University of California, Berkeley

Department of Mechanical Engineering

ME 132 Dynamic Systems and Feedback

Fall 2013 **Midterm I**

Closed book and closed lecture notes;
One 8.5 × 11 handwritten summary sheet allowed;
Scientific calculator with no graphics allowed;
Keep your phones in your bag, and set them off or in silent mode.

NAME: ______________________________

STUDENT ID #: _____________________

#1	#2	#3	#4	#5	Total
3	9	18	10	10	50

Instructions:

- Write down your name and student ID.
- Read the problems carefully.
- Write your solution clearly.
- This exam has 9 pages. The last two pages are empty. You can use them as your scrach papers. You can also use the empty space on the back side of each page for your drafts.
- Do not turn to the next page until you are instructed to do so.

1. [3 points] Explain, in one or two sentences, the following concepts:

   (a) Dynamic System:

   (b) Feedback:

2. [9 points] Match the concepts and definitions about dynamic systems and feedback. Enter your answers (i.e. the letters a through j) in the provided boxes. There can be multiple choices for each box.

plant:		disturbance:	
sensor:		noise:	
controller:		actuator:	
reference:			

   (a) the physical system to be controlled.

   (b) a device that measures a physical quantity such as pressure, acceleration, humidity, or chemical concentration.

   (c) a device that has the capacity to affect the behavior of the plant.

   (d) e.g., quantization errors in a digital implementation of the control algorithm.

   (e) e.g., windage to a launched rocket.

   (f) e.g., the desired water temperature when taking a shower.

   (g) it processes the measured signals from the sensors and the reference signals, and generates the actuation signals which in turn, affects the behavior of the plant.

   (h) a signal that represents what we would like the system output to behave like.

   (i) phenomena that adversely affect the behavior of the plant being controlled.

   (j) e.g., measurement noises that are due to inaccuracies of sensor readings.

3. [6+2+2+8 = 18 points] Consider the block diagram in Fig. 1, where $P(s)$, $C(s)$, $D(s)$, and $F(s)$ are transfer functions connecting their individual input and output signals.

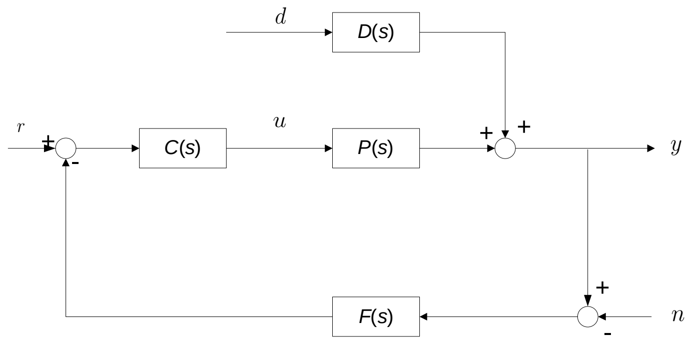

Figure 1: Block diagram for problem 3

(a) write down the following closed-loop transfer functions

i. from r to y: $G_{r\to y}(s) =$

ii. from d to y: $G_{d\to y}(s) =$

iii. from n to y: $G_{n\to y}(s) =$

(b) suppose

$$G_{r\to y}(s) = \frac{4}{s^3 + 2s^2 - 3s + 4}$$

Is the above transfer function stable? Circle your conclusion: **stable, not stable**; and provide your reasoning.

(c) suppose

$$P(s) = \frac{100}{s^2 + 2 \times 0.1 \times 10s + 100}$$

Draw the construction of the plant using simulink in MATLAB, with only the basic elements of: integral, summation/substraction, and scalar amplifiers. Use $\boxed{\int}$ to represent the integral action. Indicate where to assign the initial condition(s).

(d) a friend in Stanford has proposed a controller with the following transfer function

$$C(s) = k_p(1 + \frac{1}{T_i s} + T_d s) \tag{1}$$

For the remaining parts of the problem, denote the input and the output to the controller, respectively as $e(t)$ and $u(t)$.

i. obtain the ordinary differential equation representation of the controller in (1). Assume zero initial condition(s).

ii. is the controller linear? Circle one: **linear; nonlinear.** What is the property it has to satisfy for linearity?

iii. is the controller causal? Circle one: **causal; not causal**, and prove your answer.

iv. is the controller time-invariant (TI)? Circle one: **TI; not TI.** What is the property it has to satisfy if it is time-invariant?

4. [2+4+2+2 = 10 points] Consider the system

$$\dot{y}(t) + 3y(t) = -6u(t)$$

with intial condition $y(0) = 1$.

(a) when the input is

$$u(t) = \begin{cases} 0 & \text{for } t < 0 \\ 1 & \text{for } t \geq 0 \end{cases}$$

obtain the mathematical solution of the **transient response** and the **steady-state response**.

(b) obtain the mathematical solution of the **steady-state response** when the input is

$$u(t) = \begin{cases} 0 & \text{for } t < 0 \\ \sin(t) + 2\sin(3t) & \text{for } t \geq 0 \end{cases}$$

(c) for part 4a and part 4b, after how long (approximately) do you think the system has reached the steady state?

Reasoning:	Time to reach the steady state: $T =$

(d) consider another system

$$\dot{y}(t) - 3y(t) = -6u(t)$$

What is the steady-state value of the step response?
Circle your conclusion: **2, -2, none of these two**, and provide a short explaination.

5. [2+3+5 = 10 points] Consider a plant that is described by

$$y(t) = y_1(t) + y_2(t) \tag{2}$$

$$y_1(t) = 3u(t), \; y_1(0) = 0 \tag{3}$$

$$\dot{y}_2(t) + y_2(t) = -2u(t), \; y_2(0) = 0 \tag{4}$$

where $u(t)$ is the input and $y(t)$ is the output.

(a) derive the transfer function between $u(t)$ and $y(t)$.

Derivations:	Result:

(b) suppose the reference signal is $r(t)$ and we construct a control law

$$u(t) = (r(t) - y(t)) + r(t)$$

i. is the closed-loop system stable? Circle your conclusion: **stable; not stable**, and provide your reasoning below.

ii. what is the DC gain from r to y?

Derivations:	Result:

(c) sketch, on the same figure, the response of the plant [defined by equations (2)–(4)] to the input shown below ($u(t) = 0$ if $t < 0$). Be as accurate as you can.
Your STRATEGY: