FLUIDS

Are phases of matter that includes liquids, gasses, plasmas, and sometime plastic solids

NOTE -> difference between gasses and liquids is that gasses are **compressible** while liquids are not

PROPERTIES OF FLUIDS

Density 'p'

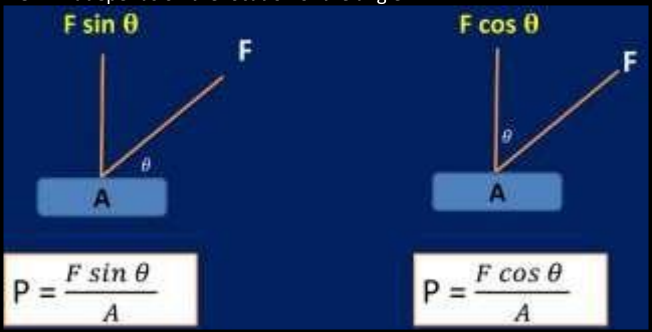
- It's the ration between mass and volume and has the unit of **kg/m³**
- The density of water is **p_w** which equals **1g/cm³** or **1000kg/m³**
- The density of air is **p_{air}** which equals **1.21 kg/m³**

Specific gravity (relative density)

- Ratio between the density of any material and the density of water at the same temperature
- **R.D** = $\frac{\rho_{substance}}{\rho_{water}}$

Pressure 'P'

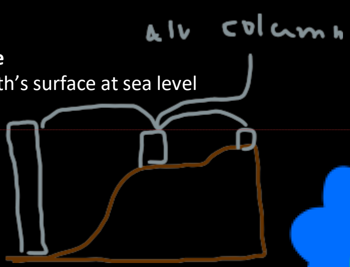
- The magnitude of the perpendicular force on a surface per unit area
- It equals $P = \frac{F}{A}$
- Where
  - **P** is the pressure
  - **F** is the force exerted by the fluid on the object
  - **A** is the area
- The SI unit of pressure is **Pascal (Pa)** which equals 1 N/m²
- If the force hit in an angle, you get the perpendicular force using this
  NOTE : it depends on the location of the angle



- Pressure is **directly related to** force **when area is constant**
- Pressure is **inversely related to** area **when force is constant**

Atmospheric (Air) Pressure

the weight of the air column over unit area of earth's surface at sea level

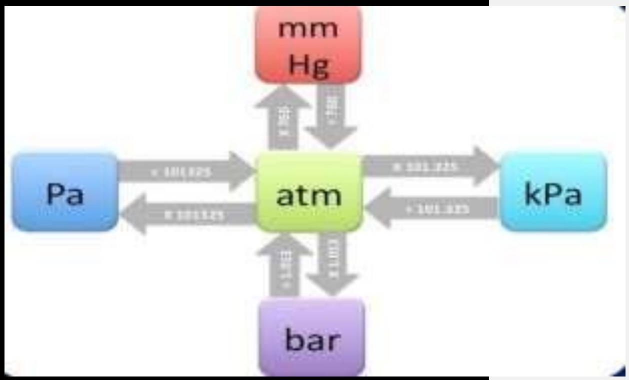


1 atm = 1.01325 x 10^5 Pa

Commented [SD1]: Where atm is the atmospheric pressure unit

Units of atmospheric pressure

Unit		Conversion
Weight	Newton/m^2	1 atm = 101,325 = 1.013 x 10^5 N/m^2
	Pascal (Pa)	1 atm = 1.013 x 10^5 N/m^2 1 N/m^2 = 1 Pascal
	Psi (lb/in²)	1 atm = 14.7 psi (Pound per square inch)
	Bar	1 atm = 1.013 bar 1 bar = 10^5 N/m^2
Length	cm Hg	1 atm = 76 cm Hg = 760 mm Hg = 29.92 inHg
	Torr	1 atm = 760 torr 1 torr = 1 mm Hg 1 Torr = 101325/760 Pascal (≈ 133.3 Pa)



Absolute pressure (P_{abs})

It's the pressure measured relative to a perfect vacuum

Gauge pressure (P_{gage})

It is the measured pressure using a measuring instrument, it can be either positive or negative depending on whether the pressure is **higher/lower** than the atmospheric pressure

$$P_{abs} = P_{atm} \pm P_{gage}$$

$$P_{gage} = P_{abs} - P_{atm}$$

So gauge pressure is the difference in pressure between the absolute pressure and the atmosphere pressure

Hydrostatic (fluids at rest) pressure

it is the pressure of bodies inside a fluid

$P_L = p\ g\ h$

where:

- Depth of the fluid (h)
- Density of the fluid (p)
- Gravitational acceleration (g)

$P_T = P_0 + p\ g\ h$

where:

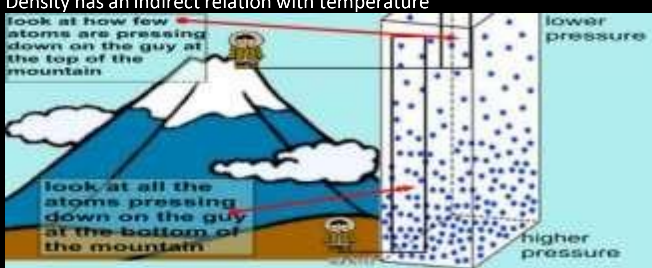
- Total pressure at the bottom of the column of fluid (P_T)
- Pressure at the top of the column . (P_0)
- Depth of the fluid (h)
- Density of the fluid (p)
- Gravitational acceleration (g)

The pressure is directly proportional with the gravitational acceleration, height, and density

IMPORTANT RELATIONS

Change in atmosphere pressure with density

- Pressure has a direct relation with density
- Density has an indirect relation with temperature



Atmospheric pressure with boiling point of water

- Pressure has a direct relation with the bond strength between molecules (aka melting & boiling point)
- Pressure has an indirect relation with the altitude

- If the atmospheric pressure is 1 atm, then the boiling point of water is 100° Celsius

Change in Atmospheric pressure with altitude/depth

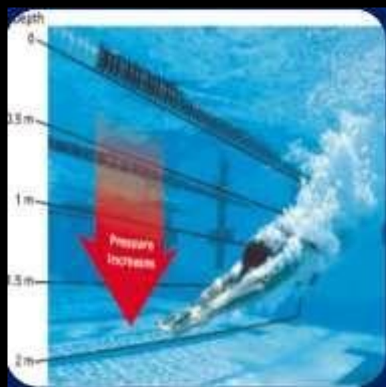
$$\Delta P = pg\Delta h$$

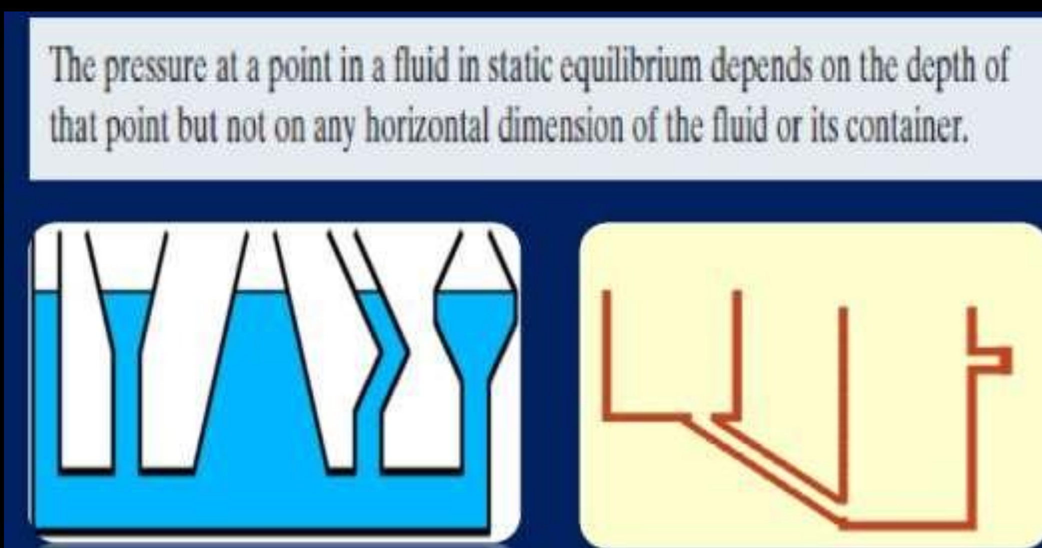
Where:

