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

Problem Set 8

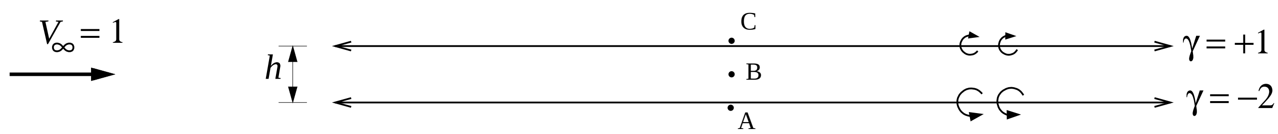
Name: ________________________

Due Date: 10/31/2006

	Time Spent (min)
F18	
F19	
F20	
M8.1	
M8.2	
M8.3	
Study Time	

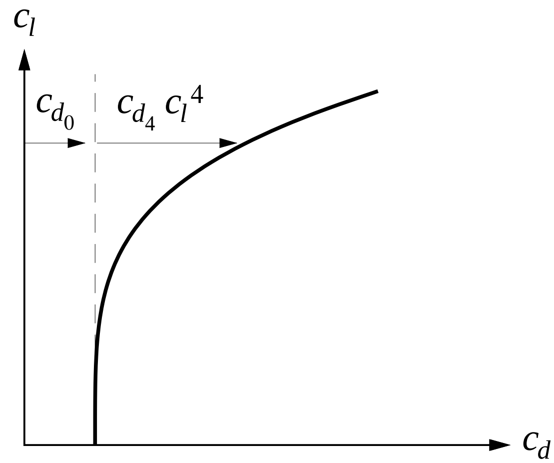
Announcements:

Two very long vortex panels of strengths $\gamma = +1$, $\gamma = -2$, as shown, are located at distance h apart. A horizontal freestream velocity $V_\infty = 1$ is also present. Determine the velocities at points A, B, C.



The drag polar of a particular airfoil at a fixed Reynolds number is closely approximated by

$$c_d(c_\ell) = c_{d_0} + c_{d_4} c_\ell^4$$
$$c_{d_0} = 0.02$$
$$c_{d_4} = 0.08$$



a) Determine the c_ℓ where this airfoil has its maximum c_ℓ/c_d (or alternatively, the minimum c_d/c_ℓ).

b) When the airfoil is used on an aircraft wing, there will be additional drag contributions from the fuselage and tail, which can be closely approximated by just an added constant Δc_{d_0}. There will also be an additional drag from the wing lift, called *induced drag*, which is proportional to c_ℓ^2 via a constant c_{d_2} (TBD next term). The overall drag for this particular aircraft can then be closely approximated as follows.

$$c_d(c_\ell) = c_{d_0} + \Delta c_{d_0} + c_{d_2} c_\ell^2 + c_{d_4} c_\ell^4$$
$$\Delta c_{d_0} = 0.01$$
$$c_{d_2} = 0.03$$

Determine the c_ℓ where the whole aircraft has its maximum c_ℓ/c_d.

c) Explain which way Δc_{d_0} and c_{d_2} each try to shift the c_ℓ value for maximum c_ℓ/c_d from case a) to case b). You may do this graphically, or by numerical experimentation.

Unified Engineering Fall 2006
Fluids Problem F20

As given in the notes, the potential flow velocity field over a circular cylinder is

$$V_r = V_\infty \cos\theta \left(1 - \frac{R^2}{r^2}\right)$$
$$V_\theta = -V_\infty \sin\theta \left(1 + \frac{R^2}{r^2}\right)$$

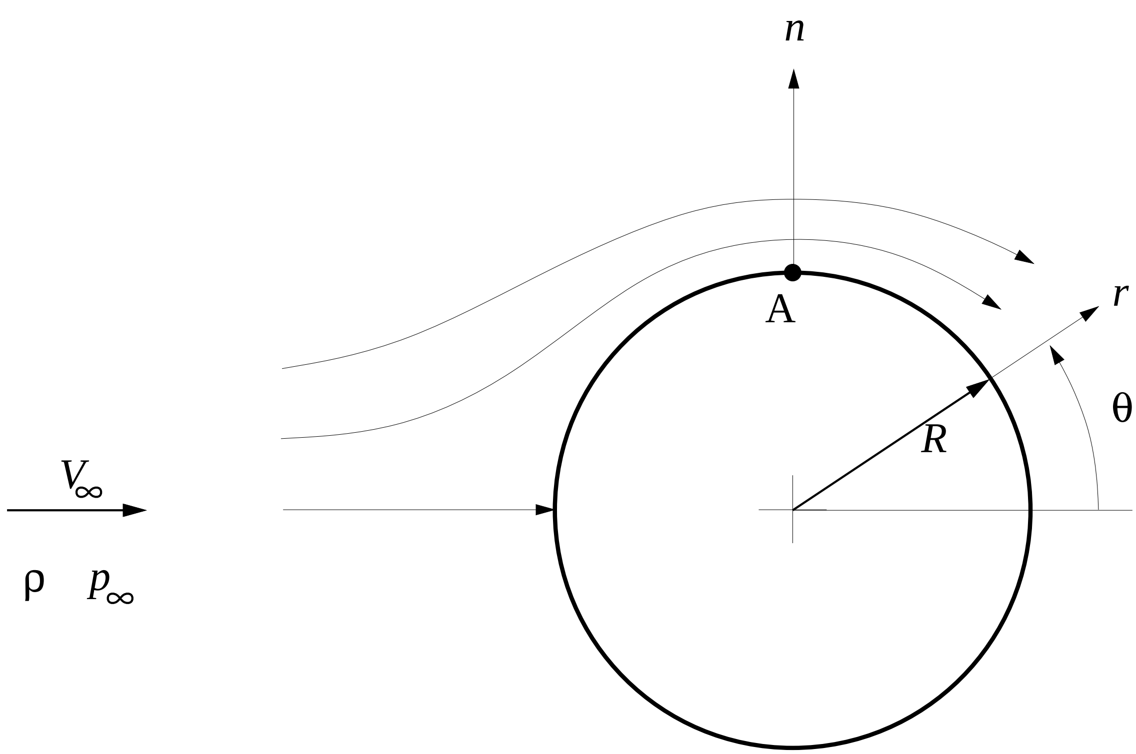
a) In the immediate vicinity of point A marked in the figure, determine

