CCE(M)/ETE–I/10/2024

ELECTRICAL ENGINEERING

(PAPER—I)

Time : 3 hours] [Full Marks : 250

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

(i) There are **eight** questions divided in **two Sections**.

(ii) Candidate has to attempt **five** questions in all.

(iii) Question Nos. **1** and **5** are compulsory and out of the remaining, **three** are to be attempted choosing at least **one** question from each Section.

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SECTION—A

1. Answer *any* **five** of the following questions : 10×5=50

(a) Determine the power consumed by 5Ω resistor in the given circuit below in Figure – 1 using mesh-current analysis method.

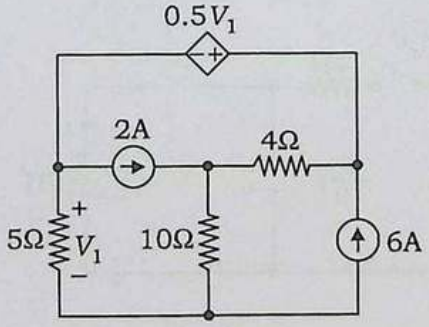

Figure – 1

(b) Find the current I using nodal technique in the circuit given below in Figure – 2.

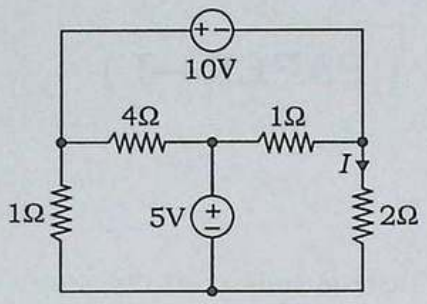

Figure – 2

(c) For the circuit shown in Figure – 3 below, the switch is at position 1 for a long time and then it is thrown in position 2 at $t = 0$. Find the expression for current $i(t)$ for $t > 0$.

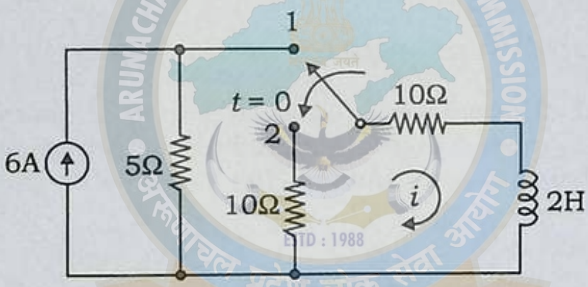

Figure – 3

(d) In the network in Figure – 4 below, the switch is closed and steady-state is reached in the network. At $t = 0$, the switch is opened. Find the expression for the inductor current, $i_L(t)$ for $t > 0$.

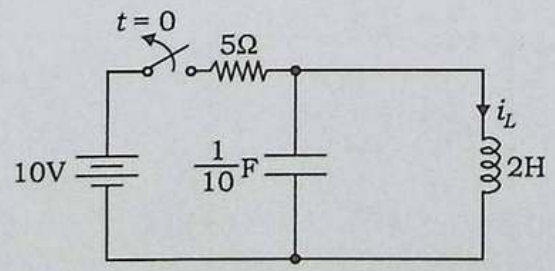

Figure – 4

(e) Conducting spherical shells with radii a = 10 cm and b = 30 cm are maintained at a potential difference of 100 V such that $V(r = b) = 0$ and $V(r = a) = 100$ V. If the relative permittivity $\varepsilon_r = 2.5$ in the region, determine total charge induced on the shells and the capacitance of the capacitor using Laplace's equation.

(f) Explain with necessary diagrams, how a dual slope integrating type ADC operates for conversion of analog input voltage into digital form.

(g) Find the response $y(t)$ of a noncausal system with the transfer function $H(s) = \frac{-1}{s-1}$ and the input $f(t) = e^{-2t}u(t)$.

2. Answer the following questions :

(a) Derive the electric field intensity $\vec{E}_1$ V/m due to an infinite charge sheet with uniform charge density σ C/m^2. Also — 20

(i) derive the electric field intensity $\vec{E}_2$ V/m at P contributed by the circular portion of this infinite sheet charge of radius b metre on the perpendicular axis at a metre from the sheet as shown in Figure – 5 below;

(ii) find b, if $a = 0.5$ m and $\vec{E}_2 = \frac{\vec{E}_1}{2}$.

