

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)(i) The current

$$i(t)=2t \ 0 \leq t \leq 1; =-2t+4 \ 1 \leq t \leq 2; =0 \text{ otherwise}$$
 is passed through a capacitor of 0.5 farad. Find the expression for the voltage across the capacitor in the time interval $1 \leq t \leq 2$. 5
- (a)(ii) In the circuit given below, A and B are mutually coupled coils. Determine coefficient of coupling K between them so that the circuit is in resonance.
 [Figure: Series circuit between two open terminals: resistor 10, capacitor $-j20$, coil A ($j8$) and coil B ($j10$) in series; coupling coefficient K marked between coils A and B; no dots shown] 5
- (a)(iii) Three identical impedances of $5 \angle -30^\circ$ ohms are connected in star to a 3-phase, 4-wire, 400 volts cba system. Express the current in phase 'a' in phasor form, assuming V_{bc} as a reference phasor. 5
- (b) For the circuit shown in the figure, assume $\beta = h_{FE} = 100$. 10
- (b)(i) Find if the silicon transistor is in cut-off, saturation or in the active region. 10
- (b)(ii) Find v_o .
 [Figure: PNP transistor Q: collector connected through 3 K to the -10 V supply, output v_o taken at the collector; emitter connected through $R_e = 500 \ \Omega$ to ground; base connected through 7 K to the negative terminal of a 3 V battery whose positive terminal is grounded] 5
- (c)(i) Explain differential compounding of a d.c. machine. 5
- (c)(ii) Which type of compounding is not commonly used? Why? Explain with relevant characteristics for a motor and a generator. 10
- (d)(i) Explain the mathematical expressions for statistical average, mean, variance and correlation coefficient of a random variable. 6
- (d)(ii) Explain, using analytical expressions, stationarity, time averages and ergodicity. 9
2. (a)(i) Using Fourier transforms, find the impulse response of the system described by the equation

$$y'(t) + 3y(t) = x(t) + 3x'(t)$$
 where x is an input and y is an output. 10
- (a)(ii) Using z transforms, obtain the convolution sum of two sequences, $y(n) = x_1(n) * x_2(n)$, where

$$x_1(n) = \{1 \ 2 \ -1 \ 0 \ 3\}$$

$$x_2(n) = u(n) - u(n-3)$$
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$u(n)$ is a unit step sequence.

(b) The figure below shows a divide-by- N counter.

(b)(i) Find N . Assume initial value of $Q_0=1$, $Q_1=0$ and $Q_2=0$.

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(b)(ii) Repeat Part (i), if initially $Q_0=1$, $Q_1=0$ and $Q_2=1$.

[Figure: Synchronous counter of three JK flip-flops (FF2, FF1, FF0 from left to right), the common Clock line connected to all three Ck inputs; $Q_2 \rightarrow J_1$, $\bar{Q}_2 \rightarrow K_1$; $Q_1 \rightarrow J_0$ (crossing the vertical feedback line without connection); $\bar{Q}_1 \rightarrow K_0$ and also, from a junction dot on the $\bar{Q}_1$ line, fed back up and over the top to J_2 ; Q_0 fed back along the bottom to K_2 ; $\bar{Q}_0$ unconnected]

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(c)(i) A d.c. series motor is powered by a d.c. chopper. The armature resistance is $R_a=0.03$ ohm and the field resistance $R_f=0.05$ ohm. The back e.m.f. constant of the motor is $K_v=15.27$ mV/A-rad/s. The average armature current $I_a=450$ A. The armature current is continuous and has negligible ripple. If the duty cycle of the chopper is 75%, determine– 1. the input power from the source; 2. the equivalent input resistance of chopper drive; 3. the motor speed.

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(c)(ii) Give the circuit of a single-phase half-bridge inverter. Draw the load current waveform for a highly inductive load. Explain the purpose of the feedback diodes.

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3. (a) Construct circuits using diodes which exhibit terminal characteristics as shown in Part (i) and Part (ii) of the figure below. Assume diodes to be ideal.

[Figure: Two I-V characteristics. Part (i): $I=0$ for $-V_1 \leq V \leq V_1$; for $V > V_1$ a straight line of positive slope rising from $(V_1, 0)$; for $V < -V_1$ a straight line of positive slope falling from $(-V_1, 0)$ into negative current. Part (ii): vertical jump at $V=0$ from $-I_1$ to I_1 (along the I-axis); for $V > 0$ a straight line of small positive slope starting at $(0, I_1)$; for $V < 0$ a straight line of small positive slope ending at $(0, -I_1)$]

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(b)(i) Explain the phenomenon of hunting in a synchronous machine.

