UZM203

Fundamentals of Electrics and Electronics

Part I Circuits

Chapter 1: Basic Concepts

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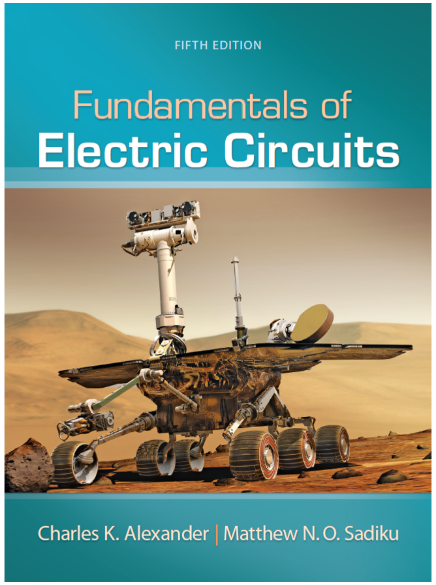
Course Material

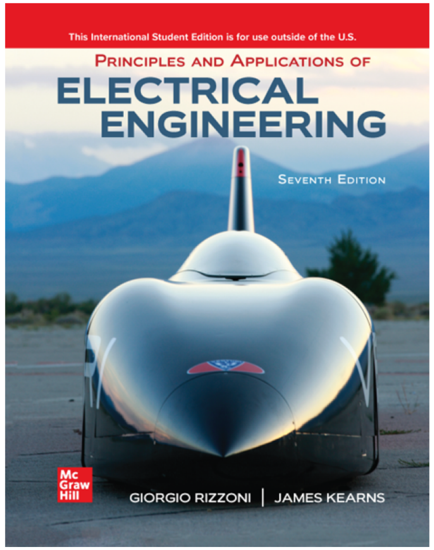
- Lecture notes (http://www.erudm.erciyes.edu.tr)
- Reference books:

  - Fundamentals of Electric Circuits, 4th Edition by Charles Alexander and Matthew Sadiku, McGraw Hill, 2009.

  - Principles and applications of electrical engineering. 5th Edition by Giorgio Rizzoni, McGraw-Hill Higher Education, 2007.

  - Electrical Engineering: Principles and Applications, 4th Edition by Allan R. Hambley, Prentice Hall Pearson Education, 2008.





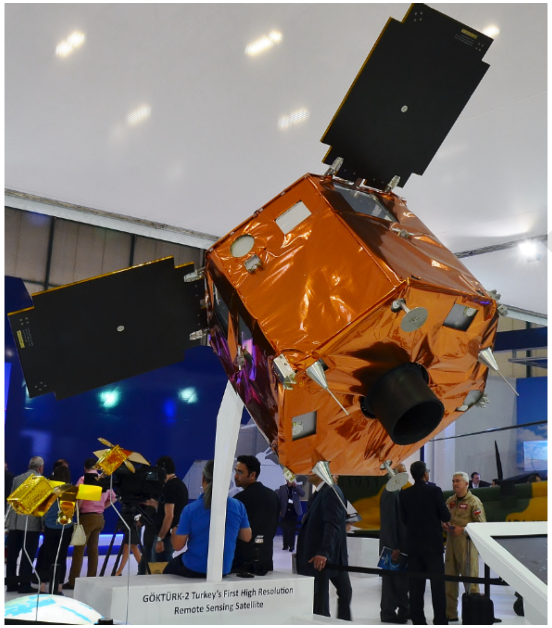
Evaluation

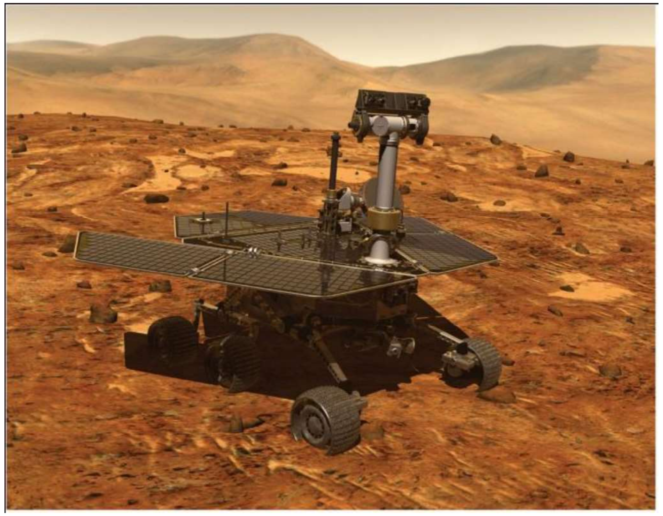
• Pop Quizzes	15%
• Midterms	35%
• Final Exam	50%

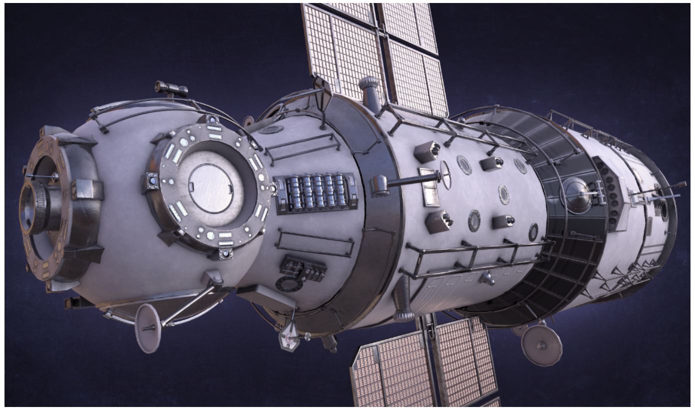
Attendance is important to avoid missing the quizzes.

Motivation

Electrical circuits take part in each space mission







What is an Electric Circuit?

- In electrical engineering, we are usually interested in transferring energy or communicating signals from one point to another.

  To do this, we often require an interconnection of electrical components.

  " An electric circuit is an interconnection of electrical components."

- Typical circuit or electrical components that we will see in this lecture:

  batteries or voltage sources, current sources, resistors, switches, capacitors, inductors, diodes, transistors, operational amplifiers. …

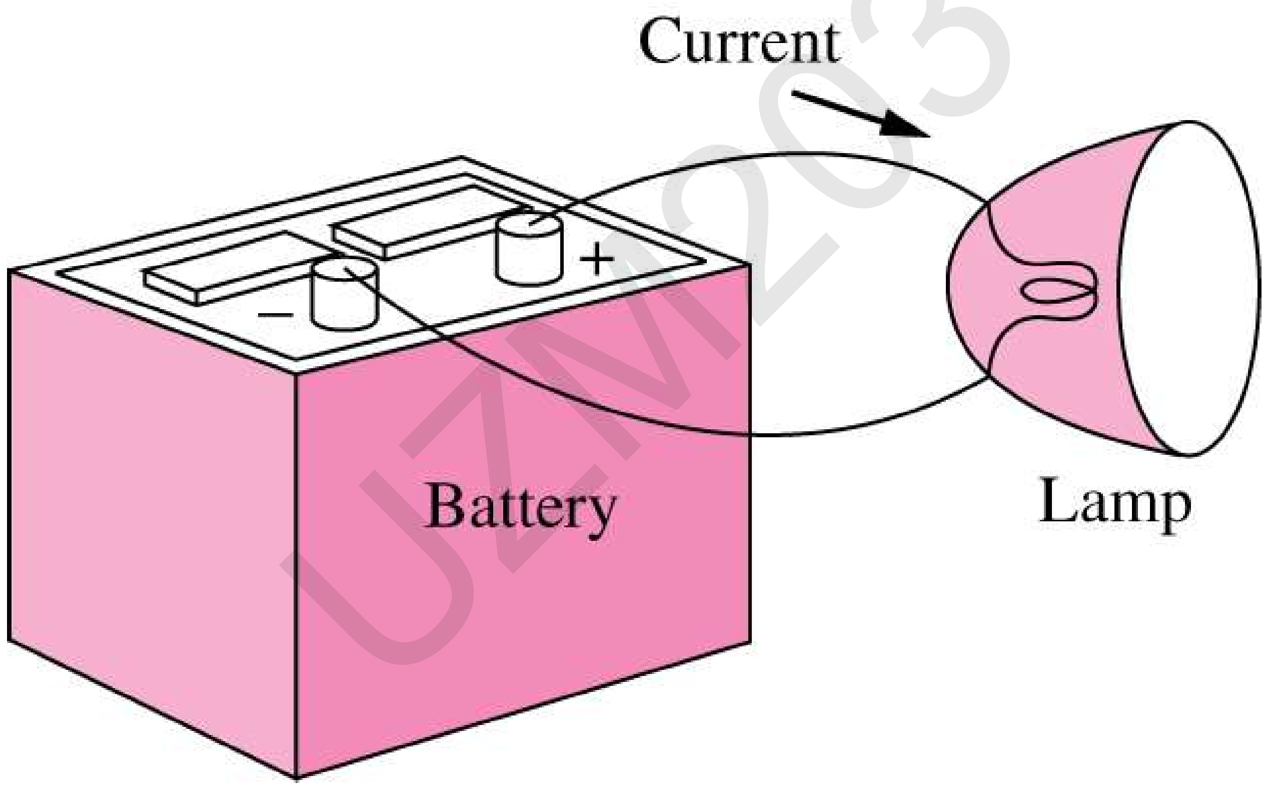
What is an Electric Circuit?

- “The complete path of an electric current including usually the source of electric energy.”

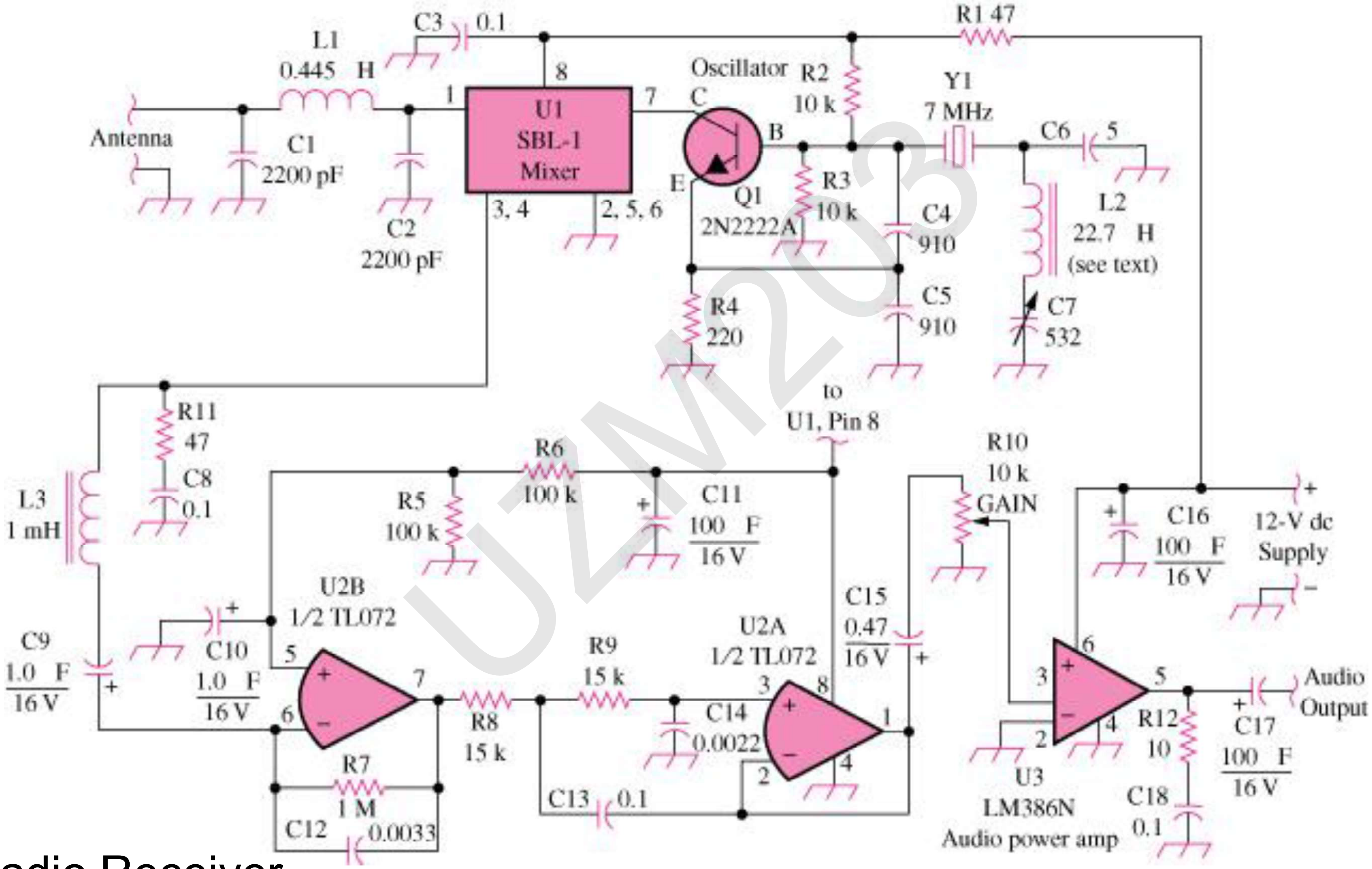
- “Path that transmits electric current.”

  “A circuit includes a battery or a generator that gives energy to the charged particles; devices that use current, such as lamps, motors, or electronic computers; and connecting wires or transmission lines. Circuits can be classified according to the type of current they carry (see alternating current, direct current) or according to whether the current remains whole (series) or divides to flow through several branches simultaneously (parallel). Two basic laws that describe the performance of electric circuits are Ohm's law and Kirchhoff's circuit rules."

A Simple Circuit



A More Complicated Circuit



A Radio Receiver

System of Units

The International System of Units, or Système International des Unités (**SI)**, also known as **metric** system uses 7 mutually independent base units. All other units are *derived* units.

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Charge	coulomb	C

SI Base Units

SI Prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

Review of Basic Circuit Concepts

- Electric Charge is the basis for describing all electrical phenomena .

- **Charge** is an electrical property of the atomic particles of which matter consists and is measured in coulombs (Charles Augustin de Coulomb (1736-1806) a French Scientist)

- Inside an atom, there is negative charge on electrons, positive charge on protons and no charge on neutrons.

- The charge of an electron is equal to that of an proton and is:
  $e = 1.602 \times 10^{-19}$ C

Charge

- Note that in 1C of charge there are:
  $1/ 1.602 \times 10^{-19} = 6.24 \times 10^{18}$ electrons

- Laboratory values of charges are more likely to be a fraction of a Coulumb (e.g., pC, nC, μC, or mC).

- *Law of conservation of charge*: charge can neither be created nor destroyed, only transferred or stored or converted.

- Electrical effects are attributed to both separation of charges and/or charges in motion!

A Material Classification

- **Conductor:** a material in which charges can move to neighboring atoms with relative ease.
  - One measure of this relative ease of charge movement is the electric resistance of the material
  - Example conductor material: metals and carbon
  - In metals the only charged particles that can move are electrons
- **Insulator:** a material that opposes the charge movement (ideally infinite opposition, i.e., no charge movement)
  - Example insulators: Dry air and glass
- **Semi-conductor:** a material whose conductive properties are somewhat in between those of conductor and insulator
  - Example semi-conductor material: Silicon with some added impurities

Electric Current (Charges in Motion!)

