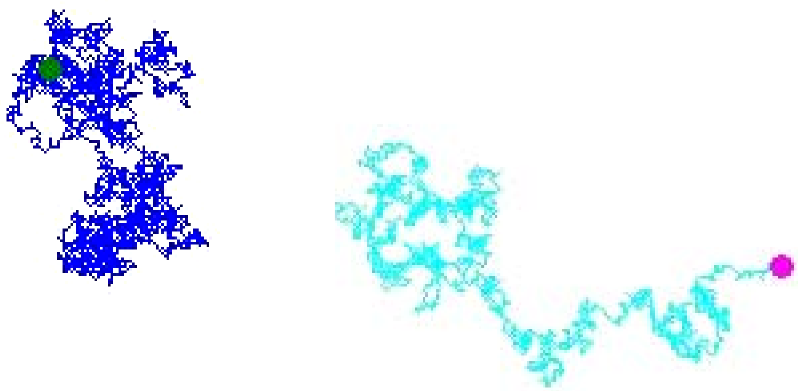
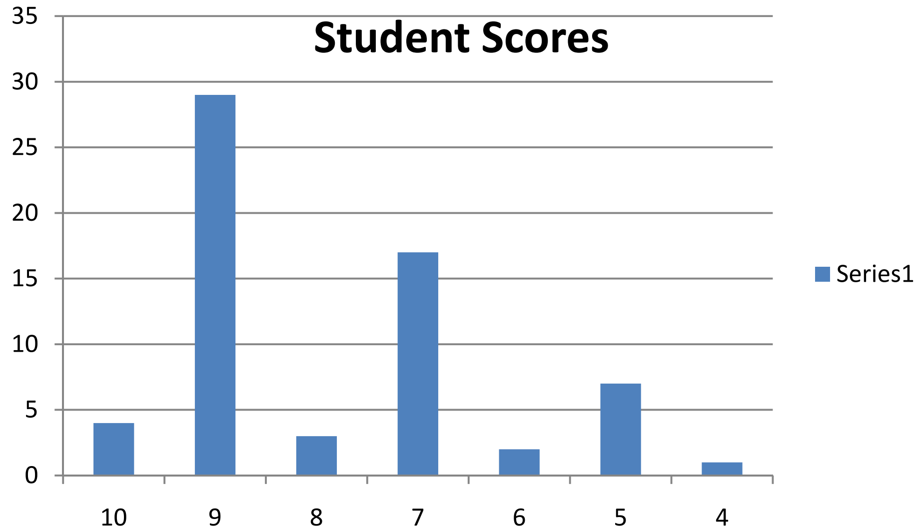
Physics 131- Fundamentals of Physics for Biologists I

