Basic Electrical Principles

Atoms and Their Structure:

- A basic understanding of the fundamental concepts of current and voltage requires a degree of familiarity with atom and its structure.
- Every atom contains one or more electrons orbiting round the nucleus.
- The atomic structure of any stable atom has an equal number of electrons and protons. That is atoms will have the same number of Electrons in the orbit as there are Protons in the center (nucleus).
- Protons have positive charge.
- Electrons have a **negative charge**.
- For all other elements except hydrogen, the nucleus also contains neutrons, which are slightly heavier than protons and have no electrical charge.
- Different atoms have different number of electrons in the orbit.
- The first orbit, which is closest to the nucleus, can contain only two electrons.
- If an atom has three electrons, the extra electron must be placed in the next orbit.
- The maximum number of electrons in each succeeding orbit is determined by $2n^2$ where n is the orbit number.
- Copper is the most commonly used metal in the electrical / electronic industry. Figure below shows its atomic structure.

Name: Copper
Symbol: Cu
Atomic Number: 29
Number of Protons: 29
Number of Electrons: 29
Number of Neutrons: 35

Number of Energy Levels: 4

First Energy Level: 2
Second Energy Level: 8
Third Energy Level: 18
Fourth Energy Level: 1

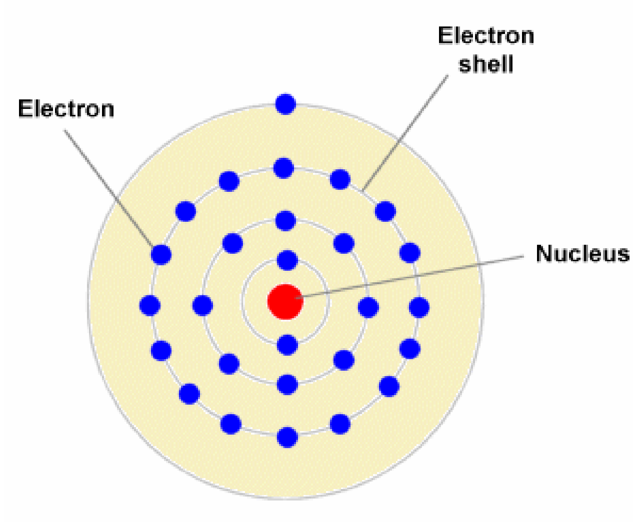
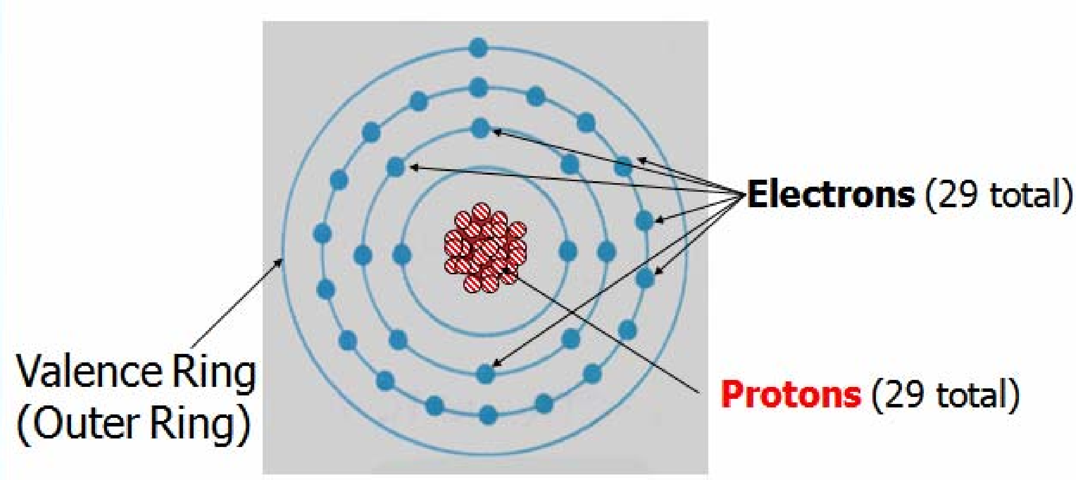


Figure: The atomic structure of copper

- There are two important things to note:
  - First, the fourth orbit, which have a total of $2n^2=2(4^2)=32$ electrons, has only one electron. Hence the outermost orbit is incomplete.
  - Atoms with complete orbit (that is a number of electrons equal to $2n^2$) are usually quite stable.
  - Those atoms in the outermost orbit are normally considered somewhat unstable and volatile.
  - Second, the 29th electron is the farthest electron from the nucleus. Opposite charges are attracted to each other, but the further apart they are, the less attraction.



A Copper Atom

- In many materials, the electrons are tightly bound to the atoms. Wood, glass, plastic, ceramic, air, cotton etc. These are all examples of materials in which electrons stick with their atoms. Because the electrons don't move, these materials cannot conduct electricity very well, if at all. These materials are **electrical insulators.**
- But most **metals** have electrons that can detach from their atoms and move around. These are called **free electrons**. Gold, silver, copper, aluminum, iron, etc., all have free electrons. The loose electrons make it easy for electricity to flow through these materials, so they are known as **electrical conductors**. They conduct electricity. The moving electrons transmit electrical energy from one point to another.

Electricity needs a **conductor** in order to move. There also has to be something to make the electricity flow from one point to another through the conductor. One way to get electricity flowing is to use a **generator**.

Conductors:

- There are some materials that electricity flows through easily. These materials are called conductors.
- **Conductors** have electrons that can detach from their atoms and move around. These are called **free electrons** that can move freely.
- The loose electrons make it easy for electricity to flow through these materials, so they are known as **electrical conductors**.
- Most conductors are metals.

- Four good electrical conductors are gold, silver, aluminum and copper. This is due to the presence of a large number of free or loosely-attached electrons in their atoms.
- Elements with less than 4 Electrons in their outer rings make good conductors, because the Electrons are easily dislodged from their orbit and pushed to the atom next to them.

Insulators:

- Insulators are materials that do not let electricity flow through them.
- In insulator, the electrons are tightly bound to the atoms and do not allow free movement of electrons.
- Because the electrons don't move, these materials cannot conduct electricity very well.
- Insulator offers relatively greater difficulty or hindrance to the passage of free electrons. In other words, insulators have very high resistance.
- Some good insulators are glass, air, plastic, dry wood, mica and porcelain.
- Elements with More than 4 Electrons in their outer rings make good insulators, because the Electrons remain in the outer rings when electromotive force (Voltage) is present.

Superconductor:

- All materials show some resistance, except for superconductors, which have a resistance of zero.

Semiconductor:

- Semiconductors are a specific group of elements that exhibit characteristics between those of insulators and conductors.
- For semiconductor materials, an increase in temperature results in a decrease in resistance level, hence an increase in the number of free carriers in the material for conduction.
- Electronic devices and integrated circuits (IC) are constructed of semiconductor materials.
- Germanium and silicon are the example of semiconductor.

- Semiconductor materials typically have four electrons in the outermost valence ring.

Electricity:

- It is the ability to perform “work” by moving electrons between atoms.
- Electricity starts with **electrons.** Every atom contains one or more electrons. Electrons have a **negative charge**.

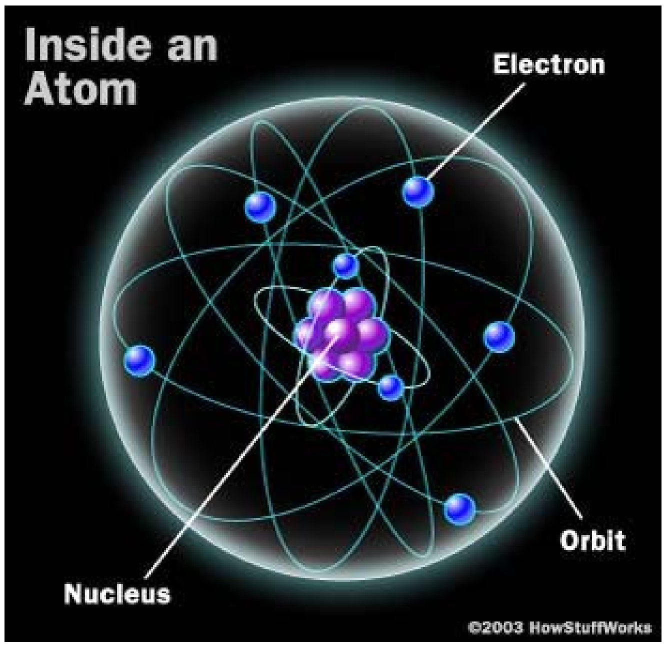
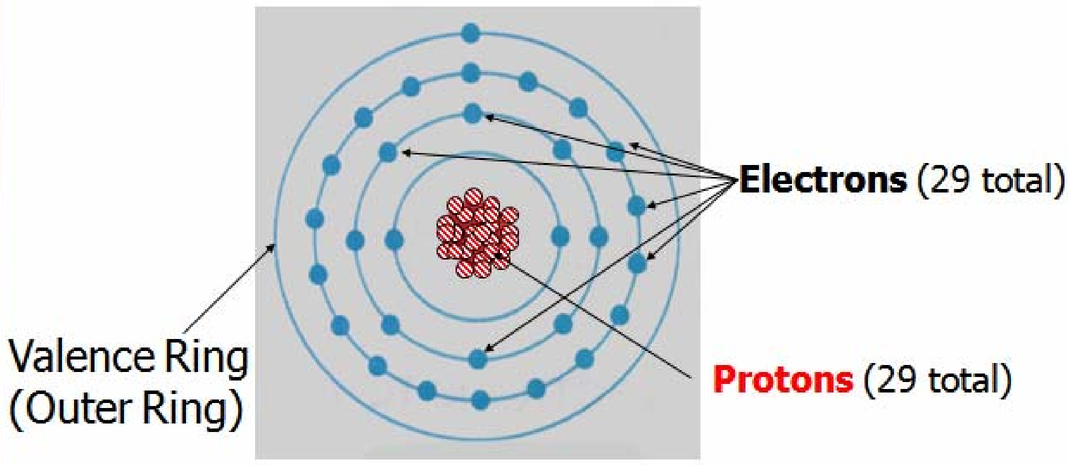


Figure: Simples Model of an Atom

- Atoms will have the same number of Electrons in the orbit as there are Protons in the center.



A Copper Atom

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- But most **metals** have electrons that can detach from their atoms and move around. These are called **free electrons**. Gold, silver, copper, aluminum, iron, etc., all have free electrons. The loose electrons make it easy for electricity to flow through these materials, so they are known as **electrical conductors**. They conduct electricity. The moving electrons transmit electrical energy from one point to another.
- Electricity needs a **conductor** in order to move. There also has to be something to make the electricity flow from one point to another through the conductor. One way to get electricity flowing is to use a **generator**.

