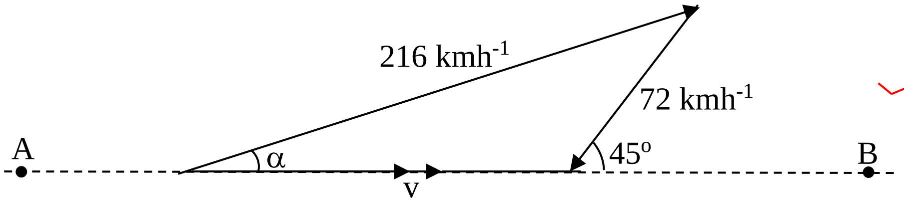
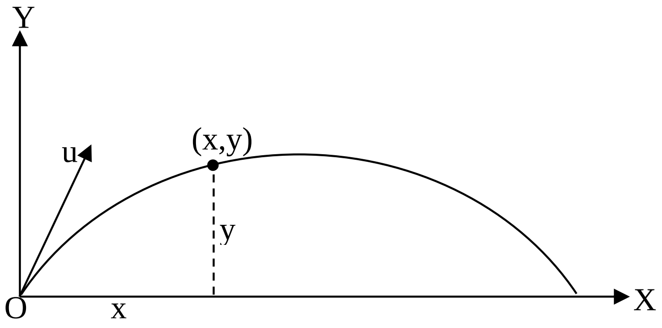
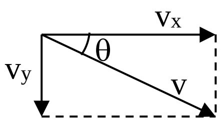
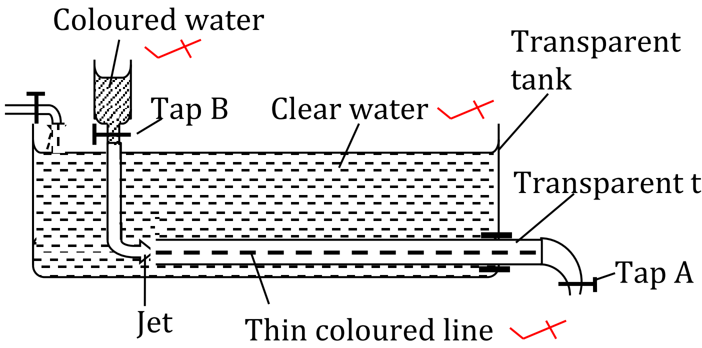
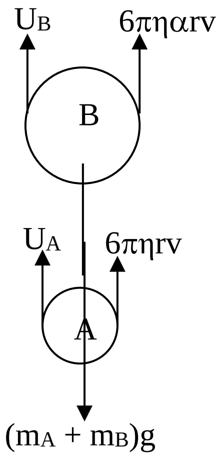
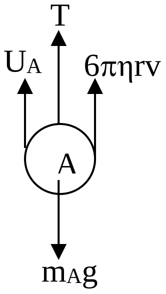
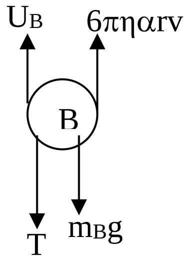
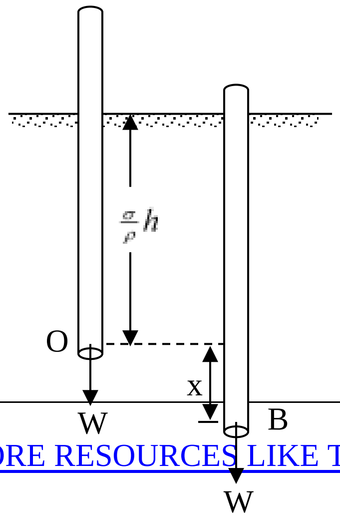
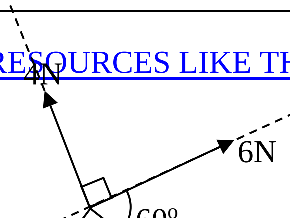
Qn	Answer	Marks
1. (a)	Relative velocity is the velocity of a body as perceived by a moving observer while resultant velocity is the single velocity having the same effect on a body as a number of velocities experienced by the body	1 1
(b)	(i)  The pilot should set the plane at an angle α N of E so that the resultant velocity, v, is along AB Now, $\frac{\sin\alpha}{72} = \frac{\sin 135^o}{216}$ ∴ $\sin\alpha = \frac{72\sin 135^o}{216} = 0.2357$ ∴ $\alpha = \mathbf{13.6^o}$	1 1 1
	(ii) $v = 216\cos\alpha - 72\cos 45^o$ $= 216\cos 13.6^o - 72\cos 45^o = 159\text{ km h}^{-1}$ Now time $= \frac{AB}{v} = \frac{300}{159}$ $= 1.887$ hrs = **1hr 53min**	1 1 1 1
(c)	(i) …the time taken from the instant of projection to landing.	1
	(ii)  Let OX be a horizontal axis through O, and OY a vertical axis. The position of the particle at any instant may be described by coordinates (x,y) with reference to these axes. $x = (u\cos\alpha)t$ ∴ $t = \frac{x}{u\cos\alpha}$ But $y = (u\sin\alpha)t - \frac{1}{2}gt^2$	1 1

