CSM – 24/19

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) Derive the condition for resonance in a R-L-C series circuit excited with a sinusoidal input. Also give one example for its practical application. 4

(ii) The current passing through an R-L-C series circuit is given by $i = I_m \sin \omega t$. Determine the voltages across each circuit element. Also verify and prove that the total applied voltage is given by :

$$v = \left\{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}\right\} I_m \sin\left[\omega t + \tan^{-1}\left(\frac{\omega L - 1/\omega C}{R}\right)\right]$$

6

(iii) Define Laplace transform with respect to a time function f(t), such that f(t) = 0, for t < 0. Hence derive the Laplace transform of the following function : 10

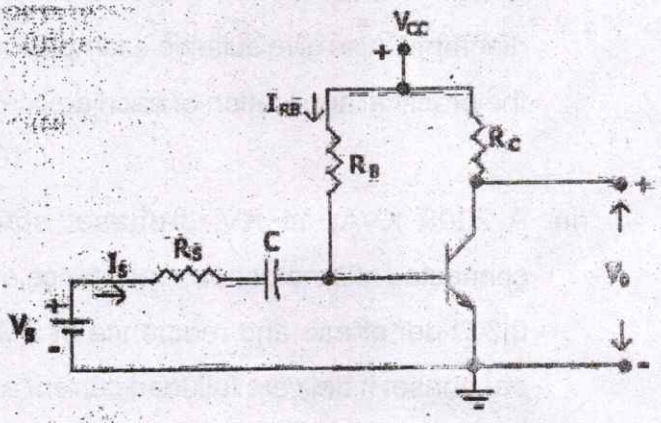
$f(t) = 0, \quad$ for $t < 0$

$f(t) = A \sin \omega t, \quad$ for $t \geq 0$

(b) (i) Derive all the four forms of Maxwell's equation. Considering the boundary conditions for wave propagation in bounded media, evaluate the electric field in the second dielectric medium, where two extensive homogeneous

isotropic dielectrics meet on plane $z = 0$, for $z > 0$, $\varepsilon_{r1} = 4$ and for $z < 0$, $\varepsilon_{r2} = 3$, such that a uniform electric field in the first dielectric medium is $E_1 = 5a_x - 2a_y + 3a_z$ kV/m exists for $z \geq 0$. 10

(ii) In the transistor circuit given below, $V_{CC} = 12V$, $V_S = 2V$, $R_C = 4\ k\Omega$, and $R_S = 100\ k\Omega$.



The given Ge transistor is characterized by $\beta = 50$, $I_{CEO} = 0$, $V_{CESAT} = 0.2\ V$.

Find the value of V_{CC} = 12, which just results in saturation for the following two conditions.

Condition-1 : The capacitor in the circuit is present.

Condition-2 : The capacitor in the circuit is replaced with a short circuit. 10

(c) (i) Explain the operation of Analog to Digital Converters (ADC) and Digital to Analog Converters (DAC) with suitable circuit diagrams. Also give suitable example for the practical application of each device. 10

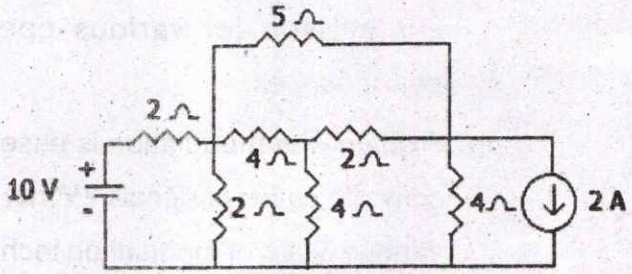
(ii) A 2000 KVA, 11 KV, 3-phase, star connected alternator has a resistance of 0.3 Ω per phase and reactance of 5 Ω per phase. It delivers full-load current at power factor 0.8 lagging and normal rated voltage. Compute the terminal voltage for the same excitation and load current at power factor 0.8 leading. 10

(d) (i) Draw the circuit diagram for a fully controlled and a half controlled bridge converter. Explain the opeartion of both fully controlled and a half controlled bridge converter and draw a table of comparison for various operating performances. 8

(ii) Explain why modulation is essential in communication of signals ? What are the various types of modulation techniques used for analog communication of signals ? Explain the procedure for calculation of signal to noise ratio for AM and FM receivers. 6

(iii) Give a classification of wave spectrum for various types of electromagnetic radiations and also give a comparison for various types of wave propagation consisting for ground waves, sky waves and space waves. Explain with example the scheme for extraterrestrial communication. 6

2. (a) Discuss the applicability, merits and demerits of nodal analysis and mesh analysis. Calculate the current flowing in the branch containing 5 Ω resistance of the circuit given below, by applying nodal analysis. 20



