

Unit-1

Basic Electrical Terms and Units

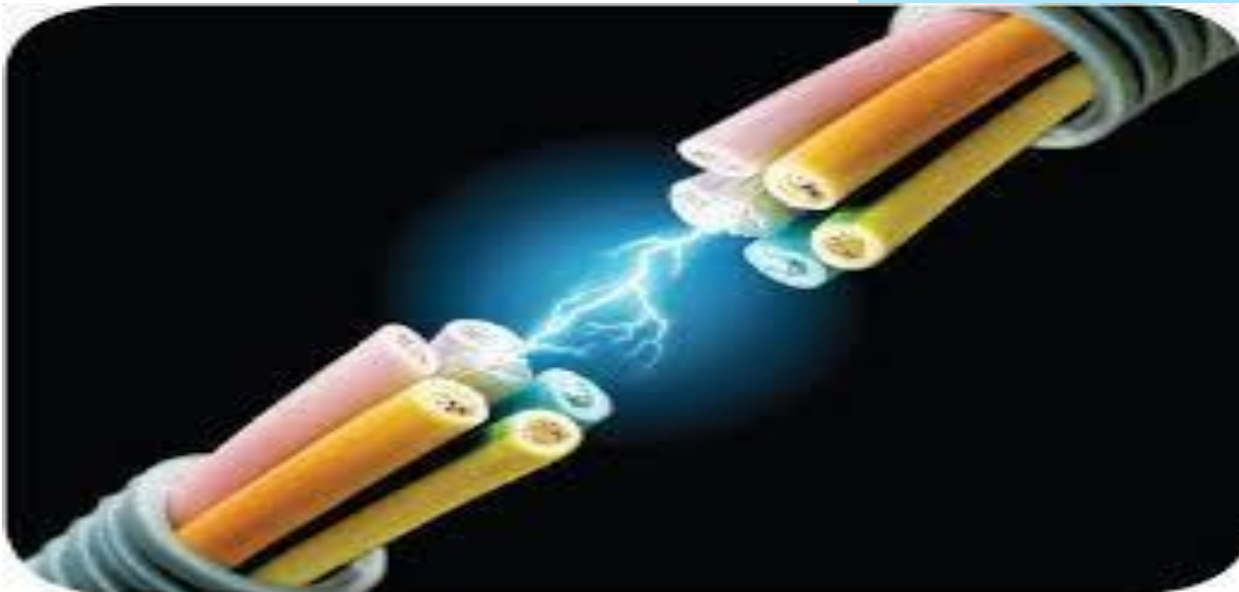
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Content



Ohm's law

Resistor and its coding

Temperature co-efficient of resistance

Resistance variation with temperature

Examples

Ohm's Law



- **Ohm's law** states that the current through a conductor between two points is directly proportional to the voltage across the two points.
- The formula for Ohm's law is **$I=V/R$** .
- where I is the current through the conductor in units of amperes, V is the voltage measured across the conductor in units of volts, and R is the resistance of the conductor in units of ohms. More specifically, Ohm's law states that the R in this relation is constant, independent of the current.
- The law was named after the German physicist Georg Ohm.

Limitations of Ohm's Law



- Ohm's law is not applicable to unilateral networks.
- **Note:-** Unilateral networks allow the current to flow in one direction. Such types of network consist elements like a diode, transistor, etc.
- Ohm's law is also not applicable to non – linear elements.

Note:- Non-linear elements are those which do not have current exactly proportional to the applied voltage that means the resistance value of those elements changes for different values of voltage and current. Examples of non – linear elements are the thyristor.

Resistors

- A resistor is an electrical component that limits or regulates the flow of electrical current in an electric and electronic circuit.
- Resistors are one of the important blocks of electrical circuits.
- They are made up of the mixture of clay or carbon, so they are not only good conductors but good insulators too.

Resistors

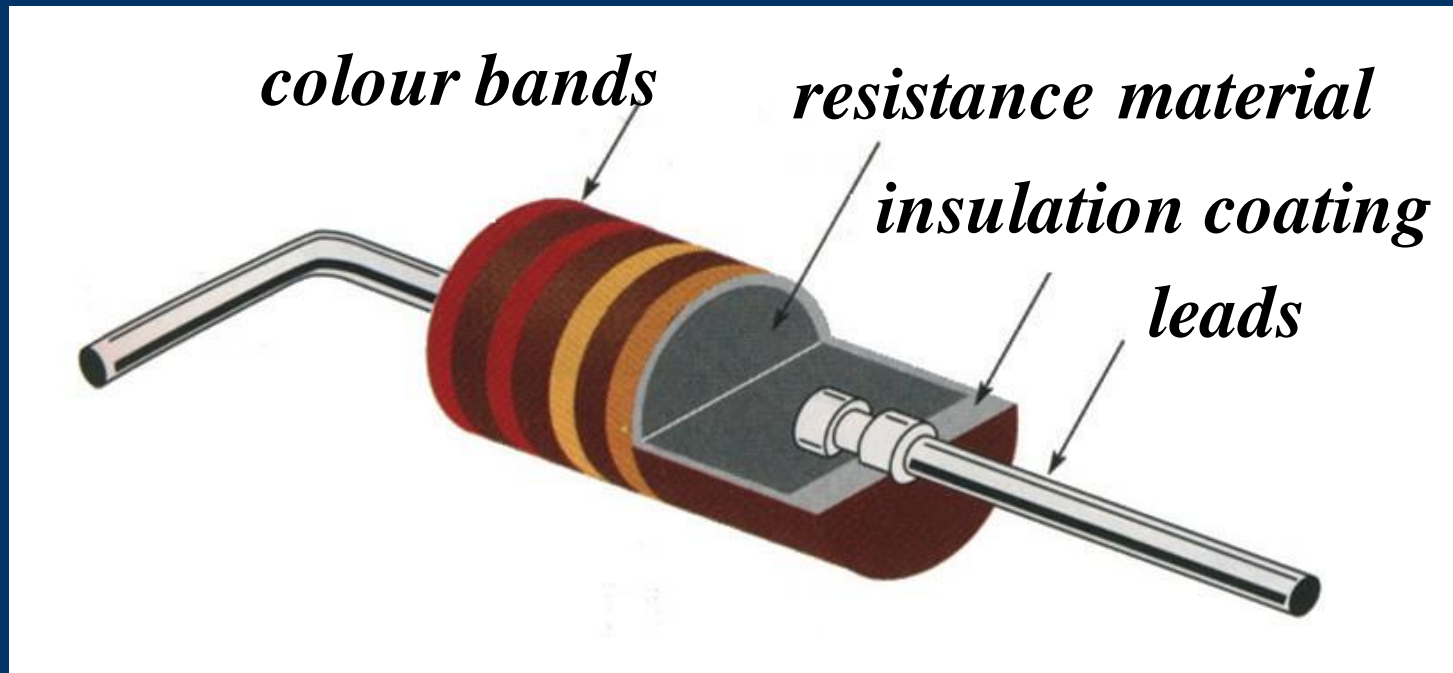
- ✦ Components that are specifically designed to have a certain amount of resistance.
 - ✦ 2 main categories
 - ★ ***fixed resistors*** 
 - ★ resistance value are set during manufacturing and ***cannot be changed***.
 - ★ ***variable resistors*** 
 - ★ resistance values ***can be changed*** easily with a manual or an automatic adjustment.

Fixed Resistors

- ✦ Carbon-composition resistors
 - ★ constructed by molding mixtures of powdered carbon and insulating materials into cylindrical shape.
 - ★ an outer sheath of insulating material affords mechanical and electrical protection.
 - ★ copper connecting wires are provided at each end.

Fixed Resistors

✦ Carbon-composition resistors

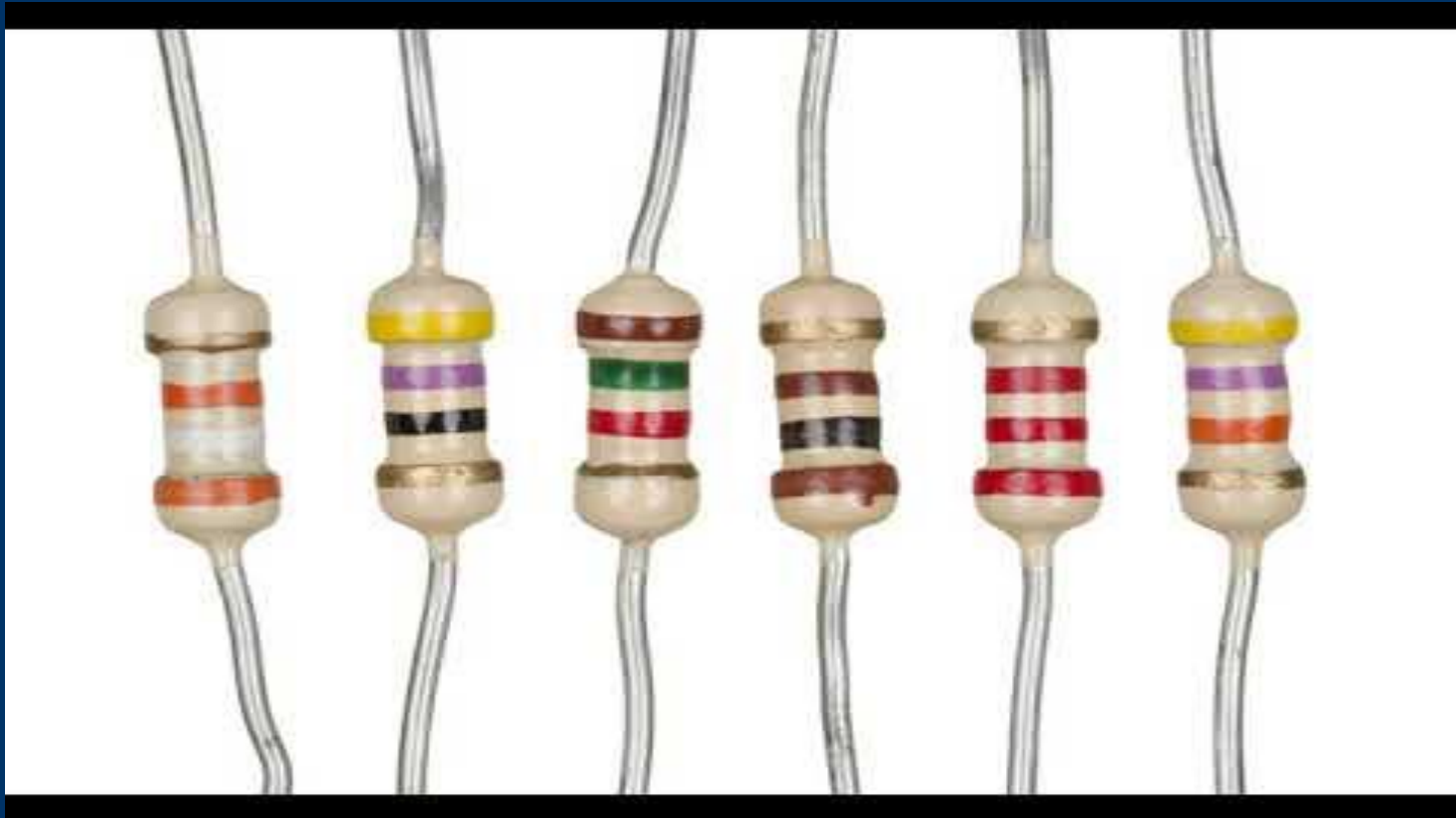


Fixed Resistors

- ✦ Carbon-composition resistors
 - ★ small in size and inexpensive but less accurate and less rugged, the most common type used in electronics.
 - ★ generally used in low current circuits with relatively low power ratings.
 - ★ values available from 20mW to 1W.

Fixed Resistors

✦ Carbon-composition resistors

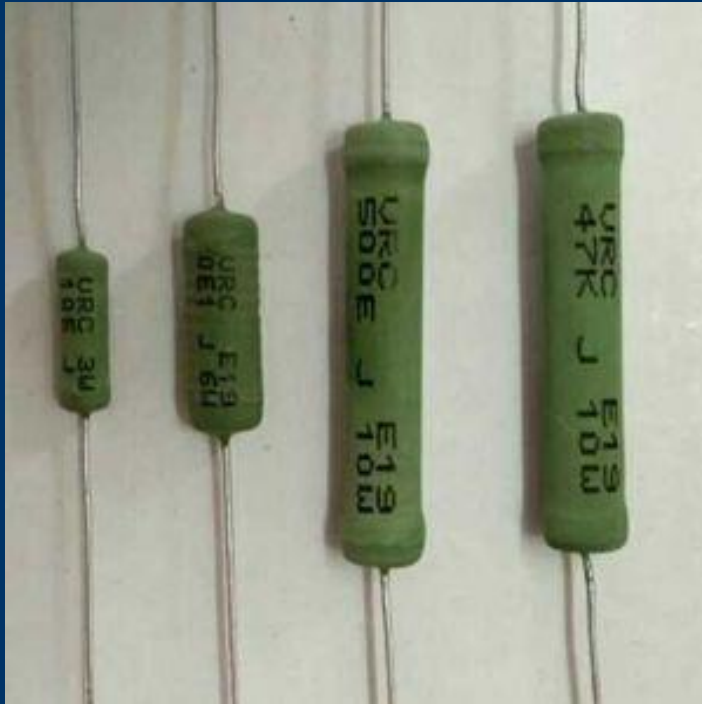


Fixed Resistors

- ✦ Wire-wound resistors
 - ★ large in size but more accurate and more rugged.
 - ★ often used in high current circuits with relatively high power ratings.
 - ★ values available from less than 1W to several 100W.

