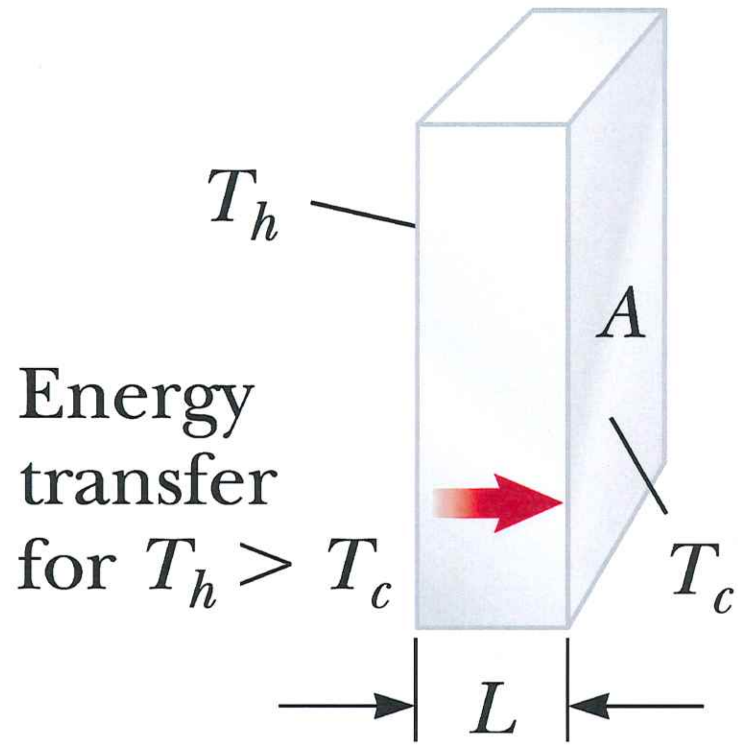
Lecture 38
(Ch. 11: 4-5)

Topic Summary

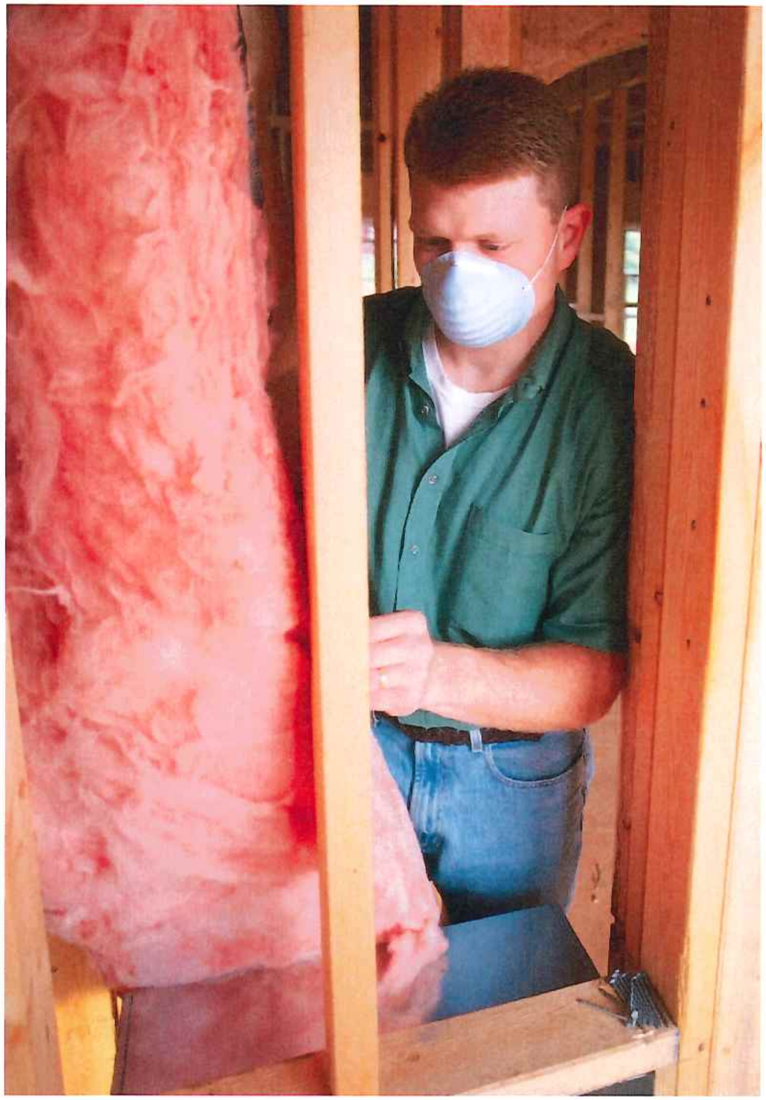
- **Energy Transfer**

$$P = kA\frac{(T_h - T_c)}{L}$$

$$P_{\text{net}} = \sigma A e\left(T^4 - T_0^{\,4}\right)$$



Home Insulation



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$$\frac{Q}{\Delta t} = \frac{A\left(T_h - T_c\right)}{\sum_i R_i}$$

Home Insulation

Table 11.4 *R*-Values for Some Common Building Materials

Material	*R* value[a] ($ft^2 \cdot °F \cdot h/Btu$)
Hardwood siding (1.0 in. thick)	0.91
Wood shingles (lapped)	0.87
Brick (4.0 in. thick)	4.00
Concrete block (filled cores)	1.93
Styrofoam (1.0 in. thick)	5.0
Fiberglass batting (3.5 in. thick)	10.90
Fiberglass batting (6.0 in. thick)	18.80
Fiberglass board (1.0 in. thick)	4.35
Cellulose fiber (1.0 in. thick)	3.70
Flat glass (0.125 in. thick)	0.89
Insulating glass (0.25-in. space)	1.54
Vertical air space (3.5 in. thick)	1.01
Stagnant layer of air	0.17
Drywall (0.50 in. thick)	0.45
Sheathing (0.50 in. thick)	1.32

[a]The values in this table can be converted to SI units by multiplying the values by 0.176 1.

 convert to SI units: multiply by 0.1761

50. A Styrofoam box has a surface area of $0.80\ m^2$ and a wall thickness of 2.0 cm. The temperature of the inner surface is $5.0°C$, and the outside temperature is $25°C$. If it takes 8.0 h for 5.0 kg of ice to melt in the container, determine the thermal conductivity of the Styrofoam.

