



MACHAKOS UNIVERSITY

University Examination 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 514: CONTROL ENGINEERING II

DATE: 24/5/2019

TIME: 8.30-10.30 AM

QUESTION ONE (30 MARKS)

- a) With aid of a circuit diagram derive the expression of the output of a proportional controller. (6 marks)
- b) Describe the following terms:
- i. Controllability
 - ii. Observability (4 marks)
- c) With aid of diagram, explain why derivative controller is never used alone. (3 marks)
- d) The circuit in fig.4 is a schematic diagram representing a dc motor and load. The field is maintained constant. Determine the state equations in the vector matrix form for the state variables $x_1 = \theta$, $x_2 = \frac{d\theta}{dt}$ and $x_3 = \frac{d^2\theta}{dt^2}$. Assume:

Moment of inertia of motor and load	$=J$	
Back emf constant	$=kb$	
Coefficient of friction of motor and load	$=f$	
Motor torque constant	$=K_T$	(10 marks)

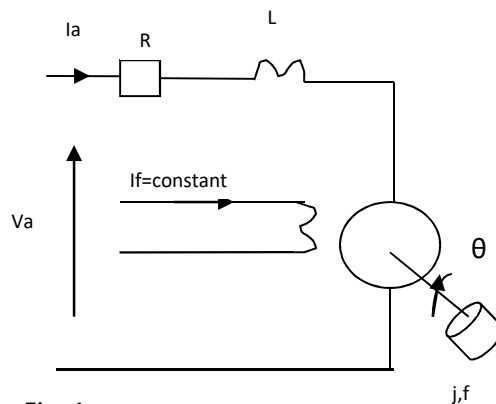


Fig. 1

- e) Construct the state model for a system characterized by the differential equation below and give the block diagram representation. (7 marks)

$$5u = \frac{d^4 y}{dt^4} + 10 \frac{d^3 y}{dt^3} + 20 \frac{d^2 y}{dt^2} + 30 \frac{dy}{dt} + 40y$$

QUESTION TWO (20 MARKS)

- a) With aid of a diagram derive the expression of the output of a derivative controller (5 marks)
- b) Briefly discuss any two common physical non-linearities. (4 marks)
- c) Sketch a labeled block diagram representation of the state model. (5 marks)
- d) The circuit in fig.2 is an integrator. $V_C=0$ at $t=0$. A step input of $V_i=-2$ is applied at $t=0$. Determine the time constant such that the output reaches +20 volts at $t=2\text{ms}$. (6 marks)

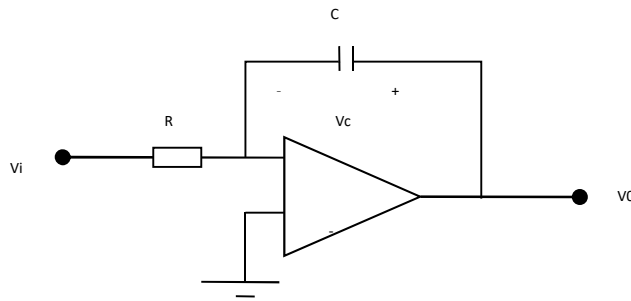
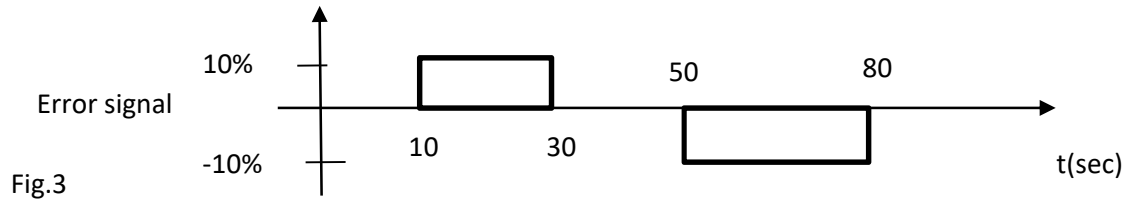


Fig2

QUESTION THREE (20 MARKS)

