



# ESE (Mains), 2022

## Electrical Paper-I

### SECTION 'A'

1. (a) Find the eigenvalues and the corresponding eigenvectors of the matrix  $\begin{bmatrix} 3 & -1 & -2 \\ -1 & 3 & 2 \\ -2 & 2 & 6 \end{bmatrix}$ . Is this matrix

diagonalizable? Justify your answer.

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1. (b) Classify the ways in which materials respond to magnetic fields and also specify their value of susceptibility.

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1. (c) The material parameters of a certain food item are given by  $\sigma = 2.2$  s/m,  $\epsilon = 48\epsilon_0$  and  $\mu = \mu_0$  at the operating frequency,  $f = 2.54$  GHz of a microwave oven. Determine  $\alpha$ ,  $\beta$ ,  $\lambda$ ,  $v_p$  and  $\bar{n}$ . Take  $\epsilon_0 = \frac{10^{-9}}{36\pi}$  and  $\mu_0 = 4\pi \times 10^{-7}$ .

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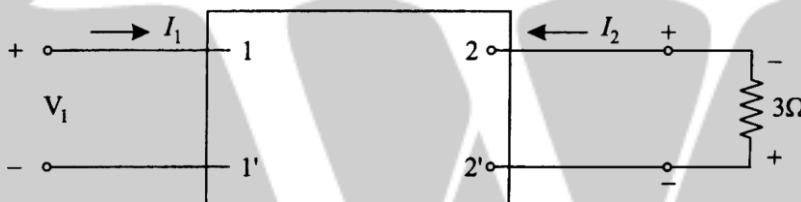
1. (d) The following equations refer to a two-port network

$$V_1 = 5I_1 + 2I_2$$

$$V_2 = 2I_1 + I_2$$

A load resistance of 3 ohms is connected across port-2 terminals as shown in figure. Calculate the input Impedance.

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1. (e) Write a program in any programming language to compute the money accumulated in a cumulative fixed deposit of a bank for the principal P after n years. The rate of interest is r percent per year compounded annually. The program should read the values of P, r and n. It should display the accumulated money as F.

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2. (a) (i) Use the residue theorem to evaluate the integral  $\int_C \frac{e^z - 1}{z(z-1)^2(z-i)} dz$ , where C is the circle

$$|z| = 3.$$

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- (ii) Find the volume of the solid bounded by the sphere  $x^2 + y^2 + z^2 = 20$  and the paraboloid  $x^2 + y^2 = z$ .

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2. (b) (i) Explain the variation of transition temperature of a superconductor with its isotopic mass M.

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- (ii) The transition temperature of Mercury with an average atomic mass of 200.6 is 4.2 K. Evaluate the transition temperature of one of its isotopes,  $^{204}_{80}\text{Hg}$ .

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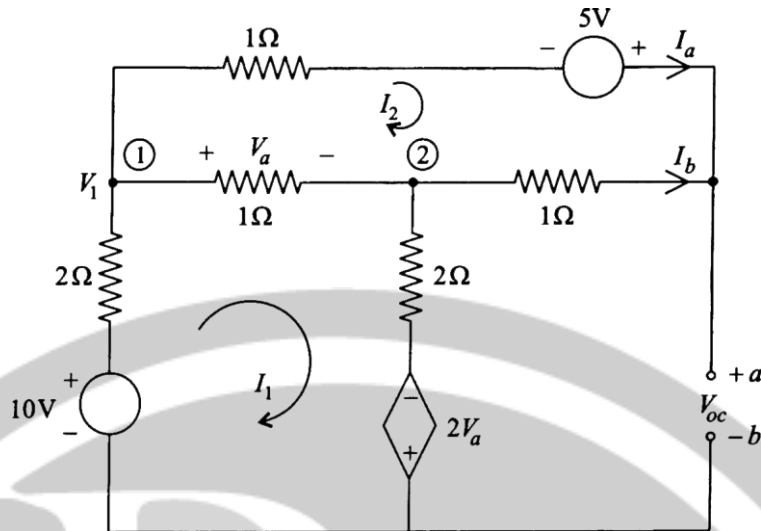


