Thermal Physics

AT Thermal (12)

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.

19) Determine the change in length of 130 miles of railroad track (steel) between a chilly winter day (20° F) and a warm summer day (95° F)

$\Delta T = 95°F - 20°F = 75°F$

$(75°F)\left(\frac{5°C}{9°F}\right) = 41.67°C$

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

$\Delta L = (130mi)(12\times10^{-6}/°C)(41.67°C)$

$\Delta L = 6.5\times10^{-2} mi$

$104m$

20) A 300 Watt immersion heater is used to warm water. If the immersion heater is placed in a well-insulated cup with 5kg of water, how long will it take for the water to warm from room temperature (22°C) to the boiling point?

$Q = mc\Delta T$

$P = \frac{Q}{t} = \frac{mc\Delta T}{t}$

$t = \frac{mc\Delta T}{P} = \frac{(5kg)(4190 J/kg°C)(78°C)}{300 Watt} = 5447 s = 90 min$

21) 3 kg of boiling water is poured into a container with 5 kg of ice at 0°C . The ice was in a 250 g Aluminum container. Assume no thermal energy is lost; determine the temperature of the water once it reaches thermal equilibrium.

$Q_{Al} + Q_{melt\ Ice} + Q_{water\ that\ was\ Ice} + Q_{water} = 0$

$(.250\,kg)(900\,J/kg^{\circ}C)(T - 0^{\circ}C) + (5\,kg)(3.3\times10^{5}\,J/kg) + (5\,kg)(4190\,J/kg^{\circ}C)(T - 0) + (3\,kg)(4190)(T - 100)$

$225T - 0 + 1.65\times10^{6} + 20950T - 0 + 12570T - 1257000 = 0$

$33745T = -3.93\times10^{6}$

T = Negative

Zero

22) Determine the final temperature if ice and water if 50 g of 30°C water are added to 200 g of ice.

$Q_{water} + Q_{Ice} + Q_{water\ that\ was\ Ice} = 0$

Zero

23) 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 28°C. The cooler is 2 cm thick.

$$\frac{Q}{t} = \frac{kA(\Delta T)}{L} = \frac{(.042\ W/m\,°C)(2m^2)(28°C)}{.02m}$$

~~$\frac{Q}{t} = 117.6\ s = 1.9\ min$~~

$$\frac{Q}{t} = 117.6\ J/s$$

Energy To melt Ice $\quad Q = mL = (2kg)(3.3\times10^5\ J/kg) = 6.6\times10^5\ J$

$$\frac{6.6\times10^5\ J}{117.6\ J/s} = 5.612\times10^3\ s = 93\ min$$

24) 2 kg of ice are placed in a black box with emissivity of 0.8. The box has a surface area of 2 m^2. 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.

Absorb - Radiate

Ice = 0°C = 273K

20°C = 293K

$P = \sigma A e (T^4 - T^4)$

$P = (5.67\times10^{-8})(2m^2)(.8)(293K^4 - 273K^4)$

$P = 1.65\times10^2$ J/s

$Q = mL = (2kg)(3.3\times10^5$ J/kg$) = 6.6\times10^5$ J

$\frac{6.6\times10^5 \text{ J}}{1.65\times10^2 \text{ J/s}} = 4.00\times10^3$

4×10^3 s = 66min