BRETT B
B.B

Willetton Senior High School — GROW · GIVE · GUIDE

Year 11 Physics
Semester 1 Examination 2020
Question & Answer Booklet

Name: -MASTER- B.B. -UPDATED

Teacher: ____________________

Time allowed for this paper:
Reading time before commencing work: 10 minutes
Working time for paper: 2.5 hours

Materials required/recommended for this paper
To be provides by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, pencils (including coloured), sharpener, correction fluid, eraser, ruler, highlighters.
Special items: up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor.

	Q	M	Amalgated
M.P	1-9 INC	42	✓
B.D	10-15ci	61	✓
B.B	15 GRAPH →	42	

STRUCTURE OF THIS PAPER

Section	Questions	Questions to be attempted	Suggested working time (mins)	Marks available	Percentage of exam
Section One: Short Response	11	11	57	55	38 %
Section Two: Problem Solving	5	5	75	72	50 %
Section Three: Comprehension	1	1	18	18	12 %
			Total	**145**	**100 %**

INSTRUCTIONS TO CANDIDATES

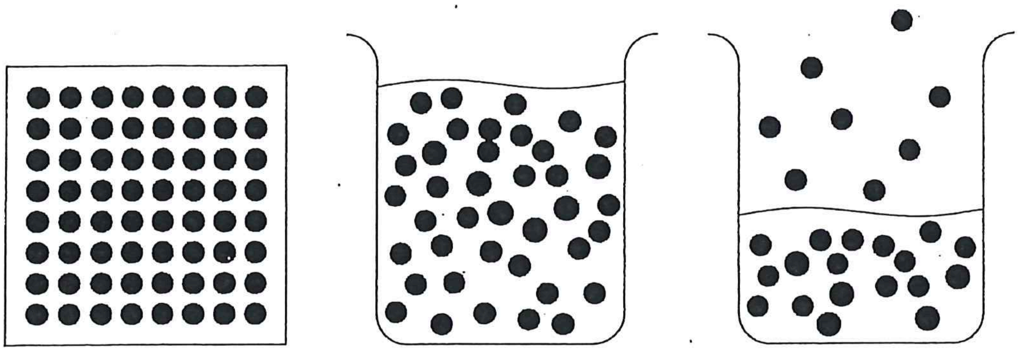
1. Write your answers in the spaces provided beneath each question. The value of each question is shown.
2. Answers to questions involving calculations should be evaluated and given in decimal form. Final answers should be given up to three significant figures and include appropriate units.
3. Questions containing the instruction "**ESTIMATE**" may give insufficient numerical data for their solution. Give final answers to a maximum of two significant figures and include appropriate units.
4. Despite an incorrect result, credit may be obtained for method and working providing these are clearly and legibly set out.
5. Questions containing specific instructions to **show working** should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; correct answers which do not show working will not be awarded full marks.
6. Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question & Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.
7. A spare graph has also been provided at the end of this Question & Answer booklet.

Section One: Short Response **38% (55 marks)**

This section has 11 questions. Answer **all** questions. Answer the questions in the spaces provided. Suggested working time: 57 minutes.

Question 1 **(4 marks)**

The diagrams below show the changes which occur between the solid, liquid and gaseous phases of a substance, with the addition of heat.



Using these diagrams and your knowledge of the kinetic particle model, state and explain **one** change which occurs when the substance changes phase from:

(a) solid to liquid. (2 marks)

- MELTING (1)
- MORE ROTATIONAL AND OR TRANSLATION MOTION OF PARTICLES. (1)

(b) liquid to gas. (2 marks)

- EVAPORATION (1)
- MORE TRANSLATION MOTION OF PARTICLES. (1)

OR • MORE KINETIC ENERGY (E_k) OF PARTICLES.

4

Question 2 OR ① Ea. **(5 marks)**

Identify the products **V**, **W**, **X**, **Y** and **Z** in the following nuclear equations.

(a) ${}^{1}_{0}n \rightarrow {}^{0}_{-1}e + V$ V = PROTON ${}^{1}_{1}p$

(b) ${}^{1}_{1}p \rightarrow {}^{1}_{0}n + W$ W = POSITRON ${}^{0}_{1}e$.

(c) ${}^{226}_{88}Ra \rightarrow X + {}^{4}_{2}He$ X = RADON - 222 ${}^{222}_{86}Rn$

(d) ${}^{200}_{80}Hg + {}^{1}_{0}n \rightarrow {}^{201}_{80}Hg + Y$ Y = GAMMA RADIATION ${}^{0}\gamma$

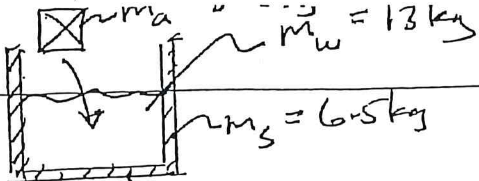
(e) ${}^{60m}_{27}Co \rightarrow Z + {}^{0}_{0}\gamma$ Z = COBALT - 60 ${}^{60}_{27}Co$.

Question 3 **(3 marks)**

In cold climates, wind chill factor and hypothermia can pose a real threat to the health of an individual. Wind chill is when cooler moving air replaces relatively still air near a person's skin, giving the person the sensation that the effective temperature has decreased. Explain why the cooling effect on the person is increased if the person is wet or wearing wet clothes.

- WATER HAS A HIGH SPECIFIC HEAT. ①
- THAT IS, THE WATER CAN CONTAIN A LARGE QUANTITY OF HEAT PER UNIT MASS. ①
- WHEN WATER ON THE SKIN OR CLOTHES EVAPORATES, IT CAN TAKE A LOT OF HEAT AWAY FROM THE BODY AND TRANSFER IT TO THE SURROUNDING AIR. ①

/8



Question 4 **(5 marks)**

A 6.50 kg steel container (specific heat capacity 4.50×10^2 J kg^{-1} K^{-1}) holds 13.0 kg of water at 24.0 °C. When 3.15 kg of a molten alloy, at its melting point of 315 °C, is poured into the water, the water reaches a final temperature of 29.1 °C. If the latent heat of fusion of the alloy is 2.30×10^4 J kg^{-1} determine the specific heat capacity of the alloy. $Q = mL_f$

LHS $Q_L = Q_G$ (½) RHS 315 °C

$$\left[(m_a L_{fa}) + (m_a c_a \Delta t_1)\right] = \left[(m_s c_s \Delta t_2) + (m_w c_w \Delta t_2)\right] \quad (1)$$

$\Delta t = 285.9$

$$\left[(3.15 \times 2.30 \times 10^4)_{72450\ (½)} + (3.15 \times c \times 285.9)_{900.585c\ (½)}\right] = \left[(6.5 \times 450 \times 5.1)_{14917.5\ (½)} + (13 \times 4180 \times 5.1)_{2.77134 \times 10^5\ (½)}\right]$$

$29.1 - 24 \Rightarrow \Delta t_2 = 5.1$ °C (½)

