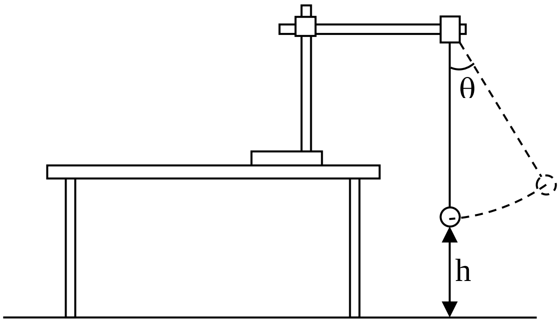
<table>
<tr><th>Qn</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1. (a)</td><td>(i) …the acceleration of a body in the earth's gravitational field</td><td>1</td></tr>
<tr><td></td><td>(ii) The bob is suspended from a retort stand such that it is at a height h from the floor.

- The length of the pendulum is adjusted to about 1.100 m
- The bob is displaced through a small angle to the vertical and then released as shown in the figure.
- The time, t, for 20 complete oscillations and the period, T, are found.
- The procedure is repeated for other five values of h.
- The results are tabulated including values of T^2.
<table><tr><th>h(m)</th><th>t(s)</th><th>T(s)</th><th>$T^2(s^2)$</th></tr><tr><td>-</td><td>-</td><td>-</td><td>-</td></tr><tr><td>-</td><td>-</td><td>-</td><td>-</td></tr></table>
- A graph of h against T^2 is plotted and the slope, s, of the graph found
- g is calculated from $g = 4\pi^2 s$</td><td>½
1
½
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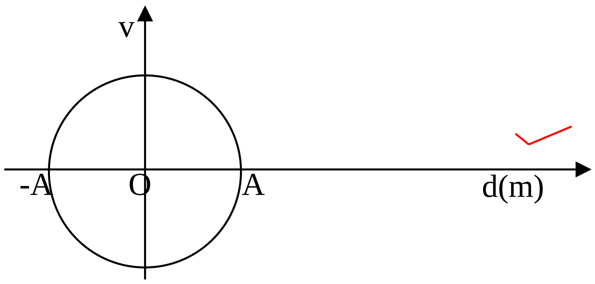
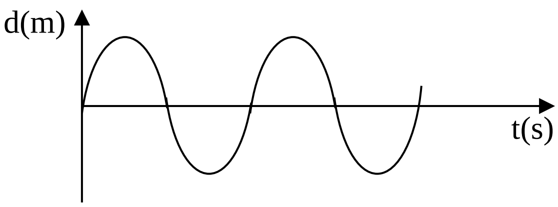
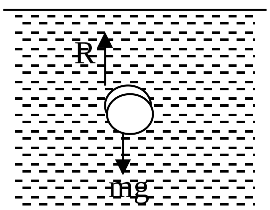
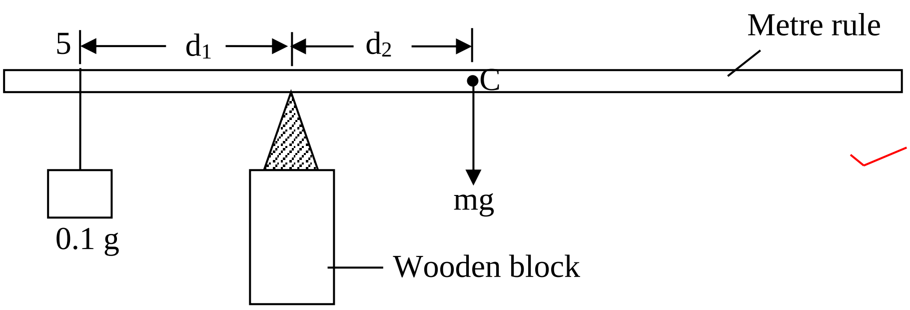
½
½
1
½</td></tr>
<tr><td>(b)</td><td><table><tr><th>l(cm)</th><th>l(m)</th><th>t(s)</th><th>T(s)</th><th>$T^2(s^2)$</th></tr><tr><td>20</td><td>0.200</td><td>17.8</td><td>0.890</td><td>0.792</td></tr><tr><td>30</td><td>0.300</td><td>22.0</td><td>1.100</td><td>1.210</td></tr><tr><td>40</td><td>0.400</td><td>25.0</td><td>1.250</td><td>1.563</td></tr><tr><td>50</td><td>0.500</td><td>28.0</td><td>1.400</td><td>1.960</td></tr></table>
Slope, $s = \frac{\Delta T^2}{\Delta l} = \frac{2.050 - 0.7625}{0.525 - 0.190} = 3.84\ s^2\,m^{-1}$
$s = \frac{4\pi^2}{g}$</td><td></td></tr>
</table>

	$\therefore \quad g = \frac{4\pi^2}{s} = \frac{4\pi^2}{3,84} = 10.3 \text{ m s}^{-2}$	
(c)	m = 0.1 kg, k = 24.5 N m^{-1}, x = 5.0 cm = 0.05 m (i) $a = -\left(\frac{k}{m}\right)x$ $\omega^2 = \frac{k}{m} = \frac{24.5}{0.1} = 245$ $\therefore \omega = \sqrt{245} = 15.65$ radians $T = \frac{2\pi}{\omega} = \frac{2\pi}{15.65} = 0.401$ s	1 ½ ½
	(ii) $x = A\cos(\omega t + \phi)$ At t = 0, x = 0.05 m $\therefore \quad 0.05 = 0.05\cos\phi$ $\therefore \quad \phi = 0^o$ $\therefore \quad x = 0.05\cos(15.652 \times 0.3)$ $= -0.001$ m i.e. the particle is 0.001 m above the equilibrium position	½ ½ 1½ ½ 1
(d)	(i)   	1 1
Total = 20		
2. (a)	(i) …the work done by the resultant force on a body is equal to the change in kinetic energy of the body	1
	(ii) m_1 = 20 g = 0.02 kg; H = 5 m	

