PHYSICS lo 9

Qena Student Club

Properties of fluids

Classification of fluids:

- **Fluids statics: it involves the study of fluids at rest or non-motion**
- **Fluids dynamics: it involves the study of fluids at motion .**

Fluids are classified into another four types depending in their flow :

- **Steady fluid : It is the fluid whose density remains constant at every point while flowing.**
- **Unsteady fluid : It is the fluid whose velocity differs between any two points while flowing.**
- **incompressible :it has Mach Number<0.3**
- **Compressible : it has Mach number between 0.3 and 1**

All properties of fluids are in lo 8.

Continuity equation

Volume flowrate :

The amount of fluid that enters equal the amount of fluid that leaves .

X is a distance so it equal v *t (v is a velocity)

M1=m2

ρ1 * v1 = ρ2 * v2 (v is a volume)

ρ1*A1*x1 = ρ2*A2*x2

A1*x1 = A2*x2

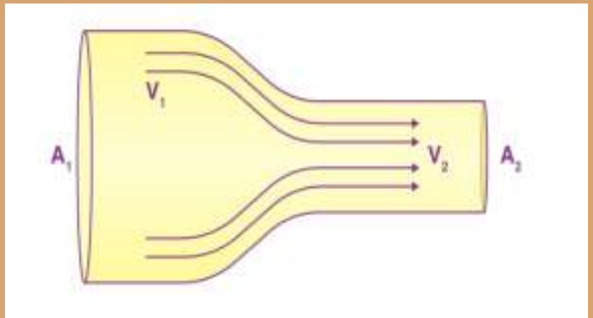
A1*v1*t = A2*v2*t (v is a velocity)

A1*v1 = A2*v2

A* v is a constant that mean A has a inverse relation with velocity.

Volume flowrate = v /t

(v is a volume)



- **Unit of volume flowrate is m^3/s**
- **Dimension analysis is L^3 T^-1**

Mass flowrate:
Volume flowrate * ρ
A * v *ρ (v is a velocity)

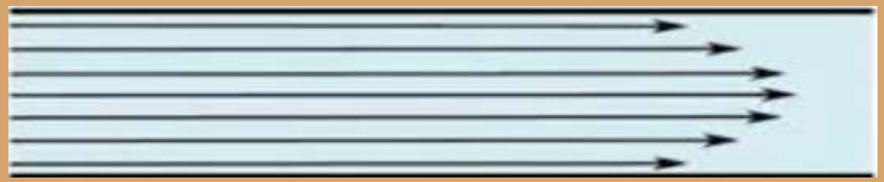
- V1/v2= A2/A1

V1/V2= πr^2(2)/πr^2(1)
V1/V2=r^2 (2)/r^2(1)
Unit of mass flowrate is kg/s
Dimension analysis is m*T^-1

Laminar vs turbulent flow

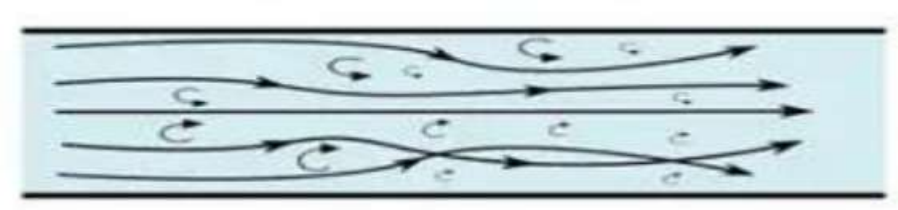
Laminar flow:

- Steady flow
- Each particle of fluids follows a smooth path and a regular streamline
- Non viscous means no frictional forces exist between the layers of the fluid
- The path of different particles never crosses each other
- The flow rate should be constant
- The amount of fluid that enters at one end equals to the amount of fluid that emerges from the other end in the same time interval according to the law of mass conservation.



Turbulent flow :

- **conductor according to Faraday's law of induction.)**
- **The speed of fluid exceeds a certain limit and is not constant**
- **Presence of small bubbles of gases**
- **Follow the irregular paths and particles cross each other**
- **Viscous fluid**



Transition flow:

It is mixture between laminar flow and turbulent flow .

