CSM – 24/21

Electrical Engineering

Paper – I

Time : 3 hours

Full Marks : 300

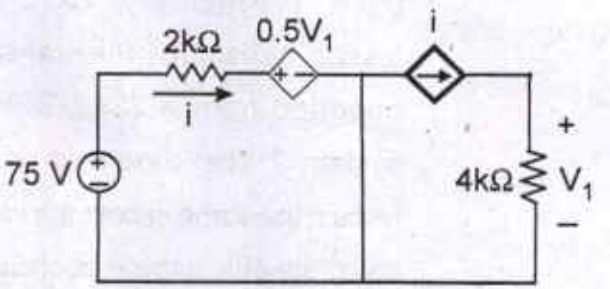
The figures in the right-hand margin indicate marks.

*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** questions of the following :

(a) (i)



In the circuit shown above, the magnitude of the voltage V_1 in volts, across the 4kΩ resistor is _____.

8

(ii) Given a ferrite material operating in linear mode with B = 0.05T, calculate the following (a)χ_m, (b)M (c) H. Assume $\mu_r = 50$. 6

(iii) "Ward-Leonard method of speed control of a dc motor provides a smooth control in both the directions". Justify on the correctness or otherwise of this statement. 6

(b) (i) 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 a 22kV, 50Hz supply system ? The current is assumed to remain the same in both the cases. Also, calculate efficiency in each case. 10

(ii) A MOSFET has a drain circuit resistance, R_d of 100 kΩ and operates at 20kHz. Calculate the voltage gain of this device as a single-stage amplifier. The MOSFET parameters are :

$f = 20kHz$; $g_m = 1.6mA/V$; $r_d = 44k\Omega$; $C_{gs} = 3pF$; $C_{ds} = 1pF$ and $C_{gd} = 2.8pF$. 10

(c) (i) Draw the logic symbols and explain the operation of D-type and T-type flip-flop. 10

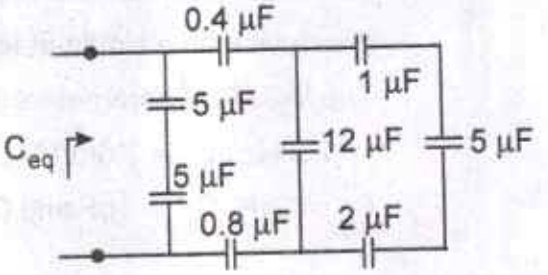
(ii) Explain the multi-quadrant operation of electric drives. 10

(d) (i) A 400 W carrier is modulated to a depth of 75%. Calculate the total power P_t in the modulated wave. 8

(ii) Determine the total energy and average power of the following signal : 12

$$x(t) = \begin{cases} 2 & -3 \le t \le 3 \\ 5-t & 3 \le t \le 5 \\ 0 & \text{otherwise} \end{cases}$$

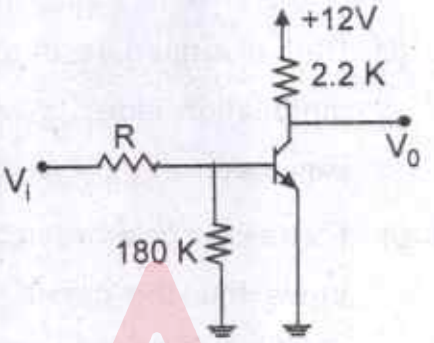
2. (a) (i) Find the charge in the capacitor C_{eq} of the below figure : 8



(ii) A 200 V, 875 rpm, 150 A separately excited dc motor has an armature resistance of 0.06 Ω. It is fed from a single-phase fully controlled rectifier with an ac source voltage of 220 V, 50Hz. Assuming continuous conduction, calculate : (i) Firing angle for rated motor torque and 750 rpm (ii) Firing angle for rated motor torque and (– 500 rpm) (iii) Motor speed for $\alpha = 160^{\circ}$ and rated torque. 12

(b) In the circuit given below, the Si transistor used has $\beta \geq 30$ and $I_{CBO} = 10$ nA. Determine : (i) For $V_i = 12V$ and $R = 20k\Omega$, show that

the transistor is in saturation. (ii) Minimum value of R for the transistor to remain in the active region for $V_i = 12V$. (iii) Value of V_o for $V_i = 1V$ and $R = 15\ K\Omega$. 20



