The Invisible Hercules

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Out of the four lessons, I found the last lesson on air pressure to be the most interesting. I have always wondered about air pressure, its characteristics, and the phenomenon related to it.

Firstly, pressure is the force applied perpendicularly to a unit area over which that force is distributed. The standard international unit is pascals, and the formula for pressure is: Pressure = force / area.

I believe the most important thing about air pressure and how it works is described in the five laws you have taught, which are: Avogadro's law, Boyle-Mariotte's law, Gay-Lussac's law(or Amonton's law), Charles' Law, and the combined ideal gas law. The first one, Avogadro's Law, states that when the temperature is the same, the product of gas pressure (P) and volume (V) is proportional to the number of total molecules (N): P1V1 / P2V2 = N1 / N2. This is derived from the fact that when the temperature is constant, the gas pressure is proportional to the molecular density(n=N/V): P1 / P2 = n1 / n2. This makes sense because when the molecular density increases, there are more molecules per unit volume. Thus more gas molecules hit and bounce off the same area of surface, and therefore an increase in pressure. And vice versa goes for when the molecular density decreases and the pressure decreases. This proportion of pressure and molecular density relates to Avogadro's law because the total number of molecules equals molecular density multiplied by volume, so if you multiply both sides of the equation by volume, you will get Avogadro's law. Some real-life applications of this law are like inflating a flat basketball or tire. When a tire is flat, there is barely any air inside it. Thus also the total number of gas molecules becomes less, therefore the volume of gas inside a flat tire is less than a fully-pumped tire, because there is more air or molecules inside the inflated tire. Similarly in blowing a balloon. If you keep pumping air into a balloon, eventually it will pop. Because of Avogadro's law, by pumping more air into a balloon the total number of gas molecules inside the balloon increases, and therefore also the pressure increases. Then eventually when you pump too much air in, the pressure will become too great for the balloon to handle, and eventually, pop. Also, Avagodro's law helps explain why Boyle-Mariotte's law works.

Boyle-Mariotte's law states that when the temperature and amount of gas are fixed: P1V1 = P2V2, or in other words that the pressure and volume are inversely proportional (when volume increases, pressure decreases). This happens because for example if you have a container of some amount of gas, and you compress it, the volume decreases. However, since there is a fixed amount of that gas, the number of molecules stays the same. When you compress it, the molecular density increases. Then as shown by Avogadro's Law, the pressure increases. Vice versa goes for when the volume decreases, thus the molecular density decreases and then the pressure increases.

This can be seen in the very first experiment we did, which was the upside-down water with paper experiment. Sometimes, when you flipped the glass of water over, a little bit of water spilled out. When the water spilled out, the volume of the inside gas expanded. Thus by Boyle-Marriotte's Law, the pressure inside the glass of water reduces, making the experiment work, if the pressure inside the glass is 1% less than the pressure outside, the pressure difference can support a water column that is 10 cm tall for the experiment to work. When I performed the experiment for the first time, I thought it would fail since I saw a little bit of gas get in when I flipped it over, since I believed there could be no air inside for the experiment to work. However, it worked! But why? It makes me wonder.

From the next lecture, I realize that when the volume of air increases by 1% the pressure inside can reduce by 1% to make this experiment work. Later I found that the air volume inside can increase a little bit because water has surface tension and a tiny gap can form between the edge of the glass and the paper cover when they are upside-down. Boyle_Mariotte's law is important in making the experiment succeed.

Boyle-Mariotte's law also explains real-life things such as potato chip bags, balloons, etc. For example, especially as a kid, I always tried to pop potato chip bags using my hands by compressing the bag or placing the bag on the ground and then stomping on it with my foot. Now, I understand why it happens. Since the air inside the bag is fixed, and when you squeeze the bag, the volume of the air inside the bag decreases, thus causing the pressure to increase, and eventually, the pressure will be too much for the bag, and cause it to pop.

The same goes for popping balloons and other related items. Also, another real-life application is opening a bottle or can of soda or coke. A new bottle of coke is usually impossible to compress or squeeze, since the pressure inside is very strong. However when you slowly open the bottle, the gas inside increases, and thus the pressure inside decreases.

Also, the experiment we did with the orange peel gun utilizes Boyle-Mariotte's law. When you use the stick to push one end of the tube, the volume of air between the two orange peels decrease, and thus the pressure increases, causing the other orange peel to shoot out as it did.

The experiment with the holes in the bottle for getting a continuous flow of water from assignment TO4B also contributed to my understanding of this law. If you poked holes at the bottom, the water inside would not flow out because the outside air pressure is stronger than the gravity of the flow of water. However, if you poke a hole near the top of the bottle, the water will begin to flow. Before I was confused, but later I know. When I first poked a hole at the bottom, a very little amount of water leaked out, but after that, there was no flow of water. This is very similar to the upside-down glass of water experiment, where the volume of the air inside the water bottle increases, and thus the pressure inside decreases. Even if the pressure difference is a very small portion of the regular air pressure, it can block some water from flowing down. You need to poke another hole near the top to get continuous water from at the bottom, because then outside air can flow inside the bottle and increase the amount of air inside the bottle, and then the inside and outside pressure will be even, and thus a continuous flow of water can be maintained. This application goes for all types of water flow, such as pouring milk through a milk cartoon, or for the intravenous infusion in question five in Assignment TO4B.

