



YABELLO IFA BORU SPECIAL BOARDING SECONDARY SCHOOL

PHYSICS SHORT NOTE FOR GRADE 9

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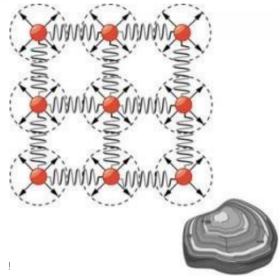
UNIT: 6

Fluid Statics

Introduction

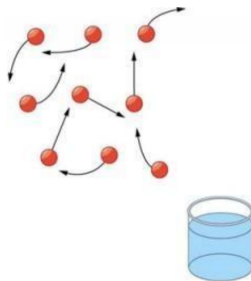
- Matter exists in three states such as **solid**, **liquid**, and **gaseous** states. In solids the molecules have such strong attraction for each other than the others. In liquids the greater molecule separation allows successive layers to flow past each other. Solids have a definite shape and a specific volume, liquids have a definite volume but their shape changes depending on the container in which they are held.
- The molecules of a gas are usually so far apart that they exert little attraction on each other and gases have neither a definite shape nor a specific volume as their molecules move to fill the container in which they are held. Liquids and gases are considered to be **fluids** because their molecules move freely until they expand and fill their container. **Fluids** are any substance that can flow.

- **Atoms in solids** are in close contact, with forces between them that allow the atoms to vibrate but not to change positions with neighboring atoms. (These forces can be thought of as springs that can be stretched or compressed, but not easily broken).



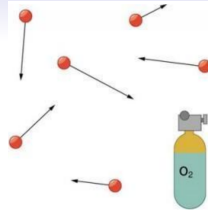
- Thus a solid resists all types of stress. A solid cannot be easily deformed because the atoms that make up the solid are not able to move about freely. Solids also resist compression, because their atoms form part of a lattice structure in which the atoms are a relatively fixed distance apart. Under compression, the atoms would be forced into one another. Most of the examples we have studied so far have involved solid objects which deform very little when stressed.

- In contrast, **liquids** deform easily when stressed and do not spring back to their original shape once the force is removed because the atoms are free to slide about and change neighbors—that is, they flow (so they are a type of fluid), with the molecules held together by their mutual attraction.



- When a liquid is placed in a container with no lid on, it remains in the container (providing the container has no holes below the surface of the liquid!). Because the atoms are closely packed, liquids, like solids, resist compression.

- Atoms in gases are separated by distances that are large compared with the size of the atoms. The forces between gas atoms are therefore very weak, except when the atoms collide with one another.



- **Gases** thus not only flow (and are therefore considered to be fluids) but they are relatively easy to compress because there is much space and little force between atoms. When placed in an open container gases, unlike liquids, will escape. The major distinction is that gases are easily compressed, whereas liquids are not.
- We shall generally refer to both **gases** and **liquids** simply as **fluids**, and make a distinction between them only when they behave differently.

Fluid statics

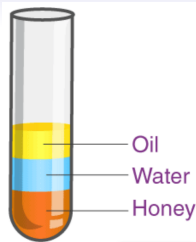
- Fluid Statics and Fluid Dynamics are the two constituents of Fluid Mechanics.
- **Fluid mechanics** is the study of fluids either at rest or in motion. A **fluid** refers to a substance that can **flow**.

- This includes liquids and gases. They change their shape as the shape of the container they are placed in or they take the shape of the container they are placed. Gases are compressible (they can be compressed by a force). Liquids are incompressible (they can't be compressed by a force)
- **Fluid Statics** deals with fluids **at rest** while **Fluid Dynamics** studies fluids in **motion**.
- In this section we will discuss about Fluid Statics. Fluid statics is generally referred to as **hydrostatics** when the fluid is a liquid, and as **aerostatics** when the fluid is a gas. In fluid statics, there is no relative motion between adjacent fluid layers.
- Fluid exerts a force on the wall of its container or in its surroundings. The force exerted by a fluid on the wall of its container must always act perpendicular to the wall.
- Fluid statics is used to determine the forces acting on floating or submerged bodies and the forces developed by devices like hydraulic presses and car jacks. The design of many engineering systems such as water dams and liquid storage tanks requires the determination of the forces acting on the surfaces using fluid statics.

6.1 Density and Relative density of substances

- Before discussing the static of fluids, it is important to understand the relation of a substance's weight to its volume. For example, we refer to lead or iron as heavy whereas wood or cork is consider light.
- This saying is wrong. We should say that a given volume of iron or lead is heavier than the same volume of wood or cork. The terms heavy and light are comparative terms. What really mean is that a block of wood is lighter than a block of lead of the similar size. The quantity which is useful to compare the masses of different substances of equal volumes is called Density.
- **Density** is the amount of mass in a unit volume of matter, every substance has a different density, to understand the concept of density let's observe different fluids poured in the a glass cup such as, honey, water, coconut oil, and food coloring.

- Notice how the different liquids from different layers, why is it so? The different substance has a different density, which means for the same volume different substances weigh differently; as they weigh differently heavier substances tend to settle at the bottom, like honey and lighter material like oil tend to float at the top which means.



- In addition to the above, figure below shows two identical flasks one filled with water to 250cm^3 mark and the other filled with kerosene to the same 250cm^3 marks, when measured in electronic balance the flask filled with water is found to be heavier than that filled with kerosene why?

The answer is in finding the mass per unit volume of kerosene and water in respective flasks.

- The mass of the flask filled with water is 330g, and the mass of flask filled with kerosene 280g, the empty flasks were measured and found to be 80g therefore mass of water only is 250g and kerosene only is 200g. Mass per unit volume of water is $250\text{g}/250\text{cm}^3$ this is $1\text{g}/\text{cm}^3$. Mass per unit volume of kerosene is $200\text{g}/250\text{cm}^3$ this is $0.8\text{g}/\text{cm}^3$. The results $1\text{g}/\text{cm}^3$ and $0.8\text{g}/\text{cm}^3$ are the densities of water and kerosene respectively.
- Therefore the density of a substance is defined as the ratio of the mass of the substance to its volume.

$$\text{density} = \frac{\text{mass of substance}}{\text{volume of substance}} \implies \rho = \frac{m}{V}$$

- Where ρ (rho) stand for density, m for mass and V for volume The SI-units of mass and volume are respectively kilogram (kg) and cubic meter(m^3). Therefore, the SI-units of density is kilogram per cubic meter and it is abbreviated as (kg/m^3)

- In practice, in laboratories, we do not use kilogram to measure mass and cubic meter to measure volume. Instead we use gram to measure the mass and cubic centimeter to measure the volume of substances. Hence, the unit practically used to measure density is gram per cubic centimeter (g/cm^3).
- Since $1kg = 1000g$ and $1m^3 = 1,000,000cm^3$, then $1kg/m^3 = 10^{-3}g/cm^3$
- Table below gives the density of some common substances

Substance	$\rho(kg/m^3)$	$\rho(g/cm^3)$
Air	1.29	0.00129
Benzene	879	0.879
Ice	920	0.920
Water	1000	1
Glass	2600	2.6
Aluminum	2700	2.7
Iron	7800	7.8
Copper	8920	8.92
Lead	11340	11.34
Mercury	13600	13.6

- The **relative density** of a substance is defined as the ratio of its density to the density of pure water. Water is a standard substance to compare the density of other substances. When its density is $1000\text{kg}/\text{m}^3$. It is usually measured at room temperature (20°C) and standard atmosphere (101.3kPa). It is unit less.
- The term relative density is used to compare the density of substances relative to the density of standard substance called water.
- The relative density of a substance will tell us whether it will float or sink. If the relative density of a substance is below 1, then it will float and if it is greater than 1, then it will sink.

$$\text{relative density} = \frac{\text{density of substance}}{\text{density of water}}$$

$$\rho_r = \frac{\rho_s}{\rho_w}$$

Example

1. A block of ice with volume $5.5m^3$ has a mass of 5060kg find the density of ice.
2. Beaker contains $262.5cm^3$ of a certain liquid weigh 410g, if the mass of an empty dry beaker is 200g, find the density of the liquid.
3. The density of wood is found to be $900kg/m^3$. What is the relative density of the wood as we compared it to water of density $1000kg/m^3$?
4. A solid metal cube has an edge length of 2cm and a mass of 21.6g.
 - a) What is the relative density of the metal?
 - b) What type of metal is it?

