Total Grade

Physics 105 grades – 10 Nov 2008. Each "•" is one student

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~10% A's

~17% A-

~12% B+

~15% B

~7% B-

~8% C+

~15% C

~7% C-

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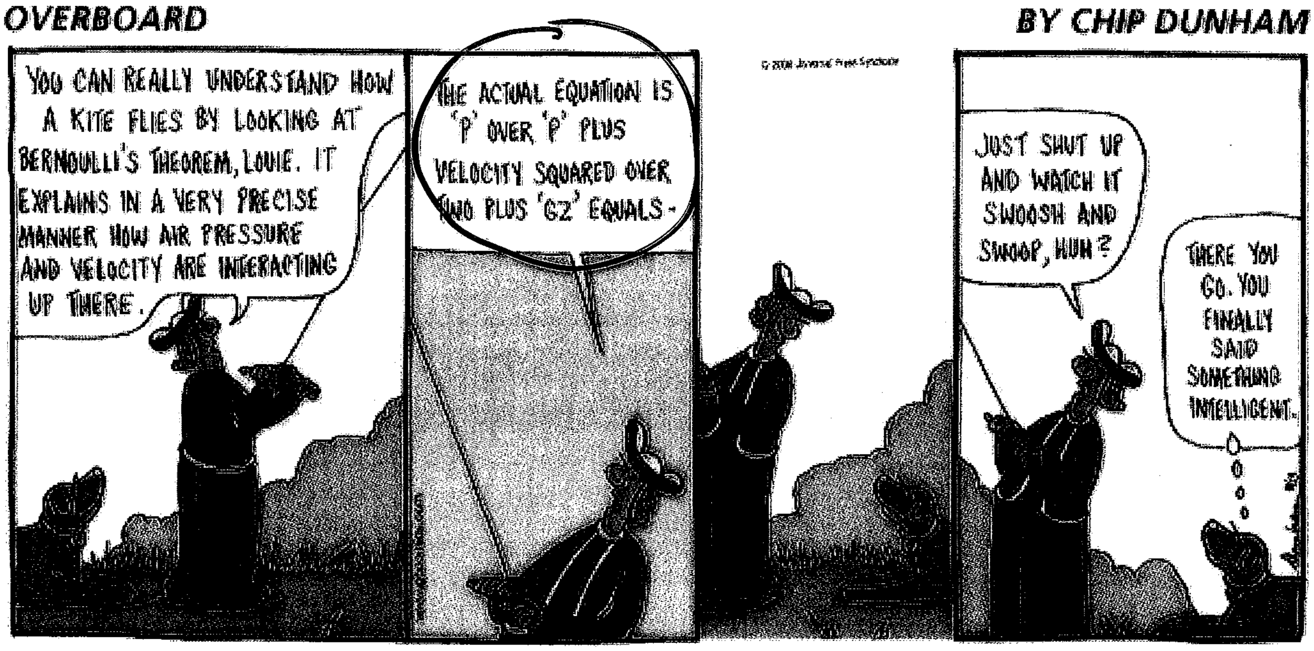
~3% D+

~.3% D

~1% D-

~5% E



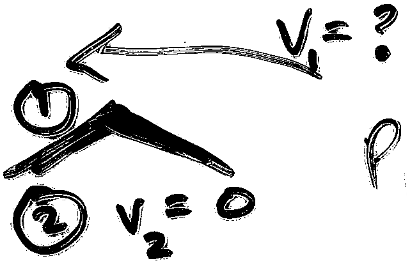
$$\frac{P}{\rho} + \frac{V^2}{2} + gz = \text{constant also}$$

$\times \rho$

$$P + \frac{1}{2}\rho V^2 + \rho g z = \text{Constant}$$

From last time…

Worked Problem: A flat roof of area 400 m^2 will rip off if it is subjected to a lift force of 5×10^5 N. What speed of horizontal wind will rip off the roof? (weight of the roof is included in 5×10^5 N number). $\rho_{air} = 1.29$ kg/m^3



$$P_1 + \frac{1}{2}\rho v_1^2 + \cancel{\rho g h_1} = P_2 + \overset{0}{\cancel{\frac{1}{2}\rho v_2^2}} + \cancel{\rho g h_2}$$

