Exam Number: ________________

Department of Mechanical Engineering

Michigan State University

Ph.D. Qualifying Examination
August 2007
Dynamic Systems and Control

Open Book
Answer All Questions
All Questions Weighted Equally

Exam Prepared by

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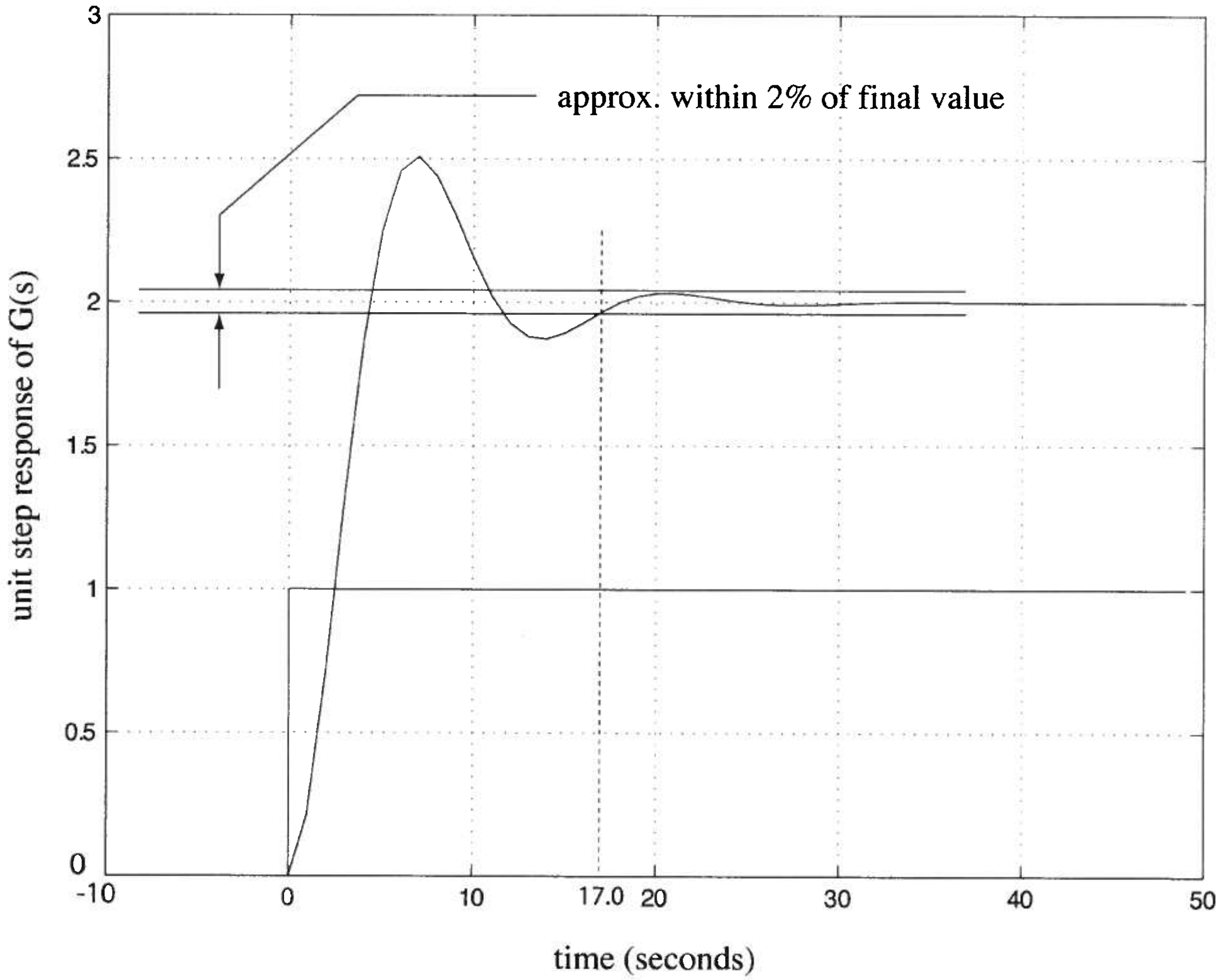
(revised 4-17-07)

