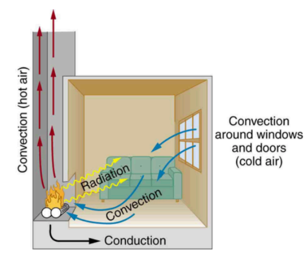
Introduction to Physical Science

Heat Transfer

Presented by Robert Wagner

Methods of Heat Transfer

- There are three methods by which heat is transferred
  - Conduction: Transfer by physical contact
  - Convection: Transfer by bulk movement of material
  - Radiation: Transfer by absorption or emission of electromagnetic radiation



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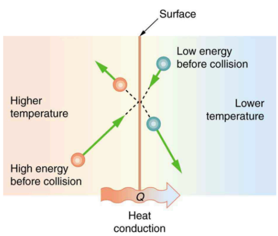
Conduction

- Conduction is a transfer of kinetic energy. It depends on:
  - Temperature difference
  - Cross-sectional area
  - Thickness of material
  - Coefficient of thermal conductivity
- Rate of heat transfer:
  -



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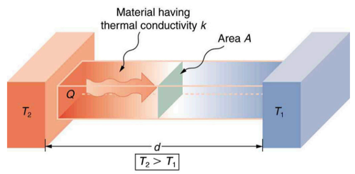
Conduction

- Conduction is a transfer of kinetic energy. It depends on:
  - Temperature difference
  - Cross-sectional area
  - Thickness of material
  - Coefficient of thermal conductivity (Table 14.3)
- Rate of heat transfer:
  -



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Example

- A styrofoam box has a total area of 0.950 m^2 and walls of thickness 2.50 cm. It contains ice and beverages at 0^oC. How much ice melts in one day if kept in a car trunk at 35.0^oC?
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$A = 0.950\ m^2\ ;\ T_1 = 0^oC\ ;\ T_2 = 35.0^oC$$
$$d = 2.50\ cm\ ;\ t = 1\ day = 86000\ s$$

$$\frac{Q}{t} = \frac{kA(T_2 - T_1)}{d}\ or\ Q = \frac{kA(T_2 - T_1)}{d}t$$

$$Q = mL_f$$

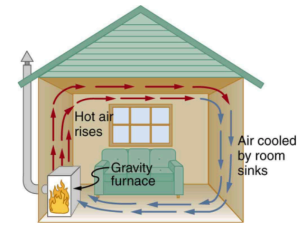
$$Q = \frac{(0.10\ J/s \cdot m \cdot {}^o C)(0.950\ m^2)(35.0^oC - 0^oC)}{0.0250\ m}(86400\ s)$$

$$Q = 1.15x10^6\ J$$

$$m = \frac{Q}{L_f} = \frac{1.15x10^6\ J}{334x10^3\ J/kg} = 3.44\ kg$$

Convection

- Convection is driven by the bulk motion of matter.
- Driven by buoyant forces
  - Hot material rises
  - Cool material sinks



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Example

- Suppose a house has inside dimensions of 12.0 m x 18.0 m x 3.00 m and that all air is replaced in 30.0 min. Calculate the heat transfer rate to warm in the incoming cold air by 10.0^oC.
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$V_{house} = 12.0mx18.0mx3.00m\ ;\ \Delta T = 10.0^oC$$

$$t = 30.0\ min = 1800\ s$$

$$m_{air} = \rho_{air}V_{house}$$

$$m_{air} = (1.29\ kg/m^3)(648\ m^3) = 836\ kg$$

$$Q = mc\Delta T$$

$$Q = (836\ kg)(1000\ J/kg \cdot {}^o C)(10.0^oC) = 8.36x10^6\ J$$

$$\frac{Q}{t} = \frac{8.36x10^6\ J}{1800\ s} = 4.64\ kW$$

Radiation

- Energy of electromagnetic radiation depends on wavelength
- Rate of heat transfer by radiation determined by color
  - Black - most effective
  - White - least effective
- Ideal Radiator - appears black

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Radiation

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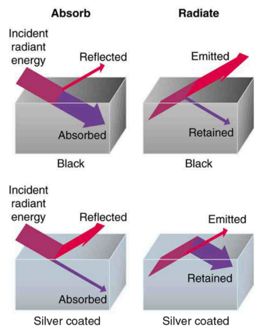

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Stefan-Boltzmann Law of Radiation

- Rate of heat transfer by emitted radiation:
  -
- Stefan - Boltzmann constant
  -
- Emissivity: e - Depends on the specific substance
  - An ideal radiator or blackbody would have e=1

Stefan-Boltzmann Law of Radiation

- Net rate of heat transfer by emitted radiation:
  -
- Net transfer is from hot —> cold

Example

- What is the net rate of heat transfer by radiation, with an unclothed person in a dark room with an ambient temperature of 22.0°C. Normal skin temperature is 33.0°C. The surface area is 1.50m^2 and the emissivity of skin of 0.97 (in the infrared.)
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$T_2 = 22.0^oC(295\ K)\ ;\ T_1 = 33.0^oC(306\ K)$$
$$A = 1.50m^2\ ;\ e = 0.97$$

$$\frac{Q}{t} = \sigma e A(T_2^4 - T_1^4)$$

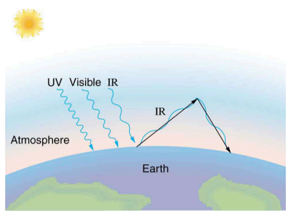
$$\frac{Q}{t} = (5.67x10^{-8}\ J/s \cdot m^2 \cdot K^4)(0.97)(1.50m^2)[(295\ K)^4 - (306\ K)^4]$$

$$\frac{Q}{t} = -\ 99\ J/s$$

$$\frac{Q}{t} = -\ 99\ W$$

Greenhouse Effect

- Depends on emissivity of Earth
  - Average value: 0.65
- More clouds => more reflectivity
- Balance between incoming solar radiation and energy radiated by Earth
- Infrared can be trapped by in Earth's atmosphere
- Makes temperature about 40°C higher and makes life on Earth possible



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Methods of Heat Transfer - Problem Solving Strategies

- Examine situation
  - Type of heat transfer involved?
  - Conduction, convection, or radiation
- Identify given quantities and unknowns
- Solve the appropriate equation for the quantity to be determined
  - Different equations discussed for conduction, convection and radiation
- Substitute in values to determine numerical answer
- Check to see if the answer is reasonable

Summary

- Heat transfer can be from conduction, convection, or radiation
- Heat transfer is calculated differently in each case
- The greenhouse effect on Earth shows transfer by radiation