

PHYSICS GRADE 9

UNIT – 6 SUMMARY

Fluid statics

6.1 Air pressure

BY:ADDIS ABABA EDUCATION BUREAU
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By the end of this section you should be able to :-

- *Define the term pressure and use the definition to solve related problem*
- *Describe atmospheric pressure and explain its variation with altitude*
- *Explain how to measure atmospheric pressure and show that 760mmHg is equal to one atmosphere*

pressure is defined as the amount of force per unit area.

Pressure is equal to force per unit area.

$$\text{Pressure} = \text{Force} / \text{area}$$

$$P = F/A$$

The Si unit of pressure is Pascal (Pa).

$$1\text{Pa} = 1 \text{ N/m}^2$$

pressure it exerts.

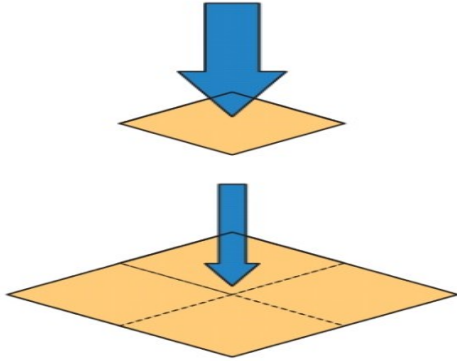


Figure 6.3 A large force pressing

➤ The larger the force acts on small area it creates a greater pressure.

Example :- A boy weighs 500N and the soles of his feet have an area of 0.05m^2 . Determine the pressure he exerts when he stand

a. on both feet

b. On one feet

Given $A = 0.05 \times 2$ when he stand in both feet

$$A = 0.025 \text{ m}^2$$

solution:- $P = F/A$

$$P = 500\text{N} / 0.025 \text{ m}^2$$

$$p = \mathbf{20,000\text{Pa} = 20\text{kpa}}$$

b. when he stand on one feet

$$A = 0.05 \text{ m}^2$$

$$P = F/A$$

$$P = 500\text{N} / 0.05 \text{ m}^2$$

$$P = 10,000\text{Pa} = 10\text{kPa}.$$

Example 2:- A block rest on the desk. It covers measures 20cm by 25cm . It exert a pressure of 100 Pa . Determine the mass of the block.

$$A = 0.2 \times 0.25 = 0.05 \text{ m}^2$$

$$\text{Then } P = F/A$$

$$F = PA$$

$$F = 100\text{Pa} \times 0.05 \text{ m}^2$$

$$F = \mathbf{5Pa} \text{ But } F = mg$$

$$m = F/g$$

$$m = 5\text{Pa} / 10\text{m/ S}^2$$

$$\mathbf{m = 0.5kg}$$

What cause air pressure ?

- Air has a mass, which means it has weight.

One cubic meter of air has a mass of 1 kg .

$1 \text{ m}^3 = 1\text{kg}$ and a weight of 10 N

- Air are traveling in different direction and some travel faster than other.
When air particles near a surface some will be bounce into it and so exert a force on the surface .It is this force that gives rise to a pressure.

Atmospheric pressure.

- The atmosphere is the layer of air that surrounds the earth .
- There is a kind of equilibrium between pressure in our body and surrounding atmosphere. If you went somewhere where the pressure was much greater than atmospheric pressure our bodies would crushed. And if you went somewhere where the pressure was very low (e.g in to space with out pressurized space unit) the pressure inside our bodies would pushed out ward with some very nasty effects.

How big atmospheric pressure?

The weight of the column of air above 1 m² at ground level is around 101000Pa. This means atmospheric pressure at ground level is 101kPa.

$$1\text{atm} = 101\text{kPa}$$

What effect does altitude have on atmospheric?

The heating effect from the sun cause small changes in pressure due to uneven heating of the earth surface. This lead to high or low pressure weather system.