	$m_2 = 5$ g = 0.05 kg Let the velocity with which the stone hits the object be u_1 k.e = mgh = ½m u_1^2 $\therefore \quad u_1 = \sqrt{2gh} = \sqrt{2\times9.81\times5} = 9.9045$ m s^{-1} Conserving momentum: $m_1u_1 + m_2u_2 = (m_1 + m_2)v$, v = common velocity of bodies 0.02 x 9.9045 + 0.005 x 0 0.025 v v 7.924 m s^{-1}	1 1



	As the bodies move in the water $(m_1 + m_2)$ g – 0.21 = $(m_1 + m_2)$ a 0.025 x 9.81 – 0.21 = 0.025 a $\therefore$ a = 1.41 m s^{-2} Velocity of bodies at the bottom ½$(m_1 + m_2)$ v^2 = 3.2 $\therefore \quad v = \sqrt{\frac{2\times3.2}{0.025}}$ = **16 m s^{-1}** Let h = height (depth) of water Using v^2 = u^2 + 2gh 16 = 7.924^2 + 2 x 1.41 h $h = \frac{16^2 - 7.924^2}{2\times1.41}$ = **68.51 m** ALT: Resultant force = $(m_1 + m_2)$ g – 0.21 = 0.025 x 9.81 – 0.21 = 0.03525 N $\therefore$ 0.03525 h = ½$(m_1 + m_2)$ v^2 - ½$(m_1 + m_2)$ u^2 (work-energy theorem) $\therefore \quad h = \frac{\frac{1}{2}(0.025)\times16^2 - \frac{1}{2}\times0.025\times7.924^2}{0.03525}$ = **68.51 m**	1 1 1 1
(b)	- The resultant force acting on a body is zero - The resultant moment of the forces about any point is zero	1 1
(c)		1 ½



<table>
<tr><td></td><td>- A metre rule is balanced on a knife edge and the balance point, C, recorded.
- A 100g mass is suspended at the 5-cm mark.
- The knife edge is adjusted until when the metre rule balances horizontally
- The distances d_1 and d_2 of the 100g mass and the point C form the knife edge are measured and recorded.
- The experiment is repeated for other positions of the 100g mass.
- A graph of d_1 against d_2 is plotted and the slope, s, calculated.
- The mass of the metre rule, m, is calculated from
$m = 0.1\,s$</td><td>½
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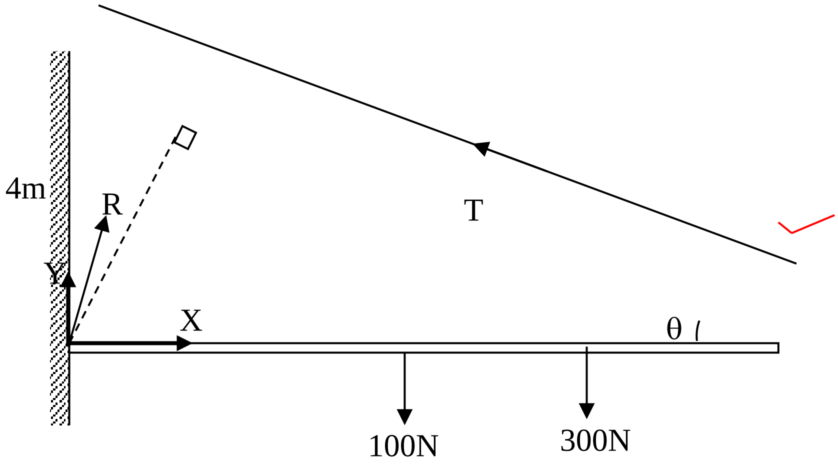
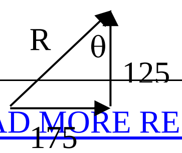
½
½

½</td></tr>
<tr><td>(d)</td><td>
Let T = tension in the string
R = reaction of the wall on the rod
X and Y are horizontal and vertical components of the reaction at the wall
$\tan\theta = 4/4 = 1$
$\therefore \theta = 45^o$

(i) Taking moments about the hinge
$100 \times 2 + 300 \times 3 = T \times 4 \sin 45^o$
$\therefore T = \mathbf{388.9\ N}$</td><td>1

1
1</td></tr>
<tr><td></td><td>(ii) Resolving
Vertically $Y + T\sin 45^o = 400$
$\therefore Y = 400 - 388.9 \sin 45^o = 125\ N$
Horizontally $X = T\cos 45^o = 275\ N$
$R = \sqrt{X^2 + Y^2} = \sqrt{275^2 + 125^2}$
$= \mathbf{302.1\ N}$
</td><td>

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tan θ = 275/125 — ½

θ = 65.56° — 1

The direction of the reaction is N 65.56°E or E 24.44°N or 22.44° above the horizontal.

Total = 20

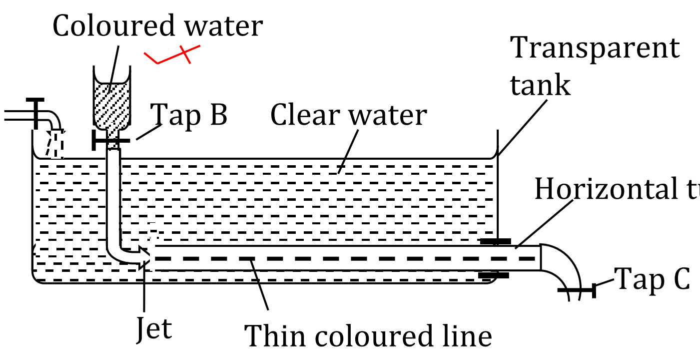
3. (a)

(i)

LAMINAR FLOW	TURBULENT FLOW
Flow where equidistant layers from the axis of flow have the same velocity	Flow where equidistant layers from the axis of flow have different velocities.
Flow lines are parallel	Flow lines are not parallel
Flow is orderly	Flow is not orderly

Any two @1 — 2

(ii)



½ ½

- A transparent tank, fitted with a horizontal transparent tube is filled with water from a tap. Tap A controls the rate of flow through the horizontal tube while tap B opens for the coloured liquid. — ½
- Tap A is opened, first slightly and then B is opened to release some coloured liquid. — ½
- Tap A is progressively opened further. — ½

Observation:

At first a thin coloured line is seen in the horizontal tube.