- ΔP = change in pressure
- p = density
- g = gravitational acceleration
- Δh = change in depth

Pressure has a **direct** relation with **depth**

And an **indirect** relation with altitude





here it means that the pressure in all the shapes are the same because they all have the same depth

NOTES

- All points that lie on the same horizontal level inside a liquid have the same pressure.
- The liquid rises to the same height (level) in the connecting vessels regardless of the geometrical shape.
- The average sea level is constant for all connected seas and oceans.
- The base of a dam is thicker than its top.
    - To withstand the increasing pressure with increasing depth

When fluid is in U shape

Pressure at point 1 = pressure at point 2

$$P_1 + \rho_1 g h_1 = P_2 + \rho_2 g h_2$$

$$\Downarrow$$

$$\rho_1 h_1 = \rho_2 h_2$$

$$\frac{\rho_2}{\rho_1} = \frac{h_1}{h_2}$$

NOTES

- Oils relative density ranging from 0.7 to 0.98 g/cm^3, so most are less dense than water .
  - For Petroleum ≅ 800 Kg/m3 or 0.8 g/cm^3

Pressure measuring devices have two types

Commented [SD2]: All barometers are manometers, but not all manometers are barometers.

Differences	Barometers	Manometers
Close-ended with Vacuum	Yes	Yes
Open-ended tube	No	Yes
Modern digital sensors	Yes	Yes
Mercury Inside	Yes	Yes
Light Liquids Inside	No (Unusual)	Yes
Calculate Atmospheric Pressure	Yes	Yes
Calculate Other Pressures	No	Yes

The barometer

It measures **the absolute pressure** represented by the weight of the mercury column using its height

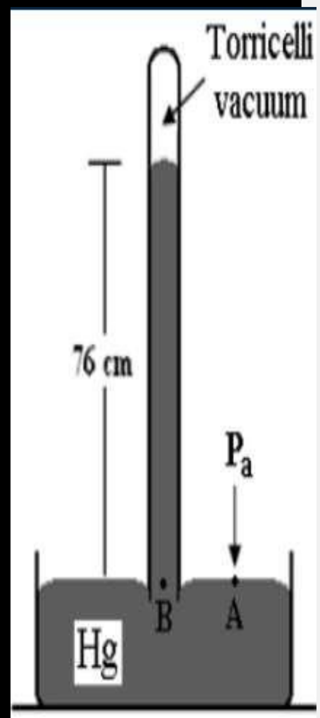
The manometer

It measures **the gauge pressure** represented by the difference between the atmospheric pressure and pressure of a trapped gas

Torricelli Barometer

It measures the atmospheric pressure

It's a long glass tube of 1m filled with mercury in a tank of mercury



How it works

- The mercury in the tube pushes down on the mercury on the tank, and the atmospheric pressure pushes down on the open surface of the mercury in the tank
- The mercury goes down until a certain level, where it's stopped by the atmospheric pressure, leaving a space in the column called the **Torricelli vacuum**
- The atmospheric pressure is equivilent to 76 cmHg or 760 mmHg (torr) at 0 degrees celcius and
- The higher the pressure, the higher the column and else

Pa	Atm.	Pascal or (N/m^2)	Bar	m Hg	cm Hg	mm Hg or Torr
	1	1.013×10^5	1.013	0.76	76	760

Bar = 10^5 Pascal. ($Kg/m.s^2$)

You can use the torricelli barometer by measuring the pressure at the bottom and the top and getting the difference, then plugging the difference into the equation **P = pgh** and getting the height

We have two types of barometers (**aneroid (digital) – mercury)**

why doesn't the diamter of the column of Hg make a difference

- **Because pressure = force/area, and force here is the weight which depends on mass, so when we increase the diamter, we increase the mass, and also the pressure, so they cancel eachother out**

