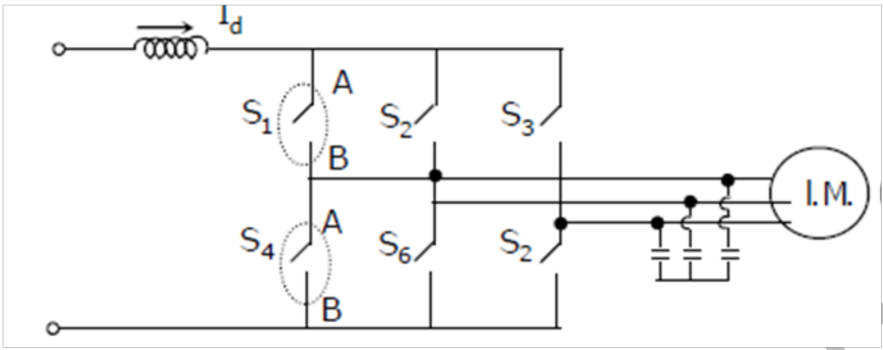
# GATE 2011

## Electrical Engineering

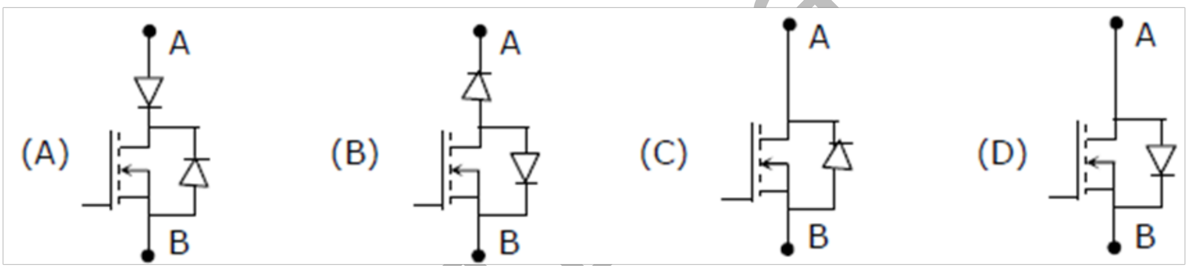
**Set – C**

**Q.1 - Q.25 Carry One Mark each.**

1. A three-phase current source inverter used for the speed control of an induction motor is to be realized using MOSFET switches as shown below. Switches $S_1$ to $S_6$ are identical switches.

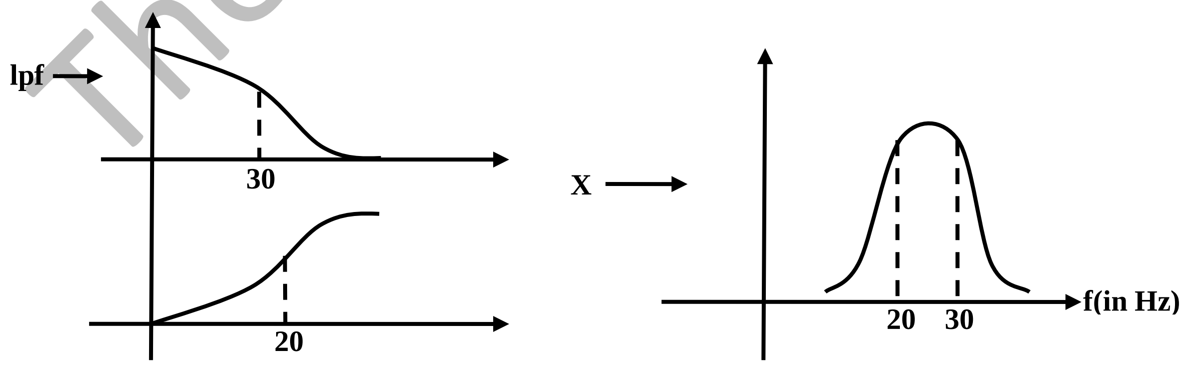



The proper configuration for realizing switches $S_1$ to $S_6$ is




**[Ans. C]**

2. A low-pass filter with a cut-off frequency of 30 Hz is cascaded with a high-pass filter with a cut-off frequency of 20 Hz. The resultant system of filters will function as
(A) an all-pass filter
(B) an all-stop filter
(C) a band stop (band-reject) filter
(D) a band-pass filter
**[Ans. D]**

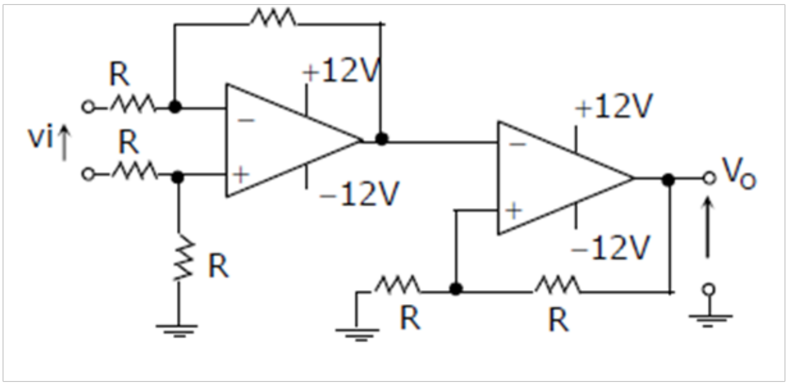



3. Consider the following statements:
(i) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the current coil.
(ii) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the voltage coil circuit.

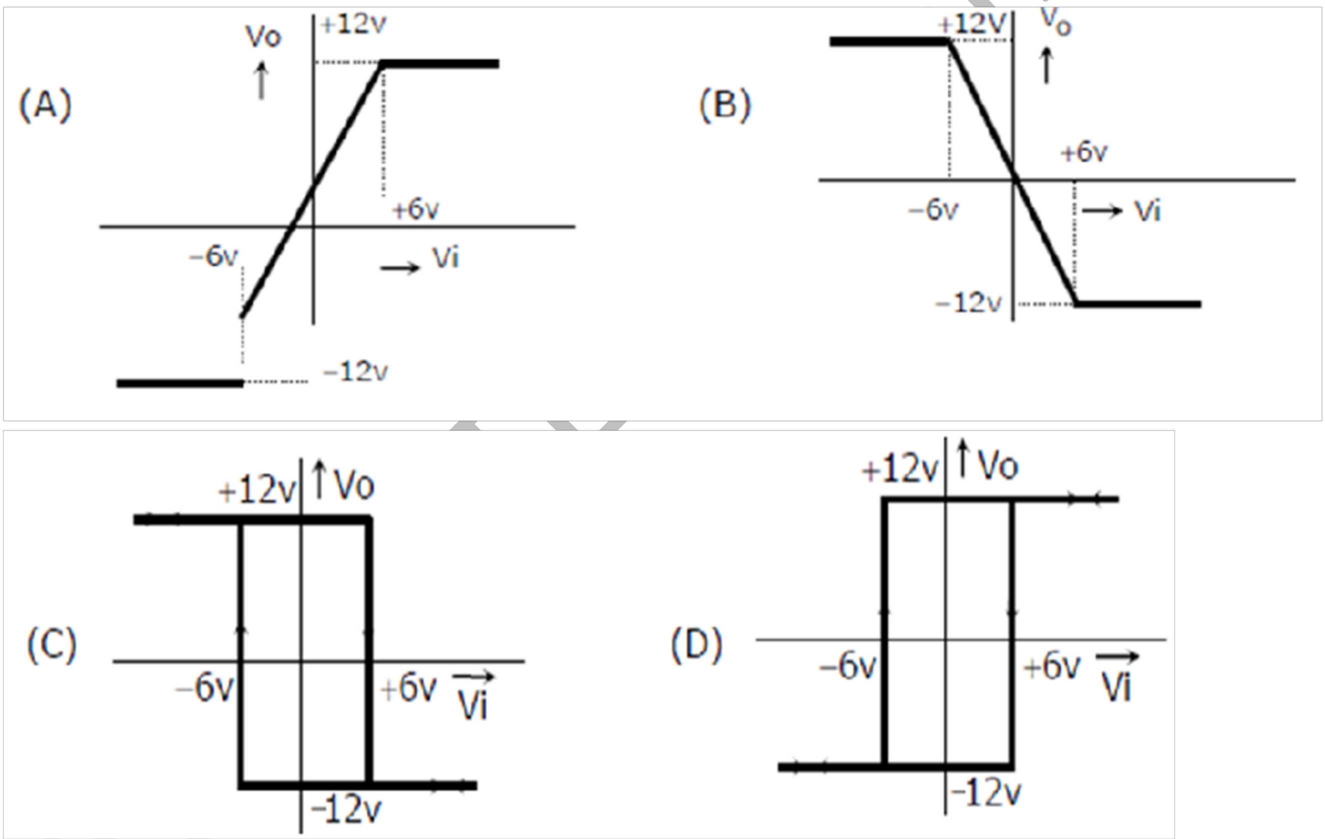
(A) (i) is true but (ii) is false
(B) (i) is false but (ii) is true
(C) both (i) and (ii) are true
(D) both (i) and (ii) are false

**[Ans. B]**

4. For the circuit shown below,



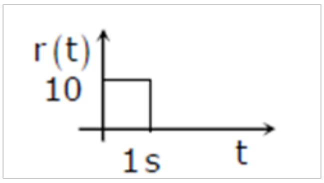

the **CORRECT** transfer characteristic is




**[Ans. D]**

It is Schmitt trigger and phase shift is zero.

