PRESSURE

To make sense of the effects of a force acting on a body, we have to also consider the area to which the force acts.

Definition:

Pressure is the force acting normally per unit area of the surface.

$$Pressure = \frac{Force\ (N)}{Area\ (m^2)}$$

The SI unit of pressure is Newton per metre squared [N/m^2 (Nm^{-2})] or Pascals (Pa).
Therefore, 1 $Newton\ per\ metre\ squared$ ($1Nm^{-2}$) $= 1\ Pascal$ ($1Pa$).

Definition:

A **Pascal** is the pressure exerted on a body when a force of $1N$ acts normally on an area of $1m^2$.

Other units of pressure include; $cmHg$, $mmHg$, $atmospheres$, kPa
Pressure is a scalar quantity.

Examples:

When calculating for pressure, the area should always be in m^2.

1. A man of mass 84kg stands on a floor. If the area of contact of his shoes on the floor is $0.042m^2$, find the pressure exerted by the man on the floor.
   $m = 84kg$, $A = 0.042m^2$

$$F = mg$$
$$F = 84 \times 10$$
$$F = 840N$$

$$P = \frac{F}{A}$$
$$P = \frac{840}{0.042}$$
$$P = 20000Nm^{-2}\ or\ Pa$$

2. A car piston exerts a force of 200N on a cross-sectional area of $40cm^2$. Find the pressure exerted by the piston.

   $F = 200N$, $A = 40cm^2 = \frac{40}{10000} = 0.004m^2$

$$P = \frac{F}{A}$$
$$P = \frac{200}{0.004}$$
$$P = 50000Nm^{-2}\ or\ Pa$$

3. A block of mass 40kg exerts a pressure of $20Nm^{-2}$ on the surface. Find the area of contact between the block and the surface.
   $m = 40kg$, $P = 20Nm^{-2}$

$$F = mg$$
$$F = 40 \times 10$$
$$F = 400N$$

$$P = \frac{F}{A}$$
$$20 = \frac{400}{A}$$
$$A = \frac{400}{20}$$
$$A = 20m^2$$

4. A force of 100N is applied to an area of $100mm^2$. What is the pressure exerted?

$$F = 100N, \quad A = 100mm^2 = \frac{100}{1000000} = 0.0001m^2$$
$$P = \frac{F}{A}$$
$$P = \frac{100}{0.0001}$$
$$P = 1000000\ Nm^{-2}\ or\ Pa$$

5. A glass block of mass 60g exerts a pressure of $1000Nm^{-2}$ on a table top. Determine the area of contact between the glass block and the table top.

$$m = 60g = \frac{60}{1000} = 0.06kg, \quad P = 1000Nm^{-2}$$
$$F = mg$$
$$F = 0.06 \times 10$$
$$F = 0.6N$$
$$P = \frac{F}{A}$$
$$1000 = \frac{0.6}{A}$$
$$A = \frac{0.6}{1000}$$
$$A = 0.0006m^2$$

MAXIMUM AND MINIMUM PRESSURE

From the formula, $P = \frac{F}{A}$ it is noted that pressure increases with a decrease in area and vice versa.

Maximum pressure:
To obtain maximum pressure, the area should be small.

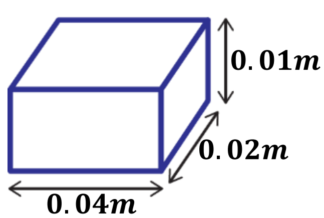
$$Maximum\ pressure = \frac{Force}{Smallest\ area}$$

Minimum pressure:
To obtain minimum pressure, the area should be large.

$$Minimum\ pressure = \frac{Force}{Largest\ area}$$

Examples:
$Where\ neccessary\ acceeleration\ due\ to\ gravity\ = 10ms^{-2}$

1. The figure below shows a block of wood of weight 25N placed on a flat horizontal surface.



a) Find the minimum pressure it can exert on the surface.
b) Find the maximum pressure it can exert on the surface

$F = 25N$

$Largest\ area = L \times W$
$Largest\ area = 0.04 \times 0.02$
$Largest\ area = 0.0008m^2$

$Smallest\ area = W \times H$
$Smallest\ area = 0.02 \times 0.01$
$Smallest\ area = 0.0002m^2$

$$Min\ pressure = \frac{Force}{Largest\ area}$$
$$Min\ pressure = \frac{25}{0.0008}$$
$$Min\ pressure = 31{,}250\ Pa$$

$$Max\ pressure = \frac{Force}{Smallest\ area}$$
$$Max\ pressure = \frac{25}{0.0002}$$
$$Max\ pressure = 125{,}000\ Pa$$

NOTE:

$Largest\ area = (Largest\ length) \times (Next\ largest\ length)$
$Smallest\ area = (Smallest\ length) \times (Next\ smallest\ length)$

2. The dimensions of a cuboid of mass 48kg are $5cm \times 10cm \times 20cm$. Calculate the maximum and minimum pressure it exerts.

$$F = mg = (48 \times 10) = 480N$$
$$Smallest\ area = \frac{5}{100} \times \frac{10}{100} = 0.005m^2$$
$$Largest\ area = \frac{10}{100} \times \frac{20}{100} = 0.02m^2$$

$$Min\ pressure = \frac{Force}{Largest\ area}$$
$$Min\ pressure = \frac{480}{0.02}$$
$$Min\ pressure = 24{,}000\ Pa$$

$$Max\ pressure = \frac{Force}{Smallest\ area}$$
$$Max\ pressure = \frac{480}{0.005}$$
$$Max\ pressure = 96{,}000\ Pa$$

3. A block of wood of mass 1200g measures by $30cm$ by $6cm$ by $5cm$. Calculate;
   a) the greatest pressure.
   b) the least pressure exerted by the wood on the surface.

$$F = mg = \left(\frac{1200}{1000} \times 10\right) = 12N$$
$$Smallest\ area = \frac{6}{100} \times \frac{5}{100} = 0.003m^2$$
$$Largest\ area = \frac{30}{100} \times \frac{6}{100} = 0.018m^2$$

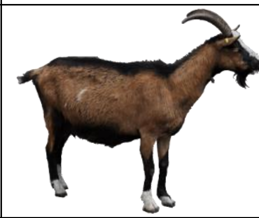
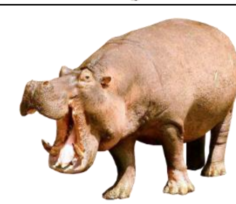
a)

$$Greatest\ pressure = \frac{Force}{Smallest\ area}$$
$$Greatest\ pressure = \frac{12}{0.003}$$
$$Greatest\ pressure = 4000\ Pa$$

b)

$$Least\ pressure = \frac{Force}{Largest\ area}$$
$$Least\ pressure = \frac{12}{0.018}$$
$$Least\ pressure = 666.7\ Pa$$

Minimum and maximum pressure explains the following;

➢ An elephant is able to walk on a soft ground without sinking because it has toes with a large surface area thus exerting less pressure on the ground.	
➢ A tractor is made with broad wheels is able to move on a soft ground without sinking because the large surface area of the wheels makes it to exert less pressure on the ground.	
➢ A nail has a pointed end hence having a small surface area at the end. This makes it to exert much pressure on material thus penetrating the material easily.	
➢ A goat sinks in mud because of the small surface area of its feet hence exerting much pressure on the mud.	
➢ A hippopotamus is able to move on a soft ground without sinking because it exerts less pressure on the ground due to its wide feet.	
➢ Bridges are made thicker at the base than at the top to avoid collapse of the bridge by exerting less pressure on water and ground.	
➢ It is not easy to move on a soft ground with high-heeled pointed shoes because they exert much pressure on the soft ground.	
➢ It is easier to peel matooke using a sharp knife than using a blunt knife because a sharp end of a knife has a small surface area thus exerting much pressure on the matooke. This makes it penetrate the matooke easily.	

EXERCISE:

1. a) Define pressure and state its SI unit.
   b) A block measuring $0.1m \times 0.2m \times 0.8m$ has a mass of 20kg. What is the maximum and minimum pressure it can exert on the ground?
   c) Explain why a sharp knife cuts easily than a blunt knife.

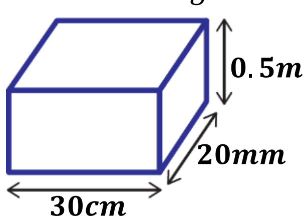
2. a) Explain why a hippopotamus can easily walk on mud without sinking than a goat.
   b) A rectangular block of wood weighs 3N and measures $2cm \times 3cm \times 4cm$. What is the greatest pressure it can exert on a horizontal surface.

3. a) Explain what happens when a balloon is placed on
      i) a sharp needle.
      ii) thumb of a hand.
   b) Calculate the maximum pressure of a glass block of density $2.5gcm^{-3}$ would exert on a horizontal surface if the block is measured $20 \times 10 \times 5cm$.

4. a) A block of concrete weighs 900N and its base is a square of side $3m$. What pressure does the block exert on the ground?
   b) Explain the following observations:
      i) A person feels much pain when pierced by a sharp nail than a blunt nail.
      ii) It is harder to walk on a soft ground with narrow-heeled shoes than wide-heeled shoes.

5. a) A box of dimensions $6m \times 2m \times 4m$ exerts its weight of 400N on the floor. Determine its;
      i) maximum pressure.
      ii) minimum pressure.
      iii) density.
   b) Explain the following observations in real life.
      i) A hippopotamus is able to walk on the mud but a goat gets stuck.
      ii) A woman putting on high-heeled shoes damages a cemented floor compared to one putting on flat shoes.
      iii) Water containers (reservoirs) are usually made wide at the base.
      iv) A very tall building is made wider and thicker at the bottom than at the top.
      v) The rear tyres of a tractor are made wider than the front ones.

6. The tank below has a mass of $2.5kg$.

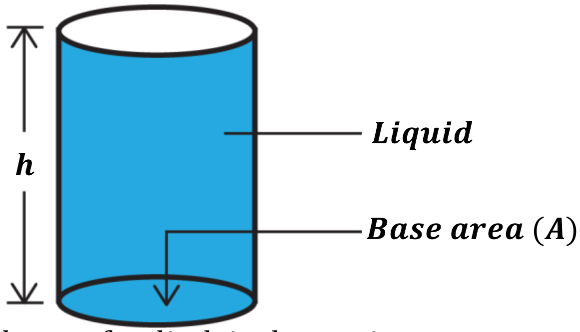


   Determine the minimum and maximum pressure exerted by the tank on the ground when it is;
   i) empty.
   ii) filled with water up to the brim.
   iii) half-filled with water
   $Density\ of\ water = 1000kgm^{-3}$

PRESSURE IN LIQUIDS

Since liquids take up the shape of the container in which they are placed, the volume of liquid filling a container is equal to the volume of the container.

