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1. $F = \frac{1}{2} C_D \rho V^2 A$

$\Delta E = \Delta F \cdot X = \frac{1}{2} \Delta C_D \rho V^2 A X$

$= \frac{1}{2}(1.17 - 0.38) \times 1.20 \ kg/m^3 \times (\frac{95}{3.6} m/s)^2 \times \frac{\pi}{4} \times (0.13m)^2 \times 24000 \times 10^3 \ m$

$= \cancel{4.38} \ 1.05 \times 10^5 \ kJ$

$\Rightarrow \Delta E_{total} = \frac{\Delta E}{\eta} = \frac{1.05 \times 10^5 \ kJ}{30\%} = 3.50 \times 10^5 \ kJ$

$\Delta V_{fuel} = \frac{\delta E_{total}}{H \cdot \rho} = \frac{3.50 \times 10^5 \ kJ}{\frac{44,000 \ kJ/kg}{0.8 \ kg/L}} = 9.957 \ L$

For one car, there are two side rearview mirrors

Therefore, $\Delta V_{total} = 2 \Delta V_{fuel} = 19.91 \ L$

$\Delta \$ = \Delta V_{total} \times \$0.60/L = \$11.947$

2. $\Sigma F_y = 0 \Rightarrow \cancel{F_D = mg}$ $\quad F_D + \rho g \forall - mg = 0$

$\Rightarrow \cancel{\frac{1}{2} C_D \rho V^2 A = mg}$ $\quad \frac{1}{2} C_D \rho V^2 A + \rho g \frac{\pi D^3}{6} - mg = 0$

$\Rightarrow \cancel{V_f = \sqrt{\frac{2mg}{C_D \rho A}}}$ $\quad \frac{1}{2} C_D \rho V^2 A + \frac{1}{6} \pi D^3 \rho g - \rho_s \forall g = 0$

$\Rightarrow V_f = \sqrt{\frac{-\rho_w g \forall + mg}{\frac{1}{2} C_D \rho_w A}}$

$= \sqrt{\frac{2 \times (\rho_s \frac{\pi D^3}{6} g - \rho_w \frac{\pi D^3}{6} g)}{C_D \rho_w \frac{\pi}{4} D^2}} = \sqrt{\frac{(\rho_s - \rho_w) \frac{\pi D^3}{3} g}{C_D \rho_w \frac{\pi}{4} D^2}} = \sqrt{\frac{4(\rho_s - \rho_w) D g}{3 C_D \rho_w}}$

$= \sqrt{\frac{4 \times (1150 - 998) \ kg/m^3 \times 0.004 \ m \times 9.81 \ m/s^2}{3 \times 0.5 \times 998 \ kg/m^3}} = 0.126 \ m/s$

Check for Re

$Re = \frac{\rho V D}{\mu}$ $\quad$ It is laminar

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3. $F_D = \frac{1}{2}C_D\rho V^2 A = ma$

(a) $\Rightarrow a = \frac{C_D\rho V^2 A}{2m}$

$F_L = \frac{1}{2}C_L\rho V^2 A = mg$

$\Rightarrow V = \sqrt{\frac{2mg}{C_L\rho A}}$

In two conditions, m, g, A C_L are the same

therefore $\frac{V_{1600}}{V_0} = \frac{\sqrt{\frac{1}{\rho_{1600}}}}{\sqrt{\frac{1}{\rho_0}}} = \sqrt{\frac{\rho_0}{\rho_{1600}}}$ #

$\Rightarrow V_{1600} = V_0\sqrt{\frac{\rho_0}{\rho_{1600}}} = 220\ km/h \times \sqrt{\frac{1.225\ kg/m^3}{1.048\ kg/m^3}} = 237.85\ km/h$

(b) ~~$V^2 - V_0^2 = 2$~~

$a_0 = \frac{v}{t} = \frac{\frac{220}{3.6}\ \cancel{km/h}\ m/s}{15s} = 4.074\ m/s^2$

$\Rightarrow t = \frac{V_{1600}}{a_{1600}} = \frac{\frac{237.85}{3.6}\ m/s}{4.074\ m/s^2} = 16.22\ s$

(c) $V^2 - V_0^2 = 2ax$

$\Rightarrow \Delta X = \frac{V_{1600}^2 - V_0^2}{2a} = \frac{\left[\left(\frac{237.85}{3.6}\right)^2 - \left(\frac{220}{3.6}\right)^2\right] m^2/s^2}{2 \times 4.074\ m/s^2} = \cancel{154.82\ m}$

77.41 m

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4. $\frac{V_1^2}{2g}+y_1=\frac{V_2^2}{2g}+y_2+Z_2$

~~For critical. $y_1=y_2 \Rightarrow V_1=V_2$~~

For critical flow, $\frac{V_2}{\sqrt{gy_2}}=1 \Rightarrow V_2=\sqrt{gy_2}$

$Q_1=Q_2 \Rightarrow V_1by_1=V_2by_2 \Rightarrow V_1y_1=V_2y_2$

$\Rightarrow 1.25\times1.8=V_2y_2$

$\Rightarrow 1.25\times1.8=\sqrt{gy_2}\ y_2$

$\Rightarrow y_2=0.802\text{ m}$

$\Rightarrow Z_2=\left(\frac{V_1^2}{2g}+y_1\right)-\left(\frac{V_2^2}{2g}+y_2\right)=\left(\frac{1.25^2}{2\times9.81}+1.8\right)-\left(\frac{3}{2}\times0.802\right)$

$=0.6765\text{ m}.$

5. $Fr_3=\frac{V_3}{\sqrt{gy_3}}=\frac{4\text{ m/s}}{\sqrt{9.81\text{ m/s}^2\times3\text{ m}}}=0.737335$

$\Rightarrow y_2=\frac{1}{2}y_3\left[\sqrt{1+8Fr_3^2}-1\right]=\frac{1}{2}\times(3\text{ m})\times\left(\sqrt{1+8\times0.737335^2}-1\right)$
$=\boxed{1.969\text{ m}}$

$\frac{Q}{w}=\frac{Q_3}{w}=V_3y_3=3\text{ m}\times4\text{ m/s}=\boxed{12\text{ m}^2/\text{s}}$

$\Rightarrow V_2=\frac{V_3y_3}{y_2}=6.09\text{ m/s}$ $\quad F_2=1.386$

$\frac{V_1^2}{2g}+y_1=\frac{V_2^2}{2g}+y_2$

$\Rightarrow y_1=\frac{V_2^2}{2g}+y_2-\frac{V_1^2}{2g}=\frac{(6.09\text{ m/s})^2}{2\times9.81\text{ m/s}^2}+1.969\text{ m}-\frac{(1.25\text{ m/s})^2}{2\times9.81\text{ m/s}^2}$
$=\boxed{3.78\text{ m}}$

$\frac{H_L}{E_2}=\frac{\left[\sqrt{1+8Fr_2^2}-3\right]^3}{8\left[\sqrt{1+8Fr_2^2}-1\right]\left[Fr_2^2+2\right]}=\frac{\left[\sqrt{1+8\times1.386^2}-3\right]^3}{8\left(\sqrt{1+8\times1.386^2}-1\right)\left(1.386^2+2\right)}$
$=\cancel{\boxed{0.0366}}$ $\boxed{0.01200}$