5. The steady state error of a unity feedback linear system for a unit step input is 0.1. The steady state error of the same system, for a pulse input r(t) having a magnitude of 10 and a duration of one second, as shown in the figure is




(A) 0
(B) 0.1
(C) 1
(D) 10

**[Ans. B]**

$r(t) = 10\,(u(t) - u(t-1))$

As system is linear, $e_{ss} = e_{ss_1} + e_{ss_2} = 10(0.1 - 0.1) = 0$

6. The frequency response of a linear system G(jω) is provided in the tabular form below.

| | | | | | | |
|---|---|---|---|---|---|---|
| $\lvert G(j\omega)\rvert$ | 1.3 | 1.2 | 1.0 | 0.8 | 0.5 | 0.3 |
| $\angle G(j\omega)$ | −130° | −140° | −150° | −160° | −180° | −200° |

The gain margin and phase margin of the system are

(A) 6 dB and 30°
(B) 6 dB and −30°
(C) −6 dB and 30°
(D) −6 dB and −30°

**[Ans. A]**

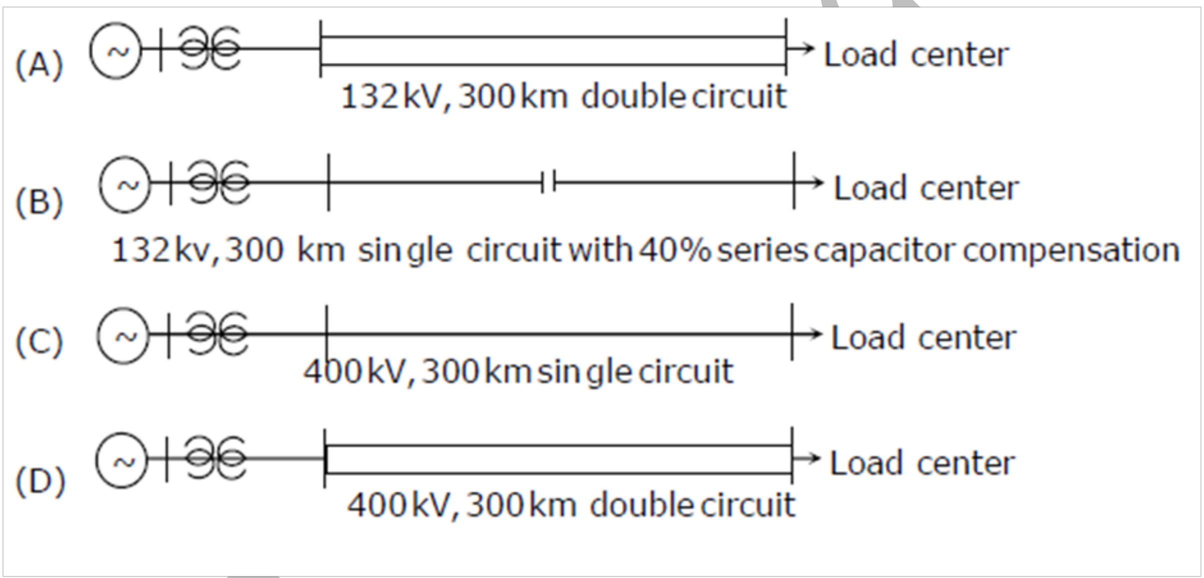
From table, $\lvert G(j\omega)\rvert$ at $\omega_p$ is 0.5

$\therefore$ GM = $20\log_{10}\left(\frac{1}{0.5}\right) = 6$ dB

Similarly, $\angle G(j\omega)$ at $\omega_g$ is $-150$

$\therefore$ PM = 180 – 150 = 30°

7. A nuclear power station of 500 MW capacity is located at 300 km away from a load center. Select the most suitable power evacuation transmission configuration among the followings options.




**[Ans. A]**

8. A three-phase, salient pole synchronous motor is connected to an infinite bus. It is operated at no load at normal excitation. The field excitation of the motor is first reduced to zero and then increased in the reverse direction gradually. Then the armature current

(A) increases continuously
(B) first increases and then decreases steeply
(C) first decreases and then increases steeply
(D) remains constant

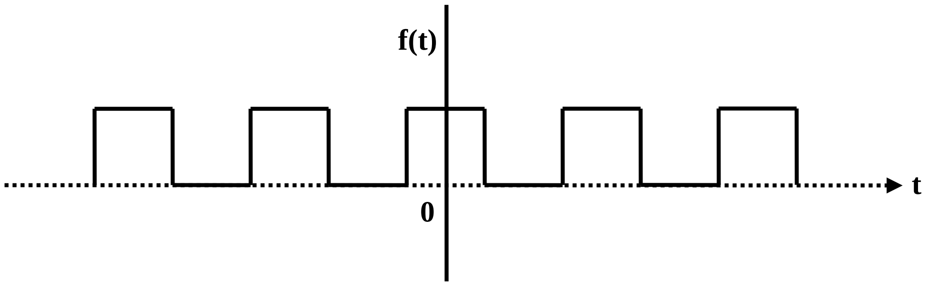
**[Ans. B]**

9. A 4-point starter is used to start and control the speed of a

(A) dc shunt motor with armature resistance control
(B) dc shunt motor with field weakening control
(C) dc series motor
(D) dc compound motor

**[Ans. A]**

10. The Fourier series expansion $f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t$ of the periodic signal shown below will contain the following nonzero terms




(A) $a_0$ and $b_n$, n = 1, 3, 5, . . . . ∞
(B) $a_0$ and $a_n$, n = 1, 2, 3, . . . . ∞
(C) $a_0, a_n$ and $b_n$, n = 1, 2, 3, . . . . ∞
(D) $a_0$ and $a_n$, n = 1, 3, 5, . . . . ∞

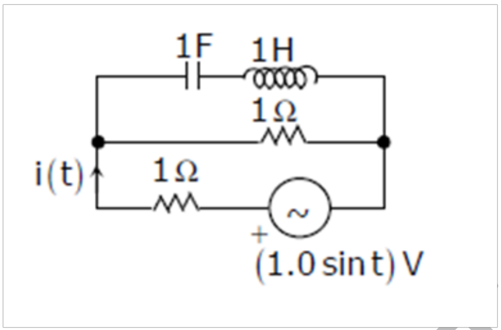
**[Ans. D]**

Signal is even

$\therefore a_0 \neq 0;\ a_n \neq 0$

Also $a_n = 0$ for even n

11. The r.m.s value of the current i(t) in the circuit shown below is




(A) $\frac{1}{2}$ A
(B) $\frac{1}{\sqrt{2}}$ A
(C) 1A
(D) $\sqrt{2}$ A

**[Ans. B]**

$Z_S = 1 + \frac{1(J-J)}{1+J-J} = 1\Omega$

$\therefore i_0(t) = 1.0 \sin(t)$ A

$\therefore I_{rms} = \frac{1}{\sqrt{2}}$ A

12. Roots of the algebraic equation $x^3 + x^2 + x + 1 = 0$ are
(A) $(+1, +j, -j)$
(B) $(+1, -1, +1)$
(C) $(0, 0, 0)$
(D) $(-1, +j, -j)$

**[Ans. D]**

$x^3 + x^2 + x + 1 = 0 \implies (x^2 + 1)(x + 1) = 0 \implies x + 1 = 0;\ x^2 + 1 = 0 \implies x = -1 \quad x = \pm j$

13. Circuit turn-off time of an SCR is defined as the time
(A) taken by the SCR to turn off
(B) required for the SCR current to become zero
(C) for which the SCR is reverse biased by the commutation circuit
(D) for which the SCR is reverse biased to reduced its current below the holding current

**[Ans. C]**

From the def, it's the time for which SCR is reverse biased.

