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HW6 Answer template

Please use these for uploading to Gradescope. Put your final answer in the box provided.

Problem 1

$$Re \simeq 2300 = \frac{\rho \vec{u} D}{\mu} \rightarrow \vec{u} = \frac{Re\,\mu}{\rho D} = \frac{2300 \cdot 1.92\times10^{-3} \frac{\cancel{kg}}{\cancel{m}\cdot sec}}{804 \frac{\cancel{kg}}{m^{\cancel{3}}} \cdot 0.05\,\cancel{m}}$$

$$= 0.1099 \frac{m}{sec}$$

$$\vec{Q} = \vec{u} A \rightarrow \vec{Q} = 0.1099 \frac{m}{sec} \cdot \frac{\pi}{4} D^2 = 0.000216 \frac{m^3}{sec} \cdot \frac{3600\,sec}{1\,hr}$$

$$\boxed{= 0.776 \frac{m^3}{hr}}$$

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Problem 2

Velocity?

$$Re = \frac{\rho D \vec{u}}{\mu}$$

$\rho_w = 997 \frac{kg}{m^3}$

$\mu_w = 1.00 \times 10^{-3} \frac{kg}{m \cdot sec}$

$\rho_A = 1.23 \frac{kg}{m^3}$

$\mu_A = 1.78 \times 10^{-5} \frac{kg}{m \cdot s}$

$$Re_w = Re_A$$

$$Re_w = \frac{997 \cdot 0.08 \cdot 2}{1 \times 10^{-3}} = 1.60 \times 10^5$$

$$= Re_A = \frac{1.23 \cdot 1.5 \cdot \vec{u}}{1.78 \times 10^{-5}}$$

$$\therefore \vec{u} = \frac{1.60 \times 10^5 \cdot 1.78 \times 10^{-5}}{1.23 \cdot 1.5} = 1.539$$

$$\boxed{1.54 \frac{m}{sec}}$$

Drag force?

$$C_{D_w} = C_{D_A}$$

$$C_D = \frac{2F}{\rho u^2 A} \rightarrow C_{D_w} = \frac{2 \cdot 5}{997 \cdot 2^2 \cdot \frac{\pi}{4}(0.08)^2}$$

$$= 0.4989 = \frac{2 \cdot F}{1.23 \cdot 1.54^2 \cdot \frac{\pi}{4}(1.5)^2}$$

$$\rightarrow F = \frac{C_D \cdot \rho_A \cdot V_A^2 \cdot A_2}{2} = 1.286$$

$$\boxed{1.29\ N}$$

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Problem 3

(a)

$\rho : \frac{M}{L^3}$

$\vec{u} : \frac{L}{T}$

$\frac{\partial u}{\partial x} : \frac{L/T}{L}$

$\frac{M}{L^{\cancel{3}2}} \cdot \frac{\cancel{L}}{T} \cdot \frac{\cancel{L}}{T\cancel{L}}$

$= \frac{M}{L^2 T^2}$

$$\boxed{\frac{M}{L^2 T^2}}$$

(b)

$P : \frac{M}{LT^2}$

$dA : L^2$

$\frac{M L^{\cancel{2}}}{\cancel{L} T^2}$

$$\boxed{\frac{ML}{T^2}}$$

(c)

$\rho : \frac{M}{L^3}$

$C_p \Rightarrow \frac{J}{gK} \Rightarrow \frac{\frac{ML^2}{T^2}}{M\ \Theta}$

$\frac{\partial^2 T}{\partial x \partial y} \Rightarrow \frac{\partial}{\partial x}\left(\frac{\partial T}{\partial y}\right) \Rightarrow \frac{\Theta}{L^2}$

$\frac{M}{L^3} \cdot \frac{\cancel{M}\cancel{L^2}}{T^2 \cancel{M} \cancel{\Theta}} \cdot \frac{\cancel{\Theta}}{\cancel{L^2}}$

$$\boxed{\frac{M}{L^3 T^2}}$$

(d)