Professor: Arpita Upadhyaya

- Pressure
- Buoyancy



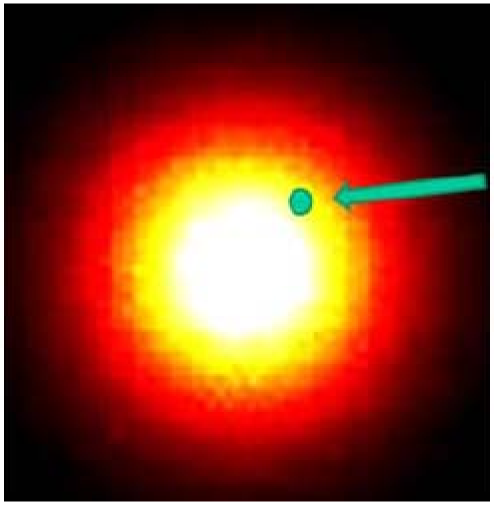
Quiz 8



Average = 7.8

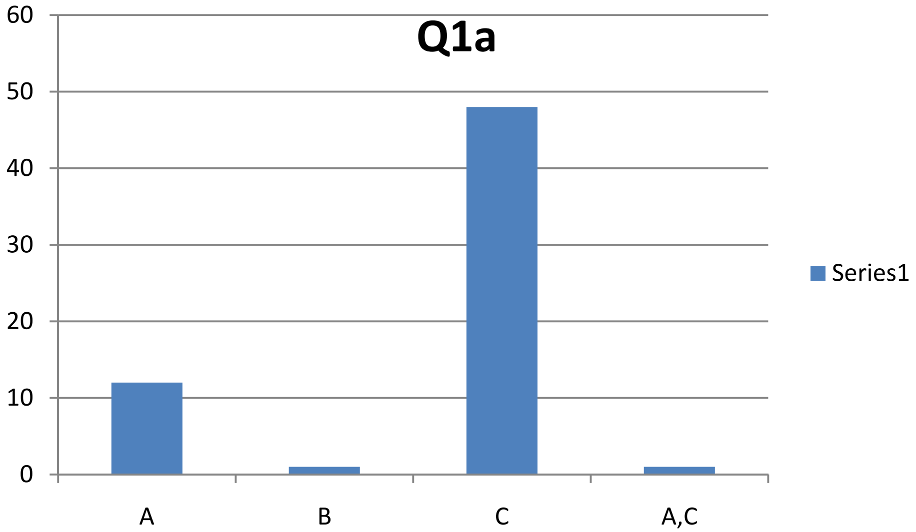
Quiz 8

1. Signaling molecules are released at a single spot inside a fluid and gradually spread throughout the fluid due to random motion. The concentration field after a time Δt_1 is shown on the right.



1a (2 pts) When you release an additional molecule in the area of the green point

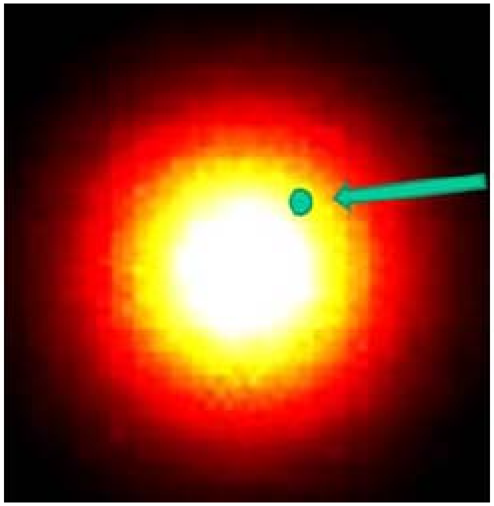
A. it is more likely to move toward areas of lower concentration
B. it is more likely to move toward areas of higher concentration
C. it is equally likely to move in any direction.