- The height above the sea level ,or altitude also has a significant effect on atmospheric pressure .
- As altitude increase the atmospheric pressure decrease. Pressure varies with altitude

Table 6.1 *Pressure at different altitudes*

Altitude (m)	Approx. pressure (Pa)
0	101 000
1000	90 000
2000	79 000
5000	54 000
10 000	26 000
15 000	12 000
20 000	6000
25 000	1300
30 000	270



F
a

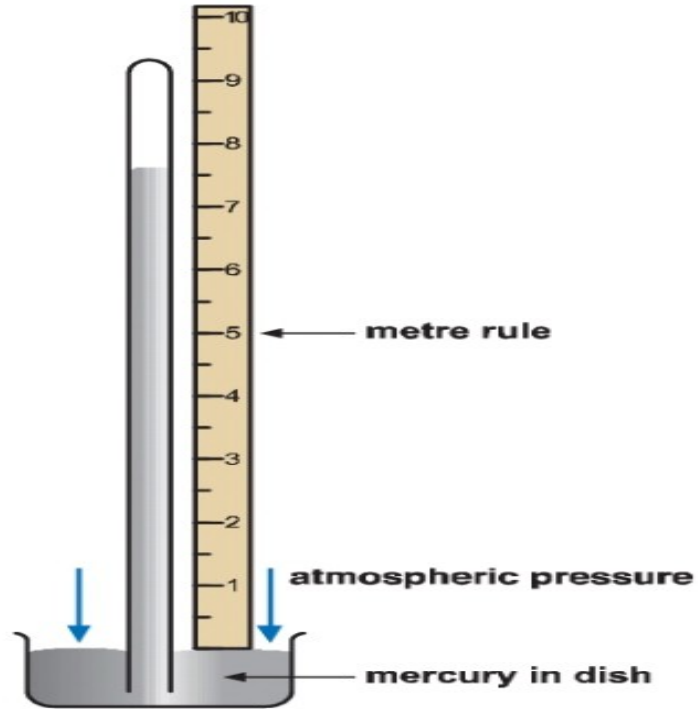
Measuring atmospheric pressure.

- There are several instrument used to measure atmospheric pressure. The most common is a **barometer**.
- A mercury barometer is long and inconvenient heavy , and contains a liquid that is hazardous and easily spilt. Therefore, an aneroid barometer is commonly used (aneroid means with out liquid). It is compact and portable construction of an aneroid barometer.



Figure 6.14 A barometer

simple barometer



Why 760mmHg?

- Pressure is often express in the unit of mmHg. If the atmospheric pressure is equal to 1atm , then the height of the column of mercury is barometer is 760mm.
- Let a column of mercury 760mm tall and with radius of 5mm.

The exert force equal to its weight.

$w = mg$, we can determine the mass of the column from its density and volume .

$$\rho = m/v$$

$m = \rho V$ and $V = \pi r^2 h$, h is the height of cylinder and ρ is density of the fluid

$$V = \pi \times (0.005)^2 \times 0.76 \text{ m}$$

$$V = 5.9 \times 10^{-5} \text{ m}^3$$

Since the density of mercury is 13570 kg/m^3

$$m = 13570 \text{ kg/m}^3 \times 5.9 \times 10^{-5} \text{ m}^3$$

$$m = 0.81 \text{ kg}$$

therefore the weight of column can be

$$w = 0.81 \text{ kg} \times 9.81 \text{ m/s}^2$$

$$= 7.9 \text{ N}$$

The weight must equal to the force due to the pressure on the bottom of the column.

UNIT 6: Fluid statics

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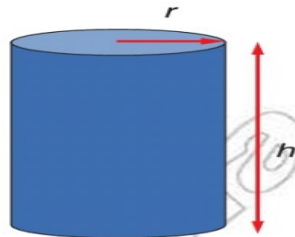


Figure 6.17 The volume of a cylinder

$P = F/A$, $A = \pi r^2$ Area of the column of the mercury

$P = 7.9\text{N} / \pi (0.005\text{m})^2$

$P = 101000\text{Pa}$

$P = 101\text{kPa}$

Mercury is quite toxic and needs to be handled very carefully. Why not use water ? This because water has a much lower density than mercury around 1000kg/ m^3 vs 13600kg/ m^3

Some use of air pressure

There are several uses of air pressure. Mostly rely on creating a pressure difference by pumping the air into or out to a chamber.

Air pressure used for :-

- a. For a **suction pad** is around rubber pad ,flat on one side . Wet in side and press the pad against a windows or smooth wall, pushing out all the air from under it.
- b. used for lifting pump (common pump):- is often used to rise water from the well.

- c. Used for a force pump :- can pump water to greater height – can force water hundreds meter high
- d. Used for Bicycle pump
- e. used for siphon:- is convenient way of removing liquid from a container such as a petrol tank.

6.2 Fluid pressure.

- Fluid include all gases as well as liquid.
- Another characteristics is that they can change their shape. This means they always take the shape of container they are put in.
- They are still some very important difference between liquid and gas

	Liquid	Gas
Particles	Quite close together, with no set pattern; particles can move past each other.	Far apart with no set pattern; particles can move past each other.
Bonding	Weak bonds between the particles	No bonding between the particles
Can flow / change their shape to match a container	Yes	Yes
Compressible	No; the particles are already close together.	Yes; there is lots of space between the particles.

