Notes for ECE 20001 - Electric Engineering Fundementals I

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These are lecture notes for fall 2023 ECE 20001 at Purdue. Modify, use, and distribute as you please.

Contents

Course Introduction

This course covers fundamental concepts and applications for electrical and computer engineers as well as for engineers who need to gain a broad understanding of these disciplines. The course starts by the basic concepts of charge, current, and voltage as well as their expressions with regards to resistors and resistive circuits. Essential concepts, devices, theorems, and applications of direct-current (DC), 1st order, and alternating-current (AC) circuits are subsequently discussed. Besides electrical devices and circuits, basic electronic components including diodes and transistors as well as their primary applications are also discussed. For more information, see the syllabus.

Equations

1. $P = \frac{dW}{dt} = IV$
2. $I = \frac{dq}{dt}$
3. $V = \frac{W}{q}$
4. $R = \frac{\rho L}{A}$
5. Coulomb's Law: $\vec{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$
6. Kirchhoff's Voltage Law:
7. Ohm's Law: $V = IR$

Charge, current, voltage, and power

Charge: A fundemental property of matter.
Current: The rate of flow of charge.
Voltage: Related to the potential energy of charges.
Power: The rate of doing work, or changing energy
Passive sign convention: Defines electric power flowing out of the circuit into an electrical component as positive, and power flowing into the circuit out of a component as negative. So a passive component which consumes power, such as an appliance or light bulb, will have positive power dissipation, while an active component, a source of power such as an electric generator or battery, will have negative power dissipation.

It's useful to have an idea of the components of circuit schematics (visual representations of a circuit). Below is a list of the terms that will be used in this course:

- Elements: The term elements means "components and sources."
- Symbols: Elements are represented in schematics by symbols. Symbols for common 2-terminal elements are displayed to the right.
- Lines: Connections between elements are drawn as lines, which we often think of as "wires". On a schematic, these lines represent perfect conductors with zero resistance. Every component or source terminal touched by a line is at the same voltage.
- Dots: Connections between lines can be indicated by dots. Dots are an unambiguous indication that lines are connected. If the connection is obvious, you don't have to use a dot.

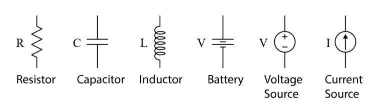
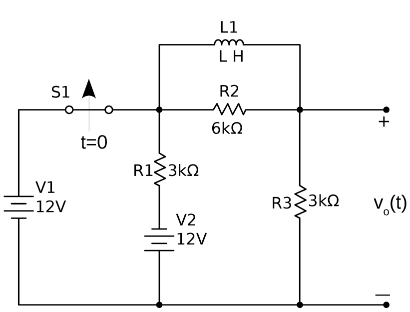


Figure 1: Common circuit symbols

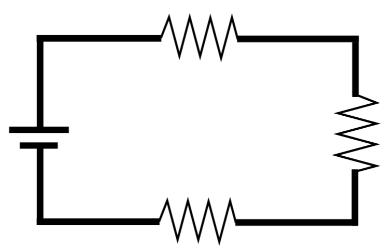
Check out the circuit schematic below and see how many components you can identify!



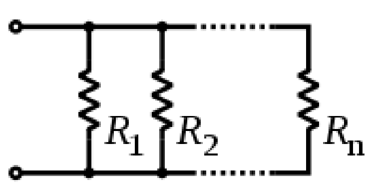
Now, on to what circuits are doing. For interesting things to happen we need electrons flowing through those wires. Current is how quickly electrons are moving along, or in more formal terms the rate of change of charge. That is, $I = \frac{dQ}{dt}$. Its units are amperes (more commonly referred to as amps) Voltage (or electric potential) is the amount of work done in moving charged particles such as electrons between two points. Whenever we want to separate two oppositely (positive and negative) charged particles or push two similarly-charged particles together, we need to do work to overcome the force between them. The work done in separating them is stored as potential energy. This stored energy is known as electric potential (or voltage) and is measured in volts. Thus, $V = \frac{W}{q}$. Just as with potential energy, voltage is always measured as a difference between two points. Power is the rate at which work is being done, i.e. $P = \frac{dW}{dt}$. This would give power units of J/s, which is known as Watts. Now, by rearranging the equation for voltage, we obtain also $P = iV$. To make sense of this equation consider a light bulb in a circuit, with an electric potential difference of 5 V and a current flowing through of 10 A. The power used by the light bulb is $P = iV = 5 * 10 = 50$ watts, meaning it uses 50 J per second.

(In)dependent sources, connections, resistance and Ohm's Law

Series Combination: In a series combination, the elements are connected with end to end in contact, such that current flow is equal in all the elements in the combination



Parallel Combination: When two or more resistances are connected between the same two points, they are said to be connected in parallel combination. In this case voltage is equal across all elements



Turning off a voltage source is equivalent to replacing it with a short circuit (line). Turning off a current source is equivalent to replacing it with an open circuit (broken line).

$Resistance = \rho * Length of resistor / cross section area$ ρ is the resistivity of the material

Conductance = 1/R