Reynolds :the ratio of inertial forces to viscous forces within a fluid that is subjected to relative internal movement due to different fluid velocities

- **If R.N (Reynolds number)< 2000it is a laminar flow**
- **If RN 2000:4000, it is transition flow**
- **If R.N >4000, it is a turbulent flow**

Ideal fluid flow

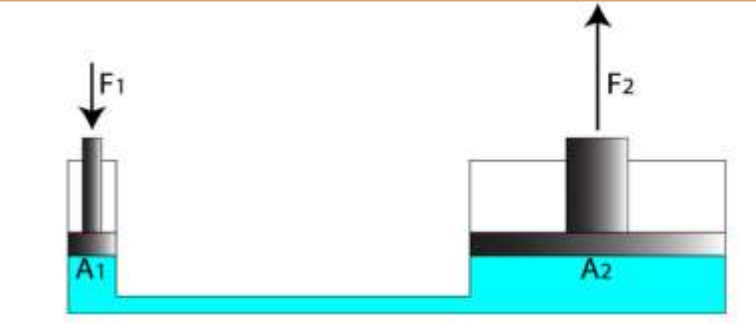
- **The fluid is not viscous : which means there is no internal friction force between adjacent layers**
- **The fluid is incompressible :which means its density is constant.**
- **The fluid motion is steady :which means that the velocity, density, and pressure at each point in the fluid are constant with time.**
- **The fluid is irritation : which means that the a flow in which each element of the moving fluid undergoes no net rotation with respect to a chosen coordinate axes from one instant to other.**

Pascal's Principle

o French mathematician Blaise Pascal stated the Pascal law in 1653.

o Pascal’s law says that pressure applied to an enclosed fluid will be transmitted without a change in magnitude to every point of the fluid and the walls of the container.

o The pressure at any point in the fluid is equal in all directions.



$\rho 1 = \rho 2$

$F1 / A1 = F2 / A2$

Formula of Pascal law:

- Hydraulic Lift: It works based on the principle of equal pressure transmission throughout a fluid (Pascal’s Law).

work

- A force acting on a system can heat it up (or cool it down), by working on it. A change in temperature produced in a system can be used to produce mechanical work.
- At any point in the process, the system (gas) will have temperature T, pressure p and volume V. dW = Fds = pAds = pdV.

There are three types of wors :

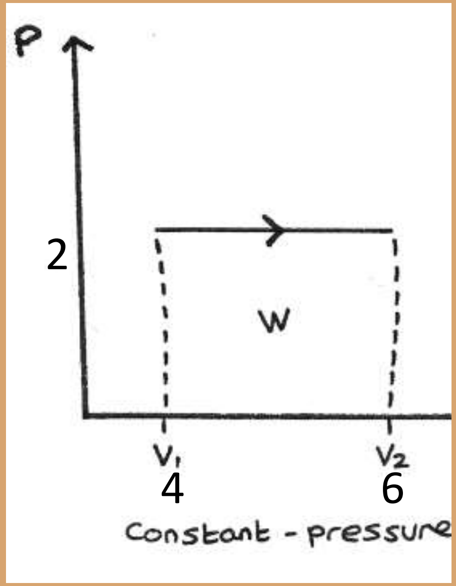
(1)Constant pressure (isobaric)

W= p(v2-v1)

For example:

W =2(6-4)

W =2*2=4 J



(2)Constant volume(isochoric):

W = p(v2-v1)

There is not different in the volume

(v2-v1)=0

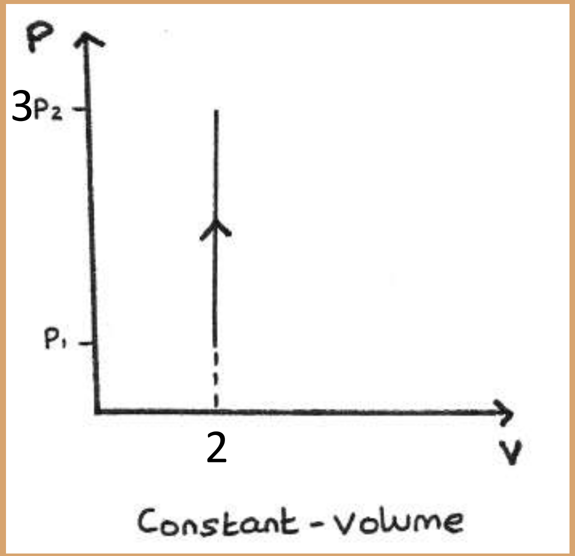
W = 0

For example:

W =p(v2-v1)

W=3(2-2)

W=3*0=0 J



(3)Constant temperature(isothermal):

pv =nRT

p =nRT/v

P has an inverse relation with volume

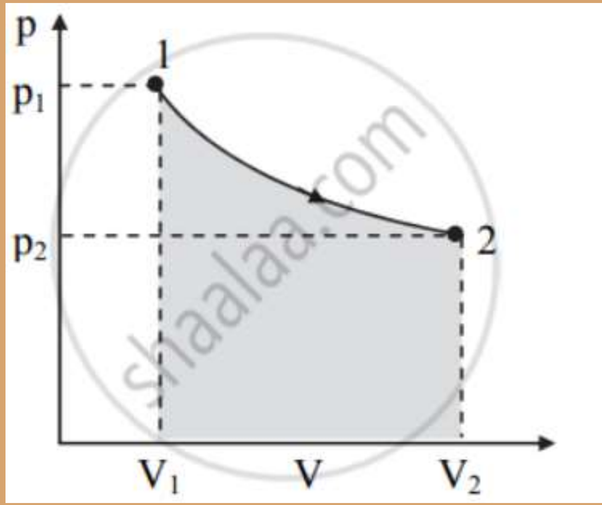
W=NRT(ln(v2/v1))

