Serial No. | 47032 | A–FRF–M–DDA

ELECTRICAL ENGINEERING

Paper—I

(Conventional)

Time Allowed : Three Hours | Maximum Marks : 200

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions.

Candidates should attempt FIVE questions in all.

Question No. 1 is compulsory. Out of the remaining SIX questions attempt any FOUR.

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

Answers must be written in ENGLISH only.

Unless otherwise mentioned, symbols and notations have their usual standard meanings.

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

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Any pages left blank in the answer book must be clearly struck out.

⚠

1. (a) Explain the concept of gradient. Determine the gradient of the given field :

$$V = \rho z \sin \phi + z^2 \cos^2\phi + \rho^2.$$ 5

(b) What is polarization ?

In a dielectric material $E_x = 5$ V/m and

$$P = \frac{1}{10\pi}(3a_x - a_y + 4a_z)\, nC/m^2.$$

Calculate :

(i) Electric susceptibility (χ_e)

(ii) Electric field intensity (E)

(iii) Electric flux density (D).   5

(c) The feedback control system has $G(s) = \dfrac{K(s+6)}{(s+4)}$

and an ideal integrator with unity gain in feedback path. Determine the following, with reference to Root locus technique :

(i) $K = 0$ and $K = \infty$ points on root loci

(ii) number of asymptotes

(iii) breakaway points, if any.   5

(d) Draw a typical RC lag network. Why is it called a lag network ? Comment on its effect on :

(i) Gain crossover frequency

(ii) Bandwidth

(iii) Signal to noise ratio.   5

(e) A balanced star-connected load is supplied from a 3-phase, 50 Hz, 415 V supply. Current in each phase is $20 \angle -30°$ A, the 30° angle being w.r.t.

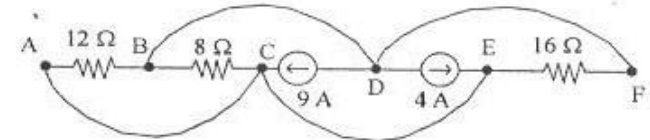△2   (Contd.)

phase voltage. Determine (i) the total power supplied, (ii) the overall p.f., and (iii) draw the phasor diagram.   5

(f) The power in a balanced 3-phase, 3-wire, star-connected system is to be measured by two watt-meters. Draw neat connection and phasor diagrams. Do not derive the expressions for the power measured by each wattmeter.   5

(g) Explain basic principle of operation of a thermocouple.   5

(h) Explain the factors affecting the resistivity of electrical materials.   5

2. (a) Calculate the power dissipation in each resistor of figure given below. Use KVL and KCL to solve the problem.   10
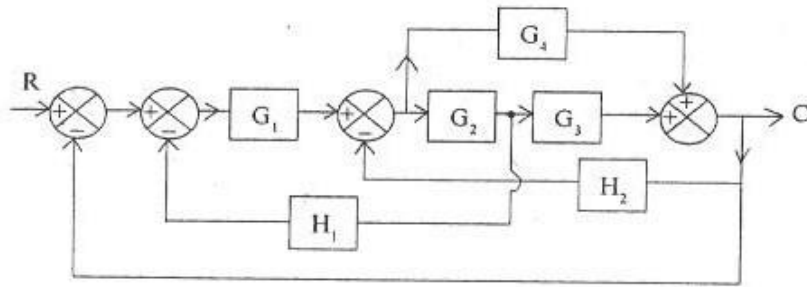

(b) Carry out the nodal analysis for the circuit given below and then compute the voltage across the 2-mhos conductance.   10
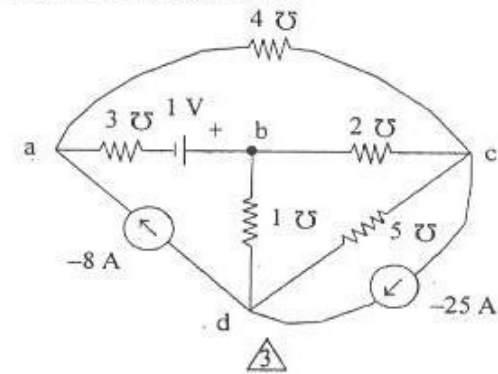
△3   (Contd.)

(c) Draw the signal flow graph corresponding to the Block Diagram of the system given below. Evaluate the closed loop transfer function of the system using Mason's gain formula.   10

(d) A unity negative feedback control system has open

loop transfer function $G(s) = \dfrac{K(s+1)}{s^3 + as^2 + 2s + 1}$.

Using Routh's criterion, determine the value of 'K' and 'a' so that system oscillates at a frequency of 2 rad./sec.   10

3. (a) A long co-axial cable with radii a and b with b > a has a uniform charge density ρ_l c/m. Find :

   (i) energy stored per unit length for a < r < b

   (ii) capacitance per unit length.   10

(b) State and explain Divergence theorem. Verify Divergence theorem for the vector A in spherical co-ordinates for the volume enclosed between r = 1 and r = 2, where $A = 5 r^2 a_r$.   10

(c) Explain with the diagram the four-point probe method to measure the conductivity of semi-conductor.   10

④   (Contd.)

(d) Explain the recombination and trapping processes in a semiconductor.   10

4. (a) A voltage of e(t) = 150 sin 1000 t is applied across a series RLC circuit where R = 40 Ω, L = 0.13 H and C = 10 μF.

   (i) Compute the rms value of the S.S. current.