	∴ $y = x\,tan\alpha - \frac{g}{2u^2cos^2\alpha}x^2$ This is an equation of a parabola.	1
(d)	(i) Using $y = x\tan\alpha - \frac{g\,x^2}{2u^2\cos^2\alpha}$ we have $u^2 = \frac{g\,x^2}{2(x\tan\alpha - y)\cos^2\alpha}$ $= \frac{9.81\times100^2}{2(100\tan30^o - 25)\cos^2 30^o} = \frac{9.81\times10^4}{2\times32.7\times0.75} = 2.0 \times 10^3$ ∴ u = **44.7 m s^{-1}**	1 1 1
	(ii) The horizontal velocity, $v_x = u\cos 30^o = 44.7\cos 30^o = 38.7$ ms^{-1} Time taken, $t = \frac{x}{v_x} = \frac{100}{38.7} = 2.58$ s The vertical velocity, $v_y = u\sin 30^o - gt$ $= 44.7\sin 30^o - 9.81 \times 2.58$ $= 3.0$ ms^{-1}  $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{3.0}{38.7}\right)$ $= 4.4^o$ i.e. **4.4°** to the horizontal	1 ½ 1 ½ 1
	Total = 20	
2. (a)	(i) …the coefficient of viscosity is the tangential force acting on an area of 1 m^2 of fluid which resists the motion of one layer over another when the velocity gradient between them is 1 s^{-1}.	1
	(ii) - Viscosity in gases is due to momentum transfer between the neighbouring layers of gases. - It is proportional to the average speed of the gas molecules. - So, increase in gas temperature increases viscosity	1 ½ ½
(b)	(i) The flow should be laminar	1
	(ii) The volume of liquid issuing per second from the pipe depends on: - the coefficient of viscosity, η - the radius of the pipe, r - the pressure gradient set up along the pipe, s i.e. volume per second $= k\eta^x r^y s^z$ where k is a constant and x, y and z are indices to be found. Using dimensions: $L^3T^{-1} = (ML^{-1}T^{-1})^x L^y (ML^{-2}T^{-2})^z$ ∴ $0 = x + z$	1 1

	$3 = {}^{-}x + y - 2z$ $1 = x + 2z$ from which $x = {}^{-}1, z = 1, y = 4$ ✓ Hence, volume per second $= \frac{kr^4s}{\eta} = \frac{k\Delta pr^4}{l\eta}$ ✓ The constant $k = \frac{\pi}{8}$ Hence, volume per second $= \frac{\pi\Delta pr^4}{8l\eta}$	1 1
(c)	 - 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. ✓ - Tap A is opened, first slightly and then B is opened to release some coloured liquid. ✓ - Tap A is progressively opened further. ✓ *Observation:* At first a thin coloured line is seen in the horizontal tube. ✓ This is streamline flow. ✓ However, as A is opened further, the coloured line disappears and instead the colour fills the whole tube. ✓ The flow has now become turbulent. ✓	½ ½ ½ ½ 1 ½ ½ ½ ½ ½ ½
(d)	(i)   	

