**DEPARTMENT OF PHYSICS**
**INDO – AMERICAN COLLEGE CHEYYAR**

**II B.SC PHYSICS – ODD SEMESTER**
**SKILL BASED SUBJECT I**
**<u>ELECTRICAL APPLIANCES – BSPH32</u>**

**SYLLABUS:**

UNIT – I: Resistance and its types – capacitance and its types – Color codes-inductance and its units – Transformers – Electrical Charge – Current – Electrical Potential.

BY

**P.Umadevi, Head, Dept. of Physics**

# Unit I

**Objectives:**

- **Introduction**
- **Resistors**
- **Types of resistors**
- **Color coding**
- **Capacitors**
- **Types of capacitor**
- **Color coding**
- **Inductance**
- **Transformer**
- **Electric charge**
- **Current**
- **Potential**

## 1. Introduction:

An **electrical appliance** is a device that uses electricity to perform a function.

### 1.1 Passive devices:

Components incapable of controlling current by means of another electrical signal are called **passive devices**. Passive devices are the main components used in electronics such as resistors, inductors, capacitors and transformers which together are required to build any electrical or electronic circuit. Therefore passive devices cannot generate, oscillate or amplify an electrical signal.

### 1.2 Resistors:

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines.

### 1.2.1 Resistor composition:

Most common, modern **resistors** are **made** out of either a carbon, metal, or metal-oxide film. In these **resistors**, a thin film of conductive (though still resistive) material is wrapped in a helix around and covered by an insulating material.

### 1.2.2 Difference between resistor and resistance:

**Resistance** is the property of a conductor, which determines the quantity of current that passes through it when a potential **difference** is applied across it. A **resistor** is a electrical component **with a** predetermined electrical **resistance**, like 1 ohm, 10 ohms 100 ohms 10000 ohms etc.

### 1.2.3 Theory of operation:

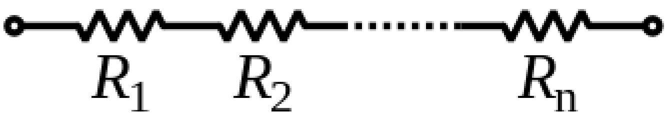
The behavior of an ideal resistor is dictated by the relationship specified by Ohm's law: V = IR

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I), where the constant of proportionality is the resistance (R).

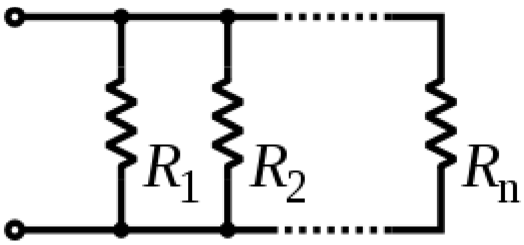
The ohm (symbol: Ω) is the SI unit of electrical resistance, named after George Simon Ohm. An ohm is equivalent to a volt per ampere. Since resistors are specified and manufactured over a very large range of values, the derived units of milliohm (1 mΩ = $10^{-3}$ Ω), kilo ohm (1 kΩ = $10^{3}$ Ω), and mega ohm (1 MΩ = $10^{6}$ Ω) are also in common usage.

### 1.2.4 Resistor connections:

The total resistance of resistors connected in series is the sum of their individual resistance values.




The total resistance of resistors connected in parallel is the reciprocal of the sum of the reciprocals of the individual resistors.



## 1.3 Types of resistors:

All modern fixed value resistors can be classified into four broad groups:

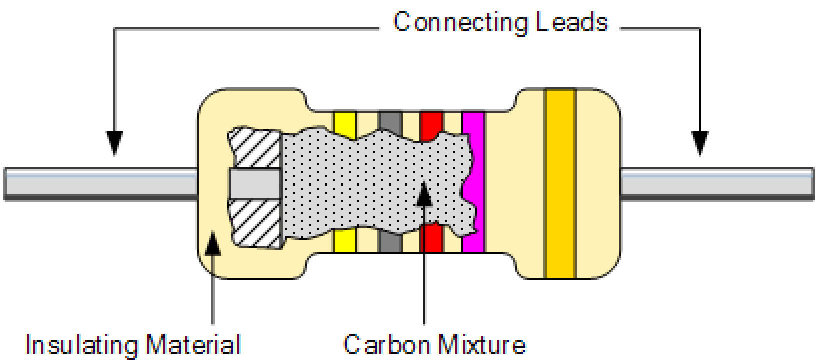
- Carbon Composition Resistor – Made of carbon dust or graphite paste, low wattage values
- Film or Cermet Resistor – Made from conductive metal oxide paste, very low wattage values
- Wire-wound Resistor – Metallic bodies for heat sink mounting, very high wattage ratings
- Semiconductor Resistor – High frequency/precision surface mount thin film technology

### Composition Types of Resistor

Carbon Resistors are the most common type of Composition Resistors. Carbon resistors are a cheap general purpose resistor used in electrical and electronic circuits. Their resistive element is manufactured from a mixture of finely ground carbon dust or graphite (similar to pencil lead) and a non-conducting ceramic (clay) powder to bind it all together.

### Carbon Resistor

The ratio of carbon dust to ceramic (conductor to insulator) determines the overall resistive value of the mixture and the higher the ratio of carbon, the lower the overall resistance. The mixture is moulded into a cylindrical shape with metal wires or leads are attached to each end to provide the electrical connection as shown, before being coated with an outer insulating material and color coded markings to denote its resistive value.



