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Lecture #3:
Circuit Fundamentals II

EEL 3003
Introduction to Electrical Engineering
Summer Semseter, 2013
Instructor: Dr. Michael Frank

Administrative Announcements

- Passing around attendance sheet as usual, please sign
- In-class Assignment #1 grades are posted
  - Graded S/U/N
  - Handing back papers
- Outline of Today's Lecture:
  1. Clarify definition of "loop," revisit example fr. last lecture.
  2. Review practice problems from lecture #2.
  3. Finish our coverage of Chapter 2 –
     - Fundamentals of Electric Circuits
  4. Begin Chapter 3, Resistive Network Analysis.
- Today's Homework Assignment:
  - Read Ch. 3 of Textbook (Rizzoni 5th ed.)
  - Practice exercises:
    - Attempt the following homework problems (randomly selected):
      - 3.6, 3.10, 3.17, 3.43, 3.60, 3.72, 3.74*, 3.75, 3.76, 3.81
        - Starred problems have solutions in the back of the book.
    - You may also want to attempt additional problems that have solutions printed in the back of the book.
  - The related quiz will be Thursday next week (May 30th).

1. Clarify definition of "loop," revisit example from last lecture

- See new slides at the end of the new version of the lec. #2 slide set.

2. Review Practice Problems from Lecture #2

- See document, "Practice exercises from Lecture #2," posted with Lec. 2 materials.

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Overview of Chapter 2 (Fundamentals of Electric Circuits)

- ~~§2.1 – Definitions~~
- ~~§2.2 – Charge, current, & Kirchhoff's Current Law~~
- §2.3 – Voltage & Kirchhoff's Voltage Law
- §2.4 – Electric Power and Sign Convention
- §2.5 – Circuit Elements and their *i*-*v* Characteristics
- §2.6 – Resistance and Ohm's Law
- §2.7 – Practical Voltage & Current Sources
- §2.8 – Measuring Devices

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§2.3 – Voltage & Kirchhoff's Voltage Law

- Differential definition of voltage
  - See supplemental lec. notes posted after lec. #2
- Discussion of ground terminals
  - Again, see lec 2 notes
- KVL
  - See lec 2 notes, also practice problem
  - Review example 2.6 (fig. 2.20) in textbook
    - Includes a non-simple branch (loop inside it)

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§2.4 – Electric Power and Sign Convention

- Already addressed in earlier discussions

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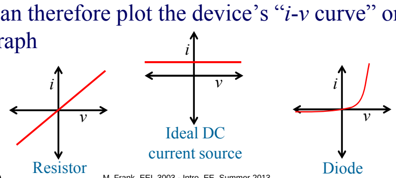
§2.5 – Circuit Elements and their *i-v* Characteristics

- Many two-terminal devices have a simple functional relationship *i*(*v*) or *v*(*i*) between the instantaneous current *i* passing through the device and the voltage *v* across its terminals.
  - Can therefore plot the device's "*i-v* curve" on a graph



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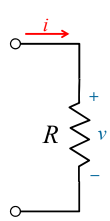
§2.6 – Resistance and Ohm's Law

- A resistor is a component that *resists the flow of current through it*.
  - It is a *load* (not a source).
  - It is a *linear*, *passive* element.
  - Typically, we label the branch current and voltage of a resistor such that the current arrow enters its "+" terminal.
    - With this convention, $p=iv$ for the resistor is always positive
    - Represents power *dissipated* by the resistor.



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Ohm's Law

- The fundamental *i*-*v* equation for a resistor:

$$v = iR$$

  - v = Instantaneous voltage across the resistor.
  - i = Instantaneous current through the resistor.
    - Current from its "+" terminal to its "–" terminal.
  - R = Resistance of the resistor.
    - Measured in ohms (Ω). 1 Ω = 1 V/A.

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Conductance

- Conductance G is simply the reciprocal of resistance R, *i.e.*, $G = 1/R$.
- In terms of conductance, Ohm's Law can be rewritten as:

$$i = Gv$$

- The unit of conductance is called the siemens (S) or sometimes mho (℧).
  - 1 S = 1 ℧ = 1 A/V.

