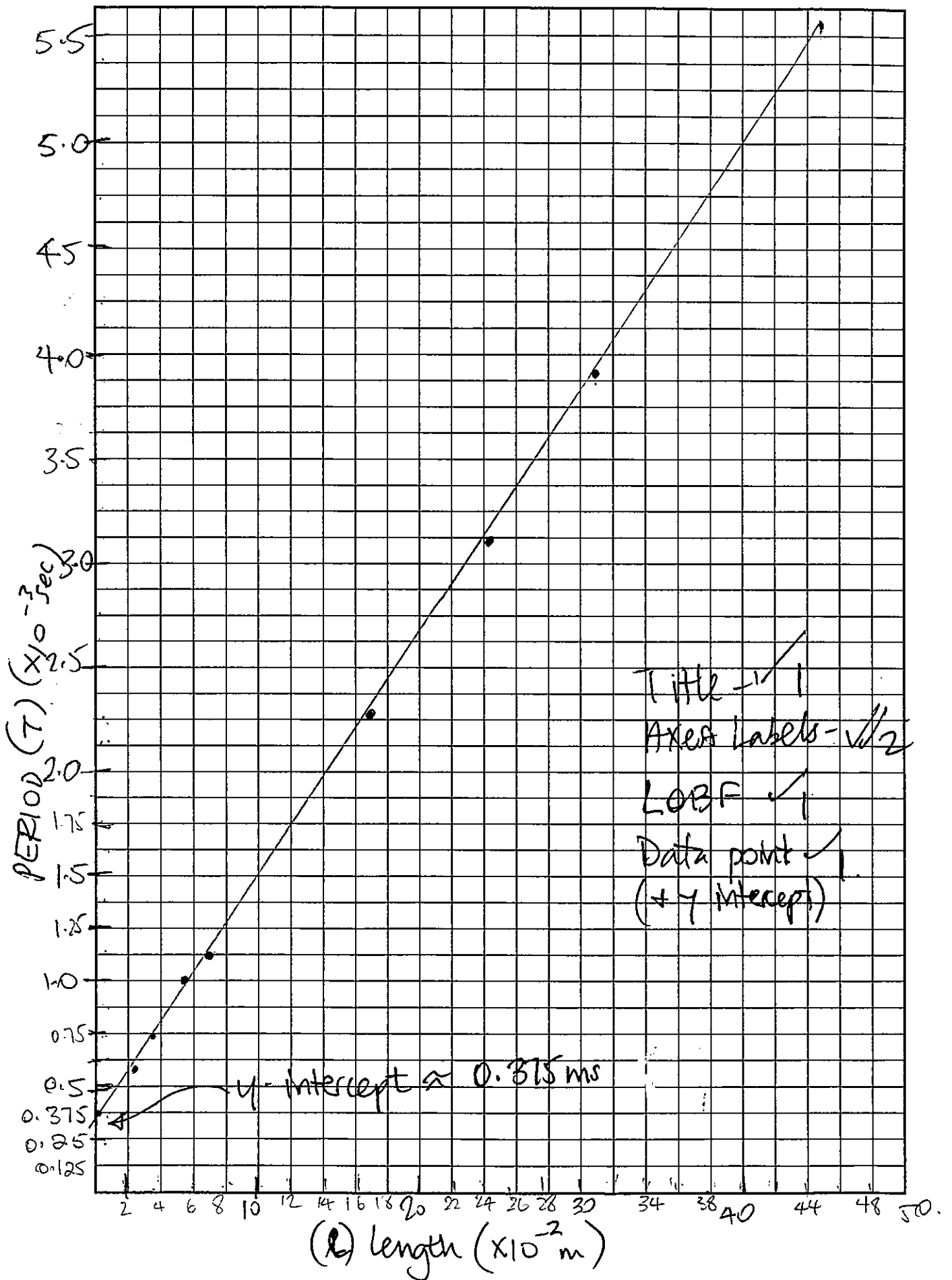
• $T = \frac{4(L+E)}{v} = b$

$= \left(\frac{4L}{v}\right) + \left(\frac{4E}{v}\right)$ straight line with $y = mx + b$ (340-350m)

$m = \frac{4}{v} \Rightarrow v = \frac{4}{m} = \frac{4}{0.011587} = 345.21 \text{ ms}^{-1}$

*If $y = \text{length}$, x-axis is Period $\Rightarrow m = \frac{4}{v} \Rightarrow v = \frac{4}{m}$

length-vs-PERIOD of vibration of air column.



- (c) "E" is the end correction of the pipe, caused when the sound doesn't reflect right at the end of the pipe, but beyond it some distance. For a cylindrical pipe closed at one end $E = 0.60r$, where r is the radius of the pipe.

Using the graph, determine the radius of the pipe that Alicia used in this investigation.

• From straight line $y = mx + b$: $\frac{1}{T} = \frac{4L}{v} + \frac{4E}{v}$
y-intercept = $\frac{4E}{v} \approx 0.375 \times 10^{-3} \text{ s}$ ← from graph
 $\therefore E = \frac{0.375 v}{4}$
 $= \frac{0.375 \cdot 345 (\times 10^{-3})}{4} = \underline{3.23 \times 10^{-2}} \text{ (3m)}$
 • Then $r = \frac{E}{0.6} = \frac{3.23 \times 10^{-2}}{0.6} = \underline{5.4 \times 10^{-2} \text{ m}} \quad [45 - 6 \text{ cm}]$

- (d) If Alicia used an open pipe with a length (L) of 45.2 cm, calculate the fundamental frequency for the resonating air column.

- From b), $v = 345.2 \text{ m s}^{-1}$.