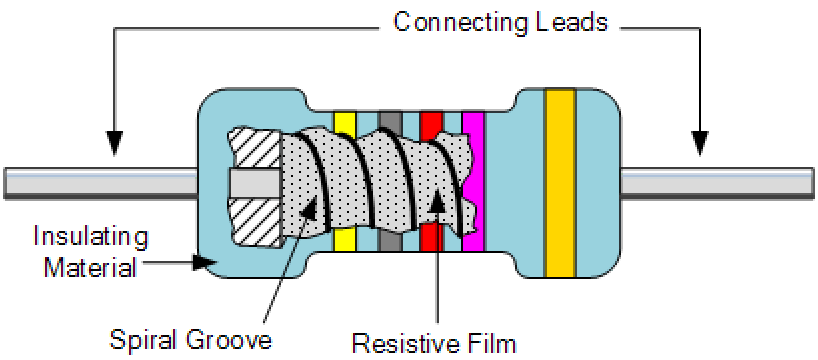

### Film Type Resistors

The generic term " **Film Resistor**" consist of *Metal Film*, *Carbon Film* and *Metal Oxide Film* resistor types, which are generally made by depositing pure metals, such as nickel, or an oxide film, such as tin-oxide, onto an insulating ceramic rod or substrate.

The resistive value of the resistor is controlled by increasing the desired thickness of the deposited film giving them the names of either “thick-film resistors” or “thin-film resistors”.

Once deposited, a laser is used to cut a high precision spiral helix groove type pattern into this film. The cutting of the film has the effect of increasing the conductive or resistive path, a bit like taking a long length of straight wire and forming it into a coil.

This method of manufacture allows for much closer tolerance resistors (1% or less) as compared to the simpler carbon composition types. The tolerance of a resistor is the difference between the preferred value (i.e, 100 ohms) and its actual manufactured value i.e, 103.6 ohms, and is expressed as a percentage, for example 5%, 10% etc, and in our example the actual tolerance is 3.6%. Film type resistors also achieve a much higher maximum ohmic value compared to other types and values in excess of 10MΩ (10 Million Ohms) are available.




**Metal Film Resistors:**

It have much better temperature stability than their carbon equivalents, lower noise and are generally better for high frequency or radio frequency applications. **Metal Oxide Resistors** have better high surge current capability with a much higher temperature rating than the equivalent metal film resistors.

Another type of film resistor commonly known as a **Thick Film Resistor** is manufactured by depositing a much thicker conductive paste of Ceramic and **Metal**, called **Cermet**, onto an alumina ceramic substrate. Cermet resistors have similar properties to metal film resistors and are generally used for making small surface mount chip type resistors, multi-resistor networks in one package for pcb’s and high frequency resistors. They have good temperature stability, low noise, and good voltage ratings but low surge current properties.

**Metal Film Resistors** are prefixed with a “MFR” notation (eg, MFR100kΩ) and a CF for Carbon Film types. Metal film resistors are available in E24 (±5% & ±2% tolerances), E96 (±1% tolerance) and E192 (±0.5%, ±0.25% & ±0.1% tolerances) packages with power ratings of 0.05 (1/20th) of a Watt up to 1/2 Watt. Generally speaking Film resistors and especially metal film resistors are precision low power components.

**Wire wound Types of Resistor**

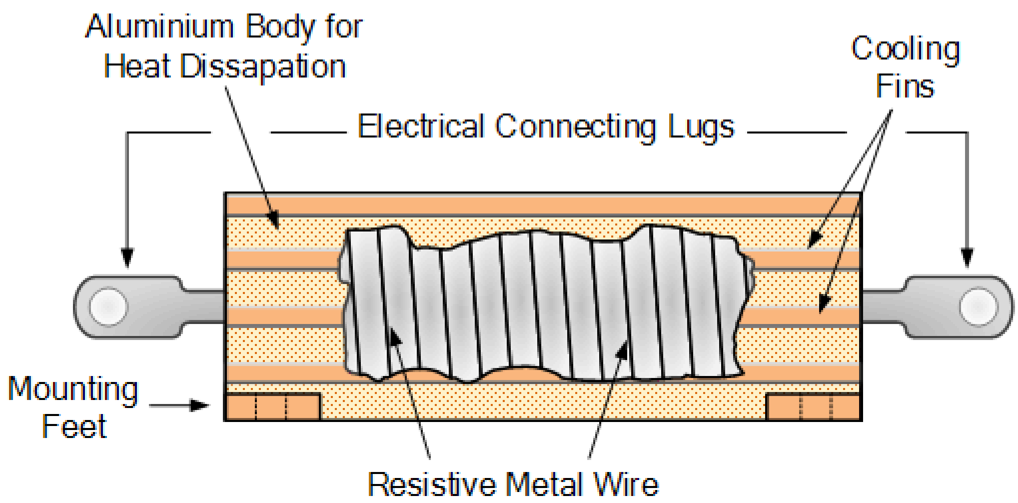
Another type of resistor, called a **Wire wound Resistor**, is made by winding a thin metal alloy wire (Nichrome) or similar wire onto an insulating ceramic former in the form of a spiral helix similar to the film resistor above.

These types of resistor are generally only available in very low ohmic high precision values (from 0.01Ω to 100kΩ) due to the gauge of the wire and number of turns possible on the former making them ideal for use in measuring circuits and Wheatstone bridge type applications.

They are also able to handle much higher electrical currents than other resistors of the same ohmic value with power ratings in excess of 300 Watts. These high power resistors are moulded or pressed into an aluminium heat sink body with fins attached to increase their overall surface area to promote heat loss and cooling.

Another type of wire wound resistor is the **Power Wire wound Resistor**. These are high temperature, high power non-inductive resistor types generally coated with vitreous or glass epoxy enamel for use in resistance banks or DC motor/servo control and dynamic braking applications. They can even be used as low wattage space or cabinet heaters.