For (c) $\therefore 900.585c = (1.49175 \times 10^4 + 2.77134 \times 10^5) - 7.245 \times 10^4$

$$\therefore c = \frac{2.9205 \times 10^5 - 7.245 \times 10^4}{900.585}$$

$= 243.84$

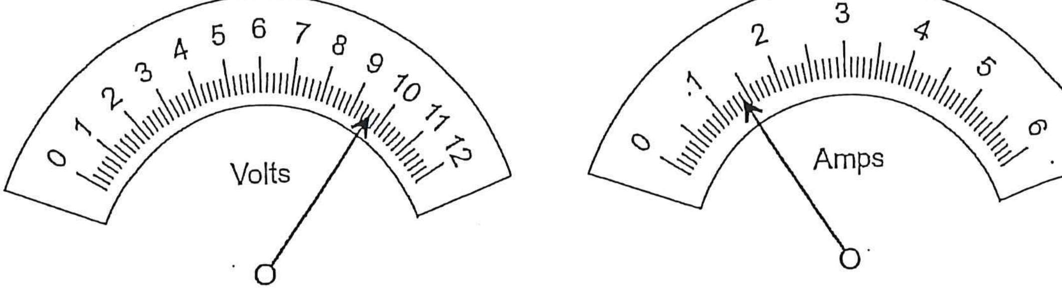
$= 244$ J kg^{-1} K^{-1} (1)

(−½) IF INC. UNITS

(−1) FOR EA MAJOR ERROR i.e. IF $(m_s c_s \Delta t_2)$ NOT CALCULATED.

Question 5 **(5 marks)**

Albert is trying to precisely measure the resistance R of a piece of fuse wire. To do so he applies a voltage across the wire and measures current passing through the wire. The meters are shown below.



Determine the resistance R of the fuse wire.

Give your answer in the form $R \pm \Delta R$ (ΔR being the uncertainty in the resistance value).

0.1 – WATCH OUT!

WATCH OUT!

$\%R = \%V + \%I$

$R_{RAW} = \frac{V}{I}$

$= \frac{9.6}{1.4}$

$= 6.8571$

UNCERTAINTY KICK IN HERE!

VAR		±	%
V	9.6	0.10	1.04
I	1.4	0.05	3.57
R	6.857	0.3	4.61 %

(1) (1)

Now For ± METHOD (1)

$$\left(\frac{6.8571}{1} \times \frac{4.61}{100} = 0.32\right)$$

ANS $R = 6.8 \pm 0.3$ OR 0.2 (1) + (1)

2 s.f. ONLY

Question 6 **(5 marks)**

Domestic smoke detectors use about 0.25 µg of a radioactive source of Americium-241 which produces alpha particles. Under normal operating conditions, the alpha particles ionise oxygen and nitrogen molecules in the air and an electric potential from a battery causes a small ionisation current to flow. When smoke enters the detector the smoke particles absorb alpha particles and thus reduce the ionisation current flowing in the circuit, setting off an alarm.

(a) Explain the effect that using a radioactive source which produces **beta particles** instead of alpha particles would have, on the operation of a domestic smoke detector. (2 marks)

- β PARTICLES ARE LESS IONISING THAN α PARTICLES. (1)
- THE DETECTOR CIRCUIT WILL ~~GO~~ OPEN CIRCUIT (ELECTRICITY WILL NOT FLOW) AND THE ALARM WILL SOUND CONTINUOUSLY. (1)

(b) If the half-life of Am-241 is 450 years, how much of the original radioactive material would be left in an old smoke detector that is 50 years old. (3 marks)

FOR (A)

$A = A_0\, 0.5^n$ (1)

$\therefore n = \frac{50}{450} = 0.111$ (1)

NOW $A = 0.25 \times (0.5)^{0.111}$

$= 0.231\ \mu g$ OR $2.31 \times 10^{-7}\ g$ (1)

Question 7 **(5 marks)**

A 416 g sample of radioisotope Promethium–147 decays into Samarium–147 as the main product. Promethium can be found in the Lanthanide series at the bottom of the periodic table.

(a) Write a balanced nuclear equation for Promethium–147 decaying to Samarium -147. (2 marks)

$^{147}_{61}Pm\ \ \cancel{Pr} \rightarrow\ ^{147}_{62}Sm + \ ^{0}_{-1}e$ (OR $^{0}_{-1}\beta$)

(b) Determine the half-life of Promethium–147 if the original sample decays to 13.0 g in 12.0 years? (3 marks)

FOR ($t_{1/2}$)

$A = A_0 (0.5)^n$ (1)

$13 = 416\, (0.5)^n$

$\therefore \frac{13}{416} = 0.5^n$

$\Rightarrow n = 5.0$ (1)

NOW $t_{1/2} = \frac{12}{5} = 2.4$ YRS (1)

/10

Question 8 **(6 marks)**

After running a long-distance marathon, Tori adds a handful of ice blocks to her partly empty water bottle. Tori knows that an average ice block contains anywhere from **30.0 to 50.0 mL** of water. Tori also wants to ensure that the ice doesn't melt too quickly and therefore only selects ice blocks that are well **below freezing point**. Using this information, **estimate** how many kilojoules (kJ) of energy were extracted from tap water in order to produce the ice blocks which Tori used. State key assumptions.

ASSUMPTIONS

15 – 30°C

$m = 0.06 \rightarrow 0.3$ kg (1)

$t = 30 \rightarrow -10.0$ (1)

$Q = (mc\Delta t_1) + (mL_{fi}) + (mc\Delta t_2)$ $\boxed{3}$ FOR METHOD

0

$Q \approx 6 - 144$ kJ (1)

–2 – 10°C

Question 9 **(4 marks)**

The label on a rechargeable Lithium-Polymer (LiPo) battery reads: "11.1 volt, 1800 mAh". The battery is being used to operate a remote-control vehicle.

(a) The term "1800 mAh" refers to which quantity below? Circle your answer. (1 mark)

Current Time Energy Charge

(b) Given that the electric motor of the vehicle draws a constant current of 12.0 A from the battery during an operating time of 9.00 minutes, calculate the efficiency of the motor, if the motor produces 5.80×10^4 J of useful energy. (3 marks)

FOR (E_{INPUT})

$E = VIt$ (½)

$= 11.1 \times 12 \times 9 \times 60$

$= 7.1928 \times 10^4$ J (½)

NOW

$EFF = \frac{E_{OUT}}{E_{IN}} \times \frac{100}{1}$ (½)

$= \frac{5.80 \times 10^4}{7.1928 \times 10^4} \times \frac{100}{1}$ (½)

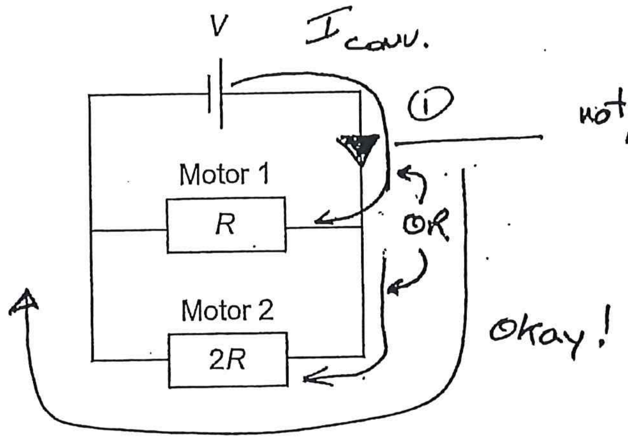
$= 80.63$

$= 80.6\ \%$ (1)

10

Question 10 **(5 marks)**

Two motors, which **initially have equal resistance (R)**, are running in parallel with each other and are powered by the same voltage source *V*.



