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%)

6) Table Tennis Tournament a week from Sat!
Email me if you want in!

$$\frac{P}{\rho} + \frac{v^2}{2} + gz = \ldots \checkmark$$

$$\frac{P}{\rho} + \frac{\frac{1}{2}\rho v^2}{\rho} + \frac{\rho g y}{\rho} = \frac{\text{Constant}}{\rho}$$

Which part of today's assignment was particularly hard or confusing?

This is more about the lesson on Tuesday. I was told that the pressure in a smaller tube will be greater and was given the example of a straw: it's easier to drink through a wider straw than a more narrow one so the more narrow one has more pressure right? But that seems to go against what we learned on Tuesday. ↓

viscosity

General comments:

I have a question. Last lecture you said that wind blowing over a roof, if going fast enough, will rip it up because of the pressure differnce. Does this mean that if i had fallen in a pit and was looking to divine intervention for rescue, all i would have to do is pray that it gets really windy. Would that even be possible to "suck" me out of the pit just by the wind? If you have enough faith...

In what situations would it be appropriate to use R=8.31 J/mol*K, and when would i use R=0.0821 L*atm/mol*K ?

↳ in Chemistry class

↳ in physics classes

did anyone get a 100 on the exam? **Yes: 18 people**

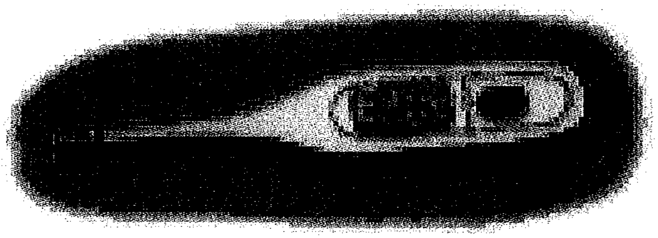
When and where do our FBD points show up from the exam?

It's not degrees Kelvin, it's just Kelvin.

or kelvins

In golf there are certain types of drivers prohibited in play because the type of metal and weight of the driver can give the golfer an unfair advantage. Are there regulations on table tennis paddles too? If not, how much do you think a pure chrome paddle would cost me?

Temperature scales



Celsius 0 100
water freezes water boils

Kelvin 0 $T_K = T_c + 273.15$
absolute zero

Fahrenheit 0 100 $T_F = \frac{9}{5} T_c + 32$
freezing pt of ice-salt body temp

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 exchange heat

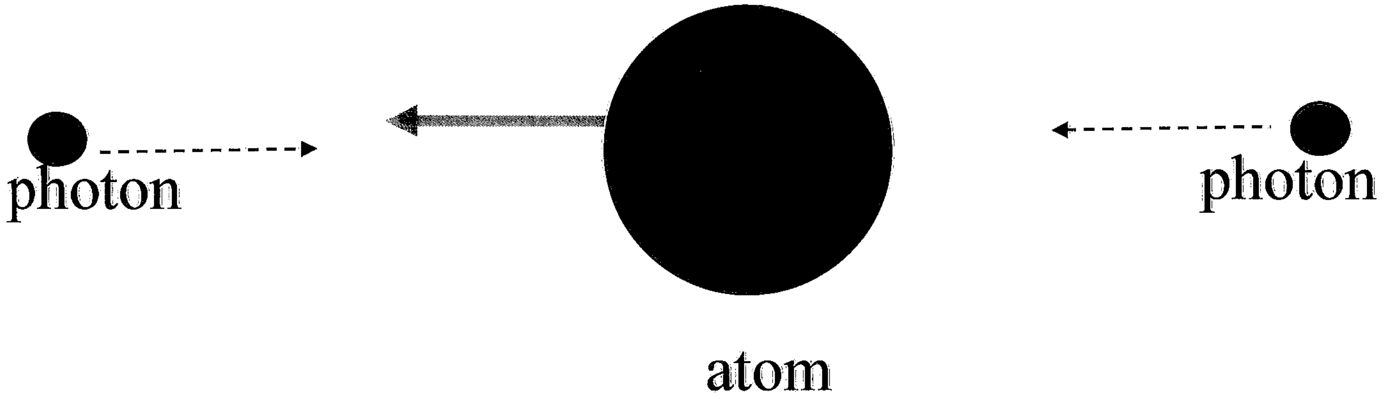
What is heat? random kinetic energy

Is there a maximum temperature? No

Is there a minimum temperature? Yes absolute

"Laser Cooling" 10 nK

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.