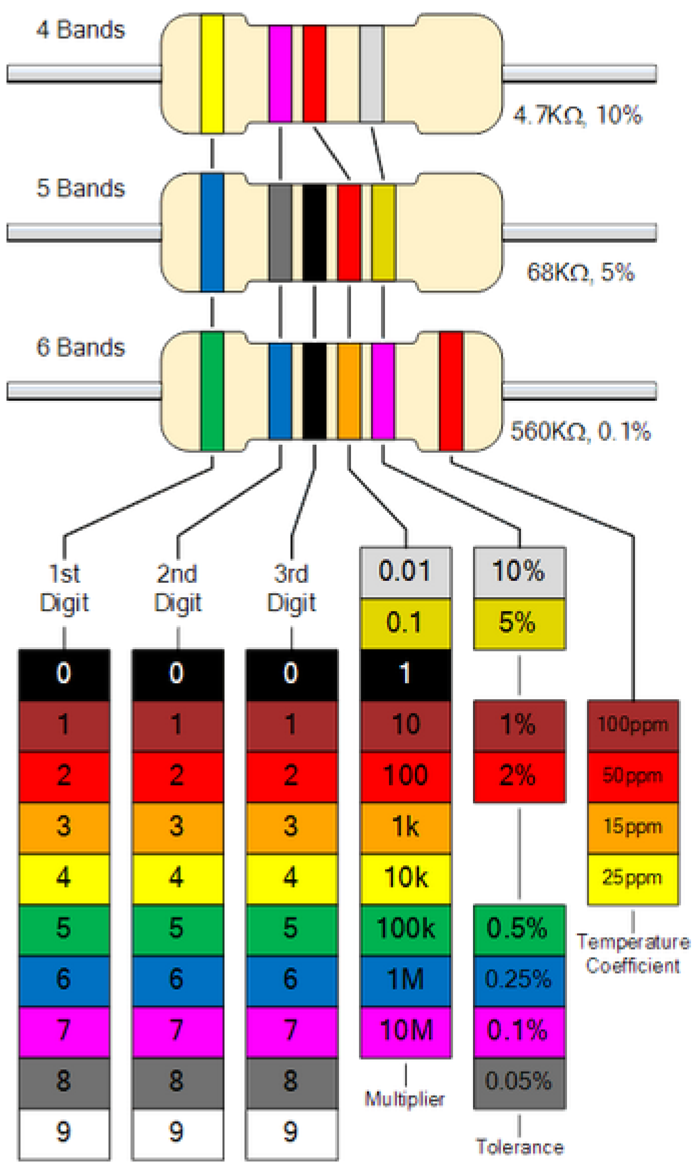
The non-inductive resistance wire is wound around a ceramic or porcelain tube covered with mica to prevent the alloy wires from moving when hot. Wire wound resistors are available in a variety of resistance and power ratings with one main use of power wire wound resistor is in the electrical heating elements of an electric fire which converts the electrical current flowing through it into heat with each element dissipating up to 1000 Watts, (1kW) of energy.



Because the wire of standard wire wound resistors is wound into a coil inside the resistors body, it acts like an inductor causing them to have inductance as well as resistance. This affects the way the resistor behaves in AC circuits by producing a phase shift at high frequencies especially in the larger size resistors.

### 1.4 Color coding:

Resistors are devices that limit current flow and provide a voltage drop in electrical circuits. Because carbon resistors are physically small, they are color-coded to identify their resistance value in ohms. The use of color bands on the body of a resistor is the most common system for indicating the value of a resistor. Color-coding is standardized by the Electronic Industries Association (EIA).




Use the Resistor Color Code Chart (below) to understand how to use the color code system. When looking at the chart, note the illustration of three round resistors with numerous color code bands. The first resistor in the chart (with 4 bands) tells you the minimum information you can learn from a resistor. The next (a 5-band code) provides a little more information about the resistor. The third resistor (a 6-band) provides even more information. Each color band is associated with a numerical value

#### 1.4.1 How to read a typical 4-band, 5-band and 6-band resistor

**4-Band:**

Reading the resistor from left to right, the first two color bands represent significant digits, the third band represents the decimal multiplier, and the fourth band represents the tolerance. 5-Band: The first three color bands represent significant digits, the fourth band represents the decimal multiplier, and the fifth band represents the tolerance. 6-Band: The first three color bands represent significant digits, the fourth band represents the decimal multiplier, the fifth band represents the tolerance, and the sixth band represents the temperature coefficient. Definitions of color bands The color of the multiplier band represents multiples of 10, or the placement of the decimal point. For example: ORANGE (3) represents 10 to the third power or 1,000. The tolerance indicates, in a percentage, how much a resistor can vary above or below its value. A gold band stands for +/- 5%, a silver band stands for +/- 10%, and if no fourth band exists, it is assumed to be +/- 20%.

### 1.4.2 For example:

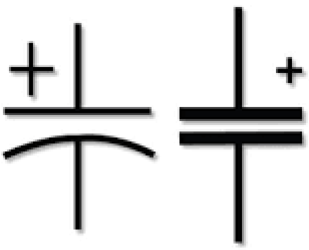
A 100-ohm 5% resistor can vary from 95 to 105 ohms and still be considered within the manufactured tolerance. The temperature coefficient band specifies the maximum change in resistance with change in temperature, measured in parts per million per degree Centigrade (ppm/°C). **Example (from chart)**

Let's look at the first resistor on the chart. In this case, the first color band is BROWN. Following the line down the chart you can see that BROWN represents the number 1. This becomes our first significant digit. Next, look at the second band and you will see it is BLACK. Once again, follow the line down to the bar scale; it holds a value of 0, our second significant digit. Next, look at the third band, the multiplier, and you will see it is ORANGE. Once again, follow the line down to the bar scale; it holds a value of 3. This represents 3 multiples of 10 or 1000. With this information, the resistance is determined by taking the first two digits, 1 and 0 (10) and multiplying by 1,000. Example: 10 X 1000 = 10,000 or 10,000 ohms. Using the chart, the fourth band (GOLD), indicates that this resistor has a tolerance of +/- 5%. Thus, the permissible range is: 10,000 X .05 = +/- 500 ohms, or 9,500 to 10,500 ohms.