Fixed Resistors

✦ Wire-wound resistors



low power rating



high power rating



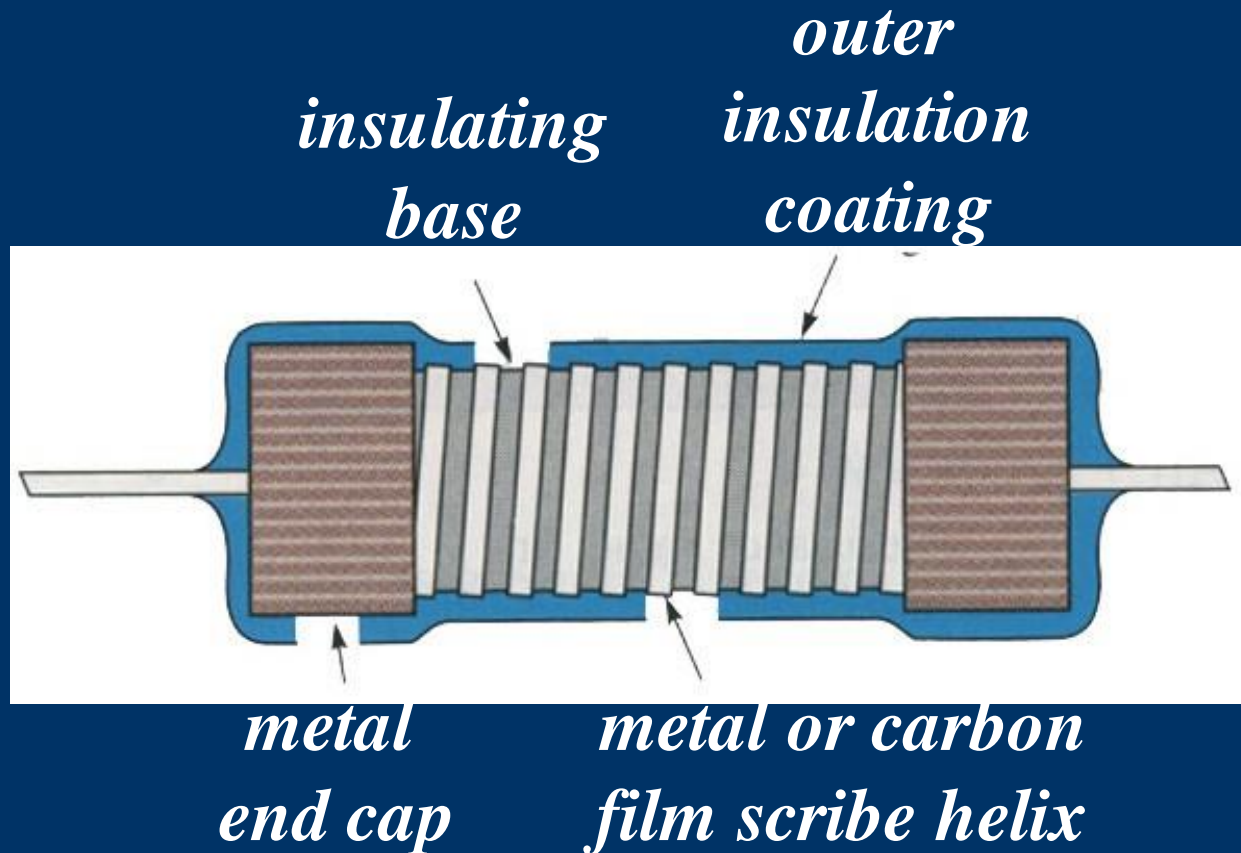
mid power rating

Fixed Resistors

- ✦ Film resistors
 - ★ similar to wire-wound resistor.
 - ★ wire replace by a resistive material and is deposited evenly onto a high-grade ceramic rod.
 - ★ the resistive film may be carbon (carbon film) or nickel chromium (metal film).
 - ★ small in size having performance in-between carbon-composition and wire-wound resistors.

Fixed Resistors

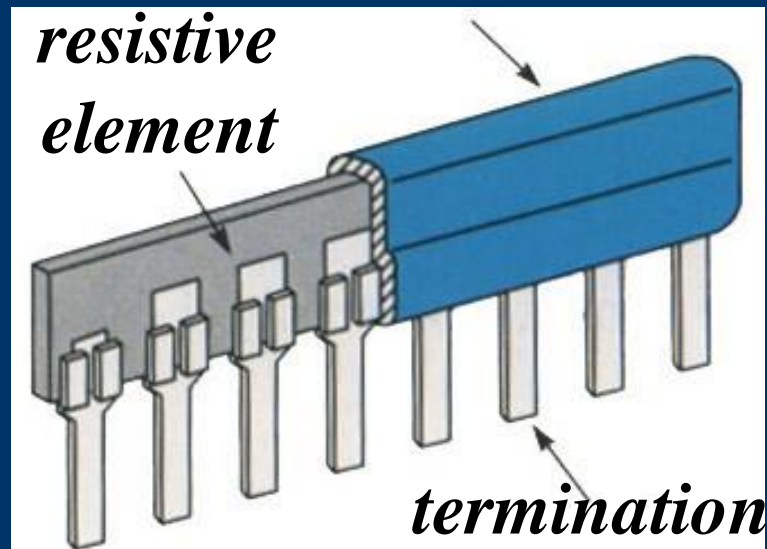
✦ Film resistors (spiraling technique)



Fixed Resistors

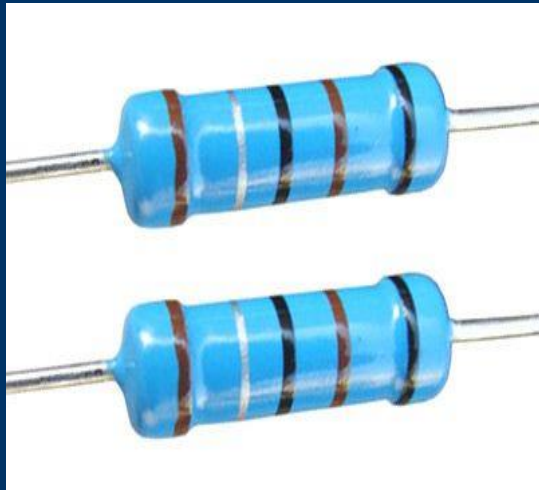
✦ Film resistors (resistor network)

*insulation
coating*



Fixed Resistors

✦ Film resistors



Variable Resistors

- ✦ Manual
 - ✦ potentiometer .
 - ✦ rheostat .
- ✦ Automatic
 - ✦ thermistor - temperature.
 - ✦ photoconductive cell - light intensity.
- ✦ Examples are the volume controls on our TV receivers and radios.

Variable Resistors



Rotary POT



Dual Gang POT



Single Turn POT



Concentric POT



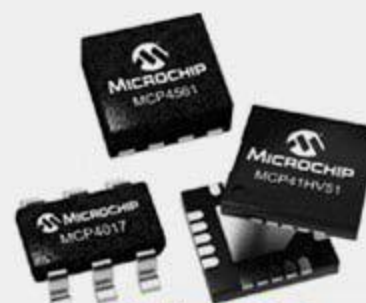
Multi Turn POT



Servo POT



Trimmer POT



Digital POT



Preset POT

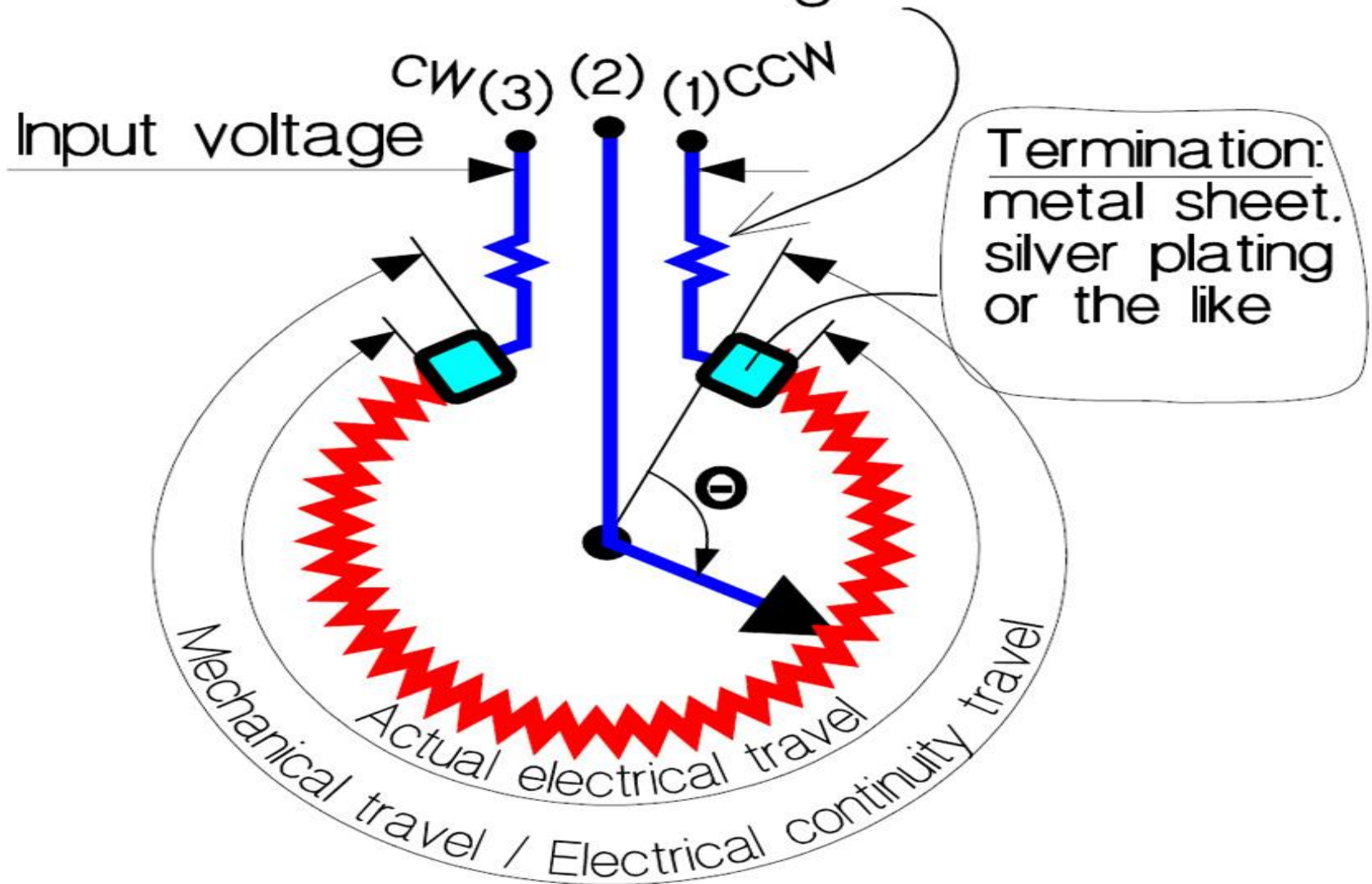


Linear POT



Slide POT

Resistance in connecting leads etc.



Resistor Color Coding



Resistor
21

STEPS IN DETERMINING THE VALUE OF THE COLOR CODED RESISTOR

- Hold the resistor. Look for the 3 colors which they are near on each other. Place it on your left side.



Resistor Color Code



Band One

First Digit

Band Two

Second Digit

Band Three

Multiplier

Band Four

Tolerance

Copy the digit

Copy the digit

Number of zero/s

Minimum and
Maximum Value

ACTUAL VALUE

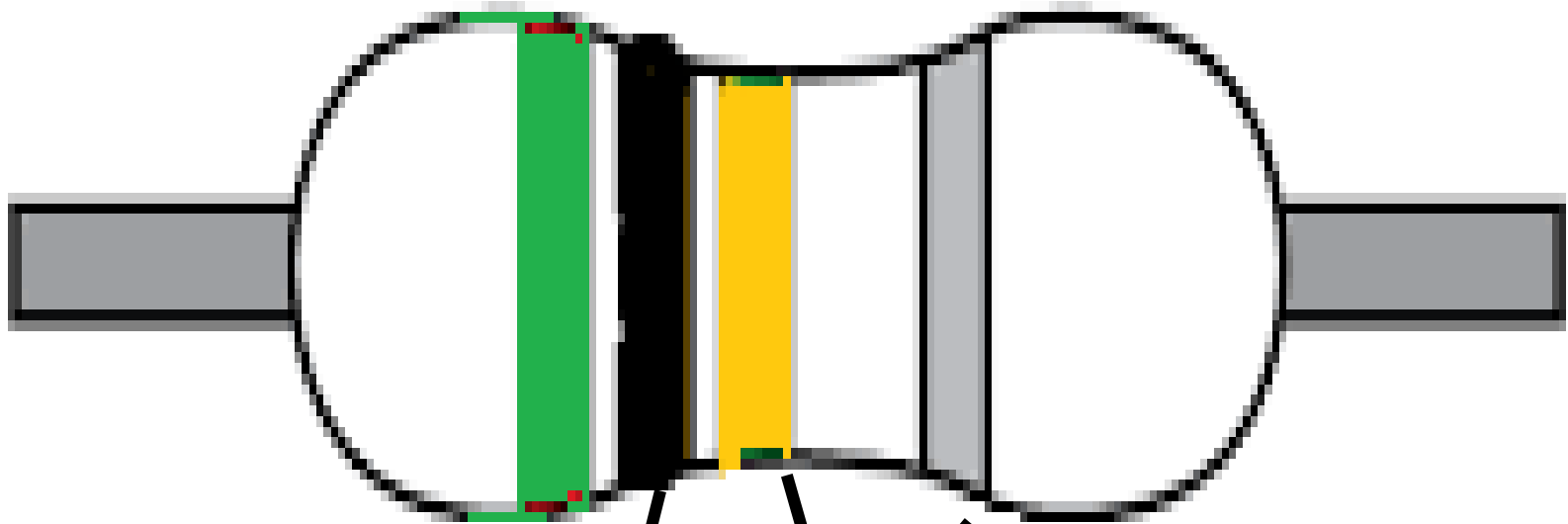
TROUBLESHOOTING

| COLOUR | 1 ST BAND | 2 ND BAND | 3 RD BAND | 4 TH BAND/ TOLERANCE |
|-----------------|----------------------|----------------------|----------------------|------------------------------------|
| BLACK | 0 | 0 | 0 | |
| BROWN | 1 | 1 | 1 | 1% |
| RED | 2 | 2 | 2 | 2% |
| ORANGE | 3 | 3 | 3 | |
| YELLOW | 4 | 4 | 4 | |
| GREEN | 5 | 5 | 5 | |
| BLUE | 6 | 6 | 6 | |
| VIOLET (Purple) | 7 | 7 | 7 | |
| GRAY | 8 | 8 | 8 | |
| WHITE | 9 | 9 | 9 | |
| GOLD | | | | ± 5% |
| SILVER | | | | ± 10% |