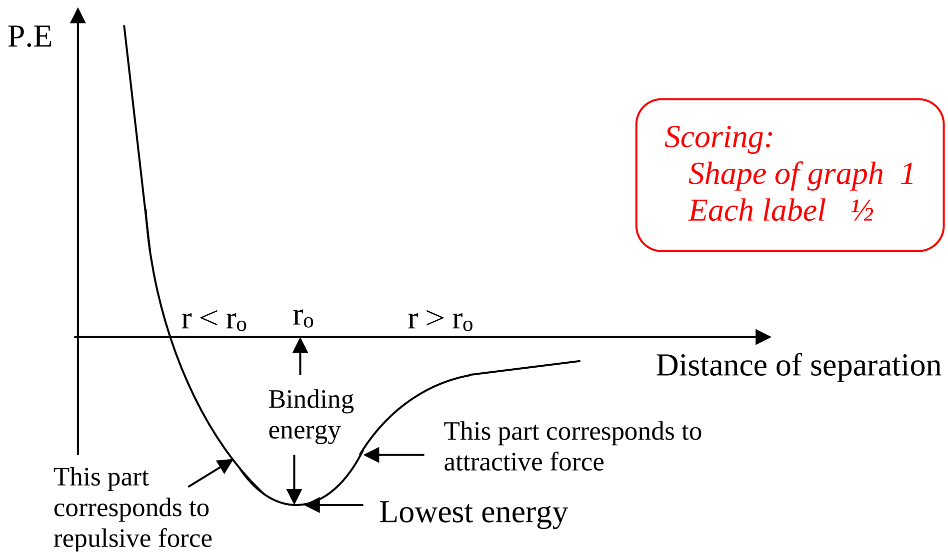
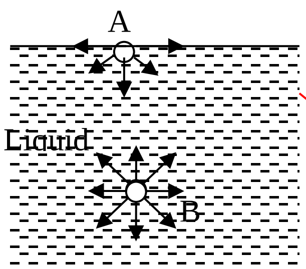
This is streamline flow. — ½

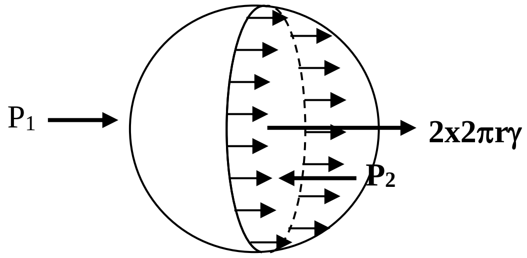
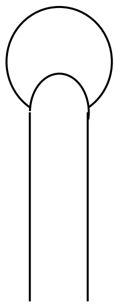
However, as A is opened further, the coloured line disappears and instead the colour fills the whole tube. — ½

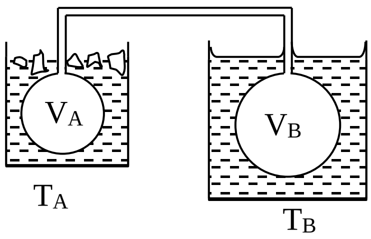
The flow has now become turbulent. — ½ ½

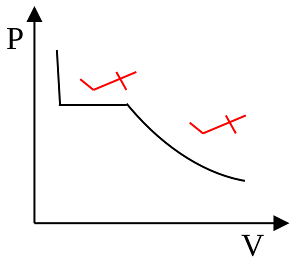
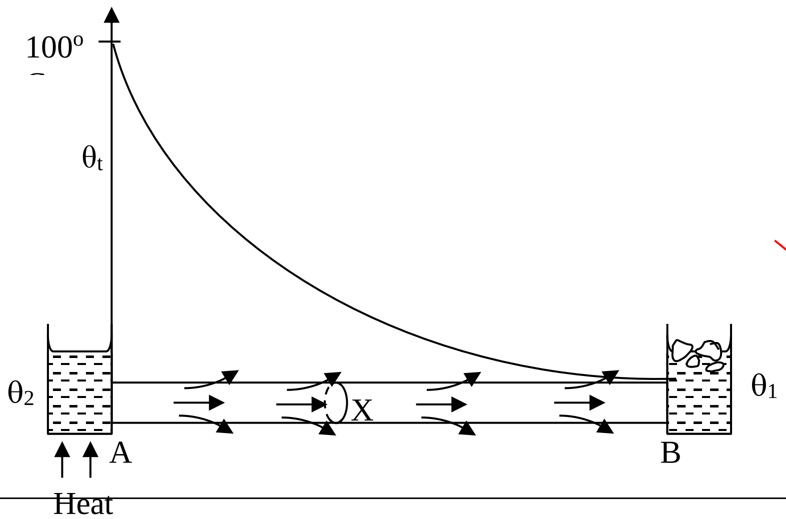
(b) For an incompressible, non-viscous fluid, the sum of the pressure at a point, the potential energy per unit volume and the kinetic energy per unit volume is a constant — 1

