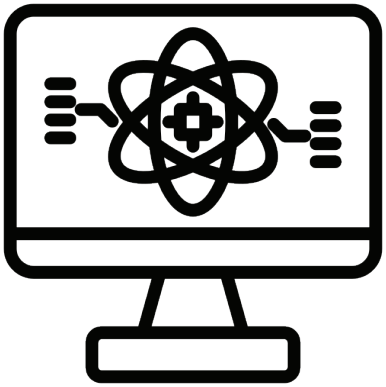
1996 TO 2026

PREVIOUS YEAR QUESTION WITH
DETAILED EXPLANATIONS

GATE

2027

COMPUTER SCIENCE AND INFORMATION TECHNOLOGY



GATE 2027

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Preface

This book has been meticulously crafted to serve as a comprehensive guide for aspirants preparing for the **GATE Computer Science and Information Technology examination**. With an ever-increasing competition, success in GATE demands a deep understanding of core concepts, coupled with a focused and strategic approach. This book has been structured to provide an all-encompassing review of essential topics while catering to the unique needs of both beginners and advanced learners.

This book is a comprehensive collection of **solutions to the GATE CS exam questions from the past 31 years, spanning 1996 to 2026**. Designed for aspirants who seek a deep understanding of question patterns and solution techniques, this book is an essential resource for efficient and effective exam preparation.

Organized into **eleven chapters**, this collection covers the entire spectrum of the syllabus. **Each chapter is subdivided into units** for clear topic segmentation, **with questions sorted year-wise** to highlight the progression of concepts and formats over time. Additionally, **questions are categorized into Multiple Choice Questions (MCQ), Multiple Select Questions (MSQ), and Numerical Answer Type (NAT) formats**, reflecting the varied question styles found in the exam. Each solution is presented in a detailed, step-by-step format, clarifying not only the approach but also the underlying concepts and problem-solving strategies required to succeed in GATE.

By working through these solutions, students can solidify their grasp of key topics, identify trends in question formats, and refine their time management skills. This book is intended to be a practical tool for achieving a high level of preparation, enabling candidates to approach the GATE exam with confidence and competence.

About GATE

Graduate Aptitude Test in Engineering (GATE) is a national examination conducted jointly by the Indian Institute of Science (IISc), Bengaluru and the seven Indian Institutes of Technology (at Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) on behalf of the National Coordination Board (NCB)-GATE, Department of Higher Education, Ministry of Education (MoE), Government of India.

Qualifying in GATE is a mandatory requirement for seeking admission and/or financial assistance to: (i) Master's programs and direct Doctoral programs in Engineering/ Technology/ Architecture and (ii) Doctoral programs in relevant branches of Arts and Science, in the institutions supported by the MoE and other Government agencies. Even in some colleges and institutions, which admit students without MoE scholarship/ assistantship, the GATE qualification is mandatory. Further, many Public Sector Undertakings (PSUs) have been using the GATE score in their recruitment process.

Exam Details:

Mode of Examination	**Computer Based Test**
Paper Code	CS
Duration of Exam	180 minutes
Total number of Questions	65
Total Marks	100
Language of Examination	English

Exam Pattern:

Sections	**Section I** (General Aptitude)	**Section II** (CS and EM)
Number of Questions	10	55
Marks	5 questions of 1 mark each and 5 questions of 2 marks each	25 questions of 1 mark each and 30 questions of 2 marks each
Negative Marking	For 1-mark MCQ, 1/3 mark will be deducted for a wrong answer. For 2-mark MCQ, 2/3 mark will be deducted for a wrong answer. There will be no negative marking for MSQ & NAT.	
Types of Question	MCQ	MCQ, MSQ, NAT

Duration and Examination Type

All the papers of the GATE 2027 examination will be for 3 hours duration and they consist of 65 questions for a total of 100 marks. Since the examination is an ONLINE computer-based test (CBT), at the end of the stipulated time (3 hours), the computer screen will automatically close the examination inhibiting any further action.

Candidates will be permitted to occupy their allotted seats 40 minutes before the scheduled start of the examination. Candidates can login and start reading the instructions 20 minutes before the start of examination. The late login time (if any) recorded by the computer system MUST NOT be beyond 30 minutes from the actual examination starting time. Candidates will NOT be permitted to login after 30 minutes from the actual examination starting time. Candidates will NOT be permitted to leave the examination hall before the end of the examination.

Pattern of Question Papers

GATE 2027 may contain questions of THREE different types in all the papers:

(i) **Multiple Choice Questions (MCQ)** carrying 1 or 2 marks each, in all the papers and sections. These questions are objective in nature, and each will have a choice of four answers, out of which ONLY ONE choice is correct.

Negative Marking for Wrong Answers: For a wrong answer chosen in a MCQ, there will be negative marking. For 1-mark MCQ, 1/3 mark will be deducted for a wrong answer. Likewise, for 2-mark MCQ, 2/3 marks will be deducted for a wrong answer.

(ii) **Multiple Select Questions (MSQ)** carrying 1 or 2 marks each in all the papers and sections. These questions are objective in nature, and each will have choice of four answers, out of which ONE OR MORE than one choice(s) are/correct.

Note: There is NO negative marking for a wrong answer in MSQ questions. However, there is NO partial credit for choosing partially correct combinations of choices or any single wrong choice.

(iii) **Numerical Answer Type (NAT)** Questions carrying 1 or 2 marks each in most of the papers and sections. For these questions, the answer is a signed real number, which needs to be entered by the candidate using the virtual numeric keypad on the monitor (keyboard of the computer will be disabled). No choices will be shown for these types of questions. The answer can be a number such as 10 or −10 (an integer only). The answer may be in decimals as well, for example, 10.1 (one decimal) or 10.01 (two decimals) or −10.001 (three decimals). These questions will be mentioned with, up to which decimal places, the candidates need to present the answer. Also, for some NAT type problems an appropriate range will be considered while evaluating these questions so that the candidate is not unduly penalized due to the usual round-off

errors. Candidates are advised to do the rounding off at the end of the calculation (not in between steps). Wherever required and possible, it is better to give NAT answer up to a maximum of three decimal places.

Note: There is NO negative marking for a wrong answer in NAT questions. Also, there is NO partial credit in NAT questions.

GATE Year Wise Organising Institute

Organizing Year	Organising Institute
2027	**IIT Madras**
2026	**IIT Guwahati**
2025	**IIT Roorkee**
2024	**IISc Bengaluru**
2023	**IIT Kanpur**
2022	**IIT Kharagpur**
2021	**IIT Bombay**
2020	**IIT Delhi**
2019	**IIT Madras**
2018	**IIT Guwahati**
2017	**IIT Roorkee**
2016	**IISc Bangalore**
2015	**IIT Kanpur**
2014	**IIT Kharagpur**
2013	**IIT Bombay**
2012	**IIT Delhi**
2011	**IIT Madras**
2010	**IIT Guwahati**
2009	**IIT Roorkee**
2008	**IISc Bangalore**
2007	**IIT Kanpur**
2006	**IIT Kharagpur**
2005	**IIT Bombay**
2004	**IIT Delhi**
2003	**IIT Madras**
2002	**IISc Bangalore**
2001	**IIT Kanpur**
2000	**IIT Kharagpur**
1999	**IIT Bombay**
1998	**IIT Delhi**
1997	**IIT Madras**
1996	**IISc Bangalore**

Scholarship/ Assistantship for Postgraduate Programs

To avail the financial assistance (scholarship/ assistantship) for a postgraduate program, the candidate must first secure the admission to a program in one of the centrally funded institutes, by a procedure that could vary from institute to institute. Depending upon the norms adopted by a specific institute or department of the institute, candidates may be admitted directly into a program based on their performance in GATE only; or based on their performance in GATE and an admission test and/or interview conducted by the department to which they have applied and/or the candidate's academic record. In the test/ interview-based selection procedure, as per the MoE guidelines, a minimum of 70% weightage will be given to the performance in GATE and the remaining will be given to the candidate's performance in test/ interview and/or academic record. However, the admitting institutes could prescribe a minimum passing mark in the test/ interview.

Candidates are advised to seek the complete details of the admission procedures and the availability of MoE scholarship/assistantship from the corresponding admitting institutions. The criteria for postgraduate admission with scholarship/ assistantship varies from one institute to the other. The management of the post-graduate scholarship/ assistantship is also the responsibility of the admitting institute. Similarly, reservation of the seats for different categories will be as per the policies and norms of the admitting institution and the Government of India rules.

The admitting institute may also specify the number of candidates who will be provided financial assistance (scholarship), if admission is secured. Qualification in GATE is also a minimum requirement to apply for various fellowships awarded by many Government organizations.

Different types of scholarships and sponsorships opportunities also exist for foreign nationals. Details may be obtained from nearby Indian Mission or from the website of Indian Council for Cultural Relations.

Use of GATE Score for Employment

In the past, several Public Sector Undertakings (PSUs) have used GATE score to shortlist the candidates for employment. A few such organizations are: Airports Authority of India (AAI), Bharat Heavy Electricals Limited (BHEL), Bharat Sanchar Nigam Limited (BSNL), Coal India Limited (CIL), Centre for Railway Information Systems (CRIS), Chenab Valley Power Projects Limited (CVPPL), Damodar Valley Corporation (DVC), Electronics Corporation of India Limited (ECIL), Engineers India Limited (EIL), Gas Authority of India Limited (GAIL), Hindustan Aeronautics Limited (HAL), Indian Oil Corporation Limited (IOCL), Mazagaon Dock Shipbuilders Limited (MDSL), National Aluminium Company Limited (NALCO), National Highways Authority of India (NHAI), NLC India Limited (NLCIL), National Mineral Development Corporation (NMDC), Nuclear Power Corporation of India Limited (NPCIL), National Thermal Power Corporation (NTPC), Oil and Natural Gas Corporation (ONGC), Odisha Power Generation Corporation Limited (OPGC), Power Grid Corporation of India Limited (POWERGRID), Power System Operation Corporation Limited (POSOCO), Rashtriya Ispat Nigam Limited (RINL), Steel Authority of India Limited (SAIL), etc.

Direct recruitment to Group-A level posts in central government, i.e., Senior Field Officer (Tele), Senior Research Officer (Crypto) and Senior Research Officer (S&T) in Cabinet Secretariat, Government of India, is now being carried out on the basis of GATE score. The details of the scheme of recruitment are normally published in National Newspapers/ Employment News/ Rozgar Samachar by the concerned authority.

Some other Government of India Organisations may also utilize GATE 2026 score for their recruitment purpose.

GATE Score

After the evaluation of the answers, the actual (raw) marks obtained by a candidate will be considered for computing the GATE Score. For multi-session test papers, raw marks obtained by the candidates in different sessions will be converted to Normalized marks for that particular subject. Thus, raw marks (for single session test papers) or normalized marks (for multi-session test papers) will be used for computing the GATE Score, based on the qualifying marks.

Calculation of Normalized Marks for Multi-Session Papers

In GATE 2027 examination, some test papers may be conducted in multi-sessions. For such test papers, a suitable normalisation is applied to take into account any variation in the difficulty levels of the question papers across sessions. The normalization is done based on the fundamental assumption that "in all multi-session GATE test papers, the distribution of abilities of candidates is the same across all the sessions". This assumption is justified since the number of candidates appearing in multisession test papers in GATE 2026 will be large and the procedure for allocation of session to candidates is random. Further, it is also ensured that for the same multi-session test paper, the number of candidates allotted in each session is of the same order of magnitude.

Based on the above, and considering various normalization methods, the committee arrived at the following formula for calculating the normalized marks for the multi-session papers.

The normalised marks of the j^{th} candidate in the i^{th} session, denoted by $\widehat{M}_{ij}$ are computed as

$$\widehat{M}_{ij} = \frac{\overline{M}_t^g - M_q^g}{\overline{M}_{ti} - M_{iq}} \left(M_{ij} - M_{iq}\right) + M_q^g$$

where,

M_{ij}, is the actual marks obtained by the j^{th} candidate in the i^{th} session;

$\overline{M}_t^g$ is the average marks of the top 0.1% of the candidates considering all sessions;

M_q^g is the sum of mean and standard deviation marks of the candidates in the paper considering all sessions;

$\overline{M}_{ti}$ is the average marks of the top 0.1% of the candidates in the i^{th} session; and

$\overline{M}_{iq}$ is the sum of the mean marks and standard deviation marks of the i^{th} session.

Calculation of GATE Score for All Test Papers

For all papers for which there is only one session, actual marks obtained by the candidates will be used for calculating the GATE 2027 Score. For papers in multi-sessions, normalized marks will be calculated corresponding to the raw marks obtained by a candidate and the GATE 2027 Score will be calculated based on the normalized marks.

