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AE311 Project 1

Statement:

"We are working on a new project focused on parachutes for autonomous spacecraft landings. The main application we are prioritizing is final deceleration to the surface of Mars although our group also wants to expand to parachutes for Earth operations. Our team's tasks will include everything related to ground testing, including the design of experiments and measurement techniques, as well the evaluation of the aerodynamic performance of different parachutes manufactured with novel textiles with different material properties (mainly permeability and behavior under loads)."

Test conditions:

task 1)

Mars

$\rho = .020 \ kg/m^3$

$\mu_M = \frac{4}{5}\mu_E$

$u = 100 \ m/s$

$L = 21.5$

Earth

$\rho = 1.204 \ kg/m^3$

$Re = \frac{\rho u L}{\mu}$

$C_d = \frac{2F_d}{\rho u^2 A}$

Situation: F_d, ρ, u change

for $C_d(\text{tunnel}) = C_d(\text{Mars})$ to be true, dynamic similarity needs to be assured

1) $Re(\text{tunnel}) = Re(\text{Mars})$

2) $A_1 = kA_2$ — — —> Already satisfied ($A_1 = A_2$)

$$Re(\text{tunnel}) = \frac{(1.204)(u)\cancel{(L)}}{\cancel{\mu_E}} = \frac{(.020)(100)\cancel{(L)}}{\frac{4}{5}\cancel{\mu_E}} \rightarrow u = \frac{2(5/4)}{1.204} = \boxed{2.076412 \ m/s}$$

task 2)

Max 40%, Area

$\pi(R^2) = .4(1.5 \cdot 1.5)$

$R = \sqrt{.286479} = .535237\,m$

$D_{max} = 1.07047\,m$

$\pi(10.75^2) = \pi(.535237^2)\,K$

$115.56 = .9\,K \rightarrow K \approx 403.389$

Since $D_{max} = 1.07047$ is not scaled,

$K = 404$ to assure $D_{actual} \leq D_{max}$

but $D_{actual} = K \cdot D$ where $K \in \mathbb{N}$

$\frac{10.75^2}{K} = r_{actual}^2 \rightarrow r_{actual} = .5348325\,m$

$\boxed{D_{actual} = 1.069665\,m}$

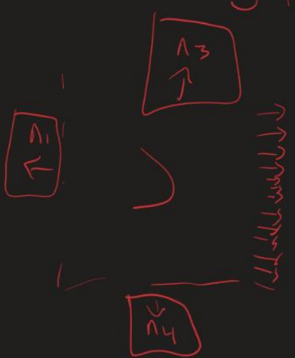
$$Re = \frac{(\cancel{1.204})(2.076412)(21.5)}{\cancel{\mu_E}} = \frac{(\cancel{1.204})(u)(1.07099)}{\cancel{\mu_E}} \rightarrow \boxed{u = 41.68373\,m/s}$$

Parachute Drag

task 1) $\int \rho_1 (v_{rel} \cdot n_1)\, dA + \int \rho_2 (v_{rel} \cdot n_2)\, dA + \int \rho_3 (v_{rel} \cdot n_3)\, dA + \int \rho_4 (v_{rel} \cdot n_4)\, dA$

$= \int \rho_2 (v \cdot n_2)\, dA + \int \rho_4 (v \cdot n_4)\, dA = 0$

ρ is constant: $\int -\rho_1 v_1\, dA + 2\rho_2 \left(\int_0^{\frac{\pi}{2}} v_2 - v_2 \cos\left(\frac{\pi y}{b}\right) + \int_0^{\frac{\pi}{2}} v_2\, dA \right) = 0$



$\rightarrow -\rho_1 v_1 H + \rho_2 \left(\frac{v_2 b(\pi - 2)}{\pi} \right) + 2v_2\left(\frac{\pi}{2} - \frac{b}{2}\right) = 0$

$\rightarrow -H + \frac{v_2}{v_1}\left(\frac{b(\pi-2)}{\pi} + H - b \right) = 0$

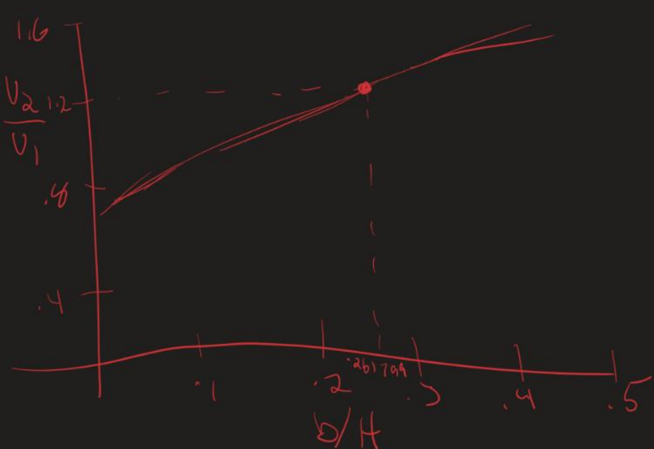
$\rightarrow \frac{v_2}{v_1} = \frac{H}{\frac{b(\pi-2)}{\pi} + (H-1)}$

