Electric and Electronic Circuits

CSE 113

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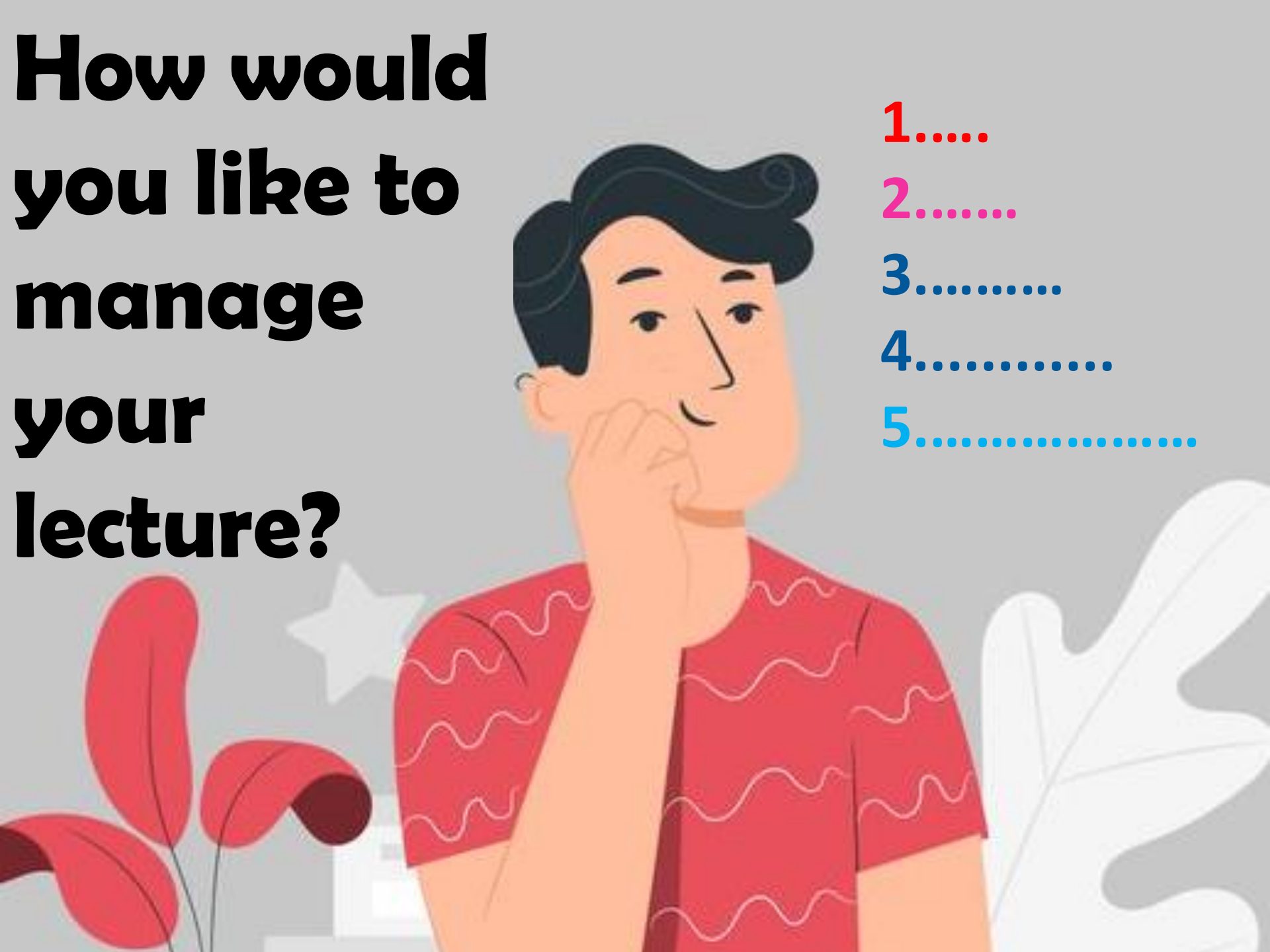
How would you like to manage your lecture?



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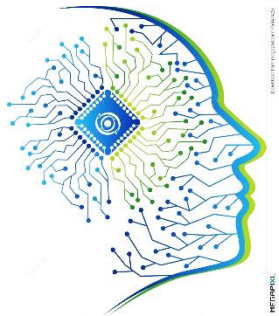
COURSE OUTLINES



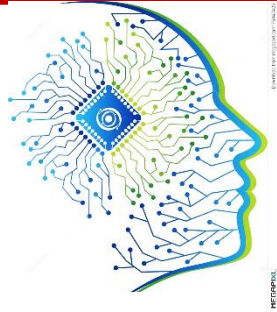
- Circuits and Circuit Elements
- Time Varying Signals
- Basic Diode Behavior

Electric Circuits

- Diode Applications
- Transistors
- Switching Applications
- Ac Circuits
- Amplifier Applications
- Operational Amplifiers

