Electric Circuits

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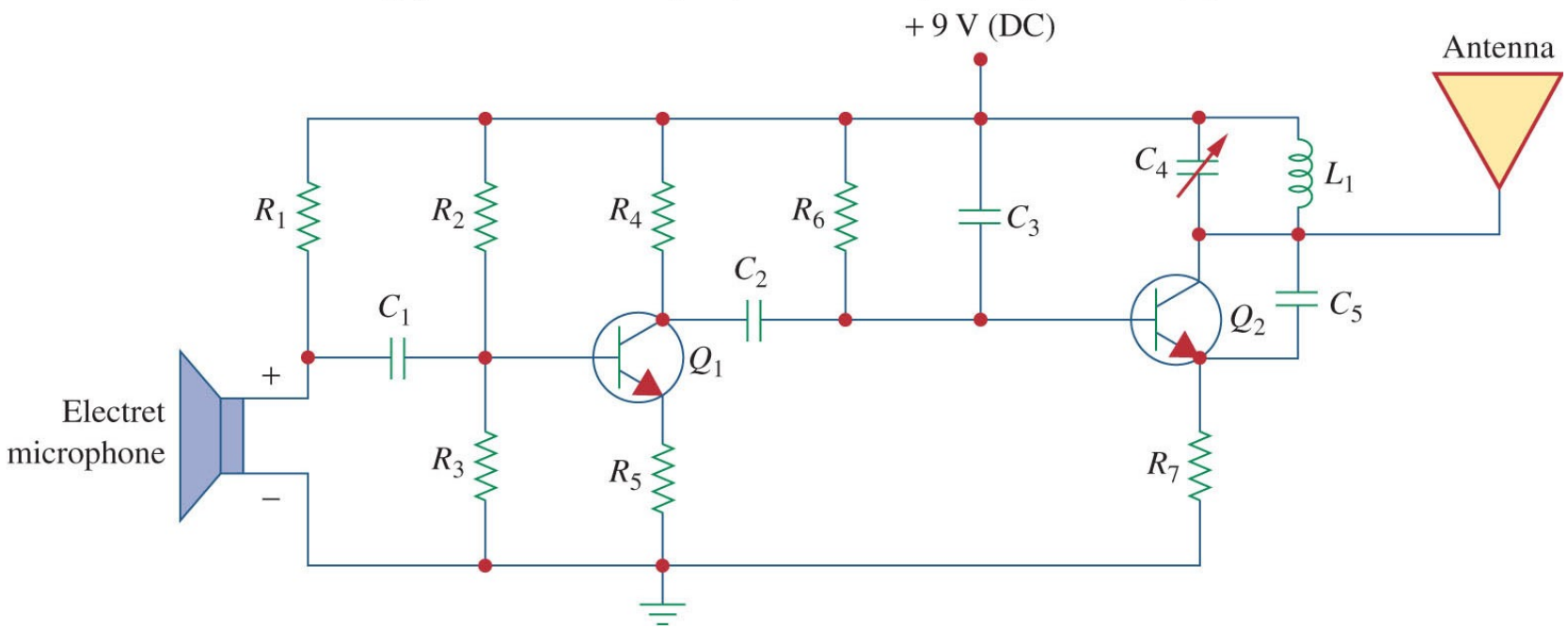
Lecture 1 (Intro)

Outline

- Systems of Units
- Electric Charge
- Current
- Voltage
- Power and Energy
- Circuit Elements

What is a circuit?

- An electric circuit is an interconnection of electrical elements.
- It may consist of only two elements or many more:



Units

- When taking measurements, we must use units to quantify values
- We use the International Systems of Units (SI for short)
- Prefixes on SI units allow for easy relationships between large and small values

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Charge

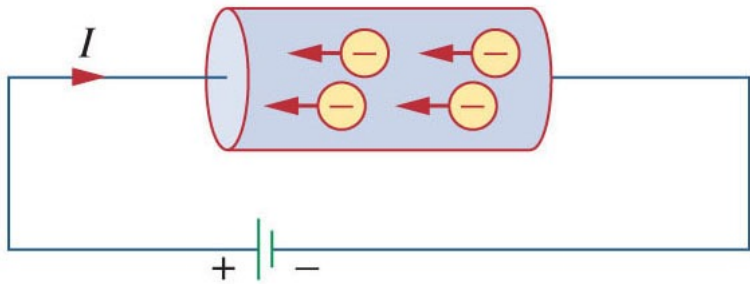
- Charge is a basic SI unit, measured in Coulombs (C)
- Counts the number of electrons (or positive charges) present.
- Charge of single electron is $1.602*10^{-19}$ C
- One Coulomb is quite large, $6.24*10^{18}$ electrons.

