CSM – 24/20

Electrical Engineering

Paper – I

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

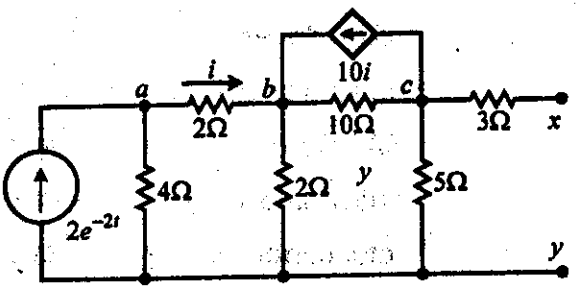
*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any **three** of the remaining questions, selecting at least **one** from each Section.*

SECTION – A

1. Answer any **three** of the following :

   (a) (i) Find Thevenin's equivalent of the network

shown in the figure at the left of terminals x-y. 8



(ii) The electric field intensity of an electro-magnetic wave in free space is given by :

$$E_y = 0, E_z = 0$$

$$E_x = E_0 \cos \omega \left(t - \frac{z}{v} \right)$$

Determine an expression for the components of magnetic intensity H, and find the skin depth ($\omega = 2\pi \times 10^{10}$ rad/sec, $\sigma = 5.88 \times 10^7$ and $\mu = 4\pi \times 10^{-7}$ H/m). 6

(iii) A DC chopper is used to control the speed of a separately-excited DC motor,

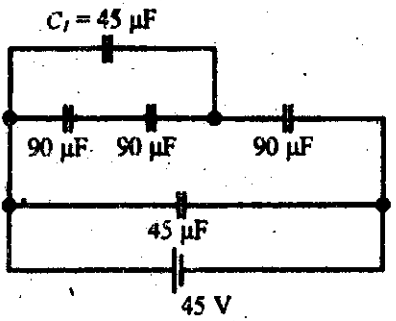
The DC supply voltage is 220 V, armature resistance r_a = 0.2 Ω and motor constant $k_a \phi$ = 0.08 V/rpm. This motor drives a constant torque load requiring an average armature current of 25A. Determine the range of speed control and duty cycle. Assumed the motor current to be continuous. 6

(b) (i) A transistor is fed with a signal having an open circuit voltage v_{sig} = 10mV and an internal resistance R_{sig} = 100 kΩ. The voltage v_i at the amplifier input and the output voltage v_0 are measured both without and with a load resistence R_L = 10 kΩ connected to the amplifier output. The measured results are as follows :

	v_1(mv)	v_0(mv)
Without R_L	9	90
With R_L	8	70

Find all the amplifier parameters. 12

(ii) Find the charge in the capacitor C_1 of below figure : 8



(c) (i) Explain with diagram the principle of operation of an A/D converter based on "successive approximation method". How is it better than an A/D converter based on "Counter type" ? 10

(ii) When a 20 kVA, 3300/220 V, 50 Hz transformer is operated on rated voltage at no load, its power input is 160 watts at a pf of 0.15. under rated load conditions, the voltage drops in the total resistance and total leakage reactance are, respectively, 1 and 3 percent of rated voltage. Determine input power

and pf when the transformer delivers 14.96 kW at 220 V at 0.8 pf lagging to a load on the LV side. 10

(d) (i) Using residue method find the inverse z-transform of : 6

$$X(z) = \frac{1 + 3z^{-1}}{1 + 3z^{-1} + 2z^{-2}}, \quad |z| > 2$$

(ii) A SSB signal is demodulated by using the synchronous demodulator. However the locally arranged carries has a phase error of zero. Determine the effect of error on demodulation. What will be effect of this error if the input is DSB-SC in place of SSB. 6

(iii) A shunt wound motor runs at 500 RPM on a 200V supply, R_a = 0.5 ohm, the current drawn is 30 A in addition to field current. What resistance must be placed in series with the armature in order that the speed may be reduced to 300 RPM, the current in the armature remaining the

same ? If the load is changed so that with the inserted resistance, the armature current reduces to 15 A, what will be the speed ? 8