Consider a cylindrical container of cross-sectional area (base area), $\boldsymbol{A}$ filled with a liquid of density, $\boldsymbol{\rho}$ to a height, $\boldsymbol{h}$ as shown below.



$$\begin{aligned} Volume\ of\ liquid &= Volume\ of\ cylindrical\ container \\ &= Area\ of\ circular\ base \times Height \\ &= \boldsymbol{Ah} \end{aligned}$$

$$\begin{aligned} Mass\ of\ liquid &= Density\ liquid \times Volume\ of\ liquid \\ &= \boldsymbol{\rho Ah} \end{aligned}$$

$$\begin{aligned} Force\ exerted\ by\ liquid\ (Weight\ of\ liquid) &= mass \times acceleration\ due\ to\ gravity \\ &= \rho Ah \times g \\ &= \boldsymbol{Ah\rho g} \end{aligned}$$

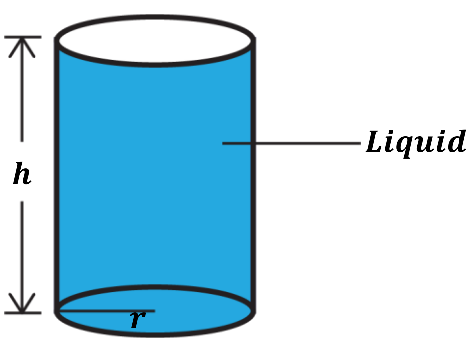
$$Pressure = \frac{Force}{Area}$$

$$P = \frac{Ah\rho g}{A}$$

$$\boxed{\boldsymbol{P = h\rho g}}$$

OR

Consider a cylindrical container with a circular base of radius, $\boldsymbol{r}$ filled with a liquid of density, $\boldsymbol{\rho}$ to a height, $\boldsymbol{h}$ as shown below.



$$\begin{aligned} Volume\ of\ liquid &= Volume\ of\ cylindrical\ container \\ &= \boldsymbol{\pi r^2 h} \end{aligned}$$

$$\begin{aligned} Mass\ of\ liquid &= Density\ of\ liquid \times Volume\ of\ liquid \\ &= \boldsymbol{\rho \pi r^2 h} \end{aligned}$$

$$\begin{aligned} Weight\ of\ liquid &= mass \times acceleration\ due\ to\ gravity \\ &= \rho \pi r^2 h \times g \\ &= \boldsymbol{\pi r^2 h\rho g} \end{aligned}$$

$$Pressure = \frac{Force}{Area}$$

$$P = \frac{\pi r^2 h\rho g}{\pi r^2}$$

$$\boxed{\boldsymbol{P = h\rho g}}$$

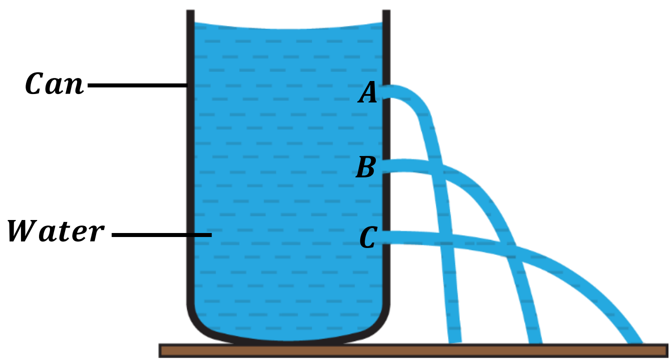
Factors affecting pressure in liquids:
From the above derivations, pressure at any point in a liquid is the same in all directions and it depends on the following factors:

a) **Depth (height) below the liquid surface (h):**
Pressure increases with an increase in the depth of the liquid and vice versa.
The higher the depth of the liquid, the more the weight of the liquid thus increasing the pressure exerted by the liquid.

b) **Density of the liquid (ρ):**
Denser liquids exert more pressure than less dense liquids.

c) **Acceleration due to gravity (g):**
Liquid pressure is higher in areas (planets) whose acceleration due to gravity is high.

Experiment to show that pressure in a liquid depends on the depth below the liquid surface.



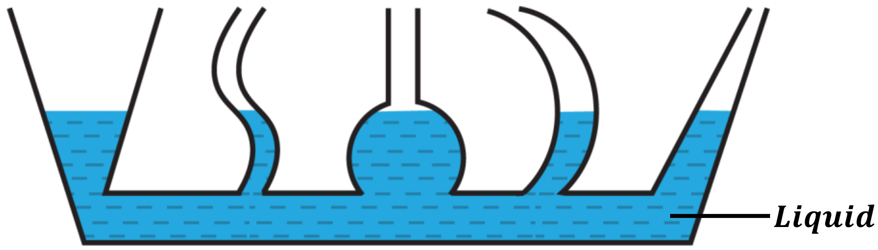
Procedures:
- Three equally spaced holes $\boldsymbol{A}$, $\boldsymbol{B}$ and $\boldsymbol{C}$ of the same size are made on one vertical side of a tall can at different depth.
- The holes are then closed and the can is filled with water.
- The holes are then opened at the same time and the jetting of water from the holes observed.

Observation:
- It is observed that water comes out fastest and lands furthest from the lowest hole $\boldsymbol{C}$ followed by $\boldsymbol{B}$ and lastly hole $\boldsymbol{A}$.
- Therefore, pressure at $\boldsymbol{A}$ is greater than pressure at $\boldsymbol{B}$ and $\boldsymbol{C}$.
- This shows that pressure increases with increase in the depth below the surface of a liquid.

WATER SUPPLY SYSTEM:
Water supply often comes from a reservoir which is at a high ground level. Water flows from the reservoir through the pipes to the taps which are below the level of the water reservoir. This increases the pressure at which water is supplied.
This explains why storage tanks are put at high level ground than the taps so that water comes through the taps at a very high pressure.

NOTE:
- Pressure of the liquid does not depend on the cross-sectional area of the container in which it is placed.
- Pressure of a liquid does not depend (independent) on the shape and size of the container.

<u>Experiment to show that pressure is independent of the cross-sectional area and the shape of the container</u>



- A liquid is poured into a set of connected tubes with different shapes called **<u>communicating tubes</u>**.
- The liquid flows until the levels of the liquid are the same in all the tubes. This shows that the liquid finds its own level and the pressure is the same in all tubes.
- Therefore, pressure in liquids is independent of the shape and the cross-sectional area of the container.

<u>Examples</u>:

($\boldsymbol{Acceleration\ due\ to\ gravity = 10ms^{-2}}$)

1. Find the pressure in a liquid of density $1000kgm^{-3}$ at a height of $8m$.

$$\boldsymbol{\rho = 1000kgm^{-3}, \qquad h = 8m}$$
$$\boldsymbol{P = h\rho g}$$
$$\boldsymbol{P = 8 \times 1000 \times 10}$$
$$\boldsymbol{P = 80,000\ Pa}$$

2. The pressure of a liquid is $10000Nm^{-2}$. What is the height of the liquid if its density is $1000kgm^{-3}$?

$$\boldsymbol{\rho = 1000kgm^{-3}, \qquad P = 10000Nm^{-2}}$$
$$\boldsymbol{P = h\rho g}$$
$$\boldsymbol{10000 = h \times 1000 \times 10}$$
$$\boldsymbol{h = \frac{10000}{10000}}$$
$$\boldsymbol{h = 1m}$$

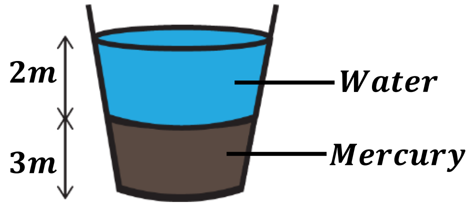
3. The pressure exerted in a liquid of density $0.4gcm^{-3}$ is $8000\ Pa$. Calculate its height.

$$\boldsymbol{\rho = 0.4gcm^{-3} = (0.4 \times 1000) = 400kgm^{-3}, \qquad P = 8000Pa}$$
$$\boldsymbol{P = h\rho g}$$
$$\boldsymbol{8000 = h \times 400 \times 10}$$
$$\boldsymbol{h = \frac{8000}{4000}}$$
$$\boldsymbol{h = 2m}$$

4. What is the pressure $100m$ below the surface of sea water of density $1150kgm^{-3}$?

$$\boldsymbol{\rho = 1150kgm^{-3}, \qquad h = 100m}$$
$$\boldsymbol{P = h\rho g}$$
$$\boldsymbol{P = 100 \times 1150 \times 10}$$
$$\boldsymbol{P = 1150000\ Pa}$$
$$\boldsymbol{P = 1.15 \times 10^6\ Pa}$$

5. The tank below contains mercury and water. The density of mercury is $13600kgm^{-3}$ and that of water is $1000kgm^{-3}$.



Find the total pressure exerted at the bottom of the tank.

$\rho_w = 1000kgm^{-3}, \quad \rho_m = 13600kgm^{-3}, \quad h_w = (2+3) = 5m, \quad h_m = 3m$

$Total\ pressure = pressure\ of\ water + pressure\ of\ mercury$

$Total\ pressure = h_w\rho_w g + h_m\rho_m g$

$Total\ pressure = (5 \times 1000 \times 10) + (3 \times 13600 \times 10)$

$Total\ pressure = 50000 + 408000$

$Total\ pressure = 458{,}000\ Pa$

6. The density of liquid is $800kgm^{-3}$. It was poured in a container to a depth of $400cm$. Calculate the pressure it exerts at the bottom of the container.

$$\rho = 800kgm^{-3}, \qquad h = 400cm = \frac{400}{100} = 4m$$

$$P = h\rho g$$
$$P = 4 \times 800 \times 10$$
$$P = 32{,}000\ Pa$$

EXERCISE:

$(Acceleration\ due\ to\ gravity = 10ms^{-2}\ and\ Density\ of\ water = 1000kgm^{-3})$

1. Calculate the pressure at the bottom of a swimming water pool $1000cm$ deep.
2. A diver dives to a depth of 20m below the surface of sea water of density $1000kgm^{-3}$. Calculate the pressure experienced.
3. A flask is filled to a depth of 16cm with a liquid of density $800kgm^{-3}$. Find the pressure exerted by the liquid on the base.
4. The pressure at the bottom of a column of mercury of density $13600kgm^{-3}$ is $50Nm^{-2}$. Calculate the height of the mercury column.
5. a) Show that the pressure of a liquid in a cylindrical can of height, h and radius, r is $h\rho g$ where ρ is the density of the liquid.
   b) Calculate the pressure due to water experienced by a diver working 15m below the surface of the sea.
   c) Describe an experiment to show that the pressure of a liquid is independent of the cross-sectional area.

TRANSMISSION OF PRESSURE IN FLUIDS

A fluid is a substance which can flow e.g. a liquid or a gas.

PASCAL'S PRINCIPLE (Principle of transmission of pressure in fluids):

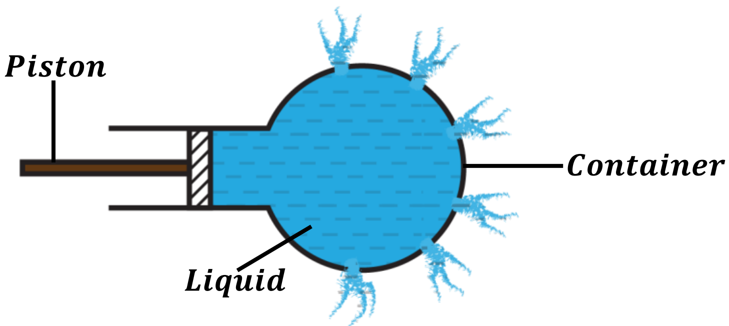
Pascal's principle states that pressure applied at any point of an enclosed fluid is transmitted equally throughout the whole fluid in all directions.

NOTE: Pascal's principle works on an assumption that the fluid is incompressible.

Definition:

An incompressible fluid is a fluid whose volume can not be reduced by squeezing i.e. it can not be compressed e.g water but not air.

Experiment to demonstrate Pascal's principle:



Procedures:

- Holes of equal size are made at different points in a container.
- The container is filled with the liquid as shown above.
- The piston is pushed inside the container to exert pressure on the liquid.

Observation:

- The liquid comes out of the holes with an equal force and pressure. This shows that pressure was equally transmitted throughout the whole liquid.