- **Current:** net flow of charge across any cross section of a conductor, measured in Amperes (Andre-Marie Ampere (1775-1836), a French mathematician and physicist)

- Current can be thought of as the rate of change of charge; so mathematically, the relationship between current *i*, charge *q*, and time *t* is

$$\boxed{i \triangleq \frac{dq}{dt}}$$

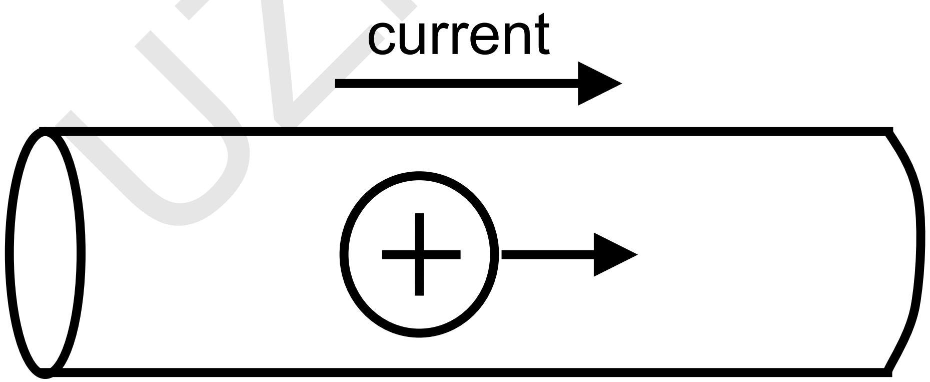
$$\boxed{Q \triangleq \int_{t_0}^{t} i\, dt}$$

$$1 \text{ ampere} = 1 \text{ coulomb/second}$$

Electric Current

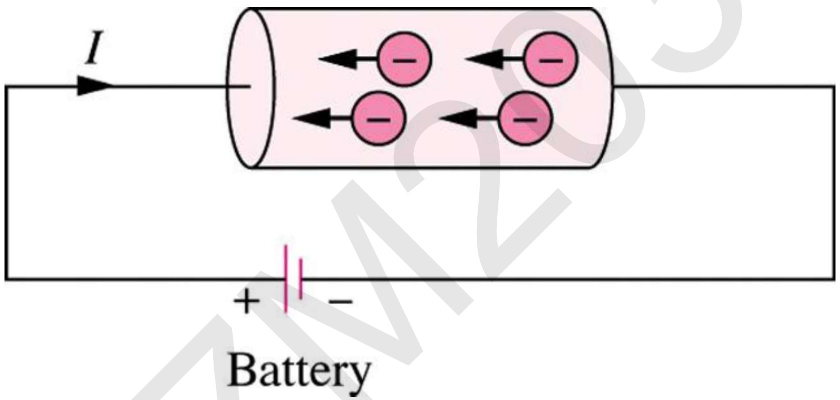
- Originally scientists (in particular Benjamin Franklin (1706-1790) an American scientist and inventor) thought that current is only due to the movement of positive charges.

- Thus the direction of the current was considered the direction of movement of positive charges.

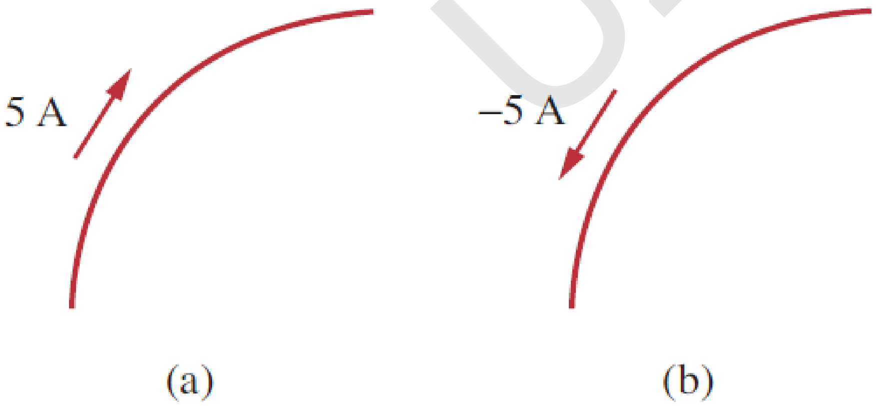


Electric Current

- In reality in metallic conductors current is due to the movement of **electrons**, however, we follow the universally accepted convention that current is in the direction of positive charge movement.

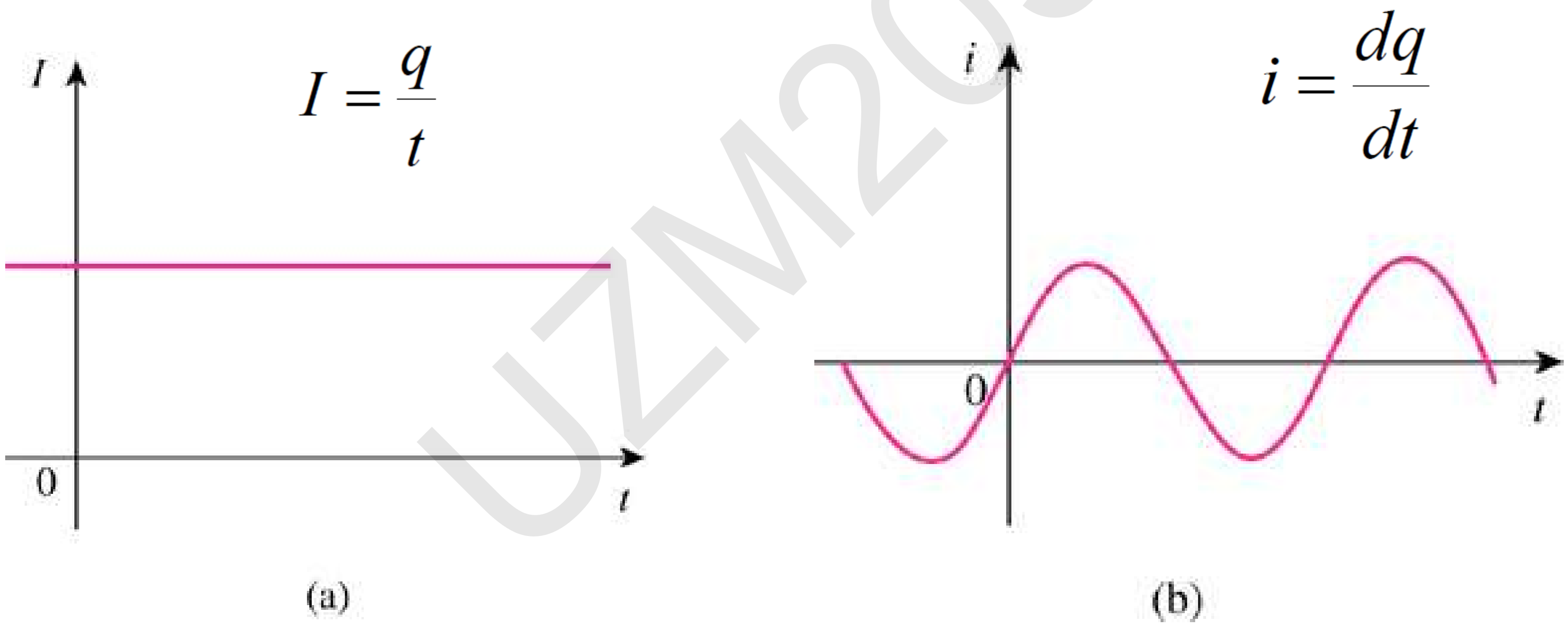


- Two ways of showing the same current:

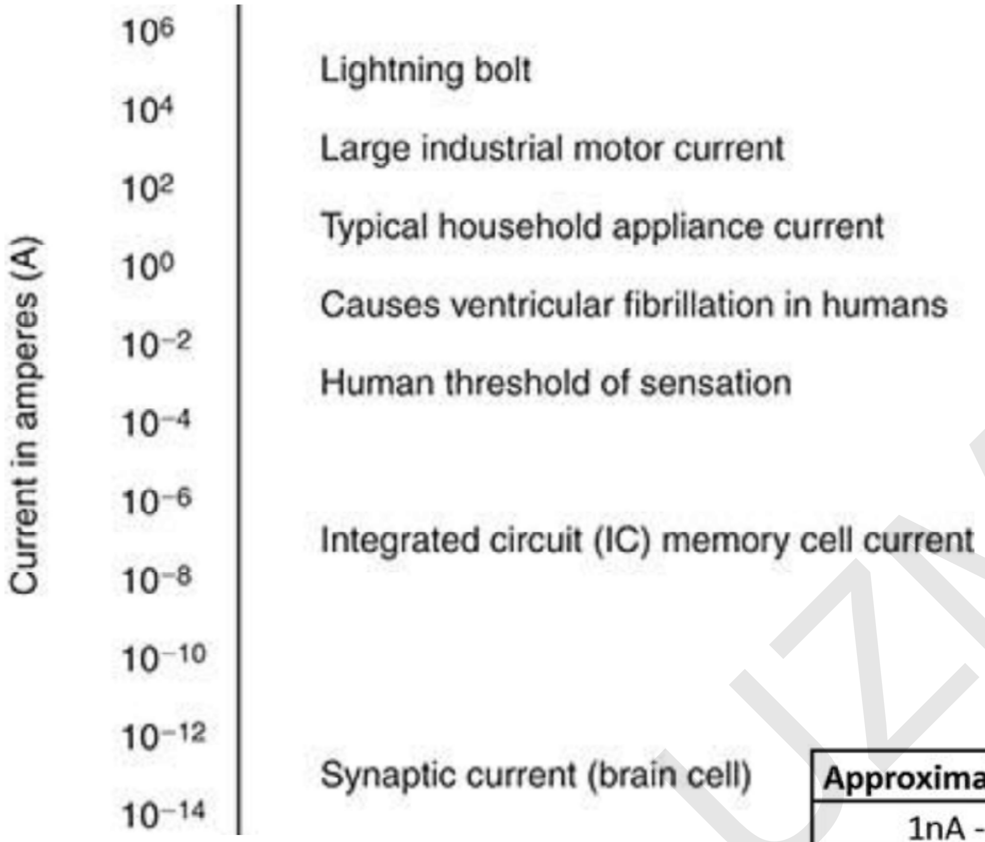


Two Important Types of Current

- Direct current (DC) is a current that remains constant with time.
- Alternating current (AC) is a current that varies sinusoidally with time.



