BPLO 2003

Q1

a)(i) Data given to 4 sig fig so results should be given to correct accuracy | 1

1.1 W only correct to 2 sig fig $\frac{1}{2}$, accuracy ± 0.05 $\frac{1}{2}$, ± 0.1 acceptable | 1

1063.9 mW correct to 4 sig fig $\frac{1}{2}$, accuracy ± 0.5, ± 1 $\frac{1}{2}$ acceptable | 1

[NB A more accurate calculation, but not required by student, would give for $P = VA$

$$\frac{\Delta P}{P} = \frac{\Delta V}{V} + \frac{\Delta A}{A} = \frac{0.005}{78.46} + \frac{0.005}{13.56} = 4.3 \times 10^{-4}$$

$\Delta P = 5 \times 10^{-4}$ W ie $P = 1.063(9 \pm 5)$ W]

(ii) Dimensions correct to 3 sig fig result only correct to 3 sig fig | 1

Volume $= 1.771 \times 10^{-4}$ m^3 accuracy ± 0.005, ± 0.01 acceptable | 2

[NB. A more accurate calculation, but not required by student

$$\frac{\Delta V}{V} = \frac{0.05}{52} + \frac{0.05}{35} + \frac{0.05}{95} = 3 \times 10^{-3}$$

$\Delta V = 5 \times 10^{-7}$ ie $V = 1.77(1 \pm 5)\,10^{-4}$ m^3.]

Density correct to 2 sig figs so mass only correct to 2 sig figs

Mass $= 7.(6 \pm 1)\,10^{-1}$ kg $\frac{1}{2}$ $7.(6 \pm 2)\,10^{-1}$ kg acceptable $\frac{1}{2}$ | 1

(iii) Net voltage 0.1 V $\frac{1}{2}$ correct to ± 0.05 $\frac{1}{2}$ | 1

Resistance $\left(\frac{1}{6.00} + \frac{1}{6.00}\right)^{-1} = 3.00\ \Omega$ → ($\frac{1}{2}$ mark for one sig. fig) correct to 3 sig fig | 1

$I = 0.033$ A $\frac{1}{2}$ | $\frac{1}{2}$

$I = 0.03 \pm .0015$ A, ± 0.02 A acceptable $\frac{1}{2}$ | $\frac{1}{2}$

TOTAL | 10

b) Energy of photon $E = hf' = \frac{hc'}{\lambda}$ 2

$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(6.39\times10^{-7})}$ J 1 | 1

Total energy $nE = 0.5\times10^{-3}\times10^{-9} = 5\times10^{-13}$ J 1 | 1

$n = \frac{(5\times10^{-13})(6.39\times10^{-7})}{(6.63\times10^{-34})(3.00\times10^{8})}$ 1 | 1

$\underline{n = 1.6\times10^{6}}$. 1 | 1

TOTAL 6

c)(i) Using $s = ut + \frac{1}{2}at^2$ with $u = 0$ & $s = 36000$ m

$36000 = \frac{1}{2}a(60)^2$

$\underline{a = 20.0 \text{ ms}^{-2}}$ 1 | 1

(ii) After 60s velocity v given by

$v = 0 + a(60) = \underline{1200 \text{ ms}^{-1}}$ 1 | 1

Maximum height $(36)10^3 + s_2$ m

Using $v^2 = u^2 + 2as_2$ where $u = 1200 \text{ ms}^{-1}$ & $v = 0$

$0 = (1200)^2 + 2(-9.81)s_2$

$\underline{s_2 = 73400 \text{ m}} = \underline{73.4 \text{ km}}$ 1 | 1

Maximum height $H = (36.0 + 73.4)$ km $= 109.4$ km 1 | 1

(iii) Time of flight after first 60s given by

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

$-36000 = 1200t - \frac{1}{2}(9.81)t^2$

$t = 1200 \pm \sqrt{(1200)^2 + 4(4.95)3600} \,/\, 9.81$ ½ | ½

Positive sign only physically admissible ½ | ½

$t = 271.6$

TOTAL TIME $(271.6 + 60)$ s $= 331.6$ s 1 | 1

c) ALTERNATIVE SOLUTION

One can determine t_2, the time to max. height after switch off and t_3, the time from max. height to ground.

t_2 : $(v = u + at)$ $\quad 0 = 1200 + (-9.81)t_2 \quad t_2 = 122.3s$ 1

t_3 : $(s = ut + \frac{1}{2}at^2)$ $\quad 10^3(109.4) = 0 + \frac{1}{2}(9.81)t_3^2 \quad t_3 = 149.3s$ 1

TOTAL TIME $= 60 + 122.3 + 149.3 = 331.6s$ 1

(iv) Work done $= Mas_1 - Mgs_2 + Mg(s_1 + s_2)$ 1

$= Mas_1 + Mgs_1$

$= Ms_1(a+g)$ ½

$= (2.00 \times 10^3)(36000)(20.0 + 9.81)$

$= 2.15 \times 10^9$ J ½

Unrealistic as mass not constant 1

TOTAL 10

d) Mass of electron in amu $= 9.11 \times 10^{-31} / 1.66 \times 10^{-27}$

$= 0.000549$ amu 1 1

(i) Mass of $^{12}_{6}C$ nucleus $= 12.00000 - 6(0.000549)$ 1 1

$= 11.99671$ amu 1 1

(ii) Mass of $(6p + 6n)$ $= 6(1.00728 + 1.00866)$ 2

$= 12.09564$ amu 1 1

Mass Defect $= 12.09564 - 11.99671$

$= 0.09893$ amu 1

(iii) Binding energy in MeV $= (0.09893)(9.315 \times 10^2)$ MeV

$= 92.15$ MeV 1

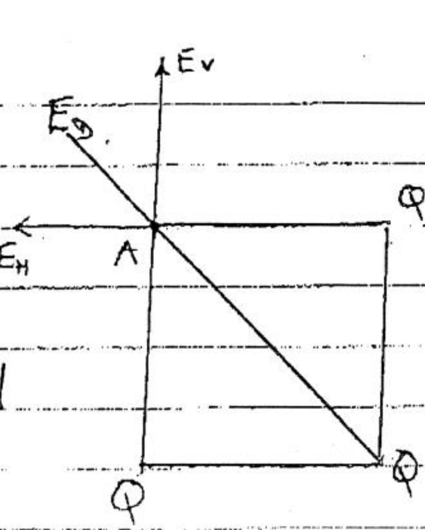
Binding energy per nucleon $= 92.15/12$ 1

$= 7.68$ MeV 1

TOTAL 10

e) Potential $V_A = \left(\overset{\frac{1}{2}}{\frac{Q}{a}} + \overset{\frac{1}{2}}{\frac{Q}{a}} + \overset{1}{\frac{Q}{\sqrt{2}a}}\right)\left(\frac{1}{4\pi\varepsilon_0}\right)$ 2

