10.

(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

FIRST YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE OF MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

COURSE CODE: EPE 810

COURSE TITLE: ENERGY CONVERSION SYSTEMS

DATE: 29th April, 2022 **TIME:08.00 a.m-10.00 a.m.**

INSTRUCTIONS TO CANDIDATES

Question ONE (1) is compulsory
Answer Any Other TWO (2) questions

TIME: 2 Hours

Question 1 (30 Marks)

(a) It is important to understand how to use the "analytical method" for designing and building real physical systems, instead of using "empirical methodologies," that is, building, observing, and using trial and error (which takes a lot of time and resources). Some steps that may lead to the best solution, consist of:

i. Modelling
ii. Setting up mathematical equations
iii. Performing analysis and design based on a model
iv. Setting the experimental evaluation or prototyping based on such analysis and design
v. Implementing the project
vi. Final adjustments and report

For the above steps (i-vi), we must be able to control the system in question. Answer the following questions:

i. Briefly describe a control system and briefly explain why we need a control system in such a scenario? (2 marks)
ii. Briefly explain the definitions of the components needed to implement a control system needed for the task above for a closed loop control system as indicated in Fig 1. (5 marks)

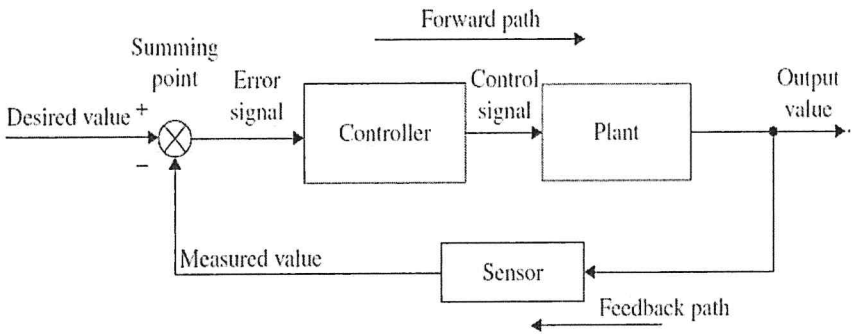

Figure 1: Control system

(b) Consider the two-coil rotor of Fig. 2. Assume the two rotor windings to be carrying a constant current $I_1 = I_2 = I$, and the rotor to have a polar moment of inertia J.

(a) Using the Lorentz force law $\vec{\mathbf{F}} = \left(\vec{\mathbf{I}} \times \vec{\mathbf{B}}\right) \cdot l$, find the force components F_r, F_y and the resultant torque $\vec{T}$ due to the two coils. (7 marks)

(b) Find the equilibrium position α_0 of the rotor. Is it stable? (3 marks)

(c) State the principle of conservation of energy. (3 marks)

(d) Three phase a.c. balanced sinusoidal waveforms are shown in fig.3 (a), fig. (b) shows projections of the three quantities in respective phasor planes on their respective axes. Explain with the aid of simple diagrams how you would get a resultant vector from the three quantities. Use time t_1 shown in fig.3 (a) to express your answer. (10 marks)

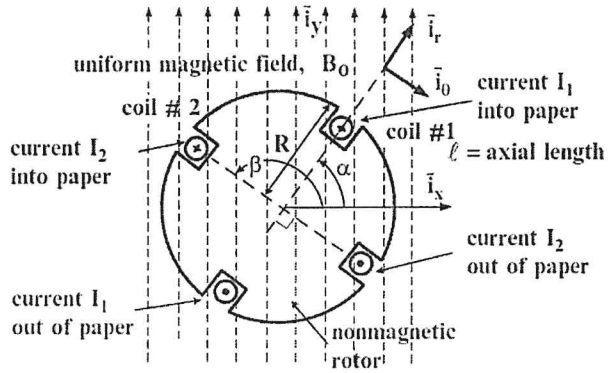

Figure 2: Two-coils residing on a nonmagnetic rotor; note $\vec{i}_x, \vec{i}_y, \vec{i}_r$ and $\vec{i}_\theta$ are unit vectors; $\beta = \alpha + 90°$. (courtesy [?])