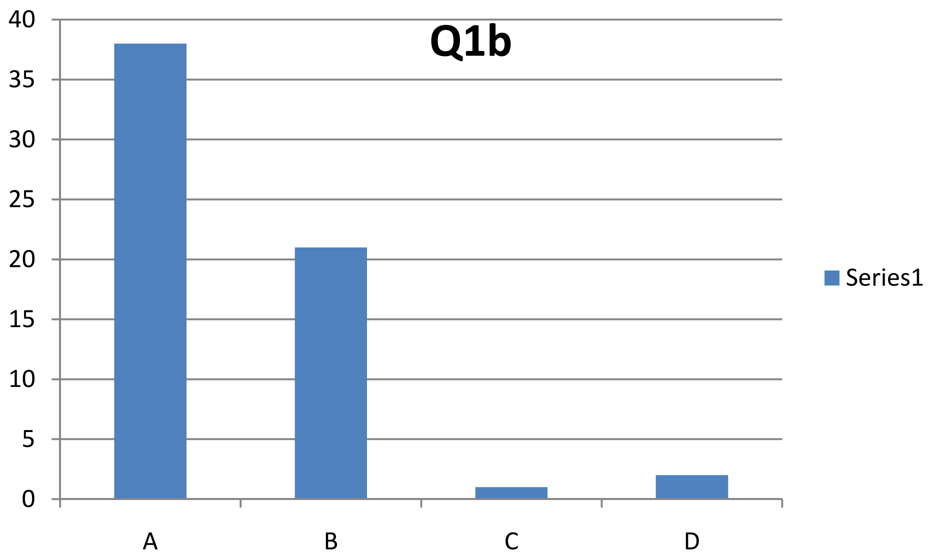


Quiz 8

1b (2 pts) If you measure the concentration field after $4\Delta t_1$,

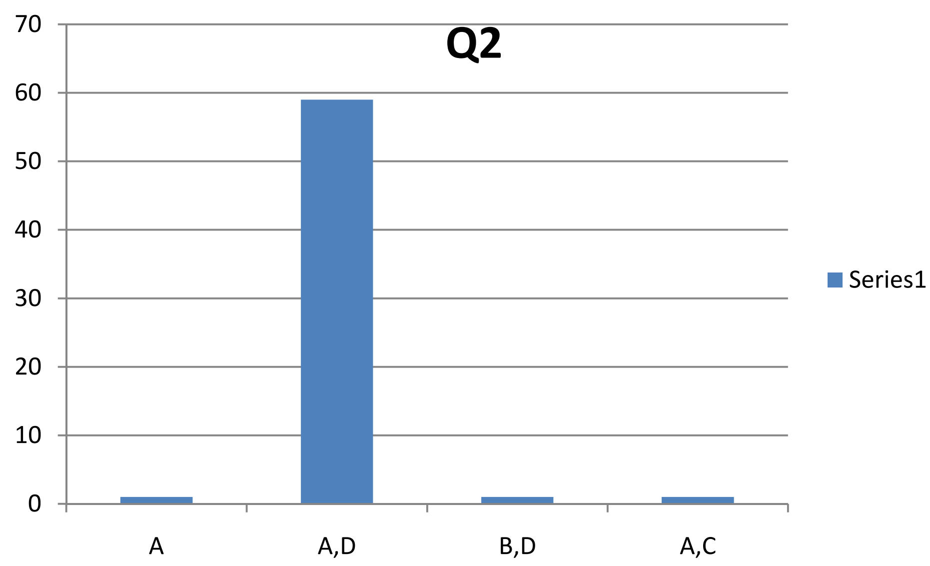
A. The width of the bright region will increase by a factor 2
B. The width of the bright region will increase by a factor 4
C. The width of the bright region will increase by a factor 8
D. The width of the bright region will not increase



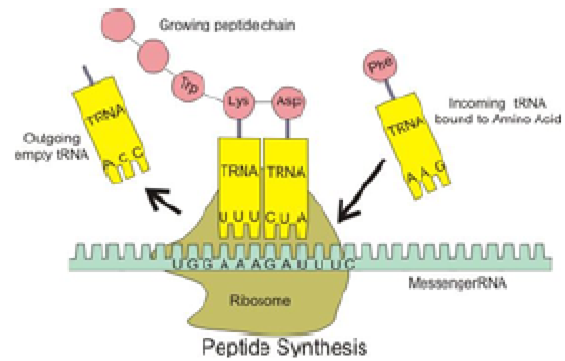


2. (4 pts) Diffusion is the phenomenon by which the molecules of a small blob of material introduced into a fluid spreads out as a result of the thermal jiggling of the atoms around it. If the blob starts out as small, it spreads into a larger 3D blob with radius r where r is given as a function of time, t, by the equation: $\langle r^2 \rangle = 6Dt$ where D is a property ("the diffusion constant") of how the material interacts with the fluid. Diffusion takes place through a balance between competing mechanisms. The material is driven into motion by the thermal jiggling of the molecules of the fluid; and the material is resisted in its motion by having to push through the fluid. As a result, we expect D to depend both on the temperature of the fluid (thermal energy density) and the viscosity of the fluid. How do you expect this to depend on the property of the fluid?