Practical example:

A glass bottle is filled with water and covered with a cork.

a) Explain why the bottom of the bottle breaks when a greater force is applied on the cork to push it down.
   When a force is applied on the cork, pressure is exerted inside the water and it is transmitted equally throughout the whole bottle. Therefore, equal pressure is exerted on the bottom by the bottle thus breaking it.

b) Explain why a liquid like water was used instead of a gas in (a) above.
   Since the experiment required transmission of pressure, it needed a fluid which is incompressible. Therefore, a liquid like water is incompressible yet a gas is not.
   RECALL: ***Pascal's principle applies only to incompressible fluids.***

APPLICATIONS PASCAL'S PRINCIPLE

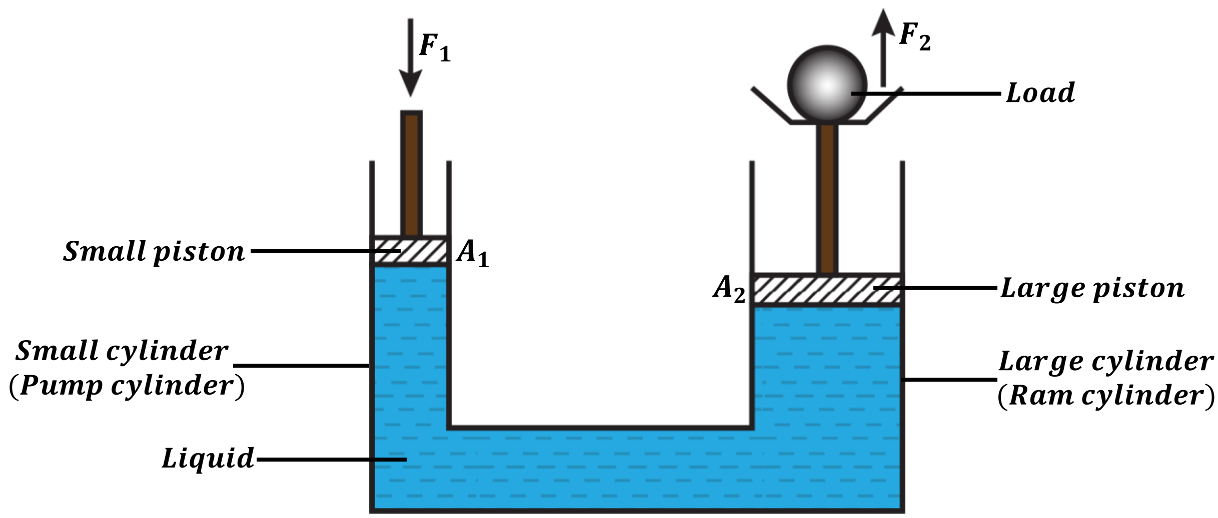
The principle of transmission of pressure in fluids is applied in hydraulic machines namely;

- Hydraulic press.
- Hydraulic lift.
- Hydraulic jack.
- Hydraulic brake.

In hydraulic machines, a small force applied at one point of an incompressible liquid produces a larger force at the points of the liquid. Therefore, a small force is used to lift heavy materials like cars.

HYDRAULIC PRESS / LIFT / JACK:

- It consists of a small piston fitted in a small cylinder and a large piston fitted in the large cylinder.
- When a force is applied on a small piston, the pressure exerted by the piston is transmitted equally throughout the liquid to the larger piston thus forcing the larger piston to move up.
- This force exerted on the larger piston raises a heavy load as shown below.



Operation of hydraulic machines

- When a small force, F_1 is applied on the small piston of cross-sectional area, A_1, then pressure, P_1 is exerted on the liquid by a small piston.

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

- The pressure, P_1 is transmitted equally throughout the liquid to the larger piston. Hence, the pressure, P_2 acting on the larger piston is equal to initial pressure, P_1.

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

$$P_1 = P_2$$

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

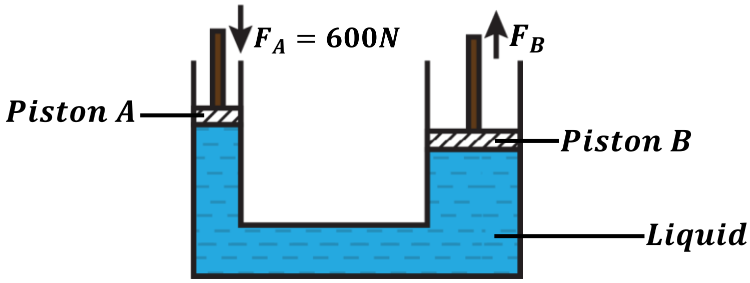
$$OR \quad \boxed{\frac{F_1}{F_2} = \frac{A_1}{A_2}}$$

NOTE:

The cross-sectional areas of small piston and large piston should have the same units. There is no need of converting if the units are the same.

Examples:

1. The figure below shows a hydraulic press. The cross-sectional area of piston B is $80m^2$ and the cross-sectional area of A is $2.5m^2$.

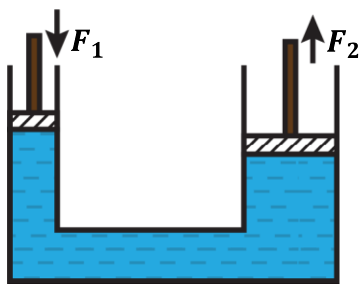


Find the force exerted on the piston B if a force of 600N is applied on piston A.

$\boldsymbol{A_A = 2.5m^2}$, $\boldsymbol{A_B = 80m^2}$

$$Pressure\ at\ A = Pressure\ at\ B$$
$$\frac{F_A}{A_A} = \frac{F_B}{A_B}$$
$$\frac{600}{2.5} = \frac{F_B}{80}$$
$$F_B = \frac{600 \times 80}{2.5}$$
$$F_B = 19200N$$

2. Calculate the force applied on the small piston of area $2cm^2$ if a mass of $80kg$ is to be lifted by a larger piston of area $10cm^2$.



$\boldsymbol{A_1 = 2cm^2}$, $\boldsymbol{A_2 = 10cm^2}$, $\boldsymbol{m = 80kg}$

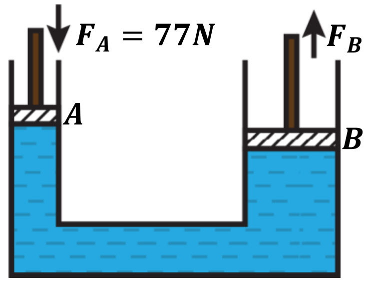
$\boldsymbol{F_2 = mg = (80 \times 10) = 800N}$

$$\frac{F_1}{F_2} = \frac{A_1}{A_2}$$
$$\frac{F_1}{800} = \frac{2}{10}$$
$$F_1 = \frac{2 \times 800}{10}$$
$$F_1 = 160N$$

OR

$$\frac{F_1}{F_2} = \frac{A_1}{A_2}$$
$$\frac{F_1}{800} = \frac{2/10000}{10/10000}$$
$$F_1 = \frac{0.0002 \times 800}{0.001}$$
$$F_1 = 160N$$

3. Given that the radius of a circular piston A is 14cm and radius of circular piston B is 28cm. If the force exerted on piston A is 77N, find the force exerted on piston B.



$r_A = 14cm,\qquad r_B = 28cm,$

$$\frac{F_A}{F_B} = \frac{A_A}{A_B}$$
$$\frac{F_A}{F_B} = \frac{\pi {r_A}^2}{\pi {r_B}^2}$$
$$\frac{77}{F_B} = \frac{14^2}{28^2}$$
$$F_B = \frac{77 \times 784}{196}$$
$$F_B = 308N$$

4. In a hydraulic press, a force of $400N$ is applied to a pump piston of area $0.1m^2$. The area of the ram piston is $4m^2$. Calculate;
   i) the pressure transmitted through the liquid.
   ii) weight on the ram piston.

$A_1 = 0.1m^2,\qquad A_2 = 4m^2,\qquad F_1 = 400N$

i)
$$P_1 = \frac{F_1}{A_1}$$
$$P_1 = \frac{400}{0.1}$$
$$P_1 = 4000\ Pa$$

ii)
$Pressure\ at\ pump = Pressure\ at\ ram$
$$P_1 = P_2$$
$$P_1 = \frac{F_2}{A_2}$$
$$4000 = \frac{F_2}{4}$$
$$F_2 = 4000 \times 4$$
$$F_2 = 16000N\ \ (Weight)$$

5. A hydraulic press machine is used to raise a load, W, on a piston of cross-sectional area $100cm^2$ by using an effort of 20N at a piston of cross-sectional area of $2cm^2$. Calculate load, W.

$A_1 = 2cm^2,\qquad A_2 = 100cm^2,\qquad F_1 = 20N,\quad F_2 = W$

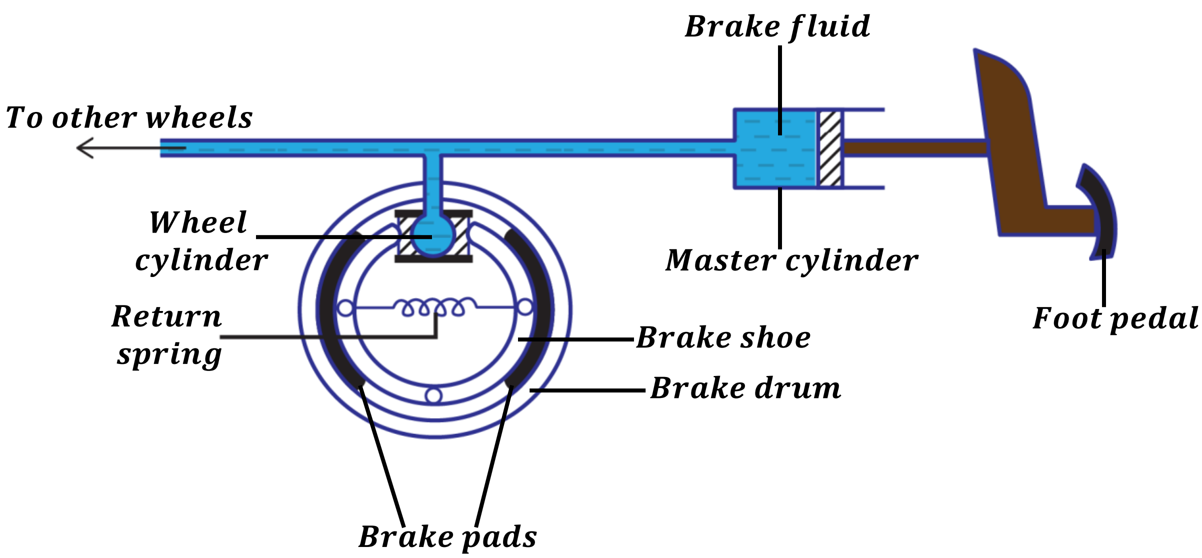
$$\frac{F_1}{F_2} = \frac{A_1}{A_2}$$
$$\frac{20}{W} = \frac{2}{100}$$
$$W = \frac{20 \times 100}{2}$$
$$W = 1000N$$

EXERCISE:

1. The area of the large piston of a hydraulic press is $10m^2$ and that of the smaller one is $0.25m^2$. A force of 100N is applied on the smaller piston. Calculate the force produced at the larger piston.
2. The area of a small piston of a hydraulic press is $0.5m^2$. If an effort of 250N is applied on the pump cylinder and raises a load of 20000N, calculate the area of the piston at the ram cylinder.
3. In a hydraulic press, a force of 200N is applied to small circular piston of area $25cm^2$. If the hydraulic press is designed to produce a force of 5000N, determine;
   i) the area of the large piston.
   ii) the radius of the large piston.
4. A hydraulic press has cylindrical pistons of radii 2cm and 0.4m respectively. Calculate the maximum load at the larger piston that can overcome a force of 78N.
5. A hydraulic jack is used to lift a car by applying a force of 120N at the pump cylinder. If the area of the ram and pump piston is $100cm^2$ and $1m^2$ respectively. Calculate the force applied to the ram piston.
6. Calculate the weight, W raised by a force of 56N applied on a small piston of area $14m^2$. Take the area of the large piston to be $42m^2$.

<u>HYDRAULIC BRAKE</u>:

A hydraulic braking system is used in motor vehicles.



<u>How a hydraulic brake works</u>:

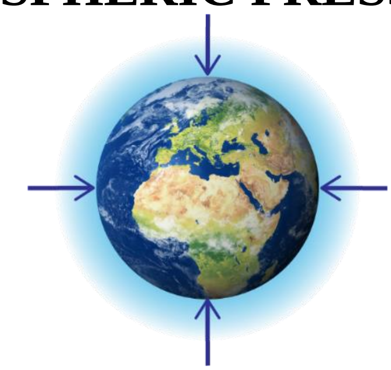
- When the driver pushes down the foot pedal, the force applied exerts pressure on the brake fluid in the master cylinder.
- This pressure is transmitted by the brake fluid to the wheel cylinder. This causes the pistons of wheel cylinders to push the brake shoes which in turn press the brake pad against the brake drum. The contact between the brake drum and brake pads stops the rotation of the wheels.
- When the force on the foot pedal is removed, the return spring pull back the brake shoe which then pushes the cylinder pistons back.

Properties of hydraulic fluids (brake fluid):
Any fluid to be used in hydraulic machines should have the following properties;

- The fluid should be incompressible. This enables pressure to be equally transmitted in all parts of the braking system.
- The fluid should have a low freezing point. This helps the fluid not to cool easily which may make it a thicker fluid thus not behaving well.
- The fluid should have a high boiling point. This helps the fluid not to warm up easily which may increase its compressibility.
- The fluid should not corrode the parts of the brake system.

Uses of hydraulic machines:
- ✓ Used to lift loads such as cars in garages. (Hydraulic Jack)
- ✓ Used to compress materials such as cotton, steel for easy transportation. (Hydraulic press)

ATMOSPHERIC PRESSURE



The air (mixture of gases) surrounding the earth is called "**atmosphere**". This air surrounds us and everything on the earth's surface.
The weight of air exerts pressure on all objects on the earth's surface and this pressure is called atmospheric pressure.

Definition:
Atmospheric pressure is the pressure exerted by the weight of air on all objects on the earth's surface.

❖ Atmospheric pressure is measured by an instrument called **Barometer**.

Variation of atmospheric pressure with number of air molecules (Air density):
The more the air molecules around an object, the more force exerted on the object hence exerting high pressure on the object. Therefore, pressure increases with increase in air molecules and pressure decreases with decrease in air molecules.

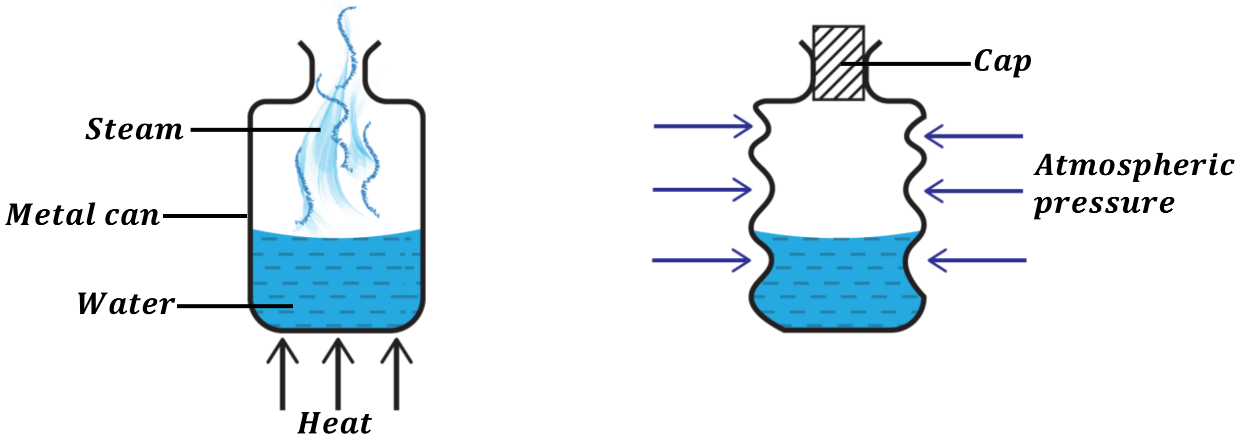
Variation of atmospheric pressure with altitude:
Atmospheric pressure increases with decrease in altitude (height) and vice versa.
The density of air above the earth's surface decreases as altitude increases leading to a decrease in atmospheric pressure at high altitudes.
Therefore, atmospheric pressure is low at high altitudes (e.g. mountain peaks) and atmospheric pressure is high at low altitudes.
This effect explains why cooking takes long at higher altitudes (*See Book 2, Heat measurement*).

NOTE:

- At sea level, the value of atmospheric pressure is very large though we do not normally feel it because **blood pressure** is slightly greater than atmospheric pressure.
- A person may faint if he/she experiences a loss in blood pressure. The low blood pressure decreases the rate at which blood flows to the brain thus causing an insufficient blood flow to the brain.

EXPERIMENT TO DEMONSTRATE ATMOSPHERIC PRESSURE

Crushing or Collapsing can experiment.

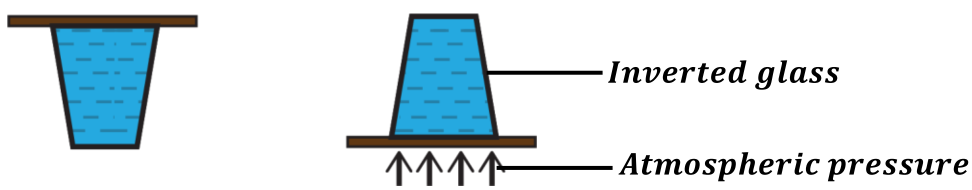


(a) On heating (b) On cooling

- An empty metal can is filled with some water and left uncovered.
- Water in the metal can is boiled for sometime until steam is produced.
- When the steam has driven out most of the air, the metal can is covered with a cap.
- Cool the metal can by pouring cold water over it.
- On cooling, steam condenses to water hence reducing air pressure inside the metal can.
- The metal can collapses inwards (crushes) because the atmospheric pressure outside the can is greater than the reduced air pressure the can.

Other important demonstrations include;

a) Liquid trapped in inverted glass full of water:



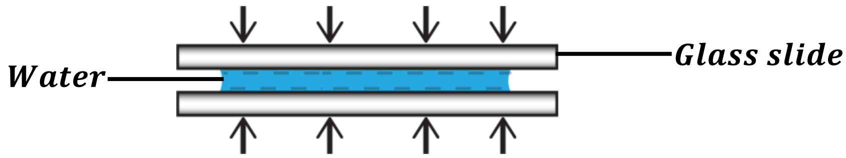
- Pour water in a glass and make it full.
- Cover the entire glass with a smooth card.
- Put one hand on the card and the other hand holds the glass.
- Quickly turn the glass upside down and then remove the hand holding the card.

Observation:

- On releasing the card, it remains tightly fixed to the glass thus preventing water from pouring out.

This is because water occupies most of the space which would have been occupied by air hence reducing air pressure inside the glass. Therefore, the atmospheric pressure outside the glass becomes greater than the inside air pressure thus acting strongly on the card.

b) Sticking two wet glass slides together:



- One face of a glass slide is wetted with a water and a second glass slide is intimately placed on it.
- Try to move the glass slides apart.

Observation:

- It becomes difficult to separate the slides. This is because water expels air molecules between the slides thus reducing the air pressure between the two glass slides. Therefore, the atmospheric pressure acting outside the slides becomes greater than the air pressure in between the slides hence forcing the slides to stick tightly together.

Practical example

Explain why mountain climbers may suffer from nose bleeding at the top of a mountain.
On top of a mountain, atmospheric pressure is lower than that at the bottom. Due to the body's metabolism, the blood pressure may exceed the low atmospheric pressure at the top of the mountain. Since the blood capillaries are weaker, they may break due to the high pressure of the blood thus causing nose bleeding.

EXERCISE:

1. Explain why it is difficult to pull a cork of a flask when it is filled with water.
2. Explain why it is difficult to separate two microscopic glass slides when water is placed between them.
3. Explain why some people moving in aero-planes may suffer from headache and nose bleeding.
4. Explain why a fainted person is laid on his back with his feet raised above the chest.
5. A senior two student at Mbuye Farm school started nose bleeding while they were in a trip at the top of mountain Elgon.
   a) Explain the possible reason for her nose bleeding.
   b) Discuss how you can help her to stop the nose bleeding.
6. Explain why cooking takes a longer time than expected at a higher altitude.

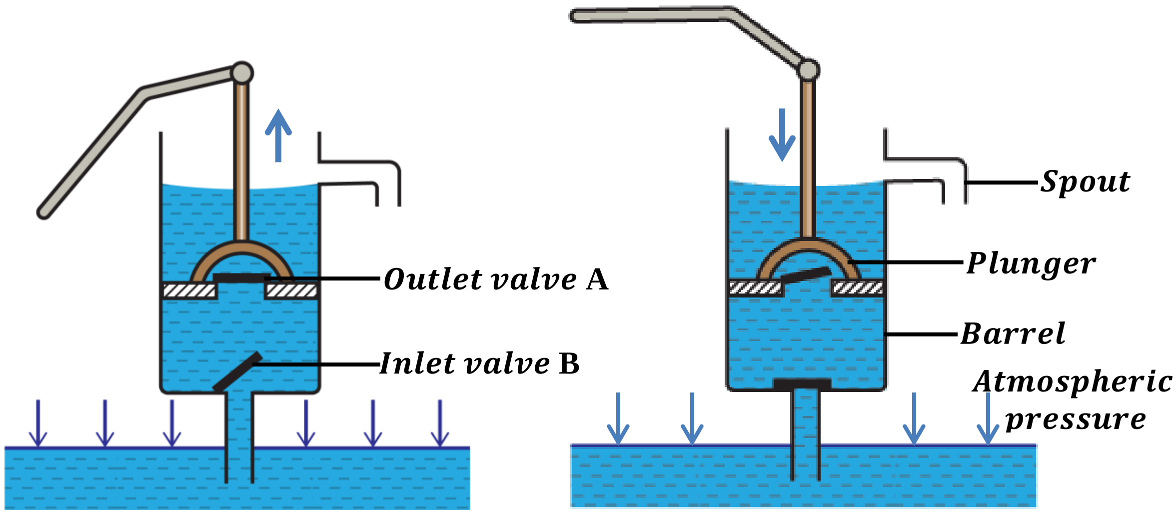
APPLICATIONS OF ATMOSPHERIC PRESSURE

Atmospheric pressure is important in;

- Lift pump (Common borehole)
- Force pump
- Drinking straw
- Siphon
- Syringe, etc.

<u>LIFT PUMP</u>:

Lift pumps are used raise water from the wells or earth's surface. It is commonly known as a **bore hole**.



During the upstroke;

- the plunger moves upwards which reduces the pressure inside the barrel.
- outlet valve A closes and inlet valve B opens.
- water is pushed up the pipe through the inlet valve B by the atmospheric pressure acting on the surface of the water and occupies the space above the inlet valve B.

