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Final Exam Answer Template

Put your final answer in the box provided. Upload your completed template and any extra pages to the assignment on Canvas. The template pages should come first in your completed pdf.

Problem 1

(a)

$Re = \frac{\rho V D}{\mu}$ assume air @ 20°C

$\rho = \frac{16.3}{9.8} = 1.66 \frac{kg}{m^3}$

$D \approx 1ft \approx 0.305m$

$V = 223.5 \frac{m}{sec}$

$\mu = 2.24 \times 10^{-5}$

$\therefore Re = 5.061636 \times 10^6$ $\therefore$ Turbulent $> 5 \times 10^5$

True

(b)

Need to use different grid sizes to test and if solver residuals converge then ✓

True

(c)

$Re \ll 1$ $\therefore$ Stokes flow

True

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Problem 1 (continued)
(d)

The vortices cause mixing ∴ turbulent

False

(e)

Choked

as $dA >$, for $Ma > 1$, $dp < 0 \rightarrow dv > 0$

(Pressure Fig 9.5)

True

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$Re = \frac{\rho v D}{\mu}$

Problem 2

(a) $C_L = \frac{L}{\frac{1}{2}\rho v^2 A}$ $\quad L = mg$ $\quad A = 2 \cdot 1.5 \cdot 0.1 = 0.3\,m^2$

$m = 0.5\,kg$

$\rho = 1.66$

$\mu = 2.24 \times 10^{-5}$

$L = 0.1$

$\rightarrow v = \sqrt{\frac{2mg}{\rho C_L A}} = 6.27 \frac{m}{sec}$

$\therefore Re = 46537 = 4 \times 10^4 < 5 \times 10^5$

Re=46537
Laminar

(b) $Re_{cri} = \frac{998 \cdot 5 \cdot 0.1}{1 \times 10^{-3}} = 4.99 \times 10^5 \simeq 5 \times 10^5$

4.99×10^5
Transitional

(c) $D \simeq$ ans $0.05\,m$

Turbulent - caused by dimples

assume $v \simeq 100\,mph = 44.7 \frac{m}{sec}$

$Re = \frac{1.66 \cdot 44.7 \cdot 0.05}{2.24 \times 10^{-5}} = 165629 \triangleq 5 \times 10^5$

1.66×10^5
Transitional

Name: Josh Whitehead
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$Re = \frac{\rho v D}{\mu}$

Problem 2 (continued)

(d)

$\varepsilon = 0.00015$

~~$D = 4.026''$~~

$v = 0.6\ ft^3/sec$

$\frac{\varepsilon}{d} = 0.000447$ → assume turbulent

$f \simeq 0.016 \rightarrow h_f \simeq \frac{f L v^2}{d 2g}$

$\rho = 1117$

$D = 0.10226$

$\mu = 2.14 \times 10^{-2}$

$Q = 0.01699\ \frac{m^3}{sec}$

$v = \frac{Q}{A} = \frac{Q}{\pi (\frac{1}{2} D)^2} = 1.41 \times 10^{-5}\ \frac{m}{sec}$

$\therefore Re = 0.07526$

Re = 0.075

Laminar

(e)

Guess $Ma_1 \simeq 0.9 \rightarrow \frac{P}{P_0} = 0.5913$

~~$\frac{P_0}{P} = (1 + 0.2 Ma^2)^{3.5}$~~

$\frac{P_2}{P_1} = \frac{1}{k+1}\left(2k Ma_1^2 - (k-1)\right)$ $\quad k = 1.4$

$\therefore Ma = 0.886 = \frac{v}{a} = \frac{v}{\sqrt{kRT}}$

$= \frac{v}{330} \rightarrow v = 292.5\ \frac{m}{sec}$

$Re = \frac{1.66 \cdot 292.5 \cdot 0.1}{2.24 \times 10^{-5}} = 2167731 \Rightarrow 2 \times 10^6$

$Re = 2.17 \times 10^6$

Turbulent

Bonus:

Choked

$Ma_2^2 = \frac{(k-1) Ma_1^2 + 2}{2k Ma_1^2 - k + 1} \simeq 1$

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Problem 3

(a)

$$Re = \frac{1.66 \cdot 44.5 \cdot 0.074}{2.24 \times 10^{-5}} = 2.44 \times 10^5 \quad \therefore C_D \approx 0.3$$

$$D = C_D \cdot \frac{1}{2} \rho v^2 A_P = 2.12 \text{ N}$$

$$a = \frac{D}{m} = 14.1 \frac{m}{sec^2}$$

$$14.1 \frac{m}{sec^2}$$

(b)

$$\frac{\theta}{x} = \frac{0.671}{Re^{1/2}} \rightarrow \theta = 6.79 \times 10^{-7}$$

$$6.79 \times 10^{-7}$$

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Problem 3 (continued)

(c)

$M = \sin^{-1}\frac{1}{M_a}$ $\quad M_a = \frac{447}{330} = 1.35$

$M = ?$ $\quad \therefore M = 0.83$

0.830

(d)

$\frac{T_1}{T_0} = \frac{2\kappa M_a^2 - \kappa + 1}{\kappa + 1}$ $\quad \frac{(2\kappa M_a^2 - \kappa + 1)((\kappa - 1)M_a^2 + 2}{(\kappa+1)^2 M_a^2}$

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Problem 4

(a)

$m = 0.454\ kg$ $\quad F = mg = 4.45N = \Sigma v \cdot \dot{m} =$

$h_f = \frac{v^2}{2g}\left(\frac{f \cdot L}{D} + K\right)$ $\quad \varepsilon = 0.00001$

$\therefore \varepsilon$

$d =$

$F = C_D \frac{\rho}{2} v^2 A$ $\quad C_D \approx 0.76$

4.45

$v = \sqrt{\frac{4.45 \cdot 2}{0.76 A \rho}} = 2.656$

$Q = v \cdot A = 2.656 \cdot 8 =$

d $\quad Q = 2.656\ m^3$

$Q = 21.24\ \frac{m^3}{sec}$

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Problem 4 (continued)

(b)

$P_{out} = \rho g Q h_{pump}$

$P = 1.66 \cdot 9.8 \cdot 21.24 \cdot 3.048\,m$

$= 1053$

1.05 kW

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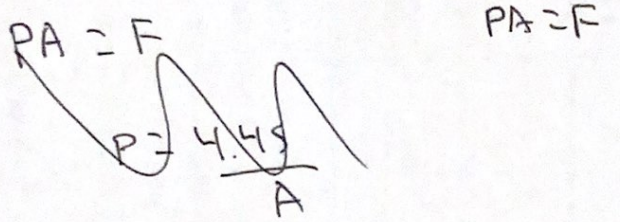
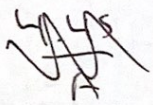
Problem 4 (continued)
(c)




Bonus: