Physics 2101
Section 3
Apr 21st

Announcements:

- Qitz on Friday
- Midterm #4, April 28th 6 pm
- Final: May 11th-7:30am
- Make up Final: May 15th-7:30am

Class Website:

http://www.phys.lsu.edu/classes/spring2010/phys2101-3/

http://www.phys.lsu.edu/~jzhang/teaching.html

David Halliday

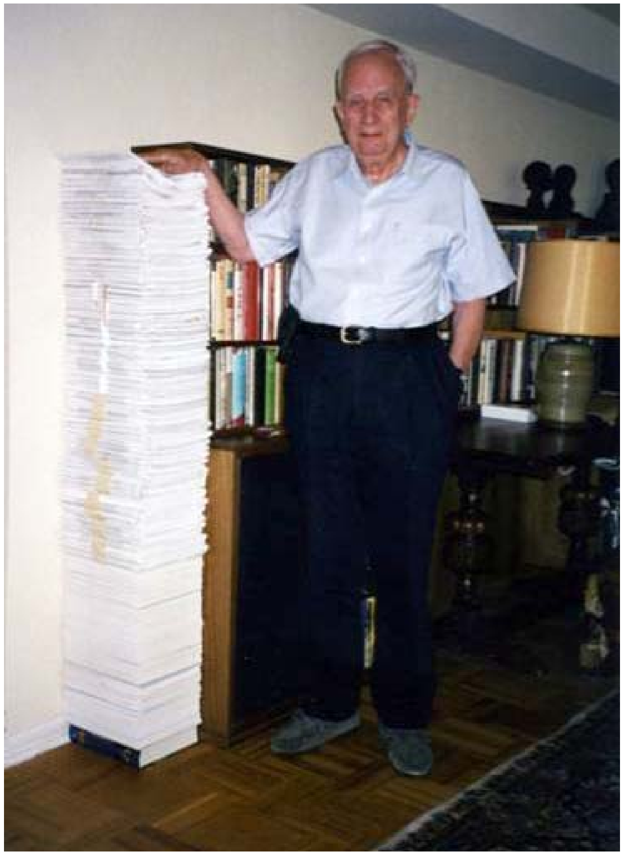
David Halliday (1916- April 2010: age 94)

He is best known as the co-author (with Bob Resnick) of the all-time best-selling introductory physics texts, Physics and Fundamentals of Physics. Together these books have sold over 3 million copies worldwide (first edition: 1960)

Dave received his PHD from the University of Pittsburgh in 1941. With the outbreak of World War Two, he moved to the MIT Radiation Lab and made important contributions to the war effort by improving radar techniques.

After the war, he returned to Pitt where he remained for the rest of his career becoming Chair of the Physics Department and then Dean of the College of Science. Dave's hobby was collecting material related to James Joyce and he had one of the best private collections in the world.

Some of the spirit of his personality comes through in this 1999 photo of him standing next to the manuscript for the 5th edition of Physics.



Area Expansion

Expansion in 1-D

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

$$L = L_0 (1 + \alpha \Delta T)$$

Expansion in 2-D

$$A = \left[L_0 \left(1 + \alpha \Delta T\right)\right]\left[W_0 \left(1 + \alpha \Delta T\right)\right]$$

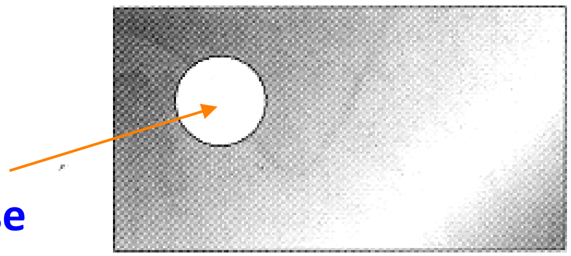
$$\begin{aligned}
\Delta A &= A_0 \left(1 + \alpha \Delta T\right)^2 - A_0 \\
&= A_0 \left(2\alpha \Delta T + \left(\alpha \Delta T\right)^2\right) \\
&\cong A_0 \left(2\alpha\right) \Delta T \\
&\cong A_0 \beta \Delta T
\end{aligned}$$