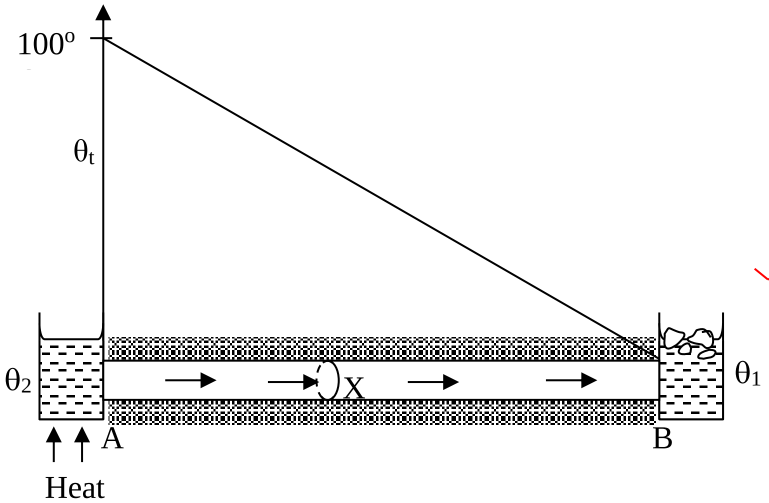
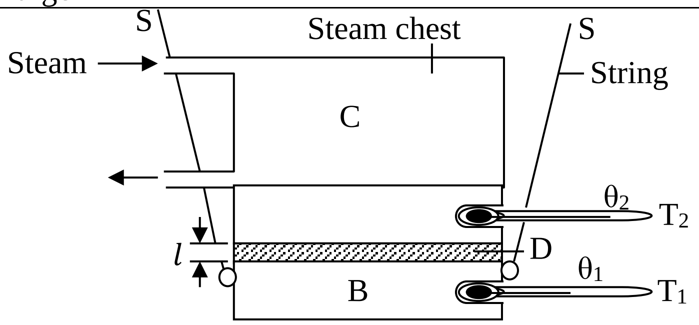
(c)	r_1 = 1.0 cm = 0.01 m r_2 = 0.5 cm = 0.005 m $P_1 = 4.0 \times 10^5$ N m^{-2} P_2 = ? $v_1 = 4.0$ m s^{-1} v_2 = ? h_1 = 0 (reference level) h_2 = 5.0 m (i) By the equation of continuity $A_1v_1 = A_2v_2$ $\pi r_1^2 v_1 = \pi r_2^2 v_2$ $\therefore\ v_2 = v_1\left(\frac{r_1}{r_2}\right)^2 = 4.0 \times \left(\frac{0.01}{0.005}\right)^2$ $= \mathbf{16\ m\ s^{-1}}$	 ½ ½ 1
	(ii) By Bernoulli's principle $P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$ $\therefore\ P_2 = 4.0 \times 10^5 + ½ \times 1000 \times 4^2 - ½ \times 1000 \times 16^2 - 5.0 \times 1000 \times 9.81$ $= 230{,}950$ N m^{-2}	 1 1 1
(d)	(i) Pressure gradient Radius of the pipe Nature of the fluid/ or coefficient of viscosity *Any two @½*	1
	(ii) Let $\frac{V}{t} = k\left(\frac{P}{l}\right)^x.a^y.\eta^z$ By dimension analysis $\left[\frac{V}{t}\right] = \left[\frac{P}{l}\right]^x[a]^y[\eta]^z$ $\therefore\ L^3T^{-1} = (ML^{-2}T^{-2})^x.\ L^y.(ML^{-1}T^{-1})^x$ Equating powers: for M: $x + z = 0$ ….. (i) L: $^-2x + y - z = 3$ ….. (ii) T: $-2x - z = -1$ …… (iii) from which $x = 1,\ z = {^-1},\ y = 4$ $\therefore\ \frac{V}{t} = \frac{kPa^4}{\eta l}$	 2 1 1
(e)	Origin of viscosity in liquids: Liquid molecules are fairly apart and have intermolecular forces of attraction. For one layer to move over the other, energy is required. The force required to drag the layers over the others constitutes the viscosity in a liquid.	 1 ½ 1½
Total = 20		
4. (a)		

	(i) Intermolecular forces are forces of attraction or repulsion which act between neighbouring particles such as molecules. These forces arise from the potential energy of the molecules, and the thermal energy of the molecules which is kinetic energy of the molecules and it depends on the temperature of the substance	3
	(ii)  *Scoring:* *Shape of graph 1* *Each label ½*	2
(b)	(i) Surface tension is the force per metre length acting in the liquid surface at right angles to one side of a line drawn in the surface. OR: it is the work done in increasing the surface area by 1 m^2 under isothermal conditions.	1
	(ii)  Liquid molecules attract each other. In bulk, a molecule B is attracted in all directions by other molecules, and the resultant attractive force is zero. A molecule A at the liquid surface has greater molecular separation than equilibrium separation. The molecule A at the surface experiences greater attraction from its neighbours and this puts molecule at the surface in tension. This is the phenomenon termed surface tension.	½ ½ ½ ½ ½ ½

	(iii) Let P_1 and P_2 be the external and internal pressures A soap bubble has two surfaces in contact with the liquid . So the surface tension force $F_\gamma = 2 \times 2\pi r\gamma = 4\pi r\gamma$  For the soap bubble in equilibrium Force due to pressure P_1 + force due to surface tension = force due to pressure P_2 Thus, $4\pi r\gamma + \pi r^2 P_1 = \pi r^2 P_2$ $\therefore \quad \mathbf{P_2 - P_1 = \frac{4\gamma}{r}}$	
(c)	r = 0.5 cm = 0.005 m  $\gamma_{soap} = 3.0 \times 10^{-2}$ N m^{-1} $\gamma_{water} = 7.0 \times 10^{-2}$ N m^{-1} Assuming zero angle of contact $h\rho g - \frac{2\gamma_{water}}{r} = \frac{4\gamma_{soap}}{r}$ $\therefore \quad h = \frac{1}{1000 \times 9.81}\left(\frac{4 \times 3.0 \times 10^{-2}}{0.005} + \frac{2 \times 7.0 \times 10^{-2}}{0.005}\right)$ $= \mathbf{3.06 \times 10^{-2}}$ **m**	1 1 2 1
(d)	Drops take on shapes for which the sum of the surface energy and gravitational potential energy is minimum For large drops, the effect of gravity is greater than that of the surface tension. Thus they flatten to reduce the gravitational potential.	1 1
	Total = 20	
5. (a)	(i) - The volume of the molecules is negligible compared with the volume occupied by the gas. - The attraction between molecules is negligible. - The molecules make perfectly elastic collisions. - The duration of collisions is negligible compared to the time between collisions.	1 1 1 1
(b)	u = 500 ms^{-1}, l = 0.05 m, m = 2.32 x 10^{-26}kg, N = 2 x 10^{22} Since the molecule reverses, momentum change on impact is	