Read ↓

(a) On the diagram above, indicate with an arrow, the **direction** of conventional current through one of the motors. No calculations are involved. (1 mark)

(b) Due to unusual heating of the wires in Motor 2, Motor 2's resistance doubles from R to 2R (as indicated on the diagram above). Show mathematically the **overall circuit current** before the heating of Motor 2 and after the heating of Motor 2.

Hint: Use **R** for Motor 1's resistance and **2R** for Motor 2's resistance after heating. (4 marks)

<u>Find $R_{\parallel}$ First</u>

$$\frac{1}{R_{\parallel\,cold}} = \frac{1}{R} + \frac{1}{R}$$

$$\therefore R_{\parallel\,cold} = \frac{R}{2} = 0.5R \quad \text{or} \quad \tfrac{1}{2}R \quad ①$$

And $$\frac{1}{R_{\parallel\,hot}} = \frac{1}{R} + \frac{1}{2R}$$

$$\therefore R_{\parallel\,hot} = \frac{2R}{3} = 0.6\dot{6}R \quad \text{or} \quad \tfrac{2}{3}R \quad ①$$

<u>Now</u> $$I_{cold} = \frac{V}{R} = \frac{V}{0.5R} \quad \text{or} \quad \frac{V}{\frac{1}{2}R} \quad ① \quad \frac{2V}{R}$$

$$I_{hot} = \frac{V}{R} = \frac{V}{0.6\dot{6}R} \quad \text{or} \quad \frac{V}{\frac{2}{3}R} \quad ① \quad \frac{3V}{R}$$

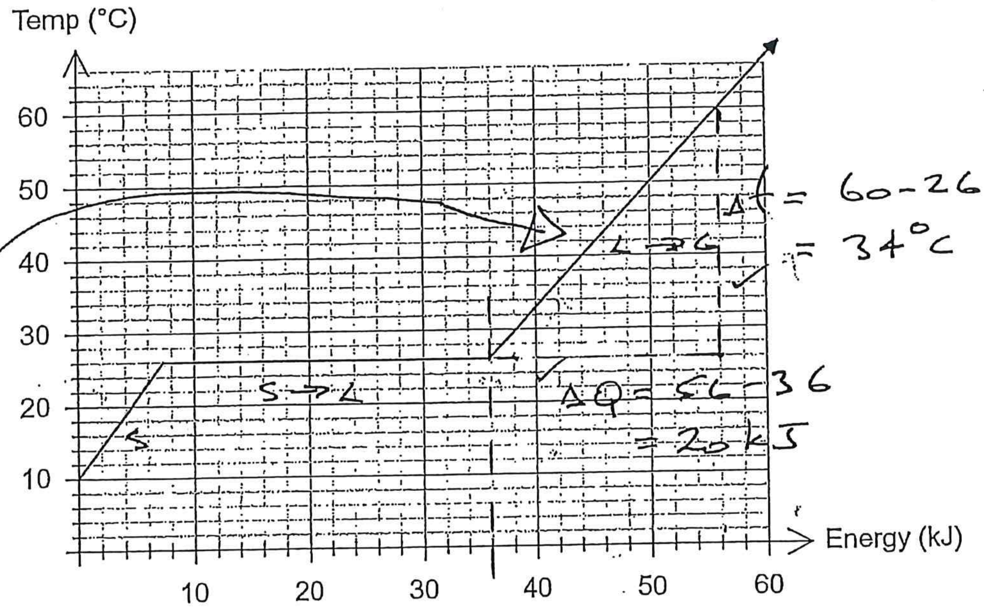
If $I = \dfrac{V}{\left(\frac{1}{R}+\frac{1}{R}\right)^{-1}}$ (cold) 2 only!

$I = \dfrac{V}{\left(\frac{1}{R}+\frac{1}{2R}\right)^{-1}}$ (hot)

/5

Question 11 **(8 marks)**

The heating curve below shows the temperature change of a 285 g sample of solid coconut oil as it is heated, with a small 40.0 W heating element, from an initial temperature of 10.0 °C.



(a) How long does it take for the coconut oil to completely melt? (3 marks)

$E_{TOT.\ MELT} = 36 - 7 = 29 \text{ kJ}$ — (1)

$P = \frac{E}{t}$ (½)

$t = \frac{E}{P} = \frac{29 \times 10^3}{40}$ (½) $= 725 \text{ s} = 7.3 \times 10^2 \text{ s}$ (1)

(2 or 3 s.f. o.k).

(b) ~~Use the graph to estimate~~ the specific heat capacity of liquid coconut oil. Show construction lines on your graph which are used to define values. (5 marks)

(2)

$Q = mc\Delta t$

$\therefore c \approx \frac{Q}{m\Delta t}$ (1)

$\approx \frac{20 \times 10^3}{0.285 \times 34}$ (1)

$\approx 2.06 \times 10^3$ (2.039) (1) $\text{J kg}^{-1} \text{K}^{-1}$

Accept $[1.9 \rightarrow 2.25 \times 10^3]$ $-\frac{1}{2}$

watch

HI	LO
$\frac{21 \times 10^3}{0.285 \times 33}$	$\frac{19 \times 10^3}{0.285 \times 35}$
$= 2.23 \times 10^5$	$= 1.90 \times 10^3$

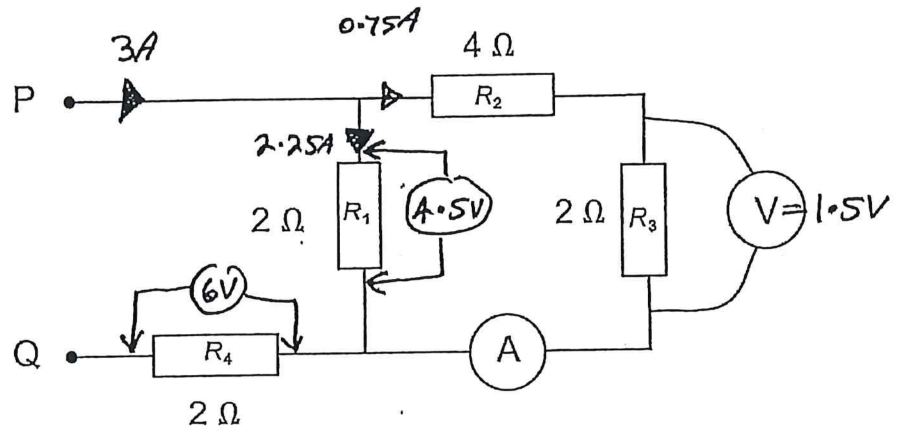
END OF SECTION ONE

Section Two: Problem Solving **50% (72 marks)**

This section contains 5 questions. Answer **all** questions. Answer the questions in the spaces provided. Suggested working time 75 minutes.

