

ELECTRICAL ENGINEERING

Paper—I

(Conventional)

Time Allowed : Three Hours

Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt SIX questions, selecting TWO questions from Part—A, ONE from Part—B, ONE from Part—C and TWO from Part—D.

The number of marks carried by each question is indicated at the end of the question.

Answers must be written only in ENGLISH.

Assume suitable data, if necessary, and indicate the same clearly.

Unless otherwise indicated, symbols and notations have their usual meanings.

Part—A

1. (a) Explain the concept of polarization and bound volumetric charge density in a material due to polarization. A parallel-plate capacitor consists of free space and two dielectrics of relative dielectric constants of 4 and 6 respectively. Obtain the electric field density (D), electric field intensity (E) and polarization (P) in all regions, if the plates have a charge density (ρ_s) of $30 \times 10^{-6} \text{ C/m}^2$.

12

(b) For a second-order underdamped system, subjected to unit-step input, the time response shows first peak to be four times of the second overshoot. Determine the damping factor of the system and expected maximum overshoot. 10

(c) (i) Differentiate clearly between 'tracking control' and 'regulatory control' problems, with the help of an example and diagram. 4

(ii) For a controlled system shown in Fig. 1, determine the safe maximum gain, $K_{c\max}$ of the controller and the steady-state error due to only 0.3 unit-step disturbance input L , with K_c set to $K_{c\max}$. 6

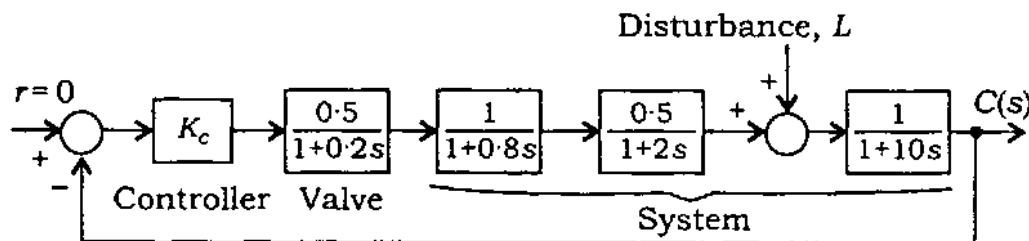


Fig. 1

2. (a) A uniform plane wave travels in free space in Z -direction and is described by

$$\vec{H} = 0.80 \cos(\omega t - \beta z) \vec{a}_x + 0.80 \sin(\omega t - \beta z) \vec{a}_y$$

where \vec{a}_x and \vec{a}_y are unit vectors in X - and Y -direction respectively. Find the corresponding electric field and the Poynting vector. Also obtain intrinsic impedance of the medium. 12

- (b) Determine the safe maximum value of K for the unity feedback system, having open-loop transfer function

$$G(s) = \frac{K(s+20)^2}{s^3}$$

Sketch the Nyquist plot with this value of K . Obtain the margins of stability and comment.

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- (c) For a liquid level tank system shown in Fig. 2, write the dynamical equations and obtain a variable model.

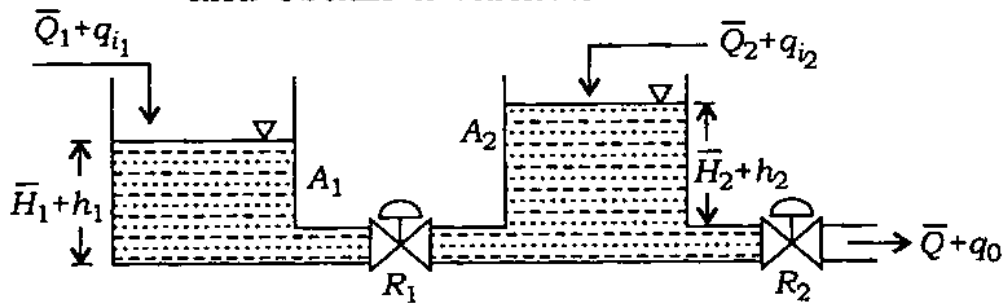


Fig. 2

The liquid levels in the tanks may be assumed as output. Also draw the block diagram and obtain transfer function $H_2(s) / Q_{i1}(s)$ for transient state.

