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القائم بالتدريس

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Alternating Current (AC)

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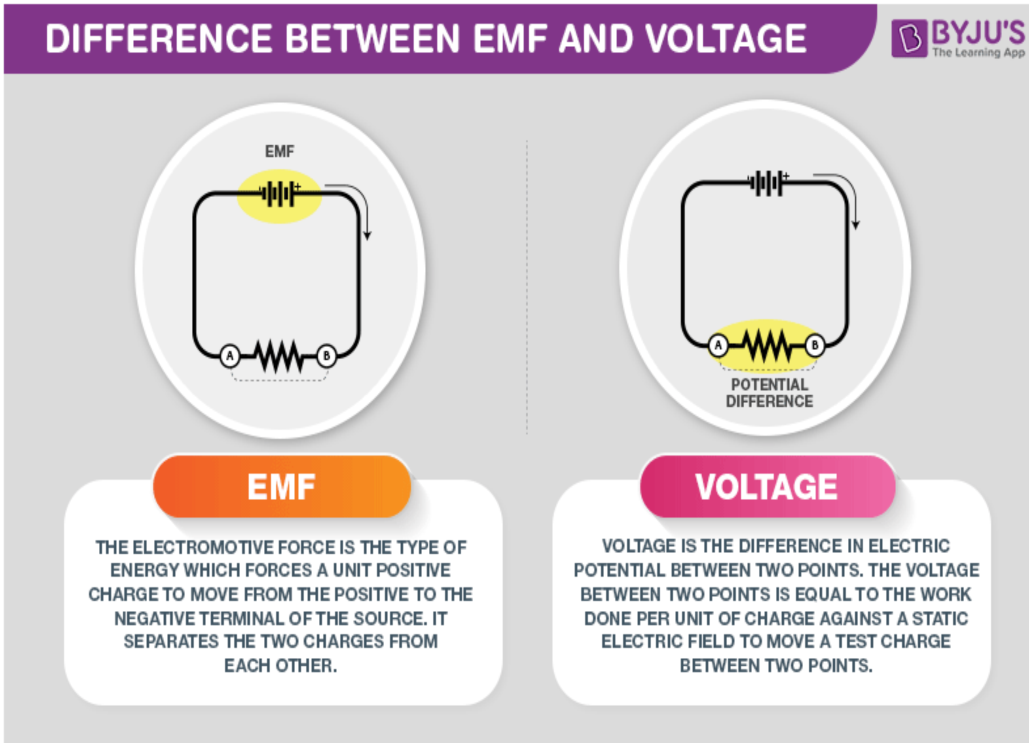
Current Electricity

Many inventions and discoveries have been made in order to facilitate human life smoothly. The discovery of current electricity is one such discovery that we are highly dependent on to make our life easier. Benjamin Franklin is credited with the discovery of electricity.

What is Current Electricity?

Current electricity is defined as the flow of electrons from one section of the circuit to another.

Electromotive Force (EMF) and Voltage:



When two bodies at different potentials are linked with a wire, free electrons stream from Point 1 to Point 2, until both the objects reach the same potential, after which the current stops flowing. Until a potential difference is present throughout a conductor, current runs.

From the above analogy, we can define electromotive force and voltage as follows:

Electromotive Force Definition: Electromotive force is defined as the electric potential produced by either an electrochemical cell or by changing the magnetic field.

Voltage Definition: Voltage is defined as the electric potential difference between two points.

Types of Current Electricity

There are two types of current electricity as follows:

- Direct Current (DC)
- Alternating Current (AC)

Direct Current

The current electricity whose direction remains the same is known as direct current. Direct current is defined by the constant flow of electrons from a region of high electron density to a region of low electron density. DC is used in many household appliances and applications that involve a battery.

Alternating Current

The current electricity that is bidirectional and keeps changing the direction of the charge flow is known as alternating current. The bidirectionality is caused by a sinusoidally varying current and voltage that reverses directions, creating a periodic back and forth motion for the current. The electrical outlets at our home and industries are supplied with alternating current.

Generation of Current Electricity

Current electricity can be generated by the following methods:

- By moving a metal wire through a magnetic field (Both alternating current and direct current can be generated by the following method)
- By a battery through chemical reactions (Direct current can be generated through this method)

Ampere

Ampere is the unit that we use to quantify the current flowing in a system. An ampere is equivalent to a charge of one Coulomb per second.

What is Ampere?

Ampere is named after the French Physicist and Mathematician Andre-Marie Ampere. One ampere of current represents one coulomb of electrical charge, i.e. 6.24×10^{18} charge carriers, moving in one second. In other words, an ampere is the amount of current produced by the force of one volt acting through a resistance of one ohm.

Ampere is defined as the unit of electric current that is equal to the flow of one Coulomb per second.

The relationship between ampere and coulomb is represented as follows:

Ampere = 1 Coulomb / Second

At any given point in an area experiencing current, if the charge on particles moving through it increases, the Ampere value will increase proportionately.

Table of Ampere Unit Prefixes

A huge range of electric current values is encountered in electrical and electronic engineering. An electric current value can be lower than 0.01 A or higher than 1000 A. By using multiples and submultiples of the standard unit we can avoid writing too many zeroes to define the position of the decimal point. The table below lists some of the commonly used ampere unit prefixes.

Name	Symbol	Conversion	Example
microampere(microamps)	µA	1 µA = 10^{-6}A	I = 40 µA = 40 × 10^{-6}A
milliampere(milliamps)	mA	1 mA = 10^{-3}A	I = 2 mA = 2 × 10^{-3} A
ampere (amps)	A	–	I = 20 A
kiloampere(kiloamps)	kA	1 kA = 10^{3}A	I = 4 kA = 4 × 10^{3} A

Ampere Conversion

Unit conversion is crucial in solving problems. Below we have listed examples of ampere conversions from one scale to another.

Conversion of amps (A) to kiloamps (kA)

One kiloamp (kA) is equal to a thousand amps (A).

1 kA = 1000 A or 1×10^3 A

For example, 5 amperes of current can be converted to kiloamperes as follows:

5 A × 1000 = 5000 A or 5 kA

Conversion amps (A) to milliamps (mA)

One milliampere is equal to 1000 amperes.

1 mA = 1000 A

For example, 2 A to milliampere is converted as follows:

2 A/1000 = 0.002 A or 2×10^{-3} A = 2 mA

Conversion of amps (A) to microamps (µA)

One Ampere is equal to 1000000 or 10^{-6} microamperes.

1 µA = 1000000 A

For example, 5 A is converted to microamps as follows:

5 A / 1000000 = 0.000005 A or 5×10^{-6} A = 5 µA

Conversion of Watt, Volt, and Ohm into Ampere

The electric current value can be calculated by knowing the values of voltage, power and resistance.

Calculation of Amps with Watts and Volts

The power of the circuit is given by the following formula:

P (Watt) = V (Volt) × I (Ampere)

Rearranging the above equation, we can calculate the value of electric current as follows:

I (Ampere) = P (Watt) / V (Volt)

Solved Example:

What is the current flow in a circuit that consumes 50 W of power and has a supply voltage of 10 V?

Using the equation, we can calculate the current as follows:

I (A) = 50 W/10 V = 5 A

Calculation of Amps with Volts and Ohms

The resistance of a circuit is calculated using the following formula:

V (Volt) = I (Ampere) × R (Ohm)

Rearranging the above formula, we can calculate the value of electric current as follows:

I (Ampere) = V (Volt) / R (Ohm)

Solved Example:

What is the current in a circuit having a voltage of 25 V with a resistance of 5 Ω?

Using the above equation, we can calculate the value of current as follows:

I = 25 V/5 Ω = 5 A

Ampere Meter/Ammeter

Ampere meter, commonly known as Ammeter is an electrical instrument used to measure electrical current in Amperes. The electrical current on the load is measured with the help of Ampere meter by connecting it in series to the load. It has zero resistance and so measured circuit remains unaffected.

What happens when an ammeter is connected in parallel to load?

The ammeter cannot be connected in parallel to the load because of its low resistance. If it is connected in parallel it becomes a short circuit path allowing all the current to flow through it which may lead to the burning of meter due to the high value of current. An ideal ammeter has zero impedance so that the power loss in the instrument is zero. But this ideal condition is not achievable practically.

Types of Ammeter

The classification of the ammeter is based on the construction design and the type of current that flows through the ammeter.

Based on the design of construction it is classified as follows:

- Moving iron ammeter
- Rectifier type ammeter
- Permanent moving coil ammeter
- Electro-dynamometer ammeter

Based on the type of current that flows through it, it is classified as follows:

- DC ammeter
- AC ammeter

The DC ammeters are mostly permanent moving coil type ammeter. The other types of ammeter can measure both AC and DC current.

Unit of Voltage

Voltage, current, and resistance are the most common terminologies we hear in physics. Current is referred to as the flow of electric charge carriers. Resistance is the measure of the opposition to the flow of electric current in an electrical circuit. Voltage is also referred to as electric potential difference, electric pressure or electric tension. In this article, let us learn voltage definition, SI unit of voltage, and other electrical units.

Voltage Definition and Formula

As per voltage definition, it is the difference in the electric potential between two points. It is the work done in moving a charge from one pole to another through a wire. To determine the voltage between any two points, both a static electric field and a dynamic electromagnetic field is considered.

The mathematical representation of voltage is as follows:

$$V = IR$$

Where,

- V is the voltage in volts
- I is the current in amperes
- R is the resistance in ohms

Symbol of voltage	**V, ΔV**
SI unit of voltage	Volt
Dimension of voltage	$ML^2T^{-3}I^{-1}$

SI Unit of Voltage

After knowing the voltage definition and voltage formula, let us learn the SI unit of voltage. The standard unit of measurement used for the expression of voltage is volt which is represented by the symbol v. However, the volt is a derived SI unit of electric potential or electromotive force. For this reason, volt can further be defined in several ways.

Volt can also be defined as electric potential along a wire when an electric current of one ampere dissipates one watt (W) of power (W = J/s).

$$V = W/A$$

Volt can be expressed as the potential difference between two points in an electric circuit that imparts one joule (J) of energy per coulomb (C) of charge that passes through the circuit.

$$V = \frac{\text{potential energy}}{\text{charge}} = \frac{J}{C} = \frac{kg{\cdot}m^2}{A{\cdot}s^3}.$$

It can also be expressed as amperes times ohms, joules per coulomb (energy per unit charge), or watts per ampere (power per unit current).

$$V = A{\cdot}\Omega = \frac{W}{A} = \frac{J}{C}$$

And finally, volt can be stated in SI base units as 1 V = 1 kg m^2 s^{-3} A $^{-1}$ (one-kilogram meter squared per second cubed per ampere).

Other Electrical Units

Some of the other electrical units are given below.

Electrical Parameter	Measuring Unit	Symbol
Voltage	Volt	V or E
Resistance	Ohm	R or Ω
Capacitance	Farad	C
Charge	Coulomb	Q
Inductance	Henry	L or H
Power	Watts	W
Impedance	Ohm	Z
Frequency	Hertz	Hz
Conductance	Siemen	G or ℧

Electromotive Force

What is Electromotive Force?

Electromotive force is defined as *the electric potential produced by either electrochemical cell or by changing the magnetic field.* EMF is the commonly used acronym for electromotive force.

A generator or a battery is used for the conversion of energy from one form to another. In these devices, one terminal becomes positively charged while the other becomes negatively charged. Therefore, an electromotive force is a work done on a unit electric charge.

Electromotive force is used in the electromagnetic flowmeter which is an application of Faraday's law.

Symbol for Electromotive Force

The electromotive force symbol is ε.

What is Electromotive Force Formula?

Following is the formula for electromotive force:

$$\varepsilon = V + Ir$$

Where,

- V is the voltage of the cell
- I is the current across the circuit
- r is the internal resistance of the cell
- ε is the electromotive force

What is the unit of EMF?

The **unit for electromotive force is Volt.**

EMF is numerically expressed as the number of Joules of energy given by the source divided by each Coulomb to enable a unit electric charge to move across the circuit.

Volts=Joules /Coulombs

Dimension of Electromotive Force

EMF is given as the ratio of work done on a unit charge which is represented as follows:

EMF=Joules /Coulombs

Therefore, EMF dimension is given as $\mathbf{M^{1}L^{2}T^{-3}I^{-1}}$

Difference between Electromotive Force and Potential Difference

Electromotive Force	**Potential Difference**
EMF is defined as the work done on a unit charge	Potential difference is defined as the energy which is dissipated as the unit charge pass through the components
EMF remains constant	Potential difference is not constant
EMF is independent of circuit resistance	The potential difference depends on the resistance between the two points during the measurement
Due to EMF, electric, magnetic, and the gravitational field is caused	Due to the potential difference, the only electric field is induced
It is represented by E	It is represented by V

Can electromotive force be negative?

Yes, the electromotive force can be negative. Consider an example where an inductor is generating the EMF such that it is opposing the incoming power. Then the produced EMF is taken as negative as the direction of flow is opposite to the real power. Therefore, the electromotive force can be negative.

Relation Between Watt and Volt

Named after James Watt, Watt is the unit of power. In terms of electromagnetism, it is the current flow of one ampere with a voltage of 1 volt. A volt is a derived unit for electric potential, electromotive force, and electric potential difference. The relation between watt and volt is direct. This implies that change in the value of watt will reflect in the change in the value of volt.

Watt and Volt

In physics, the relation between watt and volt can be written as:

1 watt = 1 ampere × 1 volt

1volt=1watt 1ampere

Where,

- Watt is the measure of power.
- Volt is the measure of electric potential.
- Ampere is the measure of current.

Volt is the measure of potential difference within two terminal of a conducting wire.
Watt is the rate at which electrical work is performed when a current of one ampere flows across the potential difference of one volt.

The relation between watt and volt are proportionate. That is watt is directly proportional to volt. Which implies that-

- When the electric power in terms of watt increases, the electric potential in terms of volt also increases keeping electric current constant.
- When the electric power in terms of watt decreases, the electric potential in terms of volt also decreases keeping electric current constant.

AC and DC

The formula for watt and volt changes for alternating current and direct current is given below:

Current Type	Formula	Terms
AC	$P_W = PF \times V_V \times I_A$	P_W is Power in watt
		PF is Power Factor
		V_V is voltage in volts
		I_A is current in ampere
DC	$P_W = V_V \times I_A$	P_W is Power in watt
		V_V is voltage in volts
		I_A is current in ampere

Electric Field Lines

What is Electric Field Line?

Electric field lines are an excellent way of visualizing electric fields. They were first introduced by Michael Faraday himself.

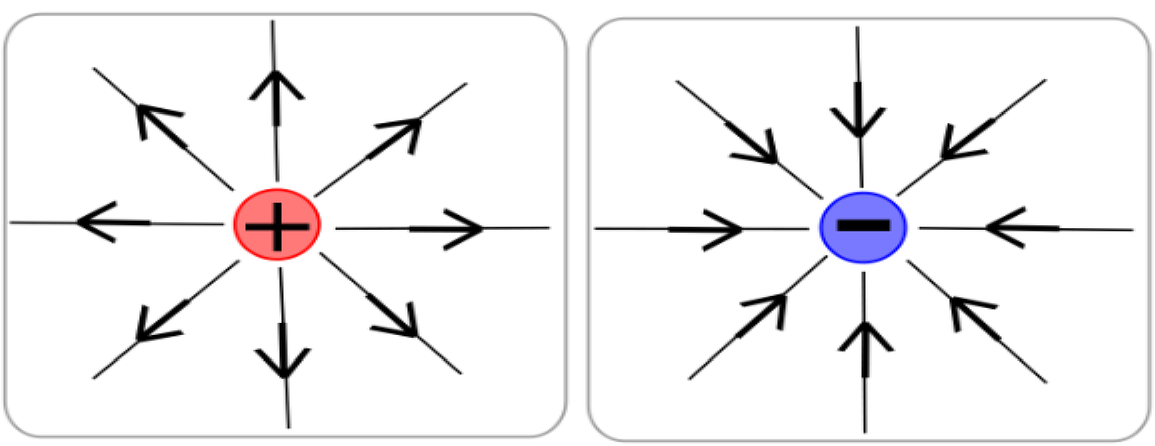
A field line is drawn tangential to the net at a point. Thus at any point, the tangent to the electric field line matches the direction of the electric field at that point. Secondly, the relative density of field lines around a point corresponds to the relative strength (magnitude) of the electric field at that point. In other words, if you see more electric field lines in the vicinity of point A as compared to point B, then the electric field is stronger at point A.

Properties of Electric Field Lines

- The field lines never intersect each other.
- The field lines are perpendicular to the surface of the charge.
- The magnitude of charge and the number of field lines, both are proportional to each other.
- The start point of the field lines is at the positive charge and end at the negative charge.
- For the field lines to either start or end at infinity, a single charge must be used.

Electric Field Lines Attraction and Repulsion

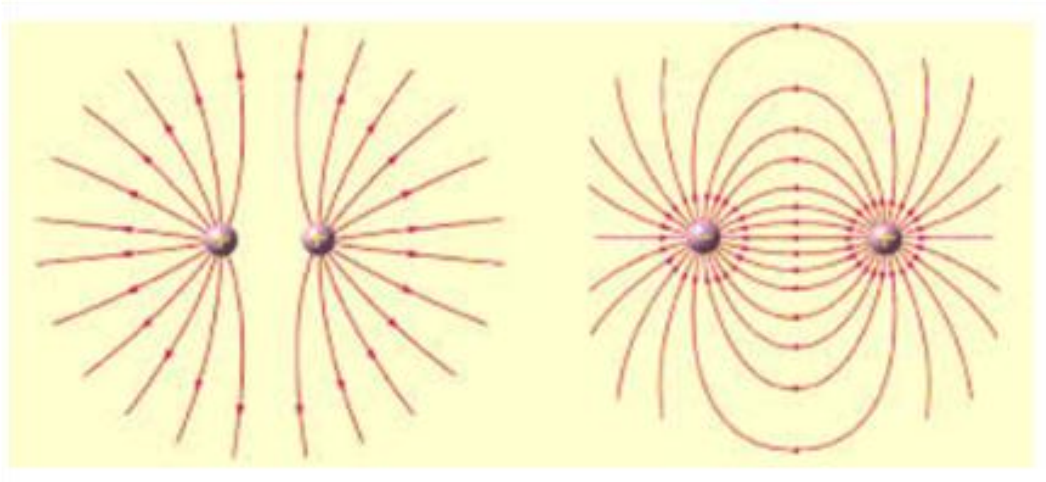
Electric field lines always point away from a positive charge and towards a negative point. In fact, electric fields originate at a positive charge and terminate at a negative charge.



Electric field of point charges

Also, field lines never cross each other. If they do, it implies that there are two directions for the electric field at that point. But this is impossible since electric fields add up vectorially at any point and remember that “A field line is drawn tangential to the net electric field at a point”. Thus, electric field lines can never intersect one another.

As said before field lines are a great way to visualize electric fields. You can almost feel the attraction between unlike charges and the repulsion between like charges as though they are trying to push each other away.



Electric field on the left image explains how like charges repel and right image explains how unlike charges attract

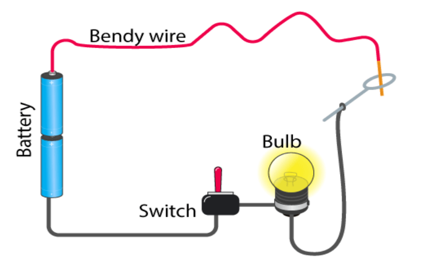
Coming to our initial example of static charge on hair, the direction in which charged hair stands up traces the local electric field lines. The charges on the hair exert forces on the hair strand as they attempt to leak into the surrounding uncharged space. The hair aligns accordingly so that there is no net force acting on it and inadvertently traces the electric field lines.

Rules for Drawing Electric Field Lines

Following are the rules for drawing electric field lines:

1. The field line begins at the charge and ends either at the charge or at infinity.
2. When the field is stronger, the field lines are closer to each other.
3. The number of field lines depends on the charge.
4. The field lines should never crossover.
5. Electric field and electric field line are tangent at the point where they pass through.

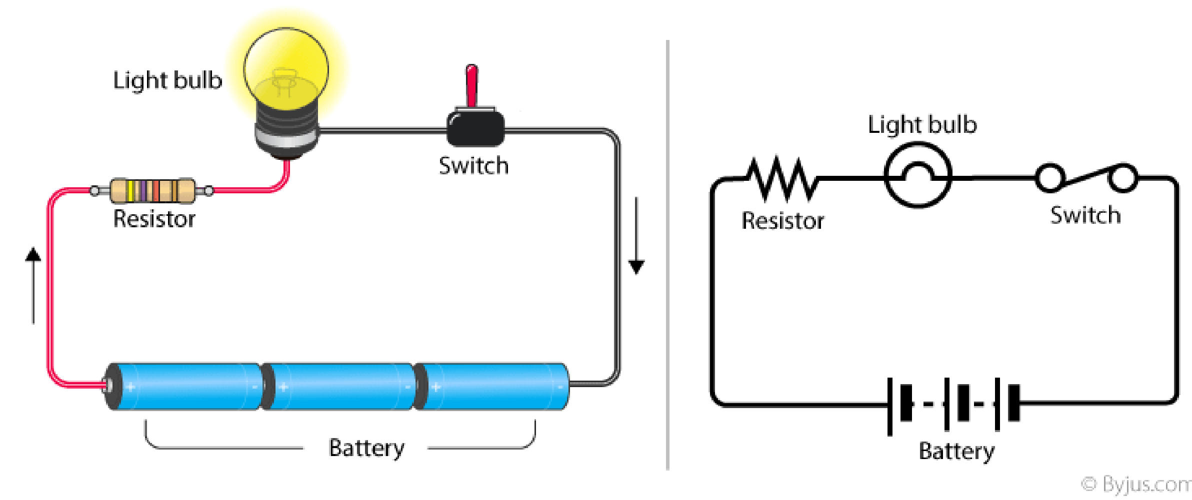
Electric Circuit and Electrical Symbols



We know there are various components needed to build an electrical circuit. To understand the electrical circuit completely and to know the flow of current one must understand the electrical symbols of circuit components. In this session, let us discuss in brief about electrical symbols of circuit components.

What is an Electric Circuit?

A system of conducting elements that are designed to conduct electric current for a particular purpose is known as an electric circuit. An electric circuit consists of a source of electrical energy; elements that either transform, dissipate, or store this energy; connecting wires. To prevent power overload, circuits often include fuse or circuit breaker.



A Short History of Circuits and Systems

The first electric circuit was invented by Alessandro Volta in 1800. Volta discovered that he could produce a steady flow of electricity using bowls of salt solution connected by metal strips. Later, he used alternating discs of copper, zinc, and cardboard that had been soaked in a salt solution to create his voltaic pile (an early battery). He successfully made the electric current to flow through the circuit by attaching a wire running from top to bottom. The first practical use of electric current was employed in electrolysis, which further led to the development of new chemical elements.

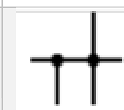
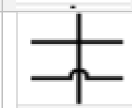
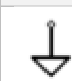
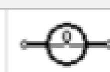
Components of an Electric Circuit

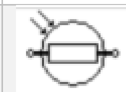
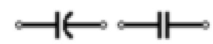
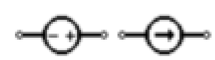
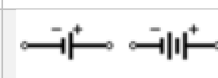
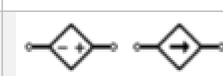
Electric circuits are amazing. Have you ever seen the game of Steady Hands? It is a circuit with a twisty wire between two points. The point of the game is to move a metallic object from one end of the electric wire to the other. If you touch the wire while moving this metallic object, the circuit buzzes and you are out. It's a really fun game that can be made with stuff you can find at home. Let's analyze an electric circuit and dive deeper into its components.

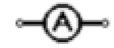
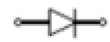
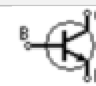
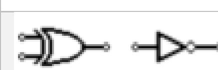
List of Electrical Components with Symbols

Electrical symbols are a graphical representation of electrical and electronic components. These symbols help us recognize a particular electronic device in a circuit. Electrical symbols are defined with national and international standards. These symbols only represent the components of electrical and electronic circuits and do not define their function or process.

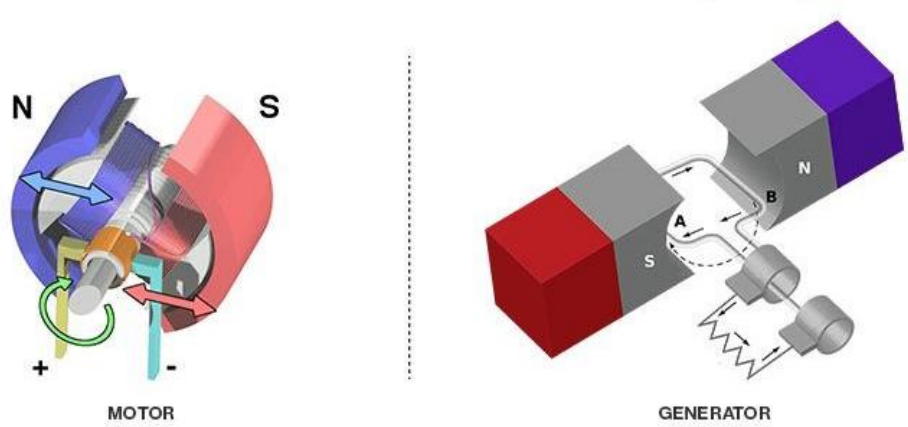
Let us have a look at how various components in a circuit are denoted:

Wire Symbols		
Name of the Component	***Component Description***	***Symbol***
Electrical Wire	*A wire is a single, usually cylindrical, flexible strand or rod of metal through which electric current flows. It is usually made of good conducting metals such as copper.*	
Connected Wire	*Connecting wires provide a medium to an electrical current so that they can travel from one point on a circuit to another.*	
Not Connected Wire	*In diagrams, we come across situations where we have wires crossing through other wires even though they are not connected to each other. Hence, it is preferred to have a hump as shown to depict the crossing of wire over another wire.*	
Ground Symbols		
Earth Ground	*The reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the earth.*	
Chassis Ground	*Chassis ground is the metal housing that some electrical device is encased in. The chassis may be connected to the green ground wire of your power lines.*	
Digital/Common Ground	*The reference voltage of digital logic ICs. This means that no analog signals are coupled into this reference plane.*	
Light Bulb Symbol		
Lamp/ Lightbulb	*It is a load that uses electric current to emanate light*	

Resistor Symbols		
Resistor (IEE)/(IEC)	*A resistor is a device that resists the flow of current through a circuit*	
Variable Resistor/ Rheostat (IEE)/(IEC)	• *A variable resistor is a resistor whose electrical resistance can be adjusted.* • *A rheostat is a variable resistor whose resistance can be varied to control the current in the circuit.*	
Potentiometer (IEE)/(IEC)	*A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider.*	
Photoresistor/ Light-dependent resistor (LDR)	*Photoresistor decreases resistance with respect to receiving luminosity*	
Thermistor	*A thermistor is a type of resistor whose resistance is dependent on temperature*	
Capacitor Symbols		
Capacitor	*A capacitor is a device that stores electrical energy in an electric field.*	
Variable Capacitor	*A variable capacitor is a capacitor whose capacitance may be intentionally and repeatedly changed mechanically or electronically.*	
Polarized Capacitor	*A capacitor whose anode is made of a metal that forms an insulating oxide layer through anodization.*	
Power Supply		
Voltage Source/ Current Source	*A voltage source is an electrical component that can maintain a fixed voltage irrespective of the load resistance and output current*	
Battery Cell/ Battery	*A battery is a device that consists of two or more electrochemical cells with external connections.*	
AC Voltage Source	*It is a source hose positive and negative terminals change periodically*	
Controlled Voltage Source/ Controlled Current source	• *A current-controlled voltage source produces a voltage that is linearly proportional to current.* • *A controlled or dependent current source, on the other hand, changes its available current depending upon the voltage.*	
Meter Symbols		

Voltmeter	*An instrument for measuring electrical potential.*	
Ammeter	*An instrument for measuring electric current.*	
Diode Symbols		
Diode	*A semiconductor device with two terminals that allows current to flow only in one direction.*	
Zener Diode	*A diode that allows the flow of reverse current when it reaches a certain Zener voltage.*	
Schottky Diode	*A diode formed by the junction of a semiconductor with a metal.*	
Verica Diode	*A type of diode designed to exploit the voltage-dependent capacitance of a reverse-biased p–n junction*	
Photodiode	*A type of a semiconductor device that converts light into an electrical current.*	
Transistor Symbols		
NPN Bipolar Transistor	*The transistor in which one p-type material is placed between two n-type materials*	
PNP Bipolar Transistor	*The transistor in which one n-type material is placed between two p-type materials*	
Logic Gates Symbol		
OR/NOR Gate	• *OR gate performs a logical operation which gives the value one if at least one operand has the value one, and otherwise gives a value of zero.* • *NOR gives the value one if and only if all operands have a value of zero and otherwise has a value of zero.*	
AND/NAND Gate	• *AND gate gives the value one if and only if all the operands are one, and otherwise has a value of zero.* • *NAND gate gives the value zero if and only if all the operands have a value of one, and otherwise has a value of one*	
XOR/ NOT Gate	• *XOR gate is a digital logic gate that gives a true output when the number of true inputs is odd.* • *NOT gate is a logic gate which implements logical negation.*	

Difference Between Motor and Generator



Difference between motor and generator is probably the most common question from the electricity topic of physics. In this article, the main differences between electric motor and generator are given here. The motor and generator difference given here is in tabular form for better understanding and clarity.

Before moving to the differences between a motor and generator, it is important to know what they are. Their functions, structure and other related details.

Difference between Motor and Generator

Sl. No.	Differentiating Property	Motor	Generator
1	Definition	An electric motor is a machine that converts electrical energy to mechanical energy.	An electric generator is a machine that converts mechanical energy to electrical energy.
2	Rule	Electric motor follows Fleming's left-hand rule.	Electric generator follows Fleming's right-hand rule.
3	Principle	The working principle of a motor is based on the current-carrying conductor that experiences a force when it is kept in the magnetic field.	The working principle of generator is based on electromagnetic induction.
4	Driving force for shaft	The shaft of an electric motor is driven by a magnetic force which is developed between the armature and field.	The shaft of an electric generator is connected to the rotor which is driven by a mechanical force.
5	Current Usage	In a motor, current is supplied to the armature winding.	In a generator, current is produced in the armature

			winding.
6	Example	Ceiling fans, cars, etc. are all examples of motor.	In power stations, generator is used to generate electricity.

These were the main motor and generator differences that can be asked in the exams. Students aspiring for engineering courses are required to get acquainted completely with the concepts of motors and generators.

AC Generator

From flipping a switch to heating a snack in the microwave, electricity is everywhere. Now that you thought about it, you might wonder how this essential energy source is generated and how it arrives at your doorstep.

Electricity is produced in power stations using turbines and generators. A turbine converts available energy into the rotation while electric generators convert rotation into electricity. Based on the electric output of the generators, they are classified into two types as AC Generators and DC Generators. This article will discuss the working principle and parts of an AC generator in detail. You can visit our article on DC Generator if you are interested to learn about the working principle and characteristics of a DC generator.

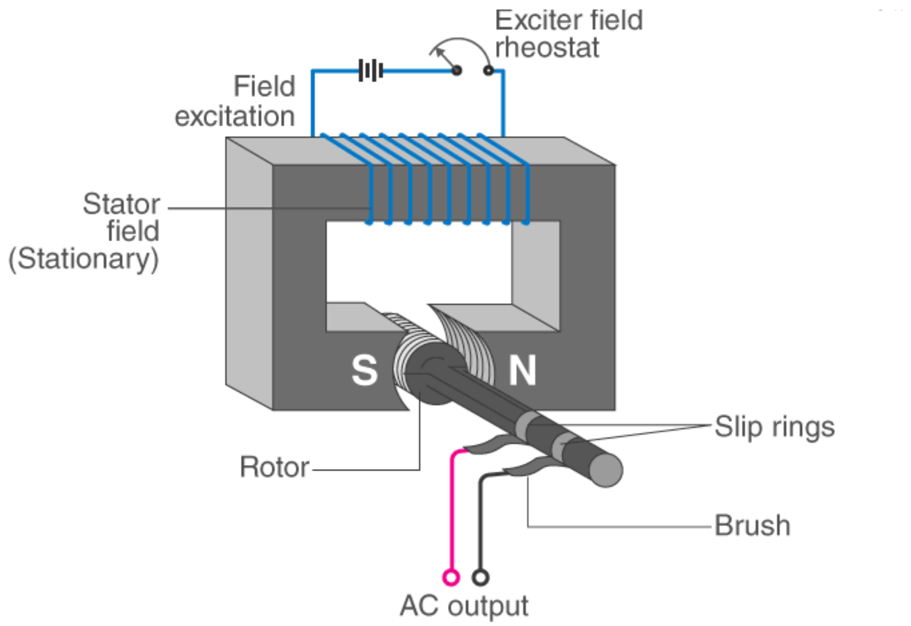
What is an AC Generator?

AC generator is a machine that converts mechanical energy into electrical energy. The AC Generator's input supply is mechanical energy supplied by steam turbines, gas turbines and combustion engines. The output is alternating electrical power in the form of alternating voltage and current.

AC generators work on the principle of Faraday's law of electromagnetic induction, which states that electromotive force – EMF or voltage – is generated in a current-carrying conductor that cuts a uniform magnetic field. This can either be achieved by rotating a conducting coil in a static magnetic field or rotating the magnetic field containing the stationary conductor. The preferred arrangement is to keep the coil stationary because it is easier to draw induced alternating current from a stationary armature coil than a rotating coil.

The generated EMF depends on the number of armature coil turns, magnetic field strength, and the speed of the rotating field.

AC Generator Parts and Function



Basic AC Generator

The various parts of an AC generator are:

- Field
- Armature
- Prime Mover
- Rotor
- Stator
- Slip Rings

The following are the functions of each of these components of an AC generator.

Field

The field consists of coils of conductors that receive a voltage from the source and produce magnetic flux. The magnetic flux in the field cuts the armature to produce a voltage. This voltage is the output voltage of the AC generator.

Armature

The part of an AC generator in which the voltage is produced is known as an armature. This component primarily consists of coils of wire that are large enough to carry the full-load current of the generator.

Prime Mover

The component used to drive the AC generator is known as a prime mover. The prime mover could either be a diesel engine, a steam turbine, or a motor.

Rotor

The rotating component of the generator is known as a rotor. The generator's prime mover drives the rotor.

Stator

The stator is the stationary part of an AC generator. The stator core comprises a lamination of steel alloys or magnetic iron to minimize the eddy current losses.

Slip Rings

Slip rings are electrical connections used to transfer power to and fro from the rotor of an AC generator. They are typically designed to conduct the flow of current from a stationary device to a rotating one.

Working of an AC Generator

When the armature rotates between the poles of the magnet upon an axis perpendicular to the magnetic field, the flux linkage of the armature changes continuously. As a result, an electric current flows through the galvanometer and the slip rings and brushes. The galvanometer swings between positive and negative values. This indicates that there is an alternating current flowing through the galvanometer. The direction of the induced current can be identified using Fleming's Right Hand Rule.