$b = 1,\ \frac{v_2}{v_1} = 1.2;\ 1.2 = \frac{H}{\frac{\pi-2}{\pi} + (H-1)} \rightarrow 1.2\left(\frac{\pi-2}{\pi} + (H-1)\right) = H$

$\rightarrow \frac{1.2\pi - 2.4}{\pi} + 1.2H - 1.2 = H$

$\rightarrow H = 3.819719$

$\frac{b}{H} = .2617994$



$\frac{v_2}{v_1}\left(@ \frac{b}{h} = 1\right) = 0$ ✓

task 2) $\frac{d}{dt}\int_{CV(t)} \rho V \, dV + \int_{CS(t)} \rho V[(V - V_{CV}) \cdot n] \, dA$

Steady flow: $F_d = \Delta M + P_{out} - P_{in} = \int_{CS(t)} \rho V[(V - V_{CV}) \cdot n] \, dA + P_{out} - P_{in}$

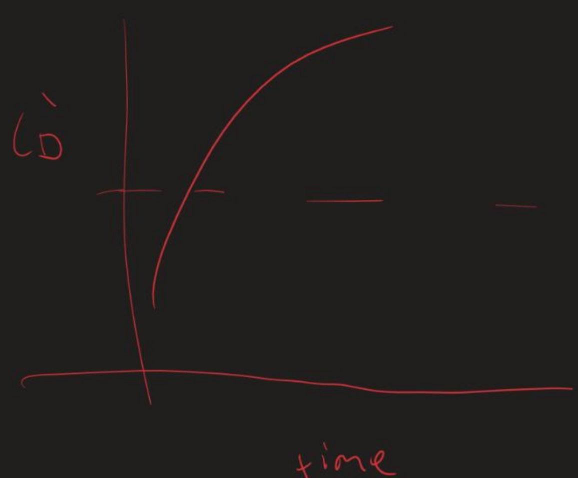
U_2 and ρ_2 are related, if diameter decreases, $\frac{V_2}{V_1}$ decreases as there is less wake and more of V_1 into U_2. The change in ΔP $(= P_{out} - P_{in})$ would affect drag and ΔM, momentum would change drag.

$$C_D = \frac{P_{out} - P_{in}}{q} = \frac{P_{out} - P_{in}}{\frac{1}{2}\rho V^2} = 1 - \left(\frac{U_2}{U_1}\right)^2 \rightarrow F_d = \frac{1}{2}\left[1 - \left(\frac{U_2}{U_1}\right)^2\right]\rho (U_1)^2 \frac{\pi b}{y}$$

task 3) $D_0 = 1$, $m = .2$, $W = 30\text{ Hz}$, $H = 1.5\text{ m}$, $\rho_1 = \rho_2$ (b changes w/ time)

$$C_D' = \frac{D'}{\frac{1}{2}\rho V_\infty^2 D_0} = \frac{D'}{\frac{1}{2}\rho V_\infty^2} \qquad D' = \frac{1}{2}\left[1 - \left(\frac{U_2}{U_1}\right)^2\right]\rho U_1^2 \left(\frac{\pi b}{y}\right)$$

$$C_D' = \frac{\frac{1}{2}\left(1 - \left(\frac{U_2}{U_1}\right)^2\right)\rho U_1^2 \left(\frac{\pi b}{y}\right)}{\frac{1}{2}\rho V_\infty^2}$$



Flow Field

task 1)

Pathlines: Path that is traced by a Particle in flow

streaklines: curve from flow of multiple Particles through Point

- blood into a stream of water follow streakline of that Point

streamlines: tangential line to instantaneous velocity

- air interacting with a moving object show streamlines

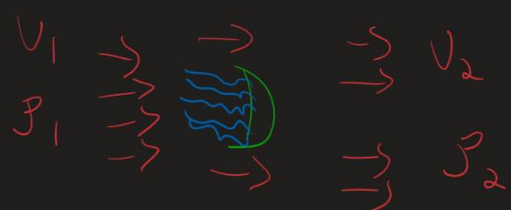
Pathlines ≃ streaklines ≃ streamlines for steady state

steam streak

1)

When breathing occurs, streaklines vary, changing streamlines.

2)



This only applies to affected region of Parachute.

task 2) 1) Flow is steady and incompressible for Part 1,

so if pressure at outlet is constant, $P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

This ensures continuity along streamline regarding velocity field for incompressible flow.

2) Flow in canopy being incompressible allows for simplification of velocity vectors ($\vec{V}$ = Potential velocity). Flow behind canopy is rotational because the parachute causes shift in directional velocity and creates a wake.

3) Neglecting the wall's frictional forces and, furthermore, assuming frictional forces in air outside of the wake are negligable, we can conclude the air outside of the wake is steady, incompressible. This means air outside of the wake is uniform. This means drag is the only frictional force at this state.