~~FM~~ S2 2012

6 (a). $\frac{e}{D} = \frac{0.6}{150} = 0.004 \Rightarrow f_F = 0.007$

$$h_s = \frac{\Delta P}{\rho g} + \frac{1}{2g}\Delta V^2 + \Delta z + h_f$$

$$= 0 + 0 + 50 + \frac{2 \times 0.007 \times 250}{0.15 \times 9.8} \times \left(\frac{Q}{\frac{\pi \times 0.15^2}{4}}\right)^2 + \frac{1}{2 \times 9.8}(1.5)\left(\frac{Q}{\frac{\pi \times 0.15^2}{4}}\right)^2$$

$$= 50 + 7869.5Q^2$$

(b) $h_p = h_{sys}$

$$150 - 25Q^2 = 50 + 7869.5Q^2$$

$$100 = 7894.5Q^2$$

$$Q = \sqrt{\frac{100}{7894.5}}$$

$$= 0.113 \text{ m}^3/\text{s}.$$

$V = 6.37 \text{ m/s}.$

(c) $NPSH_A = \frac{P_1 - P_{vap}}{\rho g} + z_1 - h_{fs}$

$$= \frac{(101 - 2) \times 10^3}{10^3 \times 9.8} + 12 - \left(\frac{2 \times 0.007 \times 50}{0.15} + \frac{0.5}{2}\right) \times \frac{1}{9.8}\left(\frac{0.113}{\pi \times 0.15^2/4}\right)^2$$

$$= 10.1 + 12 - 20.2$$

$$= 1.75 \text{ m}$$

$NPSH_A < NPSH_R$ therefore pump is not within the permissible operating range

S2 2012

7(a) $$\frac{(20\times10^5)^2-(25\times10^5)^2}{2\times8.314\times\frac{298}{2\times10^{-3}}} + \frac{2\times0.005\times400\times0.2^2\times16}{\pi^2\times D^5} = 0$$

$$\uparrow$$

$$-908147.1699 + \frac{0.259}{D^5} = 0$$

$$D^5 = \frac{0.259}{908147.1699}$$

$$D = \left(\frac{0.259}{908147.1699}\right)^{1/5}$$

$$= 0.05\ m \;//$$

(b) $$\frac{P_2}{RT/M} = \rho_2$$

$$\rho_2 = \frac{20\times10^5}{8.314\times\frac{298}{2\times10^{-3}}}$$

$$= 1.614\ kgm^{-3}$$

$$\frac{G}{A\rho_2} = \frac{0.2}{\frac{\pi\times0.05^2}{4}\times1.614} = 63.09\ m/s.$$

(c) True.

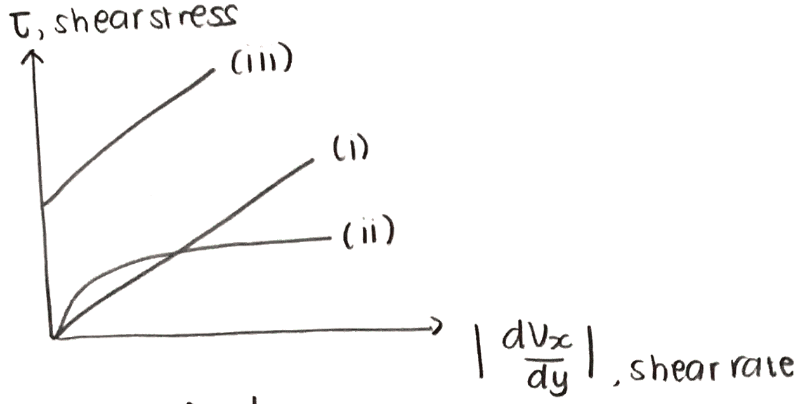
(d) $G_{max} = V_{max} = \sqrt{RT/M}$ (sonic velocity)

$$= \sqrt{8.314\times\frac{298}{2\times10^{-3}}}$$

$$= 1113\ m/s \;//$$

S2 2012

8)