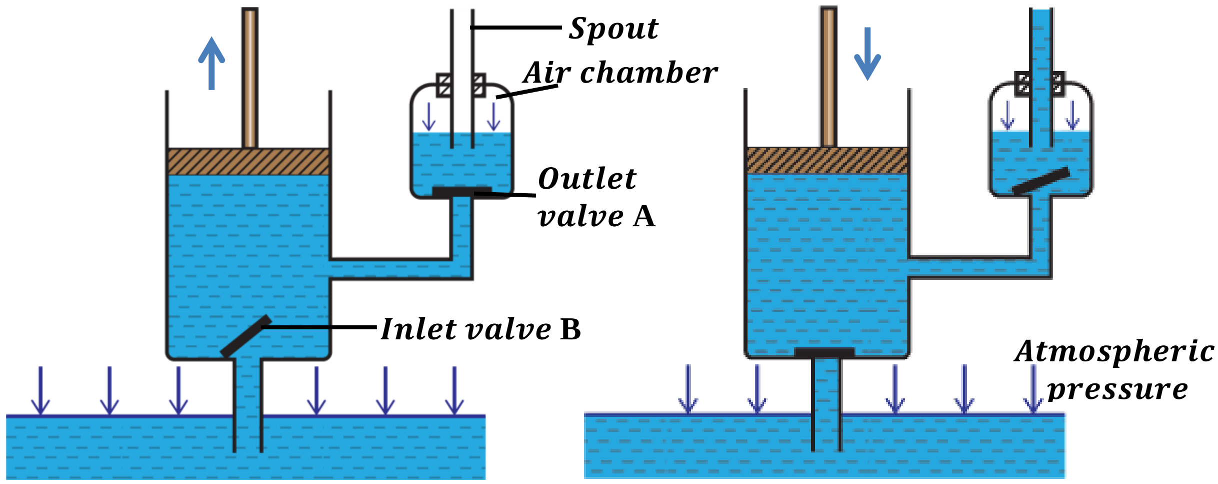
During the downstroke;

- the plunger moves downwards.
- inlet valve B closes and outlet valve A opens.
- water level in the barrel rises further through the outlet valve A and in the next repeated strokes, water reaches the spout and pours out.

<u>Limitations of the lift pump</u>

- The lift pump can't raise water beyond 10m. This is because atmospheric pressure is low in high altitudes. Atmospheric pressure can only support a water column of $10m$.
- The lift pump can not work if there are leakages in the pipe.

FORCE PUMP:
The force pump was designed to overcome the limitations of the lift pump i.e. it can raise water to heights beyond $10m$. It is commonly used to raise water from wetlands, lakes, wells to fill in storage tanks.

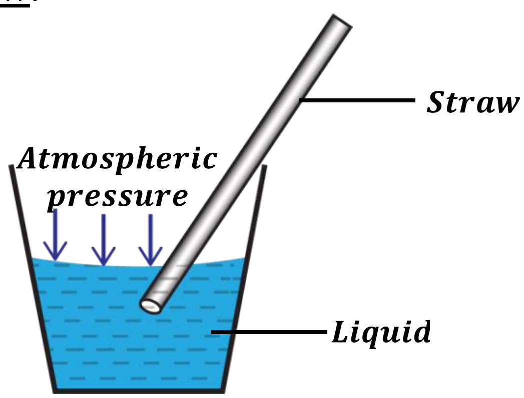


During the upstroke;
- the piston moves upwards which reduces the pressure inside the barrel.
- outlet valve A closes and inlet valve B opens
- water is pushed up the pipe through the inlet valve B by the atmospheric pressure acting on the surface of the water and occupies the space above the inlet valve B.

During the downstroke;
- the piston moves downwards thus compressing the water.
- inlet valve B closes and outlet valve A opens.
- water level in the barrel rises further and enters the air chamber through the outlet valve A and in the next repeated strokes, water reaches the spout and pours out.

NOTE:
The force pump enables continuous flow of water since the air in the air chamber is compressible.
The height to which water is raised does not depend on the atmospheric pressure but it depends on;
- Force applied during the downstroke.
- The ability of the pump and its working parts to withstand pressure of the water in the chamber.

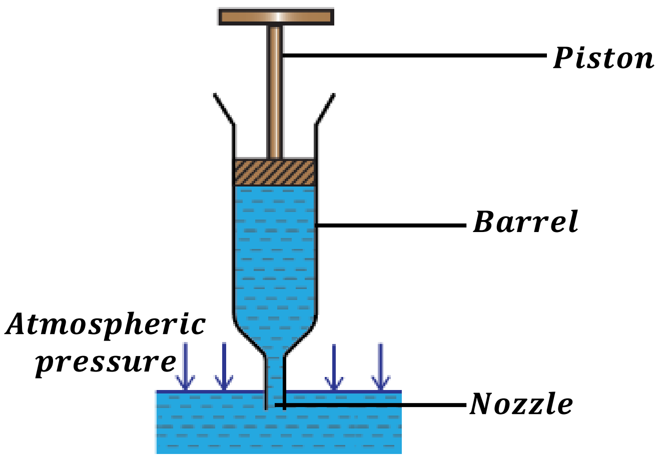
DRINKING STRAW:



- When air is sucked out from a straw dipped in a liquid, a vacuum is created and the air pressure inside the straw reduces. This causes the atmospheric pressure to be greater than the inside air pressure.
- The atmospheric pressure acting on the surface of the liquid forces the liquid to rise through the straw up to the mouth.

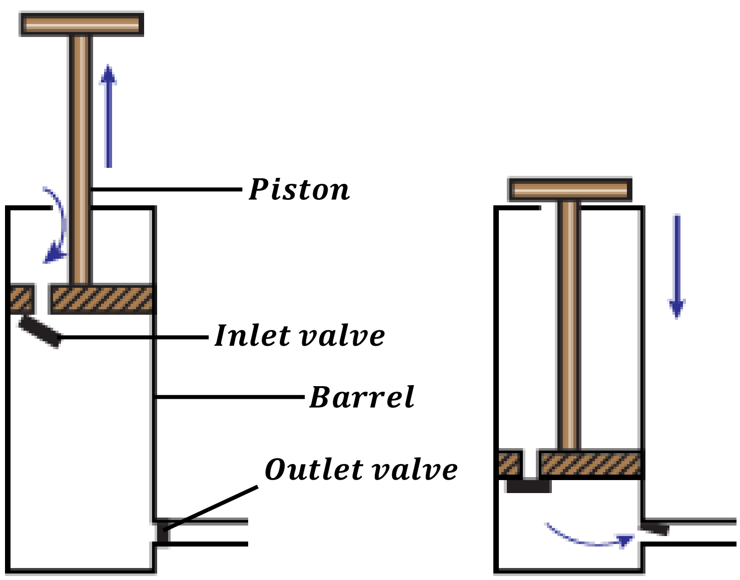
<u>Question</u>: Explain what happens when one drinks water using a straw with a hole.
Since the straw has a hole, the air keeps on entering through the hole So no vacuum is created thus the air pressure inside the straw doesn't reduce. Therefore, the atmospheric pressure doesn't force water into the straw.

<u>SYRINGE</u>:



- When a piston is pulled outwards, a vacuum is created inside the barrel thus decreasing the air pressure inside the barrel. This causes the atmospheric pressure to be greater than air pressure inside.
- The atmospheric pressure acting on the surface of the liquid forces the liquid to rise through the nozzle into the barrel.

<u>BICYCLE PUMP</u>:



During the upstroke;

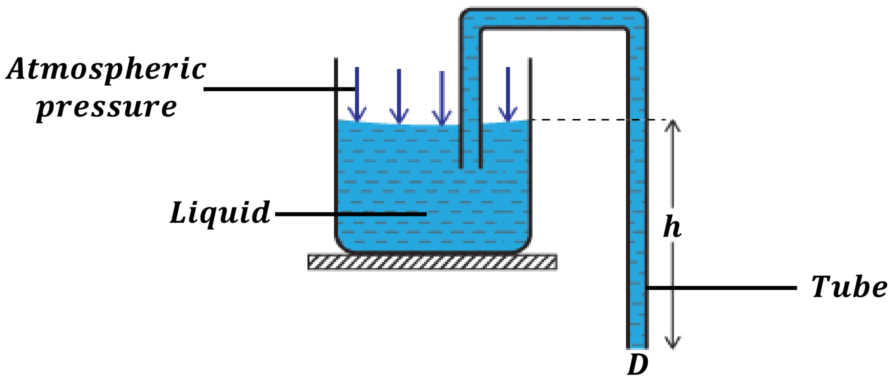
- the piston moves upwards which reduces the pressure inside the barrel.
- outlet valve closes and inlet valve opens.
- air is pushed into the barrel through the inlet valve by the atmospheric pressure outside.

During the downstroke;

- the piston moves downwards thus compressing the air inside the barrel.
- inlet valve closes and outlet valve opens.
- due to high pressure on the compressed air inside the barrel, air pushed out through the outlet valve to the tyre.

SIPHON:

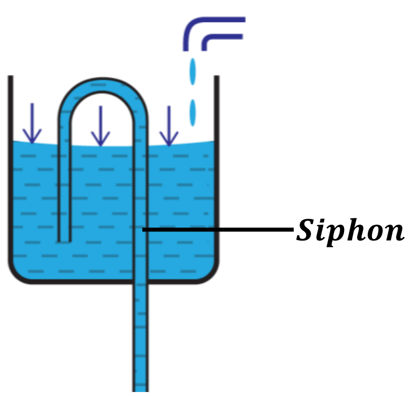
This is a tube used to remove petrol from petrol tanks and also empty toilets.



- One end of the tube D is put at a height below the surface of liquid. Therefore, pressure at this end, D is greater than the atmospheric pressure at the surface of liquid.
- Since the liquid at end D has a high pressure, it can easily flow out.
- The liquid will continue flowing out as long as tube end D is below the surface of the liquid.

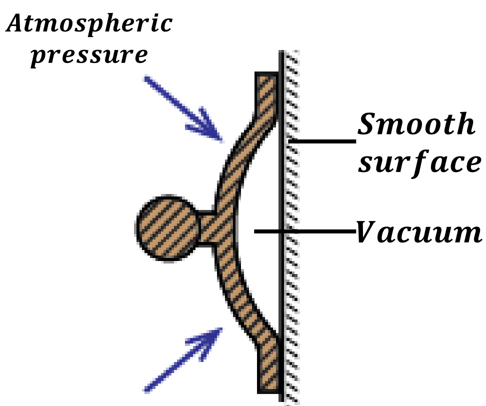
Application of the siphon principle

AUTOMATIC FLUSHING TANK



- Water drops slowly into the tank. Therefore, the water rises until it finds a bend.
- The action of the siphon starts and the tank is emptied.
- The action is then repeated again and again.

RUBBER SUCKER:
These are used in attaching car licenses to wind screens.
They are also used to lift papers to be fed into printers.



- A rubber sucker is moistened with water and then pressed on a smooth surface. The air between the rubber sucker and the smooth surface is decreased thus causing a partial vacuum.
- The atmospheric pressure outside the rubber sucker exceeds the air pressure in between the sucker and the surface.
- Therefore, the atmospheric pressure pushes the rubber sucker onto the smooth surface thus holding it firmly

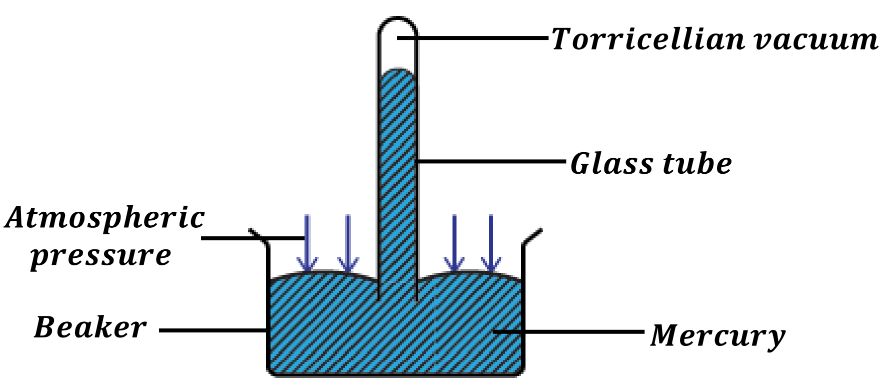
EXERCISE:
1. Explain how it is able to fetch water from a borehole.
2. Explain how one can drink Soda using a straw.
3. Explain why one gets difficulties when using a straw with a hole to drink milk.
4. Explain how one is able to pump air inside a bicycle tyre using a bicycle pump.

