Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Cambridge, MA 02139

16.01/16.02 Unified Engineering I, II
Fall 2003

Problem Set 15

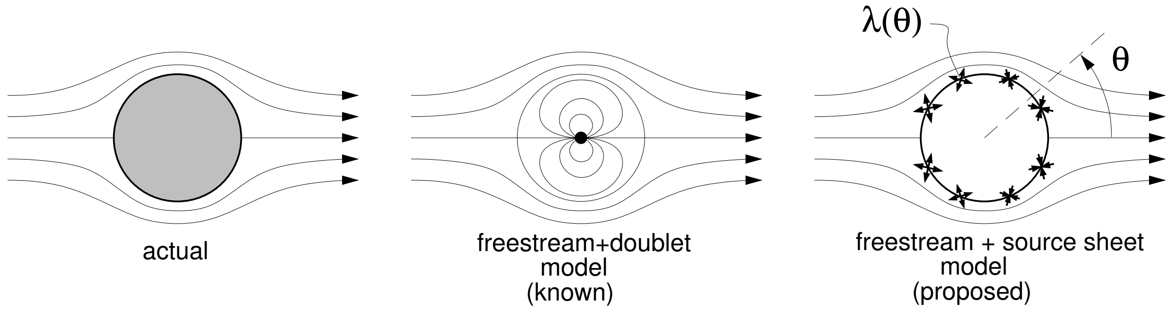
Name: ______________________

Due Date: Not Due

	Time Spent (min)
F21	
F22	
M23	
M24	
M25	
Study Time	

Announcements: Good luck on your finals. Reminder: The unified final is on Monday, 12/15 at 9am

F21. As shown in class, the nonlifting irrotational flow past a circular cylinder can be represented by superimposing the uniform freestream flow and a doublet. An alternative representation is proposed using a source sheet placed on the cylinder surface as shown. The proposed sheet strength distribution about the cylinder is $\lambda(\theta) = -2V_\infty \cos\theta$. There is no vortex sheet, so on the surface, $\gamma = 0$.



You are to determine whether the new model is correct.

a) Determine the velocity at point A from the known exterior surface velocities for the cylinder.

$$V_\theta(\theta) \; = \; -2V_\infty \sin\theta \qquad , \qquad V_r = 0$$

Using the sheet jump relations,

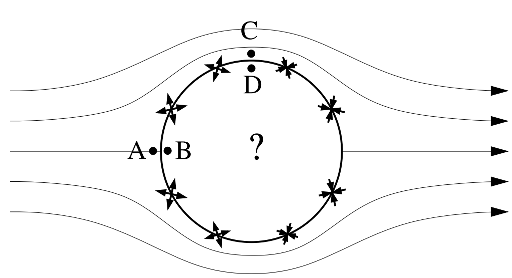
$$\Delta V_n = \lambda \qquad , \qquad \Delta V_s = \gamma$$

determine the interior velocity at point B.

b) Again using the known exterior $V_\theta(\theta), V_r$ result at point C, use the sheet jump condition to determine the velocity at point D.

c) Compare velocities at B and D. What appears to be the fictitious velocity inside the cylinder?

d) Is the source sheet jump $\Delta V_n = \lambda$ consistent with the exterior and interior normal flows everywhere on the cylinder surface? Is the proposed source-sheet model correct?



F22. A long rectangular wing has span b and chord c, and hence the wing area is $S = bc$.

