इन्जीनियरिंग सेवा परीक्षा,
Engineering Service Examination, 2010 A-GUG-K-FFA

ELECTRICAL ENGINEERING

Paper—I

(Conventional)

Time Allowed : Three Hours	Maximum Marks : 200

INSTRUCTIONS

Candidates should attempt SIX questions, selecting TWO questions from Part—A, ONE from Part—B, ONE from Part—C and TWO from Part—D.

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.

Part—A

1. *(a)* Explain the concept of polarization and bound volumetric charge density in a material due to polarization. A parallel-plate capacitor consists of free space and two dielectrics of relative dielectric constants of 4 and 6 respectively. Obtain the electric field density (D), electric field intensity (E) and polarization (P) in all regions, if the plates have a charge density (ρ_s) of 30×10^{-6} C/m^2. 12

/15

[P.T.O.

(b) For a second-order underdamped system, subjected to unit-step input, the time response shows first peak to be four times of the second overshoot. Determine the damping factor of the system and expected maximum overshoot. **10**

(c) *(i)* Differentiate clearly between 'tracking control' and 'regulatory control' problems, with the help of an example and diagram. **4**

     (ii) For a controlled system shown in Fig. 1, determine the safe maximum gain, $K_{c\,max}$ of the controller and the steady-state error due to only 0.3 unit-step disturbance input L, with K_c set to $K_{c\,max}$. **6**
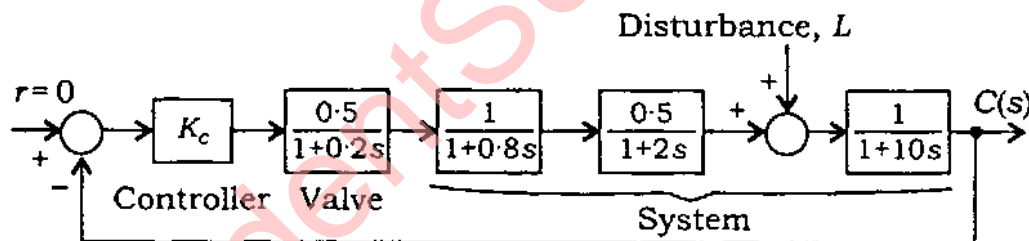

Fig. 1

2. *(a)* A uniform plane wave travels in free space in Z-direction and is described by

$$\vec{H} = 0\cdot 80\cos(\omega t - \beta z)\vec{a}_x + 0\cdot 80\sin(\omega t - \beta z)\vec{a}_y$$

where $\vec{a}_x$ and $\vec{a}_y$ are unit vectors in X- and Y-direction respectively. Find the corresponding electric field and the Poynting vector. Also obtain intrinsic impedance of the medium. **12**

(b) Determine the safe maximum value of K for the unity feedback system, having open-loop transfer function

$$G(s) = \frac{K(s+20)^2}{s^3}$$

Sketch the Nyquist plot with this value of K. Obtain the margins of stability and comment. **10**

(c) For a liquid level tank system shown in Fig. 2, write the dynamical equations and obtain a variable model.
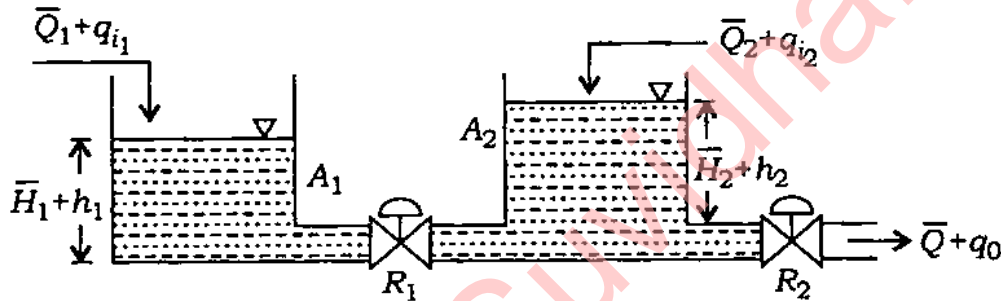

