CHAPTER 2

2.1 **(a)**

x y z	$x + y + z$	$(x + y + z)'$	x'	y'	z'	$x'y'z'$
0 0 0	0	1	1	1	1	1
0 0 1	1	0	1	1	0	0
0 1 0	1	0	1	0	1	0
0 1 1	1	0	1	0	0	0
1 0 0	1	0	0	1	1	0
1 0 1	1	0	0	1	0	0
1 1 0	1	0	0	0	1	0
1 1 1	1	0	0	0	0	0

x y z	(xyz)	$(xyz)'$	x'	y'	z'	$x' + y' + z'$
0 0 0	0	1	1	1	1	1
0 0 1	0	1	1	1	0	1
0 1 0	0	1	1	0	1	1
0 1 1	0	1	1	0	0	1
1 0 0	0	1	0	1	1	1
1 0 1	0	1	0	1	0	1
1 1 0	0	1	0	0	1	1
1 1 1	1	0	0	0	0	0

(b)

x y z	$x + yz$	$(x + y)$	$(x + z)$	$(x + y)(x + z)$
0 0 0	0	0	0	0
0 0 1	0	0	1	0
0 1 0	0	1	0	0
0 1 1	1	1	1	1
1 0 0	1	1	1	1
1 0 1	1	1	1	1
1 1 0	1	1	1	1
1 1 1	1	1	1	1

(c)

x y z	$x(y + z)$	xy	xz	$xy + xz$
0 0 0	0	0	0	0
0 0 1	0	0	0	0
0 1 0	0	0	0	0
0 1 1	0	0	0	0
1 0 0	0	0	0	0
1 0 1	1	0	1	1
1 1 0	1	1	0	1
1 1 1	1	1	1	1

(c)

x y z	x	$y + z$	$x + (y + z)$	$(x + y)$	$(x + y) + z$
0 0 0	0	0	0	0	0
0 0 1	0	1	1	0	1
0 1 0	0	1	1	1	1
0 1 1	0	1	1	1	1
1 0 0	1	0	1	1	1
1 0 1	1	1	1	1	1
1 1 0	1	1	1	1	1
1 1 1	1	1	1	1	1

(d)

x y z	yz	$x(yz)$	xy	$(xy)z$
0 0 0	0	0	0	0
0 0 1	0	0	0	0
0 1 0	0	0	0	0
0 1 1	1	0	0	0
1 0 0	0	0	0	0
1 0 1	0	0	0	0
1 1 0	0	0	1	0
1 1 1	1	1	1	1

2.2 **(a)** $xy + xy' = x(y + y') = x$

(b) $(x + y)(x + y') = x + yy' = x(x + y') + y(x + y') = xx + xy' + xy + yy' = x$

(c) $xyz + x'y + xyz' = xy(z + z') + x'y = xy + x'y = y$

(d) $(A + B)'(A' + B') = (A'B')(A B) = (A'B')(BA) = A'(B'BA) = 0$

(e) $xyz' + x'yz + xyz + x'yz' = xy(z + z') + x'y(z + z') = xy + x'y = y$

(f) $(x + y + z')(x' + y' + z) = xx' + xy' + xz + x'y + yy' + yz + x'z' + y'z' + zz' =$
$= xy' + xz + x'y + yz + x'z' + y'z' = x \oplus y + (x \oplus z)' + (y \oplus z)'$

2.3 **(a)** $ABC + A'B + ABC' = AB + A'B = B$

(b) $x'yz + xz = (x'y + x)z = z(x + x')(x + y) = z(x + y)$

(c) $(x + y)'(x' + y') = x'y'(x' + y') = x'y'$

(d) $xy + x(wz + wz') = x(y + wz + wz') = x(w + y)$

(e) $(BC' + A'D)(AB' + CD') = BC'AB' + BC'CD' + A'DAB' + A'DCD' = 0$

(f) $(x + y' + z')(x' + z') = xx' + xz' + x'y' + y'z' + x'z' + z'z' = z' + y'(x' + z') = z' + x'y'$

2.4 **(a)** $A'C' + ABC + AC' = C' + ABC = (C + C')(C' + AB) = AB + C'$

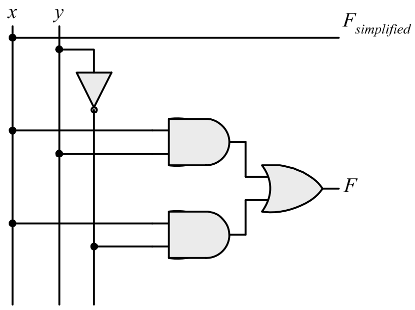
(b) $(x'y' + z)' + z + xy + wz = (x'y')'z' + z + xy + wz = [(x + y)z' + z] + xy + wz =$
$= (z + z')(z + x + y) + xy + wz = z + wz + x + xy + y = z(1 + w) + x(1 + y) + y = x + y + z$

(c) $A'B(D' + C'D) + B(A + A'CD) = B(A'D' + A'C'D + A + A'CD)$
$= B(A'D' + A + A'D(C + C') = B(A + A'(D' + D)) = B(A + A') = B$

