Contents

1 Chapter 17 - Temperature and Heat

To convert Celsius to Fahrenheit:

$$T_F = \frac{9}{5}T_C + 32^\circ \tag{1}$$

To convert Fahrenheit to Celsius:

$$T_C = \frac{5}{9}(T_F - 32^\circ) \tag{2}$$

To convert from Celsius to Kelvin:

$$T_K = T_C + 273.15 \tag{3}$$

1.1 17.3

(a)

$$\begin{aligned} T_{F_0} &= -4.0^\circ \\ T_{F_1} &= 45.0^\circ \end{aligned}$$

$$\begin{aligned} \Delta T_F &= T_{F_1} - T_{F_0} \\ \Delta T_F &= 45.0^\circ - -4.0^\circ \\ \Delta T_F &= 49.0^\circ \end{aligned}$$

$$\begin{aligned} (100)\Delta T_F &= (180)T_C \\ T_C &= 27.2\,^\circ\mathrm{C} \end{aligned}$$

1.2 17.5

$$\Delta T_K = 10.0\,\mathrm{K}$$

(a)

$$\begin{aligned} T_{F_1} &= \frac{9}{5}(10.0\,^\circ\mathrm{C} + 32.0^\circ) \\ T_{F_1} &= 18.0^\circ \end{aligned}$$

$$\begin{aligned} T_{F_0} &= \frac{9}{5}(0 + 32.0^\circ) \\ T_{F_0} &= 57.6^\circ \end{aligned}$$

$$\begin{aligned} T_F &= T_{F_1} - T_{F_0} \\ T_F &= 18.0^\circ \end{aligned}$$

2 Linear Thermal Expansion

$$\Delta L = \alpha L_0 \Delta T \tag{4}$$

2.1 Expanding Holes and Volume Expansion

$$\Delta V = \beta V_0 \Delta T, \quad \beta = 3\alpha \tag{5}$$

2.2 17.11

$$\begin{aligned} L_0 &= 1410\,\mathrm{m} \\ T_0 &= -5.0\,^\circ\mathrm{C} \\ T_1 &= 18.0\,^\circ\mathrm{C} \\ \alpha_{steel} &= 1.2 \times 10^{-5}\,^\circ\mathrm{C}^{-1} \\ \Delta L &= ? \end{aligned}$$

$$\begin{aligned} &\Delta L = L_0 \alpha \Delta T \\ &\Delta L = (1410\,\mathrm{m})(1.2 \times 10^{-5}\,^\circ\mathrm{C}^{-1})(18.0\,^\circ\mathrm{C} - (-5.0\,^\circ\mathrm{C}) \\ &\Delta L = 0.389\,16\,\mathrm{m} \end{aligned}$$

2.3 17.15

$$\begin{aligned} T_0 &= 20.0\,^\circ\mathrm{C} \\ \beta_{copper} &= 5.1 \times 10^{-5}\,^\circ\mathrm{C}^{-1} \\ V_1 &= (0.0015)V_0 \end{aligned}$$

$$\begin{aligned} \Delta V &= V_0 \beta \Delta T \\ \Delta T &= \frac{\Delta V}{V_0 \beta} \\ \Delta T &= \frac{(0.0015)V_0}{V_0 \beta} \\ \Delta T &= \frac{0.0015}{5.1 \times 10^{-5}\,^\circ\mathrm{C}^{-1}} \\ \Delta T &= 29.4118\,^\circ\mathrm{C} \end{aligned}$$

2.4 17.16

$$\begin{aligned} d &= 55.0\,\mathrm{m} \\ T_{winter} &= -15\,^{\circ}\mathrm{C} \\ T_{summer} &= 35\,^{\circ}\mathrm{C} \\ \beta_{aluminum} &= 7.2 \times 10^{-5}\,^{\circ}\mathrm{C}^{-1} \\ \Delta V &= ? \end{aligned}$$

$$\begin{aligned} \Delta V &= V_0 \beta \Delta T \\ \Delta V &= \left(\frac{2}{3}\pi\frac{55.0\,\mathrm{m}}{2}\right)(7.2 \times 10^{-5}\,^{\circ}\mathrm{C}^{-1})(35\,^{\circ}\mathrm{C} - (-15\,^{\circ}\mathrm{C})) \\ \Delta V &= 156.805\,\mathrm{m}^3 \end{aligned}$$