Question 12 **(13 marks)**

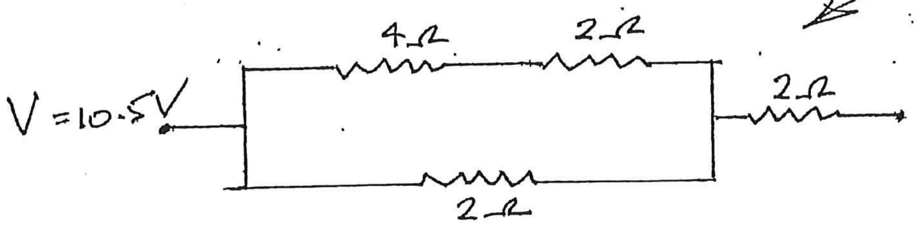
Consider the circuit shown below, containing four resistors, an ammeter and a voltmeter. The following parts of the question relate to the diagram below.



(a) Show that the total resistance between terminals P and Q is 3.50Ω. (4marks).

REDRAW/SIMPLIFY CIRCUIT

DRAWING IS OPTIONAL.



FIRSTLY, FOR $R_{\parallel}$

$$\frac{1}{R_{\parallel}} = \frac{1}{6} + \frac{1}{2} \quad (1)$$

$$= \frac{1+3}{6} \quad (1)$$

$$\therefore R_{\parallel} = \frac{6}{4} = 1.50\ \Omega \quad (1)$$

Now $R_{P-Q} = 1.50 + 2 = \underline{3.50\ \Omega}$ (1)

/4

WATCH C.O

(b) If a voltage source of 10.5 volts is placed across the terminals P and Q:

i) Find the total current drawn by the circuit. (1 mark)

$$I_{TOT} = \frac{V_{TOT}}{R_{TOT}} = \frac{10.5}{3.50} = 3.00\,A$$

(SF ignore)

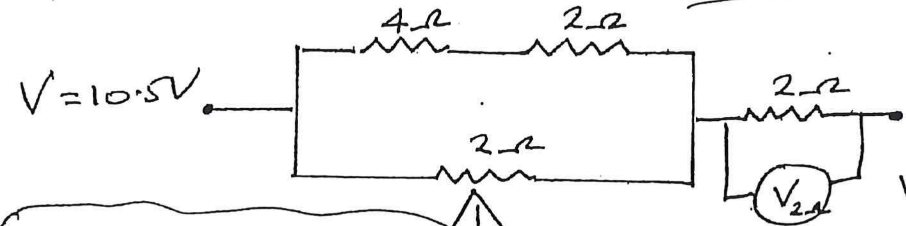
ii) Find the amount of charge drawn by the circuit in a time of 45.0 seconds. (2 marks)

WATCH C.O

$$I = \frac{q}{t} \quad (\tfrac{1}{2})$$

$$\therefore q = It = 3.00 \times 45 = 135\,C \quad (-\tfrac{1}{2})$$

iii) Show that the current measured at the ammeter is 0.750 A. (4 marks)



$$V_{2\Omega} = I_{TOT} \times 2\Omega = 3 \times 2 = 6.00\,V \quad (1)$$

MULTIPLE METHODS ..

NOW $V_{//} = V_{TOT} - 6.00 \quad (1)$

$$= 10.5 - 6.00$$

$$= 4.50\,V \quad (1)$$

AND $I_{TOP\ ARM} = \frac{V_{//}}{6\Omega} = \frac{4.50}{6.00} = 0.750\,A \quad (1)$

iv) Determine the voltage measured by the voltmeter in the original circuit diagram. (2 marks)

Ratio...

$I_T = 3A$

$I_T = x + \frac{6}{2}x$

$x = 0.750A$

WATCH C.O

$$V_{2\Omega} = I R_3 \quad (\tfrac{1}{2})$$

$$= 0.750 \times 2 \quad (\tfrac{1}{2})$$

$$= 1.50\,V \quad (1)$$

R_3

Question 13 $-\frac{1}{2}$ each error. -1 NO $2\,{}^1_0n$ $\quad 2\,{}^1_0n \neq {}^2_0n$ **(17 marks)**

A 900 MW fission reactor uses a Uranium-enriched fuel source containing Uranium–235. This fission reaction involves the absorption of Uranium–235 (235.04393 u) with a single neutron (1.00866 u) which produces Strontium–94 (93.91536 u), Xenon–140 (139.92164 u), and a number of neutrons and energy.

(a) Write a balanced nuclear equation for the neutron bombardment of Uranium–235 described above and clearly state the number of neutrons produced. (3 marks)

$${}^1_0n + {}^{235}_{92}U \rightarrow {}^{94}_{38}Sr + {}^{140}_{54}Xe + 2\,{}^1_0n + E$$

NO MARKS OFF IF 'E' IS NOT INC

(b) State why you selected the number of neutrons produced above and state the key physics formula which can be used to determine the energy released from the nuclear reaction above. (2 marks)

NEUT
- conservation of mass
- MASS NO: REACTANTS = MASS NO: PRODUCTS (1)
- Not 'Balance equation'.

E
- $\Delta m \Rightarrow u \Rightarrow MeV$
- OR $\Delta m \Rightarrow kg \Rightarrow E = mc^2$ (1)

OR SIMILAR

IF ONLY $\Delta m = m_r - m_p$ (1/2) ONLY

(c) Calculate the amount of energy, in joules, produced by this nuclear reaction. Show clear and methodical working. (5 marks)

kg $3.091847299 \times 10^{-25} - 3.915181712 \times 10^{-25} = 3.029182 \times 10^{-28}$ kg

check part (d)

FOR (Δm)

$\Delta m = m_r - m_p$ (1)

$\Rightarrow (1.00866u + 235.04393u)$ $\quad 236.05259u$ (1)

$= [93.91536u + 139.92164u + 2(1.00866u)]$ $\quad 235.85432u$

$\therefore \Delta m = 0.19827u$ (1)

OR

$u \Rightarrow J$ VIA $E = mc^2$

$u \to MeV$

$MeV = 0.19827u \times 931$

$= 184.589\ MeV$ (1)

(-1) IF INCORRECT

$MeV \to J$

$\Rightarrow 184.589 \times 1.60 \times 10^{-13}$

$= 2.9534 \times 10^{-11}$

$= 2.95 \times 10^{-11}\ J$ (1)

$u \to kg$

$0.19827u \times 1.66 \times 10^{-27}$

$= 3.29128 \times 10^{-28}\ kg$ (1)

Now $E = mc^2$

$= 3.29128 \times (3 \times 10^8)^2$

$= 2.962 \times 10^{-11}$

$= 2.96 \times 10^{-11}\ J$ (1)

NB ${}^1_0n$ $\quad \Delta m = 1.20703u$ $\quad E = 1.803 \times 10^{-10}\ J$ (5)

10

Different methods:

(d) Calculate the mass, in kilograms, of Uranium–235 fuel required to operate this 900 MW nuclear reactor for one year. **Note:** if you did not calculate part (c), you may use a value of 3.00×10^{-11} J for the energy released per fission reaction of Uranium–235.

Check!!

