# Kinematics of Fluid Flow

Lecture -5

# Introduction

- Up till now we have studied the effect of force on the liquid at rest. Now we will study the motion on liquids without any reference to the force causing motion.
- This lecture deals with the study of velocity and acceleration of the liquid particles without taking into consideration any force or energy.

# Types of Flow

- When a fluid is flowing in pipe, the countless small particles get together and form a flowing stream.
- These particles, while moving, group themselves in a variety of ways, e.g., they move in a regular formation, just as disciplined soldiers do; or they may swirl, like the individuals, in a disorderly crowd.
- The type of flow of a liquid depends upon the manner in which the particles unite and move.

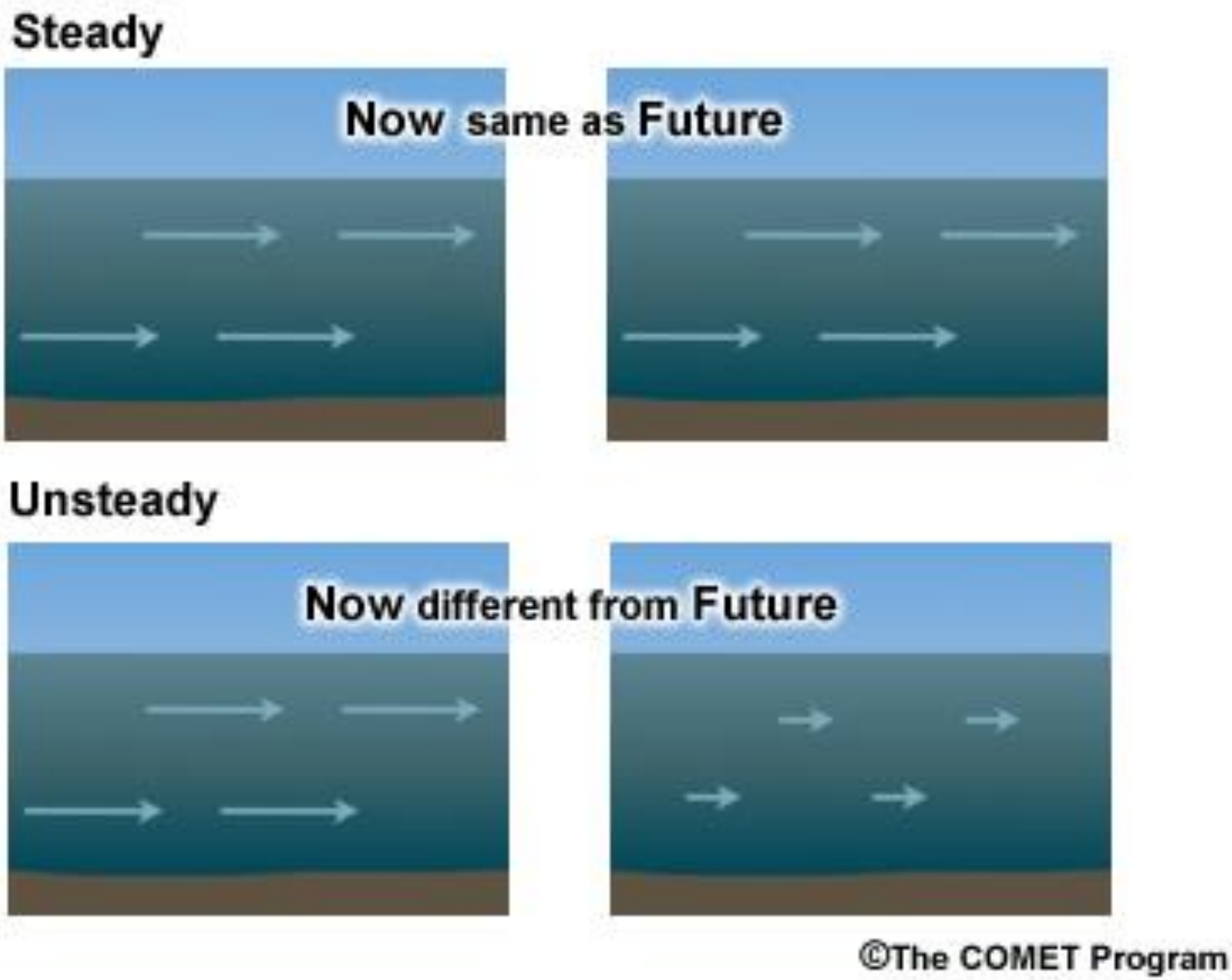
# 1. Compressibility

| Compressible Flow | Incompressible Flow |
| --- | --- |
| - A flow in which the volume of fluid and its density changes during the flow.<br>- All the gases are generally considered to have compressible flows. | - A flow in which the volume of fluid and its density does not change during the flow.<br>- All the liquid are generally considered to have incompressible flows. |

