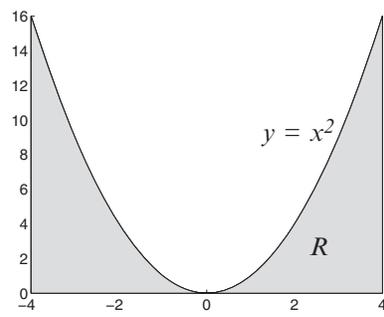


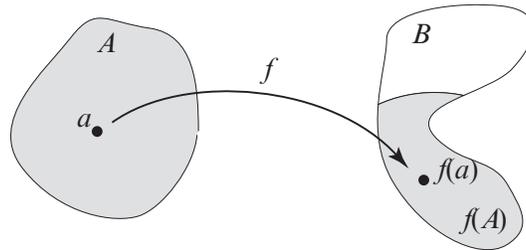
**FIGURE 2.1**

Graph of the relation of Example 2.1(b) (shaded region).



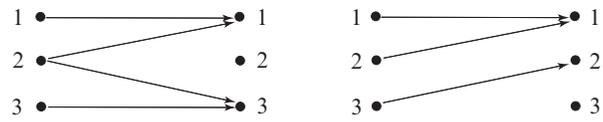
**FIGURE 2.2**

Schematic diagram of a function  $f: A \rightarrow B$  with the image  $f(a)$  of an element  $a$  in the domain  $A$ , and the range  $f(A)$  shown (shaded).



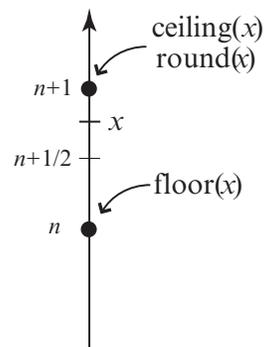
**FIGURE 2.3**

Two relations on the set  $\{1, 2, 3\}$ . (a) (left) Is not a function since the image of 2 is not unique. (b) (right) Is a function.



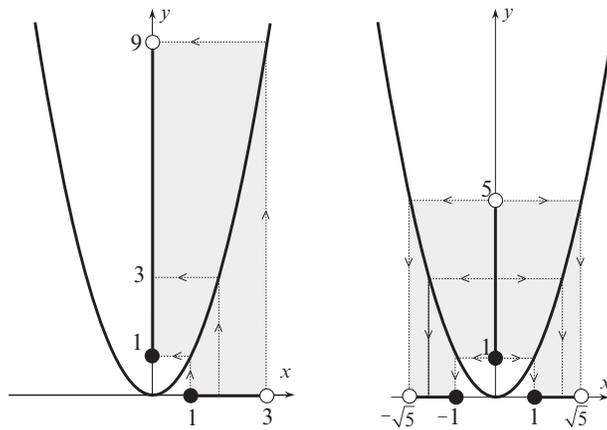
**FIGURE 2.4**

Picture illustrating the floor, round, and ceiling functions.



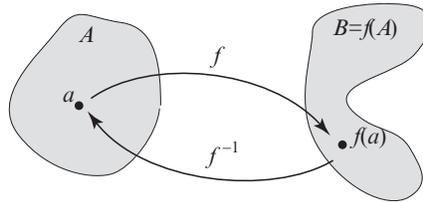
**FIGURE 2.5**

Graphical illustration of an image and a pre-image of the function  $f: \mathbb{R} \rightarrow \mathbb{R} :: f(x) = x^2$ . (a) (left) The image  $f([1,3)) = [1,9)$ . (b) (right) The pre-image  $f^{-1}([1,5)) = (-\sqrt{5}, -1] \cup [1, \sqrt{5})$ .



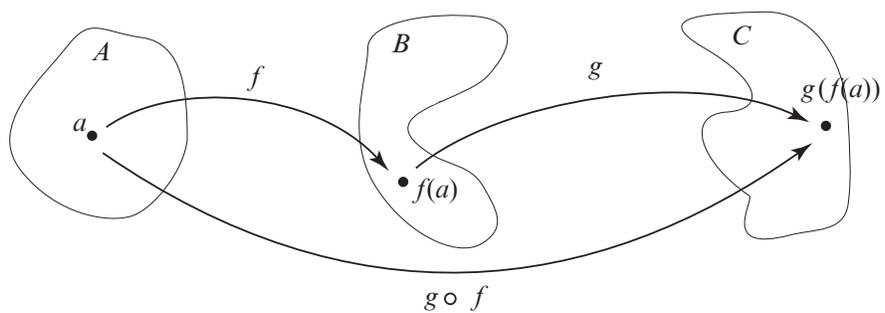
**FIGURE 2.6**

Illustration of the inverse function  $f^{-1} : B \rightarrow A$  of a bijection  $f : A \rightarrow B$ .