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(b)(ii) A 3-phase, star-connected alternator is rated at 1600 kVA, 13.5 kV. The effective armature resistance and synchronous reactance are 1.5 ohms and 30 ohms per phase respectively. Find the regulation for a load of 1280 kW at rated voltage and 0.8 lagging power factor.

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(c) A plane wave in free space ($z \leq 0$) is incident normally on a large block of material with $\epsilon_r=12$, $\mu_r=3$ and $\sigma=0$ which occupies $z \geq 0$. If the incident electric field is

$$E=30\cos(\omega t-z) \hat{a}_y \text{ V/m}$$

determine– (i) the standing wave ratio; (ii) the reflected magnetic field. [$\mu_0=4\pi \times 10^{-7}$ H/m]

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4. (a)(i) For the circuit shown below, determine the numerical value of i_1 , using nodal analysis.

[Figure: Ground at the bottom line. Node A (top left): connected to ground through 0.5Ω in series with a 2 V source (+ towards node A). Current i_1 flows from node A to node B through 1Ω . Node B: 0.5Ω to ground, and a 1 A current source from ground into node B (arrow upwards). Node B to node C through 1Ω . Node A to node C directly through 2Ω (top wire). Node C: 1Ω to ground, and a 2 V source to ground (+ towards node C)]

12

(a)(ii) For the network shown below, write mesh equations in vector-matrix form for the loop currents i_1 and i_2 . Assume mutual inductances between coils L_1 & L_3 and coils L_2 & L_3 as M_{13} and M_{23} respectively.

[Figure: Two-mesh network. Left mesh: source $v(t)$ (+ at top), R_1 and L_1 in the top branch to the middle node; the shared middle branch is L_3 in series with R_2 to the bottom line. Right mesh: L_2 in the top branch from the middle node, R_3 on the right side down to the bottom line. Mesh currents i_1 and i_2 both clockwise. Dot markings: round dot at the left (source-side) end of L_1 and round dot at the top end of L_3 (pair L_1 - L_3); square marker at the right end of L_2 and square marker at the top end of L_3 (pair L_2 - L_3)]

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(b)(i) How are choppers classified, based on direction of current and voltage? Indicate with v_L - i_L diagrams.

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(b)(ii) For a step-down chopper, derive an expression for peak-to-peak ripple current in terms of supply voltage V_s , output voltage V_o , frequency of operation and inductance.

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(c)(i) An AM wave

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$$15[1+0.4\cos 2\pi 10^3 t]\cdot \cos 2\pi 10^6 t$$

is to be detected by a linear diode detector. 1. Find the time constant, τ . 2. Find the value of R , if the capacitor used is 100 pF.

- (c)(ii) An FM signal defined as

$$x_c(t) = A_c \cos[\omega_c t + k_f \int_{-\infty}^t m(t) dt]$$

is applied to a high-pass RC filter, where $RC \ll 1/\omega$ for ω representing the FM frequency band. Show if an envelope detector after the filter can demodulate the FM signal.

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SECTION 'B'

5. (a)(i) Sketch the function

$$f(n) = u(n+4) - u(n)$$

and express it as a sum of shifted unit impulses. $u(n)$ is a unit step sequence.

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- (a)(ii) A series RC circuit with $R=1 \Omega$, $C=1 \text{ F}$ is excited by input $r(t)=e^{-2t}u(t)$. Obtain the expression for voltage across the capacitance in time domain, using the impulse response of the system.

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- (a)(iii) Determine Laplace transform of the function $f(t)$ shown below.

[Figure: Triangular pulse $f(t)$: rises linearly from 0 at $t=0$ to 2 at $t=1$, falls linearly to 0 at $t=2$, zero elsewhere]

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- (b) Realize a half-adder circuit using only NOR gates.

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- (c) With a neat circuit diagram, explain the operation of a 180° variable half-wave rectifier along with its gate trigger circuit.

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- (d)(i) Define the following: Skin depth; Intrinsic impedance; Phase velocity; Group velocity; Surface impedance.

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- (d)(ii) In a medium

$$E = 16e^{-0.05x} \sin(2 \times 10^8 t - 2x) \text{ a}_z \text{ V/m}$$

Determine the skin depth.

$$[\epsilon_0 = (10^{-9})/36\pi \text{ F/m}]$$

5

6. (a)(i) A Bridge-T network is made up of four capacitances, each having a value of 1 farad. Determine y parameters of this network, assuming that this Bridge-T network can be treated as parallel interconnection of two two-port networks.

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- (a)(ii) For the network shown below, determine R_L which will receive maximum power.

