

**Q. 1 - Q. 25 carry one mark each.**

**MCQ 1.1**

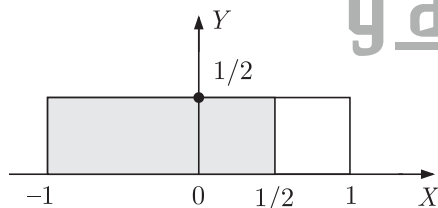
Two independent random variables  $X$  and  $Y$  are uniformly distributed in the interval  $[-1, 1]$ . The probability that  $\max[X, Y]$  is less than  $1/2$  is

- (A)  $3/4$  (B)  $9/16$   
(C)  $1/4$  (D)  $2/3$

**SOL 1.1**

Option (B) is correct.

Probability density function of uniformly distributed variables  $X$  and  $Y$  is shown as



$$P\left\{\max(x, y) < \frac{1}{2}\right\}$$

Since  $X$  and  $Y$  are independent.

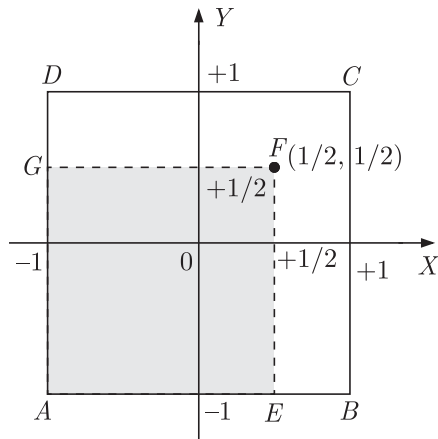
$$P\left\{\max(x, y) < \frac{1}{2}\right\} = P\left(X < \frac{1}{2}\right)P\left(Y < \frac{1}{2}\right)$$

$$P\left(X < \frac{1}{2}\right) = \text{shaded area} = \frac{3}{4}$$

Similarly for  $Y$ :  $P\left(Y < \frac{1}{2}\right) = \frac{3}{4}$

$$\text{So } P\left\{\max(x, y) < \frac{1}{2}\right\} = \frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$$

**Alternate method:**



From the given data since random variables  $X$  and  $Y$  lies in the interval  $[-1, 1]$  as from the figure  $X, Y$  lies in the region of the square  $ABCD$ .

Probability for  $\max[X, Y] < 1/2$ : The points for  $\max[X, Y] < 1/2$  will be inside the region of square  $AEFG$ .

$$\text{So, } P\left\{\max[X, Y] < \frac{1}{2}\right\} = \frac{\text{Area of } \square AEEFG}{\text{Area of square } ABCD}$$

$$= \frac{\frac{3}{2} \times \frac{3}{2}}{2 \times 2} = \frac{9}{16}$$

**MCQ 1.2**

If  $x = \sqrt{-1}$ , then the value of  $x^x$  is  
 (A)  $e^{-\pi/2}$  (B)  $e^{\pi/2}$   
 (C)  $x$  (D) 1

**SOL 1.2**

Option (A) is correct.

$$x = \sqrt{-1} = i = \cos \frac{\pi}{2} + i \sin \frac{\pi}{2}$$

$$\text{So, } x = e^{i\frac{\pi}{2}}$$

$$x^x = (e^{i\frac{\pi}{2}})^x \Rightarrow (e^{i\frac{\pi}{2}})^i$$

$$= e^{-\frac{\pi}{2}}$$

**MCQ 1.3**

Given  $f(z) = \frac{1}{z+1} - \frac{2}{z+3}$ .

If  $C$  is a counter clockwise path in the  $z$ -plane such that  $|z+1| = 1$ , the value of  $\frac{1}{2\pi j} \oint_C f(z) dz$  is

- (A)  $-2$  (B)  $-1$   
 (C) 1 (D) 2

**SOL 1.3**

Option (C) is correct.

$$f(z) = \frac{1}{z+1} - \frac{2}{z+3}$$

$\frac{1}{2\pi j} \oint_C f(z) dz =$  sum of the residues of the poles which lie inside the given closed region.

$$C \Rightarrow |z + 1| = 1$$

Only pole  $z = -1$  inside the circle, so residue at  $z = -1$  is.

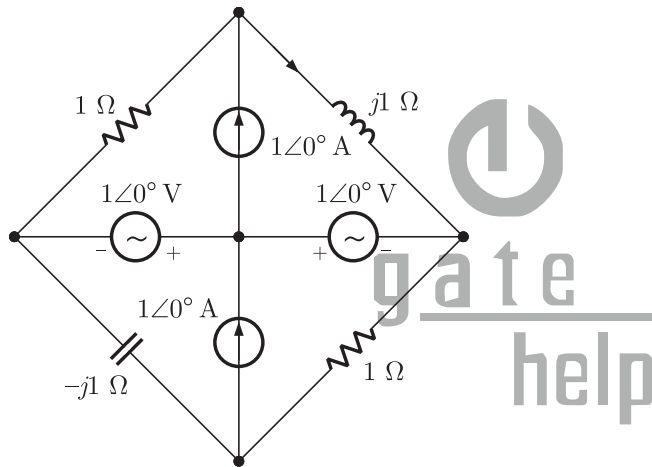
$$f(z) = \frac{-z + 1}{(z + 1)(z + 3)}$$

$$= \lim_{z \rightarrow -1} \frac{(z + 1)(-z + 1)}{(z + 1)(z + 3)} = \frac{2}{2} = 1$$

So  $\frac{1}{2\pi j} \oint_C f(z) dz = 1$

**MCQ 1.4**

In the circuit shown below, the current through the inductor is



(A)  $\frac{2}{1+j}$  A

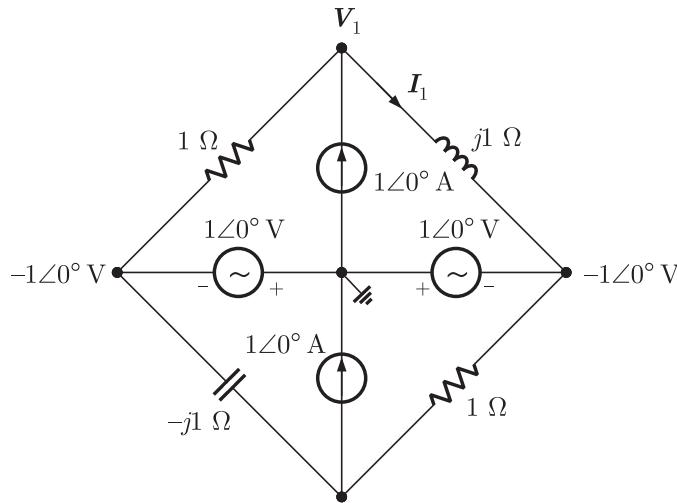
(B)  $\frac{-1}{1+j}$  A

(C)  $\frac{1}{1+j}$  A

(D) 0 A

**SOL 1.4**

Option (C) is correct.



Applying nodal analysis at top node.

$$\frac{V_1 + 1\angle 0^\circ}{1} + \frac{V_1 + 1\angle 0^\circ}{j1} = 1\angle 0^\circ$$

$$V_1(j1 + 1) + j1 + 1\angle 0^\circ = j1$$

$$V_1 = \frac{-1}{1 + j1}$$

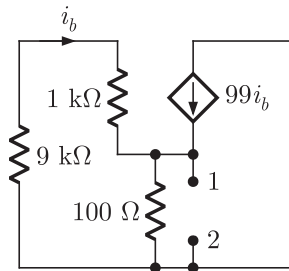
Current

$$I_1 = \frac{V_1 + 1\angle 0^\circ}{j1} = \frac{-\frac{1}{1+j} + 1}{j1}$$

$$= \frac{j}{(1+j)j} = \frac{1}{1+j} \text{ A}$$

**MCQ 1.5**

The impedance looking into nodes 1 and 2 in the given circuit is



- (A) 50 Ω
- (C) 5 kΩ

- (B) 100 Ω
- (D) 10.1 kΩ

**SOL 1.5**

Option (A) is correct.

We put a test source between terminal 1, 2 to obtain equivalent impedance



- MCQ 1.7** In the sum of products function  $f(X, Y, Z) = \sum(2, 3, 4, 5)$ , the prime implicants are  
 (A)  $\overline{X}Y, X\overline{Y}$  (B)  $\overline{X}Y, X\overline{Y}\overline{Z}, X\overline{Y}Z$   
 (C)  $\overline{X}Y\overline{Z}, \overline{X}YZ, X\overline{Y}$  (D)  $\overline{X}Y\overline{Z}, \overline{X}YZ, X\overline{Y}\overline{Z}, X\overline{Y}Z$

**SOL 1.7** Option (A) is correct.

Prime implicants are the terms that we get by solving K-map

		YZ			
		00	01	11	10
X	1	1	1		
	0			1	1

$$F = \underbrace{\overline{X}Y + X\overline{Y}}_{\text{prime implicants}}$$

- MCQ 1.8** If  $x[n] = (1/3)^{|n|} - (1/2)^n u[n]$ , then the region of convergence (ROC) of its  $z$ -transform in the  $z$ -plane will be

- (A)  $\frac{1}{3} < |z| < 3$  (B)  $\frac{1}{3} < |z| < \frac{1}{2}$   
 (C)  $\frac{1}{2} < |z| < 3$  (D)  $\frac{1}{3} < |z|$

**SOL 1.8** Option (C) is correct.

$$x[n] = \left(\frac{1}{3}\right)^{|n|} - \left(\frac{1}{2}\right)^n u[n]$$

$$x[n] = \left(\frac{1}{3}\right)^n u[n] + \left(\frac{1}{3}\right)^{-n} u[-n-1] - \left(\frac{1}{2}\right)^n u[n]$$

Taking  $z$ -transform

$$X[z] = \sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^n z^{-n} u[n] + \sum_{n=-\infty}^{\infty} \left(\frac{1}{3}\right)^{-n} z^{-n} u[-n-1] - \sum_{n=-\infty}^{\infty} \left(\frac{1}{2}\right)^n z^{-n} u[n]$$

$$= \sum_{n=0}^{\infty} \left(\frac{1}{3}\right)^n z^{-n} + \sum_{n=-\infty}^{-1} \left(\frac{1}{3}\right)^{-n} z^{-n} - \sum_{n=0}^{\infty} \left(\frac{1}{2}\right)^n z^{-n}$$

$$= \underbrace{\sum_{n=0}^{\infty} \left(\frac{1}{3z}\right)^n}_I + \underbrace{\sum_{m=1}^{\infty} \left(\frac{1}{3}z\right)^m}_II - \underbrace{\sum_{n=0}^{\infty} \left(\frac{1}{2z}\right)^n}_III$$

Taking  $m = -n$

Series I converges if  $\left|\frac{1}{3z}\right| < 1$  or  $|z| > \frac{1}{3}$

Series II converges if  $\left|\frac{1}{3}z\right| < 1$  or  $|z| < 3$

Series III converges if  $\left|\frac{1}{2z}\right| < 1$  or  $|z| > \frac{1}{2}$

Region of convergence of  $X(z)$  will be intersection of above three

So,  $\text{ROC} : \frac{1}{2} < |z| < 3$

**MCQ 1.9** The bus admittance matrix of a three-bus three-line system is

$$Y = j \begin{bmatrix} -13 & 10 & 5 \\ 10 & -18 & 10 \\ 5 & 10 & -13 \end{bmatrix}$$

If each transmission line between the two buses is represented by an equivalent  $\pi$ -network, the magnitude of the shunt susceptance of the line connecting bus 1 and 2 is

- (A) 4 (B) 2  
(C) 1 (D) 0

**SOL 1.9** Option (B) is correct.

For bus admittance matrix,

$$\begin{aligned} Y_{11} + (Y_{12} + y_{line}) + Y_{13} &= 0 \\ -j13 + (j10 + y_{line}) + j5 &= 0 \\ y_{line} &= -j2 \end{aligned}$$

Magnitude of susceptance is +2

**MCQ 1.10** The slip of an induction motor normally does not depend on  
(A) rotor speed (B) synchronous speed  
(C) shaft torque (D) core-loss component

**SOL 1.10** Option (D) is correct.

Slip is given as

$$S = \frac{n_s - n}{n_s}$$

where,

$n_s$  = synchronous speed

$n$  = rotor speed

Thus, slip depend on synchronous speed and the rotor speed. Also, torque increases with increasing slip up to a maximum value and then decreases. Slip does not depend on core/loss component.

