Notes by-

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Formulae at a Glance

Sr. No.	*Name of the Topic*	*Parameter*	*Formula*	*Unit (SI)*
1	**Properties of Fluid Flow**	Mass Density	$\rho = m/Vol.$	kg/m^3
		Specific Weight	$\gamma = W/Vol$	N/m^3
		Specific Volume	Sp. Vol = $\forall/(\rho \text{ or } \gamma)$	m^3/kg, m^3/N
		Relative Density	$S = \rho/\rho_w = \gamma/\gamma_w$	No Unit
		Dynamic Viscosity	$\mu = \tau/(dv/dy)$	$N\text{-}s/m^2$
		Kinematic Viscosity	$\nu = \mu/\rho$	m^2/s
		Surface Tension (ST)	σ	N/m
		ST for Spherical Drop	$p = 4\sigma/d$	N/m
		ST for Hollow Bubbles	$p = 8\sigma/d$	N/m
		ST for Liquid Jet	$p = 2\sigma/d$	N/m
		Capillarity	$h = 4\sigma\cos\theta/(\gamma - \gamma_s)d$	m
2	**Pressure and its Measurement**	Pressure	$p = F/A$ $p = \gamma h$	N/m^2
		Pressure Force on vertical plane surface	$F_p = \gamma A x$	N
		Centre of Pressure	$H = x + I_G/Ax$	m
		Pressure Force on inclined plane surface	$F_p = \gamma A x$	N
		Centre of Pressure	$H = x + I_G(\sin^2\theta)/Ax$	m
		Pressure on Curved Surface	$F = \sqrt{(F_H^2 + F_V^2)}$	N
3	**Buoyancy**	Metacentric Height	$GM = \pm((I/V) - BG)$	M
4 MPSC ✗	**Relative Equilibrium**	Fluid Mass subjected to uniform linear acceleration	$dz/dx = -\alpha_x/(g + \alpha_z)$	
		Liquid containers s. t. constant horizontal acceleration	$p = p_a + (\gamma\alpha/g)(x_0 - x) + \gamma(z_0 - z)$	N/m^2
		Liquid containers s. t. constant vertical acceleration	$p = p_a + \gamma h(1 + \alpha/g)$	N/m^2
		Liquid containers s. t. constant rotation	$p = p_a + \gamma/g(\omega^2 r^2/2) - \gamma(z - z_0)$	N/m^2
5	**Fluid Kinematics**	Velocity	$V = ds/dt$	M/s
		Continuity Equation (3-D, Compressible, unsteady, nonuniform)	$\partial\rho/\partial t + \partial(\rho u)/\partial x + \partial(\rho v)/\partial y + \partial(\rho w)/\partial z = 0$	

		Continuity Equation 2D, compressible, steady, uniform	$\partial u/\partial x + \partial v/\partial y + \partial w/\partial z = 0$	
		Continuity Equation 1-D, Steady, Incompressible	$Q = A_1V_1 = A_2V_2 = A_3V_3 = C$	m^3/s
		Acceleration	$a = dv/dt$	m/s^2
		X component	$u(\partial u/\partial x) + v(\partial u/\partial y) + w(\partial u/\partial z) + \partial u/\partial t = 0$	m/s^2
		Y component	$u(\partial v/\partial x) + v(\partial v/\partial y) + w(\partial v/\partial z) + \partial v/\partial t = 0$	m/s^2
		Z component	$u(\partial w/\partial x) + v(\partial w/\partial y) + w(\partial w/\partial z) + \partial w/\partial t = 0$	m/s^2
		Tangential acceleration	$a_s = V_s(\partial V_s/\partial s) + (\partial V_s/\partial t)$	m/s^2
