Lecture 3

Temperature, Thermal expansion, and Heat

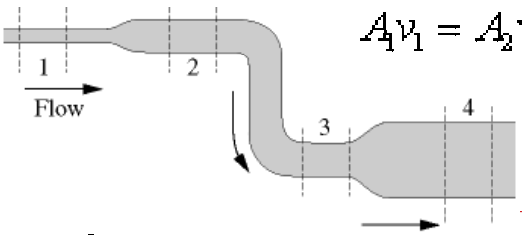
(NJIT Physics, Chapter 10)

http://web.njit.edu/~sirenko/Phys-103-2005/Phys-103-2012.htm

Physics 103 Spring 2012

Last Lecture: Bernoulli's Equation

Water flows smoothly through the pipe shown in the figure, descending in the process. Rank the four numbered sections of pipe according to (a) the volume flow rate R_V through them, (b) the flow speed v through them, and (c) the water pressure p within them, greatest first.



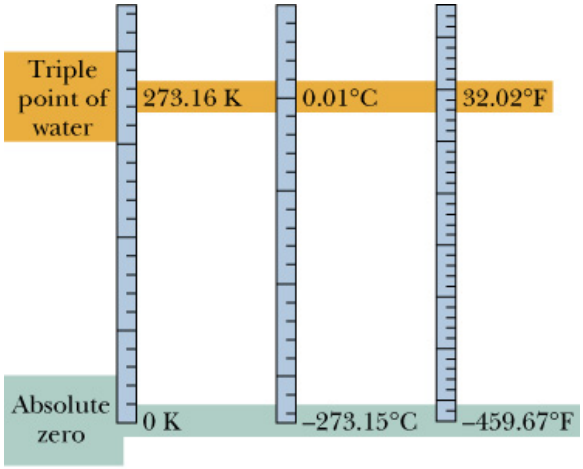
$A_1 v_1 = A_2 v_2$ (equation of continuity).

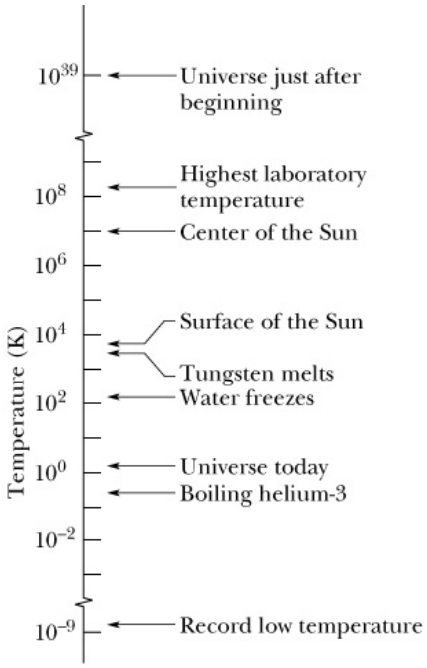
$p + \frac{1}{2}\rho v^2 + \rho g y = \text{a constant}$ (Bernoulli's equation).

$R_V = Av = \text{a constant}$ (volume flow rate, equation of continuity),

a) all tie;
b) 1, then 2 and 3 tie, 4 (wider means slower);
c) (c) 4, 3, 2, 1 (wider and lower mean more pressure)

What is Temperature anyway ?





Temperature is one of the basic SI quantities.
Cannot be expressed through kg-m-s

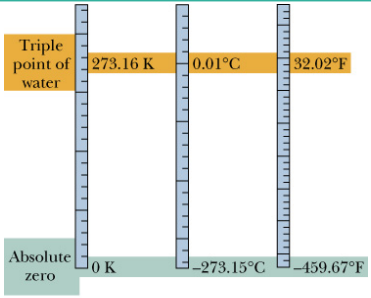
Temperature in C and F

TABLE 19-1 Some Corresponding Temperatures

Temperature	°C	°F
Boiling point of water[a]	100	212
Normal body temperature	37.0	98.6
Accepter comfort level	20	68
Freezing point of water[a]	0	32
Zero of Fahrenheit scale	≈ -18	0
Scales coincide	-40	-40