Gay-Lussac's law states that when the volume is fixed, the pressure is proportional to the absolute temperature, P1/P2 = T1/T2. The absolute temperature is in the unit Kelvin. I have definitely heard about this unit of temperature, but I have never known how to convert it between Celsius, what is special about it, or even why it exists.

However now I know that it is the absolute temperature, where 0 Kelvin or -273.15 Celsius is when the molecules stop moving and lose all of their thermal energy and motion. Gay-Lussac's law makes sense because for example when the absolute temperature increases, the molecules become more energetic and bounce and hit things more violently, thus increasing the pressure.

The soap in the microwave experiment and the question of the tire in the winter and summer all contributed to my understanding of this law. The soap microwave experiment was pretty interesting and cool, seeing something like that expand so much in front of your eyes. It expanded because there are small air pockets inside the soap, and because of the high temperature by the microwave, the pressure of those air pockets increased, and thus they expanded. Also, the microwave made some of the liquid in the soap evaporate into gas as well, and that also contributed to the expansion.

More importantly, the experiment of the upside-down water glass but this time with hot and cold water also contributed to my understanding. I did not get it the first time I did it, and my thinking was not entirely correct, but after watching the solution vids I got it. Unlike what I thought before, I was surprised that it was actually using the hot water that would make the experiment succeed so easily.

This is because initially, the hot water would make the air inside warm, and before you place the paper on top, the pressure inside and outside is the same. But then very quickly the gas inside will lose its heat to the surrounding areas, and that temperature drop would also lead to the pressure decreasing too, and thus achieving the less than 1% pressure difference needed. I thought the cold water would be better, since the cold water will make the air inside colder, and decrease the pressure, but that is before you place the paper on top, and what matters is the pressure change after the cup is covered. Also, you can possibly utilize this law to open a very tight jar, which was a question in one of the assignments. Because the jar is very hard to open, that means the inside air pressure is less than the outside air pressure. So you can put the jar under warm water for a little while, and due to Gay-Lussac's law, the pressure of the air inside the jar will increase and may become the same or greater than the outside air pressure, and therefore making it possible to open it. (Don't put glass jars into hot water suddenly through, cause in lesson 1 we learned that how sudden and uneven heating can cause some glass container burst due to thermal expansion).

Lastly, Charles' Law states that when the pressure is constant, volume and the absolute temperature are directly proportional, or $V1/V2 = T1/T2$. This is true because when you heat up a fixed amount of gas, the molecules' thermal energy and motion increase, and thus they expand more, increasing in volume. I think this law mainly just relates to how matter, in this case, gases, expands when heated.

I remember a while back we did an experiment or question on how to fix a dented ping pong ball. When you place the dented ping pong ball in hot water, the water heats up the air or gas inside the ball. By Charles' Law, the volume of the air inside expands and thus pops the ball back into shape. I think this law can also be used to explain when you put a balloon into a container of liquid nitrogen. The liquid nitrogen is obviously very cold, and it cools down the gas molecules inside the balloon, thus the gas inside occupies less space and the balloon kind of crumbles. The same explanation can be said for when you take the balloon out of the liquid nitrogen, and it goes back into shape.

Lastly, the combined ideal gas law is basically a combination of all the laws mentioned already, where there does not need to be a constant or fixed variable. Even if there was a fixed variable, you can derive any of the laws mentioned from the combined ideal gas law. Using the combined ideal gas law and the other laws mentioned above, you can make many different calculations of AP test questions related to air pressure, as I have done in Assignment TO4D, which I actually did really well.

Overall, in my opinion, this lesson was my favorite so far and the most fun. The upside-down water glass experiment and the holes in the bottle experiment were very interesting to think about and wonder.

I actually did spend quite some time thinking about why a hole near the top would make the water flow, and also whether hot water or cold water would make the upside-down water glass trick easier or harder. However, the most interesting thing about this lesson was just being able to see and understand how powerful air and atmospheric pressure is, and all the impressive things it can do. As seen by the Magdeburg hemispheres experiment you showed us, it took many horses to pull the two halves of the sphere apart. Also with the experiments and questions, they gave me a better understanding of air pressure and also how it plays a role in our everyday life.

With that, I did have one last question, which is what would happen if there was no air or atmospheric pressure? What would happen if one day all atmospheric pressure was just gone? Professor Man suggested checking out what happens to the moon, Venus, and Mars to find the answer. The Moon is so small that its gravity is too weak to keep its atmosphere. Venus is too close to the Sun hence too hot. The air on Mars becomes very dilute when the temperature of Mars raised over the years.