Guidelines:

- Part I is closed book. Part II is open book, open notes.
- You will receive Part II after you submit Part I. It is recommended that you spend no more than 30 minutes on Part I.
- Time limit: 3 hours total.
- 88 points possible.
- Show all your work.
- Complete the test independently.
- This exam is printed double-sided; be sure to complete all questions.

I agree to complete this exam without unauthorized assistance from any person, materials, or device. __________________________

Part I (Closed Book) [28 pts]: Consider use of an equation or sketch whenever that might make your answer more clear.

1. [6 pts] Give three justifications for studying process control, including one relevant to biological systems.

2. [3 pts] What is the difference between a variable and a parameter?

3. [2 pts] What is a load variable?

4. [4 pts] List two factors which may influence the accuracy of a model.

5. [3 pts] How does the Laplace transform help us solve ODEs?

6. [3 pts] How does a transfer function depend on model inputs?

7. [3 pts] What are the *zeros* of the following transfer function?

$$G(s) = \frac{(5s+1)(3s+1)}{s(7s+1)(s-1)}$$

8. [4 pts] In Matlab, what information do you need to send to ode45 to solve a system of ODEs? That is, what do you need to solve a system of ODEs?
   Hint: you should have four items.

Part II (Open Book) [60 pts]:

1. [20 pts] Create a simple dynamic model for a patient undergoing dialysis. In dialysis, a patient is connected to a machine which continuously removes and returns blood from the body while filtering out waste products. Use a pharmacokinetic approach to model the patient simply as blood plasma and a unified subsystem for all the body tissues. Model the body tissues as a diffusion-limited two-compartment system. Within the cellular part of the tissue, assume that waste is created at a constant rate. Finally, model the dialysis machine as a single compartment, and use an appropriate mass transport equation to approximate the removal of waste from the dialysis unit.

    a. [12 pts] Clearly write out the complete set of model equations for this system.

    b. [4 pts] Check that your model is well-determined by listing the state variables.

    c. [4 pts] What parameters would need to be known to simulate this model, and which variables might be considered inputs?

    d. [Bonus: 5 pts] Is the diffusion-limited tissue assumption valid? Why or why not? What other assumptions might be the weakest in this model?

2. [20 pts] Determine an expression for the output as a function of time given the following input and transfer function:

$$u(t) = \begin{cases} 0 & t < 0 \\ e^{-4t} & t \geq 0 \end{cases}$$

$$G(s) = \frac{(s+4)(3s+1)}{(s+1)(s^2+2s+5)}$$

Sketch your output function.

3. [4 pts each = 20 pts] Match the transfer functions to the responses to a unit *impulse* (delta function) input. To receive full credit, you must *justify* each selection and demonstrate proper use of control terminology. You should not need to explicitly solve for the response as a function of time.

i. $\dfrac{3e^{-1.5s}}{5s}$ ii. $\dfrac{1}{s^2+9}$ iii. $\dfrac{1}{s+1}$ iv. $\dfrac{0.3(s-1)}{-3s+1}$ v. $\dfrac{3}{s^2+2s+5}$