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Exercise

Thermo-1

Elasticity, Calorimetry,

Thermal Expansion, Heat Transfer

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Exercise-2

(Subjective Type: Level- 2)

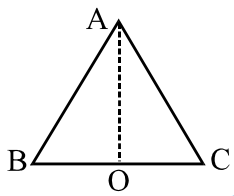
Q 1. A copper rod of length L and radius r is suspended from the ceiling by one of its ends. Find

(a) the elongation of the rod due to its own weight if ρ and Y are the density and Young's Modulus of copper respectively,

(b) The elastic potential energy stored in the rod due to its own weight.

Q 2. Three aluminium rods of equal length form an equilateral triangle ABC. Taking O (mid point of rod BC) as the origin. Find the increase in Y-coordinate of center of mass per unit change in temperature of the system. Assume the length of the each rod is 2m, and

$\alpha_{al} = 4\sqrt{3}\times10^{-6}\,/\,°C$



Q 3. A uniform slender rod of length L and density σ rotates about an axis through its end and perpendicular to the length width a constant angular velocity ω. If the Young's modulus of the rod is Y, find the elongation in the rod due to rotation. (Neglect the effect of gravity)

Q 4. A metal rod A of 25cm lengths expands by 0.050cm. When its temperature is raised from 0°C to 100°C. Another rod B of a different metal of length 40cm expands by 0.040 cm for the same rise in temperature. A third rod C of 50cm 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 lengths of each portion of the composite rod.

Q 5. A wire of cross-sectional area 4×10^{-4} m^2 modulus of elasticity 2×10^{11} N/m^2 and length 1 m is stretched between two vertical rigid poles. A mass of 1 kg is suspended at its middle. Calculate the angle it makes with the horizontal.

Q 6. A copper calorimeter of mass 100 gm contains 200 gm of a mixture of ice and water. Steam at 100°C under normal pressure is passed into the calorimeter and the temperature of the mixture is allowed to rise to 50°C. If the mass of the calorimeter and its contents is now 330 gm, what was the ratio of ice and water in the beginning? Neglect heat losses.

Given: Specific heat capacity of copper = 0.42×10^3 J kg^{-1}K^{-1},

Specific heat capacity of water = 4.2×10^3 J kg^{-1}K^{-1},

Specific heat of fusion of ice = 3.36×10^5 J kg^{-1}

Latent heat of condensation of steam = 22.5×10^5 Jkg^{-1}

Q 7. From what height must a block of ice at 0°C be dropped into a wall of water so that 50% of ice melts. Temperature of water in wall is 0°C. Assume no loss of energy.

(Given L = 80 cal/gm, J = 4.2 J/cal, g = 9.8 m/s^2)

Q 8. 50 g of Ice at 0°C is added to 200 g of water initially at 70°C in a vacuum flask. When all the ice has melted the temperature of the flask and contents is 40°C. When a further 80g of ice has been added and has all melted the temperature of the whole becomes 10°C. Find the specific latent heat of fusion of ice.

Q 9. An isosceles triangle is formed with a rod of length l_1 and coefficient of linear expansion α_1 for the base and two thin rods each of length l_2 and coefficient of linear expansion α_2 for the two pieces, if the distance between the apex and the midpoint of the base remain unchanged as the temperatures varied show that $\frac{l_1}{l_2} = 2\sqrt{\frac{\alpha_2}{\alpha_1}}$.

Q 10. A steel drill making 180 rpm is used to drill a hole in a block of steel. The mass of the steel block and the drill is 180 gm. If the entire mechanical work is used up in producing heat and the rate of raise in temperature of the block and the drill is 0.5 °C/s. Find

(a) the rate of working of the drill in watts, and

(b) the torque required to drive the drill.

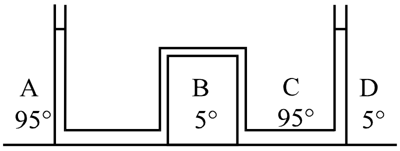
Specific heat of steel = 0.1 and J = 4.2 J/cal. Use: $P = \tau\,\omega$

Q 11. Ice at – 20°C is filled upto height h = 10 cm in a uniform cylindrical vessel. Water at temperature θ°C is filled in another identical vessel upto the same height h = 10 cm. Now, water from second vessel is poured into first vessel and it is found that level of upper surface falls through Δh = 0. 5 cm when thermal equilibrium is reached. Neglecting thermal capacity of vessels, change in density of water due to change in temperature and loss of heat due to radiation, calculate initial temperature θ of water.

Given,	Density of water,	$\rho_w = 1$ gm cm^{-3}
	Density of ice,	$\rho_i = 0.9$ gm/cm^3
	Specific heat of water,	$s_w = 1$ cal/gm ^{0}C
	Specific heat of ice,	$s_i = 0.5$ cal/gm^{0}C
	Specific latent heat of ice,	L = 80 cal/gm

Q 12. The height of a mercury column measured with a brass scale at temperature t_1 is H_1. What height H_0 will the mercury column have if t = 0°C? The coefficient of linear expansion of brass α and that for cubical expansion of mercury is γ.

Q 13. The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 49 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95º C while the columns B & D are maintained at 5º C. The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. Determine the coefficient of thermal expansion of the liquid.



Q 14. Toluene liquid of volume 300 cm^3 at 0°C is contained in a beaker an another quantity of toluene of volume 110 cm^3 at 100°C is in another beaker. (The combined volume is 410 cm^3). Determine the total volume of the mixture of the toluene liquids when they are mixed together. Given the coefficient of volume expansion γ = 0.001/°C and all forms of heat losses can be ignored. Also find the final temperature of the mixture.

