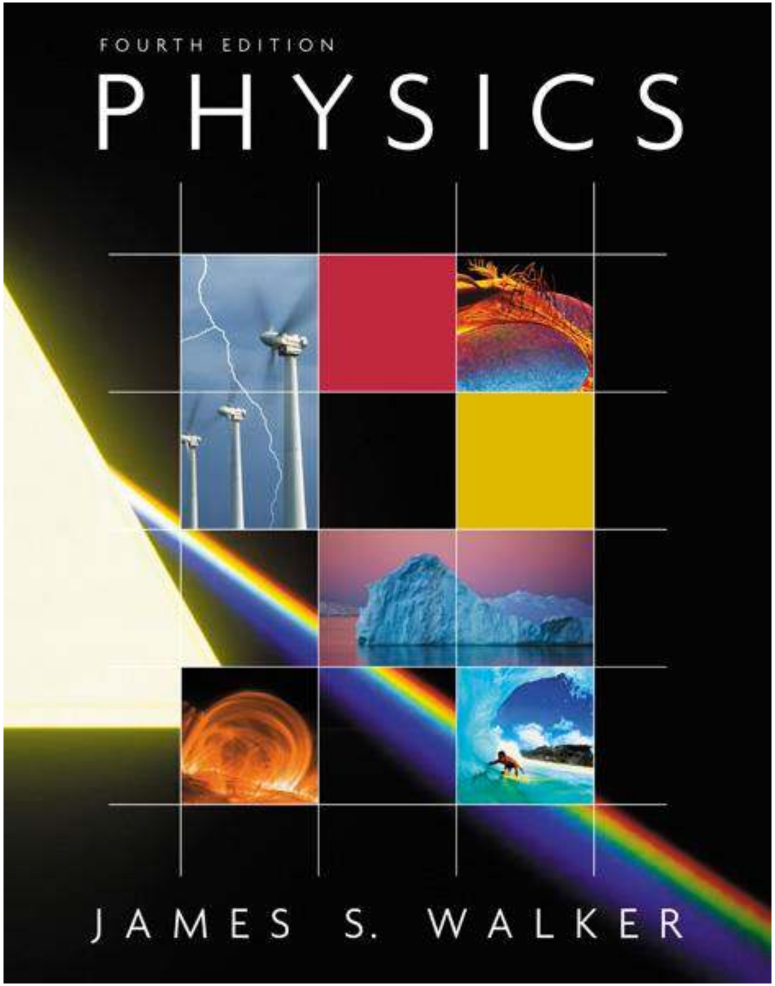


Lecture Outline

Chapter 16

Physics, 4th Edition

James S. Walker

Chapter 16

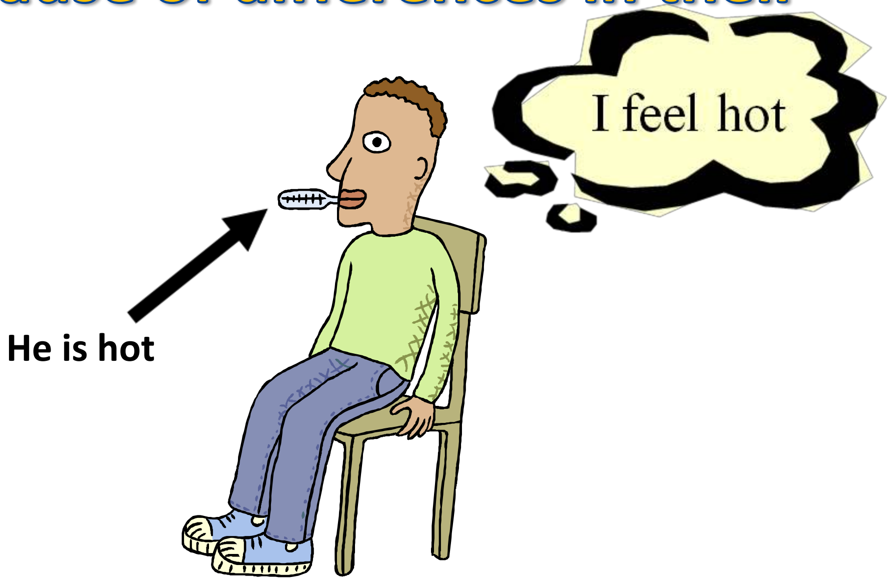
Temperature and Heat

Units of Chapter 16

- Temperature
- Temperature Scales
- Thermal Expansion
- Conduction, Convection, and Radiation

What is Temperature and Heat?

- Temperature is how hot or cold an object feels when we touch it.
- Heat is the exchange of energy between two objects because of differences in their temperatures.



