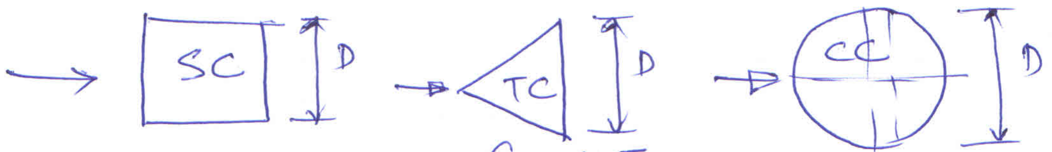
Answer to
Q1.



$C_D = 2.2$ $\quad$ $C_D = 1.5$ $\quad$ $C_D = 1.2$ (laminar)
$= 0.3$ (turbulent)

Drag co-efficient depends on the extent of pressure recovery across the cylinder in flow direction. Lower pressure recovery results in higher drag force. The bluffness is the measure of pressure recovery of a bluff body. Therefore, higher drag force means higher bluffness of the object.

(a) $\boxed{\text{CC, TC, SC} \quad \text{or} \quad \text{CC} < \text{TC} < \text{SC}}$

(b) Since all the three objects are symmetric about the streamwise centreline (horizontal line), the flow is also symmetric about the streamwise centreline. Therefore, the lift co-efficient (non-dimensional lift force) is zero for all three objects.

$\boxed{\text{NO change in lift coefficient}}$

Answer to

Q2. Given, $\rho_w = 998\ \text{Kg/m}^3$, $\mu = 0.001\ \text{Kg/m-s}$.

$\frac{\varepsilon}{D} = 0.005$, $(K_L)_{entry} = 0.5$, K_L (open glove valve) $= 6.9$

$Q = 0.004\ \text{m}^3/\text{s}$

$L = 125\ \text{m}$

$D = 5\ \text{cm} = 0.05\ \text{m}$

$$h_L = \left(f\frac{L}{D} + \Sigma K_L\right)\frac{V^2}{2g}$$

Applying Bernoulli Equn betn free surface (1) in the tank and exit of the pipe (2)

$V_1 = 0$, $\quad V_2 = V = \frac{Q}{A} = \frac{0.004}{\left(\frac{\pi}{4}\right)(0.05)^2} = 2.04\ \text{m/s}$

$$Re = \frac{\rho V D}{\mu} = \frac{(998)(2.04)(0.05)}{0.001} = 102000\ (\sim 101796)$$

$\frac{\varepsilon}{D} = 0.005$ $\qquad f = 0.028 - 0.032$

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_{turbine} + h_L$$

$p_1 = p_2 = p_{atm}$ $\qquad V_1 = 0$

$$\therefore h_{turbine} = (z_1 - z_2) - \frac{V_2^2}{2g} - h_L$$

$$= 40 - \frac{V^2}{2g} - \left(f\frac{L}{D} + 6.9 + 0.5\right)\frac{V^2}{2g}$$

$$= 40 - \left(f\frac{L}{D} + 1.0 + 6.9 + 0.5\right)\frac{V^2}{2g}$$

For $Re = 102000$ and $\frac{\varepsilon}{D} = 0.005$

$f = 0.028 - 0.032$

for $f = 0.028$, $\quad h_{turbine} = 40 - \left[0.028\,\frac{125}{0.05} + 8.4\right]\frac{(2.04)^2}{2(9.81)}$

$= 23.37\ \text{m}$

Power, $P = \rho g Q h_{turbine}$

$= (998)(9.81)(0.004)(23.37) = 915.22\ \text{W}$

for $f = 0.032$, $\quad h_{turbine} = 40 - \left[0.032\,\frac{125}{0.05} + 8.4\right]\frac{(2.04)^2}{2(9.81)} = 21.25\ \text{m}$

Power, $P = \rho g Q h_{turbine} = (998)(9.81)(0.004)(21.25)$

$= 832.16\ \text{W}$

Q3. Equating mass balance at the inlet and at any streamwise location in the developing region. | 2h = channel height.

$$\dot{m} = 2\int_0^{\delta} \rho u\,dy + 2\rho U(x)(h-\delta) = \rho U_0 (2h)$$

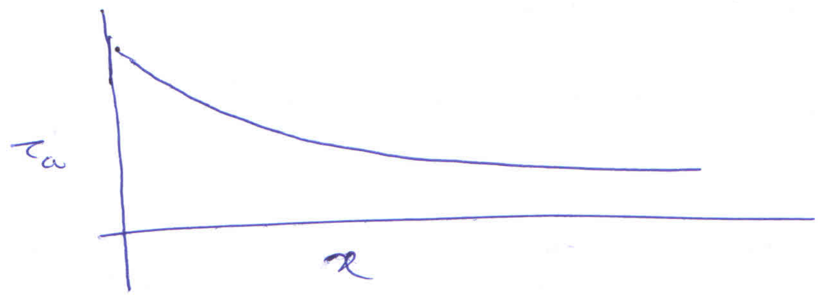
$$\Rightarrow \int_0^{\delta} u\,dy + U(x)(h-\delta) = U_0 h \Rightarrow U(x)\left[\frac{1}{U(x)}\int_0^{\delta} u\,dy\right] + U(x)h - U(x)\int_0^{\delta} dy = U_0 h$$

$$\Rightarrow U(x)\left[h - \int_0^{\delta}\left(1 - \frac{u}{U(x)}\right)dy\right] = U_0 h$$

$$\Rightarrow U(x)\,(h-\delta^*) = U_0 h \Rightarrow U(x) = \frac{U_0 h}{(h-\delta^*)}$$

$\delta \rightarrow$ boundary layer thickness

$\delta^* \rightarrow$ displacement thickness



Q4. Magnus force or Lift force, $F = \rho V \Gamma$

Circulation, $\Gamma = \int_0^{2\pi} \vec{v}_\theta \cdot d\vec{s} = \int_0^{2\pi} v_\theta\, ds = \int_0^{2\pi} (\omega R)(R\,d\theta)$

$= 2\pi \omega R^2$

Given, $\omega = 1500\ \text{rpm} = \frac{(2\pi)(1500)}{60}\ \text{rad/s} = (50\pi)\ \text{rad/s}$

$V = 20\ \text{m/s}$ $\quad \rho = 1.22\ \text{kg/m}^3$

$\Gamma = 2\pi(50\pi)(0.5)^2 = 246.74\ \text{m}^2/\text{s}$

Force $= F = \rho V \Gamma = (1.22)(20)(246.74)$

$= 6020.45\ \text{N}$