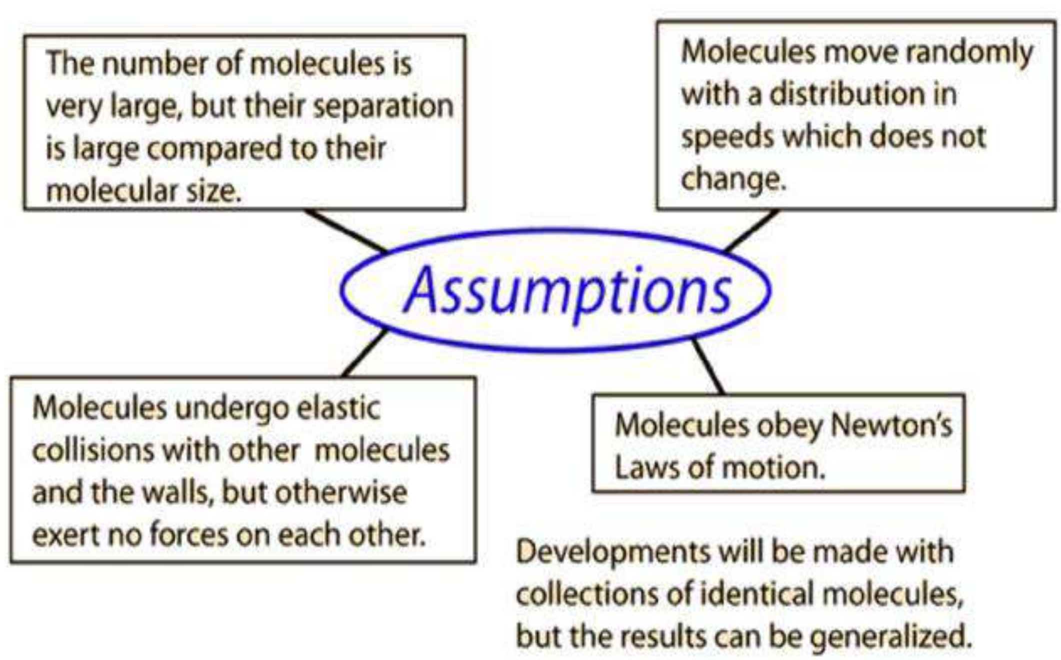
SUBSTRAND 2.2 HEAT ENERGY
LESSSON 60
LO: DISCUSS KINETIC THEORY OF GASES TO GAS PROBLEMS
KINETIC THEORY OF GASES

This is a model of ideal or perfect gas based on experimental observations of real gases. Below are set of observations on behaviour of gases.

1. Gases consist of small particles in constant random motion, which are continually colliding with each other and the wall of the container. Particles of gas move in irregular path.
2. The size of the particle is negligible in comparison with the total volume of gas. It has large spaces between particles that make it easily compressible.
3. There is no force or interactions between the particles. Therefore gas has no fixed volume or shape but occupies the entire volume of its container.
4. All collisions of the particles amongst themselves and with the wall of the container are elastic collision. If they were not then energy would be lost; soon all motion would ceases and the particle would settle at the bottom of the container. This was not observed to happen. The collision of the particles with the wall of the container is responsible for the pressure set up by the gas.
5. The average Kinetic Energy of the particles is proportional to the temperature. Increases the temperature resulted in more movements of the particles.



PRESSURE OF AN IDEAL GAS

Ideal Gas Law	$PV = nRT$	
V = volume in dm^3 T = temperature in K	P = pressure in kPa n = number of moles	R = ideal gas constant

When all laws are combined together it gives gas law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

The absolute pressure (P) of an ideal gas is proportional to the Kelvin temperature (T) and the number of moles (n) of the gas and inversely proportional to the volume (V) of the gas:

Example 1

PV = nRT where R = universal gas constant 8.31 J, n= number of moles.

A certain mass of gas occupies a volume of 350cm^3 at a pressure of 76cm of mercury. What will be its volume when the pressure is reducing to 73cm?

$\frac{P1\,V1}{\cancel{T1}} = \frac{P2\,V2}{\cancel{T2}}$

$P_1 v_1 = P_2 v_2$

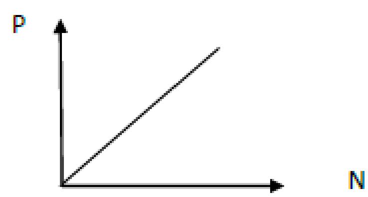
(76) (350) = (73) V_2

$V_2 = \frac{(76)(350)}{73}$

$V_2 = 364.4\ cm^3$

$= \frac{2}{3}(K.E)$

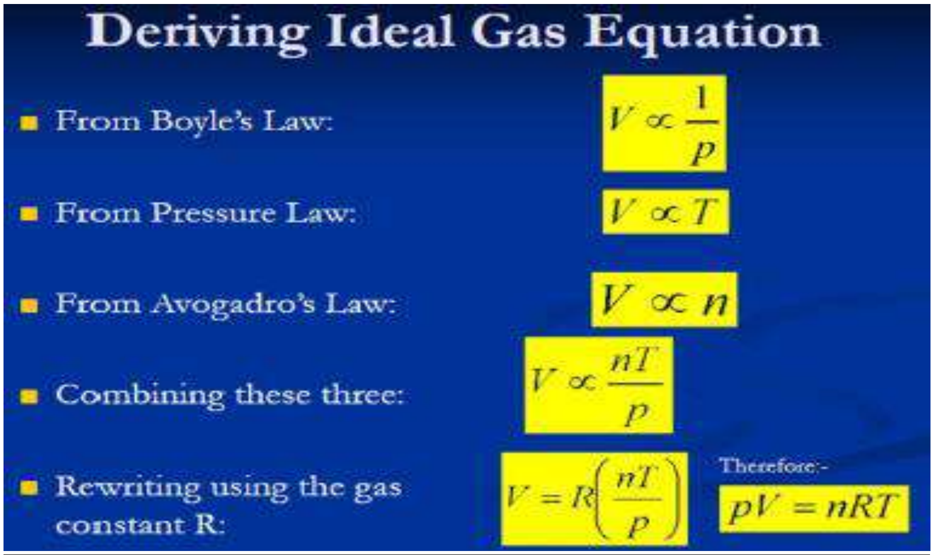
- Pressure depends on number of molecules of the gas present. (P∝ N)



But by the gas equation we know that:
PV = constant x T
$= \frac{2}{3}$(K.E)

∴ T∝ $K.E$

I.e. we have shown that the temperature is proportional to the average Kinetic Energy of the molecules.



<u>LESSON 61</u> LO: EXPLAIN MOLECULAR ROOT MEAN SQUARE SPEED

-Is the average speed(root mean square velocity) of particles in an ideal gas.
- unit (m/s)
-scalar quantity.

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

<u>Where:</u>

v_{rms} : root mean square velocity

R: ideal gas constant 8.3145(kg.m^2/sec^2)/K.mol

***T:* absolute temperature (K)**

M : mass of a mole of the gas in kg.

<u>*T (K) = T (^{o}C) + 273</u>

Example
What Is the root mean square velocity of a molecule in a sample of oxygen at 0^{0}C?

T= 0^{0}C + 273 = 273K.
M_r(Molar mass of oxygen) = 16 g/mol (Periodic table)
Molar mass of 0_2= 2 x 16 = 32 g/mol convert to kg/mol 3.2 x 10^{-2} kg/mol

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$v_{rms} = \sqrt{\frac{3(8.3145)(273)}{(3.2\ x\ 10^{-2})}}$$

$$v_{rms} = 461\ m/s$$

LESSON 62 **LO: apply ideal gas law to solve problems.**

GAS LAWS

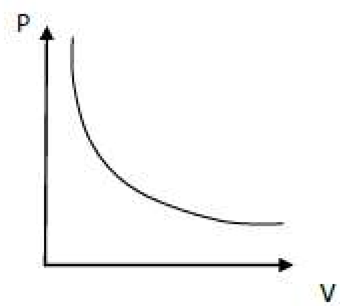
There are three main quantities in investigating the behaviour of an amount of gas: **pressure (Pa), volume (cm^3) and temperature (K).**

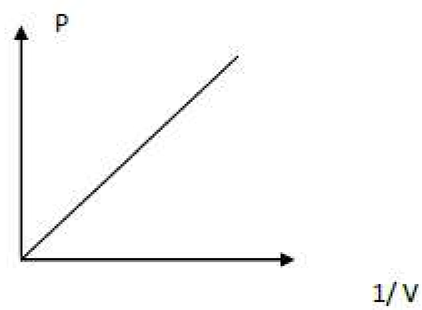
Absolut Zero Temperature – is the minimum or lowest temperature of an object to have.
- **This value is 0 Kelvin or -273^0 C**

1. **Boyles Law** – if temperature is constant, then average kinetic energy is constant. **Hence, the volume of a fixed amount of gas is inversely proportional to pressure when temperature is constant.**

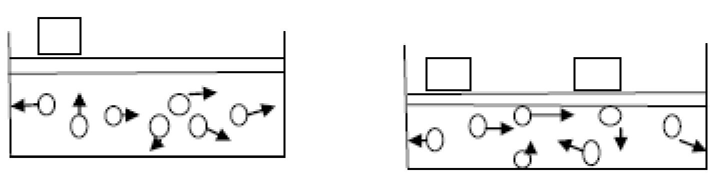
$$P_1 V_1 = P_2 V_2$$

Boyle's Law





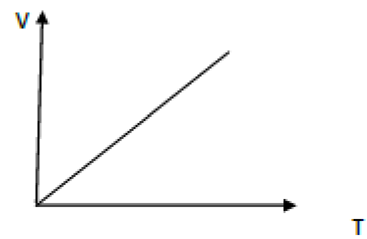
Temperature is constant; hence the average kinetic energy of the molecule is constant.



i.e., the average speed of the molecules remains constant. Pressure experienced by a gas inside cylinder depends only on the number of molecules collision per unit area of wall per second. When the volume is reduced, particles of gas collide with a wall more frequently, therefore pressure increase.

2. **Charles Law** – an increase in temperature means a rise in the average kinetic energy
Hence, the volume of a fixed amount of gas is directly proportional to absolute temperature when pressure is constant.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



3. **Ideal Gas Law**

When all laws are combined together it gives gas law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

The absolute pressure (P) of an ideal gas is proportional to the Kelvin temperature (T) and the number of moles (n) of the gas and inversely proportional to the volume (V) of the gas:

EXERCISES

2020

Distinguish between Boyle's law and Charle's law.

2020 Sample

Describe Boyle's law.

2019

A gas in a closed container occupies a volume of 0.5 litres at a temperature 23 °C. The gas is then heated to a temperature of 50 °C.

Calculate the new volume of the gas if there is no change in pressure. **(2 marks)**

State one assumption of kinetic theory of gases. **(1 mark)**

2018

An unknown volume of oxygen gas in a closed container was heated from 20°C to 100°C under constant pressure till its volume became 100 ml.

Calculate the original volume of oxygen in millilitres.

2017

The law that states pressure is inversely proportional to volume at constant temperature is

A. Boyle's Law.
B. Charles' Law.
C. Hooke's Law.
D. Pressure Law.

A volume of 0.22 m^3 of water at 23°C is heated under constant pressure to 70 °C.

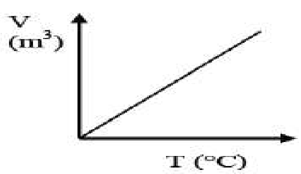
(i) Convert 23°C and 70°C to Kelvin. **(1 mark)**

(ii) Calculate the new volume of water. **(1 mark)**

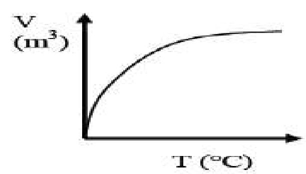
2016

Which one of the following **Volume versus Temperature** graphs is most consistent with **Charles' Law?**

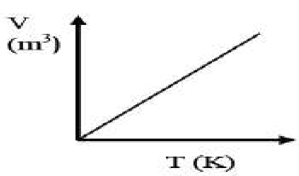
A.



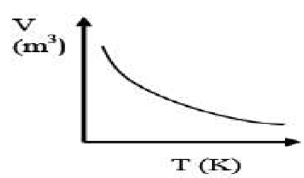
B.



C.



D.



The pressure of a gas increases at constant temperature if its volume

A. increases.
B. decreases.
C. equals to zero.
D. remains the same.

The pressure in a car tyre is 2.5×10^5 Pa at 27°C. After a long journey the pressure has risen to 3.0×10^5 Pa. Assume that the volume of the tyre remains the same.

(i) Calculate the new temperature of the tyre in degrees Celsius.

(ii) Why has the pressure in the tyre increased?

FY12CE 2015

1.

Which of these general equations best describes the ideal gas law?

A. $PV = \text{constant}$

B. $\frac{V}{T} = \text{constant}$

C. $\frac{P}{T} = \text{constant}$

D. $\frac{PV}{T} = \text{constant}$

2

What is the relationship between pressure and volume of a combined gas at constant temperature?

A. Inversely proportional
B. Directly proportional
C. Inverse square
D. No relation

3

A car tyre of volume 250 cm^3 is filled to a constant pressure at a temperature of 300 K. After driving some distance, the temperature of the air inside the tyre rises to 330 K. Assume that the pressure inside the tyre remains same.

(i) Calculate the new volume of the tyre.

(ii) Convert 330 K to degrees Celsius.

FSLC 2014

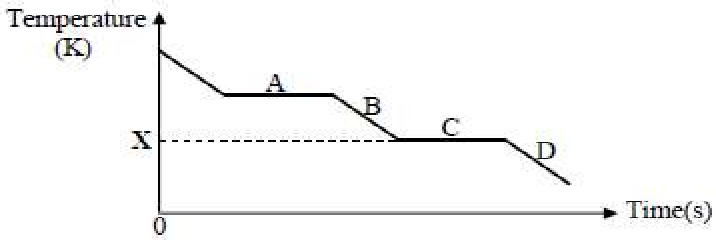
1.

The lowest possible temperature is known as

A. Kelvin.
B. Celsius.
C. Fahrenheit.
D. Absolute Zero.

2.

The graph below shows the cooling curve of water.



(i) In which section of the graph, A, B, C, or D is there a change of state from water to ice taking place?

(ii) What is the value of temperature at point X?

3.

Neon gas in a container was heated from 20 °C to 120 °C. Its new volume is 150 ml.What was the original volume?

FSLC 2013

1.

Boyle's Law states that, for a fixed mass of gas, pressure is

A. directly proportional to volume if temperature is kept constant.
B. inversely proportional to volume if temperature is kept constant.
C. directly proportional to temperature if volume is kept constant.
D. inversely proportional to temperature if volume is kept constant.

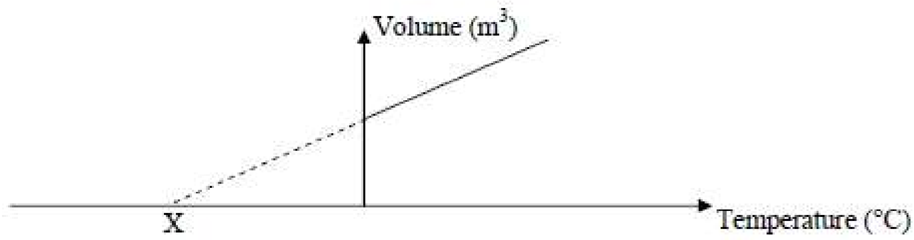
2.

The **temperature** of a solid body is defined as the

A. thermal energy required to increase the body's temperature by one degree.
B. maximum thermal energy that must be supplied to melt the solid.
C. total kinetic and potential energy of the solid's molecules.
D. average kinetic energy of the solid's molecules.

3.

The graph below illustrates Charles' Law for a fixed mass of gas.



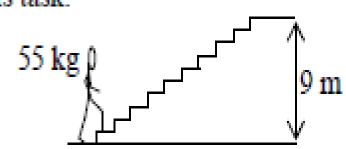
(i) Rewrite Charles' Law in words, stating clearly any necessary conditions. (

(ii) What is the significance of point X marked above? (

FSLC 2012

1.

A student of mass 55 kg has to climb a flight of stairs that has a vertical height of 9 m above the ground, everyday to get to class. On average, the student will take 36 s to do this task.



(i) What is the student's weight?

(ii) Calculate the average power needed by the student to climb these stairs.

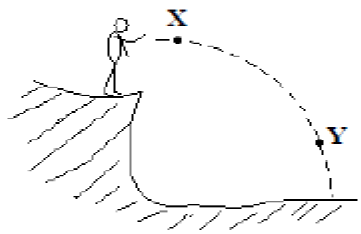
A fixed mass of gas at constant temperature is compressed to reduce its volume. How do the molecules of gas now strike the walls of the container?

A. less often than before with a higher velocity
B. less often than before with the same velocity
C. more often than before with a higher velocity
D. more often than before with the same velocity

FSLC 2011

1.

A person standing at the top of a cliff throws a stone as shown in the diagram below.



Which form of energy does the stone have at **X** and **Y**?

	Energy at X	**Energy at Y**
A.	Gravitational only	Kinetic only
B.	Kinetic only	Gravitational only
C.	Gravitational only	Gravitational and Kinetic
D.	Gravitational and Kinetic	Gravitational and Kinetic

2.

A person uses a 2.0 kW electric iron for 0.5 hours and a 0.1 kW television for 10 hours. What is the total cost of electricity used if the price of electrical energy is 35 cents per kilowatt-hour?

A. 17.5 cents
B. 35 cents
C. 70 cents
D. 140 cents

3.

A car tyre, of volume 250 cm^3 is filled to an absolute pressure of 280 kPa at 27 °C. After driving some distance, the temperature of the air inside the tyre rises to 57 °C. Assume that the pressure inside the tyre remains the same.

(i) Convert 27 °C into Kelvin.

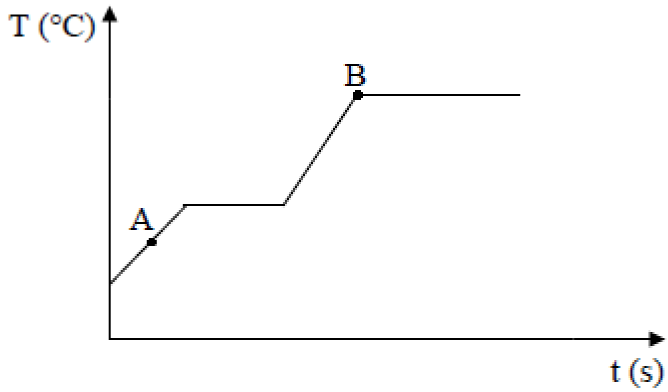
(ii) What will be the new volume of the tyre?

4.

Boyle's Law relates the Pressure and Volume of a given mass of gas. State Boyle's Law.

5.

The graph below shows the temperature changes of an ideal substance while being heated.



(i) Describe the substance at points **A** and **B**.

(ii) Describe what is happening to the average speed of the molecules from **A** to **B**.

2010

(i) State **Charles Law**.

(ii) A certain mass of oxygen has a volume of 5.0 m^3 at 27 °C. If the pressure remains constant, what will be its volume at 77 °C?

2009

Figure A below shows air enclosed in a cylinder by an airtight piston and **Figure B** shows that the piston has been pushed in so that air occupies half of the length of the cylinder.

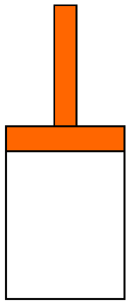


Figure A

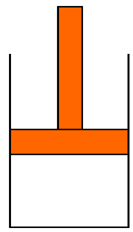


Figure B

Which of the following would occur when the piston is pushed down so that the air occupies half the length of the cylinder as shown in **Figure B** ?

A. The air pressure in the cylinder would double.
B. The number of molecules of air would double.
C. The air pressure in the cylinder would be halved.
D. The number of molecules of air would be halved.

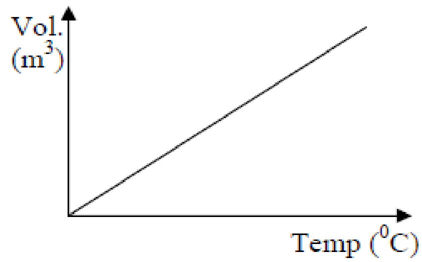
2008

Which of the following applications **best** describes the behaviour of the gas particles contained in a closed solid container when the temperature of an ideal gas increases ?

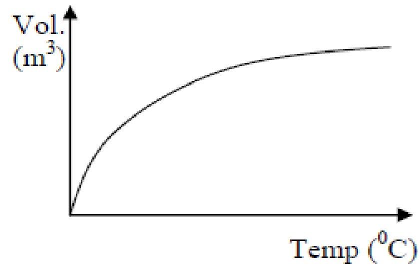
A. The potential energy of the particles of gas increases.
B. The kinetic energy of the gas particles increases.
C. The number of gas particles decreases.
D. The number of gas particles increases.

Which **one** of the following Volume versus Temperature graphs is **most** consistent with Charle's Law ?

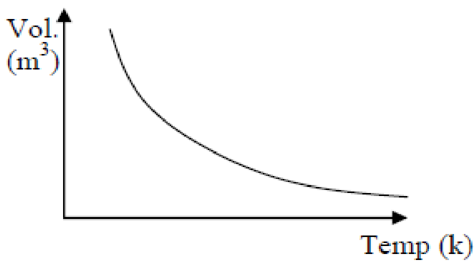
A.



B.



C.



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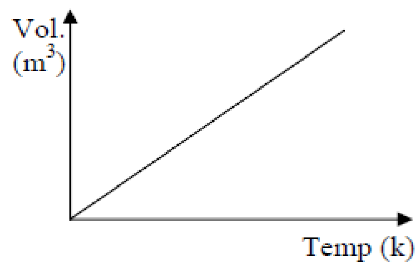


Gas Law Formula		
Gas Law	**Formula**	**Description**
Boyle's Law	$P_1V_1 = P_2V_2$	At constant *T*, as pressure increases, volume decreases.
Charles' Law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	At constant P, as volume increases, temperature increases.
Gay-Lussac's Law	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	At constant V, as pressure increases, temperature increases.
Combined Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	Obtained by combining Boyle's Law, Charles' Law and Gay-Lussac's Law.
Ideal Gas Law	$PV = nRT$	
V = volume in dm^3 T = temperature in K	P = pressure in kPa n = number of moles	R = ideal gas constant

TOPIC 3

FLUIDS

LEARNING OUTCOMES:

At the end of this topic students should be able to:

- Learn and describe the properties of fluids
- Understand and explain the Bernoulli's Principle
- Describe and apply Boules Law
- Calculate pressure using pressure gauge and atmospheric pressure

Fluids and Statics

1. $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
2. $\rho = \frac{m}{V}$
3. $P = \frac{F}{A}$
4. $P = \rho g h$

STRAND 3 FLUIDS **SUBS STRAND 3.1 PROPERTIES OF FLUIDS**
LESSON 63 **LO: Application of Bernoulli's Principle.**
FLUIDS

Fluid Mechanics is the study of fluids either in motion (FLUID DYNAMICS) or at rest (FLUID STATICS). Fluids refer to substances that deforms continuously under the action of shear stress. Fluids are either gas or liquid. Solids are NOT fluids. Solids can resist a shear stress, fluids can't.

PROPERTIES OF FLUIDS

-density, viscosity, temperature, pressure, specific volume, specific weight, specific gravity, compressibility, surface tension.

Bernoulli's Principle: **" The pressure in a fast moving stream of air is lower than in a slower stream of air."**

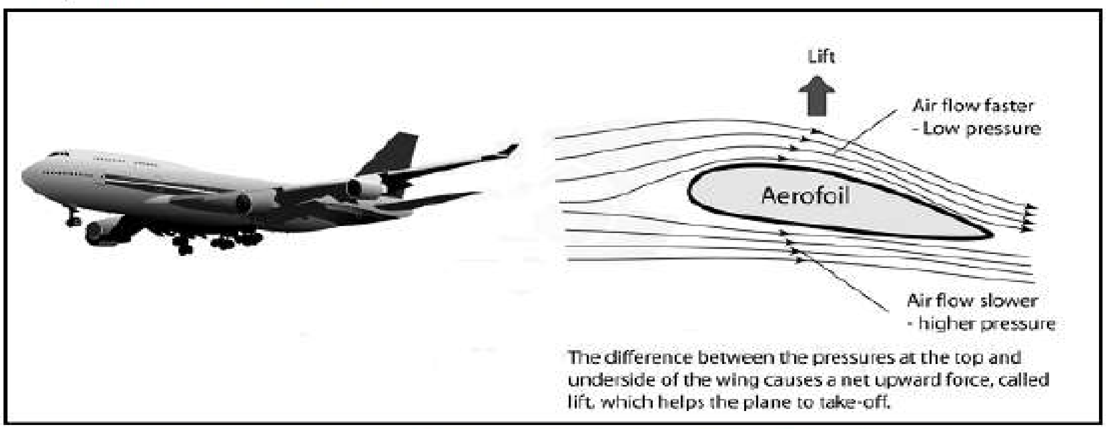
Simple terms: " As the fluid's velocity increases its pressure decreases."

- Fast air will produce low pressure and slow moving air will produce high pressure.
- Increase in fluid speed occurs simultaneously with decrease in pressure or a decrease in fluids P.E.
- Can be derived from principle of conservation of energy.

APPLICATION

I. **Airplane wings**

An aircraft wing, called an *aerofoil*, is shaped so that the air has to travel farther and so faster over the top surface than underneath