Fig. 2

The liquid levels in the tanks may be assumed as output. Also draw the block diagram and obtain transfer function $H_2(s) / Q_{i_1}(s)$ for transient state. **10**

3. *(a)* A coaxial cable of length L is used to transmit voltage. The conductor radius is a and radius of outer conducting sheath is b. The sheath is earthed. The inner conductor is maintained at potential V. The space between the inner conductor and the outer sheath is filled with a lossy dielectric material. Obtain an expression for the resistance offered by the space between the inner conductor and the outer sheath. **12**

(b) (i) For a system represented in state-space form, how can the corresponding transfer function model be obtained? 4

(ii) For the system given as

$$\dot{x} = \begin{bmatrix} 0 & 0 & -20 \\ 1 & 0 & -24 \\ 0 & 1 & -9 \end{bmatrix} x + \begin{bmatrix} 3 \\ 1 \\ 0 \end{bmatrix} u$$

$$y = [0 \quad 0 \quad 1] x$$

obtain the transfer function. 3

(iii) What is the property of invariance in state-variable models? 3

(c) (i) For a system described by state-space model in controllable canonical form, explain the concept of pole-placement design by state-variable feedback (SVFB) control approach. 5

(ii) For the system specified below, design an SVFB controller such that the closed-loop poles of system are located at $s = -3 \pm j3$: 5

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

A–GUG–K–FFA/**15**   4

Part—B

4. (a) (i) Differentiate between Type–I and Type–II superconductors. Give two examples of each type. 8

(ii) The current flowing in a superconducting ring shows no decay after 3 years. If the accuracy of the measurement is 0·01%, calculate the conductivity of the superconductor. Assume electron density as 10^{28} electrons/m^3. 8

(b) Derive an expression for the Hall voltage in a good conductor. 8

(c) What is the dielectric strength of a material? Discuss briefly the three main mechanisms that are usually blamed for dielectric breakdown—(i) intrinsic, (ii) thermal and (iii) discharge breakdown. 12

5. (a) A specimen of a semiconductor has a Hall coefficient of $3·66 \times 10^{-4}$ m^3/C and a resistivity of $8·93 \times 10^{-3}$ Ω-m. In a Hall effect experiment, a magnetic density of 0·8 T is used. Find the Hall angle. 8

(b) Summarize the differences between Soft and Hard magnetic materials in respect of (i) coercivity, (ii) anisotropy constant, (iii) energy domain walls, (iv) wall motion and (v) microstructure. 10

(c) (i) What are ferroelectric materials? State the salient features of such materials based on relative permittivity and hysteresis loop. List two examples of ferroelectric materials and two applications each. 12

(ii) The electron concentration in silicon at 300 K is $5 \times 10^{15}/cm^3$. If the intrinsic carrier concentration is $1 \cdot 5 \times 10^{10}/cm^3$, determine—

(1) hole concentration;

(2) type of material : p-type or n-type;

(3) impurity doping concentration. 6

Part—C

6. (a) A series R-L-C circuit having $R = 25 \, \Omega$, $L = 2 \, H$ and $C = 30 \, \mu F$ is connected across an a.c. variable-frequency source. At what frequencies will the phase angle of the circuit be (i) 45° lagging and (ii) 45° leading, the applied voltage? 12

(b) The following mesh equations pertain to a network :

$$8I_1 - 5I_2 - I_3 = 110$$
$$-5I_1 + 10I_2 + 0 = 0$$
$$-I_1 + 0 + 7I_3 = 115$$

(i) Draw the network showing each element.

(ii) Calculate the current in the 110 volts source. **12**

(c) A sinusoidal voltage $e(t) = 141 \sin 314t$ is applied to an initially de-energized series *R-L* circuit in which $R = 100\,\Omega$ and $L = 0 \cdot 5\,H$.

(i) If the switch which applied the voltage to *R-L* circuit is closed at the instant when $e(t)$ is passing through zero with a positive slope, determine the initial value of the transient current.

(ii) Write the complete expression for the transient solution.

(iii) Write the expression for the complete solution of the current response.

(iv) At what instantaneous value of the applied voltage will the closing of the switch result in no transient component of the current? **12**

7. *(a)* Compute the steady-state current in the $8\,\Omega$ resistor in the circuit given in Fig. 3.   12
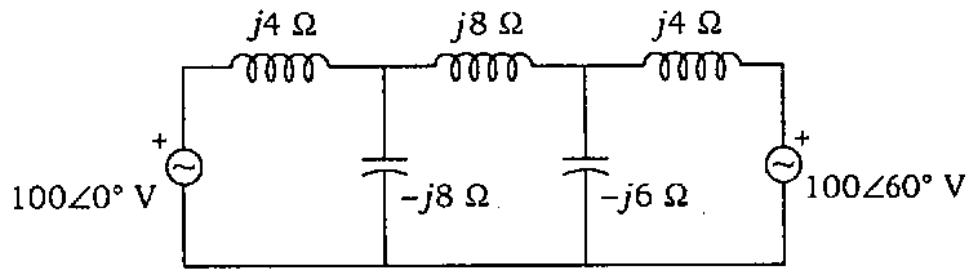

Fig. 3

(b) Three identical coils are connected in star to a 200 V, 3-phase supply and each takes 400 W. The p.f. is 0·8 lagging. What will be the magnitude of line currents and total power if the same coils are connected in delta to the same supply? If the total power in delta-connected coils is measured by two-wattmeter method, what will be the readings of the wattmeters?   12

(c) When can a two-port circuit be declared as a reciprocal circuit?

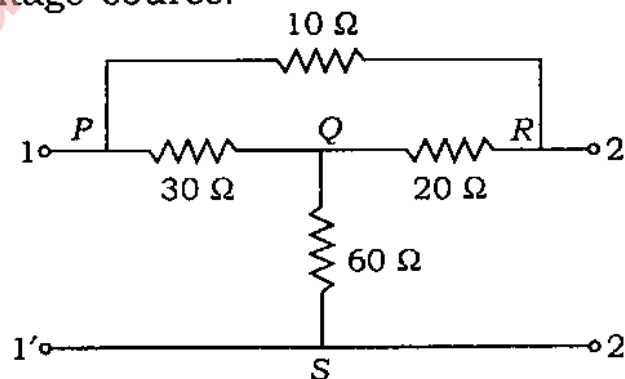Is the two-port circuit shown in Fig. 4 reciprocal? Justify the answer by a 15 V voltage source.   12

Fig. 4

Part—D

8. *(a)* *(i)* Why is it not possible to measure the temperature of a body instantaneously? **4**

(ii) Two strips of metals A and B with thermal expansion coefficients α_A and α_B ($\alpha_A > \alpha_B$) are bonded together at temperature T_1 to form a bimetallic strip. Draw the profile of the bonded strips when $T_2 > T_1$ and $T_2 < T_1$. On what factors does the bending of the bimetallic strip depend? What are the practical applications of bimetallic strips? **8**

(b) Two sets of large number of 20 kΩ and 30 kΩ resistors are used to make a large number of 12 kΩ and 50 kΩ resistors choosing one from each group. If the standard deviations of the two sets of resistors of 20 kΩ and 30 kΩ are respectively 5% and 10%, find the standard deviations of the combined resistor-sets of 12 kΩ and 50 kΩ. **10**

(c) Describe the constructional details and working of a single-phase electro-dynamometer type of power factor meter. Prove that the displacement of the moving system is proportional to the phase angle of the system. **10**

9. *(a)* *(i)* How can strain gauges be used to transduce pressure?   4

          (ii) Explain with a diagram, the placement of gauges, explaining which of the gauges are in tension and compression respectively.   4

          (iii) Give the connection diagram of the Wheatstone's bridge to be used.   4

     (b) Derive the general torque equation for a moving-iron instrument.