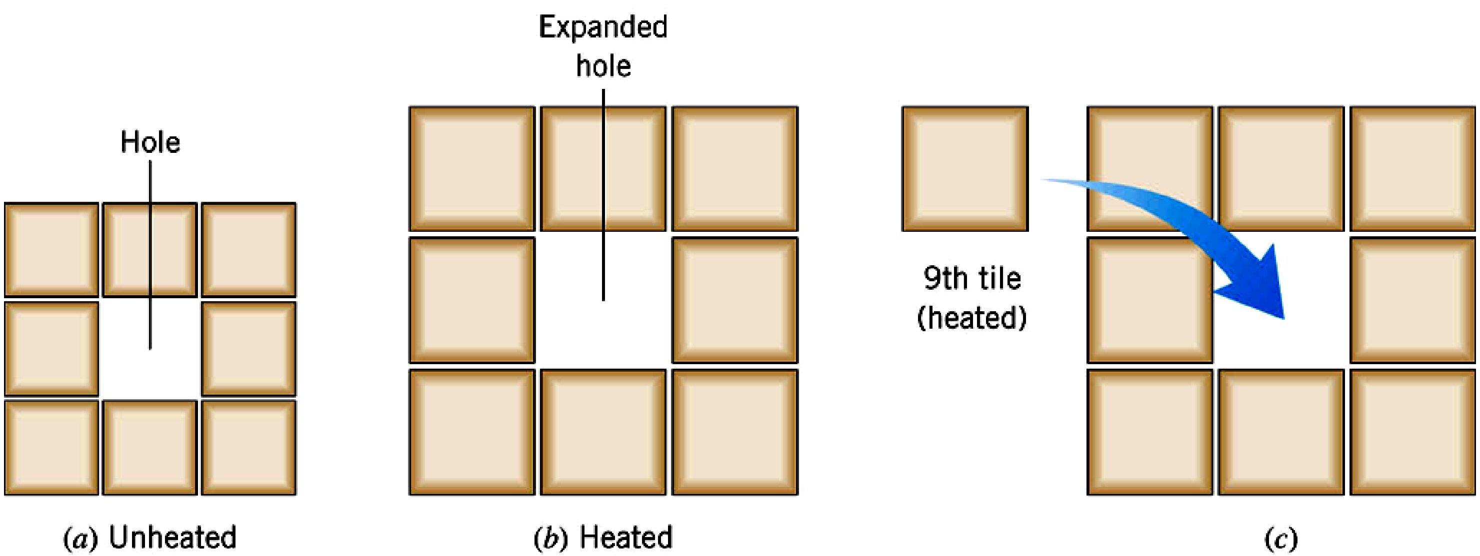
$$\beta = 2\alpha$$

Thermal Expansion of Holes

Do holes expand or contract when heated?

Does radius increase or decrease when heated?