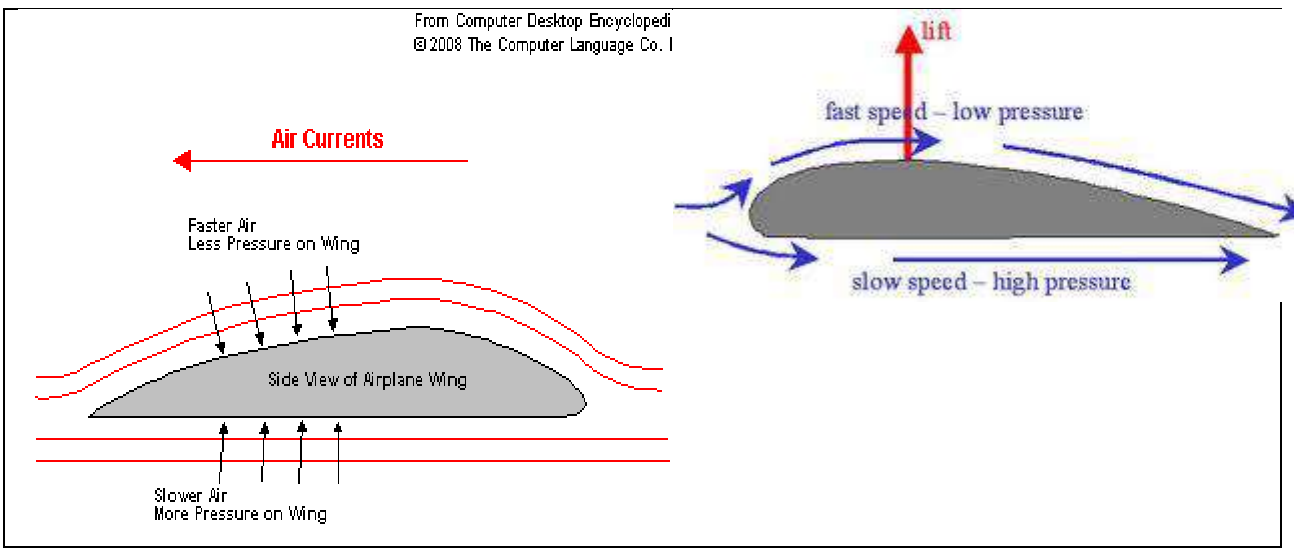


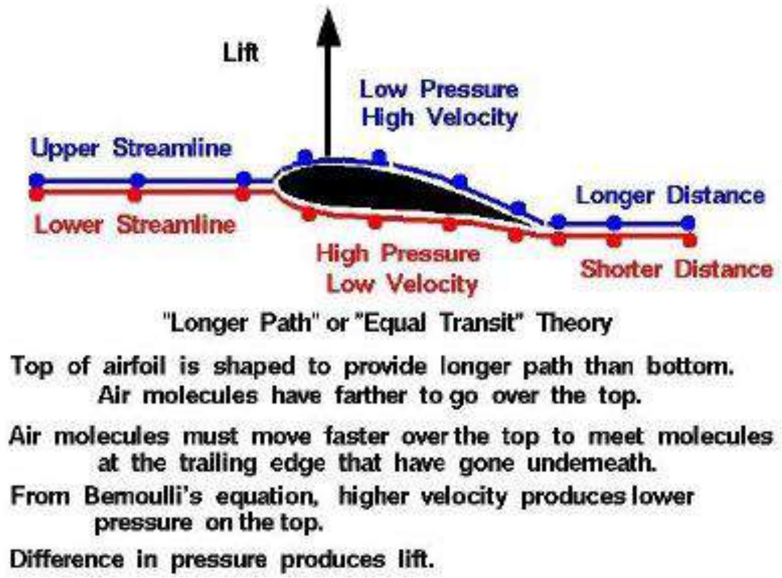
http://spmphysics.onlinetuition.com.my/2013/06/application-of-bernoullis-principle.html

1. When a wing in the form of an aerofoil moves in air, the flow of air over the top travels faster and creates a region of low pressure. The flow of air below the wing is slower resulting in a region of higher pressure.
2. The difference between the pressures at the top and underside of the wing causes a net upward force, called **lift**, which helps the plane to take-off.

Condensation visible over the upper surface of an Airbus A340 wing caused by the fall in temperature accompanying the fall in pressure.

<u>Airplane wing</u>



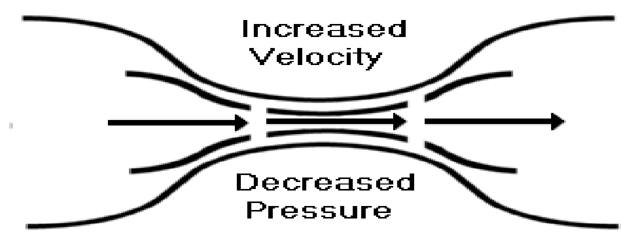


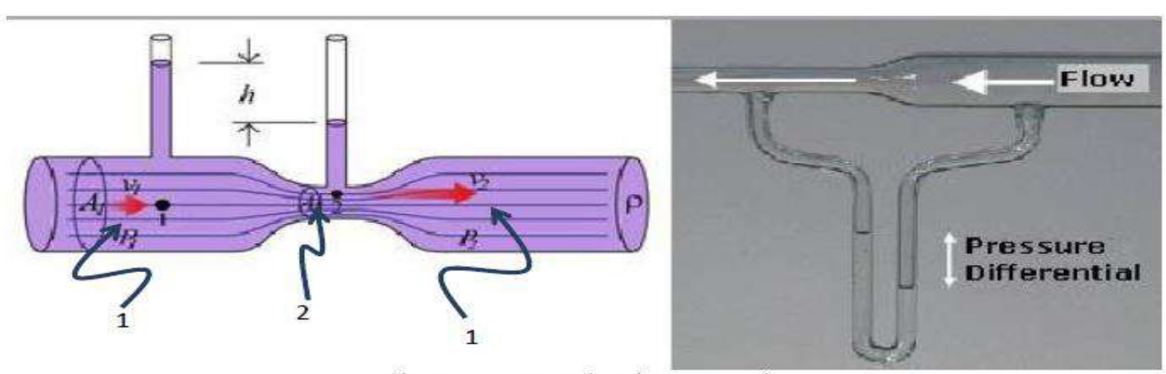
ii. **<u>Venturi meter</u>**

-device used to **measure flow speed of a fluid**.

- measures the drop in pressure that takes place as the velocity of the fluid increases.

- consists of **manometer** (device used to measure pressure) at three places: entrance, the point of constriction and at the exit.

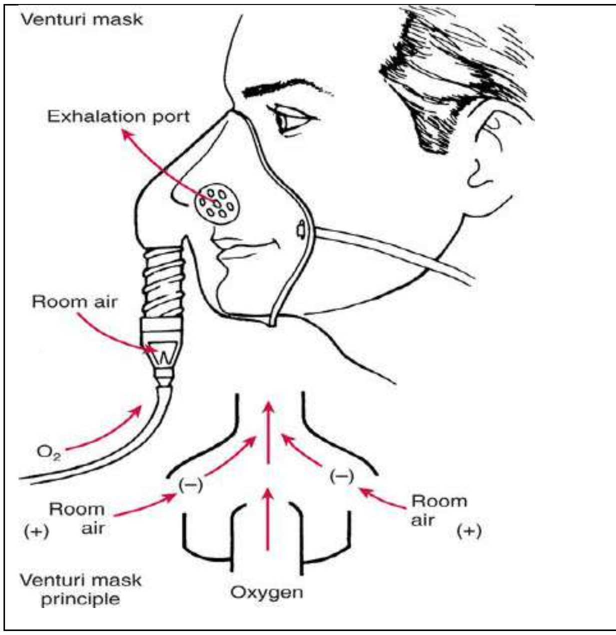




https://www.scribd.com/doc/104586852/Bernoulli-Theorem

The pressure at "1" is higher than at "2" because the fluid speed at "1" is lower than at "2".

EXAMPLE



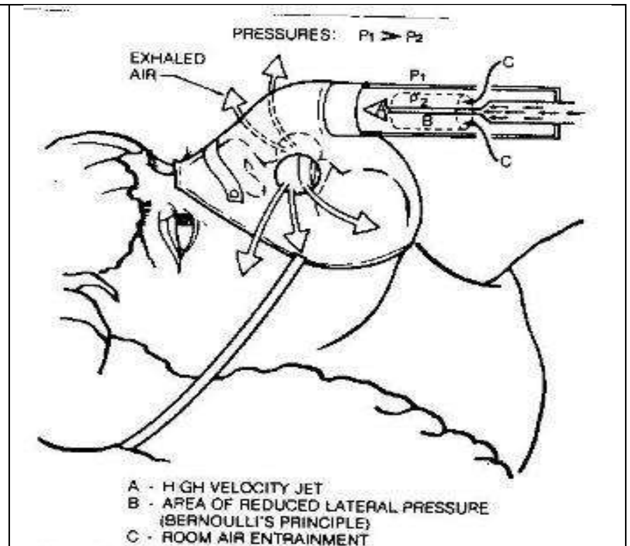
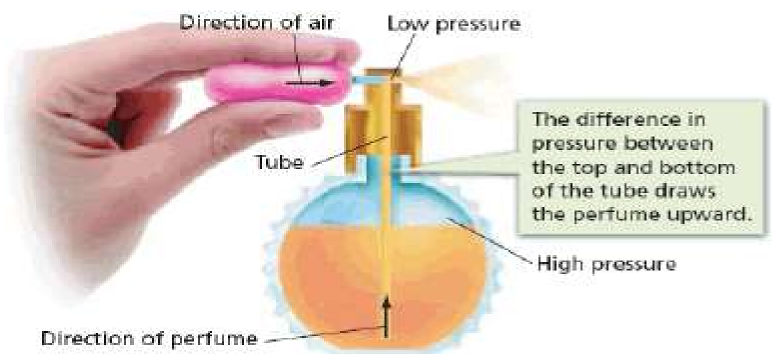