Why is mercury used rather than water

- **Mercury is 13.6 more dense than water so it can represent the pressure in smaller length like 76cm rather than water which measures the pressure at a length of 10.33m**
- **Mercury has low vapor pressure so it won't change shapes**
- **Mercury's freezing point is much lower than that of water so it can record pressure in lower temperatures**
- **Mercury does not evaporate and it shines brightly making it more visible**

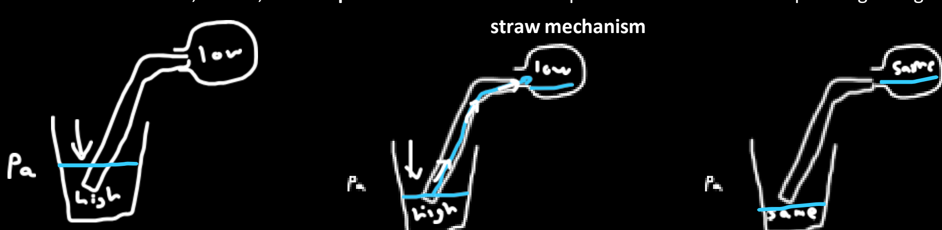
- The barometer reading depends on:
1) The density of liquid used
2) The atmospheric pressure on the mercury surface
3) Temperature

- The barometer reading doesn't depend on:
1) Tube cross section
2) Tube length
3) Vacuum volume
4) Length of part of tube impressed in mercury

Vacuum is an area devoid of matter where no friction happens and pressure is 0

Vacuum cleaners, straws, etc. use **pressure difference** which produces a force than can pull it against gravity

straw mechanism

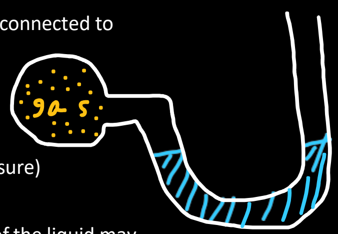


Manometer

it has two uses

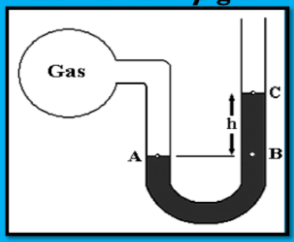
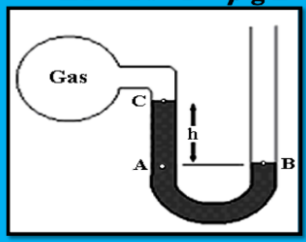
- It measures the pressure of a gas enclosed in a reservoir
- It measures the difference between an enclosed gas and the atmospheric pressure

it's a U shaped tube containing an amount of liquid with known density (preferably mercury) with one end of the tube is connected to the gas reservoir



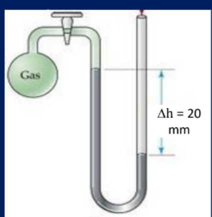
when the manometer isn't connected to a gas chamber, the level of the liquid is the same on both side, because the pressure on both sides is equal (they are both atmospheric pressure)

when the manometer is connected to a gas chamber, the level of the liquid may rise on one side or another depending on the gas

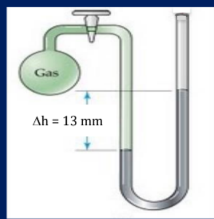
When $P > P_a$	When $P < P_a$
The level of the liquid in the free branch is higher than the branch connected to the reservoir by (**h**). **P** (gas pressure) = $P_A = P_B$ $P = P_a + \rho g h$ $\Delta P = P - P_a = \rho g h$ 	The level of the liquid in the free branch is lower than the branch connected to the reservoir by (**h**). **P** (gas pressure) = P_C $P = P_a - \rho g h$ $\Delta P = P_a - P = \rho g h$ 

Sample Problems

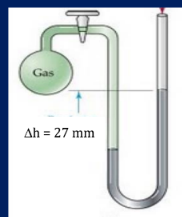
1 P_{air} = 790 mm



2 P_{air} = 753 mm



3 P_{air} = 765 mm



Find the pressure of the gas in each manometer.