State all assumptions and show clear and methodical working. (4 marks)

ASSUMPTIONS
a. 100% EFF
m → E
b. 365 d/yr

FIRSTLY, FIND TOT. ENERGY REQUIRED.

$E = Pt$

$= 900 \times 10^6 \times 365 \times 24 \times 3600$

$= 2.83824 \times 10^{16}$ J — 1

NOW, FOR NO: FISSIONS REQ.

$$\text{No:} = \frac{E_{REQ}}{E_{PER\ FISS}} = \frac{2.83824 \times 10^{16}}{2.9534 \times 10^{-11}} = 9.61007 \times 10^{26} \text{ FISS}$$ 1

WATCH C.O

LASTLY, FOR m, U-235 REQ 1

$m\ U\text{-}235 = 235.04393\,u \times 1.66 \times 10^{-27} \times 9.61007 \times 10^{26}$

$= 374.95$ 1

GIVEN

$= 375$ kg U-235

OR

MOLES → MASS. PERIOD. TABLE

$$m = \frac{9.61007 \times 10^{26} \times \boxed{238}}{6.02 \times 10^{23}}$$

$= 379.933$

$= 380$ kg

(e) A radiation **limit** for workers at the nuclear reactor facility is set at 100.0 mSv per year. If an 82.0 kg worker at the nuclear reactor accidently receives a full body exposure of 12.0 J of beta radiation from spent fuel rods, determine the worker's **absorbed dose, dose equivalent** and state if it is safe for the worker to continue working. (3 marks)

FOR AD

$$AD = \frac{E}{m} = \frac{12}{82} = 0.146 \text{ Gy}$$ 1

$-\frac{1}{2}$ IF INC. UNITS.

J kg^{-1} – ok

FOR D.E.

$DE = AD \times QF = 0.146 \times 1 = 0.146$ Sv 1

Not J kg^{-1}

SINCE D.E (146 mSv) > 100 mSv (must state....) $\frac{1}{2}$

∴ IT IS NOT SAFE FOR THE WORKER.

$\frac{1}{2}$

7

Q13 (d) other methods. 1/2

1. $M_u = 235.04393u \times 1.66 \times 10^{-27} = 3.901729 \times 10^{-25}$ kg.

2. No of nuclei in 1 kg $= 2.562966159 \times 10^{24}$ ①

3. E in 1 nuclei $= 2.962 \times 10^{-11}$ J (watch %). ②

4. Total E req/1kg $=$ ① $\times$ ② $= 7.591507 \times 10^{13}$ J ③
$(7.6889 \times 10^{13}$ J$)$

5. E for 1 year $= 900 \times 365 \times 24 \times 60 \times 60$ ④
$= 2.83382 \times 10^{16}$ J

6. ∴ mass $= \frac{④}{③} = \frac{2.8382 \times 10^{16}}{7.591507 \times 10^{13}} = 373.86$ kg
(369.129 kg)

Q required $= 2.8382 \times 10^{16}$ J — ①

Q nuclei $= 2.962 \times 10^{-11}$ J — ②

$\frac{①}{②} = 9.5882 \times 10^{26}$ No of reactions.

$M_{Total} = M_u \times$ No of reactions

$= 235.04393 \times 1.66 \times 10^{-27} \times 9.5822 \times 10^{26}$

$= \underline{373.87 \text{ kg}}$

(369.1296 kg)

Q nuclei $= 2.95 \times 10^{-11}$

mass $= 375.39$

$W = Pt = \ldots$

$= 2.83824 \times 10^{16}\ J$

$E = mc^2 \Rightarrow \Delta m = \dfrac{2.83824 \times 10^{16}}{(3\times 10^8)^2}$

$= 0.31536\ kg.$

$Toa. \rightarrow 1.899759 \times 10^{26}\ u$

No of reactions $\times$ $m_{urea} =$ $m_{u\,req.}$

$\dfrac{1.899759 \times 10^{26}}{0.19827} \times 235.04393 = 2.2521 \times 10^{29}\ u$

$\rightarrow = 373.85\ kg$

$= \underline{374\ kg}$

Question 14 **(8 marks)**

An experimental technique in the field of radiography in treating aggressive brain tumours is that of Boron Neutron Capture Therapy. This technique uses the fact that when Boron-10 is injected into the body of a patient, the Boron-10 collects in the brain tumours.

The patient is then bombarded with neutrons which are strongly absorbed by the Boron-10, becoming fissile (radioactive) Boron-11 which produces Lithium-7 and high-energy alpha particles which then kill the cancer cells. On average, each neutron has an energy of 0.650 eV.

(a) Write two nuclear equations describing the above two processes. (2 marks)

$${}^{1}_{0}n + {}^{10}_{5}B \rightarrow {}^{11}_{5}B \quad (1)$$

$${}^{11}_{5}B \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He \quad (1)$$

$${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He$$ (1)

missing.

(b) Given that the amount of Boron-10 (10.013 u) required to treat a 2.20 g brain tumour is 25.0 µg per gram of tumour, determine the absorbed dose administered to a 45.0 kg patient. (5 marks)

errors

FOR MASS OF B-10 REQ.

Bee Nice $25 \times 10^{-6} \times 2.2 = 5.5 \times 10^{-5}\,g = 5.50 \times 10^{-8}\,kg$ (1)

FOR No: B-10 ATOMS AND HENCE, No: ${}_{0}^{1}n$ REQ.

$$No: = \frac{5.50 \times 10^{-8}}{10.013u \times 1.66 \times 10^{-27}} = 3.30895 \times 10^{18}\ {}^{1}_{0}n \quad (1)$$

FOR TOTAL ENERGY ADMINISTERED

$$E = 3.30895 \times 10^{18} \times 0.65 \times 1.60 \times 10^{-19}$$

$$= 0.34413\ J \quad (1)$$

NOW, FOR A.D $\quad A.D = \frac{E}{m}$ (1) $\quad \frac{0.34413}{45} = 7.647 \times 10^{-3}$ (1) $= 7.65\ mGy$

(c) Suggest a possible reason why an alpha source (the fission of Boron-11) is used in this context rather than a beta source. (1 mark)

NOT - "not a beta source"

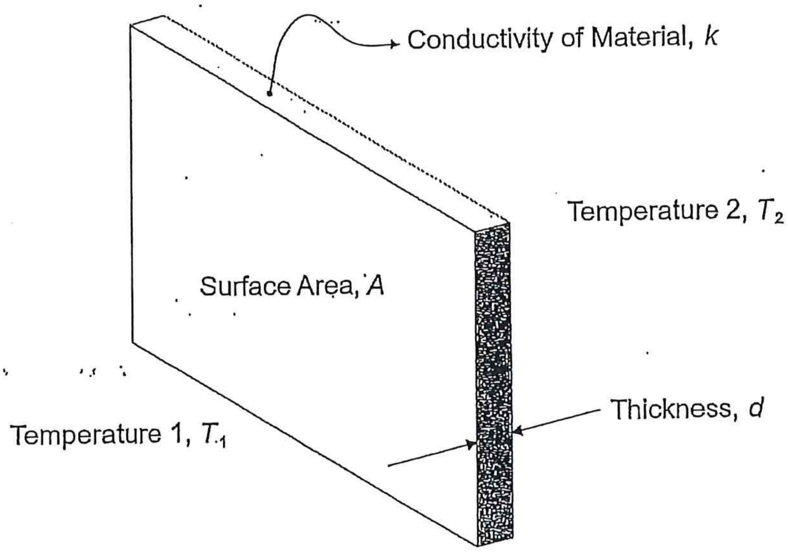
AN ALPHA SOURCE WILL ONLY PENETRATE A SHORT DISTANCE (½) THROUGH BODY TISSUE AND HENCE, THE ALPHA PARTICLES WILL ONLY KILL THE TARGET (½) TISSUE AND NOT THE SURROUNDING TISSUE (½). Ignore : More Ionising.