(c) Show that in a source-free region ($J = 0$, $\rho_v = 0$) Maxwell's equations can be reduced to two. Identify all embracing equations. 20

3. (a) Transformers with equal voltage ratios are operating in parallel. Show that the kVA load shared by any one transformer is given by

$$S_k = \frac{\sum_1^n S_k}{z_{ek}\sum_1^n \frac{1}{z_{ek}}} = \frac{\sum_1^n S_k}{z_{ek\ pu}\sum_1^n \frac{1}{z_{ek\ pu}}}$$

The symbols used have their usual meanings. 20

(b) (i) Draw the neat circuit of a voltage doubler. Explain its operation. Draw the wave forms for the voltages across the two capacitors. 12

(ii) Define Amplitude modulation and modulation index. Write down the expression of Amplitude modulation. 8

(c) (i) For a salient-pole synchronous machine, prove that the d-axis synchronous reactance X_d, can be obtained from its OCC and SCC. Neglect armature resistance. 8

(ii) Show that the starting torque per line ampere with autotransformer starting is more than that obtained by stator-reactor starting. Show that the starting torque of a polyphaser induction motor varies (i) Linearly with the starting line current in case of an autotransformer starting and (ii) Non-linearly with starting line

current in case of stator-reactor starting. Hence plot the variation of starting torque with starting line current for an induction motor with $\frac{I_{SC}}{I_{fl}} = 5$ and full-load slip equal to 0.05. 12

4. (a) (i) A 3-phase, 400 V, 50 Hz star-connected induction motor gave the following test results : 12

No load : 400 V, 7.5 A, 0.135 power factor

Blocked rotor : 150 V, 35 A, 0.44 power factor

The ratio of standstill leakage reactance of stator and rotor is estimated as 2. If the motor is running at a speed of 960 r. p. m, determine (i) Net mechanical power output, (ii) the net torque and (iii) efficiency of motor.

Assume stator and rotor copper losses are equal.

(ii) Volume charge density is the same as the divergence of the electric flux density. Using Gauss's law, derive equations to prove it. 8

(b) (i) Explain the difference between a "combinational" circuit and "sequential" circuit. Give few examples of each of them. 4

(ii) A 6.6kV star-connected synchronous motor has synchronous impedance $Z_s = (2 + j10)\Omega$ per phase. Its excitation is so adjusted that for an input power of 500kW, the motor pf is 0.7 leading. Now the motor is connected in parallel with a load drawing 1000kW power at 0.8pf lag while its input power is changed to 600kW with the same excitation as above. 10

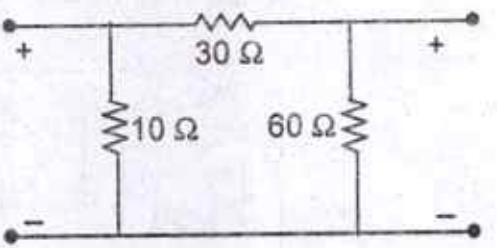
Find (i) The new load angle of the motor. (ii) The total input power factor for the load and synchronous motor combination.

(iii) Explain the construction and working of helical antenna in axial mode of radiation. 6

(c) (i) Determine the unilateral Laplace transformation of the signals given below : 12

$x(t) = u(t-1) * e^{-2t}u(t-1)$

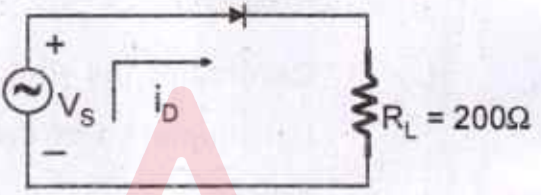
(ii) For the two port network shown in the figure, find the impedance matrix : 8