### 1.5 Capacitor:

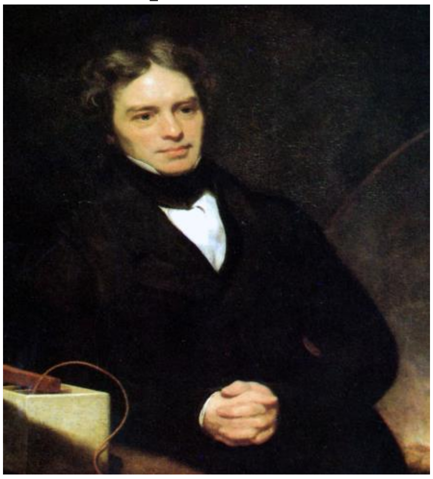
A **capacitor** is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals. The effect of a **capacitor** is known as capacitance. Used to store **energy** electro statically in an electric field, the forms of practical capacitors vary widely, but all contain at least two electrical conductors (plates) separated by a dielectric (i.e., insulator).

An ideal capacitor is characterized by a constant capacitance *C*, is, defined as the ratio of the positive or negative charge *Q* on each conductor to the voltage *V* between them



$$C = \frac{Q}{V}$$

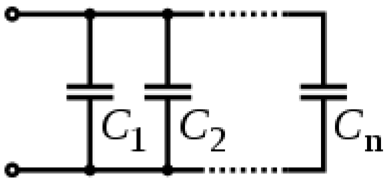
### 1.5.1 Capacitor unit:



The SI **unit** of **capacitance** is the farad (symbol: F), named after the English physicist Michael Faraday. A 1 farad **capacitor**, when charged with 1 coulomb of electrical charge, has a potential difference of 1 volt between its plates. The reciprocal of **capacitance** is called elastance.

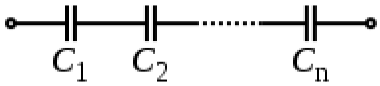
### 1.5.2 for capacitors in parallel

Capacitors in a parallel configuration each have the same applied voltage. Their capacitances add up. Charge is apportioned among them by size. Using the schematic diagram to visualize parallel plates, it is apparent that each capacitor contributes to the total surface area.




### 1.5.2 for capacitors in series

Connected in series, the schematic diagram reveals that the separation distance, not the plate area, adds up. The capacitors each store instantaneous charge build-up equal to that of every other capacitor in the series. The total voltage difference from end to end is apportioned to each capacitor according to the inverse of its capacitance. The entire series acts as a capacitor *smaller* than any of its components.

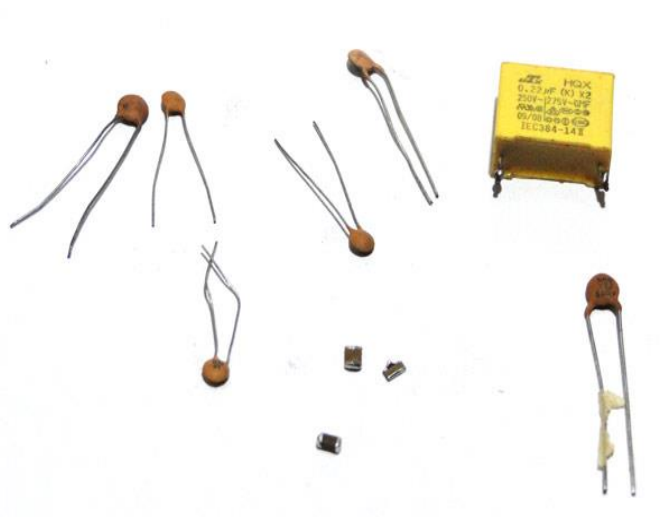



## 1.6 Different Types of Capacitors

- **Aluminium Electrolytic Capacitors**

These are probably the most recognizable **types of capacitors**. They come in distinctive metal cans with a plastic sheath, with clearly stated voltage and capacitance ratings and a white band to indicate the cathode. The name comes from the fact that, like mentioned above, the 'plates' are made of chemically etched aluminum foil. The etching process makes the aluminium porous (much like a sponge) and increases its surface area greatly, hence increasing capacitance. The dielectric is a thin layer of aluminium oxide. These capacitors are filled with oil that acts like an electrolyte, hence the name. Electrolytic capacitors are polarized because of their internal construction. They have large capacitance compared to other members of the capacitor family, but much lower voltages. You can expect to see electrolytic between 0.1uF to monsters like 100mF and with rated voltages of a few volts to around 500V. Their internal resistances, however, tend to be high.

