GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2000

System Dynamics & Controls
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

Automation and Controls Qualifying Exam

1. The velocity output of a d.c. motor and its load driven by a voltage input has the transfer function G as shown below.

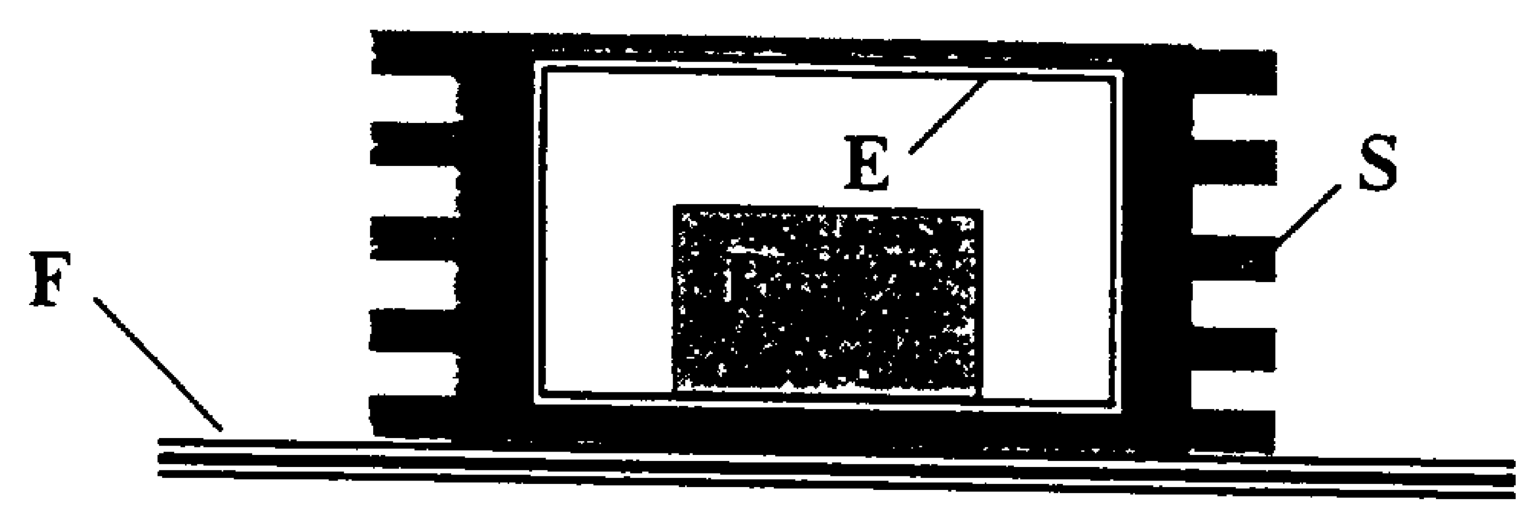
$$G(s) = \frac{K}{s+a}, \quad a = 1$$

(a) A position feedback control is to be designed with a lead compensation so that the closed loop system has a damping ratio of 1.0 and a rise time as fast as reasonably possible. Choose the compensator parameters and the amplifier gain K based on a root locus analysis. For purposes of implementation assume the pole and zero values differ by no more than a factor of 10. Your solution can be a numerical one or equations that must be solved to lead to an exact solution. In either case, sketch the root locus representative of your design.

(b) Consider the need for the specified behavior (damping ratio = 1) even with parameter variations. If this must be faithfully true even with a variation of the system G(s) parameters of up to ten percent. Explain how the parameter variation condition alters your design.

