MECHANICAL PROPERTIES OF SOLIDS

(1) A block of mass 1 kg is fastended to one end of a copper wire of cross-sectional area 1 mm^2 and is rotated in a vertical circle of radius 20 cm. If the breaking stress of copper is 5×10^8 Nm^{-2}, find the maximum number of revolution the block make in the minute without the string breaking [Ans = 477.4 rpm]

(2) A copper wire of length 2.2 m and a steel wire of length 1.6 m, both of diameter 3.0 mm, are connected end to end. When stretched by a load, the net elongation is found to be 0.70 mm. obtain the load applied. [ANS - 1.8×10^2 N]

(3) A load (M) suspended from a wire produces an elongation (e) in the wire then find the rise in temperature required to produce same elongation in the same wire.

[Ans - $\Delta t = \frac{f}{AY\alpha}$]

(4) Four identical hollow cylindrical columns of steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 cm and 60 cm respectively. Assuming the load distribution to be uniform, calculate the compression stain of each column. The young's modulus of steel is 2.0×10^{11} Pa [Ans [illegible]]

(5) Two wires of same length and radius are joined end to end and loaded. The young's modulii of the materials of the two wires are Y_1 and Y_2. If the combination behaves as a single wire then its Young's modulus is Ans - $Y_{eq} = \frac{2Y_1Y_2}{Y_1+Y_2}$

(6) Two wires of same length and radius are joined in parallel and loaded. The young's modulii of the material of the wires are Y_1 & Y_2. If the combination is taken as a single wire then its Young's modulus is Ans - $Y_{eq} = \frac{Y_1+Y_2}{2}$

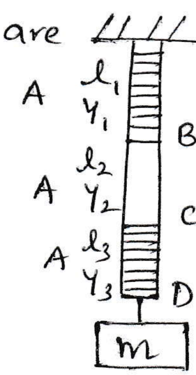
(7) The length of a metal wire is l_1 when the tension in it is T_1 and is l_2 when the tension is T_2. Then the actual length of the wire is Ans - $l = \frac{T_2 l_1 - T_1 l_2}{T_2 - T_1}$

(8) The length of a rubber cord is l_1 metres when the tension in it is 4N and l_2 metres when the tension is 5N. Then the length in meters when the tension is 9N is $l_3 = 5l_2 - 4l_1$ Ans

(9) A brass wire of length 5m and cross section $1mm^2$ is hung from a rigid support, with a brass weight of volume $1000\ cm^3$ hanging from the other end. find the decrease in the length of the wire, when the brass weight is completely ...

(10) A block of mass 1 kg is fastended to one end of a wire of Cross-sectional area 2 mm^2 and is rotated in a vertical circle of radius 20 cm. The speed of the block at the bottom of the circle is $3.5 \, ms^{-1}$. Find the elongation of the wire when the block is at the bottom (Ans - 0.6125×10^{-5} m)

(11) As shown in adjacent figure if a load of mass (m) is attached at lower end of lower wire. Then find the displacements of the points B, C, D are



Ans - displacement of B is e_1
displacement of C is $e_1 + e_2$
displacement of D is $e_1 + e_2 + e_3$

(12) A light rod of length 2 m is suspended from the ceiling horizontally by means of two vertical wires of equal length tied to its ends. One of the wires is made of steel and is of Cross-section 10^{-3} m^2 and the other is of brass of Cross-section 2×10^{-3} m^2. Find out the position along the rod at which a weight may be hung to produce; i) equal stress in both wires

(Young's modulus of brass $= 1 \times 10^{11}$ N/m^2
Young's modulus of steel $= 2 \times 10^{11}$ N/m^2

(Ans - (i) $x = \frac{4}{3}$ m (ii) $x = 1$ m)

(13) A steel wire of area of cross-section A and length 2L is clamped firmly between two points seperated by a distance '2L'. A body is hung from the middle point of the wire such that the middle point sags by a distance x. Calculate the mass of the body and the angle made by the string with the horizontal

[Ans (a) $M = \frac{YAx^3}{L^3 g}$ (b) $\theta = Tan^{-1}\left[\frac{Mg}{YA}\right]^{1/3}$