8/8

Question 15 **(21 marks)**

The following question involves heat transfer through materials and heating an office space.

The rate at which heat is conducted through a material depends on several quantities relating to the physical environment and the shape and size of the material, as shown in the diagram below.



The rate at which heat is conducted through a material depends on temperature (K) on both sides of the material (T_1 and T_2), the surface area A (m^2) exposed, the thickness of the material d (m) and the property of the material known as conductivity k.

The rate of heat transfer through the material is power P (units of J s^{-1}) and is given by:

$$P = \frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}$$

(a) Correctly determine the units of conductivity k. Very poorly done! Very basic. (1 mark)

$$\frac{J}{s} = \frac{k.m.\cancel{m}.K}{\cancel{m}}$$

$$\therefore k = \frac{J}{s.m.K} \Rightarrow k = J s^{-1} m^{-1} K^{-1}$$

WATCH C.O.

(b) A single 1.20 m high by 2.30 m wide by 6.00 mm thick glass window separates a 28.0 °C exterior from the 18.0 °C interior office space. The window is letting heat in at a rate of 3.59 kW.

i) Determine the conductivity k of the glass window. (3 marks)

$$\frac{3.59 \times 10^3}{1} = \frac{k\,(1.2 \times 2.3)\,10}{6 \times 10^{-3}} \quad ①$$

error

$$k = \frac{3.59 \times 10^3 \times 6 \times 10^{-3}}{27.6} \quad ① = 0.7804$$

$$= 0.780 \ J s^{-1} m^{-1} K^{-1} \quad ①$$

error add K to 10°C

4

Question 15 (b) continued $Q = Pt = mC\Delta T$

ii) Calculate the **theoretical** rise in temperature of 215 kg of air within the office over a period of 15 minutes (the specific heat capacity of air is 1.10×10^3 J kg^{-1} K^{-1}). (3 marks)

FIRSTLY, FIND HEATING ENERGY (Q).

$E = Pt = 3.59 \times 10^3 \times 15 \times 60 = 3.231 \times 10^6$ J (1)

error

NOW, FOR (Δt)

$Q = mc\Delta t$ (½)

$\therefore t = \frac{Q}{mc} = \frac{3.231 \times 10^6}{215 \times 1.10 \times 10^3}$ (½) $= 13.661$

$= 13.7\,^\circ C$ (1)

- To internal surrounding; objects, material (1) (explain well)

Value → discussion #Realistic#

iii) Explain why the answer to part b) ii) is impossible. Use relevant physics concept to justify your response. (2 marks)

- FOR HEAT ENERGY TO FLOW (TRANSFER) INTO THE ROOM $T_{OUTSIDE} > T_{INSIDE}$. (1)
- THE ABOVE CASE IS NOT POSSIBLE AS

$T_{INSIDE} = 18.0 + 13.7 = 31.7\,^\circ C > T_{OUTSIDE}\ (28.0\,^\circ C)$ (1)

(c) The owner of the office decides to replace the window mentioned in part b with a double-glazed window in order to reduce heat transfer. The double-glazed window has identical dimensions to the single pane window (1.20 m by 2.30 m) but is 30.00 mm thick and consists of two panes of glass separated by a sealed section containing air.

In order to test this double-glazed window, the amount of energy conducted per second through the window and the difference in temperature across the window is recorded for eight trials in the table below.

Trial	1	2	3	4	5	6	7	8
Temp Difference ΔT (K)	2	3	6	9	12	14	17	19
Energy Rate Q/t (J s^{-1})	24	30	72	100	125	155	192	212

i) State why the sealed section containing air reduces heat transfer. (1 mark)

- AIR IS A POOR CONDUCTOR OF HEAT (1)

AND/OR

- THE TRAPPED AIR REDUCES HEAT TRANSFER VIA CONVECTION.

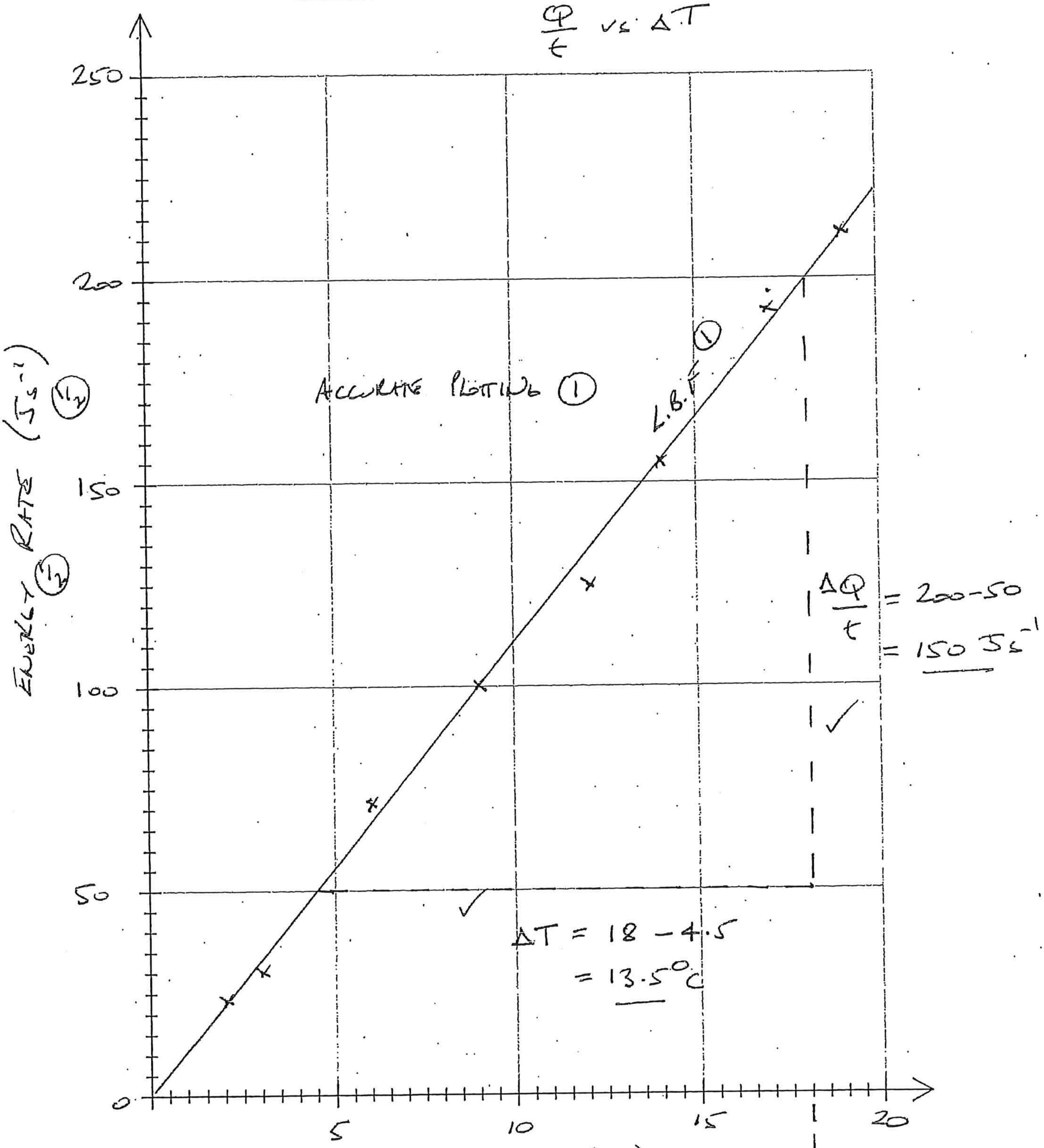
ii) Use the data in the table above to construct a graph by plotting Energy Rate Q/t on the vertical axis and Temp Difference ΔT on the horizontal axis. Include title, axes labels, units and a line of best fit. (5 marks)