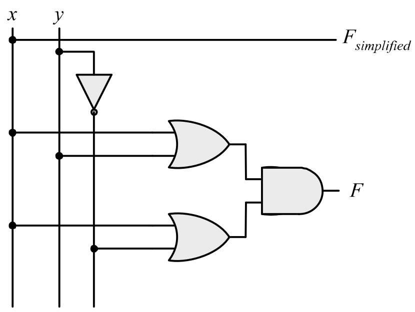
(d) $(A' + C)(A' + C')(A + B + C'D) = (A' + CC')(A + B + C'D) = A'(A + B + C'D)$
$= AA' + A'B + A'C'D = A'(B + C'D)$

(e) $ABCD + A'BD + ABC'D = ABD + A'BD = BD$

2.5 **(a)**



(b)



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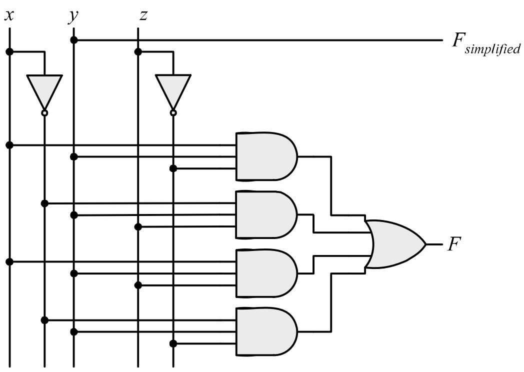

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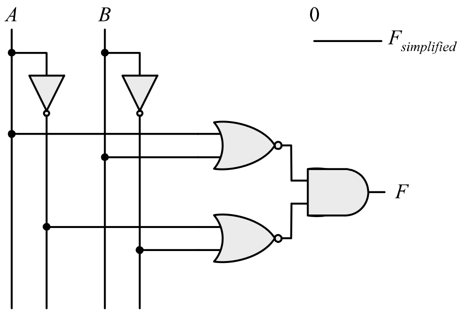

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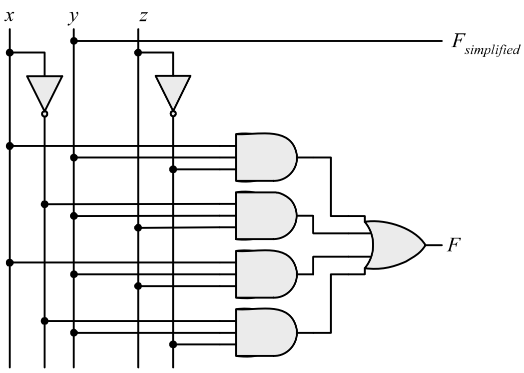

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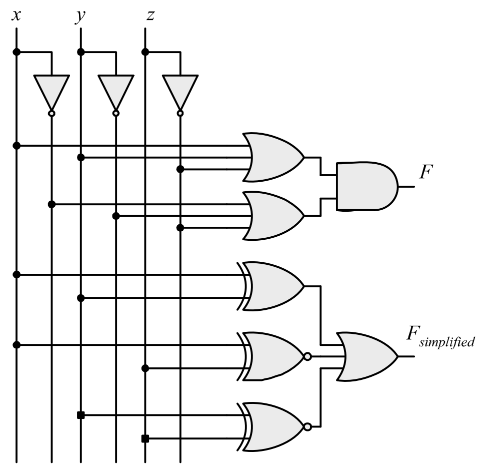
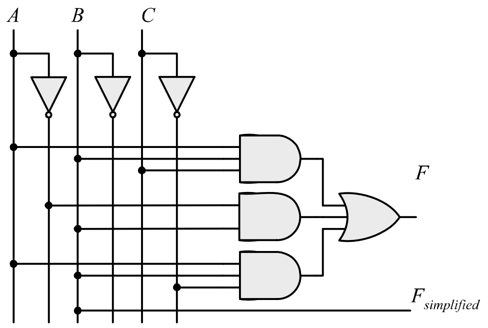
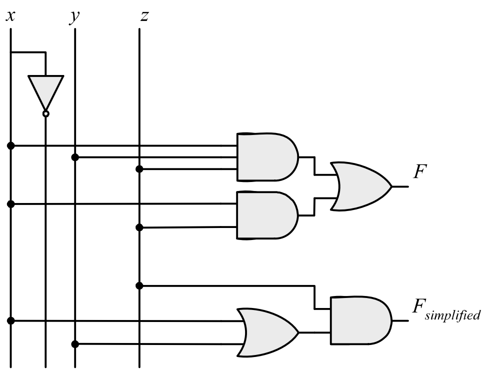