Magnitude of Some Typical Currents



Approximate current	Situation
1nA - 1µA	Tiny currents in the receiving antenna of your mobile phone
10mA	TV remote control
50mA	Keyboard & mouse
1A	High power flashlight
3A	Typical laptop
15A	Microwave ovens, vacuum cleaners
 10,000+A	A bolt of lightning

Voltage (Separation of Charge)

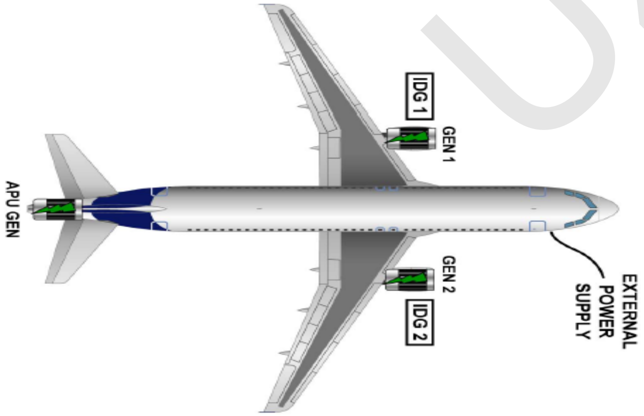
- **Voltage** (electromotive force, or potential) is the energy required to move a unit charge through a circuit element, and is measured in Volts (Alessandro Antonio Volta (1745-1827) an Italian Physicist).

$$v = \frac{dW}{dq}$$

W= energy (in Joules)

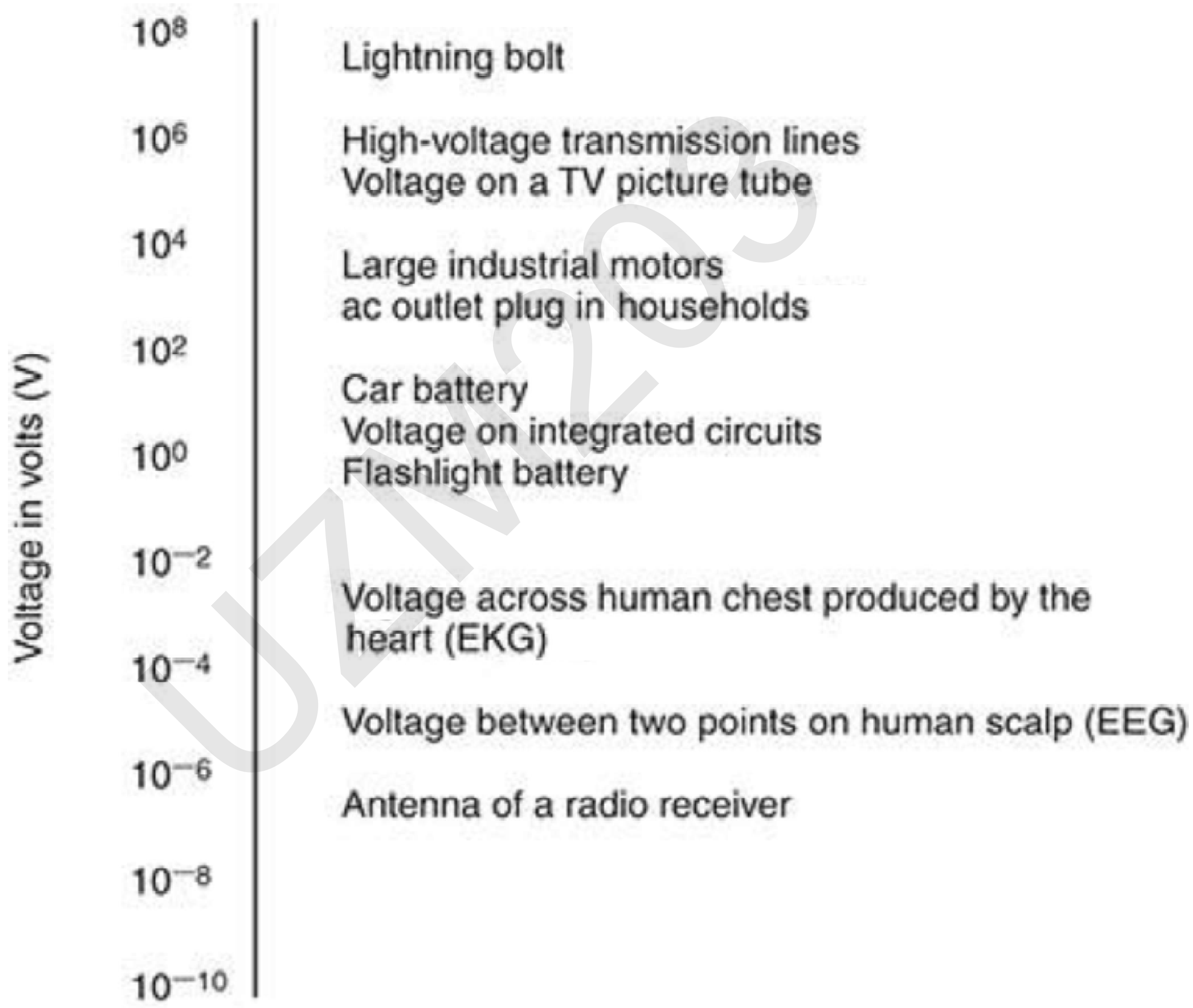
q= charge (in Coulombs)

- Similar to electric current, there are two important types of voltage: DC and AC



115V AC, 28V DC

Typical Voltage Magnitudes

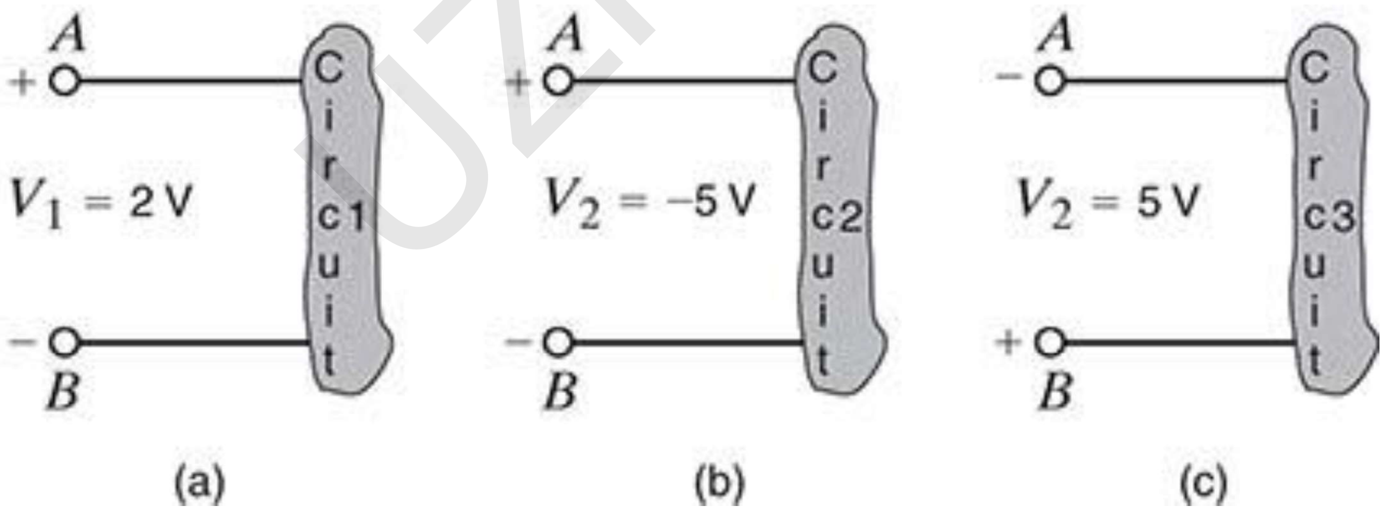


Voltage

- Voltage between two points in a circuit is the difference in energy level of a unit charge located at each of the two points.

