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Total No. of Printed Pages—7

4CCSME

ELECTRICAL ENGINEERING

PAPER—I

Full Marks : 200 *Time* : 3 hours

The figures in the margin indicate full marks

Candidates should attempt **five** questions out of **ten** questions. Question No. **1** is compulsory

1. Answer any *four* of the following :

(a) *(i)* Determine the Thevenin equivalent circuit as viewed by the resistor R in the circuit of Fig. 1.

(ii) What value of R is required for the maximum power to be dissipated by R ?

(iii) What is the value of power in part *(ii)* ?

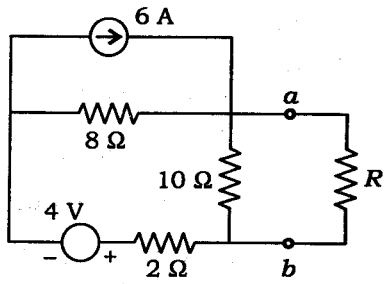

Fig. 1 10

(b) For *R-L-C* circuit shown in Fig. 2, the switch is closed at $t = 0$. Determine the nature of voltage across the capacitor if all initial conditions are zero. 10

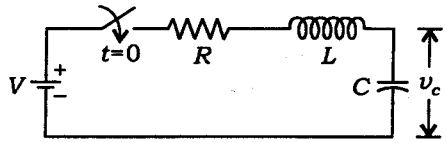

Fig. 2

(c) Find the electric potential at a point on the axis of a uniformly charged circular disc whose surface charge density is σ. 10

(d) What are meant by primary and secondary standards? With an example, explain how these are used in day-to-day life. 10

(e) Represent *p-n-p* and *n-p-n* BJTs by their physical arrangement and schematic symbols indicating positive directions for currents.

A BJT has $\alpha = 0 \cdot 99$, $i_B = I_B = 25\ \mu A$ and $I_{CBO} = 200$ nA. Find—

(i) the d.c. collector current;

(ii) the d.c. emitter current;

(iii) the percent error in emitter current when leakage current is neglected. 10

(iii) speed of the rotor magnetic field with respect to the rotor, *(iv)* speed of the rotor magnetic field with respect to the stator, *(v)* speed of the rotor field with respect to the stator field. 20

(b) A 3-ϕ, Y-connected cylindrical rotor synchronous generator, rated at 10 kVA and 230 V, has a synchronous reactance of $1 \cdot 2\ \Omega$ per phase and an armature resistance of $0 \cdot 5\ \Omega$ per phase. Calculate the percent voltage regulation at full-load with $0 \cdot 8$ lagging power factor. 20

★★★

8. *(a)* State Barkhausen's criteria for oscillation.

The tuned circuit of *L-C* oscillator has a fixed inductance of 50 μH and has to be tunable over a frequency band of 200 kHz to 1000 kHz. Find the range of variable capacitor required. 5+15

(b) Explain the working of a bistable multivibrator and show how it can be used as a basic memory element for digital logic. 20

9. *(a)* Develop equivalent circuit of a 1-ϕ transformer with all basic assumptions. How do you measure the parameters of the equivalent circuit experimentally? 20

(b) A shunt generator rated at 100 kW and 460 V was run as a motor on no-load at its rated voltage and speed. The total current taken from the supply is 9·8 A including a shunt field current of 2·7 A. The resistance at normal working temperature of the armature circuit was 0·11 Ω. Find efficiency of the generator both at *(i)* half-load and *(ii)* full-load. 20

10. *(a)* A 3-ϕ, 50 Hz induction motor has 8 poles and operates with a slip of 0·05 for a certain load. Compute (in r.p.m.) the *(i)* speed of the rotor with respect to the stator, *(ii)* speed of the rotor with respect to the stator magnetic field,

(f) The stator of a 3-ϕ induction machine is connected to a 3-ϕ power supply. Show how a rotating flux is produced in the air gap. What happens if the supply sequence is changed? 10

2. *(a)* In the circuit of Fig. 3, using nodal method, determine $v_o(t)$, where $i(t) = \sqrt{2} \times 10^{-4} \cos(4 \times 10^7 t)$. 20

