

ELECTRICAL ENGINEERING

(Paper I)

Time Allowed : Three Hours
Maximum Marks : 300

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.

SECTION 'A'

1. Answer any three of the following:
 - (a)(i) What will be the impedance of a parallel connected LCR network at resonance frequency? 4
 - (a)(ii) If an impedance Z_L is connected across a voltage source V with source impedance Z_s , then for maximum power transfer, what will be the load impedance? 4
 - (a)(iii) The voltage across an impedance in a network is $V(s)=Z(s) \cdot I(s)$ where $V(s)$, $Z(s)$ and $I(s)$ are the Laplace transforms of the corresponding time functions $v(t)$, $z(t)$ and $i(t)$. What will be the relation among them in the time domain of $v(t)$, $z(t)$ and $i(t)$? 4
 - (a)(iv) Develop the relation between unit step sequence and unit sample sequence. 4
 - (a)(v) How can you express a discrete signal as a sequence of a sum of scaled delayed unit sample sequence? 4
 - (b)(i) Determine Laplace transform of the waveform $f(t)$ as shown in the figure below:
[Figure: Rectangular waveform $f(t)$ versus t : $f(t) = 1$ for $0 < t < 2$; -2 for $2 < t < 4$; $+2$ for $4 < t < 6$; -2 for $6 < t < 8$; zero for $t > 8$ (vertical axis marked $-2, -1, 0, 1, 2$; horizontal axis marked $2, 4, 6, 8, 10$).] 4
 - (b)(ii) Draw the block diagram of the system represented by the following constant coefficient difference equation $y(n)=b_0x(n)+b_1x(n-1)+a_1y(n-1)$ where $x(n)$ = input sequence and $y(n)$ = output sequence. 10
 - (c)(i) What is the principle of operation of a repulsion motor? What are its main features, advantages and applications? 15
 - (c)(ii) Describe the working of a stepper motor. 5
 - (d)(i) A cable transmission system with a loss of (L) 240 dB and has $m = 6$ equal length repeater sections and the SNR at the destination $(S/N)_D=30$ dB. Find the new value of $(S/N)_D$ if (a) m is increased to 12 and (b) m is decreased to 4. Express your answer both in ratio and in dB. 10
 - (d)(ii) A helix travelling wave tube operates at 4 GHz with a beam voltage of 10 kV and a beam current of 500 mA. The helix impedance is 25 ohm and interaction length is 15 cm [?]. Determine the output power gain in dB. 10
2. (a)(i) Use final value theorem to find $f(\infty)$ for the function $(1-e^{-\beta t}) u(t)$, where $\beta > 0$. 4
- (a)(ii) Find the current $i(t)$ through the 8Ω resistor of the circuit diagram shown below with initial current $i(0^-)=5$ Amp. 6

[Figure: Single series loop: voltage source $6u(t)$ (+ at top, arrow upwards) on the left; inductor $L = 4 \text{ H}$ in the top wire; resistor $R = 8 \Omega$ on the right side; bottom wire returns to the source; loop current $i(t)$ clockwise.]

- (a)(iii) Obtain the frequency response of the first-order recursive system represented by constant coefficient difference equation $y(n)=a y(n-1)+x(n)$. Consider the system is initially relaxed. 10
- (b) What are commutation circuits? Design a commutation circuit for an inverter. 20
- (c)(i) Discuss transformer noise and means adopted to reduce it. 5
- (c)(ii) A 30-kVA, single phase transformer has an iron loss of 457 W and copper loss of 125 W, when delivering half the full load. At what percent of the full load will the transformer have maximum efficiency? 15
3. (a)(i) Consider the function of complex frequency s of the following expression:

$$X(s)=(s+3)/(s^2+4s+5)$$

 Find the Laplace inverse function of the above expression. 8
- (a)(ii) What do you understand by the mathematical relation between continuous and discrete system as given below?

