UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
DEPARTMENT OF ELECTRONIC ENGINEERING

MAIN EXAMINATION DECEMBER 2007

TITLE OF PAPER: **ADVANCED CONTROL**

COURSE CODE: **EIN530**

TIME ALLOWED: **THREE** HOURS

INSTRUCTIONS:

1. Answer question **one** (1) and any other three (3) questions.
2. Each question carries 25 marks.
3. Marks for different sections are shown in the right-hand margin.

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Question 1

A ship stabilization system is shown in Figure 1.

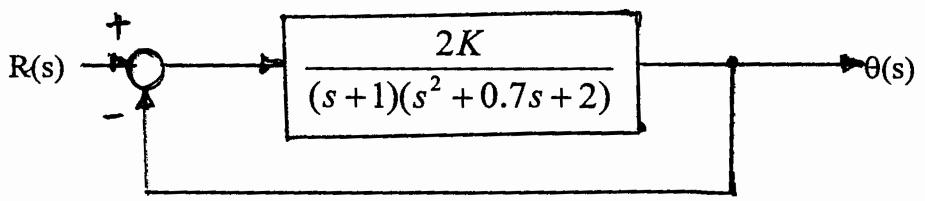

Figure 1

a) Draw the root-locus for this system [16 marks]

b) With the input as a unit step, analyse the system to determine whether a proportional controller would be introduced in the forward path to achieve the following performance specifications:

Overshoot $> 25\%$
Steady state error $= 0$

[9 marks]

Question 2

For a system shown in figure 2, we desire the steady state error to a step input to be approximately 5 % of the final output and the phase margin of the system to be approximately 45^0.
Design a lag network $G_C(s)$ to meet these specifications using Bode diagrams. [25 marks]

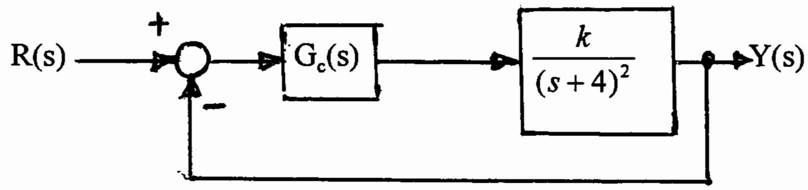

Figure 2

Question 3

Consider a second order system

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$u = -kx_1 - kx_2$$

Determine the feedback gain $\boldsymbol{k}$ that minimizes the performance index

$$J = \int_0^\infty (x^T x + u^T u)dt$$

[25 marks]

where $\boldsymbol{x}^T(0) = [1\ 0]$.

Question 4

Consider the system represented in state variable form

$$\dot{x} = Ax + Bu$$
$$y = C x$$

where

$$A = \begin{bmatrix} 1 & 2 \\ -5 & -10 \end{bmatrix}, \quad B = \begin{bmatrix} -4 \\ 1 \end{bmatrix}$$
$$C = \begin{bmatrix} 0 & -4 \end{bmatrix}$$

(a) Verify that the system is observable and controllable. [10 marks]

(b) If so, design a full state feedback law by placing the closed-loop system poles at

$$s_{1,2} = -1 \pm j$$ [15 marks]

Question 5

Consider the nonlinear control system shown in Figure 5. The describing function for this nonlinear element is given by

$$N = \frac{4}{\pi A} \quad \sin^{-1} \frac{h}{A}$$

The input to the nonlinear element is **Asin (ωt)**

Determine the effect of the hysteresis non linearity on the amplitude and frequency of the limit-cycle operation of the system. Use a polar plot.

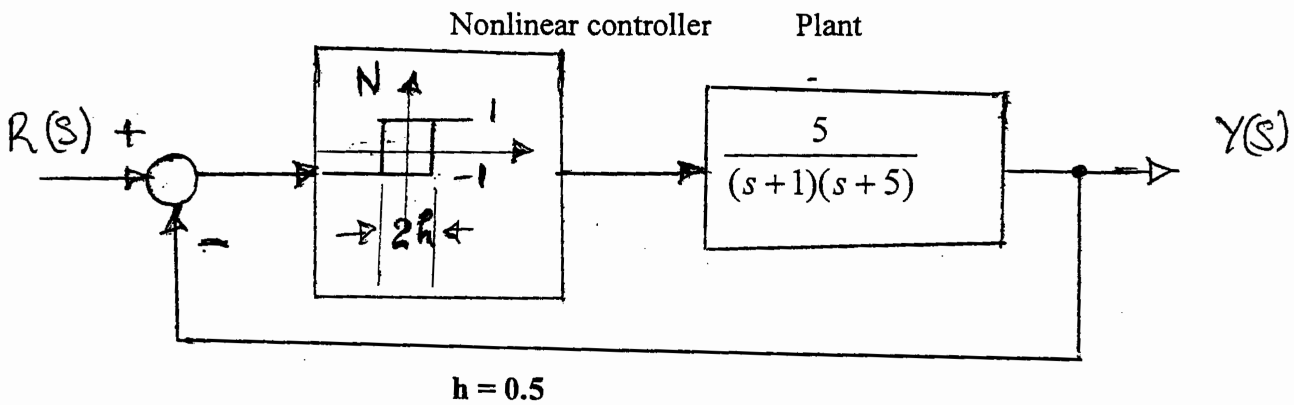

Figure 5