$= \underline{\frac{Q}{4\pi\varepsilon_0 a}\left(2 + \frac{\sqrt{2}}{2}\right)}$ 1 1



Diagonal field $E_D = \frac{Q}{4\pi\varepsilon_0}\frac{1}{(\sqrt{2}a)^2}$ 1 1

Horizontal field $E_H = \frac{Q}{4\pi\varepsilon_0}\frac{1}{a^2}$ 1 1

Vertical field $E_V = \frac{Q}{4\pi\varepsilon_0}\frac{1}{a^2}$ 1 1

Resultant of E_V and E_H along diagonal $= 2\left(\frac{Q}{4\pi\varepsilon_0}\right)\left(\frac{1}{a^2}\right)\frac{\sqrt{2}}{2}$ 1 1

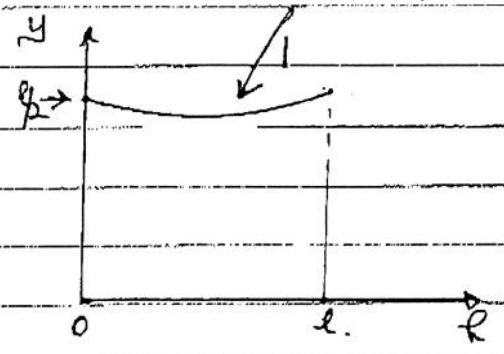
Resultant field along diagonal $= \underline{\left(\frac{Q}{4\pi\varepsilon_0}\right)\frac{1}{2a^2}\left[1 + 2\sqrt{2}\right]}$ 1 1

Correct direction 1 1

TOTAL 9

f) (i) $\frac{1}{2}\ell$ 1

(ii) $\frac{1}{2}\ell$ 1



1

Centre of gravity of cylinder + liquid is below $\frac{1}{2}\ell$ 2
as cylinder has C. of G. at $\ell/2$ and liquid C. of G. is at height below $\ell/2$ namely $y/2$.

TOTAL 5

g) (i) $g\cos 30° = \frac{\sqrt{3}}{2}g = 8.49\ ms^{-2}$. $\frac{1}{2}$ 1

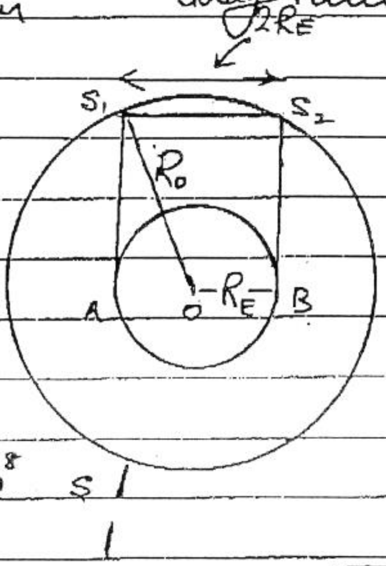
(ii) $E = \frac{1}{2}mv^2 + mgy$ $\frac{1}{2}$ $\frac{1}{2}$ 1

(iii) Resultant acceleration along y-axis 1 of magnitude $\frac{mv^2}{R}$ 1, where R radius of curve at O 2

(iv) $mgb = \frac{1}{2}mv^2$ $\frac{1}{2}$ ie $v = \sqrt{2gb}$. $\frac{1}{2}$ 1

TOTAL 5

h) Radius of orbit of satellite $R_0 = 3\cdot59 \times 10^4$ km 2 points for diagram
Radius of Earth $R_E = 6\cdot37 \times 10^3$ km 2



Path length of radio signal
$OS_1 = (3\cdot59 + 0\cdot637)\,10^4$ km

$= 2R_E + 2S_1A$ $\frac{1}{2}$ $1\frac{1}{2}$ 2

$= \left[2(0\cdot637) + 2\sqrt{(3\cdot59+0\cdot637)^2 - (0\cdot637)^2}\right]10^4$ km 2

$= [1\cdot27 + 8\cdot36]\,10^4$ km 1

$= 9\cdot63 \times 10^4$ km 1

time delay $= 9\cdot63 \times 10^4 \times 10^3 / 3\cdot00 \times 10^8$ s 1

$= \underline{0\cdot321 \text{ s}}$ 1

TOTAL 10

(i) (i) plot $\left(\frac{1}{y}\right)$ against x for straight line 1 2
(OR " (xy) against y " " ")

(ii) plot x^2 against $\left(\frac{x}{y}\right)$ 3 3
(OR " yx " (y/x))

(i) $\frac{1}{y} = ax + b$: Gradient a 1 intercept $(x=0)$ b 1 2
(or intercept $(y=0)$ $-b/a$)
(hence b obtained given a)

$xy = -\frac{by}{a} + \frac{1}{a}$ Gradient $\left(-\frac{b}{a}\right)$ intercept $\left(\frac{1}{a}\right)$
(intercept gives a hence b obtained)

(ii) $x^2 = c\frac{x}{y} - d$ gradient c $1\frac{1}{2}$ intercept $(-d)$ $1\frac{1}{2}$ 3
OR $xy = -\frac{dy}{x} + c$ gradient $(-d)$ intercept c

TOTAL 10

j) $800\ \underline{MW} = \underline{800} \times 10^6 \times 24 \times 60 \times 60\ J = 6.912 \times 10^{13}\ J$ 1 | 1

Number of atoms of ${}^{235}_{92}U$ $= \dfrac{6.912 \times 10^{13}}{200 \times 10^6 \times 1.60 \times 10^{-19}}$ 1 | 1

$= \underline{2.157 \times 10^{24}}$ 1 | 1

Mass of ${}^{235}_{92}U$ $= \dfrac{2.157 \times 10^{24}}{6.03 \times 10^{23}} \quad \dfrac{235.2}{1000} = 0.84\ kg$ 1 | 3

TOTAL | 6

k) $m = m_0 (1 - v^2/c^2)^{-\frac{1}{2}}$

$(e/m) = (e/m_0)(1 - v^2/c^2)^{\frac{1}{2}}$ or $(e/m)^2 = (e/m_0)^2 (1 - v^2/c^2)$

Plot (e/m) against $(1 - v^2/c^2)^{\frac{1}{2}}$ 1 OR e^2/m^2 against (v^2/c^2) 1 | 1

gradient (e/m_0) 1 gradient $-(e/m_0)^2$ | 1

hence (e/m_0) obtained 1

Correct use of graph paper, full scale used with points spread out over full range of paper. (points not using a small region, or subregion, of graph paper) | 2

Gradient (or − sq. rt. gradient) $= (1.78 \pm 0.03)\ 10^{11}\ C\,kg^{-1}$ (3, 3) | 6