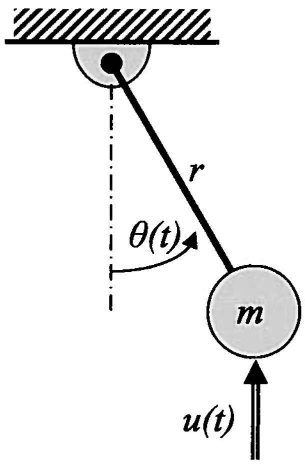
1) The unit step response of the second-order system

$$G(s) = \frac{1}{a_2 s^2 + a_1 s + a_0}$$

is shown in the figure below. Determine the values of the parameters a_0, a_1, and a_2.



2) The rotational dynamics of a pendulum with a vertical applied force are governed by the ordinary differential equation



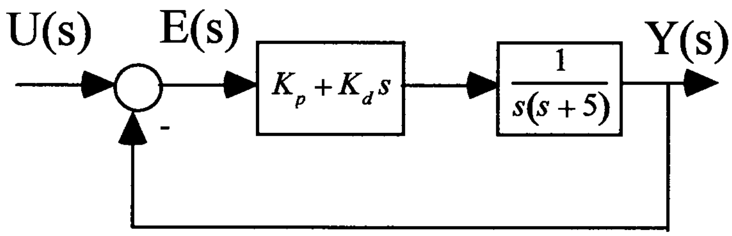
$$mr\ddot{\theta}(t) + mg\sin(\theta) = u(t)\sin(\theta)$$

To simplify the problem, assume $m = 1\ kg$ and $r = 1\ m$

a) Find a linear differential equation valid about an operating point where the operating point angle $\theta_0 = \pi/4$.

b) For the required equilibrium value of the force, u_0 required to hold the system at $\theta_0 = \pi/4$, Based on $y_{ss}(t)$, determine the approximate steady-state response $\theta_{ss}(t)$ as $t \Rightarrow \infty$ for an input force $u(t) = u_0 + 0.1\sin(0.2t)$.

3) You are to design a Proportional + Derivative controller for the system shown below.



a) Determine the range of gains K_p and K_d that will lead to a stable closed-loop system.

$< K_d <$
$< K_p <$

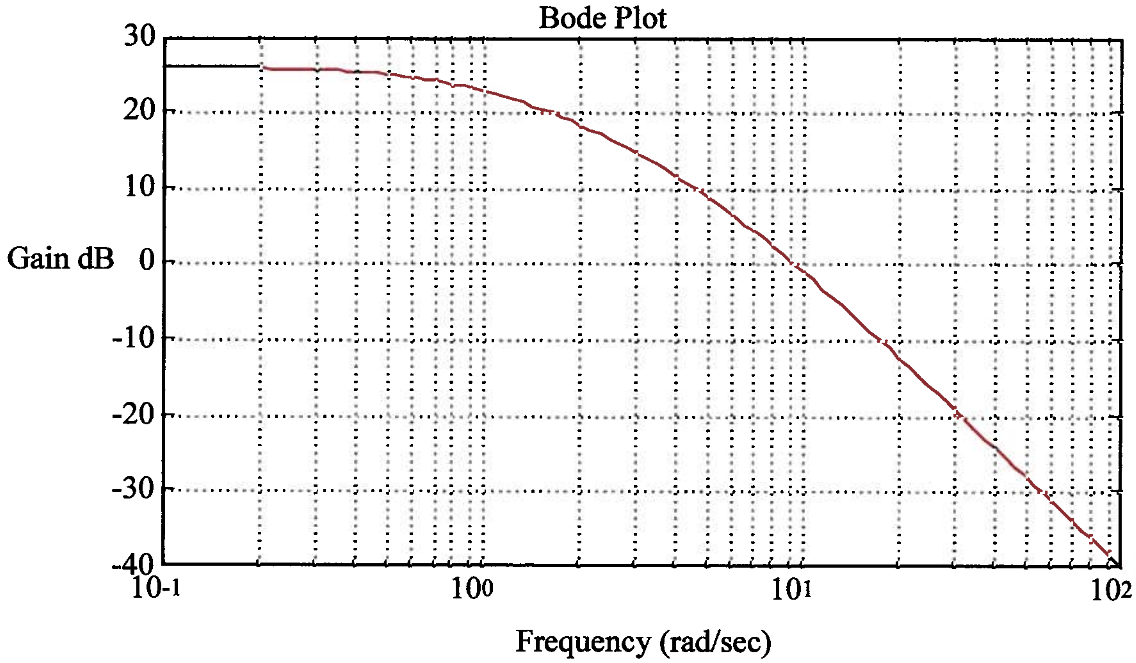
b) Determine the values of K_p and K_d that will result in the closed loop system having 70% critical damping and a natural frequency of 5 rad/sec.