Electronic Circuits

Units of Measurements

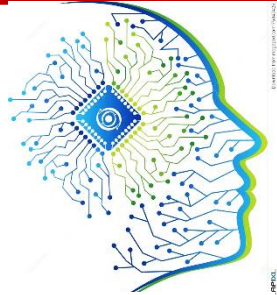


QUANTITY	SYMBOL	SI UNIT	SYMBOL
Capacitance	*C*	Farad	F
Charge	*Q*	Coulomb	C
Conductance	*G*	Siemens	S
Energy (work)	*W*	Joule	J
Frequency	*f*	Hertz	Hz
Impedance	*Z*	Ohm	Ω
Inductance	*L*	Henry	H
Power	*P*	Watt	W
Reactance	*X*	Ohm	Ω
Resistance	*R*	Ohm	Ω
Voltage	*V*	Volt	V

TABLE 1–3

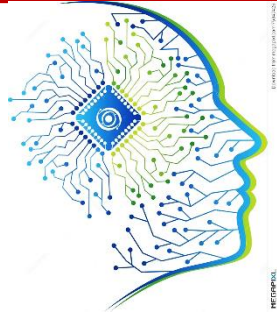
Electrical quantities and derived units with SI symbols.

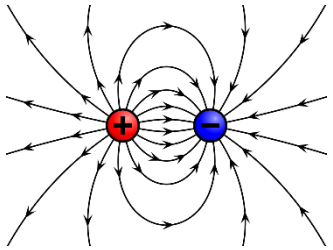
Metric Prefixes



METRIC PREFIX	SYMBOL	POWER OF TEN	VALUE
pico	p	10^{-12}	One-trillionth
nano	n	10^{-9}	One-billionth
micro	μ	10^{-6}	One-millionth
milli	m	10^{-3}	One-thousandth
kilo	k	10^{3}	One thousand
mega	M	10^{6}	One million
giga	G	10^{9}	One billion
tera	T	10^{12}	One trillion

Charge

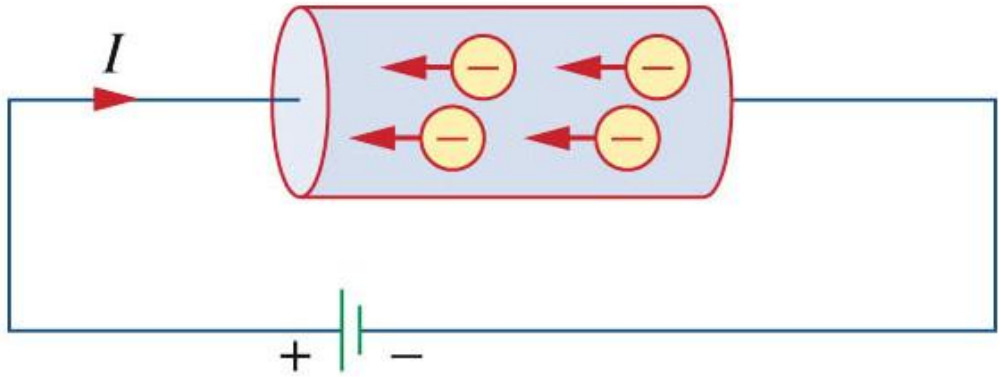




- Charge is a basic SI unit, measured in Coulombs (C).
- Counts the number of electrons (or positive charges) present.
- Charge of single electron is $1.602 * 10^{-19}$ C.
- One Coulomb is quite large, $6.24 * 10^{18}$ electrons.
- In the lab, one typically sees (pC, nC, or μC)
- Charge is always multiple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

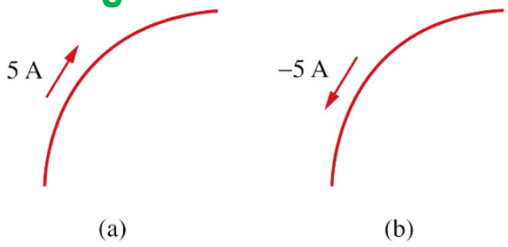


Battery

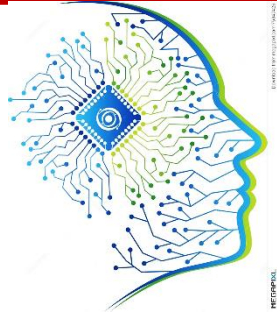
Current

- Current, i, is measured as charge moved per unit time through an element.
- Unit is Ampere (A), is one Coulomb/second.
  - One ampere (1 A) is the amount of current that exists when a number of electrons having a total charge of one coulomb (1 C) move through a given cross-sectional area in one second (1 s).
- Direction of Current
  - A positive current through a component is the same as a negative current flowing in the opposite direction.
- 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.

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



Voltage



- Electrons move when there is a difference in potential between two locations.
- This difference is expressed at the potential difference, or voltage (V).
- 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.
- Voltage, symbolized by V, is defined as energy or work per unit charge.
- The unit of voltage is the volt, symbolized by V.

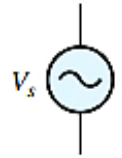
$$V \equiv \frac{W}{Q}$$

One volt is the potential difference (voltage) between two points when one joule of energy is used to move one coulomb of charge from one point to the other.

