Ref. No.: EX/PG/CNSE/T/112A/9/2017
EX/PG/ELE/T/112B/14/2017

MASTER OF ELECTRICAL ENGINEERING 1ST SEM. EXAMINATION-2017

MASTER OF CONTROL SYSTEM ENGINEERING 1ST SEM. EXAMINATION-2017

Subject: CONTROL SYSTEM ENGINEERING   Time: Three Hours   Full Marks: 100

Answer *Any Five* questions (5×20)

Question No.			Marks
Q1	(a)	Figure P-1(a) shows the block diagram of a d.c. motor control system with $$G(s)=\frac{K(s+3)}{s(s+1)(s+2)}$$ The signal $N(s)$ denotes the frictional torque at the motor shaft.	2+4

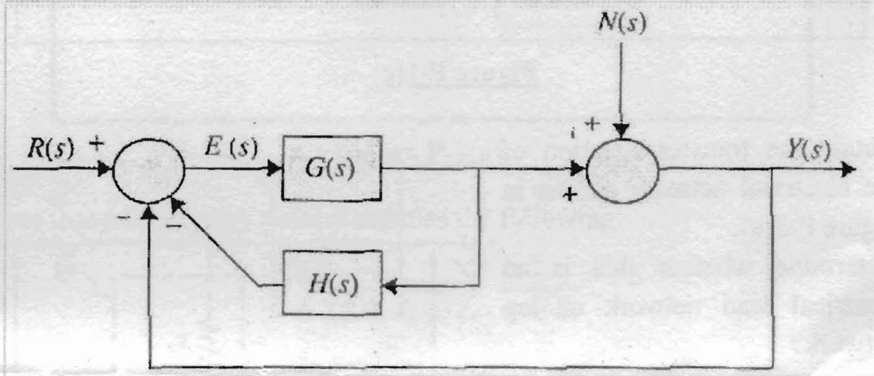

Figure P-1(a)

(i) Find the transfer function $H(s)$ so that the output $Y(s)$ is not affected by the disturbance torque $N(s)$.

(ii) With $H(s)$ as determined in (i), find the value of K so that the steady-state value of $e(t)$ is 0.1 when the input is a unit-ramp function and $N(s) = 0$.

(b) Referring to the system shown in Figure P-1(b), determine the values of K and k such that the system has a damping ratio of 0.7 and an undamped natural frequency of 4 rad/sec. **4**

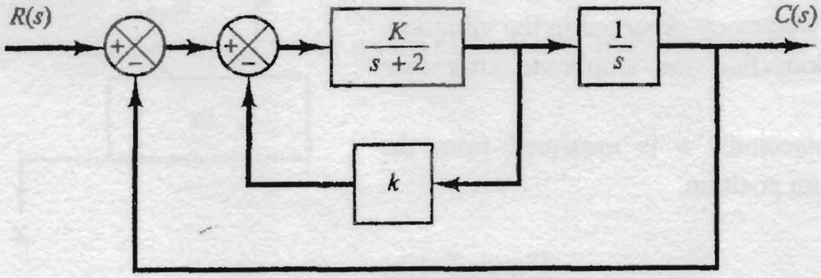

Figure P-1(b)

(c) The block diagram of a control system is shown in Figure P-1(c) with 3+7

$$G(s) = \frac{100}{(1 + 0.1s)(1 + 0.5s)}$$

(i) Find the step-, ramp-, and parabolic-error constants.

(ii) Determine the minimum steady-state error that can be achieved with a unit-ramp input by varying the values of K and K_t.

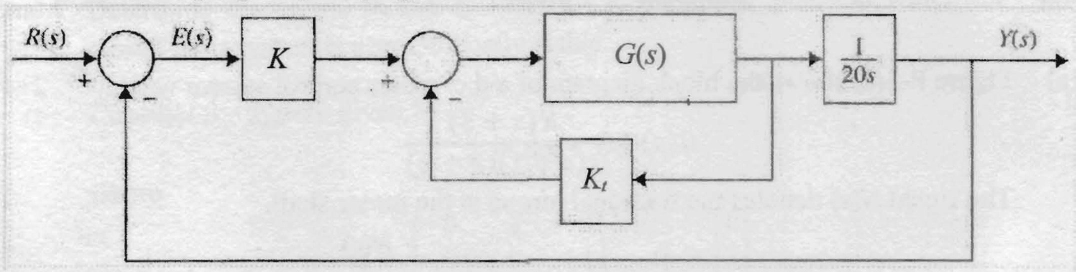

Figure P-1(c)

Q2 (a) Obtain the transfer function of the electrical network shown in Figure P-2(a). 4+2

Determine whether this is an electrical lead network or lag network?

