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HW6 Answer template

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Problem 1

Cross out any Pi groups that you do not need in the answer key.

$$\frac{\Delta P}{L} = f(\rho, \mu, D, Q)$$

$5-3=2$

$$\frac{M}{L^2T^2} = f\left(\frac{M}{L^3}, \frac{M}{LT}, L, \frac{L^3}{T}\right)$$

$$\Pi_1: \frac{M}{L^2T^2}\{=\}\left(\frac{M}{L^3}\right)^a\left(\frac{M}{LT}\right)^b(L)^c$$

$a=-1$
$b=2$
$c=-3$

$$\Pi_1 = \frac{\Delta P \cdot \rho \cdot D^3}{L \cdot \mu^2}$$

$$\Pi_2: \frac{L^3}{T}\{=\}\left(\frac{M}{L^3}\right)^a\left(\frac{M}{LT}\right)^b(L)^c$$

$a=-1$
$b=1$
$c=1$

$$\Pi_2 = \frac{Q \cdot \rho}{\mu \cdot D}$$

$$\Pi_1 = f(\Pi_2)$$

Π_1: $\dfrac{\Delta P \cdot \rho \cdot D^3}{L \cdot \mu^2}$

Π_2: $\dfrac{Q\rho}{\mu D}$

~~Π_3:~~

~~Π_4:~~

~~Π_5:~~

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Problem 2
(a) Δp/L

$D_1 = 36$ in

$Q_1 = 590000$ barrels

$=$

$D_2 = 0.05$ m

$\frac{\Delta P_2}{L_2} = 4000 \frac{Pa}{m}$

$\rho = 860 \frac{kg}{m^3}$

$\mu = 0.005 \frac{kg}{m \cdot s}$

$$\Pi_1 = \frac{\Delta P_2 \rho D_2^3}{L_2 \mu^2} = \Pi_2$$

$$\Pi_2 = \frac{4000 \frac{Pa}{\cancel{m}} \cdot 860 \frac{kg}{\cancel{m^3}} (0.05 \cancel{m})^3}{(0.005 \frac{kg}{ms})^2} = \underline{1.72 \times 10^7}$$

$$1.72 \times 10^7 = \frac{\frac{\Delta P_1}{L_1} \cdot \rho D_1^3}{\mu_s^2} \Rightarrow \frac{\Delta P}{L} = \frac{1.72 \times 10^7 \cdot 0.005^2}{860 \cdot (0.9144)^3}$$

$$= 0.654 \frac{Pa}{m}$$

$\boxed{0.654 \frac{Pa}{m}}$

(b)

$$Re_D = \frac{\rho U D}{\mu} \qquad U = Q/A$$

$$\therefore Re_D = \frac{860 \cdot 9.38 \times 10^4 \, m^3 / \pi (\frac{D}{2})^2 \cdot D}{0.005}$$

~~$= 2.56 \times 10^{12}$~~

Re: 2.25×10^{10}

~~2.56×10^{12}~~

~~1.48×10^{10}~~

Laminar, transitional, turbulent?

~~Turbulent~~

Turbulent

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Problem 3

(a) $P = f(D, \rho, v, \Omega, n) \rightarrow \frac{ML^2}{T^3}\{-\} f\left(L, \frac{M}{L^3}, \frac{L}{T}, \frac{1}{T}, -\right)$

$\Pi_1 : \frac{ML^2}{T^3}\{-\} L^a \left(\frac{M}{L^3}\right)^b \left(\frac{L}{T}\right)^c \Rightarrow \begin{matrix} a = 2 \\ b = 1 \\ c = 3 \end{matrix} \Bigg\} \Pi_1 = \frac{P}{L^2 \rho v^3}$

$\Pi_2 : \frac{1}{T}\{-\} L^a \left(\frac{M}{L^3}\right)^b \left(\frac{L}{T}\right)^c \quad \begin{matrix} a = -1 \\ b = 0 \\ c = 1 \end{matrix} \Bigg\} \Pi_2 = \frac{\Omega \cdot D}{v}$

$\Pi_3 = n$

$$\boxed{\frac{P}{D^2 \rho v^3} = f\left(\frac{\Omega D}{v}, n\right)}$$

(b)

$\frac{\Omega_1 D_1}{v_1} = \frac{\Omega_2 D_2}{v_2}$

$\Pi_2' = \frac{\frac{4800}{60} \cdot 0.5}{40} = 1 = \frac{\Omega_2 \cdot 5}{12} \rightarrow \Omega_2 = 2.4 \frac{r}{sec} \cdot \frac{60\ sec}{min} = 144$

$$\boxed{5.99\ kW}$$

(c)

$\Pi_1 = \frac{P_1}{D_1^2 \rho_1 v_1^3} = \frac{P_2}{D_2^2 \rho_2 v_2^3}$

$\Pi_1 = \frac{2700}{.5^2 \cdot 1.225 \cdot 40^3} = 0.1378 \rightarrow P_2 = 0.1378 \cdot 5^2 \cdot 1.007 \cdot 12^3$

$$\boxed{144 \frac{rot}{min}}$$

(d)

$Re_D = \frac{\rho u D}{\mu} = \frac{1.007 \cdot 12 \cdot 5}{1.726 \times 10^{-5}}$

$= 3.50 \times 10^6$

Re:

3.50×10^6

Laminar, transitional, turbulent?

