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

16.001/16.002 Unified Engineering I, II
Fall 2008

Problem Set 10

Name: ______________________

Due Date: 11/14/2008

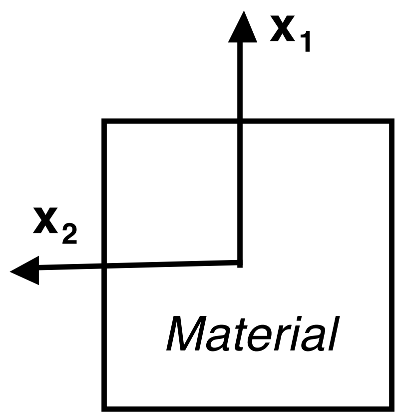
	Time Spent (min)
M18	
M19	
M20	
T21	
T22	
S5	
S6	
S7	
Study Time	

Announcements:

Unified Engineering --
Problem Set 10 **Lectures: M18, M19, M20** ***(look-ahead)***
Week 11 Fall, 2008 **Units: M2.4, M3.1 (part** ***w/look-ahead*****)**

M18 (M11.1) ***(15 points)*** A structure is subjected to the following state of plane stress in the loading axis system:

$$\sigma_{11} = -24 \text{ ksi}$$
$$\sigma_{22} = +16 \text{ ksi}$$
$$\sigma_{12} = -8 \text{ ksi}$$



Relative to the original loading axes:

(a) Determine the principal stresses and the associated directions.

(b) Find the maximum shear stresses and their associated planes.

(c) Indicate how the principal stresses, the maximum shear stresses, and their associated directions change as the initial axis system for reference changes direction relative to the original loading axes.

(d) Draw the Mohr's circle for the base loading situation and check the answers obtained for parts (a) and (b). Clearly indicate the physical/geometrical aspects of the circle that correspond to these answers.

M19 **(M11.2)** ***(7.5 points)*** Consider the surface of a material/structure under plane stress. One often hears of a "shear strain gage". A "shear strain gage" is actually a misnomer as only elongation strain can be measured directly by a strain gage (actually it is elongation over a specified length). However, shear strain can be determined by measuring elongation strain(s) in certain direction(s).

Can this be done by measuring one strain? If not, how many measurements are needed? Clearly explain your reasoning. Use equations, etc. as needed.

M20 **(M11.3)** ***(7.5 points)*** For the following cases, briefly (in one or two sentences) state the primary functional requirement that has to be met. Indicate the associated loads (e.g. tension, compression, shear, impact, cyclic, thermal, electrical), and list the five material properties that you think will be most relevant to meeting this requirement (confine your choices to the list given in Table 1.1 of *Ashby and Jones* or other properties discussed in class). Indicate for each property whether it should have a *high, medium,* or *low* value.

(a) Compressor blades of a jet engine

(b) Cable used for towing large trucks

(c) Components of a truss for a radio tower

(d) Components of a space truss

(e) Reentry shield on the space shuttle

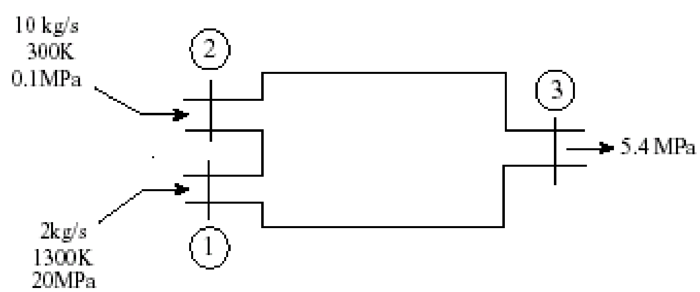
(f) Tiles for a house floor

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

Problem T21

An inventor claims that a secret device, shown schematically below, can take airstreams 1 and 2 and produce in steady flow a single high-pressure exhaust stream. Inside the device are mechanisms for mass, momentum and energy exchange between the streams, but no heat exchange occurs with the surroundings. Assume air to be a perfect gas with R = 287 J/kg-K and γ = 1.4. Is it possible that such a device can be made to operate in steady state?

One approach to this problem is to examine whether the data given imply a contradiction of the conservation laws. Another would be to take the data at stations 1 and 2 and determine the maximum possible pressure at station 3.



