IES MASTER

Institute for Engineers (IES/GATE/PSUs)

GATE 2017

Detailed Solution

ELECTRICAL ENGINEERING
SESSION - 1

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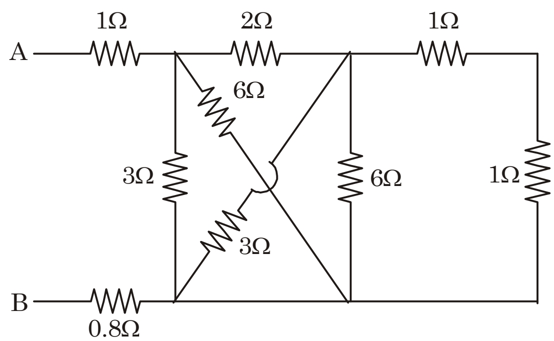
GATE—2017

Electrical Engineering Questions and Detailed Solution

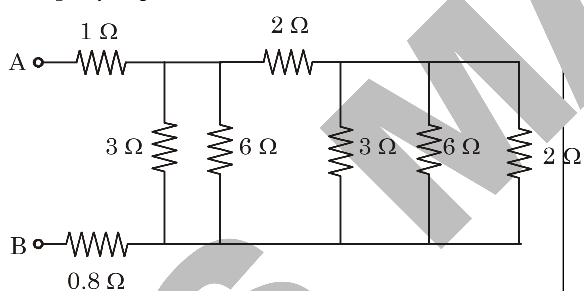
Session-1

1. The equivalent resistance between the terminals A and B is ______ Ω.



Sol. (3Ω)

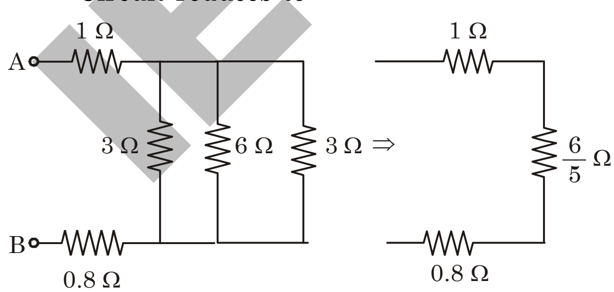
Simplifying the circuit



Combining resistances 3Ω, 6Ω, and 2Ω as these are parallel

$3\Omega \,||\, 6\Omega \,||\, 2\Omega = 1\Omega$

Circuit reduces to



$$R_{eq} = 1+\frac{6}{5}+0.8 = \frac{15}{5}\Omega$$

or $\boxed{R_{eq} = 3\Omega}$

2. Consider an electron a neutron and a proton initially at rest and placed along a straight line such that the neutron is exactly at the center of the line joining the electron and proton. At t = 0, the particles are released but are constrained to move along the same straight line. Which of these will collide first?

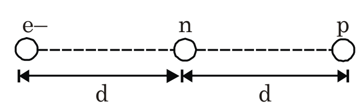
(a) The particles will never collide

(b) All will collide together

(c) Proton and neutron

(d) Electron and neutron

Sol–2 : (d)



Mass of electron = 9.1094×10^{-31} Kg

Mass of proton = 1.6726×10^{-27} Kg

Electrostatic force will exist between electron and proton only. Let say force is 'F' then by relation F = ma, where m is mass of particle and a is acceleration.

Since mass of electron is lesser than proton so acceleration of electron will be more than proton.

By equation

$$s = ut+\frac{1}{2}at^2$$

s = distance travelled

u = inital speed

As u = 0 so $s = \frac{1}{2}at^2$

To travel distance 'd' electron will take lesser time so electron will collide with neutron first.

3. The slope and level detector circuit in a CRO has a delay of 100 ns. The start-stop sweep generator has a response time of 50 ns. In order to display correctly a delay line of

(a) 150 ns has to be inserted into the y-channel

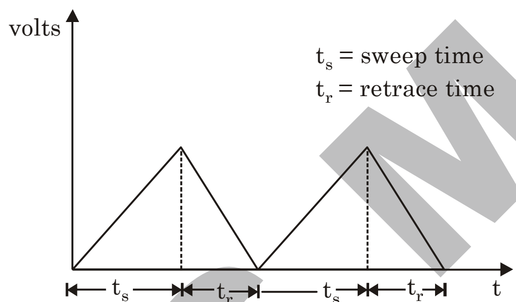
(b) 150 ns has to be inserted into the x-channel

(c) 150 ns has to be inserted into both x and y channels

(d) 100 ns has to be inserted into both x and y channels

Sol. (a)

In a CRO during the sweep time the beam moves left to right across the CRT, during the retrace time the beam quickly moves to the left side of the CRT screen as shown in figure below.



Given data slope and level detector has delay time (t_d) = 100 ns

response time (t_{re}) = 50 ns

so total time taken for one sweep cycle of x-plate

$$= (t_{re} + t_d + t_s + t_r)$$
$$= 150 \text{ ns} + (t_s + t_r)$$

In order to display correctly signal to y-channel has to be applied after a delay of 150 ns.

4. The following measurements are obtained on a single phase load V = 220 V ± 1%. I = 50A ± 1% and W = 555 W ± 2%. If the power factor is calculated using these measurements the worst case error in the calculated power factor in percent is _____(Give answer up to one decimal place)

Sol. (4%)

$$V = 220\text{V} \pm 1\%$$
$$I = 5\text{A} \pm 1\%$$
$$W = 555\text{W} \pm 2\%$$

Since,

$$W = VI\cos\phi$$

So, $$\frac{\delta W}{W} = \pm\left(\frac{\delta V}{V} + \frac{\Delta I}{I} + \frac{\delta(\cos\phi)}{\cos\phi}\right)$$

$$0.02 = \pm\left(0.01 + 0.01 + \frac{\delta(\text{p.f.})}{\text{p.f}}\right)$$

Hence in worst case

$$\frac{\delta(\text{p.f.})}{\text{p.f.}} = 0.02 + 0.01 + 0.01$$
$$= 0.04$$

or in percent 4% or 4.0%

5. A closed loop system has the characteristic equation given by $s^3 + Ks^2 + (K + 2)s + 3 = 0$. For this system to be stable, which one of the following conditions should be satisfied?

(a) $0 < K < 0.5$

(b) $0.5 < K < 1$

(c) $0 < K < 1$

(d) $K > 1$

Sol. (d)

By Routh Hurwitz Criteria

$$\begin{array}{lll} s^3 & 1 & k+2 \\ s^2 & k & 3 \\ s^1 & \dfrac{k(k+2)-3}{k} & \\ s^0 & 3 & \end{array}$$

For stability

$$k > 0 \quad \ldots(i)$$

$$\frac{k(k+2)-3}{k} > 0 \quad \ldots(ii)$$

$$\Rightarrow \quad \frac{(k-1)(k+3)}{k} > 0$$

$\Rightarrow$ Either k > 1; k > –3

or k < 1; k < –3 ...(iii)

From equation (i) and (iii)

k > 1 hence option (d) is the correct answer.

6. The matrix $A = \begin{bmatrix} \frac{3}{2} & 0 & \frac{1}{2} \\ 0 & -1 & 0 \\ \frac{1}{2} & 0 & \frac{3}{2} \end{bmatrix}$ has three distinct eigenvalues and one of its eigenvectors is $\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$. Which one of the following can be another eigenvector of A?

(a) $\begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix}$ (b) $\begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix}$

(c) $\begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}$ (c) $\begin{bmatrix} 1 \\ -1 \\ 1 \end{bmatrix}$

Sol. (c)

$$A = \begin{bmatrix} \frac{3}{2} & 0 & \frac{1}{2} \\ 0 & -1 & 0 \\ \frac{1}{2} & 0 & \frac{3}{2} \end{bmatrix}$$

To find the eigen values of A, $\det(A-\lambda I_3) = 0$ i.e.,

$$\begin{vmatrix} \frac{3}{2}-\lambda & 0 & \frac{1}{2} \\ 0 & -1-\lambda & 0 \\ \frac{1}{2} & 0 & \frac{3}{2}-\lambda \end{vmatrix} = 0$$

$$\left(\frac{3}{2}-\lambda\right)\left[(-1-\lambda)\left(\frac{3}{2}-\lambda\right)\right] + \frac{1}{2}\left[0-\frac{1}{2}(-1-\lambda)\right] = 0$$

$$(-1-\lambda)\left[\left(\frac{3}{2}-\lambda\right)^2 - \frac{1}{4}\right] = 0$$

$$-(1+\lambda)[\lambda^2 - 3\lambda + 2] = 0$$

or $-(1+\lambda)(\lambda-1)(\lambda-2) = 0$

Hence eigen values of A are –1, 1 and 2.

Now, let X be an eigen vector of A associated to λ, then

AX = λX

So, $\begin{bmatrix} \frac{3}{2} & 0 & \frac{1}{2} \\ 0 & -1 & 0 \\ \frac{1}{2} & 0 & \frac{3}{2} \end{bmatrix}\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} = \lambda\begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}$

On solving it; $\lambda = 2$

Thus for $\lambda = +1$ by taking $X = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$

$$[A + 1I_3]X = 0$$

$$\frac{1}{2}x + \frac{1}{2}z = 0$$

$$-2y = 0$$

$$\frac{1}{2}x + \frac{1}{2}z = 0$$

or $\frac{1}{2}x + \frac{1}{2}z = 0$

y = 0

Hence option (c) satisfies.

7. A 10-bus power system consists of four generator buses indexed as G1, G2, G3, G4 and six load buses indexed as L1, L2, L3, L4, L5, L6. The generator-bus G1 is considered as slack bus and the load buses L3 and L4 are voltage controlled buses. The generator at bus G2 cannot supply the required reactive power demand and hence it is operating at its maximum reactive power limit. The number of non-linear equations required for solving the load flow problem using Newton-Raphson method in polar form is _____.

Sol. (14)

Given data

Total number of buses (N) = 10

Number of PV buses (x_1) = 2 (i.e. G_3 and G_4)

Number of voltage controlled buses (x_2) = 2 (i.e. L_3 and L_4)

Number of slack buses = 1 (i.e. G_1)

Number of load buses = 5

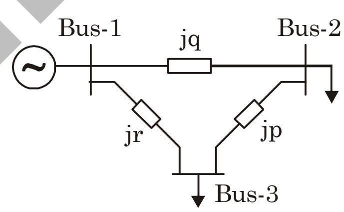
The total number of equations to be solved

$$= [2N - 2 - (x_1 + x_2)]$$
$$= [2(10) - 2 - (2 + 2)]$$
$$= 20 - 2 - 4$$
$$= 14$$

The size of the jacobian matrix

$$= [2N - 2 - (x_1 + x_2)] \times [2N - 2 - (x_1 + x_2)]$$
$$= 14 \times 14$$

8. A 3-bus power system is shown in the figure below, where the diagonal elements of Y bus matrix are : $Y_{11} = -j12$ pu, $Y_{22} = -j15$ pu and $Y_{33} = -j7$ pu



The per unit values of the line reactances p, q and r shown in the figure are

(a) p = –0.2, q = –0.1, r = –0.5

(b) p = 0.2, q = 0.1, r = 0.5

(c) p = –5, q = –10, r = –2

(d) p = 5, q = 10, r = 2

Sol. (b)

From bus diagram

$$y_{12} = y_{21} = \frac{1}{jq}$$

$$y_{13} = y_{31} = \frac{1}{jr}$$

$$y_{23} = y_{32} = \frac{1}{jp}$$

Since diagonal elements

$$Y_{11} = y_{11} + y_{12} + y_{13}$$

So, $\frac{1}{jq} + \frac{1}{jr} = -j12$

$$\frac{1}{q} + \frac{1}{r} = 12 \quad \text{...(i)}$$

Similary for $Y_{22} = -j15$

$$\frac{1}{jq} + \frac{1}{jp} = -j15$$

or $\frac{1}{q} + \frac{1}{p} = 15 \quad$ ...(ii)

For $Y_{33} = -j7$

$$\frac{1}{jr} + \frac{1}{jp} = -j7$$

or $\frac{1}{r} + \frac{1}{p} = 7 \quad$ ...(iii)

On solving equations (i), (ii) and (iii)

$$\frac{1}{p} = 5\,;\ \frac{1}{q} = 10\,;\ \frac{1}{r} = 2$$

Hence,

p = 0.2, q = 0.1, r = 0.5

9. For the power semiconductor devices IGBT, MOSFET, Diode and Thyristor, which one of the following statement is TRUE?

(a) All the four are majority carrier devices

(b) All the four are minority carrier devices

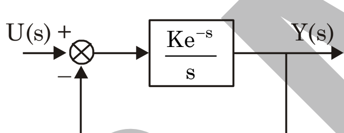
(c) IGBT and MOSFET are majority carrier devices, whereas Diode and Thyristor are minority carrier devices

(d) MOSFET is majority carrier device, whereas IGBT, Diode, Thyristor are minority carrier devices

Sol. (d)

MOSFET is the only majority carrier device among MOSFET, DIODE, Thyristor and IGBT. In majority carrier devices conduction is only because of majority carriers whereas in minority carrier devices conduction is due to both majority and minority carriers.

10. Consider the unity feedback control system shown. The value of K that results in a phase margin of the system to be 30° is _____. (Give the answer up to two decimal places.)



Sol. (1.05)

For unity feedback system with

$$G(j\omega)H(j\omega) = \frac{Ke^{-s}}{s}$$

Phase margin is given by

$$\text{P.M.} = 180° + \phi$$

where, $\phi = |G(j\omega).H(j\omega)|_{\omega=\omega_{gc}}$

and $|G(j\omega).H(j\omega)|_{\omega=\omega_{gc}} = 1$

Since, $|e^{-j\omega}| = 1$

So, $\frac{k}{\omega} = 1$ at $\omega = \omega_{gc}$

So, $\omega_{gc} = k$

Now, $\phi = \angle G(j\omega)H(j\omega) = -90° - 57.3\omega$

at $\omega_{gc} = k$

$$\phi = -90° - 57.3k$$

$\text{PM} = 180° + \phi = 30°$

$\Rightarrow$ $\phi = -150°$

$\Rightarrow$ $-90° - 57.3k = -150°$

$\Rightarrow$ $k = 1.047$

Upto two decimal places

$$k = 1.05$$

11. The transfer function of a system is given by

$$\frac{V_0(s)}{V_i(s)} = \frac{1-s}{1+s}$$

Let the output of the system be $v_0(t) = V_m \sin(\omega t + \phi)$ for the input, $v_i(t) = V_m \sin(\omega t)$. Then the minimum and maximum values of ϕ (in radians) are respectively

(a) $-\frac{\pi}{2}$ and $\frac{\pi}{2}$

(b) $-\frac{\pi}{2}$ and 0

(c) 0 and $\frac{\pi}{2}$

(d) $-\pi$ and 0

Sol. (d)

For transfer function

$$\frac{V_0(s)}{V_i(s)} = \frac{1-s}{1+s}$$

$$\left|\frac{V_0(j\omega)}{V_i(j\omega)}\right| = 1$$

$$\angle\frac{V_0(j\omega)}{V_i(j\omega)} = -2\tan^{-1}\omega$$

Here, $v_i(t) = V_m \sin(\omega t)$

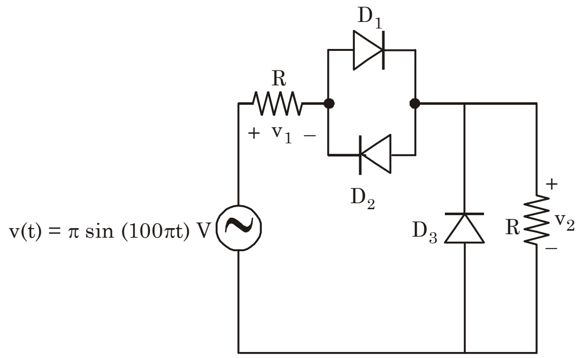
$v_0(t) = V_m \sin(\omega t + \phi)$

So, for $\omega = 0$ to $\omega = \infty$

$-2\tan^{-1}\omega$ varies from $-180°$ to $0°$

Hence, option (d) is the correct answer.

12. For the circuit shown in the figure below, assume that diodes D_1, D_2 and D_3 are ideal.



The DC components of voltages v_1 and v_2, respectively are

(a) 0 V and 1 V

(b) –0.5 V and 0.5 V

(c) 1 V and 0.5 V

(d) 1 V and 1V

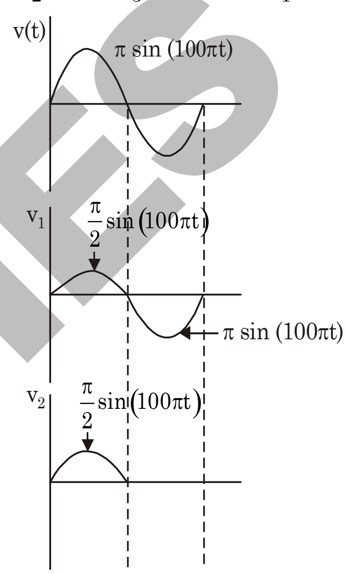
Sol. (b)

During positive half cycle

D_1 ON, D_2 and D_3 will be OFF

During negative half cycle

D_2 and D_3 ON but D_1 OFF



$$V_{1(avg)} = \frac{1}{2\pi}\left[\int_0^{\pi}\frac{\pi}{2}\sin(100\pi t)\,d(\omega t) + \int_{\pi}^{2\pi}\pi\sin(100\pi t)\,d(\omega t)\right]$$

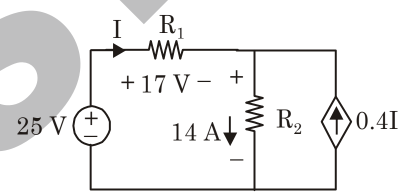
$$= \frac{1}{2\pi}[\pi - 2\pi] = -\frac{1}{2} = -0.5\text{V}$$

$$V_{2\,(avg.)} = \frac{1}{2\pi}\left[\int_0^{\pi}\frac{\pi}{2}\sin(100\pi t)\,d(\omega t)\right]$$

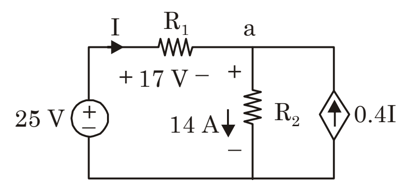
$$= \frac{1}{2\pi}\left[\frac{\pi}{2}(-\cos\pi + \cos 0)\right]$$

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

13. The power supplied by the 25V source in the figure shown below is _____W



Sol. (250)



Using Kirchoffs current law at node 'a'

$$I + 0.4I = 14$$

$$\Rightarrow \quad I = 10\text{A}$$

Power supplied by 25V source;

$$P = 25\text{V} \times 10\text{A}$$

$$\boxed{P = 250\,\text{watt}}$$

14. A three-phase, 50 Hz, star-connected cylindrical-rotor synchronous machine is running as a motor. The machine is operated from a 6.6 kV grid and draws current at unity power factor (UPF). The synchronous reactance of the motor is 30Ω per phase. The load angle is 30°. The power deliver to the motor in kW is _____.(Give the answer up to one decimal place).

Sol. (838.3 kW)

Given that,

$$V = 6.6 \text{ kV}$$

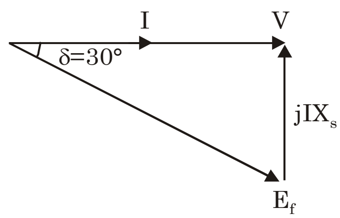
$$\delta = 30°$$

$$\text{P.f} = 1 \text{ (UPF)}$$

Synchronoces reactance $(X_s) = 30\Omega$

$$P = \frac{VE_f}{X_s}\sin\delta$$

For unity P.f. for synchronous motor.



From above phasor diagram,

$$E_f \cos\delta = V$$

or, $$E_f = \frac{V}{\cos\delta}$$

$$= \frac{6.6\text{kV}}{\cos 30°}$$

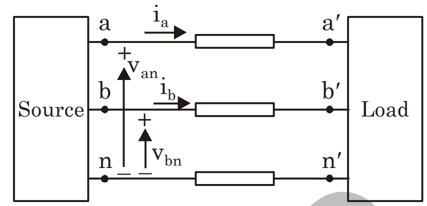
$$= 7.62 \text{ kV}$$

Hence, $$P = \frac{7.62 \times 6.6}{30}\sin 30° \text{ MW}$$

$$= 0.8383 \text{ MW}$$

or, $$\boxed{P = 838.3 \text{ kW}}$$

15. A source is supplying a load through a 2-phase, 3-wire transmission system as shown in figure below. The instantaneous voltage and current in phase-a are v_{an} = $220\sin(100\pi t)\text{V}$ and i_a = $10\sin(100\pi t)\text{A}$, respectively. Similarly for phase-b, the instantaneous voltage and current are V_{bn} = $220\cos(100\pi t)\text{V}$ and i_b = $10\cos(100\pi t)\text{A}$



The total instantaneous power flowing from the source to the load is

(a) 2200 W

(b) $2200\sin^2(100\pi t)\text{W}$

(c) 4400 W

(d) $2200\sin(100\pi t)\cos(100\pi t)\text{W}$

Sol. (a)

Instantaneous power;

$$P = v \cdot i$$

$$P = v_{an} \cdot i_a + v_{bn} \cdot i_b$$

$$= 220\sin(100\pi t)\cdot 10\sin(100\pi t)$$

$$+ 220\cos(100\pi t)\cdot 10\cos(100\pi t)$$

$$= 2200\sin^2(100\pi t) + 2200\cos^2(100\pi t)$$

$$P = 2200 \text{ W}$$

16. For a complex number z,

$$\lim_{z\to i}\frac{z^2+1}{z^3+2z-i(z^2+2)} \text{ is}$$

(a) –2i (b) –i

(c) i (d) 2i

Sol. (d)

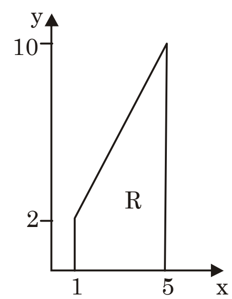
$$\lim_{z\to i}\frac{z^2+1}{z^3+2z-i\left(z^2+2\right)}$$

This is $\frac{0}{0}$ form, so on differentiating both numerator and denominator

$$\lim_{z\to i}\frac{2z}{3z^2+2-2zi}$$

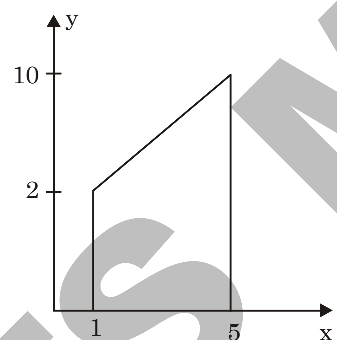
$$= \frac{2i}{3(i^2)+2-2(i)i} = \frac{2i}{-3+2+2} = 2i$$

17. Let $I = c\iint_R xy^2 dxdy$, where R is the region shown in the figure and c = 6 × 10^{-4}. The value of I equals _____. (Give the answer up to two decimal places).



Sol. (0.99)

$$I = c\iint_R xy^2 dx\,dy$$



Region R is bounded by y = 0 and y = 2x

$$I = c\left[\int_1^5 \int_0^{2x} xy^2 dy\, dx\right]$$

$$= c\left[\int_1^5 \left(\frac{xy^3}{3}\right)\Bigg|_0^{2x} dx\right]$$

$$= c\left[\int_1^5 \frac{8}{3}x^4 dx\right]$$

$$= c\left[\frac{8}{15}x^5\Bigg|_1^5\right] = c\left[\frac{8}{15}(5^5-1)\right]$$

$$= 6 \times 10^{-4} \times \left[\frac{8}{15}(5^5-1)\right]$$

$\boxed{I = 0.99}$ (upto two decimal places)

18. A 4 pole induction machine is working as an induction generator. The generator supply frequency is 60 Hz. The rotor current frequency is 5 Hz. The mechanical speed of the rotor in RPM is

(a) 1350 (b) 1650

(c) 1950 (d) 2250

Sol. (c)

For 4 pole, 60 Hz induction machine synchronous speed;

$$N_s = \frac{120 \times f}{P}$$

$$= \frac{120 \times 60}{4}$$

$$= 1800 \text{ r.p.m.}$$

$$s = \frac{f_r}{f_s}$$

$$= \frac{5}{60}$$

For induction generator slip is negative, So,

$$\frac{N_s - N_r}{N_s} = -\frac{5}{60}$$

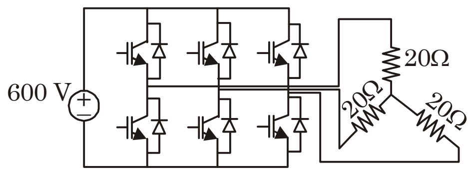
$$\Rightarrow \quad \frac{1800 - N_r}{1800} = \frac{-5}{60}$$

$$\Rightarrow \quad 1800 - N_r = -\frac{5}{60} \times 1800$$

$$\Rightarrow \quad N_r = 1800 + \frac{5}{60} \times 1800$$

$$\boxed{N_r = 1950 \text{ r.p.m.}}$$

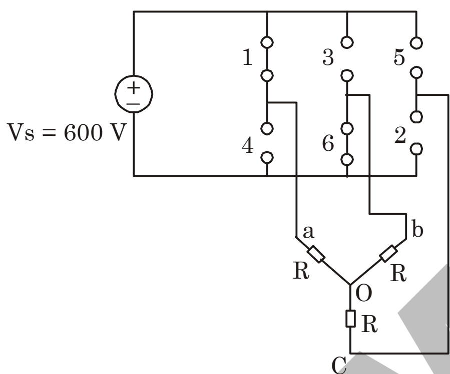
19. A 3-phase voltage source inverter is supplied from a 600 V DC source as shown in the figure below. For a star connected resistive load of 20Ω per phase, the load power for 120° device conduction, in kW, is ______

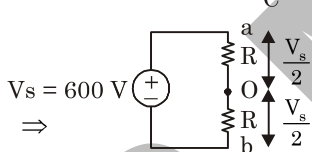


Sol. (9 kW)

In 120° device canduction mode and star connected load:

At any instant only 2 IGBTs will conduct so, when IGBT 1 and 6 are conducting in 0–60° cycle, equivalent ckt can be given as





So power,
$$P = \frac{\left(\frac{V_s}{2}\right)^2}{R} \times 2$$
$$= \frac{V_s^2}{2R}$$
$$P = \frac{(600)^2}{2 \times 20}$$
$$= 9000 \text{ watt}$$
or, $$= 9 \text{ kW}$$

20. A solid iron cylinder is placed in a region containing a uniform magnetic field such that the cylinder axis is parallel to the magnetic field direction. The magnetic field lines inside the cylinder will

(a) Bend closer to the cylinder axis

(b) Bend farther away from the axis

(c) Remain uniform as before

(d) Cease to exist inside the cycliner

Sol. (a)

The magnetic field lines will bend closer to the cylinder axis to find a minimum reluctance path.

21. Consider the system with following input-output relation

$$y[n] = (1 + (-1)^n)x[n]$$

where, x[n] is the input and y[n] is the output. The system is

(a) Invertible and time invariant

(b) Invertible and time varying

(c) Non-invertible and time invariant

(d) Non-invertible and time varying

Sol. (d)

$$y[n] = (1 + (-1)^n)\, x[n]$$

A system is said to be invertible if there is a one-to-one correspondence between its input and output signals.

for n = 1,
$$y[1] = (1 + (-1)^1)\, x[1] = 0$$
for n = 2,
$$y[2] = (1 + (-1)^2)\, x[2] = 0$$
for n = 3,
$$y[3] = (1 + (-1)^3)\, x[3] = 0$$

Here for odd values of 'n' output will always be zero so system is non-invertible.

To check time invariancy

For delayed input,
$$y[n_1 n_0] = (1 + (-1)^n)\, x[n-n_0] \quad \text{...(i)}$$
For delayed response,
$$y[n_1 n_0] = (1+(-1)^{n-n_0})x[n-n_0] \quad \text{...(ii)}$$

For time invariant system output for delayed input should be equal to delayed response.

Hence this system is time varying.

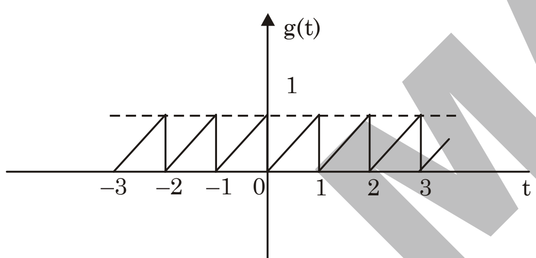
22. Consider g(t) =

$$\begin{cases} t - \lfloor t \rfloor, & t \ge 0 \\ t - \lceil t \rceil, & \text{otherwise} \end{cases}, \text{ where } t \in R$$

Here, $\lfloor t \rfloor$ represents the largest integer less than or equal to t and $\lceil t \rceil$ denotes the smallest integer greater than or equal to t. The coefficient of the second harmonic component of the Fourier series representing g(t) is _____

Sol. (0.0796)

$$g(t) = \begin{cases} t - \lfloor t \rfloor, & t > 0 \\ t - \lceil t \rceil, & \text{otherwise} \end{cases}$$



$$T = 1$$

$$\omega_0 = \frac{2\pi}{T} = 2\pi$$

$$g(t) = t \qquad 0 \le t \le 1$$

$$g(t) = \sum_{n=-\infty}^{\infty} G_n e^{-jn\omega_0 t}$$

$$G_n = \frac{1}{T}\int_{-T/2}^{T/2} g(t)\, e^{-jn\omega_0 t} dt$$

$$= \frac{1}{1}\int_0^1 (t)\, e^{-j2\pi nt} dt$$

$$= \int_0^1 (t)\, e^{-j2\pi nt} dt$$

$$G_n = \int_0^1 t\, e^{-j2\pi nt} dt$$

$$= t \cdot \frac{e^{-j2\pi nt}}{-j2\pi n}\Bigg|_0^1 - \int_0^1 1 \cdot \frac{e^{-j2\pi nt}}{-j2\pi n} dt$$

$$= \frac{-1}{j2\pi n} - \frac{1}{j^2 4\pi^2 n^2}\left(e^{-j2\pi n} - 1\right)$$

$$G_n = \frac{-1}{j2\pi n}$$

$$G_2 = \frac{-1}{j4\pi}$$

$$|G_2| = \frac{1}{4\pi} = 0.0796$$

23. The boolean expression $AB + A\bar{C} + BC$ simplifies to

(a) $BC + A\bar{C}$ (b) $AB + A\bar{C} + B$

(c) $AB + A\bar{C}$ (d) AB + BC

Sol. (a)

$$f = AB + A\bar{C} + BC$$

Using k-map,

A \ BC	00	01	11	10
0			1	
1	1		1	1

$$f = A\bar{C} + BC$$

24. Let z(t) = x(t)*y(t), where "*" denotes convolution. Let c be a positive real-valued constant. Choose the correct expression for z(ct)

(a) $c.x(ct) * y(ct)$

(b) $x(ct) * y(ct)$

(c) $c.x(t) * y(ct)$

(d) $c.x(ct) * y(t)$

Sol. (a)

z(t) = x(t) * y(t)

taking fourier transform

$$Z(j\omega) = X(j\omega) \cdot Y(j\omega) \qquad \ldots(1)$$

$$z(t) \longrightarrow \frac{1}{c} Z\left(\frac{j\omega}{c}\right) \qquad \ldots(2)$$

Also, byusing eq. (1)

$$Z\left(\frac{j\omega}{c}\right) = X\left(\frac{j\omega}{c}\right)\cdot Y\left(\frac{j\omega}{c}\right)$$

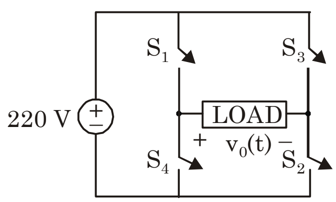
$$\therefore \quad \frac{1}{c}Z\left(\frac{j\omega}{c}\right) = \frac{1}{c}X\left(\frac{j\omega}{c}\right)\cdot Y\left(\frac{j\omega}{c}\right)$$

Multiplying and dividing R.H.S. by c

$$\frac{1}{c}Z\left(\frac{j\omega}{c}\right) = c\left[\frac{1}{c}\cdot X\left(\frac{j\omega}{c}\right)\cdot\frac{1}{c}Y\left(\frac{j\omega}{c}\right)\right]$$

$$z(t) = c\cdot x(ct) * y(ct)$$

25. In the converter circuit shown below, the switches are controlled such that the load voltage $v_0(t)$ is a 400 Hz square wave.



The RMS value of the fundamental component of $v_0(t)$ in volts is _____

Sol. (198.069)

For single phase full bridge inverter,

$$v_0 = \sum_{n=1,3,5\ldots}^{n} \frac{4V_s}{n\pi}\sin n\omega t$$

Volts

RMS value of fundamental component is given by:

$$\frac{4V_s}{\pi}\times\frac{1}{\sqrt{2}} = \frac{4\times 220}{\pi}\times\frac{1}{\sqrt{2}}$$

$$= 198.069 \text{ Volts.}$$

26. The positive, negative and zero sequence reactances of a wye-connected synchronous generator are 0.2 pu, 0.2 pu and 0.1 pu respectively. The generator is on open circuit with a terminal voltage of 1 pu. The minimum value of the inductive reactance, in pu, required to be connected between neutral and ground so that the fault current does not exceed 3.75 pu if a single line to ground fault occurs at the terminals is _____(assume fault impedance to be zero). (Give the answer up to one decimal place).

Sol. (0.1 pu)

Positive sequence reactance X_1 = 0.2 pu

Negative sequence reactance X_2 = 0.2 pu

Zero sequence reactance X_0 = 0.1 pu

Fault current i_f = 3.75 pu

For single line to ground fault,

$$i_f = \frac{3E}{X_1 + X_2 + X_0 + 3X_n}$$

Where X_n is the rectance connected between neutral and ground.

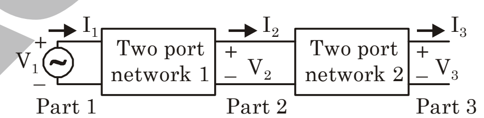
Therefore,for E = 1 pu

$$i_f = \frac{3}{0.2+0.2+0.1+3X_n} = 3.75$$

On solving,

$$\boxed{X_n = 0.1 \text{ pu}}$$

27. Two passive two-port networks are connected in cascade as shown in figure. A voltage source is connected at port 1



Given

$$V_1 = A_1V_2 + B_1I_2$$

$$I_1 = C_1V_2 + D_1I_2$$

$$V_2 = A_2V_3 + B_2I_3$$

$$I_2 = C_2V_3 + D_2I_3$$

A_1, B_1, C_1, D_1, A_2, B_2, C_2 and D_2 are the generalized circuit constants. If the Thevenin equivalent circuit at port 3 consists of a voltage source V_T and an impedance Z_T, connected in series, then

(a) $V_T = \dfrac{V_1}{A_1A_2}, Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$

(b) $V_T = \dfrac{V_1}{A_1A_2 + B_1C_2}, Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2}$

(c) $V_T = \dfrac{V_1}{A_1A_2}, Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2}$

(d) $V_T = \dfrac{V_1}{A_1A_2 + B_1C_2}, Z_T = \dfrac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$

Sol. (d)

For cascaded network, equivalent ABCD parameters are given by,

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix}\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix}$$

$$= \begin{bmatrix} A_1A_2 + B_1C_2 & A_1B_2 + B_1D_2 \\ C_1A_2 + D_1C_2 & C_1B_2 + D_1D_2 \end{bmatrix}$$

Therefore,

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_3 \\ I_3 \end{bmatrix}$$

Now, open circuit voltage $V_T = V_3$ when $I_3 = 0$.

So,
$$V_1 = AV_3$$
$$= AV_T$$

$$\Rightarrow \quad V_T = \frac{V_1}{A}$$

$$\Rightarrow \quad V_T = \frac{V_1}{A_1A_2 + B_1C_2}$$

To calculate Thevenin equivalent impedance Z_T voltage source is short circuited. So for voltage source of V_3 feeding current $(-I_3)$

$$Z_T = \frac{V_3}{-I_3}$$

$$0 = AV_3 + BI_3$$

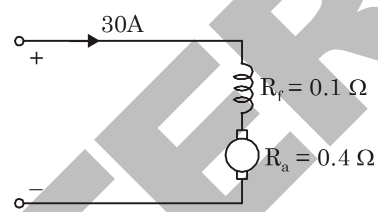
$$\Rightarrow \quad Z_T = \frac{B}{A}$$

$$Z_T = \frac{A_1B_2 + B_1D_2}{A_1A_2 + B_1C_2}$$

Hence, option (d) is the correct answer.

28. A 220 V DC series motor runs drawing a current of 30 A from the supply. Armature and field circuit resistances are 0.4Ω and 0.1Ω, respectively. The load torque varies as the square of the speed. The flux in the motor may be taken as being proportional to the armature current. To reduce the speed of the motor by 50%, the resistance in ohms the should be added in series with the armature is _____. (Give the answer up to two decimal places).

Sol. **(**10.75Ω**)**



Back E.m.f. $E_1 = 220 - 30(0.1 + 0.4)$
$= 205\text{V}$

Torque, $\tau = \phi I_a$

{where ϕ = flux, I_a = armature current}

$$\tau = I_a^2 \qquad ...(i)$$

as in series motor $\phi \propto I_a$

Also, $\tau \propto N^2$ ...(ii)

here N is the speed of motor

From eq. (i) & (ii)

$$I_a^2 \propto N^2 \text{ or } I_a \propto N \qquad ...(iii)$$

Therefore to reduce speed by 50%, I_a will reduce to 50% i.e., 15A.

Now back emf will change to

$$E_2 = 220 - 15(R + 0.1 + 0.4)$$

Where R is the external resistance added in series with armature.