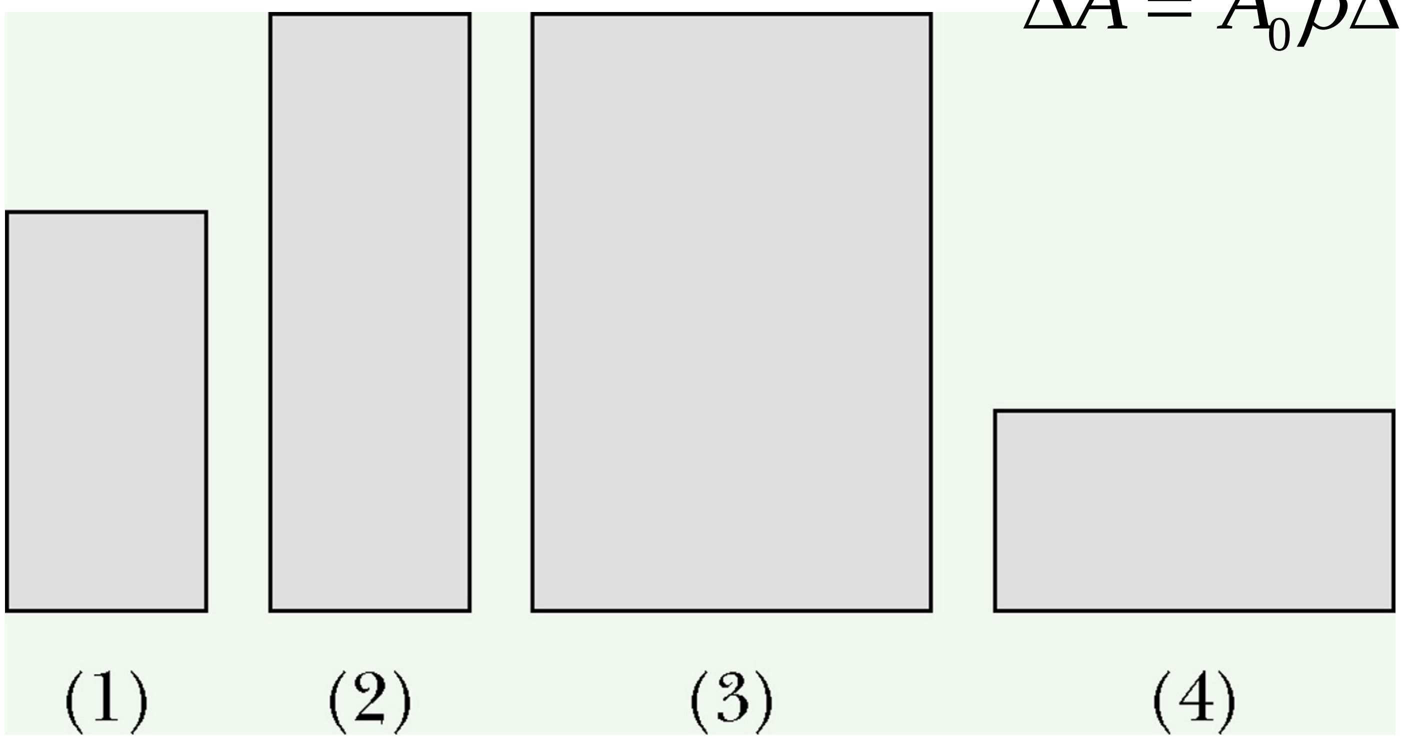




The hole gets larger too!

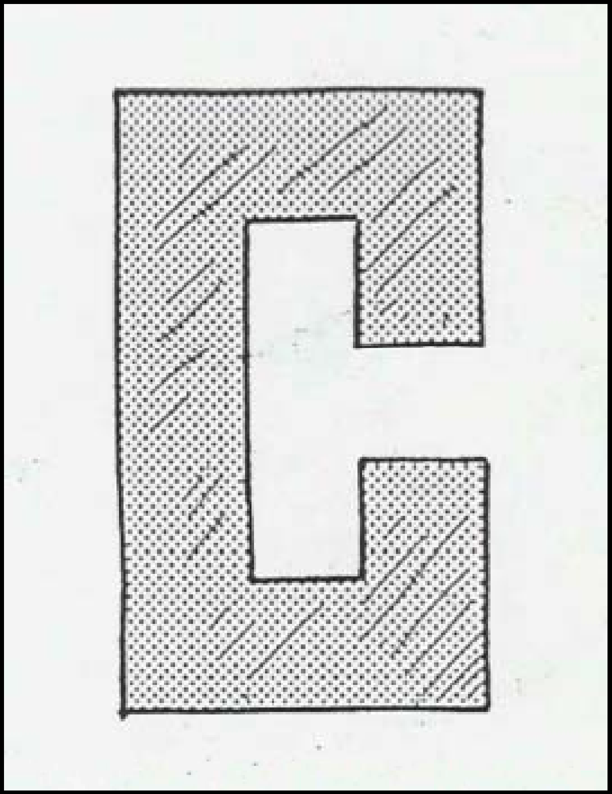
Checkpoint #2: the figure here shows four rectangular metal plates, with sides of L, 2L, or 3L. The expansion coefficient is the same. Rank the plates according to the expected increase in
(a) their vertical heights and (b) their areas, greatest first.

$$\Delta A = A_0 \beta \Delta T$$



Clicker Question

When the temperature of the piece of metal shown below is increased and the metal expands, what happens to the gap between the ends?