Current:

- Water flowing through a hose is a good way to imagine electricity. Here **Water** is like **Electrons** in a wire (flowing electrons are called **Current**).
- The number of electrons that are moving is called the **amperage** or the current, and it is measured in ampere.
- French term for current is intensity. It is alphabetically expressed as I.

Types of Current:

- Types of current are determined by the directions the current flows through a conductor.
- There are 2 types of current:
  - **Direct Current** (**DC**)

    It flows in only one direction from negative toward positive pole of source
  - **Alternating Current** (**AC**)

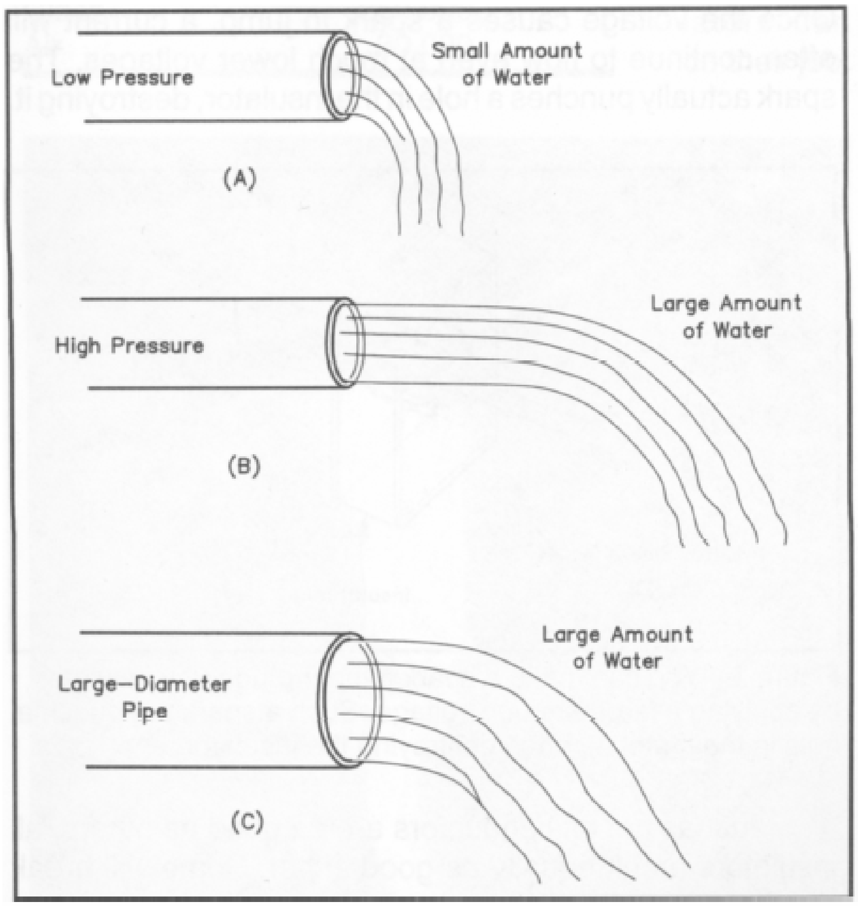
    It flows back and forth because the poles of the source alternate between positive and negative.

Voltage / Electromotive Force (EMF):

- **Pressure** is the force pushing water through a hose – **Voltage** is the force pushing electrons through a wire. The "pressure" pushing the electrons along is called the **voltage**
- **Voltage** is a driving force that causes **current** to flow.
- **Voltage increases, current increases.**

Resistance:

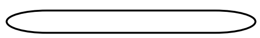
- **Friction** against the holes walls slows the flow of water – **Resistance** is an impediment that slows the flow of electrons.
- It is defined as the property of a substance due to which it opposes (or restricts) the flow of electricity (i.e. electrons) through it.
- It is measured in ohms, Ω.
- A conductor is said to have a resistance of 1 Ω if it permits 1 A current to flow through it when 1 V is impressed across its terminal. R=V/I
- Resistance increases, current decreases.



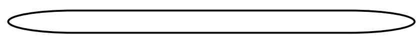
Law of Resistance:

The resistance R offered by a conductor depends on the following factors:

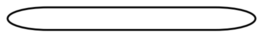
- It varies directly as its length, *l.*
- It varies inversely as the cross-section A of the conductor.
- It depends on the nature of the material.
- It depends on the temperature of the conductor.



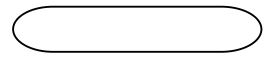
Smaller *l*, lower R



Larger *l*, greater R



Smaller *A*, larger R



Larger *A*, smaller R

Resistivity / Specific Resistance

- Neglecting the last factor above for the time being, we can say that-

  $R \propto l/A$, or

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

  where ρ is a constant depending on the nature of the material of the conductor and is known as its specific resistance or resistivity.

- If we set l= 1 meter, A= 1 meter^2, then R=ρ
- Hence resistivity of a material may be defined as the resistance between the opposite faces of a meter cube of that material.
- Unit of resistivity is ohm-meter.
- Both the resistance and resistivity of a conductor increases with the rise in temperature.

Conductance and Conductivity:

- Conductance is reciprocal of resistance.
- Whereas resistance of a conductor measures the hindrance which it offers to the flow of current, the conductance measures the inducement which it offers to its flow. Conductance is the ease at which an electric current passes.
- Unit of conductance is siemens (S, earlier it was called *mho*) and is expressed alphabetically as G, where G=1/R. G=I/V

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

$$G = \frac{1}{\rho} \cdot \frac{A}{l} = \frac{\sigma A}{l}$$

where σ =1/ ρ, is called the conductivity or specific conductance of a conductor.

- The unit of conductivity is simens/meter.

Effect of Temperature on Resistance:

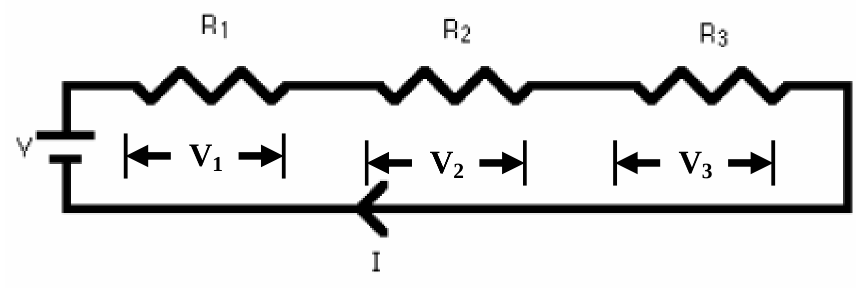
The effect of rise in temperature is:

- to increase the resistance of pure metals. Metals have a positive temperature-coefficient of resistance.
- to increase the resistance of alloys
- to decrease the resistance of electrolytes, insulators, and partial conductor such as carbon. Insulators are said to posses a negative temperature-coefficient of resistance.

Equivalent Resistance

While in series:

- A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take.
- The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors: equivalent resistance of resistors in series : R=R1+R2+R3
- Source voltage in a series circuit divides proportionately across each resistor in the circuit.



V_2

Main Characteristics of a Series Circuit:

- Same current flows through all parts of the circuit. That is, the current is the same through each resistor.
- Voltage drop across each resistor is different due to its different value.
- Sum of the voltage drops across the resistors is equal to the voltage applied across the terminal. V= V1+ V2+ V3
- Voltage drops are additive, V= V1+ V2+ V3.
- Resistances are additive, R=R1+R2+R3.
- Powers are additive, P= P1+ P2+ P3

Division of Voltage in a Series Circuit: Using Voltage-Divider Rule

- A voltage divider circuit is a series network which is used to feed other networks with a number of different voltages and derived from a single input voltage source.
- Voltage drop across each resistor in a series circuit can be calculated according to Voltage Divider Rule, as:

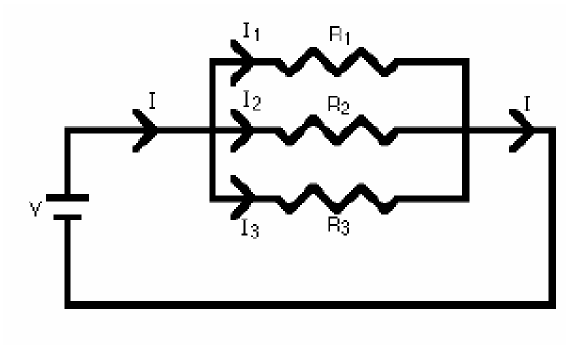
  (i) Find equivalent resistance R of the series combination: $R=R_1+R_2+R_3$

  (ii) According to VDR, voltage drop across nth resistor is $V_n= V. R_n/R$

  Example (Page-19): $V_2=V. R_2/R$; $V_3=V. R_3/R$ etc.

While in parallel:

- A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together.
- A parallel circuit has more than one current path connected to a common voltage source.
- The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total: equivalent resistance of resistors in parallel, $1/R=1/R1+1/R2+1/R3$
- The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again (the current adds up).



Main Characteristics of a Parallel Circuit:

- Potential difference across each resistance is the same as applied voltage.
- Current flowing in each resistor is different due to its different value.
- The sum of the currents flowing each resistor is the total current. $I=I1+I2+I3$.
- Branch currents are additive, $I= I1+ I2+ I3$.
- Conductance are additive, $G= G1+ G2+ G3$
- Powers are additive, $P= P1+ P2+ P3$.
- A parallel circuit is shown in the diagram above. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance.
- If the resistors in parallel are identical, it can be very easy to work out the equivalent resistance.

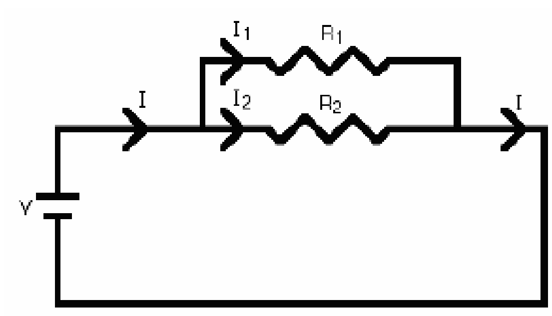
- In this case the equivalent resistance of N identical resistors is the resistance of one resistor divided by N, the number of resistors. So, two 40-ohm resistors in parallel are equivalent to one 20-ohm resistor; five 50-ohm resistors in parallel are equivalent to one 10-ohm resistor, etc.

- If you have two or more resistors in parallel, look for the one with the smallest resistance. The equivalent resistance will always be between the smallest resistance divided by the number of resistors, and the smallest resistance.

  - Here's an example. You have three resistors in parallel, with values 6 ohms, 9 ohms, and 18 ohms. The smallest resistance is 6 ohms, so the equivalent resistance must be between 2 ohms and 6 ohms (2 = 6/3, where 3 is the number of resistors). Doing the calculation gives 1/6 + 1/12 + 1/18 = 6/18. Flipping this upside down gives 18/6 = 3 ohms, which is certainly between 2 and 6.