$\rho : \frac{M}{L^3}$

$\frac{\partial u}{\partial t} : \frac{L/T}{T}$

$dx, dy, dz : L$

$\frac{M}{\cancel{L^3}} \cdot \frac{L}{T^2} \cdot \cancel{L^3}$

$$\boxed{\frac{ML}{T^2}}$$

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Problem 4

$5 - 3 = \underline{2\,\Pi \text{ groups}}$

$P(D, \rho, V, \omega)$

$\frac{ML^2}{T^3}\left(\underline{L}, \underline{\frac{M}{L^3}}, \underline{\frac{L}{T}}, \frac{1}{T}\right)$

$b = 1 \quad c = 3 \quad a = 2$

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

$\therefore \Pi_1 = \frac{P}{D^2 \rho V^3}$

$\Pi_2: \frac{1}{T} = L^d \left(\frac{M}{L^3}\right)^e \left(\frac{L}{T}\right)^f$

$d = -1$
$e = 0$
$f = 1$

$\therefore \Pi_2 = \frac{\omega D}{V}$

$$\boxed{\frac{P}{D^2 \rho V^3} = f\left(\frac{\omega D}{V}\right)}$$

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Problem 5

(a)

$$\Pi_{2a} = \Pi_{2b} = \frac{\omega D}{V} \rightarrow \Pi_{2a} = \frac{\frac{1200}{60} \cdot 0.9}{12} = 1.5$$

$$1.5 = \Pi_{2b} = \frac{\omega \cdot 50}{8} \rightarrow \omega = \frac{1.5 \cdot 8}{50} = 0.24 \frac{rot}{sec} \cdot \frac{60\ sec}{1\ min}$$

$$\boxed{14.4 \frac{rotation}{min}}$$

(b)

$$\Pi_{1a} = \Pi_{1b} = \frac{P}{D^2 \rho V^3} = \frac{280}{0.9^2 \cdot 997 \cdot 12^3} = 0.000201$$

$$= \frac{P}{50^2 \cdot 997 \cdot 8^3} \rightarrow P = 0.000201 \cdot 50^2 \cdot 997 \cdot 8^3 = 256058.5\ W$$

$$\boxed{256.\ kW}$$

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Problem 6

(a)

$$\frac{L}{T} = \sqrt{\frac{2\, L^{-2}\, L^{4} \cdot \frac{M}{LT^2} \cdot T}{T^2\ \frac{M}{LT}}}$$

$n = 7$
$j = 3$

$k = n - j = 4$

$\boxed{4}$

(b)

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

$a = 0$
$b = -1$
$c = 1/2$

$V(k, A, P, t, \alpha, \mu)$

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

$$\boxed{\Pi_1 = \frac{V\,t}{A^{1/2}}}$$

(c)

$$\Pi_{1a} = \frac{V\,t}{A^{1/2}} = \frac{6\,\frac{m}{s} \cdot 21\,\text{sec}}{5^{1/2}} = 56.3$$

Arbitrarily choose

$\boxed{56.3}$

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Problem 7

(a)

$$\tau(D, \mu, \rho, \vec{u}) \rightarrow \frac{M}{LT^2}\left(L, \frac{M}{LT}, \frac{M}{L^3}, \frac{L}{T}\right)$$

$5 - 3 = 2$ ✓

True

(b) $u = y$, $v = x$, $w = 0$

$u = y$

$v = x$

$$u = \frac{\partial \psi}{\partial y} = y \rightarrow \psi = \frac{y^2}{2} + f(x)$$

$$v = -\frac{\partial \psi}{\partial x} = x \qquad \frac{\partial \psi}{\partial x} = f'(x) \rightarrow f'(x) = -x$$

$$\psi = \frac{y^2}{2} - x$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = \frac{\partial}{\partial x}(y) + \frac{\partial}{\partial y}(x) = 0 \checkmark$$

True

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Problem 7 (continued)

(c)

$$Re_1 = Re_2 \rightarrow Re_1 = \frac{997 \cdot 180 \cdot 0.075}{1\times10^{-3}}$$

If the System has geometrically and dynamically similar conditions then it can be modeled.

The 75 mm sphere has similar geometry as the 15 mm sphere. ~~Dynamically~~

Dynamic similarity would have to be assumed

True

~~(d)~~

If there is a sudden expansion of pipe then the flow can change from laminar to turbulent

False