



CprE 281: Digital Logic

Instructor: Alexander Stoytchev

<http://www.ece.iastate.edu/~alexs/classes/>

Logic Gates

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Iowa State University, Ames, IA
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Administrative Stuff

- **HW1 is out**
- **It is due on Monday Aug 28 @ 4pm.**
- **Submit it on paper before the start of the lecture**
- **No late homeworks will be accepted.**
- **Staple all of your pages**
- **Please write clearly on the first page:**
 - **your name**
 - **student ID**
 - **lab section letter**

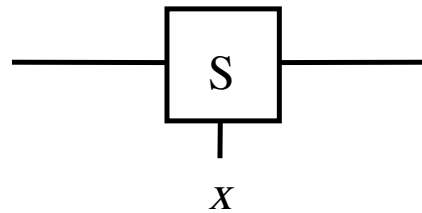
Labs Next Week

- Please download and read the lab assignment for next week before you go to your lab section.
- You must **print** the answer sheet and **do** the prelab **before** you go to the lab.
- The TAs will check your prelab answers at the **beginning of the recitation**. If you don't have it done you'll lose 20% of the lab grade for that lab.

A Binary Switch

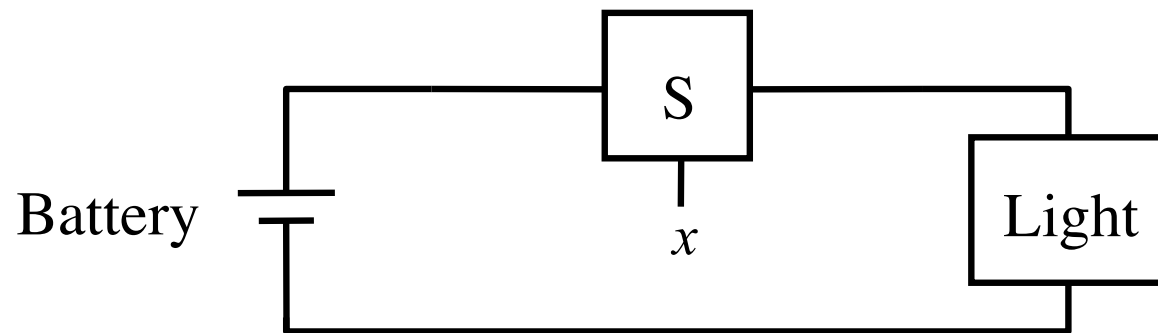


(a) Two states of a switch



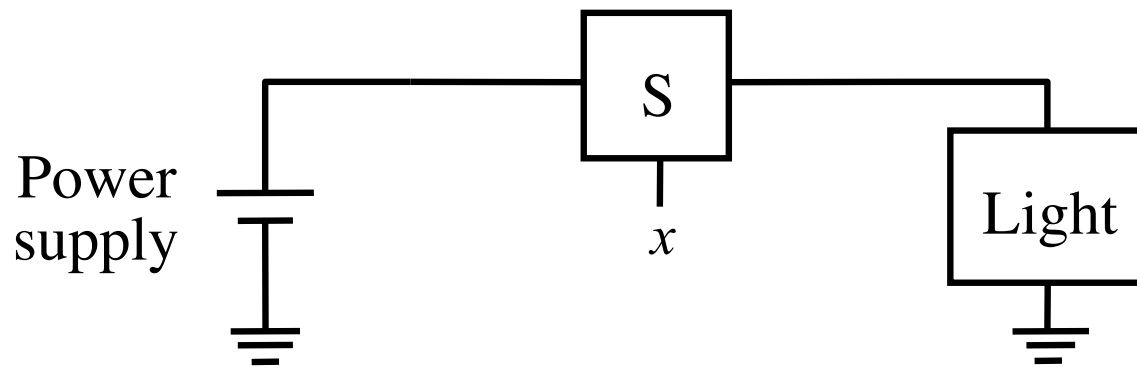
(b) Symbol for a switch

A Light Controlled by a Switch



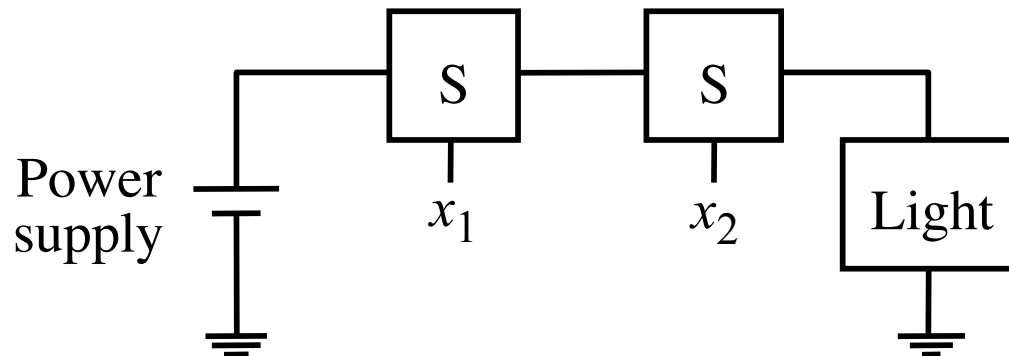
(a) Simple connection to a battery

A Light Controlled by a Switch



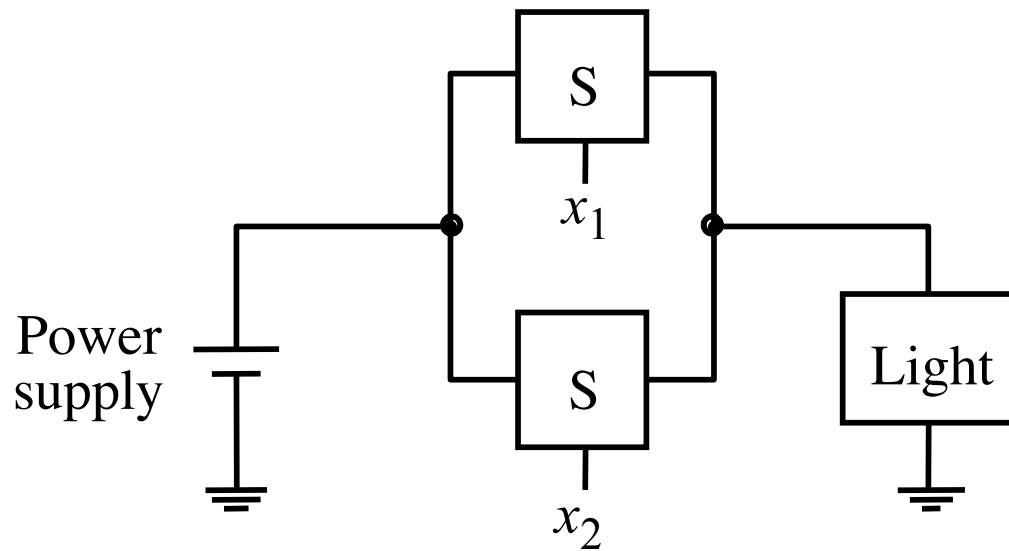
(b) Using a ground connection as the return path

The Logical AND function (series connection of the switches)

