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

16.001/16.002 Unified Engineering I, II
Fall 2008

Problem Set 9

Name: ________________________

Due Date: 11/7/2008

	Time Spent (min)
M17	
T19	
T20	
S2	
S3	
S4	
Study Time	

Announcements:

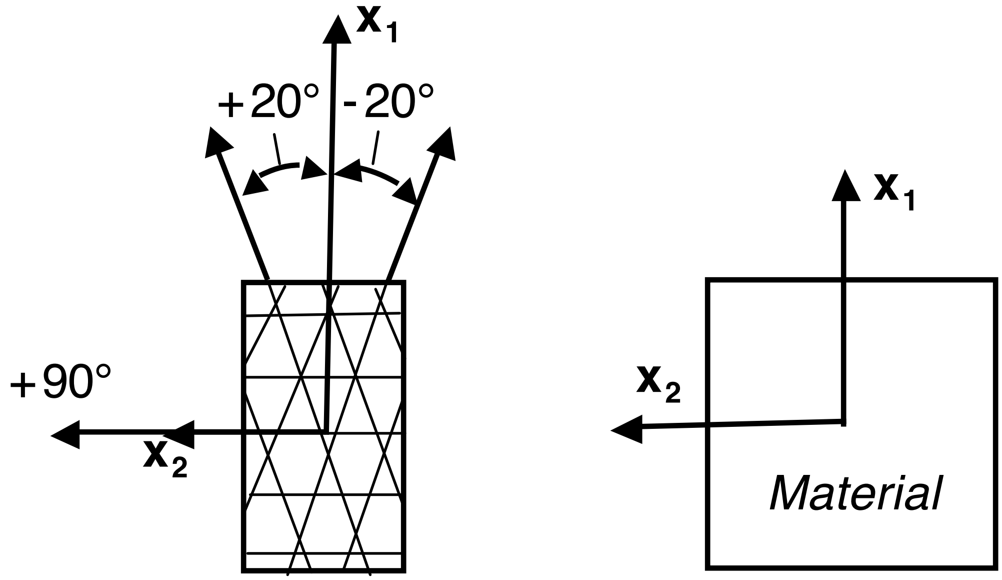
Unified Engineering Problem Set 9 **Week 10 Fall, 2008**

Lectures: M17, M18 ***(look-ahead)*** **Units: M2.4 (part** ***w/look-ahead*****)**

M17 (M10.1) ***(10 points)*** A structure made of a triaxially woven composite fabric material has its fibers oriented at angles of +20°, -20°, and +90° relative to the loading axes. The structural loading produces the following state of plane stress in the loading axis system:

$$\sigma_{11} = +20 \text{ MPa}$$
$$\sigma_{22} = -30 \text{ MPa}$$
$$\sigma_{12} = -10 \text{ MPa}$$

This situation is illustrated in the accompanying figure.



Find the stress state along each of the "composite fiber axes". These axes are defined by aligning the 1-direction along the fiber direction.

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

Problem T19

Each of two rigid vessels contains 1 kg of air. Initially, the state of the air in vessel A is identical to the state of the air in vessel B. A Carnot heat pump transfers heat from vessel A and rejects heat to vessel B. During a certain integral number of cycles of the heat pump, the work input to the pump is 1.0 kJ. At the completion of the cycles, it is found that the temperature of the air in vessel A has decreased by 27°C. Assume air to be an ideal gas with R = 287 J/kg-K and γ = 1.4, and neglect heat interaction between the vessels and the surroundings.

a) Sketch the situation.

b) What is the increase in temperature of the air in vessel B?

c) What is the entropy change for the entire system comprising the contents of vessels A and B and the heat pump during the process described?

d) What is the initial temperature of the air in each vessel?

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

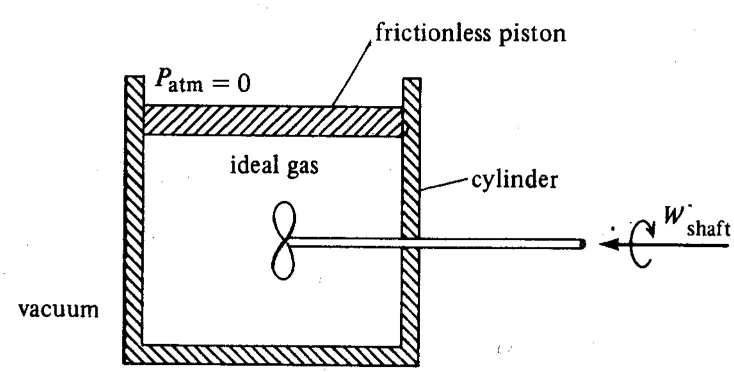
Problem T20

Consider the piston-cylinder apparatus shown below which contains 10 g of an ideal gas with R = 287 J/kg-K and γ = 1.4. The apparatus is surrounded by a vacuum. Inserted in the gas is a paddle wheel which is attached to a shaft. The shaft and paddle wheel have a thermal conductivity of zero, so the surfaces are always adiabatic. Initially the system, which consists of the ideal gas, piston-cylinder apparatus, and paddle wheel, is in mechanical and thermal equilibrium (T_i = 21°C). The shaft is set rotating for a brief period of time and then stopped. After the system has reached its final state of mechanical and thermal equilibrium, it is found that the piston, whose mass is 100 kg, is displaced upwards a distance of 150 mm during the process. The displacement occurs quasi-statically, that is, the piston and the gas are always in mechanical equilibrium. The interface between the piston and cylinder surfaces and the ideal gas is adiabatic and the gas temperature increases from 21°C to some final equilibrium temperature during the process.