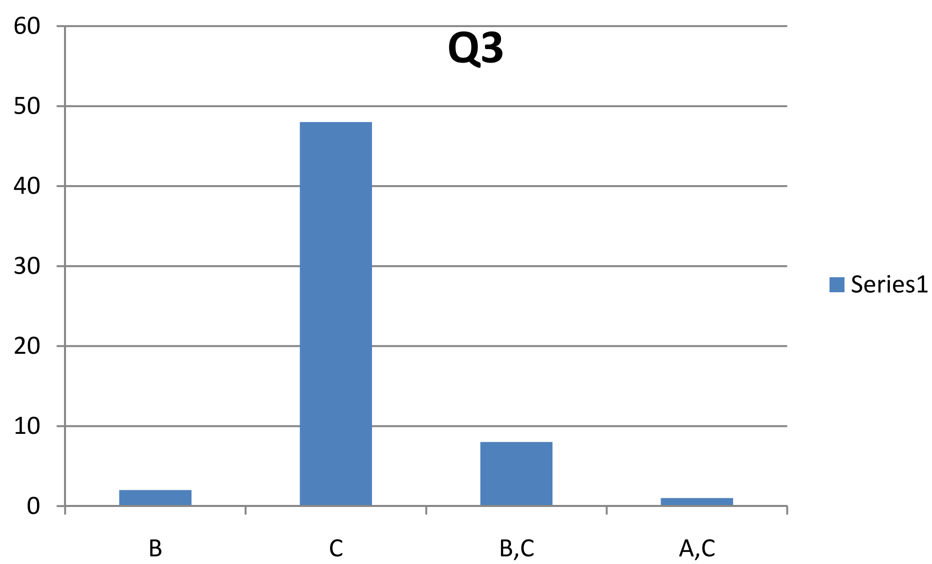
A. A higher temperature will lead to a larger diffusion constant.
B. A higher temperature will lead to a smaller diffusion constant.
C. A higher viscosity will lead to a larger diffusion constant.
D. A higher viscosity will lead to a smaller diffusion constant?



3. (2 pts) A researcher is building a computational model of how a ribosome moves along a strand of RNA to build a protein. She knows that there is some randomness involved with the ribosome stepping back and forth due to thermal fluctuations. So she begins to build her model by treating the ribosome as a pure random walker, stepping to the left or right with equal probability. To test whether her code is doing the right thing, she considers many ribosomes on many strands of RNA, starts each one at the same point, and random-walks it for N steps. She then plots a histogram of how many ribosomes went how far. What should she expect if her code correctly represents a 1D random walk?



A. There will be peaks near +N/2 and –N/2
B. The largest number will be near 0 no matter how many steps she takes.
C. The histogram will peak at 0 and getting farther away will decrease in probability.
D. There will be peaks at + and – values but not at +N/2 and –N/2; finding a displacement near 0 will be less likely.



Diffusion is a simple example of emergent behavior.

– Mean Squared Displacement

$$\left\langle \left(\Delta r\right)^2 \right\rangle = 6D\Delta t$$

– Fick’s Law

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

Connect DYNAMICS (Motion) to FORCES

– Pressure

– Ideal Gas law

Kinds of Matter

- Classify objects by how they deform.
  - *Solid*: don't change shape if you leave them alone or push on them (not too hard!)
  - *Gel*: look solid if you don't touch them but are "squishy" and change shape easily (jello, butter, clay,…)
  - *Liquid*: Have no shape of their own. Flow to fill a container but have constant volume.
  - *Gas*: Have neither shape nor volume but fill any container.
  - LOTS MORE!

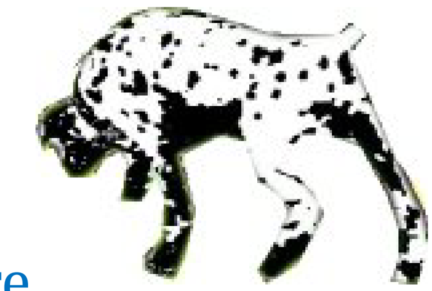
Foothold ideas:
Gases – Kinetic Theory I

- 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. A model saying that on the average the total momentum is 0 (and stays 0 by momentum conservation) is a good one.
- 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: $pV = n_{moles}RT$

Foothold ideas: Gases – Kinetic Theory II

- Newton's laws tell us that motion continues forever unless something unbalanced tries to stop 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.
- The model unifies the idea of heat and temperature with our ideas of motion of macroscopic objects.

