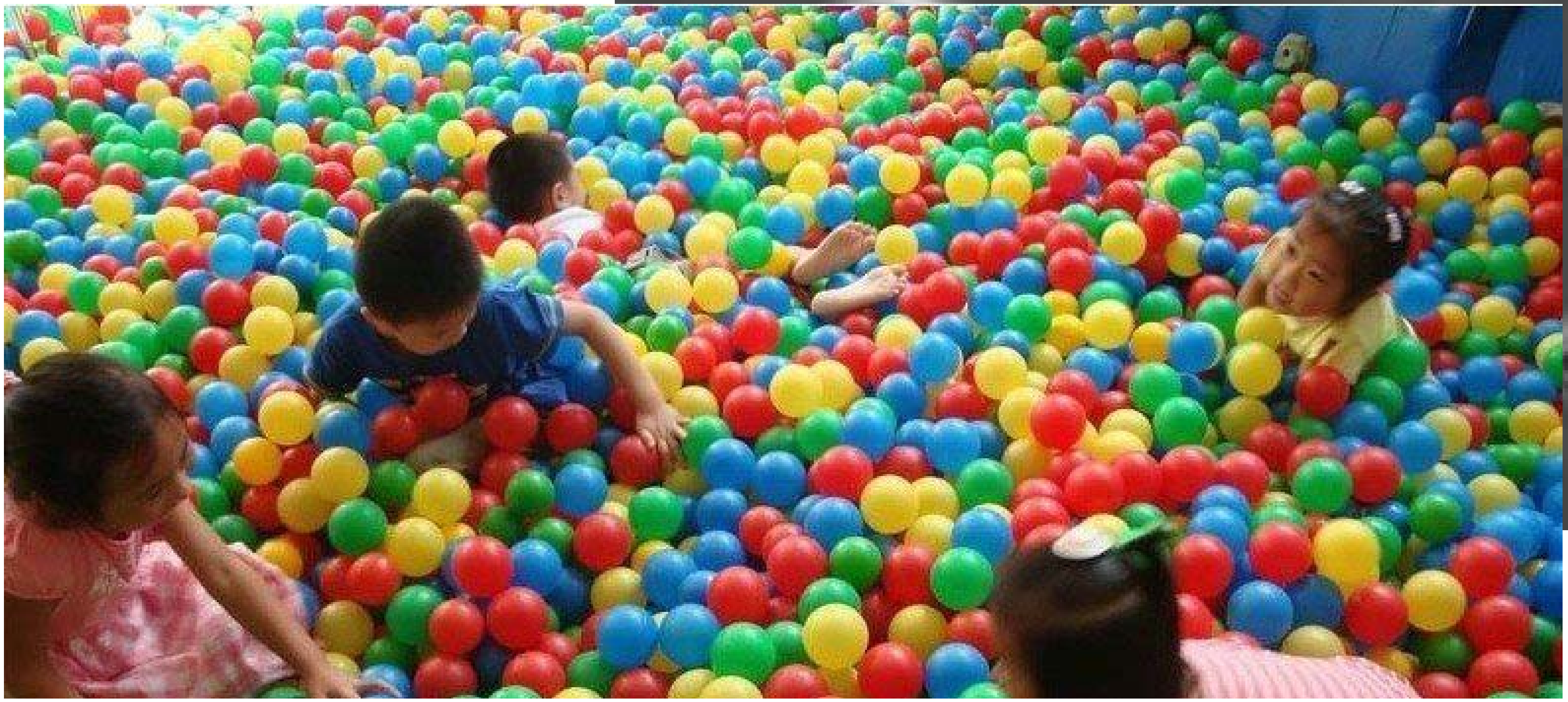
Physics 131 Dr. AP



Does *n* have the same dimension in both equations?

1. Yes
2. No
3. Depends
4. Not sure

$$J = -D\frac{dn}{dx}$$

$$\vec{J} = -D\vec{\nabla}n$$

Kinds of Matter

- Classify objects by how they deform.
  - *Solid*: doesn't change shape if you push on it (not too hard!)
  - *Gel*: looks solid if you don't touch it but is "squishy" and changes shape easily (gelatin ("jello"), butter, clay, whipped cream)
  - *Liquid*: Has no shape of its own. Flows (deforms) to fill a container but has (reasonably) constant volume.
  - *Gas*: Has neither shape nor volume but fills any container (or atmosphere on a planet)
  - LOTS MORE!

