Hydraulic earth mover

Overview: We'll finish this unit on Energy by building a pretty cool hydraulic earth mover. You'll be amazed by the power of liquid to help move the machine and help us to do work!

What to Learn: This lab shows us how fluids can specifically be used to help us to do work. This is a good example of the types of energy conversion that we use every day.

Materials

- plastic cup
- 20 tongue-depressor-size popsicle sticks
- 6 syringes (anything in the 3-10mL size range will work)
- 6 brass fasteners
- 5' of flexible tubing (diameter sized to fit over the nose of your syringes)
- four wheels (use film canister lids, yogurt container lids, milk jug lids, etc.)
- 4 rubber bands
- two naked (unwrapped) straws
- skewers that fit inside your straws
- hot glue gun (with glue sticks)
- sharp scissors or razor (get adult help)
- drill with small drill bits (You'll be drilling a hole large enough to fit the stem of a brass fastener.)

Lab Time

1. Connect two syringes with a piece of flexible tubing. Cut the tubing into three equal-sized pieces and use one to experiment with.
2. Shove the plunger on one syringe to the "empty," and leave the other in the "filled" position before connecting the tubing. What happens when you push or lift one of the plungers? Is it quick to respond, or is there "slop" in the system?
3. Now remove both plungers and, leaving the tubing attached, fill the system with water to the brim on both ends (this is a good bath-time activity!). Keep the open ends of the syringes at the same level as you fill them. What happens if you lower one of the syringes? What happens when you raise it back up? Is there now air in your system?
4. Fill your syringe-tube system up with water again, keeping the plungers at the same height as you work.
5. Insert one of the plungers into one of the syringes and play with the levels of the syringes again, lifting one and lowering the other. Now what happens, or doesn't happen?
6. Now connect your plungers into a fully hydraulic system: Push the plunger all the way down to expel the water from one of the syringes (water should leak all over the place from the open syringe).
7. Now add the second plunger to the open syringe and push the plunger down halfway. What happens? You have just made a hydraulic system!

Hydraulic Earth Mover Observations

1. Look back at the procedure for Lab Time, and at Step number 3. At this point in your experiment, what happens to the syringes when you raise and lower one but not the other?

2. After you've connected the second plunger, what happens?

3. Explain what the fluid is doing in your earth mover.

What's going on in this experiment? It's all about air pressure distribution. Because both syringes are open to the atmosphere, they both have equal amounts of air pressure pushing down on the surface of the water. When you raise one syringe higher than the other, you have increased the elevation head of the higher syringe, which works to equalize the water levels in the two syringes (thus shoving water out of the lower syringe). Elevation head is due to the fluid's weight (gravitational force) acting on the fluid and is related to the potential energy of the raised syringe (which increased with elevation). This acts as the force that is applied to the lever, helping us do work in creative ways.

Reading

When people mention the word "hydraulics," they could be talking about pumps, turbines, hydropower, erosion, or river channel flow. The term "hydraulics" means using fluid power, and deals with machines and devices that use liquids to move, lift, drive, and shove things around. Liquids behave in certain ways: They are incompressible, meaning that you can't pack the liquid into a tighter space than it already is occupying.

If you've ever filled a tube partway with water and moved it around, you've probably noticed that the water level will remain the same on either side of the tube. However, if you add pressure to one end of the tube (by blowing into the tube), the water level will rise on the opposite side. If you decrease the pressure (by blowing across the top of one side), the water level will drop on the other side.

In physics, this is defined through Pascal's law, which tells us how the pressure applied to one surface can be transmitted to the other surface. As liquids can't be squished, whatever happens on one surface affects what occurs on the other. Examples of this effect include siphons, water towers, and dams. Scuba divers know that as they dive 30 feet underwater, the pressure doubles. This effect is also shown in hydraulics – and more importantly, in the project we're about to do!

But first, let's understand what's happening with liquids and pressure:

Here's an example: If you fill a glass full to the brim with water, you reach a point where for every drop you add on top, one drop will fall out. You simply can't squish any more water molecules into the glass without losing at least the same amount. Excavators, jacks, and the brake lines in your car use hydraulics to lift huge amounts of weight, and the liquid used to transfer the force is usually oil at 10,000 psi.

Air, however, is compressible. When car tires are inflated, the hose shoves more and more air inside the tire, increasing the pressure (amount of air molecules in the tire). The more air you stuff into the tire, the higher the pressure rises. When machines use air to lift, move, spin, or drill, it's called "pneumatics." Air tools use compressed air or pure gases for pneumatic power, usually pressurized to 80-100 psi.

Different systems require either hydraulics or pneumatics. The advantage to using hydraulics lies in the fact that liquids are not compressible. Hydraulic systems minimize the "springy-ness" in a system because the liquid doesn't absorb the energy being transferred, and the working fluids can handle much heavier loads than compressible gases. However, oil is flammable, very messy, and requires electricity to power the machines, making pneumatics the best choice for smaller applications, including air tools (to absorb excessive forces without injuring the user).

Exercises Answer the questions below:

1. Hydraulics refers to the use of what to do work?
    a. Solids
    b. Gases
    c. Fluids
    d. Liquids
2. What is it called when we use air to do work?
    a. Aerodynes
    b. Pneumatics
    c. Nitrous
    d. Oxygenation
3. In general, liquids cannot be squished together. What do we call this?
    a. Impressive
    b. Immersive
    c. Inert
    d. Incompressible
4. Is the answer to the previous question important to how all hydraulic systems work?
    a. Yes
    b. No

Answers to Exercises: Hydraulic Earth Mover

1. Hydraulics refers to the use of what to do work? (fluids)
2. What is it called when we use air to do work? (pneumatics)
3. In general, liquids cannot be squished together. What do we call this? (incompressible)
4. Is the answer to the previous question important to how all hydraulic systems work? (No)