(Error estimate by variation of gradient)

Reduced marks for increased Errors. $(1.78 \pm 0.05)\ 10^{11}\ C\,kg^{-1}$ (2, 2) | 4

$(1.78 \pm 0.1)\ 10^{11}\ C\,kg^{-1}$ (1, 1) | 2

TOTAL | 10

Q2

a) (i) Separation remains constant equal to l 1 | 1

Both bars have same velocity $v = \sqrt{2gh}$ 1 | 1

(ii) $v_B = \sqrt{2gh}$

Remaining energy $E_R = \frac{1}{2}Mv_B^2 + Mgl = \underline{Mg(h+l)}$ | 2

(iii) $E = 2\left(\frac{1}{2}kx_c^2\right) + Mg(l - x_c)$ | 2

$= \underline{kx_c^2 + Mg(l-x_c)}$ — 1 | 1

(iv) From (ii) and (iii)

$$Mg(h+l) = kx_c^2 + Mg(l-x_c)$$ 1 | 1

$$x_c^2 - (Mg/k)x_c - (Mgh/k) = 0$$

$$x_c = \frac{1}{2}\left(\frac{Mg}{k}\right) \pm \frac{1}{2}\sqrt{\left(\frac{Mg}{k}\right)^2 + 4\left(\frac{Mgh}{k}\right)}$$ 2 | 2

$$= \frac{Mg}{2k}\left[1 \pm \sqrt{1 + \frac{4kh}{Mg}}\right]$$ 1 | 1

As $x_c > 0$, only acceptable solution is

$$x_c = \frac{Mg}{2k}\left[1 + \sqrt{1 + \frac{4kh}{Mg}}\right]$$ 1 | 1

b) (i) At the instant A leaves the ground, ground reaction zero 1 | 1

$$2kx_e = Mg$$ 1 | 1

$$x_e = \frac{Mg}{2k}$$ 1 | 1

(ii) Initial energy $Mg(h+l)$

To rise above the ground with finite K.E requires

for B $\quad Mg(h+l) = kx_e^2 + Mg(l+x_e) + \frac{1}{2}Mv_B^2$ | 2

The condition that $v_B > 0$ requires | 1

$$Mg(h+l) > kx_e^2 + Mg(l+x_e)$$

Sub^g for x_e $\quad Mg(h - Mg/2k) > k(Mg/(2k))^2$ | 1

$$h > \frac{3Mg}{4k}$$ | 1

TOTAL 20

Q3.

a) (i) Electrons emitted from Cathode, leaving cathode at positive potential relative to anode. 2

(ii) Energy of photon only available in descrete quanta hf in interation with electrons 2

(iii) If electrons emerge with K.E $\frac{1}{2}mv^2$, then conservation of energy requires

$$hf - hf_c = \tfrac{1}{2}mv^2 \qquad 2$$ 2

or $$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_c}\right) = V_0 e \qquad \text{or} \qquad \frac{1}{\lambda_c} = \frac{-V_0 e}{hc} + \frac{1}{\lambda} \quad 1$$ 1

$$\lambda_c = \frac{\lambda hc}{hc + \lambda V_0 e} \qquad 1$$ 1

ALTERNATIVE PROOF USING WORKFUNCTION W

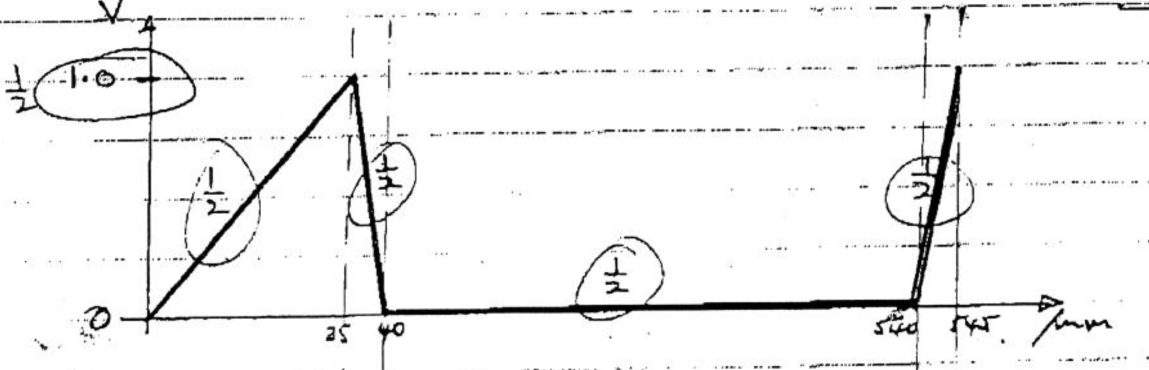
$$hf = \frac{hc}{\lambda} = We + V_0 e \qquad \& \qquad \frac{hc}{\lambda_c} = We \qquad 2$$

give $$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_c}\right) = V_0 e \qquad 1$$

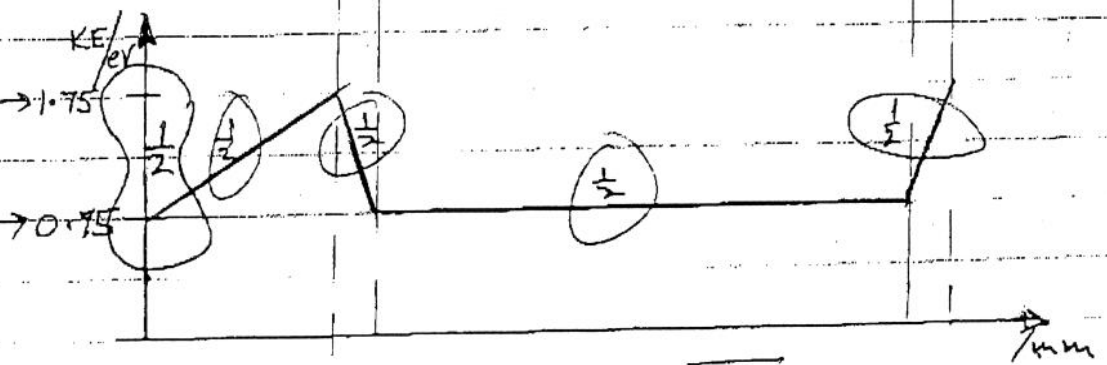
$$\lambda_c = \frac{\lambda hc}{hc - \lambda V_0 e} \qquad 1$$

TOTAL 8

b)



$2\frac{1}{2}$



$2\frac{1}{2}$

iii)

$$\tfrac{1}{2}m_e v^2 = V_0 e \quad 1 \qquad \text{ie} \qquad v = \sqrt{\frac{2eV_0}{m_e}}$$ 1

$$v = \sqrt{\frac{2(1.60\times10^{-19})(0.750)}{9.11\times10^{-31}}} \quad 1 \quad = \underline{5.1\times10^{5}\ \mathrm{ms}^{-1}} \quad 1$$ 2