**FIGURE 2.7**

The composition  $g \circ f: A \rightarrow C$  of two functions  $f: A \rightarrow B_1$  and  $g: B \rightarrow C$ , where  $f(A) \subseteq B$ .



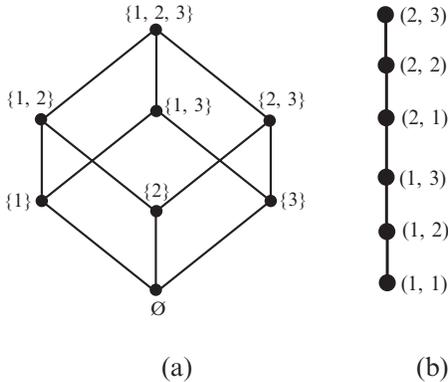
**FIGURE 2.8**

Helmut Hasse (1898–1979), German mathematician



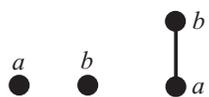
**FIGURE 2.9**

Hasse diagrams: (a) (left) for the subset partial order of Example 2.10(a), and (b) (right) for the lexicographic order of Example 2.10(b).



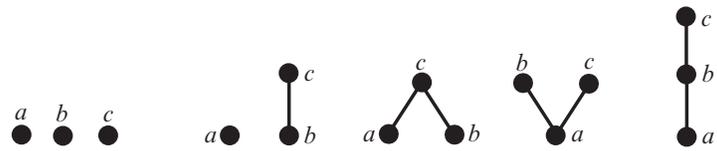
**FIGURE 2.10**

Hasse diagrams for the two isomorphism classes for two-element posets.



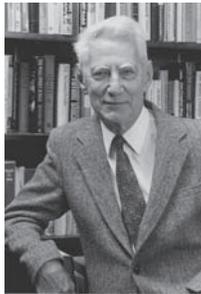
**FIGURE 2.11**

Hasse diagrams for the five isomorphism classes of three-element posets.



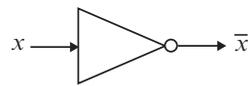
**FIGURE 2.12**

Claude E. Shannon (1916–2001), American applied mathematician

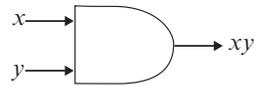


**FIGURE 2.13**

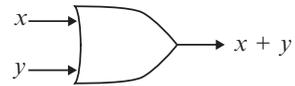
The basic logic gates of Boolean circuit design: (a) (left) The inverter, (b) (middle) The AND gate, and (c) (right) The OR gate.



