GATE : 1996

EE : Electrical Engineering

Duration : Three Hours *Maximum Marks : 150*

SECTION - A

(MARKS = 100)

EE.1. In each of the subquestions (1.1 to 1.48), four/five alternatives, A, B, C, and D(E) are provided of which one is correct. Indicate in you answer book the correct answer by writing the alphabet corresponding to the answer against the subquestion. (48 × 1 = 48)

1.1. The unit-impulse response of a unit-feedback control system is given by

$$c(t) = -te^{-t} + 2e^{-t}, (t \geq 0)$$

the open loop transfer function is equal to

(*a*) $\frac{s+1}{(s+2)^2}$ (*b*) $\frac{2s+1}{s^2}$

(*c*) $\frac{s+1}{(s+1)^2}$ (*d*) $\frac{s+1}{s^2}$

1.2. Consider the unit-step response of a unity-feedback control system whose open-loop transfer functions is $G(s) = \frac{1}{s(s+1)}$. The maximum overshoot is equal to

(*a*) 0.143 (*b*) 0.153

(*c*) 0.163 (*d*) 0.173

1.3. For a feedback control system of type 2, the steady state error for a ramp input is

(*a*) infinite (*b*) constant

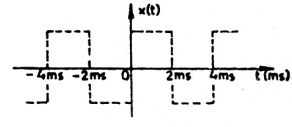
(*c*) zero (*d*) indeterminate

1.4. The closed-loop transfer function of a control system is given by $\frac{C(s)}{R(S)} = \frac{1}{1+s}$. For the input $r(t) = \sin t$, the steady state value of $c(t)$ is equal to

(*a*) $\frac{1}{\sqrt{2}} \cos t$ (*b*) 1

(*c*) $\frac{1}{\sqrt{2}} \sin t$ (*d*) $\frac{1}{\sqrt{2}} \sin\left(1 - \frac{\pi}{4}\right)$

1.5. A periodic rectangular signal, $x(t)$ has the wave form shown in Figure.Frequency of the fifth harmonic of its spectrum is



(*a*) 40 Hz (*b*) 200 Hz

(*c*) 250 Hz (*d*) 1250 Hz

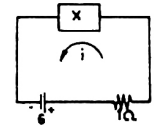
1.6. In the circuit shown in Figure.X is an element which always absorbs power. During a particular operations, it sets up a current of 1 amp in the direction shown and absorbs a power P_x. It is possible that X can absorb the same power P_x for another current i, the value of this current is

(*a*) $(3 - \sqrt{14})$ amps

(*b*) $(3 + \sqrt{14})$ amps

(*c*) 5 amps

(*d*) none of these



1.7. A water boiler at home is switched on to the a.c. mains supplying power at 230 V/50 Hz. The frequency of instantaneous power consumed by the boiler is

(*a*) 0 Hz (*b*) 50 Hz

(*c*) 100 Hz (*d*) 150 Hz

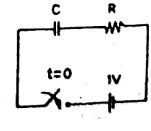
1.8. In the series RC circuit shown in Figure the voltage across C starts increasing the *d.c.* source is switched on. The rate of increase of voltage across C at the instant just after the switch is closed (*i.e.*, at $t = 0^+$), will be

(*a*) zero

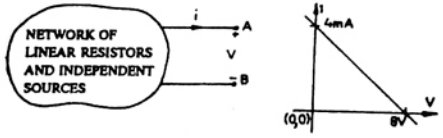
(*b*) infinity

(*c*) RC

(*d*) 1/RC



1.9. The *v-i* characteristic as seen from the terminal-pair (A, B) of the network of Figure. is shown in Figure. If an inductance of value 6 mH is connected across the terminal-pair (A, B), the time constant of the system will be



(*a*) 3 μ sec
(*b*) 12 sec
(*c*) 32 sec
(*d*) unknown, unless the actual network is specified

