P19.31 $P=\frac{nRT}{V}=\left(\frac{9.00\text{ g}}{18.0\text{ g/mol}}\right)\left(\frac{8.314\text{ J}}{\text{mol K}}\right)\left(\frac{773\text{ K}}{2.00\times10^{-3}\text{ m}^3}\right)=\boxed{1.61\text{ MPa}}=15.9\text{ atm}$

P19.38 At depth, $P=P_0+\rho gh$ and $PV_i=nRT_i$

At the surface, $P_0V_f=nRT_f$: $\frac{P_0V_f}{(P_0+\rho gh)V_i}=\frac{T_f}{T_i}$

Therefore $V_f=V_i\left(\frac{T_f}{T_i}\right)\left(\frac{P_0+\rho gh}{P_0}\right)$

$$V_f=1.00\text{ cm}^3\left(\frac{293\text{ K}}{278\text{ K}}\right)\left(\frac{1.013\times10^5\text{ Pa}+(1\,025\text{ kg/m}^3)(9.80\text{ m/s}^2)(25.0\text{ m})}{1.013\times10^5\text{ Pa}}\right)$$

$V_f=\boxed{3.67\text{ cm}^3}$

P19.44 (a) Initially the air in the bell satisfies $P_0V_{\text{bell}}=nRT_i$

or $P_0[(2.50\text{ m})A]=nRT_i$ (1)

When the bell is lowered, the air in the bell satisfies

$P_{\text{bell}}(2.50\text{ m}-x)A=nRT_f$ (2)

where x is the height the water rises in the bell. Also, the pressure in the bell, once it is lowered, is equal to the sea water pressure at the depth of the water level in the bell.

$P_{\text{bell}}=P_0+\rho g(82.3\text{ m}-x)\approx P_0+\rho g(82.3\text{ m})$ (3)

The approximation is good, as $x<2.50\text{ m}$. Substituting (3) into (2) and substituting nR from (1) into (2),

$$[P_0+\rho g(82.3\text{ m})](2.50\text{ m}-x)A=P_0V_{\text{bell}}\frac{T_f}{T_i}.$$

Using $P_0=1\text{ atm}=1.013\times10^5\text{ Pa}$ and $\rho=1.025\times10^3\text{ kg/m}^3$

Continued on next page

$$x=(2.50\text{ m})\left[1-\frac{T_f}{T_0}\left(1+\frac{\rho g(82.3\text{ m})}{P_0}\right)^{-1}\right]$$

$$=(2.50\text{ m})\left[1-\frac{277.15\text{ K}}{293.15\text{ K}}\left(1+\frac{(1.025\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(82.3\text{ m})}{1.013\times10^5\text{ N/m}^2}\right)^{-1}\right]$$

$x=\boxed{2.24\text{ m}}$

(b) If the water in the bell is to be expelled, the air pressure in the bell must be raised to the water pressure at the bottom of the bell. That is,

$$P_{\text{bell}}=P_0+\rho g(82.3\text{ m})$$
$$=1.013\times10^5\text{ Pa}+(1.025\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(82.3\text{ m})$$
$$P_{\text{bell}}=9.28\times10^5\text{ Pa}=\boxed{9.16\text{ atm}}$$

P19.50 (a) $\frac{P_0 V}{T} = \frac{P'V'}{T'}$

$V' = V + Ah$

$P' = P_0 + \frac{kh}{A}$

$\left(P_0 + \frac{kh}{A}\right)(V + Ah) = P_0 V\left(\frac{T'}{T}\right)$

$$\left(1.013\times 10^5\ \text{N/m}^2 + 2.00\times 10^5\ \text{N/m}^3\, h\right)\left(5.00\times 10^{-3}\ \text{m}^3 + \left(0.010\,0\ \text{m}^2\right)h\right) = \left(1.013\times 10^5\ \text{N/m}^2\right)\left(5.00\times 10^{-3}\ \text{m}^3\right)\left(\frac{523\ \text{K}}{293\ \text{K}}\right)$$

$2\,000h^2 + 2\,013h - 397 = 0$

$h = \frac{-2\,013 \pm 2\,689}{4\,000} = \boxed{0.169\ \text{m}}$

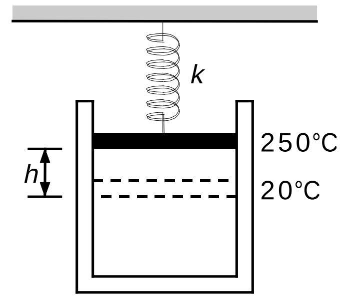

FIG. P19.50

(b) $P' = P + \frac{kh}{A} = 1.013\times 10^5\ \text{Pa} + \frac{\left(2.00\times 10^3\ \text{N/m}\right)(0.169)}{0.010\,0\ \text{m}^2}$

$P' = \boxed{1.35\times 10^5\ \text{Pa}}$

P19.61 After expansion, the length of one of the spans is

$$L_f = L_i(1 + \alpha\Delta T) = 125\ \text{m}\left[1 + 12\times 10^{-6}\ ^\circ\text{C}^{-1}(20.0^\circ\text{C})\right] = 125.03\ \text{m}.$$

L_f, y, and the original 125 m length of this span form a right triangle with y as the altitude. Using the Pythagorean theorem gives:

$$(125.03\ \text{m})^2 = y^2 + (125\ \text{m})^2$$

yielding $y = \boxed{2.74\ \text{m}}$.