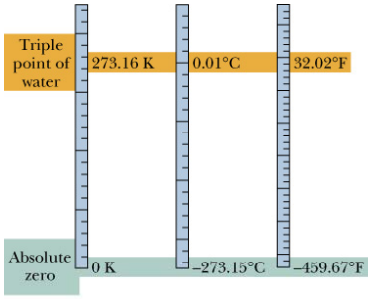
$$T_F = \frac{9}{5}T_C + 32^\circ.$$

$$T_C = T - 273.15^\circ.$$

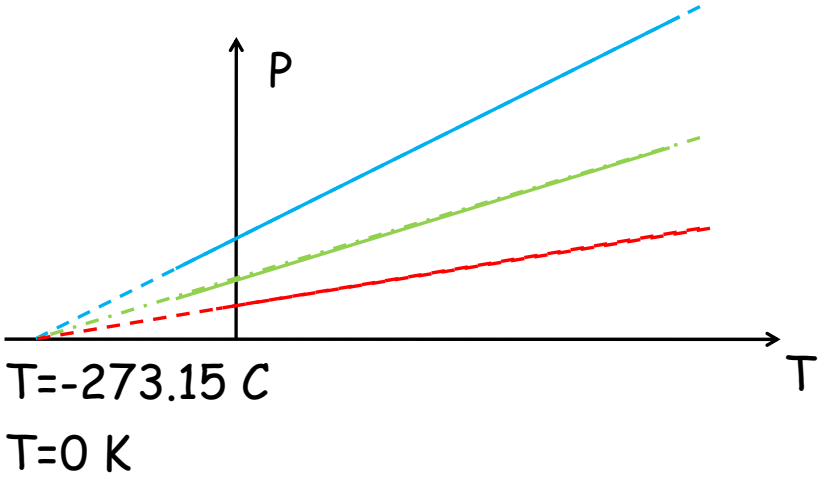


$$0^\circ\,\mathrm{C} = 32^\circ\,\mathrm{F}$$

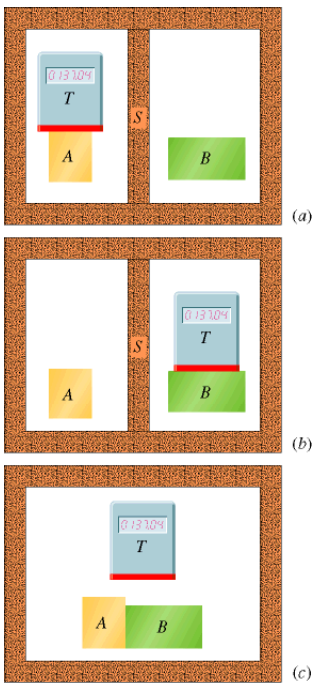
$$5\,\mathrm{C}^\circ = 9\,\mathrm{F}^\circ$$



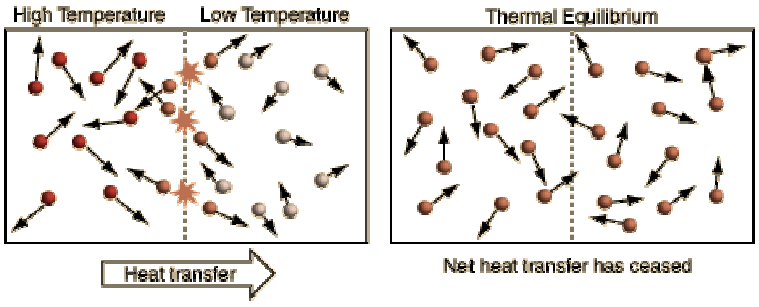
T=0 what is that?



Zero'th law of Thermodynamics

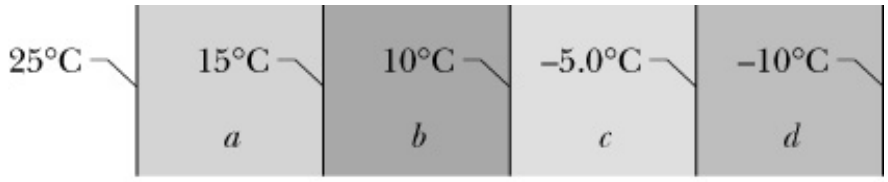


If bodies *A* and *B* are each in thermal equilibrium with a third body *T*, then they are in thermal equilibrium with each other



Temperature difference determines the Heat transfer process

What is the direction for the heat transfer Between a,b,c,d?



