

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

16.03/16.04 Unified Engineering III, IV
Spring 2004

Problem Set 2

Name: _____

Due Date: 2/17/04

	Time Spent (min)
F3	
F4	
F5	
F6	
M3	
M4	
M5	
M6	
Study Time	

Announcements: Have a happy Valentine's Day. Remember that Tuesday, 2/17 is a Monday schedule.

F3+F4. A symmetric airfoil has a trailing edge flap, with the hinge at $x_h/c = 0.75$, with the flap set at some small downward deflection angle δ .

- Define and sketch the camberline-slope dZ/dx , both versus x and versus θ .
- Use Thin Airfoil Theory to determine the airfoil's c_ℓ and $c_{m,c/4}$, as functions of α and δ .
- Important quantities for an airplane-control designer are the flap *control derivatives*

$$\frac{\partial c_\ell}{\partial \delta} \quad , \quad \frac{\partial c_{m,c/4}}{\partial \delta}$$

Determine these for the present flapped airfoil.

Note: You may wish to check your results with Xfoil. The GDES menu allows you to set a flap deflection.

F5. An experimentalist determines that the downwash velocity for a rectangular wing of span b approximately obeys the relation

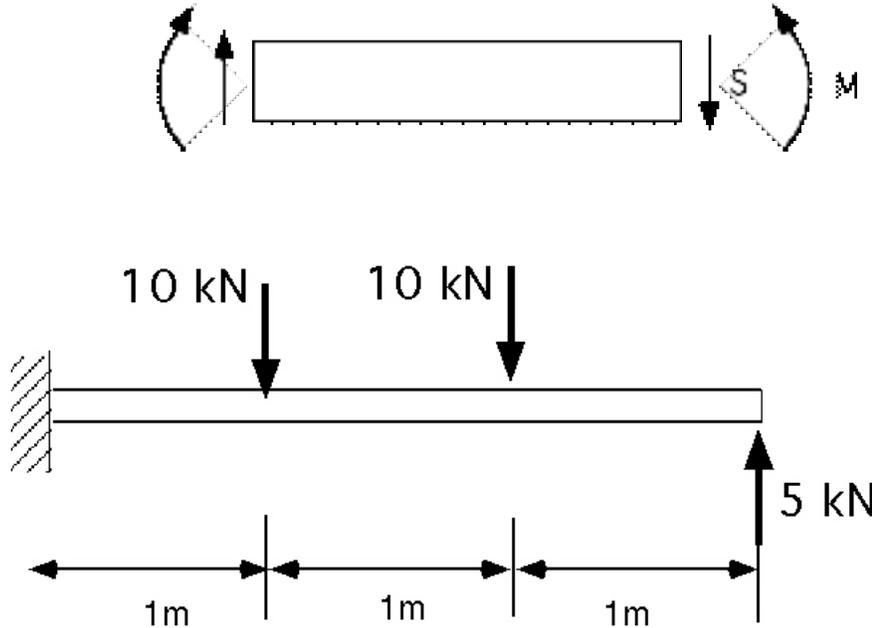
$$w = \frac{L}{2\rho V_\infty b^2}$$

- Assuming w is constant across the span, determine how C_{Di} depends on C_L for this wing.
- Determine the wing's $C_L(\alpha)$ relation, and compare its $dC_L/d\alpha$ to the 2-D value of 2π .
Hint: Start with the relation $C_L = 2\pi\alpha_{\text{eff}}$.

F6. Anderson Chapter 5, p 416. Problems 1. and 2. (closely related).

