

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. (a) Determine the transmission matrix for the circuit shown and explain why open circuit impedance parameters can not be defined for this circuit.
 [Figure: Two-port network: a single series impedance Z connected between the upper input terminal (port 1, +) and the upper output terminal (port 2, +); the lower terminals of the two ports (both -) are joined by a straight wire. V_1 across port 1, current i_1 entering at the upper port-1 terminal (arrow towards Z); V_2 across port 2, current i_2 entering at the upper port-2 terminal (arrow towards Z)] 12
- (b) Using duality property show that the Fourier transform of $[1/(1+j2\pi t)]$ is equal to $e^f u(-f)$ where $u(t)$ is the unit step. 12
- (c) A continuous time signal is given by

$$x(t) = A \cos(8000 \pi t) \cos(2000 \pi t)$$
 The signal is sampled with a sample period of 3×10^{-4} seconds. Can we recover the signal from the sampled version using an appropriate low pass filter? 12
- (d) A lossless transmission line having a length of 100 metre is terminated by a resistive load of 200 ohms. It is fed by a generator of voltage $\angle 0^\circ$ volts and has impedance 100 ohms. If characteristic impedance of the line is 300 ohms, calculate the transmission loss and return loss in decibels. 12
- (e) Assuming ideal op-amps, determine the expression for the input impedance of the given circuit and a simple passive equivalent of the circuit looking into terminal ①.
 [Figure: Terminal ① (+) and a lower return terminal (-) with V_{in} between them and input current i_{in} flowing into terminal ①. Terminal ① is connected to the non-inverting (+) input of op-amp 1, whose inverting (-) input is tied to its own output (voltage follower). The output of op-amp 1 goes through capacitor C_o to a node X; resistor R_1 is connected from X to the lower (-) terminal line. Node X is connected to the non-inverting (+) input of op-amp 2, whose inverting (-) input is tied to its own output (voltage follower). Resistor R_2 is connected between terminal ① (input line) and the output of op-amp 2] 12
2. (a) Show that there can be no value of R_L in the circuit given in Fig. that will make it resonant.
 [Figure: Two input terminals (top and bottom) feeding two parallel branches: branch 1 – variable resistor R_L in series with an inductor of reactance $j10 \text{ ohm}$; branch 2 – a 4Ω resistor in series with a capacitor of reactance $-j5$] 20
- (b) A system consists of two blocks connected in cascade. The first block has impulse response $h_1(t) = 2u(t)$. The second block is shown below: Find the impulse response of the overall system using the relation $h(t) = h_1(t) * h_2(t)$.
 [Figure: Second block (two-port): series inductor L in the upper line from the input terminal to the output terminal; a shunt element across the output, drawn with a capacitor symbol but labelled R ; lower line common between input and output. Input terminals on the left, Output terminals on the right] 20
- (c) Determine the output current of the Widlar current source; given that $\pm V = \pm 15$ volts, $I_{C_0} = 10^{-14}$ amp., $\beta = 200$, $V_T = 25$ mV. 20

[Figure: Widlar current source: p-n-p transistor Q_1 (emitter at the top, connected to the +V rail, emitter arrow pointing in) with its base and collector shorted (diode-connected); from the collector of Q_1 a 39 k Ω resistor (current I_{in} flowing downwards) to the collector of Q_2 ; Q_2 is an n-p-n transistor with base and collector shorted (diode-connected) and its emitter connected to the -V rail; the base of Q_2 is connected to the base of Q_3 ; Q_3 (n-p-n) emitter goes through a 5 k Ω resistor to -V; the collector of Q_3 goes upwards (dotted line) to the load, carrying output current I_o (downwards)]

3. (a) (i) Find Y and Z parameters for the following circuit: (ii) State Tellegen's theorem for network analysis.

[Figure: Two-port: from the upper port-1 terminal (+, current I_1 entering) a current-controlled voltage source $5I_2$ (diamond, + on the port-1 side, - on the right) in series to a node X; node X is connected directly (short circuit) to the lower common wire (node shown by a small circle); from node X a 2 Ω resistor to the upper port-2 terminal (+, current I_2 entering); V_1 across port 1, V_2 across port 2; the lower wire is common to both ports]

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- (b) A particular lossless material has $\mu_r=4$ and $\epsilon_r=9$. A 10 MHz uniform plane wave is propagating in the a_y direction with $E_x=400$ V/m and $E_y=E_z=0$ at P(0.6, 0.6, 0.6) at $t=60$ ns. Determine:– (i) β , λ , v_p and η (ii) $E^x(t)$ (iii) $H(t)$.

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- (c) Figure shows a sinusoidal oscillator. By an appropriate analysis, determine the condition of oscillation and frequency of oscillation in terms of circuit elements assuming ideal op-amps.

[Figure: Three op-amp stages in cascade with an overall feedback loop. Stage 1: from the input node R_o to the inverting (-) input and C_1 to the non-inverting (+) input; R_1 from the (+) input to ground; feedback resistor R_o from the output to the (-) input. Stage 2 (fed from stage 1 output): identical with R_o (input to -), C_2 (input to +), R_2 from (+) to ground and feedback R_o . Stage 3: inverting amplifier with input resistor R_3 from stage 2 output to the (-) input, feedback resistor R_4 from output to (-) input, (+) input grounded; its output is V_o , which is also fed back by a wire to the input node of stage 1]

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4. (a) The block diagram of a discrete time LTI system is given below: Determine the transfer function $H(z)$.

[Figure: $x(n)$ enters adder A1 whose output $w(n)$ passes through a delay z^{-1} to node $w(n-1)$ and a second z^{-1} to node $w(n-2)$; $w(n-1)$ through gain $-1/3$ and $w(n-2)$ through gain $1/6$ enter adder A2, whose output is added back into A1. Node $w(n)$ feeds two parallel branches: upper – gain $2/3$ into adder A3; the output of A3 goes through z^{-1} and gain $-1/3$ back into A3; lower – gain $1/3$ into adder A4; the output of A4 goes through z^{-1} and gain $1/6$ back into A4. The outputs of A3 and A4 are added in adder A5 to give $y(n)$]

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- (b) A 50 ohm lossless line connects a matched signal of 100 kHz to a load of 100 ohm. Load power is 100 mW. Estimate: (i) Voltage reflection coefficient of load. (ii) VSWR of the load. (iii) Position of first V_{min} and V_{max} . (iv) Impedance at V_{min} and V_{max} and values of V_{max} and V_{min} . Define the terms Attenuation loss, Reflection loss, Transmission loss, Return loss and Insertion loss.

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- (c) Explain the operation of the given circuit by sketching relevant waveforms assuming that positive and negative saturation levels of output voltage of the op-amp comparator are $+V_{sat}$ and $-V_{sat}$ respectively and are not equal. Determine an expression for the frequency of the generated output voltage.

[Figure: Op-amp (supplies +V and -V) astable circuit: resistor R from the output V_o to the inverting (-) input; capacitor C from the (-) input to ground; resistor R_b from the output to the non-inverting (+) input; resistor R_a from the (+) input to ground]

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SECTION 'B'

5. (a) Show how a D flip-flop can be converted to SR flip-flop. 12
- (b) Convert decimal 65,535 to its hexadecimal and binary. 12
- (c) A 2-pole full pitch concentrated coil of n turns is placed in the stator of an electric machine in two slots diagonally opposite to each other. A permanent magnet 2-pole rotor is rotating at N rpm producing a flux per pole ϕ with its flux density sinusoidally varying in space in the airgap. At time $t=0$ rotor field axis is in line with the stator coil axis. Write an expression for the flux linking the stator coil as a function of time. Derive from this expression the r.m.s. value of the voltage induced in the stator coil. Draw the waveform of flux linkage and voltage generated. Write expression for frequency of voltage in terms of speed. 12

