

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) The figure shows an equivalent circuit of a small two winding transformer in terms of the primary.
 [Figure: T-equivalent circuit referred to the primary, between a pair of input terminals (left) and a pair of output terminals (right) joined by a common bottom wire: on the top line from the left input terminal, $2\ \Omega$ resistor in series with $1\ \text{H}$ inductor to a junction; from the junction, $1\ \text{H}$ inductor in series with $2\ \Omega$ resistor to the right output terminal; shunt (magnetising) inductor $24\ \text{H}$ from the junction down to the bottom wire. A dashed vertical line through the shunt branch marks "Primary side" (left) and "Secondary side (equivalent)" (right).]
 If the self inductance L_2 of the secondary is $16\ \text{H}$, estimate the following
 - (a)(i) The actual winding resistance of the secondary. 6
 - (a)(ii) The secondary open circuit voltage with primary supplied with $220\ \text{V a.c.}$ 6
 - (a)(iii) The mutual inductance M , between the primary and the secondary. 8
 - (b) Write the integral form of Maxwell's equations and identify each equation with the proper experimental law. 20
 - (c) A synchronous motor is running idle on an infinite bus at its rated voltage and frequency. It is excited to have an induced voltage of 125% and its synchronous impedance is $(1 + j20)\%$. Calculate (i) the stator current, and (ii) its phase with respect to the bus voltage. Where would such idle runs be useful? 20
 - (d) A super heterodyne receiver uses an IF frequency of $455\ \text{kHz}$. The receiver is tuned to a transmitter having a carrier frequency of $1350\ \text{kHz}$. Give two permissible frequencies of the local oscillator and the image frequency for each. 20
2. (a) A filter has transfer function $H(f) = \text{rect}(f/2B)$. Where

$$\text{rect}(x) = \begin{cases} 1 & |x| < 1/2 \\ 0 & \text{elsewhere} \end{cases}$$
 An input $x(t) = 2W \text{ sinc}(2Wt)$ is applied to this filter, where $\text{sinc}(x) = \sin \pi x / \pi x$
 - (a)(i) Find the output $y(t)$ for $W < B$. 7
 - (a)(ii) Find the output $y(t)$ for $W > B$. 7
 - (a)(iii) In which case does the output suffer distortion? Justify your answer 6
 - (b) A d.c. shunt generator supplies the full load current of $50\ \text{A}$ at $500\ \text{V}$. Assume its field is drawing $2\ \text{A}$, and the armature voltage drop is 5% . The generator is being driven at the rated speed of $1500\ \text{rpm}$, and is working at an efficiency of 80% . Estimate (i) the speed at which it will run and (ii) the efficiency when the machine is working as a motor, drawing 20

50 A from a 500 V d.c. source Assume the rotational losses, (the iron, friction and windage losses) vary as the square of the speed.

(c)

(c)(i) Germanium and silicon are both semi-conducting materials and we have both diodes and triodes with germanium as well as silicon. However, in respect of controlled rectifiers, we have only silicon-controlled rectifiers but no germanium-controlled rectifiers. Explain why.

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(c)(ii) Use the two transistor equivalent circuit of the SCR and show that when reverse biased the SCR cannot conduct even if it is triggered.

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3. (a) A locker can be opened by A and B when they are both there, as the locker has 2 keys, one of which is with A and the other with B. C has both the keys, but he is permitted to open the locker only when B is not there. Show that the locker can be opened always if both A and C are there. Give the Boolean identity that symbolises this situation.

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(b) With respect to full load current why does an induction motor take higher no-load current than a transformer? A 3-phase induction motor draws 25 A from 460 V 3- phase line at a p.f. of 0.85 lagging. The stator copper loss is 1 kW, and the rotor copper loss is 500 W. The rotational losses due to windage and friction are 250 W, core loss is 800 W, and stray load loss is 200W. Calculate (i) the air gap power P_g , (ii) the developed mechanical power, (iii) the output horse power, and (iv) the efficiency.

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(c) Explain the principle of pulse with modulated inverters for induction motor control. What is the purpose of using pulse width modulation in this context?

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4. (a) Obtain the conditions under which the circuit below produced oscillations

[Figure: Op-amp Wien-bridge oscillator. The op-amp output (terminal of v_o , measured with respect to the bottom ground wire) is connected to a top wire. From the top wire: (1) resistor R in series with capacitor C down to node P; node P connected to the non-inverting (+) input; resistor R and capacitor C in parallel from node P to the bottom (ground) wire; (2) resistor R_1 from the top wire down to node Q; node Q connected to the inverting (-) input; resistor R_2 from node Q to the ground wire. v_o is taken between the output and ground.]

What is the frequency of oscillations?

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(b) Define directive gain and directivity of an antenna. The radiation intensity of a certain antenna is

$$U(\theta, \phi) = [4 \sin \theta \sin^3 \phi \quad 0 \leq \theta \leq \pi, 0 \leq \phi \leq \pi; 0 \text{ elsewhere}]$$

Determine the directivity of the antenna.

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(c)

(c)(i) An AM modulator has output $x(t) = 30 \cos 2\pi(200)t + 6 + \cos 2\pi(180)t + 6 \cos 2\pi(220)t$. Determine the modulation index and efficiency.