(b) Give examples with diagram and mathematical expression for continuous time and discrete time signals. Explain the convolution method and verify that the convolution integral is given by $x(t) \xrightarrow{h(t)} \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau \triangleq x(t) * h(t)$. Hence find the output of an LTI system having impulse response as given below.

$$h(t) = \begin{Bmatrix} 0; & t<0 \\ 1-\frac{t}{T}; & 0 \le t \le T \\ 0; & T<t \end{Bmatrix}$$ Assume that the input function is given by; $x(t) = Au(t+a)$. 20

(c) Considering the propoerty of Travelling Electro magnetic (TEM) waves that the electric field E and magnetic field H are uniquely related to the voltage (V) and current (I) parameters as indicated by $V = -\int E.\, dl$, and $I = \oint H.\, dl$, justify that the electromagnetic wave propagation expression in a two conductor transmission line is given by $V(z, t) = V_0^+ e^{-\alpha z} \cos(\omega t - \beta z) + V_0^- e^{-\alpha z} \cos(\omega t + \beta z)$. Assume that the symbols have their usual meanings. Also find out the expression for the characteristic impedance of the line and explain its significance. 20

3. (a) (i) Define the transfer bias line and dc load line of a JFET with the help of clear drawings demonstrating the drain characteristic and transfer characteristic of the device. Hence explain the difference between the transfer bias line and dc load line of a JFET. 10

(ii) Explain the construction procedure for an n-channel MOSFET and discuss the two types of MOSFET family (E-MOSFET and D-MOSFET). Hence draw the output and input characteristics of both E-MOSFET and D-MOSFET of n-type. Also deduce the expression for the drain current i_D for the two cases, namely (i) the operation is in linear region and (ii) the operation is in saturation region. 10

(b) (i) What do you understand by minimization of Boolean Functions ? Give the circuit diagram for formulation of an OR logic gate and an AND logic gate by using p-n junction diodes. Justify the operation of both the logic gates with the help of truth table. 10

(ii) Explain the functionalities of various digital IC families using DTL, TTL, ECL logic functions and hence draw up a table to investigate their merits and demerits. 10

(c) (i) What is the condition for voltage build up in a self-excited shunt DC generator ? Hence, explain the significance of critical field resistance and critical speed with the help of appropriate characteristics. 10

(ii) Two DC generators having rectilinear external characteristics, operate in parallel. One machine has a terminal voltage of 270 V on no-load and 220 V while delivering a load current of 30A. The other machine has a terminal voltage of 280 V on no-load and 220 V while delivering a load current of 40A. Calculate the output current of each machine and the bus voltage for the following two conditions :

Condition-1 : the total load current is 50A, and

Condition-2 : the load resistance is 10 Ω 10

4. (a) (i) Explain the operation thyristor, triac, and GTO with the help of their construction details and operating characteristics. 10

(ii) A single phase half wave thyristor rectifier with an AC voltage of 150 V, has a pure resistive load of 9 Ω. If the firing angle is 90°, determine (I) rectification efficiency and (II) form factor. Assume that the ratio of the input transformer is 2 : 1. 10

(b) (i) Explain the terms probability functions and probability models in the context of communication of signals. 10

(ii) Also explain how noise is created by random signals and the significance of white noise and noise equivalent bandwidth. 10

(c) (i) Explain the constructional details and method of operation of Hertzian dipole antenna and half wave dipole antenna. 8

(ii) A magnetic field strength of 5 μA/m is required at a point on $\theta = \pi/2$, which is 2 km away from an antenna in air. Neglecting ohmic loss, how much power must the antenna transmit, if the antenna is of the following types :

Case-1 : A Hertzian dipole of length $\lambda/25$.

Case-2 : A half wave dipole. 12

SECTION – B

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

(a) (i) Three inductive coils, each with a resistance of 15 Ω and an inductance of 0.03 H are connected in (i) star and (ii) delta, to a three phase, 400 V, 50 Hz supply. Calculate for each of the two cases, the phase current, line current, and total power consumed. 10.

(ii) Explain the properties of Fourier Transform signifying linearity, duality, and convolution by presenting

mathematical expressions for each case. Also explain the advantages of Fourier Transform in analyzing signals. 10

(b) (i) Explain the procedure of formation of standing waves. Assuming an incident electromagnetic wave given by $E_{is} = E_{i0}e^{-\gamma_1 t}$, compute the reflected wave necessary for this incident wave to produce a standing wave. 10

(ii) What are the advantages of using operational amplifiers (OPAMPS) ? Explain the working principle of oscillators using single transistor and OPAMPS. 10

(c) (i) Explain, in details, the working principle of semiconductor memories and programmable logic controllers (PLCs). Draw a table of comparison by showing the various aspects of semiconductor memories such as RAM, ROM and EPROM. 10

(ii) Discuss the necessity of a starter for starting of DC motors. A DC shunt machine connected to 250 V DC mains, has an armature resistance of 0.12 Ω and field circuit resistance of 100 Ω. Find the ratio of the speed while running as a generator to that of the speed while running as a motor, if the line current for each case of running is 90 A. 10