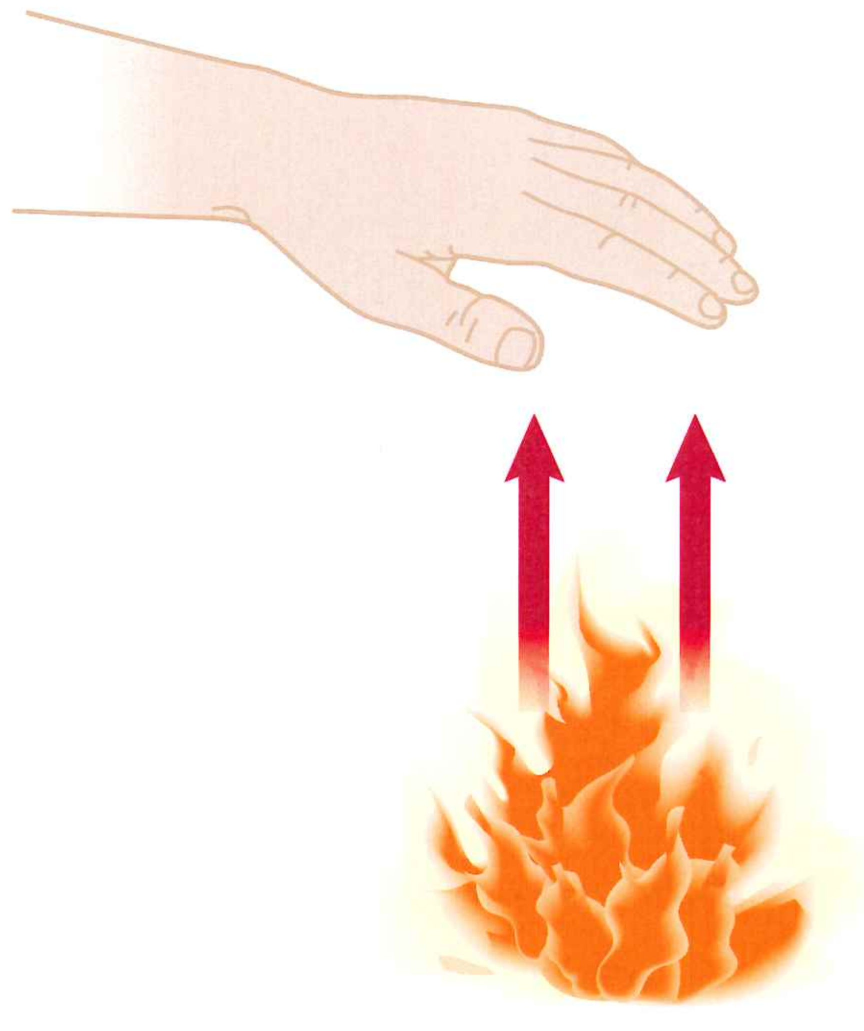
11.50 The energy transfer rate is

$$P = \frac{\Delta Q}{\Delta t} = \frac{m_{ice} L_f}{\Delta t} = \frac{(5.0\ \text{kg})(3.33\times10^5\ \text{J/kg})}{(8.0\ \text{h})(3\ 600\ \text{s/1 h})} = 58\ \text{W}$$

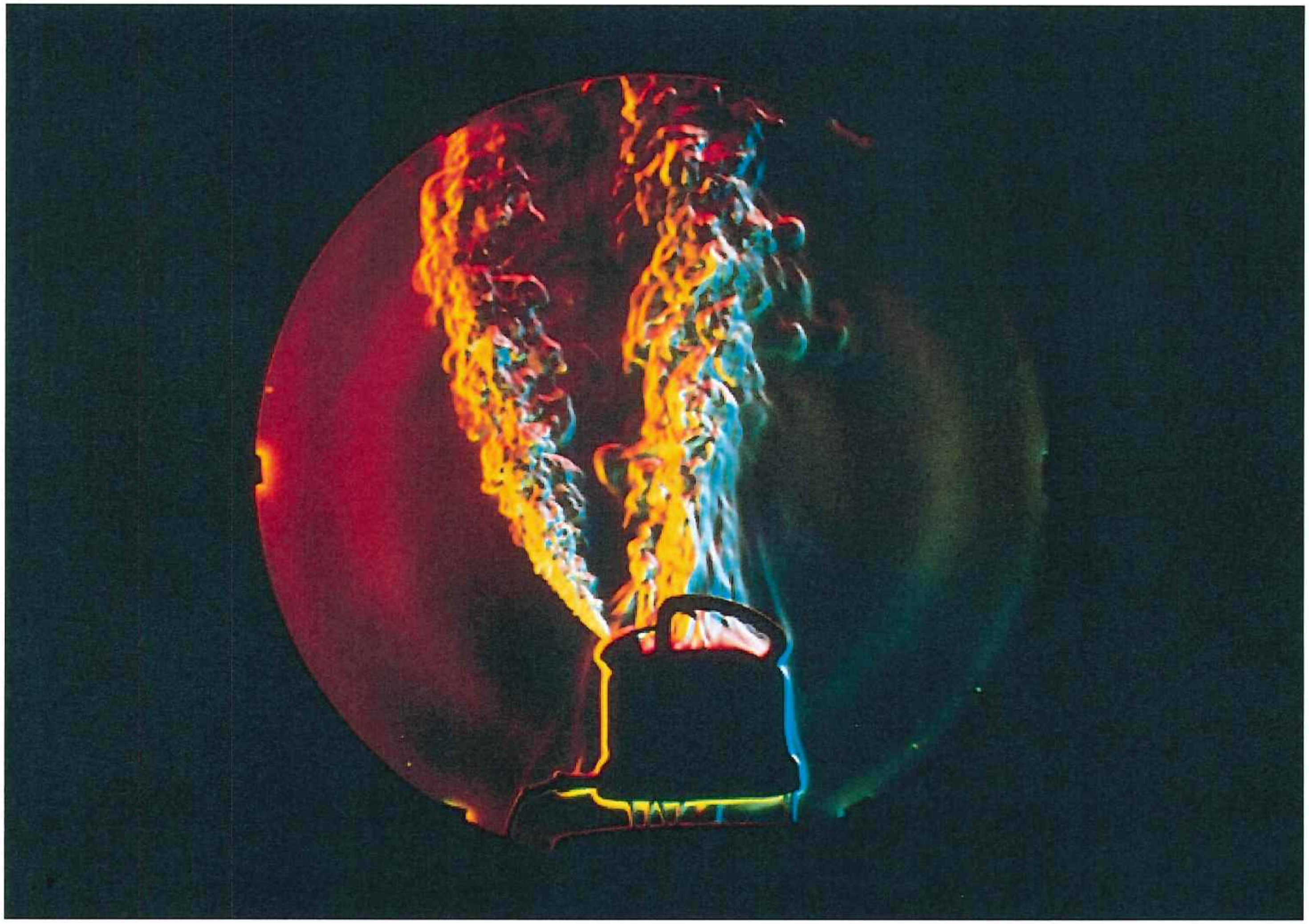
Thus, $P = \kappa A\left(\frac{\Delta T}{L}\right)$ gives the thermal conductivity as