a) Find the final equilibrium temperature.

b) Determine the work transfer to the gas from the paddle wheel and shaft.

c) Explain the physical difference between the shaft work transfer from the paddle wheel and the work transfer to the piston using some of the concepts seen in class. (HINT: You might want to consider calculating entropy change.)



16.001 | October 31
Unified Engineering I | MIT, Fall 2008

Problem S2 (Signals and Systems)

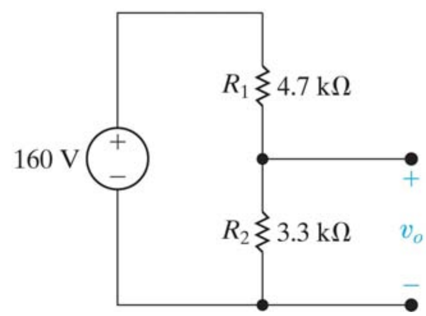


Figure 1

(a) Calculate the no-load voltage v_0 for the voltage divider circuit shown in Fig. 1.

(b) Calculate the power dissipated in R_1 and R_2.

(c) Assume that only 0.5 W resistors are available. The no-load voltage is to be the same as in (a). Specify the smallest ohmic values of R_1 and R_2.

Problem S3 (Signals and Systems)

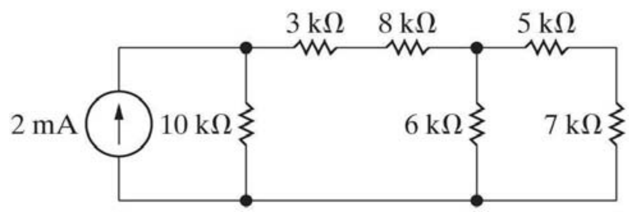


Figure 2

Look at the circuit in Fig. 2.

(a) Use current division to find the current flowing from top to bottom in the 10 kΩ resistor.

(b) Using your result in (a), find the voltage drop across the 10 kΩ resistor, positive at the top.

(c) Using your result from (b), use voltage division to find the voltage drop across the 6 kΩ resistor, positive at the top.

(d) Using your result from (c), use voltage division to find the voltage drop across the 5 kΩ resistor, positive at the left.

Problem S4 (Signals and Systems)

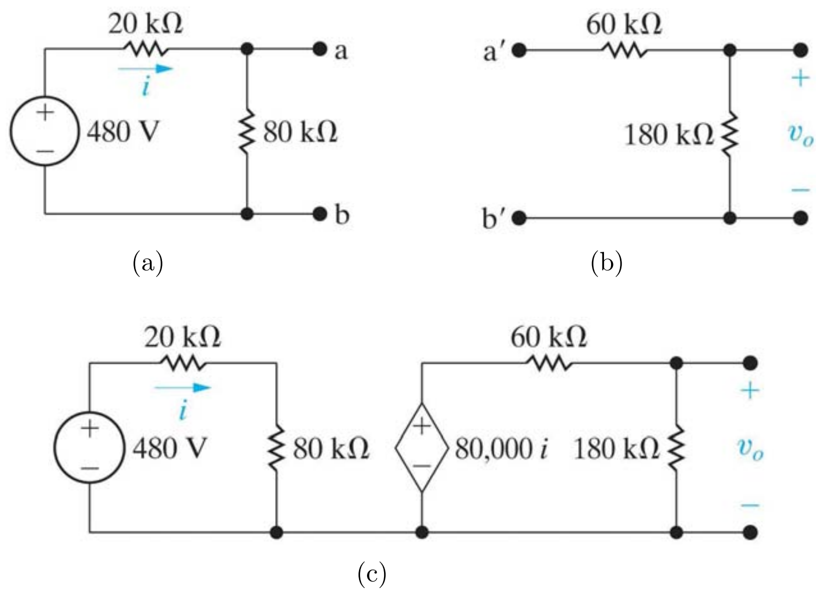


Figure 3

(a) The voltage divider in Fig. 3(a) is loaded with the voltage divider shown in Fig. 3(b): that is, a is connected to a′, and b is connected to b′. Find v_0.

(b) Now assume the voltage divider in Fig. 3(b) is connected to the voltage divider in Fig. 3(a) by means of current-controlled voltage source as shown in Fig. 3(c). Find v_0.

(c) What effect does adding the dependent-voltage source have on the operation of the voltage divider that is connected to the 480 V source?