	$(m_A + m_B)g = U_A + U_B + 6\pi\eta r v(1 + \alpha)$ ✓ ∴ $\frac{4}{3}\pi r^3 g(1 + \alpha^3)\sigma = \frac{4}{3}\pi r^3 g(1 + \alpha^3)\rho + 6\pi\eta r v(1 + \alpha)$ ✓ $v = \frac{2r^2 g(1+\alpha^3)(\sigma-\rho)}{9\eta(1+\alpha)}$ ✓	1 1 1
	(ii) From above $v = \frac{2\times4^2\times10^{-4}\times9.81\times(1+2^3)(3000-1200)}{9\times0.21\times(1+2)} = 89.7\ \text{m s}^{-1}$ Considering the forces acting on B $T = U_B + 6\pi\eta\alpha r v - m_B g$ $= \frac{4}{3}\pi r^3\alpha^3\rho g - \frac{4}{3}\pi r^3\alpha^3\sigma g + 6\pi\eta\alpha r v$ ✓ $= \frac{4}{3}\pi r^3\alpha^3 g(\rho - \sigma) + 6\pi\eta\alpha r v$ $= \frac{4}{3}\pi \times 4^3 \times 10^{-6} \times 2^3(1200 - 3000) \times 9.81 + 6\pi \times 0.21 \times 2 \times 4 \times 10^{-2} \times 89.7$ ✓ $= -37.87 + 14.2$ = **- 23.67 N (unrealistic)** ✓	1 1 1
	Total =20	
3. (a)	(i) When a body is wholly or partially immersed in a fluid it experiences an upthrust which is equal to the weight of the fluid displaced. ✓	1
	(ii) $\frac{mg - 2.06}{mg - 2.45} = 1.8$ ✓ ∴ $mg - 2.06 = 1.8mg - (1.8 \times 2.45)$ ✓ ∴ $mg(1.8 - 1) = (1.8 \times 2.45) - 2.06$ ∴ $m = \frac{4.41 - 2.06}{0.8\times9.81} = \mathbf{0.293\ kg}$ ✓	1 1 1
(b)	(i) A particle is said to execute simple harmonic motion if it moves such that its acceleration along its path is always directed towards a fixed point in that path, and is proportional to its displacement from the fixed point. ✓	1
	(ii) A damped oscillation is one whose amplitude decreases with time due to dissipation of energy ✓ A forced oscillation is one that receives periodic impulses from an external ✓ agent	1 1
(c)	(i) 	

	When freely floating, the height submerged is $\frac{\sigma}{\rho}$h Weight of the cylinder, W = weight of the liquid displaced = hAσg ✓ During motion, suppose at a certain instant the lower end is at a distance x below the equilibrium, O. Then, the upthrust, U = $(\frac{\sigma}{\rho}h + x)A\rho g$ ✓ Let a = acceleration (positive away from O) Then, using ma = W – U, where m = hAσ $ma = hA\sigma g - hA\sigma g - xA\rho g$ ✓ $\therefore \quad hA\sigma a = -xA\rho g$ $\therefore \quad a = -\frac{\rho g}{\sigma h}x$ ✓ The negative sign means that the acceleration is towards O, and since it is proportional to the displacement x from O, the cylinder executes simple harmonic motion. ✓	1 1 1 1 1
	(ii) Now $\frac{\rho g}{\sigma h} = \omega^2 = \frac{4\pi^2}{T^2}$ ✓ $\therefore \quad T = 2\pi\sqrt{\frac{\sigma h}{\rho g}}$ ✓	1 1
(d)	(i) $\omega^2 = \frac{k}{m} = \frac{4\pi^2}{T^2}$ ✓ $\therefore \quad T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.1}{24.5}}$ ✓ $=$ **0.408 s** ✓	½ ½ 1
	(ii) Since it starts from maximum displacement, the equation of motion is $y = a\cos\omega t$ ✓ Now $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{24.5}{0.1}} = 15.65$ rad s^{-1} ✓ $\therefore \quad \omega t = 15.65 \times 0.3$ radians $= 15.65 \times 0.3 = \frac{180^o}{\pi}\times 15.65 \times 0.3 = 269^o$ ✓ $\therefore \quad y = 0.05\cos 269^o$ ✓ $=$ **8.7 x 10^{-4} m** ✓	1 1 ½ ½ 1
	Total = 20	
4. (a)	(i) …a single force having exactly the same effect as the number forces it represents ✓	



(ii)

