

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) Explain the concept of complex frequency. Discuss its usefulness in specifying network functions. 20
 - (b) Determine the current in the 5 ohm resistor using Thevenin's theorem.
 [Figure: Ladder circuit: 50 V d.c. source on the left (+ at top) between the top wire and the bottom (return) wire; 1 Ω resistor in the top wire from the source to node 1; 5 Ω resistor from node 1 to the bottom wire; 1 Ω resistor in the top wire from node 1 to node 2; 1 Ω resistor from node 2 to the bottom wire; on the far right a current source of 8 A [?] (arrow pointing up, i.e. driving current from the bottom wire into node 2) connected between the bottom wire and node 2, in parallel with the last 1 Ω resistor] 20
 - (c) Determine the electric field in the overlap region of two spheres A and B shown in the above figure. Sphere A carries a charge $-\rho \text{ C/m}^3$ and the sphere B, a charge of $-\rho \text{ C/m}^3$.
 [Figure: Two overlapping spheres (drawn as circles): Sphere A on the left with radius a m, Sphere B on the right with radius b m; their centres are a distance d m apart (dimension line between the two centres); the two spheres overlap in a lens-shaped region between the centres] 20
 - (d) Discuss the merits and demerits of using counters in digital measuring instruments. 20
2. (a) A loss-less transmission of length ℓ m and characteristic impedance Z_0 ohm is excited at both the ends as shown in the above figure. Determine the currents delivered by the two sources. Determine also the current at the mid-point of the line.
 [Figure: A two-conductor loss-less line of length ℓ m (dimension line under the line); at the sending (left) end an a.c. voltage source (+ terminal to the upper conductor, – to the lower conductor) and at the far (right) end a second a.c. voltage source (+ terminal to the upper conductor, – to the lower conductor); each source carries a label of the form $V \angle 0$ [?] (labels too blurred in the source to be read with certainty)] 20
- (b) Determine (i) $V(s)/I(s)$ and (ii) $V_{AB}(s)/V(s)$ for the network shown in the above figure.
 [Figure: Source $V(s)$ (a.c. symbol) on the left delivering current $I(s)$ (arrow along the top wire) to two parallel branches connected between the top wire and the bottom wire: branch 1 – a 1 Ω resistor from the top wire down to node A, then a capacitor of impedance $1/s \Omega$ from A to the bottom wire; branch 2 – an inductor of impedance $2s \Omega$ and a 1 Ω resistor in series from the top wire down to node B, then a capacitor of impedance $1/s \Omega$ from B to the bottom wire; V_{AB} is the voltage between nodes A and B] 20
- (c) The bridge circuit, shown in the above figure, is balanced when $S = 10$ milli ohm, $P = 1100$ ohm, $Q = 1000$ ohm, $q = 500$ ohm and $r = 0.1$ ohm. Find the value of R_x .
 [Figure: Kelvin double bridge: battery with a series resistor (rheostat) on the left connected across the outer ends of two series chains; left chain (top to bottom): S, link r, R_x ; right chain (top to bottom): P, Q; inner ratio arms p (from the junction of S and r) and q (from the junction of r and R_x) meet at a common point which is connected through the galvanometer to the junction of P and Q] 20
3. (a) Determine $V \angle \theta$ so that the circuits (i) and (ii) shown in the above figure are equivalent.
 [Figure: Circuit (i): source 100 $\angle 0$ V (+ at top), 8 Ω resistor in the top wire to a node; from that node to the bottom wire an inductive reactance $j4 \Omega$ in parallel with a 4 Ω resistor. Circuit (ii): source 100 $\angle 0$ V (+ at

top), $8\ \Omega$ resistor in the top wire, then a second source $V\angle\theta$ (+ at top) from the end of the $8\ \Omega$ resistor to the bottom wire]

- (b) Determine the emf induced in the triangular loop ABC due to the flux set up by a sinusoidal current $I_m \sin\omega t$ flowing in an infinitely long wire shown in the above figure.

[Figure: An infinitely long straight vertical wire ("Long wire") carrying current $i = I_m \sin\omega t$ (arrow upwards); in the same plane a right-angled triangular loop ABC: vertex A at a distance a from the wire, vertex C at a distance b from the wire on the same horizontal line (side AC horizontal, perpendicular to the wire), vertex B vertically above C at a height c (side BC parallel to the wire); hypotenuse AB]

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- (c) Two conductors have a potential coefficient matrix $\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}$. Each conductor is given a charge 1 C. One of the conductors is then momentarily grounded. Thereafter it is connected to the other conductor. Determine the final potential of the composite conductor.

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4. (a)(i) Why does an induction type energy meter creep? How is the creep prevented?

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- (a)(ii) The calibration constant of a 3-phase energy meter is 0.14 revolutions of disc per kwh. It is used with a potential transformer of ratio 11 KV/110 V and a current transformer of ratio 500 A/5 A. The test results are: Line voltage = 100 V, Line current = 5.25 A, Power Factor = 0.9 lagging, Time to complete 30 revolutions of discs = 0 [?] sec. Determine the percentage error in the meter in terms of the actual energy consumed.

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- (b) The output of a LVDT transducer is 0.5 V at a frequency of $50/2\pi \times 10^3$ rad./sec. Determine the output if the frequency deviates by 10%. The time constants of primary and secondary circuits are 5 ms and 2 ms respectively.

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- (c) Determine the resistance across the terminals A and B of the network shown in the above figure.

