

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) Fig. 1 (a) shows a network of resistors each of R ohms. Find the resistance between the terminals P and Q.

[Figure: Fig. 1 (a): Triangle of corners A (top), B (bottom left) and Q (bottom right) with a resistor R in each side (A–B, A–Q, B–Q); an inner node P inside the triangle connected to A through a vertical resistor R and to B through a resistor R ; terminal P (small circle) is taken from the inner node and terminal Q (small circle) is joined by a wire to corner Q]

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- (b) A charge Q is distributed over two concentric hollow spheres of radii r and R ($R > r$) such that their surface densities are equal. Find the potential at the common centre of spheres.

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- (c) Two sinusoidal signals of equal amplitude and frequencies f_v and f_h (Hz) are applied simultaneously to vertical and horizontal deflecting plates respectively of a CRO. Sketch the Lissajous patterns that appear on the CRT screen, when. (i) $f_v:f_h=3:1$ (ii) $f_v:f_h=1:2$; and (iii) $f_v=f_h=1$ kHz with a phase difference of 90° between the two signals. If now, the control grid electrode is subjected to an additional sinusoidal signal of 10 kHz and of such amplitude that the grid is driven into cut-off state for part of its signal cycle what will be the change in the pattern displayed for part (iii)?

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- (d) For the voltage-series-feedback amplifier circuit shown in Fig. 1(d), the open-loop gain A of the OP-AMP varies from 15000 to 20000 as the temperature changes from 25°C to 35°C . Calculate the closed-loop gain at both the extreme temperatures, assuming $R_1=470\ \Omega$ and $R_f=47\ \text{k}\Omega$. Calculate the percentage change in open-loop and closed-loop gains and explain the results. Assume the source impedance to be zero.

[Figure: Fig. 1(d): Op-amp A (supplies V_{CC} and $-V_{EE}$) used as a non-inverting amplifier: source V_i connected between ground and the non-inverting input; a feedback resistor from the output to the inverting-input node (feedback voltage V_f marked); R_1 from that node to ground; load R_L across the output; output voltage V_o across R_L]

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2. (a) A 10 kV is applied across an air-filled capacitor formed by two parallel plates with a separation of 1.2 cm. A glass sheet of 2mm thickness and of 6.5 relative permittivity is inserted in the air dielectric and kept on one plate. Find the capacitance per unit area of the parallel plates along with the glass, the electric field intensities in air glass dielectric, and the charge density on the plates.

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- (b) Calculate the power fed to the $15\ \Omega$ resistor by using Thevenin's equivalent circuit for the portion to the left of points A and B in the circuit of Fig. 2 (b).

[Figure: Fig. 2 (b): Left loop: 100 V source (+ at top); $6.8\ \Omega$ resistor in the top line (voltage V_s marked across it); then a $4\ \Omega$ resistor and an $18\ \Omega$ [?] resistor each connected from the top line to the bottom line. Right part (not wired to the left part): a dependent current source $0.147V_s$ (arrow upwards) from the bottom line to the top line; $4.8\ \Omega$ in the top line; a $10\ \Omega$ resistor from the top line to the bottom line; $10\ \Omega$ in the top line to terminal A; $15\ \Omega$

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resistor between A and B; $6\ \Omega$ in the bottom line from B back to the bottom line of the source]

- (c) In the circuit of Fig 2 (c), when the switch is closed $t=0$, it is noticed that $i(0^+)=10\text{ mA}$ and $v_{ab}(t)=0, t \geq 0$ sec. Assuming zero initial current for inductor and zero initial charge for capacitor, find the values of R_1 and L .

[Figure: Fig. 2 (c): 5 V battery with a switch in the top line feeding two parallel branches: left branch R_1 in series with capacitor $C = 5\ \mu\text{F}$ (node a between them); right branch inductor L in series with $R_2=200\ \Omega$ (node b between them); v_{ab} is the voltage between a and b]

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3. (a) Define the attenuation coefficient and phase coefficient in the context of a transmission line. A correctly terminated transmission line has $Z_0=600\ \Omega$, $\alpha=1.2\text{ dB/m}$ and $\beta=18\text{ /m}$ (with usual notations). The line is 5 m long and is fed from a $600\ \Omega$ source of e.m.f. 3V. Find the magnitude of the received current at the output and its phase relative to the input voltage.

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- (b) The Fig. 3(b) shows the Wien's bridge for measurement of frequency. Derive suitable expressions under balanced bridge condition. What should then be the relation between R and R_1 and between C and C_1 so that the excitation frequency is expressed as $1/(2\pi RC)$?

[Figure: Fig. 3 (b): Wien bridge drawn as a diamond, supplied by a source of frequency f connected between the top and bottom corners; upper-left arm: resistor R in series with capacitor C_1 ; lower-left arm: resistor R in parallel with capacitor C ; upper-right arm: resistor R_2 [?]; lower-right arm: resistor R_1 [?]; detector D between the left and right corners]

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- (c) The output of an LVDT is connected to a 10 V voltmeter through an amplifier with a gain of 500. An output of 2.5 mV appears on the terminals of LVDT, when the core moves through a distance of 0.5 mm. Calculate the sensitivity of LVDT and that of the whole set-up. The voltmeter scale has 100 divisions and the scale can be read to 1/5 of a division. Calculate the resolution of the instrument in mm.

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4. (a) The JFET used in the circuit of Fig. 4 (a) has the following data: $R_D=2\text{ k}\Omega$, $R_S=8\text{ k}\Omega$, $V_{DD}=15\text{ V}$, $V_G=10\text{ V}$ and $V_{SS}=-8\text{ V}$. Assuming $I_{DSS}=5\text{ A}$ and $V_{PO}=-3\text{ V}$ for the JFET calculate V_{GS} and V_O .