         The inductance of a moving-iron ammeter is given by the following expression :

$$L = (30 + 10\theta - 2\theta^2)\,\mu H$$

         where θ is the deflection in radians. The control spring constant is 25×10^{-6} N-m/rad. Calculate the value of deflection for a current of 5 A.   10

     (c) With the help of circuit diagram, explain the principle and operation of Owen's bridge for the measurement of incremental inductance.   10

10. *(a)* A 2-bit D/A converter using *R*-2*R* ladder network was constructed using 2 kΩ and 8 kΩ resistors. If the bit length of the converter is to be increased by two, using resistors of the same values, what would be the total number of resistors required in the augmented version? Give the circuit diagram of the augmented converter.   12

(b) Discuss the difficulties faced in measuring high resistances. Explain the procedure adopted in the laboratory for measuring high resistance.   10

(c) Explain the advantages of electronic voltmeters over conventional voltmeters. Describe the working of a differential amplifier type electronic voltmeter using two FETs.   10

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Engineering Service Examination

A-GUG-K-FFB

ELECTRICAL ENGINEERING

Paper II

(Conventional)

| Time Allowed : Three Hours | Maximum Marks : 200 |

INSTRUCTIONS

Candidates should attempt FIVE questions in all.

Question No. 1 is compulsory. The remaining FOUR questions are to be attempted by selecting ONE question each from Sections A, B, C and D.

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.

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(Contd.)

1. [A] Choose and write the correct answer from among the four options given in each case for (a) to (j) below : 2×10=20

   (a) Improved commutation in d.c. machines cannot be achieved by

   (i) use of interpoles

   (ii) using brushes of higher resistivity

   (iii) increasing reactance voltage
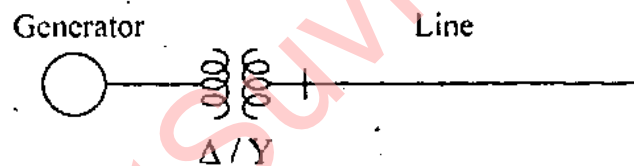
   (iv) decreasing reactance voltage

   (b) A two winding single phase transformer when connected either as a step down or step up autotransformer, under the assumptions of ignoring core loss, copper loss, magnetising current and leakage reactance, will have the maximum VA rating for the autotransformed for a given VA rating of the two winding transformer having N_1 and N_2 primary and secondary turns respectively for

   (i) $(N_1/N_2) \ll 1.0$

   (ii) $(N_1/N_2) = 1.0$

   (iii) $(N_1/N_2) \simeq 1.0$ but > 1.0

   (iv) $(N_1/N_2) \gg 1.0$

(c) A surge of 10 kV travels along a cable towards its junction with an overhead line. The surge impedances of the cable and the line are 50 Ω and 450 Ω, respectively. The surge voltage transmitted into the line is

   (i) 18·0 kV

   (ii) 4·0 kV

   (iii) 20·0 kV

   (iv) 2·0 kV

(d)

Generator   Line

Δ / Y

The one line diagram of a simple power system is given above. The transformation ratio of the step-up transformer is 11/220 kV. The base MVA = 100 and base kV = 11 on the generator side. The base kV on the transmission side is

   (i) 11 kV

   (ii) 220 kV

   (iii) $\dfrac{220}{\sqrt{3}}$ kV

   (iv) $\sqrt{3} \times 220$ kV

(e) An ideal current-controlled voltage source has the input resistance and the output resistance, respectively,

    (i) ∞, ∞

    (ii) 0, ∞

    (iii) 0, 0

    (iv) ∞, 0

(f) Consider the following assembly language program for the 8085 microprocessor :

LxI H, 2000 H

MOV A, M

CMA

MOV A, M

After the execution of this program,

    (i)   content of 2000 H is complemented and is moved to 2001 H.

    (ii) content of 2000 H is complemented and is stored in the accumulator.

    (iii) content of 2000 H is moved to the accumulator.

    (iv) content of 2000 H is compared with the accumulator.

(g) For data-transfer between microprocessor and I/O device, the term hand-shake refers to

    (i) the conversion of parallel data to serial format for the I/O device

    (ii) The conversion of serial data to parallel format for the micropro-cessor

    (iii) the exchange of control-signals between the microprocessor and I/O device

    (iv) the I/O device, gaining control of the microprocessor buses

(h) Companding is used in PCM to

    (i) increase the signal to noise ratio

    (ii) reduce the bandwidth

    (iii) reduce the power

    (iv) get almost uniform signal to noise ratio

(i) A freewheeling diode in a phase-controlled converter

    (i) decreases the possibility of dis-continuous conduction in the load

    (ii) increases the possibility of discon-tinuous conduction

    (iii) impairs the power factor

    (iv) causes additional reactive power requirement

(j) The quality of output ac voltage of a cycloconverter is improved with

  (i) increase in output voltage at reduced frequency

  (ii) increase in output voltage at increased frequency

  (iii) decrease in output voltage at reduced frequency

  (iv) decrease in output voltage at increased frequency

[B] Answer the following questions : 4×5=20

(a) What are the various conditions which have to be fulfilled before a shunt excited d.c. generator will generate rated voltage across the armature terminals ?