$$\kappa = \frac{P\cdot L}{A(\Delta T)} = \frac{(58\ \text{W})(2.0\times10^{-2}\ \text{m})}{(0.80\ \text{m}^2)(25°\text{C}-5.0°\text{C})} = \boxed{7.3\times10^{-2}\ \text{W/m}\cdot°\text{C}}$$

Convection

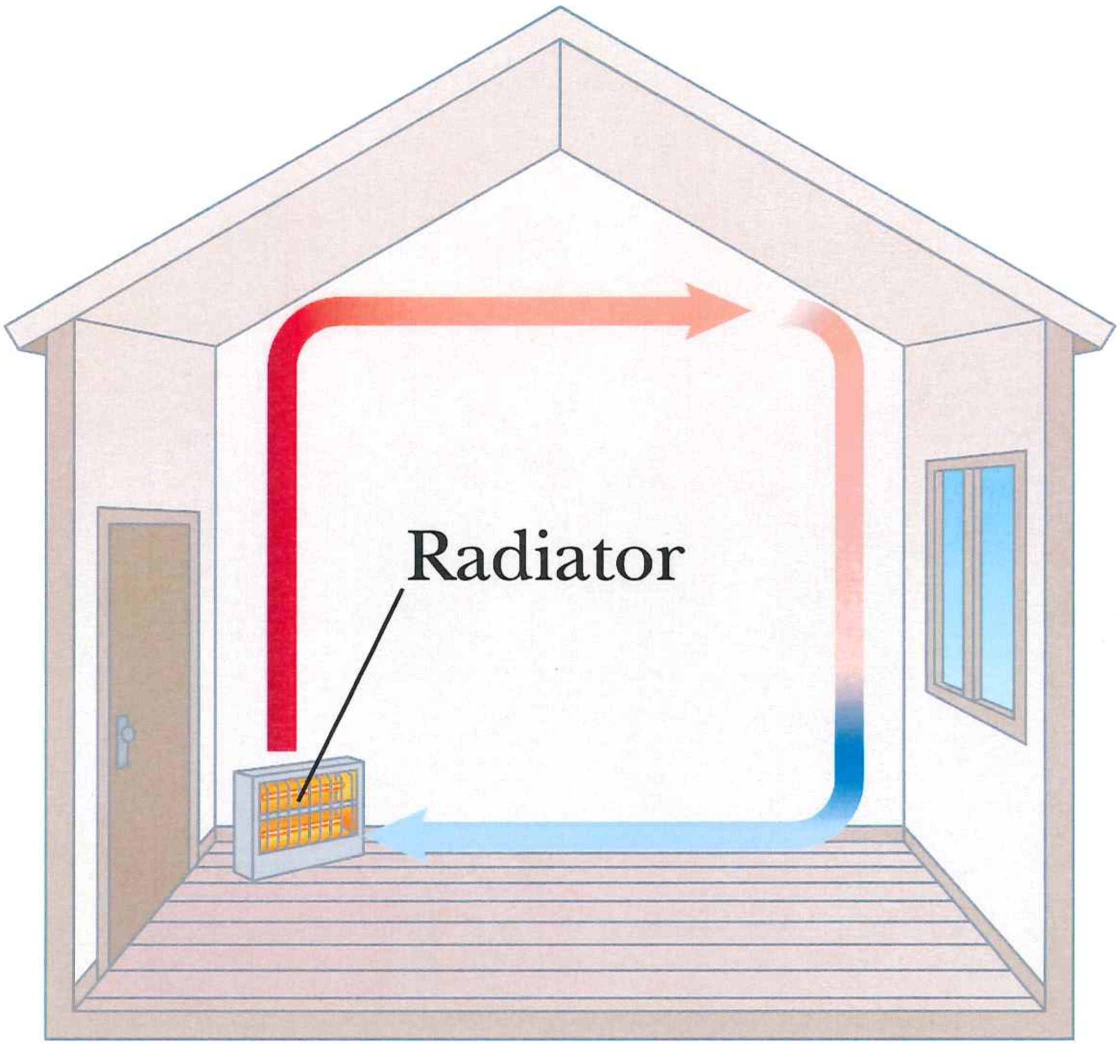


Convection

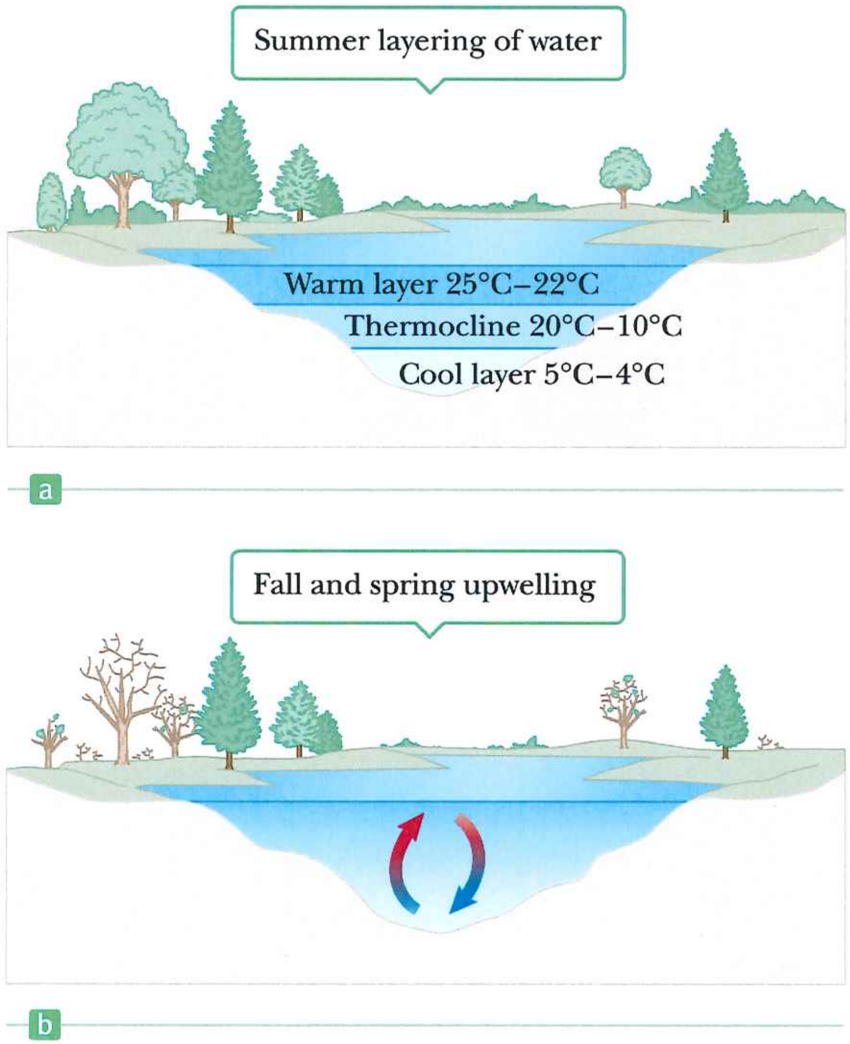


Gary S. Settles/Science Source