$L = 0.452 \text{ m}$

OPEN pipe \therefore Fund. freq (f_1) = $\frac{v}{2L} \checkmark$
 $= \frac{345.2}{2 \cdot 0.452} \checkmark \quad (3\text{m})$
 $= 381.86 \text{ Hz} \checkmark$

[if use ~~open~~ ^{closed} pipe, $f = \frac{v}{4L} \Rightarrow f \approx 190 \text{ Hz} \Rightarrow \underline{1\text{m}}$]

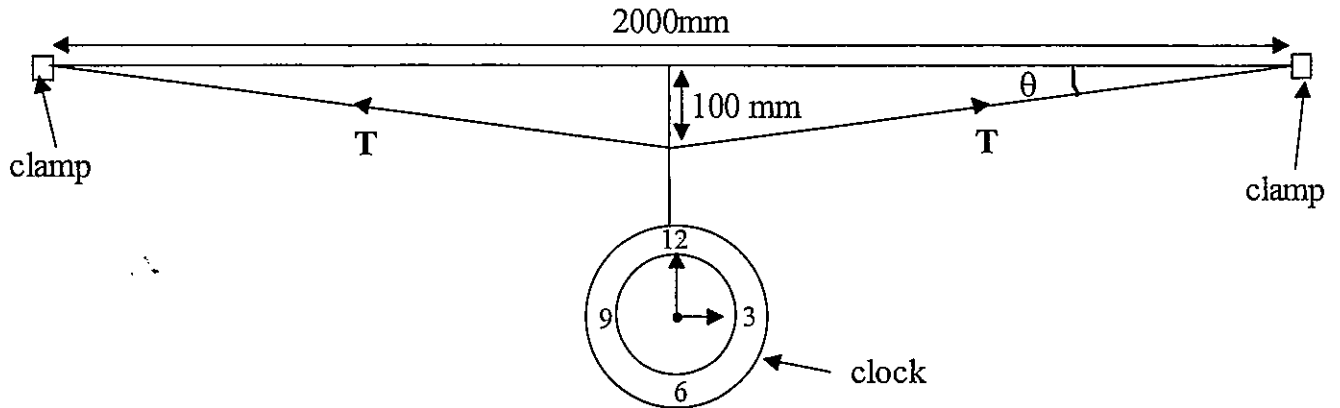
OR// use data point:

$T = \frac{1}{f} = \frac{4(L+E)v}{345}$
 $= \frac{4(0.452 + 3.23 \times 10^{-2})}{345}$
 $\approx \underline{180 \text{ Hz}} \checkmark$
 $\underline{1\text{m}}$

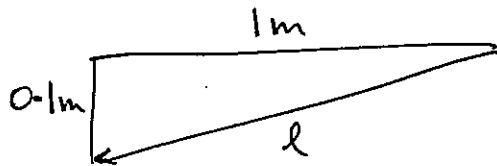
3. (13 marks)

A light steel wire is used to support a clock, in a railway station. The diagram below shows how the clock is suspended and the dimensions of the structure. Before the clock is attached to the wire, it is fixed horizontally in clamps 2 000 mm apart and is taut but may be considered to be not under tension. When the clock is attached the wire sags so its mid point is 100.0 mm below the original position.

The cross sectional area of the wire is $8.00 \times 10^{-7} \text{ m}^2$.



(a) Calculate the length of the wire when it is supporting the clock.



$$l = \sqrt{1^2 + 0.1^2} \checkmark_1$$

$$= 1.00498$$

$$\therefore \text{Total length} = 2.00996 \text{ m}$$

$$= (2.01 \text{ m}) \checkmark_2 \quad (3\text{m})$$

(b) Calculate the tension in the wire when it is supporting the clock.

$$A = 8 \times 10^{-7} \text{ m}^2$$

$$Y_{\text{steel}} = 2.1 \times 10^{11} \text{ Pa} \checkmark_1$$

$$Y = \frac{\sigma}{\epsilon}$$

$$= \frac{FL}{A \cdot \Delta L}$$

$$\text{OR} // \epsilon = \frac{0.01}{2} = 0.005.$$

$$Y = \frac{\sigma}{\epsilon}$$

$$\sigma = \frac{F}{A} \dots$$

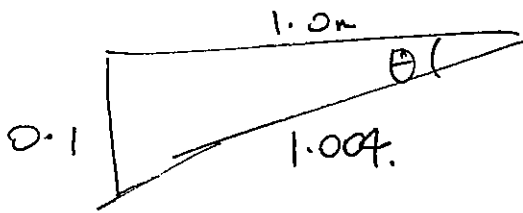
$$\therefore F = \frac{Y \cdot A \cdot \Delta L}{L} \checkmark_1$$

$$= \frac{2.1 \times 10^{11} \cdot 8 \times 10^{-7} \cdot 0.01}{2} \checkmark_1 \quad (4\text{m})$$

$$= \underline{8.40 \times 10^2 \text{ N}} \checkmark_1$$

(along wire)

- (c) Calculate the angle (θ) the wire makes with the horizontal when it is supporting the clock.



$$\tan \theta = \frac{0.1}{1}$$

$$\therefore \theta = \underline{\underline{5.71^\circ}}$$

easy!!

(3m)

- (d) Calculate the mass of the clock.

$\sum F_{up} = \sum F_{down}$
 ie $2 \cdot 840 \cdot \sin 5.71 = m \cdot g$
 $m = \frac{2 \cdot 840 \cdot \sin 5.71}{9.8}$
 "needs" \rightarrow $= 17.056 \text{ kg}$
 $= \underline{\underline{17.0 \text{ kg}}}$

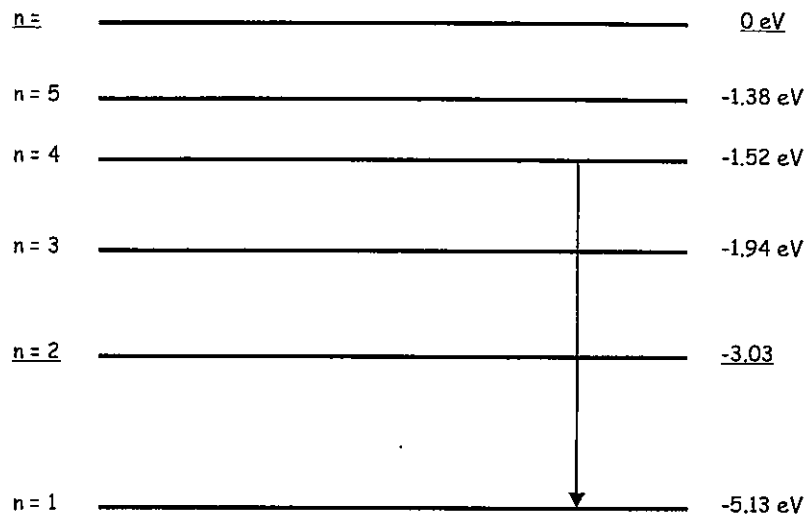
(3m)

[If $8.54 \text{ kg} \Rightarrow 2 \text{ m}$
(not used 2 cables)]

4. (14 marks)

This is an energy level diagram for an individual atom of an unknown substance. One possible electron transition is shown.