Pay attention to whether the manometer is open or closed!

Sample Problem Answers

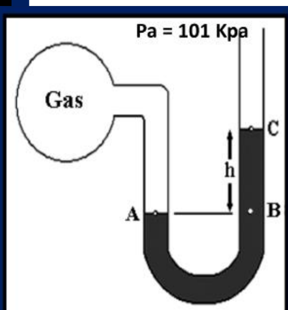
1. $P_{gas} + \Delta h = P_{air}$

P_{gas} = 790 mm - 20 mm = 770 mm Hg

2. P_{gas} = vacuum + 13 mm = 13 mm Hg

3. $P_{gas} = P_{air} + \Delta h$

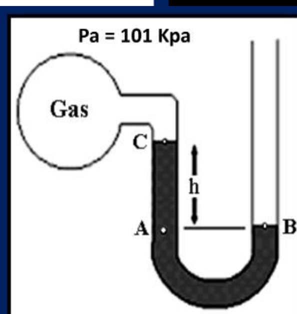
P_{gas} = 765 + 27 = 792 mm Hg



Calculate the gas pressure in each case?

h = 30 cm

ρ_{Hg} = 13.55 Kg/m^3



$P_{gas} = P_a + \rho g h$

= 141 K Pa

$P_{gas} = P_a - \rho g h$

= 61 K Pa

Archimedes' Principle

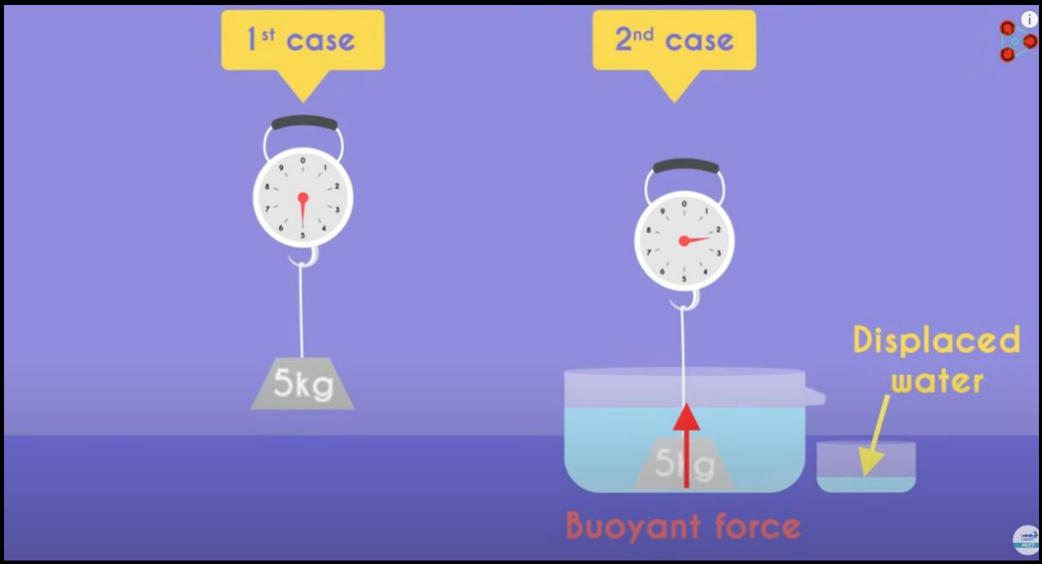
It states that a body partially/fully immersed in fluid (liquid/gas) is pushed upwards by a buoyant force equal to the weight of the displaced fluid by the body

Buoyancy is the tendency of a body to float/rise when submerged in fluid

$F_{buoyancy} = m_f g$

The buoyant force has the same magnitude as the weight but in opposite direction

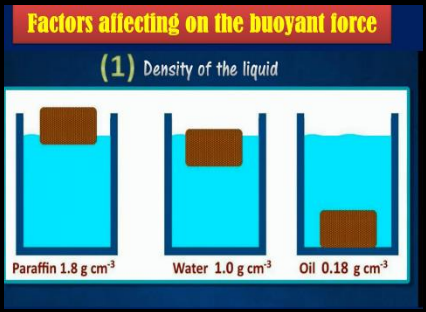
Apparent weight test



Case 1
- The apparent weight of the object is equal to the actual weight of the object which is **mg**

