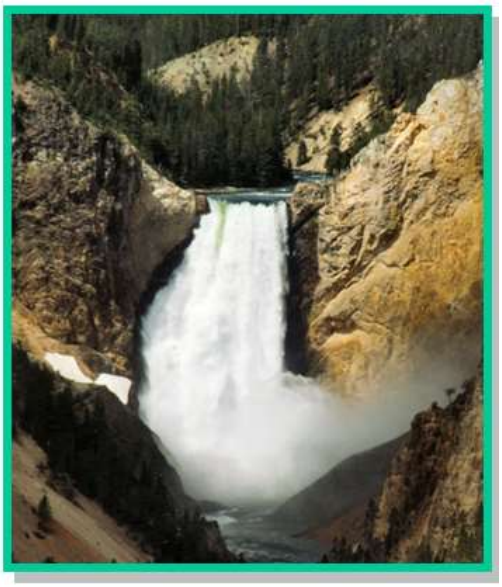
Dynamic Fluid

- Fluid Flow
- Streamlines
- Fluids characteristics
  - Steady and unsteady flow
  - Uniform and Non-uniform flow
  - Rotational and irrotational.
  - Laminar and turbulent flows
  - Viscous or non-viscous.
  - Incompressible and compressible
  - Ideal and Real flow
- Ideal Fluids in Motion
- Flow Rate and the Equation of Continuity
- Bernoulli's Equation
- Torricelli Theorem



14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Fluid Flow

Types of Flow

1- **Depending upon properties of flow**

- Steady and unsteady flow
- Uniform and Non-uniform flow
- Rotational and irrotational.
- Laminar and turbulent flows.
- Viscous or non-viscous.

2- **Depending upon fluid properties**

- Incompressible and compressible
- Ideal and Real flow

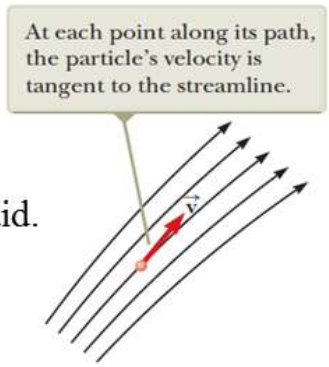
14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

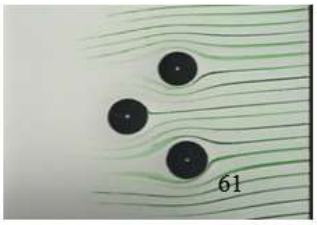
Streamlines خط الانسياب (الجريان)



Descriptions of Fluid Motion

- Streamlines are imaginary curves drawn to show the direction of fluid.
- The **tangent** at any point gives the velocity direction.
- A group of streamlines construct what is known as a **flow pattern**.

- So the streamlines are describing the direction of the flow.
- Streamlines form the flow pattern



14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

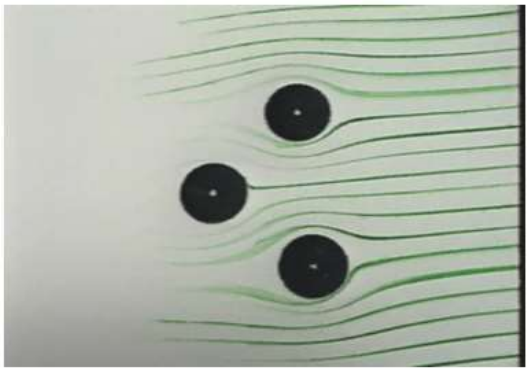
المفاهيم العامة لانسياب مائع

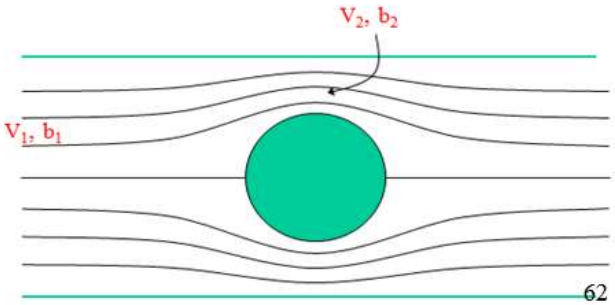
Fluids characteristics:

Streamlines خط الانسياب:

Descriptions of Fluid Motion

- Streamlines are very effective in illustrating the geometry of the fluid flow or even the speed of the flow. As the speed is inversely proportional to the spacing between the streamlines.





14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon properties of flow

Steady Fluid Flow

v is constant

It occurs when the velocity of the fluid particles at any point doesn't change with time.

