ELECTRICAL ENGINEERING

PAPER - I

Time Allowed: Three Hours **Maximum Marks: 300**

INSTRUCTION

Candidates should attempt Question 1 and 5 which are compulsory, and any three of the remaining questions selecting at least one question from each Section.

Some useful data is given at the end of the question paper. Assume, any other data if considered necessary and indicate the same clearly.

All questions carry equal marks.

Parts of the same question must be answered together and must not be interposed between answers to other questions.

SECTION A

1. Answer any three of the following:

(a) The h-parameters of a 2-port network used in the circuit of Fig. 1a are $h_{11} = 100\ \Omega$, $h_{12} = 0.0025$, $h_{21} = 20$ and $h_{22} = 1$ mS. Find the ratio V_2/V_1.

(20)

Fig. 1a

(b) A hollow cylindrical conductor of length L and radius R and carrying a surface current of density $J_b = J_z$ iz A/m is placed in a B-field given by

$$B = \frac{a}{r} i_\phi - b i_x T$$

Find the magnitude and direction of torque on the conductor.

(20)

(c) Using Thevenin's theorem, determine the current in the 2 Ω resistor in the circuit of Fig. 1c.

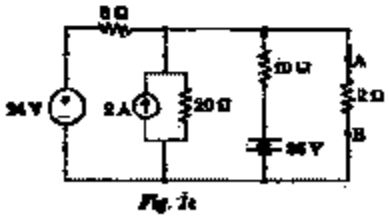

Fig. 1c

(20)

(d) (i) Give the schematic of two synchro pairs, one pair being useful for remote control and the other pair functioning as a transducer for converting angular position into an electrical signal.

(10)

(ii) Give a typical set up for measuring the stain of a cantilever beam, with temperature compensation.

(10)

2. (a) A series R-L circuit with R = 50 Ω and L = 0.2 H has a sinusoidal voltage v(t) = 75 sin (500 t + 0.785) applied at t = 0, t being taken in sec. Find the complete current for t > 0. What is the current at t = 0 + ? Why?

(20)

(b) Show that an n-mesh, passive, three-terminal network may be replaced by a delta connection of three impedances. Here n can be arbitrarily large.

(20)

(c) A 300 kW, 0.65 lagging power factor load is shunted by a capacitor so that the power factor improves to 0.90 lagging. Find the kVAr that the capacitor must furnish and the reduction in apparent power.

(20)

3. (a) An aeroplane flies over the surface of the ocean and sends a 1 MHz plane wave vertically downwards with a field intensity of 1000 V/m just at the ocean surface. If a submarine requires a 10 μV/m field, how deep can it be submerged and still be contacted by the aeroplane. The ocean water constants are $\sigma = 4$ S/m, $\mu_r = 1$ and $\varepsilon_r = 81$.

(20)

(b) A 2 μC charge is located at (0, 3, 0) m and a 4 μC charge at (4, 0, 0)m. Find the electric field at (0, 0, 5) m due to both these charges.

(20)

(c) The phase velocity v_p of a wave of frequency f and wavelength λ is given by $v_p = c(\lambda_0/\lambda)^2$ where c and λ_0 are constants. Derive an expression for the group velocity v_g in terms of v_p and v_p.

(20)

4. (a) Using an RTD with 0.00251/°C coefficient and R (25°C) as 1000 Ω, design a Wheatstone bridge with an OP-AMP arrangement to provide a 0 to 10 V signal for a temperature span of 25°C to 125°C.

(20)

(b) (i) Define the terms 'Dynamic error' and 'Resolution' of an instrument. Explain how these can be determined in the laboratory.

(10)

(ii) Give two examples each of active and passive transducers. Suggest suitable signal conditioning circuits for the same.

(10)

(c) For the R-2R type of digital-to-analog converter shown in Fig. 4c, find the output voltage when S_4 is closed and S_3, S_2 and S_1 are grounded.

(20)

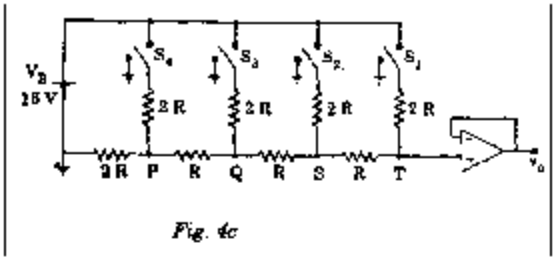

Fig. 4c

SECTION B

5. Answer any three of the following:

(a) In the circuit of Fig. 5a, the diode is ideal, R = 1.2 kΩ and I = 5 mA. Draw the v – i characteristics of the circuit (i) with S open and –10 volt <v < 15 volt and (ii) with S closed and 0 <v < 15 volt What happens when v <0 with S closed ?

