ELECTRONICS AND TELECOMMUNICATION ENGINEERING

Paper—I

(Conventional)

Time Allowed : Three Hours	Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt FIVE questions.

The number of marks carried by each question is indicated at the end of the question.

Answers must be written in ENGLISH.

Assume suitable data, if necessary and indicate the same clearly.

Values of the following constants may be used wherever necessary.

Electronic charge $= -1 \cdot 6 \times 10^{-19}$ **coulomb.**

Free space permeability $= 4\pi \times 10^{-7}$ **henry/m.**

Free space permittivity $= \left(\dfrac{1}{36\pi} \right) \times 10^{-9}$ **farad/m.**

Velocity of light in free space $= 3 \times 10^{8}$ **m/sec.**

Boltzmann constant $= 1 \cdot 38 \times 10^{-23}$ **joule/K.**

Planck constant $= 6 \cdot 626 \times 10^{-34}$ **joule-sec.**

Wherever a question is attempted, all its subdivisions must be attempted.

Unless otherwise indicated, symbols and notations have their usual meanings.

1. (a) The mobilities of electron and hole in silicon sample are 0.125 m^2/V-s and 0.048 m^2/V-s respectively. Determine the conductivity of intrinsic silicon at 27 °C, if the intrinsic carrier concentration is 1.6×10^{16} atoms/m^2. When it is doped with 10^{23} phosphorus atoms/m^2, determine the equilibrium hole concentration, conductivity and position of the Fermi level relative to the intrinsic level. 15

   (b) Differentiate between Light Emitting Diodes (LEDs) and Laser Diodes (LDs). An LED is made of GaAsP having a band gap of 1.9 eV. Determine the wavelength and colour of the radiation emitted. 15

   (c) Sketch the electron distribution in insulator, intrinsic semiconductor and metal at 0 K. 10

2. (a) Draw the low-frequency small-signal models of FET and bipolar junction transistor, and compare the two models. Justify the statement that FET is a much more ideal amplifier than the bipolar junction transistor at low frequencies. 15

(b) For the circuit shown in Fig. 1, assume $\beta = h_{FE} = 100$. Find if the transistor is in cutoff, saturation or in the active region. 15
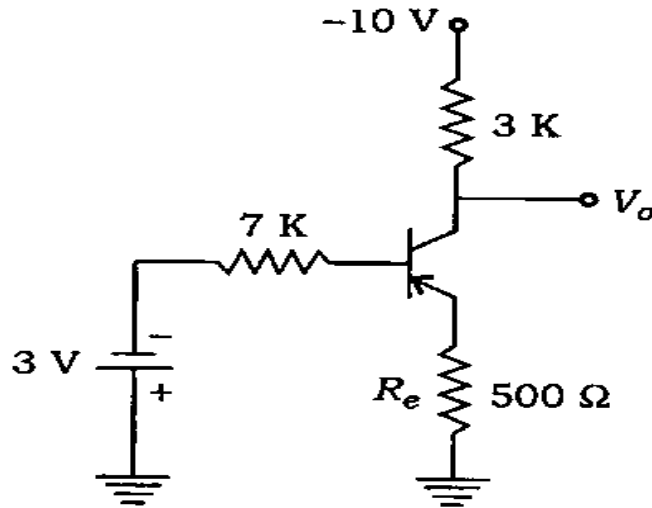

Fig. 1

(c) Describe how an FET can be used as a Voltage Variable Resistor (VVR). 10

3. (a) The input and output of a causal LTI system is related by the differential equation

$$\frac{d^2 y(t)}{dt^2} + 6\frac{dy(t)}{dt} + 8y(t) = 2x(t)$$

(i) Find the impulse response of the system.

(ii) What is the response of this system, if $x(t) = te^{-2t}u(t)$? 15

(b) Describe the Hall effect in a semi-conductor bar. Derive the expression for the Hall voltage.   15

(c) Evaluate the cross-correlation between the following signals :   10

$$x(t) = u(t) - 2u(t-1) + u(t-2)$$
$$y(t) = u(t+1) - u(t)$$

4. *(a)* *(i)* Show that if $x(t)$ is an even function, so that $x(t) = x(-t)$, then $X(s) = X(-s)$.

