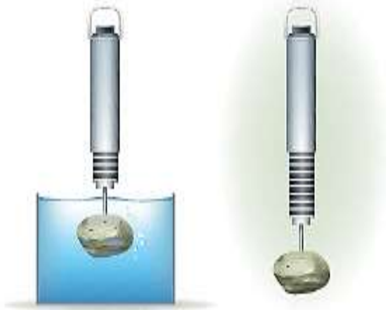
UPTHRUST (BUOYANT) FORCE

ARCHIMEDES PRINCIPLES

UPTHRUST OR BUOYANT FORCE (LIQUIDS)

The body that is immersed in the fliquid decreases the weight. Here are some examples:

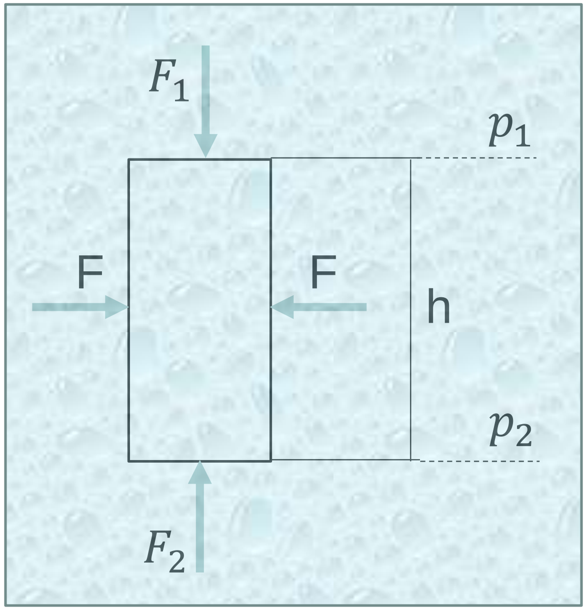
If you try to lift up a weight in a swimming pool and then try to lift the same weight on the edge of the pool, it feels much lighter in the water. The dynamometer shows less weight when the body is immersed in water (picture 1).
When the object is completely or partially immersed in the fluid, the object will push the liquid, so the liquid pushes back with as much upward force as it can.



picture 1

The upthrust force is the resultant upward force exerted on an object in a fluid by the surrounding fluid. It acts against gravity.

Let's consider a solid body (square) completely submerged in a homogeneous liquid as shown in picture 2. Hydrostatic pressure forces act on the entire surface of the body. If the pressure on the left side of the body is equal to the pressure on the right side of the body, then forces are equal in horizontal direction **(all points at the same depth must be at the same pressure).** Two vertical forces act on this volume of body: the upward force $p_1 A$ exerted by the liquid below it; and a downward force $p_2 A$ exerted by the liquid above it. The force $p_2 A$ is greater than the force $p_1 A$ by exactly the weight of liquid between the two points so, we can find the total upward force on the body exerted by liquid pressure by simply taking the difference between the magnitudes of the downward force $p_2 A$ and upward force $p_1 A$,



picture 2

$$B = F_2 - F_1 = p_2 \cdot A - p_1 \cdot A \quad \Rightarrow \quad B = (p_2 - p_1) \cdot A$$

It is known that $p_2 - p_1 = \rho g h$ $\Rightarrow$ $B = \rho g h \cdot A$

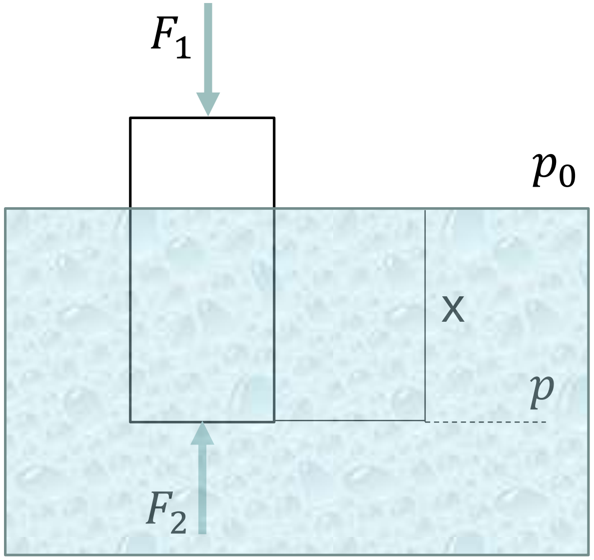
The product $A \cdot h$ is equal to the volume of the body (V), so: $\boldsymbol{B = \rho g V}$