linear coefficient of expansion

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

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

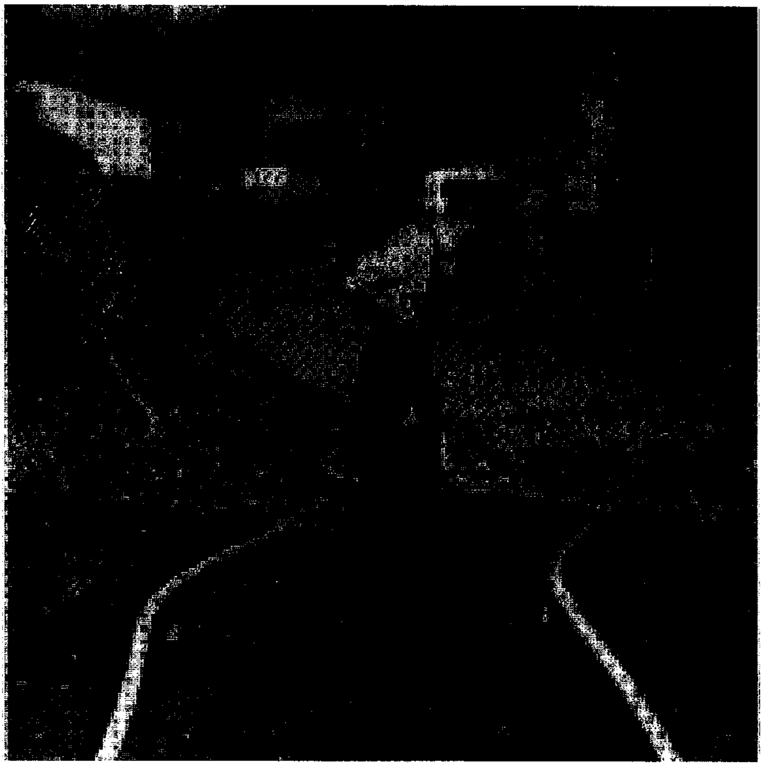
For reference: $\alpha_{\text{steel}} \approx 11\times10^{-6}$ /°C .000011

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

1.000011 m

Demo: bimetallic strip

What went wrong here?



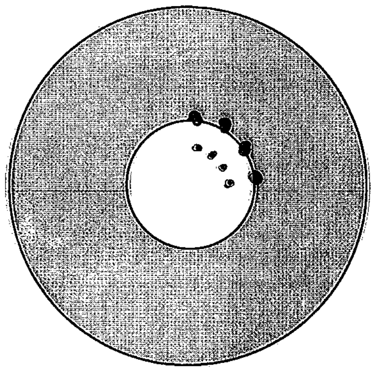
Microscopic View

Why do most materials expand when heated?

atoms "jiggle"

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: far from condensing

Ideal gas law:

$$\underset{\text{pressure}}{P}\,\underset{\text{volume}}{V} = \underset{\substack{\text{number}\\\text{of moles}}}{n}\,\underset{\text{constant}}{R}\,T \leftarrow \text{temperature}$$

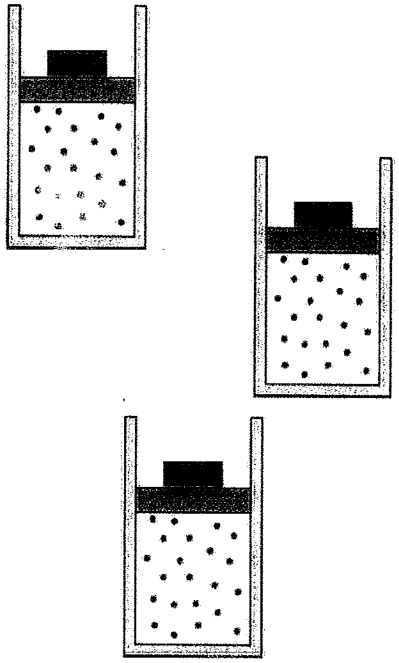
Where does it come from?

1. Experiment : Charles, Gay-Lussac, Boyle
2. Kinetic Theory

Thermodynamics:

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

Experiments on gases:



Hold T constant, increase P
    Volume… decrease

Hold P constant, increase T:

    Volume… increases

Hold P, T constant, increase N
    Volume… increases

Combine the experimental results

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

$$k_B = 1.381 \times 10^{-23} \text{ J/°K}$$

Must use:
T in Kelvin
Absolute P

$$\boxed{PV = Nk_BT}$$

Ideal gas law!
(Physics version)

Important: N is number of *molecules*

From warmup: 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.)