1. It becomes narrower
2. It becomes wider
3. It remains unchanged

Thermal Expansion of the Brooklyn Bridge

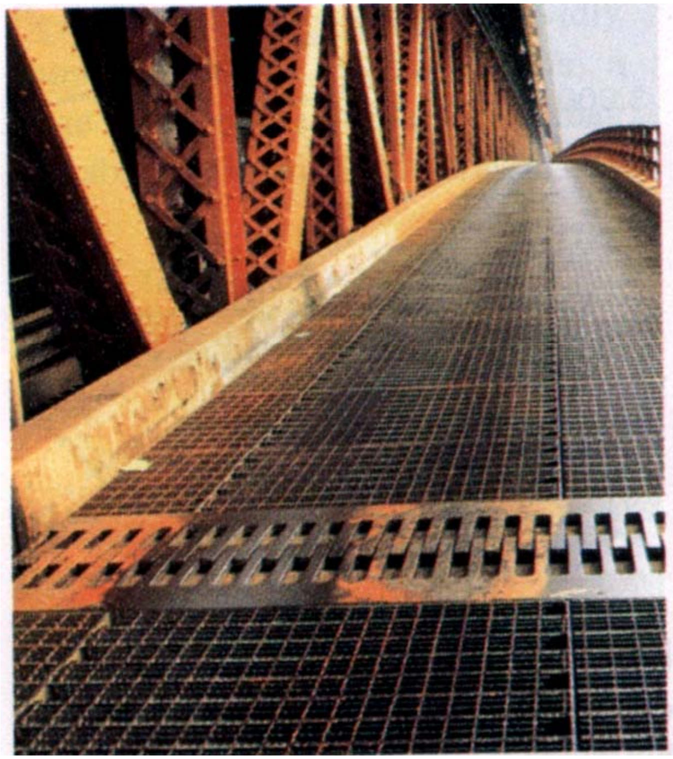
Problem 1: Brooklyn Bridge Expansion

The steel bed of the main suspension bridge is 490 m long at + 20°C. If the extremes in temperature are - 20°C to + 40°C, how much will it contract and expand?

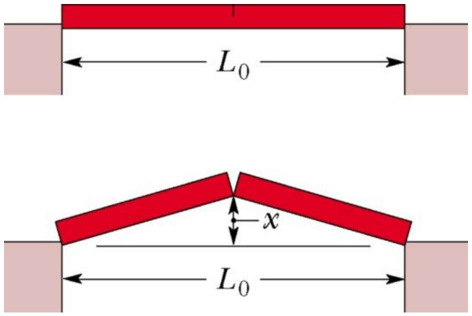
$$\alpha_{steel} = 12 \times 10^{-6} (°C)^{-1}$$

$$\Delta L = \alpha_{steel} L_0 \Delta T$$
$$= 12 \times 10^{-6} (°C)^{-1} (490 m)(60°C)$$
$$= 35\ cm$$

The solution is to use expansion joints



Linear Expansion: 18#21



As a result of a temperature raise of 32 C^0 the red bar with a crack at its center buckles as shown. If the fixed distance L_0=3.77m and the coefficient of linear expansion of the bas is $25\text{x}10^{-6}$/C find the raise at the center.

We are assuming that L_0 does not change.

look only and one half of the bar $l_0 = \frac{L_0}{2}$

$$l_0(final) = \frac{L_0}{2} + \alpha\frac{L_0 \Delta t}{2}$$

The height x is

$$x^2 = \left[l_0(final)\right]^2 - l_o^2$$

$$x^2 = \left[\frac{L_0}{2} + \alpha\frac{L_0 \Delta t}{2}\right]^2 - \left[\frac{L_0}{2}\right]^2$$

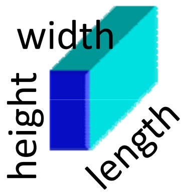
$$x^2 = 2\alpha\Delta t\left(\frac{L_0}{2}\right)^2$$

Volume Expansion

Expansion in 1-D

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

$$L = L_0 (1 + \alpha \Delta T)$$



Expansion in 2-D

$$\Delta A \cong A_0 (2\alpha) \Delta T$$

$$\cong A_0 \beta_A \Delta T$$

Expansion in 3-D

$$V = [L_0 (1 + \alpha \Delta T)][W_0 (1 + \alpha \Delta T)][H_0 (1 + \alpha \Delta T)]$$

$$\Delta V = V_0 (1 + \alpha \Delta T)^3 - V_0$$

$$= V_0 \left(3\alpha \Delta T + 3(\alpha \Delta T)^2 + (\alpha \Delta T)^3\right)$$