Interpreting



The model unifies the idea of heat and temperature with our ideas of motion of macroscopic objects.

- The "physicist's form" of the ideal gas law lets us interpret where the *p* comes from and what *T* means.
- *p* arises from molecules hitting the wall and transferring momentum to it;
- *T* corresponds to the KE of <u>one</u> molecule (up to a constant factor).

$$p = nmv_x^2 \qquad\qquad k_B T = \tfrac{2}{3}\left(\tfrac{1}{2}mv^2\right)$$

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

$$pV = Nk_B T$$

$$p = nmv_x^2$$

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

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

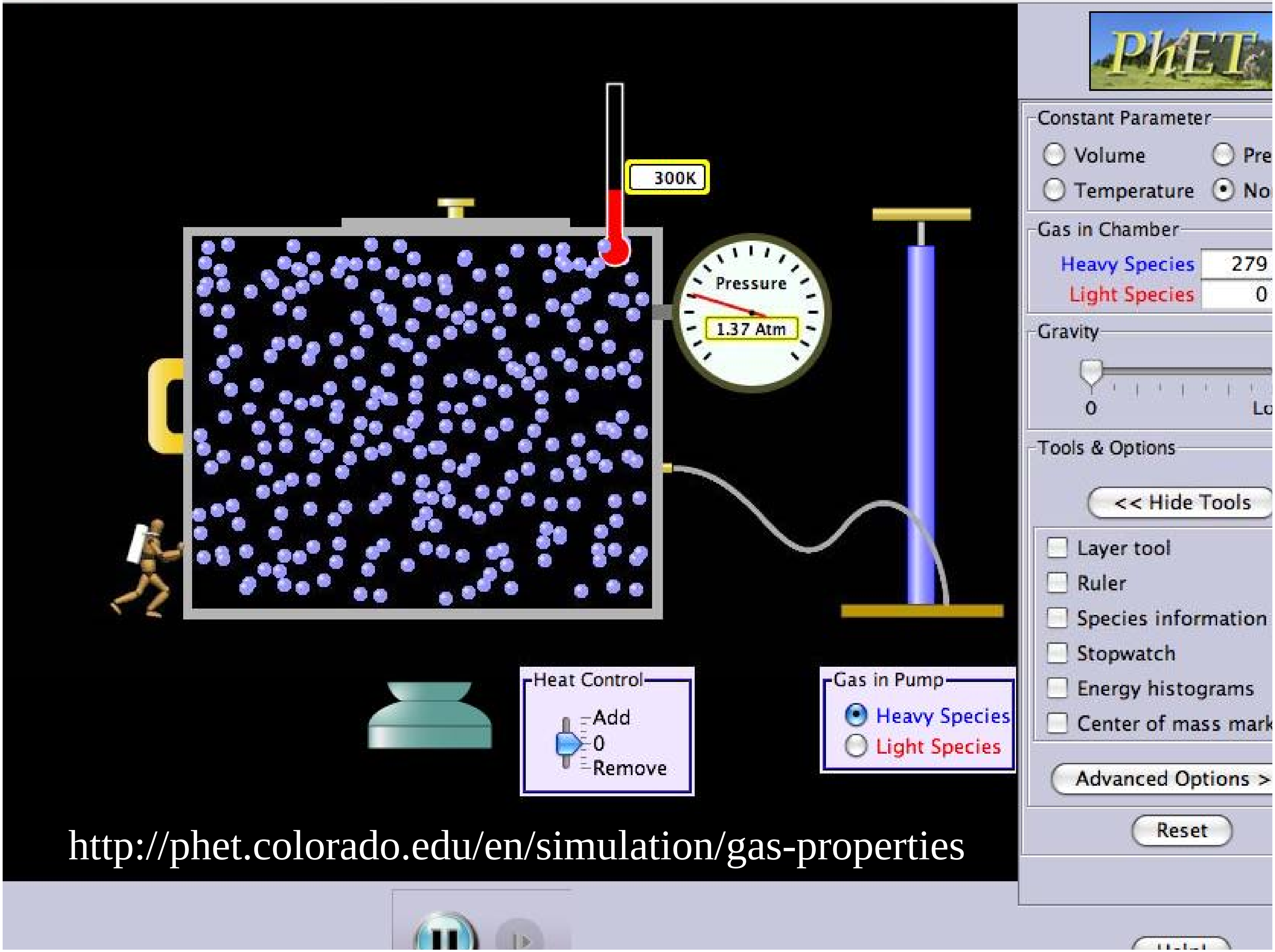
1. It more than doubles.
2. It doubles.
3. It increases by between 50% and 100%.
4. It increases but by less than 50%.
5. It stays the same
6. It decreases.