Energy Level Diagram



- (a) On the figure above draw an arrow to show one other transition which results in the emission of light of **shorter** wavelength. Label this transition S.

short $\lambda = \text{greater } E \Rightarrow$ "longer arrow"
(any o.k.) (2 m)

- (b) From $n=4$ how many electron transitions are possible which **emit** energy?

$E_4 \rightarrow E_3$ $E_3 \rightarrow E_2$ $E_2 \rightarrow E_1$ 6.
 $E_4 \rightarrow E_2$ $E_3 \rightarrow E_1$
 $E_4 \rightarrow E_1$ (2 m)

- (c) The atom fluoresces when it is bombarded with photons of ultraviolet light. The bombarding photons have a frequency of 9.05×10^{14} Hz. Between which energy levels will the electron jump? Support your answer with calculations

$$E_{\text{photon}} = \frac{hc}{\lambda} = hf = 6.63 \times 10^{-34} \times 9.05 \times 10^{14} = 6.00 \times 10^{-19} \text{ J} \checkmark \quad (\div 1.6 \times 10^{-19})$$

$$= \underline{3.75 \text{ eV}} \checkmark$$

From $E_1 (-5.13 \text{ eV})$ to $E_5 (-1.38 \text{ eV}) \Delta E = 3.75 \text{ eV}$

\therefore Transition is $E_1 \rightarrow E_5$ (4 m)

When returning to ground state, excited e^- then jumps $E_5 \rightarrow E_1$ (753 nm) then $E_2 \rightarrow E_1$ (592 nm), each transition is visible. \uparrow

- (d) What frequencies of radiation can be emitted when the excited electron mentioned in part (c) falls directly to a lower level from this excited state?

Transition	$\Delta E (E_2 - E_1)$	E (Joules)	$f = \frac{E}{h}$
$E_5 \rightarrow E_4$	0.14 eV	2.24×10^{-20}	3.38×10^{13} Hz
$E_5 \rightarrow E_3$	0.56 eV	8.96×10^{-20}	1.35×10^{14} Hz
$E_5 \rightarrow E_2$	1.65 eV	2.64×10^{-19}	3.98×10^{14} Hz
$E_5 \rightarrow E_1$	3.75 eV	6×10^{-19}	9.05×10^{14} Hz
[or - 1m each x]	↑ 1m	↑ 2m	↑ (3m) 3m

- (e) An external electron collides with the atom with an energy of 10 eV. The colliding electron causes an electron in the $n = 1$ energy level to be promoted to the $n = 4$ energy level. What is the velocity with which the original colliding electron bounces off the atom?

$$E_{\text{elect.}} = 10 \text{ eV}$$

$$\begin{aligned} \Delta E_{1 \rightarrow 4} &= 5.13 - 1.52 \\ &= \underline{3.61 \text{ eV}} \text{ absorbed to promote } e^- \end{aligned}$$

$$\begin{aligned} \therefore \text{remaining } E &= \underline{6.39 \text{ eV}} \quad (10 - 3.61) \quad (3 \text{ m}) \\ &= \underline{1.02 \times 10^{-18} \text{ J}} \text{ of KE} \end{aligned}$$

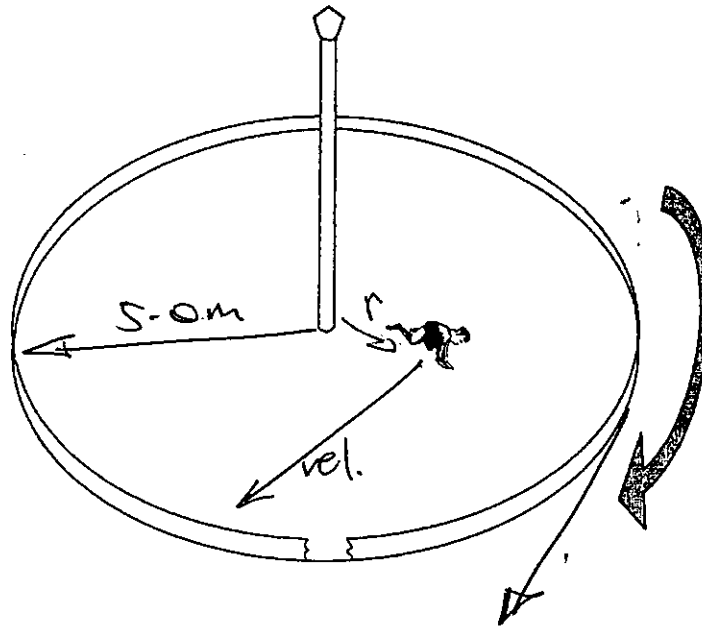
$$\begin{aligned} KE &= \frac{1}{2}mv^2 \\ v &= \sqrt{\frac{2E}{m}} \end{aligned}$$

$$= \sqrt{\frac{2 \cdot 1.02 \times 10^{-18}}{9.11 \times 10^{-31}}}$$

$$= \underline{1.50 \times 10^6 \text{ m s}^{-1}}$$

5. (12 marks)

A fun ride at the Royal Show consists of a giant disk, which rotates, in a horizontal plane. While the disk is stationary, the riders sit in the centre of the disk. When the disk is rotating at full speed, the riders must start to crawl towards the perimeter of the disk. The first rider to reach the perimeter without being flung off the disk wins a prize. The disk is rotating at a constant rate of 12.0 revolutions per minute and its radius is 5.0 m.



- (a) When the disk is rotating at full speed, one rider, who has a mass of 70.0 kg, commences to crawl towards the perimeter at a constant velocity of 0.35 m s^{-1} . Derive an expression to show the relationship between tangential velocity (ms^{-1}) and time (s) as the rider crawls towards the perimeter.