NOTE:

Only Gold and Silver
are the 2 colors that can
be found in the 4th band

4th band : TOLERANCE



1st band

2nd band

3rd band

4th band

GREEN

BLACK

ORANGE

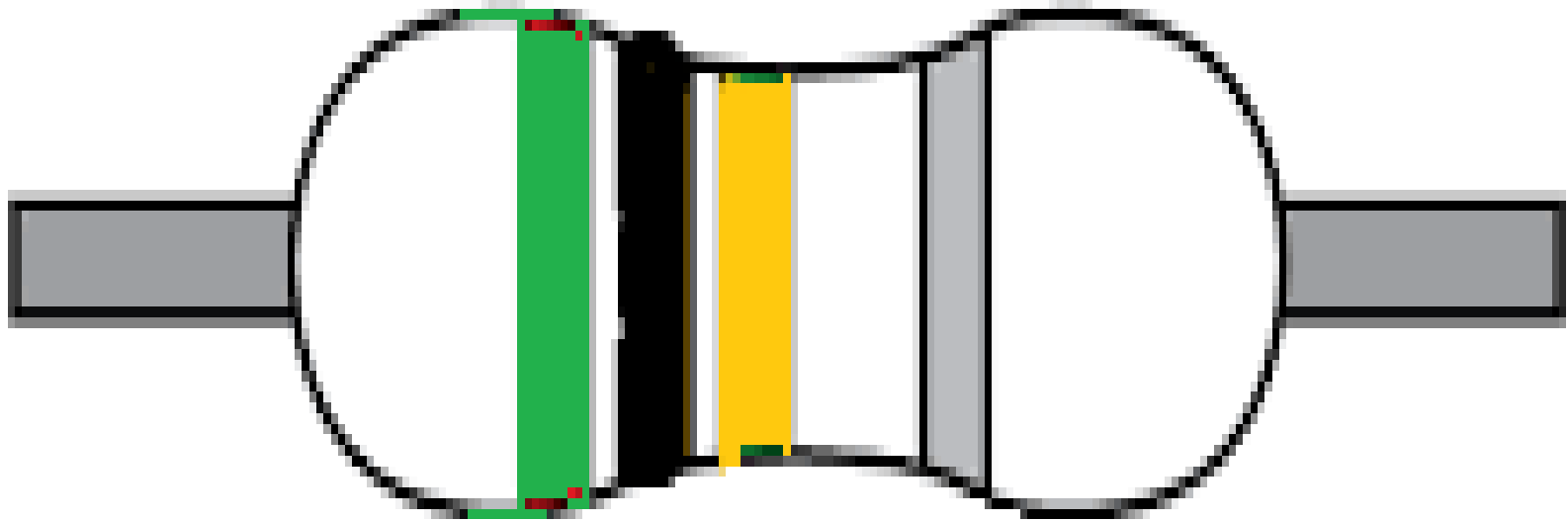
SILVER

5

0

000 OHMS

±10%



GREEN

BLACK

ORANGE

SILVER

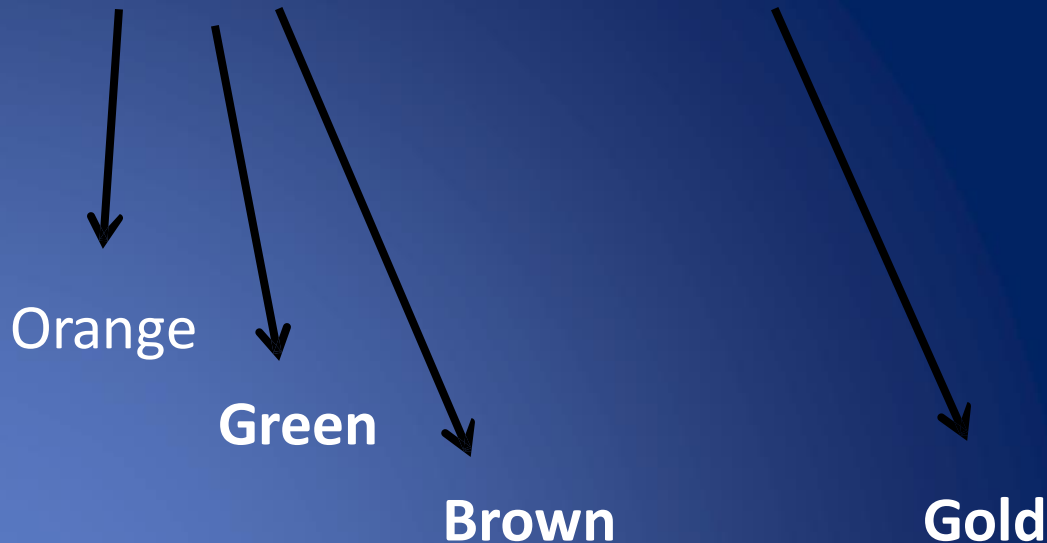
ACTUAL VALUE

50000 OHMS $\pm 10\%$

REVERSE

VALUE  COLOR BANDS

350 OHMS $\pm 5\%$

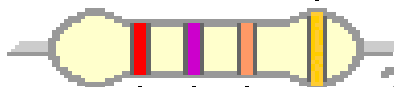


Resistor Colour Code

| | | | | | | | | | |
|------|--------|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | Black | | | | | | | | |
| 1 | Brown | | | | | | | | |
| 2 | Red | | | | | | | | |
| 3 | Orange | | | | | | | | |
| 4 | Yellow | | | | | | | | |
| 5 | Green | | | | | | | | |
| 6 | Blue | | | | | | | | |
| 7 | Purple | | | | | | | | |
| 8 | Grey | | | | | | | | |
| 9 | White | | | | | | | | |
| ±5% | Gold | | | | | | | | |
| ±10% | Silver | | | | | | | | |

Color Codes

| | |
|--------|--------|
| Brown | ±1% |
| Red | ±2% |
| Gold | ±5% |
| Silver | ±10% * |




27K
EXAMPLE

| | |
|---|---------------|
| 0 | ×1 |
| 1 | 1 ×10 |
| 2 | 2 ×100 |
| 3 | 3 ×1000 |
| 4 | 4 ×10000 |
| 5 | 5 ×100000 |
| 6 | 6 ×1000000 |
| 7 | 7 ÷10 Gold |
| 8 | 8 ÷100 Silver |
| 9 | 9 |

4 Band Resistors

| | |
|--------|--------|
| Brown | ±1% |
| Red | ±2% |
| Gold | ±5% * |
| Silver | ±10% * |



15K
EXAMPLE

| | | |
|---|---|---------------|
| 0 | 0 | ×1 |
| 1 | 1 | 1 ×10 |
| 2 | 2 | 2 ×100 |
| 3 | 3 | 3 ×1000 |
| 4 | 4 | 4 ×10000 |
| 5 | 5 | 5 ÷10 Gold |
| 6 | 6 | 6 ÷100 Silver |
| 7 | 7 | 7 |
| 8 | 8 | 8 |
| 9 | 9 | 9 |

5 Band Resistors

Resistor Colour Code

✦ Normal resistors

★ colour coded with **4 bands**

- ★ start from the end that does not begin with a gold or silver band (banded end).
- ★ first band is the **first digit** of the resistance value.
- ★ second band is the **second digit**.
- ★ third band is the **multiplier**.
- ★ fourth band indicates the **tolerance**.

