THE MOMBASA POLYTECHNIC UNIVERSITY COLLEGE

(A Constituent College of Jkuat)

Faculty of Engineering and Technology

DEPARTMENT OF MECHANICAL & AUTOMOTIVE ENGINEERING

UNIVERSITY EXAMINATION FOR DEGREE IN BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMG 2410: CONTROL ENGINEERING I

END OF SEMESTER EXAMINATION

SERIES: DECEMBER 2011

TIME: 2HOURS

INSTRUCTION TO CANDIDATES

You should have the following for this examination

- *Answer booklet*
- *Non-programmable Scientific calculator*

This paper consists of **FIVE** questions. Answer question **ONE (Compulsory)** and any **TWO** questions.
Maximum marks for each part of a question are as shown.
This paper consists of **FOUR** printed pages

Question One (20 Marks)

a) (i) Compare and contrast classical control systems with state-space approach control techniques

(ii) Define the following

- State of a system
- State variables
- State space
- State space equation (s) (12 marks)

b) Write down the state equation and output equation for the spring-mass damper system shown in figure Q1 (b) (7 marks)

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c) (i) Represent the given transfer function in state space by using the general method. Explain all the steps of the transformation

(ii) Draw a block diagram and give state-space equations and matrices

$$G(s) = \frac{3s+5}{s^2+3s+2}$$

(11 marks)

Question Two (20 Marks)

The matrices of the state-space system are:

$$A = \begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix}, \; B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \; C = \begin{bmatrix} 2 & 1 \end{bmatrix}$$

a) Derive an analytical expression for the matrix transfer function (5 marks)

b) Calculate the matrix transfer function in Laplace domain (12 marks

c) Calculate the matrix transfer function in time domain (3 marks)

Question Three (20 Marks)

The state space equation of a plant is described by the following matrices.

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, C = \begin{bmatrix} 3 & 1 \end{bmatrix}$$

a) Find the full state feedback matrix H which will place the poles of the closed loop system at positions. (17 marks)

$$S_1 = (-2 + j2),\ S_2 = (-2, -j2)$$

b) Draw the diagram of the plant with feedback matrix (3 marks)

Question Four (20 Marks)

a) Figure Q4(a) produces an output in the PID controller with proportional gain $K_P = 5$, integral constant $K_I = 0.7S^{-1}$ and derivative time constant $K_D = 0.5S$. If the initial controller output $P_I(o) = 20\%$; draw a plot of controller output Vs time.

Fig Q4 (a)

(13 marks)

b) (i) Explain what is meant by a floating mode controller action.

(ii) A liquid-level control system linearly converts a displacement of 2-3 meters into a 4-20mA control signal. A relay serves as a two-position controller to open or close an inlet value. The relay closes at 12mA and opens at 10mA. Determine the neutral zone or differential gap in meters (7 marks)

Question Five (20 Marks)

a) With the aid of mathematical analysis, output and input waveforms of a saturation nonlinearity of slope K, deduce the expression for the describing function.

b) Figure Qu5b shows the control system of a simple satellite model. The statellite is simply a rotational unit inertia controlled by a pair of thruster which can provide either a positive torque U (positive firing) or a negative torque –U(negative firing) The purpose of the control system is to maintain the satellite antenna at zero angle by appropriately firing the thrusters. The mathematical model of the satellite is $\ddot{\theta} = U$, where U is the torque provided by the thruster and θ is the satellite angle.

Fig. Q5(b)

Sketch the phase portrait (trajectories) of the control system when thrusters are fired according to the control law

$$U(t) = \begin{cases} -u; & if \quad \theta > \theta \\ +u; & if \quad \theta < 0 \end{cases}$$