Science-1A Lecture: Week-3, Friday, August 27, 2021

The Crash Course videos referred to during the past two Friday lectures largely cover the material in Chapter 2 of your text. We will go over more of that next week as we prepare for Quiz 2.

The focus today is on pressure which is explained in detail in the handout at *https://yosemitefoothills.com/Science-1A/Handouts/Week-02/Chapter-2-Notes.pdf* .
Normally, as I describe the material in that handout, I do some demonstrations. I prefer to stress the phenomenology more than the mathematics. The Crash Course presentations by Dr. Shini Somara have more math than you will need to know. As mentioned before, the Practice Quizzes show you what is required for this course.

Here are additional Crash Course videos along with discussions and links about relevant demonstrations.

Statics (CC 13) 9 min, 7 s
https://www.youtube.com/watch?v=9cbF9A6eQNA&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV

Just sit back and enjoy this video. The main idea needed for our fluids discussion is the idea of pressure introduced near the end. **Pressure is force per unit area,** $p=\frac{F}{A}$. It has units of N/m^2, but that combination of units is also called a **pascal**, with the abbreviation **Pa**. **The symbol for pressure can be a capital P or lower case p, but must be distinguished from the curvy Greek letter rho, ρ .**
Knives and nails are useful because they concentrate force on a small area – an edge or point – so that the pressure on that area can exceed the strength of the material against which the knife or nail is being pushed against. **It is pressure that damages things.** An elephant will not damage a well-supported hardwood floor, but a person in stiletto heels can permanently damage the wood.

The handout entitled "Mechanical Tools" at
https://yosemitefoothills.com/Science-1A/Handouts/Week-03/MechanicalToolsAndForceBalancing.pdf
describes common tools that share the physics of knives and nails.

Fluids at Rest (CC 14) 9 min 58 s
https://www.youtube.com/watch?v=b5SqYuWT4-4&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV

Here, you are shown a formula $p=\rho g h$ for the pressure *p* at distance *h* below the surface of a fluid of density ρ. For water $\rho_{\text{water}}=1000\,\frac{\text{kg}}{\text{m}^2}$ and for mercury $\rho_{\text{mercury}}=13600\,\frac{\text{kg}}{\text{m}^2}$. Here $g=9.80\,\text{m}/s^2$ is the acceleration of gravity at the surface of the Earth. In the "Chapter 2 + Fluids" handout mentioned above, I show how this formula comes about by calculating the pressure from the weight of all water up to the surface.

I don't test you about Pascal's Principle, but you should simply understand that incompressible fluids flow to balance out any pressure differences in a container except for those caused by gravity. Pascal's Principle makes a hydraulic lift possible.

The discussion of pistons is important. Similar rules apply to levers and electrical transformers. These devices never give you something for nothing, but rather provide a trade off. With two pistons of different areas, a small force on the smaller piston must be applied for a longer distance than the large force that is exerted by the larger piston. Since we have learned that work is force multiplied by distance, the work done on the small piston will (ignoring friction) be identical to the work done by the large piston. **Force and distance are traded off, but the work is the same.** This is discussed in "Teeter-Totter Physics" at *https://yosemitefoothills.com/Science-1A/Handouts/Week-02/Teeter-TotterPhysics.pdf* .

In the discussion of a manometer, keep in mind that there must be a vacuum (the absence of air) in the top part of the manometer. (Actually, there is a very small pressure of mercury vapor there.) To show my daughters this idea, I used water. In that case, I had to go the the roof of a 3-story building and hang a water-filled hose over the edge which was closed at the top. Water is much less dense than mercury and a "water" manometer needs to be about 10.3 meters high. Unfortunately, air dissolved in the water bubbled frantically during that demonstration, and limited the water rise to about 9 m.

Atmospheric pressure near sea level is 101 kPa. I like to ask the class "Where does this 101 kPa pressure come from? The answer is that it is from the weight of all the air from sea level up to the top of the atmosphere. All this weight is pushing down on each 1 m^2 of area on the surface. It is squeezing our bodies, but luckily we have a matching internal pressure that pushes out to keep us from being squished. Submarines that go too deep get crushed by the enormous water pressure.