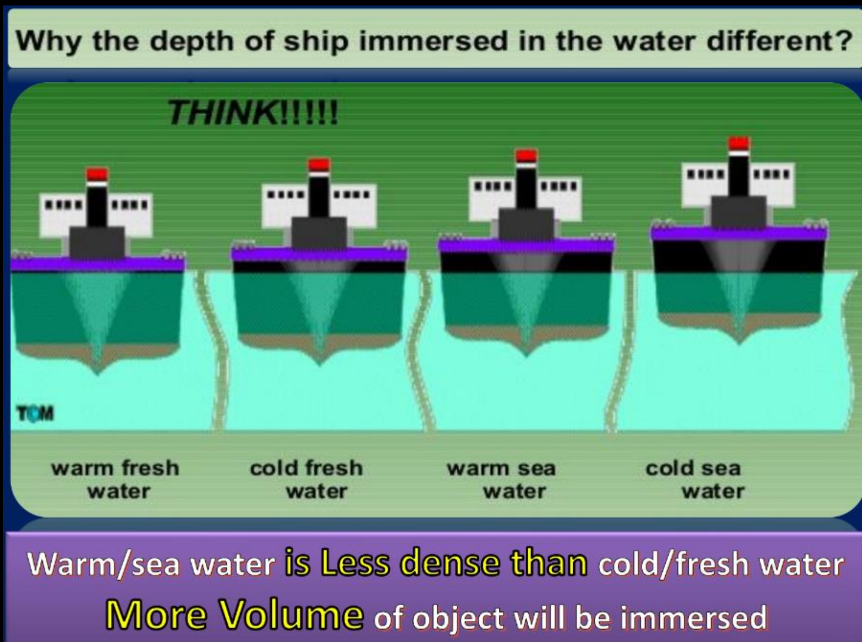
Case 2
- The apparent weight of the object is less than the actual weight of the object as there is buoyant force acting against gravity
  so the apparent weight = mg – F_b (buoyant force)
- Some water got displaced, archimedes' principle says that the weight of the displaced water is equal to the buoyant force acting on the object, this is called an "upthrust"

Archimedes' principle says that the buoyant force = gravitional force, right?
- Then the magnitude of the buoyant force is equal to
  $F_b = mg$
- We know that mass is just **volume x density**
  so we can say that
  $F_b = p_f V_f g$
  where
  - P_f is the density of the fluid
  - V_f is the volume of displaced fluid / object
  - g is gravitional acceleration



The reason big iron ships float over water is because they are hollow with air inside (aka less dense)
So their mass isn't that big but their volume is, so the upthrust is able to push against gravity

The reason an iron nail sinks is because its volume is small so the upthrust is not able to push against gravity