1.10. Inside a hollow conducting sphere
(*a*) electric field is zero
(*b*) electric field is an non-zero constant
(*c*) electric field changes with the magnitude of the charge given to the conductor
(*d*) electric field changes with distance from the centre of the sphere

1.11. If *v*, *w*, q stand for voltage, energy and charge, then *v* can be expressed as

(*a*) $v = \frac{dq}{dw}$ (*b*) $v = \frac{dw}{dq}$

(*c*) $dv = \frac{dw}{dq}$ (*d*) $dv = \frac{dq}{dw}$

1.12. The energy stored in the magnetic field of solenoid 30 cm long and 3 cm diameter wound with 1000 turns of wire carrying a current of 10 A is
(*a*) 0.015 joule (*b*) 0.15 joule
(*c*) 0.5 joule (*d*) 1.15 joule

1.13. The function of oil in a transformer is
(*a*) to provide insulation and cooling
(*b*) to provide protection against lightning
(*c*) to provide protection against short circuit
(*d*) to provide lubrication

1.14. Auto-transformer is used in transmission and distribution
(*a*) when operator is not available
(*b*) when iron losses are to be reduced
(*c*) when efficiency considerations can be ignored
(*d*) when the transformation ratio is small

1.15. Keeping in view the requirement of parallel operation, which of the 3-phase connections given below are possible ?
(*a*) delta-delta to delta-star
(*b*) delta-delta to star-delta
(*c*) star-star to delta-delta
(*d*) delta-star to star-delta

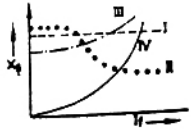
1.16. A 4 pole generator with 16 coil has a two layer lap winding. The pole pitch is
(*a*) 32 (*b*) 16
(*c*) 8 (*d*) 4

1.17. A 4 pole dynamo with wave wound armature has 51 slots containing 20 conductors in each slot. The induced emf is 357 volts and the speed is 8500 rpm. The flux per pole will be
(*a*) 3.5 mWb (*b*) 1.2 mWb
(*c*) 14 mWb (*d*) 21 mWb

1.18. A cylindrical rotor synchronous motor is switched on the supply with its field windings shorted on themselves. It will
(*a*) not start
(*b*) start but not run at synchronous speed
(*c*) start as an induction motor and then run as synchronous motor
(*d*) start and run as a synchronous motor

1.19. In Figure. the characteristic that corresponds to the variation of synchronous reactance of a synchronous motor with field current is

(*a*) curve I
(*b*) curve II
(*c*) curve III
(*d*) curve IV



1.20. During hunting of synchronous motor
(*a*) negative phase sequence currents are generated
(*b*) harmonics are developed in the armature circuit
(*c*) damper bar develops torque
(*d*) field excitation increases

1.21. Unbalanced supply voltage given to a 3-phase, delta-connected induction motor will cause
(a) zero sequence currents
(b) less heating of the rotor
(c) negative sequence component current
(d) all of these

1.22. When the supply voltage to an induction motor is reduced by 10%, the maximum torque will decrease by approximately
(a) 5% (b) 10%
(c) 20% (d) 40%

1.23. An induction motor having full load torque of 60 Nm when delta-connected develops a starting torque of 120 Nm. For the same supply voltage, if the motor is changed to star-connection, the starting torque developed will be
(a) 40 Nm (b) 60 Nm
(c) 90 Nm (d) 120 Nm

1.24. The torque speed characteristic of a repulsion motor resembles which of the following *dc* motor characteristic ?
(a) Separately excited (b) Shunt
(c) Series (d) Compound

1.25. Which type of motor is most suitable for computer printer drive ?
(a) Reluctance motor
(b) Hysteresis motor
(c) Shaded pole motor
(d) Stepper motor

1.26. In case of a split phase motor, the phase shift between currents in the two windings is around
(a) 30 degrees (b) 70 degrees
(c) 90 degrees (d) 120 degrees