6.2 Pressure

- In every day affairs, people use the term Force and Pressure interchangeably. However, the two terms are not the same. There are vast differences between them, which you can understand only if you have thorough knowledge.
- Have you ever thought about how football moves away? or how the car speeding up or slowing down? This happens when the force is applied to an object. In simple word, force is the pull or push which changes the state of motion or the state of rest or the direction of the motion.
- Think about the following events. Suppose in each case equal force is exerted, but the effect varies.
 1. A sharp knife cuts meat while a blunt one will not. Why?
 2. A pointed nail can easily be hammered into a piece of wood than round rod.
 3. A woman wearing narrow heels will do much more damage to the floors than a woman of the same weight wearing flat heels shoes. Why?

- Here comes the concept of pressure. Even though the same force is exerted in each case, the effect of the force changes when the area over which it acts is changed. That is, when the area of contact is made small, the force per unit area is large, and when the area of contact is relatively large, the force per unit area is small. This effect or the normal force per unit area is known as **Pressure**. Therefore, the effectiveness of a given force depends upon the area over which it acts.
- **Pressure** is defined as the amount of force acting per unit area perpendicularly.
- mathematically

$$\text{Pressure} = \frac{\text{Normal Force}}{\text{Area of contact}} \implies P = \frac{F}{A}$$

- Where A is the area over which the perpendicular force F is applied. The SI-unit of pressure is N/m^2 or Pascal (Pa). Pressure can be also measured by kilo pascal(kPa)
 $1kPa = 1000Pa$.

Example

1. Consider a rectangular block of wood is placed on the floor as shown below.



Determine the pressure exerted by the block on the floor when it is placed on its:

- a) biggest face. b) smallest face. Assume that the mass of the block is 8kg and its dimensions are 20cmx40cmx30cm.
2. A woman of mass 60kg is wearing high-heeled shoes with heels of total area 5cm^2 . What pressure will she exert when all her weight rests on the heels? Use $g=10\text{m/s}^2$.
 3. A standing boy exerts a force equal to his weight on the ground below his feet. If his weight is 500N and the total area of his shoes is 100cm^2 , then what is the average pressure that he exerts on the ground when he stands on a) both feet? b) one foot?

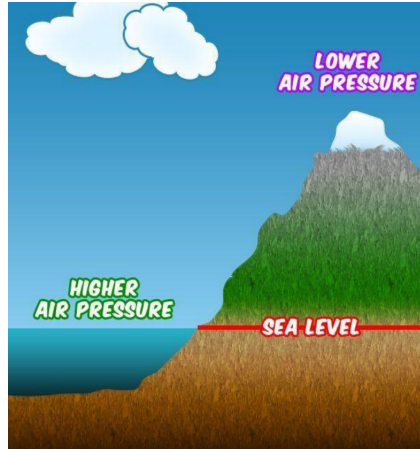
6.3 Air Pressure and Atmospheric Pressure

6.3.1 Air pressure

Air is a composition of various gases therefore it has specific weight. The force of gravity acts on air, as on any object on the Earth, as a result its weights enable it to exert pressure on objects. Air and air pressure are invisible elements which influences other elements in specific ways.

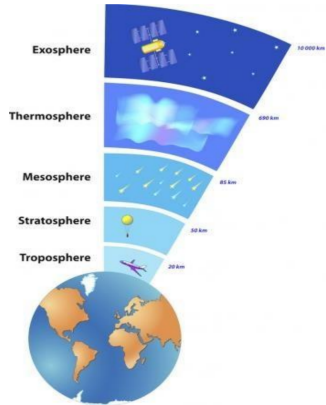
- Therefore, Air pressure is a pressure exerted by the air around us. Air pressure is caused due to the weight of the air molecules above. Even tiny air molecules have some weight, and the huge numbers of air molecules that make up the layers of our atmosphere collectively have a great deal of weight, which presses down on whatever are below.
- This pressure causes air molecules at the Earth's surface to be more tightly packed together than those that are high in the atmosphere. On the surface of the Earth, air pressure is balanced in and around human body.

- Generally, air pressure is treated as pressure due to the weight of the air above pushing down on a certain area. Air pressure decreases with increasing altitude. This is because the weight or the density of the air decreases as the altitude increases. Over higher altitudes, outer air pressure comes down and air pressure in the human body is more than outer atmosphere. For example, the air pressure is higher at sea level than at the top of the mountain.



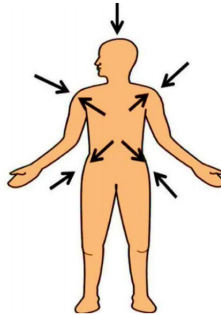
6.3.2 Atmospheric pressure and its layers

- The **atmosphere** is the layer of air that surrounds the Earth. The atmosphere basically can be divided into layers based on its temperature as shown in the figure.
- These layers from the ground to the space are the Troposphere, the Stratosphere, the Mesosphere and the Thermosphere and a further region above the Earth's surface is called the Exosphere.
 - **Troposphere** is the very lowest layer, which contains the largest percent of the atmosphere's mass. This is also where all living things are found and where all weathers occur. Airplanes fly at the very top of the troposphere, so they can fly over the weather, which causes turbulence.



- **Atmospheric pressure** is the force exerted at any given point on the Earth's surface by the weight of the air above that point. In short: the air that surrounds the Earth creates atmospheric pressure and this pressure is determined by the collective weight of air molecules.
- Air molecules at higher altitudes have fewer molecules pressing down on them from above and therefore experience lower pressure, while lower molecules have more force or pressure exerted on them by molecules piled on top of them and are more tightly packed together. The atmospheric pressure decreases as we go up from the Troposphere to Exosphere.
- Even on the surface of the Earth, as you go up to the mountains or fly high in an airplane, the air is thinner and the pressure is lower. The air pressure at sea level at a standard temperature and pressure is equal to one atmosphere (atm), and this is the baseline reading for determining relative pressure.

- We don't normally notice atmospheric pressure. If you move your hands up and down you can't feel it, because it does not only push on you equally from all direction but your body also pushes back out.
- There is a kind of equilibrium between the pressures in our bodies and the surrounding atmosphere.
 - If you went somewhere where the pressure was much greater than atmospheric pressure your bodies would be crushed. For example, deep-sea submarines have to be very strong to withstand the crushing effect caused by the pressure of the water. The pressure inside our bodies is also equal to the atmospheric pressure and cancels the pressure from outside.



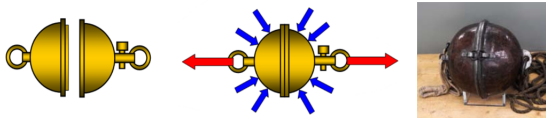
- A spacesuit is a pressurized garment worn by astronauts during space flights. It is designed to protect them from the potentially damaging conditions experienced in space. On Earth, our atmosphere provides us with the environmental conditions we need to survive.



