Quiz#3 -Ch.#19 (Dr. Naqvi-Phys.102.10, 12)

Q#1: An iron ball has a diameter of 7.0 cm and is 0.02 cm too large to pass through a hole in a brass ring when both are at a temperature of 25 degrees Celsius. To what temperature should the brass ring be heated so that the ball just passes through the hole? [The coefficient of volume expansion of iron = 3.6*10(-5) K**-1 and of brass = 5.7*10**(-5) K**-1]**

Solution: Brass ring internal diameter is to be expanded to fit iron ball diameter.

Diameter of brass ring D_B=7.00-0.02=6.98 cm; ΔD_B=0.02 cm; T_i=25°C; $\alpha=\beta/3=(5.7*10^{-5})/3$; $\Delta D_B=\alpha*D_B*\Delta T$; then $0.02=(1.9*10^{-5})*6.98*\Delta T$; ΔT=150.80 ; $T_f=T_i+\Delta T$=150.80+25=175.80°C

Q#2: 100 g of water at 100 degrees Celsius is added to 120 g of ice at -10ºC. What is the equilibrium temperature of the mixture? [The heat of fusion of ice = 333 kJ/(kg) ; the specific heat of water = 4186 J/kg*K and specific heat of ice=2220 J/kg.K].

Solution: **Hint: Assuming 100g of water at 100°C will be cooled to 0°C. Energy released in this process will be used to heat the ice from -10°C to 0°C and then melt the ice. Check if the energy available is sufficient to melt the whole mass of the ice. If not, then ice has not completely melted and the mixture final temperature is that of the ice at 0°C.**

Energy released in cooling the 100 g water $=Q_-=m_w*c_w*\Delta T=0.1*4186*100=41860$ J

Energy absorbed by ice to completely melt $Q_+=Q_{ice\text{-}heating}+Q_{ice\text{-}melting}$; $Q_{ice\text{-}heating}=m_{ice}*c_{ie}*\Delta T$

$Q_{ice\text{-}heating}=0.12*2220*10^3*10=2664$ J; $Q_{ice\text{-}melting}=m_{ice}*L_F=0.12*333*10^3=39960$ J;

$Q_+=Q_{ice\text{-}heating}+Q_{ice\text{-}melting}=2664+39960=42624$ J and Q_-= 41860 J; Since $Q_+>Q_-$, ice has not completely melted. The final temperature of the mixture is T_f=0°C

Q#3: A composite rod is made of two different metals pieces with same cross sectional area A, one piece is 30 cm long and has a thermal conductivity k_1= 235 W/m.K and the other piece has a length 50 cm and thermal conductivity k_2=401 W/m.K. One of the ends of the composite rod is in boiling water, while the other end is in ice. What is the steady state temperature at the interface of the two pieces?

Solution: Hint: Energy flowing through a rod in heat form in heat conduction process in steady state is $P_{cond}=\kappa*A*(T_H-T_C)/L$; For a composite rod consisting of two pieces of lengths L_1 and L_2 having thermal conductivities κ_1 and κ_2 the heat flow $P_{cond\text{-}1}$, $P_{cond\text{-}2}$ through each piece of rod in steady state is same. If T_J is interface temperature, $P_{cond\text{-}1}=[\kappa_1*A_{cross}*(T_H-T_J)]/L_1$; $P_{cond\text{-}2}=[\kappa_2*A_{cross}*(T_J-T_C)]/L_2$; Then $(T_H-T_J)=[(\kappa_2*L_1)/(\kappa_1*L_2)](T_J-T_C)=[(401*0.3)/(235*0.5)]*(T_J-T_C)=1.024*(T_J-T_C)$

$(T_H-T_J)=1.024*(T_J-T_C)$; T_H=100°C and T_C=0°C; Then $(100-T_J)=1.024*(T_J-0)=1.024*T_J$; T_J= 49.41°C

Quiz#3 -Ch.#19 (Dr. Naqvi-Phys 102.11)

Q#1: A steel washer (ring) has an inner diameter of 4.000 cm and an outer diameter of 4.500 cm at 25 deg C. To what temperature must the washer be heated to just fit over a rod that is 4.015 cm in diameter? (Coefficient of volume expansion of steel, beta, = 33*10(-6) per C deg).**

Solution: Steel ring internal diameter is to be expanded to fit rod diameter.

Diameter of steel ring D_S=4.000 cm; ΔD_S=0.015 cm; T_i=25°C; $\alpha=\beta/3=(33*10^{-5})/3$; $\Delta D_s=\alpha*D_s*\Delta T$;

Then $0.015=33*10^{-6}*4.00*\Delta T$; ΔT=113.6; $T_f=T_i+\Delta T$=113.6+25=138.6°C

Q#2: Fifty grams of ice at 267 Kelvin temperature is placed in a thermos bottle containing 100 grams of water at 6.0 degrees Celsius. How many grams of ice will melt? [The heat of fusion of ice = 333 kJ/(kg) ; the specific heat of water = 4186 J/kg*K and specific heat of ice=2220 J/kg*K].

Solution: See the Hint in Q# 2 above: Energy released by 100 g water $Q_-=m_w*c_w*\Delta T=0.1*4186*6=2511.6$ J

Energy absorbed by ice to melt $Q_+=Q_{ice\text{-}heating}+Q_{ice\text{-}melting}$; $Q_{ice\text{-}heating}=m_{ce}*c_{ie}*\Delta T=0.05*2220*6=666$ J;

Energy available to melt ice= $Q_- - Q_{ice\text{-}heating}=2511.6-666.0=1845.6$ J; $m_{ice\text{-}melted}=(Q_- - Q_{ice\text{-}heating})/L_F$

$m_{ice\text{-}melted}=1845.6/333*10^3=0.00554$ kg= 5.5 g

Q#3: A solid aluminum rod, of length 40 cm and cross-sectional area of 6.0*10**(-4) m**2, has one end in boiling water and the other end in ice. How much ice melts in one minute? [The thermal conductivity of aluminum is 205 Watts/(m*K) and the heat of fusion of water is 3.35*10**5 J/kg.] (Neglect any heat loss, by the system, to the surrounding) (Ans: 7.2*10**(-4) kg)

Solution. See Hint under Q#3 above: $P_{cond}=\kappa*A*(T_H-T_C)/L=[205*6.0*10^{-4}*(373-273)]/0.4=30.75$ J/s

Heat flowing in one minute $Q=P_{cond}*60=30.75*60=1845$ J; **Q is absorbed by the ice to melt.**

Mass of ice melted $m_{ice\text{-}melted}=Q/L_F=1845/(335*10^3)=0.005507$ kg= 5.51 g