(b) Determine the positive-sequence component of the three currents $I_a = 10 \angle 0°$ A, $I_b = 10 \angle 230°$ A and $I_c = 10 \angle 130°$ A.

(c) The open circuit voltage and the resistance of a microphone are 15 mV and 100 kΩ, respectively. An amplifier with an input resistance of 50 kΩ is used for amplifying the microphone output so as to deliver 2·0 W power into a load of 8 Ω. Find the voltage gain of the amplifier.

(d) How does the CPU come to know about the number of bytes to be fetched from memory to execute an instruction ? During which clock cycles of an instruction cycle does ALE appear ? What is its function ?

(e) For a single phase ac voltage controller, which type of gating signal is more suitable, when the load is inductive ? Give reasons for your answer.

Section 'A'

2. (a) Explain the various methods of speed control of d.c. series motors including the case when two identical d.c. series motors are available.

A 4 pole d.c. series wound motor takes 20 A from 250 V d.c. supply to run at 600 rpm when all the four field coils are in series. If the load torque increases as the square of speed, find the speed and the input current when the field coils are connected in two parallel groups of two coils in series each. Assume that the flux is proportional to the current and ignore losses.   6+4=10

(b) Classify 1-phase induction motors by the methods of starting and compare their performance and mention typical application areas.

A 230 V 6 pole 50 Hz 375 Watt single phase induction motor has the following parameters at standstill

$r_1 = 11.4$ ohm $x_1 = 14.3$ ohm $x_0 = 275$ ohm

$r_2' = 13.8$ ohm $x_2' = 14.3$ ohm   Ignore R_0

Find the input current, power and power factor when the motor is operating at $s = 0.06$.

6+4=10

(c) What is 'Hunting' in synchronous machines and what are its effects ? Does it occur in synchronous generators only or in synchronous motors also ? How is it reduced in salient pole synchronous generators and in turbo alternators ? Formulate analytically the dynamics of hunting in case of round rotor synchronous generators and identify when hunting may lead to operational instability.

(5+2)+1+2×2+6+2=20

3. (a) Explain the different methods of electrical braking of d.c. motors and compare their advantages and disadvantages.   6+4=10

(b) Explain the various methods of starting large induction motors with wound rotors and compare their values of starting torques.

6+4=10

(c) A 3-phase synchronous generator is excited by d.c. field to give rated voltage at its terminals on no load when a sudden short (symmetric) circuit occurs at the terminals.

Show the typical plots of the three armature phase and field current and also show the typical plot of the ac component of short circuit current in both actual and semi logarithmic plot identifying different operational conditions.

Draw the approximate equivalent circuits of the synchronous generators for x_d'', x_d' and x_d in terms of leakage, demagnetising field and damper winding reactances.

Define direct axis transient open circuit time constant T_{do}'.
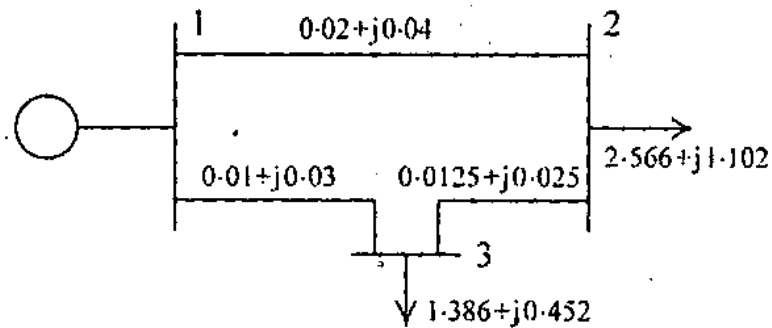
15+3+2=20

Section 'B'

4. (a) A 220-kV, three-phase transmission line is 40 km long. The resistance per phase is 0·15 Ω per km and the inductance per phase is 1·5923 mH per km. The line is supplying a 3-phase load of 381 MVA at 0·8 power factor lagging. Find

(i) the voltage and power at the sending end of the line.

