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

**16.001/16.002 Unified Engineering I, II**
**Fall 2006**

# Problem Set 14

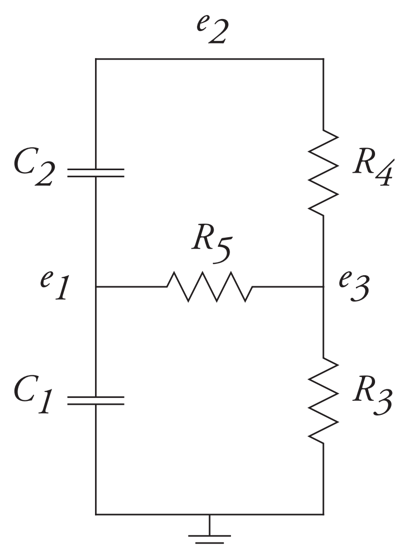
Name: ________________________

Due Date: 12/12/2006

| | Time Spent (min) |
|---|---|
| **S9** | |
| **S10** | |
| **S11** | |
| **S12** | |
| **T16** | |
| **T17** | |
| **T18** | |
| **Study Time** | |

Announcements:

**Problem S9 (Signals and Systems)**




Consider the network above, with

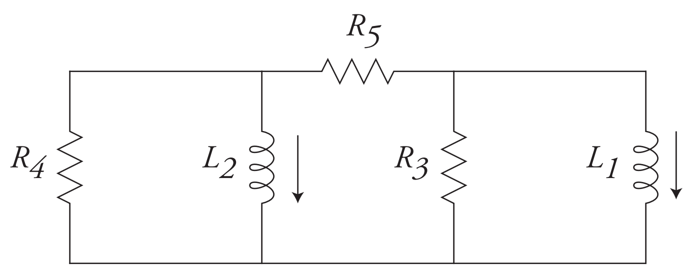
$$C_1 = 1 \text{ F}, \quad C_2 = 2 \text{ F}, \quad R_3 = 2\ \Omega, \quad R_4 = 1\ \Omega, \quad R_5 = 1\ \Omega$$

The capacitor voltages at time $t = 0$ are such that

$$e_1(0) = 3 \text{ V}, \quad e_2(0) = 6 \text{ V}$$

Find the node voltages $(e_1(t),\, e_2(t),\, e_3(t))$ as a function of time.

## Problem S10 (Signals and Systems)




Consider the network above, with

$$L_1 = 1 \text{ H}, \quad L_2 = 1 \text{ H}, \quad R_3 = 1\ \Omega, \quad R_4 = 1\ \Omega, \quad R_5 = 0.5\ \Omega$$

The inductor currents at time $t = 0$ are

$$i_1(0) = 10 \text{ A}, \quad i_2(0) = 0 \text{ A}$$

Find the inductor currents $(i_1(t), i_2(t))$ as a function of time.

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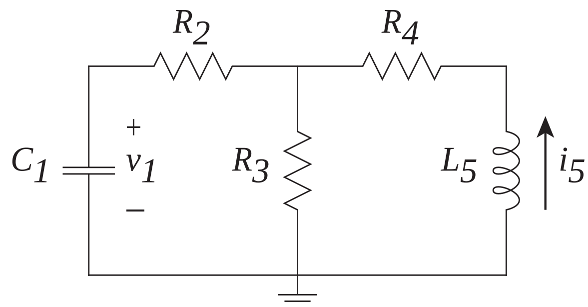
**Problem S11 (Signals and Systems)**




Consider the circuit above, with

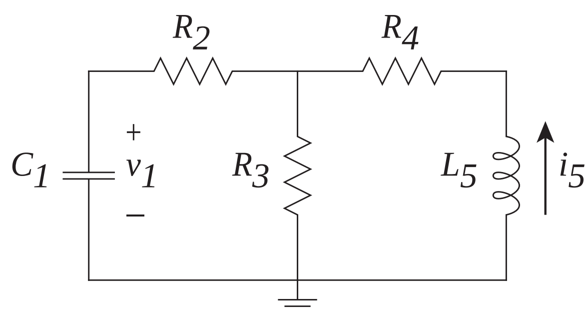
$$C_1 = 0.25\ \text{F}, \quad R_2 = 4\ \Omega, \quad R_3 = 4\ \Omega, \quad R_4 = 1\ \Omega, \quad L_5 = 1\ \text{H}$$

The initial conditions on the capacitor and inductor are

$$v_1(0) = 2\ \text{V}, \quad i_5(0) = 1\ \text{A}$$

Find $v_1(t)$ and $i_5(t)$, using the methods discussed in Lecture. Note: If you wish, you may use the loop method instead of the node method.