1.27. In an induction motor, if the air gap is increased
(a) speed will reduce
(b) efficiency will improve
(c) power factor will be lowered
(d) breakdown torque will reduce

1.28. Which semiconductor power device out of the following is not a current triggered device ?
(a) Thyristor (b) G.T.O.
(c) Triac (d) MOSFET

1.29. The Triac can be used only in
(a) inverter
(b) rectifier
(c) multiquadrant chopper
(d) cycloconverter

1.30. Which of the following does not cause permanent damage of an SCR ?
(a) High current
(b) High rate of rise of current
(c) High temperature rise
(d) High rate of rise of voltage

1.31. In a thyristor dc chopper, which type of commutation results in best performance ?
(a) voltage commutation
(b) current commutation
(c) load communication
(d) supply commutation

1.32. In a 3-phase controlled bridge rectifier, with an increase of overlap angle, the output dc voltage
(a) decreases
(b) increases
(c) does not change
(d) depends upon load inductance

1.33. During a disturbance on a synchronous machine, the rotor swings from A to B before finally settling down to a steady state at point C on the power angle curve. The speed of the machine during oscillation is synchronous at point(s)
(a) A and B (b) A and C
(c) B and C (d) only at C

1.34. If the reference bus is changed in two load flow runs with same system data and power obtained for reference bus taken as specified P and Q in the latter run
(a) the system losses will be unchanged but complex bus voltages will change
(b) the system losses will change but complex bus voltages remain unchanged
(c) the system losses as well as complex bus voltage will change
(d) the system losses as well as complex bus voltage will be unchanged

1.35. Resistance switching is normally employed in
(a) all breakers
(b) bulk oil breakers
(c) minimum oil breakers
(d) air blast circuit breakers

1.36. Which material is used in controlling chain reaction in a nuclear reactor ?

(*a*) Thorium (*b*) Heavy water

(*c*) Boron (*d*) Beryllium

1.37. For a 500 Hz frequency excitation, a 50 km long power line will be modelled as

(*a*) short line

(*b*) medium line

(*c*) long line

(*d*) data insufficient for decision

1.38. For an unbalanced fault, with paths for zero sequence currents, at the point of fault

(*a*) the negative and zero sequence voltages are minimum

(*b*) the negative and zero sequence voltages are maximum

(*c*) the negative sequence voltage is minimum and zero sequence voltage is maximum

(*d*) the negative sequence voltage is maximum and zero sequence voltage is minimum

1.39. If the fault current is 2000 A, the relay setting is 50% and CT ratio is 400.5, the plug setting multiplier will be

(*a*) 25 A (*b*) 15 A

(*c*) 50 A (*d*) 10 A

1.40. An advantage of a permanent magnet moving coil instrument is that it is

(*a*) free from friction error

(*b*) has high (torque/weight of the moving parts) ratio

(*c*) has low (torque/weight of the moving parts) ratio

(*d*) can be used on both a.c. and d.c.

1.41. The moving coil in a dynamometer wattmeter is connected

(*a*) in series with the fixed coil

(*b*) across the supply

(*c*) in series with the load

(*d*) across the load

1.42. For a given frequency, the deflecting torque of an induction ammeter is directly proportional to

(*a*) current^2 (*b*) current^3

(*c*) $\sqrt{\text{current}}$ (*d*) current

1.43. The scale of a voltmeter is uniform. Its type is

(*a*) moving iron

(*b*) induction

(*c*) moving coil permanent magnet

(*d*) moving coil dynamometer

1.44. The depletion region or space charge region or transition region in a semiconductor *p-n* junction diode has

(*a*) electrons and holes

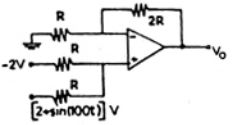
(*b*) positive ions and electrons

(*c*) positive ions and negative ions

(*d*) negative ions and holes

(*e*) no ions, electrons or holes

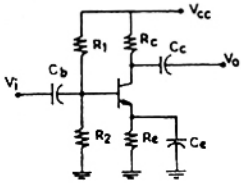
1.45. A non-inverting Op-Amp amplifier is shown in Figure. The output voltage V_o is



