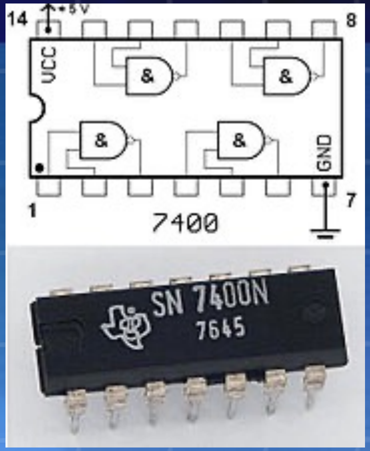
SCIENCE OLYMPIAD
Exploring the World of Science

Inputs		Truth Table Outputs For Each Gate					
A	B	AND	NAND	OR	NOR	EX-OR	EX-NOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1



Circuit Lab

Practice #Digital Logic

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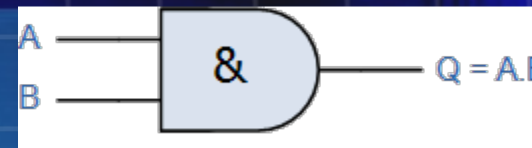
Digital or Boolean Logic

- Boolean Algebra deals mainly with the theory that both logic and set operations are either “TRUE” or “FALSE” but not both at the same time
  - All inputs and outputs are either “TRUE” or “FALSE”
  - Inputs and Outputs are normally shown in a Truth Table
  - There are multiple electronic logic circuits and devices including relays, switches, diodes, discrete electronics, etc.
  - Basic Logic Functions include
    - AND (all inputs must be True for the output to be True, otherwise output is False)
    - OR (all inputs must be False for the output to be False, otherwise output is True)
    - NOT (the output is always the opposite of input, so if the input is True then the output is False and if the input is False the output is True)

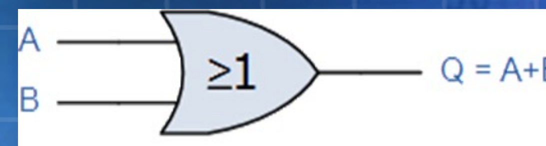
https://en.wikipedia.org/wiki/Boolean_algebra
https://en.wikipedia.org/wiki/Logic_gate
https://www.electronics-tutorials.ws/boolean/bool_1.html

AND, OR, and NOT

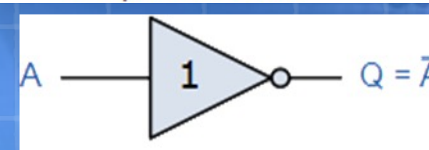
- Three most common and basic
- NOT is also called an Inverter
- 0 means False and 1 means True
- You can also show a NOT by a Bar over an Input or Function
  - NOT X can also be shown by $\overline{X}$
  - NOT A & B can be shown by $\overline{A \,\&\, B}$



2-input AND Gate



2-input OR Gate



Inverter or NOT Gate

x	y	$x \wedge y$	$x \vee y$
0	0	0	0
1	0	0	1
0	1	0	1
1	1	1	1

x	$\neg x$
0	1
1	0

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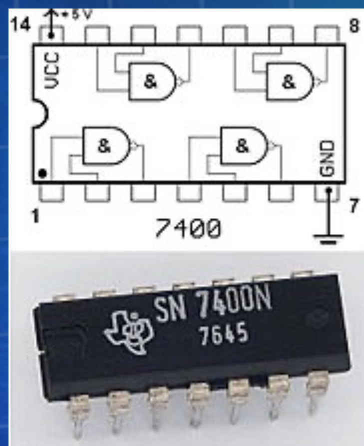
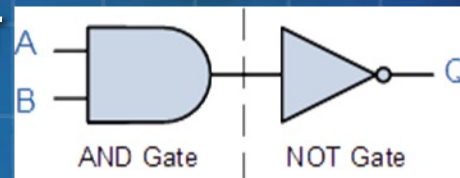
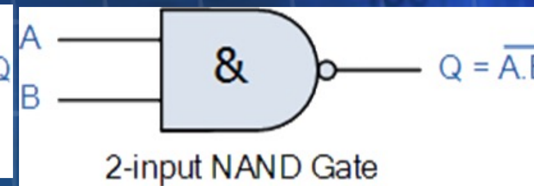
NAND and NOR