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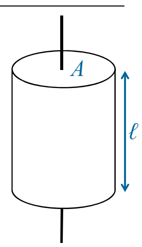
Resistivity & Conductivity

- The resistance along the length of a piece of conductor with length ℓ and cross-sectional area A is:

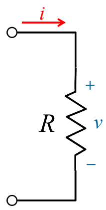
$$R = \rho \frac{\ell}{A}.$$

  - ρ is called the *resistivity* of the material. It is a bulk property.
- $\sigma = 1/\rho$ is called *conductivity*. $G = \sigma \frac{A}{\ell}.$



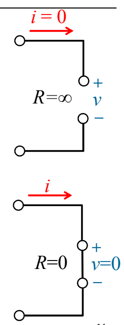
Resistor Power Dissipation

- A resistor with a voltage v across it and current i through it dissipates power $p = iv$.
  - Because the current going out carries iv less electrostatic power than the current going in.
- Combining $p = iv$ and $v = iR$, we get:
  - $p = i^2R = i^2/G$.
- Since $i = v/R$, we can also express the power dissipation in terms of v:
  - $p = v^2/R = v^2G$.



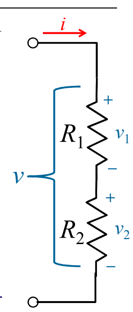
Open and Short Circuits

- Limiting cases of a real resistor, in the limits as $R \to \infty$ and $R \to 0$, respectively.
- Open circuit: $R = \infty$ (ideally)
  - Current across gap = 0 (for any v).
- Closed circuit: $R = 0$ (ideally)
  - Identical to an ideal wire.
  - Voltage across wire = 0 (for any i).



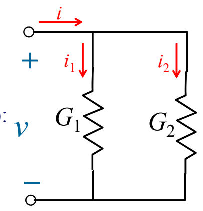
Series Resistors and the Voltage Divider Rule

- Consider two resistors R_1 and R_2 connected in series.
  - Voltages across them are:
    - $v_1 = iR_1$, $v_2 = iR_2$.
  - The overall voltage across both of them together is just:
    - $v = v_1 + v_2 = iR_1 + iR_2 = i(R_1 + R_2)$.
  - Therefore, they are equivalent to a single resistor with resistance $R = R_1+R_2$.
- Note that v_1 and v_2 can be expressed as fractions of v:
  - $v_1 = v(R_1/R)$; $v_2 = v(R_2/R)$.
  - Thus this structure is called a *voltage divider*.



Parallel Resistors and the Current Divider Rule

- For resistors (non-ideal conductors) in parallel,
  - Currents through them are:
    - $i_1 = G_1 v;\ i_2 = G_2 v.$
  - Total branch current is (by KCL):
    - $i = i_1 + i_2 = (G_1+G_2)v.$
  - Thus, they are equivalent to a single conductor with conductance:
    - $G = G_1 + G_2.$
  - Current divider rule:
    - $i_1 = i\cdot(G_1/G);\ i_2 = i\cdot(G_2/G).$



Or in terms of resistance, $1/R = 1/R_1 + 1/R_2.$

$\therefore R = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}}$

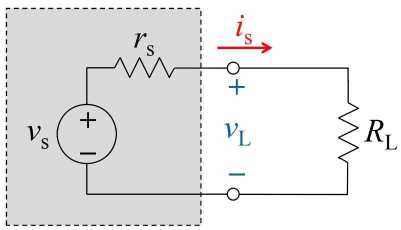
§2.7 – Practical Voltage & Current Sources

- Model a non-ideal voltage source by putting a resistor in series with an ideal voltage source.

$i_S = \frac{v_S}{r_s + R_L}$

$\bar{i}_S = \frac{v_S}{r_s}$ (short-circuit current)

$v_L = v_S \frac{R_L}{r_s + R_L}$



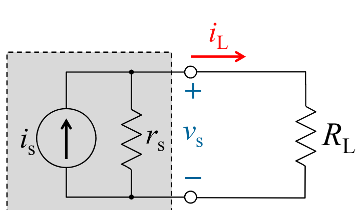
Non-Ideal Current Sources

- Model a non-ideal *current* source by putting a resistor in *parallel* with an ideal current source.

$v_S = \frac{i_S}{\frac{1}{r_S}+\frac{1}{R_L}}$

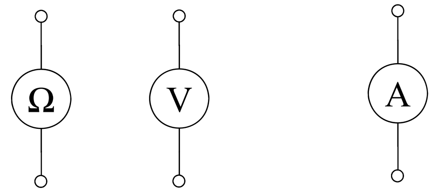
$\bar{v}_S = i_S r_S$ (open-circuit voltage)

$i_L = \frac{i_S}{R_L\left(\frac{1}{r_S}+\frac{1}{R_L}\right)}$



§2.8 – Measuring Devices

- Some commonly encountered devices:



ohmmeter voltmeter — Place in parallel with subcircuit to be measured, spanning across it, between + and − terminals

ammeter — Place in series with branch to be measured, insert before one of its terminals