(d) (i) A 200 V DC shunt motor develops 23 hp when taking 20 KW. The field resistance is 50 Ω and the armature resistance is 0.05 Ω. Determine the efficiency and the power input when the output is 10 hp. 8

(ii) Explain the basic concepts of speed control of dc and ac drives. Also explain the operation of choppers. 6

(iii) What do you mean by de-emphasis and pre-emphasis mechanism ? Explain the mechanism of generation and detection of FM and PM. 6

6. (a) (i) Given a two port network derive the formulae for expression of z-parameters in terms of y-parameters and y-parameters in terms of z-parameters. 10

(ii) The z-parameters of a two port network are $z_{11} = 10\ \Omega$, $z_{22} = \Omega$, $z_{12} = z_{21} = 5\Omega$. Find the ABCD parameters and its equivalent T-network. 10

(b) (i) Define sampling theorem and deduce the mathematical expression to justify the significance of the definition. Explain the necessity of low pass or high pass filters in case of signal sampling. 10

(ii) Find out the Z-transform of a complex exponential function, an impulse function, and a unit step function. Also explain the properties of Z-transform. Also find the Z-transform of a signal is represented by $w(n) = 5\left(\frac{2}{3}\right)^n + 6\left(-\frac{1}{3}\right)^n$.

10

(c) A plane wave given by $H_i = 10 \cos (10^8 t - \beta z)\, a_x$ mA/m, is incident in free space normally on a lossless medium having parameters $\varepsilon = 2\varepsilon_0$ and $\mu = 8\mu_0$, in a region given by $z \geq 0$. Determine the reflected waves (H_r, E_r) and the transmitted waves (H_t, E_t).

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7. (a) (i) What is the function of a function generator ? How does a function generator find application in wave

shaping ? Explain with proper justification with circuit diagrams and waveforms. 10

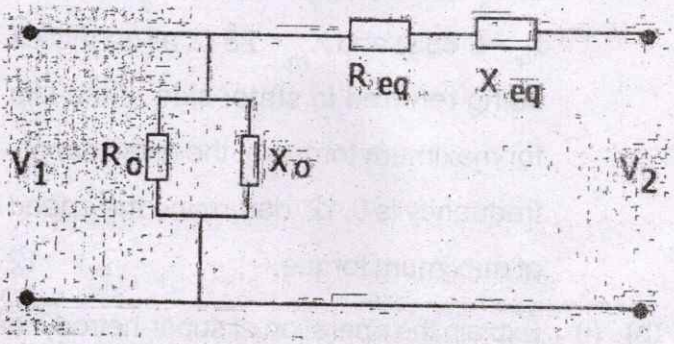
(ii) Explain the working of single stage amplifiers, multi-stage amplifiers, differential amplifiers and feedback amplifiers with the help of individual circuit diagram and illustrations. 10

(b) (i) Explain the role of sequential circuits. List the differences between sequential circuits and combinational circuits. 10

(ii) Give a brief note on the working principle and practical application of flip-flops, counters, multiplexors and decoders. Draw the circuit diagram of one multi-vibrator and explain its working principle. 10

(c) Calculate the values of R_o, X_o, R_{eq}, and X_{eq} in the equivalent circuit of a single phase

transformer as shown below, referred to LV side. Given that the transformer ratings are 5 KVA, 220/440 V, 50 Hz.



The transformer gives the following test results.

OC test : 220 V, 0.8 A, 90 W on the LV (primary) side

SC test : 18 V, 8 nA, 80 W on the HV (secondary) side. 20

8. (a) (i) Discuss the ramp comparator method for gate firing of a three phase full wave controlled bridge converter with the help of suitable circuit diagram. 8

(ii) A three phase, 50 KW, 1470 rpm, 400 V, 50 Hz, 4 pole, star connected induction motor has equivalent circuit parameters of $R_s = 0.42\ \Omega$, $R_r = 0.23\ \Omega$, $X_s = 0.95\ \Omega$, $X_r = 0.85\ \Omega$ and $X_m = 28\ \Omega$, all quantities being referred to stator side. If the slip for maximum torque at the given supply frequency is 0.12, determine the speed at maximum torque. 12

(b) (i) Explain the operation of super-hetrodyne receivers, AM receivers, communication receivers and FM receivers with a mention of advantages and disadvantages of each scheme. 12

(ii) Explain phase locked loop mode of operation and the working of SSB receiver. 8

(c) (i) What are the various types of gains associated with the antenna used for transmission and reception of signals ? Explain each scheme with examples. 8

(ii) Explain bandwidth and polarization. Also explain the effect of ground on antenna performance and antenna coupling. 6

(iii) Give a brief explanation on microwave integrated circuits and microwave measurements as regard to microwave communication. 6