(ii) the voltage regulation and efficiency of the line.

15

(b)

The one-line diagram of a simple three-bus power system with generator at bus 1 is given above. The line impedances are marked in per unit on 100 MVA base. The voltages obtained by performing load flow are :

$$V_1 = 1.05 \angle 0° \text{ pu}$$

$$V_2 = 0.98183 \angle{-3.5035°}$$

$$V_3 = 1.00125 \angle{-2.8624°}$$

Determine :
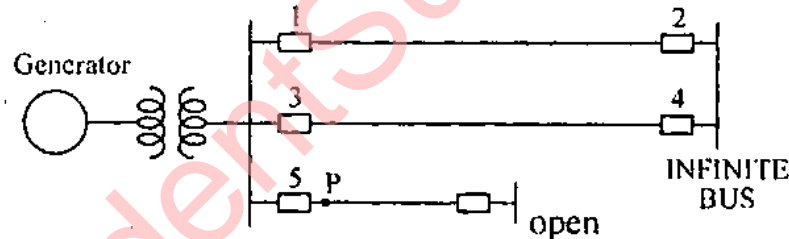
(i) slack-bus power

(ii) complex power flow on line 1–2.　　15

(c) The bus impedance matrix of a four-bus network with values in per unit is

$$Z_{bus} = j \begin{bmatrix} 0.15 & 0.08 & 0.04 & 0.07 \\ 0.08 & 0.15 & 0.06 & 0.09 \\ 0.04 & 0.06 & 0.13 & 0.05 \\ 0.07 & 0.09 & 0.05 & 0.12 \end{bmatrix}$$

Generators are connected to buses 1 and 2, and their sub-transient reactances were included when finding Z_{bus}. Find the sub-transient current in the fault for a three-phase fault on bus 4 neglecting prefault current. Assume the voltage at the fault is 1·0 per unit before the fault occurs. Find also the per-unit current from generator 2 whose subtransient reactance is 0·2 per unit. 10

5. (a) A power system has a total load of 1260 MW at 50 Hz. The load varies 1·5% for every 1% change in frequency. Find the steady state frequency deviation when a 60 MW load is suddenly tripped. The speed regulation parameter R = 0·0025 Hz per MW. 10

(b)

The single-line diagram of a three-phase power system is given above. The generator is delivering 1·0 per unit power to the infinite bus. The pre-fault power angle equation is

$$P_e = 2\cdot10 \sin \delta$$

Calculate the critical clearing angle and critical clearing time when the system is subjected to a 3-phase fault at point P (i.e. sending end of the short line). The fault is cleared by opening the circuit breaker 5. The inertia constant H = 5·0 MJ/MVA. 15

(c) What are the types of HVDC transmission system applications ? 10

(d) Draw a neat circuit diagram of Merz-Price per cent differential protection scheme for a 3-phase Δ-Y connected transformer. 5

Section 'C'

6. (a) (i) State four most important characteristics of an ideal Op Amp. Explain with the help of a suitable circuit diagram its use as

(ii) a weighted resistor

(iii) an inverting amplifier

(iv) a non-inverting integrator

(v) an instrumentation amplifier

4+3+2+5+6=20

(b) (i) Why is a synchronous counter faster than a ripple counter ?

(ii) Draw the circuit of a 4-bit synchronous up-counter using JK flip-flops.

(iii) Explain its operation. 2+4+4=10

(c). (i) Draw the circuit of an inverting Schmitt trigger using an Op Amp.

(ii) Draw its voltage transfer characteristic.

