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

16.001/16.002 Unified Engineering I, II
Fall 2006

Problem Set 10

Name: ________________________

Due Date: 11/14/2006

	Time Spent (min)
M10.1	
M10.2	
T4	
T5	
T6	
S1	
S2	
Survey	
Study Time	

Announcements:

Unified Engineering Problem Set **Lectures: M23, M24**
Week 10 Fall, 2006 **Units: M3.3, M3.4**

M10.1 ***(10 points)*** A material has a rectangular crystal lattice structure. The potential energy of two atoms in the lattice, a distance r apart, is:

$$U = - A/r + B/(r^m) + U_i$$

with a value of the exponent m of 9. It is known that the atoms form a stable pair at a separation of 0.21 nm with an energy of -26.1 eV. The value of the base energy, U_i, is 2.1 eV.

(a) Determine the values of the constants A and B and indicate the type of bonding that this represents.

(b) Making no further assumptions (i.e. just use this single bond model), estimate the extensional modulus, E, of the material.

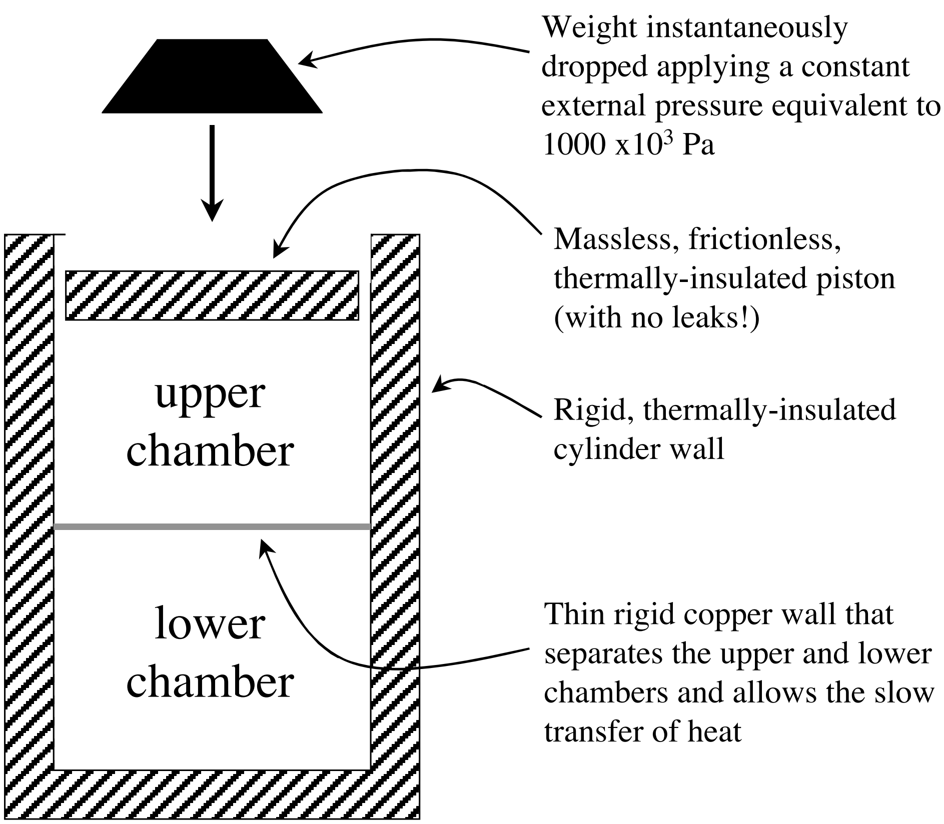
(c) Comment on possible discrepancies between this estimated value of the modulus and an actual measured value for the material.

M10.2 ***(10 points)*** A unidirectional composite material is to be made of glass fibers with a fiber modulus of 14.0 Msi and an epoxy matrix with a modulus of 2.1 Msi. Determine estimates for the composite ply modulus along and perpendicular to the fiber direction as a function of the fiber volume fraction v_f. Plot these estimates.

Problem T4 (Unified Thermodynamics)

Below is a piston-cylinder arrangement where the piston has two chambers. Although the cylinder is thermally-insulated from the surroundings, the lower chamber is isolated by a thin copper barrier, which is rigid but which allows the slow transfer of heat between the two chambers. The cylinder walls are rigid. The chambers are filled with air which behaves as an ideal gas with R=287 J/kg-K and you can assume the specific heats are constant at c_v=716.5 J/kg-K, c_p=1003.5 J/kg-K.

