

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

16.03/16.04 Unified Engineering III, IV
Spring 2004

Problem Set 5

Name: _____

Due Date: 3/9/04

	Time Spent (min)
F15	
F16	
M14	
M15	
M15	
M17	
M18	
Study Time	

Announcements: Q2F is on Friday, 3/5 at 9am in WALKER.

F15. Our analysis for determining the speed of sound assumed that the sound wave had infinitesimal strength. But for the 120 dB sound waves produced by *Linkin Park* near the stage, this assumption may be suspect.

a) One suitable definition of sound dB level is:

$$\text{dB} = 20 \log_{10} \left(\frac{\Delta p}{20 \times 10^{-6} \text{ Pa}} \right)$$

where Δp is a pressure variation caused by an average passing sound wave. Treating this sound wave as a shock wave, determine its propagation Mach number into still air.

Hint: Put the propagating-shock situation into the shock's frame of reference.

b) Determine the temperature fluctuations associated with the passing waves. Would you say *Linkin Park* makes strong or wimpy shock waves?

F16.

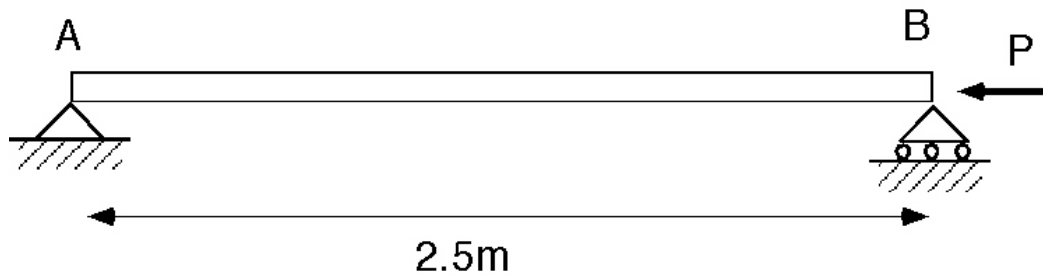
a) Anderson p. 502, Problem 15.

b) For Problem 15, also calculate the stagnation pressure at the very tip of the SR-71 nose sting.

Problem M14

A circular cross-section aluminum tube is simply supported at its ends and is loaded eccentrically as shown. The external diameter of the tube is 50 mm, the wall thickness is 5 mm. The Young's modulus is 70 GPa, The allowable normal stress is 85 MPa. The length of the tube is 2.5 m.

- a) Determine the allowable load P , and the corresponding lateral central deflection.
 Note, you will need to calculate the axial stress due to the combined axial loading and bending moment due to the eccentricity and lateral deflection
- b) What would be the critical buckling load if the column was loaded centrally.



Problem M15

Give short answers (3-5 sentences) to the following questions. This material may not be covered in lectures. Ashby and Jones Ch. 8-15 will be a useful resource.

- a) Explain briefly what is meant by a “dislocation” and explain with an appropriate diagram how edge dislocations can contribute to yield and plastic deformation of a material.
- b) Why are the skins of aerospace structures often made by a hot rolling process, followed by a cold rolling process? I.e. the initial reduction in thickness from a billet (large ingot) of material is performed at elevated temperatures, but the final steps in thickness reduction are performed at room temperature?
- c) Explain why a single crystal of a metal or alloy is usually softer (lower yield strength) than a polycrystalline specimen of a metal.
- d) Why are higher yield strength metal alloys usually more brittle than lower yield strength alloys?
- e) Why do carbon fibers or glass-fibers have such high strengths compared to the bulk materials (graphite and glass)?
- f) Explain this observation. The first aerospace aluminum alloy (Duralumin) was found to have a hardness that depends on the length of time that it is exposed to an elevated temperature. Initially the hardness increases with exposure time until it reaches a maximum value, after which the hardness decreases with additional elevated temperature exposure.

Problem M16

A cylindrical specimen of stainless steel having a diameter of 12.8 mm and a gauge length of 50.8 mm is pulled in tension. Use the load-elongation characteristics tabulated below to complete problems (a) through (f).

Load (N)	Length (mm)
0	50.800
12700	50.825
25400	50.851
38100	50.876
50800	50.902
76200	50.952
89100	51.003
92700	51.054
102500	51.181
107800	51.308
119400	51.562
128300	51.816
149700	52.832
159000	53.848
160400	54.356
159500	54.864
151500	55.880
124700	56.642
FRACTURE	

