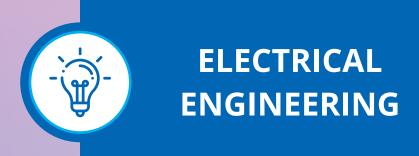


GATE - 2021

Questions Questions Detailed Solutions



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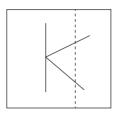
SUBJECTWISE WEIGHTAGE

S.No.	Name of the Subject	No. of Questions
01	Electric Circuits	7
02	EM Theory	4
03	Signals and Systems	5
04	Electrical Machines	7
05	Power Systems	6
06	Control Systems	5
07	Electrical & Electronic Measurements	1
08	Digital Electronics & Microprocessors	2
09	Analog Electronics	6
10	Power Electronics	4
11	Engineering Mathematics	8
12	Aptitude	6
13	English	4
		65

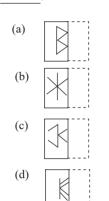


General Aptitude

01.



A transparent square sheet shown above is folded along the dotted line. The folded sheet will look like



01. Ans: (a)

02. Oasis is to sand as island is to

Which one of the following options maintains a similar logical relation in the above sentence?

(a) Land

(b) Water

(c) Mountain

(d) Stone

02. Ans: (b)

Sol: Oasis is a water pool amidst sand just as island is a piece of land amidst water.

03. Seven cars P.Q,R,S,T,U and V are parked in a row not necessarily in that order. The cars T and U should be parked next to each other. The cars S and V also should be parked next to each other, whereas P and Q cannot be parked next to each other. Q and S must be parked next to each other. R is parked to the immediate right of V. T is parked to the left of U.

Based on the above statements, the only INCORRECT option given below is:

- (a) Q and R are not parked together
- (b) There are two cars parked in between Q and V.
- (c) V is the only car parked in between S and R
- (d) Car P is parked at the extreme end.



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03. Ans: (b)

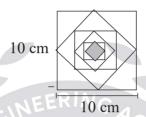
Sol: As per the conditions given, we get two possibilities

- 1. PTUOSVR
- 2. TUQSVRP

Going by any of the above two possibilities there can't be two cause between Q and V.

.: Option (b) is suitable answer.

04.



In the figure shown above, each insided square is formed by joining the midpoints of the sides of the next larger square. The area of the smallest square(shaded) as shown, in cm² is:

(a) 6.25

(b) 12.50

(c) 1.5625

(d) 3.125

04. Ans: (d)

Sol: When a square is formed by joining the midpoints of the next larger square, the area of inner square is exactly of the area of the larger square.

Area of
$$1^{st}$$
 square = $10 \times 10 = 100$ Sq.cm

Area of 1st square =
$$10 \times 10 = 100$$
 Sq.cm
Area of 2nd square = $\frac{1}{2} \times 100 = 50$ Sq.cm

Area of
$$3^{\text{rd}}$$
 square = $\frac{1}{2} \times 50 = 25 \text{ Sq.cm}$ Since 1995

Area of 4th square =
$$\frac{1}{2} \times 25 = 12.5$$
 Sq.cm

Area of 5th square =
$$\frac{1}{2} \times 12.5 = 6.25$$
 Sq.cm

Area of the smallest square is 6^{th} square = $\frac{1}{2} \times 6.25 = 3.125$ Sq.cm

Option (d) is the correct answer.

- 05. For a regular polygon having 10 sides, the interior angle between the sides of the polygon, in degrees, is:
 - (a) 216

(b) 396

(c) 324

(d) 144



05. Ans: (d)

Sol: Each interior angle in a regular polygon =
$$\frac{(2n-4)90^{\circ}}{n}$$

Where n is the number sides.

∴ Each interior angle =
$$\frac{[(2 \times 10) - 4]90^{\circ}}{10} = 144^{\circ}$$

- The poeple were at the demonstration were from all sections of society.
 - (a) whom

(b) whose

(c) which

(d) who

06. Ans: (d)

Sol: The subject of the verb is 'who'.

07. Let X be a continuous random variable denoting the termperature measured. The range of temperature is [0, 100] degree Celsius and let the probability density function of X be f(x) = 0.01 for $0 \le X \le 100$.

The mean of X is (a) 5.0

(b) 25.0

(c) 50.0

(d) 2.5

07. Ans: (c)

Sol:
$$f(x) = 0.01, 0 \le x \le 100$$

$$E(x) = \int_{0}^{100} x f(x) dx = \int_{0}^{100} 0.01x dx$$
$$= 0.01 \left(\frac{x^{2}}{2}\right)_{0}^{100} = 0.01 \left\{\frac{(100)^{2}}{2}\right\} = 50$$

- 08. Which one of the following numbers is exactly divisible by $(11^{13} + 1)$?
 - (a) $11^{33} + 1$

(b) $11^{39} - 1$ (d) $11^{26} + 1$

(c) $11^{52} - 1$

08. Ans: (c)

Sol: $a^n - b^n$ is divisible by (a + b), only when n is even.

Take the 3rd option put $11^{13} = a$, $1^{13} = b$

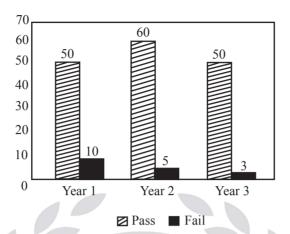
Now
$$\frac{11^{52}-1^{52}}{11^{13}+1^{13}} = \frac{(11^{13})^4-(1^{13})^4}{11^{13}+1^{13}}$$

$$\Rightarrow \frac{a^4 - b^4}{a + b}$$

:. Option (c) is correct.



09.



The number of students passing or failing in an exam for a particular subject is presented in the bar chart above. Students who pass the exam cannot appear for the exam again. Students who fail the exam in the first attempt must appear for the exam in the following year. Students always pass the exam in their second attempt.

The number of students who took the exam for the first time in the year 2 and the year 3 respectively,

are _____.

(a) 60 and 50

(b) 65 and 53

(c) 55 and 48

(d) 55 and 53

09. Ans: (c)

Sol: Out of 65 students appeard in year-2, 10 are from year-1

Therefore 55 students appeared for the 1st time in year-2.

Out of 53 students appeared in year-3, 5 are from year-2 (who failed in year-2)

Therefore 48 students appeared for the first time in year-3.

Option (c) is correct.

10. The importance of sleep is often overlooked by students when they are preparing for exams. Research has consistently shown that sleep deprivation greatly reduces the ability to recall the material learnt. Hence, cutting down on sleep to study longer hours can be counterproductive.

Which one of the following statements is the CORRECT inference from the above passage?

- (a) Students are efficient and are not wrong in thinking that sleep is a waste of time.
- (b) To do well in an exam, adequate sleep must be part of the preparation.
- (c) If a student is extremely well prepared for an exam, he needs little or no sleep.
- (d) Sleeping well alone is enough to prepare for an exam. Studying has lesser benefit.

10. Ans: (b)

Sol: Deprivation of sleep during exams will have negative effect on exams. So, considerable sleep is necessary to do well in exams.



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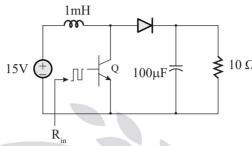
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Electrical Engineering

Consider the boost converter shown. Swithch Q is operating at 25 kHz with a duty cycle of 0.6. Assume the diode and switch to be ideal. Under steady-state condition, the average resistance Rinas seen by the source is Ω .

(Round off to 2 decimal places)



01. Ans: 1.6

Sol: f = 25 kHz

$$D = 0.6$$

Find
$$R_{in} = ? (in \Omega)$$

To check continuous conduction or discontinuous conduction

$$K = K = \frac{2fL}{R}$$
 and $k_{cr} = D(1 - D)^2$

Now k =
$$\frac{2\text{fL}}{R} = \frac{2 \times 25\text{k} \times 0.001}{10} = 5$$

$$k_{cr} = D(1-D)^2 = 0.6 \times (1-0.6)^2 = 0.096$$

As $[k > k_{cr}]$ means continuous conduction case

In C.C.C.
$$V_0 = \frac{V_S}{(1-D)}$$

According to Power balance equation

$$\frac{P_i}{P} = \frac{P_o}{P}$$

$$V_{s}i_{s \text{ avg}} = V_{0}I_{0}$$

$$V_{S} i_{S \text{ avg}} = \frac{V_{0}^{2}}{R} = \frac{V_{S}^{2}}{R(1-D)^{2}}$$

$$i_{\text{s avg}} = \frac{15}{10(1-0.6)^2}$$

$$i_{sava} = 9.375 \text{ amp}$$

 $i_{s \text{ avg}} = 9.375 \text{ amp}$ Now average resistance (R_{in})

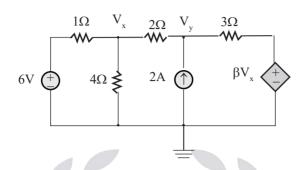
$$R_{in} = \frac{V_s}{i_{s,avg}} = \frac{15}{9.375}$$

$$R_{in} = 1.6 \Omega$$
.

Since 1995



02. In the given circuit, for voltage V_y to be zero, the value of β should be ______ (Round off to 2 decimal places).



02. Ans: -3.25

Sol: By KCL at V_x:

$$\frac{V_{x}-6}{1} + \frac{V_{x}}{4} + \frac{V_{x}-V_{y}}{2} = 0$$

$$4V_x - 24 + V_x + 2V_x - 2V_y = 0$$

If
$$V_y = 0$$
, $7V_x = 24 \Rightarrow V_x = \frac{24}{7}$

By KCL at V_v:

$$2 = \frac{V_{y} - V_{x}}{2} + \frac{V_{y} - \beta V_{x}}{3}$$

If
$$V_y = 0$$

$$2 = \frac{-V_x}{2} + \frac{-\beta V_x}{3}$$

$$2 = -V_x \left[\frac{1}{2} + \frac{\beta}{3} \right]$$

$$2 = \frac{-24}{7} \left[\frac{1}{2} + \frac{\beta}{3} \right]$$

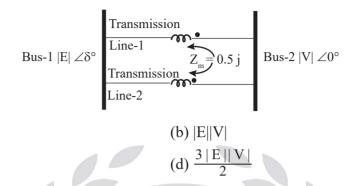
$$\frac{-7}{12} = \frac{1}{2} + \frac{\beta}{3} \Rightarrow \frac{\beta}{3} = \frac{-7}{12} - \frac{1}{2} = \frac{-7 - 6}{12}$$

$$\frac{13}{3} = \frac{-13}{2} \Rightarrow \beta = \frac{-13}{4} \Rightarrow \beta = -3.25$$

Since 1995



03. In the figure shown, self-impedances of the two transmission lines are 1.5j p.u each, and $Z_m = 0.5$ j p.u is the mutual impedance. Bus voltages shown in the figure are in p.u. Given that $\delta > 0$, the maximum steady-state real power that can be transferred in p.u from Bus-1 to Bus-2 is

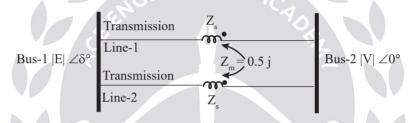


03. Ans: (b)

(a) $\frac{|E||V|}{2}$

(c) 2|E||V|

Sol: Given figure of a 2 bus power system network



The self impedance of each line $Z_5 = j1.5$ p.u.

Mutual impedance between lines, $Z_m = j0.5$ p.u.

As the network is lossless, the expression for maximum power transfer capacity will be $P_{max} = \frac{|E| \cdot |V|}{|B|}$ Where 'B' is the short circuit transfer impedance of the network.

If two reactors of self reactance X_1 and X_2 connected in parallel with a mutual reactance of X_m then the equivalent reactance will be

$$X_{m} = -M$$

$$X_{eq} = \frac{X_{1}.X_{2} - X_{m}^{2}}{X_{1} + X_{2} - 2X_{m}}$$

So, the equivalent transfer reactance between the buses will be

$$X_{eq} = \frac{X_{S}.X_{S} - X_{m}^{2}}{X_{S} + X_{S} - 2X_{m}}$$

$$= \frac{1.5 \times 1.5 - (0.5)^{2}}{1.5 + 1.5 - 1}$$

$$= 1 \text{ p.u.}$$

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	Hours	1 st & 17 th June 2021		Kothapet (CE, ME, PI)
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Flexible	Daily	5 th , 20 th July 2021	3 to 4	Abids (CS&IT) Dilsukhnagar (EC, EE, IN)
Batches	6 to 8 Hours	4 th , 18 th August 2021	Months	Kothapet (CE, ME, PI)
	GA [*]	ΓE + PSUs – 2022 (SPAR	K BATCHES)	
Spark	Daily 5 to 8 Hours	17 th May 2021	5 to 6	Abids (CE, ME, CS)
Spark		1 st & 17 th June 2021	Months	Kukatpally (EC, EE)
	ESE + G	ATE + PSUs – 2022 (REG	ULAR BATCH	ES)
	Daily	2 nd & 17 th April 2021		
Regular	6 to 8 Hours	1 st & 17 th May 2021	9 to 10 Months	Kukatpally (EC, EE) Abids (CE, ME)
110013		1 st & 17 th June 2021		
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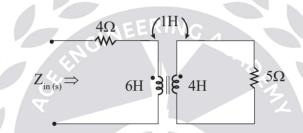
So, the given two bus system can be redrawn as,

In this model, $B = j \cdot 1 \text{ p.u.}$

So,
$$P_{max} = \frac{|E|.|V|}{1} = |E|.|V|$$

Correct option is (b)

04. The input impedance, $Z_{in}(s)$, for the network shown is



(a)
$$\frac{25s^2 + 46s + 20}{4s + 5}$$

(b)
$$6s + 4$$

(c)
$$7s+4$$

$$(d)\frac{23s^2+46s+20}{4s+5}$$

04. Ans: (d)

Sol:

$$Z_{\text{in (s)}} \Rightarrow \overbrace{I_{1}}^{4\Omega} \qquad 6H \Rightarrow 4H \qquad 5\Omega$$

$$Since 1995$$

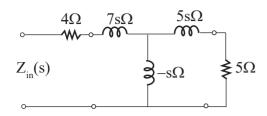
$$I_{2} \Rightarrow 5\Omega$$

The above coupled circuit is magnetic opposing

The equivalent circuit is



Convert into s-domain circuit



$$Z_{in}(s) = ((5s+5) // -s) + (7s+4)$$

$$= \frac{(5s+5)(-s)}{(7s+5)} + 7s + 4$$

$$= \frac{-5s^2 - 5s + 28s^2 + 16s + 35s + 20}{(4s+5)}$$

$$Z_{in}(s) = \frac{23s^2 + 46s + 20}{(7s+5)}$$

$$Z_{in}(s) = \frac{23s^2 + 46s + 20}{(7s + 5)}$$

- Two single-core power cables have total conductor resistances of 0.7Ω and 0.5Ω , respectively, and their insulation resistances (between core and sheath) are $600 \, \mathrm{M}\Omega$ and $900 \, \mathrm{M}\Omega$, respectively. When the two cables are joined in series, the ratio of insulation resistance to conductor resistance is
- 05. Ans: 300

Sol: Details of the two single core power cables given,

Cable-1:
$$R_{C1} = 0.7 \Omega$$
, $R_{i1} = 600 M\Omega$

Cable 2:
$$R_{C2} = 0.5 \Omega$$
, $R_{i2} = 900 M\Omega$

If these two cables are connected in series, the conductor resistance will be in series and insulation resistances will be in parallel.

Equivalent conductor resistance,
$$R_{Ceq} = R_{C1} + R_{C2} = 1.2 \Omega$$

Equivalent conductor resistance,
$$R_{C eq} = R_{C1} + R_{C2} = 1.2 \Omega$$

Equivalent insulation resistance, $R_{i eq} = R_{i1} \parallel R_{i2} = \frac{600 \times 900}{600 + 900}$

$$=360 \mathrm{M}\Omega$$

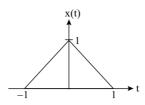
The ratio of equivalent insulation resistance to conductor resistance,

$$\frac{R_{\text{i eq}}}{R_{\text{C eq}}} = \frac{360 \times 10^6}{1.2} = 300 \times 10^6$$

- 06. Consider a continuous-time signal x(t) defined by x(t) = 0 for |t| > 1, and x(t) = 1 |t| for $|t| \le 1$. Let the Fourier transform of x(t) be defined as $X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$. The maximum magnitude of $X(\omega)$ is
- 06. Ans: 1

Sol: Given
$$x(t) = 1-|t|$$
 $|t| \le 1$
0 $|t| > 1$





So, given signal is a triangular function

$$x(t) = Tri(t)$$

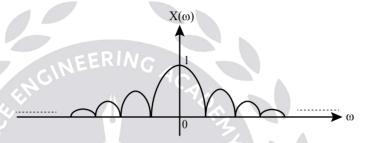
from standard F.T pair

If
$$x(t) = ATri\left(\frac{t}{T}\right)$$
, then

$$X(\omega) = ATsa^2 \left(\frac{\omega T}{2}\right)$$

Here
$$x(t) = Tri(t) [A = 1, T = 1]$$

$$X(\omega) = Sa^2 \left(\frac{\omega}{2}\right)$$



Maximum magnitude of $X(\omega)$ is '1'

- 07. The power input to a 500 V, 50 Hz, 6-pole, 3-phase induction motor running at 975 RPM is 40 kW. The total stator losses are 1 kW. If the total friction and windage losses are 2.025 kW, then the efficinecy is %.
- 07. Ans: 90
- **Sol:** Stator input $(P_{si}) = 40 \text{ kW}$

Stator losses $(P_{sl}) = 1 \text{ kW}$

Stator output power/Rotor input power $P_{ri} = P_{si} - P_{sl}$ = 40 - 1= 39 kW

Rotor speed, $N_r = 975 \text{ rpm}$

$$P = 6$$
; $f = 50 \text{ Hz}$,

Synchronous speed,

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

Slip,
$$s = \frac{1000 - 975}{1000} = 0.025$$

We have $P_{ri}: P_{ri}: P_{ro} = 1:s:(1-s)$

$$P_{r0}^{n} = Rotor$$
 output power

$$\therefore \frac{P_{ro}}{P_{ri}} = (1 - s) \Rightarrow P_{r0} = P_{ri}(1 - s)$$



 P_{ro} or Gross mechanical power (P_{sm})

$$=39(1-0.025)$$
 kW

$$= 38.025 \text{ kW}$$

 P_{ml} (Mech loss) = 2.025 kW

(friction and windage loss)

:. Net power =
$$P_{ro} - P_{mc}$$

= 38.025 - 2.025

$$= 36 \text{ kW}$$

$$\eta = \frac{36}{40} \times 100 = 90\%$$

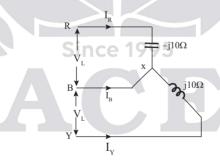
08. A three-phase balanced voltage is applied to the load shown. The phase sequence is RYB. The ratio $\frac{|I_B|}{|I_R|}$

is _____.



08. Ans: 1

Sol: A 3- ϕ balanced supply



The phase sequence is RYB

$$V_{RY} = V_{L} \angle 0^{\circ}, V_{YB} = V_{L} \angle -120^{\circ}, V_{BR} = V_{L} \angle 120^{\circ},$$

$$I_R = \frac{V_{RB}}{-j10} = \frac{-V_{BR}}{-j10} = \frac{-V_L \angle + 120}{-j10}$$

$$I_{\rm Y} = \frac{V_{\rm YB}}{j10} = \frac{V_{\rm L} \angle - 120}{j10}$$

By KCL at (X)

$$\boldsymbol{I}_{\mathrm{B}} = - \left(\boldsymbol{I}_{\mathrm{R}} + \boldsymbol{I}_{\mathrm{Y}}\right)$$



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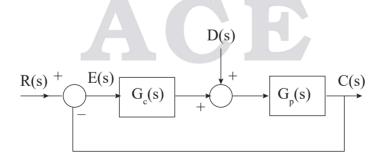
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$$\begin{split} &\frac{I_{B}}{I_{R}} = -\left(1 + \frac{I_{Y}}{I_{R}}\right) \\ &= -\left(1 + \frac{V_{L} \angle - 120}{j10}\right) \\ &= -\left(1 + \frac{\left(-0.5 - j0.866\right)}{-0.5 + j0.866}\right) \\ &\frac{I_{B}}{I_{R}} = -\left(1 + \frac{\left(-1 - j\sqrt{3}\right)}{\left(-1 + j\sqrt{3}\right)}\right) \\ &= -\frac{\left(-1 + j\sqrt{3} + \left(-1 - j\sqrt{3}\right)}{\left(-1 + j\sqrt{3}\right)} \\ &= \frac{2}{\left(-1 + j\sqrt{3}\right)} = \frac{2\left(-1 - j\sqrt{3}\right)}{4} \\ &\frac{I_{B}}{I_{R}} = \frac{2}{2} = 1 \end{split}$$

09. In the given figure, plant $G_p(s) = \frac{2.2}{(1+0.1s)(1+0.4s)(1+1.2s)}$ and compensator $G_c(s) = K\left[\frac{1+T_1s}{1+T_2s}\right]$. The external disturbance input is D(s). It is desired that when the disturbance is a unit step, the steady-state error should not exceed 0.1 unit. The minimum value of K is ____. (Round off to 2 decimal places.)



09. Ans: -10.45

Sol:
$$\frac{E(s)}{D(s)} = \frac{-G_p(s)}{1 + G_p(s)G_c(s)}$$

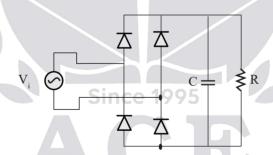


$$\begin{split} &= \frac{\frac{-2.2}{(1+0.1s)(1+0.4s)(1+1.2s)}}{1+\frac{2.2}{(1+0.1s)(1+0.4s)(1+1.2s)} \times \frac{K(1+T_1s)}{(1+T_2s)}} \\ &= \frac{E(s)}{D(s)} = \frac{-2.2(1+T_2s)}{(1+0.1s)(1+0.4s)(1+1.2s)(1+T_2s) + 2.2K(1+T_1s)} \\ D(s) &= \frac{1}{s} (\text{unit step}) \end{split}$$

Steadt state errir =
$$\underset{s \to 0}{\text{LtsE}}(s)$$

= $\underset{s \to 0}{\text{Lt}} s \left[\frac{-2.2(1 + T_2 s)}{(1 + 0.1 s)(1 + 0.4 s)(1 + 1.2 s)(1 + T_2 s) + 2.2 K(1 + T_1 s)} \right] \frac{1}{s}$
 $\frac{-2.2}{1 + 2.2 K} = 0.1$
 $\Rightarrow K = \frac{-23}{2.2} = -10.45$

10. In the circuit shown, the input V_i is a sinusoidal AC voltage having an RMS value of 230 V \pm 20%. The worst-case peak-inverse voltage seen across any diode is _____ V. (Round off to 2 decimal places.)



10. Ans: 390.32

Sol: The given circuit is bridge full wave rectifier with RC filter. In bridge FWR, peak inverse voltage of each diode is V_m .

