Indian Institute of Engineering Science and Technology, Shibpur

M.E. (Mech. Engg.) 2nd Semester Examination, 2014

Subject: Dynamics and Control of Mechanical Systems (ME- 1008)

Duration: 3 hours **Full Marks: 70**

Answer <u>question No. 1 and any three</u> from the rest

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1. Answer the following questions

a) Estimate the *percent overshoot*, *settling time*, *peak time* and *rise time* of the step response given by

$$c(t) = 0.009804 - 0.0001857e^{-5.1t} - 0.009990e^{-2t}\cos(9.796t) - 0.001942e^{-2t}\sin(9.796t)$$

b) The state-space representation of a system is given below. Find the poles of the system

$$\dot{\mathbf{x}} = \begin{bmatrix} -2 & -1 \\ -3 & -5 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 1 \\ 2 \end{bmatrix}u(t)$$

$$y = \begin{bmatrix} 3 & 2 \end{bmatrix}\mathbf{x}$$

c) The transfer function of a system is given by $G(s) = \dfrac{s^2 + 3s + 2}{s^4 + 5s^3 + 3s^2 + 2s + 2}$. Give a state-space representation of the system.

d) Consider the system shown in Fig. 1. Develop a state-space model of the system. $m_1 = 9$ kg, $m_2 = 1$ kg, $k_1 = 24$ kN/m, $k_2 = 3$ kN/m.

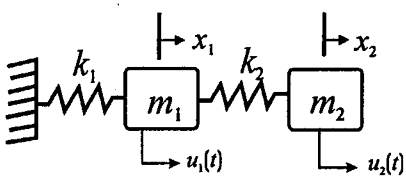

Figure 1

[4+2+3+4=13]

2. The open-loop transfer function of a system is $G(s) = \dfrac{1}{s(s+2)}$.

a) Represent the system in controllable canonical form
b) Design a state-feedback controller to place the closed-loop poles at -2, -3.
c) Design a PID controller for placing the dominant closed-loop poles at $-2 \pm 2j$.

[3+8+8=19]

3. The control system of a boring machine is shown in Fig. 2 where R(s) and Y(s) are the required and achieved boring angles, respectively. D(s) is the disturbance

to the system. Determine the range of values of K for satisfying the following requirements.

a) the closed-loop system is stable
b) output due to the step disturbance in less than 10%
c) overshoot due to step input is less than 10%

[19]

4. The open-loop transfer function of a unity feedback system is given by

$$G = \frac{K(s+2)}{(s+3)(s+1)(s^2+2s+5)}$$

a) Sketch the root-locus of the system
b) Determine the value of K beyond which the system become oscillatory. Also find the oscillation frequency
c) Draw the Nyquist plot for K=10
d) Determine the gain margin and phase margin of the system for K=10

[5+4+6+4=19]

5. Design a Positive Position Feedback Controller for assigning 40% damping ratio to both the modes of vibration of the system described in question No. 1(d) and Fig. 1.

[19]

6. Fig. 2 depicts the acceleration feedback control system of a single degree-of-freedom vibrating structure. Show that when the filter frequency is tuned to the structural natural frequency

a) the condition of equal damping of the closed-loop poles is $\zeta_f \le \frac{K_c}{\omega_n^2}$
b) the condition of equal natural frequency of the closed-loop poles is $\zeta_f \ge \frac{K_c}{\omega_n^2}$
c) Find the natural frequencies of the system when condition (a) is satisfied
d) Find the closed-loop damping ratios when condition (b) is satisfied

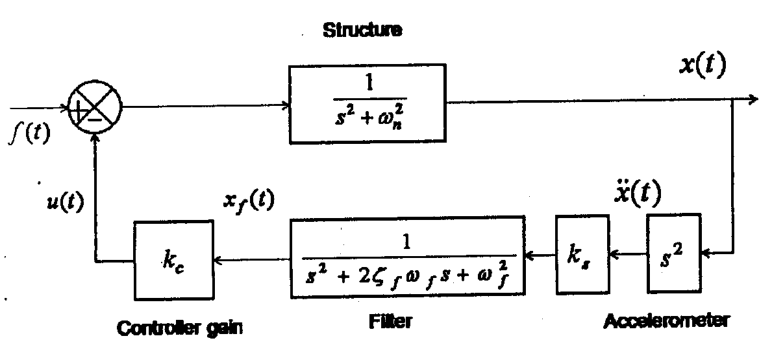

Figure 2 $K_c = k_s k_c$

[3+3+7+6=19]