$$\cong V_0 (3\alpha) \Delta T$$

$$\cong V_0 \beta_V \Delta T$$

$\beta_V = 3\alpha$

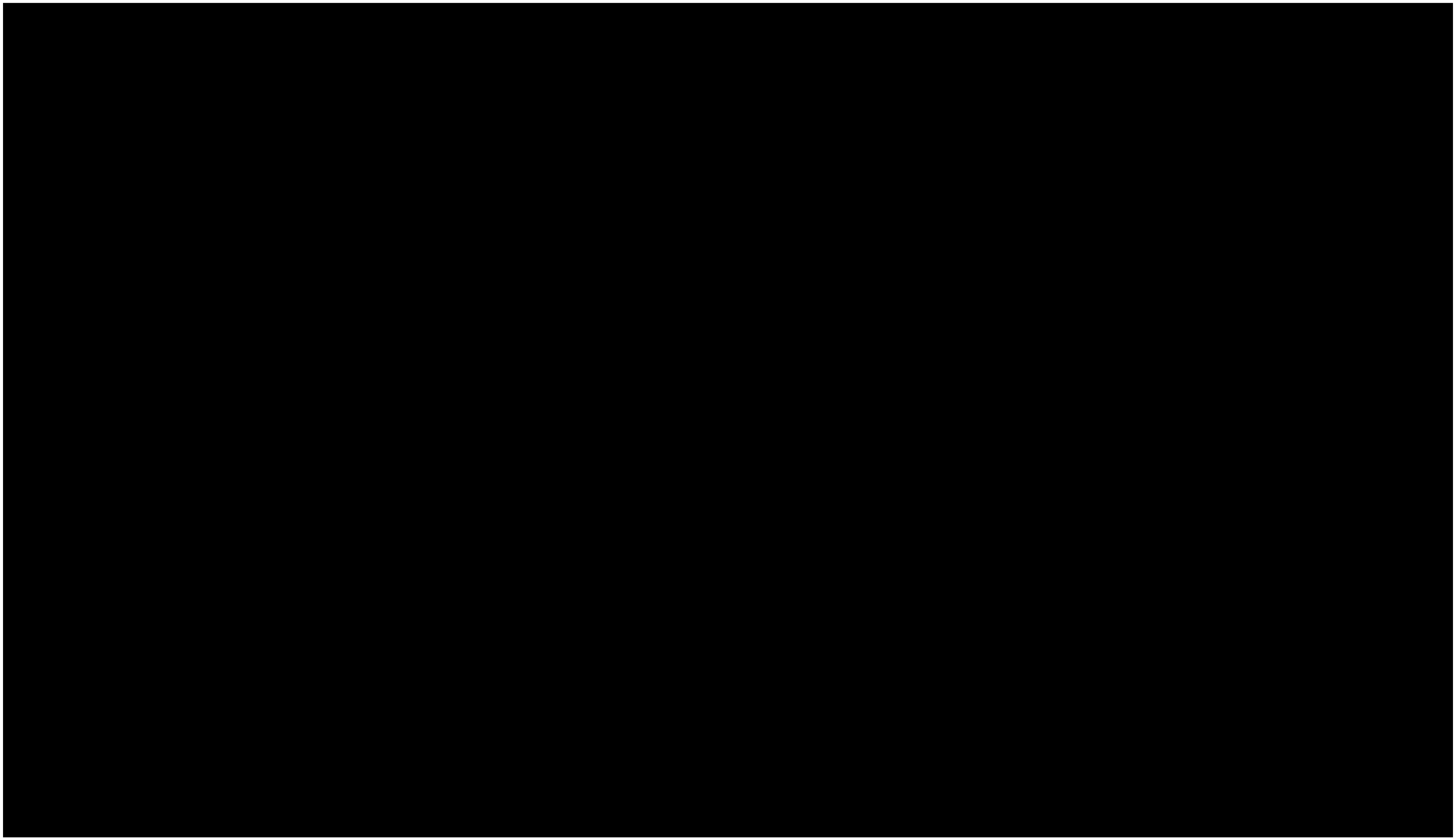
--- coefficient of volume expansion

Volume expansion coefficients

solids : $1 - 87 \times 10^{-6} / {}^\circ C$ liquids : $210 - 1100 \times 10^{-6} / {}^\circ C$ gasses : $3400 \times 10^{-6} / {}^\circ C$

