

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) Prove that an ideal transformer shown below for which $v_1/v_2=n$ can be identical with a perfectly coupled transformer
 [Figure: Two magnetically coupled coils with mutual inductance M. Primary: terminals + (top) and – (bottom) with voltage v_1 between them; current i_1 flows along the top wire (arrow pointing right, towards the coil) into coil L_1 , whose dotted end is at the top; the bottom of L_1 returns to the – terminal. Secondary: coil L_2 , dotted end at the top, connected by the top wire to the + output terminal and by the bottom wire to the – output terminal, with voltage v_2 across the output terminals; current i_2 marked on the top wire of the secondary.]
 if $n=\sqrt{L_1/L_2}$, where L_1 and L_2 are the self inductances of the primary and secondary windings of the transformer and M is the mutual inductance. Discuss about the current ratio. Obtain the expression for $i_1(t)$ and conditions that the perfect transformer will be an ideal transformer. 20
 - (b) A farmer (F) has two sheds (N_1 & S_1) in his farm to keep his farm produce and belongings. He keeps vegetables (V) as farm produce, a goat (G) which can eat the vegetables and a dog (D) that can bite the goat in the absence of the farmer. The farmer along has to manage both sheds without loosing either vegetables or the goat. Suggest a logic circuit that can alarm him under any catastrophic condition by means of a buzzer. 20
 - (c) A 3-phase induction motor has an efficiency of 0.9 when the load is 37 kW. At this load, the stator copper and rotor copper loss each equals the iron loss. The mechanical losses are one-third of the no load loss. Calculate the slip. 20
 - (d) A two-tone modulating signal $e_m(t)=5\cos 2\pi \cdot 10^3 t + 4\cos 4\pi \cdot 10^3 t$ modulates a carrier voltage $e(t)=10\cos 2\pi \cdot 10^6 t$. Find various frequency components present and corresponding modulation indices. Also obtain the amplitude of the signals present in each sideband and the bandwidths. 20
2.
 - (a) Show that the multiplication of a sinusoidal signal by a signal $f(t)$ translates the whole frequency spectrum. Can we retranslate the spectrum to its original position? If yes how? 20
 - (b) A separately excited d.c. motor supplied with rated voltage and rated field current is driving a fan delivering rated torque. The load torque of the fan is proportional to square of speed. The motor exhibited linear load characteristics such that the speed dropped by 10% from no load to full load torque at rated voltage and field current. If the supply voltage is halved at the same field current develops an expression for the new speed in terms of no Load speed (at rated voltage), full load torque and other constants. 20

- (c) While the Thyristors is used in Power Electronic convertors it is being replaced by other devices recently. Mention any two of these devices and explain how they differ from the Thyristors. Name typical convertors in which the Thyristors are being replaced. **20**
3. (a)
- (a)(i) Draw the truth table of an octal-to-binary encoder with the condition that the output $F = 1$ when at least one of the inputs is a 1. The octal input with highest number has the highest priority. What is the condition of binary outputs and F output, if the inputs $D_5 = D_3 = 1$? **10**
- (a)(ii) Design a combinational circuit using AND gates and half adders that can multiply two 2-bit numbers $a_1 a_0$ and $b_1 b_0$ to produce 4-bit number S_3, S_2, S_1 and S_0 . **10**
- (b) Figure below shows a singly excited electro mechanical system with a stationary member and a rotating member. The stationary member is an electromagnet excited by a coil of N turns carrying a current i wound on a ferromagnetic core of infinite permeability. The rotating member is an unwound ferromagnetic core of infinite permeability causing variable permeance at changing rotor position θ from a maximum permeance of P_1 at $\theta = 0$ to a minimum permeance of P_2 at $\theta = 90^\circ$. Assuming this variation of permeance to be sinusoidal develop an expression for the developed torque on the rotating member as a function of θ .
 [Figure: C-shaped stationary member (core marked $\mu = \infty$) with a coil of N turns carrying current i wound on its left limb; the two pole faces of the gap (on the right limb) are curved and face each other; an elongated (oval) rotating member, also $\mu = \infty$, is pivoted in the gap between them, its axis (dashed line) making an angle θ with the vertical (dashed) axis of the poles. Labels: "rotating member", "stationary member".] **20**
- (c) In an electric traction d.c. series motor has been used with single-phase a.c. overhead lines. Gradually it is being replaced by another motor along with suitable speed control mechanism. Explain this new system comprising the motor and its control from the same overhead supply system and compare with the one using d.c. series motor. **20**
4. (a) Define a uniform plane wave, Show that a uniform plane wave progressing in x-direction does not have the x-component of E. Explain what does this mean physically. **20**
- (b) Obtain the voltage gain and output resistance of the composite amplifier shown in Fig. above.
 [Figure (printed above the text): Composite FET-BJT follower. Input v_i applied between the input line and the ground (bottom) line; resistor R_G from the input line to ground; the input line goes to the gate of FET T_1 ; drain of T_1 to the supply V_{CC} (top line); source of T_1 connected to the base of bipolar transistor T_2 ; collector of T_2 to V_{CC} ; emitter of T_2 to ground through resistor R_E ; output v_o taken across R_E (between the emitter and ground).] **20**
- (c) A rectangular wave guide has cross-sectional area $a = 7$ cm and $b = 4$ cm. Obtain all TE modes that will propagate frequency less than 5 GHz. How these modes are designated and what are the corresponding cut-off frequencies. **20**