Advantages of AC Generators over DC Generators

Following are a few advantages of AC generators over DC generators:

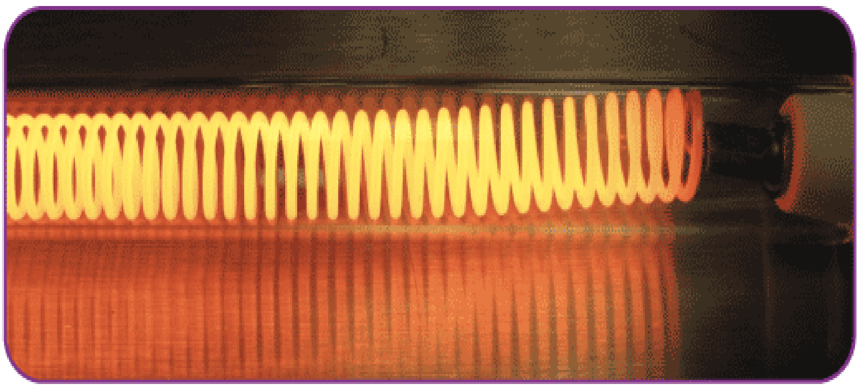
- AC generators can be easily stepped up and stepped down through transformers.
- Transmission link size in AC Generators is thinner because of the step-up feature.
- Losses in AC generators are relatively lesser than in DC machine
- The size of an AC generator is smaller than a DC generator

Most of us begin our study with Direct Current, but eventually, we learn that direct current is not the only type of current we come across. There are sources of electricity that produce voltages and currents which are alternating in nature. This type of current is called an alternating current or an AC

Heating Effect of Electric Current

Introduction:

The heating effect of electric current is widely used in our day-to-day life. The electric iron, kettle, toaster, heater, etc. are used as alternatives to the conventional methods of cooking and laundry. The same is used in electric bulbs which is the alternative of conventional lamps. These devices have revolutionized the world over the years. In this section, we will discuss the concept of the heating effect of electric current and its applications.



Electric coil

When an electric current is passed through a conductor, it generates heat due to the hindrance caused by the conductor to the flowing current. The work done in overcoming the hindrance to the current generates heat in that conductor.

Application:

Following are the devices in which heating effect of current is harnessed for other purposes:

Electric Iron:

Mica is an insulator that is placed between the metal part and the coil in an iron. The coil becomes heated with the passage of current which is then transferred to the metallic part through mica. Finally, the metal part becomes heated which is then used for ironing clothes.

Electric Iron

Electric Bulb:

Electric bulb contains a thick metallic wire made up of tungsten metal. The metal is kept in an inert environment with a neutral gas or vacuum. When current flows through the tungsten wire, it becomes heated and emits light. Most of the electric power drawn in the circuit from the electrical source is dissipated in the form of heat and the rest is emitted in the form of light energy.

Electric Bulb

Electric Heater:

In an electric heater, high resistance nichrome wire is used as a coil. The coil is wound on grooves made up in ceramic material or china clay. When the current flows in the coil, it becomes heated, which is then used to heat cooking vessels.

Electric Heater

Electric Fuse:

In any electrical instrument, due to sudden rise of current, the instrument gets burnt down which sometimes results in fire. A conducting wire with low melting point is connected in series with the circuit to avoid this type of accident. When the current rises, the wire melts due to excessive heating, thus breaking the electrical circuit.

Electric Fuse

For harnessing the heating effect of electric current, the element of appliances is required to have high melting points to retain more heat.

Magnetic Effect of Electric Current

Magnetic Effect of Electric Current – A magnetic field is a force field that is created by magnetic dipoles and moving electric charges, and it exerts a force on other nearby moving charges and magnetic dipoles. Magnetic Field is a vector quantity because it has both magnitude and direction.

Magnetic Field Lines

A magnetic field line or lines of forces shows the strength of a magnet and the direction of a magnet's force. It was discovered by Michael Faraday to visualize the magnetic field.

Direction of Field Lines

Magnetic field lines are directed from South Pole to North Pole inside the magnet and from North Pole to South Pole outside the magnet.

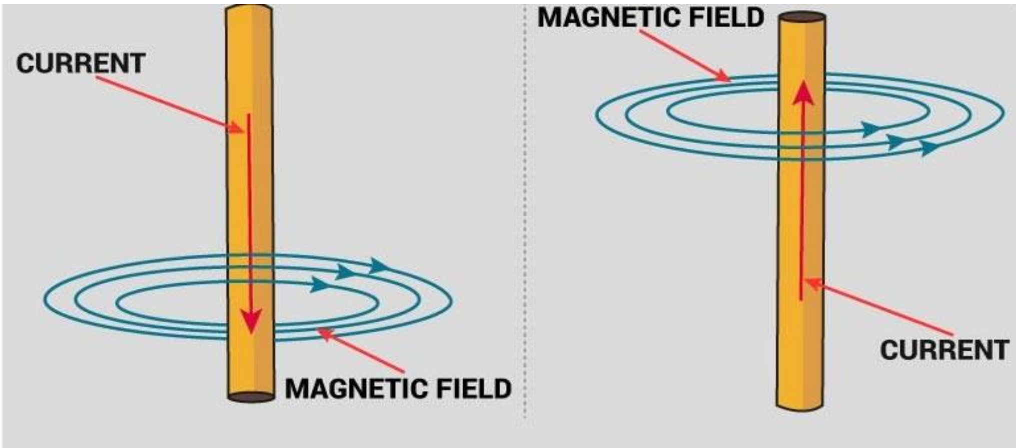
Strength of Magnetic Field Lines

A straight current-carrying conductor has a magnetic field in the shape of concentric circles around it. The magnetic field of a straight current-carrying conductor can be visualized by magnetic field lines.

The direction of a magnetic field produced due to a current-carrying conductor rely upon the same direction in which the current is flowing

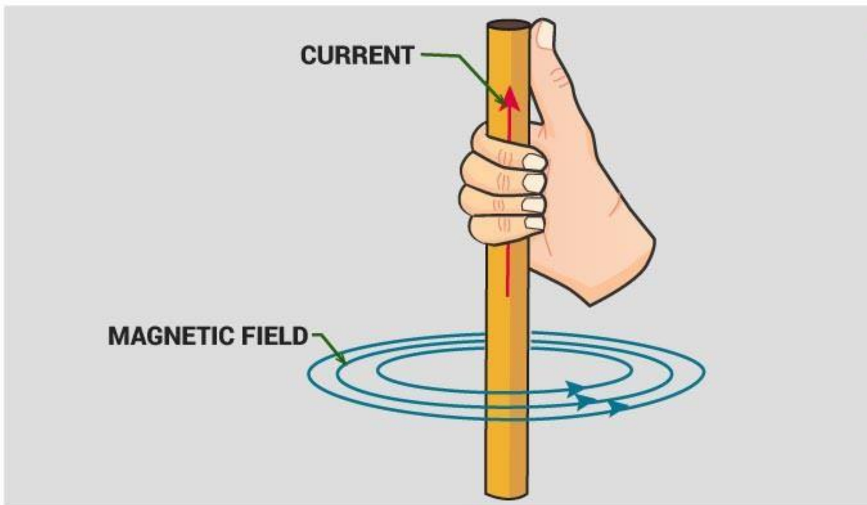
The direction of the electric field gets reversed if the direction of electric current changes.

Let us understand Magnetic Effect of Electric Current using a simple experiment:



Suppose a straight current-carrying conductor is hung vertically, and an electric current is flowing from north to south i.e., from up to down. In this situation, the direction of the magnetic field will be clockwise. And if the same current is flowing from south to north through the same conductor, the direction of the magnetic field will be anti-clockwise.

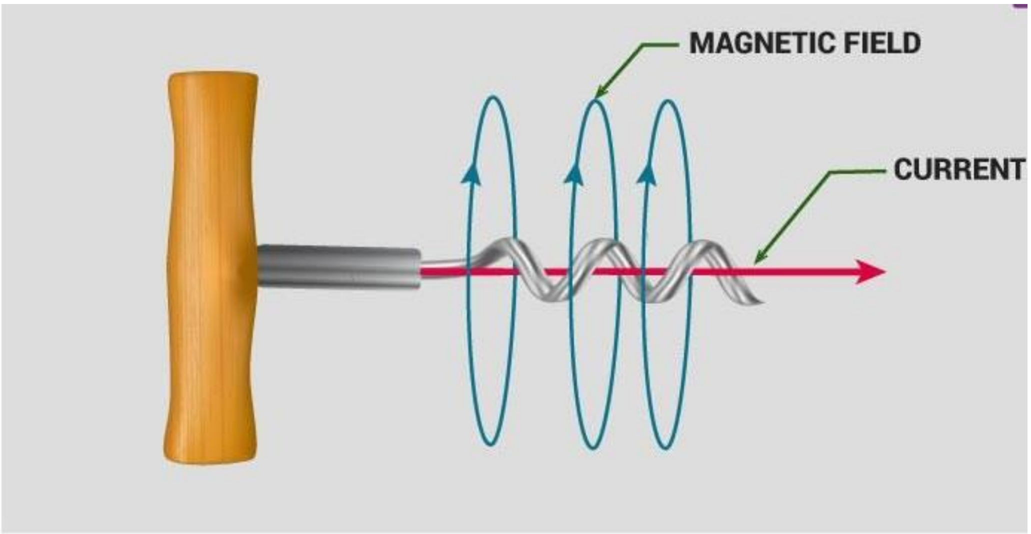
The direction of the magnetic field in electric current through a straight conductor can be represented by using the Right-Hand Thumb Rule.



Right-Hand Thumb rule

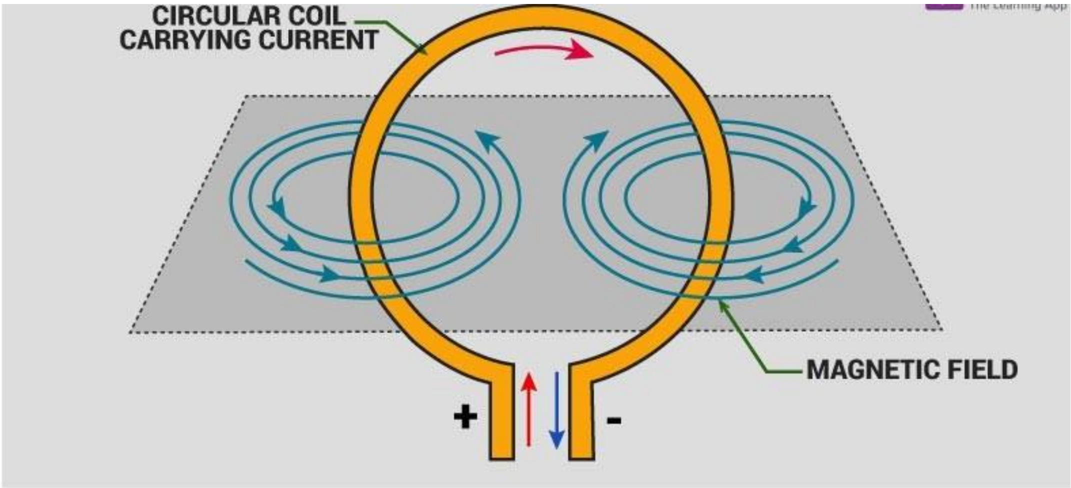
Assume that you are holding a straight current-carrying conductor in your right hand such that the thumb points towards the direction of the current. Then your fingers will wrap around the conductor in the direction of field lines of the magnetic field.

The Right-Hand Thumb rule is also known as Maxwell's corkscrew rule. If we consider ourselves driving a corkscrew in the direction of the current, then the direction of the corkscrew is in the direction of the magnetic field.



Magnetic Field Due to Flow of Current through a Circular Loop

The magnetic field produced in a circular current carrying conductor is the same as that of the magnetic field due to a straight current-carrying conductor and the current-carrying circular loop will behave like a magnet.

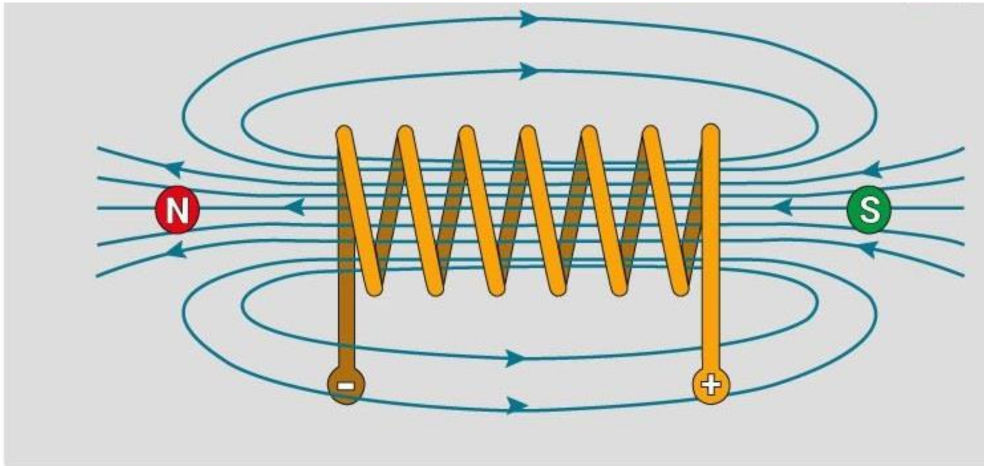


The magnetic field lines in a current-carrying circular loop would be in the shape of concentric circles, and at the center of the circular wire, field lines will become straight and perpendicular to the plane of the coil.

The direction of the magnetic field in a circular loop can be recognized using Right-Hand Thumb Rule

Magnetic Field due to flow of current in a Solenoid

A solenoid is a tightly wound helical coil of wire whose diameter is small compared to its length.



Solenoid

The magnetic field produced by the current-carrying solenoid is similar to a bar magnet. One end of a solenoid behaves as a south pole and the other end behaves as a north pole. The magnetic field produced inside a solenoid is parallel which is similar to a bar magnet.

The strong magnetic force produced by a solenoid can be used to magnetize a piece of magnetic material. The magnet so formed is known as an electromagnet.

Direct Current

- Direct Current is the unidirectional flow of electric current. The flow of current does not change periodically. In the case of direct current, the current flows in a single direction at a steady voltage.
- Direct current power is widely used in low voltage applications such as charging batteries, light aircraft electrical systems.
- By using a rectifier, a direct current can be obtained from an alternating current. A rectifier contains electronic elements or electromechanical elements that allow current to flow only in one direction.
- Direct current can also be converted into alternating current by using a motor-generator set or by an inverter.
- The direction of the magnetic field in electric current through a straight conductor can be represented by using Right-Hand Thumb Rule.

Difference between AC and DC

Electric current flows in two ways as an alternating current (AC) or direct current (DC). In alternating current, current keeps switching directions periodically – forward and backward. While in the direct current it flows in a single direction steadily. The main difference between AC and DC lies in the direction in which the electrons flow. In DC, the electrons flow steadily in a single direction while electrons keep switching directions, going forward and then backwards in AC. Let us learn more differences between them in the next few sections.

What is an Alternating Current (AC)?

In alternating current, the electric charges flow changes its direction periodically. AC is the most commonly used and most preferred electric power for household equipment, office, and buildings, etc. It was first tested, based on the principles of Michael Faraday in 1832 using a Dynamo Electric Generator.

Alternating current can be identified in waveform called a sine wave. In other words, it can be referred to as the curved line. These curved lines represent electric cycles and are measured per second. The measurement is read as Hertz or Hz. AC is used to powerhouses and buildings etc. because generating and transporting AC across long distances is relatively easy. AC is capable of powering electric motors which are used on refrigerators, washing machine, etc.

What is Direct Current (DC)?

Unlike alternating current, the flow of direct current does not change periodically. The current electricity flows in a single direction in a steady voltage. The major use of DC is to supply power to electrical devices and also to charge batteries. Example: mobile phone batteries, flashlights, flat-screen television and electric vehicles. DC has the combination of plus and minus sign, a dotted line or a straight line.

Everything that runs on a battery and uses an AC adapter while plugging into a wall or uses a USB cable for power relies on DC. Examples would be cellphones, electric vehicles, flashlights, flat-screen TVs (AC goes into the TV and is converted into DC).

Difference between AC and DC

The major differences between Alternating Current and Direct Current are given in the table below:

Alternating Current	Direct Current
AC is safe to transfer longer distance even between two cities and maintain the electric power.	DC cannot travel for a very long distance. It loses electric power.
The rotating magnets cause the change in direction of electric flow.	The steady magnetism makes DC flow in a single direction.
The frequency of AC is dependent upon the country. But generally, the frequency is 50 Hz or 60 Hz.	DC has no frequency of zero frequency.
In AC the flow of current changes its direction backwards periodically.	It flows in a single direction steadily.
Electrons in AC keep changing its directions – backward and forward	Electrons only move in one direction – that is forward.

Frequently Asked Questions on Difference between AC and DC

Why can't AC be stored in batteries instead of DC?

It is important to understand that batteries do not store the energy directly in them. They store electrical energy in the form of chemical energy. The positive terminal of an AC source is connected to the positive terminal of the battery and the negative terminal of an AC source is connected to the negative terminal of the battery. The current starts to flow. But AC changes its polarity and there is no actual supply of the energy. This is because the positive half cycle cancel outs the negative half cycle. If this process continues, it can damage the battery. Therefore, AC is not stored in batteries.

What are the advantages of AC over DC?

Following are the advantages of alternating current over direct current:

- AC is less expensive and easy to generate than DC.
- The distance covered by AC is more than that of the DC.

- The power loss during transmission in AC is less when compared to the DC.

Why is the use of AC voltage preferred over DC voltage?

There are two reasons why the use of AC voltage is preferred over DC voltage:

- The loss of energy during the transmission in AC voltage is less when compared with the DC voltage and this makes its installations easy when the transformers are at distance.
- AC voltage has the advantage of stepping up and stepping down as per the requirement.

