Chapter 16
Heat Energy Transfer

I. Thermal Conduction

- Heat energy conduction occurs by electron and atomic collisions.
- Metals are good conductors of thermal or heat energy.
- Insulators (also called dielectrics) are poor conductors of heat energy.
- Heat energy travels from hot to cold.

**Figure** Conduction of energy through a uniform, insulated rod of length $L$. The opposite ends are in thermal contact with energy reservoirs at different temperatures.

**Figure 16.1** The tile floor feels colder than the wooden floor, even though both floor materials are the same temperature. This is because tile is a better conductor of heat than wood, and so heat is more readily conducted out of the foot touching the tile.
II. Convection

- This is heat energy transfer by the actual movement of a fluid. Liquids and gases mainly.
- Convection currents in the atmosphere make up the winds which result from different parts of the Earth being at different temperatures.
III. Electromagnetic Radiation

- Heat energy transfer by means of *electromagnetic waves*.
- Any object with a temperature $T$ on its surface emits electromagnetic radiation of various frequencies. The frequency $f$ at which the intensity of the emitted radiation is a maximum is proportional to the surface temperature of the object.

**FIGURE 16.11** Radiation curves for different temperatures. The peak frequency of radiant energy is directly proportional to the absolute temperature of the emitter.

\[
T \bar{\lambda} = 2.898 \times 10^{-3} \text{ K} \cdot \text{m}
\]

but since $\bar{\lambda}f = c = 3 \times 10^8 \text{ m/s (speed of light)}$

then

\[
T = 9.66 \times 10^{-12} \frac{\bar{\lambda}}{f} \text{ K in Kelvin, } f \text{ in Hertz}
\]
• The atmosphere is transparent to the higher frequency solar radiation, but is opaque to the much lower terrestrial radiation. ⇒ Greenhouse effect leading to global warming.

**FIGURE 16.19** The hot sun emits short waves, and the cool Earth emits long waves, terrestrial radiation. Water vapor, carbon dioxide, and other “greenhouse gases” in the atmosphere retain heat that would otherwise be radiated from Earth into space.

**FIGURE 16.20** Glass is transparent to short-wavelength radiation but opaque to long-wavelength radiation. Reradiated energy from the plant is long wavelength because the plant has a relatively low temperature.

*Short-wavelength radiation from the sun is transmitted through the glass.*

*Long-wavelength reradiated energy is not transmitted out through the glass and is trapped inside.*
IV. Absorption of Radiant Energy

- A “good absorber” is also a “good emitter” of electromagnetic radiation.
- If a surface absorbs more radiant energy than it emits, then it is a net absorber and its temperature rises. If it emits more than it absorbs, then it is a net emitter and its temperature drops.

V. Reflection of Radiant Energy

- Absorption and reflection are opposite processes. $\Rightarrow$ Good reflectors are poor absorbers.
- Clean snow is a good reflector and therefore it is a bad absorber resulting in it not melting rapidly in sunlight.

- Light-colored buildings stay cooler in the summer because they reflect much of the incoming radiation. Also, since light-colored buildings are poor emitters, they retain more of their internal energy than
darker buildings and stay warmer in the winter.

- *Cooling at night by radiation*... *Grass* is a poor conductor so not much heat energy is conducted into it from the ground. At night grass is a net radiator and can get colder than the surrounding air leading to the formation of frost on grass at night.

- *Newton’s Law of Cooling*: The rate of cooling of a hot object is proportional to the difference in temperatures between the hot object and its surroundings.

- *Thermos Bottle*: A double-walled glass container with a vacuum between the walls. The glass walls are silvered to reflect heat waves and the vacuum prevents heat loss due to conduction.