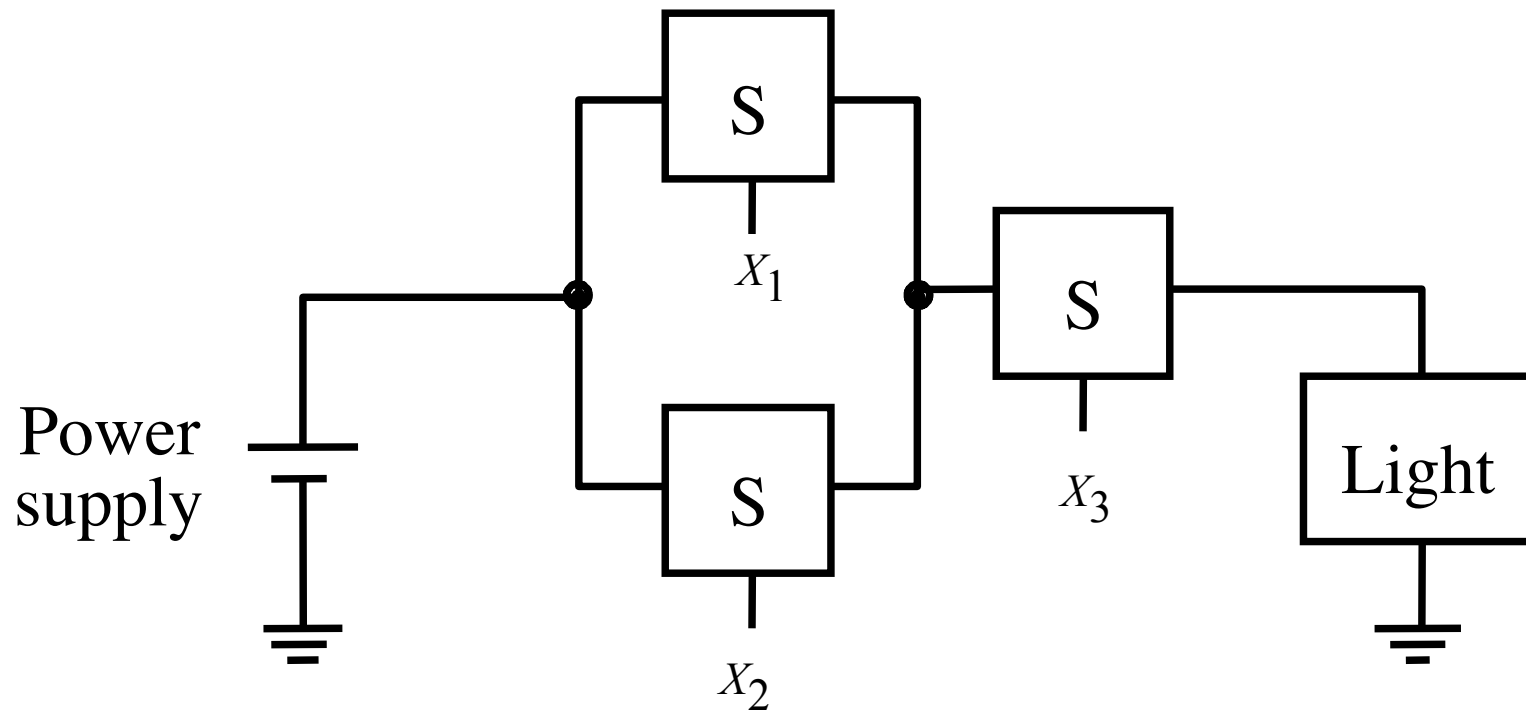


The Logical OR function

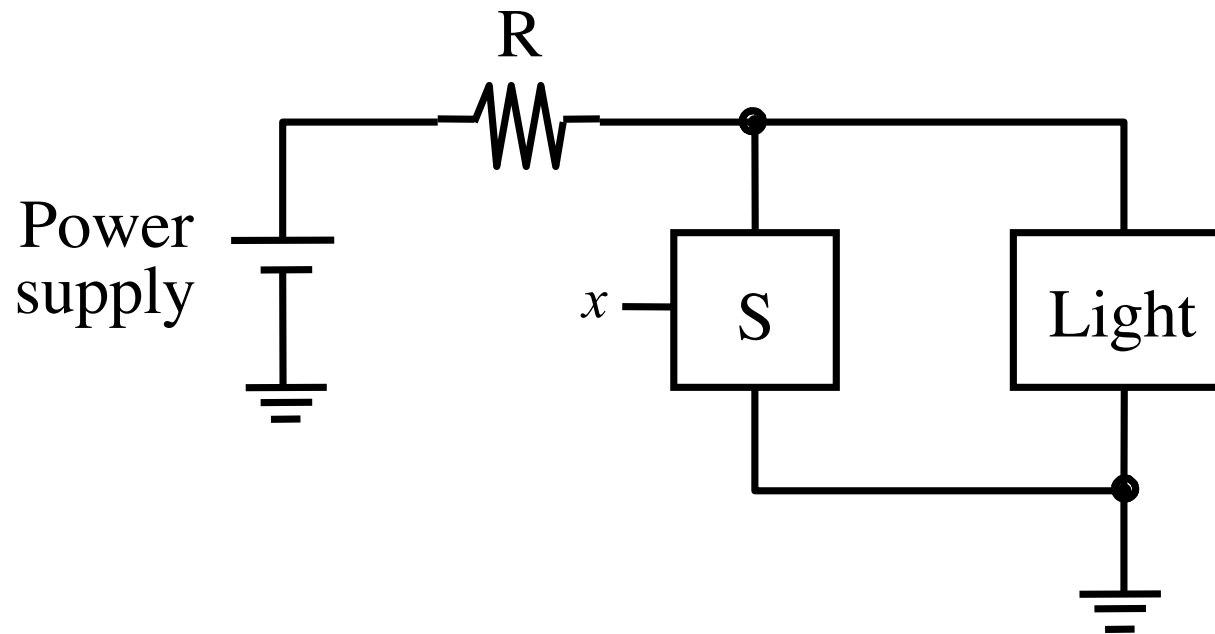
(parallel connection of the switches)



A series-parallel connection of the switches

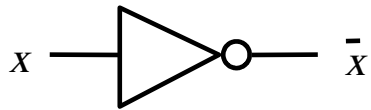


An Inverting Circuit

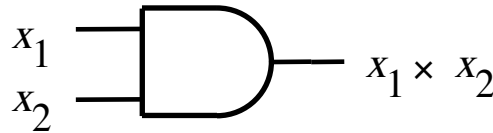


[Figure 2.5 from the textbook]

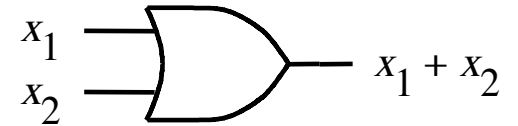
The Three Basic Logic Gates



NOT gate

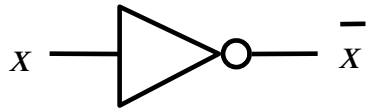


AND gate



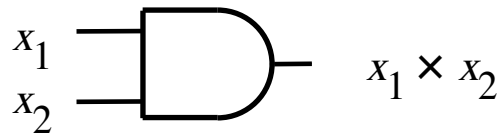
OR gate

Truth Table for NOT



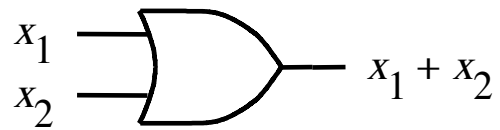
x	\bar{x}
0	1
1	0

Truth Table for AND



x_1	x_2	$x_1 \cdot x_2$
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table for OR



x_1	x_2	$x_1 + x_2$
0	0	0
0	1	1
1	0	1
1	1	1

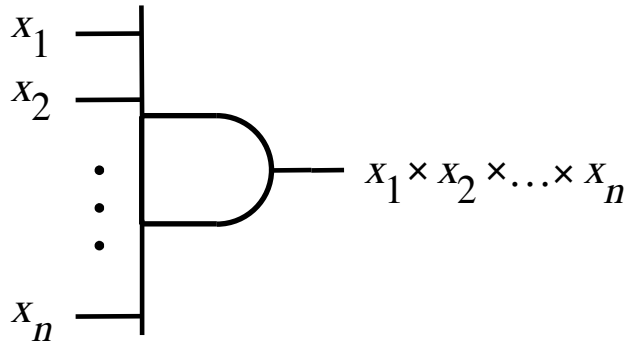
Truth Tables for AND and OR

x_1	x_2	$x_1 \cdot x_2$	$x_1 + x_2$
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

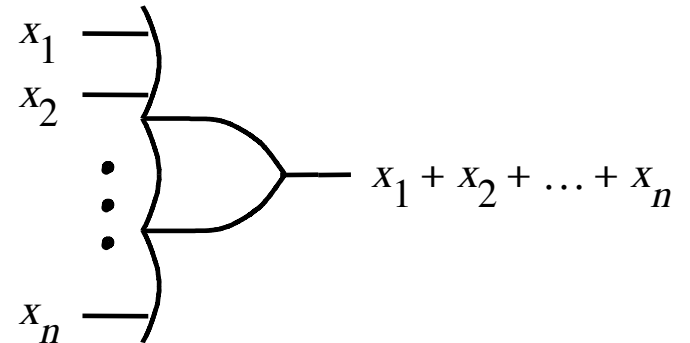
AND

OR

Logic Gates with n Inputs



AND gate

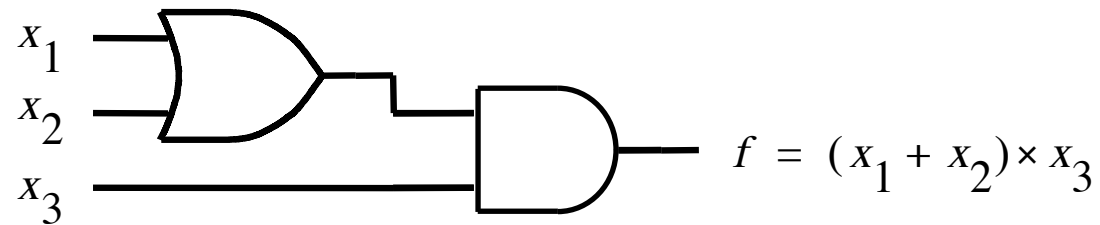


OR gate

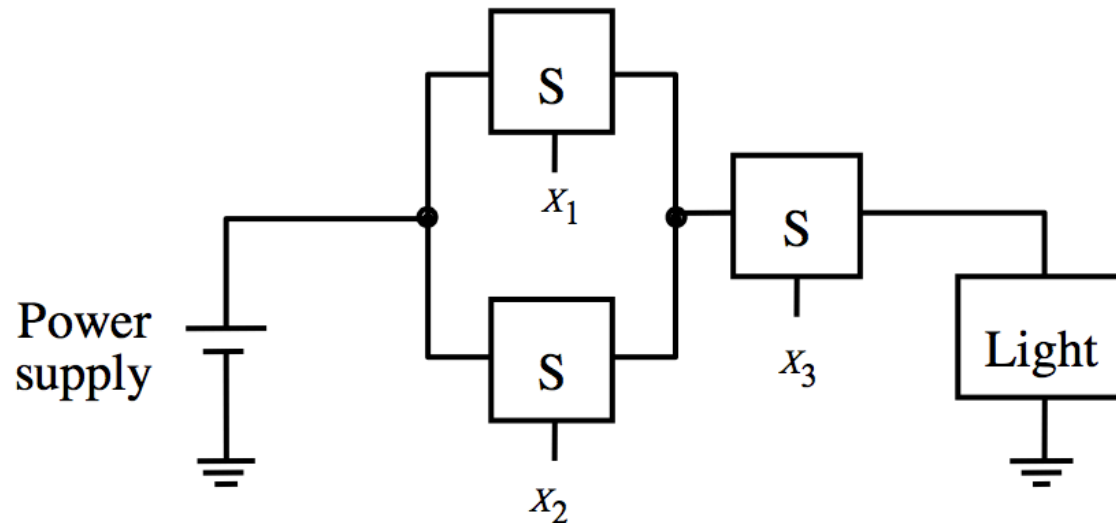
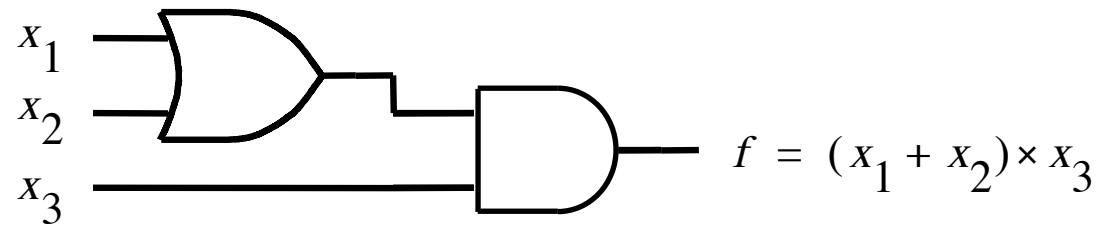
Truth Table for 3-input AND and OR

x_1	x_2	x_3	$x_1 \cdot x_2 \cdot x_3$	$x_1 + x_2 + x_3$
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

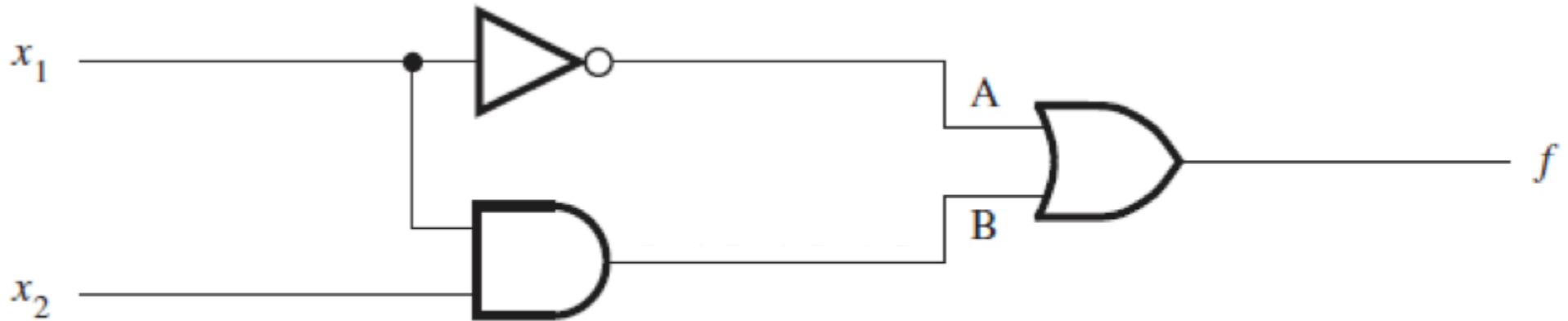
Example of a Logic Circuit Implemented with Logic Gates



Example of a Logic Circuit Implemented with Logic Gates

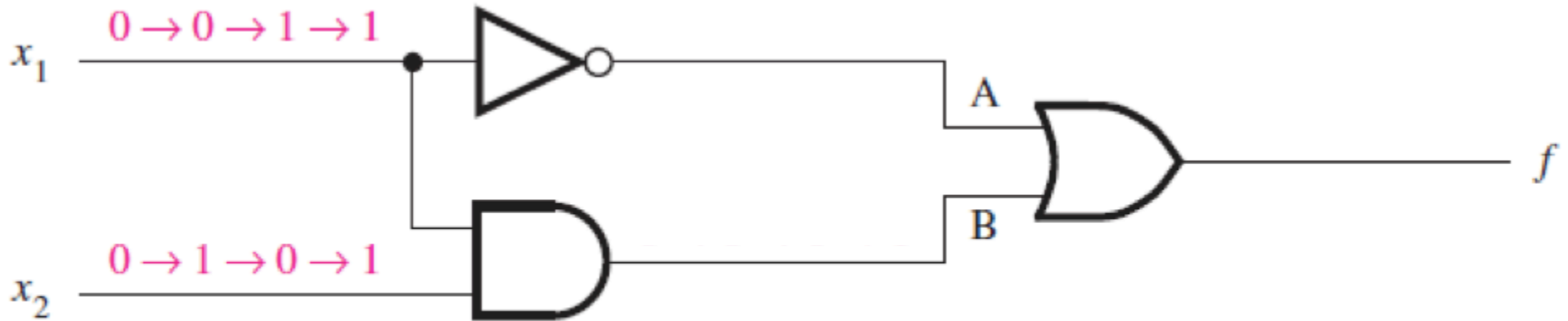


Network Analysis



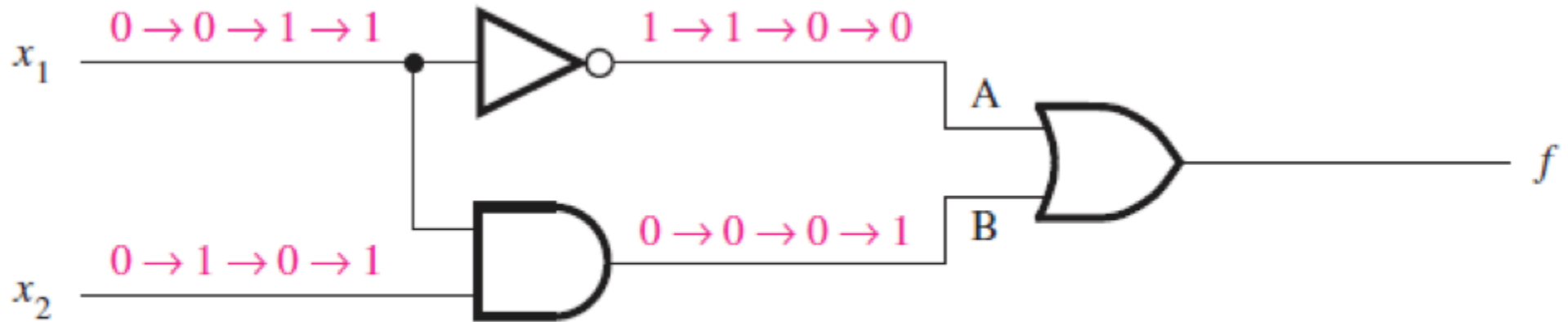
(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$

Network Analysis



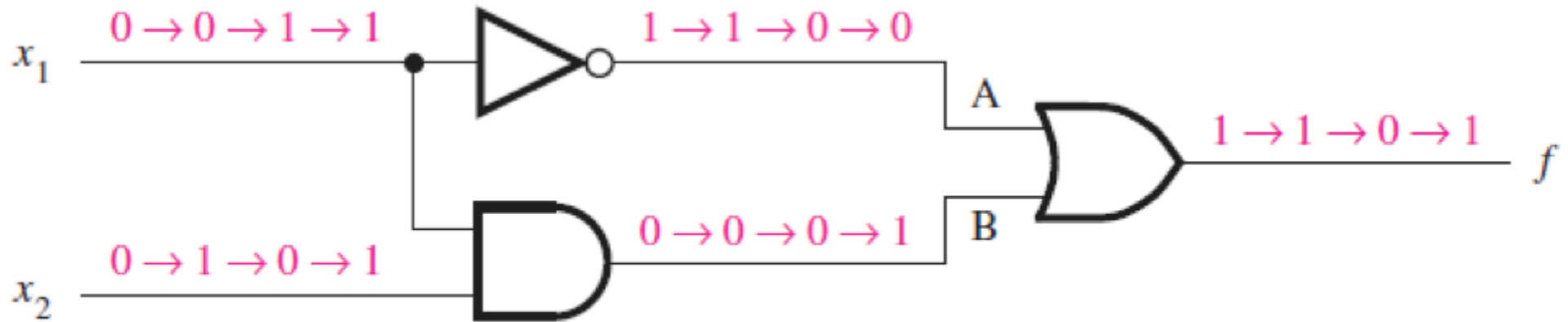
(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$

Network Analysis



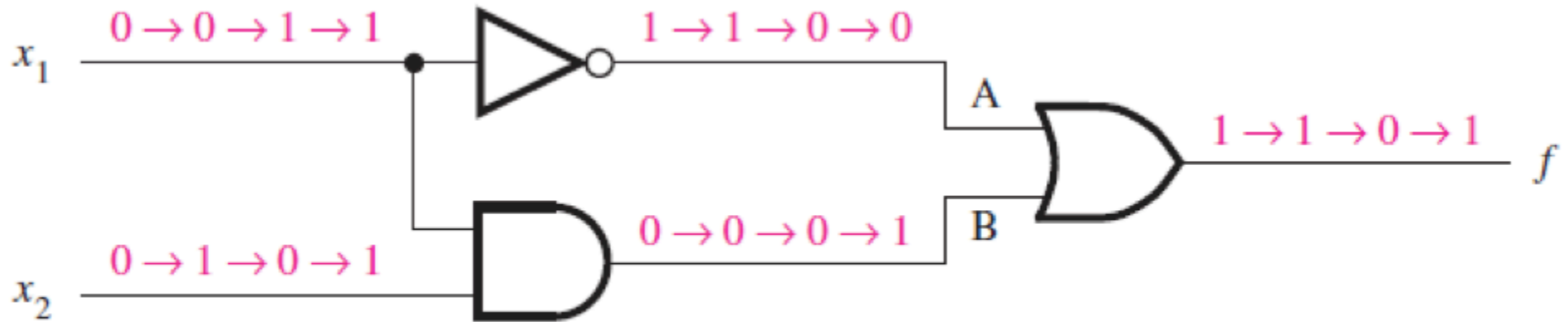
(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$

Network Analysis

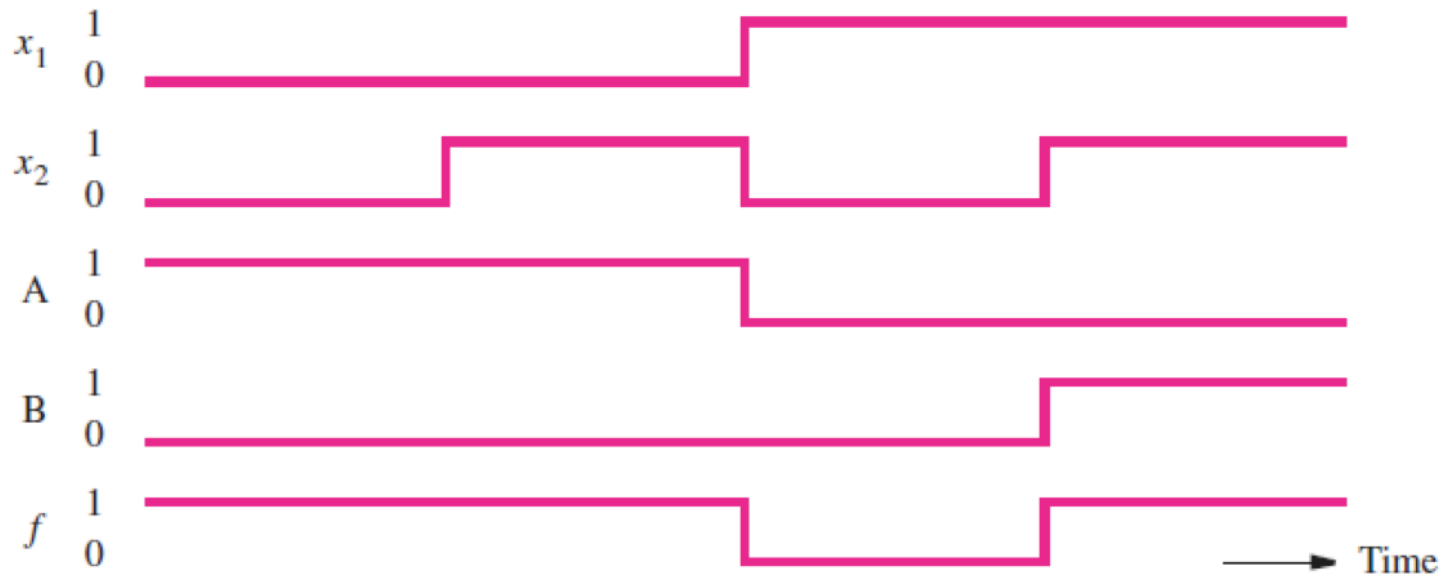


(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$

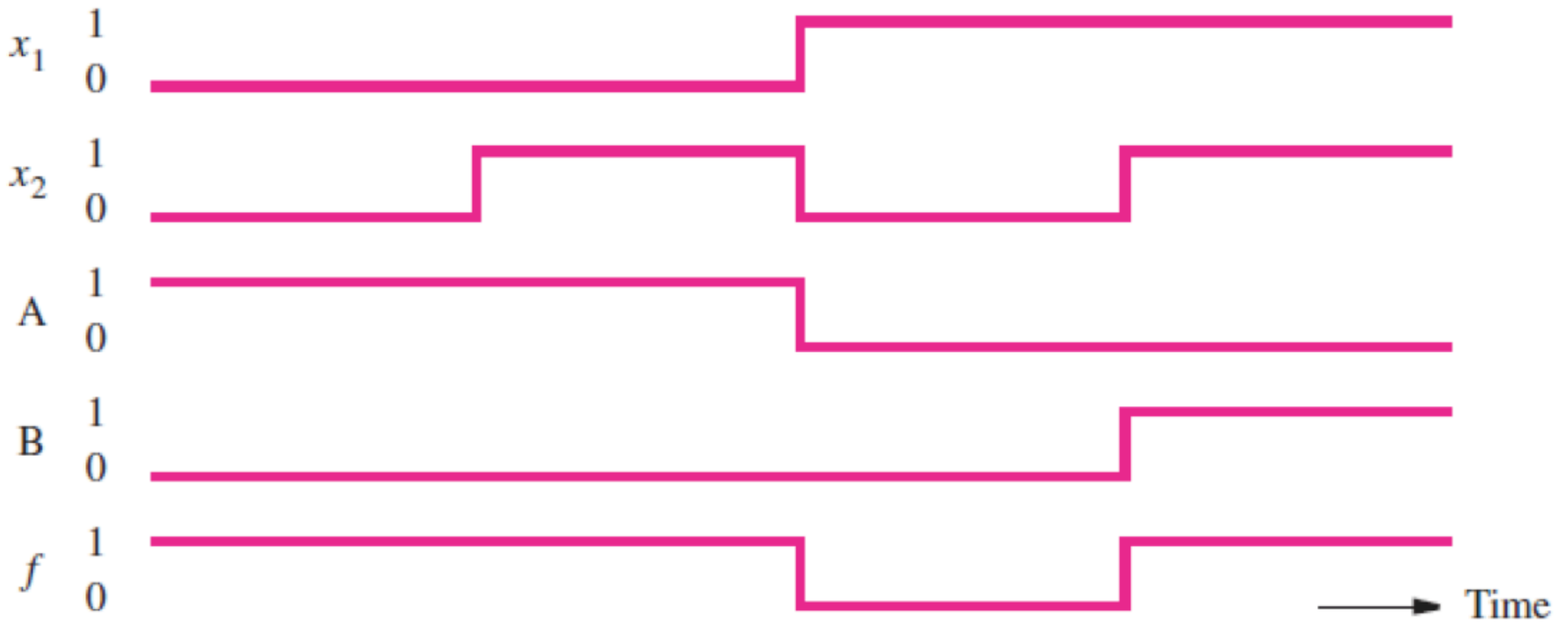
Network Analysis



(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$



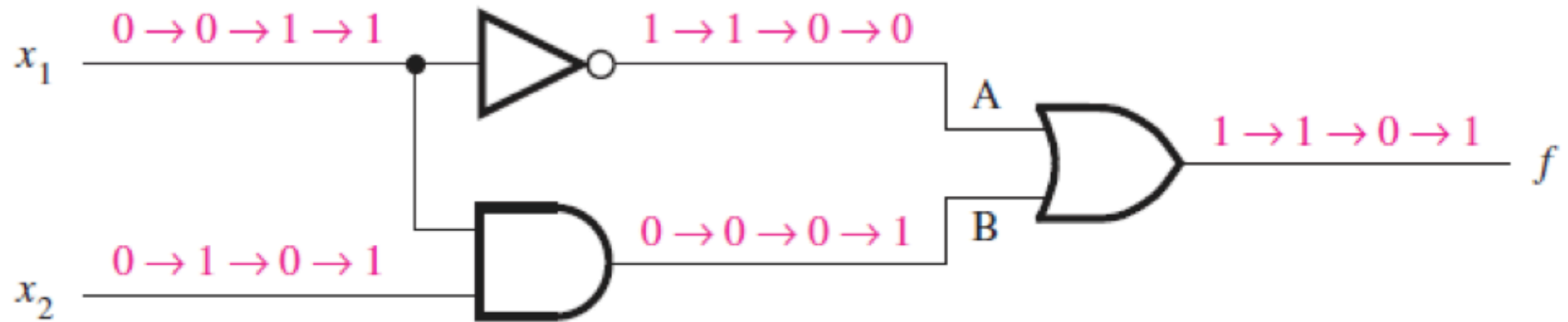
Timing Diagram



Truth Table for this Network

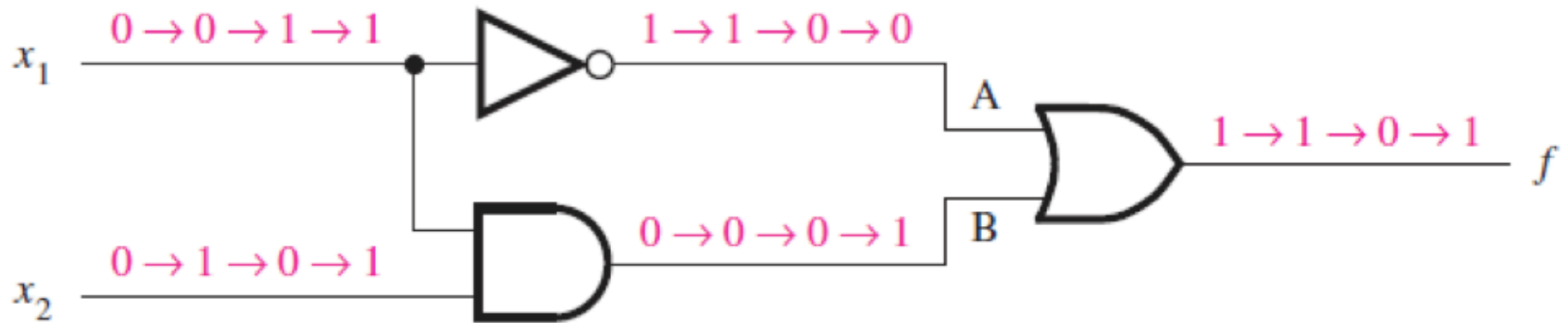
x_1	x_2	$f(x_1, x_2)$	A	B
0	0	1	1	0
0	1	1	1	0
1	0	0	0	0
1	1	1	0	1

