इन्जीनियरिंग सेवा परीक्षा, 2010

Engineering Service Examination. **A–GUG–K–FUA**

Sl. No. 68570

ELECTRONICS AND TELECOMMUNICATION ENGINEERING

Paper—I

(Conventional)

Time Allowed : Three Hours	Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt Question No. 1 which is compulsory and any FOUR from the remaining questions.

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

Answers must be written only in ENGLISH.

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

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

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

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

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

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

1. *(a)* Sketch the covalent bonding of Si atoms in an intrinsic Si crystal.

Illustrate with sketches the formation of bonding in presence of donor and acceptor atoms. Sketch the energy-band diagram, indicating the position of donor and acceptor levels at 0 K. Explain how the semiconductor behaves as n-type (in case of donor) and p-type (in case of acceptor) at a finite room temperature ($T > 0$ K). 10

(b) Write down the expression for Fermi-Dirac distribution function. Explain the meaning of each parameter. Show that the probability that a state ΔE above the Fermi level, E_F is filled equals the probability that a state below E_F by the same amount ΔE is empty. 10

(c) Show that $X^*(\omega) = X(-\omega)$ is the necessary and sufficient condition for $x(t)$ to be real. 10

(d) What is P-R function? Obtain a canonic realization of the driving-point

admittance represented by the circuit of Fig. 1 and draw its pole-zero diagram. 10

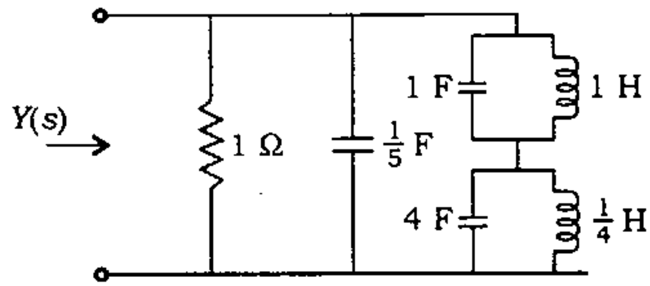

Fig. 1

(e) *(i)* For a good conductor, derive the expressions of attenuation constant, phase constant and the depth of penetration as functions of relevant parameters of the conductor. 5

(ii) The conductivity of copper is given as $\sigma = 58 \times 10^6$ S/m. Determine the skin depth of copper at a frequency of 30 GHz. 5

(f) A d.c. Wheatstone bridge as shown below in Fig. 2

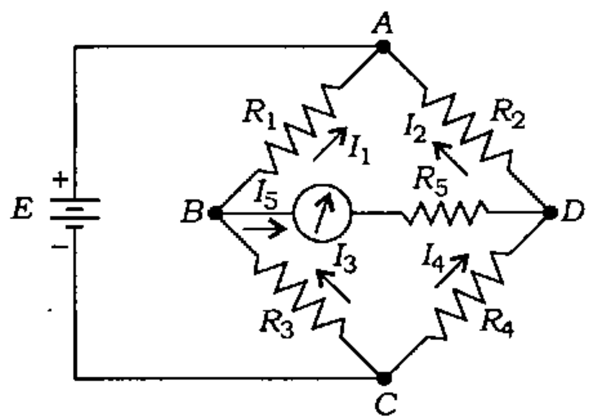

Fig. 2

uses a 12 V battery for excitation and has $R_1 = 1 \cdot 2\ \text{k}\Omega$, $R_2 = 1 \cdot 5\ \text{k}\Omega$, $R_3 = 4\ \text{k}\Omega$, $R_4 = 3 \cdot 6\ \text{k}\Omega$ and $R_5 = 1\ \text{k}\Omega$. Calculate the meter current. 10

2. *(a)* Derive the current-voltage characteristics of a *p-n* junction under ideal condition. How do the *I-V* characteristics of a practical diode vary from the ideal characteristics? 15

(b) Explain the breakdown mechanisms in *p-n* junction diode. 10

(c) Explain with necessary energy-band diagrams the formation of Schottky contact and ohmic contact in the case of metal-semiconductor contacts. 10

3. *(a)* Obtain an expression for the intrinsic Fermi level (E_i) of a semiconductor with respect to the conduction band edge.

Estimate the shift of E_i from the middle of the band gap ($E_g/2$) at 300 K for InSb. Assume that the relevant ratio of electron to hole effective mass for InSb is 0·014. Sketch the energy-band diagram, indicating the position of the intrinsic Fermi level with respect to the middle of the gap. 15

(b) Explain drift and diffusion mechanisms of current flow in a semiconductor.

In a region of a semiconductor, the electric field is directed from left-to-right (→) while the carrier concentrations decrease with increasing x, i.e., from left-to-right. Indicate the directions of flux of charge carriers (electrons and holes) due to drift and diffusion. Also indicate the direction of flow of the corresponding current components. 10

(c) Obtain Ebers-Moll equations for a p-n-p bipolar junction transistor. Show that these equations are true for any arbitrary geometry of the device. 10

4. (a) A causal discrete time LTI system is described by

$$y(n) - \frac{3}{4} y(n-1) + \frac{1}{8} y(n-2) = x(n)$$

where $x(n)$ and $y(n)$ are the input and output of the system respectively.

