ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIRST SEMESTER EXAMINATION, 2019/2020 ACADEMIC SESSION

COURSE TITLE: Control Engineering

COURSE CODE: EEE 515

EXAMINATION DATE: February 11, 2020

COURSE LECTURER: Prof Dr. M.J.E. Salami

TIME ALLOWED: 3 Hours

HOD's SIGNATURE

INSTRUCTIONS:

1. ANSWER **ANY FIVEQUESTIONS**
2. SEVERE PENALTIES APPLY FOR MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM.
3. YOU ARE **NOT** ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS DURING THE EXAMINATION.

QUESTION 1 [12 Marks]

a) The idle speed control system for a fuel injected engine is shown in Fig.Q1a. Draw the signal flow graph and use the Mason gain formula to determine the transfer function, $\frac{Y(s)}{R(s)}$. (7 Marks)

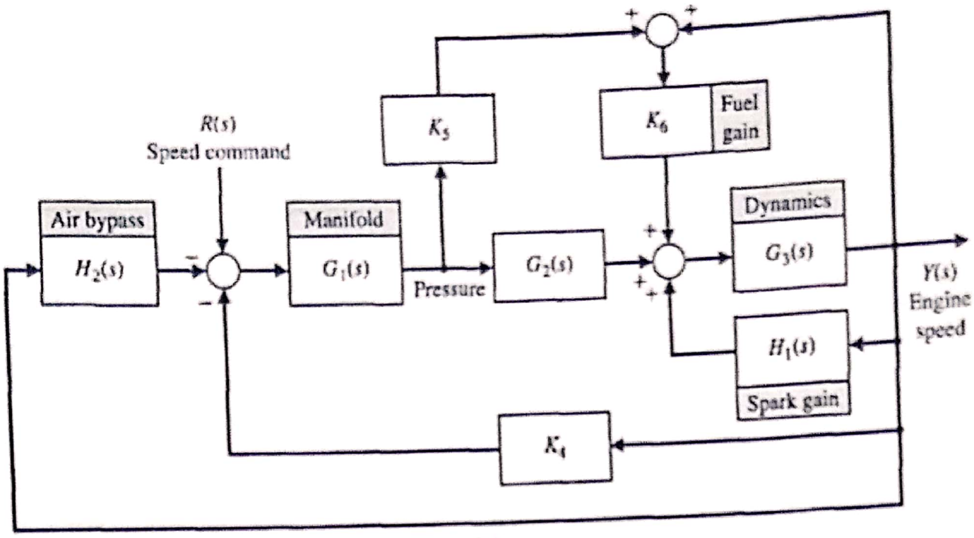

Fig. Q1a

b) The two-mass system shown in Fig. Q1b has a constant rolling friction, denoted as b. Determine a state variablematrix representation of the system when the output variable is $y_2(t)$, that is, $y(t) = y_2(t)$. (5 Marks)

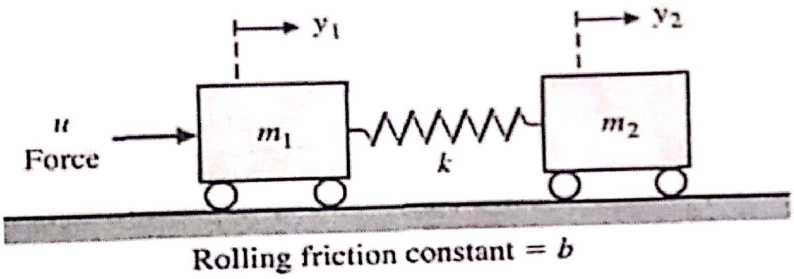

Fig. Q1b

Question2 [12 Marks]

a) The unity feedback system of Fig. Q2a, where

$$G(s) = \frac{K(s+\alpha)}{s(s+\beta)},$$

is to be designed to meet the following specifications:

1. The steady-state error for a unity ramp input equals 0.1.
2. The closed-loop poles will be located at $-1 \mp j1$.

Determine K, α, and β so as to meet the specified conditions. (6 Marks)

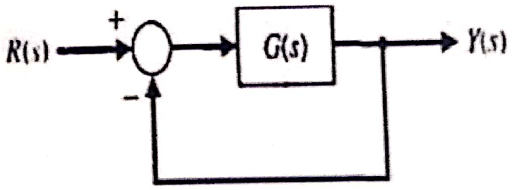

Fig. Q2a

b) Consider a system with loop-transfer function

$$\frac{Y(s)}{R(s)} = \frac{77(s+2)}{(s+7)(s^2+8s+22)}$$

i) Determine the steady-state error for a unit step input, $U(s) = \frac{1}{s}$. (2 Marks)

ii) Assume that the complex poles dominate, determine the percent overshoot and the settling time to within2% of the final value. (4 Marks)

