SECTION TWO: Problem-solving 50% (90 marks)

This section has **six (6)** questions. Answer **all** questions. Write your answers in the spaces provided.

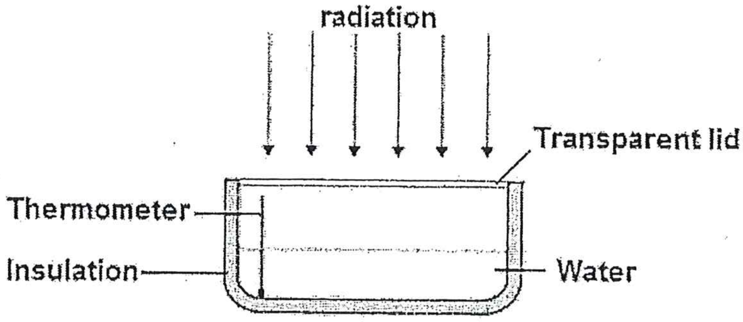
Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Suggested working time: 90 minutes.

Question 16 (14 marks)

Amandeep is conducting an experiment to find out how much energy from the Sun is striking (hitting) the Earth's surface in Perth. He put an insulated tray, containing 155 g of water in direct sunlight. The apparatus that he used is shown below. The tray had an area of 122 cm^2. Assume that the tray has almost no mass.



Amandeep found that the temperature of the water increased by 1.5° C after 17 minutes of heating by the sun.

(a) Find amount of solar energy absorbed by the water in the 17 minutes. (3 marks)

$Q = mc\Delta t$ (1)

$= 0.155 \times 4180 \times 1.5$ (1)

$= 971.85$

$= 972$ J (1)

WATCH C.O

MINUS (1) MARK IF MASS NOT IN kg.

(b) Show that the solar power incident on the tray was approximately 950 mW. (2 marks)

$P = \frac{E}{t} = \frac{Q}{t} = \frac{971.85}{17 \times 60}$ (1)

$= 0.9527$

$= 953$ mW (1) ≈ 950 mW

IF INCORRECT VALUE (J) CARRIES OVER, BUT CORRECT METHOD ⇒ NO MARK PENALTY.

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WATCH C.O

(c) Find the intensity of the sun's radiation in Wm^{-2}. (2 marks)

STUDENTS CAN INTERPRETE FORMULA FROM UNITS.

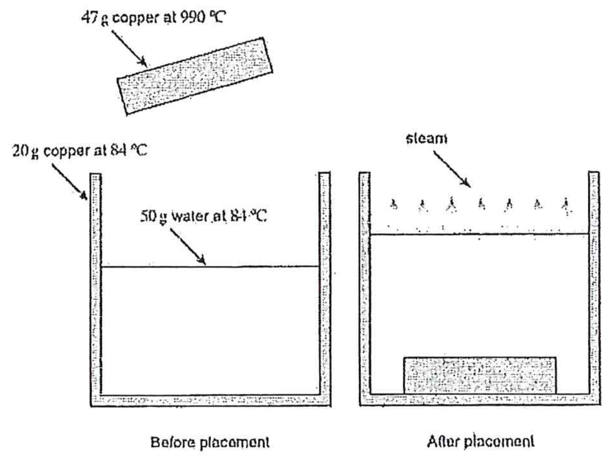
$\text{INTENSITY} = \frac{P}{A}$

$= \frac{0.9527\ W}{122 \times 10^{-4}\ m^2}$ ① $= 78.09$

$= 78.1\ Wm^{-2}$ ①

(-1) ONLY IF $cm^2 \Rightarrow m^2$ IS INCORRECT.