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?

1. It more than doubles.
2. It doubles.
3. It increases by between 50% and 100%.
4. It increases but by less than 50%.
5. It stays the same
6. It decreases.

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?

1. It more than doubles.
2. It doubles.
3. It increases by between 50% and 100%.
4. It increases but by less than 50%.
5. It stays the same
6. It decreases.



http://phet.colorado.edu/en/simulation/gas-properties

Foothold ideas: Pressure

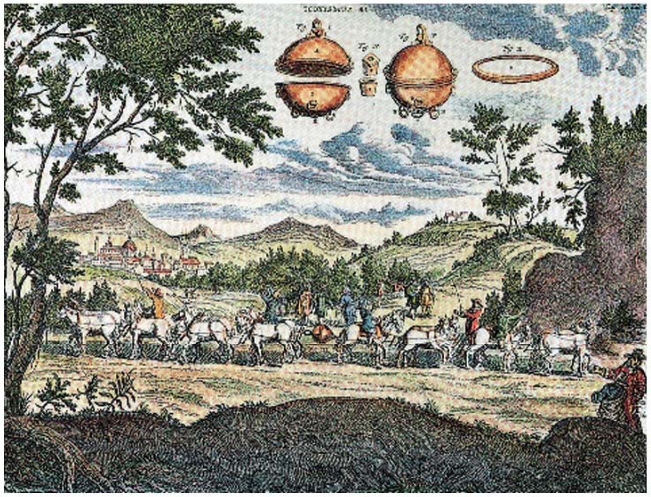
- At a boundary or wall, the pressure in a constrained fluid creates a force perpendicular to the surface.

$$\vec{F} = p\vec{A}$$

- The constrained gas or liquid has an internal pressure, meaning that it would create a force against any surface placed anywhere inside the gas or liquid in any orientation.

Atmospheric Pressure

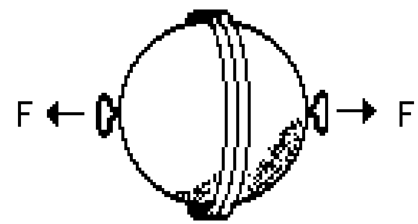
- Atmosphere exerts pressure, like water in a lake. We are at the bottom of an “ocean of air”.
- “Magdeburg hemisphere” experiment (1654): Make sphere from 2 copper hemispheres, ½ m in diameter. Evacuate the sphere with vacuum pump. Two teams of 8 horses each couldn’t pull the spheres apart!



What is holding the two hemispheres so tightly together?

Question

It would be easier to pull evacuated Magdeburg hemispheres apart when they are



A) 20 km above the ocean surface.
B) at sea level.
C) 20 km beneath the ocean surface.
D) held upside down.
E) none of these

