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

16.03/16.04 Unified Engineering III, IV
Spring 2004

Problem Set 1

Name: ______________________

Due Date: 2/10/04

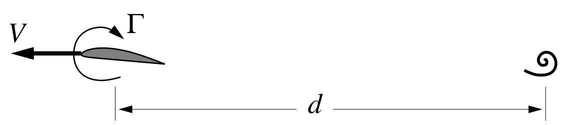
	Time Spent (min)
F1	
F2	
M1	
M2	
Study Time	

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

Unified Engineering Spring 2004
Fluids Problems F1–F2

F1a. An aircraft's wing is at zero angle of attack when all wheels are on the ground. Qualitatively describe the flow behind the wing airfoil a short time after landing touchdown. Assume 2-D flow.

F1b. A short time after starting its motion at speed V, a 2-D airfoil of chord c has a circulation Γ, and its starting vortex is some distance $d \gg c$ downstream. The fluid is incompressible and inviscid. Determine the c_ℓ and c_d of the airfoil, by convention taken perpendicular and parallel to the direction of travel. How do these change in time? Hint: First determine the apparent freestream flow velocity vector (magnitude and direction) seen by the airfoil.



F2a. Use Profili or Xfoil to compute the "exact" inviscid $c_l(\alpha)$ curves for the following airfoils, over the range $\alpha = 0° \ldots 10°$:
1) NACA 0010
2) NACA 0020
Also determine $c_\ell(\alpha)$ using thin airfoil theory for:
3) Zero-camber airfoil

Plot all three curves superimposed. Are the panel results and thin airfoil theory results consistent? Explain.

F2b. Use Profili or Xfoil to compute the following three polars for the NACA 0010 airfoil, for $\alpha = 0° \ldots 14°$:
1) Inviscid
2) Viscous at $Re = 10^6$
3) Viscous at $Re = 10^5$

Plot the $c_\ell(c_d)$ drag polars and the $c_\ell(\alpha)$ curves overlaid, and comment on the validity of the inviscid approximation.

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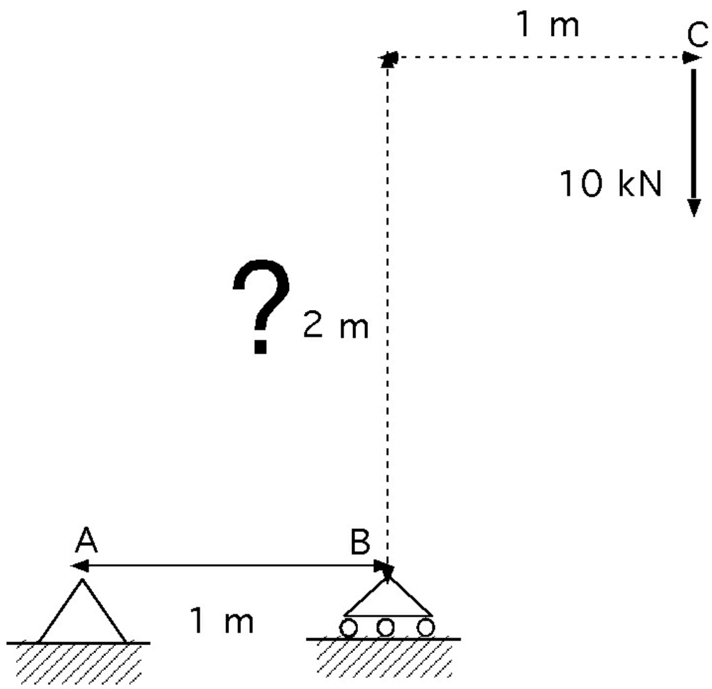
Problem M1

This is question is designed to provide you with a chance to revise material we met last term, and an opportunity to start thinking about structural design. You are asked to design a minimum mass truss structure that will be attached at points A, and B, 1 m apart on a horizontal floor in order to support a vertical load of 10 kN, without exceeding the strength (assume that the tensile and compressive strengths are the same) of the bars, at a distance 2 m above the floor and 1m to the right of the right hand support point (B).. The truss will be made of constant cross-section members of whatever material you choose to select. All of the bars will have the same cross-section. The following materials are available for selection. Select a material, and then choose an appropriate truss configuration and then estimate the mass of the truss, such that it will meet the design requirement. Explain your thought processes at each step.

Material	**Density, ρ,** (Mg/m^3)	**Modulus, E,** (GPa)	**CTE, α,** x 10^{-6} K^{-1}	**Price , p,** ($/Mg)	**Tensile Strength,** σ_f, (MPa)
Mild Steel	7.9	203	12	300	220
Aluminum alloy (2000 series)	2.8	71	24	1500	350
Titanium alloy Ti-6Al4V	4.5	120	9.0	8000	850
Carbon fiber composite*	1.5	70	3.0	100000	700
Wood (e.g spruce)*	0.6	12	4.0	300	30
Silicon Carbide (SiC)	3.0	410	4.0	50000	300



Note. Although the design objective is to minimize the mass of the structure, the credit for the question will be based on demonstrating a logical approach to selecting a material and a truss configuration, and then obtaining an estimate for the mass of the truss. Do not spend more than an hour on this question, and do not analyze multiple truss configurations. A useful exercise is to estimate what you think the mass of the truss will be before you do any analysis - developing an intuition for the correct size for structures is a useful skill to cultivate.

Problem M2

A cable (i.e. a rope, string or chain) is a structural member that can only carry axial tensile loads (i.e the tension in the cable at a particular point acts in the direction of the cable at that point) . Nevertheless it can deflect in the transverse direction. The deflection is related to the load that it is carrying and the tension in the cable.

a) A flexible cable weighing 10 N/m is stretched between two points at the same level 100 m apart. In addition to its weight it supports a vertical load of 500 N at a horizontal distance of 30 m from one end. The dip (distance below the horizontal) at that point being 1.9 m. Find (approximately) the horizontal component of the cable tension and the dip at midspan.

b) If the cable has an effective cross-sectional area of 1000 mm^2 and an effective Young's modulus of 2 GPa, *estimate* the extension of the cable due to the loading in part (a). Would this extension affect the assumptions you made to evaluate the tension in the cable in part (a)?.