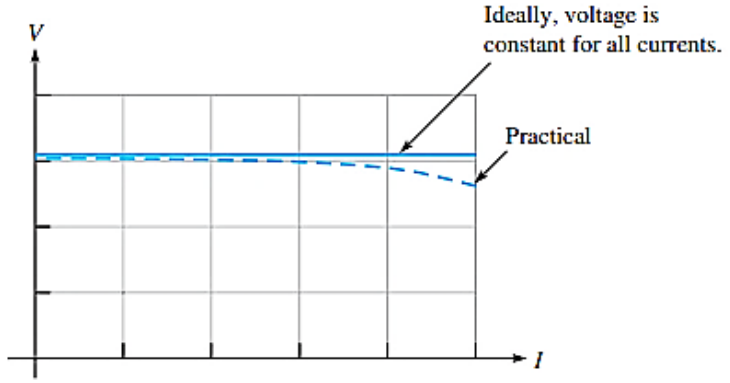
The Voltage Source

- A voltage source provides electrical energy or electromotive force (emf), more commonly known as voltage. Voltage can be produced by means of chemical energy, light energy, or magnetic energy combined with mechanical motion.
- Voltage sources can be either dc or ac.
- The 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.

(a) DC voltage source



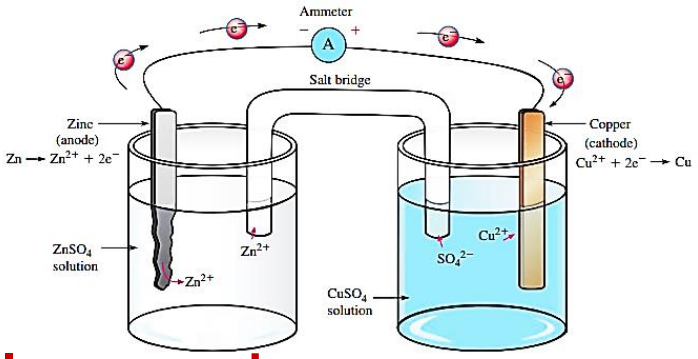
(b) AC voltage source



Types of DC Voltage Sources

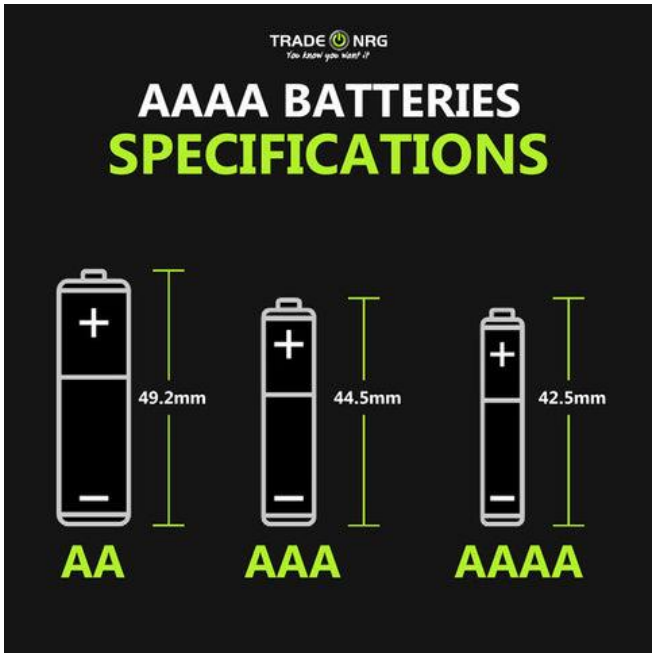
Batteries

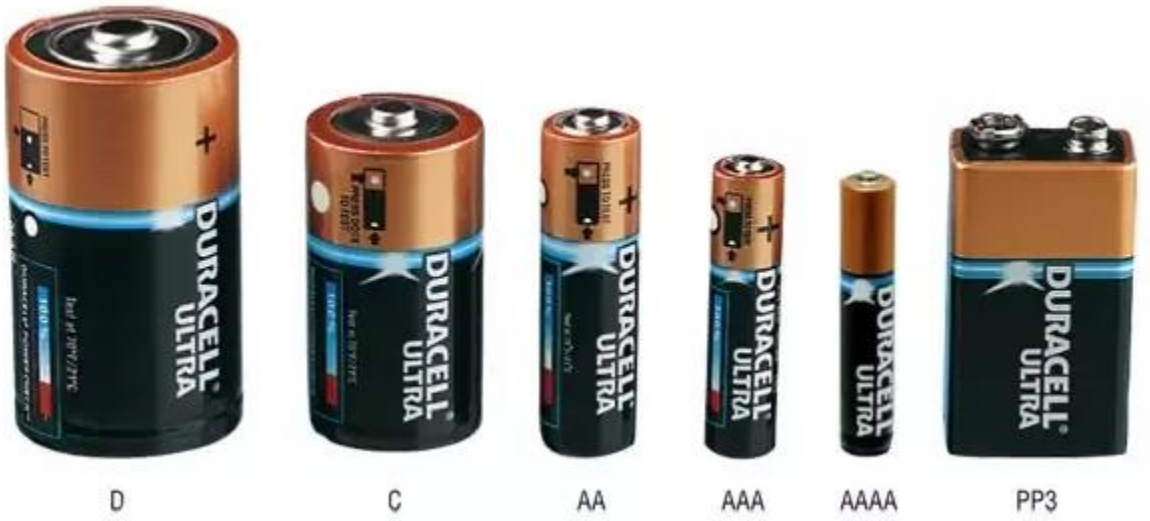
- A battery is a type of voltage source that converts chemical energy directly into electrical energy.