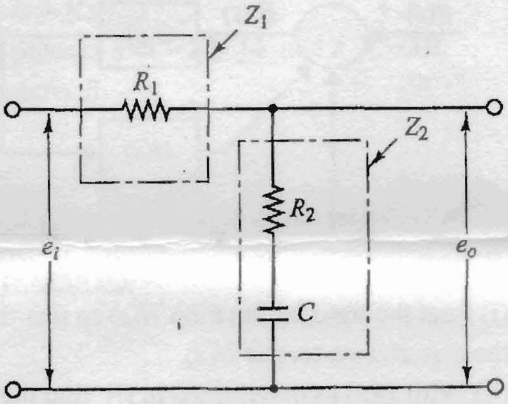

Figure P-2(a)

(b) In the system shown in Figure P-2(b), the numerical values of m, b, and k are given as m = 1 kg, b = 2 N-sec/m, and k = 100 N/m. The mass is displaced 0.05 m and released without initial velocity. 10

Find the frequency observed in the vibration. In addition, find the amplitude after four cycles.

The displacement x is measured from the equilibrium position.

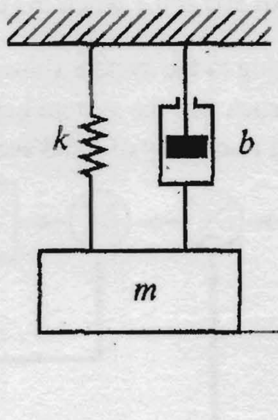

Figure P-2(b)

(c) The unit impulse response of an LTI system is the unit step function $u(t)$. Find the response of the system to an excitation $e^{-at}u(t)$. 4

Q3 (a) Consider the system shown in Figure P-3(a). Plot the root loci as the value of k varies from 0 to ∞. 10

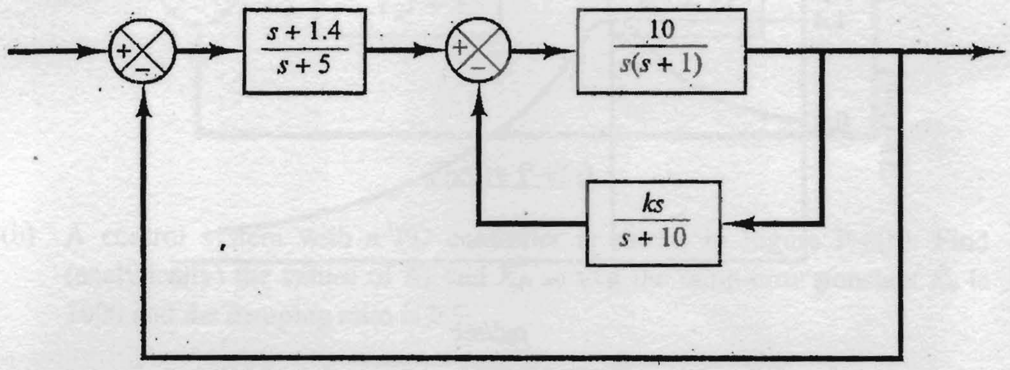

Figure P-3(a)

(b) Prove that a breakaway point α satisfies the following: 5

$$\sum_{i=1}^{n} \frac{1}{\alpha + P_i} = \sum_{i=1}^{m} \frac{1}{\alpha + Z_i}$$

(c) Show that the root loci for a control system with 5

$$G(s) = \frac{K(s^2 + 6s + 10)}{s^2 + 2s + 10}, \quad H(s) = 1$$

are arcs of the circle centered at the origin with radius equal to $\sqrt{10}$.

Q4 (a) The characteristic equation of a linear control system is given in the following equation 8+4

$$s(s^3 + 2s^2 + s + 1) + K(s^2 + s + 1) = 0$$

(i) Apply the Nyquist criterion to determine the values of K for system stability.

(ii) Verify the values of K by means of the Routh-Hurwitz criterion.

(b) The closed-loop frequency response of a second-order prototype system is shown in Figure P-4(b). Sketch the corresponding unit-step response of the system. Indicate the values of the maximum overshoot, peak time, and the steady-state error due to a unit-step input. 8

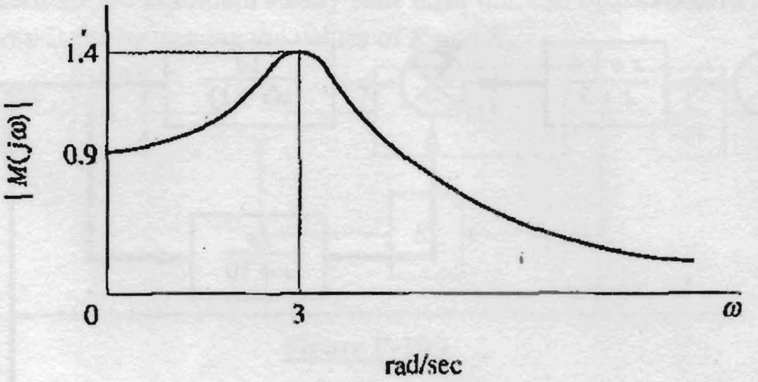

Figure P-4(b)

Q5 (a) Consider the unity-feedback control system whose open-loop transfer function is 6

$$G(s) = \frac{\alpha s + 1}{s^2}$$

Determine the value of α so that the phase margin is 45°.