(14) Two rods of different metals, having the same area of cross-section A, are placed end to end between two massive walls as shown in fig. If the temperature of both the rods are now raised by Δt°c then (a) find the force with which the rods acts on each other at higher temperature. (b) Find the lengths of the rods at the higher temperature. Assume that there is no change in the cross-sectional area of the rods and the rods do not bend. There is no deformation of walls. (Ans (a) $F = \frac{A(l_1\alpha_1 + l_2\alpha_2)\Delta t}{\left(\frac{l_1}{Y_1} + \frac{l_2}{Y_2}\right)}$

(b) $l_1' = l_1 + l_1\alpha_1\Delta t - \frac{Fl_1}{AY_1}$

(b) $l_2' = l_2 + l_2\alpha_2\Delta t - \frac{Fl_2}{AY_2}$

(15) Calculate the force 'F' needed to punch a 1·46 cm diameter hole in a steel plate 1·27 cm thick. (as shown in fig). The ultimate shear strength of steel is 345 M N/m². [Ans - 200 KN]

(16) A solid sphere of radius 'R' made of a material of bulk modulus B is surrounded by a liquid in a cylindrical container. A massless piston of area 'A' floats on the surface of the liquid. Find the fractional change in the radius of the sphere $\left[\frac{dR}{R}\right]$, when a mass M is placed on the piston to compress the liquid. [Ans - $\frac{dR}{R} = \frac{Mg}{3AB}$]

(17) When a rubber ball of volume V, bulk modulus 'K' is taken to a depth 'h' in water, then decrease in its volume is

[Ans - $\frac{h\rho g\, V}{K}$]

(18) A stone of mass 'm' is projected from a rubber catpult of length 'l' and cross-sectional area A stretched by an amount 'e'. If Y be the young's modulus of rubber then find the velocity of projection of stone?

[Ans - $V = \sqrt{\frac{YAe^2}{lm}}$]

(19) A steel rod of cross-sectional area $1\,m^2$ is acted upon by forces shown in the fig. Determine the total elongation of the bar. Take $Y = 2.0 \times 10^{11}\ N/m^2$. [Ans - $13 \times 10^{-7}\,m$]

(20) A thin uniform metallic rod of length 0.5 m and radius 0.1 m rotates with an angular velocity 400 rad/s in a horizontal plane about a vertical axis passing through one of its ends. Calculate tension in the rod and the elongation of the rod. The density of [illegible]

MECHANICAL PROPERTIES OF FLUIDS

(1) Two syringes of different cross sections (without needles) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1.0 cm and 3.0 cm respectively. (a) find the force exerted on the larger piston when a force of 10N is applied to the smaller piston. (b) If the smaller piston is pushed in through 6.0 cm, how much does the larger piston move out? [Ans (a) 90N (b) 0.67 cm]

(2) Two bodies are in equilibrium when suspended in water from the arms of a balance. The mass of one body is 28g and its density is 5.6g/c.c. If the mass of the other body is 36g. find its density d.

[Ans - 2.8 g/cc.]

(3) A ball of relative density 0.8 falls into water from a height of 2m. find the depth to which the ball will sink (neglect viscous forces) [Ans - 8m]

(4) A ball of mass m and density ρ is immersed in a liquid of density 3ρ at a depth h and released. To what height will the ball jump up above the surface of liquid? (neglect the resistance of water

(5) A horizontal pipe line carries water in a streamline flow. At a point along the pipe where the cross-sectional area is $10\,cm^2$, the velocity of water is $1\,m/s$ and the pressure is 2000 Pa. What is the pressure at another section where the cross-sectional area is $5\,cm^2$. [Ans - $P_2 = 500\,Pa$]

(6) Calculate rate of flow of glycerin of density $1.25 \times 10^3\,kg/m^3$ through the conical section of a horizontal pipe, if the radii of its ends are 0.1 m and 0.44 m and pressure drop across its length is $10\,N/m^2$ [A - $6.28 \times 10^{-4}\,m^3/s$]