[Figure: Twelve $10\ \Omega$ resistors forming the edges of a cube, drawn as two nested rhombuses: outer rhombus with corners L (left), T (top), B (right, terminal B) and D (bottom), edges L-T, T-B, L-D, D-B each $10\ \Omega$; inner rhombus with corners A (left, terminal A), T' (top), R' (right) and D' (bottom), edges A-T', T'-R', A-D', D'-R' each $10\ \Omega$; four connecting resistors L-A, T-T', R'-B and D-D', each $10\ \Omega$. Terminals A and B are diagonally opposite corners of the cube]

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SECTION 'B'

5. Answer any three of the following:

- (a) The above figure shows the circuit of a voltage follower. Calculate its closed loop voltage gain, input impedance and output impedance. Determine also the output offset voltage. The parameters of 741 C are: Open loop gain $A_{OL} = 10^5$, $r_{in} = 2\ \text{M}\Omega$, $r_{out} = 75\ \Omega$, $V_{in}(\text{off}) = 2\ \text{mV}$, $I_{in}(\text{bias}) = 80\ \text{nA}$ and $I_{in}(\text{off}) = 20\ \text{nA}$.

[Figure: Voltage follower using a 741 C op-amp: a.c. signal source (+ terminal up, other terminal grounded) connected through a $33\ \text{K}\Omega$ resistor to the non-inverting input; output V_{OUT} connected directly back to the inverting input]

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- (b)(i) Simplify the Boolean function $Z = \overline{((A+B))}.B.(A+\overline{C})$ and realise it using NAND gates.

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- (b)(ii) What is a race condition? How is it prevented?

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- (c) A 400 V, 3-phase, star connected synchronous motor has $x_d = 8\ \Omega$ and $x_q = 6\ \Omega$. It is running on infinite bus. If its field current is reduced to zero, determine the maximum load that the synchronous motor can carry. Determine also the corresponding armature current.

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- (d) A d.c. shunt motor draws an armature current of 50 A from 250 V mains. It is required to increase its speed by 40% by weakening of the field flux. If the torque at the increased speed is also increased by 40%, find the per cent change in the field flux. The armature resistance is $0.2\ \Omega$.

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6. (a) For the class C tuned amplifier shown in the above figure, calculate the maximum load power and the transistor power rating if $V_{CE(\text{sat})} = 0.75\ \text{V}$.

[Figure: Class C tuned amplifier: a.c. input source (sine wave sketched beside it; + terminal up, other terminal grounded) through a series resistor and a coupling capacitor to the base of an NPN transistor; a resistor from

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the base to ground; emitter grounded; collector connected to a parallel LC tank (capacitor in parallel with the transformer primary) whose other end goes to the supply +60 V [?]; the primary is coupled through a 2:1 transformer to a 60 Ω load resistor on the secondary]

- (b) The transistor shown in the above figure has following h parameters: $h_{ie}=1000\ \Omega$, $h_{fe}=50$, $h_{re}=3\times 10^{-4}$ and $h_{oe}=5\times 10^{-5}$ Find the voltage gain and ac. input impedance of the amplifier. Neglect capacitor impedances.
[Figure: Common-emitter amplifier, supply +20 V: voltage-divider bias – 60 k Ω from +20 V to the base and 30 k Ω from the base to ground; input V_{in} applied to the base through a coupling capacitor; 10 k Ω collector resistor from +20 V to the collector; 10 k Ω emitter resistor from the emitter to ground, bypassed by a capacitor; output V_{out} taken from the collector through a coupling capacitor across a 30 k Ω load resistor to ground] 20
- (c) Describe any two types of A to D converters. Discuss their merits and demerits. 20
7. (a) A 500 KVA, 11 KV 3-phase, star connected alternator has the following data: Friction and windage loss = 1500 W Open circuit core loss = 2500 W Effective armature resistance per phase 4 ohm Field copper loss = 1000 W Find (i) alternator efficiency at half-full load and 0.8 power factor lagging (ii) maximum efficiency of the alternator. 20
- (b) Describe, giving reasons, the choice of materials for the following applications: (i) Magnetic tapes (ii) Recording heads (iii) Super conductors (iv) Insulation for 11 KV cable 20
- (c) Three 600 KVA, 33000/11000 V, 50 Hz, 3-phase, Delta/Star transformers are connected in parallel. These transformers give the following test results when operated at the rated full load current with their low voltage windings short-circuited: Transformer A–300 V, 3000 W Transformer B–400 V, 3500 W Transformer C–450 V, 4000 W Determine the maximum load at unity power factor which can be supplied by the parallel combination without overloading any of them. 20
8. (a) Describe the constructional features of E-MOSFET. Calculate the voltage gain from gate to drain of the circuit shown in the above figure.
[Figure: E-MOSFET amplifier, $g_m=4000\ \mu\text{S}$: a.c. source (one terminal grounded) through a 1 M Ω resistor to the gate; 100 M Ω resistor from the gate to ground; drain connected through 12 k Ω to +20 V; source connected to ground through an unbypassed 400 Ω resistor; drain coupled through a capacitor to a 48 k Ω [?] load resistor to ground] 20
- (b) Explain the operation of colpitts oscillator. A colpitts oscillator has a tank circuit as shown in the above figure. Calculate its frequency of oscillation. What should be the minimum gain of the amplifier for the oscillations to start?
[Figure: Colpitts tank circuit: two capacitors in series, 0.001 μF (upper) and 0.01 μF (lower), connected in parallel with a 12 μH inductor; the junction of the two capacitors is brought out through a capacitor to the (grounded) common terminal] 20
- (c)(i) Show that the use of a synchronous condenser improves the efficiency and regulation of a system. 10
- (c)(ii) A consumer has a total load of 2000 KW at a p.f. of 0.8 lagging. If it is required to improve the power factor to 0.95 lagging, determine the KVA rating of the synchronous condenser required for the purpose. 10