	mu – (-mu) = 2mu Since the duration of collision is assumed negligible, the time between collisions at A is $2l/u$ The rate of change of momentum $= \dfrac{\text{momentum change}}{\text{time}}$ $= \dfrac{2mu}{2l/u} = \dfrac{mu^2}{l}$ By Newton's second law, the force on a face $= \dfrac{mu^2}{l}$ ∴ pressure on a face $= \dfrac{force}{area} = \dfrac{mu^2}{l \times l^2} = \dfrac{mu^2}{l^3}$ For the N molecules, P $= \dfrac{Nmu^2}{l^3}$ (each molecule has velocity u) $= \dfrac{2\times10^{22}\times2.32\times10^{-26}\times500^2}{0.05^3}$ = **9.28×10^5 N m^{-2}**	½ ½ ½ ½ 1 1
(c)	(i) The pressure of a mixture of gases is the sum of the partial pressures of its constituents.	1
	(ii)  $V_A = 3 \times 10^3$ cm^3 $V_B = 6 \times 10^3$ cm^3 $T_1 = 300$K, $P_1 = 1.0 \times 10^3$ Pa $T_A = 373$K, $T_B = 273$K Let m_1 = mass of gas in the cool bath m_2 = mass of gas in the hot bath Then, the equation of state for the original condition is $(m_1 + m_2)rT_1 = P_1(V_A + V_B)$ ∴ $m_1 + m_2 = \dfrac{P_1(V_A+V_B)}{rT_1}$ …………… (1) For each of the two bulbs in the second case we have $m_1rT_A = P_2V_A$ ……… ……… (2) and $m_2rT_B = P_2V_B$ ………………… (3) where P_2 is the final common pressure Then, from the equations (1), (2) and (3) $\dfrac{P_2V_A}{rT_A} + \dfrac{P_2V_B}{rT_B} = \dfrac{P_1(V_A+V_B)}{rT_1}$ ∴ $P_2\left(\dfrac{V_A}{T_A} + \dfrac{V_B}{T_B}\right) = \dfrac{P_1(V_A+V_B)}{T_1}$ ∴ $P_2 \times \left(\dfrac{3\times10^3}{373} + \dfrac{6\times10^3}{273}\right) = \dfrac{1.0\times10^3(3+6)\times10^3}{300}$	½ ½ ½ ½ 1

	∴ $P_2(8.04 + 22.0) = 3.0 \times 10^4$ ∴ $P_2 = \mathbf{1.0 \times 10^3\ Pa}$	1 1
(d)	(i) Warming the vessel at constant volume increases the rate of evaporation and hence the density of the vapour. The kinetic energy of the molecules is also increased. So more molecules bombard a unit area per second and with greater momentum. This implies rise in pressure	1 ½ 1 ½
	(ii)  *Both axes must be labelled* - At first, when the vapour is not saturated, it tends to obey Boyle's law approximately - Eventually the vapour becomes saturated when it starts condensing. - So the pressure remains constant as the volume is decreased. - When all the vapour has turned into liquid, the volume cannot decrease anymore. Hence the vertical portion of the graph	½ ½ ½ ½ ½ ½
	Total = 20	
6. (a)	(i) 	1 ½

	When the bar is not lagged, heat escapes through its sides by convection. Thus, the heat flowing per second past a cross-section like X, is less than that entering at A. Therefore the heat flow rate through a section in the bar decreases from the hot end to the cold along the bar.	½
	(ii)  When the bar is lagged, the escape of heat through the sides is negligible so that the heat flow rate along the bar is constant.	1 1
(b)	(i) In poor conductors it is very hard to get a measurable heat flow rate. So the two factors required for high heat flow rate must be maximised. The short distance ensures a high temperature gradient while the cross-sectional area is made large	½ ½ 1
	(ii)  To get an adequate heat flow rate the cork, D, is made in form of a thin circular disc. - The diameter, and the thickness, l, of the specimen are first measured and the apparatus is set up as shown in the diagram. B is a thick brass block containing a thermometer. - The whole apparatus is hung in air by three strings, S, attached to B. For good thermal contact, the adjoining faces of C, D and B must be flat and clean. - The specimen is heated by a steam chest, C, whose bottom is a thick brass block, thick enough to accommodate a thermometer.	1 ½ ½

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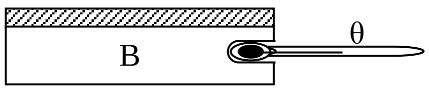
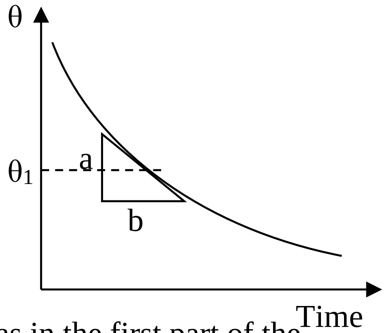
- When steady conditions have been attained, the temperatures θ_1 and θ_2 are recorded
Since brass is an extremely good conductor, θ_1 and θ_2, can be taken as the temperatures of the faces of the specimen.
Therefore the temperature gradient $= \frac{\theta_2 - \theta_1}{l}$
Next is to find the heat flow rate through the specimen as follows:
- The specimen, D, is removed and B is heated directly from C until its temperature has risen by about 10°C. Then the specimen alone is placed back on B (See illustration below) and the temperature of B is recorded at intervals and plotted against time as shown on the right below.