(7) A fully loaded Boeing aircraft has a mass of $3.3 \times 10^5\,kg$, its total wing area is $500\,m^2$. It is in level fight with a speed of 960 km/h, (a) Estimate the pressure difference between the lower and upper surfaces of the wings (b) Estimate the fractional increases in the speed of the air on the upper surface of the wing relative to the lower surface. (The density of air is $\rho = 1.2\,kg\,m^{-3}$)

[Ans (a) $6.5 \times 10^3\,N\,m^{-2}$ (b) 8%]

(8) A tank is filled with two immiscible liquids of densities 2ρ and ρ each of height h. Two holes are made to the side wall at h and 3h ...

of efflux of the liquids through the holes

[Ans - $\therefore \frac{v_1}{v_2} = \frac{1}{\sqrt{2}}$]

(9) Three Capillary tubes of same radius 1 cm but of lengths 1 m, 2 m and 3 m are fitted horizontally to the bottom of the long vessel Containing a liquid at constant pressure and flowing through these tubes. What is the length of a single tube which can replace the three Capillaries. [Ans - $\frac{6}{11}$ m]

THERMAL PROPERTIES OF MATTER

(1) An ideal gas is trapped between a mercury column and the closed lower end of a narrow vertical tube of uniform bore. The upper end of the tube is open to the atmosphere. (Atmospheric pressure is 76 cm of mercury). The length of the mercury and the trapped gas columns are 20 cm and 43 cm, respectively, what will be the length of the gas column when the tube is tilted slowly in a vertical plane through an angle of 60° Assume the temperature to be Constant. [Ans - 48 cm of Hg]

(2) A metre long narrow bore held horizontally (and closed at one end) Contains a 76 cm long mercury thread, which traps a 15 cm column of air. What happens if the tube is held vertically with the open end at the bottom? (Ans - In the vertical position of the tube, 23.8 cm of mercury flows out and the remaining 52.2 cm of mercury thread plus the 48 cm of air above it remain in equilibrium with the outside atmospheric pressure.

(3) A faulty barometer tube is 90 cm long and it Contains some air above mercury. The reading is 74.5 cm when the true atmospheric pressure is 76 cm. What will be the true atmospheric pressure if the reading on this barometer is 74 cm? (H = 10 m of water column). Ans - 75.45 cm

(4) A gas is enclosed in a vessel of volume V at a Pressure P. It is being pumped out of the vessel by means of piston - pump with a stroke volume v. What is the final pressure in the vessel after 'n' strokes of the pump? Assume temperature remains Constant. Ans $P\left[\frac{1}{1+(v/V)}\right]^n$

(5) Two chambers, one containing m_1 g of a gas at P_1 pressure and other containing m_2 g of a gas at P_2 pressure are put in communication with each other. If temperature remains constant, the common pressure reached will be

[Ans - $\dfrac{P_1P_2(m_1+m_2)}{(P_2m_1+m_2P_1)}$]

(6) A column of Hg of 10 cm length is contained in the middle of a narrow horizontal 1 m long tube which is closed at both ends. Both the halves of the tube contain air at a pressure 76 cm of Hg. By what distance will the column of Hg be displaced, if the tube is held vertical? (Assume temperature to be constant) [Ans - 3 cm]

(7) Two containers, each of volume V_0, joined by a small pipe initially contain the same gas at pressure P_0 and at absolute temperature T_0. One container is now maintained at the same temperature while the other is heated to $2T_0$. Find (1) common pressure of the gas, and (2) the number of moles of gas in the container at temperature $2T_0$

[Ans - (1) $P = \dfrac{4P_0}{3}$ (2) $\dfrac{2P_0V_0}{3RT_0}$

(8) The pressure of a gas in a vessel is 80 cm of Hg. Now 25% of the same gas is also introduced into the same vessel. If the process is done at the same temperature, find the final pressure of the gas [Ans - 100 cm of Hg]

(9) An air bubble comes from the bottom to the surface of a lake of depth 2.5 m. The surface temperature of the lake is 40°c. The diameter of the bubble at the bottom and at the surface are 3.6 mm and 4 mm respectively. Find the temperature of the lake at the bottom. (Ans - 10.3°c)