Division of Current in a Parallel Circuit: Using Current-Divider Rule

Case-1: Current Divider Rule for two Resistors in Parallel



- In the above figure, two resistors are joined in parallel across a voltage V.
- The current in each branch can be calculated by Ohm's Law:

$$I_1 = \frac{V}{R_1} \text{ and } I_2 = \frac{V}{R_2}$$

$$\therefore \frac{I_1}{I_2} = \frac{R_2}{R_1} \qquad \text{..................(i)}$$

$$As \quad \frac{1}{R_1} = G_1 \quad and \quad \frac{1}{R_2} = G_2$$

$$\therefore \quad \frac{I_1}{I_2} = \frac{G_1}{G_2}$$ .... (ii)

- From equation (i) and (ii) it is apparent that the division of current in the branch of a parallel circuit is:

  - directly proportional to the conductance of the branch
  - inversely proportional to their resistances.

- We may also express the branch current in terms of total circuit current as:

$$I_1 + I_2 = I$$
$$\therefore I_2 = I - I_1$$
$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \quad (\,from\ equation - 1)$$
$$\Rightarrow \frac{I_1}{I - I_1} = \frac{R_2}{R_1}$$
$$\Rightarrow I_1 R_1 = R_2 (I - I_1)$$
$$I_1 (R_1 + R_2) = I R_2$$
$$\therefore \ I_1 = I . \frac{R_2}{R_1 + R_2}$$
$$Similarly, \ I_2 = I . \frac{R_1}{R_1 + R_2}$$
$$In\,terms\,of\ conduc\tan ce\ I_1 = I . \frac{G_1}{G_1 + G_2} \quad and \quad I_2 = I . \frac{G_2}{G_1 + G_2}$$

Example-1:

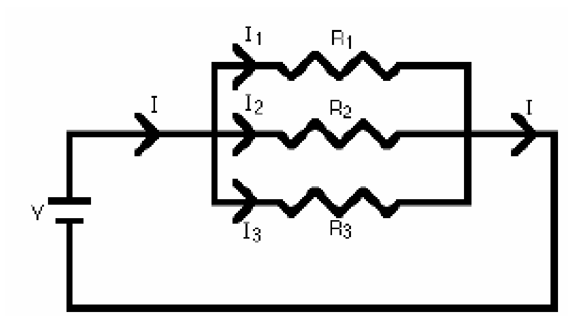
If the values of the three resistors in the above figure are: R1= 8 ohm, R2= 8 ohm and R3=4 ohm with a 10 V battery, then determine total current I and branch currents I1, I2, and I3.

- Determine equivalent resistance R.
- Use I = V / R to calculate total current in the circuit is: I = V / R = 10 / 2 = 5 A.

- The individual currents can also be found using I = V / R. Since parallel circuit, the voltage across each resistor is 10 V, so:
- I1 = 10 / 8 = 1.25 A
- I2 = 10 / 8 = 1.25 A
- I3=10 / 4 = 2.5 A
- Note that the currents add together to 5A, the total current.

Example-2 (Page-20 1.25):

Case-2: Current Divider Rule for three Resistors in Parallel



- In the above figure, three resistors are joined in parallel across a voltage V.
- The current in each branch can be calculated by Ohm's Law.
- Total current is $I=I_1+I_2+I_3$.
- If R is the equivalent resistance, then according to Ohm's law:

V=IR

$$V = I_1 R_1$$
$$\therefore IR = I_1 R_1$$
$$\Rightarrow \frac{I}{I_1} = \frac{R_1}{R}$$
$$or\ I_1 = I\frac{R}{R_1} \qquad (i)$$

$$Now\,\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

$$\therefore R=\frac{R_1R_2R_3}{R_1R_2+R_2R_3+R_3R_1}$$

$$from\,equation\,(i)\,I_1=I\left(\frac{R}{R_1}\right)$$

$$\Rightarrow \qquad I_1=I\left(\frac{R_2R_3}{R_1R_2+R_2R_3+R_3R_1}\right)$$

$$Similarly\;\; I_2=I\left(\frac{R_1R_3}{R_1R_2+R_2R_3+R_3R_1}\right)$$

$$I_3=I\left(\frac{R_1R_2}{R_1R_2+R_2R_3+R_3R_1}\right)$$

$$In\,terms\,of\;conduc\tan ce\;\; I_1=I\left(\frac{G_1}{G_1+G_2+G_3}\right)$$

$$I_2=I\left(\frac{G_2}{G_1+G_2+G_3}\right)$$

$$I_3=I\left(\frac{G_3}{G_1+G_2+G_3}\right)$$

Example-1: Page 32 (1.37)

While in series-parallel:

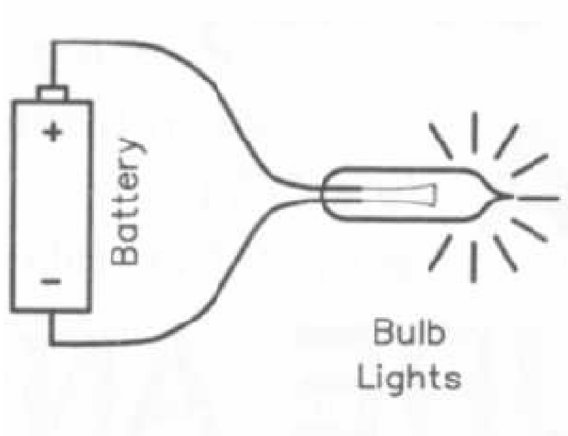
- Many circuits have a combination of series and parallel resistors.
- Generally, the total resistance in a circuit like this is found by reducing the different series and parallel combinations step-by step to end up with a single equivalent resistance for the circuit. This allows the current to be determined easily.
- The current flowing through each resistor can then be found by undoing the reduction process.
- General rules for doing the reduction process include:

- Two (or more) resistors with their heads directly connected together and their tails directly connected together are in parallel, and they can be reduced to one resistor using the equivalent resistance equation for resistors in parallel.
- Two resistors connected together so that the tail of one is connected to the head of the next, with no other path for the current to take along the line connecting them, are in series and can be reduced to one equivalent resistor.
- Finally, remember that for resistors in series, the current is the same for each resistor, and for resistors in parallel, the voltage is the same for each one.

Example-1 (Page-20 1.26):

Power:

- Every circuit uses a certain amount of power.
- Power describes how fast electrical energy is used. It is the rate of energy consumption.
- A good example is the light bulbs used in each circuit of your home. When you turn on a light bulb, light (and heat) are produced. This is because of the current flowing through a resistor built into the bulb. The resistance turns the electrical power into primarily heat, and secondarily light.
- Each light bulb is rated at a certain power rating. This is how much power the bulb will use in a normal 110 Volt house circuit. Three of the most popular power values for inside light bulbs are 60, 75, and
- 100 Watts (Power is measured in Watts). Which of these light bulbs uses the most power? The 100 Watt bulb uses the most power.
- The basic unit of power is the watt (W)



Calculating Power:

- Power can be calculated as follows:
  - » $P = I \times E$
  - » Since $E = I \times R$, we can also say:
    $P = I^2 \times R$
  - » Since $I = E / R$, we can also say:
    $P = E^2 / R$

Examples:

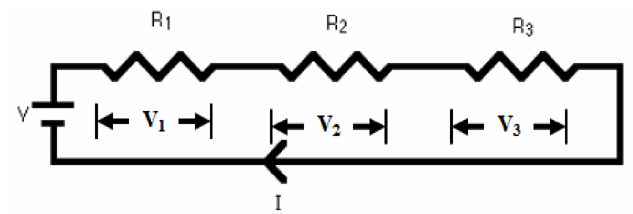
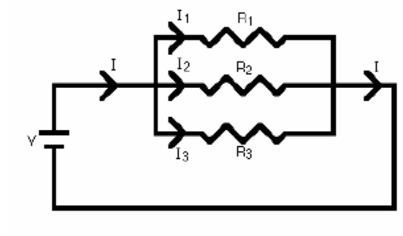
- How much power is represented by a voltage of 13.8 volts DC and a current of 10 amperes?
  $P = I \times E$, $P = 10 \times 13.8 = 138$ watts

- How many amperes is flowing in a circuit when the applied voltage is 120 volts DC and the load is 1200 watts?

  $I = P/E$, $I = 1200/120 = 10$ amperes.

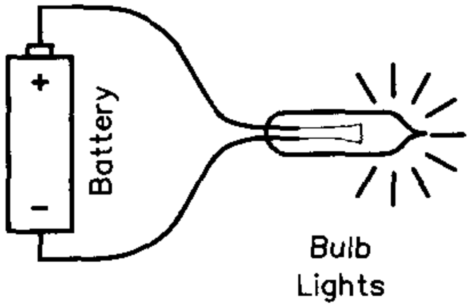
Duality between Series and Parallel Circuits:

- There is a certain peculiar pattern of relationship between series and parallel circuits.
- For example,
  - ➢ in a series circuit, current is the same whereas in a parallel circuit, voltage is the same.
  - ➢ in a series circuit, individual voltages across each resistor are added and in a parallel circuit, individual currents are added.
- It is seen that while comparing series and parallel circuits, voltage takes the place of current and the current takes the place of voltage. Such a pattern is known as duality and the two circuits are said to be duals of each other.
- Table below shows the equations involving voltage, current and resistance in a series circuit and corresponding dual counterparts in terms of current, voltage, and conductance for a parallel circuit.

Series Circuit	**Parallel Circuit**
	
$I_1 = I_2 = I_3 = I$	$V_1 = V_2 = V_3 = V$
$V = V_1 + V_2 + V_3$	$I = I_1 + I_2 + I_3$
$R = R_1 + R_2 + R_3$	$G = G_1 + G_2 + G_3$
$\frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V_3}{R_3} = I$	$\frac{I_1}{G_1} = \frac{I_2}{G_2} = \frac{I_3}{G_3} = V$
Voltage Divider Rule: $V_1 = V.\frac{R_1}{R}$, $V_2 = V.\frac{R_2}{R}$, $V_3 = V.\frac{R_3}{R}$	Current Divider Rule: $I_1 = I.\frac{G_1}{G}$, $I_2 = I.\frac{G_2}{G}$, $I_3 = I.\frac{G_3}{G}$

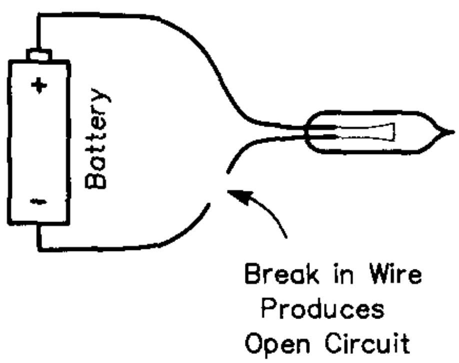
Circuit:

- It is a loop that has a start point- a route- an end point.
- A circuit is necessary for current to flow. A circuit must close to be complete to flow current through it.
- Two main types of circuits:
  - **Series circuit:**
    - Has a single loop for electrons to travel round.
    - Components are connected one after another
    - Current has to travel through all components
    - Current is the same at all points
    - Voltage is shared between components
  - **Parallel circuit:**
    - Has two or more paths for electrons to flow down
    - Current is shared between the branches
    - Sum of the current in each branch = total current
    - Voltage loss is the same across all components



The Open Circuit

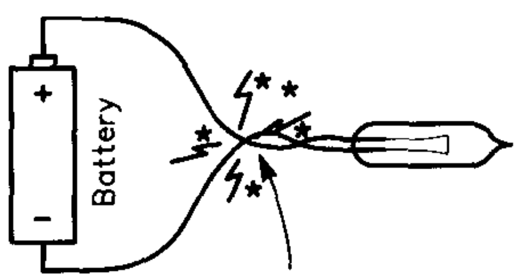
- The open circuit is a very basic circuit that we should all be very familiar with.
- It is the circuit in which no current flows because there is an open in the circuit that does not allow current to flow.
- Two points are said to be open-circuited when there is no direct connection between them.
- Since an 'open' represents a break in the continuity of the circuit, it gives rise to two important factors:
    - Resistance between the two points is infinite.
    - There is no flow of current between the two points.
- A good example is a light switch. When the light is turned off, the switch creates an opening in the circuit, and current can no longer flow.
- A fuse is a device that is used to create an open circuit when too much current is flowing.