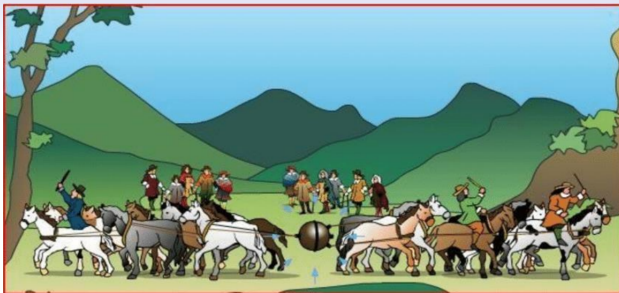
- In space, none of these protective characteristics are present. For example, an environment without consistent pressure doesn't contain breathable oxygen. Also, the temperature in space is as cold as -273°C . For humans to survive in space, these protective conditions had to be synthesized.
- A spacesuit is designed to re-create the environmental conditions of Earth's atmosphere. It provides the basic necessities for life support such as oxygen, temperature control, pressurized enclosure, carbon dioxide removal, and protection from sunlight, solar radiation and tiny micrometeoroids. It is a life-support system for astronauts working outside Earth's atmosphere.
- Spacesuits have been used for many important tasks in space as mentioned above. This astronaut protects himself from these several difficulties by wearing a pressurized space suit.

Magdeburg Hemispheres

- In the 17th century a German scientist named **Otto Von Guericke** (who was mayor of Magdeburg) invented a **vacuum pump**.
- This machine is used to remove the air from inside a chamber and so the force due to atmospheric pressure could really be seen.
- Von Guericke used his pump to remove air from inside two brass hemispheres touching each other. They are called the Magdeburg hemispheres.
- The **Magdeburg hemispheres** are a pair of large brass or copper hemispheres, with mating rims. The Magdeburg hemispheres were designed by German scientist Otto Von Guericke in 1650 to demonstrate the air pump he had invented and the concept of air pressure. They were used to demonstrate the power of atmospheric pressure.



- When the rims were sealed with grease and the air was pumped out, the sphere contained a vacuum and could not be pulled apart by teams of horses.
- With the air removed the pressure from the atmosphere squeezed the two hemispheres together. With no counter pressure from the air inside, the hemispheres were locked tightly together.
- In 1654, this can be demonstrated in front of **Emperor Ferdinand III**, how tightly held them by using thirty horses in two teams of 15 horses from both sides to try to separate the hemispheres.



- They couldn't do it. Thirty horses were unable to pull apart the evacuated hemispheres. The reason is when air is removed from the interior of the hemispheres, at the time there is no longer any force pushing outward. On the other hand, the atmospheric pressure outside dominates and pushing the hemispheres together with too strong pressure and keeping them from being separated. It was not until air was allowed back inside the hemispheres that the difference in pressure was small enough to allow them to be pulled apart. It would take over 300 pounds to pull the hemispheres apart.

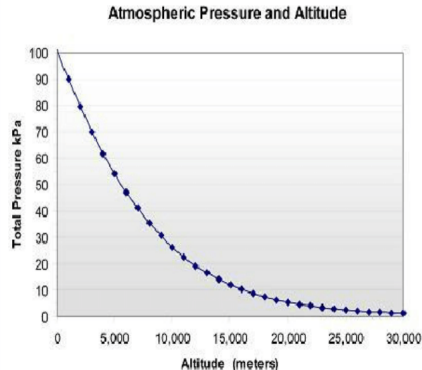
The effect of altitude on the atmospheric pressure

- The weight of the column of air above 1m^2 at ground level is around 101300N . This means the atmospheric pressure at sea level is about 101.3kPa or 1atm . The layer of the air near the surface of the Earth is more compressed than the air at a higher altitude above the Earth's surface. This is because of the density or the weight of the air becomes smaller and smaller as we go away from the
- Earth's surface and the air pressure correspondingly decreases. This implies that pressure decreases as the altitude increases. If you know the pressure at a certain level in the atmosphere, it is possible to know the altitude of the level above the earth's surface.
- A device that is used to measure altitude is called **Altimeter**. The table below shows, how the pressure varies with altitude. This does not give simple relationship since it depends also on the temperature change of the air and the position of the Earth.

Altitude	Approx. pressure(kPa)
0	101
1000	90
2000	79
5000	54
10000	26
15000	12
20000	6
25000	1.3
30000	0.27



- One can calculate the atmospheric pressure at a given altitude. Temperature and humidity also affect the atmospheric pressure, and it is necessary to know these to compute an accurate figure. The above graph was developed for a temperature of 15 °C and a relative humidity of 0% near the surface of the Earth.



Example

- Suppose that on average for every 120m rise in altitude above the sea level, the height of the column of mercury in a barometer falls by 1cm-Hg keeping that all other factors remains content. If the reading of a barometer placed at a certain high land is found to be 58cm-Hg, what will be the altitude of this high land from the sea level?

Height of Hg at sea-level 76cm-Hg

Height of Hg at high land 58cm-Hg

The difference

$$(76 - 58)cmHg = 18cmHg$$

$$\frac{1cmHg}{18cmHg} = \frac{120m}{x}$$

$$x = \frac{120m \times 18cmHg}{1cmHg} = 2160m$$

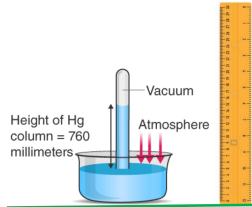
- The height the high land is 2160m

At the top $P_a = 56cmHg$



Measuring Atmospheric pressure

- Atmospheric pressure is usually measured by an instrument called barometer. A barometer is a scientific instrument used to measure atmospheric pressure, also called barometric pressure.
- There are different kinds of barometer but here we will discuss only the Mercury barometer. The principle of its operation is shown in Figure below.

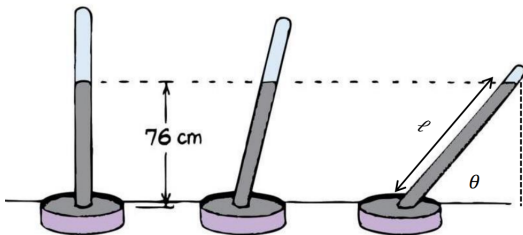


Principle of mercury barometer

- A glass tube closed at one end is filled with mercury and the open end is covered then turned upside down into a container filled with mercury.
- When the open end is uncovered, part of the mercury flows out of the glass tube into the container until the pressure exerted by the column of mercury exactly balances the atmospheric pressure acting on the mercury in the dish or bowl.

- Then "**Torricellian vacuum**" is produced at the top of the glass tube and the mercury level stabilizes at approximately 76 cm from the mercury level in the container.
- Since the pressure in the tube above the column of mercury is zero, the height of the column above the level of mercury in the bowl indicates the atmospheric pressure.
- As the level of mercury in the tube falls, it leaves an empty space (vacuum) at the top. The level of the mercury in the tube rises as the external atmospheric pressure increases and falls down as it decreases.
- The column of mercury is represented by 'h'. The pressure in the tube above the column of mercury is zero. The column of mercury above the level of mercury in the bowl indicates the atmospheric pressure at that particular place. This is the pressure due to the mercury's weight (ρgh).
- The atmosphere exerted on the mercury in the bowl able to force the mercury in the tube to a height 'h' because the pressure above the mercury is zero.

- At sea level an atmospheric pressure of 101.3kPa will cause the level of the mercury in the tube to stabilize at a height of 76cm or 760 mm.
- That is $P_{atm} = 1atm = 76cmHg = 760mmHg$
 $P_{atm} = \text{Density of mercury} \times \text{gravity} \times \text{column of mercury}$
 $P_{atm} = \rho gh = (13,600kg/m^3)(9.8m/s^2)(0.76m)$
 $P_{atm} = 101292.8N/m^2$
 $p_{atm} \approx 101300Pa \text{ or } 101.3kPa$
- When the tube is inclined the horizontal level of the mercury should then be constant as shown, indicating a constant vertical height above the mercury surface in the trough.

