Massachusetts Institute of Technology
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16.001/16.002 Unified Engineering I, II
Fall 2006

Problem Set 2

Name: ________________________

Due Date: 9/26/2006

	Time Spent (min)
F5	
F6	
F7	
M3.1	
M3.2	
Study Time	

Announcements:

Lab 1 used a 47:1 scale model of the Boeing Blended Wing Body (BWB). The actual BWB is designed to operate at 10km altitude, where the air properties compare to the sea level values as follows:

$$\begin{aligned} \rho &= 0.35\,\rho_{\text{SL}} \\ a &= 0.94\,a_{\text{SL}} \\ \mu &= 0.94\,\mu_{\text{SL}} \end{aligned}$$

The model was operated at $V_\infty = 18\,\text{m/s}$, while the actual BWB is designed to operate at $V_\infty = 250\,\text{m/s}$ at the 10km altitude.

a) Using the centerline chord as the reference length ($c_o = 37.7\,\text{in}$), determine Re and M_∞ for the BWB model in the wind tunnel, and the full-size BWB at altitude. Assume the tunnel is at standard atmospheric conditions at sea level.

b) If the model and full-size BWB are both operating at $\alpha = 5°$, can the model's measured C_L and C_D value be used to compute the lift and drag on the full-size BWB? Explain why or why not.

c) By varying the tunnel speed, is it possible to match both Re and M_∞ between the model and full-size BWB? Explain why or why not.

Consider the 2-D velocity field $\vec{V} = u\hat{\imath} + v\hat{\jmath}$

$$u = y \qquad\qquad v = x$$

whose hyperbolic-shape streamlines are sketched below. The density ρ is everywhere constant.

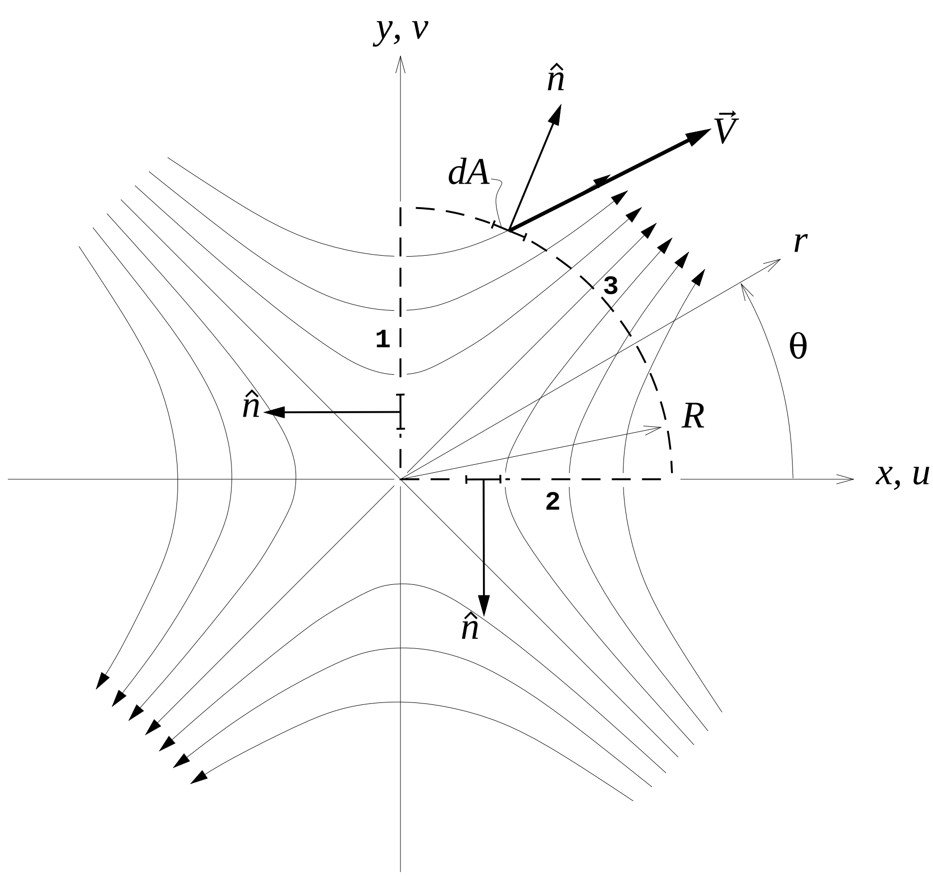
a) Evaluate the mass-flow integral

$$I \;=\; \oint \rho\,(\vec{V}\cdot\hat{n})\,dA$$

for the pie-slice control volume of radius R shown in the figure.