(iv) Electrons that pass through G1, during the +ve potential, have to travel to G2 a distance of 500 mm. Thus when they reach G2 the gate is +ve for a remaining time that is less than 1.5 μs for which gate "open". Electrons that pass through G2 form the periodic pulses in Figure 3.4. 2

(v) Time of travel from G1 to G2 $= \frac{0.50}{v} = \frac{0.50}{5.13 \times 10^5}$ s

$= 0.975 \times 10^{-6}$ s 1

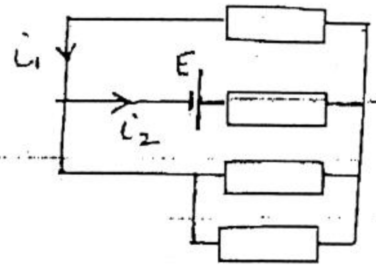
Therefore pulse width $= (1.50 - 0.97)10^{-6}$ s $= 0.53$ μs 1

(Any answer from (0.51 – 0.54) μs acceptable)

TOTAL 12

Q4 a) (i) 3 resistances in parallel

Total resis. $\left(\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\right)^{-1} = \frac{1}{3}R$ 1 | 1



$\therefore \quad i_2\left(R+\frac{1}{3}R\right)=E$ 1 | 1

$\underline{i_2 = 3E/4R}$ 1 | 1

By symmetry (or otherwise)

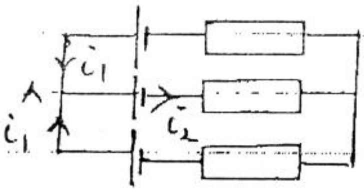
$3i_1 = i_2$

$\underline{i_1 = \frac{1}{3}\left(3E/4R\right) = \frac{E}{4R}}$ 1 | 1

(ii) By symmetry $i_1 = -i_2$

At A : $i_1 + i_1 + (-i_2) = 0$

$\underline{i_1 = i_2 = 0}$ | 1



b) If $i_1=0$ for STAR $\quad i_3 = -i_2$ | $\frac{1}{2}$

PD between (3,2) $\quad (R_3+R_2)i_2$ | 1

If $i_1=0$ for TRIANGLE $\quad i_3 = -i_2$ | $\frac{1}{2}$

PD between (3,2) $\quad i_2 \times$ TOTAL RESIS. ACROSS (2,3)

$= i_2\left[\frac{1}{R_{23}}+\frac{1}{R_{31}+R_{12}}\right]^{-1}$ (resis in parallel) | 1

Equating PDs

$$R_3+R_2 = \left(\frac{1}{R_{23}}+\frac{1}{R_{31}+R_{12}}\right)^{-1} \quad | \ 1$$

$$R_3+R_2 = \frac{R_{23}(R_{31}+R_{12})}{R_{31}+R_{12}+R_{23}} \quad | \ \tfrac{1}{2}$$

or

$$\underline{(R_2+R_3)(R_{31}+R_{12}+R_{23}) = R_{23}(R_{31}+R_{12})} \quad | \ \tfrac{1}{2}$$

c) Similarly for

$i_2=0$: $\quad \underline{(R_3+R_1)(R_{31}+R_{12}+R_{23}) = R_{31}(R_{23}+R_{12})}$ | 1

$i_3=0$: $\quad \underline{(R_1+R_2)(R_{31}+R_{12}+R_{23}) = R_{12}(R_{23}+R_{31})}$ | 1

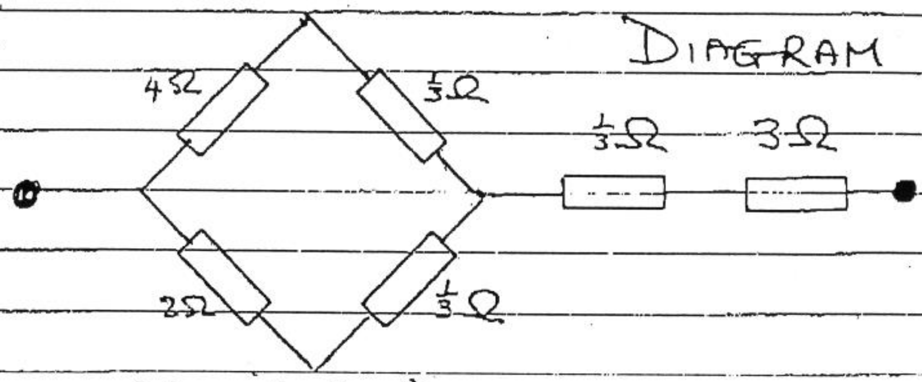
d) If $R_{12}=R_{31}=R_{23}=1\Omega$ the above 3 equations give

$$\left.\begin{aligned} R_2+R_3 &= \tfrac{2}{3} \\ R_3+R_1 &= \tfrac{2}{3} \\ R_2+R_1 &= \tfrac{2}{3} \end{aligned}\right\} 1 \quad | \ 1$$

Solution $\quad \underline{R_1 = R_2 = R_3 = \frac{1}{3}\ \Omega}$ 2 | 2

e) Circuit reduces, after substituting "star" for "triangle" to

DIAGRAM | 1 | 1



$(4+\frac{1}{3})\Omega$ in parallel with $(2+\frac{1}{3})\Omega$ | 1 | 1

Total resistance $\left(\frac{3}{13}+\frac{3}{7}\right)^{-1} + \frac{1}{3} + 3 = \left(\frac{60}{91}\right)^{-1} + \left(\frac{10}{3}\right)$ | 1 | 1

$= \frac{91}{60} + \frac{10}{3} = \frac{291}{60}\,\Omega$ | 1 | 1

$= \underline{4 \cdot 85\,\Omega}$ | 1 | 1

TOTAL 20

Q5 10

a) Force F_T on a wire carrying a current I is $BI\ell$, where ℓ is the length of the wire, B is the component of the field perpendicular to the wire.

$$F_T = \left(\frac{\mu_0 I_1}{2\pi r}\right) I_2 \ell$$

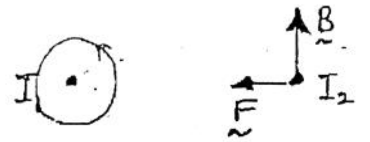
or force per unit length

$$F = \frac{\mu_0 I_1 I_2}{2\pi r} \quad \text{due to current } I_1 \text{ on } I_2.$$ 1