2.5 17.19

$$\begin{aligned} d &= 1.35\,\mathrm{cm} = 0.0135\,\mathrm{m} \\ T_0 &= 25.0\,^{\circ}\mathrm{C} \\ \alpha_{steel} &= 1.2 \times 10^{-5}\,^{\circ}\mathrm{C}^{-1} \end{aligned}$$

(a)

$$\begin{aligned} A_0 &= \pi r^2 \\ A_0 &= \pi\left(\frac{0.0135\,\mathrm{m}}{2}\right)^2 \\ A_0 &= 0.001\,43\,\mathrm{m}^2 \end{aligned}$$

(b)

$$\begin{aligned} \Delta A &= 2\alpha A_0 \Delta T \\ \Delta A &= 2(1.2 \times 10^{-5}\,^{\circ}\mathrm{C}^{-1})(0.001\,43\,\mathrm{m}^2)(175\,^{\circ}\mathrm{C} - 25.0\,^{\circ}\mathrm{C}) \\ \Delta A &= 5.148 \times 10^{-6}\,\mathrm{m}^2 \end{aligned}$$

$$\begin{aligned} A &= A_0 + \Delta A \\ A &= 0.001\,43\,\mathrm{m}^2 + 5.148 \times 10^{-6}\,\mathrm{m}^2 \\ A &= 0.001\,435\,\mathrm{m}^2 \end{aligned}$$

3 Thermal Expansion of Water

3.1 Thermal Stress

$$\frac{F}{A} = -Y\alpha\Delta T \tag{6}$$

3.2 17.22

$$
\begin{aligned}
L_0 &= 185\,\text{cm} = 1.85\,\text{m} \\
d &= 1.60\,\text{cm} = 0.016\,\text{m} \\
T_0 &= 120.0\,^\circ\text{C} \\
T_1 &= 10.0\,^\circ\text{C} \\
Y_{brass} &= 9.0 \times 10^{10}\,\text{Pa} \\
\alpha_{brass} &= 2.0 \times 10^{-5}\,^\circ\text{C}^{-1} \\
F &=?
\end{aligned}
$$

$$
\begin{aligned}
\frac{F}{A} = -Y\alpha\Delta T \\
F &= -AY\alpha\Delta T \\
F &= -\left(\pi\left(\frac{0.016\,\text{m}}{2}\right)^2\right)(9.0 \times 10^{10}\,\text{Pa})(2.0 \times 10^{-5}\,^\circ\text{C}^{-1})(10.0\,^\circ\text{C} - 120.0\,^\circ\text{C}) \\
F &= 39\,810.3\,\text{N}
\end{aligned}
$$

$$
F_0 = F_1 = \frac{F}{2} = \frac{39\,810.3\,\text{N}}{2} = 19\,905.1\,\text{N}
$$

4 Quantity of Heat

The quantity of heat Q required to increase the temperature of a mass m of a certain material by ΔT is:

$$
Q = mc\Delta T \tag{7}
$$

$$
1\,\text{cal} = 4.186\,\text{J} \tag{8}
$$

Specific heat is found by:

$$
\begin{aligned}
dQ &= mcdT \\
c &= \frac{1}{m}\frac{dQ}{dT} \qquad (9)
\end{aligned}
$$

4.1 17.29

$$
\begin{aligned}
w &= 28.4\,\text{N} \\
Q &= 1.25 \times 10^4\,\text{J} \\
\Delta T &= 18.0\,^\circ\text{C} \\
c &=?
\end{aligned}
$$

$$\begin{aligned}
Q &= mc\Delta T \\
c &= \frac{Q}{\frac{w}{g}\Delta T} \\
c &= \frac{1.25 \times 10^4\,\mathrm{J}}{\left(\frac{28.4\,\mathrm{N}}{9.80\,\mathrm{m\,s^{-2}}}\right)(18.0\,^\circ\mathrm{C})} \\
c &= 239.632\,\mathrm{J\,kg^{-1}\,K}
\end{aligned}$$

