Preview of Period 4: Transfer of Thermal Energy

4.1 Temperature and Thermal Energy

How is temperature measured?

What temperature scales are used?

4.2 How is Thermal Energy Transferred?

How do conduction, convection, and radiation energy transfer differ?

4.3 How Can Thermal Energy Transfer be Minimized?

What determines the amount of heat flow through a surface?

Summary of Forms of Energy

Mechanical Energy of Motion: The energy exhibited by objects in motion.

Thermal Energy: The unorganized energy of motion of vibrating atoms and molecules.

Sound Energy: The organized energy of motion of vibrating atoms and molecules.

Electrical Energy: The energy resulting from forces between charged particles.

Magnetic Energy: The energy resulting from the forces between magnets.

Radiant Energy: The energy resulting from vibrations of charges, such as radio waves, microwaves, or visible light.

Gravitational Potential Energy: The energy stored in raised objects, which could fall.

Strain Potential Energy: The energy stored in a stretched or compressed spring.

Chemical Potential Energy: The energy available in the chemical bonds binding atoms together.

Electrical Potential Energy: The energy stored by static electric charges.

Nuclear Energy: Energy available in the nuclei of radioactive atoms.

Temperature and Thermal Energy

- **Temperature:** a measure of the AVERAGE kinetic energy of the atoms and molecules of a substance.

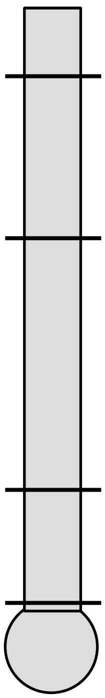
- **Thermal Energy:** a measure of the TOTAL internal energy of the atoms and molecules of a substance.

If you put two identical materials at the same temperature in contact, their temperatures are the same, but the total thermal energy doubles.

Measuring Temperature

Three temperature scales are commonly used

Fahrenheit, Celsius, or Kelvin



	°Fahrenheit	°Celsius	Kelvin
Water boils	212	100	373
Water freezes	32	0	273
Nitrogen boils	– 320	– 196	77
Absolute zero	– 460	– 273	0

Transfer of Thermal Energy: Conduction

- During conduction, energy is transferred by collisions between adjacent molecules.
- No matter is transported.
- The materials must be touching.
- Different materials conduct thermal energy at different rates. This property is called thermal conductivity.

Material	K = Thermal Conductivity (J/s m °C)
Silver	430
Aluminum	237
Brass	120
Copper	398
Iron	80
Nickel	<80

Transfer of Thermal Energy: Convection

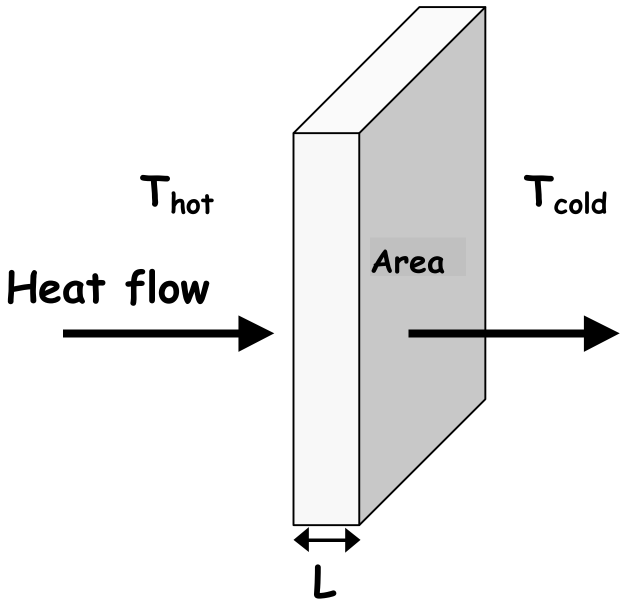
- Thermal energy is transferred due to the motion of the substance containing thermal energy (examples: water or air)
- Warmer matter rises because it is less dense.
- This motion can set up convection currents.
- Convection has more effect in gasses and liquid than in solids.

Transfer of Thermal Energy: Radiation

- Electromagnetic radiation can transfer thermal energy – usually as infrared radiation.
- No medium such as air or water is required.
- Radiation can be reflected to reduce energy transfer.

