0.1 Fluids formulas

Density

$$v = \frac{1}{\rho} \tag{1}$$

Specific weight

$$\gamma = \rho g \tag{2}$$

Specific gravity

$$SG = \frac{\rho}{\rho_{H_2O@4^\circ C}} \tag{3}$$

Ideal gas law

$$P = \rho RT \tag{4}$$

$$Pv = RT \tag{5}$$

$$PV = nR_uT \tag{6}$$

Kinematic viscosity

$$v = \frac{\mu}{\rho} \tag{7}$$

Surface tension

$$\sigma = \frac{F}{L} \tag{8}$$

Capillary action

$$h = \frac{2\sigma\cos\theta}{\gamma R} \tag{9}$$

Centre of mass

$$\bar{x} = \frac{\int_m (x)dm}{m} \tag{10}$$

$$= \frac{\int_m (x)dm}{\int_m dm} \tag{11}$$

Stable equilibrium: the centre of gravity is directly below the centre of buoyancy.

Reynolds Number

$$Re = \frac{\rho L u}{\mu} \tag{12}$$

$$Re < 2000 \rightarrow \text{ Laminar}$$

$$Re > 2000 \rightarrow \text{ Turbulent}$$

Material derivative

$$\frac{D}{Dt}() = \frac{\partial}{\partial t}() + u\frac{\partial()}{\partial x} + v\frac{\partial()}{\partial y} + w\frac{\partial()}{\partial z} \tag{13}$$

$$\underline{a} = \frac{D}{Dt}(\underline{v}) = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} \tag{14}$$

Streamline coordinates

$$\underline{a} = \frac{Dv}{Dt} = a_s\hat{s} + a_n\hat{n} \tag{15}$$

$$= v\frac{\partial v}{\partial s}\hat{s} + \frac{v^2}{R}\hat{n} \tag{16}$$

$$a_s = \frac{-v\sin\theta - \frac{\partial P}{\partial s}}{\rho} = v\frac{\partial v}{\partial s}//a_n \qquad = \frac{-v\cos\theta - \frac{\partial P}{\partial n}}{\rho} = \frac{v^2}{R} \tag{17}$$

RTT

$$\left(\frac{DB}{Dt}\right)_{sys} = \frac{\partial}{\partial t}\int_{cv}(\rho b)d\forall + \int_{cs}(\rho b(\underline{v}\cdot\underline{\hat{n}}))dA \tag{18}$$

$$\text{When B=M} \rightarrow 0 = \frac{\partial}{\partial t}\int_{cv}(\rho)d\forall + \int_{cs}(\rho(\underline{v}\cdot\underline{\hat{n}}))dA \tag{19}$$

$$\text{When } \underline{\text{B}} = \text{m}\underline{\text{v}} \rightarrow \sum F_{sys} = \frac{\partial}{\partial t}\int_{cv}(\rho\underline{v})d\forall + \int_{cs}(\rho\underline{v}(\underline{v}\cdot\underline{\hat{n}}))dA \tag{20}$$

$$\tag{21}$$

Propeller stages

1. Bernoulli equation between 1 and 2.

$$P_1 = P_2 + 0.5\rho(v_2^2 - v_1^2)$$

2. Bernoulli equation between 3 and 4.

$$P_4 = P_3 + 0.5\rho(v_3^2 - v_4^2)$$

3. $P_1 = P_4$.

$$\therefore \Delta P = P_3 - P_2 = 0.5\rho(v_4^2 - v_1^2)$$

4. $F = \Delta P \times A$.

$$\therefore F_{thrust} = \Delta P \times A = 0.5\rho A(v_4^2 - v_1^2)$$

5. Apply momentum equation.

$$\begin{aligned} \sum F_x &= \int_{inlet} \rho v_1(-v_1)dA + \int_{outlet} \rho v_4(v_4)dA \\ &= -\dot{m}_1 v_1 + \dot{m}_2 v_4 \\ &= \dot{m}(v_4 - v_1) \text{ (assume steady state, no viscous force, neglect g)} \end{aligned}$$