**MCQ 1.11** A two-phase load draws the following phase currents :  $i_1(t) = I_m \sin(\omega t - \phi_1)$ ,  $i_2(t) = I_m \cos(\omega t - \phi_2)$ . These currents are balanced if  $\phi_1$  is equal to.  
(A)  $-\phi_2$  (B)  $\phi_2$   
(C)  $(\pi/2 - \phi_2)$  (D)  $(\pi/2 + \phi_2)$

**SOL 1.11** Option (A) is correct.

$$\begin{aligned} i_1(t) &= I_m \sin(\omega t - \phi_1) \\ i_2(t) &= I_m \cos(\omega t - \phi_2) \end{aligned}$$

We know that,

$$\cos(\theta - 90^\circ) = \sin \theta$$

So,  $i_1(t)$  can be written as

$$i_1(t) = I_m \cos(\omega t - \phi_1 - 90^\circ)$$

$$i_2(t) = I_m \cos(\omega t - \phi_2)$$

Now, in phasor form

$$\mathbf{I}_1 = I_m \angle \phi_1 + 90^\circ$$

$$\mathbf{I}_2 = I_m \angle \phi_2$$

Current are balanced if

$$\mathbf{I}_1 + \mathbf{I}_2 = 0$$

$$I_m \angle \phi_1 + 90^\circ + I_m \angle \phi_2 = 0$$

$$I_m \cos(\phi_1 + 90^\circ) + jI_m \sin(\phi_1 + 90^\circ) + \cos \phi_2 + j \sin \phi_2 = 0$$

$$I_m [\cos(\phi_1 + 90^\circ) + j \sin(\phi_1 + 90^\circ)] + I_m [\cos \phi_2 + j \sin \phi_2] = 0$$

$$I_m [\cos(\phi_1 + 90^\circ) + \cos \phi_2] + jI_m [\sin \phi_2 + \sin(\phi_1 + 90^\circ)] = 0$$

$$\cos(\phi_1 + 90^\circ) + \cos \phi_2 = 0$$

$$\cos(\phi_1 + 90^\circ) = -\cos \phi_2 = \cos(\pi + \phi_2)$$

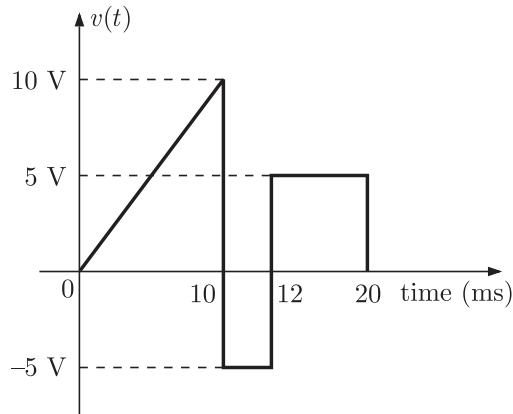
$$\phi_1 + 90^\circ = \pi + \phi_2$$

or,

$$\phi_1 = \frac{\pi}{2} + \phi_2$$

**MCQ 1.12**

A periodic voltage waveform observed on an oscilloscope across a load is shown. A permanent magnet moving coil (PMMC) meter connected across the same load reads



(A) 4 V

(B) 5 V

(C) 8 V

(D) 10 V

**SOL 1.12**

Option (A) is correct.

PMMC instrument reads average (dc) value.

$$\begin{aligned} V_{avg} &= \frac{1}{T} \int_0^T v(t) dt \\ &= \frac{1}{20 \times 10^{-3}} \int_0^{20} v(t) dt \end{aligned}$$



$$\begin{aligned}
 &= \frac{1}{20} \left[ \int_0^{10} t dt + \int_{10}^{12} (-5) dt + \int_{12}^{20} 5 dt \right] \\
 &= \frac{1}{20} \left( \left[ \frac{t^2}{2} \right]_0^{10} - 5[t]_{10}^{12} + 5[t]_{12}^{20} \right) \\
 &= \frac{1}{20} [50 - 5(2) + 5(8)] \\
 &= \frac{80}{20} = 4 \text{ V}
 \end{aligned}$$

- MCQ 1.13** The bridge method commonly used for finding mutual inductance is  
 (A) Heaviside Campbell bridge (B) Schering bridge  
 (C) De Sauty bridge (D) Wien bridge

**SOL 1.13** Option (A) is correct.  
 Heaviside mutual inductance bridge measures mutual inductance in terms of a known self-inductance.

- MCQ 1.14** With initial condition  $x(1) = 0.5$ , the solution of the differential equation  $t \frac{dx}{dt} + x = t$ , is

- (A)  $x = t - \frac{1}{2}$  (B)  $x = t^2 - \frac{1}{2}$   
 (C)  $x = \frac{t^2}{2}$  (D)  $x = \frac{t}{2}$

**SOL 1.14** Option (D) is correct.

$$t \frac{dx}{dt} + x = t$$

$$\frac{dx}{dt} + \frac{x}{t} = 1$$

$$\frac{dx}{dt} + Px = Q \text{ (General form)}$$

Integrating factor,  $IF = e^{\int P dx} = e^{\int \frac{1}{t} dt} = e^{\ln t} = t$

Solution has the form

$$x \times IF = \int (Q \times IF) dt + C$$

$$x \times t = \int (1)(t) dt + C$$

$$xt = \frac{t^2}{2} + C$$

Taking the initial condition

$$x(1) = 0.5$$

$$0.5 = \frac{1}{2} + C$$

$$C = 0$$

So, 
$$xt = \frac{t^2}{2} \Rightarrow x = \frac{t}{2}$$

**MCQ 1.15** The unilateral Laplace transform of  $f(t)$  is  $\frac{1}{s^2 + s + 1}$ . The unilateral Laplace transform of  $tf(t)$  is

(A)  $-\frac{s}{(s^2 + s + 1)^2}$  (B)  $-\frac{2s + 1}{(s^2 + s + 1)^2}$   
 (C)  $\frac{s}{(s^2 + s + 1)^2}$  (D)  $\frac{2s + 1}{(s^2 + s + 1)^2}$

**SOL 1.15** Option (D) is correct.

Using  $s$ -domain differentiation property of Laplace transform.

If 
$$f(t) \xrightarrow{\mathcal{L}} F(s)$$

$$tf(t) \xrightarrow{\mathcal{L}} -\frac{dF(s)}{ds}$$

So, 
$$\begin{aligned} \mathcal{L}[tf(t)] &= -\frac{d}{ds} \left[ \frac{1}{s^2 + s + 1} \right] \\ &= \frac{2s + 1}{(s^2 + s + 1)^2} \end{aligned}$$

**MCQ 1.16** The average power delivered to an impedance  $(4 - j3) \Omega$  by a current  $5 \cos(100\pi t + 100)$  A is

(A) 44.2 W (B) 50 W  
 (C) 62.5 W (D) 125 W

**SOL 1.16** Option (B) is correct.

In phasor form

$$\begin{aligned} Z &= 4 - j3 \\ Z &= 5 \angle -36.86^\circ \Omega \\ I &= 5 \angle 100^\circ \text{ A} \end{aligned}$$

Average power delivered.

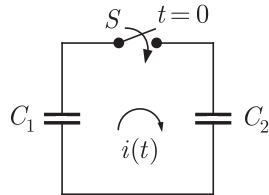
$$\begin{aligned} P_{avg.} &= \frac{1}{2} |I|^2 Z \cos \theta \\ &= \frac{1}{2} \times 25 \times 5 \cos 36.86^\circ \\ &= 50 \text{ W} \end{aligned}$$

**Alternate method:**

$$\begin{aligned} Z &= (4 - j3) \Omega \\ I &= 5 \cos(100\pi t + 100) \text{ A} \\ P_{avg} &= \frac{1}{2} \text{Re}\{ |I|^2 Z \} \\ &= \frac{1}{2} \times \text{Re}\{ (5)^2 \times (4 - j3) \} \end{aligned}$$

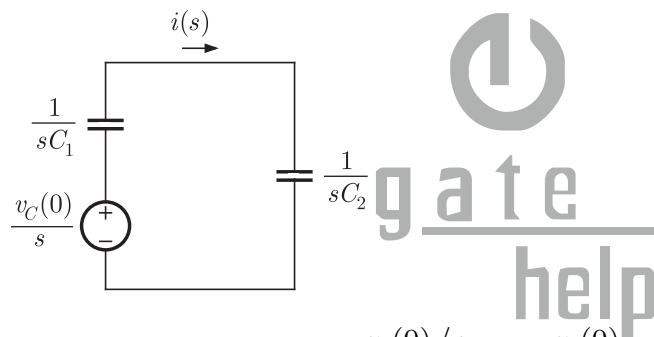
$$= \frac{1}{2} \times 100 = 50 \text{ W}$$

**MCQ 1.17** In the following figure,  $C_1$  and  $C_2$  are ideal capacitors.  $C_1$  has been charged to 12 V before the ideal switch  $S$  is closed at  $t = 0$ . The current  $i(t)$  for all  $t$  is



- (A) zero (B) a step function  
 (C) an exponentially decaying function (D) an impulse function

**SOL 1.17** Option (D) is correct.  
 The  $s$ -domain equivalent circuit is shown as below.



$$I(s) = \frac{v_c(0)/s}{\frac{1}{C_1 s} + \frac{1}{C_2 s}} = \frac{v_c(0)}{\frac{1}{C_1} + \frac{1}{C_2}}$$

$$I(s) = \left( \frac{C_1 C_2}{C_1 + C_2} \right) (12 \text{ V})$$

$$v_c(0) = 12 \text{ V}$$

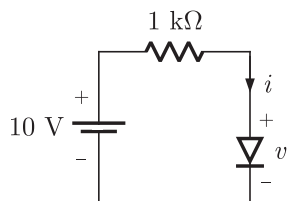
$$I(s) = 12 C_{eq}$$

Taking inverse Laplace transform for the current in time domain,

$$i(t) = 12 C_{eq} \delta(t) \quad \text{(Impulse)}$$

**MCQ 1.18** The  $i$ - $v$  characteristics of the diode in the circuit given below are

$$i = \begin{cases} \frac{v - 0.7}{500} \text{ A}, & v \geq 0.7 \text{ V} \\ 0 \text{ A} & v < 0.7 \text{ V} \end{cases}$$



The current in the circuit is

- (A) 10 mA (B) 9.3 mA  
(C) 6.67 mA (D) 6.2 mA

**SOL 1.18** Option (D) is correct.

Let  $v > 0.7$  V and diode is forward biased. By applying Kirchoff's voltage law

$$10 - i \times 1k - v = 0$$

$$10 - \left[ \frac{v - 0.7}{500} \right] (1000) - v = 0$$

$$10 - (v - 0.7) \times 2 - v = 0$$

$$10 - 3v + 1.4 = 0$$

$$v = \frac{11.4}{3} = 3.8 \text{ V} > 0.7 \quad (\text{Assumption is true})$$

So, 
$$i = \frac{v - 0.7}{500} = \frac{3.8 - 0.7}{500} = 6.2 \text{ mA}$$

- MCQ 1.19** The output  $Y$  of a 2-bit comparator is logic 1 whenever the 2-bit input  $A$  is greater than the 2-bit input  $B$ . The number of combinations for which the output is logic 1, is
- (A) 4 (B) 6  
(C) 8 (D) 10

**SOL 1.19** Option (B) is correct.



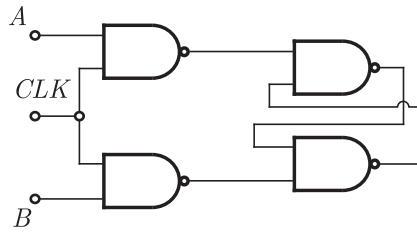
$$Y = 1, \text{ when } A > B$$

$$A = a_1 a_0, B = b_1 b_0$$

$a_1$	$a_0$	$b_1$	$b_0$	$Y$
0	1	0	0	1
1	0	0	0	1
1	0	0	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1

Total combination = 6

- MCQ 1.20** Consider the given circuit



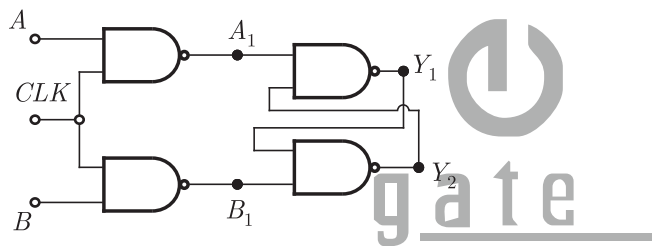
In this circuit, the race around

- (A) does not occur
- (B) occur when  $CLK = 0$
- (C) occur when  $CLK = 1$  and  $A = B = 1$
- (D) occur when  $CLK = 1$  and  $A = B = 0$

**SOL 1.20**

Option (A) is correct.

The given circuit is



Condition for the race-around

It occurs when the output of the circuit ( $Y_1, Y_2$ ) oscillates between '0' and '1' checking it from the options.

1. Option (A): When  $CLK = 0$

Output of the NAND gate will be  $A_1 = B_1 = \bar{0} = 1$ . Due to these input to the next NAND gate,  $Y_2 = \bar{Y_1} \cdot 1 = \bar{Y_1}$  and  $Y_1 = \bar{Y_2} \cdot 1 = \bar{Y_2}$ .

If  $Y_1 = 0$ ,  $Y_2 = \bar{Y_1} = 1$  and it will remain the same and doesn't oscillate.