Sze Ching is conducting another experiment in Physics. She is using a 20 g insulated copper calorimeter that contains 50 g of water at 84° C. She then places a 47 g block of copper at 990° C into the water. The water heats rapidly to 100°C and some water is converted into steam. The apparatus is shown below. Assume that the specific heat of copper is 385 J $kg^{-1}K^{-1}$



(d) Find the amount of heat lost by the copper block as it cooled to 100° C. (2 marks)

MINUS ① MARK ONLY IF MASS IN GRAMS OR Δt INCORRECT

$Q_L = mc\Delta t$

$= 0.047 \times 385 \times 890$ ①

$= 1.6104 \times 10^4$

$= 1.61 \times 10^4\ J$ OR $16.1\ kJ$ ①

990°C – 100°C: $\Delta t = 890°C$

(e) Find the amount of heat absorbed by the water and copper container as their temperature is raised to 100° C and hence the amount of energy available from the block to produce steam. (3 marks)

C.O

$Q_{L\,BLOCK} = Q_{G\,WATER + CAN}$

$\Rightarrow Q_L = (m_W c_W \Delta t) + (m_{Cu} c_{Cu} \Delta t)$

$\Rightarrow (50 \times 10^{-3} \times 4180 \times 16) + (20 \times 10^{-3} \times 385 \times 16)$ ① [3344] [123.2]

$= 3467.2\ J = 3.467 \times 10^3\ J$ ①

100°C – 84°C: $\Delta t = 16.0°C$

#See 16(f) over the page.

NOW $Q_{AVAIL} = 1.6104 \times 10^4 - 3.467 \times 10^3$

$= 1.263 \times 10^4 = 1.26 \times 10^4\ J$ ①

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(f) Find the mass of steam produced. (2 marks)

WATCH C.O!

$Q = mL_v$

$\therefore m = \frac{Q}{L_v}$

$= \frac{1.263 \times 10^4}{2.26 \times 10^6}$ (1)

$= 5.588 \times 10^{-3}$

$= 5.59 \times 10^{-3}$ kg

OR 5.59 g (1)

NO PENALTY IF CORRECT METHOD!

/2

Question 17 **(16 marks)**

(a) Uranium-238 consists of 92 protons and 146 neutrons. The mass of a U-238 nucleus is less than the sum of the masses of its protons and neutrons. Explain why. (2 marks)

THE MASS CAN BE CONVERTED INTO ENERGY AND IS KNOWN AS THE MASS DEFECT.

NOTE – "BINDING ENERGY" IS THE ENERGY REQUIRED TO PULL A NUCLEUS APART

(b) When a rod of Uranium-238 is placed in the core of a nuclear reactor, it absorbs a neutron and decays to Neptunium-239. The Neptunium-239 then decays to Plutonium-239. In the space below, show the two nuclear equations that represent the above reactions. (4 marks)

$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{93}Np + ^{0}_{-1}e$ OR $^{0}_{-1}\beta$

$^{239}_{93}Np \rightarrow ^{239}_{94}Pu + ^{0}_{-1}e$

(−1) MARK FOR EACH INCORRECT SPECIES

(c) (i) Find the energy released when one nucleus of Uranium-238 decays to Neptunium-239. Express your answer in MeV. (3 marks)

The following data will assist in this calculation:

Mass of U-238:	238.05078 u
Mass of Np-239:	239.05293 u
Mass of Pu-239:	239.05216 u
Mass of beta particle:	0.00054858 u
Mass of neutron:	1.008664 u

$\Delta m = m_r - m_p$

Σ MASS REACTANTS

$^{238}U = 238.05078u$

$n = 1.008664$

$= 239.059444u$ (1)

Σ MASS PRODUCTS

$^{239}Pu = 239.05293u$

$^{0}_{-1}\beta = 0.00054858$

$= 239.0534786$ (1)

Now $\Delta m = 239.059444 - 239.0534786$

$= 5.96542 \times 10^{-3} u$

⇒ MeV $= 5.96542 \times 10^{-3} \times 931$

$= 5.55$ MeV (1)

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(WATCH C.O) MeV FOR 1 DECAY ONLY

(ii) Given that 1 kg of Uranium-238 contains 2.52 x 10^{24} atoms, find the energy released by 1 kg of Uranium-238 decaying to Neptunium-239. Express your answer in J.

