

**B.E. ELECTRICAL ENGINEERING
FOURTH YEAR SECOND SEMESTER EXAM 2024**

ADVANCED ELECTRICAL MACHINE MODELLING & ANALYSIS

Full Marks:100

(50 marks for each part)

Use separate Answer-script for each part

PART-I

Answer any three questions. Two marks are 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.

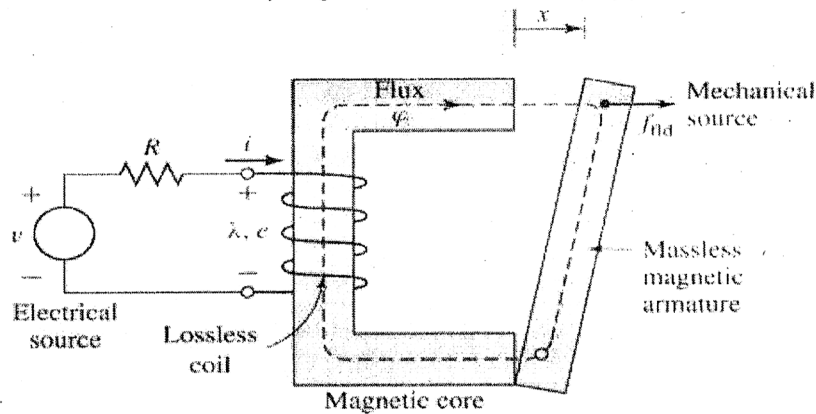


Fig.1

- 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.a) Explain magnetostriction and its equation.

- b) In an electromagnetic relay shown in fig. 1, the exciting winding has 2000 turns. The cross-sectional area of the magnetic core is $20 \text{ cm} \times 20 \text{ cm}$. The reluctance of the magnetic circuit may be assumed to be negligible. Also neglect fringing effects.

- i) 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 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 A .

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

4+12=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

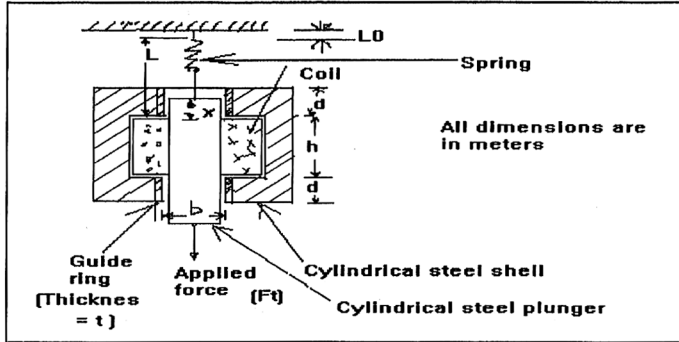


Fig.2

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.

- Derive the **dynamic equations of motion** of the electromechanical system.
- 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. For the electromechanical system shown in **fig.2**, considering linearized incremental dynamic equations of motion of the system operating for incremental motion around a quiescent point, develop the **equivalent circuit** where the mechanical variables and parameters are replaced by electrical variables and parameters: mechanical forces by currents, velocities by voltages, masses by capacitances and spring constants by reciprocal inductances and friction coefficients by conductances.

Also Develop **transfer-functions** and draw and explain the **block diagram** for the equivalent circuit of the above system.

8+8=16

5. 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 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.

10+6=16

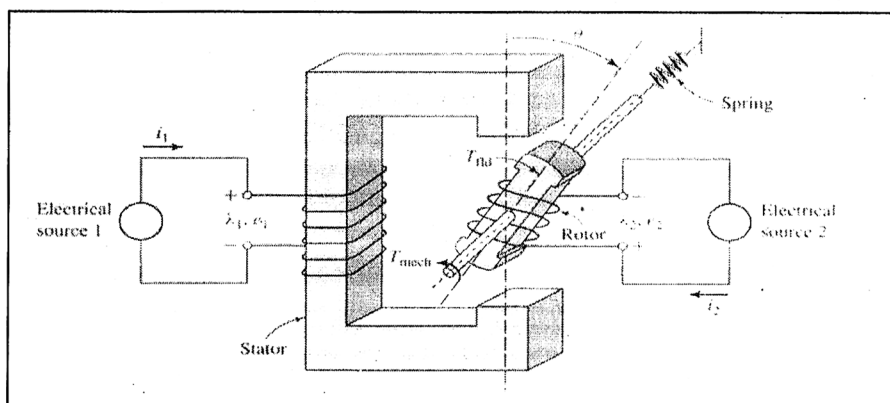


Fig.3

PART – II

Answer any three questions.

Two marks are for well-organized answer.

6. Write a note on generalized Impedance matrix of Wheatstone Bridge and hence find the expression for current through detector. (Q1) 16
7. Develop the voltage equations of a generalized machine in the non-holonomic / holonomic reference frame. (Q2) 16
8. Develop the impedance matrix of a compound wound DC motor and derive the expression for current flowing through different branches. (Q3) 16
9. What do you mean by bucking impedance of a transformer? Find an expression for the Bucking Impedance of a Single Phase Transformer. (Q4) 16
10. 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. (Q5) 16