# Chapter 14: Heat and Transfer Methods

## Internal energy U:

**Internal energy is the energy associated with the microscopic components of a system – atoms and molecules. This includes kinetic energy and potential energy.**

## Heat:

**Heat is a mechanism by which energy is transferred between a system and its environment because of a temperature difference between them.**

**1 calorie is the heat needed to raise the temperature of 1 g of water from 14.5°C to 15.5°C.**

## Mechanical equivalent of heat:

**1 cal = 4.186 J**

# Specific Heat

**Heat Capacity of an object** is the amount of heat required to change the temperature of the object by 1.0°C.

$$C \equiv \frac{Q}{\Delta T}$$

**Specific Heat of a substance** is the amount of heat, per unit mass, required to change the temperature of an object by 1.0°C.

**It has units of J/(kg*°C).**

$$c \equiv \frac{Q}{m\,\Delta T}$$

**43. The ceramic coffee cup with m =116 g and c= 1090 J/(kg*K), is initially at room temperature (24.0°C). If 225 g of 80.3°C coffee and 12.2 g of 5.00°C cream are added to the cup, what is the equilibrium temperature of the system? Assume that no heat is exchanged with the surroundings, and that the specific heat of coffee and cream are the same as the specific heat of water.**

## Thermal Conduction

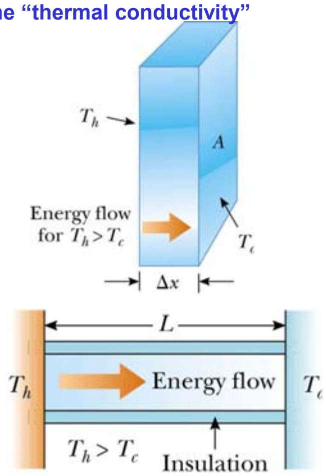
**The rate of energy transfer is the amount of heat transferred across a plane in a unit time. It has units of power (watts). Heat flow is proportional to the "temperature gradient" and the cross-sectional area of the conduction path. It is also proportional to the "thermal conductivity" of the material.**

$$P = \frac{Q}{\Delta t} \propto A\frac{\Delta T}{\Delta x}$$

$$\frac{\Delta T}{\Delta x} = \frac{T_h - T_c}{L}$$

$$P = k\,A\left(\frac{T_h - T_c}{L}\right)$$

thermal conductivity    J $s^{-1}$ $m^{-1}$ $^{o}C^{-1}$

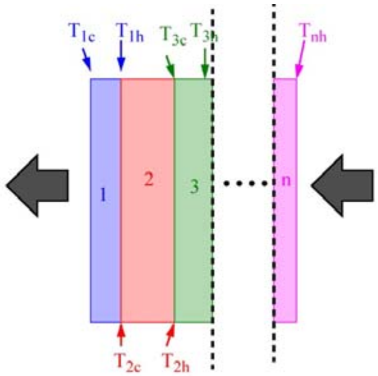



## Multi-Layer Thermal Conduction

**Steady-state**

$$P = k_1\,A\left(\frac{T_{1h} - T_{1c}}{L_1}\right)$$

$$= k_2\,A\left(\frac{T_{2h} - T_{2c}}{L_2}\right) = \ldots = k_n\,A\left(\frac{T_{nh} - T_{nc}}{L_n}\right)$$




$$\Delta T = T_{1h} - T_{nc}$$

$$\Delta T = (T_{1h} - T_{1c}) + (T_{2h} - T_{2c}) + \ldots + (T_{nh} - T_{nc})$$

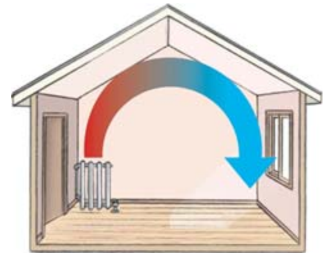
$$\Delta T = \frac{P}{A}\left(\frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots + \frac{L_n}{k_n}\right)$$

$R_i$

$$\frac{Q}{\Delta t} = P = \frac{A\Delta T}{\frac{L_1}{k_1} + \frac{L_2}{k_2} + \ldots + \frac{L_n}{k_n}}$$

## Energy Transfer by Convection and Radiation

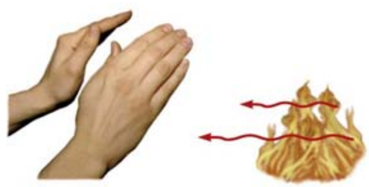
Energy transfer characterized by the movement of a substance is known as transfer by convection.