- NAND = AND combined with a NOT



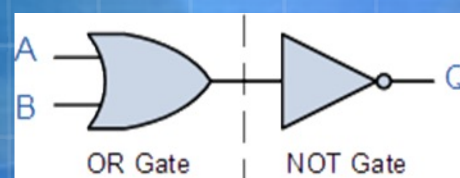


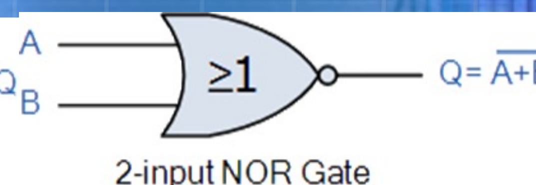


$\overline{A \cdot B}$ or $A \uparrow B$

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

- NOR = OR combined with a NOT





$\overline{A + B}$ or $A \downarrow B$

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

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XOR and XNOR

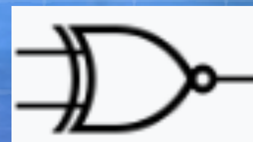
- XOR is true only if A OR B is TRUE, FALSE for all other conditions

$A \oplus B$

INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

- XNOR is true only if A NOR B is TRUE, FALSE for all other conditions

$\overline{A \oplus B}$ or $A \odot B$



INPUT		OUTPUT
A	B	A XNOR B
0	0	1
0	1	0
1	0	0
1	1	1

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Common Truth Table

Inputs		Truth Table Outputs For Each Gate					
A	B	AND	NAND	OR	NOR	EX-OR	EX-NOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

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De Morgan's Laws

- The complement of the union of two sets is the same as the intersection of their complements; and

$$\overline{A + B} \equiv \overline{A} \cdot \overline{B}$$

- The complement of the intersection of two sets is the same as the union of their complements

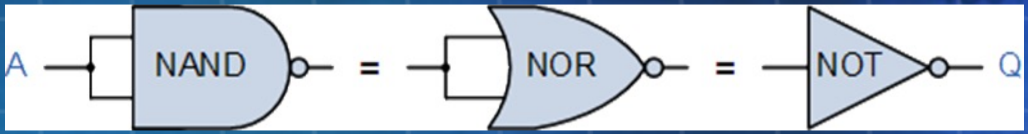
$$\overline{A \cdot B} \equiv \overline{A} + \overline{B}$$

- There are several ways to write this in English and notation, please try to have them all in your binder as you don't know which one they will want to use

https://en.wikipedia.org/wiki/De_Morgan%27s_laws

Equivalents

- NOT equivalents



- In class practice, Create equivalents for the following using AND, OR, and NOT gates
  - NAND
  - NOR
  - XOR
  - XNOR

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https://www.electronics-tutorials.ws/boolean/bool_1.html

Common Logic Expressions

- These are the most common expressions, symbols, and values for one or two input logic gates
- Note all the ways you can show the functions
- Please note that in addition
  - X AND Y can be shown as $X \wedge Y$
  - X AND Y can be shown as $X \vee Y$
  - NOT X can be shown as $\neg X$

Expression	Symbol	Venn diagram	Boolean algebra	Values
AND			$A \cdot B$	A B Output 0 0 0 0 1 0 1 0 0 1 1 1
OR			$A + B$	A B Output 0 0 0 0 1 1 1 0 1 1 1 1
XOR			$A \oplus B$	A B Output 0 0 0 0 1 1 1 0 1 1 1 0
NOT			$\overline{A}$	A Output 0 1 1 0
NAND			$\overline{A \cdot B}$	A B Output 0 0 1 0 1 1 1 0 1 1 1 0
NOR			$\overline{A + B}$	A B Output 0 0 1 0 1 0 1 0 0 1 1 0
XNOR			$\overline{A \oplus B}$	A B Output 0 0 1 0 1 0 1 0 0 1 1 1
BUF			A	IN Output 0 0 1 1

Venn Diagram for logic gates is a schematic representation of A and B overlapping each other inside a rectangle area, the diagram shows the relation of the boolean operators.