16-1-- Temperature

Definition of heat:

Heat is the energy transferred between objects because of a temperature difference.

Objects are in thermal contact if heat can flow between them.

When the transfer of heat between objects in thermal contact ceases, they are in **thermal equilibrium.**

16-1-- Temperature

That is, temperature is the only factor that determines whether two objects in thermal contact are in thermal equilibrium or not.

Some important definitions

* Two objects are in **Thermal contact** with each other if energy can be exchanged between them.

- **Thermal equilibrium** *is a situation in which two objects would not exchange energy by heat if they were placed in thermal contact.*

Kelvin = SI unit of temperature

16-2-- Temperature Scales

The Celsius scale:

Water freezes at 0° Celsius.

Water boils at 100° Celsius.

The Fahrenheit scale:

Water freezes at 32° Fahrenheit .

Water boils at 212° Fahrenheit .

16-2-- Temperature Scales

Converting between Celsius and Fahrenheit:

$$T_F = (\tfrac{9}{5}\,F°/C°)T_C + 32\ °F$$

$F: \left(\frac{180}{100}\,C°\right) + 32°$

Converting between Fahrenheit and Celsius :

$$T_C = (\tfrac{5}{9}\,C°/F°)(T_F - 32\ °F)$$

$C: \frac{100}{180}(F° - 32)$

Example:- 16-1(541)

- On a fine spring day you notice that the temperature is 75^0 F.
- A)What is the corresponding temperature on the celsius scale?-
- Sol:- 24 ^{0}c
- B) If the temperature on the brisk winter morning is -2.0^0 C, what is the corresponding Fahrenheit temperature
- Sol:- 28^0F

a) $C^\circ = \frac{5}{9}(f^\circ - 32)$

$$\frac{5}{9}(75 - 32) = 23.8^\circ C$$

b) $f^\circ = (\frac{9}{5} \times C^\circ) + 32$

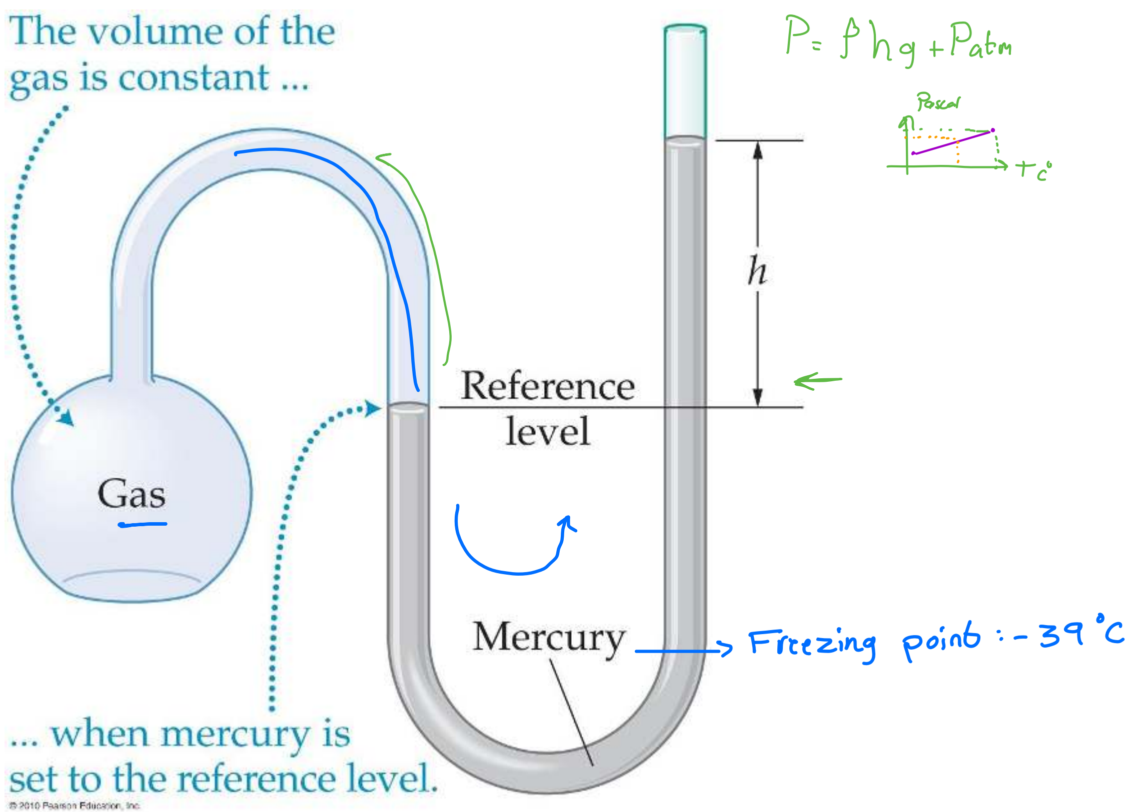
$$(\frac{9}{5} \times -2) + 32 = 28.4^\circ f$$ degree before