Example: Open in a Series Circuit (1.22 Page-30)

The Short Circuit

- A short circuit is an accidental path of low resistance which passes an abnormally high amount of current.
- When two points of circuit are connected together by a thick metallic wire, they are said to be short-circuited.
- A short often occurs as a result of improper wiring or broken insulation.
- Since 'short' has practically zero resistance, it gives rise to two important factors:
    - No voltage can exist across it, because V=IR=Ix0=0.
    - Current through it (called short-circuit current) is very large (theoretically, infinity), because I=V/R=V/0=∞.
- Therefore a short circuit will have too much current flowing through it and may even cause the power source to be destroyed.
- Short circuits can produce very high temperatures due to the high power dissipation in the circuit.
- What's the best way to stop a short circuit from doing damage (because it is drawing too much power from the source)?—By using a fuse. Fuses are designed to work up to a certain amount of current (e.g. 1 amp, 15 amps, etc). When that maximum current is exceeded, then the wire within the fuse burns up from the heat of the current flow. With the fuse burnt up, there is now an "open circuit" and no more current flows.
- A short circuit may be in a direct- or alternating-current (DC or AC) circuit. If it is a battery that is shorted, the battery will be discharged very quickly and will heat up due to the high current flow.



Broken Insulation Allows Wires to Touch, Producing a Short Circuit

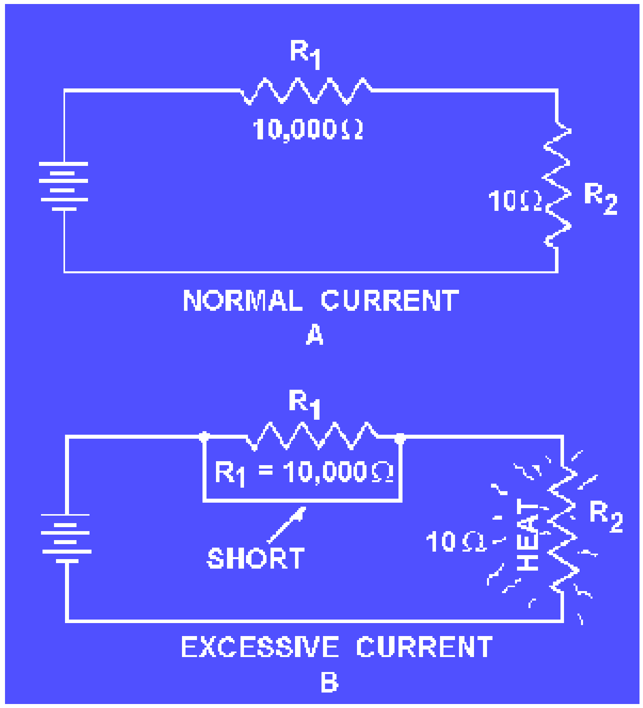


Figure: Normal and short circuit conditions.

Since the resistor has in effect been replaced with a piece of wire, practically all the current flows through the short and very little current flows through the resistor. Due to the excessive current flow, the 10-ohm resistor becomes heated. As it attempts to dissipate this heat, the resistor will probably be destroyed.

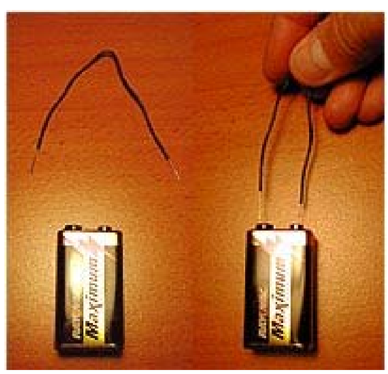


Figure: The simplest example of a 'short circuit'.

All you need is a battery and a piece of wire. If you do this in dark, you may notice faint sparking when you connect + to – of the battery.

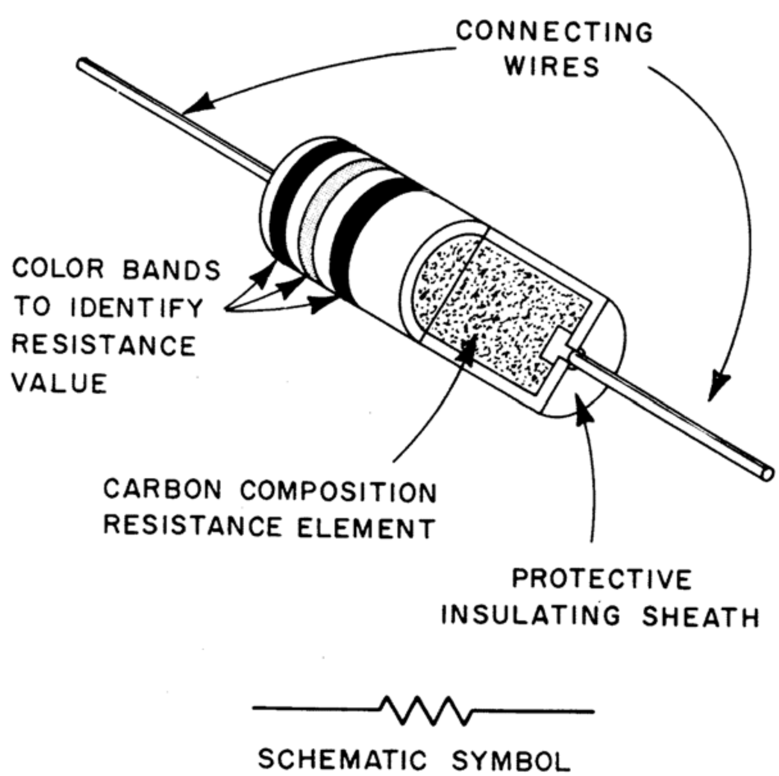
Example: Short in a Series Circuit (1.21 Page-29)

Fuse / Circuit Breaker:

- A fuse is a device with a very thin piece of wire that is used to create an open circuit when too much current is flowing.
    - The wire has a quite low melting point. As current flows through the wire it heats up.
    - If **too large a current** flows, it **melts;** thus **breaking** the circuit
- Fuses are designed to work up to a certain amount of current (e.g. 1 amp, 15 amps, etc). When that maximum current is exceeded, then the wire within the fuse burns up from the heat of the current flow. With the fuse burnt up, there is now an "open circuit" and no more current flows.

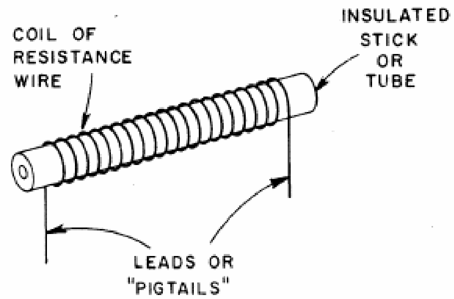
Circuit Elements:

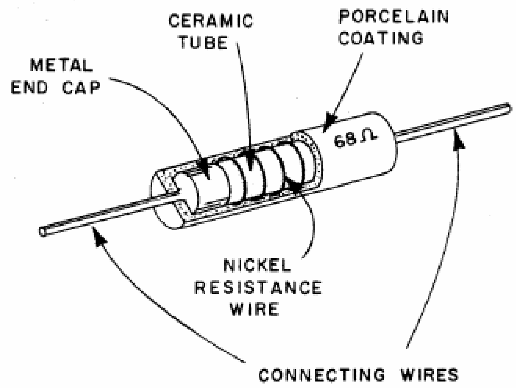
Resistor:



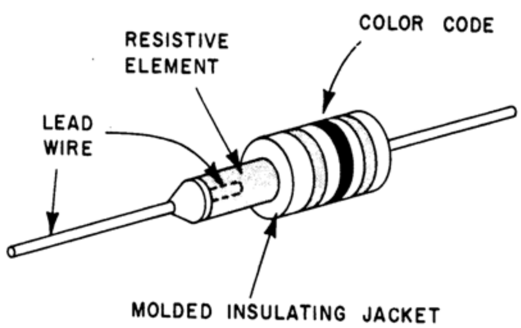
Types of Resistors:

- Precision Type

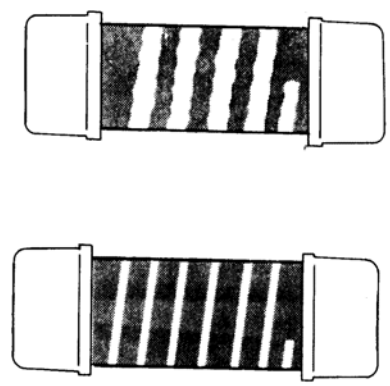




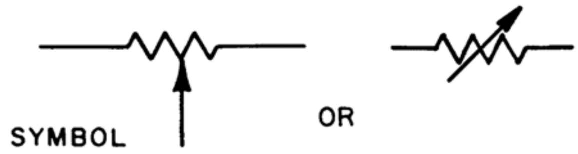
- **Film Type**

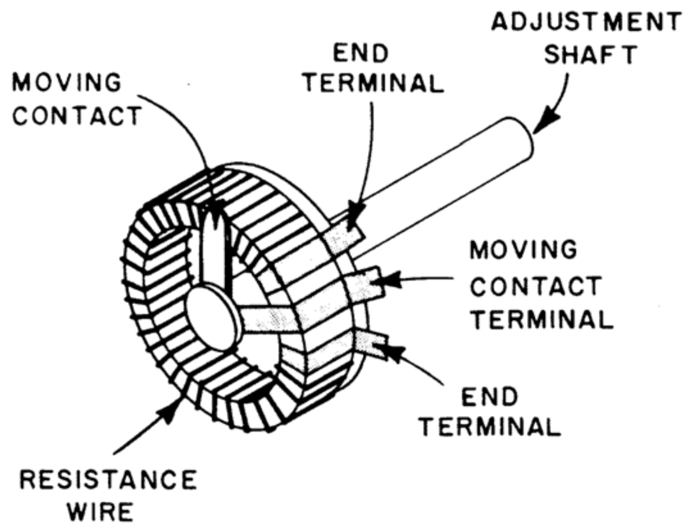


FILM TYPE RESISTOR



- **Variable Type**





How to read the value of a resistor by reading the color bands?