Both chambers start in thermodynamic equilibrium with T=300K, p=100x10^3 Pa with a volume of 0.1 m^3. A weight equivalent to an external pressure of 1000x10^3 Pa is instantaneously dropped on the upper cylinder. You can assume that the piston itself is massless and free to move without friction. <u>Your objective is to devise a simplified thermodynamic model of this system and to use it to estimate the temperature the gas in the lower chamber would come to when the two-chamber system eventually comes to thermodynamic equilibrium.</u>



Problem T4 (Unified Thermodynamics) continued…

a) Describe the energy exchange processes in the device in terms of heat, work and various forms of energy. (LO's #1, #2)
b) What processes will you use to model this system? Why? (LO's #2, #4, #5)
c) What is the temperature the gas in the upper chamber comes to shortly after the instantaneous dropping of the weight? (LO #4)
d) What is the temperature the gas in the lower chamber comes to when the whole system eventually reaches thermodynamic equilibrium? (LO #4)

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Problem T5 (Unified Thermodynamics)

A thermally-insulated cylinder holds a thermally perfect gas at p = 4 atm and T = 300K. The gas is contained by a thermally-insulated massless piston with a stack of many small weights on top of it. The surroundings are at p = 1 atm and T = 300K. Initially the system is in mechanical and thermal equilibrium. Consider the following three processes:

a) All of the weights are removed from the piston instantaneously and the gas expands until the pressure matches that of the surroundings. How much work was done by the system? In the final state, what is the temperature and pressure of the system? Draw this process on a p-v diagram.

b) Half of the weight is removed from the piston instantaneously, the system is allowed to come to equilibrium, and then the remaining half of the weight is removed from the piston and the gas expands until the pressure matches that of the surroundings. How much work was done by the system? During the intermediate state and the final state, what is the temperature and pressure of the system? Draw this process on a p-v diagram.

c) Each small weight is removed from the piston one at a time, so that the pressure inside the cylinder can be assumed always to be in equilibrium with the weight on top of the piston. When the last weight is removed the gas has fully expanded to a pressure that matches that of the surroundings. How much work was done by the system? In the final state, what is the temperature and pressure of the system? Draw this process on a p-v diagram.

d) If your goal is to get as much work out of a system as possible without adding heat, what type of a process would you use?

Assume that c_p = 1.0035 kJ/kg-K and c_v = 0.7165 kJ/kg-K are constants, and that R = 0.287 kJ/kg-K.

(MO# 4, MO#5)

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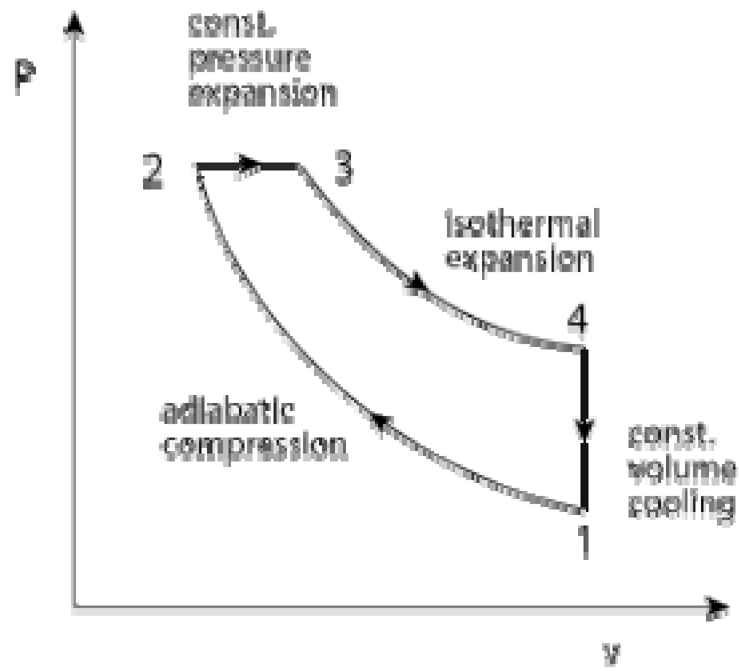
Problem T6. (Thermodynamics)

Consider the following thermodynamic cycle. Assume all processes are quasi-static and involve an ideal gas.