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(c)(ii) An upper sideband SSB modulator has the message signal $m(t) = A_m \cos \omega_m t$. The unmodulated carrier is given by $c(t) = A_c \sin \omega_c t$. Sketch the modulator output $x(t)$.

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SECTION 'B'

5. Answer any three of the following:

(a) Consider the op-amp circuit shown.

[Figure: Op-amp circuit: input v_i through resistor R_1 to the inverting (-) input; feedback resistor R_2 from the inverting (-) input node to the output v_o ; the non-inverting (+) input connected to ground through an unlabelled resistor.]

In the circuit make the usual assumption that (i) the inverting and non-inverting terminals are virtually at the same potential and (ii) the op - amp does not take any input current at its terminals. You would arrive at the normal conclusion that $v_o = -v_i/R_1.R_2$. Is this conclusion valid? If yes give reasons why operational amplifiers are never used in this manner with inverting input grounded and input to be amplified given to the

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non-inverting terminal.

- (b) Use the properties of the unit impulse function $\delta(t)$ to evaluate the following integrals
- (b)(i) $\int_{-\infty}^{\infty} [t^2 + \cos \pi t] \delta(t-5) dt$ 10
- (b)(ii) $\int_{-\infty}^{\infty} [e^{-\pi t} + (10 \cos \pi t)] \delta(2t+1) dt$ 10
- (c) Describe any brushless excitation system for large alternators. Explain the working. 20
- (d) What is a Hertzian dipole? Find the radiation resistance of a Hertzian dipole. 20
6. (a) A standard air-filled rectangular waveguide with dimensions $a = 8.6$ cm and $b = 4.3$ cm is fed by 4 GHz carrier from a coaxial cable. Determine if a TE_{10} mode will be propagated. If so, calculate the phase velocity and the group velocity. 20
- (b) An FM modulator has input $m(t) = 4 \cos 10 \pi t$. The peak frequency deviation is 25 Hz. The modulator is followed by an ideal band pass filter with a center frequency given by the carrier frequency and a bandwidth of 54 Hz. Determine the power at the filter output assuming that the modulator output power is 100 W. Express the answer in terms of appropriate Bessel function values. 20
- (c) In a certain region with $\sigma=0$, $\mu=\mu_0$ and $\epsilon=6.25 \epsilon_0$, the magnetic field of an EM wave is $\vec{H} = 0.6 \cos \beta x \cos 10^8 t \vec{a}_z$ A/m Find the phase constant β and the corresponding $\vec{E}$ (electric field) using Maxwell's equations. 20
7. (a) Devise a 4-bit odd parity generator function using 3-level NOT-NOR-NOR logic. 20
- (b) A delta modulator has the message signal $m(t) = 6 \sin 2\pi(10)t + 4 \sin 2\pi(20)t$. Determine the minimum sampling frequency required to prevent slope overload, assuming the step size to be 0.1 m. 20
- (c) In a non-magnetic medium $\vec{E} = 5 \sin(2\pi \times 10^7 t - 0.8x) \vec{a}_z$ V/m Find
- (c)(i) relative permittivity and intrinsic impedance. 10
- (c)(ii) the time average power carried by the wave. 10
8. (a) N_1 and N_2 are two 2-port networks connected in parallel on both input port side as well as output port side, to form a composite 2 - port network N as indicated
[Figure: Composite two-port N (dashed box): the pair of input terminals of N ("Input port") feeds, in parallel, the input port of two-port N_1 (upper) and the input port of two-port N_2 (lower); the output ports of N_1 and N_2 are connected in parallel to the pair of output terminals of N ("Output port").]
 N_1 and N_2 are defined by the Z-parameters as below $[Z_{N1}] = \begin{bmatrix} 4 & 3 \\ 3 & 5 \end{bmatrix} \Omega$, $[Z_{N2}] = \begin{bmatrix} 3 & 2 \\ 2 & 4 \end{bmatrix} \Omega$ Obtain the Z-parameters for the composite 2-port network N. 20
- (b) What is all day efficiency of a transformer? Why is it necessary to calculate such efficiency? A 300 KVA transformer has a core loss of 1.5 kW and a full load copper loss of 4.5 kW. Calculate the efficiency at 75% of full load output at a p.f. of 0.8 lag. Calculate the maximum efficiency and the load at which it occurs. 20
- (c)
- (c)(i) Explain the main advantage of power MOSFETs over SCRs 5
- (c)(ii) A fully controlled bridge rectifier has a voltage of 200 V d.c applied to its input terminals as shown.
[Figure: Single-phase full bridge of four SCRs fed from a 200 V dc source (+ terminal on the top rail, - terminal on the bottom rail). Left leg: T_1 from the + rail (anode) to node A (cathode); T_2 from the - rail (anode) to node A (cathode). Right leg: T_3 from node B (anode) to the + rail (cathode); T_4 from node B (anode) to the - rail (cathode). LOAD between A and B: 20 Ω resistor in series with 1 H inductor.]
Identify the forwarded and reverse biased SCRs in the circuit. Assume the forward biased SCRs have a leakage resistance of 100 M Ω and the reverse biased SCRs have 200 M Ω . Show that each of the devices is blocking a voltage of approximately 100 V in the circuit, irrespective of whether it is forward biased or reverse biased 15