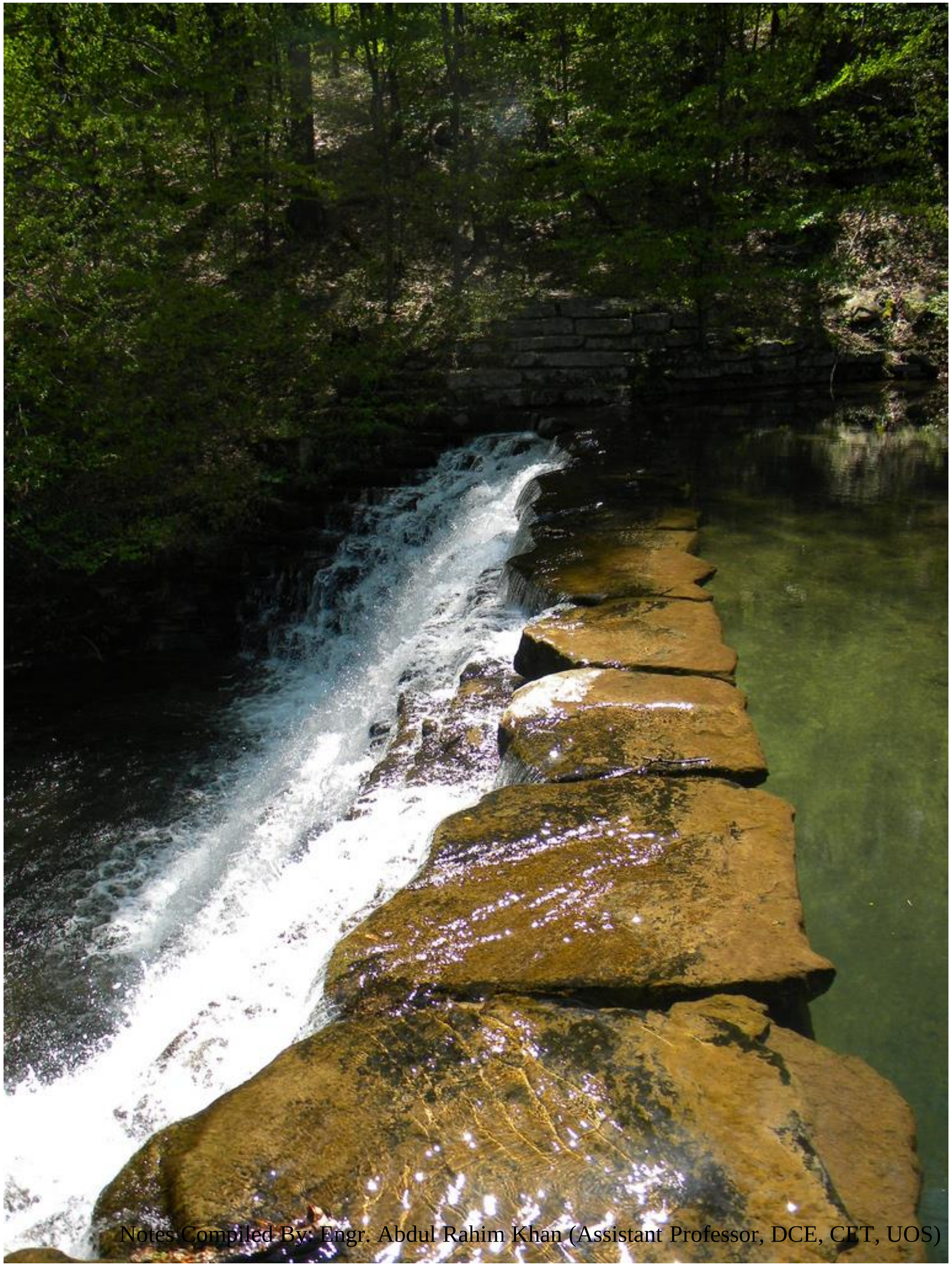
# 2. Steady & Unsteady Flow

| Steady Flow | Unsteady Flow |
| --- | --- |
| A flow in which all conditions (Velocity, pressure, density, discharge) at any point in a stream remains constant with respect to time, but the conditions may be different at different point, is called steady flow. | A flow in which all conditions (Velocity, pressure, density, discharge) at any point in a stream changes with respect to time is called un-steady flow. |