Figure 5–13. Application of the Bernoulli principle to dilute oxygen from a mask (Note the flow of ambient air in response to the pressure gradient)

III. Atomizer

Bernoulli's principle can help you understand how the perfume atomizer shown in the figure below works.

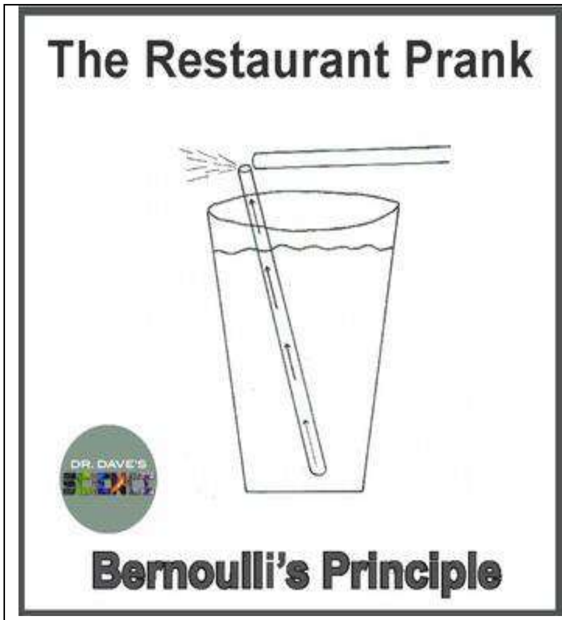


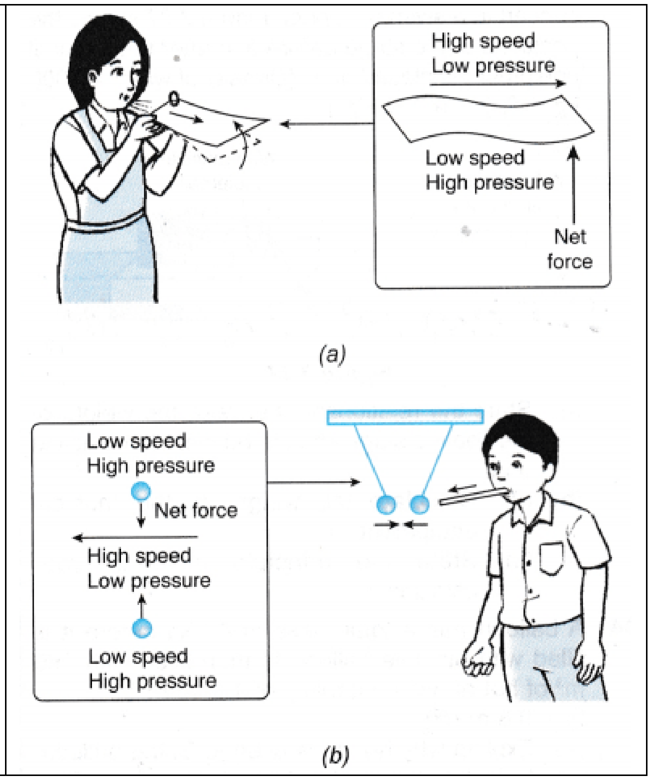
Perfume Atomizer An atomizer is an application of Bernoulli's principle.
http://mycampus.nationalhighschool.com/doc/sc/Physical%20Science/iText/products/0-13-190327-6/ch11/ch11_s4_2.html

When you squeeze the rubber bulb, air moves quickly past the top of the tube. The moving air lowers the pressure at the top of the tube. The greater pressure in the flask pushes the liquid up into the tube. The air stream breaks the liquid into small drops, and the liquid comes out as a fine mist.

Other Applications of Bernoulli's Principle

iv. Straw Pipe toy **v.Paper Airplane** **vi. Ping pong Balls**





ACTIVITY

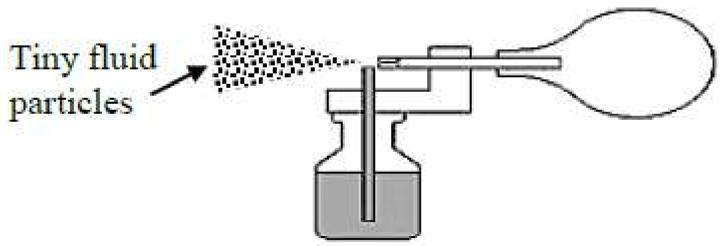
FY12CE 2019

Using Bernoulli's effect, explain how an airplane works.

FY12CE 2018

1.

The diagram given below shows a schematic diagram of an atomiser.



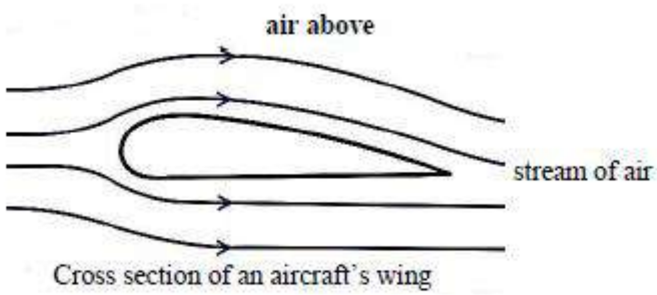
The atomiser works based on

A. Pascal's Principle.
B. Torricelli's Principle.
C. Bernoulli's Principle.
D. Archimedes' Principle.

FY12CE 2017

1.

Use the diagram given below which shows a stream of air passing over the cross section of an aircraft's wing to answer **Question 10**.



Which of the following correctly describes the pressure and speed of air above the aircraft's wing?

	Pressure	Speed
A.	low	slow
B.	low	fast
C.	high	slow
D.	high	fast

2.

Refer to the diagram given below which shows a section of a Venturi tube

Section of a Venturi tube

Which of the following is true about velocity of fluid in the Venturi tube?

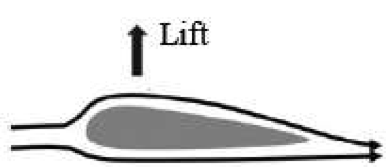
A. $v_1 = 0$
B. $v_1 < v_2$
C. $v_1 > v_2$
D. $v_1 = v_2$

FY12CE 2016

1.