(ii) Determine which, if any, of the pole-zero plots of Fig. 2 could correspond to an even function of time. For those that could, indicate the required ROC.   15
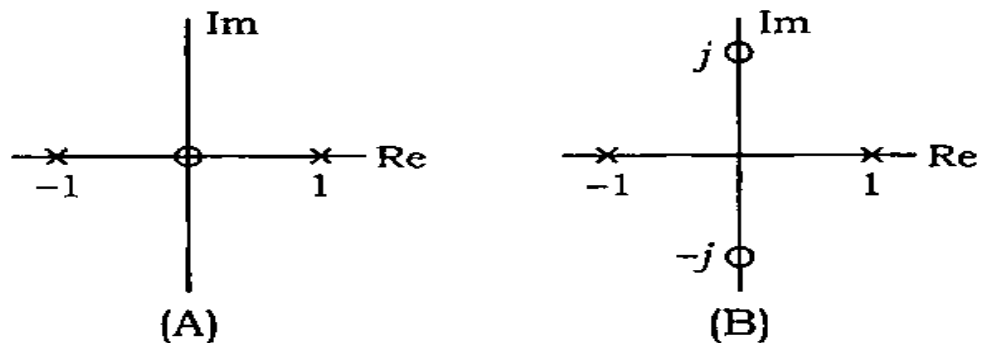

Fig. 2

(b) Realize driving-point impedance

$$\frac{s^2 + 12s + 35}{s^3 + 15s^2 + 62s + 48}$$

in Foster-I and Cauer-I forms.   15

(c) A certain 2-terminal linear network, including a generator, has an open-circuit voltage of 125 V, and on short circuit produces a current of 5·59 A. When a 10 Ω resistive load is connected, the load current is 4·41 A. Find Thevenin's equivalent of this network. How could the sign of reactance be determined? 10

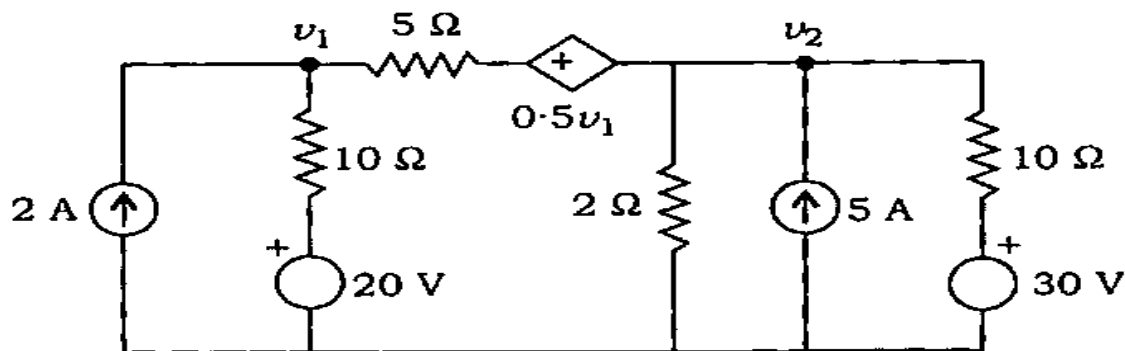**5.** (a) (i) Determine v_1 and v_2 node voltages in the circuit of Fig. 3.

Fig. 3

(ii) Fundamental circuit (tie-set) matrix for a certain network is given as

$$B_f = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix}$$

Determine the corresponding fundamental cutset matrix. State the relationship used. 15

(b) (i) The switch in the circuit of Fig. 4 has been closed for a very long time. It opens at $t = 0$. Find $v_c(t)$ for $t > 0$.
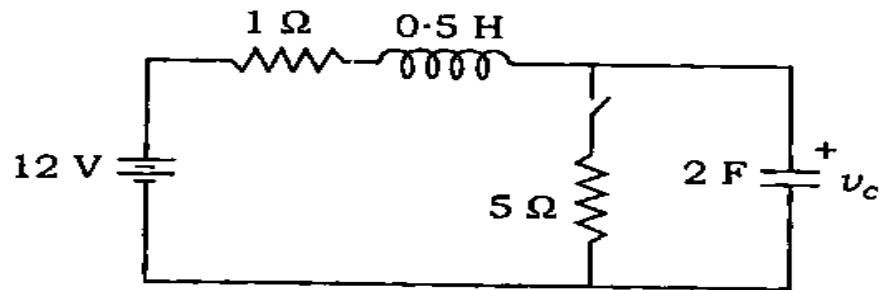