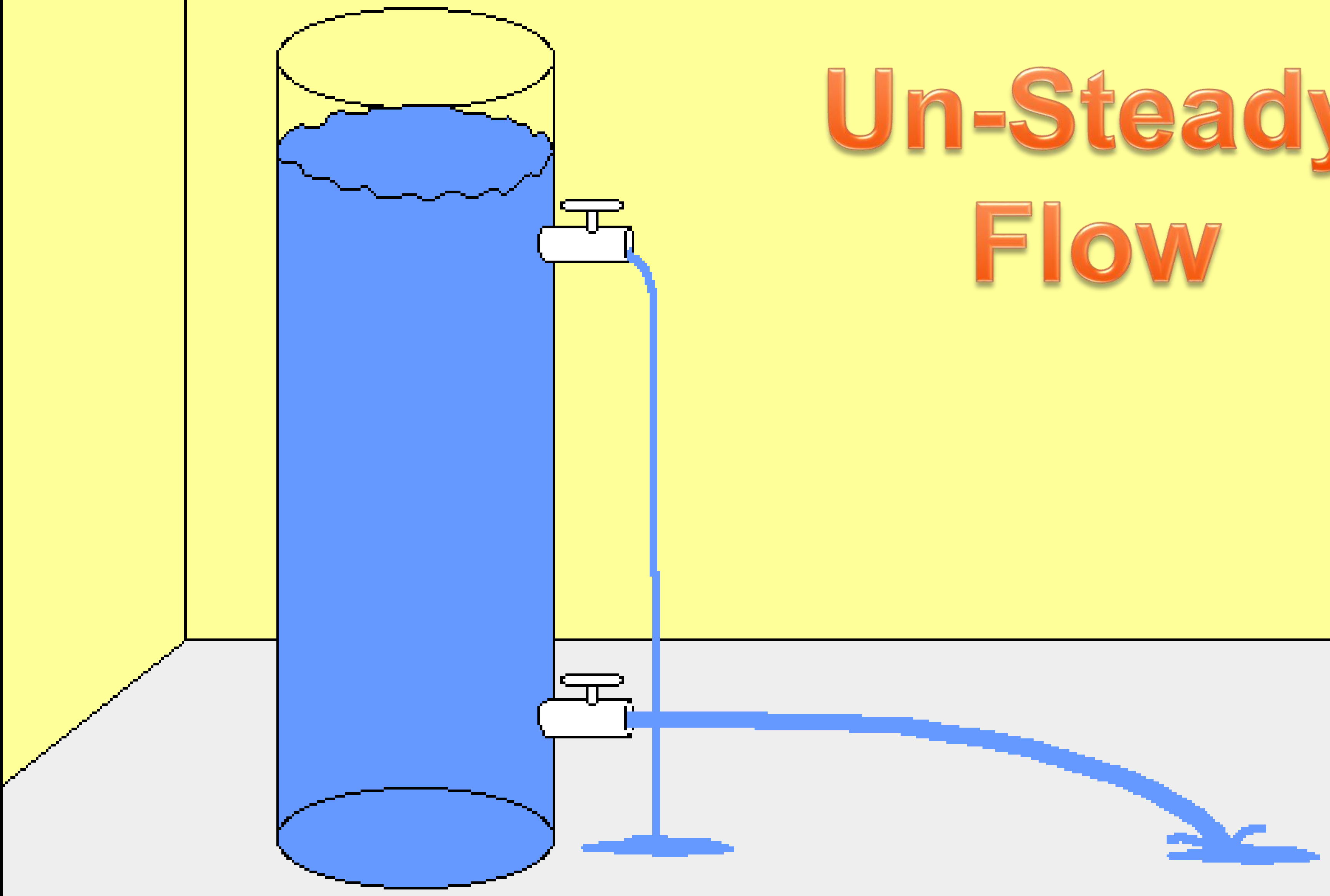
# Steady vs. Non-Steady Flow



# Steady Flow



# Un-Steady Flow



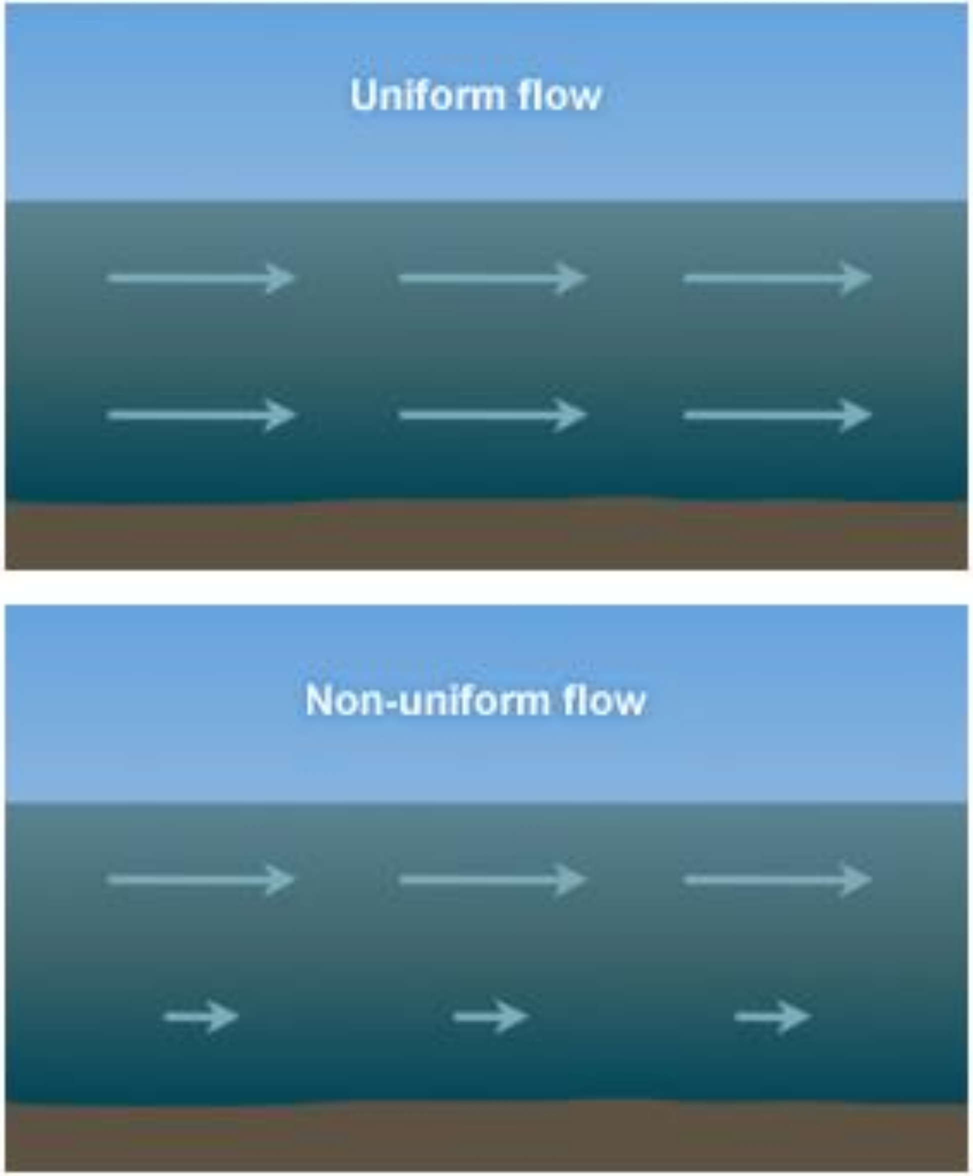
# Steady or Un-Steady Flow…??

**ISLAMABAD: August 03 – All the gates of Rawal Dam Spillway are open to reduce the water level which rises due to recent monsoon rains. APP photo by Irshad Sheikh**

# 3. Uniform & Non-Uniform Flow

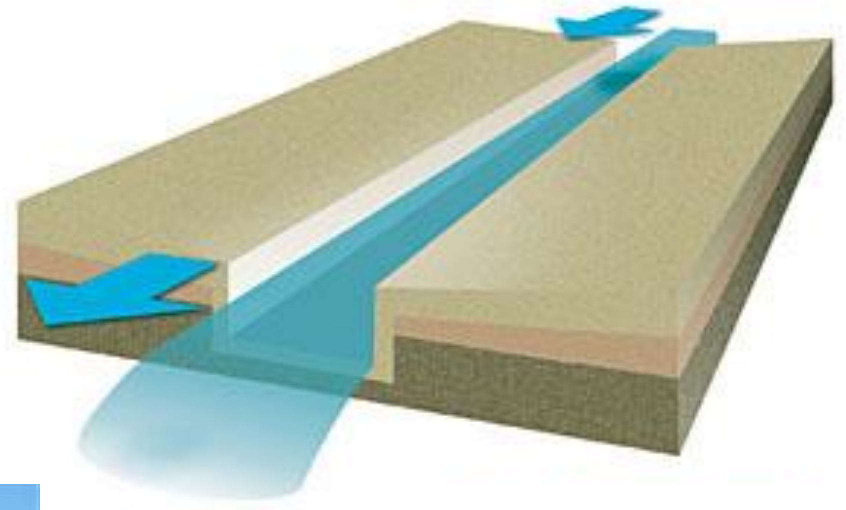
| Uniform Flow | Non- Uniform Flow |
|---|---|
| If the flow velocity at a given instant of time does not change within a given length of pipe or channel, then the flow is called uniform flow. | If the flow velocity at a given instant of time changes within a given length of pipe or channel, then the flow is called non-uniform flow. |