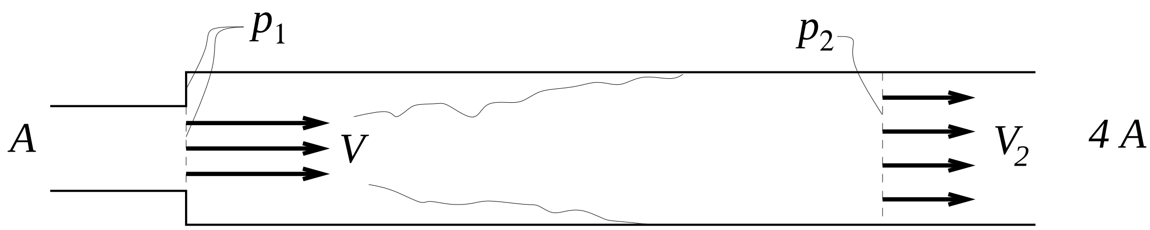
Hint: First express I as three separate integrals I_1, I_2, I_3 over each of the three segments of the C.V. boundary. Also, I_3 is most easily evaluated by first writing $\vec{V}$, $\hat{n}$, and dA as functions of the polar coordinates r, θ. Note that dA is a length in 2-D.

b) Does this flow satisfy the mass conservation law? Explain.



Unified Engineering Fall 2006
Fluids Problem F7

A pipe of cross-sectional area A has air flowing in it at a known velocity V_1. The pipe then suddenly increases to an area of $4A$, at station 1 where the pressure is some p_1.
After undergoing mixing in the larger pipe, the velocity becomes uniform again at station 2, where the velocity is V_2, and the pressure is p_2. Assume the density ρ is constant everywhere (low speed flow). Be sure to clearly draw the control volume you will be using.



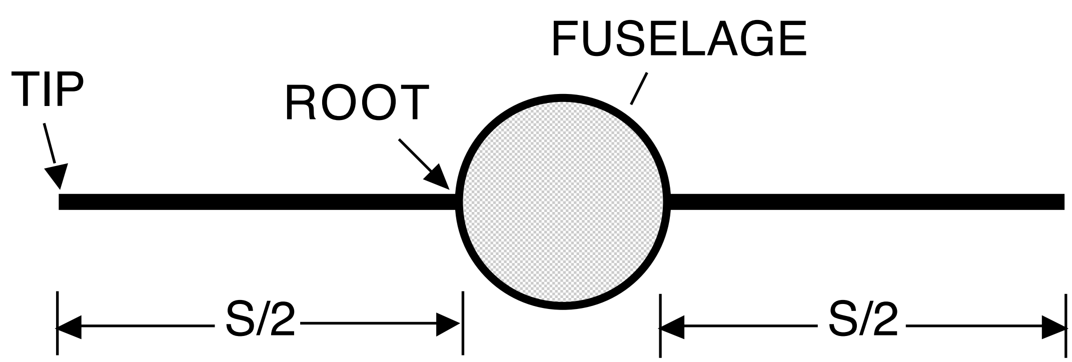
a) Determine the velocity V_2.

b) Determine the pressure difference $p_2 - p_1$.

Unified Engineering Problem Set **Lectures: M4, M5, M6**
Week 3 Fall, 2006 **Units: M1.2, M1.3**

M3.1 ***(15 points)*** In this problem, we consider a Boeing 777 and learn about the modeling of the lift on a wing in order to consider the loads acting on the structure. The 777 has approximate values for the gross takeoff weight of 506,000 pounds and for the wing half-span of 100 feet. The overall weight can be considered to act at the center of the *fuselage*. The half-*span* of the wing is the distance from the *root* (where the wing connects to the *fuselage*) to the *tip*. (See the simple diagram of the geometry below.)

For structural purposes, an airplane wing can be modeled in two dimensions as a linear structural member of length s/2 (the half-*span*) emanating from the *root*. Consider the fuselage to be a point for this initial structural consideration (not too comfortable for the passengers!). The *lift* (pressure differential between the top and bottom surfaces) on the wing can be represented as a *lineload* and thus has dimensions of [force/length]. Let's consider different possible models for the lift distribution: (1) constant along the *span* of the wing; (2) linear variation along the *span* of the wing with its maximum value at the *root* and with a value of zero at the *tip*; (3) quadratic variation along the *span* of the wing such that Lift = b - ax^2 with its maximum value at the *root* and with a value of zero at the *tip*. For each case, assume that in steady flight, each wing must provide sufficient *lift* to support half the total weight.