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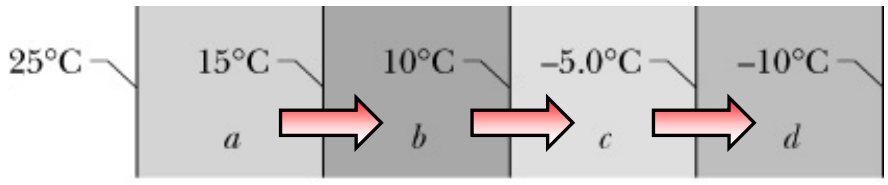

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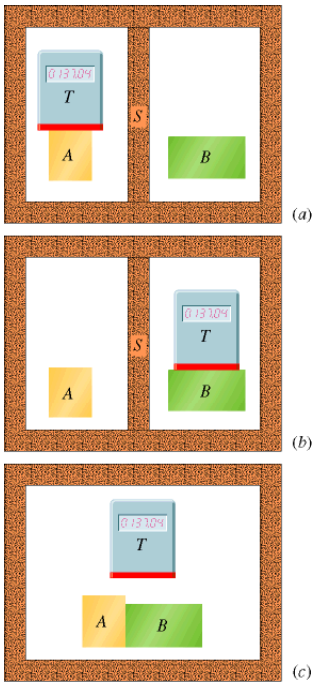

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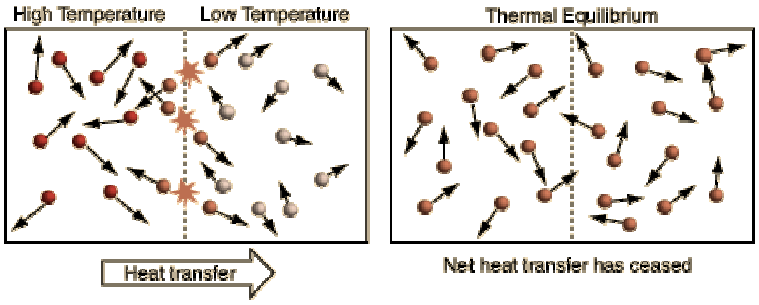
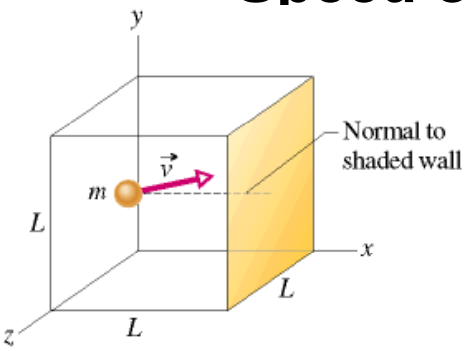
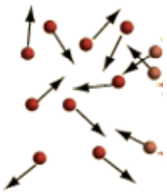


Pressure, Temperature, and Speed of molecules





$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

mN_A is the molar mass M

Root-mean-square speed

$$K_{avg} = \frac{1}{2}mv_{avg}^2 \sim T$$

$$K_{avg} = \frac{1}{2}mv_{avg}^2 = \frac{3}{2}k_BT$$

k_B – Boltzman Constant

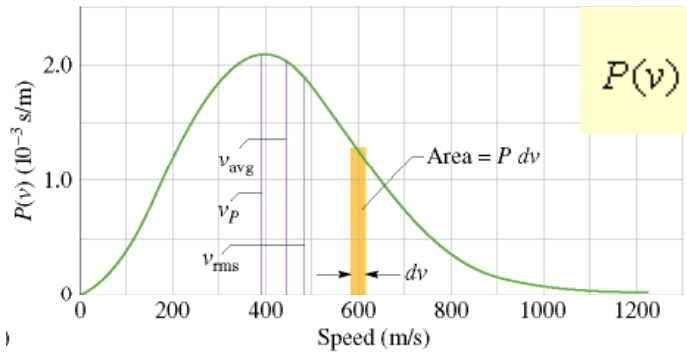
Boltzmann constant = 1.3806503 × 10^{-23} m^2 kg s^{-2} K^{-1}

