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)

$$T_{F_0} = -4.0^\circ$$
$$T_{F_1} = 45.0^\circ$$

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

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

1.2 17.5

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

(a)

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

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

$$T_F = T_{F_1} - T_{F_0}$$
$$T_F = 18.0^\circ$$

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

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

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

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)

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

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

3 Thermal Expansion of Water

3.1 Thermal Stress

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

3.2 17.22

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

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

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

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:

$$dQ = mcdT$$

$$c = \frac{1}{m}\frac{dQ}{dT} \tag{9}$$

4.1 17.29

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

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

4.2 17.25

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

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

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

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

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

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

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