If  $Y_2 = 0$ ,  $Y_1 = \bar{Y_2} = 1$  and it will also remain the same for the clock period. So, it won't oscillate for  $CLK = 0$ .

So, here race around doesn't occur for the condition  $CLK = 0$ .

2. Option (C): When  $CLK = 1, A = B = 1$

$$A_1 = B_1 = 0 \text{ and so } Y_1 = Y_2 = 1$$

And it will remain same for the clock period. So race around doesn't occur for the condition.

3. Option (D): When  $CLK = 1, A = B = 0$

$$\text{So, } A_1 = B_1 = 1$$

And again as described for Option (B) race around doesn't occur for the condition.

So, Option (A) will be correct.

**MCQ 1.21**

The figure shows a two-generator system applying a load of  $P_D = 40 \text{ MW}$ , connected at bus 2.



Total power,

$$P_L = P_{G_1} + P_{G_2} - P_L$$

$$40 = 20 + P_2 - 2$$

$$P_{G_2} = 22 \text{ MW}$$

- MCQ 1.22** The sequence components of the fault current are as follows :  $I_{\text{positive}} = j1.5 \text{ pu}$ ,  $I_{\text{negative}} = -j0.5 \text{ pu}$ ,  $I_{\text{zero}} = -j1 \text{ pu}$ . The type of fault in the system is  
 (A) *LG* (B) *LL*  
 (C) *LLG* (D) *LLLG*

**SOL 1.22** Option (C) is correct.

For double line-to-ground (*LLG*) fault, relation between sequence current is

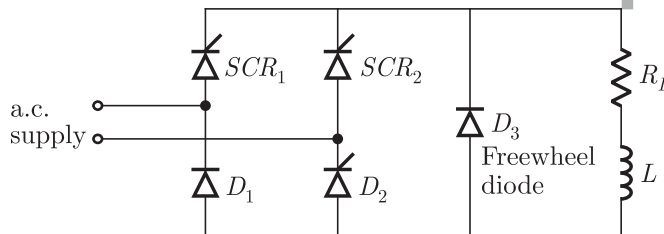
$$I_{\text{positive}} = -(I_{\text{negative}} + I_{\text{zero}})$$

Gives values satisfy this relation, therefore the type of fault is *LLG*.

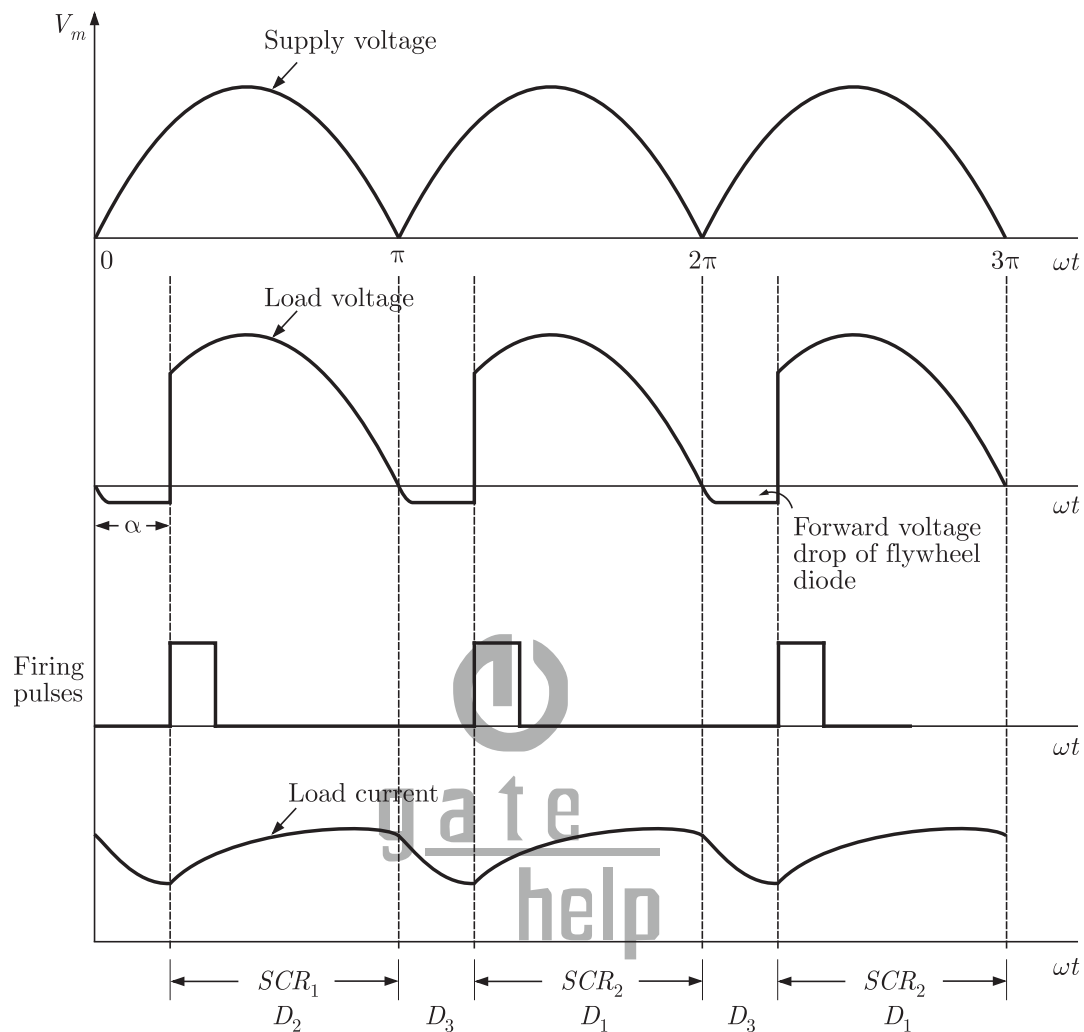
- MCQ 1.23** A half-controlled single-phase bridge rectifier is supplying an *R-L* load. It is operated at a firing angle  $\alpha$  and the load current is continuous. The fraction of cycle that the freewheeling diode conducts is  
 (A)  $1/2$  (B)  $(1 - \alpha/\pi)$   
 (C)  $\alpha/2\pi$  (D)  $\alpha/\pi$

**SOL 1.23** Option (D) is correct.

The circuit of a single-phase half controlled bridge rectifier with *RL* load and free wheel diode is shown as below.



The voltage current wave forms are shown in figure below.



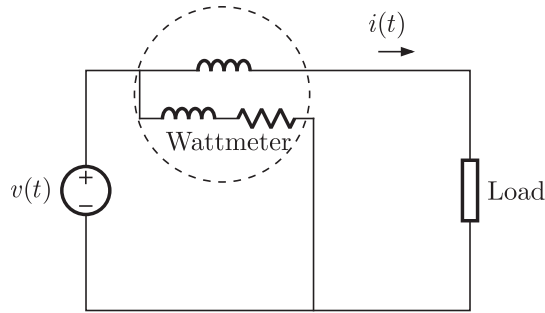
We note that, for continuous load current, the flywheel diode conducts from  $\pi$  to  $\pi + \alpha$  in a cycle. Thus, fraction of cycle that freewheel diode conducts is  $\alpha/\pi$ . Thus fraction of cycle that freewheel diode conducts is  $\alpha/\pi$ .

- MCQ 1.24** The typical ratio of latching current to holding current in a 20 A thyristor is  
 (A) 5.0 (B) 2.0  
 (C) 1.0 (D) 0.5

**SOL 1.24** Option (B) is correct.  
 The latching current is higher than the holding current. Usually, latching current is taken two to three times the holding currents.

- MCQ 1.25** For the circuit shown in the figure, the voltage and current expressions are  
 $v(t) = E_1 \sin(\omega t) + E_3 \sin(3\omega t)$  and  
 $i(t) = I_1 \sin(\omega t - \phi_1) + I_3 \sin(3\omega t - \phi_3) + I_5 \sin(5\omega t)$   
 The average power measured by the wattmeter is





- (A)  $\frac{1}{2} E_1 I_1 \cos \phi_1$  (B)  $\frac{1}{2} [E_1 I_1 \cos \phi_1 + E_1 I_3 \cos \phi_3 + E_1 I_5]$   
 (C)  $\frac{1}{2} [E_1 I_1 \cos \phi_1 + E_3 I_3 \cos \phi_3]$  (D)  $\frac{1}{2} [E_1 I_1 \cos \phi_1 + E_3 I_1 \cos \phi_1]$

**SOL 1.25**

Option (C) is correct.

Let  $\omega t = \theta$ , we have instantaneous voltage and current as follows.

$$v(t) = E_1 \sin \theta + E_3 \sin 3\theta$$

$$i(t) = I_1 \sin(\theta - \phi_1) + I_3 \sin(3\theta - \phi_3) + I_5 \sin(5\theta)$$

We know that wattmeter reads the average power, which is gives as

$$P = \frac{1}{2\pi} \int_0^{2\pi} v(t) i(t) d\theta \quad \dots(i)$$

We can solve this integration using following results.

$$(i) \frac{1}{2\pi} \int_0^{2\pi} A \sin(\theta + \alpha) \cdot B \sin(\theta + \beta) d\theta = \frac{1}{2} AB \cos(\alpha - \beta)$$

$$(ii) \frac{1}{2\pi} \int_0^{2\pi} A \sin(\theta + \alpha) \cdot B \cos(\theta + \alpha) d\theta = \frac{1}{2} AB \sin(\alpha - \beta)$$

$$(iii) \frac{1}{2\pi} \int_0^{2\pi} A \sin(m\theta + \alpha) \cdot B \cos(n\theta + \beta) d\theta = 0$$

$$(iv) \frac{1}{2\pi} \int_0^{2\pi} A \sin(m\theta + \alpha) \cdot B \cos(n\theta + \beta) d\theta = 0$$

Result (iii) and (iv) implies that power is transferred between same harmonics of voltages and currents.

Thus integration of equation (i) gives.

$$P = \frac{1}{2} E_1 I_1 \cos \phi + \frac{1}{2} E_3 I_3 \cos \phi_3$$

**Q. 26 to Q. 55 carry two marks each.**

**MCQ 1.26**

Given that

$$\mathbf{A} = \begin{bmatrix} -5 & -3 \\ 2 & 0 \end{bmatrix} \text{ and } \mathbf{I} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \text{ the value of } \mathbf{A}^3 \text{ is}$$

- (A)  $15\mathbf{A} + 12\mathbf{I}$  (B)  $19\mathbf{A} + 30\mathbf{I}$   
 (C)  $17\mathbf{A} + 15\mathbf{I}$  (D)  $17\mathbf{A} + 21\mathbf{I}$

**SOL 1.26** Option (B) is correct.

Characteristic equation.

$$|\mathbf{A} - \lambda \mathbf{I}| = 0$$

$$\begin{vmatrix} -5 - \lambda & -3 \\ 2 & -\lambda \end{vmatrix} = 0$$

$$5\lambda + \lambda^2 + 6 = 0$$

$$\lambda^2 + 5\lambda + 6 = 0$$

Since characteristic equation satisfies its own matrix, so

$$\mathbf{A}^2 + 5\mathbf{A} + 6 = 0 \Rightarrow \mathbf{A}^2 = -5\mathbf{A} - 6\mathbf{I}$$

Multiplying with  $\mathbf{A}$

$$\mathbf{A}^3 + 5\mathbf{A}^2 + 6\mathbf{A} = 0$$

$$\mathbf{A}^3 + 5(-5\mathbf{A} - 6\mathbf{I}) + 6\mathbf{A} = 0$$

$$\mathbf{A}^3 = 19\mathbf{A} + 30\mathbf{I}$$

**MCQ 1.27** The maximum value of  $f(x) = x^3 - 9x^2 + 24x + 5$  in the interval  $[1, 6]$  is

(A) 21

(B) 25

(C) 41

(D) 46

**SOL 1.27** Option (B) is correct.

$$f(x) = x^3 - 9x^2 + 24x + 5$$

$$\frac{df(x)}{dx} = 3x^2 - 18x + 24 = 0$$

$$\Rightarrow \frac{df(x)}{dx} = x^2 - 6x + 8 = 0$$

$$x = 4, x = 2$$

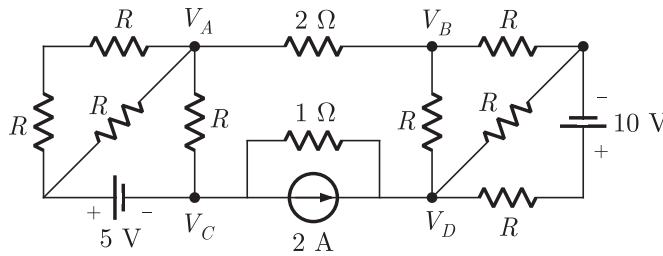
$$\frac{d^2f(x)}{dx^2} = 6x - 18$$

$$\text{For } x = 2, \frac{d^2f(x)}{dx^2} = 12 - 18 = -6 < 0$$

So at  $x = 2$ ,  $f(x)$  will be maximum

$$\begin{aligned} f(x)|_{\max} &= (2)^3 - 9(2)^2 + 24(2) + 5 \\ &= 8 - 36 + 48 + 5 \\ &= 25 \end{aligned}$$