(b) Referring to the closed-loop system shown in Figure P-5(b), design a lead compensator $G_c(s)$ such that the phase margin is 45°, gain margin is not less than 8 dB, and the static velocity error constant K_v is 4 sec^{-1}. 14

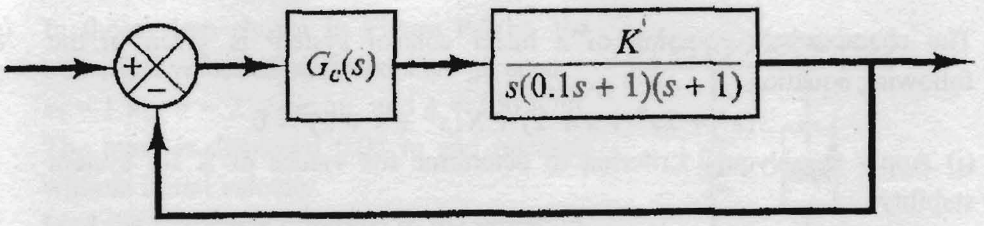

Figure P-5(b)

Q6 (a) Determine the values of K, T_1, and T_2 of the system shown in Figure P-6(a) so that the dominant closed-loop poles have the damping ratio of 0.5 and the undamped natural frequency of 3 rad/sec. 14

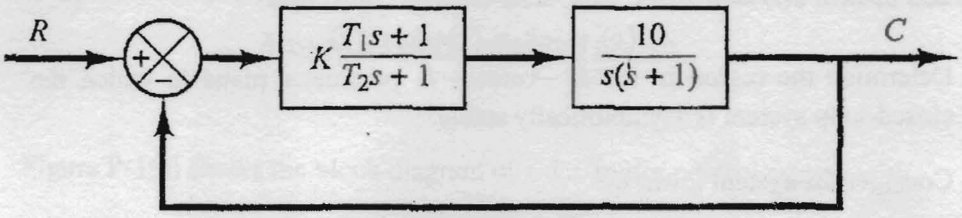

Figure P-6(a)

(b) A control system with a PD controller is shown in Figure P-6(b). Find (analytically) the values of K_P and K_D so that the ramp-error constant K_v is 1000 and the damping ratio is 0.5. 6

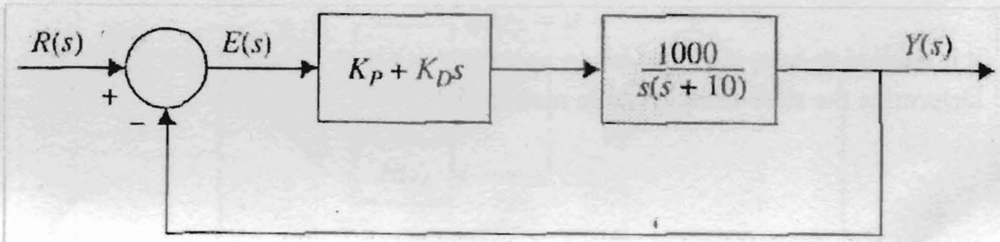

Figure P-6(b)

Q7 (a) Find $x_1(t)$ and $x_2(t)$ of the system described by 8

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -3 & -2\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

where the initial conditions are $x_1(0) = 1$ and $x_2(0) = -1$.

(b) Consider the system defined by 8

$$\dot{x} = Ax + Bu, \quad y = Cx$$

where

$$A = \begin{bmatrix}1 & 2\\ -4 & -3\end{bmatrix}, \quad B = \begin{bmatrix}1\\ 2\end{bmatrix}, \quad C = [1\ 1]$$

Transform the system equations into the controllable canonical form.

(c) Given the system in state equation form, $\dot{x} = Ax + Bu$, with 4

$$A = \begin{bmatrix}1 & 0 & 0\\ 0 & -3 & 0\\ 0 & 0 & -2\end{bmatrix}, \quad B = \begin{bmatrix}1\\ 0\\ 1\end{bmatrix}$$

Can the system be stabilized by state feedback $u = -Kx$?

Q8 (a) A controlled process is modeled by the following state equations 6

$$\frac{dx_1(t)}{dt} = x_1(t) - 2x_2(t), \qquad \frac{dx_2(t)}{dt} = 10x_1(t) - u(t)$$

The control $u(t)$ is obtained from state feedback such that

$$u(t) = -k_1x_1(t) - k_2x_2(t)$$

Determine the region in the k_1 –versus– k_2 parameter plane in which the closed-loop system is asymptotically stable.

(b) Consider the system given by 14

$$\dot{x} = \boldsymbol{A}x + \boldsymbol{B}u$$

where

$$\boldsymbol{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{bmatrix}, \quad \boldsymbol{B} = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$$

By using the state-feedback control

$$u = -\boldsymbol{K}x$$

it is desired to have the closed-loop poles at $s = -2 \pm j4$ and $s = -10$. Determine the state-feedback gain matrix $\boldsymbol{K}$.