(2 marks)

$E_{1kg} = 5.5538 \times 2.52 \times 10^{24}$

$= 1.399559 \times 10^{25}$ MeV (1)

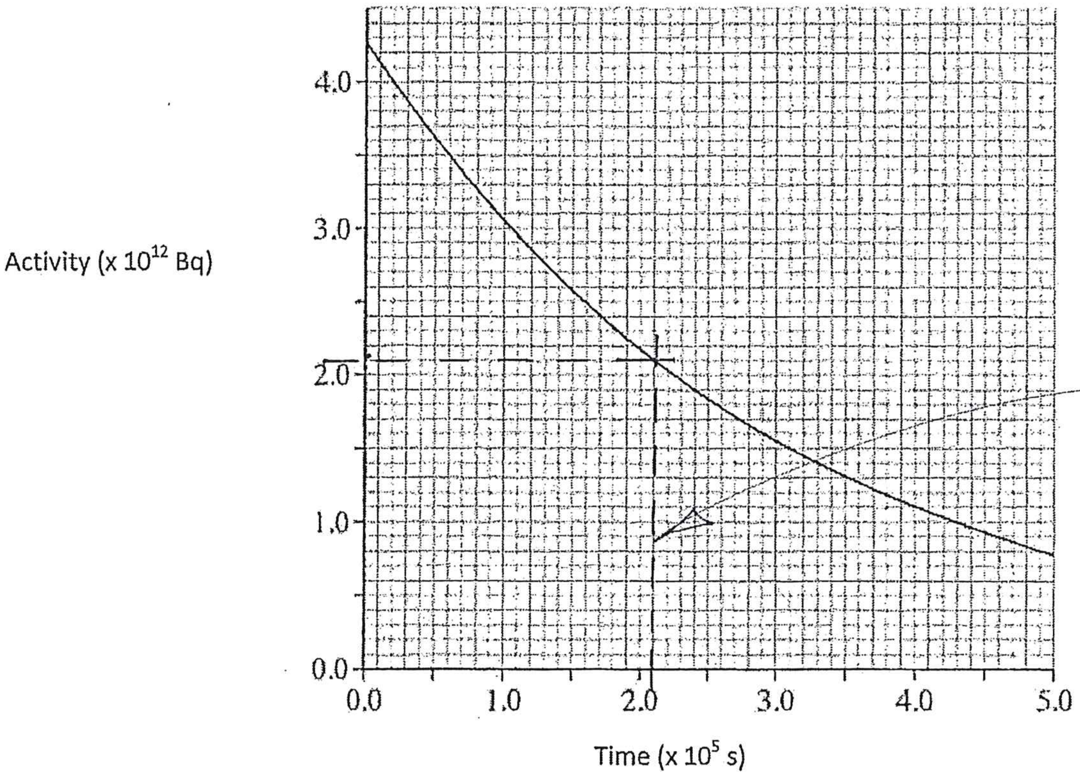
IF $\times 10^{-19}$ MINUS (1) MARK ONLY

Now MeV ⇒ J

$E_J = 1.399559 \times 10^{25} \times 1.6 \times 10^{-13}$ J

$= 2.24 \times 10^{12}$ J (1)

A sample of the nuclear fuel rod is removed from the reactor core and its radioactivity is monitored over time. The activity from t = 0, to t = 5 x 10^5 s is shown below. You may assume that the Uranium-238 decays almost instantly and that the activity in the figure below comes only from the decay of Neptunium.



NO CONSTRUCT LINES = (−1)

(d) Use the graph above to state the half-life for the decay of the Neptunium. Show construction lines on the graph above to show how the half life was determined.

(2 marks)

The half life is 2.1×10^5 s [± 0.1×10^5 s]

(e) Find the activity of the Neptunium after 25 days.

(3 marks)

FOR (n)

$n = \frac{t}{H.L}$

$= \frac{25 \times 24 \times 3600}{2.1 \times 10^5}$

$= 10.285$ (1) [ACCEPT n = 10 → 11]

FOR ACTIVITY

$A = N_0 \frac{1}{2}^n$ (1)

$= 4.25 \times 10^{12} \times (0.5)^{10.285}$

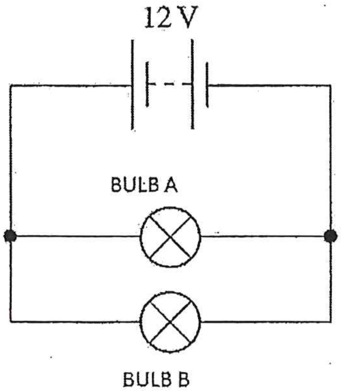
$= 3.42 \times 10^9$ Bq

ACCEPT [1.9×10^9 Bq (n = 11) TO 4.2×10^9 Bq (n = 10)]

7/7

Question 18 **(16 marks)**

Two light bulbs are connected in parallel to a 12 V battery as shown below. Bulb A is rated at 12 V, 20 W and bulb B is rated at 12 V, 5 W.