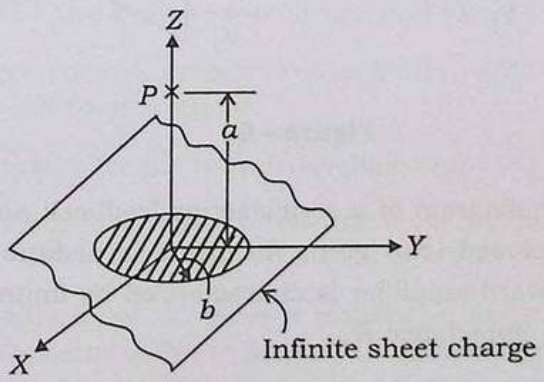

Figure – 5

(b) A uniform plane wave propagating in a medium has $E = 2e^{-\alpha z} \sin(10^8 t - \beta z) a_y$ V/m. If the medium is characterized by $\varepsilon_r = 1$, $\mu_r = 20$ and $\sigma = 3$ mhos/m, then find α, β and H. 15

(c) A charged particle of mass 2 kg and 3 C starts at point (1,–2,0) with velocity $4a_x + 3a_z$ m/s in an electric field of $(12a_x + 10a_y)$ V/m. At time $t = 1$ s, determine —

(i) the acceleration of the particle;

(ii) its velocity;

(iii) its kinetic energy. 15

3. Answer the following questions :

(a) Explain the different configurations of a BJT amplifier along with their characteristics and applications. 20

(b) For the circuit shown in Figure – 6 below, derive the expression for output voltage and sketch the nature of the output when V_2 = 10 V and V_1 = 5 V. 15

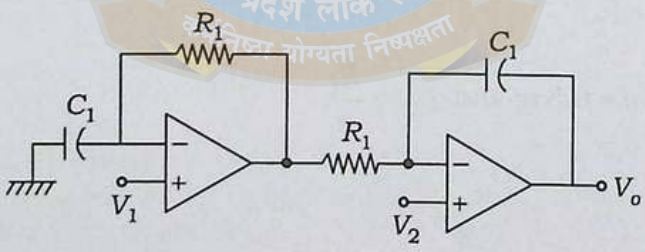

Figure – 6

(c) Draw the schematic diagram of a series-series feedback amplifier and obtain expression for (i) closed-loop gain, (ii) input impedance and (iii) output impedance. The forward amplifier is characterized by finite input impedance R_i and finite output impedance R_o. 15

4. Answer the following questions :

(a) Consider the function $Y(A,B,C)$ given in the truth table.

A	B	C	$Y(A,B,C)$
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

(i) Write a logic expression for $Y(A,B,C)$.

(ii) Implement $Y(A,B,C)$ using only 2-input basic logic gates.

(iii) Implement $Y(A,B,C)$ using only 2-input NAND gates. 20

(b) Explain the working principle of a sample-and-hold circuit. Discuss its applications in analog-to-digital conversion. 15

(c) Explain with necessary diagrams the working principle of (i) an enhancement-type MOSFET, (ii) a depletion-type MOSFET and (iii) an IGBT. 15

SECTION—B

5. Answer *any* **five** of the following questions : 10×5=50

(a) Explain the principle of operation of a 3-phase induction motor. Also, derive the expression for the synchronous speed and slip.

(b) Why a 3-phase synchronous motor is not self-starting? Explain the use of damper winding in a synchronous motor.

(c) Derive an expression for the torque developed in a DC motor.

(d) Describe the effect of armature reaction in a DC machine. How can it be minimized?

(e) What are the differences between a transistor and a thyristor? Explain the operation of a thyristor with the help of its *V-I* characteristics.

(f) What is a Triac? Draw its *V-I* characteristics and explain its operating modes.

(g) Describe the different modes of operation of an SCR.

6. Answer the following questions :

(a) Explain the method of armature voltage control for speed control of a DC shunt motor. What are the advantages and disadvantages of armature voltage control technique? 20

(b) A 440 V, 4-pole, lap connected shunt motor has a no-load input current of 15 A and a shunt field current of 10 A. At full load it takes a current of 150 A. If armature resistance = 0.1 ohm, flux per pole on no-load = 0.05 Wb, number of armature conductor = 750 and contact drop per brush = 1 V, calculate *(i)* no-load speed, *(ii)* full load speed and *(iii)* speed regulation. Armature reaction weakens the field by 1.5% on full load. 15

(c) A 10 kVA, 400/200 V single-phase 50 Hz transformer has a maximum efficiency of 92% at 80% of full load at unity pf. Determine its efficiency at full load at 0.8 pf lagging. 15

7. Answer the following questions :

(a) Draw the speed-torque characteristics of a three-phase induction motor. A 3-phase, 50 Hz, 400 V, 8-pole, star-connected induction motor has the following circuit parameters referred to stator side in an exact equivalent circuit model : R_1 = 0.21 ohm, R_2' = 0.32 ohm, $X_1 + X_2'$ = 4.8 ohm, R_i = 138 ohm, X_m = 18.1 ohm. Assuming $X_1 = X_2'$ and slip S = 4%, find — 20

(i) total impedance seen from the stator side (per phase);

(ii) input line current;

(iii) input power drawn;

(iv) gross mechanical power developed;

(v) gross torque developed.