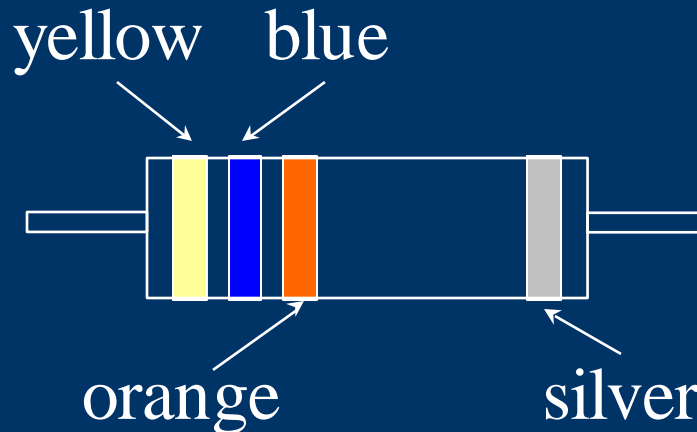
Resistor Colour Code

✦ Precision resistors

✦ colour coded with **5 bands**

- ✦ first band is the ***first digit*** of the resistance value.
- ✦ second band is the ***second digit***.
- ✦ third band is the ***third digit***.
- ✦ fourth band is the ***multiplier***.
- ✦ fifth band indicates the ***tolerance***.

Example 1



yellow = 4

blue = 6

orange = 10^3

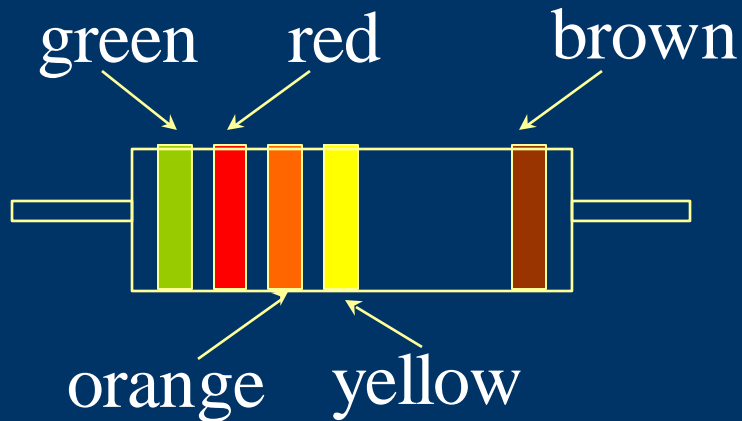
silver = 10%

$$\downarrow R = 46 \times 10^3 \Omega = 46\,000 \Omega = 46\text{ k}\Omega \pm 10\%$$

$$\text{tolerance} = 10\% \text{ of } 46\,000 \Omega = 4\,600 \Omega$$

$$\begin{aligned} R &= (46\,000 \Omega - 4\,600 \Omega) \text{ to } (46\,000 \Omega + 4\,600 \Omega) \\ &= 41\,400 \Omega \text{ to } 50\,600 \Omega \\ &= 41.4\text{ k}\Omega \text{ to } 50.6\text{ k}\Omega \end{aligned}$$

Example 2



green = 5

red = 2

orange = 3

yellow = 10^4

brown = 1%

$$\downarrow R = 523 \times 10^4 \Omega = 5\,230\,000 \Omega = 5.23 \text{ M}\Omega \pm 1\%$$

$$\text{tolerance} = 1\% \text{ of } 5.23 \text{ M}\Omega = 0.0523 \text{ M}\Omega$$

$$\begin{aligned} R &= (5.23 \text{ M}\Omega - 0.0523 \text{ M}\Omega) \text{ to } (5.23 \text{ M}\Omega + 0.0523 \text{ M}\Omega) \\ &= 5.177 \text{ M}\Omega \text{ to } 5.2823 \text{ M}\Omega \end{aligned}$$

What is the value of the resistor?

1. Blue, Green, Black, Orange, Gold

2. Yellow, White, Red, Silver

3. Brown, Black, Brown, Silver

Ans.1- 6,17,500 to 6,82,500

Ans.2- 4410 to 5390

Ans.3- 90 to 110

What is the set of colors of this given 4 Band resistance?

- 1. $10\Omega \pm 5\%$**
- 2. $850,000 \Omega \pm 10\%$**
- 3. $70,000,000 \Omega \pm 5\%$**

Ans.1-BROWN,BLACK,BLACK,GOLD

Ans.2- GRAY,GREEN,YELLOW,SILVER

Ans.3- PURPLE,BLACK,BLUE,GOLD

EVALUATION

A. Identify the value of resistor with the given set of colors.

1. Brown, Black, Brown, Gold
2. Red, Green Black, Silver
3. Brown, Green, Orange, Silver
4. White, Yellow, Yellow, Silver
5. Green, Violet, Blue, Gold

B. Determine the colors of the 4 band resistor.

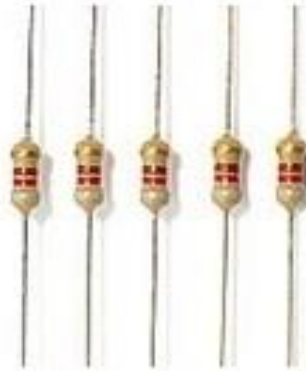
1. $12 \pm 5\%$
2. $47 \pm 5\%$
3. $100 \pm 10\%$
4. $37,000 \pm 5\%$
5. $22,000,000 \pm 10\%$

Wattage Rating

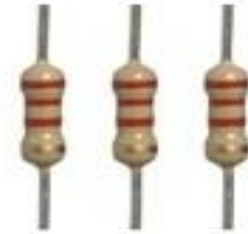
- ✦ The maximum amount of power that a resistor can *dissipate* without being damaged by excessive heat buildup.
- ✦ Not related to the ohmic value (resistance).
- ✦ Determined mainly by the physical size and shape of the resistor.