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3. (a) A coaxial cable of length L is used to transmit voltage. The conductor radius is a and radius of outer conducting sheath is b . The sheath is earthed. The inner conductor is maintained at potential V . The space between the inner conductor and the outer sheath is filled with a lossy dielectric material. Obtain an expression for the resistance offered by the space between the inner conductor and the outer sheath.

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(b) (i) For a system represented in state-space form, how can the corresponding transfer function model be obtained? 4

(ii) For the system given as

$$\dot{x} = \begin{bmatrix} 0 & 0 & -20 \\ 1 & 0 & -24 \\ 0 & 1 & -9 \end{bmatrix} x + \begin{bmatrix} 3 \\ 1 \\ 0 \end{bmatrix} u$$

$$y = [0 \ 0 \ 1] x$$

obtain the transfer function. 3

(iii) What is the property of invariance in state-variable models? 3

(c) (i) For a system described by state-space model in controllable canonical form, explain the concept of pole-placement design by state-variable feedback (SVFB) control approach. 5

(ii) For the system specified below, design an SVFB controller such that the closed-loop poles of system are located at $s = -3 \pm j3$: 5

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

Part—B

4. (a) (i) Differentiate between Type-I and Type-II superconductors. Give two examples of each type. 8
- (ii) The current flowing in a superconducting ring shows no decay after 3 years. If the accuracy of the measurement is 0.01%, calculate the conductivity of the superconductor. Assume electron density as 10^{28} electrons/m³. 8
- (b) Derive an expression for the Hall voltage in a good conductor. 8
- (c) What is the dielectric strength of a material? Discuss briefly the three main mechanisms that are usually blamed for dielectric breakdown—(i) intrinsic, (ii) thermal and (iii) discharge breakdown. 12
5. (a) A specimen of a semiconductor has a Hall coefficient of 3.66×10^{-4} m³/C and a resistivity of 8.93×10^{-3} Ω-m. In a Hall effect experiment, a magnetic density of 0.8 T is used. Find the Hall angle. 8

(b) Summarize the differences between Soft and Hard magnetic materials in respect of (i) coercivity, (ii) anisotropy constant, (iii) energy domain walls, (iv) wall motion and (v) microstructure. 10

(c) (i) What are ferroelectric materials? State the salient features of such materials based on relative permittivity and hysteresis loop. List two examples of ferroelectric materials and two applications each. 12

(ii) The electron concentration in silicon at 300 K is $5 \times 10^{15} / \text{cm}^3$. If the intrinsic carrier concentration is $1.5 \times 10^{10} / \text{cm}^3$, determine—
(1) hole concentration;
(2) type of material : *p*-type or *n*-type;
(3) impurity doping concentration. 6

Part—C

6. (a) A series *R-L-C* circuit having $R = 25 \Omega$, $L = 2 \text{ H}$ and $C = 30 \mu\text{F}$ is connected across an a.c. variable-frequency source. At what frequencies will the phase angle of the circuit be (i) 45° lagging and (ii) 45° leading, the applied voltage? 12

- (b) The following mesh equations pertain to a network :

$$8I_1 - 5I_2 - I_3 = 110$$

$$-5I_1 + 10I_2 + 0 = 0$$

$$-I_1 + 0 + 7I_3 = 115$$

- (i) Draw the network showing each element.

- (ii) Calculate the current in the 110 volts source.

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- (c) A sinusoidal voltage $e(t) = 141 \sin 314t$ is applied to an initially de-energized series R - L circuit in which $R = 100 \Omega$ and $L = 0.5 \text{ H}$.

- (i) If the switch which applied the voltage to R - L circuit is closed at the instant when $e(t)$ is passing through zero with a positive slope, determine the initial value of the transient current.

- (ii) Write the complete expression for the transient solution.

- (iii) Write the expression for the complete solution of the current response.

- (iv) At what instantaneous value of the applied voltage will the closing of the switch result in no transient component of the current?

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7. (a) Compute the steady-state current in the $8\ \Omega$ resistor in the circuit given in Fig. 3.