Functionally Equivalent Networks

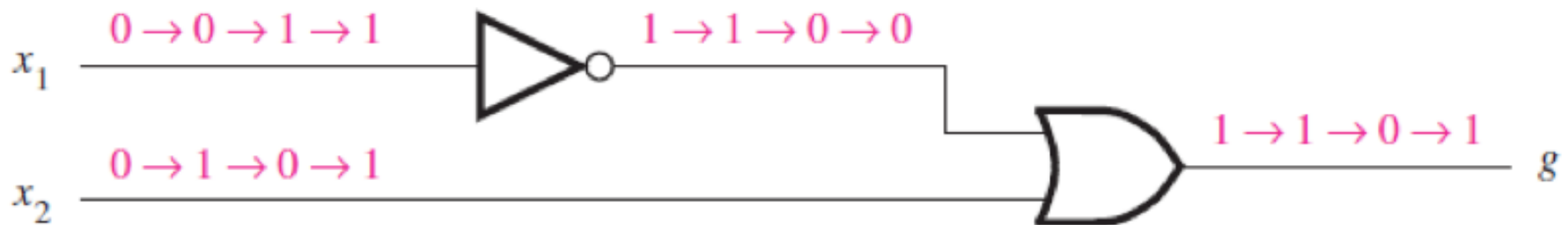


(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$

Functionally Equivalent Networks

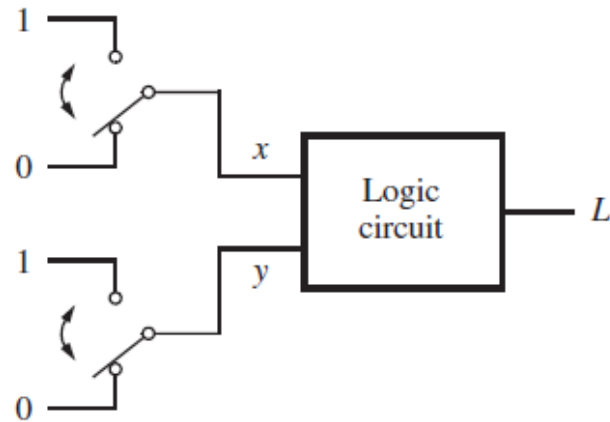


(a) Network that implements $f = \bar{x}_1 + x_1 \cdot x_2$



(d) Network that implements $g = \bar{x}_1 + x_2$

The XOR Logic Gate

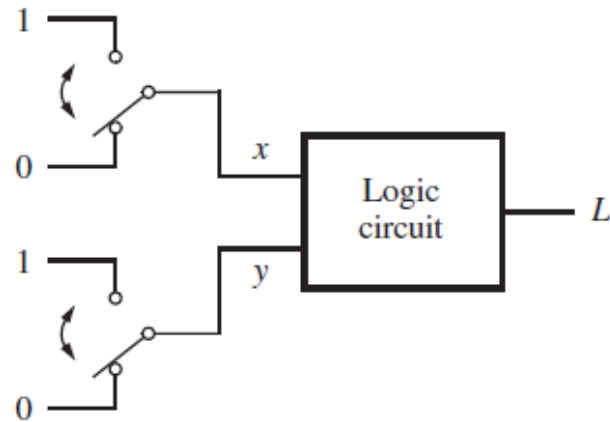


(a) Two switches that control a light

x	y	L
0	0	0
0	1	1
1	0	1
1	1	0

(b) Truth table

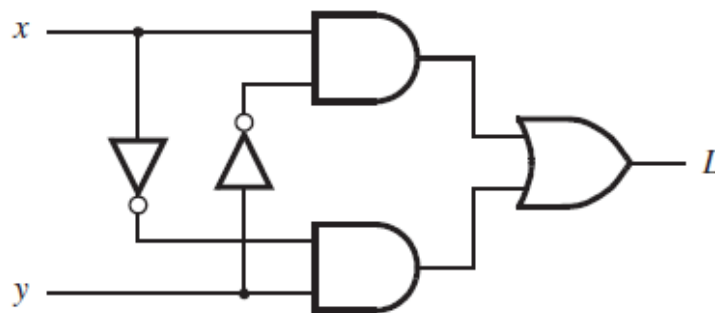
The XOR Logic Gate



(a) Two switches that control a light

x	y	L
0	0	0
0	1	1
1	0	1
1	1	0

(b) Truth table

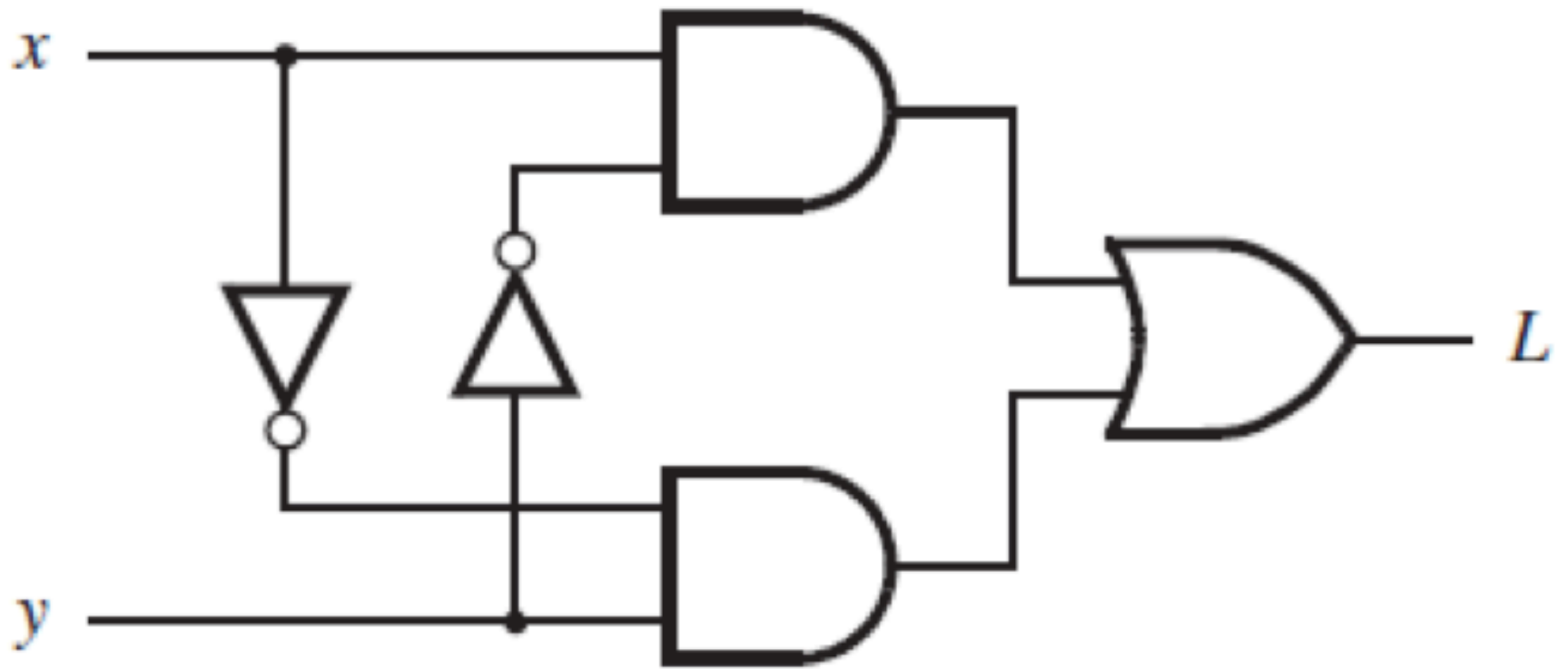


(c) Logic network



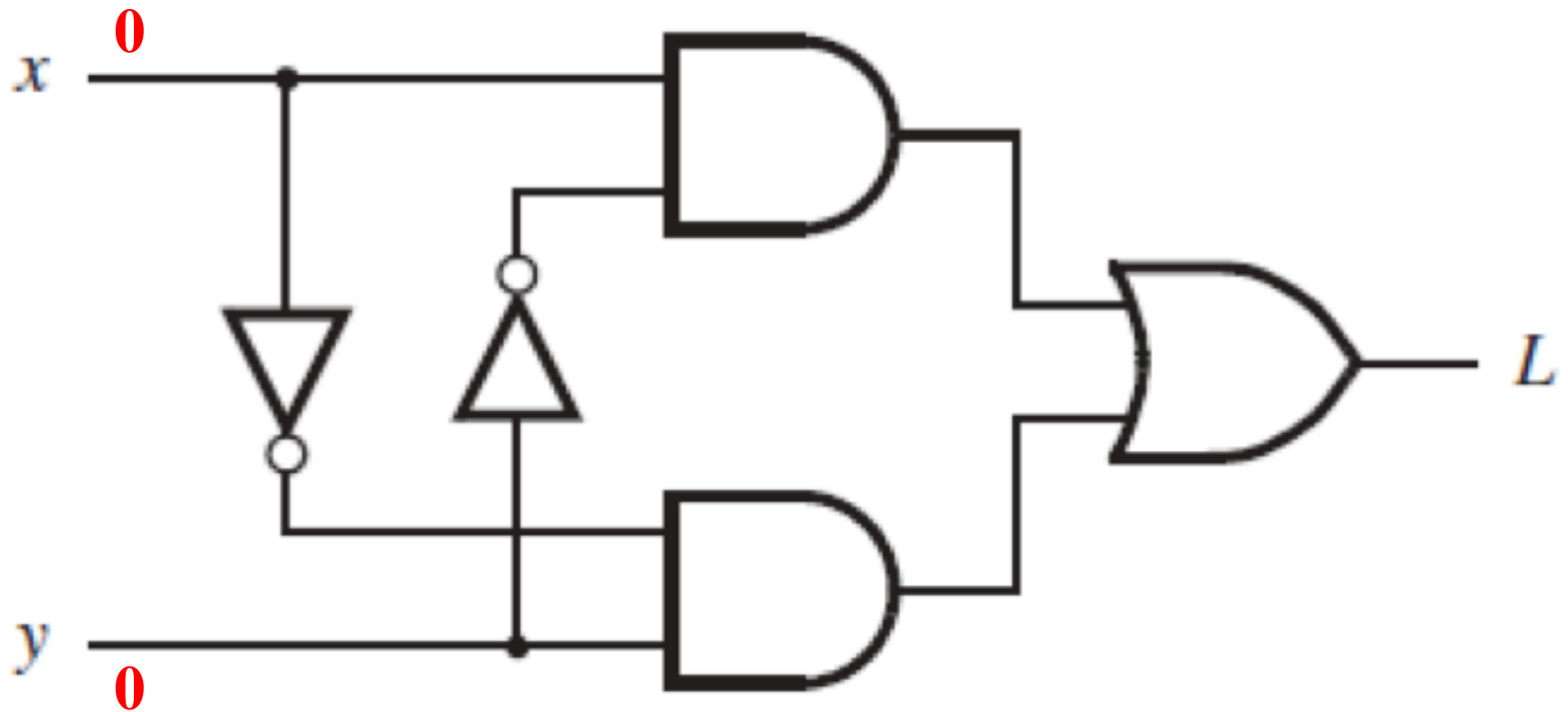
(d) XOR gate symbol

XOR Analysis

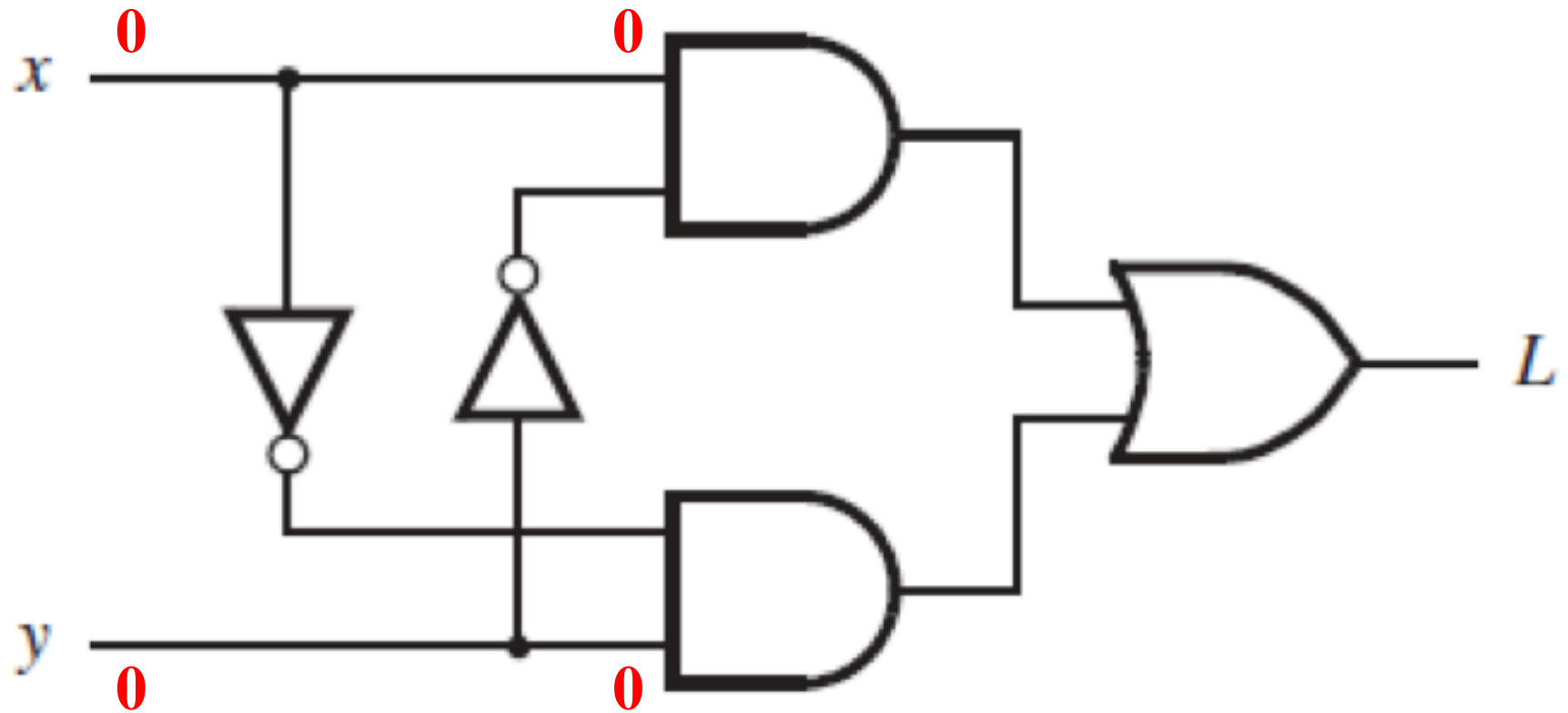


[Figure 2.11c from the textbook]

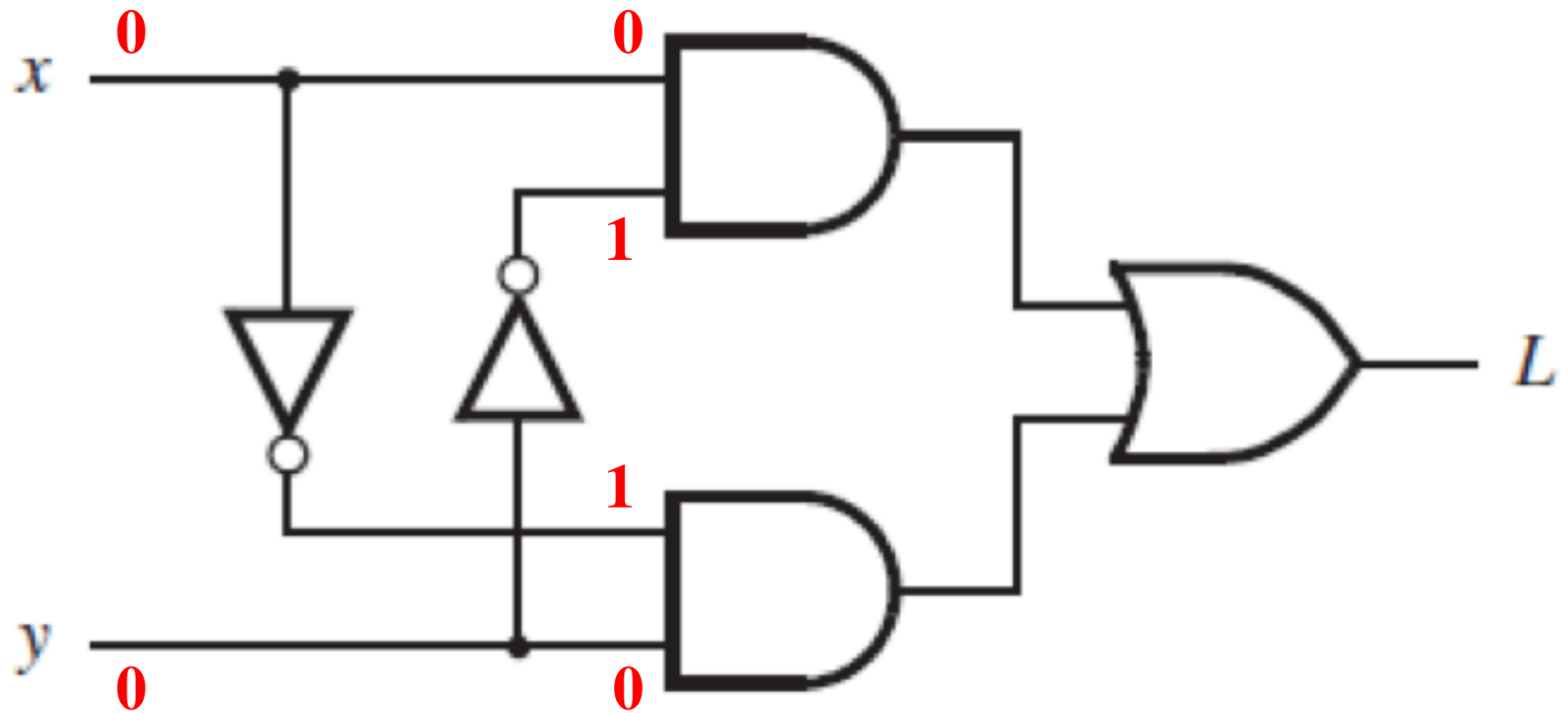
XOR Analysis (x=0, y=0)



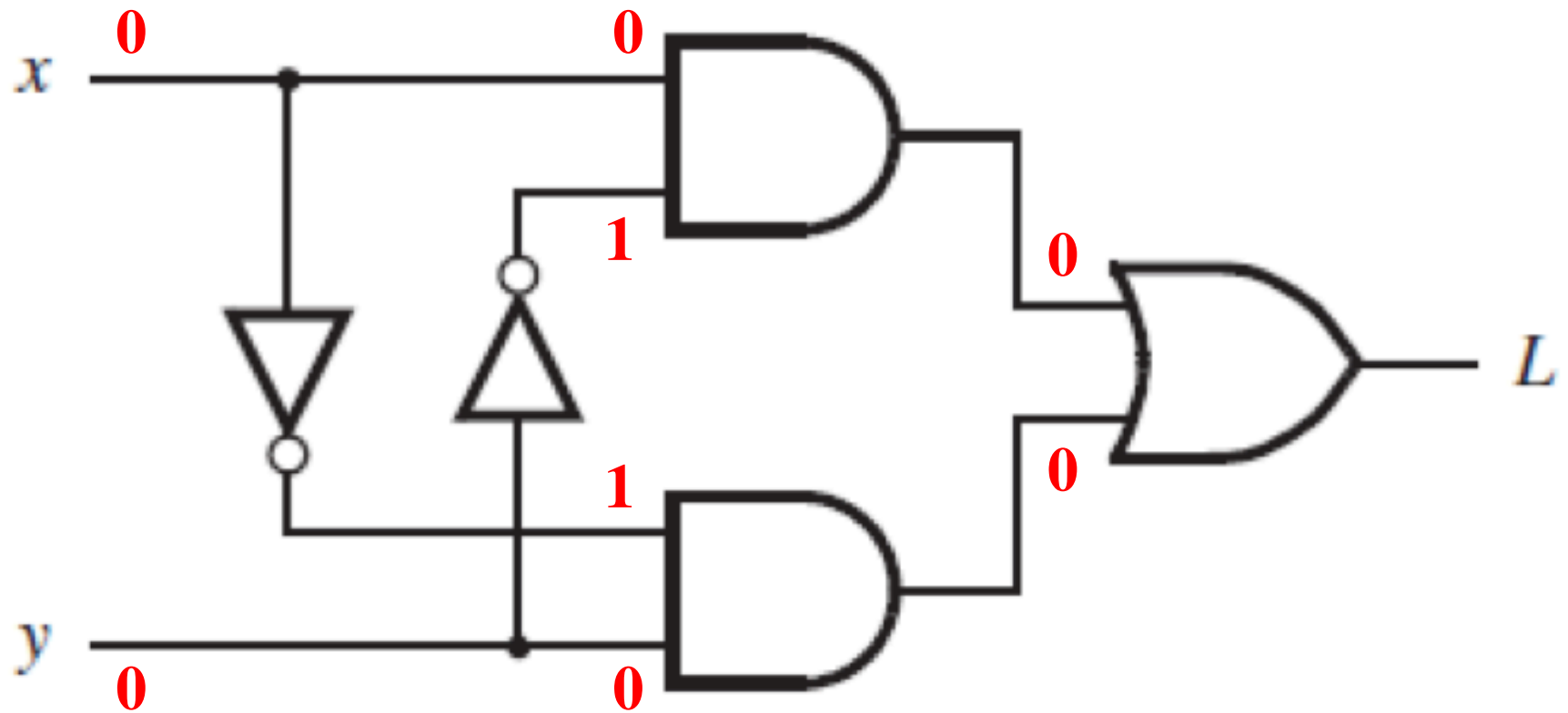
XOR Analysis (x=0, y=0)



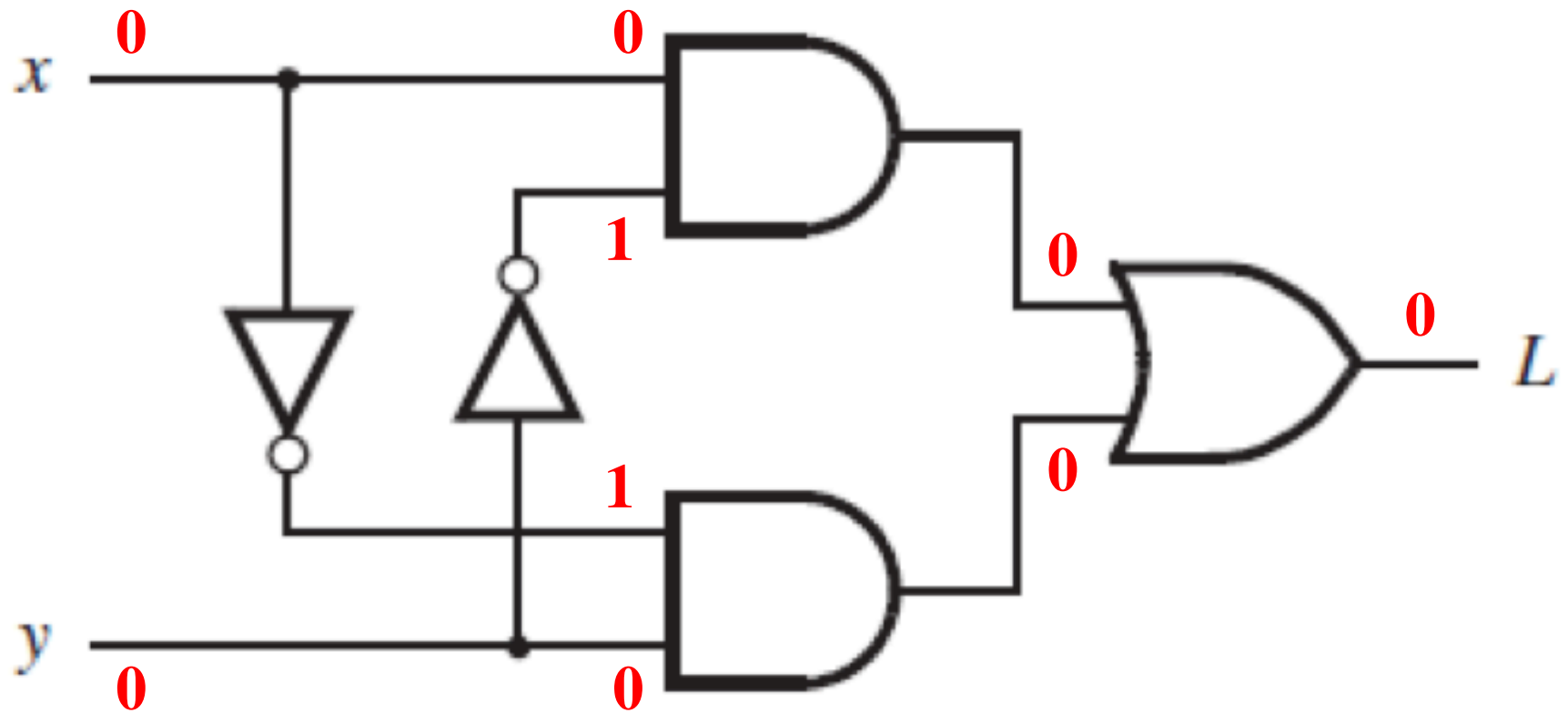
XOR Analysis (x=0, y=0)



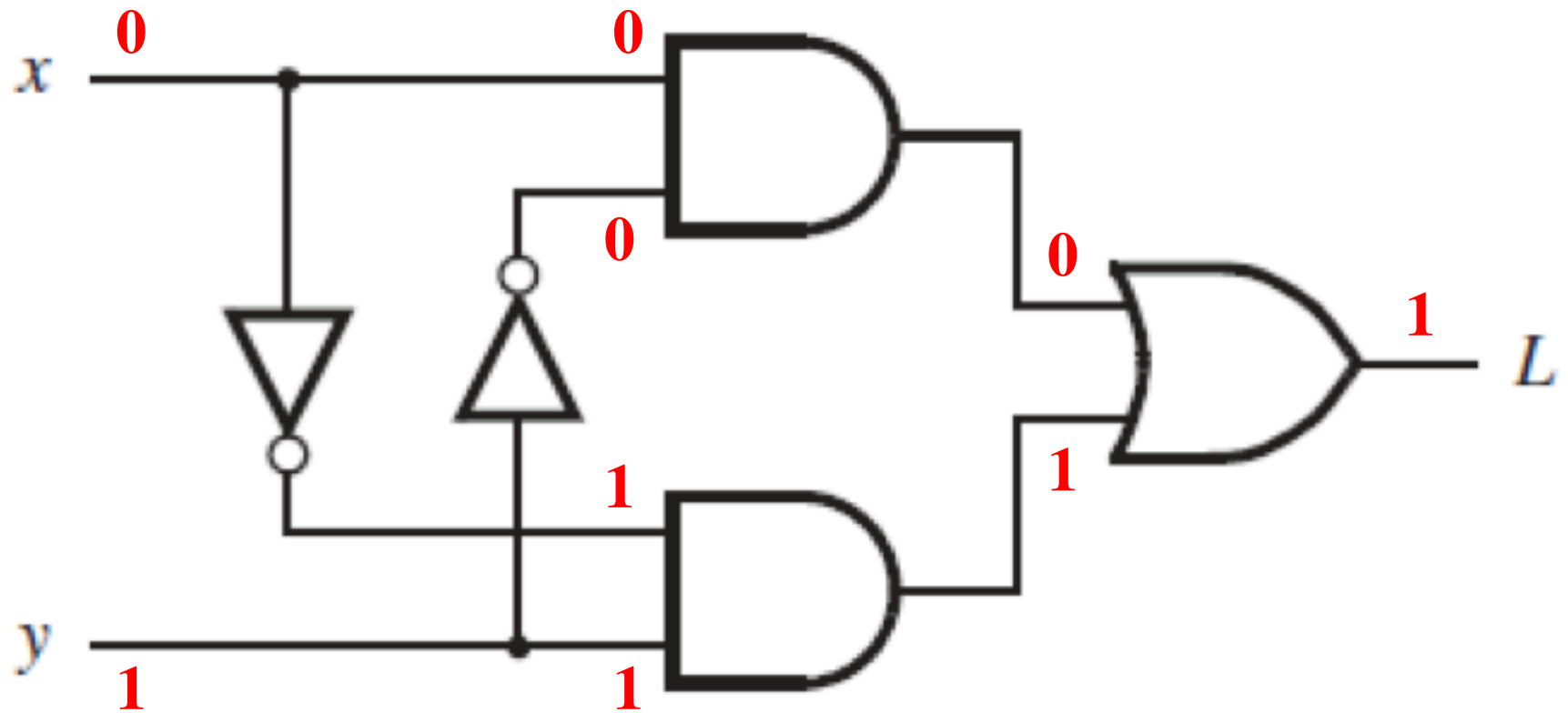
XOR Analysis (x=0, y=0)