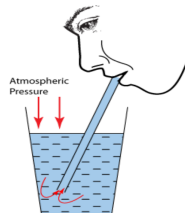


Some applications of atmospheric pressure

- There are different devices that operate under atmospheric pressure. Some common uses of air pressure or atmospheric pressure in daily life are:
- Drinking through straw, Inflating tires, Playing musical wind instrument, Flushing toilets Drawing water from well, Operating barometer, Blowing up balloon, Breathing, Maintaining body shape especially abdomen, Vacuum cleaner has fan inside that create low pressure and helps to suck all dust, the area of the edge of knife's blade is small this create pressure high and help to cut material and so on. Let us discuss some of them.

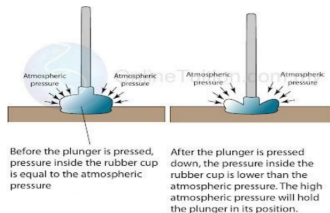
1. Drinking Straw

- When a person sucks through the straw the pressure in the straw becomes low. The external atmospheric pressure outside which is higher will force the water into the straw and consequently into the mouth.



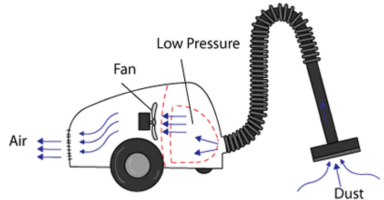
2. Rubber Sucker/ A suction pad

- When the rubber sucker is pressed into place, the air inside rubber sucker is forced out. This causes the space between the surface and the sucker to have low pressure. The sucker is then held in position by the high atmospheric pressure on the outside surface.
- The contact between the rubber sucker and the smooth surface is airtight. The external atmospheric pressure, which is much higher, acts on the rubber sucker, pressing it securely against the surface.



3. Vacuum Cleaner

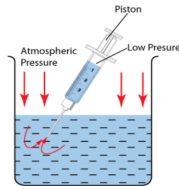
- Vacuum cleaner applies the principle of atmospheric pressure to remove dust particles. When it is switched on, the fan sucks out the air from space inside the vacuum (space A). Space A then become a partial vacuum.



- When a vacuum cleaner is switched on, it sucks out the air inside the cleaner, causes the pressure inside the cleaner become low.
- The atmospheric pressure which is higher in magnitude, forces the air and duct particles into the cleaner.
- The atmospheric pressure outside, which is greater, then forces air and dust particles into the filter bag. This traps the dust particles but allows the air to flow through an exit at the back.

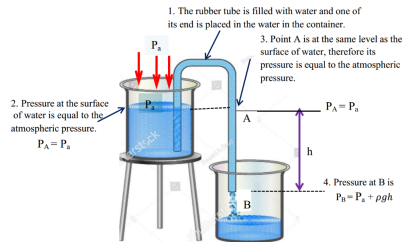
4. A Syringe

- The syringe works on the existence of atmospheric pressure. When the nozzle of a syringe is dipped in a liquid and its piston is withdrawn or pulled up, the atmospheric pressure inside the syringe will decrease.
- The greater atmospheric pressure acting on the surface of the liquid, outside, pushes the liquid up into the syringe. When the piston is pushed downwards, water will be pushed out.



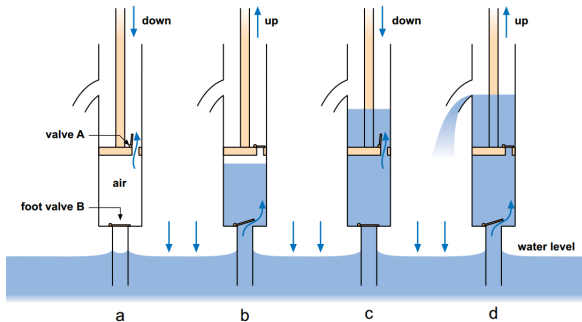
5. Siphon

- A siphon is a convenient way of removing liquid from a container such as a petrol tank. A rubber tube can be used to siphon liquid from a container at a higher level to another at a lower level.
- For example, we can remove petrol from the petrol tank of a vehicle or dirty water from aquarium.
- The tube is first filled with the liquid and one end is placed in the liquid in the container A. The other end is placed at a level which must be lower than the surface of the liquid in container A.
- 5. The pressure in the rubber at the lower end, at B, is equal to atmospheric pressure plus the pressure due to h column of liquid. So, the pressure at the lower end is greater than the atmospheric pressure, the liquid flows out from the rubber tube.



6. Lift Pump

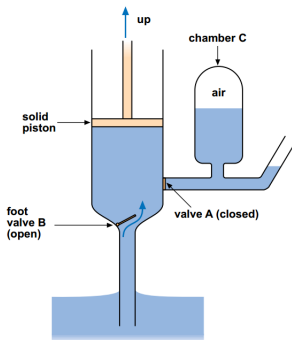
- A lift pump is used to pump water out of a well or to a higher level. A piston moves up and down a tube. There is a valve in the piston and also one at the end of the tube. A valve is usually made of leather, and has brass on it to make it heavy. The valves are normally shut. They let water pass upwards but not downwards.



1. Down-stroke: Foot valve B closes under its own weight. Valve A opens and lets air pass through it into the space above the piston.
 2. Upstroke: Valve A closes under its own weight. The pressure under the piston is less than atmospheric. Atmospheric pressure forces water into the tube through B.
 3. Down-stroke: Valve B closes and A opens. Water passes through A into the space above the piston.
 4. Upstroke: Valve A closes and water is lifted up the tube and out of the spout. More water passes through B to keep the pump filled.
- Atmospheric pressure determines the height to which water can be pumped. Even a perfect pump can raise water only 10.4 m. In practice, because of leaks at the valves and piston and of dissolved gases from the water, most pumps raise water about 7 m only. Delivery of water is not continuous.

7. Force Pump

- A force pump can pump water to a great height. Some, used by firemen, can force water hundreds of metres high.

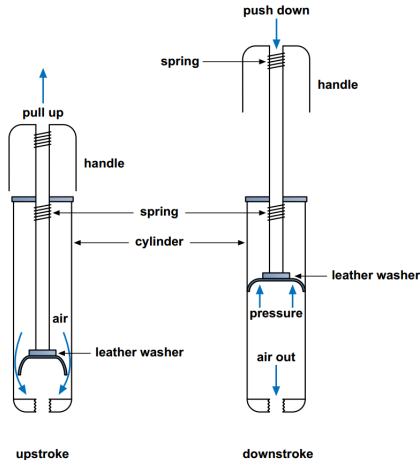


- There is a foot valve B, as in the lift pump, but it has a solid piston and a delivery tube at the bottom of the pump. There is a valve A in the delivery tube where it joins a chamber.

- **Upstroke:** The pressure in the tube under the piston becomes less. Valve A closes and foot valve B opens. Water is forced through B into the tube by atmospheric pressure.
- **Down-stroke:** B closes. Valve A opens; water is forced through it and the delivery pipe into chamber C. The pressure on the piston (and not atmospheric pressure) determines the height to which the water is pumped.
- The force pump itself delivers water only on the downstroke; the flow of water stops on the upstroke. However, the air trapped in chamber C is compressed during every downstroke. The pressure of this air continues to force out water during the upstroke, and therefore the pump delivers a steady stream of water.

8. Bicycle pump

- The handle moves a piston in a metal cylinder. There is a cup-shaped leather or rubber washer on the end of the piston. This acts as a valve and lets air move in one direction only. The soft edge of the washer fits closely to the sides of the cylinder.



- **Upstroke:** The pressure below the piston is reduced. Atmospheric pressure forces air between the washer and the wall of the cylinder.
- **Down-stroke:** The pressure below the piston is increased. The washer is pressed tightly against the walls of the cylinder, making it airtight. When the pressure rises above the pressure inside the tyre, the tyre valve opens and air is forced into the tyre.
- A bicycle pump with the washer reversed acts as a vacuum pump or suction pump.

