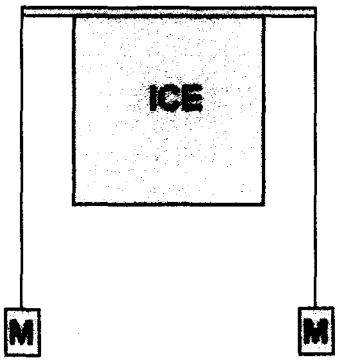
Additional Problem for Chapter 4

1. A rigid metal bar with a rectangular cross section lies on a block of ice. Suspended from each end of the bar with a wire is a weight of mass **M.** The atmospheric pressure is 1 atm, and the temperature of the ice is –3.0 °C. The width of the bar is 2.0 mm, and the length of the portion of the bar in contact with the ice is 20 cm. The enthalpy of fusion of water is 6008. J mol^{-1}. The densities of ice and liquid water at 0 °C, are 0.9168 g mL^{-1}, and 0.9999 g mL^{-1}, respectively. What is the minimum value of the mass **M** required to cause the bar to pass through the ice block? Neglect the mass of the bar and the wire. (hint: the pressure exerted by the bar on the surface of the ice is 2Mg/A, where A is the area of the bar in contact with the surface, and g is the acceleration of gravity, 9.807 m/s^2. *Answer: 830 kg.*



$$P - P^* = \frac{\Delta_{fus} H}{\Delta_{fus} V \, T^*} (T - T^*)$$

$P^* = 1.01325 \times 10^5$ Pa

$T = 270.15$ K

$T^* = 273.15$ K

$$\Delta_{fus} V = 18.02 \frac{g}{mol} \left[\frac{1}{0.9999 g mL^{-1}} - \frac{1}{0.9168 g mL^{-1}} \right] \times 10^{-6} m^3/mL$$

$$= -1.633 \times 10^{-6} m^3 mol^{-1}$$

$$P - P^* = \frac{6008 J mol^{-1} (270.15 - 273.15) K}{(273.15 K)(-1.633 \times 10^{-6} m^3 mol^{-1})} = 4.0408 \times 10^7 \text{ Pa}$$

$P - P^*$ is the pressure increase above 1 atm, that must be exerted on the ice to cause it to melt at –3.0°C.

$$\therefore \underline{M} = \frac{(P - P^*) A}{2g} = \frac{4.0408 \times 10^7 \text{ Pa}}{2 \times 9.807 m/s^2} \times 0.20 cm \times 20 cm \times 1 \times 10^{-4} \frac{m^2}{cm^2}$$

$$= 824.1 \text{ kg}$$