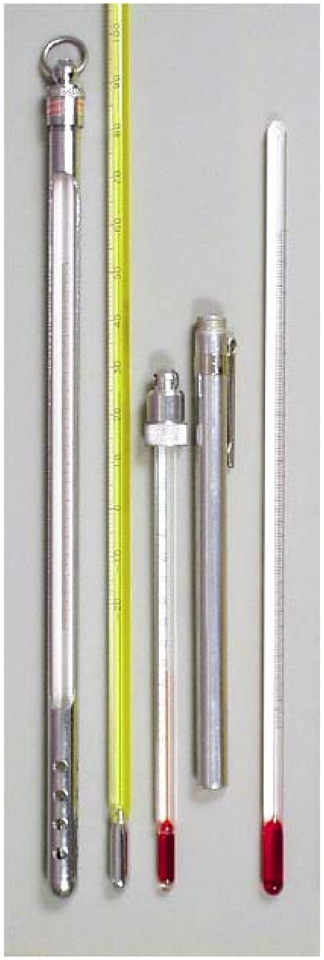
Problem 3: **Gas tank in the sun**

The 70-L steel gas tank of a car is filled to the top with gasoline at 20°C. The car is then left to sit in the sun, and the tank reaches a temperature of 40°C. How much gasoline do you expect to overflow from the tank? [gasoline has a coefficient of volume expansion of $950\times10^{-6}/°C$]



How does a thermometer work?

Is it linear expansion? Mercury $\alpha \approx 61\times10^{-6}/°C$



$$\Delta L \approx 61\times10^{-6}/°C(20cm)(20°C)$$
$$\approx 0.2mm$$

…so it can't be linear expansion

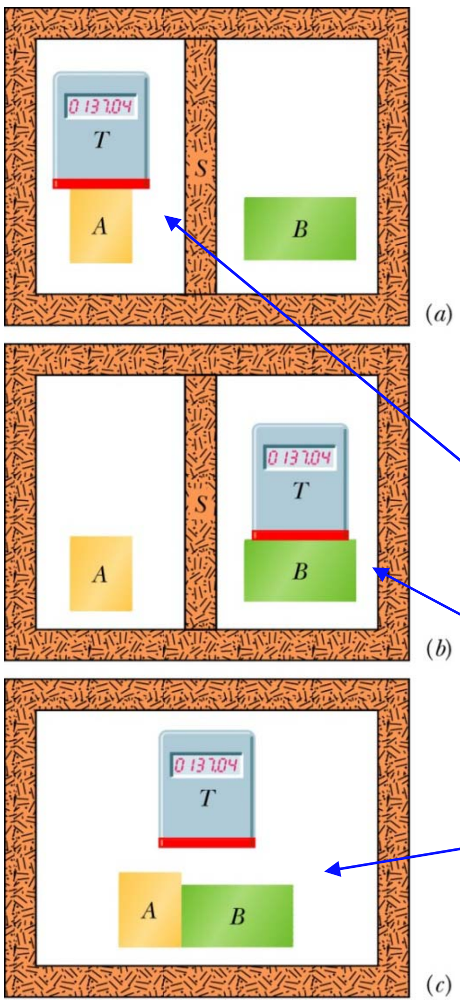
How about bulk (volume) expansion?

assume that the bulb is 10mmx2mmx2mm=40mm^3

$$\Delta V = (182\times10^{-6}\ °C^{-1})(40mm^3)(20°C)$$
$$= 0.145mm^3$$

So if the column is 0.1mm x 0.1mm then it will go up 14.5 mm

Zeroth Law of Thermodynamics



Defines THERMAL EQUILIBRIUM

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

$T_1 = T_2 = T_3$

No Heat flow

In this case:

a) A is in thermal equilibrium with T

b) B is in thermal equilibrium with T

c) A & B are in thermal equilibrium

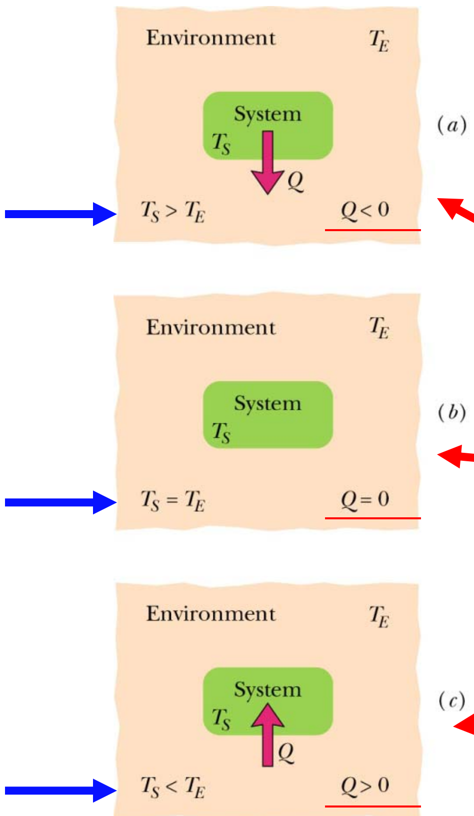
Temperature and Heat

If two objects are NOT in thermal equilibrium, their temperatures must be different.