x
y
z
F
F simplified

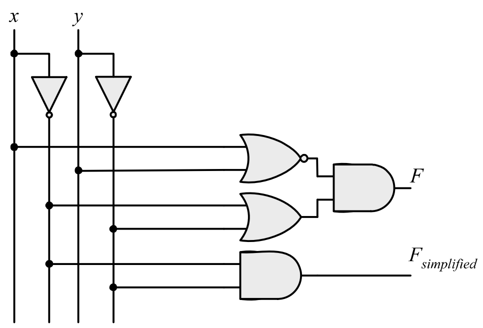
2.6 **(a)**


A
B
C
F
F simplified

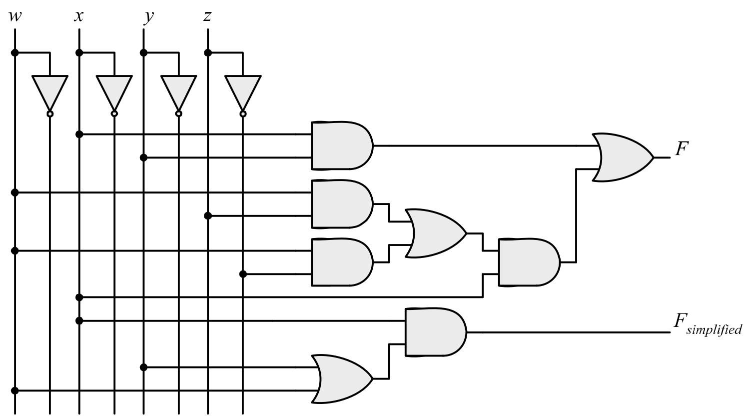
(b)


x
y
z
F
F simplified

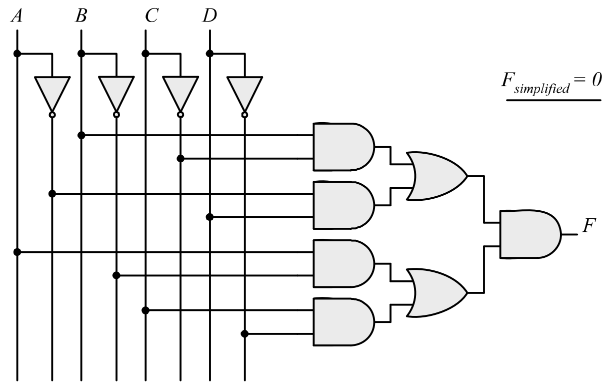
(c)


x
y
F
F simplified

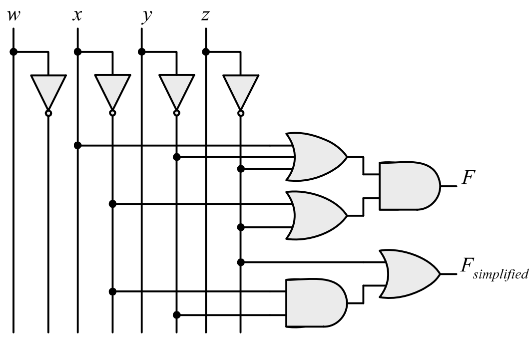
(d)


w
x
y
z
F
F simplified

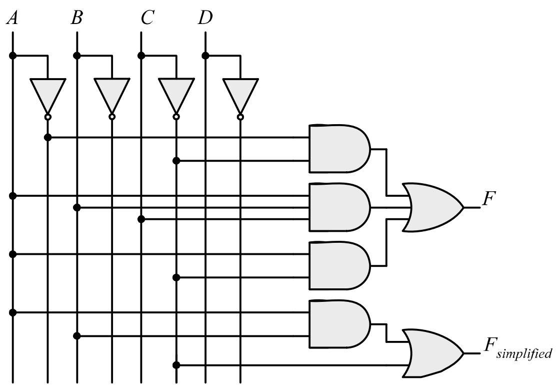
(e)


A
B
C
D
F simplified = 0
F

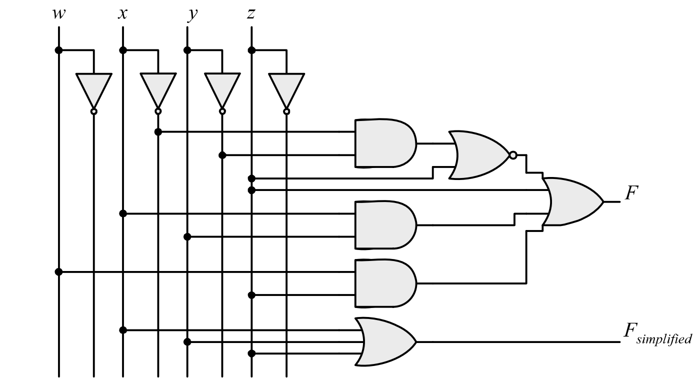
(f)


