Fluid Mechanics I – Detailed Notes (Based on R.K. Bansal & CUSAT 2024 Syllabus)

MODULE I – Properties of Fluids

Fluid: A substance that deforms continuously when subjected to shear stress. The study of fluids in motion and at rest is essential for understanding flow in pipes, tanks, and marine systems.

1. Basic Properties:

Density (ρ) = mass/volume (kg/m^3); Specific weight (γ) = ρg (N/m^3); Specific gravity (S) = $\rho/\rho w$

Dynamic viscosity (μ): $\tau = \mu$ (du/dy); Kinematic viscosity (ν) = μ/ρ (m^2/s)

Compressibility (β): $-(1/V)(dV/dp)$; Surface tension (σ): force per unit length; Capillarity: $h = (4\sigma\cos\theta)/(\rho g d)$

Newton's law of viscosity $\tau = \mu(du/dy)$; Non-Newtonian fluids deviate from this relation.

MODULE II – Fluid Statics

Pressure variation in static fluid: $dp/dz = -\rho g \rightarrow p = p_0 + \rho g h$. Pascal's Law: Pressure at a point acts equally in all directions.

Hydrostatic Forces:

On plane surfaces: $F = \rho g A h_c$; Center of pressure $h_{cp} = h_c + (I_G / (h_c A))$

On curved surfaces: Resolved into horizontal and vertical components; Vertical = weight of fluid above surface.

Buoyancy and Stability:

Buoyant Force $F_B = \rho g V_{displaced}$. Center of Buoyancy (B) is centroid of displaced volume.

Metacentric height (GM) = BM – BG, BM = I/V. Stable if M above G.

Accelerated Fluids: Inclination $\theta = \tan^{-1}(a_x/g)$; Rotational motion $z = \omega^2 r^2/(2g)$.

MODULE III – Fluid Kinematics & Dynamics

Types of Flow: Steady/Unsteady, Uniform/Non-uniform, Laminar/Turbulent, Rotational/Irrotational.
Flow lines: Streamline, pathline, streakline.
Continuity Equation: $\partial u/\partial x + \partial v/\partial y + \partial w/\partial z = 0$. For steady 1D, A■V■ = A■V■.
Bernoulli's Equation:
From Euler's equation: $dp/\rho + V\,dV + g\,dz = 0 \rightarrow (p/\rho g) + (V^2/2g) + z = \text{constant}$.
Applications: Venturimeter, Orifice meter, Pitot tube, Weirs, Notches.
Momentum Equation: F = ■(V■ – V■). Used for jet impact and pipe bends.
Head Losses: Major $h_f = f(L/D)(V^2/2g)$; Minor $h_m = K(V^2/2g)$.

MODULE IV – Flow Measurement

Venturimeter: $Q = Cd\,(A■A■ / \sqrt{(A■^2 – A■^2)})\,\sqrt{(2gh)}$.
Orifice Meter: $Q = Cd\, a\,\sqrt{(2gh)}$.
Pitot Tube: $V = C\,\sqrt{(2gh)}$.
Notches & Weirs: Rectangular: $Q = (2/3)Cd\, b\sqrt{(2g)}H^{3■2}$; Triangular (V-notch): $Q = 1.417Cd\, H^{■■2}$.

MODULE V – Dimensional Analysis & Similitude

Buckingham's π Theorem: If a phenomenon depends on n variables with k fundamental dimensions, there are (n–k) dimensionless Π terms.
Dimensionless Numbers:
$Re = \rho VL/\mu$ (Inertia/Viscous); $Fr = V/\sqrt{(gL)}$; $We = \rho V^2L/\sigma$; $Eu = p/(\rho V^2)$; $Ma = V/a$.
Similarity Laws: Geometric (length ratios same), Kinematic (Re, Fr same), Dynamic (forces scale similarly).

Exam-Oriented Tips:

8-Mark Topics: Bernoulli's derivation, Continuity eqn, Metacentric height, Venturimeter derivation.
16-Mark Topics: Flow through pipes (losses), Dimensional analysis using π theorem, Hydrostatic pressure on curved surface, Jet impact problems.
Ensure diagrams are labeled (lines plan, manometer, weir setup). Always show assumptions and stepwise derivation.