Administrivia

- Waiting list
- Fixed grading scale error in lecture 1 and course policies handout
- HW 1 has been assigned. Due Wednesday, July 2nd 2003 @ 12:10 PM in lecture.
- Will be posted online by Friday, 06/27:
  - TA office hours/location
  - Webpage updates
    - ∗ Under newsgroup: getting a UNIX account and HOW-TO access the newsgroup
- Public computers (Windows and UNIX) in Cory Hall: 199 Cory. You still need cardkey access to get into the building after 7:00 pm and on weekends.

Last Time...

- Intro. to Electrical Engineering
- Circuit variables: Voltage, Current, Power and Energy
- The Ideal Basic Circuit Element
- **Do you have questions on any of these concepts?**

This Time...

- Some Terminology (thanks to Sheila Ross' notes)
- Dependent Sources
- Ohm's Law
- Open circuits and short circuits
- Intro. to I-V graphs
- Kirchoff's Laws
- Analysis of a circuit with a dependent source

This Time (contd)...

- Series and Parallel Circuits

Some Terminology

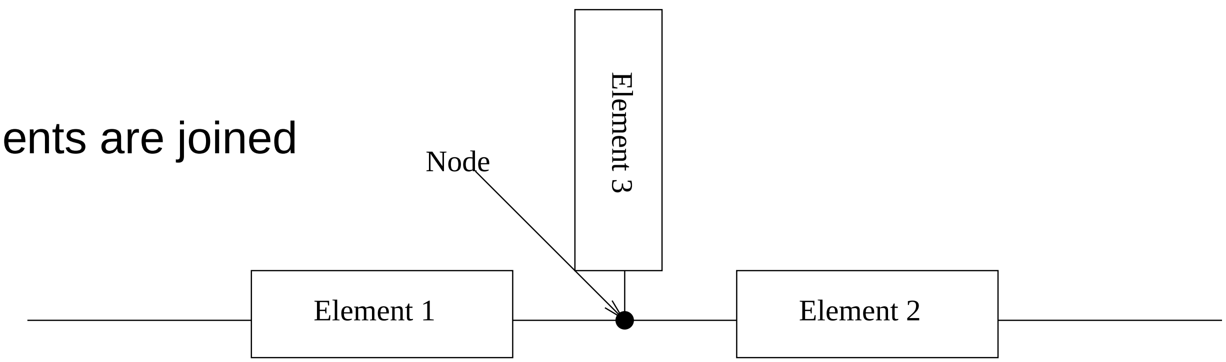
1. Active elements
2. Passive elements
3. Node
4. Branch

Some Terminology

- Active element - is an ideal basic circuit element that models a device capable of generating/amplifying electrical energy.
  - Example: voltage sources
- Passive element - is an ideal basic circuit element that models a device which cannot generate/amplify electrical energy.
  - Example: resistor

Some Terminology (thanks to Sheila's notes)

- Node - A place where elements are joined
  - Example:



A node

- Branch - elements connected end-to-end, nothing coming off in between
  - Example:

A single branch

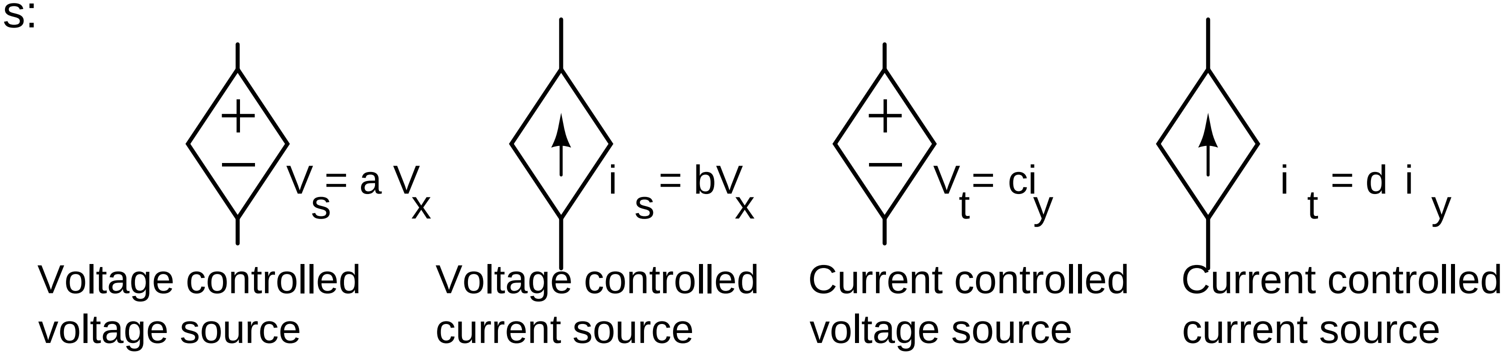
Dependent Sources

- Four types

1. Voltage Controlled Voltage Source
2. Voltage Controlled Current Source
3. Current Controlled Voltage Source
4. Current Controlled Current Source

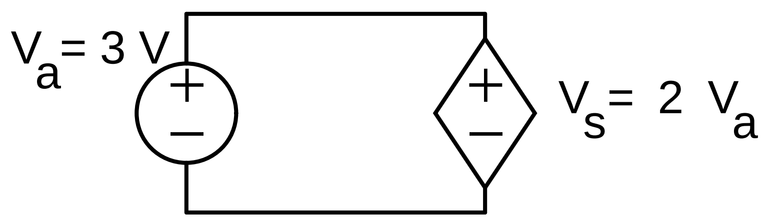
Dependent Sources

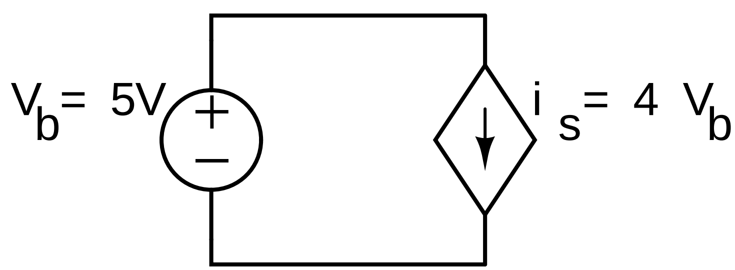
- Symbols:



Dependent Sources

- Examples: Are the circuits below valid?





Dependent Sources

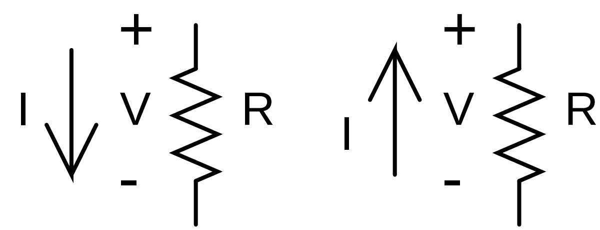
- Solution:
- Circuit (a) is **invalid**. This is because the dependent source puts out $2 \times V_a$ which is $2 \times 3 = 6$ V. 6 V cannot be in parallel with 3 V.
- Circuit (b) is **valid**. The current source is absorbing power from the voltage source and is generating $4 \times 5 = 20$ A.

Ohm's Law

- Resistance is the capacity of materials to impede the flow of current
- What causes resistance?
  - Answer: Electrons colliding with the atoms of the wire as they move through the wire.
- Unit of resistance: Ohm. Named after Georg Simon Ohm
- Symbol: Ω
- Another unit: Conductance, reciprocal of resistance.
- Symbol: Siemens (S), mho (ohm spelled backward, $\mho$)

Ohm's Law

- Resistor symbol and IV relationship



V = IR   V = -IR

  - V = voltage (in volts)
  - I = current (in amps)
  - R = resistance (in Ωs)