w
x
y
z
F
F simplified

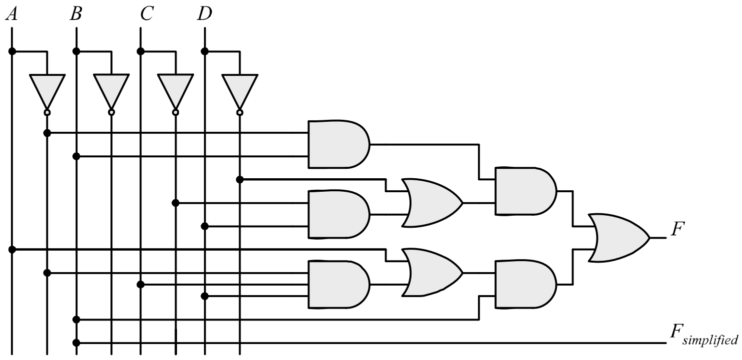
2.7 **(a)**


A
B
C
D
F
F simplified

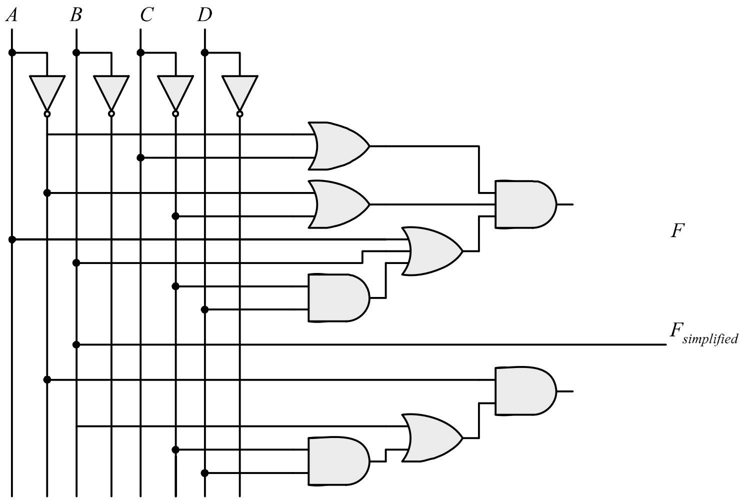
(b)



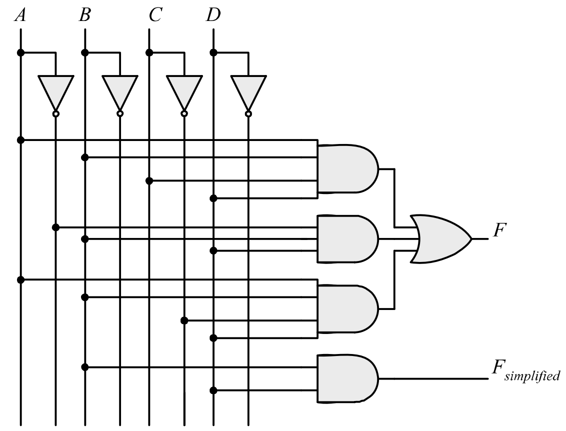
(c)



(d)



(e)



2.8 $F' = (wx + yz)' = (wx)'(yz)' = (w' + x')(y' + z')$

$FF' = wx(w' + x')(y' + z') + yz(w' + x')(y' + z') = 0$
$F + F' = wx + yz + (wx + yz)' = A + A' = 1 \text{ with } A = wx + yz$

2.9 **(a)** $F' = (xy' + x'y)' = (xy')'(x'y)' = (x' + y)(x + y') = xy + x'y'$

(b) $F' = [(A'B + CD)E' + E]' = [(A'B + CD) + E]' = (A'B + CD)'E' = (A'B)'(CD)'E'$
$F' = (A + B')(C' + D')E' = AC'E' + A D'E' + B'C'E' + B'D'E'$

(c) $F' = [(x' + y + z')(x + y')(x + z)]' = (x' + y + z')' + (x + y')' + (x + z)' =$
$F' = xy'z + x'y + x'z'$

2.10 **(a)** $F_1 + F_2 = \Sigma\, m_{1i} + \Sigma m_{2i} = \Sigma\, (m_{1i} + m_{2i})$

(b) $F1\ F2 = \Sigma\, m_i\, \Sigma m_j$ where $m_i\, m_j = 0$ if $i \neq j$ and $m_i\, m_j = 1$ if $i = j$

2.11 **(a)** $F(x, y, z) = \Sigma(1, 4, 5, 6, 7)$

(b) $F(x, y, z) = \Sigma(0, 2, 3, 7)$

$F = xy + xy' + y'z$

x y z	F
0 0 0	0
0 0 1	1
0 1 0	0
0 1 1	0
1 0 0	1
1 0 1	1
1 1 0	1
1 1 1	1

$F = x'z' + yz$

x y z	F
0 0 0	1
0 0 1	0
0 1 0	1
0 1 1	1
1 0 0	0
1 0 1	0
1 1 0	0
1 1 1	1

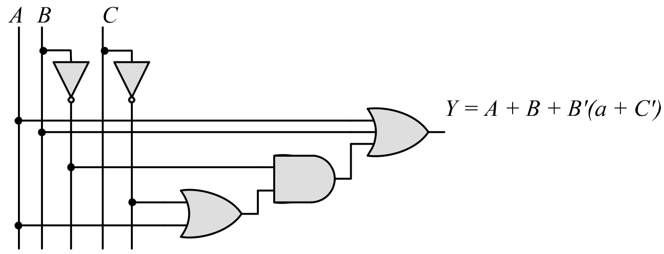
2.12 $A = 1011\_0001$
$B = 1010\_1100$

(a) $A \text{ AND } B = 1010\_0000$
(b) $A \text{ OR } B = 1011\_1101$
(c) $A \text{ XOR } B = 0001\_1101$

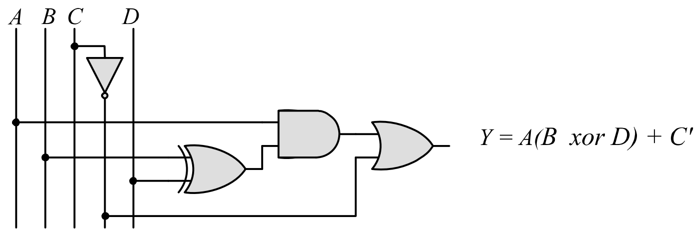
(d) *NOT A = 0100_1110*

(e) *NOT B = 0101_0011*

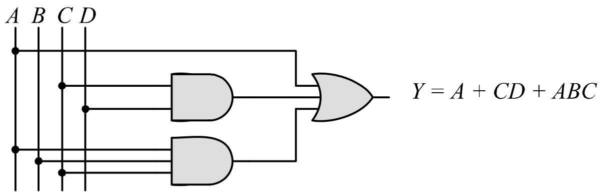
2.13 **(a)**



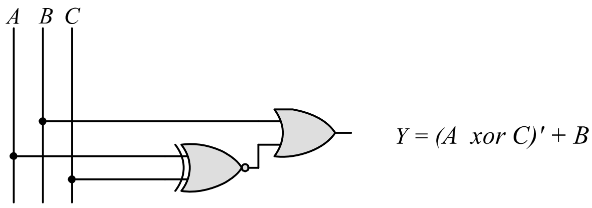
(b)



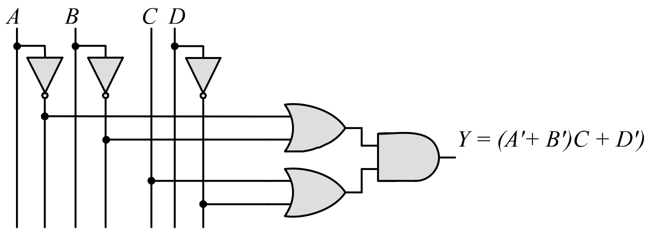
(c)



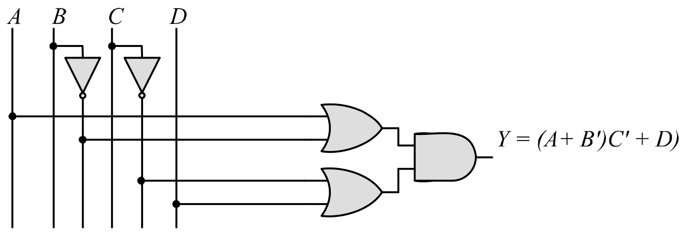
(d)



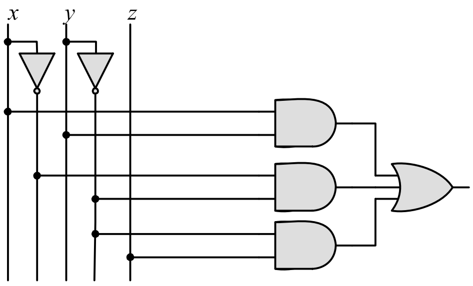
(e)



(f)

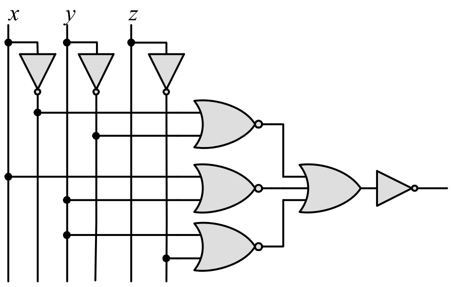


2.14 **(a)**



$F = xy + x'y' + y'z$

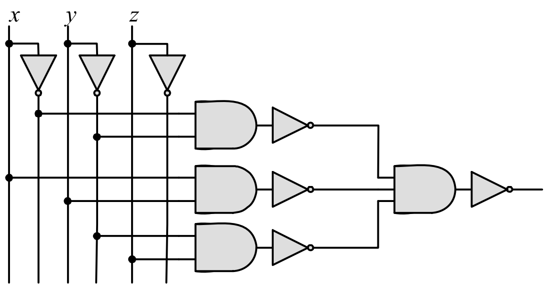
(b)



$F = xy + x'y' + y'z$

$= (x' + y')' + (x + y)' + (y + z')'$

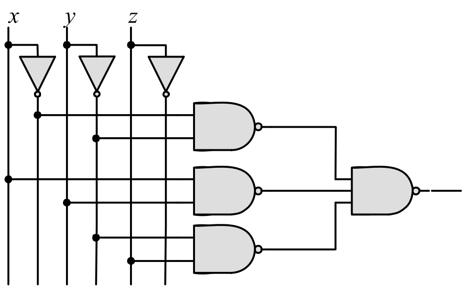
(c)



$F = xy + x'y' + y'z$

$= [(xy)' (x'y')' (y'z)']'$

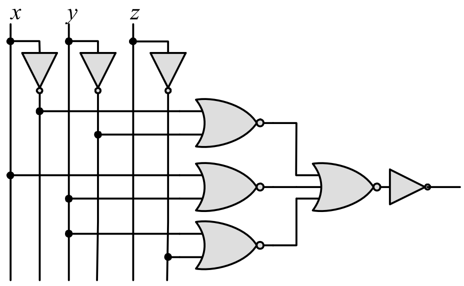
(d)



$F = xy + x'y' + y'z$

$= [(xy)' (x'y')' (y'z)']'$

(e)