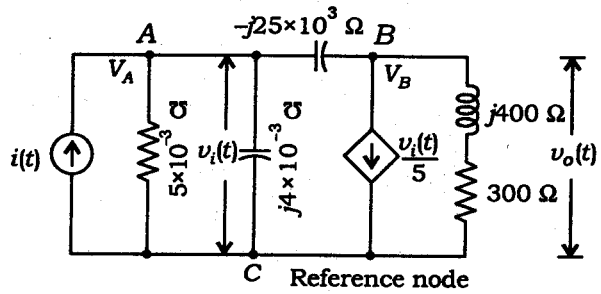

Fig. 3

(b) For the parallel *R-L-C* circuit shown in Fig. 4, assume $R = 10\ k\Omega$, $L = 50 \cdot 7\ \mu H$ and $C = 500$ pF. Find the resonance frequency, quality factor, lower- and upper-half power frequencies, and bandwidth. 20

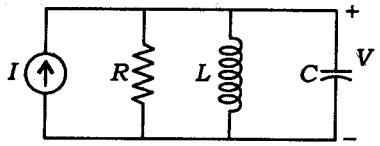

Fig. 4

3. *(a)* For the impedance function given below, realize Foster I form network : 20

$$z(s) = \frac{(s^2+1)(s^2+3)}{s(s^2+2)(s^2+4)}$$

(b) Determine an *R-C* network from the driving-point impedance function

$$z(s) = \frac{10(s+1)(s+3)}{s(s+2)(s+4)}$$ 20

4. *(a)* A charge $Q_2 = 129 \times 10^{-9}$ C is placed in vacuum at a point $P_2(-0{\cdot}03, 0{\cdot}01, 0{\cdot}04)$. Find the force on Q_2 due to a point charge $Q_1 = 110\,\mu C$ at a point $P_1(0{\cdot}03, 0{\cdot}08, -0{\cdot}02)$. 20

(b) A long cylindrical wire of radius R carries a current i_0 distributed uniformly over the cross-sectional area. Determine B at a distance r from centre of the wire, $r < R$ and $r > R$. 20

5. *(a)* Represent Maxwell's equations in both integral and differential forms, expressing their physical meaning. Develop Laplace equation for free space. 20

(b) Explain the functioning of Kelvin's double-bridge method to measure very low resistances. How do you increase accuracy of measurement? 20

6. *(a)* Explain two-wattmeter method to measure 3-ϕ unbalanced power. 20

(b) Develop an experimental scheme to localize an open-circuit fault in a cable. Indicate precautionary measure to be taken. 20

7. *(a)* The amplifier of Fig. 5 uses a silicon transistor for which $V_{BEQ} = 0 \cdot 7$ V. Assuming that the collector circuit presents no limitation, classify the amplifier according to bias (Class A, AB, B or C) if—

(i) $V_B = 1 \cdot 0$ V, $v_s = 0 \cdot 25 \cos \omega t$ (V)

(ii) $V_B = 1 \cdot 0$ V, $v_s = 0 \cdot 5 \cos \omega t$ (V)

(iii) $V_B = 0 \cdot 5$ V, $v_s = 0 \cdot 6 \cos \omega t$ (V)

(iv) $V_B = 0 \cdot 7$ V, $v_s = 0 \cdot 5 \cos \omega t$ (V) 20

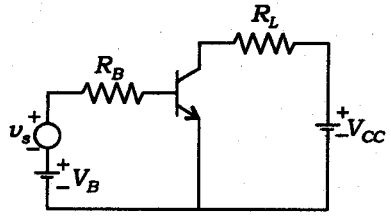

Fig. 5

(b) If the emitter-base junction of a transistor is modelled as a forward-biased diode, express h_{ie} in terms of emitter current. 20

of θ, *(ii)* (using your graph) estimate the main beam efficiency of this antenna, and *(iii)* estimate the directivity of this antenna. 20

(b) State and prove sampling theorem. Is ideal low-pass filter realizable? 20

15. *(a)* What are the elements of pulse code modulation (PCM)? Explain each of them clearly. 20

(b) The signal

$$g(t) = 10\cos(20\pi t)\cos(200\pi t)$$

is sampled at the rate of 250 samples per second.

(i) Determine the spectrum of the resulting sampled signal.

(ii) Specify the cut-off frequency of the ideal reconstruction filter so as to recover $g(t)$ from its sampled version.

