

ELECTRICAL ENGINEERING

(Paper I)

Time Allowed : Three Hours
Maximum Marks : 250

QUESTION PAPER SPECIFIC INSTRUCTIONS

(Please read each of the following instructions carefully before attempting questions)

There are EIGHT questions divided in two Sections.

Candidate has to attempt FIVE questions in all.

Question Nos. 1 and 5 are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE question from each Section.

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Word limit in questions, wherever specified, should be adhered to.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

SECTION 'A'

1. (a) Find the values of E and I in the circuit shown in Fig. 1.
 [Figure: Fig. 1 – Ladder network. Voltage source E on the left (+ terminal at top) between the top rail and the bottom (return) rail; current I flows from the + terminal of E to the right through a series $2\ \Omega$ resistor along the top rail to node 1. From node 1 a $6\ \Omega$ resistor goes down to the bottom rail; a second series $2\ \Omega$ resistor goes along the top rail from node 1 to node 2. From node 2 a $4\ \Omega$ resistor goes down to the bottom rail carrying a marked current of 2 A (arrow pointing downward through the $4\ \Omega$); a $2\ \Omega$ resistor from node 2 to the bottom rail is in parallel with the $4\ \Omega$ (rightmost branch).] 10
- (b) Starting from Maxwell's equations

$$\nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t \text{ and } \nabla \times \mathbf{H} = \mathbf{J} + \partial \mathbf{D} / \partial t$$
 show that $\nabla \cdot \mathbf{B} = 0$ and $\nabla \cdot \mathbf{D} = \rho$. 10
- (c) Determine the inverse z-transform of

$$X(z) = 1 / (1 - 1.5z^{-1} + 0.5z^{-2})$$
 for ROC $|z| > 1$ 10
- (d) A comparator and limiter circuit is shown in Fig. 2. Develop transfer characteristics V_O vs. V_I and explain.
 [Figure: Fig. 2 – Op-amp inverting circuit: input V_I through resistor R_1 to the inverting (–) input; non-inverting (+) input grounded. Feedback from the output V_O to the inverting input through resistor R_2 , and in parallel with R_2 two Zener diodes connected back to back in series (cathode to cathode): Zener V_{Z_2} with its anode at the inverting-input side, and Zener V_{Z_1} with its anode at the output side.] 10
- (e) A three-phase balanced delta-connected load gives wattmeter readings of 1050 W and 550 W , when the two-wattmeter method is applied. Calculate the impedance in each arm of the load. Given, line voltage = 200 V . 10
2. (a) The net power flowing out of a given volume v is equal to the time rate of decrease in the energy stored within v minus the conduction losses. Derive equations to explain. 20
- (b) A delta-connected balanced three-phase load is supplied from a three-phase, 400 V supply. The line current is 20 A and power taken by the load is 10000 W . Find (i) impedance in each branch and (ii) the line current, power factor and power consumed if the same load is connected in star. 20
- (c) Determine whether the following system is linear, time invariant, stable or dynamic:

$$y(n) = 5x(2n)$$
 10
3. (a) Find the Laplace transform of the signal $x(t) = e^{-3t}u(t) + e^{-2t}u(t)$ and find ROC. 20

- (b) Derive Helmholtz equation in terms of magnetic field. 20
- (c) The z-parameters of a two-port network are $z_{11}=20\ \Omega$, $z_{22}=30\ \Omega$, $z_{12}=z_{21}=10\ \Omega$. Find y and ABCD parameters of the network. 10
4. (a) (i) Why the output voltage of an Op-Amp does not respond immediately to the fast-changing input? (ii) Develop the expression for the slew rate of Op-Amp. (iii) An open-loop configuration of Op-Amp 741C changes its output from +14 V to -14 V each time its input crosses zero volt. If 741C has a typical slew rate of 0.5 V/ μ s, calculate the time between the zero crossings and the maximum frequency at which the output will be distorted. 20
- (b) Obtain the Norton's equivalent circuit at the terminals A and B for the network shown in Fig. 3. 20
- [Figure: Fig. 3 – Network with top rail and bottom rail (bottom rail ends at terminal B). Leftmost branch: 1 Ω resistor in series with a 100 V source (+ terminal toward the 1 Ω , i.e. upper end), connected between top-left node P and the bottom rail. Middle branch: 10 Ω resistor from node P to the bottom rail. From node P along the top rail: a 20 V source (- terminal at the P side, + terminal to the right) in series with a 2 Ω resistor to node Q, which connects to terminal A. Right branch: 10 Ω resistor from node Q to the bottom rail (B).]
- (c) Determine whether the following signal is periodic or aperiodic. Find the fundamental period, if it is periodic:

$$x(n)=\sin(3\pi/7n+\pi/4)+\cos\pi/3n \quad 10$$

SECTION 'B'