The GATE 2026 score will be computed using the formula given below.

$$\text{GATE Score} = S_q + (S_t - S_q)\frac{M - M_q}{\overline{M_t} - M_q}$$

where

M is the marks obtained by the candidate (actual marks for single session papers and normalized marks for multi-session papers);

M_q is the qualifying marks for the General Category candidate in the paper;

$\overline{M_t}$ is the mean of marks of top 0.1% or top 10 (whichever is larger) of the candidates who appeared in the paper (in case of multi-session papers including all sessions);

$S_q = 350$ is the score assigned to M_q ; and

$S_t = 900$ is the score assigned to $\overline{M_t}$

In GATE 2026, the qualifying marks (M_q) for the general category candidate in each subject will be

Cut-off marks for GENERAL category$= \max(25, \min(40, \mu + \sigma))$

Where μ denotes the mean of marks of all candidates and a denotes the standard deviation of positive marks of all the candidates who appeared for the test paper. The cut-off marks for the other categories may be calculated as per the standard ratio:

Cut-off for OBC-NCL/EWS categories = (9/10) × GENERAL cut-off
Cut-off for SC/ST/PWD categories = (2/3) × GENERAL cut-off

Past Years Cut-off

YEAR	General	OBC-NCL	SC/ST
2026	30	27	20
2025	29.2	26.2	19.4
2024	27.6	24.8	18.4
2023	32.5	29.2	21.6
2022	25	22.5	16.6
2021	26.1	23.4	17.4
2020	28.5	25.6	19.0
2019	29.5	26.6	19.7
2018	25	22.5	16.6
2017	25	22.5	16.6
2016	25	22.5	16.6
2015	25	22.5	16.6
2014	25	22.5	16.6

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CHAPTER 3

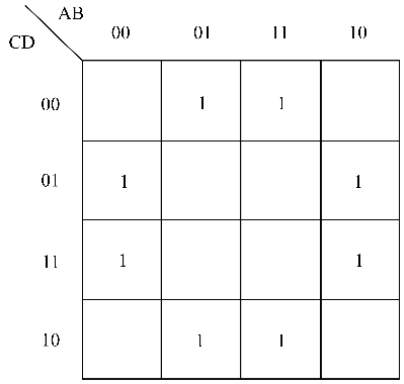
Digital Logic

Unit 3.1: Boolean Algebra and Minimization

Multiple Choice Questions (MCQ)

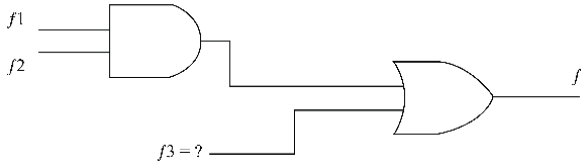
[1996]

1. What is the equivalent Boolean expression in product-of-sums form for the Karnaugh map given in Fig.



(A) $B\bar{D} + \bar{B}D$
(B) $(B + \bar{C} + D)(\bar{B} + C + \bar{D})$
(C) $(B + D)(\bar{B} + \bar{D})$
(D) $(B + \bar{D})(\bar{B} + D)$

2. Consider a logic circuit shown in figure below. The functions f_1, f_2 and f(in canonical sum of products form in decimal notation) are:
$\boldsymbol{f_1(w,x,y,z) = \sum(8,9,10)}$
$\boldsymbol{f_2(w,x,y,z) = \sum(7,8,12,13,14,15)}$
$\boldsymbol{f(w,x,y,z) = \sum(8,9)}$



The function f_3 is
(A) $\sum 9,\ 10$ (B) $\sum 9$
(C) $\sum 1,\ 8,\ 9$ (D) $\sum 8,\ 10,\ 18$

[1997]

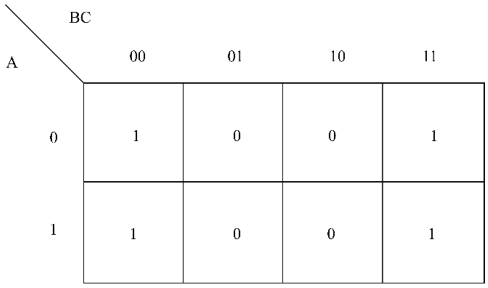
3. Let $f(x,\ y,\ z) = \bar{x} + \bar{y}x + xz$ be a switching function. Which one of the following is valid?
(A) $\bar{y}x$ is a prime implicant of f
(B) xz is a minterm of f
(C) xz is an implicant of f
(D) y is a prime implicant of f

[1997]

4. Let * be defined as $x * y = \bar{x} + y$. Let $z = x * y$. Value of $z * x$ is
(A) $\bar{x} + y$ (B) x
(C) 0 (D) 1

[1998: 2 Mark]

5. The function represented by the Karnaugh map given below is



(A) $A.B$ (B) $AB + BC + CA$
(C) $\overline{B \oplus C}$ (D) $A.BC$

[1998: 2 Mark]

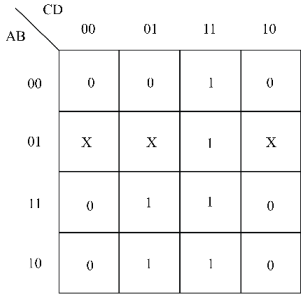
6. Which of the following operations is commutative but not associative?
(A) AND (B) OR
(C) NAND (D) EXOR

[1998: 1 Mark]

7. What happens when a bit string is XORed with itself n-times as shown:
$[\boldsymbol{B} \oplus (\boldsymbol{B}\ \oplus (\boldsymbol{B} \oplus\ (\boldsymbol{B}\ldots \boldsymbol{n\ times})]$
(A) complements when n is even
(B) complements when n is odd
(C) divides by 2 always
(D) remains unchanged when n is even

[1999]

8. Which of the following functions implements the Karnaugh map shown below?



(A) $\bar{A}B + CD$
(B) $D(C + A)$
(C) $AD + \bar{A}B$
(D) $(C + D)(\bar{C} + D)(A + B)$

[1999]

9. Which of the following expressions is not equivalent to $\overline{x}$?

(A) x NAND x (B) x NOR x
(C) x NAND 1 (D) x NOR 1

[2000]

10. Which functions does NOT implement the Karnaugh map given below?

wz → / xy ↓	00	01	11	10
00	0	X	0	0
01	0	X	1	1
11	1	1	1	1
10	0	X	0	0

(A) $(w + x)y$
(B) $xy + yw$
(C) $(w + x)(w + y)(x + y)$
(D) None of the above

[2000]

11. The simultaneous equations on the Boolean variables x, y, z and w,

$$x + y + z = 1$$
$$xy = 0$$
$$xz + w = 1$$
$$xy + \overline{z}\overline{w} = 0$$

have the following solution for x, y, z and w, respectively:

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

[2001]

12. Given the following Karnaugh map, which one of the following represents the minimal sum-of-Products of the map?

yz \ wx	00	01	11	10
00	0	X	0	X
01	X	1	X	1
11	0	X	1	0
10	0	1	X	0

(A) $xy + y'z$ (B) $wx'y' + xy + xz$
(C) $w'x + y'z + xy$ (D) $xz + y$

[2002: 1 Mark]

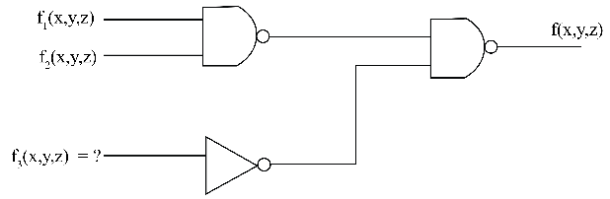
13. Minimum SOP for $f(w, x, y, z)$ shown in Karnaugh-map below is

yz \ wx	00	01	11	10
00	0	1	1	0
01	X	0	0	1
11	X	0	0	1
10	0	1	1	X

(A) xz + y'z (B) xz' + zx'
(C) x'y + zx' (D) None of these

[2002: 2 Marks]

14. Consider the following logic circuit whose inputs are functions f_1, f_2, f_3 and output is f. Given that



$\mathbf{f_1(x, y, z) = \Sigma(0, 1, 3, 5)}$,
$\mathbf{f_2(x, y, z) = \Sigma(6, 5)}$, $\boldsymbol{and}$
$\mathbf{f(x, y, z) = \Sigma(1, 4, 5)}$
$\mathbf{f_3}$ $\boldsymbol{is}$

(A) Σ(1, 4, 5) (B) Σ(6, 7)
(C) Σ(0, 1, 3, 5) (D) None of these

[2002: 2 Marks]

15. $f(A, B) = A' + B$. Simplified expression for function $\mathbf{f(f(x + y, y), z)}$ is

(A) $x' + z$ (B) xyz
(C) $xy' + z$ (D) None of these

[2003: 2 Marks]

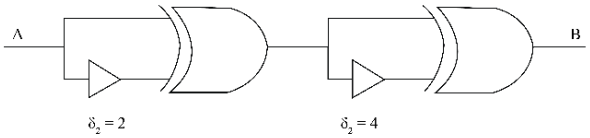
16. The literal count of a boolean expression is the sum of the number of times each literal appears in the expression. For example, the literal count of $\mathbf{(xy + xz)}$ is 4. What are the minimum possible literal counts of the product-of-sum and sum-of- product representations respectively of the function given by the following Karnaugh map? Here, X denotes "don't care"

xy \ zw	00	01	11	10
00	X	1	0	1
01	0	1	X	0
11	1	X	X	0
10	X	0	0	X

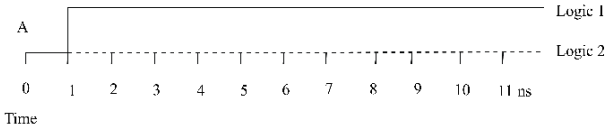
(A) (11, 9) (B) (9, 13)
(C) (9, 10) (D) (11, 11)

[2003: 2 Marks]

17. Consider the following circuit composed of XOR gates and non-inverting buffers.



The non-inverting buffers have delays $\delta_1 = 2$ ns and $\delta_2 = 4$ ns as shown in the figure. Both XOR gates and all wires have zero delay. Assume that all gate inputs, outputs and wires are stable at logic level 0 at time 0. If the following waveform is applied at input A, how many transition (s) (change of logic levels) occur (s) at B during the interval from 0 to 10 ns?



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

[2004: 1 Mark]

18. The Boolean function $x'y' + xy + x'y$ is equivalent to

(A) x' + y' (B) x + y
(C) x + y' (D) x' + y

[2004: 1 Mark]

19. What is the minimum number of NAND gates required to implement a 2-input EXCLUSIVE-OR function without using any other logic gate?

(A) 3 (B) 4
(C) 5 (D) 6

[2004: 2 Marks]

20. The function $AB'C + A'BC + ABC' + A'B'C + AB'C'$ is equivalent to

(A) $AC' + AB + A'C$ (B) $AB' + AC' + A'C$
(C) $A'B + AC' + AB'$ (D) $A'B + AC + AB'$

[2004: 2 Marks]

21. Which are the essential prime implicants of the following Boolean function?
$f(a, b, c) = a'c + ac' + b'c$

(A) a'c and ac' (B) a'c and b'c
(C) a'c only (D) ac' and bc'

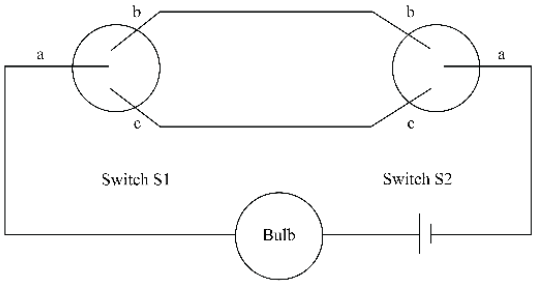
[2005: 1 Mark]

22. Which of the following expressions is equivalent to $(A \oplus B) \oplus C$?

(A) $(A + B + C)\,(\bar{A} + \bar{B} + \bar{C})$
(B) $(A + B + C)\,(\bar{A} + \bar{B} + C)$
(C) $ABC + \bar{A}(B \oplus C) + \bar{B}(A \oplus C)$
(D) None of these

[2005: 1 Mark]

23. A two-way switch has three terminals a, b and c. In ON position (logic value 1), a is connected to b, and in OFF position, a is connected to c. Two of these two-way switches S1 and S2 are connected to a bulb as shown below.

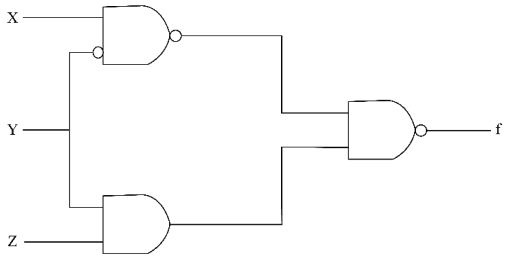


Which of the following expressions, if true, will always result in the lighting of the bulb?

(A) $S1 \cdot \overline{S2}$ (B) $S1 + S2$
(C) $\overline{S1 \oplus S2}$ (D) $S1 \oplus S2$

[2005: 1 Mark]

24. Consider the following circuit:



Which one of the following is TRUE?

(A) f is independent of X
(B) f is independent of Y
(C) f is independent of Z
(D) None of X, Y, Z is redundant

[2005: 1 Mark]

25. The switching expression corresponding to $f(A, B, C, D) = \Sigma(1, 4, 5, 9, 11, 12)$ is

(A) BC'D' + A'C'D + AB'D (B) ABC' + ACD + B'C'D
(C) ACD' + A'BC' + AC'D' (D) A'BD + ACD' + BCD'

[2006: 2 Marks]

26. Consider a boolean function f(w, x, y, z). Suppose that exactly one of its inputs is allowed to change at a time. If the function happens to be true for two input vectors $i_1 =< w_1, x_1, y_1, x_1 >$ and $i_2 =< w_2, x_2, y_2, z_2 >$, we would like the function to remain true as the input changes from i_1 to i_2 (i_1 and i_2 differ in exactly one bit position), without becoming false momentarily.
Let $f(w, x, y, z) = \Sigma(5, 7, 11, 12, 13, 15)$. Which of the following cube covers of f will ensure that the required property is satisfied?

(A) $\bar{w}xz, wx\bar{y}, x\bar{y}z, xyz, wyz$
(B) $wxy, \bar{w}xz, wyz$
(C) $wx\bar{y}\bar{z}, xz, w\bar{x}yz$
(D) $wyz, wxz, \bar{w}xz, x\bar{y}z, xyz$

[2006: 2 Marks]

27. Consider numbers represented in 4-bit gray code. Let $h_3h_2h_1h_0$ be the gray code representation of a

number n and let $g_3g_2g_1g_0$ be the gray code of (n+1) (modulo 16) value of the number. Which one of the following functions is correct?