Some Molecular Speeds at Room Temperature (T = 300 K)[a]

Gas	Molar Mass (10^{-3} kg/mol)	v_{rms} (m/s)
Hydrogen (H_2)	2.02	1920
Helium (He)	4.0	1370
Water vapor (H_2O)	18.0	645
Nitrogen (N_2)	28.0	517
Oxygen (O_2)	32.0	483
Carbon dioxide (CO_2)	44.0	412
Sulfur dioxide (SO_2)	64.1	342

[a]For convenience, we often set room temperature = 300 K even though (at 27°C or 81°F) that represents a fairly warm room.

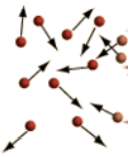
The Distribution of Molecular Speeds

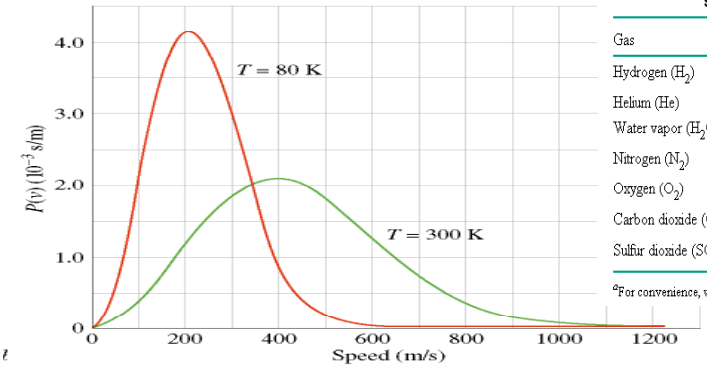


$$P(v) = 4\pi \left(\frac{M}{2\pi RT}\right)^{3/2} v^2 e^{-Mv^2/2RT}$$

$$v_{escape} \approx (2gR)^{1/2}$$

$$v_{escape} \approx 11{,}000 \text{ m/s}$$





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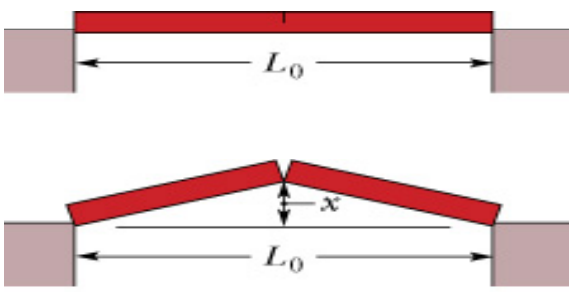
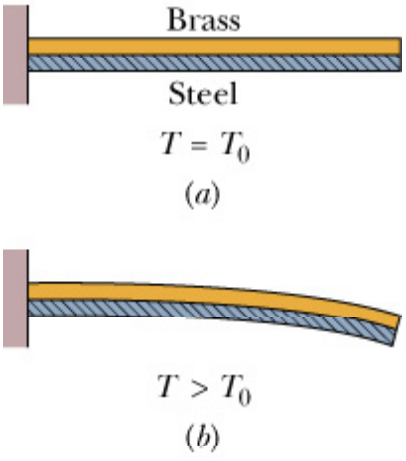
Linear thermal expansion





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

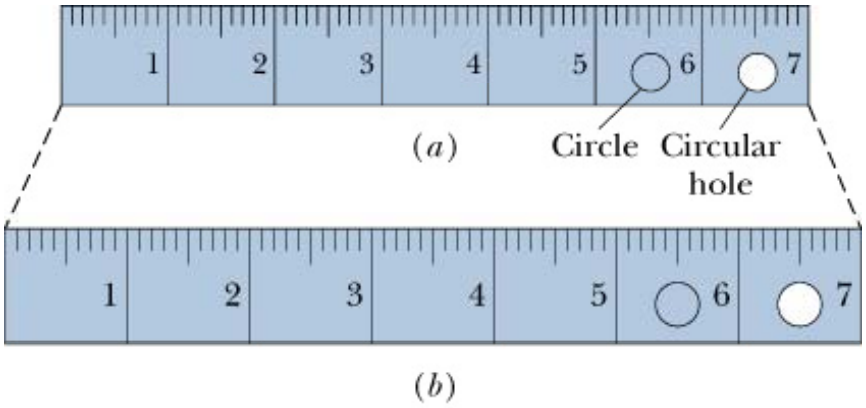
Some Coefficients of Linear Expansion[a]