MEASUREMENT OF ATMOSPHERIC PRESSURE

In a physics laboratory, atmospheric pressure is measured by an instrument called **Barometer**.
There are three types of barometers namely;

- Simple mercury barometer (Nm^{-2})
- Fortin barometer (Pa)
- Aneroid barometer ($Atmospheres$)

How to construct (make) a simple mercury barometer in a laboratory:
- A dry glass tube is filled with mercury.
- The open end of the glass tube is covered with a finger and inverted into a beaker filled with mercury.
- The finger is then removed.
- When the finger is removed, the mercury level in the tube falls until it is equal to the atmospheric pressure.



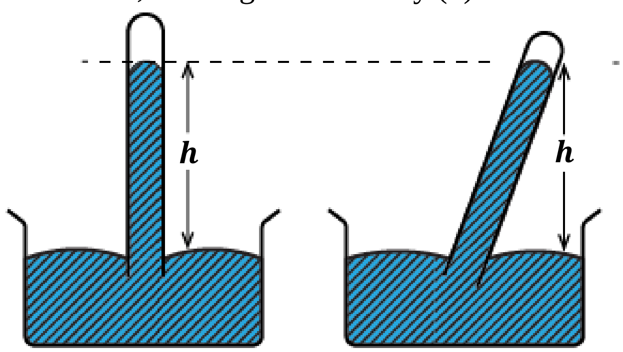
NOTE:

- The space left after the falling of the mercury level in the glass tube is called the **Torricellian vacuum.** This space is not a true vacuum because it has some mercury vapour.

- The height of mercury in the glass tube above the surface of mercury in the beaker is called the **barometric height.**

- After carrying out an experiment at sea level, atmospheric pressure is found to be equal to; $\mathbf{1.03 \times 10^5 Pa}$ or $\mathbf{1\ atmoshere}$ or $\mathbf{76cmHg}$ or $\mathbf{760mmHg.}$

- When the glass tube is tilted, the height of mercury (h) remains the same as shown below.



<u>Reasons why mercury is more convenient to use in a barometer</u>

- Mercury doesn't wet the glass tube and it is opaque. This makes it easier for someone to read the barometric height.
- Mercury has a high density thus giving a low barometric height hence a short glass tube (capillary tube) may be used.

<u>Reasons why water is not more convenient to use in a barometer</u>

- Water wets the glass tube and it is not opaque. This makes it not easier for someone to read the barometric height.
- Water has a low density thus giving a high barometric height hence a long glass tube (capillary tube) is required.

<u>Examples</u>:

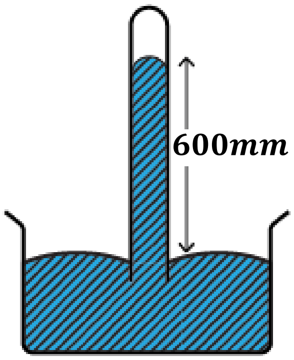
$$\boldsymbol{Atmospheric\ pressure\ (H) = barometric\ height \times density\ of\ mercury \times acceleration\ due\ to\ gravity}$$
$$\boldsymbol{H = h\rho g}$$

1. If the barometer reads $76cmHg$. Find the atmospheric pressure if the density of mercury is $13600kgm^{-3}$.

   $$\boldsymbol{h = 76cm = \frac{76}{100} = 0.76m, \qquad \rho = 13600kgm^{-3}, \qquad g = 10ms^{-1}}$$

   $$\boldsymbol{Atmospheric\ pressure, H = h\rho g}$$
   $$\boldsymbol{Atmospheric\ pressure, H = 0.76 \times 13600 \times 10}$$
   $$\boldsymbol{Atmospheric\ pressure, H = 103,360\ Nm^{-2}}$$

2. The figure below shows a mercury barometer used to measure atmospheric pressure. (Density of mercury is $13600kgm^{-3}$)



Calculate the atmospheric pressure;

a) In cmHg

$$h = 600mm = \frac{600}{10} = 60cm \qquad (1cm = 10mm)$$
$$H = 60cmHg$$

b) In Pascals (Nm^{-2})

$$h = 600mm = \frac{600}{1000} = 0.6m$$
$$Atmospheric\ pressure, H = h\rho g$$
$$H = 0.6 \times 13600 \times 10$$
$$H = 81600\ Nm^{-2}$$

3. The height of mercury column of the barometer supported by the atmospheric pressure is $76cm$. Calculate the height of the column of water supported by the same atmospheric pressure. (Density of mercury is $13600kgm^{-3}$ and Density of water is $1000kgm^{-3}$)

For mercury;

$$h = 76cm = \frac{76}{100} = 0.76m$$
$$Atmospheric\ pressure, H = h\rho g$$
$$H = 0.76 \times 13600 \times 10$$
$$H = 103,360\ Nm^{-2}$$

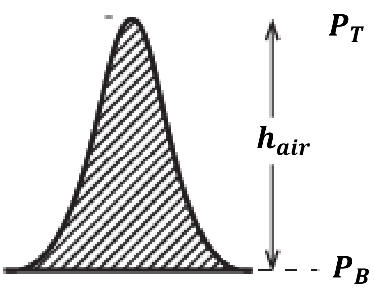
For water;

$h = ?$

$$Atmospheric\ pressure, H = h\rho g$$
$$103360 = h \times 1000 \times 10$$
$$h = \frac{103360}{10000}$$
$$h = 10.336m$$

The above example explains why water is not used in barometers because it gives a high barometric height thus requiring a long glass or capillary tube.

HOW TO MEASURE HEIGHT OF A MOUNTAIN



- Pressure at the top P_T and pressure at the bottom P_B are determined using a mercury barometer.
- The difference between the two pressures is got i.e. $Pressure\ difference = P_B - P_T$
- The pressure difference is equal to the pressure of air between the bottom and the top of the mountain.
- The height of the air h_{air} is calculated and it is equal to the height of the mountain.

Examples:

(Density of mercury is $13600kgm^{-3}$ and Density of air is $1.25kgm^{-3}$)

1. A mercury barometer reads a pressure of $75cmHg$ at the bottom of the mountain and $73.5cmHg$ at the top. Calculate the height of the mountain.

$$P_B = 75cmHg, \quad P_T = 73.5cmHg$$

In Nm^{-2};

$$P_B = h\rho g$$
$$P_B = \frac{75}{100} \times 13600 \times 10$$
$$P_B = 102,000\ Nm^{-2}$$

$$P_T = h\rho g$$
$$P_T = \frac{73.5}{100} \times 13600 \times 10$$
$$P_T = 99,960\ Nm^{-2}$$

But;

$$Pressure\ of\ air = Pressure\ difference$$
$$h_{air}\rho_{air}g = P_B - P_T$$
$$h_{air} \times 1.25 \times 10 = 102,000 - 99,960$$
$$12.5h_{air} = 2040$$
$$h_{air} = \frac{2040}{12.5}$$
$$h_{air} = 163.2m$$

Height of mountain $= 163.2m$

2. The pressure at the bottom of a mountain is $75.0cmHg$. If one climbs a mountain $1Km$ high, what would be the pressure at the top?

$$P_B = 75.0cmHg, \quad P_T = ?, \quad h_{air} = 1km = 1000m$$

In Nm^{-2};

$$P_B = h\rho g$$
$$P_B = \frac{75}{100} \times 13600 \times 10$$
$$P_B = 102,000\ Nm^{-2}$$

$$Pressure\ of\ air = Pressure\ difference$$
$$h_{air}\rho_{air}g = P_B - P_T$$
$$1000 \times 1.25 \times 10 = 102,000 - P_T$$
$$12500 = 102,000 - P_T$$
$$P_T = 102,000 - 12500$$
$$P_T = 89,500Nm^{-2}$$

<u>Converting it to cmHg</u>

$$P_T = h\rho g$$
$$89500 = \frac{h}{100} \times 13600 \times 10$$
$$h = \frac{89500}{1360}$$
$$h = 65.8cm$$
$$P_T = 65.8cmHg$$

3. A barometer reads $638.7mmHg$ at the top of a hill. Calculate the pressure reading at the bottom if the hill is $2km$ high.

$P_T = 638.7mmHg$, $P_B = ?$, $h_{air} = 2km = 2000m$

In Nm^{-2};

$P_T = h\rho g$

$P_T = \frac{638.7}{1000} \times 13600 \times 10$

$P_T = 86863.2\ Nm^{-2}$

$Pressure\ of\ air = Pressure\ difference$

$h_{air}\rho_{air}g = P_B - P_T$

$2000 \times 1.25 \times 10 = P_B - 86863.2$

$25000 = P_B - 86863.2$

$P_B = 25000 + 86863.2$

$P_B = 111863.2Nm^{-2}$

Converting it to mmHg

$P_B = h\rho g$

$111863.2 = \frac{h}{1000} \times 13600 \times 10$

$h = \frac{111863.2}{136}$

$h = 822.5mm$

$P_B = 822.5mmHg$

EXERCISE:

(Density of mercury is $13600kgm^{-3}$ and Density of air is $1.25kgm^{-3}$)

1. The air pressure at the top of a mountain is $60cmHg$. Given that the height of the mountain is $850m$. Find the pressure at the bottom of the mountain in Nm^{-2}.
2. The barometric height at sea level is $76cmHg$ while that at the top of a highland is $74cmHg$. What is the altitude?
3. The difference between the atmospheric pressure at the top and bottom of a mountain is $10{,}000\ Nm^{-2}$. Calculate the height of the mountain.
4. A barometer reads $76cmHg$ and $73.8cmHg$ at the bottom and top respectively. Find the height of the mountain.
5. A barometer is taken to the top of a mountain $440m$ high. If the atmospheric pressure is $76cmHg$ at the bottom, calculate the barometer reading.

PRESSURE IN FLUIDS

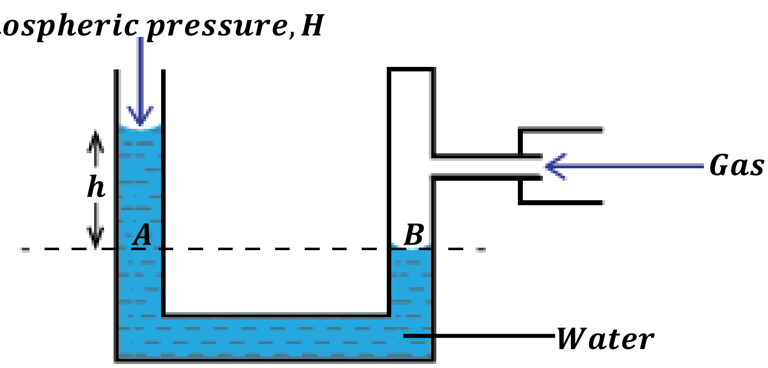
A fluid may be a liquid or a gas. The pressure of fluids is usually measured by an instrument known as a manometer.

MEASUREMENT OF PRESSURE IN GASES (GAS PRESSURE)

In a physics laboratory, the instrument used to measure gas pressure is called a **manometer**.