Where:

N , t are constant

R is constant = 8.31*J/mole*k

K is kelvin that = Celsius +273



pressure

Life application viscosity:

- **Lubrication of machines**
- **Blood precipitation rate test**

Pdv work:

- **The Principle of Detailed Variance (PDV) work is a principle that states that any energy changes experienced by a thermodynamic system must be accounted for by changes in the enthalpy, internal energy, and/or entropy of the system.**
- **This means that when energy is added to or removed from a system, the resulting changes to its enthalpy, internal energy, and/or entropy can be calculated with the help of thermodynamic equations.**
- **The PDV considers all three sources of heat: non-flow (enthalpy), heat transfer (internal energy), and entropy. By considering these three aspects together, this principle helps define the relationship between events throughout the entire process.**

Pdv work is A force acting on a system can heat it up (or cool it down), by working on it. A change in temperature produced in a system can be used to produce mechanical work.

- **At any point in the process, the system (gas) will have temperature T, pressure p and volume V. $dW = Fds = pAds = pdV$.**

dW: Infinitesimal amount of work done on the system.

F: Force applied on the system.
ds: Infinitesimal displacement of the system.
p: Pressure of the system.
A: Cross-sectional area of the system.
dV: Infinitesimal change in the volume of the system.

- The first term "dW = Fds" represents the work done on the system due to an external force applied to it, where "F" is the force and "ds" is the displacement of the system.
- The second term "pAds" represents the work done on the system due to a change in its

volume against a constant external pressure, where "p" is the pressure, "A" is the cross-sectional area, and "ds" is the displacement of the system.

- The third term "pdV" represents the work done on the system due to a change in its volume against a constant pressure, where "p" is the pressure and "dV" is the change in volume.

Together ,these equations express the difference forms of work done on a system , debending on conditions under which the work is done:

- **Consider a system consisting of a gas in a cylinder fitted with a piston. During the initial condition of the piston i.e., when the piston is at position (1), the pressure inside the cylinder is P1 and the volume is V1. Let the gas expands as the piston moves to position**

2). Then the pressure falls to P2 and volume will increase to V2.
• Now, consider a small movement of the piston dl during which pressure P is assumed to be constant. If a is the cross sectional area in m2

, then the force acting on the piston is given by –
• F = P x a work energy theorm

Work- energy theorm

If I have a ball in my hand and I throw it, it will speed up, Why it will speed up?
Because when I push it I put force on it.
• Any object you put force on it, it will accelerate.
(Newton's second law) states that: F = ma
• After I throw the ball it was gained Kinetic Energy (K.E); Due to the work done by me.

+Work → Add K.E
-Work → Remove K.E
Being at rest → K.E = Zero

Work is an action done on an object that displaces the object

- if you push a box with your hand pararel to the displacement of the box

All the force goes towards work.

- But in case of pushing, it with a downward angle only the x component will affect it

(work is a scalar quantity)

Energy is the capacity to do work

- Net work = change in kinetic energy
- If I add work for object on rough surface, it will increase K.E, but the friction will

decrease

it and remove K.E.

So, W = F S, where (s) is Displacement

I → want in this equation velocities; Due to K.E → W = m a s

the work done on an object is equal to its change in kinetic energy, where "W" is the work done, "m" is the mass of the object, "a" is its acceleration, and "s" is the distance over which the work is done

- There is , V2= U2+ 2 a s

V2/u2=as

W = M[v2-u2/2}

2 → Is the Final K.E (Kf), and divided by 2 to get

the Initial K.E (Ki), So the final equation will be → W = Kf – Ki

conservation of energy:

- **The total energy of the fluid is conserved as a consequence of the law of conservation of energy.**
- **The total energy of a fluid system is equal to the sum of the kinetic and potential energies of the fluid.**

Total mechanical energy =K-E-+P-E-

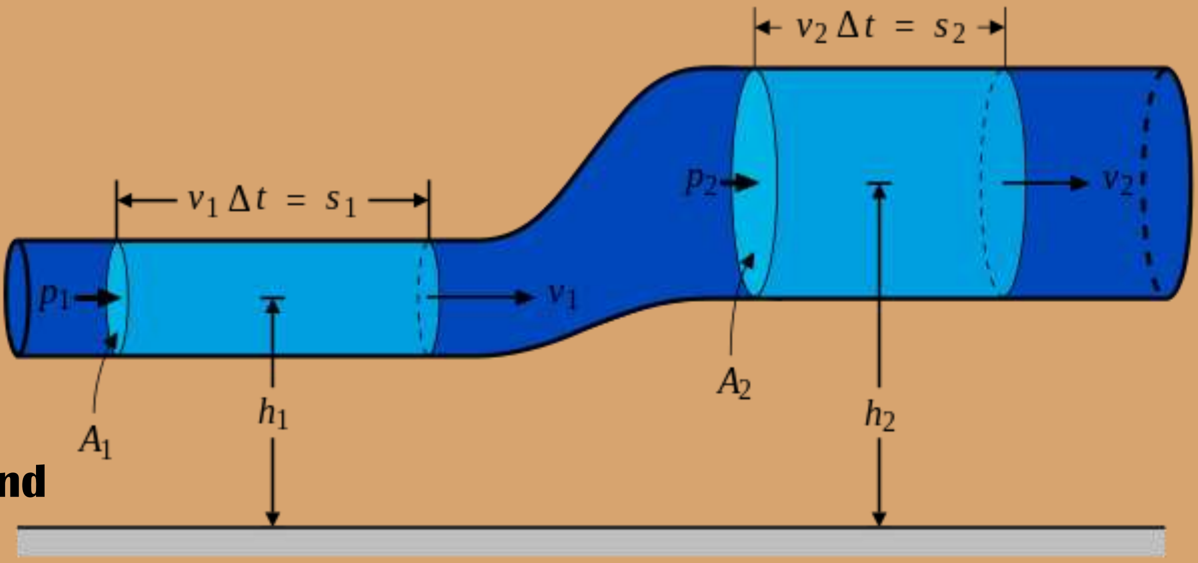
In a fluid flow system, the conservation of energy states that the change in the total energy of the fluid is equal to the energy added to or removed from the system

In reality, the head loss due to friction results in an equivalent increase in the fluid's internal energy (temperature increases). This phenomenon can also be seen in the case of reactor coolant pumps.

Bernoulli equation

- Bernoulli equation, or the incompressible steady flow energy equation, is considered one of the most well-known equations in physics (fluid mechanics) and it explains the conservation of mechanical work energy of a fluid in a mainstream.
- Bernoulli's principle states that as the speed of a moving fluid increases (liquid or gas), the pressure within the fluid decreases.
- Occurs in inviscid incompressible laminar steady fluid (ideal fluid)
- The equation was published in 1738 by Daniel Bernoulli (a Swiss physicist) to help us understand the fluid flow.
- It relates the pressure, speed, and height of any two points (1 and 2) in a steady streamlined flowing fluid of density ρ.

p1: pressure caused in the A1
P2: pressure caused in the 2nd on
A2
A1: 1st cross section
A2 : 2nd cross section
V1: initial velocity of the fluid
V2: final velocity of the fluid
S1: the displacement covered by
the fluid in the 1st part
S2: the displacement covered
by the fluid in the 2nd part
h1: the height in the 1st part from a
reference ground
h2: the height in the 2nd part from the reference ground
v : volume of the fluid entered the steam
F1: is the force caused on the fluid in 1st part
F2: is the force caused on the fluid in 2nd part in the opposite direction



1-we learned from the previous LO that P= F/A
so, $F1= P1A1$
$F2 = P2A2$
2-Also, We have known that Work = force * displacement
so, work in the 1st part =
$W1= F1S1$ (using 1) $W1=P1A1S1$
and we know from math that base area* distance = volume (v)
so, $W1=P1\ v$
by doing the same steps in W2: $W2= -P2\ v$
(the negative is because the force caused here is in the opposite direction)
3- We can calculate the net work caused by the fluid in the whole stream by saying Wnet=
$W1+W2=P1\ v- P2\ v$
we can also write it by $Wnet= v(P1-P2)$
So, this equation makes a change in the mechanical energy which =kinetic energy + potential energy
4- So, we can say that $Wnet = \Delta K.E+ \Delta P.E$
5- by taking density and gravitational acceleration as common factors will get:

1) $V(p1-p2)=(1/2mvf2-1/2mvi2)+(mgh2-mgh1)$

by dividing the whole equation by volume (v) :

when we divide mass by volume we get the density of the fluid (d)

- **The symbol of density is rho (Ρ) but to make difference between it and pressure**

2) So. $p1-p2=(1/2dvf2-1/2dvi2)+(dgh2-dgh1)$

5- by taking density and gravitational acceleration as common factors will get:

3) $p1-p2=1/2\ d\ (vf2-vi2)+dg\ (h2-h1)$

4) $P1+1/2\ dvi2+dgh1=p2+1/2\ dvf2+dgh2$

7- from that, we can conclude that:

Where the1/2 dV2 is the kinetic energy per unit volume and dgh is potential energy per unit volume too.
so, we get a relationship between pressure, velocity, and height at any two points in a steady fluid inside a streamline.
the continuity equation and Bernoulli's equation control the fluid in the streamline, where the continuity equation = A1V1=A2V2
so from Bernoulli's equation and from the continuity equation, we can say that when
Area increases
velocity decreases
pressure increases
and vice versa, so, the area is inversely proportional to velocity and varies directly with Pressure.

Warning!!!!!
There are some special cases Bernoulli equation

1-we have two cases to neglect the potential energy used in the equation
firstly, when we had the fluid in a horizontal line so the difference between the two heights will be equal to zero

$$P_1 - P_2 = 1/2\, d\, (V_f^2 - V_i^2) + dg\, (h_2 - h_1)$$

$$P_1 - P_2 = 1/2\, d\, (V_f^2 - V_i^2) + dg\, (0)$$

so, the equation will be

$$P_1 - P_2 = 1/2\, d\, (V_f^2 - V_i^2)$$

secondly, when the kinetic energy is very high like during flying in plans, the P.E will be equal to zero, too.
(important: we measure the height from the center line of the fluid)
2- sometimes, we have the first cross-sectional area is much bigger than the other one, and by applying the continuity equation, and by squaring in Bernoulli's equation we can neglect the first velocity so the equation will be

$$P_1 - P_2 = 1/2\, d V_f^2$$

applications in Bernoulli theorm

How aircraft wings generate lift can be explained by Bernoulli's equation for fluids.

In the case of flight, the fluid flowing above the wing of the aircraft moves faster than the flowing under the wing, and according to Bernoulli's principle this causes the creation of a region of low pressure above the surface of the air and a region of high pressure under the plane and this pressure difference is what generates altitude.

That is, we can explain the reason for the shape of the wings and their upward curvature (according to Bernoulli's theory) that the air passes at a higher speed on the upper surface than the lower one.

The difference in air velocity is calculated using Bernoulli's principle of difference in pressure.

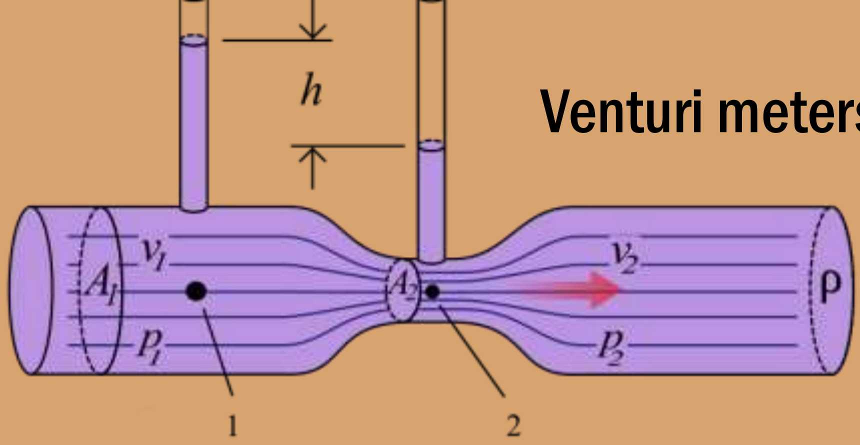
and we know $\Delta P = F/A = 1/2\ d\ (Vf2 - Vi2)$

so the force of lifting of the plan $= 1/2\ dA\ (Vf2 - Vi2)$

Venturi meters

Venturi meters are used to measure the speed of liquid that use a converging section of pipe to give an increase in the flow velocity and a corresponding pressure drop from which the flow rate can be deduced.

They have been in common use for many years, especially in the water supply industry.



Venturi meters

but how does it work??

Venturi meter's operation is based on Bernoulli's equation.

This states that an incomprehensible fluid's flow has constant energy at any point.

This particular relationship means that the pressure decreases when the velocity increases, so Venturi meters are used where velocity increases are desired.

Venturi meters are constructed in such a way the cross-sectional area in the middle of the meter is smaller than that of the inlet.

This increases the velocity of the flow and means that there is a pressure difference between the inlet and the throat of the meter.