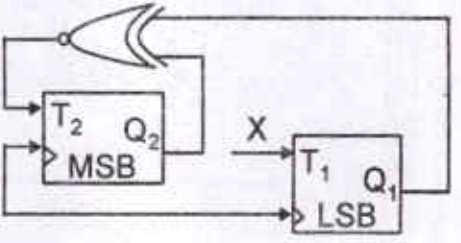
SECTION – B

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

(a) (i) Find the circulating current in the circuit shown in figure, If the source voltage $V_S = 1.2 + 0.5 \sin 500t$ Volts. Assume $\eta V_T = 50mV$ and $V_{ON} = 0.7$ V. 10



(ii) The implementation of a 2-bit counter using T flip-flop following the sequence 0-2-3-1-0 is shown below. For completing the circuit, what should be input X in terms of the outputs ? 10



(b) (i) An electrostatic field in xy-plane is given by $\phi(x, y) = 3x^2y - y^3$. Find the stream function ψ such that the complex potential $\omega = \phi + i\psi$ is an analytic function. 6

(ii) Discuss, with the help of a circuit example, the purpose of providing negative feedback and positive feedback in amplifiers. 6

(iii) A 20 MHz carrier is modulated by a 450Hz audiosine wave. If the carrier voltage is 4.5 V and the maximum deviation is 10 kHz, write down the equation of this modulated wave for F. M. and P. M. If modulated frequency changed to 2kHz, write down the new equation. 8

(c) (i) A causal LTI system is described by the difference equation :

$$y(n) - ay(n-1) = bx(n) + x(n-1)$$

where a is real, and its magnitude is less than 1. (i) Find the value of b ($b \neq a$) such that the frequency response is independent of frequency. (ii) Find the value of b such that the frequency response satisfies $|H(e^{j\omega})| = 1$ for all ω, an all-pass system and the magnitude is constant and independent of its frequency. 10

(ii) A 2.8 kW, 400 V, 50Hz, 4 pole, 1370 rpm, delta-connected squirrel-cage induction motor has the following parameters referred to stator : $R_s = 2\,\Omega$, $R'_r = 5\,\Omega$, $X_s = X'_r = 5\,\Omega$, $X_m = 80\Omega$. Motor speed is controlled by stator voltage control. When driving a fan load, it runs at rated speed at rated voltage. Claculate : (i) Motor terminal voltage,

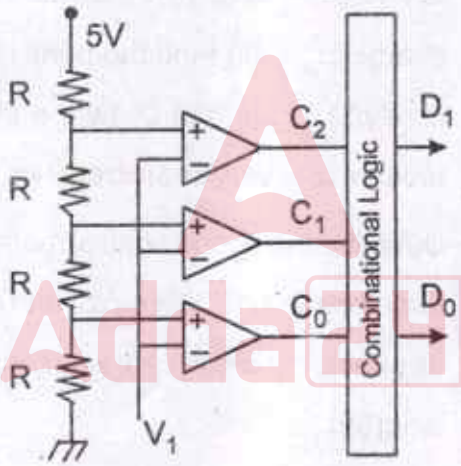
current and torque at 1200 rpm (ii) Motor speed, current and torque for the terminal voltage of 300V. 10

(d) (i) The reverse recovery time of a diode is t_{rr} = 6μs and the rate of fall of the diode current di / dt = 10 A/μs. If the softness factor SF = 0.5. (i) Find the storage charge Q_{RR}. (ii) Find the peak reverse current I_{RR} and (iii) Draw the labelled reverse recovery characteristics. 12

(ii) Describe the speed control methods of three-phase induction motor and explain its speed vs torque characteristics with diagram. 8

6. (a) The circuit shown below is a 2-bit A/D converter. The combinational logic is to be designed to provide a natural binary representation using D_1 and D_0 for the analog input V_1D_1 is to be the MSB.