(i)


B is now losing heat under the same conditions as in the first part of the experiment. Thus, by drawing a tangent at θ_1 as shown, the rate of heat loss when B was at θ_1 is calculated.
Let k = conductivity of the specimen
A = cross-sectional area of the specimen
m = mass of B
c = specific heat capacity of B
Then $kA\frac{(\theta_2 - \theta_1)}{l} = mc\frac{a}{b}$
$\therefore \quad k = \frac{ml}{A(\theta_2 - \theta_1)} \times \frac{a}{b}$
</td>
<td>½
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<tr>
<td>(c)</td>
<td>
(i) $d = 2 \times 10^{-1}$ m, $t = 2 \times 10^{-3}$ m, $m = 5 \times 10^{-3}$ kg s^{-1},
$L = 2.26 \times 10^{6}$ J kg^{-1}, $k = 380$ W m^{-1}K^{-1}
$kA\frac{(\theta_2 - \theta_1)}{t} = mL$
$\therefore \theta_2 - \theta_1 = \frac{4mLt}{\pi d^2 k}$
$\therefore \theta_2 = \frac{4mLt}{\pi d^2 k} + \theta_1 = \frac{4 \times 5 \times 10^{-3} \times 2.26 \times 10^{6} \times 2 \times 10^{-3}}{\pi \times 2^2 \times 10^{-2} \times 380} + 100$
$= 1.9 + 100$
$=$ **101.9°C**
</td>
<td>1
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1</td>
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<td></td>
<td>(ii) No heat is lost to the surroundings</td>
<td>1</td>
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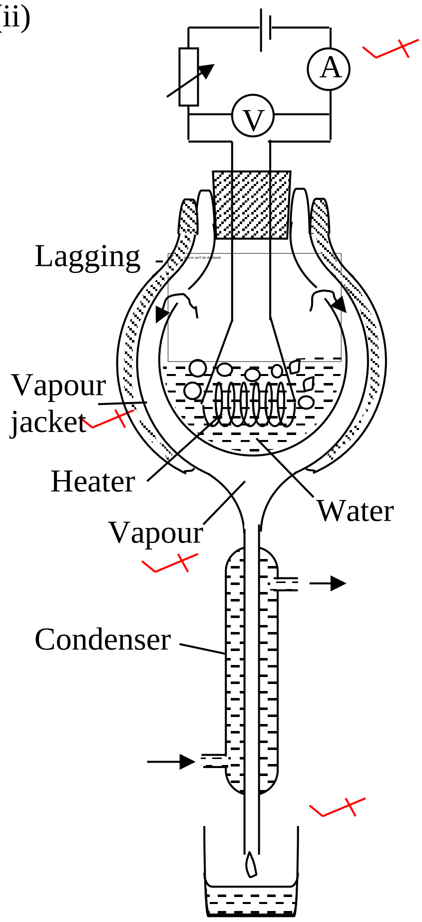
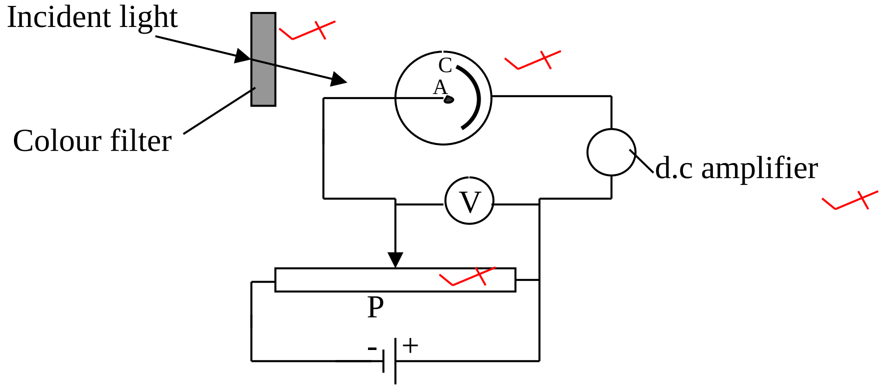
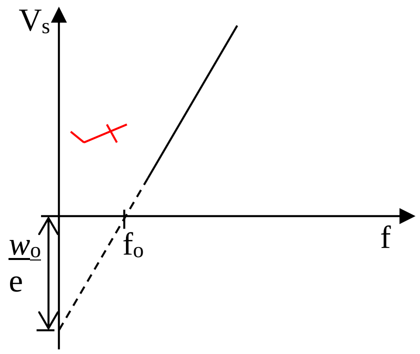
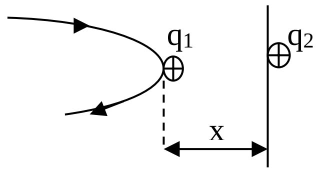
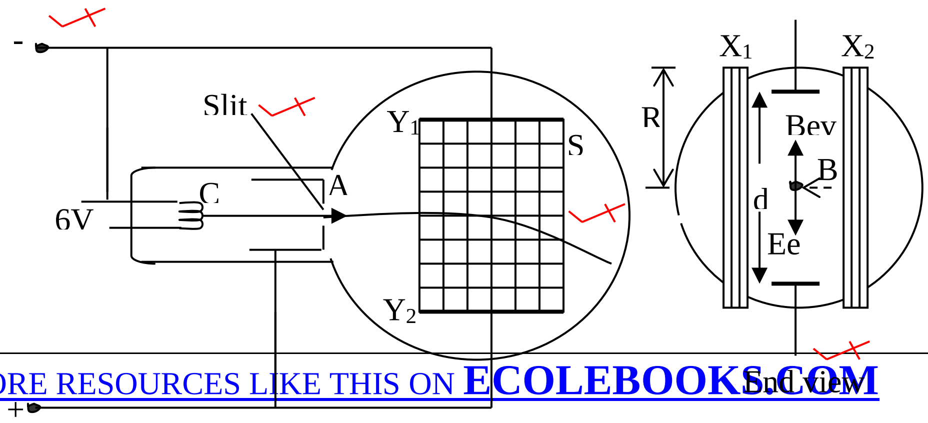
(d)	(i) The total power radiated per m^2 from a black body is proportional to the forth power of the body's absolute temperature	1
	(ii) This is because as the temperature rises, the intensity of all the wavelengths increases but that of the shorter wavelengths increases more rapidly. So the peak intensity shifts from the red end of the spectrum into the visible spectrum. Since the visible spectrum is a narrow band, the peak encompasses the entire spectrum of white light.	1 1 1
	Total = 20	
7. (a)	(i) …the quantity of heat required to convert 1 kg mass of a substance from liquid to vapour at constant temperature.	1
	(ii)  The apparatus is set up as shown in the diagram. The setup is switched on and given time to attain steady conditions, with the liquid at its boiling point. Under these conditions, the heat supplied by the heater is used in evaporating the liquid and offsetting the losses. - The condensed liquid is then collected in a weighed beaker over a measured time interval. Let m_1 = mass of liquid collected per second V_1 = p.d across the heater coil I_1 = current through the coil h = heat lost per second L = specific latent heat of vaporisation of the liquid Then $I_1V_1 = m_1L + h$ ……………(1) - The experiment is repeated at new values I_2 and V_2 of current and p.d respectively. Let m_2 = new mass of liquid collected per second. Then $I_2V_2 = m_2L + h$ ……………(2) From (1) and (2) $L = \frac{I_1V_1 - I_2V_2}{m_1 - m_2}$	½ 1 1 1 ½ ½ 1 ½ 1
(c)	(i) … the quantity of heat required to raise the temperature of 1 kg of a substance by 1 K.	1

