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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V SEMESTER B. TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, NOVEMBER 2019

LINEAR CONTROL THEORY [ELE 3101]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 14th November 2019** **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Semi-log graph sheet may be provided.

1A. For the mechanical system shown in **Fig. Q1A**:
(i) Write down the dynamic equations that describe the system.
(ii) Obtain transfer function $X_3(s)/F(s)$ considering $M_1 = M_2 = M_3 = 1kg;\ B_1 = B_2 = 1\ N-s/m; K_1 = K_2 = K_3 = K_4 = 1\ N/m$ ***(03)***

1B. For the system shown in **Fig. Q1B**, determine the transfer function ${Y(s)}/{R(s)}$ using Mason's gain formula ***(03)***

1C. Assuming positive value for the gain "K", sketch the root locus and comment on the stability of the system whose transfer function is given as:
$$G(s)H(s) = \frac{K(s+2)(s+3)}{s(s+1)}$$
Further, determine the values of "K" for which the system will be
(i) Underdamped
(ii) Overdamped. ***(04)***

2A. The magnitude of the frequency response of an underdamped second order system ($T(s)$) is 5 at $0\ rad/sec$ and it peaks to ${10}/{\sqrt{3}}$ at $5\sqrt{2}\ rad/sec$. Through detailed analyses, derive the transfer function $T(s)$:
$$T(s) = \frac{K\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$ ***(03)***

2B. The asymptotic bode plot of the transfer function ${K}/{(1+a^{-1}s)}$ is given in **Fig. Q2B**. Obtain analytically, the errors in phase angle as well as in the gain (dB) at a frequency of $\omega = 0.5a$. ***(03)***

2C. The asymptotic Bode plot of a unity feedback system whose open-loop transfer function G(s) is shown in **Fig. Q2C**. With detailed analyses, derive the transfer function G(s). ***(04)***

3A. A unity feedback system has the open loop transfer function is given below:
$$G(s) = \frac{K(s+6)}{s(s+1)(s+4)}$$
Draw the Nyquist diagram and determine the range of K for which the system remains stable. ***(03)***

3B. The forward path model of a system cascaded with a proportional controller configured in unity feedback control loop is given as:

$$G(s) = \frac{K(s+4)}{s(s+1.2)(s+2)}$$

Determine:

(i) The range of gain "K" that keeps the system stable.
(ii) The value of gain "K" that makes the system oscillate
(iii) The frequency of oscillation when K is set to that value which makes the system oscillate **(03)**

3C. A unity feedback system has an open loop transfer function given by the following expression is operating with a dominant pole damping ratio of 0.707

$$Gp(s) = \frac{K\,(s+6)}{(s+2)(s+3)(s+5)}$$

Design a suitable PD controller so as to reduce the settling time by a factor of 2. Also comment on the transient as well as steady state performance of the system with and without the controller. **(04)**

4A. Justify appropriately whether, the transfer function $G_c(s) = {(s+5)}/{(s+10)}$ can indeed function as a lead compensator. Further, determine the frequency at which the phase of $G_c(s)$ is maximum. **(03)**

4B. With a neat diagram, derive the mathematical model of a lag compensator using an operational amplifier. Justify its phase lag nature from resultant phase equation. **(03)**

4C. Consider a unity negative feedback system with a plant transfer function as:

$$G_{plant}(s) = \frac{K}{s(s+5)(s+10)}$$

The gain "K" is set to 100 so as to achieve a static error constant of 2 s^{-1}. Prove through appropriate frequency domain analysis that introduction of a lead-lag compensator in the forward path of the system whose transfer function is given by:

$$G_{comp}(s) = \frac{(s+0.15)(s+0.7)}{(s+0.015)(s+7)}$$

results in the overall gain and phase margins of 28.6 dB and 75.4^0 respectively. **(Use the semi-log graph sheet)** **(04)**

5A. A control system with a PI controller is shown in **Fig Q5A**. Select the appropriate controller gains so that the overshoot to a unit step input is equal to 5% and the error constant 5 s^{-1}. **(03)**

5B. Represent the electrical network shown in **Fig. Q 5B**, in state space physical variable form if the output is current through the resistor. Convert the state space to represent the same electrical network in transfer function form. **(03)**

5C. For the system shown below, design a state feedback controller such that the compensated system has an overshoot of 10% and settling time of 3secs. Further design an observer which is ten times faster than the designed controller.

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u\,;\; y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$ **(04)**