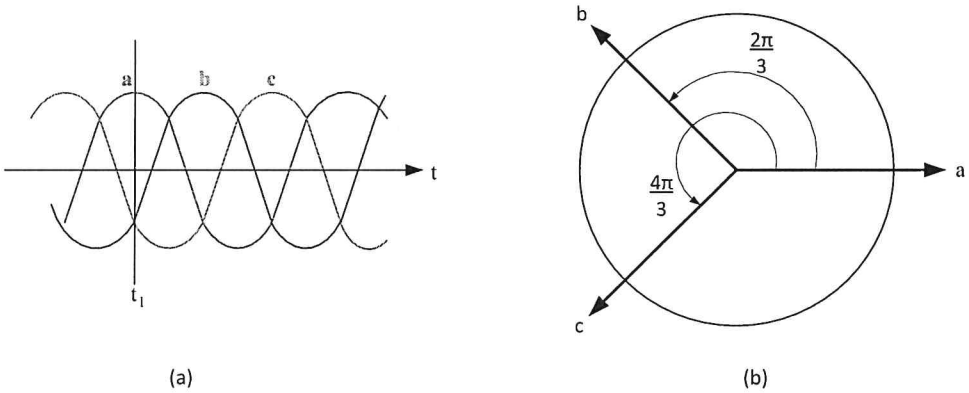

Figure 3: 3-phase waveforms

(e) In general, eigenvalues and eigenvectors satisfy the expression of eq. 1

$$A\xi = \lambda\xi \tag{1}$$

Eq. 1 is a very special relationship and is NOT TRUE for any vector λ. Explain the sense in which λ is special and how it scales the vector ξ. (5 marks)

Question 2 (20 Marks)

(a) With the aid of suitable sketches, differentiate between an open loop and closed loop control system. (8 marks)

(b) A set of three phase stator currents i_a, i_b, i_c are given by the vector of eq. (2)

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} \cos(\omega_s t) \\ \cos(\omega_s t - 120°) \\ \cos(\omega_s t + 120°) \end{bmatrix} \tag{2}$$

In order to transform the eq. (2) currents to the two-phase α, β,

(Clarke's) orthogonal coordinate system, eq. (2) is multiplied by the transformation matrix of eq. (3).

$$\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \tag{3}$$

i. Perform a two-phase α, β, (Clarke's) orthogonal transformation of the currents by multiplying eq. 2 with the eq. (3) transformation matrix. You should get a matrix in the form of (4), i.e. (12 marks)

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \tag{4}$$

.

Question 3 (20 Marks)

(a) The Kenyan Government has issued a statutory requirement to employ use of renewable energy for electricity generation in Kenya. Based on locally available resources and globally available technology, using very brief arguments, provide a solution by way of stating (i) readily available resources. (ii) appropriate primary energy conversion technology suitable to your choice from the available resources. (iii). appropriate means of converting your choice of primary source of energy to electrical energy. (10 marks).

(b) Differentiate between steady state and transient operation of an electrical machine. (4 marks)

(c) State four **4** reasons why we need feedback in machine control systems. (4 marks)

(d) Which is easier to control between an a.c. and a d.c machine? Give one reason. (2 marks)

Question 4

(a) With the aid of a suitable sketch explain the principle of operation of a doubly fed induction generator as used for wind power generation. (12 marks)

(b) When we need to change system dynamics, one of the basic analytical mathematical architectures we use is a state space system of Ordinary Differential Equations (ODE's) relevant to the purpose. In terms of state space representation explain your understanding of the following:

i. State variable. (3 marks)

ii. The System matrix (3 marks)

iii. Input matrix. (2 marks)

Question 5

(a) With the aid of a suitable diagram, define four quadrant operation of an electric drive. (6 marks)

(b) When we need to change system dynamics, one of the basic analytical mathematical architectures we use is a state space system of Ordinary Differential Equations (ODE's) relevant to the purpose. In terms of state space representation explain your understanding of the following:

i. State variable. (3 marks)

ii. The System matrix (3 marks)

iii. Input matrix. (2 marks)

(c) You are writing an MSc thesis in electrical engineering, List the sections you deem necessary and briefly explain why you think they are necessary. (12 marks)