$$v = \frac{2\pi r}{T} \quad \text{and} \quad r = 0.35 \cdot t$$

(crawling)
 ($s = v \cdot t$)

$$\therefore v = \frac{(2\pi)(0.35 t)}{T} \quad \text{and} \quad f = 12 \frac{\text{r.p.m.}}{\text{min}}$$

$$\therefore T = 5 \text{ sec}$$

$$v = \frac{2.199 t}{5}$$

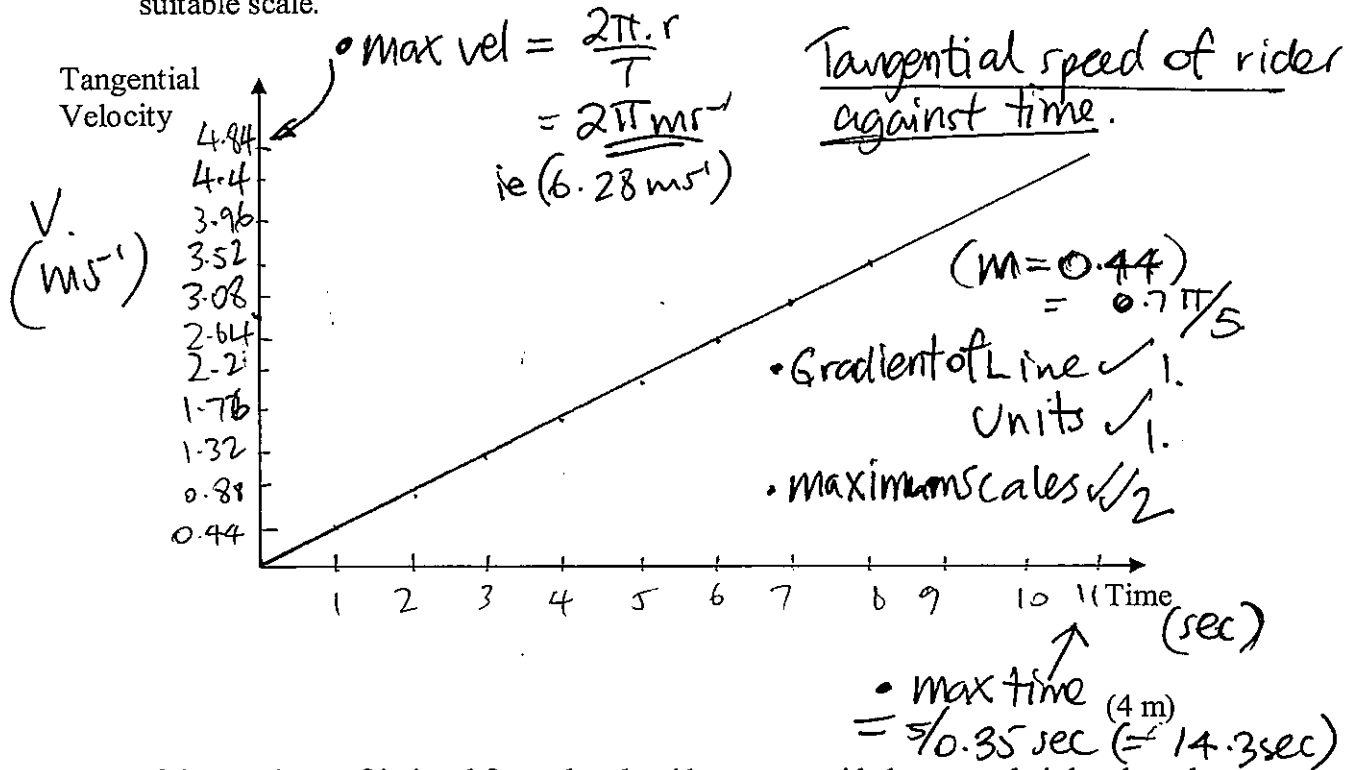
$$v = 0.4398 t$$

either OK

(4m)

$$y = mx + b$$

- (b) Using your graphics calculator, or otherwise, draw a graph on the axes below showing how the rider's tangential velocity varies with time as they crawl towards the perimeter. Your graph must be accurate and the axes must be marked clearly with a suitable scale.



- (c) If the maximum frictional force that the rider can provide between their hands and feet and the disk is 456 N, what radius will the rider reach before being flung off the disk?

$$F_{\text{max}} = \frac{mv^2}{r}$$

where $v = 0.44t$ } from (a) ✓

$$\therefore F_{\text{max}} = \frac{m \cdot v^2}{F_{\text{max}}}$$

*v must be TANGENTIAL velocity

$$0.35t = \frac{70 \cdot (0.44t)^2}{456}$$

By solver (or quadratic formula) $t = 11.79 \text{ sec}$ ✓

$$\therefore r = 0.35 \cdot 11.79$$

$$= 4.1265$$

$$\underline{\underline{4.13 \text{ m}}} \checkmark 1.$$

$$\text{IF } F = \frac{mv^2}{r}$$

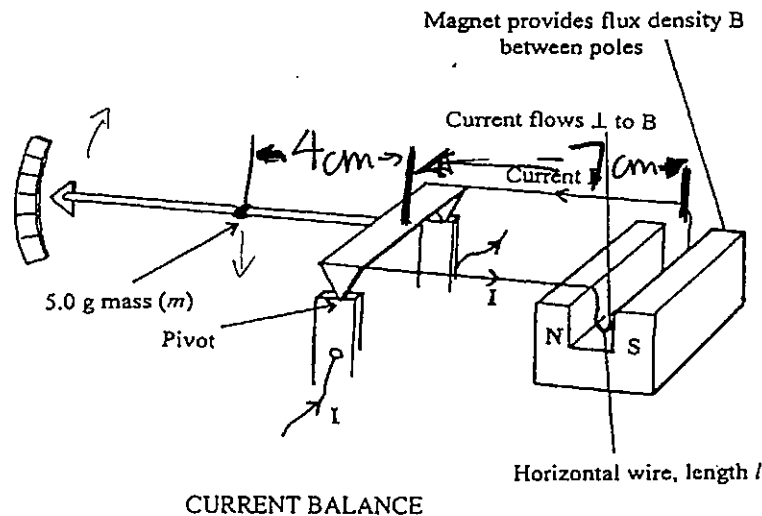
$$r = \frac{70(0.35)^2}{456}$$

$$r = 1.88 \times 10^{-2}$$

⇒ 1m

6. (16 marks)

An experiment that is done to examine the force a current carrying conductor experiences when it is placed in a magnetic field makes use of a "current balance". The diagram below shows how the magnet, current carrying wire, pivot and pointer, of negligible mass, are arranged. Before any current (I) is passed through the conductor, the pointer is adjusted to read zero (horizontal) by placing a 5.0 g mass on it, half way along the pointer.



- (a) Which way would the pointer move (up or down) when a current is passed through the conductor as shown? Explain your answer.

UP - R.H rule shows that conductor between N + S pole moves down, hence pointer moves UP

(2m)

- (b) With the current still being passed through the conductor, what adjustment could be made to the current balance to bring the pointer back to the horizontal?

- Move 5.0g mass away from pivot point.
- Increase mass, but leave position.

any ONE point

(2m)

[reverse current \Rightarrow Im]
 [reduce current \Rightarrow Im]
 [reverse magnet \Rightarrow Im]

- c) List the measurements you would need to make to be able to calculate the magnetic flux density the conductor is experiencing.