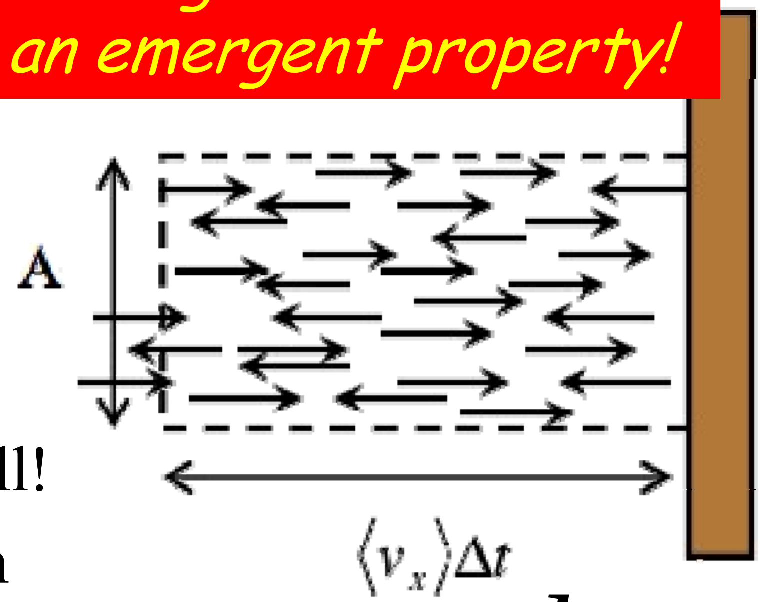
Foothold ideas: Gases – Kinetic Theory I

- We model the gas as lots of tiny little hard spheres far apart (compared to their size) and moving very fast.
- The motions are in all directions and change directions very rapidly. The model that on the average the total momentum is 0 (and stays 0 by momentum conservation) is a good one. (Ignoring wind!)
- Because there are some many particles and the collisions so sensitive to initial conditions, we can't predict the motion of individual particles for long.
- Dilute gases satisfy the Ideal Gas Law, $PV = n_{moles}RT$

Summarizing the model

Average force is an emergent property!

- In between collisions each molecule moves in a straight line – ignoring gravity. (We've used N1!)
- Ignore up and down motions.
- Molecule's change in momentum bouncing off wall exerts a force on wall!
- The force on wall will be the change in momentum of all the molecules that bounce off the wall in time Δt (N2+N3!)
- First, you calculate for **<u>one</u>** molecule in terms of m and v_x. *Hint:* switch from *d/dt* to Δ's. (NOTE just the v_x, not v…why?)



$$F = \frac{dp}{dt}$$

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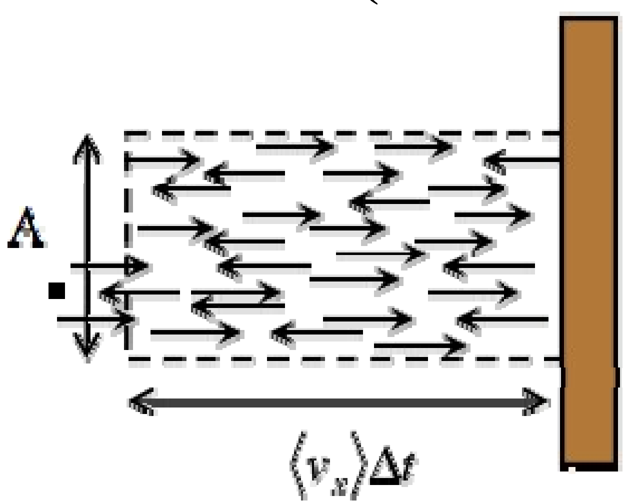
Summarizing the model

- Molecule's change in momentum bouncing off wall exerts a force on wall!

$$F^{contact}_{\text{one molecule on wall}} = \frac{dp}{dt} \approx \frac{2mv_x}{\Delta t}$$

- The force on the wall will be the sum of momentum change from *all* molecules that bounce off the wall in a time Δt (N2 & N3!)



$$F^{contact}_{\text{all molecules on wall}} = \frac{2mv_x}{\Delta t} N$$

But what is *N*? <u>You</u> figure it out in terms of the volume and particle density *n*!

