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HW8 Answer template

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Problem 1

$$\cancel{\frac{P_1}{\rho g}} + \cancel{\frac{v_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\rho g}} + \cancel{\frac{v_2^2}{2g}} + z_2 + h_f + \cancel{0} - h_p$$

$V_2 = V_1 \approx 0$

$P_1 = P_2 \therefore h_p = \Delta z + h_f = \Delta z + \frac{v^2}{2g}\frac{fL}{D}$

$\Delta z = 36.6\,m$

$v = \frac{Q}{A} = \frac{0.08495 \frac{m^3}{sec}}{\pi \cdot \left(\frac{0.152}{2}\right)^2} = 4.66 \frac{m}{sec}$

$L = 609.6\,m$

$D = 0.152\,m$

$\epsilon = 0.00026\,m \rightarrow \frac{\epsilon}{d} = 0.0017$

$Re = \frac{VD}{\nu} = \frac{4.66 \cdot 0.152}{1.005\times10^{-6}} = 7.06\times10^5$

using moody chart: $f \approx 0.024$

$\therefore h_p = 36.6 + \frac{4.66^2 \cdot 0.024 \cdot 609.6}{2 \cdot 9.8 \cdot 0.152} = 142.8\,m$

$\boxed{212\ hp}$

~~$P = \rho g Q L h_p$~~

$P = \rho g Q h_p = 998 \cdot 9.8 \cdot 0.085 \cdot 142.8$

$P = 118646 \frac{Nm}{sec} \cdot \frac{1\,hp}{746} = \frac{159\,hp}{0.75} = 212\,hp$

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Problem 2

$$h_p = \Delta z + \frac{v^2 f L}{2gD} \rightarrow D = \frac{v^2 f L}{2g(h_p - \Delta z)}$$

$$P = h_p \cdot \rho g Q \rightarrow h_p = \frac{P}{\rho g Q}$$

$$80 \cdot 746 = 59680 \text{ W} \rightarrow h_p = \frac{59680}{998 \cdot 9.8 \cdot 0.085} = 71.8 \text{ m}$$

$$D = \frac{4.66^2 \cdot 0.024 \cdot 609.6}{2 \cdot 9.8 (71.8 - 36.6)} = 0.459 \text{ m} \cdot \frac{39.37 \text{ in}}{1 \text{ m}} = 18.1 \text{ m}$$

$\boxed{18.1 \text{ m}}$

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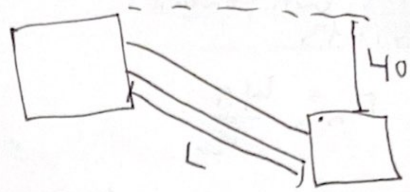
Problem 3



$Q = 200 \frac{N}{sec}$

$$\frac{\cancel{P_1}}{\cancel{\rho g}} + \frac{\cancel{v_1^2}}{\cancel{2g}} + z_1 = \frac{\cancel{P_2}}{\cancel{\rho g}} + \frac{\cancel{v_2^2}}{\cancel{2g}} + z_2 + h_f - \cancel{h_p}$$

$v_1 = v_2 \approx 0$

$P_1 = P_2$

$$h_f = +\Delta z = \frac{v^2 fL}{2gD} \rightarrow L = \frac{\Delta z\, 2gD}{v^2 f}$$

$$Q = \frac{200 \frac{N}{sec}}{891 \cdot 9.8} = 0.0229 \frac{m^3}{sec}$$

$\epsilon = 0.000046$ m

$\frac{\epsilon}{D} = 0.000575$

$$v = \frac{Q}{A} = \frac{0.229}{\pi\left(\frac{0.08}{2}\right)^2} = 4.56 \frac{m}{sec}$$

$$Re = \frac{4.56 \cdot 0.08}{1.005 \times 10^{-6}} = 362727$$

Moody $\rightarrow$ $f \approx 0.019$

$$\therefore L = \frac{40 \cdot 2 \cdot 9.8 \cdot 0.08}{4.56^2 \cdot 0.019} = 158.75 \text{ m}$$

$\boxed{159 \text{ m}}$

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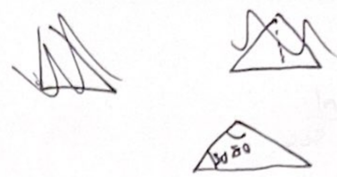
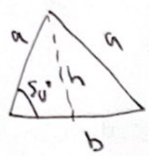
Problem 4

$D_h = \frac{4A}{P_w}$





$b = 2 \cdot 2\,cm \cos(50°)$
$= 2.57\,cm$

$h = 2 \cdot \sin(50) = 1.53\,cm \rightarrow A = \frac{b \cdot h}{2} = \frac{2.57 \cdot 1.53}{2} = 1.97\,cm^2$

$P_w = a + a + b = 4 + 2.57 = 6.57\,cm$

$\therefore D_h = \frac{4 \cdot 1.97}{6.57} = 1.20\,cm$

$\rho = 870$
$\mu = 0.104$

$Re = \frac{870 \cdot 2 \cdot 0.012}{0.104} = 201$

$fRe @ 40° = 52.9 \rightarrow f = \frac{52.9}{201} = 0.263$

$h_f = \frac{v^2}{2g}\frac{fL}{D} = \frac{2^2 \cdot 0.263 \cdot 0.6}{2 \cdot 9.8 \cdot 0.012} = 2.69\,m$

$\frac{P_1}{\rho g} + \cancel{\frac{v_1^2}{2g}} + \cancel{z_1} = \frac{P_2}{\rho g} + \cancel{\frac{v_2^2}{2g}} + \cancel{z_2} + h_f$ $\quad v_1 = v_2$