To make their temperatures equal (i.e. thermal equilibrium), HEAT MUST FLOW.

HEAT has to do with the transfer of thermal energy.

Symbol for HEAT: **Q** - **BE VERY CAREFUL ABOUT THE SIGN**



"System"- particular object or set of objects

"Environment" - everything else in the universe

Heat is negative when energy is transferred from the system's thermal energy to its environment (heat is released or lost)

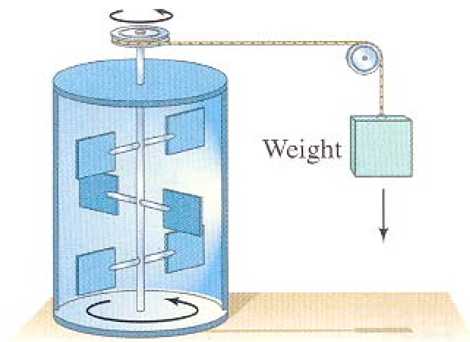
Heat is zero when no energy is transferred between the system's thermal energy and its environment (AT THERMAL EQUILIB)

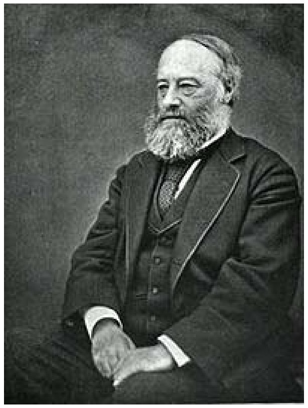
Heat is positive when energy is transferred to the system's thermal energy from its environment (heat is absorbed)

Heat: transfer of thermal energy

Remember: WORK (W) - energy transferred to system via a force acting on it

James Joule (1818-1889)
-> A given amount of work done is equivalent to a particular amount of heat input





Units :

Joule : "the amount of work done when a force of one Newton acts through a distance of one meter"

calorie : "the amount of heat that would raise the temperature of 1 g of water from 14.5°C to 15.5°C

Btu : "the amount of heat that would raise the temperature of 1 lb of water from 63°F to 64°F

Mechanical equivalent to Heat :

$$1 \text{ cal} = 3.969\times10^{-3} \text{ Btu} = 4.1860 \text{ J}$$

Absorption of Heat by Solids and Liquids

If heat is put into a solid, the temperature rises.   How much?

Heat Capacity

$$Q = C\Delta T = C(T_f - T_i)$$

"Change of system energy with change of temperature"

Heat Transfer

Heat Capacity [J/ºC or cal/ºC]
- depends on the material

Specific Heat **(heat capacity ∝ mass)**

$$Q = cm\Delta T = cm(T_f - T_i)$$

Water : c_{water} = 1 cal/g·°C = 1 Btu /lb·°F = 4190 J/kg·°C

~ independent of temperature $c \sim\neq c(T)$

Molar Specific Heat **(heat capacity ∝ # of particles)**

$$Q = c_{molar} n\Delta T$$

1 mol = 6.02×10^{23} elementary units

Specific Heat

$$Q = cm\,\Delta T = cm(T_f - T_i). \qquad (18\text{-}14)$$

$$c = \frac{1cal}{gC^0} = \frac{1BTU}{lbF^0} = \frac{4190J}{kgK}$$

Molar Specific Heat

1 mol= 6.02×10^{23} elementary units
--1 mol of Aluminum is = 6.02×10^{23} atoms
--1 mol of CO is = 6.02×10^{23} molecules
Molar Specific Heat