# Uniform vs. Non-Uniform Flow



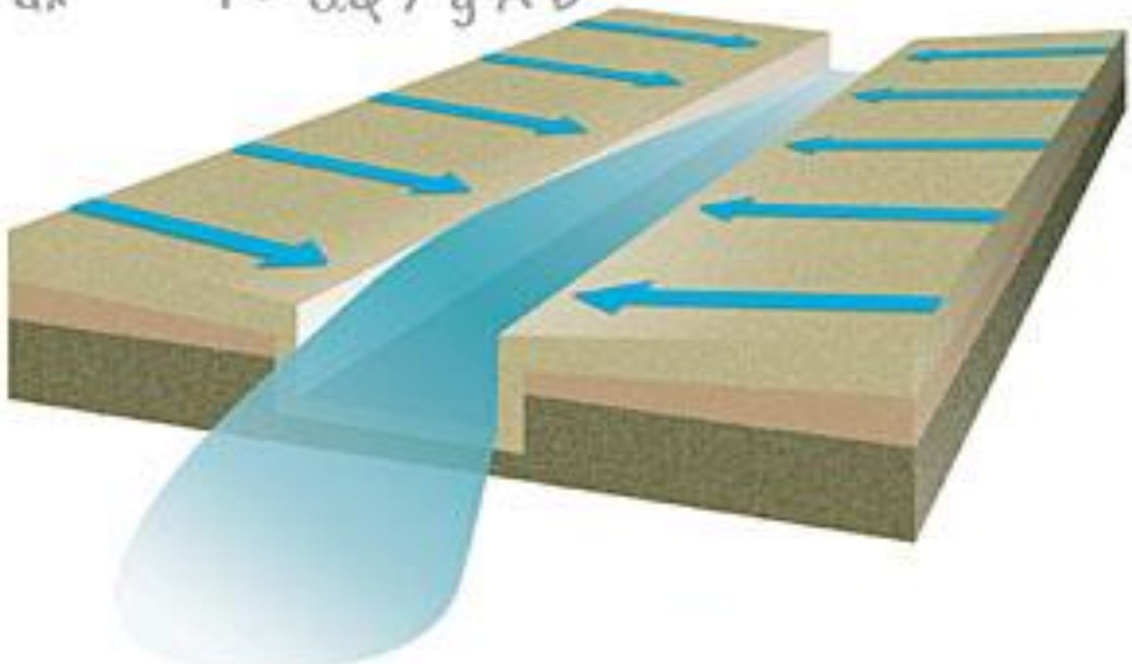
# Uniform Flow

$$Q = A \times V\left(1/n \times m^{2/3} \times s^{1/2}\right)$$



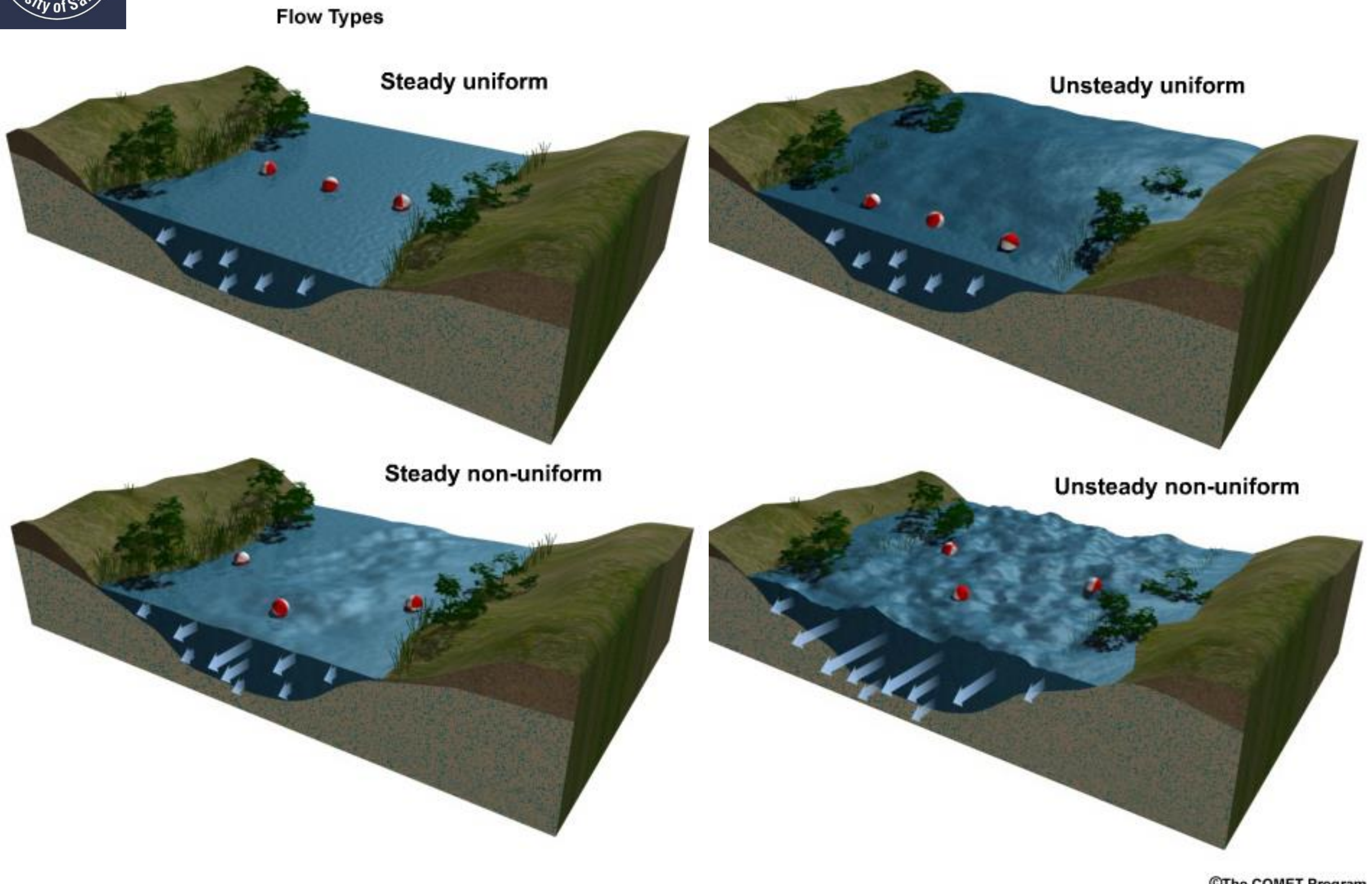
# Non-Uniform Flow

$$\frac{dy}{dx} = \frac{S_o - S_f - 2\alpha Q q / g A^2}{1 - \alpha Q / g A^3 D}$$



# Flow Types (All Combinations):

- **Steady uniform flow:**
  Conditions do not change with position in the stream or with time.
- **Steady non–uniform flow:**
  Conditions change from point to point in the stream but do not change with time.
- **Unsteady uniform flow:**
  At a given instant in time the conditions at every point are the same, but will change with time.
- **Unsteady non–uniform flow:**
  Every condition of the flow may change from point to point and with time at every point.


Flow Types
Steady uniform
Unsteady uniform
Steady non-uniform
Unsteady non-uniform
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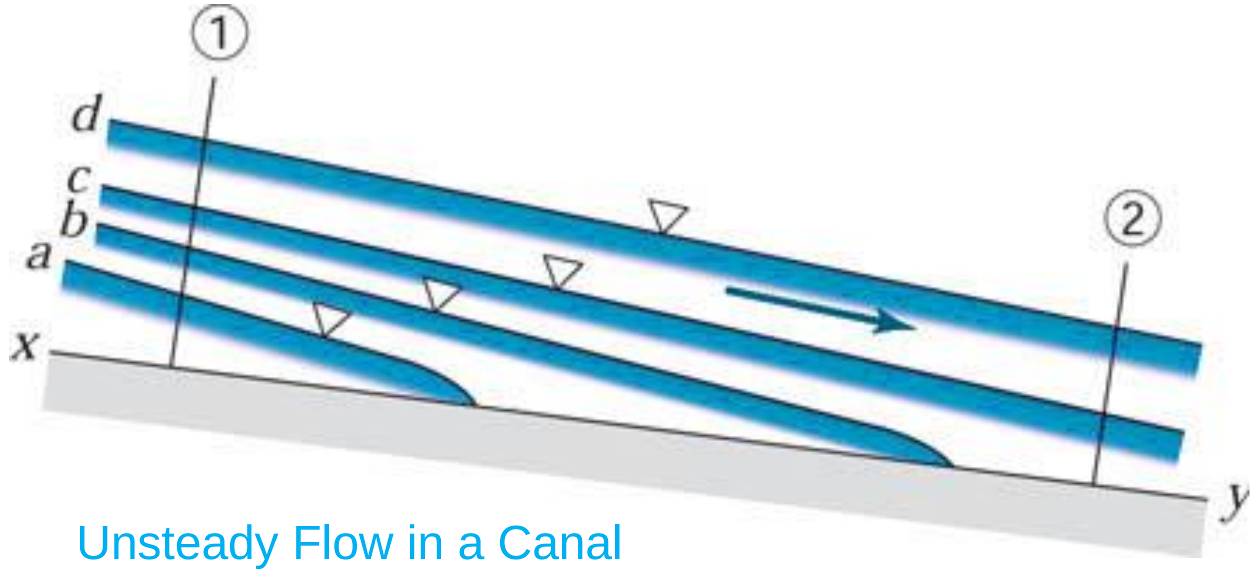
# Unsteady Flow-A transient Phenomenon:

- Unsteady flow is a transient (temporary) phenomenon, which may in time becomes either steady flow or zero flow.
- Example:




Unsteady Flow in a Canal

# Unsteady Flow-A transient Phenomenon:

## Reference - Previous Figure:

- ‘a’ denotes the surface of stream that has just been admitted to the bed of canal by the sudden opening of a gate.
- After a time the water surface will be at ‘b’, later at ‘c’, and finally it reaches equilibrium at ‘d’.
- The unsteady flow has then become mean steady flow.