Unsteady flow

v is variable

It occurs when the velocity at a point in the fluid changes with time.

e.g. flow in a pipe whose valve is opening or closing

14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

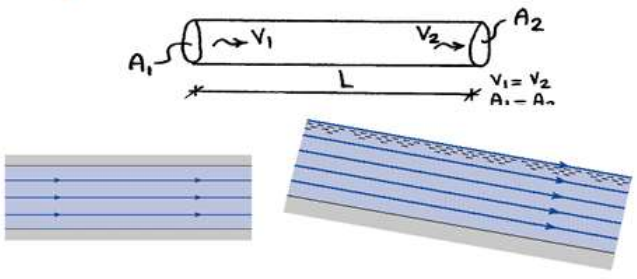
Fluids characteristics:

Depending upon properties of flow

Uniform Flow

v , A is constant

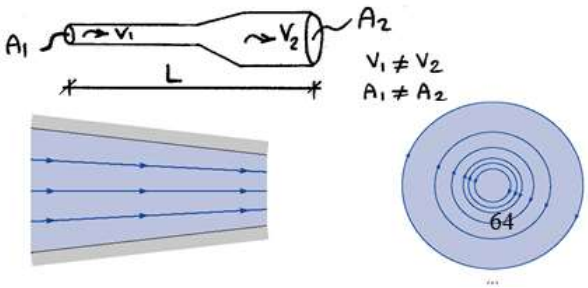
- It occurs when the velocity and cross-section remains constant over a given length.
- The streamlines are straight and parallel.



Non-uniform Flow

v, A varies

- It occurs when the velocity and cross-section changes over a given length.
- The streamlines may not be straight and/or parallel.



14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon properties of flow

Rotational flow

It occurs when fluid particles have a rotation about an axis.

Irrotational flow

It occurs when fluid particles don't have a rotation about an axis.

14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon properties of flow

Laminar Flow

- It occurs when fluid particles followed in parallel paths and do not intersect (a regular straight path to the boundaries of the tube).
- the velocity only in the direction of flow.
- Particles move in layers

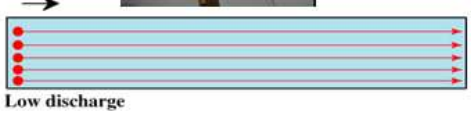
Transitional Flow

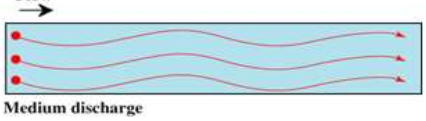
every fluid molecule followed wavy but parallel path that was not parallel to the boundaries of the tube.

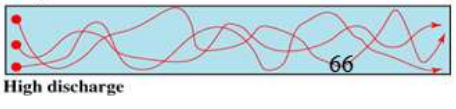
Turbulent Flow

- It occurs when fluid particles moves in random motion. (very complex and irregular path)

e.g. Nearly in all flow in pipes.







14-8 Ideal Fluids in Motion

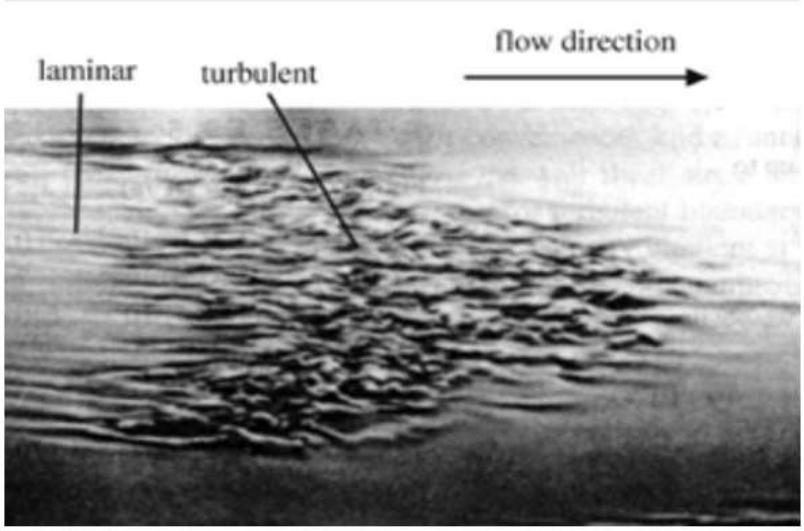
General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon properties of flow

Laminar Flow **Turbulent Flow**



14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon properties of flow

Viscous Flow **Non-viscous Flow**

What is Viscosity?