Convection



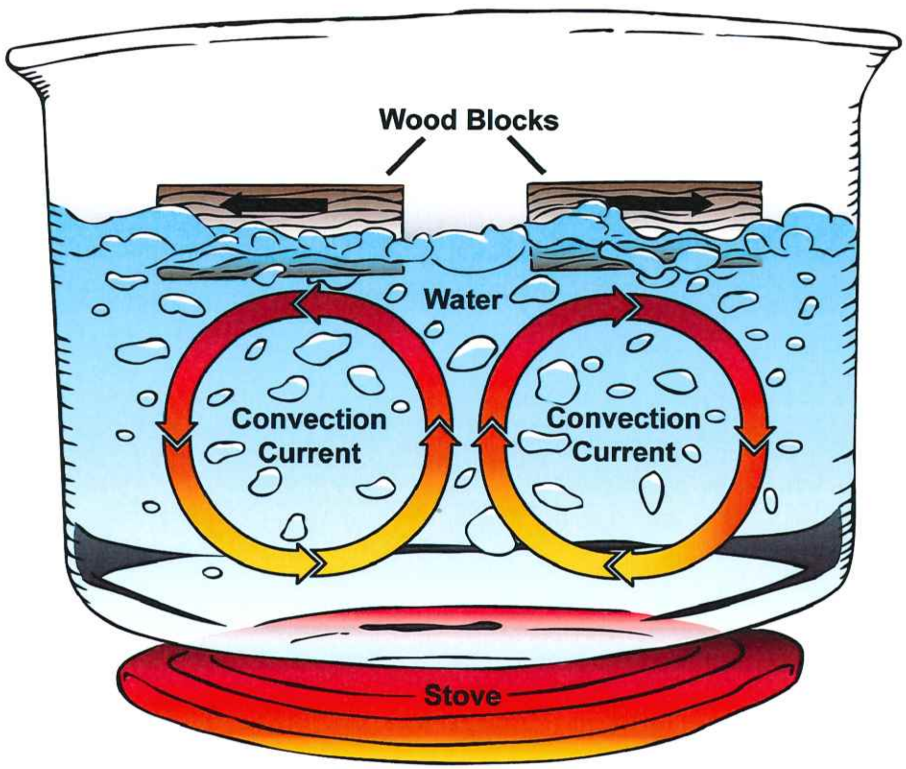
Convection

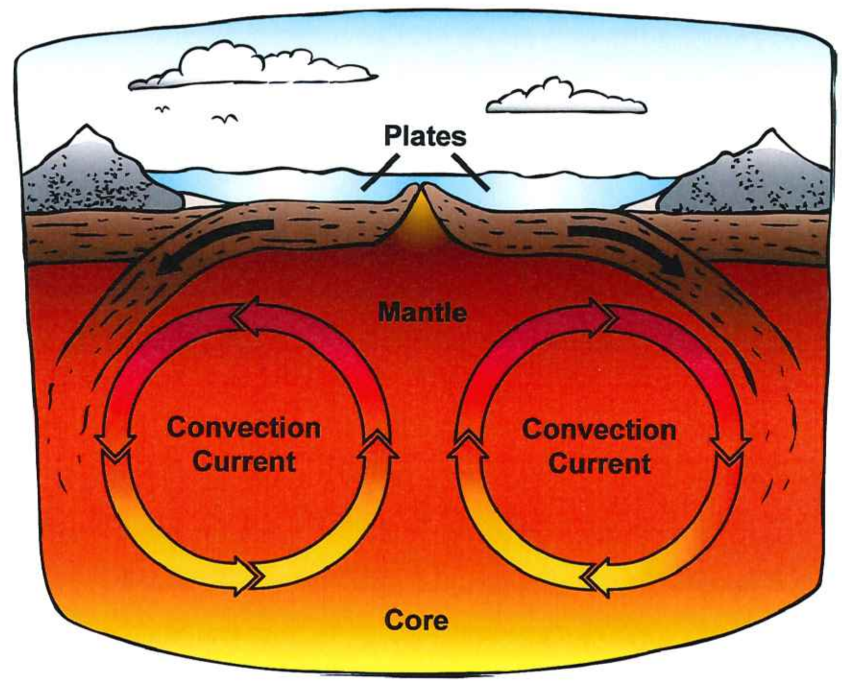

Summer layering of water
Warm layer 25°C–22°C
Thermocline 20°C–10°C
Cool layer 5°C–4°C
a
Fall and spring upwelling
b

Chapter 11: Heat – Convection

Convection

