University Physics with Modern Physics - Modern Physics by Young and Freedman Problems

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Contents

17 Temperature and Heat

17.1 Guided Practice

17.1.1

(a)

$$\begin{aligned}\Delta L &= \alpha L_0 \Delta T \\ \alpha &= \frac{\Delta L}{L_0 \Delta T} \\ &= 2.0 \times 10^{-5}\,\mathrm{K}^{-1}\end{aligned}$$

(b)

$$\begin{aligned}\Delta L &= \alpha L_0 \Delta T \\ &= -0.27\,\mathrm{mm}\end{aligned}$$

17.1.2

$$
\begin{aligned}
\Delta V_C &= \beta V_{C0} \Delta T \\
&= (5.1 \times 10^{-5})(250)(-70) \\
&= -0.893\,\mathrm{cm}^3 \\
\Delta V_E &= \beta V_{E0} \Delta T \\
&= (75 \times 10^{-5}\ )(250)(-70) \\
&= -13.1\,\mathrm{cm}^3 \\
\Delta V_C - \Delta V_E &= 12.2\,\mathrm{cm}^3 \\
&= 12.2\,\mathrm{mL}
\end{aligned}
$$

17.1.3

$$
\begin{aligned}
\frac{\Delta L}{L_0} &= \alpha \Delta T \\
Y &= \frac{F/A}{\Delta L/L_0} \\
\frac{\Delta L}{L_0} &= \frac{F}{AY} \\
\alpha \Delta T + \frac{F}{AY} &= 0 \\
\frac{F}{AY} &= -\alpha \Delta T \\
F &= -\alpha A Y \Delta T \\
&= -(2.0 \times 10^{-5})(\pi 0.005^2)(9.0 \times 10^{10})(-12) \\
&= 1.70 \times 10^3\,\mathrm{N}
\end{aligned}
$$

Tensile

17.1.4

$$
\begin{aligned}
\Delta L &= \alpha_A L_A \Delta T + \alpha_B L_B \Delta T \\
\frac{\Delta L}{\Delta T} &= \alpha_A L_A + \alpha_B (L - L_A) \\
&= (\alpha_A - \alpha_B) L_A + \alpha_B L \\
L_A &= \frac{1}{\alpha_A - \alpha_B} \left(\frac{\Delta L}{\Delta T} - \alpha_B L \right)
\end{aligned}
$$

17.1.5

$$\begin{aligned} 0 &= m_{Al}c_{Al}\Delta T_{Al} + m_W c_W \Delta T_W \\ &= m_{Al}c_{Al}(T - T_{Al}) + m_W c_W (T - T_W) \\ m_{Al} &= -\frac{m_W c_W (T - T_W)}{c_{Al}(T - T_{Al})} \\ &= 0.20\,\mathrm{kg} \end{aligned}$$

17.1.6

$$\begin{aligned} 0 &= m_I L_f + m_C c_C \Delta T \\ &= m_I L_f - m_C c_C T \\ T &= \frac{m_I L_f}{m_C c_C} \\ &= 14.0\,^{\circ}\mathrm{C} \end{aligned}$$

17.1.7

$$\begin{aligned} 0 &= m_I L_F + m_I c_I \Delta T_I + m_E c_E \Delta T_E \\ &= m_I (L_F + c_I \Delta T_I) + m_E c_E \Delta T_E \\ m_I &= -\frac{m_E c_E \Delta T_E}{L_F + c_I \Delta T_I} \\ &= 0.176\,\mathrm{kg} \end{aligned}$$

17.1.8

Cooling the silver to $0\,^{\circ}\mathrm{C}$ would take

$$Q = mc\Delta T = 92\,137.5\,\mathrm{J}$$

whereas melting all of the ice would take

$$Q = mL_f = 83\,500\,\mathrm{J}$$

so all of the ice will melt.

$$\begin{aligned} 0 &= m_{Ag}c_{Ag}\Delta T_{Ag} + m_I L_f + m_I c_I \Delta T_I + m_I c_W \Delta T_W \\ &= m_{Ag}c_{Ag}(T - T_{Ag}) + m_I L_F - m_I c_I T_I + m_I c_W T \\ &= (m_{Ag}c_{Ag} + m_I c_W)T - m_{Ag}c_{Ag}T_{Ag} + m_I L_F - m_I c_I T_I \\ T &= \frac{m_{Ag}c_{Ag}T_{Ag} + m_I c_I T_I - m_I L_F}{m_{Ag}c_{Ag} + m_I c_W} \\ &= 3.31\,^{\circ}\mathrm{C} \end{aligned}$$

17.1.9

(a)

$$
\begin{aligned}
H &= kA\frac{T_H - T_C}{L} \\
k &= \frac{HL}{A(T_H - T_C)} \\
&= 0.754\,\mathrm{W/(m\,K)}
\end{aligned}
$$

(b)

$$
H = kA\frac{T_H - T_C}{L} = 733\,\mathrm{W}
$$

17.1.10

(a)

$$
\begin{aligned}
L &= 0.250\,\mathrm{m} \\
A &= 2.00 \times 10^{-4}\,\mathrm{m}^2 \\
k_B &= 109.0\,\mathrm{W/(m\,K)} \\
k_{Pb} &= 34.7\,\mathrm{W/(m\,K)} \\
T &= 185\,^\circ\mathrm{C} \\
H &= 6.00\,\mathrm{W}
\end{aligned}
$$

$$
\begin{aligned}
H &= k_B A\frac{T_H - T}{L} \\
T_H &= \frac{HL}{k_B A} + T \\
&= 254\,^\circ\mathrm{C}
\end{aligned}
$$

(b)

$$
\begin{aligned}
H &= k_{Pb} A\frac{T - T_C}{L} \\
T_C &= T - \frac{HL}{k_{Pb} A} \\
&= -31.1\,^\circ\mathrm{C}
\end{aligned}
$$

17.1.11

$$
\begin{aligned}
H &= 4\pi(kr_E)^2 e\sigma T^4 \\
(kr_E)^2 &= \frac{H}{4\pi e\sigma T^4} \\
k &= \frac{1}{r_E}\sqrt{\frac{H}{4\pi e\sigma T^4}} \\
&= 1.70
\end{aligned}
$$

17.1.12

(a)

$$
\begin{aligned}
H &= Ae\sigma T^4 \\
&= \pi r^2 \sigma T^4 \\
H &= kA\frac{T_H - T_C}{L} \\
&= k\pi r^2 \frac{T_H - T_C}{L} \\
\pi r^2 \sigma T^4 &= k\pi r^2 \frac{T_H - T_C}{L} \\
T_H &= \frac{L\sigma T^4}{k} + T_C \\
&= 14.26\,\mathrm{K}
\end{aligned}
$$

(b)

$$
\begin{aligned}
H &= mL_f \\
\pi r^2 \sigma T^4 &= mL_f \\
m &= \frac{\pi r^2 \sigma T^4}{L_f} \\
&= 1.19 \times 10^{-4}\,\mathrm{kg/s} \\
&= 0.427\,\mathrm{kg/h}
\end{aligned}
$$