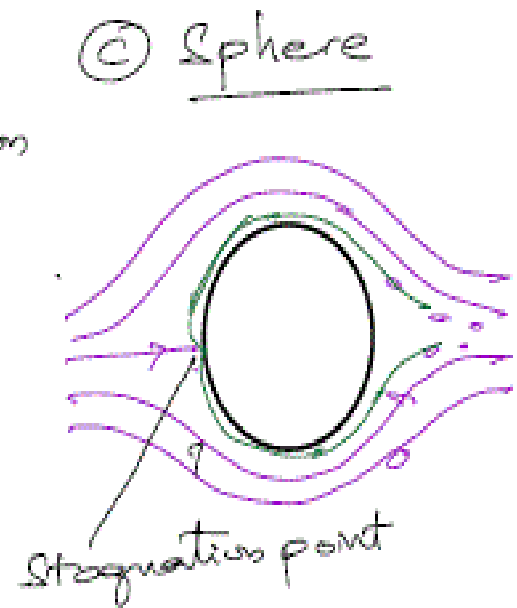
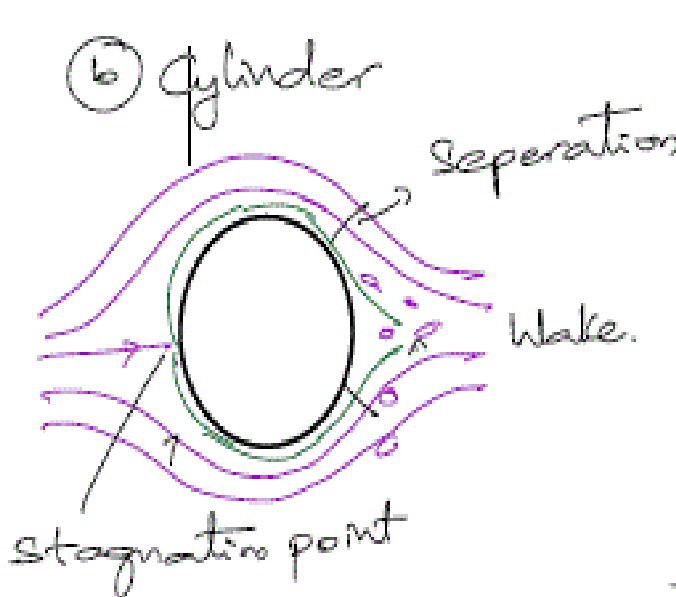
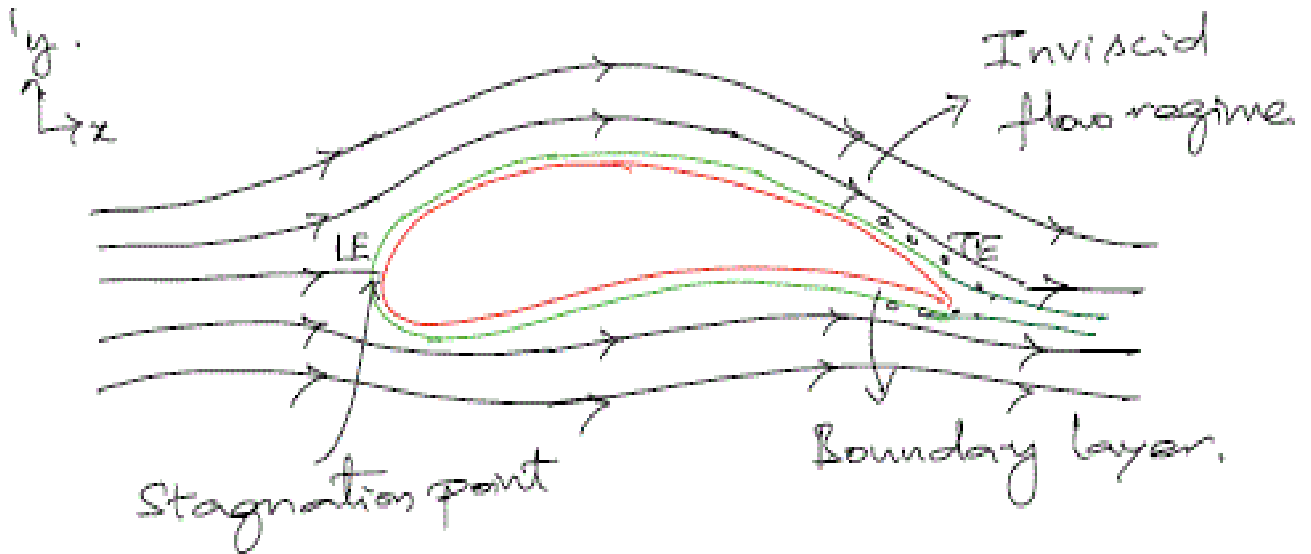




② External flow:

Flow over submerged bodies.

① Aerofoil [plate].



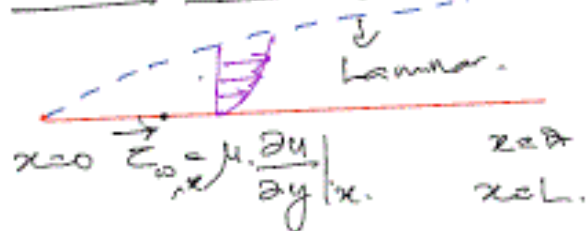


Flow over flat plates:

Drag coefficient (or) skin friction coefficient

i) Local drag coefficient:

$$C_{fx} = \frac{\tau_{w,x}}{\frac{1}{2} \rho u_{\infty}^2}$$



ii) Average drag coefficient

$$C_{f,avg} = \frac{1}{L} \int_0^L C_{fx} dx$$

$$\tau_{w,avg} = \frac{\text{Drag force}}{\text{Area}}$$

$$\tau_{w,avg} = \frac{F_D}{A}$$

$$C_{f,avg} = \frac{\tau_{w,avg}}{\frac{1}{2} \rho u_{\infty}^2}$$

$$\left. \begin{aligned} Re_x &= \frac{\rho V x}{\mu} \rightarrow \text{Local} \\ Re_L &= \frac{\rho V L}{\mu} \rightarrow \text{Average} \end{aligned} \right\}$$

Drag on a plate:

$$\left. \begin{aligned} C_{fx} &= 0.664 Re_x^{-0.5} \\ C_{fL} &= 1.328 Re_L^{-0.5} \end{aligned} \right\} \text{for } Re < 10^5, \text{ Laminar}$$

$$\left. \begin{aligned} C_{fx} &= 0.0592 Re_x^{-0.2} \\ C_{fx} &= 0.37 [\log_{10} Re_x]^{-2.584} \end{aligned} \right\} \begin{aligned} &5 \times 10^5 < Re < 10^7 \\ &Re > 10^7 \end{aligned} \text{ Turbulent}$$

$$C_{fL} = 0.074 Re_L^{-0.2} - 1742 Re_L^{-1} \rightarrow \text{Laminar \& Turbulent}$$

$$\left[C_{fL} = \frac{1}{L} \int_0^{x_c} C_{f, \text{laminar}} dx + \int_{x_c}^L C_{f, \text{turbulent}} dx \right]$$