Air undergoes a quasi-static thermodynamic cycle 1-2-3-4-1 as shown above. Process 1-2 is adiabatic compression, 2-3 is constant pressure expansion, process 3-4 is isothermal expansion, and process 4-1 is constant volume cooling. The conditions at state 1 are p_1 = 100kPa, T_1=300K. The pressure ratio (p_2/p_1) over process 1-2 is 20 and the peak temperature of the cycle is 1800K. Assume that c_p = 1.0035 kJ/kg-K and c_v = 0.7165 kJ/kg-K are constants, and that R = 0.287 kJ/kg-K.

a) For each leg of the cycle identify whether the heat added to the system, Q, and the work done by the system, W, are positive, negative or zero.

b) For each leg of the cycle calculate the work and heat transfer, the change in internal energy and the change in enthalpy.

c) What is the net work of the cycle?

d) What is the thermal efficiency of the cycle?

e) If you reversed the direction of the cycle and used it as a refrigerator, what is the maximum amount of heat you could you remove per Joule of power input?

(LO# 4, LO#6)

Problem S1 (Signals and Systems)

Note: Please read the linear algebra notes associated with Lecture S1 carefully before you begin this problem.

The two most common methods used by students to solve systems of equations are elimination of variables and Cramer's rule. Unfortunately, these can be unwieldy for large systems of equations. You should really use Gaussian elimination, which is elimination of variables in disguise, but much more organized. This problem will give you some practice using Gaussian elimination.

1. Consider the system of equations

$$\begin{aligned} 1x &+ 2y + 2z = 3 \\ 3x &+ 2y + 1z = 2 \\ 1x &+ 3y + 3z = 4 \end{aligned}$$

   Solve for x, y, and z, in three separate ways.

   (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) Which method is fastest?

2. Consider the system of equations

$$\begin{aligned} 2x &+ 3y + 9z = 1 \\ 5x &+ -3y + -3z = 6 \\ 2x &+ 1y + 4z = 2 \end{aligned}$$

   This time, solve for x, y, and z, using only Gaussian elimination.

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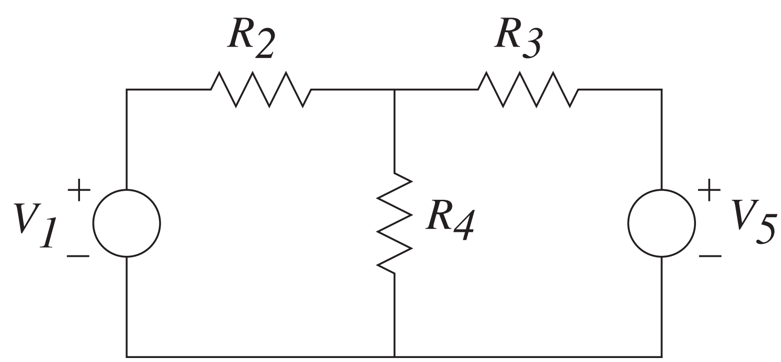
Problem S2 (Signals and Systems)

For the circuit below, solve for all the branch currents and branch voltages, using the following steps. (Note: This problem will be easier once you learn the node method and the loop method. You should do just this one problem the long way.)

1. Label each circuit element with a branch voltage and branch current.
2. Write down Kirchhoff's voltage law for each loop in the circuit.
3. Write down Kirchhoff's current law for all the nodes, except one.
4. Write down the constitutive relation for each circuit element.
5. Verify that there are as many equations as unknowns, and solve for all the unknowns. Hint: You should do this in an organized way, as there are a large number of variables.



$V_1 = 7$ V, $R_2 = 1\ \Omega$, $R_3 = 2\ \Omega$, $R_4 = 2\ \Omega$, $V_5 = 2$ V

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November 2006

A Study of Student Self-Efficacy in Eight Selected Skill Areas

Background
In the past six years, the CDIO approach to engineering education has been implemented in MIT Aeronautics and Astronautics programs and in more than 20 other engineering programs worldwide. In this study, we are gathering data on how well you are achieving the intended learning outcomes expected by industry, government agencies, faculty and alumni of MIT Aeronautics and Astronautics programs. The attached survey focuses on eight of your program's intended learning outcomes: engineering reasoning and problem solving, experimentation, systems thinking, critical thinking, professional ethics and integrity, teamwork, communication, and design. The results will be used to determine the overall effectiveness of Aeronautics and Astronautics programs, and will contribute to the teaching and learning improvement process.

Your Participation
We are asking you to complete this brief survey to help us to plan more effective learning experiences for you. We will ask you to complete a similar survey at the end of Unified Engineering III/IV, and again just prior to your graduation. Your responses will be collected and summarized by an assessment specialist and reported anonymously to subject and program faculty. **Survey results will have no effect on your grades. You will, however, get homework credit for completing the survey**. Because we would like to track pre-and-post-subject responses, we need to match the forms. Your identity will be known to the assessment specialist only.

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Please write the last four digits of your MIT Student Identification Number at the top of the survey on the next page.