What is watt less current?

Watt less current is defined as the current in an AC circuit when the average power consumption is zero.

What will be the value of the power factor in the circuit when it is at resonance?

The value of the power factor in the circuit when it is at resonance will be 1.

Give reasons for loss in energy in the transformer.

Following are the reasons due to which there is loss in energy in the transformer:

- Hysteresis
- Eddy current loss
- Leakage of flux

Transducer

A transducer is an electronic device that converts energy from one form to another. The process of converting energy from one form to another is known as transduction.

Some common examples of transducers include loudspeakers, microphones, thermometers, and LEDs.

Why do we need a transducer?

To determine the exact magnitude of physical forces such as temperature and pressure is difficult. But, if these physical forces are converted into an electrical signal, then their values can be easily determined using a meter. The primary function of transducers is to convert a physical force into an electrical signal so that it can be easily handled and transmitted for measurement.

Advantages of converting a physical quantity into an electrical signal

Here, we have listed the various advantages of converting a physical quantity into an electrical signal:

- Electrical signals are easily transmitted and processed for measurement.
- Electrical signals process less friction error.
- Small power is needed to control the electrical systems.
- Amplification and attenuation of electrical signals are easy.
- The measuring instrument used for measuring the electrical signal is very compact and accurate.

Parts of Transducer

A transducer consists of the following two important parts:

- Sensing element
- Transduction element

Transducers have other vital parts such as signal processing equipment, amplifiers and power supplies.

Sensing Element

It is the part of a transducer that responds to the physical sensation. The response of the sensing element depends on the physical phenomenon.

Transduction Element

The transduction element of the transducer converts the output of the sensing element into an electrical signal. The transduction element is also called the secondary transducer.

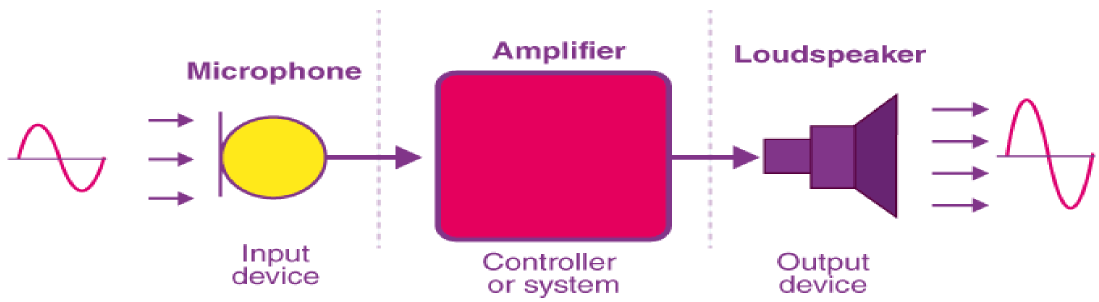
Types of Transducers

There are two types of transducers, as follows:

- Input Transducer
- Output Transducer

What is an Input Transducer?

An input transducer or a sensor takes in physical energy and converts it into an electrical signal that can be read. A microphone, for example, converts physical sound waves into an electrical signal that can be transferred through wires.



What is an Output Transducer?

An output transducer, or an actuator, takes in electrical signals and converts them into other forms of energy. A lamp converts electricity into light and a motor, on the other hand, converts electricity into motion.

Factors to consider while selecting a transducer

- Transducers should have high input impedance and low output impedance to avoid the loading effect.
- A transducer should be highly sensitive to desired signals and insensitive to unwanted signals.
- Transducers should be able to work in corrosive environments.
- The transducer circuit should have overload protection to withstand overloads.

Transducer Efficiency

Transducer efficiency is defined as the ratio of output power in the desired form to the total power input. Mathematically, the ratio is represented as follows:

E=QP

P represents the input in the above ratio, and Q represents the power output in the desired form. The efficiency of the transducer always falls between 0 and 1.

No transducer is 100% efficient; some power is always lost in the conversion process. This loss is manifested in the form of heat. In incandescent lamps of certain wattage, only a few watts are transformed into visible light. Most of the power is dissipated as heat. Due to this, an incandescent lamp is a bad transducer in terms of efficiency.

Applications of Transducer

- A transducer measures load on the engines
- They are used to detect the movement of muscles; this process is known as acceleromyograph.
- Transducers are used in an ultrasound machine.
- The transducers in a speaker convert electrical signals into acoustic sound.
- A transducer is used in the antenna to convert electromagnetic waves into electrical signal.

Difference between a Transducer and a Sensor

A sensor is a device that measures a physical quantity. For example, in a mercury thermometer, the mercury simply expands when the temperature rises to give a reading for the user. Here there are no electrical inferences or changes. On the other hand, a transducer, measures similar quantities as a sensor but the signal in a transducer is converted from one form to another. This is the reason why transducers are also referred to as energy converters.

Transducers	**Sensors**
It converts energy from one form to another.	It senses physical quantities and converts it into a readable form.
Cable extension transducer, linear transducer and microphones are some examples of transducers.	Thermistors, pressure switches and motion sensors are some examples of sensors.

Frequently Asked Questions on Transducer

What is the difference between a sensor and a transducer?

Both sensors and transducers sense change within the environment they are surrounded by. The difference lies in the output of each device. In a sensor, the output is in the same form as the input, but the input is converted into an electrical signal in a transducer.

Why is a transducer important?

Transducers transform physical quantity into an electrical signal. Transducers are essential in detecting and quantifying such signals (pressure, air humidity, temperature, etc.)

Give an example of a transducer.

Any device that converts energy from one form to another is known as a transducer. A loudspeaker is one of the common examples of a transducer. A speaker converts an electrical signal to sound waves.

Is a thermometer a sensor or a transducer?

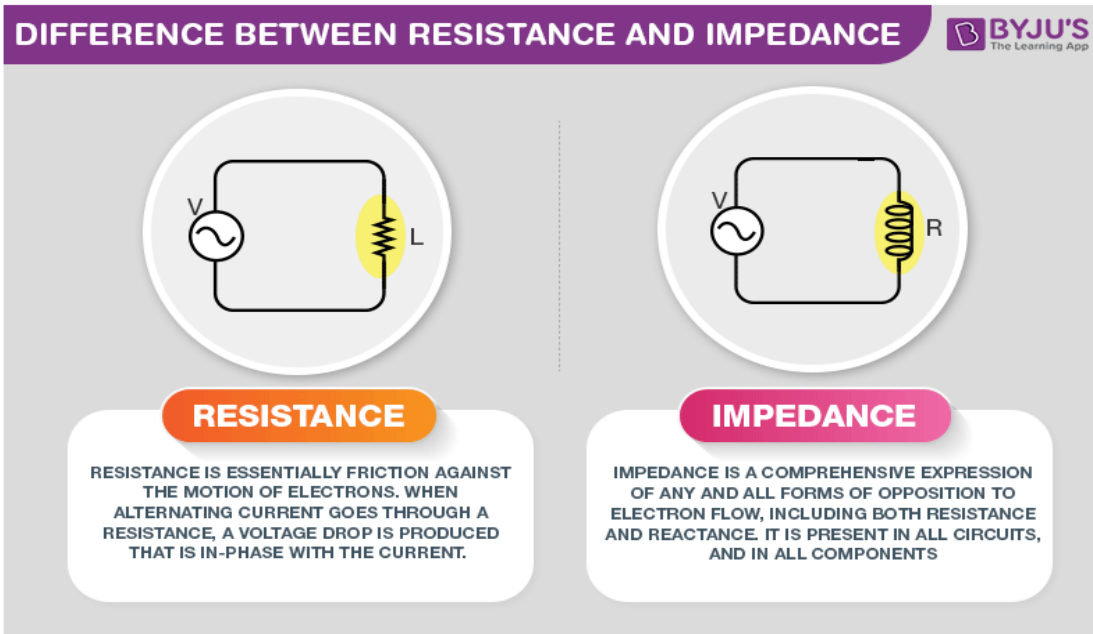
A thermometer is both a transducer and a sensor.

Where is a transducer used?

Transducers are commonly used in applications that require automation and measurement. In such applications, the electrical signals are converted to and from other physical quantities.

Difference Between Resistance and Impedance

Before knowing the difference between resistance and impedance, we should know that impedance is a concept related to AC whereas resistance is a concept related to DC. Their calculation of value is same which is R=V/I.



Difference Between Resistance and Impedance

Resistance is caused due to the electrons in a conductor colliding with the ionic lattice of the conductor which results in the conversion of electrical energy in heat. It could be said that electrical resistance is the opposition to steady electric current. An ideal resistance does change with frequency when connected with DC.

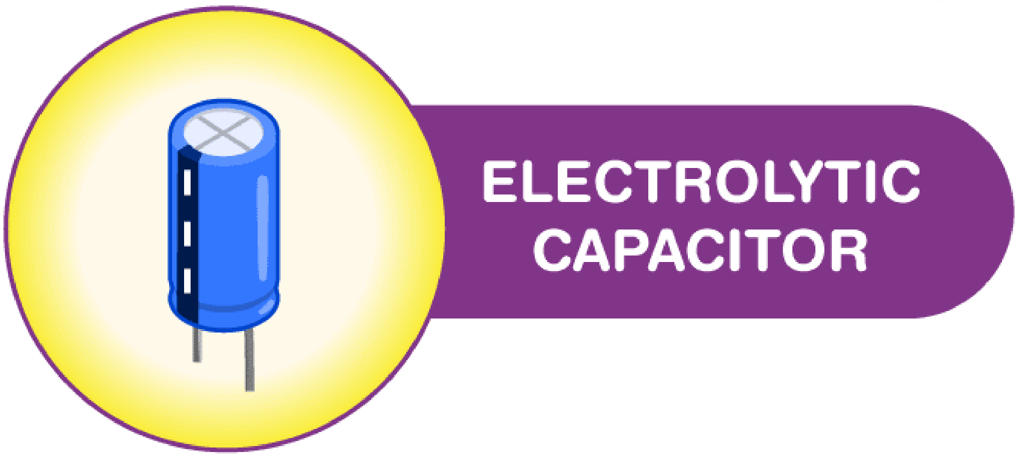
Impedance is the measure of the nature of opposition of the AC electricity which is created due to inductance and capacitance. This opposition varies with the frequency. Very often, reactance and impedance are thought to be the same and are interchangeably used. It is important to understand that reactance is the resistance offered to the AC current by inductors and capacitors only while impedance is the sum of the resistance and reactance. In the table below, important differences between resistance and impedance are given.

Difference Between Resistance and Impedance	
Resistance	**Impedance**
It is used in DC circuits	It is used in AC circuits
Resistance can be seen in both AC and DC circuits	Impedance can be seen only in AC circuits
It happens due to resistive elements	It happens due to reactance and resistance
It is represented by letter R	It is represented by letter Z
It is represented using real numbers such as 5.3 ohms	It is represented using real and imaginary values such as R + ik
It does not vary depending upon the frequency of DC current	It varies according to the frequency of AC current.
It does not have a magnitude and phase angle	It does have a phase angle and magnitude
If kept in a electromagnetic field, it only shows the power dissipation	If kept in a electromagnetic field, it shows power dissipation and energy stored

Electrolytic Capacitor

An electrolytic capacitor is a sort of capacitor that utilizes an electrolyte to obtain greater capacitance than the other type of capacitors. An electrolyte is a gel or fluid in which the concentration of ions is very high. An electrolytic capacitor is a general term used for three different capacitor family members:

- Aluminum electrolytic capacitors
- Tantalum electrolytic capacitors
- Niobium electrolytic capacitors



Almost all the electrolytic capacitors are polarized which means the voltage of anode must be always higher than the cathode. The ability of large capacitance makes them highly useful for sending low-frequency signals. They are extensively used for noise filtering or decoupling in power supplies. The advantage of large capacitance comes with few drawbacks as well. Drawbacks include leakage currents, equivalent series resistance, and a limited lifetime. Electrolytes are made up of aluminum or tantalum and few other metals.

A special type of electrolytic capacitors with capacitances of hundreds and thousands of farads are known as supercapacitors. They are also known as double-layer electrolytic capacitors.

Applications:

- Used to reduce voltage fluctuations in various filtering devices.
- Used in output and input smoothing to filter when the DC signal is weak with the AC component.
- They are extensively used for noise filtering or decoupling in power supplies.

- They are used for coupling signals between amplifier stages and also to store energy in flashlamps.

Capacitor - Types of Capacitors and Capacitance

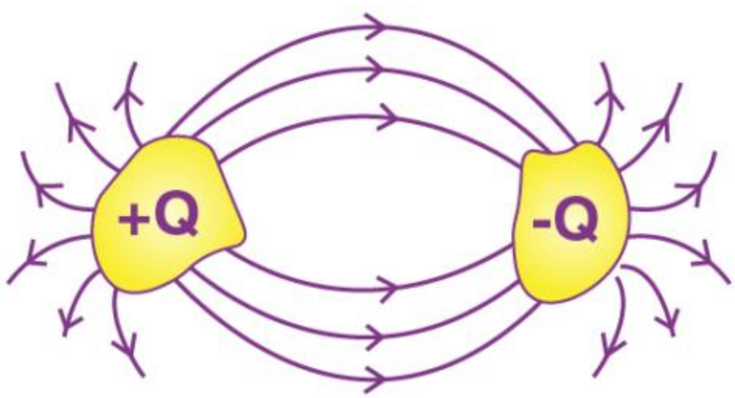
What is a Capacitor?

The capacitor is a device in which electrical energy can be stored. It is an arrangement of two-conductor generally carrying charges of equal magnitudes and opposite sign and separated by an insulating medium. The non-conductive region can either be an electric insulator or vacuum such as glass, paper, air or semi-conductor called as a dielectric.

Capacitor vary in shape and size, they have many important applications in electronics.

What are Capacitors Used For?

- Storing electric potential energy such as batteries.
- Filtering out unwanted frequency signals
- Delaying voltage changes when coupled with resistors.
- Used as a sensing device.
- Used in the audio system of the vehicle.
- Used to separate AC and DC.



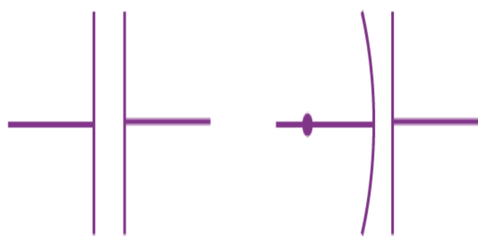
One of the conductors has a positive charge +Q and it is at potential +V. whereas the other has an equal negative charge, -Q and is at potential –V.

Charge on Capacitor

Note: Charge on the capacitor is Q.

Total charge/ the net charge on the capacitor is –Q + Q = 0.

Circuit Symbols



Capacitance

The charge on the capacitor (Q) is directly proportional to the potential difference (V) between the plates i.e., **Q = CV**

The constant of proportionality (C) is termed as the **capacitance of the capacitor**.

Dimensional Formula and Unit of Capacitance

- **Unit of Capacitance:** Farad (F)

The capacitor value can vary from a fraction of pico-farad to more than a micro Farad. Voltage level can range from a couple to a substantial couple of hundred thousand volts.

- **Dimensional Formula:** $M^{-1}L^{-2}I^{2}T^{4}$

Commonly Used Scales

- μF = 10^{-6}F
- nF = 10^{-9}F
- pF = 10^{+2}F

Factors Affecting the Capacitance

Capacitance depends on the following factor:

1. Shape and size of the conductor
2. Medium between them
3. Presence of other conductors near it.

Calculation of Capacitance

We will try to calculate the capacitance of differently shaped capacitors, the steps are followed;

1. Assume the charge on the conductors(Q)
2. Calculate the electric field between the plates (E)
3. Calculate potential difference from electric field(V)
4. Apply the relation, *C*=*Q*/V

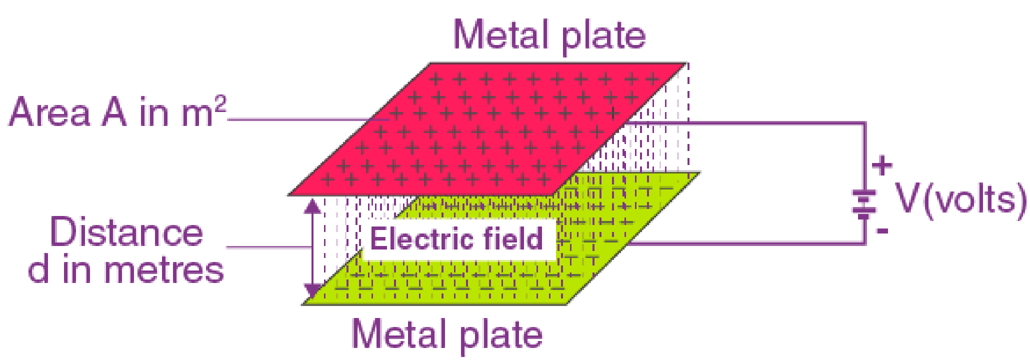
Types of Capacitor

- **Parallel Plate Capacitor**
- **Spherical capacitor**
- **Cylindrical capacitor**

Parallel Plate Capacitor

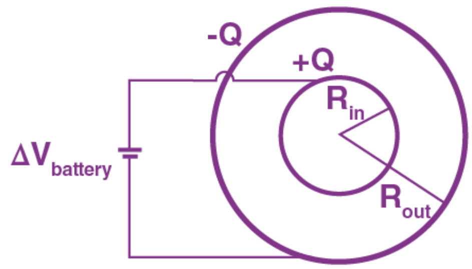
The parallel plate capacitor consists of two metal plates of Area, A and is separated by a distance d. The plate on the top is given a charge +Q and that at the bottom is given the charge –Q. A potential difference of V is developed between the plates.

The separation is very small compared to the dimensions of the plate so that the effect of bending outward of electric field lines at the edges and the non-uniformity of surface charge density at the edges can be ignored.



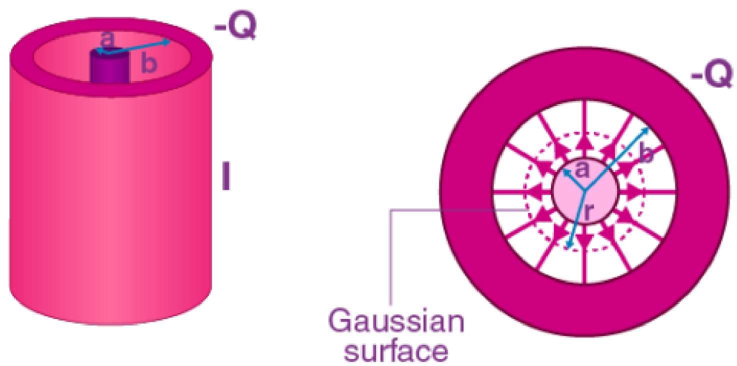
Spherical Capacitor

Let's consider a spherical capacitor that consists of two concentric spherical shells. Suppose the radius of the inner sphere, R_{in} = a and radius of the outer sphere, R_{out} = b. The inner shell is given a positive charge +Q and the outer shell is given –Q.



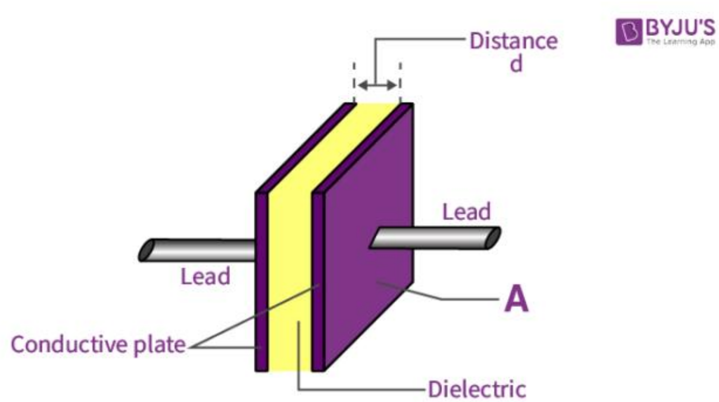
Cylindrical Capacitor

Consider a solid cylinder of radius, a surrounded by a cylindrical shell, b. The length of the cylinder is l and is much larger than a-b to avoid edge effects. The capacitor is charged so that the charge on the inner cylinder is +Q and the outer cylinder is –Q.



Dielectrics and Capacitance

What are Dielectrics?

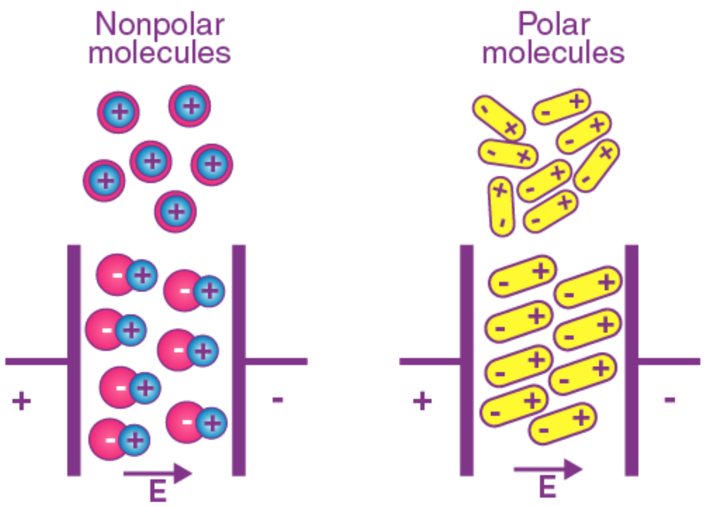


It is an insulating material (non-conducting) which has no free electrons. But a microscopic displacement of charges is observed in the presence of an electric field. It is found that the capacitance increases as the space between the conducting plates are filled with dielectrics.

Polar and Non-polar Dielectrics

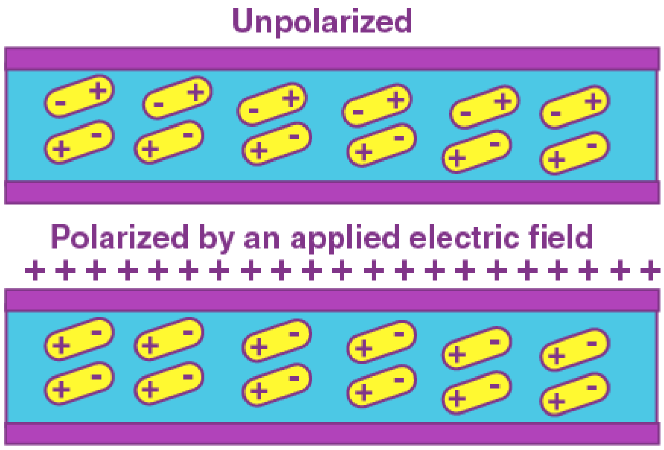
Each atom is made of a positively charged nucleus surrounded by electrons. If the center of the negatively charged electrons does not coincide with the center of the nucleus, then a permanent dipole (separation of charges over a distance) moment is formed. Such molecules are called *polar molecules.* If a polar dielectric is placed in an electric field, the individual dipoles experience a torque and try to align along the field.

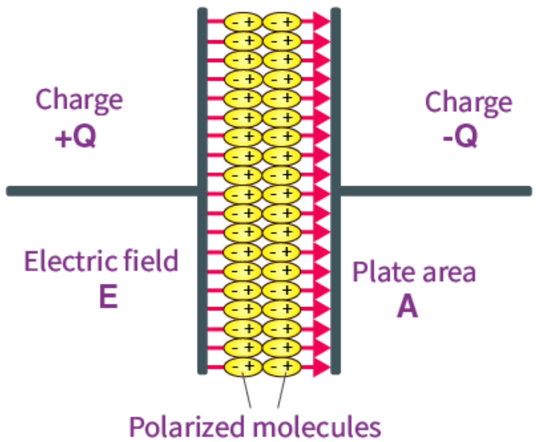
In non-polar molecules, the centers of the positive and negative charge distributions coincide. There is no permanent dipole moment created. But in the presence of an electric field, the centers are slightly displaced. This is called *induced dipole moments.*



Polarization of a Dielectric Slab

It is the process of inducing charges on the dielectric and creating a dipole moment. Dipole moment appears in any volume of a dielectric. The *polarization vector* is defined as the dipole moment per unit volume.

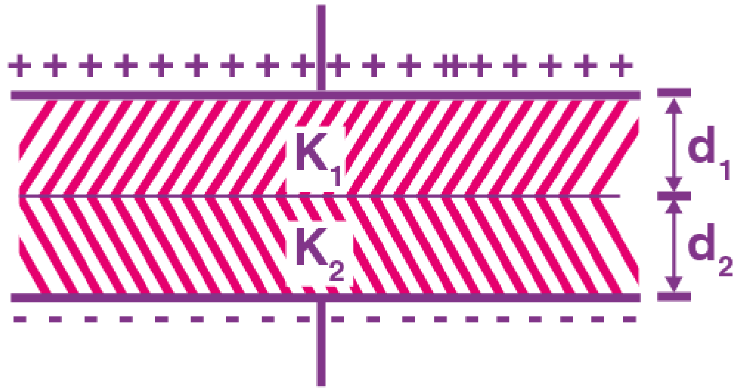




Effect of Dielectric in Capacitance

Dielectric Slabs in Series

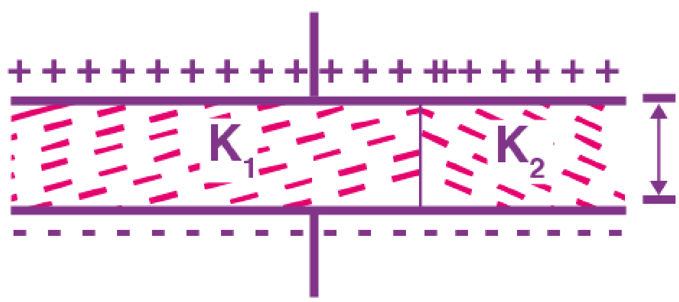
A parallel plate capacitor contains two dielectric slabs of thickness d_1, d_2 and dielectric constant k_1 and k_2 respectively. The area of the capacitor plates and slabs is equal to A.



Considering the capacitor as combination of two capacitors in series, the equivalent capacitance C is given by:

$$1/C = 1/C_1 + 1/C_2$$

Dielectric Slabs in Parallel

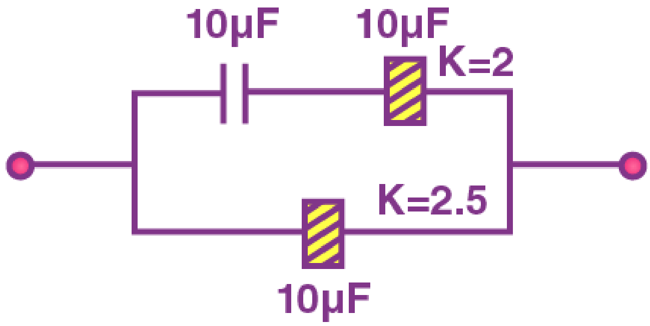


Consider a capacitor with two dielectric slabs of same thickness d placed inside it as shown. The slabs have dielectric constants k_1 and k_2 and areas A_1 and A_2 respectively. Treating the combination as two capacitors in parallel,

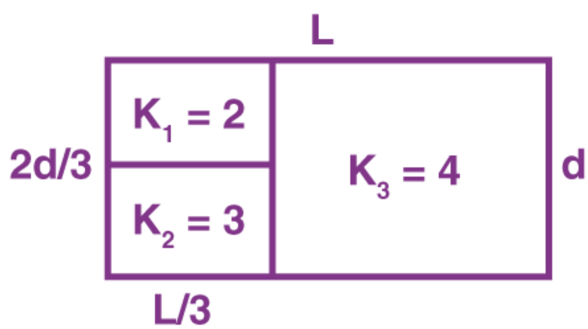
$$C = C_1 + C_2$$

Problems on Capacitance and Dielectrics

Problem 1: Three capacitors of 10μF each are connected as shown in the figure. Two of them are now filled with dielectric with K = 2, K = 2.5 as shown. Find the equivalent capacitance.



Problem 2: Find the equivalent capacitance of the system shown (assume square plates).



Taking $K_1 = 2$ to be series in $K_2 = 3$

Now C_{left} and C_{right} are in parallel

$C_{eq}=C_{left}+C_{right}=7d6\varepsilon_0L_2+3d8\varepsilon_0L_2=21d74\varepsilon_0L_2$

Problem 3: Calculate the effective capacitance connected in series and parallel? And the capacitors connected to 40 V battery. Calculate the voltage across the capacitors for each connection type.

Given

C_1 = 12 F

C_2 = 6 F

Solu:

When capacitors are connected in series

$C1=C_11+C_21$

$C1=121+61$

$C_1 = 0.25$

C = 4 F

$C = Q/v$

Q = CV

Q = 4 × 40

Q = 160 C

For the 12 F capacitor:

V = 13.33V

For the 6F capacitor:

V = 26.66V

When capacitors are connected in parallel

$C = C_1 + C_2$

C = 12 + 6

C = 18 F

The voltage is same as 40V across each capacitor.

Combination of Capacitors

How are Capacitors connected?

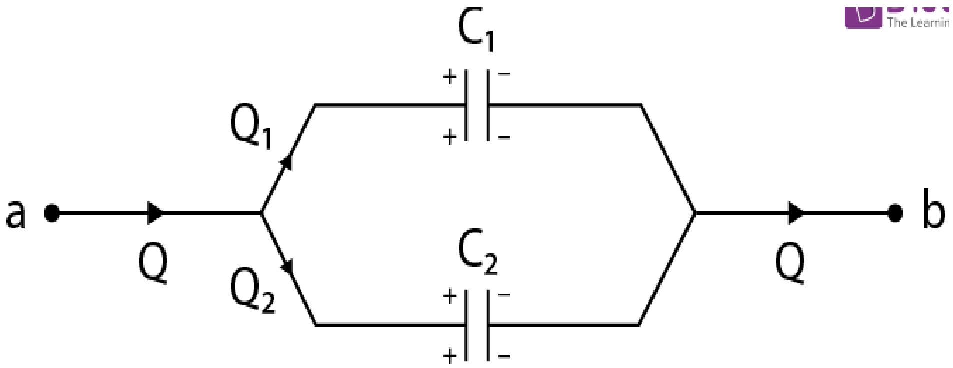
Capacitor's combination can be made in many ways. The combination is connected to a battery to apply a potential difference (V) and charge the plates (Q). We can define the equivalent capacitance of the combination between two points to be

$$C = Q/V$$

Two frequently used methods of combination are: Parallel combination and Series combination

Parallel Combination of Capacitors

When capacitors are connected in parallel, the potential difference V across each is the same and the charge on C_1, C_2 is different i.e., Q_1 and Q_2.



The total charge is Q given as:

$Q=Q1+Q2$

$Q=C1V+C2V$

$=C1+C2$

Equivalent capacitance between a and b is:

$C = C_1 + C_2$

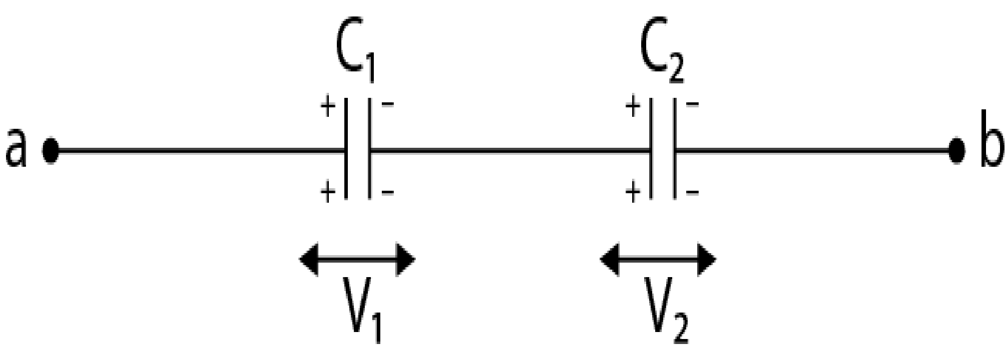
The charge on capacitors is given as:

- $Q1=C_1+C_2C_1Q$
- $Q2=C_1+C_2C_2Q$

In case of more than two capacitors, $C = C_1 + C_2 + C_3 + C_4 + C_5 + \ldots\ldots\ldots$

Series Combination of Capacitors

When capacitors are connected in series, the magnitude of charge Q on each capacitor is same. The potential difference across C_1 and C_2 is different i.e., V_1 and V_2.



$$\mathbf{Q = C_1 V_1 = C_2 V_2}$$

Important Points:

- If N identical capacitors of capacitance C are connected in series, then effective capacitance = C/N
- If N identical capacitors of capacitance C are connected in parallel, then effective capacitance = CN

Problems on Combination of Capacitors

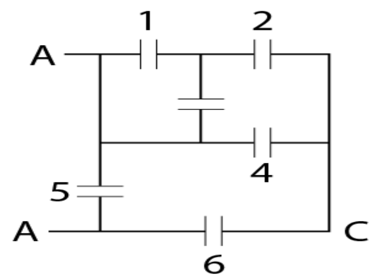
Problem 1: Two capacitors of capacitance C_1 = 6 μ F and C_2 = 3 μ F are connected in series across a cell of emf 18 V. Calculate:

- The equivalent capacitance
- The potential difference across each capacitor
- The charge on each capacitor

Charge on each capacitor = C_{eq} V = 2μF x 18 volts = 36μC

In the above problem, note that the smallest capacitor has the largest potential difference across it.

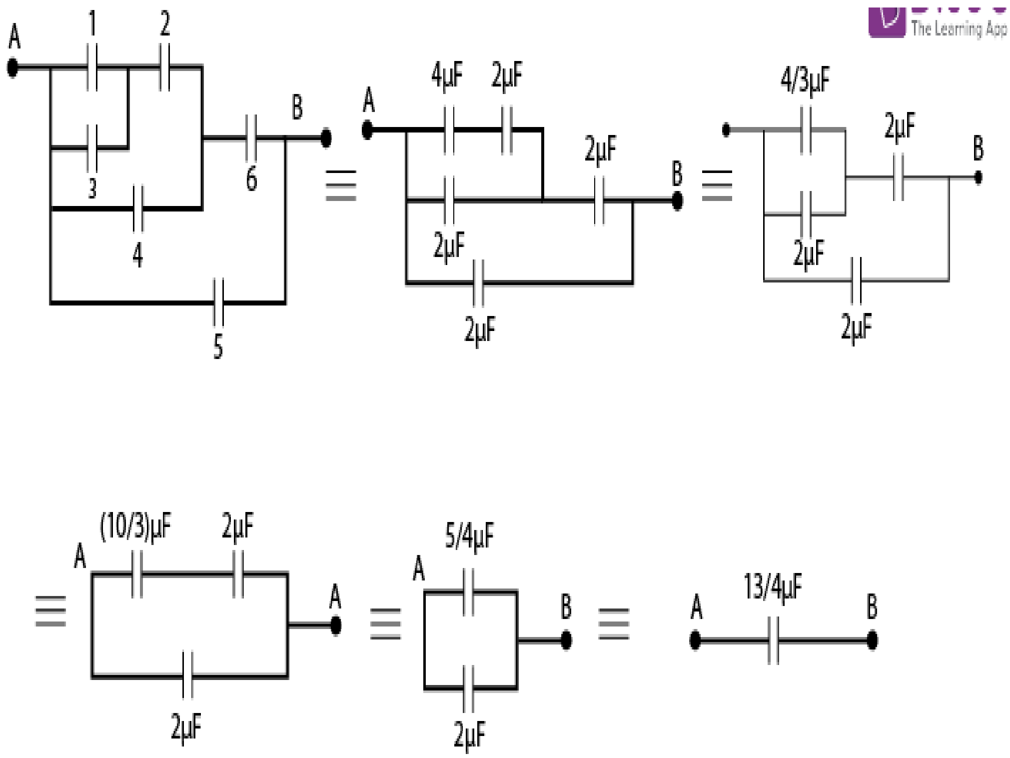
Example 2: Find the equivalent capacitance between points A and B capacitance of each capacitor is 2 μF.