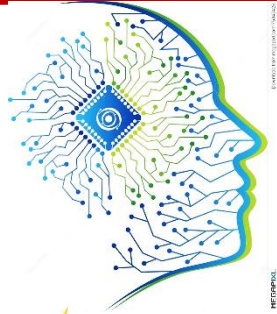
- **Batteries are divided into two major classes, primary and secondary.**
  - Primary batteries are used once and discarded because their chemical reactions are irreversible.
  - Secondary batteries can be recharged and reused many times because they are characterized by reversible chemical reactions
  - primary and secondary batteries are available in a variety of shapes and sizes. Some of the sizes that you are most familiar with are AAA, AA, C, D, and 9 V but there are many others that are less common. Batteries are also typed according to their chemical makeup.

Types of DC Voltage Sources



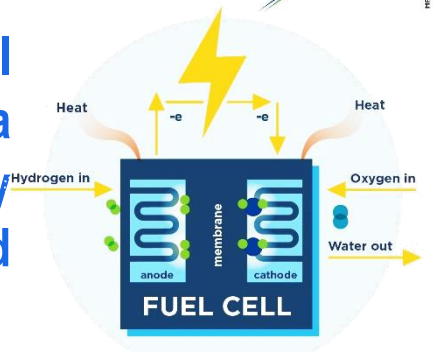


Types of DC Voltage Sources



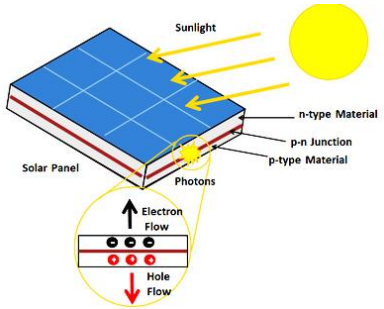
Fuel Cells

- A fuel cell is a device that converts electrochemical energy into dc voltage directly. Fuel cells combine a fuel (usually hydrogen) with an oxidizing agent (usually oxygen). In the hydrogen fuel cell, hydrogen and oxygen react to form water.



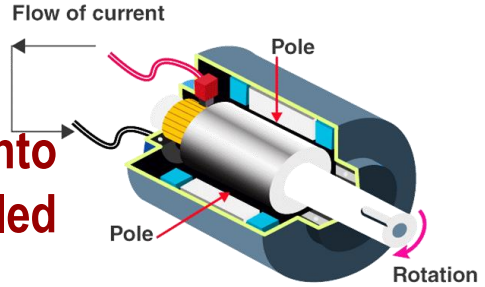
Solar Cells

- The operation of solar cells is based on the photovoltaic effect, which is the process whereby light energy is converted directly into electrical energy. The most common type of solar cell is the crystalline silicon cell



DC Generator

- Electrical generators convert mechanical energy into electrical energy using a principle called electromagnetic induction



Types of DC Voltage Sources

- **The Electronic Power Supply**
  - Electronic power supplies convert the ac voltage from a wall outlet to a dc voltage that can be varied over a specified range.

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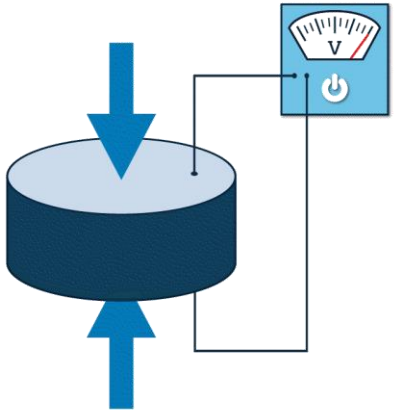
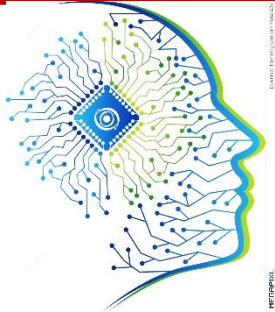
- **Piezoelectric Sensors**
  - These sensors act as voltage sources and are based on the piezoelectric effect where a voltage is generated when a piezoelectric material is mechanically deformed by an external force.



Power and Energy



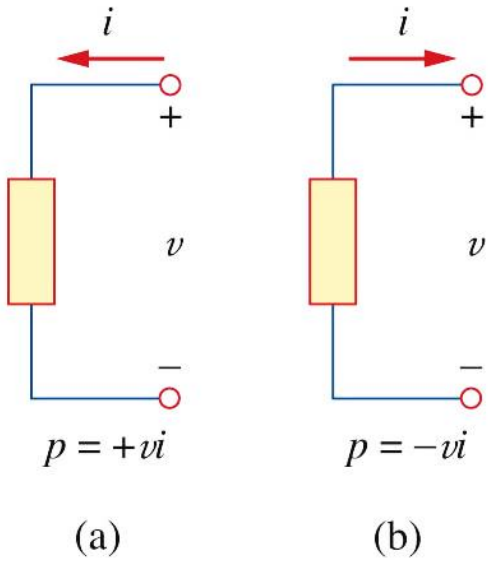
- Voltage alone does not equal power.
- It requires the movement of charge, that is, a current.
- Power is the product of voltage and current.

$$p = vi$$

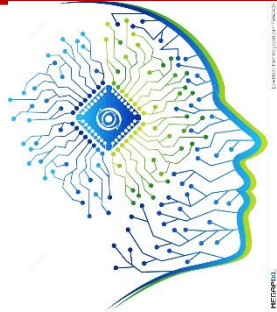
- It is equal to the rate of energy provided or consumed per unit time.
- It is measured in Watts (W).