$PV = nRT$

a. jar of helium
b. jar of neon
[✓ c.] same number

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:

270-------------------------
little n is the number of moles and big N is the number of molecules so N/Avogadro's number is equal to little n and can be substituted and simplified to NkB because kB = R /Avogadro's number

Avagadro's Number
…and other chemistry concepts"

Chemists measure quantity in **moles**: like a "dozen"

N_A = 1 mole = $6.022 \cdot 10^{23}$ Avagadro's number (N_A)

N = # molecules

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

1 mole of H atoms = 1 gram

1 mole of O_2 molecule = 32 grams

"molar mass": mass of one mole

(careful: commonly given in *grams*)

$n = m/MM$

May need to convert to kg!

Chemistry Ideal Gas Law:

$$\boxed{PV = nRT}$$

with R = $N_A \times k_B$ = 8.314 J/mole°K

= 0.08206 liter-atm/mole°K

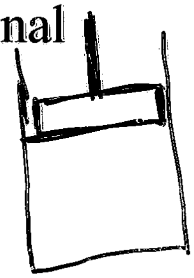
Demo: liquid nitrogen and balloons

$200\,\cancel{cm}^{\cancel{3}\,2} \times \frac{1\,m}{100\,\cancel{cm}} \times \frac{1\,m}{100\,\cancel{cm}} \times \frac{1\,m}{100\,\cancel{cm}}$

$\boxed{1.01 \cdot 10^5\,Pa}$

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.

$200\,cm^3 \times \left(\frac{1\,m}{100\,cm}\right)^3$



Method 1: Find N (or n)

$PV = nRT$

initially $n = \frac{PV}{RT} = \frac{(1.01 \cdot 10^5)\left(\frac{200}{1000000}\right)}{(8.31)(300)} = \underline{\qquad}$

final $PV = nRT$

$P_f = \frac{nRT}{V} = \frac{(\quad)(8.31)(600)}{\frac{40}{1000000}} = \boxed{1.01 \cdot 10^6\,Pa}$

Method 2: ratios

$n = \text{constant}$

$nR = \text{constant}$

$\frac{PV}{T} = \text{constant}$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \rightarrow \frac{(1\,atm)(200\,\cancel{cm^3})}{(300\,\cancel{K})} = \frac{(P_2)(40\,\cancel{cm^3})}{(600\,\cancel{K})}$

$\boxed{P_2 = 10\,atm}$

Answer: 1.01×10^6 Pa, 10 atm

(1 liter) = .001 m^3

293 K

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.

773K

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

$PV = nRT \qquad \frac{nR}{V} = \text{constant}$

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

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = P_1 \frac{T_2}{T_1} = (1\,\text{atm})\left(\frac{773}{293}\right)$$

$$= 2.6\ \text{atm}$$

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)? $PV = nRT$

$$P = \frac{nRT}{V}$$

$$= \frac{(1\ \text{mole})(8.31\ \frac{\text{J}}{\text{mol}\cdot\text{K}})(773\ \text{K})}{.001\ \text{m}^3}$$

$$= 6.42 \times 10^6\ \text{Pa} = \boxed{63\ \text{atm}}$$

Demo: nitrogen in tube and balloon

$30\text{m} \times 20\text{m} \times 6\text{m}$

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.)

$$PV = nRT$$

$$(1.01 \cdot 10^5\,\text{Pa})(30 \times 20 \times 6\ \text{m}^3) = n\left(8.31\,\frac{\text{J}}{\text{mole}\cdot\text{K}}\right)(298\,\text{K})$$

$$n = \underline{\ 1.47 \cdot 10^5\ }\ \text{moles}$$

$$1.47 \cdot 10^5\ \text{moles} \times \frac{.029\,\text{kg}}{\cancel{.029\,\text{kg}}\ 1\,\text{mole}} = \boxed{\underline{4257\,\text{kg}}}$$

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)

$$PV = nRT \qquad n = \frac{m}{MM}$$

$$PV = \left(\frac{m}{MM}\right)RT$$

$$\text{rho}\ \rho = \frac{m}{V} = \frac{P(MM)}{RT} = \frac{(1.01 \cdot 10^5\,\text{Pa})(.029\,\text{kg/mole})}{\left(8.31\,\frac{\text{J}}{\text{mol}\,\text{K}}\right)(300\,\text{K})}$$

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

$$= \boxed{1.175\,\frac{\text{kg}}{\text{m}^3}}$$

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