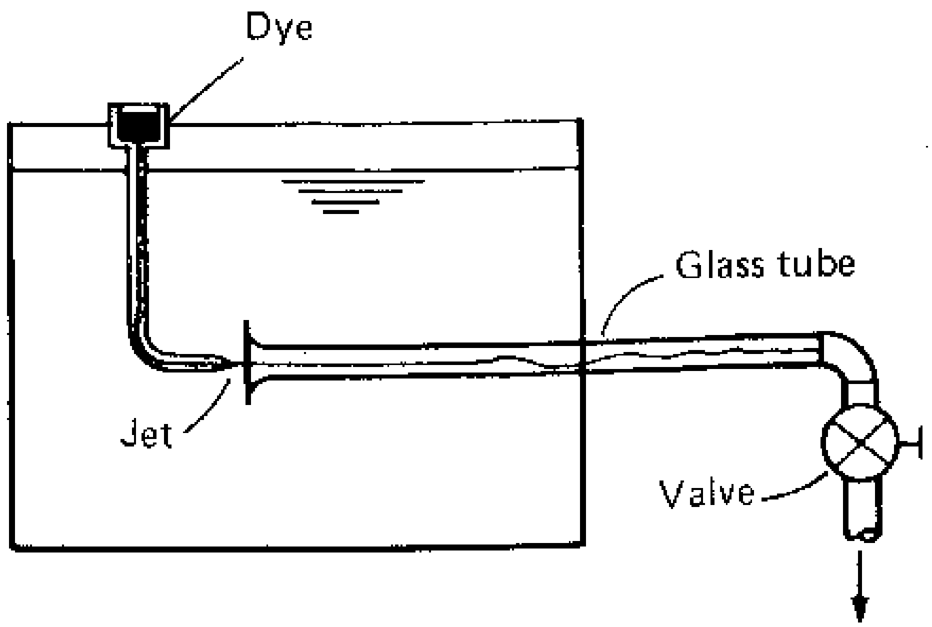
# 3. Viscous Flows

- The viscous flows may be classified into the following two types depending upon the factor, whether the viscosity is dominating or not:

a) Laminar Flow
b) Turbulent Flow

# Reynolds Experiment:

- Osborne Reynolds demonstrated in 1883 that there are two distinctly different type of fluid flow.
- He injected a fine, threadlike stream of colored liquid having the same density as water at the entrance to a large glass tube through which water was flowing from a tank.
- A valve at the discharge end permitted him to vary the flow.



# Reynold's Experiment:

- When the velocity in the tube was small, he saw this colored liquid as a straight line throughout the length of the tube, showing that the particles of water moved in a parallel straight lines.
- As he gradually increased the velocity of water by opening the valve further, at a certain velocity the flow changed.
- The line first become wavy, and then at a short distance from the entrance it broke into numerous vortices, beyond which the color became uniformly diffused so that no streamlines could be distinguished.

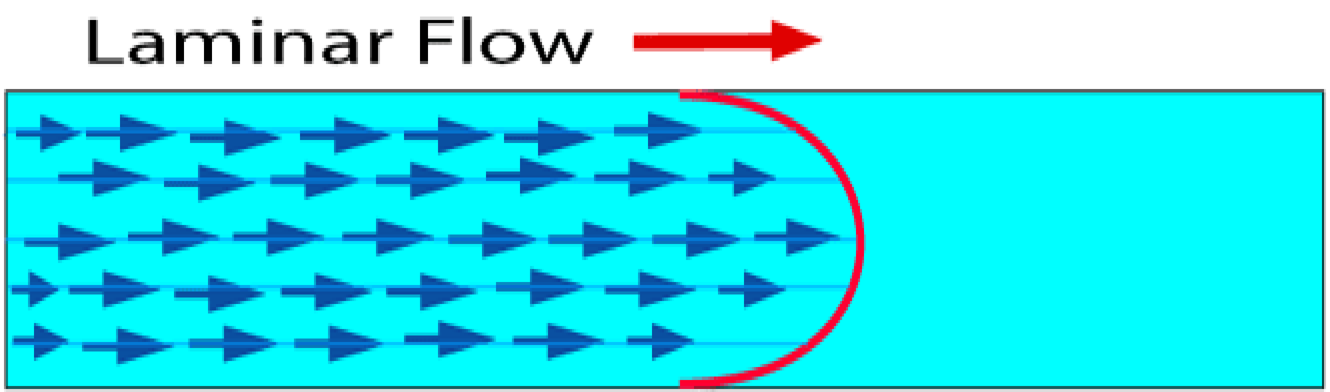
# Reynold’s Experiment:

- Later observations have shown that in this latter type of flow the velocities are continuously subject to irregular fluctuations.
- Reynolds Number may be defined as “Ratio of Inertial to viscous force” it is unit less.
- Flow will be Laminar if Rn< 2300
- Flow will be Turbulent if Rn> 4000
- Transition state if 2300<Rn<4000

# a. Laminar Flow:

- The first type of flow is known as laminar, streamline, or viscous flow.
- Now we can define Laminar Flow as:

"If the liquid particles appear to move in definite smooth paths and flow appears to be as a movement of thin layers on top of each other, then the flow is called laminar flow."