(iii) What is the Nyquist rate for $g(t)$?

(iv) By treating $g(t)$ as a bandpass signal, determine the lowest permissible sampling rate for this signal. 20

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Total No. of Printed Pages—12

4CCSME

ELECTRICAL ENGINEERING

PAPER—II

Full Marks : 200 *Time* : 3 hours

The figures in the margin indicate full marks

Note :

(i) Candidates should attempt totally **five** questions from Section—A, and Section—B or Section—C.

(ii) Section—A is compulsory. 1st question is compulsory and attempt at least **one** or **two** more questions from this Section.

(iii) Attempt Section—B or Section—C fully. Out of the selected Section, 1st question is compulsory (i.e., Question No. **6** of Section—B or Question No. **11** of Section—C) and attempt at least **one** or **two** more questions from the selected Section.

SECTION—A

1. Answer any *four* of the following :

(a) *(i)* What do you understand by an open-loop control system and a closed-loop control system?

(ii) Explain the control action of a ceiling fan regulator and draw component block diagram.

(iii) Discuss the control scheme in the manual steering system of an automobile. 10

(b) Obtain the transfer function of a two-phase a.c. servomotor shown in Fig. 1(a). The torque-speed characteristic curve is shown in Fig. 1(b). 10

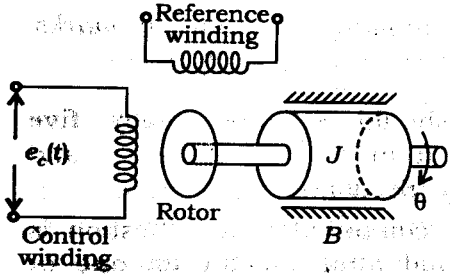

Fig. 1(a)

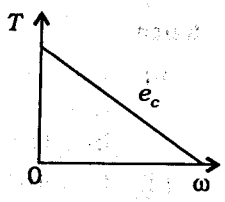

Fig. 1(b)

(c) Define BIBO stability. The open-loop transfer function of a unity negative feedback system is given by

$$G(s) = \frac{K}{(s+3)(s+5)(s^2+2s+2)}$$

Determine the value of K for which the closed-loop system is stable. 10

(d) Explain the working of a three-terminal reverse-blocking thyristor using two-transistor model. Draw the thyristor characteristic and explain it. 10

(e) Explain the functioning of a two-pulse converter with free-wheeling diode. 10

(f) Explain the functioning of a d.c. chopper. 10

(f) A differential amplifier has a differential mode gain of 100 and a common mode gain of 0·01. Calculate CMRR in decibel. 10

12. (a) Explain the terms (i) phase modulation and (ii) frequency modulation. Present schemes to generate phase-modulated and frequency-modulated signals. 20

(b) An air-filled cavity resonator operates in the TE_{110} mode. The cavity is square, $x_1 = z_1 = 80$ mm with height $y_1 = 35$ mm. The cavity is of copper with gold plating inside. Find (i) resonant wavelength, (ii) resonant frequency, and (iii) Q. 20

13. (a) Through block diagram representation, explain the functioning of Time Division Multiplexing (TDM). Explain the role of each block separately. 20

(b) Discuss the functioning of a two-stage direct coupled amplifier (DC amplifier). How is it suited for communication system? 20

14. (a) For an antenna with field pattern

$$E_n = \frac{\sin\theta}{\theta} \cdot \frac{\sin\phi}{\phi}$$

where θ = zenith angle (radians) and ϕ = azimuth angle (radians), (i) plot the normalized power pattern as a function

(ii) Find the Fourier transform of $g_2(t)$. 10

(b) A carrier wave of frequency 1 MHz is modulated 50 percent by a sine wave of frequency 5 kHz. The resulting AM wave is transmitted through the resonant circuit of Fig. 3 which is tuned to the carrier frequency and has a Q-factor of 175. Determine the modulated wave after transmission through the circuit. What is the percentage modulation of this modulated wave? 10