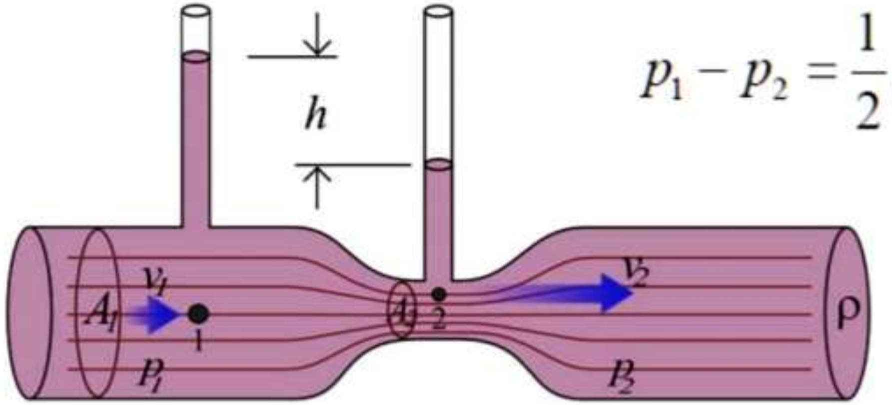
Using a differential manometer, this pressure difference can be measured and the flow rate can be determined from this. There is very little pressure loss with a Venturi meter, meaning that it measures flow rate with very high accuracy.

In order to understand how the flow will change, we can calculate the expected changes in the flow rate. Bernoulli's equation is used as a base to define the system.

(Shown below; where p1 and p2 are the pressures, v1 and v2 are the velocity [flow rate] and p is the density of the liquid)

to sum up

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2.$$



$$p_1 - p_2 = \frac{1}{2}\rho v_1^{\,2}\left(\frac{A_1^{\,2}}{A_2^{\,2}} - 1\right)$$

Get p1 – p2 from hydrostatics

$$p_2 = p_1 + \rho g h_1.$$

$$Q = A_1\sqrt{\frac{2}{\rho}\cdot\frac{p_1 - p_2}{\left(\frac{A_1}{A_2}\right)^2 - 1}} = A_2\sqrt{\frac{2}{\rho}\cdot\frac{p_1 - p_2}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

Iorriecelli's theorem

Torricelli's law is a principle of fluid dynamics. The law describes the relationship between the exit velocity of an ideal fluid from a small hole and the depth of fluid above that hole.
The fluid leaves through the hole with velocity same as it would experience if dropped from the same height to the hole level.
If the liquid is dropped from a height "h", it would have a velocity v and this "v" is the same velocity at which the liquid leaves the hole when the height of fluid "h" is same as the liquid dropped in the container.
Assuming that the fluid is incompressible,

Viscosity

measure of a fluid's resistance to flow.
The amount of resistance offered by the fluid to shear stress.
Or
The resistance of a fluid to a change in shape or movement

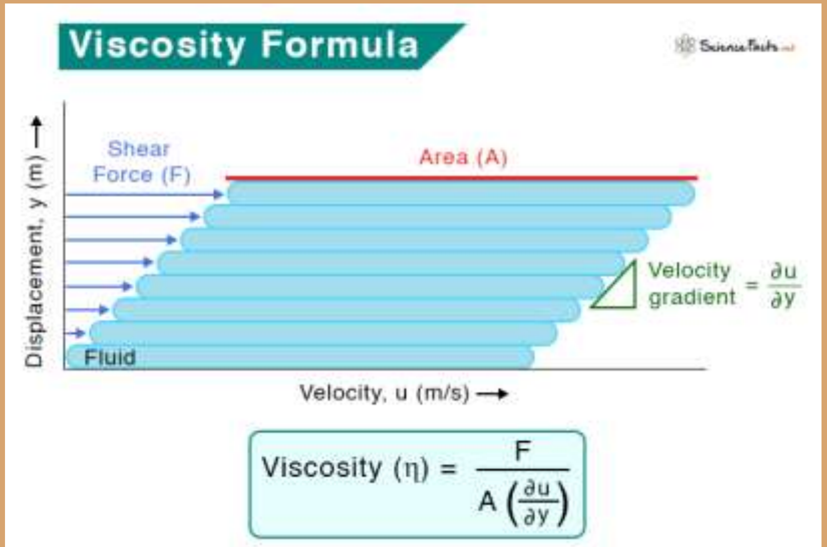
- **A fluid that offers no resistance to shear stress is called an inviscid fluid.**

The friction between the liquid layers during its flow. This friction produces a force that resists the sliding of the liquid layers above each other when it flows.