14. With K as a constant, the possible solution for the first order differential equation $\frac{dy}{dx} = e^{-3x}$ is

(A) $-\frac{1}{3}e^{-3x} + K$

(B) $-\frac{1}{3}e^{3x} + K$

(C) $-3e^{-3x} + K$

(D) $-3e^{-x} + K$

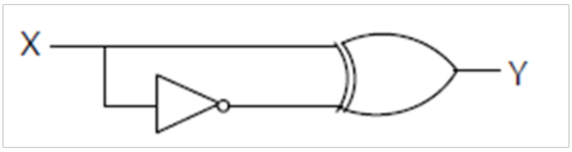
**[Ans. A]**

$\frac{dy}{dx} = e^{-3x} \Rightarrow dy = e^{-3x}dx$

Integrate on both sides

$y = \frac{e^{-3x}}{-3} + K = -\frac{1}{3}e^{-3x} + K$

15. The output **Y** of the logic circuit given below is




(A) 1

(B) 0

(C) X

(D) $\overline{X}$

**[Ans. A]**

$Y = X.\overline{\overline{\overline{X}}} + \overline{X}.\overline{X} = X + \overline{X} = 1$

16. A dual trace oscilloscope is set to operate in the ALTernate mode. The control input of the multiplexer used in the y-circuit is fed with a signal having a frequency equal to

(A) the highest frequency that the multiplexer can operate properly

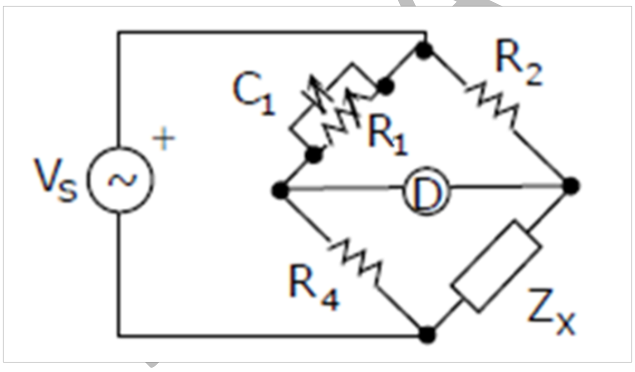
(B) twice the frequency of the time base (sweep) oscillator

(C) the frequency of the time base (sweep) oscillator

(D) half the frequency of the time base (sweep) oscillator

**[Ans. C]**

17. The bridge circuit shown in the figure below is used for the measurement of an unknown element $Z_x$. The bridge circuit is best suited when $Z_x$ is a




(A) low resistance

(B) high resistance

(C) low Q inductor

(D) lossy capacitor

**[Ans. C]**

18. An open loop system represented by the transfer function $G(s) = \frac{(s-1)}{(s+2)(s+3)}$ is

(A) stable and of the minimum phase type

(B) stable and of the non-minimum phase type

(C) unstable and of the minimum phase type

(D) unstable and of the non-minimum phase type

**[Ans. B]**

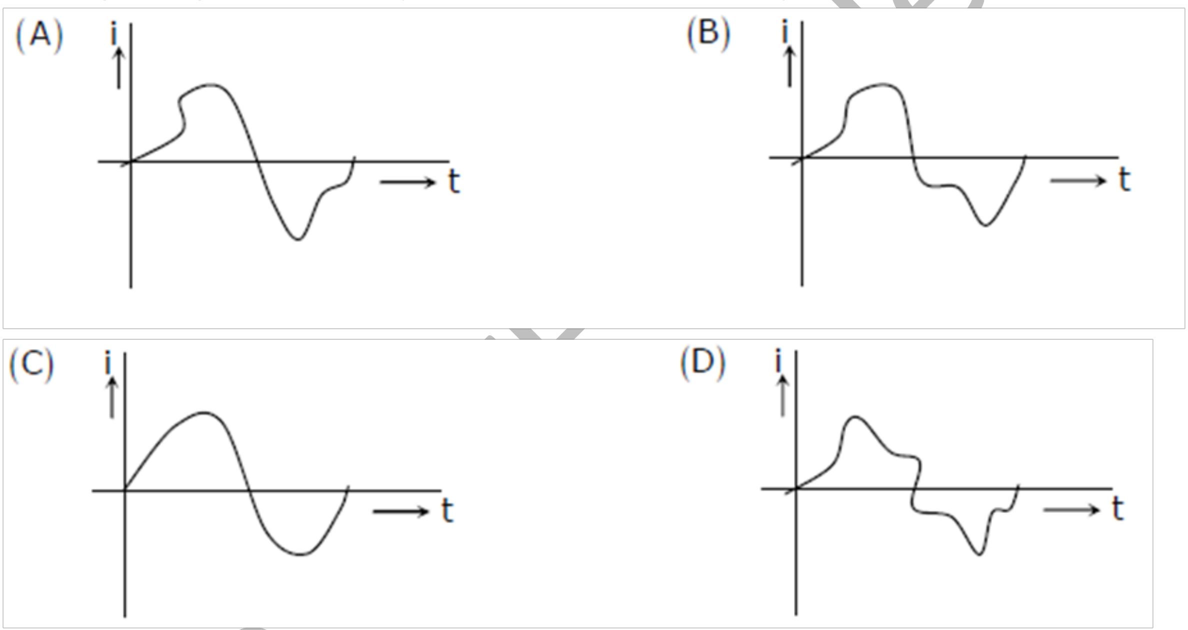
For G(s), poles are at $-2$ and $-3 \Rightarrow$ Stable

Also, zeroes are to the right of S-plane $\Longrightarrow$ non-minimum phase type

19. For enhancing the power transmission in a long EHV transmission line, the most preferred method is to connect a
(A) series inductive compensator in the line
(B) shunt inductive compensator at the receiving end
(C) series capacitive compensator in the line
(D) shunt capacitive compensator at the sending end
**[Ans. C]**
$P \propto \frac{1}{X}$ Where, $X = (X_L - X_C)$

20. A negative sequence relay is commonly used to protect
(A) an alternator
(B) a transformer
(C) a transmission line
(D) a bus bar
**[Ans. A]**

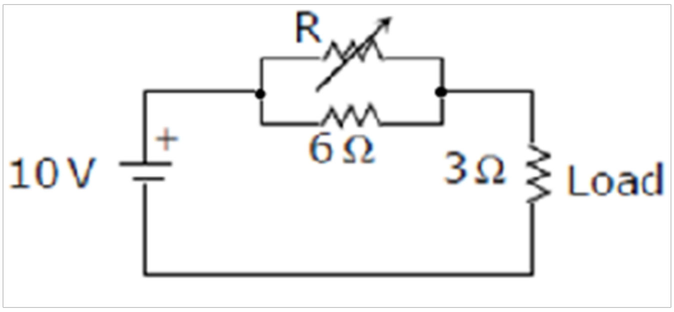
21. A single-phase air core transformer, fed from a rated sinusoidal supply, is operating at no load. The steady state magnetizing current drawn by the transformer from the supply will have the waveform




**[Ans. C]**
It is an air core transformer. So, there is no saturation effect.

22. Given two continuous time signals $x(t) = e^{-t}$ and $y(t) = e^{-2t}$ which exist for $t > 0$ the convolution $z(t) = x(t) * y(t)$ is
(A) $e^{-t} - e^{-2t}$
(B) $e^{-3t}$
(C) $e^{+t}$
(D) $e^{-t} + e^{-2t}$
**[Ans. A]**
$X(s) = \frac{1}{(s+1)}; Y(s) = \frac{1}{(s+2)}$
$\therefore Z(s) = X(s).Y(s) = \frac{1}{(s+1)} - \frac{1}{(s+2)} \Longrightarrow z(t) = (e^{-t} - e^{-2t})u(t)$

23. In the circuit given below, the value of R required for the transfer of maximum power of the load having a resistance of 3 Ω is




(A) zero
(B) 3 Ω
(C) 6 Ω
(D) infinity

**[Ans. C]**

$R_L = 3 = R_{th} = \frac{R.6}{(R+6)} \Rightarrow R = 6\Omega$

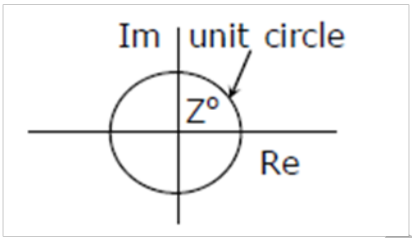
24. The voltage applied to a circuit is $100\sqrt{2}\cos(100\pi t)$ volts and the circuit draws a current of $10\sqrt{2}\sin(100\pi t + \pi/4)$ amperes. Taking the voltage as the reference phasor, the phasor representation of the current in amperes is

(A) $10\sqrt{2}\angle -\pi/4$
(B) $10\angle -\pi/4$
(C) $10\angle +\pi/4$
(D) $10\sqrt{2}\angle +\pi/4$

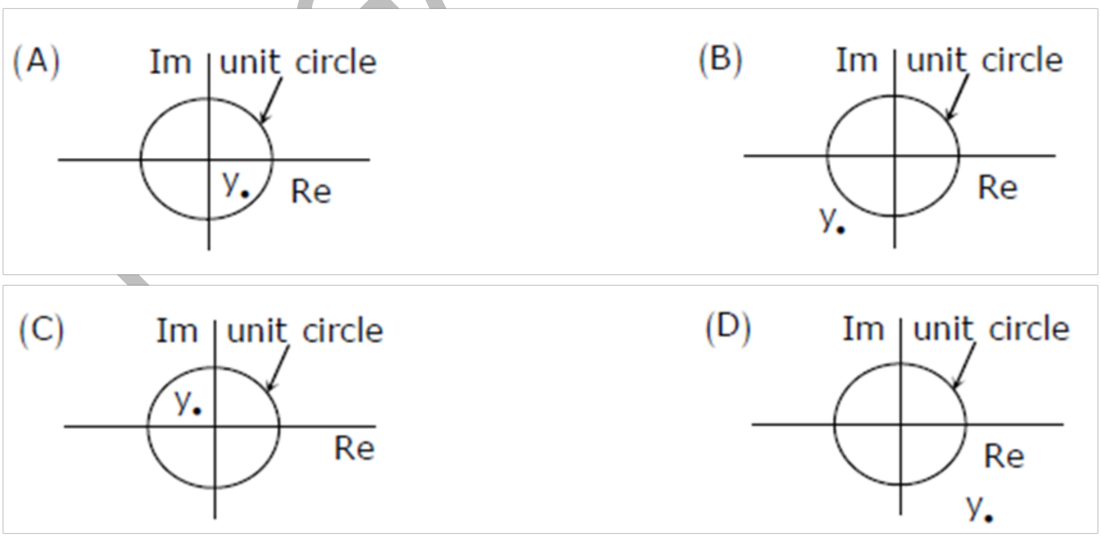
**[Ans. B]**

$i(t) = 10\sqrt{2}\sin\left(100\pi t + \frac{\pi}{4}\right) = 10\sqrt{2}\cos\left(100\pi t - \frac{\pi}{4}\right) \Rightarrow \underline{I} = 10\angle -\frac{\pi}{4}A$

