Module-1

Viscous Flow

- What is viscous flow?
- Viscosity: Dynamic and Kinematic.
- Introduction to Navier-Stokes equation.

Arindom Das

Assistant Professor

BBEC Kokrajhar

CE181401	**Hydraulics and Hydraulics Machines**	3-1-0	4

MODULE 1: Viscous flow:

Viscosity- dynamic and kinematic; equation of motion- Navier- Stokes equation; laminar flow in circular pipes- Hagen Poisseuille equation; laminar flow between parallel plates- Couette flow.

MODULE 2: Turbulent flow:

Smooth and rough pipes or surfaces, Pandtle mixing length theory, velocity distribution for turbulent flow over smooth and rough surfaces, friction factor for smooth and rough pipes, Moody's diagram.

MODULE 3: Boundary Layer Theory:

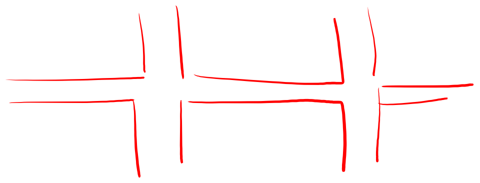
Laminar and turbulent boundary layer along a flat plate; laminar sub-layer; boundary layer thickness- displacement, momentum and energy thickness; momentum integral equation; computation of boundary layer thickness, shear stress and drag force for laminar and turbulent boundary layer.

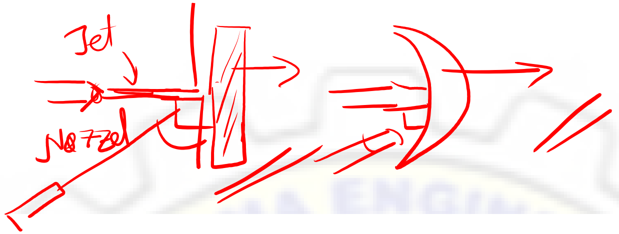
MODULE 4: Flow around Submerged Bodies:

Drag and lift; drag and lift coefficients; pressure and friction drag on sphere, cylinder and disc; separation of flow- Karman vortex street; circulation; lift on a Cylinder-Magnus effect.

MODULE 5: Advanced pipe flow:

Pipe network analysis- Hardy Cross method; water hammer in pipes- rigid and elastic water column theories, gradually and instantaneous closure of valves; surge tank.





MODULE 6: Impact of Jet:

Force of jet on stationary and moving flat plates, force of jet on hinged plate, force of jet on stationary and moving curved vanes (symmetrical and unsymmetrical), force of jet on a series of plates (flat and curved) mounted on a wheel.

MODULE 7: Turbines:

Classification- impulse and reaction turbines; Work done, power, heads and efficiencies of turbines; Pelton wheel; Francis turbine; Kalpan and Propeller turbine; draft tube; unit quantities, specific speed.

MODULE 8: Pumps:

Centrifugal pump- classification, work done, heads and efficiencies of centrifugal pump, minimum starting speed, multi stage pump; Reciprocating pump- classification, discharge, work done and power, indicator diagram, effect of acceleration and friction on indicator diagram, air vessels.

M-1 *** Viscous flow: (Laminar flow)

criteria

*→ **Reynold's number:**

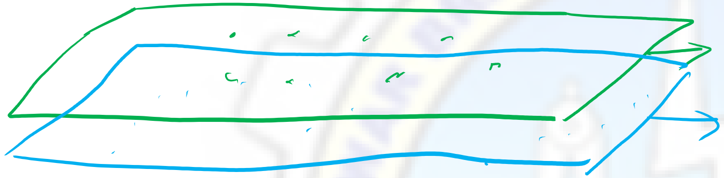
$$Re = \frac{\rho V D}{\mu}$$

- $Re < 2000$ → Laminar
- $Re > 4000$ → Turbulent
- $2000 < Re < 4000$ → Transition

} Pipe flow

→ **Velocity** → Low velocities the flow is Laminar.

(*) "In a flow of layers of fluid are moving in lamina or "If there is no exchange of fluid particles betn two layers of fluid" → Laminar"



Laminar

(*) Laminar flow follows Newton's Law of viscosity

$$\tau \propto \frac{du}{dy}$$

$$\tau = \mu \cdot \frac{du}{dy}$$

$\mu \rightarrow$ dynamic viscosity

Viscosity : Resistance to movement of fluid layer over another layer.

→ Resistance offered by fluid to any deformation.