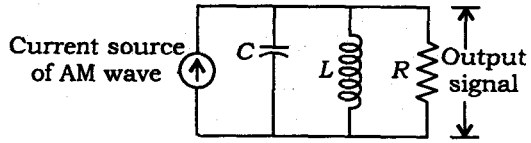

Fig. 3

(c) A signal of 10 V is applied to a 50 Ω coaxial transmission line terminated in a 200 Ω load. Find (i) the voltage reflection coefficient, (ii) the magnitude of the reflected voltage, and (iii) the magnitude of the reflected current. 10

(d) How is a signal transmitted through the hollow rectangular waveguide? 10

(e) Explain with necessary illustrations that the function $C\cos(\omega t - \beta z)$, where $\beta = \omega\sqrt{\mu\varepsilon}$, is a travelling wave that moves at a velocity $v = 1/\sqrt{\mu\varepsilon}$ in positive z-direction. 10

2. (a) For the system shown in Fig. 2, find the transfer function $\frac{V_o(s)}{V_i(s)}$ from its signal flow graph. 20

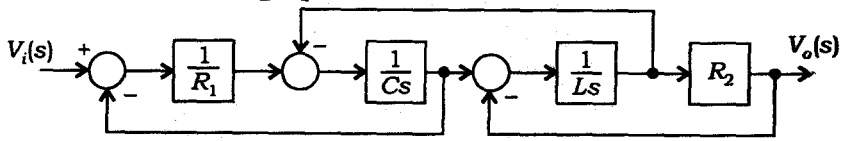

Fig. 2

(b) Determine the values of damping ratio and the natural frequency of oscillations for the following system and hence specify the nature of the step response with respect to the value of damping ratio : 20

$$\frac{C(s)}{R(s)} = \frac{16}{s^2 + 7s + 16}$$

3. (a) A single-phase, half-wave converter operating on a 220 V, 50 Hz supply charges a 72 V battery having an internal resistance of 0·5 Ω. Determine the value of the firing angle so that the charging current does not exceed 20 A. Determine PIV of the thyristor. 20

(b) A d.c. chopper fed from 150 V feeds a load comprising $R = 0{\cdot}2\ \Omega$, $L = 0{\cdot}1$ mH and a back e.m.f. of 20 V. $T_{ON}/T = 0{\cdot}33$ and the period is 3 ms.

(i) Determine the mode of operation of the chopper.

(ii) Find the average values of output voltage and current. 20

4. (a) A three-phase fully controlled bridge rectifier is fed from a three-phase balanced supply at 400 V and 50 Hz. The load consists of $R = 15\ \Omega$ and a large smoothing inductance causing a perfect smoothing. Determine the average value of the load voltage, current and power dissipation for a firing angle of $\alpha = 75°$. Assume the thyristors and supply to be ideal. 20

(b) A feedback system has open-loop transfer function

$$G(s)\,H(s) = \frac{K(s+5)}{(s+1)^2}$$

Sketch the root locus, illustrating salient points and explain its construction. 20

5. (a) A single-phase bridge converter fed from a 250 V, 50 Hz supply is used to control the speed of a separately excited d.c. motor having an armature resistance of $1 \cdot 5\ \Omega$ and inductance 30 mH. The back e.m.f. at one speed of operation is 100 V and the converter control angle is 30°. Determine the average and r.m.s. values of the armature current, the power input to the motor and power factor of operation. 20

motor drives a fan load having characteristic $T_L = (1 \cdot 4 \times 10^{-3})\,\omega^2$. Calculate the range of firing angles. 20

(b) (i) In a certain organization, the meter readings are as follows :

kWh : 98600 units
kVARh : 58000 units
kVA : 180 contracted demand=150 kVA
Billing charges : ₹ 4·25/unit
Demand charges : ₹ 250/kVA
Extra charges for low p.f. : ₹ 1,000 per 0·01 of p.f. when p.f. is less than 0·85

Prepare the bill for electrical charges.

(ii) The readings in the next month are as follows :

kWh : 76600 units
kVARh : 51600 units
kVA demand : 145 kVA

Prepare the bill. 20

SECTION—C

11. Answer any *four* of the following :

(a) A signal $g_1(t)$ is defined by $g_1(t) = \exp(-\alpha t)u(t)$, where $\alpha > 0$.

(i) Find the function $g_2(t)$ obtained by convolving $g_1(t)$ with itself.