http://www.ambrsoft.com/Equations/LogicalGates/LogicalGates.htm

Common Logic Expressions

- Very common Basic Boolean (logic) algebra laws
  - Not allowed per rule 3.e

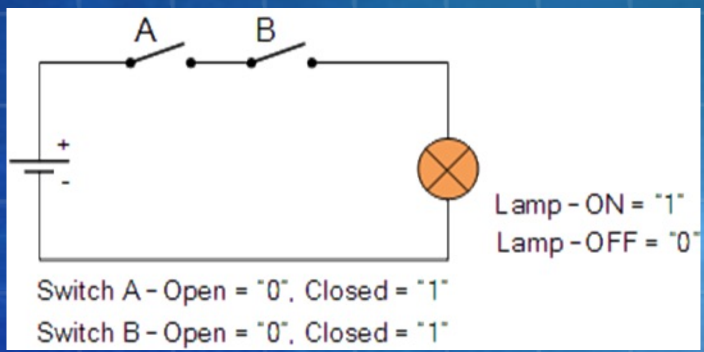
Basic Boolean algebra laws

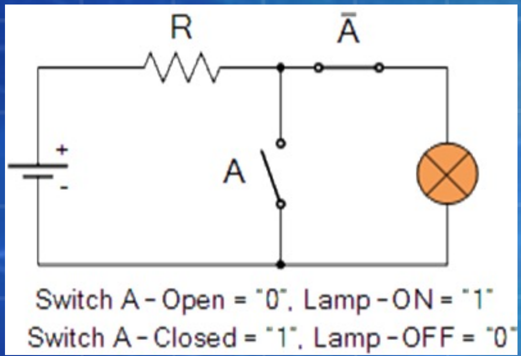
	AND	OR
Commutative	$A \cdot B = B \cdot A$	$A + B = B + A$
Associative	$(A \cdot B) \cdot C = A \cdot (B \cdot C)$	$(A + B) + C = A + (B + C)$
Distributive	$A \cdot (B + C) = A \cdot B + A \cdot C$	$A + (B \cdot C) = (A + B)(A + C)$
De Morgan's Theorem	$(A \cdot B)' = A' + B'$	$(A + B)' = A' \cdot B'$
	$(A \cdot B \cdot C)' = A' + B' + C'$	$(A + B + C)' = A' \cdot B' \cdot C'$
	$(A \cdot B \cdot C \cdot \ldots.)' = A' + B' + C' + \cdots$	$(A + B + C + \cdots)' = A' \cdot B' \cdot C' \cdot \ldots.$
	$A \cdot 0 = 0$	$A + 0 = A$
	$A \cdot 1 = A$	$A + 1 = 1$
	$A \cdot A = A$	$A + A = A$
	$A \cdot A' = 0$	$A + A' = 1$
	$A \cdot (A + B) = A$	$A + (A \cdot B) = A$
	$A \cdot (A' + B) = A \cdot B$	$A + (A' \cdot B) = A + B$
	$A \cdot B + A \cdot B' = A$	$(A + B)(A + B') = A$
	$(A')' = A$	$0' = 1$

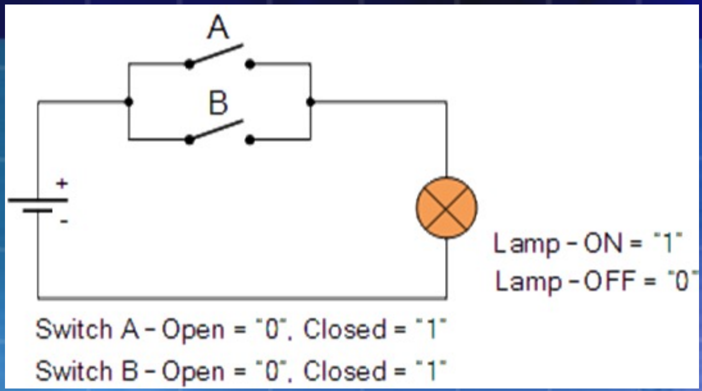
http://www.ambrsoft.com/Equations/LogicalGates/LogicalGates.htm