2. (c) (i) A 10HP induction motor runs from a 3-phase 400 volts supply on no-load. The motor takes a line current of 4 A at a power factor of 0.208 (lag). On full load it operates at power factor of 0.88 (lag) and with an efficiency of 89%. Determine the readings on each of the two watt-meters connected to read total power (1) on no-load and (2) on full-load. 10
- (ii) What is a filter? State the ideal characteristics of a filter. 10

3. (a) (i) Obtain the equations of regression lines and the correlation coefficient for the following data. Justify the sign of correlation coefficient. 10

x	1	2	3	4	5
y	2	5	3	8	7

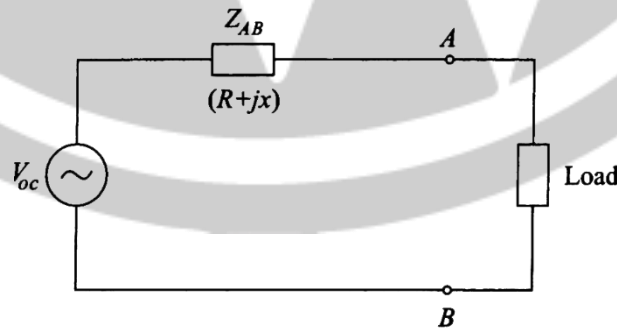
- (ii) The probability density function of a random variable  $x$  is
- $$f(x) = \begin{cases} ax(2-x), & 0 \leq x \leq 2 \\ 0, & \text{otherwise} \end{cases}$$
- for some real number  $\alpha$ . Find the value of  $\alpha$  and the variance of  $x$ . 10
3. (b) (i) Evaluate value of frequency at which conduction current density and displacement current density are equal
- (a) distilled water, where,  $\sigma = 2.0 \times 10^{-4}$  s/m and  $\epsilon_r = 81$
- (b) sea water where  $\sigma = 4.0$  s/m and  $\epsilon_r = 1$  10
- (ii) In spherical co-ordinates  $V = -35$  V on a conductor at  $r = 3$  cm and  $V = 150$  V at  $r = 40$  cm. The space between conductors is a dielectric for which  $\epsilon_r = 3.12$ . Evaluate surface charge densities on the conductors. 10
3. (c) (i) Distinguish between a power transformer and current transformer (CT) and discuss the effect of secondary CT open circuit, while primary winding is energized.
- (ii) A 1000/5 A, 50 Hz CT has a bar primary and a resistive burden of 12.5VA at rated current. The secondary winding has a leakage inductance of 0.96mH. The core requires a magnetising mmf of 16AT and a loss component of 12AT, when rated current flows in the secondary. Calculate the secondary turns at which the ratio error is eliminated.
4. (a) Obtain the Thevenin's equivalent at the terminals a, b for the figure shown. What will be the maximum power supplied by the circuit to a load resistance? 20



4. (b) (i) Compare the phenomenon of Piezoelectricity and Ferroelectricity. 8
4. (b) (ii) Compute the packing efficiency and density of diamond. Consider diamond as diamond cubic (DC) structure and lattice parameter,  $a = 3.57 \text{ \AA}$  and mass of atom  $m = 1.66 \times 10^{-27} \text{ kg}$ . 12
4. (c) An AC bridge with terminals A, B, C, D (consecutively marked) has in arm AB, a pure resistance; arm BC a resistance of  $800\Omega$  in parallel with a capacitor of  $0.5\mu\text{F}$ ; arm CD, a resistance of  $400\Omega$  in series with a capacitor of  $1\mu\text{F}$ ; and arm DA a resistance of  $1000\Omega$ 
  - (i) obtain the value of the frequency for which the bridge can be balanced by first deriving the balance equations connecting the branch impedance, and draw phasor diagram and
  - (ii) Calculate value of the resistance in arm AB to produce balance. 20

### SECTION 'B'

5. (a) Two terminals shown in figure coming out of a network show a voltage of  $150 \text{ V}$  on open circuit and give a current of  $3 \text{ A}$  on short-circuit. If a resistor of  $10\Omega$  is connected as a load between the two terminals the current falls to  $2.65 \text{ A}$ . Determine the equivalent voltage generator circuit and find whether the circuit is capacitive or inductive. 12



5. (b) Zinc has HCP structure. The height of the unit cell is  $0.494 \text{ \AA}$ . The nearest neighbour distance is  $0.27 \text{ nm}$ . The atomic weight of zinc is  $65.37$ . Evaluate,
  - (i) The volume of the unit cell
  - (ii) The density of zinc

Take  $N_A = 6.0238 \times 10^{26}$  Molecules /Kg Mole.

