Fluids: Some Key Equations

WEIGHT-MASS RELATIONSHIP	$w = mg$	(1–1)
PRESSURE	$p = \dfrac{F}{A}$	(1–2)
BULK MODULUS	$E = \dfrac{-\Delta p}{(\Delta V)/V}$	(1–3)
DENSITY	$\rho = m/V$	(1–4)
SPECIFIC WEIGHT	$\gamma = w/V$	(1–5)
SPECIFIC GRAVITY	$\text{sg} = \dfrac{\gamma_s}{\gamma_w \text{ @ } 4°\text{C}} = \dfrac{\rho_s}{\rho_w \text{ @ } 4°\text{C}}$	(1–6)
γ-ρ RELATION	$\gamma = \rho g$	(1–8)
DYNAMIC VISCOSITY	$\mu = \dfrac{\tau}{\Delta v/\Delta y} = \tau\left(\dfrac{\Delta y}{\Delta v}\right)$	(2–2)
KINEMATIC VISCOSITY	$\nu = \mu/\rho$	(2–3)
ABSOLUTE AND GAGE PRESSURE	$p_{\text{abs}} = p_{\text{gage}} + p_{\text{atm}}$	(3–2)
PRESSURE-ELEVATION RELATIONSHIP	$\Delta p = \gamma h$	(3–3)
RESULTANT FORCE ON A RECTANGULAR WALL	$F_R = \gamma(d/2)A$	(4–3)
RESULTANT FORCE ON A SUBMERGED PLANE AREA	$F_R = \gamma d_c A$	(4–4)
LOCATION OF CENTER OF PRESSURE	$L_p = L_c + \dfrac{I_c}{L_c A}$	(4–5)
PIEZOMETRIC HEAD	$d_a = p_a/\gamma$	(4–14)
BUOYANT FORCE	$F_b = \gamma_f V_d$	(5–1)
VOLUME FLOW RATE	$Q = Av$	(6–1)
WEIGHT FLOW RATE	$W = \gamma Q$	(6–2)
MASS FLOW RATE	$M = \rho Q$	(6–3)

CONTINUITY EQUATION FOR ANY FLUID

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2 \tag{6–4}$$

CONTINUITY EQUATION FOR LIQUIDS

$$A_1 v_1 = A_2 v_2 \tag{6–5}$$

BERNOULLI'S EQUATION

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} \tag{6–9}$$

TORRICELLI'S THEOREM

$$v_2 = \sqrt{2gh} \tag{6–16}$$

TIME REQUIRED TO DRAIN A TANK

$$t_2 - t_1 = \frac{2(A_t/A_j)}{\sqrt{2g}}\,(h_1^{1/2} - h_2^{1/2}) \tag{6–26}$$

GENERAL ENERGY EQUATION

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} \tag{7–3}$$

POWER ADDED TO A FLUID BY A PUMP

$$P_A = h_A W = h_A \gamma Q \tag{7–5}$$

PUMP EFFICIENCY

$$e_M = \frac{\text{Power delivered to fluid}}{\text{Power put into pump}} = \frac{P_A}{P_I} \tag{7–6}$$

POWER REMOVED FROM A FLUID BY A MOTOR

$$P_R = h_R W = h_R \gamma Q \tag{7–8}$$

MOTOR EFFICIENCY

$$e_M = \frac{\text{Power output from motor}}{\text{Power delivered by fluid}} = \frac{P_O}{P_R} \tag{7–9}$$

REYNOLDS NUMBER—CIRCULAR SECTIONS

$$N_R = \frac{vD\rho}{\mu} = \frac{vD}{\nu} \tag{8–1}$$

HYDRAULIC RADIUS

$$R = \frac{A}{WP} = \frac{\text{area}}{\text{wetted perimeter}} \tag{8–5}$$

REYNOLDS NUMBER—NONCIRCULAR SECTIONS

$$N_R = \frac{v(4R)\rho}{\mu} = \frac{v(4R)}{\nu} \tag{8–6}$$

DARCY'S EQUATION FOR ENERGY LOSS

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g} \tag{9–1}$$

HAGEN-POISEUILLE EQUATION

$$h_L = \frac{32\mu L v}{\gamma D^2} \tag{9–2}$$

FRICTION FACTOR FOR LAMINAR FLOW

$$f = \frac{64}{N_R} \tag{9–3}$$

FRICTION FACTOR FOR TURBULENT FLOW	$f = \dfrac{0.25}{\left[\log\left(\dfrac{1}{3.7\,(D/\epsilon)} + \dfrac{5.74}{N_R^{0.9}}\right)\right]^2}$	**(9–5)**
REYNOLDS NUMBER FOR NONCIRCULAR SECTIONS	$N_R = \dfrac{v(4R)\rho}{\mu} = \dfrac{v(4R)}{\nu}$	**(9–6)**
DARCY'S EQUATION FOR NONCIRCULAR SECTIONS	$h_L = f\dfrac{L}{4R}\dfrac{v^2}{2g}$	**(9–7)**
HAZEN-WILLIAMS FORMULA U.S. CUSTOMARY UNITS	$v = 1.32\,C_h R^{0.63} s^{0.54}$	**(9–11)**
HAZEN-WILLIAMS FORMULA SI UNITS	$v = 0.85\,C_h R^{0.63} s^{0.54}$	**(9–12)**
HYDRAULIC RADIUS	$R = \dfrac{A}{WP} = \dfrac{\text{area}}{\text{wetted perimeter}}$	**(14–1)**
REYNOLDS NUMBER FOR OPEN CHANNELS	$N_R = \dfrac{vR}{\nu}$	**(14–3)**
FROUDE NUMBER	$N_F = \dfrac{v}{\sqrt{g y_h}}$	**(14–4)**
HYDRAULIC DEPTH	$y_h = A/T$	**(14–5)**
MANNING'S EQUATION—SI UNITS	$v = \dfrac{1.00}{n} R^{2/3} S^{1/2}$	**(14–6)**
NORMAL DISCHARGE—SI UNITS	$Q = \left(\dfrac{1.00}{n}\right) A R^{2/3} S^{1/2}$	**(14–8)**
MANNING'S EQUATION—U.S. CUSTOMARY UNITS	$v = \dfrac{1.49}{n} R^{2/3} S^{1/2}$	**(14–10)**
NORMAL DISCHARGE—U.S. CUSTOMARY UNITS	$Q = AV = \left(\dfrac{1.49}{n}\right) A R^{2/3} S^{1/2}$	**(14–11)**
GENERAL FORM OF FORCE EQUATION	$F = (m/\Delta t)\Delta v = M\,\Delta v = \rho Q\,\Delta v$	**(16–4)**

FORCE EQUATIONS IN x, y, AND z DIRECTIONS

$$F_x = \rho Q\,\Delta v_x = \rho Q(v_{2_x} - v_{1_x}) \quad (16\text{–}5)$$

$$F_y = \rho Q\,\Delta v_y = \rho Q(v_{2_y} - v_{1_y}) \quad (16\text{–}6)$$

$$F_z = \rho Q\,\Delta v_z = \rho Q(v_{2_z} - v_{1_z}) \quad (16\text{–}7)$$

EFFECTIVE VELOCITY AND VOLUME FLOW RATE

$$v_e = v_1 - v_0 \quad (16\text{–}11)$$

$$Q_e = A_1 v_e \quad (16\text{–}12)$$

DRAG FORCE

$$F_D = \text{drag} = C_D(\rho v^2/2)A \quad (17\text{–}1)$$

STOKES'S LAW—DRAG ON A SPHERE RELATED TO CROSS SECTIONAL AREA

$$F_D = \frac{12\mu v A}{D} = \left(\frac{12\mu v}{D}\right)\left(\frac{\pi D^2}{4}\right) = 3\pi\mu v D \quad (17\text{–}8)$$

LIFT FORCE

$$F_L = C_L(\rho v^2/2)A \quad (17\text{–}10)$$

IDEAL GAS LAW

$$\frac{p}{\gamma T} = \text{constant} = R \quad (18\text{–}1)$$

CRITICAL PRESSURE RATIO

$$\left(\frac{p_2'}{p_1}\right)_c = \left(\frac{2}{k+1}\right)^{k/(k-1)} \quad (18\text{–}12)$$

SONIC VELOCITY

$$c = \sqrt{\frac{kgp_2'}{\gamma_2}} \quad (18\text{–}13)$$

EQUIVALENT DIAMETER FOR A RECTANGULAR DUCT

$$D_e = \frac{1.3(ab)^{5/8}}{(a+b)^{1/4}} \quad (19\text{–}1)$$

VELOCITY PRESSURE FOR AIR FLOW (U.S.)

$$H_v = \left(\frac{v}{4005}\right)^2 \text{ in } H_2O \quad (19\text{–}4)$$

VELOCITY PRESSURE FOR AIR FLOW (SI)

$$H_v = \left(\frac{v}{1.289}\right)^2 \text{ Pa} \quad (19\text{–}6)$$