Fluid density

The density of any fluid calculated as:-

The ratio of mass to volume

$$\text{Density } (\rho) = \frac{\text{mass } (m)}{\text{Volume } (V)}$$
$$= m/V \quad \rho = m/V$$

➤ As particles are closer together in a liquid higher density than gas.

Table below shows some typical density of the fluid

Fluid	Density (kg/m^3)
Mercury	13 600
Honey	1400
Water	1000
Sea water	1020
Diesel	950
Alcohol	800
Petrol	740
Air	1.20
Carbon dioxide	1.98
Nitrogen gas	1.25

What is relative density?

- The relative density is used to compare density between two fluids.
- The relative density of substance is the ratio of its density to density of substance.
- The relative density of substance is the ratio of its density to density of substance.
- $\text{Relative density}() = \frac{\text{density of substance}()}{\text{density of water}()}$
- $\text{Relative density}(\rho_r) = \frac{\text{density of substance}(\rho_s)}{\text{density of water}(\rho_w)}$

Example :- What the relative density of alcohol ?

Given $\rho_A = 800 \text{ kg/m}^3$
 $\rho_w = 1000 \text{ kg/m}^3$

Solution $\rho_r = \rho_A / \rho_w$

$$= 800 \text{ kg/m}^3 / 1000 \text{ kg/m}^3$$

$$= 0.8$$

From this relative density has no unit

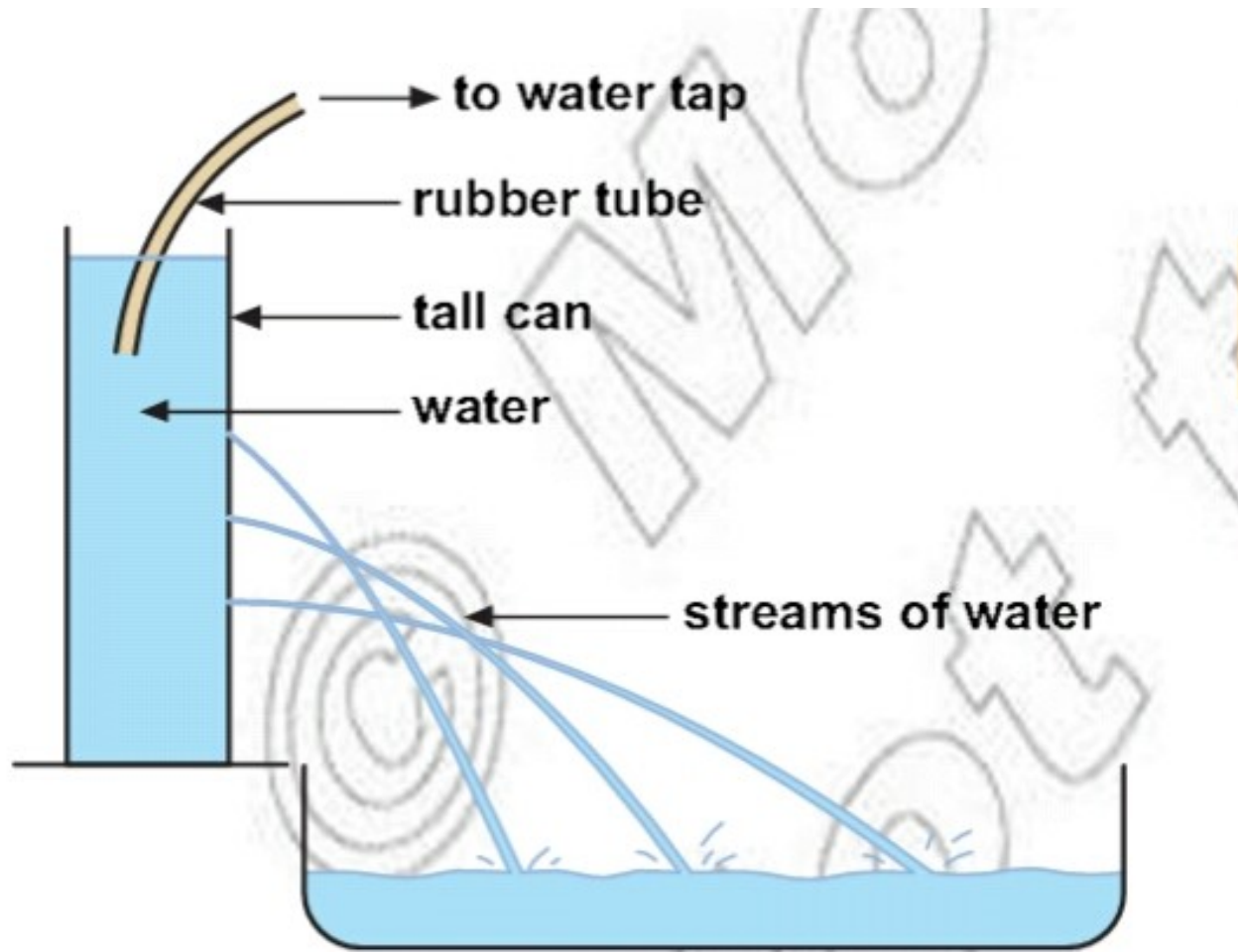
If we are comparing two identical volume of fluid then the relative density can be calculated as :-