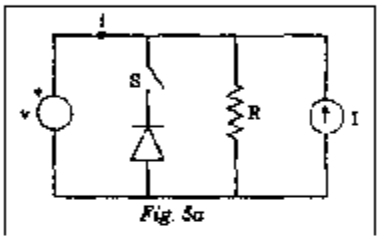

Fig. 5a

(20)

(b) Show that the NMOS circuit of Fig. 5b is a NAND gate for positive logic. Write down the various combinations of inputs and output in a tabular form and clearly state the meanings of any symbols or parameters used therein.

(20)

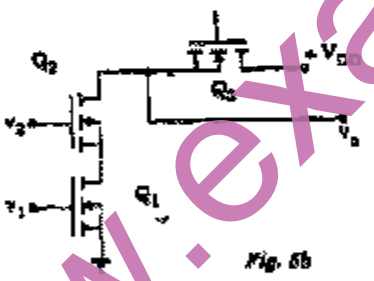

Fig. 5b

(c) Describe different methods for starting of synchronous motors.

(20)

(d) (i) Explain the following terms as referred to an operational amplifier:

(a) Input offset voltage and

(b) Input offset current

(10)

(ii) The input v_i (t) in the circuit of Fig. 5d is v_i (t) = 1.5 sin $2\pi \times 10^3$ t volt with t in sec, Sketch v_0 (t) and label important points.

(10)

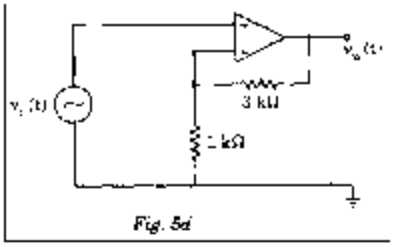

Fig. 5a

6. (a) Two single-phase transformers T_1 and T_2, rated at 300 kVA and 400 WA respectively, when operated in parallel share a 500 WA, 0.8 lagging power factor as follows:

T_1 : 192 + j 117 kVA

T_2 : 210 + j 184 kVA

Find the regulation of T_2 for rated kVA output at 0.8 lagging power factor when the percentage impedance of T_1 is 1.5 + j 6.

Also find the total load that the two transformers can share without any of these getting overloaded at 0.9 lagging p.f.

(20)

(b) Two shunt generators rated at 150 kW and 250 kW when running at rated speeds have rated open circuit voltages of 245 V and 243 V respectively. Their external characteristics are linear. The regulation of the 150 kW machine is 5% and that of the 250 kW machine is 4%, both in terms of their full Load terminal voltages. If these machines are connected in parallel, how much load will be carried by each machine when supplying a connected load of 360 kW? What will be the common terminal voltage?

(20)

(c) (i) Name different types of single phase induction motors. 'Draw a comparison of their performance features.

(5)

(ii) 'The range of stable operation of a three-phase induction motor can be extended by connecting a large resistance in the rotor.' Justify the statement.

(5)

(iii) Show that the reactive power drawn by a three- phase induction motor is maximum at standstill and decreases as the slip increases, the motor being operated at constant voltage.

(10)

7. (a) A 6-pole, 400 V, 50 Hz, 3-phase induction motor has a rotor resistance such that the maximum torque occurs at a sup of 0.2. An additional resistance of 0.5 Ω has to be inserted to obtain 75% of the maximum torque at starting. Find the rotor resistance and reactance.

(20)

(b) A 6600 V, 3-phase star-connected alternator has a resistance of 0.4 Ω and a synchronous reactance of 6.0 Ω per phase. If the regulation at fill load 0.8 power factors leading is 7.5%, find the kVA rating of the alternator.

(20)

(c) (i) What do you understand by the terms 'short-circuit ratio and 'synchronizing torque' as applied to a synchronous generator ?

(10)

(ii) A 1500 kVA, 4–pole, 3-phase, 50 Hz non-salient pole synchronous motor of negligible armature resistance having a synchronous reactance of 45 Ω is operating on an infinite bus with its voltage at 6.6 kV 50 Hz. Find the synchronising torque per mechanical degree of rotor displacement (a) at no load and (b) when the motor is operating at full load with 0.85 leading power factor.

8. (a) Find the relation between v_o and v_s for the circuit of Fig. 8a and show that, with proper adjustments, the voltage v_0 can be made proportional to the logarithm of the input voltage v_s.