Then
$$(PIV)_{diode} = \sqrt{2} \left[230 \pm 20\% \right]$$

= $\sqrt{2} \left[230 + \frac{20}{100} \times 230 \right]$
= $\sqrt{2} (230 + 46)$
= 390.32 Volts

11. Two discrete-time linear time-invariant systems with impulse responses $h_1[n] = \delta[n-1] + \delta[n+1]$ and $h_2[n] = \delta[n] + \delta[n-1]$ are connected in cascade, where $\delta[n]$ is the Kronecker delta. The impulse response of the cascaded system is

(a)
$$\delta[n-1]$$
 $\delta[n]+\delta[n+1]$ $\delta[n-1]$

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(b)
$$\delta[n-2] + \delta[n-1] + \delta[n] + \delta[n+1]$$

(c)
$$\delta[n-2] + \delta[n+1]$$

(d)
$$\delta[n] \delta[n-1] + \delta[n-2]\delta[n+1]$$

11. Ans: (b)

Sol: Given
$$h_1(n) = \delta(n-1) + \delta(n+1)$$

$$h_2(n) = \delta(n) + \delta(n-1)$$

When two LTI systems are connected in cascade, the resultant impulse response is convolution of individual impulse responses. i.e $h(n) = h_1(n) * h_2(n)$

$$h(n) = [\delta(n-1) + \delta(n+1)] * [\delta(n) + \delta(n-1)]$$

$$h(n) = \delta \; (n-1) \; * \; \delta \; (n) + \delta \; (n-1) \; * \; \delta \; (n-1) + \; \delta \; (n+1) * \; \delta \; (n) + \; \delta \; (n+1) * \; \delta \; (n-1)$$

$$\delta (n-n_1) *\delta (n-n_2) = \delta (n-n_1-n_2)$$

$$h(n) = \delta(n-1) + \delta(n-2) + \delta(n+1) + \delta(n)$$

$$h(n) = \delta(n-2) + \delta(n-1) + \delta(n) + \delta(n+1)$$

12. Let f(t) be an even function, i.e. f(-t) = f(t) for all t. Let the Fourier transform of f(t) be defined as

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt.$$
 Suppose $\frac{dF(\omega)}{d\omega} = -\omega F(\omega)$ for all ω , and $F(0) = 1$. Then

(a)
$$f(0) = 0$$

(b)
$$f(0) > 1$$

(c)
$$f(0) < 1$$

(d)
$$f(0) = 1$$

12. Ans: (c)

Sol: Given f(-t) = f(t). [f(t) is even]

Given
$$\frac{dF(\omega)}{d\omega} = -\omega F(\omega)$$
......(1)

From differentiation in time domain property

$$\frac{\mathrm{df}(t)}{\mathrm{dt}} \longleftrightarrow \mathrm{j}\omega \mathrm{F}(\omega)$$

From differentiation in freugency domain property

$$tf(t) \longleftrightarrow \frac{jdF(\omega)}{d\omega}$$

Apply IFT to equation (1)

$$-jt f(t) = \frac{jdf(t)}{dt}$$

$$\frac{\mathrm{df}(t)}{\mathrm{dt}} = -\mathrm{tf}(t)....(2)$$

From equation (1) & (2)

f(t) is a chance of gaussian function

$$f(t) = \frac{1}{\sqrt{2\pi}} e^{-t^2/2}$$



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$$\begin{split} \left[e^{-at^2} &\longleftrightarrow \sqrt{\frac{\pi}{a}} \cdot e^{-\omega^2/4a} \right] \\ \left[e^{-t^2/2} &\longleftrightarrow \sqrt{2\pi} \cdot e^{-\omega^2/2} \right] \\ &\frac{1}{\sqrt{2\pi}} e^{-t^2/2} &\longleftrightarrow e^{-\omega^2/2} \\ f(t) &= \frac{1}{\sqrt{2\pi}} e^{-t^2/2} \\ f(0) &= \frac{1}{\sqrt{2\pi}} \\ &= < 1 \end{split}$$

- 13. Suppose the probability that a coin toss shows 'head' is p, where 0 . The coin is tossed repeatedly until the first "head" appears. The expected number of tosses required is
 - (a) 1/p

(b) (1-p)/p

(c) p/(1-p)

(d) $1/p^2$

13. Ans: (a)

Sol: Let x = number of tosses required

X	1	2	3	••••
p(x)	p	qp	q ² p	

$$E(x) = p + 2qp + 3q^{2}p + \dots$$

$$= p(1+2q + 3q^{2} + \dots)$$

$$= p(1-q)^{-2} \quad [\because (1-x)^{-2} = 1+2x+3x^{2}+\dots]$$

$$= pp^{-2}$$

$$= p^{-1}$$

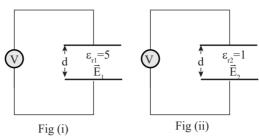
$$= \frac{1}{p}$$

14. Consider a large parallel plate capacitor. The gap d between the two plates is filled entirely with a dielectric slab of relative permittivity 5. The plates are initially charged to a potential difference of V volts and then disconnected from the source. If the dielectric slab is pulled out completely, then the ratio of the new electric field E₂ in the gap to the original electric field E₁ is ______.



14. Ans: 5

Sol: Method-1:



For the given medium, Electric field intensity, $E \propto \frac{1}{\epsilon}$

$$\frac{E_2}{E_1} = \frac{\epsilon_{r1}}{\epsilon_{r2}} = \frac{5}{1} = 5$$

$$\therefore \text{ The ratio } \frac{E_2}{E_1} = 5$$

Method-2:

From the concept of capacitance

$$C = \frac{Q}{V} = \frac{Q}{Ed}$$

$$C_1 = \frac{Q}{E_1 d} \& C_2 = \frac{Q}{E_2 d}$$
 (: maintaining same charge in both the cases)

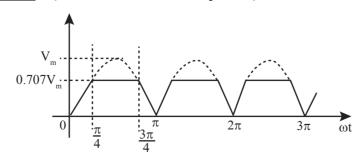
$$\frac{C_1}{C_2} = \frac{E_2}{E_1}$$

$$\frac{E_2}{E_1} = \frac{\left(\frac{\epsilon_0 \, \epsilon_{r1} \, A}{d}\right)}{\left(\frac{\epsilon_0 \, \epsilon_{r2} \, A}{d}\right)} \ = \frac{\epsilon_{r1}}{\epsilon_{r2}} = \frac{5}{1}$$

$$\therefore \text{Ratio } \frac{E_2}{E_1} = 5$$

15. The waveform shown in solid line is obtained by clipping a full-wave rectified sinusoid (shown dashed). The ratio of the RMS value of the full-wave rectified waveform to the RMS value of the clipped waveform is ______. (Round off to 2 decimal places.)

Since 1995





15. Ans: 1.21

Sol: The rms value of the full wave rectified waveform

$$\begin{split} \left(V_{R}\right)_{rms} &= \sqrt{\frac{1}{\pi}} \int_{0}^{\pi} V_{m}^{2} sin^{2} \omega t. d\omega t \\ &= \frac{V_{m}}{\sqrt{2\pi}} \Bigg[\int_{0}^{\pi} (1 - \cos 2\omega t) d\omega t \Bigg]^{\frac{1}{2}} \\ &= \frac{V_{m}}{\sqrt{2\pi}} \Bigg[(\pi - 0) - \frac{1}{2} \sin 2\omega t \Bigg|_{0}^{\pi} \Bigg]^{\frac{1}{2}} \\ &= \frac{V_{m}}{\sqrt{2\pi}} \Bigg[(\pi - 0) - \frac{1}{2} (\sin 2\pi - \sin 0) \Bigg]^{\frac{1}{2}} \\ \left(V_{R}\right)_{rms} &= \frac{V_{m}}{\sqrt{2}} \end{split}$$

The rms value of clipped waveform is

$$\begin{split} &(V_{_{C}})_{rms} = \sqrt{\frac{1}{\pi}} \left[\int_{0}^{\frac{\pi}{4}} V_{m}^{2} sin^{2} \omega t d\omega t + \int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} \left(\frac{V_{m}}{\sqrt{2}} \right)^{2} d\omega t + \int_{\frac{3\pi}{4}}^{\pi} V_{m}^{2} sin^{2} \omega t d\omega t \right] \\ &= \sqrt{\frac{1}{\pi}} \left[2 \times \int_{0}^{\frac{\pi}{4}} V_{m}^{2} sin^{2} \omega t d\omega t + \int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} \left(\frac{V_{m}}{\sqrt{2}} \right)^{2} d\omega t \right] \\ &= \sqrt{\frac{1}{\pi}} \left[2 V_{m}^{2} \int_{0}^{\frac{\pi}{4}} (1 - \cos 2\omega t) d\omega t + \frac{V_{m}^{2}}{2} \int_{\frac{\pi}{4}}^{\frac{3\pi}{4}} 1 . d\omega t \right] \\ &= \sqrt{\frac{1}{\pi}} \left[V_{m}^{2} \left\{ \frac{\pi}{4} - \frac{1}{2} \sin 2\omega t \Big|_{0}^{\frac{\pi}{4}} \right\} + \left\{ \frac{V_{m}^{2}}{2} \left(\frac{3\pi}{4} - \frac{\pi}{4} \right) \right\} \right] \\ &= \sqrt{\frac{1}{\pi}} \left[V_{m}^{2} \left\{ \frac{\pi}{4} - \frac{1}{2} \left(\sin \frac{\pi}{2} - \sin 0 \right) \Big| \right\} + \frac{V_{m}^{2}}{2} \left(\frac{2\pi}{4} \right) \right] \\ &= \frac{V_{m}}{\sqrt{\pi}} \sqrt{\frac{\pi}{4} - \frac{1}{2}} + \frac{\pi}{4} \\ &(V_{C})_{rms} = 0.584 V_{m} \\ &Now, \frac{(V_{R})_{rms}}{(V_{C})_{rms}} = \frac{0.707 V_{m}}{0.584 V_{m}} = 1.21 \end{split}$$



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- 16. In the open interval (0,1), the polynomial $p(x) = x^4 4x^3 + 2$ has
 - (a) no real roots
 - (b) two real roots
 - (c) one real root
 - (d) three real roots
- 16. Ans: (c)

Sol:
$$p(0) = 2$$
 and $p(1) = -1$

According to intermediate mean value theorem, there exists at least one real root (or) odd number of real roots lie between 0 and 1.

So, option (c) is correct.

- 17. An 8-pole, 50 Hz, three-phase, slip-ring induction motor has an effective rotor resistance of 0.08Ω per phase. Its speed at maximum torque is 650 RPM. The additional resistance per phase that must be inserted in the rotor to achieve maximum torque at start is _____ Ω . (Round off to 2 decimal places.) Neglect magnetizing current and stator leakage impedance. Consider equivalent circuit parmaeters referred to stator.
- 17. Ans: 0.52

Sol:
$$P = 8$$
; $f = 50$ Hz; $N_s = \frac{120 \times 50}{8} = 750$ rpm

Effective Rotor resistance $R_2 = 0.08$

Rotor speed at Max torque = 650 rpm

We have s_{Tmax} (slip at max torque)

$$= \frac{750 - 650}{750} = 0.1333$$
 Since R_2

$$s_{Tmax} = \frac{R_2}{X_{20}}$$

Where X_{20} is the standstill rotor leakage reactance

$$0.1333 = \frac{0.08}{X_{20}}$$

$$X_{20} = 0.600 \Omega$$

:. Additional Resistance required to obtain Max torque at starting

$$R_{add} = X_{20} - R_2$$

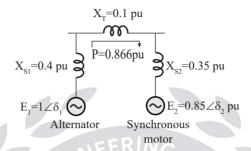
= 0.6 - 0.08
= 0.52 \Omega



18. An alternator with internal voltage of $1 \angle \delta_1$ p.u and synchronous reactance of 0.4 p.u is connected by a transmission line of reactance 0.1 p.u to a synchronous motor having synchronous reactance 0.35 p.u and internal voltage of $0.85 \angle \delta_2$ p.u. If the real power supplied by the alternator is 0.866 p.u, then $(\delta_1 - \delta_2)$ is ______ degrees. (Round off to 2 decimal places.) (Machines are of non-salient type. Neglect resistances.)

18. Ans: 60

Sol:



Alternator internal voltage, $E_1 = 1 \angle \delta_1$ pu

Alternator synchronous reactance $X_{s1} = 0.4$ pu

Reactance of transmission line $X_T = 0.1$ pu

Synchronous motor reactance, $X_{S2} = 0.35 \text{ pu}$

Synchronous motor internal voltage, $E_2 = 0.85 \angle \delta$, pu

Real power supplied by alternator is 0.866 pu

Then
$$\delta_1 - \delta_2 = ?$$

 $P = \frac{E_1 E_2}{X_{S1} + X_T + X_{S2}} \sin(\delta_1 - \delta_2)$

$$0.866 = \frac{1 \times 0.85}{0.4 + 0.1 + 0.35} \sin(\delta_1 - \delta_2)$$
$$= \frac{0.85}{0.85} \sin(\delta_1 - \delta_2)$$

$$0.866 = \sin(\delta_1 - \delta_2)$$

$$(\delta_1 - \delta_2) = \sin^{-1}(0.866) = 60^{\circ}$$

- 19. Which one of the following vector functions represents a magnetic field \vec{B} ?
 - (a) $10x\hat{x} 30z\hat{y} + 20y\hat{z}$

(b)
$$10x\hat{x} + 20y\hat{y} - 30z\hat{z}$$

(c) $10z\hat{x} + 20y\hat{y} - 30x\hat{z}$

(d)
$$10y\hat{x} + 20x\hat{y} - 10z\hat{z}$$

19. Ans: (b)

Sol: The vector field which represents the magnetic field (or) flux density (\vec{B}) , should satisfy the following condition.

Since 1995

i.e.
$$\nabla \cdot \vec{B} = 0$$



Option (a): Let $\vec{B} = 10x\hat{x} - 30z\hat{y} + 20y\hat{z}$

 $\nabla . \vec{B} = 10 - 0 \neq 0$, hence this does not represent magnetic field.

Option (b):Let $\vec{B} = 10x\hat{x} + 20y\hat{y} - 30z\hat{z}$

 $\nabla . \vec{B} = 10 + 20 - 30 = 0$ and hence this represents magnetic field

Option (c): Let $\vec{B} = 10z \hat{x} + 20y \hat{y} - 30x \hat{z}$

 $\nabla . \vec{B} = 0 + 20 - 0 \neq 0$ and hence this does not represent magnetic field

Option (d): Let $\vec{B} = 10y\hat{x} + 20x\hat{y} - 10z\hat{z}$

 $\nabla . \vec{B} = 0 + 0 - 10 \neq 0$ and hence this does not represent a magnetic field

Therefore option (b) is correct.

- 20. A 16-bit synchronous binary up-counter is clocked with a frequency f_{clk}. The two most significant bits are OR-ed together to form an output Y. Measurements show that Y is periodic, and the duration for which Y remains high in each period is 24ms. The clock frequency f_{clk} is _____ MHz. (Round off to 2 decimal places.)
- 20. Ans: 2.05

Sol:

$$y = 0 \qquad \begin{cases} 00 & 00 & \dots & 0 & 0 \\ 00 & 11 & \dots & 1 & 1 \end{cases} \qquad 2^{14} \text{ states}$$

$$y = 1 \qquad \begin{cases} 01 & 00 & \dots & 0 & 0 \\ 11 & 11 & \dots & 1 & 1 \end{cases} \qquad (2^{16} - 2^{14}) \text{ states}$$

$$Y = 1$$
, for 24 ms

$$\therefore (2^{16}-2^{14})T = 24 \text{ ms}$$

$$f_{clk} = \frac{1}{T} = \frac{2^{16} - 2^{-14}}{24ms}$$

$$=\frac{2^{16}-2^{-14}}{24\times10^{-3}}$$

 $\simeq 2.05 \text{ MHz}$



- 21. Let f(x) be a real-valued function such that $f'(x_0)=0$ for some $x_0 \in (0,1)$, and f''(x) > 0 for all $x \in (0,1)$. Then f(x) has
 - (a) exactly one local minimum in (0,1)
- (b) one local maximum in (0,1)

(c) no local minimum in (0,1)

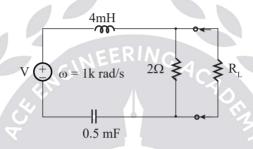
(d) two distinct local minima in (0,1)

21. Ans: (a)

Sol: $f''(x_0) = 0$ and $f''(x_0) > 0$ for all $x \in (0, 1)$

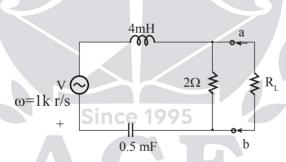
f(x) has exactly one local minimum in (0, 1)

22. In the given circuit, for maximum power to be delivered to R_L its value should be ____ Ω . (Round off to 2 decimal places.)



22. Ans: 1.414

Sol:

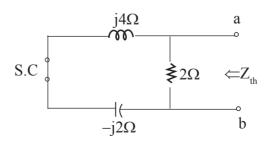


For maximum power transfer across R₁, the Thevenens equivalent impedance

For
$$Z_{th}$$
 (V \rightarrow S.C)

$$Z_L = j\omega L = j10^3 \times 4m = j4\Omega$$

$$Z_{c} = \frac{1}{j\omega c} = \frac{1}{j10^{3} \times 0.5 \times 10^{-3}} = -j2\Omega$$



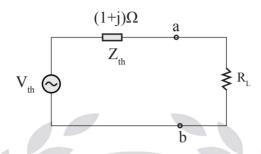
$$Z_{\text{th}} = 2 || (j4 - j2) = 2 || j2 = \frac{2(j2)}{(2 + j2)}$$



$$Z_{\text{th}} = \frac{4j(2-j2)}{8} = \frac{(2j+2)}{2} = (1+j)\Omega$$

$$Z_{th} = (1+j)\Omega$$

Thevenin equivalent



For maximum power transfer

$$R_{ll} = \sqrt{R_{th}^2 + X_{th}^2} = \sqrt{1^2 + 1^2} = \sqrt{2}$$

$$R_L = 1.414 \Omega$$

- - $(\hat{x}, \hat{y}, \text{ and } \hat{z})$ are unit vectors along x-axis, y-axis, and z-axis, respectively.)
- 23. Ans: 100

Sol:
$$Q = 1 C$$

Velocity,
$$\vec{v} = 10\hat{x}$$
 m/sec

Magnetic field,
$$\vec{B} = 10y \hat{x} + 10x \hat{y} + 10 \hat{z}$$
 T

Magnetic force on moving charge is given by

$$\vec{F} = \vec{Qv} \times \vec{B}$$

$$= 1 \times 10\,\hat{x} \times (10y\,\hat{x} + 10x\,\hat{y} + 10\,\hat{z})$$

$$= 100(0) + 10x\,\hat{z} - 100\,\hat{y}$$

$$\vec{F} = 100x\,\hat{z} - 100\,\hat{y} \ N$$

The force at $x = 0^+$ is

$$\vec{F} = -100\,\hat{y}\ N$$

Magnitude of force F = 100 N

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- 24. A counter is constructed with three D flip-flops. The input-output pairs are named (D_0, Q_0) , (D_1, Q_1) and (D_2, Q_2) , where the subscript 0 denotes the least significant bit. The output sequence is desired to be the Gray-code sequence 000,001,011,010,110,111,101, and 100, repeating periodically. Note that the bits are listed in the Q_2Q_1
 - Q₀ format. The combinational logic expression for D₁ is
 - (a) $\overline{Q}_2Q_0 + Q_1\overline{Q}_0$

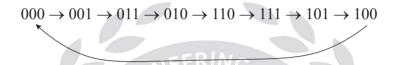
(b) $Q_2Q_1+\overline{Q}_2\overline{Q}_1$

 $(c) Q_2 Q_1 Q_0$

 $(d) Q_2 Q_0 + Q_1 \overline{Q}_0$

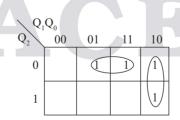
24. Ans: (a)

Sol:



	PS	NS	FF(i/p)
	$Q_2 Q_1 Q_0$	$Q_2 Q_1 Q_0$	$D_2D_1D_0$
0	0 0 0	0 0 1	0 0 1
1	0 0 1	0 1 1	0 1 1
3	0 1 1	0 1 0	0 1 0
2	0 1 0	1 1 0	1 1 0
6	1 1 0	1 1 1	111
7	1 1 1	1 0 1	1 0 1
5	1 0 1	1 0 0	1 0 0
4	1 0 0	0 0 0	0 0 0

$$D_1 = \sum m(1,3,2,6)$$



$$\mathbf{D}_{_{1}} = \overline{\mathbf{Q}}_{2}\mathbf{Q}_{0} + \mathbf{Q}_{1}\overline{\mathbf{Q}}_{0}$$

- 25. Inductance is measured by
 - (a) Wein bridge
 - (c) Kelvin bridge

- (b) Maxwell bridge
- (d) Schering bridge

25. Ans: (b)



Sol: Wein's bridge is used for measurement of frequency.

Maxwell's bridge is used for measurement of inductance.

Kelvin's bridge is used for measurement of low value of resistance

Schering bridge is used for measurement of capacitance, dilectric loss and permittivity etc.

- 26. Suppose I_A , I_B and I_C are a set of unbalanced current phasors in a three-phase system. The phase-B zero sequence current $I_{B0} = 0.1 \angle 0^\circ$ p.u. If phase-A current $I_A = 1.1 \angle 0^\circ$ p.u and phase-C current $I_C = (1 \angle 120^\circ + 0.1)$ p.u, then I_B in p.u is
 - (a) $1.1\angle 240^{\circ} 0.1\angle 0^{\circ}$

(b) $1\angle -120^{\circ} + 0.1\angle 0^{\circ}$

(c) $1.1\angle -120^{\circ} + 0.1\angle 0^{\circ}$

(d) $1\angle 240^{\circ} - 0.1\angle 0^{\circ}$

- 26. Ans: (b)
- **Sol:** The phase-B zero sequence current, $I_{R0} = 0.1 \angle 0^{\circ}$ p.u.

Phase-A and phase-C currents,

$$I_A = 1.1 \angle 0^{\circ} \text{ p.u.}, I_C = 1 \angle 120^{\circ} + 0.1 \text{ p.u.}$$

$$As I_A + I_B + I_C = 3.I_{B0}$$

$$1.1 + I_B + 1 \angle 120^\circ + 0.1 = 0.3$$

$$I_B = 0.3 - 1.2 - 1 \angle 120^{\circ}$$

$$=-0.9-1\angle 120^{\circ}$$

It can be rewritten as,

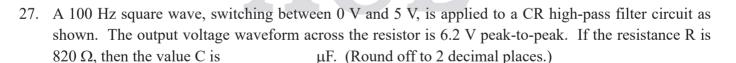
$$I_{B} = 0.1 + [-1 - 1 \angle 120^{\circ}]$$

$$=0.1-(1+1\angle 120^{\circ})$$

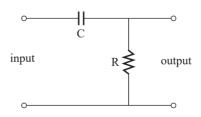
$$= 0.1 - [-(1\angle -120^{\circ})]$$

$$= 0.1 + 1 \angle -120^{\circ} \text{ p.u.}$$

Correct answer is (b).



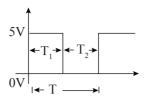
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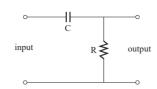




27. Ans: 12.46

Sol:



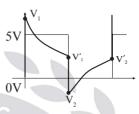


Given f = 100 Hz, T = 10 msec

Consider the input is symmetrical square wave.

$$T_1 = T_2 = 5$$
 msec then

steady state output wave form is



$$V_1' = V_1 e^{-T/2RC}$$
.....(1)

$$V_2' = V_2 e^{-T/2RC}$$
......(2)

$$V'_1 - V_2 = 5$$
(3)

$$V_1 - V_2' = 5$$
(4)

voltage across resistor is output voltage = $V_1 - V_2$

(peak to peak)

$$\therefore V_1 - V_2 = 6.2 \text{ V}$$

$$V_1' = V_1 e^{-T/2RC} \Rightarrow V_1 = V_1' e^{T/2RC}$$
 (5)

$$V_2' = V_2 e^{-T/2RC} \Rightarrow V_2 = V_2' e^{T/2RC}.....(6)$$

By adding (3) & (4) equations

$$(V_1' - V_2) + (V_1 - V_2') = 10$$

$$(V_1' - V_2') + (V_1 - V_2) = 10$$

Now subtracting (5) & (6)

$$V_1 - V_2 = e^{T/2RC}(V_1' - V_2')$$

$$e^{T/2RC} = \frac{(V_1 - V_2)}{(V_1' - V_2')} = \frac{6.2}{3.8}$$

apply natural logarithm on both sides

$$\frac{T}{2RC} = \ln\left(\frac{6.2}{3.8}\right)$$



$$C = \frac{T}{2R\ln\left(\frac{6.2}{3.8}\right)}$$
$$= \frac{10 \times 10^{-3}}{2 \times 820 \times \ln\left(\frac{6.2}{3.8}\right)}$$

$$C=12.46\mu F$$

- 28. If the input x(t) and output y(t) of a system are related as y(t) = max(0, x(t)), then the system is
 - (a) linear and time-variant

(b) non-linear and time-variant

(c) linear and time-invariant

(d) non-linear and time-invariant

28. Ans: (d)

Sol:
$$y(t) = max(0,x(t))$$

$$y(t) = 0$$
; $x(t) < 0$

$$x(t)$$
; $x(t) > 0$

$$y(t) = x(t) u[x(t)]$$

(1)
$$y_1(t) = x_1(t) u [x_1(t)]$$

$$y_2(t) = x_2(t) u [x_2(t)]$$

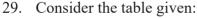
$$y_3(t) = [ax_1(t) + bx_2(t)]u [ax_1(t) + bx_2(t)]$$

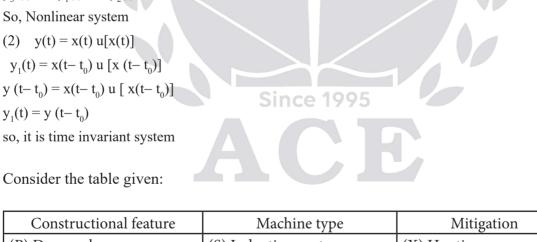
$$y_3(t) \neq a y_1(t) + b y_2(t)$$

(2)
$$y(t) = x(t) u[x(t)]$$

$$y(t-t_0) = x(t-t_0) u [x(t-t_0)]$$

$$y_1(t) = y_1(t-t_0)$$





Constructional feature	Machine type	Mitigation
(P) Damper bars	(S) Induction motor	(X) Hunting
(Q) Skewed rotor slots	(T) Transformer	(Y) Magnetic locking
(R) Compensating winding	(U) Synchronous machine	(Z) Armature reaction
	(V) DC machine	

The correct combination that relates the constructional feature, machine type and mitigation is

(a) P-T-Y, Q-V-Z, R-S-X

(b) P-U-X, Q-V-Y, R-T-Z

(c) P-U-X, Q-S-Y, R-V-Z

(d) P-V-X, Q-U-Z, R-T-Y



29. Ans: (c)

Sol: P: Damper bars used in synchronous machine (U) to prevent hunting (X)

-325V

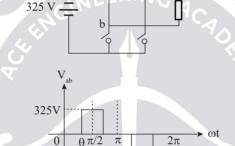
O: Skewed rotor slots used in induction motor (S) to avoid magnetic locking (Y)

R: Compensating winding used in DC machine (V) to neutralize cross magnetizing effectr of armature reaction (Z) under main poles (polar zone).

30. A single phase full bridge inverter fed by a 325 V DC produces a symmetric quasi-square waveform across 'ab' as shown. To achieve a modulation index of 0.8, the angle θ expressed in degrees should be . (Rounded off to 2 decimal places.)

(Modulation index is defined as the ratio of the peak of the fundamental component of V_{ab} to the applied

DC value.)



30. Ans: 51.07

Sol:
$$V_S = 325 \text{ volt (DC)}$$

$$M.I. = 0.8$$

$$M.I. = \frac{(V_{ab1})_{peak}}{V_s}$$

$$(V_{ab1})_{peak} = M.I. \times V_s = 0.8 \times 325 = 260 \text{ volts}$$

Now according to FSA

$$\begin{array}{c|ccccc}
V_0 \\
+V_s \\
\hline
0 & \pi/2 & \pi \\
-V_s \\
\hline
\left(\frac{\pi}{2}-d\right) & \left(\frac{\pi}{2}+d\right) & 2d
\end{array}$$

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$$V_0 = \frac{a_0}{2} + \sum_{n=1}^{\infty} [a_n \cos n\omega t + b_n \sin n\omega t]$$

Here,
$$\frac{a_0}{2} = 0$$
, $a_n = 0$



$$b_{n} = \frac{2}{\pi} \int_{\frac{\pi}{2}-d}^{\frac{\pi}{2}+d} V_{s} \sin(n\omega t) d\omega t = \frac{4V_{s}}{n\pi} \sin\left(\frac{n\pi}{2}\right) \cdot \sin(nd)$$

$$V_0 = \sum_{n=1,3.5}^{\infty} \frac{4V_s}{n\pi} \sin\left(\frac{n\pi}{2}\right) \cdot \sin(nd)\sin(n\omega t)$$

$$(V_{ab1})_{peak} = (V_{01})_{peak} = \frac{4V_s}{\pi} sin(d)$$

Now, as
$$(V_{01})_{\text{neak}} = 260$$

$$\frac{4V_s}{\pi}\sin(d) = 260$$

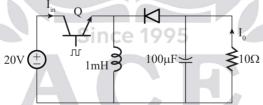
$$\frac{4 \times 325}{\pi} \sin(d) = 260$$

$$d = 38.93^{\circ}$$

According to given waveform, $2\theta = \pi - 2d$ $\theta = \frac{\pi - 2d}{2}$ or $\frac{180^{\circ} - 2d}{2}$

$$\theta = 51.07^{\circ}$$

31. Consider the buck-boost converter shwon. Switch Q is operating at 25 kHz and 0.75 duty-cycle. Assume diode and switch to be ideal. Under steady-state condition, the average current flowing through the inductor is



31. Ans: 24

Sol: Given:
$$f = 25 \text{ kHz}$$

$$D = 0.75$$

Find
$$(i_L)_{avg} = ?$$

To check continuous conduction or discontinuous conduction

$$K = \frac{2fL}{R}$$
 and $k_{cr} = (1 - D)^2$

Now
$$k = \frac{2fL}{R} = \frac{2 \times 25k \times 1m}{10} = 5$$

$$k_{cr} = (1-D)^2 = (1-0.75)^2 = 0.0625$$



As $[k > k_{cr}]$ means continuous conduction case

Mode (1) from [t = 0] to [t = DT] [when switch is ON]

$$C \frac{dV_0}{dt} + \frac{V_0}{R} = 0$$
(1)

Mode (2) from [t = DT] to [t = DT] [when switch is ON]

$$C \frac{dV_0}{dt} + \frac{V_0}{R} = 0$$
(2)

Now applying Amp. sec balance equation then it results

$$I_{L} = \frac{I_{o}}{(1-D)} = \frac{V_{0}}{R(1-D)} = \frac{DV_{s}}{R(1-D)^{2}} = \frac{0.75 \times 20}{10(1-0.75)^{2}} = 24 \text{ Amp}$$

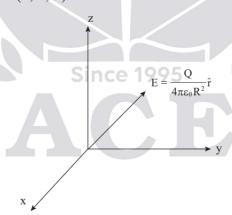
32. A 1 μ C point charge is held at the origin of a cartesian coordinate system. If a second point charge of 10 μ C is moved from (0, 10, 0) to (5, 5, 5) and subsequently to (5, 0, 0), then the total work done is _____ mJ. (Rounded off to 2 decimal places.)

Take $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ in SI units. All coordinates are in meters.

32. Ans: 9

Sol: $1 \mu C$ at (0, 0, 0)

10 μ C: $(0, 10, 0) \rightarrow (5, 5, 5) \rightarrow (5, 0, 0)$



- ⇒ Path independent
- ⇒ Conservative field

$$\begin{split} W &= -q \int\limits_{initial}^{final} \vec{E}.d\vec{\ell} = -q \int\limits_{initial}^{final} \frac{Q}{4\pi\epsilon_0 R^2} \hat{r} dr \\ &= \frac{-1 \times 10^{-6} \times 10 \times 10^{-6}}{4\pi\epsilon_0} \bigg[\frac{-1}{R} \bigg]_{in}^{fin} \end{split}$$



$$= 10 \times 10^{-12} \times 9 \times 10^{9} \left[\frac{1}{R} \right]_{in}^{fin}$$
$$= 90 \times 10^{-3} \left[\frac{1}{R} \right]_{in}^{fin}$$

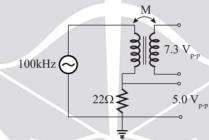
Initial point:
$$\sqrt{0^2 + 10^2 + 0^2} = 10$$

Final point:
$$\sqrt{5^2 + 0^2 + 0^2} = 5$$

$$= 90 \times 10^{-3} \left[\frac{1}{R} \right]_{10}^{5}$$
$$= 90 \times 10^{-3} \left[\frac{1}{5} - \frac{1}{10} \right]$$
$$= 9 \text{ mJ}$$

=9 mJ

33. An air-core radio frequency transformer as shown has a primary winding and a secondary winding. The mutual inductance M between the winding of the transformer is _____ µH. (Rounded off to 2 decimal places.)



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33. Ans: 50.95

Sol:

$$I_1 = \frac{2.5 \sin \omega t}{22}$$

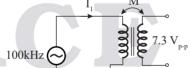
$$I_1 = 0.114 \sin \omega t$$

$$\therefore e_2 = M. \frac{dI_1}{dt}$$

$$\frac{7.3}{2} = M[0.114 \omega \cos \omega t]_{\text{max}}$$

$$\frac{7.3}{2} = M \times 0.114 \times 2\pi \times 10^{5}$$

$$M = 50.95 \mu H$$





34. Consider a power system consisting of N number of buses. Buses in this power system are categorized into slack bus, PV buses and PQ buses for load flow study. The number of PQ buses is N_L. The balanced Newton-Raphson method is used to carry out load flow study in polar form. H, S, M, and R are sub-matrices of the Jacobian matrix J as shown below:

$$\begin{bmatrix} \triangle P \\ \triangle Q \end{bmatrix} = J \begin{bmatrix} \triangle \delta \\ \triangle V \end{bmatrix} \text{, where } J = \begin{bmatrix} H & S \\ M & R \end{bmatrix}$$

The dimension of the sub-matrix M is

(a)
$$N_{I} \times (N - 1 + N_{I})$$

(b)
$$(N-1) \times (N-1+N_{r})$$

(c)
$$N_{I} \times (N \times 1)$$

(d)
$$(N-1) \times (N-1-N_{_{\rm I}})$$

34. Ans: (c)

Sol: Number of buses in the system = N

Number of PQ buses = N_r

Number of slack busses = 1

Number of PV buses = $N - 1 - N_{I}$

The NR (polar) load flow formulation,

$$\begin{bmatrix} \triangle P \\ \triangle Q \end{bmatrix} = \begin{bmatrix} H & S \\ M & R \end{bmatrix} \begin{bmatrix} \triangle \delta \\ \triangle V \end{bmatrix}$$

M is the submatrix that relates $[\Delta Q]$ and $[\Delta \delta]$

Number of elements in ΔQ vector = number of Q's known

$$=N_{I}$$

Number of elements in $\Delta\delta$ vector = number of unknown δ 's

$$= N - 1$$

So, size of matrix 'M' will be = $N_L \times (N-1)$

Correct answer is (c)

35. Let A be a 10×10 matrix such that A⁵ is a null matrix, and let I be the 10×10 identity matrix. The determinant of A + I is

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35. Ans: 1

Sol: A^5 is a null matrix i.e., $A^5 = 0$

 \Rightarrow A is a nilpotent matrix of index 5

 \Rightarrow All eigen values of nilpotent matrix are zeros

for $\lambda = 0$, the eigen value of A + I is

$$\lambda + 1 \Rightarrow 0 + 1 = 1$$

 $det (A + \lambda I) = product of eigen values$

= 1



36. The causal signal with z-transform $z^2(z-a)^{-2}$ is (u[n] is the unit step signal)

(a)
$$a^{2n}u[n]$$

(b)
$$(n + 1)a^nu[n]$$

(c)
$$n^{-1}a^nu[n]$$

(d)
$$n^2a^nu[n]$$

36. Ans: (b)

Sol: Assume $X(z) = z^2 (z-a)^{-2}$

$$X(z) = \frac{z^2}{(z-a)^2}$$

From standard Z.T pair

$$n(a)^n u(n) \longleftrightarrow \frac{az}{(z-a)^2}$$

$$n(a)^{n-1}u(n) \longleftrightarrow \frac{z}{(z-a)^2}$$

From time shifting property

$$x(n-n_0) \leftrightarrow z^{-n_0} X(z)$$

$$(n+1)(a)^{n+1-1}u(n+1)\longleftrightarrow z\left[\frac{z}{(z-a)^2}\right]$$

$$(n+1)(a)^n u(n+1) \longleftrightarrow \frac{z^2}{(z-a)^2}$$

So,
$$x(n) = (n+1)(a)^n u(n+1)$$

Given causal signal

So,
$$x(n) = (n+1) (a)^n u(n)$$

(or)

Assume $X(z) = z^2 (z - a)^{-2}$

$$X(z) = \frac{z^2}{(z-a)^2}$$

$$X(z) = \frac{z}{z-a} \cdot \frac{z}{z-a}$$

Given causal so, $(a)^n u(n) \longleftrightarrow \frac{z}{z-a}$,

$$X(z) = X_1(z). X_2(z)$$
(1)

$$X_1(n) * X_2(n) \leftrightarrow X_1(z) X_2(z)$$

Apply IZT to equation (1)

$$x(n) = x_1(n) * x_2(n)$$

$$x(n) = (a)^n u(n)*(a)^n u(n)$$

$$x(n) = (n+1) (a)^n u(n)$$

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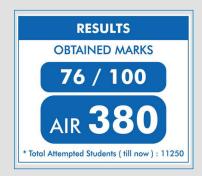
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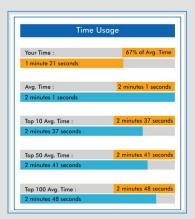
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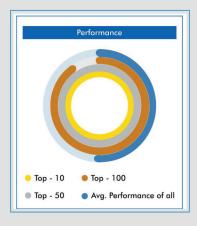


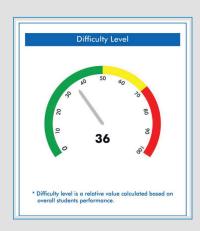




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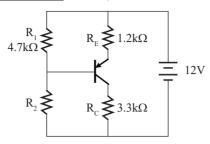


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37. In the BJT circuit shown, beta of the PNP transistor is 100. Assume $V_{BE} = -0.7 \text{ V}$. The voltage across R_{C} will be 5 V when R_{2} is _____ k Ω . (Rounded off to 2 decimal places.)

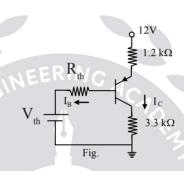
34



37. Ans: 17.06

Sol: The thevenins equivalent circuit is

$$R_{th} = \frac{4.7R_2}{4.7 + R_2}, V_{th} = \frac{12R_2}{4.7 + R_2}$$



Given that
$$V_{Rc} = 5V$$

$$I_c(3.3k) = 5$$

 $I_c = 1.515 \text{ mA}$

then
$$I_{\scriptscriptstyle B} = \frac{I_{\scriptscriptstyle c}}{\beta} = 15.15\,\mu A$$

$$I_E = I_c + I_B = 1.5303 \text{ mA}$$

$$V_E = 12 - 1.2 \times 10^3 I_E$$

= 10.1636 V

$$V_{BE} = -0.7 \Rightarrow V_{B} - V_{E} = -0.7$$

$$V_{R} = V_{E} - 0.7 = 9.4636 \text{ V}$$

Apply KVL from base to ground of transistor circuit.

$$V_{B} - I_{B}R_{th} - V_{th} = 0$$

$$9.4636 - 15.15 \times 10^{-6} \left(\frac{4.7 \times 10^3 R_2}{4.7 + R_2} \right) - \frac{12R_2}{4.7 + R_2} = 0$$

$$9.4636 - \frac{0.0712R_2}{4.7 + R_2} - \frac{12R_2}{4.7 + R_2} = 0$$

$$9.4636 (4.7 + R_2) - 12.0712R_2 = 0$$

$$44.4789 - 2.6076R_2 = 0$$

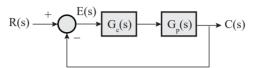
$$R_2 = \frac{44.4789}{2.6076} = 17.057$$

$$\therefore R_2 \approx 17.06 \text{ k}\Omega$$

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38. Consider a closed-loop system as shown. $G_p(s) = \frac{14.4}{s(1+0.1s)}$ is the plant transfer function and $G_c(s) = 1$ is the compensator. For a unit step input, the output response has damped oscillations. The damped natural frequency is _____ rad/s. (Rounded off to 2 decimal places.)



38. Ans: 10.91

Sol: Characteristic equation $1 + G_c(s)G_p(s) = 0$

$$1 + \frac{14.4}{s(1+0.1s)} = 0$$

$$0.1s^2 + s + 14.4 = 0$$

$$s^2 + 10s + 144 = 0$$

$$\omega_{\rm p} = \sqrt{144} = 12$$

$$2\zeta\omega_{\rm n}=10$$

$$\zeta = \frac{10}{2(12)} = \frac{10}{24}$$

$$\omega_{\rm d} = \omega_{\rm n} \sqrt{1 - \zeta^2} = 12 \sqrt{1 - \left(\frac{10}{24}\right)^2} = 10.91 \text{ rad/s}$$

39. Suppose the circle $x^2 + y^2 = 1$ and $(x - 1)^2 + (y - 1)^2 = r^2$ intersect each other orthogonally at the point (u, v). Then $u + v = \underline{\hspace{1cm}}$.

39. Ans: 1

Sol: Given: $x^2 + y^2 = 1$

Differentiating with respect to x

$$2x + 2y \frac{dy}{dx} = 0$$

$$2x = -2y \frac{dy}{dx}$$

$$\frac{dy}{dx} = \frac{2x}{-2y} = \frac{-x}{y}$$

$$m_1 = \frac{-x}{v}$$

and
$$(x-1)^2 + (y-1)^2 = r^2$$

Differentiating with respect to x.

$$2(x-1) + 2(y-1)\frac{dy}{dx} = 0$$



$$2(x-1) = -2(y-1) \frac{dy}{dx}$$

$$\frac{dy}{dx} = -\frac{(x-1)}{(y-1)} = m_2 \quad (say)$$

Two circles cut each other othogonally

$$m_1 m_2 = -1$$
 at (u, v)

$$\left(\frac{-x}{y}\right)\left[-\frac{(x-1)}{(y-1)}\right]=-1$$

$$\frac{-x}{y}\frac{(x-1)}{(y-1)} = 1$$

$$-x^2 + x = y^2 - y$$

$$-x^2 - y^2 + x + y = 0$$

$$x^2 + y^2 - x - y = 0$$

At
$$(u, v) u^2 + v^2 - u - v = 0$$

$$u^2 + v^2 = u + v$$

$$u + v = 1$$
 (: $u^2 + v^2 = 1$)

40. The state space representation of a first-order system is given as

$$\dot{\mathbf{x}} = -\mathbf{x} + \mathbf{u}$$

$$y = x$$

where, x is the state variable, u is the control input and y is the controlled output. Let u = -Kx be the control law, where K is the controller gain. To place a closed loop pole at -2, the value of K is

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40. Ans: 1

Sol:
$$\dot{x} = -x + u$$
 ; $u = -kx$

$$\dot{\mathbf{x}} = -\mathbf{x} - \mathbf{K}\mathbf{x}$$

$$\dot{\mathbf{x}} = -(\mathbf{K} + 1)\mathbf{x}$$

$$A = -(K+1)$$

Characteristic equation |sI - A| = 0

$$s - [-(K+1)] = 0$$

$$s + K + 1 = 0$$

$$s = -(K+1)$$
 pole

$$s = -2$$
 given pole

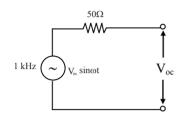
$$\therefore -(K+1) = -2$$

$$\Rightarrow$$
 K = 1



- 41. A signal generator having a source resistance of 50 Ω is set to generate a 1 kHz sinewave. Open circuit terminal voltage is 10 V peak-to-peak. Connecting a capacitor across the terminals reduces the voltage to 8 V peak-to-peak. The value of this capacitor is μF . (Rounded off to 2 decimal places.)
- 41. Ans: 0.8

Sol: $V_{oc} = V_{m} \sin \omega t = 10 V_{p-p}$ $2V_m = 10 \Rightarrow V_m = 5V$





when 'C' connected output becomes 8 V_{pp}

$$V' = V_i \left(\frac{-jx_c}{R - jx_c} \right) \Rightarrow 8 = 10 \left(\frac{-jx_c}{R - jx_c} \right)$$

$$8R - 8jx_c = -j10x_c$$

$$8R = -2jx_c$$

$$|x| = 4R$$

$$|x_c| = 4R$$

$$\frac{1}{\omega c} = 4R \Rightarrow c = \frac{1}{4\omega R}$$

$$c = \frac{1}{4 \times 2\pi \times 10^3 \times 50}$$

$$c = 0.7957 \ \mu F$$

$$\approx 0.80 \ \mu F$$

Since 1995

42. Two generators have cost function F₁ and F₂. Their incremental-cost characteristics are

$$\frac{dF_1}{dP_1} = 40 + 0.2P_1$$

$$\frac{dF_2}{dP_2} = 32 + 0.4P_2$$

They need to deliver a combined load of 260 MW. Ignoring the network losses, for economic operation, the generations P_1 and P_2 (in MW) are

(a)
$$P_1 = 140$$
, $P_2 = 120$

(b)
$$P_1 = 120$$
, $P_2 = 140$
(d) $P_1 = 160$, $P_2 = 100$

(c)
$$P_1 = P_2 = 130$$

(d)
$$P_1 = 160, P_2 = 100$$

42. Ans: (d)

Sol: The incremental fuel cost of two generators,

$$\frac{dF_1}{dP_1} = 40 + 0.2P_1$$



$$\frac{dF_2}{dP_2} = 32 + 0.4P_2$$

Where P₁ and P₂ are real power generation by units

Total load, $P_L = 260 \text{ MW}$

$$P_1 + P_2 = 260 \text{ MW} \dots (1)$$

For economic operation (by neglecting losses)

$$\frac{dF_1}{dP_1} = \frac{dF_2}{dP_2} \implies 40 + 0.2P_1 = 32 + 0.4P_2$$

$$0.2P_1 - 0.4P_2 = -8 \dots (2)$$

Eqn.
$$(1) \times 0.4 + \text{Eqn}(2)$$

$$0.4P_1 + 0.4P_2 + 0.2P_1 - 0.4P_2 = 104 - 8$$

$$0.6P_1 = 96$$

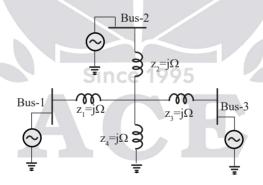
$$P_1 = 160 \text{ MW}$$

Now,
$$P_2 = 260 - 160$$

= 100 MW

Correct answer is (d)

43. A 3-Bus network is shown. Consider generator as ideal voltage sources. If rows 1, 2 and 3 of the Y_{Bus} matrix correspond to Bus 1, 2 and 3, respectively, then Y_{Bus} of the network is



(a)
$$\begin{bmatrix} -4j & 2j & 2j \\ 2j & -4j & 2j \\ 2j & 2j & -4j \end{bmatrix}$$

(c)
$$\begin{bmatrix} -\frac{3}{4}j & \frac{1}{4}j & \frac{1}{4}j \\ \frac{1}{4}j & -\frac{3}{4}j & \frac{1}{4}j \\ \frac{1}{4}j & \frac{1}{4}j & -\frac{3}{4}j \end{bmatrix}$$

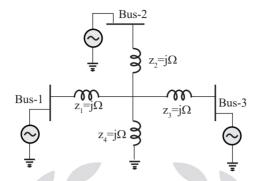
(b)
$$\begin{bmatrix} -4j & j & j \\ j & -4j & j \\ j & j & -4j \end{bmatrix}$$

(d)
$$\begin{bmatrix} -\frac{1}{2}j & \frac{1}{4}j & \frac{1}{4}j \\ \frac{1}{4}j & -\frac{1}{2}j & \frac{1}{4}j \\ \frac{1}{4}j & \frac{1}{4}j & -\frac{1}{2}j \end{bmatrix}$$



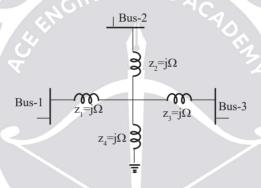
43. Ans: (c)

Sol: Given three buse power system



Voltage sources at buses -1, 2, 3 are said as ideal which has internal impedance.

