

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) A continuous time LTI system is described by

$$y(t) = 1/T \int_{t-T/2}^{t+T/2} x(\tau) d\tau$$

Find the impulse response of the system. Is the system casual?

5

(a)(ii) For the circuit shown below, find i_1 , i_2 , i_3 and i_4 .

[Figure: Circuit drawn as a horizontal chain of elements between six nodes A–F from left to right: 25 Ω resistor from A to B, with voltage V_1 across it (+ at A); a dependent (diamond) current source $0.2V_1$ from B to C, arrow pointing towards C; 10 Ω resistor from C to D; independent 25 A current source from D to E, arrow pointing towards D (leftwards); 100 Ω resistor from E to F. Four curved wires short pairs of nodes: an upper arc from A to C carrying current i_1 (arrow left to right), an upper arc from C to E carrying i_2 (arrow left to right), a lower arc from B to D carrying i_3 (arrow left to right) and a lower arc from D to F carrying i_4 (arrow left to right).]

5

(a)(iii) A transmission line of characteristics impedance $Z_0 = 50 \Omega$ is terminated by load impedance $R_L = Z_L = 100 \Omega$. Find voltage standing wave ratio VSWR, minimum impedance Z_{min} and maximum impedance Z_{max} .

5

(a)(iv) Find the quality factor Q_p at resonance for the circuit shown below.

[Figure: Four branches connected in parallel between two horizontal bus wires: (1) resistor R; (2) R_{coil} in series with L_{coil} ; (3) capacitor C; (4) voltage source V (+ on the left terminal) delivering current I (arrow upwards on the left vertical wire).]

5

(b)(i) Design a combinational circuit that accepts a three-bit number and generates an output binary number equal to the square of the input number.

10

(b)(ii) Design a second-order active RC band-pass filter with a mid-band voltage gain $-A_0 = 34$ dB, carrier frequency 160 Hz and 3 dB bandwidth 16 Hz. Assume $C_1 = C_2 = 0.1 \mu\text{F}$.

10

(c)(i) Explain the principle of split-phase, single-phase induction motor. Discuss resistance split-phase motors and capacitor split-phase motors.

15

(c)(ii) Explain why an induction motor is not run under conditions of maximum load.

5

(d)(i) Calculate the depth of penetration for copper at 1 MHz. The conductivity for copper is 58 M Ω /m and permeability is 1.26 $\mu\text{H}/\text{m}$

5

(d)(ii) Discuss the merits of delayed AGC as compared with simple ACC.

5

(d)(iii) Show that the first minor lobe is -13.5 dB to principal maxima for broadside array for large n.

10

2. (a)(i) Find $i_L(0^+)$, $V_C(0^+)$, $(dV_C(0^+)/dt)$ and $(di_L(0^+)/dt)$ for the circuit shown below. Use $(dV_C(0^+)/dt)$ to denote $dV_C(t)/dt|_{t=0^+}$. Assume the switch 1 has been opened for switch 2

6

has been closed for along time and steady-state condition prevails at $t=0^-$.

[Figure: 10 V source (+ at top) in the left vertical branch; from its top terminal a $1\ \Omega$ resistor in series with Switch 1 (operated at $t = 0$) leads to node X; capacitor $V_C, \frac{1}{2}\text{ F}$ (+ at top) from X to the bottom (ground) wire; a second $1\ \Omega$ resistor from X to node Y; 1 H inductor from Y to ground carrying i_L (arrow downwards); a separate upper branch from X to Y consists of a 2 A current source (arrow pointing right, towards Y) in series with Switch 2 (operated at $t = 0$). The bottom wire is common to the source, capacitor and inductor.]

- (a)(ii) A parallel plate waveguide consists of two parallel perfectly conducting infinite planes situated 8 cm apart. Determine the propagating TE_{mo} for a wave of 6000 MHz, assuming free space between the plates. Find also the cut-off frequency f_c , waveguide wavelength λ_g , waveguide intrinsic impedance η_g . 9
- (a)(iii) List the three sources of instability of collector current Define the three stability factors. Which biasing arrangement gives you better stability? 5
- (b)(i) Define voltage regulation of a transformer. Derive the expression for voltage regulation at lagging power factor. Draw phasor diagram. 10
- (b)(ii) A single-phase transformer working at unity power factor as an efficiency of 90% at both half full load and full load. Full load is 500 W. Determine the efficiency at 60% of full load condition. 10
- (c)(i) What is a TRIAC? Explain its characteristic. Discuss its applications, advantages and disadvantages. 15
- (c)(ii) A voltage across SCR is 1 V when it is conducting. It has a holding current of 2 mA when gate current (I_G)=0. If the SCR is triggered on by momentary pulse of gate current to what value must V_A be reduced in order to turn the SCR off? The figure is shown below.
[Figure: Input terminal V_A connected through a $45\ \Omega$ resistor to the anode of an SCR whose cathode is connected to ground; a gate pulse is applied to the gate; V_{AK} is marked across the SCR (from the anode side to the grounded cathode).] 5
3. (a)(i) Using the difference equation design method with a backward difference, design a digital filter to simulate the analog filter whose transfer function is

$$H(s)=s/(s^2+400s+2\times 10^5)$$
using the sampling rate $f_s=1\text{ kHz}$ 10
- (a)(ii) Find the poles and zeros of the networks shown below.
[Figure: One-port between two input terminals (top and bottom wires) with three parallel branches across it: (1) 1 H inductor in series with $1\ \Omega$ resistor; (2) 1 F capacitor; (3) $1\ \Omega$ resistor.] 5
- (a)(iii) Implement the Boolean function $F(A,B,C,D) \Sigma(0,1,3,4,8,9,15)$ with an 8×1 multiplexer with A, B and D connected to selection lines s_2, s_1, s_0 , respectively. 5
- (b)(i) Explain speed-current and torque-current characteristics of d.c. series motor. 8
- (b)(ii) A 4-pole d.c. generator has 1200 armature conductors and generates 250 volts on open circuit when running at a speed of 600 r.p.m. The diameter of the pole-shoe circle is 0.35 m and the ratio of pole arc to pole pitch is 0.7 while the length of pole-shoes is 02 m. find the mean flux density in the air gap. Assume lap-connected armature winding. 12
- (c)(i) What are the steps involved for the generation of gating signals for thyristors of ac. to d.c. converters? Draw a block diagram incorporating various stages of firing circuits for a single-phase fully controlled rectifier. 12
- (c)(ii) If the SCR in the following figure is continuously fired by a d.c. signal, what is average value of the current $i(t)$?
[Figure: Single series loop: a.c. source $330\sin 314t$ on the left, an SCR (anode on the left) in the top wire, a $12\ \Omega$ resistor carrying $i(t)$ (arrow to the right), and a 165 V battery on the right side with its positive (long) plate at the top, i.e. opposing the forward current of the SCR.] 8
4. (a)(i) For the network shown below, Find the current ratio transfer function given by $\alpha=I_2/I_1$.
[Figure: Ladder network between a common bottom (ground) wire and a top wire, from left to right: current source I_1 (arrow up) feeding the top wire with current I_1 (arrow to the right); $1\ \Omega$ shunt resistor to ground; series dependent voltage source $2I_1$ (diamond, - on the left, + on the right) in the top wire; $1\ \Omega$ shunt resistor 10

to ground carrying current I_c (arrow upwards); series $2\ \Omega$ resistor in the top wire; shunt dependent current source (diamond, arrow upwards) labelled $I_c/2$ [?]; current I_2 flowing leftwards in the top wire from the right end into this node; $1\ \Omega$ shunt resistor to ground at the right end.]

- (a)(ii) Explain boundary conditions for time-varying fields. 5
- (a)(iii) Draw the small signal model of FET. Define μ , g_m and r_d , and obtain relationship between them. 5
- (b)(i) When a super heterodyne receiver is turned to 555 kHz, its local oscillator provides the mixer with an input at 1010 kHz. What is the image frequency? The antenna of this receiver is connected to the mixer via a tuned circuit whose loaded Q is 40. What will be the rejection ratio for the calculated image frequency? 10
- (b)(ii) Show that power contained in one sideband is 1/6 to the total power of amplitude-modulated signal at 100% modulation index. 10
- (c)(i) Explain Faraday rotation isolator. A matched isolator has insertion loss of 0.5 dB and isolation 25 dB, Calculate the scattering coefficient. 15
- (c)(ii) Explain construction of Ionosphere. 5

SECTION 'B'

5. Answer any three of the following

- (a)(i) Determine $v(t)$ for the circuit shown below when $v_s = 10\cos 30t$ V
[Figure: Source v_s (+ at top) in the left branch; from its top terminal a $1/50$ F capacitor in the top wire leads to node X; 0.3 H inductor from X to the bottom wire with voltage $v(t)$ across it (+ at top, dot at the top end); from X a $28\ \Omega$ resistor leads to the right top corner, from which a 0.2 H inductor (dot at the top end) goes down to the bottom wire; mutual inductance 0.1 H between the 0.3 H and 0.2 H coils (double-headed arrow).] 5
- (a)(ii) Find the Fourier transform of the signal
$$x(t) = (\sin(t)\sin(t/2))/\pi t^2$$
 5
- (a)(iii) Find the Laplace transform of the stepped waveform shown below.
[Figure: Staircase waveform $f(t)$ versus t : $f(t) = 1$ for $0 < t < T$, 2 for $T < t < 2T$, 3 for $2T < t < 3T$, 4 for $3T < t < 4T$, and zero after $4T$ (the step heights 2, 3, 4 are marked by double-headed arrows at T , $2T$ and $3T$; vertical axis marked 1, 2, 3, 4; horizontal axis marked T , $2T$, $3T$, $4T$).] 5
- (a)(iv) An air-filled rectangular waveguide of dimension $a = 4$ cm, $b = 2$ cm, transports energy in the dominant mode at a rate of 2 mW if the frequency of operation is 10 GHz. Determine the peak value of electric field in the waveguide. 5
- (b)(i) The 741C op-amp having the following parameters is connected as shown in the figure. $A = 20000$, $R_i = 2\ \text{M}\Omega$, $R_o = 75\ \Omega$, $f_0 = 5$ Hz, supply voltage = ± 15 V, output voltage swing ± 13 V. Identify the circuit. Compute the values of A_F , R_{IF} , R_{OF} , f_F & V_{OUT}
[Figure: 741C op-amp with supplies V_{CC} and V_{EE} ; input source v_i between the non-inverting (+) input and ground; $1\ \text{k}\Omega$ resistor from the inverting (–) input to ground and $10\ \text{k}\Omega$ feedback resistor from the output to the inverting input; load R_L from the output v_o to ground.] 10
- (b)(ii) How much noise voltage is generated in a $1\ \text{M}\Omega$ resistance at 27°C over a 10 kHz bandwidth? List the sources of noise in an amplifier. 5
- (b)(iii) What are the conditions for distortion less transmission in continuous time LTI systems and discrete time LTI systems? 5
- (c)(i) A three-phase star-connected synchronous generator is rated at 1.5 MVA and 11 kV. The armature effective resistance and synchronous reactance are 1.2 ohms and 25 ohms respectively per phase. Calculate the percentage voltage regulation for a load of 1.4375 MVA at (1) 0.8 power factor lagging and (2) 0.8 power factor leading. 10
- (c)(ii) Explain qualitatively with sketches as to how armature reaction effect in a synchronous machine can be modeled as an inductive reactance. 10

- (d)(i) In a trapezoidal pattern displaying modulation, the length of the long vertical side is 5 cm, and of the short vertical side, 2 cm. Determine the modulation depth. 5
- (d)(ii) Explain Foster-Seeley discriminator circuit with the help of phasor diagram. 10
- (d)(iii) Describe transmission & radiation modes of helix. 5
6. (a)(i) Find the inverse z-transform of

$$x(z) = ((e^{-2} - 2)z) / ((z - e^{-2})(z - 2))$$

 Where $|z| > 2$ and $e^{-2} < |z| < 2$. 7
- (a)(ii) Obtain the three-dimensional wave equation for an absorbing medium, assumed to be both magnetically and electrically homogenous and isotropic. The charge density in the field may be assumed to be zero. Hence, determine the wave equation if the field is varying harmonically with time. 8
- (a)(iii) A sequential circuit has one input and one output. The state diagram is shown in the figure. Design the sequential circuit using D flip-flop.
 [Figure: State diagram with five states 000, 001, 010, 011, 100; transitions labelled input/output: 001 → 001 on 0/0 (self-loop), 001 → 100 on 1/1; 100 → 011 on 1/0, 100 → 010 on 0/0; 011 → 001 on 0/0, 011 → 010 on 1/1; 010 → 010 on 0/0 (self-loop), 010 → 000 on 1/1 (printed "1/3"); 000 → 100 on 1/1; a line labelled 0/0 joins 011 and 000 (arrowhead direction unclear in the scan, probably 000 → 011) [?].] 5
- (b)(i) Three regular dice are thrown. Assign probabilities to the following events. The sum of the points appearing on three dice is 4; 9; and 15. 10
- (b)(ii) Explain central limit theorem. 10
- (c)(i) Explain the term 'virtual height' with respect to ionospheric transmission. Calculate the transmission-path distance for an ionospheric transmission that utilizes a layer of virtual height 200 km. The angle of elevation of the antenna beam is 20°. Consider flat earth. 10
- (c)(ii) Explain varactor diode. Give its equivalent circuit. Give its application. 10
7. (a)(i) Explain the different input statements in SPICE. 5
- (a)(ii) Design an m-derived π -section high-pass filter having characteristic impedance 600 Ω , cut-off frequency 5 kHz and infinite attenuation at 4 kHz. 10
- (a)(iii) Using a bipolar 32×8 PROM, implement the following equations simultaneously:
 $F_1 = \sum m(0,1,3,5,7,21)$; $F_2 = \sum m(2,3,4,7,11,12,15,26)$; $F_3 = \sum m(8,9,11,13,20,23)$ 5
- (b)(i) Describe 'third method' of generating an SSB-SC signal. 10
- (b)(ii) Explain envelop detector circuit with input and output waveforms. 10
- (c)(i) Draw and explain construction details of reflex klystron. Explain electronic tuning. 10
- (c)(ii) Explain test setup for VSWR measurement. 10
8. (a)(i) Find the CTFS harmonic function for the signal $x(t) = 4 + 2\cos(20\pi t) - 3\sin(40\pi t)$ by sampling above the Nyquist rate over exactly one fundamental period and finding the DTFS harmonic function of the samples. 10
- (a)(ii) Find the input impedance Z of the circuit shown below, $\omega = 1000$ rad/s.
 [Figure: From the upper input terminal: 8 mH inductor (dot at its input-terminal end) in series with a 1/6 μ F capacitor to node X; from X a 6 mH inductor (dot at its top end) to the bottom (lower input terminal) wire, and a 3 Ω resistor also from X to the bottom wire (in parallel with the 6 mH coil); mutual inductance 5 mH between the 8 mH and 6 mH coils; Z is the impedance seen at the input terminals.] 5
- (a)(iii) Draw the circuit diagram of voltage-to-current converter with floating load using op-amp. Derive the necessary equation. 5
- (b)(i) Describe the effect on the speed-torque characteristic of a 3-phase induction motor by (1) reducing the applied voltage to half the normal voltage but normal frequency and (2) reducing both applied voltage and frequency to half the normal value. 10

- (b)(ii)** A 4-pole, 50 Hz, 3-phase induction motor has a rotor resistance of 4.5 ohms per phase and a standstill reactance of 8.5 ohms per phase. With no external resistance in the circuit, the starting torque of the motor is 85 Nm. Calculate (1) the rotor voltage at standstill, (2) starting torque if a resistance of 2 ohms is added in each rotor phase. **10**
- (c)(i)** Describe single-phase d.c. drive considering a phase-controlled converter supplying a d.c. motor load. With the help of a circuit diagram, explain the operation of a single-phase full converter circuit feeding a separately excited motor. **12**
- (c)(ii)** A d.c. drive runs at 900 r.p.m. on no load when fed at 200 V d.c. from a full converter. Calculate the triggering angle of the converter thyristors if the motor has to run at 600 r.p.m. on no load. Input to the converter is 230 V a.c. Neglect $I_a R_a$ drop. **8**