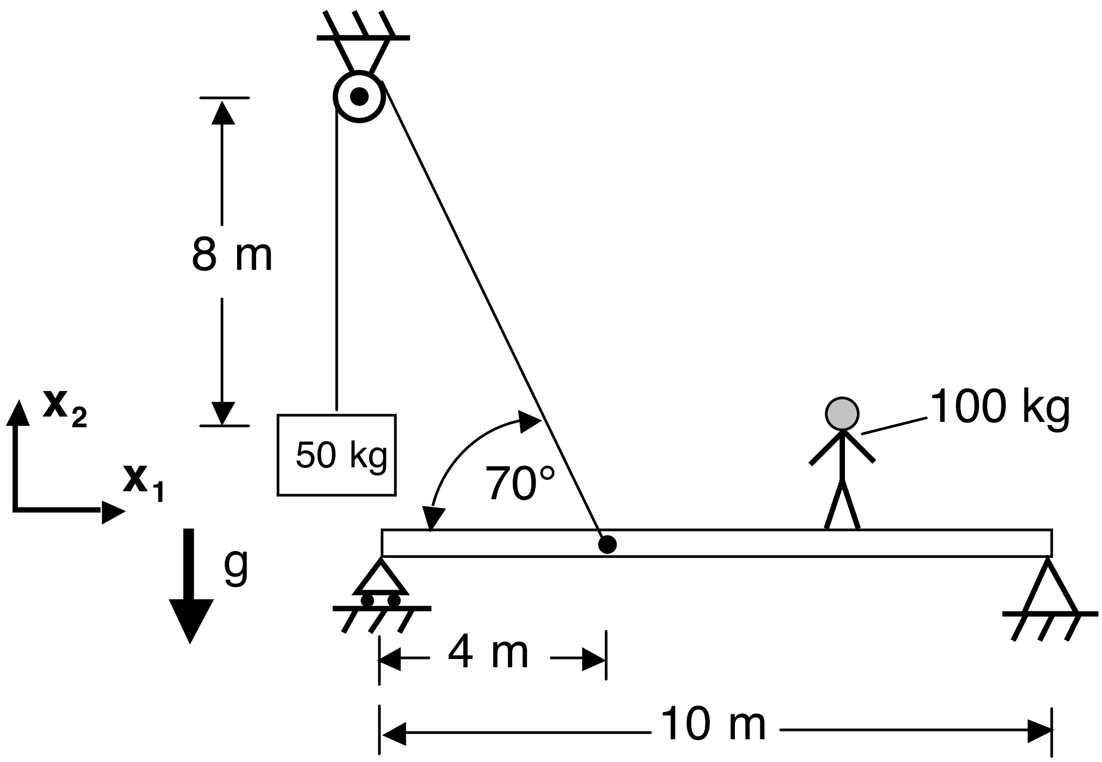
We work to see how the model for *lift* changes the following results. For each of the three models:

(a) Draw this configuration showing all loads.

(b) Determine the maximum magnitude of the lineload of lift and where it occurs.

(c) For one wing, determine the equipollent force system at the root for the lift.

M3.2 ***(15 points)*** A 10-meter long beam is attached via a roller at one end and is pinned at the other end. This configuration is known as *simply-supported*. A 100 kg person walks back and forth across this beam. In addition to the person, the beam has a cable attached to it 4 meters from the roller end. This cable makes a 70° angle with the beam and goes through a pulley, with a radius of r, attached by a pin to a ceiling 8 meters above the beam. At the other end of the cable is a mass of 50 kg. The overall situation is illustrated in the accompanying figure.



(a) Draw the free body diagram for this situation (choose any location for the person).

(b) If possible, determine the reaction forces as a function of the point on the beam at which the person is located.

(c) With the person at any location, determine if the mass hanging from the cable can be changed in such a way that the reaction(s) at the roller is(are) zero. Clearly explain your reasoning.

(d) The end with the pin is now clamped. Draw the free body diagram for this case and then determine the reaction forces or, if the reaction forces cannot be exactly determined, clearly explain the reasons for that.