**MCQ 1.28** If  $V_A - V_B = 6 \text{ V}$  then  $V_C - V_D$  is



- (A) -5 V
- (B) 2 V
- (C) 3 V
- (D) 6 V

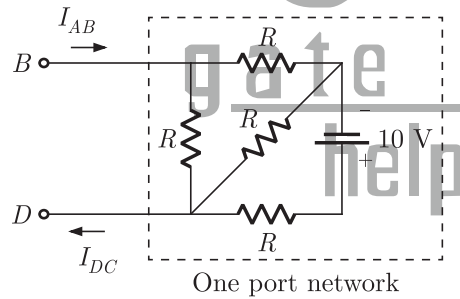
**SOL 1.28** Option (A) is correct.  
In the given circuit

$$V_A - V_B = 6 \text{ V}$$

So current in the branch will be

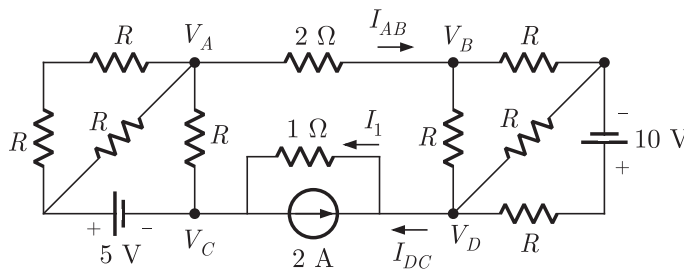
$$I_{AB} = \frac{6}{2} = 3 \text{ A}$$

We can see, that the circuit is a one port circuit looking from terminal *BD* as shown below



For a one port network current entering one terminal, equals the current leaving the second terminal. Thus the outgoing current from *A* to *B* will be equal to the incoming current from *D* to *C* as shown

i.e.  $I_{DC} = I_{AB} = 3 \text{ A}$



The total current in the resistor 1Ω will be

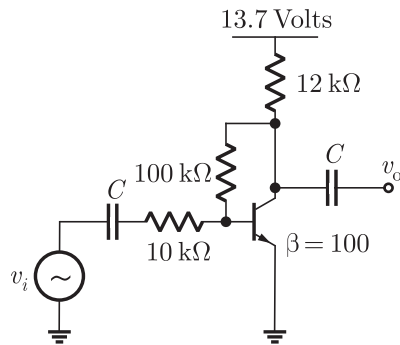
$$I_1 = 2 + I_{DC} = 2 + 3 = 5 \text{ A}$$

(By writing KCL at node *D*)

So,  $V_{CD} = 1 \times (-I_1)$

$$= -5 \text{ V}$$

**MCQ 1.29** The voltage gain  $A_v$  of the circuit shown below is



(A)  $|A_v| \approx 200$

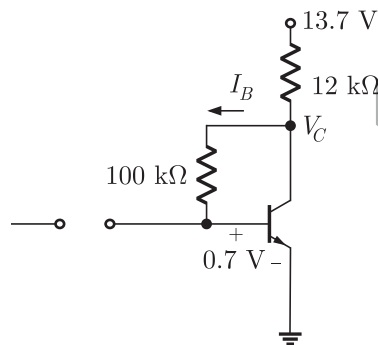
(B)  $|A_v| \approx 100$

(C)  $|A_v| \approx 20$

(D)  $|A_v| \approx 10$

**SOL 1.29** Option (D) is correct.

**DC Analysis :**



Using KVL in input loop,

$$V_C - 100I_B - 0.7 = 0$$

$$V_C = 100I_B + 0.7 \quad \dots(i)$$

$$I_C \simeq I_E = \frac{13.7 - V_C}{12k} = (\beta + 1) I_B$$

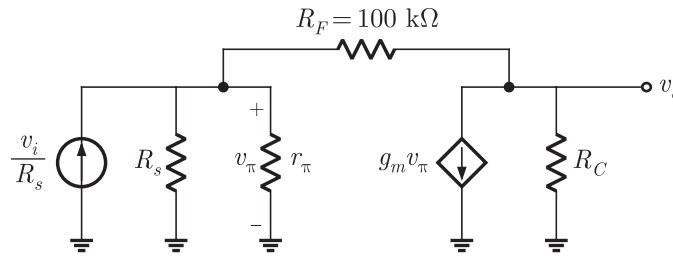
$$\frac{13.7 - V_C}{12 \times 10^3} = 100I_B \quad \dots(ii)$$

Solving equation (i) and (ii),

$$I_B = 0.01 \text{ mA}$$

**Small Signal Analysis :**

Transforming given input voltage source into equivalent current source.



This is a shunt-shunt feedback amplifier.

Given parameters,

$$r_{\pi} = \frac{V_T}{I_B} = \frac{25 \text{ mV}}{0.01 \text{ mA}} = 2.5 \text{ k}\Omega$$

$$g_m = \frac{\beta}{r_{\pi}} = \frac{100}{2.5 \times 1000} = 0.04 \text{ s}$$

Writing KCL at output node

$$\frac{v_o}{R_C} + g_m v_{\pi} + \frac{v_o - v_{\pi}}{R_F} = 0$$

$$v_o \left[ \frac{1}{R_C} + \frac{1}{R_F} \right] + v_{\pi} \left[ g_m - \frac{1}{R_F} \right] = 0$$

Substituting  $R_C = 12 \text{ k}\Omega$ ,  $R_F = 100 \text{ k}\Omega$ ,  $g_m = 0.04 \text{ s}$

$$v_o (9.33 \times 10^{-5}) + v_{\pi} (0.04) = 0$$

$$v_o = -428.72 V_{\pi} \quad \dots(i)$$

Writing KCL at input node

$$\frac{v_i}{R_s} = \frac{v_{\pi}}{R_s} + \frac{v_{\pi}}{r_{\pi}} + \frac{v_{\pi} - v_o}{R_F}$$

$$\frac{v_i}{R_s} = v_{\pi} \left[ \frac{1}{R_s} + \frac{1}{r_{\pi}} + \frac{1}{R_F} \right] - \frac{v_o}{R_F}$$

$$\frac{v_i}{R_s} = v_{\pi} (5.1 \times 10^{-4}) - \frac{v_o}{R_F}$$

Substituting  $V_{\pi}$  from equation (i)

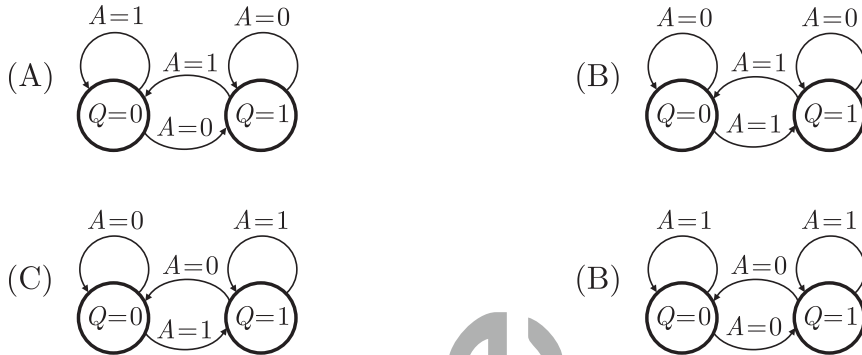
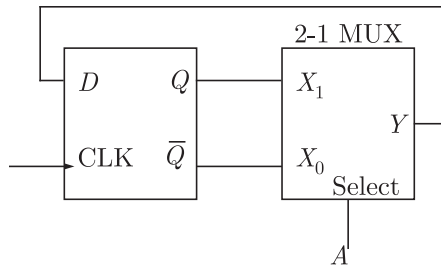
$$\frac{v_i}{R_s} = \frac{-5.1 \times 10^{-4}}{428.72} v_o - \frac{v_o}{R_F}$$

$$\frac{v_i}{10 \times 10^3} = -1.16 \times 10^{-6} v_o - 1 \times 10^{-5} v_o \quad R_s = 10 \text{ k}\Omega \text{ (source resistance)}$$

$$\frac{v_i}{10 \times 10^3} = -1.116 \times 10^{-5} v_o$$

$$|A_v| = \left| \frac{v_o}{v_i} \right| = \frac{1}{10 \times 10^3 \times 1.116 \times 10^{-5}} \simeq 8.96$$

**MCQ 1.30** The state transition diagram for the logic circuit shown is



**SOL 1.30**

Option (D) is correct.

Let  $Q_{n+1}$  is next state and  $Q_n$  is the present state. From the given below figure.

$$D = Y = \overline{A}X_0 + AX_1$$

$$Q_{n+1} = D = \overline{A}Q_n + AQ_n$$

$$Q_{n+1} = \overline{A}Q_n + AQ_n$$

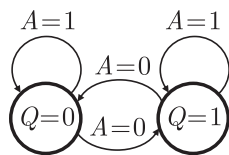
$$\text{If } A = 0, \quad Q_{n+1} = \overline{Q}_n$$

$$\text{If } A = 1, \quad Q_{n+1} = Q_n$$

$$X_0 = \overline{Q}, X_1 = Q$$

(toggle of previous state)

So state diagram is



**MCQ 1.31**

Let  $y[n]$  denote the convolution of  $h[n]$  and  $g[n]$ , where  $h[n] = (1/2)^n u[n]$  and  $g[n]$  is a causal sequence. If  $y[0] = 1$  and  $y[1] = 1/2$ , then  $g[1]$  equals

- (A) 0
- (B) 1/2
- (C) 1
- (D) 3/2

**SOL 1.31**

Option (A) is correct.

Convolution sum is defined as

$$y[n] = h[n] * g[n] = \sum_{k=-\infty}^{\infty} h[n] g[n - k]$$

For causal sequence,  $y[n] = \sum_{k=0}^{\infty} h[n] g[n - k]$

$$y[n] = h[n]g[n] + h[n]g[n-1] + h[n]g[n-2] + \dots$$

For  $n = 0$ ,

$$y[0] = h[0]g[0] + h[1]g[-1] + \dots$$

$$y[0] = h[0]g[0]$$

$$g[-1] = g[-2] = \dots = 0$$

$$y[0] = h[0]g[0]$$

...(i)

For  $n = 1$ ,

$$y[1] = h[1]g[1] + h[1]g[0] + h[1]g[-1] + \dots$$

$$y[1] = h[1]g[1] + h[1]g[0]$$

$$\frac{1}{2} = \frac{1}{2}g[1] + \frac{1}{2}g[0]$$

$$h[1] = \left(\frac{1}{2}\right)^1 = \frac{1}{2}$$

$$1 = g[1] + g[0]$$

$$g[1] = 1 - g[0]$$

From equation (i),

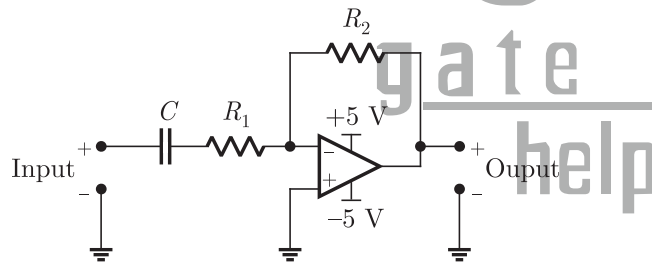
$$g[0] = \frac{y[0]}{h[0]} = \frac{1}{1} = 1$$

So,

$$g[1] = 1 - 1 = 0$$

**MCQ 1.32**

The circuit shown is a



(A) low pass filter with  $f_{3dB} = \frac{1}{(R_1 + R_2)C}$  rad/s

(B) high pass filter with  $f_{3dB} = \frac{1}{R_1 C}$  rad/s

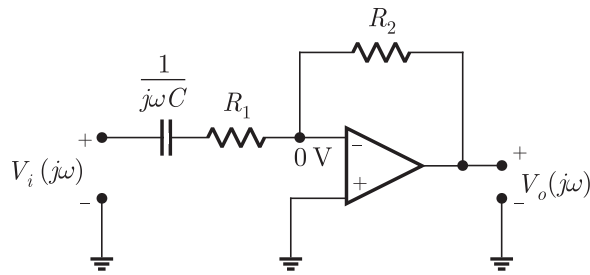
(C) low pass filter with  $f_{3dB} = \frac{1}{R_1 C}$  rad/s

(D) high pass filter with  $f_{3dB} = \frac{1}{(R_1 + R_2)C}$  rad/s

**SOL 1.32**

Option (B) is correct.