Turbulent

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Problem 4
Final answer: Yes/No

$\rho = 891 \frac{kg}{m^3}$

$\mu = 2.9\times10^{-1} \frac{kg}{ms}$

$D = 0.05\ m$

$\dot{w} = 1\times10^{6} \frac{N}{hour}$

$\dot{Q} = \frac{\dot{w}}{\rho g} = \frac{1\times10^{6} \cdot \frac{1}{3600}}{891 \cdot 9.8}$

$= 0.03181 \frac{m^3}{sec}$

$V = \frac{Q}{A} = \frac{0.03181}{\pi\left(\frac{D}{2}\right)^2} = 16.2 \frac{m}{sec}$

$\therefore Re_D = \frac{\rho V D}{\mu} = \frac{891 \cdot 16.2 \cdot 0.05}{2.9\times10^{-1}} = 2489$

transitional / Turbulent

$\boxed{NO}$

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Problem 5

Height H?

$$Re = \frac{\rho v D}{\mu} = 2300 \rightarrow v = \frac{2300 \cdot 0.001}{998 \cdot 0.002} = 1.152 \frac{m}{sec}$$

$$h_f = H - \frac{v_2^2}{2g} = H - \frac{v^2}{2g} = \frac{32 \mu L v}{\rho g D^2}$$

$$H = \frac{32 \mu L v}{\rho g D^2} + \frac{v^2}{2g} = 1.01\ m$$

Yes

$\boxed{1.01\ m}$

Flow rate at H = 50 cm?

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

$$h_f = H - \frac{v_2^2}{2g} = 0.5 - \frac{v^2}{2g} = \frac{32 \mu L v}{\rho g d^2}$$

$\mu = 0.001 \frac{kg}{m \cdot s}$

$\rho = 998 \frac{kg}{m^3}$

$L = 1\ m$

~~d = 2 m~~

$d = 0.002\ m$

$g = 9.8$

$$\rightarrow v = 0.5895 \frac{m}{sec}$$

$$Q = v \cdot A = 0.5895 \cdot \pi \cdot \left(\frac{d}{2}\right)^2 = 1.85 \times 10^{-6}$$

$\boxed{1.85 \times 10^{-6} \frac{m^3}{sec}}$

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Problem 6

Kinematic viscosity? $\nu = \frac{m^2}{sec} = \mu$

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

$$\therefore h_f = H - \frac{v^2}{2g} \Rightarrow h_f = 10 - \frac{\left(\frac{Q}{A}\right)^2}{2g}$$

$$\frac{Q}{A} = \frac{35 \cdot \frac{1}{3600}}{\pi\left(\frac{1/24}{2}\right)^2} = 7.13 \frac{ft}{sec}$$

$$\therefore h_f = 10 - \frac{7.13^2}{2g} = 9.21 \text{ ft}$$

$$h_f = \frac{32 \mu L V}{\rho g D^2} \rightarrow \mu = \frac{h_f \rho g D^2}{32 L V} = 3.39 \times 10^{-4}$$

$$\nu = \frac{\mu}{\rho} = \frac{3.39 \times 10^{-4}}{0.9} = 3.76 \times 10^{-4} \frac{ft^2}{sec}$$

$$\boxed{3.76 \times 10^{-4} \frac{ft^2}{sec}}$$

Laminar?

$$Re = \frac{VD}{\nu} = 790.$$

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

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Problem 7

(a)

$\rho = 891 \frac{kg}{m^3}$

$HGL_B = z_B + \frac{P_B}{\rho g}$

$\mu = 0.29 \frac{kg}{m \cdot sec}$

$= 15 m + \frac{180000}{891 \cdot 9.8} = 35.61 m$

$HGL_A = z_A + \frac{P_A}{\rho g} = 0 + \frac{500000}{891 \cdot 9.8} = 57.26 m$

$HGL_B < HGL_A \therefore A \to B$

$\boxed{UP}$

(b)

$h_f = \frac{128 \mu L Q}{\pi \rho g D^4} \rightarrow Q = \frac{h_f \pi \rho g D^4}{128 \mu L}$

$= \frac{(HGL_A - HGL_B) \pi \cdot 891 \cdot 9.8 \cdot (0.03)^4}{128 \cdot 0.29 \cdot \cancel{Sin} \, 15/\sin(37°)} = 5.199 \times 10^{-4} \frac{m^3}{sec}$

$= 5.199 \times 10^{-4} \frac{m^3}{sec} \cdot \frac{3600 \, sec}{hr} = 1.87$

$\boxed{1.87 \frac{m^3}{hr}}$