(Question 15 continued)

1

RATE OF HEAT FLOW VS TEMP. DIFFERENCE

$\frac{Q}{t}$ vs ΔT



GRAPH TOO SMALL -1

/5

IF TOO SMALL $-\frac{1}{2}$ ONLY. /18

(Question 15 continued)

iii) Calculate the gradient of the line of best fit. **Show construction lines** on the graph. (3 marks)

1

$$\text{GRADIENT} = \frac{\frac{Q}{t}}{\Delta T} = \frac{200-50}{18-4.5} = 11.11$$

1

$$= 11.\dot{1}\dot{1}\ J s^{-1} K^{-1}$$

1

$P K^{-1}$ O.K.

$\left(-\frac{1}{2}\right)$ IF INC. UNITS.

!!!

iv) Use the value of the gradient of the line of best fit, and information given in the question, to determine a value for the conductivity *k* of the double-glazed window. **Note:** if you didn't determine a value for the gradient, you may use a gradient of 11.0 J s^{-1} K^{-1}. (3 marks)

NOTE: A LOT OF STUDENTS WROTE:

$$11 = \frac{kA\Delta T}{d}$$

THIS IS NOT POWER!

FROM

$$\frac{Q}{t} = \frac{kA\Delta T}{d}$$

$$\times \frac{kA}{d} = \frac{\frac{Q}{t}}{\Delta T} \quad \text{GRADIENT}$$

IF THE STUDENTS DIDN'T USE THE GRADIENT AS INSTRUCTED.

(-1) i.e

$$k = \frac{Pd}{A\Delta T}$$

POINT READINGS FROM TABLE

$\Rightarrow$ 2 MARKS ONLY IF 'k' IS CORRECT

$$\therefore k = \frac{\text{GRADIENT}}{1} \times \frac{d}{A}$$

WATCH ROUNDING ERRORS

$$= \frac{11.\dot{1}\dot{1}}{1} \times \frac{30\times10^{-3}}{1.2\times2.3}$$

$$= 0.12077$$

$$= \underbrace{0.121 \quad \text{OR} \quad 1.21\times10^{-1}}_{} J s^{-1} K^{-1}$$

OR $P K^{-1}$ O.K.

1 CLOSE TO.

/6.

Question 16 **(13 marks)**

An electric kettle contains 450 mL of water at an initial temperature of 18.0 °C. The kettle operates on mains voltage (240.0 V) and draws a current of 6.25 A when switched on. The kettle is 90.0 % efficient at converting electrical energy into thermal energy in the water only.

(a) Calculate the amount of heat that the kettle supplies to the water every second after it is switched on. (2 marks)

$Q = E = Pt = VIt$ (½)

$= 240 \times 6.25 \times 1 \times \frac{90}{100}$ (½)

$= \frac{135000}{100}$

$= 1350$

$= 1.35$ kJ (1)

(−1) IF EFF. NOT TAKEN INTO ACCOUNT [1500 J ×]

(b) How much heat is supplied by the kettle to heat the water to reach boiling point (100°C)? (3 marks)

$Q = mc\Delta t$ (½)

$= 0.45 \times 4180 \times 82$ (½)

$= 1.54242 \times 10^5$

$= 1.54 \times 10^5$ J

or 154 kJ (1)

100°C

$\Delta t = 82°C$ (1)

18°C

WATCH C.O

(c) How long will it take for the water to reach boiling point? (3 marks)

NOTE TO TEACHERS – REMIND STUD TO LEAVE ANS. IN SECONDS UNLESS OTHERWISE INSTRUCTED

$P = \frac{E}{t} = \frac{Q}{t}$

$t = \frac{Q}{P}$ (1) $= \frac{1.54242 \times 10^5}{240 \times 6.25 \times 1 \times \frac{90}{100}}$ (1)

$= \frac{1.54242 \times 10^5}{1350}$

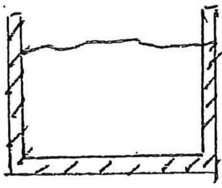
$= 114.25 = 114$ s (1)

[1 MIN: 54 s]

8

THERMAL OR ELECTRICAL — NOT STATED.

(d) How much more energy is required if the 1.20kg stainless steel kettle was included in the heat calculation? Note: The specific heat capacity for stainless steel is 468 J $kg^{-1}K^{-1}$ (3 marks)



$m_{ss} = 1.20kg$

RECALL

$Q_{TOT} = Q_w + Q_{S.ST}$

$= (m_w c_w \Delta t_w) + (m_{ss} c_{ss} \Delta t_{ss})$

FOR (Q_{ss})

$Q = m_{ss} c_{ss} \Delta t$ ①

$= 1.2 \times 468 \times 82$ ①

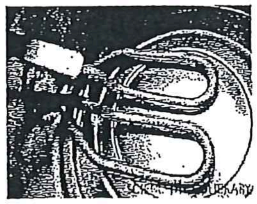
$= 4.61 \times 10^4$ J ①

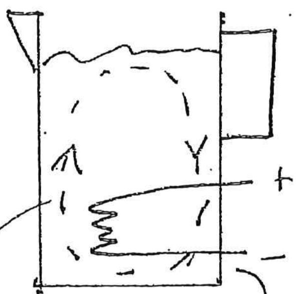
$E_{ELEC} = 4.61 \times 10^4 \times \frac{100}{90} = 5.12 \times 10^4$ J

OR $\frac{4.6051 \times 10^4}{1.542 \times 10^5} \times \frac{100}{1}$

= AN EXTRA 29.9%

(e) The manufacturer of the electric kettle placed the heating element very close to the bottom of the kettle in order to maximise its efficiency. Briefly explain the benefit of this design. Include a well labelled sketch to aid your explanation. (2 marks)