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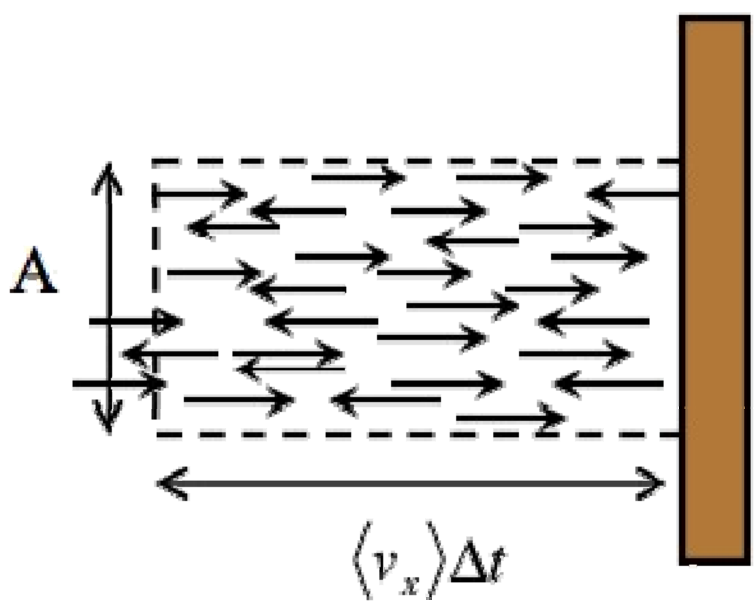
Summarizing the model

- The force on the wall will be the sum of momentum change from *all* molecules that bounce off the wall in a time Δt (N2 & N3!)

$$F_{\text{gas on wall}}^{contact} = \frac{2m\langle v_x\rangle}{\Delta t}\left(\frac{1}{2}nA\lambda\right) = \frac{m\langle v_x\rangle}{\cancel{\Delta t}}\left(nA\langle v_x\rangle\cancel{\Delta t}\right)$$

- So what's the pressure? Think units here… how are pressure and force related?

$$P = \frac{F_{\text{gas on wall}}^{contact}}{A} = nm\langle v_x\rangle^2$$

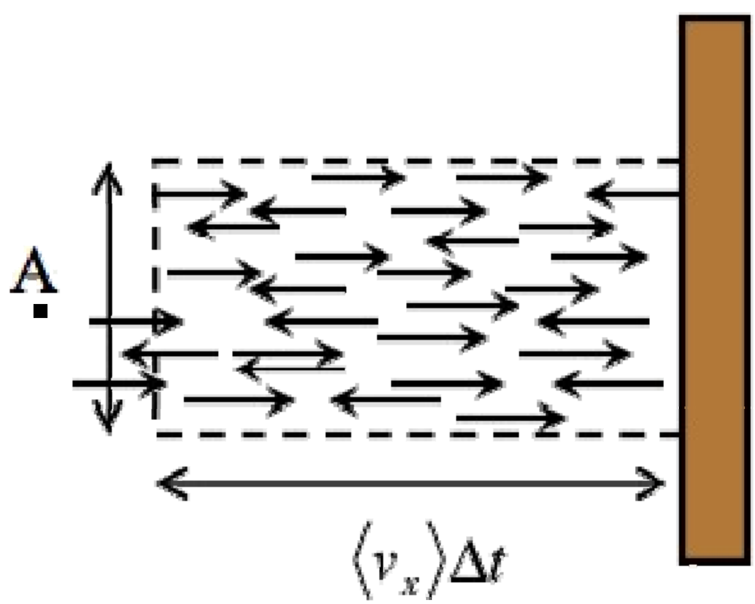


Summarizing the model

- In terms of particle density…

$$P = \frac{F^{contact}_{\text{gas on wall "x"}}}{A} = nmv_x^{\ 2} = \frac{N}{V} mv_x^{\ 2}$$

- And how does v_x relate to the average speed?
- Note that pressure does not have a direction!!!



$$P = nmv_x^{\ 2} = \frac{N}{V} m \frac{\langle v^2 \rangle}{3}$$

Where does temperature come into all this?

Reading questions

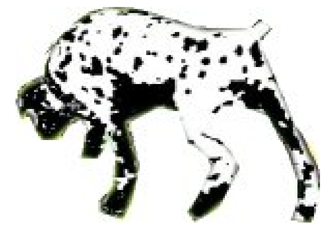
- Why can we ignore the motion of molecules in the y and z motion and not the x motion? Why can't we just look at the y motion and ignore x and z?
- I don't understand why we can just ignore the y and z directions of gas molecules, but only consider the x direction. I understand that it may be for simplicity, but will we always be ignoring those two directions?