Fig. 4

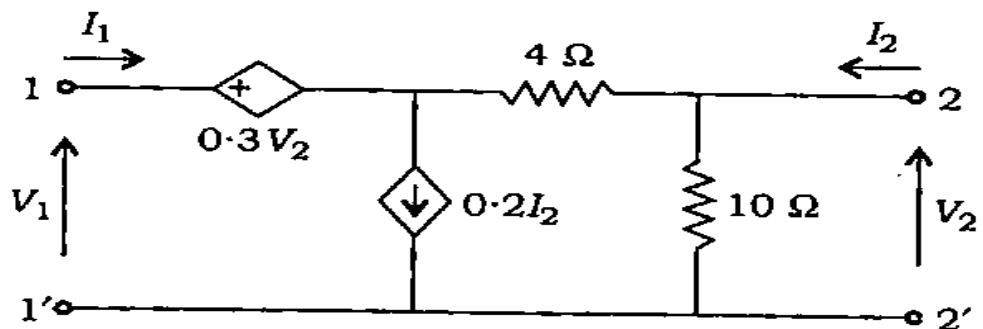(ii) Determine h_{12}, z_{12} and y_{12} parameters for the 2-port network of Fig. 5. 15

Fig. 5

(c) The step response of a certain initially relaxed device is $y(t) = (1 - \frac{1}{2}e^{-t/3})u(t)$.

Determine the impulse response of the system of two such devices connected in cascade, assuming that the loading effect due to cascading is negligible. 10

6. (a) A plane wave with

$$\overline{E} = 30e^{-\alpha z} \sin(\omega t - z)\hat{X} \text{ V/m}$$

is propagating through a lossy dielectric medium having an intrinsic impedance

of $300\angle30°\,\Omega$ and $\mu_r = 1$. Establish the phasor and instantaneous field expressions for $\overline{H}$, and find the loss tangent, propagation constant, wave polarization and the dielectric constant of the medium at 15 MHz. Also determine the skin depth and the depth at which the amplitude of the field is 1% of the value at $z = 0$. 15

(b) A 10 cm long vertical dipole radiates into air at 60 MHz with a peak input current of 100 mA. Find its radiation resistance, radiated power and efficiency, if its loss resistance is $0 \cdot 1\,\Omega$. At what distance its radiated field strength will be 1 mV/m, for a field point at $\theta = \frac{\pi}{2}$? Also find the directivity, if this antenna is used as a monopole.

If a dipole of same length and input current is to radiate at 1500 MHz, find the power radiated and far field strengths at the above-mentioned field point. 15

(c) A 60 Ω half-wavelength lossless line is open circuited at the load end and has a load voltage of 12 V. Find the voltage and current at the middle of the line, listing out the relevant transmission line equations for both lossy and lossless lines.

If this 60 Ω line is connected to a load of 100 Ω resistance in series with a capacitance of 8·84 pF, find the load

reflection coefficient and VSWR at 100 MHz, and the ⸱maximum and minimum impedances along the line, assuming a line length of 5 metres.   10

7. *(a)* Explain the working of a Resistance Temperature Detector (RTD).

In a load cell, all four strain gauges are connected in a bridge circuit. If a stress of 1050 kg/cm^2 is applied on the top of such a load cell, calculate the change in the resistance $\Delta R / R$. The load cell is made up of steel and the modulus of elasticity of steel is approximately $2 \cdot 1 \times 10^6$ kg/cm^2; the gauge factor of the strain gauge is 2.   .   15

(b) Define 'accuracy', 'precision', 'absolute error' and 'relative accuracy' of a measurement. A resistor of value 4·7 K is read as 4·65 kohms in a measurement. Calculate *(i)* absolute error, *(ii)* % errors and *(iii)* accuracy.

Design a universal shunt meter with current range of 0·1 mA, 10 mA and 50 mA; with a d.c. ammeter of internal resistance 100 Ω and full-scale current of 100 μA.   15

(c) Determine the binary output of a Successive Approximation Register (SAR) type digital voltmeter with 10-bit output and reference voltage of +5 V for an input of 2·567 V. Draw the block diagram for the display in 3½-digit LCD.   10

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