ELEN 50 Class 01 – Class Organization and Intro to Units: Power and Energy

S. Hudgens

Syllabus

ELEN 050 – Electric Circuits I

Winter, 2017

Instructor:	**Stephen Hudgens**
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Room:	**EC 107 (MWF 9:15 – 10:20)**
Office Hours:	**MECH 603B Mon/Wed 10:45 – 12:00 and by appointment**
Canvas Website:	**https://camino.instructure.com/courses/26188/modules**

Course Objectives:

1. To understand the fundamental principles of DC and AC circuit analysis sufficiently well to solve practical problems in all branches of engineering.

2. To apply circuit principles toward the development of practical systems.

Expected learning outcomes:

1. Formulate Kirchoff current and voltage law equations in a systematic manner.
2. Formulate and solve node voltage and loop current equations
3. Compute Thevenin equivalent circuits and apply them in circuit analysis
4. Analyze circuits using operational amplifiers
5. Use phasor techniques to compute sinusoidal steady state solutions in linear circuits.
6. Design and test circuits that meet a given set of specifications.

Textbook: Electric Circuits – Nilsson and Riedel 8 th or 9th Edition Prentice Hall.

Course Content: A list of course topics can be found on the attached course time schedule grid.

Homework: Homework is assigned more or less on a bi-weekly basis, with the assignment date and the due date established by the course instructor.

Laboratory: The laboratory will parallel class work. The TAs will give you more details, and general guidelines and lab documents are posted on the Canvas website for the class in the LAB folder. Be sure to check this site for Prelabs, Tutorials, and Lab writeups. The grade for the lab is separate from the grade for the main part of the ELEN 50 course.

Grading:	Homework	20%
	Midterms	35%
	Final	45

ELEN 50 Class Organization Structure

The upper left entry shows calendar date and the upper right entry is the sequential class number. The topic for each class and the relevant pages in the Nilsson and Riedel 9th Edition textbook are also shown.

Week	Class	Class	Class	Lab
1	1/9 01 Units, Power and Energy 1 -30	02 V and I Sources , Resistance 23-30	03 Ohms Law – Ckt Topology 30-36	Lab 0 Intro to MATLAB
2	1/16 04 MLK Day Holiday	05 Circ. Models, Kirchhoff's Laws 37-46	06 Resistive Circuits 56-70	Lab 1 Vectors and Matrices in MATLAB
3	1/23 07 Source Transformation 109-116	08 Δ to Y Y to Δ 70–76	09 Ckt. Analysis: Node Voltages 93-94	Lab 2 Series and Parallel Resistors
4	1/30 10 Dependent Sources and Supernodes 95-98	11 Node Voltage Examples	12 Thevenin and Norton Equiv. 113-120	Lab 3 Wheatstone Bridge
5	2/6 13 Maximum Power Transfer . 120 -122	14 Midterm Review	15 Midterm Exam I	Project 1 Optimal Power Delivery
6	2/13 16 Mesh Current Method 99- -102	17 Mesh Current Examples 92-95	18 Superposition and Solution by Inspection 97-98	Project 1 Optimal Power Delivery
7	2/20 19 Operational Amplifiers 131 -144	20 Midterm Review	21 Midterm Exam II	Lab 4 Op Amp Circuits
8	2/27 22 Op.Amp. Examples 145 -153	23 Capacitors and Inductors 182-208	24 RC and RL Examples 208 -220	Lab 5 Transient Response
9	3/6 25 Sinusoidal Steady State 330 -337	26 Complex Number Review Phasors 337 -346	27 More Phasor Problems	Project 2 Basic Filter Design
10	3/13 28 Steady State AC Power 390 -398	29 RMS Values Complex Power 390 -407	Final Review	Project 2 Basic Filter Design
	3/20 Final Exam Week			

Circuit Theory

- Circuit theory is a method of solving the behavior of electrical circuits that results from a simplification of the Maxwell Equations.

