key Level I Physics Pd 2

# Thermal Physics

AT Thermal (11)

Solve the following problems showing ALL work and CIRCLING your answers. Each is worth 5 points. There is a table of information on the back of the test.

1) Determine the change in length of 30 miles of railroad track (steel) between a chilly winter day (0°C) and a warm summer day (32°C).

$\Delta L = L_0 \alpha \Delta T$

$\Delta L = (30mi)(12\times10^{-6}/^{\circ}C)(32^{\circ}C)$

$\Delta L = .01152mi = 18.4m$

2) A 300 Watt immersion heater is used to warm water. If the immersion heater is placed in a well-insulated cup with 0.5kg of water, how long will it take for the water to warm from room temperature (20°C) to the boiling point?

$Q = mc\Delta T$ $(100^{\circ}C - 20^{\circ}C)$

$Q = (.5kg)(4190\ J/kg^{\circ}C)(80^{\circ}C)$

$Q = 167600\ J$

$(167600J)\left(\frac{1\ s}{300\ J}\right)$ $558.7s = 9.3min$

3) 3 kg of boiling water are poured into a 5 kg aluminum kettle at room temperature (20°C). Assume no thermal energy is lost; determine the temperature of the kettle and the water once it reaches thermal equilibrium.

$$Q_{Water} + Q_{Al} = 0$$

$$mC\Delta T + mc\Delta T = 0$$

$$m_w c_w (T - T_{0_w}) + m_A c_A (T - T_{0_A}) = 0$$

$$(3kg)(4190\ J/kg°C)(T - 100°C) + (5kg)(900\ J/kg°C)(T - 20°C) = 0$$

$$(12570\ J/°C)(T) - 1257000J + (4500\ J/°C)T - 90000\ J = 0$$

$$(12570\ J/°C)T + (4500\ J/°C)T = 1257000J + 90000J$$

$$(17070\ J/°C)T = ~~215700~~\ 1347000\ J$$

$$T = 78.9°C$$

4) Determine the amount of ice (mass) that is needed to cool 5 kg of water at 20°C to water that is at 2°C. Assume no energy is lost to the surroundings.

$mL + mc\Delta T + mc\Delta T = 0$

Ice — Water That was Ice — Water

$m(3.34\times10^5 \text{ J/kg}) + m(4190 \text{ J/kg°C})(2°C - 0°C) + (5 \text{ kg})(4190 \text{ J/kg°C})(2 - 20°C) = 0$

$m(342360 \text{ J/kg}) - 377100 \text{ J} = 0$

$m(342380 \text{ J/kg}) = 377100 \text{ J}$

$m = \dfrac{377100 \text{ J}}{342380 \text{ J/kg}} =$

$m = 1.1 \text{ kg}$

Thickness 2cm

5) A Styrofoam cooler has a surface area of 2 m². Determine how long it will take for 2 kg of ice to melt if all of the energy is lost by conduction. Assume the air temperature outside the cooler remains constant at 20°C

$$\frac{Q}{t} = \frac{kA(\Delta T)}{L}$$

$$\frac{mL}{t} = \frac{kA(\Delta T)}{L_{Thickness}}$$

$$\frac{mL\,L_{Thickness}}{kA(\Delta T)} = t$$

$$\frac{(2\,kg)(3.34\times10^5\,J/kg)(.02\,m)}{(.042\,J/ms^{\circ}C)(2\,m^2)(20^{\circ}C-0^{\circ})} = t = 7952\,s = 132\,min = 2.2\,hrs$$

6) 2 kg of ice are placed in a black box with emissivity of 0.8. The box has a surface area of 2 m². Determine how long it will take for the ice to melt if all of the energy exchange is only by radiation. The air outside the box is at 20°C.

$20°C = 293K$

$$\frac{Q}{t}_{\text{Absorbed from Air}} - \frac{Q}{t}_{\text{Radiated}} = \frac{Q}{t}_{net}$$

$$\sigma e A T^4 - \sigma \epsilon A T^4 = \frac{Q}{t}_{net}$$

$$\sigma e A(T_{Air}^4 - T_{ice}^4) = \frac{Q}{t}$$

$$(5.67\times10^{-8})\frac{W}{m^2K^4}(.8)(2m^2)(293K^4 - 273K^4) = \frac{Q}{t}$$

$$164.7\frac{J}{s} = \frac{Q}{t}$$ Rate

$Q = mL \Rightarrow$ Energy To melt Ice

$$Q = (2kg)(3.34\times10^5 J/kg) = 668{,}000 J$$

$$(668{,}000 J)\left(\frac{1}{164.7 J/s}\right) = 4055 s = 67 min$$