(20)

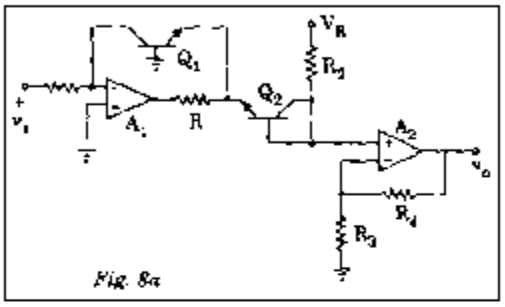

Fig. 8a

(b) Find the mid-frequency gain of the amplifier shown in Fig. 8b. Neglect the loading effect of R_1 and R_2. The transistor parameters with usual notations are $g_m = 0.015$ S, $r_{b'e} = 1$ Ωk, $r_{bb'} = 90$ Ω, $C_{b'e} = 20$ pF and $C_{b'c} = 3$ pF while $R_E = 1$ kΩ.

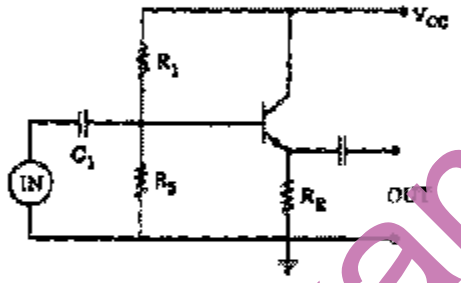

Fig. 8b

(c) Design a combinational logic circuit to generate the 2's complement of a 2-bit number. You may use two flat adders and other gates as required but keeping the number of other gates to a minimum.

(20)

Some useful data:

Electronic charge	: $e = 1.6 \times 10^{-19}$ C
Permeability of free space	: $\mu_o = 4\pi \times 10^{-7}$ H/m
Permittivity of free space	: $\varepsilon_o = 8.85 \times 10^{-12}$ F/m

ELECTRICAL ENGINEERING

PAPER - II

Time Allowed: 3 Hours **Maximum marks: 300**

SECTION A

Question no. 1 is compulsory.

1. Select any three of the following statements, read them carefully and identify the correct and incorrect ones. Justify your answer using not more than 200 words in each case.

(20 x 1 = 60)

(a) State equations are first order differential equations that can be applied to portray only the linear time-invariant systems.

(b) By adding a pole to the closed loop transfer function, the maximum overshoot increases and the effect is opposite to that of adding a pole to the open loop transfer function.

(c) For a closed-loop system to be asymptotically stable, there is no restriction on the location of the poles and zeros of the loop transfer function F(s), but the poles of the closed loop transfer function must all be located in the left half of S-plane.

(d) A vacuum tube oscillator has small power outputs high at frequencies and is less efficient compared to SCR.

2. (a) Describe a simple position control system.

A certain position control system is driven by 100 : 1 gear by a motor whose torque characteristics is of the form $(1.0\ V_m - 0.3\ N)\ 10^{-4}$ N-m, where N is the speed in R.P.M. and is the voltage supplied by the amplifier. If the synchros produce 1 V/ degree error and if the steady state error should be 5° for a speed input of 20 RPM, calculate the required amplifier gain. Viscous friction at the motor shaft is 60×10^{-6} Nm-sec.

(b) Distinguish between open-loop and closed-loop system. Convert the system of Fig. 1 into a unity feedback system.

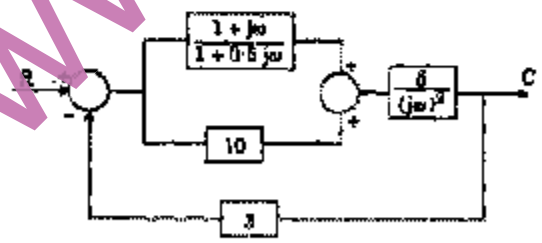

Fig. 1

(20)

(c) Obtain the state equations in (i) the controller form, and (ii) and observer form for the transfer function G(s) given by

$$G(s) = \frac{3s^2 + 5s + 7}{s4 + 5s^3 + 18s^2 + 29s + 35}$$

(20)

3. (a) What do you mean by Root-locus of a system ? Give properties of the root-locus.

A unity feedback system has a forward path transfer function

$$G(s) = \frac{K}{s(s+4)(s+5)}$$

Sketch the locus of the poles of the transfer function of the closed-loop system as 'K' varies from zero to infinity, explaining all the steps involved.

(20)

(b) What is a servomotor ? Give the characteristics of a 2-phase servomotor and obtain its transfer function.