Convection is heat transfer through the bulk motion of fluid (gas or liquid). The motion of the fluids is called ***convection currents*** (or ***thermals***).



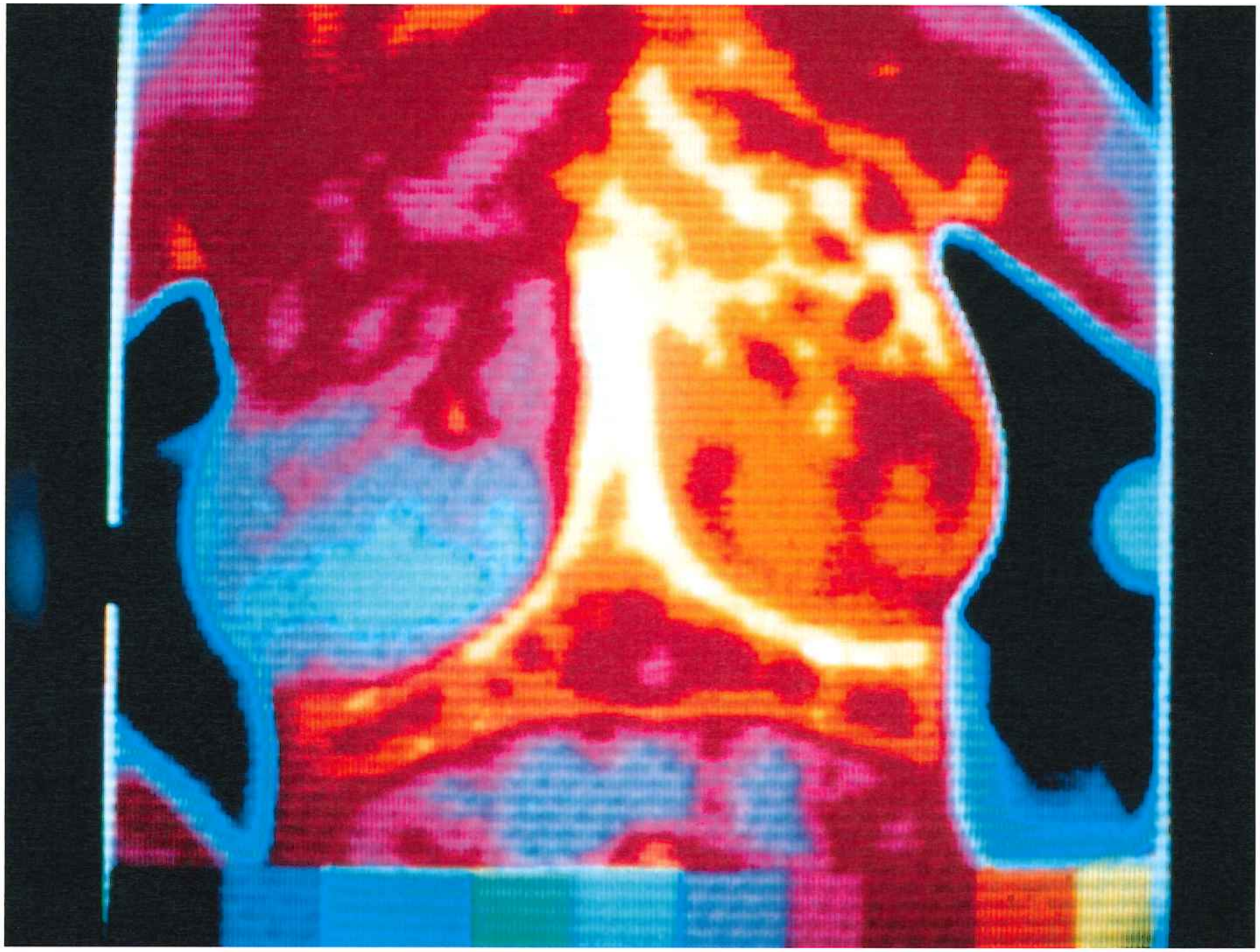


Radiation

Radiation


Blue and purple indicate areas of least energy loss.
White and yellow indicate areas of greatest energy loss.
Science Source