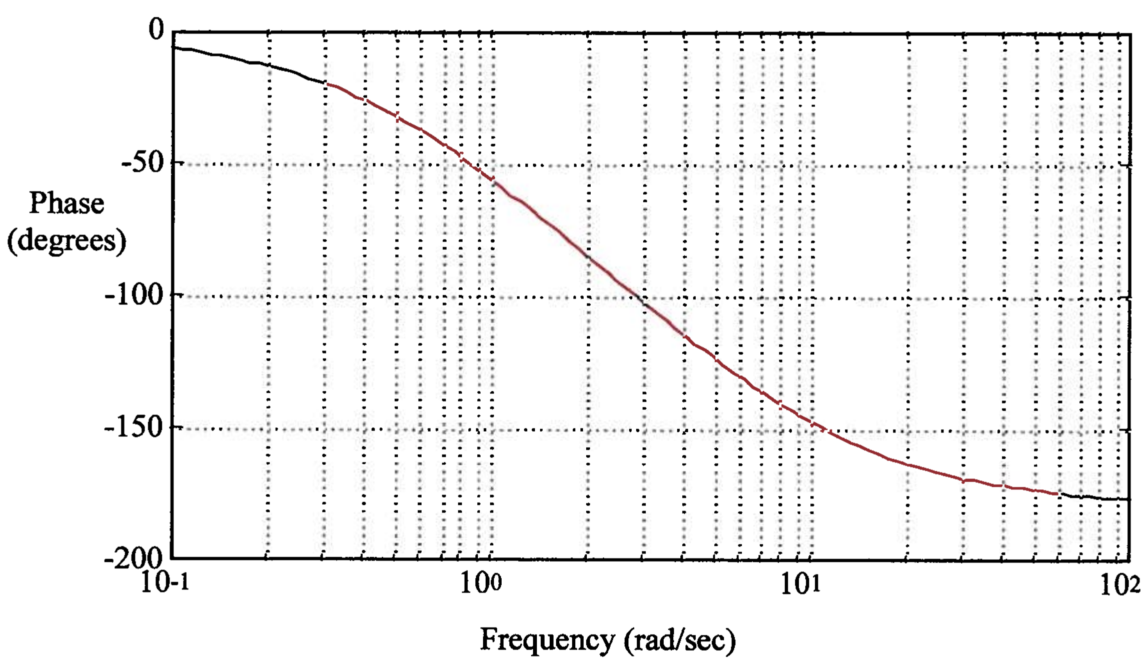
$K_P =$
$K_d =$

c) At the gains you supplied in part b), what is the steady state error for a unit step input to this system?

$e_{ss} =$

4) Shown below is the Bode diagram of an uncompensated industrial process that is open-loop stable.





Rev. 4-17-07

4a) Determine the "best" (widest bandwidth) Proportional feedback control system that will yield a phase margin of at least 80 degrees and a gain margin of at least 10 dB.

$K_p =$

b) If you were to augment the control designed in part A with either "integral" or "derivative" control action, which would you choose and why? Be specific, choose and control action and show the analysis that justifies you choice.