Final Exam (December 21, 2004) for

ME 431 – Control Systems I and ME 862 – Analysis & Synthesis of Linear Control Systems

Instructor: Dr. Daniel CHEN

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 $M = 2\text{ kg}$, $f_v = 6\text{ N}-\text{s/m}$, 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.

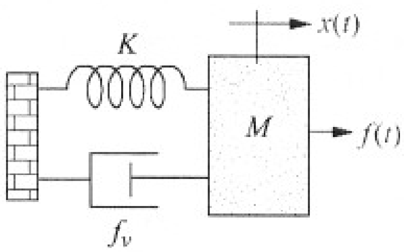

Figure 1

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

   a) $G(s) = \dfrac{100(s+1)}{s}$ b) $G(s) = \dfrac{s(s+10)}{10(s+1)}$

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

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

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

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

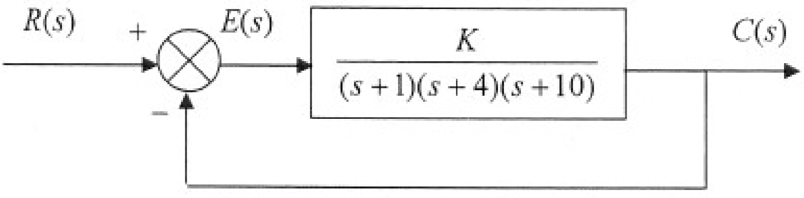

Figure 2

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.

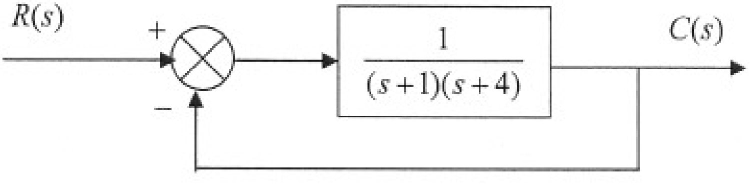

Figure 3

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

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

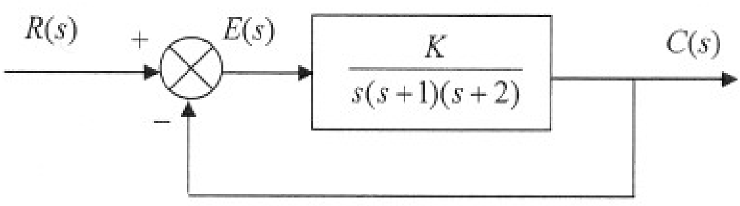

Figure 4

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.

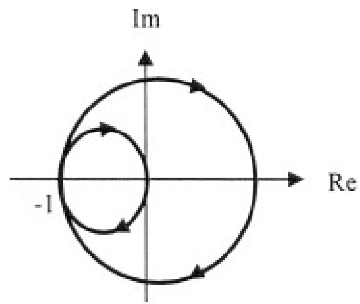

Figure 5

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