4.2 17.25

$$\begin{aligned}
m_{kettle} &= 1.10\,\mathrm{kg} \\
m_{water} &= 1.80\,\mathrm{kg} \\
T_0 &= 20.0\,^\circ\mathrm{C} \\
T_1 &= 85.0\,^\circ\mathrm{C} \\
c_{aluminum} &= 910\,\mathrm{J\,kg^{-1}\,K} \\
c_{water} &= 4190\,\mathrm{J\,kg^{-1}\,K} \\
Q &= ?
\end{aligned}$$

$$\begin{aligned}
Q_{water} &= m_{water}c_{water}\Delta T \\
Q_{water} &= (1.80\,\mathrm{kg})(4190\,\mathrm{J\,kg^{-1}\,K})(85.0\,^\circ\mathrm{C} - 20.0\,^\circ\mathrm{C}) \\
Q_{water} &= 490\,230\,\mathrm{J}
\end{aligned}$$

$$\begin{aligned}
Q_{aluminum} &= m_{aluminum}c_{aluminum}\Delta T \\
Q_{aluminum} &= (1.10\,\mathrm{kg})(910\,\mathrm{J\,kg^{-1}\,K})(85.0\,^\circ\mathrm{C} - 20.0\,^\circ\mathrm{C}) \\
Q_{aluminum} &= 65\,065\,\mathrm{J}
\end{aligned}$$

$$\begin{aligned}
Q &= Q_{water} + Q_{aluminum} \\
Q &= 490\,230\,\mathrm{J} + 65\,065\,\mathrm{J} \\
Q &= 555\,295\,\mathrm{J}
\end{aligned}$$

4.3 17.31

$$\begin{aligned}
y_1 &= 225\,\mathrm{m} \\
m &= 1.00\,\mathrm{L} \\
y_0 &= 0 \\
c_{water} &= 4190\,\mathrm{J\,kg^{-1}\,K} \\
\Delta T &= ?
\end{aligned}$$

$$
\begin{aligned}
U &= Q \\
mgy_1 &= mc\Delta T \\
\Delta T &= \frac{gy_1}{c} \\
\Delta T &= \frac{(9.80\,\mathrm{m\,s^{-2}})(225\,\mathrm{m})}{4190\,\mathrm{J\,kg^{-1}\,K}} \\
\Delta T &= 0.5262\,^{\circ}\mathrm{C}
\end{aligned}
$$

4.4 17.33

$$
\begin{aligned}
m_{bullet} &= 15.0\,\mathrm{g} = 0.015\,\mathrm{kg} \\
v_0 &= 865\,\mathrm{m\,s^{-1}} \\
m_{water} &= 13.5\,\mathrm{kg} \\
v_1 &= 534\,\mathrm{m\,s^{-1}} \\
c_{water} &= 4190\,\mathrm{J\,kg^{-1}\,K} \\
\Delta T &= ?
\end{aligned}
$$

$$
\begin{aligned}
E_0 &= E_1 \\
\frac{1}{2}m_{bullet}v_0^2 &= \frac{1}{2}m_{bullet}v_1^2 + m_{water}c_{water}\Delta T \\
\Delta T &= \frac{m_{bullet}(v_0^2 - v_1^2)}{2m_{water}c_{water}} \\
\Delta T &= \frac{(0.015\,\mathrm{kg}\left[(865\,\mathrm{m\,s^{-1}})^2 - (534\,\mathrm{m\,s^{-1}})^2\right])}{2(13.5\,\mathrm{kg})(4190\,\mathrm{J\,kg^{-1}\,K})} \\
\Delta T &= 0.613\,99\,^{\circ}\mathrm{C}
\end{aligned}
$$

5 Molar Heat Capacity

Total mass m of material = Mass per mole $M\times$ Number of moles n:

$$m = nM \tag{10}$$

$$Q = nMc\Delta T \tag{11}$$

The produce Mc is called the **molar heat capacity**.

$$Q = nC\Delta T \tag{12}$$

5.1 Phase Changes

The **latent heat**, L, is the heat per unit mass that is transferred in a phase change.

$$Q = \pm mL \tag{13}$$

5.2 Problem

(a)

$$
\begin{aligned}
m_{water} &= 1\,\mathrm{kg} \\
T_{water} &= 100\,^{\circ}\mathrm{C} \\
m_{water\_vapor} &= 1\,\mathrm{kg} \\
T_{water\_vapor} &= 100\,^{\circ}\mathrm{C}
\end{aligned}
$$

$$
\begin{aligned}
Q_{water} &= m_{water} L_{water} \\
Q_w &= (1\,\mathrm{kg})(2256 \times 10^{3}\,\mathrm{J\,kg^{-1}}) \\
Q_w &= 2.256 \times 10^{6}\,\mathrm{J}
\end{aligned}
$$

