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

16.001/16.002 Unified Engineering I, II
Fall 2008

Problem Set 8

Name: ______________________

Due Date: 10/31/2008

	Time Spent (min)
M14	
M15	
M16	
T17	
T18	
S1	
Study Time	

Announcements:

Happy Halloween!

Unified Engineering Problem Set 8 **Lectures: M14, M15, M16**
Week 9 Fall, 2008 **Units: M2.2, M2.3**

M14 (M9.1) ***(10 points)*** A three-dimensional body is subjected to a state of stress such that the three extensional stresses are all constant and of the same value, A. The shear stress in the 1-2 plane has a linear variation in both the x_1 and x_2 directions. Each variation is of the same magnitude, B, but is positive in x_1 and negative in x_2. Determine as much as you can about the overall stress field of this three-dimensional body using functional forms with further description as needed. Be sure to explain all reasoning clearly.

M15 (M9.2) ***(10 points)*** For each of the following two-dimensional displacement fields (no displacement in the x_3- direction), draw a neat sketch of a unit square (with the bottom left corner at the origin) before and after deformation (exaggerate deformation by a factor of 10). Calculate the associated two-dimensional strain field. Identify the "type" of deformation/strain that characterizes the displacement.

(a) $\underline{u} = (0.015\, x_1)\, \underline{i}_1 - (0.030\, x_2)\, \underline{i}_2$

(b) $\underline{u} = (0.030\, x_2)\, \underline{i}_1 + (0.020\, x_1)\, \underline{i}_2$

(c) $\underline{u} = (0.030)\, \underline{i}_1 - (0.015)\, \underline{i}_2$

(d) $\underline{u} = (0.040\, x_2)\, \underline{i}_1 - (0.040\, x_1)\, \underline{i}_2$

(e) $\underline{u} = (0.050\, x_1 - 0.050\, x_2)\, \underline{i}_1 + (-\,0.050\, x_1 - 0.020\, x_2)\, \underline{i}_2$

M16 (M9.3) ***(10 points)*** The following is known as the functional variation of the extensional strains in the x_1 and x_2 directions:

$$\varepsilon_{11} = ax_1 + bx_2^2 + c_{11}$$
$$\varepsilon_{22} = -\,(b/2)x_1^2 + ax_2 + c_{22}$$

The extensional strain in the x_3-direction is of value zero and there are also no strains in the x_1-x_3 and x_2-x_3 planes. With this information:

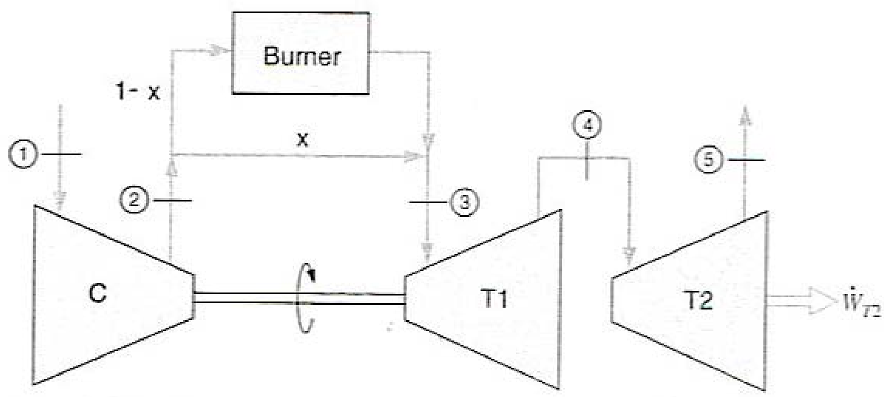
(a) Determine all you can about the displacements along each of the three directions.

(b) Determine the shear strain in the x_1-x_2 plane or whatever can be determined about such.

(Add a short summary of the concepts you are using to solve the problem)

Problem T17

A gas turbine with air as the working fluid has two ideal turbine sections, as shown below. The first turbine drives the ideal compressor and the second turbine, the power turbine, produces the power output. The compressor inlet conditions are T_1 = 290 K and p_1 = 100 kPa, and the exit pressure is p_2 = 450 kPa. A fraction of the flow, x, bypasses the burner and the rest goes through the burner where 1200 kJ/kg of heat is added by combustion. The two flows then mix before entering the first turbine and continue through the power turbine where the exhaust pressure is p_5 = 100 kPa. You can assume γ = 1.4 and R= 287 J/kg-K for air.



If the mixing results in a temperature of T_3 = 1000 K into the first turbine, find:

a) the flow fraction x,

b) the required pressure and temperature into the power turbine, p_3 and T_3,

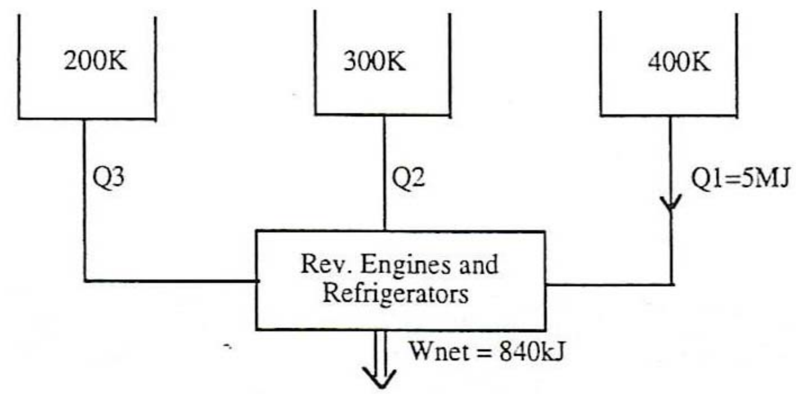
c) the specific shaft work output of the power turbine w_{T2}.

Unified Engineering Fall 2008
Thermodynamics & Propulsion Z. S. Spakovszky

(Add a short summary of the concepts you are using to solve the problem)

Problem T18

A set of reversible engines and refrigerators interact with three infinite heat reservoirs (infinite sources/sinks of heat whose temperature remains constant in any heat transfer process). During a cycle of operation, 5MJ is drawn from the 400K source and the net work done is 840kJ. Find the amount and direction of heat interaction with the other reservoirs.



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Problem S1 (Signals and Systems)

1. Consider the system of equations

$$\begin{array}{rcrcrcr} x & + & 2y & - & z & = & 1 \\ x & - & 3y & + & 2z & = & -2 \\ -2x & + & 3y & + & z & = & 3. \end{array}$$

   Solve for x, y, and z, in three separate ways. The goal of part (1) is to practice solving systems of equations, so that when you get to part (2), you will have a fair basis of comparison.

   (a) Determine x, y, and z using (symbolic) elimination of variables.

   (b) Determine x, y, and z by Gaussian reduction.

   (c) Determine x, y, and z using Cramer's rule.

2. Consider the system of equations

$$\begin{array}{rcrcrcr} x & + & 6y & - & 6z & = & 2 \\ 3x & - & 2y & + & 3z & = & 3 \\ -4x & - & 2y & + & 3z & = & -4. \end{array}$$

   Again, solve for x, y, and z, in three separate ways. This time, please time each part (a), (b), (c) below.

   (a) Determine x, y, and z using (symbolic) elimination of variables.

   (b) Determine x, y, and z by Gaussian reduction.

   (c) Determine x, y, and z using Cramer's rule.

   (d) How much time did each method take?

   (e) Which method do you prefer?

   (f) When answering this question, think about how much time might be required for a larger system, say, one that is 5×5.