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HW11 Answer template

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Problem 1

(a)

$Re_b = \frac{\rho v L}{\mu}$

$\rho = 902 \frac{kg}{m^3}$

$v = 0.2 \frac{m}{sec}$

$L = b = 4$

$\mu = 0.86 \frac{kg}{m \cdot sec}$

$\therefore Re = 0.839 < 1$ ✓

0.839

(b)

$F \approx \frac{6\pi}{5} \cdot \left(4 + \frac{a}{b}\right) \cdot \mu v b \rightarrow 4 + \frac{a}{b} = \frac{5F}{6\pi \mu v b}$

$a = b\left(\frac{5F}{6\pi \mu v b} - 4\right) = 0.0148\ m$

$= 14.8\ mm$

$2a = 29.7\ mm$

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Problem 2

$C_D A = 8.5\ m^2$

$v = 357.2 \frac{mi}{hr} = 159.7 \frac{m}{sec}$

$\rho = 1.225 \frac{kg}{m^3}$

$F = C_D \frac{\rho}{2} v^2 A = C_D A \frac{\rho}{2} v^2 = 1327751.2\ N$

~~$P = Fv = 211980.9 \cdot 159.7 = 28$~~

$P = Fv = 1327751.2 \cdot 159.7 = 211980.19\ W \cdot \frac{0.00134\ hp}{1\ W}$

$\approx 28405\ hp$

$2.84 \times 10^4\ hp$

Problem 3

$F_{ball} = mg = 0.0026 \cdot 9.8 = 0.0255\ N$

$F_{sphere} = 3\pi\mu V D \qquad Re_D = \frac{\rho V D}{\mu}$

$V = \frac{F}{3\pi\mu D} = \frac{Re\,\mu}{\rho D} \rightarrow Re = \frac{F\rho}{3\pi\mu^2} = 1.02 \times 10^7$

@ $Re = 10^7$ $C_D \approx 0.5$

$C_D = \frac{2F}{\rho v^2 A} \rightarrow v = \sqrt{\frac{2F}{\rho C_D A}}$

$= 8.57 \frac{m}{sec}$

$8.57 \frac{m}{sec}$

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Problem 4

(a)

$C_L = \frac{L}{\frac{1}{2}\rho V^2 A_p}$

$L = 67000\ N$

$\rho = 0.4125$

$A_p = 32\ m^2$

$C_L = 0.21$

$\rightarrow V = \left(\frac{L \cdot 2}{\rho C_L A}\right)^{1/2}$

$= 219.9 \frac{m}{sec} = 491.8 \frac{mi}{hr}$

$492. \frac{mi}{hr}$

(b)

$D = C_D \cdot \frac{1}{2}\rho V^2 A$

$C_D = 0.015$

$\therefore D = 4786\ N$

$Dv = 1052210\ W \cdot \frac{1\ hp}{745.7\ W} = 1411\ hp$

$1.41 \times 10^3\ hp$

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Problem 5

(a)

$v = \frac{10700\ m}{35.60\ sec} = 5.095\ \frac{m}{sec}$

$P_g = v \cdot 70 \cdot 9.8 \sin(0.08) = 279.6\ W$

$\%_{load} = 1 - \frac{P_g}{P_{tot}} = 1 - \frac{279.6}{332} = 0.158$

15.8 %

(b)

$P_{ad} = P_{tot} - P_g = 52.37\ W$

$F = P_{ad} \cdot v = 266.9\ N$

$C_D A = \frac{2F}{\rho v^2} \quad 20.411\ m^2$

20.4 m^2

Problem 5, continued

(c)

$C_D A = 20.41 - 0.01 = 20.40$ $\quad m = 70 - 1 = 69\ kg$

~~$P_g = m \cdot g \cdot 0.08 = 69 \cdot$~~

$\frac{P_g}{V} = mg \cdot 0.08 \quad F = \frac{P_{tot}}{V} - \frac{P_g}{V} \rightarrow C_D = \frac{\frac{P_{tot}}{V} - mg \cdot 0.08}{0.5 \rho v^2 A}$

$\rightarrow C_D A = \frac{\frac{P_{tot}}{V} - mg \cdot 0.08}{0.5 \rho v^2} \rightarrow$ Iterate until $C_D A \approx 20.40$

$V = 2.64 \frac{m}{sec}$

No

(d)

$Re = \frac{\rho v L}{\mu}$ $\quad$ assume $L \approx 1.5\ m$

$Re = \frac{1.022 \cdot 2.64 \cdot 1.5}{2 \times 10^{-5}} = 2.02 \times 10^5$

Transitional

$Re = \frac{\rho V D}{\mu} = \frac{VL}{\nu}$

Problem 6

(a)

using water @20°C 1atm → $\nu = 1.61 \times 10^{-4} \frac{ft^2}{sec}$

$Q = 500 \frac{gal}{min} = \frac{1 ft^3}{7.48 gal} \cdot \frac{1 min}{60 sec} = 1.11 \frac{ft^3}{sec}$

$V = \frac{Q}{A} = \frac{1.11}{\frac{\pi}{4} D^2} = 0.355 \frac{ft}{sec}$

$Re = \frac{0.355 \cdot 2}{1.61 \times 10^{-4}}$

4405 close to 2300

i) 4405

ii) Transitional

(b)

assume $V \approx 95 mph = 42.47 \frac{m}{sec}$

$L \approx 20 ft = 6.096 m$

$\nu = 1.61 \times 10^{-4}$

$Re = \frac{42.47 \cdot 6.096}{1.61 \times 10^{-4}} = 1.61 \times 10^6$

1.61×10^6 close to 10^5

i) 1.61×10^6

ii) Transitional

assume speed of sound $= 331.3 \frac{m}{s}$

$Ma = \frac{42.47}{331.3} = 0.128 < 0.3$

Bonus: Yes

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Problem 6, continued

(c)

Stokes flow: $Re \leq 1$ $\quad Re = 1 = \frac{Dv}{\nu} = \frac{\rho D v}{\mu}$

$\rightarrow v = \frac{1 \cdot 0.8[illegible]}{891 \cdot 0.001} = 0.325 \frac{m}{sec}$

$F = 3\pi \mu v D = 8.9 \times 10^{-4}$

$C_D = \frac{F}{0.5 \rho v^2 \frac{\pi}{4} D^2} = 24$

i)

1

ii)

Laminar

(d)

$\frac{\rho}{\rho_0} = 0.0277$ $\quad \rho_0 = 1.582$

$\therefore \rho = 0.0277 \cdot 1.582 = 0.0438 \frac{kg}{m^3}$

$\mu = 14.56 \times 10^{-6}$ $\quad v = M_a \cdot a = 4.331 = 1324 \frac{m}{sec}$

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

$= \frac{0.0438 \cdot 1324 \cdot 2}{14.56 \times 10^{-6}}$

i)

7.97×10^{6}

ii)

Transitional – turbulent

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Problem 6, continued

(e)

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

$\Delta P = \frac{1}{2}\rho(v_2^2 - v_1^2)$

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

$\frac{\Delta P}{\rho} + g(z_1 - z_2) = \frac{v_2^2}{2}$

$v_2 = \sqrt{\frac{2\Delta P}{\rho}} = \sqrt{\frac{2 \cdot 100000}{998}}$

$= 14.2 \frac{m}{sec}$

$Re = \frac{998 \cdot 14.2 \cdot 1 \times 10^{-8}}{1.003 \times 10^{-3}}$

i)

0.141

ii)

Laminar

Bonus:

Yes

$K_n = \frac{\lambda}{L} = \frac{2 \times 10^{-10}}{0.02} = 10^{-8} << 1$