	F E D E R A L U N I V E R S I T Y O F T E C H N O L O G Y , M I N N A **SCHOOL OF ELECTRICAL ENGINEERING AND TECHNOLOGY** **DEPARTMENT OF MECHATRONICS ENGINEERING** **FIRST SEMESTER 2019/2020 ACADEMIC SESSION**	
	COURSE: MCE 514: MODERN CONTROL ENGINEERING	
	TIME ALLOWED: 2 HOURS	**CREDIT UNIT:** 2 **LEVEL:** 500
Instruction: Answer **Question 1** and any other 2 questions.		

Question One (Compulsory) [50 mks]

Consider the robot arm shown in Figure Q1.

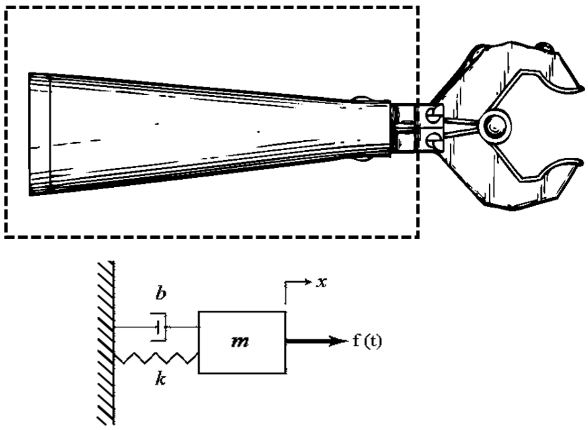

Figure Q1: 1 DOF Robot Arm

As a control systems student, you have been contacted to analyse the system and determine if it would require a controller or not. Hence, you are required to evaluate the plant in order to ascertain its system response.

a. Obtain the system transfer function of the plant taking all variables as unity. (11 mks)

b. Evaluate the following from the model obtained in Q1(a):
   i. Peak Time (3 mks)
   ii. Settling Time (3 mks)
   iii. Rise Time (3 mks)
   iv. Percentage Overshoot (3 mks)
   v. What is the implication of the values of the parameters obtained in (i) to (iv) ? (3 mks)

c. Find the frequency response of a plant represented as

$$G(s) = \frac{1}{s+2}$$

to an input of

$$r(t) = 4\sin(10t - 15^o) \qquad \text{(12 mks)}$$

d. Evaluate the steady state error, to a unit step input, of the plant

$$G(s) = \frac{1}{(s+2)(s+3)} \qquad \text{(12 mks)}$$

Question Two [25 mks]

An engineering firm has designed an electromechanical system to regulate the torque of a wind turbine for power generation. The plant is modelled as:

$$G(s) = \frac{1}{s(s+1)(s+2)}$$

The client wants the system to give a constant torque value when given an input and has contacted you, as a mechatronics engineer, to solve his problem. The system requires a controller to regulate the torque and provide the desired torque to drive the turbine.

a. Design a PID controller using Ziegler-Nichols second rule for the electromechanical system. (17 mks)

b. Differentiate between the following:

i. Classical Control and Modern Control (4 mks)

ii. Linear Control and Nonlinear Control (4 mks)

Question Three [25 mks]

A chemical producing plant is represented by the transfer function:

$$G(s) = \frac{1}{s^3 + 6s^2 + 9s + 6}$$

a. The closed poles of the system are not at satisfactory positions. You have been contacted as a control engineer to design a controller to place the closed loop poles at specific positions. Design a state feedback controller, using direct substitution, to place the poles at:

$S_1 = -1 + j2$
$S_2 = -1 - j2$
$S_3 = -2$ (17 mks)

b. Consider the plant represented as:

$$G(s) = \frac{1}{S^2 + 4S + 2}$$

i. Obtain the system's controllability matrix (4 mks)

ii. Obtain the system's observability matrix (4 mks)

Question Four [25 mks]

A juice production firm has contacted you to develop a controller to optimise the taste of their product. The two major factors to be considered are the amount of sweetener and amount of fruit flavour to be added to the mixture. If the system is represented as:

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

a. Find the control matrix K, using the algebraic Ricatti equation.

(Hint: set R = 1 and Q = $\begin{bmatrix} 1 & 0 \\ 0 & u \end{bmatrix}$) (17 mks)

b. A borehole drilling company has reached out to you regarding a regular problem they encounter. The pumps they use keep getting damaged due to power surges. Considering the feature of Internal Model Controllers to minimize overshoots, the development of this type of control scheme was proposed and agreed upon. If the plant is represented as:

$$G(s) = \frac{1}{2s^2 + 3s + 4}$$

Design an Internal Model Controller for the system using λ = 7 (8 mks)