Along the 6N force: $F_x = 6 + 5\cos 60^o - 15\cos 40^o$ 1

$= 6 + 2.5 - 11.5 = -3\text{ N}$ ½

Perpendicular to the 6N force: $F_y = 4 - 5\sin 60^o - 15\sin 40^o$ 1

$= 4 - 4.33 - 9.64 = -9.97\text{ N}$ ½

Resultant force, $F = \sqrt{F_x^2 + F_y^2}$

$= \sqrt{3^2 + 9.97^2} = 10.4\text{ N}$ 1

Now, acceleration, $a = \frac{F}{m} = \frac{10.4}{2} = 5.2\text{ m s}^{-2}$ 1

Using $s = ut + ½at^2$, we have

$s = 0 + ½ \times 5.2 \times 3^2$

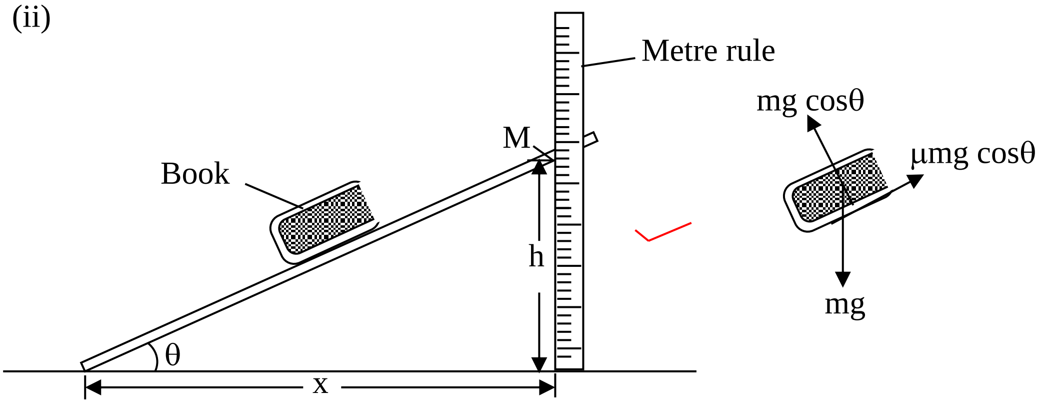
$=$ **23.4 m** 1

(b) (i)

Solid friction	Fluid friction
- Independent of area of contact - Independent of relative velocity of the layers in contact - Independent of temperature	- Depends on area of layers considered - Depends on the relative velocity of the layers involved - Depends on temperature

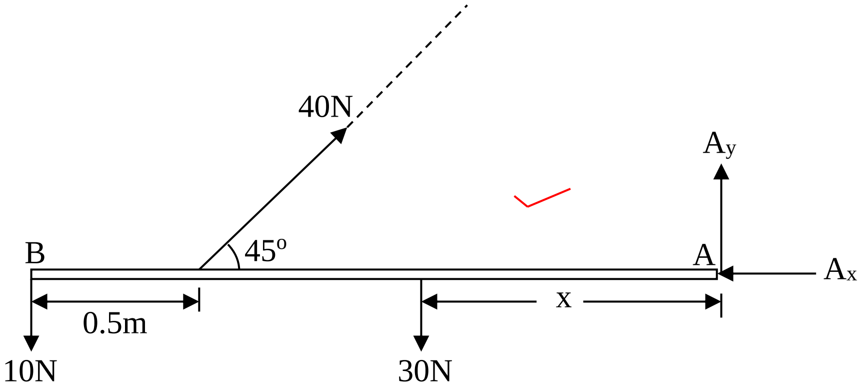
2

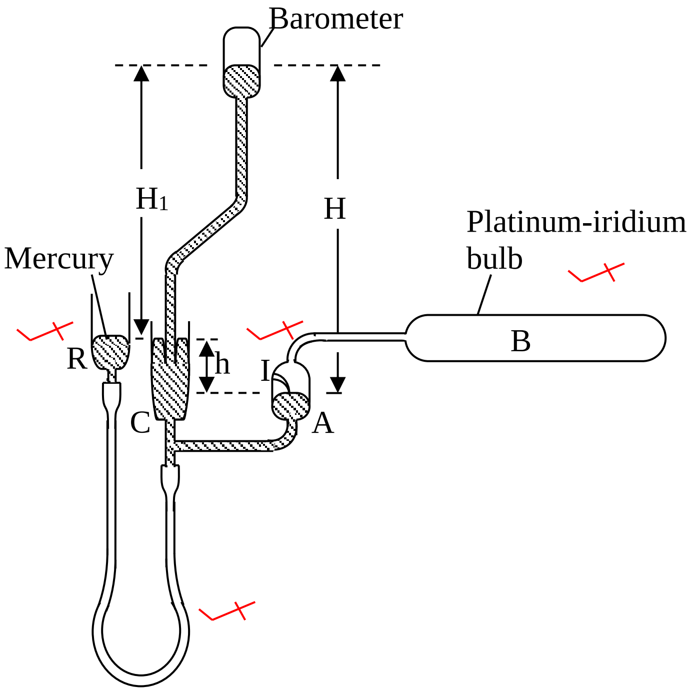
(ii)

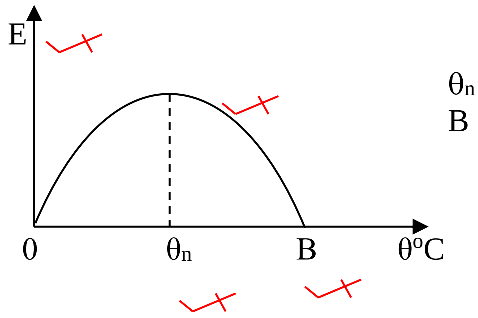
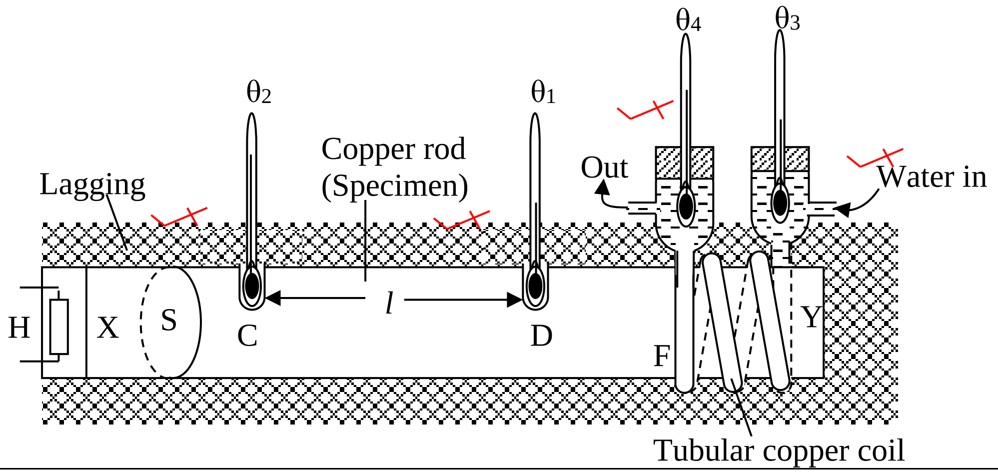


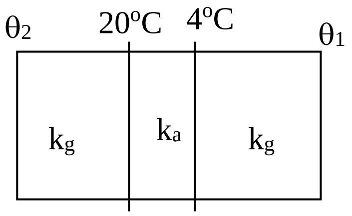
1

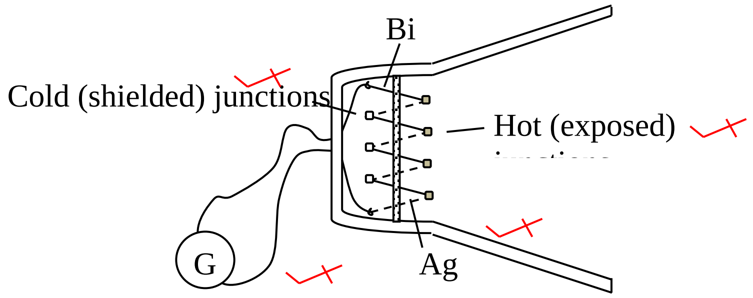
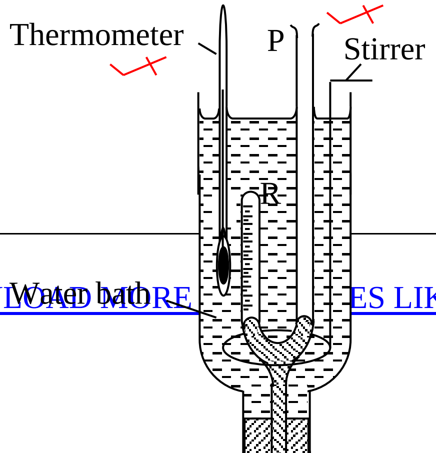
- A mark, M, is made at a suitable location on the board
- Then the board is gently tilted until the block is just beginning to slide down ½
- Then the height, h, of the mark, M, above the bench is measured ½