Ohm's Law

- Power at the terminals of a resistor:
- As I told you in lecture 1, P = VI for ANY electrical device.
- Hence, for a resistor, we have the following expressions:

$$P = VI$$

$$P = (IR)I$$

$$P = I^2R = \frac{V^2}{R}$$

Open circuits and short circuits

- Open circuit
  - Symbol:

  - Mathematical model: $R \to \infty$
  - Current through an open circuit is 0
    whereas the voltage across it is unknown
- Short circuit
  - Symbol:

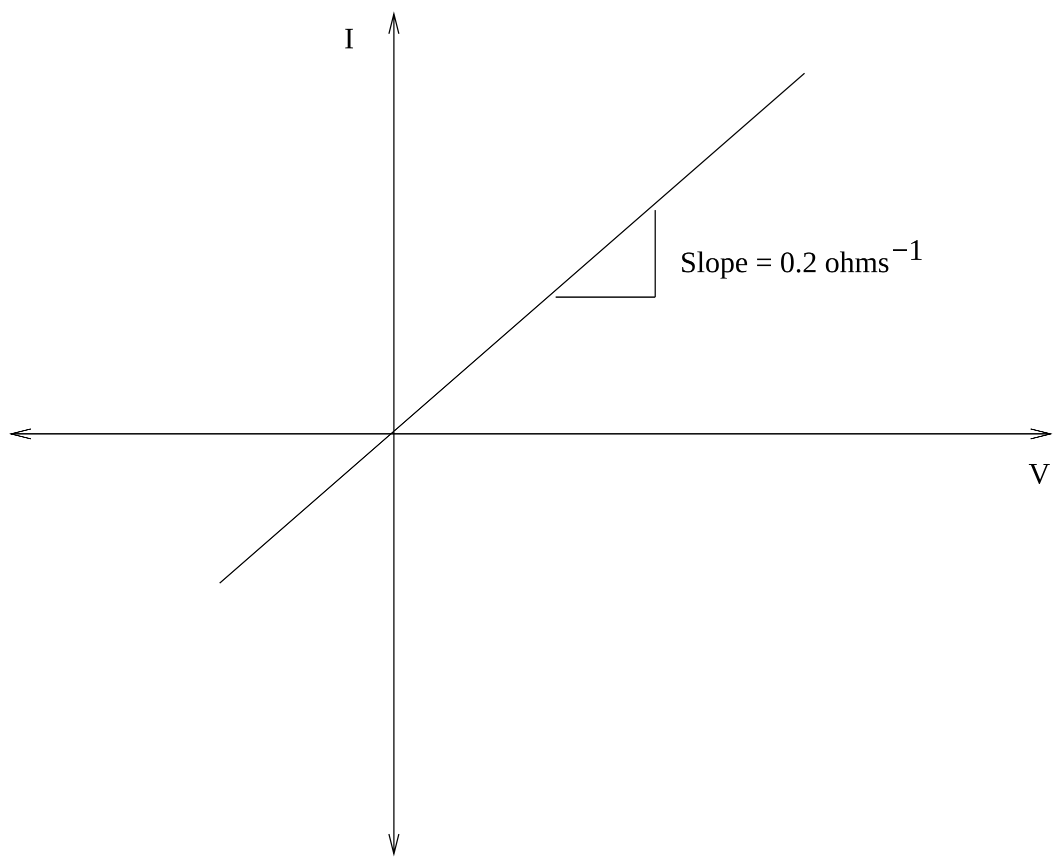
  - Mathematical model: $R = 0$
  - Current through a short circuit is unknown
    whereas the voltage across it is 0

Intro. to I-V graphs

- I-V graphs: graphical method to solve circuits
- A circuit is solved when the voltage across and the current through every element has been determined
- I-V graph for a 5 Ω resistor:

Intro. to I-V graphs

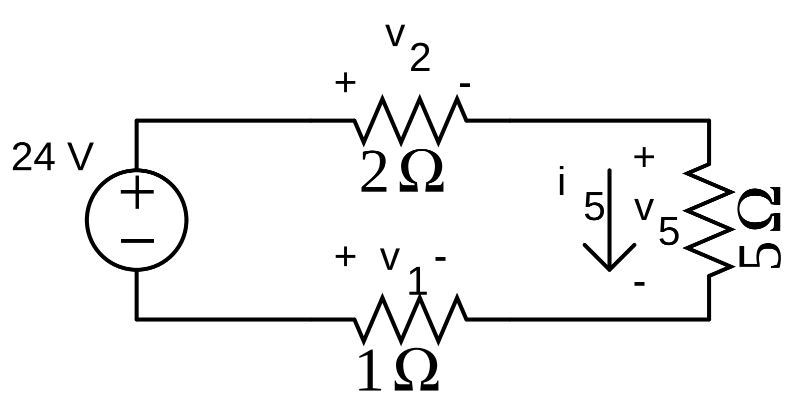
- Solution:



IV graph for a 5 Ω resistor

Kirchoff's Laws

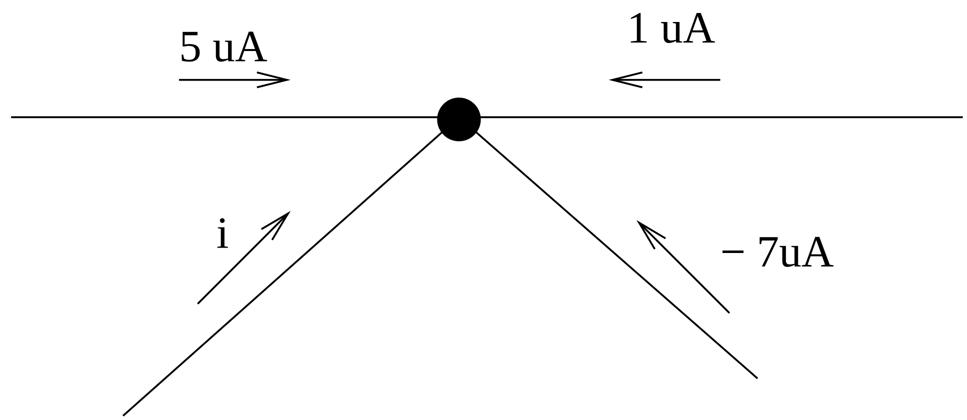
- Recap: we now understand how to work with voltage sources, current sources and resistors.
- Not enough to solve circuits. For example, solve the circuit below (drill exercise 2.2, p. 37):



Kirchoff's Laws

- Before we can solve the circuit, we need Kirchoff's laws.
- Kirchoff's Current Law (KCL) statement:
  - **The algebraic sum of all the currents at any node in a circuit equals zero**
  - Hence to apply KCL, just assign an algebraic sign (+ or -) to every current at the node. That is:
    1. If currents leaving the node are positive, then currents entering are negative
    2. If currents leaving the node are negative, then currents entering are positive
- Let us look at a simple example

Kirchoff's Laws



- Find i
- Solution: Assume current entering the node is positive. Therefore, current leaving the node will be negative. Hence, applying KCL at the node yields:

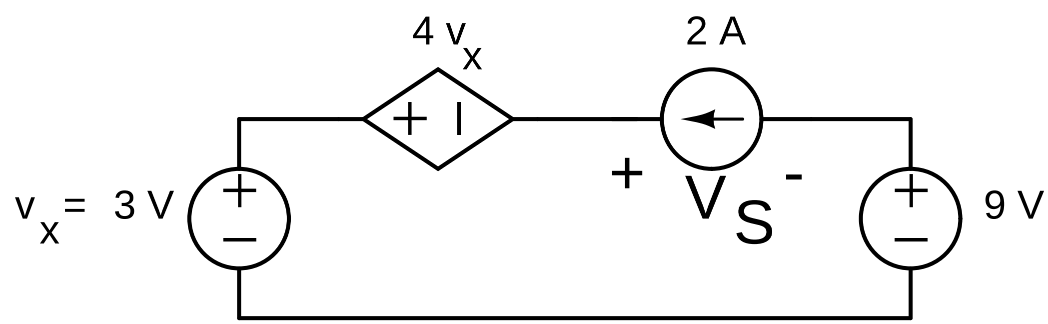
  5 uA + 1 uA + i + (-7 uA) = 0

  i = 1 uA

Kirchoff's Laws

- Kirchoff's Voltage Law (KVL) statement:
  - **The algebraic sum of all the voltages around any loop equals zero.**
  - To apply KVL:
    1. Assign an algebraic sign to every voltage in the loop
    2. Trace a closed path around the loop, and sum each voltage as you "hit the sign".
- Lets look at a simple example.

Kirchoff's Laws



- Find the voltage drop across the current source.
- Solution: Let V_S be the voltage drop across the current source as shown in the figure. We know V_X = 3 V, hence the voltage across the dependent voltage source is 4 * 3 V = 12 V. Applying KVL, we can sum starting from the negative terminal of the 3 V source and moving clockwise around the loop:

  $-3\text{ V} + 12\text{ V} + V_S + 9\text{ V} = 0$

  $V_S = -18\text{ V}$

Kirchoff's Laws

- Now we can attack drill problem 2.2.

- Solution : Apply KVL by starting at the negative terminal of the 24 V source and moving clockwise around the loop:

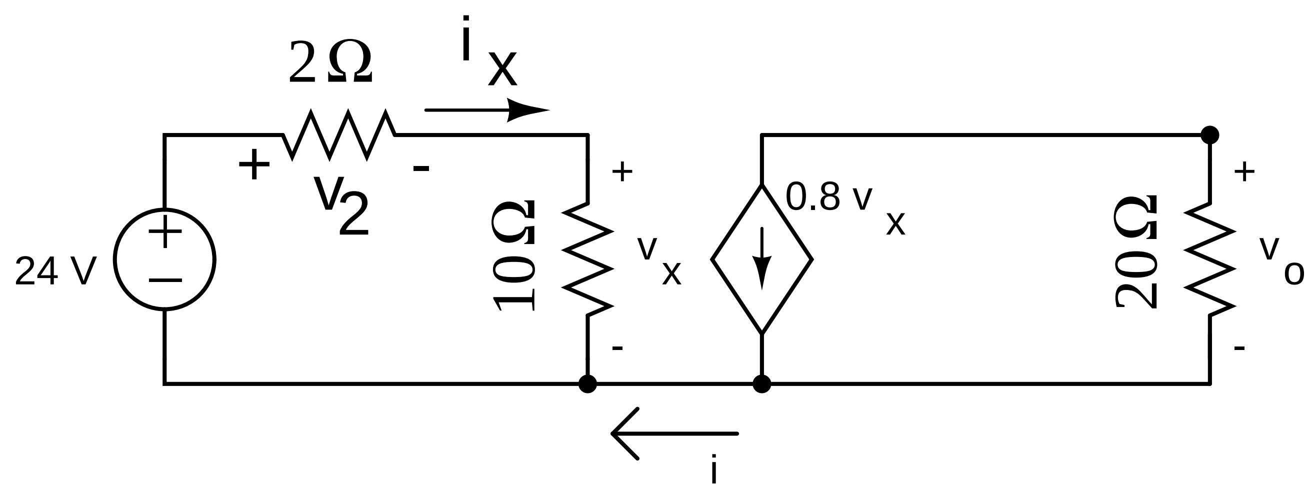
  $-24\text{ V} + v_2 + v_5 - v_1 = 0$

  Since all elements are in series, the same current flows through them (more on this later). Hence, $v_2 = 2i_5$ volts, $v_5 = 5i_5$ and $v_1 = -1i_5$. v_1 is negative because of the passive sign convention. Substituting these variables in the KVL equation, we can find i_5:

  $-24 + 2i_5 + 5i_5 + i_5 = 0$

  Therefore $i_5 = 3$ A. Hence, $v_2 = 6$ V, $v_5 = 15$ V and $v_1 = -3$ V. The currents through all the elements and the voltage across each element has been found. Hence, the circuit has been solved.