5.3 17.34

$$
\begin{aligned}
m_{water} &= 750\,\mathrm{g} = 0.750\,\mathrm{kg} \\
T_{water_0} &= 10.0\,^{\circ}\mathrm{C} \\
T_{water_1} &= 75.0\,^{\circ}\mathrm{C} \\
T_{boil_0} &= 100.0\,^{\circ}\mathrm{C} \\
T_{boil_1} &= 75.0\,^{\circ}\mathrm{C}
\end{aligned}
$$

$$
\begin{aligned}
m_{water} c_{water} \Delta T_{water} + m_{boil} c_{water} \Delta T_{boil} &= 0 \\
m_{boil} &= -\frac{m_{water} \Delta T_{water}}{\Delta T_{boil}} \\
m_{boil} &= -\frac{(0.750\,\mathrm{kg})(75.0\,^{\circ}\mathrm{C} - 10.0\,^{\circ}\mathrm{C})}{75.0\,^{\circ}\mathrm{C} - 100.0\,^{\circ}\mathrm{C}} \\
m_{boil} &= 1.95\,\mathrm{kg}
\end{aligned}
$$

5.4 17.36

$$
\begin{aligned}
T_1 &= 32.0\,^{\circ}\mathrm{C} \\
m_{patient} &= 70.0\,\mathrm{kg} \\
T_{ice} &= 0\,^{\circ}\mathrm{C} \\
m_{ice} &= ? \\
c_{human} &= 3480\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}} \\
T_{human} &= 37.0\,^{\circ}\mathrm{C}
\end{aligned}
$$

$$m_{ice}L_{ice} + m_{human}c_{human}\Delta T = 0$$

$$m_{ice} = -\frac{m_{human}c_{human}\Delta T}{L_{ice}}$$

$$m_{ice} = -\frac{(70.0\,\mathrm{kg})(3480\,\mathrm{J\,kg^{-1}\,{}^{\circ}C^{-1}})(32.0\,{}^{\circ}\mathrm{C} - 37.0\,{}^{\circ}\mathrm{C})}{334 \times 10^{3}\,\mathrm{J\,kg^{-1}}}$$

$$m_{ice} = 3.646\,71\,\mathrm{kg}$$

5.5 17.37

$$\begin{aligned} m_{iron} &= 1.20\,\mathrm{kg} \\ T_{iron_0} &= 650.0\,{}^{\circ}\mathrm{C} \\ T_{water} &= 15.0\,{}^{\circ}\mathrm{C} \\ T_{iron_1} &= 120.0\,{}^{\circ}\mathrm{C} \\ m_{water} &= ? \end{aligned}$$

$$\begin{aligned} Q_0 + Q_1 + Q_2 &= 0 \\ m_{iron}c_{iron}\Delta T_{iron} + m_{water}c_{water}\Delta T_{water} + m_{water}L_{water\_vapor} &= 0 \end{aligned}$$

$$m_{water} = -\frac{m_{iron}c_{iron}\Delta T_{iron}}{c_{water}\Delta T_{water} + L_{water\_vapor}}$$

$$m_{water} = -\frac{(1.20\,\mathrm{kg})(0.47 \times 10^{3}\,\mathrm{J\,kg^{-1}\,K^{-1}})(120.0\,{}^{\circ}\mathrm{C} - 650.0\,{}^{\circ}\mathrm{C})}{(4190\,\mathrm{J\,kg^{-1}\,K^{-1}})(100.0\,{}^{\circ}\mathrm{C} - 15.0\,{}^{\circ}\mathrm{C}) + 2256 \times 10^{3}\,\mathrm{J\,kg^{-1}}}$$

$$m_{water} = 0.114\,\mathrm{kg}$$

5.6 17.40

$$\begin{aligned} m_{ice} &= 0.200\,\mathrm{kg} \\ T_{ice_0} &= -40.0\,{}^{\circ}\mathrm{C} \\ m_{water} &= ? \\ T_{water_0} &= 80.0\,{}^{\circ}\mathrm{C} \\ T_1 &= 28.0\,{}^{\circ}\mathrm{C} \end{aligned}$$

$$\begin{aligned} Q_0 + Q_1 + Q_2 + Q_3 &= 0 \\ m_{ice}c_{ice}\Delta T_{ice} + m_{ice}L_{ice} + m_{ice}c_{water}\Delta T_{melted} + m_{water}c_{water}\Delta T_{water} &= 0 \end{aligned}$$

$$m_{water} = -\frac{m_{ice}\left[c_{ice}\Delta T_{ice} + L_{ice} + c_{water}\Delta T_{melted}\right]}{c_{water}\Delta T_{water}}$$

$$m_{water} = -\frac{0.200\,\mathrm{kg}\left[(2100\,\mathrm{J\,kg^{-1}\,{}^{\circ}C^{-1}})(0 - -40.0\,{}^{\circ}\mathrm{C}) + 334 \times 10^{3}\,\mathrm{J\,kg^{-1}} + (4190\,\mathrm{J\,kg^{-1}\,K^{-1}})(28.0\,{}^{\circ}\mathrm{C} - 0)\right]}{(4190\,\mathrm{J\,kg^{-1}\,K^{-1}})(28.0\,{}^{\circ}\mathrm{C} - 80.0\,{}^{\circ}\mathrm{C})}$$

$$m_{water} = 0.491\,39\,\mathrm{kg}$$

5.7 17.49

$$\begin{aligned}
d_{asteroid} &= 10\,\text{km} = 10\,000\,\text{m} \\
m_{asteroid} &= 2.60\times10^{15}\,\text{kg} \\
v_{asteroid} &= 32.0\,\text{km}\,\text{s}^{-1} = 32\,000\,\text{m}\,\text{s}^{-1} \\
T_{water_0} &= 10.0\,^\circ\text{C} \\
m_{water} &= ?
\end{aligned}$$

$$\begin{aligned}
KE &= Q_0 + Q_1 \\
\frac{1}{2}m_a v_a^2 &= m_w c_w \Delta T + m_w L_w \\
m_w &= \frac{m_a v_a^2}{c_w \Delta T + L_w} \\
m_w &= \frac{0.01(2.60\times10^{15}\,\text{kg})(32\,000\,\text{m}\,\text{s}^{-1})^2}{2\left[(4190\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1})(100.0\,^\circ\text{C} - 10.0\,^\circ\text{C}) + 2256\times10^3\,\text{J}\,\text{kg}^{-1}\right]} \\
m_w &= 5.055\,64\times10^{15}\,\text{kg}
\end{aligned}$$

5.8 17.51

$$\begin{aligned}
m_{water} &= 0.250\,\text{kg} \\
T_{water_0} &= 75.0\,^\circ\text{C} \\
T_{ice} &= -20.0\,^\circ\text{C} \\
m_{ice} &= ? \\
T_1 &= 40.0\,^\circ\text{C}
\end{aligned}$$

$$Q_{ice,water} + Q_{water} + Q_{water,system} = Q_{water,system}$$
$$m_{ice}c_{ice}\Delta T_{ice,water} + m_{ice}L_{water} + m_{ice}c_{water}\Delta T_{water,system} = m_{water}c_{water}\Delta T_{water,system}$$

$$\begin{aligned}
m_{ice} &= \frac{m_{water}c_{water}\Delta T_{water,system}}{c_{ice}\Delta T_{ice,water} + L_{water} + c_{water}\Delta T_{water,system}} \\
m_{ice} &= \frac{(0.250\,\text{kg})(4190\,\text{J}\,\text{kg}^{-1}\,^\circ\text{C}^{-1})(40.0\,^\circ\text{C} - 75.0\,^\circ\text{C})}{(2100\,\text{J}\,\text{kg}^{-1}\,^\circ\text{C}^{-1})(0 - -20.0\,^\circ\text{C}) + 334\times10^3\,\text{J}\,\text{kg}^{-1} + (4190\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1})(40.0\,^\circ\text{C} - 0)} \\
m_{ice} &= -0.0674\,\text{kg}
\end{aligned}$$

6 Mechanisms of Heat Transfer

Three mechanisms of heat transfer:

- **Conduction** occurs within an object or between two objects in contact.

- **Convection** depends on motion of mass from one region of space to another.