5. (a) A single-phase fully controlled bridge converter supplies an inductive load. Assuming that the output current is virtually constant and is equal to 20 A, determine the following performance measures, if the supply voltage is 230 V and the firing angle is maintained at 30°: (i) Average output voltage (ii) Supply r.m.s. current (iii) Supply fundamental r.m.s. current (iv) Fundamental power factor (v) Supply power factor (vi) Supply harmonic factor (vii) Voltage ripple factor (viii) Reactive power input 10
- (b) Prove that the torque produced in a shunt motor is proportional to armature current I_a and in case of series motor, it is proportional to I_a^2 . 10
- (c) A single-phase converter feeds an R-L load having a resistance of 10 ohms in series with an inductance of 20 mH. The converter operates such that the d.c. voltage across the load is 250 V. The thyristor used in the converter has holding current of 300 mA and a delay time of 5 μ s. Determine the pulse width of gate current. 10
- (d) A random variable has an exponential probability function given by $f(x)=ae^{-b|x|}$, where a and b are constants. Find (i) the relationship between a and b , and (ii) the distribution function of x . 10
- (e) Design a circuit that gives the input-output relationship shown in Fig. 4. 10
- [Figure: Fig. 4 – Timing diagram. Input: a train of five positive rectangular pulses numbered 1, 2, 3, 4, 5. Output: low throughout, goes high at the falling (trailing) edge of input pulse 4 and returns low at the falling edge of input pulse 5 (dashed lines mark these two edges); i.e. one output pulse lasting from the end of pulse 4 to the end of pulse 5.]
6. (a) A d.c. shunt motor takes a current of 80 A on a 480 V supply and runs at 960 r.p.m. The armature resistance is 0.25 ohm and the field resistance is 120 ohms. A chopper is used to control the speed of the motor in the range of 400–750 r.p.m. having constant torque. The on-period of the chopper is 3 ms. The field is supplied directly from 480 V supply. Determine the range of frequencies of the chopper. 20
- (b) (i) Find 2's complement of the following numbers: (1) 10010010 (2) 11011000 (ii) Convert the logical equation $Y=(A+BC)(B+\bar{C}A)$ into product-of-sums (POS) form and design circuits using (1) OR and AND gates and (2) NOR gates. (iii) Explain the function of Schottky diode connected between the collector and base of transistors of TTL gate. 20

- (c) A 550 V, 55 kVA, single-phase alternator has effective resistance of 0.2Ω . A field current of 10 A produces an armature current of 200 A on short circuit and an e.m.f. of 450 V on open circuit. Calculate (i) the synchronous reactance and (ii) the full-load regulation with power factor 0.8 lagging. **10**
7. (a) Describe all-day efficiency of a transformer. **10**
- (b) The two random variables X and Y are independent and identically distributed each with a Gaussian density function with mean equal to zero and variance equal to σ^2 . If these two random variables denote the coordinates of a point in the plane, find the probability density function of the magnitude and the phase of that in polar coordinates. **20**
- (c) Describe the voltage-commutated chopper controlling the speed of a d.c. series motor with relevant schematic diagram and associated voltage and current waveforms as a function of time. **20**
8. (a) Discuss the effect of excitation on armature current for a synchronous motor and compare the performance of 3ϕ synchronous motor with 3ϕ induction motor. **20**
- (b) Explain the method of frequency demodulation using PLL. **15**
- (c) A three-phase, four-pole, 50 Hz induction motor has a chopper-controlled resistance in the rotor circuit for speed control. Load torque is ω^2 . When the thyristor is ON, the torque is 30 N-m at a slip of average 0.03. If $T_{ON}/T_{OFF}=1$, compute the average torque and speed. The motor develops a torque of 80 percent of ON torque when the thyristor is OFF. The speed variation ranges down to 1200 r.p.m. from synchronous speed. Determine the ratio T_{ON}/T_{OFF} to give an average torque of 25 N-m. **15**