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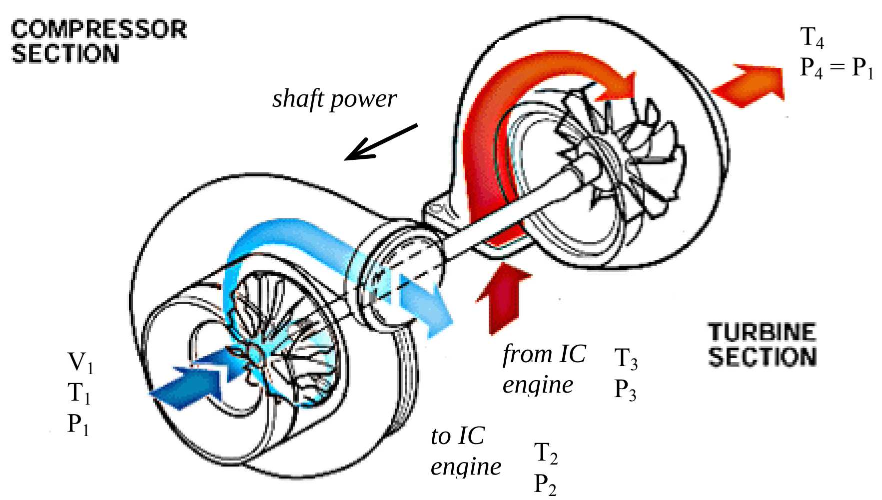
Thermodynamics & Propulsion Z. S. Spakovszky

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

Problem T22

The compressor of a turbocharger shown below has an inlet flow rate of 7.5 m^3/minute of air as measured at the inlet condition. This condition is P_1 = 1 bar and T_1 = 288 K. The compressor has a pressure ratio of 1.5. The compressor is driven directly by an exhaust turbine which expands engine exhaust gas to ambient pressure $P_4 = P_1$. The compressor can be assumed ideal but the turbine experiences losses such that the actual turbine shaft work is 70% of the ideal shaft work at the same pressure ratio. The turbocharger and IC engine are arranged such that both turbine and compressor operate under conditions of steady flow. The turbine pressure ratio is the same as that for the compressor and the effect of IC engine fuel may be neglected. Assume air and exhaust gas to be perfect gases with γ = 1.4 and R = 287 J/kg-K and neglect kinetic energy changes.



a) Sketch the compression in the compressor and the expansion in the turbine in an *h-s* diagram. Indicate the shaft work and how the inlet and exit pressures of the turbine relate to the ones of the compressor.

b) Calculate the shaft power produced by the turbine.

c) Calculate the inlet and exit temperatures of the turbine.

d) How much entropy is generated in the turbine per unit mass of air?

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Problem S5 (Signals and Systems)

1.

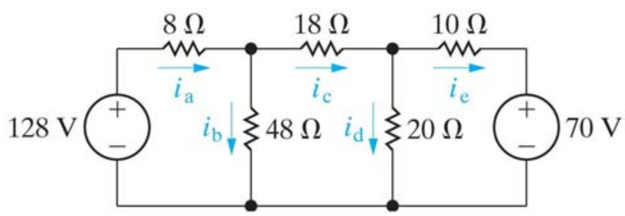

Figure 1

(a) Use the node-voltage method to find the branch currents $i_a - i_e$ in the circuit shown in Fig. 1.

(b) Find the total power developed in the circuit.

2. The circuit shown in Fig. 2 is a dc model of a residential power distribution circuit.

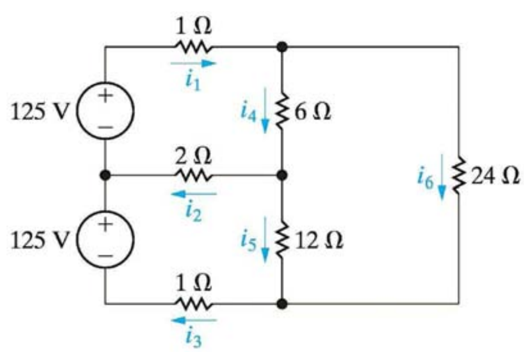

Figure 2

(a) Use the node-voltage method to find the branch currents $i_1 - i_6$.

