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BOCES Science Laboratory Investigation

PASCAL’S LAW

**Introduction**

Blaise Pascal, aside from having a pretty fantastic name, was a French scholar who lived in the mid 1600s. Among other things, he came up with what became known as Pascal’s Law, which deals with fluids in a closed chamber. Put simply, Pascal’s Law states:

“A change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.”

That means that if you push on a fluid in, say, a bottle, the force that your finger gives to the fluid at that point is spread to all the other points in the bottle. This might seem to defy the first law of thermodynamics, which, of course, you know. In case you have forgotten, the first law states that energy can neither be created nor destroyed, it can only change forms. So you might say to yourself that if your finger-pushing is being transferred all over the bottle, aren’t you creating energy? You are not. Let’s consider the illustration below:

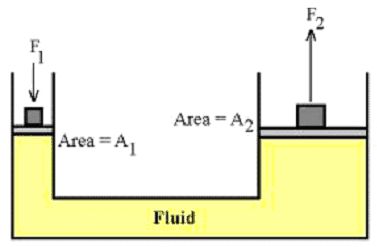


Figure 1. An illustration of Pascal’s Law with differently-sized pistons.

If you apply a force to the left piston, then that force travels throughout the fluid. It pushes up on the right piston, too. However, let us suppose that the right piston is three times larger than the left piston. So if you push the left piston down 3 cm, because the right one is three times larger, it only moves up 1 cm. Thus, no energy is created or destroyed.

It behooves us to discuss pressure and force in slightly more detail, though. Force is very simply described by the formula below:

**F = ma**

Where F is the force, m is the mass and a is the acceleration. Force is measured in a unit called the newton, after the famous scientist of the same name (not the cookies). As a convenient reference point, a medium-sized apple resting on the palm of your hand exerts a force of about 1 N. That’s not much force. As you examine the formula, you can see that there are two things that can determine the force that an object exerts: the mass of the object and how fast it is accelerating. Mass is easy – the more matter something is made out of, the more massive it is. A bowling ball has more mass than a mouse; a planet has more mass than you.

Acceleration is a bit trickier to understand. Acceleration is the change in velocity over time. We measure velocity in meters per second, and time in seconds. So acceleration is how many m/s a velocity changes every second. This results in the unit m/s/s. On earth, the force of gravity pulls everything down with an acceleration of 9.81m/s/s.

In contrast to force, pressure takes into account the *area* over which a force acts. Take the example of a woman wearing sneakers. If she were to walk through some soft grass, she might do so rather easily and not get stuck. If she tried to do the same thing while wearing high-heeled shoes, she would surely sink in and get stuck. Not because her mass changed, but because all the force of her body, instead of being spread out across the entire bottom of her sneaker, is now concentrated on the very tip of the high heel. Pressure, for those of you who are curious, is measured in pascals, named, of course, after Blaise himself. One pascal is equivalent to a force of 1 N spread over 1 square meter. Remember that 1 N is not that much, so 1 Pa is a very small amount of pressure. Indeed, most pressure gauges used measure in kPa, kilopascals.

QUESTION 1: If an object is accelerating at 10 m/s/s and it has a mass of 5 kg, what force does it exert?

QUESTION 2: With how much force would you need to push a wooden block that had a mass of 25 kg to get it to accelerate to 15 m/s/s?

QUESTION 3: How much force does a 1,300 kg smart car exert on the ground on earth?

QUESTION 4: How much pressure is exerted by a 2,000 kg car on the surface of the earth if the total contact area of the tires on the ground is 1 square meter?

QUESTION 5: Suppose you have a tube that has an opening that is 1 square cm on one end and 10 square cm on the other end. You apply a force of 10 N to the small end.

a. What force results on the larger end?

b. What pressure results on the larger end?

c. Suppose that you push down on the small end with the same force (10 N), and you move it 20 cm. How far will the larger end move?

QUESTION 6: Determine the force that is exerted on a hydraulic lift in the shop by a car. This is easily done by converting the weight of a car in pounds into Newtons. Based on the diameter of the tubes on the lift, how much force do you think the pump is generating in order to lift the car?

QUESTION 7: Average atmospheric pressure is 101.392 kPa. Many car lifts operate at a pressure of 14 MPa! Does the pump that provides the pressure have to generate 14 MPa? Explain.