   (ii) Find the rms voltage across the inductor.

   (iii) Find the rms voltage across the capacitor.

   (iv) Draw the complete phasor diagram showing all voltage components.

   (v) Determine the reactive power supplied by the source.   10

(b) A 3-phase, star-connected motor, connected across a 3-phase, star-connected supply of 400 V, 50 Hz takes a current of 20 A at 0.8 power factor lagging. Determine the capacitance of the capacitors per phase that are to be connected in delta across the terminals of the motor to raise the power factor to unity and also the new value of the supply line current with the capacitors connected.   10

(c) Draw the circuit of a Kelvin's Double-Bridge used to measure low resistance. Derive the condition for balance. Calculate insulation resistance of a cable in which the voltage falls from 100 to 80 V in 20 s. The capacitance is 300 pF.   10

(d) A circuit was tuned for resonance by eight different students, and the values of resonant frequency in kHz were recorded as 532, 548, 543, 535, 546, 531, 543 and 536.

Calculate :

   (i) the arithmetic mean,

   (ii) deviations from mean,

   (iii) the average deviation,

   (iv) the standard deviation, and

   (v) variance.   10

⑤   (Contd.)

5. (a) In free space, the magnetic flux density is
$$B = y^2\, a_x + z^2\, a_y + x^2\, a_z \ \ Wb/m^2$$
  (i) Show that B is a magnetic field.
  (ii) Find the magnetic flux through $x = 1$, $0 < y < 1$ and $1 < z < 4$.   10
  (iii) Calculate current density (J).

(b) Define intrinsic impedance.

A uniform plane wave in free space is given by
$$E_S = 200\ \angle 30°\ e^{-j\,250\,z} \cdot a_x\ \ V/m.$$
Find :
  (i) phase constant (β)
  (ii) angular frequency (ω)
  (iii) wavelength (λ)
  (iv) intrinsic impedance (η)   10
  (v) magnetic field (H_s).

(c) The loop transfer function of a negative feedback control system is given by,
$$G(s)\,H(s) = \frac{K(1+s)}{s^2(1+0.316\,s)}.$$

Determine *analytically* :
  (i) Possible maximum phase margin and the frequency at which it occurs.
  (ii) What should be the gain K for this phase margin ?   10

(d) Consider a negative unity feedback system with
$$G(s) = \frac{0.4\,s+1}{s(s+0.6)}.$$

(Contd.)

Obtain peak overshoot, damped frequency of oscillation, settling time on 2% tolerance band, and response of the system to unit step input.   10

6. (a) Describe the boundary condition in magnetic fields.

The xy plane serves as interface between two different media. Medium 1 ($z < 0$) has $\mu_r = 6$ and medium 2 ($z > 0$) has $\mu_r = 4$. If the interface carries a surface current density of :
$$J_s = \frac{2}{\mu_o}\, a_y \ \text{and}$$
$$B_2 = 5a_x + 8a_z,\ \text{find}\ B_1. \qquad 10$$

(b) Explain the phenomenon of superconductivity. Estimate the critical magnetic field for superconductivity of niobium at 5°K.   10

(c) It is required to measure the voltage across 10 kΩ resistor of the circuit shown in Figure below. Two voltmeters are available. Voltmeter A is a 1 mA movement and voltmeter B is 50 μA movement. Both use their 50 V scales. Calculate :
  (i) The reading of each voltmeter
  (ii) The error from true reading.   10
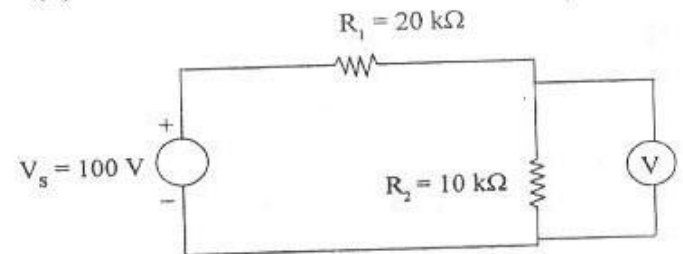
(Contd.)

(d) A negative feedback control system has $G(s) = \dfrac{10}{s(s+1)}$ and H(s) = 5. Determine sensitivity of closed loop transfer function with respect to G and H, for w = 1 rad./sec.   10

7. (a) State and explain Poynting vector. A plane 200 MHz wave is travelling in a medium for which conductivity $\sigma = 0$, $\mu_r = 2$, $\varepsilon_r = 4$. If the average Poynting vector is 5 W/m^2, find E_{rms}, H_{rms}, phase velocity and impedance of the medium.   10

(b) For the π-network shown below :
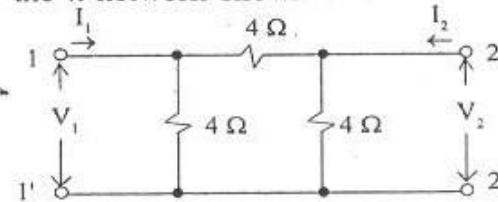
(i) Determine y-parameters.

(ii) If two such identical networks are connected in series, obtain the z-parameters of the resultant network.   10

(c) A feedback system has closed loop transfer function :

$$\frac{C(s)}{U(s)} = \frac{10(s+4)}{s(s+1)(s+3)}.$$

Obtain its canonical state model. Also, write STM (State Transition Matrix) of canonical state model.   10

(d) Explain with the diagram band structure of metals, insulators and semiconductors.   10

8