Charge II

- In the lab, one typically sees (pC, nC, or μC)
- Charge is always multiple of electron charge
- Charge cannot be created or destroyed, only transferred.

Current

- The movement of charge is called a current
- Historically the moving charges were thought to be positive
- Thus, we always note the direction of the equivalent positive charges, even if the moving charges are negative.



Battery

Current II

- Current, i, is measured as charge moved per unit time through an element.

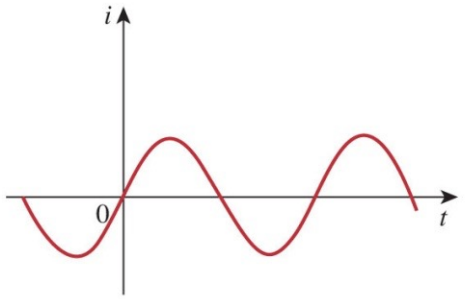
$$i \equiv \frac{dq}{dt}$$

- Unit is Ampere (A), is one Coulomb/ second

DC vs. AC

- A current that remains constant with time is called Direct Current (DC)
- Such current is represented by the capital I, time varying current uses the lowercase, i.
- A common source of DC is a battery.
- A current that varies sinusoidally with time is called Alternating Current (AC)
- Main power is an example of AC

(a)



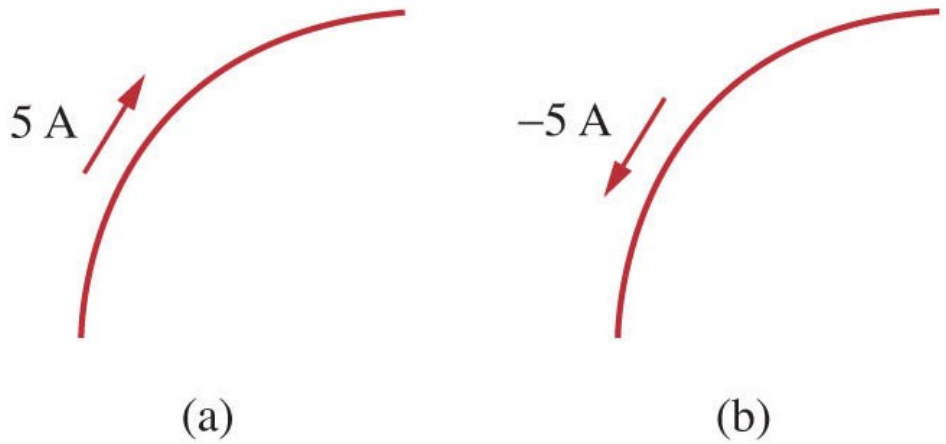
(b)

Direction of current

- The sign of the current indicates the direction in which the charge is moving with reference to the direction of interest we define.
- We need not use the direction that the charge moves in as our reference.

Direction of Current II

- A positive current through a component is the same as a negative current flowing in the opposite direction.



Solved Problem

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Voltage

- Electrons move when there is a difference in charge between two locations.
- This difference is expressed at the potential difference, or voltage (V).
- It is always expressed with reference to two locations

Voltage II

- It is equal to the energy needed to move a unit charge between the locations.
- Positive charge moving from a higher potential to a lower yields energy.
- Moving from negative to positive requires energy.

Power and Energy

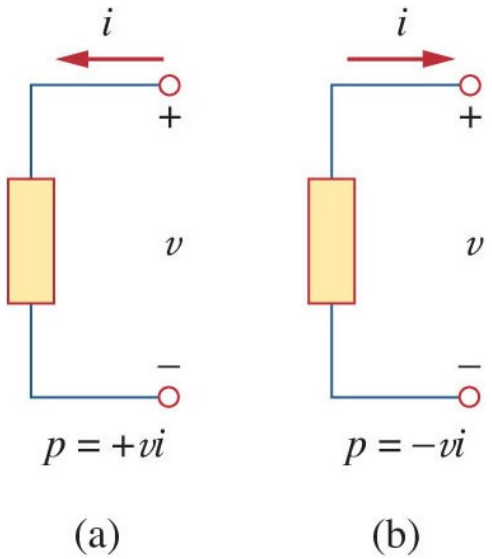
- Voltage alone does not equal power.
- It requires the movement of charge, i.e. a current.
- Power is the product of voltage and current

$$p = vi$$

- It is equal to the rate of energy provided or consumed per unit time.
- It is measured in Watts (W)

