GATE 2020

Electronics and Communication Engineering

Previous Year Solved Questions

(1991-2019)

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Second Edition 2018

Third Edition **2019**

Preface

This book is designed to give the readers in depth solutions of the Previous Year GATE Questions. Solving Previous Year Questions is the most integral part of any exam preparation as it gives a student insight on what can be expected in the coming years.

This book contains all subjects of GATE Electronics and Communication Engineering including Engineering Maths and Aptitude from the year 1991 to 2018. The questions have been segregated into standard chapters within each subject so that a student can practice problems chapter-wise.

I would also like to thank various GATE 2016 and GATE-2017 toppers who have made valuable contributions to this book like (GATE 2016 AIR -06, AIR-103, GATE 2017 AIR-132 and many more. Without their dedication and hard work this book would not have been possible. Also, I would appreciate the effort of Team Kreatryx who worked day and night for completion of this book.

In order to gain most from this book, it is recommended that the student attempts previous year problems while revising a subject and not directly after completion of a subject. Immediately after studying a subject these problems may seem trivial and not help you much but in exam environment where knowledge of all subjects at same time is must then they may not seem too trivial. While revising if a student solves the previous year problems and is able to solve most of them then he/she is on the right track.

After revising and solving previous year problems a student can attempt any test series and that would be the recommended strategy from my side. So, this book is targeted towards effective revision to boost your rank in GATE exam.

Best of Luck!

Ankit Goyal
Co-Founder, Kreatryx
AIR-1, GATE 2018 EE | AIR-1, GATE 2014 EE | AIR-8, GATE 2013 EE

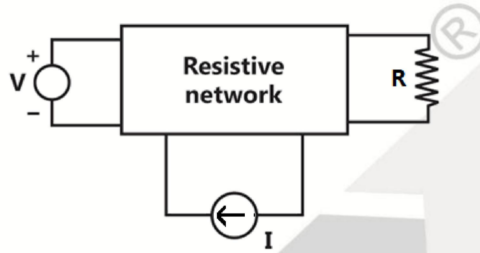
CONTENTS

Network Analysis

01

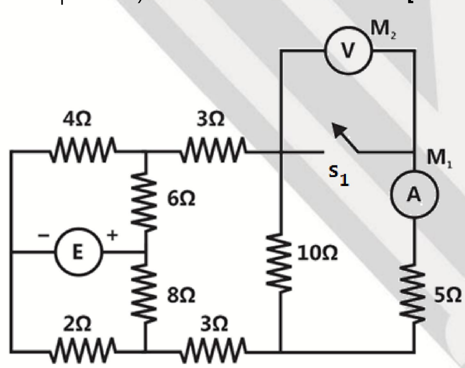
Chapter 1 – Network Basics

01. A dc circuit shown in figure has a voltage source V, a current source I and several resistors. A particular resistor R dissipates a power of 4 watts when V alone is active. The same resistor R dissipates a power of 9 watts when I alone is active. The power dissipated by R when both sources are active will be **[1993]**



(a) 1 W
(b) 5 W
(c) 13 W
(d) 25 W

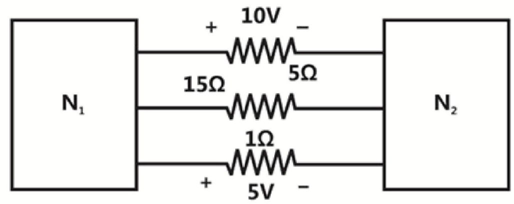
02. In the circuit of figure, when switch S_1 is closed, the ideal ammeter M_1 reads 5A. What will be ideal voltmeter M_2 read when S_1 is kept open? (The value of E is not specified). **[1993]**



03. A network contains linear resistors and ideal voltage sources. If values of all the resistors are doubled, then the voltage across each resistor is **[1993]**

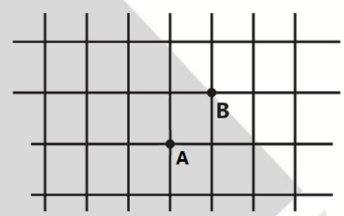
(a) halved
(b) doubled
(c) increased by four times
(d) not changed

04. The two electrical sub network N_1 and N_2 are connected through three resistors as shown in figure. The voltage across 5 ohm resistor and 1 ohm resistor are given to be 10 V and 5V, respectively. Then voltage across 15 ohm resistor is **[1993]**



(a) – 105 V
(b) + 105 V
(c) – 15 V
(d) + 15 V

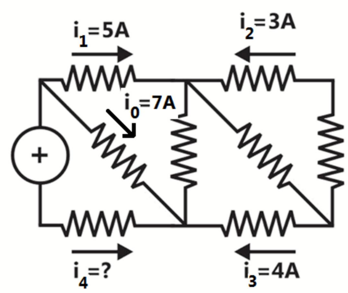
05. An infinite grid is built up by connecting resistors in the manner indicated in figure, where each branch represents one ohm resistor. Calculate the effective resistance between the nodes A and B. **[1993]**



06. The RMS value of a rectangular wave of period T, having a value of + V for a duration, $T_1 (< T)$ and –V for the duration, $T - T_1 = T_2$, equals **[1995]**

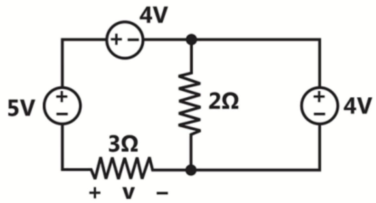
(a) V
(b) $\frac{T_1 - T_2}{T} V$
(c) $\frac{V}{\sqrt{2}}$
(d) $\frac{T_1}{T_2} V$

07. The current i_4 in the circuit of the figure is equal to **[1997]**



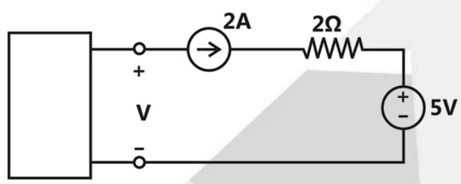
(a) 12 A
(b) – 12 A
(c) 4 A
(d) None of these

08. The voltage V in the figure is equal to **[1997]**



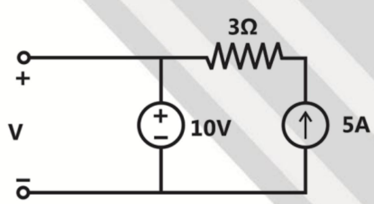
(a) 3 V (b) – 3V
(c) 5 V (d) None of these

09. The voltage V in the figure is always equal to **[1997]**



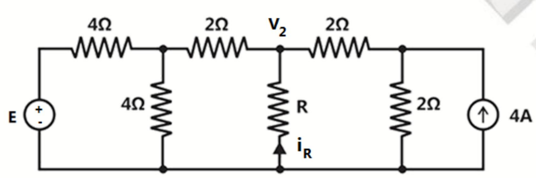
(a) 9 V (b) 5 V
(c) 1 V (d) None of these

10. The voltage V in the figure is **[1997]**



(a) 10 V (b) 15 V
(c) 5 V (d) None of the above

11.



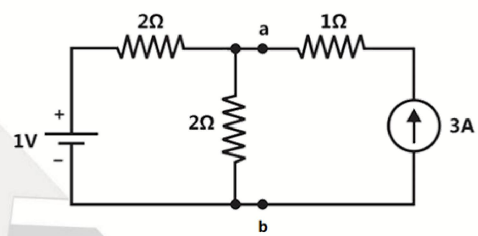
In the circuit of figure when $R = 0\ \Omega$, the current i_R equals to 10 A **[1997]**

(a) Find the value of R for which it absorbs maximum power
(b) Find the value of E
(c) Find V_2 when $R = \infty$ (open circuit)

12. The nodal method of circuit analysis is based on **[1998]**

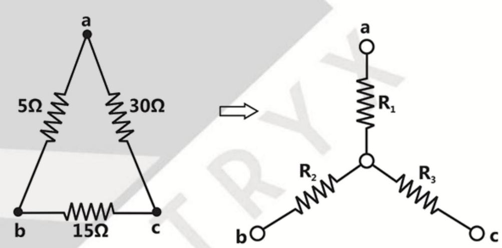
(a) KVL and Ohm's law
(b) KCL and Ohm's law
(c) KCL and KVL
(d) KCL, KVL and Ohm's law

13. The voltage across the terminals a and b in Figure is **[1998]**



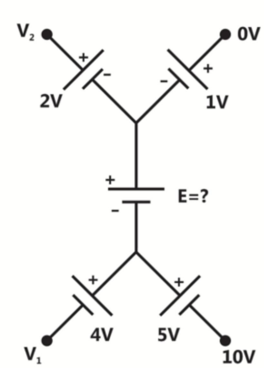
(a) 0.5 V (b) 3.0 V
(c) 3.5 V (d) 4.0 V

14. A Delta-connected network with its Wye-equivalent is shown in Figure. The resistance R_1, R_2 and R_3 (in ohms) are respectively **[1999]**



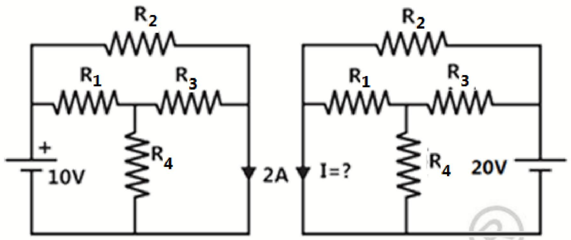
(a) 1.5, 3 and 9 (b) 3, 9 and 1.5
(c) 9, 3 and 1.5 (d) 3, 1.5 and 9

15. In the circuit of Figure, the value of the voltage source E is **[2000]**



(a) – 16 V
(b) 4 V
(c) – 6 V
(d) 16 V

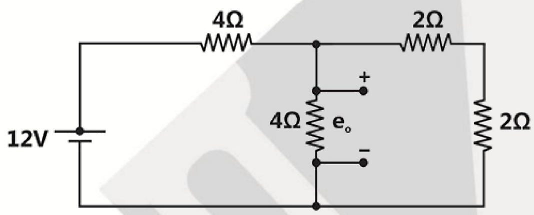
16. Use the data of Figure (a). The current I in the circuit of Figure (b) is **[2000]**



(a) (b)

(a)-2A (b) 2A
(c) -4A (d) +4A

17. The voltage e_0 in figure is **[2001]**

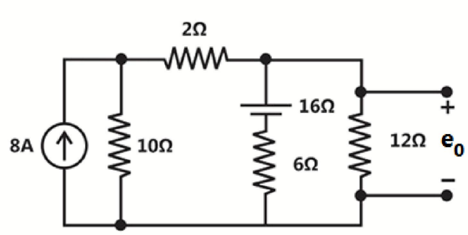


(a) 2V (b) $\frac{4}{3}$V
(c) 4V (d) 8V

18. If each branch of a Delta circuit has impedance $\sqrt{3}Z$, then each branch of the equivalent Wye circuit has impedance. **[2001]**

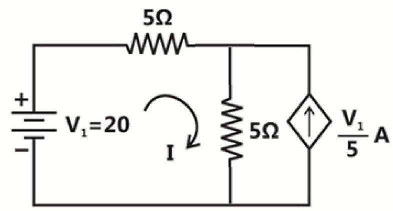
(a) $\frac{Z}{\sqrt{3}}$ (b) 3Z
(c) $3\sqrt{3}Z$ (d) $\frac{Z}{3}$

19. The voltage e_0 in figure is **[2001]**



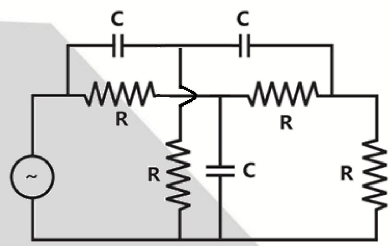
(a) 48 V (b) 24 V
(d) 36 V (d) 28 V

20. The dependant current source shown in Figure **[2002]**



(a) Delivers 80 W (b) Absorbs 80 W
(c) Delivers 40 W (d) Absorbs 40 W

21. The minimum number of equations required to analyse the circuit shown in Figure is **[2003]**

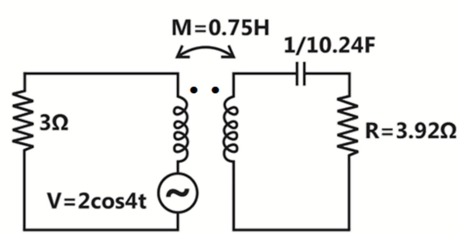


(a) 3 (b) 4
(c) 6 (d) 7

22. Twelve 1Ω resistances are used as edges to form a cube. The resistance between two diagonally opposite corners of the cube is **[2003]**

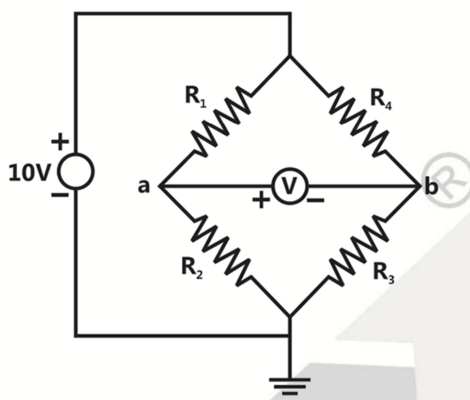
(a) $\frac{5}{6}\Omega$ (b) $\frac{1}{6}\Omega$
(c) $\frac{6}{5}\Omega$ (d) $\frac{3}{2}\Omega$

23. The current flowing through the resistance R in the circuit in figure has the form P cos 4t, where P is **[2003]**



(a) (0.18+j0.72) (b) (0.46+j1.90)
(c) -(0.18+j1.90) (d) –(0.192+j0.144)

24. If $R_1 = R_2 = R_4$ and $R_3 = 1.1R$ in the bridge Circuit shown in figure, then the reading in the ideal Voltmeter connected between **a** and **b** is **[2005]**



(a) 0.238 V (b) 0.138 V
(c) -0.238 V (d) 1 V

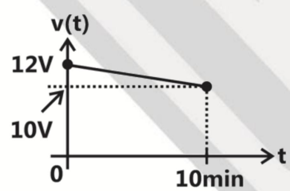
25. A fully charged mobile phone with a 12 V battery is good for a 10 minute talk-time. Assume that, during the talk-time, the battery delivers a constant current of 2 A and its voltage drops linearly from 12 V to 10 V as shown in the figure. How much energy does the battery deliver during this talk-time? **[2009]**

(a) 220 J

(b) 12 kJ

(c) 13.2 kJ

(d) 14.4 kJ



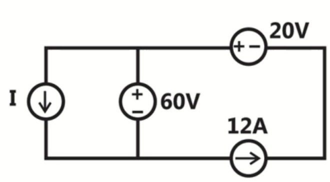
26. In the interconnection of ideal sources shown in the figure, it is known that the 60 V source is absorbing power. Which of the following can be the value of the current source I? **[2009]**

(a) 10 A

(b) 13 A

(c) 15 A

(d) 18



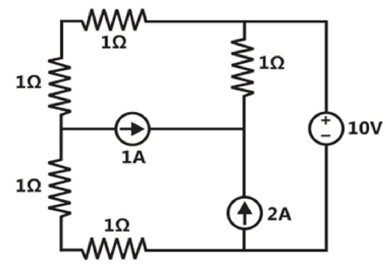
27. In the circuit shown, the power supplied by the voltage source is **[2010]**

(a) 0W

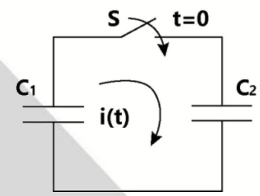
(b) 5W

(c) 10W

(d) 100W

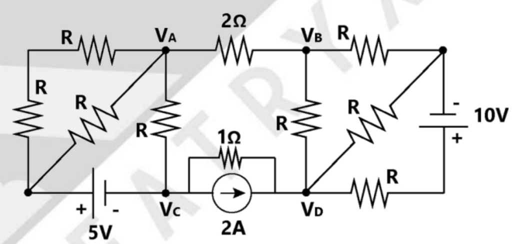


28. In the following figure, C_1 and C_2 are ideal capacitors. C_1 has been charged to 12V before the ideal switch S is closed at t = 0. The current i(t) for all t is **[2012]**



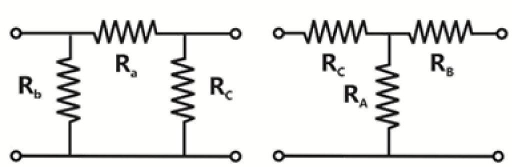
(a) Zero
(b) A step function
(c) An exponentially decaying function
(d) An impulse function

29. If $V_A - V_B = 6$ V, then $V_C - V_D$ is **[2012]**



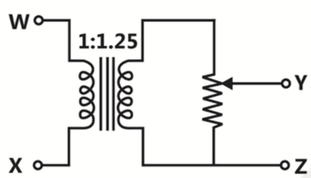
(a) –5 V (b) 2 V
(c) 3 V (d) 6 V

30. Consider a delta connection of resistors and its equivalent star connection as shown below. If all elements of the delta connection are scaled by a factor κ, $\kappa > 0$, the elements of the corresponding star equivalent will be scaled by a factor of **[2013]**



(a) κ^2 (b) κ
(c) $1/\kappa$ (d) $\sqrt{\kappa}$

31. The following arrangement consists of an ideal transformer and an attenuator which attenuates by a factor of 0.8. An ac voltage $V_{WX1} = 100V$ is applied across WX to get an open circuit voltage V_{YZ1} across YZ. Next, an ac voltage $V_{YZ2} = 100V$ is applied across YZ to get an open circuit voltage V_{WX2} across WX. Then, V_{YZ1} / V_{WX1}, V_{WX2} / V_{YZ2} are respectively, **[2013]**



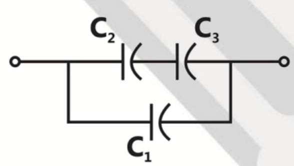
(a) $125/100$ and $80/100$

(b) $100/100$ and $80/100$

(c) $100/100$ and $100/100$

(d) $80/100$ and $80/100$

32. Three capacitors C_1, C_2 and C_3 whose values are $10\mu F$, $5\mu F$ and $2\mu F$ respectively, have breakdown voltages of 10V, 5V and 2V respectively. For the interconnection shown below, the maximum safe voltage in Volts that can be applied across the combination, and the corresponding total charge in μC stored in the effective capacitance across the terminals are respectively, **[2013]**



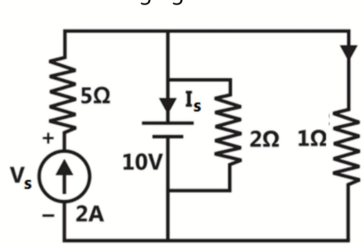
(a) 2.8 and 36

(b) 7 and 119

(c) 2.8 and 32

(d) 7 and 80

Common Data for Questions 33 and 34:
Consider the following figure

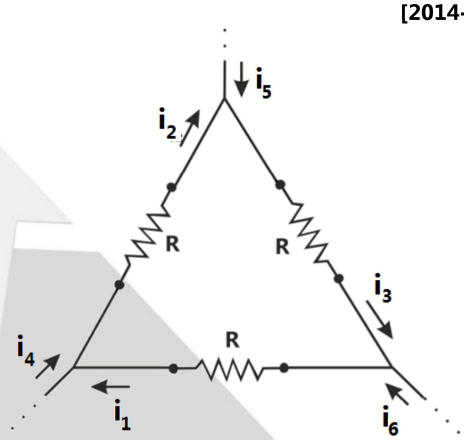


33. The current I_S in Amps in the voltage source and voltage V_S in Volts across the current source respectively, are **[2013]**

(a) 13, -20 (b) 8, -10
(c) -8, 20 (d) -13, 20

34. The current in the 1Ω resistor in Amps is **[2013]**
(a) 2 (b) 3.33
(c) 10 (d) 12

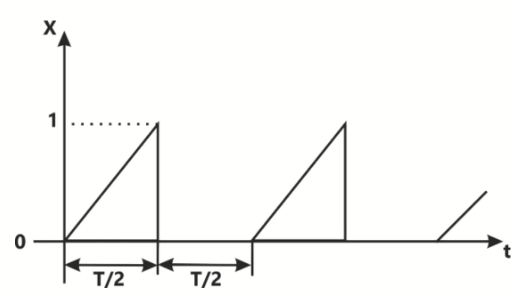
35. Consider the configuration shown in the figure which is a portion of a larger electrical network **[2014-01]**



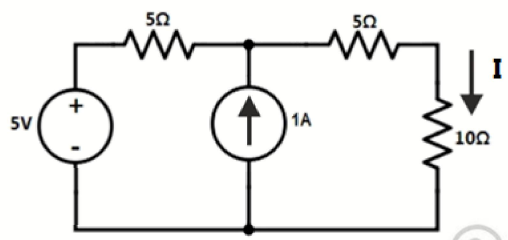
For $R = 1\Omega$ and currents $i_1 = 2A$, $i_4 = -1A$, $i_5 = -4A$, which of the following is **TRUE**?
(a) $i_6 = 5A$
(b) $i_3 = -4A$
(c) Data is sufficient to conclude that the supposed currents are impossible
(d) Data is insufficient to identify the currents i_2, i_3 and i_6

36. A Y-network has resistances of 10Ω each in two of its arms, while the third arm has a resistance of 11Ω. In the equivalent Δ-network, the lowest value (in Ω) among the three resistances is _______. **[2014-01]**

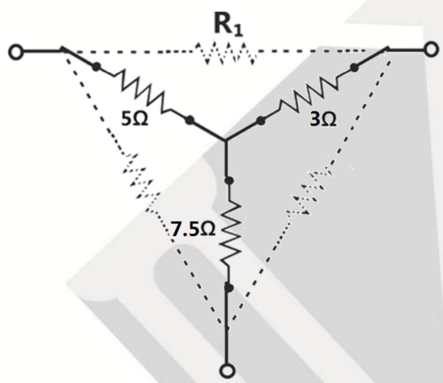
37. A periodic variable x is shown in the figure as a function of time. The root-mean-square (rms) value of x is ________. **[2014-01]**



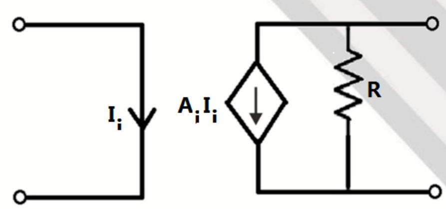
38. In the figure shown, the value of the current I (in Amperes) is ________. **[2014-03]**



39. For the Y-network shown in the figure, the value of R1 (in Ω) in the equivalent Δ-network is ____. **[2014-03]**

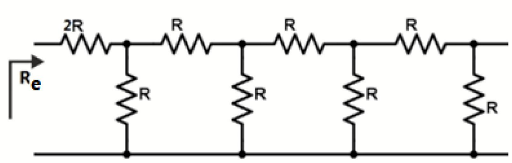


40. The circuit shown in the figure represents a **[2014-04]**

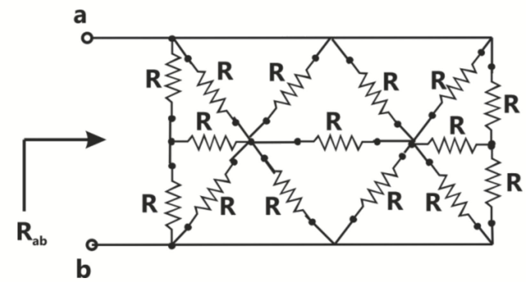


(a) Voltage controlled voltage source
(b) Voltage controlled current source
(c) Current controlled current source
(d) Current controlled voltage source

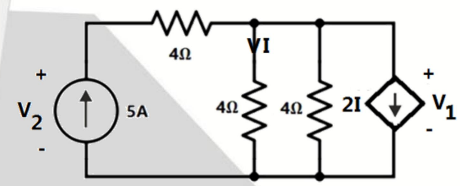
41. The equivalent resistance in the infinite ladder network shown in the figure, is R_e. The value of R_e/R is _______. **[2014-04]**



42. In the network shown in the figure, all resistors are identical with R = 300 Ω. The resistance R_{ab} (in Ω) of the network is _____. **[2015-01]**

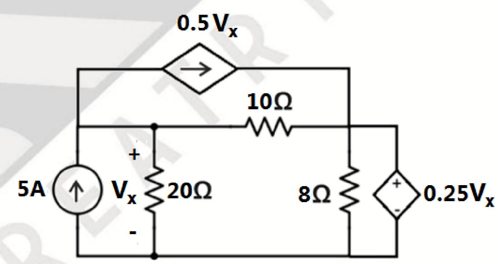


43. In the given circuit, the values of V_1 and V_2 respectively are **[2015-01]**

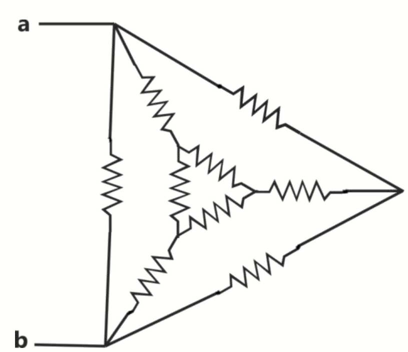


(a) 5 V, 25 V
(b) 10 V, 30 V
(c) 15 V, 35 V
(d) 0 V, 20 V

44. In the circuit shown, the voltage V_X (in Volts) is __________. **[2015-03]**



45. In the given circuit, each resistor has a value equal to 1Ω.

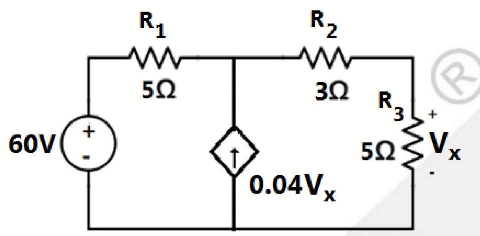


What is the equivalent resistance across the terminals a and b? **[2016-02]**

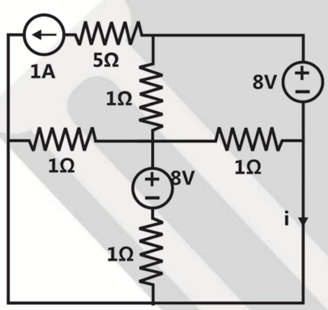
(a) 1/6 Ω (b) 1/3 Ω

(c) 9/20 Ω (d) 8/15 Ω

46. In the circuit shown in the figure, the magnitude of the current (in amperes) through R_2 is ______. **[2016-02]**

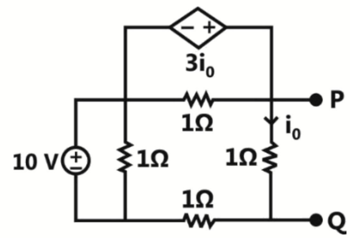


47. In the figure shown, the current i (in ampere) is ___. **[2016-03]**



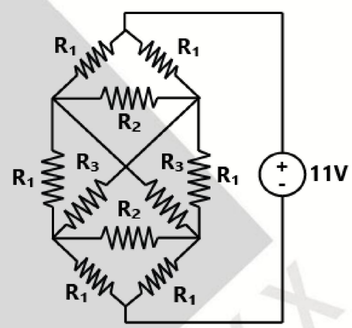
48. A connection is made consisting of resistance A in series with a parallel combination of resistances B and C. Three resistors of value $10\Omega, 5\Omega, 2\Omega$ are provided. Consider all possible permutations of the given resistors into the positions A, B, C, and identify the configurations with maximum possible overall resistance, and also the ones with minimum possible overall resistance. The ratio of maximum to minimum values of the resistances (up to second decimal place) is ____________. **[2017-02]**

49. Consider the circuit shown in the figure.



The Thevenin equivalent resistance $(\text{in}\Omega)$ across P-Q is ____________. **[2017-02]**

50. Consider the network shown below with $R_1 = 1\Omega$, $R_2 = 2\Omega$ and $R_3 = 3\Omega$. The network is connected to a constant voltage source of 11V. **[2018]**



The magnitude of the current (in amperes. accurate to two decimal places) through the source is ______

Please help us identify the typo or conceptual errors in our books so that we can improve the future editions. Scan the QR code to get the form.

Solution

01. Ans: (d)
Solution:
Apply Superposition theorem
Let current in resistor R be I_1
When only source 'V' is active

$\therefore I_1^2 R = 4$

$I_1 = \sqrt{\frac{4}{R}}$

And let current in resistor R be I_2
When only source I is active

$\therefore I_2^2 R = 9$

$I_2 = \sqrt{\frac{9}{R}}$

By using superposition theorem

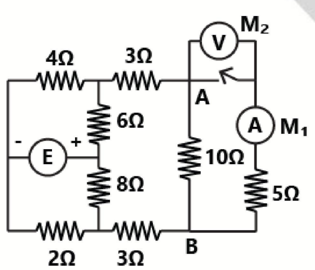
$I = I_1 + I_2$

$I = \sqrt{\frac{4}{R}} + \sqrt{\frac{9}{R}}$

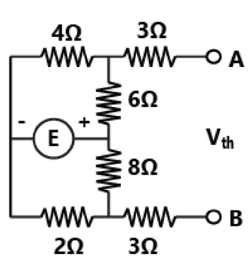
Total power dissipated $P = I^2 R$

$P = \left(\sqrt{4} + \sqrt{9}\right)^2 = 25W$

02. Ans: ---
Solution:
Find the Thevenin's Equivalent across AB



For Thevenin's Voltage

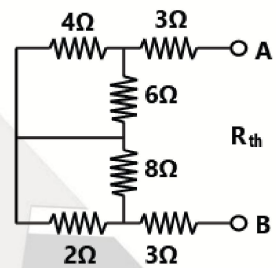


$V_{th} = -E \times \frac{6}{6+4} + E \times \frac{8}{8+2}$

[∵ Correct in this A and B terminal is zero]

$V_{th} = E\left[-\frac{3}{5} + \frac{4}{5}\right] = \frac{E}{5}V$

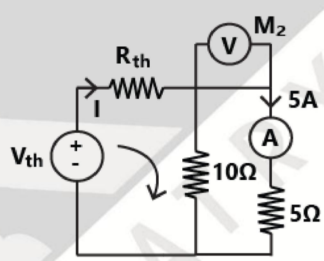
For Thevenin's Resistance



$R_{th} = (4 \,||\, 6) + (8 \,||\, 2) + 3 + 3$

$R_{th} = 2.4 + 1.6 + 6 = 10\ \Omega$

When Switch S_1 is closed
Ammeter reads 5A
Voltmeter reads 0V



Current in 10Ω resistor

$10 \times I = 5 \times 5$

$I = 2.5A$

$I = 5 + 2.5 = 7.5A$

Apply KVL in input loop

$Y_{th} - IR_{th} - 10 \times 2.5 = 0$

$\frac{E}{5} - 7.5 \times 10 - 25 = 0$

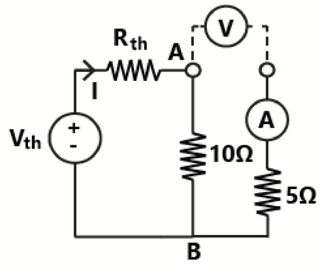
$E = 5 \times [75 + 25]$

$E = 500\ V$

$\therefore V_{th} = \frac{E}{5} = 100V$

When Switch S_1 is opened

No current will flow in Ammeter & the reading of Ammeter will be zero



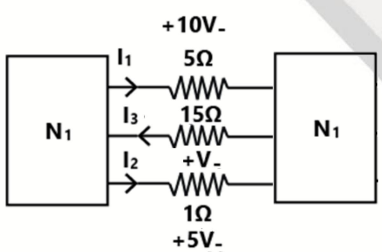
$$I = \frac{V_{th}}{R_{th}+10} = \frac{100}{10+10} = 5A$$

$$V_A = 10\times 5 = 50V$$

Reading of the voltmeter $= 50V$

03. Ans: (d)
Solution:
Voltage dividing and current dividing rule does not depend upon the actual value of impedance,
Instead they depend upon ratio of impedances.
Hence, if the entire resistors are doubled, then voltage across each resistance is not changed.

04. Ans: (a)
Solution:
Let the current in 5 Ω , 1 Ω and 15 Ω be I_1, I_2 and I_3 respectively



Apply Kirchhoff's current law
Net current entering a network = net current leaving the network

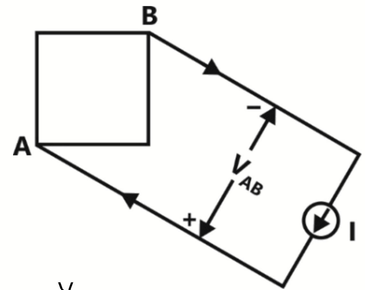
$$I_3 = I_1 + I_2$$

$$\therefore -\frac{V}{15} = \frac{10}{5} + \frac{5}{1}$$

$$-V = 7\times 15$$

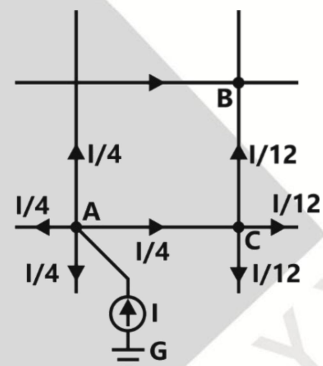
$$V = -105 \text{ V}$$

05. Ans: ---
Solution:



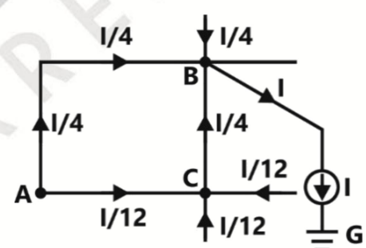
$$R_{AB} = \frac{V_{AB}}{I}$$

Assume G is the ground terminal.
Connect current source of I A between A and G. I enters terminal A, goes through the infinite grid and comes back to through ground, G.



$$V_{1AB} = V_{AC} + V_{CB} = \left(\frac{I}{4}\times 1\right) + \left(\frac{I}{12}\times 1\right) = \frac{I}{3}$$

Connect a current source, I between B & G. I enters the infinite gird through G and leaves B.



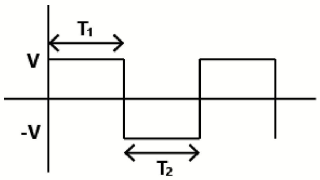
$$V_{2AB} = V_{AC} + V_{CB}$$

$$V_{2AB} = \left(\frac{I}{12}\times 1\right) + \left(\frac{I}{4}\times 1\right) = \frac{I}{3}$$

$$V_{AB} = V_{1AB} + V_{2AB} = \frac{I}{3} + \frac{I}{3} = \frac{2I}{3}$$

$$R_{AB} = \frac{V_{AB}}{I} = \frac{2}{3}\Omega$$

06. Ans: (a)
Solution:

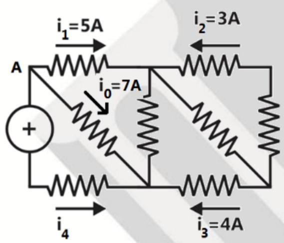


$$RMS = \sqrt{\frac{1}{T}\int f^2(t)dt}$$

$$\therefore \text{R.M.S of V} = \sqrt{\frac{1}{T}\left(\int_0^{T_1} V^2 dt + \int_{T_1}^{T}(-V)^2 dt\right)}$$

$$= \sqrt{\frac{1}{T}\left(V^2T_1 + V^2(T - T_1)\right)} = V$$

07. Ans: (b)
Solution:



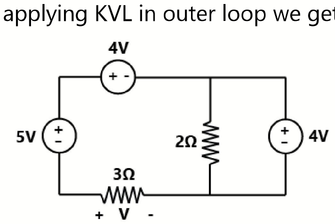
Apply Kirchhoff's current law at node A
Net current entering = Net leaving current

$\therefore I_1 + I_0 + I_4 = 0$

$5 + 7 + I_4 = 0$

$I_4 = -12A$

08. Ans: (a)
Solution:
By applying KVL in outer loop we get



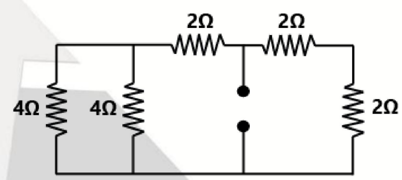
$5 - 4 - 4 + V = 0$

$V = 3$

09. Ans: (d)
Solution:
Since the voltage across the current source is not given, so it is not possible to find out the value of the value of 'V'.

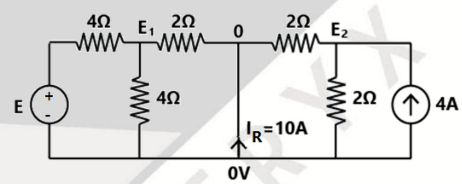
10. Ans: (a)
Solution:
Since voltage source and voltage 'V' connected in parallel, Hence value of voltage V=10V.
For parallel connection voltage will be same and for series connection current will be same.

11.
(a) Ans: 2
Solution:
To absorb minimum power, we need to find Thevenin's resistance
To find Thevenin's resistance across R short circuit voltage source and open circuit current source.



$\therefore R_{th} = 2\Omega$

(b) Ans: 4
To find E,
We will use condition $i_R = 10A$ when R=0



Applying nodal analysis at node E_1

$$\frac{E_1 - E}{4} + \frac{E_1}{4} + \frac{E_1}{2} = 0$$

$E = 4E_1 \cdots\cdots\cdots\cdots(1)$

At node E_2

$$\frac{E_2 - 0}{2} + \frac{E_2}{2} = 4$$

$E_2 = 4V$

Now $I_R = \dfrac{0 - E_1}{2} + \dfrac{0 - E_2}{2}$

$$10 = -\frac{E_1}{2} - \frac{4}{2}$$

$$12 = -\frac{E_1}{2}$$

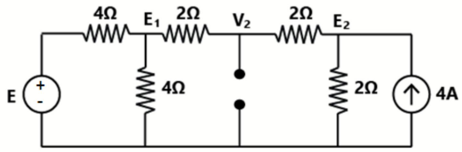
$E_1 = -24V$

From equation (1)

$E = 4E_1 = 4 \times -24 = -96$

(c) Ans: -20

When $R = \infty$



Apply KCL at node E_1

$$\frac{E_1+96}{4}+\frac{E_1}{4}+\frac{E_1-V_2}{2}=0$$

$V_2 = 2E_1 + 48$ ....(i)

Apply KCL at node E_2

$$\frac{E_2-V_2}{2}+\frac{E_2}{2}=4$$

$2E_2 = 8 + V_2$ ....(ii)

And $V_2 = \dfrac{E_1+E_2}{2}$ ....(iii)

From eq. (i), (ii) & (iii)

$E_1 = -34V,\ E_2 = -6V\ \&\ V_2 = -20V$

12. Ans: (b)
Solution:
The Nodal method of circuit analysis is bases on KCL and Ohm's law

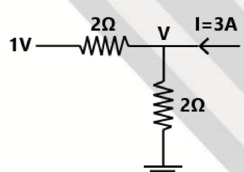
13. Ans: (c)
Solution:
By applying Nodal analysis at Node 'a'

$$\frac{1-V}{2}+3=\frac{V}{2}$$

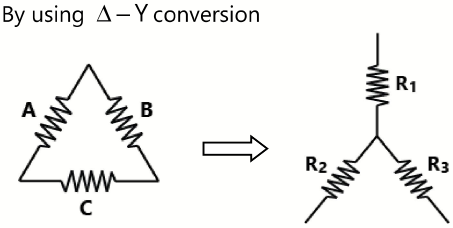
$$1-V+6=V$$

$$2V=7$$

$$V=3.5V$$



14. Ans: (d)
Solution:
By using $\Delta - Y$ conversion

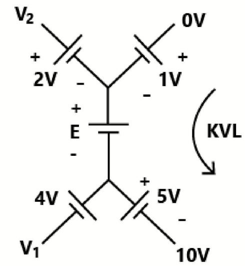


$$R_1 = \frac{A\times B}{A+B+C};\ R_2 = \frac{A\times C}{A+B+C};\ R_3 = \frac{B\times C}{A+B+C}$$

Putting $A = 5\Omega,\ B = 30\Omega\ \&\ C = 15\Omega$

$R_1 = 3\Omega, R_2 = 1.5, R_3 = 9\Omega$

15. Ans: (a)
Solution:



By applying KVL we get

$$0-1-E-5=10$$

$$E=-16V$$

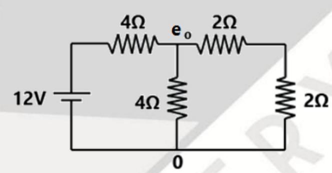
16. Ans: (d)
Solution:
By applying reciprocity theorem

$$\frac{\text{Response}}{\text{Excitation}} = \text{constant}$$

$$\frac{2}{10}=\frac{I}{20}$$

$$I = 4A$$

17. Ans: (c)
Solution:

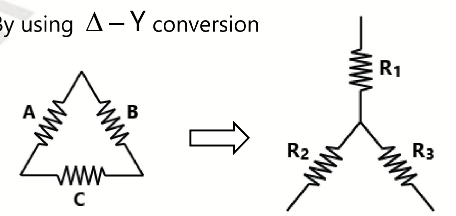


By applying Nodal analysis

$$\frac{12-E_0}{4}=\frac{E_0}{4}+\frac{E_0}{4}$$

$E_0 = 4V$

18. Ans: (a)
Solution:
By using $\Delta - Y$ conversion

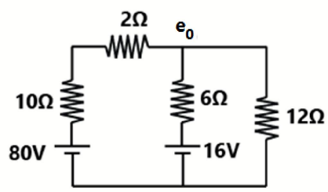


$$R_1 = \frac{A\times B}{A+B+C};\ R_2 = \frac{B\times C}{A+B+C};\ R_3 = \frac{A\times C}{A+B+C}$$

Given, $A = B = C = \sqrt{3}Z$

Then, $R_1 = R_2 = R_3 = \dfrac{Z}{\sqrt{3}}$

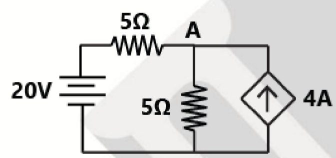
19. Ans: (d)
Solution:
By using source transformation



Now applying Nodal analysis

$$\frac{80-e_0}{12} = \frac{e_0-16}{6} + \frac{e_0}{12}$$
$$80 - e_0 = 2e_0 - 32 + e_0$$
$$112 = 4e_0$$
$$e_0 = 28V$$

20. Ans: (a)
Solution:



Apply KCL at node A

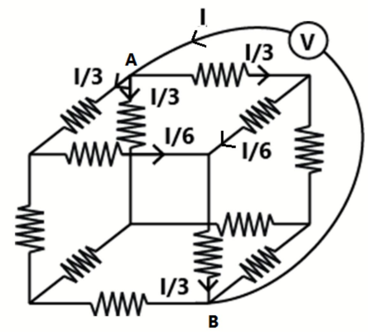
$$\frac{V_A - 20}{5} + \frac{V_A}{5} = 4$$
$$2V_A - 20 = 20$$
$$V_A = 20V$$

Voltage across dependent source = 20
Power delivered by the dependent source
$= 20 \times 4 = 80\ \text{W}$
[$\because$ Voltage across dependent source is positive, so it will deliver the power]

21. Ans: (a)
Solution:
Total number of Nodes = 5
Voltage at one node is already known and one node is considered as reference node, so by using nodal analysis minimum number of equations required to analyse this circuit are 3.

22. Ans: (a)
Solution:
Assuming a voltage source applied across the two diagonally opposite terminals A & B.

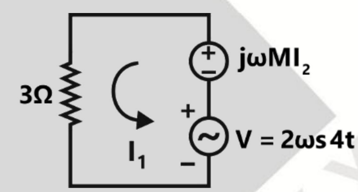
$$R_{AB} = \frac{V}{I}$$

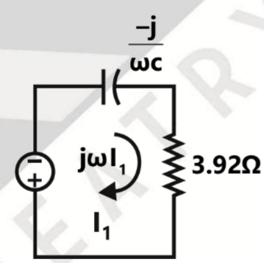


And apply KVL in the loop we get,

$$V = \frac{I}{3} + \frac{I}{6} + \frac{I}{3} = \frac{5I}{6}$$
$$\therefore R_{AB} = \frac{V}{I} = \frac{5}{6}\Omega$$

23. Ans: ---
Solution:
Assume 0 self inductance





$$2\angle 0^0 - j\omega M I_2 - 3I_1 = 0$$

And $-j\omega M I_1 - \left(\frac{-j}{\omega c}\right) I_2 - 3.92 I_2 = 0$

Based on given source, $\omega = 4$

$2\angle 0 - j3I_2 - 3I_1 = 0$ ....(i)

$$3I_1 + j3I_2 = 2\angle 0^0$$

$j3I_1 + \left(3.92 - j\frac{10.24}{4}\right) I_2 = 0$ ....(ii)

Form (i)

$$I_1 = \frac{2\angle 0^0 - j3I_2}{3}$$

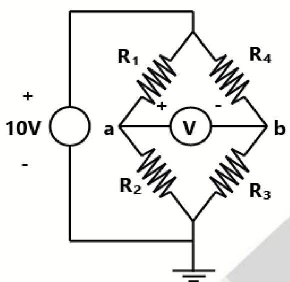
$$j\left(2\angle 0^0 - j3I_2\right) + \left(3.92 - j2.56\right)I_2 = 0$$

$$2\angle 90^0 = \left(-6.92 + j2.56\right) I_2$$

$$I_2 = 0.27\angle -69.69 = 0.094 - j0.254$$

No option is correct

24. Ans: (c)
Solution:
Given: $R_1 = R_2 = R_4 = R$
$R_3 = 1.1R$



Since voltmeter is ideal,
No current will flow through it
Potential of point 'a'

$$V_a = \frac{10 \times R_2}{R_1 + R_2} = 5V$$

Potential of point 'b'

$$V_b = \frac{10 \times R_3}{R_3 + R_4} = \frac{10 \times 1.1}{2.1} = 5.238V$$

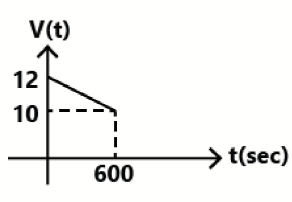
$$\therefore V_a - V_b = 5 - 5.238 = -0.238V$$

25. Ans: (c)
Solution:

$$\text{Power} = V \times i = V(t) \times 2 = 2V(t) J$$

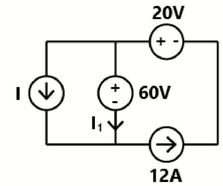
$$\text{Energy} = \int P dt = \int_0^{600} 2V(t) dt$$

$$\text{Energy} = 2 \times \text{Area under the } V - t \text{ curve}$$



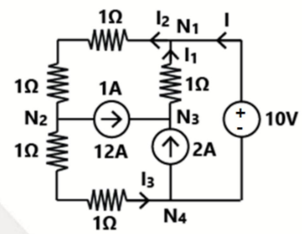
$$\text{Energy} = 2 \times \left[\frac{1}{2} \times 600 \times 2 + 600 \times 10\right] = 13.2 \text{ KJ}$$

26. Ans: (a)
Solution:
Since 60V source is absorbing power
$\therefore$ The direction of current would be as shown in figure



$I + I_1 = 12$
Hence $I < 12$
$\therefore I = 10A$

27. Ans: (a)
Solution:



Applying Nodal analysis a Node N_3

$1 + 2 = I_1$

$I_1 = 3A$

Applying Nodal analysis Node N_1

$I + 3 = I_2$

Applying KVL in outer loop we get,

$10 = I_2 \times 2 + I_3 \times 2$

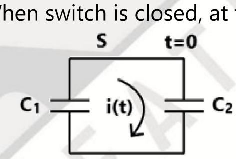
$10 = (I + 3) \times 2 + (I + 2) \times 2$

$10 = 2I + 6 + 2I + 4$

$I = 0$

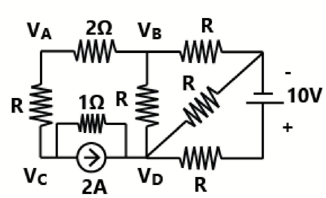
Hence power supplied by the voltage source is 0 W

28. Ans: (d)
Solution:
When switch is closed, at t=0



No resistance is present in the circuit, so after closing the switch voltage across C_2 will become same as C_1 instantly. This is possible only when the current in the circuit will be impulse.

29. Ans: (a)
Solution:



Apply Kirchhoff's current law,
Current entering Network = Current leaving Network

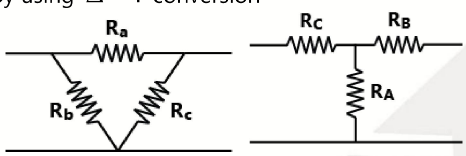
Current enter at V_A terminal = current leaving at V_C terminal

$$\frac{V_A - V_B}{2} = \frac{V_D - V_C}{1} - 2$$

$$\frac{6}{2} + 2 = V_D - V_C$$

$$V_C - V_D = -5V$$

30. Ans: (b)
Solution:
By using $\Delta - Y$ conversion



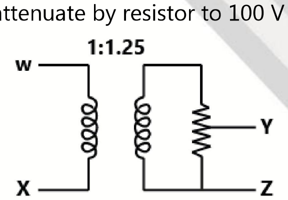
$$R_A = \frac{R_b \times R_C}{R_a + R_b + R_c}$$

If R_b, R_c, R_a are scaled by factor κ

Then,

R_A, R_B, R_C are also scaled by the factor κ

31. Ans: (b)
Solution:
When voltage across WX is 100V voltage of secondary winding would be 125 V which will be attenuate by resistor to 100 V i.e, $V_{YZ1} = 100V$



But when, $V_{YZ2} = 100V$

Since primary circuit is open circuited hence No current will flow neither in primary nor in secondary

Hence voltage across secondary = 100 V

And $V_{WX2} = \frac{100}{1.25} = 80V$

$$\therefore \frac{V_{YZ1}}{V_{WX1}} = \frac{100}{100} \text{ and } \frac{V_{WX2}}{V_{YZ2}} = \frac{80}{100}$$

32. Ans: (c)
Solution:
Given: $C_1 = 10\mu F,\quad C_2 = 5\mu F,\quad C_3 = 2\mu F$

$V_{BC\ 1} = 10V, V_{BC\ 2} = 5V, V_{BC\ 3} = 2V$

Maximum voltage across $C_2 + C_3$ can be 7V, hence voltage should be less than 7V

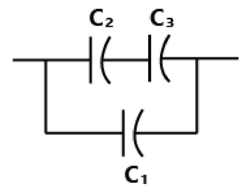
Maximum voltage across smallest capacitor $C_3 = 2V$

So by voltage division

$$\frac{V \times C_2}{C_2 + C_3} = 2$$

$$\frac{V \times 5}{7} = 2$$

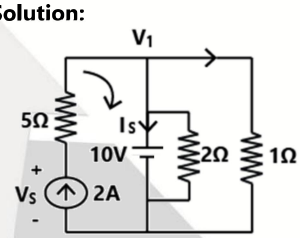
$$V = \frac{14}{5} = 2.8V$$



Net capacitance, $= \frac{C_2 \times C_3}{C_2 + C_3} + C_1 = \frac{10}{7} + 10 = \frac{80}{7}\mu F$

$$Q = \frac{80}{7} \times 2.8 = 32\ \mu C$$

33. Ans: (d)
Solution:



By applying KVL in this loop we get

$$10 + 5 \times 2 - V_S = 0$$

$$V_S = 20V$$

Now by applying KCL at Node V_1

$$2 = I_S + \frac{V_1}{2} + \frac{V_1}{1}$$

Since $V_1 = 10V$

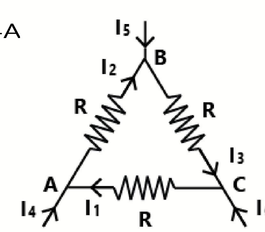
$$I_S = -13A$$

34. Ans: (c)
Solution:
Voltage across 1Ω resistor $= 10V$

$$I = \frac{10}{1} = 10A$$

35. Ans: (a)
Solution:
Given $R = 1\Omega$

$i_1 = 2A,\ i_4 = -1A,\ i_5 = -4A$



Applying KCL at A

$$I_4 + I_1 = I_2$$

$$-1 + 2 = I_2$$

$$I_2 = 1A$$

Applying KCL at B

$$I_2 + I_s = I_3$$

$$1 + (-4) = I_3$$

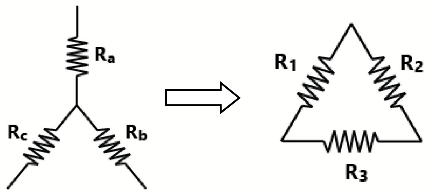
$$I_3 = -3A$$

Applying KCL at C

$$I_3 + I_6 = I_1$$

$$-3 + I_6 = 2$$
$$I_6 = 5A$$

36. Ans: 29.09
Solution:
By using star – delta conversion



$$R_1 = R_a + R_c + \frac{R_a R_c}{R_b}$$

$$R_2 = R_a + R_c + \frac{R_a R_b}{R_c}$$

$$R_3 = R_b + R_c + \frac{R_b R_c}{R_a}$$

Given,
$$R_a = R_b = 10\ \Omega\ \&\ R_c = 11\ \Omega$$

$$R_1 = 10 + 11 + \frac{110}{10} = 32\ \Omega$$

$$R_2 = 10 + 10 + \frac{100}{11} = 29.09\ \Omega$$

$$R_3 = 10 + 11 + \frac{110}{10} = 32\ \Omega$$

Hence lowest value $= 29.09\ \Omega$

37. Ans: 0.39 to 0.41
Solution:

$$\text{RMS value} = \sqrt{\frac{1}{T}\int_0^T X^2(t)\,dt}$$

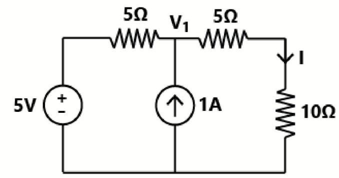
$$X(t) = \begin{cases} \frac{2}{T}t & 0 \le t \le \frac{T}{2} \\ 0 & \frac{T}{2} \le t \le T \end{cases}$$

$$\therefore \text{RMS value} = \sqrt{\frac{1}{T}\int_0^{\frac{T}{2}}\left(\frac{2}{T}t\right)^2 \times dt + \frac{1}{T}\int_0^{\frac{T}{2}} 0dt}$$

$$\text{value} = \sqrt{\frac{4}{T^3}\left[\frac{t^3}{3}\right]_0^{\frac{T}{2}}}$$

$$= \sqrt{\frac{4}{T^3} \times \frac{T^3}{3 \times 8}} = \sqrt{\frac{1}{6}} = 0.4082$$

38. Ans: 0.5
Solution:
By applying Nodal analysis we get

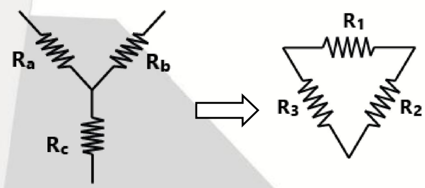


$$\frac{5 - V_1}{5} + 1 = \frac{V_1}{15}$$
$$15 - 3V_1 + 15 = V_1$$
$$30 = 4V_1$$
$$V_1 = 7.5V$$

$$I = \frac{V_1}{15} = \frac{1}{2}A$$

The value of current I (in amperes) is 0.5

39. Ans: 10
Solution:
By using star-delta conversion



$$R_1 = R_a + R_b + \frac{R_a R_b}{R_c}$$

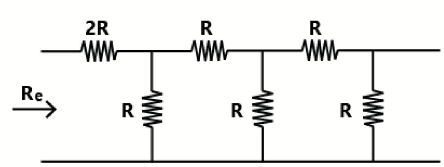
$$R_a = 5\ \Omega, R_b = 3\ \Omega, R_c = 7.5\ \Omega$$

$$R_1 = 5 + 3 + \frac{5 \times 3}{7.5} = 10\Omega$$

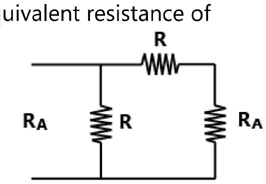
40. Ans: (c)
Solution:

Since the dependent source has a factor of input current I, in it hence it is a current controlled and output of the circuit is voltage so it is a current controlled voltage source

41. Ans: 2.62
Solution:



To find R_e we need to find equivalent resistance of remaining network



$$R_A = \frac{R \times (R + R_A)}{2R + R_A}$$

$$2RR_A + R_A{}^2 = R^2 + RR_A$$

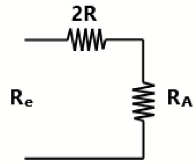
$R_A^{\ 2} + RR_A - R^2 = 0$

$R_A = -\dfrac{-R \pm \sqrt{R^2 + 4R^2}}{2} = \dfrac{-R + \sqrt{5}R}{2}$

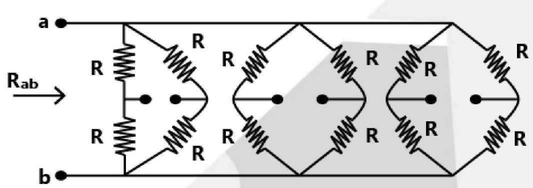
$R_A = 0.62\ R$

$R_e = 2 + 0.62\ R$

$\dfrac{R_e}{R} = 2.62$



42. Ans: 100
Solution:
By using symmetry concept or Wheatstone bridge concept, the equipment circuit will be



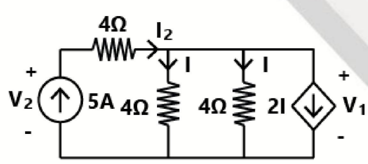
Hence adding resistance in parallel we get

$R_{ab} = \dfrac{R}{3}$

Since, $R = 300\Omega$

$R_{ab} = 100\Omega$

43. Ans: (a)
Solution:



Current through 4Ω resistor is I,

$I_2 = 4I$ by KCL

Now $I_2 = 5A$

Hence, $4I = 5A$

$I = \dfrac{5}{4}A$

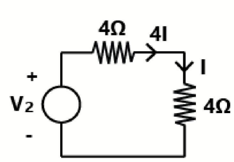
Now, $V_1 = 4I = 4 \times \dfrac{5}{4} = 5V$

Now applying KVL in loop

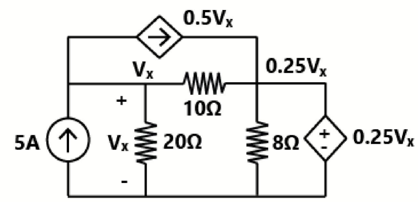
$16I + 4I - V_2 = 0$

$V_2 = 20I$

$V_2 = 25V$



44. Ans: 9
Solution:



By applying KCL at Node of potential V_x

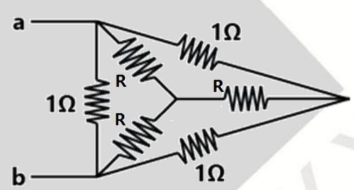
$5 = 0.5V_x + \dfrac{V_x}{20} + \dfrac{0.75V_x}{10}$

$100 = 10V_x + V_x + 1.5V_x$

$100 = 12.5V_x$

$V_x = 8V$

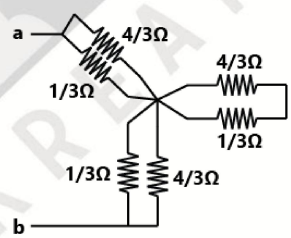
45. Ans: (d)
Solution:
By converting inner delta into star by using delta – star conversion

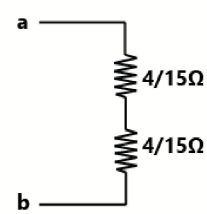


We get

$R = 1 + \dfrac{1 \times 1}{1+1+1} = \dfrac{4}{3}\Omega$

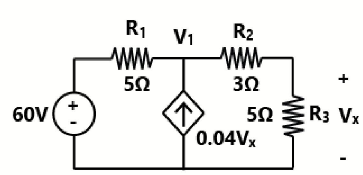
Now converting outer delta into star we get





So equivalent resistance between a and b is $\dfrac{8}{15}\Omega$

46. Ans: 5
Solution:



Digital Electronics 03

Chapter 1 – Number system

01. 2's complement representation of a 16-bit number (one sign bit and 15 magnitude bits) is FFF7. Its magnitude in decimal representation is **[1993]**

(a) 0 (b) 1
(c) 32,767 (d) 65, 535

02. An equivalent 2's complement representation of the 2's complement number 1101 is **[1998]**

(a) 110100 (b) 001101
(c) 110111 (d) 111101

03. The 2's complement representation of -17 is **[2001]**

(a) 01110 (b) 01111
(c) 11110 (d) 10001

04. 4-bit 2's complement representation of a decimal number is 1000. The number is **[2002]**

(a) +8 (b) 0
(c) -7 (d) -8

05. The range of signed decimal numbers that can be represented by 6-bite 1's complement number is **[2004]**

(a) -31 and +31 (b) -63 and +64
(c) -64 and +63 (d) -32 and +31

06. A digital system is required to amplify a binary-encoded audio signal. The user should be able to control the gain of the amplifier from a minimum to a maximum in 100 increments. The minimum number of bits required to encode, in straight binary is **[2004]**

(a) 8 (b) 6
(c) 5 (d) 7

07. 11001, 1001 and 111001 correspond to the 2's complement representation of which one of the following sets of number? **[2004]**

(a) 25, 9 and 57 respectively
(b) -6, -6 and -6 respectively
(c) -7, -7 and -7 respectively
(d) -25, -9 and -57 respectively

08. Decimal 43 in Hexadecimal and BCD number system is respectively **[2005]**

(a) B2, 0100 0011 (b) 2B, 0100 0011
(c) 2B, 0011 0100 (d) B2, 0100 0100

09. A new Binary Coded Pentary (BCP) number system is proposed in which every digit of a base-5 number is presented by its corresponding 3-bit binary Code. For example, the base-5 number 24 will be represented by its BCP code 010100. In this numbering system, the BCP code 100010011001 corresponds to the following number in base-5 system **[2006]**

(a) 423 (b) 1324
(c) 2201 (d) 4231

10. X = 01110 and Y = 11001 are two 5-bit binary numbers represented in two's complement format. The sum of X and Y represented in two's complement format using 6 bits is **[2007]**

(a) 100111 (b) 001000
(c) 000111 (d) 101001

11. The two numbers represented in signed 2's complement form are
P = 11101101 and Q = 11100110. If Q is subtracted from P, the value obtained in signed 2's complement form is **[2008]**

(a) 100000111 (b) 00000111
(c) 11111001 (d) 111111001

12. The number of bytes required to represent the decimal number 1856357 in packed BCD (Binary Coded Decimal) form is _________ . **[2014-02]**

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Solution

01. Ans: (c)
Solution:
The binary representation of given number is
1111 1111 1111 0111
If we consider the first bit as sign bit and other bits as magnitude bits then the magnitude is
0111 1111 1111 0111
The decimal value of magnitude is, 32767

02. Ans: (d)
Solution:
In 2's complement number, the number can be extended by repeating the MSB of the number
So option (d) is correct
1 1 1 1 0 1

03. Ans: (b)
Solution:
17= 1 0 0 0 1
Taking 2's complement of positive number is equivalent of finding the negative of that number
2's complement of 1 0 0 0 1= 0 1 1 1 1

04. Ans: (d)
Solution:
4 bit decimal number is 1 0 0 0
MSB indicates the sign so the number is negative as MSB is '1'
Take the 2's complement of number then the number become negative number
$\text{MSB} = 1 \rightarrow$ Number is negative
$\text{MSB} = 0 \rightarrow$ Number is positive
So 1 0 0 0= -8

05. Ans: (a)
Solution:
The range of signed decimal numbers with n-bits is,
$-\left(2^{n-1}-1\right)$ to $\left(2^{n-1}-1\right)$
For 6 bit
$-\left(2^{5}-1\right)$ to $\left(2^{5}-1\right)$ = -31 to 31

06. Ans: (d)
Solution:
Number of steps in increment = 100
$2^n = 100$
$2^n \geq 100$
So, n=7

07. Ans: (c)
Solution:
$$\left.\begin{aligned} 11001 &\xrightarrow[\text{complement}]{2\text{'s}} 00111 = 7 \\ 1001 &\xrightarrow[\text{complement}]{2\text{'s}} 0111 = 7 \\ 111001 &\xrightarrow[\text{complement}]{2\text{'s}} 000111 = 7 \end{aligned}\right\}$$
As MSB is 1 so number is negative i.e., -7

08. Ans: (b)
Solution:
$$43 \xrightarrow{\text{BCD}} 0100\ 0011$$
$$(43)_{10} = (2B)_{16}$$

09. Ans: (d)
Solution:
For representing a base-5 number we need to encode each digit in 3-bits. The given number
100 010 011 001
When each digit is converted to decimal value, the result is 4231

10. Ans: (c)
Solution:
$X = 01110$
$Y = 11001$
Take 2's complement of y
$$11001 \xrightarrow[\text{complement}]{2\text{'s}} 00111$$
$$\begin{array}{rr} X= & 0\ 1\ 1\ 1\ 0 \\ +\ Y= & \underline{1\ 1\ 0\ 0\ 1} \\ & \underline{1\ 0\ 0\ 1\ 1\ 1} \end{array}$$
Since, there is a carry generated the carry must be discarded and the result is positive and hence in 6 bits the sign bit can be taken to be 0.
$X + Y = 000111$

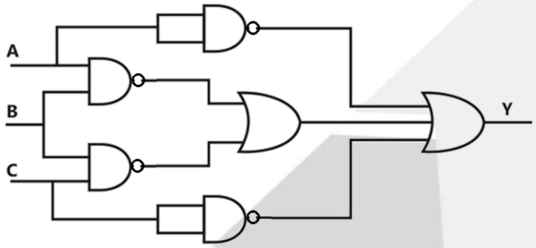
11. Ans: (b)
Solution:
$P = 111011101$
$Q = 11100110$
$P - Q = ?$
Take 2's complement of Q to find-Q
$$11100110 \xrightarrow[\text{complement}]{2\text{'s}} 00011010$$
$$\begin{array}{rcccccccc} P = 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 \\ Q = 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ \hline 1\ \ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ \hline \end{array}$$
$P - Q = 00000111$

12. Ans: (4)
Solution:
In the given number there are 7 digits and each digit in BCD can be represented by 4 bits so overall 28 bits are required and hence in bytes we need a minimum of 4 bytes.

Chapter 2 – Boolean algebra

01. The four variable function f is given in terms of min-terms as: $f(A,B,C,D)=\sum m(2,3,8,10,11,12,14,15)$. Using the k-map minimize the function in the sum of products form also given the realization using only two-input NAND gates. **[1991]**

02. For the logic circuit shown in figure, the output Y is equal to **[1993]**



(a) $\overline{ABC}$ (b) $\bar{A}+\bar{B}+\bar{C}$
(c) $\overline{AB}+\overline{BC}+\bar{A}+\bar{C}$ (d) None

03. The truth table for the output Y in terms of three inputs A, B and C are given in table. Draw a logic circuit realization using only NOR gates. **[1993]**

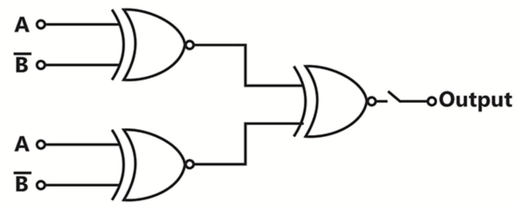
A	0	1	0	1	0	1	0	1
B	0	0	1	1	0	0	1	1
C	0	0	0	0	1	1	1	1
Y	1	1	1	0	1	0	0	0

04. Boolean expression for the output of XNOR (Equivalent) logic gate with inputs A and B is: **[1993]**

(a) $A\bar{B}+\bar{A}B$ (b) $\overline{AB}+AB$
(c) $(\bar{A}+B)(A+\bar{B})$ (d) $(\bar{A}+\bar{B})(A+B)$

05. The output of a logic gate is '1' when all its inputs are at logic '0'. Then gate is either **[1994]**
(a) A NAND or an EX-OR gate
(b) A NOR or an EX-NOR gate
(c) AN OR or an EX-NOR gate
(d) AN AND or an EX-OR gate

06. The output of the circuit in the figure is equal to **[1995]**



(a) 0 (b) 1
(c) $\bar{A}B+A\bar{B}$ (d) $\overline{(A*B)}*\overline{(A*B)}$

07. The minimum number of NAND gates required to implement the Boolean function $A+A\bar{B}+A\bar{B}C$, is equal to **[1995]**
(a) Zero (b) 1
(c) 4 (d) 7

08. The output of the logic gate in the figure is **[1997]**
(a) 0
(b) 1
(c) A
(d) $\bar{A}$

09. The Boolean function $A+BC$ is a reduced form of **[1997]**
(a) $AB+BC$ (b) $(A+B).(A+C)$
(c) $\bar{A}B+A\bar{B}C$ (d) $(A+C).B$

10. The minimum number of 2-input NAND gates required to implements the Boolean function $Z=A\bar{B}C$, assuming that A, B and C are available, is **[1998]**
(a) Two (b) Three
(c) Five (d) Six

11. Two 2's complement number having sign bits x and y are added and the sign bit of the result is z. Then, the occurrence of overflow is indicated by the Boolean function **[1998]**
(a) xyz (b) $\bar{x}\bar{y}\bar{z}$
(c) $\bar{x}\bar{y}z+xy\bar{z}$ (d) $xy+yz+zx$

12. For the identify $AB+\bar{A}C+BC=AB+\bar{A}C$, the dual form is **[1998]**

(a) $(A + B)(\bar{A} + C)(B + C) = (A + B)(\bar{A} + C)$

(b) $(\bar{A} + \bar{B})(A + \bar{C})(\bar{B} + \bar{C}) = (\bar{A} + \bar{B})(A + \bar{C})$

(c) $(A + B)(\bar{A} + C)(B + C) = (\bar{A} + \bar{B})(A + \bar{C})$

(d) $\bar{A}\,\bar{B} + A\,\bar{C} + \bar{B}\,\bar{C} = \bar{A}\,\bar{B} + A\,\bar{C}$

13. The K-map for a Boolean function is shown in Fig. 2.13. The number of essential prime implicants for this function is **[1998]**

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

(a) 4 (b) 5
(c) 6 (d) 8

14. The logical expression $y = A + \bar{A}B$ is equivalent to **[1999]**

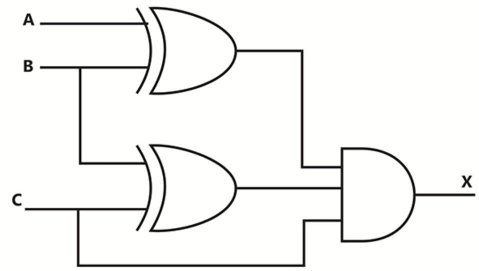
(a) $y = AB$ (b) $y = \bar{A}B$
(c) $y = \bar{A} + B$ (d) $y = A + B$

15. The minimized form of the logical expression $(\bar{A}\,\bar{B}\,\bar{C} + \bar{A}B\bar{C} + \bar{A}BC + AB\bar{C})$ is **[1999]**

(a) $\bar{A}\,\bar{C} + B\bar{C} + \bar{A}B$ (b) $A\bar{C} + \bar{B}C + \bar{A}B$
(c) $\bar{A}C + \bar{B}C + \bar{A}B$ (d) $A\bar{C} + \bar{B}C + A\bar{B}$

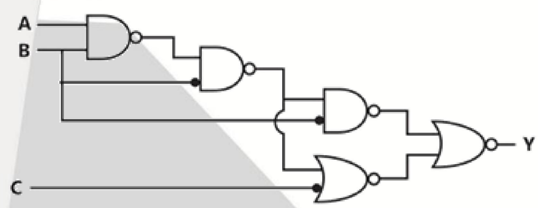
16. In a certain application four inputs A, B, C, D (both true and complement forms available) are fed to logic circuit, producing an output F, which operates a relay. The relay turns on when $F(ABCD) = 1$ for the following states of the input $(ABCD)$: '0000', '0010', '0101', '0110', '1101' and '1110'. States '1000' and '1001' do not occur, and for the remaining states, the relay is off. Minimize F with the help of a Karnaugh map and realize it using a minimum number of 3 – input NAND gates.

17. For the logic circuit shown in Figure, the required input condition (A, B, C) to make the output (X)=1 is **[2000]**



(a) 1, 0, 1 (b) 0, 0, 1
(c) 1, 1, 1 (d) 0, 1, 1

18. For the logic circuit shown in figure, the simplified Boolean expression for the output Y is **[2000]**



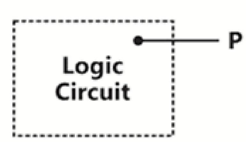
(a) A+B+C (b) A
(c) B (d) 0

19. The operating conditions (ON = 1, OFF = 0) of three pumps (x, y, z) are to be monitored. $X = 1$ implies that pump X is on. It is required that the indicator (LED) on the panel should glow when a majority of the pumps fail.

(a) Enter the logical values in the K-map in the format shown in figure. Derive the minimal Boolean sum of products expression whose output is zero when a majority of the pumps fail.

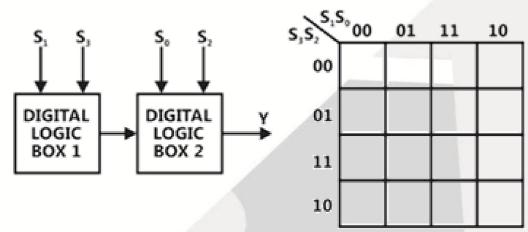
(b) The above expression is implemented using logic gates, and point P is the output of this circuit, as shown in figure. P is at 0 V when a majority of the pumps fails and is at 5 V otherwise. Design a circuit to drive the LED using this output. The current through the LED should be 10mA and the voltage drop across it is 1V. Assume that P can source or sink 10mA and a 5V supply is available. **[2000]**

	$\bar{Z}$	Z
$\bar{X}\,\bar{Y}$		
$\bar{X}\,Y$		
$X\,Y$		
$X\,\bar{Y}$		

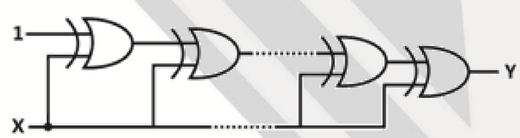


20. For the digital block shown in Figure , the output $Y = f(S_3, S_2, S_1, S_0)$ where S_3 is MSB and S_0 is LSB. Y is given in terms of minterms as $Y = \sum m(1,5,6,7,11,12,13,15)$ and its complement is $Y = \sum m(0,2,3,4,8,9,10,14)$ **[2001]**

(a) Enter the logical values in the given karnaugh map [Figure] for the output Y.
(b) Write down the expression for Y in sum-of products from using minimum number of terms
(c) Draw the circuit for the digital logic boxes using four 2-input NAND gates only for each of the boxes.

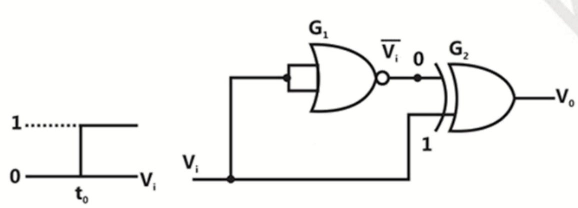


21. If the input to the digital circuit (Figure) consisting of a cascade of 20 XOR-gates in X, then the output Y is equal to **[2002]**

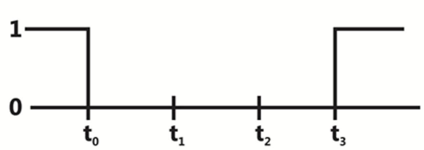


(a) 0 (b) 1
(c) $\overline{X}$ (d) X

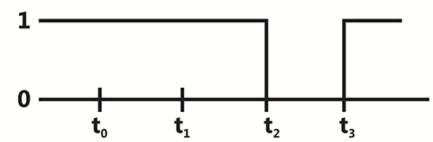
22. The gates G_1 and G_2 in figure have propagation delays of 10nsec 20nsec respectively. If the input V_i makes an abrupt change from logic 0 to 1 at time $t = t_0$ then the output waveform V_0 is **[2002]**



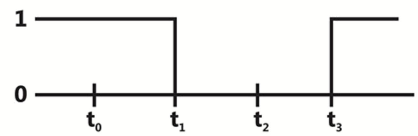
(a)



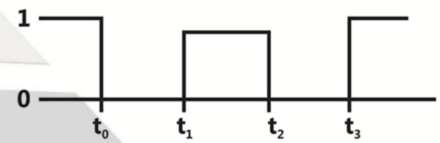
(b)



(c)



(d)



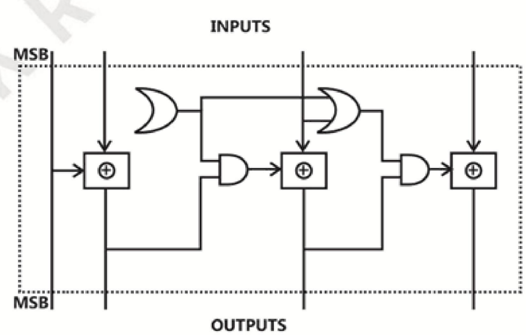
23. The number of distinct Boolean expression of 4 variables is **[2003]**
(a) 16 (b) 256
(c) 1024 (d) 65536

24. If the functions W, X, Y and Z are as follows **[2003]**

$$W = R + \overline{P}Q + \overline{R}S$$
$$X = PQ\overline{R}\ \overline{S} + \overline{P}\ \overline{Q}\ \overline{R}\ \overline{S} + P\ \overline{Q}\ \overline{R}\ \overline{S}$$
$$Y = RS + \overline{PR + P\overline{Q} + \overline{P}.\overline{Q}}$$
$$Z = R + S + \overline{PQ + \overline{P}.\overline{Q}.\overline{R} + P\overline{Q}.\overline{S}}$$

Then
(a) W = Z, $X = \overline{\overline{Z}}$ (b) W = Z, X = Y
(c) W = Y (d) $W = Y = \overline{\overline{Z}}$

25. The circuit shown in figure converts **[2003]**

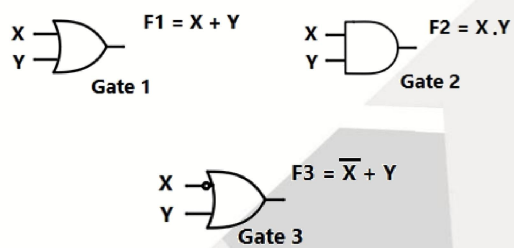


(a) BCD to binary code
(b) Binary to excess - 3 code
(c) Excess – 3 to Gray code
(d) Gray to Binary code

(c) $\left[\begin{array}{r}(\bar X + \bar Y + Z)\cdot(\bar X + Y + \bar Z)\cdot(X + \bar Y + Z)\\ (X + Y + \bar Z)\cdot(X + Y + Z)\end{array}\right]$

(d) $\left[\begin{array}{l}(X + Y + \bar Z)\cdot(\bar X + Y + Z)\cdot\\ (\bar X + Y + \bar Z)\cdot(\bar X + \bar Y + Z)\cdot(\bar X + \bar Y + \bar Z)\end{array}\right]$

53. A universal logic gate can implement any Boolean function by connecting sufficient number of them appropriately. Three gates are shown.



Which one of the following statements is TRUE? **[2015-03]**

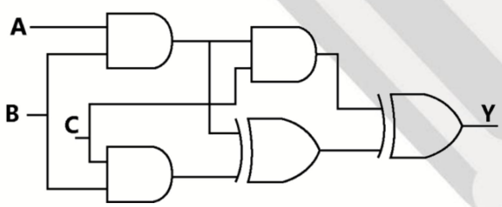
(a) Gate 1 is a universal gate.

(b) Gate 2 is a universal gate.

(c) Gate 3 is a universal gate.

(d) None of the gates shown is a universal gate.

54. The output of the combinational circuit given below is **[2016-01]**



(a) A+B+C
(b) A(B+C)
(c) B(C+A)
(d) C(A+B)

55. The minimum number of 2-input NAND gates required to implement a 2-input XOR gate is **[2016-03]**

(a) 4
(b) 5
(c) 6
(d) 7

56. Following is the K-map of a Boolean function of five variables P, Q, R, S and X. The minimum sum-of-product (SOP) expression for the function is **[2016-03]**

X=0

RS \ PQ	00	01	11	10
00	0	0	0	0
01	1	0	0	1
11	1	0	0	1
10	0	0	0	0

X=1

RS \ PQ	00	01	11	10
00	0	1	1	0
01	0	0	0	0
11	0	0	0	0
10	0	1	1	0

(a) $\bar P \bar Q S \bar X + P \bar Q S \bar X + Q \bar R \bar S X + Q R \bar S X$

(b) $\bar Q S \bar X + Q \bar S X$

(c) $\bar Q S X + Q \bar S \bar X$

(d) $\bar Q S + Q \bar S$

57. Which one of the following gives the simplified sum of products expression for the Boolean function $F = m_0 + m_2 + m_3 + m_5$, where m_0, m_2, m_3 and m_5 are minterms corresponding to the inputs A, B and C with A as the MSB and C as the LSB? **[2017-01]**

(a) $\bar A B + \bar A \bar B \bar C + A \bar B C$

(b) $\bar A \bar C + \bar A B + A \bar B C$

(c) $\bar A \bar C + A \bar B + A \bar B C$

(d) $\bar A BC + \bar A \bar C + A \bar B C$

58. A function $F(A,B,C)$ defined by three Boolean variables A, B and C when expressed as sum of products is given by **[2018]**

$F = \bar A.\bar B.\bar C + \bar A.B.\bar C + A.\bar B.\bar C$

Where $\bar A.\bar B$ and $\bar C$ are the complements of the respective variables. The product of sums (PUS) form of the function F is

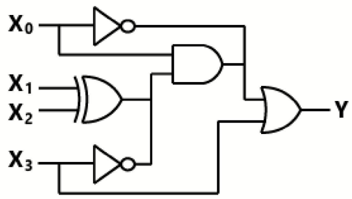
(a) $F = (A + B + C).(A + \bar B + C).(\bar A + B + C)$

(b) $F = (\bar A + \bar B + \bar C).(\bar A + B + \bar C).(A + \bar B + \bar C)$

(c) $F = \left[\begin{array}{l}(A + B + \bar C).(A + \bar B + \bar C).\\ (\bar A + B + \bar C).(\bar A + \bar B + C).(\bar A + \bar B + \bar C)\end{array}\right]$

(d) $F = \left[\begin{array}{l}(\bar A + \bar B + C).(\bar A + B + C).\\ (A + \bar B + C).(A + B + \bar C).(A + B + C)\end{array}\right]$

59. The logic gates shown in the digital circuit below use strong pull-down NMOS transistors for LOW logic level at the outputs. When the pull-downs are off, high-value resistors set the output logic levels to HIGH (i.e. the pull-ups are weak). Note that some nodes are intentionally shorted to implement -wired logic". Such shorted nodes will be HIGH only if the outputs of all the gates whose outputs are shorted are HIGH. **[2018]**



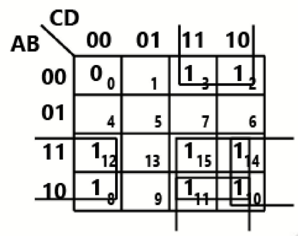
The number of distinct values of $X_3X_2X_1X_0$ (out of the 16 possible values) that give Y =1 is ______

Solution

01. Ans: ---
Solution:
The given function is,

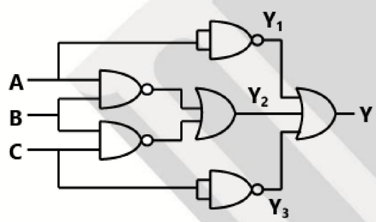
$$f(A,B,C,D) = \sum m(2,3,8,10,11,12,14,15)$$

The K-map for the above function is,



$$f = A\bar{D} + \bar{B}C + AC$$

02. Ans: (b)
Solution:



$$Y_1 = \bar{A}$$

$$Y_2 = \overline{AB} + \overline{BC}$$

$$Y_3 = \bar{C}$$

$$Y = Y_1 + Y_2 + Y_3$$

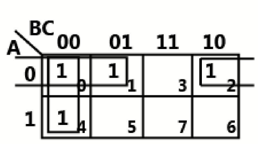
$$Y = \bar{A} + \overline{AB} + \overline{BC} + \bar{C} = \bar{A} + \bar{A} + \bar{B} + \bar{B} + \bar{C} + \bar{C}$$

$$Y = \bar{A} + \bar{B} + \bar{C}$$

03. Ans: ---
Solution:

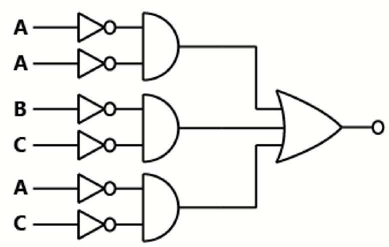
$$f(A,B,C) = \sum m(0,1,2,4)$$

Drawing K-map for above function

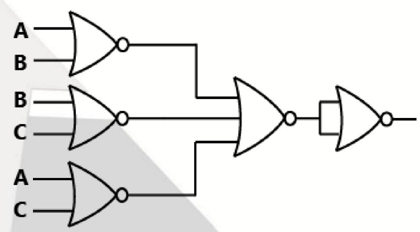


$$f(A,B,C) = \bar{A}\bar{B} + \bar{B}\bar{C} + \bar{A}\bar{C}$$

The realization using A.O.I logic



The realization using NOR gate is



04. Ans: (c)
Solution:
XNOR Truth Table:

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

$$Y = \bar{A}\bar{B} + AB$$

$$Y = (\bar{A} + B)(A + \bar{B})$$

05. Ans: (b)
Solution:
NAND Truth Table

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

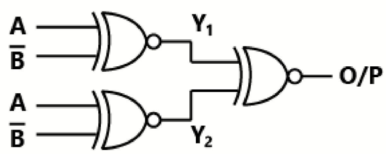
NOR Truth Table

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

EX-NOR Truth Table

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

06. Ans: (b)
Solution:



XNOR of $A \,\&\, \overline{B}$ and $B \,\&\, \overline{A}$ is equal to XOR of A & B

Hence, output of both XNOR Gate is equal so the final output is 1.

07. Ans: (a)
Solution:

$$Y = A + A\overline{B} + A\overline{B}C$$
$$Y = A\left(1 + \overline{B} + \overline{B}C\right)$$
$$\left(\because 1 + A = 1\right)$$
$$Y = A.1$$
$$Y = A$$

No gate is required

08. Ans: (c)
Solution:

$$A \oplus 0 = A$$

09. Ans: (b)
Solution:

$$Y = \left(A+B\right)\left(A+C\right)$$
$$Y = A + AC + AB + BC$$
$$Y = A.\left(1 + C + B\right) + BC$$
$$Y = A + BC$$

10. Ans: (c)
Solution:

By using one two input NAND we can generate $\overline{AC}$

By using one more NAND Gate we can generate $\overline{BB} = \overline{B}$

Using NAND Gate to invert first output we get, AC

Taking NAND of these we get, $\overline{AC.\overline{B}}$

Using last NAND Gate to invert this function, we get $AC.\overline{B}$

Hence, a total of 5 NAND Gates are required.

11. Ans: (c)
Solution:

If both the given numbers are positive then the sign bits x and y are both zero but if the sign bit of result is 1 then it indicates that the result is negative which is not possible and hence it indicates overflow.

This condition can be checked by the term: $\overline{x}\,\overline{y}\,z$

If the sign bits of both the numbers are 1 then their sum will be 0 and sign bit of result is 0 which indicates a positive result which is not possible as addition of two negative numbers cannot be positive and hence it also indicates overflow.

This condition can be checked by the term: $x\,y\,\overline{z}$

Hence, option (C) is correct.