$$\Delta P = P_2 - P_1 = \frac{1}{2}\rho v_1^2$$

$h_1 \approx h_2$

$P = F/A$

$F_{net} = (\Delta P)A$

$$F_{net} = \left(\frac{1}{2}\rho \textcircled{v_1}^2\right) A$$

$$5\cdot10^5 = \frac{1}{2}(1.29)v_1^2\ (400)$$

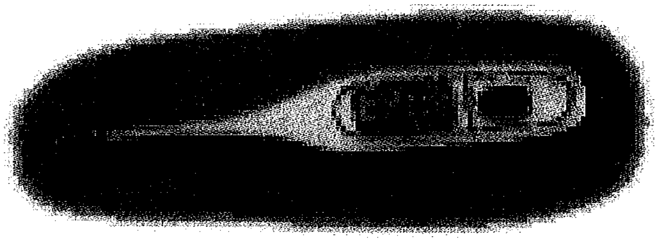
$$\boxed{v_1 = 44.0\ \text{m/s}}$$

Answer: 44.0 m/s

Clicker quiz: A ball is thrown toward you, spinning so that the left side of the ball (as you look at it) spins toward you, and the right side away. The ball will

a. "float" more than a nonspinning ball
b. "sink" faster than a nonspinning ball
c. curve to your left
[✓ d.] curve to your right

Temperature scales



~~Demo: fanning jar~~

Celsius (Centigrade) melting pt 0°C
boiling pt 100°C

Kelvin 0 K = −273.15 °C

Fahrenheit melting pt of water 32°F
boiling pt " " 212°F

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? Joules

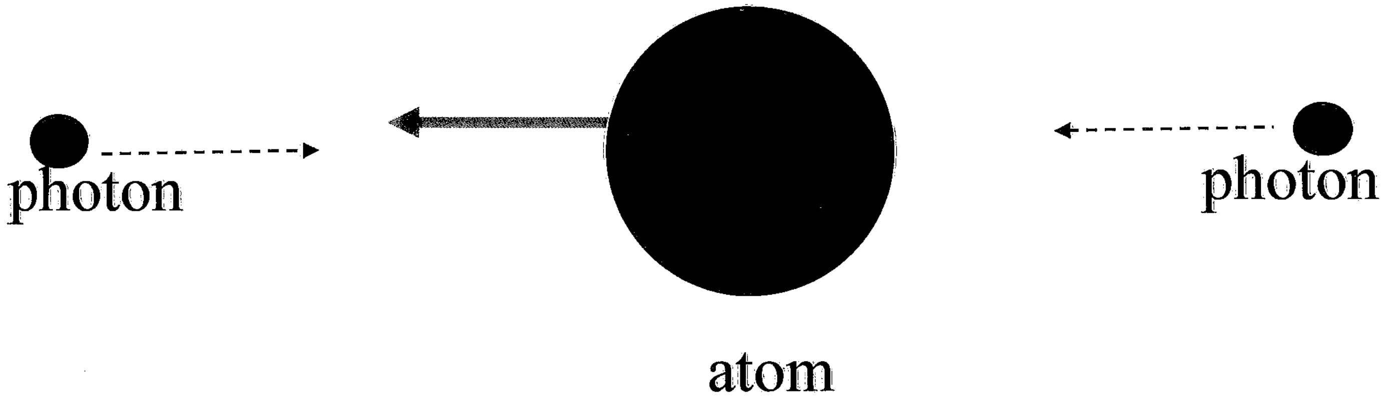
random kinetic energy

Is there a maximum temperature? No

Is there a minimum temperature? Yes 0K

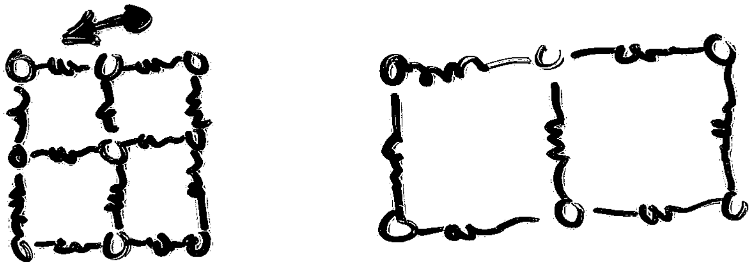
"Laser Cooling" ≈ 100nK $100 \cdot 10^{-9}$ K

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



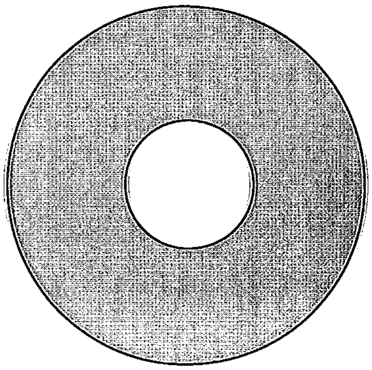
Microscopic View

Why do most materials expand when heated?