Calculate the shaft power output. If the mechanical torque lost in friction and that for core loss is 10 N m, compute—

(i) the copper loss in the rotor windings;

(ii) the input to the motor;

(iii) the efficiency.

The total stator loss is given to be 800 W. 20

(b) A series motor having a combined series field and armature resistance of $1 \cdot 5\,\Omega$ drives a fan load having a torque-speed characteristic given by $T_1 = kN^2$ N m, where N is in r.p.m. At 220 V, the motor runs at 350 r.p.m. taking a current of 8 A. The speed of the fan has to be increased to 500 r.p.m. by increasing the armature voltage. Determine the voltage and current at the new speed. Neglect saturation. 20

10. *(a)* A 240 V, 50 Hz, 4-pole, star-connected, three-phase induction motor has the following equivalent circuit parameters :

$r_1 = 0 \cdot 25\,\Omega$; $x_1 = 0 \cdot 36\,\Omega$; $x_m = 17 \cdot 3\,\Omega$; $r_2 = 0 \cdot 60\,\Omega$; $x_2 = 0 \cdot 36\,\Omega$.

The speed of the motor is to be controlled by a three-phase voltage controller from 1400 to 600 r.p.m. The

(b) For a unity feedback system, the plant transfer function is

$$G_p(s) = \frac{25}{s^2 + 5s + 25}$$

The plant is controlled by a PI controller

$$G_c(s) = K_c + \frac{K_I}{s}$$

Find the range of controller gains (K_c, K_I) for the system to remain stable. 20

SECTION—B

6. Answer any *four* of the following :

(a) What are the conditions of connecting two three-phase transformers in parallel? What do you understand by vector group of a transformer? 10

(b) A three-phase, 50 Hz, star-connected alternator with 2-layer winding is running at 600 r.p.m. It has 12 turns/coil, 4 slots/pole/phase and a coil pitch of 10 slots. If the flux per pole is 0·035 Wb sinusoidally distributed, find the phase and line e.m.f.'s induced. Assume total turns/phase are series connected. 10

(c) Explain what is meant by—

(i) load factor;

(ii) diversity factor;

(iii) contribution factor.

Discuss the characteristics of different loads. 10

(d) A three-phase line has a line impedance of $(0 \cdot 6 + j0 \cdot 6)\,\Omega$ and has a load of 900 kVA. If the receiving-end voltage is to be 3300 V, find the sending-end voltage for load p.f. (i) 0·8 lag and (ii) 0·707 lag. 10

(e) What are the different types of faults that can occur on distribution networks? Explain them with line diagrams. 10

(f) What are the objectives of a distribution protection? What are the different protective devices used in the distribution system? 10

7. (a) A 600 kVA, single-phase transformer with 0·012 p.u. resistance and 0·06 p.u. reactance is connected in parallel with a 300 kVA transformer with 0·014 p.u. resistance and 0·045 p.u. reactance to share a load of 800 kVA at 0·8 p.f. lagging. Find how they share the load (i) when both the secondary voltages are 440 V and (ii) when the open-circuit voltages are respectively 445 V and 455 V. 20

(b) A 50 hp, 50 Hz, 415 V delta-connected induction motor has a full-load efficiency of 0·85 and power factor 0·75. The power factor is to be improved to 0·9 using static capacitors.

Determine (i) rating of capacitor bank kVAR and (ii) capacitance of each unit, if they are connected (1) as delta and (2) as star, in μF. 20

8. (a) A 6 MVA, 11 kV, 8-pole, 50 Hz synchronous generator having saturated synchronous reactance of 0·5 p.u. is synchronized to 11 kV bus. Calculate its synchronizing power and torque coefficient per degree mechanical shift of rotor angle (i) at no load and (ii) at full load 0·8 lagging p.f. 20

(b) A single-phase, 3-wire distribution line 120 V–0–120 V, feeds a load of 10 kVA line-to-line and 3 kVA on each line to ground. The transformer is 7620 V/240 V, 25 kVA with 5% impedance. The line impedance is $j0 \cdot 05\,\Omega$ per wire. Calculate the fault current and fault MVA for L-L fault 1 km from the transformer. 20

9. (a) A 6-pole, 50 Hz, three-phase induction motor running on full load develops a useful torque of 160 N·m when the rotor e.m.f. makes 120 cycles per minute.