- **A measure of a material's resistance to flow**

The coefficient of viscosity معامل لزوجة السائل

$$\eta = \frac{F}{A}\frac{d}{v}$$

The unit used for viscosity is: **N.s/m²**

1 Pas = **N.s/m²**

Another unit used for the viscosity is the poise.

1 Poise = 0.1 **N.s/m²**

14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

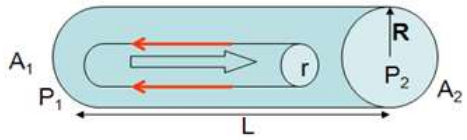
Depending upon properties of flow

Viscous Flow — **Non-viscous Flow**

Fluid velocity

Horizontal tube — **Vertical tube**

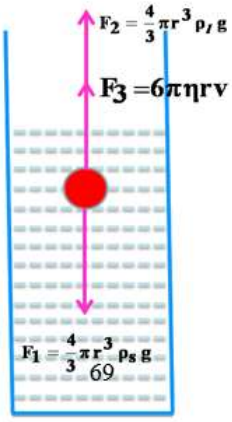
Poiseulle's Equation



$$v = \frac{(P_1 - P_2)}{4\eta L}(R^2 - r^2)$$

Stoke's Method

$$v = \frac{2g}{9\eta} r^2 (\rho_s - \rho_f)$$



14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon fluid properties

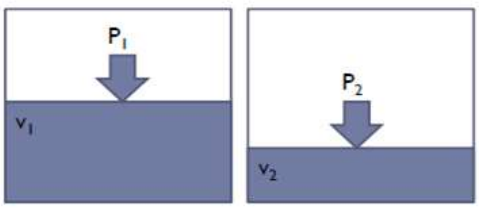
Compressible — **Incompressible**

ρ is variable

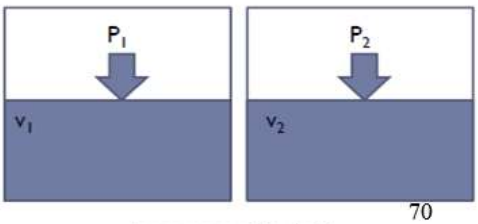
It occurs when the density of fluid changes from point to point and becomes function of temperature and pressure.

ρ is constant

It occurs when the density is constant for fluid flow.



Compressible fluid



Incompressible fluid

14-8 Ideal Fluids in Motion

General Concepts of Fluid Flow

المفاهيم العامة لانسياب مائع

Fluids characteristics:

Depending upon fluid properties

Real fluid

- All fluid that has viscosity, surface tension and is compressible which exists in nature.

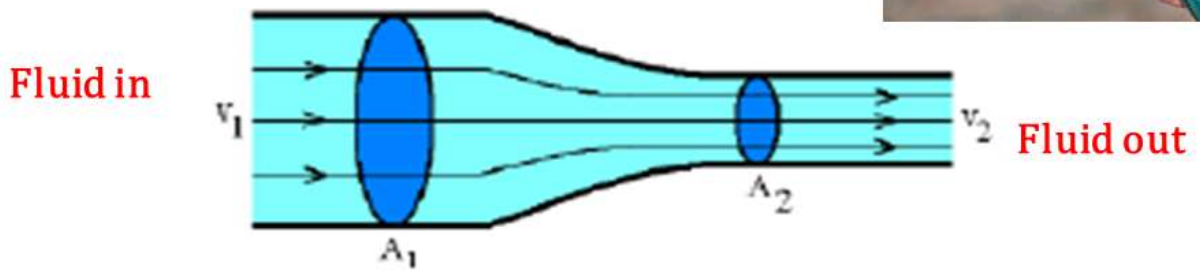
Ideal fluid

An *ideal fluid* is assumed

- to be incompressible
- to flow at a steady rate,
- to be nonviscous
- flows irrotationally.

14-9 The Equation of Continuity

Consider a hose with a decreasing diameter along its length, as shown in the figure



Continuity Equation is a direct consequence of the fact that what goes into the hose must come out

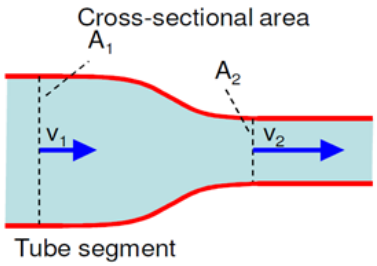
$$R_{in} = R_{out}$$

14-9 The Equation of Continuity

Rate of flow: Quantity of fluid passing through any section in a unit time.

$$\text{Rate of flow} = \frac{\text{Quantity of fluid}}{\text{time}}$$

$$\text{volume flow rate} = \frac{\text{volume of fluid}}{\text{time}} = \frac{V}{t}$$



$$R_v = A\,v = \text{constant}$$ **Equation of Continuity**

R_v = volume flow rate of the fluid: is the volume of the fluid passing through point in a unit time.