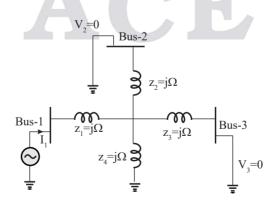
The network of impedances can be drawn as



Method-1: Let us keep a voltage source at Bus-1 and keep short circuit at other buses.

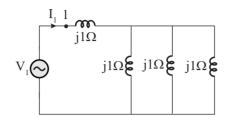
Let I₁ will be the current injected by source V₁
Since 1995

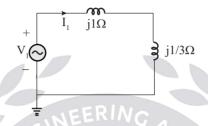
Now,
$$Y_{11} = \frac{I_1}{V_1} \Big|_{\substack{V_2 = V_3 = 0 \\ V_1 \neq 0}}$$





By basic network reduction technique





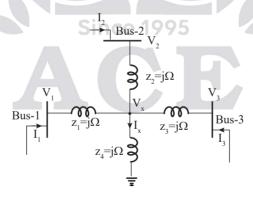
Now
$$Y_{Bus}$$
 element, $Y_{11} = \frac{I_1}{V_1} = \frac{1}{j_1 + j\frac{1}{3}}$

$$=-j\frac{3}{4}$$

In the four options given only option (c) has $Y_{11} = -j\frac{3}{4}$.

So correct answer will be option (c)

Method-2: (By KCL application on at each node)



Let node voltages are V_1 , V_2 , V_3 node current injections are I_1 , I_2 , I_3

There is an extra node which is not identified as bus.

Let that node voltage is V_x .

Where
$$V_x = I_x Z_4$$

= $(I_1 + I_2 + I_3)(j1)$



Where
$$I_1 = \frac{V_1 - V_x}{j1}$$
 $I_2 = \frac{V_2 - V_x}{j1}$, $I_3 = \frac{V_3 - V_x}{j1}$

$$V_x = \left(\frac{V_1 - V_x}{i1} + \frac{V_2 - V_x}{i1} + \frac{V_3 - V_x}{i1}\right)(j1)$$

$$V_{v} = V_{1} + V_{2} + V_{3} - 3V_{v}$$

$$4V_{x} = V_{1} + V_{2} + V_{3}$$

$$V_x = \frac{1}{4}(V_1 + V_2 + V_3)$$

Now, currents

$$I_{1} = \frac{V_{1} - V_{x}}{j1}$$

$$= -j \left[V_{1} - \frac{1}{4} (V_{1} + V_{2} + V_{3}) \right]$$

$$= -j V_{1} + j \frac{V_{1}}{4} + j \frac{V_{2}}{4} + j \frac{V_{3}}{4}$$

$$I_1 = V_1 \left(\frac{-j1}{4} \right) + V_2 \left(\frac{j1}{4} \right) + V_3 \left(\frac{j1}{4} \right) \dots (1)$$

$$I_{2} = \frac{V_{2} - V_{x}}{j1}$$

$$= -j1 \left[V_{2} - \frac{1}{4} (V_{1} + V_{2} + V_{3}) \right]$$

$$I_{2} = V_{1} \left(\frac{j1}{4}\right) + V_{2} \left(\frac{-j3}{4}\right) + V_{3} \left(\frac{j1}{4}\right) \dots (2)$$

$$I_{1} = \frac{V_{3} - V_{x}}{2}$$
Since 1995

$$I_{3} = \frac{V_{3} - V_{x}}{j1}$$
$$= -j1 \left[V_{3} - \frac{1}{4} (V_{1} + V_{2} + V_{3}) \right]$$

$$I_3 = V_1 \left(\frac{j1}{4}\right) + V_2 \left(\frac{j1}{4}\right) + V_3 \left(\frac{-j3}{4}\right) \dots (3)$$

From equations (1), (2), (3)

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} \frac{-j3}{4} & \frac{j1}{4} & \frac{j1}{4} \\ \frac{j1}{4} & \frac{-j3}{4} & \frac{j1}{4} \\ \frac{j1}{4} & \frac{j1}{4} & \frac{-j3}{4} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$

Y_{Bus} matrix

Correct answer is (c)

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A belt-driven DC shunt generator running at 300 RPM delivers 100 kW to a 200 V DC grid. It continues to run as a motor when the belt breaks, taking 10 kW from the DC grid. The armature resistance is 0.025Ω , field resistance is 50 Ω , and brush drop is 2 V. Ignoring armature reaction, the speed of the RPM. (Rounded off to 2 decimal places.)

42

44. Ans: 275.19

Sol: DC shunt generator

$$P_{L} = V I_{L}$$

$$100 \times 10^{3} = 200 \times I_{L}$$

$$I_{L} = \frac{100 \times 10^{3}}{200} = 500A$$

$$I_{100} \times 10^{3} = 200 \times I_{L}$$

$$I_{L} = \frac{100 \times 10^{3}}{200} = 500A$$

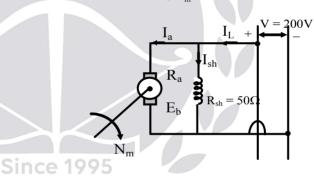
$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{50} = 4A$$

$$V_{g} = 300 \text{ rpm}$$

$$V_{g} = 300 \text{ rpm}$$

If belt breaks, generator continues to run as a motor (shunt motor) taking $P_{in} = 10 \text{kW}$

$$\begin{aligned} & P_{in} = V \times I_{L} \\ & 10 \times 10^{3} = 200 \times I_{L} \\ & I_{L} = \frac{10 \times 10^{3}}{200} = 50A \\ & I_{sh} = 4A \\ & I_{a} = I_{L} - I_{sh} \end{aligned}$$



$$\begin{split} &= 50 - 4 = 46 \text{ A} \\ E_b &= V - I_a R_a - BD = 200 - (46 \times 0.025) - 2 = 196.85 \text{ V} \\ E_g &= \frac{\varphi_g Z N_g}{60} \times \frac{P}{A} & E_b = \frac{\varphi_m Z N_m}{60} \times \frac{P}{A} \\ E_g &= k N_g \varphi_g & E_b = k N_m \varphi_m \varphi_g \propto I_{sh} \end{split}$$

$$E_{\rm b} = kN_{\rm m}\phi_{\rm m}\phi_{\rm m}\phi_{\rm g} \propto I_{\rm sh} = 4A$$

$$\phi_{\rm m} \propto I_{\rm sh} = 4A$$

$$E_{g} = kN_{g}I_{sh}$$

$$E_{b} = kN_{m}I_{sh}$$

$$\frac{E_{b}}{E_{g}} = \frac{kN_{m}I_{sh}}{kN_{g}I_{sh}} \Rightarrow \frac{196.85}{214.6} = \frac{N_{m}}{300}$$
motor spee $(N_{m}) = \frac{196.85}{214.6} \times 300$

motor spee
$$(N_m) = \frac{190.83}{214.6} \times 300$$

= 275.19 rpm



- 45. Let p and q be real numbers such that $p^2 + q^2 = 1$. The eigen values of the matrix $\begin{vmatrix} p & q \\ q & -p \end{vmatrix}$ are
 - (a) j and -j

(b) pq and -pq

(c) 1 and -1

(d) 1 and 1

45. Ans: (c)

Sol: Let
$$A = \begin{bmatrix} p & q \\ q & -p \end{bmatrix}$$

the characteristic equation is

$$\lambda^2 - \lambda (-p + p) + (-p^2 - q^2) = 0$$

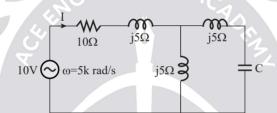
$$\lambda^2 - (p^2 + q^2) = 0$$

$$\lambda^2 - 1 = 0$$

$$\lambda^2 - 1 = 0$$
 [: $p^2 + q^2 = 1$]

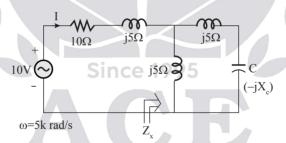
$$\lambda = 1, -1$$

46. In the given circuit, the value of capacitor C that makes current I = 0 is μF.



46. Ans: 20

Sol: In the given circuit, the value 'C' for I = 0



For current $I = 0 \Rightarrow I = \frac{V}{Z}$

i.e
$$Z_T = \frac{V}{I} = \infty$$
 (infinity)

$$Z_{T} = \infty \Rightarrow Z_{x} = \infty \quad (:10+j5+\infty = \infty)$$

$$Z_{x} = j5 || j(5 - X_{c})$$

$$Z_{x} = \frac{j5(j(5-X_{c}))}{j(10-X_{c})} = \frac{j5(5-X_{c})}{(10-X_{c})}$$

If
$$I = 0 \Rightarrow Z_x = \infty$$

$$\frac{1}{0} = \infty = \frac{j5(5 - X_c)}{(10 - X_c)}$$

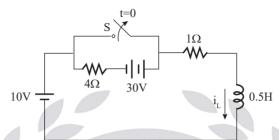
$$10 - X_c = 0 \Rightarrow X_c = 10 \Rightarrow \frac{1}{\omega c} = 10$$



$$C = \frac{1}{10\omega} = \frac{1}{10 \times 5 \times 10^3} = 20 \times 10^{-6} F = 20 \mu F$$

$$C = 20 \mu F$$

47. In the circuit, switch 'S' is in the closed position for a very long time. If the switch is opened at time t = 0, then $i_1(t)$ in amperes, for $t \ge 0$ is



(a)
$$8 + 2e^{-10t}$$

(c)
$$10(1 - e^{-2t})$$

(b)
$$8e^{-10t}$$

47. Ans: (a)

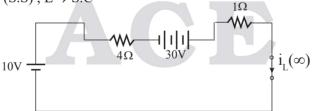
Sol: For t < 0 'S' is closed $t = 0^{-}(S.S) L \rightarrow S.C$



$$i_L(0^-) = \frac{10}{1} = 10A = i_L(0^+) = I$$

For t > 0, 'S' is opened

For find value take $t = \infty$ (S.S), $L \rightarrow S.C$



Since 1995

$$i_L(\infty) = \frac{10+30}{4+1} = \frac{40}{5} = 8 \text{ Amps}$$

Time constant
$$\tau = \frac{L}{R_{eq}} = \frac{0.5}{4+1} = \frac{1}{10} \sec$$

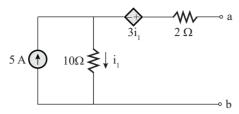
$$i_{L}(+) = i_{L}(\infty) + (i_{L}(0) - i_{L}(\infty)) e^{-t/\tau}$$

= 8 + (10 - 8) e^{-10t}

$$i_L^{}(+) = (8+2e^{-10t}) \text{ Amps } t \ge 0$$



48. For the network shown, the equivalent Thevenin voltage and Thevenin impedance as seen across terminals 'ab' is

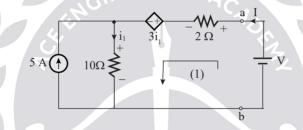


- (a) 10 V in series with 12 Ω .
- (c) 65 V in series with 15 Ω .