First we obtain the transfer function.



$$\frac{0 - V_i(j\omega)}{\frac{1}{j\omega C} + R_1} + \frac{0 - V_o(j\omega)}{R_2} = 0$$

$$\frac{V_o(j\omega)}{R_2} = \frac{-V_i(j\omega)}{\frac{1}{j\omega C} + R_1}$$

$$V_o(j\omega) = -\frac{V_i(j\omega) R_2}{R_1 - j\frac{1}{\omega C}}$$

At  $\omega \rightarrow 0$  (Low frequencies)

$$\frac{1}{\omega C} \rightarrow \infty, \text{ so } V_o = 0$$

At  $\omega \rightarrow \infty$  (higher frequencies)

$$\frac{1}{\omega C} \rightarrow 0, \text{ so } V_o(j\omega) = -\frac{R_2}{R_1} V_i(j\omega)$$

The filter passes high frequencies so it is a high pass filter.

$$H(j\omega) = \frac{V_o}{V_i} = \frac{-R_2}{R_1 - j\frac{1}{\omega C}}$$

$$|H(\infty)| = \left| \frac{-R_2}{R_1} \right| = \frac{R_2}{R_1}$$

At 3 dB frequency, gain will be  $\sqrt{2}$  times of maximum gain  $[H(\infty)]$

$$|H(j\omega_0)| = \frac{1}{\sqrt{2}} |H(\infty)|$$

$$\text{So, } \frac{R_2}{\sqrt{R_1^2 + \frac{1}{\omega_0^2 C^2}}} = \frac{1}{\sqrt{2}} \left( \frac{R_2}{R_1} \right)$$

$$2R_1^2 = R_1^2 + \frac{1}{\omega_0^2 C^2}$$

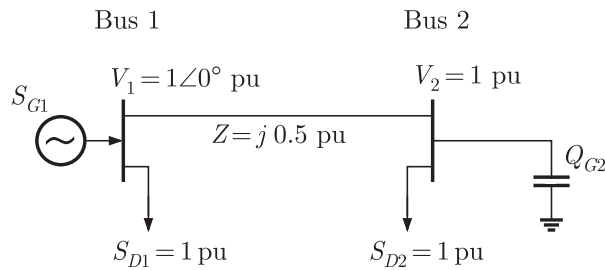
$$R_1^2 = \frac{1}{\omega^2 C^2}$$

$$\omega_0 = \frac{1}{R_1 C}$$

**MCQ 1.33** For the system below,  $S_{D1}$  and  $S_{D2}$  are complex power demands at bus 1 and bus 2 respectively. If  $|\mathbf{V}_2| = 1$  pu, the VAR rating of the capacitor ( $Q_{C2}$ ) connected at



bus 2 is



- (A) 0.2 pu (B) 0.268 pu  
(C) 0.312 pu (D) 0.4 pu

**SOL 1.33** Option (B) is correct.

Complex power for generator

$$S_{G_1} = S_{D_1} + S_{D_2} = 1 + 1 = 2 \text{ pu} \quad (\text{Line is lossless})$$

Power transferred from bus 1 to bus 2 is 1 pu, so

$$1 = \frac{|\mathbf{V}_1| |\mathbf{V}_2| \sin(\theta_1 - \theta_2)}{X}$$

$$= \frac{1 \times 1}{0.5} \sin(\theta_1 - \theta_2)$$

$$|\mathbf{V}_1| = |\mathbf{V}_2| = 1 \text{ pu} \\ X = 0.5 \text{ pu}$$

$$0.5 = \sin(\theta_1 - \theta_2)$$

$$\theta_1 - \theta_2 = 30^\circ$$

$$\theta_2 = \theta_1 - 30^\circ = -30^\circ$$

$$(\theta_1 = 0^\circ)$$

So,

$$\mathbf{V}_1 = 1 \angle 0^\circ \text{ V}$$

$$\mathbf{V}_2 = 1 \angle -30^\circ \text{ V}$$

Current,

$$\mathbf{I}_{12} = \frac{\mathbf{V}_1 - \mathbf{V}_2}{Z} = \frac{1 \angle 0^\circ - 1 \angle 30^\circ}{j0.5}$$

$$= (1 - j0.288) \text{ pu}$$

Current in  $S_{D_2}$  is  $\mathbf{I}_2$ ,

$$S_{D_2} = \mathbf{V}_2 \mathbf{I}_2^*$$

$$1 = 1 \angle -30^\circ \mathbf{I}_2^*$$

$$\mathbf{I}_2 = 1 \angle -30^\circ \text{ pu}$$

Current in  $Q_{G_2}$ ,

$$\mathbf{I}_G = \mathbf{I}_2 - \mathbf{I}_{12}$$

$$= 1 \angle -30^\circ - (1 - j0.288)$$

$$= 0.268 \angle -120^\circ$$

VAR rating of capacitor,

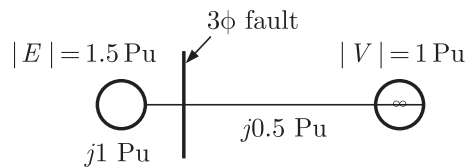
$$Q_C = |\mathbf{V}_2| |\mathbf{I}_G| = 1 \times 0.268 = 0.268 \text{ pu}$$

**MCQ 1.34** A cylinder rotor generator delivers 0.5 pu power in the steady-state to an infinite

bus through a transmission line of reactance 0.5 pu. The generator no-load voltage is 1.5 pu and the infinite bus voltage is 1 pu. The inertia constant of the generator is 5 MW-s/MVA and the generator reactance is 1 pu. The critical clearing angle, in degrees, for a three-phase dead short circuit fault at the generator terminal is

- (A) 53.5 (B) 60.2  
(C) 70.8 (D) 79.6

**SOL 1.34** Option (D) is correct.



Total reactance,  $X = j1 + j0.5 = j1.5$  pu

Critical angle is given as,

$$\delta_{cr} = \cos^{-1}[(\pi - 2\delta_0) \sin \delta_0 - \cos \delta_0] \quad \dots(i)$$

$\delta_0 \rightarrow$  steady state torque angle.

Steady state power is given as

$$P_m = P_{\max} \sin \delta_0$$

where,

$$P_{\max} = \frac{|E||V|}{|X|}$$

So,

$$P_m = \frac{|E||V|}{|X|} \sin \delta_0$$

$$0.5 = \frac{(1.5)(1)}{1.5} \sin \delta_0$$

$$P_m = 0.5 \text{ pu}$$

$$\sin \delta_0 = 0.5$$

$$\delta_0 = 30^\circ$$

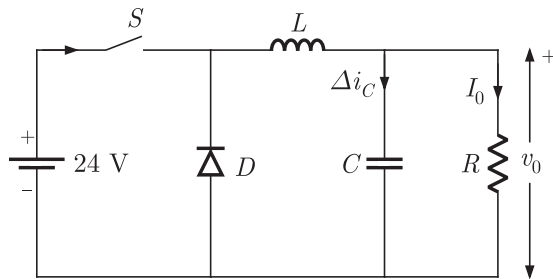
In radian,

$$\delta_0 = 30^\circ \times \frac{\pi}{180^\circ} = 0.523$$

Substituting  $\delta_0$  into equation (i)

$$\begin{aligned} \delta_{cr} &= \cos^{-1}[(\pi - 2 \times 0.523) \sin 30^\circ - \cos 30^\circ] \\ &= \cos^{-1}[(2.095)(0.5) - 0.866] \\ &= \cos^{-1}(0.1815) \\ &\simeq 79.6^\circ \end{aligned}$$

**MCQ 1.35** In the circuit shown, an ideal switch  $S$  is operated at 100 kHz with a duty ratio of 50%. Given that  $\Delta i_c$  is 1.6 A peak-to-peak and  $I_0$  is 5 A dc, the peak current in  $S$ , is



- (A) 6.6 A (B) 5.0 A  
(C) 5.8 A (D) 4.2 A

**SOL 1.35** Option (C) is correct.

$$I_S = I_0 + \frac{\Delta i_C}{2} = 5 + 0.8 = 5.8 \text{ A}$$

**MCQ 1.36** A 220 V, 15 kW, 100 rpm shunt motor with armature resistance of  $0.25 \Omega$ , has a rated line current of 68 A and a rated field current of 2.2 A. The change in field flux required to obtain a speed of 1600 rpm while drawing a line current of 52.8 A and a field current of 1.8 A is

- (A) 18.18% increase (B) 18.18% decrease  
(C) 36.36% increase (D) 36.36% decrease

**SOL 1.36** Option (D) is correct.

$$E \propto n\phi$$

where  $n \rightarrow$  speed,  $\phi \rightarrow$  flux and  $E \rightarrow$  back emf

Given that,

$$V_t = 250 \text{ V}, R_a = 0.25 \Omega$$

$$n_1 = 1000 \text{ rpm}, I_{L1} = 68 \text{ A}, I_{F1} = 2.2 \text{ A}$$

Armature current,

$$I_{a1} = I_{L1} - I_{F1} = 68 - 2.2 = 65.8 \text{ A}$$

$$\begin{aligned} E_1 &= V_t - I_{a1} R_a \\ &= 250 - (65.8)(0.25) \\ &= 203.55 \text{ V} \end{aligned}$$

Now,

$$n_2 = 1600 \text{ rpm}, I_{L2} = 52.8 \text{ A}, I_{F2} = 1.8 \text{ A}$$

Armature current,

$$\begin{aligned} I_{a2} &= I_{L2} - I_{F2} \\ &= 52.8 - 1.8 \\ &= 51 \text{ A} \end{aligned}$$

$$\begin{aligned} E_2 &= V_t - I_{a2} R_a \\ &= 220 - (51)(0.25) \\ &= 207.25 \text{ V} \end{aligned}$$

$$\frac{E_1}{E_2} = \left( \frac{n_1}{n_2} \right) \left( \frac{\phi_1}{\phi_2} \right)$$

$$\frac{203.55}{207.25} = \left( \frac{1000}{1600} \right) \left( \frac{\phi_1}{\phi_2} \right)$$

$$\phi_2 = 0.6369\phi_1$$

$$\begin{aligned} \% \text{ reduce in flux} &= \frac{\phi_1 - \phi_2}{\phi_1} \times 100 \\ &= \frac{\phi_1 - 0.6369\phi_1}{\phi_1} \times 100 \\ &\simeq 36.3\% \end{aligned}$$

**MCQ 1.37** A fair coin is tossed till a head appears for the first time. The probability that the number of required tosses is odd, is

- (A) 1/3 (B) 1/2  
(C) 2/3 (D) 3/4

**SOL 1.37** Option (C) is correct.

Probability of appearing a head is 1/2. If the number of required tosses is odd, we have following sequence of events.

$$H, TTH, TTTTH, \dots$$

Probability  $P = \frac{1}{2} + \left(\frac{1}{2}\right)^3 + \left(\frac{1}{2}\right)^5 + \dots$

$$P = \frac{\frac{1}{2}}{1 - \frac{1}{4}} = \frac{2}{3}$$

**MCQ 1.38** The direction of vector  $\mathbf{A}$  is radially outward from the origin, with  $|\mathbf{A}| = kr^n$ , where  $r^2 = x^2 + y^2 + z^2$  and  $k$  is a constant. The value of  $n$  for which  $\nabla \cdot \mathbf{A} = 0$  is

- (A) -2 (B) 2  
(C) 1 (D) 0

**SOL 1.38** Option (A) is correct.

Divergence of  $\mathbf{A}$  in spherical coordinates is given as

$$\begin{aligned} \nabla \cdot \mathbf{A} &= \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 A_r) \\ &= \frac{1}{r^2} \frac{\partial}{\partial r} (kr^{n+2}) \\ &= \frac{k}{r^2} (n+2) r^{n+1} \\ &= k(n+2) r^{n-1} = 0 \quad (\text{given}) \\ n+2 &= 0 \\ n &= -2 \end{aligned}$$

**MCQ 1.39** Consider the differential equation

$$\frac{d^2 y(t)}{dt^2} + 2 \frac{dy(t)}{dt} + y(t) = \delta(t) \text{ with } y(t)|_{t=0^-} = -2 \text{ and } \frac{dy}{dt} \Big|_{t=0^-} = 0$$

The numerical value of  $\left. \frac{dy}{dt} \right|_{t=0^+}$  is  
 (A)  $-2$  (B)  $-1$   
 (C)  $0$  (D)  $1$

**SOL 1.39** Option (D) is correct.

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

By taking Laplace transform with initial conditions

$$\left[ s^2 Y(s) - sy(0) - \left. \frac{dy}{dt} \right|_{t=0} \right] + 2[sY(s) - y(0)] + Y(s) = 1$$

$$\Rightarrow [s^2 Y(s) + 2s - 0] + 2[sY(s) + 2] + Y(s) = 1$$

$$Y(s)[s^2 + 2s + 1] = 1 - 2s - 4$$

$$Y(s) = \frac{-2s - 3}{s^2 + 2s + 1}$$

We know that,

If,  $y(t) \xleftrightarrow{\mathcal{L}} Y(s)$

then,  $\frac{dy(t)}{dt} \xleftrightarrow{\mathcal{L}} sY(s) - y(0)$

So, 
$$sY(s) - y(0) = \frac{(-2s - 3)s}{(s^2 + 2s + 1)} + 2$$

$$= \frac{-2s^2 - 3s + 2s^2 + 4s + 2}{(s^2 + 2s + 1)}$$

$$sY(s) - y(0) = \frac{s + 2}{(s + 1)^2} = \frac{s + 1}{(s + 1)^2} + \frac{1}{(s + 1)^2}$$