- This simplification is possible in systems which can satisfy the following conditions:
  - Electrical effects can be assumed to occur instantaneously throughout the system. This is another way of saying that the system is small enough for electrical signals travelling at or near the speed of light to reach every part of the system simultaneously. This permits the use of a lumped parameter representation.

  - The net charge on every component in the system is zero.

  - There is no magnetic coupling between system components.

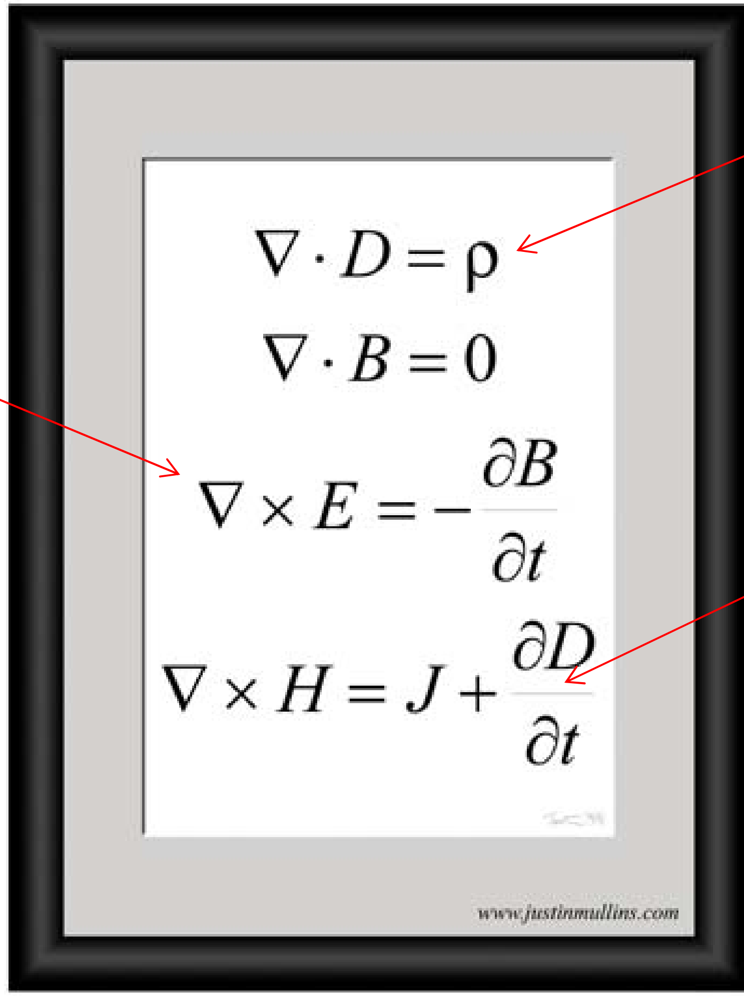
- Most importantly, this level of abstraction allows circuits to be solved by simple linear algebra techniques – no electric and magnetic field calculations ..no partial differential equations!!!

- You might be interested to see how circuit theory is taught to EE students at MIT -- the course, taught by Anant Agarwall, is famous and it's called 6.002 (http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-002-circuits-and-electronics-spring-2007/video-lectures/)

The **Maxwell Equations** – you must have learned this in PHYS 33 (a pre-requisite for ELEN 50!)

