Binary Variables and Functions

Binary Variables:

$$A, B, C \in \{0,1\}$$

Binary Functions:

$$f(A, B, C): \{0,1\} \times \{0,1\} \times \{0,1\} \rightarrow \{0,1\}$$
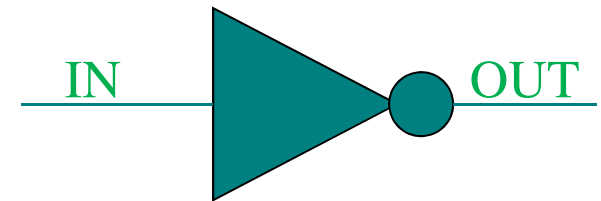
Example:

A	B	C	f(A,B,C)
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

Logic operations, Truth Tables & Gates

IN	OUT
0	1
1	0

Not (Inverter)

OUT=IN'

IN — OUT

A	B	OUT
0	0	0
0	1	0
1	0	0
1	1	1

AND

OUT=A·B

A

B

OUT
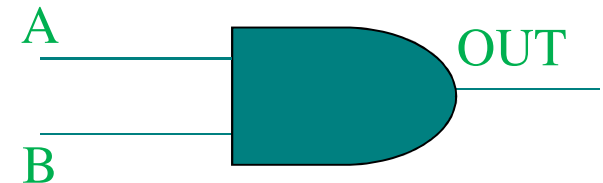
A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	1

OR

OUT=A+B

A

B

OUT
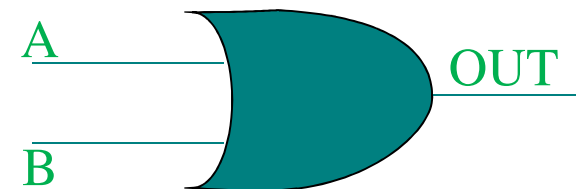
Logic operations, Truth Tables & Gates

A	B	OUT
0	0	1
0	1	1
1	0	1
1	1	0

NAND

$$OUT=(A{\cdot}B)'=(A'+B')$$

A

OUT

B
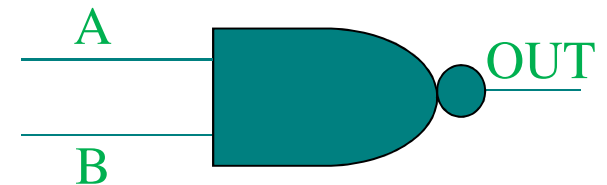
A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	0

NOR

$$OUT=(A+B)'=A'{\cdot}B'$$

A

OUT

B

UT DALLAS
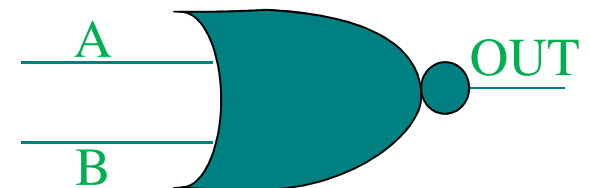
Logic operations, Truth Tables & Gates

A	B	OUT
0	0	0
0	1	1
1	0	1
1	1	0

XOR
$$OUT=A\oplus B=(A'\cdot B)+(A\cdot B')$$

A
OUT
B
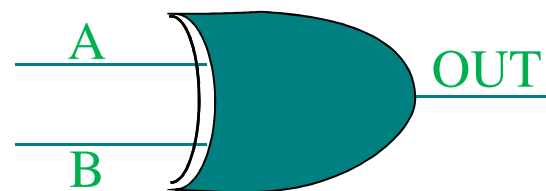
A	B	OUT
0	0	1
0	1	0
1	0	0
1	1	1

XNOR
$$OUT= A\odot B=(A\cdot B)+(A'\cdot B')$$

A
OUT
B
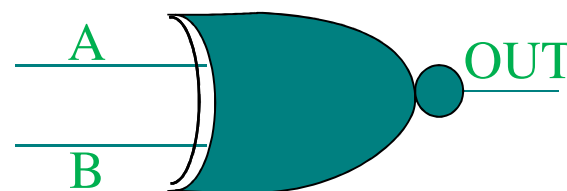
Multiple Input Logic Gates

A	B	C	OUT
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

3-input AND
OUT=A·B·C

A
B
C

OUT

Equivalent to:

Commutativity & Associativity:

A
B
C

OUT

A
C
B

OUT

B
C
A

OUT
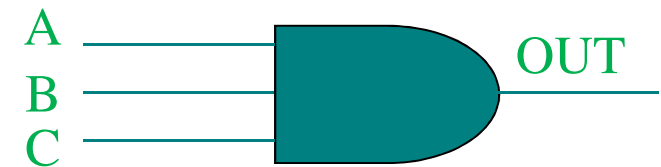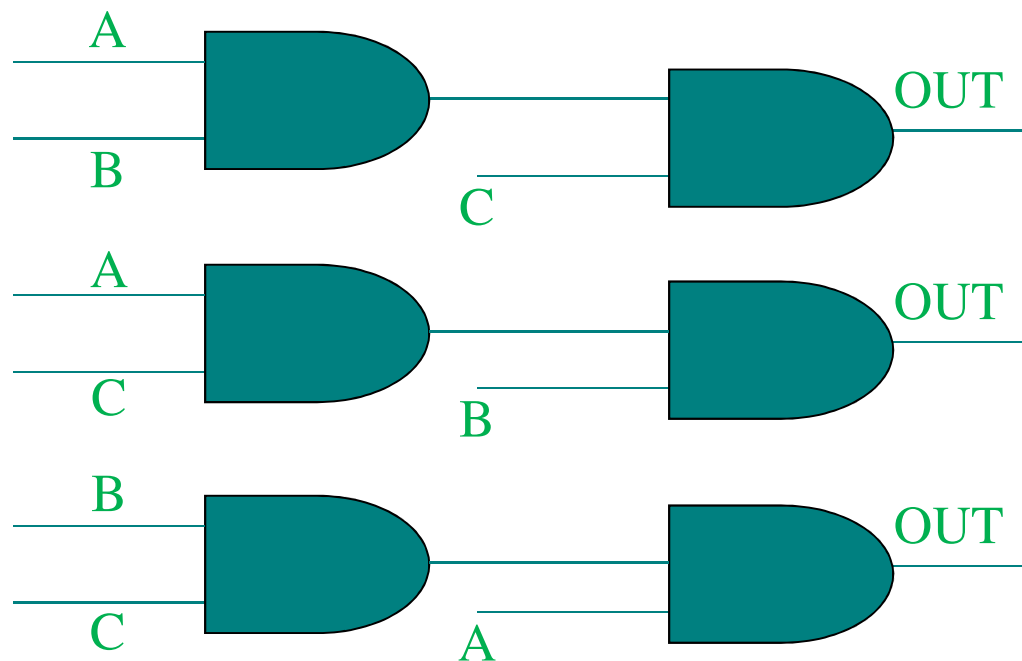
Multiple Input Logic Gates

A	B	C	D	OUT
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

4-Input OR

OUT=A+B+C+D

Equivalent to:

Commutativity & Associativity

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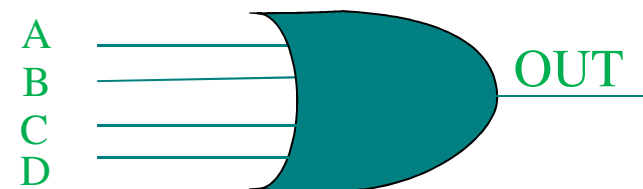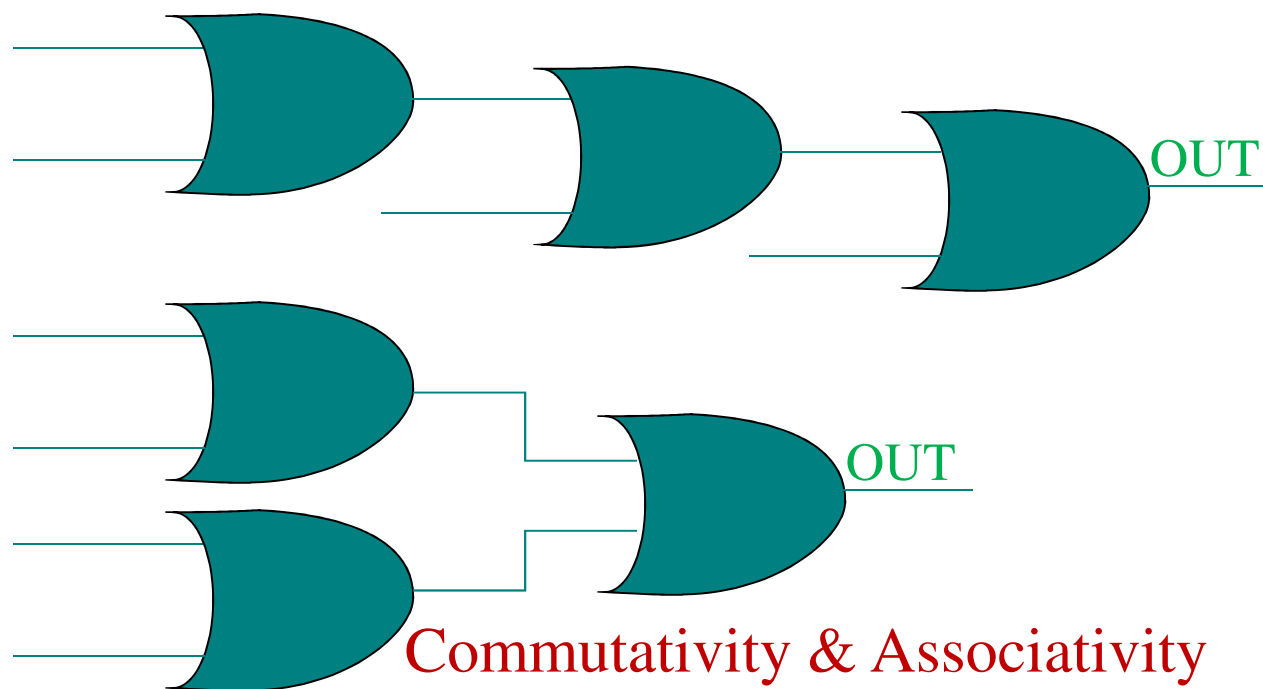
Universal Set of Gates

Definition:

A set of gates is universal if any binary function can be implemented by using only gates from this set
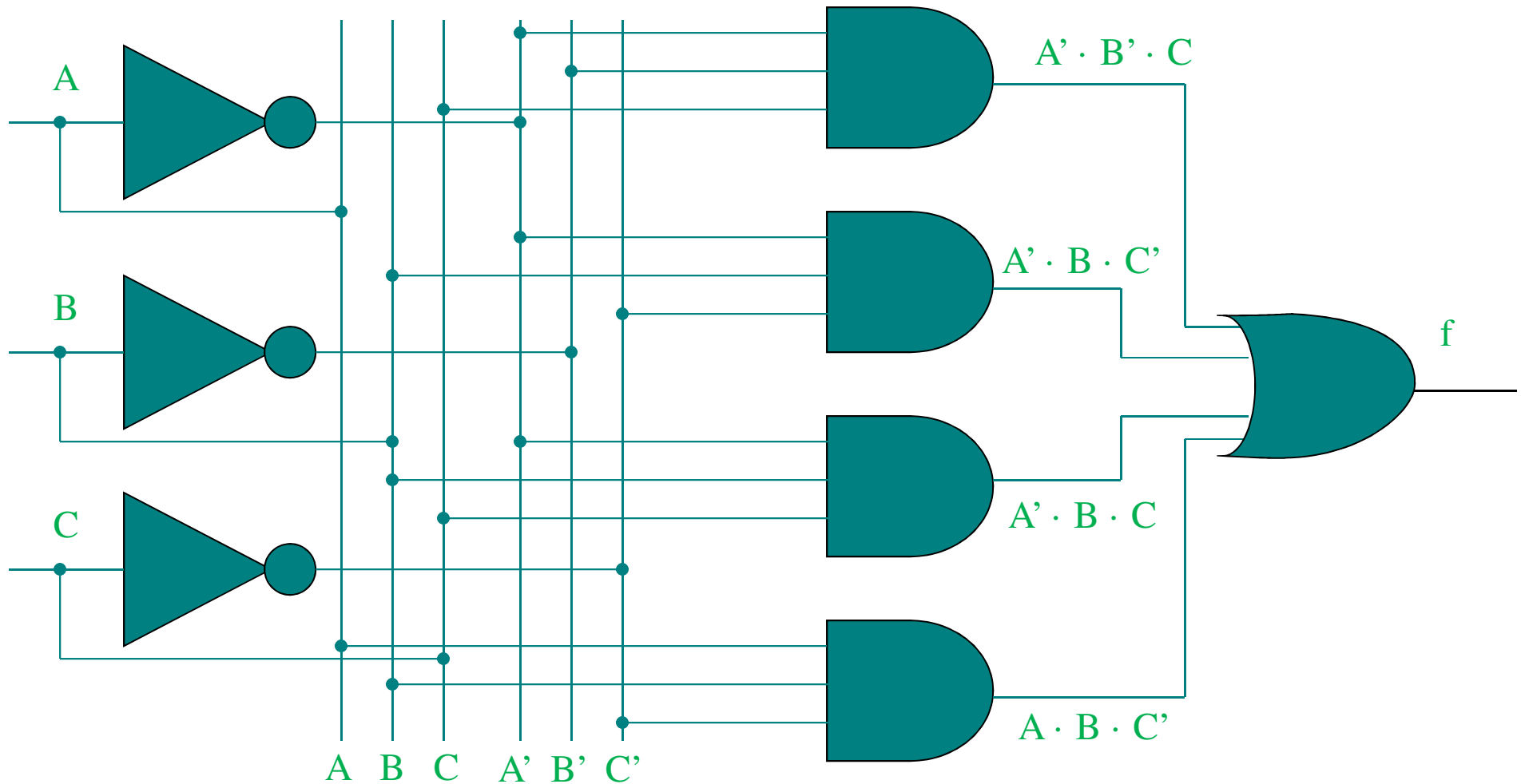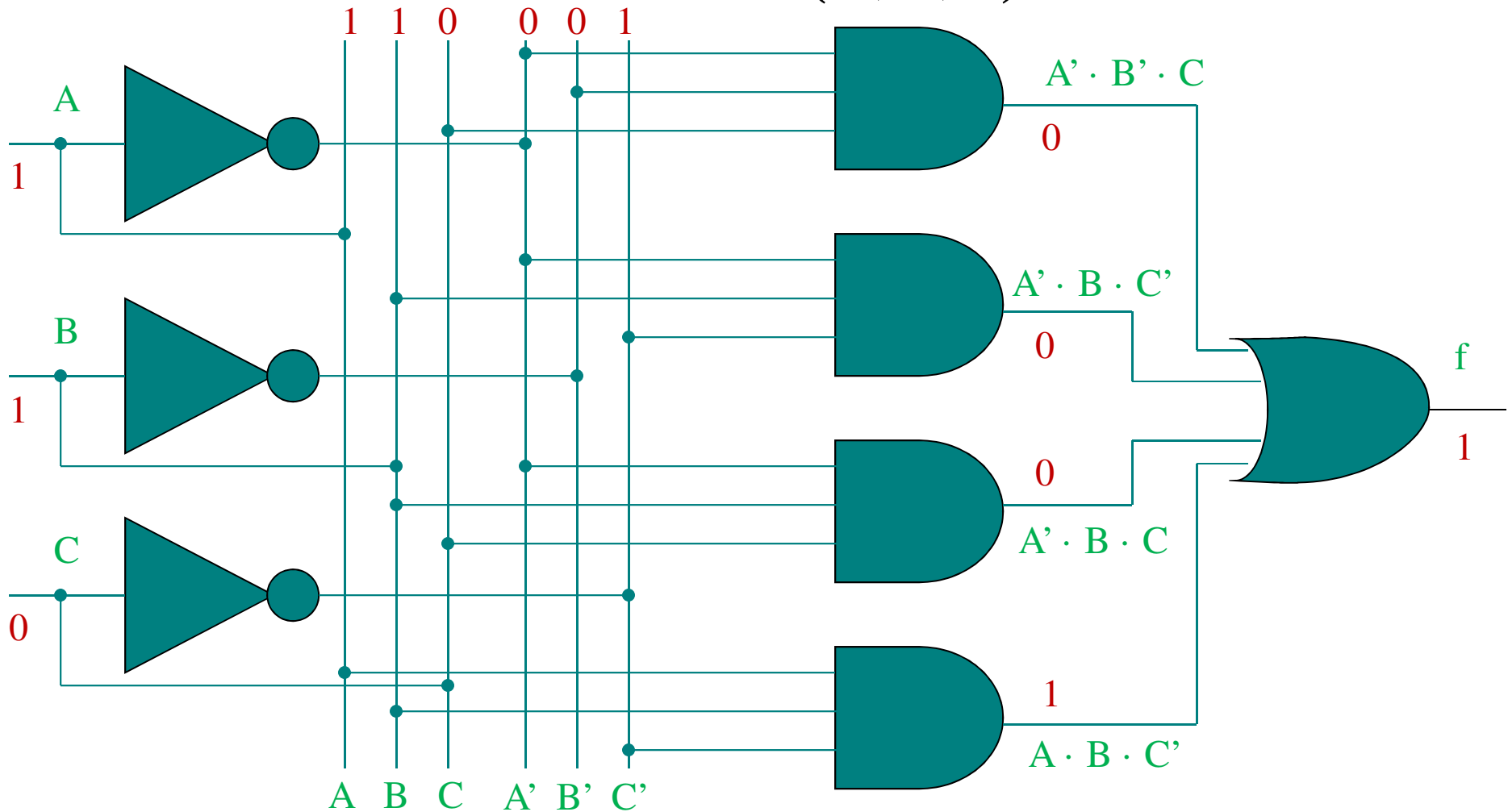
Example:

The set {AND, OR, NOT} is universal

A	B	C	f(A,B,C)
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

$f(A,B,C)=$
$(A' \cdot B' \cdot C) +$
$(A' \cdot B \cdot C') +$
$(A' \cdot B \cdot C) +$
.
.
.
$(A \cdot B \cdot C')$

Examples for Circuit Implementation

A

B

C

A   B   C   A'   B'   C'

A' · B' · C

A' · B · C'

A' · B · C

A · B · C'

f
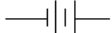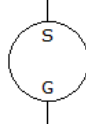
Simulation: f(1,1,0) = 1

DC resistor Circuits

- This section deals with resistor circuits that have both DC and AC voltages applied.

- In solving electrical engineering problems, we usually have a circuit with applied voltages and we seek to discover the currents in the circuit (sometimes we have an applied current and we are solving for voltages, but not in this exercise).

- We will need to use three basic electrical engineering formulas: **Ohm's** Law, and **<u>Kirchoff's</u>** Voltage and Current Laws.

Circuit Symbols

- Resistor
- DC battery or voltage source
- Capacitor
- Polarized capacitor
- Inductor
- Signal generator

Notational Conventions

- Some notational conventions in electrical engineering:
  - Current flows from the <u>positive side</u> of a DC source to the <u>negative side</u>. A relic of early circuit theory before we understood that electrons, not positive charges, move.
  - A voltage <u>drop</u> (e.g., as through a resistor due to current flow) is considered <u>positive</u>. This is simply a convention.
  - A voltage <u>rise</u> (as that through a battery from the negative side to the positive) is <u>negative</u>. Also simply a convention.
  - **Node:** A point at which two or more circuit elements are connected together.
  - Most generally, current <u>entering</u> a node is labeled <u>negative</u>; current <u>leaving</u> a node is labeled <u>positive</u>. Another convention.
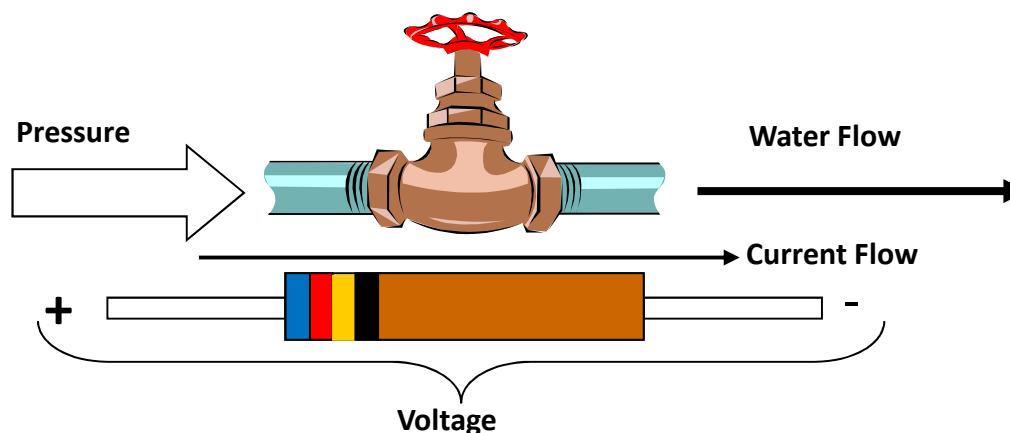
Ohm's Law