Dynamic viscosity ↑

$(\mu) \rightarrow$ (Poise)
(mu)

Kinematic viscosity Ratio of dynamic viscosity to density of fluid (mass density)

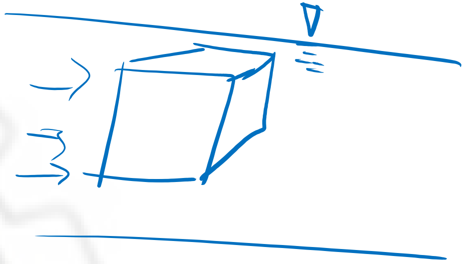
$$\nu = \frac{\mu}{\rho} \longrightarrow \text{(stokes)}$$

(nu)

Navier-Stoke's eq^n :

Newton's 2nd law of motion,

$$F_x = ma_x$$



For fluid flow,

$$F_x = F_B + F_P + F_V + F_T + F_C$$

In case of viscous flow,

$$F_x = F_B + F_p + F_V = m \cdot a_x$$

F_B → Need not to calculate

F_p → σ

F_V → τ

* a_y

* a_z

Acceleration in 3D

$$V = u\hat{i} + v\hat{j} + w\hat{k}$$

$$u = f(t, x, y, z), \quad v = f(t, x, y, z), \quad w = f(t, x, y, z)$$

$$du = \frac{\partial u}{\partial t} \cdot dt + \frac{\partial u}{\partial x} \cdot dx + \frac{\partial u}{\partial y} \cdot dy + \frac{\partial u}{\partial z} \cdot dz$$

$$\frac{du}{dt} = \frac{du}{dt} + \frac{\partial u}{\partial x} \cdot \frac{dx}{dt} + \frac{\partial u}{\partial y} \cdot \frac{dy}{dt} + \frac{\partial u}{\partial z} \cdot \frac{dz}{dt}$$

✓ $$a_x = \frac{dU}{dT} = \frac{du}{dt} + u \cdot \frac{du}{dx} + v \cdot \frac{du}{dy} + w \cdot \frac{du}{dz}$$

✓ $$a_y = \frac{dV}{dT} = \frac{dV}{dt} + u \cdot \frac{dv}{dx} + v \cdot \frac{dv}{dy} + w \cdot \frac{dv}{dz}$$

✓ $$a_z = \frac{dw}{dT} = \frac{dw}{dz} + u \cdot \frac{dw}{dx} + v \cdot \frac{dw}{dy} + w \cdot \frac{dw}{dz}$$

Total acceleration = acceleration (t) + acceleration (space)

Total acceleration = Local or Temporal acceleration + Convective acceleration.

$$\circledast \quad \frac{D}{DT} = \frac{d}{dt} + u \cdot \frac{d}{dx} + v \cdot \frac{d}{dy} + w \cdot \frac{d}{dz}$$