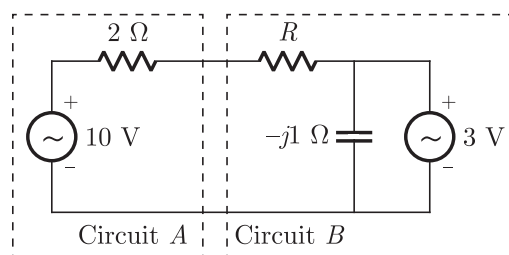
$$= \frac{1}{s + 1} + \frac{1}{(s + 1)^2}$$

By taking inverse Laplace transform

$$\frac{dy(t)}{dt} = e^{-t} u(t) + te^{-t} u(t)$$

At  $t = 0^+$ ,  $\left. \frac{dy}{dt} \right|_{t=0^+} = e^0 + 0 = 1$

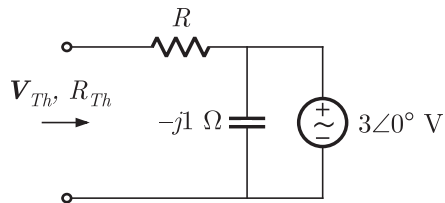
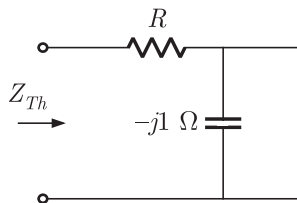
**MCQ 1.40** Assuming both the voltage sources are in phase, the value of  $R$  for which maximum power is transferred from circuit A to circuit B is



- (A)  $0.8 \Omega$  (B)  $1.4 \Omega$   
 (C)  $2 \Omega$  (D)  $2.8 \Omega$

**SOL 1.40**

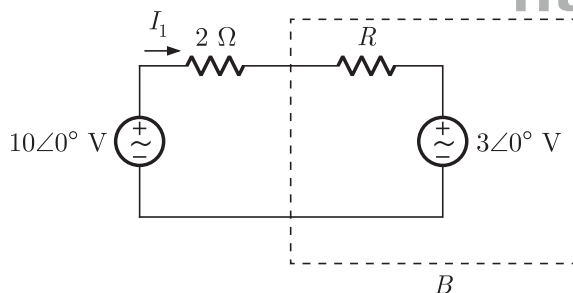
Option (A) is correct.

We obtain Thevenin equivalent of circuit  $B$ .**Thevenin Impedance :****Thevenin Voltage :**

$$Z_{Th} = R$$

$$V_{Th} = 3\angle 0^\circ \text{ V}$$

Now, circuit becomes as



Current in the circuit, 
$$I_1 = \frac{10 - 3}{2 + R}$$

Power transfer from circuit  $A$  to  $B$ 

$$P = (I_1^2)R + 3I_1$$

$$P = \left[ \frac{10 - 3}{2 + R} \right]^2 R + 3 \left[ \frac{10 - 3}{2 + R} \right]$$

$$P = \frac{49R}{(2 + R)^2} + \frac{21}{(2 + R)}$$

$$P = \frac{49R + 21(2 + R)}{(2 + R)^2}$$

$$P = \frac{42 + 70R}{(2 + R)^2}$$

$$\frac{dP}{dR} = \frac{(2 + R)^2 70 - (42 + 70R) 2(2 + R)}{(2 + R)^4} = 0$$

$$(2 + R)[(2 + R) 70 - (42 + 70R) 2] = 0$$

$$140 + 70R - 84 - 140R = 0$$

$$56 = 70R$$

$$R = 0.8 \Omega$$

**MCQ 1.41** The state variable description of an LTI system is given by

$$\begin{pmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{pmatrix} = \begin{pmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} u$$

$$y = (1 \ 0 \ 0) \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$$

where  $y$  is the output and  $u$  is the input. The system is controllable for

- (A)  $a_1 \neq 0, a_2 = 0, a_3 \neq 0$  (B)  $a_1 = 0, a_2 \neq 0, a_3 \neq 0$   
 (C)  $a_1 = 0, a_3 \neq 0, a_2 = 0$  (D)  $a_1 \neq 0, a_2 \neq 0, a_3 = 0$

**SOL 1.41** Option (D) is correct.

General form of state equations are given as

$$\begin{aligned} \dot{x} &= \mathbf{A}x + \mathbf{B}u \\ \dot{y} &= \mathbf{C}x + \mathbf{D}u \end{aligned}$$

For the given problem

$$\mathbf{A} = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\mathbf{A}\mathbf{B} = \begin{bmatrix} 0 & a_1 & 0 \\ 0 & 0 & a_2 \\ a_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ a_2 \\ 0 \end{bmatrix}$$

$$\mathbf{A}^2\mathbf{B} = \begin{bmatrix} 0 & 0 & a_1 a_2 \\ a_2 a_3 & 0 & 0 \\ 0 & a_3 a_1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} a_1 a_2 \\ 0 \\ 0 \end{bmatrix}$$

For controllability it is necessary that following matrix has a rank of  $n = 3$ .

$$\mathbf{U} = [\mathbf{B} : \mathbf{A}\mathbf{B} : \mathbf{A}^2\mathbf{B}]$$

$$= \begin{bmatrix} 0 & 0 & a_1 a_2 \\ 0 & a_2 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

So,

$$a_2 \neq 0$$

$$a_1 a_2 \neq 0 \Rightarrow a_1 \neq 0$$

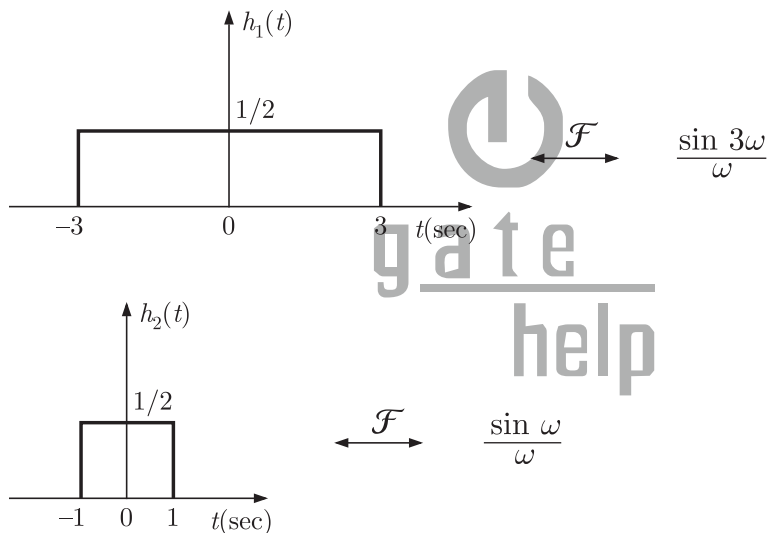
$a_3$  may be zero or not.

- MCQ 1.42** The Fourier transform of a signal  $h(t)$  is  $H(j\omega) = (2 \cos \omega) (\sin 2\omega) / \omega$ . The value of  $h(0)$  is
- (A) 1/4 (B) 1/2  
(C) 1 (D) 2

**SOL 1.42** Option (C) is correct.

$$\begin{aligned} H(j\omega) &= \frac{(2 \cos \omega) (\sin 2\omega)}{\omega} \\ &= \frac{\sin 3\omega}{\omega} + \frac{\sin \omega}{\omega} \end{aligned}$$

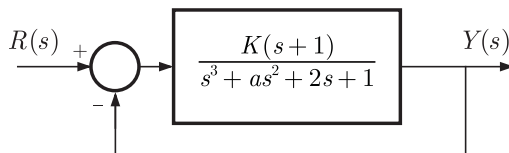
We know that inverse Fourier transform of  $\sin c$  function is a rectangular function.



So, inverse Fourier transform of  $H(j\omega)$

$$\begin{aligned} h(t) &= h_1(t) + h_2(t) \\ h(0) &= h_1(0) + h_2(0) \\ &= \frac{1}{2} + \frac{1}{2} = 1 \end{aligned}$$

- MCQ 1.43** The feedback system shown below oscillates at 2 rad/s when



- (A)  $K = 2$  and  $a = 0.75$  (B)  $K = 3$  and  $a = 0.75$   
(C)  $K = 4$  and  $a = 0.5$  (D)  $K = 2$  and  $a = 0.5$

**SOL 1.43** Option (A) is correct.



$$Y(s) = \frac{K(s+1)}{s^3 + as^2 + 2s + 1} [R(s) - Y(s)]$$

$$Y(s) \left[ 1 + \frac{K(s+1)}{s^3 + as^2 + 2s + 1} \right] = \frac{K(s+1)}{s^3 + as^2 + 2s + 1} R(s)$$

$$Y(s) [s^3 + as^2 + s(2+k) + (1+k)] = K(s+1) R(s)$$

Transfer Function

$$H(s) = \frac{Y(s)}{R(s)} = \frac{K(s+1)}{s^3 + as^2 + s(2+k) + (1+k)}$$

Routh Table :

$s^3$	1	$2+K$
$s^2$	$a$	$1+K$
$s^1$	$\frac{a(2+K) - (1+K)}{a}$	0

For oscillation,

$$\frac{a(2+K) - (1+K)}{a} = 0$$

$$a = \frac{K+1}{K+2}$$

Auxiliary equation

$$A(s) = as^2 + (k+1) = 0$$

$$s^2 = -\frac{k+1}{a}$$

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

$$s^2 = -(k+2)$$

$$s = j\sqrt{k+2}$$

$$j\omega = j\sqrt{k+2}$$

$$\omega = \sqrt{k+2} = 2$$

(Oscillation frequency)

$$k = 2$$

and

$$a = \frac{2+1}{2+2} = \frac{3}{4} = 0.75$$

**MCQ 1.44**

The input  $x(t)$  and output  $y(t)$  of a system are related as  $y(t) = \int_{-\infty}^t x(\tau) \cos(3\tau) d\tau$ . The system is

- (A) time-invariant and stable                      (B) stable and not time-invariant  
 (C) time-invariant and not stable                (D) not time-invariant and not stable

**SOL 1.44**

Option (D) is correct.

$$y(t) = \int_{-\infty}^t x(\tau) \cos(3\tau) d\tau$$

**Time invariance :**

Let,

$$\begin{aligned}
 x(t) &= \delta(t) \\
 y(t) &= \int_{-\infty}^t \delta(\tau) \cos(3\tau) d\tau \\
 &= u(t) \cos(0) \\
 &= u(t)
 \end{aligned}$$

For a delayed input  $(t - t_0)$  output is

$$\begin{aligned}
 y(t, t_0) &= \int_{-\infty}^t \delta(\tau - t_0) \cos(3\tau) d\tau \\
 &= u(t) \cos(3t_0)
 \end{aligned}$$

Delayed output

$$\begin{aligned}
 y(t - t_0) &= u(t - t_0) \\
 y(t, t_0) &\neq y(t - t_0)
 \end{aligned}$$

System is not time invariant.

**Stability :**

Consider a bounded input  $x(t) = \cos 3t$

$$\begin{aligned}
 y(t) &= \int_{-\infty}^t \cos^2 3\tau d\tau = \int_{-\infty}^t \frac{1 + \cos 6\tau}{2} d\tau \\
 &= \frac{1}{2} \int_{-\infty}^t 1 d\tau + \frac{1}{2} \int_{-\infty}^t \cos 6\tau d\tau
 \end{aligned}$$

As  $t \rightarrow \infty$ ,  $y(t) \rightarrow \infty$  (unbounded)

System is not stable.

**MCQ 1.45**

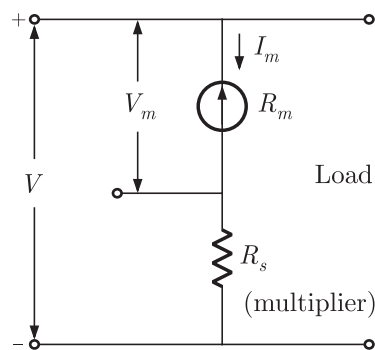
An analog voltmeter uses external multiplier settings. With a multiplier setting of  $20 \text{ k}\Omega$ , it reads  $440 \text{ V}$  and with a multiplier setting of  $80 \text{ k}\Omega$ , it reads  $352 \text{ V}$ . For a multiplier setting of  $40 \text{ k}\Omega$ , the voltmeter reads

- (A)  $371 \text{ V}$  (B)  $383 \text{ V}$   
 (C)  $394 \text{ V}$  (D)  $406 \text{ V}$

**SOL 1.45**

Option (D) is correct.