Q 15. A double-pane window used for insulating a room thermally from outside, consists of two glass sheets each of area 1 m^2 and thickness 0.01 m separated by a 0.05 m thick stagnant air space. In the steady state the room-glass interface and the glass-outdoor interface are at constant temperature of 27^0C and 0^0C respectively. Calculate the rate of heat flow through the window pane. Also find the temperatures of other interfaces. Given thermal conductivities of glass and air as 0.8 and 0.08 $Wm^{-1}\ K^{-1}$ respectively.

Q 16. A wall is made of 7.5 cm thick magnesia, surfaced with 0.5 cm thick steel plate on one side & 2.5 cm thick asbestos on the other side. The thermal conductivities of steel, magnesia and asbestos are 52.3, 0.075 & 0.081 w/m-K respectively. If the outer surface temperature of steel plate is 150^0C and that of asbestos is 38^0C find
(a) rate of heat loss per square meter of surface area of wall &
(b) interface temperatures.

Q 17. A highly conducting solid cylinder of radius a and length *l* is surrounded by a co-axial layer of a material having thermal conductivity K and negligible heat capacity. Temperature of surrounding space (out side the layer) is T_0, which is higher than temperature of the cylinder. If heat capacity per unit volume of cylinder material is s and outer radius of the layer is b, calculate time required to increase temperature of the cylinder from T_1 to T_2. Assume end faces to be thermally insulated.

Q 18. There are 6 long slabs of rectangular cross-section area 'a' and length ℓ. The thermal conductivity of each rod is 'k'. when they are piled one over other and one end is heated a constant ΔT temperature difference between the ends is observed at steady state. Than again rods are arranged with one's end touching the other. Find the temperature of other end, if one end's temperature is maintained at T_1 for same heat flow as in the first case and total heat flow in t time.

Q 19. End A of a rod AB of length l_0 = 5 cm and cross sectional area S = 1 m^2 is maintained at some constant temperature. The heat capacity of the rod is varying with the distance x form, the end A as $k = k_0(1+ax)$, where $k_0 = 11.4\ J/s-m^{-1}K^{-1}$ and a = 0.2 m/s. The other end B of this rod is radiating energy at the rate of P = 4560 J/s and the wavelength with the maximum energy density emitted from this end is 14500 A^0. Express the variation of temperature as a function of x and determine the temperature of the end A. (Assume that except the ends, the rod is thermally insulated. Given Wein's constant $b = 2.9 \times 10^{-3}$ m – K .)

Q 20. A vertical brick duct (tube) is filled with cast iron. The lower end of the duct is maintained at a temperature T_1 which is greater than the melting point T_m of cast iron and the upper end at a temperature T_2 which is less than the temperature of the melting point of cast iron. It is given that the conductivity of liquid cast iron is equal to k times the conductivity of solid cast iron. Determine the fraction of the duct filled with molten metal.

Q 21. A lagged stick of cross section area 1 cm^2 and length 1 m is initially at a temperature of 0°C. It is then kept between 2 reservoirs of temperature 100°C and 0°C. Specific heat capacity is 10 J/kg°C and linear mass density is 2 kg/m. Find

(a) temperature gradient along the rod in steady state.
(b) total heat absorbed by the rod to reach steady state.

Q 22. A cylindrical block of length 0.4 m an area of cross-section 0.04m^2 is placed coaxially on a thin metal disc of mass 0.4 kg and of the same cross-section. The upper face of the cylinder is maintained at a constant temperature of 400K and the initial temperature of the disc is 300K. If the thermal conductivity of the material of the cylinder is 10 watt/m-K and the specific heat of the material of the disc in 600 J/kg-K, how long will it take for the temperature of the disc to increase to 350K? Assume, for purposes of calculation, the thermal conductivity of the disc to be very high and the system to be thermally insulated except for the upper face of the cylinder.

Q 23. A liquid takes 5 minutes to cool from 80°C to 50°C. How much time will it take to cool from 60°C to 30°C ? The temperature of surrounding is 20°C. Use exact method.

Q 24. A point source of power W watt is buried deep inside the earth. The thermal conductivity of the earth is k. Under steady state condition the temperature far away from the power source is found to be T_0. Show that the temperature T at a distance r from the source is given by $T = T_0 + \dfrac{W}{4\pi kr}$.

Answer Key

Ans 1. (a) $\frac{\rho g L^2}{2Y}$ (b) $\frac{1}{6}\frac{\pi r^2 \rho^2 g^2 L^3}{Y}$

Ans 2. 4 × 10–6 m/°C

Ans 3. $\frac{\sigma L^3 \omega^2}{3Y}$

Ans 4. 10cm , 40cm

Ans 5. 1/200 rad

Ans 6. 1 : 1.26

Ans 7. 1714.3m

Ans 8. 3.78×10^5 J/kg

Ans 10. (a) 37.8 J/s (Watts), (b) 2.005 N-m

Ans 11. 45°C

Ans 12. $H_1(1+\alpha t_1 - \gamma t_1)$

Ans 13. 2 × 10–4 C

Ans 14. Decrease by 0.75 cm3, 25°C

Ans 15. 41.5 W 0.520 C

Ans 16. (a) 85.58 w/m2 (b) 149.990C 64.40C

Ans 17. $\frac{a^2 s}{2K} \log_e\left(\frac{b}{a}\right) \log_e\left(\frac{T_0 - T_1}{T_0 - T_2}\right)$

Ans 18. $\frac{6k\alpha\Delta T}{\ell}$

Ans 19. $T = 2000\left[ln\left(\frac{2}{1+0.2x}\right) + 1\right], 3386K$

Ans 20. $\frac{l_1}{l} = \frac{k(T_1 - T_m)}{k(T_1 - T_m) + (T_m - T_2)}$

Ans 21. (a) –100 °C/m, (b) 1000 J

Ans 22. 166.3 sec

Ans 23. 10 Min.