(A) $g_0(h_3h_2h_1h_0) = \sum(1,2,3,6,10,13,14,15)$
(B) $g_1(h_3h_2h_1h_0) = \sum(4,9,10,11,12,13,14,15)$
(C) $g_2(h_3h_2h_1h_0) = \sum(2,4,5,6,7,12,13,15)$
(D) $g_3(h_3h_2h_1h_0) = \sum(0,1,6,7,10,11,12,13)$

[2006: 2 Marks]

28. The boolean function for a combinational circuit with four inputs is represented by the following Karnaugh map.

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

Which of the product terms given below is an essential prime implicant of the function?

(A) QRS (B) PQS
(C) PQ'S' (D) Q'S'

[2007: 1 Mark]

29. What is the maximum number of different Boolean functions involving n Boolean variables?

(A) n^2 (B) 2^n
(C) 2^{2^n} (D) 2^{n^2}

[2007: 1 Mark]

30. Consider the following Boolean function of four variables:

$\boldsymbol{f\ (w,x,y,z) = \Sigma(1,3,4,6,9,11,12,14)}$

The function is:

(A) independent of one variable.
(B) independent of two variables.
(C) independent of three variables.
(D) dependent on all the variables.

[2007: 2 Mark CSE]

31. Let f(w,x,y,z)=Σ(0,4,5,7,8,9,13,15). Which of the following expressions are NOT equivalent to f?

(P) x'y'z' + w'xy' + wy'z + xz
(Q) w'y'z' + wx'y' + xz
(R) w'y'z' + wx'y' + xyz + xy'z
(S) x'y'z' + wx'y' + w'y
Code:

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

[2007: 2 Mark CSE]

32. Define the connective * for the Boolean variables X and Y as: X * Y = XY + X'Y'. Let Z= X*Y. Consider the following expressions P, Q and R.

P: X = Y * Z
Q:Y = X * Z
R: X *Y * Z = 1

Which of the following is TRUE?

(A) Only P and Q are valid.
(B) Only Q and R are valid
(C) Only P and R are valid..
(D) All P, Q, R are valid.

[2008: 1 Mark IT]

33. A set of Boolean connectives is functionally complete if all Boolean functions can be synthesized using those. Which of the following sets of connectives is NOT functionally complete?

(A) EX-NOR (B) implication, negation
(C) OR, negation (D) NAND

[2008: 1 Mark IT]

34. Consider the following Boolean function of four variables f(A,B,C,D)=Σ(1,3,4,6,9,11,12,14) The function is

(A) independent of one variable
(B) independent of two variables
(C) independent of three variable
(D) dependent on all the variables

[2008: 1 Mark CSE]

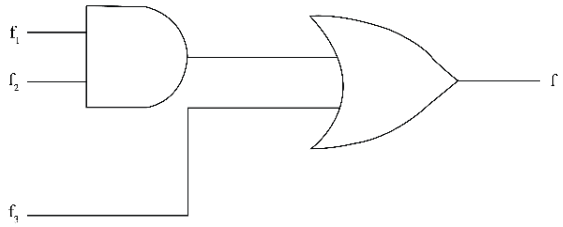
35. In the Karnaugh map shown below, X denoted a don't care term. What is the minimal form of the function represented by the Karnaugh map?

cd \ ab	00	01	11	10
00	1	1		1
01	X			
11	X			
10	1	1		X

(A) $\bar{b}\cdot\bar{d} + \bar{a}\cdot\bar{d}$ (B) $\bar{a}\cdot\bar{b} + \bar{b}\bar{d} + \bar{a}\cdot b\cdot\bar{d}$
(C) $\bar{b}\cdot\bar{d} + \bar{a}\cdot b\cdot\bar{d}$ (D) $\bar{a}\cdot\bar{b} + \bar{b}\cdot\bar{d} + \bar{a}\cdot\bar{d}$

[2008: 1 Mark CSE]

36. Given f_1, f_3 and f in canonical sum of products form (in decimal) for the circuit



$\boldsymbol{f_1 = \sum m(4,5,6,7,8)}$
$\boldsymbol{f_3 = \sum m(1,6,15)}$
$\boldsymbol{f = \sum m(1,6,8,15)}$
then f_2 is

(A) $\sum m(4,6)$ (B) $\Sigma m(4,8)$
(C) $\Sigma m(6,8)$ (D) $\Sigma m(4,6,8)$

[2008: 2 Mark CSE]

37. If P, Q, R are Boolean variables, then $(\boldsymbol{P}+\overline{\boldsymbol{Q}})(\boldsymbol{P}.\overline{\boldsymbol{Q}}+\boldsymbol{P}.\boldsymbol{R})(\overline{\boldsymbol{P}}.\overline{\boldsymbol{R}}+\overline{\boldsymbol{Q}})$ simplifies to
(A) $P\bar{Q}$ (B) $P\cdot\bar{R}$
(C) $P\bar{Q}+R$ (D) $P\cdot\bar{R}+Q$

[2009: 1 Mark]

38. What is the minimum number of gates required to implement the Boolean function (AB+C) if we have to use only 2-input NOR gates?
(A) 2 (B) 3
(C) 4 (D) 5

[2009: 2 Mark]

39. The binary operation □ is defined as follows

P	Q	P□Q
T	T	T
T	F	T
F	T	F
F	F	T

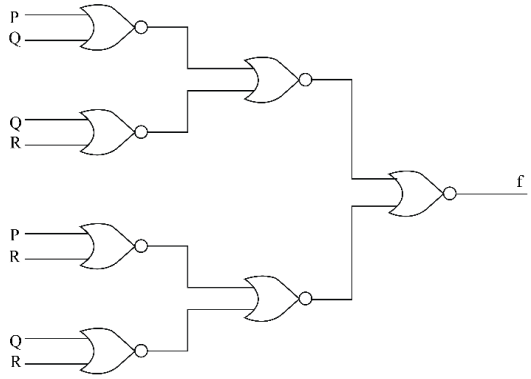
Which one of the following is equivalent to $\boldsymbol{P}\vee\boldsymbol{Q}$?
(A) $\neg Q_{\square}\neg P$ (B) $P_{\square}\neg Q$
(C) $\neg P_{\square}Q$ (D) $\neg P_{\square}\neg Q$

[2010: 1 Mark]

40. The minterm expansion of $\boldsymbol{f(P,\ Q,\ R)=PQ+Q\bar{R}+P\bar{R}}$ is
(A) $m_2+m_4+m_6+m_7$ (B) $m_0+m_1+m_3+m_5$
(C) $m_0+m_1+m_6+m_7$ (D) $m_2+m_3+m_4+m_5$

[2010: 2 Mark]

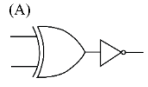
41. What is the Boolean expression for the output f of the combinational logic circuit of NOR gates given below?

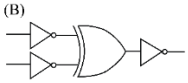


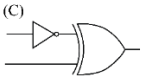
(A) $\overline{Q+R}$ (B) $\overline{P+Q}$
(C) $\overline{P+R}$ (D) $\overline{P+Q+R}$

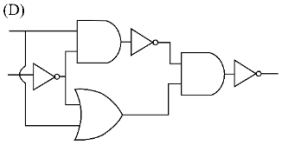
[2011: 1 Mark]

42. Which one of the following circuits is NOT equivalent to a 2-input XNOR (exclusive NOR) gate?

(A)


(B)


(C)


(D)


[2011: 1 Mark]

43. The simplified SOP (Sum of Product) form of the Boolean expression $(\boldsymbol{P}+\overline{\boldsymbol{Q}}+\overline{\boldsymbol{R}})\cdot(\boldsymbol{P}+\overline{\boldsymbol{Q}}+\boldsymbol{R})\cdot(\boldsymbol{P}+\boldsymbol{Q}+\overline{\boldsymbol{R}})$ is
(A) $(P+\bar{Q}+\bar{R})$ (B) $(P+\bar{Q}\cdot\bar{R})$
(C) $(\bar{P}Q+R)$ (D) $(PQ+R)$

[2012: 1 Mark]

44. The truth table

X	Y	f(X, Y)
0	0	0
0	1	0
1	0	1
1	1	1

Represents the Boolean function
(A) X (B) $X+Y$
(C) $X\oplus Y$ (D) Y

[2012: 2 Mark]

45. What is the minimal form of the Karnaugh map shown below? Assume that X denotes a don't care term.

ab / cd	00	01	11	10
00	1	X	X	1
01	X			1
11				
10	1			X

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

[2013: 1 Mark]

46. Which one of the following expressions does NOT represent exclusive NOR of x and y?
(A) $xy+x'y'$ (B) $x\oplus y'$
(C) $x'\oplus y$ (D) $x'\oplus y'$

[2014: 1 Mark SET 1]

47. Consider the following Boolean expression for $\boldsymbol{F}$:
$F(P,Q,R,S)=PQ+\bar{P}QR+\bar{P}Q\bar{R}S$
The minimal sum-of-products form of $\boldsymbol{F}$ is
(A) $PQ+QR+QS$ (B) $P+Q+R+S$
(C) $\bar{P}+\bar{Q}+\bar{R}+\bar{S}$ (D) $\bar{P}R+\bar{P}\bar{R}S+P$

[2014: 1 Mark SET 2]

48. The dual of a Boolean function $\boldsymbol{F(x_1,x_2,\ldots,x_n,+,\cdot,')}$, written as $\boldsymbol{F^D}$, is the same expression as that of F with $\boldsymbol{+\ and\ \cdot}$ swapped. F is said to be self-dual if $\boldsymbol{F=F^D}$. The number of self-dual functions with n Boolean variables is
(A) 2^n (B) 2^{n-1}
(C) 2^{2^n} (D) $2^{2^{n-1}}$

[2014: 1 Mark SET 3]

49. Consider the following minterm expression for F:
F(P,Q,R,S) = Σ(0, 2, 5, 7, 8, 10, 13, 15)
The minterms 2, 7, 8 and 13 are 'do not care terms. The minimal sum of-products form for F is
(A) $Q\bar{S} + \bar{Q}S$
(B) $\bar{Q}\bar{S} + QS$
(C) $\bar{Q}\bar{R}\bar{S} + \bar{Q}R\bar{S} + Q\bar{R}S + QRS$
(D) $\bar{P}\bar{Q}\bar{S} + \bar{P}QS + PQS + P\bar{Q}\bar{S}$

[2014: 2 Mark SET 3]

50. Let $\oplus$ denote the Exclusive OR (XOR) operation. Let ' 1 ' and ' 0 ' denote the binary constants. Consider the following Boolean expression for F over two variables P and Q:
$F(P, Q) = ((1 \oplus P) \oplus (P \oplus Q)) \oplus ((P \oplus Q) \oplus (Q \oplus 0))$
The equivalent expression for F is
(A) $P + Q$ (B) $\overline{P + Q}$
(C) $P \oplus Q$ (D) $\overline{P \oplus Q}$

[2015: 2 Mark SET 1]

51. Consider the operations:
$f(X, Y, Z) = X'YZ + XY' + Y'Z'$ **and** $g(X, Y, Z) = X'YZ + X'YZ' + XY$
Which one of the following is correct?
(A) Both $\{f\}$ and $\{g\}$ are functionally complete
(B) Only $\{f\}$ is functionally complete
(C) Only $\{g\}$ is functionally complete
(D) Neither $\{f\}$ nor $\{g\}$ is functionally complete

[2015: 1 Mark SET 3]

52. Let # be a binary operator defined as
$X\#Y = \overline{X} + \overline{Y}$ **where X and Y are Boolean variables.**
Consider the following two statements.
(S1) (P # Q) # R = P # (Q # R)
(S2) Q # R = R # Q
Which of the following is/are true for the Boolean variables P, Q and R?
(A) Only S 1 is true
(B) Only S 2 is true
(C) Both S1 and S2 are true
(D) Neither S1 nor $2 are true

[2015: 2 Mark SET 3]

53. Given the function F=P'+QR, where F is a function in three Boolean variables P, Q and R and P'=!P, consider the following statements.
(S1) F=Σ(4,5,6)
(S2) F=Σ(0,1,2,3,7)
(S3) F=Π(4,5,6)
(S4) F=Π(0,1,2,3,7)
Which of the following is true?
(A) (S1)-False, (S2)- True, (S3)- True, (S4)-False
(B) (S1)- True, (S2)- False, (S3)- False, (S4)- True
(C) (S1)-False, (S2)-False, (S3)-True, (S4)-True
(D) (S1)- True, (S2)- True, (S3)-False, (S4)-False

[2016:1 Mark SET 1]

54. Consider the Boolean operator # with the following properties:
$x\#0 = x,\ x\#1 = \bar{x},\ x\#x = 0$ **and** $x\#\bar{x} = 1$.
Then $x\#y$ is equivalent to
(A) $x\bar{y} + \bar{x}y$ (B) $x\bar{y} + \bar{x}\bar{y}$
(C) $\bar{x}y + xy$ (D) $xy + \bar{x}\bar{y}$

[2016:1 Mark SET 2]

55. Let $x_1 \oplus x_2 \oplus x_3 \oplus x_4 = 0$ where x_1, x_2, x_3, x_4 are Boolean variables, and $\oplus$ is the XOR operator. Which one of the following must always be TRUE?
(A) $x_1 \cdot x_2 \cdot x_3 \cdot x_4 = 0$
(B) $x_1 x_3 + x_2 = 0$
(C) $\bar{x}_1 \oplus \bar{x}_3 = \bar{x}_2 \oplus \bar{x}_4$
(D) $x_1 + x_2 + x_3 + x_4 = 0$