		Normal acceleration	$a_n = V_s(\partial V_n/\partial s) + (\partial V_n/\partial t)$	m/s^2
		Rotation Z- component	$\omega_z = \frac{1}{2}[(\partial v/\partial x) - (\partial u/\partial y)]$	rad/s
		Rotation X- component	$\omega_x = \frac{1}{2}[(\partial w/\partial y) - (\partial v/\partial z)]$	rad/s
		Rotation Y- component	$\omega_y = \frac{1}{2}[(\partial u/\partial z) - (\partial w/\partial x)]$	rad/s
		Circulation	$\Gamma = [(\partial v/\partial x) - (\partial u/\partial y)]\,\delta x\,\delta y$	
		Vorticity	$\zeta = [(\partial v/\partial x) - (\partial u/\partial y)] = 2\omega_z$	Rad/s
		Velocity Potential ϕ	$u = -(\partial\phi/\partial x)$ $v = -(\partial\phi/\partial y)$ $w = -(\partial\phi/\partial z)$	m/s
		Stream Function ψ	$u = -(\partial\psi/\partial y)$ $v = (\partial\psi/\partial x)$ $d\psi = -u\,\delta y + v\,\delta x$	m/s
		Laplace eqn. in ϕ	$(\partial^2\phi/\partial x^2) + (\partial^2\phi/\partial y^2) + (\partial^2\phi/\partial z^2) = 0$	
		Cauchy-Rieman Eqn.s	$(\partial\phi/\partial x) = (\partial\psi/\partial y)$ $-(\partial\phi/\partial y) = (\partial\psi/\partial x)$	
6	**Fluid dynamics**	Equation of Motion	$Ma = F_g + F_p + F_v + F_t + F_s + F_e$	N
		Reynolds equation of Motion	$Ma = F_g + F_p + F_v + F_t$	N
		Navier-Stoke's equation of Motion	$Ma = F_g + F_p + F_v$	N
		Euler's equation of Motion	$Ma = F_g + F_p$	N
		Euler's equation of Motion (X-component)	$X - 1/\rho(\partial p/\partial x) = u(\partial u/\partial x) + v(\partial u/\partial y) + w(\partial u/\partial z) + \partial u/\partial t$	
		Euler's equation of Motion (X-component)	$Y - 1/\rho(\partial p/\partial y) = u(\partial v/\partial x) + v(\partial v/\partial y) + w(\partial v/\partial z) + \partial v/\partial t$	
		Euler's equation of Motion (X-component)	$Z - 1/\rho(\partial p/\partial z) = u(\partial w/\partial x) + v(\partial w/\partial y) + w(\partial w/\partial z) + \partial w/\partial t$	
		Force Potential Ω	$X = -(\partial\Omega/\partial x)$, $Y = -(\partial\Omega/\partial y)$, $Z = -(\partial\Omega/\partial z)$,	
		Bernoulli's Equation	$P/\gamma + V^2/2g + z = C$	
		Kinetic Energy Correction Factor	$\alpha = (1/AV^3)\int_A v^3\,dA$	
		Discharge through Venturimeter	$Q_{act} = C_d\,Q_{th}$ $C_d = [a_1a_2\sqrt{(2gh)}]/\sqrt{(a_1^2 - a_2^2)}$	m^3/s

		Discharge through orifice	$Q_{act} = C_d Q_{th.}$ $C_d = [a_1 a_2 \sqrt{(2gh)}] / \sqrt{(a_1^2 - a_2^2)}$	m^3/s
		Velocity by Pitot Tube	$V = \sqrt{(2gh)}$	m/s
		Momentum Equation	$\sum F = \rho Q [\beta_2(V_2) - \beta_1(V_1)]$	N
		Momentum Correction Factor	$\beta = (1/AV^2) \int_A v^2 dA$	