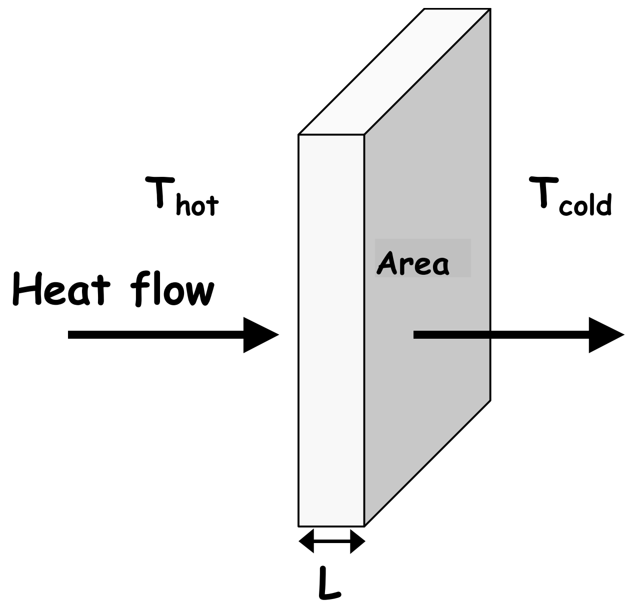
What one condition must exist for the transfer of thermal energy by any of these methods?

Reducing Thermal Energy (Heat) Flow



Which variables affect the rate of heat flow through the window?

Thermal Energy (Heat) Flow Equation



$$\text{Heat flow} = \frac{\text{energy transferred}}{\text{time}} =$$

$$\frac{E}{t} = \frac{K\ A\,(T_{hot} - T_{cold})}{L}$$

K **= the thermal conductivity (J/s m °C or BTU inch/hour foot^2 °F)**

A **= the cross sectional area (meters^2 or feet^2)**

T **= temperature (°C or °F)**

L **= thickness (meters or inches)**

Using Insulation to Reduce Heat Flow

The effectiveness of insulation is called its R-value.

The R-value is based on the insulation thickness and its thermal conductivity.

$$R = \frac{L}{K}$$

R = the R-value of the material

L = thickness (meters or inches)

K = the thermal conductivity (J/s m ^{o}C or BTU inch/hour ft^{2} ^{o}F)

Material	K = Thermal Conductivity (J/s m ^{o}C)
Brick	0.84
Glass	0.84
Water	0.56
Cork	0.042
Wood	0.04
Air	0.023

Thermal Energy Flow Equation II

We have written the equation:

$$\frac{E}{t} = \frac{K\ A\,(T_{hot} - T_{cold})}{L}$$

By substituting $R = L/K$, we can write this equation as:

$$\frac{E}{t} = \frac{A\ (T_{hot} - T_{cold})}{R}$$

A = the cross sectional area (meters^2 or feet^2)

T = temperature (^{o}C or ^{o}F)

R = the R-value of the material $\left(\frac{m^2\ {}^oC}{J/s} \text{ or } \frac{ft^2\ {}^oF}{BTU/hr}\right)$

Period 4 Summary

4.1: **Thermal energy is the total internal energy of the molecules of a substance.**

Temperature is the average kinetic energy of the molecules of a substance.

4.2: **The transfer of thermal energy requires a difference in temperature.**

Heat may be transferred by means of conduction (substances touching), convection (flow of matter), or radiation (electromagnetic radiation).

4.3: **Thermal conductivity *K* indicates how easily heat is transferred through a substance.**

$$\frac{E}{t} = \frac{K\,A\,(T_{hot} - T_{cold})}{L}$$

4.4: **The R-value of insulation is the ratio of the insulation thickness to the thermal conductivity: $R = L/K$**

Heat flow in terms of *R* is

$$\frac{E}{t} = \frac{A\,(T_{hot} - T_{cold})}{R}$$

Period 4 Review Questions

R.1 What is temperature? What is heat? What is thermal energy?

R.2 How is heat transferred to your hand if you touch a hot light bulb? If you place your hand beside (but not touching) a light bulb? If you place your hand above the light bulb?

R.3 Why does an unheated waterbed feel colder than air at the same temperature?

R.4 In class you touch pieces of glass, cork, and aluminum. Which felt the warmest? Why?

R.5 Hot water or steam radiators warm a room primarily via convection and by which other methods of heat transfer?