Passive Sign Convention

- By convention, we say that an element being supplied power has positive power.
- A power source, such as a battery has negative power.
- Passive sign convention is satisfied if the direction of current is selected such that current enters through the terminal that is more positively biased.



Conservation of Energy

- In a circuit, energy cannot be created or destroyed.
- Thus, power also must be conserved
- The sum of all power supplied must be absorbed by the other elements.
- Energy can be described as watts x time.
- Power companies usually measure energy in watt-hours

Solved Problem

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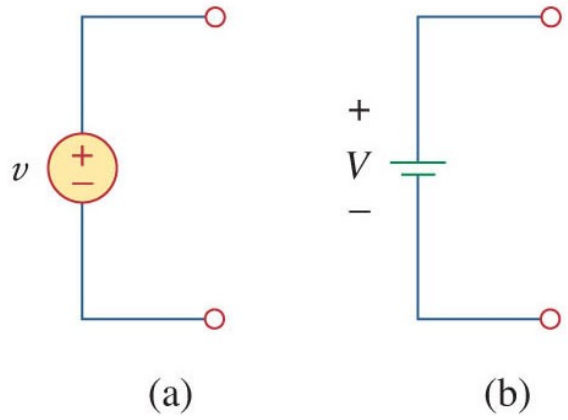
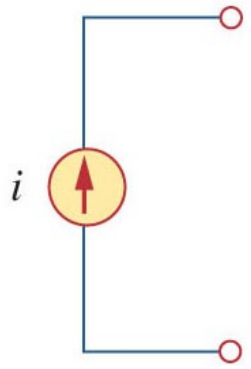
Circuit Elements

- Two types:
  - Active
  - Passive
- Active elements can generate energy
  - Generators
  - Batteries
  - Operational Amplifiers





Circuit Elements II

- Passives absorb energy
  - Resistors
  - Capacitors
  - Inductors
- But it should be noted that only the resistor dissipates energy ideally.
- The inductor and capacitor do not.

Ideal Voltage Source

- An ideal voltage source has no internal resistance.
- It also is capable of producing any amount of current needed to establish the desired voltage at its terminals.
- Thus, we can know the voltage at its terminals, but we don't know in advance the current.

Ideal Current Source

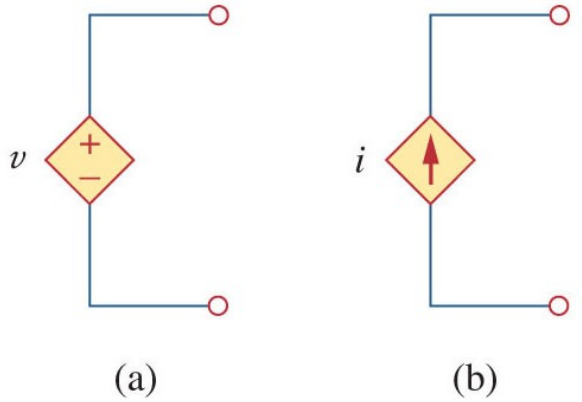
- Current sources are the opposite of the voltage source:
- They have infinite resistance
- They will generate any voltage to establish the desired current through them.
- We can know the current through them in advance, but not the voltage.

Ideal sources

- Both the voltage and current source ideally can generate infinite power.
- They are also capable of absorbing power from the circuit.
- It is important to remember that these sources do have limits in reality:
- Voltage sources have an upper current limit.
- Current sources have an upper voltage limit.