The ratio of the mass of the same volumes of fluid.

$$\text{Relative density} = \frac{\text{mass of the substance}}{\text{Mass of equal volume of water}}$$

Pressure in fluid

- The key point we should have to consider about pressure in fluids are:-
 - ✓ Pressure increase with depth
 - ✓ At any given depth the pressure are increase with depth. The taller the column of the fluid above you the greater the pressure it exert.
- Let us see the effect of depth on pressure.



We know that pressure in fluid is given by :-

$$P = \rho gh ,$$

The pressure caused by the weight of the water in the tank pressing down to the bottom .

Volume of water = **$h \times A$** , **h** is height and **A** is the area and

$$\begin{aligned}\text{Mass of water} &= \rho \times V, \text{ but } V = h \times A \\ &= \rho \times h \times A\end{aligned}$$

$$\begin{aligned}\text{Therefore, } P &= w/A \\ &= mg/A \\ &= \rho \times h \times A \times g/A \\ &= \rho \times h \times g \\ &= \mathbf{\rho hg}\end{aligned}$$

The equation shows that the pressure increase with depth(h).

Example :-Calculate the pressure exerted by the water at the bottom of a swimming pool deep.

Given :- $\rho_w = 1000 \text{ kg/m}^3$

$$g = 10 \text{ m/s}^2$$

$$h = 6 \text{ m}$$

Required $P = ?$

$$P = \rho h g$$

$$P = 1000 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 6 \text{ m}$$

$$p = \mathbf{60,000 \text{ Pa}}$$

Example 2 :- calculate the force this pressure would exert on a concrete block and area of 3 m^2

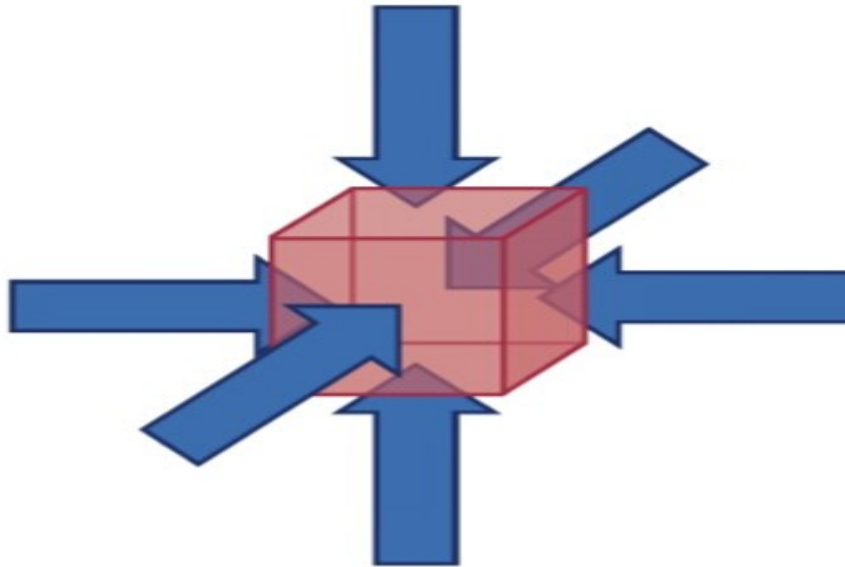
Given $p = 60,000 \text{ Pa}$, $A = 3 \text{ m}^2$ Required $F = ?$