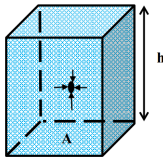
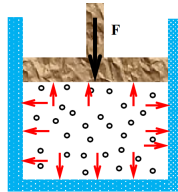
Exercise

1. The mercury barometer is exposed to air at sea level, what is the height of the mercury column?
2. The mercury column in a barometer is 72cm tall at a certain elevation.
 - a) What is the pressure of the air at this elevation in Pascal?
 - b) If the barometer was filled with water instead of mercury, what height of water can this air support?
3. The height of mercury in an open barometer is 69cm. The height of another fluid in the same barometer is 176cm, what is the density of the fluid?
4. The height of water ($\rho_w = 1000\text{kg}/\text{m}^3$) and oil ($\rho_{oil} = 720\text{kg}/\text{m}^3$) are 6m and 5m inside an open barometer. What is the atmospheric pressure in kPa and atm?
5. If the reading of a mercury barometer at the base of a mountain is 76cm and 66cm at the top of the mountain, what will be the height of the mountain if the atmospheric pressure falls by 1cm-Hg for every 120m rise in altitude?

6.4 Fluids Pressure

- Fluid pressure is the pressure at a point within a fluid arising due to the weight of the fluid. There is a very significant difference between the way a force acts on a fluid and on a solid. Since a solid is a rigid body, it can withstand the application of a force without a significant change in shape. A liquid, on the other hand, can sustain a force only at an enclosed surface or boundary. If a fluid is not restrained, it will flow under a shearing stress instead of being deformed elastically. A solid object can exert only a downward force due to its weight whereas a liquid can exert force in all directions.
- The force exerted by a fluid on the walls of its container must always act perpendicular to the wall. Fluids exert pressure in all directions.
- Consider a liquid enclosed in a container is under pressure due to the force exerted by the face of the piston in Figure below. The fluid exerts pressure in all directions perpendicularly to the wall of the container.

- At any particular point in a fluid, the pressure is the same in all directions. If this is not true, the fluid would flow under the influence of a resultant pressure until a new condition of equilibrium was reached.



- Pressure due to the weight of water is called **“hydrostatic pressure”**. The weight of water is cumulative; the deeper the dive, the more water there is above the diver and the greater the weight of that water. This weight affects a diver from all sides equally and increases with depth. To determine the pressure exerted by a liquid on the bottom and walls of a container, consider a rectangular tank of base area A filled with a liquid of density " ρ ". Suppose the base is at a depth h .

- The pressure at the bottom of the tank is caused due to the weight of the water above it.

$$\text{Pressure} = \frac{\text{Weight of water}}{\text{Base area of the container}}$$

- $\text{Weight of water} = \text{mass of water} \times \text{gravity} = mg$ and
 $\text{Mass} = \text{density} \times \text{volume} = \rho hA$

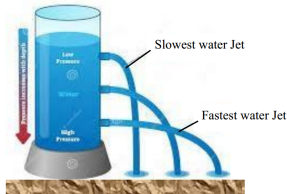
$$P = \frac{mg}{A} = \frac{\rho hAg}{A} = \rho hg$$

$$P = \rho gh$$

- This equation shows that the pressure in a liquid increases with depth (h) and density (p). It is directly proportional both to the depth of fluid and density. But pressure in a fluid does not depend on the base area of the container.

Pressure and depth

- Pressure and depth have a directly proportional relationship. This is due to the greater column of water that pushes down on an object submersed. Conversely, as objects are lifted, and the depth decreases, pressure is reduced. Figure below shows the direct correlation between an increase in depth and an increase in pressure.



- Take a tall tin cylinder and carefully make three or four vertical holes on its lateral surface at different height from the bottom going up one side.
- Close the holes with match sticks and fill the cylinder with water to the brim.

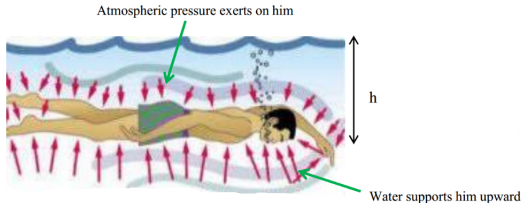
- Finally open the holes at the same time and watch the jet of water shooting out of the cylinder. Why does the water flow out of the hole? Why does the water shoot out faster through the lower hole than it does through the other holes?
- This activity shows (1) pressure in water acts in all directions that is why water has come through the side holes and the holes at the bottom. (2) The pressure of water depends on the depth of the column of water in the cylinder that is why water has moved faster through the bottom hole of the lateral surface than through the upper holes.
- Generally, pressure in a liquid at rest depends on the
 - 1) depth of the fluid
 - 2) density of the fluid
 - 3) gravity on the Earth

Example

1. Calculate the pressure exerted by the water at the bottom of the sea when its depth is 50m? Assume that the density of sea water is $1030\text{kg}/\text{m}^3$ and use $g = 10\text{m}/\text{s}^2$

The effect of atmospheric pressure in a fluid

- Consider a person swimming in a swimming pool as shown below. Pressure is exerted perpendicular to all sides of this swimmer. The arrows represent the directions and magnitudes of the forces exerted at various points on the swimmer.



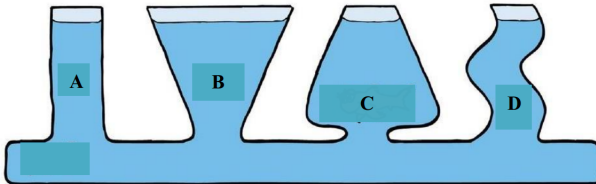
- The pressure on the swimmer would be the sum of the pressure due to the fluid and the atmospheric pressure. The equation used to determine the total pressure exerted on the person is given by the sum of Atmospheric pressure and the pressure due to the liquid

$$P = P_{atm} + \rho gh$$

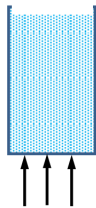
- Where ρ the density of the liquid, h is the depth of the liquid and g acceleration due to gravity.

Fluid pressure in different containers

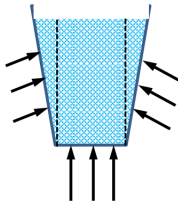
- Does the shape of a container have any effect on liquid pressure?
- Consider a series of vessels of different area and shape interconnected together and the liquid observed to rise to the same height “ h ” in each of tube, as shown in Figure below.
- It would seem at first glance that the greater volume of water in vessel B should develop a greater pressure at the bottom than vessel D. The effect of such a different in pressure would then force the liquid to rise higher in vessel D.
- However, filling the vessels with identical liquids shows the levels to be the same for each vessel.



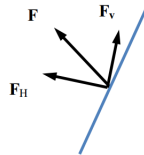
- Part of the problem in understanding this paradox results from confusing the terms pressure and total force. For example, in vessel A the area of the liquid at the bottom of the vessel is much greater than the area at the bottom of vessel D. This means that the liquid in vessel A will exert a greater total force on the bottom than the liquid in vessel D. But the greater force is applied over a large area so that the pressure is the same in both vessels.



b)



b)

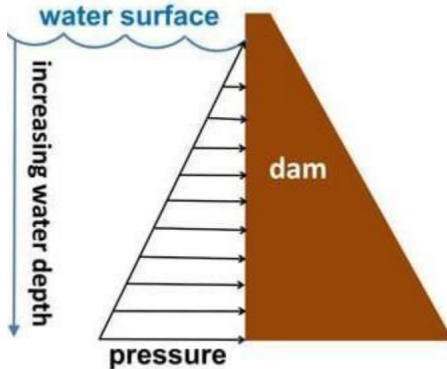


F_v = Vertical component

c)

- If the bottom of vessels B, C, and D have the same area, we can say that the total forces are also equal at the bottom of these containers. You may wonder how the total forces can be equal when vessels B and C contain a greater volume of water. The additional water in each case is supported by vertical components of forces exerted by the wall of the container on the fluid. (See Figure (c))
- When the walls of the container are vertical, the forces acting on the sides have no upward components. Here the total force at the bottom of the container is there for equal to the weight of a straight column of water above the base area. See Figure(a)
- The pressure at the bottom of each vessel, Figure (a) and (b), is a function of the depth of the liquid only and it is the same in all direction. Since the area at the bottom is the same for both vessels, the total force exerted on the bottom of each container is also the same.