Another Scale…

- Kelvin is another way of measuring temperature.
- Scientists use Kelvin to explain the behaviour of gases.
- “Absolute Zero” is measured in Kelvin – which is the coldest possible temperature
- 0 Kelvin = -273 ºC

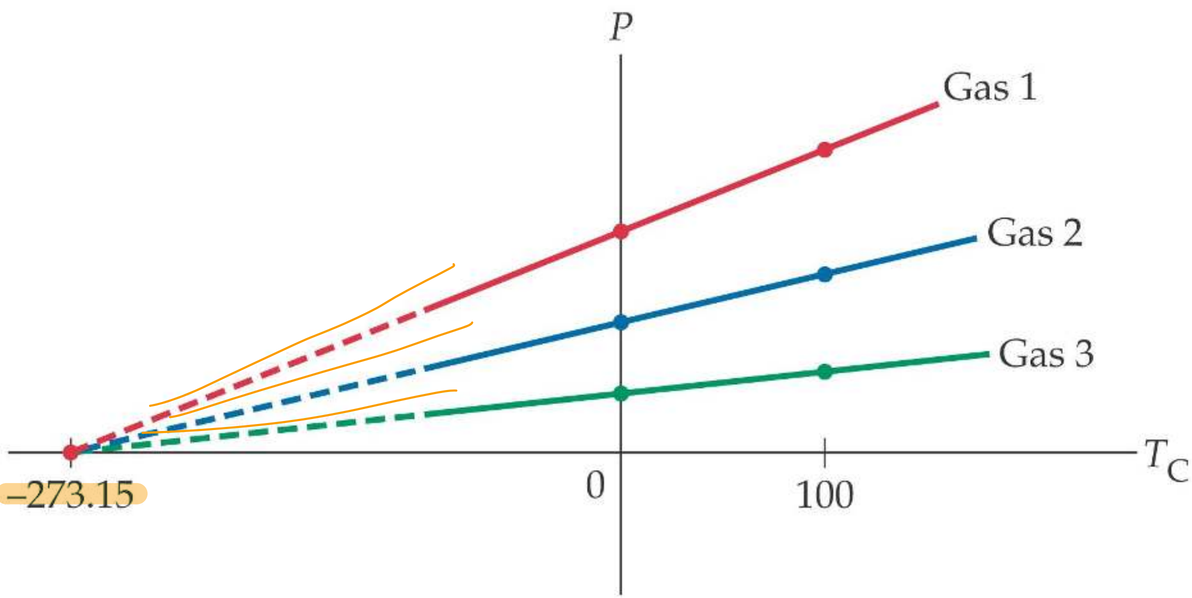
16-2 Temperature Scales

A constant–volume gas thermometer



16-2 Temperature Scales

The pressure in a gas is proportional to its temperature. The proportionality constant is different for different gases, but they all reach zero pressure at the same temperature, which we call absolute zero:



16-2-- Temperature Scales

The Kelvin scale is similar to the Celsius scale, except that the Kelvin scale has its zero at absolute zero.

Conversion between a Celsius temperature and a Kelvin temperature:

- $$T = T_C + 273.15$$

- $f^\circ = \left(\frac{9}{5} \times C^\circ\right) + 32$

- $C^\circ = \frac{5}{9}$

The three common thermal scales.