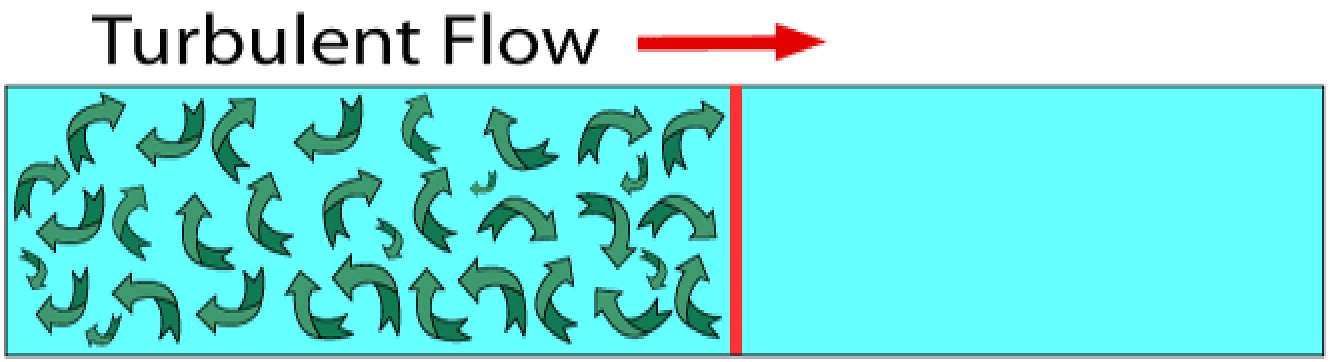


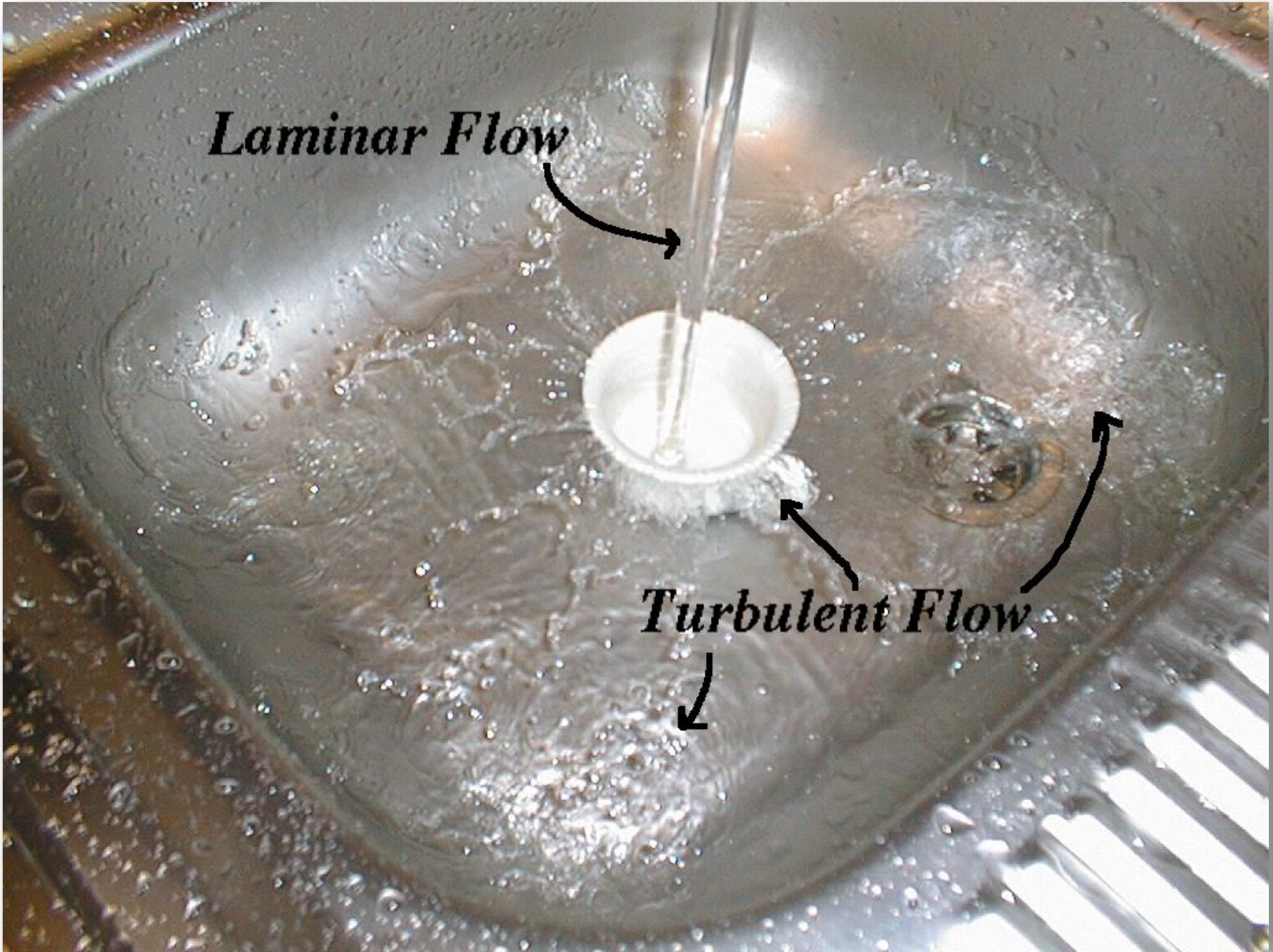
# Laminar Flow

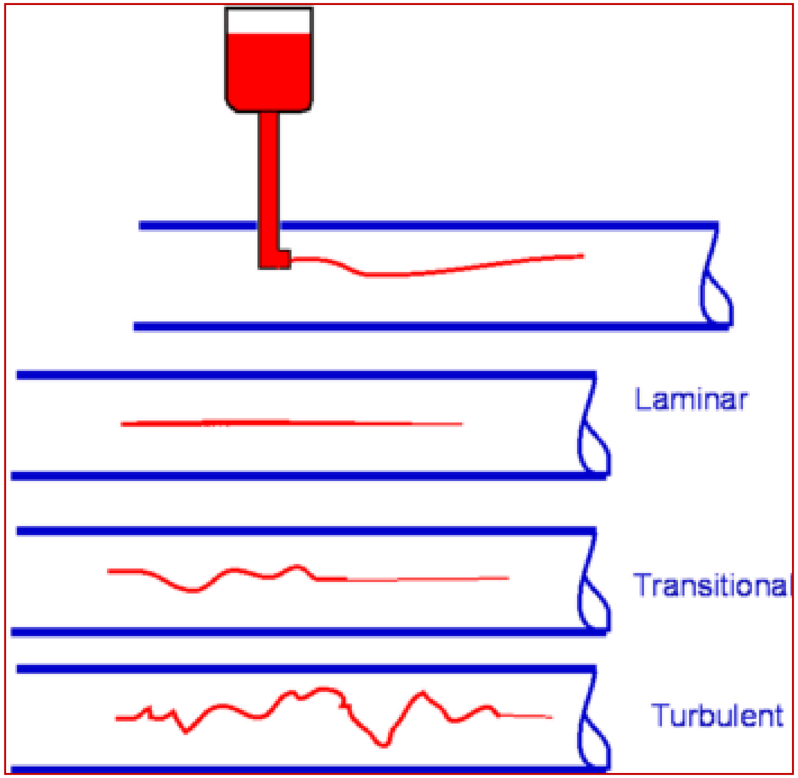
# b. Turbulent Flow:

- The second type of flow is known as turbulent flow.
- It can be defined as:

"The liquid particles move in irregular paths which are not fixed with respect to either time or space."