(*a*) (3/2) sin (100 *t*) (*b*) 3 sin (100 *t*)

(*c*) 2 sin (100 *t*) (*d*) None of these

1.46. In the transistor amplifier shown in figure., the ratio of small signal voltage gain, when the emitter resistor R_e is bypassed by the capacitor C_e to when it is not bypassed, (assuming simplified approximate h-parameter model for transistor, is



(*a*) 1 (*b*) h_{fe}

(*c*) $\dfrac{(1+h_{fe})\,R_e}{h_{ie}}$ (*d*) $1+\dfrac{(1+h_{fe})\,R_e}{h_{ie}}$

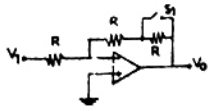
1.47. Let the magnitude of the gain in the inverting OP-Amp amplifier circuit shown in be *x* with switch S1 open. When the switch S1 is closed, the magnitude of gain becomes

(*a*) $x/2$

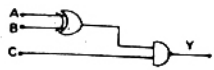
(*b*) $-x$

(*c*) $2x$

(*d*) $-2x$



1.48. The Boolean expression for the output of the logic circuit shown in Figure. is



(*a*) $Y = \overline{A}\,\overline{B} + AB + \overline{C}$

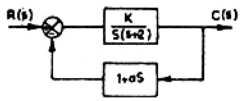
(*b*) $Y = \overline{A}\,\overline{B} + AB + \overline{C}$

(*c*) $Y = \overline{AB} + \overline{A}B + C$

(*d*) $Y = \overline{AB} + \overline{A}\,\overline{B} + \overline{C}$

EE.2. The question consists of 6 parts. Each part is accompanied by four answers of which one is correct. Indicate the correct answer by writing the alphabet A, B, C, or D. (6 × 2 = 12)

2.1. For the system shown in Figure, with a damping ratio ζ of 0.7 and an undamped natural frequency ω_n of 4 rad/sec, the values of K and a are



(*a*) K = 4, *a* = 0.35 (*b*) K = 8, *a* = 0.455

(*c*) K = 16, *a* = 0.225 (*d*) K = 64, *a* = 0.9

2.2. The unit impulse response of a system is given as $c(t) = -4e^{-t} + 6e^{-2t}$. The step response of the same system for $t \geq 0$ is equal to

(*a*) $-3e^{-2t} - 4e^{-t} + 1$ (*b*) $-3e^{-2t} + 4e^{-t} - 1$

(*c*) $-3e^{-2t} - 4e^{-t} - 1$ (*d*) $3e^{-2t} + 4e^{-t} - 1$

2.3. A coil (which can be modeled as a series RL circuit) has been designed for high-Q performance at a rated voltage and a specified frequency. If the frequency of operation is doubled, and the coil is operated at the same rated voltage, then the Q-factor and the active power P consumed by the coil will be affected as follows

(*a*) P is doubled, Q is halved

(*b*) P is halved, Q is doubled

(*c*) P remains constant, Q is doubled

(*d*) P decreased 4 times Q is doubled

2.4. Out of the following factors for a dc machine,

(*i*) Interpole

(*ii*) Armature resistance

(*iii*) Armature

(*iv*) Reduction in field current

the factors that are responsible for decrease in the terminal voltage of a shunt generator are

(*a*) I, II and IV (*b*) II, III and V

(*c*) II, IV and V (*d*) II, IV and V

2.5. For equilateral spacing of conductors of an untransposed 3-phase line, we have

(*a*) balanced receiving end voltage and no communication interference

(*b*) unbalanced receiving end voltage and no communication interference

(*c*) balanced receiving end voltage and communication interference

(*d*) unbalanced receiving end voltage and communication interference

2.6. The voltage series feedback in a feedback amplifier leads to

(*a*) increase in band width, while the voltage gain becomes less sensitive to variations in components and device characteristics