Since, $E \propto \phi \cdot N$

So, $E_1 \propto \phi_1 \cdot N_1$

$E_2 \propto \phi_2 \cdot N_2$

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

$$N_2 = \frac{N_1}{2}$$

Thus,

$$205 = \phi_1 N_1 \quad \text{...(iv)}$$

$$220 - 15(R + 0.5) = \phi_2 N_2 \quad \text{...(v)}$$

dividing eq. (v) by eq. (iv),

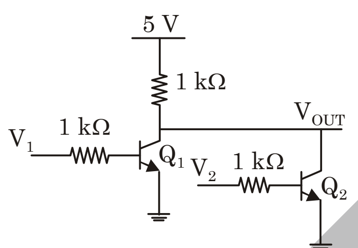
$$\frac{220 - 15(R + 0.5)}{205} = \frac{\phi_2 N_2}{\phi_1 N_1} = \frac{(\phi_1/2)\cdot(N_1/2)}{\phi_1 \cdot N_1}$$

$$\frac{220 - 15(R + 0.5)}{205} = \frac{1}{4}$$

on solving,

$$R = 10.75\Omega$$

29. The logical gate implemented using the circuit shown below where, V_1 and V_2 are inputs (with 0 V as digital 0 and 5 V as digital 1) and V_{OUT} is the output, is



(a) NOT (b) NOR

(c) NAND (d) XOR

Sol. (b)

From the given circuit it can be deduced that Q_1 will be ON when V_1 is high, Q_2 is ON when V_2 is high

Truth Table

V_1	Q_1	V_2	Q_2	V_{out}
High	ON	High	ON	Low
High	ON	Low	OFF	Low
Low	OFF	High	ON	Low
Low	OFF	Low	OFF	High

This is the truth table of NOR gate.

30. A function f(x) is defined as f(x) = $\begin{cases} e^x, & x < 1 \\ \ln x + ax^2 + bx & x \ge 1 \end{cases}$, where $x \in \mathbb{R}$.

Which one of the following statement is TRUE?

(a) f(x) is **NOT** differentiable at x = 1 for any values of a and b.

(b) f(x) is differentiable at x = 1 for the unique value of a and b.

(c) f(x) is differentiable at x = 1 for all values of a and b such that a+b = e.

(d) f(x) is differentiable at x = 1 for all values of a and b

Sol. (b)

$$f(x) = \begin{cases} e^x, & x < 1 \\ \ln x + ax^2 + bx, & x \ge 1 \end{cases}$$

Left hand derivative = $\lim\limits_{x \to 1} \frac{f(x) - f(1)}{x - 1}$

where $f(1) = \ln(1) + a(1)^2 + b(1) = a+b$

so,

Left hand derivatives (LHD)

$$= \lim_{x \to 1} \frac{e^x - (a+b)}{x - 1}$$

this limit exists if e = a + b ...(1)

then

$$\text{LHD} = \lim_{x \to 1} \frac{e^x}{1} = e$$

Right hand derivative (RHD)

$$= \lim_{x \to 1} \frac{f(x) - f(1)}{x - 1}$$

$$= \lim_{x \to 1} \frac{\ln x + ax^2 + bx - (a+b)}{x - 1}$$

this limit exist if 1 + 2a + b = a+b

or $a = -1$ ...(2)

Hence

$$\text{RHD} = \lim_{x \to 1} \frac{\frac{1}{x} + 2ax + b}{1} = 1 + 2a + b$$

LHD will be equal to RHD if a = –1 and b = e+1

Hence, f(x) is differentiable at x = 1 for unique values of a and b.

31. The switch in the figure below was closed for a long time. It is opened at t = 0. The current in the inductor of 2 H for $t \ge 0$, is

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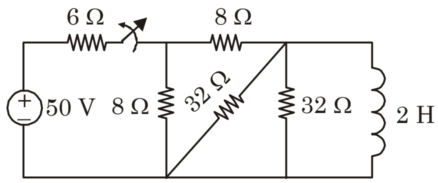
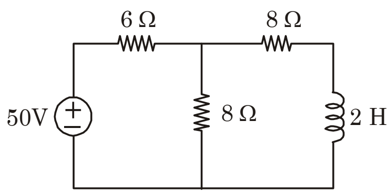


(a) $2.5e^{-4t}$ (b) $5e^{-4t}$

(c) $2.5e^{-0.25t}$ (d) $5e^{-0.25t}$

Sol. (a)

For t = 0^- circuit can be represented as below



Inductor can be taken as short circuit at steady state.

So current in inductor at t = 0^- will be

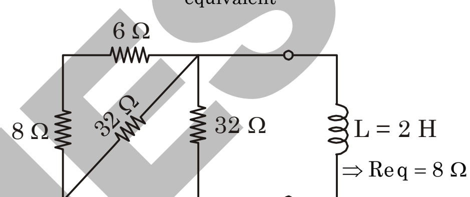
$$i_L(0^-) = \frac{50}{6+(8118)} \times \frac{8}{(8+8)}$$

$$\Rightarrow \quad i_L = 2.5 \text{ A}$$

On opening of switch at t = 0, i_L can be given by $i_L(t) = i_L(0)\, e^{-t/\tau}$ where τ = L/R

R is $R_{equivalent}$ across L

to calculate $R_{equivalent}$,



$$\tau = \frac{L}{R} = \frac{2}{8} = \frac{1}{4}$$

Hence $\quad i_L(t) = 2.5\, e^{-\frac{t}{1/4}}$

or $\quad i_L(t) = 2.5e^{-4t}$

32. A three-phase, three winding $\Delta/\Delta/Y$ (1.1 kV/6.6 kV/400 V) transformer is energized from AC mains at the 1.1 kV side. It supplies 900 kVA load at 0.8 power factor lag from the 6.6 kV winding and 300 kVA load at 0.6 power factor lag from the 400 V winding. The RMS line current in ampere drawn by the 1.1 kV winding from the mains is _____. (Give the answer up to one decimal place).

Sol. (625.1 A)

$\Delta/\Delta/Y$ (1.1kV/6.6kV/400 V)

For secondary winding (Δ)

$$900 \text{ kVA} = 3V_{ph_2}I_{ph_2}$$

$$\Rightarrow \quad I_{ph_2} = \frac{900\text{kVA}}{3\times 6.6\text{kV}} = 45.45\text{A}$$

For P.f of 0.8 lag.

$$I_{ph_2} = 45.45\underline{|-\cos^{-1}0.8} = 45.45\underline{|-36.87°}\text{A}$$

For tertiary winding (Y)

$$300 \text{ kVA} = \frac{\sqrt{3}\times 400\times I_{ph3}}{1000}$$

$$I_{ph3} = 433.01 \text{ A}$$

For p.f. of 0.6 log

$$I_{ph_3} = 433.01\underline{|-\cos^{-1}0.6} = 433.01\,\underline{|-53.13°}\text{A}$$

Corresponding currents in primary winding for I_{ph_2} is given by

$$I'_{ph_2} = \left(\frac{6.6}{1.1}\right)I_{ph_2} = 6\times I_{ph_2}$$

$$= 6\times 45.45\underline{|-36.87} = 272.73\underline{|-36.87°}\text{A}$$

similarly $\quad I'_{ph_3} = \left(\frac{400/\sqrt{3}}{1.1\times 1000}\right)\times I_{ph_3}$

$$= 90.91\underline{|-53.13°}\text{A}$$

Total RMS phase current = $I'_{ph_2} + I'_{ph_3}$

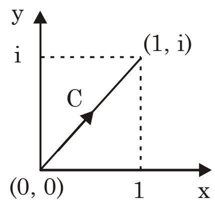
$$= 272.73\,\underline{|-36.87°} + 90.91\underline{|-53.13°}$$

$$= 360.90\underline{|-40.91}$$

Total RMS line current = $360.87\times\sqrt{3} = 625.101$

or I_1 = 625.1 A (upto one decimal place)

33. Consider the line integral $I = \int_c (x^2 + iy^2)\,dz$, where z = x + iy. The line c is shown in the figure below



The value of I is

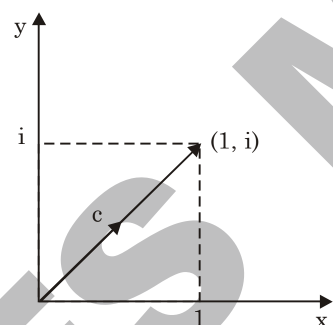
(a) $\frac{1}{2}i$ (b) $\frac{2}{3}i$

(c) $\frac{3}{4}i$ (d) $\frac{4}{5}i$

Sol. (b)

Given integral $I = \int_c (x^2 + iy^2)\,dz,\ z = x + iy$

the line C is a straight line passing through origin and its equation is given by y = x



substituting y = x in given integral we get

$$I = \int_c (x^2 + ix^2)(dx + idx)$$

$$= \int_c x^2(1+i)(1+i)dx$$

$$= \int_c x^2(1-1+2i)dx$$

$$= \int_c 2i\,x^2 dx$$

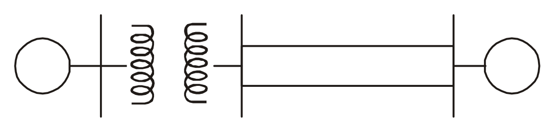
$$= 2i\int_0^1 x^2\,dx$$

$$= 2i\left[\frac{x^3}{3}\right]_0^1$$

$$= 2i\left[\frac{1}{3} - \frac{0}{3}\right]$$

$$= \frac{2i}{3}$$

34. The figure shows the single line diagram of a power system with a double circuit transmission line. The expression for electrical power is 1.5 sin δ, where δ is the rotor angle. The system is operating at the stable equilibrium point with mechanical power equal to 1 pu. If one of the transmission line circuits is removed, the maximum value of δ, as the rotor swings, is 1.221 radian. If the expression for electrical power with one transmission line circuit removed is $P_{,max}$ sin δ, the value of P_{max}, in pu is _____ (Give the answer up to three decimal places.)



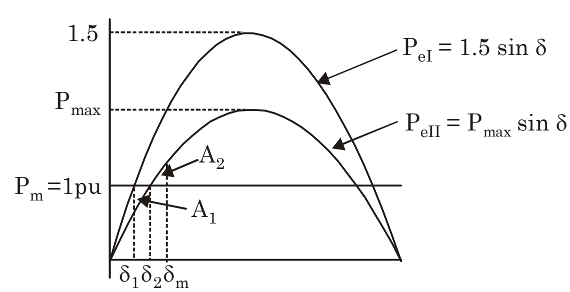
Sol. (1.220pu)

With double circuit transmission line

$$P_{eI} = 1.5 \sin \delta$$

with single line

$$P_{eII} = P_{max} \sin \delta$$



Here,

$$\delta_1 = \sin^{-1}\left(\frac{1}{1.5}\right) = 41.81°$$

or 0.7297 radian

$$\delta_m = 1.221 \text{ radian or } 69.96°$$

For stability

$$A_1 = A_2$$

$$\int_{\delta_1}^{\delta_2}(1 - P_{max}\sin\delta)d\delta = \int_{\delta_2}^{\delta_m}(P_{max}\sin\delta - 1)d\delta$$

$$\delta\Big|_{\delta_1}^{\delta_2} - P_{max}(-\cos\delta)\Big|_{\delta_1}^{\delta_2}$$

$$= P_{max}(-\cos\delta)\Big|_{\delta_2}^{\delta_m} - \delta\Big|_{\delta_2}^{\delta_m}$$

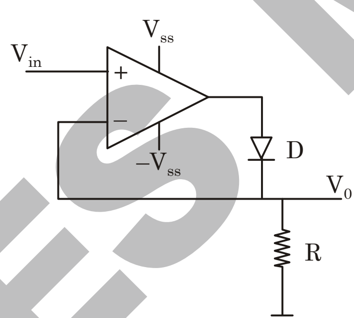
$$P_{max}\ (\cos\delta_m - \cos\delta_1) = \delta_1 - \delta_m$$

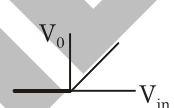
substituting values and solving for P_{max}

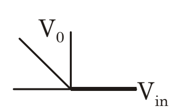
P_{max} (cos 69.96° – cos 41.81°) = 41.81°– 69.96°

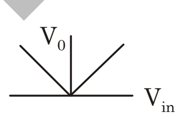
$$\boxed{P_{max} = 1.220 \text{ pu}}$$

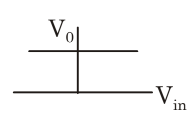
35. The approximate transfer characteristic for the circuit shown below with an ideal operational amplifier and diode will be



(a) 

(b) 

(c) 

(d) 

Sol. (a)

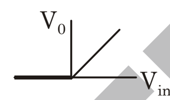
For $V_{in} < 0$

Output of operational amplifier will be negative hence due to presence of diode (reversed biased) in this case output will be zero

For $V_{in} > 0$

Diode will be forward biased so $V_{in} = V_0$

Thus transfer characteristics



36. A load is supplied by a 230 V, 50 Hz source. The active power P and the reactive power Q consumed by the load are such that $1\text{kW} \le P \le 2\text{kW}$ and $1\text{kVAR} \le Q \le 2\text{kVAR}$. A capacitor connected across the load for power factor correction generates 1 kVAR reactive power. The worst case power factor after power factor correction is

(a) 0.447 lag (b) 0.707 lag

(c) 0.894 lag (d) 1

Sol. (b)

For worst case power factor

$$P = 1 \text{ kW},$$

$$Q = 2\text{kVAR}$$

After addition of capacitor for power factor correction Q becomes 2–1 = 1kVAR new

$$\text{P.f} = \cos\left(\tan^{-1}\frac{Q}{P}\right)$$

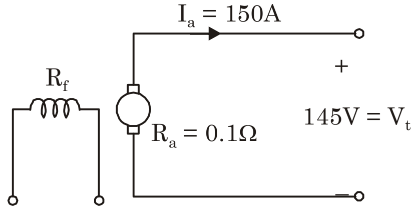
$$= \cos\left(\tan^{-1}\frac{1}{1}\right)$$

$$= \cos 45°$$

or $\text{P.f} = 0.707$ lag

37. A separately excited DC generator supplies 150 A to a 145 V DC grid. The generator is running at 800 RPM. The armature resistance of the generator is 0.1Ω. If the speed of the generator is increased to 1000 RPM, the current in amperes supplied by the generator to the DC grid is _____. (Give the answer up to one decimal place).

Sol. (550A)



N = 800 rpm (speed of generator)

Since back emf $E = V_t + I_aR_a$ ...(i)

and $E \propto \phi N$ ...(ii)

For separately excited generator ϕ remains constant so $E \propto N$ ...(iii)

For $N = 800$ rpm

$E_1 = 145 + 150 \times 0.1 = 160$ V

Using equation (iii)

$E_1 \propto N_1$

or $160 \propto 800$ ...(iv)

For N = 1000 rpm

$E_2 \propto 1000$ ...(v)

On solving equation (iv) and (v)

$E_2 = 200$ V

Thus $200 = 145 + I_a \times 0.1$

$$I_a = \frac{200-145}{0.1}$$

or $\boxed{I_a = 550\text{ A}}$

38. Consider the differential equation

$(t^2-81)\frac{dy}{dt}+5ty = \sin(t)$ with $y(1) = 2\pi$.

There exists a unique solution for this differential equation when t belongs to the interval

(a) (–2, 2) (b) (–10, 10)

(c) (–10, 2) (d) (0, 10)

Sol. (a)

Given differential equation is

$$\left(t^2-81\right)\frac{dy}{dt}+5ty = \sin t \quad ...(1)$$

initial condition $y(1) = 2\pi$

Converting the given equation into standard form

$$\frac{dy}{dt}+\left(\frac{5t}{t^2-81}\right)y = \frac{\sin t}{t^2-81} \quad ...(2)$$

this is of the form

$$\frac{dy}{dt}+py = Q$$

where $P = \frac{5t}{t^2-81}, Q = \frac{\sin t}{t^2-81}$

we know integrating factor (IF) $= e^{\int \rho dt}$

$$= e^{\int \frac{5t}{t^2-81}dt}$$

$$= e^{\int \frac{5}{2}\left(\frac{2t}{t^2-81}\right)}$$

$$= e^{\frac{5}{2}\ln\left(t^2-81\right)^{5/2}} \quad \left[\because e^{\ln x} = x\right]$$

$$IF = \left(t^2-81\right)^{5/2}$$

$$y(IF) = \int Q\, IF\, dt + c$$

$$y(t^2-81)^{5/2} = \int \frac{\sin t}{\left(t^2-81\right)}\left(t^2-81\right)^{5/2} dt + c$$

$$y = \int \frac{\sin t\left(t^2-81\right)^{3/2}}{\left(t^2-81\right)^{5/2}} dt + c\left(t^2-81\right)^{-5/2}$$

$$y = \int \sin t\left(t^2-81\right)^{-1} dt + c\left(t^2-81\right)^{-5/2}$$

and solving from the options by verifying initial condition we get unique solution If $t = \pm 9$ then solution is not unique hence range (–10, 10), (–10, 2), (0, 10) can be eliminated, then left option is (–2, 2)

39. The input voltage V_{DC} for the buck-boost converter shown below varies from 32 V to 72 V. Assume that all components are ideal, inductor current is continuous and output voltage is ripple free. The range of duty ratio D of the convector for which the magnitude of the steady-state output voltage remains constant at 48 V is

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ESE-2017 Conventional Test Schedule, Electrical Engineering

Date		Topic
5th Mar 2017	**N.T.** :	ECF-1, MC-1, MC-2, ADE-2
	R.T. :	
11th Mar 2017	**N.T.** :	ECF-2, MI-1, CS-1, CS-2
	R.T. :	ECF-1, MC-1, MC-2, ADE-2
19th Mar 2017	**N.T.** :	ECF-3, MI-2, MC-3, MC-4
	R.T. :	ECF-2, MI-1, CS-1, CS-2
26th Mar 2017	**N.T.** :	ECF-4, BEX-1, ADE-1, ADE-3
	R.T. :	ECF-3, MI-2, MC-3, MC-4
2nd Apr 2017	**N.T.** :	EM-1, MATH-1, PS-1, SSP-1
	R.T. :	ECF-4, BEX-1, ADE-1, ADE-3
9th Apr 2017	**N.T.** :	CF-1, MATH-2, PS-2, PE-1
	R.T. :	EM-1, MATH-1, PS-1, SSP-1
16th Apr 2017	**N.T.** :	BEX-2, MI-3, CS-3, SSP-2
	R.T. :	CF-1, MATH-2, PS-2, PE-1
23rd Apr 2017	**N.T.** :	EM-2, PS-3
	R.T. :	BEX-2, MI-1, MI-3,. CS-3, SSP-2, ADE-3, MC-1, MC-2
30th Apr 2017	**N.T.** :	CF-2, PE-2
	R.T. :	EM-2, ECF-1, ECF-3, MI-2, PS-2, PS-3, ADE-2, CS-2
3rd May 2017	**N.T.** :	CF-3, MATH-3
	R.T. :	CF-2, ECF-2, MI-1, BEX-1, EM-1, CS-1, MI-3, CS-3, ADE-3, PE-2, SSP-1
7th May 2017	**N.T.** :	
	R.T. :	MATH-1, MATH-3, EM-1, EM-2, ECF-1, ECF-4, BEX-2, CF-3, ADE-2, CS-2, PS-1, PS-3 PE-1, SSP-2
9th May 2017		Full Length (Test Paper-1 + Test Paper-2)

Test Type	Timing	Day
Conventional Test	10:00 A.M. to 1:00 P.M.	Sunday
Conventional Full Length Test Paper-1	10:00 A.M. to 1:00 P.M.	Tuesday
Conventional Full Length Test Paper-2	02:00 P.M. to 5:00 P.M.	Tuesday

Note : The timing of the test may change on certain dates. Prior information will be given in this regard.

***N.T. :** New Topic. ***R.T. :** Revision Topic

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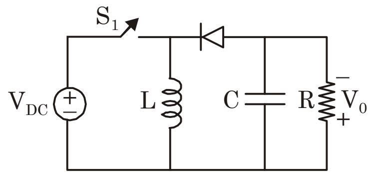
Subject	Code	Topics
Engineering Mathematics (MATH)	MATH-1	♦ Linear Algebra ♦ Complex Variables ♦ Transform Theory
	MATH-2	♦ Calculus ♦ Differential Equations
	MATH-3	♦ Probability and Statistics ♦ Numerical Methods
Electrical Materials (EM)	EM-1	♦ Crystal Structures & Solid State ♦ Band Theory ♦ Dielectrics ♦ Magnetic materials
	EM-2	♦ Conductive materials ♦ Photo conductivity ♦ Nano materials ♦ Superconductors
Electric Circuits & Fields (ECF)	ECF-1	♦ Circuit Elements ♦ 3-phase Circuits ♦ Network Graphs ♦ Transient and steady state Response
	ECF-2	♦ Network Theorems ♦ Two-port networks ♦ Network Functions ♦ Resonance
	ECF-3	♦ Electrostatics and Magneto statics
	ECF-4	♦ Time varying fields & Maxwell's Equations
Electrical & Electronic Measurements	MI-1	♦ Errors, Units, Dimensions & standards ♦ Galvanometers ♦ Types of Instruments ♦ Measurement of Power
	MI-1	♦ Measurement of Energy ♦ Measurement of resistance ♦ Potentiometers ♦ AC bridges
	MI-1	♦ Electronic Instrumentation ♦ Data Acquisition System ♦ Transducers
Computer Fundamentals (CF)	CF-1	♦ Architecture, CPU, I/O, Memory, Peripheral devices ♦ Boolean algebra ♦ Number system arithmetic functions
	CF-2	♦ Basic of OS, Virtual memory ♦ File system ♦ Networking
	CF-3	♦ Data Representation and Programming, Programming languages
Basic Electronics Engineering (BEX)	BEX-1	♦ Basics of diodes, BJT, FET, MOSFET
	BEX-1	♦ Transistor amplifiers – equivalent circuits & frequency response ♦ Oscillators, Feedback amplifiers
Analog Digital Electronics (ADE)	ADE-1	♦ OPAMP ♦ Multivibrator, Sample and Hold circuits ♦ Filters
	ADE-2	♦ Digital Electronics ♦ Microprocessors
	ADE-3	♦ Communications
Systems and Signal Processing (SSP)	SSP-1	♦ Continuous & discrete-time signals ♦ Shifting and scaling ♦ Linear, time-invariant and causal system ♦ Laplace & Z-transform
	SSP-1	♦ Fourier series ♦ Discrete Fourier Transform ♦ FFT ♦ FIR and IIR Filters ♦ Bilinear Transformation
Control System (CS)	CS-1	♦ Basics ♦ Block diagram Algebra ♦ Signal flow ♦ Mathematical Modeling
	CS-2	♦ Time Response Analysis ♦ Stability ♦ Frequency Response & its stability
	CS-3	♦ Root Locus ♦ Controllers & Compensators ♦ State Variable Analysis
Electrical Machines (MC)	MC-1	♦ Transformers ♦ Basic concepts of Rotating Machines
	MC-2	♦ Polyphase Induction Machines ♦ Single Phase motors
	MC-3	♦ DC Machines
	MC-4	♦ Synchronous Machines
Power System (PS)	PS-1	♦ Electric Power Sources-Thermal, Hydro Nuclear, Wind & Solar ♦ Performance of lines & cables ♦ HVDC & Corona ♦ Smart Grid; Environment Implications
	PS-2	♦ Symmetrical Components & Fault Analysis ♦ Power System stability & dynamics ♦ Load flow; Matrix Representation
	PS-3	♦ Economic Load Dispatch & Power Economics ♦ Load Frequency control ♦ Voltage Control & Compensation ♦ FACTS ♦ Power System Protection ♦ Solid state Relays
Power Electronics and Drivers (PE)	PE-1	♦ Power Semiconductor Devices ♦ High Frequency Inductors & transformers ♦ Diode Rectifiers ♦ Phase Controlled Rectifiers
	PE-1	♦ Choppers; DC-DC switched mode converters ♦ Inverters; DC-AC switched mode converters ♦ AC Voltage Controllers ♦ Cycloconverters ♦ Electric Drives ♦ Resonant Converters



(a) $\frac{2}{5} \le D \le \frac{3}{5}$ (b) $\frac{2}{3} \le D \le \frac{3}{4}$

(c) $0 \le D \le 1$ (d) $\frac{1}{3} \le D \le \frac{2}{3}$

Sol. (a)

For buck-boost converter

$$V_0 = \frac{\alpha}{1-\alpha} V_s$$

where α is duty cycle of converter

V_s = supply voltage

V_0 = output voltage

For V_s = 32 V and V_0 = 48 V

$$48 = \frac{\alpha}{1-\alpha} \times 32$$

$$\Rightarrow \qquad \alpha = \frac{3}{5}$$

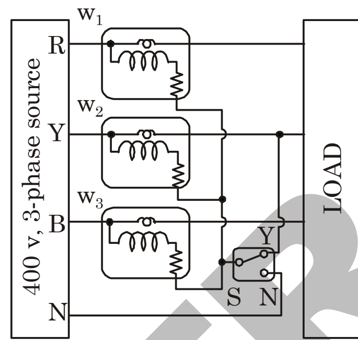
For V_s = 72 V and V_0 = 48 V

$$48 = \frac{\alpha}{1-\alpha} \times 72$$

$$\alpha = \frac{2}{5}$$

$$\frac{2}{5} \le \alpha \le \frac{3}{5}$$

40. The load shown in the figure is supplied by a 400 V(line-to-line), 3-phase source (RYB sequence). The load is balanced and inductive, drawing 3464 VA. When the switch S is in position N, the three wattmeters W_1, W_2 and W_3 read 577.35 W each. If the switch is moved to position Y, the readings of the wattmeters in watts will be:



(a) W_1 = 1732 and W_2 = W_3 = 0

(b) W_1 = 0, W_2 = 1732 and W_3 = 0

(c) W_1 = 866, W_2 = 0, W_3 = 866

(d) W_1 = W_2 = 0 and W_3 = 1732

Sol. (d)

Apparent power = 3464 VA

Real power = 3 × 577.35 W = 1732.05 Watts

$$\text{P.f.} = \frac{\text{Real power}}{\text{Apperent power}}$$

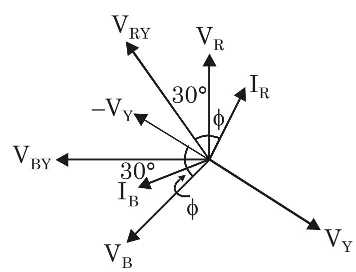
$$= \frac{1732.05}{3464}$$

$$\text{P.f.} = 0.5$$

When switch is moved to position Y

$\Rightarrow$ Voltage across potential coil of wattmeter two is zero so $W_2 = 0$

For RYB phase sequence



Voltage across potential coil of wattmeter one is V_{RY}.