[Figure: Fig. 4 (a): n-channel JFET source follower: drain connected through R_D to V_{DD} ; gate G driven by the input voltage (V_G , + at the gate, - at the common line); source connected through R_S to V_{SS} ; output V_O taken between the source and the common line]

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- (b) For full-wave rectification, what circuit configuration would be preferred and why? A bridge rectifier fed through a transformer from a 230 V, 50 Hz supply is used to deliver power to a transistor radio at 9V d-c. Assuming ideal diodes and load resistance of $90\ \Omega$, specify the turns-ratio and current rating of transformer. Also find the d-c and a-c (rms) values of Load current and Peak-Inverse-Voltage.

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- (c) The mid-band equivalent circuit of a common emitter transistor amplifier is shown in Fig. 4(c). The h-parameters of the transistor used are $h_{ie}=1500\ \Omega$, $h_{re}=10^{-3}$, $h_{fe}=100$, $h_{oe}=50 \times 10^{-6}\ \Omega$ Find the mid-band gain i_{S_1}/i_{be} [?] where i_{S_1} [?] where is the current in $5\text{ k}\Omega$ resistor.

[Figure: Fig. 4(c) (hand-drawn, partly illegible): input side – signal current source i_s (arrow up) with its source resistance [?] in parallel, feeding terminals B–E through a bias resistance [?]; then h_{ie} in series with a controlled voltage source $h_{re}v_{ce}$; output side between C and E – controlled current source $h_{fe}i_{be}$ (arrow down), $1/h_{oe}$, the collector resistor $R_c = 10\text{ k}\Omega$ and the $5\text{ k}\Omega$ load (current i_{S_2} [?]) all in parallel; output voltage v_{ce} between C and E]

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SECTION 'B'

5. Answer any three of the following:

- (a) Minimize the following logic functions using Karnaugh maps and realize them using NAND gates. (i) $f(A,B,C,D)=\Sigma m(2,3,6,7,8,9,10,11,12,13,14,15)$ (ii) $f(A,B,C,D)=\Pi M(0,1,2,3,4,5,6,7,8,9,10,12,13)$

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- (b) It is desired to add two one-bit binary words and produce the result as Sum and Carry. Prepare a truth table, Karnaugh map and Boolean expressions to design a Half-Adder using minimum number of NAND gates.

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- (c) What do you understand by the forbidden gap in energy bands? Electrons are excited across the forbidden energy gap E_0 in Germanium by bombarding of photons. Calculate the maximum wavelength for a photon which will produce electron-hole pairs in Germanium, if $E_0 = 0.71$ eV. 20
- (d) A 10kW, 1440rpm d-c shunt generator has resistance Loss of 400 watts in its field winding under normal operating conditions. The time-constant of the field winding is 0.2 second. Calculate the energy stored in the magnetic field produced by the field winding. 20
6. (a) Draw the circuit diagram of a NOR gate using MOS transistors (n-channel) and verify the NOR operation with. The description of the functioning of this gate. 15
- (b) Name the different types of Read- Only-Memories and briefly discuss their attributes in terms of programmability volatility, erasability, technology used and utility. 20
- (c) A 3-phase star-connected alternator, rated at 11kV, 1600k VA, has negligible armature resistance and a synchronous reactance of 30Ω per phase. When delivering full-load current at a certain power factor, the voltage regulation of the machine is zero. Estimate the power factor of the load and the power delivered by the machine. 25
7. (a) Two similar 200 k VA, single-phase transformers gave the following results when tested by the back-to-back method: (i) Wattmeter W_1 in the supply line reads 4kW; and (ii) Wattmeter W_2 in the secondary sends [?] circuit reads 6 kW, when the full-load current is circulated through the secondaries. Show the diagram of connections and calculate the full-load efficiency of each transformer. 15
- (b) A 4-pole D-C Series motor runs normally at 800 rpm taking 22 A on 260 V supply, when all the four field coils are connected in series. If now the field coils are reconnected in two parallel groups of two coils in series, estimate the speed and current taken by the motor. Assume that, (i) the load torque is proportional to square of speed, (ii) the field flux is directly proportional to the current, and (iii) the losses are negligible. 25
- (c) A 3-phase, star-connected, 1200 kW. 3.3 kV, 20-pole, 50 Hz synchronous motor has a synchronous reactance of 4Ω per phase and negligible resistance. The motor is fed from infinite bus-bar at 3.3 kV and is operated at unity power factor by so adjusting its excitation. Calculate the maximum power and torque that the motor can deliver for the same excitation. 20
8. (a) The normal full-load slip and shaft torque of a 373 kW, 50 Hz, 3-phase induction motor are respectively 1.9% and 2400 N-m. The rotor winding has a resistance of 0.25Ω and a standstill reactance of 1.5Ω per phase. Estimate the slip and power output for the same full-load stator current when external resistors of 2Ω per phase are inserted in the rotor circuit. Neglect no-load current. 20
- (b) Two 100 kVa, 1-phase transformers are connected in parallel on both primary and secondary sides. One transformer has an ohmic drop of 0.5% and reactive drop of 8% of the voltage on full load. The other has the corresponding drops of 0.75% and 4% respectively. How will the total load of 200 kW at unity power factor be shared? 20
- (c) The bulk n-type region of a particular Germanium junction has conductivity of 10^4 S/m at 300 K and that the for the p-region is 10^2 S/m. Find the voltage drop across the junction in equilibrium at 300K, assuming intrinsic carrier concentration as $2.5 \times 10^{19} \text{ m}^{-3}$ mobility of electron and holes as $0.36 \text{ m}^2/\text{v-s}$ and $0.17 \text{ m}^2/\text{v-s}$ respectively. 20