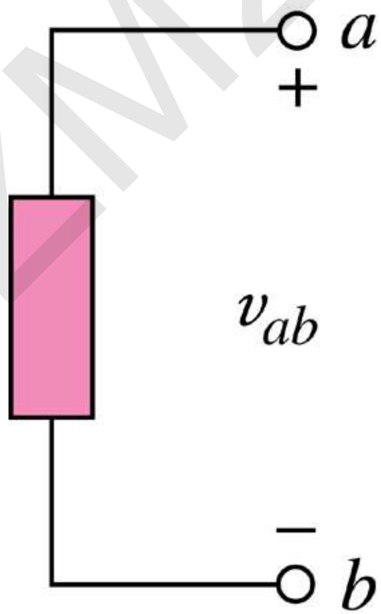
- Voltage is very similar to a gravitational force. It is always referenced to some point.

- Some examples:



Voltage Polarity

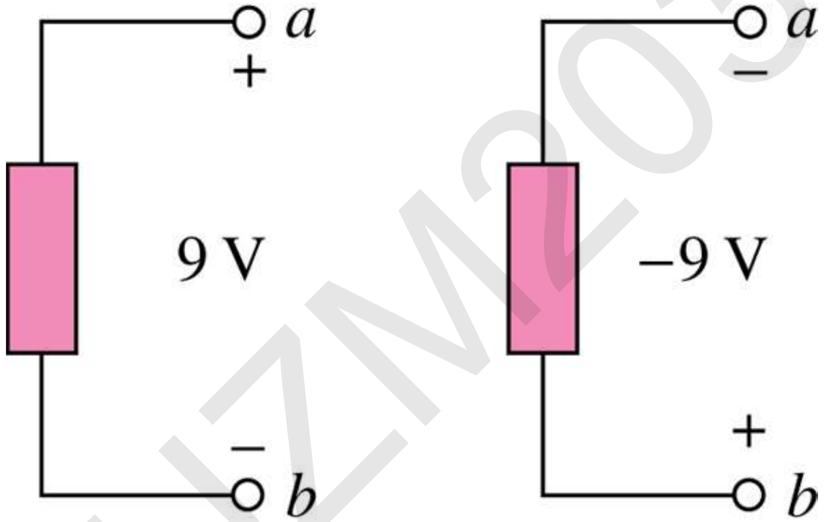
- The plus (+) and minus (-) sign are used to define voltage polarity.
- The assumption is that the potential of the terminal with (+) polarity is higher than the potential of the terminal with (-) polarity by the amount of voltage drop.



$$v_{ab} = v_a - v_b$$

Voltage Polarity

- Figures (a) and (b) are two equivalent representation of the same voltage:



$$v_{ab} = -v_{ba}$$

- Both show that the potential of terminal a is 9V higher than the potential of terminal b.

Power

- The rate of change of (expending or absorbing) energy per unit time, measured in Watts (James Watt (1736-1819) a Scottish inventor and mechanical engineer)

$$p = \frac{dW}{dt} = \frac{dW}{dq} \times \frac{dq}{dt} = vi$$

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Work}}{\text{Charge}}\,\frac{\text{Charge}}{\text{Time}} = \text{Voltage} \times \text{Current}$$

- Power can be generated or dissipated by a circuit element. The electric power of a circuit element is the product of the voltage across the element and the current flowing through it.

Tellegan’s Theorem

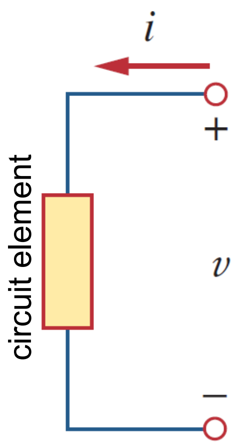
- **Principle of Conservation of the Power:** The algebraic sum of the powers absorbed by all elements in a circuit is zero at any instance of time. That is, the sum of absorbed powers is equal to the sum of generated powers at each instance of time.

$$\boxed{\sum p = 0}$$

- This principle is also known as Tellegan’s theorem. (Bernard D.H. Tellegan (1900-1990), a Dutch electrical engineer)

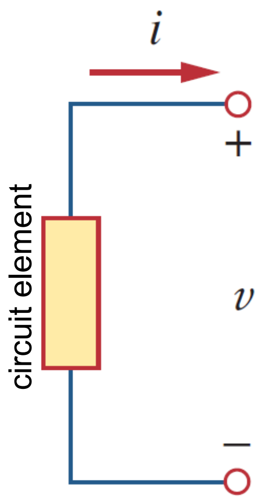
- Similarly, one can write the principle of conservation of energy.

Power Polarity



$p = +vi$ absorbing power

If a positive charge *q* moves through a drop in voltage *v*, it loses energy. So the circuit element absorbs power by converting electrical energy into heat (resistors in toasters), light (light bulbs).



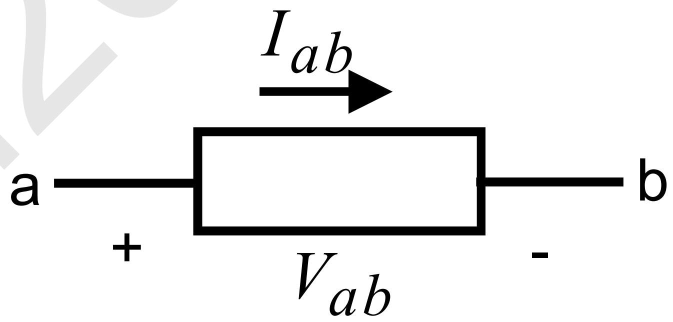
$p = -vi$ supplying power.

If a positive charge *q* moves through a rise in voltage *v*, it gains energy. So the circuit element supplies power.

Simply, if the current enters through the positive terminal of an element, ***power is absorbed***; if the current exits through the positive terminal of an element, ***power is supplied*** by the element.

Passive Sign Convention

- For calculating absorbed power: The power absorbed by any circuit element with terminals A and B is equal to the voltage drop from A to B multiplied by the current through the element from A to B, i.e., $P = V_{ab} \times I_{ab}$