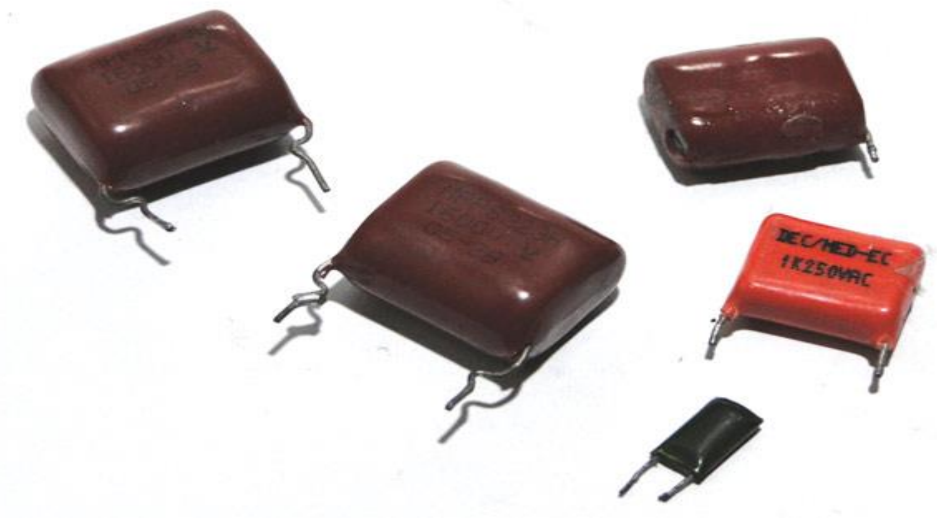
- **Ceramic Capacitors**



These are caps with a ceramic dielectric. Since the breakdown limit for the ceramic dielectric is quite high, you can expect to see ceramic caps with crazy breakdown voltages like 10kV. However, capacitance tends to be low, in the range of Pico farads (0.000000000001F) to a few tens of microfarads. They are generally a lot smaller than **other types of capacitors**, as shown in the picture. They also have very small internal resistances.

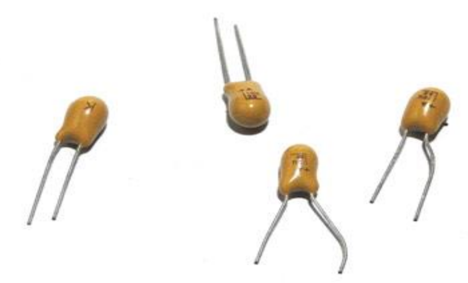
- **Film capacitors**

As the name suggests, the dielectric in these capacitors is a plastic film, often familiar plastics such as Mylar and polyester. They have the same properties as ceramic caps, high breakdown voltages (because of the way the plastic polymers behave) and low capacitances. The only difference is that they tend to be slightly larger though they look superficially like ceramic caps. Internal resistance is comparable to ceramic caps.



## ➢ Tantalum and Niobium capacitors

These caps technically fall under the electrolytic category of capacitors. Here, the electrolyte is a solid material made of tantalum or niobium oxides. They have very low internal resistance for a given capacitance, however they are less immune to overvoltage compared to other types (ceramic has the best) and tend to go kaput without much warning and with a lot of nasty black smoke.

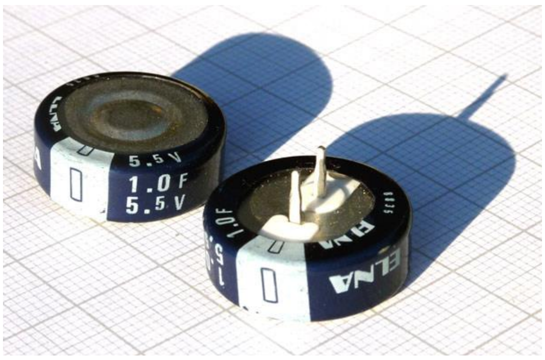


## ➢ Special purpose capacitors

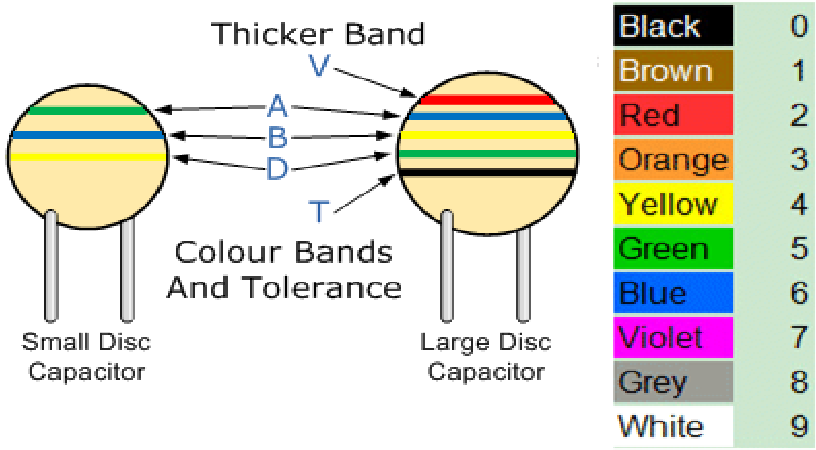
These include silver – mica caps, X and Y rated caps, etc. X and Y rated capacitors, for example, are built for line filtering – more robust construction and higher voltage ratings, also low capacitances, to reduce the current passing through it if AC voltage is applied and to limit the energy stored in the cap if DC voltage is applied.

## ➢ Super capacitors and ultra capacitors

They take capacitors to a whole new level, with largely increased capacitances, sometimes in the range of hundreds of Farads! This is possible because of some clever chemistry. Super capacitors and ultra capacitors bridge the gap between capacitors and chemical batteries. They come in very low voltages and those are pretty much all the **common types of capacitors** you might commonly



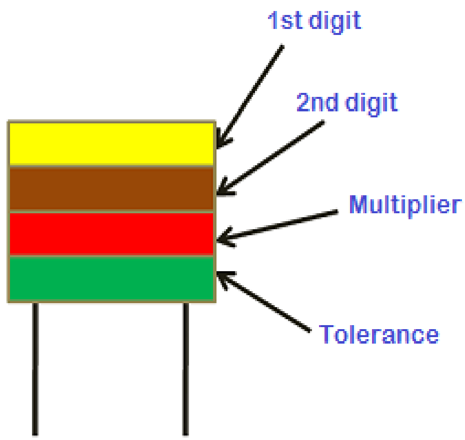
## 1.7 Capacitor color codes:




Generally, code refers to representation of information in different form by using signals, symbols and letters for the purpose of secrecy. Here, the symbols or signals act as codes. In the similar way, in capacitors we use different colors as codes to specify the capacitance (information) of the capacitor. Here, the different colors coated on the capacitor acts as codes. The color codes are used not only in capacitors but also in other electronic components such as resistors and inductors. Specifying the values of electronic components such as capacitors, resistors and inductors by using the color codes printed on them is called electronic color code system. This system was developed in the early 1920s by the radio manufactures association which is now part of Electronic Industries Alliance (EIA).