The higher Viscous liquid:

shows higher resistance to its own motion and its flow.
shows higher resistance to the motion of bodies through it.
Force of viscosity
1-The layer which is adjacent to the moving plate is moving with the same velocity of the plate(v).
2-The layer which is adjacent to the fixed plate is static (boundary plate)
3-The remaining layers between the two plates are moving with velocities that increases gradually from zero at the fixed plate to v at the moving plate.
So, the force of viscosity (tangential force) = $\mu * (Av/d)$

- **μ is viscosity coefficient**
- **A is an upper area that force acting on**
- **V is velocity**
- **D is the perpendicular distance that separated the two layers**



what are the factors those affecting the force?

- **Area of moving layer is directly proportional to the force**
- **Velocity difference between the two layers is directly proportional to the force**
- **The distance between two layers is inversely proportional to the force**

Viscocty coefficient

It equals numerically the tangential force that acts upon a unit area of a liquid causing a velocity difference of one unit between two layers separated by a perpendicular distance of one unit.

μ=fd+/au =n.s/m2

The SI unit of viscosity is Poiseuille (PI)

1) Types of fluid at the same temperature

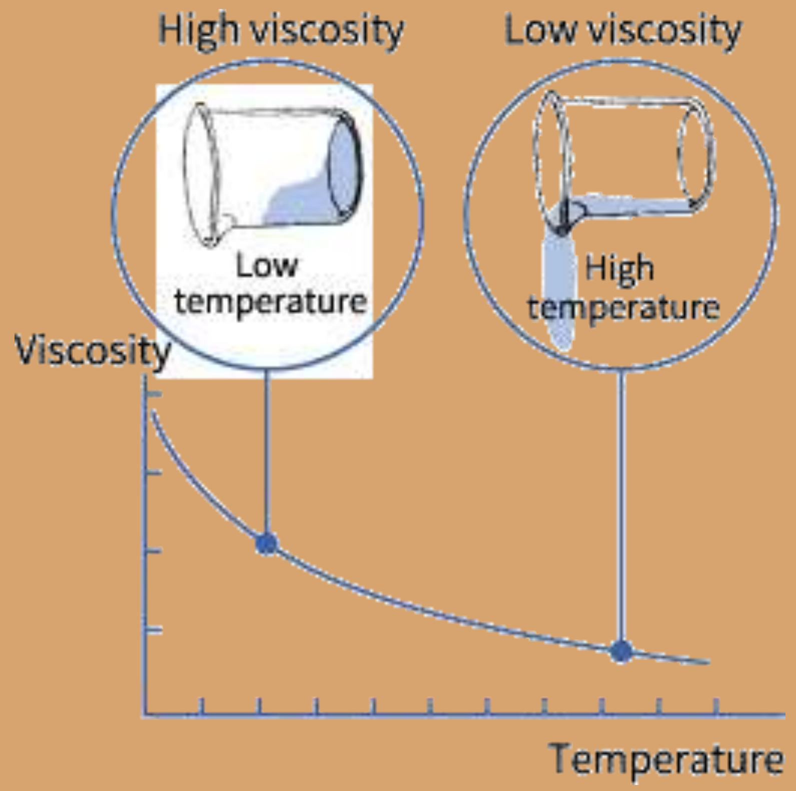
- Honey has low flow rate bec, it has high viscosity
- Water has high flow rate bec, it has low viscosity

2) Temperature of fluid

- The liquid viscosity decreases by increasing temperature
- The gases viscosity increases by increasing temperature

3) Flow conditions

- For laminar flow, the viscosity of liquid remains constant
- For turbulent flow viscosity of liquids changes.



1)How much power is theoretically available from a mass flow of 1 000 kg/s of water that falls a vertical distance of 100 m?

a. 980 kW

b. 98 kW

c. 4 900 W

d. 980 W

ANS: A

2)A fluid is drawn up through a tube as shown below. The atmospheric pressure is the same at both ends. Use Bernoulli's equation to determine the speed of fluid flow out of the tank. If the height difference from the top of the tank to the bottom of the siphon is 1.0 m, then the speed of outflow is:

a. 1.1 m/s

b. 2.2 m/s

c. 4.4 m/s

d. 8.8 m/s

ANS: C

3) It takes 2.0 minutes to fill a gas tank with 40 liters of gasoline. If the pump nozzle is 1.0 cm in radius, what is the average speed of the gasoline as it leaves the nozzle? (1 000 liters = one cubic meter)

a. 0.27 m/s
b. 1.1 m/s
c. 11 m/s
d. 64 m/s

ANS: B

4) Water is being sprayed from a nozzle at the end of a garden hose of diameter 2.0 cm. If the nozzle has an opening of diameter 0.50 cm, and if the water leaves the nozzle at a speed of 10 m/s, what is the speed of the water inside the hose?

a. 0.63 m/s
b. 0.80 m/s
c. 2.5 m/s
d. 10 m/s

ANS: A

5)Water comes down the spillway of a dam from an initial vertical height of 170 m. What is the highest possible speed of the water at the end of the spillway?