$F = B \cdot I \cdot l$ hence need to measure:

- Force on wire
- length of wire in \vec{B} field
- current thru the wire

1 each - (3m)

- (d) If the diagram on the previous page is drawn half the actual size, estimate the magnitude of the average magnetic flux density (B) between the poles of the magnet when a current of 3.0 A is carried by the conductor.

$l = 3\text{cm}$
 0.03m
 $I = 3.0\text{A}$

If Balance is "balanced"

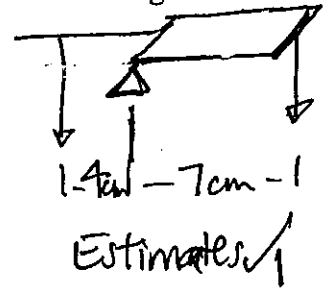
$\sum \tau_{cm} = \sum \tau_{cm} \checkmark$

$(\vec{B} \cdot I \cdot l) l = 0.005 \cdot 9.8 \cdot A$

ie $(\vec{B} \cdot 0.03 \cdot 3) \cdot 7 = 0.196\text{N}$

$= \frac{0.196}{0.63}$

$= \underline{\underline{3.11 \times 10^{-1} \text{ T}}}$ (4m)



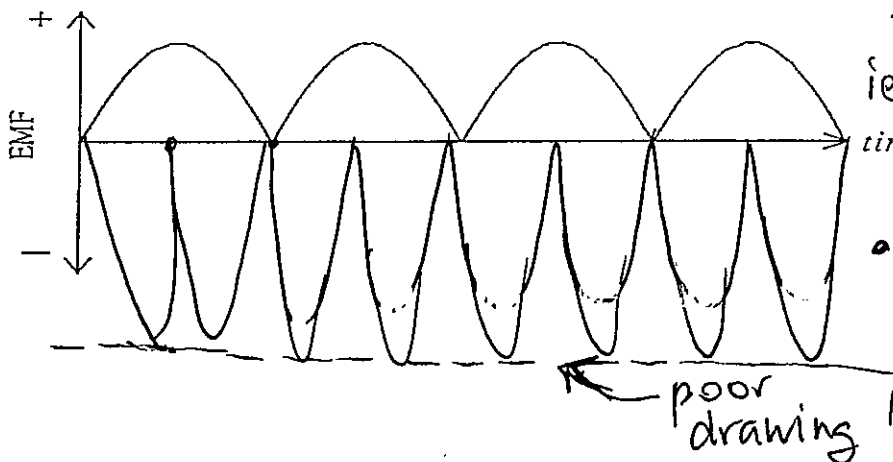
[If no moments used \Rightarrow 1m] B
 $[\approx 10^{-1} \text{ T}]$

- (e) The principle of the simple electric motor depends upon a conductor experiencing a force in a magnetic field. How can an electric motor be made to also "generate" electricity.

Conductor experiences a force, hence moves in a \vec{B} field. A conductor moving in a \vec{B} field is cutting flux, hence generating current itself (Back EMF)

(2m)

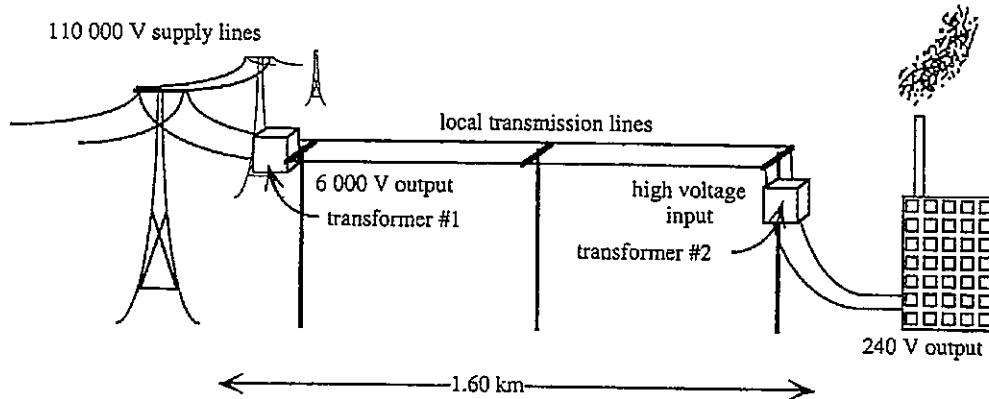
- (f) If the motor was made to "generate" electricity and an EMF was generated, a graph of the output would look like the one below. Draw on the graph of the output of the "generator" if it is turned in the reverse direction at twice the speed.



$f \times 2$
 $ie \omega \div 2$ (about)
 • EMF $\times 2$
 • sine wave
 (3m)

7. (17 marks)

Large heavy industry sites are often supplied with electrical power at high voltages which are then stepped down near the machinery which consumes the power. Such an arrangement is represented below. Here the power from the high tension wires is transformed to 6.00 kV then passed along 1.60 km of local transmission lines at this voltage before being stepped down by the second transformer to 240 V for use in the factory.



- (a) Explain fully why the two transformers are used. Why not just step down the 110 kV supply directly to 240 V at transformer number one?

Need to keep voltage as high as possible until the consumer as $P=IV$ and $P_{loss}=I^2R$, hence current must be minimized. High current means lots of line heating, \rightarrow inefficient.

(4m)

- (b) In this example the factory draws 5.00×10^5 W of power from the grid and the local supply lines have a combined resistance of $2.25 \text{ m}\Omega \text{ m}^{-1}$. How much power is lost in the local transmission wires?

$$P_{used} = 5 \times 10^5 \text{ W}$$

$$R = 2.25 \times 10^{-3} \cdot 1.6 \times 10^3$$

$$= 3.6 \Omega \text{ (total)}$$

$$P_{loss} = ?$$

Current in local trans. wires

$$= \frac{P}{V} \checkmark$$

$$= \frac{5 \times 10^5}{6000}$$

$$= 83.33 \text{ A} \checkmark$$

$$P_{loss} = I^2 R \checkmark$$

$$= (83.33)^2 \cdot 3.6$$

$$= 2.5 \times 10^4 \text{ W}$$

(6m)

[If use 2x power lines, $R_T = 7.2 \Omega \Rightarrow P_{loss} = 5 \times 10^4 \text{ W} \Rightarrow 6 \text{ m}^2$]

(c) What is the voltage drop along the lines as a percentage of that in the supply lines?

$$V_{\text{drop}} = I \cdot R \quad \checkmark$$

$$= 83.3 \cdot 3.6 \quad \checkmark$$

$$= \underline{300V} \quad \checkmark$$

$$\frac{300}{110,000} \times 100 = \underline{0.27\% \text{ drop}} \quad \checkmark$$

[2 power lines \Rightarrow 10% drop \checkmark 4m]
 If 5% (use $V = 6000V \Rightarrow 3m$)]

OR $V_{\text{drop}} = \frac{P_{\text{loss}}}{I} \quad \checkmark$

$$= \frac{2.5 \times 10^4}{83.33} \quad \checkmark$$

$$= \underline{3 \times 10^2 V} \quad \checkmark$$

$$\frac{300}{110,000} \times 100 = \underline{0.27\% \text{ drop}} \quad \checkmark$$

(4m)

(d) Describe the origin of the energy loss in the power lines, and give another example of where this may occur.

