Chapter 17   Problem 44 [†]

Given

$A = 82,000 \; km^2 = 8.2 \times 10^{10} \; m^2$

$d = 1.3 \; m$

$\rho = 917 \; kg/m^3$

$L_f = 334 \; kJ/kg$

Solution

a) Find the amount of energy required to melt all the ice on Lake Superior.

The heat required for a phase change is

$$Q = mL_f = \rho V L_f = \rho d A L_f$$

Substitute in the given values we have

$$Q = (917 \; kg/m^3)(1.3 \; m)(8.2 \times 10^{10} \; m^2)(334 \; kJ/kg)$$

$$Q = 3.26 \times 10^{16} \; kJ = 3.26 \times 10^{19} \; J$$

b) Find the average power needed to melt the ice in 3 weeks.
First convert 3 weeks into seconds.

$$\Delta t = 3 \; weeks \left(\frac{7 \; days}{1 \; week} \right) \left(\frac{24 \; h}{1 \; day} \right) \left(\frac{3600 \; s}{1 \; h} \right) = 1.81 \times 10^6 \; s$$

Heat flow is just an indication of the energy that has gone into melting the ice. Power is the rate of change of energy.

$$P = \frac{\Delta Q}{\Delta t} = \frac{3.26 \times 10^{19} \; J}{1.81 \times 10^6 \; s} = 1.80 \times 10^{13} \; W$$

$$P = 18.0 \; TW$$

This may look like a large number, but if you calculate the power per square meter, you get $220 \; W/m^2$. This could be done by sunlight if the ice did not reflect too much of it. Also conduction from warm air over the ice will contribute to the melting too.