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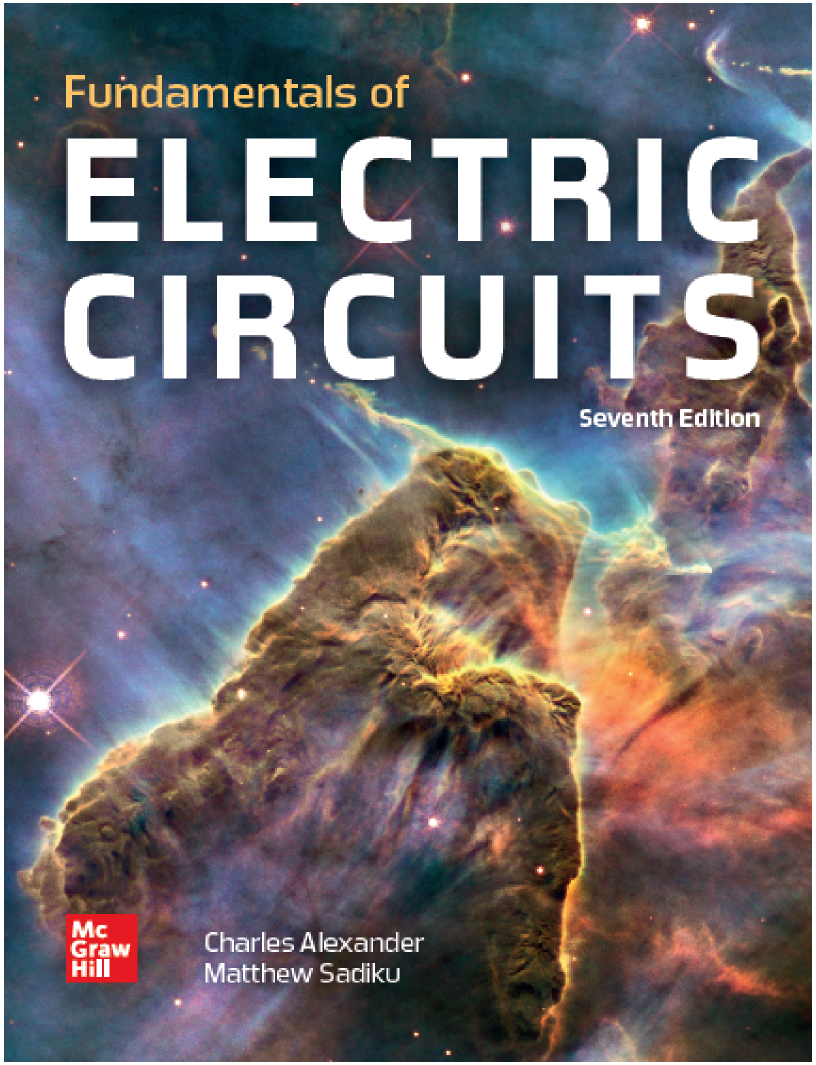
Fundamentals of Electric Circuits