- **Radiation** is heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between objects.

$$H = \frac{dQ}{dt} = kA\frac{T_H - T_C}{L} \tag{14}$$

6.1 17.56

$$\begin{aligned}
T_1 &= 100.0\,^\circ\mathrm{C} \\
T_0 &= 0.00\,^\circ\mathrm{C} \\
L &= 60.0\,\mathrm{cm} = 0.60\,\mathrm{m} \\
A &= 1.25\,\mathrm{cm}^2 = 0.000\,125\,\mathrm{m}^2 \\
m_{ice} &= 8.50\,\mathrm{g} = 0.008\,50\,\mathrm{kg} \\
\Delta t &= 10.0\,\mathrm{min} = 600\,\mathrm{s} \\
k &= ?
\end{aligned}$$

$$\begin{aligned}
\frac{Q}{\Delta t} &= \frac{kA(T_1 - T_0)}{L} \\
k &= \frac{mLL}{\Delta t A(T_1 - T_0)} \\
k &= \frac{(0.008\,50\,\mathrm{kg})(334\times10^3\,\mathrm{J\,kg^{-1}})(0.60\,\mathrm{m})}{(600\,\mathrm{s})(0.000\,125\,\mathrm{m}^2)(100.0\,^\circ\mathrm{C} - 0.00\,^\circ\mathrm{C})} \\
k &= 227.12\,\mathrm{J\,m^{-1}\,s^{-1}\,^\circ C^{-1}} = 227.12\,\mathrm{W\,m^{-1}\,^\circ C^{-1}}
\end{aligned}$$

6.2 17.57

$$\begin{aligned}
l_{out} &= 3.0\,\mathrm{cm} = 0.03\,\mathrm{m} \\
l_{in} &= 2.2\,\mathrm{cm} = 0.022\,\mathrm{m} \\
k_{wood} &= 0.080\,\mathrm{W\,m^{-1}\,K^{-1}} \\
k_{styrofoam} &= 0.027\,\mathrm{W\,m^{-1}\,K^{-1}} \\
T_{in} &= 19.0\,^\circ\mathrm{C} \\
T_{out} &= -10.0\,^\circ\mathrm{C}
\end{aligned}$$

(a)

$$\begin{aligned}
H_w &= k_w A \left(\frac{T - T_{out}}{l_{out}}\right) \\
H_s &= k_s A \left(\frac{T_{in} - T}{l_{in}}\right) \\
k_w A \left(\frac{T - T_{out}}{l_{out}}\right) &= k_s A \left(\frac{T_{in} - T}{l_{in}}\right) \\
k_w \left(\frac{T - T_{out}}{l_{out}}\right) - k_s \left(\frac{T_{in} - T}{l_{in}}\right) &= 0 \\
T\left[\frac{k_w}{l_{out}} + \frac{k_s}{l_{in}}\right] &= \frac{k_w T_{out}}{l_{out}} + \frac{k_s T_{in}}{l_{in}} \\
T &= \frac{\frac{k_w T_{out}}{l_{out}} + \frac{k_s T_{in}}{l_{in}}}{\frac{k_w}{l_{out}} + \frac{k_s}{l_{in}}} \\
T &= \frac{\frac{(0.080\,\mathrm{W\,m^{-1}\,K^{-1}})(-10.0\,^\circ\mathrm{C})}{0.03\,\mathrm{m}} + \frac{(0.027\,\mathrm{W\,m^{-1}\,K^{-1}})(19.0\,^\circ\mathrm{C})}{0.022\,\mathrm{m}}}{\frac{0.080\,\mathrm{W\,m^{-1}\,K^{-1}}}{0.03\,\mathrm{m}} + \frac{0.027\,\mathrm{W\,m^{-1}\,K^{-1}}}{0.022\,\mathrm{m}}} \\
T &= -0.860\,^\circ\mathrm{C}
\end{aligned}$$

(b)

$$\begin{aligned}
\frac{H}{A} &= k_s \left(\frac{T_{in} - T}{l_{in}}\right) \\
\frac{H}{A} &= (0.027\,\mathrm{W\,m^{-1}\,K^{-1}}) \left(\frac{19.0\,^\circ\mathrm{C} - (-0.860\,^\circ\mathrm{C})}{0.022\,\mathrm{m}}\right) \\
\frac{H}{A} &= 24.4\,\mathrm{W\,m^{-2}}
\end{aligned}$$