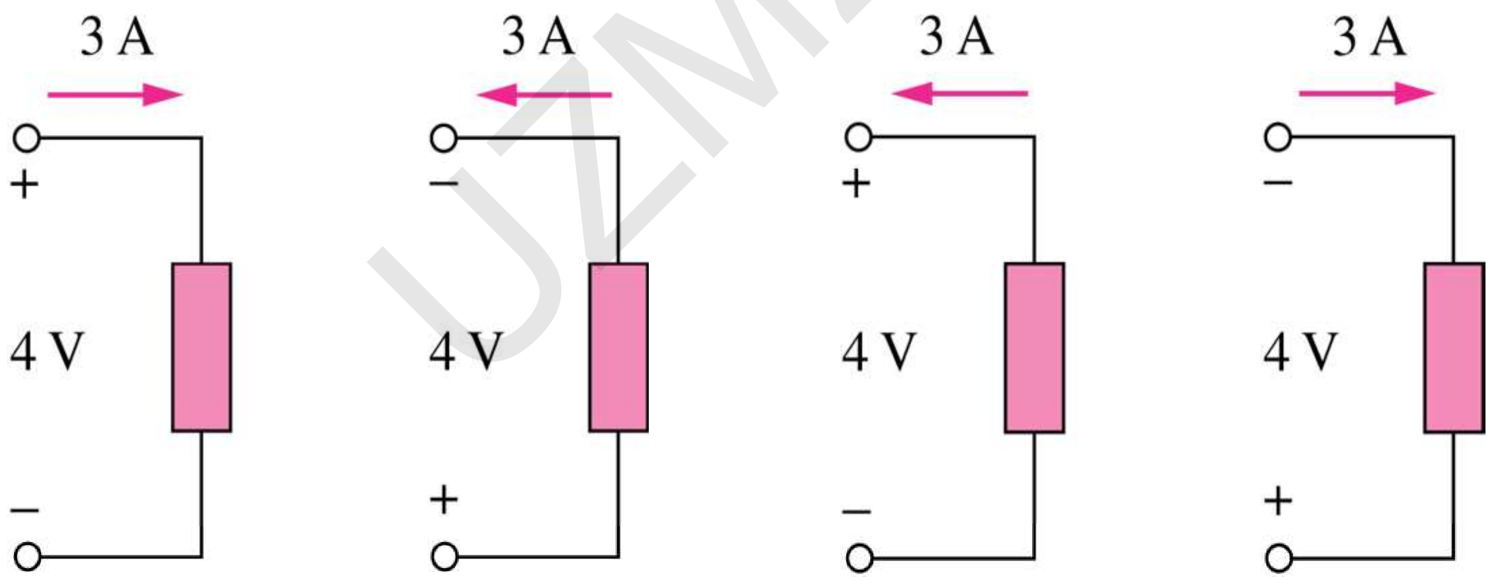


- With this convention if $P \geq 0$, then the element is absorbing (consuming) power. Otherwise (i.e., $P < 0$) is absorbing negative power or actually generating (delivering) power.

Passive Sign Convention

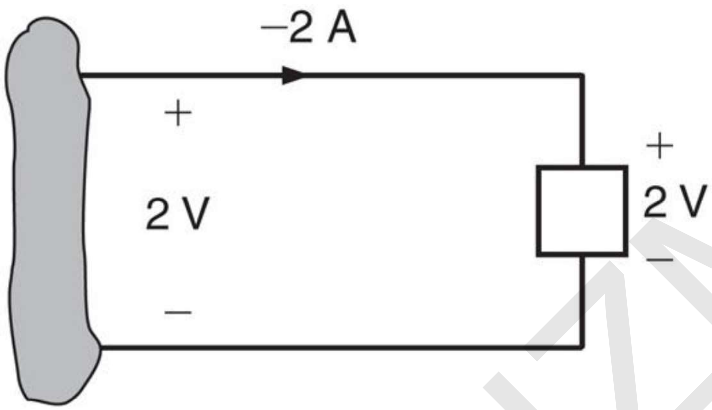
- Passive Sign Convention simply states that the power dissipated by a load is a positive quantity (or, conversely, that the power generated by a source is a positive quantity)

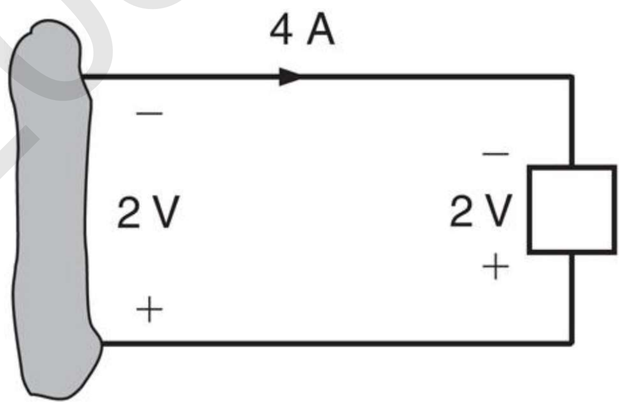
- Calculate the power absorbed or supplied by each of the following elements:



Example

- Given the two diagrams shown below, determine whether the element is absorbing or supplying power and how much.





Hint: If current exits trough positive terminal it is a supplier, and its power is negative.

Energy

Energy is the capacity to do work, measured in joules (J).

The energy absorbed or supplied by an element from time t_0 to t is

$$W = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

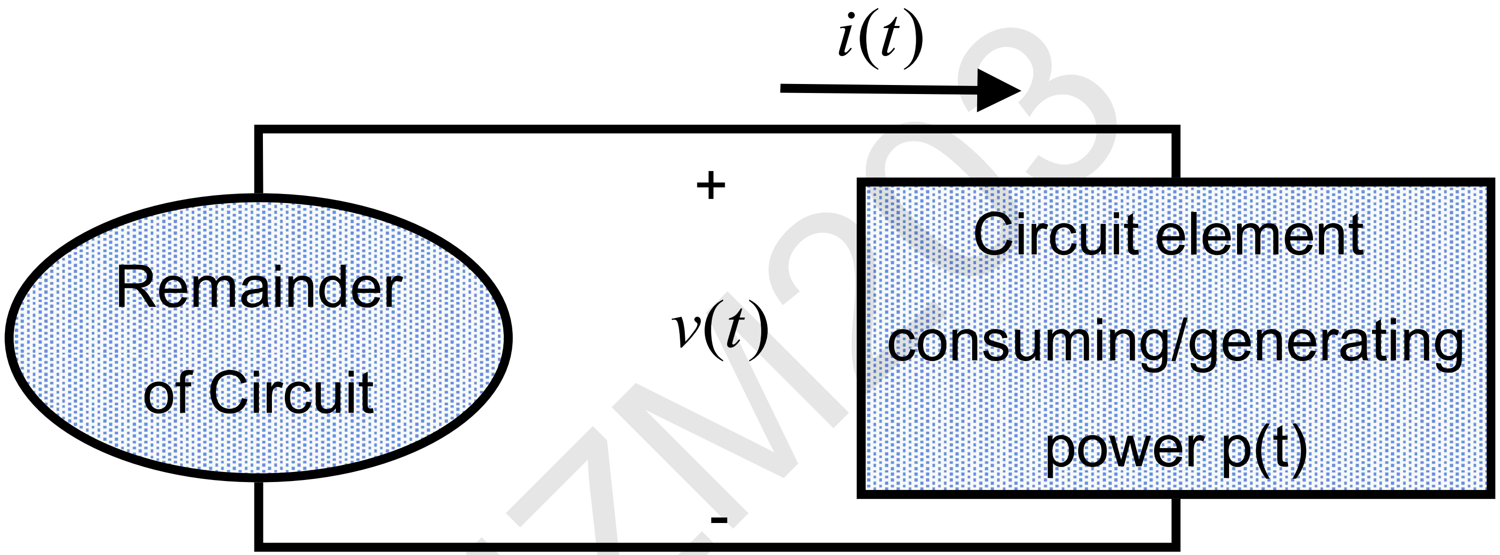
Energy can neither be created nor destroyed, only transferred.

The algebraic sum of power in a circuit, at any instant of time, must be zero.

The total power supplied to the circuit must balance the total power absorbed.

Energy Calculation

- Instantaneous power: $p(t) = v(t)i(t)$



- Energy absorbed or supplied by an element from time t_0 to time $t > t_0$

$$W = W(t_0, t) = \int_{t_0}^{t} p(\tau)d\tau = \int_{t_0}^{t} v(\tau)i(\tau)d\tau$$

Circuit Elements

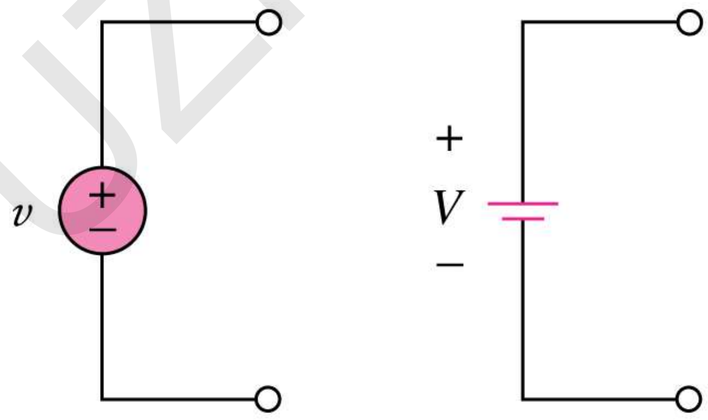
- One common classification for circuit elements/components is to group them in two major groups:

1) Active components or active elements
   that are capable of generating energy such as generators, batteries, and operational amplifiers.

2) Passive components or passive elements
   that are not active such as resistors, capacitors, and inductors. They can either consume or store energy.