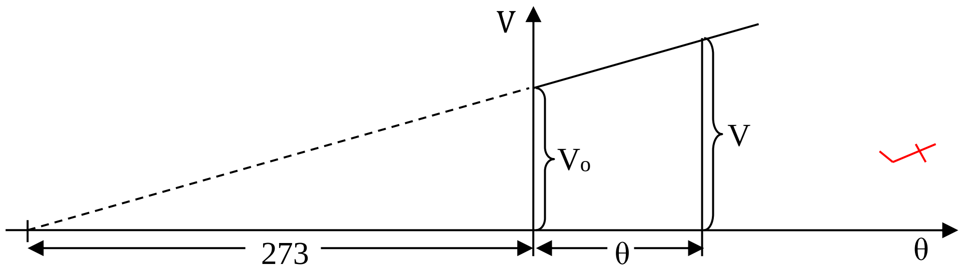
	- The horizontal distance, x, of M from the line of contact of the board and the bench is also measured (where x is perpendicular to the line of contact). The diagram on the right shows the forces on the block at the start of slipping, in which μ is the coefficient of friction So, $\mu mg\cos\theta = mg\sin\theta$ $\therefore \quad \mu = \tan\theta = \frac{h}{x}$	½ ½ ½ ½
(c)	(i)  Let x = distance of centre of gravity from end A Taking moments about end A, we have $30x + 10 \times 2 = 40 \times 1.5\sin 45^o$ $\therefore \quad x = \frac{40 \times 1.5 \sin 45^o - 20}{30}$ = **0.748 m from end A**	1 1 1
	(ii) $A_x = 40\cos 45^o = 28.28$ N $A_y + 40\sin 45^o = 10 + 30$ $\therefore \quad A_y = 40 - 28.28 = 11.72$ N $\therefore$ reaction at A $= \sqrt{A_x^2 + A_y^2} = \sqrt{28.28^2 + 11.72^2}$ = **30.6 N** at an angle α to the horizontal, where $\alpha = \tan^{-1}\left(\frac{11.72}{28.28}\right)$ = **22.5°**	1 1 1 1
	Total = 20	
5. (a)	(i) Temperature is the degree of hotness of a body expressed as a number on some scale. Heat is the sum of the kinetic energy and potential energy of a substance's molecules.	1 1
	(ii) The material should have a property which - varies continuously with temperature, in value or otherwise, over a wide range *Any two @1*	

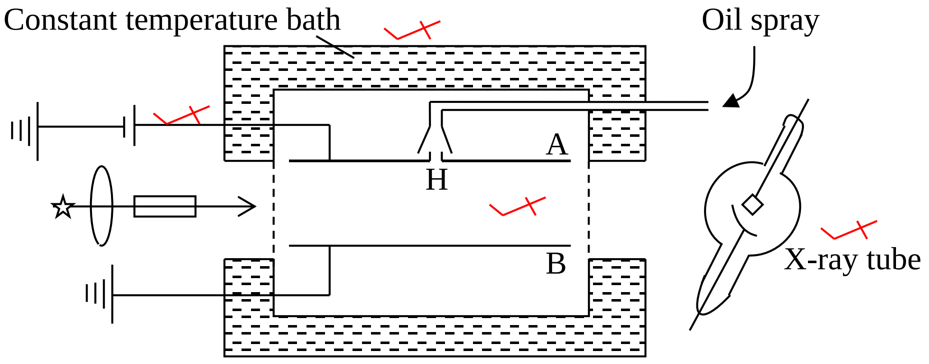
	- is observable - is measurable - exhibits reproducible values at the respective temperatures - has distinguishable values even for small differences in temperature	2
	(iii) - volume of a liquid - pressure of a fixed mass of gas at constant volume - volume of a fixed mass of gas at constant pressure - electrical resistance of a wire - emf of a thermocouple *Anv four @½*	2
(b)	(i)  	½ 1 ½
	(ii) - The gas in the capillary tube E is not at the temperature being measured. The error due to this can be reduced by making the capillary tube very narrow compared to the bulb. - The bulb B expands. The error due to this is minimized by using a metal of very small expansivity for the bulb B. - The density of the mercury changes with temperature. A correction for these changes is carried out.	½ ½ ½ ½ ½ ½
(c)	(i) The discrepancy arises because thermometric properties do no vary the same way as the temperature changes.	1
	(ii) $\theta = 100\left(\frac{V_t - V_0}{V_{100} - V_0}\right)$ °C	1

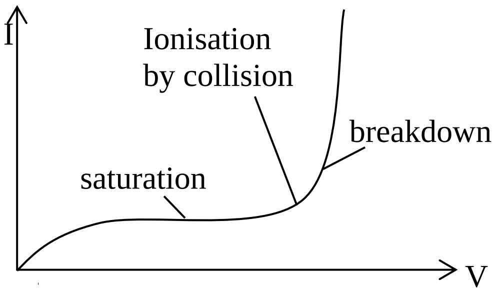
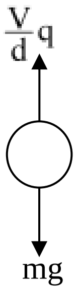
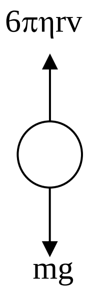
	$= \left[\frac{V_o(1+80\times1000\beta+80^2\beta)-V_o}{V_o(1+100\times1000\beta+100^2\beta)-V_o}\right]\times100^\circ C$ ✓ $= \frac{80,000+6,400}{100,000+10,000}\times100^\circ C$ ✓ $= 78.5^\circ C$ ✓	1 1
(d)	(i) A thermojunction is one made by fusing together ends of two different metals ✓	1
	(ii)  θ_n = neutral temperature B = inversion temperature	½ ½ 1
	Any one adv. (iii) Advantages: - It can measure temperature at a point - It is quick-acting and can therefore measure a rapidly changing temperature. ✓ Disadvantage - An emf corresponds to two temperatures, which could lead to wrong interpretation ✓	1 1
Total = 20		
6. (a)	…the heat flow rate per unit area per unit temperature gradient. ✓	1
(b)		½ ½ 1