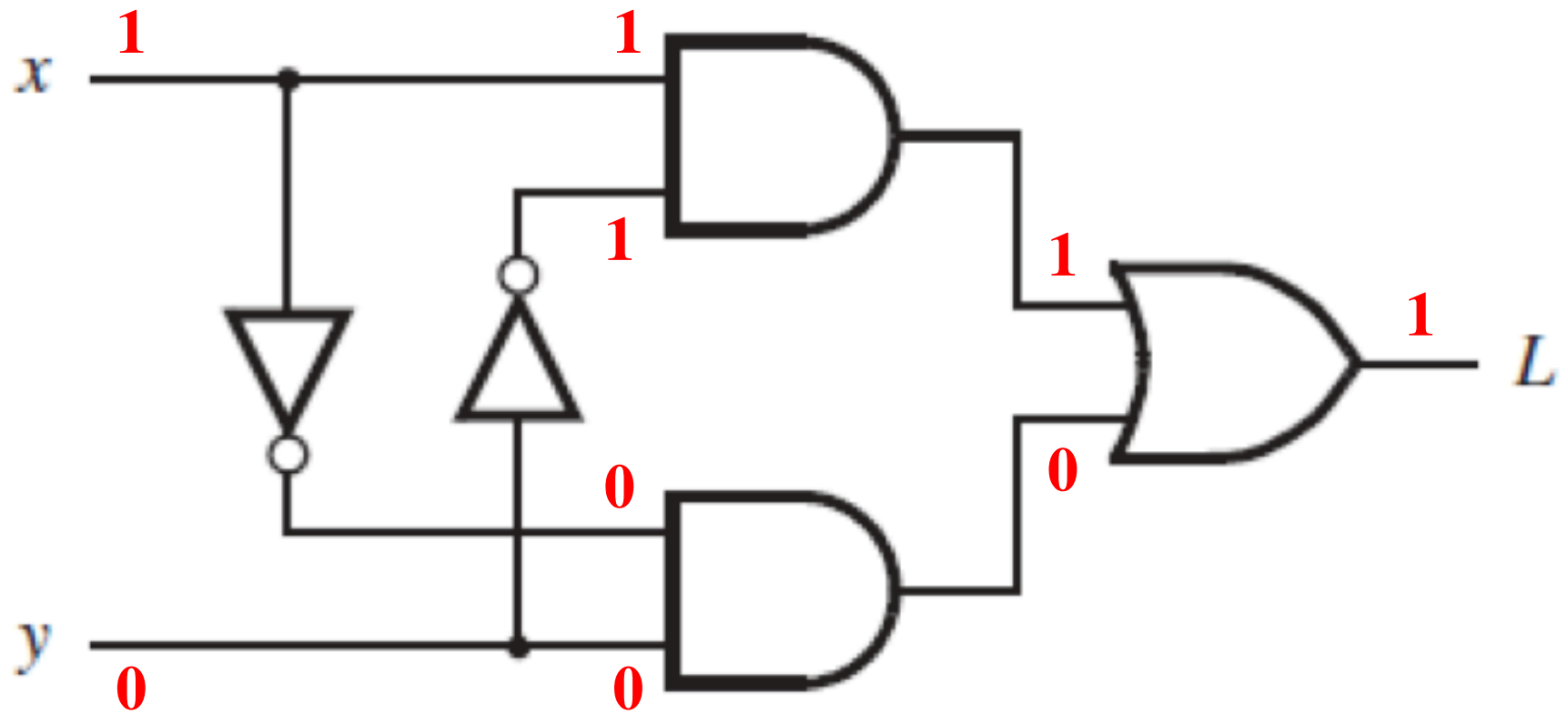
XOR Analysis (x=0, y=0)



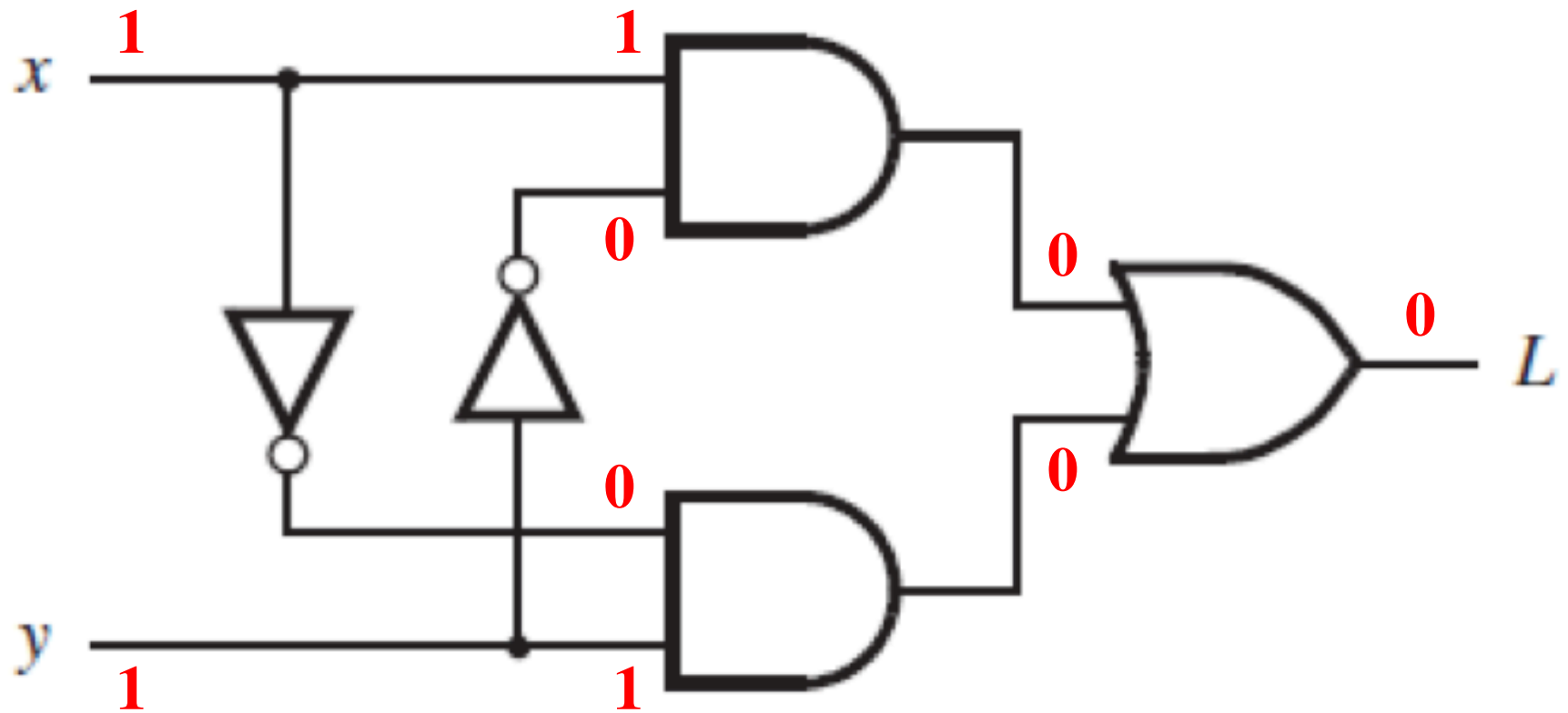
XOR Analysis (x=0, y=1)



XOR Analysis (x=1, y=0)



XOR Analysis (x=1, y=1)



Addition of Binary Numbers

a	0	0	1	1
$+ b$	$+ 0$	$+ 1$	$+ 0$	$+ 1$
<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
$s_1 s_0$	0 0	0 1	0 1	1 0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

<i>a</i>	0	0	1	1
<u>+ <i>b</i></u>	<u>+ 0</u>	<u>+ 1</u>	<u>+ 0</u>	<u>+ 1</u>
<i>s</i> ₁ <i>s</i> ₀	0 0	0 1	0 1	1 0

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

a	0	0	1	1
$+b$	$+0$	$+1$	$+0$	$+1$
\hline	\hline	\hline	\hline	\hline
$s_1 s_0$	0 0	0 1	0 1	1 0

a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

<i>a</i>	0	0	1	1
<u>+ <i>b</i></u>	<u>+ 0</u>	<u>+ 1</u>	<u>+ 0</u>	<u>+ 1</u>
<i>s</i> ₁ <i>s</i> ₀	0 0	0 1	0 1	1 0

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

a	0	0	1	1
$+b$	$+0$	$+1$	$+0$	$+1$
$s_1 s_0$	0 0	0 1	0 1	1 0

a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 \ 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 \ 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 \ 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 \ 0 \end{array}$$

a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 \ 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 \ 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 \ 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 \ 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 \boxed{s_0} \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 \boxed{0} \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 \boxed{1} \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 \boxed{1} \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 \boxed{0} \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

$$\begin{array}{r} a \\ + b \\ \hline s_1 s_0 \end{array} \quad \begin{array}{r} 0 \\ + 0 \\ \hline 0 0 \end{array} \quad \begin{array}{r} 0 \\ + 1 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 0 \\ \hline 0 1 \end{array} \quad \begin{array}{r} 1 \\ + 1 \\ \hline 1 0 \end{array}$$

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

?

<i>a</i>	<i>b</i>		<i>s</i> ₁	<i>s</i> ₀
0	0		0	0
0	1		0	1
1	0		0	1
1	1		1	0

Addition of Binary Numbers

AND

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

?