An identical expression is obtained for field due to I_2 on I_1

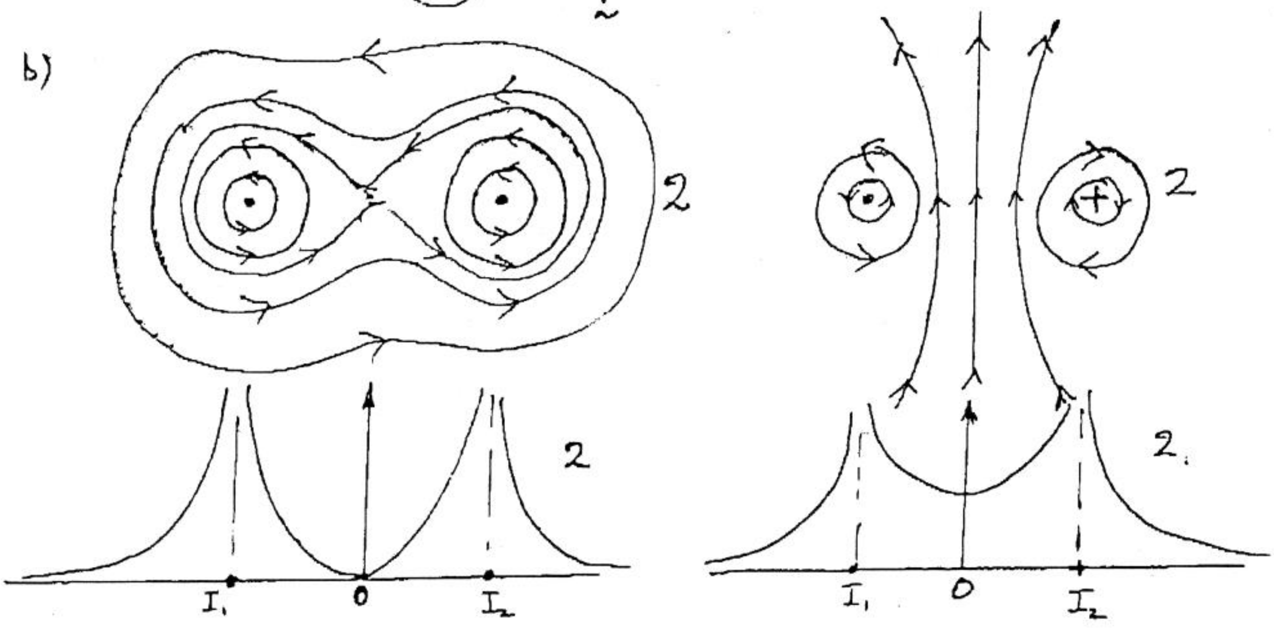
The direction of F is given by Flemings left hand rule 1

It is indicated in the diagram for parallel currents I_1 and I_2



TOTAL 2

b)



4

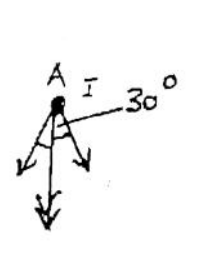
4

$$B_{resultant} = \frac{\mu_0 I_1}{4\pi r_1}\hat{i} + \frac{\mu_0 I_2}{4\pi r_2}\hat{j}.$$ 1

directions $\hat{i}$ and $\hat{j}$ given by field line diagrams

TOTAL 9

c) Force per metre on A has two components one from B in direction $\overline{AB}$ and an equal one from C in direction $\overline{AC}$.



Resultant force on A $= 2\left(\frac{\mu_0 I^2}{2\pi r}\right)\cos 30^\circ$ 1 1

$$= \frac{2\mu_0 (200)^2}{2\pi(0{\cdot}50)}\left(\frac{\sqrt{3}}{2}\right)$$ 1 1

$$= \frac{4\pi 10^{-7}(200)^2\sqrt{3}}{\pi} = 16\times10^{-7}\times10^4\sqrt{3}$$

$$= 2{\cdot}77\times10^{-2}\ N$$ 1 1

Q5 c)

11

Direction of force from A to mid point BC 1
Similarly for forces on the other wires have same magnitude
and directions that are along the bisectors of the angles of the
equilateral triangle towards the centre of the triangle 1

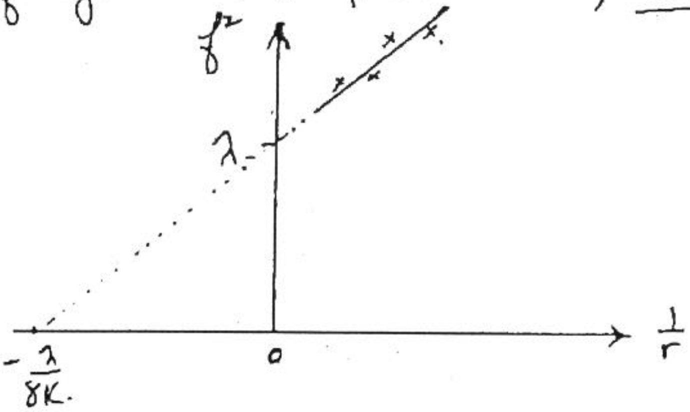
TOTAL 5

d) λ depends on torsional constant of thread 1

Make experimental measurements of f and r for a range of r.
Plot f^2 against $\frac{1}{r}$ (relation valid for small θ) 1
As $B = \frac{K}{r}$ where K is a constant

$$f^2 = \frac{\gamma K}{r} + \lambda$$ 1

Plot f^2 against $\frac{1}{r}$. Gradient γK, intercept λ 1



Straight line graph.

TOTAL 4

Q6 12

a) Eclipse of the Sun 2

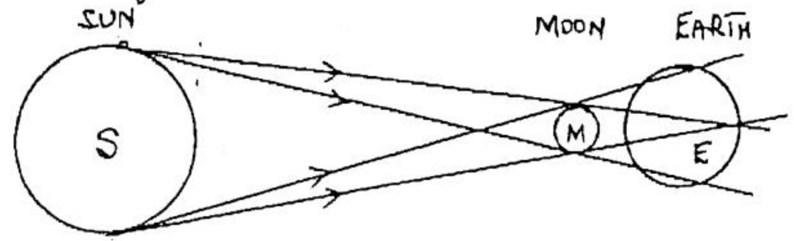


Diagram 1

Shadow of the Moon falls on the Earth as indicated in diagram
Observers in the shaded region cannot see the Sun; region of totality
Explanation 1

Eclipse of the Moon 2

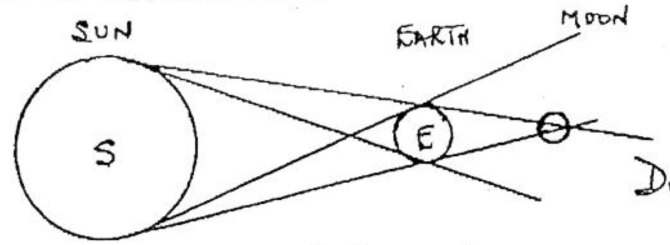


Diagram 1

Shadow of Earth falls on Moon, shaded region cannot be seen from Earth
Explanation 1