A : cross-sectional area at the point

v : Speed of the fluid at the point.

فيض الحجم

Volume Flux

معدل انسياب المائع

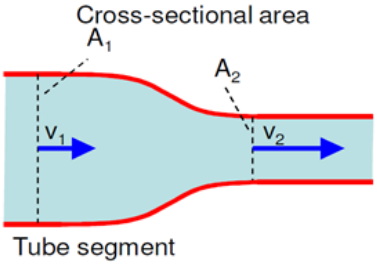
The SI unit of volume flow rate R_V is m^3/s.

14-9 The Equation of Continuity

$$R_v = A\,v = \text{constant}$$

If the pipe is narrower, the flow is faster

If the pipe is wider, the flow is slower



$$A_1\,v_1 = A_2\,v_2$$ **Equation of Continuity**

For an incompressible, frictionless fluid, the flow speed increases when we decrease the cross-sectional area through which the fluid flows.

$$v_1 d_1^2 = v_2 d_2^2$$

$$v_1 r_1^2 = v_2 r_2^2$$

$$A = \pi r^2 = \pi \frac{d^2}{4}$$

The flow **speed increases** when we **decrease the diameter** through which the fluid flows

14-9 The Equation of Continuity

Example

Water flows through a rubber hose 2 cm in diameter at a velocity of 4 m/s.
(a) What must be the diameter of the nozzle in order that the water emerge at 16 m/s?
(b) What is the rate of flow in m^3/s?

14-9 The Equation of Continuity

If no fluid is added or removed from the pipe in any length then the mass passing across different section shall be the same.

$$\text{mass flow rate} = \frac{\text{mass of fluid}}{\text{time}} = \frac{m}{t}$$

$$R_m = \rho R_v = \text{constant}$$

R_m = mass flow rate of the fluid: is the mass of the fluid passing through point in a unit time.
ρ : density of the fluid (uniform)
R_v : volume flow rate of the fluid

the mass that flows into the tube segment each second must be equal to the mass that flows out of that segment each second.

mass Flux

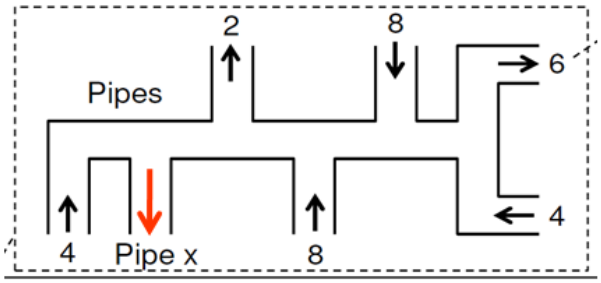
The SI unit of mass flow rate R_m is kg/s.

فيض الكتلة

14-9 The Equation of Continuity

Checkpoint 3

The figure shows a pipe and gives the volume flow rate (in cm3/s) and the direction of flow for all but one section.
What are the volume flow rate and the direction of flow for that section?



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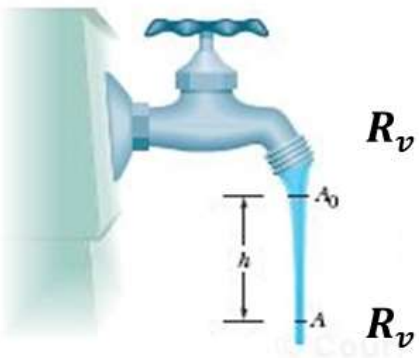
14-9 The Equation of Continuity

Sample Problem:

Figure shows how the stream of water emerging from a faucet "necks down" as it falls. The indicated cross-sectional areas are A_0=1.2cm² and A=0.35cm². The two levels are separated by a vertical distance h=45mm. What is the volume flow rate from the tap?