A 50 Hz, 2-phase, ac. servomotor has the following parameters:

Starting torque	= 0.186 N-m
Rotor inertia	= 1 x 10^{-5} kg m^2
Supply voltage	= 120 V
No-load angular velocity	= 304 rad/sec

Assuming straight line torque-angular speed characteristics of the motor and zero viscous friction derive the transfer function.

(20)

(c) A system is described by

$\dot{X} = AX+BU$

$Y = CX$

where

$$A = \begin{bmatrix} 0 & 1 & -8 \\ 1 & 0 & -5 \\ 0 & 2 & -6 \end{bmatrix} \quad B = \begin{bmatrix} 2 \\ 1 \\ 0 \end{bmatrix}$$

and $C = [1 \quad 2 \quad 1]$

Determine whether the system is stable.

(20)

4. (a) Describe with a neat sketch a step up chopper and discuss its merits and demerits.

(20)

(b) Explain the principle of electric welding. Describe with the help of a neat diagram the principle of operation of a timer circuit used for electric welding.

(20)

(c) Fig. 2 shows a circuit used for self-commutation by resonance.

(i) With the thyristor in blocking state, what is steady state capacitor voltage and load current ?

(ii) Derive an expression for the load current, thyristor current and V_c (t) after a thyristor is triggered at t = 0.

(iii) Calculate the time when the thyristor would stop conducting.

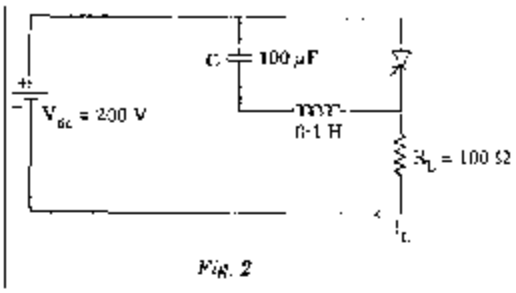

Fig. 2

(20)

SECTION B

Question no. 5 is compulsory.

5. Comment with justification on the correctness or otherwise of any three of the following statements, restricting your answer to within 200 worth for each.

(20x3=60)

(a) Single phase induction motors with auxiliary winding neither develop starting torque nor the running torque.

(b) For EHV transmission lines, it is dangerous to use bundle conductors from the viewpoint of sub-synchronous resonance.

(c) Sudden loss of load may cause severe disturbance in the operation of a power system.

(d) Self-excitation of an induction generator requires the machine to be run at super synchronous speed.

6. (a) Derive an expression for the charge (complex) value per meter length of conductor 'A' of untransposed 3-phase line shown in Fig. 3. The applied voltage is balanced 3-phase, 50 Hz. Take the voltage of phase 'A' as reference phasor. All conductors have the same radii. Also find the charging current of phase A'. Neglect the effect of ground.

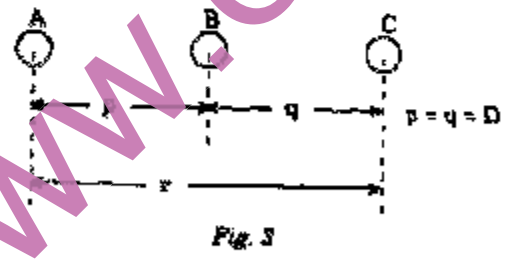

Fig. 3

(b) Discuss briefly different methods used for Load-Flow studies. Give their merits and demerits.

(20)

(c) A single-phase, 50 Hz generator supplies an inductive load of 5 MW at a p.f. of 0.707 lagging by means of an overhead line 20 km long. The line R and L are 0.0195 Ω/km and 0.63 mH/km. The voltage at the receiving end is required to be kept constant at 10 kV. Find

(i) the sending end voltage regulation of the line,

(ii) the value of the capacitors to be placed in parallel with the load such that the regulation is reduced to 50% of that obtained in part (i),

(iii) transmission efficiencies in both the cases.

(20)

7. (a) Discuss the behaviour of a 3-phase induction motor on single-phasing. Compare its characteristics, rating and efficiency with that under balanced 3-phase supply.

(20)

(b) Give the constructional features, principle of operation and applications of a variable reluctance stepper motor.

(20)

(c) A salient-pole synchronous motor has $x_d = 0.85$ p.u and $x_q = 0.55$ pu. It is connected to bus-bars of 1-0 p.u. voltage, while-its excitation is adjusted to 1.2 p.u. Calculate the maximum power output that the motor can supply without loss of synchronism. Compute the minimum p.u. excitation that is necessary for the machine to stay in synchronism while supplying the full-load torque.