Manometer

A manometer consists of a U-tube or J-tube filled with a liquid. Water is used as a liquid in a manometer if the gas pressure to be measured is "**low**". Mercury is used as a liquid in a manometer if the gas pressure to be measured is "**high**".



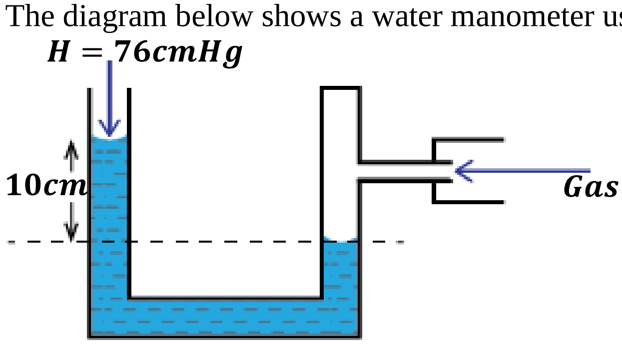
- One end of the manometer is closed and the other end is left open.
- The closed end is connected to the gas supply.
- When the gas is turned on, it exerts a pressure at point B causing a rise in the level of water in the open end of the manometer.
- The height, $\boldsymbol{h}$ due to the rise of water is obtained.
- Since pressure is transmitted equally (Pascal's principle), $pressure\ at\ A = Pressure\ at\ B$
- Therefore, $\boldsymbol{Gas\ pressure\ at\ B = Atmospheric\ pressure + pressure\ of\ liquid\ (water)\ at\ A}$

$$\boxed{\boldsymbol{G_P = H + h}}$$

- In Pascals (Nm^{-2}), the heights must be in metres and $\boldsymbol{G_P = (H + h)\rho g}$
- If the gas pressure is less than the atmospheric pressure, the level of the liquid in closed end of the manometer will be lower than that in the open end. Then $\boldsymbol{G_P = H - h}$
- If the closed end of a manometer is opened, the trapped gas escapes and liquid levels in both arms of the manometer remain the same. Therefore, $gas\ pressure = atmospheric\ pressure.$

Examples:

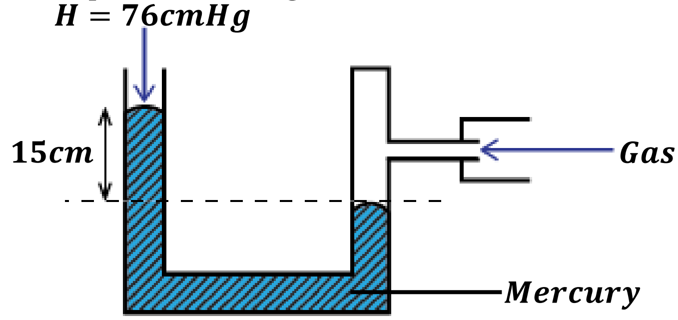
1. The diagram below shows a water manometer used to measure gas pressure.



Find the gas pressure in
(i) $cmHg$
(ii) $mmHg$
(iii) Pascals
$(density\ of\ water\ = 1000kgm^{-3})$

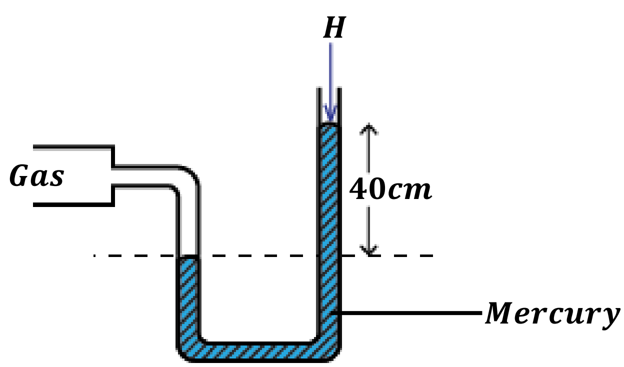
(i) $cmHg$	(ii) $mmHg$	(iii) Pascals
$H = 76cmHg, h = 10cmHg$	Recall; $1cm = 10mm$	Heights in metres.
$G_P = H + h$	$G_P = H + h$	$G_P = (H + h)\rho g$
$G_P = (76 + 10)cmHg$	$G_P = (76 \times 10 + 10 \times 10)$	$G_P = (\frac{76}{100} + \frac{10}{100}) \times 1000 \times 10$
$G_P = 86cmHg$	$G_P = (760 + 100)mmHg$	$G_P = (0.76 + 0.1) \times 10000$
	$G_P = 860mmHg$	$G_P = 0.86 \times 10000$
		$G_P = 8600Nm^{-2}$

2. The figure below shows a mercury manometer. If the atmospheric pressure is $76cmHg$ and density of mercury is $13600kgm^{-3}$, find the pressure of the gas in
   (i) $cmHg$
   (ii) Nm^{-2}



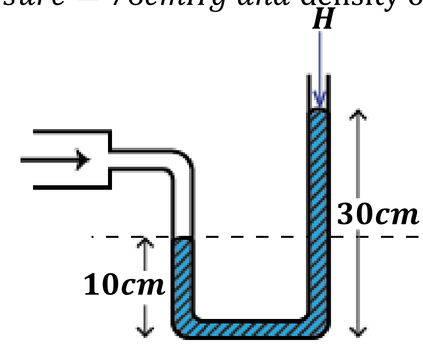
(i) $cmHg$	(i) Nm^{-2}
$H = 76cmHg, \quad h = 15cmHg$	$G_P = (H + h)\rho g$
$G_P = H + h$	$G_P = (\frac{76}{100} + \frac{15}{100}) \times 13600 \times 10$
$G_P = (76 + 15)cmHg$	$G_P = (0.76 + 0.15) \times 136000$
$G_P = 91\ cmHg$	$G_P = 0.91 \times 136000$
	$G_P = 123760Nm^{-2}$

3. The diagram below shows a manometer used to measure gas pressure. Find the gas pressure if the atmospheric pressure is $76cmHg$ and density of mercury is $13600kgm^{-3}$.



$G_P = (H + h)\rho g$
$G_P = (\frac{76}{100} + \frac{40}{100}) \times 13600 \times 10$
$G_P = (0.76 + 0.4) \times 136000$
$G_P = 1.16 \times 136000$
$G_P = 157,760Nm^{-2}$

4. The figure below shows a J-tube containing mercury used to measure gas pressure. ($Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$)



Find the pressure in;

(i) $cmHg$

$$\boldsymbol{H = 76cmHg,}$$
$$\boldsymbol{h = 30 - 10 = 20cm}$$
$$\boldsymbol{G_P = H + h}$$
$$\boldsymbol{G_P = (76 + 20)cmHg}$$
$$\boldsymbol{G_P = 96cmHg}$$

(ii) $mmHg$

Recall; $\boldsymbol{1cm = 10mm}$

$$\boldsymbol{G_P = H + h}$$
$$\boldsymbol{G_P = (76 \times 10 + 20 \times 10)}$$
$$\boldsymbol{G_P = (760 + 200)mmHg}$$
$$\boldsymbol{G_P = 960mmHg}$$

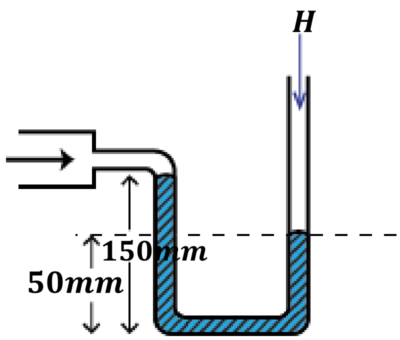
(iii) Pascals

Heights in metres.

$$\boldsymbol{G_P = (H + h)\rho g}$$
$$\boldsymbol{G_P = (\frac{76}{100} + \frac{20}{100}) \times 13600 \times 10}$$
$$\boldsymbol{G_P = (0.76 + 0.2) \times 136000}$$
$$\boldsymbol{G_P = 0.96 \times 136000}$$
$$\boldsymbol{G_P = 130,560\ Pa}$$

5. The figure below shows a mercury manometer connected to a gas supply tank. Determine the pressure of the gas in Nm^{-2}.

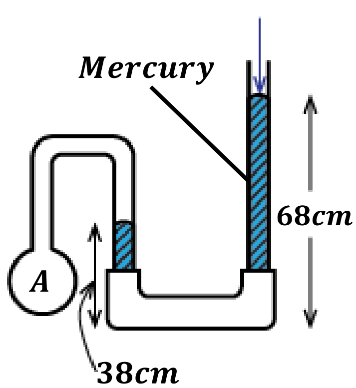
($Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$)



Level of liquid is lower in open end than closed end

$$\boldsymbol{h = 150 - 50 = 100mm}$$
$$\boldsymbol{G_P = (H - h)\rho g}$$
$$\boldsymbol{G_P = (\frac{76}{100} - \frac{100}{1000}) \times 13600 \times 10}$$
$$\boldsymbol{G_P = (0.76 - 0.1) \times 136000}$$
$$\boldsymbol{G_P = 0.66 \times 136000}$$
$$\boldsymbol{G_P = 89,760\ Pa}$$

6. In the figure below, a fixed mass of dry air is trapped in bulb A. Calculate the total pressure of the air in A given that $Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$



$$\boldsymbol{h = 68 - 38 = 30cm}$$
$$\boldsymbol{G_P = (H + h)\rho g}$$
$$\boldsymbol{G_P = (\frac{76}{100} + \frac{30}{100}) \times 13600 \times 10}$$
$$\boldsymbol{G_P = (0.76 + 0.3) \times 136000}$$
$$\boldsymbol{G_P = 1.06 \times 136000}$$
$$\boldsymbol{G_P = 144,160\ Pa}$$

NOTE:
Sometimes, the atmospheric pressure may be given in $\boldsymbol{Pascals}$ *or* $\boldsymbol{Nm^{-2}}$. Therefore, there is no need of first finding the atmospheric pressure.

7. Calculate the gas pressure if a mercury manometer reads $86cmHg$.
   ($Atmospheric\ pressure = 1.03 \times 10^5\ Pa\ and$ density of mercury is $13600kgm^{-3}$)

$$\boldsymbol{Gas\ pressure = Atmospheric\ pressure + Pressure\ of\ the\ liquid}$$

$\boldsymbol{G_P = H + h\rho g}$

$\boldsymbol{G_P = 1.03 \times 10^5 + \left(\frac{86}{100} \times 13600 \times 10\right)}$

$\boldsymbol{G_P = 103000 + 116960}$

$\boldsymbol{G_P = 219,960\ Pa}$

8. A man blows air in one end of a water U-tube manometer until the level differ by $40.0cm$. If the $Atmospheric\ pressure = 1.0 \times 10^5\ Nm^{-2}\ and$ density of water is $1000kgm^{-3}$. Calculate the pressure of air.

$$\boldsymbol{Gas\ pressure = Atmospheric\ pressure + Pressure\ of\ the\ liquid}$$

$\boldsymbol{G_P = H + h\rho g}$

$\boldsymbol{G_P = 1.0 \times 10^5 + \left(\frac{40.0}{100} \times 1000 \times 10\right)}$

$\boldsymbol{G_P = 100000 + 4000}$

$\boldsymbol{G_P = 104,000\ Pa}$

9. A mercury manometer connected to a gas supply mains $70mmHg$. Calculate the gas pressure in Nm^{-2}. ($Atmospheric\ pressure = 103360\ Pa\ and$ density of mercury is $13600kgm^{-3}$)

$$\boldsymbol{Gas\ pressure = Atmospheric\ pressure + Pressure\ of\ the\ liquid}$$

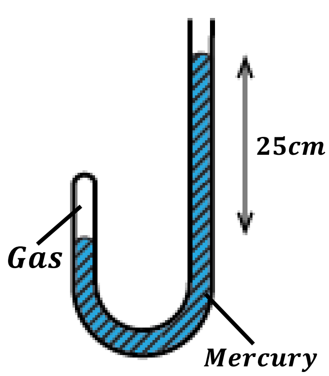
$\boldsymbol{G_P = H + h\rho g}$

$\boldsymbol{G_P = 103360 + \left(\frac{70}{1000} \times 13600 \times 10\right)}$

$\boldsymbol{G_P = 103360 + 9520}$

$\boldsymbol{G_P = 112,880\ Pa}$

10. The figure below shows a gas trapped by a mercury column in a J-tube. The atmospheric pressure is $1.0 \times 10^5\ Pa$ and density of mercury is $13600kgm^{-3}$.
    a) Find the pressure at which the gas is.