Substance	α (10^{-6}/C°)	Substance	α (10^{-6}/C°)
Ice (at 0°C)	51	Steel	11
Lead	29	Glass (ordinary)	9
Aluminum	23	Glass (Pyrex)	3.2
Brass	19	Diamond	1.2
Copper	17	Invar[b]	0.7
Concrete	12	Fused quartz	0.5

[a]Room temperature values except for the listing for ice.

[b]This alloy was designed to have a low coefficient of expansion. The word is a shortened form of "invariable."

2D and 3D expansion

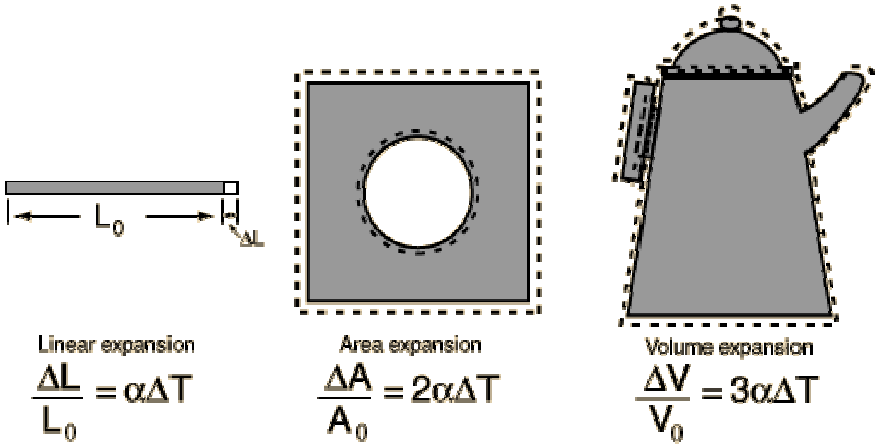


$$\Delta V = V \beta \Delta T,$$

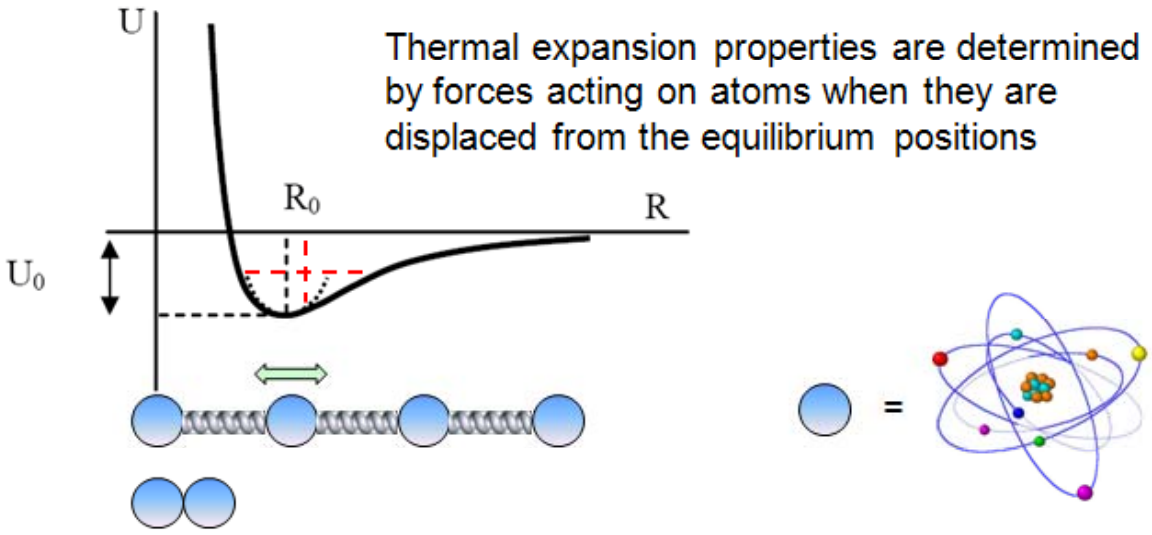
$$\beta = 3\alpha.$$

Thermal expansion (continued)

Why days are longer
During the Summer time?



