EE 141 – Midterm
Winter 2017

02/15/17

Duration: 1 hour and 40 minutes

The midterm is closed book and closed lecture notes. No calculators.
You can use a single sheet (front and verse) of handwritten notes.
Please carefully justify all your answers.

Problem 1: We are interested in modeling and controlling the amount of blood delivered to cells in the human body. We will use the following analogy between blood flow and the flow of electrons in an electric circuit: blood pressure p is analogous to voltage and blood flow f is analogous to current. A small blood vessel is then modeled by the circuit:

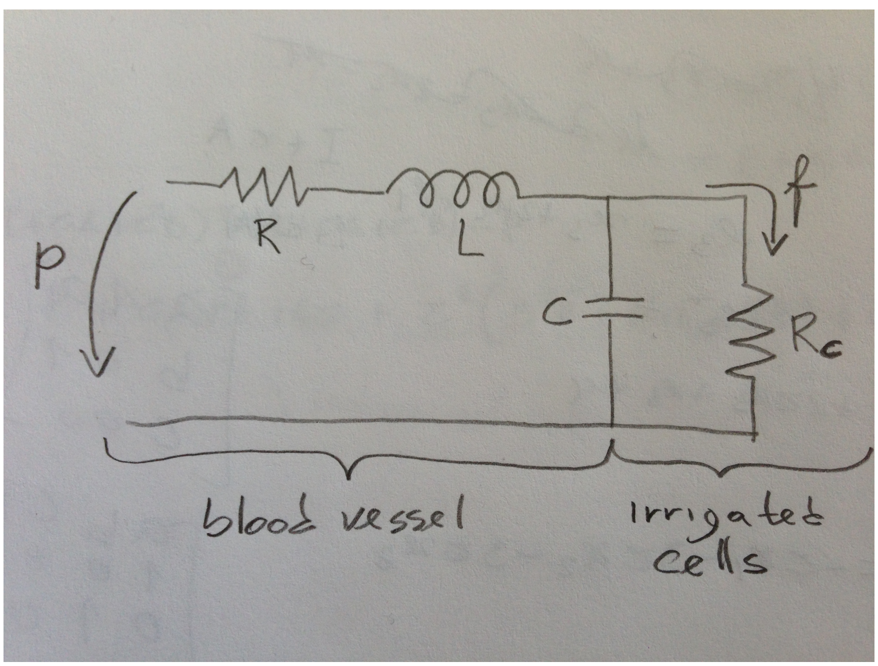

Figure 1: Electrical circuit modeling a small blood vessel delivering blood to human cells.

where we treat blood pressure p as a control input and the blood flow f through the irrigated cells as the output.

1. Show that the differential equation governing the evolution of the blood flow f is given by:

$$LCR_c\frac{d^2f}{dt^2} + (L + RCR_c)\frac{df}{dt} + (R + R_c)f = p.$$

2. What is the transfer function from p to f assuming zero inicial conditions?

3. If $L = 1$ and $R_c = 2$, what values would you choose for R and C so that the following specifications are satisfied:

   (a) rise time no greater than 0.6

   (b) settling time no greater than 4.6.

4. What is the output (in the time domain) if the input is a step of magnitude 2 for $R = 4$, $L = 1$, $C = 1/2$, and $R_c = 2$?

5. For the parameters in question 4, design a controller in a unit feedback loop configuration enforcing the requirements in question 3.

Problem 2: Consider the transfer function:

$$H(s) = \frac{3s^2 + 3s + 2}{s^3 + 2s^2 + ks + 2k - 4}.$$

1. For which values of k is the system stable?
2. What is the steady state error to a unitary step input when $k = 5$?
3. Design a controller, in a unit feedback loop configuration, so that the controlled system has zero steady state error to step inputs.