Chapter 15 Fluids

Section 15-1

- The density ρ of an object is equal to how much mass per unit volume $\left(\frac{m}{V}\right)$ the object contains (this is actually the average density). An object placed in a fluid will sink when the object's density is greater than the surrounding fluid's density.

Section 15-2

- Pressure $\left(P = \frac{F_\perp}{A}\right)$ is a measure of the force per unit area that is exerted on that area A. Here, $F_\perp$ is the force component perpendicular to the area A. The MKS unit of pressure is the Pascal (Pa) = 1 N/m^2. The gauge pressure P_g at a point is the difference between the total pressure P and atmospheric pressure P_{at}: $P_g = P - P_{at}$.

Section 15-3

- The pressure at a depth h within a fluid (due to the depth h of fluid) is called the hydrostatic pressure ($P_H = \rho\, g\, h$). The total pressure is then $P_2 = P_1 + \rho g h$, where P_1 is the external pressure acting on the fluid's surface (see Pascal's principle below).

- Pascal's principle states that any pressure exerted on the surface of a fluid is transmitted equally to all parts of the fluid. This means that the pressure at the bottom of an open fluid-filled container is the sum of the hydrostatic pressure and atmospheric pressure. Pascal's principle also explains the working of hydraulic jacks: $\left(\frac{F_0}{F_i} = \frac{A_0}{A_i} = \frac{d_i}{d_0}\right)$.

Section 15-4,5

- Archimedes' principle is a consequence of the existence of hydrostatic pressure. The difference in hydrostatic pressure between the top and bottom of a submerged object results in a upward buoyant force on the object. The buoyant force is equal to the weight of the volume V_{sub} of displaced fluid: $F_b = W_f = \rho_f\, g\, V_{sub}$.

- If the buoyant force is less than the weight of the object, the object will sink ($V_{sub} = V_s$). If the buoyant force is equal to the weight of the object, the object will float (partially submerged and $V_{sub} \neq$ volume of the object V_s).

Section 15-6

- Fluids can be described as: compressible or incompressible, viscous (friction present and the flow laminar) or non–viscous, and turbulent or laminar flow. All the fluids we will find in the text and in the homework problems will be: incompressible, non–viscous, and laminar flow. We will skip section 15-9.

- The continuity equation (mass flow rate = $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$) must include density only if the density changes between the points where A and v are measured. For an incompressible fluid, ρ stays constant and the continuity equation becomes: $A_1 v_1 = A_2 v_2$. Thus, area and flow speed are inversely proportional. The product Av = volume flux or volume flow rate ($\Delta V/\Delta t$).

Section 15-7,8

- Bernoulli's theorem is a consequence of applying the conservation of energy (per volume) to fluids. Each term in Bernoulli's equation has units of energy divided by volume. Thus, $\frac{1}{2}\rho v^2 =$ K per unit volume, $\rho g y =$ U per unit volume, and $P =$ work per unit volume (e.g., to move the fluid a distance x).

- The general form of Bernoulli's equation applied at two different locations within a fluid then becomes: $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$.

- Applying Bernoulli's equation usually requires a combination of the continuity equation ($A_1 v_1 = A_2 v_2$) and knowing heights (y) and pressures (P) to find the requested unknown quantity.

- Note that Bernoulli's equations can be re-written as $\Delta P + \frac{1}{2}\rho \Delta v^2 + \rho g \Delta y = 0$; that is, it can be worked in terms of differences (Δy, Δp,...) if that is all that is asked for.