Thermal expansion (atomic model)



Thermal expansion properties are determined by forces acting on atoms when they are displaced from the equilibrium positions

Thermal expansion

The coefficient of expansion of a certain steel is 0.000012 per C°. The coefficient of volume expansion, in $(C°)^{-1}$, is:

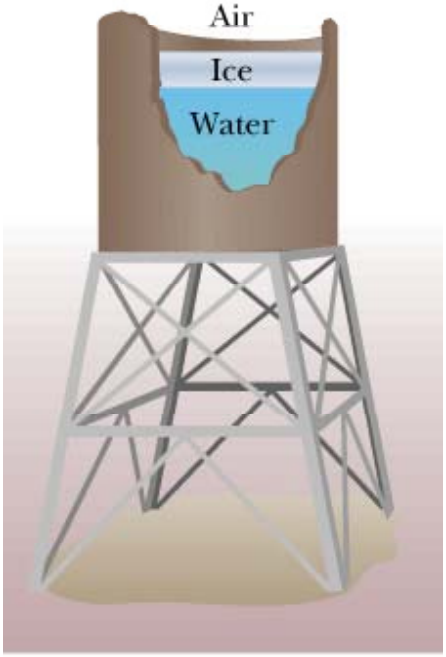
- **A.** $(0.000012)^3$
- **B.** $(4\pi/3)(0.000012)^3$
- **C.** 3×0.000012
- **D.** 0.000012
- **E.** depends on the shape of the volume to which it will be applied

What is the ocean level increase due to +1 C° global warming ?
Water linear expansion coefficient is ~69e-6/C° at 20 C°.
Average ocean depth is 4 km

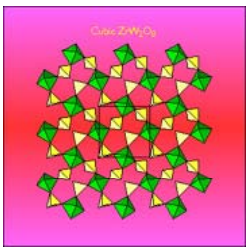
Properties of Water (H_2O)

negative thermal expansion of water between 0 and 4 C

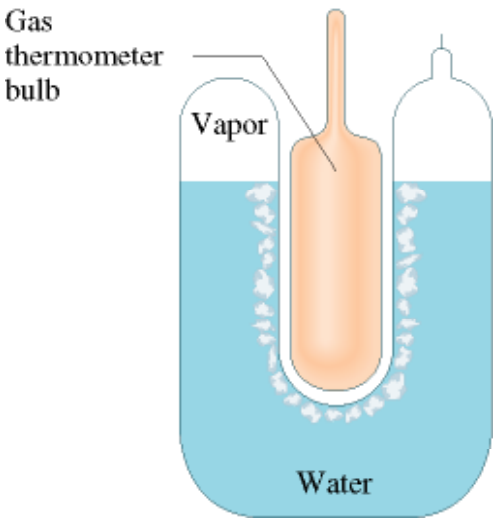
Freezes at 0 C, boils at 100 C



negative thermal expansion in ZrW_2O_8



The Triple Point of Water



A triple-point cell, in which solid ice, liquid water, and water vapor coexist in thermal equilibrium. By international agreement, the temperature of this mixture has been defined to be 273.16 K. The bulb of a constant-volume gas thermometer is shown inserted into the well of the cell.

Thermal Expansion: QZ#2

When is the Empire State building taller?

A. On Mondays
B. During rush hour
C. On a sunny Summer day
D. During Moon eclipse
E. Valentines Day

Metal pipes, used to carry water, sometimes burst in the winter because:

- **A.** metal contracts more than water
- **B.** outside of the pipe contracts more than the inside
- **C.** metal becomes brittle when cold
- **D.** ice expands when it melts
- **E.** water expands when it freezes