

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) A storage battery has a no-load terminal voltage of 6 V. When the current through the battery is 100 A, the terminal voltage drops to 5 V. Show a pictorial representation of the battery as a constant current source. 15
- (b) Find the Fourier transform of the signum function. 15
- (c) Three small spheres each carrying a charge q are placed on the circumference of a circle of radius r to form an equilateral triangle. Find the electric field and the potential at the centre of the circle. 15
- (d) With reference to a BJT, show that

$$\frac{\partial P_c}{\partial T_j} < 1/\theta_{JA}$$
 must be satisfied in order to prevent thermal runaway. 15
2. (a) Using Millman's theorem, find the current I in the 10-ohm resistor in Fig. 2 (a).
 [Figure: Fig. 2 (a): Ladder network with a common bottom (return) wire. Left branch: voltage source $E_1 = 24$ V (arrow upwards). From the top of E_1 a $2\ \Omega$ resistor to node P. Branch from P to the bottom wire: voltage source $E_2 = 20$ V (arrow upwards) in series with a $2\ \Omega$ resistor. From P a $2\ \Omega$ resistor to node Q; a $9\ \Omega$ resistor from Q to the bottom wire. From Q a $1\ \Omega$ resistor to node R; the $10\ \Omega$ resistor from R to the bottom wire, carrying current I (downwards)] 20
- (b) State and prove maximum power transfer theorem. 20
- (c) The switch S is closed at $t=0$ in Fig. 2 (c). Using Laplace transforms, find $i_1(t)$, $i_2(t)$ and the voltage across the inductance.
 [Figure: Fig. 2 (c): 12 V battery (current i_1 leaving its upper terminal) in series with switch S and a $2\ \Omega$ resistor to node N; a $2\ \Omega$ resistor from N to the bottom (return) wire; from N a second branch carrying i_2 through a $2\ \Omega$ resistor in series with a $1/2$ H inductor to the bottom wire, which returns to the battery] 20
3. (a) A power signal $f(t)$ has a power $S_f(\omega)$. Find the power density spectrum of the signal df/dt . 20
- (b) Fig. 3 (b) shows two identical parallel-plate capacitors connected to a battery with switch S closed. The switch S is opened and the free space between the plates of the capacitors is filled with a dielectric of dielectric coefficient $K=2$. Find the ratio of the total electrostatic energy stored in both capacitors after the introduction of the dielectric.
 [Figure: Fig. 3 (b): Battery V connected directly across capacitor C_1 ; capacitor C_2 connected in parallel with C_1 through switch S in its upper lead (S between the top of C_1 and the top of C_2)] 20
- (c) A uniform plane wave is described by the phasor $H = 2e^{(-j0.1\pi z)} \cdot \hat{a}_y$ A/m. If the velocity of the wave is 2×10^8 m/s and the relative permeability is 1.8, determine the frequency, relative permittivity, wavelength and electric intensity. 20

4. (a) Using an OP-AMP, several capacitors of 0.1 μ F and number of resistances of your choice, design a phase-shift oscillator to oscillate at 100 Hz. 20
- (b) Using IC 555 and other suitable components, draw the circuit diagram of a missing pulse detector and explain its working. 20
- (c) For the current mirror shown in Fig. 4 (c), determine the emitter current of transistor Q_3 . (Assume $\beta=100$ and $V_{BE}=0.6$ V) 20
- [Figure: Fig. 4 (c): From ground, current I flows through a 4K7 resistor to node a. Transistor Q_1 (n-p-n): collector at node a (current I_{C1}), emitter to the -10 V rail, base connected to the horizontal line just right of a (base current I_{B1}); current I_1 flows along the line from a to the base tap and I_1' onward to node b. Transistor Q_2 (n-p-n): collector at node b (current I_{C2}), emitter to -10 V, base connected to the line just right of b (base current I_{B2}); current I_2 flows from b along the line, which continues as base current I_{B3} into the base of Q_3 . Q_3 (n-p-n): collector through a 4K7 resistor to +10 V (current I_{C3} downwards), emitter to the -10 V rail (current I_{E3} downwards)]

SECTION 'B'

5. (a) Implement the following: (i) Half-adder using basic gates (ii) T flip-flop using J-K flip-flop (iii) 2 to 4 decoder using 1×4 demultiplexers 15
- (b) (i) Draw torque vs. slip curve for an induction motor. (ii) Specify the condition for a DC machine so that its rotor does not draw any current. (iii) What will be the effect on VA rating of a transformer if we double the supply frequency? 15
- (c) Draw circuit diagram for the following: (i) Three-phase FW bridge rectifier (ii) Boost switching regulator (iii) DC trigger circuit for an SCR 15
- (d) Specify the types of modulation used in the following and give reason for the same: (i) TV–video signal (ii) TV–sound signal (iii) Long-distance telephone system 15
6. (a) Convert decimal number 40 into binary and hexadecimal numbers. 20
- (b) Draw symbolic representation for +ve edge triggered clock input in a flip-flop and mark transition time by an arrow in clock input waveform for it. 20
- (c) Write the full form of FPGA and explain why it is useful for prototyping of digital circuits. 20
7. (a) A DC motor with permanent magnet field is running with 200 V DC supply and consuming 2 A current. A voltmeter is connected across its armature and DC supply is disconnected. The voltmeter reads 190 V just after disconnection of DC supply. Calculate the armature resistance of the machine. 20
- (b) Explain working of a synchronous machine as a synchronous condenser. 20
- (c) Why are the frequency and voltage both varied in the same proportion for a full-range variable speed control of AC motor? 20
8. (a) The RMS value of the antenna current before amplitude modulation is 10 A and after modulation is 12 A. Calculate the percentage modulation. Assume that there is no distortion. 20
- (b) Explain how a PLL can be used in FM detection. In what way is this scheme better than the ratio detector? 20
- (c) A receiver, connected to an antenna of resistance 50 ohms, has an equivalent noise resistance of 30 ohms. Find the noise figure of the receiver in dB. 20