MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 416: CONTROL ENGINEERING I

DATE: 26/9/2019 **TIME: 11.00-1.00 PM**

INSTRUCTIONS:

Answer question 1 (compulsory) and any other TWO questions

QUESTION 1 (30marks)

a) Many luxury automobiles have thermostatically controlled air-conditioning systems for the comfort of the passengers. Sketch a block diagram of an air-conditioning system where the driver sets the desired interior temperature on a dashboard panel (3 marks)

b) A Mechanical System is shown in Figure Q.1b)

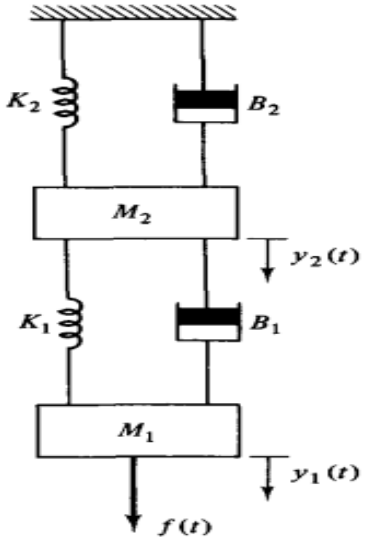

Figure Q 1b)

i. Draw the *Free-Body diagram(s)* for the system (2 marks)

ii. Write the Newtons Force Equation(s) from b(i) above (1 mark)

iii. By defining the respective *State Variables*, write the Differential Equations of the system using the equations in b(ii) above (2 marks)

iv. Draw the *State Diagram* of the System using the Equations in b(iii) above (3 marks)

v. Using the *Mason's Gain Formula*, determine the *Transfer Functions* of the System from the State Diagram in b(iv) above (3 marks)

c) The open loop transfer function of a control system is given by the expression

$$G(s)H(s) = \frac{K\,(S+0.5)(S+2)}{S^3(S+6)(S+8)}$$

Determine the range of the gain constant, K, for stability using the *Ruoth-Hurwitz Criteria* (4 marks)

d) Determine the Transfer Function of a Control System whose *Bode Plot* Approximation is shown in Figure 1 d) (4 marks)

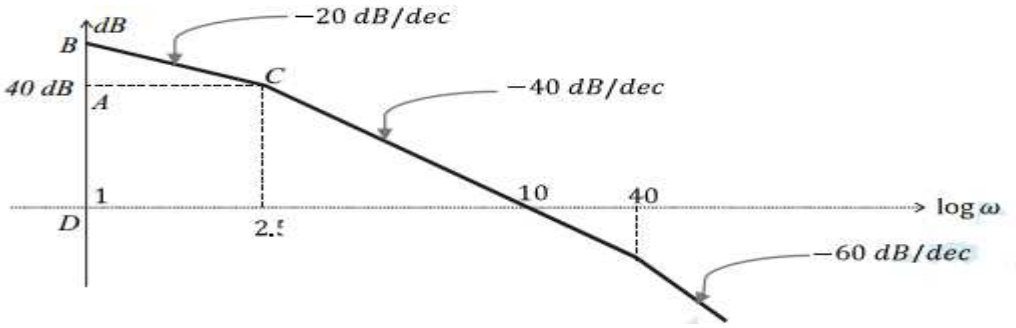

Figure Q 1d)

e) By *Block Reduction Approach*, derive the Transfer Function of the Control System shown in Figure Q 1 e) (4 marks)

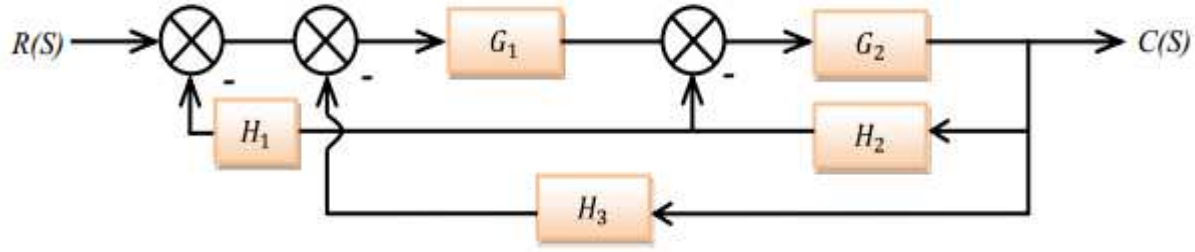

Figure 1e)

f) Determine and Sketch the *Root Locus* defined by the following Characteristic Equation (4 marks)

$$S^2 + 2S + 2 + K(S + 2) = 0$$

QUESTION 2 (20marks)

a) Define the following terms

(i) Closed loop system

(ii) Feedback

(iii) Overall Gain

(iv) Feedback Control (2 marks)

b) State the Features of the Transfer Function (TF) (2 marks)

c) A closed loop system has open loop gain G(S), a Negative Feedback Loop Gain H(S) Output signal C(S) and an Input signal R(S).Beginning from a block diagram, determine the TF of the system (2.5 marks)

d) An armature controlled DC motor can be represented by Figure Q 2.0d)