(*b*) decrease in overall gain, while the input resistance decreases

(*c*) increase in distortion, while the output resistance decreases

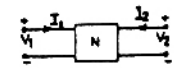
(*d*) decrease in input resistance, while the output resistance increases

EE.3. This question contains five parts. In each part (3.1 to 3.5), three items are given on the left side and more than three on the right. For each item on the left, match a suitable answer from the list given on the right. (5 × 3 = 15)

3.1. The performance of a general two-port network N shown in the Figure. can be described in terms of its z-parameters of h-parameters as indicated below

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

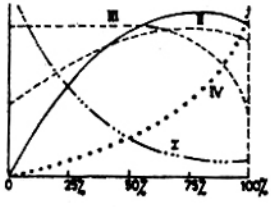
$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$



If the two-port is further characterized by additional constraints, a few conditions have to be satisfied by the parameters of the network. For each of the constraints specified in Table A, choose the appropriate condition to be satisfied, from amongst those listed in Table B.

Table A	Table B
(a) Reciprocity at the ports	(P) $h_{11}\,h_{22} - h_{12}\,h_{21} = 1$
(b) Passivity at the ports	(Q) $z_{12} = -z_{21}$
(c) Electrical symmetry at the ports	(R) $h_{12} = h_{21}$
	(T) absence of negative resistors inside the 2-port
	(U) energy input to the network from the ports is non-negative for all conditions at the ports

3.2. Out of the several characteri.stics shown in Figure. identify the appropriate ones to match the following for a 3-phase induction motor.



	x-axis	y-axis	
(a)	Load	efficiency	(P) curve I
(b)	Speed	current	(Q) curve II
(c)	Speed	power factor	(R) curve III
			(S) curve IV
			(T) curve V

3.3. The per unit voltages of two synchronous machines connected through a lossless line are $0.95 \angle 10°$ and $1.0 \angle 0°$. Match the two sides in the following

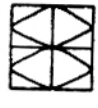
(a)	Real power of Machine 1	(P) Positive real power
(b)	Reactive power of Machine 1	(Q) Positive reactive power
(c)	Power factor of Machine 1	(R) Negative real power
		(S) Negative reactive power
		(T) Leading power factor
		(U) Lagging power factor

3.4. In a 8085 microprocessor, the following instructions may result in change of accumulator contents and change in status flags. Choose the correct match for each instruction.

		Contents of ACC	Cy flag	AC flag
(a)	ANA r	(P) unchanged	may by SET	unchanged
(b)	XRA r	(Q) unchanged	SET	SET
(c)	CMP r	(R) unchanged	SET	RESET
		(S) may change	RESET	RESET
		(T) may change	RESET	SET

3.5. In an oscilloscope, the input to the horizontal plates is a 100 Hz voltage signal. The Lissajous patterns (A), (B) and (C) will be generated when different frequency voltage signals are applied to vertical plates. Match each Lissajous pattern to the corresponding frequency fy.

(a)



(b)

(c)

(P) $fy = 50$
(Q) $fy = 66.66$
(F) $fy = 125$
(S) $fy = 150$
(T) $fy = 200$
(U) $fy = 300$

ANSWERS

1.1 (b)	1.2 (b)	1.3 (c)	1.4 (d)	1.5 (d)	1.6 (d)	1.7 (c)	1.8 (a)	1.9 (a)	1.10 (a)
1.11 (b)	1.12 (b)	1.13 (a)	1.14 (d)	1.15 (c)	1.16 (d)	1.17 (b)	1.18 (b)	1.19 (b)	1.20 (c)
1.21(c)	1.22 (c)	1.23 (a)	1.24 (c)	1.25 (d)	1.26 (a)	1.27 (c)	1.28 (d)	1.29 (c)	1.30 (a)
1.31 (a)	1.32 (a)	1.33 (c)	1.34 (a)	1.35 (d)	1.36 (b)	1.37 (c)	1.38 (b)	1.39 (d)	1.40 (b)
1.41 (b)	1.42 (a)	1.43 (b)	1.44 (c)	1.45(b)	1.46 (*)	1.47 (c)	1.48 (b)		

EXPLANATIONS

EE.1.