$F = xy + x'y' + y'z$

$= (x' + y')' + (x + y)' + (y + z')'$

2.15 **(a)** $T_1 = A'B'C' + A'B'C + A'BC' = A'B'(C' + C) + A'C'(B' + B) = A'B' + A'C' = A'(B' + C')$

(b) $T_2 = T_1' = A'BC + AB'C' + AB'C + ABC' + ABC$
$= BC(A' + A) + AB'(C' + C) + AB(C' + C)$
$= BC + AB' + AB = BC + A(B' + B) = A + BC$

$\Sigma(3, 5, 6, 7) = \Pi(0, 1, 2, 4)$

$T_1 = A'B'C' + A'B'C + A'BC'$

$A'B'$ $A'C'$

$T_1 = A'B'\ A'C' = A'(B' + C')$

$T_2 = A'BC + AB'C' + AB'C + ABC' + ABC$

AC' AC

BC

$T_2 = AC' + BC + AC = A + BC$

2.16 **(a)** $F(A, B, C) = A'B'C' + A'B'C + A'BC' + A'BC + AB'C' + AB'C + ABC' + ABC$
$= A'(B'C' + B'C + BC' + BC) + A((B'C' + B'C + BC' + BC)$
$= (A' + A)(B'C' + B'C + BC' + BC) = B'C' + B'C + BC' + BC$
$= B'(C' + C) + B(C' + C) = B' + B = 1$

(b) $F(x_1, x_2, x_3, \ldots, x_n) = \Sigma m_i$ has $2^n/2$ minterms with x_1 and $2^n/2$ minterms with x'_1, which can be factored and removed as in (a). The remaining 2^{n-1} product terms will have $2^{n-1}/2$ minterms with x_2 and $2^{n-1}/2$ minterms with x'_2, which and be factored to remove x_2 and x'_2. continue this process until the last term is left and $x_n + x'_n = 1$. Alternatively, by induction, F can be written as $F = x_nG + x'_nG$ with $G = 1$. So $F = (x_n + x'_n)G = 1$.

2.17 **(a)** $(xy + z)(y + xz) = xy + yz + xyz + xz = \Sigma(3, 5, 6, 7) = \Pi(0, 1, 2, 4)$

(b) $(A' + B)(B' + C) = A'B' + A'C + BC = \Sigma(0, 1, 3, 7) = \Pi(2, 4, 5, 6)$

(c) $y'z + wxy' + wxz' + w'x'z = \Sigma(1, 3, 5, 9, 12, 13, 14) = \Pi(0, 2, 4, 6, 7, 8, 10, 11, 15)$

(d) $(xy + yz' + x'z)(x + z) = xy + xyz' + xyz + x'z$
$= \Sigma(1, 3, 9, 11, 14, 15) = \Pi(0, 2, 4, 5, 6, 7, 8, 10, 12, 13)$

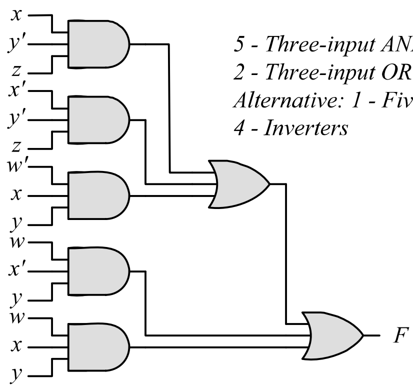
2.18 (a)

wx y z	F
00 0 0	0
00 0 1	1
00 1 0	0
00 1 1	0
01 0 0	0
01 0 1	1
01 1 0	1
01 1 1	1
10 0 0	0
10 0 1	1
10 1 0	1
10 1 1	1
11 0 0	0
11 0 1	1
11 1 0	1
11 1 1	1

$F = xy'z + x'y'z + w'xy + wx'y + wxy$

$F = \Sigma(1, 5, 6, 7, 9, 10\ 11, 13, 14, 15\ )$

(b)

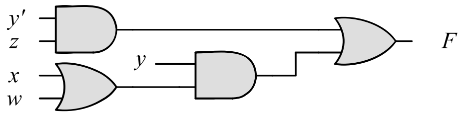


5 - Three-input AND gates
2 - Three-input OR gates
Alternative: 1 - Five-input OR gate
4 - Inverters

(c) $F = xy'z + x'y'z + w'xy + wx'y + wxy = y'z + xy + wy = y'z + y(w + x)$

(d) $F = y'z + yw + yx) = \Sigma(1, 5, 9, 13\ , 10, 11, 13, 15, 6, 7, 14, 15)$
$= \Sigma(1, 5, 6, 7, 9,\ 10, 11, 13, 14, 15)$

(e)



1 – Inverter, 2 – Two-input AND gates, 2 – Two-input OR gates

2.19 $F = B'D + A'D + BD$

ABCD	*ABCD*	*ABCD*
-B'-D	A'--D	-B-D
0001 = 1	0001 = 1	0101 = 5
0011 = 3	0011 = 3	0111 = 7
1001 = 9	0101 = 5	1101 = 13
1011 = 11	0111 = 7	1111 = 15

$F = \Sigma(1, 3, 5, 7, 9, 11, 13, 15) = \Pi(0, 2, 4, 6, 8, 10, 12, 14)$

2.20 **(a)** $F(A, B, C, D) = \Sigma(3, 5, 9, 11, 15)$
$F'(A, B, C, D) = \Sigma(0, 1, 2, 4, 6, 7, 8, 10, 12, 13, 14)$