Radiation



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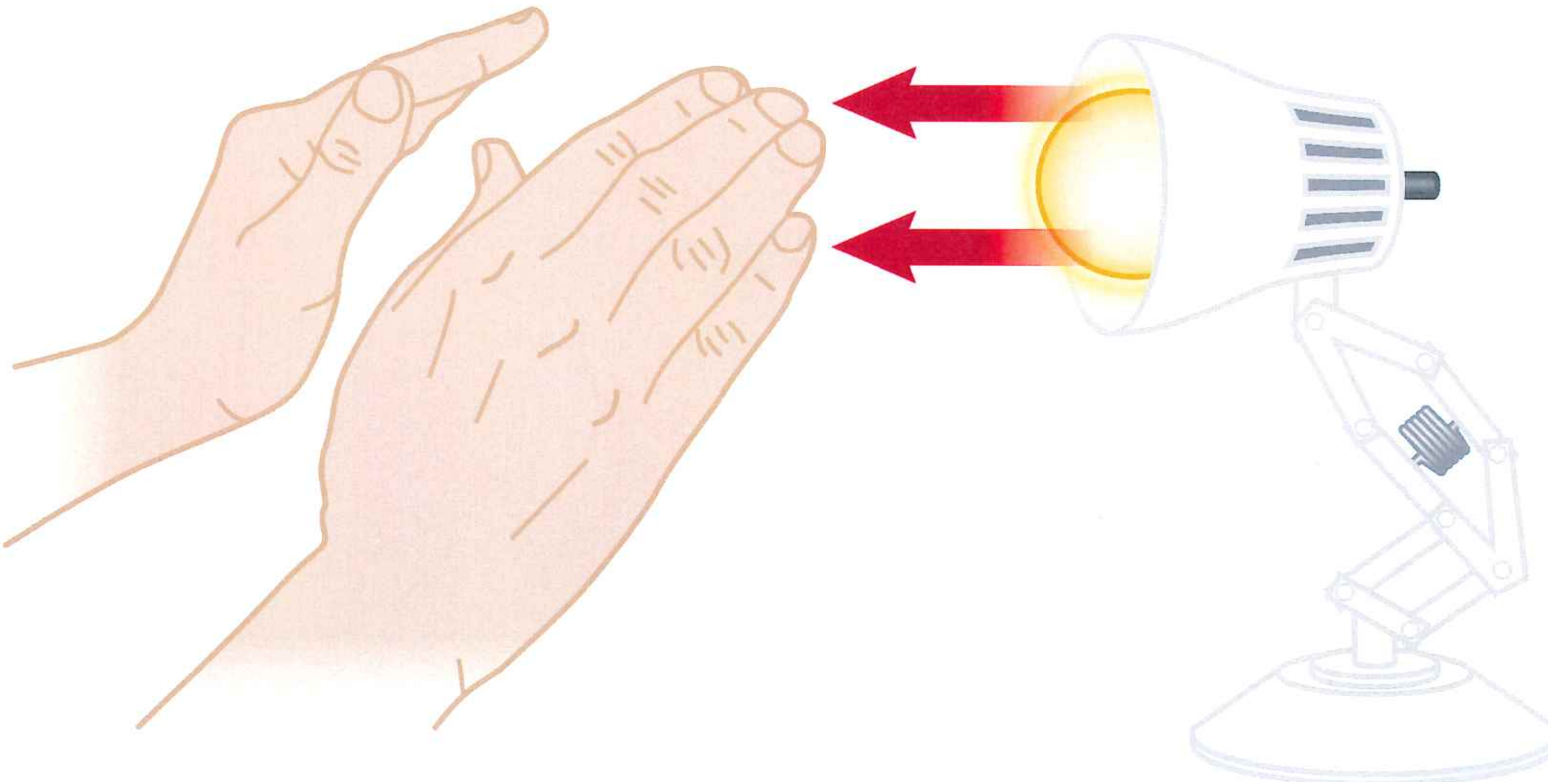
Radiation



$$P = \sigma A e T^4 \quad \text{(Stefan's Law)}$$

$$\sigma = 5.669 \times 10^{-8}\ \text{W/m}^2 \cdot \text{K}^4$$

Chapter 11: Heat – Radiation

Radiation

Radiation is heat transfer through electromagnetic waves. Electromagnetic waves are photons, that despite having no rest mass, they have relativistic momentum, thus transport energy.

$$P = e \cdot \sigma A T^4$$, Stefan-Boltzman law; in SI: W

$$\sigma = 5.67 \times 10^{-8} \, W/(m^2 \cdot K)$$, Stefan-Boltzman constant

0 < e < 1 is the ***emissivity*** and shows how reflective the surface is.

Radiation

$$P_{\text{net}} = \sigma A e\left(T^4 - T_0^{\,4}\right)$$

A sphere of surface area 2 m^2 and emissivity of 0.5 is at temperature of 300 °C. What is the rate at which the sphere radiates heat into empty space ?

The rate, P, at which an object at temperature T radiates energy is:

$P = e. \sigma. A. T^4$, where $\sigma = 5.67 \times 10^{-8}$ W/(m^2.K^2)

In our case e =0.5, A= 2 m^2 and T = 300 + 273.15 = 573.15 K

Therefore,

$P = (0.5). (5.67 \times 10^{-8}).(2). (573.15)^4 = 6118$ W

52. A granite ball of radius 2.00 m and emissivity 0.450 is heated to 135°C.

a. Convert the given temperature to Kelvin.

b. What is the surface area of the ball?

c. If the ambient temperature is 25.0°C, what net power does the ball radiate?