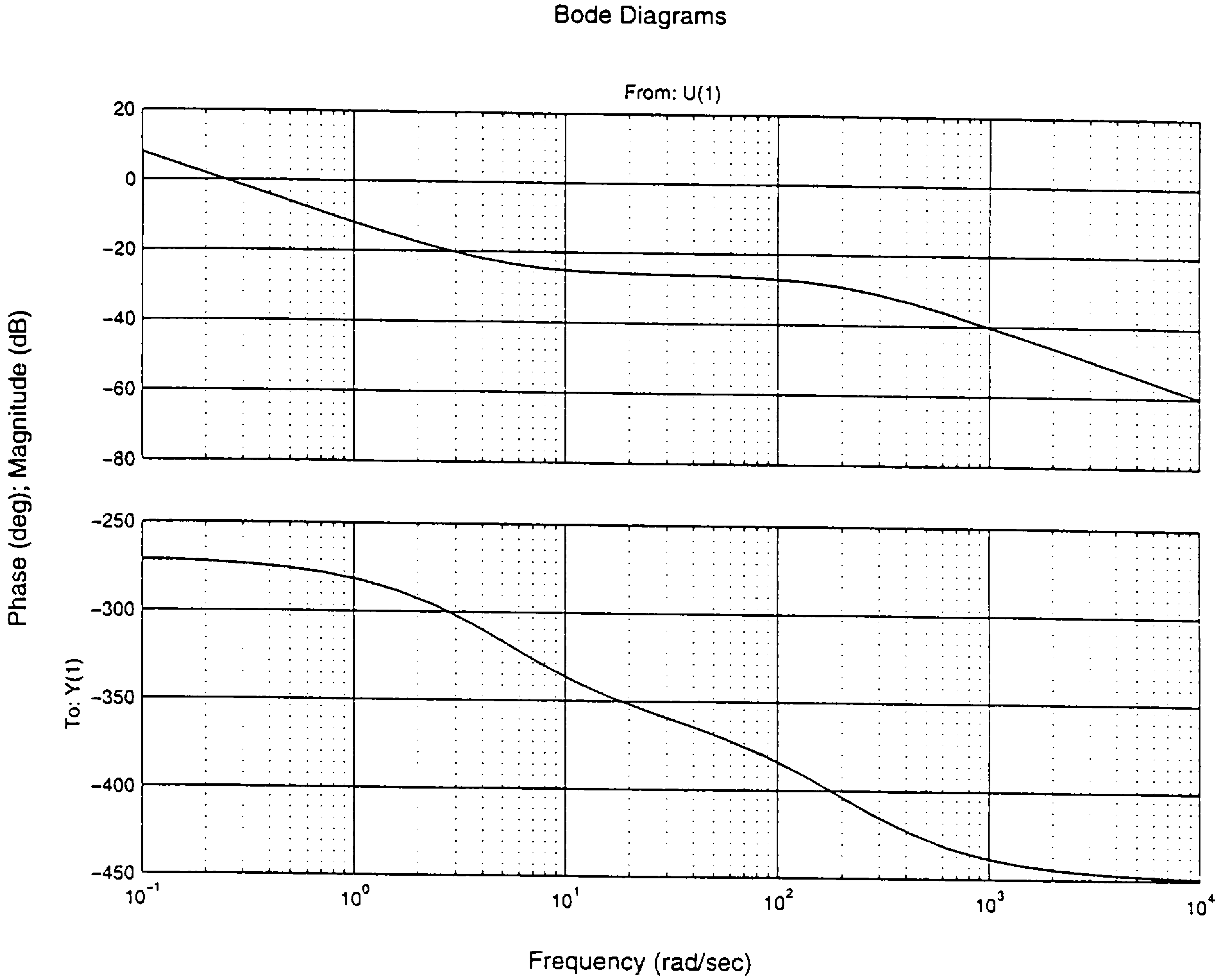
(c) An alternative controller is proposed with a measurement of velocity and position being feed back with an appropriate velocity gain. Choose the gains to meet the same design criteria as in part (a) above. Explain any practical limitations to your solution.

2. The figure below shows an active electronic package, where **P** is a power supply mounted inside an enclosure **E** that is installed in a computer; and **F** (a perfect insulator) is part of the computer frame. Both the frame F and the enclosure E are connected to the heat sink **S**. Assume that heat transfer from P to E is by radiation, $q_r = C(T_p^4 - T_e^4)$ where the proportionality C is a constant, as well as by conduction; that the average heat sink temperature is constant; and that the rate of heat generation within P is known and is at $\mathbf{q_p}$.



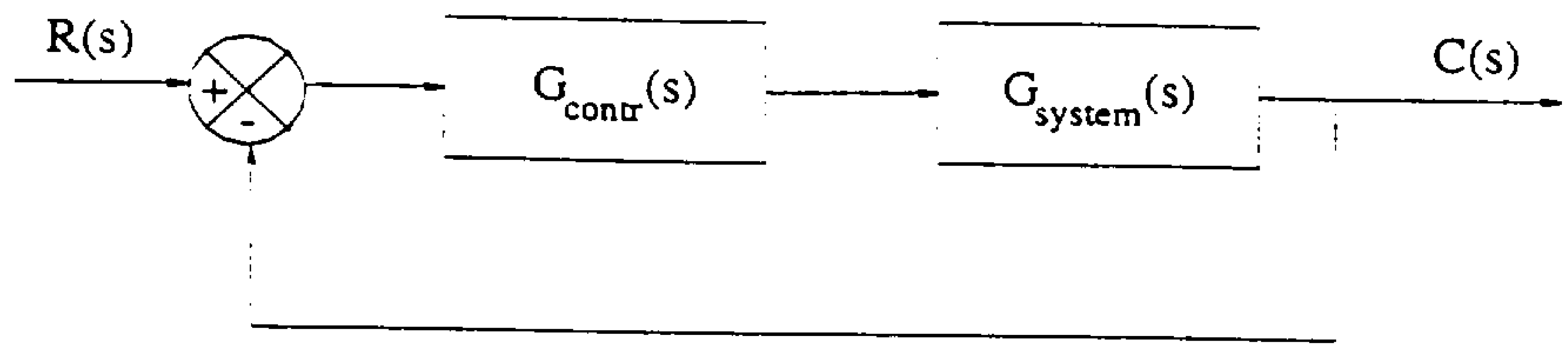
(1) Derive a dynamic model that will give the temperature of the power supply, $\mathbf{T_p}$, following the turning on of electric power to the system.
(2) Derive the equations that will determine the steady-state operating point.
(3) Linearize the dynamic model about the steady-state operating point, and obtain the transfer function that relates the temperature of the power supply to the rate of heat generation within P.

Problem 3



(a) Consider the Bode plot of a system shown above.
Determine the transfer function $G_{\text{system}}(s)$ of the system from the Bode plot, **including ALL constants.** **15 points**

(b) Consider the following block diagram for the remainder of Problem 3:



where $G_{\text{system}}(s)$ is the transfer function you determined in (a).

Question:
If no controller is used, i.e. $G_{\text{contr}}(s) = 1$, can you guarantee that the steady-state error of the **closed-loop system** for a unit step is zero (Yes/No)?
Clearly explain your answer based on the TF you determined in (a). **5 points**

(c) Only a PD- and PI- controller are available. Which one is more appropriate for the system above if the objective is to make sure that the steady-state error of the closed-loop system for a unit step is zero?
Explain your answer. **5 points**