[2017: 2 Mark SET 2]

56. If w, x, y, z are Boolean variables, then which one of the following is INCORRECT?
(A) $wx + w(x + y) + x(x + y) = x + wy$
(B) $\overline{w\bar{x}(y + \bar{z})} + \bar{w}x = \bar{w} + x + \bar{y}z$
(C) $(w\bar{x}(y + x\bar{z}) + \bar{w}\bar{x})y = x\bar{y}$
(D) $(w + y)(wxy + wyz) = wxy + wyz$

[2017: 2 Mark SET 2]

57. Given $f(w, x, y, z) = \sum_m(0, 1, 2, 3, 7, 8, 10) + \sum_d(5, 6, 11, 15)$, where d represents the don't-care condition in Karnaugh maps. Which of the following is a minimum product-of-sums (POS) form of (w, x, y, z)?
(A) $f = (\bar{w} + \bar{z})(\bar{x} + z)$
(B) $f = (\bar{w} + z)(x + z)$
(C) $f = (w + z)(\bar{x} + z)$
(D) $f = (w + \bar{z})(\bar{x} + z)$

[2018: 1 Mark]

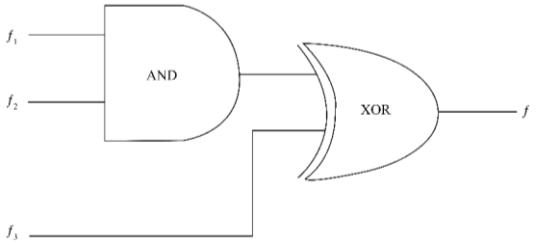
58. Let $\oplus$ and $\odot$ denote the Exclusive OR and Exclusive NOR operations, respectively. Which one of the following is NOT CORRECT?
(A) $\overline{P \oplus Q} = P \odot Q$
(B) $\bar{P} \oplus Q = P \odot Q$
(C) $\bar{P} \oplus \bar{Q} = P \oplus Q$
(D) $(P \oplus \bar{P}) \oplus Q = (P \odot \bar{P}) \odot \bar{Q}$

[2019: 1 Mark]

59. Which one of the following is NOT a valid identity?
(A) $(x \oplus y) \oplus z = x \oplus (y \oplus z)$
(B) $(x + y) \oplus z = x \oplus (y + z)$
(C) $x \oplus y = x + y$, if $xy = 0$
(D) $x \oplus y = (xy + x'y')'$

[2019: 2 Marks]

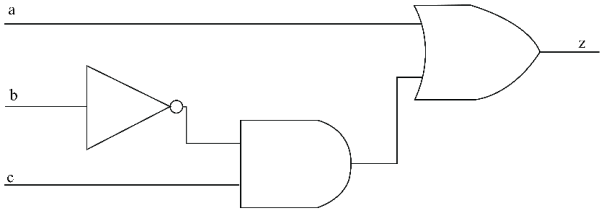
60. Consider three 4-variable functions f_1, f_2 and f_3, which are expressed in sum-of-minterms as
$f_1 = \Sigma(0, 2, 5, 8, 14)$
$f_2 = \Sigma(2, 3, 6, 8, 14, 15)$
$f_3 = \Sigma(2, 7, 11, 14)$
For the following circuit with one AND gate and one XOR gate, the output function f can be expressed as:



(A) $\Sigma(7,8,11)$
(B) $\Sigma(2,7,8,11,14)$
(C) $\Sigma(2,14)$
(D) $\Sigma(0,2,3,5,6,7,8,11,14,15)$

[2020: 2 Mark]

61. Consider the Boolean function z(a, b, c):



Which one of the following minterm lists represents the circuit given above?

(A) $z = \sum\ (0,1,3,7)$ (B) $z = \sum\ (1,4,5,6,7)$
(C) $z = \sum\ (2,4,5,6,7)$ (D) $z = \sum\ (2,3,5)$

[2025, set-1; 2 Marks]

62. Consider the following four variable Boolean function in sum-of-product form $F(b_3, b_2, b_1, b_0) = \sum\ (0,2,4,8,10,11,12)$.
where the value of the function is computed by considering $b_3b_2b_1b_0$ as a 4-bit binary number, where b_3 denotes the most significant bit and b_0 denotes the least significant bit. Note that there are no don't care terms. Which ONE of the following options is the CORRECT minimized Boolean expression for?

(A) $\bar{b}_1\bar{b}_0 + \bar{b}_2\bar{b}_0 + b_1\bar{b}_2b_3$ (B) $\bar{b}_1\bar{b}_0 + \bar{b}_2\bar{b}_0$
(C) $\bar{b}_2\bar{b}_0 + b_1b_2b_3$ (D) $\bar{b}_0\bar{b}_2 + \bar{b}_3$

[2026, SET-2: 2 Marks]

63. Consider the following 4-variable Boolean function $F(A, B, C, D) = \Sigma m(0,1,2,3,8,9,10,11)$
Consider A as MSB, D as LSB. Which one of the following options represents the minimal sum of products form for the above function?
Note: + is OR operation, . is AND operation, ' is NOT operation

(A) $A' + B' + C' + D'$ (B) B'
(C) $A' \cdot B' + A \cdot B$ (D) A'

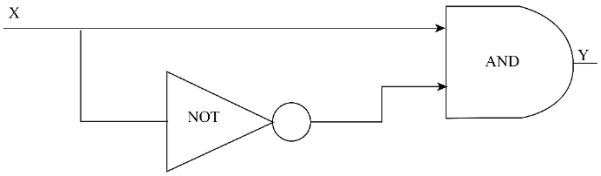
Multiple Select Question (MSQ)

[2021: 2 Marks Set-1]

1. Consider the following Boolean expression.
$F = (X + Y + Z)(\bar{X} + Y)(\bar{Y} + Z)$
Which of the following Boolean expressions is/are equivalent to $\bar{F}$ (complement of F)?
(A) $(\bar{X} + \bar{Y} + \bar{Z})(X + \bar{Y})(Y + \bar{Z})$
(B) $X\bar{Y} + \bar{Z}$
(C) $(X + \bar{Z})(\bar{Y} + \bar{Z})$
(D) $X\bar{Y} + Y\bar{Z} + \bar{X}\bar{Y}\bar{Z}$

[2024: 1 Mark SET 1]

2. Consider the circuit shown below where the gates may have propagation delays. Assume that all signal transitions occur instantaneously and that wires have no delays. Which of the following statements about the circuit is/are CORRECT?



(A) With no propagation delays, the output Y is always logic Zero
(B) With no propagation delays, the output Y is always logic One
(C) With propagation delays, the output Y can have a transient logic One after X transitions from logic Zero to logic One
(D) With propagation delays, the output $\boldsymbol{Y}$ can have a transient logic Zero after $\boldsymbol{X}$ transitions from logic One to logic one

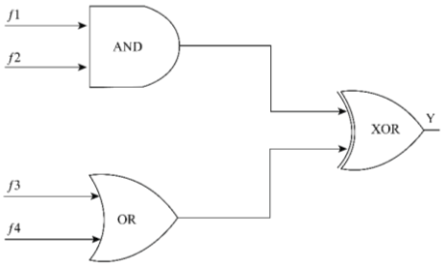
[2024: 2 Mark SET 1]

3. Consider a Boolean expression given by $F(X, Y, Z) = \Sigma(3,5,6,7)$.
Which of the following statements is/are CORRECT?
(A) $F(X, Y, Z) = \Pi(0,1,2,4)$
(B) $F(X, Y, Z) = XY + YZ + XZ$
(C) $F(X, Y, Z)$ is independent of input Y
(D) $F(X, Y, Z)$ is independent of input X

[2024: 2 Mark, SET-2]

4. Consider 4-variable functions $f1, f2, f3, f4$ expressed in sum-of-minterms form as given below.

$$f1 = \sum\ (0,2,3,5,7,8,11,13)$$
$$f2 = \sum\ (1,3,5,7,11,13,15)$$
$$f3 = \sum\ (0,1,4,11)$$
$$f4 = \sum\ (0,2,6,13)$$



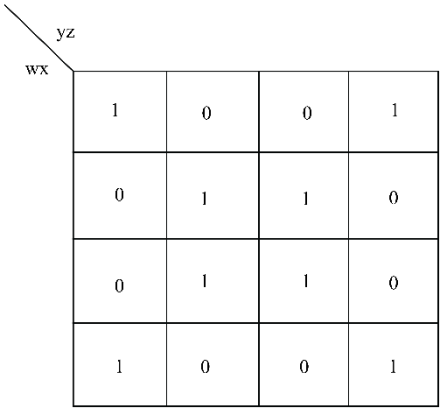
With respect to the circuit given above, which of the following options is/are CORRECT?
(A) $\boldsymbol{Y} = \sum(0,1,2,11,13)$
(B) $\boldsymbol{Y} = \Pi(3,4,5,6,7,8,9,10,12,14,15)$
(C) $\boldsymbol{Y} = \Sigma(0,1,2,3,4,5,6,7)$
(D) $\boldsymbol{Y} = \Pi(8,9,10,11,12,13,14,15)$

[2024: 1 Mark, SET-2]

5. **For a Boolean variable x, which of the following statements is/are FALSE?**
   (A) $x.1 = x$ (B) $x + 1 = x$
   (C) $x.x = 0$ (D) $x + \bar{x} = 1$

[2025, SET-2, MARK 2]

6. **Given the following Karnaugh Map for a Boolean function (w, x, y, z):**



Which one or more of the following Boolean expression(s) represent(s) F?
(A) $\bar{w}\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}\bar{z} + \bar{w}\bar{x}y\bar{z} + w\bar{x}y\bar{z} + xz$
(B) $\bar{w}\bar{x}\bar{y}\bar{z} + \bar{w}\bar{x}y\bar{z} + w\bar{x}yz + xz$
(C) $\bar{w}\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}z + xz$
(D) $\bar{x}\bar{z} + xz$

[2025, SET-2, MARK 2]

7. **Which of the following Boolean algebraic equation(s) is/are CORRECT?**
   (A) $\bar{A}BC + A\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} + A\bar{B}C + ABC = BC + \bar{B}\bar{C} + \bar{A}\bar{B}$
   (B) $AB + \bar{A}C + BC = AB + \bar{A}C$
   (C) $(A + C)(\bar{A} + B) = AB + \bar{A}C$
   (D) $\overline{(A + \bar{B} + \bar{D})(C + D)(\bar{A} + C + D)(A + B + \bar{D})} = \bar{A}D + \bar{C}\bar{D}$

[2026, SET-1: 1 Mark]

8. **Consider the following Boolean expression of a function F:**
   $\boldsymbol{F(P, Q) = (\bar{P} + Q) \oplus (\bar{P}Q)}$
   Which of the following expressions is/are equivalent to F?
   (A) $\overline{P \oplus Q}$ (B) $P \oplus Q$
   (C) $\bar{P} \oplus Q$ (D) $\bar{P} \oplus \bar{Q}$

[2026, SET-1: 2 Marks]

9. **Consider a Boolean function F with the following minterm expression:**
   $\boldsymbol{F(P, Q, R, S) = \sum\ m(1, 2, 3, 4, 5, 7, 10, 12, 13, 14)}$
   Which of the following options is/are the minimal sum-of-products expression(s) of ?
   (A) $\bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + \bar{Q}R\bar{S}$
   (B) $\bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + PR\bar{S}$
   (C) $\bar{P}S + Q\bar{R} + PQ\bar{S} + PR\bar{S}$
   (D) $\bar{P}S + Q\bar{R} + PQ\bar{S} + \bar{Q}R\bar{S}$

Numerical Answer Type Questions (NAT)

[2015: 2 Mark SET 2]

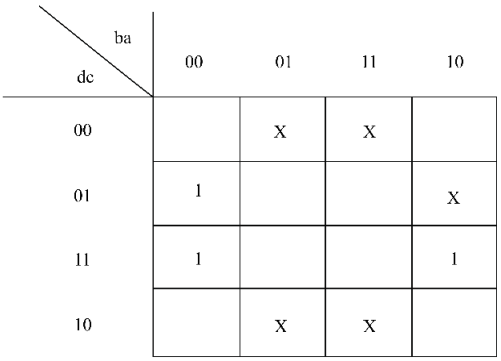
1. **The number of min-terms after minimizing the following Boolean expression is _____.** $\boldsymbol{[D' + AB' + A'C + AC'D + A'C'D]'}$

[2015: 2 Mark SET 3]

2. **The total number of prime implicants of the function $\boldsymbol{f(w, x, y, z) = \Sigma(0, 2, 4, 5, 6, 10)}$ is _____.**

[2017: 1 Mark, SET-1]

3. **Consider the Karnaugh map given below, where x represents "don't care" and blank represents 0.**



Assume for all inputs (a, b, c, d) the respective complements $(\overline{a}, \overline{b}, \overline{c}, \overline{d})$ are also available. The above logic is implemented 2-input NOR gates only. The minimum number of gates required is_____ .

[2018: 2 Mark]

4. **Consider the minterm list form of a Boolean function F given below.**
   $$\boldsymbol{F(P, Q, R, S) = \sum\ m(0, 2, 5, 7, 9, 11) + d(3, 8, 10, 12, 14)}$$
   Here, m denotes a minterm and d denotes a don't care term. The number of essential prime implicants of the function F is _____.

[2019: 2 Mark]

5. **What is the minimum number of 2-input NOR gates required to implement 4-variable function expressed in sum-of-minterms from as $f =$ $\Sigma(0, 2, 5, 7, 8, 10, 13, 15)$? Assume that all the inputs and their complements are available.**

[2021: 2 Mark, Set-2]

6. **Consider a Boolean function $f(w, x, y, z)$ such that**
   $f(w, 0, 0, z) = 1$
   $f(1, x, 1, z) = x + z$
   $f(w, 1, y, z) = wz + y$
   The number of literals in the minimal sum-of-products expression of f is _____.

ANSWER KEY

Multiple Choice Questions (MCQ)

1	2	3	4	5	6	7	8	9	10
C	B	C	B	C	C	D	B	D	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	A	B	A	C	*	D	D	B	B

21	22	23	24	25	26	27	28	29	30
A	C	C	A	A	*	C	D	C	B
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
D	D	A	A	A	C	A	B	B	A
41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
A	D	B	A	B	D	A	D	B	D
51	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
B	B	A	A	C	C	A	D	B	A
61	**62**	**63**							
B	A	B							

Numerical Answer Type Questions (NAT)			
1	**2**	**3**	**4**
1	3	1.0 to 1.0	3 to 3
5	**6**		
3 to 3	6 to 6		

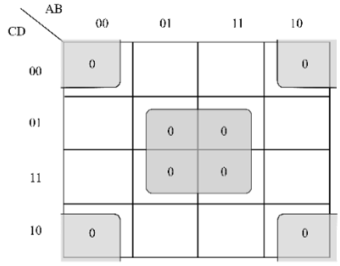
Multiple Select Question (MSQ)		
1	**2**	**3**
B,C,D	A,C	A,B
4	**5**	**6**
C,D	B,C	A,D
7	**8**	**9**
B,C,D	A, C	B, D

EXPLANATIONS

Multiple Choice Questions (MCQ)

1. Explanation: (C)

Convert into Product of Sum format:



Now,

$f = (B + D)(\bar{B} + \bar{D})$

So, Correct option is C.

2. Explanation: (B)

$f = (f_1 \wedge f_2) \vee f3$

Since f1 and f2 are in canonical sum of products form, $f_1 \wedge f_2$ will only contain their common terms- that is $f1 \wedge f2 = \Sigma 8$

Now, $\Sigma 8 \vee f3 = \Sigma 8{,}9$

$So,\ f3 = \Sigma 9$

So, Correct option is B.

3. Explanation: (C)

$f(x, y, z) = \overline{x} + \overline{y}x + xz$

Or $\overline{x} + x\overline{y} + xz$

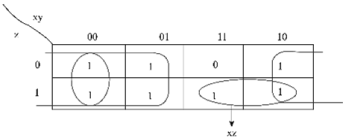
Lets, expand

$\therefore\ \overline{x}(y + \overline{y})(z + \overline{z}) + x\overline{y}(z + \overline{z}) + x(y + \overline{y})z$

$= \overline{x}yz + \overline{x}y\overline{z} + \overline{x}\overline{y}z + \overline{x}\,\overline{y}\,\overline{z} + x\overline{y}\,\overline{z} + xyz + x\overline{y}z$

$011 + 010 + 001 + 000 + 101 + 100 + 111 + 101$

K-Map



Option analysis:-

A → $\overline{y}x$ is prime implicant of f (101 & 100) – No, can be implicant but not prime. As its covered under $\overline{y}$

B → xz is a mintcom of f. (111 & 101) – covered under z, so definitely not mintcom but is an implicant

C → xz is an implicant of f. – yes

D → y cant be an implicant because, 110 is 0 so, y cant be prime implicant.

4. Explanation: (B)

$z * x = (x * y) * x \quad \{\because z = x * y\ \}$

$= (\bar{x} + y) * x \quad \{\because x * y = \bar{x} + y\}$

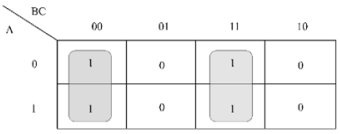
$= (\overline{\bar{x} + y}) + x$

$= x.\bar{y} + x$

$= x$

So, Correct option is B.

5. Explanation: (C)



which gives

$BC + \bar{B}\bar{C} = B\ XNOR\ C = B \odot C$

This can be represented as negation of $XOR = \overline{B \oplus C}$

So, Correct option is C.

6. Explanation: (C)

1. for any operator to follow cumulative it must

Satisfy → A operator B = operator A

2. for any operator to follow Associative it must

Satisfy → A operator (B operator C) = (A operator B) operator C

Option (A) (AND) operator follow both cumulative & associative property

(1) A.B=B.A (2) A.(B.C)=(A.B).C

Option (B) (OR)……also follow both cumulative & associative property

(1) A+B=B+A (2) A+(B+C)=(A+B)+C

Option (C) (NAND) follow cumulative but not associative property

(1) $\overline{AB} = \overline{BA}$ (2) $\overline{A \cdot (\overline{BC})} \neq \overline{(\overline{AB})C}$

$(\overline{A} + \overline{B} \equiv \overline{B} + \overline{A}) \qquad = \overline{A} + (\overline{BC})$

$(\overline{AB}) + \overline{C}$

$= (\overline{A} + BC) \neq AB + \overline{C}$

Option (D) (EXOR) follow both associative & cumulative property

(1) $A \oplus B = B \oplus A = A\overline{B} + \overline{A}\,B$

(2) $A \oplus (B \oplus C) = (A \oplus B) \oplus C$ | $Put\ A \oplus B = A\overline{B} + \overline{A}B$ & $B \oplus C = B\overline{C} + \overline{B}C$

$= A \oplus (B\overline{C} + \overline{B}C)$

$= (\overline{A \oplus B})C + (A \oplus B)\overline{C}$

$[\overline{A \oplus B}\ (EXOR) = A \odot B(EXNOR)]$

$= \overline{A}(B\overline{C} + \overline{B}C) + A(\overline{B\overline{C} + \overline{B}C})$

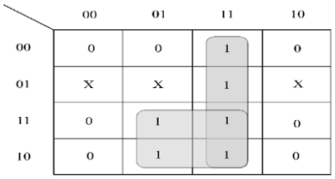
$= (A \odot B)C + (A\overline{B} + \overline{A}B)\overline{C}$

$= \overline{A}B\overline{C} + \overline{A}\,\overline{B}C + A((\overline{B\overline{C}}) \cdot (\overline{\overline{B}C}))$

$= (AB + \overline{A}\,\overline{B})C + A\overline{BC} + \overline{A}B\overline{C}$
$= \overline{A}B\overline{C} + \overline{A}\,\overline{B}C + A[(\overline{B} + C)(B + \overline{C})]$
$= ABC + \overline{A}\,\overline{B}C + A\overline{BC} + \overline{A}B\overline{C}$
$= \overline{A}B\overline{C} + \overline{A}\,\overline{B}C + A\overline{B}\,\overline{C} + ACB$

7. Explanation: (D)
$Let\ number\ of\ \oplus\ be\ two\ (even\ case)$:
$B \oplus B \oplus B = B \oplus 0 =$
$B\ (remains\ unchanged)$ {$\because$ $B \oplus B = 0$ $and\ B \oplus 0 = B$ }
$Let\ number\ of\ \oplus\ be\ three\ (odd\ case)$:
$B \oplus B \oplus B \oplus B = B \oplus B \oplus 0 =$
$B \oplus B = 0$
So, Correct option is D.

8. Explanation: (B)

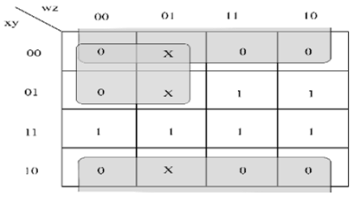


$f = AD + CD$
$= D(A + C)$
So, Correct option is B.

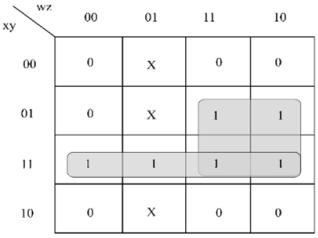
9. Explanation: (D)
$\overline{x.x} = \bar{x} + \bar{x} + \bar{x} = \bar{x}$
$\overline{x + x} = \bar{x}.\bar{x} = \bar{x}$
$\overline{x.1} = \bar{x} + 0 = \bar{x}$
$\overline{x + 1} = \bar{x}.0 = 0$
So, Correct option is D.

10. Explanation: (D)
We can solve this question with the help of options:

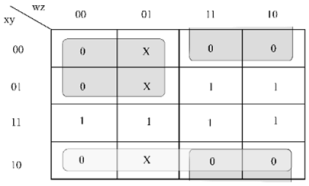
(A) $(w + x)y$ => it is implemented by K-map.



(B) $xy + yw$ => it is implemented by K-map.



(C) $(w + x)(\overline{w} + y)(\overline{x} + y)$ => it is implemented by K-map.



So, Correct option is D.

11. Explanation: (C) Take each option one by one and try to put the values of x,y,z and w in question:

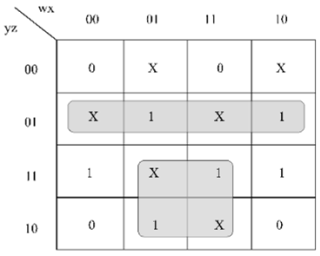
(A) 0 1 0 0
- 0+1+0=1
- 0.1=0
- 0.0+0=0 (went wrong) So, this is not the right option

(B) 1 1 0 1
- 1+1+0=1
- 1.1=1 (went wrong) not right

(C) 1 0 1 1
- 1+0+1=1
- 1.0=0
- 1.1+1=1
- 1.0+1.0=0 This is the right option

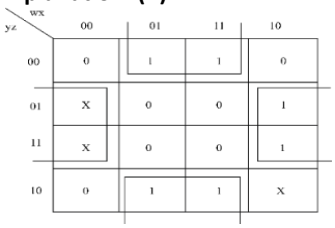
So, Correct option is C.

12. Explanation: (A)



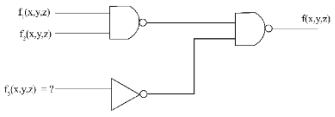
$f = (xy + y'z)$
So, Correct option is A.

13. Explanation: (B)



Minimum SOP for f(w, x, y, z)
$= xz' + zx'$

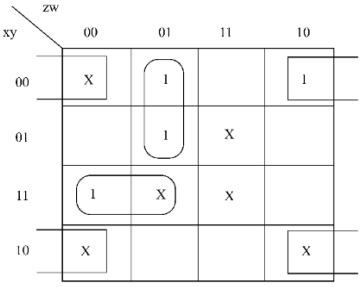
14. Explanation: (A)



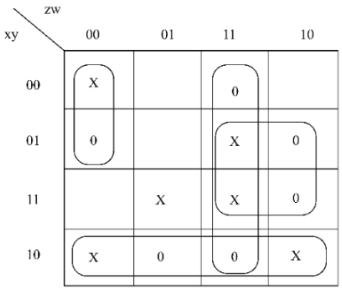
$f = \overline{\overline{f_1 \cdot f_2} \cdot \overline{f_3}} = f_1 \cdot f_2 + f_3$ ... (1)
Given $f_1(x, y, z) = \Sigma m(0,1,3,5)$ and
$f_2(x, y, z) = \Sigma m(6,5)$
$f_1 \cdot f_2 = \Sigma m(5)$ ... (2)
Common minterms of function f_1 and f_2 are minterms in $f_1 \cdot f_2$.
Hence f_3 can be $f_3(x, y, z) = \Sigma m(1,4,5)$ or $f_3 = (x, y, z) = \Sigma m(1,4)$
From the given options answer is option (a).

15. Explanation: (C)
= f(f(x + y, y), z)
= f((x + y)′ + y, z)
= f(x′y′ + y, z)
= f(x′ + y, z)
$= (x' + y)' + z = xy' + z$

16. (*)
Find the sum-of-product from as follows:

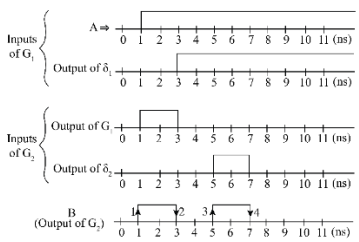


$= w'y' + z'wx' + xyz'$ ... (i)
Total literal count=8 literals
Find product – of – sum form as follows



f(z, w, x, y) = $(y' + z')(w' + z')(z' + y)(x + z + w)$
Total literal count = 9 literals
Note: From the given options no answer is matching.

17. Explanation: (D)
Consider left side EX-OR gate as G_1 and right side EX-OR gate as G_2
1. To find number of transitions at B i.e. the output of gate G_2, it is required to identify the inputs of gate G_2
2. To identify gate G_2 inputs it is required to find gate G_1 output waveform.
3. To find gate G_1 output waveform, it is required to identify δ_1 output waveform.



Total numbers of transitions at B during interval from 0 to 10 ns are '4'

Hence option (d).

18. Explanation: (D)

$x'y' + xy + x'y = x'y' + x'y + xy$

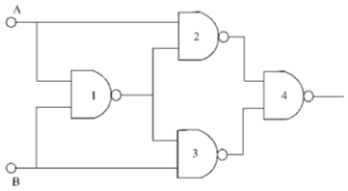
$= x'(y' + y) + xy\,[a + a' = 1]$

$= x' + xy \quad [a + a'b = a + b]$

$= x' + y$

19. Explanation: (B)

Minimum four 2 input NAND gates required to realise 2 input EX-OR function.



1^{st} NAND gate: Input: A, B Output: (A B)'

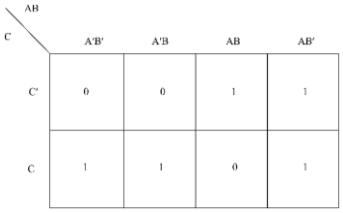
2^{nd} NAND gate: Input: (AB)', A, Output: A+ AB

3^{rd} NAND gate: Input: (AB)', B, Output: B' + AB

4^{th} NAND gate: Input: $A' + AB, B' + AB$, Output: $A'B + AB'$ (Exclusive OR function)

20. Explanation: (B)

K-map



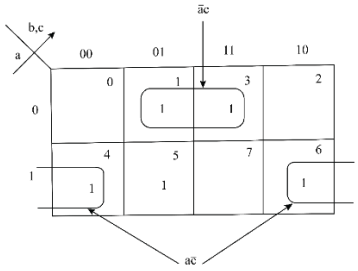
Equivalent expression of above K-map is A'C+AC'+AB'.

21. Explanation: (A)

$f(a, b, c) = \bar{a}c + a\bar{c} + \bar{b}c$

$= \Sigma m(1, 3, 4, 5, 6)$

The K-map of the function is



To cover the minterm m_3 the prime implicant $\bar{a}c$ is an essential prime implicant. To cover the minterm m_6 the prime implicant $a\bar{c}$ is an essential prime implicant. Hence answer is option (a).

22. Explanation: (C)

$(A \oplus B) \oplus C$

$[A\bar{B} + B\bar{A}] \oplus C$

$[A\bar{B} + B\bar{A}]\bar{C} + \overline{[A\bar{B} + \bar{A}B]}C$

$A\bar{B}\bar{C} + \bar{A}B\bar{C} + [(\bar{A} + B) \cdot (A + \bar{B})]C$

$A\bar{B}\bar{C} + \bar{A}B\bar{C} + \bar{A}\bar{B}C + ABC$

$= ABC + \bar{A}[B \oplus C] + \bar{B}(A \oplus C)$

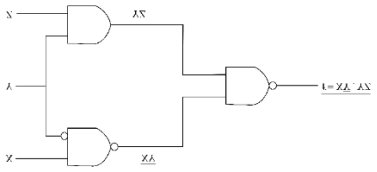
23. Explanation: (C)

Bulb is On when both swich s1 and s2 are in same state, either off or on.

S1	S2	Bulb
0	0	On
0	1	Off
1	0	Off
1	1	On

Above truth table derives Ex-NOR operation.

24. Explanation: (A) The given circuit is



$f = \overline{\overline{X\bar{Y}} + YZ}$

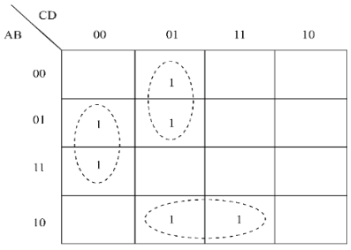
$= \overline{(\bar{X} + Y)} \cdot YZ$

$= \overline{\bar{X}YZ} + YZ$

$= \overline{YZ}$

f is independent of X.

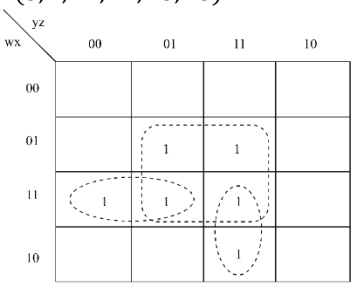
25. Explanation: (A) F (A, B, C, D) = Σ(1, 4, 5, 9, 11, 12) The K-map for f is



$B\bar{C}\bar{D} + \bar{A}\bar{C}D + A\bar{B}D$

26. Explanation: (*)

Static 1 hazard free solution is required. $f(w, x, y, z) = \Sigma(5, 7, 11, 12, 13, 15)$



$f = \{xz, wx\bar{y}, wyz\}$

Static 1 hazard free set.

It is not given in the options.

Note: From the the given options suitable answer not available.

27. Explanation: (C) For a binary number $b_3b_2b_1b_0$ the corresponding gray code $h_3h_2h_1h_0$ is given is Table-1.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
b_3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
b_2	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
b_1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
b_0	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
h_3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
h_2	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0
h_1	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0
h_0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0

For a binary number 'n' the gray code is $h_3h_2h_1\ h_0$, the required output is $g_3g_2g_1g_0$ (it is corresponding gray code of binary number $n + 1$), is given in Table-2.

	0	1	3	2	6	7	5	4	12	13	15	14	10	11	9	8
h_3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
h_2	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0
h_1	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0
h_0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
g_3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
g_2	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0
g_1	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0
g_0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0

Table-2

From the table-2, read the equations for $g_3, g_2, g_1\ and\ g_0$

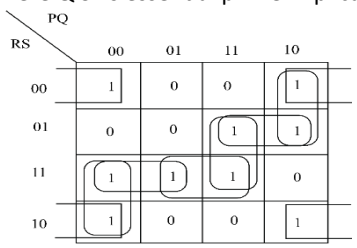
The answer g_2 will match.

$g_2(h_3, h_2, h_1, h_0)$

$= \Sigma m(2, 4, 5, 6, 7, 12, 13, 15)$

28. Explanation: (D)

Here Q'S' is essential prime implicant.



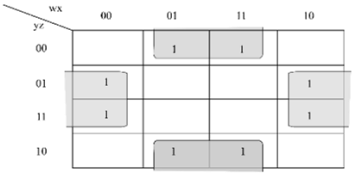
29. Explanation: (C) The number of m-ary functions in p-valued algebra having n-variables is given by m^{p^n}

Here, m = 2 (boolean functions), p = 2 (boolean variables) and n = n (number of variables)

So, total functions = 2^{2^n}

So, Correct option is C.

30. Explanation: (B)



Minimized expression is $f(w, x, y, z) = \bar{x}z + x\bar{z}$

Here w and y are independent variables

So, Correct option is B.

31. Explanation: (D)

Go with Minterm representation of each option, (Note that order of W,X,Y,Z should be preserved.)

Here, x means do not care (x takes value either 0 or 1)

(P) X'Y'Z'+W'XY'+WY'Z+XZ
=xX'Y'Z'+W'XY'x+WxY'Z+xXxZ
=x000+010x+1x01+x1x1
=0000+1000+0100+0101+1001+1101+0101+0111+1101+1111
=0+8+4+5+9+13+5+7+13+15
=∑m(0,4,5,7,8,9,13,15)

(Q) W'Y'Z'+WX'Y'+XZ
=W'xY'Z'+WX'Y'x+xXxZ
=0x00+100x+x1x1
=0000+0100+1000+1001+0101+0111+1101+1111
=0+4+8+9+5+7+13+15
=∑m(0,4,5,7,8,9,13,15)

(R) W'Y'Z'+WX'Y'+XYZ+XY'Z
=W'xY'Z'+WX'Y'x+xXYZ+xXY'Z
=0x00+100x+x111+x101
=0000+0100+1000+1001+0111+1111+0101+1101
=0+4+8+9+7+15+5+13
=∑m(0,4,5,7,8,9,13,15)

(S) X'Y'Z'+WX'Y'+W'Y
=xX'Y'Z'+WX'Y'x+W'xYx
=x000+100x+0x1x
=0000+1000+1000+1001+0010+0011+0110+0111
=0+8+8+9+2+3+6+7
=∑m(0,2,3,6,7,8,9)

So, Correct option is D.

32. Explanation: (D)

P: Y∗Z=Y∗(X∗Y)
=Y∗(XY+X'Y')
=Y(XY+X'Y')+Y'(XY+X'Y')'
=XY+Y'((X'+Y')(X+Y))
=XY+Y'(X'Y+XY')
=XY+XY'
=X(Y+Y')
=X
So, P is valid.

Q: X∗Z=X∗(X∗Y)
=X∗(XY+X'Y')
=X(XY+X'Y')+X'(XY+X'Y')'
=XY+X'((X'+Y')(X+Y))
=XY+X'(X'Y+XY')
=XY+X'Y
=Y(X+X')
=Y
So, Q is also valid.

R: X∗Y∗Z=(X∗Y)∗(X∗Y)
=(XY+X'Y')∗(XY+X'Y')
=(XY+X'Y')(XY+X'Y')+(XY+X'Y')'(XY+X'Y')'
=(XY+X'Y')+(XY+X'Y')'(∵AA=A)
=1(∵A+A'=1)
So, R is also valid.

So, Correct option is D.

33. Explanation: (A)

A set of Boolean connectives is **functionally complete** if it can express all possible Boolean functions, including AND, OR, and NOT.
Let's analyze each option:

(A) **EX-NOR**
The EX-NOR (≡) operation alone is not functionally complete because it cannot independently generate NOT, AND, or OR. It is a parity function and lacks the ability to express all Boolean functions.

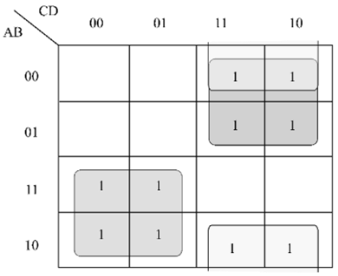
(B) **Implication (→), Negation (¬)**
The implication (→) and negation (¬) are functionally complete. They can be used to derive AND, OR, and other operations.

(C) **OR, Negation (¬)**
This set is functionally complete. Using De Morgan's laws, we can derive AND as:
A∧B=¬(¬A∨¬B)
So, it can express all Boolean functions.

(D) **NAND**
NAND is functionally complete because we can derive NOT, AND, and OR using only NAND gates.

So, Correct option is A.

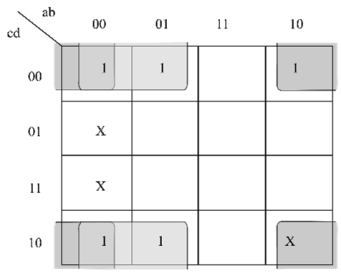
34. Explanation: (A)



Now,
$f(A,B,C,D) = A\bar{C} + \bar{B}C + \bar{A}C$ { it is the minimized expression}
Here, D is not used. So, only 1 variable is independent.

So, Correct option is A.

35. Explanation: (A)



$F(a,b,c,d) = \bar{b}\bar{d} + \bar{a}\bar{d}$
So, Correct option is A.

36. Explanation: (C) AND gates gives intersection of min-terms.
OR gates gives union of min-terms.
Now, Expression of above circuit:
$f1.f2 + f3 = f$
$(f1 \cap f2) \cup f3 = f$
$\sum m(4,5,6,7,8) \cap f_2 \ \cup \ \sum m(1,6,15) = \sum m(1,6,8,15)$
$f_2 = \sum m(8)$ f2 must contain 8, and optional elements are 1,6,15
So, Correct option is C.

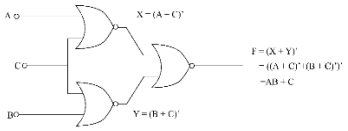
37. Explanation: (A)

Given: $(P+\bar{Q})(P\bar{Q}+PR)(\bar{P}\bar{R}+\bar{Q})$
$= (PP\bar{Q} + PPR + P\bar{Q}\bar{Q} + P\bar{Q}R)(\bar{P}\bar{R}+\bar{Q})$
$= (P\bar{Q} + PR + P\bar{Q} + P\bar{Q}R)(\bar{P}\bar{R}+\bar{Q})$
$= P\bar{Q}\bar{P}\bar{R} + PR\bar{P}\bar{R} + P\bar{Q}\bar{P}\bar{R}P + P\bar{Q}R\bar{P}\bar{R} + P\bar{Q}\bar{Q} + PR\bar{Q} + P\bar{Q}\bar{Q} + P\bar{Q}R\bar{Q}$ $\{\because A\bar{A}=0\} = P\bar{Q} + P\bar{Q}R$
$= P\bar{Q}(1+R)$
{1+A=1}$= P\bar{Q}$

So, Correct option is A.

38. Explanation: (B)

Given boolean function:
$f = AB + C$
$= (A+C).(B+C)$
$= ((A+C)' + (B+C)')'$



Therefore, 3 NOR gates required.
So, correct option is B.

39. Explanation: (B)

From the truth table we can write,
$P \square Q = PQ + PQ' + P'Q'$
$= P(Q+Q') + P'Q'$ {Q+Q'=1}
$= P + P'Q'$
$= (P+P').(P+Q')$
$= P + Q'$
So, Correct option is B.

40. Explanation: (A)

$f(P,Q,R) =$
$= PQ(R+R') + QR'(P+P') + PR'(Q+Q')$
$= PQR + PQR' + PQR' + P'QR' + PQR' + PQ'R'$
$= PQR + PQR' + P'QR' + PQ'R'$
111 110 010 100
$= m_7 + m_6 + m_2 + m_4$
So, Correct option is A.

41. Explanation: (A)

[((P'Q') + (Q'R'))' + (P'R') + (Q'R'))']'
[(Q'(P' + R'))' + (R'(P' + Q'))']'
[(Q + PR + R + PQ)]'

[Q(1 + P) + R(1 + P)]'
[Q + R]'
So, Correct option is A.

42. Explanation: (D) This question is solved by option elimination method:

$(AB' + A'B)' = A \odot B$

$(A'(B')' + (A')'B')' = (A \oplus B)'$
$= A \odot B$

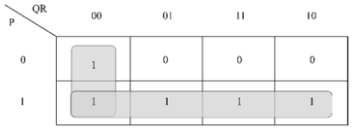
$A'B' + (A')'B = A \odot B$

$\big((AB')'.(A + B')\big)'$
$= (AB') + (A + B')' = AB' + A'B$
$= A \oplus B$

So, Correct option is D.

43. Explanation: (B)

K-Map for SOP:



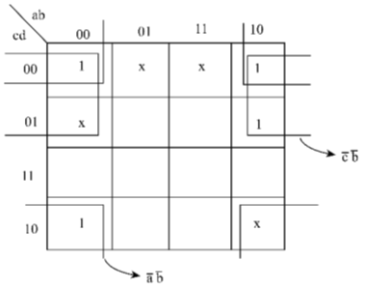
Now,
$F(P, Q, R) = P + \bar{Q}.\bar{R}$ is the minimal expression

44. Explanation: (A)

$f(X, Y) = XY' + XY$
$= X(Y' + Y)$
$= X$

So, Correct option is A.

45. Explanation: (B)



So, minimal for K-map= $\bar{b}\,\bar{c} + \bar{b}\,\bar{d}$

46. Explanation: (D)

$x \odot y = x.y + x'.y'$ $(exclusive\ NOR\ or\ XNOR)$
$x \oplus y = x'y + xy'$

Now, we solve this question with the help of options:

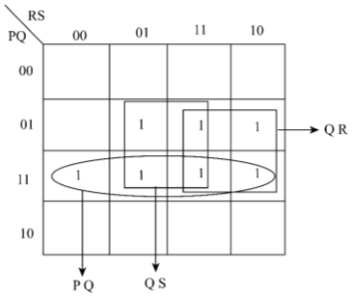
(A) $x \odot y = xy + x'y'$, it is true
(B) $x \oplus y' = x'y' + xy$, it is true
(C) $x' \oplus y = xy + x'y'$, it is true
(D) $x' \oplus y' = xy' + x'y$, it is false

So, Correct option is D.

47. Explanation: (A)

$F(P, Q, R, S) = PQ + \overline{P}QR + \overline{P}Q\overline{R}S$
$= PQ\big(R + \overline{R}\big)\big(S + \overline{S}\big) + \overline{P}QR\big(S + \overline{S}\big) + \overline{P}Q\overline{R}S$
$= \big(PQR + PQ\overline{R}\big)\big(S + \overline{S}\big) + \overline{P}QRS + \overline{P}QR\overline{S} + \overline{P}Q\overline{R}S$
$= PQRS + PQR\overline{S} + PQ\overline{R}S + PQ\overline{R}\,\overline{S} + \overline{P}QRS + \overline{P}QR\overline{S} + \overline{P}Q\overline{R}S$

$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow$
$= 1111 \quad 1110 \quad 1101 \quad 1100 \quad 0111 \quad 0110 \quad 0101$



$= F(P, Q, R, S) = PQ + QR + QS$ is the minimal SOP

48. Explanation: (D)

A function is self dual if it is equal to its dual (A dual function is obtained by interchanging and +).

For self-dual functions,

1. Number of min terms equals number of max terms
2. Function should not contain two complementary minterms - whose sum equals $2^n - 1$, where n is the number of variables.

	A	B	C
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

So, here $(0,7)(1,6)(2,5)(3,4)$ are complementary terms so in self-dual we can select any one of them but not both.

Totally $2 \times 2 \times 2 \times 2 = 24$ possibility because say from (0,7) we can pick anyone in minterm but not both.

For example, let $f = \sum(0,6,2,3)$

NOTE: here I have taken only one of the complementary term for min term from the sets.

So, remaining numbers will go to MAXTERMS

For above example, $2^4 = 16$ self dual functions are possible So, if we have N variables, total Minterms possible is 2^n

Then half of them we selected so $2^n - 1$.

Now we have 2 choices for every pair for being selected.

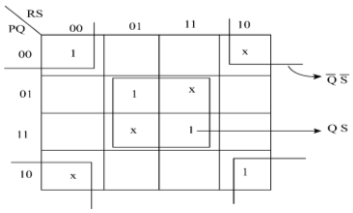
So total such choices $= 2 \times 2 \times 2 \times 2 \ldots (2^n - 1)$ times

total such choices $= \mathbf{2^{2^n - 1}}$

49. Explanation: (B)

$\boldsymbol{F(P, Q, R, S)}$
$\boldsymbol{= \Sigma(0, 2, 5, 7, 8, 10, 13, 15)}$
Given that d $\boldsymbol{\Sigma(2, 7, 8, 13)}$

So,



So,$\boldsymbol{F = \bar{Q}\bar{S} + QS}$

50. Explanation: (D)

XOR is associative and commutative.

Also, $A \oplus A = 0\ and\ A \oplus 1 = \bar{A}\ and\ A \oplus 0 = A.$

So,

$((1 \oplus P) \oplus (P \oplus Q)) \oplus ((P \oplus Q) \oplus (Q \oplus 0))$
$\Longrightarrow (\bar{P} \oplus (P \oplus Q)) \oplus (P \oplus Q)) \oplus (Q)$
$\Longrightarrow ((\bar{P} \oplus P) \oplus Q) \oplus (P \oplus (Q \oplus Q))$
$\Longrightarrow (1 \oplus Q) \oplus (P \oplus 0)$
$\Longrightarrow (\bar{Q} \oplus P)$
$\Longrightarrow \overline{P \oplus Q}$

So, Correct option is D.

51. Explanation: (B)

$f(x, y, z) = x'yz + xy' + y'z'$
$f(x, x, x) = 0 + 0 + x'$
$= x'(complement)$
$f(y', y', z') = 0 + 0 + yz$
$= yz\ (AND)$
$< AND, Complement > fc$
$g(x'y, z) = x'yz + x'yz' + xy$
$= y[x'z + x'z' + x]$
$= y[x' + x]$
$= y$ Not fc

So, f is functional complete and g is not functional complete.

52. Explanation: (B)

S1: $(P\#Q)\#R = P\#(Q\#R)$
$L.H.S\ is\ (P\#Q)\#R$
$=> (\bar{P} + \bar{Q})\#R$
$=> \overline{(\bar{P} + \bar{Q})} + \bar{R} => P.Q + \bar{R}\ (Using\ Demorgans\ theorem)$
$R.H.S\ is\ P\#(Q\#R)$
$=> P\#(\bar{Q} + \bar{R})$
$=> \bar{P} + \overline{(\bar{Q} + \bar{R})} => \bar{P} + Q.R$
$L.H.S\ != R.H.S$

So, S1 is not true.

S2: $Q\#R = (R\#Q)$
$L.H.S\ Q\#R = \bar{Q} + \bar{R}$
$and\ R.H.S\ is\ R\#Q = \bar{R} + \bar{Q}$
$so\ L.H.S = R.H.S$

So S2 is true.

53. Explanation: (A)

$F = P' + QR$

for SOP we have:

$F = P.1.1 + 1.QR' = P'(Q + Q')(R + R') + (P + P')QR$

$P'QR + P'QR' + P'Q'R + P'Q'R' + PQR + P'QR$

$P'QR + P'QR' + P'Q'R + P'Q'R' + PQR$

F=∑(0,1,2,3,7)

now for POS we have:

$F = \prod(4,5,6).$

So, Correct option is A.

54. Explanation: (A)

The truth table for the function #:

x	y	#
0	0	0
0	1	**1**
1	0	**1**
1	1	0

So, f is in SOP form:

$$\boldsymbol{f = \Sigma\{1,2\} = \bar{x}y + x\bar{y}}$$

55. Explanation: (C)

Let $x_1 = 1,\ x_2 = 1,\ x_3 = 1\ and\ x_4 = 1$

such that $x1 \oplus x2 \oplus x3 \oplus x4 = 1 \oplus 1 \oplus 1 \oplus 1 = 0$

Now, this question is solved by options:

A. $x_1.x_2.x_3.x_4 = 1.1.1.1 = 1\ ,\ False$

B. $x_1.x_3 + x_2 = 1.1 + 1 = 1\ ,\ False$

C. $\bar{x}_1 \oplus \bar{x}_3 = \bar{x}_2 \oplus \bar{x}_4 => 1 \oplus 1 = 1 \oplus 1$ True.

D. $x_1 + x_2 + x_3 + x_4 = 1 + 1 + 1 + 1 = 1\ ,\ False$

So, Correct option is C.

56. Explanation: (C)

Let us try to simplify (minimize) the expression given in each option

(A): $wx + w(x + y) + x(x + y) = x + wy$

$wx + wx + wy + x$

$wx + wy + x$

$x(1 + w) + wy$

$x + wy$ (LHS= RHS)

(B): $\overline{w\bar{x}(y + \bar{z})} + \bar{w}x = \bar{w} + x + \bar{y}z$

$\overline{w\bar{x}} + \overline{(y + \bar{z})} + \bar{w}x$

$\bar{w} + x + \bar{y}z + \bar{w}x$

$\bar{w} + \bar{w}x + x + \bar{y}z$

$\bar{w} + x + \bar{y}z$ (LHS=RHS)

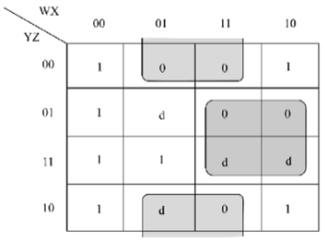
(D): $(w + y)(wxy + wyz) = wxy + wyz$

$wxy + wyz + wxy + wyz$

$wxy + wyz$ (LHS=RHS)

So, answer is C.

57. Explanation: (A)



$f(w,x,y,z) = (\bar{w} + \bar{z})(\bar{x} + z)$

So, correct option is A.

58. Explanation: (D)

We know that,

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

$P \odot Q = PQ + \bar{P}\bar{Q}$

Now, We solve this question with the help of option:

(A) $\overline{P \oplus Q} = P \odot Q$

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

$\overline{P \oplus Q} = \overline{P\bar{Q}}\,.\,\overline{\bar{P}Q}$

$\overline{P \oplus Q} = (\bar{P} + Q).(P + \bar{Q})$

$\overline{P \oplus Q} = PQ + \bar{P}\bar{Q}$

(TRUE)

(B) $\bar{P} \oplus Q = P \odot Q$

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

(TRUE)

(C) $\bar{P} \oplus \bar{Q} = P \oplus Q$

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

(TRUE)

(D) $(P \oplus \bar{P}) \oplus Q = (P \odot \bar{P}) \odot \bar{Q}$

$(P \oplus \bar{P}) \oplus Q = (P\bar{\bar{P}} + \bar{P}\bar{P}) \oplus Q$

$(P \oplus \bar{P}) \oplus Q = 1 \oplus Q$

$(P \oplus \bar{P}) \oplus Q = \bar{Q}\ \ldots\ldots\ldots..(LHS)$

$(P \odot \bar{P}) \odot \bar{Q} = P\bar{P} + \bar{P}P = 0\ \ldots\ldots\ldots.(RHS)$

LHS ≠ RHS

(FASLE)

59. Explanation: (B)

1. XOR is associative so $(x \oplus y) \oplus z = x \oplus (y \oplus z)$
2. For 2 input, XOR and XNOR are complement to each other i.e. $x \oplus y = (xy + x'y')'$
3. $x \oplus y = x + y\ if\ xy = 0$

Only false statement is option B.

60. Explanation: (A)

$f_1\ AND\ with\ f_2$ (∴ when we perform AND operation only common minterms will we selected)

$f_1.f_2 = \Sigma(0,2,5,8,14).\Sigma(2,3,6,8,14,15) = \Sigma(2,8,14)$

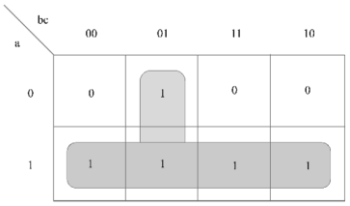
Now, $f_1.f_2 \oplus f_3$ (∴ when we perform XOR operation only uncommon minterms will we selected

$\boldsymbol{f = f_1.f_2 \oplus f_3 = \Sigma(2,8,14) \oplus \Sigma(2,7,11,14) = \Sigma(7,,8,11)}$

61. Explanation: (B)

Given circuit: $z = a + b'c$

K-Map for the above expression is:



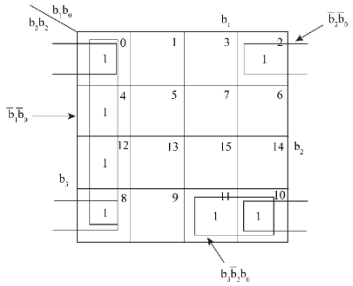
$z = \sum(1,4,5,6,7)$

So, correct option is B.

62. Explanation: (A)

Given expression:

$F(b3,b2,b1,b0) = \sum(0,2,4,8,10,11,12).$

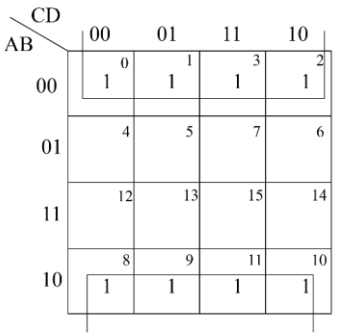


$F(b3,b2,b1,b0) = \bar{b_1}\,\bar{b_0} + \bar{b_2}\,\bar{b_0} + b_1\,\bar{b_2}\,\bar{b_3}$

So, Correct option is A.

63. Explanation: (B)

$F(A,B,C,D) = \Sigma m(0,1,2,3,8,9,10,11)$



$F(A,B,C,D) = \bar{B}$

So, Correct option is B.