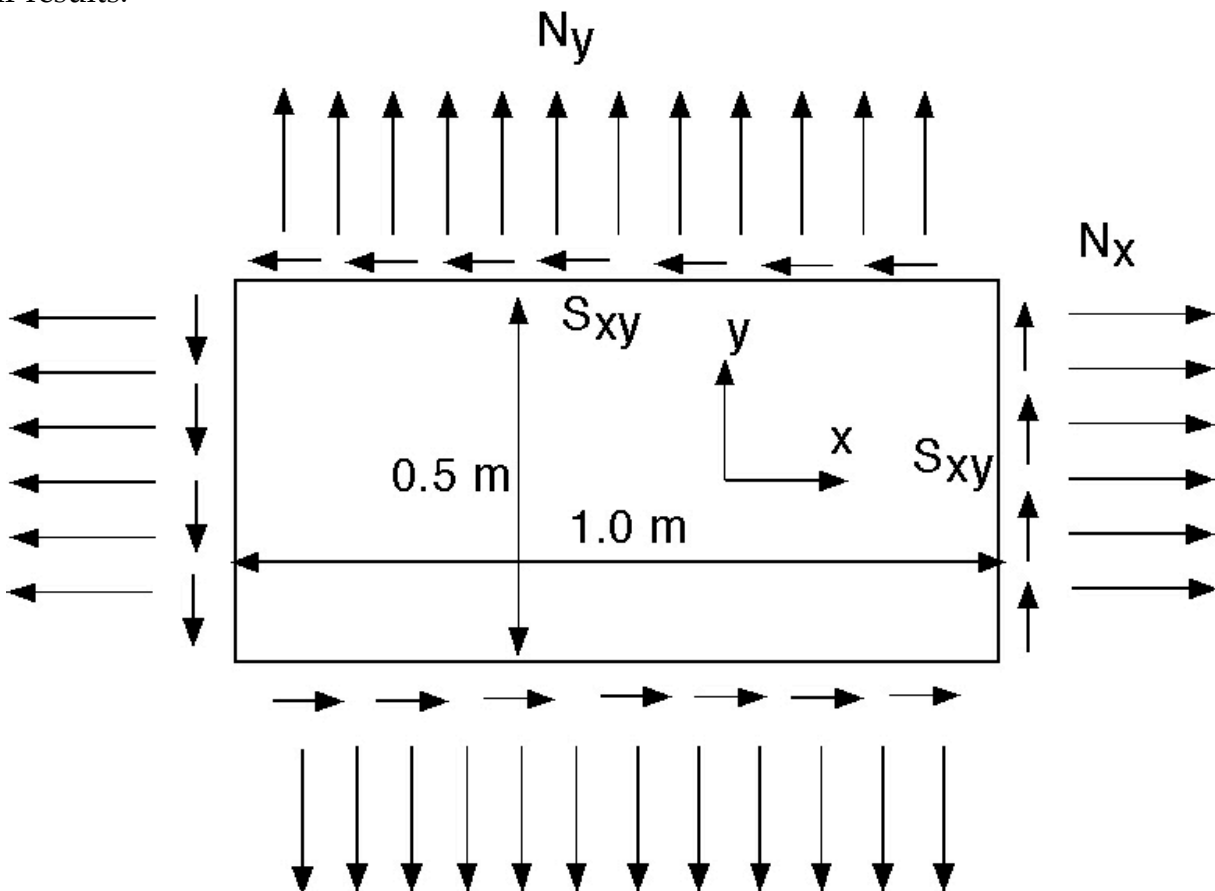
- a) Plot the data as engineering stress vs. engineering strain.
- b) Compute the Young's modulus
- c) Determine the yield strength at a strain offset of 0.002 (0.2%)
- d) Determine the tensile strength of this alloy
- e) What is the approximate ductility expressed as a percentage of elongation?
- f) Estimate the energy that must have been supplied to cause the specimen to reach failure.

Problem M17

An aircraft wing structure is being designed. You are responsible for "sizing" a rectangular panel of the wing skin (in this case sizing means specifying the thickness). The material to be used is Aluminum 7075 T6, which has a uniaxial yield stress of 500 MPa. The loading is specified in terms of line forces (i.e. forces per unit length in the x-y plane), N_x , N_y , S_{xy} , where N_x and N_y are tensile line forces and S_{xy} is the shear loading. These line forces are derived from the estimated design loads on the airframe due to different flight conditions, gust loading etc. The three critical load cases for this component are thought to be:

Load case	N_x (kN/m)	N_y	S_{xy}
1	+250	-500	+200
2	+300	+500	-400
3	+600	-300	0

Calculate the required thickness of the wing skin for this component so that it will survive all three loading conditions. Assume that the material obeys Von Mises Yield criterion, assume that the out of plane (z direction) loading is negligible) and apply a factor of safety of 1.5 to your results.



Problem M18: Aluminum 7075-T6 has a fracture toughness of $24 \text{ MPa}\sqrt{\text{m}}$. As part of the design for damage tolerance requirements for the wing skin component you analyzed in M17 it is required that the critical crack size be greater than 5 mm (so that it can be detected by non destructive evaluation (NDE) techniques). Assume that the worst case is for a crack orientated perpendicular to the maximum tensile stress component. Verify that the thicknesses you specified in M17 will meet the damage tolerance requirement. If they do not, then specify a new value of the thickness that will allow the panel to meet both the strength and the damage tolerance requirements.