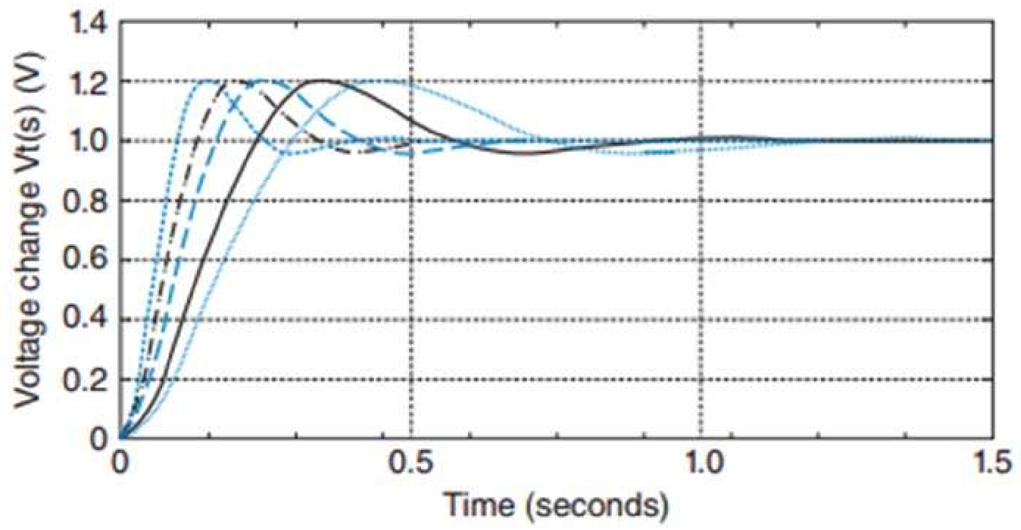
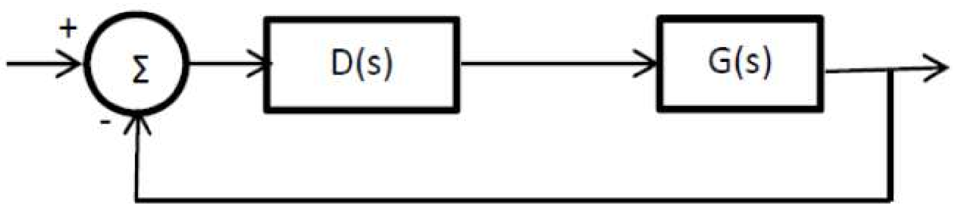
EE 302 HW2 **Due Date: 1st April 2018 Sunday, Time: 23:55**

Q1. The figure below shows five step-responses of an automatic voltage regulation system as one of the system parameters varies. Assume for all five responses that they are those of a second-order system in standard form. Show the positions of the poles in the complex plane approximately for each of the responses. Label the responses from A to E (from left to right).



Q2. Consider the feedback system in the following figure. It is given that $G(s) = \frac{1}{s+1}$ and $D(s) = 4$.



a. Determine the step-response of the closed-loop system <u>analytically</u>. What is the steady-state error (to a unit-step input), 2% settling-time and percent-overshoot (if any)?.

b. Use Matlab to plot the step-response and compare the simulation result with the analytically computed performance measures in part-a (You might consider using the functions `tf(.)` and `step(.)` in Matlab).

In parts-c and d you need to consider that the closed-loop transfer functions you obtain are <u>not</u> in standard form, i.e., you should <u>not</u> neglect the transfer function zeros and derive the formulas for the required performance measures from scratch.

c. Now set $D(s) = 4\left(1 + \frac{1}{5\,s}\right)$, which is a Proportional-Integral (PI) controller. Repeat the analytical calculations and simulations in parts-a and b for the new $D(s)$.

d. Now set $D(s) = 4\left(1 + \frac{1}{0.4\,s}\right)$. Again, repeat the analytical calculations and simulations.

e. Compare the performance measures for the three cases above and comment on the results.

Q3. A system in a basic feedback control loop with negative unity feedback has the following closed-loop transfer function

$$T(s) = \frac{K\,s + b}{s^2 + a\,s + b}$$

a. Determine the open-loop transfer function $G_o(s)$.

b. Now, suppose that $G_o(s) = \frac{r\,s+m}{s^2+n\,s}$. Determine $r,\ m,\ n$ such that the following three conditions are simultaneously satisfied:

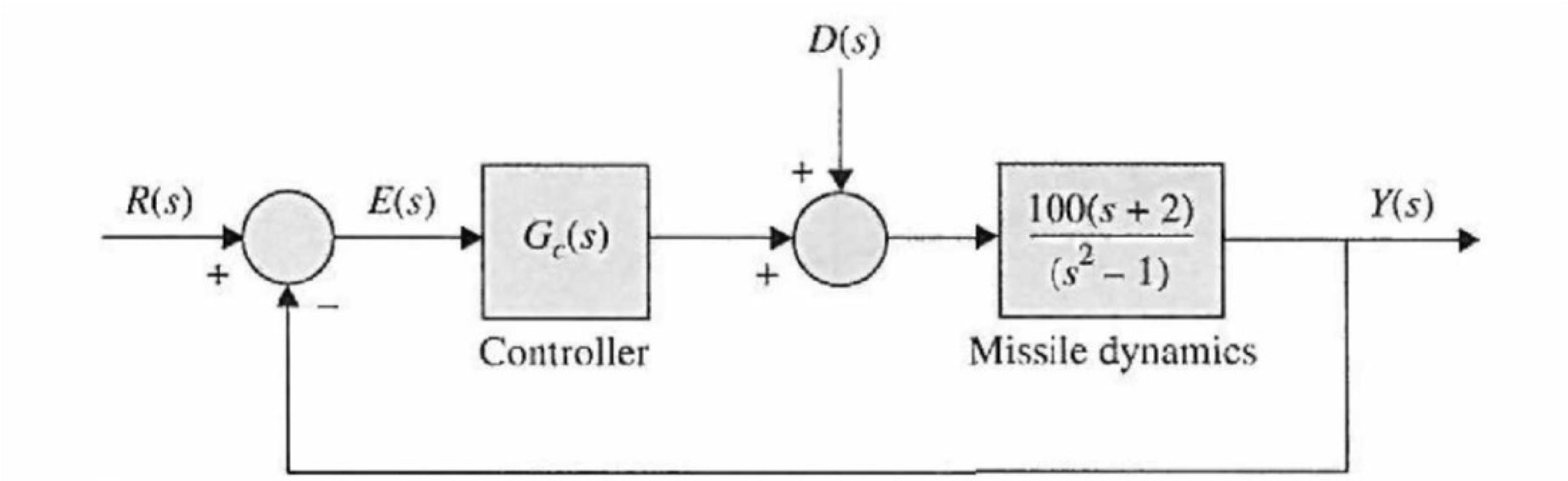
i. steady-state error to a unit-ramp input is equal to 0.04;
ii. the undamped natural frequency is $\omega_n = 5$ rad/sec;
iii. the unit-step response $y(t)$ is of the form $y(t) = A - e^{-3t}(\delta \cos(\omega t) + \beta \sin(\omega t))$.

c. Determine A, δ, β that correspond to the values found in part-b.
d. Evaluate the maximum % overshoot analytically.
e. Draw the step-response of the system in Matlab and compare your theoretical result in part-e with that you found using Matlab.

Q4. Consider the same block diagram as in Problem 2 with $D(s) = \frac{K_I}{s}$ (integral controller) and $G(s) = \frac{4}{s+2}$.

a. If $K_I = 1$, find the steady-state error to a unit-step input, steady-state error to a unit-ramp input and the percentage overshoot.
b. Find K_I such that the steady-state error to a unit-ramp input is less than or equal to 0.125 with least possible percentage overshoot.
c. For the K_I value obtained in part-b, find the percentage overshoot.
d. What is the effect of increasing K_I on the percentage overshoot?

Q5. The block diagram representation of a guided missile attitude control system is shown below. The reference command input is $r(t)$, and $d(t)$ represents the disturbance input. The objective of this problem is to study the effect of the controller $G_c(s)$ on the steady-state and transient responses of the system.



a. Since this is an LTI system, we can write

$$Y(s) = G_r(s)R(s) + G_d(s)D(s)$$

Find $G_r(s)$ and $G_d(s)$.
b. Let $G_c(s)$ = 1. Find the steady-state error of the system when $r(t)$ is the unit-step function.
c. Set $d(t) = 0$. Let $G_c(s) = \frac{(s+\alpha)}{s}$. Find the steady-state error when $r(t)$ is the unit-step function.
d. Draw the unit-step response of the system for $0 \le t \le 0.5$ sec using Matlab with $G_c(s)$ as given in part-c and $\alpha = 5,\ 50,\ 500$. Record the maximum overshoot of $y(t)$ for each case. Comment on the effect of varying the value of α of the controller on the transient response.
e. Set $r(t) = 0$, and $G_c(s) = 1$. Find the steady-state value of $y(t)$ when $d(t)$ is the unit-step function.
f. Set $r(t) = 0$, let $G_c(s) = \frac{(s+\alpha)}{s}$. Find the steady-state value of $y(t)$ when $d(t)$ is the unit-step function (for $\alpha = 5,\ 50,\ 500$).
g. Draw the response for $0 \le t \le 0.5$ sec. using Matlab for $G_c(s)$ as given in part-f when $r(t) = 0$, $d(t)$ is the unit-step function (for $\alpha = 5,\ 50,\ 500$).