12. Ans: (a)
Solution:

Dual form means AND is exchanged with OR

$$AB + \overline{A}C + BC = AB + \overline{A}C$$
$$\left(A+B\right)\left(\overline{A}+C\right)\left(B+C\right) = \left(A+B\right)\left(\overline{A}+C\right)$$

13. Ans: (a)
Solution:

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

Total 4 essential prime implicants which are

$$\overline{A}\,\overline{B}\,\overline{C},\ \overline{A}C\overline{D},\ A\overline{C}\,\overline{D},\ \overline{B}\,\overline{D}$$

14. Ans: (d)
Solution:

$$Y = A + \overline{A}B$$
$$Y = \left(A+\overline{A}\right)\left(A+B\right)$$
$$\left(\because A + \overline{A} = 1\right)$$
$$Y = 1.\left(A+B\right)$$
$$Y = A + B$$

15. Ans: (a)
Solution:

The given function is,

$$Y = \overline{A}\,\overline{B}\,\overline{C} + \overline{A}B\overline{C} + \overline{A}BC + AB\overline{C}$$

This function can be expressed in min-terms as,

$$Y = \sum m\left(0,2,3,6\right)$$

A \ BC	00	01	11	10
0	1 (0)	(1)	1 (3)	1 (2)
1	1 (4)	(5)	(7)	1 (6)

$$Y=\overline{A}B+B\overline{C}+\overline{A}\overline{C}$$

16. Ans: (a)
Solution:
The function can be expressed in minterms as,

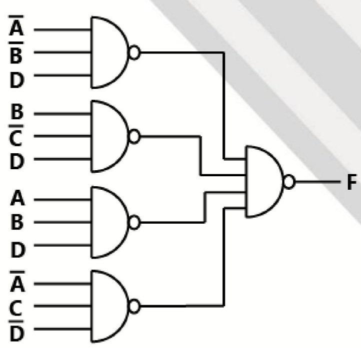
$$F(A,B,C,D)=\sum m(0,2,5,6,13,15)+d(8,9)$$

K-map for given function is

AB \ CD	00	01	11	10
00	1 (0)	(1)	(3)	1 (2)
01	(4)	1 (5)	(7)	1 (6)
11	(12)	1 (13)	1 (15)	(14)
10	X (8)	X (9)	(11)	(10)

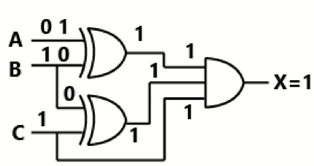
$$F(A,B,C,D)=\overline{A}\overline{B}\overline{D}+B\overline{C}D+ABD+\overline{A}C\overline{D}$$

Since, all terms & all its complements are available
We can implement the function using 3-input NAND gates as,



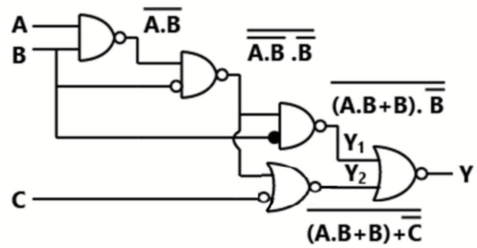
So, a minimum of 5 3-input NAND gates are required

17. Ans: (a)
Solution:
For the output of first XOR Gate to be 1 both the inputs must be different.



Hence, $A=1, B=0, C=1$

18. Ans: (d)
Solution:
The signals at the output of different gates is shown below,



$$Y_1=\overline{(AB+B)\overline{B}}$$
$$Y_1=\overline{(A+1)B.\overline{B}}$$
$$Y_1=\overline{(A+1)0}=\overline{0}$$
$$Y_1=1$$
$$Y_2=\overline{(A+1)B+\overline{C}}$$
$$Y_2=\overline{B+\overline{C}}=\overline{B}C$$

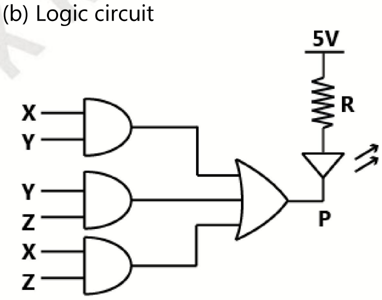
The final output Y is, $Y=\overline{1+\overline{B}C}=0$

19. Ans:
Solution:
(a) If either 2 or 3 pumps fail, the output should go to 0,

	$\overline{Z}$	Z
$\overline{X}\,\overline{Y}$	0	0
$\overline{X}Y$	0	1
XY	1	1
$X\overline{Y}$	0	1

$$P=XY+YZ+XZ$$

(b) Logic circuit



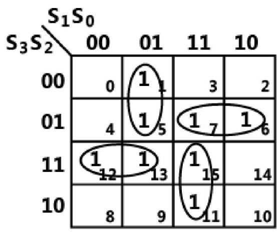
Since, the output is active low;
The cathode of LED must be connected to output
Since, P can sink a current of 10mA
When LED voltage drop is 1V
$V_R=5-1=4V$

$$I = 10mA$$

$$R = \frac{4}{10 \times 10^{-3}} = 400\Omega$$

20. Ans:
Solution:

(a) $Y = \sum m(1,5,6,7,11,12,13,15)$

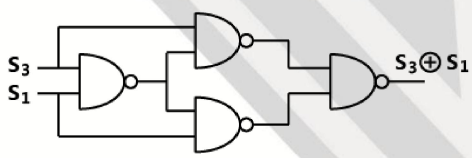


(b) $Y = S_3S_2\overline{S_1} + S_3S_1S_0 + \overline{S_3}S_2S_1 + \overline{S_3}\,\overline{S_1}S_0$

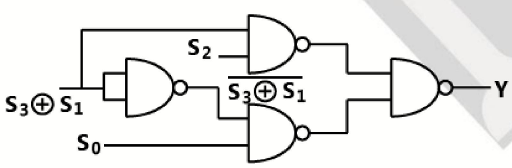
$$Y = S_2\left(S_3\overline{S_1} + \overline{S_3}S_1\right) + S_0\left(S_3S_1 + \overline{S_3}\,\overline{S_1}\right)$$

$$= S_2\left(S_3 \oplus S_1\right) + S_0\left(\overline{S_3 \oplus S_1}\right)$$

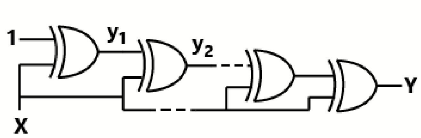
(c) First block will be used to compute XOR of S_3 & S_1



For second block we will implement as



21. Ans: (b)
Solution:



$$Y_1 = 1 \oplus X = \overline{X}$$

$$Y_2 = \overline{X} \oplus X = 1$$

Total number of gate is even

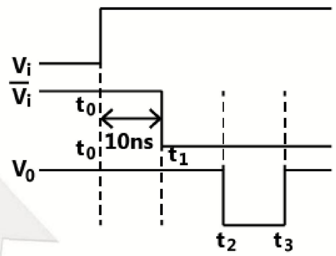
So output of 20 numbers of XOR gates is 1

22. Ans: (b)
Solution:

Due to 10nsec delay the waveform for $\overline{V_i}$ is,

The output of XOR gate is initially 1 & it goes to 0 when both inputs are 1 but after a delay of 20ns & hence it becomes 0 at t_2

After 10ns more the output again becomes 1



23. Ans: (d)
Solution:

Number of distinct Boolean expression $= 2^{2^n}$

For n=4

Number of distinct Boolean expression $= 2^{16} = 65536$

24. Ans: (a)
Solution:

$$Z = R + S + \overline{PQ + \overline{P}\,\overline{Q}\,\overline{R} + P\overline{Q}\,\overline{S}}$$

$$Z = R + S + \overline{P\left(Q + \overline{Q}\,\overline{S}\right) + \overline{P}\,\overline{Q}\,\overline{R}}$$

$$Z = R + S + \overline{PQ + P\overline{S} + \overline{P}\,\overline{Q}\,\overline{R}}$$

$$Z = R + S + \left(\overline{PQ}\right)\left(\overline{P\overline{S}}\right)\left(\overline{\overline{P}\,\overline{Q}\,\overline{R}}\right)$$

$$Z = R + S + \left(\overline{P} + \overline{Q}\right)\left(\overline{P} + S\right)\left(P + Q + R\right)$$

$$Z = R\left(1 + \overline{P} + \overline{P}\,\overline{Q}\right) + S\left(1 + P\overline{Q} + \overline{P}Q + \overline{P}R + R\overline{Q}\right) + \overline{P}Q$$

$$Z = R + S + \overline{P}Q = R + \overline{R}S + \overline{P}Q = W$$

Similarly, since $Z = R + S + \overline{PQ + \overline{P}\,\overline{Q}\,\overline{R} + P\overline{Q}\,\overline{S}}$

$$\overline{Z} = \overline{\left(R + S + \overline{PQ + \overline{P}\,\overline{Q}\,\overline{R} + P\overline{Q}\,\overline{S}}\right)}$$

$$\overline{Z} = \overline{\left(R + S\right)}.\left(PQ + \overline{P}\,\overline{Q}\,\overline{R} + P\overline{Q}\,\overline{S}\right)$$

$$\overline{Z} = \overline{R}\,\overline{S}.\left(PQ + \overline{P}\,\overline{Q}\,\overline{R} + P\overline{Q}\,\overline{S}\right)$$

$$\overline{Z} = PQ\overline{R}\,\overline{S} + \overline{P}\,\overline{Q}\,\overline{R}\,\overline{S} + P\overline{Q}\,\overline{R}\,\overline{S} = X$$

25. Ans: (d)
Solution:

Gray to Binary code

$$B_3 = G_3$$

$$B_2 = G_3 \oplus G_2$$

$B_1 = G_3 \oplus G_2 \oplus G_1$
$B_0 = G_3 \oplus G_2 \oplus G_1 \oplus G_0$

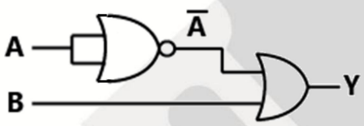
26. Ans: (d)
Solution:

$$Y = AC + B\bar{C}$$
$$Y = A\left(B+\bar{B}\right)C + \left(A+\bar{A}\right)B\bar{C}$$
$$Y = ABC + A\bar{B}C + AB\bar{C} + \bar{A}B\bar{C}$$

27. Ans: (d)
Solution:

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

$$Y = \bar{A} + B$$

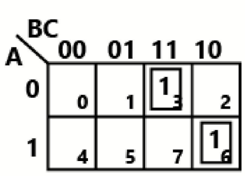


Hence, only 2 gates are required so the cost is 2 unit.

28. Ans: (a)
Solution:

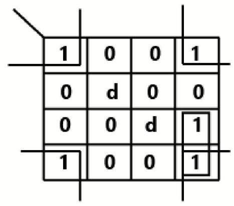
A	B	C	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

The K-Map for the above truth table,



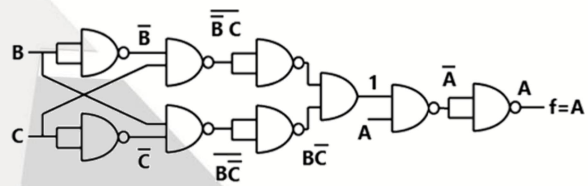
$$f = \bar{A}BC + AB\bar{C}$$
$$f = B\left(\bar{A}C + A\bar{C}\right)$$
$$f = B\left(A+C\right)\left(\bar{A}+\bar{C}\right)$$

29. Ans: (a)
Solution:



One quad & one pair
So total number of product term SOP =2

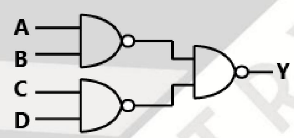
30. Ans: (d)
Solution:



31. Ans: (b)
Solution:
Y= SOP form= Realized using NAND gate
Y= POS form= Realized using NOR gate

$$Y = \overline{\overline{AB + CD}} = \overline{\overline{AB}.\overline{CD}}$$

The realization using NAND Gates is shown below,



Hence, 3 gates are required.

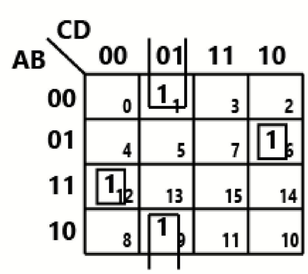
32. Ans: (d)
Solution:
The given function is,

$$Y = \bar{A}\bar{B}\bar{C}D + \bar{A}BC\bar{D} + A\bar{B}\bar{C}D + AB\bar{C}\bar{D}$$

This can be expressed in minterms as,

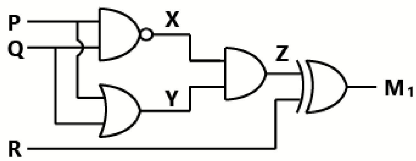
$$Y = \sum m\left(1,6,9,12\right)$$

The K-Map for this function is shown below,



$$Y = \bar{B}\bar{C}D + \bar{A}BC\bar{D} + AB\bar{C}\bar{D}$$

33. Ans: (d)
Solution:



$X = \overline{PQ} \qquad Y = P + Q$

$Z = X.Y$

$Z = \left(\bar{P}+\bar{Q}\right)\left(P+Q\right)$

$Z = P\bar{Q} + P\bar{Q} = P \oplus Q$

$Z = P \oplus Q \oplus R$

34. Ans: (d)
Solution:

$\left[X + Z\bar{Y}\left(\bar{Z} + X\bar{Y}\right)\right]\left\{\bar{X} + \bar{Z}\left(X+Y\right)\right\} = 1$

If X=1

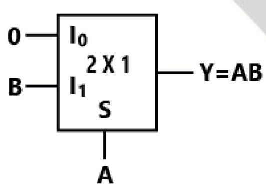
$\left[1 + X\left\{\bar{Y} + \bar{Z} + \bar{Y}\right\}\right]\left\{0 + \bar{Z}\left(1+Y\right)\right\} = 1$

$1.\left\{\bar{Z}.1\right\} = 1$

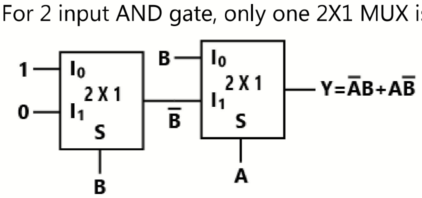
$\bar{Z} = 1$

$Z = 0$

35. Ans: (a)
Solution:



For 2 input AND gate, only one 2X1 MUX is required



$Y = \bar{A}B + A\bar{B}$

For 2 input EX-OR gate, two 2x1 MUX is required

36. Ans: (b)
Solution:

The truth table for the description is shown below,

P_1	P_2	a	b	c	d	e	f	g
0	0	1	1	1	1	1	1	0
0	1	1	1	0	1	1	0	1
1	0	1	0	1	1	0	1	1
1	1	1	0	0	1	1	1	1

From the above table we can write:

$g = P_1 + P_2,\ d = c + e$

37. Ans: (d)
Solution:

From the truth table the values of various outputs can be expressed as,

$a = 1$

$b = \overline{P_1}$

$c = \overline{P_0}$

$d = 1$

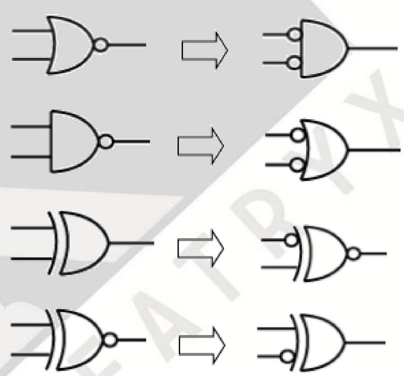
$e = \overline{P_1} + P_0$

$f = P_1 + \overline{P_0}$

$g = P_1 + P_0$

Hence, 2 NOT Gates and 3 OR Gates are required.

38. Ans: (d)
Solution:

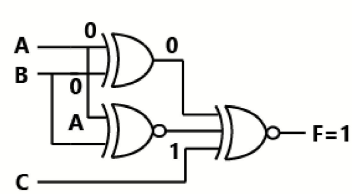


$P \to 4, Q \to 2, R \to 3, S \to 1$

39. Ans: (d)
Solution:

For the output of final XNOR Gate to be 1 there must be even number of 1's at the input of gate.

So when A and B are 0 and C = 1, the outputs of different gates are shown below,



Communication Systems 07

Chapter 1 – Analog Communication

01. The maximum power efficiency of an AM modulator is **[1992]**
(a) 25% (b) 50%
(c) 75% (d) 100%

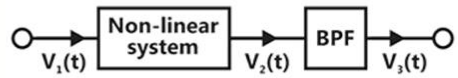
02. Coherent demodulation of FSK signal can be effected using **[1992]**
(a) Correlation receiver
(b) Band pass filters and envelope detectors
(c) Matched filter
(d) Discriminator detection

03. A sinusoidal signal of 4 kHz frequency is used as a modulating signal for an FM and an AM transmitter. Both of the transmitters use the same amplitude for the un-modulated carrier. The peak frequency deviation in the FM transmitter is set to four times the bandwidth of the AM transmitter and, the magnitudes of the spectral components at $f_c \pm 4\text{kHz}$ (f_c = carrier frequency) are same for both of the transmitters.
Determine the modulation indices for the AM and FM transmitters.
[If required use the values of the Bessel function given below:
$J_1(2)=0.577$, $J_1(4)=0.066$, $J_1(8)=0.235$,
$J_1(16)=0.094$] **[1992]**

04. Which of the following demodulator(s) can be used for demodulating the signal $x(t)=5(1+2\cos 2000\pi t)\cos 2000\pi t$. **[1993]**
(a) Envelope demodulator
(b) Square law demodulator
(c) Synchronous demodulator
(d) None of the above

05. A super-heterodyne radio receiver with an intermediate frequency of 455 KHz is tuned to a station operating at 1200 KHz. The associated image frequency is ________ KHz. **[1993]**

06. Obtain an expression for the signal $v_3(t)$ in figure, for $v_1(t)=10\cos(2000\pi t)+4\sin(200\pi t)$. Assume that $v_2(t)=v_1(t)+0.1v_1^2(t)$ and that the BPF is an ideal unity gain filter with pass band form 800 Hz to 1200 Hz. **[1993]**



07. $v(t)=5\left[\cos(106\pi t)-\sin(103\pi t)\times\sin(106\pi t)\right]$ represents **[1994]**
(a) DSB suppressed carrier signal
(b) AM signal
(c) SSB upper sideband signal
(d) Narrow band FM signal

08. A 10 MHz carrier is frequency modulated by a sinusoidal signal of 500Hz, the maximum frequency deviation being 50 kHz. The bandwidth required, as given by the Carson's rule is ________. **[1994]**

09 **[1994]**

(A) Single side band	(1) Envelope detector
(B) Amplitude modulation	(2) Integrate and dump
(C) Binary phase-shift keying	(3) Hilbert transform
	(4) Ratio detector
	(5) Phase-locked loop

10. The image (second) channel selectivity of a super heterodyne communication receiver is determined by **[1995]**
(a) Antenna and pre-selector
(b) The pre-selector and RF amplifier
(c) The pre-selector and IF amplifier
(d) The RF and IF amplifier

11. A PLL can be used to demodulate **[1995]**
(a) PAM signals (b) PCM signals
(c) FM signals (d) DSB-SC signals

12. **[1995]**

(A) AM system	(1) Coherent detection
(B) DSB-SC system	(2) Envelope detection
(C) PAM system	(3) Correlation detection
	(4) PLL
	(5) LPF

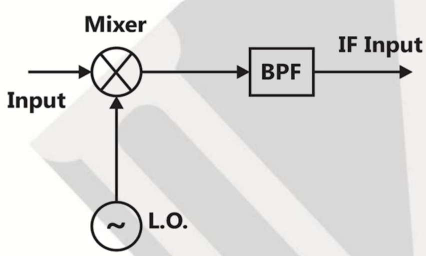
13. **[1995]**

(A) AM system	(1) 2B (Band width of the modulating signal)
(B) SSB system	(2) B
(C) PCM (n bit) system	(3) Between B and 2B
	(4) 2nB
	(5) nB

14. The image channel rejection in a super heterodyne receiver comes from **[1996]**
(a) IF stages only
(b) RF stages only
(c) Detector and RF stages only
(d) Detector RF and IF stages

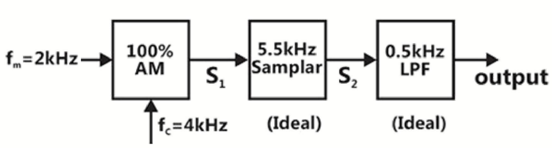
15. An FM signal with a modulation index 9 is applied to a frequency Tripler. The modulation index in the output signal will be **[1996]**
(a) 0 (b) 3
(c) 9 (d) 27

16. The figure is shows the first stage of a super heterodyne receiver. The desired input signal is at a frequency of 700MHz. The local oscillator (L. O) frequency is 1 GHz. The mixer is an ideal multiplier with a gain independent of frequency. A band-pass filter (BPF) is used to select the Intermediate Frequency (IF) output at 300MHz. **[1997]**



(a) What is the image frequency of the desired input?
(b) A Low Pass Filter (LPF) can be used before the mixer to reject the image frequency. If a perfect rejection (zero transmission) of the image is desired, what type of LPF should be employed?
(c) The input in the figure is corrupted by an undesired 750 MHz signal which has the same amplitude as that of the desired signal at 700MHz. Let the BPF be of second order. At the BPF output, the undesired signal should be 20 dB below the desired signal. Calculate the Q required for the BPF.

17. A block diagram of a system is shown in the figure. Draw the spectrum of the output signal with relative aptitudes of the frequencies. **[1997]**



18. The image channel selectivity of super heterodyne receiver depends upon **[1998]**
(a) If amplifiers only
(b) RF and IF amplifiers only
(c) Pre-selector, RF and IF amplifiers
(d) Pre-selector and RF amplifiers only

19. A DSB-SC signal is generated using the carrier $\cos(\omega_e t+\theta)$ and modulating signal x(t). The envelope of the DSB-SC signal is **[1998]**
(a) x(t)
(b) $|x(t)|$
(c) Only positive portion of x(t)
(d) $x(t)\ \cos\theta$

20. An SSB signal is demodulated by using a synchronous demodulator. However, the locally arranged carrier has a phase error θ. Determine the effect of the error on demodulation. What will be the effect of this error if the input is DSB-SC in place of SSB? **[1998]**

21. The input to a channel is a band pass signal. It is obtained by linearly modulating a sinusoidal carrier with a single-tone signal. The output of the channel due to this input is given by

$$y(t)=\left(\frac{1}{100}\right)\cos\left(100t-10^{-6}\right)\cos\left(10^{6}t-1.56\right)$$

The group delay (t_g) and the phase delay (t_p) in seconds, of the channel are **[1999]**
(a) $t_g=10^{-6}$, $t_p=1.56$
(b) $t_g=1.56$, $t_p=10^{-6}$
(c) $t_g=10^{8}$, $t_p=1.56\times10^{-6}$
(d) $t_g=10^{8}$, $t_p=1.56$

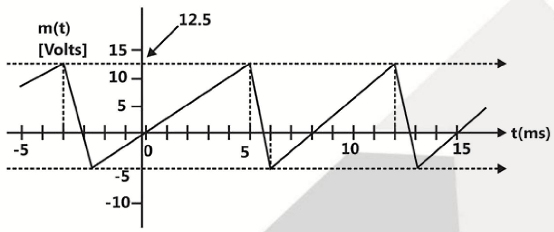
22. A modulated signal is given by,
$s(t)=m_1(t)\cos(2\pi f_c t)+m_2(t)\sin(2\pi f_c t)$
where the baseband signal $m_1(t)$ and $m_2(t)$ have bandwidths of 10 kHz and 15 kHz, respectively. The bandwidth of the modulated signal, in kHz, is **[1999]**
(a) 10 (b) 15
(c) 25 (d) 30

23. A modulated signal is given by
$s(t)=e^{-at}\cos\left[(\omega_c+\Delta\omega)t\right]u(t)$, where a, ω_c and $\Delta\omega$ are positive constants, and $\omega_c \square \Delta\omega$.
The complex envelope of s(t) is given by **[1999]**
(a) $\exp(-at)\exp\left[j(\omega_c+\Delta\omega)t\right]u(t)$
(b) $\exp(-at)\exp(j\Delta\omega t)u(t)$

(c) $\exp\left[j\Delta\omega t\right].u(t)$

(d) $\exp\left[\left(j\omega_c + \Delta\omega\right)t\right]$

24. A baseband signal m(t) modulates a carrier to produce the angle modulated signal, $A_c \cos\left[2\pi\times10^8 t + k_p m(t)\right]$, where m(t) is shown in Figure. Determine the value of k_p so that the peak-to-peak frequency deviation of the carrier is 100 kHz. **[1999]**

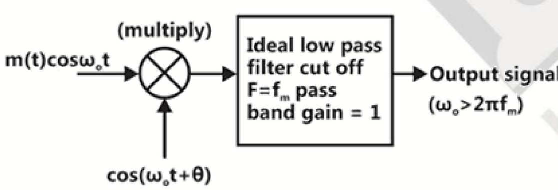


25. The amplitude modulated wave from $s(t) = A_c\left[1 + K_a m(t)\right]\cos\omega_C t$ is fed to an ideal envelope detector. The maximum magnitude of $K_0 m(t)$ is greater than 1. Which of the following could be the detector output? **[2000]**

(a) $A_c m(t)$ (b) $A_c^2\left[1 + K_a m(t)\right]^2$

(c) $\left|A_c\left[1 + K_a m(t)\right]\right|$ (d) $A_c\left[1 + K_a m(t)\right]^2$

26. A message m(t) band-limited to the frequency f_m has a power of P_m. The power of the output signal in the Figure is **[2000]**



(a) $\frac{P_m \cos\theta}{2}$ (b) $\frac{P_m}{4}$

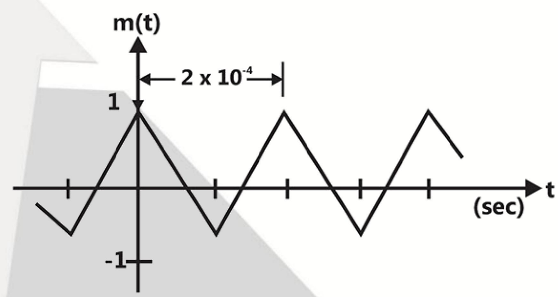
(c) $\frac{P_m \sin^2\theta}{4}$ (d) $\frac{P_m \cos^2\theta}{4}$

27. In an FM system, a carrier of 100 MHz is modulated by a sinusoidal signal of 5 KHz. The bandwidth by Carson's approximation is 1MHz. If $y(t) = (\text{modulated waveform})^3$, than by using Carson's approximation, the bandwidth of y(t) around 300 MHz and the spacing of spectral components are, respectively. **[2000]**

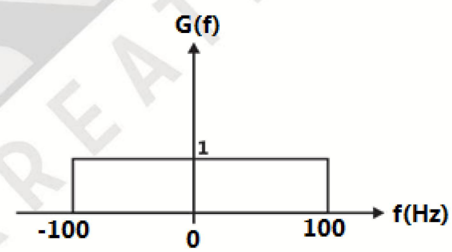
(a) 3 MHz, 5 KHz (b) 1 MHz, 15 KHz

(c) 3 MHz, 15 KHz (d) 1 MHz, 5 KHz

28. The periodic modulating signal m(t) is shown in Fig.17. Using Carson's rule estimate B_{FM} (bandwidth of the FM signal) and B_{PM} (bandwidth of the PM signal) for $Kf = \pi\times10^4$ and $kp = \frac{\pi}{4}$. Assume the essential bandwidth of m(t) to consist only up to and including the third harmonic. **[2001]**



29. A baseband signal g(t) band limited to 100 Hz modulates a carrier of frequency f_0 Hz. The modulated signal $g(t)\cos 2\pi f t$ is transmitted over a channel whose input x and output y are related by $y = 2x + x^2$. The spectrum of g(t) is shown in Figure 18. Sketch the spectrum of the transmitted signal and the spectrum of the received signal. **[2001]**



30. A 1 MHz sinusoidal carrier is amplitude modulated by a symmetrical square wave of period 100μsec. Which of the following frequencies will NOT be present in the modulated signal? **[2002]**

(a) 990 KHz (b) 1010 KHz

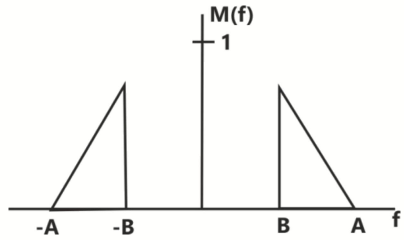
(c) 1020 KHz (d) 1030 KHz

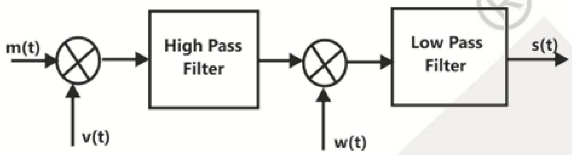
31. Consider a sampled signal

$y(t) = 5\times10^{-6} x(t)\sum_{n=-\infty}^{+\infty}\delta(t - nT_s)$

where $x(t) = 10\cos\left(8\pi\times10^3\right)t$ and $T_s = 100\mu\sec$

.





The bandwidth of the signal at the output of the modulator (in Hz) is _____ **[2014-02]**

71. A modulated signal is $y(t) = m(t)\cos(40000\pi t)$, where the baseband signal m(t) has frequency components less than 5 kHz only. The minimum required rate (in kHz) at which y(t) should be sampled to recover m(t) is _______. **[2014-03]**

72. The phase response of a pass-band waveform at the receiver is given by

$\varphi(f) = -2\pi\alpha(f - f_c) - 2\pi\beta f_c$

Where f_c is the centre frequency, and α and β are positive constants. The actual signal propagation delay from the transmitter to receiver is **[2014-03]**

(a) $\frac{\alpha - \beta}{\alpha + \beta}$ (b) $\frac{\alpha\beta}{\alpha + \beta}$

(c) ∝ (d) β

73. Consider an FM signal

$f(t) = \cos[2\pi f_c t + \beta_1 \sin 2\pi f_1 t + \beta_2 \sin 2\pi f_2 t]$.

The maximum deviation of the instantaneous frequency from the carrier frequency f_c is **[2014-03]**

(a) $\beta_1 f_1 + \beta_2 f_2$ (b) $\beta_1 f_2 + \beta_2 f_1$

(c) $\beta_1 + \beta_2$ (d) $f_1 + f_2$

74. In a double side-band (DSB) full carrier AM transmission system, if the modulation index is doubled, then the ratio of total sideband power to the carrier power increases by a factor of ______.

[2014-04]

75. Consider the signal

$s(t) = m(t)\cos(2\pi f_c t) + \hat{m}(t)\sin(2\pi f_c t)$ where $\hat{m}(t)$ denotes the Hilbert transform of m(t) and the bandwidth of m(t) is very small compared to f_c. The signals s(t) is a **[2015-01]**

(a) High-pass signal

(b) Low-pass signal

(c) Band-pass signal

(d) Double sideband suppressed carrier signal

76. In the system shown in Figure (a), m(t) is a low-pass signal with bandwidth W Hz. The frequency response of the band-pass filter H(f) is shown in Figure (b). If it is desired that the output signal z(t)=10x(t), the maximum value of W (in Hz) should be strictly less than _______ **[2015-01]**

$x(t) = m(t)\cos(2400\pi t)$

$y(t) = 10x(t) + x^2(t)$

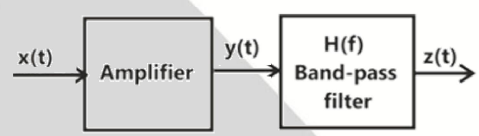


Figure a

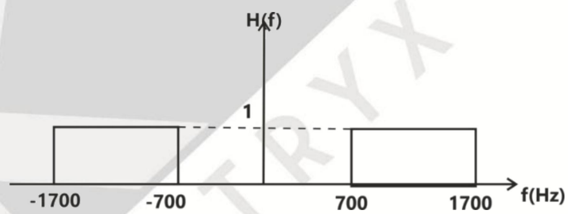


Figure b

77. A message signal m(t) = $A_m \sin(2\pi f_m t)$ is used to modulate the phase of a carrier $A_c\cos(2\pi f_c t)$ to get the modulated signal y(t)= $A_c\cos(2\pi f_c t + m(t))$ .The bandwidth of y(t) **[2015-03]**

(a) Depends on A_m but not on f_m

(b) Depends on f_m but not on A_m

(c) Depends on both A_m and f_m

(d) Does not depend on A_m or f_m

78. The complex envelope of the band-pass signal $x(t) = -\sqrt{2}\left(\frac{\sin(\pi t/5)}{\pi t/5}\right)\sin\left(\pi t - \frac{\pi}{4}\right)$, centered about $f = \frac{1}{2}$Hz, is **[2015-03]**

(a) $\left(\frac{\sin(\pi t/5)}{\pi t/5}\right)e^{j\frac{\pi}{4}}$ (b) $\left(\frac{\sin(\pi t/5)}{\pi t/5}\right)e^{-j\frac{\pi}{4}}$

(c) $\sqrt{2}\left(\frac{\sin(\pi t/5)}{\pi t/5}\right)e^{j\frac{\pi}{4}}$ (d) $\sqrt{2}\left(\frac{\sin(\pi t/5)}{\pi t/5}\right)e^{-j\frac{\pi}{4}}$

79. A super-heterodyne receiver operates in the frequency range of 58 MHz - 68 MHz. The intermediate frequency f_{IF} and local oscillator frequency f_{LO} are chosen Such that $f_{IF} < f_{LO}$ It is required that the image frequencies fall outside the 58 MHz - 68 MHz band. The minimum required f_{IF} (in MHz) is____________ **[2016-01]**

80. The amplitude of a sinusoidal carrier is modulated by a single sinusoid to obtain the amplitude modulated signal s(t) = 5cos 1600πt + 20cos 1800πt + 5cos 2000πt. The value of the modulation index is______________ **[2016-01]**

81. For a super-heterodyne receiver, the intermediate frequency is 15 MHz and the local oscillator frequency is 3.5 GHz. If the frequency of the received signal is greater than the local oscillator frequency, then the image frequency (in MHz) is _______ **[2016-03]**

82. A modulating signal given by x(t)=5 sin $\left(4\pi 10^3 t - 10\pi\cos 2\pi 10^3 t\right)$V is fed to a phase modulator with phase deviation constant $k_p = 5\text{rad/V}$. If the carrier frequency is 20 kHz, the instantaneous frequency (in kHz) at t = 0.5 ms is __________ **[2017-02]**

83. The unmodulated carrier power in an AM transmitter is 5 kW. This carrier is modulated by a sinusoidal modulating signal. The maximum percentage of modulation is 50%. If it is reduced to 40% then the maximum unmodulated carrier power (in kW) that can be used without overloading the transmitter is _________ **[2017-02]**

84. Consider the following amplitude modulated signal: **[2018]**

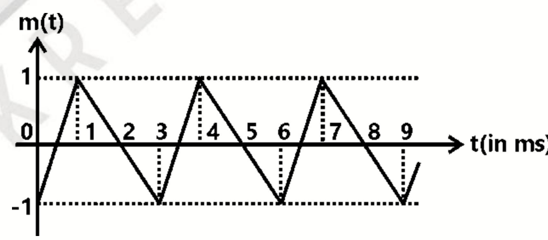
$$s(t) = \cos(2000\pi t) + 4\cos(2400\pi t) + \cos(2800\pi t)$$

The ratio (accurate to three decimal places) of the power of the message signal to the power of the carrier signal is _______

85. Let $c(t) = A_c\cos(2\pi f_c t)$ and $m(t) = \cos(2\pi f_m t)$. It is given that $f_c >> 5f_m$. The signal $c(t) + m(t)$ is applied to the input of a non-linear device, whose output $v_0(t)$ is related to the input $v_i(t)$ as $v_0(t) = av_f(t) + bv_f^2(t)$, where a and b are positive constants. The output of the non-linear device is passed through an ideal band-pass filter with centre frequency f_c and bandwidth $3f_m$ to produce amplitude modulated (AM) wave. If it is desired to have the sideband power of the AM wave to be half of the carrier power, then a/b is **[2018]**

(a) 0.25 (b) 0.5
(c) 1 (d) 2

86. The baseband signal $m(t)$ shown in the figure is phase modulated to generate the PM signal $\varphi(t) = \cos(2\pi f_c t + km(t))$. The time t on the x-axis in the figure is in milliseconds. If the carrier frequency is $f_c = 50\text{kHz}$ and $k = 10\pi$, then the ratio of the minimum instantaneous frequency (in kHz) to the maximum instantaneous frequency (in kHz) is ______ (rounded off to 2 decimal places) **[2019]**



Solution

01. Ans: (b)
Solution:

Power efficiency: $\eta = \dfrac{\overline{m}^2(t)}{A_C{}^2 + \overline{m}^2(t)}$

$\overline{m^2(t)} \rightarrow$ Mean square value of $m(t)$

For sinusoidal signal: $\overline{m^2(t)} = \dfrac{A_m{}^2}{2} : \eta = \dfrac{\dfrac{A_m{}^2}{2}}{A_C{}^2 + \dfrac{A_m{}^2}{2}}$

$\eta = \dfrac{\dfrac{A_m{}^2}{A_C{}^2}}{2 + \dfrac{A_m{}^2}{A_C{}^2}}$ and $m_a = \dfrac{A_m}{A_C}$

$\eta = \dfrac{m_a{}^2}{2 + m_a{}^2}$

For % $\%\eta_{max}$

$m_a = 1 \qquad \%\eta_{max} = \dfrac{1}{3} \times 100\% = 33.3\%$

For square wave signal

$\overline{m^2(t)} = A_m{}^2$

$\eta = \dfrac{A_m{}^2}{A_C{}^2 + A_m{}^2} = \dfrac{m_a{}^2}{1 + m_a{}^2}$

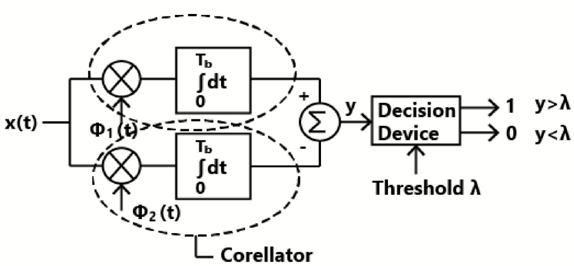
$m_a = 1$

$\%\eta_{max} = \dfrac{1}{2} \times 100\% = 50\%$

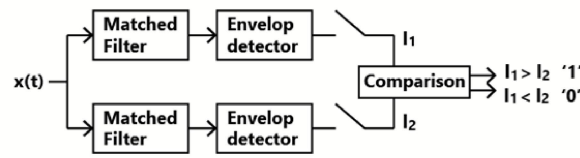
Maximum powers efficiency of an AM modulator is 50% if the message signal $m(t)$ is square wave.

For different message signal efficiency will be different

02. Ans: (a)
Solution:
Coherent detection of Binary FSK signal



Note: Coherent demodulation of FSK is affected by using correlation receiver
Non coherent detection of BFSK signal



Non coherent demodulation of FSK is effected by matched filter and Envelop detector.

03. Ans: 0.47
Solution:

$f_m = 4KHZ$

$m(t)$____ $\boxed{AM}$

$m(t)$____ $\boxed{FM}$

$c(t) = A_C \cos\omega_c t$ For both AM and FM

$\Delta f = 4[2f_m] \qquad \Delta f = \beta f_m$

$\beta = \dfrac{\Delta f}{f_m} = 8$

$\beta = 8$

$$S_{AM}(t) = \begin{bmatrix} A_C \cos\omega_C t + \dfrac{A_C m_a}{2}\cos[2\pi(f_c + 4k)] \\ + \dfrac{A_C m_a}{2}\cos[2\pi(f_c - 4k)] \end{bmatrix}$$

$$S_{FM}(t) = \begin{bmatrix} A_C J_0(\beta)\cos 2\pi f_c t \\ + A_C J_1(\beta)\cos[2\pi(f_c + 4k)] \\ + A_C J_{-1}(\beta)\cos[2\pi(f_c - 4k)] + ... \end{bmatrix}$$

While comparing both

$\left|\dfrac{A_C m_a}{2}\right| = |A_C J_1(\beta)|$

$\dfrac{m_a}{2} = J_1(\beta)$

$m_a = 2 \times .235 = 0.47$

04. Ans: (c)
Solution:

$x(t) = 5[1 + 2\cos(2000\pi t)]\cos 2000\pi t$

Signal x(t) is an amplitude modulated signal
Above signal is neither under modulated nor critical modulated.

Since $m_a = \left|K_a m(t)\right|_{max} = 2$

Standard equation of AM signal is given by:

$x(t) = A_C\left[1 + m_a \cos\omega_m t\right]\cos\omega_C t$

Where $m_a =$ modulation index

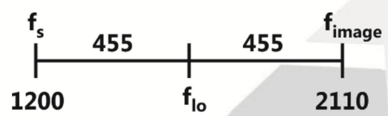
When modulation index of given wave is more than one than it is the case of over modulation

When modulation index of given wave is more than one than the detection is possible only with synchronous modulator only

Such signal are not detected with envelop detector.

05. Ans: 2110

Solution:



$f_{TF} = 455$ KHZ

$f_s = 1200$ KHZ

$f_{image} = f_S + 2f_{IF} = 1200 + 2\times 455 = 1200 + 910$

$f_{image} = 2110$ kHZ

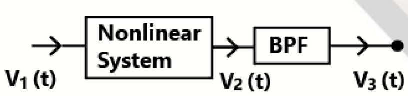
06. Ans:---

Solution:

$V_1(t) = 10\cos(2000\pi t) + 4\sin(200\pi t)$

$v_2(t) = v_1(t) + 0.1v_1^{\,2}(t)$

$$v_1^{\,2}(t) = \begin{bmatrix} 100\cos^2(2000\pi t) + 16\sin^2(200\pi t) \\ +80\cos(2000\pi t)\sin(200\pi t) \end{bmatrix}$$



$v_1^{\,2}(t) = 50\left[1 + \cos(4000\pi t)\right] + 8\left[1 - \cos(400\pi t)\right]$
$+ 40\sin(2200\pi t) + 40\sin(-1800\pi t)$

$$v_1^{\,2}(t) = \begin{bmatrix} 58 + 50\cos(4000\pi t) - 8\cos(400\pi t) \\ +40\sin(2200\pi t) - 40\sin(1800\pi t) \end{bmatrix}$$

$v_2(t) = 10\cos 2000\pi t \rightarrow \omega = 2000\pi \quad f = 1000$ Hz

$+ 4\sin(200\pi t) \rightarrow \omega = 200\pi \quad f = 100$ Hz

$+ 50 \rightarrow f = 0$ Hz

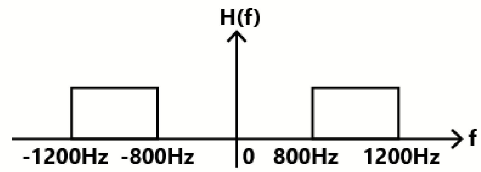
$+ 50\cos(4000\pi) \rightarrow \omega = 4000\pi, \quad f = 2000$ Hz

$- 8\cos(400\pi t) \rightarrow \omega = 400\pi \quad f = 200$ Hz

$+ 40\sin 2200\pi t \rightarrow \omega = 2200\pi \quad f = 1100$ Hz

$- 40\sin 1800\pi t \rightarrow \omega = 1800\pi \quad f = 900$ Hz

BPF:



Output of BPF

$10\cos 2000\pi t + 4\sin 2200\pi t - 4\sin 1800\pi t$

07. Ans: (d)

Solution:

$u(t) = 5\left[\cos(10^6\pi x) - \sin(10^3\pi t)\sin(10^6\pi t)\right]$

$V(t) = 5\cos(10^6\pi x) - \frac{5}{2}\left[2\sin(10^3\pi t)\sin(10^6\pi t)\right]$

$2\sin A\sin B = \cos(A - B) - \cos(A + B)$

$$V(t) = 5\cos(10^6\pi x) - \frac{5}{2}\begin{bmatrix} \cos(10^6\pi t - 10^3\pi t) \\ -\cos(10^6\pi t + 10^3\pi t) \end{bmatrix}$$

$$V(t) = \begin{bmatrix} \underbrace{5\cos(10^6\pi t)}_{\text{Carrier}} + \underbrace{\frac{5}{2}\cos(10^6\pi t + 10^3\pi t)}_{\text{Upper sideband}} \\ \underbrace{-\frac{5}{2}\cos\left[(10^6\pi - 10^3\pi)t\right]}_{\text{Lower sideband}} \end{bmatrix}$$

The lower sideband is in phase opposition to upper sideband which is found in NBFM signal

08. Ans: 101

Solution:

$f_C = 10$ MHz

$f_m = 500$ Hz

$\Delta f\big|_{max} = 50$ KHz

$BW = 2\left[\Delta f\big|_{max} + f_m\right] = 2\left[50k + 0.5k\right]$

$BW = 101$ kHZ

09. Ans:

Solution:

(A) Single side band – (3) Hilbert transform

(B) Amplitude modulation – (1) Envelop detector

(C) Binary phase shift keying – (2) Integrate and damp

10. Ans: (b)
Solution:
Image signal is a signal whose frequency is above the local oscillator frequency by the same another, as the desired signal frequency is below the local oscillator frequency.

$f_m = f_s + 2IF = f\ell + IF$

The superior IF signal produced by image signal is also amplified by the IF amplifies and produces – interface in the receiver output. There of the image signal should be reflected the RF amplifier adds one more turned circuit per stage and thereby increases the image frequency attenuated.

11. Ans: (c)
Solution:
PLL can be used to de-modulate FM signals.

12. Ans: ---
Solution:
(A) AM signal system ______ (2) Envelop Detection
(B) DSB –SC system ________ (1) Coherent Detection
(C) PAM system ________ (5) LPF

13. Ans: ---
Solution:
(A) AM system ________ (1)
(B) SSB system _______(2)
(C) PCM (n bit) system___ (4)

14. Ans: (b)
Solution:
Super-heterodyne receiver should provide image rejection at RF stage only, otherwise image signal is amplified by IF amplifier

15. Ans: (d)
Solution:

$$S_{FM}(t) \rightarrow \boxed{xn} \rightarrow S_{FM\,1}(t)$$

Frequency
Multiplier

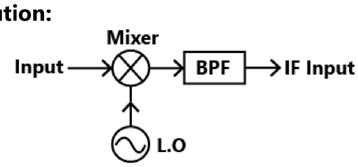
$$S_{FM}(t) = A_C \cos\left[\omega_c t + \beta \sin\omega_m t\right]$$

$$S_{FM\,1}(t) = A_C \cos\left[\omega_c t + n\beta \sin\omega_m t\right]$$

$$n\beta = 3 \times 9 = 27$$

β is given as 9

16. Ans: ---
Solution:



$f_s = 700$ MHz

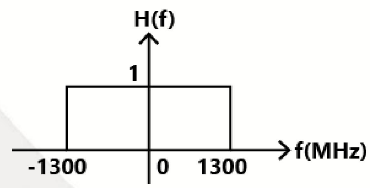
$f_\ell = 1$ GHz $= 1000$ MHz

$f_{IF} = 300$ MHz

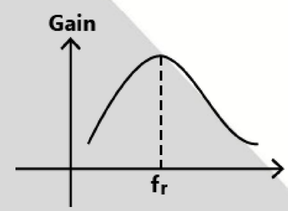
$f_i = f_s + 2IF$ (when $f_{lo} > f_s$)

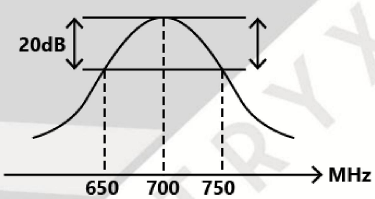
(a) $f_{image} = f_s + 2f_{IF} = 700 + 600 = 1300$ MHz

(b) Frequency response of ideal LPF



(c) Gain frequency characteristics of bit



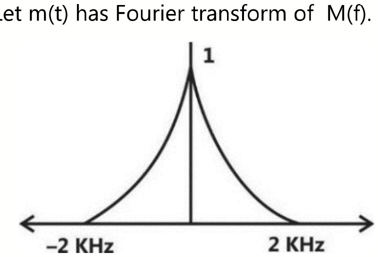


$f_r = 700$ MHz

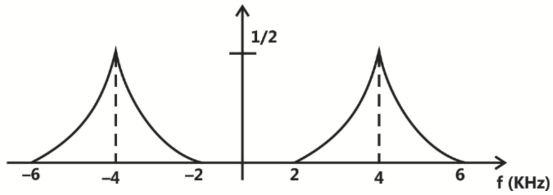
$BW = 100$ MHz

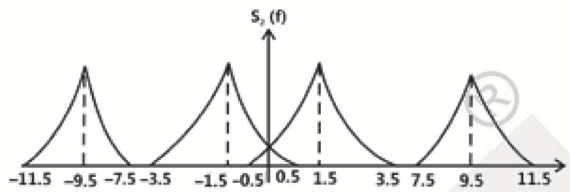
$$Q = \frac{f_r}{BW} = \frac{700}{100} = 7$$

17. Ans: ---
Solution:
Let m(t) has Fourier transform of M(f).

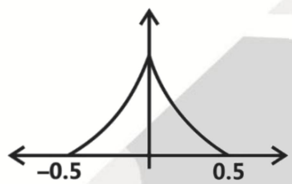


$$S_1(f) = \frac{1}{2}\left[M_1(f - f_c) + M_1(f + f_c)\right]$$





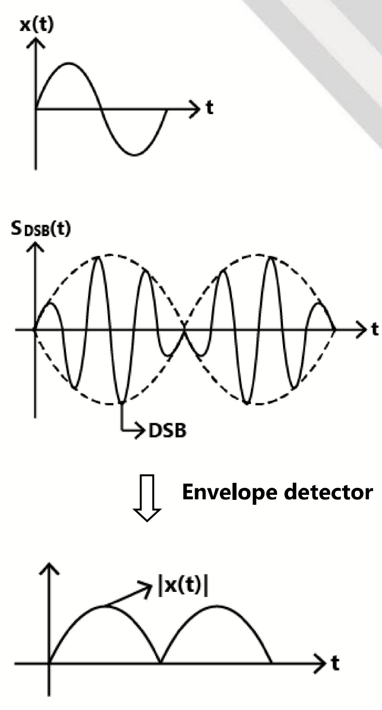
After LPF



18. Ans: (d)
Solution:
Pre-selected is used to get desired frequency

19. Ans: (b)
Solution:

$$S_{DBS}(t) = x(t)\cos(\omega_0 t + \theta)$$



20. Ans: ---
Solution:
Synchronous Detector

$$x(t) = S_{SSB}(t)\cos(\omega_C t + \theta)$$

$$S_{SSB}(t) = m(t)\cos\omega_C t \pm \hat{m}(t)\sin\omega_C t$$

$$x(t) = \begin{bmatrix} m(t)\cos\omega_C t\cos(\omega_C t + \theta) \\ \pm\hat{m}(t)\sin\omega_C t\cos(\omega_C t + \theta) \end{bmatrix}$$

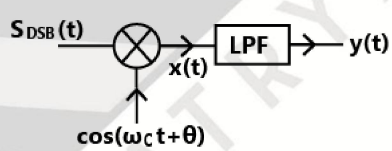
$$x(t) = \begin{bmatrix} \frac{m(t)}{2}\left[\cos(2\omega_C t + \theta) + \cos\theta\right] \\ \pm\frac{\hat{m}(t)}{2}\left[\sin(2\omega_C t + \theta) + \sin(-\theta)\right] \end{bmatrix}$$

$$\downarrow \text{LPF}$$

$$y(t) = \frac{m(t)}{2}\cos\theta \pm \frac{\hat{m}(t)}{2}\sin(-\theta)$$

$$y(t) = \underbrace{\frac{m(t)}{2}\cos\theta}_{\text{Attenuated Message Signal}} \pm \underbrace{\frac{\hat{m}(t)}{2}\sin(-\theta)}_{\text{Interference}}$$

Demodulated signal will have interference along with attenuated message signal
FOR DSB:



$$S_{DSB}(t) = m(t)\cos\omega_C t$$

$$x(t) = m(t)\cos\omega_C t\cos(\omega_C t + \theta)$$

$$x(t) = \frac{m(t)}{2}\left[\cos(2\omega_C t + \theta) + \cos\theta\right]$$

$$\downarrow \text{LPF}$$

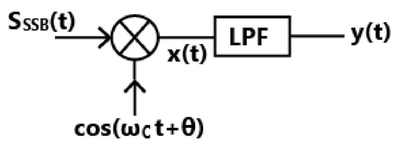
$$y(t) = \frac{m(t)}{2}\cos\theta$$

$$\downarrow$$

Attenuated message signal
In case of DSB-SC only attenuated message signal is obtained. There is no interference.

21. Ans: (c)
Solution:

$$y(t) = \frac{1}{100}\cos\left(100t - 10^{-6}\right)\cos\left(10^{6}t - 1.56\right)$$



$$y(t)=\frac{1}{100}\cos\left[100\left(t-10^{-8}\right)\right]\cos\left(10^{6}t-1.56\times10^{-6}\right)$$

Group delay: $t_g=10^{-8}$ sec

Phase delay: $t_p=1.56\times10^{-6}$ sec

22. Ans: (d)
Solution:

$BW=2f_{max}$

$f_{max}=\{15,10\}$

$f_{max}=15$

$B=2f_m$

$f_m=15\text{kHz}$

$B=30\text{kHz}$

23. Ans: (b)
Solution:

$S(t)=e^{-at}\cos\left[\left(\omega_C+\Delta\omega\right)t\right]u(t)$

Complex envelop

$g_C(t)=g_P(t)e^{-j\omega_C t}$

$S_C(t)=S_P(t)e^{-j\omega_C t}$

$\downarrow$ $\downarrow$

Complex Pre

Envelop envelop

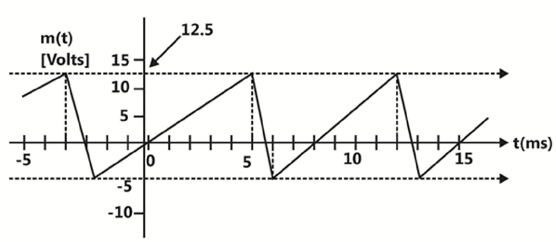
$S_P(t)=S(t)+j\hat{S}(t)$

$S_P(t)=e^{-at}u(t)\left[\cos\left(\omega_C+\Delta\omega\right)t+j\sin\left(\omega_C+\Delta\omega\right)t\right]$

$S_P(t)=e^{-at}u(t)e^{j\omega_C t}e^{j\Delta\omega_C t}$

$S_C(t)=e^{-at}e^{j\Delta\omega_C t}u(t)$

24. Ans: ---
Solution:



$A_C\cos\left(2\pi\times10^{8}t+k_p\ m(t)\right)$

$\theta_i(t)=\omega_i t=\omega_c t+k_p\ m(t)$

$\Delta\phi=k_p\ m(t)$

$\omega_i=\omega_C+k_p\frac{d}{dt}m(t)$

$\left(\omega_i\right)_{max}=\omega_C+k_p\left[\frac{d}{dt}m(t)\right]_{max}$

$\left(\omega_i\right)_{min}=\omega_C+k_p\left[\frac{d}{dt}m(t)\right]_{min}$

$\Delta\omega_{p\text{-}p}=\left(\omega_i\right)_{max}-\left(\omega_i\right)_{min}$

$100\text{ kHz}=\frac{k_p}{2\pi}\times2.185+\frac{k_p}{2\pi}\times8.75$

$100\text{ kHz}=\frac{10.935}{2\pi}\ k_p$

$2\pi\times\frac{100\times10^{3}}{10.935}=k_p$

$k_p=57.45\times10^{3}\ \text{rad/V}$

25. Ans: (c)
Solution:

When $S_{AM}(t)=A_C\left[1+K_a m(t)\right]\cos\omega_c t$

$\left|K_a m(t)\right|_{max}=$ Modulation index $=m_a$

$m_a>1$

Since the modulation index is greater than unity.
The output of the envelop detector is mod of envelop.

Envelop = $A_C\left(1+K_a m(t)\right)$

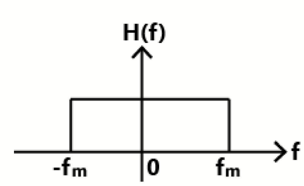
$\left|A_C\left(1+K_a m(t)\right)\right|=$ Mod of envelope.

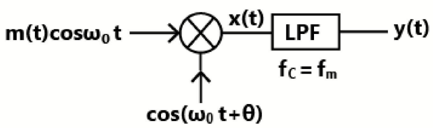
26. Ans: (d)
Solution:

$x(t)=m(t)\cos\omega_0 t\cos\left(\omega_0 t+\theta\right)$

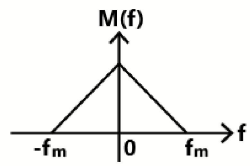
$x(t)=\frac{m(t)}{2}\left[2\cos\omega_0 t\cos\left(\omega_0 t+\theta\right)\right]$

$x(t)=\frac{m(t)}{2}\left[\cos\left(2\omega_0 t+\theta\right)+\cos\theta\right]$

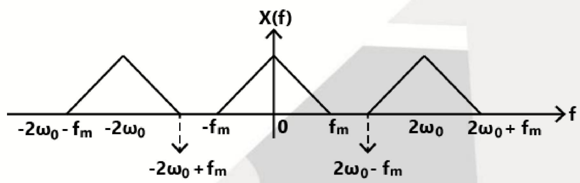




$m(t) \xleftrightarrow{F.T}$



$x(t) \xleftrightarrow{F.T}$



After passing through LPF, $2\omega_0$ frequency is blocked so output of filter becomes

$$y(t) = \frac{m(t)\cos\theta}{2}$$

Taking mean square values of both sides

$$\overline{y^2(t)} = \overline{m^2(t)} \times \frac{\cos^2\theta}{4}$$

$\overline{m^2(t)} =$ Mean square values of $m(t) =$ Power of $m(t) = P_m$

$$\overline{y^2(t)} = \frac{P_m \cos^2\theta}{4}$$

27. Ans: (a)
Solution:
Y(t) = (modulated waveform)^3
By Carson rule.

$$BW = 2(\beta+1)\, f_m$$

$$1\times10^6 = 2\times(\beta+1)\times5\times10^3$$

$$\beta = 99$$

Modulated waveform =

$$\text{Cos}\left(2\pi\times10^8 t + \beta\sin\left(2\pi\times50\times10^3 t\right)\right)$$

$$y(t) = (\text{Modulated waveform})^3$$

$$y(t) = \text{Cos}^3\left(2\pi\times10^8 t + \beta\sin\left(2\pi\times5\times10^3 t\right)\right)$$

$$f_c^{'} = 300\,\text{MHz}$$

$$\beta' = 3\beta$$

$f_m = 5\text{KHz}.$ {signal freq. does not change}

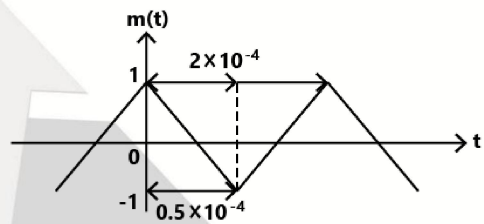
$$Bw' = 2\times\left(\beta^1+1\right)f_m = 2\times298\times5\times10^3$$

$$BW' \cong 3\text{MHz}$$

$$\phi_{FM}\left(H = A\sum_{K=-\infty}^{\infty} J(\beta)\right)\cos\left[\left(\omega_c + K\omega_m\right)t\right]$$

Thus the spectral width of FM signal y(t) does not change.

28. Ans: 35
Solution:



$$\frac{dm(t)}{dt} = \text{Slope} = \frac{1}{0.5\times10^{-4}} = 2\times10^4$$

$$K_f = \pi\times10^4\,\frac{\text{rad}}{\text{sec V}} : K_P = \frac{\pi}{4}\frac{\text{rad}}{\text{V}}$$

$m(t)$ is half wave symmetric

It will contain only odd Harmonics

$f_0,\ 3f_0,\ 5f_0$

Where, $f_0 = \frac{1}{T} = \frac{1}{2\times10^{-4}}$

$$f_0 = 5\ \text{kHz}$$

Maximum frequency component of

$$m(t) = 3f_0 = 15\ \text{kHz}$$

$$f_{max} = 15\ \text{kHz}$$

FM:

$$BW_{FM} = 2\left(|\Delta f|_{max} + f_{max}\right)$$

K_f is in $\frac{\text{rad}}{\text{sec V}} \longrightarrow \omega_i = \omega_C + k_f m(t)$

$$f_i = f_C + \frac{k_f}{2\pi}m(t)$$

$$f_i = f_C + \Delta f$$

$$|\Delta f|_{max} = \left|\frac{K_f}{2\pi}m(t)\right|_{max}$$

$$|\Delta f|_{max} = \frac{10^4}{2}\times1 = \frac{10^4}{2}$$

$$BW_{FM} = 2\left[\frac{10^4}{2} + 15\times10^3\right]$$

$$BW_{FM} = 2\left[\frac{10\times10^3}{2} + 15\times10^3\right] = 2\left[5\times10^3 + 15\times10^3\right]$$

$$BW_{FM} = 40\ \text{kHz}$$

PM:

$$BW_{FM} = 2\left[\left|\Delta f\right|_{max} + f_{max}\right]$$

$$\omega_i t = \omega_C t + k_P m(t) \rightarrow \left[K_P \text{ is in } \frac{rad}{V}\right]$$

$$\omega_i = \omega_C + k_P\frac{dm(t)}{dt}$$

$$f_i = f_C + \frac{K_P}{2\pi}\frac{dm(t)}{dt}$$

Comparing with $f_i = f_C + \Delta f$

$$\left|\Delta f\right|_{max} = \frac{K_P}{2\pi}\left|\frac{dm(t)}{dt}\right|_{max} = \frac{\pi}{4[2\pi]}\times2\times10^4$$

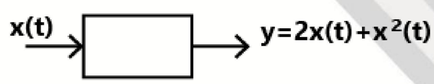
$$\left|\Delta f\right|_{max} = \frac{2\times10^4}{8} = 2.5\times10^3\ \text{Hz}$$

$$BW_{PM} = 2\left[2.5\times10^3 + 15\times10^3\right]$$

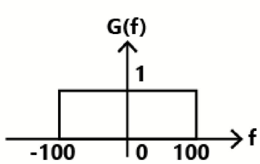
$$BW_{PM} = 35\ \text{kHz}$$

29. Ans: ---
Solution:

$$x(t) = g(t)\cos 2\pi f_C t$$



$g(t) \leftrightarrow$



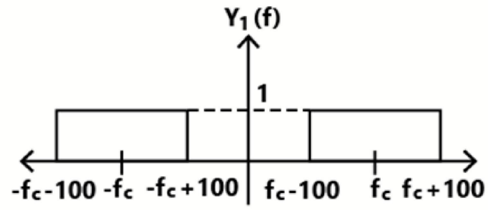
$$y(t) = 2g(t)\cos 2\pi f_C t + g^2(t)\cos^2 2\pi f_C t$$

$$y(t) = 2g\cos 2\pi f_C t + \frac{g^2(t)}{2} + \frac{g^2(t)}{2}\cos 4\pi f_C t$$

$$y(t) = y_1(t) + y_2(t) + y_3(t)$$

$$y_1(t) = 2g(t)\cos 2\pi f_C t$$

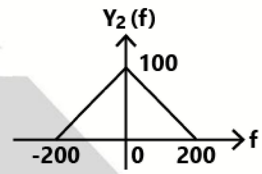
$$Y_1(f) = \left[G\left[f + f_C\right] + G\left(f - f_C\right)\right]$$



$$y_2(t) = \frac{g^2(t)}{2} = \frac{1}{2}\left[g(t).g(t)\right]$$

$$Y_2(f) = \frac{1}{2}\left[G(f)*G(f)\right]$$

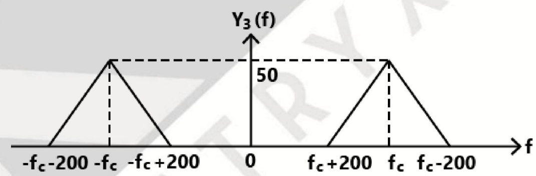
$Y_2(f) =$

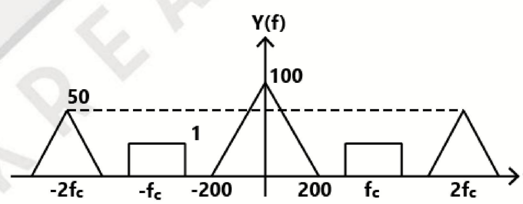


$$y_3(t) = \frac{g^2(t)}{2}\cos 4\pi f_C t$$

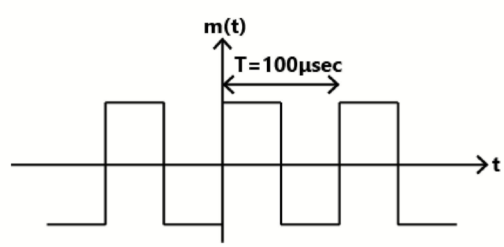
$$y_3(t) = y_2(t)\cos 4\pi f_C t$$

$$Y_3(f) = \frac{Y_2\left[f + 2f_C\right] + Y_2\left[f - 2f_C\right]}{2}$$





30. Ans: (c)
Solution:



$f_C = 1$ MHz

Symmetrical square wave

$m(t)$ is half symmetric (HWS)

Frequency components present in

$m(t) = f_0,\ 3f_0,\ 5f_0 \cdots\cdots$

$$f_0 = \frac{1}{T} = \frac{1}{100\mu\text{sec}} = 10 \text{ kHz}$$

Frequency component present in AM signal when message signal is HWS.

$f_c \pm f_m \qquad f_C \pm 3f_m \qquad f_C \pm 5f_m$

$f_C = 1000$ kHz

$$f_C \pm 3f_m \rightarrow \begin{vmatrix} \rightarrow 1030 \text{ kHz} \\ \rightarrow 970 \text{ kHz} \end{vmatrix}$$

$$f_C \pm 3f_m \rightarrow \begin{vmatrix} \rightarrow 1010 \text{ kHz} \\ \rightarrow 990 \text{ kHz} \end{vmatrix}$$

31. Ans: (c)
Solution:

$$y(t) = 5\times10^{-6}\sum_{n=-\infty}^{\infty} x(t)\delta(t - nT_S)$$

$y(t)$ is sampled signal

$$y(t) \xleftrightarrow{F.T} Y(f)$$

$$Y(f) = 5\times10^{-6}\left[\sum_{n=-\infty}^{\infty} f_S x(f - nf_S)\right]$$

$T_S = 100\ \mu$sec

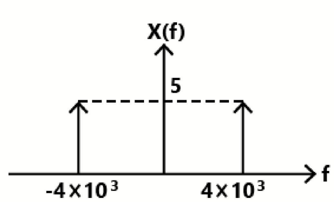
$f_S = 10^4 = 10$ kHz

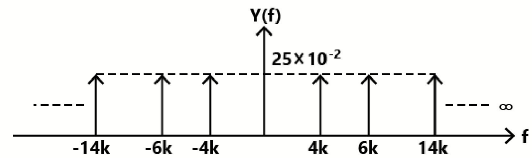
$$Y(f) = 5\times10^{-6} f_S \sum_{n=-\infty}^{\infty} x(f - nf_S)$$

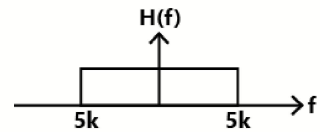
$$Y(f) = 5\times10^{-2}\sum_{n=-\infty}^{\infty} x(f - nf_S)$$

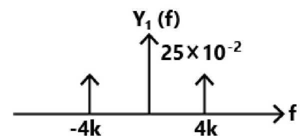
$$x(t) = 10\cos\left[8\pi\times10^3 t\right]$$

$$x(f) = \frac{10}{2}\left[\delta\left(f - 4\times10^3\right) + \delta\left(f + 4\times10^3\right)\right]$$









$$y_1(f) = 25\times10^{-2}\left[\delta(f - 4k) + \delta(f + 4k)\right]$$

$$y_1(f) = 50\times10^{-2}\frac{\left[\delta(f - 4k) + \delta(f + 4k)\right]}{2}$$

$$y_1(t) = 5\times10^{-1}\cos\left[8\pi\times10^3 t\right]$$

32. Ans: (d)
Solution:

$$S(t) = \left[\cos 2\pi\left[\begin{matrix} 2\times10^6 t + 30\sin150t \\ + 40\cos150t \end{matrix}\right]\right]$$

$$\theta_i(t) = 2\pi\left[2\times10^6 t + 30\sin150t + 40\cos150t\right] \rightarrow (1)$$

Comparing with:

$\theta_i(t) = \omega_C(t) + \Delta\phi$

$\Delta\phi = \left[30\sin150t + 40\cos150t\right]2\pi$

$$|\Delta\phi|_{max} = \left[\sqrt{(30)^2 + (40)^2}\right]2\pi = 50\times2\pi$$

$|\Delta\phi|_{max} = 100\pi$

Differentiation of equation (1)

$$\frac{d\theta_i(t)}{dt} = \omega_i$$

$\theta_i = 2\pi\left[2\times10^6 t + 30\sin150t + 40\cos150t\right]$

Comparing with $\omega_i(t) = \omega_C(t) + \Delta\omega$

$\Delta\omega = 2\pi\left[30(150)\cos150t - 40(150)\sin150t\right]$

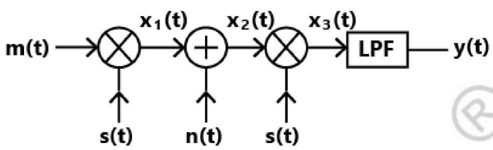
$$|\Delta\omega|_{max} = 300\pi\sqrt{(30)^2 + (40)^2}$$

$|\Delta\omega|_{max} = 300\pi\times50$

$$|\Delta f|_{max} = 7500 \text{ Hz}$$

$$|\Delta f|_{max} = 7.5 \text{ kHz}$$

33. Ans: (c)
Solution:



$$x_1(t) = m(t)s(t)$$

$$x_1(t) = \frac{2\sin 2\pi t}{t} \times \cos 200\pi t$$

$$x_1(t) = \frac{1}{t}\left[\sin 202\pi t - \sin 198\pi t\right]$$

$$x_2(t) = \frac{\sin 202\pi t}{t} - \frac{\sin 198\pi t}{t} + \frac{\sin 199\pi t}{t}$$

$$x_3(t) = x_2(t) \times \cos 200\pi t$$

$$x_3(t) = \left[\begin{array}{l} \dfrac{\sin 202\pi t \cos 200\pi t}{t} - \dfrac{\sin 198\pi t \cos 200\pi t}{t} \\ \qquad + \dfrac{\sin 199\pi t \cos 200\pi t}{t} \end{array}\right]$$

$$x_3(t) = \left[\begin{array}{l} \dfrac{1}{2t}\left[\sin(402\pi t) + \sin 2\pi t\right] \\ -\dfrac{1}{2t}\left[\sin(398\pi t) + \sin(-2\pi t)\right] \\ +\dfrac{1}{2t}\left[\sin 399\pi t + \sin(-\pi t)\right] \end{array}\right]$$

Frequency component of signal $x_3(t)$ are

201, 1, 199, 0.5, 199.5 Hz

Since cut-off frequency is 1 Hz for LPF so

$$y(t) = \frac{\sin 2\pi t}{2t} + \frac{\sin 2\pi t}{2t} - \frac{\sin \pi t}{2t}$$

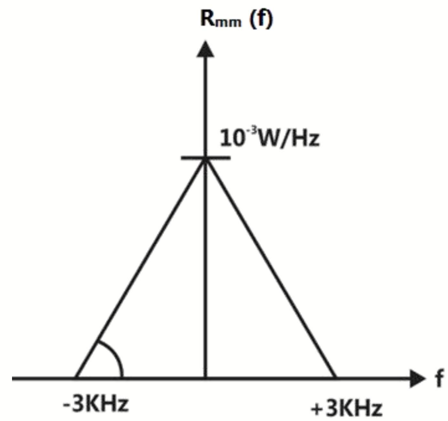
$$y(t) = \frac{1}{2t}\left[\sin 2\pi t + 2\sin\frac{(2\pi - \pi)}{2}t + \cos\frac{(2\pi + \pi)t}{2}\right]$$

$$y(t) = \frac{\sin 2\pi t}{2t} + \frac{\sin 0.5\pi t \cos 1.5\pi t}{t}$$

34. Ans: ---

Solution:

$$s(t) = 10\cos\left(2\pi \times 10^6 t + \phi\right) m(t^-)$$



$\phi \sim [0, 2\pi]$

$$R_{ss}(\tau) = E\{s(t)\, s(t+\tau)\}$$

$$R_{ss}(\tau) = \left[E\left\{\begin{array}{l} 10\cos\left(2\pi \times 10^6 t + \phi\right) m(t^-) \\ \times 10\cos\left(2\pi \times 10^6 (t+\tau) + \phi\right) m(t+\tau) \end{array}\right\}\right]$$

$$R_{ss}(\tau) = 100\, E\left\{\begin{array}{l} \cos\left(2\pi \times 10^6 t + \phi\right) \\ \times \cos\left(2\pi \times 10^6 (t+\tau) + \phi\right) m(t) \times m(t+\tau) \end{array}\right\}$$

In question it states to assume necessary assumption.
We assume $\phi(t)$ & $m(t)$ as independent.
If $\phi(t)$ & $m(t)$ are independent then

$$E\left[\phi(t) \cdot m(t)\right] = E\left[\phi(t)\right] \cdot E\left[m(t)\right]$$

$$R_s(\tau) = 100.E\left\{\begin{array}{l} \cos\left(2\pi \times 10^6 t + \phi\right) \\ \cos\left(2\pi \times 10^6 (t+\tau) + \phi\right) \end{array}\right\}$$

$$E\{m(t)\ m(t+\tau)\}$$

We know,

$$R_{mm}(t) = E\{m(t)\ m(t+\tau)\}$$

And $E\left\{\text{Cos}\left(2\pi \times 10^6 t + \phi\right)\cos\left(2\pi \times 10^6 (t+\tau) + \phi\right)\right\}$

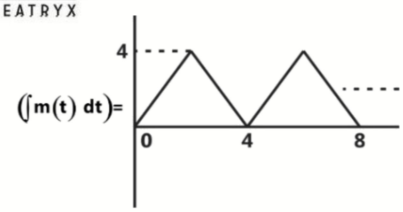
$$R_{mm}(\tau) = \left[\frac{1}{2} E\left\{\begin{array}{l} \cos\left(2\pi \times 10^6 \tau\right) \\ +\cos\left(2\pi \times 10^6 (2t+\tau) + 2\phi\right) \end{array}\right\}\right]$$

$$R_{mm}(\tau) = \frac{1}{2}\cos\left(2\pi \times 10^6 \tau\right) + 0$$

$$R_{ss}(\tau) = 50\cos\left(2\pi \times 10^6 \tau\right) \times R_{mm}(\tau)$$

$$S_{ss}(f) \leftrightarrow Ft\left[R_{ss}(\tau)\right]$$

$$S_{ss}(f) = \frac{50}{2}\left[\delta\left(f - 2\pi \times 10^6 t\right) + \delta\left(f + 2\pi \times 10^6\right)\right] \times S_{xx}(f)$$



$K_p \times 2 = K_f \times 2\pi \times 4$

$\frac{K_p}{K_f} = 4\pi$

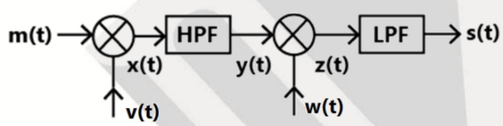
69. Ans: 0.5
Solution:

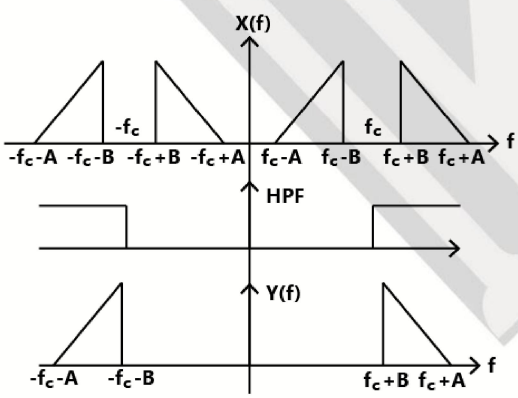
$m_a = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

$m_a = \frac{3-1}{3+1}$

$m_a = 0.5$

70. Ans: 60
Solution:





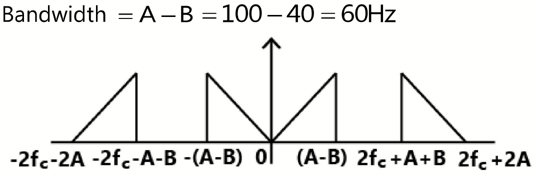
$x(t) = m(t)v(t)$

$x(t) = m(t)\cos(2\pi f_c t)$

$z(t) = y(t)\cos[2\pi(f_c + A)t]$

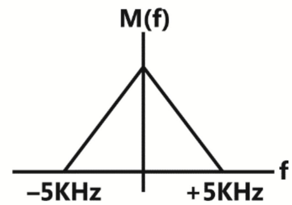
After passing through LPF

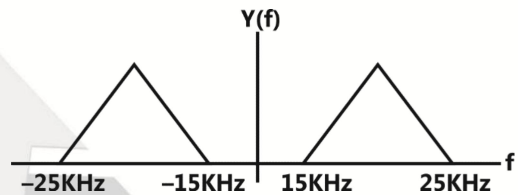
Bandwidth $= A - B = 100 - 40 = 60\text{Hz}$



71. Ans: 50
Solution:

$y(t) = m(t)\cos(40000\,\pi t)$





To recover $m(t)$ from band pass signal, where $m(t)$ is a base band signal

$-(\text{lowest frequency}) + f_s = f_{max}$ of $M(f)$

$f_s = f_{max}$ of $M(f) + [\text{lowest frequency of } Y(f)]$

$= 5 + 15 = 20\text{KHz}$

73. Ans: (a)
Solution:

$\theta_i(t) = 2\pi f_c t + \beta_1 \sin 2\pi f_1 t + \beta_2 \sin 2\pi f_2 t$

$\frac{d\theta_i(t)}{dt} = \omega_i = 2\pi f_c + 2\pi f_1 \beta_1 \cos 2\pi f_1 t + 2\pi f_2 \beta_2 \cos 2\pi f_2 t$

$f_i = f_c + f_1\beta_1 \cos 2\pi f_1 t + f_2 \beta_2 \cos 2\pi f_2 t$

$\Delta f = f_1\beta_1 \cos 2\pi f_1 t + f_2\beta_2 \cos 2\pi f_2 t$

$|\Delta f|_{max} = f_1\beta_1 + f_2\beta_2$

74. Ans: 4
Solution:

$A_C[1 + \mu m(t)]\cos w_C t$

$\frac{\text{total side band power}}{\text{carrier power}} = \frac{P_c \mu^2}{P_c 2} = \frac{\mu^2}{2}$

When μ becomes double $\frac{P_{SB}}{P_c} = 4 \times \frac{\mu^2}{2}$

$P_C = \frac{A^2}{2}$

$P_{SB} \propto \mu^2$

$\mu_2 = 2\mu_1$

$P_{SB(new)} \propto (\mu_2)^2$

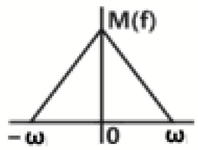
$\frac{P_{SB}}{P_{carrier}} = 4$

75. Ans: (c)
Solution:

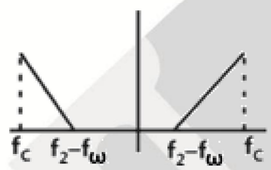
$\phi_{SDB} = m(t)\cos\omega_C f \mp \hat{m}(t)\sin\omega_C f$

$-V_C$ sign for upper band + sign for lower band

Let



$\phi(f) \rightarrow$



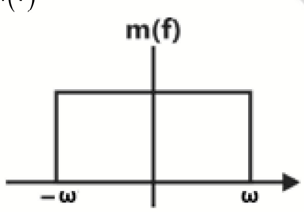
So it is band pass signal

Since frequency component near 0 is not present

76. Ans: 350
Solution:

$m(t) \rightarrow m_1(f)$

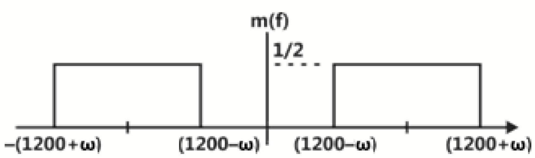
Let $m(f)$



$x(t) = m(t)\cos 2400\pi t$

$x(f) = \frac{1}{2}\left[m(f - f_C) + m(f + f_C)\right]$

$f_C = 1200$



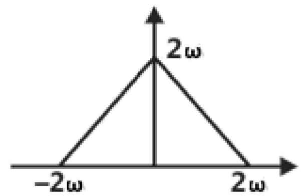
$y(t) = 10x(t) + x^2(t)$

$y(t) = 10m(t)\cos 2400\pi t + m^2(t)\cos^2 2400\pi t$

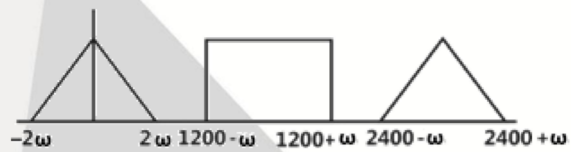
$y(t) = 10m(t)\cos 2400\pi t + \frac{m^2(t)}{2}\left[1 + \cos 4800\pi t\right]$

$y(t) = \frac{m^2(t)}{2} + \frac{m^2(t)}{2}\cos 4800\pi t + 10m(t)\cos 2400\pi t$

$m^2(t) \leftrightarrow$



$Y(f)$ for positive frequencies



The spectrum of $x^2(t)$ should lie in the stop land from 700 Hz to 1700 Hz.

$2\omega \le 700$

And $2400 - 2\omega \ge 1700$

$\omega_{max} = 350$

77. Ans: (c)
Solution:

$m(t) = A_m \sin(2\pi f_m t)$

Carrier $= A_C \cos(2\pi f_C t)$

$y(t) = A_C \cos(2\pi f_C t + m(t))$

$y(t) = A_C \cos(2\pi f_C t + A_m \sin 2\pi f_m t)$

$\theta_i = 2\pi f_C t + A_m \sin 2\pi f_m t$

$f_i = \frac{1}{2\pi}\frac{d\theta_i}{dt} = f_C + \frac{2\pi f_m}{2\pi} A_m \cos 2\pi f_m t$

$\Delta f_{max} = \frac{f_m A_m}{1}$

$\beta = \frac{\Delta f_{max}}{f_{max}} = A_m$

$BW = 2(\beta + 1) f_m$

$BW = 2(A_m + 1) f_m$

BW depends on both A_m & f_m

78. Ans: (c)
Solution:

$$x(t)=-\sqrt{2}\sin\frac{(\pi t/5)}{(\pi t/5)}\sin(\pi t-\pi/4)$$

$$x(t)=\begin{bmatrix}-\cos\frac{\pi}{4}\sin\pi t\times\sqrt{2}\sin\frac{(\pi t/5)}{(\pi t/5)}\\+\sin\frac{\pi}{4}\cos\pi t\times\sqrt{2}\sin\frac{(\pi t/5)}{(\pi t/5)}\end{bmatrix}$$

$$x(t)=\frac{\sin(\pi/5)}{(\pi t/5)}\cos\pi t-\frac{\sin\left(\frac{\pi t}{5}\right)}{\left(\frac{\pi t}{5}\right)}\sin(\pi t)$$

$$x(t)=x_c(t)\cos 2\pi f_c t-x_s(t)(\sin 2\pi f_c t)$$

(Low pass representation of Bandpass Signals

$$x_c(t)=\frac{\sin(\pi t/5)}{(\pi t/5)}$$

$$x_s(t)=\frac{\sin(\pi t/5)}{(\pi t/5)}$$

$$x_{ce}(t)=x_c(t)+jx_s(t)=\frac{\sin(\pi t/5)}{(\pi t/5)}[1+j]$$

$$x_{ce}(t)=\sqrt{2}\frac{\sin(\pi t/5)}{(\pi t/5)}e^{j\pi/4}$$

79. Ans: 5
Solution:

Image frequency $=f_C+2f_{if}\geq 68$

$58+2f_{if}\geq 68$

$f_{if}\geq 5$

80. Ans: 0.5
Solution:

$$S(t)=5\cos 1600\pi t+20\cos 1800\pi t+5\cos 2000\pi t$$

$$20\cos 1800\pi t+5(\cos 1600\pi t+\cos 2000\pi t)$$

$$20\cos 1800\pi t+10\cos 1800\pi t\cos 200\pi t$$

$$20\left(1+\frac{1}{2}\cos 200\pi t\right)\cos 1800\pi t$$

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

81. Ans: 3485
Solution:

$f_{if}=15\text{MHz}$

$f_{Lo}=3.5\text{GHz}$

$f_{signal}>f_{Lo}$

$f_S=f_{Lo}+f_{if}=3.5\times10^9+15\times10^6$

$f_S=3515\text{MHz}$

Since local oscillator is having less value than received signal value then.

Image freq $=f_S-2\times\text{IF}=3515-2\times15=3485$

82. Ans: 70
Solution:

$$x(t)=5\sin\left[4\pi\times10^3 t-10\pi\cos 2\pi\times10^3 t\right]$$

$$\theta_i(t)=\omega_c t+k_p x(t)$$

$$\omega_i=\omega_c+k_p\frac{d}{dt}x(t)$$

$$f_i=f_c+\frac{K_p}{2\pi}\frac{d}{dt}x(t)\text{ ....(i)}$$

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=\begin{bmatrix}\frac{5}{2\pi}\left[5\cos\left[4\pi\times10^3 t-10\pi\cos(2\pi\times10^3 t)\right]\right]\\\times\left[4\pi\times10^3+10\pi\sin(2\pi\times10^3 t)(2\pi\times10^3)\right]\end{bmatrix}$$

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=\begin{bmatrix}\frac{25}{2\pi}\cos\left(4\pi\times10^3 t-10\pi\cos(2\pi\times10^3 t)\right)\\\times\left[4\pi\times10^3+10\pi\sin(2\pi\times10^3 t)(2\pi\times10^3)\right]\end{bmatrix}$$

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=\begin{bmatrix}25\cos\left(4\pi\times10^3 t-10\pi\cos\left(2\pi\times10^3 t\right)\right)\\\times\left[2\times10^3+10\pi\times10^3\sin\left(2\pi\times10^3 t\right)\right]\end{bmatrix}$$

At t=0.5ms

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=25\begin{bmatrix}\cos(2\pi-10\pi\cos\pi)\\\times\left(2\times10^3+10\pi\times10^3\sin\pi\right)\end{bmatrix}$$

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=25\left[\cos(2\pi+10\pi)\left(2\times10^3+0\right)\right]$$

$$\frac{K_p}{2\pi}\frac{d}{dt}x(t)=25\times2\times10^3\cos 12\pi=50\text{ kHz}$$

From eq. (i)

f_i= 20k+50k = 70 kHz

83. Ans: 5.2
Solution:

Given $P_c=5\text{k watt}$ and $\mu_{max}=0.5=\frac{1}{2}$

$$P_{AM}=P_c\left[1+\frac{\mu^2}{2}\right]=5k\left[1+\frac{1}{2}\times\frac{1}{4}\right]$$

$$P_{AM}=5\times10^3\times\frac{9}{8}=5.625\text{k watt}$$

$$P_{cmax}\left[1+\frac{(0.4)^2}{2}\right]=5.625k$$

$$P_{cmax}\left[1+\frac{(0.16)}{2}\right]=5.625k$$

$$P_{cmax}(1.08)=5.625k$$

$$P_{cmax}=5.2k\text{ watt}$$

84. Ans: (0.25)
Solution:

$$4\cos(2400\pi t)+\cos(2000\pi)+\cos(2800\pi t)$$

Comparing with standard eg.

$$\left[\begin{array}{r}A_c\cos\omega_c t+\frac{A_c m_a}{2}\cos(\omega_c-\omega_m)t\\ +\frac{A_c m_a}{2}\cos(\omega_c+\omega_m)t\end{array}\right]\therefore$$

$$m_a=\frac{2}{A_c}\Rightarrow m_a=0.5$$

$$\text{Now } m_a=\frac{A_m}{A_c}=\frac{1}{2}\Rightarrow A_m=2$$

$$\text{Now } \frac{P_m}{P_c}=\frac{2}{8}=0.25$$

85. Ans: (d)
Solution:

$$c(t)=A_c\cos 2\pi f_c t$$

$$m(t)=\cos(2\pi f_m t)$$

$$F_c>>5f_m$$

$$V_i=c(t)+m(t)$$

$$V_0=av_i+bv_i^2(t)=a(c(t)+m(t))+b(c(t)+m(t))^2$$

$$V_0=a(c(t)+m(t))+bc^2(t)+bm^2(t)+2bm(t)c(t)$$

V_0 is passed through 1 deal band pass filter centre as f_c

$$m(t)\Rightarrow -f_m\,;f_m$$

$$c(t)\Rightarrow -f_c,\ f_c$$

$$c^2(t)\Rightarrow -2f_c,\ 2f_c$$

$$m^2(t)\Rightarrow -2f_m,\ 2f_m$$

$$m(t)c(t)\Rightarrow f_c-f_m \text{ to } f_c+f_m$$

$$f_c>>5_m$$

After band pass filter

$$a\cos\pi f_c t+2b\ \cos 2\pi f_m t\cos 2\pi f_c t$$

$$(a+2b\ \cos 2\pi f_m t)\cos 2\pi f_c t$$

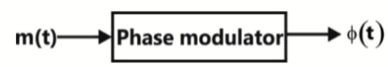
$$P_c=\frac{a^2}{2}$$

$$P\text{ side band }=\frac{4b^2}{4}=b^2$$

$$\frac{P\text{ side band}}{p_c}=\frac{b^2}{a^2}\times 2=\frac{1}{2}$$

$$a=2b\Rightarrow a/b=2$$

86. Ans: 0.74 to 0.76
Solution:



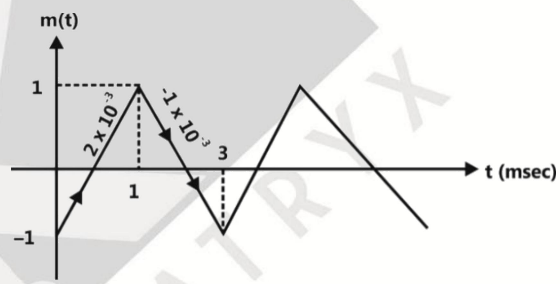
In phase modulation:
Instantaneous phase

$$\theta_i(t)=\omega_c t+Km(t)$$

$$\frac{d\theta_i(t)}{dt}=\omega_i(t)=2\pi f_i(t)=\omega_c+k\frac{dm(t)}{dt}$$

$$f_i(t)=f_c+\left(\frac{k}{2\pi}\right)\frac{dm(t)}{dt}$$

$$\frac{dm(t)}{dt}=\text{ slope of } m(t)$$



$$\left[\frac{dm(t)}{dt}\right]_{max}=2\times10^{-3}$$

$$\left[\frac{dm(t)}{dt}\right]_{min}=-1\times10^{-3}$$

$$[f_i(t)]_{max}=f_c+\frac{k}{2\pi}\left[\frac{dm(t)}{dt}\right]_{max}$$

$$=50k+\frac{10\pi}{2\pi}\times 2k=50k+10k=60k$$

$$[f_i(t)]_{min}=f_c+\frac{k}{2\pi}\left[\frac{dm(t)}{dt}\right]_{min}=50k-\frac{10\pi k}{2\pi}=45k$$

$$\text{Ratio }\frac{(f_i(t))_{min}}{(f_i(t))_{max}}=\frac{45}{60}=0.75$$

Electromagnetic Theory

08

Chapter 5 – Antennas

01. A radio wave is incident on a layer of ionosphere at an angle of 30 degree with the vertical. If the critical frequency is 1.2 MHz, the maximum usable frequency is **[1991]**
(a) 1.2 MHz (b) 2.4 MHz
(c) 0.6 MHz (d) 1.386 MHz

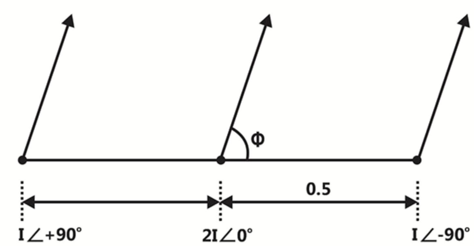
02. In a broad side array of 20 isotropic radiators, equally spaced at a distance of $\frac{\lambda}{2}$ the beam width between first nulls is **[1991]**
(a) 51.3 degrees (b) 11.46 degrees
(c) 22.9 degrees (d) 102.6 degrees

03. In the radiation pattern of a 3-element array of isotropic radiators equally spaced at distances of $\frac{\lambda}{4}$ it is required to place a null at an angle of 33.56 degrees off the end-fire direction. Calculate the progressive phase shifts to be applied to the elements. Also calculate the angle at which the main beam is placed for this phase distribution. **[1991]**

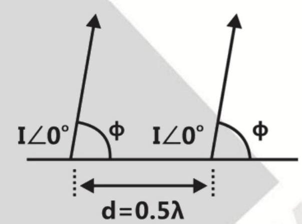
04. Two dissimilar antennas having their maximum directives equal, **[1992]**
(a) Must have their beams-widths also equal
(b) Cannot have their beam widths equal because they are dissimilar antennas
(c) May not necessarily have their maximum power gains equal
(d) Must have their effective aperture areas (capture areas) also equal.