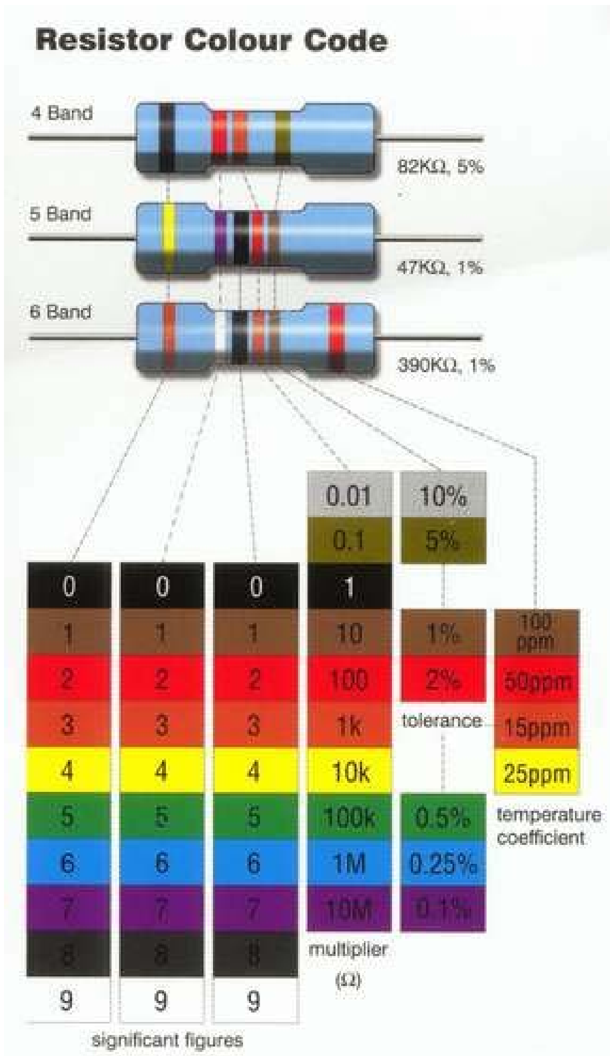
- Small resistors are labeled with a color code to show their value.
- how many ohms your resistor can carry?
- demonstrate the way to determine the value of a resistor by just calculating the color codes in each resistor.

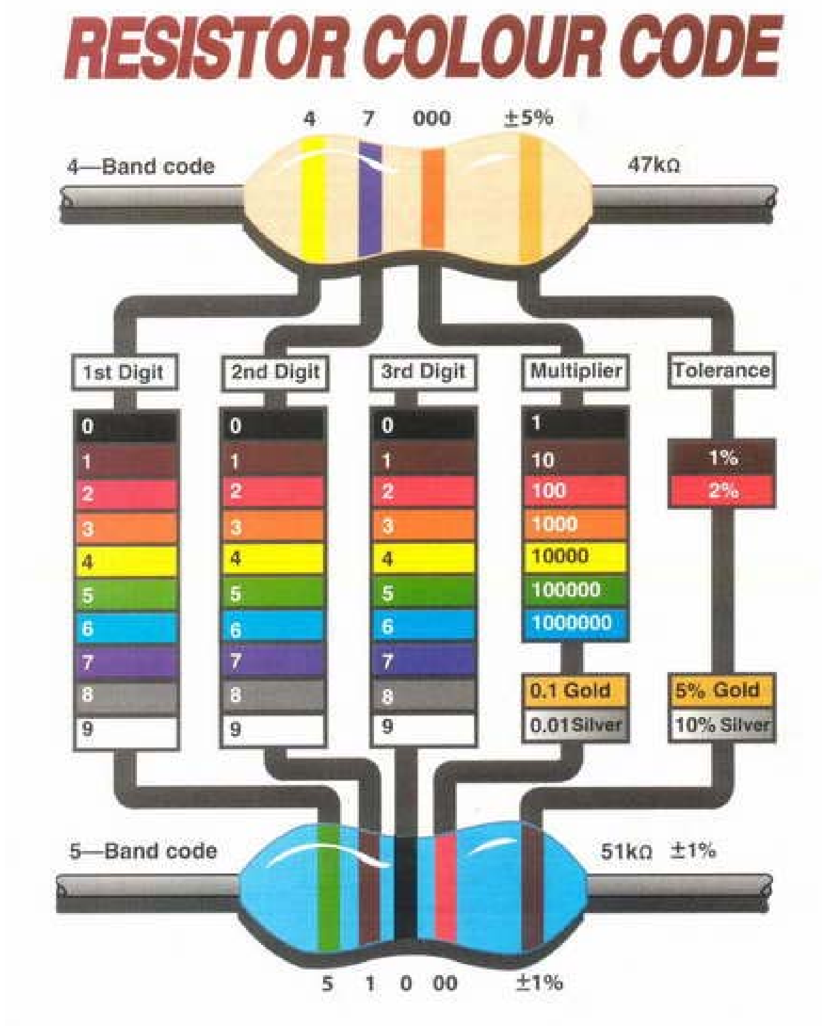
Step 1:

At first identify the color bands in each resistor.

- To identify each color in a resistor you must first memorize the color codes
- Some resistors have 4 band color codes and some resistors have 5 band color codes and some 6
- Memorize them for the mean time, because you are about to calculate the color codes on step 3

- **B**a**d** **Bo**ys **R**avage **O**ur **Y**oung **G**irls **B**ehind **V**ictory **G**arden **W**alls
- **B B ROY** of **G**reat **B**ritain had a **V**ery **G**ood **W**ife wearing with **G**old and **S**ilver **N**ecklace.
- Bad Beer Rots Our Young Guts But Vodka Goes Well





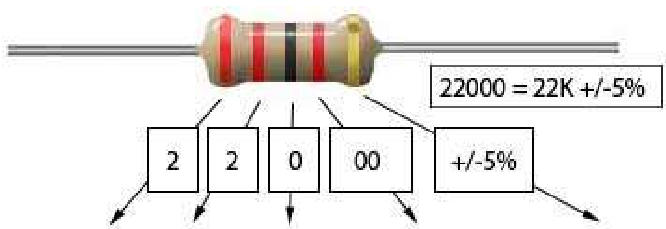
Step 2:

Read the color codes by starting from the first band to the last

- To read the brands you start from the color not the color of the tolerance
- Now, here is a 4 band resistor. As you can see, the first band starts with a color not the color of the tolerance
- To calculate, you can see that the first band is Yellow, where the code is 4 (you can see the color codes on step 1).

- The second band is Violet where the code is 7
- Finally the third band is color Green where the code is 5, (now read carefully, remember that every color that come before the color of the tolerance is the number of zeros with codes) so now we have green color where the code is 5, so THERE ARE FIVE ZEROS (00000)
- So the value of this resistor when you calculate It will be :- 4700000 ohms where the tolerance is 10% because the color is silver. You can see the color of every tolerances on step 1

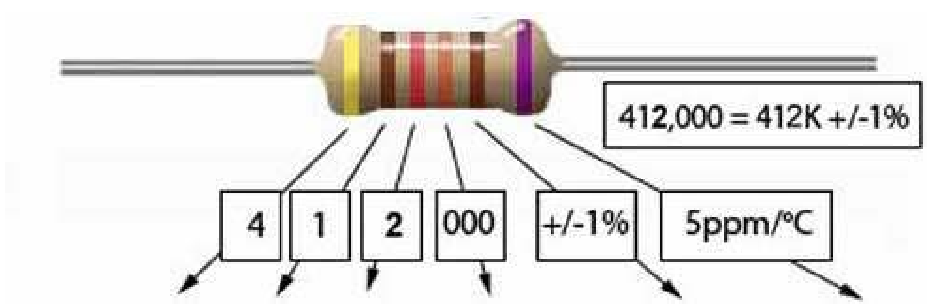
Example: Fifth brand of a resistor



- Here is a fifth brand resistor
- Now lets start a bit manually

First color red = 2
Second, red= 2
Third, black = 0
Fourth one is red where the number of zeros of its value = two zeros (00)
Calculate total= 22000 ohms

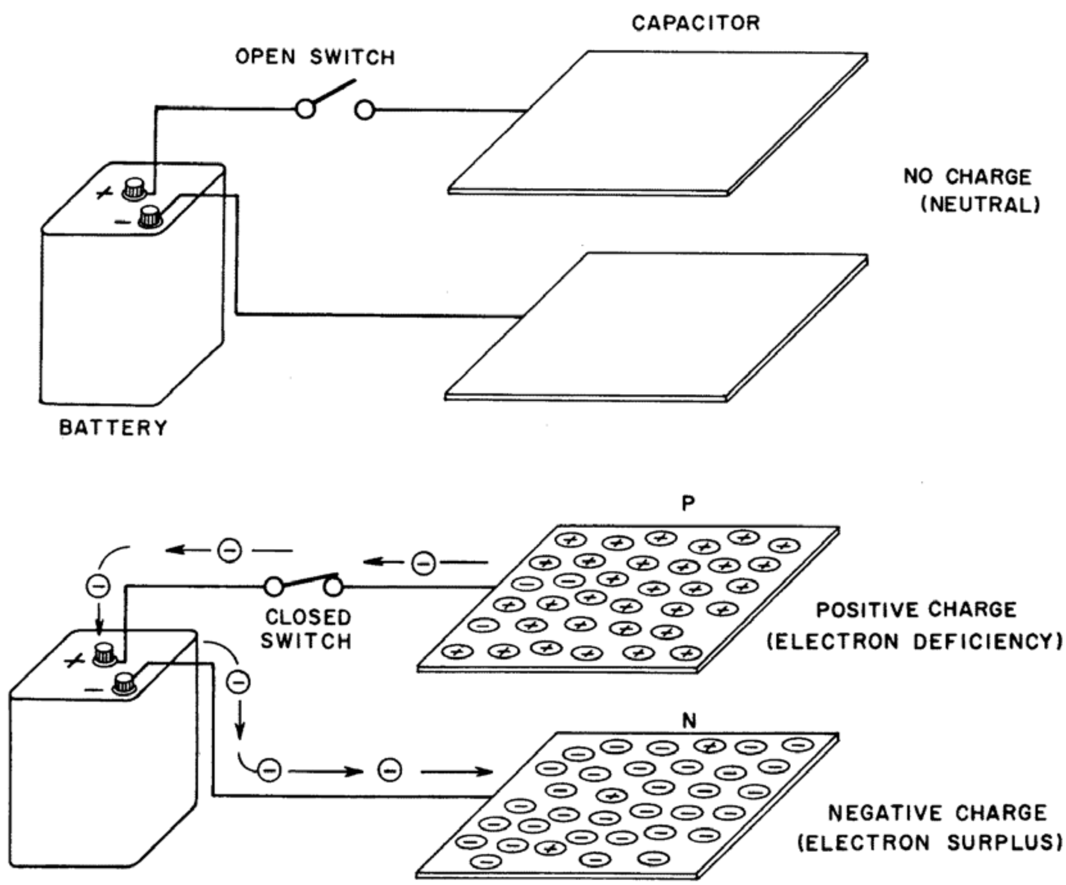
Example: Sixth band of a resistor



- Here is a sixth band resistor (remember do not include the tolerance)

Capacitors

- Capacitors store energy in an electric field.
- A capacitor essentially consists of two conducting surfaces separated by a layer of an insulating medium called dielectric.