[Figure: Left: 15 V source (+ at top) with current I_1 flowing from its + terminal through a 5Ω resistor to node X; 10 A current source from the bottom line up into node X; from node X a current-controlled voltage source $10I_1$ (diamond, + on the node-X side, - on the right) in series with the load R_L (between two terminals), then a 1Ω resistor and a 10 V source (+ at top, - to the bottom line); the bottom line joins all the negative terminals]

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- (b)(i) An n - p - n silicon transistor is used in a common-collector circuit as shown in the figure below. The circuit component values are $V_{CC}=3.0 \text{ V}$, $R_e=1 \text{ K}$, $R_1=R_2=5 \text{ K}$. If $\beta=44$, find the quiescent point.

[Figure: Common-collector (emitter follower) bias circuit: collector connected directly to $V_{CC}=3.0 \text{ V}$; voltage divider $R_1=5 \text{ K}$ from V_{CC} to the base and $R_2=5 \text{ K}$ from the base to ground; emitter connected through $R_e=1 \text{ K}$ to ground]

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- (b)(ii) Three identical cascaded stages have an overall upper 3-dB frequency of 20 kHz and a lower 3-dB frequency of 20 Hz. What are f_L and f_H of each stage? Assume non-interacting stages.

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- (c)(i) Explain how a separately excited d.c. generator and a d.c. shunt generator be operated below the knee of its magnetization curve.

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- (c)(ii) A series motor has an armature resistance of 0.7 ohm and field resistance of 0.3 ohm. It takes a current of 15 A from a 200 V supply and runs at 800 r.p.m. Find the speed at

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which it will run, when connected in series with a 5-ohm resistance and taking the same current at the same supply voltage.

7. (a)(i) Design a combinational logic circuit which produces an output equal to '1' if the input variables have more 1's in the sequence than 0's. The output is zero otherwise. Design the circuit for three variable inputs. Draw the realization. **10**
- (a)(ii) The waveforms shown in the figure below are applied to– 1. positive edge-triggered SR flip-flop; 2. master-slave SR flip-flop. Draw the output waveforms in each case.
[Figure: Timing diagram. Clock: five positive pulses; the edges are labelled in order a (rising), b (falling), c (rising), d (falling), e (rising), f (falling), g (rising), h (falling), i (rising), j (falling). S: low at first, goes high shortly before a, goes low between b and c, high between d and e, low between f and g, high between g and h, low between h and i, and stays low to the end. R: low at first, goes high between b and c (at the same instant S goes low), low between c and d, high between f and g (at the same instant S goes low), low between g and h (at the same instant S goes high), high again between i and j and stays high to the end]
- (b)(i) Distinguish between voltage-controlled power devices and current-controlled power devices with examples. **6**
- (b)(ii) What are the characteristic features of a GTO in relation to a thyristor? **8**
- (b)(iii) Distinguish between the minimum current required to turn-on a thyristor and the minimum current to keep the thyristor in conduction. Explain with reference to the static characteristics of a thyristor. **6**
- (c)(i) Explain sensitivity, selectivity, fidelity and tracking in super-heterodyne receiver with relevant diagram. **6**
- (c)(ii) What is tracking error in super-heterodyne receiver? How is receiver aligned to achieve three-point tracking? **6**
- (c)(iii) Bring out the SSB spectrum with modulating signal

$$m(t) = \cos 2\pi 1500t + \cos 2\pi 3000t$$
and carrier is

$$c(t) = \cos 2\pi 15000t$$
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8. (a)(i) A signal $x(t) = 1 + \cos 100\pi t$ is sampled with sampling interval of 0.02 second. Can the original signal be recovered from these samples? **5**
- (a)(ii) Find z transform of the function

$$f(n) = a^n \cos(n\pi/2) u(n)$$
Sketch its RoC. **8**
- (a)(iii) Determine Fourier transform of the function $f(t) = e^{-a|t|}$. Sketch its magnitude spectrum. Assume $a > 0$. **7**
- (b)(i) A single-phase, 50 Hz, 1200/120 V transformer gave the following results of open-circuit test with high-voltage winding open circuited–applied voltage 120 V, current 16 A, power input 400 W. Find magnetizing and core-loss components of no-load current. **8**
- (b)(ii) The power input to a 50 Hz, 4-pole induction motor running at 1442 r.p.m. is 60 kW. Find the total mechanical power developed and the rotor copper loss per phase, if the total stator loss is 1 kW. **12**
- (c)(i) What is characteristic impedance of a transmission line? Write the expression of characteristic impedance of lossless line and distortionless line in terms of the primary constants R, L, G, C of the transmission line. What is the relation between characteristic impedance and input impedance of a matched line? **8**
- (c)(ii) Explain the use of quarter-wave transformer for transmission line matching. **6**
- (c)(iii) A lossless transmission line having characteristic impedance of 500Ω is connected to a load Z_L . Determine the reflection coefficient and transmission coefficient. **6**