2. (a) Describe with the aid of a diagram what happens when a battery is connected across a simple capacitor comprising two metal plates separated by dielectric, A capacitor consists of two metal plates, each 400 × 400 mm, spaced 6mm apart, the space between the metal plates is filled with glass plates 5 mm thick and a layer of paper 1mm thick. The relative permittivity of the glass and paper are 8 and 2 respectively, calculate the capacitance, neglecting any firing flux and the electric field strength in each dielectric in kolovolts per millimeter due to a potential difference of 10 kV between the metal. 20

(b) Find the difference between the values of $\int_c \phi d\vec{r}$, $\phi(x, y) = x^3y + 2y$ from (1, 1,0) to (2, 4,0) along the curve $y = x^2, z = 0$ and along the straight line joining (1, 1,0) and (2, 4,0).

Hence evaluate $\int_c \left(\nabla . \vec{f}\right) d\vec{r}$, where $\vec{f} = \frac{1}{4}x^4 y\hat{i} + y^2\hat{j} + xy\hat{k}$ along the curve which is a parabola $y = x^2$, $z = 0$ from (1, 1,0) to (2, 4,0). 20

(c) A Causal system is represented by the following difference equation :

$$y(n) + \frac{1}{4}y(n-1) = x(n) + \frac{1}{2}x(n-1)$$

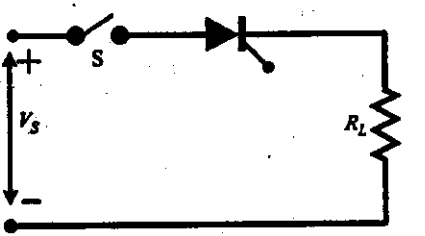
Find the system function H(z), the corresponding region of convergence, the unit sample response of the system, and the frequency response $H(e^{j\omega})$ also determine its magnitude and phase. 20

3. (a) Find the output produced by miller integrator in response to an input pulse of 1 V height and 1-ms width. Let R = 10 kΩ and C = 10 nF. If the integrator capacitor is shunted by a 1 MΩ resistor, Describe with the aid of a diagram, how will the response be modified ? The op amp is specified to saturated at ±13 V. 20

(b) A 3-phase delta-connected squirrel-cage induction motor has certain equivalent circuit parameters. With the same stator core, the motor is rewound with star-connected windings of same poles for operation at the same supply voltage and frequency to give same rated power output at the same slip. By what factors each of the equivalent circuit parameters would be changed ? 20

(c) Explain the working of binary ladder digital to analog converter using R-2R ladder network with four input voltages. If in the above DAC a reference voltage of 12 V is used, what will be its resolution and full scale output ? An equality detector gives the output Y = 1, if both the inputs A and B are either 1 or 0. Construct the truth table, write the Boolean expression for Y, Implement the circuit using NAND gates only. 20

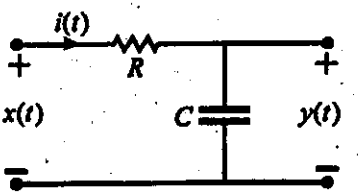
4. (a) (i) A thyristor controlling the power in a load resistance R_L. the supply voltage is 240 V dc and the specified limits for di/dt and dv/dt for the SCR are 50 a/μsec and 300 V/μsec respectively. Determine the values of the di/dt inductance and the Snubber circuit parameters R_s and C_s. 12



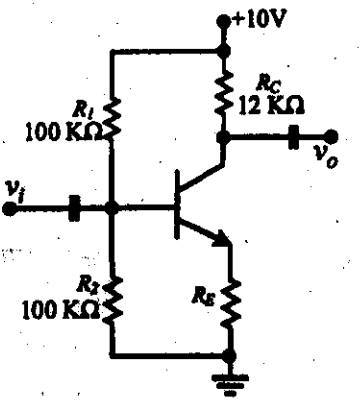
(ii) Give the general layout of a firing circuit scheme and explain the function of various components used in it. Describe RC half-wave trigger circuit for one SCR and discuss the function of the various components used. Describe, with the help of waveforms, how the output voltage is controlled by varying the resistance ? Draw the voltage waveform across SCR also. 8