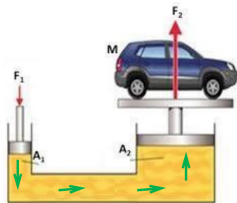
- Pressures exerted by water in the reservoir behind a dam are hydrostatic and increase linearly with depth. The pressures are hydrostatic and increase with depth. On the assumption that the pressures are directed normal to the floor and sides, they are shown as vectors of increasing in magnitude with depth.



6.4.1 Pascal's principle

- This principle deals about the transmission of pressure in a fluid. According to Pascal's principle, **“The pressure applied to an enclosed fluid is transmitted to every part of the fluid, as well as to the walls of the container without reducing in value”**.
- When a force is applied to incompressible fluid in a container the pressure transmitted equally in all directions throughout the fluid.

- Since the force applied to the contained fluid is distributed throughout the system, you can multiply the applied force through this application of Pascal's Principle in the following manner.



- Assume you have a closed container filled with an incompressible fluid with two pistons of differing areas of a simple hydraulic lift, A_1 and A_2 .
- If you apply a force, F_1 , to the piston of cross-sectional area A_1 , you create a pressure P_1 in the fluid. Where F_1 is an effort applied to the smaller piston.

$$P_1 = \frac{F_1}{A_1} \implies F_1 = P_1 \times A_1$$

- Similarly, the pressure at the second piston, P_2 , must be equal to F_2 divided by the cross-sectional area of the second piston, A_2 . Where F_2 is the load (the car) placed on the larger piston.

$$P_2 = \frac{F_2}{A_2} \implies F_2 = P_2 \times A_2$$

- Since the pressure is transmitted equally throughout the fluid in all directions according to Pascal's Principle, P_1 must equal P_2 .

- *P on the left hand piston = P on the right hand piston*

$$P_1 = P_2 \quad \text{but} \quad A_2 > A_1$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \implies \frac{F_1}{F_2} = \frac{A_1}{A_2}$$

- Rearranging to solve for F_2 , you find that F_2 is increased by the ratio of the areas A_2 over A_1 .

$$F_2 = F_1 \frac{A_2}{A_1}$$

- Therefore, you have effectively increased the applied force F_1 . Of course, the law of conservation of energy cannot be violated, so the work done on the system must balance the work done by the system.
- In the hydraulic lift diagram shown on the above, the distance over which F_1 is applied will be greater than the distance over which F_2 is applied, by the exact same ratio as the force multiplier.

- This ratio gives the mechanical advantage of the hydraulic press or lift.

$$MA = \frac{\text{Load}}{\text{Effort}} = \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

- *Work out input = Work input + Waste energy*

$$Wi = Wo + \text{Waste energy} = F_1 D_1 + F_2 d_2 + \text{Waste energy}$$

Example

1. The smaller and the larger pistons of a hydraulic press have cross-sectional areas of 20cm^2 and 80cm^2 respectively. a) What is the MA of the machine? b) What input force is applied to the smaller piston in order to lift a 2400N load placed on the larger piston?
2. A barber raises his customer's chair by applying a force of 150N to a hydraulic piston of area 0.01m^2 . If the chair is attached to a piston of area 0.1m^2 , how massive a customer can the chair raise? Assume the chair itself has a mass of 5kg .

Application of Pascal's principle

- According to Pascal's principle, pressure in an enclosed system is transmitted equally throughout the fluid. This fundamental characteristic of fluids provides the foundation for hydraulic systems found in barbershop chairs, construction equipment and the brakes in your car.

1. A hydraulic lift

- This simple machine is used to lift a heavy load, like a car, off the ground. A small force is applied to a smaller area piston. This creates a pressure inside the hydraulic fluid, which is transferred to the larger area piston. This piston creates a greater force and if the object to be lifted sits on the top of this piston, then it can be easily lifted by a smaller force applied to the smaller area piston.

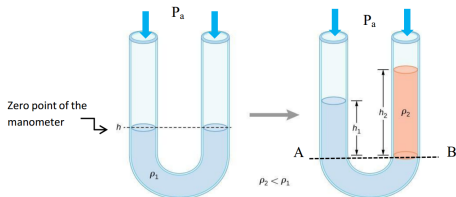
2. A hydraulic press

- This machine also operates based on Pascal's principle. It is used shape metals, eg. make motor bodies, to press wasted paper or cotton wool into bales of small size, to press oil from oil seeds.

3. Manometer

- A manometer is a scientific instrument used to measure gas pressures. Open manometer measures gas pressure relative to atmospheric pressure. A mercury or oil manometer measures gas pressure as the height of a fluid column of mercury or oil that the gas sample supports.
- A simple manometer can be built by partially filling a clear U-shaped plastic tube with a colored liquid to allow the fluid level to be easily observed and fixed in an upright position. The levels of the fluid in the two vertical columns should be equal at this point, as they are currently exposed to the same pressure.

- This level is therefore marked and identified as the zero point of the manometer.



- Suppose two types of liquids having different densities ρ_1 and ρ_2 are poured into the U-shaped tube which are separated in color. When the liquid in both sides of the tube is stable and balanced then the pressure is the same at A and B.

$$P_A = P_B$$

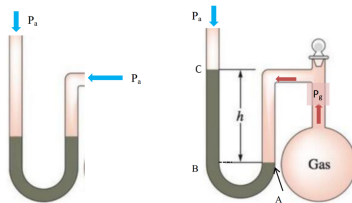
$$\rho_1 h_1 = \rho_2 h_2$$

$$P_{atm} + \rho_1 gh_1 = P_{atm} + \rho_2 gh_2$$

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

$$\rho_1 g h_1 = \rho_2 g h_2$$

- This helps us to determine the density of unknown liquid if the column of each liquid is given. If one end of the tube is connected to a gas supply, the liquid would be pushed down as the gas supply is at a greater pressure than the surrounding atmosphere. At the same time the liquid on the other side rises upwards by the same amount until the pressure on both sides be equal at the lower point. That is at A and B. If atmospheric pressure is greater than the pressure on the other side of the fluid, air pressure pushes the column toward the other gas. If the opposing gas pressure is greater than atmospheric pressure, the column is pushed toward the side open to air.



- The height difference between B and C can then be used to determine the pressure of the gas supply. The pressure is the same at A and B since the liquid in both sides stable and balanced.

$$P_A = P_B$$

- Pressure of gas = atmospheric pressure + pressure due to the column of liquid BC.

$$P_{gas} = P_{atm} + gh_{BC}$$

Example

1. If the liquid used in the above manometer is water and the column of water at that time is 12cm, what will be the pressure of the gas in the tank? Assume that the measurement is taken at sea-level.

Absolute, Gauge and Atmospheric pressure

- When we want to measure the pressure of fluid there are different terms you may come across. These include atmospheric pressure, gauge pressure and absolute pressure. What is the difference among these pressures?

Absolute pressure/ System pressure (P_s)

- The absolute pressure is the actual or the true pressure at a given point if all of the factors are taken into account.

Atmospheric pressure (P_{atm})

- Atmospheric pressure is pressure due to the layer of air that surrounds the Earth.

Gauge pressure (P_{gauge})

- Gauge pressure is the pressure differences between a system and atmospheric pressure.