Voltage across potential coil of wattmeter two is V_{BY}.

So $\quad W_1 = V_{RY} \cdot I_R \cdot \cos(30 + \phi)$

$\quad W_2 = V_{BY} \cdot I_B \cos(30° - \phi)$

For P.f = 0.5; $\phi = \cos^{-1}(0.5) = 60°$

Thus

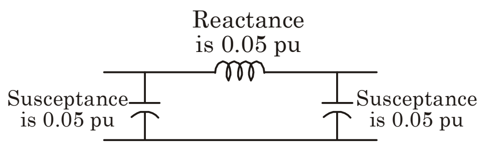
$W_1 = V_{RY} \cdot I_R \cdot \cos(30+60°) = 0$

$W_3 = V_{BY} \cdot I_B \cdot \cos(30-60°) = 1732$ W

41. The bus admittance matrix for a power system network is

$$\begin{bmatrix} -j39.9 & j20 & j20 \\ j20 & -j39.9 & j20 \\ j20 & j20 & -j39.9 \end{bmatrix} \text{pu}$$

There is a transmission line, connected between buses 1 and 3, which is represented by the circuit shown in figure



If this transmission line is removed from service, what is the modified bus admittance matrix?

(a) $\begin{bmatrix} -j19.9 & j20 & 0 \\ j20 & -j39.9 & j20 \\ 0 & j20 & -j19.9 \end{bmatrix} \text{pu}$

(b) $\begin{bmatrix} -j39.95 & j20 & 0 \\ j20 & -j39.9 & j20 \\ 0 & j20 & -j39.9 \end{bmatrix} \text{pu}$

(c) $\begin{bmatrix} -j19.95 & j20 & 0 \\ j20 & -j39.9 & j20 \\ 0 & j20 & -j19.95 \end{bmatrix} \text{pu}$

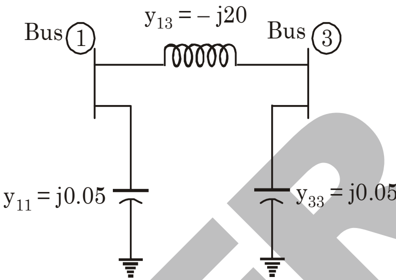
(d) $\begin{bmatrix} -j19.95 & j20 & 0 \\ j20 & -j39.9 & j20 \\ j20 & j20 & -j19.95 \end{bmatrix} \text{pu}$

Sol. (c)

Given y-bus $[Y]_{3\times3}$

$$= \begin{bmatrix} -j39.9 & j20 & j20 \\ j20 & -j39.9 & j20 \\ j20 & j20 & -j39.9 \end{bmatrix}$$

Converting the given transmission line parameters into Y parameters we get



whenever we remove the transmission line between Bus 1 and Bus 3 the parameters Y_{11}, Y_{13}, Y_{31}, Y_{33} will get affected

$Y_{11} = -j39.9 - y_{11} - y_{13} = -j39.9 - (j0.05) - (-j20)$

$= -j39.9 - j0.05 + j20 = -j\ 19.95$

$Y_{13} = j20 + y_{13} = j20 - j20 = 0$

$Y_{31} = j20 + y_{13} = j20 - j20 = 0$

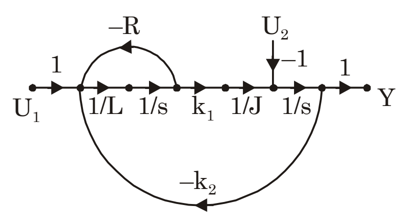
$Y_{33} = -j39.9 - y_{33} - y_{31}$

$= -j39.9 - j0.05 - (-j20) = -j19.95$

$\therefore$ New Y bus matrix $[Y]_{3\times3}$

$$= \begin{bmatrix} -j19.95 & j20 & 0 \\ j20 & -j39.9 & j20 \\ 0 & j20 & -j19.95 \end{bmatrix}$$

42. In the system whose signal flow graph is shown in the figure, $U_1(s)$ and $U_2(s)$ are inputs. The transfer function $\dfrac{Y(s)}{U_1(s)}$ is



(a) $\dfrac{k_1}{JLs^2 + JRs + k_1k_2}$

(b) $\dfrac{k_1}{JLs^2 - JRs - k_1k_2}$

(c) $\dfrac{k_1 - U_2(R + sL)}{JLs^2 + (JR - U_2L)s + k_1k_2 - U_2R}$

(d) $\dfrac{k_1 - U_2(sL - R)}{JLs^2 - (JR + U_2L)s - k_1k_2 + U_2R}$

Sol. (a)

Using mason's gain formula

$$\text{T.F.} = \frac{\Sigma P_k \Delta_k}{\Delta}$$

$$P_1 = \frac{1}{L}\cdot\frac{1}{s}\cdot k_1\cdot\frac{1}{J}\cdot\frac{1}{s} = \frac{k_1}{JLs^2}$$

$$\Delta_1 = 1$$

$$\Delta = 1-\left[\left(\frac{-R}{Ls}\right)+\left(\frac{-k_1k_2}{JLs^2}\right)\right]$$

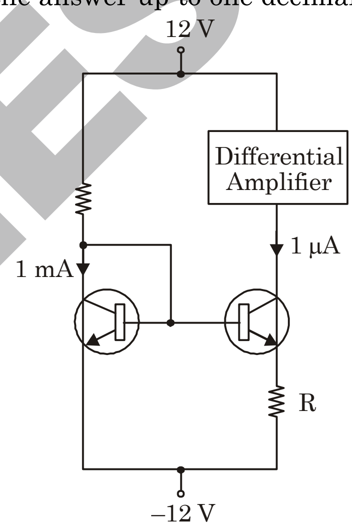
$$= 1+\frac{R}{Ls}+\frac{k_1k_2}{JLs^2}$$

$$\Delta = \frac{JLs^2+JRs+k_1k_2}{JLs^2}$$

$$\text{T.F.} = \frac{\dfrac{k_1}{JLs^2}}{\dfrac{JLs^2+JRs+k_1k_2}{JLs^2}}$$

$$\text{T.F.} = \frac{k_1}{JLs^2+JRs+k_1k_2}$$

43. The circuit shown in the figure uses matched transistors with a thermal voltage V_T = 25 mV. The base currents of the transistors are negligible. The value of the resistance R in $k\Omega$ that is required to provide $1\mu A$ bias current for the differential amplifier block shown in _____. (Give the answer up to one decimal place).



Sol. (12.2 MΩ)

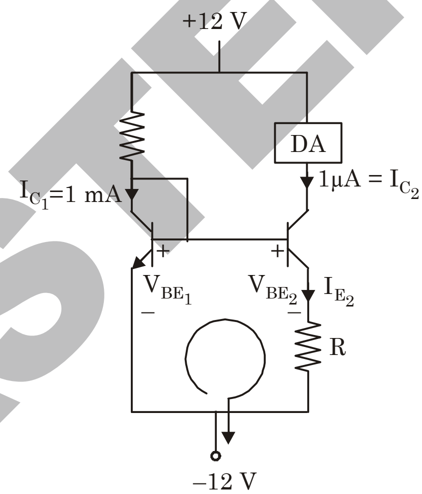
Given data V_T = 25 mV

given $I_{B_1} = I_{B_2} \approx 0A$

I_{C_1} = 1mA

I_{C_2} = 1μA (Bias current)

Applying the KVL for the given circuit we get



$$-V_{BE_1}+V_{BE_2}+I_{E_2}R-12 = 0$$

$$I_{E2}R = V_{BE_1}-V_{BE_2}+12 \quad \text{...(1)}$$

$\because I_{B_2} = 0$ we get

$$I_{E_2} = I_{C_2} = 1\mu A \quad \text{...(2)}$$

substituting eq (2) in eq (1) we get

$$(1\mu)R = V_{BE_1}-V_{BE_2}+12 \quad \text{...(3)}$$

$$V_{BE_1} = V_T \ln\left(\frac{I_{C_1}}{I_s}\right) \quad \text{...(4)}$$

$$V_{BE_2} = V_T \ln\left(\frac{I_{C_2}}{I_s}\right) \quad \text{...(5)}$$

substituting equations (4) and (5) in eq. (3) we get

$$(1\mu)R = V_T \ln\left(\frac{I_{C_1}}{I_s}\right)-V_T \ln\left(\frac{I_{C_2}}{I_s}\right)+12$$

$$R = \frac{V_T \ln\left(\dfrac{I_{C_1}}{I_{C_2}}\right)+12}{(1\mu)}$$

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171	CE	BUDDI PRAKASH MEENA
173	CE	DHEERESH KR.
174	CE	VINITA
175	CE	SAURAV SHIVHARE
179	CE	LALIT KUMAR
180	CE	NAVALPREET KAUR
183	CE	SANTOSH KR. MEENA
184	CE	ABHISHEK KUMAR
187	CE	RAHUL JAJORIA
188	CE	BHARTI MEENA
189	CE	JITENDRA KR. MEENA
190	CE	SAURAV DEO
193	CE	PRADEEP KR. MEENA
194	CE	NITESH KR. SINGH
199	CE	AMIT KR. MEENA
203	CE	ACHAL KUMAR
207	CE	LALIT MOHAN MEENA
210	CE	SUNIL KR. MEENA
212	CE	AKASH CHANDRA
213	CE	MAHENDRA KR. MEENA
216	CE	SUMAN JEE
221	CE	ALOK OJHA
224	CE	ANKIT KR. SHUKLA

Received so far..... [If found any discrepancy please bring it to our notice.]

$$= \frac{25m\ln\left(\frac{1m}{1\mu}\right)+12}{(1\mu)}$$

$R = 12.172\ M\Omega \simeq 12.2 M\Omega$

44. For a system having transfer function $G(s) = \frac{-s+1}{s+1}$ a unit step input is applied at time t = 0. The value of the response of the system at t = 1.5 sec (rounded off to three decimal places) is _____

Sol. (0.554)

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

For unit step input $R(s) = \frac{1}{s}$

So output $y(s) = R(s).\ G(s) = \frac{1}{s}\cdot\frac{(-s+1)}{s+1}$

$$y(t) = L^{-1}\left(\frac{-1}{s+1}\right)+L^{-1}\left(\frac{1}{s(s+1)}\right)$$

$$= -e^{-t}+\int_0^t e^{-t}dt$$

$$= -e^{-t}+\left(-e^{-t}\right)+1$$

$$y(t) = 1-2e^{-t}$$

at $t = 1.5$ sec

$$y(1.5) = 1-2e^{-1.5}$$

$$= 0.5537$$

or $\boxed{y(1.5) = 0.554}$

45. Two parallel connected, three-phase, 50 Hz, 11 kV, star-connected synchronous machines A and B are operating as synchronous condensers. They together supply 50 MVAR to a 11 kV grid. Current supplied by both the machines are equal. Synchronous reactances of machine A and machine B are 1Ω and 3Ω, respectively. Assuming the magnetic circuit to be linear, the ratio of excitation current of machine A to that of machine B is _____. (Give the answer up to two decimal places).

Sol. (0.74)

Total current supplied by both machine to grid.

$$I_T = I_A + I_B$$

$$I_T = \frac{50\,MVAR}{11kV}$$

$$= 4.54545\ kA$$

$$I_A = I_B = \frac{I_T}{2} = 2.27273\ kA$$

$E_A = V_t + I_A X_s = 11$ kV + $2.2723 \times 1 = 13.273$ kV

$E_B = V_t + I_B X_s = 11$ kV + $2.2723 \times 3 = 17.817$ kV

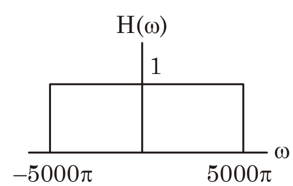
$$\frac{E_A}{E_B} = \frac{13.273}{17.817} = 0.745 \simeq 0.74$$

Therefore, the ratio of excitation current of machine A to that of machine B will be 0.74.

46. Let the signal

$$x(t) = \sum_{k=-\infty}^{+\infty}(-1)^k\,\delta\left(t-\frac{k}{2000}\right)$$

be passed through an LTI system with frequency response $H(\omega)$, as given in the figure below



The Fourier series representation of the output is given as

(a) $4000+4000\cos(2000\pi t)+4000\cos(4000\pi t)$

(b) $2000+2000\cos(2000\pi t)+2000\cos(4000\pi t)$

(c) $4000\cos(2000\pi t)$

(d) $A\,2000\cos(2000\pi t)$

Sol. (c)

Given function in time domain

$$x(t) = \sum_{k=-\infty}^{\infty}(-1)^k\,\delta\left(t-\frac{k}{2000}\right)$$

This function looks like f(t–T) delayed by time T

here $\delta\left(t-\frac{k}{2000}\right)$ is compared with $\delta(t-kT)$

Where $T = \frac{1}{2000}$

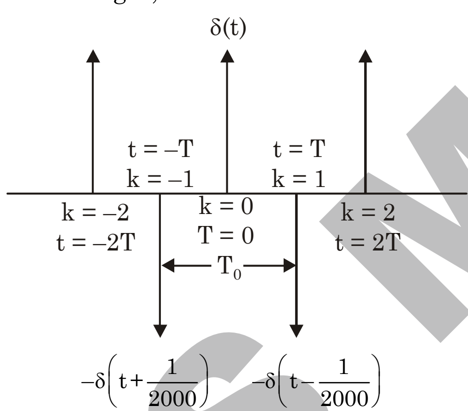
the values of x(t) for k = 0,1,2,.... are
k = –1,–2, –3,....

$$x(t) = \delta(t) \quad \text{for } k = 0$$

$$x(t) = (-1)\delta\left(t-\frac{1}{2000}\right) \quad \text{for } k = 1$$

$$x(t) = (-1)^{-1}\delta\left(t-\frac{1}{2000}\right) \quad \text{for } k = -1$$

Drawing the function x(t) for various values of k we get,



The figure shown above passess even half wave symmetry with time period

$$T_0 = 2T = \frac{2}{2000} = \frac{1}{1000}$$

$$\omega_0 = \frac{2\pi}{T} = \frac{2\pi}{\left(\frac{1}{1000}\right)} = 2000\pi$$

In the case of even half wave symmetry b_n = 0 and consists of only odd harmonics of a_n.

The frequency components are $\omega_0, 3\omega_0 ...$

i.e. $2000\pi, 6000\pi.....$

and 2000π is the only frequency available in the above range or -5000π to 5000π

$$\therefore \quad a_n = \frac{2\pi}{T}\int_{-T_0/2}^{T_0/2} f(t)\cos n\omega_0 t\,dt$$

$$= \frac{4}{T_0}\int_{0}^{T_0/2} f(t)\cos n\omega_0 t\,dt$$

$$a_2 = \frac{4}{T_0}\int_{0}^{T_0/2} \delta(t)\cos 2\omega_0(0)\,dt$$

$$= \frac{4}{T_0}\int_{0}^{T_0/2} \delta(t)\,dt$$

$$= \frac{4}{T_0}(1) = 4000$$

$\therefore$ The output

$$y(t) = 4000\cos\omega_0 + 4000\cos(3\omega_0 t) + ...$$
$$= 4000\cos 2000\pi t + 4000\cos 6000\pi t + ...$$

Hence, 4000 $\cos 2000\pi t$ is in the range of -5000π to 5000π.

47. The output expression for the Karnaugh map shown below is

AB \ CD	00	01	11	10
00	0	0	0	0
01	1	0	0	1
11	1	0	1	1
10	0	0	0	0

(a) $B\bar{D} + BCD$
(b) $B\bar{D} + AB$
(c) $\bar{B}D + ABC$
(d) $B\bar{D} + ABC$

Sol. (d)

AB \ CD	00	01	11	10
00	0	0	0	0
01	1	0	0	1
11	1	0	1	1
10	0	0	0	0

$$f = B\bar{D} + ABC$$

48. The transfer function of the system Y(s)/U(s) whose state-space equations are given below is:

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 2 & 0 \end{bmatrix}\begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u(t)$$

$$y(t) = [1\ 0]\begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

(a) $\dfrac{(s+2)}{(s^2-2s-2)}$

(b) $\dfrac{(s-2)}{(s^2+s-4)}$

(c) $\dfrac{(s-4)}{(s^2+s-4)}$

(d) $\dfrac{(s+4)}{(s^2-s-4)}$

Sol. (d)

Transfer function T.F = $C(sI-A)^{-1}B$

$$sI–A = \begin{bmatrix} s-1 & -2 \\ -2 & s \end{bmatrix}$$

$$|sI-A| = s(s-1)-4 = s^2-s-4$$

$$[sI-A]^{-1} = \frac{1}{s^2-s-4}\begin{bmatrix} s & +2 \\ +2 & s-1 \end{bmatrix}$$

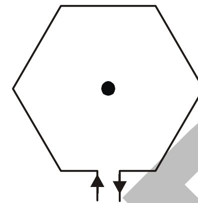
$$[sI-A]^{-1}B = \frac{1}{s^2-s-4}\begin{bmatrix} s & +2 \\ 2 & s-1 \end{bmatrix}\begin{bmatrix} 1 \\ 2 \end{bmatrix}$$

$$= \frac{1}{s^2-s-4}\begin{bmatrix} s+4 \\ 2s \end{bmatrix}$$

$$C[sI-A]^{-1}B = \frac{1}{s^2-s-4}[1\ \ 0]\begin{bmatrix} s+4 \\ 25 \end{bmatrix}$$

$$\text{T.F.} = \frac{s+4}{s^2-s-4}$$

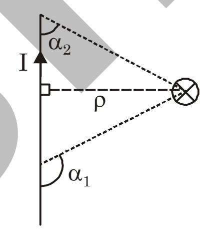
49. The magnitude of magnetic flux density (B) in micro Teslas (μT), at the center of a loop of wire wound as a regular hexagon of side length 1 m carrying a current (I = 1A) and placed in vacuum as shown in the figure is _____. (Give the answer up to two decimal places).



Sol. (0.69)

Magnetic field due to finite length of current carrying conductor is given by

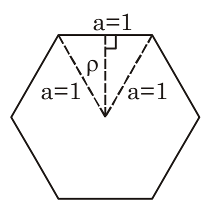
$$H = \frac{I}{4\pi\rho}(\cos\alpha_2 - \cos\alpha_1)\hat{a}_\phi \quad ..\ (1)$$



$\alpha_2 = 60°$

$\alpha_1 = 120°$

In case of regular hexagon



$$\rho = \sqrt{a^2 - \frac{a^2}{4}} \text{ where } a = 1$$

$$= \sqrt{1-\frac{1}{4}} = \frac{\sqrt{3}}{2}\text{m}$$

Using formula in eq-(i) magnetic field intensity at centre due to one side of regular Hexagon

$$H' = \frac{1}{4\pi\left(\frac{\sqrt{3}}{2}\right)}[\cos 60° - \cos 120°]\alpha_\phi$$

= 0.091888 H/m

Magnetic field intensity due to all six sides of regular hexagon will be

$H = 6 \times H' = 6 \times 0.091888$

$= 0.551329$ H/m

Magnetic flux density $B = \mu H$

Hence $B = \mu_0 H$ (in vaccum)

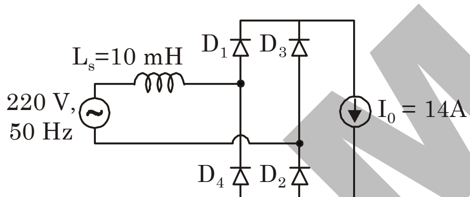
$= 4\pi \times 10^{-7} \times 0.551329$

$= 6.9282 \times 10^{-7}$ Tesla

or $\boxed{B = 0.6928\ \mu T}$

$\boxed{B = 0.69\ \mu T}$ upto two decimal places

50. The figure below shows an uncontrolled diode bride rectifier supplied from a 220 V, 50 Hz, 1-phase ac source. The load draws a constant current $I_0 = 14$ A. The conduction angle of the diode D_1 in degrees (rounded off to two decimal places) is _____



Sol. (210.84°)

For single phase controlled bridge rectifier effect of source inducfance will modify the average output voltage as,

$$V_0 = \frac{V_m}{\pi}[\cos\alpha + \cos(\alpha + \mu)]$$

where μ is overlap angle

But for diode (uncontrolled) bridge, $\alpha = 0$

so $V_0 = \frac{V_m}{\pi}[1 + \cos\mu]$ ...(1)

Also

$$V_0 = \frac{2V_m}{\pi} - \frac{\omega L_s}{\pi} I_0 \quad \text{... (2)}$$

where L_s = source inductance

From eq. (1) and eq (2).

$$\frac{2V_m}{\pi} - \frac{\omega L_s}{\pi} I_0 = \frac{V_m}{\pi}[1 + \cos\mu]$$

Substituting all the values in above equation

$$\frac{2 \times 220 \times \sqrt{2}}{\pi} - \frac{2\pi \times 50 \times 10 \times 10^{-3} \times 14}{\pi}$$

$$= \frac{220 \times \sqrt{2}}{\pi}[1 + \cos\mu]$$

Solving for $\cos\mu$

$\cos\mu = 0.8586$

$\Rightarrow \mu = 30.836°$

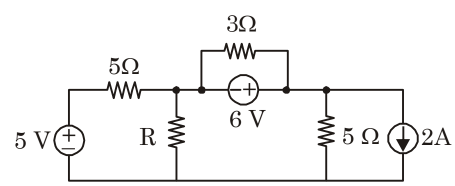
Conduction angle for diode will be 180° + μ

Hence conduction angle $\gamma = 180° + \mu$

$= 180° + 30.836$

$\boxed{\gamma = 210.84°}$ upto two decimal places.

51. In the circuit shown below, the maximum power transferred to the resistor R is_____W



Sol. (3.025 W)

P_{max} across R will be given by

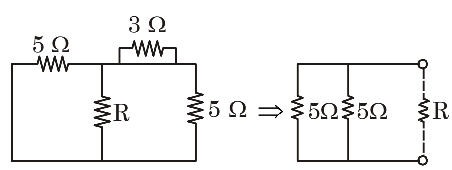
$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

Where V_{Th} = Thevenin's voltage across 'R'

R_{Th} = Thevenin's resistance across 'R'

To Calculate R_{th}

Short cirauiting all voltage sources and open circuiting all current sources, circuit reduces to



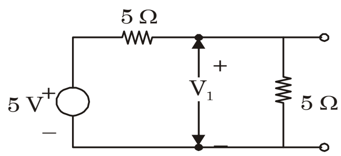
Hence $R_{Th} = 5\Omega \| 5\Omega = 2.5\ \Omega$

To calculate V_{th}

Using superposition theorem

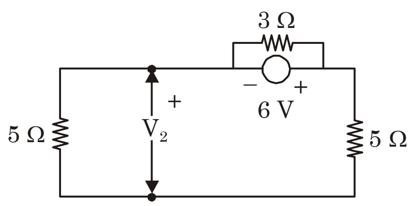
Taking 5V source only

Circuit reduces to



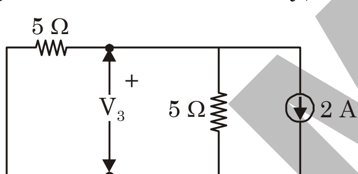
$$V_1 = \frac{5}{2} = 2.5$$

Taking 6V source only, circuit reduces to



$V_2 = -3V$

Taking 2A current source only,



$V_3 = -5V$

$V_{Th} = V_1 + V_2 + V_3 = 2.5 - 3 - 5 = -5.5V$

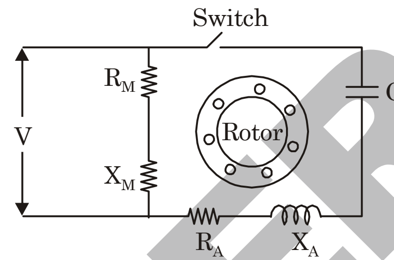
$$P_{max} = \frac{(5.5)^2}{4 \times 2.5}$$

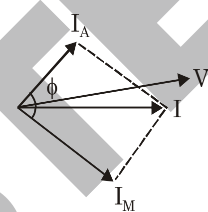
or $\boxed{P_{max} = 3.025\ W}$

52. A 375 W, 230 V, 50 Hz, capacitor start single-phase induction motor has the following constants for the main and auxiliary windings (at starting): $Z_m = (12.50 + j15.75)\Omega$ (main winding), $Z_a = (24.50 + j12.75)\Omega$ (auxiliary winding). Neglecting the magnetizing branch, the value of the capacitance (in μF) to be added in series with the auxiliary winding to obtain maximum torque at starting is _____

Sol. (98.87 μF)

Capacitor start single phase mduction motor





Torque will be maximum when $\phi = 90°$ between currents of auxiliary winding and mains winding.

$$I_M = \frac{230}{(12.50 + j15.75)}$$

$$\phi_M = -\tan^{-1}\left(\frac{15.75}{12.50}\right)$$

Taking X_c as reactance of capacitor C_s

$$I_A = \frac{230}{(24.50 + j12.75 - jX_c)}$$

$$\phi_A = -\tan^{1}\left(\frac{12.75 - X_C}{24.50}\right)$$

Taking $\phi_m + 90° = \phi_A$

$$\tan^{-1}\left(\frac{15.75}{12.50}\right) + 90° = \tan^{-1}\left(\frac{12.75 - X_c}{24.50}\right)$$

$$\tan^{-1}\left(\frac{15.75}{12.5}\right) - \tan^{-1}\left(\frac{12.75 - X_c}{24.50}\right) = 90°$$

Taking tan on both sides

$$\frac{\left(\frac{15.75}{12.5}\right) - \left(\frac{12.75 - X_c}{24.50}\right)}{1 + \left(\frac{15.75}{12.5}\right)\left(\frac{12.75 - X_c}{24.50}\right)} = \tan 90° = \infty$$

$$\therefore \quad 1+\left(\frac{15.75}{12.5}\right)\left(\frac{12.75-X_c}{24.50}\right) = 0$$

Solving for X_c

$X_c = 32.194$

$$\text{also } X_c = \frac{1}{\omega C_s}$$

$$\Rightarrow \quad C_s = \frac{1}{\omega X_c} = \frac{1}{2\pi\times 100\times 32.194}$$

or $\boxed{C_s = 98.87\ \mu F}$

53. Consider a causal and stable LTI system with rational transfer function H(z), whose corresponding impulse response begins at n = 0. Furthermore, $H(1) = \frac{5}{4}$. The poles of H(z) are $p_k = \frac{1}{\sqrt{2}}\exp\left(j\frac{(2k-1)\pi}{4}\right)$ for k = 1, 2, 3, 4. The zeros of H(z) are all at z = 0. Let $g[n] = j^n h[n]$. The value of g[8] equals _____. (Give the answer up to three decimal places).