25. A point z has been plotted in the complex plane, as shown in figure below.




The plot of the complex number $y = \frac{1}{2}$ is



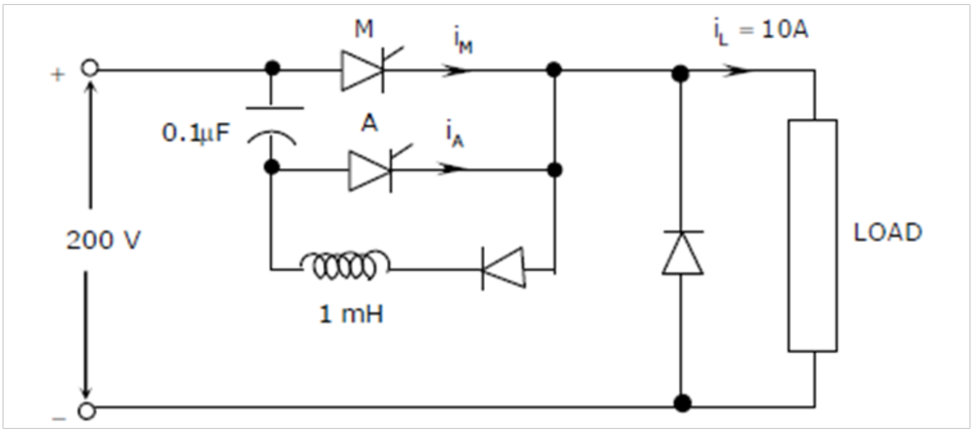

**[Ans. D]**

$|Z| < 1$, so $|Y| > 1$

Z is having +ve real part and positive imaginary part (∴ from the characteristics). So Y should have +ve real part and negative imaginary part.

**Q.26 - Q.55 Carry Two Marks each.**

26. A voltage commutated chopper circuit, operated at 500 Hz, is shown below.




If the maximum value of load current is 10 A, then the maximum current through the main (M) and auxiliary (A) thyristors will be

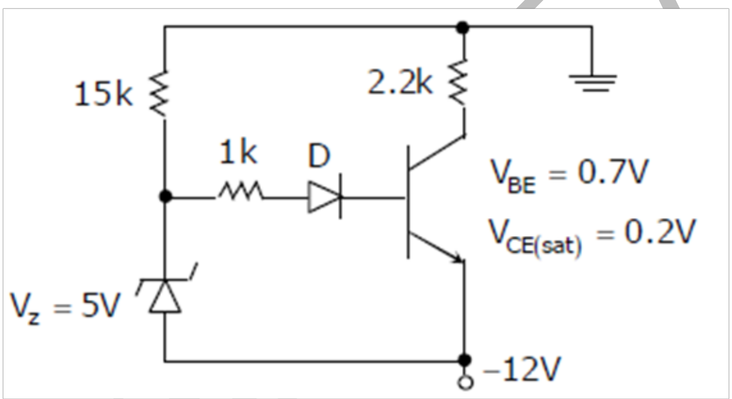
(A) $i_{M\,max} = 12A$ and $i_{A\,max} = 10A$
(B) $i_{M\,max} = 12A$ and $i_{A\,max} = 2A$
(C) $i_{M\,max} = 10A$ and $i_{A\,max} = 12A$
(D) $i_{M\,max} = 10A$ and $i_{A\,max} = 8A$

**[Ans. A]**

$i_{M\,max} = i_L + V_S\sqrt{\frac{C}{L}} = 10 + 200\sqrt{\frac{0.1\times10^{-6}}{10^{-3}}} = 12A$

$i_{A\,max} = i_L = 10A$

27. The transistor used in the circuit shown below has a β of 30 and $I_{CBO}$ is negligible.




If the forward voltage drop of diode is 0.7V, then the current through collector will be

(A) 168 mA
(B) 108 mA
(C) 20.54 mA
(D) 5.36 mA

**[Ans. D]**

Transistor is in Saturation region

$I_C = \frac{12-0.2}{2.2K} = 5.36$ mA

28. A portion of the main program to call a subroutine SUB in an 8085 environment is given below.

```
        :
        :
        LXI     D, DISP
LP:     CALL    SUB
        :
        :
```

It is desired that control be returned to LP + DISP + 3 when the RET instruction is executed in the subroutine. The set of instructions that precede the RET instruction in the subroutine are

(A) POP D
DAD H
PUSH D

(B) POP H
DAD D
INX H
INX H
INX H
PUSH H

(C) POP H
DAD D
PUSH H

(D) XTHL
INX D
INX D
INX D
XTHL

**[Ans. C]**

29. The open loop transfer function G(s) of a unity feedback control system is given as,

$G(s) = \frac{k\left(s+\frac{2}{3}\right)}{s^2(s+2)}$

From the root locus, it can be inferred that when k tends to positive infinity.

(A) three roots with nearly equal real parts exist on the left half of the s-plane
(B) one real root is found on the right half of the s-plane
(C) the root loci cross the jω axis for a finite value of k; k ≠ 0
(D) three real roots are found on the right half of the s-plane

**[Ans. A]**

RL starts from 0 and −2 and ends at $-\frac{2}{3}$ or ∞

Number of RL branches = 3

RL exists to the left of −2 on real axis ⟹ one poles tends to −∞ as real part ⟹ (D) is not correct.

Angle of asymptotes = $\frac{(2K+1)\pi}{2}$; K = 0, 1

$= \frac{\pi}{2}, \frac{3\pi}{2}$

⟹ (B) is not correct.

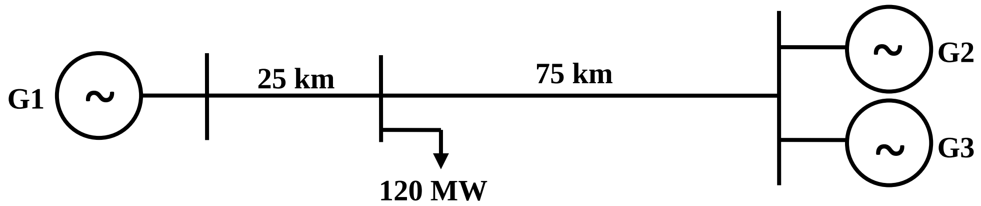
Intersection of RL branches on real axis = $\frac{-2+\frac{2}{3}}{2} = -\frac{2}{3}$

C.E is $S^3 + 2S^2 + KS + \frac{2}{3}K = 0$

| | | |
|---|---|---|
| $S^3$ | 1 | K |
| $S^2$ | 2 | $\frac{2K}{3}$ |
| S | $\frac{2K}{3}$ | |
| 1 | $\frac{2K}{3}$ | |

For marginal stability, K = 0 ⟹ (C) is not correct.

30. A load center of 120 MW derives power from two stations connected by 220 kV transmission lines of 25 km and 75 km and 75 km as shown in the figure below. The three generators G1, G2 and G3 are of 100 MW capacity each and have identical fuel cost characteristics. The minimum loss generation schedule for supplying the 120 MW load is



(A) P1 = 80 MW + losses
P2 = 20 MW
P3 = 20 MW

(B) P1 = 60 MW
P2 = 30 MW + losses
P3 = 30 MW

(C) P1 = 40 MW
P2 = 40 MW
P3 = 40 MW + losses

(D) P1 = 30 MW + losses
P2 = 45 MW
P3 = 45 MW

**[Ans. A]**

Loss α $p^2$; Loss α length

For checking all options only option A gives less losses.