Laminar Flow
Turbulent Flow



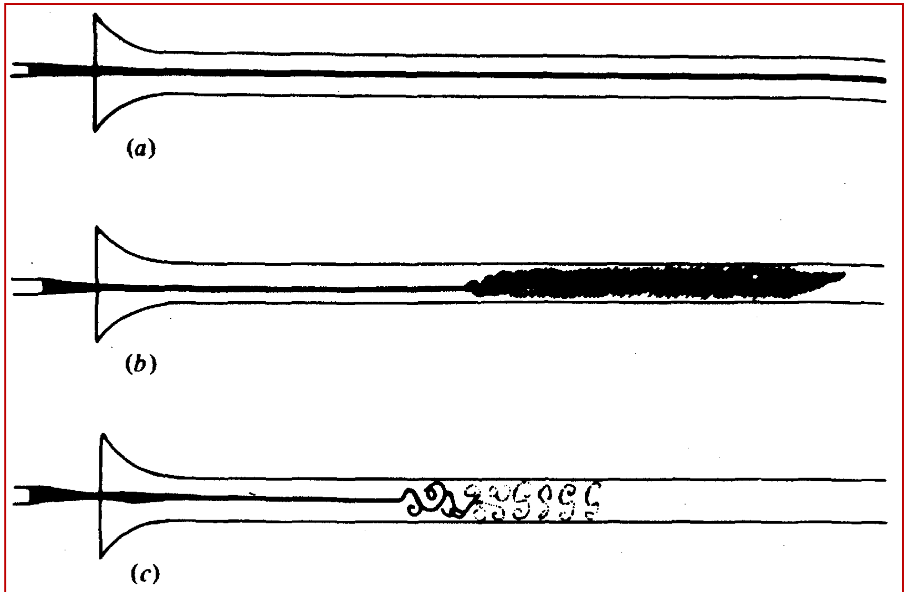
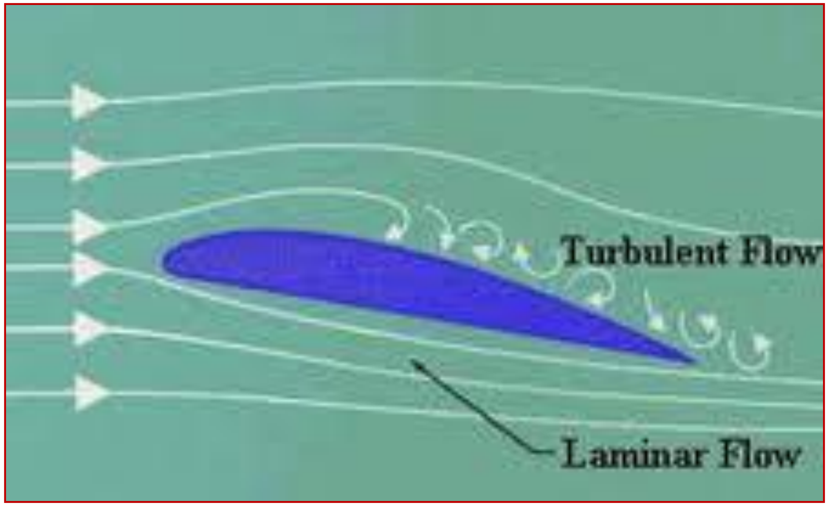
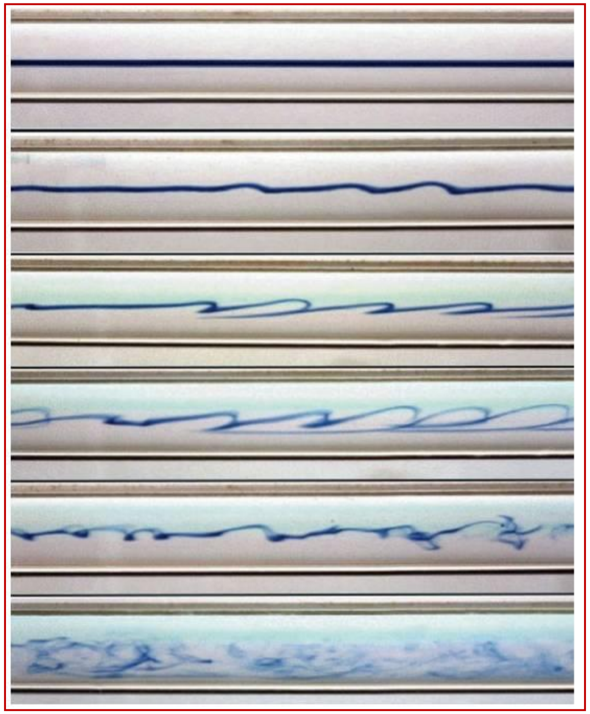




Fig. 9.2. Reynolds's drawings of the flow in his dye experiment.



# Path Lines

- "A path line is a trace made by single particle over a period of time."

  Or

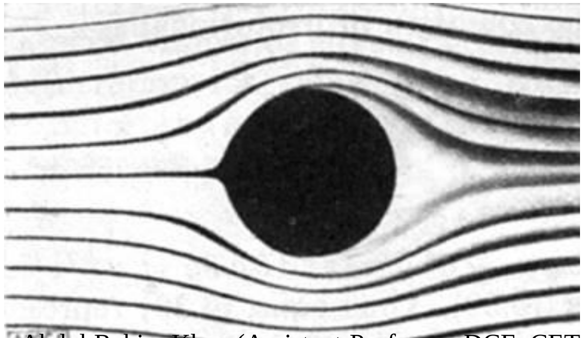
- "The path followed by a fluid particle in motion is called path line."
- Thus the path line shows the direction of a particle for a certain period of time or between two given sections.

# Stream Lines

- Streamlines show the mean direction of a number of particles at the same instant of time.
- Definition:

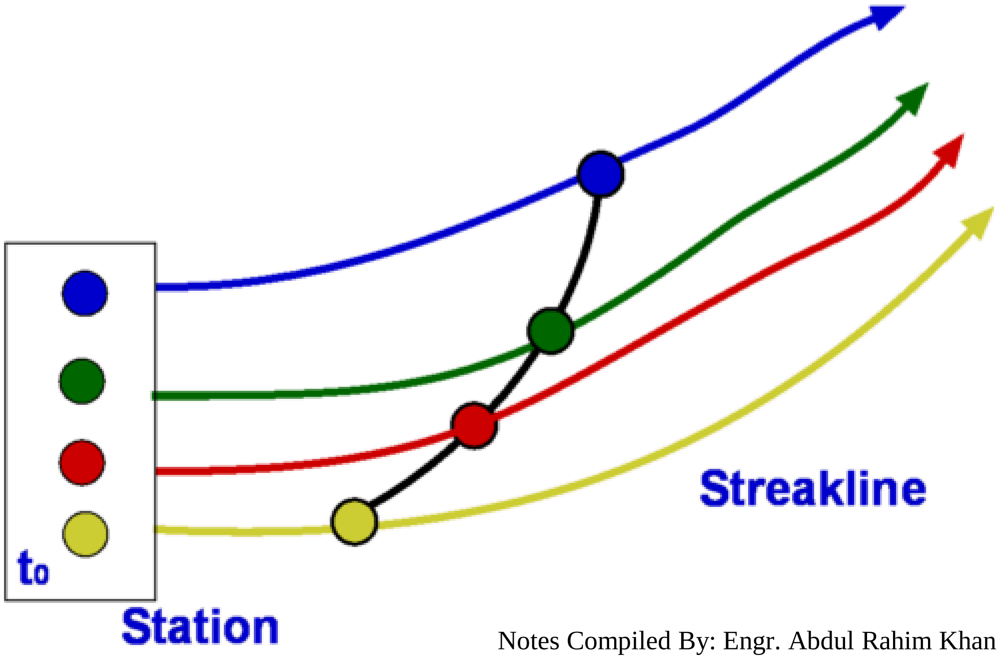
  “The **imaginary line**, drawn in the fluid in such a way that the tangent to any point gives the direction of motion at the point, is called stream line.”

- *Path lines and streamlines are identical in the steady flow of a fluid.*



# Streak Lines

- In experimental fluid mechanics, a dye or other tracer is frequently injected into the flow to trace the motion of the fluid particles.
- If the flow is laminar, a ribbon of color results. This is called a streak line, or filament line.