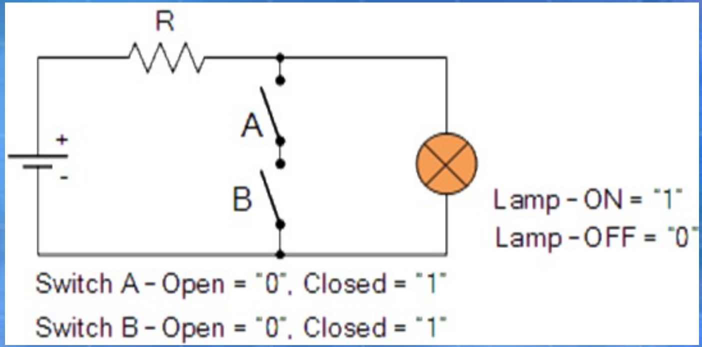
Switch Representation

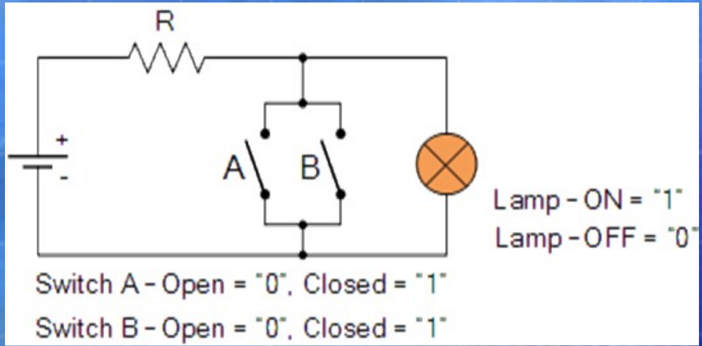
- **Which logic gate is represented by the following?**











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Using Diodes

- Logic gates can also be represented by diodes

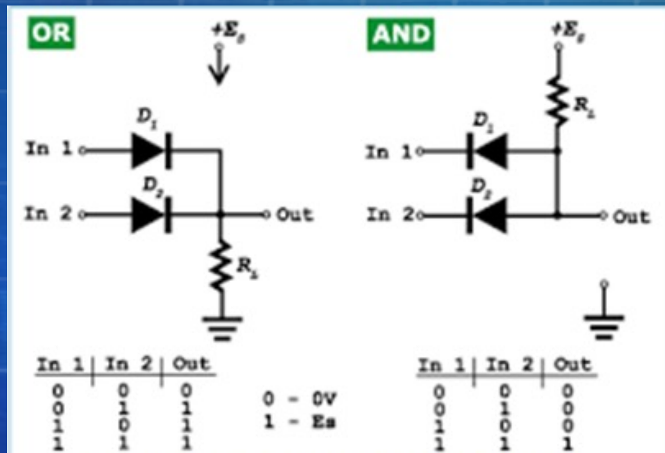
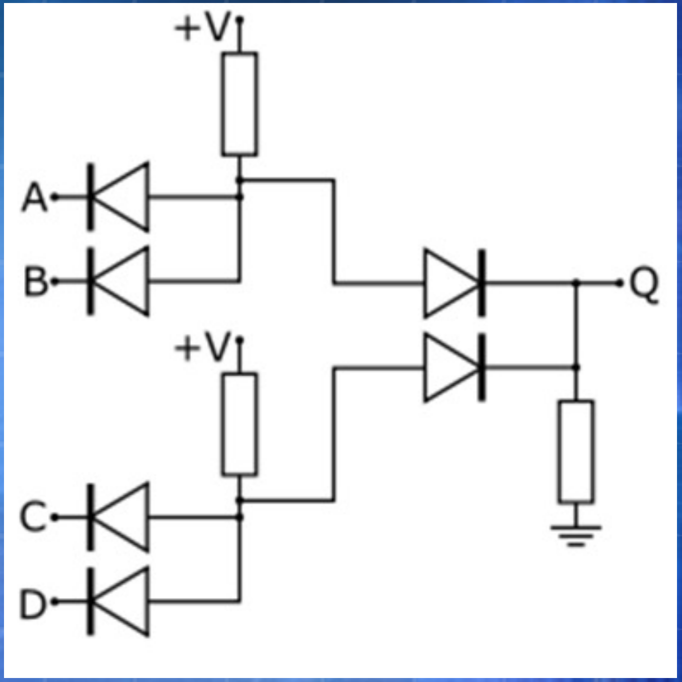


Fig. 2.1 p-n-junction diode's OR and AND gates.



- What is the diagram to the right representing?

- Can you create a NOT out of a Diode circuit?

https://www.seminarsonly.com/Engineering-Projects/Physics/Logic-Gate.php
https://en.wikipedia.org/wiki/Diode_logic

Homework

- Update your binder to get it competition ready
- Find all the different ways to write De Morgan's Laws
- Find all the different ways to represent AND, OR, NOT, NAND, NOR, XOR, and XNOR.
- Create switch and diode representations of each of the logic gates, without using transistors
- Using Boolean logic gates and the following inputs, designa system which determines if something is a mammal or not
  - A—has a vertebrae
  - B—has a neocortex in the brain
  - C—is a animal
  - D—has hair
  - E—breathes oxygen
- Using two resistors, an op amp, and an independent voltage source create a logical NOT gate
- Using that NOT gate plus diodes and resistors create NAND and NOR gates