SECTION 'B'

5. Answer any THREE of the following
- (a) How do you determine the Laplace transform of a function $f(t)$? Are there any restrictions on $f(t)$ for this? State them. Determine the Laplace transforms of (i) signal in the form of a triangular pulse and (ii) impulse train as shown below. The strength of each impulse is unity.
 [Figure: Left, "Triangle pulse": $x(t)$ rises linearly from 0 at $t = 0$ to a peak value 1 at $t = T/2$ and falls linearly to 0 at $t = T$. Right: impulse train $x(t)$ of unit impulses (height 1) at $t = 0, T, 2T, 3T, 4T$.] **20**
- (b) Figure below shows a coil of N turns placed in a time varying flux $\phi(t)$, The coil direction is such that for the direction of current i (as shown) in the flux direction is an indicated in the figure. Assume infinite conductivity of the conductor of the coil. Using relevant Maxwell's equation obtains an expression for e . Indicate how this expression will be in conformity with Lenz's law. **20**

[Figure: A coil of N turns wound helically around a vertical flux path carrying flux $\phi(t)$ (arrow pointing upward); the top end of the coil is connected by a wire to the upper terminal on the left, current i flowing along this wire (arrow pointing right, from the terminal towards the coil); the bottom end of the coil is connected to the lower terminal; the emf e is marked between the two terminals with an arrow pointing up towards the upper terminal.]

- (c) A 3-phase induction motor is driving a constant torque load. If one of the supply lines to the motor is disconnected discuss the changes you would observe in supply current, speed and efficiency. 20
- (d)
- (d)(i) Differentiate between FDM and TDM pictorially. Enumerate the advantages of one over the other. 10
- (d)(ii) 24-telephones, each band limited to 3.4 kHz, are to be time division multiplexed using PCM. Calculate the bandwidth of the PCM system for 128 quantization levels with 8 kHz sampling frequency 10
6. (a) What is the order of magnitude of velocity of an electromagnetic wave in a good conductor as compared to sound wave in air? Discuss. Calculate the depth of penetration of a MHz wave into copper which has $\sigma=5.8 \times 10^7 \text{ } \Omega/\text{m}$ and permeability equal to that of free space. 20
- (b) The simplified circuit of a radio oscillator is shown in Fig. above. Draw its equivalent circuit and obtain the condition of oscillation. Obtain the frequency of oscillation and the value of h_{fe} required for the oscillation in the case of Hartley oscillator
[Figure (printed above the text): Transistor oscillator (common emitter, emitter grounded). Impedance Z_1 between the top wire (connected to the collector) and the base; impedance Z_3 [?] between the base and the bottom (ground) wire; impedance Z_2 [?] between the top (collector) wire and the bottom (ground) wire on the right. Subscripts of the two lower/right boxes are blurred.] 20
- (c) A transmitting antenna at a height of h_2 above a smooth perfectly flat-earth surface sends a signal to a receiving antenna of height h_1 with ground range between them equal to a . Obtain the path difference between the direct and reflected signals reaching the receiving antenna. Assume $h_2 > h_1$. 20
7. (a) What is cut-set in linear graph theory? Explain with an example. In the graph
[Figure: Oriented graph with nodes ① (left), ② (middle of the top horizontal line), ⑤ (right) and ④ (bottom, also marked 0). Branches: 3 – upper arc from node 1 to node 5 (arrow towards 5); 2 – from node 1 to node 2 (arrow towards 2); 4 – from node 5 to node 2 (arrow towards 2); 6 – vertical, from node 2 down to node 4 (arrow downwards); 1 – between node 4 and node 1, arrow pointing towards node 1; 5 – between node 4 and node 5, arrow towards node 5 [?].]
check if the sets of branches $\{1, 3, 4, 6\}$ $\{1, 2, 3\}$, $\{1, 2, 3, 5\}$ constitute cut-sets. 20
- (b) Show that the output of a balanced modulator using semiconductor diode is DSB-SC. 20
- (c) Obtain relationship between the skip distance and maximum usable frequency over the flat earth surface. 20
8. (a) For the pole-zero configuration of an impedance function shown below draw the schematic diagrams of the two Foster and two Cauer networks without determining element values.
[Figure: Pole-zero plot along the $j\omega$ axis (drawn horizontally, origin at the left on the vertical axis): pole ($\times$) at the origin, then alternately zero ($\circ$), pole ($\times$), zero ($\circ$), pole ($\times$), and a zero ($\circ$) at $\omega = \infty$.]
What more information do you need to determine the element values? 20
- (b) Measurements on a small permanent magnet d.c. motor indicate that it has an armature resistance of 7.5 ohm. With an applied armature voltage of 6 V. the motor is observed to achieve a no load speed to 10570 r/min while drawing an armature current of 13 mA. (i) Calculate the motor torque constant (ii) Find the no load rotational losses of the motor. (iii) Find the stall current and torque of the motor at an applied armature voltage of 6 V. 20

- (c) How are the Power Semiconductor devices specified? What do these specifications signify?

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