Let's consider a solid body (square) partially submerged in a homogeneous liquid as shown in picture 3. Hydrostatic pressure forces act on the partially submerged surface of the body.

Two vertical forces act on this volume of body: the upward force $p_0 A$ exerted by the atmospheric pressure below it; and a downward force pA exerted by the liquid above it. We can find the total upward force on the body by simply taking the difference between the magnitudes of the downward force pA and upward force $p_0 A$,

$$B = F_2 - F_1 = p \cdot A - p_0 \cdot A = (p - p_0) \cdot A$$

It is known that $p = p_0 + \rho g x$ → $B = \rho g x \cdot A$



picture 3

The product x ·A is equal to the volume of body partially immersed (V) so: $\boldsymbol{B = \rho g V}$

This formula applies to the body of arbitrary shape. We conclude that:

Upthrust force is an upward force resulting from an object being wholly or partially immersed in a fluid. The intensity of this force is equal to the product of the density of the liquid, the gravitational acceleration and the volume of a part of the submerged body:

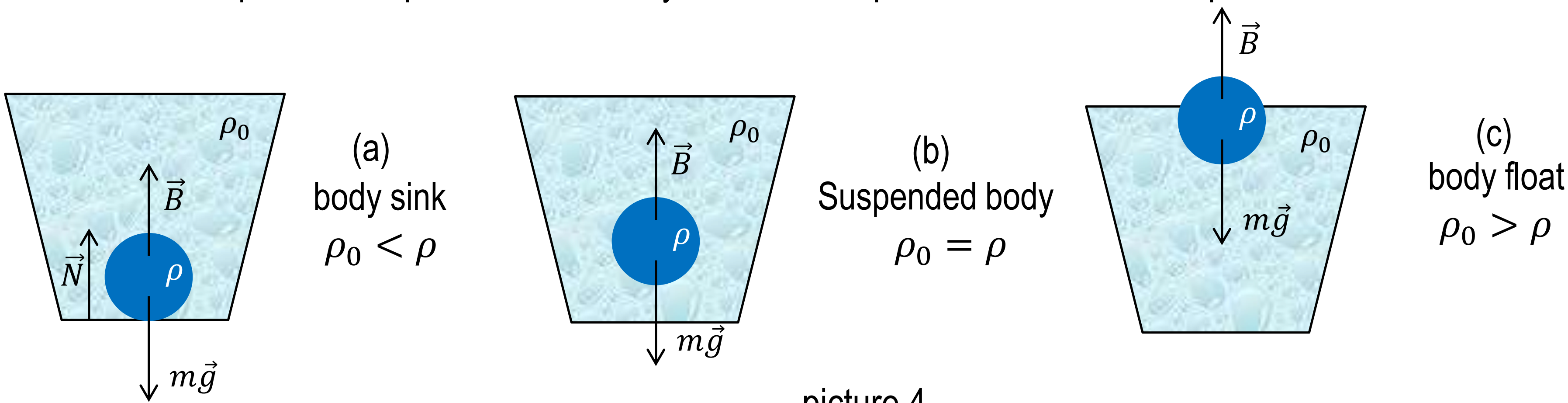
Archimedes' principle states that:
When a body is immersed fully or partially in a fluid, it experiences a upthrust force in upward direction which is equal to the weight of the fluid displaced by the body.

