

Time: 3 hours

- Instructions:**
1. Answer ALL questions
 2. Calculators are allowed
 3. Students may bring two pages (both sides) of letter-size notes
 4. Question sheets are to be returned with examination booklets

1. [Marks: 15] A translational mechanical system is shown schematically in Figure 1. Given that $M = 2 \text{ kg}$, $f_v = 6 \text{ N-s/m}$, and $K = 8 \text{ N/m}$, do the following for the system:
- a) Find the transfer function $G(s) = X(s)/F(s)$.
 - b) Find ζ (damping ratio) and ω_n (natural frequency).
 - c) Evaluate %OS (percent overshoot), T_s (settling time), and T_p (peak time) for the step response.
 - d) Find the steady-state value of $x(t)$ if $f(t)$ is a step.
 - e) Find the analytical expressions for the magnitude and phase frequency responses.

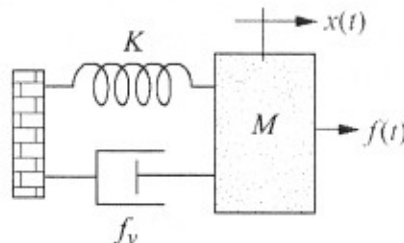


Figure 1

2. [Marks: 12] Sketch the Bode magnitude and phase plots for the following transfer functions.

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

b) $G(s) = \frac{s(s+10)}{10(s+1)}$

3. [Marks: 12] Determine the stability for the systems with closed-loop transfer functions of

a) $T(s) = \frac{1}{s^5 + 3s^4 + 5s^3 + 4s^2 + s + 3}$

b) $T(s) = \frac{1}{2s^5 + 2s^4 + 6s^3 + 6s^2 + 10s + 3}$

4. [Marks: 20] Given the unity feedback system of Figure 2, do the following for the system:

- Sketch the root locus.
- Find the range or value of gain, K , that will make the system unstable, marginally stable, and stable, respectively.
- Find the steady-state value of system output and the steady-state error for a step input if the gain $K = 60$.

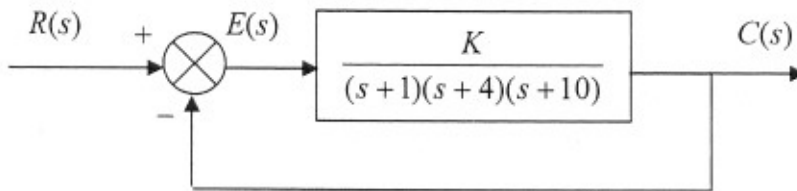


Figure 2

5. [Marks: 18] You are required to design a controller for the system of Figure 3 such that the system has a settling time of 1.0 second and a peak time of $\pi/3$ seconds, with the zero steady-state error for a step input. Specify what controller that you need to use and then design the controller.

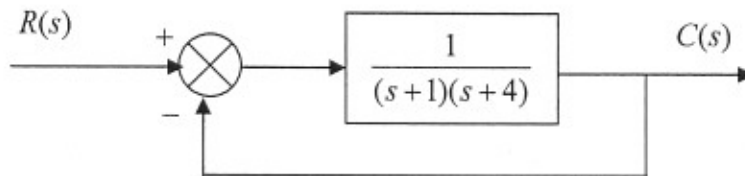


Figure 3

6. [Marks: 18] Given the unity feedback system of Figure 4, do the following for the system:

- Sketch the Nyquist diagram for the system. Your answer should clearly show your derivations and the Nyquist contour that you have used.
- Apply the Nyquist criterion to determine the range of gain, K , such that the system is stable.

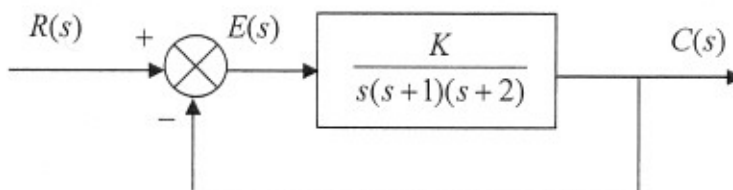


Figure 4

7. [Marks: 5] Figure 5 shows the Nyquist diagram of a system. It is known that the diagram crosses -1 on the real axis. Also, it is known that no open-loop poles are in the right half plane. What is the system stability? Explain why.

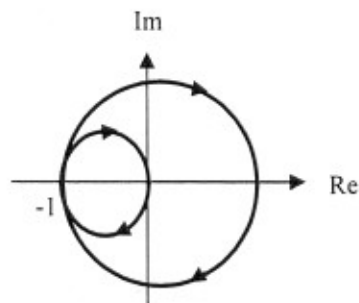


Figure 5