Sol: In the system given, 1 and 3 are in parallel. 5 is connected between A and B. So, they can also be represented as follows.

1. As 1 and 3 are in parallel, their effective capacitance is 4μF
2. 4μF and 2μF are in series, their effective capacitance is 4/3μF
3. 4/3μF and 2 μF are in parallel, their effective capacitance is 10/3μF
4. 10/3μF and 2μF are in series, their effective capacitance is 5/4μF
5. 5/4μF and 2μF are in parallel, their effective capacitance is 13/4μF

Therefore, the equivalent capacitance of the given system is 13/4μF.


A
1
2
3
4
5
6
B
4μF
2μF
2μF
2μF
2μF
4/3μF
2μF
2μF
2μF
(10/3)μF
2μF
2μF
5/4μF
2μF
13/4μF
The Learning App

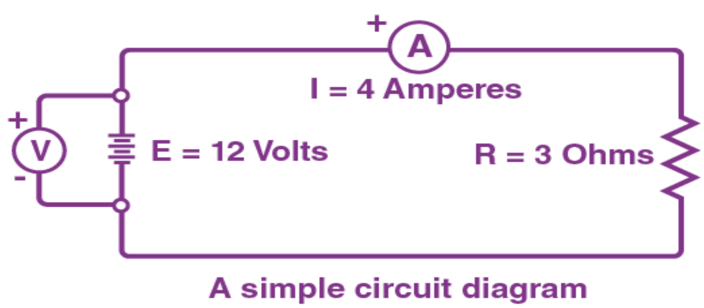
Circuit Diagram and Its Components

Circuit Diagram Explanation

A circuit diagram is a graphical representation of an electrical circuit. A circuit diagram also called an electrical diagram, elementary diagram or electronic schematic is defined as a simplified graphical representation of an electrical circuit. Circuit diagrams are used for the design, construction and maintenance of electrical and electronic equipment.

What is a Circuit Diagram?

A circuit diagram is a simplified representation of the components of an electrical circuit using either the images of the distinct parts or standard symbols. It shows the relative positions of all the elements and their connections to one another. It is often used to provide a visual representation of the circuit to an electrician. The following figure shows a simple circuit diagram.



Simple Circuit Diagram

Components of Circuit Diagram

In this section, let us learn about some important circuit diagram symbols.

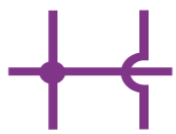
An electric cell: It provides the source of current. In its symbol, the larger terminal is positive, whereas the smaller one is the negative terminal.

A battery: It is a combination of cells and its utility is the same as the cell.

Switch: It is a plug key used to allow or stop the flow of current upon being pressed. It may be an open or a closed switch.

Wire joint: One device may be connected to the other using wires. This is shown by drawing 'blobs' at their point of connectivity.

Wires crossing without joining: The wires that do not touch each other are drawn without blobs. The following figure shows how the separated wires are represented.



Electric bulb: The electrical device which uses electricity to glow.

Resistor (R): It is used to restrict the amount of current flow in the circuit.

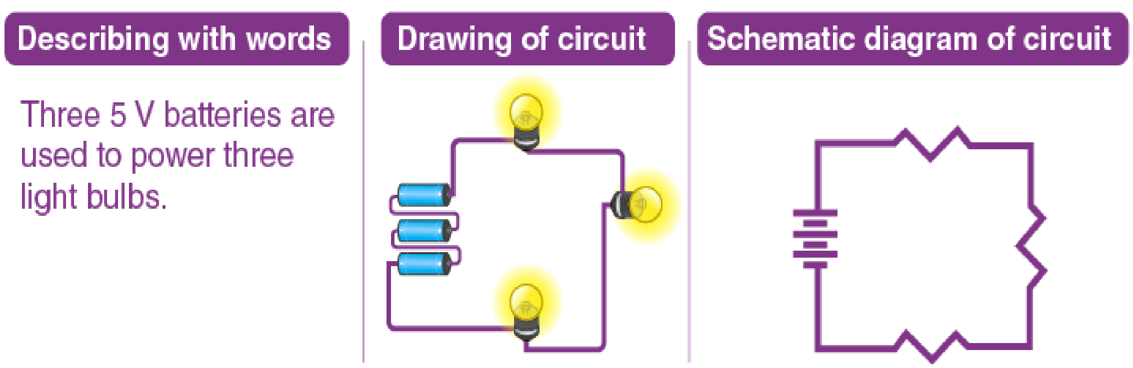
Variable resistance: Also known as the rheostat, it is used to regulate the amount of current flow by increasing or decreasing the resistance to the current flow.

Ammeter: It is used to measure the current passing at a particular point.

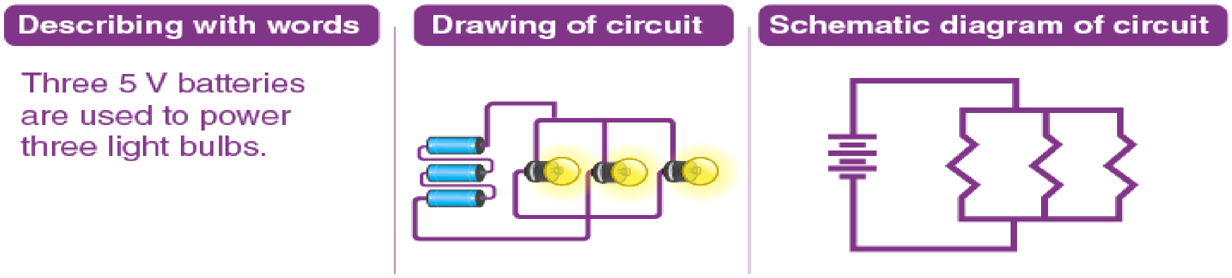
Voltmeter: It is used to measure the voltage between two points in a circuit.

Circuit Diagram Examples

Example: Three 5 V batteries are used to power a circuit containing three light bulbs.

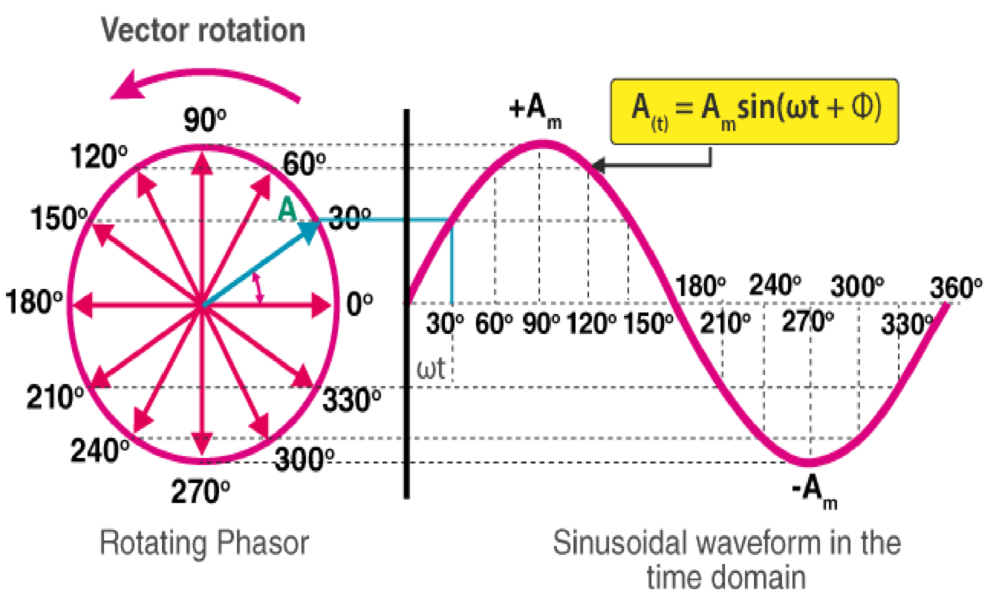


The verbal description of the circuit stated in the problem statement can be represented by drawing three lightbulbs, three cells connected by wires. The above circuit diagram presumed that the light bulbs were connected in series. But it should be noted that it doesn't necessarily need to be connected in series. The same description of the circuit can be drawn differently as shown below:



Representation of AC current and voltage by phasor diagram

Alternating Current (AC) is a type of electric current that reverses its direction periodically in contrast to the Direct Current (DC) which flows in a single direction. We have read about electrical circuits which contain a resistor connected across an AC source, an inductor connected across an AC source, a capacitor connected across an AC source or the combination of any two or all three of these components connected across an AC source. We know that, in the device like a resistor, the current across the resistor is in phase with the voltage source. But for the devices like inductor or a capacitor, the current either lags or leads the voltage source to a certain value. This theory of phasors is used to relate the current and the voltage in the latter case. In this section, we will learn about the phasor diagrams in detail.



Relation between phasor and sinusoidal representation of the function with respect to time

A phasor is a vector that is used to represent a sinusoidal function. It rotates about the origin with an angular speed ω. The vertical component of phasors represents the quantities that are sinusoidally varying for a given equation, such as v and i. Here, the magnitude of the phasors represents the peak value of the voltage and the current. From the figure shown above, we can see the relation between a phasor and the sinusoidal representation of the function with respect to time. The projection of the phasor on the vertical axis represents the value of the quantity. For example, in the case of a current or a vector phasor, the projection of the phasor on the vertical axis, given by $v_m \sin \omega t$ and $i_m \sin \omega t$ respectively, gives the value of the current or the voltage at that instant. From the phasor diagram, it is easy to detect those one of two quantities are in the same phase.

For example, if for a given circuit, the phasors for the voltage and the current are in the same direction for all instances, the phase angle between the voltage and the current is zero.

Circuit Components

Ancient literature from the Greeks and the Mediterranean suggests that people had knowledge about the rods of amber when rubbed to cat fur, attracted small pieces of paper. Long before the concept of electricity and electrical circuit existed, people were aware of the shocks due to an electric eel. Now as we know, electricity is one of the most convenient ways of the transfer of energy. But electronic circuit components are the physical entity in an electronic system.

Electricity has been adapted for a huge and growing number of uses in our everyday life. Be it to power our devices such as bulbs, fans, air conditioners, electric irons, washing machines, or charging our batteries, mobile phones, etc. We cannot imagine our lives without them. But ever wondered how pressing a switch makes the light bulb slow. Why does the torch stop working when used for too long? In order to understand these, we need to take a closer look at the concept of electricity with a basic electric circuit.

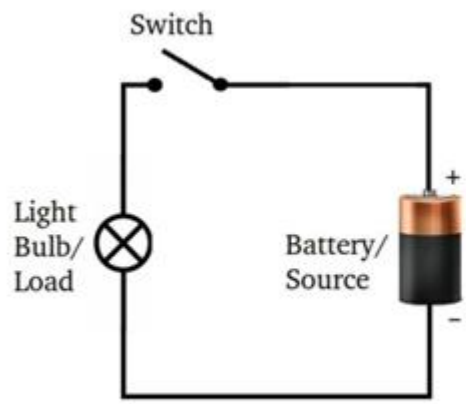


Fig. 3 Basic electrical circuit

Just by looking at the diagram, we cannot understand the working of the circuit, as the components are still new to us. Let us find out what these symbols stand for.

Electronic Components Used in Circuits (Circuit Components)

Some basic circuit components which are used in an electronic system is given below.

Cell

A cell is a device used to power electrical circuits. It has two terminals; positive and negative. The terminal marked negative is the source of electrons, that when connected to a circuit delivers energy. We can take the example of a normal torch battery. A battery is a combination of multiple cells. If we take a closer look at it, we can see positive and negative marks. The same marks are present on the torch we put our batteries into.

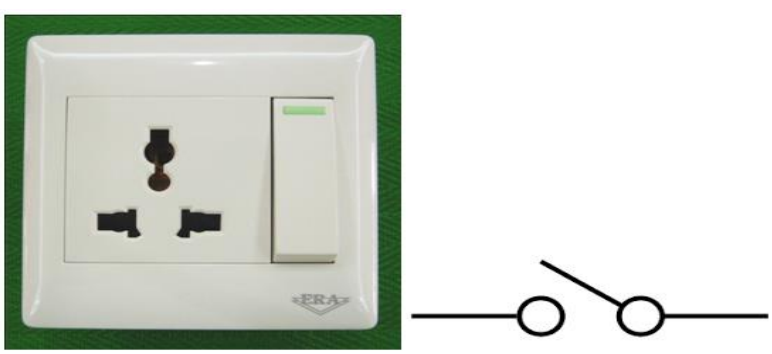
When we insert the battery into our devices matching these signs, we complete a circuit and that is how the circuit gets its power. Once the reserve of an excess electron inside the cells is over, the delivery of energy stops, and the circuit breaks. Thus, the device connected to the circuit, such as a bulb, stops working. Batteries come in various shapes and sizes, starting from the miniature batteries used in hearing aids and watches, torch, and mobile batteries to lead-acid batteries used in cars and to power inverters.

Cell

Switch

A switch is a device that can break an electrical circuit by diverting the current from one conductor to another conductor or an insulator. These set of contacts are termed as open and closed. Open circuit means that the contacts are separated and the circuit is broken, so no current is flowing.

Whereas closed circuit means that the contacts are touching, the circuit is complete and the current is flowing. Switches are of many types and are used depending upon the device we are using. Generally, we use them in our house for controlling the fans, bulbs, call bells, power switches for devices like refrigerators, washing machines, etc.



Switch

Light Bulb

A light bulb is a device that produces light from electricity. Light bulbs turn the electricity to light by sending current through a thin wire called filament. The filament is usually made of tungsten, a material that emits light when electricity is passed through it. The emission of light is due to the high resistance offered by the material tungsten, which we will learn in higher classes.

Apart from lighting, the light bulbs are used in electronic items as an indicator, traffic signals, indicator lights in cars, etc.

Light Bulb

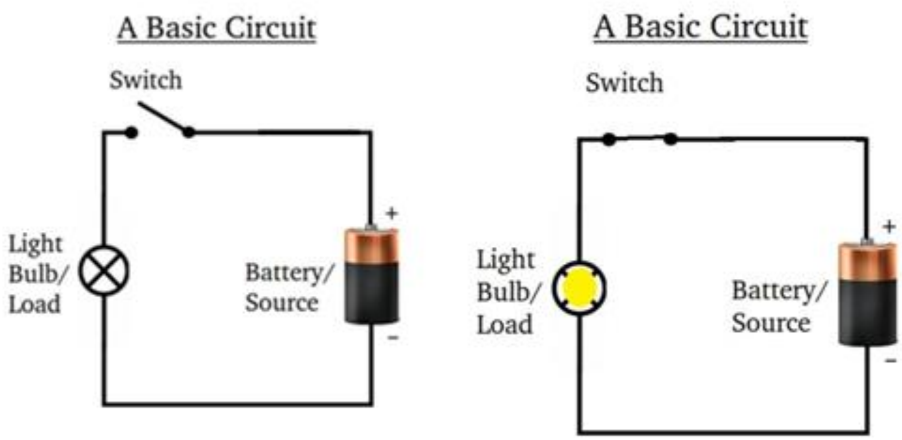
Connecting Wires

A wire is a flexible strand of metal, usually cylindrical. Wires are used for establishing electrical conductivity between two devices of an electrical circuit. They possess negligible resistance to the passage of current. The wires are covered by an insulated coating of different colors. The color codes are used to distinguish between neutral and ground, and live wire, which differs from one country to another.

Connecting Wires

Basic Electrical Circuit

Let us consolidate these elements to complete the circuit. A basic circuit is shown in the image below:

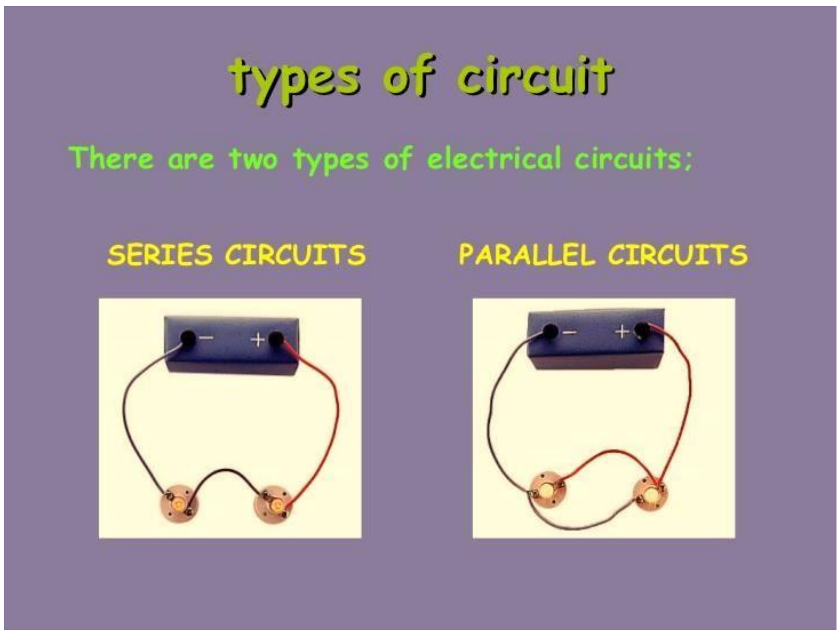


Basic Electrical Circuit

We see here, electrical wires are connecting a light bulb to a battery with a switch in between them. Here as the switch is closed, the circuit gets completed, the electrons start to flow and deliver energy from the battery to the light bulb, thus making it glow.