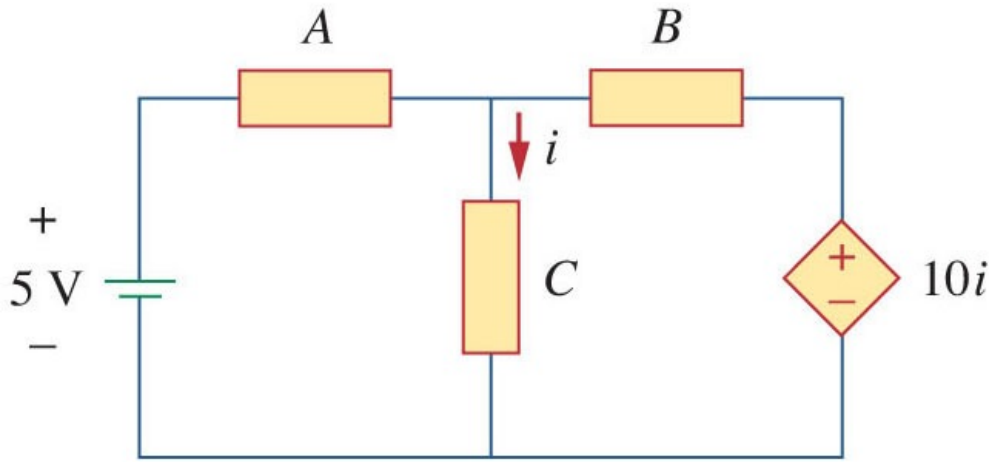
Dependent Sources

- A dependent source has its output controlled by an input value.
- Symbolically represented as a diamond
- Four types:
  - A voltage-controlled voltage source (VCVS).
  - A current-controlled voltage source (CCVS).
  - A voltage-controlled current source (VCCS).
  - A current-controlled current source (CCCS).



Dependent Source example

- The circuit shown below is an example of using a dependent source.
- The source on the right is controlled by the current passing through element C.



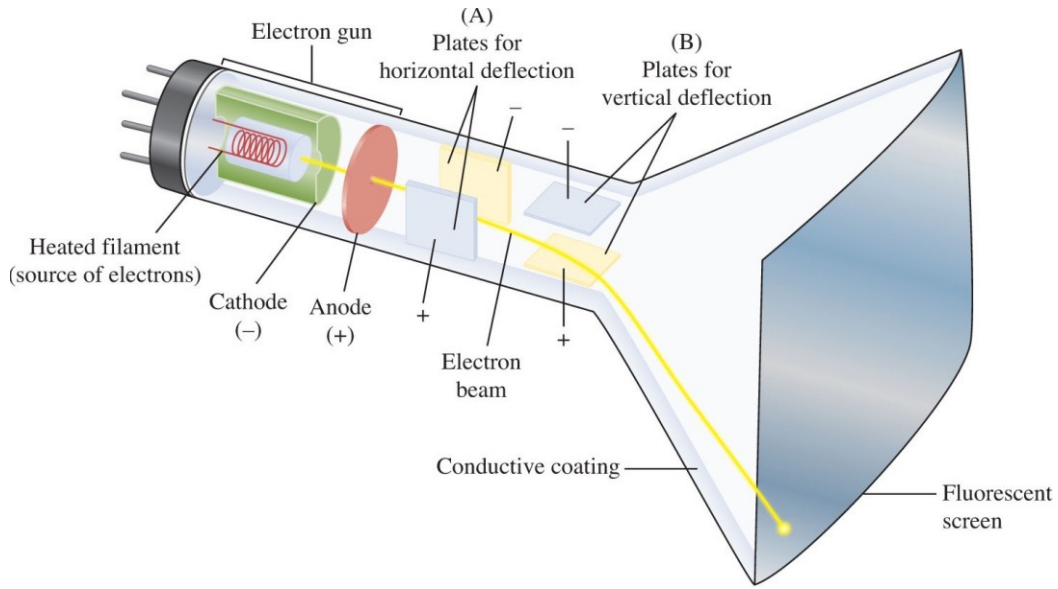
Circuit Applications of Dependent Sources

- Dependent sources are good models for some common circuit elements:
  - Transistors: In certain modes of operation, transistors take either a voltage or current input to one terminal and cause a current that is somehow proportional to the input to appear at two other terminals.
  - Operational Amplifiers: Not covered yet, but the basic concept is they take an input voltage and generate an output voltage that is proportional to that.

Solved Problem

TV Picture Tube

- Old style cathode Ray Tubes (CRT) are a good example of the flow of electrons
- A hot filament is the source of electrons
- Charged plates accelerate and steer a thin stream (beam) of electrons
- The beam strikes a phosphor coated screen causing light emission.



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