	During conductivity measurement the following conditions should fulfilled: - Heat must flow through the specimen at a measurable rate - The temperature gradient along the specimen must be steep The specimen is in form of a uniform cylindrical copper rod - The diameter of the rod is measured from which its cross-sectional area is, A, is worked out - Two holes, C and D a distance *l* apart, are made in the specimen. These are to accommodate thermometers. These holes are filled with mercury for good thermal contact. - The apparatus is set up as shown, in which XY is the specimen, heated by at source H and cooled by water circulating through a tubular copper coil at Y. - The apparatus is kept running until all the temperatures have become steady. - Then the cooling water circulating is collected over a measured time interval and the mass of it, m, flowing per second is found. *Calculations:* Let k = thermal conductivity of the specimen Then the heat flow rate per second, $Q/_t = \frac{kA(\theta_2 - \theta_1)}{l}$ This heat is carried away by the cooling water. If c_w is the specific heat capacity of water, then $\frac{kA(\theta_2 - \theta_1)}{l} = mc_w(\theta_4 - \theta_3)$ $\therefore \quad k = \frac{mc_w(\theta_4 - \theta_3)l}{A(\theta_2 - \theta_1)}$	½ ½ ½ ½ ½ ½ ½ ½
(c)	(i)  Heat flow rate per m², q = $\frac{k_g}{l_g}(\theta_2 - 20) = \frac{k_a}{l_a}(20 - 4)$ $\therefore \quad \theta_2 - 20 = 16 \text{ x } \frac{k_a l_g}{k_g l_a}$ $\theta_2 = 16 \text{ x } \frac{k_a l_g}{k_g l_a} + 20 = \frac{16 \times 0.025 \times 0.03}{0.72 \times 0.01} + 20$ $= 1.7 + 20 = \mathbf{21.7^o}$ Also $q = \frac{k_g}{l_g}(4 - \theta_1) = \frac{k_a}{l_a}(20 - 4)$ $\therefore \quad 4 - \theta_1 = 16 \text{ x } \frac{k_a l_g}{k_g l_a}$	1 1 1

	∴ $\theta_1 = 4 - 16 \text{ x } \frac{k_a l_g}{k_g l_a} = 4 - \frac{16 \times 0.025 \times 0.03}{0.72 \times 0.01}$ $= 4 - 1.7 = \mathbf{2.3^o}$	1
	(ii) $Q = qAt = 2 \text{ x } 2 \text{ x } 60 \text{ x } 60 \text{ x } \frac{k_g}{l_g}(\theta_2 - 20)$ $= 14400 \text{ x } \frac{0.72}{0.03} \times 1.7$ $= 5.875 \text{ x } 10^5 \text{ J}$	1 1
(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)  It is a pile of many thermal junctions connected in series. The junctions are attached to thin tin discs. The discs on a set of alternate junctions are blackened and are the ones exposed to the radiation while the other set is shield off from the radiation. The blackened junctions are made to face the area under test. When they absorb radiation they become hotter than the unexposed ones and each pair of a hot and a cold junction generates an emf. The total emf from the whole combinations is connected to a galvanometer, G. Deflection of the galvanometer indicates presence of radiation.	½ ½ ½ ½ 1 1 1
Total = 20		
7. (a)	(i) The volume of a fixed mass of gas, at constant pressure is directly proportional to the absolute temperature.	1
	(ii) 	½ ½