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.

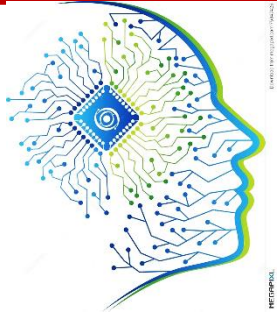


Conservation of Energy



- 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.

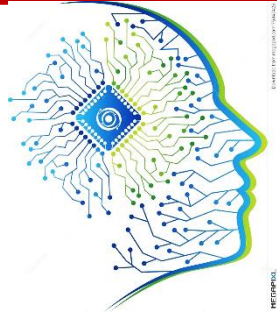
Resistance



Resistance is the opposition to current.

- Resistance is expressed in ohms, symbolized by the Greek letter omega (Ω).
- One ohm (1 Ω) of resistance exists if there is one ampere (1 A) of current in a material when one volt (1 V) is applied across the material.
- **Conductance** The reciprocal of resistance is conductance, symbolized by G. It is a measure of the ease with which current is established.

Resistors



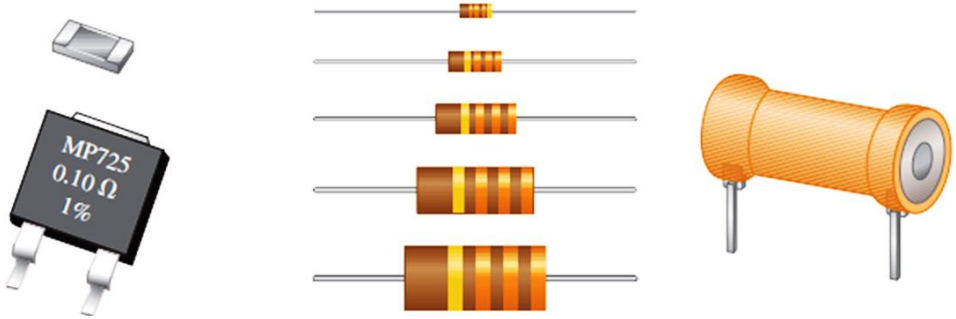
A component that is specifically designed to have a certain amount of resistance is called a resistor.

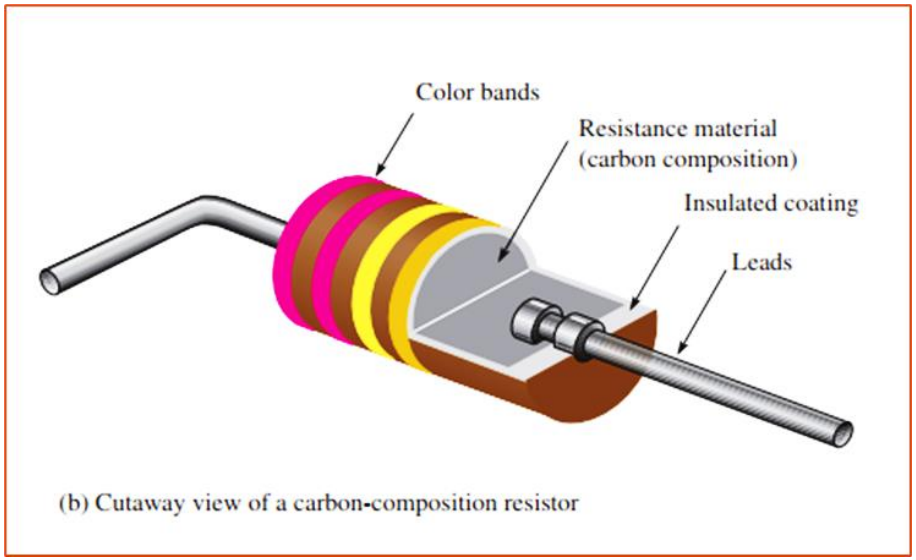
- The principal applications of resistors are to limit current in a circuit, to divide voltage, and, in certain cases, to generate heat.

- Although resistors come in many shapes and sizes, they can all be placed in one of two main categories: fixed or variable.

Fixed Resistors

- **Fixed resistors** are available with a large selection of resistance values that are set during manufacturing and cannot be changed easily

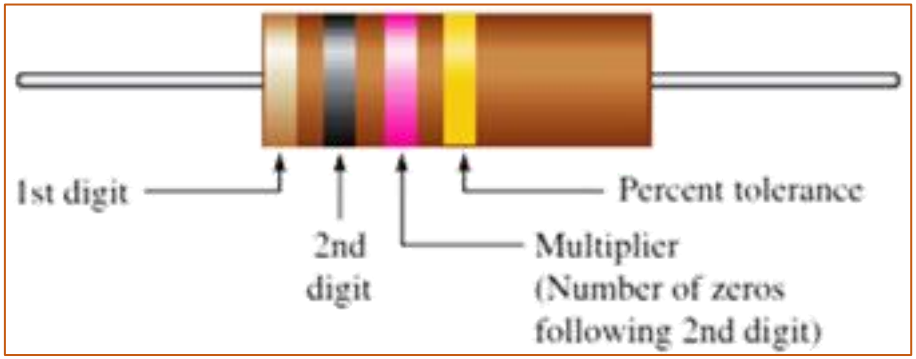




(b) Cutaway view of a carbon-composition resistor

Resistor Color Codes

- Fixed resistors with value tolerances of 5% or 10% are color coded with four bands to indicate the resistance value and the tolerance.