The lift on an aircraft's wing as shown in the cross section diagram below can be explained by

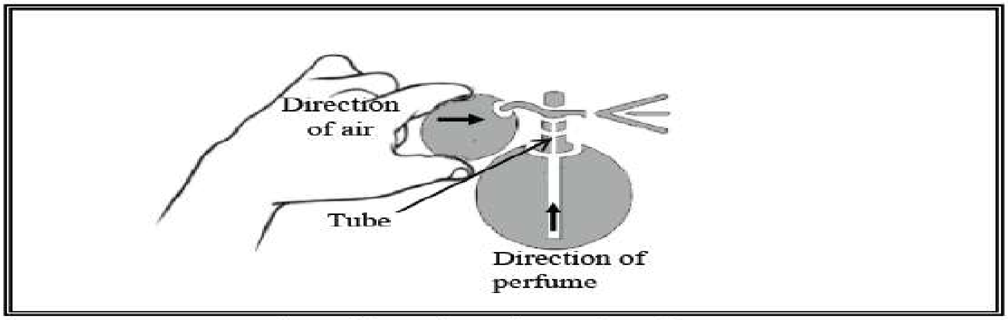
A. Boyle's Principle.
B. Pascal's Principle.
C. Bernoulli's Principle.
D. Archimedes' Principle.



Cross section of aircraft's wing

2.

The diagram below shows how perfume is drawn upwards.



Adapted from: *http://www.freepik.com*

(i) Name the Bernoulli's application shown in the diagram. **(1 mark)**

(ii) Give the reason why perfume is drawn upwards. **(1 mark)**

FY12CE 2015

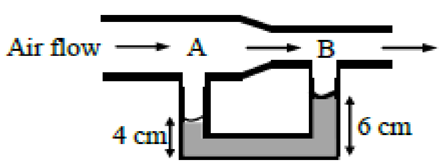
1.

According to **Bernoulli's Principle**, fast moving air will create a region of

A. constant pressure.
B. varying pressure.
C. high pressure.
D. low pressure.

2.

The diagram below shows air flowing through a venturi meter that is connected to a water filled manometer.

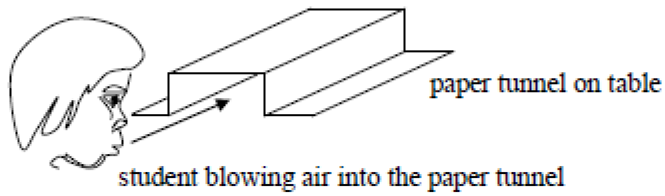


(i) Which of the two regions marked A and B has the greater pressure? **(1 mark)**

(ii) Calculate the pressure differential in cm of water if the heights of water in the manometer are 4 cm and 6 cm. **(2 marks)**

2012

During a Bernoulli Effect experiment, a piece of A4 paper is folded into a tunnel and placed on a table, as shown below. A student blows air into the paper tunnel.



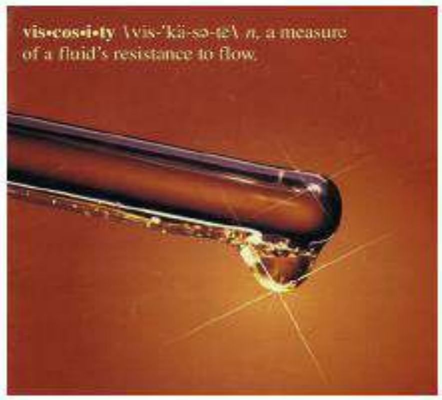
Which of the following observations and explanations would the student **most likely** to record?

	Observation	Explanation
A.	The paper tunnel rises and flies away.	Fast moving air creates high pressure in the tunnel and pushes the paper away.
B.	The paper tunnel collapses.	Fast moving air creates low pressure in the tunnel and the high pressure outside pushes it down.
C.	The paper tunnel rises and flies away.	Fast moving air creates low pressure in the tunnel and pushes the paper away.
D.	The paper tunnel collapses.	Fast moving air creates high pressure in the tunnel and the low pressure outside pushes it down.

LESSON 64 -65 EXPERIMENT 7 BERNOULLI'S EFFECT

LESSON 66 LO: apply the concept of fluid "viscosity" to shear stress in a fluid.

VISCOSITY



- Is the measure of resistance.
- Expresses the fluid's resistance against either tensional stress or shear stress.
- In Simple terms it means 'how "thick" a fluid is'. Eg. we can easily move through air but difficult to move through water.
- Exists both in liquids and gases.
- Liquid: viscosity is due to cohesive forces between the molecules.
- Gases: viscosity is due to collisions between the molecules.
- **The thicker the fluid, the higher the viscosity.**

KINEMATIC VISCOSITY

- Indicates the flow volume over a period of time. (The time it takes to watch a fluid pour out of a container.)
- Expressed in units.
- Common units is **stokes** and **cm^2/s**
- SI unit **m^2/s**

DYNAMIC VISCOSITY (Absolute Viscosity)

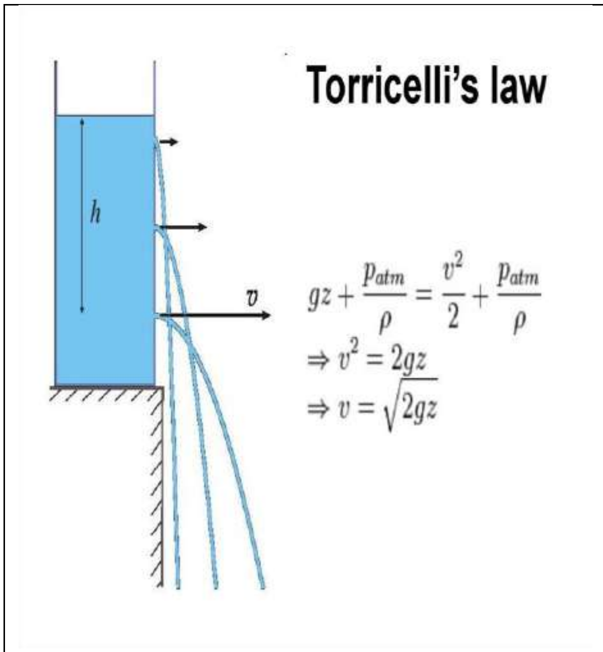
- measures the resistance of a fluid flow. Or (the internal friction of the fluid.) or (How easily can fluid deform under mechanical stress at a given temperature and pressure.)
- SI unit **pascal-seconds. (pressure for shear stress/time taken to deform)**
- Another unit is **poise.**

