1a(i) Three Conditions of Cattle flow

1. The flow rate
2. the Velocity
3. Shear Stress

(ii) Conditions used to determine the nature of flow

1. the Density (ρ)
2. The flow Velocity (V)
3. Fluid Viscosity (μ)
4. the pipe Diameter (D)

(iii)

Aerofoil	Hydrofoil
→ is the cross sectional shape of a wing, blade or sail	is an attachment to the hull of a ship that raises the ship out of water traveling at speed
→ it has a shape of the wing of an aircraft, a wing	It can be artificial such as a rudder in a boat, submarine and surfboard fin
→ This is an air structure shaped to produce lift when moving in the air	used in lifting element, the hydrofoil beat the upward force.

1b) Viscosity of the liquid μ = 0.9 Centi poise = 0.009 poise

Convert poise to si unit.

$$10 \text{ poise} = 1.0 \text{ Ns/m}^2$$

$$0.009 \text{ poise} = \frac{0.009 \times 1.0}{10} \text{ Ns/m}^2$$

Viscosity μ = 0.0009 Ns/m²

Distance b/w the plates (b) = 10mm = 0.01 m
velocity of the upper plate (U) = 1 m/s
Pressure difference b/w the Section 60m apart = 60 kN/m²

$$\therefore \left(-\frac{\partial p}{\partial x}\right) = \frac{60\times10^3}{60} = 10^3 \ N/m^2/m$$

(i) Velocity distribution

$$u = \frac{U}{b}y + \frac{1}{2\mu}\left(-\frac{\partial p}{\partial x}\right)(by - y^2)$$

$$= \frac{1}{0.01}y + \frac{1}{2\times0.0009}(10^3)(0.01y - y^2)$$

$$= \frac{1}{0.01}y + 555555.5556\,(0.01y - y^2)$$

$$= \frac{1}{0.01}y + 5555.555556y - 555555.5556y^2$$

$$= \frac{y}{0.01} + 5555.555556y - 555555.5556y^2$$

$$= 100y + 5555.555556y - 555555.5556y^2$$

$$= 5655.555556y - 555555.5556y^2$$

$$= y(5655.555556 - 555555.5556y)$$

Hence the velocity distribution:

$$u = y(5655.555556 - 555555.5556y)$$

(ii) Discharge per unit width of q:

$$q = \int_0^b u\,dy$$

$$= \int_0^{0.01}(5655.555556y - 555555.5556y^2)$$

Velocity & Shear stress distribution between the plates

$$h_1 - h_2 = \left(\frac{p_1}{w} + z_1\right) - \left(\frac{p_2}{w} + z_2\right)$$

$$= \left(\frac{250 \times 10^3}{1.26 \times 9810} + 1\right) - \left(\frac{80 \times 10^3}{1.26 \times 9810}\right) + 0$$

$$= 21.22555538 - 6.472177720$$

$$= 14.75337766$$

$h_1 - h_2 = 14.755$ ... $\sqrt{2}$ m or 1.414m

$$\frac{\partial h}{\partial x} = -\frac{14.755}{1.414} = -10.435$$

$$\frac{\partial p}{\partial x} = w\frac{\partial h}{\partial x} = (1.26 \times 9810) \times (-10.435)$$

$$= -128983 \text{ N/m}^3 \text{ ans.}$$

$$u = \frac{U}{b} \cdot y - \frac{1}{2\mu}\left(\frac{\partial p}{\partial x}\right)(by - y^2)$$

$$u = -\frac{1.5}{0.01} y - \frac{1}{2 \times 0.9} \times (-128.983 \times 10^3)(0.01y - y^2)$$

$$= -150y + 716.5722222 - 71657.22222y^2$$

$$u = 566.57y - 71657y^2$$

Velocity distribution is

$$u = 566.57y - 71657 \times 10^4 y^2$$

Shear distribution

$$\tau = \mu \cdot \frac{U}{b} - \frac{1}{2}\frac{\partial p}{\partial x}(b - 2y)$$

$$\left[5655.555556 \times \frac{y^2}{2} - 555555.5556 \times \frac{y^3}{3}\right]_0^{0.01}$$

$$= \left[5655.555556 \times \frac{0.01^2}{2} - 555555.5556 \times \frac{0.01^3}{3}\right]$$

$$= (0.282777778 - 0.185185185 2)$$

$$= 0.0975925926 \; m^3/s$$

(ii) The shear stress on the upper plate.

Shear stress, $\tau = \mu \left(\frac{\partial u}{\partial y}\right)$

$$= \mu \frac{\partial}{\partial y}\left(5655.555556y - 555555.5556y^2\right)$$

$$\tau = 0.0009\,(5655.555556 - 1111111.111y)$$

$y = b = 0.01m$ from top plate

$$\tau_0 = 0.0009\,(5655.555556 - 1111111.111 \times 0.01)$$

$$= -4.909999999$$

$$\simeq -5 N/m^3$$

(c) Viscosity $= 0.9\ Ns/m^2$

Density $= 1260\ kg/m^3 = 1.26$

Distance between plates $= 10mm = 0.01m$

Velocity of the upper plate $= 1.5m/s$

$P_1 = 250\ kN/m^2$

$P_2 = 80kN/m^2$

$$\tau = 0.9 \times \left(\frac{-1.5}{0.01}\right) - \frac{1}{2} \times (-128983)(0.01 - 2y)$$

$$= 135 + 644.92 - 128983y$$

$$\tau = 509.92 - 128983y$$

Maximum flow velocity u_{max}

$$\frac{du}{dy} = 0$$

$$\frac{d}{dy}\left(566.57y - 71657y^2\right) = 0$$

$$566.57 - 143314y = 0$$

$$y = 3.9533 \times 10^{-3} \text{ m}$$

$$V_{max} = 566.57\,(3.95 \times 10^{-3}) - 71657\,(3.95 \times 10^{-3})^2$$

$$= 2.238 - 1.118$$

$$= 1.12 \text{ m/s}$$

The shear stress on the upper plate

$$(\tau)_{0.01} = 509.92 - 128983 \times 0.01$$

$$= -779.91 \approx -780 \text{ N/m}^2$$