Analysis of a circuit with a dependent source



- Lets put it all together and find v_0 and i in the circuit above.

Analysis of a circuit with a dependent source

- Solution: The important idea behind this circuit is that the loop on the left is isolated from the loop on the right. That is, they are completely independent of each other. To see why this is true, apply KCL. If i amps enters the loop on the left as shown in the figure, how can it flow back to the loop on the right? It has to do so or KCL will be violated since current going in will not be equal to the current coming out. It certainly cannot flow back through the same wire. Thus, i = 0 A.

  Now, $v_0 = -20 * 0.8v_X$, according to ohm's law and the passive sign convention. But, v_X is the voltage across the 10 Ω resistor. To find this voltage, we can apply KVL and ohm's law to the loop on the left:

Analysis of a circuit with a dependent source

$$-24\text{ V} + v_2 + v_X = 0$$

$$-24 + 2i_X + 10i_X = 0$$

$$i_X = 2\text{ A}$$

Hence, $v_X = 20$ V. Therefore, $v_0 = 20 * 0.8 * 20 = 320$ V.

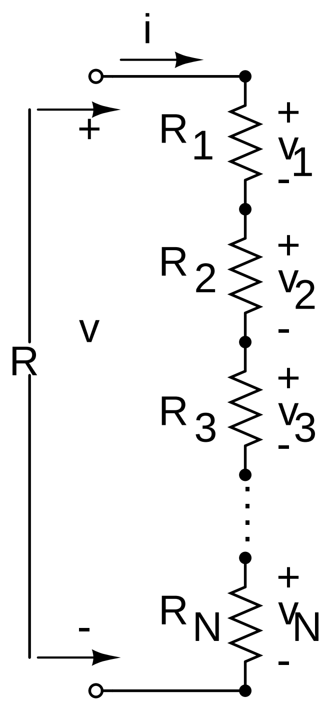
Before we go on...

- How do you become good with circuits?
  - Answer:
    * **PRACTICE, PRACTICE, PRACTICE ...** ∞
    * Build circuits as well!!!!!
    * Takes a really long time...

Series and Parallel Circuits

- Series circuits
  - Definition: When just two elements are connected at a single node, they are said to be series.
  - **Series-connected circuit elements have the same current through them**
  - Concept of series-equivalent resistance:

Series-Equivalent Resistance



$$R = R_1 + R_2 + R_3 + \cdots + R_N$$

Derivation:

Concept: Current through series elements is the same
Start with KVL:

$$v = v_1 + v_2 + v_3 + \cdots + v_N$$

$$\Rightarrow iR = iR_1 + iR_2 + iR_3 + \cdots + iR_N$$

Notice how we used ohm's law and the fact that the current through series elements is the same. Cancelling the i on both sides gives the result.

Series and parallel Circuits

- Parallel circuits
  - When two elements are connected at a single node pair, they are said to be in parallel
  - **Parallel-connected circuit elements have the the same voltage across them**
  - Concept of parallel-equivalent resistance: Same as the series resistance. Use the fact that voltages across parallel circuit elements is the same. I will just state the result:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

Summary

- We added more tools to our circuit analysis toolbox:
  - Dependent sources
  - Resistors
  - KVL, KCL
  - Series and Parallel circuits

In Conclusion...

- Make sure you:
  - get the reader
  - get a keycard
  - activite your UNIX and Windows account.
  - take a look at the homework
  - practice them circuits!
- Next time: More circuit analysis tools
- Reading: Sections 4.1 - 4.8
- Labs 1 and 2 should help you understand KCL, KVL etc better
- Questions?