(a) Show that the resistances of bulb A and bulb B are 7.2 Ω and 28.8 Ω respectively. (2 marks)

① $P = VI$

② $I = \frac{V}{R}$

② → ① ⇒ $R = \frac{V^2}{P}$

$R_A = \frac{V^2}{P} = \frac{12^2}{20} = 7.20\,\Omega$ ①

$R_B = \frac{12^2}{5} = 28.8\,\Omega$ ①

WATCH C.O

(b) Find the total current flowing through bulb B . (2 marks)

$I_B = \frac{V}{R_B} = \frac{12}{28.8}$ ①

$= 0.416\dot{6}$ ①

$= 0.417\text{ A}$ or 417 mA

(c) Find the total current flowing from the battery (2 marks)

$I_{TOT} = I_B + I_A$

where $I_A = \frac{12}{7.20} = 1.66\dot{6}\text{ A}$ ①

$\therefore I_{TOT} = 0.417 + 1.666 = 2.083 = 2.08\text{ A}$ ①

or

OR $\frac{1}{R_T} = \frac{1}{28.8} + \frac{1}{7.218} \Rightarrow R_{TOT} = 5.7603\,\Omega$ ①

AND $I = \frac{V}{R} = \frac{12}{5.7603} = 2.08\text{ A}$ ①

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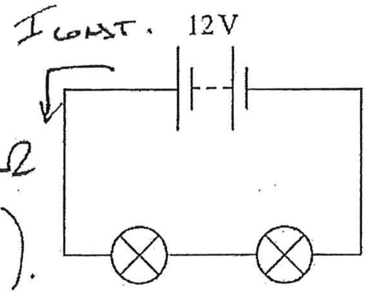
The circuit is re-arranged so that bulb A and bulb B are connected as shown below

I CONST.



R_{TOT} (PARALLEL) = 5.76 Ω (FROM PREV. CALC).

$R_{TOT} = R_A + R_B = 7.2 + 28.8 = 36.0\ \Omega$

(d) Explain why both bulbs are observed to glow less brightly in this configuration. (2 marks)

- R_{TOT} SERIES > R_{TOT} PARALLEL (½) [NO CALC. NECESSARY]
- THE CURRENT FLOWING IN EACH RESISTOR IS LESS (FROM $V = IR$) (½)
- FROM $P = VI$ OR $P = I^2R$, ↓I ⇒ ↓P ⇒ ↓BRIGHTNESS (1)

(e) Which of the bulbs will be brightest when they are connected in series as shown above? Justify your answer with suitable calculations. (4 marks)

STUDENTS CAN SHOW CALCS. WITH EITHER

Light Bulb A or B (circle) will be the brightest. (1)

Justification.....

- BRIGHTNESS ∝ $P = VI$ (OR $P = I^2R$)
- BULB 'B' WILL HAVE THE GREATEST V VOLTAGE DROP AND HENCE THE LARGEST POWER DISSIPATED i.e. ↑P = ↑V I_{CONST} (1)
- I = CONSTANT IN A SERIES CIRCUIT.

FOR VOLTAGE DROPS ACROSS R_A AND R_B

$I_{TOT} = \frac{V_{TOT}}{R_{TOT}} = \frac{12}{7.2 + 28.8} = 0.33\ A$ AND $P_A = VI = 2.4 \times 0.33 = 0.8\ W$ (1)

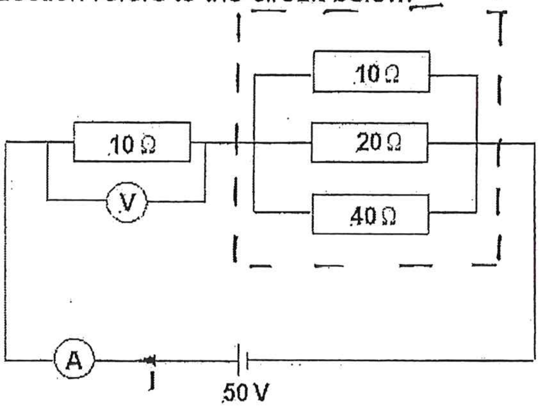
$V_A = IR = 0.333 \times 7.2 = 2.4\ V$

$V_B = 0.333 \times 28.8 = 9.59\ V$

$P_B = 9.59 \times 0.33 = 3.16\ W$ (1)

6

(e cont). The rest of this question refers to the circuit below.



(f) Find the reading on the ammeter in the circuit. (2 marks)

FIRSTLY, FIND $R_{//}$

$\frac{1}{R_{//}} = \frac{1}{10} + \frac{1}{20} + \frac{1}{40}$

$= \frac{4+2+1}{40}$

$\therefore R_{//} = \frac{40}{7}$

$= 5.714$ (½)

NOW $R_{TOT} = 10\Omega + R_{//}$

$= 10 + 5.714$

$= 15.714\,\Omega$ (½)

AND... $I_{TOT} = \frac{V_{TOT}}{R_{TOT}}$

$= \frac{50}{15.714}$

$= 3.18\,A$ (1)

(g) Find the reading on the voltmeter in the circuit. (2 marks)

WATCH C.O

$V_{10\Omega} = I_{TOT} R_{10\Omega}$

$= 3.18 \times 10$ (1)

$= 31.8\,V$ (1)

4

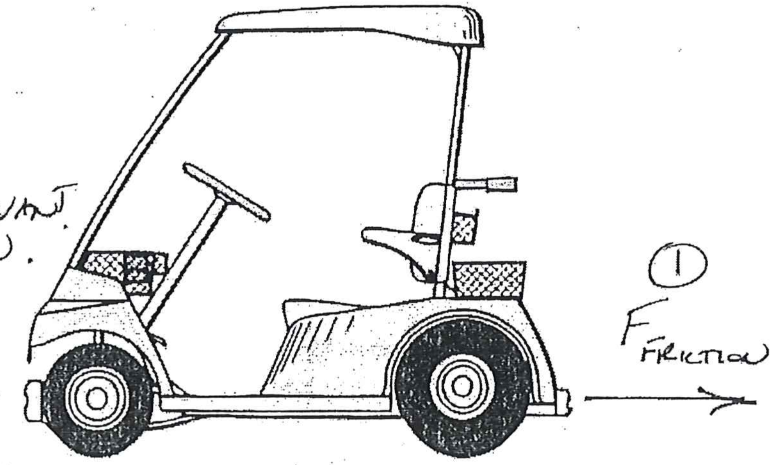
Question 19 **(18 marks)**

The following data refers to the electric vehicle shown below.

Mass of empty vehicle: 525 kg
Maximum speed: 10 kmh^{-1}
Battery voltage: 24 V

* LENGTH OF ARROWS NOT RELEVANT FOR THIS QUESTION. (1)

F_{THRUST}



Mr Dopson's electric car is being driven by a 92 kg man. The car is observed to take 4.4 seconds to accelerate from rest to its top speed.

(a) Find the acceleration of the vehicle in m s^{-2}. (2 marks)

$V = 10\ kmh^{-1} \Rightarrow 2.77\ ms^{-1}$

$a = \frac{v-u}{t}$ (½)

$= \frac{2.777-0}{4.4}$ (½)

$= 0.631\ ms^{-2}$ (1)

(−1) IF V LEFT IN kmh^{-1}

C.O.