Types of Circuits

An electrical circuit consists of an organization of elements for the storage, transmission, and conversion of energy. Energy enters a circuit through one or more sources and leaves through one or more sinks. In the sources energy is transformed from the thermal, chemical, electromagnetic or mechanical form into electrical form; in the sinks a reverse procedure takes place. In an electrical circuit, energy is transported through the agency of electrical charge and through the medium of magnetic and electric fields. There are different types of circuits, parallel and series circuits.



Series Circuits

A series circuit is one in which numerous resistances are linked one after the other. Such connection is also termed as an end to end connection or a cascade connection. There is a single path for the flow of current.

Properties of Series circuit:

- The same current travels through every resistance.
- The supply voltage V is the total of the individual voltage dips across the resistances.

$$V = V_1 + V_2 + V_3 + \ldots + V_n$$

- The equivalent electrical resistance is equivalent to the total of the individual resistances.

- The equivalent resistance is the biggest of all the individual resistances.

$R > R_1$, $R > R_2$,….., $R > R_n$

Parallel Circuits

The parallel circuit is one in which numerous resistances are linked across one another in such a manner that one terminal of every resistance is connected to form a junction point while the remaining end is also linked to form another point.

Properties of Parallel Circuits:

- A similar potential difference gets across all the resistances in parallel.
- The total current gets distributed into the number of paths equivalent to the number of resistances in parallel. The aggregate current is always the summation of all the individual currents.

$I = I_1 + I_2 + I_3 + \ldots\ldots + I_n$

- The reciprocal of the equivalent resistance of a parallel circuit is equivalent to the sum of the reciprocal of the individual resistances.
- The equivalent resistance is the minutest of all the resistances.

$R < R_1$, $R < R_2$, ….., $R < R_n$

- The equivalent conductance is the mathematical addition of the single conductance's.

The equivalent resistance is lesser than the smallest of all the resistances linked in parallel.

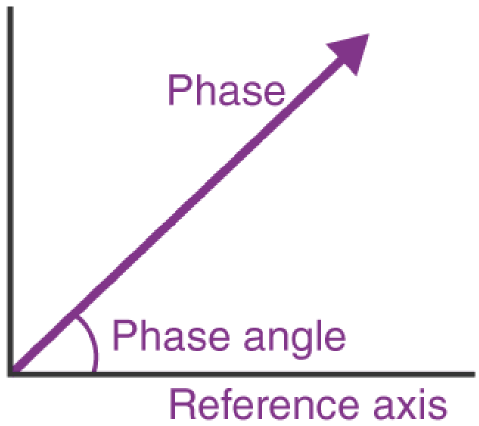
Dissimilarities

The variances between series and parallel circuits are demonstrated in the table underneath.

Circuit In Series	***Circuit In Parallel***
There is a single current pathway	There are multiple current pathways
All components have similar current running through them	All components have similar potential difference across them
The sum of the potential dips across each component is equivalent to the emf of the source.	The sum of the currents flowing into any point in the circuit is equivalent to the sum of the currents flowing out of that point.

LCR Circuit: Analysis of A LCR Series Circuit

From the article, we understood that a *series circuit is one in which the current remains the same along with each element*. With this context, let us discuss the LCR circuit and its analysis in detail. An LCR circuit, also known as a resonant circuit, tuned circuit, or an RLC circuit, **is an electrical circuit consisting of an inductor (L), capacitor (C) and resistor (R) connected in series or parallel**. The LCR circuit analysis can be understood better in terms of phasors. A phasor is a rotating quantity.



Current Vs Voltage Graph

Current Vs Voltage Graph

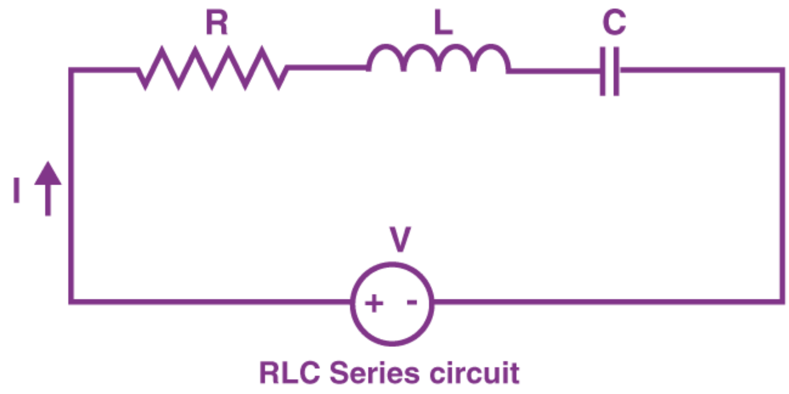
For an inductor (L), if we consider I to be our reference axis, then voltage leads by 90°, and for the capacitor, the voltage lags by 90°. But the resistance, current and voltage phasors are always in phase.

In this article, let us understand in detail about the RLC series circuit.

Following is the table explaining other **related concepts of the circuit**:

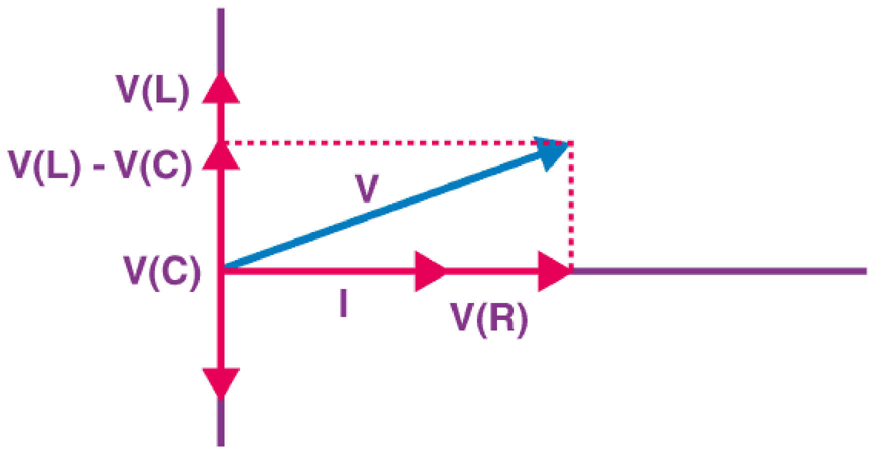
Analysis of An RLC Series Circuit

Let's consider the following RLC circuit using the current across the circuit to be our reference phasor because it remains the same for all the components in a series RLC circuit.



RLC Series circuit

As described above the overall phasor will look like below:



Phasor diagram of current Vs voltage for resistor, inductor, and capacitor for RLC series circuit

From the above phasor diagram we know that,

$V^2 = (V_R)^2 + (V_L - V_C)^2$ —– (1)

Now Current will be equal in all the three as it is a series LCR circuit. Therefore,

$V_R = IR$—– (2)
$V_L = IX_L$ —– (3)
$V_C = IX_C$ —– (4)
Using (1), (2), (3) and (4)

$II= V/\surd R^2 + (X_L - X_C)^2$
Also the angle between V and I is known phase constant,
$\tan \emptyset = V_L - V_C V_R$
It can also be represented in terms of impedance,

$\tan \emptyset = X_L - X_C R$

Depending upon the values of X_L and X_C
We have three possible conditions,

1. If $X_L > X_c$, then tanØ>0 and the voltage lead the current and the circuit is said to be inductive
2. If $X_L < X_c$, then tanØ<0 and the voltage lags the current and the circuit is said to be capacitive
3. If $X_L = X_c$, then tan Ø = 0 and the voltage is in phase with the current and is known as resonant circuit.

Frequently Asked Questions – FAQs

Is there a difference between RLC circuit and LCR circuit?

There is no difference between an RLC circuit and an LCR circuit except for the order of the symbol represented in the circuit diagram.

What is the phase difference between the current in the capacitor and the current in the resistor in a series LCR circuit?

The voltage across the capacitor lags the current in the circuit by 900. Hence, the phase difference between the voltage across the capacitor and the current in the circuit is 900.

What is an RLC circuit?

It is an electrical circuit, which includes a resistor (R), an inductor (L), and a capacitor (C) that are connected in either series or parallel way.

What is an inductor?

It is a two-terminal passive electrical component that opposes sudden changes in current. It is used to store energy in the form of magnetic energy when electricity is applied to it.

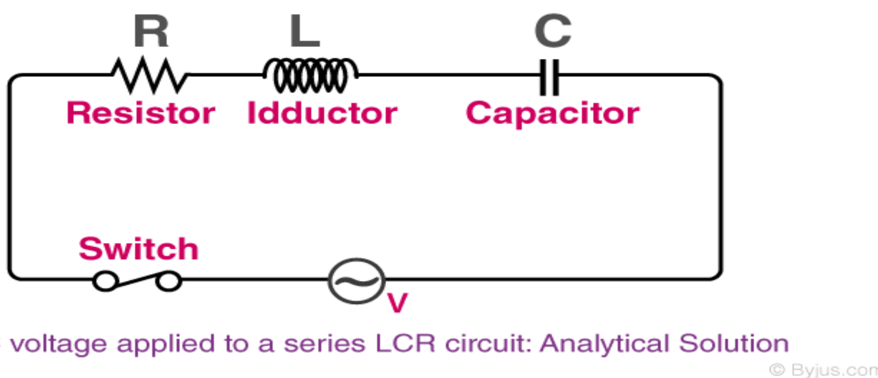
What is a capacitor?

A capacitor is a two-terminal electrical device that can store energy in the form of an electric charge. Capacitors include two electrical conductors, which are separated by a distance.

Derivation of AC Voltage Applied to Series LCR Circuit

Consider the circuit shown above. Here, we have an inductor, a resistor, and a capacitor connected through a series connection across an AC voltage source given by V. Here, the voltage is sinusoidal in nature and is given by the equation,

$v = v_m \sin \omega t$



AC voltage applied to a series LCR circuit: Analytical Solution

Here, v_m is the amplitude of the voltage and ω is the frequency.

If q is the charge on the capacitor and i the current at time t, we have, from Kirchhoff's loop rule:

$$L\frac{di}{dt} + iR + \frac{q}{C} = v$$

Here, q is the charge held by the capacitor, I is the current passing through the circuit, R is the resistance of the resistor and C is the capacitance of the capacitor. In order to determine the instantaneous current or the phase of the relationship, we will follow the analytical analysis of the circuit.

Analytical solution

As i

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

, we can write

$$\frac{di}{dt} = \frac{d^2q}{dt^2}$$

Hence, writing the voltage equation in terms of the charge q through the circuit, we can write,

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = v_m \sin \omega t$$

The above equation can be considered analogous to the equation of a forced, damped oscillator. In order to solve the equation, we assume a solution given by,

$$q = q_m \sin(\omega t + \theta)$$

So,

$$\frac{dq}{dt} = q_m \omega \cos(\omega t + \theta)$$

And

$$\frac{d^2q}{dt^2} = -q_m \omega^2 \sin(\omega t + \theta)$$

Substituting these values in the voltage equation, we can write,

$$q_m \omega [R\cos(\omega t + \theta) + (X_c - X_L)\sin(\omega t + \theta)] = v_m \sin \omega t$$

Here, we have substituted the value of X_c and X_L by Xc = 1/ωC and XL = ω L.

As we know,

$$Z = \sqrt{R^2 + (X_C^1 - X_L^1)^2}$$

hence, substituting this value in the above equation, we get,

$$\frac{q_m \omega}{Z}\left[\frac{R}{Z}\cos(\omega t + \theta) + (\frac{X_c - X_L)}{Z}\sin(\omega t + \theta)\right] = v_m \sin \omega t$$

Now, let

$$\frac{R}{Z} = \cos \emptyset,$$

$$\frac{X_C - X_L}{Z} = \sin \emptyset,$$

So we can say,

$$\varnothing = \tan^{-1}\frac{X_C - X_L}{R}$$

$$q_m \omega Z[\cos(\omega t + \theta - \varnothing)] = v_m \sin \omega t$$

Now, comparing the two sides of the equation, we can write,

$$q_m \omega Z = v_m = i_m Z$$

And,

$$\theta - \varnothing = -\frac{\pi}{2}$$

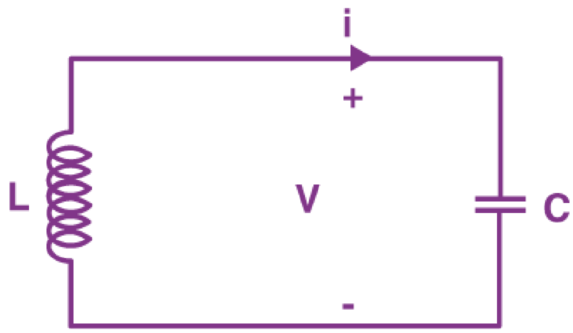
$$\theta = -\frac{\pi}{2} + \varnothing$$

Hence, the equation for current in the circuit can be given as,

$$i = \frac{dq}{dt} = q_m \omega \cos(\omega t + \theta) = i_m \cos(\omega t + \theta) = i_m \sin(\omega t + \varnothing)$$

LC Circuit

An LC circuit is a type of an electric circuit that is made up of an inductor which is expressed by the letter L and a capacitor represented by the letter C. Here, both are connected in a single circuit. An LC circuit is also sometimes referred to as a tank circuit, resonant circuit, or tuned circuit. LC circuits act as major components in various electronic devices like radio equipment, in circuits like filters, oscillators, and tuners.



LC circuit is a suitable model in many cases mainly because by using this type of circuit we can assume that there is no dissipation of energy even in if there is any resistance. However, if we were to be practical any implementation will involve loss because of the small electrical resistance in the connecting wires or components. This type of circuit is used because it can oscillate with minimum damping making the resistance as low as possible. Nonetheless, most of the circuits work with some loss.

When an LC circuit oscillates at its natural resonant frequency, it can reserve electrical energy. The capacitor depending on the voltage it receives will store energy in the electric field (E) between its plates whereas an inductor depending on the current, it will accumulate energy in its magnetic field (B).

Nomenclature

The di elemental LC circuit that we talked about in the above paragraphs is a basic example of an inductor-capacitor network. Moreover, it is also called a second-order LC circuit to differentiate it from highly complicated LC networks that have more capacitors and inductors. These LC networks that consist of more than two reactance's can consist of several resonant frequencies.

A resonant frequency is defined as an undamped or natural frequency of a system. In the case of LC circuits, the resonant frequency is usually determined by the impedance L and capacitance C.

Meanwhile, the network order is an order of rational function which describes the network in complex frequency variables s. The order generally equals the number of L and C elements of the circuit and cannot exceed in any event.

Applications or Uses of LC Circuit

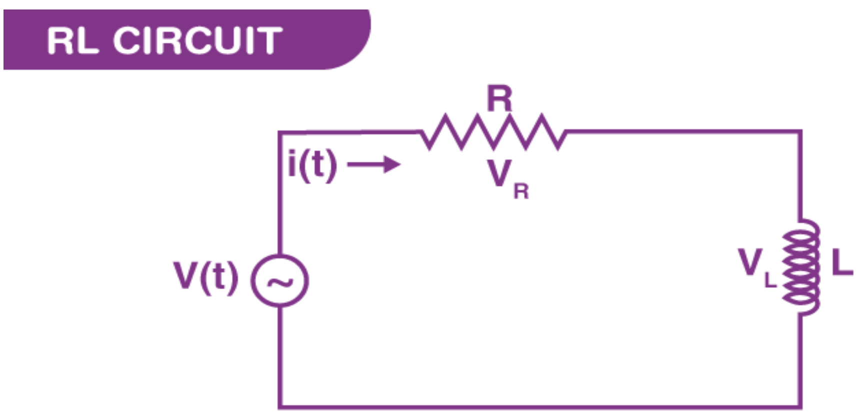
The resonance effects of LC circuits have various applications which are important in communication systems and signal processing.

- LC circuits are utilized either to pick out or generate a signal at a certain frequency.
- Tuning radio transmitters and receivers are the most common application of tank circuits. For instance, when you tune a radio to some station, the LC circuits set a resonance for that carrier frequency.
- A parallel resonant circuit yields current magnification.
- A series resonant circuit yields voltage magnification.
- Both series and parallel resonant circuits are utilized in induction heating.

RL Circuit

RL Circuits (resistor – inductor circuit) also called RL network or RL filter is a type of circuit having a combination of inductors and resistors and is usually driven by some power source. As such, an RL circuit has the inductor and a resistor connected in either parallel or series combination with each other. They are either driven by the current (parallel) or a voltage (series) source. Besides, the resistor (R), inductor (L), and capacitor(C) form the basic passive linear circuit elements. They can form an electrical circuit in four different ways like the RC circuit, the LC circuit and the RLC circuit.

Alternatively, an RL circuit is also described as an electric circuit with resistance and self-inductance. We already know, the process of induction occurs when an emf source is applied by a continuous change in the magnetic flux. The mutual inductance is an effect of the laws of induction presented by Faraday, while self-inductance is an effect of the laws of induction of Faraday of a device coming on itself. The inductor is a circuit or a device component that exhibits self-inductance. However, since there is a presence of a resistor in the ideal form of the circuit, an RL circuit will consume energy, akin to an RC circuit or RLC circuit.



Consider the above circuit having a battery, a resistor, and a switch. The switch can either have the battery in the series connection to the circuit or the battery can be removed from the circuit. When the switch is closed, the current jumps to the maximum value and when the switch is opened, the value of current decreases immediately.