(10) A glass capillary tube sealed at both ends is 100 cm long. It lies horizontally with the middle 10 cm containing mercury. The two ends of the tube which are equal in length contain air at 27°c at pressure of 76 cm of Hg. Now the air column at one end of the tube is kept at 0°c and the other end is maintained at 127°c. Calculate the length of the air column which is at 0°c and its pressure. (Neglect the change in volume of Hg and glass)

[Ans - 36.51 cm.] [85.25 m of Hg]

(11) A glass bulb of volume 200 cc is sealed at 27°C. If the Pressure of the gas inside the bulb is 1.25×10^{-4} cm of Hg, Calculate the number of molecules inside the bulb. (Avogadro's number = 6.0225×10^{23}, $R = 8.314 \times 10^{7}$ erg/mole - k) [Ans 8.018×10^{15}]

(12) Find the minimum attainable pressure of one mole of an ideal gas, if during its expansion its temperature and volume are related as $T = T_0 + \alpha V^2$ where T_0 and α are positive Constants [Ans - $2R\sqrt{T_0 \alpha}$]

(13) A vertical hollow cylinder of height 1.52 m is fitted with a movable piston of negligible mass and thickness. The lower half portion of the cylinder Contains an ideal gas and the upper half is filled with mercury. The cylinder is initially at 300 k. When the temperature is raised, half of the mercury Comes out of the cylinder. Find this temperature, assuming the thermal expansion of mercury to be negligible [Ans - 337.5k]

(14) A vessel of volume V = 5.0 litre Contains 1.4 g of nitrogen at temperature T = 1800 k. Find the Pressure of the gas. if 30% of its molecules are

(15) In a certain region of space, there are only 5 molecules per cm^3 on an average. The temperature is 3k. what is the average pressure of this very dilute gas? ($k = 1.38 \times 10^{-23}$ J/mol k) [Ans $- 2.07 \times 10^{-16}$ Pa]

(16) During an experiment, an ideal gas is found to obey an additional law Vp^2 = constant. The gas is initially at temperature T and volume V. what will be the temperature of the gas when its expands to a volume 2V? [Ans - $(\sqrt{2})T$]

(17) The coefficient of linear expansion of gold is $14 \times 10^{-6}/°c$. Find the coefficient of linear expansion on Fahrenheit scale. [Ans - $7.778 \times 10^{-6} °F^{-1}$]

(18) An iron rod of length 50 cm is joined at an end to copper rod of length 100 cm at 20°c. Find the length of the system at 100°c and average coefficient of linear expansion of the system. ($\alpha_{iron} = 12 \times 10^{-6}/°c$ and $\alpha_{copper} = 17 \times 10^{-6}/°c$.) (Ans - $15.33 \times 10^{-6}/°c$)

(19) An equilateral triangle ABC is formed by joining three rods of equal length and D is the mid point of AB. The coefficient of linear expansion for AB is α and for AC

small changes in temperature. Find the relation between α_1 and α_2 [Ans - $4\alpha_2 = \alpha_1$]

(20) A metal rod of 50 cm length expands by 0.10 cm when its temperature is raised from 0°c to 100°c. Another rod B of a different metal of length 60 cm expands by 0.06 cm for the same rise in temperature. A third rod C of 50 cm length is made up of pieces of rods A and B placed end to end expands by 0.03 cm on heating from 0°c to 50°c. find the length of each portion of composite rod C. [Ans - $l_1 = 10$ cm and $l_2 = 40$ cm]

(21) In an aluminium sheet there is a hole of diameter 1 m and is horizontally mounted on a stand. onto this hole an iron sphere of diameter 1.004 m is resting. Initial temperature of this system is 25°c. find at what temperature, the iron sphere will fall down through the hole in sheet. The coefficients of linear expansion for aluminium and iron are 2.4×10^{-5} and 1.2×10^{-5} respectively

[Ans - 359.7°c]

