Expansion

Expansion ← Δt

Expansion → Force

Expansion due to Δt

-KM Theory $\longrightarrow \Delta t \sim KE$

$\therefore$ *as objects heat up the molecules move faster*

$\therefore$ *the faster, the more momentum (the more inertia of motion), the farther apart they move------expand*

This *Thermal Expansion* of a substance is a formal property of matter!

$$\Delta l = \alpha l \Delta t$$

Coefficient of linear expansion

change in temperature

$$\Delta l = \alpha l \Delta t$$

change in length

length of object

$$\alpha = \frac{\Delta l}{l \Delta t}$$

note how "α" is a <u>ratio</u> of lengths per degree C (C^{-1})

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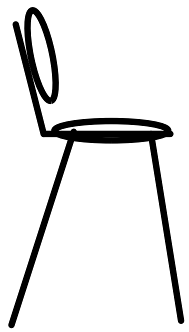
ex



Lab chair legs:

l = 60.0 cm

steel

t_i = -10.0 C *in winter*

t_f = 32.0 C *in summer*

Δl = ?

$$\Delta l = \alpha l \Delta t$$

$$\Delta l = 12x10^{-6} /^{o}C(.600m)42.0^{o}C$$

$$\Delta l = 3.00x10^{-4}m$$

or, $\Delta l = .300mm$

ex| How much do the railroad tracks from Milwaukee to West Bend expand and contract from winter to summer?

l = 32km

t_i = -10.0 C

t_f = 32.0 C

steel

$\Delta l = ?$

$$\Delta l = \alpha l \Delta t$$

$$\Delta l = 12x10^{-6} /^{o} C(3.2x10^{4} m)42^{o} C$$

Δl = 16 m

Sometimes we need to know how much an object expands in*all* directions-----volume

for linear expansion $\Delta l = \alpha l \Delta t$

for volume expansion its in all three dimensions, therefore, 3x linear expansion

$$\Delta V = \beta V \Delta t$$

$$\beta = 3\alpha$$

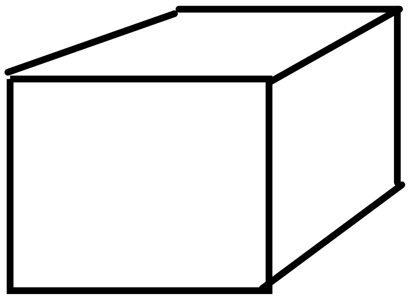
also on pg 317

A cylinder shaped steel tank 6m tall and 4 m wide is filled with gasoline. How much gas overflows if it is filled to the top at 10 C and heats up to 25 C?

$$\Delta V = \left(950 \times 10^{-6}/^\circ C - 35 \times 10^{-6}/^\circ C\right)\left[\pi (2m)^2 6m\right) 15^\circ C$$

$$\Delta V = 1.03\ m^3$$

How much does the steel cube (from Heat Exchange Lab) increase in volume when it went from 20.0 C to 100 C in our experiment?



$V = 3.2x10^{-5} m^3$

steel

$\beta = 35x10^{-6} C^{-1}$

$t_i = 20.0$ C

$t_f = 100.0$ C

$\Delta V = ?$

$$\Delta V = \beta V \Delta t$$

$$\Delta V = 35x10^{-6} C^{-1} (3.2x10^{-5} m^3)(100.0^{\circ} C - 20.0^{\circ})$$

$$\Delta V = 9.0x10^{-8} m^3$$

Δt

Expansion

Force

stretching (elastic)

Change in length due to applied force

elastic property of a substance (Young's Modulus)

$$E = \frac{stress}{strain} = \frac{F / A}{\Delta l / l}$$

or, $$E = \frac{Fl}{\Delta l A}$$

How much does our chair change in length due to someone sitting on it?

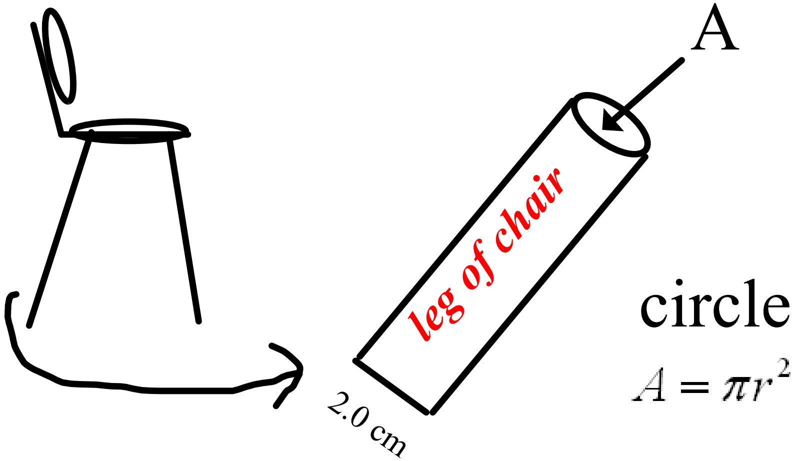
Lab chair legs:

l = 60.0 cm

steel

diameter = 2.00 cm

m_s = 55 kg



$$F_w = 55kg(9.8m/s^2) = 540N$$

$$\Delta l = ?$$

$$E = \frac{Fl}{\Delta l A} \qquad \Delta l = \frac{Fl}{EA}$$

$$\Delta l = \frac{540N(.60m)}{200x10^9 N/m^2(\pi)(.01m)^2} = 5.2x10^{-6}m$$

Force applied due to change in length because of a temperature change *is called "Thermal Stress"*

Usually this is measured when two rigid objects are "tied" together and are incapable of moving. An internal stress results.

This equation comes from putting "Young's Modulus" together with "thermal expansion".

$$E = \frac{Fl}{\Delta l A} \rightarrow \Delta l = \frac{Fl}{EA}$$

and,

$$\Delta l = \alpha l \Delta t$$

$$\frac{Fl}{EA} = \alpha l \Delta t$$

$$\frac{F}{EA} = \alpha \Delta t$$

$$F = \alpha E A \Delta t$$

What force of compression is applied between two cement slabs 10.0 m long with a contace area of 0.20 square meters if the temperature goes from -10.0 C to 35.0 C?

$$E = 20x10^9\, N/m^2$$

$$t_i = -10.0^o C$$

$$t_f = 35.0^o C$$

$$F = \alpha E A \Delta t$$

$$F = (12x10^{-6}\, /^o C)(20x10^9\, N/m^2)(0.20 m^2)(45^o C)$$

$$F = 2.2x10^6\, N$$

$TS = F/A$

$$TS = \frac{2.2 \times 10^6 N}{.2 m^2}$$

$TS = 1.1 \times 10^7 N/m^2$

ok

Temperature Scales:

$$^oF = 9/5^oC + 32 \quad \Big| \quad ^oC = 5/9(^oF - 32) \quad \Big| \quad ^oC = K + 273$$

Zeroth Law of Thermodynamics

If two systems are in thermal equilibrium with a third system, then they are in thermal equalibrium with each other.

Water/Ice

1) Water has it greatest density (least volume) at 4 degrees C

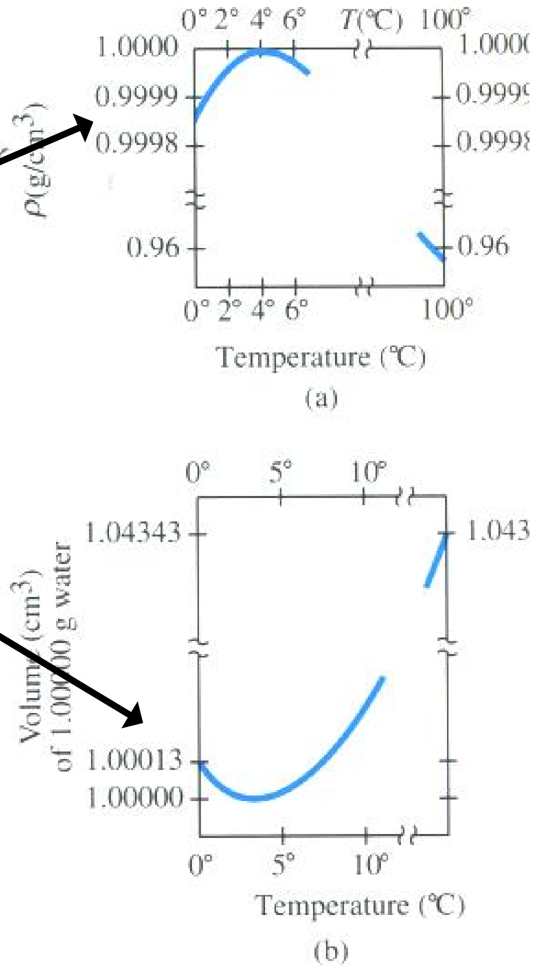


FIGURE 13–7 Behavior of water as a function of temperature near 4°C. (a) Density vs. temperature; (b) Volume, of 1.00000 gram of water, as a function of temperature. [Note the break in each axis.]

Water/Ice

1) Water has it greatest density at 4 degrees C

2) As water at O degrees is heated it decreases in volume (increases in density) until it reaches 4 degrees

3) As warmer water cools by contact with cold air it increases in density and sinks to the bottom and in replaced by warmer water. This continues until it all reaches 4 degrees---as the surface water cools further it remains on the top because it is less dense than the lower 4 degree water and freezes on the top