(20)

8. (a) Explain the principle and applications of (i) induction heating, and (ii) dielectric heating. Discuss the range of frequencies used in these systems of heating.

(20)

(b) Discuss the electrical, mechanical and economic characteristics to be considered in selecting a motor for a given drive. What are the special features required for selecting electrical equipment for mines with fire hazard ?

(20)

(c) An 11 kV, 1-MVA, Y-connected generator has a reactance of 4.2 ohms/phase. The generator neutral is grounded through a resistance of 2.2 ohms. Determine what percent of the generator winding remains unprotected by the percentage differential relaying. Assume for simplicity that the percentage differential relay operates when out-of-balance current exceeds 25% of the full-load current.

(20)

SECTION C

Question no. 9 is compulsory.

9. Select any three of the following statements and indicate with justification whether they are correct or incorrect. Your answer must not exceed 200 words for each statement.

(20x3=60)

(a) Modem communication system is concerned with development of transmission and not with the sorting, processing and storing of information.

(b) AM is more likely to be affected by noise than is FM.

(c) In comparison with wave-guides and co-axial lines, strip line has reduced bulk, lower bandwidth, higher power-handling capability and components made of it are readily adjustable.

(d) The conical scanning method of tracking an acquired target is an improvement over lobe switching.

10. (a) (i) What are the three main systems of SSB generation ? Give the salient characteristics of each system.

(ii) Prove that the balanced modulator produces an output consisting of side bands only, with the carriers removed.

(20)

(b) What is an RF amplifier ? Give its advantages. What do you understand by image frequency and its rejection ratio?

In a broadcast super-heterodyne receiver having no RF amplifier, the loaded Q of the antenna coupling circuit (at the input to the mixer) is 100. If the intermediate frequency is 555 KHz, calculate

(i) the image frequency and its rejection ratio at 1000 KHz, and

(ii) the image frequency and its rejection ratio at 25 MHz.

(20)

(c) Give the properties of paraboloid reflectors. Explain why an antenna using a paraboloid reflector is likely to be a highly directive receiving antenna.

Describe the Cassegrain method of feeding a paraboloid reflector. Give some shortcomings and difficulties associated with the method.

(20)

11. (a) What is the importance of impedance matching in RF transmission lines ? Explain single stub-matching and double stub-matching.

A loss-less line has a characteristic impedance of 75 ohms and is terminated in a load of 300 ohms. The line is energised by a generator which has an open circuit voltage of 20 V (r.m.s) and output impedance of 75 ohms. The line is assumed to be 2¼ wavelengths long. Determine :

(i) the input impedance

(ii) the magnitude of instantaneous load voltage, and

(iii) the instantaneous power delivered to the load. 20

(b) (i) What is meant by saying that colour TV must be compatible ?

(ii) Explain what is meant by the Y, I and Q signals in colour TV, and why they are generated. With the help of circuit diagram of a simplex matrix, explain how the I, Q and Y signals are generated in a colour TV transmitter.

(20)

(c) Give the advantages and disadvantages of submarine cables and communication satellites for intercontinental telephone and television. Show how the two media may be complementary.

Explain what is done to ensure that intercontinental telephone calls are not misrouted.

(20)

12. (a) What do you understand by S-parameters of a 2-port network ? Why are these parameters preferred to H, Y and Z parameters for operation in microwave range of frequencies ? Show that the S-matrix of a directional coupler may be reduced to the form

$$S = \begin{bmatrix} 0 & p & 0 & jq \\ p & 0 & jq & 0 \\ 0 & jq & 0 & p \\ jq & 0 & p & 0 \end{bmatrix}$$

(20)

(b) With the help of a schematic diagram, explain a four-cavity klystron amplifier.

A four-cavity klystron amplifier has the following parameters:

Beam voltage : $V_0 = 20$ kV

Beam current : $I_0 = 2$ A

Operating frequency : $f = 10$ GHz

d.c. charge density : $\rho_0 = 10^{-6}$ C/m^2

RF charge density : $\rho = 10^{-8}$ C/m^2

Velocity perturbation : $v = 10^5$ m/s

Determine

(i) The d.c. electron velocity

(ii) The d.c. phase constant

(iii) The plasma frequency

(iv) The reduced plasma frequency for R = 0.5

(v) The d.c. beam current density

(vi) The instantaneous beam current density

(20)

(c) Explain what you understand by:

(i) MMIC

(ii) MOSFET

(iii) NMOS Growth

(iv) CMOS Development

(v) RAM Device

(vi) SRAM Cell

(vii) DRAM Cell

(20)