→ $\mathbf{B = \rho g V = Mg}$ →

Where M- Mass of fluid which would take up some volume as object,
Mg- weight of the fluid displaced by the body

ARCHIMEDES LAW OF FLOATATION

When in liquid, the object experiences two forces: the force of gravity which acts downwords and the upthrust force which acts upward. The position of the body in the fluid depends on the relationship of these two forces.



picture 4

♦ If the upthrust force is less than the force of gravity then the body will sink (picture 4-a) .

$$B < F_g \Rightarrow \rho_0 \cdot V \cdot g < \rho \cdot V \cdot g \Rightarrow \rho_0 < \rho$$

♦ If the upthrust force is equal to the force of gravity, then the body will be suspended in the liquid (picture 4-b).

$$B = F_g \Rightarrow \rho_0 \cdot V \cdot g = \rho \cdot V \cdot g \Rightarrow \rho_0 = \rho$$

♦ If the upthrust force is greater than the force of gravity then the body will float (picture 4-c).

$$B > F_g \Rightarrow \rho_0 \cdot v \cdot g > \rho \cdot v \cdot g \Rightarrow \rho_0 > \rho$$

Where m- mass of the object, g- acceleration due to gravity, V- volume of object when totally submerged, v- volume of object when partially immersed, ρ- density of object, ρ_0- density of liquid

The density of lead is greater than iron, and both metals are denser than water. Is the buoyant force on a solid lead object : (a) greater than, (b) equal to, or (c) less than the buoyant force acting on a solid iron object of the same dimensions?

UPTHRUST OR BUOYANT FORCE (GASES)

Picture 5

The upthrust force in the gases is considerably weaker than the upthrust force in the liquids, since the gases have a lower density than the liquid. The upthrust force in the air is more weaker than the force of the gravity, so the upthrust force in the air can be ignored.

However, if there is a large volume of the body then the upthrust force in the air can not be neglected, because the upthrust force is lifted and maintained in the air of a large balloon that carry a few people and heavy equipment.(picture 5).

PROBLEMS

1. a) An object of volume $4cm^3$ is totally immersed in liquid of density $1030\,kg/m^3$. Find the upthrust force that act on that object

   b) A solid cube of material is 0,75m on each edge. If floats in oil of density $800\,kg/m^3$ with one third of the block out of the oil. Find the upthrust force that act on the cube.

2. A copper ball hangs on a dynamometer. A dynamometer registrs 10N in air.

   a) find mass and volume of the ball

   b) find the force which registrs the dynamometer, if the ball is immersed in machine oil.

   Density of copper and machine oil are:8900 kg/m^3 and 900 kg/m^3.

3. A solid ball floats on the interface of the two immiscible liquid (mercury and machine oil). Find the density of the ball, if half of its volume is in mercury and other half is in machine oil.

4. A submarine of volume V floats on water with half of its volume above the water. What volume of water should be pumped into its ballast tank so that the submarine floats submerged in water?

5. Find the work done by tension force to raise the stone (with the cable) from the water, at depth of 1m. Density and volume of stone are: $2500\,kg/m^3$ and $1{,}5\,m^3$. Stone moves with constant speed.

6. Find the work done by force F to push 200 g ball (with radius of 10 cm) into the water of a depth of 1m.

ARCHIMEDES PRINCIPLE

The Greek Mathematician and inventor Archimedes lived during the 3rd century BC. According to history he was in the bath one day when he discovered the principle of buoyancy which is the reason why huge Greek ships weighing thousands of pounds could float on water. He noticed that as he lowered himself into the bath, the water displaced by his body overflowed the sides and he realised that there was a relationship between his weight and the volume of water displaced. It is said that he ran naked into the street yelling eureka (I found it).

picture
determining the composition of the crown

Archimedes was not thinking about ships at the time, he was on a mission to solve a question that was asked of him by King Hieron II of Syracuse. The question that the king had asked was about his crown. Was it pure gold or partly silver? Archimedes reasoned that if the crown had any silver in it, it would take up more space than a pure gold crown of the same weight because silver is not as dense as gold. He compared the crown's volume (measured by the amount of water displaced) with the volume of equal weights of gold and then silver, he found the answer. He had to inform his king that the crown was not pure gold.