Exercise - IV (TOUGH SUBJECTIVE PROBLEMS)

1. 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 beginning? Neglect heat losses.
Given : Specific heat capacity of copper
$= 0.42 \times 10^3$ J kg^{-1} K^{-1},
Specific heat capacity of water
$= 4.2 \times 10^3$ J kg^{-1}K^{-1},
Specific heat of fusion of ice
$= 3.36 \times 10^5$ J kg^{-1}
Latent heat of condensation of steam
$= 22.5 \times 10^5$ Jkg^{-1}

2. A solid substance of mass 10 gm at –10°C was heated to –2°C (still in the solid state). The heat required was 64 calories. Another 880 calories was required to raise the temperature of the substance (now in the liquid state) to 1°C, while 900 calories was required to raise the temperature from –2°C to 3°C. Calculate the specific heat capacities of the substance in the solid and liquid state in calories per kilogram per kelvin. Show that the latent heat of fusion L is related to the melting point temperature t_m by $L = 85400 + 200\, t_m$.

3. 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 : $P = \tau\omega$

4. A flow calorimeter is used to measure the specific heat of a liquid. Heat is added at a known rate to a stream of the liquid as it passes through the calorimeter at a known rate. Then a measurement of the resulting temperature difference between the inflow and the outflow points of the liquid stream enables us to compute the specific heat of the liquid. A liquid of density 0.2 g/cm^3 flows through a calorimeter at the rate of 10 cm^3/s. Heat is added by means of a 250-W electric heating coil, and a temperature difference of 25°C is established in steady-state conditions between the inflow and the outflow points. Find the specific heat of the liquid.

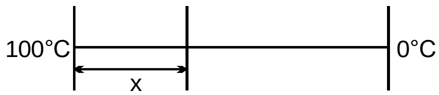
5. Ice at –20°C is filled upto height h = 10 cm in a uniform cylindrical vessel. Water at temperature θ°C is filled in another identical vessel upto the same height h = 10 cm. Now, water from second vessel is poured into first vessel and it is found that level of upper surface falls through $\Delta h = 0.5$ 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 rediation, 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 °C
Specific heat of ice $s_i = 0.5$ cal/gm ºC
Specific latent heat of ice, L = 80 cal/gm

6. A composite body consists of two rectangular plates of the same dimensions but different thermal conductivities K_A and K_B . This body is used to transfer heat between two objects maintained at different temperatures. The composite body can be placed such that flow of heat takes place either parallel to the interface or perpendicular to it. Calculate the effective thermal conductivities $K_{||}$ and $K_{\perp}$ of the composite body for the parallel and perpendicular orientations. Which orientation will have more thermal conductivity ?

7. 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.

8. 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.

9. 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



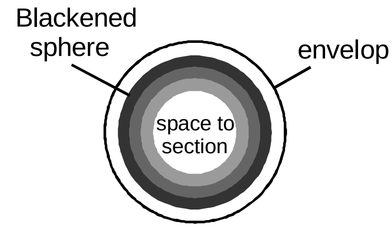
(a) temperature gradient along the rod in steady state.
(b) total heat absorbed by the rod to reach steady state.

10. A cylindrical block of length 0.4 m an area of cross-section 0.04 m^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.

11. A solid copper sphere cools at the rate of 2.8°C per minute, when its temperature is 127°C. Find the rate at which another solid copper sphere of twice the radius lose its temperature at 327°C, if in both the cases, the room temperature is maintained at 27°C.

12. End A of a rod AB of length L = 0.5 m and of uniform cross-sectional area is maintained at some constant temperature. The heat conductivity of the rod is k = 17 J/s-m°K. The other end B of this rod is radiating energy into vaccum and the wavelength with maximum energy density emitted from this end is λ_0 = 75000 Å. If the emissivity of the end B is e = 1, determine the temperature of the end A. Assuming that except the ends, the rod is thermally insulated.

13. The shell of a space station is a blackened sphere in which a temperature T = 500K is maintained due to operation of appliances of the station. Find the temperature of the shell if the station is enveloped by a thin spherical black screen of nearly the same radius as the radius of the shell.



14. 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.

15. A barometer is faulty. When the true barometer reading are 73 and 75 cm of Hg, the faulty barometer reads 69 cm and 70 cm respectively.
(i) What is the total length of the barometer tube ?
(ii) What is the true reading when the faulty barometer reads 69.5 cm?
(iii) What is the faulty barometer reading when the true barmeter reads 74 cm?

16. A vessel of volume V = 30 l is separated into three equal parts by stationary semipermeable thin membrances as shown in the Figure. The left, middle and right parts are filled with $m_{H_2} = 30g$ of hydorgen, $m_{O_2} = 160g$ of oxygen, and $m_{N_2} = 70g$ of nitrogen respectively. The left partition lets through only hydrogen, while the right partition lets through hydrogen and nitrogen. What will be the pressure in each part of the vessel after the equilibrium has been set in if the vessel is kept at a constant temperature T = 300K?

H_2	O_2	N_2

17. Twelve conducting rods form the riders of a uniform cube of side 'l'. If in steady state, B and H ends of the rod are at 100°C and 0°C. Find the temperature of the junction 'A'.