◦ Resistive heating - large currents in a conductor causing heat due to friction \checkmark

eg: - light globe filament

- Transformer cores

eg \checkmark

(3m)

Section C: Comprehension and Interpretation

Marks allotted: 40 marks out of 200 (20%)

BOTH questions should be attempted. Each question is worth 20 marks.

Read each passage carefully and answer all of the questions at the end of each passage.

You are reminded of the need for clear and concise presentation of answers. Diagrams (sketches), equations and /or numerical results should be included as appropriate.

1. *X-ray Imaging (Radiography & Fluoroscopy)*

Why is X-ray Imaging Done?

X-ray imaging is one of the fastest and easiest ways for a physician to view the internal organs and structures of the body. X-ray imaging has been available for 100 years and is an excellent tool for assessing skeletal trauma (e.g. broken bones), for diagnosing the gastro-intestinal system (digestive tract), for high resolution diagnostic imaging of the breasts (mammography), and for comprehensive imaging of the thoracic cavity including the lungs and heart. A host of other applications for x-ray imaging are also available including imaging the kidneys, teeth and jaws, and the fine structures of the ear, nose and throat. X-ray diagnostic imaging still comprises a majority of all the diagnostic procedures done on a worldwide annual basis.

X-ray imaging is also an important part of bone density measurement for the detection of osteoporosis and also plays a key role in orthopedic surgery and the treatment of sports injuries. X-ray imaging is a mainstay in the detection, diagnosis and treatment of cancer.

Conventional x-ray imaging encompasses a wide range of techniques and applications.

However, in general, x-ray imaging is broken into two major categories:

1. Radiographic imaging where a "still image" is made of a bone or organ and shown on film or on a computer screen. A radiograph may be likened to taking a picture with a 35 mm camera.
2. Fluoroscopic imaging where a "movie" is made of an organ (e.g. swallowing) and viewed on a TV monitor or computer screen.

Several types of radiography and fluoroscopy are available to image the anatomy and function of a wide variety of organs and bones. Some include:

- Angiography (imaging of the blood vessels)
- Arthrography (imaging of the joints)
- Barium x-ray (radiograph or fluoroscopy of the gastro-intestinal tract)
- Chest films (radiograph of the thoracic cavity and heart)
- Cholangiography (imaging of the bile duct)
- Cholecystography (imaging of the gall bladder)

How Does X-ray Imaging Work?

X-rays are also referred to as radiographs or roentgenograms (after W. C. Roentgen).

Conventional x-ray imaging has evolved over the past 100 years, but the basic principle is still the same as in 1895. An x-ray source is turned on and x-rays are radiated through the

body part of interest and onto a film cassette, coated with a special phosphor positioned under or behind the body part. The resulting film is then developed much like a regular photograph. It is the special energy and the wavelength of the x-rays that allow them to pass through the body part and create the image of the internal structures like the bones of the hand. As the x-rays pass through the hand, for instance, they are attenuated by the different density tissues they encounter. Bone is very dense and attenuates far more x-ray energy. It is these differences in absorption and the corresponding varying exposure level of the film that creates the images which can clearly show broken bones, clogged blood vessels, cancerous tissues and other abnormalities.

How X-rays Are Created

X-rays are created by bombarding a tungsten target with electrons inside a device known as the x-ray tube. To generate this stream of electrons inside the x-ray tube, a powerful x-ray generator first takes the regular alternating current (AC) electricity from the power line at about 120 to 480 volts and transforms it into power in the range of 35 to 150 kilovolts. When this very high voltage potential is applied to the x-ray tube, a tight beam of electrons is fired out of a small wire (called the cathode) and strikes a rotating metal disk (called the anode). When this stream of electrons hits the special metal compound of the anode (often tungsten or alloys including tungsten), it causes x-ray energy to be released from the metal's atomic structure. The x-rays produced vary in intensity and wavelength as shown in the graph below. These x-rays are often filtered and collimated (or focused) as they leave the x-ray tube. The rays pass through the body part of interest in a straight line and are then captured by an image intensifier and TV system to make the final image.

X-ray tubes are precision designed and manufactured and have evolved tremendously over the past 100 years. X-ray tubes are often the most expensive component in an x-ray system and can cost up to \$50,000 each. The x-ray tube is a glass or metal envelope with a vacuum seal inside and is encased in lead. X-ray tubes create tremendous heat while the beam of electrons is bombarding the cathode to produce x-rays. Like a light bulb, an x-ray tube requires replacement up to a few times per year, depending on use.

Questions:

1. Describe one of the applications that x-ray imaging is put to.

- Detect broken bones / diseased bone
 - Viewing internal organs function (Barium meal to check digestion)
- (Anything reasonable)

(2m)

2. Explain why in an x-ray, bone appears to be white, whilst soft tissue appears dark.

- Bone attenuates the x-rays more, so they don't reach the film / sensor. Soft tissue is more transparent, so x-rays are able to penetrate + blacken the film / detector.