(i) Determine the system function, $H(z)$. 5

(ii) Find the impulse response, $h(n)$. 5

(iii) Find the step response, $s(n)$. 5

(b) Compute the output $y(t)$ for a continuous time LTI system whose impulse response $h(t)$ and the input $x(t)$ are given by

$$h(t) = e^{-\alpha t} u(t)$$
$$x(t) = e^{\alpha t} u(-t), \quad \alpha > 0$$ 10

(c) If the input to a low-pass filter as shown below in Fig. 3 is a random process $x(t)$ with autocorrelation function, $R_x(\tau) = 5\,\delta(t)$, then find—

(i) power spectral density of the output random process; 6

(ii) average power of output random process. 4

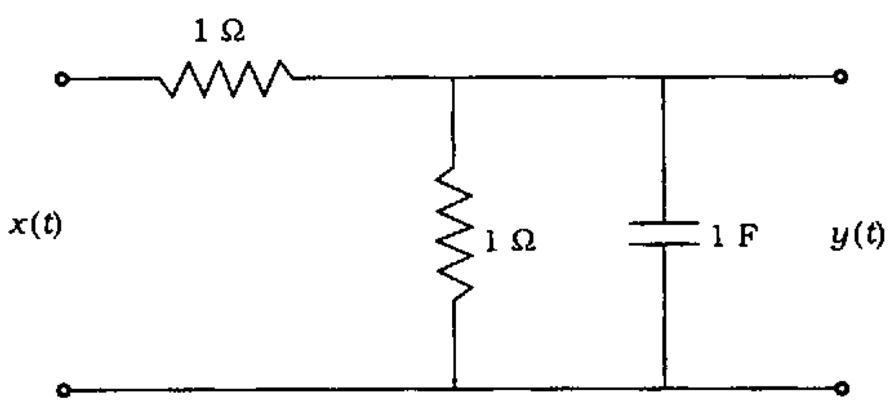

Fig. 3

5. *(a)* *(i)* Find $v_0(t)$ for $t > 0$ in the circuit of Fig. 4, if switch is changed at $t = 0$ after having remained in the position shown for long time. 8

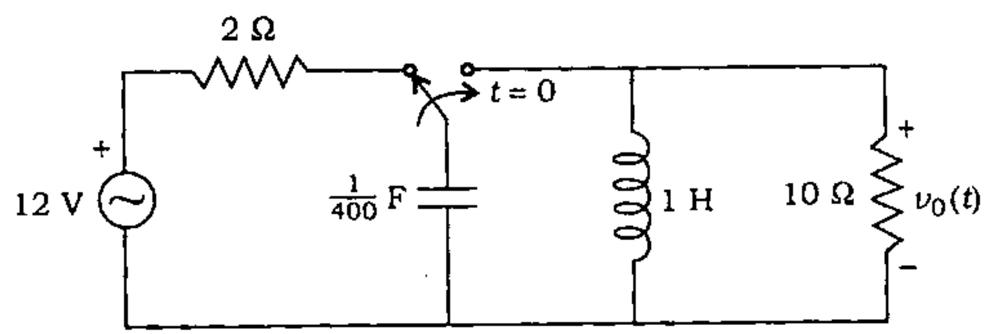

Fig. 4

(ii) Consider the circuit of Fig. 5. If $Q = 7$, find the value of L needed for antiresonance. Find R, the coil resistance, and R_g for maximum power supply to the circuit. 7

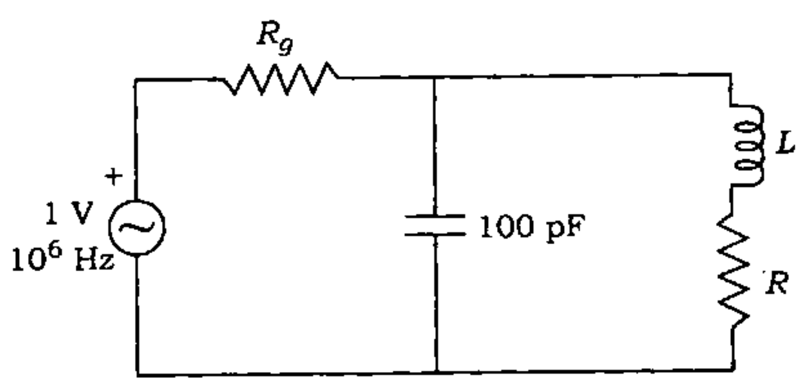

Fig. 5

(b) (i) Determine Thevenin equivalent circuit for the network of Fig. 6 as a function of α looking into terminals AB. 7