11.52 **(a)** Use the conversion $T = T_C + 273.15$ to find $T = 135 + 273.15 = \boxed{408\text{ K}}$

(b) The ball has the surface area of sphere: $A = 4\pi R^2 = 4\pi(2.00\text{ m})^2 =$

$\boxed{50.3\text{ m}^2}$

(c) With $T_0 = 25.0°\text{C} = 298\text{ K}$, the net radiated power is

$$\begin{aligned} P_{net} &= \sigma A e\left(T^4 - T_0^4\right) \\ &= \left(5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4\right)\left(50.3\text{ m}^2\right)(0.450)\left((408\text{ K})^4 - (298\text{ K})^4\right) \\ &= \boxed{2.54\times10^4\text{ W}} \end{aligned}$$

54. The filament of a 75-W light bulb is at a temperature of 3 300 K. Assuming the filament has an emissivity $e = 1.0$, find its surface area.

11.54 From Stefan's law, the power radiated by an object at absolute temperature T and surface area A is $P = \sigma A e T^4$, where $\sigma = 5.669\,6 \times 10^{-8}$ W/m$^2 \cdot$ K and e is the emissivity. Thus, the surface area of the filament must be

$$A = \frac{P}{\sigma e T^4} = \frac{75\text{ W}}{\left(5.669\,6\times 10^{-8}\text{ W/m}^2\cdot\text{K}^4\right)(1.0)\left(3\,300\text{ K}\right)^4} = \boxed{1.1\times 10^{-5}\text{ m}^2}$$

67. Earth's surface absorbs an average of about 960. W/m^2 from the Sun's irradiance. The power absorbed is $P_{\text{abs}} = (960.\ \text{W/m}^2)\ (A_{\text{disc}})$, where $A_{\text{disc}} = \pi R_E^2$ is Earth's projected area. An equal amount of power is radiated so that Earth remains in thermal equilibrium with its environment at nearly 0 K. Estimate Earth's surface temperature by setting the radiated power from Stefan's law equal to the absorbed power and solving for the temperature in Kelvin. In Stefan's law, assume $e = 1$ and take the area to be $A = 4\pi R_E^2$, the surface area of a spherical Earth. (*Note*: Earth's atmosphere acts like a blanket and warms the planet to a global average about 30 K above the value calculated here.)

11.67 The power radiated by Earth is $P_{\text{radiated}} = \sigma A e T^4$. Equating this to the absorbed power P_{abs} and solving for the temperature (with $e = 1$) gives

$$\sigma A e T^4 = P_{\text{abs}} = \left(960\ \text{W/m}^2\right)\pi R_{\text{E}}^2$$

$$T^4 = \frac{\left(960\ \text{W/m}^2\right)\pi R_{\text{E}}^2}{\left(5.67\times10^{-8}\ \text{W/m}^2\cdot\text{K}^4\right)4\pi R_{\text{E}}^2(1)} = \frac{\left(960\ \text{W/m}^2\right)}{4\left(5.67\times10^{-8}\ \text{W/m}^2\cdot\text{K}^4\right)}$$

$$T = \boxed{255\ \text{K}}$$

71. The surface of the Sun has a temperature of about 5 800 K. The radius of the Sun is 6.96×10^8 m. Calculate the total energy radiated by the Sun each second. Assume the emissivity of the Sun is 0.986.

11.71 The total power radiated by the Sun is $P = \sigma A e T^4$ where $\sigma = 5.669\,6 \times 10^{-8}$ W/m$^2 \cdot$ K^4 the emissivity is $e = 0.986$, the surface area (a sphere) is $A = 4\pi r^2$ and the absolute temperature is $T = 5\,800$ K. Thus,

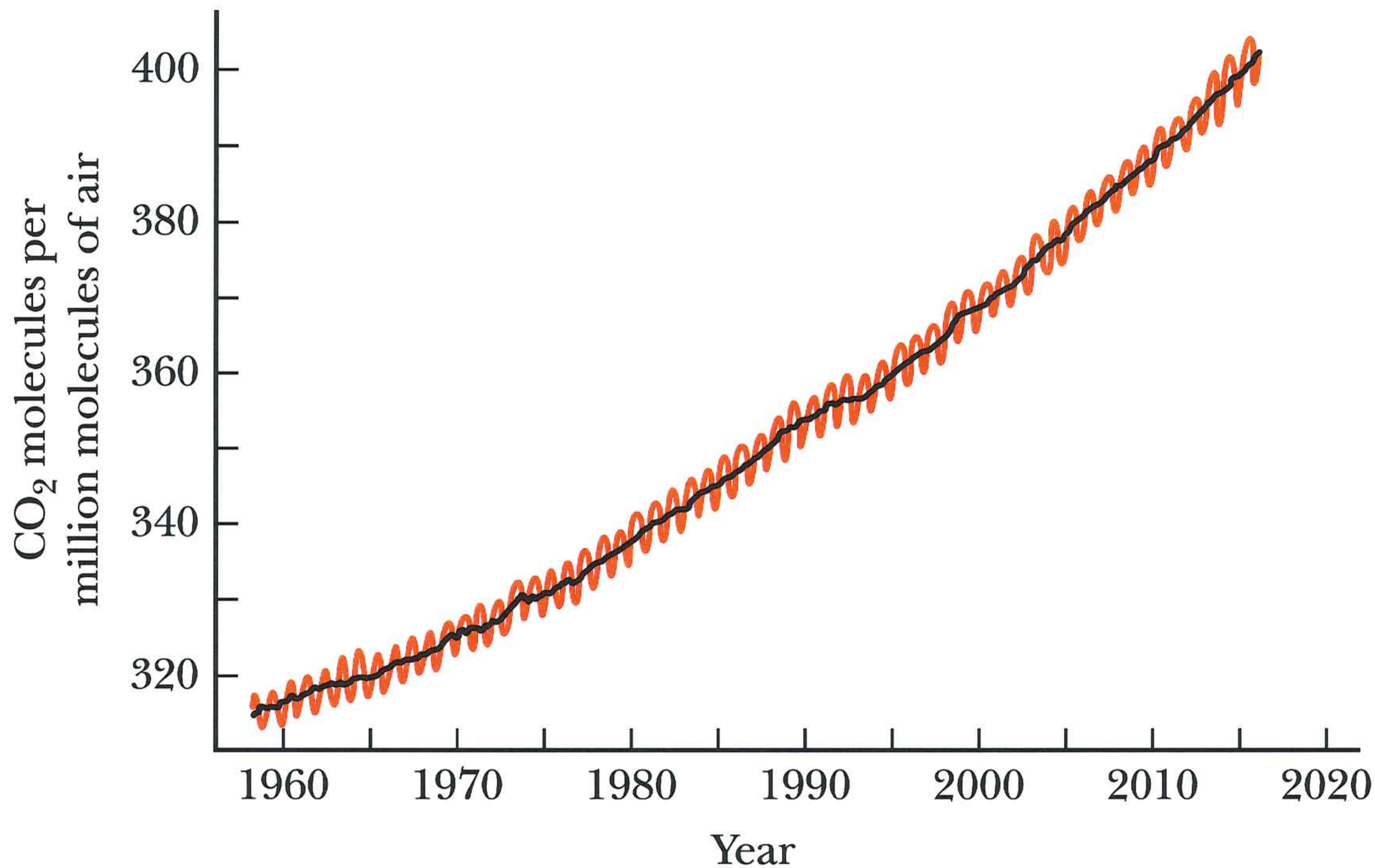
$$P = (5.669\,6 \times 10^{-8}\ \text{W/m}^2 \cdot \text{K}^4)4\pi(6.96 \times 10^8\ \text{m})^2(0.986)(5\,800\ \text{K})^4$$