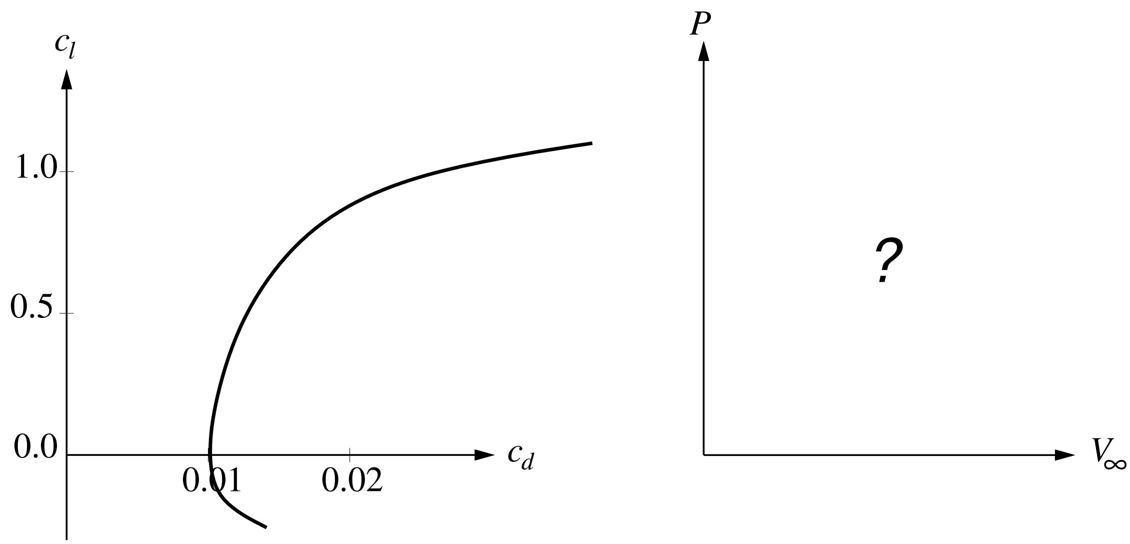
a) The wing airfoil has certain lift and drag coefficients c_ℓ and c_d which are constant across the span. Determine how these relate to the wing's overall C_L and C_D.
(Hint: Determine L' and D', then get L and D, then from these determine C_L and C_D).

The wing airfoil has a drag polar which can be approximated by

$$c_d \simeq 0.01 + 0.015\, c_\ell^3$$

in the range $c_\ell = 0.1 \ldots 1.2$. The propulsive power P needed to overcome drag D at flight speed V_∞ is given by

$$P = D\, V_\infty$$



b) Determine the form of the $P(V_\infty)$ relation in level flight, and plot it for the range $c_\ell = 0.1 \ldots 1.2$. Any constant multiplicative factors on the P and V_∞ axes are not important – only the shape of the curve is of interest. Hint: Simplest approach is to plot $P(c_\ell)$ versus $V(c_\ell)$ with c_ℓ as a dummy parameter.

(Note: Using only the airfoil's c_d ignores other contributions such as induced drag, which become especially significant at low flight speeds!)

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Problem M23 (Materials and Structures)

The potential energy, U of a pair of atoms in a solid can be written as:

$$U = \frac{-A}{r^m} + \frac{B}{r^n}$$

where r is the separation of the atoms and A, B, m and n are positive constants. Indicate the physical significance of the two terms in this equation.

A material has a simple cubic unit cell with atoms placed at the corners of the cubes. Show that, when the material is stretched in a direction parallel to one of the cube edges, Young's modulus E is given by:

$$E = \frac{mnkT_M}{\Omega}$$

Where Ω is the mean atomic volume, k is Boltzmann's constant and T_M is the absolute melting temperature of the solid. You may assume that $U_0(r_0) = -kT_M$,where r0 is the equilibrium separation of a pair of atoms.

Problem M24

Two metals of current and historical interest for aerospace applications, nickel and magnesium, have face centered cubic and close packed hexagonal structures respectively.

a) Assuming that the atoms can be represented as hard spheres, calculate the percentage of the volume occupied by atoms in each material.

b) Calculate, from first principles, the dimensions of the unit cell in nickel and in magnesium.
(The densities of nickel and magnesium are 8.90 Mgm^{-3} and 1.74 Mgm^{-3} respectively, the atomic weight of Nickel is 58.69, Magnesium is 24.31, Avogadro's number is 6.023×10^{23}).

Problem M25

In addition to chapters 4-7 of Ashby and Jones Engineering Materials, you may also find the chapters on polymers in Ashby and Jones, Engineering Materials 2, helpful (this is a green covered book, available in the Aero-Astro library).

a) Define the term *polymer* and list three engineering polymers.

b) Define a *thermoplastic* and a *thermoset.*

c) Distinguish between a cross-linked and a non-cross-linked polymer.

d) What is the glass transition temperature?

e) Explain the change in moduli of polymers at the glass transition temperature.

f) What is the range of temperature in which T_G lies for most engineering polymers?

g) How would you increase the modulus of a polymer?