(b) Find the distance covered by the vehicle while accelerating to its top speed. (2 marks)

$s = ut + \frac{1}{2}at^2$ (½)

$= 0.5 \times 0.631 (4.4)^2$ (½)

$= 6.108$

$= 6.11\ m$ (1)

OR

$v^2 = u^2 + 2as$ (½)

$s = \frac{v^2 - u^2}{2a}$

$= \frac{(2.777)^2}{2 \times 0.631}$ (½)

$= 6.11\ m$ (1)

4

(c) Find the net force acting on the vehicle whilst accelerating. (2marks)

WATCH C.O

WORKS

$m_{TOT} = 525 + 92 = 617 kg$

$F_{NET} = m_{TOT} a$ (½)

$= 617 \times 0.631$ (½)

$= 389.32$

$= 389 N$ (1)

−1 IF 525kg

(d) On the diagram of Mr Dopson's electric car on the previous page, draw clearly labelled arrows to show any horizontal forces acting during the car's acceleration. (2 marks)

NOTE $F_{THRUST} > F_f$, BUT VECTORS WERE NOT ASKED SPECIFICALLY, TO BE DRAWN.

It is found that the car's electric motor provides 500 watts of power while the car is travelling at its top speed on level ground.

(e) Explain why the motor needs to provide power although the car is not accelerating. (2 marks)

THE MOTOR IS DOING WORK TO OVERCOME FRICTION. (2) OR THE MOTOR PROVIDES A THRUST TO OVERCOME FRICTION (AIR & ROLLING RESISTANCE)

(f) Find the power provided by the motor while the car was accelerating. (4 marks)
You may assume that the force of friction was constant for the whole time that the car was accelerating and the force of friction has the same magnitude as when the car is travelling at top speed on level ground.

→ OR $P_f = 500 W + 540.62 = 791 W$

FOR AV. FRICTION

$F_f = \frac{P_f}{V} = \frac{500}{2.777} = 180.05 N$ (1)

AND ... FOR POWER TO ACCELERATE VEHICLE.

$P_{ACCEL} = \frac{F_{NET} \cdot s}{t}$

$= \frac{389.32 \times 6.11}{4.4}$ (1)

$= 540.62$

NOW, FOR POWER REQUIRED TO OVERCOME FRICTION ONLY

$P_f = \frac{F_f s}{t}$

$= \frac{180.05 \times 6.11}{4.4} = 250.02 W$ (1)

THUS ...

$P_{TOT} = P_{ACCEL} + P_f$

$= 540.62 + 250.02$

$= 791 W$ (1)

SEE ALTERNATE METHOD OVER.

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Q19f. FOR POWER – TOTAL (ALTERNATE METHOD)

$$P_{TOT} = \frac{F_{TOT} \cdot S}{t}$$

$$F_f = \frac{P_f}{V} = \frac{500}{2.777} = 180.05N \quad (1)$$

$$= \frac{(F_{ACCEL} + F_f) \cdot S}{t} \quad (1)$$

$$= \frac{(389.32 + 180.505)\ 6.11}{4.4} \quad (1)$$

$$= 791\ W \quad (1)$$

SEE TYPED ANSWER SHEET FOR OTHER METHODS

(2) MARKS ONLY IF ...

OR $P = F_V$ $\quad P = \frac{W}{t} = \frac{mas}{t}$ (1) $\quad$ OR $P = \frac{Fs}{t}$ OR $P = \frac{\Delta E_K}{t}$ ✓

$$= \frac{617 \times 0.631 \times 6.11}{4.4}$$

$$= 539\ W \quad (1)$$

THIS IS THE POWER REQUI[RED] NOT TAKING FRICTION INTO ACCOUNT!!

(g) During a typical 18 hole game of golf, the car's motor operates for 40 minutes. Assuming that the average power output of the motor for the course is 6750 W, find the total energy provided by the motor in joules. (2 marks)

$E = Pt$ (½)

$= 6.75\times10^{3} \times 40 \times 60$ (½)

$= 1.62\times10^{7}$ J (1)

(h) The battery is then recharged with a 1.5 A battery charger. Find the time it takes to recharge the battery after the day's use. (2 marks)

$E = Pt$

$E = VIt$ (½)

$\therefore t = \frac{E}{VI}$

$= \frac{1.62\times10^{7}}{24\times1.5}$ (½)

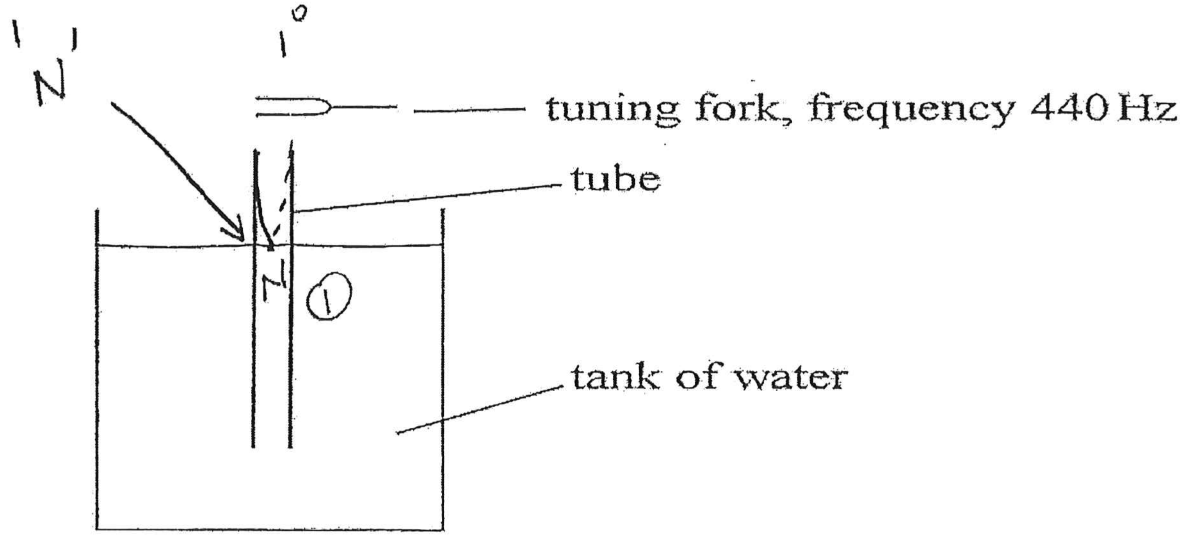
$= \frac{1.62\times10^{7}}{36}$

$= 4.50\times10^{5}$ sec (1) (125 HRS!)

/4

Question 20 **(13 marks)**

An experiment is being carried out to estimate the speed of sound. The equipment used is shown below.



A hollow tube is placed vertically in a tank of water, until the top of the tube is just at the surface of the water. A tuning fork of frequency 440Hz is sounded above the tube. The tube is slowly raised out of the water until the loudness of the sound reaches a maximum for the first time, due to the formation of a standing wave.

AIR COLUMN RESONATES WITH TUNING FORK ⇒ (½) ONLY

(a) Explain how the standing wave is formed in the tube. (2 marks)

✓ = ½ MARK

• TWO WAVES 180° OUT OF PHASE WITH THE SAME FREQUENCY ✓ TRAVEL IN OPPOSITE DIRECTIONS IN THE AIR COLUMN IN THE TUBE AND INTERFERE ✓ WITH EACH OTHER TO FORM PARTICLE DISPL. NODES AND ANTINODES. ✓

It is found that when the tube is raised an extra 37 cm, the sound at the opening reaches a maximum for the second time.

(b) Label with an "N" the point in the tube which is always a displacement node during this experiment. (1 mark)

(c) Using the information provided on the previous page, estimate the speed of sound. Show all working. (3 marks)

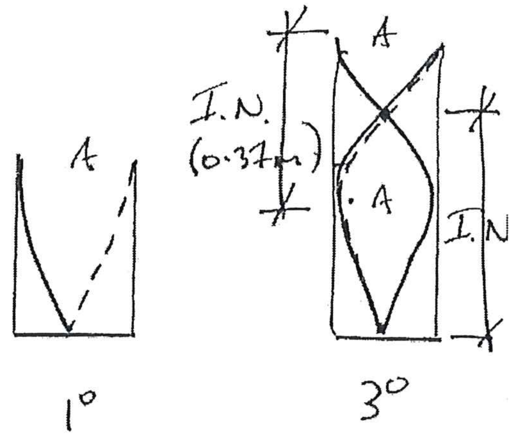
$v = f\lambda$

FIRSTLY, FIND (λ)