(b) (i) Find the response of the circuit to the input: 4

$$x(t) = r(t) - 2r(t-1) + r(t-2)$$



(ii) The common emitter amplifier shown in the Figure has voltage gain 400 when $R_E = 0$. Stability is brought through



negative feedback by adding resistor R_E. Find the value of resistor R_E using

feedback concepts so that final voltage gain is equal to 200. 10

(iii) The electric field of a uniform plane wave $\bar{E} = E_0\cos(\omega t - \beta z)\bar{i}_x + E_0\sin(\omega t - \beta z)\bar{i}_y$ E_0 is constant. Find corresponding magnetic field $\bar{H}_r$. Finding Poynting vector and evaluate value of $E_0 = 10$ v/m. 6

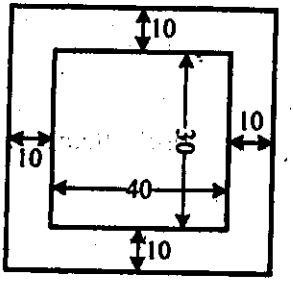
(c) A salient-pole synchronous generator has the following per-unit parameters : $X_d = 1.2$, $X_q = 0.8$, $r_a = 0.025$. Compute the excitation voltage E_f on a per unit basis, when the generator is delivering rated kVA at rated voltage and at a power factor of (i) 0.8 lagging and (ii) 0.8 leading. 20

SECTION – B

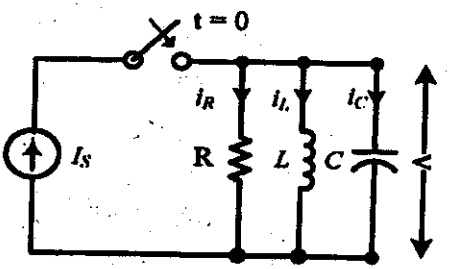
5. Answer any **three** of the following :

(a) (i) A single-phase transformer has its core dimensions in cm as shown in figure. The core is square in cross-section. For a maximum flux density of 1.2T in the core, the magnetic field intensity is 600 A/m and the core loss is 2 W/kg at 50Hz. Core density is 7.8 g/cm^3. For an applied

voltage of 1200v, 50Hz at primary terminals, calculate the number of primary turns, and current, pf and power on the primary side under no-load conditions. 10



(ii) In the R-L-C circuit shown in Figure, I_s = 10A, R = 1Ω, L = 1H, C = 1μF, $i_L(0^-)$ = 0. Determine $v(0^+)$, $\frac{dv}{dt}(0^+)$, $\frac{d^2v}{dt^2}(0^+)$ after the switch is closed at t = 0. 10

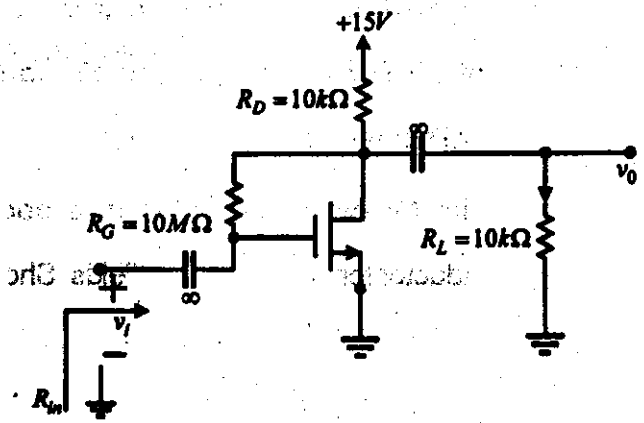


(b) (i) Describe the working of an IGBT. How does latch-up occur in an IGBT ? Give a comparison between an IGBT and a PMOSFET. 6

(ii) Explain the construction and working of helical antenna in axial mode of radiation. Which mode of helical antenna is of practical use ? And why ? 4

