Gas Properties and Balloons & Buoyancy SIM Homework

1) In class, we have been discussing how gases behave and how we observe this behavior in our daily lives. In this homework assignment, you will need to use the **Gas Properties Simulation** to help you develop a visual and conceptual model of how the bulk properties of a gas (such as pressure, temperature and volume) relate to what the individual gas molecules are doing and how this enters into your everyday life.

a) Put a moderate amount of gas into a constant volume box. Without varying any of the controls, what general information about the nature of gases can you extract from the simulation's representation? (Describe the visual picture you have of a gas, noting any characteristic features of gases that you observe from the applet. You should include at least 3 things. Think of things that make a gas unique and distinguishable from a solid.)

b) Look at the animation of the particles bouncing around in the volume. Describe what visual information you can use to get a sense of the pressure that the gas particles are exerting on the walls. Play around with controls and see how the pressure responds. What **visual** cues are associated with an increase in pressure? Be sure to focus not only on the walls, but also on the gas in the center of the box, what visual cues can you use to get a sense of the pressure of the gas at any point in the volume?

c) It is well known that the higher you climb in the mountains, the less oxygen there is (fewer air molecules). (Use the simulation to create a gravitational attraction to the floor).

i) Describe the changes you observe in the distribution of air particles within the atmosphere as you increase the gravitational attraction.

ii) What do the visual changes you observed in the distribution of the gas particles tell you about how the pressure and temperature of the gas varies throughout the box? How is this consistent or inconsistent with you experience in real life?

iii) Explain the physics behind WHY the observation that there is less oxygen the higher you climb makes sense in terms of the forces acting in the system (namely gravity and air pressure).

d) Using the visual model of the behavior of gas molecules presented in the simulation explain how a suction cup works. The suction cup is being

pulled towards the wall.

pushed towards the wall.

neither pushed nor pulled.

Explain what is happening with the forces that cause the cup to stay against the wall and that support your answer whether the suction cup is being pulled, pushed, or something else?

Using your understanding of the forces, why does the suction cup start to fail if it leaks too much?

2) In reading the car manual you see that they tell you to check the tire pressure when the tires are cold, and that it should read 24 psi with the tire gauge (so 24 psi + 14 psi atmospheric pressure gives 38 total psi inside the tire). Unfortunately you have read this only after having driven on them for 100 miles and you have measured that the gauge reads 27 psi. You have 1000 miles more to drive and so it is important to know if they are under-inflated or over-inflated. Fortunately you have taken Physics 1020, so you take out a thermometer and measure that the tire temperature is about 30˚ Celsius HOTTER than the 25˚ C air temperature.

Given that your current tire pressure read 27 psi according to the gauge, what would the gauge read for pressure if you allowed the tires to cool to be the same as the air temperature of 25 C (which is the temperature at which you were supposed to check the tires)?

Explain the physics principles and reasoning you used to calculate this answer. (Again, the simulation can help you figure out how to solve this or check your reasoning. Remember, the absolute temperature and pressure readings in the simulation are not meaningful, but the proportional changes are.)

3) You are flying from Denver to Boston, and you bring along a 1⁄2 full bottle of shampoo that was well sealed before you left Denver. You land in Boston and proceed to your hotel.

a) The number of air molecules within the shampoo bottle:

has decreased has stayed the same has increased

b) If the walls of the shampoo bottle are strong and rigid so that the bottle retains the same shape as it was before you left, how does the pressure of the air inside the bottle compare to the pressure of the air in Boulder and to the pressure of the air in Boston?

The pressure of the air in the bottle is (…) the pressure of the air in Boulder and (…) the pressure of the air in Boston

less than, less than less than, same as less than, greater than

same as, less than same as, same as same as, greater than

greater than, less than greater than, same as greater than, greater than

c) The air pressure at sea level is 14.7 lbs/in2. The air pressure in Boulder is 20% less then the air pressure at sea level. How many lbs of force are being exerted on each square inch of the shampoo bottle?

d) If your shampoo bottle is like most, and its walls are not very rigid, you notice that the walls have collapsed a bit (for this problem, consider the bottle to be like a plastic Ziploc, so not at all rigid).

i) When the shampoo bottle collapses, the volume of the shampoo bottle (…) and the pressure of the air inside the bottle (…).