Foothold ideas: Gases – Kinetic Theory II

- Newton's laws tell us that motion continues forever unless an "unbalanced" force acts on it, yet we observe motion always dies away.
- Our model of matter as lots of little particles in continual motion lets us "hide" the energy of motion that has "died away" at the macro level in the ***internal incoherent motion – heat!***
- The model unifies the ideas of heat and temperature (NOTE: not the same thing!) with our ideas of motion of macroscopic objects.
- (Involved a lot of effort in the 19^{th} c.)

$$P = nmv_x^2$$

Interpreting



- The physicist's form of the ideal gas law lets us connect *P* and *T* and explains what temperature is on the microscopic scale.
- *P* arises from molecules hitting the wall and transferring momentum to it;
- *T* corresponds to the motion energy ("kinetic energy") of the average molecule up to a constant.

$$\frac{1}{2}k_B T = \frac{1}{2}mv_x^2 \rightarrow \frac{3}{2}k_B T = \frac{1}{2}m\left\langle v^2 \right\rangle$$

The Ideal Gas Law

Chemist's form

$$PV = n_{moles} RT$$

$$n_{moles} = \frac{N}{N_A}$$

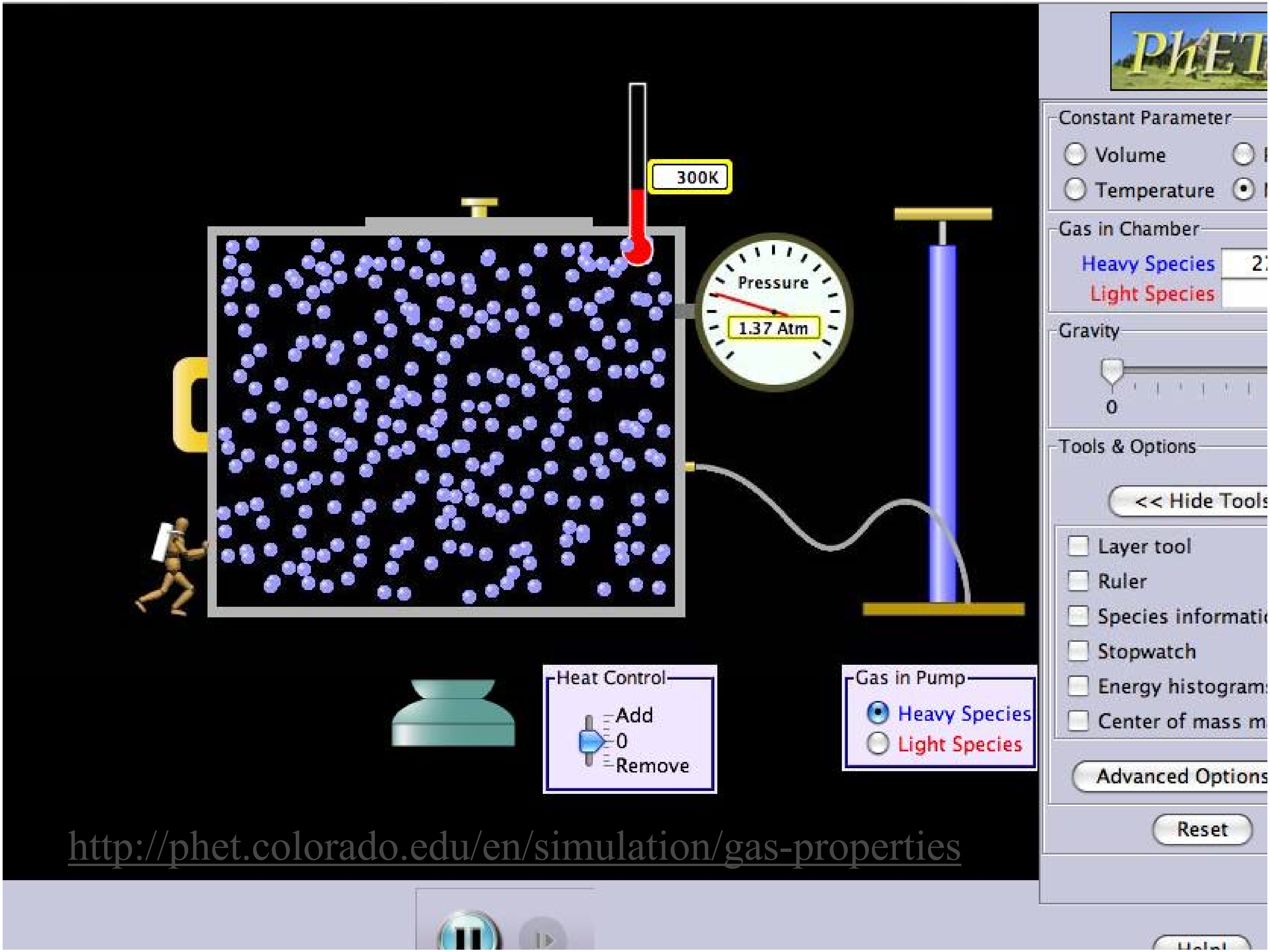
$$R = k_B N_A$$

Physicist's form

$$PV = N k_B T$$

$$P = n m v_x^2$$

$$\tfrac{3}{2} k_B T = \tfrac{1}{2} m v^2$$



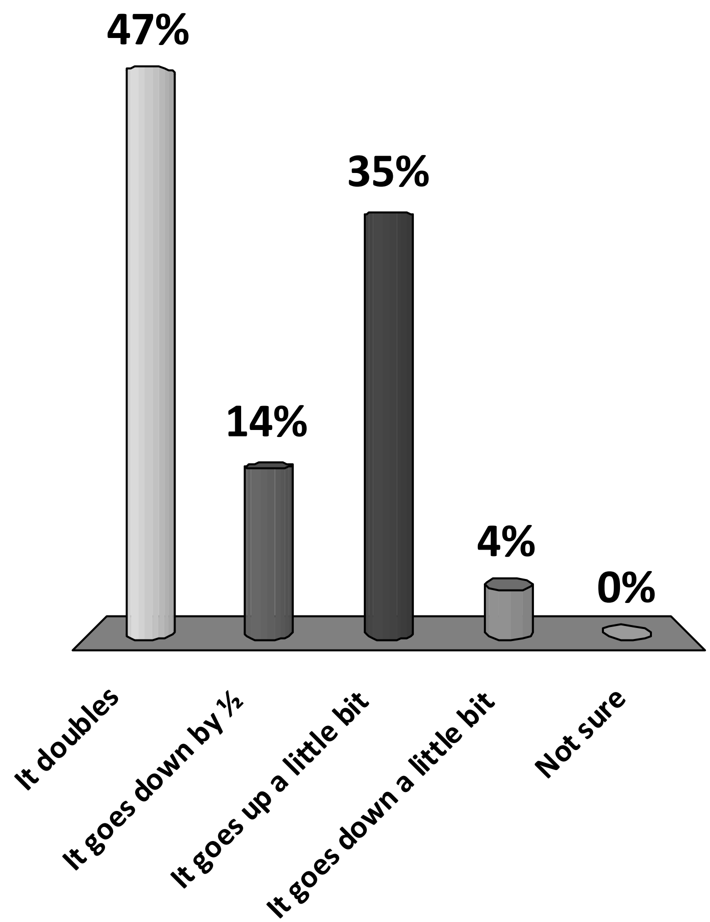
PhET
Constant Parameter
Volume
Temperature
Gas in Chamber
Heavy Species