Eclipses do not occur periodically as S, E and M do not move in a plane; paths roughly approximate to a plane. 1

TOT. 5

b) For circular motion of Moon around the Earth 1

$$M_M R_{EM} \omega^2 = G M_M M_E / R_{EM}^2 \quad 1$$

$$R_{EM} \omega^2 = G M_E / R_{EM}^2$$ 1+1

Sub^n $T = \frac{2\pi}{\omega}$ 1

$$R_{EM} \left(\frac{2\pi}{T}\right)^2 = G M_E / R_{EM}^2 \quad 1$$

$$T^2 = \frac{4\pi^2}{G M_E} R^3 \quad \text{where } R = R_{EM} \quad 1$$ 1

TOT. 4

c) (i) $\tau = \frac{1}{2} T' = \frac{1}{2}\sqrt{\frac{4\pi^2 R^3}{G M_E}}$ 1 1+1

$$= \frac{1}{2}\left[\frac{4\pi^2 \left(\frac{1}{2}\right)^3 (3.82\times10^8)^3}{6.67\times10^{-11}\,(5.97\times10^{24})}\right]^{\frac{1}{2}} \quad \text{as } R = \tfrac{1}{2} R_{EM}$$ 1

$$= 2.96\times10^5\,\mathrm{s} \quad 1$$ 1

NOTE
(1 year ~ 3.15×10^7 s)
(1 month ~ 3×10^6 s)
(1 day ~ 8.6×10^4 s)

TOT 4

(ii) Av. speed, $v_a = \frac{\text{distance}}{\text{time}} = \frac{3.82\times10^8}{2.96\times10^5}$ 1 $= 1.29\times10^3\,\mathrm{ms^{-1}}$ 1 1+1

Q6 13

(iii) Conservation of energy gives

$$\tfrac{1}{2}M_E V_M^2 = G M_E M_M \left(\frac{1}{R_E} - \frac{1}{R_{EM}}\right)$$ 1

$$V_M^2 = 2GM_M \left(\frac{1}{R_E} - \frac{1}{R_{EM}}\right)$$

$$= 2(6.67\times10^{-11})(5.97\times10^{24})\left[\frac{1}{6.37\times10^{6}} - \frac{1}{3.82\times10^{8}}\right]$$ 1

$$= 1.23\times10^{8}$$

$$\underline{V_M = 1.11\times10^{4}\ \mathrm{ms}^{-1}}$$ 1

TOT. 5

(iv) Using the result in (i) with M_E replace by M_S, the time τ_S is

$$\tau_S = \frac{1}{2}\left[\frac{4\pi^2\left(\frac{1}{2}\right)^3(2.00\times1.50\times10^{11})^3}{(6.67\times10^{-11})(1.99\times10^{30})}\right]^{\frac{1}{2}}$$ 1 1

$$= \frac{1}{2}\left[\frac{4\pi^2(1.50\times10^{11})^3}{(6.67\times10^{-11})(1.99\times10^{30})}\right]^{\frac{1}{2}}$$

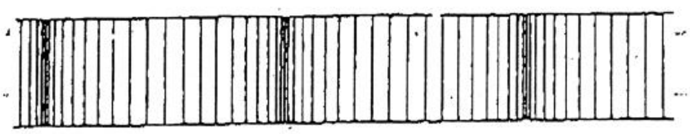
$$\underline{= 1.58\times10^{7}\,s}$$ 1 (NB. 1 year ~ 3×10^7 s) 1

TOT. 2.

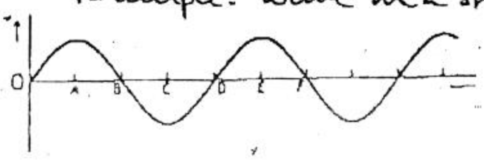
14

Q7

a) Longitudinal wave: propagation of periodic compressions and rarefactions in the direction of the wave. Example sound wave (alternatives accepted) 1



Transverse wave: periodic oscillations perpendicular to direction of wave motion. Example: Wave on a string (alternatives accepted) 1



POLARIZED WAVE — LIGHT WAVE PASSED THROUGH A POLARIZER OR LIGHT REFLECTED AT BREWSTER ANGLE 1

TOT. 3

b) (i) Beats

Two waves of nearly equal frequencies, ω and $\omega+\Delta\omega$, gives rise to a wave of frequency ω modulated by the frequency $\Delta\omega$. $\Delta\omega$ is called the beat frequency. 2

(ii) Doppler Effect

If there is motion between source of sound frequency f and the observer, or motion of the medium, the frequency received by the observer differs from that produced by the source ie number of waves arriving at observer differs from that emitted by source. 2

TOT. 4

c) If source stationary f_0 waves emitted per sec. toward the observer, occupying a distance c, wavelength c/f_0.
If source moving with velocity v_s towards observer waves will occupy a distance $(c-v_s)$ as source moves a distance v_s towards observer. Thus wavelength reaching observer $(c-v_s)/f_0$
Apparent frequency

$$f = \frac{c}{(c-v_s)/f_0} = \frac{f_0}{(1-v_s/c)}$$

TOT. 5

d) If source moves away from observer v_s changes sign and

$$f = \frac{f_0}{(1+v_s/c)} \quad 1$$

1

At $v=c$, in (c), waves build up to produce a sonic bang 1 1

Rigidity modulus zero (or equivalent) 1

TOT. 3

Q7 Some explanation explaining why the Doppler formula can be applied to the beat frequency, when derived for pure frequency

c) Let f_0 be beat frequency of the two engines

Motion towards observer gives, from (c),

$$8 = \frac{f_0}{1-(v_s/c)}$$

Motion away from observer gives, from (c),

$$2 = \frac{f_0}{1+(v_s/c)}$$

The ratio of these two equations gives

$$4 = \frac{1+v_s/c}{1-v_s/c}$$

or

$$\frac{4-1}{4+1} = \frac{2(v_s/c)}{2}$$

$$\frac{V_s}{c} = \frac{3}{5}$$

$$V_s = 198\ \mathrm{ms}^{-1}$$

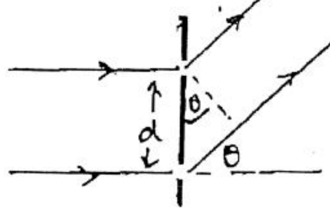
TOT. 5

Q8

a) The radiation emerging from medium is dispersed, ie different wavelengths emerge at different angle (eg white light split into its colours) 2 /10

TOT. 2

b)