7	**Conduit Flow**	Reynold's number	$R_e = F_i / F_v = \rho VD/\mu$	
		Darcy-Weisbach Equation	$h_f = 4f LV^2 / 2gD$	m
		1. Loss of energy due to sudden enlargement	$h_L = (V_1 - V_2)^2 / 2g$	m
		2. Loss of energy due to sudden contraction	$h_L = 0.5 V^2 / 2g$	m
		3. Loss of energy at the entrance to a pipe	$h_L = 0.5 V^2 / 2g$	m
		4. Loss of energy at the exit from a pipe	$h_L = V^2 / 2g$	m
		5. Loss of energy due to gradual contraction or enlargement	$h_L = k (V_1 - V_2)^2 / 2g$	m
		6. Loss of energy in bends	$h_L = k V^2 / 2g$	m
		7. Loss of energy in various pipe fittings	$h_L = k V^2 / 2g$	m
		Flow through Long pipes	$H = V^2 / 2g (1.5 + f L/D)$	m
		Pipe in series	$H = 4f_1 L_1 V_1^2 / 2gD_1$ $+ 4f_2 L_2 V_2^2 / 2gD_2$ $+ 4f_3 L_3 V_3^2 / 2gD_3$	m
		Equivalent pipe	$L/D^5 = L_1 D_1^5 + L_2/D_2^5 + L_3/D_3^5 + \ldots$	
		Pipes in parallel	$h_f = 4f_1 L_1 V_1^2 / 2gD_1$ $= 4f_2 L_2 V_2^2 / 2gD_2$	
		Flow through a bye-pass	$Q = (Q + q) / 1 + \sqrt{[(D/d)^5 (l + kd)/L]}$	m^3/s
		Branched pipes	$Z_1 = (p/\gamma + Z_d) + h_{f1}$	
			$(p/\gamma + Z_d) = Z_2 + h_{f2}$	
			$(p/\gamma + Z_d) = Z_3 + h_{f3}$	
			$Q_1 = Q_2 + Q_3$	
		Siphon	$H = V^2 / 2g (1.5 + f L/D)$	
		Head Loss in Tapering Pipes	$h_f = 4f Q L^5 [(1/\ell^4) - (1/(L + l)^4]/ 2g \pi^2 D_2^5$	m
		Heads Loss due to friction in pipes with side tappings	$h_f = (f/D) (V^2 / 2g) (L/3)$	m
		Time of emptying a reservoir through pipe	$t = [8A \sqrt{1.5 + (f l / D)}(H_1^{1/2} - H_2^{1/2})] / \pi D^2 \sqrt{2g}$	S

		Transmission of power through pipe	$P = \gamma Q (H - h_f)$, $H = 3 h_f$, for P_{max}	W m
8	**Boundary Layer Theory**	Nominal Thickness	δ is y at which $u = 0.99V$	m
	MPSC Not	Displacement Thickness	$\delta^* = \int (V-u)\, dy$	m
		Momentum Thickness	$\theta = \int (u/V) [1-(u/V)]\, dy$	m
		Energy Thickness	$\delta_E = \int (u/V) [1-(u^2/V^2)]\, dy$	m
		Prandtl's Boundary Layer Equations	1) $\partial u/ \partial x + \partial v/ \partial y = 0$ 2) $u(\partial u/ \partial x) + v(\partial u/ \partial y) = -1/\rho(\partial p/\partial x) + \upsilon (\partial^2 u/ \partial y^2)$ 3) $-1/\rho(\partial p/\partial y) = 0$	
		Momentum Integral Equation of Boundary Layer	$d(V^2\theta)/dx + dV/dx\, (V\delta^*) = \tau_0 / \rho$	
		Laminar BL	$u/V = y/\delta$	
			$\delta/x = k \sqrt{(x\upsilon/V)}$	
			$\tau_0 = \sqrt{(\mu \rho V^3/ x)}$	
			$C_f = 1.328/\sqrt{Re_L}$	
			$\delta^*/x = 1.729 / \sqrt{Re_x}$	
			$\theta/x = 0.664 / \sqrt{Re_x}$	
		Turbulent BL	$u/V = (y/\delta)^n$	
			$\delta/x = 0.376 / (Re_x)^{1/5}$	