- (d) Draw the simplified circuit diagram for a voltage step-up DC-converter and show that when duty cycle is zero, the output of DC-converter is equal to source voltage whereas DC voltage is infinity if the duty cycle is unity. 12
- (e) Evaluate whether the following function given by expression

$$f_X(x) = \begin{cases} 0 & \text{for } x < 2 \\ 1/18(3+2x) & \text{for } 2 \leq x \leq 4 \\ 0 & \text{for } x > 4 \end{cases}$$
is a probability density function (PDF). 12
6. (a) Indicate how many flip-flops are required to construct each of the following counters: (i) mod-3 (ii) mod 6 (iii) mod-9. 20
- (b) Two winding 10 kVA, 500/50 V transformer is converted to an auto-transformer to obtain the rating of: (i) 550/50 V, (ii) 500/550 V, and (iii) 500/450 V. Compute the kVA rating of auto transformer for the above connections, VA transferred conductivity and magnetically. 20
- (c) (i) Consider a superhet receiver with $f_{Lo} = f_e + f_{IF}$, $f_{IF} = 455$ kHz, $f_e = 2$ MHz. The RF amplifier is preceded by a first order RLC band pass filter with $f_o = 2$ MHz and $B = 0.5$ MHz. Assume the IF-BPF is nearly ideal and mixer has unity gain. What is the minimum spurious frequency input rejection ratio in dB? (ii) If the above receiver has a LO with a second harmonic whose voltage level is half that of the fundamental component, determine what input frequencies will be accepted and at what power level in dB as compared to the correct input. 20
7. (a) What would be the binary address for a memory system having a capacity of 10^{24} bits. For the above memory system, what is the decimal address for the binary address 1011001101? What is the address in hexadecimal? 20
- (b) (i) Explain with diagram the soft starting of induction motor to start from zero speed to rated speed. Briefly compare with a star-delta starter used for the same purpose. (ii) A 3-phase, 4-pole 50 Hz induction motor is controlled by a variable frequency inverter that maintains the ratio of voltage to frequency across the motor constant. Torque-speed curve in stable region is a straight line. It has a maximum torque of 2 p.u. and slip speed at maximum torque at all frequency is constant at 150 rpm. Draw a family of Torque speed characteristics (on a graph paper) at 10, 20, 30, 40 & 50 Hz with usual assumptions. It is driving a load whose torque is directly proportional to speed giving rated torque at 50 Hz. Graphically calculate speeds at all the above frequencies. 20
- (c) (i) In an FM system, when the audio frequency (AF) is 500 Hz and AF voltage is 2.4 V, the deviation is 4.8 kHz. If the AF voltage is now increased to 7.2 V, what is the new deviation? If the AF voltage is raised to 10 V while AF is dropped to 200 Hz, what is the deviation? Evaluate modulation index in each case. (ii) If $x(t) = \cos 200 \pi t$, determine AM transmission bandwidth B_T and average transmitted power S_T for the AM modulated signal assuming $A_c = 10$ and μ (modulation index) = 0.6. What will be the values of B_T and S_T in the case of DSB transmission? 20
8. (a) A d.c. shunt motor is driving a constant torque load. If the voltage across the motor is halved explain how the armature current and speed would be changed. 20
- (b) A 11 kV dc source having internal resistance of 1 ohm supplies 600 A to a 5 kV, 3 phase, 6-pulse 50 Hz inverter. Compute the: (i) reactive power absorbed by the inverter, (ii) effective value of the ac line current, (iii) the required firing angle, (iv) dc voltage generated by the inverter, and (v) dc current carried by each SCR. 20
- (c) (i) A commercial FM radio station alternates between music and talk show/call in formats. The broadcasted CD music is band limited to 15 kHz based on convention. Assuming D (deviation ratio) = 5 is used for both music and voice, what percentage of the available transmission bandwidth is used during the talk show if we take $W = 5$ kHz for voice signals? (ii) An AM system with envelope detection has $(S/N)_D = 30$ dB under full load tone modulation condition with $W = 8$ kHz. If all bandwidths are increased accordingly, while 20

other parameters are held fixed, what is the largest usable value of W ?