- Gauge pressure = System pressure - Atmospheric pressure

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

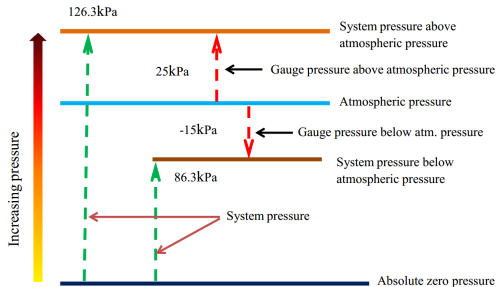
- Gauge pressure can be measured by a device called **Pressure gauge**.
The reading on a pressure gauge is either positive or negative relative to the atmospheric pressure.



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

- If the reading on the pressure gauge is positive, it would mean that the system pressure is above the atmospheric pressure.
- On the other hand, if the reading on the pressure gauge is negative, it would mean that the system pressure is below the atmospheric pressure. If the gauge was disconnected, it would read zero Pa even though the absolute or system pressure is still 101.3kPa.

- The relationship among atmospheric pressure, gauge pressure and absolute pressure.

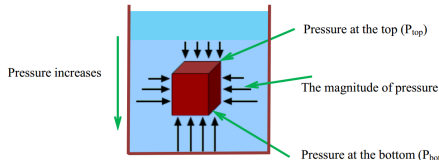


Example

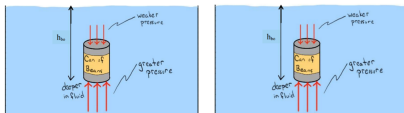
- Suppose the pressure gauge reads 25kPa at one time and -15kPa on another time. What would be the absolute pressure during these two times? Indicate it on the above figure.

6.4 Force in a fluid

- If you hold a cork under water and then release it, then it accelerates back towards the surface of the water. Equally if you drop a stone into the water, it accelerates through the water much more slowly than it did through the air. Why it seems less heavy in water than in air? This is because the force from the water pushes or supports the object up against gravity.
- This force is called **buoyant force** or **up thrust**. Buoyant force arises due to the fact that the pressure increases with depth. Therefore, the pressure at the bottom of the object will be greater than the pressure on the top of the object so there is a net force that buoyed up or acting upward on the object.



- So why do fluids exert an upward buoyant force on submerged objects? It has to do with differences in pressure between the bottom of the submerged object and the top. Suppose you dropped a can of beans in a pool of water as shown in Figure below.



- The force from pressure exerted downward on the top of the can of beans will be less than the force from pressure exerted upward on the bottom of the can because pressure ($P = \rho gh$) increases as you go deeper in a fluid as mentioned above.
- The reason there's a buoyant force is because of the upward force from water has to be greater than the downward force from water.

- We can start with the fact that the water on the top of the can is pushing down by F_{down} and the water on the bottom of the can is pushing up by F_{up} .
- We can find the total upward force on the can exerted by water pressure (which we call the buoyant force $F_{bou.}$) simply by taking the difference between the magnitudes of the upward force F_{up} and downward force F_{down}

$$F_{bou} = F_{up} - F_{down}$$

- We can relate these forces to the pressure by using the definition of pressure $P = F/A$, which can be solved for force to get $F = PA$. So the force exerted upward on the bottom of the can will be

$$F_{up} = P_{bot}A$$

- The force exerted downward on the top of the can will be

$$F_{down} = P_{top}A$$

- Substituting these expressions respectively in the previous equation we get,

$$F_{bou} = P_{bot}A - P_{top}A$$

- We can use the formula for hydrostatic gauge pressure $P_{gauge} = \rho gh$ to find expressions for the upward and downward directed pressures.
- The force from pressure directed upward on the bottom of the can is $P_{bot} = \rho gh_{bot}$ and the force from pressure directed downward on the top of the can is $P_{top} = \rho gh_{top}$. We can substitute these into the previous equation for each pressure respectively to get

$$F_{bou} = \rho gh_{bot}A - \rho gh_{top}A = \rho gA(h_{bot} - h_{top})$$

- The difference between the depth of the bottom of the can h_{bot} and the depth of the top of the can h_{top} is just equal to the height of the can.

- So we can replace $(h_{bot} - h_{top})$ in the previous formula with the height of the can h_{can} to get:

$$F_{bou} = \rho g A h_{can}$$

- Here's the interesting part. Since $A \times h$ is equal to the volume of a cylinder, we can replace the term $A h_{can}$ with a volume V . This volume is equal to both the volume of the can and the volume of the water displaced by the can (V_f). By displaced water we mean the volume of water that was once in the volume of space now occupied by the can.
- **Notice:** The two volumes could be different if the object is only partially submerged in the fluid.

$$F_{bou} = \rho g V_f$$

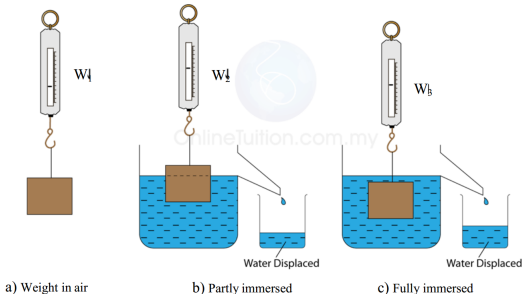
- On what factors does the buoyant force depend? Sometimes people think the buoyant force increases as an object is brought to deeper and deeper depths in a fluid. But the buoyant force doesn't depend on the overall depth of the object submerged. In other words, as long as the object is fully submerged or bringing it to a deeper and deeper depth will not change the buoyant force. Why? Because the key idea is that the pressures at the top and bottom of the object (the can) will both increase by the same amount and therefore cancel to each other, leaving the total buoyant force the same.
- The size of the buoyant force on an object submerged wholly or partially in a fluid only depends on the density of the fluid in which the object is submerged, the acceleration due to gravity g , and the volume of the displaced fluid V_f . Buoyant force exists both in liquids and air.

- But it is very small in air since the density of air is much less than that of liquid. Hot air balloon floats in the air due to the buoyant force of the air pushing them up, acting against their weight.
- Hot air balloons rise into the air because the density of the air (warmer air) inside the balloon is less dense than the air outside the balloon (cooler air).



Archimedes' principle

- Archimedes' principle tells us about the relationship between the buoyant force exerted on a submerged by fluids and the weight of the liquid it displaced. It is stated as: **A body partly or completely immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.**
- Consider a block of mass 'm' is partially or completely immersed into water as shown in Figure below. Measure the weight of the block in air and in water by using spring balance.



- Where:
- W_1 is Weight of a block in air = Actual weight
- W_2 is Weight of the block in water when partly immersed = Apparent weight
- W_3 is Weight of the block in water when fully immersed = Apparent weight
- According to Archimedes' principle, the magnitude of the buoyant force is equal to the weight of the fluid displaced by the submerged object in all cases.
- Buoyant force (F_{bou}) = Weight of liquid displaced

$$F_{bou} = W_{dis} = m_{dis}g = \rho V_{dis}g$$

1. If the object is completely submerged in the fluid, the volume of displaced fluid is equal to the volume of the submerged object: $V_{dis} = V_{ob}$. Then

$$F_{bou} = \rho_l g V_{ob}$$

- The difference between the actual weight and the apparent weight is also equal to the buoyant force.
- Buoyant force (F_{bou}) = Weight in air - Weight in liquid

$$F_{bou} = W_1 - W_3$$

- From the above equations

$$\rho_l g V_{ob} = W_1 - W_3$$

- But $V_{ob} = m_{ob} / \rho_{ob}$

$$\rho_l m_{ob} / \rho_{ob} = W_1 - W_3$$



$$\frac{\rho_l}{\rho_{ob}} = \frac{W_1 - W_3}{m_{ob}} = \frac{W_1 - W_3}{W_1}$$

$$\frac{\rho_{ob}}{\rho_l} = \frac{W_1}{W_1 - W_3}$$

- The above equation is used to determine the density of the body immersed in the liquid of known density. If the liquid is pure water of density $1g/cm^3$, then equation is also used to determine the relative density of the body.