Question 3 [12 Marks]

a) Consider a control system represented in state variable form

$\dot{x} = Ax + Bu, \qquad y = Cx + Du$

where

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -k & -k & -k \end{bmatrix}, \mathbf{B} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\mathbf{C} = [1 \quad 0 \quad 0], \mathbf{D} = [0].$$

Determine the range of K for system stability. (4 Marks)

b) The feedback control system shown in Fig. Q3b is marginally stable. A proportional-derivative controller of the form

$$G_c(s) = K_P + sK_D$$

is used as compensator for the system.

i) Determine whether it is possible to find the values of K_P and K_D such that the closed-loop system is stable. (3 Marks)

ii) Compute the values of the controller parameters such that the steady-state tracking error for a unit step input is less than 0.1 and the damping of the closed-loop system, $\xi = 0.5\sqrt{2}$. (5 Marks)

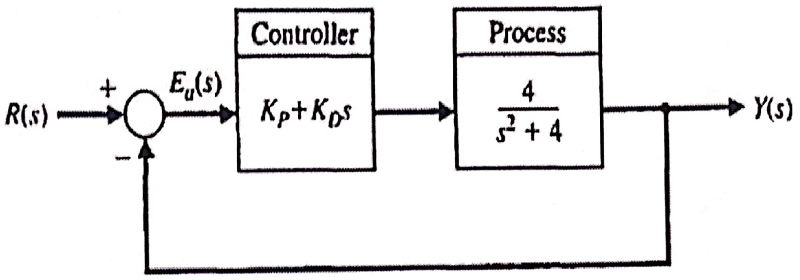

Fig. Q3b

Question 4[12 Marks]

a) A unity feedback control system has the loop transfer function

$$L(s) = G_c(s)G(s) = \frac{K(s+10)}{s(s+5)}.$$

i) Compute the breakaway and entry points of the root locus and sketch the root locus for $K > 0$. (2 Marks)

ii) Determine the gain K when the characteristic roots have a ξ of $\frac{1}{\sqrt{2}}$. Calculate the roots. (3 Marks)

b)The attitude control system for a rigid satellite has an open-loop uncompensated transfer function

$$GH(s) = \frac{K}{s^2}$$

whichis marginally stable.

i) Use the root locus analysis to identify a simple controller (in the form of P, PI, or PD) that guaranteesthe system stability. (3 Marks)

ii) Use the root locus technique to design a phase-lead compensator of the form (4 Marks)

$$G_c(s) = \frac{s+z}{s+p}; |z| < |p|,$$

to satisfy the following specifications:

1. Settling time (with 2% criterion), $T_s \leq 4$ s.
2. Percentage overshoot for a step input, $PO \leq 10\%$.

Question 5 [12 Marks]

a) The magnitude plot of a transfer function

$$G(s) = \frac{K(1+0.5s)(1+as)}{s(1+s/_8)(1+bs)(1+s/_{36})}$$

is shown in Fig. Q5a. Determine K, a, and b from the plot. (3 Marks)

b) Obtain the Bode diagrams (magnitude and phase plots) of the transfer function (4 Marks)

$$G(s) = \frac{50(s+2)}{s(s^2+4s+100)}.$$

c) Consider a plant having a loop transfer function

$$GH(s) = \frac{K}{s(s+2)}.$$

Design a lead compensator of the form (5 Marks)

$$G_c(s) = \frac{s+z}{s+p}; \quad |z| < |p|,$$

that satisfies the following specifications:

1. Velocity error, $e_{ss} \leq 5\%$
2. Phase margin, $\emptyset_{pm} \geq 60°$
3. Gain margin, $GM \geq 12\ dB$.

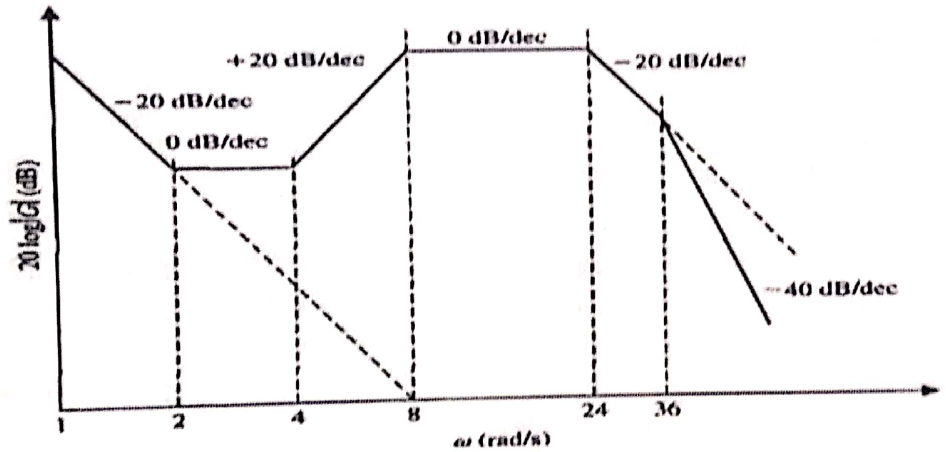

Fig. Q5a

Question 6 [12 Marks]

a) (i) Obtain a state variable representation for the control system shown in Fig. Q6a. (2 Marks)
(ii) Determine if the system is both controllable and observable. (4 Marks)

b) Hydraulic power actuators were used to derive the dinosaurs of the movie "Jurassic Park". The motion of the large monsters used high-power actuators requiring 1200 *watts*. One specific limb motion has its dynamics

$$\dot{\mathbf{x}} = \begin{bmatrix} -4 & 0 \\ 1 & -1 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 1 \\ 0 \end{bmatrix}u$$

$$y = [0 \quad 1]\mathbf{x} + [0]u.$$

It is required to place the closed-loop poles at $s = -1 \pm 3j$. Determine the required state variable feedback using Ackerman's formula. Assume that the complete state vector is available for feedback. (6 Marks)

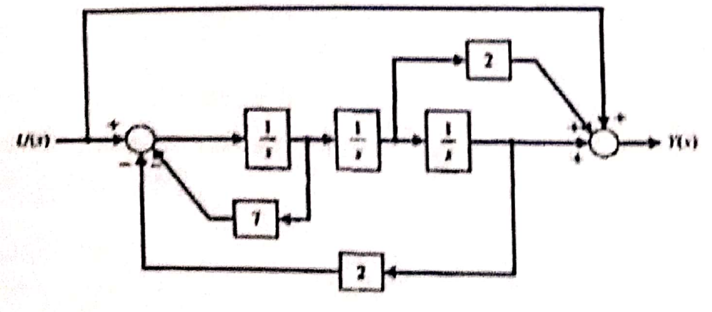

Fig.Q6a

Question 7 [12 Marks]

(a) Using appropriate diagrams, explain the essential difference(s) between digital and analog control systems. State two advantages and two disadvantages of digital control systems over analog control systems. (3 Marks)

(b) Given

$$E(s)=\frac{(s+1)\left(1-e^{-0.5s}\right)^2}{s(0.5s+1)},T=0.5\,s.$$

Determine i) $E^*(s)$, and hence ii) $E(z)$. (3 Marks)

c) For the digital control shown in **Fig. Q7c**, determine the

i) Original signal flow graph. (1 Mark)

ii) System transfer function, $\frac{C(z)}{R(z)}$. (3 Marks)

iii) Sampled signal flow graph. (2 Marks)

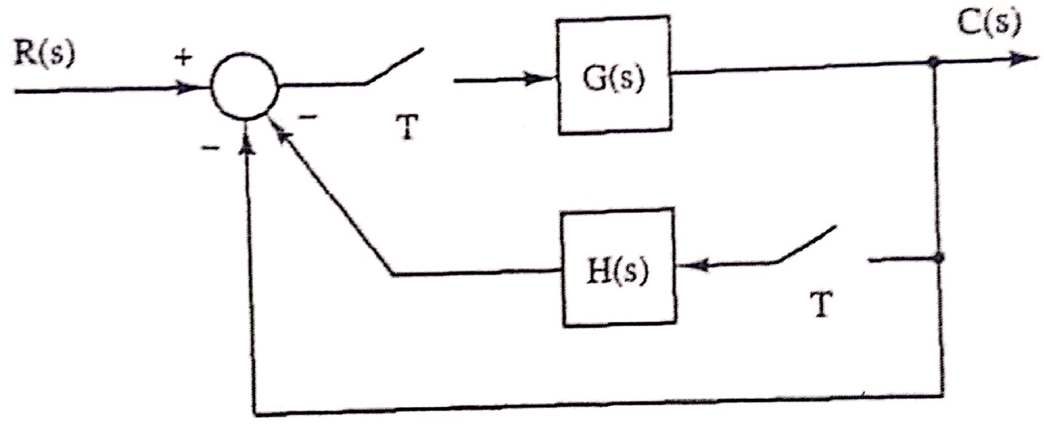

Fig. Q7c