- (b) 50 V in series with 2 Ω .
- (d) 35 V in series with 2 Ω .

48. Ans: (c)

Sol: For Thevenins equivalent circuit use the V-I method for V_{th} & R_{th}



Since 1995

$$V = R_{th} I + V_{th}$$

By KCL at (X)

$$5 + I = i_1 \implies i_1 = (5 + I)$$
(1)

By KVL for (1)

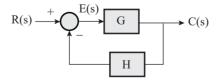
$$-V + 2I + 3i_1 + 10i_1 = 0$$

$$V = 2I + 13i_1 = 2I + 13(5+I)$$

$$V = 15 I + 65 \Rightarrow V = R_{th} I + V_{th}$$

$$\boldsymbol{R}_{th} = 15\Omega$$
 , $\boldsymbol{V}_{th} = 65\Omega$

49. For the closed-loop system shown, the transfer function $\frac{E(s)}{R(s)}$ is



(a)
$$\frac{1}{1 + GH}$$

(b)
$$\frac{GH}{1+GH}$$

(c)
$$\frac{1}{1+G}$$

(d)
$$\frac{G}{1+GH}$$



49. Ans: (a)

Sol: From Massion's Gain formula

Number of loops $L_1 = -GH$

Forward path M = 1

$$\frac{E(s)}{R(s)} = \frac{1}{1 + GH}$$

50. Let (-1-j), (3-j), (3+j) and (-1+j) be the vertices of a rectangle C in the complex plane. Assuming that C is traversed in counter-clockwise direction, the value of the counter integral $\oint_C \frac{dz}{z^2(z-4)}$ is

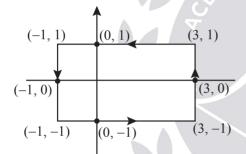
Since 1995

(a)
$$\frac{j\pi}{16}$$

(b)
$$\frac{-j\pi}{8}$$

50. Ans: (b)

Sol:



Let
$$f(z) = \frac{1}{z^2(z-4)}$$

z = 0, 4 are singular points

z = 0 lies inside the rectangle

z = 4 lies outside the rectangle

$$\int_{c} \frac{dz}{z^{2}(z-4)} = \int_{c} \frac{\left(\frac{1}{z-4}\right)}{(z-0)^{1+1}} dz$$

$$= 2\pi j \frac{F'(0)}{1!} \qquad \{ F(z) = \frac{1}{(z-4)}$$

$$= 2\pi j F'(0) \qquad F'(z) = \frac{-1}{(z-4)^{2}}$$

$$= 2\pi j \left(\frac{-1}{16}\right) \qquad F'(0) = \frac{-1}{(0-4)^{2}} = \frac{-1}{16}$$

$$= \frac{-\pi j}{8}$$



51. Let $p(z) = z^3 + (1+j)z^2 + (2+j)z + 3$, where z is a complex number.

Which one of the following is true?

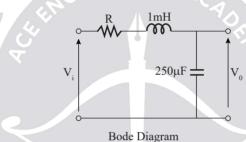
- (a) The complex roots of the equation p(z) = 0 come in conjugate pairs
- (b) All the roots cannot be real
- (c) conjugate $\{p(z)\} = p(\text{conjugate}\{z\})$ for all z
- (d) The sum of the roots of p(z) = 0 is a real number
- 51 Ans: (b)

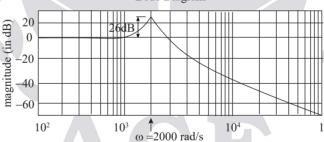
Sol:
$$p(z) = z^3 + (1+i)z^2 + (2+i)z + 3$$

Every non zero constant polynomial with complex coefficients has at least one complex root. So, option (b) is correct.

52. The Bode magnitude plot for the transfer functon $\frac{V_0(s)}{V_i(s)}$ of the circuit is as shown.

The value of R is $\underline{\hspace{1cm}}$ Ω . (Rounded off to 2 decimal places.)





52. Ans: 0.1

Sol:
$$\frac{V_{o}(s)}{V_{i}(s)} = \frac{1}{1 + RCs + LCs^{2}}$$

$$= \frac{1}{1 + RCj\omega + LC(j\omega)^{2}}$$

$$= \frac{1}{1 - \omega^{2}LC + j\omega RC}$$

$$= \left| \frac{V_{o}(j\omega)}{V_{i}(j\omega)} \right| = \frac{1}{\sqrt{(1 - \omega^{2}LC)^{2} + \omega^{2}R^{2}C^{2}}} = 20 \text{ (i.e., 26 dB)}$$



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58





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$$\frac{1}{(1 - \omega^2 LC)^2 + \omega^2 R^2 C^2} = 400$$

$$1 + \omega^4 L^2 C^2 - 2\omega^2 LC + \omega^2 R^2 C^2 = \frac{1}{400}$$

$$1 + \omega^2 C[\omega^2 L^2 C - 2L + R^2 C] = \frac{1}{400}$$

Given

$$\omega = 2000$$
, L = 10^{-3} , C = 250×10^{-6}

$$1 + 2000^{2} (250 \times 10^{-6}) [2000^{2} (10^{-3})^{2} 250 \times 10^{-6} - (2 \times 10^{-3}) + R^{2} 250 \times 10^{-6}] = \frac{1}{400}$$

$$1 + 1 - 2 + R^2 (250 \times 10^{-6}) = 0.25 \times 10^{-2}$$

After simplification, R = 0.1

Method-2:

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{1 + RCs + LCs^2}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}$$
 and $M_r = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$

$$\zeta = \frac{R}{2} \sqrt{\frac{250 \times 10^{-6}}{10^{-3}}} = \frac{R}{4}$$

Given that magnitude = 26 dB

$$26 = 20 \log M_{\odot}$$

$$\Rightarrow$$
 $M_r = 20$

$$20 = \frac{1}{2\left(\frac{R}{4}\right)\sqrt{1-\left(\frac{R}{4}\right)^2}}$$

$$\frac{8}{R\sqrt{16-R^2}} = 20$$

$$\Rightarrow 16 = 100R^2 (16 - R^2)$$

$$\Rightarrow 0.16 = 16R^2 - R^4$$

$$\Rightarrow$$
 R⁴ - 16R² + 0.16 = 0

Let
$$R^2 = x$$

$$\Rightarrow$$
 x² - 16x + 0.16 = 0

After solving x = 0.01 and $15.98 \approx 16$

$$\therefore R = \sqrt{x} = 0.1$$
 and 4

$$M_r$$
 is valid for $0 < \zeta < \frac{1}{\sqrt{2}}$

 \therefore Suitable value of R = 0.1 Ω .



- 53. In a single-phase transformer, the total iron loss is 2500 W at nominal voltage of 440 V and frequency 50 Hz. The total iron loss is 850 W at 220 V and 25 Hz. Then, at nominal voltage and frequency, the hysteresis loss and eddy current loss respectively are
 - (a) 900 W and 1600 W

(b) 1600 W and 900 W

(c) 250 W and 600 W

(d) 600 W and 250 W

53. Ans: (a)

Sol: Iron loss at 440 V, 50 Hz = 2500W

Iron loss at 220 V, 25 Hz = 850 W

$$\frac{440}{50} = \frac{220}{25}$$

$$\frac{V_1}{f}$$
 = constant

$$W_i = Af + Bf^2$$

At 50 Hz,
$$2500 = A(50) + B(50)^2$$

At 25 Hz
$$850 = A(25) + B(25)^2$$

By solving
$$A = 18$$
, $B = 0.64$

$$W_h$$
 at $f = 50$ Hz = Af

$$= 18 \times 50$$

$$= 900 W$$

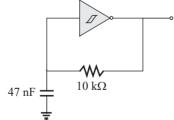
$$W_{e}$$
 at $f = 50 \text{ Hz} = \text{Bf}^{2}$

$$= 0.64 \times (50)^2$$

$$= 1600 \text{ W}$$

54. A CMOS Schmitt-trigger inverter has a low output level of 0 V and a high output level of 5 V. It has input thresholds of 1.6 V and 2.4 V. The input capacitance and output resistance of the Schmitt-trigger are negligible. Thge frequency of the oscillator shown in ______ Hz. (Rounded off to 2 decimal places.)

Since 1995



54. Ans: 3158

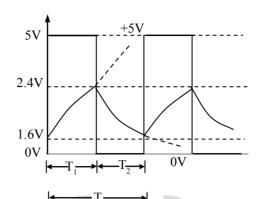
Sol: Given that $(V_0)_{Low} = 0V$

$$(V_0)_{High} = 5V, V_{LTP} = 1.6V, V_{UTP} = 2.4V$$

$$\tau = RC = 10^4 \times 47 \times 10^{-9} = 0.47 \text{ msec}$$



The output wave form is



Voltage across cap is $V_c = V_f + (V_i - V_f)e^{-t/\tau}$

$$V_{c} - V_{f} = (V_{i} - V_{f})e^{-t/\tau}$$

$$e^{t/\tau} = \left(\frac{V_f - V_i}{V_f - V_c}\right)$$

$$\Rightarrow t = \tau \ell n \left(\frac{V_{\rm f} - V_{\rm i}}{V_{\rm f} - V_{\rm c}} \right)$$

T₁ calculation:

$$V_i = 1.6V, V_f = 5V, \tau = RC, \text{ at } t = T_1, V_c = 2.4 \text{ V}$$

$$T_1 = \tau \ln \left(\frac{5 - 1.6}{5 - 2.4} \right)$$

$$= 0.47 \times 10^{-3} \ln \left(\frac{3.4}{2.6} \right)$$

$$= 0.12608$$
 msec

T, calculation:

$$V_i = 2.4V$$
, $V_f = 0$, $\tau = RC$, at $t = T_2$, $V_c = 1.6V$

$$T_2 = \tau \ln \left(\frac{0 - 2.4}{0 - 1.6} \right)$$

$$=0.47\times10^{-3}\ln\left(\frac{2.4}{1.6}\right)$$

= 0.190568 msec

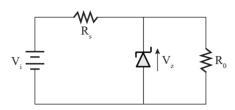
Then $T = T_1 + T_2 = 0.316648$ msec

frequency of oscillations $f = \frac{1}{T}$

= 3158.08 Hz

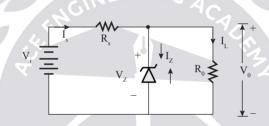


55. In the circuit shown, a 5 V Zener diode is used to regulate the voltage across load R_0 . The input is an unregulated DC voltage with a minimum value of 6 V and a maximum value of 8 V. the value of R_s is 6 Ω . The Zener diode has a maximum rated power dissipation of 2.5 W. Assuming the Zener diode to be ideal, the minimum value of R_0 is _____ Ω .



55. Ans: 30

Sol:



Since 1995

Given that
$$V_0 = V_z = 5V$$

$$V_i \min = 6V, V_i \max = 8V, R_s = 6 \Omega$$

$$P_{x}max = 2.5 \text{ W} \Rightarrow V_{x} max = 2.5$$

$$\Rightarrow I_z \max = \frac{2.5}{5} = 500 \text{mA}$$

$$I_{s} = \left(\frac{V_{i} - V_{z}}{R_{c}}\right)$$

$$I_{s} max = \left(\frac{V_{i} max - V_{z}}{R_{s}}\right) = \left(\frac{8 - 5}{6}\right) = 500 \text{ mA}$$

$$I_{s} \min = \left(\frac{V_{i} \min - V_{z}}{6}\right) = 166.67 \text{ mA}$$

To get minimum value of R₀, current through R₀ must be maximum for this

$$I_s min = I_r min + I_r max$$

As zener is ideal consider I_min=0

$$I_{L}$$
max= I_{s} min = 166.67 × 10⁻³

$$\frac{5}{(R_0)_{\min}} = 166.67 \times 10^{-3} \Rightarrow (R_0)_{\min} = \frac{5}{166.67 \times 10^{-3}}$$

$$=29.9994\Omega$$

 (R_0) min $\approx 30\Omega$



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