(b) $F(x, y, z) = \Pi(2, 4, 5, 7)$
$F' = \Sigma(2, 4, 5, 7)$

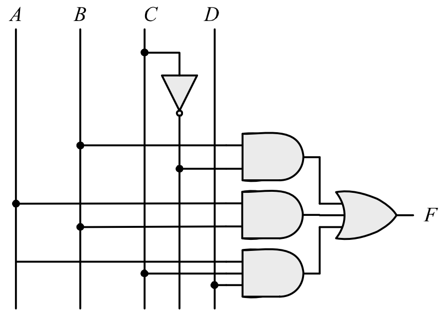
2.21 ***(a)*** $F(x, y, z) = \Sigma(2, 5, 6) = \Pi(0, 1, 3, 4, 7)$

(b) $F(A, B, C, D) = \Pi(0, 1, 2, 4, 7, 9, 12) = \Sigma(3, 5, 6, 8, 10, 11, 13, 14, 15)$

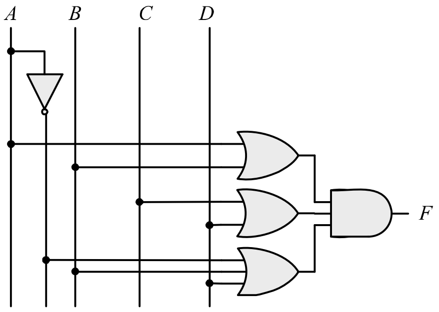
2.22 **(a)** $(AB + C)(B + C'D) = AB + BC + ABC'D + CC'D = AB(1 + C'D) + BC$
$= AB + BC$ (SOP form)
$= B(A + C)$ (POS form)

(b) $x' + x(x + y')(y + z') = (x' + x)[x' + (x + y')(y + z')] =$
$= (x' + x + y')(x' + y + z')$
$= x' + y + z'$

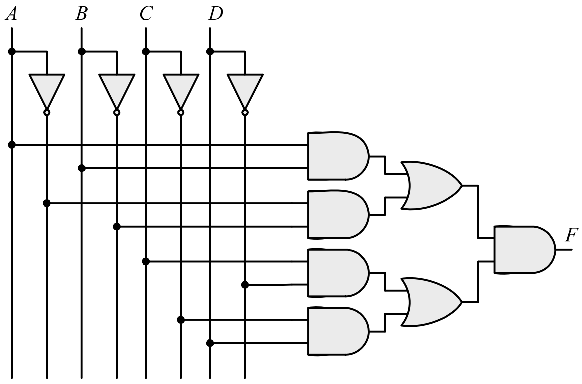
2.23 **(a)** $B'C + AB + ACD$



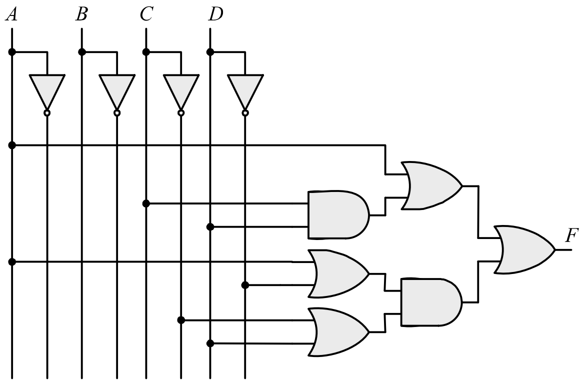
(b) $(A + B)(C + D)(A' + B + D)$



(c) $(AB + A'B')(CD' + C'D)$



(d) $A + CD + (A + D')(C' + D)$



2.24 $x \oplus y = x'y + xy'$ and $(x \oplus y)' = (x + y')(x' + y)$

Dual of $x'y + xy' = (x' + y)(x + y') = (x \oplus y)'$

2.25 **(a)** $x | y = xy' \neq y | x = x'y$ Not commutative
$(x | y) | z = xy'z' \neq x | (y | z) = x(yz')' = xy' + xz$ Not associative

(b) $(x \oplus y) = xy' + x'y = y \oplus x = yx' + y'x$ Commutative

$(x \oplus y) \oplus z = \sum(1, 2, 4, 7) = x \oplus (y \oplus z)$ Associative

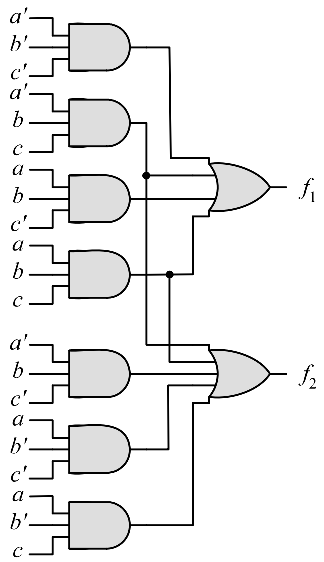
2.26

Gate		NAND (Positive logic)		NOR (Negative logic)	
x y	z	x y	z	x y	z
L L	H	0 0	1	1 1	0
L H	H	0 1	1	1 0	0
H L	H	1 0	1	0 1	0
H H	L	1 1	0	0 0	1