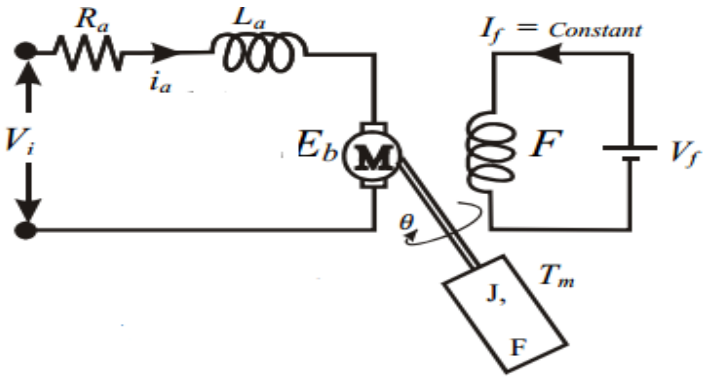

Figure Q 2.0 d)

(i) Derive the *Transfer Function* of the System (3.5 marks)

(ii) By block representation, show that this is a *Closed Negative Feedback System* (2 marks)

e) Many cars are fitted with cruise control that, at the press of a button, automatically maintains a set speed. In this way, the driver can cruise at a speed limit or economic speed without continually checking the speedometer. Design a *Feedback Control* in block diagram for a cruise control system (3 marks)

f) A precise optical signal source can control the output power level to within 1%. A laser is controlled by an input current to yield the output power. A microprocessor controls the input current to the laser. The microprocessor compares the desired power level with a measured signal proportional to the laser power output obtained from a sensor. Design the block diagram representing the *Closed Loop Control System* (3 marks)

g) The role of air traffic control systems is increasing as airplane traffic increases at busy airports. Engineers are developing air traffic control systems and collision avoidance systems using the Global Positioning System (GPS) navigation satellites. GPS allows each aircraft to know its position in the airspace landing corridor very precisely. Sketch a *Feedback Block Diagram* depicting how an air traffic controller might utilize GPS for aircraft collision avoidance (3 marks)

QUESTION 3 (20marks)

a) Distinguish between the following terms as used in Signal Flow Graph Analysis

(i) Source and Sink

(ii) Loop and Loop Gain

(iii) Forward Path and Forward Path Gain (1.5 marks)

b) State and Explain the Mason's Gain Formula (MGF) (2.5 marks)

c) By Block Reduction Algebra, derive the Transfer Function for the closed loop system shown in Figure Q 3c) (4 marks)

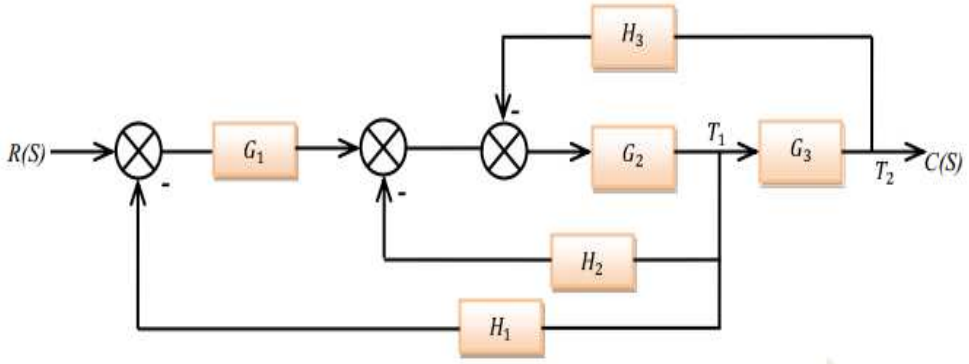

Figure Q 3c)

d) A closed loop control system is represented by the Block Diagram shown in Figure Q 3 d).

(i) Derive the transfer function by Block Reduction Method (4 marks)

(ii) Verify the results in 3di) above using the Signal Flow Graph Approach (4 marks)

