Announcements – 5 Nov 2009

1. Exam solutions posted to the website

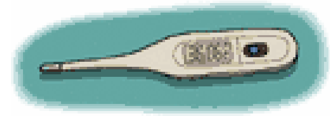
2. If your exam grade doesn't match what you remember from the Testing Center, it's probably because our website shows you the grade out of 92 (not the percentage)

3. You can pick up your exams at the usual place

4. The handwritten problems (out of 8 pts) will hopefully be graded within a couple of days.
   a. You will be able to pick them up same place, too

5. In case you are curious…
   a. 80% of class got velocity vs. time graph right (up from 66%)
   b. 72% of class got work done by normal force (up from 62%)
   c. 76% of class got cat burglar (up from 44%)
   d. 74% of class got tension in hanging mass problem (up from 46%)

Temperature scales



Celsius

Kelvin

Fahrenheit

From warmup: Which is coldest?
  a. 0 degrees Centigrade (Celsius)
  b. 0 degrees Kelvin
  c. 0 degrees Fahrenheit

What is a **thermometer**?

Expansion
Thermocouples
Resistors
Semiconductors

Demo: two thermometers

→ Just find some property you can measure that changes consistently with temperature

What is **temperature**?

Two objects in thermal contact will come to thermal equilibrium: they then have the "same temperature"

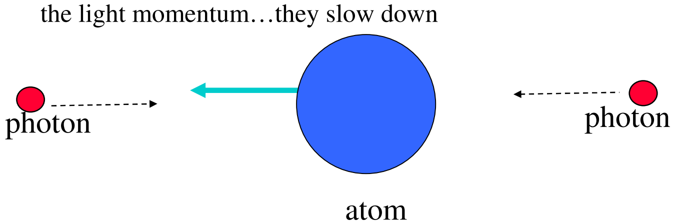
What is "thermal contact"?
→ able to e____________ h________

What is heat?

Is there a maximum temperature?

Is there a minimum temperature?

"Laser Cooling"
Atoms slowed by light (2000 Nobel Prize)
tuned so only atoms moving *toward* the laser beam can absorb the light momentum…they slow down



Thermal expansion:

For a given material, lengths all change by the same percentage, per degree.

$$\Delta L = \alpha L_o \Delta T$$
$$\Delta A = \gamma A_o \Delta T$$
$$\Delta V = \beta V_o \Delta T$$

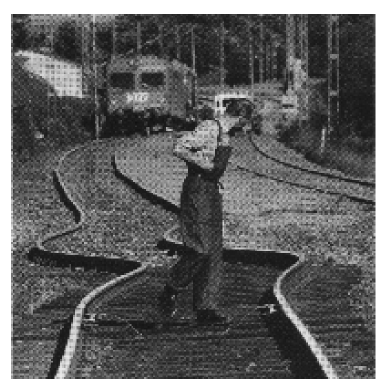
For solids:
$\gamma = 2\alpha$
$\beta = 3\alpha$

For reference: $\alpha_{steel} \approx 11\times10^{-6}$ /°C

You heat up a 1 meter steel rod by 1 degree C. How long is it now?

Demo: bimetallic strip

What went wrong here?

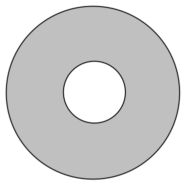


Microscopic View

Why do most materials expand when heated?

From warmup: You heat a disc with a hole in it. Will the radius of the hole get larger, smaller, or stay the same?

a. Larger
b. Smaller
c. Stay the same



Demo: ball and washer

Ideal gases

1. Molecules collide like superballs (elastic) due to repulsive forces
2. No attractive forces
3. Never condense into liquids or solids
4. Are like "frictionless surfaces", "massless pulleys", "perfect fluids", etc.

Essentially ideal:

Ideal gas law:

Where does it come from?

1.

2.

Thermodynamics:

Wish to explain behavior of huge numbers of particles in terms of simple variables

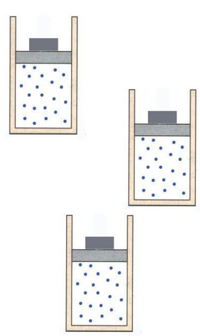
Experiments on gases:

Hold T constant, increase P
Volume…

Hold P constant, increase T:

Volume…

Hold P, T constant, increase N
Volume…



Combine the experimental results

$$\frac{PV}{NT} = \text{constant} = k_B$$ Boltzmann's constant

$k_B = 1.381 \times 10^{-23}$ J/°K

Must use:
T in Kelvin
Absolute P

$$\boxed{PV = Nk_BT}$$ Ideal gas law! (Physics version)

Important: N is number of *molecules*

From warmup: Ralph is confused…the book calls two different equations "the ideal gas law". In equation 10.8 (8th edition), the equation is "PV = nRT". But in equation 10.11 (8th edition), the equation is "PV = Nk_BT". Why are they both called the ideal gas law, when only the first equation looks like what he learned in chemistry?

Answer from the class:

From warmup: Suppose we have two jars of gas: one of helium and one of neon. If both jars have the same volume, and the two gases are at the same pressure and temperature, which jar contains the greatest number of gas molecules? (Both gases obey the ideal gas law. The mass of a neon molecule is greater than the mass of a helium molecule.)

a. jar of helium
b. jar of neon
c. same number

Avagadro's Number
…and other chemistry concepts

Chemists measure quantity in **moles**:
N_A = 1 mole = Avagadro's number (N_A)

N = # molecules
n = # moles: $n = N/N_A$

"molar mass": mass of one mole
(careful: commonly given in *grams*)
$n = m/MM$

May need to convert to kg!

Chemistry Ideal Gas Law:

$$PV = nRT$$

with R = $N_A \times k_B$ = 8.314 J/mole°K
= 0.08206 liter-atm/mole°K

Demo: liquid nitrogen and balloons

Worked Problem: In an engine piston, with air at 1 atm, the volume is decreased from 200 cm^3 to 40 cm^3, while the temperature increases from 300 K to 600 K. Find the final pressure.

Method 1: Find N (or n)

Method 2: ratios

Answer: 1.01×10^6 Pa, 10 atm

An old-fashioned glass milk jug is "empty" (still has air), at 20° C. You seal it, then put it into a fire at 500° C.

Note: assuming the jug doesn't burst, N and V are constant.

Clicker quiz: Using the ideal gas law, what is the final pressure in the jug?

a. 0-1 atm
b. 1-2 atm
c. 2-4 atm
d. 4-10 atm
e. 10+ atm

Worked Problem: If instead of being totally empty the jug had a mole of water molecules in it (about 18 g), how much pressure would they exert after being vaporized (assuming the jug still doesn't break)?

Demo: nitrogen in tube and balloon

Worked Problem: What is the mass of all the air in this room? (The average molar mass of molecules in air is 29.0 g/mol.)

Worked Problem: Use the ideal gas law to determine the density of air at 1 atm and 300K (80° F). (MM_{air} = 29 g/mol)

Answers: depends on room size; 1.175 kg/m^3

Hard Worked Problem (if time): A hot air balloon wants to lift off on an 80° F day. The balloon fabric and basket weight 200 kg, and there are four 80 kg passengers. The balloon is spherical, with an 8 m radius. How hot do they have to get the air inside the balloon? *Hint*: Do not neglect the weight of the hot air inside the balloon!
Plan: (a) figure out the maximum mass of hot air, (b) then the density of the hot air, then (c) figure out what temperature gives that density

Answers: 2000.0 kg; 0.9325 kg/m^3; 378 K