(a) Inverter



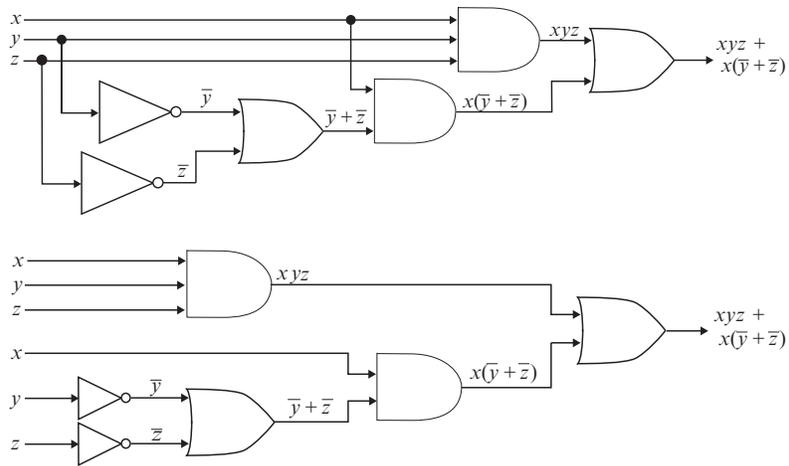
(b) AND Gate



(c) OR Gate

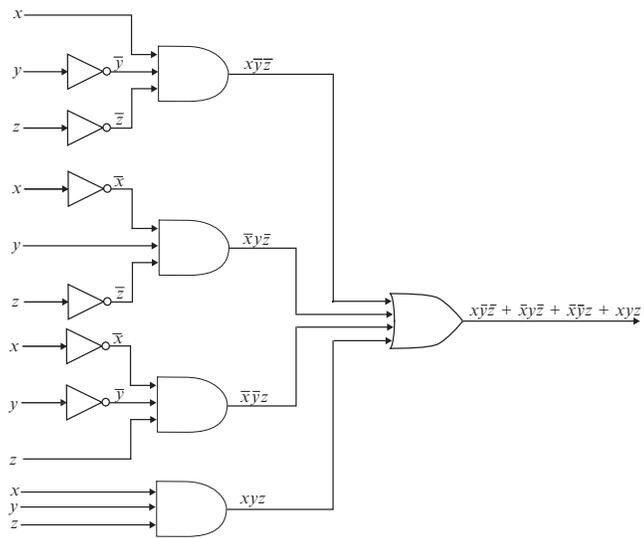
**FIGURE 2.14**

Two circuit drawings for the Boolean expression of Example 2.16: (a) (top) Using single input lines for each input variable. (b) (bottom) Using separate input lines for each occurrence of each input variable.



**FIGURE 2.15**

Diagram for the switching circuit of Example 2.17.



**FIGURE 2.16**

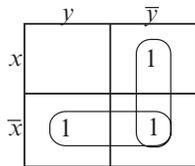
(a) (left) The correspondence of minterms with cells for a general Karnaugh map for a Boolean function of two variables. (b) (right) The specific Karnaugh map for the Boolean function presented in Table 2.2.

|           | $y$        | $\bar{y}$        |
|-----------|------------|------------------|
| $x$       | $xy$       | $x\bar{y}$       |
| $\bar{x}$ | $\bar{x}y$ | $\bar{x}\bar{y}$ |

|           | $y$ | $\bar{y}$ |
|-----------|-----|-----------|
| $x$       |     | 1         |
| $\bar{x}$ | 1   | 1         |

**FIGURE 2.17**

Completed Karnaugh map for the function of Table 2.2.



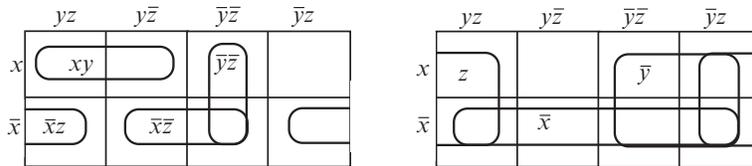
**FIGURE 2.18**

The correspondence of minterms with cells for a general Karnaugh map with three Boolean variables.

|           | $yz$        | $y\bar{z}$        | $\bar{y}z$        | $\bar{y}\bar{z}$        |
|-----------|-------------|-------------------|-------------------|-------------------------|
| $x$       | $xyz$       | $xy\bar{z}$       | $x\bar{y}z$       | $x\bar{y}\bar{z}$       |
| $\bar{x}$ | $\bar{x}yz$ | $\bar{x}y\bar{z}$ | $\bar{x}\bar{y}z$ | $\bar{x}\bar{y}\bar{z}$ |

**FIGURE 2.19**

Sample blocks for the three variable Karnaugh map: (a) (left) 2-cell blocks demonstrating the Boolean identities:  $xy = xyz + xy\bar{z}$ ,  $\bar{y}\bar{z} = x\bar{y}\bar{z} + \bar{x}\bar{y}\bar{z}$ ,  $\bar{x}z = \bar{x}yz + \bar{x}\bar{y}z$ ,  $\bar{x}\bar{z} = \bar{x}y\bar{z} + \bar{x}\bar{y}\bar{z}$ . (b) (right) 4-cell blocks demonstrating the Boolean identities:  $z = xyz + x\bar{y}z + \bar{x}yz + \bar{x}\bar{y}z$ ,  $\bar{y} = x\bar{y}\bar{z} + x\bar{y}z + \bar{x}\bar{y}\bar{z} + \bar{x}\bar{y}z$ ,  $\bar{x} = \bar{x}yz + \bar{x}\bar{y}z + \bar{x}y\bar{z} + \bar{x}\bar{y}\bar{z}$ .