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If you have questions or concerns about this survey, please contact
Doris R. Brodeur, 37-391, dbrodeur@mit.edu, (617) 253-1695

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By continuing, I agree to participate voluntarily in this survey about the knowledge, skills, and attitudes related to my program. I understand that any information provided by me will remain confidential with regard to my identity. If you prefer not to be included in the study, please return the completed survey and check the box below:

☐ I have completed the survey, but prefer not to be included in the study.

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A Study of Student Self-Efficacy in Eight Selected Skills Areas

Last four digits of your MIT ID: _________
(for participation credit and to match responses in May 2007 and May 2009)

These questions ask you about your confidence that you can perform specific tasks. For each statement, mark an X in the column that best represents how confident you are that you could perform that skill or ability now. *(Mark one response for each statement.)*
Scale:
Not at all confident, Not very confident, Confident, Very confident, Completely confident

	How confident are you in your current skill and ability to …	**Not at all confident**	**Not very confident**	**Confident**	**Very confident**	**Completely confident**
1	Apply an abstract concept or idea to a real problem or situation					
2	Identify critical questions in an inquiry and formulate reasonable hypotheses					
3	Explain to a non-technical person what is meant by an engineering system					
4	Work on collaborative projects as a member of a team					
5	Give credit to members of your team for their contributions to a successful project					
6	Translate user needs into requirements for a design that will satisfy users					
7	Estimate orders of magnitude and boundary conditions in the solution of a problem					
8	Develop your own original hypothesis and a research plan to test it					
9	Identify common characteristics of a diverse set of events or objects					
10	Raise critical questions on a topic of discussion					
11	Deliver on a job or project you agreed to do within the accepted time frame					
12	Listen to other points of view with an open mind					
13	Organize a message so that it is clear and logical					
14	Evaluate contradictory positions in a proposal or argument					

	How confident are you in your current skill and ability to …	Not at all confident	Not very confident	Confident	Very confident	Completely confident
15	Lead a group with members who strongly disagree with one another					
16	Write reports that communicate clearly to the intended audience					
17	Design and build something new that performs to design specifications					
18	Use probability and statistics to estimate solutions to problems with more than one possible answer					
19	Evaluate several courses of action and combine ideas into the best approach					
20	Offer reasons and evidence in your critique of opposing positions					
21	Accept valid criticism of your work without becoming defensive					
22	Develop ways to resolve conflict and reach agreement in a group					
23	Give an oral briefing that clearly shows the relationship between ideas					
24	Design a product that can be used safely by the general public					
25	Estimate the degree of uncertainty in the results of an analysis					
26	Analyze data for reliability and validity					
27	Evaluate evidence to judge the strengths and weaknesses of competing alternatives					
28	Admit to an error in your work despite negative consequences to you					
29	Give constructive criticism to members of your team					
30	Analyze alternative designs in terms of operability, manufacturability, and cost					
31	Reconcile differences in the results of analyses that used two different methods					
32	Draw valid conclusions based on experimental data					
33	Recognize unintended consequences resulting from a specific event					
34	Identify situations on a job or project that could compromise your personal integrity					
35	Use consensus-building techniques to make team decisions effectively					

	How confident are you in your current skill and ability to …	**Not at all confident**	**Not very confident**	**Confident**	**Very confident**	**Completely confident**
36	Answer questions accurately and concisely following a technical briefing					
37	Use models and prototypes to test the feasibility of alternative designs					
38	Report the results of an experiment in a form acceptable to the intended audience					
39	Recommend improvements to an engineering system					
40	Come to well-reasoned conclusions, testing them against relevant criteria and standards					
41	Use good decision-making skills to resolve ethical dilemmas					
42	Lead a team in setting ground rules and standards at the beginning of a project					
43	Follow accepted norms of communication when using email and teleconferencing					
44	Understand the concept and limits of a new technology well enough to see the best ways to use it					
45	Recognize constraints that may limit the ideal solution to a problem					
46	Evaluate experimental procedures and results and recommend improvements for subsequent experiments					
47	Create technical drawings, tables, and graphs that communicate ideas clearly and accurately					
48	Balance competing factors and resolve tensions to design the best possible system					

49. Anticipated Year of Graduation: ____2007 ____2008 ____2009 ____2010

50. Major Course: _____ 16-1 _____undecided
_____ 16-2 _____ not majoring in Course 16

51. Gender: _______ male _______female

Thank you for your participation.

Please return your responses by **November 9, 2006**
to Doris R. Brodeur, dbrodeur@mit.edu, MIT 37-391, 617-253-1695