Fluid Mechanics & Surface Tension

BY AP Sir, Sakaar Classes

Fluid Properties & Hydrostatics

Formula Name / Topic	Formula	Condition / Note
Density & Relative Density (RD)	$\rho = \frac{m}{V}$	$\rho_{\text{water}} = 1000\,\text{kg/m}^3$. RD has no units.
	$\text{RD} = \frac{\rho_{\text{substance}}}{\rho_{\text{water at }4^\circ\text{C}}}$	
Pressure at Depth	$P = P_0 + h\rho g$	P_0: Atmospheric Pressure
		h: Depth below free surface.
Gauge Pressure	$P_g = P_{\text{absolute}} - P_{\text{atm}} = h\rho g$	Pressure due to fluid column only.
Pascal's Law	$\frac{F_1}{A_1} = \frac{F_2}{A_2}$	Pressure applied to enclosed fluid is transmitted undiminished.
Force on Vertical Dam Wall	$F = \frac{1}{2}\rho g w H^2$	w: Width, H: Depth. Force acts at $H/3$ from bottom.
Archimedes' Principle	$F_B = V_{\text{in}} \cdot \rho_L \cdot g$	V_{in}: Submerged volume
		ρ_L: Density of Liquid.
Condition for Floatation	$mg = F_B$	Body floats if $\rho_S \le \rho_L$. Weight of body = Weight of fluid displaced.
	$\frac{V_{\text{in}}}{V_{\text{total}}} = \frac{\rho_S}{\rho_L}$	
Accelerated Fluid (Horizontal)	$\tan\theta = \frac{a}{g}$	θ: Angle of free surface with horizontal.
Accelerated Fluid (Vertical)	$P = P_0 + h\rho(g_{\text{eff}})$	$g_{\text{eff}} = g + a$ (up), $g_{\text{eff}} = g - a$ (down).

Rotating Fluid (Vortex)	$y = \frac{\omega^2 x^2}{2g}$	Parabolic meniscus shape.

Fluid Dynamics

Formula Name / Topic	Formula	Condition / Note
Equation of Continuity	$A_1 v_1 = A_2 v_2$	Conservation of Mass. Incompressible, non-viscous flow.
Bernoulli's Principle	$P + \rho g h + \frac{1}{2}\rho v^2 = \text{Constant}$	Conservation of Energy per unit volume. Ideal fluid.
Torricelli's Law	$v = \sqrt{2gh}$	h: Depth of hole from top.
Horizontal Range of Efflux	$R = 2\sqrt{h(H-h)}$	$R_{\text{max}} = H$ when hole is at $H/2$.
Time to empty tank	$t = \frac{A}{a}\sqrt{\frac{2}{g}}(\sqrt{H_1} - \sqrt{H_2})$	A: Tank area, a: Hole area.
Venturimeter	$Q = A_1 A_2 \sqrt{\frac{2gh}{A_1^2 - A_2^2}}$	h: Height diff in manometer.

Viscosity

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Newton's Law of Viscosity	$F = -\eta A \frac{dv}{dx}$	η: Coeff. of viscosity, $\frac{dv}{dx}$: Velocity gradient.
Stoke's Law	$F = 6\pi\eta r v$	Viscous drag on sphere of radius r.
Terminal Velocity	$v_T = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$	Constant max velocity. ρ: sphere, σ: fluid.
Poiseuille's Equation	$Q = \frac{\pi P r^4}{8\eta l}$	Volume flow rate in capillary tube.
Reynolds Number	$R_e = \frac{\rho v d}{\eta}$	$R_e < 1000$: Laminar, $R_e > 2000$: Turbulent.

Surface Tension

Formula Name / Topic	Formula	Condition / Note

Surface Tension	$T = \frac{F}{L}$	Force per unit length.
Surface Energy	$U = T \times \Delta A$	ΔA: Change in area.
Work done (Liquid Drop)	$W = T \cdot 4\pi(r_2^2 - r_1^2)$	Single surface.
Work done (Soap Bubble)	$W = T \cdot 8\pi(r_2^2 - r_1^2)$	Two surfaces (inner & outer).
Excess Pressure (Drop)	$\Delta P = \frac{2T}{R}$	Pressure inside > outside.
Excess Pressure (Bubble)	$\Delta P = \frac{4T}{R}$	Two free surfaces.
Capillary Rise	$h = \frac{2T\cos\theta}{r\rho g}$	Jurist's Law. θ: Contact angle.
Force to lift wire frame	$F = 2Tl + mg$	Surface tension acts on both sides.
Force to lift Ring	$F \approx 4\pi r T + mg$	Ring of radius r.
Splitting of Drops	$\Delta U = 4\pi R^2 T(n^{1/3} - 1)$	Energy absorbed (Temp falls).
Coalescence of Drops	$E_{\text{released}} = 4\pi T(nr^2 - R^2)$	Energy released (Temp rises).

"Success is the sum of small efforts, repeated day in and day out."