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5. (c) Distinguish between

(i) High level language and low level language

(ii) Machine cycle and instruction cycle

(iii) Memory mapped Input/Output and Input/Output mapped Input/Output

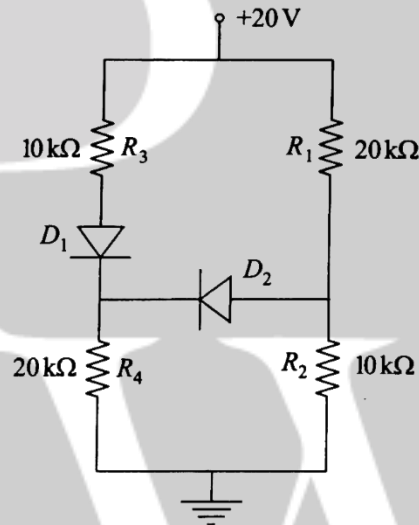
4×3 = 12

5. (d) A coil of 300 V Moving Iron Voltmeter has a resistance of 500ohms and an inductance of 0.8H. The instrument reads correctly at 50 HzAC supply and takes 100 mA at full scale deflection. What is the percentage error in the instrument reading, when it is connected to 200 V DC supply?

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5. (e) Find the currents through diodes  $D_1$  and  $D_2$  and the voltage across resistor  $R_4$  in the figure shown. Assume forward voltage drop of 0.7 V for each diode.

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6. (a) Calculate the value of contact potential and the total width of the depletion region under unbiased condition of an abrupt silicon P-N junction at 300°K. The intrinsic carrier concentration of silicon is  $1.7 \times 10^{16}$  atoms /m<sup>3</sup> and its relative permittivity is 11.8. The junction has acceptor density  $N_A = 10^{22}$  atoms /m<sup>3</sup> on P-side and donor density of  $N_D = 10^{20}$  atoms /m<sup>3</sup> on n-side.

Derive the Equation used for calculations.

Boltzmann's constant =  $1.381 \times 10^{-23}$  J/°K

Electron charge =  $1.602 \times 10^{-19}$  C

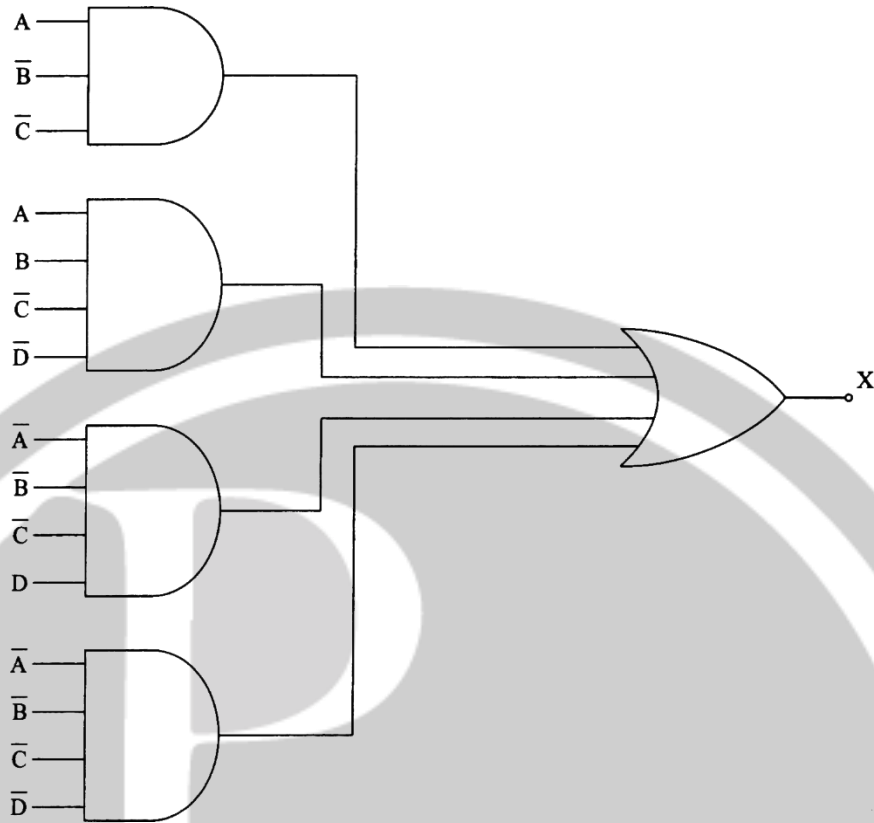
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6. (b) Draw the circuit diagram and explain the operation of a practical Q-meter and write its applications.