31. A 220 V, DC shunt motor is operating at a speed of 1440 rpm. The armature resistance is 1.0 Ω and armature current is 10 A. If the excitation of the machine is reduced by 10%, the extra resistance to be put in the armature circuit to maintain the same speed and torque will be

(A) 1.79 Ω
(B) 2.1 Ω
(C) 3.1 Ω
(D) 18.9 Ω

**[Ans. A]**

$I_{a1} = 10$

Now flux is decreased by 10%, so $\phi_2 = 0.9\,\phi_1$

Torque is constant so $I_{a1}\phi_1 = I_{a2}\phi_2 \Rightarrow I_{a2} = \frac{10}{0.9} = 11.11$ A

$N \,\alpha\, \frac{E_b}{\phi} \Rightarrow \frac{N_1}{N_2} = \frac{E_{b1}}{E_{b2}} \times \frac{\phi_2}{\phi_1} = \frac{220 - I_{a1}r_1}{220 - I_{a2}(r_1 + R)} \times \frac{0.9\phi_1}{\phi_1}$

$1 = \frac{210 \times 0.9}{220 - 11.11(1+R)} \Rightarrow 1 + R = 2.79 \Rightarrow R = 1.79\ \Omega$

32. A zero mean random signal is uniformly distributed between limits –a and +a and its mean square value is equal to its variance. Then the r.m.s value of the signal is

(A) $\frac{a}{\sqrt{3}}$
(B) $\frac{a}{\sqrt{2}}$
(C) $a\sqrt{2}$
(D) $a\sqrt{3}$

**[Ans. A]**

Variance = $\frac{(a-(-a))^2}{12} = \frac{4a^2}{12} = \frac{a^2}{3}$; R.M.S value = $\sqrt{\text{variance}} = \frac{3}{\sqrt{3}}$

33. Let the Laplace transform of a function f(t) which exists for t > 0 be $F_1(s)$ and the Laplace transform of its delayed version $f(t-\tau)$ be $F_2(s)$. Let $F_1^*(s)$ be the complex conjugate of $F_1(s)$ with the Laplace variable set as a s = σ + jω. If $G(s) = \frac{F_2(s)F_1^*(s)}{|F_1(s)|^2}$, then the inverse Laplace transform of G(s) is

(A) an ideal impulse δ(t)
(B) an ideal delayed impulse δ(t – τ)
(C) an ideal step function u(t)
(D) an ideal delayed step function u(t – τ)

**[Ans. B]**

$F_2(s) = e^{-s\tau} F_1(s) \Rightarrow G(s) = e^{-s\tau} \Rightarrow L^{-1}(G(s)) = \delta(t-\tau)$

34. A lossy capacitor $C_X$, rated for operation at 5 kV, 50 Hz is represented by an equivalent circuit with an ideal capacitor $C_P$ in parallel with a resistor $R_P$. The value of $C_P$ is found to be 0.102 μF and the value of $R_P = 1.25$ MΩ. Then the power loss and $\tan\delta$ of the lossy capacitor operating at the rated voltage, respectively, are

(A) 10 W and 0.0002
(B) 10 W and 0.0025
(C) 20 W and 0.025
(D) 20 W and 0.04

**[Ans. C]**

35. The function $f(x) = 2x - x^2 + 3$ has

(A) a maxima at x = 1 and a minima at x = 5
(B) a maxima at x = 1 and a minima at x = −5
(C) only a maxima at x = 1
(D) only a minima at x = 1

**[Ans. C]**

$f(x) = 2x - x^2 + 3$

$f'(x) = 0 \Rightarrow 2 - 2x = 0 \;\Rightarrow x = 1$

$f"(x) = -2f"(x) < 0$

So the equation f(x) having only maxima at x = 1

36. Solution of the variables $x_1$ and $x_2$ for the following equations is to be obtained by employing the Newton-Raphson iterative method.

equation (i) $10x_2 \sin x_1 - 0.8 = 0$

equation (ii) $10x_2^2 - 10x_2 \cos x_1 - 0.6 = 0$

Assuming the initial values $x_1 = 0.0$ and $x_2 = 1.0$, the Jacobian matrix is

(A) $\begin{bmatrix} 10 & -0.8 \\ 0 & -0.6 \end{bmatrix}$
(B) $\begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$
(C) $\begin{bmatrix} 0 & -0.8 \\ 10 & -0.6 \end{bmatrix}$
(D) $\begin{bmatrix} 10 & 0 \\ 10 & -10 \end{bmatrix}$

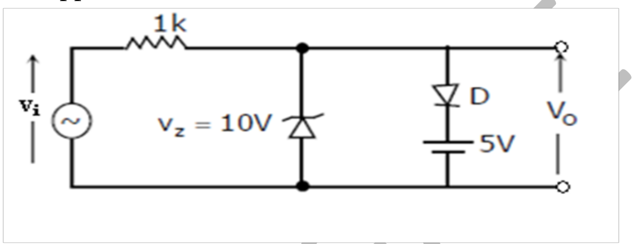
**[Ans. B]**

$10x_2 \sin x_1 - 0.5 = 0 \qquad \ldots\ldots (i)$

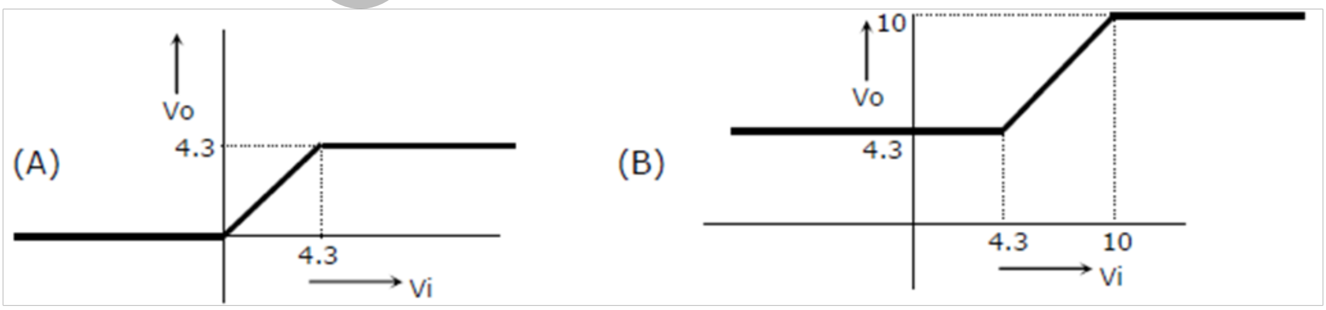
$10x_2^2 - 10x_2 \cos x_1 - 0.6 = 0 \qquad \ldots\ldots (ii)$

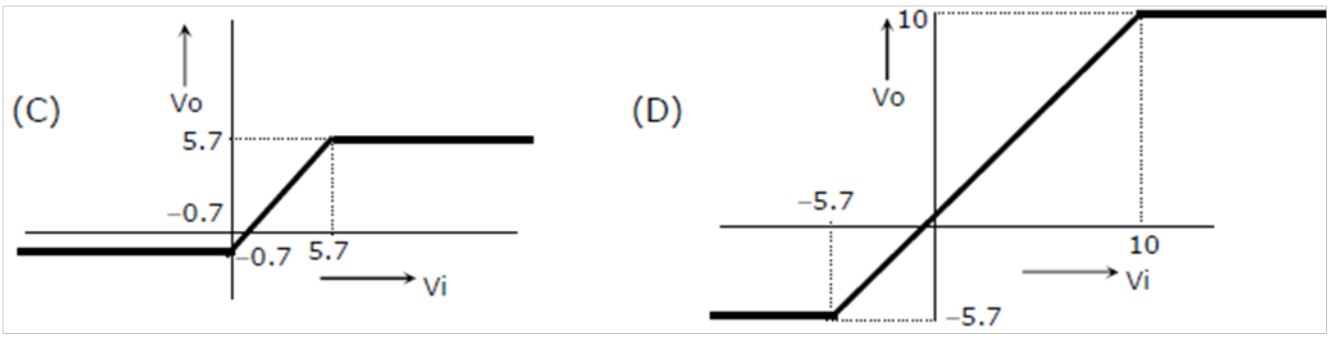
$$J = \begin{bmatrix} \frac{\partial(i)}{\partial x_1} & \frac{\partial(i)}{\partial x_2} \\ \frac{\partial(ii)}{\partial x_1} & \frac{\partial(ii)}{\partial x_2} \end{bmatrix} \text{ at } x_1 = 0 \text{ and } x_2 = 1 \; J = \begin{bmatrix} 10 & 0 \\ 0 & 10 \end{bmatrix}$$

37. A clipper circuit is shown below.




Assuming forward voltage drops of the diodes to be 0.7 V, the input-output transfer characteristics of the circuit is



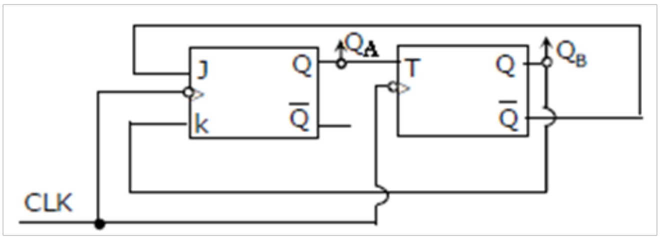
**[Ans. C]**

When $-0.7V < V_i < 5.7V$ output will follow input, because zener diode and normal diodes are off

When $V_i \le -0.7V$ Zener diode forward bias and $V_0 = -0.7V$

When $V_i \ge 5.7V$ Diode is forward bias and $V_0 = 5.7V$

38. A two-bit counter circuit is shown below.




If the state $Q_AQ_B$ of the counter at the clock time $t_n$ is "10" then the state $Q_AQ_B$ of the counter at $t_n + 3$ (after three clock cycles) will be