(2m)

3. What is meant by the term "attenuated"?

Energy of the (X-ray) beam is absorbed more (per unit thickness) ✓✓
2

(2m)

4. Briefly explain why the anode would be rotating, rather than stationary.

Reduce heating of one section of the anode.
(→ increase efficiency)

(2m)

5. Estimate the turns ratio of the transformer in an x-ray generator.

Mains supply = 120-480V
output : 35-150 kV

USING MIN.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{38 \times 10^3}{120} = \underline{\underline{292:1}}$$

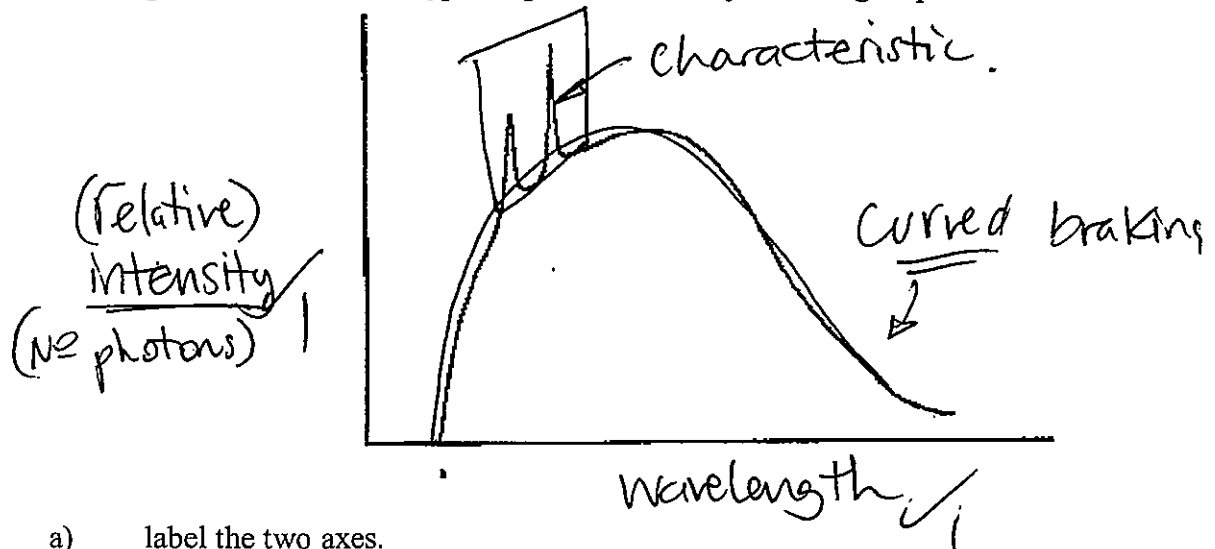
USING MAX

$$\frac{N_s}{N_p} = \frac{150 \times 10^3}{480} = \underline{\underline{312:1}}$$

↔ Either is OK ✓✓

(2m)

6. The diagram below shows a typical spectrum of x-ray wavelengths produced.



- a) label the two axes.

(2m)

- b) Clearly indicate the portion of the spectrum that is due to Bremsstrahlung (braking radiation).

main part of curved spectrum (1m)
(NOT peaks)

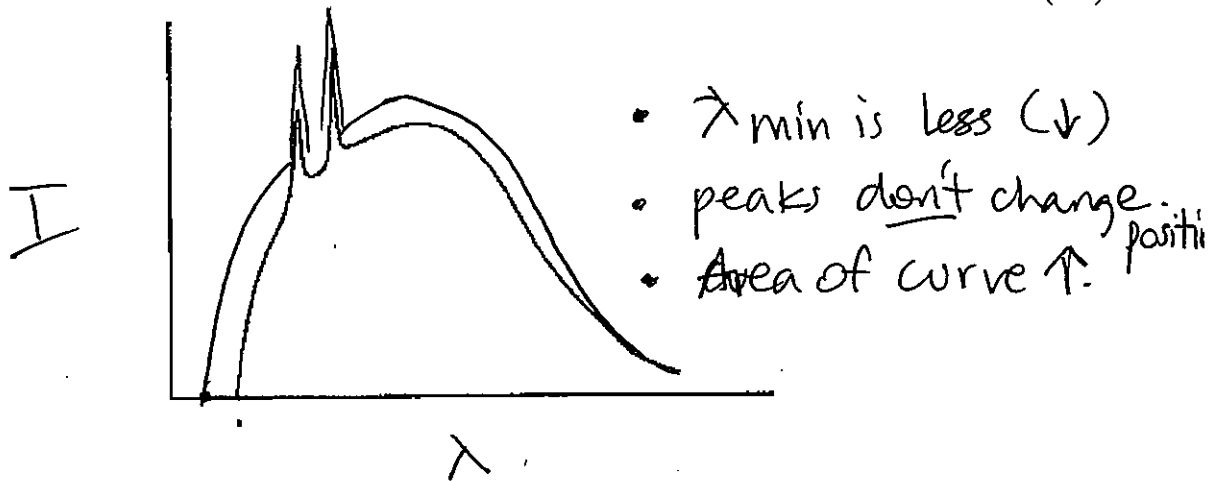
- c) Indicate on the plot the characteristic portion of the graph and briefly explain how it is produced.

Peaks ✓: inner orbital e^- is removed by accelerated tube e^- 's. An outer e^- drops down to replace it, producing light as a result. (X-rays)

(3m)

6. On the diagram below sketch in the new x-ray spectrum that would be produced if the electrons were accelerated through a greater potential difference.

(2m)



7. Calculate the velocity of electrons accelerated by a 100kV machine as they strike the rotating anode.

$$KE = \frac{1}{2}mv^2 = V \cdot q_e$$

$$\text{ie } v = \sqrt{\frac{2 \cdot V \cdot q}{m}} \quad \checkmark$$

$$= \sqrt{\frac{2 \cdot 100 \times 10^3 \cdot 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}}$$

(2m)

$$= \underline{\underline{1.87 \times 10^8 \text{ ms}^{-1}}} \quad \checkmark$$

OR

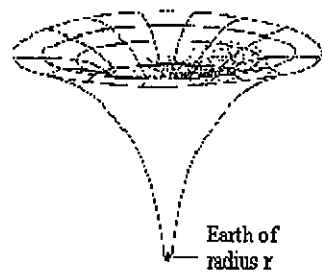
$$\begin{aligned} E &= V \cdot q \\ &= 100 \text{ keV} \\ &= \underline{\underline{1.6 \times 10^{-14} \text{ J}}} \end{aligned}$$

$$KE = \frac{1}{2}mv^2 \dots$$

2. Speed of Escape

What is often termed escape velocity from a particular planet is more accurately called the launch velocity. The speed of escape of a satellite is not what it appears to be. That is, it is not the speed of a satellite when it escapes from the Earth. Indeed, if it were possible to keep a rocket motor going for a long time, it would be possible to escape from the Earth at any speed. The escape speed of the Earth is 11.2 km s^{-1} . The time taken for astronauts going to the Moon was about 3 days.

