

**BACHELOR OF ENGINEERING (ELECTRICAL ENGINEERING)**  
**FIFTH YEAR**  
**SECOND SEMESTER EXAM 2023**  
**ADVANCED ELECTRICAL MACHINE MODELLING & ANALYSIS**

Time:3 hours

Full Marks:100

(50 marks for each part)

Use separate Answer-script for each part

## PART-I

**Answer any three questions. Two marks for neatness. All symbols have their usual significance**

1. a) Consider the operation of an electromagnetic relay shown in fig.1, where one winding is mounted on a stationary member of iron and a movable member of iron is attached to a wall of the relay by a spring on one side. Now show that the energy converted to mechanical form equals the area between the two magnetization characteristics (flux vs.mmf) respectively for the open position and closed position with respect to movement of the plunger. Assume the necessary parameters for the system concerned.

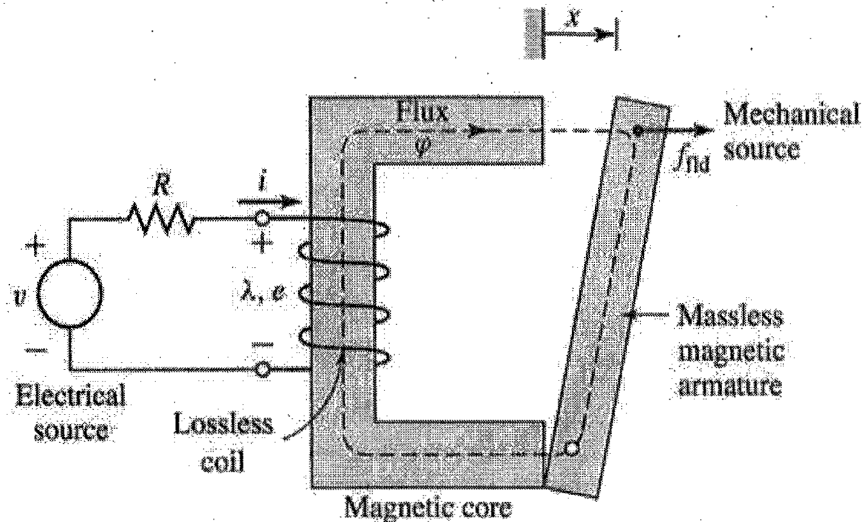


Fig.1

- b) Derive the expressions for mechanical force in terms of field energy and co-energy if the plunger shown in fig.1 is allowed to move an infinitesimal distance in the direction of magnetic force acting upon it. **8+8=16**

2. In an electromagnetic relay shown in fig. 1, the exciting winding has 3000 turns. The cross-sectional area of the magnetic core is  $30 \text{ cm} \times 30 \text{ cm}$ . The reluctance of the magnetic circuit may be assumed to be negligible. Also neglect fringing effects.

- i) Draw this figure showing the flux and find the coil inductance for an air-gap of  $x = 2 \text{ cm}$  at both ends of the plunger. What is the field energy when the coil carries a current of  $10 \text{ A}$ ? What are the forces on the plunger under these conditions?
- ii) Find the mechanical energy output when the plunger moves in the direction of magnetic force acting upon it, from  $x = 2 \text{ cm}$  to  $x = 1 \text{ cm}$  at both ends of the plunger assuming that the coil current is maintained constant at  $10 \text{ A}$ .

Also find the mechanical energy output if the flux linkage is maintained constant during plunger movement. **16**

3. Cross section of a cylindrical solenoid magnet is shown in fig.2; which shows the cylindrical plunger of mass 'M' kg. moves vertically in brass guide rings of thickness 't' meter and mean diameter 'b' meter . The permeability of brass is the same as that of free space. The plunger is supported by a spring whose elastance is 'K' newtons/m. Its un-stretched

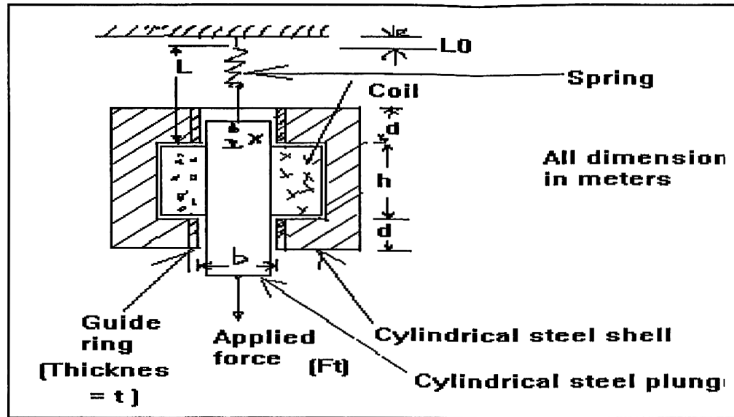


Fig.2

length is ' $L_0$ '. A mechanical load force ' $F_t$ ' newtons is applied to the plunger from the mechanical system connected to it. Assume that the frictional force is linearly proportional to velocity and that coefficient of friction is ' $p$ ' newtons-sec/m. The coil has ' $N$ ' turns and a resistance of ' $r$ ' ohms. Its terminal voltage is ' $v$ ' volts and its current is ' $i$ ' Amps. The effects of magnetic leakage and reluctance of the steel are negligible.

- i) Draw this figure showing the flux and derive the **dynamic equations of motion** of the electromechanical system.
- ii) Adjust this electromechanical system to have a stable quiescent point. Find the relations among the quiescent values of the terminal voltage, current, applied mechanical force, and displacement in terms of the spring constant ' $K$ ', the dimensions of the spring and magnet and the weight of the plunger. Then **linearize** the differential equations for incremental operation around the quiescent point. **8+8=16**

4. In an electromagnetic-energy-conversion-device shown in fig.3, if one winding is mounted on a stationary member of iron and another winding is mounted on the movable member of iron then draw this figure showing the flux and obtain the expression for electromagnetic torque in this doubly excited rotational electromechanical energy converter. Assume the necessary parameters for the system concerned. Also derive expressions for the speed and the transformer emfs. **16**

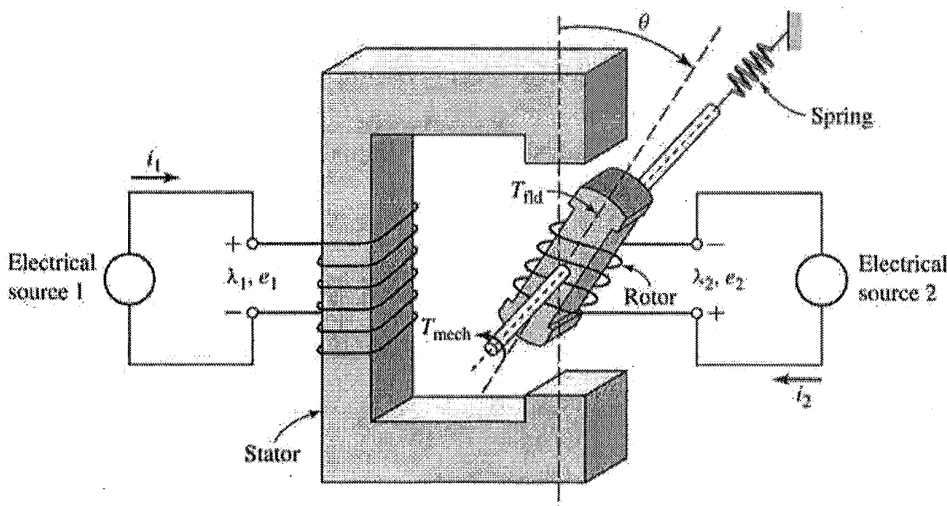


Fig.3

**PART – II**Answer *any three* questions

Two marks are for well-organized answers.

6. What do you mean by 'Connection Matrix' or 'Transformation Matrix'? Find the Connection Matrix of a Generalized Wheatstone Bridge. Also find the expression for mesh currents. 16
7. Develop the voltage equations of a generalized machine. 16
8. Develop the impedance matrix of a compound wound DC motor and derive the expression for current flowing through different branches. 16
9. What do you mean by bucking impedance of a transformer? Describe the methods for determining the bucking impedance between two coils of a three limbed core type transformer having a turns ratio ' $n$ ' when the two coils are on the same limb. Discuss the limitation(s) of the method, if any. 16
10. Write short notes on (i) Impedance and Torque matrices (ii) Flux linkage and (ii) Flux Density Matrices. 8+8