(iii) The transistor shown in figure has $V_t = 1.5V$, $K_n'(W/L) = 0.25\ mA/V^2$, and $V_A = 50\ V$. The input signal v_i is coupled to the gate via a large capacitor, and the output signal at the drain is coupled to the load resistance R_L via another large capacitor. Determine its small signal voltage gain, its input resistance and largest allowable input signal. Assume the coupling capacitors to be sufficiently large so as to act as short

circuits at signal frequencies of interest. 10



(c) (i) Show that for a right-handed signal satisfying $x(t) = 0$ for $t < t_0$, $X(s)$ converges for some value of s, the ROC $X(s)$ is $Re(s) > \alpha_{max}$ where α_{max} equals the maximum real part of any of the poles of, $X(s)$. 6

(ii) Define Amplitude modulation and modulation index. Write down the equations for the Amplitude. The instantaneous voltage of the amplitude

modulated wave, and sketch the graph of an amplitude modulated wave. 8

(iii) Why is the starting current high in a DC motor ? Explain the working of a four-point starter for a DC machine. 6

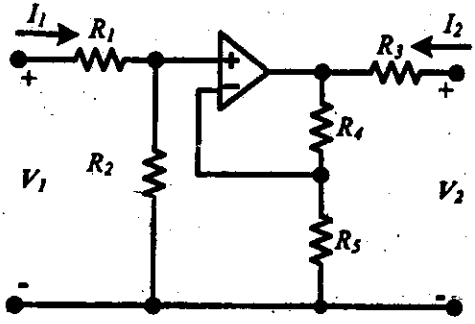
(d) (i) Write Maxwell's equation in a good conductor for time harmonic fields. Show that the conduction current density J in a good conductor must satisfy. 6

$$\nabla(\nabla.J) - \nabla^2 J = -j\omega\mu\sigma J$$

(ii) What information do the 'power-load angle curves' of synchronous machines convey, and how do they look like for the two types of synchronous machines ? A synchronous generator is running overexcited with E_f = 1.40 pu. This machine, with a synchronous reactance of 1.20 pu, is delivering a synchronous

power of 0.50 pu to the bus. If the prime-mover torque is increased by 1% by how much will the synchronous power P and reactive power Q change ? 8

(iii) Find the z parameters of the network shown in the figure. Is the network reciprocal ? If so, why ? Assume the Op-amp is ideal. 6



6. (a) (i) For the Wein-Bridge oscillator find the poles of the closed loop system. Give the expression for the pole, and use it to show that to locate the poles in the right half of the s-plane, R2/R1 must be selected to be greater than 2. 8

(ii) A 12 bit dual-slope ADC utilizes a 1 MHz clock and has V_{ref} = 10 V. Its analog input voltage is in the range of 0 to – 10 V. Find out the time required to convert an input signal equal to the full scale value. Also find the integrator time constant if the peak voltage reached at the output of the integrator is 10 V. 12

(b) (i) Find the potential at a point P which is 1m radial distance from the midpoint of a 2m straight line charge of uniform density 10 nC/m in air. If this line charge is bent to form an arc of a circle of radius 1m, find the percentage change in potential at the same point P. Give reason for this change. 10

(ii) Make statements about tangential components of $\vec{E}$ and H, and normal components of B and D at any surface

of discontinuity. Derive Maxwell's equation for harmonically varying fields in integral and differential forms. For co-axial capacitor (having outer radius b, inner radius a and length ℓ), find the displacement current flowing across a surface at a radius r between a and b assume $V = V_{max} \sin \omega t$. 10

(c) (i) The following data refers to a 12-pole, 420 V, 50 Hz, 3-phase mesh connected induction motor : $r_1 = 2.95\Omega$, $x_1 = 6.82\Omega$, $r'_2 = 2.08\Omega$, $x'_2 = 4.11\Omega$ per phase. On no load, the line value of magnetizing current is 6.7A and the total core loss is 269 W. Determine of pf, input current equivalent rotor current and torque developed by the motor at a slip of 3% using exact equivalent circuit. Determine the maximum torque developed and the corresponding speed. 8