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

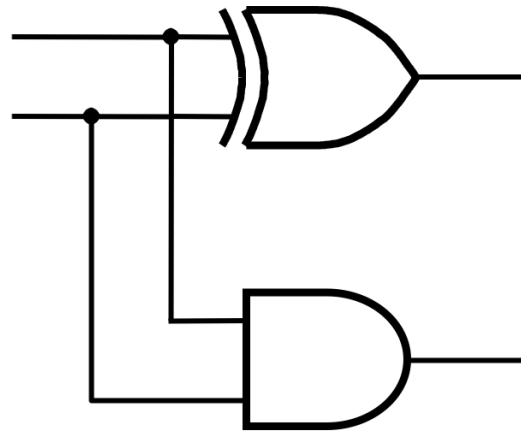
XOR

<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers

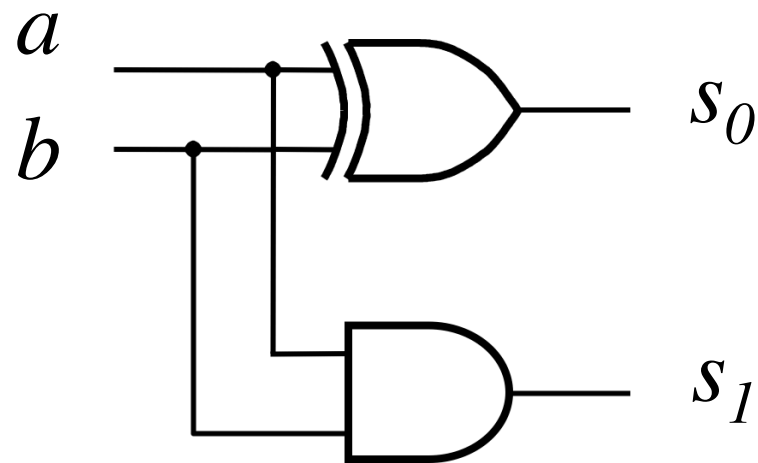
<i>a</i>	<i>b</i>	<i>s</i> ₁	<i>s</i> ₀
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Addition of Binary Numbers



a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

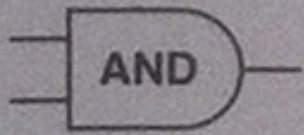
Addition of Binary Numbers



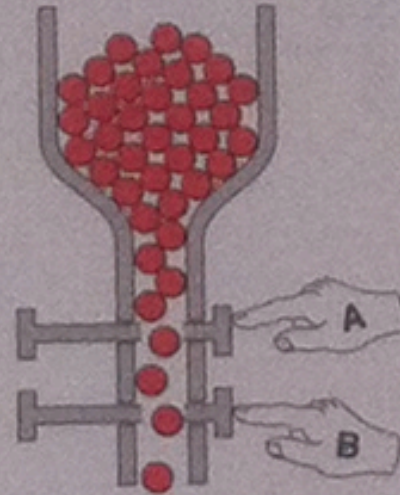
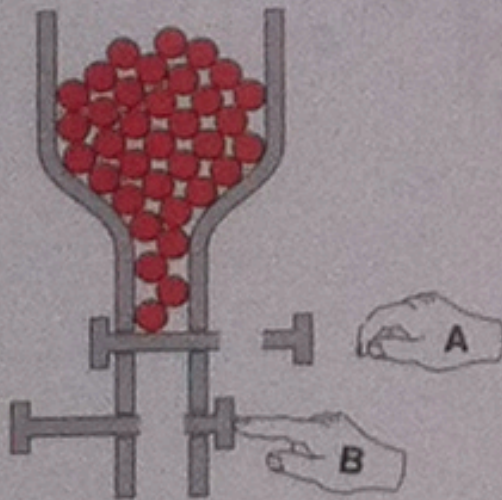
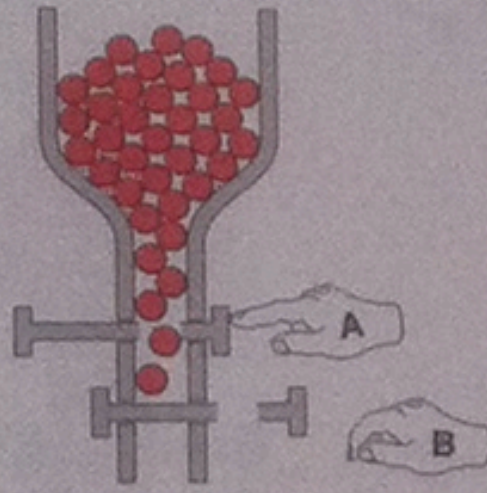
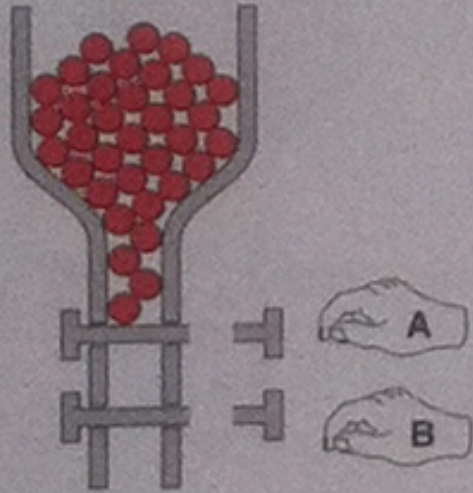
a	b	s_1	s_0
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

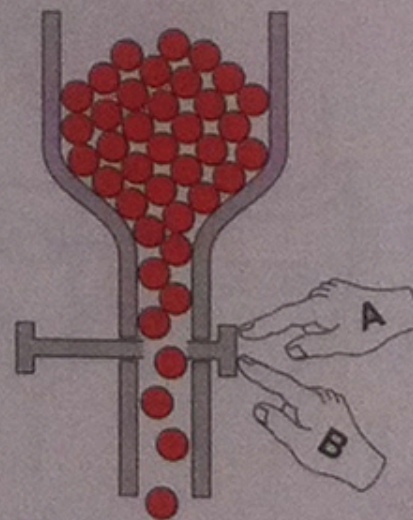
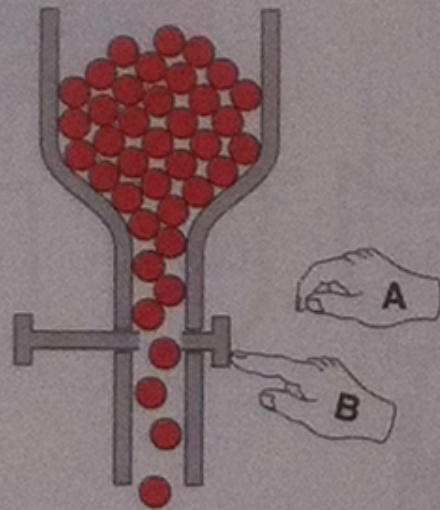
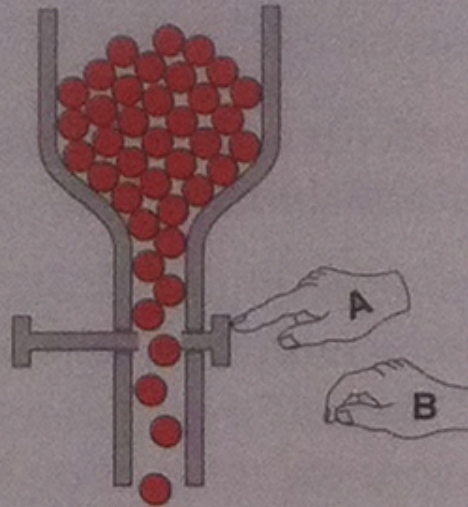
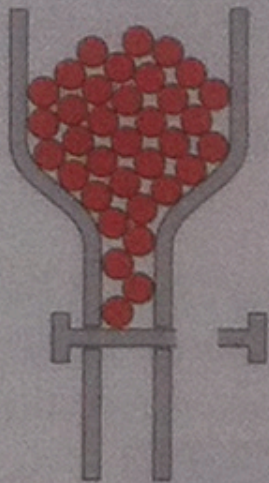
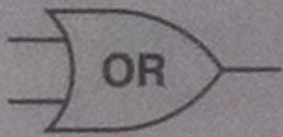
The following examples came from this book



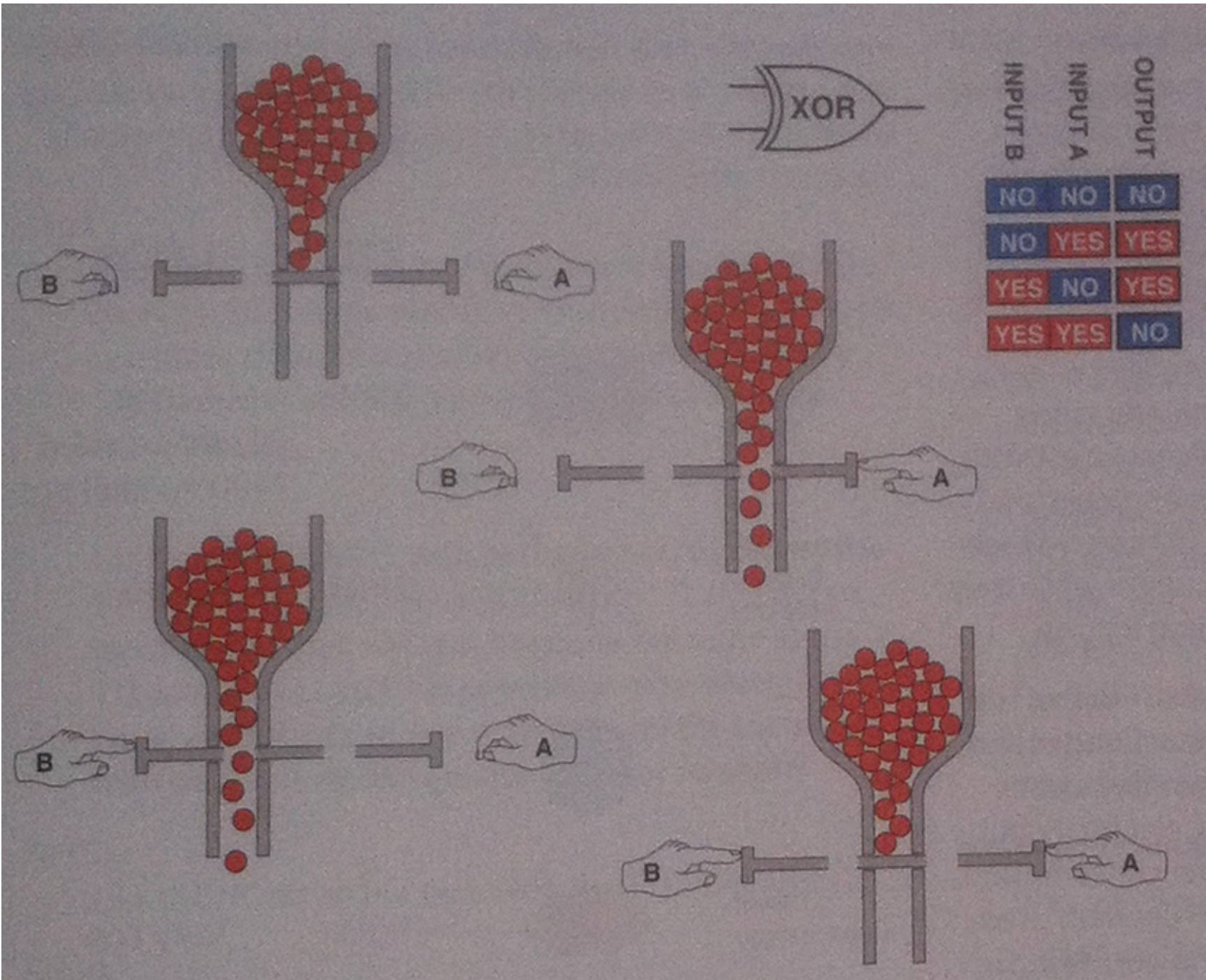


INPUT B	INPUT A	OUTPUT
NO	NO	NO
NO	YES	NO
YES	NO	NO
YES	YES	YES





INPUT B	INPUT A	OUTPUT
NO	NO	NO
NO	YES	YES
YES	NO	YES
YES	YES	YES



Questions?

THE END