Some Thermal Conductivities

Substance	Thermal Conductivity (W/m · °C)
Metals (at 25°C)	
Aluminum	238
Copper	397
Gold	314
Iron	79.5
Lead	34.7
Silver	427

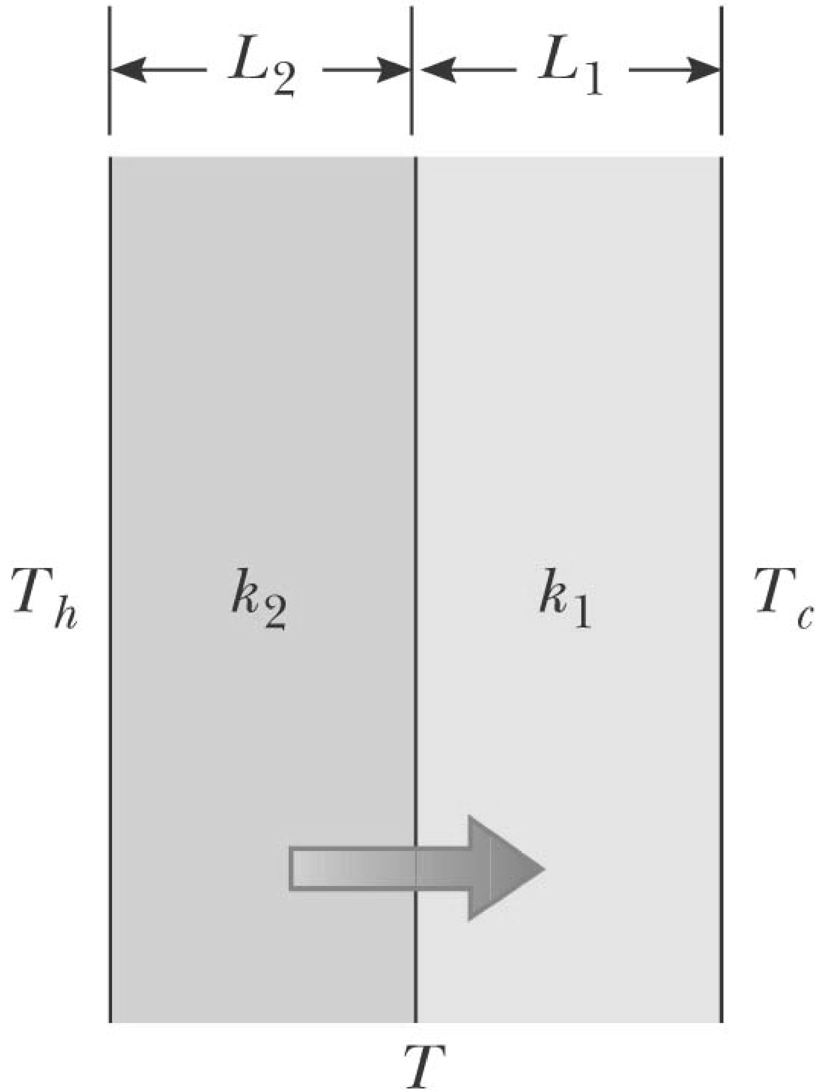
More Thermal Conductivities

Substance	Thermal Conductivity (W/m · °C)
Nonmetals (approximate values)	
Asbestos	0.08
Concrete	0.8
Diamond	2 300
Glass	0.8
Ice	2
Rubber	0.2
Water	0.6
Wood	0.08

More Thermal Conductivities

Substance	Thermal Conductivity (W/m · °C)
Gases (at 20°C)	
Air	0.023 4
Helium	0.138
Hydrogen	0.172
Nitrogen	0.023 4
Oxygen	0.023 8

Compound Slab



Compound Slab

- For a compound slab containing several materials of various thicknesses (L_1, L_2, …) and various thermal conductivities (k_1, k_2, …) the rate of energy transfer depends on the materials and the temperatures at the outer edges:

$$\wp = \frac{A\left(T_h - T_c\right)}{\sum_i \left(L_i / k_i\right)}$$

Home Insulation

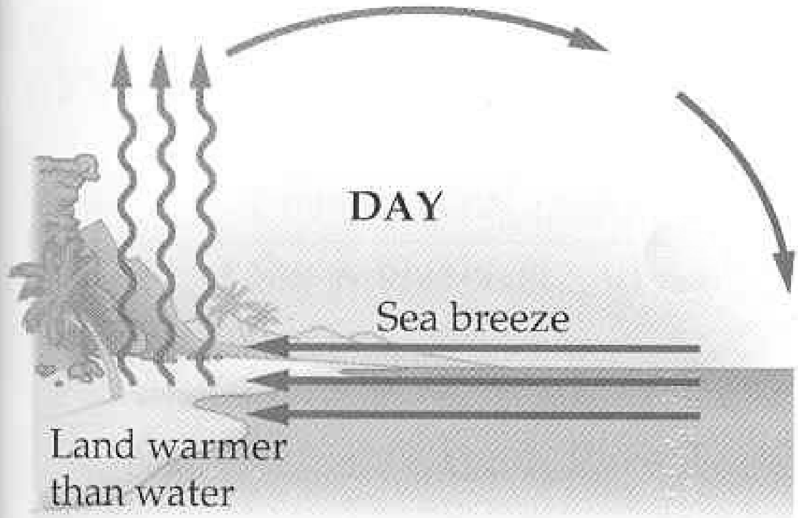
- Substances are rated by their *R values*
  - $R = L / k$ and the rate becomes