05. The beam width between first null of uniform linear array of N equally spaced (element spacing = d), equally excited antennas is determined by **[1992]**
(a) N alone and not by d
(b) d alone and not by N
(c) the ratio, $\left(\frac{N}{d}\right)$
(d) the product, (Nd)

06. Elements of a linear array of three equally spaced (element spacing = 0.5λ) vertical mast radiators, are excited as given in figure. For the horizontal plane radiation pattern of the array, determine the direction of the major lobe (main lobe or principal lobe), and calculate its half-power beam width in degrees. **[1992]**



07. Consider an array of two non-directional radiators with spacing $d = 0.5\lambda$. Determine the directions of maximum radiation when the radiators are excited as shown in figure. Calculate the phase shift required for turning the direction of the maximum radiators by 90^o, keeping the separation, d, unchanged. **[1993]**



08. For a short wave radio link between two stations via the ionosphere, the ratio of the maximum usable frequency to the critical frequency **[1994]**
(a) Is always less than 1
(b) Is always greater than 1
(c) May be less than or more than 1 depending on the distance between the two stations
(d) Does not depend on the distance between the two stations.

09. For a dipole antenna **[1994]**
(a) The radiation intensity is maximum along the normal to the dipole axis
(b) The current distribution along its length is uniform irrespective of the length
(c) The effective length equals its physical length
(d) The input impedance is independent of the location of the feed-point.

10. An antenna, when radiating, has a highly directional radiation pattern. When the antenna is receiving, its radiation pattern **[1995]**
(a) Is more directive
(b) Is less directive
(c) Is the same
(d) Exhibits no directivity at all

11. A transverse electromagnetic wave with circular polarisation is received by a dipole antenna. Due to polarisation mismatch, the power transfer efficiency from the wave to the antenna is reduced to about **[1996]**

(a) 50% (b) 35.3%
(c) 25% (d) 0%

12. The critical frequency of an ionospheric layer is 10MHz. What is the maximum launching angle from the horizon for which 20 MHz wave will be reflected by the layer? **[1996]**

(a) 0° (b) 30°
(c) 45° (d) 90°

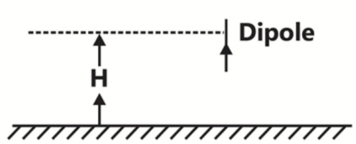
13. A 1 km long microwave link uses two antennas each having 30 dB gain. If the power transmitted by one antenna is 1W at 3 GHz, the power received by the other antenna is approximately **[1996]**

(a) $98.6\ \mu W$
(b) $76.8\ \mu W$
(c) $63.4\ \mu W$
(d) $55.2\ \mu W$

14. A parabolic dish antenna has a conical beam 2° wide, the directivity of the antenna is approximately **[1997]**

(a) 20 dB (b) 30 dB
(c) 40 dB (d) 50 dB

15. A dipole antenna has $\partial \sin\theta$ radiation pattern where the angle θ is measured from the axis of the diode. The diode is vertically located above an ideal ground plane the figure is. What should be the height of the diode H in terms of wavelength so as to get a null in the radiation pattern at an angle of 45^o from the ground plane? Find the direction of maximum radiation also. **[1997]**



16. The vector H in the far field of an antenna satisfies **[1998]**

(a) $\nabla.\vec{H} = 0$ and $\nabla \times \vec{H} = 0$
(b) $\nabla.\vec{H} \neq 0$ and $\nabla \times \vec{H} \neq 0$
(c) $\nabla.\vec{H} = 0$ and $\nabla \times \vec{H} \neq 0$
(d) $\nabla.\vec{H} \neq 0$ and $\nabla \times \vec{H} = 0$

17. An antenna in free space receives $2\mu W$ of power when the incident electric field is $20\ mV/m$ rms. The effective aperture of the antenna is **[1998]**

(a) $0.005\ m^2$ (b) $0.05\ m^2$
(c) $1.885\ m^2$ (d) $3.77\ m^2$

18. The maximum usable frequency of an ionospheric layer at 60° incidence and with 8MHz critical frequency is **[1998]**

(a) 16 MHz (b) $\frac{16}{\sqrt{3}}$MHz
(c) 8 MHz (d) About 6.93 MHz

19. The far field of an antenna varies with distance r as **[1998]**

(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$
(c) $\frac{1}{r^3}$ (d) $\frac{1}{\sqrt{r}}$

20. A transmitting antenna radiates 251 W isotropically. A receiving antenna, located 100 m away from the transmitting antenna, has an effective aperture of $500\,cm^2$. The total received by the antenna is **[1999]**

(a) $10\ \mu W$ (b) $1\ \mu W$
(c) $20\ \mu W$ (d) $100\ \mu W$

21. The average power of an omni directional antenna varies as the magnitude $\cos\theta$, where θ is the azimuthal angle. Calculate the maximum Directive Gain of the antenna and the angles at which it occurs. **[1999]**

22. If the diameter of a $\frac{\lambda}{2}$ dipole antenna is increased from $\frac{\lambda}{100}$ to $\frac{\lambda}{50}$, then its **[2000]**

(a) Bandwidth increases (b) Bandwidth decreases
(c) Gain increases (d) Gain decrease

23. For 8 feet (2.4 m) parabolic disk antenna operating at 4 GHz, the minimum distance required for far field measurement is closest to **[2000]**

(a) 7.5 cm (b) 15 cm
(c) 15 m (d) 150 m

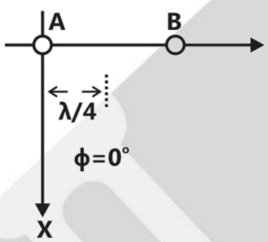
24. The line-of-sight communication requires the transmit and receive antenna to face each other. If the transmitted antenna is vertically polarized, for best reception the receive antenna should be **[2002]**

(a) Horizontally polarized
(b) Vertically polarized
(c) At 45° with respect to horizontal polarization
(d) At 45° with respect to vertically polarization

25. A person with a receiver is 5 Km away from the transmitter. What is the distance that this person must move further to detect a 3-dB decrease in signal strength? **[2002]**

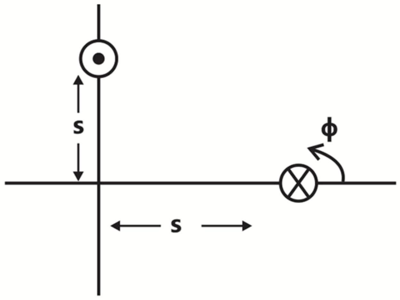
(a) 942 m (b) 2070 m
(c) 4978 m (d) 5320 m

26. Consider a linear array of two half-wave dipoles A and B as shown in Figure. The dipoles are $\frac{\lambda}{4}$ apart and are excited in such a way that the current on element B legs that on element A by 90° in phase. **[2002]**



(a) Obtain the expression for the radiation pattern for the radiation pattern for E_0 in the XY plane (i.e. $\theta = 90°$)
(b) Sketch the radiation pattern obtained in (a).

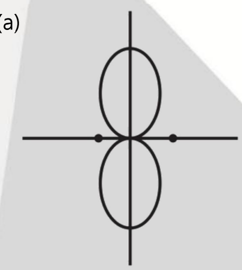
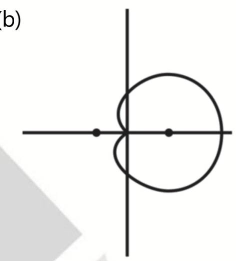
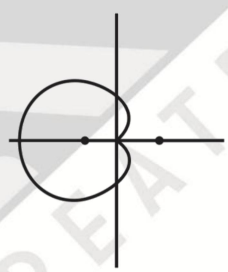
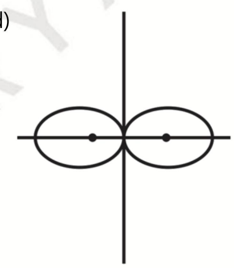
27. Two identical antennas are placed in the $\theta = \frac{\pi}{2}$ plane as shown in figure. The elements have equal amplitude excitation with 180° polarity difference, operating at wavelength λ. The correct value of the magnitude of the far-zone resultant electric field strength normalized with that of a single element, both computed for $\phi = 0$, is **[2003]**



(a) $2\cos\left(\frac{2\pi s}{\lambda}\right)$ (b) $2\sin\left(\frac{2\pi s}{\lambda}\right)$
(c) $2\cos\left(\frac{\pi s}{\lambda}\right)$ (d) $2\sin\left(\frac{\pi s}{\lambda}\right)$

28. Consider a lossless antenna with a directive gain of +6db. If 1mW of power is fed to it the total power radiated by the antenna will be **[2004]**
(a) 4mW
(b) 1mW
(c) 7mW
(d) $\frac{1}{4}$mW

29. Two identical and parallel dipole antennas are kept apart by a distance of $\frac{\lambda}{4}$ in the H-plane. They are fed with equal currents but the right most antenna has a phase shift of $+90^{\circ}$. The radiation pattern is given as **[2005]**

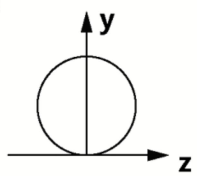
(a)

(b)

(c)

(d)


30. A mast antenna consisting of a 50 meter long vertical conductor operates over a perfectly conducting ground plane. It is base-fed at a frequency of 600 kHz. The radiation resistance of the antenna in Ohm is: **[2006]**

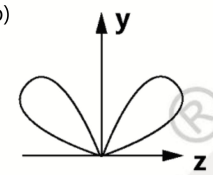
(a) $\frac{2\pi^2}{5}$
(b) $\frac{\pi^2}{5}$
(c) $\frac{4\pi^2}{5}$
(d) $20\pi^2$

31. A $\frac{\lambda}{2}$ dipole is kept horizontally at a height of $\frac{\lambda_0}{2}$ above a perfectly conducting infinite ground plane. The radiation pattern in the plane of the dipole ($\vec{E}$ plane) looks approximately as **[2007]**

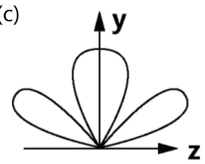
(a)



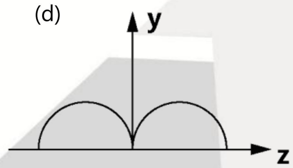
(b)



(c)



(d)



32. For a Hertz dipole antenna, the half power beam width (HPBW) in the E-plane is **[2008]**

(a) 360° (b) 180°
(c) 90° (d) 45°

33. At 20 GHz, the gain of a parabolic dish antenna of 1 meter diameter and 70% efficiency is **[2008]**

(a) 15 dB (b) 25 dB
(c) 35 dB (d) 45 dB

34. The radiation pattern of an antenna in spherical co-ordinates is given by **[2012]**

$F(\theta)=\cos^4\theta;\ 0\le\theta\le\pi/2$

The directivity of the antenna is

(a) 10 dB (b) 12.6 dB
(c) 11.5 dB (d) 18 dB

35. In spherical coordinates, let $\hat{a}_\theta, \hat{a}_\phi$ denote unit vectors along the θ, ϕ directions. **[2014-01]**

$$E=\frac{100}{r}\sin\theta\cos(\omega t-\beta r)\,\hat{a}_\theta\ V/m$$

And $$H=\frac{0.265}{r}\sin\theta\cos(\omega t-\beta r)\hat{a}_\phi V/m$$

Represent the electric and magnetic field components of the EM wave at large distances r from a dipole antenna, in free space. The average power (W) crossing the hemispherical shell located at r=1km, $0\le\theta\le\pi/2$ is__________.

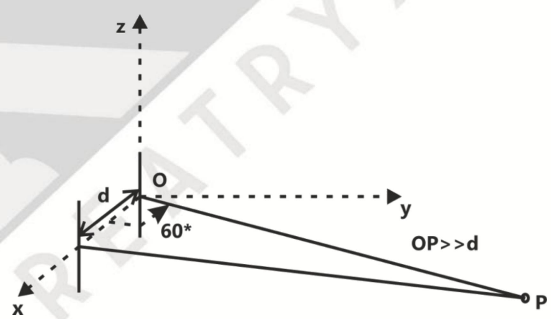
36. For an antenna radiating in free space, the electric field at a distance of 1 km is found to be 12mV/m. Given that intrinsic impedance of the free space is 120π Ω, the magnitude of average power density due to this antenna at a distance of 2 km from the antenna (in nW/m^2) is ____. **[2014-04]**

37. Match column A with column B. **[2014-04]**

Column A	Column B
1. Point electromagnetic source	P. Highly directional
2. Dish antenna	Q. End fire
3. Yagi-Uda antenna	R. Isotropic

(a) $1\rightarrow P$, $2\rightarrow Q$, $3\rightarrow R$
(b) $1\rightarrow R$, $2\rightarrow P$, $3\rightarrow Q$
(c) $1\rightarrow Q$, $2\rightarrow P$, $3\rightarrow R$
(d) $1\rightarrow R$, $2\rightarrow Q$, $3\rightarrow P$

38. Two half-wave dipole antennas placed as shown in the figure are excited with sinusoidally varying currents of frequency 3 MHz and phase shift of π/2 between them (the element at the origin leads in phase). If the maximum radiated E-field at the point P in the x-y plane occurs at an azimuthal angle of 60°, the distance d (in meters) between the antennas is ________. **[2015-02]**



39. The directivity of an antenna array can be increased by adding more antenna elements, as a larger number of elements **[2015-03]**

(a) Improves the radiation efficiency
(b) Increases the effective area of the antenna
(c) Results in a better impedance matching
(d) Allows more power to be transmitted by the antenna

40. Two lossless X-band horn antennas are separated by a distance of 200λ. The amplitude reflection coefficients at the terminals of the transmitting and receiving antennas are 0.15 and 0.18, respectively. The maximum directivities of the transmitting and receiving antennas (over the isotropic antenna) are 18 dB and 22 dB, respectively. Assuming that the input power in the lossless transmission line connected to the antenna is 2 W, and that the antennas are perfectly aligned and polarization matched, the power (in mW) delivered to the load at the receiver is____________ **[2016-01]**

41. The far-zone power density radiated by a helical antenna is approximated as:

$$\vec{W}_{rad} = \vec{W}_{average} \approx a_r C_0 \frac{1}{r^2} \cos^4 \theta$$

The radiated power density is symmetrical with respect to Ø and exists only in the upper hemisphere: $0 \le \theta \le \frac{\pi}{2}; 0 \le \phi \le 2\pi; C_0$ is a constant. The power radiated by the antenna (in watts) and the maximum directivity of the antenna, respectively, are **[2016-01]**

(a) $1.5C_0$, 10dB
(b) $1.256C_0$, 10dB
(c) $1.256C_0$, 12dB
(d) $1.5C_0$, 12dB

42. A radar operating at 5 GHz uses a common antenna for transmission and reception. The antenna has a gain of 150 and is aligned for maximum directional radiation and reception to a target 1 km away having radar cross-section of 3 m^2. If it transmits 100 kW, then the received power (in μW) is ______________ **[2016-03]**

43. Consider a wireless communication link between a transmitter and a receiver located in free space, with finite and strictly positive capacity. If the effective areas of the transmitter and the receiver antennas, and the distance between them are all doubled, and everything else remains unchanged, the maximum capacity of the wireless link **[2017-01]**

(a) increases by a factor of 2
(b) increases by a factor of 2
(c) remains unchanged
(d) decreases by a factor or $\sqrt{2}$

44. A half wavelength dipole is kept in the x-y plane and oriented along 45° from the x-axis. Determine the direction of null in the radiation pattern for $0 \le \phi \le \pi$. Here the angle $\theta(0 \le \theta \le \pi)$ is measured from the z-axis, and the angle $\phi(0 \le \phi \le 2\pi)$ is measured from the x-axis in the x-y plane. **[2017-01]**

(a) $\theta = 90°, \phi = 45°$
(b) $\theta = 45°, \phi = 90°$
(c) $\theta = 90°, \phi = 135°$
(d) $\theta = 45°, \phi = 135°$

45. Radiation resistance of a small dipole current element of length I at a frequency of 3GHz is 3 ohms. If length is changed by 1% then the percentage change in the radiation resistance, rounded off to two decimal places, is ____% **[2019]**

Solution

01. Ans: (b)
Solution:
The maximum usable frequency of radio wave incident ion a layer of ionosphere is given by,

$$f_{max} = \frac{f_c}{\sin\theta_i}$$

θ_i : Angle of incidence

f_c : critical frequency

Thus,

$$f_{max} = \frac{1.2\times10^6}{\sin30^\circ} = 2.4 \text{ MHz}$$

02. Ans: (b)
Solution:
Broadside antenna array of 20 isotropic radiators are equally spaced at distance of,

$$d = \frac{\lambda}{2}; \qquad N = 20$$

The directions of nulls, θ_{null} is given by,

$$\sin\left(\frac{N\psi}{2}\right) = 0 \quad \text{(Array factor)}$$

Where, $\psi = \beta d\cos\theta + \alpha$

OR $\psi = \beta d(\cos\theta_{null} - \cos\theta_{max})$

$$\frac{N\psi}{2} = \pm m\pi,\ m = 1,2,3....$$

$$\beta d(\cos\oplus_{null} - \cos\oplus_{max}) = I\ \frac{2m\pi}{N}$$

Thus, $\cos\theta_{null} = \cos\theta_{max} \pm = \frac{m\lambda}{dN}$, m = 1,2,3....

For Broadside; $\theta_{max} = 90^\circ \Rightarrow \cos\theta_{max} = 0$

Thus, $\theta_{null} = \cos^{-1}\left[\frac{m.\lambda}{N.d}\right] = \cos^{-1}\left[\frac{\lambda}{20(\lambda/2)}\right]$;

m = 1,2,3.... First null

$$\theta_{null} = \cos^{-1}(0.1) = 84.26^\circ \text{ or } 5.739^\circ$$

$$\theta_{BWFN} = 2.\theta_{null} = 11.47^\circ$$

03. Ans: - $\pi/4$
Solution:
3 – element array of isotropic radiators equally spaced at $d = \frac{\lambda}{4}$

$$\therefore N = 3;\ d = \frac{\lambda}{4}$$

The direction of nulls is given by,

$$\sin\left(\frac{N\psi}{2}\right) = 0$$

$$\frac{N\psi}{2} = \pm m\pi; \quad m = 0,1,2,3....$$

$$\beta d(\cos\phi_{null} - \cos\phi_{max}) = \frac{\pm 2m\pi}{N}$$

Also, $\beta d = \frac{2\pi}{\lambda}\times\frac{\lambda}{4} = \frac{\pi}{2}$, N = 3, m = 1

$$\cos\phi_{null} = \cos\phi_{max} \pm \frac{2\pi}{\left(\frac{3\pi}{2}\right)}$$

$\because$ It is required to place a null at 33.56°.

$(\phi_{null} = 33.56^\circ)$

$$\cos(\phi_{max}) = \left(\frac{4}{3}\right) - \cos(33.56^\circ) \simeq 0.5$$

$\therefore \phi_{max} = 60^\circ$

<u>Note:</u> Direction of max radiation is independent of "N".

Also, $\phi_{max} = \cos^{-1}\left(\frac{-\delta}{\beta d}\right)$

$$\delta = \pi/4$$

04. Ans: (c)
Solution:
The directivity and the effective aperture area of any antenna is related by,

$$\frac{Ae}{D} = \frac{\lambda^2}{4\pi}; \qquad \lambda_1 \neq \lambda_2 \text{ (dissimilar)}$$

Thus, two dissimilar antennas may not have effective areas equal.

The power gain and directive gain are related by,

$$G_P(\theta_1\phi) = \frac{4\pi\ .\ U(\theta_1\phi)}{P_{in}}$$

Maximum power gain is given by,

$$G_{Pmax} = \frac{4\pi.\upsilon_{max}}{P_{in}}(\theta_1\phi) = D.\left(\frac{Prad}{P_{im}}\right)$$

Given: $D_1 = D_2$, but however the power accepted by both antennas may offer as they are dissimilar

$\therefore$ The maximum power gains may not necessarily be equal

05. Ans: (d)
Solution:
The array factor of N – equally spaced and excited antennas is given by,

$$|AF| = \left|\frac{\sin\frac{N\psi}{2}}{\sin\frac{\psi}{2}}\right|; \qquad \psi = \beta d\cos\oplus + \alpha$$

The directions of the nulls ϕ_{null} is given by,

$$\sin\frac{N\psi}{2} = 0$$

$$\frac{N\psi}{2} = \pm m\pi,\ m = 1,2,3\ldots$$

$$\psi = \frac{\pm 2m\pi}{N}$$

Thus, $\beta \,.\, d\left(\cos\phi_{null} - \cos\phi_{max}\right) = \frac{\pm 2m\pi}{N}$

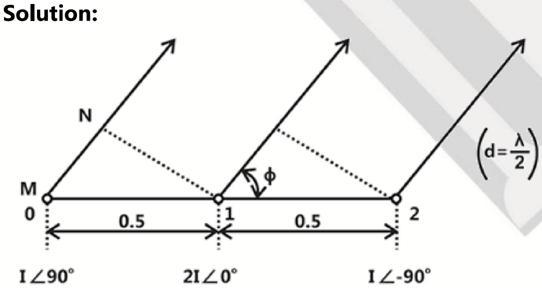
Where $\beta = \frac{2\pi}{\lambda}$

$$\cos\phi_{null} = \cos\phi_{max} \pm \frac{m\lambda}{Nd}$$

Where, $\cos\phi_{max} = \frac{-\lambda}{\beta d}$

$\therefore$ The Beam width between first nulls depends on the product (N. d)

06. Ans:---
Solution:



Path difference $(MN) = d\cos\phi$

Phase difference $= \beta d\cos\phi$

$$\therefore \beta d = \frac{2\pi}{\lambda}\times\frac{\lambda}{2} = \pi$$

Also, Progressive phase shift b/w the currents,

$$\alpha = -\pi/2$$

$$\therefore\ \psi = \beta d\cos\phi + \alpha$$

$$\psi = \pi\cos\phi - \frac{\pi}{2}$$

Note: $\psi = \beta d\left(\cos\phi - \cos\phi_{max}\right)$

Where $\cos\phi_{max} = \frac{-\alpha}{\beta d}$

The direction of major lobe is given by,

$$\phi_{max} = \cos^{-1}\left[\frac{-\alpha}{\beta d}\right] = \omega s^{-1}\left[\frac{1}{2}\right]$$

$$\therefore \phi_{max} = 60^{o}$$

The half power Beam width is given by,

$$\sin\left(\frac{N\psi}{2}\right) = \frac{1}{2}$$

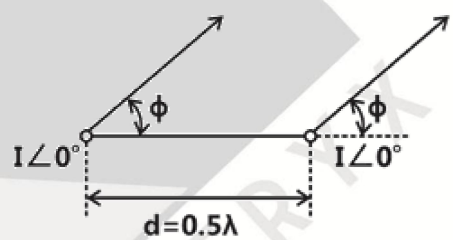
$$\psi = \frac{2}{N}\left(\pi/6\right) = \frac{\pi}{9}$$

$$\therefore\ \beta d\ \left(\cos\phi_{HPBW} - \cos\phi_{max}\right) = \pi/9$$

$$\cos\phi_{HPBW} = \frac{1}{9} + \frac{1}{2} = 0.6111$$

Thus, $\phi_{HPBW} \simeq 52.33°$

07. Ans:-180°
Solution:



Array factor for 2-element array (normalized) =

$$\cos\left[\frac{1}{2}(\beta d\cos\phi + \alpha)\right]$$

$$\beta d = \frac{2\pi}{\lambda}\times\frac{\lambda}{2} = \pi; \qquad \lambda = 0\ \text{(given)}$$

To find maxima,

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

$$\cos\phi_{max} = 0$$

$$\therefore\ \phi_{max} = \pm 90°\ \text{(Broadside)}$$

The phase shift (α) required for turning the direction of maximum radiators by 90°

$$\cos\left[\frac{1}{2}\left(\pi\cos\phi_{max} + \alpha\right)\right] = 1$$

Where $\phi_{max} = 180°$ and $\alpha = \pi$ (shifted ϕ_{max} by 90°)

08. Ans: (b)
Solution:
The maximum usable frequency depends on:
a) Angle of incidence on the layer of ionosphere
b) Critical frequency

i.e. $f_{max} = \dfrac{f_c}{\sin\theta_i}$

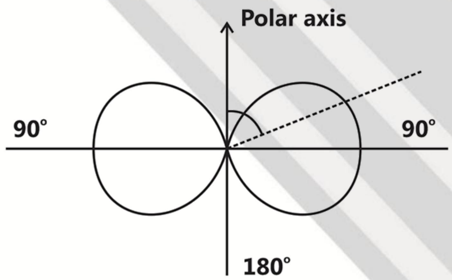
$$\frac{f_{max}}{fc} = \frac{1}{\sin\theta_i}$$

$\because$ $\sin\theta_i$ is always $0 \le \sin\theta_i \le 1$

$$\frac{f_{max}}{fc} \ge 1$$

09. Ans: (a)
Solution:
For a dipole antenna, the radiation intensity is maximum along the normal to the axis.
For Hertzian dipole, the normalized power pattern is given by,

$$f^2(\theta) = \sin^2\theta$$



$\therefore$ The maximum average power is at $\theta = 90^o$ (normal to the axis)
Also, Radiation intensity $(\upsilon(\theta,\phi)) = r^2$
υ_{max} is along the normal to the axis of dipole.

10. Ans: (c)
Solution:
The Radiation pattern of the antenna is the same regardless of whether it is radiating or receiving.
An antenna is a Reciprocal device, principle of reciprocity holds.

