Lesson 57: Pascal's Principle (AP Only)

Imagine that you have a container of fluid.

- From what we've learned so far, we know that the pressure the fluid exerts on the sides of the container is the same everywhere.
  - If they were not, the fluid would no longer be static.
- Now we exert a force somewhere on the outside of the container. What can we expect will happen to the pressure inside the container?
  - Well, for starters, it makes sense to say that the pressure will increase.
  - The important part is that, according to **Pascal's Principle**, the pressure will increase everywhere in the fluid, not just where you are applying the force.

Application of Pascal's Principle

Probably the most easily understood example of Pascal's principle at work is when a hydraulic lift (like in a mechanics garage) lifts up a large mass.

We don't care what the original pressure was in the cylinder, only that the force we are exerting now causes a change in pressure.

- On one side we have a **small cylinder** (filled with an incompressible liquid) with a piston. This is where we will exert a force downwards.

$$\Delta P = \frac{F_1}{A_1}$$

- This is connected by a pipe to another, **larger cylinder**, with a large piston, where the large mass will be lifted by a force upwards.

$$\Delta P = \frac{F_2}{A_2}$$

According to Pascal's principle, the change on both sides must be the same.

- If ΔP is the same, then we can combine the two formulas from above into one equation...

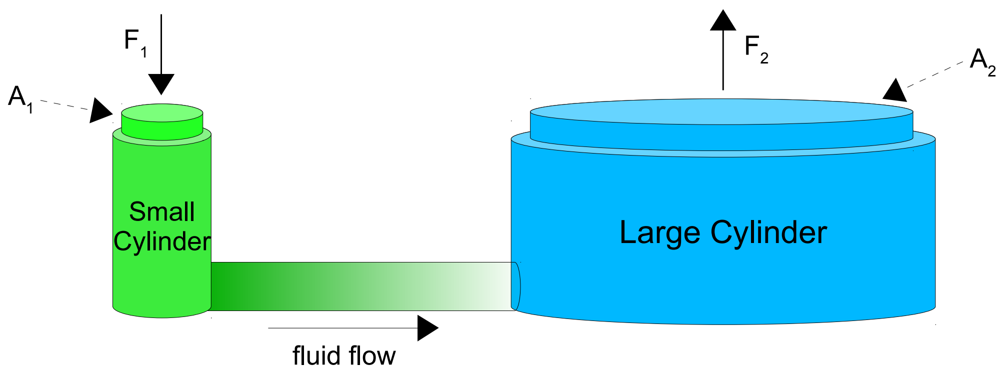

Illustration 1: A hydraulic lift works according to Pascal's principle.

$$\Delta P = \Delta P$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

- Since $A_2 > A_1$, then $F_2 > F_1$ for the two sides to be equal. This just means that we can exert a small force on the small piston and get a bigger force on the big piston.

Does this sound like getting something for nothing? It isn't, if you keep a few ideas in mind.

- First of all, even though we only push the small piston with a small force, we have to push it a big distance down. On the other side the large piston has a large force up, but it only moves a small distance up.
  - This is because we are moving a constant volume of fluid (it is incompressible, remember). This can be calculated for either side...

$$V = A_1 d_1 \qquad V = A_2 d_2$$

$$A_1 d_1 = A_2 d_2$$

  - Both of these sides are equal, so we can multiply a formula by either side and not change anything...

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$
$$\frac{F_1}{A_1}(A_1 d_1) = \frac{F_2}{A_2}(A_2 d_2)$$
$$F_1 d_1 = F_2 d_2$$
$$W_1 = W_2$$

If I have a formula like 5x = 10 I can multiply both sides by 2 and get 10x = 20 and not really change anything. Same idea here; from above we know that Ad calculated using either pair of numbers is the same, so if I multiply using A_1d_1 or A_2d_2, it's really the same thing.

  - This shows that the work done is the same on both pistons. Conservation of energy is ok, since we haven't created or destroyed any energy.

Example 1: I want to build a hydraulic press to be able to squeeze all my gold bars down to thin gold disks. The small piston has an radius of 1.0 cm and I will be able to exert a force of 150 N on it. If the large piston has a radius of 10 cm **determine** the force against the gold bars.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$
$$\frac{F_1}{\pi r_1^2} = \frac{F_2}{\pi r_2^2}$$
$$\frac{F_1}{r_1^2} = \frac{F_2}{r_2^2}$$
$$\frac{150}{0.010^2} = \frac{F_2}{0.10^2}$$
$$F_2 = 1.5\text{e}4\ N$$

We can cancel pi on both sides.

Homework

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