Question #1

a) Design an integrator circuit based on an opamp, an inductor, and a resistor. Assuming an ideal opamp, derive the transfer function to show that it performs as an integrator.
b) Sketch where you would add a compensation resistor to increase the phase margin of the circuit.
c) Derive the transfer function for the circuit with compensation resistor, assuming an ideal opamp.
d) Now assuming the opamp has a frequency response of $G/s$, determine the optimum relationship among the circuit components for maximum phase margin.

Question #2

For the circuit shown at right,
a) Redraw the circuit, replacing the opamp and with an amplifier having gain $k$. Find $k$ as a function of the circuit components.
b) Determine the loop gain $AB$ for this new circuit.
c) Determine the relationship among the component values for this circuit to work as an oscillator.
d) Determine the frequency $\omega_0$ of the oscillator.

Question #3

For the ladder network shown at right,
a) Write the four equations that govern the voltages and currents.
b) Convert these equations into a signal flow diagram.
c) Determine all loop gains and the gain of the forward path.
d) Use Mason’s gain rule to find the transfer function.

Question #4

You are taking a shower, and you want to set the water temperature to 310 K. You feel the water at the showerhead, and adjust the shower knob to try to reach your desired temperature. You turn the knob at an angular velocity of 0.1 rad/(sec*K). Note that this is proportional to the difference between the shower temperature and your desired temperature. The shower valve adjusts the temperature according to the knob position at 10 K/rad. There is a delay of $\tau$ between the valve and the showerhead.
a) Draw a signal flow diagram for this system, with the input being the desired temperature, and the output being the water temperature at the showerhead. Label all branch transmittances, and nodes for the temperature difference, knob velocity, knob position, water temperature at the valve, and water temperature at the showerhead. You may use a first order Pade approximation for delay.
b) Determine the transfer function $H=$(temperature at showerhead)/(desired temperature).
c) Assume there is a 1 meter pipe between the knob and the showerhead, and the water flows at 1 m/s. Will the water reach equilibrium at the desired temperature?
d) Now assume the water is flowing at 0.5 m/s. What will happen to the water temperature?