Sol. (0.098)

$$P_k = \frac{1}{\sqrt{2}}\exp\left(j\frac{(2k-1)\pi}{4}\right),$$

$$k = 1, 2, 3, 4$$

$$P_1 = \frac{1}{\sqrt{2}}e^{\frac{j\pi}{4}}$$

$$= \frac{1}{\sqrt{2}}\left[\cos\left(\frac{\pi}{4}\right)+j\sin\left(\frac{\pi}{4}\right)\right]$$

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

$$P_2 = \frac{1}{\sqrt{2}}e^{\frac{j3\pi}{4}}$$

$$= \frac{1}{\sqrt{2}}\left[\cos\left(\frac{3\pi}{4}\right)+j\sin\left(\frac{3\pi}{4}\right)\right]$$

$$= \frac{(-1+j)}{2}$$

$$P_3 = \frac{1}{\sqrt{2}}e^{\frac{j5\pi}{4}}$$

$$= \frac{1}{\sqrt{2}}\left[\cos\left(\frac{5\pi}{4}\right)+j\sin\left(\frac{5\pi}{4}\right)\right]$$

$$= \frac{(-1-j)}{2}$$

$$P_4 = \frac{1}{\sqrt{2}}e^{\frac{j7\pi}{4}}$$

$$= \frac{1}{\sqrt{2}}\left[\cos\left(\frac{7\pi}{4}\right)+j\sin\left(\frac{7\pi}{4}\right)\right]$$

$$= \left(\frac{1-j}{2}\right)$$

System is causal so order of numerator can not be greater than order of denominator. Therefore,

$$H(z) = \frac{K\cdot Z^4}{(Z-P_1)(Z-P_2)(Z-P_3)(Z-P_4)}$$

$$= \frac{K\cdot Z^4}{\left[Z-\left(\frac{1+j}{2}\right)\right]\left[Z-\left(\frac{-1+j}{2}\right)\right]\left[Z-\left(\frac{-1-j}{2}\right)\right]\left[Z-\frac{(1-j)}{2}\right]}$$

$$H(z) = \frac{KZ^4}{Z^4+\frac{1}{4}}$$

$$H(1) = \frac{5}{4}$$

$$\frac{K}{1+\frac{1}{4}} = \frac{5}{4}$$

$$\frac{4}{5}K = \frac{5}{4}$$

$$\boxed{K = \frac{25}{16}}$$

$$H(z) = \frac{25}{16}\frac{Z^4}{Z^4+\frac{1}{4}}$$

$$H(z) = \frac{25}{16}\left[1-\frac{1}{4}Z^{-4}+\frac{1}{16}Z^{-8}+.....\right]$$

$$h[n] = \frac{25}{16}\left[\delta(n) - \frac{1}{4}\delta(n-4) + \frac{1}{16}\delta(n-8).....\right]$$

$$h[8] = \frac{25}{16}\left[\delta(8) - \frac{1}{4}\delta(4) + \frac{1}{16}\delta(0).....\right]$$

$$= \frac{25}{16}\left[0 - \frac{1}{4}\times 0 + \frac{1}{16}\times 1 + ...0\right]$$

$$h[8] = \frac{25}{16}\times\frac{1}{16} = \frac{25}{256} = 0.098$$

$$g[n] = j^n h[n]$$

$$g[8] = j^8 h[8] = h[8] = 0.098$$

$$\boxed{g[8] = 0.098}$$

54. Let a causal LTI system be characterized by the following differential equation, with initial rest condition

$$\frac{d^2y}{dt^2} + 7\frac{dy}{dt} + 10y(t) = 4x(t) + 5\frac{dx(t)}{dt}$$

where, x(t) and y(t) are the input and output respectively. The impulse response of the system is [u(t) is the unit step function]

(a) $2e^{-2t}u(t) - 7e^{-5t}u(t)$

(b) $-2e^{-2t}u(t) + 7e^{-5t}u(t)$

(c) $7e^{-2t}u(t) - 2e^{-5t}u(t)$

(d) $-7e^{-2t}u(t) + 2e^{-5t}u(t)$

Sol. (b)

Differential equation

$$\frac{d^2y}{dt^2} + 7\frac{dy}{dt} + 10y(t) = 4x(t) + 5\frac{dx(t)}{dt}$$

Taking Laplace on both sides (initial rest condition)

$$s^2Y(s) + 7sY(s) + 10Y(s) = 4X(s) + 5s\,X(s)$$

$$H(s) = \frac{Y(s)}{X(s)} = \frac{5s+4}{s^2+7s+10}$$

Impulse response $h(t) = L^{-1}(H(s))$

$$h(t) = L^{-1}\left(\frac{5s+4}{(s+2)(s+5)}\right)$$

$$= L^{-1}\left(\frac{-2}{s+2} + \frac{7}{s+5}\right)$$

$h(t) = -2e^{-2t}\,4(t) + 7e^{-5t}\,4(t)$

55. Only one of the real roots of $f(x) = x^6 - x - 1$ lies in the interval $1 \le x \le 2$ and bisection method is used to find its value. For achieving an accuracy of 0.001, the required minimum number of iterations is _____

Sol. (10)

In bisection method, the minimum number of iterations is given by $\frac{|b-a|}{2^n} < \varepsilon$

where

a: lower limit of interval

b: upper limit of interval

ε : Error in approximation

n : Number of iteration

Thus

$$\frac{|2-1|}{2^n} < 0.001$$

$\Rightarrow 2^n > 1000$

$\Rightarrow \boxed{n = 10}$

Aptitude

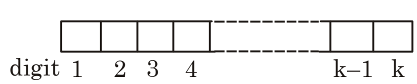
1. The probability that a k-digit number does NOT contain the digits 0, 5 or 9 is

(a) 0.3^k (b) 0.06^k

(c) 0.7^k (d) 0.9^k

Sol. (c)

k- digit number



Excluding digits 0, 5 or 9

Probability

$$P = \frac{{}^{7}C_1 \cdot {}^{7}C_1 \cdot {}^{7}C_1 \ldots {}^{7}C_1 \;\; (k - \text{times})}{{}^{10}C_1 \cdot {}^{10}C_1 \cdot {}^{10}C_1 \ldots {}^{10}C_1 \;\; (k - \text{times})}$$

$$= \frac{7.7.7\ldots.7 \;\; (k - \text{times})}{10.10.10\ldots.10 \;\; (k - \text{times})}$$

or $P = (0.7)^k$

2. Rahul, Murali, Srinivas and Arul are seated around a square table. Rahul is sitting to the left of Murali. Srinivas is sitting to the right of Arul. Which of the following pairs are seated opposite each other?

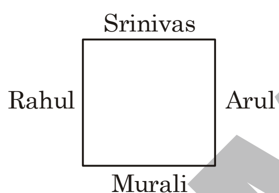
(a) Rahul and Murali

(b) Srinivas and Arul

(c) Srinivas and Murali

(d) Srinvas and Rahul

Sol. (c)



3. Research in the workplace reveals that people work for many reasons _____

(a) money beside

(b) beside money

(c) money besides

(d) besides money

Sol. (d)

Beside $\rightarrow$ 'next to'

Besides $\rightarrow$ 'Except'

4. After Rajendra Chola returned from his voyage to Indonesia, he _____ to visit the temple in Thanjavur.

(a) was wishing

(b) is wishing

(c) wished

(d) had wished

Sol. (c)

5. Find the smallest number y such that y × 162 is a perfect cube

(a) 24

(b) 27

(c) 32

(d) 36

Sol. (d)

$y \times 162$ as perfact cube

$16^2 = 2 \times 3 \times 3 \times 3 \times 3$

to make it perfect cube y $= 2 \times 2 \times 3 \times 3$

or $\boxed{y = 36}$

6. The expression $\frac{(x+y) - |x-y|}{2}$ is equal to

(a) The maximum of x and y

(b) The minimum of x and y

(c) 1

(d) None of the above

Sol. (b)

Given expression is $\frac{(x+y)-|x-y|}{2}$

we know modulus of any number should be a positive value

Case (1): x > y (here y is minimum)

then $|x-y| = (x - y)$ positive value

$$\text{then } \frac{(x+y)-(x-y)}{2} = \frac{(x+y)-(x-y)}{2}$$

$$= \frac{2y}{2}$$

= y (minimum of x and y)

Case (2): y > x (here x is minimum)

then $|x-y| = (y-x)$ (positive value)

$$\text{then } \frac{(x+y)-|x-y|}{2} = \frac{(x+y)-(y-x)}{2}$$

$$= \frac{2x}{2}$$

= x (minimum of x and y)

In both the cases we get the minimum of x and y and the corretion option is (b).

7. "The hold of the nationalist inagination on our colonial past is such that anything inadequately or improperly nationlist is just not history."

Which of the following statements best reflects the author's opinion?

(a) Nationalists are highly imaginative

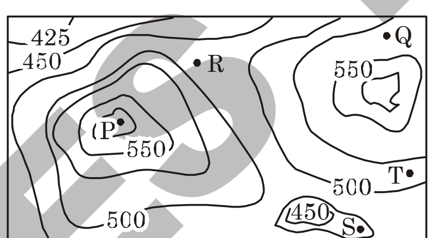
(b) History is viewed through the filter of nationalism

(c) Our colonial past never happened

(d) Nationalism has to be both adequately and properly imagined

Sol. (b)

8. A contour line joins locations having the same height above the mean sea level. The following is a contour plot of a geographical region. Contour lines are shown at 25 m intervals in this plot. If in a flood, the water level rises to 525 m. Which of the villages P, Q, R, S, T get submerged?



(a) P, Q

(b) P, Q, T

(c) R, S, T

(d) Q, R, S

Sol. (c)

Height above mean sea level for

P $\Rightarrow$ H_P = 575 m

Q $\Rightarrow$ H_Q = 525 m

R $\Rightarrow$ H_R = 475 m

S $\Rightarrow$ H_s = 475 m

T $\Rightarrow$ H_T = 500 m

if water level in a flood is 252 m then R,S,T will be submerged.

9. Six people are seated around a circular table. There are at least two men and two women. There are at least three right-handed persons. Every woman has a left-handed person to her immediate right. None of the women are right-handed. The number of women at the table is

(a) 2

(b) 3

(c) 4

(d) Cannot be determined

Sol. (a)

Total perosns–6

Conditions:

1. Atleast two men and two women
2. Atleast 3-right handed persosn
3. Every women has a left handed person to her immediate right and all women are left handed.

Let us choose at least two women (minimum) then total left handed persons = 2 + 1 (1 man is immediate right of one woman when both woman are sitting together) = 3

Remaining three will be right handed

Hence correct answer is (a).

10. Arun, Gulab, Neel and Shweta must choose one shift each from a pile of four shirt coloured red, pink, blue and white respectively. Arun dislike the colour red and Shweta dislikes the colour white. Gulab and Neel like all the colours. In how many different ways can they choose the shirts so that no one has a shirt with a colour he or she dislikes?

(a) 21 (b) 18

(c) 16 (d) 14

Sol. (d)

Colour – Red, Pink, Blue, White

Arun $\leftarrow$ ~~Red~~

Shweta $\leftarrow$ ~~White~~

Case–Arun chooses pink shirt then Shweta will have two options Red and blue so number of ways

$$n_1 = {}^1C_1 \cdot {}^2C_1 \cdot {}^2C_1 \cdot {}^1C_1 = 4$$

Case–2

Arun chooses bule shirt, Shweta will have two options Red and Pink, so

$$n_2 = {}^1C_1 \cdot {}^2C_1 \cdot {}^2C_1 \cdot {}^1C_1 = 4$$

Case–3

Arun chooses white, then Shweta will have three options, so

$$n_3 = {}^1C_1 \cdot {}^3C_1 \cdot {}^2C_1 \cdot {}^1C_1 = 6$$

So total number of ways = 4 + 4 + 6 = 14