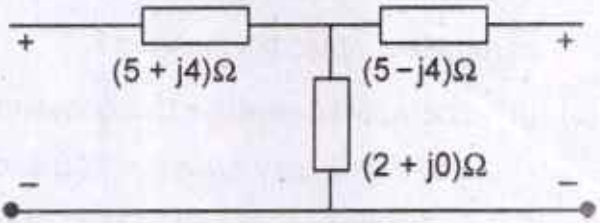
(a) Draw the k-maps for D_1 and D_0 in terms of C_2C_1 and C_0. (b) Obtain the minimal sum of products (SOP) for D_1 and D_0.(c) Realize the logic for D_1 and D_0 using 2-input NAND gate only. (ii) Find the resolution of the A/D converter. 20



(b) (i) Using residue method find the inverse z-transform of : 10

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

(ii) Calculate the ABCD parameters of the following 2-port network : 10



(c) (i) A single phase ac controller supplied from a source, V_{in} = 220 sin (314.28t) produces an rms output voltage of 110V for a resistive load of 10Ω at firing angle α. Determine the value of α. 10

(ii) Given the logic function of three variables f (A, B, C) = A + $\bar{B}$C. Express f in the standard product-of-sum form. 10

7. (a) 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

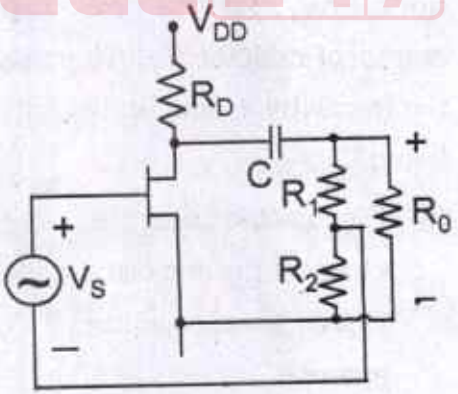
same supply voltage and frequency to give same rated power output at the same slip. By what factors each of the equivalent circuit parameters would be changed ? 20

(b) (i) The input voltage of a Cuk converter V_S = 12V. The duty cycle d = 0.25 and the switching frequency is 25kHz. The filter inductance is L_2 = 150μH and filter capacitance is C_2 = 220μF. The energy transfer capacitance is C_1 = 200μF and inductance L_1 = 180μH. The average load current is I_a = 1.25A. Determine (a) the average output voltage V_a (b) the average input current I_s (c) the peak-to-peak ripple voltage of capacitor C_1, ΔV_{C_1} (d) the peak current of transistor I_p. 8

(ii) A DC shunt motor 200V, 10.5 A, 2000 rpm has the armature and field resistance of 0.5Ω and 400Ω,

respectively. It drives a load whose torque is constant at rated motor torque. What is the value of armature current if the source voltage drops to 175V ? 12

(c) The JFET circuit in the figure is operating in the mid-frequency range. Identify the type of feedback. (i) Draw the mid-frequency small signal model and the closed loop feedback block diagram indicating the forward gain and feedback factor. (ii) Write the equation for gain without and with feedback. (iii) Calculate the amplifier gain with and without feedback if $R_1 = 80k\Omega$, $R_2 = 20k\Omega$, $R_0 = 25k\Omega$. Assume FET gm = 5.5 mS. 20



8. (a) Consider the sequence :

$$x(n) = \left(\frac{1}{2}\right)^n u(n) \text{ and } y(n) = \left(\frac{1}{3}\right)^{n-2} u(n-2)$$

Use the convolution property of Z-transform to find the convolution of the two sequences, $q(n) = x(n) * y(n)$. Validate your result using time-domain method of convolution. 20

(b) A buck-boost regulator has an input voltage V_S = 12V. The duty cycle d = 0.25 and the switching frequency is 25kHz. The inductance L = 150μH and filter capacitance C = 220μF. The average load current I_a = 1.25A. Determine (a) the average output voltage V_a, (b) the peak-to-peak output voltage ripple, ΔV_c, (c) the peak-to-peak ripple current of inductor, ΔI, (d) the peak current of the transistor, I_p and (e) the critical value of L and C. 20

(c) (i) Discuss the salient features of Uniform Linear Array and discuss the Half Wave Dipole antenna and Full Wave Dipole antenna. 8

(ii) A modulated signal is represented below as : $e(t) = 1500 \sin (2\pi \times 10^9 t + 2 \sin (\pi \times 10^4 t))$ Determine : (i) type of modulation, (ii) carrier frequency, (iii) transmitted power, if the signal is applied to a 75 Ω antenna, (iv) modulation index and (v) frequency deviation. 12