## Problem S12 (Signals and Systems)




Consider the circuit of Problem S11 above, with

$$C_1 = 0.25 \text{ F}, \quad R_2 = 4\ \Omega, \quad R_3 = 4\ \Omega, \quad R_4 = 1\ \Omega, \quad L_5 = 1 \text{ H}$$

Find the state-space equations that describe the evolution of the circuit, in the form

$$\frac{d}{dt}\underline{x}(t) = A\underline{x}(t)$$

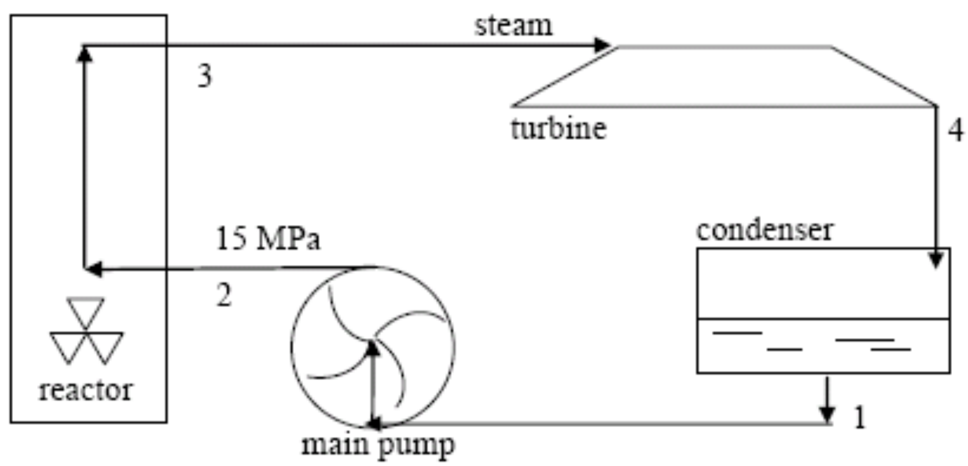
where

$$\underline{x}(t) = \begin{bmatrix} v_1(t) \\ i_5(t) \end{bmatrix}$$

Confirm that the eigenvalues of the matrix $A$ are the same as the characteristic values found in Problem S11.

**Problem T16 (Unified Thermodynamics)**

Consider the following proposal for a nuclear power plant, which consists of a nuclear reactor as the heat source and a steam Rankine cycle to generate power. The peak cycle pressure is 15 MPa. Saturated steam passes through the turbine, expanding to a pressure of 6 MPa. The fluid is condensed in the condenser to the saturation point. The liquid water is then pumped through the main pumps and heated in the reactor. A sensor measures that the temperature at state 2 is 280ºC.




a) Sketch the cycle on a p-v diagram.
b) The turbine must resist water droplet erosion for the life of the plant such that the liquid water content in the turbine flow should not exceed 20% by mass. What is the quality at state 4 to satisfy this requirement? (i.e. What is $x_4$?)
c) What mass flow of water is required to sustain a power generation of 500 MW? How does this compare to typical air flows in an aircraft engine?
d) How much power is required to drive the main pump?
e) What is the required heat input from the reactor?
f) What is the thermal efficiency?

It is suggested to modify the cycle by superheating the steam to 400°C. In this case the steam emerges from the turbine at saturated conditions (i.e. $x_4 = 1$) and with a pressure of 6 MPa.

g) What is the net cycle work with superheating for the flow rate calculated in part c?
h) What is the thermal efficiency with superheating?

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**Problem T17 (Unified Thermodynamics) (LO#4)**

A rigid, insulated vessel is fitted with a single port for filling and emptying. Initially, the valve on the port is closed after the vessel has been evacuated. The vessel is to be filled with steam from a steam line with constant supply conditions of p = 10 atm, and T = 300°C. The valve is opened and the steam is allowed to flow until the pressure in the vessel reaches 10 atm. At this time the valve is closed.

a) What is the temperature of the steam in the vessel the instant the valve is closed?

The steam in the vessel is now allowed to come to thermal equilibrium with the environment at 40°C.

b) Draw this second process on a p-v diagram.

c) What is the pressure on the steam in the vessel at this time?

d) If the volume of the vessel is 3 liters, what is the heat transfer during the thermal equilibration process?

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**Problem T18 (Unified Thermodynamics) (LO#4)**

Liquid octane ($C_8H_{18}$) is burned with the stoichiometric amount of air in an internal combustion engine operating at steady state. Both the fuel and the air enter at 25°C and 1 atm, and the products leave the engine at 900 K. If the engine develops 30 kW of power, and the mass rate of fuel is 2 $x10^5$ k-mol/s, determine the rate of heat transfer from the engine to the surroundings.