(22) what should be the lengths of steel and copper rod so that the length of steel rod is 10 cm longer than the copper rod at all the temperatures. Coefficients of linear

and $\alpha_{steel} = 1.1 \times 10^{-5}\,°c^{-1}$ [Ans - 18.3 cm $l_2 = 28.3$ cm]

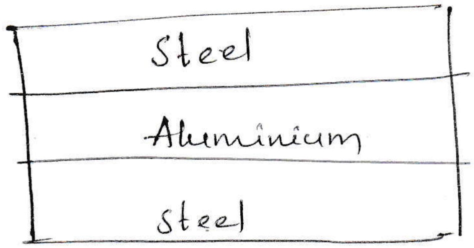
(23) A clock with a metallic pendulum is 5 seconds fast each day at a temperature of 15°c and 10 seconds slow each day at a temperature of 30°c. Find Coefficient of linear expansion for the metal.

[Ans - $\alpha = (2.31 \times 10^{-5}\,°c^{-1})$]

(24) Two steel rods and an aluminium rod of equal length l_0 and equal cross section are joined rigidly at their ends as shown in the fig. All the rods are at zero tension at 0°c. Find the strain of the system when the temp is raised to θ. The Coefficient of linear expansion of aluminium and steel are α_a and α_s respectively. Y_A and Y_s are Young's modulus of Aluminium and steel respectively.

Ans $\left[\dfrac{2Y_s\alpha_s\theta + Y_A\alpha_{Al}}{2Y_s + Y_{Al}}\right]\theta$

(25) Two steel rods and an aluminium rod of equal length L_0 and equal cross-section are joined rigidly at their ends as shown in the figure. All the rods are in a state of zero tension at 0°c find the length of the system when the temperature is raised to θ, Coefficient of linear expansion of aluminium and steel are α_1 and α_2 respectively, Young's modul...



$$\left(\text{Ans} - \frac{l_0 \theta (Y_1 \alpha_1 + 2Y_2 \alpha_2)}{Y_1 + 2Y_2} \right)$$

(26) A particular block floats in water at 4°c so that 0.984 of its height is under water. At what temperature will it just sink in water? Neglect expansion of block (volume coefficient of expansion of water) = 2.1×10^{-4} per °c.

Ans - 81.43°c

(27) A block of quartz of mass 13.5 g is weighed in aniline at 0°c and 100°c. The weighings are 8.905 g and 9.29 g respectively. Calculate the coefficient of cubical expansion of quartz to be zero (Ans - 9.166×10^{-4}/°c)

(28) A piece of metal weighs 46 g in air. When it is immersed in a liquid of specific gravity 1.24 at 27°c, it weighs 30 g. When the temperature of the liquid is raised to 42°c, the metal piece weighs 30.5 g. Specific gravity of liquid at 42°c is 1.2. Calculate the coefficient of linear expansion of the metal (Ans - 2.4×10^{-5}/K)

(29) A piece of metal floats on mercury. The volume coefficient of expansion of the metal and mercury

mercury and metal are increased by ΔT, by what factor does the fraction of the volume of the metal submerged in mercury change? [Ans $(\gamma_2-\gamma_1)\Delta T, (1-\gamma_1\Delta T)$]

(30) The specific heat of a substance varies as $(3t^2+t) \times 10^{-3}$ Cal/g-°c. what is the amount of heat required to raise the temperature of 1 kg of substance from 10°c to 20°c? [Ans - 7150 Cal]

(31) A liquid of specific heat 0·5 cal/g° at 60°c, is mixed with another liquid of specific heat 0·3 cal/gm° c at 20°c. After mixing, the temperature of the mixture becomes 30°c. In what proportion by weight are the liquids mixed?