**Color coding in capacitor**

In color coding technique, the capacitance value is marked on the capacitors body by using colors. The colors painted on the capacitors body are called color bands. All the color bands painted on the capacitors body are used to indicate the capacitance value and capacitance tolerance. Each color painted on the capacitors body represents a different number. The color codes used to represent the capacitance values and capacitance tolerance is similar to that used to represent resistance values and resistance tolerance. Generally, the capacitors are marked with four or more color bands.



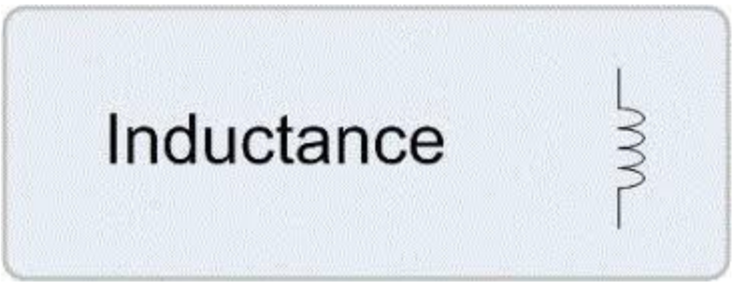
**4 color band capacitor**

In a 4 color band capacitor, the 1st and 2nd color bands coated on the capacitor represents the 1st and 2nd digits of the capacitors capacitance. The 3rd color band represents the decimal multiplier and 4th color band represents tolerance.

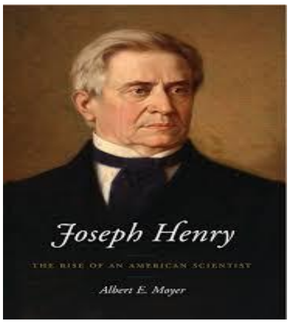
For example, if the colors on a 4 color band capacitor is in this order: yellow, brown, red and green. The values of color band will be likes this: Yellow = 4, Brown = 1, Red = 100 or $10^2$ and Green = 5%.

**1.8 Inductance:**

Inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it or Inductance is defined as the ratio of the induced voltage to the rate of change of current causing it.




**Unit:**



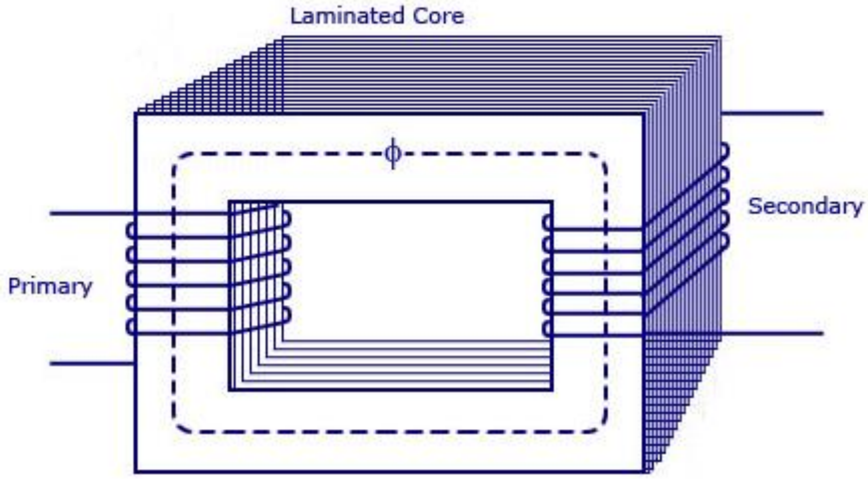

Henry, **unit** of either self-**inductance** or mutual **inductance**, abbreviated h (or hy), and named for the American physicist Joseph Henry. One Henry is the value of inductance in a closed circuit or coil in which one volt is produced by a variation of the inducing current of one ampere per second.

**1.9 Transformer:**

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

**1.9.1 Transformer – Working Principle**

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below.




As shown above the electrical transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$$e=M*dI/dt$$

If the second coil circuit is closed, a current flow in it and thus electrical energy is transferred magnetically from the first to the second coil.

The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.

In short, a transformer carries the operations shown below:

1. Transfer of electric power from one circuit to another.
2. Transfer of electric power without any change in frequency.
3. Transfer with the principle of electromagnetic induction.
4. The two electrical circuits are linked by mutual induction.

### 1.9.2 Transformer Construction

For the simple construction of a transformer, you must need two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and from the steel core. The device will also need some suitable container for the assembled core and windings, a medium with which the core and its windings from its container can be insulated. In order to insulate and to bring out the terminals of the winding from the tank, apt bushings that are made from either porcelain or capacitor type must be used.

In all transformers that are used commercially, the core is made out of transformer sheet steel laminations assembled to provide a continuous magnetic path with minimum of air-gap included. The steel should have high permeability and low hysteresis loss. For this to happen, the steel should be made of high silicon content and must also be heat treated. By effectively laminating the core, the eddy-current losses can be reduced. The lamination can be done with the help of a light coat of core plate varnish or lay an oxide layer on the surface. For a frequency of 50 Hertz, the thickness of the lamination varies from 0.35mm to 0.5mm for a frequency of 25 Hertz.