	- A dry gas is trapped by mercury in a closed limb, R, which is graduated to measure the volume, V, of the trapped gas. - The mercury levels in P and R are equalized by pouring mercury in at P, or running it off at Q. Thus the gas in R is always kept at constant pressure. - The temperature, θ, and the volume, V, of the gas are read and recorded. - The temperature of the gas is varied. - After stirring and ensuring uniform temperature, the mercury levels in P and R are equalized once again and the new values of θ and V are taken. - The procedure is repeated for various temperatures of the gas and a graph of V against θ is plotted. It is a straight line By extrapolation back to the temperature axis gives a point at which the temperature is about -273°C. (See the graph below) 	½ ½ ½ ½ ½ ½ ½ ½ ½ ½
(b)	(i) - The intermolecular forces in gases are negligible. So the molecules wander freely to any part of the container. - The molecules are continuously bombarding the walls of the container - Because the momentum changes involved a force is exerted on the walls and therefore pressure on the walls of the container	1 1 1
	(ii) The pressure of a gas depends on its density and the mean square speed of its molecules. When the temperature rises at constant volume, the density remains constant but the mean square speed is increased. So the pressure rises	1 1
(c)	(i) Boyle's law: PV = A ………… (1) Charles's law: V = BT ……….. (2) Pressure law: P = CT ……….. (3) where A, B and C are constants	½ ½ ½

	Eq(1) x eq(2) x eq(3): $P^2V^2 = ABCT^2$ $\therefore$ $PV = KT$, where $K = \sqrt{ABC}$, a constant	1 ½
	(ii) Let m_1 = original mass of the gas m = mass of gas used r = specific gas constant Then $P_1V_1 = m_1rT_1$ ……………. (1) and $P_2V_2 = (m_1 - m)rT_2$ ………. (2) Eq(2) ÷ eq(1): $\frac{P_2V_2}{P_1V_1} = \left(\frac{m_1 - m}{m_1}\right)\frac{T_2}{T_1}$ But $V_1 = V_2$ $\therefore$ $\frac{P_2}{P_1} = \left(\frac{m_1 - m}{m_1}\right)\frac{T_2}{T_1}$ $\therefore$ $1 - \frac{m}{m_1} = \frac{P_2}{P_1}\frac{T_1}{T_2}$ $\therefore$ $m = \left(1 - \frac{P_2}{P_1}\frac{T_1}{T_2}\right)m_1$ $= \left(1 - \frac{4 \times 300}{6 \times 278}\right) \times 15$ $=$ **4.21 kg**	1 1 ½ ½ ½ ½ 1
	Total = 20	
8. (a)	 A and B are parallel plates. H is a small hole in the centre of A	2
	(i) The terminal velocity of the drops depends on the viscosity of the air. Viscosity depends on temperature So a constant temperature bath maintains a constant value of viscosity	1 ½ ½
	(ii) The distance moved by the drop. The time taken to cover the distance	1 1
(b)	(i) …. to establish the magnitude of charge on an electron	1

	(ii) Very high voltages are required There is a risk of producing x-rays due to the high accelerating p.ds involved. ✓	1 1
(c)	(i)  ✓ ✓	1
	(ii) - Electrons are emitted from the cathode by photoelectric effect. ✓ - The electrons are accelerated towards the anode. ✓ - As the p.d is increased more electrons are enabled to reach the anode per second- This is depicted as increase in current. ✓ - When all the available electrons per second are reaching the anode, there is no more increase in current. The current is said to be saturated. ✓ - As the p.d is increased further, the electrons' kinetic energy is increased until they are able to ionize the gas atoms on their way. ✓ - The ions so formed move to the cathode while the additional electrons join in the flight to the anode – This processes of ionization leads to increase in current. ✓ - The knocked–out electrons gain kinetic energy and produce more ions and electrons. ✓ - Eventually, as the p.d is increased, a point is reached at which the current grows uncontrollably – This is a state of breakdown (avalanche) ✓	½ ½ ½ ½ ½ ½ ½ ½
(d)	The upthrust is negligible.  ✓  ✓ $6\pi\eta rv = mg = \frac{4}{3}\pi r^3\rho g$ ✓ $\therefore \quad r = \sqrt{\frac{9\eta v}{2\rho g}} = \sqrt{\frac{9\times1.8\times10^{-5}\times1.5\times10^{-3}}{2\times900\times9.81\times11.2}}$	1 1

	$= \sqrt{1.229\times10^{-12}} = 1.11 \times 10^{-6}$ m ✓ Also $\frac{V}{d}q = mg = 6\pi\eta rv$ ✓ $\therefore \quad q = \frac{6\times\pi\times\eta\times rvd}{V} = \frac{6\pi\times1.8\times10^{-5}\times1.11\times10^{-6}\times1.5\times10^{-3}}{780\times11.2}$ ✓ $= 6.47 \times 10^{-17}$ C ✓	1 1 1 1
	Total = 20	