or $P = 3.85 \times 10^{26}$ W Thus, the energy radiated each second is

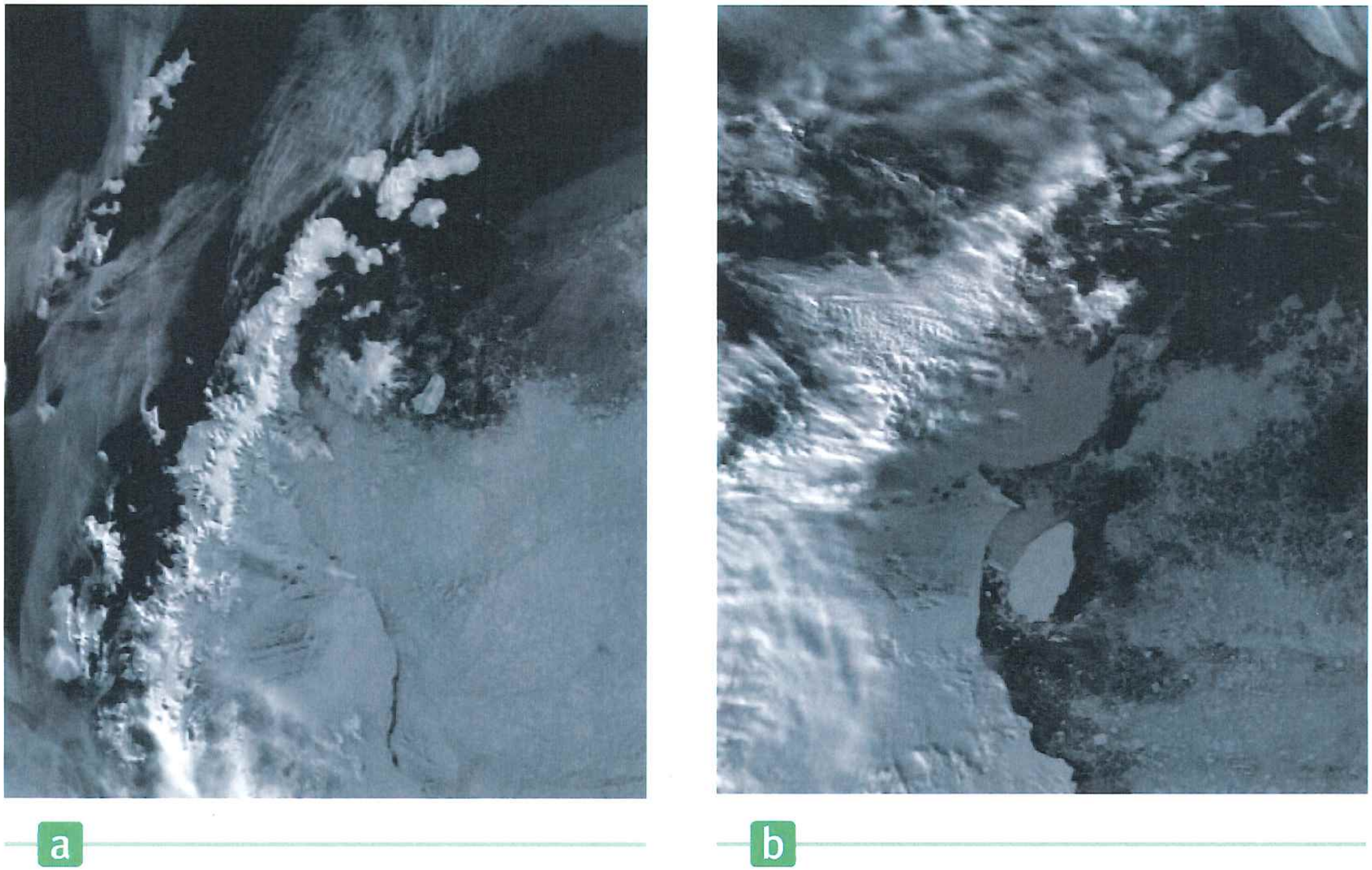
$$E = P \cdot \Delta t = (3.85 \times 10^{26}\ \text{J/s})(1.00\ \text{s}) = \boxed{3.85 \times 10^{26}\ \text{J}}$$

Climate Change and Greenhouse Gases

Climate Change and Greenhouse Gases



Climate Change and Greenhouse Gases



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