	(ii) Let m = mass of liquid evaporated M = original mass of liquid P = electrical power C = heat capacity of flask Then Pt = (Mc + C)(78 -28) + mL ∴ mL = Pt – (Mc + C)(78 – 28) = (500 x 10 x 60) – (2 x 2500 + 840) x 50 = $3.0 \times 10^5 - 2.92 \times 10^5 = 8 \times 10^3$ ∴ m = $\frac{8\times10^3}{8.54\times10^3}$ = **0.937 kg** It is assumed that all the electrical energy is used to heat and evaporate the liquid.	2 1 1 1 1
(d)	(i) …the temperature at which the saturated vapour pressure of a liquid is equal to the external pressure acting on the liquid.	1
	(ii) When the external pressure is increased, the liquid molecules will need a higher kinetic energy in order to develop the vapour pressure that will equal to the external. So the liquid boils at a higher temperature	2
	Total = 20	
8.(a)	(i) to establish the electronic charge.	1
(b)	(ii) Photoelectric emission is the emission of electrons from a metal surface when electromagnetic radiation of high enough frequency falls on it while thermionic emission is emission of electrons from a metal surface as a result of heating the metal.	2
	(i) Work function – minimum energy required for an electron to be ejected from a metal surface. (ii) Stopping potential – is the value of the negative potential difference which just stops the electrons with maximum kinetic energy from reaching the anode from the cathode.	1 1
(c)	**(i) Laboratory Experiment to verify Einstein's photoelectric**  	½ ½ ½ ½

	The circuit is connected as shown in which P is a potential divider. The incident light is passed through a colour filter to select a desired frequency f. The frequency of the filter is noted. The p.d V, applied to the anode A, is increased negatively until the current, measured by the d.c amplifier just becomes zero. Then the reading, V_s, of the voltmeter is noted. It is the stopping potential for the frequency used. The procedure is repeated using different colour filters, each time noting the corresponding stopping potentials V_s. A graph of V_s against f is plotted. It is a straight line with a negative intercept on the V_s axis.  The slope, s of the graph is obtained. Then Planck's constant is calculated from $h = slope \times e$, where e is the electronic charge. (ii) $f = 8.8 \times 10^{14}\ Hz,\ W_0 = 2.5eV = 2.5 \times 1.6\times10^{-19} = 4\times10^{-19}\ J$ By Einstein's equation, $\frac{1}{2}mv^2 = hf - W_0$ $\frac{1}{2}mv^2 = 6.6\times10^{-34}\times8.8\times10^{14} - 4\times10^{-19} = 1.808\times10^{-19}$ $v^2 = \frac{2\times1.808\times10^{-19}}{9.11\times10^{-31}} = 3.96926\times10^{11}$ $v = 6.30\times10^5\ ms^{-1}$	½ ½ ½ ½ ½ ½ ½ 4
(d)	Given: D = 4.0 x10^{-2} m, d = 4.0 x 10^{-2} m, V = 12V, v = 1.0 x 10^6 ms^{-1}, The horizontal velocity remains the same = v The time taken between the plates is $t = \frac{D}{v}$ and the vertical acceleration, $a_y = \frac{Ve}{dm}$ Let v_y = the vertical velocity Then, using v = u + at, where u = 0, we have $v_y = \frac{VeD}{dmv}$	½ ½ ½ ½

	Now, $\tan\theta = \frac{v_y}{v} = \frac{VeD}{dmv^2}$ $= \frac{12\times1.6\times10^{-19}\times4.0\times10^{-2}}{4.0\times10^{-2}\times9.11\times10^{-31}1.0\times10^{12}} = 2.11$ $\therefore \theta$ = **64.6°**	1 1 1
	Total = 20	
9. (a)	Bohr's postulates of the hydrogen atom (i) Electrons in the atom can revolve round the nucleus only in certain allowed orbits and while in these orbits they do not emit radiation. (ii) an electron can jump from one orbit to another of lower energy emitting radiation of energy equal to the energy difference of the two orbits (or of higher energy by absorbing a definite amount of energy equal to the energy difference of the orbits)	1 1
(b)	He proposed a model of a hydrogen atom in which one electron of charge -e and mass m was moving with speed v in an orbit of of radius r round a central nucleus of charge +e and in an orbit where the electron's angular momentum is a multiple of $h/2\pi$ the energy is constant, h being the Planck constant i.e.where $mvr = nh/2\pi$ ………………………………..(1) The total energy of an electron = k.e + p.e $= \frac{1}{2}mv^2 + \frac{-e^2}{4\pi\varepsilon_o r}$ …….(2) The force of attraction between the electron and the nucleus is $F = \frac{e^2}{4\pi\varepsilon_o r^2}$ and this is the centripetal force $\frac{mv^2}{r}$ $\therefore \frac{mv^2}{r} = \frac{e^2}{4\pi\varepsilon_o r^2}$ ……………………………………….. (3) Thus $\frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_o r}$ $\therefore$ total energy, $E = \frac{e^2}{8\pi\varepsilon_o r} - \frac{e^2}{4\pi\varepsilon_o r} = \frac{-e^2}{8\pi\varepsilon_o r}$ …………… (4) Now, r can be eliminated using (1) and (3) as follows from (1) $v = \frac{nh}{2\pi rm}$ Substituting for v in (3) and solving for r, we have that $r = \frac{\varepsilon_o n^2h^2}{\pi me^2}$ Substituting for r in (4) gives	½ ½ ½ ½ 1