$$a = a_{Local} + a_{convective}$$

Newton's 2nd Law,

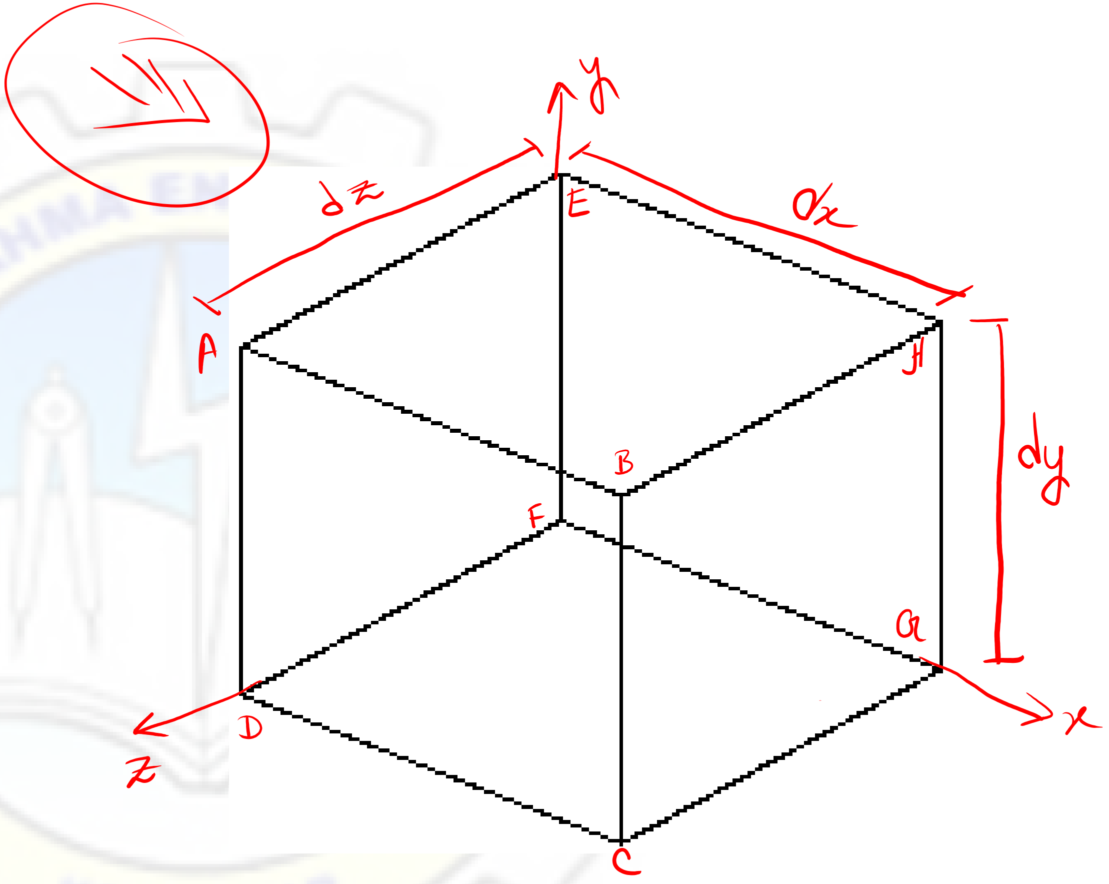
$$F_B \quad F_p + F_v = m \cdot a$$

$F_p \rightarrow \sigma$

$F_v \rightarrow \tau$

Body is in fluid (3-D flow)

↳ Cartesian coordinate



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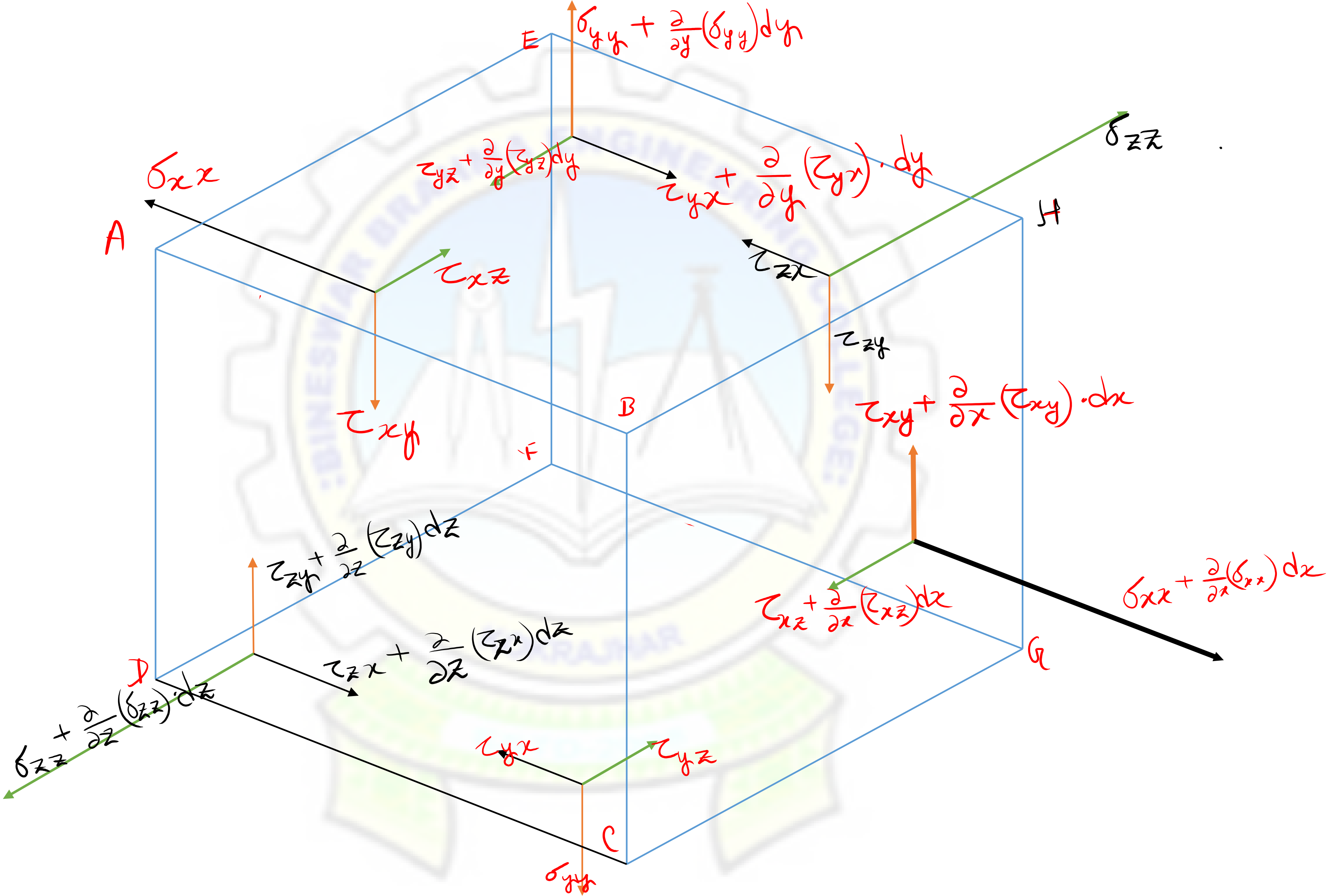
1 → Plane ⊥r to which axis

2 → Acting in the direction



Thank You