**Voltage:** \( V = \frac{dW}{dq} \), Volts \to\) Joules

Coulombs

The work done on energy expended per unit charge in moving that charge from point A to point B. The separation of charges gives rise to the nature of how voltage is measured. Voltage is always measured between two points.

**Current:** \( i = \frac{dq}{dt} \), Amps \to\) Coulombs

Time

The measure of how much charge is passing through a single point in a circuit element or conductor.

**Power:** \( P = \frac{dW}{dt} \), Watts \to\) Joules

Time

The amount of work done per unit time. The time rate of expending (generating) or absorbing (dissipating) energy.
From Before:

Circuit Elements (sources)

- Independent voltage
- Independent current
- Dependent current
- Dependent voltage
- Current-controlled current
- Voltage-controlled voltage
- Voltage-controlled current
- Current-controlled voltage
- Voltage

Is = GxV
Is = Fx
Vs = Hx
Vs = EVx

OPAMP (voltage)
OPAMP (current)

To maintain a current flow, Is through the terminals.

Produce whatever voltage is necessary.

Sources current-controlled is necessary.
Ohm's Law:

Elements that resist current flow are resistors. We assume conductors (wires) have no resistance to current flow. Resistance is measured in ohms \( \Omega \).

Ohm's Law:

The voltage across a resistor is directly proportional to the current flowing through it. OR...

\[ V = IR, \quad I = \frac{V}{R}, \quad R = \frac{V}{I} \]

where the constant of proportionality is the resistance of the resistor.

To work, you must stay true to the passive sign convention:

\[ \begin{array}{c}
+ \quad V \\
\downarrow \\
R \\
\uparrow \\
- \\
\end{array} \]

Positive current flowing \( L \) to \( R \) will (most) result in a positive voltage given the assignment of polarity (of voltage) shown.

\[ I = \frac{2}{8} = 0.25A \]

Note current is flowing from higher potential to lower.
Ohms Law at the Limits

- **Open Circuit**
  - The current path is broken, thus
  - \( R = \infty \)

\[ I = \frac{V}{R} ; \text{if } R = \infty, \ I = 0 \]

- What is the voltage across the open circuit at points A and B? Across the resistor \( R_L \)?

- **Short Circuit**
  - A zero resistance path is formed across the intended load or resistance
  - \( R = 0 \)

\[ I = \frac{V}{R} ; \text{if } R = 0, \ V = \infty \]

- What is the current through resistor \( R_L \). Voltage across \( R_L \)?
Nodes, Branches & Loops

A node is an unbroken piece of conductor.
- It is a unipotential conductor; anywhere on a node, we have the same, identical voltage.
- If there is no voltage across any two parts of the node, then the conductor constituting the node has zero resistance.

A branch is formed by any single two-terminal element connected across two nodes.

A loop is a closed path formed by starting at one node, traversing a set of nodes and arriving back at the starting node.

In the circuit above, how many loops exist?
- How is the voltage across R1 expressed algebraically (2 ways)?

Notes are easier to identify than loops. Node voltage method is often more useful than mesh current method.

Numerical:
- Voltage between nodes B+C, considering node C to be the reference node is written V_{BC}.
- Current through R3 is written I_{R3}.
- Connection dots are not nodes!
Series + Parallel

Elements in series are connected end-to-end with nothing else connected to the intermediate node.

If elements are in series, they will have the same current flowing through them.

Series:

Not in Series

why?

why?
Parallel elements share the same pair of nodes or terminals. (definition)
If the elements are parallel, they have the same voltage across them.

Parallel:

Not Parallel:

Are $R_1, R_2$ in series or parallel? $I_{R_1}, I_{R_2}$?

Are $R_1, R_2, R_3, R_4$ in series or parallel? $V_{R_1}, V_{R_2}, V_{R_3}, V_{R_4}$?