Clicker quiz: 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



(Ralph question)

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: Temp is much higher than boiling (Far from condensing)

Ideal gas law: $PV = nRT$ → temp in K

pressure Pa

Volume m^3

"moles"

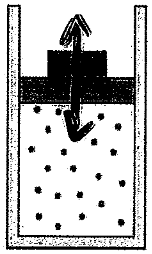
$8.31 \frac{Pa\, m^3}{mole \cdot K}$

Where does it come from?

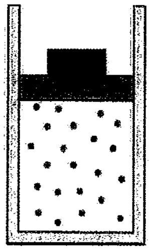
Thermodynamics:

Wish to explain behavior of huge numbers of particles in terms of simple variables: P, V, T, etc

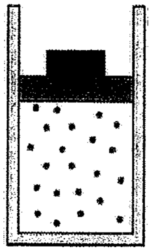
Experiments on gases:



Hold T constant, increase P add more weight
Volume… decreases



Hold P constant, increase T:
Volume… increases



Hold P, T constant, increase N = #molecules
Volume… increases

Combine the experimental results

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

$k_B = 1.381 \times 10^{-23}$ J/°K

$$\boxed{PV = Nk_BT}$$

Ideal gas law!
(Physics version)

Must use:
T in Kelvin
Absolute P

N is number of *molecules*

Avagadro's Number
…and other Chemistry concepts

Chemists measure quantity in **moles**:

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

N = # molecules

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

$$N = n \times 6.022 \times 10^{23} \frac{\text{molecules}}{\text{mole}}$$

"molar mass": mass of one mole

(careful: commonly given in *grams*)

$n = m/MM$

$N_2 = 28\ \text{g/mole}$

May need to convert!

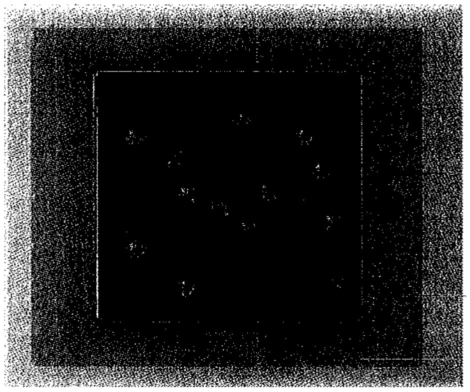
Chemistry Ideal Gas Law:

$$\boxed{PV = nRT} = \left(\frac{N}{N_A}\right) R\, T \quad \left(\text{also} = N k_B T\right)$$

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

= 0.08206 liter-atm/mole°K

Demo: liquid nitrogen and balloons



Molecular view

Not in book

Equipartition Theorem and speed of molecules:

> The total kinetic energy of a system is shared equally among all of its <u>independent parts</u>, on the average, once the system has reached thermal equilibrium.

Specifically, each "degree of freedom", of each molecule, has "thermal energy" of: $\underline{k_B T}/2$

<u>independent parts</u>: larger for molecules that can

- rotate
- vibrate

(requires more than one atom)

→ **such molecules have more "internal energy"**

Average ("rms") <u>kinetic energy</u> of a molecule:

$$\frac{1}{2} m v_{ave}^2 = 3 \times \left(\frac{k_B T}{2}\right)$$

Result: $$\boxed{v_{rms} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{MM}}}$$

An ideal gas has a mixture of heavy and light molecules

Clicker quiz 1: The molecules that move the fastest are…

- a. heavy
- [✓ b. light]
- c. same

Clicker quiz 2: (warmup) The molecules with the most KE are…

$$KE = \frac{1}{2} m v_{ave}^2 = \frac{3}{2} k_B T$$

- a. heavy
- b. light
- [✓ c. same]

Clicker quiz 3: If you have equal numbers of heavy and light molecules in the gas, the ones that exert the most pressure on average are:

$$PV = nRT$$

- a. heavy
- b. light
- [✓ c. same]

(Hint: think of the ideal gas law)