Gate		NOR (Positive logic)		NAND (Negative logic)	
x y	z	x y	z	x y	z
L L	H	0 0	1	1 1	0
L H	L	0 1	0	1 0	1
H L	L	1 0	0	0 1	1
H H	L	1 1	0	0 0	1

2.27 $f_1 = a'b'c + a'bc + abc' + abc$

$f_2 = a'bc' + a'bc + ab'c' + ab'c + abc'$



2.28 **(a)** $y = a(bcd)'e = a(b' + c' + d')e$

$$y = a(b' + c' + d')e = ab'e + ac'e + ad'e$$
$$= \Sigma(17, 19, 21, 23, 25, 27, 29)$$

a bcde	y	a bcde	y
0 0000	0	1 0000	0
0 0001	0	**1 0001**	1
0 0010	0	1 0010	0
0 0011	0	**1 0011**	1
0 0100	0	1 0100	0
0 0101	0	**1 0101**	1
0 0110	0	1 0110	0
0 0111	0	**1 0111**	1
	0		0
0 1000	0	1 1000	0
0 1001	0	**1 1001**	1
0 1010	0	1 1010	0
0 1011	0	**1 1011**	1
0 1100	0	1 1100	0
0 1101	0	**1 1101**	1
0 1110	0	1 1110	0
0 1111	0	1 1111	0

(b) $y_1 = a \oplus (c + d + e) = a'(c + d + e) + a(c'd'e') = a'c + a'd + a'e + ac'd'e'$

$y_2 = b'(c + d + e)f = b'cf + b'df + b'ef$

$y_1 = a \ (c + d + e) = a'(c + d + e) + a(c'd'e') = a'c + a'd + a'e + ac'd'e'$

$y_2 = b'(c + d + e)f = b'cf + b'df + b'ef$

a'-c---	*a'--d--*	*a'---e-*	*a-c'd'e'-*
001000 = 8	000100 = 8	000010 = 2	100000 = 32
001001 = 9	000101 = 9	000011 = 3	100001 = 33
001010 = 10	000110 = 10	000110 = 6	110000 = 34
001011 = 11	000111 = 11	000111 = 7	110001 = 35
001100 = 12	001100 = 12	001010 = 10	
001101 = 13	001101 = 13	001011 = 11	
001110 = 14	001110 = 14	001110 = 14	
001111 = 15	001111 = 15	001111 = 15	
011000 = 24	010100 = 20	010010 = 18	
011001 = 25	010101 = 21	010011 = 19	
011010 = 26	010110 = 22	010110 = 22	
011011 = 27	010111 = 23	010111 = 23	
011100 = 28	011100 = 28	011010 = 26	
011101 = 29	011101 = 29	011001 = 27	
011110 = 30	011110 = 30	011110 = 30	
011111 = 31	011111 = 31	011111 = 31	

-b' c--f	-b' -d-f	-b' --ef
001001 = 9	001001 = 9	000011 = 3
001011 = 11	001011 = 11	000111 = 7
001101 = 13	001101 = 13	001011 = 11
001111 = 15	001111 = 15	001111 = 15
101001 = 41	101001 = 41	100011 = 35
101011 = 43	101011 = 43	100111 = 39
101101 = 45	101101 = 45	101011 = 51
101111 = 47	101111 = 47	101111 = 55

$y_1 = \Sigma$ (2, 3, 6, 7, 8, 9, 10 ,11, 12, 13, 14, 15, 18, 19, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35)

$y_2 = \Sigma$ (3, 7, 9, 13, 15, 35, 39, 41, 43, 45, 47, 51, 55)

ab cdef	y_1 y_2
00 0000	0 0
00 0001	0 0
00 0010	1 0
00 0011	1 1
00 0100	0 0
00 0101	0 0
00 0110	1 0
00 0111	1 1
00 1000	1 0
00 1001	1 1
00 1010	1 0
00 1011	1 0
00 1100	1 0
00 1101	1 1
00 1110	1 0
00 1111	1 1

ab cdef	y_1 y_2
01 0000	0 0
01 0001	0 0
01 0010	1 0
01 0011	1 0
01 0100	0 0
01 0101	0 0
01 0110	1 0
01 0111	1 0
01 1000	1 0
01 1001	1 0
01 1010	1 0
01 1011	1 0
01 1100	1 0
01 1101	1 0
01 1110	1 0
01 1111	1 0

ab cdef	y_1 y_2
10 0000	1 0
10 0001	1 0
10 0010	1 0
10 0011	1 1
10 0100	0 0
10 0101	0 0
10 0110	0 0
10 0111	0 1
10 1000	0 0
10 1001	0 1
10 1010	0 0
10 1011	0 1
10 1100	0 0
10 1101	0 1
10 1110	0 0
10 1111	0 1

ab cdef	y_1 y_2
11 0000	0 0
11 0001	0 0
11 0010	0 0
11 0011	0 1
11 0100	0 0
11 0101	0 0
11 0110	0 0
11 0111	0 1
11 1000	0 0
11 1001	0 0
11 1010	0 0
11 1011	0 0
11 1100	0 0
11 1101	0 0
11 1110	0 0
11 1111	0 0