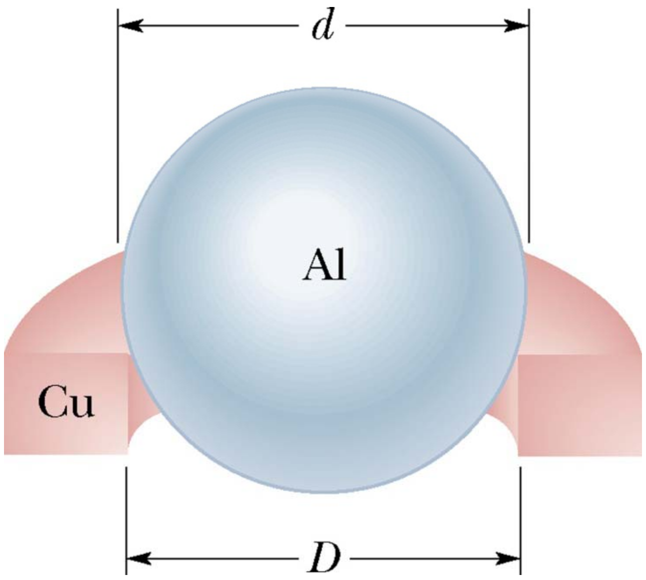
TABLE 18-3

Some Specific Heats and Molar Specific Heats at Room Temperature

Substance	Specific Heat $\frac{cal}{g \cdot K}$	Specific Heat $\frac{J}{kg \cdot K}$	Molar Specific Heat $\frac{J}{mol \cdot K}$
Elemental Solids			
Lead	0.0305	128	26.5
Tungsten	0.0321	134	24.8
Silver	0.0564	236	25.5
Copper	0.0923	386	24.5
Aluminum	0.215	900	24.4
Other Solids			
Brass	0.092	380	
Granite	0.19	790	
Glass	0.20	840	
Ice (−10°C)	0.530	2220	
Liquids			
Mercury	0.033	140	
Ethyl alcohol	0.58	2430	
Seawater	0.93	3900	
Water	1.00	4180	

Absorption of heat: 18#42

A 20.0 g copper ring at 0.000 ^{0}C has an inner diameter of D=2.54000 cm. An Al sphere at 100.0 ^{0}C has a diameter of d= 2.54508 cm. The sphere is placed on top of the ring and the two are allowed to come to thermal equilibrium, with no heat lost to the surroundings. The sphere just passes through the ring at the equilibrium temperature. What is the mass of the sphere???



First find the temperature where D=d

$$\text{D}=\text{D}_0\left(1+\alpha_{Cu}\left(T_f-0\right)\right)$$

$$d_f=d_i\left(1+\alpha_{Al}\left(T_f-100\right)\right)$$

$$2.54000\left(1+\alpha_{Cu}\left(T_f-0\right)\right)=2.54508\left(1+\alpha_{Al}\left(T_f-100\right)\right)$$

$$T_f=50.38\,^{0}C$$

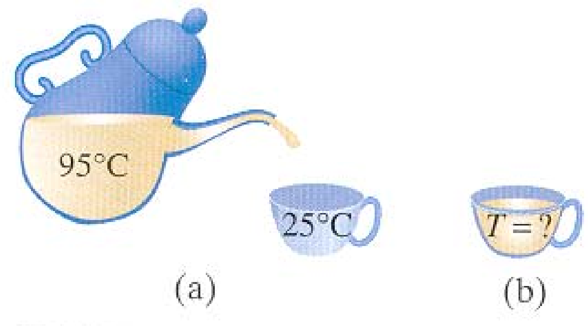
$$\textit{Heat}\text{ into ring Q=c}_{Cu}m_rT_f$$

$$\text{Heat from Sphere }|Q|=c_{Al}m_s\left(T_f-T_i\right)$$

$$m_s=\frac{\text{c}_{Cu}m_rT_f}{c_{Al}\left(T_f-T_i\right)}$$

Example: Calorimetry

If 0.20 kg of tea at 95°C is poured into a 0.15 kg glass cup initially at 25 °C , what will be the final temperature T_f of the mixture when equilibrium is reached, assuming no heat flows to the surroundings
(c_{glass} = 840 J/kg·K & c_{water} = 4190 J/kg·K)



Heat lost = heat gained or ∑Q=0

$$c_w m_w (95 - T_f) = c_g m_g \left(T_f - 25\right)$$

$$4190 \bullet 0.25(95 - T_f) = 840 \bullet 0.15\left(T_f - 25\right)$$

I get

$$T_f = 87.5\,^0C$$