Chapter 1

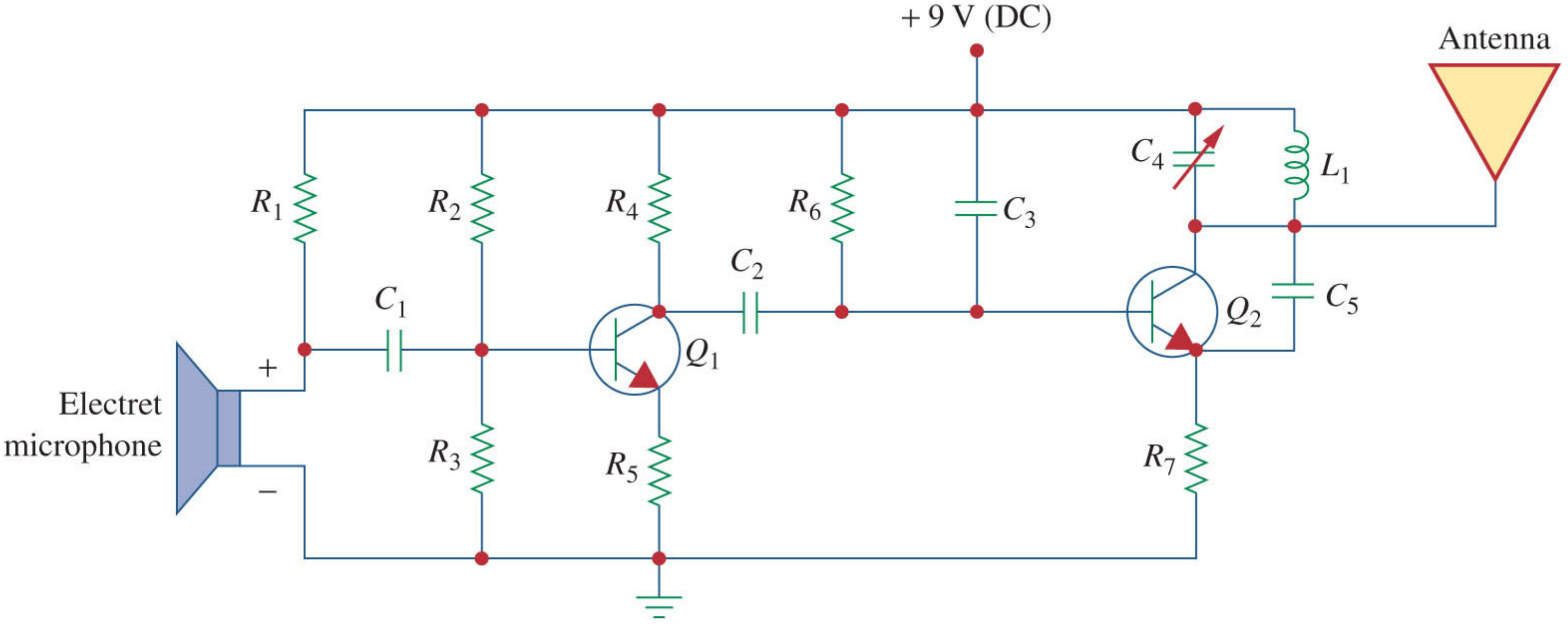


Introduction

- This chapter introduces the concept of voltage and current.
- The concept of a circuit will be introduced.
- Sources will be introduced.
- These can provide either a specified voltage or current.
- Dependent and independent sources will be discussed.
- Also a strategy for solving problems will be introduced.

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.

TABLE 1.2

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

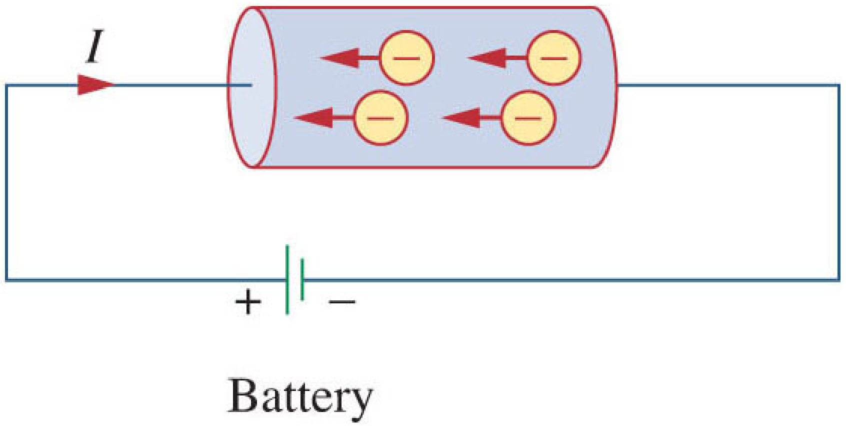
- Charge is a basic SI unit, measured in Coulombs (C).
- Counts the number of electrons (or positive charges) present.
- Charge of single electron is $1.602*10^{-19}$ C.
- One Coulomb is quite large, $6.24*10^{18}$ electrons.

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.