$\frac{\Delta P}{\rho g} = h_f \rightarrow \Delta P = h_f \rho g$

$\boxed{22.9\,kPa}$

$\cancel{= \frac{v^2 fL}{2gD}\rho g = \frac{v^2 fL\rho}{2D}}$

$\Delta P = h_f \cdot \rho \cdot g = 2.69 \cdot 870 \cdot 9.8 = 22923\ Pa$

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Problem 5

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \cancel{\frac{P_2}{\rho g}} + \cancel{\frac{v_2^2}{2g}} + z_2 + h_m + h_f$$

$$P_1 = \left(\Delta z + h_m + h_f - \frac{v^2}{2g}\right)\rho g$$

$$h_m = \sum K = 4(0.3) + 2(0.2) + 8.5 + 1$$
$$= 11.1$$

Moody: $f \approx 0.03$

$$\cancel{h_f = \frac{v^2 fL}{2gD} \rightarrow \text{Moody: } f \approx 0.03}$$

$$v = \frac{Q}{A} = \frac{0.005}{\frac{\pi}{4}\cdot 0.05^2} = 2.55\ \frac{m}{sec}$$

$$\cancel{h_f \approx 238}$$

$$\cancel{P_1 = \left(100 + 11.1 + 238 - \frac{2.55^2}{2g}\right)998\cdot 9.8 = 3.40\times 10^3\ kPa}$$

$$P_1 = \left(\Delta z - \frac{v^2}{2g} + \frac{v^2}{2g}\left(\frac{fL}{D} + \sum K\right)\right)\rho g$$

$$= \left(100 - \frac{2.55^2}{2g} + \frac{2.55^2}{2g}\left(\frac{0.03\cdot 1200}{0.05} + 11.1\right)\right)998\cdot 9.8$$

$$= 3.35\times 10^3\ kPa$$

$$\boxed{\cancel{3.40\times 10^3\ kPa} \quad 3.35\times 10^3\ kPa}$$

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Problem 6

(a)

$$h_f = \frac{Q^2}{\left(\sum\sqrt{C_i/f_i}\right)^2} \qquad C_i = \frac{\pi^2 g D_i^5}{8L_i} \qquad Q_i = \left(C_i h_f/f_i\right)^{1/2}$$

$$\Delta h_{tot} = \Delta h_1 = \Delta h_2 \qquad Q_{tot} = Q_1 + Q_2$$

guess $f_i \rightarrow$ Solve $h_f \longrightarrow$ Solve $Q_i \longrightarrow$ Solve $Re_i \longrightarrow$ New f_i

$f_{guess} = 0.014$

$$h_f = \frac{0.036^2}{\left(\sqrt{6.3\times10^{-8}/0.014} + \sqrt{2.25\times10^{-8}/0.014}\right)^2} = 112.9$$

$\rightarrow Q_1 = 0.02253$

$\rightarrow Re_1 = 570861 \rightarrow f_{new} = 0.0297$

$\boxed{Q_{top} = 2.27\times10^{-2}\ \frac{m^3}{sec} \quad Q_{bottom} = 1.33\times10^{-2}\ \frac{m^3}{sec}}$

(b)

$$\frac{\Delta P}{\rho g} = \Delta h_{tot} = h_{f_1} \rightarrow \Delta P = \left(\frac{V_{top}^2}{2g} \cdot \frac{f_1 \cdot L_1}{D}\right)\rho g$$

$\Delta P = 2421681\ Pa$

$\boxed{2.42\times10^3\ kPa}$

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Problem 7

(a)

Non - slip

False

(b)

True

(c)

False

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Problem 8

(a) $P_1 = P_2 \quad v_1 = v_2 \quad \therefore \Delta z = h_f + h_m - h_p$

$$\Delta z = \left(\frac{fL}{D} + \Sigma K\right)\frac{v^2}{2g} - h_p$$

$D_{actual} = .1541\ m$

$\epsilon = 0.002\ m \rightarrow \underbrace{\frac{\epsilon}{D} = 0.013}_{f \approx 0.042}$

$$v = \sqrt{\frac{2g(\Delta z + h_p)}{fL/D + \Sigma K}}$$

$$v = \sqrt{\frac{2g(50+100)}{\frac{0.042 \cdot 200}{0.1541} + 0.7}} \rightarrow 7.297 \cdot \frac{\pi}{4}D^2 = 0.883\ \frac{m^3}{sec}$$

$$\boxed{0.883\ \frac{m^3}{sec}}$$

(b)

$$Re = \frac{v\rho D}{\mu} = \frac{7.297 \cdot 870 \cdot D}{0.008} = 122292\ \checkmark$$

$$\boxed{\text{Yes}}$$

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Problem 8 continued

(c)

if $\sum K = 0$: $Q = 0.889 \frac{m^3}{sec}$

$\underbrace{0.889 - 0.883 = 0.006 \frac{m^3}{sec}} = 21.6 \frac{m^3}{hr}$

$\frac{0.006}{0.883} \approx 0.68\%$ loss

Yes

(d)

$h_p = \left(\frac{fL}{D} + K\right)\frac{v^2}{2g} - \Delta z$

$\epsilon = 0.0000046$

$\underbrace{\frac{\epsilon}{D} = 0.000299}_{f \approx 0.026}$

$h_p = \left(\frac{0.026 \cdot 200}{0.1541} + 0.7\right)\frac{7.297^2}{2g} - 50$

$= 43.6\ m$

$P_{new} = \rho g Q h_p = 870 \cdot 9.8 \cdot 0.883 \cdot 43.6 = 3.28\ kW$

$P_{old} = \rho g Q \cdot 100 = 7.53\ kW$

4.25 kW smaller

$P_{old} - P_{new} = 4.25\ kW$