Multiple Select Question (MSQ)

1. Explanation: (B, C, D)

$F = (X + Y + Z)(\bar{X} + Y)(\bar{Y} + Z)$

$\bar{F} = \overline{(X + Y + Z)(\bar{X} + Y)(\bar{Y} + Z)}$

$\bar{F} = \overline{XYZ} + X\bar{Y} + Y\bar{Z}$ $---$ $--$ $(\boldsymbol{D})$

$\bar{F} = \bar{Y}(\overline{XZ} + X) + Y\bar{Z}$

$\bar{F} = \bar{Y}(\bar{X} + X)(\bar{Z} + X) + Y\bar{Z}$

$\bar{F} = \bar{Y}(\bar{Z} + X) + Y\bar{Z}$

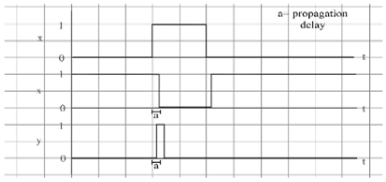
$\bar{F} = \bar{Y}\bar{Z} + \bar{Y}X + Y\bar{Z}$

$\bar{F} = \bar{Y}X + \bar{Z}(\bar{Y} + Y)$

$\bar{F} = \bar{Y}X + \bar{Z}$ $-----$ $(\boldsymbol{B})$

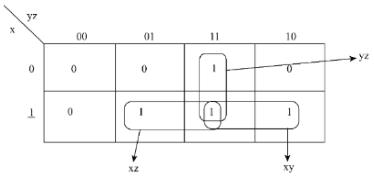
$\bar{F} = (\bar{Y} + \bar{Z})(X + \bar{Z})$ $---$ $--$ $(\boldsymbol{C})$

2. Explanation: (A, C)



From the above graph, we observe option C is True and option D is False.
Y = X.X' = 0, hence A is True and B is False.

3. Explanation: (A, B)



Now, we find the answer with help of options:
$F(X,Y,Z) = \pi(0,1,2,4)$
$F(X,Y,Z) = XZ + XY + YZ$
$F(X,Y,Z)$ is dependent on X, Y, Z
So, correct option is A, B

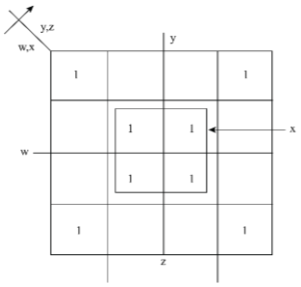
4. Explanation: (C, D)

∴ **AND gate** is performed as intersection operations as it will return common elements between f_1, f_2
∴ **OR gate** is performed as a union operation as it will return all the elements present in both f_3, f_4
Assume the output of the AND gate is y_1 and the output of the OR gate is y_2.
$y_1 = f_1.f_2 = \sum m(3,5,7,11,13)$
$y_2 = f_3 + f_4 = \sum m(0,1,2,4,6,11,13)$
Now both y_1, y_2 act as input for XOR gate which returns the elements that is in either in y_1 or in y_2. It will discard the common elements between y_1, y_2.
So the output $Y = y_1 \oplus y_2 = \sum_m (0,1,2,3,4,5,6,7) \equiv \Pi_m(8,9,10,11,12,13,14,15)$
So Option (C, D) is correct.

5. Explanation: (B, C)

(A) $x.1 = x \quad it\ is\ true$
$(\because\ identity\ law)$
(B) $x + 1 = x \quad it\ is\ false.$
$(\because\ x + 1 = 1)$
(C) $x.x = 0 \quad it\ is\ false,$
$(\because\ x.x = x)$
$(D)\ x + \bar{x} = 1 \quad it\ is\ true$
$(\because\ complement\ law)$
So option (B,C) is false here.

6. Explanation: (A, D)



$f(w,x,y,z) = \bar{w}\,\bar{x}\,\bar{y}\,\bar{z} + w\,\bar{x}\,\bar{y}\,\bar{z} + \bar{w}\,\bar{x}\,y\,\bar{z} + w\,\bar{x}\,y\,\bar{z} + x\,z$
$f(w,x,y,z) = \bar{x}\,\bar{z} + x\,z$
So, Correct option is A, D.

7. Explanation: (B, C, D)

This question is solved by option elimination method:

(a) LHS $= \bar{A}BC + A\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} + A\bar{B}C + ABC$
$= BC + \bar{B}\bar{C} + AC$
$\neq$ RHS

(b) LHS $= AB + \bar{A}C + BC$
$= AB + \bar{A}C$
$\leftarrow$ using consensus property
$=$ RHS

(c) LHS $= (A + C)(\bar{A} + B)$
$= AB + \bar{A}C + BC$
$= AB + \bar{A}C$
$\leftarrow$ using consensus property
$=$ RHS

(d) LHS$=$
$\overline{(A + \bar{B} + \bar{D})(C + D)(\bar{A} + C + D)}$
$(A + B + \bar{D})$
$=$ RHS

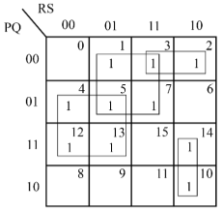
So, Correct options are B, C, D.

8. Explanation: (A, C)

The XOR operation can be expressed as:
$A \oplus B = \overline{A}B + A\overline{B}$ or $(\overline{A} + \overline{B})(A + B)$.
The given expression: $F(P,Q) = (\bar{P} + Q) \oplus (\bar{P}Q)$
$\Longrightarrow (\overline{P} + Q + \bar{P}Q)(\mathrm{P}\bar{Q} + P + \bar{Q})$
$\Longrightarrow (Q + \overline{P}(1 + Q))(P(1 + \overline{Q}) + \overline{Q})$
$\Longrightarrow (\overline{P} + Q)(P + \overline{Q})$
$\Longrightarrow P \odot Q$
So, Correct options are A, C.

9. Explanation: (B, D)

Given:
$F(P,Q,R,S) = \sum m(1,2,3,4,5,7,10,12,13,14)$

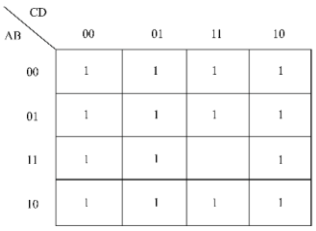


$F(P,Q,R,S) = \bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + PR\bar{S}$
Or
$F(P,Q,R,S) = \bar{P}S + Q\bar{R} + PQ\bar{S} + \bar{Q}R\bar{S}$
SO, Correct options are B, D.

Numerical Answer Type Questions (NAT)

1. Explanation: (1)

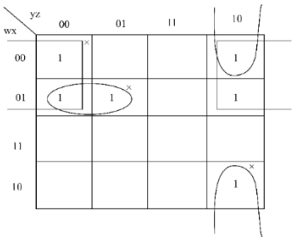
$F(A,B,C,D) =$
$\overline{\bar{D} + A\bar{B} + \bar{A}C + A\bar{C}D + \bar{A}\bar{C}\bar{D}}$
$\bar{F}(A,B,C,D) =$
$\overline{\overline{\bar{D} + A\bar{B} + \bar{A}C + A\bar{C}D + \bar{A}\bar{C}\bar{D}}}$
$\bar{F}(A,B,C,D) = \bar{D} + A\bar{B} + \bar{A}C + A\bar{C}D + \bar{A}\bar{C}\bar{D}$
Now, we make K-map for min terms for $\bar{F}$:



$\bar{F}(A,B,C,D) =$
$\sum (0,1,2,3,4,5,6,7,8,9,10,11,12,13,14)$
So,
$F(A,B,C,D) = \sum (15)$
Only 1 minterm is here.

2. Explanation: (3)

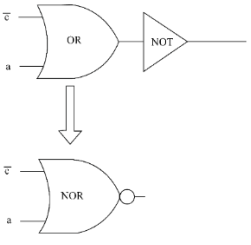
Prime Implicant: A group of squares or rectangles made up of a bunch of adjacent minterms that is allowed by definition of a Karnaugh Map are known as prime implicants or PI, i.e. all the possible groups that are formed in K-Map.



Here, there are 3 prime implicants

3. Explanation: (1)

$f(a,b,c,d) = \bar{a}.c$
So, the expression should be in POS form for NOR gate
$\overline{\overline{\bar{a}.c}} = \overline{\bar{c} + a}$



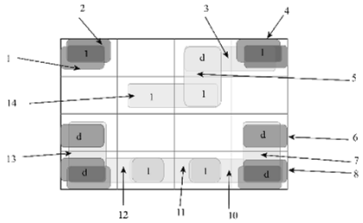
So only 1 NOR gate required

4. **Explanation: (3)**

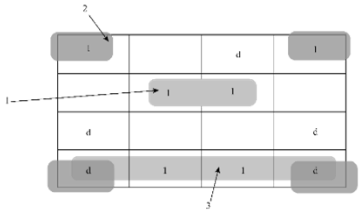
Prime Implicants: A group of squares or rectangles made up of a bunch of adjacent minterms that is allowed by definition of a Karnaugh Map are known as prime implicants or PI, i.e. all the possible groups that are formed in K-Map.

Essential Prime Implicants: These refer to those subcubes or groups that cover at least one of the minterms that can't get covered by another prime implicant. The EPI or essential prime implicants refer to the prime implicants that always appear in the final solution.

Now,



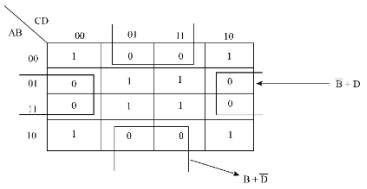
From this K-map we find PI:



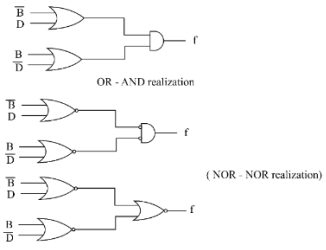
No. of Essential Prime Implicants= 3.

5. **Explanation: (3)**

If we want to implement expression using only NOR- Gate than we use Sum of Product form.



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



There are 3 NOR Gates are used.

6. **Explanation: (6)**

From equation: $f(w,0,0,z) = 1$, here x and y are always 0 and w and z takes both value 0, 1

w=0 and z=0: $f(0,0,0,0) = 1$

w=0 and z=1: $f(0,0,0,1) = 1$

w=1 and z=0: $f(1,0,0,0) = 1$

w=1 and z=1: $f(1,0,0,1) = 1$

From equation: $f(1,x,1,z) = x + z$, here w and y are always 1 , x and z takes both value 0, 1

x=0 and z=0: $f(1,0,1,0) = 0 + 0 = 0$

x=0 and z=1: $f(1,0,1,1) = 0 + 1 = 1$

x=1 and z=0: $f(1,1,1,0) = 1 + 1 = 1$

x=1 and z=1: $f(1,1,1,1) = 1 + 1 = 0$

From equation: $f(w,1,y,z) = wz + y$, here x is always 1 and w,y and z takes both values 0,1

w=0, y=0, z=0: $f(0,1,0,0) = 0.0 + 0 = 0$

w=0, y=0, z=1: $f(0,1,0,1) = 0.1 + 0 = 0$

w=0, y=1, z=0: $f(0,1,1,0) = 0.0 + 1 = 1$

w=0, y=1, z=1: $f(0,1,1,1) = 0.1 + 1 = 1$

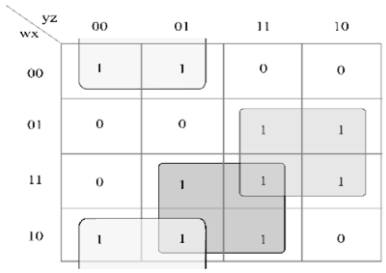
w=1, y=0, z=0: $f(1,1,0,0) = 1.0 + 0 = 0$

w=1, y=0, z=1: $f(1,1,0,1) = 1.1 + 0 = 1$

w=1, y=1, z=0: $f(1,1,1,0) = 1.0 + 1 = 1$

w=1, y=1, z=1: $f(1,1,1,1) = 1.1 + 1 = 0$

Now,



We can see 3 squares, so number of literals

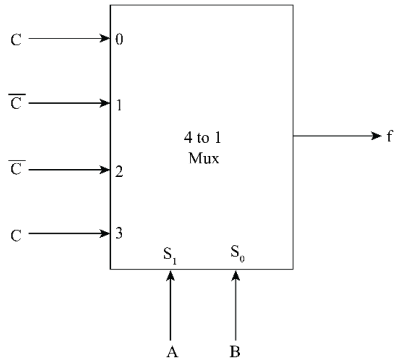
$= 3 \times 2 = 6$

Unit 3.2: Combinational Circuits

Multiple Choice Questions (MCQ)

[1996]

1. **Consider the circuit in figure shown. f implements**

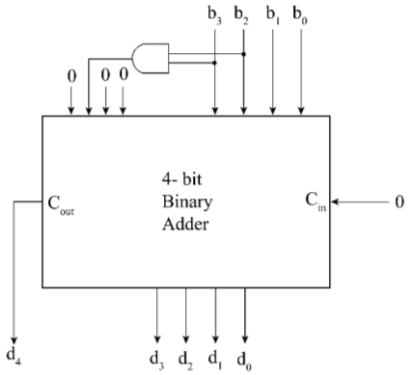


(A) $\bar{A}\bar{B}C + \bar{A}\,B\bar{C} + ABC$ (B) $A + B + C$

(C) $A \oplus B \oplus C$ (D) $AB + BC + CA$

[1996]

2. **Consider the circuit in below figure which has a four bit binary number $b_3b_2b_1b_0$ as input and a five bit binary number $d_4d_3d_2d_1d_0$ as output. The circuit implements:**



(A) Binary to Hex conversion

(B) Binary to BCD conversion

(C) Binary to grey code conversion

(D) Binary to radix-12 conversion

[1998: 1 Mark]

3. **A multiplexor with a 4 bit data select input is a**

(A) 4:1 multiplexor (B) 2:1 multiplexor

(C) 16: 1 multiplexor (D) 8:1 multiplexor