A voltmeter with a multiplier is shown in figure below.



Here

$I_m$  = Fully scale deflection current of meter.

$R_m$  = Internal resistance of meter

$R_s$  = Voltage across the meter

$V =$  Full range voltage of instrument

$$V_m = I_m R_m$$

$$V = I_m (R_m + R_s)$$

$$\frac{V}{V_m} = \frac{R_m + R_s}{R_m} = 1 + \frac{R_s}{R_m}$$

Here when,  $R_{s1} = 20 \text{ k}\Omega$ ,  $V_{m1} = 440 \text{ V}$

$$\text{So, } \frac{V}{440} = 1 + \frac{20\text{k}}{R_m} \quad \dots(i)$$

When,  $R_{s2} = 80 \text{ k}\Omega$ ,  $V_{m2} = 352 \text{ V}$

$$\text{So, } \frac{V}{352} = 1 + \frac{80\text{k}}{R_m} \quad \dots(ii)$$

Solving equation (i) and (ii), we get

$$V = 480 \text{ V}, R_m = 220 \text{ k}\Omega$$

So when  $R_{s3} = 40 \text{ k}\Omega$ ,  $V_{m3} = ?$

$$\frac{480}{V_{m3}} = 1 + \frac{40\text{k}}{220\text{k}}$$

$$V_{m3} \simeq 406 \text{ V}$$

**MCQ 1.46** The locked rotor current in a 3-phase, star connected 15 kW, 4 pole, 230 V, 50 Hz induction motor at rated conditions is 50 A. Neglecting losses and magnetizing current, the approximate locked rotor line current drawn when the motor is connected to a 236 V, 57 Hz supply is

- (A) 58.5 A (B) 45.0 A  
(C) 42.7 A (D) 55.6 A

**SOL 1.46** Option (B) is correct.

Given that magnetizing current and losses are to be neglected. Locked rotor line current.

$$I_2 = \frac{E_2}{Z_2} = \frac{E_2}{\sqrt{R_2^2 + X_2^2}} \quad (R_2 = 0)$$

$$I_2 = \frac{E_2}{X_2}$$

$$I_2 = \frac{E_2}{\omega L_2}$$

$$I_2 \propto \frac{E_2}{f}$$

$$\text{So } \frac{50}{I_2'} = \left(\frac{230}{236}\right)\left(\frac{57}{50}\right)$$

$$I_2' = 45.0 \text{ A}$$

**MCQ 1.47** A single phase 10 kVA, 50 Hz transformer with 1 kV primary winding draws 0.5 A

and 55 W, at rated voltage and frequency, on no load. A second transformer has a core with all its linear dimensions  $\sqrt{2}$  times the corresponding dimensions of the first transformer. The core material and lamination thickness are the same in both transformer. The primary winding of both the transformers have the same number of turns. If a rated voltage of 2 kV at 50 Hz is applied to the primary of the second transformer, then the no load current and power, respectively, are

- (A) 0.7 A, 77.8 A (B) 0.7 A, 155.6 W  
(C) 1 A, 110 W (D) 1 A, 220 W

**SOL 1.47**

Option (B) is correct.

Since the core length of the second transformer is  $\sqrt{2}$  times of the first, so the core area of the second transformer is twice of the first.

Let subscript 1 is used for first transformer and 2 is used for second transform.

Area

$$a_2 = 2a_1$$

Length

$$l_2 = \sqrt{2} l_1$$

Magnetizing inductance,

$$L = \frac{N^2 \mu a}{l}$$

$N$  = no. of turns

$\mu$  = length of flux path

$a$  = cross section area

$l$  = length

$$L \propto \frac{a}{l}$$

$N$  and  $\mu$  are same for both the transformer

$$\frac{L_1}{L_2} = \frac{a_1}{a_2} \cdot \frac{l_2}{l_1}$$

$$\frac{L_1}{L_2} = \frac{a_1}{2a_1} \cdot \frac{\sqrt{2} l_1}{l_1}$$

$$L_2 = \sqrt{2} L_1$$

Thus, magnetizing reactance of second transformer is  $\sqrt{2}$  times of first.

Magnetizing current  $X_{m2} = \sqrt{2} X_{m1}$

$$I_m = \frac{V}{X_m}$$

$$\frac{I_{m1}}{I_{m2}} = \frac{V_1}{V_2} \cdot \frac{X_{m2}}{X_{m1}}$$

$$= \left( \frac{V_1}{2V_1} \right) \left( \frac{\sqrt{2} X_{m1}}{X_{m1}} \right) \quad (V_2 = 2V_1)$$

$$I_{m2} = \sqrt{2} I_{m1}$$

Thus, magnetizing current of second transformer

$$I_{m2} = \sqrt{2} \times 0.5 = 0.707 \text{ A}$$

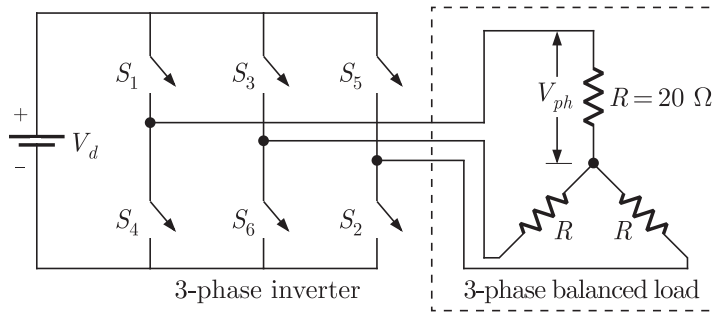
Since voltage of second transformer is twice that of first and current is  $\sqrt{2}$  times that of first, so power will be  $2\sqrt{2}$  times of first transformer.

$$P_2 = 2\sqrt{2} \times 55 = 155.6 \text{ W}$$

### Common Data Question

#### Common Data for Questions 48 and 49

In the 3-phase inverter circuit shown, the load is balanced and the gating scheme is  $180^\circ$  conduction mode. All the switching devices are ideal.



- MCQ 1.48** The rms value of load phase voltage is  
 (A) 106.1 V (B) 141.4 V  
 (C) 212.2 V (D) 282.8 V

- SOL 1.48** Option (B) is correct.  
 For a three-phase bridge inverter, rms value of output line voltage is

$$\begin{aligned}
 V_L &= \frac{\sqrt{2}}{3} V_{dc} \\
 &= \frac{\sqrt{2}}{3} \times 300 & V_{dc} = 300 \text{ V} \\
 &= 141.4 \text{ V}
 \end{aligned}$$

- MCQ 1.49** If the dc bus voltage  $V_d = 300 \text{ V}$ , the power consumed by 3-phase load is  
 (A) 1.5 kW (B) 2.0 kW  
 (C) 2.5 kW (D) 3.0 kW

- SOL 1.49** Option (D) is correct.

$$\begin{aligned}
 P &= 3 \times \frac{V_L^2}{R} \\
 &= 3 \times \frac{(141.4)^2}{20} \\
 &\simeq 3 \text{ kW}
 \end{aligned}$$

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

With 10 V dc connected at port A in the linear nonreciprocal two-port network shown below, the following were observed :

- (i)  $1 \Omega$  connected at port B draws a current of 3 A

(ii)  $2.5\ \Omega$  connected at port  $B$  draws a current of  $2\ \text{A}$

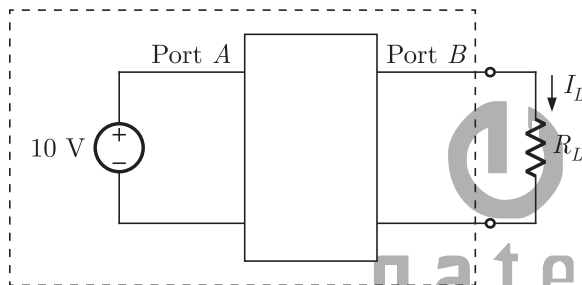


**MCQ 1.50** With  $10\ \text{V}$  dc connected at port  $A$ , the current drawn by  $7\ \Omega$  connected at port  $B$  is

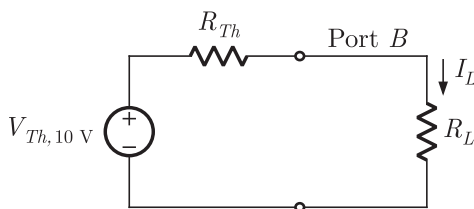
- (A)  $3/7\ \text{A}$  (B)  $5/7\ \text{A}$   
 (C)  $1\ \text{A}$  (D)  $9/7\ \text{A}$

**SOL 1.50** Option (C) is correct.

When  $10\ \text{V}$  is connected at port  $A$  the network is



Now, we obtain Thevenin equivalent for the circuit seen at load terminal, let Thevenin voltage is  $V_{Th,10\ \text{V}}$  with  $10\ \text{V}$  applied at port  $A$  and Thevenin resistance is  $R_{Th}$ .



$$I_L = \frac{V_{Th,10\ \text{V}}}{R_{Th} + R_L}$$

For  $R_L = 1\ \Omega$ ,  $I_L = 3\ \text{A}$

$$3 = \frac{V_{Th,10\ \text{V}}}{R_{Th} + 1} \quad \dots(i)$$

For  $R_L = 2.5\ \Omega$ ,  $I_L = 2\ \text{A}$

$$= \frac{V_{Th,10\ \text{V}}}{R_{Th} + 2.5} \quad \dots(ii)$$

Dividing above two

$$\frac{3}{2} = \frac{R_{Th} + 2.5}{R_{Th} + 1}$$

$$3R_{Th} + 3 = 2R_{Th} + 5$$

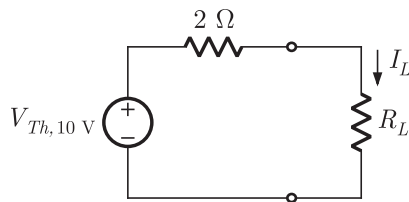
$$R_{Th} = 2 \Omega$$

Substituting  $R_{Th}$  into equation (i)

$$V_{Th,10V} = 3(2 + 1) = 9 \text{ V}$$

Note that it is a non reciprocal two port network. Thevenin voltage seen at port  $B$  depends on the voltage connected at port  $A$ . Therefore we took subscript  $V_{Th,10V}$ . This is Thevenin voltage only when 10 V source is connected at input port  $A$ . If the voltage connected to port  $A$  is different, then Thevenin voltage will be different. However, Thevenin's resistance remains same.

Now, the circuit is



For  $R_L = 7 \Omega$

$$I_L = \frac{V_{Th,10V}}{2 + R_L} = \frac{9}{2 + 7} = 1 \text{ A}$$

**MCQ 1.51**

For the same network, with 6 V dc connected at port  $A$ , 1  $\Omega$  connected at port  $B$  draws 7/3 A. If 8 V dc is connected to port  $A$ , the open circuit voltage at port  $B$  is

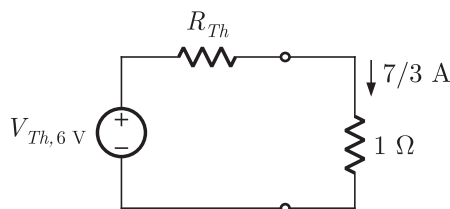
- (A) 6 V (B) 7 V  
(C) 8 V (D) 9 V

**SOL 1.51**

Option (B) is correct.

Now, when 6 V connected at port  $A$  let Thevenin voltage seen at port  $B$  is  $V_{Th,6V}$ .

Here  $R_L = 1 \Omega$  and  $I_L = \frac{7}{3} \text{ A}$



$$\begin{aligned} V_{Th,6V} &= R_{Th} \times \frac{7}{3} + 1 \times \frac{7}{3} \\ &= 2 \times \frac{7}{3} + \frac{7}{3} = 7 \text{ V} \end{aligned}$$

This is a linear network, so  $V_{Th}$  at port  $B$  can be written as

$$V_{Th} = V_1 \alpha + \beta$$

where  $V_1$  is the input applied at port  $A$ .

We have  $V_1 = 10 \text{ V}$ ,  $V_{Th,10V} = 9 \text{ V}$

$$\therefore 9 = 10\alpha + \beta \quad \dots(i)$$

When  $V_1 = 6 \text{ V}$ ,  $V_{Th,6V} = 9 \text{ V}$

$$\therefore 7 = 6\alpha + \beta \quad \dots(ii)$$

Solving (i) and (ii)

$$\alpha = 0.5, \beta = 4$$

Thus, with any voltage  $V_1$  applied at port  $A$ , Thevenin voltage or open circuit voltage at port  $B$  will be

$$\text{So, } V_{Th,V_1} = 0.5V_1 + 4$$

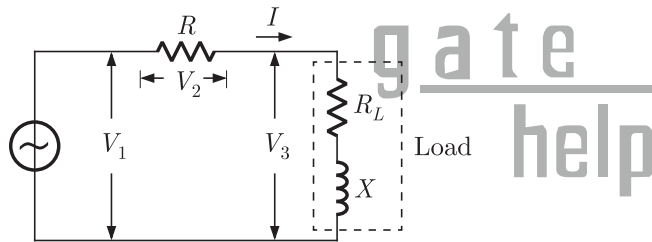
$$\text{For } V_1 = 8 \text{ V}$$

$$V_{Th,8V} = 0.5 \times 8 + 4 = 8 = V_{oc} \quad (\text{open circuit voltage})$$

### Linked Answer Question

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

In the circuit shown, the three voltmeter readings are  $V_1 = 220 \text{ V}$ ,  $V_2 = 122 \text{ V}$ ,  $V_3 = 136 \text{ V}$ .