All objects emit radiation at a rate of

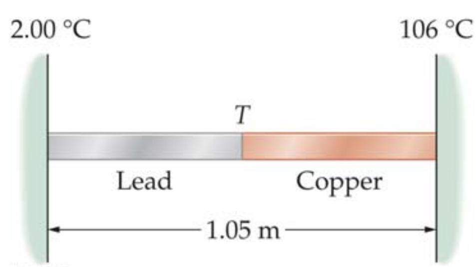
$$P = \sigma A e T^4$$

$\sigma = 5.6696 \times 10^{-8}$ W m$^{-2}$ K$^{-4}$
e: emissivity (a number between 0 and 1)
e = 1 perfect absorber (black body)



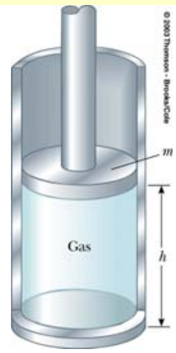
## Example Problem

**56.** Two metal rods – one lead, the other copper – are connected in series. Note that each rod is 0.525 m in length and has a square cross section 1.50 cm on a side. The temperature at the lead end of the rods is 2.00°C; the temperature at the copper end is 106°C. Given that the heat flow through each of these rods in 1.00 s is 1.41 J, find the temperature at the lead-copper interface.



## Problems

**50.** **A vertical cylinder of cross-sectional area 0.050 m$^2$ is fitted with a tight-fitting, frictionless piston of mass 5.0 kg (Fig. P10.50). If there is 3.0 mol of an ideal gas in the cylinder at 500 K, determine the height *h* at which the piston will be in equilibrium under its own weight.**



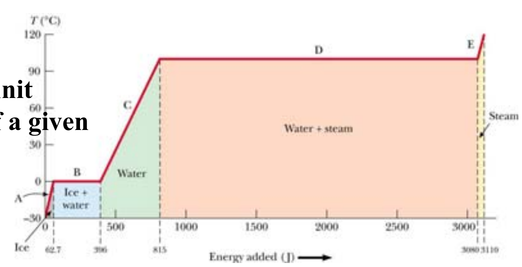

**60. Two small containers of equal volume, 100 cm$^3$, each contain helium gas at 0°C and 1.00 atm pressure. The two containers are joined by a small open tube of negligible volume, allowing gas to flow from one container to the other. What common pressure will exist in the two containers if the temperature of one container is raised to 100°C while the other container is kept at 0°C?**

## Latent Heat

### Latent Heat:

**is the energy required, per unit mass, to change the phase of a given pure substance.**

$$Q = \pm m L$$




**Latent Heat of Fusion:** **is the heat required for melting or freezing.**

**Latent Heat of Vaporization:** **is the heat required for vaporization or condensation**

**Latent Heat of Sublimation:** **is the heat required to sublime a solid directly to a gas, or to condense a gas to solid.**

## Chapter 14 Summary

• **Heat is a form of energy:** $1 \text{ cal} = 4.186 \text{ J}$

• **Specific heat is heat capacity per unit mass:** $c = \frac{Q}{m\Delta T}$

• **Conduction: heat exchange from one part of a material to a cooler part, with no bulk motion of the material.**

• **Heat exchanged in time *t*:** $Q = kA\left(\frac{\Delta T}{L}\right)t$

• **Convection and Radiation** $P = e\sigma AT^4$