Ref. No.: Ex/PG/ME/T/128A/2018

ME Mechanical Engineering 1st year 2nd semester Examination, 2018

Subject: Principles and Applications of Linear Control Theory
Time: Three hours

Answer any five questions
(All questions carry equal marks)

Question 1

Describe an armature controlled dc servo motor with appropriate block diagram.

If the applied voltage is considered as the input and the angular position of the motor is taken as the output, show that the transfer function can be written as

$$\frac{k_m}{s(\tau_m s + 1)}$$

Where the symbols k_m and τ_m stand for motor gain constant and motor time constant respectively

Question 2

a. Comment of the stability of the following characteristic equation using Routh's criterion: -

$$s^4 + 3s^3 + 4s^2 + 6s + 10 = 0$$

b. Comment on the significance of the root locus plot?

Question 3

Sketch Bode plot of the following system using asymptotes. The open loop transfer function of the system is given by

$$G(s) = \frac{20}{s(s+2)(s+3)}$$

Question 4

a. For a resistive-inductive circuit subjected to a step voltage input what do you understand by the term 'time constant'? Express 'time constant' in terms of inductance and resistance of the circuit.
b. What will be the nature of frequency response of the above first order system? What do you mean by 'cut off frequency'?
c. Show for determining transient response due to a step input, how can a higher order system can be broken up into several first and second order systems

Question 5

a. Write down the transfer functions for lead and lag compensators.

b. Draw the Bode plots for lead and lag compensators.

c. Consider a unity feedback system with $G(s)=\frac{4}{s(s+2)}$. A lead compensator of the form $\frac{K_c\alpha(1+sT)}{(1+\alpha sT)}$ is added to the system. The requirements are as follows:-

$K_v = 25/s$

$PM = 50^0$

$GM = 10dB(\min)$

If the designer takes a value of $\alpha = 0.24$ and $\frac{1}{T} = 4.4$, please qualitatively explain the effectiveness of the lead compensator using Bode plot.

Question 6

For a state space the matrices

$$[A]=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -2 & -10 & -12 \end{bmatrix} \qquad \{B\}=\begin{Bmatrix} 0 \\ 0 \\ 1 \end{Bmatrix} \qquad \lfloor C \rfloor = \lfloor 1 \quad 0 \quad 0 \rfloor \qquad [D]=0$$

(a) How many state variables are there? What is the number of inputs?

(b) What is the characteristic equation for the system?

(c) The eigenvalues of the system are $\lambda_1 = -0.5649, \lambda_2 = -0.3185, \lambda_3 = -11.11663$. Find out the Vandermonde matrix

(d) What will be state-space representation for the system in canonical (diagonal $[A]$) form?

(e) Can you comment on controllability and observability from the canonical form?

Question 7

What do you understand by full state feedback control? Draw the block diagram for a regulator with full state feedback (Figure 7).

What is a Linear Quadratic Regulator?

Consider an inverted pendulum controlled by a motor torque at its base. Show that the equation of motion can be written in the form

$$\begin{Bmatrix}\dot{\theta}\\ \ddot{\theta}\end{Bmatrix} = \begin{bmatrix}0 & 1\\ \Omega^2 & 0\end{bmatrix}\begin{Bmatrix}\theta\\ \dot{\theta}\end{Bmatrix} + \begin{Bmatrix}0\\ 1\end{Bmatrix}u$$

Determine the full state feedback matrix using the algebraic Riccati equation. The algebraic Riccati equation is given below:

$$[M][A] + [A]^T[M] - [M][B][R]^{-1}[B]^T[M] + [Q] = [0]$$

The full state feedback is given by

$$[K] = [R]^{-1}[B]^T[M]$$

You may take $[Q] = \begin{bmatrix}1 & 0\\ 0 & 0\end{bmatrix}$ & $R = {}^1/_{c^2}$

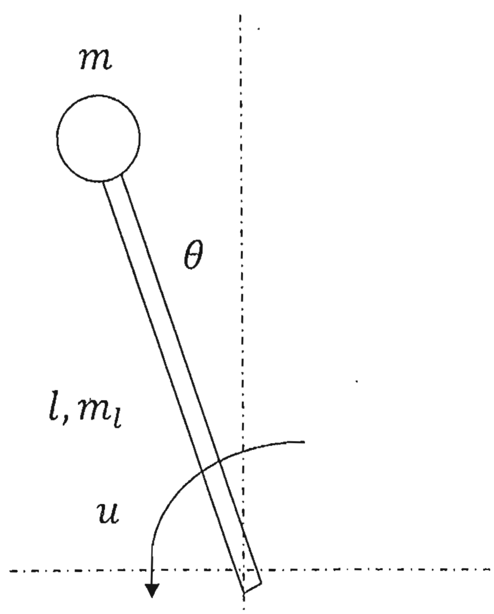

Figure Q7