$$K = \quad {}^{\circ}C = \quad {}^{\circ}F$$

$\boxed{T_K = T_C + 273.15}$

$\boxed{T_C = \frac{5}{9}(T_F - 32)}$

$T_F = \frac{9}{5}T_C + 32$

Freezing point of water

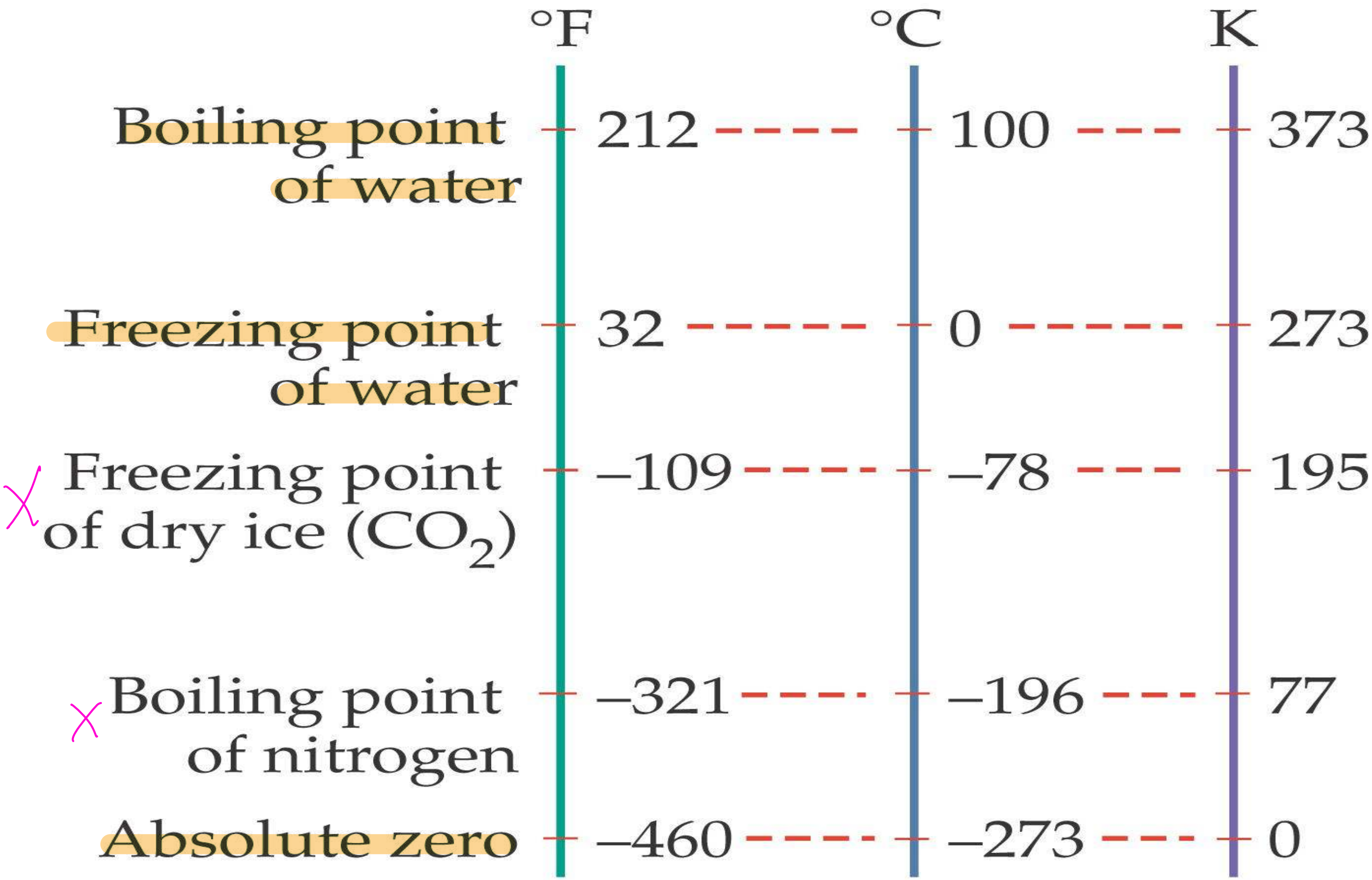
Kelvin	Celsius	Fahrenheit
273.15 K	0°C	32°F
373.15 K	100°C	212°F

Boiling point of water at atmospheric pressure

** The SI unit of absolute temperature is the kelvin

16-2 ---Temperature Scales

The three temperature scales compared:



Exercise 16-1(pg 544)

- Convert 55^0F to K

Answer :T= 286K

① $C^\circ = \frac{5}{9}(55-32)$

$= 12.7^\circ C$

② $K = 12.7^\circ + 273^\circ$

$= 286K$

...ceptual and numerical parts; **BIO** *identifies problems of biological or medical intere... two responses:* **(a)** *your prediction of a physical outcome, and* **(b)** *the best explanation ... indicate the level of difficulty.*

SECTION 16–2 TEMPERATURE SCALES

1. • **Lowest Temperature on Earth** The official record for the lowest temperature ever recorded on Earth was set at Vostok, Antarctica, on July 21, 1983. The temperature on that day fell to −89.2 °C, well below the temperature of dry ice. What is this temperature in degrees Fahrenheit?

2. • More than likely, there is a glowing incandescent lightbulb in your room at this moment. The filament of that bulb, with a temperature of about 4500 °F, is almost half as hot as the surface of the Sun. What is this temperature in degrees Celsius?