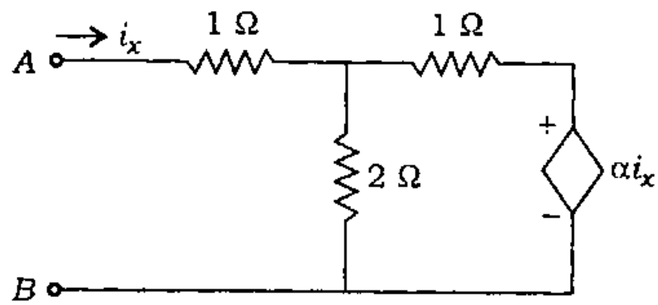

Fig. 6

(ii) Define tree, f-cutset and f-circuit. 3

(c) When port-2 of a 2-port network is short-circuited and port-1 is excited by a unit-step current source, then port-1 voltage v_1 and port-2 current i_2 are measured and are found to be

$$v_1(t) = (1 - e^{-4t})u(t) \text{ V}$$
$$i_2(t) = -e^{-3t}u(t) \text{ A}$$

Next, port-2 is terminated with $1\,\Omega$ resistor and the new unit-step responses measured are

$$v_1(t) = (1 - e^{-4t} + te^{-4t})u(t) \text{ V}$$
$$i_2(t) = -e^{-7t}u(t) \text{ A}$$

Determine y-parameters of the 2-port network and input impedance when port-2 is terminated by $1\,\Omega$ resistor. 10

6. *(a)* Write down the Maxwell's equations in point form for free space, explaining the meanings of the parameters used.

For time-harmonising electromagnetic waves, establish that $\overline{E}$ and $\overline{H}$ fields cannot exist independently. 15

(b) Define and explain what is meant by each of the following terms : 10

(i) Linear Polarization

(ii) Circular Polarization

(iii) Elliptical Polarization

(c) A uniform plane wave at 2 GHz is propagating along z-direction. The electric field has two components, $E_x = 5$ (V/m) and $E_y = 10\angle 30°$ (V/m). In case E_x becomes maximum at $t = 0$, find the magnitude and direction of the field at $t = 0$ and $t = 0 \cdot 1$ ns. 10

7. *(a)* Explain briefly about sensitivity and loading effect of a voltmeter.

The voltage across the 50 kΩ resistor in the circuit shown below in Fig. 7 are measured with two voltmeters separately. Voltmeter 1 has a sensitivity of 1000 Ω/V and voltmeter 2 has a sensitivity of 20000 Ω/V. Both the meters are used on their 50 V range. Calculate *(i)* the reading of each meter and *(ii)* the error in each reading, expressed as a percentage of the true value. 15

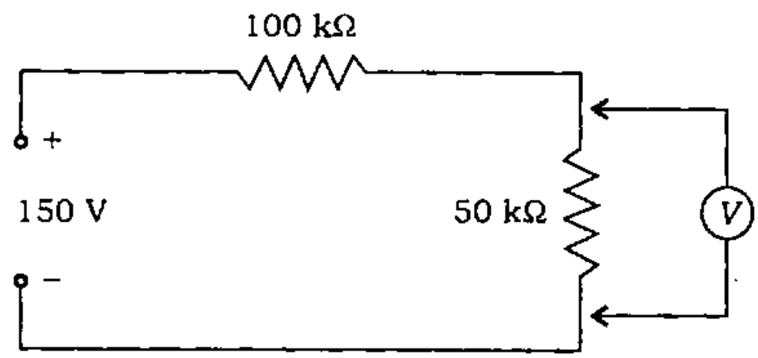

Fig. 7

(b) For the shunt-type ohmmeter shown below in Fig. 8, determine the resistance R_x at which the meter shows half-scale deflection. 10

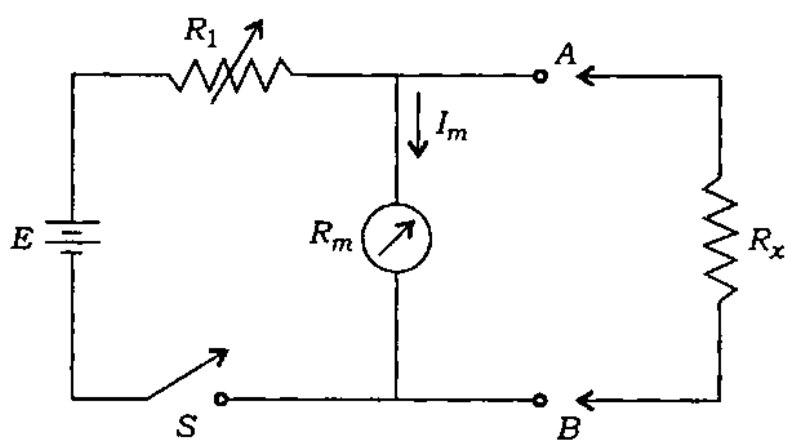

Fig. 8

(c) Explain the parameters—sensitivity, bandwidth and rise time in reference to oscilloscopes.

What is the maximum frequency response required for an oscilloscope to reproduce without distortion a pulse of 15 ns rise time? 10

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