There is a nice demonstration of this which I urge you to do at your house. It is described in a video entitled "Can Crush Experiment" at *https://www.youtube.com/watch?v=lT3PJ0RY4oY* . A small amount (about 10 mL) of water is put into an empty aluminum can which is then heated on a hot plate or stove until evaporating water in the can can be seen flowing out the top opening as steam. That steam has replaced the air in the can so that when the can is quickly flipped into a dish of cool water, it condenses to about 1% of atmospheric pressure. The outside air pressure then squishes the can and also pushes water up inside it.

When the video talks about the "air" inside the can, they should really be talking about water vapor. Air would only drop in pressure to about 80% of atmospheric pressure when cooled, not 1%.

I bought a pair of very cheap suction cups sold as "toilet plungers" for unplugging drains. One is shown at the right. Its rubber end has a diameter of about 8 cm = 0.08 m. To calculate the force on that area, we do the following using the standard 101 kPa atmospheric pressure

$$p=\frac{F}{A} \quad so \quad F=p\,A=(101\times10^3\,\text{Pa})\cdot\pi\frac{(0.08\,\text{m})^2}{4}$$
$$=508\,\text{Pa}\cdot\text{m}^2=508\,\text{N}$$

Here the formula for the area A of a circle in terms of its diameter d is used, $A=\pi\frac{d^2}{4}$. I use two of these pushed against each other (with a small amount of water to help the rubber seal), and then ask a student to pull one while I pull the other. A surprising amount of force is needed to pull them apart. They come apart with a loud pop. The rubber seal often comes off the yellow plastic, but it is easy to reattach. This is a crude replication of a famous demonstration by a German named Otto von Guericke.

Every time you use a straw, you are using atmospheric pressure to push the liquid up to the reduced pressure in your mouth. Without the pressure of the atmosphere, a straw would not work.

A siphon (*https://en.wikipedia.org/wiki/Siphon*) can move water over a high point as long as the siphon is filled with water and that its outlet is lower than its inlet. Air entering the siphon, can stop the flow. That is another easy demonstration for a K-6 classroom.

Flowing fluids introduce another group of fascinating effects. First watch the following video:

Fluids in Motion (CC 15) 9 min 46 s
https://www.youtube.com/watch?v=fJefjG3xhW0&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV

> **Bernoulli's Principle** is very important. It explains lots of interesting phenomena, but we will not be concerned with the mathematical discussion in this presentation - just remember its result: **Faster fluid motion produces lower pressure**.
> Also, enjoy the discussion of Torricelli's Theorem, but you will not be tested about it.

In lab, I do a number of demonstrations to illustrate Bernoulli's Principle. Luckily, a teacher has shown those and a few more in the following video entitled "PHYS1550 Everyday Physics The Bernoulli Principle" at *https://www.youtube.com/watch?v=lbkllCjUETQ* .

The floating ball demonstration is particularly amazing, especially when done at a tilted angle. If you have a "shop vacuum", you can probably disconnect its hose from its inlet and put it on its outlet making it into a blower. (If you do this, remove its filter and clean it first or you will be breathing lots of dust.) A leaf blower should also work. All these demonstrations are explained by the idea that faster moving air has a lower pressure.

I also like talk about the formation of ocean waves by considering a perfectly flat section of ocean with wind blowing smoothly across its surface. Nothing happens if it is truly flat, but if a fish in the water causes a little bump in the water surface, the wind will need to flow over the bump. That detour will cause the wind speed to move faster over the top of the bump to stay with the rest of the air flowing higher up. But faster speed means lower pressure across the top of the bump. That lower pressure will cause the bump to raise slightly. Now, the bigger bump will cause a still greater detour for the wind, forcing an even greater wind speed and an even lower pressure over the top of the larger bump. The bump will then get even larger, and eventually become part of an ocean wave.

Within a day, the wind will have produced growing waves over a large region of the ocean until the waves get so large that whitecaps are formed and the air flow becomes turbulent. That then weakens the Bernoulli Effect and the wave growth maxes out. Interestingly, wind beyond Hawaii, can lead to excellent surfing conditions off the coast of California a few days later. Dedicated surfers pay close attention to distant ocean weather activity.

This growth-causing-more-growth is called **positive feedback**. It often happens in public address systems where a microphone is too close to a speaker causing a shrill screech. Our hydrogen and oxygen explosion is also a case of positive feedback. The small initial spark causes reactions of nearby gas molecules that release heat. That heat then triggers even more reactions in surrounding molecules which quickly become an explosive chain reaction. Bacteria, viruses, rabbits, and nuclear bombs tend to grow exponentially until limited by lack of energy or opportunity to spread.

