1. Attempt any two parts of the following:

(a) (i) Describe the principle of energy conversion. From a consideration of the various energies involved, develop the model of an electromechanical energy-conversion device.

(ii) For a linear magnetic circuit, derive the following relations for the stored magnetic energy $W_{fld}$ and co-energy $W'_{fld}$:

$$W_{fld} = W'_{fld} = \frac{1}{2} F \phi = \frac{1}{2} \psi_i = \frac{1}{2} \phi^2 Rl = \frac{F^2}{Rl} = \frac{1}{2} L i^2 \text{ Joules}$$

where

$F =$ Instantaneous mmf

$\psi =$ Magnetic flux linkage
\[ \phi = \text{Instantaneous flux} \]
\[ RL = \text{Reluctance} \]
\[ i = \text{Instantaneous current} \]
\[ L = \text{Self-inductance} \]

(b) For the simple magnetic relay of Fig. 1. (b), the variation of flux linkage \( \psi \) in terms of current \( i \) and displacement \( x \) from the open position is given by the relation \( \psi = ix^{1/2} \); obtain an expression for the magnetic force.

(c) (i) What are the advantages of analysing energy conversion devices by field-energy concept?
(ii) Describe the principle of virtual work and hence show that the magnetic force \( f_e \) is given by

\[
f_e = -\frac{\partial W_{fld}}{\partial x} (\phi, x) = -\frac{\partial W_{fld}}{\partial x} (\phi, x)
\]

Above terms have usual meanings.
2 Answer any two of the following:

(a) (I) Give the materials and functions of the following parts of a DC machine:
(i) Field poles
(ii) Yoke
(iii) Commutator
(iv) Commutating Poles
(v) Armature.

(II) Explain lapwinding with suitable example.

(b) A 2-pole dc shunt generation charges a 100-V battery of negligible internal resistance. The armature of the machine is made up of 1000 conductors, each of 2 milli-ohm resistance. The charging currents are found to be 10A and 20A for generator speeds of 1055 and 1105 rpm respectively. Find the field circuit resistance and flux per pole of the generator. Neglect armature reaction effects.

(c) (i) The effect of armature reaction is to decrease the flux under one pole tip and to increase it under the other pole tip. Explain this with respect to a dc generator by using the developed view of armature current sheet and poles.

(ii) What are interpoles? Why are the interpoles designed to provide mmf more than the armature mmf in the commutating zone?
Attempt any two parts of the following:

(a) (i) Draw the speed-torque characteristics of d.c. shunt, series and compound motors in one figure and compare them. Which characteristic is more suitable for traction purposes and why?  
(ii) A 6-pole, 230 V d.c. series motor has a flux per pole of 4 mWb/Amp over the working range of the magnetization curve which is assured to be linear. The load torque is proportional to speed squared and its value is 20 Nm at 800 rpm. There are 432 wave-connected conductors and the total resistance of the motor is 1.0 Ω. Determine the motor speed and current when this motor is connected to rated supply voltage.

(b) (i) A 250 V, 15 kW, shunt motor has a maximum efficiency of 88% and a speed of 700 rpm, when delivering 80% of its rated output. The resistance of its shunt field is 100 Ω. Determine the efficiency and speed when the motor draws a current of 78 A from mains.

(ii) Explain in brief how efficiency is obtained from HOPKINSON'S Test.
(c) A d.c. shunt motor is connected to a 3-point 5×2 starter. Explain what would happen if:

(i) The starter handle is moved rapidly from OFF to the ON position.

(ii) The field circuit is open and an attempt is made to start the motor.

(iii) The field circuit becomes open circuit with the motor running at no-load, with the assumption that the starter is not provided with the no-volt release and the spring.

(iv) The starter handle is pulled back to stop the motor.

(v) There is a sudden overload of 100%.

4 Answer any two of the following:

(a) (i) Explain how the 3-phase core type transformer was evolved from three single-phase core type transformers having both their windings on one leg.

(ii) In 3-phase shell type transformers, a considerable economy is achieved in the core material if the middle phase winding is wound in the reversed direction as compared with the outer two phase windings. - Explain.
(b) Describe in detail the four phasor groups pertaining to 3-phase transformers. Draw the phasor diagrams and connection schemes for each of these four groups.

(c) (i) Scott-connected transformers supply two single-phase loads at 100 V. The load across the teases secondary is 300 kW at unity power factor and that across the main secondary is 200 kW at 0.8 power factor lagging. For a 3-phase input voltage of 11000 V, calculate the primary line currents and the leakage impedance drops are ignored.

(ii) In open-delta transformers, show that the secondary line voltages form a balanced 3-phase system of voltages, in case the supply voltages are balanced.

Answer any two of the following:

(a) (i) In Sumpner's test, the reading of the wattmeter recording the core losses, remains unaffected when low-voltage is injected in the secondary series circuit.

- Explain.

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(ii) Explain why the exciting current of a single-phase transformers contains harmonics even when the supply voltage is a Sine wave.

(b) (i) Discuss the conditions necessary for the successful parallel operation of single-phase transformers. How can you check these conditions?

(ii) Two single-phase transformers rated 1000 kVA and 500 kVA have per unit leakage impedance of (0.02+j0.06) and (0.025+j0.08) respectively. What is the largest kVA load that can be delivered by the parallel combination of these two transformers without overloading any one.

(c) (i) Discuss the relative merits and demerits of an auto-transformer.

(ii) A 2000/1000/500 V, single-phase three winding transformer is to be used as an auto-transformer, with supply voltage of 3000 V. Two loads, one of 1050 kVA at
3500 V and the other of 180 kVA at 1000 V, are to be energised from this auto-transformer output. Draw a suitable diagram of connections and find the currents in various parts of the circuit. Assume the loads to have the same power factor.