1.1. $C(t) = -te^{-t} + 2e^{-t}$, $(t \geq 0)$

$$C(s) = -\frac{1}{(s+1)^2} + \frac{2}{s+1^2} = \frac{2s+1}{(s+1)^2}$$

$$C(s) = \frac{G(s)}{1+G(s)},$$

$$G(s) = \frac{C(s)}{1-C(s)} = \frac{\dfrac{2s+1}{(s+1)^2}}{1-\dfrac{2s+1}{(s+1)^2}} = \frac{2s+1}{s^2}$$

1.2. $$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)},$$

$$\frac{G(s)}{1-G(s)} = \frac{\dfrac{1}{s(s+1)}}{1+\dfrac{1}{s(s+1)}} = \frac{1}{s^2+s+1}$$

$$\omega_n = 1, \qquad \omega_n = \frac{1}{2}, \qquad \zeta = \frac{1}{2}$$

$$M_p = e^{-\xi\sqrt{1-\zeta^2}} = e^{(-\pi/2)/\sqrt{1-(1/4)}}$$

$$= e^{-\pi/\sqrt{3}} = 0.163$$

1.4. $$\frac{C(s)}{R(s)} = \frac{1}{1+s}, \qquad \frac{C(j\omega)}{R(j\omega)} = \frac{1}{1+j\omega}$$

From $r(t) \sin t$, $\omega = 1$, $$\left|\frac{C(j\omega)}{R(j\omega)}\right| = \frac{1}{\sqrt{1+1}} = \frac{1}{\sqrt{2}}$$

$$\left|\frac{C(j\omega)}{R(j\omega)} = -\tan^{-1} 1 = -\frac{\pi}{4}\right.$$

$\therefore$ SS value of $c(t)$ $= \dfrac{1}{\sqrt{2}} \sin\left(t - \dfrac{\pi}{4}\right)$

1.5. The Periodic time = 4 ms = 4×10^{-3} sec.

$\therefore$ Fundamental frequency

$$= \frac{10^3}{4} = 250 \text{ Hz}$$

$\therefore$ Frequency of the 5th harmonic

$= 250 \times 5 = 1250$ Hz

1.6. As the element absorbs power, let it be R_x.

$$i = 1 = \frac{6}{R_x + 1}$$

$$R_x = 5\ \Omega$$

$$P = \left(\frac{6}{6}\right)^2 2 \times 5 = 5 \text{ W}.$$

For 5 A, $P = 52 \times 5 = 125$ W

For $3 + \sqrt{14}$, $P = 227$ W

For $3 - \sqrt{14}$, $P = 2.75$ W.

Hence none of the above is correct

1.7. $$P = \frac{1}{2}(1 - \cos 2\omega t) = 100 \text{ Hz}$$

1.8. Voltage across the capacitor at any time t

$$v_c = V(1 - e^{-t/RC})$$
$$= 1 - e^{-t/RC}$$

since $V = 1$ volt

$$\therefore \quad \frac{dv_c}{dt} = \frac{1}{RC} e^{-t/RC}.$$

At $t = 0^+$, $$\frac{dv_c}{dt} = \frac{1}{RC}$$

1.9. $$R = \frac{8}{4 \times 10^{-3}} = 2000\ \Omega.$$

Time constant $= \dfrac{L}{R} = \dfrac{6 \times 10^{-3}}{2 \times 10^3} = 3\ \mu\text{sec.}$