$$F = PA = 60,00 \text{ Pa} \times 3 \text{ m}^2$$

$$= \mathbf{180 \text{ kN}}$$

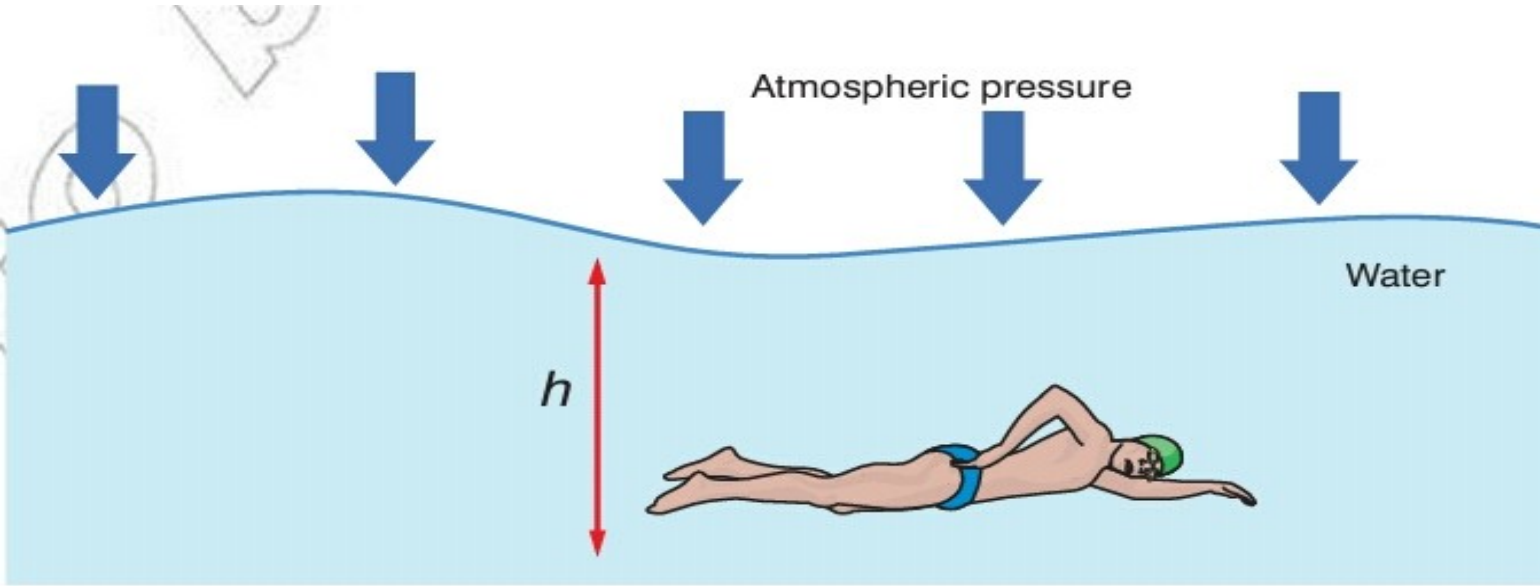
Pressure acts equally in all direction.

In fluid ,despite the pressure being caused by the column of fluid above you ,the pressure acts equally in all direction. If you imagine a very small cube placed under water , the pressure in each cube face would be same



What the effect of atmospheric pressure?

If you go swimming the pressure acting on you is not just due to the water above you. You must not forget to include atmospheric pressure



$$p = p_{atm} + p_{fluid}$$

The pressure on the swimmer would be the sum of the pressure due to the fluid and the atmospheric pressure. In terms of the equation this could be written as :-