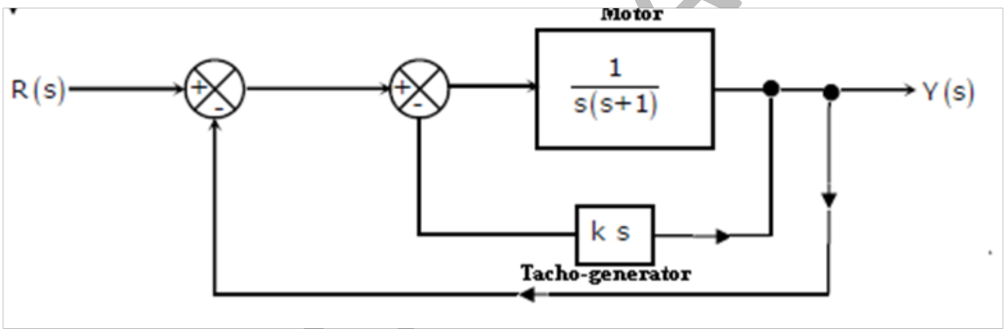
(A) 00 (C) 10

(B) 01 (D) 11

**[Ans. C]**

| Clock | Input | | | Output | |
|---|---|---|---|---|---|
| | $J_A = \bar{Q}_B$ | $K_A = Q_B$ | $T_B = Q_A$ | $Q_A$ | $Q_B$ |
| Initial state | | | | 1 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 |
| 2 | 0 | 1 | 1 | 0 | 0 |
| 3 | 1 | 0 | 0 | 1 | 0 |

39. A two-loop position control system is shown below.




The gain k of the Tacho-generator influences mainly the

(A) peak overshoot

(B) natural frequency of oscillation

(C) phase shift of the closed loop transfer function at very low frequencies ($\omega \to 0$)

(D) phase shift of the closed loop transfer function at very high frequencies ($\omega \to \infty$)

**[Ans. A]**

$$T(s) = \frac{\frac{1}{s(s+1)}}{1+(Ks+1).\frac{1}{s(s+1)}} = \frac{1}{s^2+s(K+1)+1}$$

$\therefore \omega_n = 1$ rad/sec; $\xi = \frac{(K+1)}{2}$

$\therefore M_P$ is dependent on K $\Longrightarrow$ (A) is correct

$\omega_m$ is independent of K $\Longrightarrow$ (B) is not correct

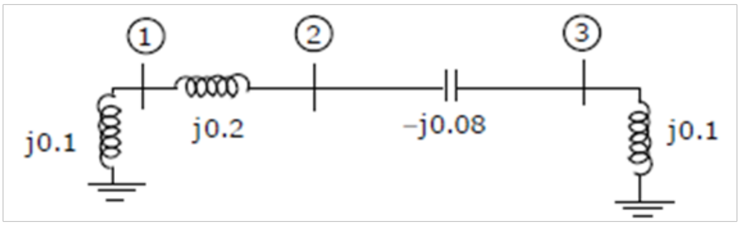
$T(J\omega) = \frac{1}{(1-\omega^2)+J\omega(K+1)} \Longrightarrow \angle T(J\omega) = -\tan^{-1}\left(\frac{\omega(K+1)}{1-\omega^2}\right)$

At low frequencies, $\angle T(J\omega) \approx 0$

At high frequencies, $\angle T(J\omega) \approx \frac{\pi}{2}$

$\therefore$ (C) and (D) are partially correct

40. A three-bus network is shown in the figure below indicating the p.u. impedance of each element.




The bus admittance matrix, Y-bus, of the network is

(A) $j\begin{bmatrix} 0.3 & -0.2 & 0 \\ -0.2 & 0.12 & 0.08 \\ 0 & 0.08 & 0.02 \end{bmatrix}$

(B) $j\begin{bmatrix} -15 & 5 & 0 \\ 5 & 7.5 & -12.5 \\ 0 & -12.5 & 2.5 \end{bmatrix}$

(C) $j\begin{bmatrix} 0.1 & 0.2 & 0 \\ 0.2 & 0.12 & -0.08 \\ 0 & -0.08 & 0.10 \end{bmatrix}$

(D) $j\begin{bmatrix} -10 & 5 & 0 \\ 5 & 7.5 & 12.5 \\ 0 & 12.5 & -10 \end{bmatrix}$

**[Ans. B]**

$h(t) = e^{-t} + e^{-2t} \Rightarrow H(s) = \frac{(2s+3)}{(s+1)(s+2)}$

$\therefore y_u(s) = \frac{(2s+3)}{s(s+1)(s+2)} = \frac{3}{2s} + \frac{-1}{(s+1)} + \frac{-1}{2(s+2)}$

$\Rightarrow y_u(t) = (1.5 + e^{-t} - 0.5e^{-2t})u(t)$

41. A 4½ digit DMM has the error specification as: 0.2% of reading + 10 counts. If a dc voltage of 100 V is read on its 200 V full scale, the maximum error that can be expected in the reading is

(A) $\pm$ 0.1%
(B) $\pm$ 0.2%
(C) $\pm$ 0.3%
(D) $\pm$ 0.4%

**[Ans. C]**

42. The direct axis and quadrature axis reactances of a salient pole alternator are 1.2 p.u and 1.0 p.u respectively. The armature resistance is negligible. If this alternator is delivering rated kVA at upf and at rated voltage then its power angle is

(A) 30°
(B) 45°
(C) 60°
(D) 90°

**[Ans. B]**

$\text{Tan}\,\delta = \frac{I_a(x_q\cos\theta + r_a\sin\theta)}{V_t + I_a(x_q\sin\theta - r_a\cos\theta)}$

$I_a = 1\text{ p.u}; \; V_t = 1\text{ p.u} \;\; \theta =$ Power factor angle = 0°

$x_d = 1.2\text{p.u}; \; x_q = 1\text{p.u}; \; r_a = 0$

$\text{Tan}\,\delta = 1 \Rightarrow \delta = 45°$

43. The response h(t) of a linear time invariant system to an impulse δ(t), under initially relaxed condition is $h(t) = e^{-t} + e^{-2t}$. The response of this system for a unit step input u(t) is

(A) $u(t) + e^{-t} + e^{-2t}$
(B) $(e^{-t} + e^{-2t})u(t)$
(C) $(1.5 - e^{-t} - 0.5e^{-2t})u(t)$
(D) $e^{-t}\delta(t) + e^{-2t}u(t)$

**[Ans. C]**

L(Impulse response) = T.F = $\frac{1}{(S+1)} + \frac{1}{(S+2)}$

Step response = $L^{-1}\left[\frac{1}{S(S+1)} + \frac{1}{S(S+2)}\right] = L^{-1}\left[\left(\frac{1}{S} - \frac{1}{S+1}\right) + \left(\frac{0.5}{S} - \frac{0.5}{(S+2)}\right)\right]$

$= (1 - e^{-t} + 0.5 - 0.5e^{-2t})u(t)$

$= (1.5 - e^{-t} - 0.5e^{-2t})u(t)$

44. A capacitor is made with a polymeric dielectric having an $\varepsilon_r$ of 2.26 and a dielectric breakdown strength of 50 kV/cm. The permittivity of free space is 8.85 pF/m. If the rectangular plates of the capacitor have a width of 20 cm and a length of 40 cm, then the maximum electric charge in the capacitor is

(A) 2 μC
(B) 4 μC
(C) 8 μC
(D) 10 μC

**[Ans. C]**

$q = CV = \frac{\varepsilon.A}{d} \times V = \varepsilon.A\left(\frac{V}{d}\right) = \varepsilon_r\varepsilon_0\, A \times E = 2.26 \times 8.85 \times 10^{-14} \times 50 \times 10^3 \times 20 \times 40 = 8\mu C$

45. A three-phase 440V, 6 pole, 50 Hz, squirrel cage induction motor is running at a slip of 5%. The speed of stator magnetic field with respect to rotor magnetic field and speed of rotor with respect to stator magnetic field are

(A) zero, −5 rpm
(B) zero, 955 rpm
(C) 1000 rpm, −5 rpm
(D) 1000 rpm, 955 rpm

**[Ans. *]**

46. The two vectors [1, 1, 1] and [1, a, $a^2$], where a = $\left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right)$, are

(A) orthonormal
(B) orthogonal
(C) parallel
(D) collinear

**[Ans. B]**

Dot product of two vectors = $1 + a + a^2 = 0$

So orthogonal

47. The matrix[A] = $\begin{bmatrix} 2 & 1 \\ 4 & -1 \end{bmatrix}$ is decomposed into a product of a lower triangular matrix [L] and an upper triangular matrix [U]. The properly decomposed [L] and [U] matrices respectively are

(A) $\begin{bmatrix} 1 & 0 \\ 4 & -1 \end{bmatrix}$ and $\begin{bmatrix} 1 & 0 \\ 0 & -2 \end{bmatrix}$
(B) $\begin{bmatrix} 2 & 0 \\ 4 & -1 \end{bmatrix}$ and $\begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$
(C) $\begin{bmatrix} 1 & 0 \\ 4 & 1 \end{bmatrix}$ and $\begin{bmatrix} 2 & 1 \\ 0 & -1 \end{bmatrix}$
(D) $\begin{bmatrix} 2 & 0 \\ 4 & -3 \end{bmatrix}$ and $\begin{bmatrix} 1 & 0.5 \\ 0 & 1 \end{bmatrix}$