(ii) Give the general layout of Ward-Leonard method of speed control and explain its torque-speed and power-speed characteristics. Discuss advantages and disadvantages of Ward-Leonand method of speed control. 4

(iii) An 11/0.4 kV, 25 Hz single-phase transformer has ohmic, hysteresis and eddy current losses of 1.8, 0.8 and 0.3% respectively. What do these losses become if the transformer is operated from 22 kV, 50 Hz supply system ? The current is assumed to remain the same in both the cases. Also calculate efficiency in each case. 8

7. (a) Design a circuit that takes as input two 2-bit numbers, N_1 and N_2 for comparison and generates three outputs : $N_1 = N_2$, $N_1 < N_2$

and $N_1 > N_2$. These three binary outputs are represented by F_{eq}, F_{lt} and F_{gt} respectively. Realize the outputs in Sum of Products (SoP) form. 20

(b) (i) Explain the principle of frequency modulation and its advantages over amplitude modulation. Between AM and FM, which one gives better noise immunity ? 6

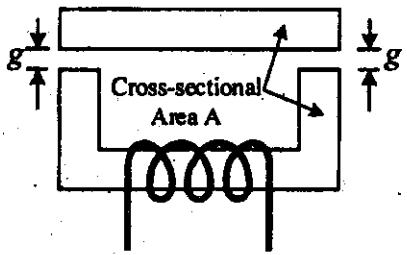
(ii) Show that the efficiency of single tone AM is 33.3% for the modulation index to be equal to unity. 4

(iii) Explain briefly the working of a PCM communication system. A rectangular pulse with duration T = 2 is sampled and reconstructed using an ideal low pass filter with $B = \frac{f_s}{2}$. Determine the output signal when $T_s = 0.8$. 10

(c) A 3-phase full converter, fed from delta-star transformer is connected to load RL requiring ripple free load current. For a firing angle delay of around 45°, sketch waveforms for input voltage V_{ab}, V_{bc}, V_{ac}, load voltage, load current, thyristor T1 and T4 currents, and phase a, b, c currents. In case ac supply is 3-phase, 400V, 50Hz, level load current = 15A and $\alpha = 45^{\circ}$, calculate rectification efficiency, TUF and input power factor. 20

8. (a) (i) Distinguish between singly-excited and doubly-excited magnetic systems. An inductor is made from magnetic core with two air gaps of equal length 'g' as shown in fugure. The exciting coil has 1000 turns, A = 5cm × 5cm and g = 1cm. Core is assumed to have infinite permeability and fringing is neglected. Find the coil inductance. In case coil

current is 5A, find the magnetic energy stored in the inductor. Find also the force in its armature. With coil current held fixed at 5A, find the electrical energy supplied by source if the gap length decreases from 1cm to 0.5cm. find also the mechanical work done. 10



(ii) In a doubly-excited rotary machine, the inductance co-efficients are $L_{11} = (1.1 + 0.4 \cos 2\theta)$; $L_{22} = (0.03 + 0.005 \cos 2\theta)$; $L_{12} = (0.2 \cos \theta)$. The exciting currents are $i_1 = 8A$ and $i_2 = 50A$. Obtain the torque/angular displacement relation. Derive the expression used, if any. 10

(b) (i) Solve the following difference equation for y(n) using z-transform and the specified initial conditions. 12

$$y(n) - y(n-1) + \frac{1}{4}y(n-2) = x(n) \quad n \geq 0$$

Where $x(n) = 2\left(\frac{1}{8}\right)^n$; $y(-1) = 2$ and $y(-2) = 4$

(ii) Bring out the relation between s-plane and z-plane. 8

(c) (i) Discuss the salient features of Uniform Linear Array and discuss the BWFN and HPBW of the antenna. 8

(ii) The antenna current of an AM transmitter is 7.5A ; when only the carrier is sent, but it increases to 8.65A, when the carrier is Sinusoidal modulation. Find the percentage modulation. Determine the antenna current when the depth of modulation is 0.75. 12