3. • Normal body temperature for humans is 98.6 °F. What is the corresponding temperature in **(a)** degrees Celsius and **(b)** kelvins?

4. • What is the temperature 1.0 K on the Fahrenheit scale?

5. • The temperature at the surface of the Sun is about 6000 K. Convert this temperature to the **(a)** Celsius and **(b)** Fahrenheit scales.

16-3-- Thermal Expansion

Most substances expand when heated; the change in length or volume is typically proportional to the change in temperature.

The proportionality constant is called the coefficient of linear expansion.

Definition of Coefficient of Linear Expansion, α

$$\Delta L = \alpha L_0 \Delta T$$

SI unit for α: $\mathrm{K}^{-1} = (\mathrm{C}^\circ)^{-1}$

Exercise 16-2(pg-545)

- The Eiffel tower constructed in 1889 by Alexandre Eiffel, is an impresive lattice work structure made of iron. If the tower is 301m high on a 22^0C day, how much does its height decreases when the temperature cools to 0.0^0C
- Sol:- -7.9cm
- Iron (12×10^{-6} K^{-1})

Lengthi: 301 m $\quad L_f = ?$ $\quad \alpha_{iron} = 12 \times 10^{-6}\ K^{-1}$

$T_i = 22.C$ $\quad T_f = 0.00C$

① $\Delta L = \alpha L_i \Delta T$.

$12 \times 10^{-6} \times 301 \times (0-22) = -0.079m$

② $\Delta L = L_f - L_i \longrightarrow L_f = \Delta L + L_i$

$= (-0.079) + (301) = 300.92$

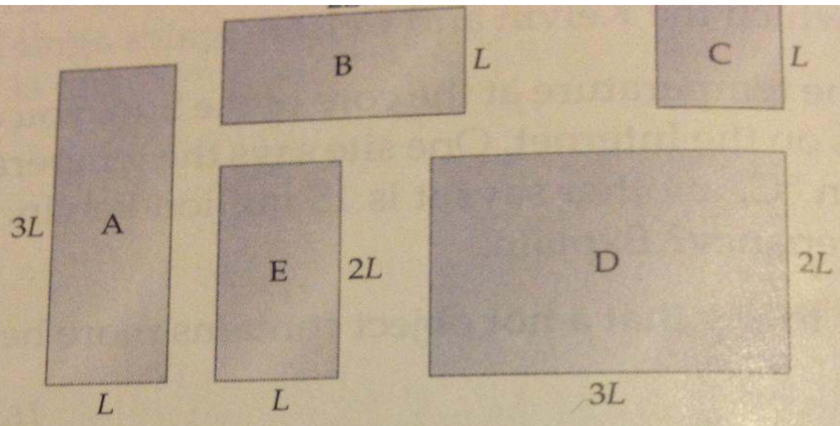


FIGURE 16–13 Problems 15 and 16

16. • **CE** Referring to Problem 15, rank the metal plates in order of increasing expansion in area. Indicate ties where appropriate.

17. • **Longest Suspension Bridge** The world's longest suspension bridge is the Akashi Kaikyo Bridge in Japan. The bridge is 3910 m long and is constructed of steel. How much longer is the bridge on a warm summer day (30.0 °C) than on a cold winter day (−5.00 °C)?

17 $L_i = 3910\,m$, $T_f = 30.0c$, $T_i = -5.00c$, $\alpha = 12 \times 10^{-6}$

1 $\Delta L = \alpha L_i \, \Delta T$

$= 12 \times 10^{-6} \times (3910) \times (30 - -5)$

$= 1.64m$

2 $\Delta L = L_f - L_i \rightarrow L_f = \Delta L + L_i$

$1.64 + 3910 = 3911.64\ m$

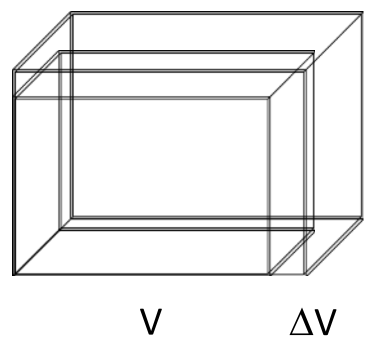
Thermal expansion

- is the tendency of matter to change in length (or volume)in response to a change in temperature.

increase → expand , decrease → shrink

Hotter colder

- This effect is limited in size, and only occurs within limited temperature ranges.



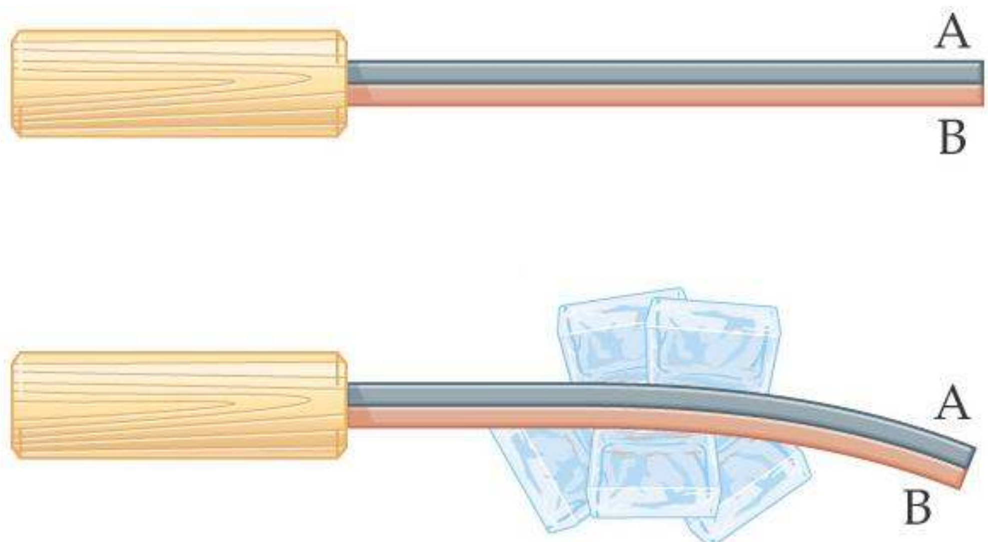
16-3 --Thermal Expansion

Some typical coefficients of thermal expansion:

Substance	Coefficient of linear expansion, $\alpha (K^{-1})$
Lead	29×10^{-6}
Aluminum	24×10^{-6}
Brass	19×10^{-6}
Copper	17×10^{-6}
Iron (steel)	12×10^{-6}
Concrete	12×10^{-6}
Window glass	11×10^{-6}
Pyrex glass	3.3×10^{-6}
Quartz	0.50×10^{-6}

16-3 --Thermal Expansion

A bimetallic strip consists of two metals of different coefficients of thermal expansion, A and B in the figure. It will bend when heated or cooled.



16-3-- Thermal Expansion

The change in volume of a solid is also derived from the linear expansion:

Solid :

$V = L^3$

$$\Delta V \approx 3\alpha V \Delta T$$

For liquids and gases, only the coefficient of volume expansion is defined:

Definition of Coefficient of Volume Expansion, β

Liquid or gas

$$\Delta V = \beta V \Delta T$$

SI unit for β: $\mathrm{K}^{-1} = (\mathrm{C}^{\circ})^{-1}$ $\frac{1}{C^{\circ}}$, $\frac{1}{K}$

Volume = $V = L^3$

Thermal expansion:

Solids: $$\Delta V \approx 3\alpha V \Delta T$$

Liquids & gasses: $$\Delta V = \beta V \Delta T$$

16-3 --Thermal Expansion

Some typical coefficients of volume expansion:

Substance	Coefficient of volume expansion, $\beta\,(K^{-1})$
Ether	1.51×10^{-3}
Carbon tetrachloride	1.18×10^{-3}
Alcohol	1.01×10^{-3}
Gasoline	0.95×10^{-3}
Olive oil	0.68×10^{-3}
Water	0.21×10^{-3}
Mercury	0.18×10^{-3}

16-3-- Thermal Expansion

The change in volume of a solid is also derived from the linear expansion:

$$\Delta V \approx 3\alpha V \Delta T$$

For liquids and gases, only the coefficient of volume expansion is defined:

Definition of Coefficient of Volume Expansion, β

$$\Delta V = \beta V \Delta T$$

SI unit for β: $\mathrm{K}^{-1} = (\mathrm{C}^\circ)^{-1}$

Example: 3

A copper flask with a volume of 150 cm^3 is filled to the brim with olive oil. If the temperature of the system is increased from 6°C to 31° C, how much oil spills from the flask?