(i) Path difference $= d\sin\theta$

Constructive interference arises if $d\sin\theta = n\lambda$ n integer 1

Destructive interference arises if $d\sin\theta = (n+\frac{1}{2})\lambda$ 1

(ii) For small θ ($\theta < 0.1$ radian) $\sin\theta \simeq \theta$

Thus constructive interference, for $n=1$, occurs when 1

$$d\sin\theta = d\theta = \lambda$$

ie $\theta = \lambda/d$ 1

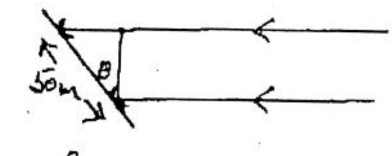
(iii) In dispersive medium of refractive index μ optical path difference becomes $\mu d\sin\theta$ 1

Thus the result in (ii) becomes

$$\theta = \frac{\lambda}{\mu d}$$ 1

TOT. 6

c)



If telescope moves through angle θ path difference producing interference is

$50\sin\theta$ m 1

For first order maximum (zero order max. is that produced when $\theta = 0$, at noon)

$$50\sin\theta = \lambda = 0.75$$ 1

$$\sin\theta = \frac{3}{200}$$

$$\theta \simeq \frac{3}{200} \text{ radians}$$

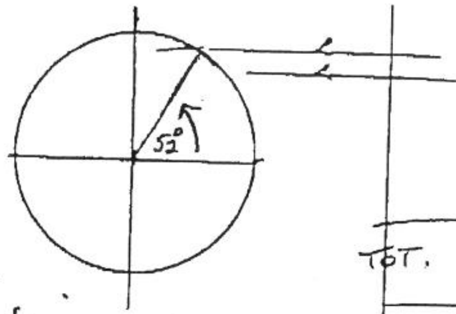
As Earth rotates through 2π in 24 hours time interval between maxima

$$= \frac{3(24)60}{(200)2\pi} = 3.438 \text{ minutes}$$ 1

$= 3$ minutes 26 s 1

Q.8 c)(ii) Amplitude of radiation reduced by $\cos 52°$ 1

Intensity reduced by factor $\cos^2 52° = 0.38$ 1 1



TOT. 6

d) (i) If radius reduced conservation of angular momentum requires the frequency of rotation to increase. Thus pulsar frequency increases. This increase could be detected. 3

(ii) Due to refractive index of medium, different frequencies would arrive at different times. For non-dispersive medium all frequencies arrive at same time. Alternatively if refractive index of medium changes arrival times for different frequencies alters. This can be measured by a suitable apparatus 3

TOT. 6

14

Q9 (a)

(i) Energy increased, photon absorbed 1 — 1

(ii) $h\nu = \frac{hc}{\lambda} = (-3.40 + 13.60)^1 = 10.20 \text{ eV}$ — 1

$\lambda = \frac{1}{hc}(10.20)\,e \text{ m}$ — 1

$= (10.20)(1.60 \times 10^{-19}) / (6.63 \times 10^{-34})(3.00 \times 10^{8})$

$\lambda = 1.22 \times 10^{-7} \text{ m} = 122 \text{ nm}$ — 1

(iii) Ionization energy is $\underline{13.60 \text{ eV}}$ 1 (energy required to remove electron from ground state) — 1

TOT. 5

b) Energy levels discrete for bound electron, continuous for free electron — TOT. 1

c) (i) Conservation of momentum requires $\frac{h}{\lambda_1} = \frac{h}{\lambda_2}$ ie $\lambda_1 = \lambda_2$ — 1

(ii) No difference, additional momentum taken up by neighbouring particles — 1

(iii) Energy equation: $m_e c^2 = 2h\nu = \frac{2hc}{\lambda}$ — 1

$\lambda = \frac{2hc}{m_e c^2} = \frac{2h}{m_e c}^1 = \frac{2(6.63 \times 10^{-34})}{(9.11 \times 10^{-31})(3 \times 10^{8})}^1$ — 2

$\lambda = 4.85 \times 10^{-12} \text{ m}$ — 1

TOT. 6

d) ENERGY $\quad hf^{\frac{1}{2}} = \frac{1}{2} m_e^{\frac{1}{2}} v^2 + h f_b^{\frac{1}{2}}$ ① — $1\frac{1}{2}$

MOMENTUM $\quad \frac{hf}{c}^{\frac{1}{2}} = m_e v^{\frac{1}{2}} - \frac{hf_b}{c}^{\frac{1}{2}}$ — $1\frac{1}{2}$

or $hf = m_e c v - h f_b$ ②

Adding ① + ② $\quad f = (\frac{1}{2}v + c) m_e v / 2h$ ③ — 1

But $\frac{1}{2} m_e v^2 = Ve$ ie $v \sqrt{2Ve/m_e}$ — 1

So ③ becomes

$f = \frac{1}{2h}\left(Ve + m_e c \sqrt{\frac{2Ve}{m_e}}\right)$

Hence as $f = \frac{c}{\lambda}$, $\quad \frac{1}{\lambda} = \frac{1}{2hc}\left(Ve + m_e c \sqrt{\frac{2Ve}{m_e}}\right)$ — 1

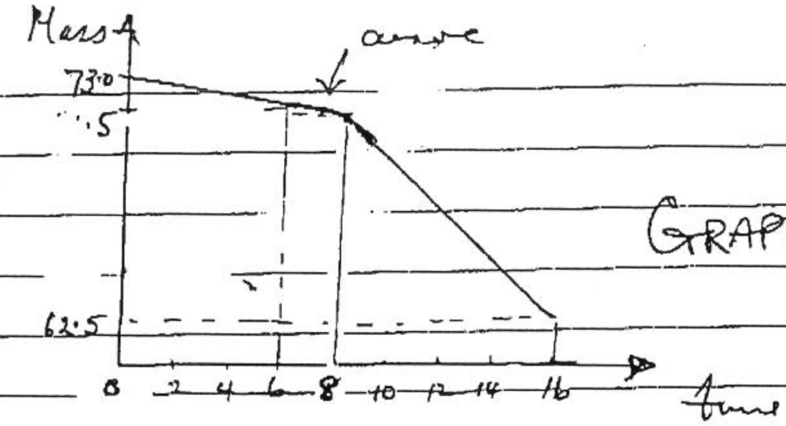
$= \frac{1}{2hc}\left(Ve + c\sqrt{2 m_e V}\right)$

$= \frac{[5 \times 10^3 \times 1.60 \times 10^{-19} + 3.00 \times 10^{8} \sqrt{2(9.11 \times 10^{-31})(5 \times 10^3 \times 1.6 \times 10^{-19})}]}{2(6.63 \times 10^{-34})(3.00 \times 10^{8})}$ — 1

$\lambda = 3.25 \times 10^{-9} \text{ m}$ — 1

TOT. 8

Q10 (b) Graph



GRAPH 1

R_S = Rate of evaporation due to surroundings $= \frac{1.50 \text{ gms}}{6.00 \text{ mins}} = \frac{1}{4}$ gm/min 1