i) the speed distribution $V(n)$, and
ii) the corresponding pressure distribution $p(n)$ via Bernoulli.

b) Using your $p(n)$ result from a), determine the normal pressure gradient $\partial p/\partial n$ at point A (i.e. at $r = R$, $\theta = \pi/2$).

c) Determine the flow curvature κ at point A, and apply the normal-momentum equation to compute $\partial p/\partial n$ there. Compare this result with the result in b).

(Warning: Do not confuse the flow curvature κ in lecture F20 with the doublet strength κ in lecture F15. They are different things with the same symbol).

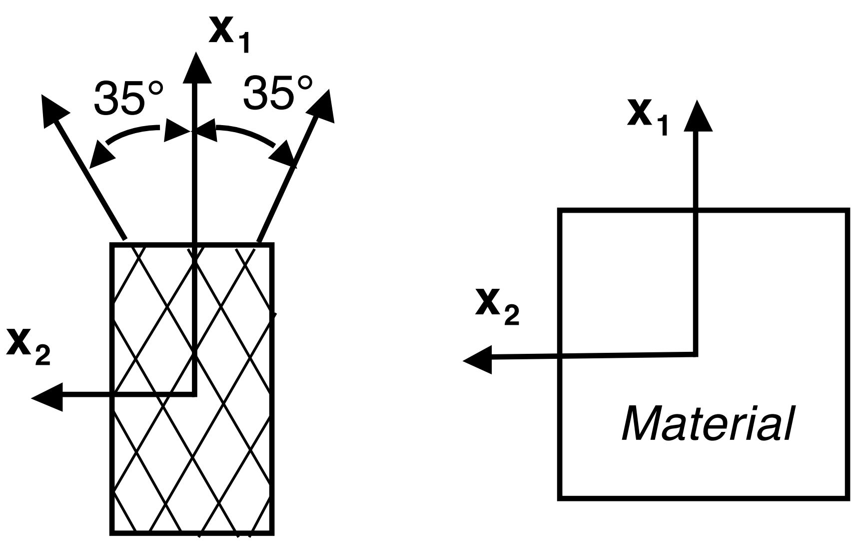


Unified Engineering Problem Set **Lectures: M17, M18, M19**
Week 8 Fall, 2006 **Units: M2.4, M3.1 (part)**

M8.1 ***(15 points)*** A structure is made of a bi-directional composite material that has one set of fibers oriented at an angle of 35° relative to the loading axes, and the other set at -35° relative to the loading axes. The structural loading produces the following state of plane stress in the loading axis system:

$$\sigma_{11} = 40 \text{ MPa}$$
$$\sigma_{22} = -15 \text{ MPa}$$
$$\sigma_{12} = -20 \text{ MPa}$$

This situation is illustrated in the accompanying figure.



(a) Find the stress state along each of the "composite fiber axes". These axes are defined by aligning the 1-direction along the fiber direction.

(b) Determine the principal stresses and the associated directions. Indicate how these are affected by the direction of the composite fiber axes.

(c) Find the maximum shear stresses and their associated planes.

(d) Draw the Mohr's circle for this situation and check the answers to parts b and c. Clearly indicate the physical/geometrical aspects of the circle that correspond to these answers.

M8.2 ***(7.5 points)*** Consider the surface of a material/structure under plane stress. One often hears of a "shear strain gage". A "shear strain gage" is actually a misnomer as only elongation strain can be measured directly by a strain gage (actually it is elongation over a specified length). However, shear strain can be determined by measuring elongation strain(s) in certain direction(s).

Can this be done by measuring one strain? If not, how many measurements are needed? Clearly explain your reasoning. Use equations, etc. as needed.

M8.3 ***(7.5 points)*** For the following cases, briefly (in one or two sentences) state the primary functional requirement that has to be met. Indicate the associated loads (e.g. tension, compression, shear, impact, cyclic, thermal, electrical), and list the five material properties that you think will be most relevant to meeting this requirement (confine your choices to the list give in Table 1.1 of *Ashby and Jones* or other properties discussed in class). Indicate for each property whether it should have a *high*, *medium*, or *low* value.

(a) Components of a truss used in a building

(b) Components of a space truss

(c) Reentry shield on a person-carrying space capsule (e.g. the old Apollo capsule)

(d) Tiles for a house floor (such as a mudroom)

(e) Cable used for towing cars

(f) Compressor blades of a jet engine