$$\rho_r = \frac{\rho_{ob}}{\rho_l} = \frac{W_1}{W_1 - W_3}$$

2. If the object is partially submerged, $V_{dis} = V_{pv}$ = partial volume of the object that is submersed.
- Now the volume of liquid displaced is not equal to the volume of the submerged body.

$$F_{bou} = \rho_l V_{dis} g = \rho_l V_{pv} g$$

$$F_{bou} = \text{weight of liquid displaced}$$

$$F_{bou} = W_1 - W_2$$

$$\rho_l V_{pv} g = W_1 - W_2$$

- Partial volume is $V_{pv} = m_{ob}/\rho_{ob}$

$$\rho_l \frac{m_{ob}}{\rho_{ob}} g = W_1 - W_2$$

$$\frac{\rho_l}{\rho_{ob}} = \frac{W_1 - W_2}{m_{ob} g} \implies \frac{\rho_l}{\rho_{ob}} = \frac{W_1 - W_2}{W_1}$$

- When the liquid is the standard water of density $1000\text{kg}/\text{m}^3$, the above equation is used to determine the relative density of a body.

$$\rho_r = \frac{\rho_{ob}}{\rho_l} = \frac{W_1}{W_1 - W_2}$$

- If the density of the body is less than the density of water, for a floating body, the above equation or ratio also is used to determine the fraction submerged into the liquid. Fraction submerged tell us about the part of the body immersed in the liquid.

$$f_{sub} = \frac{\rho_{ob}}{\rho_l} = \frac{W_1}{W_1 - W_2}$$

- And the equation

$$F_{exp} = 1 - f_{sub}$$

is used to determine the part of the body exposed to the air or not submerged. It is called fraction exposed (F_{exp}).

Example

- A body weighs 86N in air and 60N when it is immersed wholly in water of density $1000\text{kg}/\text{m}^3$. What is the
 - a) buoyant force
 - b) weight of the liquid displaced
 - c) density of the body
 - d) volume of the body.

Solution

a)

$$F_{bou} = W_1 - W_3 = 86\text{N} - 60\text{N} = 26\text{N}$$

b)

$$W_{dis} = F_{bou} = 26\text{N}$$

c)

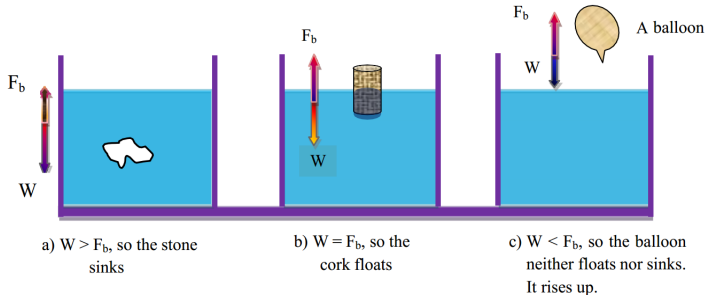
$$\rho_{ob} = \frac{W_1}{W_1 - W_3} \rho_w = 3,307.7\text{kg}/\text{m}^3$$

d)

$$V_{ob} = \frac{W_1 - W_3}{g \rho_w} = 0.0026\text{m}^3 = 2600\text{cm}^3$$

Floating and Sinking

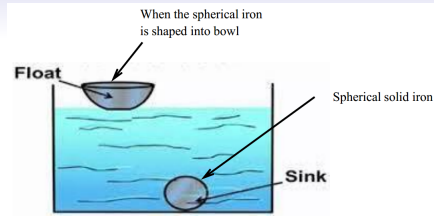
- Archimedes' principle allows the buoyancy of any floating object partially or fully immersed in a fluid to be calculated. Whether or not an object floats or sinks depends on the
 - weight of the object
 - size of the buoyant force acting on the object.
 - density of the object
- Consider three different objects such as stone, a cork and a balloon filled with air as shown in Figure below.



- a. When the weight of the object is greater than the buoyant force the object sinks.
- b. When the weight of the object is equal to the buoyant force the object floats
- c. When the weight of the object is less than the buoyant force the object neither sink nor floats but it rises up.

Principle of floatation

- Consider a small spherical solid iron. As iron is nearly eight times denser than water, it displaces only $1/8$ volume of water when submerged, which is not enough to keep it afloat. Suppose the same spherical iron is reshaped into a bowl. It still weighs the same as before reshaped, but when it is put in water, it displaces a greater volume of water than when it was a solid sphere.
- That is the bowl displaces a volume more than the volumes of the solid sphere (The volume of the solid sphere + the volume inside the bowl). In this case it is possible that the weight of the extra volume of water displaced can be equal to the weight of the solid spherical iron and hence the shaped iron floats.



- The deeper the iron bowl is immersed, the more water it displaces, and the greater the buoyant force acting on it and it will sink. For example, when any boat displaces a weight of water equal to its own weight, it floats. Every ship, submarine, and airship must be designed to displace a weight of fluid equal to its own weight.
- For example, a 10,000-ton ship must be built wide enough to displace 10,000 tons of water before it sinks too deep in the water. Therefore, the principle of floatation is applied in the construction of ships or boats which carry a large amount of load.

Flotation and Density

- Density plays a crucial role in Archimedes' principle. The average density of an object is what ultimately determines whether it floats or not. If its average density is less than that of the surrounding fluid, it will float. This is because the fluid, having a higher density, contains more mass and thus more weight in the same volume. The buoyant force, which equals the weight of the fluid displaced, is thus greater than the weight of the object. Likewise, an object denser than the fluid will sink.
- This means we need to consider the relative density between the object and the fluid. If the relative density is less than one the object will float. That is when the weight of the object will be less than the weight of the volume of fluid it displaces. If the relative density is greater than one the object will sink. That is the weight of the object will be more than the weight of the volume of fluid it displaces.

- The extent to which a floating object is submerged depends on how the object's density is related to that of the fluid. For example, an unloaded ship has a lower density, and less of it is submerged compared with the same ship loaded with cargo.



- A full cargo ship or a heavily loaded ship on the right sits much lower in the water than an empty or unloaded ship on the left. A ship that is not heavily loaded displaces a smaller volume of water in order to float while a ship that is heavily loaded needs to displace a much larger volume of water in order to float. We can derive a quantitative expression for the fraction submerged by considering density.

Condition for Flotation

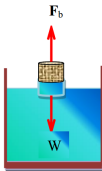
- An object will float if the buoyancy force exerted on it by the fluid balances its weight. This is often called the “**principle of flotation**” where a floating object displaces a weight of fluid equal to its own weight.

Weight of fluid displaced = Weight of the floating body

- But the Archimedes principle states that the buoyant force is the weight of the fluid displaced. So, for a floating object, the weight of the displaced fluid is equal to the weight of the object. Thus, only in the special case of floating does the buoyant force acting on an object equal the object's weight.
- That is:

Buoyant force = Weight of liquid displaced = Weight of the floating body

- Consider a body of mass “m” and density of ρ_{ob} floating in a liquid of density ρ_l . From principle of floatation we have the following.



$$W_{ob} = W_{dis} = F_{bou}$$

$$m_{ob}g = m_l g$$

item From $m = \rho V$ and cancel gravity from both sides, then we have

$$\rho_{ob} V_{ob} g = \rho_l V_l g$$

$$\rho_{ob} V_{ob} = \rho_l V_l$$



$$\frac{\rho_{ob}}{\rho_l} = \frac{V_l}{V_{ob}}$$

- This equation is used to determine the fraction submerged or the part of the floating body under the fluid. The fraction submerged is the ratio of the volume submerged to the volume of the object, or the ratio of density of the object to the density of the fluid.

Example

1. A floating wooden block has a volume of 500000cm^3 and displaces 200000cm^3 of water. Determine the density of the block. The density of water is $1000\text{kg}/\text{m}^3$.

THE END