The term escape speed is in many ways unfortunate. To begin with, it is never possible to escape from the pull of the Earth's gravitational field. If you go far enough the pull of the Earth's gravity will certainly be very small but it is not zero. The term can best be considered in conjunction with the term gravitational well. This is illustrated in the diagram opposite where the gravitational potential is plotted on a three-dimensional sketch and shows how the potential falls as the Earth is approached.



A sketch of the gravitational potential well of the earth

The potential goes on rising forever as the distance from the Earth increases, but the slope gets less and less. The depth of the gravitational potential well is GM/r . Now consider a piece of matter, stationary relative to the Earth and a long way from it. It is pulled very gently by the Earth and accelerates towards the Earth a little. As it approaches the Earth it gets faster and faster and will eventually collide with the Earth. Its speed on collision is the escape speed, because if it bounced perfectly back off the Earth it would retrace its path and just stop when it was a great distance from the Earth. If only the journey outward from the Earth is considered it is possible to think of the escape speed as the speed needed at the Earth, if something is to be thrown off the Earth.

The speed of an object when it is thrown upwards does, of course, fall as it rises. A rocket at the Earth, moving upwards at 11.2 km s^{-1} , will gradually slow down as it rises and will just have enough kinetic energy to reach the top of the gravitational well. A similar rocket travelling at only 10 km s^{-1} does not have enough kinetic energy to reach the top of the gravitational well, and so will eventually fall backwards. One with an upward speed of 12 km s^{-1} has more than enough kinetic energy and so will have some kinetic energy remaining when it has reached the top of the gravitational well.

The escape speed can be obtained by realising that the kinetic energy the mass must have at the Earth's surface needs to be equal to the gain in the potential energy in escaping from the gravitational well.

Working with a mass of 1, we get:

Kinetic energy per unit mass = gain in potential in leaving gravitational well

$$\frac{1}{2} m v^2 = \frac{GM}{r} \times m$$

Questions

1. Why does a rocket moving upwards at an initial speed of 11.2 km s^{-1} gradually slow down?

Gravity! — Acceleration is down, hence
velocity ↓.

(2 m)

2. Why is it **illogical** to talk about the “velocity of escape” from the gravity of a planet?

It is impossible to completely escape the
gravitational field of a planet/body.

(1 m)

3. When matter approaches the Earth its potential gets smaller. Why does the potential get smaller?

• $PE = mgh$, and h is decreasing.

(Getting closer to centre of earth)

OR/• KE increases, hence PE decreases. E_{TOTAL} is constant.

(2 m)

4. Examine the diagram of the gravitational potential well. Why is the well represented with sloping sides rather than straight sides? Use an equation to support your answer.

$$PE = mgh, \text{ but } g = \frac{GM}{r^2}$$

∴ $PE \propto \frac{1}{r^2}$, giving sloping, not straight
sides

(2m)

5. (a) Calculate the average speed for astronauts going to the moon.

$$E \rightarrow \text{moon dist} \\ = 3.84 \times 10^8 \text{ m}$$

$$t = 3 \text{ days} \\ = 3 \cdot 24 \cdot 60 \cdot 60 \\ = 2.592 \times 10^5 \text{ sec}$$

$$V_{av} = \frac{s}{t} \\ = \frac{3.84 \times 10^8}{2.592 \times 10^5} \\ = 1.48 \times 10^3 \text{ m s}^{-1}$$

(2 m)

- (b) Would the average speed calculated in (a) be large enough to escape the Earth's pull and get to the Moon? Explain your answer.

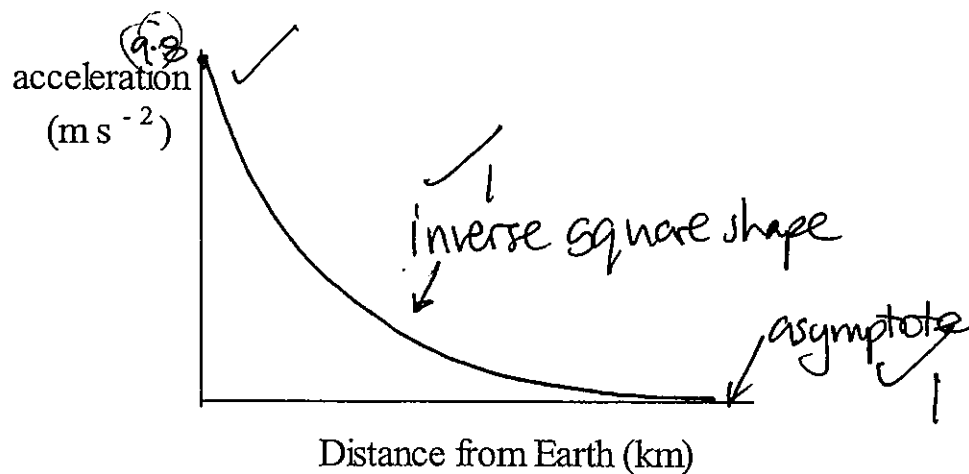
$$\text{escape vel. (Earth)} = 11.2 \text{ km s}^{-1}$$

$$\text{and } 1.48 < 11.2 \text{ km s}^{-1} \\ \therefore \text{NO}$$

reason
2

(3 m)

6. On the axis below sketch a graph to show how a body would be accelerated from a stationary position at the top of the gravitational well to when it struck the surface of the Earth. Label the axis with any relevant values and explain its mathematical shape



$$a = \frac{Gm}{r^2} \therefore a \propto \frac{1}{r^2}$$

(3 m)

7. Using the expression:

Kinetic energy per unit mass = gain in potential in leaving gravitational well

$$\frac{1}{2} m v^2 = \frac{GM}{r} \times m$$

show, step by step, that the escape speed v is $(2rg)^{1/2}$

$$\frac{1}{2} m v^2 = \frac{GMm}{r}$$

$$\text{ie } v^2 = \frac{2 \cdot GM}{r} \quad \text{--- (1) } \checkmark$$

$$\text{* but } g = \frac{GM}{r^2}, \text{ so sub into (1) } \rightarrow \checkmark$$

$$v^2 = 2 \cdot g \cdot r$$

$$\therefore v = \sqrt{(2 \cdot g \cdot r)} \quad \checkmark \checkmark$$

(3 m)

8. a) What type of collision would be referred to in the phrase "if it bounced perfectly back off the Earth"

Elastic collision

(1 m)

b) What is conserved in this type of collision?

Kinetic Energy.

(no loss to heat, light, sound, etc)

(1 m)

[Just "Energy" \rightarrow 0m]

END OF EXAMINATION