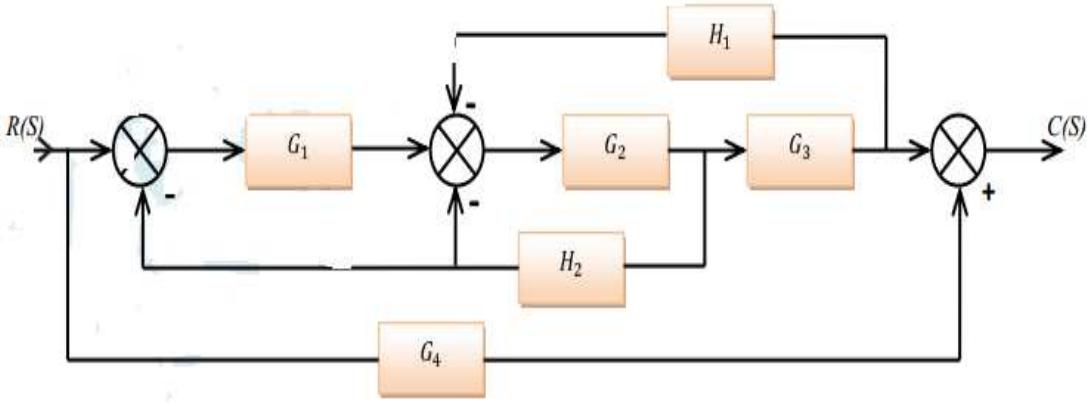

Figure Q3d)

e) Determine the restrictions on K for which the system represented by the SFG in Figure Q3e) is stable (4 marks)

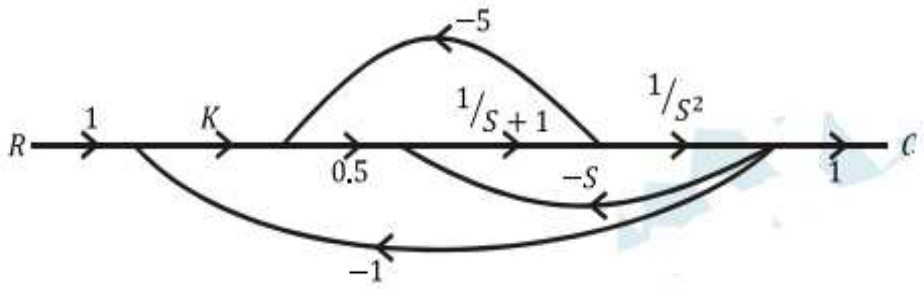

Figure Q3e)

QUESTION 4 (20marks)

a) Define the term System *Stability* as broadly as possible (3 marks)

b) Discuss the *Ruoth-Hurwitz Criteria for* system stability (4 marks)

c) The open loop system transfer function of a unity feedback is given by the expression

$$G(s) = \frac{K(S+2)}{S(S+1)(S+3)(S+5)}$$

Determine the value of K for which the system is just stable (4 marks)

d) The open loop system transfer function of a unity feedback is given by the expression

$$G(s) = \frac{K}{(S+2)(S+4)(S^2+6S+25)}$$

Determine the value of K which will cause sustained oscillations in the closed loop system, hence the corresponding oscillation frequency (4 marks)

g) Determine the value of K for the Stability of the control system defined by the Characteristic Equation (3 marks)

$$S^3 + 34.5S^2 + 7500S + 7500K = 0$$

e) State and explain Four other methods for stability studies for linear time-invariant systems (2 marks)

QUESTION 5 (20marks)

a) State the Rules that govern the Construction of *Root Locus* (4 marks)

b) State the Merits of using Bode Plots in Control System Analysis (2 marks)

c) Determine and Sketch the Root Locus defined by each of the following Characteristic Equations

$$(i) S(S+2)+K(S+4)=0 \quad \text{(3 marks)}$$

$$(ii) S(S+4)(S^2+4S+20)+K=0 \quad \text{(6 marks)}$$

d) A Control System is defined by the Bode Plot Shown in Figure .Q 5 d) .Derive the Open-Loop Transfer Function of the System (5 marks)

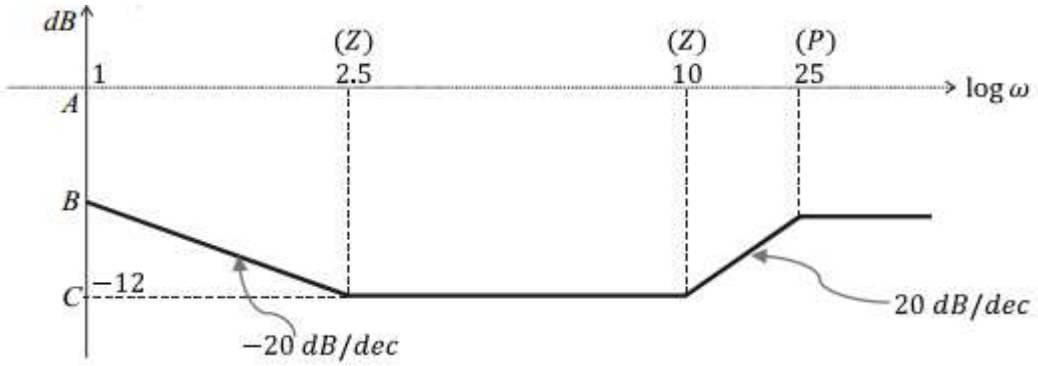

Figure 5d)