[$\beta_{oil} = 0.68 \times 10^{-3}\ K^{-1}$; $\alpha_{copper} = 17 \times 10^{-6}\ K^{-1}$]

Answer: 2.4 cm^3

$V_i = 150\ cm^3$ $T_i = 6\ c$,

$Vf = ?$ $Tf = 31$

① $\Delta V_{cup} = 3 \alpha V \Delta T$

$= 3 \times (17 \times 10^{-6}) \times (150) \times (31-6)$

$= 0.19\ cm^3$

② $\Delta V_{oil} = b V \Delta T$

$= 0.68 \times 10^{-6} \times (150) \times (31-6)$

$= 2.55 cm^3$

③ Spill from flask $= 2.55 - 0.19$

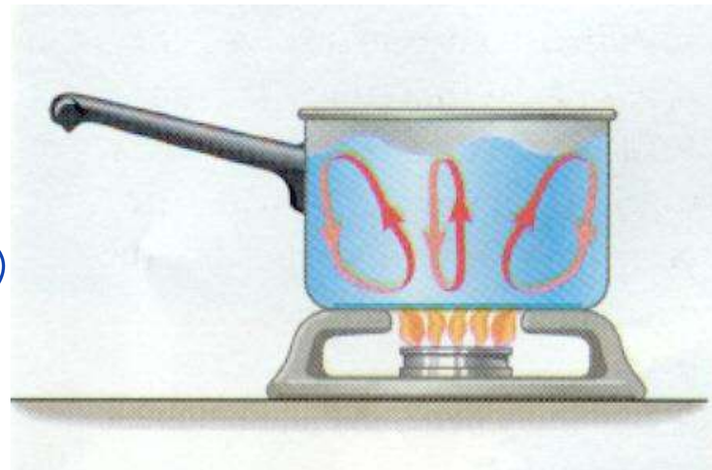
$= 2.36\ cm^3$

Topic : Transferring Energy

- There are 3 main ways to transfer energy

- 1) Radiation
- 2) Conduction
- 3) Convection

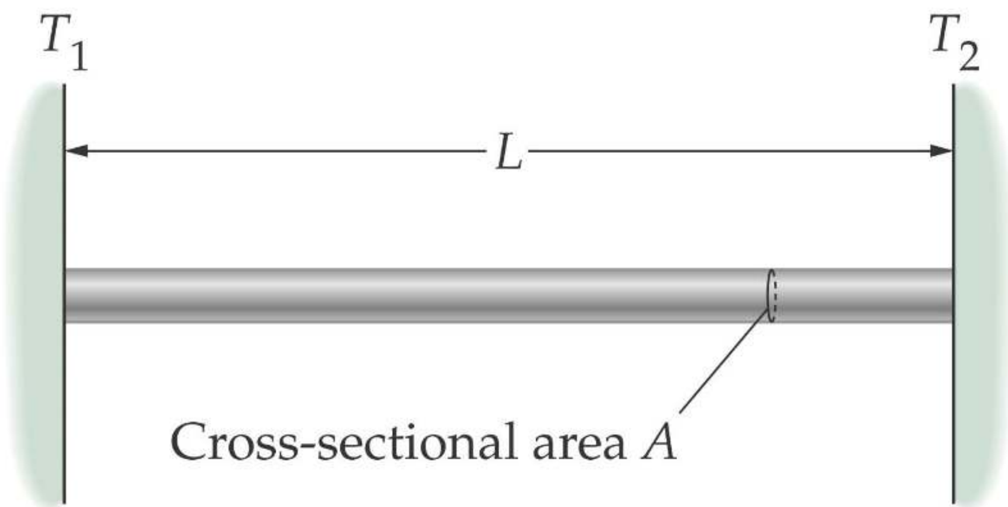
  Liquides &
  gasses



16-6 Conduction, Convection, and Radiation

Conduction, convection, and radiation are three ways that heat can be exchanged.

Conduction is the flow of heat directly through a physical material.