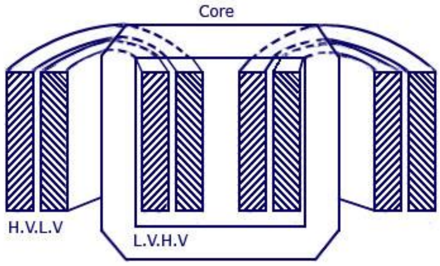
### 1.9.3 Types of Transformers:

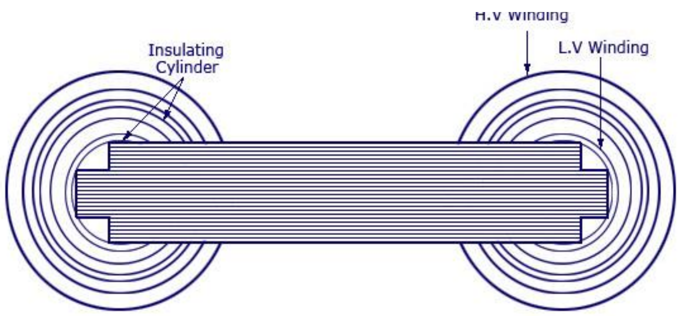
The types of transformers differ in the manner in which the primary and secondary coils are provided around the laminated steel core. According to the design, transformers can be classified into two

***1. Core- Type Transformer***

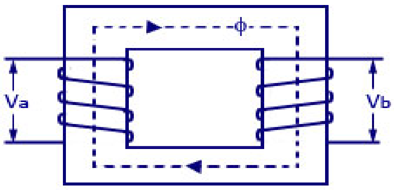
In core-type transformer, the windings are given to a considerable part of the core. The coils used for this transformer are form-wound and are of cylindrical type. Such a type of transformer can be applicable for small sized and large sized transformers. In the small sized type, the core will be rectangular in shape and the coils used are cylindrical. The figure below shows the large sized type. You can see that the round or cylindrical coils are wound in such a way as to fit over a cruciform core section. In the case of circular cylindrical coils, they have a fair advantage of having good mechanical strength. The cylindrical coils will have different layers and each layer will be insulated from the other with the help of materials like paper, cloth, micarta board and so on. The general arrangement of the core-type transformer with respect to the core is shown below. Both low-voltage (LV) and high voltage (HV) windings are shown.The low voltage windings are placed nearer to the core as it is the easiest to insulate. The effective core area of the transformer can be reduced with the use of laminations and insulation.

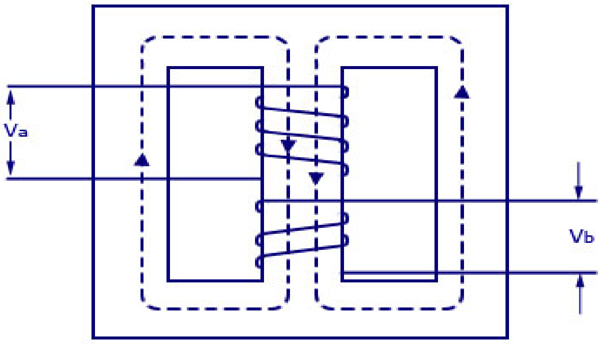
***2. Shell-Type Transformer***



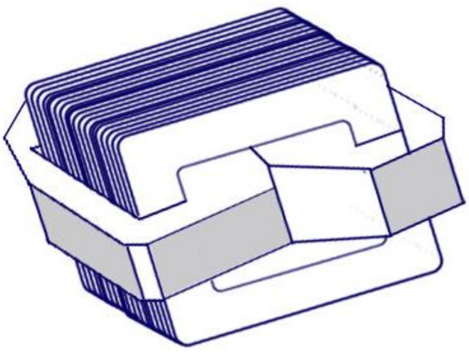



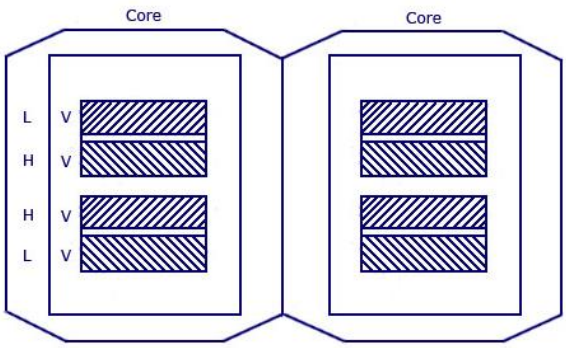
In shell-type transformers, the core surrounds a considerable portion of the windings. The comparison is shown in the figure below.




The coils are form-wound but are multi layer disc type usually wound in the form of pancakes. Paper is used to insulate the different layers of the multi-layer discs. The whole winding consists of discs stacked with insulation spaces between the coils. These insulation spaces form the horizontal cooling and insulating ducts. Such a transformer may have the shape of a simple rectangle or may also have a distributed form. Both designs are shown in the figure below:






### 1.9.4 Types of Transformers based on cooling method

***1. Oil Filled Self-Cooled Type***

Oil filled self-cooled type uses small and medium-sized distribution transformers. The assembled windings and core of such transformers are mounted in a welded, oil-tight steel tanks provided with a steel cover. The tank is filled with purified, high quality insulating oil as soon as the core is put back at its proper place. The oil helps in transferring the heat from the core and the windings to the case from where it is radiated out to the surroundings.