When an inductor is added in series with the resistor of the circuit, we come to observe changes in the current. The role of an inductor in the circuit is to oppose the change in the magnetic flux, i.e the inductor does not allow the spontaneous changes in the current. When we close the switch of the circuit, there is a gradual increase in the value of current to a maximum value. When we open the switch and remove the battery, the inductor voltage causes the current to reduce gradually to the value of zero again.

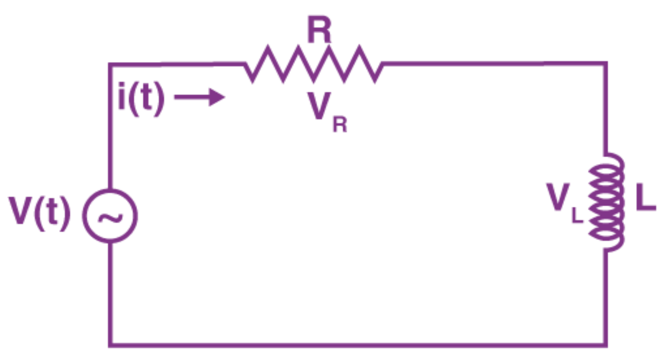
A first-order RL circuit mainly comprises one resistor & one inductor to form an RL circuit. The power factor of this circuit is low because of the inductive load like a 3-phase induction motor. Even the lamps, transformers, welding devices operate at low lagging power factors.

In the RL series circuit, the flow of current is lagging behind the voltage through an angle 'φ' due to the inductor effect. So here, the power factor (PF) can be given like the cosine of lagging angle 'φ'

The power factor = Cos φ = Resistance/Impedance = R/Z

RL Series Circuit

A circuit that contains a resistance R connected in series with the coil having an inductance L is known as an RL Series Circuit. When a supply voltage (V) is applied across the current element I flowing in the circuit. IL and IR are the currents flowing in the inductor and resistor, but the current flowing across both the elements are the same as they are said to be connected in the series connection with each other. The diagram of the RL Series Circuit is as shown below-



where V_R is the voltage across resistor R

V_L is the voltage across inductor L

V(t) is the total voltage across the circuit

In the above simple RL Series circuit where the resistor, R and the inductor, L are combined in series combination with the voltage source having V volts. The current flowing in the whole circuit is I amps and the current through the resistor and the inductor is IR and IL. Since both the resistance as well as the inductor are connected in the series combination, the current in both of the elements of the circuit remains to be the same.

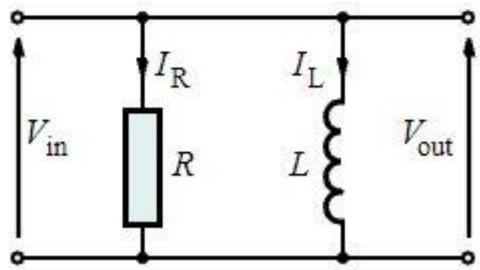
Here, IL = IR = I. Consider V_L and V_R to be the voltage drops across the inductor and resistor. By the application of Kirchhoff voltage law (sum of the voltage drops must be the same across the circuit to apply the voltage) to this circuit, we get,

$V(t) = V_R + V_L$

Thus, this is the equation for the voltage across the RL series circuit.

RL Parallel Circuit

The parallel RL circuit is generally of less interest than the series circuit. It can be interesting until it is fed by a current source. This is the case with a parallel RL circuit mainly because the output voltage V_{out} is equal to the input voltage V_{in}. As a result, this circuit does not act as a filter for a voltage input signal.



The parallel circuit can be found on the output of many amplifier circuits. It is basically used to isolate the amplifier from capacitive loading effects at high frequencies.

Use of RL Circuit

- In chokes of luminescent tubes.
- For supplying DC power to radio-frequency amplifiers where the inductor is used to pass DC bias current and block the RF returning back into the power supply.
- RL circuits can form a single-pole filter. The filter is low-pass or high-pass is dictated by whether the reactive element (C or L) is in series with the load or parallel with the load.
- Radio Wave Transmitters.
- Resonant LC Circuit/RLC Circuit.
- Communication Systems.
- Processing of Signal.
- Oscillator Circuits.
- Magnification of Current or Voltage.
- Variable Tunes Circuits.
- Filtering Circuits.

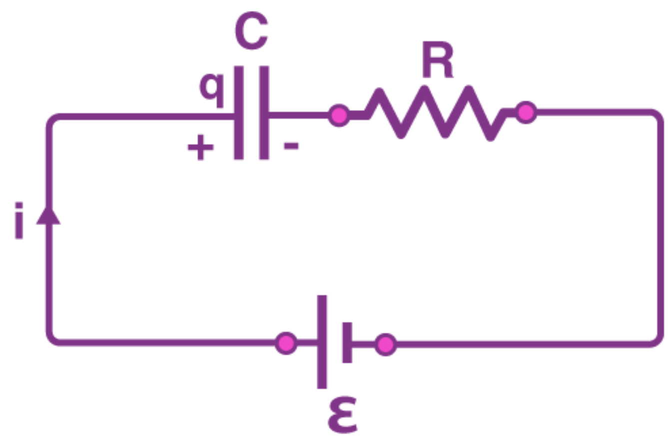
RC Circuit

A resistor-capacitor circuit (RC Circuit) is an electrical circuit consisting of passive components like resistors and capacitors, driven by the current source or the voltage source.

The capacitor stores energy and the resistor connected to the circuit control the rate of charging or discharging.

The charging and the discharging of the capacitor is not an instant process but takes some time. If the resistor and capacitor are connected in series, the capacitor charges gradually through the resistor, until the voltage across the resistor is equal to the supply voltage.

Charging of Capacitor



Let us consider that a fully discharged capacitor is connected to the circuit and the switch is open. The initial condition of the circuit is time (t) = 0, charge (q) = 0 and current (i) = 0. When the switch is closed, the time will start from t = 0, and the current starts flowing through the capacitor and the resistor. An initially uncharged capacitor can be assumed to be a connecting wire just after the circuit is completed.

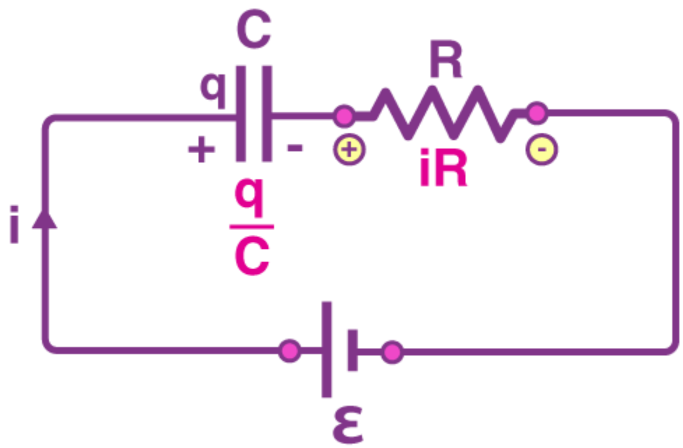
At time t = 0, the potential difference across the capacitor is zero and continues to be equal to zero just after the time t = 0.

The current flowing at this time is called the charging current and it is calculated using Ohm's law. The value of current is

$i = i_0 = \varepsilon/R$.

Here, ε is the emf of the cell.

R is the resistance of the resistor.



As time progresses, the capacitor charges up and a potential difference develops across the capacitor. Let us consider at any time "t", the charge across the capacitor is "q" and the current in the circuit is "i". The potential difference across the capacitor is q/C and the potential difference across the resistor is iR.

Solved Examples

Question 1: A capacitor of capacitance 1000 µF is connected to a resistor of resistance 150 kΩ and a battery of 1.5 V in series. Find the maximum current that flows through the resistor while charging.

Answer:

I = Ɛ/R = 1.5 V/150 kΩ = 0.01 mA

Question 2: A 50 V AC is applied across an RC series network. The RMS voltage across the resistance is 40 V, then the potential across the capacitance would be

a) 10 V

b) 20 V

c) 30 V

d) 40 V

Answer: c) 30 V

Question 3: The impedance of the RC circuit is Z_1 for the frequency f, and Z_2 for frequency 2f. Then, Z_1/Z_2 is

a) between 1 and 2

b) 2

c) Between ½ and 1

d) ½

Answer: a) between 1 and 2

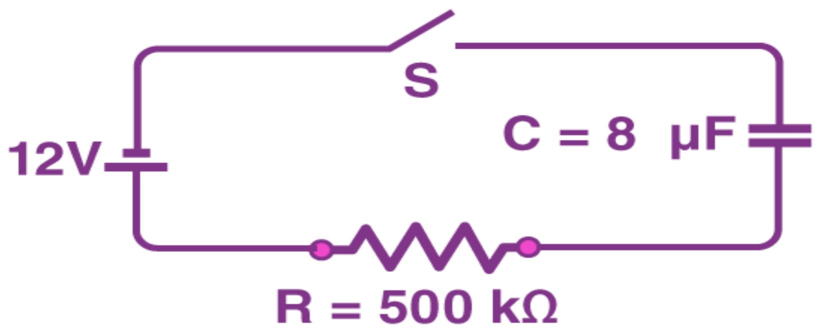
Question 4: An uncharged capacitor and a resistor are connected in series as shown in the figure below. The emf of the battery is $\varepsilon = 12$ V, C = 8 μF , R = 500 kΩ

After the switch is closed, find

(a) The time constant of the RC circuit.

(b) The maximum charge on the capacitor.

(c) The charge on the capacitor 6 s after the switch is closed.



Solution:

(a) The time constant of the RC circuit, $\tau = (500 \times 10^{-3}\ \Omega)\ (8 \times 10^{-6}) = 4S$

(b) $Q = Q_f\ (1 - e^{-t/RC})$

$Q_f = C\mathcal{E}$ is the final charge

The maximum charge on the capacitor, $Q_{max} = C\mathcal{E}$

$= (8 \times 10^{-6})\ (12) = 96\ \mu C$

(c) The charge on the capacitor 6 s after the switch is closed is given by

$Q = Q_f\ (1 - e^{-t/\tau})$

$= 96\ (1 - e^{-6/4})$

$= 74.5\ \mu C$

Alternating Current MCQs

Alternating current is a current whose magnitude changes with time, and direction reverses periodically.

The alternating emf E at any time is given by the equation:

$E=E_0\sin\omega t$ $E=E0\sin\omega t$

The alternating current I at any time is given by:

$I=I_0\sin(\omega t-\phi)$ $I=I0\sin(\omega t-\phi)$

Following are a few important terms related to alternating current:

1. **Peak Value –** Maximum values of voltage and current in a cycle
2. **Instantaneous Value –** The value of alternating voltage and current at an instant *t*.
3. **Root Mean Square Value –** The value of direct current which produces the same heating effect in a given resistor as is produced by the given alternating current when passed for the same time.
4. **Mean or average value –** It is defined as that value of direct current which sends the same charge in a circuit in the same time as is sent by the given alternating current in its half time period.

<u>Question and Answer</u>

1. What is the frequency of a 5μF capacitor that has a reactance of 1000 Ω?

a. 200 cycle/sec
b. 100/π cycle/sec
c. 5000 cycles/sec
d. 1000/π cycles/sec

Answer: (b) 100/π cycle/sec

2. What is the reciprocal of impedance?

a. Admittance
b. Inductance
c. Reactance
d. Conductance

Answer: (a) Admittance

3. What is the time taken by the alternating current of 50 Hz with an r.m.s value of 10 ampere to reach from zero to a maximum value and the peak value of current?

a. 2×10^{-2} sec and 14.24 amp
b. 5×10^{-3} sec and 8.07 amp

c. 5×10^{-3} sec and 14.14 amp
d. 1×10^{-2} sec and 7.07 amp

Answer: (c) 5×10^{-3} sec and 14.14 amp

4. What is the voltage applied across the resonant circuit if the ac voltage across resistance R, inductance L and capacitance C is 5 V, 10 V and 10 V respectively?

a. 5 V
b. 10 V
c. 20 V
d. 25 V

Answer: (a) 5 V

5. Why can't the DC ammeter measure an alternating current?

a. AC cannot pass through a DC ammeter
b. AC changes its direction
c. AC is virtual
d. The average value of a complete cycle is zero

Answer: (d) The average value of a complete cycle is zero

6. If the peak current is given by I_p, then how much power is dissipated by a sinusoidal ac current which flows through resistor of resistance R?

a. $I_{p}2$RcosΘIp2RcosΘ
b. 4πIp2R4πIp2R
c. 1πIp2R1πIp2R
d. 12Ip2R12Ip2R

Answer: (d) 12Ip2R12Ip2R
7. What is the frequency of ac mains in India?

a. 120 Hz
b. 60 Hz
c. 50 Hz
d. 30 Hz

Answer: (c) 50 Hz

8. If a current I given by I_0sin(ωt−π2)I0sin(ωt−π2) flows across an AC circuit with potential E=E_0sinωtE=E0sinωt, then what is the power consumption in the circuit?

a. P=$E_0I_0$2P=E0I02
b. P=√2 E_0I_0P=2E0I0

c. P=$E_0I_0\sqrt{2}$P=E0I02
d. P=0P=0

Answer: (d)P=0P=0
9. What is the r.m.s current value of an alternating current given by the equation of i=$i_1$cosωt+$i_2$sinωti=i1cos⁡ωt+i2sin⁡ωt?

a. $1\sqrt{2}(i_1^2+i_2^2)^{1/2}$12(i12+i22)1/2
b. $12(i_1^2+i_2^2)^{1/2}$12(i12+i22)1/2
c. $1\sqrt{2}(i_1+i_2)^2$12(i1+i2)2
d. $1\sqrt{2}(i_1+i_2)$12(i1+i2)

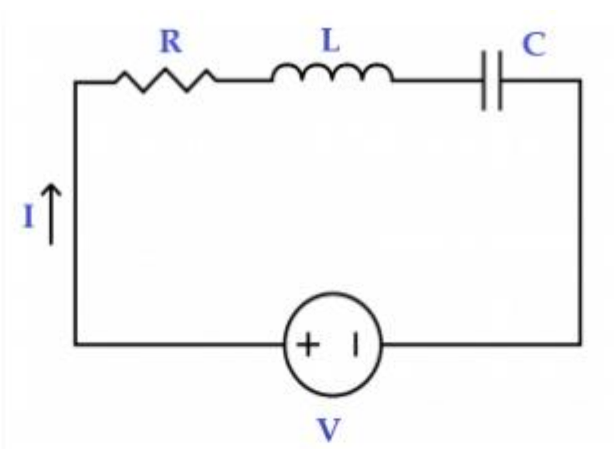
Answer: (a) $1\sqrt{2}(i_1^2+i_2^2)^{1/2}$12(i12+i22)1/2
10. What is the peak value of the voltage of an electric lamp connected to a 220 V, 50 Hz supply?

a. 311 V
b. 320 V
c. 211 V
d. 210 V

Answer: (a) 311 V

RLC Circuit MCQs

The circuit consisting of a resistor (R), an inductor (L) and a capacitor (C) connected in series or parallel is called RLC circuit.



RLC Series circuit

Q1: A 6.8 kΩ resistor, a 7 mH coil, and a 0.02 µF capacitor are in parallel across a 17 kHz ac source. The coil's internal resistance Rw is 30 Ω. The equivalent parallel resistance, Rp (eq) is

a. 1,878 Ω
b. 18,780 Ω
c. 18,750 Ω
d. 626 Ω

Answer: (b) 18,780 Ω

Q2: A 15 kΩ resistor, a 220 µH coil, and a 60 pF capacitor are in series across an ac source. What is the bandwidth of the circuit?

a. 138 MHz
b. 10,866 Hz
c. 1,907 Hz
d. 138 kHz

Answer: (b) 10,866 Hz

Q3: A 90 Ω resistor, a coil with 30 Ω of reactance, and a capacitor with 50 Ω of reactance are in series across a 12 V ac source. The current through the resistor is

a. 9 mA
b. 90 mA
c. 13 mA
d. 130 mA

Answer: (d) 130 mA

Q4: The total impedance, expressed in polar form for a certain series RLC circuit with a 200 Hz, 15 V ac source has the following values: R = 12 Ω, C = 80 µF, and L= 10 mH is

a. $12.28 \angle 12.34^0$ Ω
b. $12.57 \angle 12.34^0$ Ω
c. $9.95 \angle 12.34^0$ Ω
d. $12.62 \angle 12.34^0$ Ω

Answer: (a) $12.28 \angle 12.34^0$ Ω

Q5: If the resistance in parallel with a parallel resonant circuit is reduced, the bandwidth

a. Disappears
b. Becomes Sharper
c. Increases
d. Decreases

Answer: (d) Decreases

Q6: To tune a parallel resonant circuit to a higher frequency, the capacitance should be

a. Increased
b. Decreased
c. Left alone
d. Replaced with inductance

Answer: (b) Decreased

Q7: A 15 Ω resistor, an inductor with 8 Ω inductive reactance, and a capacitor with 12 Ω capacitive reactance are in parallel across an ac voltage source.

a. 12.7 Ω
b. 127 Ω
c. 4.436 Ω
d. 6,174 Ω

Answer: (a) 12.7 Ω

Q8: What is the value of resonant frequency if the value of C in a series RLC circuit is decreased?

a. Is not affected
b. Increases
c. Is reduced to zero
d. Decreases

Answer: (b) Increases

Q9: In a series RLC circuit that is operating above the resonant frequency the current

a. Lags the applied voltage
b. Leads the applied voltage
c. Is in phase with the applied voltage
d. Is zero

Answer: (a) Lags the applied voltage

Q10: An inductor with a reactance of 120 Ω, a capacitor with a reactance of 120 Ω and a 24 Ω resistor are in series across a 60 V source. The circuit is at resonance. The voltage across the inductor is

a. 60 V
b. 660 V
c. 30 V
d. 300 V

Answer: (d) 300 V