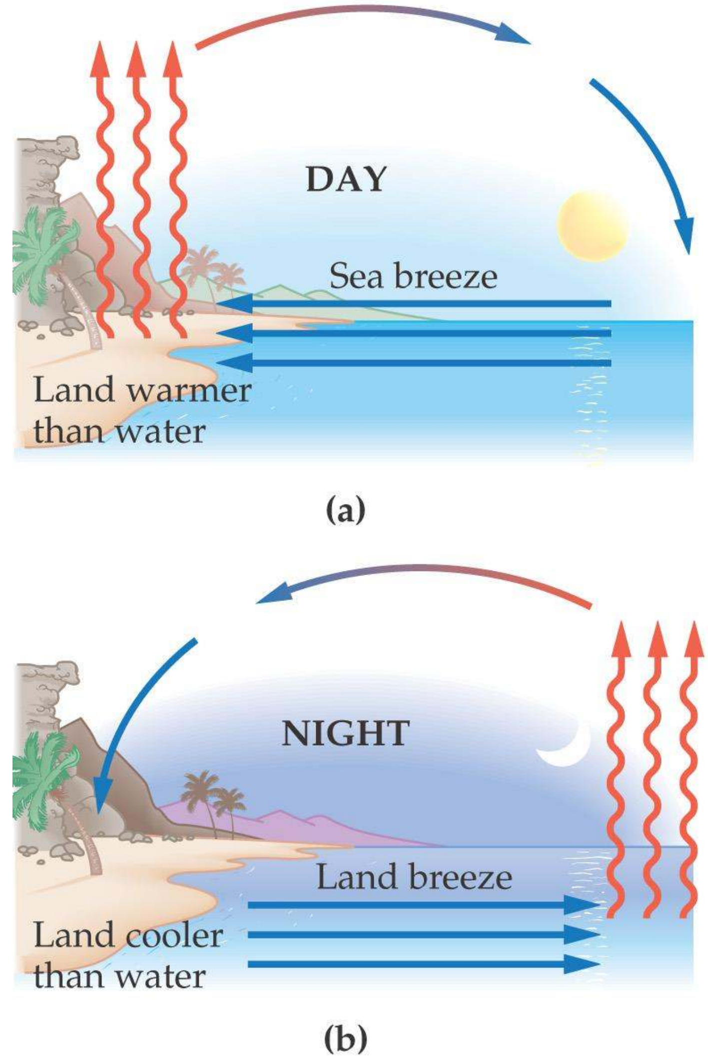
Conduction: The transfer of heat on molecular/atomic level from one substance to another by direct contact. Denser substances are better conductors; the transfer is always from warmer to colder substances. Medium necessary eg metals are good conductors.
Insulators are those which do not conduct heat eg wood, glass, ceramic, rubber .

Convection: Convection is the mass movement of molecules within fluids (i.e. liquids, gases). It cannot take place in solids. Needs a medium

Radiation: energy that is radiated or transmitted in the form of rays or waves or particles. It is the heat transfer by electromagnetic waves or photons. It does not need a propagating medium. The energy transferred by radiation moves at the speed of light eg light, IR etc.

16-6 --Conduction, Convection, and Radiation

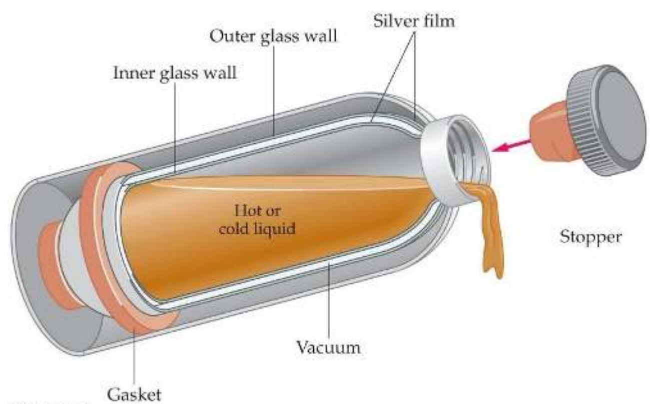
Convection is the flow of fluid due to a difference in temperatures, such as warm air rising. The fluid "carries" the heat with it as it moves.



16-6-- Conduction, Convection, and Radiation

All objects give off energy in the form of radiation, as electromagnetic waves – infrared, visible light, ultraviolet – which, unlike conduction and convection, can transport heat through a vacuum.

Objects that are hot enough will glow – first red, then yellow, white, and blue. Objects at body temperature radiate in the infrared, and can be seen with night vision binoculars.



Summary of Chapter 16

• Heat is the energy transferred between objects due to a temperature difference.

• Objects are in thermal contact if heat can flow between them.

• Objects that are in thermal contact without any flow of heat are in thermal equilibrium.

• Thermodynamics is the study of physical processes that involve heat.

Summary of Chapter 16

- Temperature determines whether two objects will be in thermal equilibrium.

- Celsius scale: water freezes at 0° C, boils at 100° C

- Fahrenheit: water freezes at 32° F, boils at 212° F

- The lowest attainable temperature is absolute zero.

- Kelvin: absolute zero is 0 K; water freezes at 273.15 K and boils at 373.15 K

Summary of Chapter 16

- Temperature scale conversions:

$$T_F = \frac{9}{5}T_C + 32$$

$$T_C = \frac{5}{9}(T_F - 32)$$

$$T = T_C + 273.15$$

- Most substances expand when heated.
- Linear expansion: $\Delta L = \alpha L_0 \Delta T$
- Volume expansion: $\Delta V = \beta V \Delta T$

Summary of Chapter 16

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

• Convection is heat exchange due to the bulk motion of an unevenly heated fluid.

• Radiation is heat exchange due to electromagnetic radiation.

Summary of Chapter 16

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

- Energy is conserved in heat flow.