(b) Explain briefly the different methods of speed control of 3-phase induction motors. 15

(c) Describe the construction and operation of a shaded pole motor. 15

8. Answer the following questions :

(a) A signal $m(t) = 2\cos(20\pi t) - \cos(40\pi t)$, where the unit of time is millisecond, is amplitude modulated using the carrier frequency f_c of 600 kHz. The AM signal is given by

$$s(t) = 5\cos 2\pi f_c t + m(t)\cos 2\pi f_c t$$

(i) Sketch the magnitude spectrum of $s(t)$. What is its bandwidth?

(ii) What is the modulation index?

(iii) The AM signal is passed through a high pass filter with cut-off frequency 595 kHz (i.e., the filter passes all frequencies above 595 kHz and cuts off all frequencies below 595 kHz).

Find an explicit time-domain expression for the quadrature component of the filter output with respect to 600 kHz frequency reference. 20

(b) Derive an expression for the rms load current in a single phase resistive circuit in which the load voltage is controlled by symmetrical phase current triggering of a pair of antiparallel thyristor. If the voltage is given by $e = 100\sin\omega t$ and $R = 50$ ohm, then what is the rms load current at firing angles; $\alpha = 0°, 30°, 60°$? 15

(c) A step-up chopper has input voltage of 220 V and output voltage of 660 V. If the non-conducting time of thyristor is 100 μ sec. compute the pulse width of output voltage. If the pulse width is halved for a constant frequency operation, then find the new output voltage. 15

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SPACE FOR ROUGH WORK

CCE(M)/ETE–II/10/2024

ELECTRICAL ENGINEERING

(PAPER—II)

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SECTION—A

1. Answer *any* **five** of the following questions : 10×5=50

(a) Define stability in a control system and explain Routh-Hurwitz stability criterion.

(b) What is a PID controller? Explain its working and applications.

(c) What are the different addressing modes of an 8085 microprocessor?

(d) Explain the interrupt system of an 8085 microprocessor.

(e) What is a transducer? Explain its working principle with a detailed block diagram.

(f) Explain the working principle of a Digital Multimeter.

(g) Explain the instruction set of an 8085 microprocessor.

2. Answer the following questions :

(a) The loop transfer function $G(s)H(s)$ of a single feedback-loop control system is given by

$$G(s)H(s) = \frac{K}{s^2(s+2)(s+10)}$$

Apply the Nyquist criterion and determine the value of K for the system to be stable. Also, determine the gain margin if $K = 10$. 20

(b) The open-loop transfer function of a unity feedback system is given by

$$G(s) = \frac{K(s+1)}{s^3 + as^2 + 2s + 1}$$

Using Routh's criterion, determine the value of K and a so that system oscillates at frequency of 2 rad/sec. 15

(c) Given a system in state space representation as :

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y = [1 \quad 0] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

(i) Check whether the system is observable or not.

(ii) Find the state transition matrix and transfer function $Y(S)/U(S)$. 15

3. Answer the following questions :

(a) Explain the architecture of the 8085 microprocessor and describe its various components. 20

(b) Draw memory read machine cycle of 8085 microprocessor and explain the same. 15

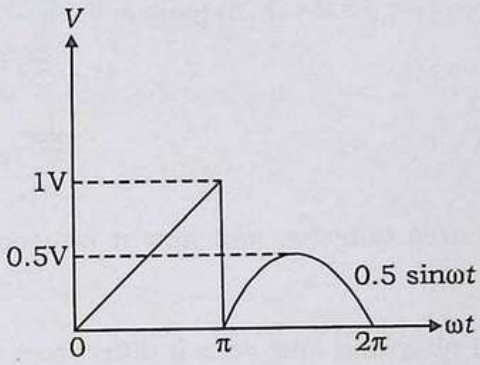
(c) Explain the mathematical function that is performed by the following instructions of 8085 microprocessor :

```
MVI A, 07H
RLC
MOV B, A
RLC
RLC
ADD B
```

15

4. Answer the following questions :

(a) Calculate the reading of *(i)* moving coil voltmeter and *(ii)* moving iron voltmeter when these voltmeters are measuring the voltage of the waveform shown in the figure below. 20



(b) Draw the circuit diagram and explain the operation of a practical Q-meter and write its applications. 15

(c) A standard cell of 1.0185 V used with a simple potentiometer balances at 50 m. Calculate –

(i) the emf of cell which balances at 72 cm;

(ii) the percentage error in voltmeter which balances at 64.5 cm when reading 1.33 V and

(iii) the percentage error in ammeter that reads 0.43 A and balance is obtained at 43.2 cm with potential difference across a 2 ohm resistor in the ammeter circuit. 15