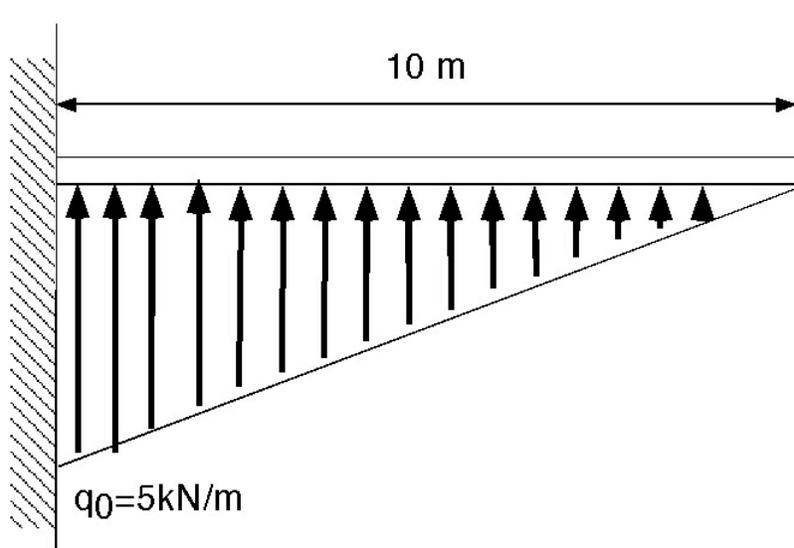
Problem M3

Draw loading, shear and bending moment diagrams for the following beam under the loading shown. Label all key values (i.e. where changes in magnitude or slope occur). Maintain the convention shown below for positive shear forces and bending moments:



Problem M4

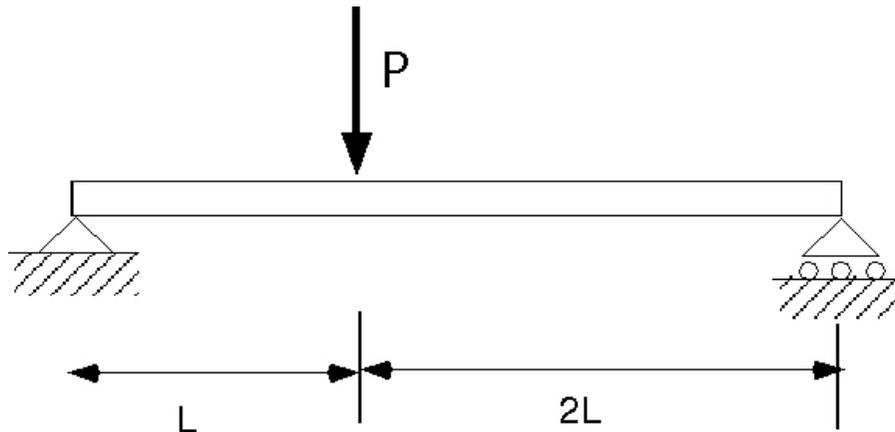
The spar in a wing is modeled as a 10 m long beam. The combination of lift and self-weight is modeled as resulting in a load distribution varying linearly from 5 kN/m at the root to zero at the tip. The beam has a rectangular cross section, height, h , of 100 mm and breadth, b , of 50 mm. Calculate the maximum bending stress in the beam, stating its location(s) and calculate the deflection of the tip of the beam



Problem M5

A simply supported beam, length $3L$, is loaded by a load P applied at a distance of L from the left hand end. The beam has a flexural stiffness EI .

- Calculate the deflection of the beam as a function of position along the beam.
- Calculate the maximum deflection of the beam and state its location.
- Calculate the location at which the bending moment is a maximum (is this the same as for (b)?)



Problem M6

This question is a first step towards designing a beam-like structure – e.g. a wing. You are asked to specify a material for a cantilever beam (i.e. a beam clamped at one end) which is to be of a specified length, L , and to be of the lowest possible mass to support a load, P , applied at its tip while minimizing the tip deflection, δ , without failing.

- Assuming that the beam is constrained to have a solid square cross-section, side, h , express the mass of the beam, m , in terms of, L , the relevant material properties and the stiffness of the beam (P/δ). (Note: The key to achieving this is to eliminate the cross-sectional dimension, h , from the expression). What is the figure of merit (combination of material properties) that must be minimized in order to achieve the lightest weight beam for a given desired stiffness?
- If instead of a requirement on minimizing deflection the beam is required to support the same load, P , without exceeding the failure strength, σ_f ? What should the figure of merit for selecting a material now be in order to create a beam of minimum

mass?. Assume that failure will occur when the maximum bending stress equals the strength of the material.

c) For the materials listed in the table below, identify the material(s) that you would choose to meet the criteria of part (a) and part (b). What other factors should be considered in selecting a material for this application?.

d) Square solid sections are structurally not very efficient – “I” beams or hollow “box” beams are much more efficient – why is this? What other factors would need to be considered in selecting a material if a “box” cross-section was to be considered in (c)?.

Material	Density, ρ (Mg/m ³)	Modulus, E, (GPa)	CTE, α , $\times 10^{-6} \text{ K}^{-1}$	Price , p, (\$/Mg)	Tensile Strength, σ_f , (MPa)
Stainless Steel 17-7 PH	7.9	193	12	1500	1435
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	300
Silicon Carbide (SiC)	3.0	410	4.0	50000	300

* These materials are anisotropic. You can assume that the values given are available in the requisite directions for this problem.