Current II

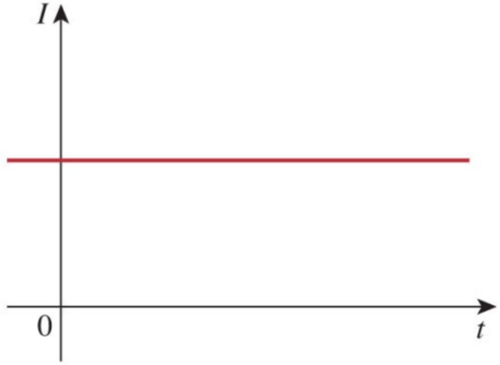
- Current, *i*, is measured as charge moved per unit time through an element.

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

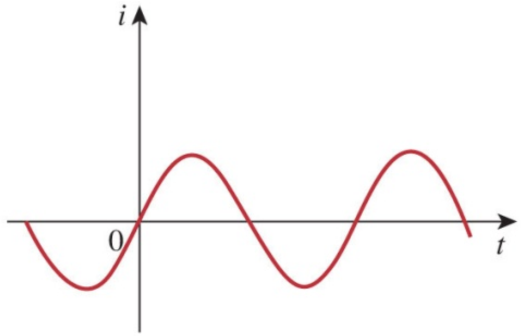
- Unit is Ampere (A), is one Coulomb/second.

DC versus 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).
- Mains power is an example of AC.



(a)



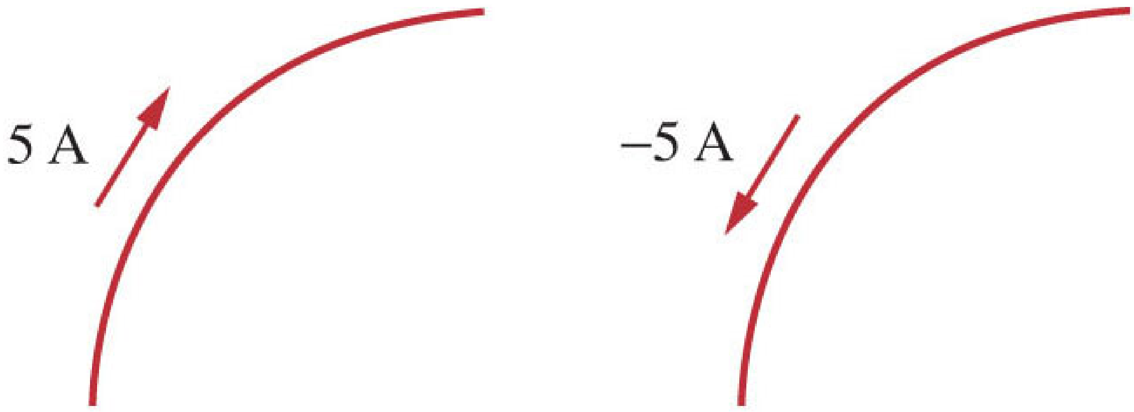
(b)

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, and often have no choice in the matter.

Direction of Current II

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



(a) (b)

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

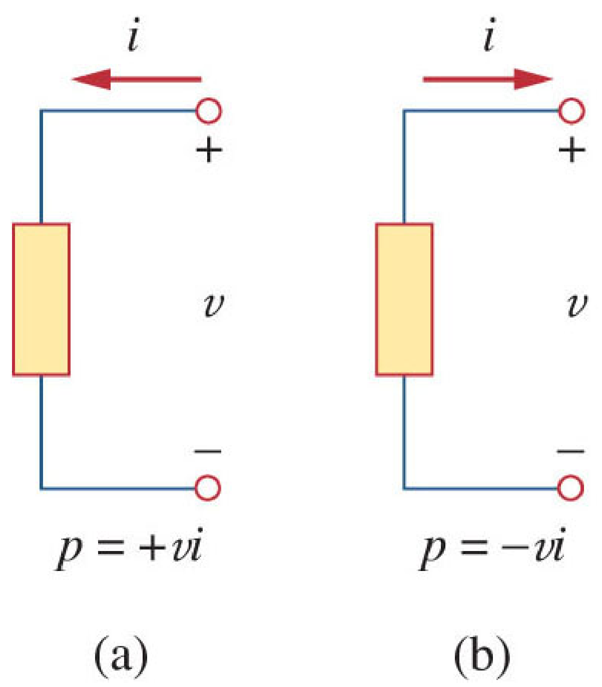
- Voltage alone does not equal power.
- It requires the movement of charge, *that is,* a current.
- Power is the product of voltage and current.

$$p = vi$$

- 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.