Light Species
Gravity
0
Tools & Options
<< Hide Tools
Layer tool
Ruler
Stopwatch
Advanced Options
Reset
300K
Pressure
1.37 Atm
Heat Control
Add
0
Remove
Gas in Pump
Heavy Species
Light Species
http://phet.colorado.edu/en/simulation/gas-properties

If have an enclosed volume of gas and I double the number of molecules, but keep the temperature the same, what happens to the pressure in the gas?

A. It more than doubles.
B. It doubles.
C. It increases by between 50% and 100%.
D. It increases but by less than 50%.
E. It stays the same
F. It decreases.

If an enclosed box of gas goes from 10^o C to 20^o C, what happens to the pressure?

A. It doubles
B. It goes down by ½
C. It goes up a little bit
D. It goes down a little bit
E. Not sure



If I heat an enclosed volume of gas so that its Kelvin temperature doubles, what happens to the average speed of the molecules in the gas?

A. It more than doubles.
B. It doubles.
C. It increases by between 50% and 100%.
D. It increases but by less than 50%.
E. It stays the same
F. It decreases.

Question

?

- If the molecules in a gas are all moving freely except when they collide with each other (rarely), why don't they fall to the ground?
- Consider a FBD for a gas molecule.
- How far apart are molecules in a gas at STP?
- How fast are they travelling?

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