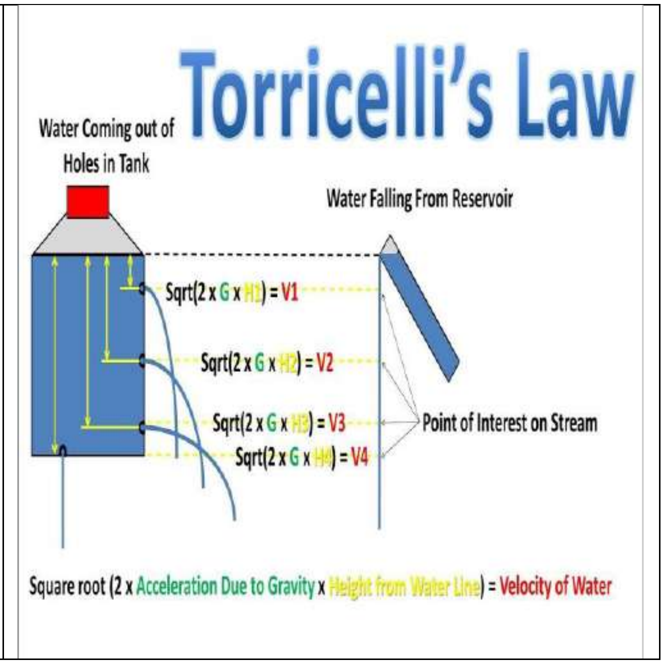
TORRICELLI'S PRINCIPLE (TORRICELLI'S THEOREM)

$$v = \sqrt{2gh}$$

-is a theorem about the relation between the exit velocity of a fluid from a hole in a reservoir to the height of fluid above the hole when pressure remains constant.

-the speed,v, of fluid flowing out of an **orifice** under the force of gravity in a tank is proportional to the square root of the vertical distance, h, between the liquid surface and the centre of the orifice and to the square root of twice the acceleration caused by the gravity.



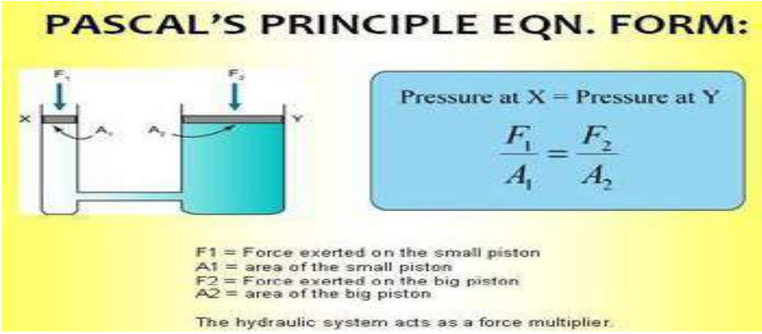


PASCALS PRINCIPLE

- **"Pressure at a point in a fluid is equal in all directions."**

- Relates that the pressure at two points in an incompressible static fluid is equally transmitted throughout the fluid.

- Application: **hydraulic lift** used to raise a car off the ground so it can be repaired at a garage.

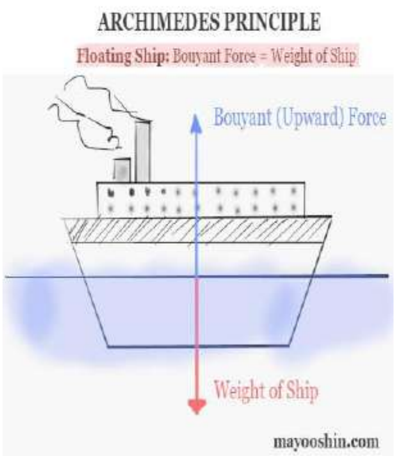


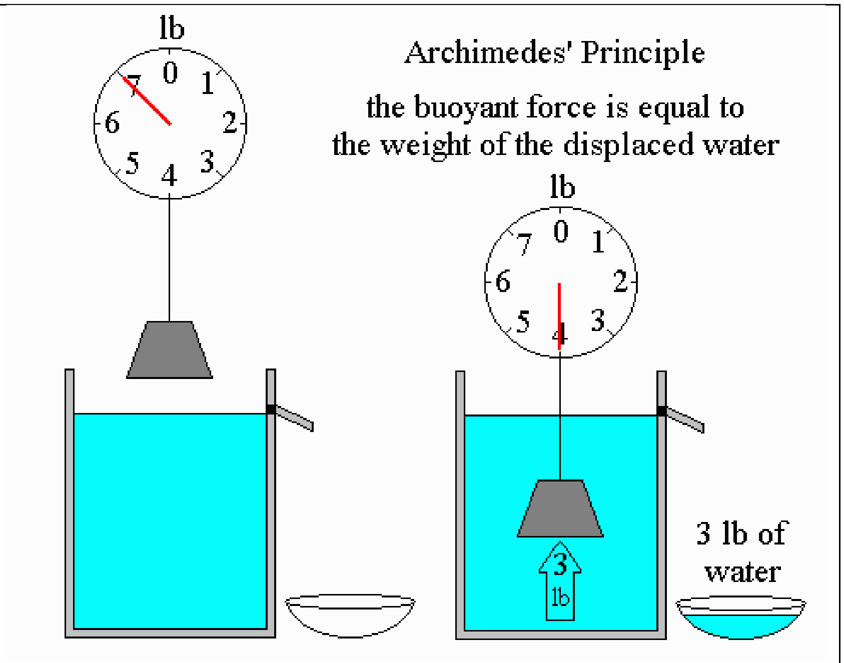
ACHIMEDES PRINCIPLE

-States that when a body is immersed in a liquid, completely or partially, it loses its weight. The loss in weight is equal to the weight of liquid displaced by the body. The loss in weight of a body is due to the presence of upthrust which is equal to the weight of liquid displaced.

-example: the **floating** of a ship.

- application: **Designing** ships and submarines.





2019

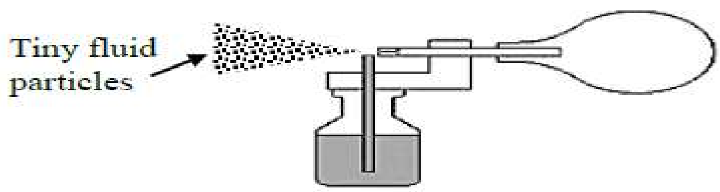
A liquid with a low viscosity

A. Flows slowly
B. Flows quickly
C. Does not move
D. Has a definite shape

FY12CE 2018

1.

The diagram given below shows a schematic diagram of an atomiser.



The atomiser works based on

A. Pascal's Principle.
B. Torricelli's Principle.
C. Bernoulli's Principle.
D. Archimedes' Principle.

2.

Liquid viscosity can be viewed as kinematic viscosity and dynamic viscosity.

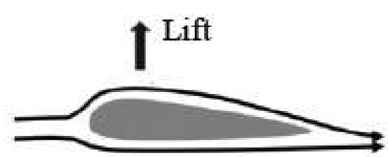
(i) Define dynamic viscosity. **(1 mark)**

(ii) State **one** unit that can be used for dynamic viscosity. **(1 mark)**

FY12CE 2016

The lift on an aircraft's wing as shown in the cross section diagram below can be explained by

A. Boyle's Principle.
B. Pascal's Principle.
C. Bernoulli's Principle.
D. Archimedes' Principle.



Cross section of aircraft's wing