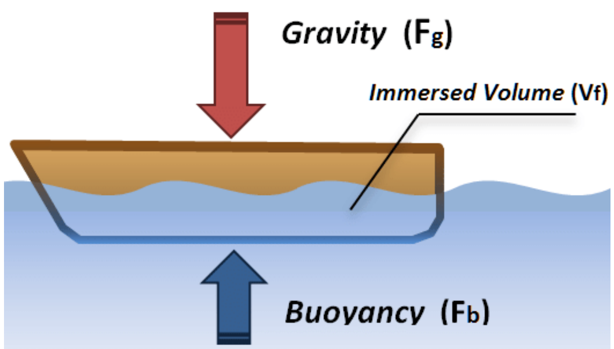
2021Q22 (BUOYANCY)

Have you ever wondered why a small rock might sink but a big cargo ship that weighs thousands of tons can float in water? Why is it hard to force an inflated ball underwater, and why does it shoot up if you do? The answer to all these mysteries is buoyancy.

Buoyancy, also commonly referred to as the buoyant force, is the force that a fluid applies to any object that is completely or partially submerged in it; like other forces, buoyancy is measured in newtons. This force always acts straight upwards, opposing the direction of gravity. For anything to float, the buoyant force must be as strong as gravity; oftentimes, engineers ensure that the buoyant force is even stronger than gravity for extra safety. Buoyancy is one of many scientific principles accounted for when wind turbine parts are shipped overseas.

The amount of buoyancy that a fluid applies to an object is based on three factors: the density of the fluid, the acceleration due to gravity, and the volume of the fluid that has been displaced. Because the acceleration due to gravity is a constant on Earth (9.8 $^{m}/_{s^2}$) and the density is a property of the material, the displaced volume of the fluid is the variable in this equation. The volume of the submerged portion of the object is the same as the displaced fluid's volume.

The buoyant force formula is:



$$Buoyant\ Force = Density\ of\ Fluid * 9.8\ ^{m}/_{s^2} * Displaced\ Volume\ of\ Fluid$$

Source: https://www.mech4study.com/2019/05/what-is-buoyancy-full-explaination.html

Level 1: A wind turbine blade is being shipped across the ocean. The mass of the blade is 8,200 kg, and the mass of the cargo ship carrying the blade is 90,000,000 kg. What is the minimum buoyant force needed to counteract the weight of this blade?

Level 2: Let's say the cargo ship carrying our blade has a length of 400 meters, a width of 60 meters, and extends into the water 20 meters. If we model the cargo ship as a rectangular prism, how much buoyant force does the cargo ship have? The density of water is 1,000 $^{kg}/_{m^3}$.

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Level 1: To find the minimum buoyant force needed, we need to find the gravitational force that we know is acting on the boat. Remember, these two forces need to have at least equal magnitude to ensure the boat floats instead of sinks. The gravitational force would be the mass of what's floating on water (the boat's mass plus the blade's mass) multiplied by the gravitational constant.

$$Gravitational\ Force = (Mass_{boat} + Mass_{blade}) * Gravitational\ Constant$$

$$Gravitational\ Force = (90{,}000{,}000kg + 8{,}200kg) * 9.8\ {}^{m}/_{s^2}$$

$$Gravitational\ Force = 882.98\ meganewtons = 882{,}980{,}000\ N$$

Therefore, the buoyant force must also be equal to 882.98 meganewtons for the ship to float.

Level 2: To solve this problem, we can look back at our equation for the buoyant force:

$$Buoyant\ Force = Density\ of\ Fluid\ \times 9.8\ {}^{m}/_{s^2} \times Displaced\ Volume\ of\ Fluid$$

We are given the density of water as 1,000 ${}^{kg}/_{m^3}$, so we need to solve for the volume of the displaced fluid. We can do this using the dimensions given! The volume of the displaced fluid is the volume of the cargo ship underwater.

$$Volume_{cargo\ ship\ underwater} = length * width * depth\ into\ water$$

$$Volume_{cargo\ ship\ underwater} = 400\ m * 60\ m * \ 20\ m = 480{,}000\ m^3$$

$$Buoyant\ Force = \ 1{,}000\ {}^{kg}/_{m^3} \times 9.8\ {}^{m}/_{s^2} \times 480{,}000\ m^3 = 4.7\ giganewtons = 4{,}700{,}000{,}000\ N$$

Source: https://theconversation.com/suez-canal-blockage-how-cargo-ships-like-ever-given-became-so-huge-and-why-theyre-causing-problems-158090