**MCQ 1.52** The power factor of the load is

- (A) 0.45 (B) 0.50  
(C) 0.55 (D) 0.60

**SOL 1.52** Option (A) is correct.

By taking  $V_1$ ,  $V_2$  and  $V_3$  all are phasor voltages.

$$V_1 = V_2 + V_3$$

Magnitude of  $V_1$ ,  $V_2$  and  $V_3$  are given as

$$V_1 = 220 \text{ V}, V_2 = 122 \text{ V}, V_3 = 136 \text{ V}$$

Since voltage across  $R$  is in same phase with  $V_1$  and the voltage  $V_3$  has a phase difference of  $\theta$  with voltage  $V_1$ , we write in polar form

$$V_1 = V_2 / 0^\circ + V_3 / \theta$$

$$V_1 = V_2 + V_3 \cos \theta + jV_3 \sin \theta$$

$$V_1 = (V_2 + V_3 \cos \theta) + jV_3 \sin \theta$$

$$|V_1| = \sqrt{(V_2 + V_3 \cos \theta)^2 + (V_3 \sin \theta)^2}$$

$$220 = \sqrt{(122 + 136 \cos \theta)^2 + (136 \sin \theta)^2}$$



By solving, power factor

$$\cos \theta = 0.45$$

**MCQ 1.53** If  $R_L = 5 \Omega$ , the approximate power consumption in the load is

- (A) 700 W (B) 750 W  
(C) 800 W (D) 850 W

**SOL 1.53** Option (B) is correct.

Voltage across load resistance

$$\begin{aligned} V_{RL} &= V_3 \cos \theta \\ &= 136 \times 0.45 \\ &= 61.2 \text{ V} \end{aligned}$$

Power absorbed in  $R_L$

$$P_L = \frac{V_{RL}^2}{R_L} = \frac{(61.2)^2}{5} \simeq 750 \text{ W}$$

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

The transfer function of a compensator is given as

$$G_c(s) = \frac{s+a}{s+b}$$

**MCQ 1.54**  $G_c(s)$  is a lead compensator if

- (A)  $a = 1, b = 2$  (B)  $a = 3, b = 2$   
(C)  $a = -3, b = -1$  (D)  $a = 3, b = 1$

**SOL 1.54** Option (A) is correct.

$$G_C(s) = \frac{s+a}{s+b} = \frac{j\omega + a}{j\omega + b}$$

Phase lead angle

$$\phi = \tan^{-1}\left(\frac{\omega}{a}\right) - \tan^{-1}\left(\frac{\omega}{b}\right)$$

$$\begin{aligned} \phi &= \tan^{-1}\left(\frac{\frac{\omega}{a} - \frac{\omega}{b}}{1 + \frac{\omega^2}{ab}}\right) \\ &= \tan^{-1}\left(\frac{\omega(b-a)}{ab + \omega^2}\right) \end{aligned}$$

For phase-lead compensation  $\phi > 0$

$$b - a > 0$$

$$b > a$$

**Note:** For phase lead compensator zero is nearer to the origin as compared to pole, so option (C) can not be true.

**MCQ 1.55** The phase of the above lead compensator is maximum at

- (A)  $\sqrt{2}$  rad/s  
 (B)  $\sqrt{3}$  rad/s  
 (C)  $\sqrt{6}$  rad/s  
 (D)  $1/\sqrt{3}$  rad/s

**SOL 1.55** Option (A) is correct.

$$\phi = \tan^{-1}\left(\frac{\omega}{a}\right) - \tan^{-1}\left(\frac{\omega}{b}\right)$$

$$\frac{d\phi}{d\omega} = \frac{1/a}{1 + \left(\frac{\omega}{a}\right)^2} - \frac{1/b}{1 + \left(\frac{\omega}{b}\right)^2} = 0$$

$$\frac{1}{a} + \frac{\omega^2}{ab^2} = \frac{1}{b} + \frac{\omega^2}{ba^2}$$

$$\frac{1}{a} - \frac{1}{b} = \frac{\omega^2}{ab}\left(\frac{1}{a} - \frac{1}{b}\right)$$

$$\omega = \sqrt{ab}$$

$$= \sqrt{1 \times 2} = \sqrt{2} \text{ rad/sec}$$

### General Aptitude (GA) Question (Compulsory)

**Q. 56 - Q. 60** carry one mark each.

**MCQ 1.56** One of the parts (A, B, C, D) in the sentence given below contains an ERROR. Which one of the following is **INCORRECT**?

**I requested that he should be given the driving test today instead of tomorrow.**

- (A) requested that  
 (B) should be given  
 (C) the driving test  
 (D) instead of tomorrow

**SOL 1.56** Option (B) is correct.

**MCQ 1.57** If  $(1.001)^{1259} = 3.52$  and  $(1.001)^{2062} = 7.85$ , then  $(1.001)^{3321}$

- (A) 2.23  
 (B) 4.33  
 (C) 11.37  
 (D) 27.64

**SOL 1.57** Option (D) is correct option.

Let  $1.001 = x$

So in given data :

$$x^{1259} = 3.52$$

$$x^{2062} = 7.85$$

Again  $x^{3321} = x^{1259+2062}$

$$= x^{1259} x^{2062}$$

$$= 3.52 \times 7.85$$

$$= 27.64$$

**MCQ 1.58** Choose the most appropriate alternate from the options given below to complete the following sentence :

**If the tired soldier wanted to lie down, he.....the mattress out on the balcony.**

- (A) should take (B) shall take  
(C) should have taken (D) will have taken

**SOL 1.58** Option (C) is correct.

**MCQ 1.59** Choose the most appropriate word from the options given below to complete the following sentence :

**Give the seriousness of the situation that he had to face, his.....was impressive.**

- (A) beggary (B) nomenclature  
(C) jealousy (D) nonchalance

**SOL 1.59** Option (D) is correct.

**MCQ 1.60** Which one of the following options is the closest in meaning to the word given below ?

**Latitude**

- (A) Eligibility (B) Freedom  
(C) Coercion (D) Meticulousness

**SOL 1.60** Option (B) is correct.

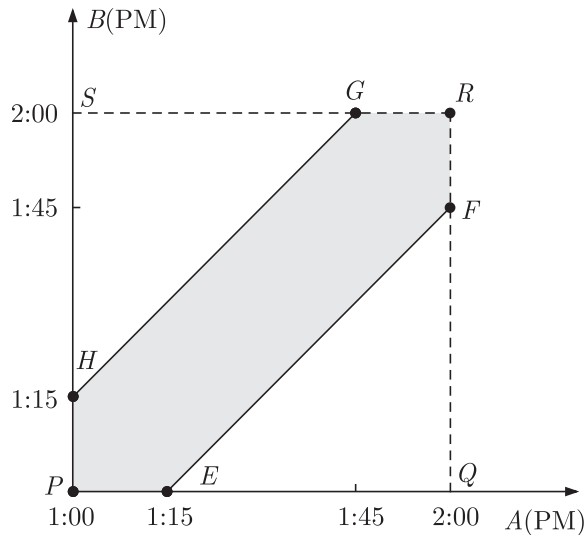
**Q. 61 - Q. 65 carry two marks each.**

**MCQ 1.61** A and B are friends. They decide to meet between 1 PM and 2 PM on a given day. There is a conditions that whoever arrives first will not wait for the other for more than 15 minutes. The probability that they will meet on that days is

- (A)  $1/4$  (B)  $1/16$   
(C)  $7/16$  (D)  $9/16$

**SOL 1.61** Option (C) is correct.

The graphical representation of their arriving time so that they met is given as below in the figure by shaded region.



So, the area of shaded region is given by

$$\begin{aligned} & \text{Area of } \square PQRS - (\text{Area of } \triangle EFQ + \text{Area of } \triangle GSH) \\ &= 60 \times 60 - 2\left(\frac{1}{2} \times 45 \times 45\right) \\ &= 1575 \end{aligned}$$

So, the required probability =  $\frac{1575}{3600} = \frac{7}{16}$

**MCQ 1.62** One of the legacies of the Roman legions was discipline. In the legions, military law prevailed and discipline was brutal. Discipline on the battlefield kept units obedient, intact and fighting, even when the odds and conditions were against them.

Which one of the following statements best sums up the meaning of the above passage ?

- (A) Through regimentation was the main reason for the efficiency of the Roman legions even in adverse circumstances.
- (B) The legions were treated inhumanly as if the men were animals
- (C) Disciplines was the armies inheritance from their seniors
- (D) The harsh discipline to which the legions were subjected to led to the odds and conditions being against them.

**SOL 1.62** Option (A) is correct.

**MCQ 1.63** Raju has 14 currency notes in his pocket consisting of only Rs. 20 notes and Rs. 10 notes. The total money values of the notes is Rs. 230. The number of Rs. 10 notes that Raju has is

- (A) 5
- (B) 6
- (C) 9
- (D) 10

**SOL 1.63**

Option (A) is correct.

Let no. of notes of Rs.20 be  $x$  and no. of notes of Rs. 10 be  $y$ .

Then from the given data.

$$x + y = 14$$

$$20x + 10y = 230$$

Solving the above two equations we get

$$x = 9, y = 5$$

So, the no. of notes of Rs. 10 is 5.

**MCQ 1.64**

There are eight bags of rice looking alike, seven of which have equal weight and one is slightly heavier. The weighing balance is of unlimited capacity. Using this balance, the minimum number of weighings required to identify the heavier bag is

(A) 2

(B) 3

(C) 4

(D) 8

**SOL 1.64**

Option (A) is correct.

We will categorize the 8 bags in three groups as :

(i)  $A_1A_2A_3$ , (ii)  $B_1B_2B_3$ , (iii)  $C_1C_2$

Weighting will be done as bellow :

1<sup>st</sup> weighting  $\rightarrow A_1A_2A_3$  will be on one side of balance and  $B_1B_2B_3$  on the other. It may have three results as described in the following cases.

**Case 1 :**  $A_1A_2A_3 = B_1B_2B_3$

This results out that either  $C_1$  or  $C_2$  will heavier for which we will have to perform weighting again.

2<sup>nd</sup> weighting  $\rightarrow C_1$  is kept on the one side and  $C_2$  on the other.

if  $C_1 > C_2$  then  $C_1$  is heavier.

$C_1 < C_2$  then  $C_2$  is heavier.

**Case 2 :**  $A_1A_2A_3 > B_1B_2B_3$

it means one of the  $A_1A_2A_3$  will be heavier So we will perform next weighting as:

2<sup>nd</sup> weighting  $\rightarrow A_1$  is kept on one side of the balance and  $A_2$  on the other.

if  $A_1 = A_2$  it means  $A_3$  will be heavier

$A_1 > A_2$  then  $A_1$  will be heavier

$A_1 < A_2$  then  $A_2$  will be heavier

**Case 3 :**  $A_1A_2A_3 < B_1B_2B_3$

This time one of the  $B_1B_2B_3$  will be heavier, So again as the above case weighting will be done.

2<sup>nd</sup> weighting  $\rightarrow B_1$  is kept one side and  $B_2$  on the other

if  $B_1 = B_2$   $B_3$  will be heavier

$B_1 > B_2$   $B_1$  will be heavier

$B_1 < B_2$   $B_2$  will be heavier

So, as described above, in all the three cases weighting is done only two times to give out the result so minimum no. of weighting required = 2.

**MCQ 1.65** The data given in the following table summarizes the monthly budget of an average household.

Category	Amount (Rs.)
Food	4000
Clothing	1200
Rent	2000
Savings	1500
Other expenses	1800

The approximate percentages of the monthly budget **NOT** spent on savings is

- (A) 10% (B) 14%  
(C) 81% (D) 86%

**SOL 1.65** Option (D) is correct.

$$\begin{aligned}\text{Total budget} &= 4000 + 1200 + 2000 + 1500 + 1800 \\ &= 10,500\end{aligned}$$

The amount spent on saving = 1500

$$\begin{aligned}\text{So, the amount not spent on saving} \\ &= 10,500 - 1500 = 9000\end{aligned}$$

$$\begin{aligned}\text{So, percentage of the amount} \\ &= \frac{9000}{10500} \times 100\% \\ &= 86\%\end{aligned}$$

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