Chapter 17 Problem 45 †

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.

†Problem from Essential University Physics, Wolfson