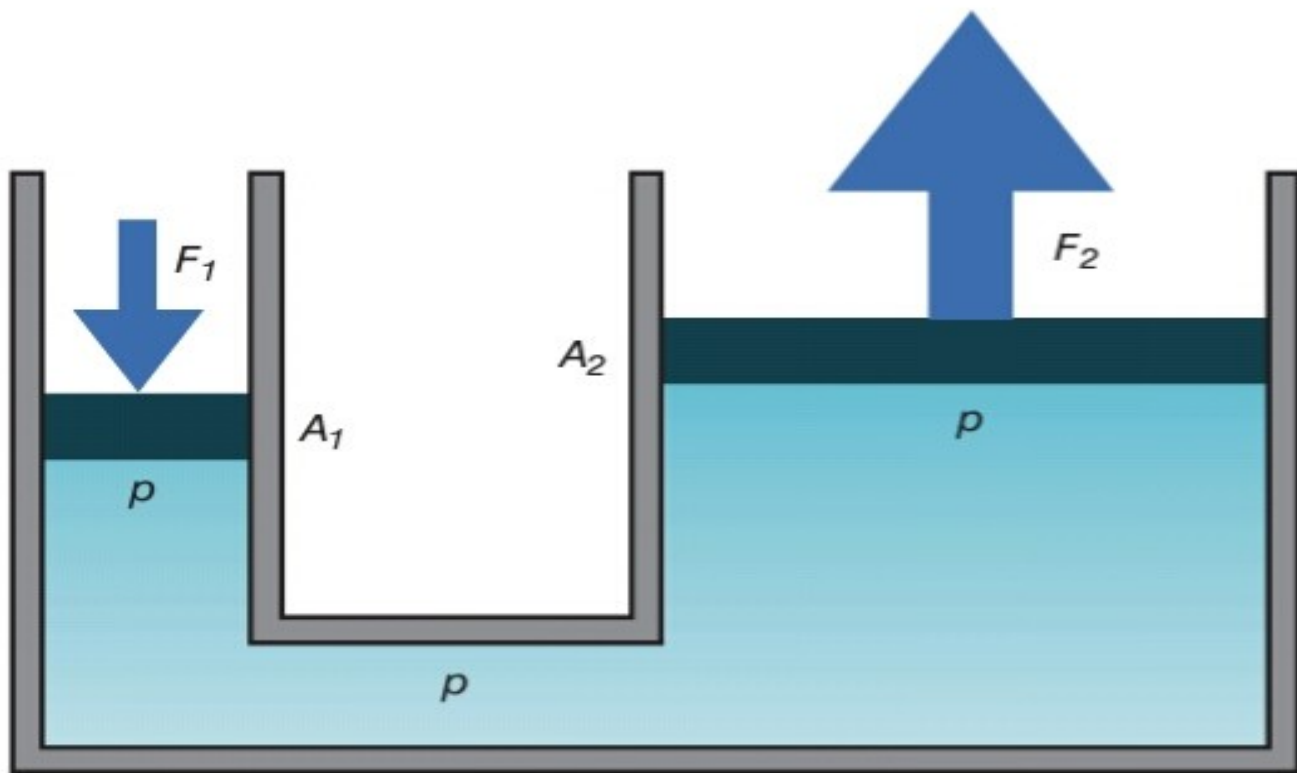
$$P = P_{\text{atm}} + P_{\text{fluid}}$$

P = total pressure acting on the swimmer.

Pascal's principles

Pascal principle states that :-

- The pressure applied to an enclosed fluid is transmitted to every part of the fluid, as well as to the wall of the container without reducing in value. Pascal principle is used in the design and construction of hydraulic machines. If the force applied to the left-hand piston, it will create the pressure inside the fluid.



$$P = F_1/A_1$$

- This pressure transmitted throughout the liquid , it is the same every where.
- **Pressure on the left hand = pressure on the right hand.**
- The piston on the right hand has much larger area. The force from this piston is equal to
- $F_2 = P \times A_2$
- As A_2 is much larger than A_1 , F_2 will also bigger than F_1 . in fact if the piston has doubled the area the force would be doubled. For example imagine
- $A_1 = 2\text{m}^2$ $A_2 = 6\text{m}^2$
- If a force of 100N is applied on A_1 then the force at A_2 will be 300N (three times larger). Let's prove through calculation.

$$P = F/A$$

$$P = F_1/A_1$$

$$P = 100\text{N} / 2\text{m}^2$$

$$P = \mathbf{50\text{Pa}}$$

➤ From Pascal principle

$$➤ P = F_2/A_2$$

$$➤ F_2 = P \times A_2$$

$$➤ F_2 = 50\text{N} \times 6\text{m}^2$$

$$➤ F_2 = \mathbf{300\text{N}}$$

From this

$$➤ \mathbf{F_1/A_1 = F_2 /A_2}$$

Example 2:- Two piston are connected together to make hydraulic lift. The smaller piston has a force of 100N , an area of 0.05m^2 and the larger piston has an area of 2m^2 . Calculate the following :-

- a. The pressure in the fluid and the force the force act the larger piston.
- b. The pressure in the fluid and the force from the smaller piston to lift a car of mass 1200kg .

Hydraulic machines

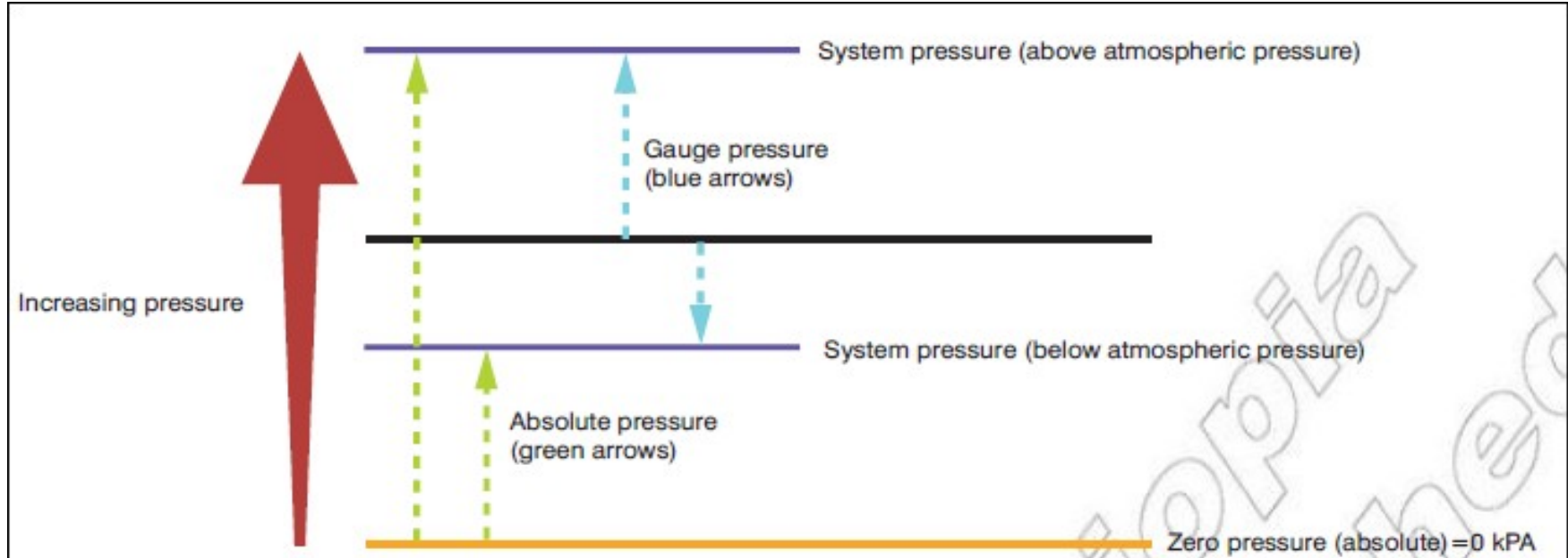
It is a machine that used to shape metals or compress materials in to smaller volume. Eg. Used to make motor-car bodies.

What is the difference between atmospheric, gauge and absolute pressure ?

- **Absolute pressure** is the actual pressure at a given point. It is the true pressure of the system if all of the factor are taken in to account.
- **Atmospheric pressure** is the pressure of the surrounding air.
- **Gauge pressure** is the pressure difference between the system and atmospheric pressure

Example:- If the gauge pressure is 25kpa it would mean 25kpa above atmospheric pressure.

$$P_g = P_s - P_{atm}$$



Example:- If the gauge pressure of the system is 49kpa ,then what is the absolute pressure//