Gauss' Law

Faraday's Law



Ampere's Law

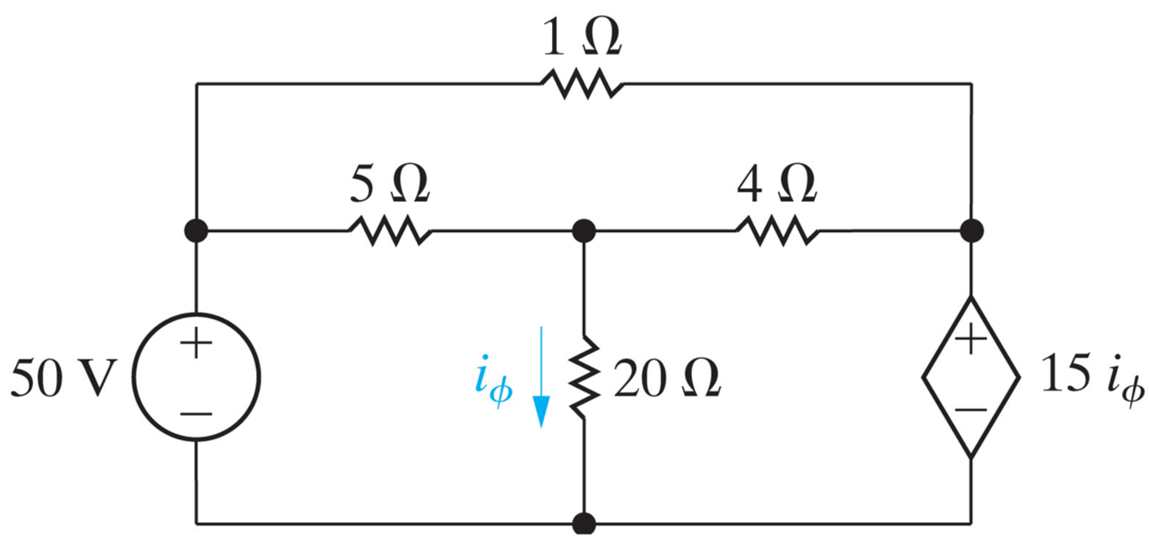
Let There Be Light--Maxwell's Equations

It's always possible to analyze electrical circuits by using the Maxwell equations – but we're not going to do that -- it's just really inconvenient! Circuit theory is much easier.

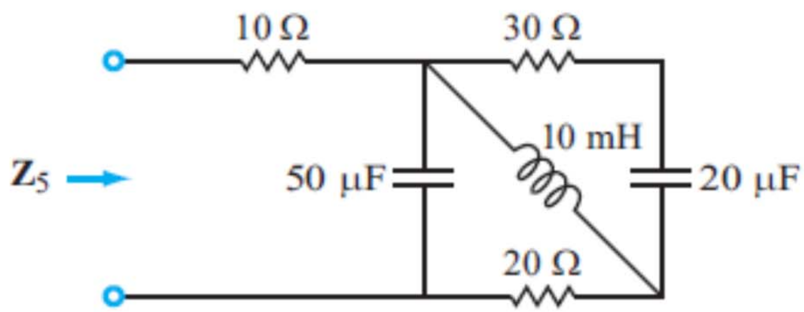
So what is circuit theory (aka network analysis) – what does "solving the behavior of electrical circuits" mean ?

It means finding the <u>current through every element in a circuit and the voltage across every element in a circuit</u>. It is the basis for all of electrical engineering. In addition there are analogies in many other branches of engineering (fluid flow, heat flow, ___ flow (where the "fill in the blank" is something that obeys a conservation law.

For example …you can use circuit theory to solve this DC circuit:

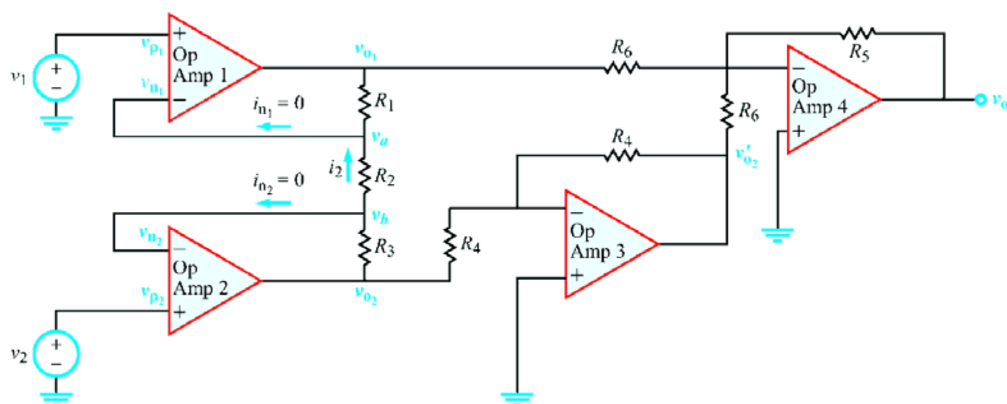


Or this AC steady-state circuit:



Calculate Z_5 at ω = 2000 rad/s

Or this operational amplifier circuit



And you will learn how to do all these things in the next 10 weeks

The lumped parameter abstraction (or lumped circuit abstraction) describes electrical circuits as a network of interconnected circuit elements where:

- Ideal basic circuit element:
  - o Has only two terminals
  - o Is described mathematically in terms of current and voltage
  - o Cannot be subdivided further into other elements

The lumped parameter abstraction is a way that electrical engineering can simplify the physics involved in circuits – ignoring magnetic and electric fields and all the other messiness that happens when electrons move through solids. From the perspective of circuit theory, circuits are networks of two-terminal circuit elements that are completely defined by their current-voltage (I –V) relationships.

OK…what is "current" and "voltage ? "

System of Units in the SI System (aka M

- System of Units:
  - o Most engineering uses SI units (also known as mks) ..based on seven defined quantities
    - [mass] kg (kilogram) -- symbol is m
    - [length] m (meter) -- symbol is l
    - [time] s (second) -- symbol is t
    - [current] A (ampere) -- symbol is i
    - [temperature] K (degree Kelvin) -- symbol is T
    - [quantity] mol (mole)
    - [luminous intensity] cd (candela)
  - o Other units in the SI system are derived from these units:- here are some useful ones:
    - [electric charge] C (coulomb) = A s – symbol is q
    - [energy] J (joule) = kg m^2/s^2 -- symbol is w
    - [electrical potential] V (volt) = J/C -- symbol is v
    - [power] W (watt) J/s -- symbol is P

Definitions

- Definition of voltage: $$v = \frac{dw}{dq}$$ energy, charge (think of voltage as "pressure")

- Definition of current $$i = \frac{dq}{dt}$$ (think of current as "flow")

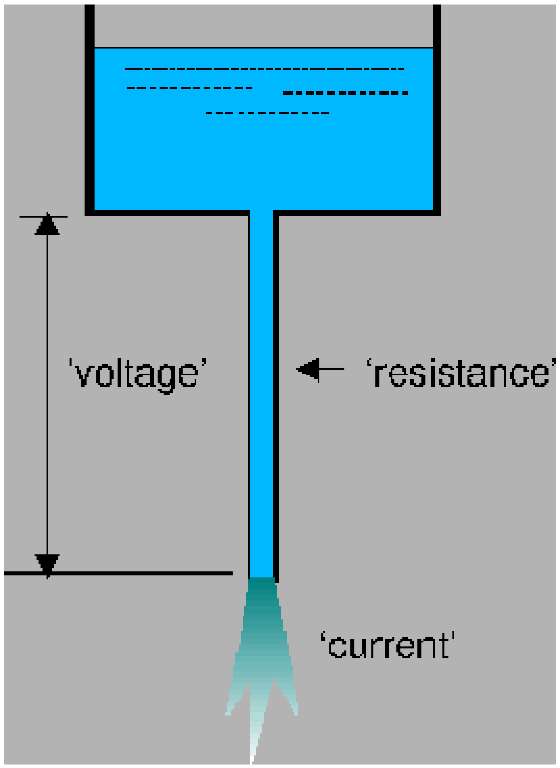
- Definition of power $$p = \frac{dw}{dt}$$ $$p = vi$$

("flow" times "pressure" is the <u>rate</u> of doing work by the moving fluid for our analogy)

- Ideal basic circuit element:
    - o Has only two terminals
    - o Is described mathematically in terms of current and voltage
    - o Cannot be subdivided further into other elements

- Passive sign convention:

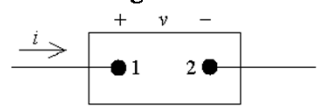
Here's a water analogy for voltage, current, and resistance (which we haven't defined yet but it's coming soon)



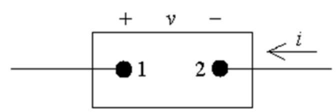
Voltage is analogous to the pressure difference between two places in the system. Voltage is always expressed as a "voltage difference" between two points in a circuit. The voltage at a point doesn't make sense – and is not defined.