- The color code is read as follows:
  1. The first band is the first digit of the resistance value.
  2. The second band is the second digit of the resistance value.
  3. The third band is the number of zeros following the second digit, or the multiplier. The multiplier is actually a power of ten multiplier; thus a black band in the third position represents multiplying by 100 or 1.
  4. The fourth band indicates the percent tolerance and is usually gold or silver.

Resistor Color Codes

- **For example,**

a 5% tolerance means that the actual resistance value is within ;5% of the color-coded value. Thus, a 100 Ω resistor with a tolerance of ;5% can have an acceptable range of values from a minimum of 95 Ω to a maximum of 105 Ω.

	DIGIT	COLOR
Resistance value, first three bands: First band—1st digit Second band—2nd digit Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

EXAMPLE

2–4 Find the resistance value in ohms and the percent tolerance for each of the color-coded resistors shown in Figure 2–28.

▲ FIGURE 2–28

Solution

(a) First band is red = 2, second band is violet = 7, third band is orange = 3 zeros, fourth band is silver = 10% tolerance.

$$R = \mathbf{27{,}000\ \Omega\ \pm 10\%}$$

(b) First band is brown = 1, second band is black = 0, third band is brown = 1 zero, fourth band is silver = 10% tolerance.

$$R = \mathbf{100\ \Omega\ \pm 10\%}$$

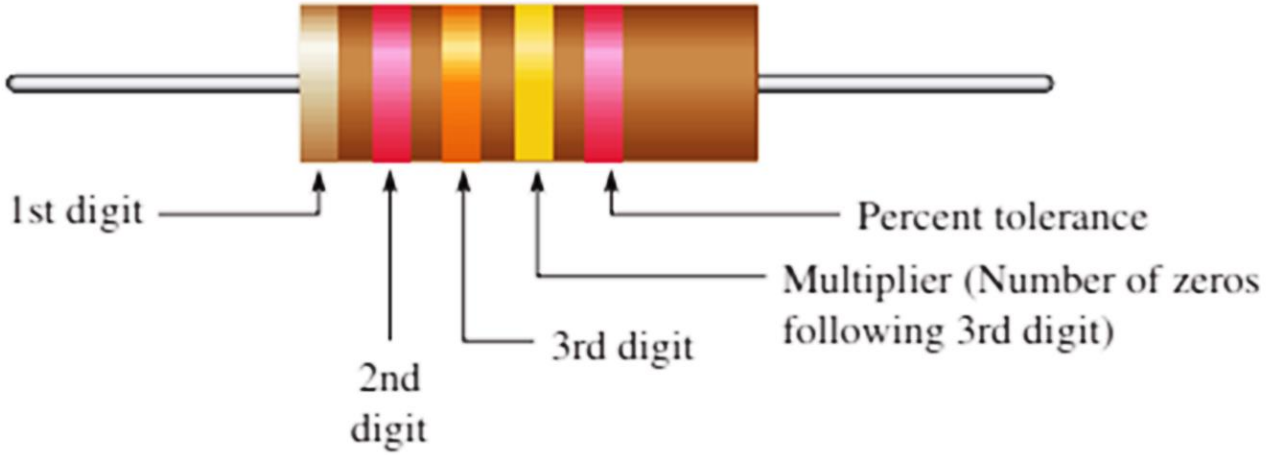
(c) First band is green = 5, second band is blue = 6, third band is green = 5 zeros, fourth band is gold = 5% tolerance.

$$R = \mathbf{5{,}600{,}000\ \Omega\ \pm 5\%}$$

Related Problem A certain resistor has a yellow first band, a violet second band, a red third band, and a gold fourth band. Determine its value in ohms and its percent tolerance.

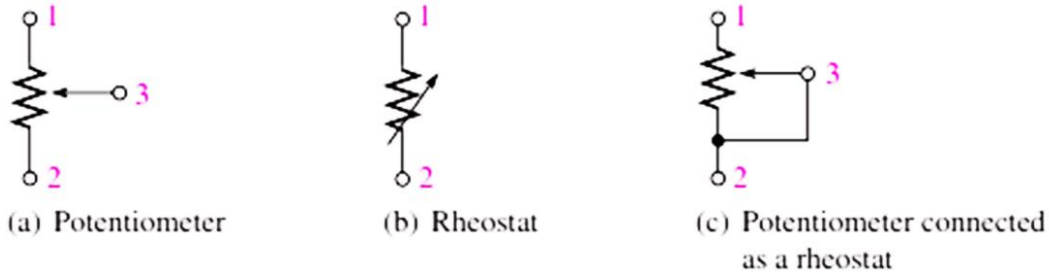
Five-Band Color Code

- Certain precision resistors with tolerances of 2%, 1%, or less are generally color coded with five bands, as shown. Begin at the band closest to one end.