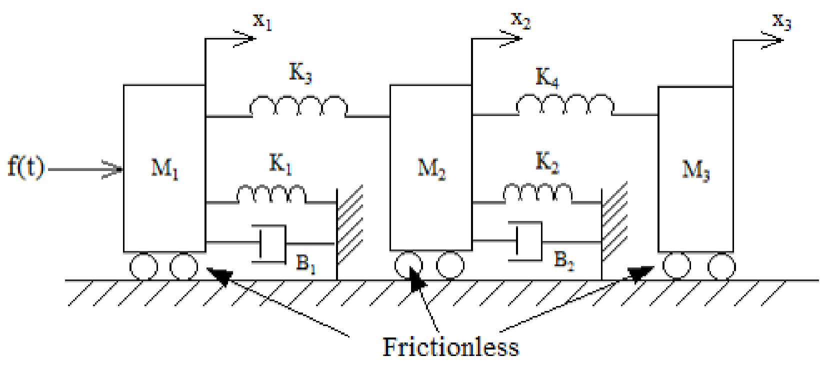


Fig. Q1A

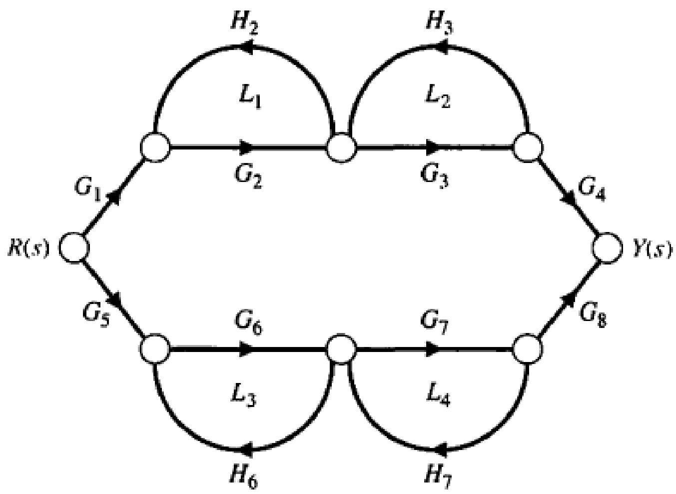
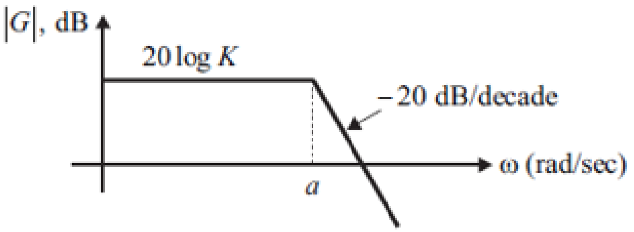
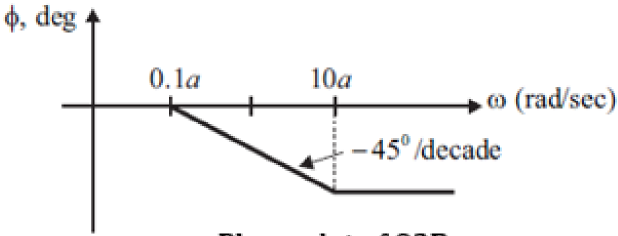


Fig. Q1B



Magnitude plot of Q2B



Phase plot of Q2B

Fig. Q2B

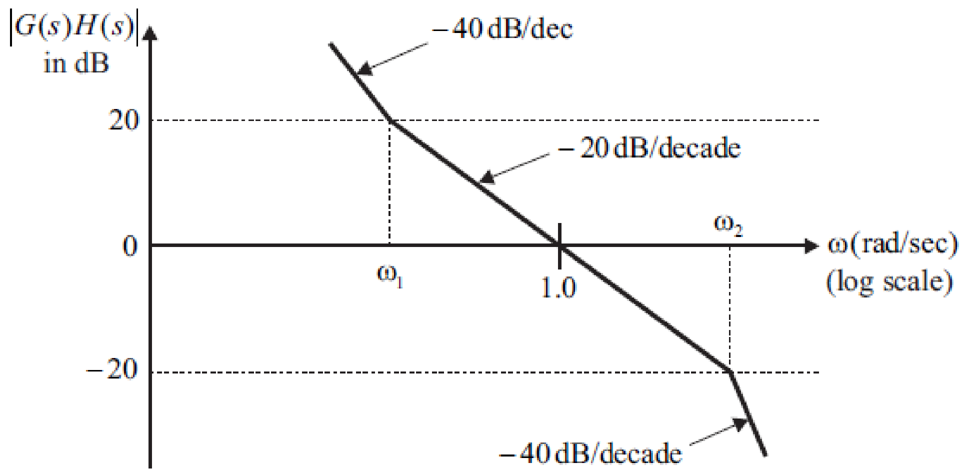


Fig. Q2C

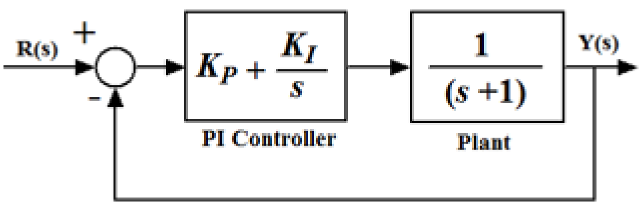


Fig. Q5A

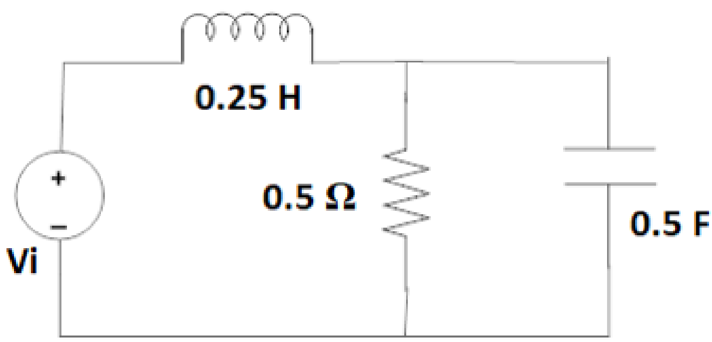


Fig. Q5B