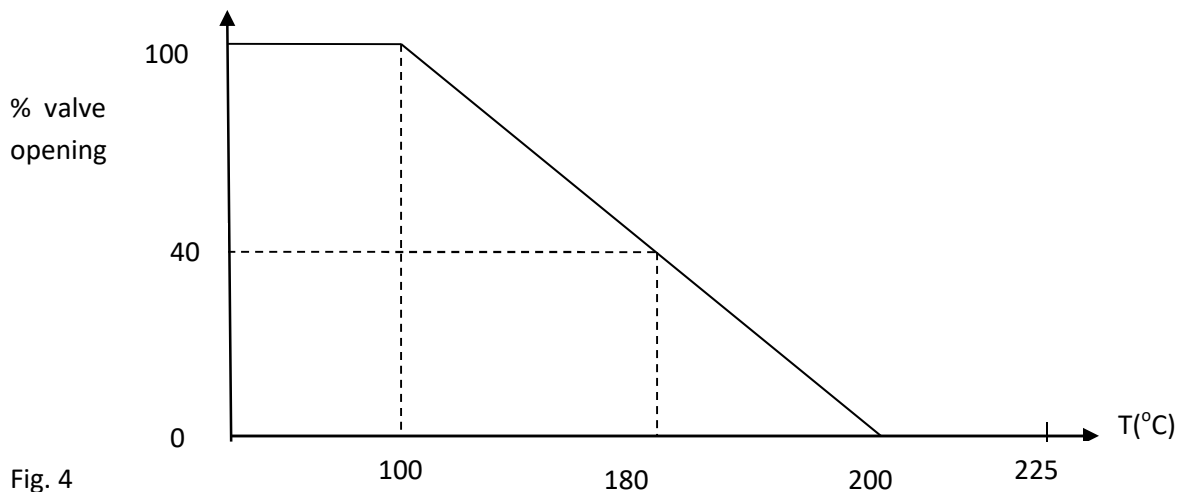
- a) With aid of a circuit diagram derive the expression of the output of a proportional plus integral controller. (6 marks)
- b) Determine the values of R_1 and R_2 of an electronic proportional plus integral controller with a proportional gain of 4 and integral action of 40 seconds. Use 10 microfarad capacitor. If the controller has an output of 40% at time $t=0$. Using error graph in fig.3, determine controller output for the following times:
- At $t=20$ seconds.
 - At $t=60$ seconds. (8 marks)



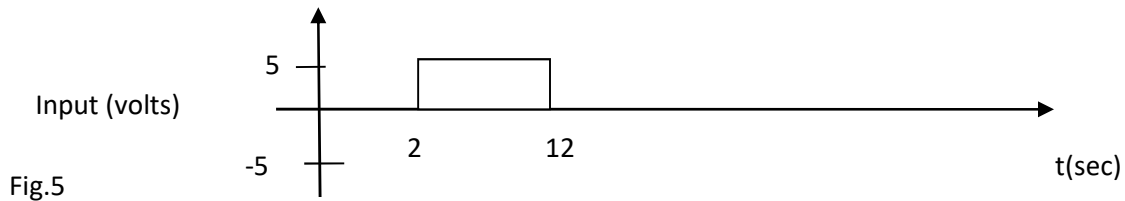
- c) When using canonical state model, diagonalization of matrix is necessary. This is facilitated by use of eigenvectors. Let $A = \begin{pmatrix} 10 & -8 \\ 4 & -2 \end{pmatrix}$. Find all eigenvalues of A. (6 marks)

QUESTION FOUR (20 MARKS)

- a) Briefly describe system optimal control (3 marks)
- b) The diagram in fig.4 shows the relationship between solutions's controlled temperature and percentage gas valve opening. Given proportional controller has controller range between 40°C and 240°C. Determine the percentage proportional band. (7 marks)



- c) The waveform in fig.5 shows an input signal. Assuming zero initial conditions, sketch the output waveforms when the given signal is applied to:
- Proportional controller
 - Integral controller
 - Derivative controller
 - Proportional plus integral controller

**QUESTION FIVE (20 MARKS)**

- With aid of a diagram briefly describe adaptive controller. (5 marks)
- Briefly explain what is meant by 'the state of a dynamic system'. (2 marks)
- The state of the system in fig.6 at any time, t , is given by variables $x(t)$ and $v(t)$ which are state variables of the system. Derive expression of displacement $x(t)$ at any time $t \geq 0$. Initial velocity is $v(t_0)$ and initial displacement is $x(t_0)$. $F(t)$ is the input variable from $t=t_0$. (10 marks)

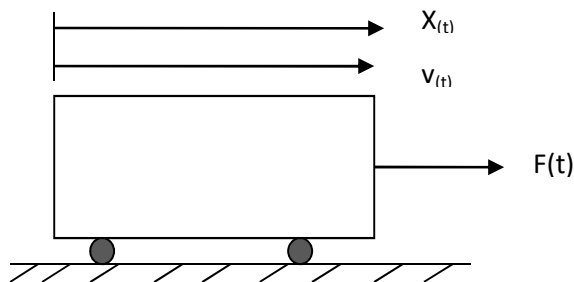


Fig. 6

- With aid of expressions explain the difference between time invariant and time varying systems. (3 marks)