Variable Resistors

- Variable resistors are designed so that their resistance values can be changed easily. Two basic uses for variable resistors are to divide voltage and to control current. The variable resistor used to divide voltage is called a potentiometer. The variable resistor used to control current is called a rheostat.

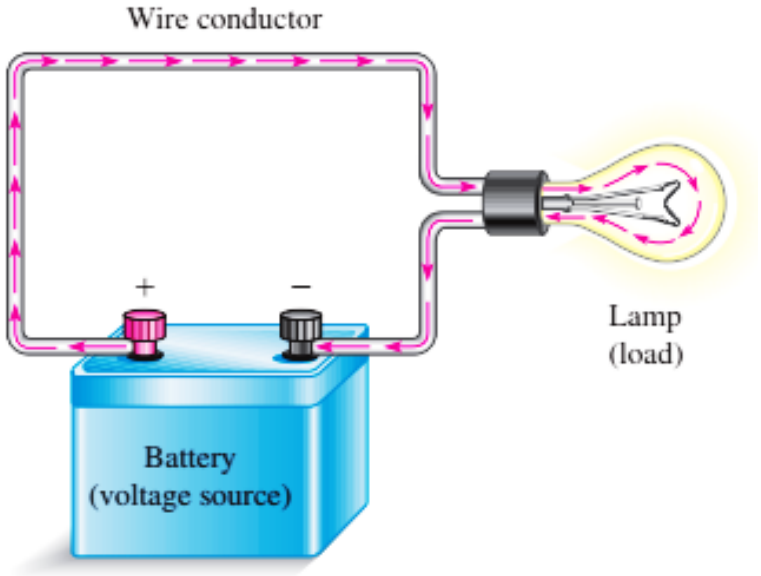


(a) Potentiometer (b) Rheostat (c) Potentiometer connected as a rheostat

Electric Circuit

- A basic electric circuit is an arrangement of physical components that use voltage, current, and resistance to perform some useful function.
- The Basic Circuit

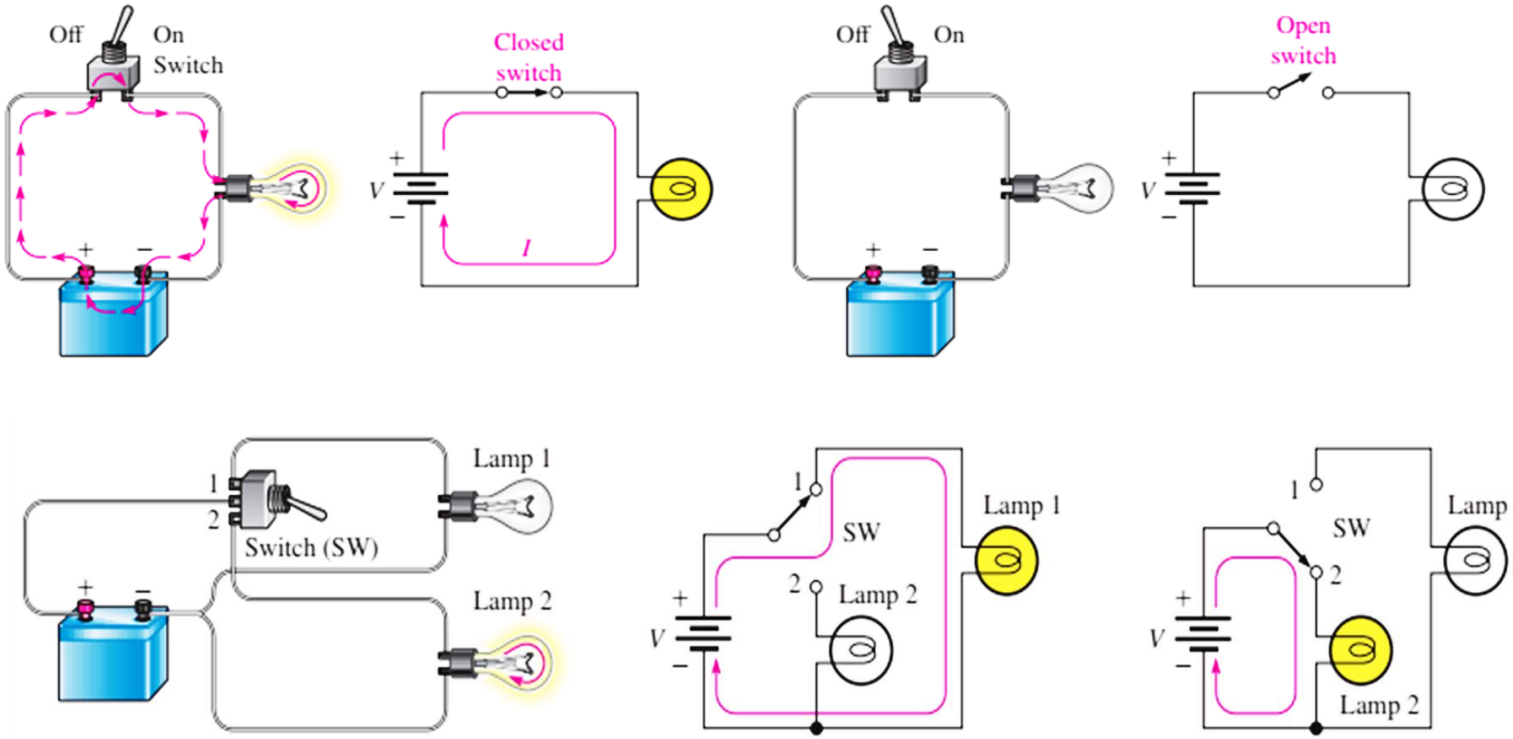
- Basically, an electric circuit consists of a voltage source, a load, and a path for current between the source and the load.