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

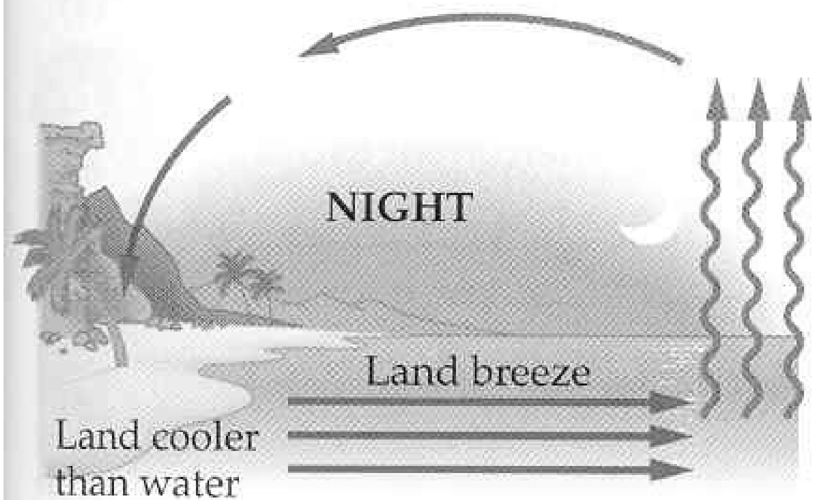
  - For multiple layers, the total *R* value is the sum of the *R* values of each layer
- Wind increases the energy loss by conduction in a home

Convection

- Energy transferred by the movement of a substance
  - When the movement results from differences in density, it is called *natural convection*
  - When the movement is forced by a fan or a pump, it is called *forced convection*


DAY
Sea breeze
Land warmer than water

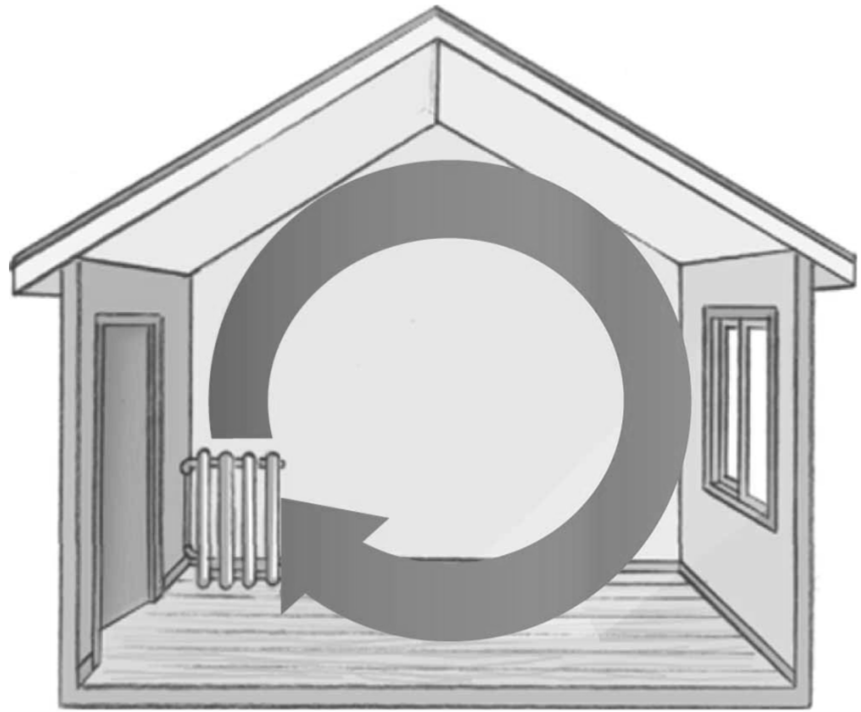
(a)


NIGHT
Land breeze
Land cooler than water

(b)

Convection example

- Air directly above the radiator is warmed and expands
- The density of the air decreases, and it rises
- A continuous air current is established



Radiation

- Radiation does not require physical contact
- All objects radiate energy continuously in the form of electromagnetic waves due to thermal vibrations of their molecules
- Rate of radiation is given by **Stefan’s law**

Stefan's Law

- $P = sAeT^4$
  - P is the rate of energy transfer, in Watts
  - $s = 5.6696 \times 10^{-8}\ W/m^2 \cdot K^4$
  - A is the surface area of the object
  - e is a constant called the **emissivity**
    - e varies from 0 to 1
    - The emissivity is also equal to the **absorptivity**
  - T is the temperature in Kelvins

Energy Absorption and Emission by Radiation

- The rate at which the object at temperature T with surroundings at T_o radiates is
  - $P_{net} = \quad sAe\,(T^4 - T_o^4)$
  - **When an object is in equilibrium with its surroundings, it radiates and absorbs at the same rate**
    - Its temperature will not change

Ideal Absorbers

- An *ideal absorber* is defined as an object that absorbs all of the energy incident on it
  - $e = 1$
- This type of object is called a **black body**
- An ideal absorber is also an ideal radiator of energy

Ideal Reflector

- An ideal reflector absorbs none of the energy incident on it
  - $e = 0$

The Dewar Flask

- A Dewar flask is a container designed to minimize the energy losses by conduction, convection, and radiation
- It is used to store either cold or hot liquids for long periods of time
  - A Thermos bottle is a common household equivalent of a Dewar flask

Dewar Flask

- The space between the walls is a vacuum to minimize energy transfer by conduction and convection
- The silvered surface minimizes energy transfers by radiation
  - Silver is a good reflector
- The size of the neck is reduced to further minimize energy losses