Capacitance:

- Capacitance is the property of a capacitor that store electricity.
- The capacitance of a capacitor may be defined as the amount of charge required to create a unit potential difference between its plates.

- Suppose, we give Q coulombs of charge to one of the two plates of a capacitor. If a potential difference of V volts is established between the two, then its capacitance is:

$$C=Q/V$$

- Basic unit of capacitance is the farad (f) or coulomb/volt.
- One farad is actually too large for practical purposes. Hence much smaller units like microfarad (μF), picofarad (pF) are generally used.

Types of Capacitors:

A few of the commonly used capacitors are as follows:

(i) Ceramic capacitors

(ii) Mica capacitors

(iii) Paper capacitors

(iv) Electrolytic capacitors

Calculating Capacitance

While in series:

- $1/C=1/C1+1/C2+1/C3$

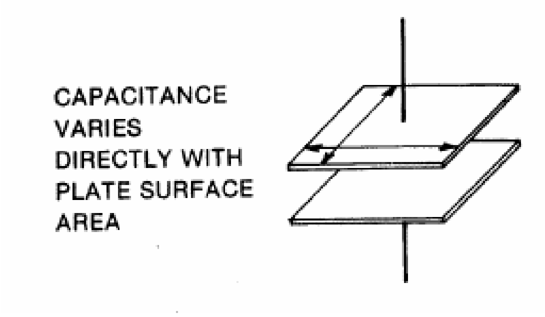
While in parallel:

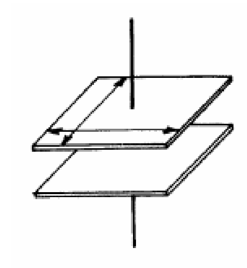
- $C=C1+C2+C3$

Parameters or Variables determining capacitance:

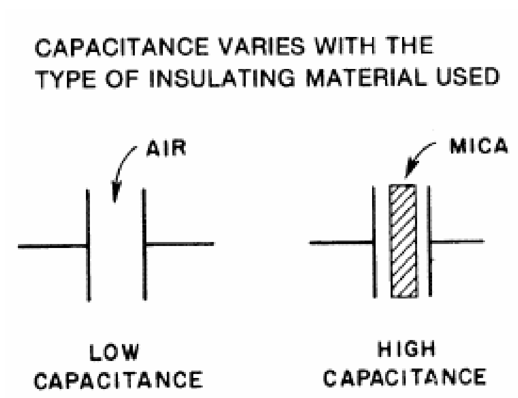
- Capacitance is determined by 3 factors:
  - » plate surface area
  - » plate spacing
  - » insulating material (dielectric)
- Parallel capacitors increase plate area; so increase charge and hence increase capacitance.

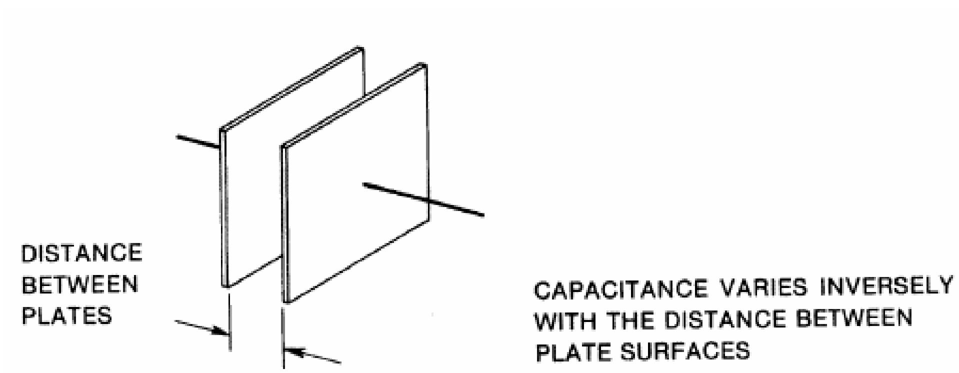
- Series capacitors decrease plate area; so decrease charge and hence decrease capacitance.





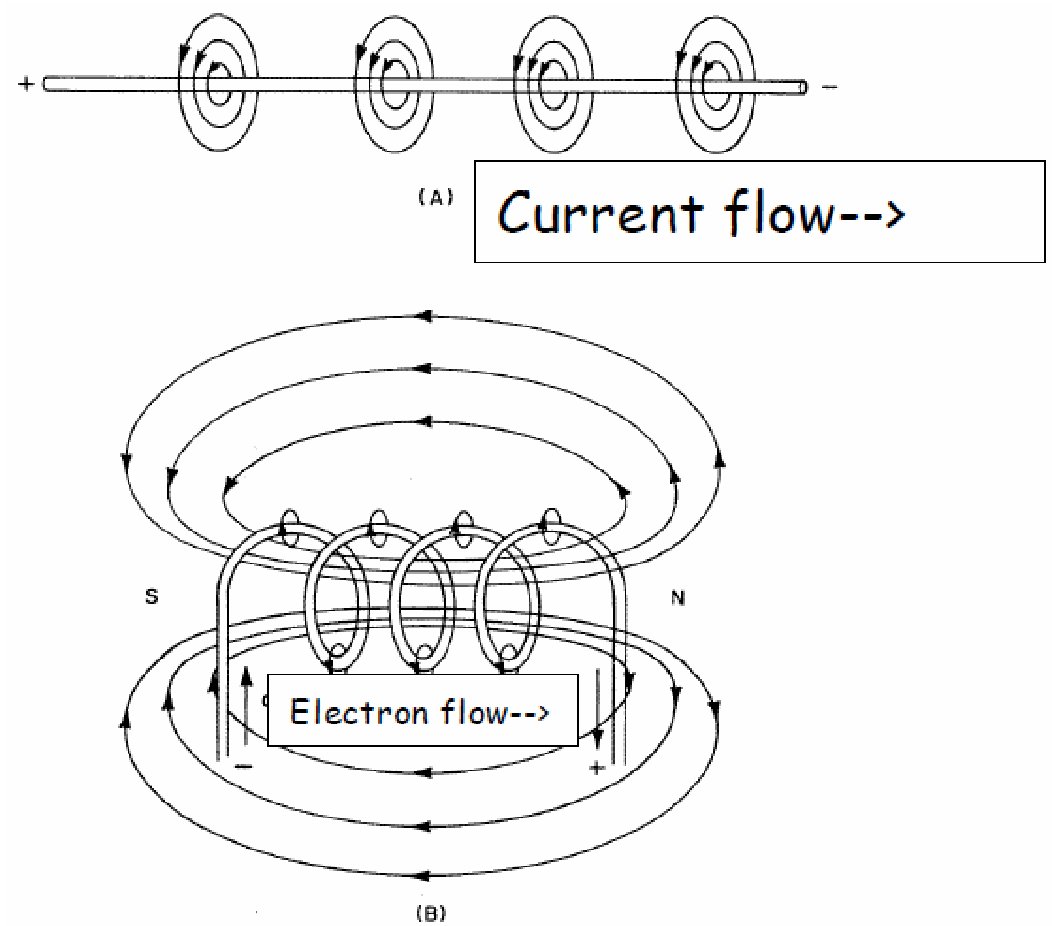
HIGH CAPACITANCE LOW CAPACITANCE





Inductors

- There are two fundamental principles of electromagnetics:
    1. Moving electrons create a magnetic field.
    2. Moving or changing magnetic fields cause electrons to move.
- An inductor is a coil of wire through which electrons move, and energy is stored in the resulting magnetic field.
- Like capacitors, inductors temporarily store energy.
- Unlike capacitors:
    - Inductors store energy in a magnetic field, not an electric field.
    - The magnetic field is proportional to the current. When the current drops to zero, the magnetic field also goes to zero.
- Basic unit of inductance is the henry (h).
- Alphabetically, it is expressed as L.
- The rate at which current through an inductor changes is proportional to the voltage across it.
- A coil (or inductor) has a property called its inductance. The larger the inductance, slower the rate at which the current changes.



Note:

- Current flows from + to -, but is carried by electrons which flow from - to +.

Calculating Inductance

While in series:

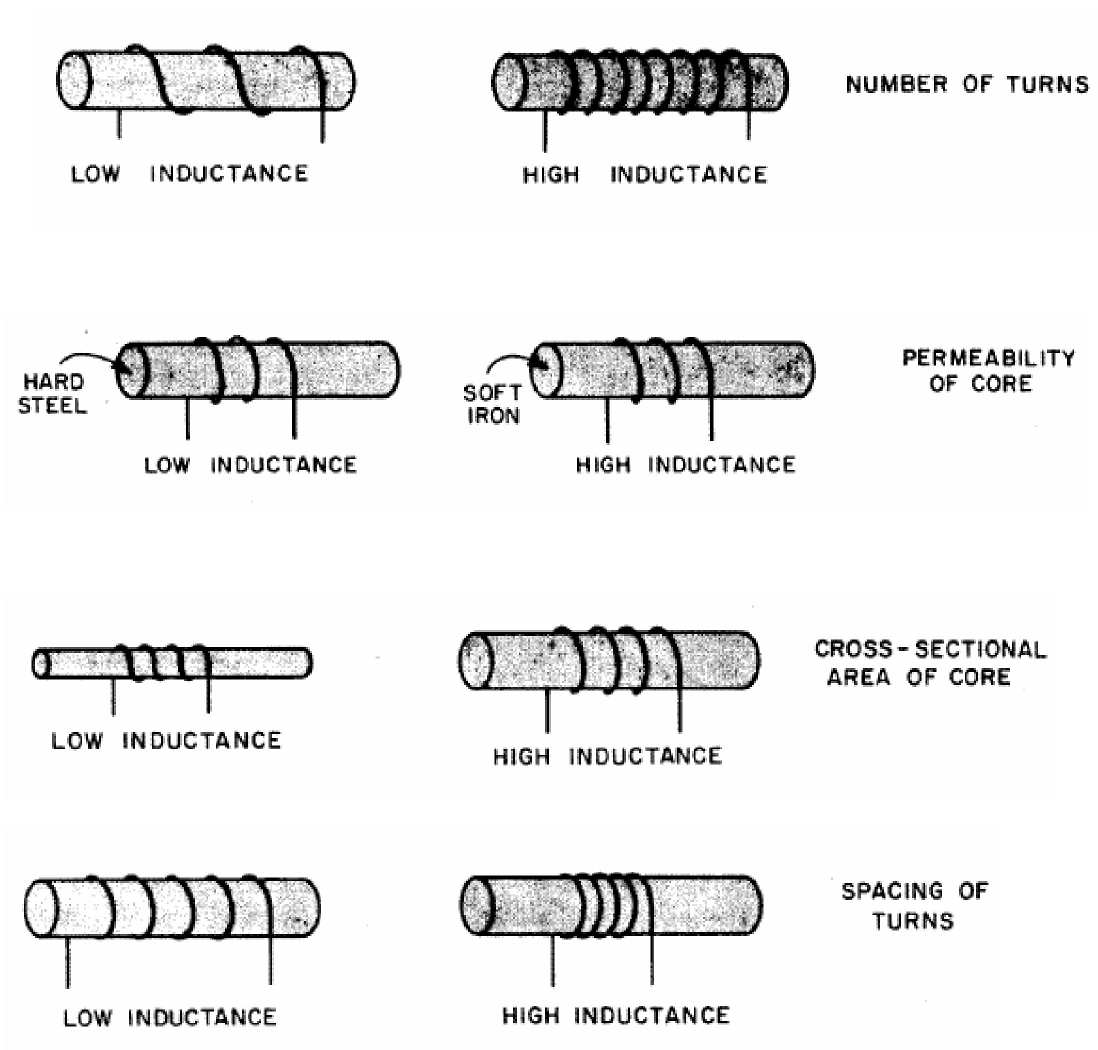
- L=L1+L2+L3

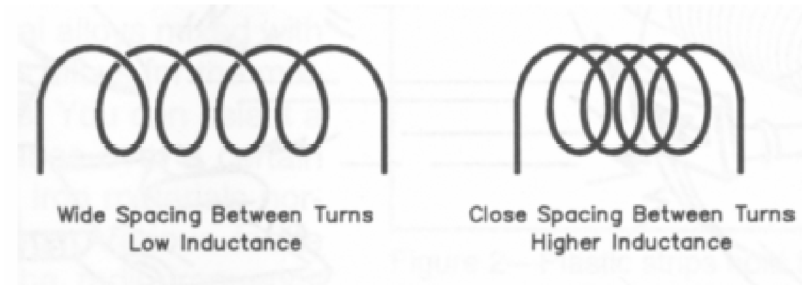
While in parallel:

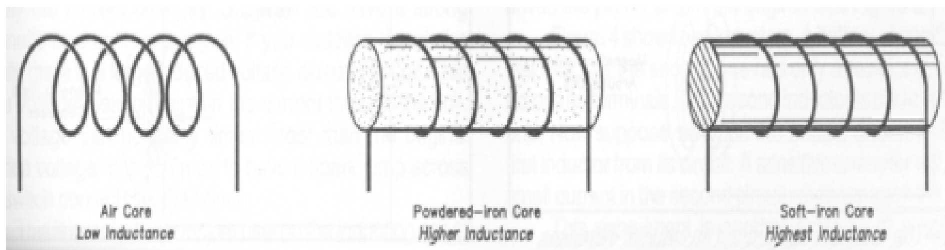
- 1/L=1/L1+1/L2+1/L3

Parameters or Variables determining inductance:

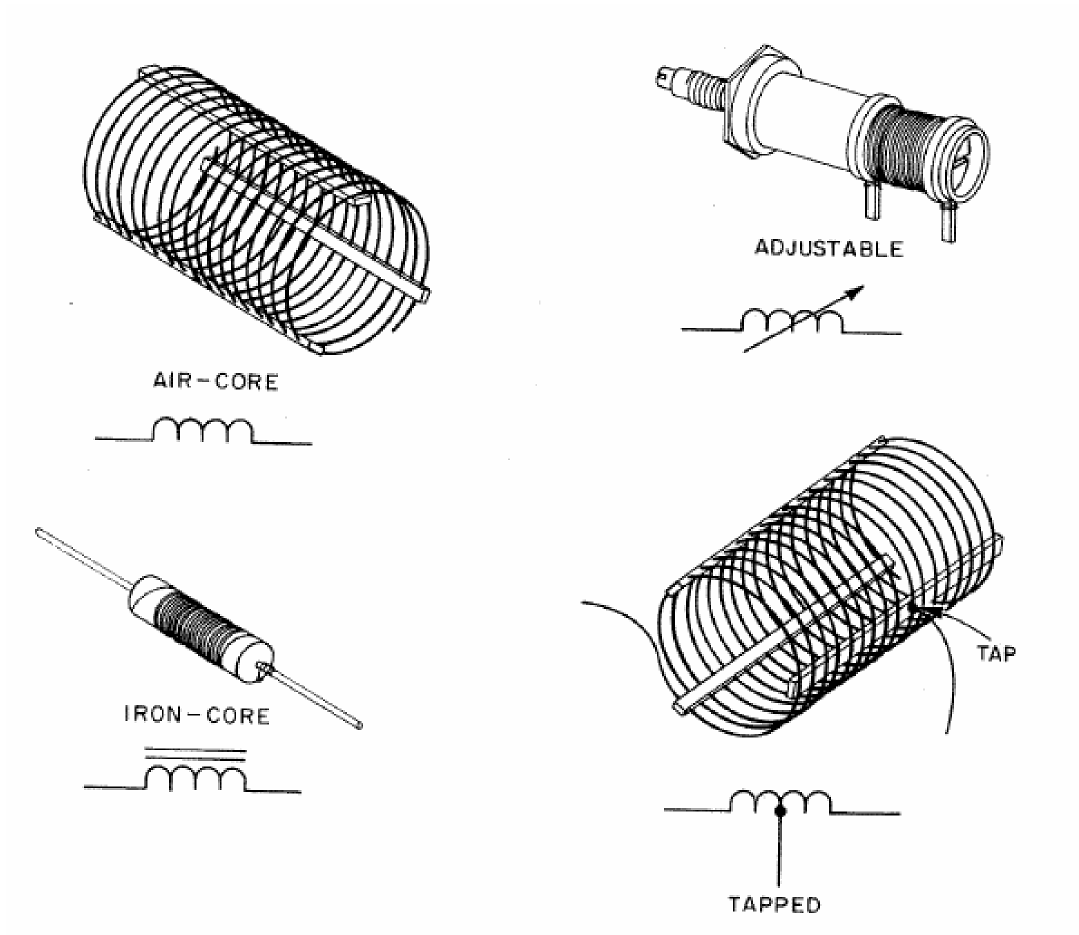
- Inductance (L) of a coil is influenced by 4 factors:
  - » number of turns of the coil
  - » permeability of the core
  - » cross sectional area of the core
  - » spacing of the turns
  - » diameter of the coil
  - » spacing between turns
  - » size of the wire used
  - » type of material used inside the coil







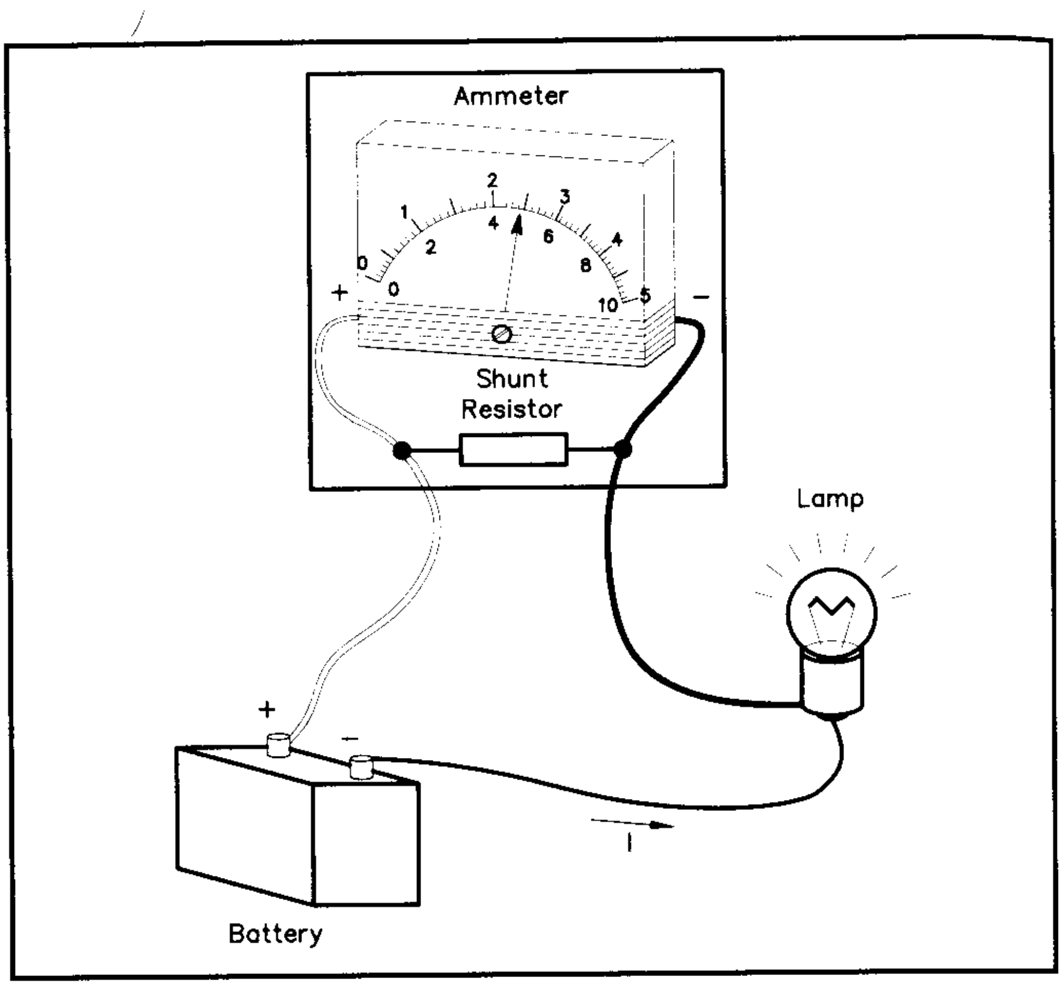
Types of Inductors:


ADJUSTABLE
AIR-CORE
IRON-CORE
TAP
TAPPED

Testing Equipments

Ammeter:

- It is a kind of instrument that measures current.
- To measure current, you must break the current at some point and connect the meter in series at the break. That is, it is hooked up in series with the circuit to be tested.
- A shunt resistor in parallel with the ammeter expands the scale of the meter to measure higher currents than it could normally handle.