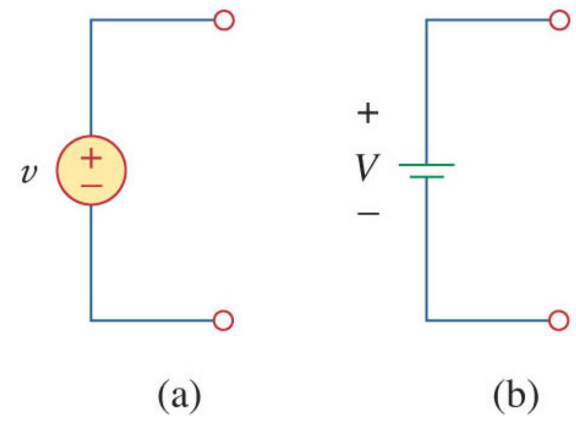
Circuit Elements

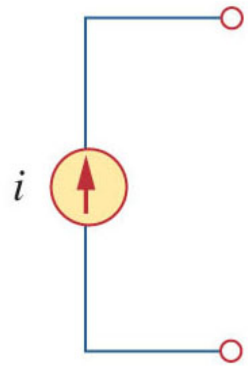
Two types:

- 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.

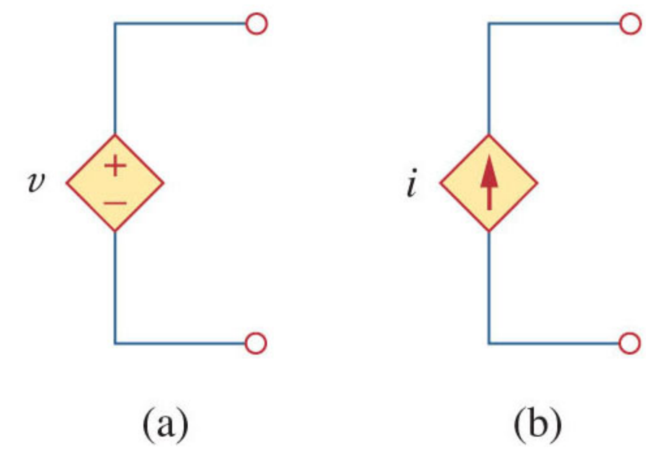
Dependent Sources

A dependent source has its output controlled by an input value.

Symbolically represented as a diamond.

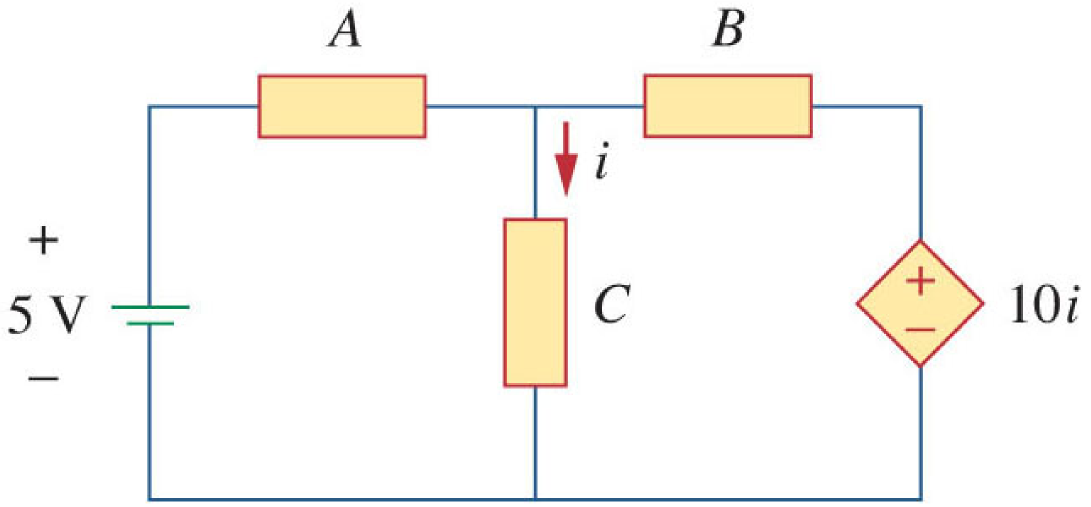
Four types:

- A voltage-controlled voltage source (V CVS).
- A current-controlled voltage source (C CVS).
- A voltage-controlled current source (V CCS).
- A current-controlled current source (C CCS).



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.



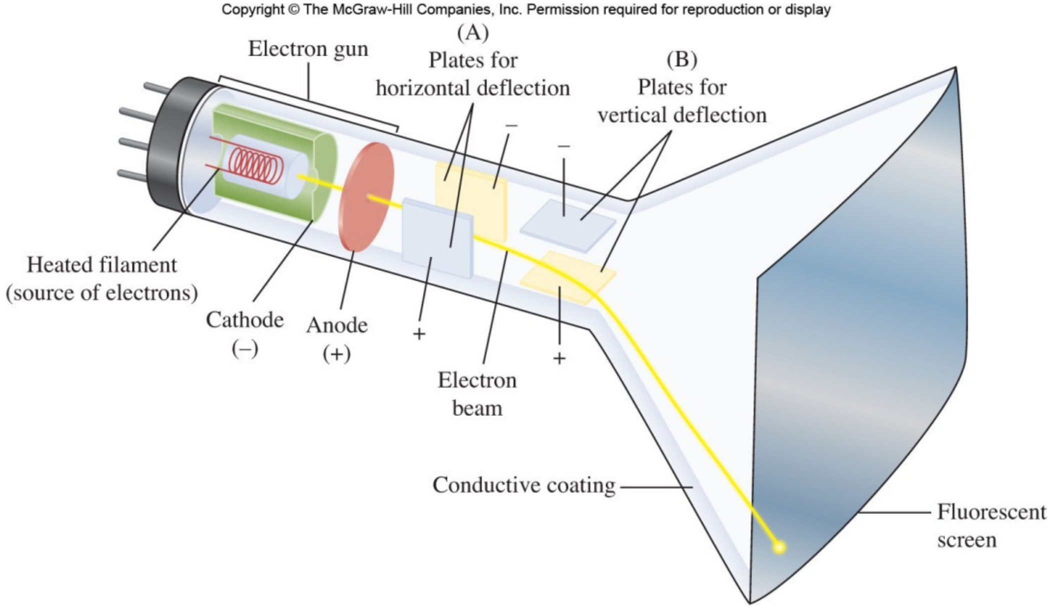
Circuit Applications of Dependent Sources

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.

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.



Problem Solving I

- Successfully solving an engineering problem requires a process.
- Shown here is an effective method for determining the solution any problem.

1. Carefully define the problem.
2. Present everything you know about the problem.
3. Establish a set of alternative solutions and determine the one that promises the greatest likelihood of success.

Problem Solving II

4. Attempt a problem solution.
5. Evaluate the solution and check for accuracy.
6. Has the problem been solved satisfactorily? If so, present the solution; if not, then return to step 3 and continue through the process again.

Problem Solving III

Carefully define the problem.

- This is the most important step.
- What needs to be solved?
- What questions need to be addressed before solving? Find the sources to answer them.

Present everything you know about the problem.

- What do you know?
- What don’t you?

Problem Solving IV

Establish a set of alternative solutions and determine the one that promises the greatest likelihood of success.

- Most problems have more than one way to be solved.
- But not all solutions are as simple.
- Are the required tools available?

Problem Solving V

Attempt to solve the problem.

- Documenting this process is very important.

Evaluate the solution and check for accuracy.

- Does it makes sense?
- Is it consistent with any assumptions made?

Is the solution satisfactory? If not, try an alternate solution.

End of Main Content

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