Current is analogous to the water flow …the amount of water per unit time passing through a part of the system. Current, unlike voltage, is always defined at a particular point.

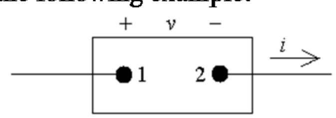
a) The passive sign convention is extremely important, so make sure you understand it. We will use the passive sign convention to determine whether a given equation involving voltage and current should use a positive sign or a negative sign. One way to remember the passive sign convention is to realize that the current arrow always points to the correct sign! Consider the following ideal basic circuit element with current and voltage defined as shown:



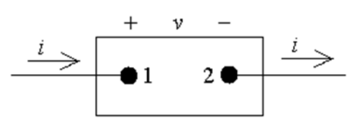
Here, the passive sign convention tells us to use a "+" sign in any expression involving voltage and current. You can see that the current arrow points to the "+" sign. Consider the next example:



Now the passive sign convention tells us to use a "—" in any expression involving voltage and current. You can see that the current arrow points to the "—" sign. Finally, consider the following example:

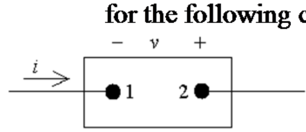


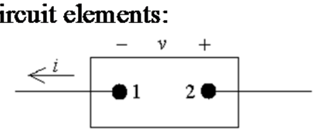
In this example the current doesn't appear to point at either the "+" or "—" sign. But since current must flow *through* the circuit element, we can redraw the current on the other side of the circuit element in the same direction:

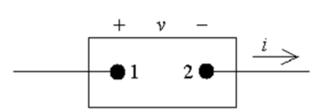


Now we can see that the current arrow points at the "+" sign so we should use the "+" sign in any expression involving voltage and current.

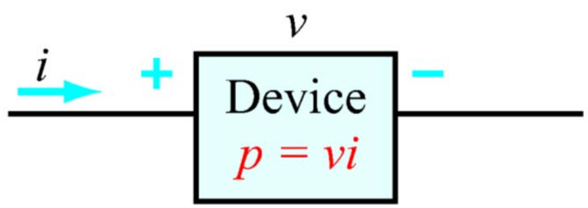
b) Decide whether the passive sign convention tells you to use a "+" or a "—" sign for the following circuit elements:







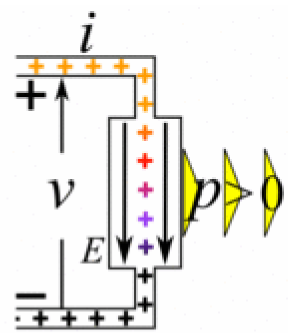
Passive Sign Convention



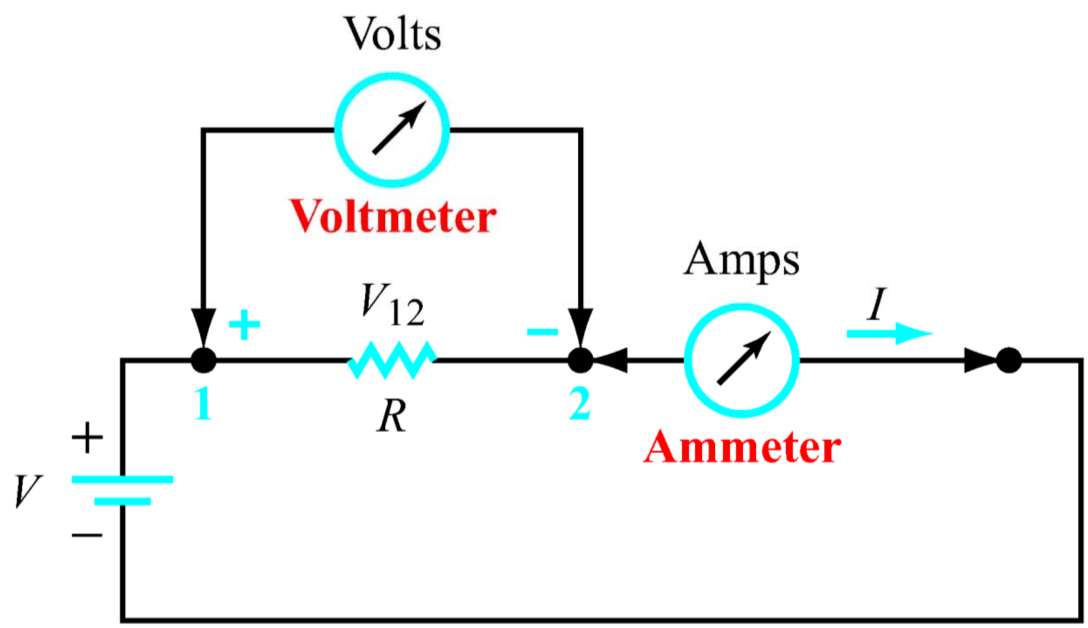
$p > 0$ power delivered to device

$p < 0$ power supplied by device

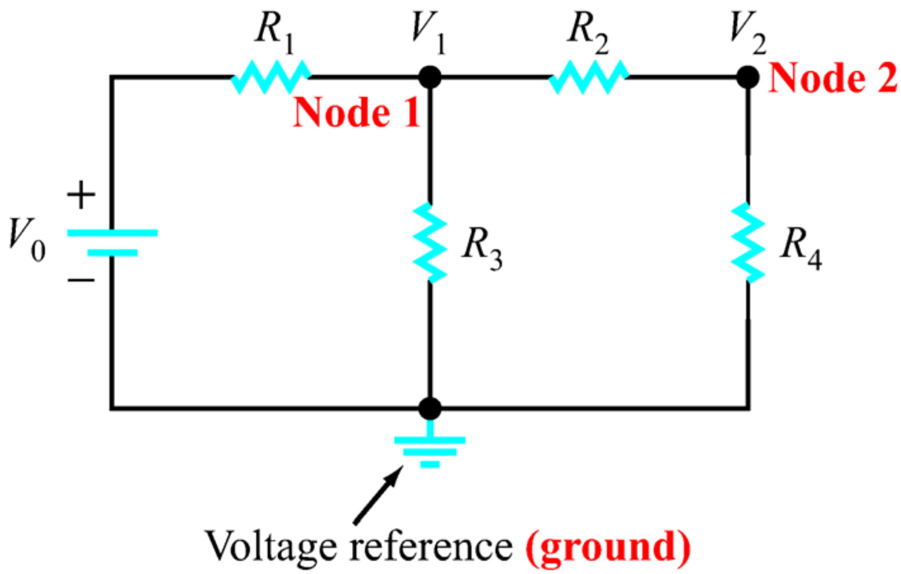
*Note that i direction is defined as entering (+) side of v.



Voltmeters and Ammeters



An ideal voltmeter measures the voltage difference between two points, such as nodes 1 and 2, without interfering with the circuit (i.e. without drawing any current). Similarly, an ideal ammeter measures the current magnitude and direction, without causing a voltage drop across itself.



Ground is any point in the circuit, selected to serve as a <u>common reference point for the voltages</u> at all points in the circuit. Voltage is always a difference (that's why it's often called "potential difference.") If you want to specify a voltage at a particular point in a circuit …it must always be in reference to the voltage at another point. If this other point isn't specified, it is assumed that it is the ground reference. If there's no ground reference shown in the circuit, voltages will all have to be shown with regard to stated reference nodes.