SECTION—B

5. Answer *any* **five** of the following questions : 10×5=50

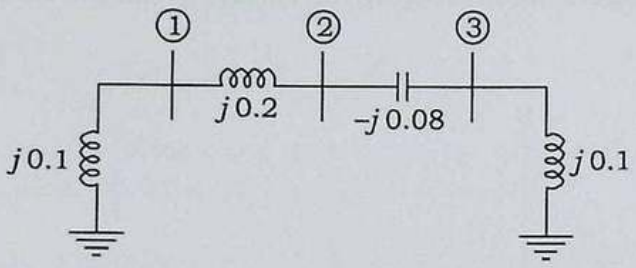
(a) A lossless power system has to serve a load of 250 MW. There are two generators (G_1 and G_2) in the system with cost curves C_1 and C_2 respectively defined as follows :

$$C_1(P_{G1}) = P_{G1} + 0.055P_{G1}^2$$

$$C_2(P_{G2}) = 3P_{G2} + 0.03P_{G2}^2$$

where P_{G1} and P_{G2} are the MW injections from generator G_1 and G_2 respectively. What will be the minimum cost dispatch?

(b) A three-bus network is shown in the figure below indicating the p.u. impedance of each element. Find the admittance matrix, *Y*-bus of the network.



(c) Describe the equal area criterion and how it is used for transient stability analysis.

(d) What is a numerical relay and how does it differ from traditional relay?

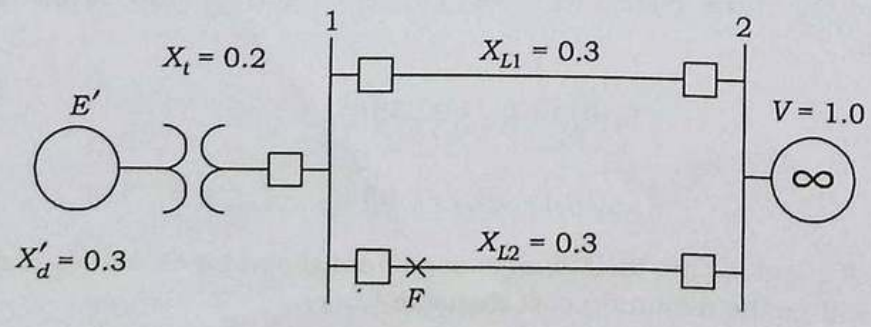
(e) Derive the complex power in terms of symmetrical components.

(f) Explain the role of Automatic Voltage Regulator (AVR) in generators.

(g) What are quantization errors in PCM and how can they be reduced?

6. Answer the following questions :

(a) A 60 Hz synchronous generator having inertia constant $H = 5$ MJ/MVA and a direct axis transient reactance $X'_d = 0.3$ pu is connected to an infinite bus through a purely reactive circuit as shown in the figure below. Reactances are marked on the diagram on a common system base. The generator is delivering real power $P_e = 0.8$ pu and $Q = 0.074$ pu to the infinite bus at a voltage of $V = 1$ pu. A temporary three-phase fault occurs at the sending end of the line at point *F*. When the fault is cleared, both lines are intact. Determine the critical clearing angle and the critical fault clearing time. 20



(b) With a neat flow chart, explain the load flow by Gauss-Seidel method. 15

(c) A power system with two generating stations supplied a total load of 300 MW. Neglecting transmission losses the economic schedule for the plant generation are 175 MW and 125 MW. Find the saving in generation cost in Rs/hr due to this economic schedule as compared to equal distribution of the same load between the two units.
The incremental cost characteristics are : 15

$$\frac{dC_1(P_1)}{dP_1} = 30 + 0.3P_1$$

$$\frac{dC_2(P_2)}{dP_2} = 32.5 + 0.4P_2$$

7. Answer the following questions :

(a) Explain how arc is initiated and sustained in a circuit breaker when breaker contacts separate. Also, explain the terms *(i)* restriking voltage, *(ii)* recovery voltage and *(iii)* RRRV. Derive an expression for the restriking voltage in terms of system voltage, inductance and capacitance across a circuit breaker when a 3-phase fault takes place. Assume the neutral of the system to be solidly grounded. 20

(b) Describe the construction, principle of operation and application of an *(i)* induction disc and *(ii)* induction cup type relay. Also, derive the torque equation for the induction type relay. 15

(c) What is a Solid State Relay (SSR)? Explain its working principle. How does a solid state relay differ from an Electromechanical Relay (EMR)? 15

8. Answer the following questions :

(a) Explain the concept of digital modulation. What are the types of digital modulation schemes? Discuss the advantages and disadvantages of each. 20

(b) Discuss the concept of Error Control in Digital Communication. What are the different error control techniques used in digital communication systems? 15

(c) A digitizing system specifies 55 dB of dynamic range. How many bits are required to satisfy the dynamic range specification? What is the signal-to-noise ratio for the system? What is the signal-to-quantization noise (S/N) q for the system? 15

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SPACE FOR ROUGH WORK

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