$$X(e^{j\omega T})=1/T \sum_{m=-\infty}^{\infty} X_A(\omega+2\pi/Tm)$$

 where $X(e^{j\omega T})$ is the frequency response of the sequence $x(nT)$, T is the sampling period and $X_A(j\Omega)$ is the Fourier transform of the continuous-time waveform. If the analog frequency response is band limited to the range $|\Omega| \leq \pi/T$ what will the new relation be? 12
- (b)(i) Illustrate and compare speed-current and torque-current characteristics of a compound wound d.c. motor with that of series and shunt motor. 5
- (b)(ii) A 3-phase, 50 Hz, 16 pole generator with star connected windings has 144 slots with 10 conductors per slot. The flux/pole of 24.8 mWb is sinusoidally distributed. The coil is full pitched. Find the line emf. 15
- (c) The speed of a 20 HP, 460 V, 1000 rpm separately excited d.c. motor is controlled by a single-phase full-wave bridge circuit as shown in the figure: The rated motor armature current is 35 A and the armature resistance is 0.15Ω . The a.c. supply voltage is 480 V [?]. The motor back emf constant is $k_b \phi = 0.45 \text{ V/rpm}$. The motor current is continuous and ripple free. For rectifier operation (d.c. machine running as a motor) and for a firing angle $\alpha = 60^\circ$ and rate armature current, calculate (i) torque, (ii) speed and (iii) supply power factor.
 [Figure: Single-phase fully controlled bridge: a.c. supply v between two input terminals, input current i ; four thyristors SCR1 (top left), SCR2 (top right), SCR4 (bottom left), SCR3 (bottom right), with SCR1 and SCR2 cathodes on the top (positive) d.c. rail and SCR4 and SCR3 anodes on the bottom d.c. rail; one supply terminal goes to the junction SCR1–SCR4, the other to the junction SCR2–SCR3; output voltage V_a across the d.c. rails; load: armature current i_a through R_a , L_a and the motor armature (back emf E_b , + at top) in series between the rails; separately excited field winding shown beside the motor.] 20
4. (a)(i) A sinusoidal voltage source is applied to the parallel RC network as shown in the figure below. Find the energy stored and energy dissipated in the resistor over the interval $0 < t < 0.5 \text{ sec}$.
 [Figure: Source $10\sin 2\pi t$ connected across two parallel branches: a $1 \mu\text{F}$ capacitor carrying i_C (downwards) and a $1 \text{ k}\Omega$ resistor carrying i_R (downwards).] 10
- (a)(ii) Find the output response to an input $x(n)=u(n)-u(n-p)$ for the system whose unit sample response is as follows: $h(n)=\alpha^n$ for $n \geq 0$ [?]; $=0$ for $n < 0$. 10
- (b) The joint probability density of the random variables X and Y is $f(x,y)=Ke^{-(x+y)}$ in the range $0 \leq x < \infty$ and $0 \leq y < \infty$ and $f(x, y) = 0$ otherwise. (i) Find the value of the constant K . (ii) Find the probability density $f(x)$, the probability density of X independently of Y . (iii) Find the probability $P([0 \leq X \leq 2; ; 2 \leq Y \leq 3])$ (iv) Are the random variables dependent or independent? Justify. 20

- (c) What is troposphere? State the parameters that characterise troposphere. Write empirical formulae for the variation of these parameters within the first 1 – 2 km of the troposphere. Write expressions for the permittivity (ϵ_r) and refractive index (n) of the tropospheric medium. What is the value of n at an altitude of 1 km? 20

SECTION 'B'

5. Answer any three of the following:
- (a)(i) Circuit diagram shown below is initially under steady-state condition, the switch is moved from position 1 to position 2 at $t = 0$. Find the current after switching.
 [Figure: 10 V battery on the left, its positive terminal connected by the top wire to switch contact 1; the switch blade is connected (common terminal) to one end of resistor R_2 (value illegible under the watermark) [?]; the other end of R_2 goes to the top of inductor $L = 5$ H, whose bottom goes to the bottom wire; switch contact 2 is connected through resistor R_1 (value illegible under the watermark) [?] to the bottom wire, which also returns to the battery negative terminal; the switch moves from 1 to 2 at $t = 0$; current $i(t)$ marked clockwise in the loop R_2 – L – R_1 .] 8
- (a)(ii) Find the z-transform of $\cos(n\pi/2).u(n)$. 12
- (b)(i) For plane waves in free space, show that the intrinsic impedance of free space is given by $120\pi \Omega$. 10
- (b)(ii) A TEM wave travels in free space with the electric field component $E_s = 100 e^{j(0.866y + 0.5z)} a_x$ V/m. Determine ω and λ . 10
- (c)(i) In the circuit of the figure shown below, the source voltage $E = 120$ V and the current through loads R_1 and R_2 is 20 A. The turn-off time of both the SCRs is 60 μ sec. Find the value of C for successful commutation.
 [Figure: Complementary (parallel capacitor) commutation circuit: battery E on the left; the top wire feeds two branches to the bottom wire: R_1 in series with SCR_1 (anode at the bottom of R_1 , cathode to the bottom wire) and R_2 in series with SCR_2 (same orientation); capacitor C connected between the anode of SCR_1 (– plate) and the anode of SCR_2 (+ plate).] 10
- (c)(ii) Give interpretation of negative, unity and $>$ unity slips of induction motor. 10
- (d) A paraboloidal reflector antenna of cross-sectional area of 8000 cm^2 works at 3 GHz. Calculate the (i) beam width between first nulls, (ii) half power beam width, and (iii) gain of the antenna. 20
6. (a)(i) Design a second-order Butterworth low-pass filter with cut off frequency of 1 kHz [?]. Use only Sallen and Key network configuration as shown below:
 [Figure: Sallen–Key low-pass filter: V_{in} through resistor R to node A; from A a second resistor R to the non-inverting (+) input of the op-amp; capacitor C from the + input to ground; a second capacitor C from node A to the op-amp output (feedback); resistor R_1 from the inverting (–) input to ground and resistor R_2 from the output to the inverting input; output V_{out} .] 8
- (a)(ii) Find the impulse response of the system whose transfer function is given as follows:

$$H(z) = 1/(1 - 2r\cos\theta \cdot z^{-1} + r^2 z^{-2})$$
 which converges $|z| > r$, it has a pair of poles at $z = r \cdot e^{\pm j\theta}$ and a double zero at $z = 0$. 12
- (b) It is desired to transmit an audio signal which has a bandwidth of 10 kHz with an output SNR of 40 dB. The channel introduces a 30 dB power loss and channel noise is AWGN with power spectral density $\eta/2 = 10^{-9}$ W/Hz. Assume $\mu^2 S_x = 0.5$ for AM. Calculate the (i) transmission bandwidth B_T (ii) required transmitter power S_T for DSB, SSB and AM systems. 20
- (c) A microstrip line is to be designed on alumina substrate having relative dielectric constant $\epsilon_r = 8.2$. The W/h ratio = 0.95. Compute (i) effective relative dielectric constant (ii) characteristic impedance Z_0 (iii) phase velocity (iv) guide wavelength 20
7. (a) Draw the circuit diagram of a half wave rectifier with a reservoir capacitor that smooths the output. Draw its output waveform. Determine the reservoir capacitor value for a HWR and smoothing circuit to supply 20 V to a load of 500 Ω . Maximum ripple 20

amplitude is to be 10% [?] of the average output voltage, and the input signal frequency is 50 Hz.

- (b) In an Armstrong modulator, the crystal oscillator frequency is 200 kHz. The angular deviation is set to 0.2. The system is to accommodate modulation frequencies between 50 Hz and 15 kHz. The carrier frequency at the output is 108 MHz and the maximum frequency deviation is 80 kHz. Draw the block diagram of the modulator showing the details and select multiplier and mixer oscillator frequencies to accomplish this end. **20**
- (c) Find the field strength at distances of 500 m and 2,500 m from a dipole centre fed with $I_m = 0.1$ A. Dipole has a length of 200 cm and the frequency of operation is 3 GHz. Consider E_θ only in the maximum direction. **20**
8. (a) The discrete time system is described by the constant coefficient difference equation $y(n) = x(n) + a y(n-1)$ with initial condition $y(-1) = K$. If the input $x(n) = e^{j\omega n} \cdot u(n)$ is applied to the system, what will be the output response? [Solve the problem using z-transform and its inverse transform operation only] **20**
- (b)(i) Derive conditions for maximum starting torque to be obtained in case of an induction motor. **5**
- (b)(ii) A 4-pole, 50 Hz, 7.46 kW motor at rated voltage and frequency has a starting torque of 160% [?] and a maximum torque of 200% of full load torque. Determine (a) full load speed and (ii) speed at maximum torque. **15**
- (c) A 6 MW, 3-phase, 11 kV, Y-connected, 6-pole, 50 Hz, 0.9 (leading) power factor synchronous motor has $X_s = 9 \Omega$ and $R_s = 0$. Rated field current is 50 amperes. Machine is controlled by variable frequency control at constant (V/f) ratio up to the base speed and at constant V above base speed. Determine the torque and field current for the rated armature current, 750 rpm and 0.8 leading power factor. **20**