Name ______________________ Class ________________ Date __________

Summary

13.1 Fluid Pressure

Pressure is the result of a force distributed over an area. To calculate pressure, divide the force by the area over which the force acts.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

In the formula, force should be in newtons (N) and area should be in square meters (m^2). The resulting unit—newtons per square meter (N/m^2)—is the SI unit of pressure, also known as a pascal (Pa).

A fluid is a substance that takes the shape of its container. Both liquids and gases are fluids. Water, oil, gasoline, air, and helium are fluids.

A fluid exerts pressure. The amount of pressure a fluid exerts depends on several factors. Water pressure increases as depth increases. The pressure in a fluid at any given depth is constant, and it is exerted equally in all directions.

Surprisingly, the shape of a container and the area of its bottom do not affect fluid pressure. For a fluid that is not moving, depth and the type of fluid are the two factors that determine the pressure the fluid exerts. Thus, the amount of fluid, measured in terms of volume or weight, does not affect pressure.

Air pressure increases with the depth of the atmosphere. Instead of referring to a certain depth of the atmosphere, however, people refer to their altitude above sea level. Air pressure decreases as the altitude increases.

The atmosphere is exerting more than 1000 newtons of force on the top of your head. Fortunately, the inside of your body also exerts pressure. The pressure inside your body balances the air pressure outside. The balanced forces cancel, resulting in a net force of zero.

13.2 Forces and Pressure in Fluids

Imagine a two-liter soda bottle completely filled with water, with its cap tightly screwed on. Note that at any given depth, equal pressure acts against any point on the inside of the bottle. Note also that the pressure increases with depth.

If you squeeze the bottle in the middle, the pressure increases equally throughout the water, not just at the point where you squeeze. The French scientist Blaise Pascal discovered this phenomenon in the 1600s. His observations led to a general principle. According to Pascal's principle, a change in pressure at any point in a fluid is transmitted equally and unchanged in all directions throughout the fluid.

Hydraulics is the science of applying Pascal's principle. A hydraulic system is a device that uses pressurized fluid acting on pistons of different sizes to change a force. In a hydraulic lift system, an input force is applied to a small piston, which pushes against the fluid sealed in the hydraulic system. The pressure produced by the small piston is transmitted through the fluid to the large piston. Thus, the pressure on both pistons is the same.

However, the pressure pushing against the large piston acts on a much larger area, which is the key to how the system works. In a hydraulic lift system, an increased output force is produced because a constant fluid pressure is exerted on the larger area of the output piston. If the large piston has eight times the area of the small piston, then the output force is eight times greater than the input force. Recall that force is equal to the product of pressure and area. Because the pressure on each piston is the same, the difference in forces is directly related to the difference in areas.

When you blow across the top of a single sheet of paper, the far end of the paper lifts upward. The Swiss scientist Daniel Bernoulli discovered the reason why the sheet of paper behaves as it does. According to Bernoulli's principle, as the speed of a fluid increases, the pressure within the fluid decreases. The air blowing across the top of the paper exerts less pressure than the stationary air underneath. Because the air below the paper is nearly motionless, it exerts a greater pressure. The difference in pressure forces the paper upward.

The ability of birds and airplanes to fly is largely explained by Bernoulli's principle. The air traveling over the top of an airplane wing moves faster than the air passing underneath. This creates a low-pressure area above the wing. The pressure difference between the top and the bottom of the wing creates an upward force known as lift. The lift created in this way is a large part of what keeps the airplane aloft. The wings of birds produce lift in much the same way as an airplane.

13.3 Buoyancy

Buoyancy is the ability of a fluid to exert an upward force on an object placed in it. Buoyancy results in the apparent loss of weight of an object in a fluid. In fact, every object in a fluid experiences buoyancy. When an object is submerged in water, the water exerts an upward force on the object, making it easier to lift. This upward force, which acts in the opposite direction of gravity, is called a buoyant force.

Because water pressure increases with depth, the forces pushing up on the bottom of a submerged object are greater than the forces from pressure pushing down on the top of the object. All other non-vertical forces cancel out one another. The result is a net upward force—the buoyant force.

The ancient Greek mathematician Archimedes is credited with an important discovery that bears his name. According to Archimedes' principle, the buoyant force on an object is equal to the weight of the fluid displaced by the object. When an object is submerged, it pushes aside—or displaces—a volume of fluid equal to its own volume.

Density and buoyancy are closely related. Recall that density is the ratio of an object's mass to its volume. If an object is less dense than the fluid it is in, it will float. If the object is more dense than the fluid it is in, it will sink. Different fluids can also float or sink in one another.

You can also determine if an object will float by analyzing the forces acting on it. The force of gravity—equal to the object's weight—acts downward on the object. The buoyant force—equal to the weight of the volume of displaced fluid—acts upward on the object. When the buoyant force is equal to the weight, an object floats or is suspended. When the buoyant force is less than the weight, the object sinks.

- An object that has the same density as the fluid it is submerged in will be suspended (it will float at any level) in the fluid. The buoyant force acting on the suspended object exactly equals the object's weight.
- When an object's weight becomes greater than the buoyant force acting on it, the object will sink.
- A heavy steel ship floats because of the shape of its hull. The hull is shaped so that it displaces a large volume of water, creating a large buoyant force. The buoyant force created by the ship's hull is large enough to counteract the ship's tremendous weight.

Objects float more easily in dense fluids. For a given displacement, the denser the fluid is, the greater the weight displaced. This greater displaced weight results in a greater buoyant force.