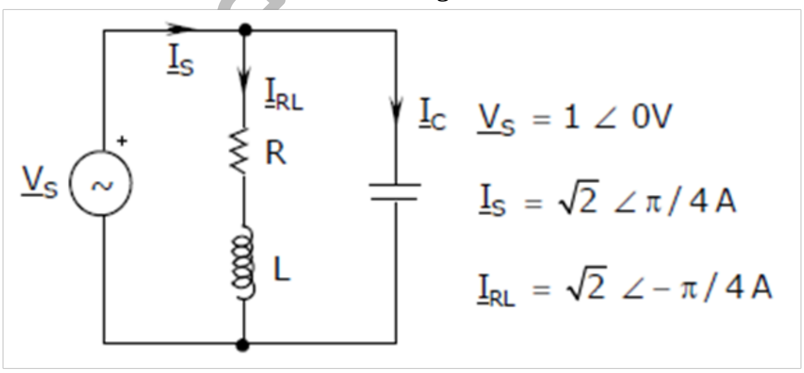
**[Ans. D]**

$[A] = [L][U] \Rightarrow$ Options D is correct

**Common Data Questions**

**Common Data for Questions 48 and 49:**

An RLC circuit with relevant data is given below.




48. The power dissipated in the resistor R is

(A) 0.5 W
(B) 1 W
(C) $\sqrt{2}$ W
(D) 2 W

**[Ans. B]**

$P_R = I_{RL}^2.R;\; Z_{RL} = R + J\omega L = \frac{1\angle 0^\circ}{\sqrt{2}\angle -\frac{\pi}{4}} = \frac{1}{\sqrt{2}}\angle\frac{\pi}{4} = (0.5 + J0.5)\Omega$

$\therefore\; P_R = \left(\sqrt{2}\right)^2 \times 0.5 = 1W$

49. The current $\underline{I}_C$ in the figure above is

(A) −j2 A
(B) $-j\frac{1}{\sqrt{2}}A$
(C) $+j\frac{1}{\sqrt{2}}A$
(D) +j2 A

**[Ans. D]**

$\underline{I}_C = \underline{I}_S - \underline{I}_{R_L} = \sqrt{2}\angle\frac{\pi}{4} - \sqrt{2}\angle -\frac{\pi}{4} = 2\sqrt{2}J\sin\left(\frac{\pi}{4}\right) = J2A$

**Common Data for Questions 50 and 51:**

The input voltage given to a converter is

$$v_i = 100\sqrt{2}\sin(100\pi t)\ V$$

The current drawn by the converter is

$$i_i = \left(10\sqrt{2}\sin(100\pi t - \pi/3) + 5\sqrt{2}\sin(300\pi t + \pi/4) + 2\sqrt{2}\sin(500\ \pi t - \pi/6)\right)\ A$$

50. The input power factor of he converter is

(A) 0.31
(B) 0.44
(C) 0.5
(D) 0.71

**[Ans. C]**

Input pf = $\cos\left(\frac{\pi}{3}\right) = 0.5$

51. The active power drawn by the converter is

(A) 181 W
(B) 500 W
(C) 707 W
(D) 887 W

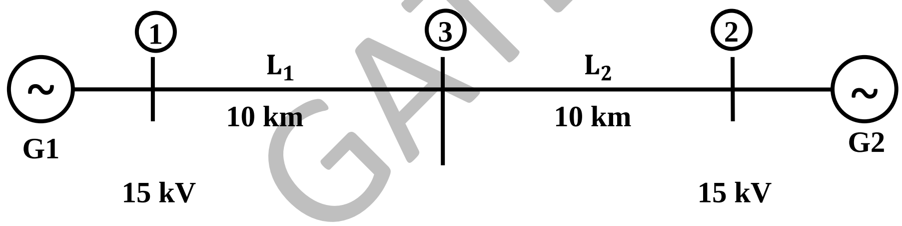
**[Ans. B]**

$P = 100 \times 10 \times \cos\left(\frac{\pi}{3}\right) = 500\ W$

**Linked Answer Questions**

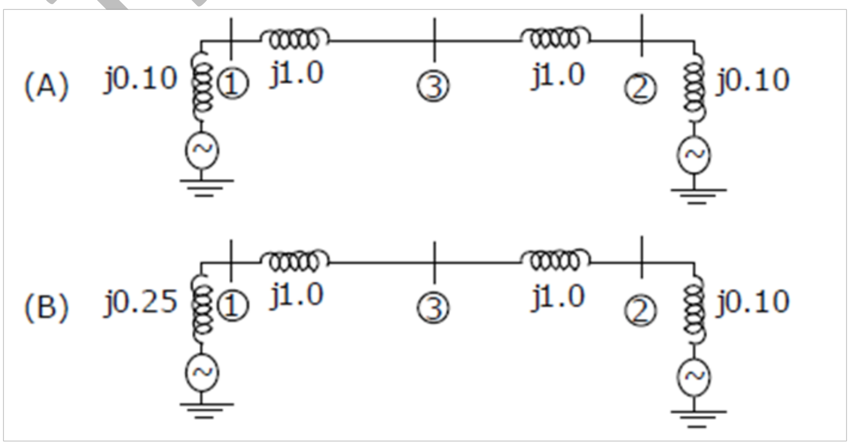
**Statement for Linked Answer Questions 52 and 53:**

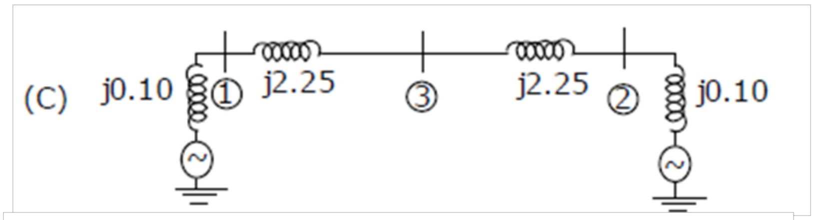
Two generator units G1 and G2 are connected by 15 kV line with a bus at the mid-point as shown below.

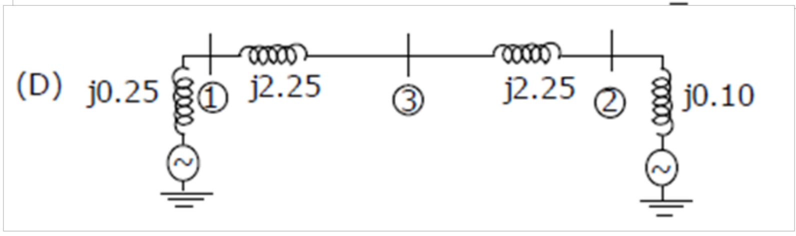



G1 = 250 MVA, 15 kV, positive sequence reactance X = 25 % on its own base
G2 = 100 MVA, 15 kV, positive sequence reactance X = 10 % on its own base
$L_1$ and $L_2$ = 10 km, positive sequence reactance X = 0.225 Ω/km

52. For the above system, the positive sequence diagram with the p.u values on the 100 MVA common base is






**[Ans. A]**

$X_{L1} = 0.225 \times 10 = 2.25\Omega$

$X_{L2} = 0.225 \times 10 = 2.25\Omega$

Take 100 MVAs 15 kV as base

For generator (G1)

$X_{g1} = 0.25 \times \frac{100}{25} = 0.1 \text{ p.u}$

For Transmission Line (L1 and L2)

$Z_{Base} = \frac{(15)^2}{100} = 2.25\Omega$

$XT_{L1}(\text{p.u}) = \frac{2.25}{2.25} = 1\text{p.u}$

$XT_{L2}(\text{p.u}) = 1\text{p.u}$

For generator (G2)

$X_{g2}(\text{p.u}) = 0.1 \times \left(\frac{100}{100}\right) = 0.1 \text{ p.u}$

53. In the above system, the three-phase fault MVA at the bus 3 is

(A) 82.55 MVA
(B) 85.11 MVA
(C) 170.91 MVA
(D) 181.82 MVA

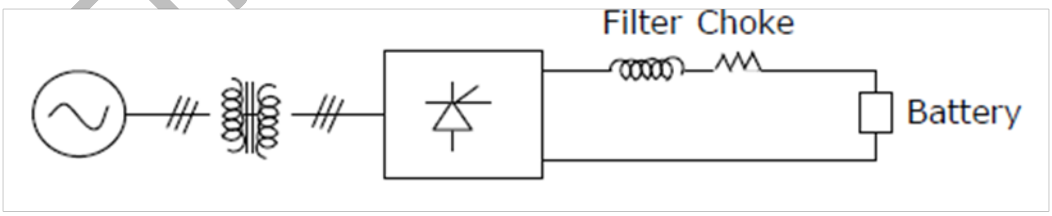
**[Ans. A]**

$X_{Th1} = 1.1||1.1 = 0.55$

$\text{Fault (MVA)} = \frac{\text{Base MVA}}{\text{fault Thevenin's Impedance}} = \frac{100}{0.55} = 181.82 \text{ MVA}$

**Statement for Linked Answer Questions 54 and 55:**

A solar energy installation utilizes a three-phase bridge converter to feed energy into power system through a transformer of 400 V/400 V, as shown below.