We know that $P_g = P_s - P_{atm}$

$$= P_s = P_g + P_{atm}$$

$$= 49 \text{ kpa} + 101 \text{ kpa}$$

$$= 150 \text{ kpa}$$

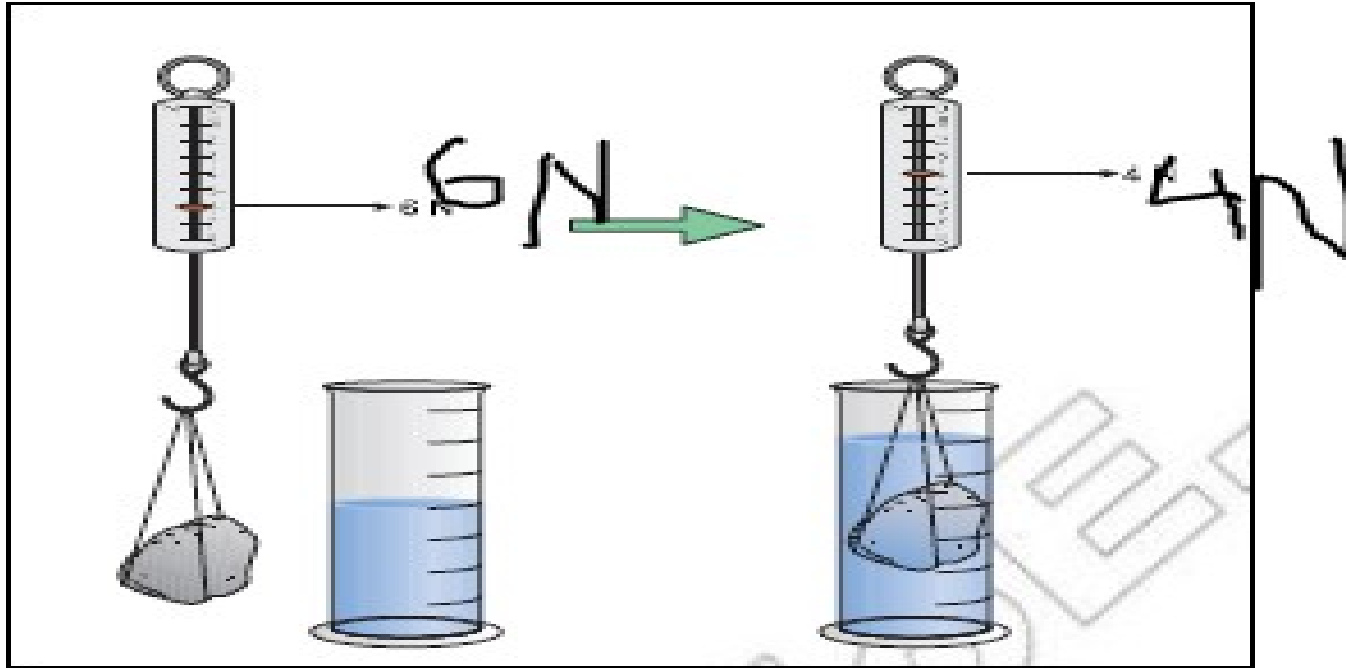
Measuring pressure:

- Bourdon gauge is an instrument that is used for measuring pressure of the a gas.
- Manometer is a simple instrument (u-shaped tube filled with liquid which is used to measure pressure.

Force in fluid

- There is a force from the water that opposes upthrust against gravity. This force is called a buoyant force (sometimes upthrust).
- The change in pressure of the fluid:-
 - $\Delta P = \rho h g$
 - $\Delta P = \Delta h \rho$
- The pressure difference means there is a difference in a force acting on the top and bottom of the object.
- The size of the buoyant force depend on:-
 - 1. Density of the fluid ,increasing density means decreasing buoyant force
 - 2. The volume of the object. Increasing volume means increasing buoyant force

- An object immersed in water (liquid) appear to weight less.



The apparent weight can be calculated:-

Apparent weight = weight – buoyant force.

Buoyant force = weight – Apparent weight

From the figure

Weight of the liquid = 6N

Apparent weight = 4N

Calculate Buoyant force

$$\begin{aligned} b_f &= w - A_w \\ &= 6\text{N} - 4\text{N} \\ &= 2\text{N} \end{aligned}$$

Archimedes' principles

Archimedes' principles is state that the weight of the fluid displaced by an object is equal to the buoyant force acting on it.in other word:-

- An object ,wholly or partially immersed in fluid is buoyed up by a force equal to the weight of the fluid displaced by the object.
- Buoyant force = weight of fluid displaced
- The greater the volume of the liquid displaced the greater the buoyant force.
- Apparent weight = weight – buoyant force.
- buoyant force = weight of fluid displaced

Apparent weight = weight – weight of fluid displaced

Floating and sinking

- **In order to float** an object must displaced a volume of fluid equal to its weight.
- If the weight of the volume of the fluid displaced is equal to the weight of an object , then the object will float.
- For sinking the reverse is true.i.e the weight of the volume of liquid displaced is less than the weight of an object it will sink.

- ❖ An object is float if and only buoyant force is equal to weight of an object
- ❖ An object is sinking if and only if buoyant force less than weight of an object.
- ❖ An object rising up through water if and only if buoyant force is greater than weight of an object.

A floating wooden block has a volume of 0.4m^3 and displaced 0.3 of 0.3m^3 of water. Determine the density of the block

Given:-

Example 2:- Describe the relation between the buoyant force and the weight of an object, if the object

- a. is floating
- b. is sinking
- c. rising up through the water

Thank you!