Another use of the Bernoulli Principle is in the design of airplane wings. The Wright brothers were able to make their airplane fly by studying the shape of bird wings and building a wind tunnel to test their ideas. The first 1 minute and 41 seconds of the following video entitled "How Wings ACTUALLY Create Lift!" is the basic story I tell when I talk about airplane wings, but the remainder of the video is a more complete explanation. View it at *https://www.youtube.com/watch?v=YDeQXPNpLeY* .

After you give this explanation to a precocious 3rd grader, you might be asked "At an air show, I saw an airplane fly upside down. Shouldn't it have gone into the ground?" The answer is that with a sufficiently powerful engine, the shape of the airplane's wings can be unimportant.

The Bernoulli Effect causes the storm surge of a hurricane in which the ocean water under a hurricane is lifted by a lowered atmospheric pressure created by the high speed winds spinning around the center of the hurricane.

A tornadoes can lift cars or even house roofs because of the low pressure caused by the whirling winds around their cores.

Simple Harmonic Motion (CC 16) 9 min 10 s
https://www.youtube.com/watch?v=jxstE6A_CYQ&list=PL8dPuuaLjXtN0ge7yDk_UA0ldZJdhwkoV

Oscillation is repeated back and forth motion. Simple Harmonic Motion is just a fancier term for simple oscillations. As she talks about the spring-ball motion, think of the pendulum experiment you did (or will do) for this week's Wednesday lab. The trade-off between potential and kinetic energy is the same for all such oscillating systems.

The simple math associated with period and frequency, $T=\frac{1}{f}$ is important to us, but the discussions of angles and trigonometry in this video is not.

Resonance is an important concept you will be tested about. The child pumping a swing is using her action to pump the swing at its **resonant frequency**. All wind and string musical instruments depend on resonance to enhance their sound.

It is not required, but I hope some of you will be interested in doing some of the Bernoulli Effect demonstrations.

An unrelated note about rural life on a ranch:

As I was competing the first draft of this lecture at around 3 AM Thursday morning, a bird started frantically flying against my window screen 2 m from where I was working. This happens once in a while, but this time as I looked at it, a bobcat jumped up and caught the bird. My wife then heard the bobcat hop over our front gate to go off to enjoy its meal away from the house.

I have had a critter cam taking videos about 200 m from the house looking into a gully. It has operated all day long for the past couple of years and I have seen coyotes daily, bobcats weekly, and badgers, deer, and skunks once or twice a year. Squirrels, birds, lizards, and rabbits are, of course, common. And every so often a mouse can be seen or a gopher pops up out of the ground.

The birds we find most exciting are roadrunners and an occasional heron, hawk and eagle. One of my critter cams caught a roadrunner eating a small snake. I know that they do eat rattlesnakes, but this was probably a garter snake. Another time a roadrunner looked right into my camera appearing very much like a velociraptor from Jurassic Park. We have hundreds of Quail parading around the ranch.

While reviewing the critter cam videos, I can't help but think about what it is like to be wild animal. Every day, they are faced with the challenge of finding food while avoiding being eaten. A top predator is likely to starve if injured because evolution has carefully balanced the predator-prey relationship.

We love our coyotes and bobcats. It is fun to have them around. My wife (before I knew her) has seen mountain lions, but I have not. Even when doing hundreds of mountain hikes, I only saw bears a couple of times, but never a mountain lion. I am pretty sure, however, that mountain lions have watched me many times on mountain trails.

Rattlesnakes, however, are a problem. We usually see several a year, sometimes within our house perimeter wall and in our vegetable and pond gardens. We keep many shovels strategically located around the yard for rattlesnake control. When we kill a rattlesnake, we remain aware that the head can bite and deliver poison for 20 minutes after being chopped off. We smash its head flat and bury it. The body is left out for the ravens and other scavengers. Rattlesnakes are said to bite themselves to discourage something trying to eat them. We have met people who eat rattlesnakes, but they make sure that their meal has not bitten itself first.

We are happy to have other snakes – gopher snakes and garter snakes, and we especially love kingsnakes. Kingsnakes are immune to rattlesnake venom and kill rattlesnakes by constriction. Check out YouTube to see a kingsnake doing that job. Also, there is a great video of a bobcat killing a rattlesnake just for fun (or vengeance for some past encounter) and then leaving it to rot in the sun.

Gee. I miss being able digress for story telling during class.