The energy is collected in a bank of 400 V battery and is connected to converter through a large filter choke of resistance 10 Ω.

54. The maximum current through the battery will be

(A) 14 A
(B) 40 A
(C) 80 A
(D) 94 A

**[Ans. A]**

$V_0 = I_a r_a + E$

$(V_0)_{max} = \frac{3\sqrt{6}V_{phase}}{\pi} \quad (\because \cos\alpha = 1)$

$= I_a r_a + E$

$540.2 = I_a(10) + 400$

$I_a = 14A$

55. The kVA rating of the input transformer is
(A) 53.2 kVA
(B) 46.0 kVA
(C) 22.6 kVA
(D) 19.6 kVA
**[Ans. *]**

**General Aptitude (GA) Questions**

**Q.56 – Q. 60 carry one mark each.**

56. Choose the word from the options given below that is most nearly opposite in meaning to the given word:
**Frequency**
(A) periodicity
(B) rarity
(C) gradualness
(D) persistency
**[Ans. B]**
The best antonym here is rarity which means shortage or scarcity.

57. There are two candidates P and Q in an election. During the campaign, 40% of the voters promised to vote for P, and rest for Q. However, on the day of election 15% of the voters went back on their promise to vote for P and instead voted for Q. 25% of the voters went back on their promise to vote for Q and instead voted for P. Suppose, P lost by 2 votes, then what was the total number of voters?
(A) 100
(B) 110
(C) 90
(D) 95
**[Ans. A]**

| P | Q |
|---|---|
| 40% | 60% |
| −6% | +6% |
| +15% | −15% |
| 49% | 51% |

$\therefore 2\% = 2$

$100\% = 100$

58. Choose the most appropriate word from the options given below to complete the following sentence:
**Under ethical guidelines recently adopted by the Indian Medical Association, human genes are to be manipulated only to correct diseases for which ___________ treatments are unsatisfactory.**
(A) similar
(B) most
(C) uncommon
(D) available
**[Ans. D]**
The context seeks to take a deviation only when the existing/present/current/alternative treatments are unsatisfactory. So the word for the blank should be a close synonym of existing/present/alternative. Available is the closest of all.

59. Choose the most appropriate word from the options given below to complete the following sentence:
**It was her view that the country's problems had been __________ by foreign technocrats, so that to invite them to come back would be counter-productive.**
(A) identified
(B) ascertained
(C) exacerbated
(D) analysed
**[Ans. C]**

The clues in the question are ---foreign technocrats did something negatively to the problems – so it is counter-productive to invite them. All other options are non-negative. The best choice is exacerbated which means aggravated or worsened.

60. The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair:

**Gladiator : Arena**

(A) dancer : stage
(B) commuter : train
(C) teacher : classroom
(D) lawyer : courtroom

**[Ans. D]**

The given relationship is worker: workplace. A gladiator is (i) a person, usually a professional combatant trained to entertain the public by engaging in mortal combat with another person or a wild. (ii) A person engaged in a controversy or debate, especially in public.

**Q. 61 to Q. 65 carry two marks each.**

61. Given that f(y) = |y|/y, and q is any non-zero real number, the value of |f(q) − f(−q)| is

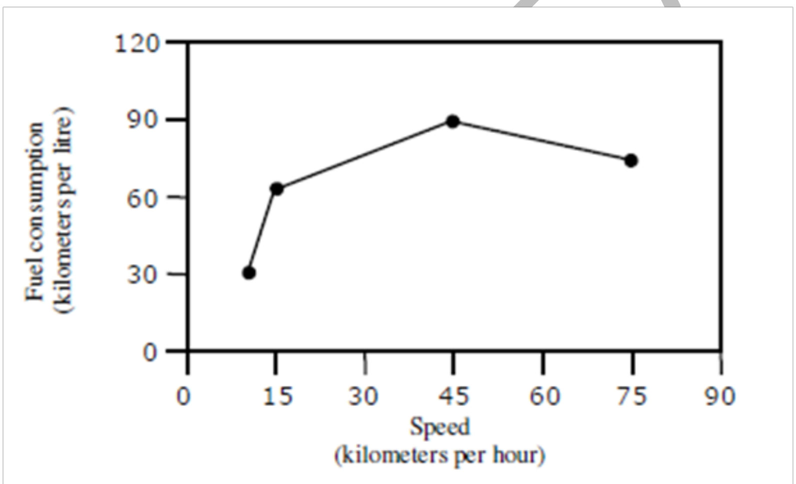
(A) 0
(B) −1
(C) 1
(D) 2

**[Ans. D]**

Given, $f(y) = \frac{|y|}{y} \Rightarrow f(q) = \frac{|q|}{q}; f(-q) = \frac{|-q|}{-q} = \frac{-|q|}{q}$

$|f(q) - f(q)| = \frac{|q|}{q} + \frac{|q|}{q} = \frac{2|q|}{q} = 2$

62. The fuel consumed by a motorcycle during a journey while travelling at various speeds is indicated in the graph below.




The distances covered during four laps of the journey are listed in the table below

| Lap | Distance (Kilometres) | Average speed (Kilometres per hour) |
|---|---|---|
| **P** | 15 | 15 |
| **Q** | 75 | 45 |
| **R** | 40 | 75 |
| **S** | 10 | 10 |

From the given data we can conclude that the fuel consumed per kilometre was least during the lap

(A) P
(B) Q
(C) R
(D) S

**[Ans. A]**

| | Fuel consumption | Actual |
|---|---|---|
| P | 60km/l | $\frac{15}{60} = \frac{1}{4}$l |

| | | |
|---|---|---|
| Q | 90km/l | $\frac{75}{90}=\frac{5}{6}$l |
| R | 75km/l | $\frac{40}{75}=\frac{8}{15}$l |
| S | 30km/l | $\frac{10}{30}=\frac{1}{3}$l |

63. The sum of n terms of series 4 + 44 + 444 + . . . . . is

(A) $(4/81)[10^{n+1}-9n-1]$
(B) $(4/81)[10^{n-1}-9n-1]$
(C) $(4/81)[10^{n+1}-9n-10]$
(D) $(4/81)[10^{n}-9n-10]$

**[Ans. C]**

Let S = 4 (1 + 11 + 111 + . . . . . . . . ) = $\frac{4}{9}$(9 + 99 + 999 + . . . . . . )

$$=\frac{4}{9}\{(10-1)+(10^2-1)+(10^3-1)+\ \ldots\ldots\}$$

$$=\frac{4}{9}\{(10+10^2+\ \ldots\ldots\ 10^n)-n\}=\frac{9}{4}\left\{10\ \frac{(10^n-1)}{9}-n\right\}=\frac{4}{81}\{10^{n+1}-9n-10\}$$

64. Three friends, R, S and T shared toffee from a bowl. R took $1/3^{rd}$ of the toffees, but returned four to the bowl. S took $1/4^{th}$ of what was left but returned three toffees to the bowl. T took half of the remainder but returned two back into the bowl. If the bowl had 17 toffees left, how many toffees were originally there in the bowl?

(A) 38
(B) 31
(C) 48
(D) 41

**[Ans. C]**

Let the total number of toffees is bowl e x

R took $\frac{1}{3}$ of toffees and returned 4 to the bowl

∴ Number of toffees with R = $\frac{1}{3}x-4$

Remaining of toffees in bowl = $\frac{2}{3}x+4$

Number of toffees with S = $\frac{1}{4}\left(\frac{2}{3}x+4\right)-3$

Remaining toffees in bowl = $\frac{3}{4}\left(\frac{2}{3}x+4\right)+4$

Number of toffees with T = $\frac{1}{2}\left(\frac{3}{4}\left(\frac{2}{3}x+4\right)+4\right)+2$

Remaining toffees in bowl = $\frac{1}{2}\left[\frac{3}{4}\left(\frac{2}{3}x+4\right)+4\right]+2$

Given, $\frac{1}{2}\left[\frac{3}{4}\left(\frac{2}{3}x+4\right)+4\right]+2=17 \Rightarrow \frac{3}{4}\left(\frac{2}{3}x+4\right)=27\ \Rightarrow x=48$

65. **The horse has played a little known but very important role in the field of medicine. Horses were injected with toxins of diseases until their blood built up immunities. Then a serum was made from their blood. Serums to fight with diphtheria and tetanus were developed this way.**

It can be inferred from the passage, that horses were

(A) given immunity to diseases
(B) generally quite immune to diseases
(C) given medicines to fight toxins
(D) given diphtheria and tetanus serums

**[Ans. B]**

From the passage it cannot be inferred that horses are given immunity as in (A), since the aim is to develop medicine and in turn immunize humans. (B) is correct since it is given that horses develop immunity after some time. Refer "unit their blood built up immunities". Even (C) is invalid since medicine is not built till immunity is developed in the horses. (D) is incorrect since specific examples are cited to illustrate and this cannot capture the essence.