For smaller sized transformers the tanks are usually smooth surfaced, but for large size transformers a greater heat radiation area is needed, and that too without disturbing the cubical capacity of the tank. This is achieved by frequently corrugating the cases. Still larger sizes are provided with radiation or pipes.

***2. Oil Filled Water Cooled Type***

This type is used for much more economic construction of large transformers, as the above-told self-cooled method is very expensive. The same method is used here as well- the windings and the core are immersed in the oil. The only difference is that a cooling coil is mounted near the surface of the oil, through which cold water keeps circulating. This water carries the heat from the device. This design is usually implemented on transformers that are used in high voltage transmission lines. The biggest advantage of such a design is that such transformers do not require housing other than their own. This reduces the costs by a huge amount. Another advantage is that the maintenance and inspection of this type is only needed once or twice in a year.

***3. Air Blast Type***

This type is used for transformers that use voltages below 25,000 volts. The transformer is housed in a thin sheet metal box open at both ends through which air is blown from the bottom to the top.

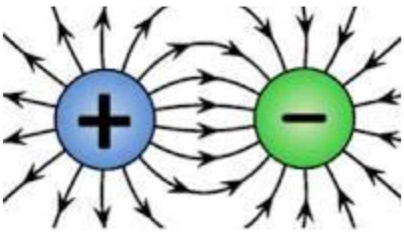
### 1.9.5 Applications of a transformer

Transformers are used in most electronic circuits. A transformer has only 3 applications;

1. To step up voltage and current.
2. To Step down voltage and current
3. To prevent DC – transformers can pass only Alternating Currents so they totally prevent DC from passing to the next circuit.

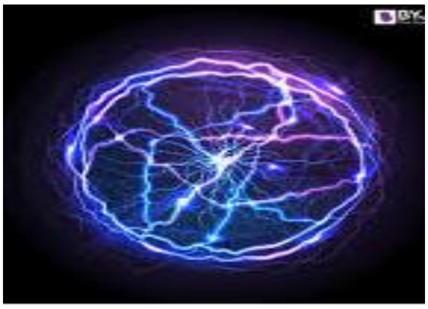
## 2.0 Electric charge:

Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. Electric charge is carried by subatomic particles. In ordinary matter, negative charge is carried by electrons, and positive charge is carried by the protons in the nuclei of atoms.



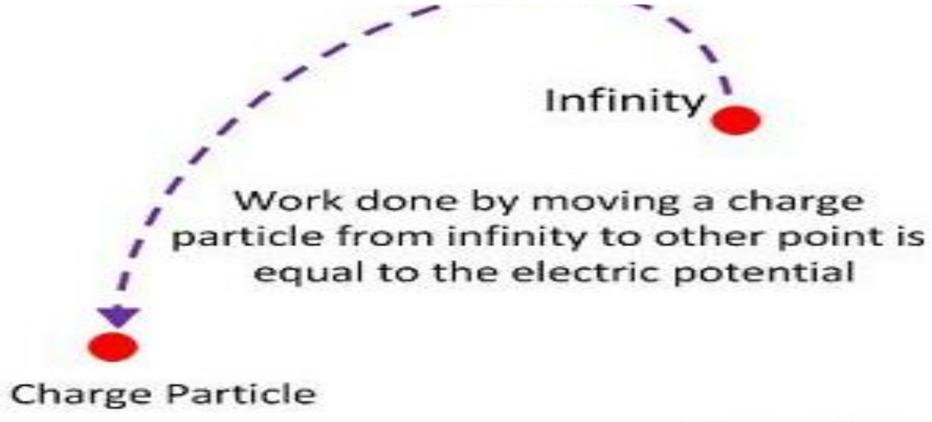
### 2.1 Electric current:

Electric current is the rate of flow of charge. It is the quantity of charge that passes through a surface (for example the cross section of a wire) per unit time. In electric circuits we usually think of the amount of charge that passes through a point on a wire per unit time.



### 2.2 Electric potential:

An electric potential is the amount of work needed to move a unit of charge from a reference point to a specific point inside the field without producing acceleration.



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**Important Questions:**

**2 mark:**

**1.** Define current.

Current is defined as flow of electrons. Its unit is Ampere.

**2.** What is meant by resistance?

The resistance R of an element denotes its ability to resist the flow of electric current. Its unit is ohm.

3. Define resistance.

The resistance R of any material with a uniform cross sectional area A and length $l$ is directly proportional and inversely proportional to its area of cross section.

$$R = \rho \frac{l}{A} \text{ Ohm}$$

4. List out the types of resistance.

The two common types are,

1. Wire wound resistors
2. Composition resistors.

5. Define charge.

The unit of electric charge is the coulomb. Ordinary matter is made up of atoms which have positively charged nuclei and negatively charged electrons surrounding them. Charge is quantized as a multiple of the electron or proton charge.

6. Define voltage.

Voltage is electric potential energy per unit charge, measured in joules per coulomb (= volts). It is often referred to as "electric potential"

7. What is meant by electric potential?

The energy required to bring a unit positive charge from infinity to that point is called potential.

8. What is meant by potential difference?

The work done to move a unit positive charge from one point another point is defined as potential difference.

9. Define capacitance.

The capacitance C of a capacitor is defined as the ratio of the magnitude of the charge to the potential difference between the conductors. Its unit Farad(F).

$$C = \frac{Q}{V}$$

10. Write the types of capacitor.

    1. Tubular
    2. Oil filled
    3. Electrolytic

**5 mark:**

1. **Define resistor and explain its types**
2. **Explain capacitor color coding**
3. **Write a note on passive devices**
4. **Compare star and delta connections.**
5. **Explain the types of capacitor.**

**10 mark:**

1. **What is a resistor? Explain its types and color coding.**
2. **Write a note on capacitor and its color coding**