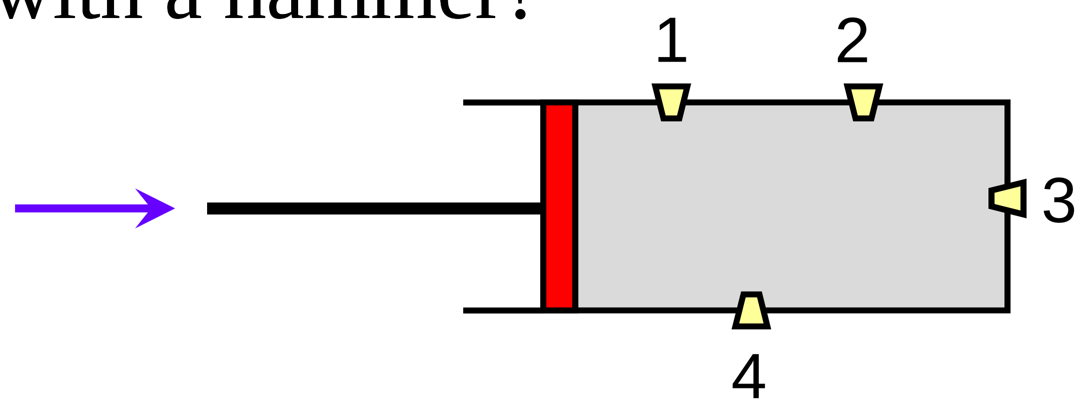
Foothold ideas: Pressure 1

- In a gas the molecules are moving very fast in all directions. On the average the momentum cancels out.
- If you put in a wall keeping the gas on only one side, only the momentum in one direction acts on the wall (N2, N3), creating a force.
- In a non-flowing gas, the force/area is a constant, the pressure. It is proportional to the number of molecules and their mv^2.

Foothold ideas: Liquids

- In a liquid the molecules are close enough that their mutual (short ranged) attractions hold them together (e.g. H-bonding in H_2O).
- A liquid maintains its volume but changes its shape easily in response to small forces.
- The relation of *p*, *V*, and *T* in a liquid is <u>WAY</u> more complicated than in a gas.

A cylinder with a movable piston is filled with a uniform fluid. If the corks are all in equally tightly, which are most likely to pop when we hit the piston with a hammer?

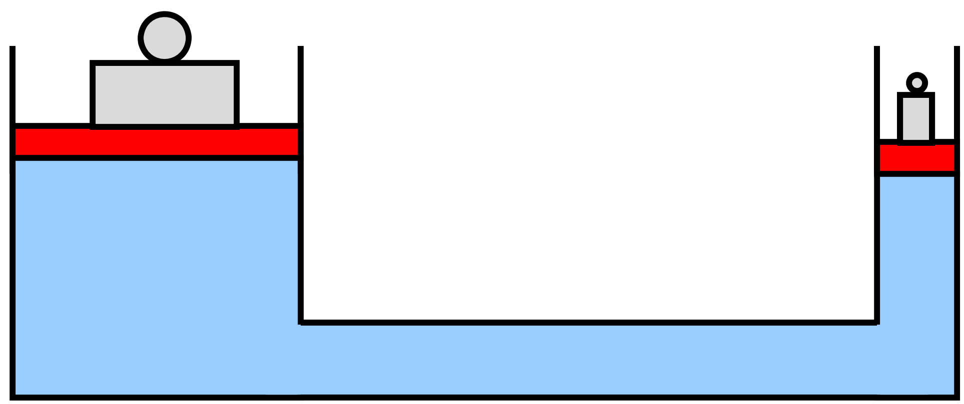


1. Cork 1
2. Corks 1 & 2
3. Cork 3
4. Cork 4
5. Some other combination
6. All
7. None

Pascal's Principle

A force exerted
on a part of a fluid
is transmitted through
the fluid and expressed
in all directions.

$$\frac{W_1}{A_1} = \frac{W_2}{A_2}$$



Foothold ideas: Pressure 2

- A constrained fluid has an internal pressure –like an internal force at every point in all directions. (Pressure has no direction.)
- At a boundary or wall, the pressure creates a force perpendicular to the wall. $\vec{F} = p\vec{A}$
- The pressure in a fluid increases with depth. (N0, N2)

$$p = p_0 + \rho g d$$

- The pressure in a fluid is the same on any horizontal plane no matter what the shape or openings of the container. (Vessel shaped like Utah.)

Consider the containers at right. Which of the following correctly compares the *pressure* (*P*) of the water at the bottoms of the containers?