Electric Circuit

Mechanical Switches

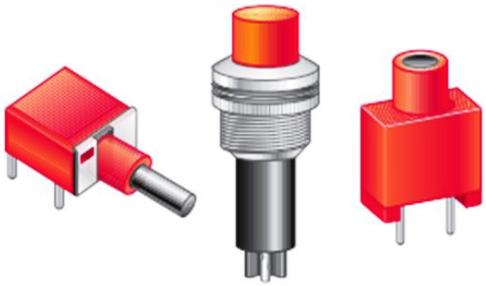
- Switches are commonly used for controlling the opening or closing of circuits. For example, a switch is used to turn a lamp on or off,



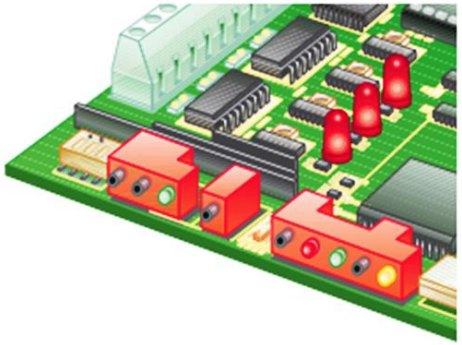
Mechanical Switches

Toggle switch

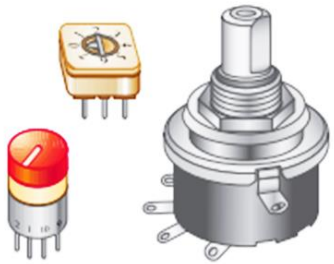
Rocker switch



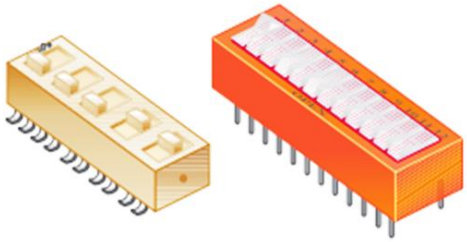
Push-button switches



PC board mounted push-button switches



Rotary switches



DIP switches for mounting on PC boards

Protective Devices

- Fuses and circuit breakers are used to deliberately create an open circuit when the current exceeds a specified number of amperes due to a malfunction or other abnormal condition in a circuit.
- For example, a 20 A fuse or circuit breaker will open a circuit when the current exceeds 20 A

The basic difference between a fuse and a circuit breaker

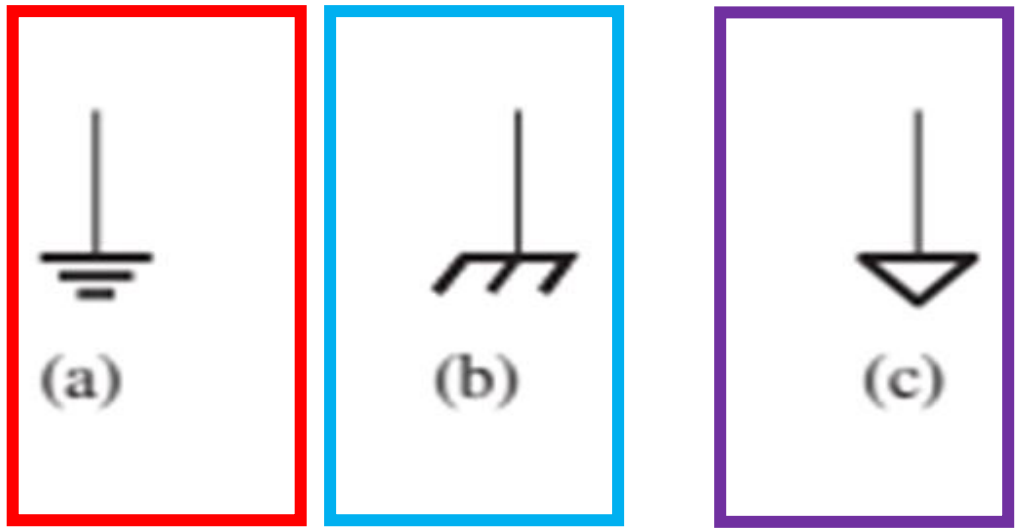
- is that when a fuse is "blown," it must be replaced; but when a circuit breaker opens, it can be reset and reused repeatedly.

Ground

- Ground is the reference point in electric circuits

Chassis ground

Earth ground



Signal ground

Commonly used ground symbols.