INTERNODAL DIST. = $\frac{1}{2}\lambda$ (1)

$\therefore \lambda = 2 \times 0.37$

$= 0.74\text{m}$ (1)



NOW $v = f\lambda$ (½)

$= 440 \times 0.74$

$= 325.6$

$= 326\ \text{ms}^{-1}$ (½)

OR $f = \frac{nV}{4L}$ (½)

$\lambda_n = \frac{4L}{n}$ (½)

$L = 1\frac{1}{2} \times$ THE INTERNODAL DISTANCE. SEE DIAGRAMS ABOVE,

$\therefore V = \frac{f \cdot 4L}{3}$

$= \frac{440 \times 4 \times (1.5)(0.37)}{3}$ (½)

$= 326\ \text{ms}^{-1}$ (1)

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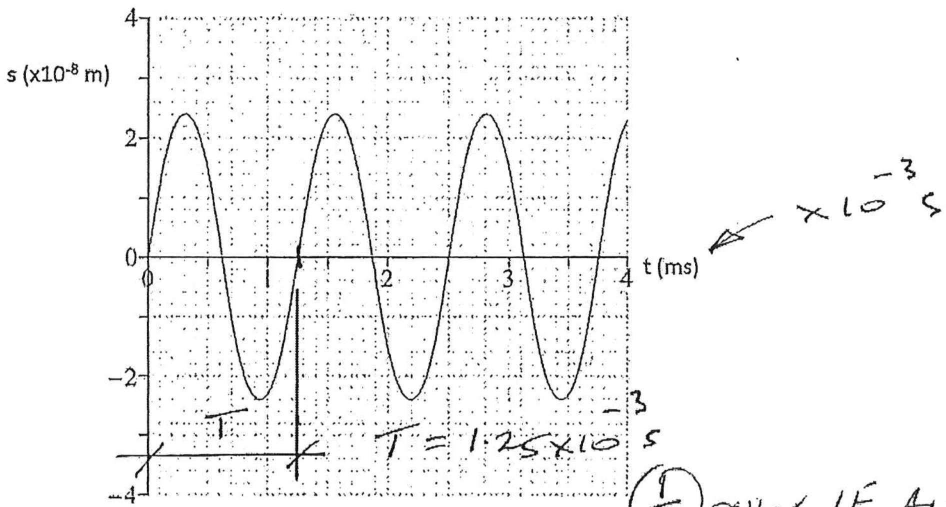
A standing wave is established in a tube **open at both ends**. Point A shows the position of an air particle at one of the open ends.

The graph below shows how the position of point A varies with time.



(½) ONLY IF ANTINODE AT END OF OPEN PIPE.

(d) Is point A a displacement node or antinode? Explain. (2 marks)

(1) ANTINODE. PARTICLES (VIBRATE / OSCILLATE) (1) TO THE LEFT AND RIGHT OVER TIME AT POINT 'A'.

(e) What is the frequency and wavelength of the standing wave? (3 marks)

FROM (c) OR DATA SHEET.

$T = \frac{1}{f}$

$\therefore f = \frac{1}{1.25 \times 10^{-3}}$ (1)

$= 800 \text{ Hz}$ (1)

NOW $v = f\lambda$

$\therefore \lambda = \frac{v}{f} = \frac{346}{800}$

$= 0.4325$

$= 0.433 \text{ m}$ (1)

(f) The standing wave formed in the tube corresponds to the fourth harmonic for the tube. Find the length of the tube. (2 marks)

$f_n = \frac{nV}{2L}$ (½)

$\therefore L = \frac{nV}{2f}$

$= \frac{4 \times 346}{2 \times 800}$ (½) C.O

$= 0.865 \text{ m}$ (1)

OR

$\lambda = \frac{2L}{n}$ (½)

$\therefore L = \frac{\lambda n}{2}$ C.O

$= \frac{0.433 \times 4}{2}$ (½)

$= 0.865 \text{ m}$ (1)

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