14-6 Heat Transfer: Conduction

Heat **conduction** can be visualized as occurring through molecular **collisions**.

The **heat flow** per unit time is given by:

$$\frac{Q}{t} = kA\frac{T_1 - T_2}{l} \qquad \text{(14-4)}$$

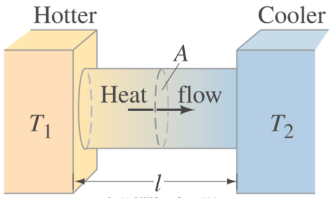


TABLE 14–4 Thermal Conductivities

Substance	Thermal Conductivity, k $\frac{\text{kcal}}{(\text{s}\cdot\text{m}\cdot\text{C}^\circ)}$	Thermal Conductivity, k $\frac{\text{J}}{(\text{s}\cdot\text{m}\cdot\text{C}^\circ)}$
Silver	10×10^{-2}	420
Copper	9.2×10^{-2}	380
Aluminum	5.0×10^{-2}	200
Steel	1.1×10^{-2}	40
Ice	5×10^{-4}	2
Glass	2.0×10^{-4}	0.84
Brick	2.0×10^{-4}	0.84
Concrete	2.0×10^{-4}	0.84
Water	1.4×10^{-4}	0.56
Human tissue	0.5×10^{-4}	0.2
Wood	0.3×10^{-4}	0.1
Fiberglass	0.12×10^{-4}	0.048
Cork	0.1×10^{-4}	0.042
Wool	0.1×10^{-4}	0.040
Goose down	0.06×10^{-4}	0.025
Polyurethane	0.06×10^{-4}	0.024
Air	0.055×10^{-4}	0.023

14-6 Heat Transfer: Conduction

The constant ***k*** is called the **thermal conductivity**.

Materials with large ***k*** are called **conductors**; those with small ***k*** are called **insulators**.

14-6 Heat Transfer: Conduction

Building materials are measured using ***R*****–values** rather than thermal conductivity:

$$R = \frac{l}{k}$$

Here, ***l*** is the thickness of the material.

TABLE 14–5 *R*-values

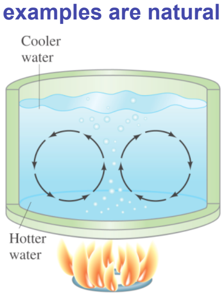
Material	Thickness	*R*-value ($\text{ft}^2\cdot\text{h}\cdot\text{F}^\circ/\text{Btu}$)
Glass	$\frac{1}{8}$ inch	1
Brick	$3\frac{1}{2}$ inches	0.6–1
Plywood	$\frac{1}{2}$ inch	0.6
Fiberglass insulation	4 inches	12

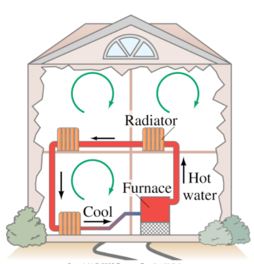
Ch 14: Problem 33

- One end of a 33-cm-long aluminum rod with a diameter of 2.0 cm is kept at 460^0C, and the other end is immersed in water at 22^0C. Calculate the heat conduction rate along the rod.

14-7 Heat Transfer: Convection

Convection occurs when heat flows by the mass **movement** of molecules from one place to another. It may be **natural** or **forced**; both these examples are natural convection.





14-7 Heat Transfer: Convection

Many home heating systems are **forced** hot-air systems; these have a **fan** that blows the air out of registers, rather than relying completely on natural convection.

Our **body** temperature is regulated by the **blood**; it runs close to the surface of the skin and transfers heat. Once it reaches the surface of the skin, the heat is released through **convection**, **evaporation**, and **radiation**.

Ch 14: Problem 37

- Two rooms, each a cube 4.0m per side, share a 12-c-thick brick wall. Because of a number of 100-W bulbs in one room, the air is at 30^{0}C, while in the other room it is at 10^{0}C. How many 100-W lightbulbs are needed to maintain the temperature difference across the wall?

14-8 Heat Transfer: Radiation

The most familiar example of **radiation** is our own **Sun**, which radiates at a temperature of almost **6000 K**.

14-8 Heat Transfer: Radiation

The **energy** radiated has been found to be proportional to the **fourth** power of the temperature:

$$\frac{\Delta Q}{\Delta t} = e\sigma A T^4 \qquad \textbf{(14-5)}$$

The constant σ is called the **Stefan-Boltzmann** constant:

$$\sigma = 5.67 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4}$$

The **emissivity** e is a number between zero and one characterizing the surface; black objects have an emissivity near one, while shiny ones have an emissivity near zero.

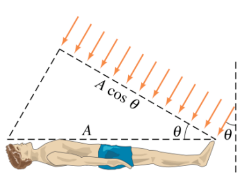
14-8 Heat Transfer: Radiation

If you are sitting in a place that is too **cold**, your body **radiates** more heat than it can produce. You will start **shivering** and your metabolic rate will **increase** unless you put on **warmer** clothing.

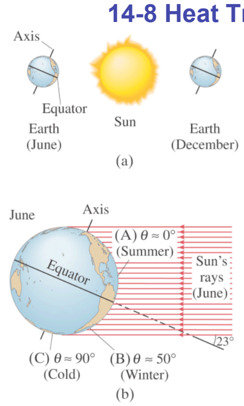
14-8 Heat Transfer: Radiation

If you are in the **sunlight**, the Sun's radiation will warm you. In general, you will not be perfectly perpendicular to the Sun's rays, and will absorb energy at the rate:

$$\frac{\Delta Q}{\Delta t} = (1000\ \mathrm{W/m^2})eA\cos\theta \qquad \textbf{(14-6)}$$



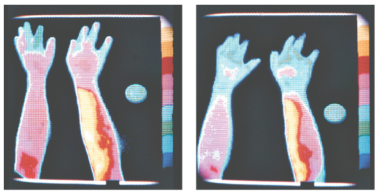
14-8 Heat Transfer: Radiation



This **cos θ** effect is also responsible for the **seasons**.

14-8 Heat Transfer: Radiation

Thermography – the detailed measurement of radiation from the body – can be used in medical imaging. Warmer areas may be a sign of **tumors** or **infection**; cooler areas on the skin may be a sign of **poor** circulation.



(a) (b)

Ch 14: Problem 40

- (a) Using the solar constant, estimate the rate at which the whole Earth receives energy from the Sun.
- (b) Assume the Earth radiates an equal amount back into space (that is, the Earth is in equilibrium). Then, assuming the Earth is a perfect emitter (e = 1.0), estimate its average surface temperature.