[Ans - 1:5]

(32) 1g steam at 100°c is passed in to an insulating vessel having 1g of ice at 0°c. find the equlibrium tempera-ture of the mixture, neglecting heat Capacity of the vessel [Ans - 100°c]

(33) A Caloriemeter of heat Capacity 83·72 J K^{-1} Contains 0·48 kg of water at 35°c. How much mass of ice at 0°c should be added to decrease the temperature of the Calorie meter to 20°c. [Ans - 0·07498 kg]

(34) A wall of two layers P and Q each made of different materials. Both the layers have same thickness. The thermal conductivity of the material P is twice that of Q. Under thermal equilibrium, the temperature difference across the wall is 36°C. What is the temperature difference across the layer P? [Ans - 12°C]

(35) An electric heater is used in a room of total wall area $137 m^2$ to maintain a temperature of +20°C inside it, when the outside temperature is -10°C. The walls have three different layers and materials. The innermost layer is of wood of thickness 2.5 cm, the middle layer is of cement of thickness 1.0 cm and the outermost layer is of brick of thickness 25.0 cm. Find the power of the electric heater. Assume that there is no heat loss through the floor and the ceiling. The thermal conductivities of wood, cement and brick are 0.125, 1.5 and 1.0 W/m°C respectively.

[Ans - 9000 W]

(36) Three rods of identical cross-sectional area and made ~~from~~ form the sides of an isosceles triangle ABC right-angled at B. The points A and B are maintained at temperatures T and $\sqrt{2}T$ respectively in steady state

the temperature at point c. Ans - $T_c = \frac{3T}{\sqrt{2}+1}$

(37) Two solid spheres of same material but diameters in the ratio of 5 : 4 are at temperatures 227°c and 127°c respectively. The temperature of the surroundings is 27°c and stefan's law holds. Calculate the ratio of loss of heat of the two spheres? Ans = ~~[illegible]~~ 34/7

(38) A sphere with a diameter of 80 cm is held at a temperature of 250°c and is radiating energy. If the intensity of the radiation detected at a distance of 2.0 m from the sphere's centre is 102 W/m², what is the emissivity of the sphere? Ans - 0.61

(39) The rate of cooling of water in a calorimeter is one tenth of a degree per second when its temperature is 40°c above that of the surroundings. what is the (temperature) rate of cooling and heat per second when the excess temperature over the surroundings is 30°c? Thermal capacity of water and calorimeter is 4600 J/°c. Ans - 345 J/sec

THERMODYNAMICS

(1) A 10kW drilling machine is used for 5 minutes to bore a hole in an aluminium block of mass 10×10^3 kg. If 40% of the work done is utilised to raise the temperature of the block, find the rise in temperature of the aluminium block? (Specific heat of Aluminium = $0.9\ J kg^{-1} k^{-1}$) [Ans - 133.3°c]

(2) A person of mass 60 kg wants to lose 5 kg by going up and down a 10 m high stairs. Assume he burns twice as much fat while going up than coming down. If 1 kg of fat is burnt on expending 7000 kilo calories, how many times must he go up and down to reduce his weight by 5 kg? [Ans - 16.3×10^3 times]

(3) When 1 g of water at 100°c is converted into steam at 100°c, it occupies a volume of 1671 cc at normal atmospheric pressure, find the increase in internal energy of the molecules of steam. [Ans - 2098.8 J]

(4) A piston divides a closed gas cylinder into two parts. Initially the piston is kept pressed such that one part has a pressure P and volume 5V and the other part has pressure 8P and volume Vi

the piston is now left free. find the new pressure and voleeme for the isothermal and adiabatic process.

($\gamma = 1.5$) [Ans (a) = $\frac{48}{13}$ V (b) = $\frac{8}{3}$ V]

(5) P–V diagram of a diatomic gas is a straight line Passing through origin. What is the molar heat capacity of the gas in the process (Ans – $C = 3R$)

(6) A monoatomic gas undergoes a process given by $2dU + 3dW = 0$, then what is the process (Ans – poly-tropic process)

(7) The relation between U, P and V for an ideal gas is $U = 2 + 3PV$. What is the atomicity of gas [Ans $\gamma = \frac{4}{3}$]

(8) Consider a cycle type being filled with air by a Pump. Let V be the volume of the tyre (fixed) and at each stroke of the pump $\Delta V (\simeq V)$ of air is transferred to the tube adiabatically. What is the work done when the pressure in the tube is increased from P_1 to P_2 ? [Ans – $\frac{(P_2 - P_1)}{\gamma} V$]