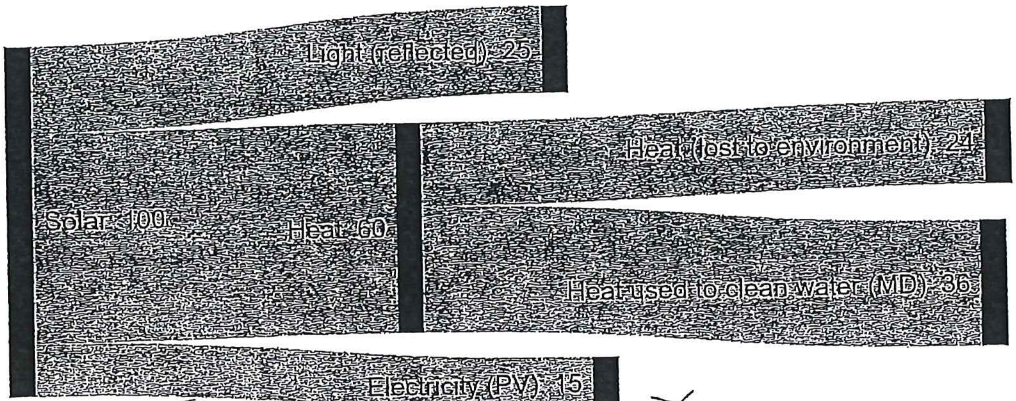


• NEATLY LABELLED SKETCH ①

EXPL. • THE ELEMENT AT THE BOTTOM ENABLES THE WATER TO CONVECT ① AND TRANSFER HEAT THROUGHOUT THE JUG WATER.

END OF SECTION TWO

Figure 2 below shows the energy flow of 100 J of solar energy incident on the PV-MD device. The solar panel is 15% efficient (converting 15 J out of every 100 J into electrical energy), 25 J is reflected as light, and of the remaining 60 J absorbed as heat, 36 J of heat is used to create clean drinking water with 24 J of heat lost to the surrounding environment.



• ELEC → THERMAL ✗

Figure 2 Energy flow diagram for 100 J of incoming solar energy

• HEAT → ELECTRICAL ✗

(a) State one energy transformation taking place in a typical PV–MD device. (1 mark)

• LIGHT → ELECTRICITY ✓ (1)

OR • LIGHT → HEAT ✓

~~• LIGHT → KINETIC / MECHANICAL~~ (WATER CONVERT.

(b) With reference to the design of a typical PV-MD device and the kinetic particle model, explain why the hot vapour condenses as it nears the clean water outlet. (3 marks)

• THE INLET WATER IS AT A LOWER TEMPERATURE (1) THAN THE HOT VAPOUR.

• THERMAL ENERGY WILL BE TRANSFERRED FROM THE VAPOUR TOWARDS THE WATER INLET. (1)

• SOME OF THE KINETIC AND POTENTIAL (1) ENERGY OF THE VAPOUR PARTICLES IS TRANSFERRED TO COOLER PARTICLES IN THE MEMBRANE.

(c) Using data from Figure 2, explain how a PV-MD device makes better use of solar energy than a conventional solar panel. As part of your explanation determine an overall efficiency of the PV-MD device described in Figure 2. (3 marks)

• A CONVENTIONAL PV PANEL IS ONLY 15% EFF. (1)

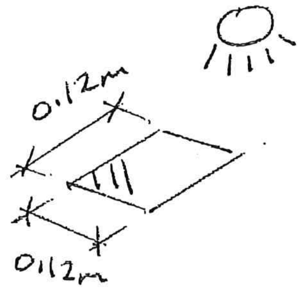
• A PV-MD IS $\frac{15+36}{100}$ = 51 % EFF (1)

• THUS, THE PV-MD UNIT IS MORE THAN 3 TIMES MORE EFFICIENT (1) THAN A CONVENTIONAL PV PANEL.

/7

(d) The prototype used in the lab experiments consisted of a solar panel measuring 12.0 cm by 12.0 cm, placed under a lamp of intensity 1.00 kW m^{-2} (like that of the Sun) for one hour, during which time the solar panel produced 1296 C of charge. Given that the efficiency of the solar panel used is 15.0%:

i) determine the radiant energy incident on the solar panel in one hour. (3 marks)



FOR ENERGY / SEC.

$1000\ J/s : 1\ m^2$ 1

$x : (0.12 \times 0.12)$

$\therefore x = 14.4\ J\,s^{-1}$

NOW $E_{1hr} = 14.4 \times 3600$ 1

$= 5.184 \times 10^{4}\ J$

$= 51.8\ kJ$ 1

ii) determine the electrical energy produced by the panel in one hour. (1 mark)

$E_{ELEC} = \dfrac{5.184 \times 10^{4}}{1} \times \dfrac{15}{100}$ ½

$= 7.776 \times 10^{3}\ J$

OR $= 7.78\ kJ$ ½

iii) determine the output current and voltage of the panel. (2 marks)

$I = \dfrac{q}{t}$ ½

$= \dfrac{1296}{3600}$

$= 0.360\ A$ OR $3.60 \times 10^{-1}\ A$ ½

$V = \dfrac{W}{q} = \dfrac{E}{q}$ ½

$= \dfrac{7.776 \times 10^{3}}{1296}$

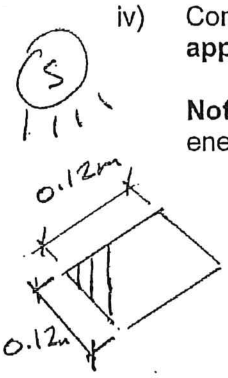
$= 6.00\ V$ ½

/6

WATCH C.D

iv) Confirm by calculations below that the amount of clean water produced by the prototype is **approximately** 0.50 kg per hour per square metre. State your assumptions clearly.

Note: If you could not calculate a value for part (i) you may use a value of 5.0 × 10^4 J of solar energy incident (falling on) on the solar panel in one hour. (5 marks)



For $E_{HEAT} = 5.184 \times 10^4 \text{ J/HR}$

$$= \frac{5.184 \times 10^4}{1} \times \frac{36}{100}$$

$$= 1.8662 \times 10^4 \text{ J} \quad (1)$$

Now, $E_{HEAT}/m^2 \Rightarrow 1.8662 \times 10^4 : (0.12 \times 0.12)$

$$x : 1m^2$$

$$= \frac{1.8662 \times 10^4}{0.0144}$$

$$= 1.2959 \times 10^6 \text{ J hr}^{-1} m^{-2} \quad (1)$$

For m_w/hr METHOD (1)

$$Q = (m_w c \Delta t) + (m_w L_v)$$

$$= (m \times 4180 \times 82) + (m \times 2.26 \times 10^6)$$

(3.4276×10^5)

ASSUME

100 — $Q = mL_v$

(1) $\Delta t = 82°C$

≈ 18°C

Now $1.2959 \times 10^6 = 3.4276 \times 10^5 m + 2.26 \times 10^6 m$

$$\therefore m = \frac{1.2959 \times \cancel{10^6}}{2.60276 \times \cancel{10^6}}$$

$$= 0.4978 \quad (1)$$

≈ 0.5 kg of WATER PER HOUR PER m^2

END OF EXAMINATION

QED

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