UNIFIED ENGINEERING Fall 2006

Ian A. Waitz

Problem T19 (Unified Thermodynamics) (LO#4)

Ethane C2H6(*g*) at 298 K is burned with 20 percent excess air at 298 K in a steady flow atmospheric process. If the products of combustion are cooled to 600 K, determine:

a) the air-fuel ratio by mass

b) the molar analysis of the products

c) the enthalpy of a reaction at the standard state

d) the amount of heat transfer

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Problem T20 (Unified Thermodynamics) (LO#4, LO#5)

Air flows in steady-state through a thermally-insulated duct that increases in area from inlet to outlet. Between the inlet and the outlet there is no external work. At the inlet to the duct, the stagnation temperature is 300K, the static pressure is 95kPa, and the velocity is 150m/s. The flow exits the duct at a static pressure of 100kPa with a velocity of 10m/s. Assume that the air behaves as an ideal gas with constant specific heats c_p = 1.0035kJ/kg-K, and c_v = 0.7165kJ/kg-K

a) What are the static temperature and the stagnation pressure at the duct inlet?

b) What are the stagnation temperature and stagnation pressure at the exit of the duct?

c) What is the change in entropy (per kg) from inlet to exit?

d) If the flow were to be expanded in a *reversible* manner in a thermally-insulated duct from the same inlet conditions to the same exit static pressure, what would be the velocity, stagnation temperature and stagnation pressure at the exit? What would be the change in entropy from inlet to exit?

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Problem T21 (Unified Thermodynamics) (LO#4, LO#5)

Hydrogen at T_1=300K and V_1=100cm^3 expands adiabatically in a piston-cylinder assembly to T_2=270K and V_2=200cm^3. Assume that hydrogen behaves as an ideal gas with constant specific heats c_v=10085 J/kg-K, c_p=14209 J/kg-K, and R=4124 J/kg-K.

a) Find the change in entropy and the work done per kilogram of hydrogen.

b) If the expansion were adiabatic and quasi-static between the same volumes, what would be the final temperature, the work done and the change in entropy?

c) In homework problem T4 you calculated the difference in work for two adiabatic processes: one impulsive and the other quasi-static. Calculate the change in entropy for each of these processes.

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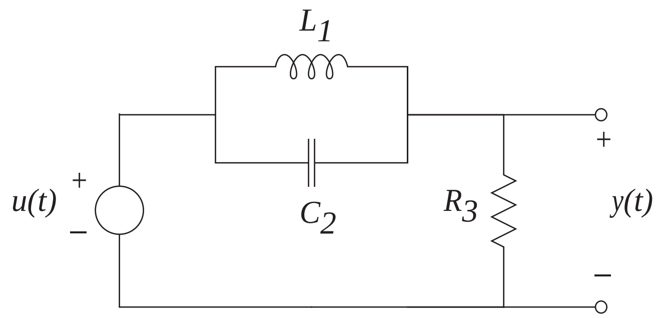
Problem S13 (Signals and Systems)

Consider the RLC circuit below:



This circuit is a *notch filter*, meaning that the output $y(t)$ is almost the same as the input $u(t)$, except that the circuit "filters out" frequencies in a narrow range, determined by the component values. For example, this circuit might be used to filter out 60 Hz noise caused by electrical wiring from the input to an audio system, to prevent 60 Hz "hum." For this circuit, find a state-space description of the system, in the form

$$\frac{d\underline{x}(t)}{dt} = A\underline{x}(t) + Bu(t)$$
$$y(t) = C\underline{x}(t) + Du(t)$$

No component values are given, so just find the matrices A, B, C, and D in symbolic form.

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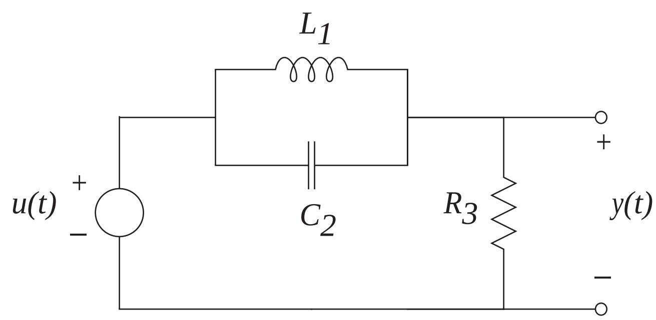
Problem S14 (Signals and Systems)

Consider the RLC circuit of Problem S13, shown below:



1. Find the transfer function, $G(s)$, of the system, using

$$G(s) = C(sI - A)^{-1}B + D$$

2. Find the transfer function using impedance methods. Show that your result agrees with the result in part (1).

3. For component values

$$L_1 = 1 \text{ H}, \quad C_2 = 0.25 \text{ F}, \quad R_3 = 10 \ \Omega$$

plot the magnitude of the transfer function $G(j\omega)$ vs. ω. Explain why the filter is called a notch filter.

Note: You may find it useful to use Matlab or a spreadsheet to calculate values of the transfer function, since there is a fair amount of complex arithmetic.

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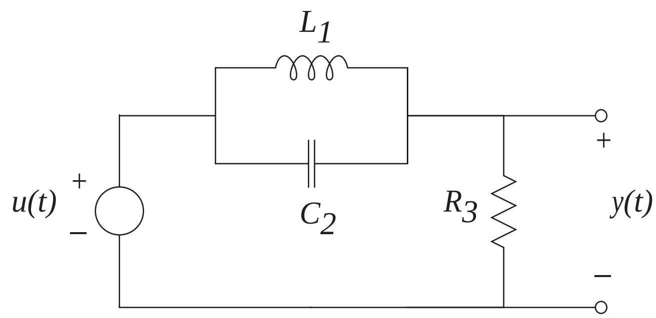
Problem S15 (Signals and Systems)

Consider the RLC circuit below:



In Problems S13 and S14, you found the state and measurement equations for this circuit, and transfer function. For component values

$$L_1 = 1 \text{ H}, \quad C_2 = 0.25 \text{ F}, \quad R_3 = 10 \ \Omega$$

find the response of the circuit, $y(t)$, for the following input signals:

1. $u(t) = \cos t$
2. $u(t) = 3 \sin 2t$
3. $u(t) = 2 \cos 4t + \sin 4t$

You need find only the particular solution, that is, the steady-state sinusoidal response. You do not need to find the homogenous solutions, which are exponentially decaying sinusoids.