R_{S+H} Rate of evaporation due to surroundings + heater $= \frac{6.00 \text{ grams}}{6.00 \text{ mins}} = 1$ gm/min 1

R_H = Rate of evaporation due to heater alone $= \frac{3}{4}$ gm/min $= \frac{3}{4(60)}$ gms^{-1} 1/2

Power dissipated by heater = rate of loss of heat by evaporation by heater

$VI = R_H L_V$ where L_V = specific heat of evaporation 1

$$L_V = \frac{VI}{R_H} = \frac{(0.90)^2(2.00)}{(\frac{3}{4}\times 10^{-3}/60)} \text{ J kg}^{-1}$$

$$= 1.30\times 10^5 \text{ J kg}^{-1}$$ 1/2

c) HEAT LOST = HEAT GAINED

$$10^{-3}\{225(4200)(70-T)\} = \{200(1200)(T-20) + 15(4000)(T-5)\}10^{-3}.$$ 1

$$45(42)(70-T) = 40(12)(T-20) + 3(40)(T-5)$$

$$378(70-T) = 96(T-20) + 24(T-5)$$

$$T(96+24+378) = 26460 + 1920 + 120.$$ 1

$$T = 28500/498$$

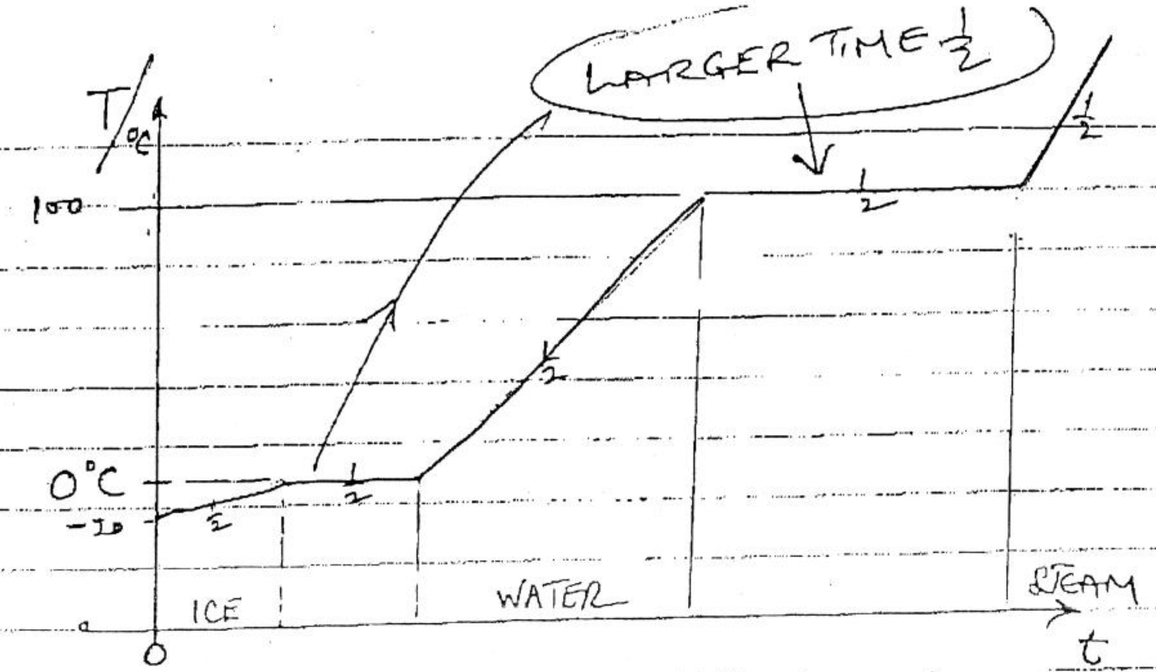
$$T = 57.2\,°C$$ 1

, for a fixed mass of black coffee,

Heat required to raise temperature of white coffee + mug the same if at T_1 or T_2. However if at T_1 $(T_1 > T_2)$, more heat retained by additional coffee to ensure it at T_1 than is the case at T_2, so less heat available to heat white coffee + mug. Thus more black coffee required. 3

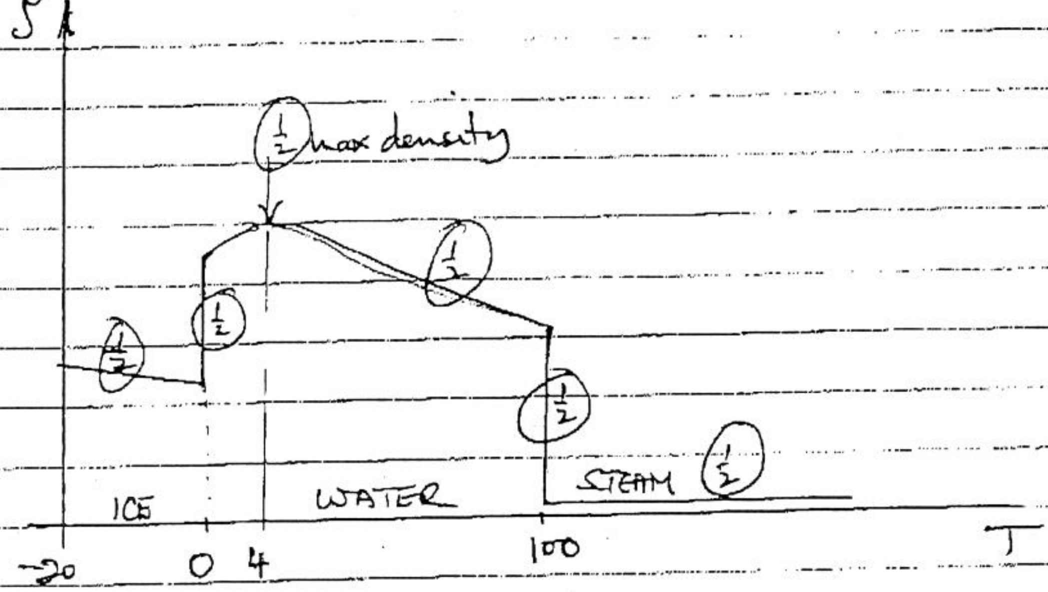
TOTAL 20

Q10(a)



3

[NB $L_F = 3.35 \times 10^5$ J/kg , $L_v = 2.26 \times 10^6$ J/kg]



3

ARRANGEMENT AND MOTIONS

	ICE	WATER	STEAM
ARRANGEMENT	Crystal ½	Random/Pseudo-Random ½	Random ½
MOTION	Vibrational ½	Diffusion-translation + collisions ½	Translational few collisions ½

3