(i) Newtonian fluid

↳ constant viscosity with increasing shear rate

(ii) Shear-thinning fluid

↳ decreasing viscosity with increasing shear rate

↳ power law index < 1

$$|\tau_{yx}| = k\left|\frac{dv_x}{dy}\right|^{n-1}\left|\frac{dv_x}{dy}\right|$$

(iii) Bingham fluid

↳ produces shear stress with increasing shear rate only after threshold stress is surpassed

$$|\tau_{yx}| = \tau_y + k\left|\frac{dv_x}{dy}\right|^{n-1}\left|\frac{dv_x}{dy}\right|$$

S2 2012

9) (a) $V_x(y)$ only

cont eq satisfied

equation of motions

x-component

$$\frac{\partial P}{\partial x} = \mu \frac{\partial^2 V_x}{\partial y^2}.$$

y-component

$$\frac{\partial P}{\partial y} = 0$$

z-component

$$\frac{\partial P}{\partial z} = 0 \,//$$

$$\frac{P_2 - P_1}{L} = \mu \frac{\partial^2 V_x}{\partial y^2}$$

$$V_x(y) = \frac{P_2 - P_1}{2\mu L} y^2 + C_1 y + C_2$$

$V_x(y=0) = V$ $\Rightarrow$ $C_2 = V$.

$V_x(y=D) = 0$. $\Rightarrow$ $\frac{P_2 - P_1}{2\mu L} D^2 + V = -C_1 D$

$$C_1 = -\left(\frac{P_2 - P_1}{2\mu L}\right) D. - \frac{V}{D}.$$

$$V_x(y) = \frac{P_2 - P_1}{2\mu L}\left(y^2 - Dy\right) - \frac{V}{D} y. + V$$

$V_x(y) = 0$.

(b) $\frac{P_2 - P_1}{L} = \left(\frac{\frac{V}{D} y - V}{y^2 - Dy}\right) \times 2\mu$. ???

$$Q = VA$$

$$0 = z \int_0^D V_x(y)\, dy$$

$$= z \left[\frac{P_2 - P_1}{2\mu L} \left(\frac{y^3}{3} - \frac{Dy^2}{2}\right)_0^D - \frac{V}{2D} y^2 + Vy \right] \quad , z \neq 0.$$

$$0 = \frac{P_2 - P_1}{2\mu L}\left(\frac{D^3}{3} - \frac{D^3}{2}\right) - \frac{VD}{2} + VD.$$

$$\frac{P_2 - P_1}{\cancel{2}\mu L}\left(\frac{1}{6} D^{\cancel{3}\,2}\right) = \frac{V\cancel{D}}{\cancel{2}}$$

$$\frac{P_2 - P_1}{L} = \frac{6\mu V}{D^2} \,//.$$

S2 2012

(c) $$\frac{V_x}{V} = \frac{\frac{P_2-P_1}{2\mu L}(y^2-Dy) - \frac{V}{D}y + V}{V}$$

$$= \frac{P_2-P_1}{2\mu LV}(y^2-Dy) - \frac{y}{D} + 1$$

$$= \frac{6\mu V}{2\mu LVD^2}(y^2-Dy) - \frac{y}{D} + 1$$

$$= 3\left[\left(\frac{y}{D}\right)^2 - \frac{y}{D}\right] - \frac{y}{D} + 1$$

$$= 3\left(\frac{y}{D}\right)^2 - 4\left(\frac{y}{D}\right) + 1$$

let $y = \frac{V_x}{V}$ and $x = y/D$.

$$y = 3x^2 - 4x + 1$$

$$\frac{dy}{dx} = 6x - 4$$

$\hookrightarrow 0$ when $x = \frac{4}{6}$

$\frac{d^2y}{dx^2} = 6$ (minimum point)

$y = 0$ when $x = \frac{1}{3}$ and $x = 1$

$$\frac{y}{D} = \frac{4}{6} \Rightarrow y = \frac{4}{6}D.$$

$$\frac{V_x}{V} = 3\left(\frac{4}{6}\right)^2 - 4\left(\frac{4}{6}\right) + 1$$

$$= -\frac{1}{3}$$