- Ohm's Law:

The voltage across a resistor is equal to the current in the resistor times the resistance, voltage in Volts(V), current in Amperes(A), resistance in Ohms(Ω): **$V=I\times R$**

- Note: Amperes × Ohms = Volts
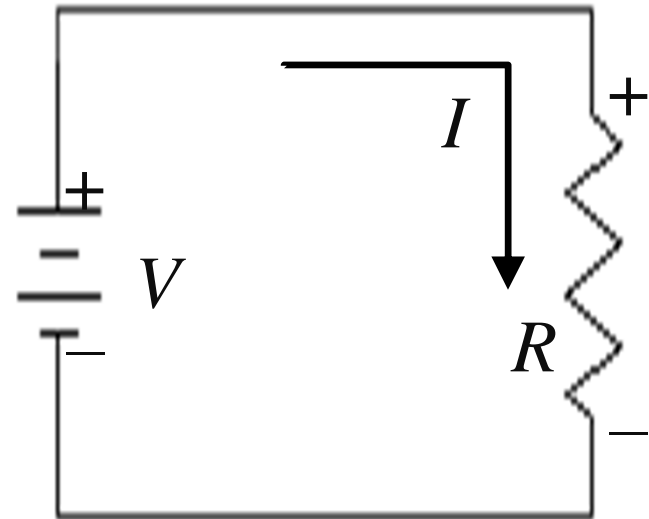
Analogy of Water flow and Pressure

Pressure

Water Flow

Current Flow

+   −

Voltage

- DC current flow is analogous to water flow in a pipe:
  - Pressure is similar to voltage, forcing movement of water as voltage forces current flow in a conductor.
  - Pipe diameter is analogous to resistance; a smaller pipe diameter reduces water flow for a given pressure, just as a larger resistance (smaller <u>conductance)</u> reduces current flow.

Kirchoff's Voltage Law

- **KVL:** The net voltage around a closed loop circuit is zero.

- Another way to state this is that the voltage rises (sources) in a closed loop equal the voltage drops (caused by resistors).
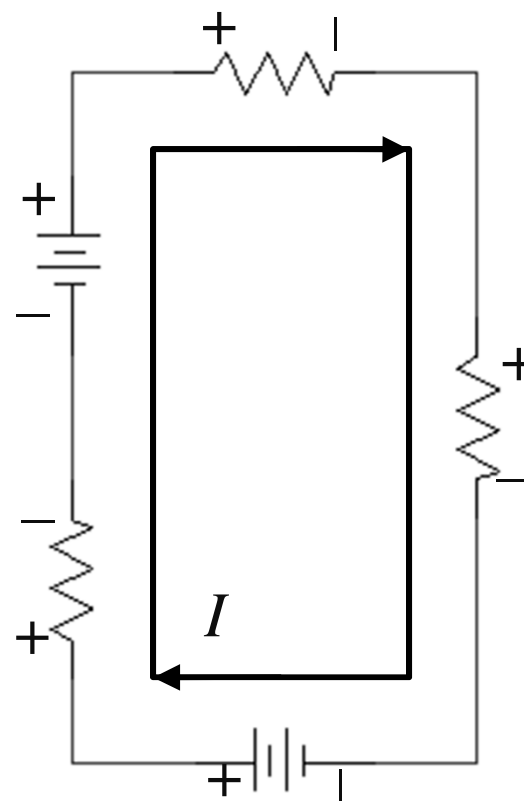
Kirchoff's Current Law

- **KCL:** The algebraic sum of currents in any node is <u>zero</u>.

- Another way to say this is that the sum of currents <u>entering</u> the node is equal to the sum of currents <u>leaving</u> the node.