11. Ans: (a)
Solution:
The circularly polarized wave up of two linearly polarized components orthogonal to each other
A dipole antenna is a linearly polarized antenna. Thus, it receives only one of the components in phase with the polarization of the dipole
Thus, there is a 3dB power loss, as only one half is received.
$\therefore$ The power transfer efficiency is 50%

12. Ans: (b)
Solution:

$$f_{max} = \frac{f_c}{\sin\theta_i}$$

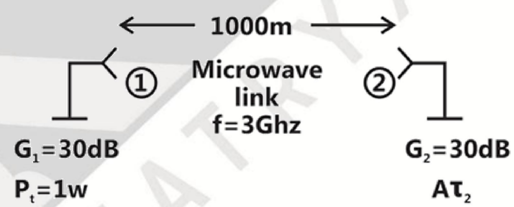
$$\sin\theta_i(max) = \left(\frac{f_c}{f_{inc}}\right)$$

Thus, $\theta_i(max) = \sin^{-1}\left[\dfrac{f_c}{f_{inc}}\right]$

Where θ_i – max launching angle
f_c – critical frequency at ionosphere
f_{inc} – incident frequency
$\because f_c = 10MHz$, $\because f_{inc} = 20MHz$

$$\theta_i \max = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$

13. Ans: (c)
Solution:



Power transmitted per unit area by antenna (1) is:

$$P^r = \frac{P_t G_1}{4\pi r^2}$$

The received power by antenna (2)

$$P_r = \frac{P_t G_1}{4\pi r^2}.Ae_2 \qquad \because \lambda = \frac{L}{f} = \underline{\underline{0.1m}}$$

But, $Ae_2 = \dfrac{\lambda^2}{4\pi}.G_2$ $\qquad G_1 = G_2 = 10^3$

$r = 1000m$

Thus,

$$P^r = \frac{P_t.G_1.G_2.\lambda^2}{(4\pi r)^2}$$

$$P^r = \frac{1\times(1000)^2\times(0.1)^2}{(4\pi\times1000)^2} = \underline{\underline{63.4\ \mu w}}$$

14. Ans: (c)
Solution:
The half power beam width of the parabolic antenna in both planes is given as;

$$\phi_{3dB} = \theta_{3dB} = 2^o$$

Directivity of a parabolic antenna is given by,

$$D = \frac{4\pi}{\phi_{3dB}.\theta_{3dB}}$$; angle in radians 4π (stendions)

OR

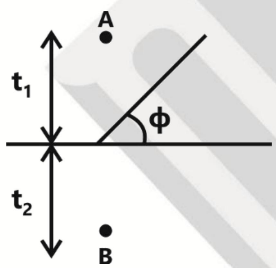
$$D = \frac{41,253}{\phi_{3dB}.\theta_{3dB}}; \qquad \because\ 4\pi \text{ str} = \left(\frac{4\pi\times180^o}{\pi^2}\right)$$

Angle in degree

Thus, $D = \dfrac{41,253}{2\times 2} \simeq 10,000$

In dB,
D = 40dB

15. Ans: ---
Solution:



Because of perfect reflection form ideal ground dipole configuration is equivalent to 2-element array.
Where B is mirror image antenna.

$$\alpha = 0\ ;\ \ \beta d = \frac{2\pi}{\lambda}\times 2H = \frac{4\pi H}{\lambda}$$

$$\psi = \beta d \sin\phi + \alpha$$

$$E = E_A\left(1+ke^{j\psi}\right) = E_A\sqrt{\left(1-k\cos\psi\right)^2 + k^2\sin^2\psi}$$

For k = 1

$$\frac{E_T}{E_A} = 2\cos\left(\frac{\psi}{2}\right)$$

$$\psi = \beta d\cos\phi = \begin{cases} 2 & \text{max at } \psi = 0 \\ 0 & \text{min at } \psi = \pi \end{cases}$$

For null at $\phi = 45°$

$$\psi = \pi = \frac{4\pi H}{\lambda}\left(\frac{1}{\sqrt{2}}\right)$$

$$H = \frac{\lambda}{2\sqrt{2}}$$

For maximum radiation

$\psi = 0,$

$\beta d\cos\phi = 0$

$\phi = 90°$

16. Ans: (c)
Solution:
The $\vec{H}$ In the for field of an antenna is satisfies

$\vec{\nabla}\times\vec{H} = J_c + j_d$ (Modified Amperes Law)

$\vec{\nabla}.\vec{H} = 0$ (Gauss's Law)

Thus, $\vec{\nabla}\times\vec{H} \neq 0$, $\vec{\nabla}.\vec{H} = 0$

17. Ans: (c)
Solution:

$$P_r = \frac{E^2}{\eta}\times A_e$$

Here $E = \text{rms value of electric field} = 20\text{mV}$

$A_e = 1.885\text{m}^2$

18. Ans: (b)
Solution:
The maximum usable frequency of an ionosphere is given by,

$$f_{max} = \frac{f_c}{\sin\theta i}$$

$\because\ f_c = 8$ MHz, $\theta i = 60^o$

$$f_{max} = \frac{8\times10^6}{\sin 60^o} = \frac{16}{\sqrt{3}}\text{MHz}$$

$$f_{max} = \frac{16}{\sqrt{3}}\text{ MHz}$$

19. Ans: (a)
Solution:

20. Ans: (d)
Solution:
Power density at 100 m away,

$$P_{av} = \frac{P_t}{4\pi R^2} = \frac{251}{4\pi\times100^2} = 1.997\times10^3\ \text{w/m}^2$$

Effective apertures is,

$A_e = 500\text{cm}^2 = 5\times10^{-2}\text{m}^2$

Thus,
Power received is given by,

$$P_r = P_{av}\times A_e$$

$$P_r = \frac{251}{4\pi\times10^4}\times5\times10^{-2} \simeq 100\mu\text{W}$$

$$P_r = 100\ \mu\text{W}$$

21. Ans: ---
Solution:
Radiation intensity in (θ,ϕ) direction

$\phi(\theta,\phi)=\phi_m|\cos\theta|$

Total power radiated

$$W_r=\int\phi(\theta,\phi)d\Omega=\int\phi_m\cos\theta d\theta d\phi=\pi\phi_m$$

$$\phi_{avg}=\frac{W_r}{4\pi}=\frac{\phi_m}{4}$$

Directive gain $g_d(\theta,\phi)=\dfrac{\phi(\theta,\phi)}{\phi_{avg}}$

$$g_d(\theta,\phi)=\frac{4\phi_m|\cos\theta|}{\phi_m}=4|\cos\theta|$$

Directivity (max) = 4
at $\theta=0°,180°$

22. Ans: (c)
Solution:

$$\text{Gain}(G)=\frac{4\pi}{\lambda^2}\times A_e$$

$A_e=\text{aperture area}\propto(\text{diameter})^2$

Diameter $\uparrow\rightarrow A_e\uparrow\rightarrow G\uparrow$

23. Ans: (d)
Solution:
The far field boundary is given by,

$$d_{min}=\frac{2d^2}{\lambda}$$

l = Largest dimension of antenna
λ = wave length
$\therefore$ f = GHz

$$\lambda=\frac{c}{f}=0.75\times10^{-1}=7.5\text{cm}$$

And
l = 2.4 m (Given)

$$\therefore d_{min}=\frac{2\times2.4^2}{0.075}=153.6\text{ m}$$

$d_{min}\simeq150\text{ m}$

24. Ans: (b)
Solution:
Line of sight communication, for it reception, both the transmit and over antennas should be of same polarisations.

Thus, if the transmit antenna is verticallty polarized, for best reception receive antenna must also be vertically polarized.

25. Ans: (b)
Solution:
The power Vane's inversely with square of distance,

$$P\ \alpha\ \frac{1}{r^2}$$

Thus, $\dfrac{P_1}{P_2}\ \alpha\ \dfrac{r_2^2}{r_1^2}$

The 3 – dB decrease in signal strength corresponds to having of the power.

$$\therefore P_2=\frac{1}{2}\cdot P_1$$

$$\frac{r_2^2}{r_1^2}=2$$

$$r_2^2=2\times5^2$$

$\therefore r_2=\underline{5\sqrt{2}\text{ km}}$

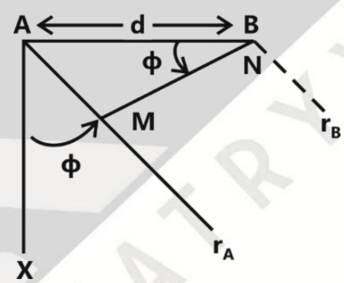
The distance to move to reduce to 3dB,

$\Delta r=r_2-r_1$

$\Delta r=5\sqrt{2}-5\simeq2070\text{m}$

$\therefore\Delta r=2070\text{m}$

26. Ans: ---
Solution:



(a) Linear array

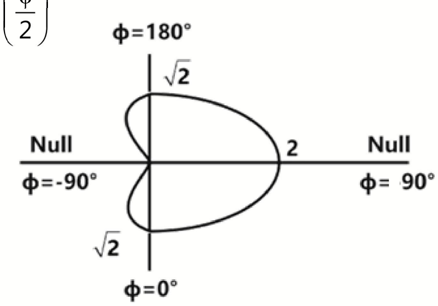
Path difference = $r_B-r_A=-d\sin\phi$

$\psi=\beta d\sin\phi+\alpha$

$$E=E_A\left(1+ke^{j\psi}\right)=E_A\sqrt{(1-k\cos\psi)^2+k^2\sin^2\psi}$$

For k = 1

$$\left|\frac{E_T}{E_A}\right|=2\cos\left(\frac{\psi}{2}\right)$$



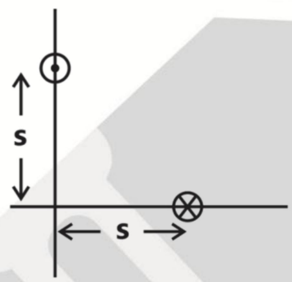
(b) For $d = \frac{\lambda}{4}$, $\beta d = \frac{\pi}{2}$ $\alpha = -\frac{\pi}{2}$

$$\psi = \beta d \sin\phi + \alpha = \frac{\pi}{2}\sin\phi - \frac{\pi}{2}$$

$$\left|\frac{E_T}{E_A}\right| = 2\cos\left[\left(\frac{\pi}{4}\sin\phi - \frac{\pi}{4}\right)\right]$$

27. Ans: (d)
Solution:
Normalised array factor $= 2\left|\cos(\psi/2)\right|$

$$\psi = \beta d \sin\theta\cos\phi + \delta$$
$$\theta = 90°$$
$$\phi = 45°$$
$$\delta = 180°$$
$$d = \sqrt{2}s$$



28. Ans: (a)
Solution:
Directive Gain (G_0) = + 6 dB, P_{input} = 1mW

Converting dB to $\left(W/_W\right)$ form,

$$G_D = 10^{0.6} = 3.98 = 4$$
$$P_{rad} = G_D \times P_{input}$$
$$P_{rad} = 4 \times 10^{-3}$$
$$P_{rad} = 4\text{ mW}$$

29. Ans: (a)
Solution:
The array factor is given by,

$$AF = \cos\left(\frac{\beta d \sin\theta + \alpha}{2}\right)$$

Here, $\beta = \frac{2\pi}{\lambda}$; $d = \frac{\lambda}{4}$ and $\alpha = 90^0$

Thus, $AF = \cos\left[\frac{\frac{2\pi}{\lambda}\cdot\frac{\lambda}{4}\sin\theta + \pi/_2}{2}\right]$

$$= AF = \cos\left(\frac{\pi}{2}\sin\theta + \frac{\pi}{4}\right)$$

For maxima, $AF = 1$

$$\frac{\pi}{4}\sin\theta + \frac{\pi}{4} = \pm m\pi$$
$$\sin\theta = \pm(4m - 1)$$

for $m = 0$

$$\sin\theta = \pm 1$$

So $\theta = \pm\frac{\pi}{2}$

Only option (A) satisfies above equation.

30. Ans: (a)
Solution:
Most antenna,

Weight = 50m

∵ The antenna is installed above a conducting plane (ground),

$$\text{Radiation Resistance} = \frac{40\pi^2 \text{ x } (dl)^2}{\lambda^2}$$

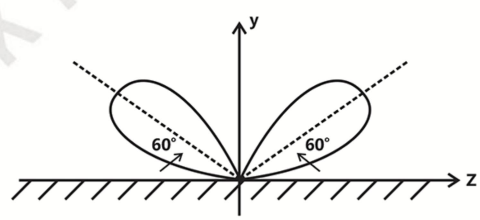
$$= \frac{40\pi^2 \text{ x } (50)^2}{\lambda^2}$$

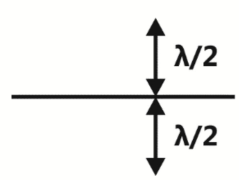
∵ f = 600kHz

$$\therefore \lambda = \frac{c}{f} = \frac{3\times10^8}{6\times10^5} = 0.5\times10^3\text{m}$$

$$\therefore P_{rad} = 40\pi^2\left(\frac{50}{0.5\times10^3}\right) = \frac{2\pi^2}{5}$$

31. Ans: (b)
Solution:





Method of images

$\beta d = \frac{2\pi}{\lambda} \times \lambda = 2\pi$

$\delta = \pi$

$AF = \cos\left(\frac{\beta d \cos\phi + \delta}{2}\right)$

$= \cos\left(\frac{2\pi\cos\phi + \pi}{2}\right)$

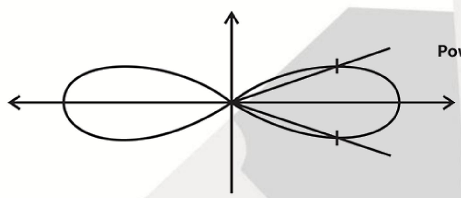
$= \sin(\pi\cos\phi)$

On plotting array factor (AF) we get option b

32. Ans: (c)

Solution:

For Hertzion dipole antenna, the E – plane pattern is,



The total beamwidth = 180°

Thus, the beam width between half power points is given by,

Normalized $|E_s|^2 = |\sin^2\theta|$

Thus, $\sin^2\theta = \frac{1}{2}$ (at half power)

$\theta = \sin^{-1}\left[\frac{1}{\sqrt{2}}\right] = 45^0$

$\therefore HPBW = 2\theta = 90^0$

33. Ans: (d)

Solution:

f = 20 GHz,

Diometer of parabolic (d) = 1m

Dish antenna

Efficiency = 70%

The directive gain is given by,

$\frac{Ae}{D} = \frac{\lambda^2}{4\pi}$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{2\times10^{10}} = 1.5 \text{ cm}$

$D = \frac{4\pi}{(1.5\times10^{-2})^2} \times Ae$

$\therefore Ae = \frac{\pi D^2}{4} = \frac{\pi}{4} m^2$

$D = \frac{\pi}{2.25\times10^{-4}} \times \pi/4 = 43,864.9$

Power gain = η x directive gain

$G_p = 0.7 \times 43,864.9 = 30,705.4$

Converting to dB,

$G_{p\,(dB)} = 44.87dB \simeq 45dB$

34. Ans: (a)

Solution:

The radiation intensity is given by,

$F(\theta) = \cos^4\theta\ ;\ 0 \le \theta \le \frac{\pi}{2}$

Directivity is given by;

$D = \left(\frac{F_{max}}{F_{avg}}\right)$

$F(\theta) = \cos^4\theta = 1$ (maximum at $\theta = 0^0$)

$\therefore F_{max} = 1$

$F_{avg} = \frac{1}{4\pi}\int F(\theta,\phi).d\Omega$

Thus, $F_{avg} = \frac{1}{4\pi}\left[2\pi.\left(\frac{-\cos^5\theta}{5}\right)\right]_0^{\pi/2}$

$F_{avg} = \frac{1}{10} = 0.1$

$D = \frac{F_{max}}{F_{avg}} = \frac{1}{0.1} = 10$

In dB,

$D_{dB} = 10\log D = 10\log(D) = 10dB$

35. Ans: 55.4 to 55.6

Solution:

$\vec{E} = \frac{100}{r}\sin\theta\cos(\omega t - \beta r)\, a\hat{\theta}$

$\vec{H} = \frac{0.265}{r}\sin\theta\cos(\omega t - \beta r)\, a\hat{\phi}$

Time avg. poynting vector

$\vec{E}_s = \frac{100}{r}\sin\theta\, e^{-\beta r}\, a\hat{\theta}$

$\vec{H}_s = \frac{0.265}{r}\sin\theta\, e^{-\beta r}\, a\hat{\phi}$

$\vec{H}_s = \frac{1}{2}\text{Re}[\vec{E}_s \times \vec{H}_s]$

$$\vec{H}_s = \frac{1}{2}\text{Re}\frac{[100\times 265]}{r^2}\sin^2\theta\, a\hat{r}$$

$$\vec{P}_{avg}(r) = \frac{26.5}{2r^2}\sin^2\theta\, a\hat{r}$$

Average power crossing at r = 1 km.

$$P = \iint P_{avg}.d\vec{s} = \iint \frac{26.5}{2r^2}\sin^2\theta\, r^2 \sin\theta\, d\theta\, d\phi$$

$$\left[d\vec{s} = dr\, a\hat{i} + rd\theta\, a\hat{\theta} + \sin\theta\, d\phi\, a\hat{\phi}\right]$$

Hemispherical shell hence limit of θ will be 0 to $\frac{\pi}{2}$

$$P = \iint \frac{2.65}{2}\sin^3\theta\, d\theta\, d\phi = \frac{26.5}{2}\times 2\pi\int_0^{\pi/2}\sin^3\theta\, d\theta$$

$$P = \left[\begin{array}{l}\iint \frac{2.65}{2}\sin^3\theta\, d\theta\, d\phi = 26.5\,\pi\int_0^{\pi/2}\sin^3\theta\, d\theta \\ \qquad\qquad = 26.5\pi\times\frac{2}{3} = 55.50\text{ W}\end{array}\right]$$

36. Ans: 47.75
Solution:

$r_1 = 1\text{km}$

$\vec{E}$ at 1 km = 12 mv/m

$\eta_o = 120\pi\Omega$

The electric of an antenna is,

$$E_\theta = \frac{\eta I_o dl}{4\pi}\left[\frac{j\beta}{r} + \frac{1}{r^2} - \frac{1}{\beta r^3}\right]$$

For field,

$$E_\theta\, \alpha \frac{1}{r}$$

$$\frac{E_1}{E_2} = \frac{r_2}{r_1}$$

$$E_2 = \left(\frac{r_1}{r_2}\right)E_1$$

At $r_2 = 2\text{km}$,

$$\therefore E_2 = \frac{E_1}{2} = 6m\, v/m$$

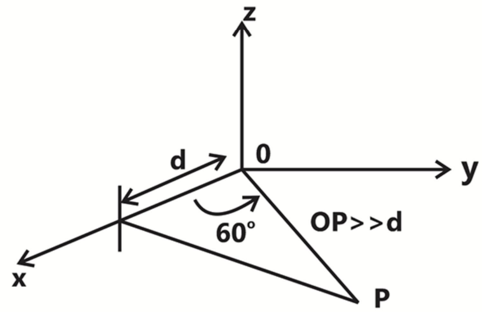
$$P_{av} = \frac{E^2}{2\eta} = \frac{0.5\times 36\times 10^{-6}}{120\pi} = 47.75\text{nw/m}^2$$

37. Ans: (b)
Solution:

1) Point electromagnetic source is isotropic, Can radiate fields in all directions equally.
2) Dish antenna is an highly directional.
3) Yagi – uda antenna is an end – fire type.

38. Ans: 50
Solution:

f=3MHz



The maximum field at point 'p' is given by,

$$\psi = \alpha + \beta d\cos\theta = 0°$$

$$\theta = 60^0\ ,\ \alpha = -\pi/2$$

Also, $\beta d = 2\pi\frac{d}{\lambda}$

$$\lambda = \frac{C}{f} = \frac{3\times 10^8}{3\times 10^8} = 100\text{m}$$

Thus, $\psi = \frac{-\pi}{2} + \frac{2\pi}{100}(d).\frac{1}{2}$

For maxima,

$$\psi = 0$$

$$\frac{\pi d}{100} = \frac{\pi}{2}$$

$$\therefore d = 50\text{m}$$

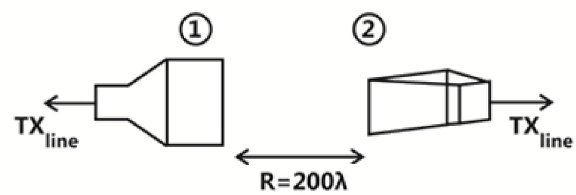
39. Ans: (b)
Solution:

The directivity of an antenna can be increased by increasing the effective area of antenna.
One technique for increasing the effective area is by adding more antenna elements.

$$A_e = \frac{\lambda^2}{4\pi}D$$

Thus, As directivity increases when $A_e\uparrow$

40. Ans: 3
Solution:



$G_{1(dB)} = 18dB$; $G_{2(dB)} = 22dB$; $P_t = 2w$

The power transmitted by transmitter horn antenna per unit area,

$$P_t(avg) = \frac{P_{in} \cdot G_1}{4\pi R^2}\left(\frac{W}{m^2}\right)$$

$$\therefore G_1 = 10^{1.8} = 63.09 \text{ , } R = 200\lambda m \text{ ; } P_{in} = 2W$$

$$P_t(avg) = \frac{2 \times 63.09}{4\pi \times (200\lambda)^2}$$

The power received at antenna 2 is given by;

$$P_r = P_t(avg) \times A_{e2}$$

$$P_r = \frac{P_{in} \cdot G_1}{4\pi R^2} \times A_{e2}$$

$$\therefore A_{e2} = \frac{\lambda^2}{4\pi} G_2$$

$$\therefore P_r = \frac{2 \times 10^{1.8} \times 10^{2.2} \times \lambda^2}{(4\pi \times 200)^2 \times \lambda^2} = \frac{2 \times 10^4}{16\pi^2 \times 4 \times 10^4}$$

$$= P_r = 3.16mW$$

As there is reflection at the terminal of Rx antenna power delivered to load

$$P_L = P_L\left(1 - |0.18|^2\right) = 3mW$$

41. Ans: (b)
Solution:

$$W_{rad} = \hat{a}_r \frac{C_o}{r^2} \cos^4 \theta$$

The power radiated over $0 \le \theta \le \pi/2$; $0 \le \theta \le 2\pi$ is given by,

$$P_{rad} = \int_0^{2\pi} \int_0^{\pi/2} \frac{C_o \cos^4 \theta}{r^2} . r^2 \sin\theta d\theta d\phi$$

Let $\cos\theta = t$;

$+\sin\theta d\theta = -dt$

$$\therefore P_{rad} = 2\pi C_o \int_0^1 t^4 dt = \frac{2\pi}{5} C_o \quad W$$

$$P_{rad} = 1.256 C_o$$

The maximum directivity is given by;

$$D = \frac{4\pi U_{max}}{P_{rad}}$$

$$\therefore U_{max} = r^2 W_{rad}(max) = C_0 \cos^4 \theta (max) = C_0$$

$$D = \frac{4\pi \times C_o}{1.256 \times C_o} = 10$$

In dB,

$$\therefore D_{dB} = 10 \log D = 10dB$$

42. Ans: 0.0122
Solution:

Parameter

f = 5GHZ $\qquad \lambda = \frac{C}{f} = 0.6 \times 10^{-1} = 0.06m$

Gain = 150

Cross section area

Of target $(\sigma) = 3m^2$

$d = 10^3 m$

So, $P_c = 100kw$

$$P_r = \left(\frac{P_t G}{4\pi d^2}\right) . \sigma . \left(\frac{A_c}{4\pi d^2}\right)$$

$$\therefore A_c = \frac{\lambda^2 G}{4\pi}$$

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 (d)^4}$$

$$P_r = \frac{10^5 \times (150)^2 \times (0.06)^2 \times 3}{(4\pi)^3 \times \left(10^{12}\right)}$$

$$P_r = 1.2245 \times 10^{-5} W$$

$$P_r = 0.0122 \mu W$$

43. Ans: (c)
Solution:

Capacity of wireless link

$$C = B \log_2\left[1 + \frac{\bar{P}}{N_0 B}\right] \text{bits/sec}$$

$\bar{P}$ = Average received power

$$\bar{P} = \frac{P_t G_t}{4\pi d^2} \times A_{er} \ldots\ldots (1)$$

$G_t = A_{et} \times \frac{4\pi}{\lambda^2} ....(2)$

P_t = Transmitted power

G_t = Gain of Transmission antenna

d=Distance between transmitter and receiver

A_{er}= Effective area of receiving antenn

A_{et}= Effective area of Transmission antenna

From (i) and (ii)

$$\bar{P} = \frac{P_t G \times A_{er}}{4\pi d^2}$$

$$\bar{P} = \frac{P_t A_{er}}{4\pi d^2} \times \frac{4\pi}{\lambda^2}$$

$$\bar{P} = \frac{P_t A_{et} A_{er}}{d^2 \lambda^2}$$

$A_{et} \rightarrow$ Double

$A_{er} \rightarrow$ Double

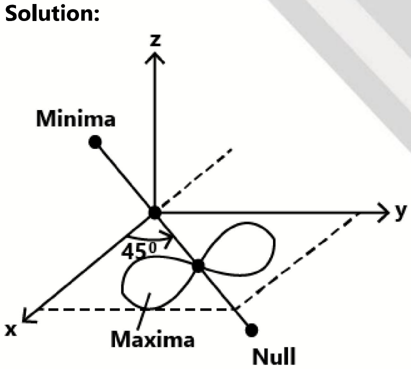
d $\rightarrow$ Double

$$\bar{P}_2 = \frac{P_t(2A_{ct})(2A_{er})}{\lambda^2 (2d)^2}$$

$$\bar{P}_2 = \bar{P}$$

Hence, Channel capacity remains same

44. Ans: (a)
Solution:



$0 < \phi < \pi$

$\phi = 45^0$

$\theta = 90^0$

For dipole $|E| = \sin\phi$

So, maximum will be at

$\phi = 90°$ and null $\theta = 0°,\ 180°$ etc

But the dipole is oriented along $45°$ from the x-axis

$\phi_{null} = (0+45)° = 45°$

$\phi_{max} = 135°$

So, answer (a) $\theta = 90°$ (as at ϕ plane $\theta = 90°$ always)

$\phi = 45°$

45. Ans. 1.98 to 2.02
Solution:

$$R_{rad} = 80\pi^2 \left(\frac{dl}{\lambda}\right)^2$$

$$R_1 \propto (dl)^2$$

$$R_2 = 80\pi^2 \left(\frac{dl \times (1.01)}{\lambda}\right)^2$$

$$R_2 \propto (1.01\,dl)^2$$

$$R_2 \propto 1.0201\,dl^2$$

$$\%\ change = \frac{1.0201 - 1}{1} \times 100\% = 2\% = 2.01\%$$

My GATE Story

Shivhari Sharma (AIR-18 in GATE 2018 ECE)

I am SHIVHARI SHARMA, I secured AIR 18 in GATE 2018 in ECE branch. I did my B.Tech from NIT Bhopal in 2017.

Firstly I would like to tell you that GATE is an exam which checks your temperament and confidence apart from technical knowledge. So first ensure that before starting your preparation you should be confident enough that you can achieve your goal by hard work and determination. Believe me, if I can then you also do the same or maybe better.

Your rank depends on your attitude, I'll give you my example here – my academics was just average then I thought about BSNL JTO and I started my preparation in NOV 2016 and I was able to get 816 AIR in GATE 2017. But because BSNL does not allow for fresher's I could not get the job. I didn't want to join M.Tech. Course and software job because I believed in myself I took a decision of drop in spite of having software job. I joined classroom coaching in Delhi and "KREATRYX Test Series" for MOCK TESTs, this helped me a lot by providing the same platform and conceptually GATE standard questions. I used to revise my notes thoroughly. By reading the notes multiple times I was confident enough in my concepts. I had that much confidence in my concepts that even if my question will be wrong in exam this will happen only because of silly mistake not because of my lack of study so try to study any concept in very much detail and precisely, for making concept I would like to suggest you join any good coaching which will help you in understanding the GATE exam, what type of concepts are asked, how do you change strategy according to paper.

After completing my syllabus of GATE in coaching, I had two months left so I again revised notes (not short notes). And started to write mock tests from November itself. In my first mock, I got only 52 marks. There were many times during my preparation I lost hope and again next day I strongly believed in myself that I can get under 100 rank and again started my preparation with full determination. I was slowly able to increase my marks in MOCK tests by using

KREATRYX analysis of Mock tests. KREATRYX provided subject wise analysis of mock test which really helped me to find my weaker areas. After giving so much time finally I was able to get top 20 Rank in all test series (mock test), which worked for me as a confidence booster. In last 10 days I wrote 5 mock tests, my performance was consistent in all of them and revised short notes. I didn't take chance to solve those questions in test series which I didn't study before rather than I gave more time to that question which I knew already. I always tried to tick answer in test series when I calculated the same on my copy. I avoided guessing the answer which leads you towards negative marks. In last mock, I got 81 marks and a top 10 rank. I practiced around 40 mock tests on same time 9 AM to 12 PM. In this, I learned time management, approach to attempt exam. I had my own approach to attempt question sequence which I followed in approx 35 mock tests and same approach I applied for GATE exam as well. Because I had experience of so many tests I was able to manage my time in GATE exam as well. So one thing I recommend you do more practice, it will lead you to a different level from others.

I would like to dedicate this result to my parents and respected teachers without their guidance it can't be possible.

I did not talk too much with others during my preparation. I used social media but not for very long time. I tried to be happy and my friends and they always encouraged me to achieve my goal. My father inspires me to do hard work with honesty, life ultimately gives you the best result at the end. Thanks to all, I will be happier if someone gets inspiration from this story.