6.3 17.60

$$
\begin{aligned}
l_{copper} &= 1.00\,\mathrm{m} \\
l_{steel} &= ? \\
A &= 4.00\,\mathrm{cm}^2 = 4.0 \times 10^{-4}\,\mathrm{m}^2 \\
T_{steel,copper} &= 65.0\,^\circ\mathrm{C}
\end{aligned}
$$

(a)

$$
\begin{aligned}
\frac{Q}{t} &= \frac{k_c A(T_{boil} - T_{s,c})}{l_c} \\
\frac{Q}{t} &= \frac{(385\,\mathrm{W\,m^{-1}\,K^{-1}})(4.0 \times 10^{-4}\,\mathrm{m}^2)(100.0\,^\circ\mathrm{C} - 65.0\,^\circ\mathrm{C})}{1.00\,\mathrm{m}} \\
\frac{Q}{t} &= 5.39\,\mathrm{J\,s^{-1}}
\end{aligned}
$$

$$
\begin{aligned}
l_{steel} &= \frac{k_s A(T_{s,c} - T_{ice})}{\left(\frac{Q}{t}\right)^{-1}} \\
l_{steel} &= \frac{(50.2\,\mathrm{W\,m^{-1}\,K^{-1}})(4.0 \times 10^{-4}\,\mathrm{m}^2)(65.0\,^\circ\mathrm{C} - 0.00\,^\circ\mathrm{C})}{(5.39\,\mathrm{J\,s^{-1}})^{-1}} \\
l_{steel} &= 0.242\,\mathrm{m}
\end{aligned}
$$

7 Convection of Heat

Stefan-Boltzmann law:

$$H = Ae\sigma T^4 \tag{15}$$

Stefan-Boltzmann constant:

$$\sigma = 5.670\,374\,42 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}} \tag{16}$$

7.1 17.64

(a)

$$
\begin{aligned}
\frac{H}{A} &= e\sigma T^4 \\
\frac{H}{A} &= (1)(5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}})(273\,\mathrm{K})^4 \\
\frac{H}{A} &= 314.944\,\mathrm{W\,m^{-2}}
\end{aligned}
$$

(b)

$$\begin{aligned}
\frac{H}{A} &= e\sigma T^4 \\
\frac{H}{A} &= (1)(5.67\times10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}})(2730\,\mathrm{K})^4 \\
\frac{H}{A} &= 3.15\times10^{6}\,\mathrm{W\,m^{-2}}
\end{aligned}$$

7.2 17.65

$$\begin{aligned}
T_{light_bulb} &= 2450\,\mathrm{K} \\
e &= 0.350 \\
A &=? \\
H &= 150\,\mathrm{W}
\end{aligned}$$

$$\begin{aligned}
H &= Ae\sigma T^4 \\
A &= \frac{H}{e\sigma T^4} \\
A &= \frac{150\,\mathrm{W}}{(0.350)(5.6\times10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}})(2450\,\mathrm{K})^4} \\
A &= 1.96\,\mathrm{m}^2
\end{aligned}$$

7.3 17.67

$$\begin{aligned}
e &= 1 \\
r &=?
\end{aligned}$$

(a)

$$\begin{aligned}
H &= 2.7\times10^{32}\,\mathrm{W} \\
T &= 11\,000\,\mathrm{K}
\end{aligned}$$

$$\begin{aligned}
H &= Ae\sigma T^4 \\
H &= 4\pi r^2 e\sigma T^4 \\
r &= \sqrt{\frac{H}{4\pi e\sigma T^4}} \\
r &= \sqrt{\frac{2.7\times10^{32}\,\mathrm{W}}{4\pi(1)(5.6\times10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}})(11\,000\,\mathrm{K})^4}} \\
r &= 1.62\times10^{11}\,\mathrm{m}
\end{aligned}$$

(b)

$$H = 2.1 \times 10^{23}\,\mathrm{W}$$
$$T = 10\,000\,\mathrm{K}$$

$$r = \sqrt{\frac{H}{4\pi e\sigma T^4}}$$
$$r = \sqrt{\frac{2.1 \times 10^{23}\,\mathrm{W}}{4\pi(1)(5.6 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}})(10\,000\,\mathrm{K})}}$$
$$r = 5.46 \times 10^{12}\,\mathrm{m}$$