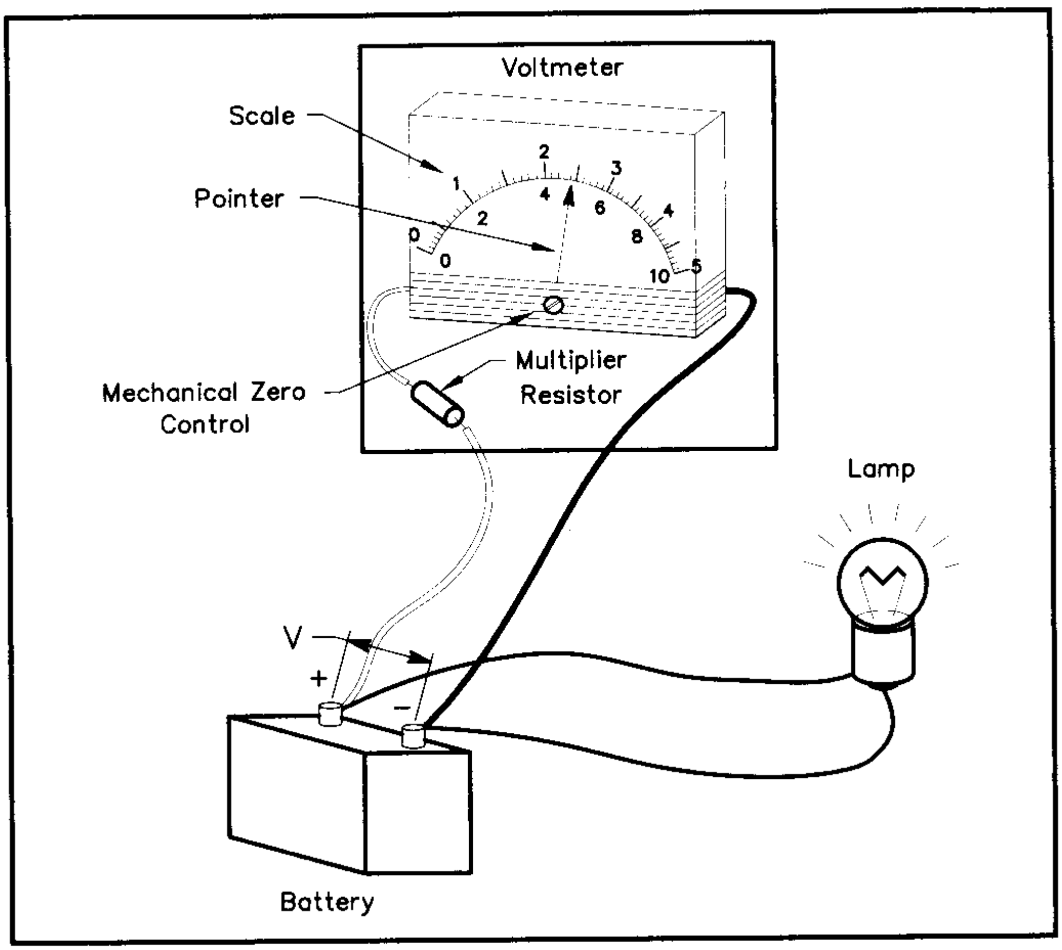


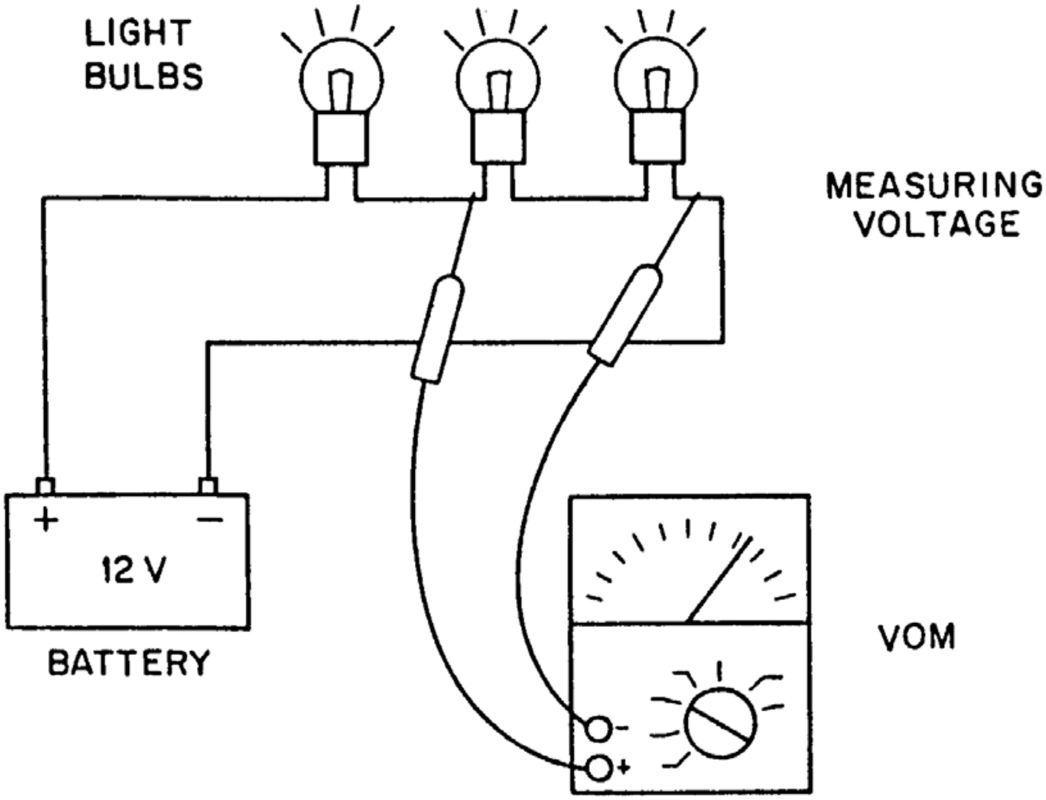
Multimeter (VOM):

- A kind of instrument that combines the function of ammeter, voltmeter, and ohmmeter. It is used to measures volt, resistance, and current.

Voltmeter:

- It is a kind of instrument that measures voltage.
- When you use a voltmeter to measure voltage, the meter must be connected in parallel with the voltage you want to measure. That is, it is used in parallel with a circuit to be measured.
- A series resistor, called the **multiplier resistor** extends the range of the meter.





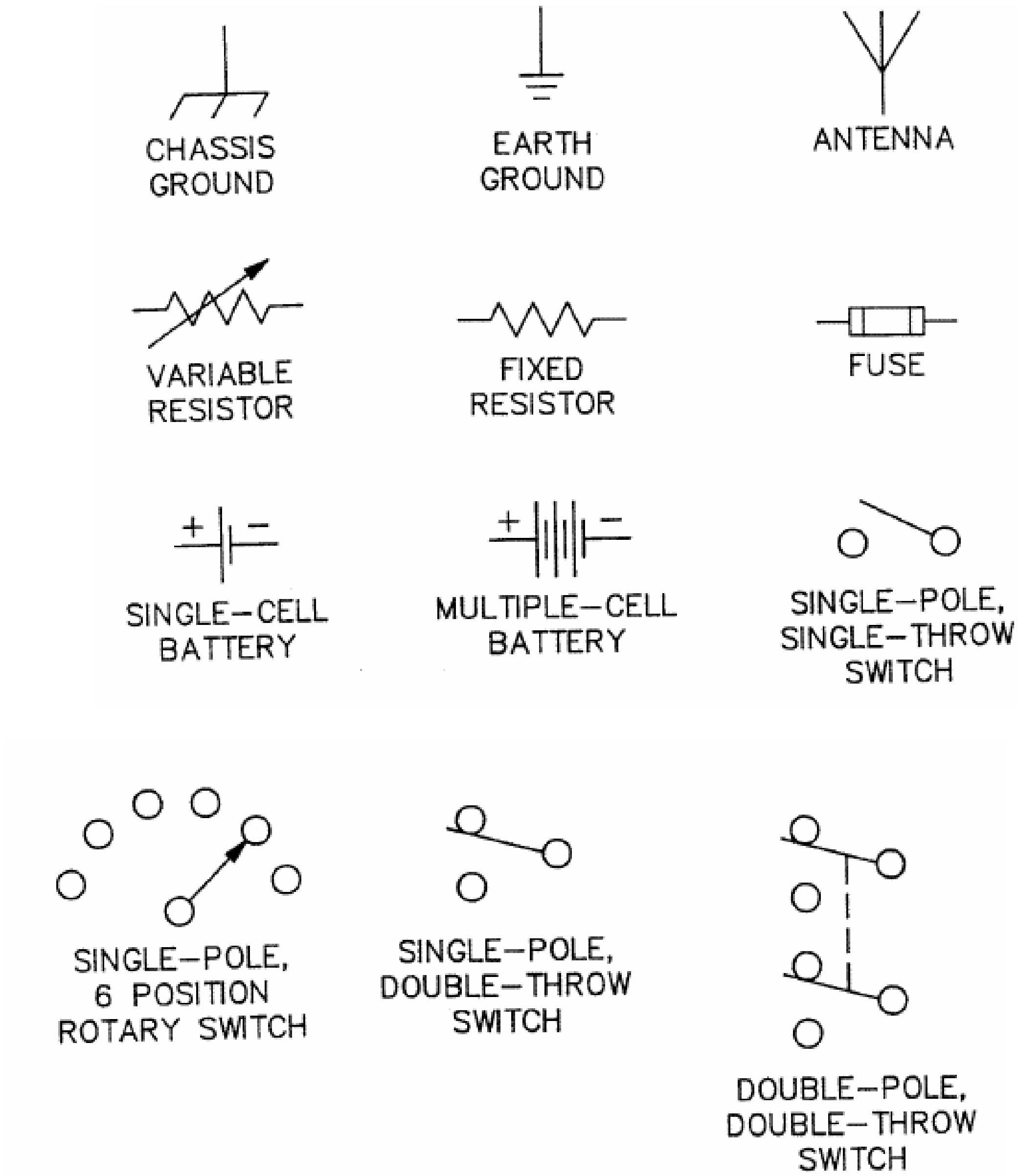
Ohmmeter:

- It is a kind of meter that measures the resistance across a resistor.

Wattmeter:

- It is a device that measures power coming from a transmitter through the antenna feed line.
- A directional wattmeter measures forward and reflected power. Wattmeter generally is useful in certain frequency ranges.

Schematic Symbol of Various Electrical Quantities:



International System of Unit

Prefix	Symbol	Multiplication Factor
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	106
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
UNIT		10^{0}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}