$\boldsymbol{G_P = H + h\rho g}$

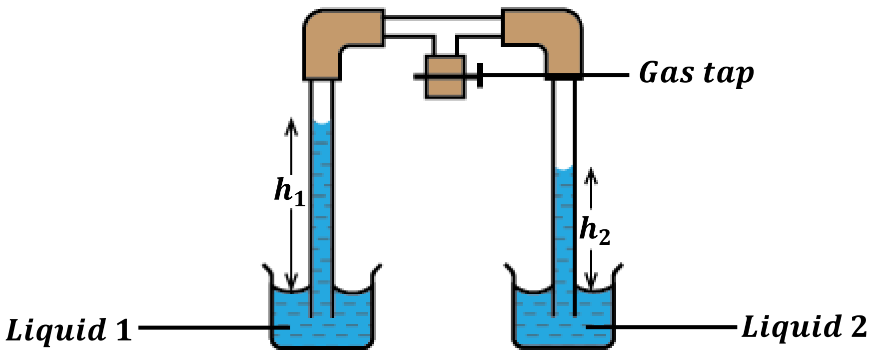
$\boldsymbol{G_P = 1.0 \times 10^5 + \left(\frac{25}{100} \times 13600 \times 10\right)}$

$\boldsymbol{G_P = 100000 + 34000}$

$\boldsymbol{G_P = 134,000\ Pa}$

b) What would happen if the closed end of the J-tube was opened.
If the closed end of the J-tube manometer is opened, the trapped gas escapes and liquid levels in both arms of the manometer remain the same. Therefore, $\boldsymbol{gas\ pressure = atmospheric\ pressure}$.

COMPARISONS OF DENSITIES OF LIQUIDS THAT DON'T MIX
($\boldsymbol{HARE'S\ APPARATUS}$)

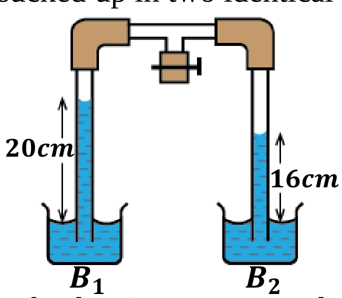


- Liquids of different densities are poured in the glass beakers as shown above.
- When the gas tap is opened, air is let out and each liquid rises to different heights h_1 and h_2.
- Since the liquids are pressurized by the same gas;

$$\boldsymbol{Pressure\ on\ liquid\ 1 = Pressure\ on\ liquid\ 2}$$
$$\boldsymbol{h_1\rho_1 g = h_2\rho_2}g$$

Examples:

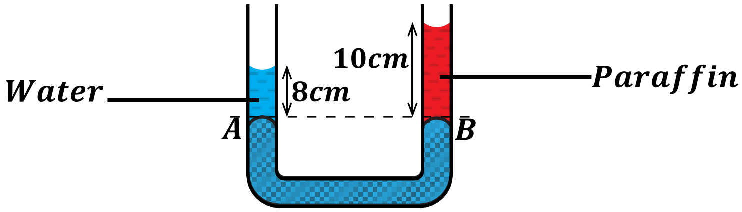
1. Two liquids were sucked up in two identical tubes as shown below.



Given that liquid in beaker B_1 is water. Calculate the density of liquid in beaker B_2.
(density of water is $1000kgm^{-3}$)

$$\boldsymbol{Pressure\ on\ liquid\ 1 = Pressure\ on\ liquid\ 2}$$
$$\boldsymbol{h_1\rho_1 g = h_2\rho_2}g$$
$$\boldsymbol{20 \times 1000 \times 10 = 16 \times \rho_2} \times 10$$
$$\boldsymbol{200,000 = 160\rho_2}$$
$$\boldsymbol{\rho_2 = \frac{200000}{160}}$$
$$\boldsymbol{\rho_2 = 1250\ kgm^{-3}}$$

2. The figure below shows a mercury manometer having two liquids. Find the density of paraffin. (Density of water is $1000kgm^{-3}$)



$$\textbf{Pressure on water} = \textbf{Pressure on Paraffin}$$

$$h_w \rho_w g = h_p \rho_p g$$

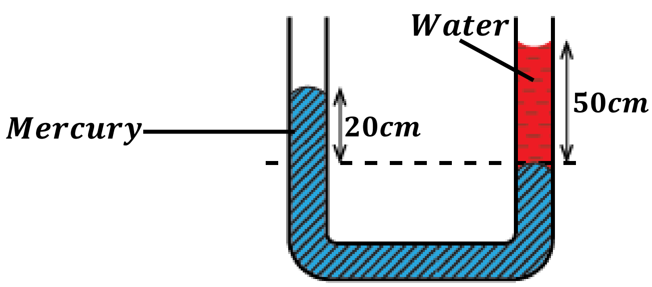
$$8 \times 1000 \times 10 = 10 \times \rho_p \times 10$$

$$80,000 = 100\rho_p$$

$$\rho_p = \frac{80000}{100}$$

$$\rho_p = 800\ kgm^{-3}$$

3. In the figure below, find the density of mercury given that density of water is $1000kgm^{-3}$.



$$\textbf{Pressure on mercury} = \textbf{Pressure on water}$$

$$h_m \rho_m g = h_w \rho_w g$$

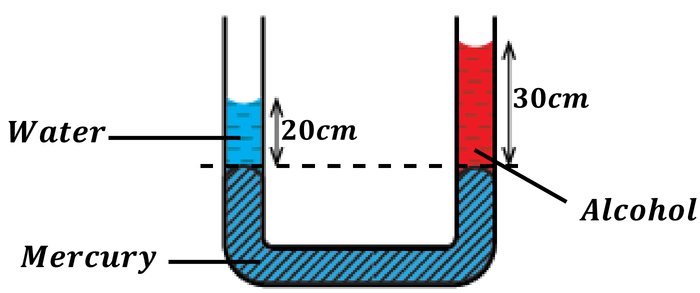
$$20 \times \rho_m \times 10 = 50 \times 1000 \times 10$$

$$200\rho_m = 500,000$$

$$\rho_m = \frac{500,000}{200}$$

$$\rho_m = 2500\ kgm^{-3}$$

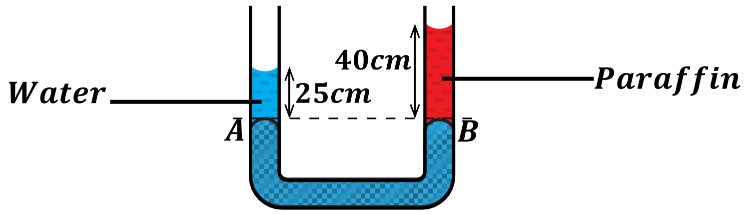
4. The levels of mercury in a manometer are found to be as shown below. Given that density of water is $1000kgm^{-3}$, find the density of alcohol.



$$\textbf{Pressure on water} = \textbf{Pressure on Alcohol}$$
$$h_w\rho_w g = h_a\rho_a g$$
$$20 \times 1000 \times 10 = 30 \times \rho_a \times 10$$
$$200{,}000 = 300\rho_a$$
$$\rho_a = \frac{200000}{300}$$
$$\rho_a = 666.7\ kgm^{-3}$$

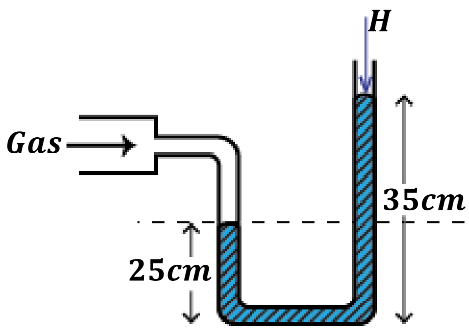
EXERCISE:

1. The levels of liquids in the arms of a mercury manometer are as shown in the figure below.

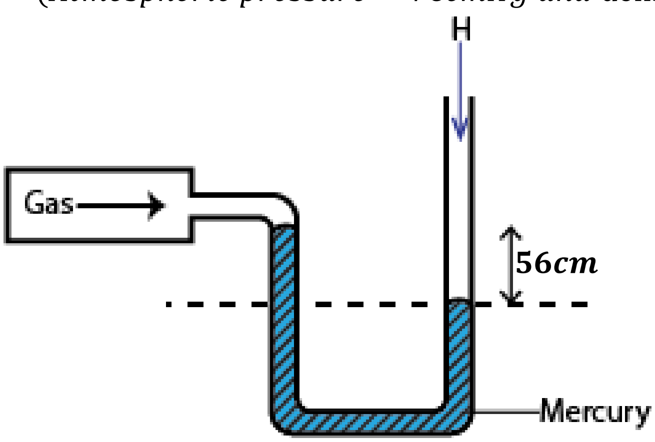


If the density of water is $1000kgm^{-3}$, determine the density of paraffin.

2. In the figure below, determine the pressure exerted by the gas.
($Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$)

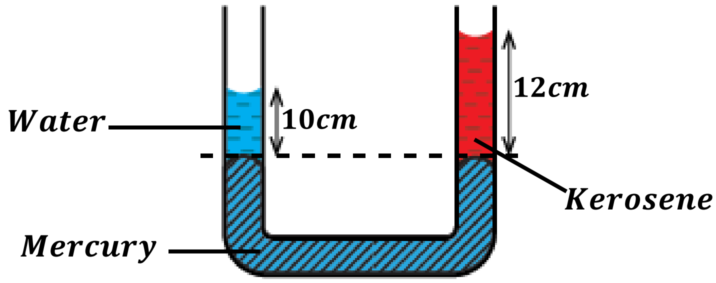


3. In the figure below, determine the pressure of the gas in.
($Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$)



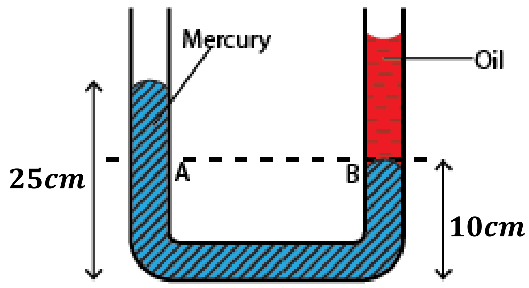
i) $cmHg$
ii) $mmHg$
iii) Pa

4. The level of mercury in the arms of the manometer shown below is equal.
   (density of water is $1000kgm^{-3}$)



Determine the;
(i) Density of kerosene.
(ii) Relative density of kerosene.

5. The U-tube in the figure below contains mercury and oil of density $13600kgm^{-3}$ and $600kgm^{-3}$ respectively. Calculate the height of the oil column.



6. The diagram below shows air trapped by a column of mercury in a J-tube.
   ($Atmospheric\ pressure = 76cmHg\ and$ density of mercury is $13600kgm^{-3}$)
   Calculate the pressure of the enclosed air.