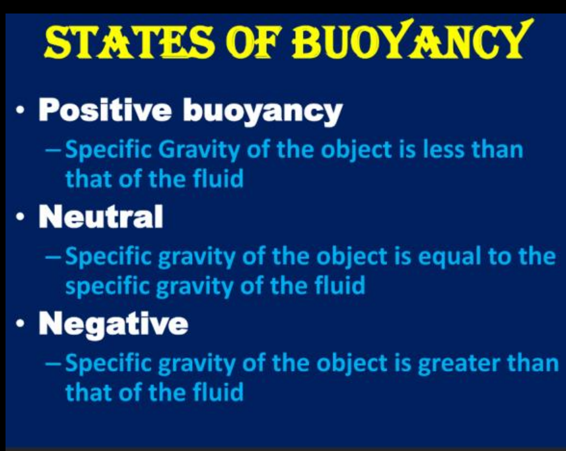


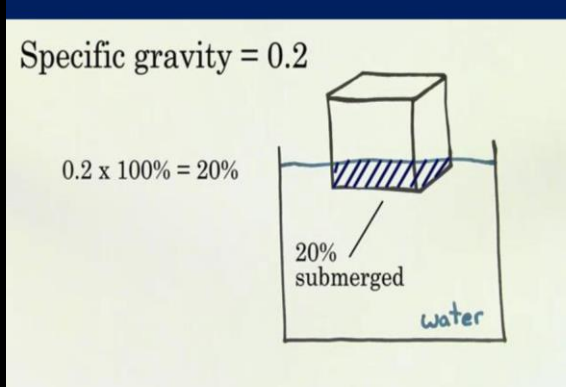
Specific gravity is ratio of densities

Specific weight (unit weight) (γ)

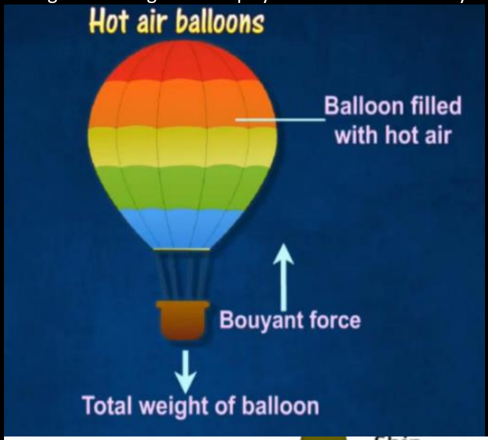
is the weight exerted by gravity on a unit volume of a fluid and takes the unit **N/m³**

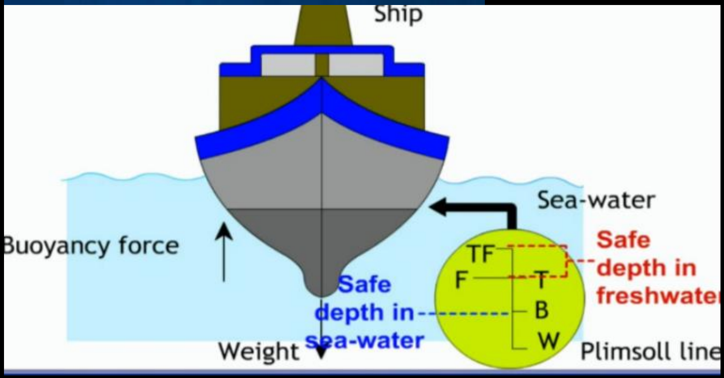
$$\gamma = \frac{mg}{V} \text{ or } \rho g$$





APPLICATIONS OF ARCHIMEDES PRINCIPLE

1. Hydrotherapy : immersing weak patients in water helps them move because their bodies are near weightless
2. Diving : breathing in air helps you become more buoyant
3. 

4. 

PROBLEM

When water freezes, it expands about nine percent. What would be the pressure increase inside your automobile engine block if the water in there froze? The bulk modulus of ice is 2.0 × 109 N/m2, and 1 ATM = 1.01 × 105 N/m2.

The **pressure** increase inside your **automobile** engine block will be **1782.18 atm.** The **force** involved **vertical** to the **surface** of an object per unit area is **pressure**.

What is pressure?

The **force** applied **perpendicular** to the surface of an **item** per unit area across which that **force** is spread is known as **pressure.**

It is denoted by **P.** The **pressure** relative to the **ambient pressure** is known as **gauge pressure**.

The **given** data in the problem is;

ΔV is the **change** in **volume** of water = 9%

K is the **bulk modulus** of ice = 2×10^9 N/m^2

dP is the **change** in the **presure**=?

The **bulk modulus** is found as;

$$K = -V\frac{dp}{dv}$$

The **change** in the **presure** is obtained as;

$$dP = K\frac{dV}{V}$$

$$dP = K\frac{0.09V}{V}$$

$$dP = 0.09K$$

$$dP = 0.09 \times 2 \times 10^9$$

$$dP = 1.8 \times 10^8$$

$$dP = 1782.18 \text{ atm}$$

Hence the **pressure** increase inside your **automobile engine** block will be **1782.18 atm.**