Learning Objectives
a. Draw a schematic of a typical electrical circuit, and explain the purpose of each component and indicate the polarity and current direction
b. Describe the basic function of a fuse or a switch
c. Discuss the difference between an open circuit and a short circuit
d. Apply the concept of voltage potential between two points to the use of subscripts and the location of the reference voltage

Basic circuit function
All circuits require three things to function:
1. Source of power
2. Load (something you want powered)
3. Path for current to flow with two terminals
   o Current must be able to flow from the source to the load and back from the load to the source, i.e., it must make a loop for electricity to flow

For the rest of the semester, whether we add more sources, more loads, or alternate paths, all circuits must have these three things.

Basic Electrical Distribution

Electricity generation, transmission, and distribution

In the picture above, the power plant is the source and the house is the load. In the wire shown, there would be positive and negative cables to complete the circuit. Electricity on a ship functions similarly with a generator providing electricity to the loads on the ship. After the twelve-week exam, we will go in more depth to understand generators and transformers shown above. The majority of the material in this class will be learning about and analyzing different configurations of loads (e.g. inside the house on the diagram).
Circuit Diagrams

A circuit diagram is a visual representation of an electrical circuit that uses either basic images of components or industry standard symbols. The circuit below is the most basic circuit diagram with a source, load, and path of two terminals.

A node is the point of connection between two or more elements. The circuit above contains two nodes. The voltage is the same throughout a node. There is no voltage drop in the horizontal lines shown above. The voltage doesn’t change until it crosses the resistor.

Example: Determine the number of nodes in the circuits below.

It is worth pausing to remind you that the polarity of the voltage across a resistor is determined by the direction of current flow.
Example: The voltage source is 50 V and the resistor is 10 Ω. Solve for current. Fully label the circuit with a current arrow, E, V_R, I, and R. Label the nodes on the circuit.

Open Circuits
Current can only exist where there is a conductive path.

An Open Circuit is a condition where there is no path for current to flow (i.e., \( I = 0 \) A).

Since current is zero, the circuit has an infinite resistance.

This is called an open circuit.

\[
R = \frac{E}{I} = \frac{E}{0} \Rightarrow \infty \text{ ohms}
\]

Short Circuits
A short circuit condition is where the resistance of the circuit is essentially zero (i.e. \( R = 0 \) Ω).

Since resistance is near zero, all current will bypass the rest of circuit and go through the short.

With zero resistance, current draw will approach the limits of the power source (infinite current), frequently causing damage to wiring or the power source. Essentially there is no load, or at least very little to negligible load.

\[
I = \frac{E}{R} = \frac{E}{0} \Rightarrow \infty \text{ amps}
\]

“Short circuiting” is not a good thing. Even in non-technical writing, a shortcut is considered good while short-circuiting is bad. Writers use it to convey that something was supposed to happen but the short circuit prevented that. The technical term is that there was a load intended to receive the electricity, but it was bypassed by the short.
Common components
As the circuits become more complex, the need for symbols and understanding them becomes more necessary. Below are some common symbols and their functions.

DC Sources
We’ve already shown the most common symbol of a DC source.

DC voltage sources also include:

Point Sources If the voltage at two nodes is known, then the voltage can be represented as a point source like this:

Switches A basic circuit component you will see as the course progresses is a switch. The switch shown below is known as a single-pole, single-throw (SPST) switch. A switch can be used to disconnect or connect components in an electrical circuit, interrupting the electric current or diverting it from one conductor to another. In the circuit below, the switch is closed, so the lamp is on.
Components for safety
In electric power systems, an overcurrent condition is a situation where a larger than intended electrical current exists through the circuit’s conductors. This can lead to excessive generation of heat and the risk of fire damage to equipment.

Different types of overcurrent conditions include:
**Overload** – the electrical loading on the circuit is causing current draw in excess of the conductor or component ratings

**Short circuits** - High-magnitude fault over-currents that are the result of a low resistance path in parallel with the resistance of the connected load

**Ground fault** – Specific type of short circuit where an energized conductor has been shorted around the loads through the ground.

**Fuses** A fuse is an overcurrent protection device that consists of either a metal wire or conductive strip that melts when too much current flows through it, thereby creating an open-circuit and interrupting the current. Fuses are sacrificial devices; once a fuse has operated (i.e. once the fuse has blown), it is an open circuit, and it must be replaced.

**Circuit Breakers** A circuit breaker is an electrical switch designed to automatically trip (open) in the presence of an overcurrent condition. Circuit breakers come in varying sizes, from small low-voltage residential applications, up to large switchgear designed to protect high voltage circuits. It uses an electro-mechanical spring mechanism that opens a switch. A “popped” or “tripped” circuit breaker can be reset by pulling the switch to fully off and then fully on, thereby resetting the spring mechanism.
Ground
Some of you may have heard the term ground and are wondering what a ground is. Ground for any circuit is the region of relatively neutral potential that is beyond the capacity for the power supply of the circuit to energize.

A typical ground for a residence or a building is a group of grounding rods which are dug into the earth and electrically connected to the grounding wires for the building. The grounding rods themselves are steel or copper rods that are interconnected and share a conductive path with the soil around them (hence the name ground).

Note: For ship, submarine, and aircraft electrical systems there is no ground; however, there may be a common point of reference.

Circuit Ground In our circuit diagrams, the circuit ground is also used as a point of reference, or a common point in a circuit for making measurements. When the actual ground is unknown, then a node can be chosen as a reference node.

Ground represents a point of zero reference potential. Ground is 0 volts.

Single subscript notation for voltage: In a circuit with a ground, the point voltages may be expressed with respect to that reference point (e.g. \( V_c \) is the voltage at node \( c \) with respect to the 0 volts found at the ground).

Your friend says that no current flows in the circuit shown on the right, since there is no loop for current to flow. Is your friend correct?

Double subscript notation for voltage: Voltage between any two node points \( (a \) and \( b) \) can be written as \( V_{ab} \).

\[
V_{ab} = (V_a - V_b)
\]

If \( b \) is at a higher potential than \( c \), then \( V_{bc} \) is positive. If \( a \) is at a lower potential than \( b \), then \( V_{ab} \) is negative.

Another way to think of single subscript is with ground as the second node.

\[
V_c = (V_c - V_{\text{gnd}}) = (V_c - 0) = V_c
\]

Negative voltage?
If a voltage measurement is negative, that means you are measuring from the reverse of the positive direction (negative voltage is the same potential just measured oppositely, it can still shock you).
Example: Determine the readings, magnitude, and polarity for each measurement.

\[
\begin{align*}
\text{(a)} & \quad 8 \, \Omega \quad V = 6 \, V \\
\text{(b)} & \quad 8 \, \Omega \quad V = 6 \, V
\end{align*}
\]

Solution:

**Circuit Redrawing** In order to simplify analysis, we will often be redrawing circuits. Many times, a simplified circuit may already be provided. Two common ways are labeling between two open nodes that still signifies a closed/completed circuit would still exist.
Example: In the circuits below, which resistor(s) would not be part of the circuit?

a) 

b) 

$110V$