**FIGURE 2.20**

Completed Karnaugh map for the Boolean function of Table 2.4.

|           | $yz$ | $y\bar{z}$ | $\bar{y}\bar{z}$ | $\bar{y}z$ |
|-----------|------|------------|------------------|------------|
| $x$       | 1    | 1          | 1                | 1          |
| $\bar{x}$ | 1    |            |                  | 1          |
|           |      |            |                  |            |

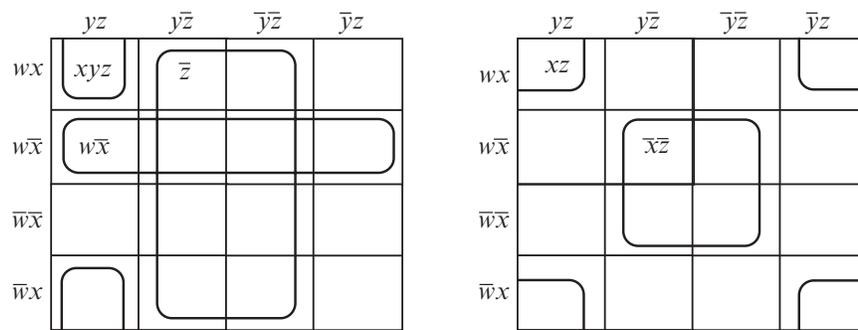
**FIGURE 2.21**

The correspondence of minterms with cells for a general Karnaugh map with four Boolean variables.

|                  | $yz$               | $y\bar{z}$               | $\bar{y}\bar{z}$               | $\bar{y}z$               |
|------------------|--------------------|--------------------------|--------------------------------|--------------------------|
| $wx$             | $wxyz$             | $wxy\bar{z}$             | $wx\bar{y}\bar{z}$             | $wx\bar{y}z$             |
| $w\bar{x}$       | $w\bar{x}yz$       | $w\bar{x}y\bar{z}$       | $w\bar{x}\bar{y}\bar{z}$       | $w\bar{x}\bar{y}z$       |
| $\bar{w}\bar{x}$ | $\bar{w}\bar{x}yz$ | $\bar{w}\bar{x}y\bar{z}$ | $\bar{w}\bar{x}\bar{y}\bar{z}$ | $\bar{w}\bar{x}\bar{y}z$ |
| $\bar{w}x$       | $\bar{w}xyz$       | $\bar{w}xy\bar{z}$       | $\bar{w}x\bar{y}\bar{z}$       | $\bar{w}x\bar{y}z$       |

**FIGURE 2.22**

Sample blocks for the four variable Karnaugh map along with the Boolean expressions that the sum of their minterms represent.



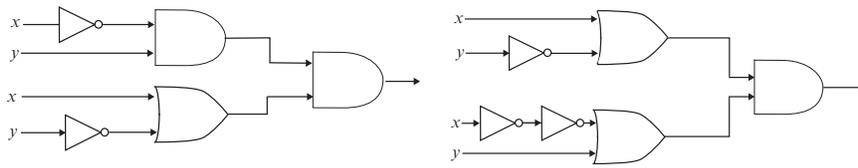
**FIGURE 2.23**

Completed Karnaugh map for the Boolean function of Example 2.20 with the six don't care conditions marked by Xs.

|                  | $yz$ | $y\bar{z}$ | $\bar{y}\bar{z}$ | $\bar{y}z$ |
|------------------|------|------------|------------------|------------|
| $wx$             | X    | X          | X                | X          |
| $w\bar{x}$       | X    | X          | 1                | 1          |
| $\bar{w}\bar{x}$ |      | 1          | 1                |            |
| $\bar{w}x$       |      | 1          | 1                |            |

**FIGURE 2.24**

(a) (left) Circuit diagram for Exercise 15. (b) (right) Circuit diagram for Exercise 16.



**FIGURE 2.25**

(a) (top) Circuit diagram for Exercise 17. (b) (bottom) Circuit diagram for Exercise 18.