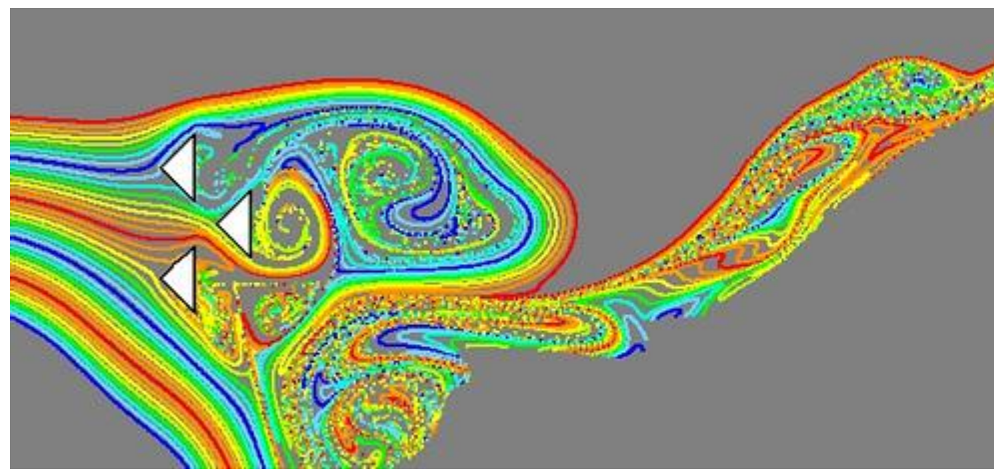
# Streak Lines

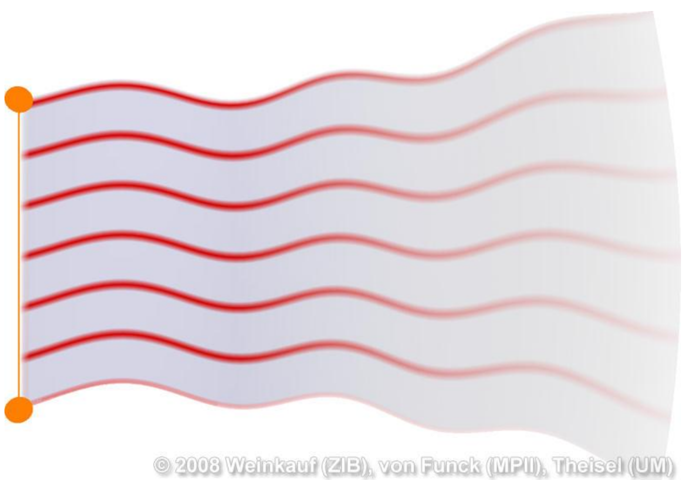
- “The **instantaneous pictures of the position** of all fluid particles in flow, which have passed through a given point (namely, the point of injection), are called streak lines.”
- Example:

1. The line formed by smoke particles ejected from a nozzle.
2. The line of color in a flow into which a dye is continuously introduced through a small tube, all dyed fluid particles having passed the tube's end.

# Streak Lines

- A streak line is physical line of particles that have passed through some position in the flow field.
- *In a steady flow, streamlines, streaklines, and path lines coincide.*





# Rate of Discharge

- "The quantity of liquid, flowing per second through a section of a pipe or channel, is known as the rate of discharge or simply discharge."
- It is generally denoted by Q.
- Now consider a liquid flowing through a pipe.

  Let a = Cross-sectional area of pipe, and

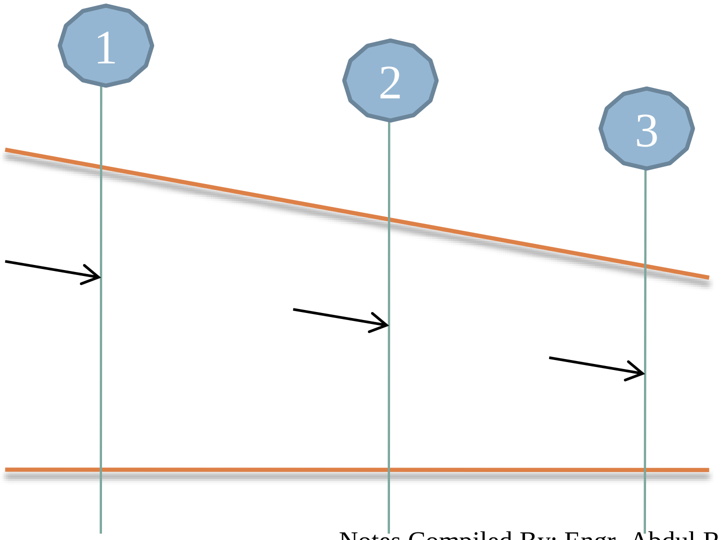
  v = Average Velocity of a liquid

  Discharge **Q = a . v**

- **Units: Cumecs (m3/s) or Cusecs (ft3/s)**

# Equation of Continuity

- If an incompressible liquid is continuously flowing through a pipe or a channel (whose cross-sectional area may or may not be constant) the quantity of liquid passing per second is the same at all sections. This is known as equation of continuity of liquid flow.
- Consider a tapering pipe through which some liquid is flowing.



*Let* $a_1$ = Cross-sectional area of pipe at section 1

$v_1$ = Velocity of the liquid at section 1

Similarly

$a_2, v_2$ = Corresponding values at section 2

$a_3, v_3$ = Corresponding values at section 3

We know that the total quantity of liquid passing through section 1,

$$Q_1 = a_1.v_1$$

Similarly, the total quantity of liquid passing through section 2

$$Q_2 = a_2.v_2$$

And the total quantity of liquid passing through section 3

$$Q_3 = a_3.v_3$$

From the law of conservation of matter, we know that the total quantity of liquid passing through the sections 1, 2 and 3 is the same.

Therefore,

$$Q_1 = Q_2 = Q_3$$

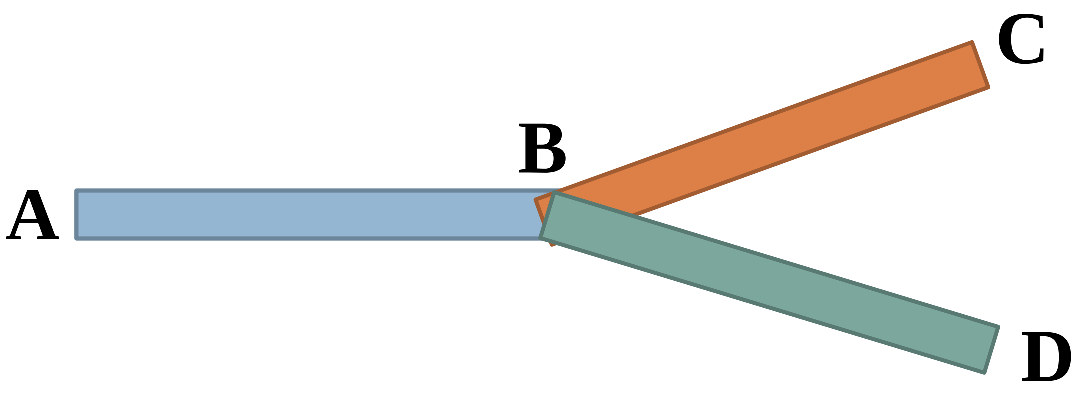
or $$a_1.v_1 = a_2.v_2 = a_3.v_3$$

# Problem-1

- Water is flowing through a pipe of 100mm diameter with an average velocity of 10m/s. Determine rate of discharge of water in l/s. Also determine the velocity of water at the other end of the pipe, if the diameter of the pipe is gradually changed to 200mm.

# Problem-2

- A pipe AB branches into two pipes C and D as shown in figure.




The pipe has diameter of 0.45m at A, 0.3m at B,0.2m at C and 0.15m at D. Find the discharge at A, if the velocity of water at A is 2m/s. Also find out the velocities at B and D, if the velocity at C is 4m/s.