a. 15 m/s

b. 25 m/s

c. 58 m/s

d. 1 370 m/s

ANS: C

6). Water pressurized to 3 · 105 Pa is flowing at 5.0 m/s in a pipe which contracts to 1/3 of its former area. What are the pressure and speed of the water after the contraction? (Density of water = 1 · 103 kg/m3.)

a. 2 · 105 Pa, 15 m/s

b. 3 · 105 Pa, 10 m/s

c. 3 · 105 Pa, 15 m/s

d. 4 · 105 Pa, 1.5 m/s

ANS: A

7) A fountain sends water to a height of 100 m. What must be the pressurization (above atmospheric) of the underground water system? (1 atm = 105 N/m2)

a. 1 atm

b. 4.2 atm

c. 7.2 atm

d. 9.8 atm

ANS: D

8) The Garfield Thomas water tunnel at Pennsylvania State University has a circular cross-section that constricts from a diameter of 3.6 m to the test section, which is 1.2 m in diameter. If

the speed of flow is 3.0 m/s in the large-diameter pipe, determine the speed of flow in the test section.

a. 9.0 m/s

b. 18 m/s

c. 27 m/s

d. 10m/s

ANS: C

9) A Boeing-737 airliner has a mass of 20 000 kg. The total area of the wings is 100 m2. What must be the pressure difference between the top and bottom of the wings to keep the airplane up?

a. 1 960 Pa
b. 3 920 Pa
c. 7 840 Pa
d. 15 700 Pa

ANS: A

10) How much air must be pushed downward at 40.0 m/s to keep an 800-kg helicopter aloft?

a. 98.0 kg/s
b. 196 kg/s
c. 294 kg/s
d. 392 kg/s

ANS: B

11) An ideal fluid through a pipe of circular cross-section made of two sections with a diamer 2.5cm and 3.75cm . the ratio of the velocities in the two pipes

a. 9:4
b. 3:2
c. 6:7
d. 8:15

ANS: A

12) water is flowing trough a horizontal tube having unequal area of cross section. At the most narrow place of pipe

a. pressure maximum and velocity minimum
b. velocity of water is maximum and pressure minimum
c. both velocity and pressure will be minimum
d. both velocity and pressure will be maximum

ANS: B

13) water flows through a horizontal pipe at a constant volumetric rate. At a location where the cross-sectional area decreases, the velocity of the fluid

a. stays the same

b. decreases

c. increases

d. none

ANS: c

14) water is flowing with the rate of 2kg/m3 through a water tap. If the area of tap is 10-4 m2 find velocity through this tap (given density of water is 1000 kg/m3)

a. 20 m/s

b. 30 m/s

c. 40 m/s

d. 10 m/s

ANS: A

15) An ideal liquid is flowing trough a pipe of varying cross section area, the velocity of flowing liquid

a. will decreases where cross section area increases
b. will remain constant trough pipe
c. initially will be maximum and later decreases continually
d. will increases where cross section area decreases

ANS: d

16) water flows into a pipe of diameter 7cm at 20 km/hr and exits trough ‘n” number of holes each diameter 1cm from the other end at 70 km/hr . find n

a. 14
b. 7
c. 21
d. 28

ANS: A

17) One end of a cylindiric pipe of cross-section 6.6 cm2 has 14 holes each of radius 1mm . if water is flowing in the pipe at 1m/min then what is the speed (in m/s) of efflux through the holes ?

a. .25
b. .125
c. .625
d. .5
ANS: a

18) Principle of continuity is based on conversation of :
A. both c&b
b. energy
c. mass
d. none

ANS: c

19) For a liquid flowing in a pipe where cross section area changes from A1 to A2 and velocity of flow changes from v1 to v2 ,then A1.V1=A2.V2 is called

a. equation of conversation of energy
b. equation of continuity
c. equation of translation

d. equation of magnification

ANS: b

20) water is flowing inside a tube of uniform radius ratio of radius of entry and exit terminals of the tube is 3:2 then the ratio of velocities at entry and exit terminals will be:

a. 8:27
b. 9:4
c. 1:1
d. 4:9

ANS: d

21) A stream of water flowing horizontally with a speed of 20 m/s pushes out of a tube of cross-sectional area 10-1 m2 and hits at a vertical wall assuming that it does not rebounded ?

a. 40000 N
b. 400N
c. 2250N
d. 4000N

ANS: A

22) The depth of ocean is 5000m. calculate the pressure exerted by water at the bottom of the ocean (take g= 10 m/s2)

a. 50.107 N/m2
b. 2.5.107 N/m2
c. 5.107 N/m2
d. 25.107 N/m2

ANS: C