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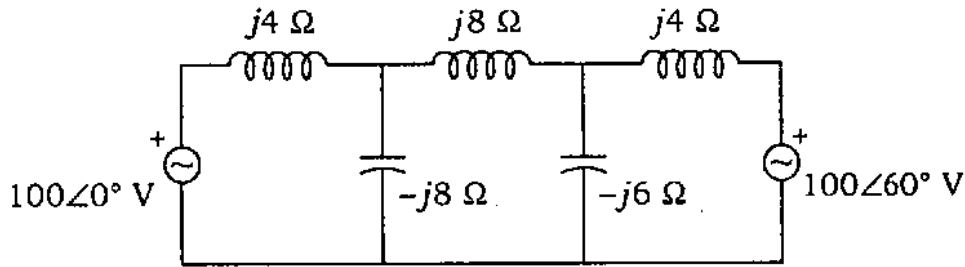


Fig. 3

- (b) Three identical coils are connected in star to a 200 V, 3-phase supply and each takes 400 W. The p.f. is 0.8 lagging. What will be the magnitude of line currents and total power if the same coils are connected in delta to the same supply? If the total power in delta-connected coils is measured by two-wattmeter method, what will be the readings of the wattmeters?
- (c) When can a two-port circuit be declared as a reciprocal circuit?

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Is the two-port circuit shown in Fig. 4 reciprocal? Justify the answer by a 15 V voltage source.

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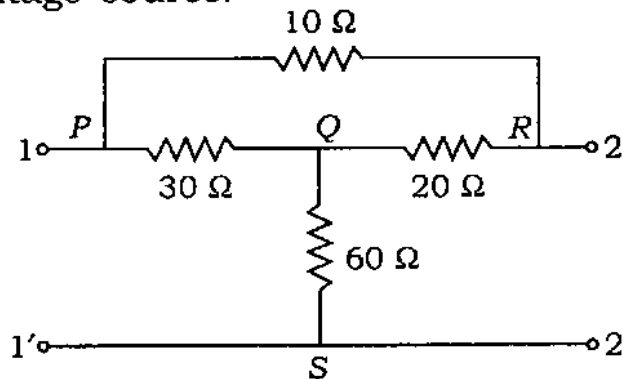


Fig. 4

Part—D

8. (a) (i) Why is it not possible to measure the temperature of a body instantaneously? 4
- (ii) Two strips of metals A and B with thermal expansion coefficients α_A and α_B ($\alpha_A > \alpha_B$) are bonded together at temperature T_1 to form a bimetallic strip. Draw the profile of the bonded strips when $T_2 > T_1$ and $T_2 < T_1$. On what factors does the bending of the bimetallic strip depend? What are the practical applications of bimetallic strips? 8
- (b) Two sets of large number of 20 k Ω and 30 k Ω resistors are used to make a large number of 12 k Ω and 50 k Ω resistors choosing one from each group. If the standard deviations of the two sets of resistors of 20 k Ω and 30 k Ω are respectively 5% and 10%, find the standard deviations of the combined resistor-sets of 12 k Ω and 50 k Ω . 10
- (c) Describe the constructional details and working of a single-phase electro-dynamometer type of power factor meter. Prove that the displacement of the moving system is proportional to the phase angle of the system. 10

9. (a) (i) How can strain gauges be used to transduce pressure? 4
- (ii) Explain with a diagram, the placement of gauges, explaining which of the gauges are in tension and compression respectively. 4
- (iii) Give the connection diagram of the Wheatstone's bridge to be used. 4

- (b) Derive the general torque equation for a moving-iron instrument.

The inductance of a moving-iron ammeter is given by the following expression :

$$L = (30 + 10\theta - 2\theta^2) \mu\text{H}$$

where θ is the deflection in radians. The control spring constant is 25×10^{-6} N-m/rad. Calculate the value of deflection for a current of 5 A. 10

- (c) With the help of circuit diagram, explain the principle and operation of Owen's bridge for the measurement of incremental inductance. 10

10. (a) A 2-bit D/A converter using R - $2R$ ladder network was constructed using $2 \text{ k}\Omega$ and $8 \text{ k}\Omega$ resistors. If the bit length of the converter is to be increased by two, using resistors of the same values, what would be the total number of resistors required in the augmented version? Give the circuit diagram of the augmented converter. 12

(b) Discuss the difficulties faced in measuring high resistances. Explain the procedure adopted in the laboratory for measuring high resistance. 10

(c) Explain the advantages of electronic voltmeters over conventional voltmeters. Describe the working of a differential amplifier type electronic voltmeter using two FETs. 10