			$C_f = 0.074 / (Re_L)^{1/5}$	
		Laminar Sublayer	$\delta' = 11.6\, \upsilon/ \sqrt{(\tau_0/\rho)}$	
		Hydrodynamically smooth boundary	$(V_* k_s) / \upsilon < 5$	
		Transition	$5 < (V_* k_s) / \upsilon < 70$	
		Hydrodynamically smooth boundary	$(V_* k_s) / \upsilon > 70$	
9	**Laminar Flow**	Relation between shear and pressure gradient	$\partial \tau / \partial y = \partial p/ \partial x$	
	MPSC-Not	**Laminar Flow through circular pipe**, shear stress	$\tau = (-\partial p/ \partial x)\, r/2$ $\tau_0 = (-\partial p/ \partial x)\, R/2$	N/m^2
		Velocity distribution	$v = 1/4\mu\, (-\partial p/ \partial x) (R^2 - r^2)$	m/s
		Max. velocity	$v_{max} = 1/4\mu\, (-\partial p/ \partial x) (R^2)$	m/s
			$v = v_{max} [1 - (r/R)^2]$	m/s
		Discharge	$Q = 1/128\mu\, (-\partial p/ \partial x) (D^4)$	m^3/s
		Average velocity	$V = 1/32\mu\, (-\partial p/ \partial x) (D^2)$	m/s
			$V = v_{max}/ 2$	m/s
		Pressure difference	$(p_1 - p_2) = 32\, \mu\, V\, L / D^2$	N/m^2
		Pressure difference	$(p_1 - p_2) = 128\, \mu\, Q\, L / \pi D^4$	N/m^2
		Head loss due to friction	$h_f = 32\, \mu\, V\, L / \gamma D^2$	m
		Friction factor	$f = 64/Re$	
		Shear velocity	$\sqrt{(\tau_0 /\rho)} = V_* = V \sqrt{(f/8)}$	

		Laminar flow through flat plates: Plane Poiseuille's flow		
		Velocity distribution	$v = 1/2\mu\ (-\partial p/\partial x)(By - y^2)$	m/s
		Max. velocity	$v_{max} = B^2/8\mu\ (-\partial p/\partial x)$	m/s
		Discharge per unit width	$q = B^3/12\mu\ (-\partial p/\partial x)$	$m^3/s/m$
		Average velocity	$V = B^2/12\mu\ (-\partial p/\partial x)$	m/s
			$V = 2v_{max}/3$	m/s
		Pressure difference	$(p_1 - p_2) = 12\ \mu\ V\ L / B^2$	N/m^2
		Head loss due to friction	$h_f = 12\ \mu\ V\ L / \gamma B^2$	m
		shear stress	$\tau = (-\partial p/\partial x)(B/2 - y)$	N/m^2
			$\tau_0 = (-\partial p/\partial x)(B/2)$	N/m^2
		Laminar flow through flat plates: Coutte flow		
		Velocity distribution	$v = (U/B)y - 1/2\mu\ (-\partial p/\partial x)(By - y^2)$	m/s
		Discharge per unit width	$q = B^3/12\mu\ (-\partial p/\partial x)$	$m^3/s/m$
		Average velocity	$V = B^2/12\mu\ (-\partial p/\partial x)$	m/s
			$V = 2v_{max}/3$	m/s
		Pressure difference	$(p_1 - p_2) = 12\ \mu\ V\ L / B^2$	N/m^2
		Head loss due to friction	$h_f = 12\ \mu\ V\ L / \gamma B^2$	m
		shear stress	$\tau = \mu (U/B) + (-\partial p/\partial x)(B/2 - y)$	N/m^2
			$\tau_0 = (-\partial p/\partial x)(B/2)$	N/m^2
		Laminar flow through porous media	$V = K\ I$	m/s
		Stoke's law	$F_D = 3\ \pi\mu\ V\ D$	N
		Terminal velocity	$V = (D^2/18\mu)(\gamma_s - \gamma)$	m/s
		Coefficient of drag	$C_D = 24/Re$	