(Ideal) Independent Sources

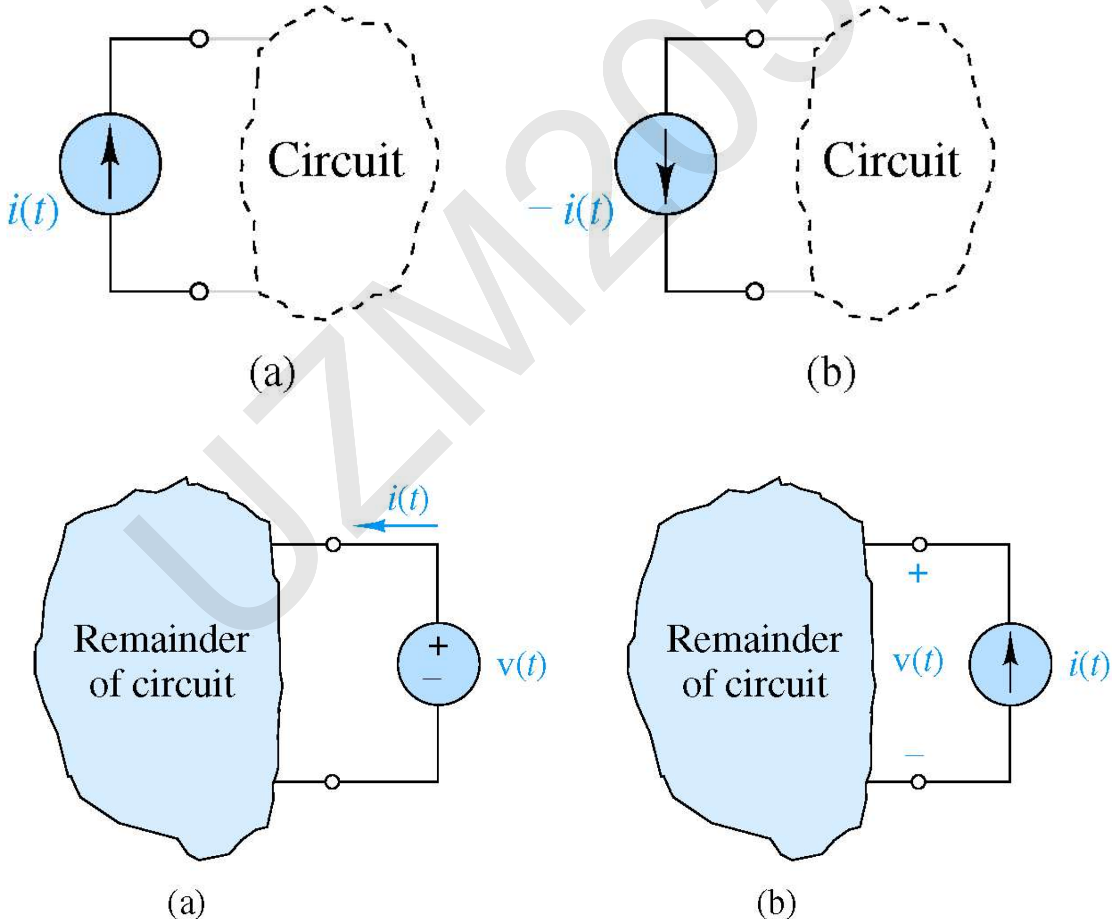
- Independent sources: An (ideal) independent source is an active element that provides a specified voltage or current that is independent of other circuit elements and/or how the source is used in the circuit.
- Symbol for independent voltage source
  (a) Used for constant or time-varying voltage
  (b) Used only for constant voltage



(a) (b)

Independent Sources

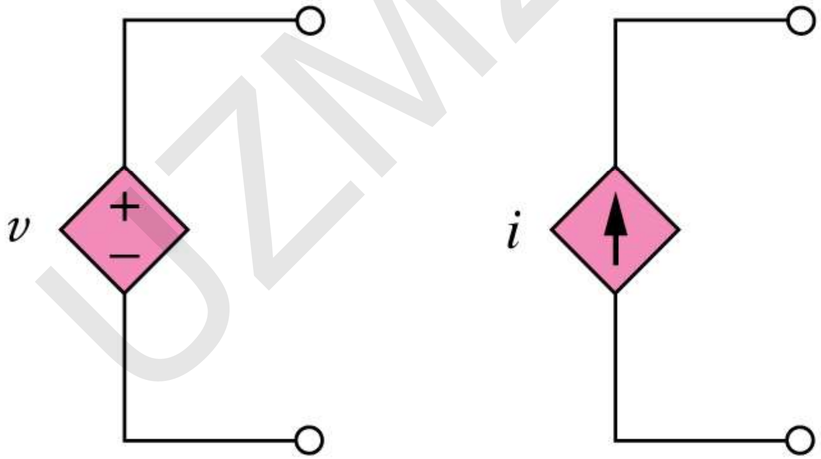
- Equivalent representation of ideal independent current sources whose current *i(t)* is maintained under all voltage requirements of the attached circuit:



Ideal Dependent (Controlled) Source

- An ideal dependent (controlled) source is an active element whose quantity is controlled by a voltage or current of another circuit element.

- Dependent sources are usually presented by diamond-shaped symbols:

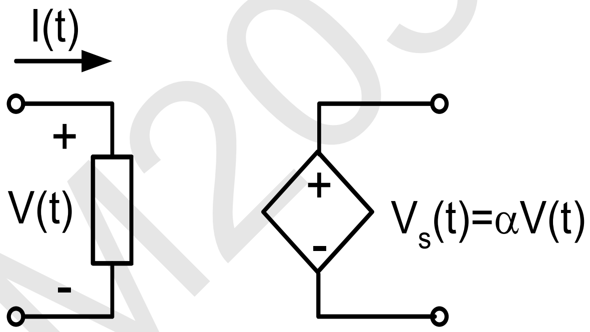


(a) (b)

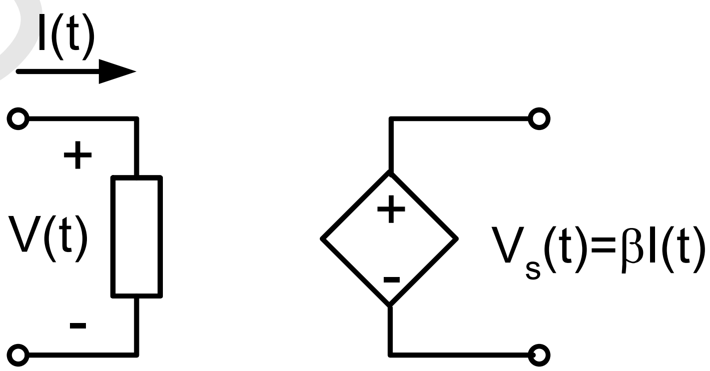
Dependent (Controlled) Source

- There are four types of dependent sources:

- Voltage-controlled voltage source (VCVS)

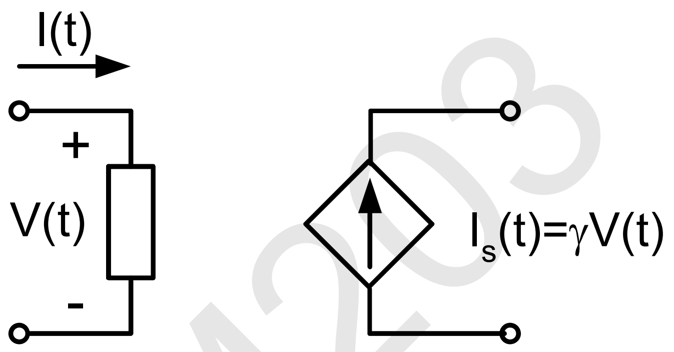


- Current-controlled voltage source (CCVS)

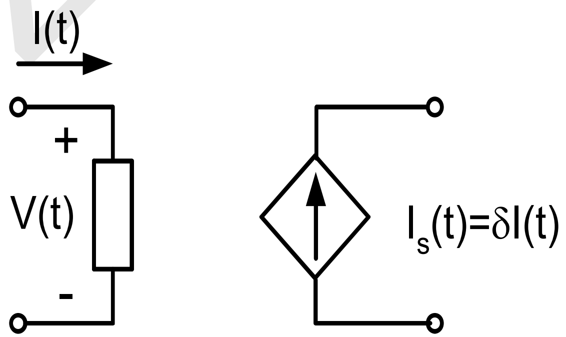


Dependent (Controlled) Source

- Voltage-controlled current source (VCCS)

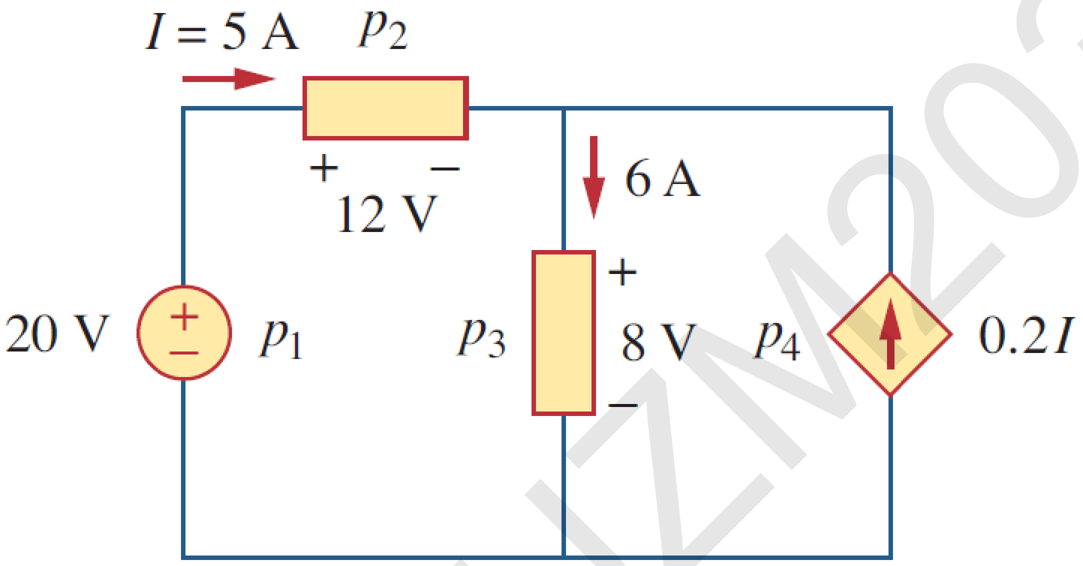


- Current-controlled current source (CCCS)



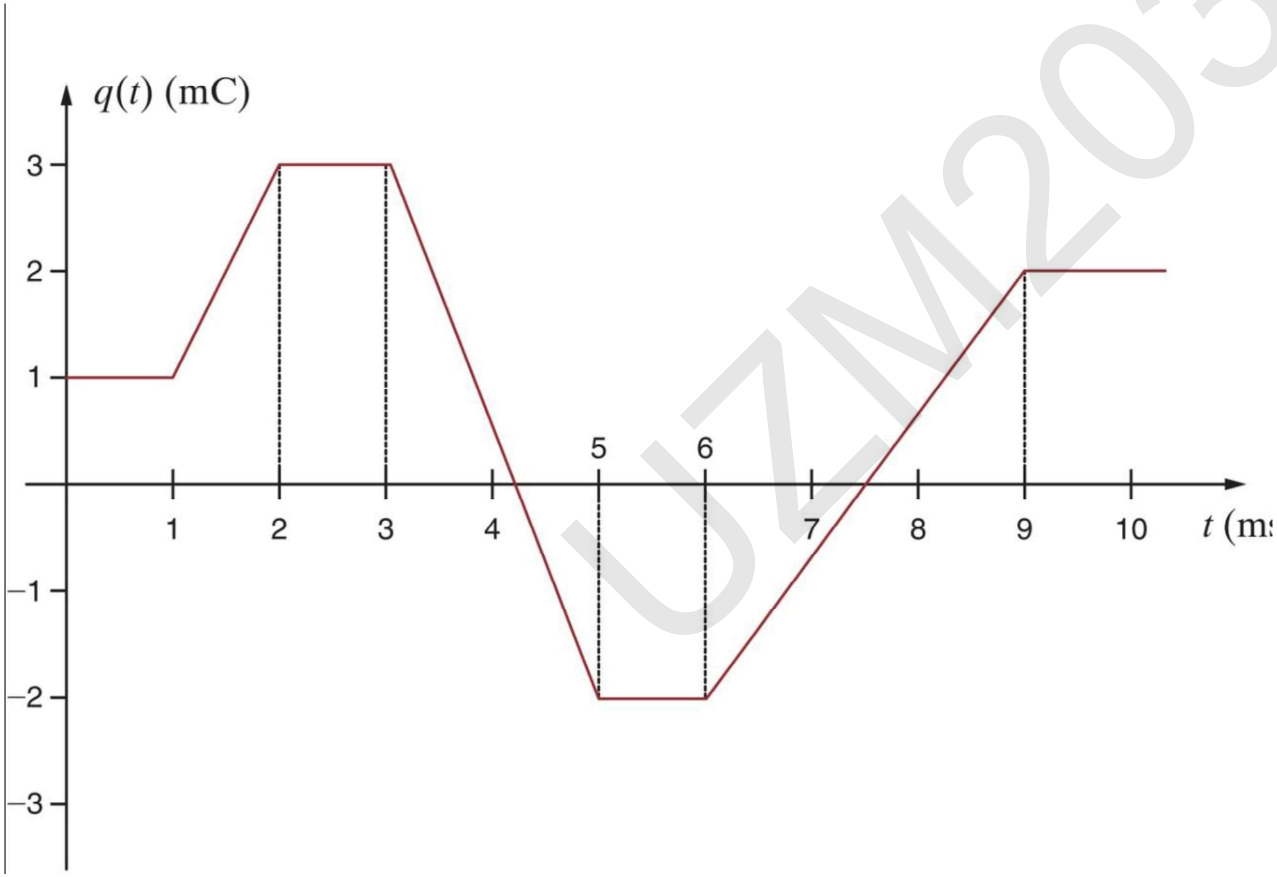
Example

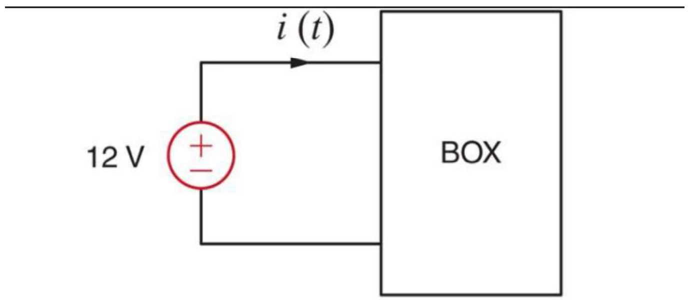
- Calculate the power absorbed or supplied by the elements of the following network:



Example

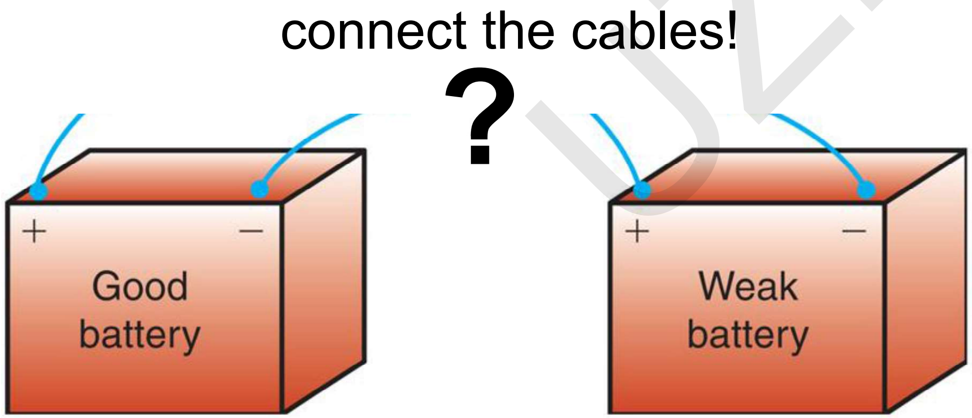
- The charge that enters the BOX is shown below. Calculate and sketch the current flowing into the BOX and the power absorbed by the BOX between 0 and 10 milliseconds.





Homework 1

- Suppose that your car is not starting. To determine whether the battery is faulty, you turn on the light switch and find that the lights are very dim, indicating a weak battery. You borrow a friend's car and a set of jumper cables. However, how do you connect his car's battery to yours? If proper connection is maintained for 1 min, how much energy is transferred to the weak battery? (Assume the current suplied by the good batter is 60 A)



Homework 2

Find the power absorbed by each of the elements