JME 3700
April 17, 2017

Homework #12

1. (10 pts) A smooth upward air flow suspends a sphere of radius R just above the flow outlet (Fig. 1). The sphere is solid and made of a material that is twice as dense as air, the latter's density being ρ. The coefficient of drag of a sphere is $C_D \approx 0.5$ over a wide range Reynolds number, $10^4 \leq Re \leq 10^5$. Assuming this condition is satisfied, show that the flow velocity is

$$u = \sqrt{\frac{32\, R\, g}{3}}$$

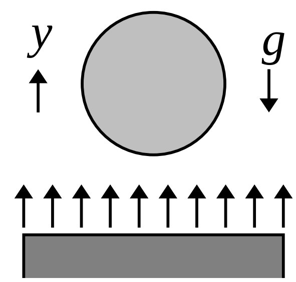

Fig. 1: *Suspended sphere.*

2. (10 pts) Fluid at an approach speed of u_0 flows around a cylinder of width b and radius R. The pressure distribution around the top half of the cylinder, $0 \leq \theta \leq \pi$, is shown in Fig. 2 in units of ρu_0^2. (The distribution is symmetric about $\theta = \pi$, i.e. for the bottom half, $\pi \leq \theta \leq 2\,\pi$.) Determine the drag coefficient if shear stress can be neglected.

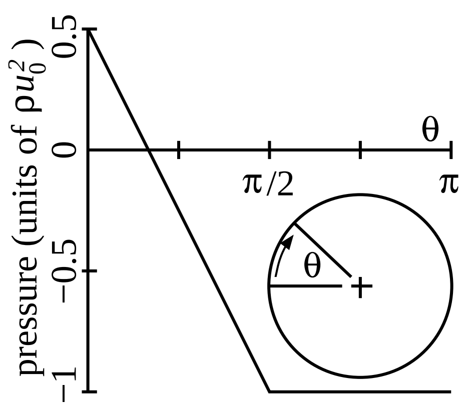

Fig. 2: *Pressure distribution.*

3. (10 pts) A barrier is in the form of a 1–1–$\sqrt{2}$ right triangle having a leg length of L and a width of W "into the paper" (Fig. 3). A flow creates a positive linear pressure distribution on the front vertical face, i.e. $P(y) = P_0 y/L$, and a similar linear negative distribution on the back side (the hypotenuse) having the same maximum magnitude of $|P_0|$. Here, the coefficient of drag is defined as

$$C_D = \frac{F_D}{\frac{1}{2}\,\rho\, u_\infty^2\, A_F}\,,$$

where ρ and u_∞ are fluid density and approach velocity, F_D is the total drag force, and $A_F = L \cdot W$. If the flow structure is such that $P_0 = \rho\, u_\infty^2/4$, determine C_D.

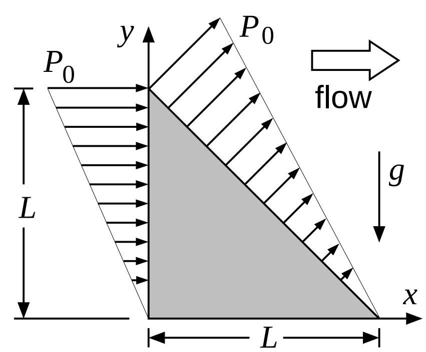

Fig. 3: *Triangle barrier.*

4. (10 pts) The triangular barrier in Question 3 has a mass of m and its center of gravity (centroid) is at $(x, y) = (L/3, L/3)$. Noting that gravitational acceleration g acts in the negative y–direction, show that the minimum value for m such that barrier does not begin to lift at its

front, i.e. at $(x, y) = (0, 0)$ and rotate about $(x, y) = (L, 0)$ is

$$m > \frac{3\,\rho\,u_\infty^2\,W\,L}{8\,g}\,.$$

5. (10 pts) A dragster of mass $m = 730\,kg$ crosses the finish line at $u_0 = 120\,m/sec$, after which the driver deploys a chute to slow the vehicle. The chute has an effective area of $2.3\,m^2$ and exerts a drag force, F_D (Fig. 4). It can be taken as a hemisphere having a coefficient of drag of $C_D = 1.4$. If the aerodynamic drag and the rolling resistance of the car itself are neglected (as being presumably small compared to the chute drag), determine the required time for the car to slow to a speed of $u_1 = 45\,m/sec$. Take local air density as $\rho = 1.2\,kg/m^3$.

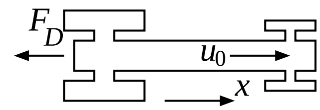

Fig. 4: *Dragster.*