(iii) If the upper and lower threshold voltages are 3V and –2V, respectively· and the saturation voltages of the Op Amp = ± 10 V, draw the waveforms of the output voltage when

(A) the input is a sinusoidal voltage of peak value 5 V,

(B) the same sinusoidal voltage is applied through a half-wave recti-fier. 2+4+2+2=10

7. (a) (i) The squares of data (0 to 9) are stored in 10 consecutive memory locations (e.g. 2600 to 2609) in the tabular form, which is called a look-up table. Values of square are in decimal. Using look-up table, write an assembly level program for 8085 microprocessor to find a square· of a given decimal number (0 to 9). Write comments in each of the instruction in the program.

(ii) Write two varieties of single instruction (in assembly language) to perform the following individual operations :

(p) clear the, accumulator

(q) clear the carry flag

(r) assume that register pair HL has 0010 H. Make it 0020 H. 6+6=12

(b) Write a time efficient subroutine that arranges in increasing order a block of twenty numbers each of single byte. The starting address of the block is stored in the memory location START. Program is to be written in 8085 assembly language. Write comments in selected instructions.   12

(c) (i) In the 8085 microprocessor, a special kind of JUMP instruction is the CALL instruction. How does the CALL/ RETURN instruction executed in the microprocessor ?

(ii) The hardware interrupts can be classified into three types, depending on their maskability and the way they can be masked. Explain all these interrupts.   8+8=16
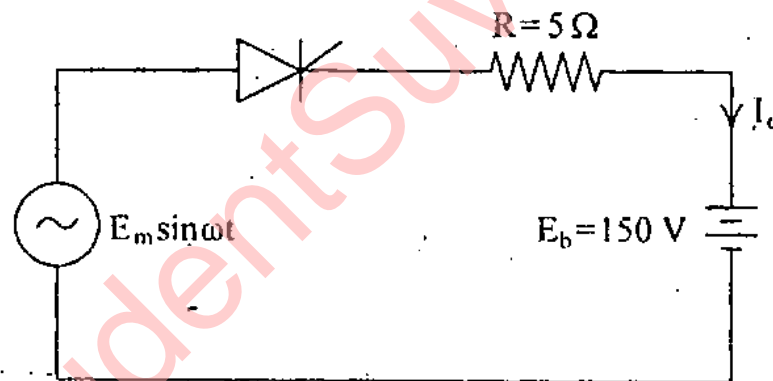
Section 'D'

8. (a) A radio receiver has three main blocks : R.F. Amplifier, Mixer and I.F. Amplifier. The noise figure of R.F.A. is 9 dB and has the available power gain of 15 dB. The mixer stage has a noise figure of 20 dB and power gain of 10 dB. This is followed by an I.F.A. having the noise figure of 10 dB and power gain of 120. Calculate the overall noise figure of the receiver referred to its input.   10

(b) Draw the circuit diagram of a balanced modulator using FETs and explain the generation of SSB. 4+6=10

(c) What is quantizing ? What for it is done ? Choose an arbitrary waveform and show the quantizing operation. Also indicate the quantizing error on this sketch. 2+2+4+2=10

(d) Draw the block diagrams of FM transmitters using direct and indirect methods of FM generation. Give their brief explanation indicating the advantages of indirect method. 4+4+2=10

9. (a)

A dc battery is charged through a resistor R as shown in the above figure. Derive an expression for the average value of charging current in terms of E_m, E_b, R. Assume that the SCR is fired in every cycle.

(i) For an ac supply voltage of 230 V, 50 Hz, find the value of average charging current.

(ii) Find average power supplied to the battery and that dissipated in the resistance.

(iii) Calculate the power factor at the supply. (Neglect SCR drop)   3+5+5+5=18

(b) A single phase semi converter using two SCRs and two diodes is supplying dc voltage to RLE (Resistance, Inductance, Battery) load. A freewheeling diode is connected across the load. Draw the circuit diagram of the semi converter and show the region of converter operation. Draw waveforms for the input voltage, output voltage, input current and current through the SCRs and diodes. Derive expressions for average output voltage and rms output voltage. (Assume highly inductive load) 4+6+2+2=14

(c) Adding an inductance L in series and a freewheeling diode (FWD) in parallel to the load circuit of an SCR-converter has several advantages. Enumerate the advantages of the load inductance and freewheeling diode.

4+4=8