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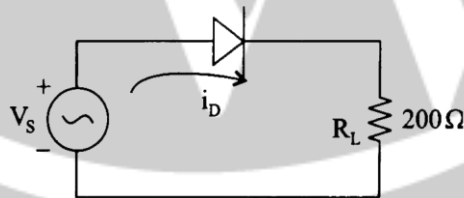
6. (c) (i) Minimize the combinational logic shown in figure.

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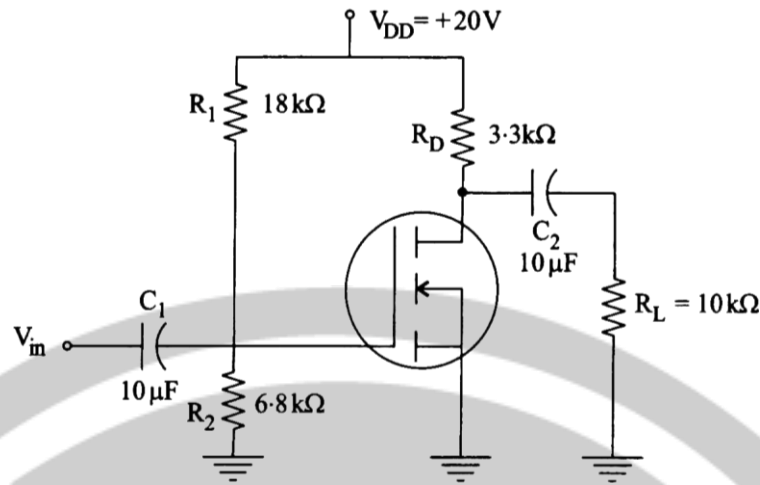


- (ii) A machine has 32 bit Architecture, with 1 word long instruction. It has 64 registers each of which is 32 bits long. It needs to support 48 instructions which have an immediate operand in addition to two register operands. If the immediate operand is an unsigned integer, find the maximum value of the immediate operand. 10

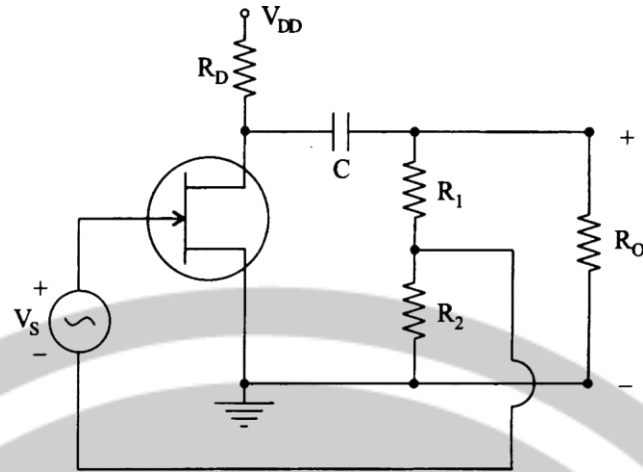
7. (a) (i) Find the circulating current in the circuit shown below operated at a room temperature of  $27^\circ\text{C}$ , if the source voltage  $V_s = 1.2 + 0.5\sin 500 t$  volts. Assume  $\eta V_T = 50 \text{ mV}$  and  $V_{ON} = 0.7$  volts. Neglect contact resistance. 8



- (ii) Find  $V_{GS}$ ,  $I_D$ ,  $V_{DS}$  and the AC output voltage of the E-MOSFET Amplifier shown in the figure for an input of 25 m Volts. The device parameters are  $I_{DON} = 18 \text{ mA}$  at  $V_{GS} = 10 \text{ Volts}$ ,  $V_{GS(th)} = 2.5 \text{ Volts}$  and  $g_m = 23 \text{ mS}$ . 12



7. (b) (i) A Standard Cell of 1.0186 volts used with a conventional slide wire potentiometer balances at 45 cm. Calculate
- the emf of the cell which balances at 65 cm and
  - the percentage error in voltmeter which balances at 57 cm when reading 1.27 volts. 10
- (ii) A moving coil instrument is designed to give a full scale reading of 30 mA and the corresponding drop across is 72mV. Calculate the shunt resistance required for full scale deflection corresponding to 10Amps and the series resistance for full scale reading with 400 V. 10
7. (c) (i) What are the functions of Data link layer and Network layer according to ISO-OSI-7 layer Network Architecture. 6 + 6 = 12
- (ii) If the signal speed in the cable is  $2 \times 10^5$  km/sec find the maximum length of cable required to transmit the data at a rate of 600Mbps in an Ethernet LAN with frame size of 12000 bits. 8
8. (a) The JFET circuit shown in the figure is operating in the mid frequency range. Identify the type of feedback. 2
- Draw the mid frequency small signal model indicating the output, input, feedback points and the closed loop feedback block diagram indicating the forward gain and feedback factor. 6
  - Write the equation for gain without feedback and with feedback. 6
  - Calculate the Amplifier gain with and without feedback if  $R_1 = 80 \text{ k}\Omega$ ,  $R_2 = 20 \text{ k}\Omega$ ,  $R_o = 25 \text{ k}\Omega$  and  $R_D = 5 \text{ k}\Omega$ . Assume FET  $g_m = 5.5 \text{ mS}$ . 6



8. (b) (i) A solenoid of length  $l$  and radius  $a$  consists of  $N$  turns wire carrying current  $I$ . Derive an expression for  $H$  at point  $P$  along its axis. Also find expression for  $H$  if  $l \gg a$ . 10

- (ii) Show that the capacitor of Figure (a) has capacitance

$$C_{eq} = \frac{\epsilon_0 \epsilon_1 A_1}{d} + \frac{\epsilon_0 \epsilon_2 A_2}{d} \text{ and capacitor of Figure (b) has reciprocal}$$

$$\text{capacitance } \frac{1}{C_{eq}} = \frac{1}{\frac{\int_0 \epsilon_1 A}{d_1}} + \frac{1}{\frac{\int_0 \epsilon_2 A}{d_2}} = \frac{1}{C_1} + \frac{1}{C_2}.$$

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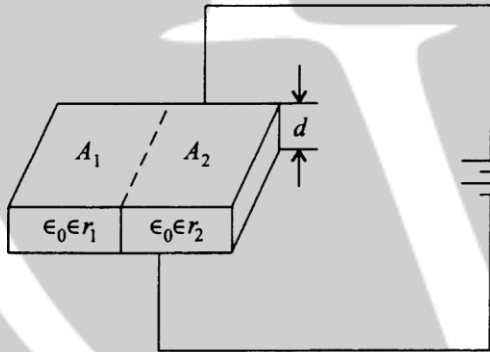


Figure (a)

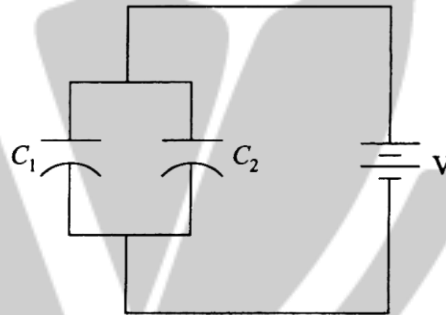


Figure (b)

8. (c) (i) Find the general solution of the partial differential equation

$$\frac{\partial^3 z}{\partial x^3} - 2 \frac{\partial^3 z}{\partial x^2 \partial y} = 9(e^{3x} + 10xy^2).$$

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- (ii) Find the root of  $xe^x - 1 = 0$  correct to four decimal places by the Newton Raphson method starting with  $x_0 = 0.6$ . 10