(b) Test your solution for the branch currents by showing that the total power dissipated equals the total power developed.

3.

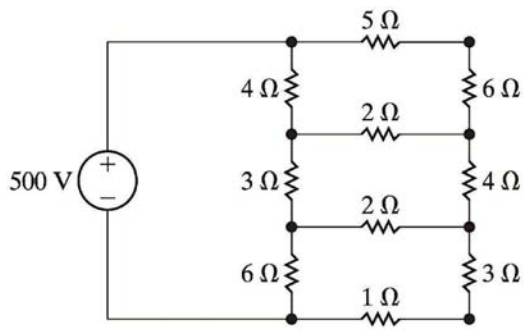

Figure 3

(a) Use the node-voltage method to find the power dissipated in the 5 Ω resistor in the circuit in Fig. 3.

(b) Find the power supplied by the 500 V source.

Problem S6 (Signals and Systems)

1. Solve problem 1 of problem set S5 using the mesh-current method.
2. Solve problem 2 of problem set S5 using the mesh-current method.
3. Solve problem 3 of problem set S5 using the mesh-current method.

Problem S7 (Signals and Systems)

1.

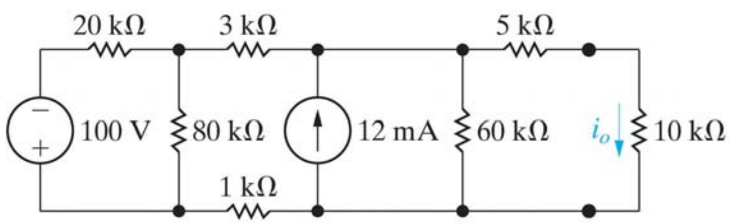

Figure 4

(a) Find the current in the 10 kΩ resistor in the circuit in Fig. 4 by making a succession of appropriate source transformations.

(b) Using the result obtained in (a), work back through the circuit to find th power developed by the 100 V source.

2.

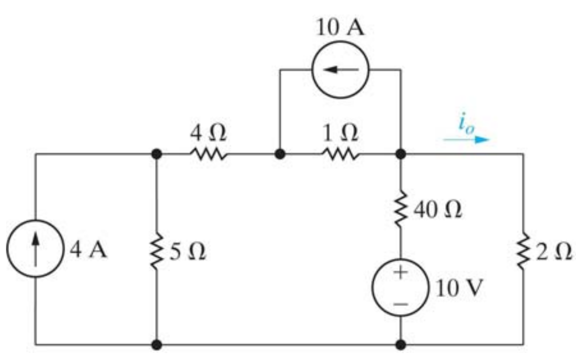

Figure 5

(a) Use a series of source transformations to find i_0 in the circuit in Fig. 5.

(b) Verify your solution by using the mesh-current method to find i_0.

3. Find the Thévenin equivalent with respect to the terminals a, b in the circuit in Fig. 6.

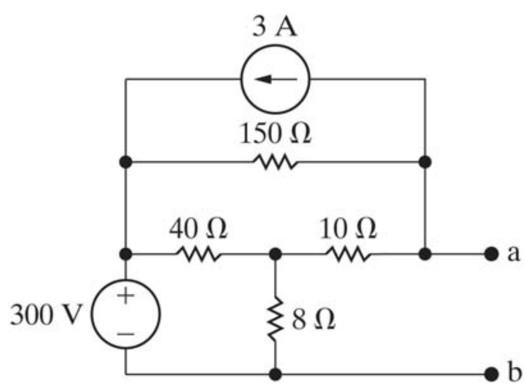

Figure 6

4. Find the Norton equivalent with respect to the terminals a, b in the circuit in Fig. 7.

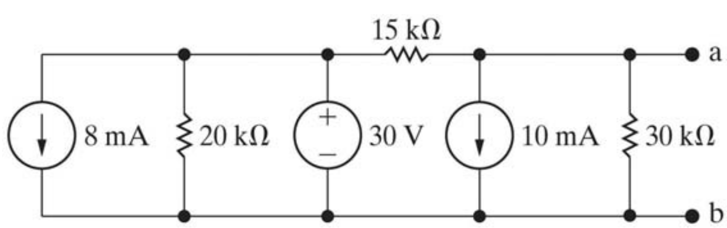

Figure 7