decreases, decreases decreases, stays the same decreases, increases

stays the same, decreases stays the same, stays the same stays the same, increases

increases, decreases increases, stays the same increases, increases

Explain the physics principles and reasoning behind your answer. In the simulation, keep temperature constant and try changing the volume. (*Note*: the temperature of the gas will increase as you change the volume. Wait for the simulation to automatically return the temperature to its original value (removing it) and then evaluate how the pressure has changed and why).

ii) If the walls are flaccid as in the plastic Ziploc case, how will the pressure inside compare to the pressure outside the bottle when you are in Boston but have not yet opened the shampoo?

the pressure inside will be lower

the pressure outside will be lower

the pressure inside and outside will be the same.

Explain your reasoning behind your answer.

iii) Assuming the temperature in Boston and Boulder are the same and using an original volume of 1/2 liter of air (1 L bottle). What is the new volume of air in the bottle?

iv) If you now heat your shampoo bottle up, you can get it to expand back to its original volume. Explain why this works.

4) There are 2 balloons in a room. They are identical in size and material. Balloon #1 is filled with air and balloon #2 is filled with Helium.

a) A balloon does not have rigid walls… they can contract or expand if the forces acting on them change. For the 2 balloons in this room, the pressure of the air inside balloon #1 (…) the pressure of the He inside balloon #2 and (…) the pressure of the air in the room.

less than, less than less than, same as less than, greater than

same as, less than same as, same as same as, greater than

greater than, less than greater than, same as greater than, greater than

b) How does the number of air molecules in balloon #1 compare to the number of He atoms in balloon #2?

There are more air molecules in #1 than He atoms in #2.

There are fewer air molecules in #1 than He atoms in #2.

The number of air molecules in #1 is the same as He atoms in #2.

c) Use the Gas Properties applet to simulate the air molecules (the heavy or blue species in the simulation) inside the balloon and repeat the simulation for the same conditions (T, P, V) for Helium atoms (the light or red species in the simulation). What is different about the motion of the molecules inside the air balloon compared to the motion of the atoms inside the He balloon that supports your answers for a) and b)? Include your reasoning.

d) If the volume of the balloon is 1 meter in diameter and the density of air in Boulder is 1 kg/m^3, what is the buoyancy force of the air in the room on each of the balloons? (Remember the volume of a sphere is $(4*\pi*r^3)/3$

e) Explain why the He balloon rises and the Air balloon falls.

f) If the mass of the material the balloon is made of is 0.01 kg, how much mass could you attach to the He balloon and still have it float (in kg)? (The density of He gas at the pressure and temperature in the room is 0.14 kg/m^3).

5) Now let's explore how hot air balloons work using the **Balloons & Buoyancy Simulation**. We know that hot air balloons heat the air inside them in order to rise. Observe closely what happens when you heat the air **inside** the balloon and when you let the air inside the balloon cool back down.

a) When the heat is on and the balloon is floating, how do the number of air molecules inside the balloon compare to the number of air molecules that would be occupying that volume if the balloon wasn't there? If these are different, why doesn't the balloon grow or shrink until they are the same?

b) Assume we have a hot air balloon with the same volume as the balloons in problem 4.

i) What is the buoyancy force upwards due to the air surrounding the balloon? (Hint: look at what you did in problem 5).

ii) If we heat the air inside the balloon from 293 K (or 20˚ C) to 393 K (or 120˚ C), how does the mass of the air inside the balloon compare to the mass of an **equivalent** volume of air outside the balloon?

The mass of the air inside the balloon is larger.

The mass of the air inside the balloon is smaller.

The mass of the air inside the balloon is the same as the mass of the air in an equivalent volume outside the balloon.

If we heat the air inside the balloon from 293 K (or 20 C) to 393 K (or 120 C), what is the numerical value for the mass (in kg) of the air inside the balloon for this hotter temperature? (Hint, think about how the number of air molecules inside the balloon has changed. Is it 1/2 (or 1/3 or etc) as many molecules?)

iii) If again the balloon material had a mass of 0.01 kg, how much mass could you attach to the hot air balloon and still have it float?

Discuss how this compares to the mass that the He balloon could lift and why it makes sense.