A. $P_1 = P_2 = P_3$

B. $P_3 > P_1 > P_2$

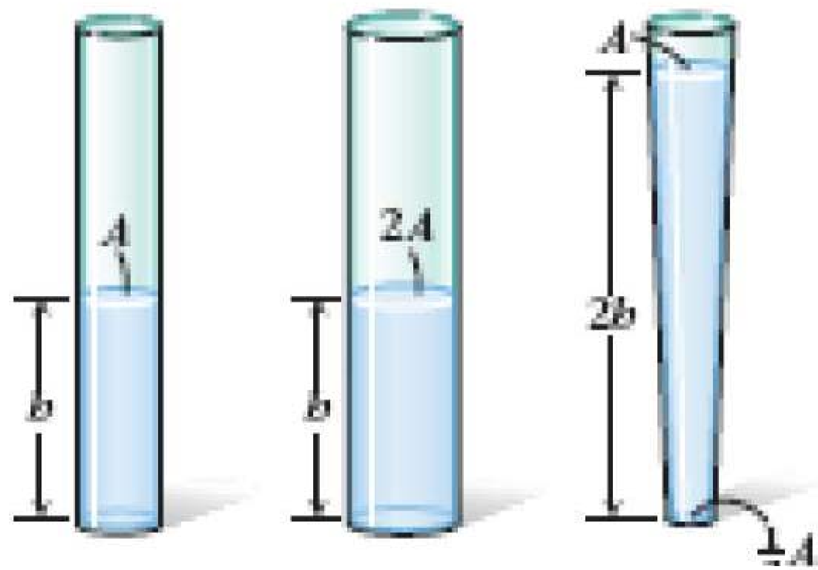
C. $P_3 > P_1 = P_2$

D. $P_2 > P_1 > P_3$

E. $P_1 = P_2 > P_3$

F. $P_2 > P_1 = P_3$

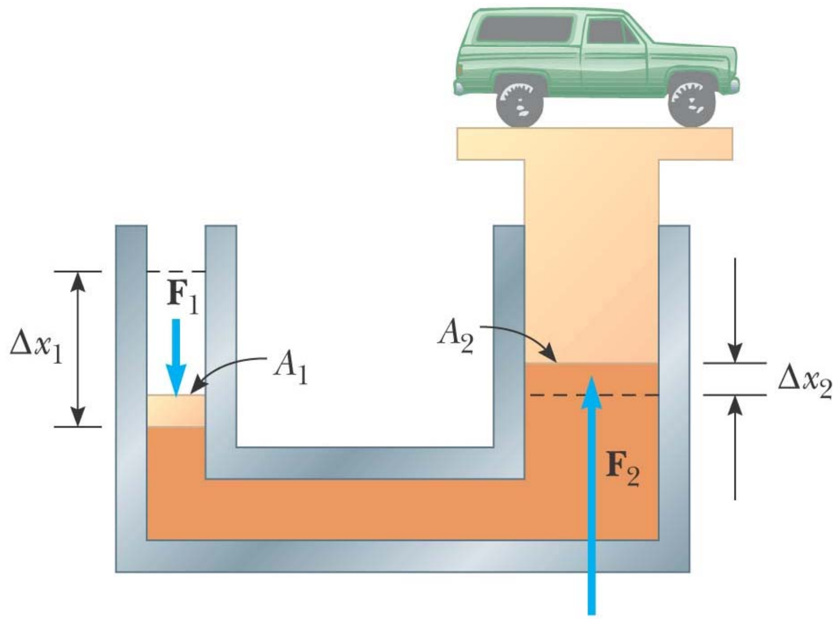
G. None of these



(1) (2) (3)

A container is filled with oil and fitted on both ends with pistons. The area of the left piston is (0.1 inch)^2 ; that of the right piston (10inch)^2. What weight must I place on the piston to balance the weight of a 1 ton (1000 kg) car?

1. 0.1 kg
2. 10 kg
3. 1,000 kg
4. 10^6 kg
5. 10^8 kg
6. insufficient information



(a)

Response Grid