FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA
SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY
DEPARTMENT OF MECHATRONICS ENGINEERING
FIRST SEMESTER 2018/2019 B.Eng. DEGREE SEMESTER EXAMINATION
COURSE: MCE 317 (System Dynamics and Control)

INSTRUCTION: Attempt any Four (4) Questions of your choice
TIME ALLOWED: 3 Hours

Question 1 (25marks)

(a.) From engineering perspective, the general equation for the state space representation of a system is as given in equation 1:

$$\dot{X} = AX + Bu$$
$$Y = CX + Du \quad \ldots\ldots \textbf{Equation 1}$$

Take advantage of your state space concept to define each of its parameter hence show that the solution of $det(SI - A)$ represents the poles of the system.

(7marks)

(b.) After modelling a Garri processing plant in Gidan Kwano, its State-Space representation is found to be as shown in equation 2 below:

$$\dot{X} = \begin{bmatrix} 1 & 3 \\ -4 & -6 \end{bmatrix} x + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u \;\; ; Y = \begin{bmatrix} 1 & 4 \end{bmatrix} x \quad \ldots\ldots \textbf{Equation 2}$$

Determine:

i. the eigenvalues and comments on its stability of the Garri processing plant in Gidan Kwano.
ii. the eigenvectors for the same plant. **(8marks)**

(c.) As a design Engineering, express the Garri processing plant in Gidan Kwano as analyzed in Q1b (i & ii) in canonical form hence comments on the stability of the system.

(10marks)

Question 2 (25marks)

(a.) As a Mechatronics Engineering student, write down the laws from which the following equations were derived from for it to have contributed to the dynamics and control system engineering.

Note that it is needless to state what these laws say. **(6marks)**

i. $F_N = ma$
ii. $F_e = Kx$
iii. $F_D = b\dot{x}$ **Equation 3**

$$Where\ m = mass, a = acceleration, K = elastic\ constant, x = distance\ and\ b = damping\ constant.$$

(b.) The derived transfer function for an intelligent battery charging system is shown in equation 4 below:

$$\frac{Y(s)}{U(s)} = \frac{1}{s^2+s+1} \quad \textbf{Equation 4}$$

Determine the state space representation for the modelled intelligent battery charging system.

(10marks)

(c.) Find the overall gain of the signal flow graph from figure 1below using Mason's gain formula:

(9marks)

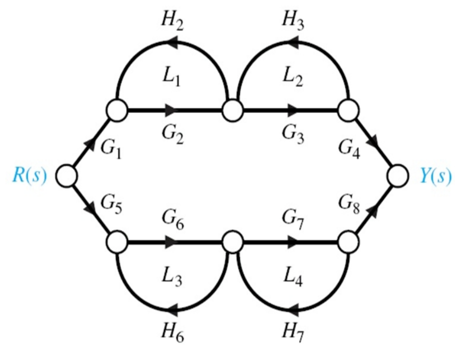

Figure 1

Question 3 (25marks)

(a.) The mathematical representation for the water processing plant is given by $y^{II} - 6y^{I} + 5y = 0 \;\; with\ the\ following\ condirtions\ \ y(0) = 1\ and\ y^{I}(0) =- 3$ **Equation 5**

i. Determine the transfer function for these water processing plant

ii. Determine the zeros and poles for the said water processing plant

iii. Comments whether the water processing plant will be stable or not during its fullscale operations. **(7marks)**

(b.) Assuming the water processing plant was redesigned, reduce its block diagram in Figure 2 below to a single transfer function for optimal modelling. **(8marks)**

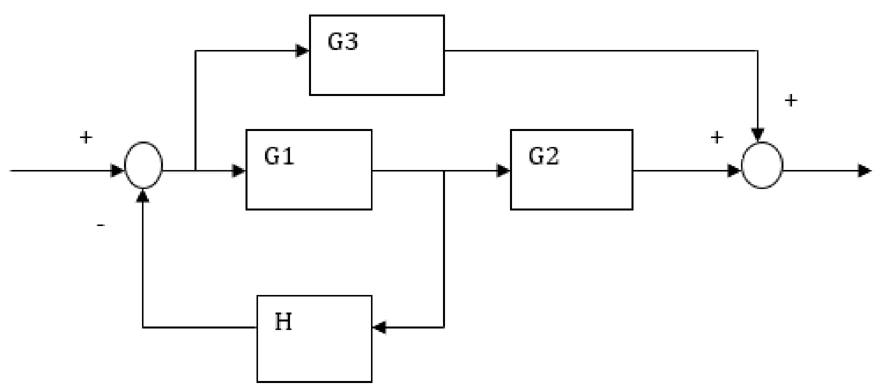

Figure 2

(c.) The water processing plant was found to be a second order system , with the help of well labelled diagram, explain the following terms:

(i.) Delay time (ii.) Rise time (iii.) Peak time (vi.) Maximum Overshoot (v.) Settling time

(vi.) Steady state error **(10marks)**

Question 4 (25marks)

(a.) In dynamic and Control engineering, regulating and motioning a system is one of its focal objectives, using appropriate diagram, discus the meaning of observability and controllability as its applied to state space system in **Equation 6**.

Given that

$$\dot{x} = \begin{bmatrix} -2 & 0 \\ 3 & -5 \end{bmatrix} x + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u \; ; \; y = [1 \quad -1]x \qquad \text{..Equation 6}$$

Determine through calculations whether the system is controllable or observable. **(7marks)**

(b.) As an upcoming visiting student, you are expected to determine the transfer function for the given mechanical Model in Figure 3. What will be your response? **(8marks)**

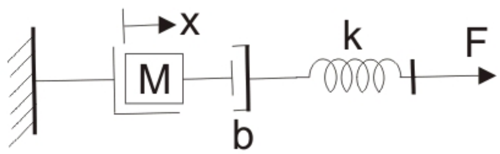

Figure 3

(c.) With relevant diagram, explain the effects of transient and steady state response of a system **(10marks)**

Question 5 (25marks)

(a.) Enumerate any three condition that satisfy the concept of system stability and states the Routh-Hurwitz criterion **(5marks).**

(b.) Draw an S-plane (Routh-Hurwitz criterion) and explain the following term as it relates to system stability: i. Stable system ii. Unstable system iii. Limitedly or Marginally stable **(8marks).**

(c.) Determine the stability of the system in equation 7 using R-H method and comments on your results (**12 marks).**

$$R(s) \rightarrow \boxed{\frac{1000}{s^3 + 10s^2 + 31s + 1030}} \rightarrow C(s)$$

Equation 7

Question 6 (25marks)

(a.) Define the terms as it relates to signal flow graphical representation of the system: (i.) Forward Path (ii.) Forward path gain (iii.) loop (iv.) loop gain (v.) Non-touching loops (vi) Node. **(12marks)**

(b.) With relevance illustration differentiate between signal flow graph and block diagram **(3marks)**

(c.) Draw an equivalent block to satisfy the state space system given in equation 8 below: **(10marks)**

$$\dot{x} = \begin{bmatrix} -2 & 0 \\ 3 & -5 \end{bmatrix} x + \begin{bmatrix} -10 \\ 12 \end{bmatrix} u$$

$$y = \begin{bmatrix} 3 & 3\frac{1}{4} \end{bmatrix} x$$ **Equation 8**