	Total energy, $E = \frac{-e^2}{8\pi\varepsilon_o r} \times \frac{\pi m e^2}{\varepsilon_o n^2 h^2} = \frac{-me^4}{8\varepsilon_o^2 n^2 h^2}$ $E_3 = -\frac{9.11\times10^{-31}\times(1.6\times10^{-19})^4}{8\times(8.85\times10^{-12})^2\times3^2\times(6.6\times10^{-34})^2} = -2.416\times10^{-19}\ J$ $E_2 = -\frac{9.11\times10^{-31}\times(1.6\times10^{-19})^4}{8\times(8.85\times10^{-12})^2\times2^2\times(6.6\times10^{-34})^2} = -5.44\times10^{-19}\ J$ Energy radiated $E = E_3 - E_2 = -2.416\times10^{-19} - -5.44\times10^{-19} = 3.024\times10^{-19}$ $\frac{hc}{\lambda} = 3.024\times10^{-19}$: $\lambda = \frac{6.6\times10^{-34}\times3.0\times10^{8}}{3.024\times10^{-19}} = 6.548\times10^{-7}\ m$	½ 1 1 ½ 1
(c)	E_1 = -10.4 eV, E_2 = -5.5 eV, E_3 = -3.7 eV, E_4 = -1.6 eV (i) Ionisation energy = $E_\infty - E_1$ = 0 - ⁻10.4 eV = 10.4 x 1.6 x 10^{-19} = 1.664 x 10^{-18} J	 1 1
	(ii) $E_f - E_i$ = 4.0 eV ∴ E_f = 4.0eV + ⁻10.4eV = ⁻6.4 eV, the atom remains unexcited. E_f = 11.0eV + ⁻10.4eV = 0.6 eV, since E_f is positive, the atom is ionised.	 ½ 1 ½ 1
(d)	 For closest distance of approach k.e lost by the α-particle = electrostatic p.e of the z-nuclei charge system $\frac{1}{2}mv^2 = \frac{q_1 q_2}{4\pi\varepsilon x}$ ∴ $x = \frac{q_1 q_2}{2\pi\varepsilon x m v^2}$ But $q_1 = 2e$; $q_2 = ze$ ∴ $x = \frac{2e\times ze}{2\pi\ \varepsilon m v^2} = \frac{ze^2}{\pi\ \varepsilon m v^2}$	½ 1 ½ 1
(e)	If a continuous spectrum passes through a gas or sodium flame at a lower temperature dark lines are observed in the emerging spectrum It is as a result that gases can absorb radiation at the same frequency as they emit.	1 1 1
	Total = 20	
10.(a)	(i)	

	- Electrons are thermionically emitted from the cathode heated by a low voltage supply. - The electrons are accelerated to high speeds by e.h.t. applied between the anode and the cathode - On hitting the target metal, electrons in deeper energy levels are displaced. - On falling back X-ray radiation is emitted.	1 1 1 1
	(ii) see table below	2
	(iii) X-rays are produced when energetic electrons hit matter and the energy of the X-rays depends on the energy of the bombarding electrons, whereas Photoelectric effect is emission of electrons when electromagnetic radiation of high enough frequency strikes a metal surface. The energy emitted depends on the frequency of the incident radiation	1 1
(b)	$V = 1.5 \times 10^5 V$; $c = 2.5 \times 10^2\ J\,kg^{-1}K^{-1}$; $m = 0.25\ kg$; $\frac{\Delta\theta}{t} = 8\ k\,s^{-1}$ (i) 99% of electric energy supplied = heat gained by metal target material $\frac{99}{100} neV = mc\left(\frac{\Delta\theta}{t}\right)$ $\therefore \quad n = \frac{0.25 \times 2.5 \times 10^2 \times 8}{1.6 \times 10^{-19} \times 1.5 \times 10^5 \times 0.99}$ = **2.10×10^{16}** electrons per second	1 1 2
	(ii) $eV = hf = h\frac{c}{\lambda}$ $\therefore \quad \lambda = \frac{hc}{eV} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 1.5 \times 10^5}$ = **8.25×10^{-12} m**	1 1
(c)	(i) …the ratio of charge of an electron to its mass	1
	(ii) 	½ ½ ½

(ii) table:

X-rays	β-particle
Carry no charge	Carry a negative charge
Not deflected by electric field	Deflected by electric field
Travel at the speed of light	Do not travel at speed of light

X_1, X_2 = Helmholtz coils

½

- A vacuum-type cathode-ray tube, connected as shown, is used, with the accelerating p.d, V, also applied between the parallel deflecting plates Y_1Y_2 which support a vertical fluorescent screen S set at an angle.
- A fine flat electron beam, emerging through the slit, produces a fine trace on S as shown. ½
- The current I in the Helmholtz coils, arranged as shown, is switched on and adjusted so that the trace suffers no deflection. ½

Under these conditions:

{The electric force produced by plates the Y_1Y_2 on an electron} = {Magnetic force produced by the current in the Helmholtz coils} ½

Let d = distance between plates Y_1

v = velocity of electrons on e

B = magnetic field density

½

Then $\frac{Ve}{d} = Bev$ ……………………………….. (1) ½

and $\frac{1}{2} mv^2 = eV$,where m = mass of electron ………..(2)

½

Eliminating v from (1) & (2) $e/m = \frac{V}{2B^2d^2}$

The flux density B for the Helmholtz coils is given by $B = \frac{0.72\mu_o NI}{R}$

where N = no. of turns in one coil

Total = 20