Problem Set 11 (PS11) due Monday April. 16

9.30 9.36 9.32

<u>9.30</u>

Write energy equation between surface of water in funnel to exit from pipe:

$$gz_0 = \frac{1}{2}\bar{V}^2 + gz_2 + gh_e (\alpha = 1)$$

$$\therefore g(z_0 - z_2) = \frac{1}{2}\bar{V}^2 + \frac{1}{2}\bar{V}^2 (k_1 + k_2 + f\frac{L}{d})$$

$$= \frac{1}{2}\bar{V}^2 (1 + k_1 + k_2 + f\frac{L}{d})$$

$$\therefore \bar{V}^2 = \frac{2g(z_0 - z_2)}{1 + k_1 + k_2 + f\frac{L}{d}}$$

$$\therefore \bar{V}^2 = \frac{2g \times 140d}{1 + 0.5 + 1.0 + 0.01 \times 100} = 80gd$$

$$\therefore \bar{V} = \sqrt{80gd}$$

9.36

$$\frac{u}{U_{CL}} = 1 - (\frac{r}{R})^2$$

$$(a)\bar{V} = \frac{1}{A}\int u dA = \frac{1}{\pi R^2}\int_0^R u(2\pi r)dr$$

$$= \frac{2U_{CL}}{R^2}\int_0^R r(1-(\frac{r}{R})^2)dr$$

$$= \frac{2U_{CL}}{R^2}[\frac{r^2}{2} - \frac{r^4}{4R^4}]_0^R$$

$$= \frac{U_{CL}}{2}$$

$$(b)\mathrm{Re} = \frac{2\bar{V}R}{\upsilon} = \frac{\bar{V}D}{\upsilon}$$

When Re>2300, the flow can be turbulent,
An exact value for turbulent Re does not exsit became the transition to turbulence depent on many things, including the surface roughness, the pressure of flow disturbances, vibrations, noise and thermal disturbances, as well as the Re number.

9.36

(c)For a Newtonian flow, $\tau_{\mathrm{w}} = \mu \dfrac{\partial u}{\partial y}$

$$Inthiscse: \tau_{\mathrm{w}} = \mu U_{CL}\left(-\frac{2r}{R^2}\right)_{r=R} = -\frac{2\mu U_{CL}}{R}$$

$$\therefore \tau_{\mathrm{w}} = -\frac{2\mu U_{CL}}{R}$$

The negative sign is caused by the choose of coordinate system.

$$\text{Now } \mathrm{c_f} = \frac{\tau_{\mathrm{w}}}{\frac{1}{2}\rho \bar{V}^2} = \frac{4\mu \bar{V}}{\frac{1}{2}\rho \bar{V}^2 R} = \frac{16\mu}{\rho \bar{V} D} = \frac{16}{\mathrm{Re}}$$

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Energy equation from free surface of reservoir to the exit:

$(p_0 = p_a, V_1 = \bar{V})$

$$gz_0 = \frac{\alpha \bar{V}^2}{2} + gh_e - \frac{\dot{w}_{shaft}}{\dot{m}} + gz_1$$

$$That\ is: \frac{\dot{w}_{shaft}}{\dot{m}} = \frac{\alpha \bar{V}^2}{2} + f\frac{L}{d}\frac{\bar{V}^2}{2} + g(z_0 - z_1),\ (\alpha = 1)$$

$$Hence: \frac{\dot{w}_{shaft}}{\dot{m}} = \frac{\bar{V}^2}{2}(1 + f\frac{L}{d}) - g(z_0 - z_1)$$

$$Now: \bar{V} = \frac{\dot{q}}{\frac{\pi D^2}{4}} = 12.7\ m/s$$

$$\therefore \frac{\dot{w}_{shaft}}{\dot{m}} = \frac{(12.7)^2}{2}(1 + 0.025 \times \frac{100}{0.1}) - 9.8(10)\ m^2/s^2$$

$$= 1999\ m^2/s^2$$

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$$\therefore \dot{w}_{shaft} = 1999\,\dot{m} = 1999\,\rho\,\dot{g}$$

$$= 1999 \times 999 \times \frac{100}{1000}\, watt \;\; (15\ ^{o}C)$$

$$\because \dot{w}_{shaft} = +200kw$$

$\dot{w}_{shaft}$ *is positive, so that work is done on the fluid,*

so machine is a pump.