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14-9 Bernoulli's Equation

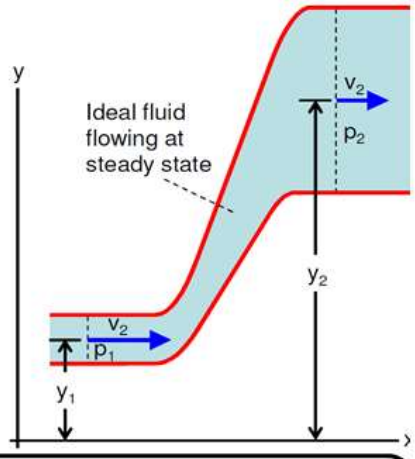
In solid: **E(Total) = E (Potential) + E (Kinetic)**

In fluid: **E(Total) = E (Potential) + E (Kinetic) + PV**

Bernoulli derived an important equation to describe the flow of fluids. This equation is stated that ***the work done on a fluid as it flows from one place to another is equal to the change in its mechanical energy.***

Conservation of energy leads to

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



Total energy per unit volume is constant at **any** point in fluid.

$$p + \tfrac{1}{2}\rho v^2 + \rho g y = const$$

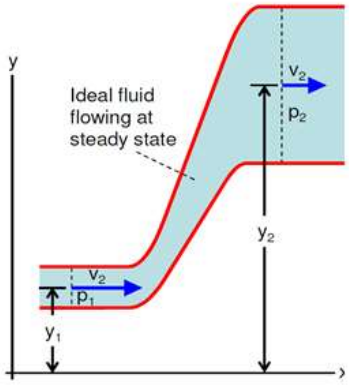
14-9 Bernoulli's Equation

Bernoulli's equation

$$p + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

Pressure, Density, Speed, Elevation, Free-fall acceleration

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



- For a stationary fluid, $v_1 = v_2 = 0$ and we have:

$$p_2 = p_1 + \rho g (y_1 - y_2)$$

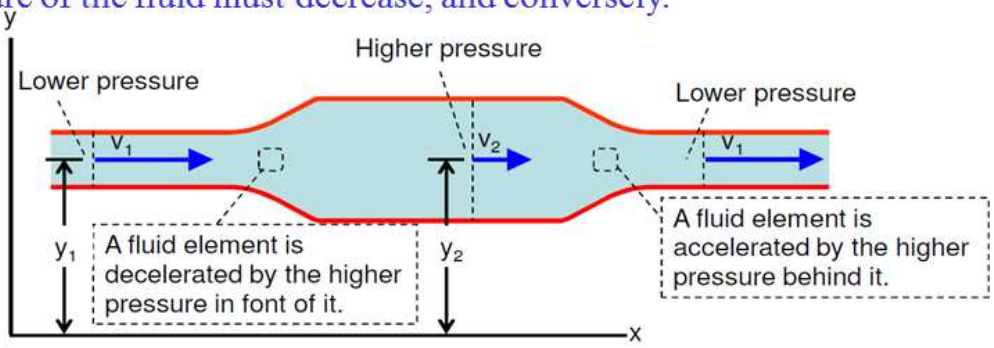
14-9 Bernoulli's Equation

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

- For a horizontal pipe (same elevation), $y_1 = y_2$ and we obtain:

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

If the speed of a fluid element increases as the element travels along a horizontal streamline, the pressure of the fluid must decrease, and conversely.



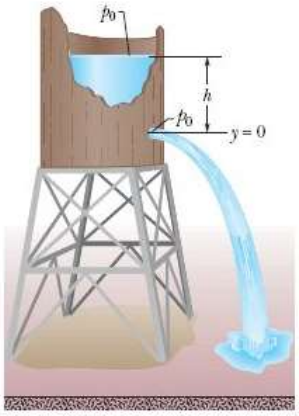
14-9 Bernoulli's Equation

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

- For no change in pressure, $P_1 = P_2$ and we have:

Torricelli's Theorem

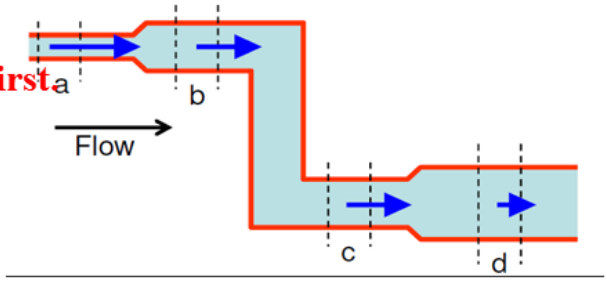
$$v = \sqrt{2gh}$$



14-9 Bernoulli's Equation

Check Point 4:

Water flows smoothly through the pipe shown in the figure.
Rank the four letters sections of pipe according to
(a) the volume flow rate R_V through them,
(b) the flow speed v through them, and
(c) the water pressure p within them, greatest first



14-9 Bernoulli's Equation

Sample Problem 14-7:

Ethanol ($\rho = 791\ kg/m^3$) flows in a horizontal pipe that tapers in cross-sectional area from $A_1 = 1.20 \times 10^{-3}\ m^2$ to $A_2 = A_1/2$.
The pressure difference between the wide and narrow sections is 4120 Pa.
What is the volume flow rate of the ethanol?