- Or: $-I_1 - I_2 + I_3 + I_4 = 0$
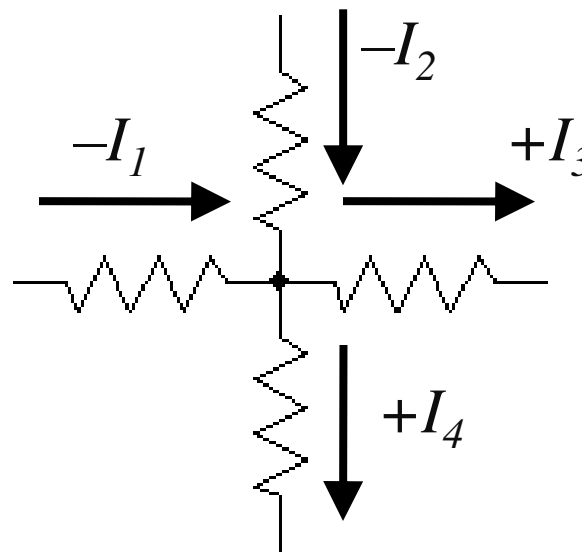
AC Resistor Circuits

- Resistor circuits with an applied AC voltage obey the same three laws as DC circuits.

- Your AC circuits will be identical to the DC resistor circuits except for replacing the DC power source with an AC signal generator.

$$V = IR$$

$$-I_1 \quad -I_2 \quad +I_3 \quad +I_4$$

$$\Sigma I_N = 0$$

$$\Sigma V_L = 0$$
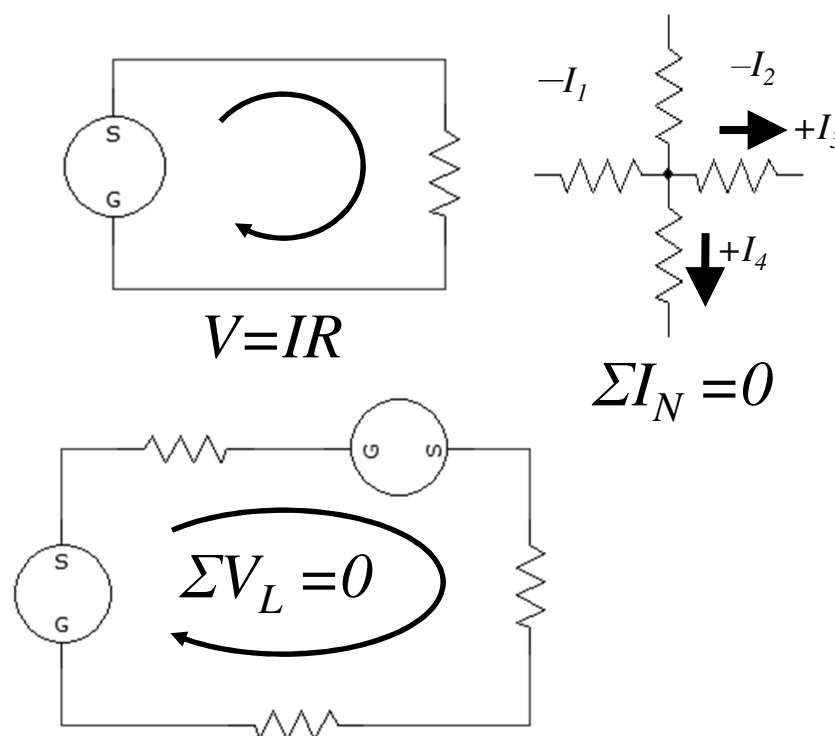
Measurement of AC Voltage

- We will be applying a sinusoidal AC voltage to a resistor, that is a voltage of the form, $v(t) = V_P \cos(\omega t)$ where V_P is the maximum AC amplitude.

- You will be able to see this sinusoidal waveform on the oscilloscope.

- A digital Multi-meter ("DMM") can be used to measure the AC sinusoidal voltage. However, the DMM measures a constant value for this time-varying voltage.

- Question: What does the DMM measure?

Measurement of AC Voltage

- The DMM measures "effective" AC voltage, the "RMS" (root-mean-square) AC voltage, which is equivalent to a DC voltage in terms of delivering power to the circuit.

- For the sinusoidal voltage $v(t) = V_P \cos(\omega t)$ discussed above, the peak voltage is clearly V_P. The peak-to-peak voltage swing, which you will see on the oscilloscope, is V_{PP} ($= 2\, V_P$). Skipping a calculus derivation, the RMS value of any sinusoidal voltage is $V_P / \sqrt{2}$, or $V_{PP} / (2\sqrt{2})$.