1/8 Watt Resistors



1/4 Watt Resistors



1/2 Watt Resistors



1 Watt Resistors



2 Watt Resistors

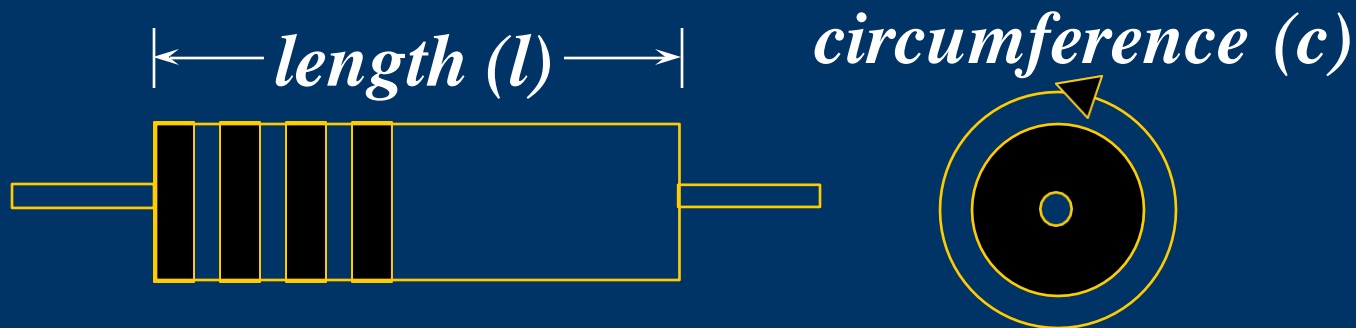


5 Watt Resistor

Wattage Rating

- ✦ The larger the surface area of a resistor, the more power it can dissipate.

*surface area
of a cylindrically
shaped resistor = (l x c)*



Wattage Rating

- ✦ Carbon-composition resistors
 - ★ from 20mW to 1W.
- ✦ Wire-wound resistors
 - ★ less than 1W to several 100W.
- ✦ Film resistors
 - ★ up to 10W.

Resistance Factors

- ✦ Resistance of resistor is affected by **4 factors**
 - ★ environmental
 - ★ **temperature** (temperature coefficient).
 - ★ manufacturer
 - ★ **diameter** (cross-sectional area, A).
 - ★ **length** (l)
 - ★ **type of material** (resistivity, ρ).

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

Resistance Factors

✦ Temperature coefficient

- ✦ indicates the change in resistance with temperature
 - ✦ positive - proportional.
 - ✦ negative - inversely proportional.

Applications

- ✦ *Limit/reduce current.*
- ✦ *Divide voltage to produce a desired voltage drop.*
- ✦ *Generate heat in certain cases.*

- Resistance of the conducting material is calculated using

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

ρ = resistivity
 L = length
 A = cross sectional area

- The resistance of a conducting material is found to
 1. be directly proportional to the length L of the material.
 2. be inversely proportional to the cross- section are A of the material.
 3. depend on the nature of the material.
 4. depend upon the temperature.

| Conductor | Insulator | Semi-Conductor |
|--|--|---|
| <ul style="list-style-type: none"> ➤ It is a material which has a large number of free electrons so, the current can easily flow through it. ➤ All materials with resistivity less than 10^{-8} ohm.m behave as conductor. ➤ E.g. Silver, Copper, Aluminium, Carbon and almost all metals. | <ul style="list-style-type: none"> ➤ If the outer electrons of a material are very tightly bound to the nucleus, it becomes very difficult to remove from their orbits. Hence current cannot flow through such materials and they are known as insulators. ➤ All materials with resistivity above 10^5 ohm.m behave as insulator. ➤ E.g. Mica, Porcelain, Glass, oil, rubber, etc. | <ul style="list-style-type: none"> ➤ It is material in which outer electrons are bound to the nucleus but the electrons can be made free by some means. For examples by adding some impurity. ➤ All material with resistivity between 10^{-8} and 10^5 ohm.m behave as semi-conductor. ➤ E.g. Germanium and Silicon. |

Temperature co-efficient of resistance

- Resistance of almost all the materials changes with the change in the temperature.

R_0 = Resistance of the material at 0 degree Celsius

R_t = Resistance of the material at t degree Celsius

- Then the change in resistance is found to be

$$\Delta R = R_t - R_0$$

- directly proportional to its initial resistance, and
- directly proportional to the change in temperature.

- Thus,

$$\Delta R \propto R_0 t \quad \Rightarrow \quad (R_t - R_0) \propto R_0 t \quad \Rightarrow \quad (R_t - R_0) = \alpha R_0 t$$

α = constant known as the temperature co-efficient of resistance.

Continue....

- The variation of resistance with change in temperature of any material is governed by this property.

$$\alpha = \frac{(R_t - R_0)}{R_0 t} \quad (1)$$

- Temperature co-efficient of resistance α is defined as the change in resistance per unit rise in temperature per ohm original resistance.
- Usually temperature co-efficient is taken at a particular reference temperature which is normally taken as 0 degree Celsius.
- It is denoted by α_0
- Rewriting the equation (1), $R_t = R_0 * [1 + \alpha_0 * t]$

Resistance at different temperatures

- If at a standard temperature of '0' degree Celsius a material has a resistance of R_0 ohms,
 - at t_1 degree Celsius resistance of R_1 ohms and
 - at t_2 degree Celsius resistance of R_2 ohms, then

$$R_1 = R_0 * [1 + \alpha_0 * t_1] \text{ and}$$
$$R_2 = R_0 * [1 + \alpha_0 * t_2]$$

$$\frac{R_2}{R_1} = \frac{[1 + \alpha_0 * t_2]}{[1 + \alpha_0 * t_1]}$$

Continue....

- If temperature co-efficient α_0 and resistance R_0 are not given then the relation between the known resistance R_{t_1} and t_1 degree Celsius and the unknown resistance R_{t_2} and t_2 degree Celsius can be found as follows:

R_{t_1} = resistance at t_1 degree Celsius

R_{t_2} = resistance at t_2 degree Celsius

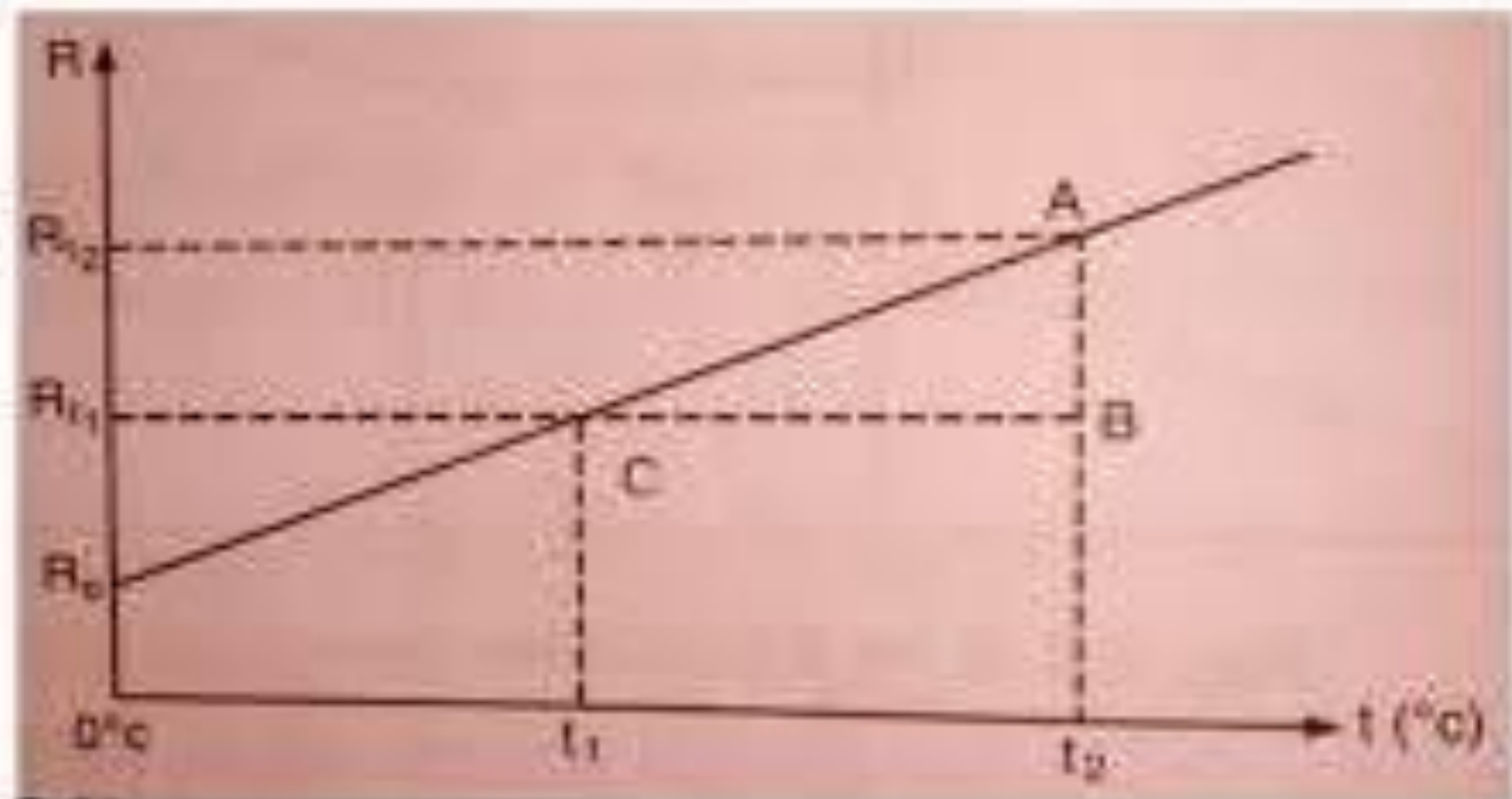
- Suppose,

α_{t_1} = temperature co-efficient of resistance at t_1 degree Celsius

α_{t_1} = Slope of the graph / resistance at t_1 degree Celsius

Slope of the graph = $\alpha_{t_1} * R_{t_1}$

Resistance at Different temperature



Continue....

$$\begin{aligned}\text{Slope of the graph} &= AB/BC \\ &= \frac{R_{t2} - R_{t1}}{t_2 - t_1}\end{aligned}$$

$$\alpha_{t1} * R_{t1} = \frac{R_{t2} - R_{t1}}{t_2 - t_1}$$

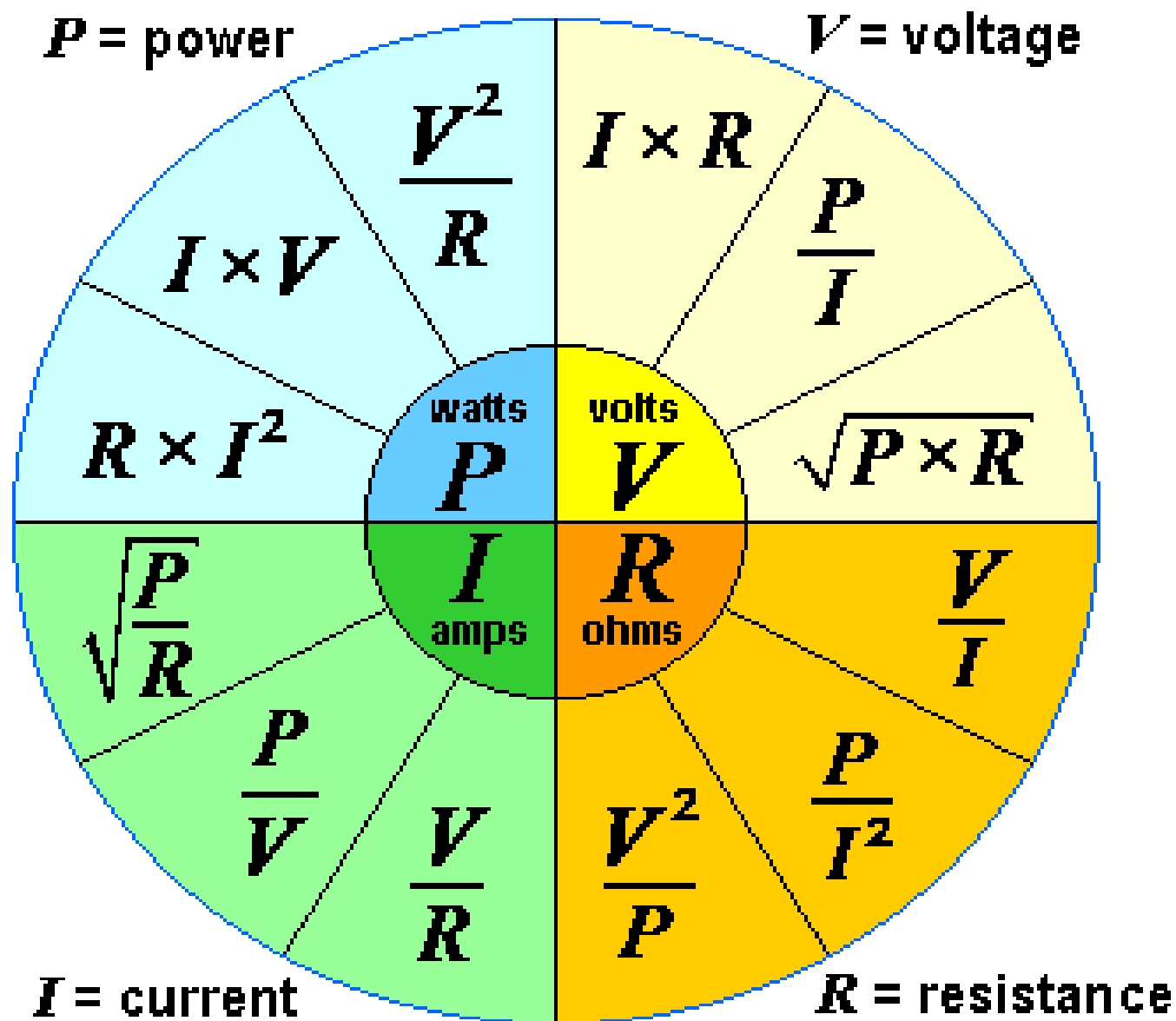
$$R_{t2} - R_{t1} = \alpha_{t1} * R_{t1} * (t_2 - t_1)$$

$$R_{t2} = \alpha_{t1} * R_{t1} * (t_2 - t_1) + R_{t1}$$

$$= R_{t1} [1 + \alpha_{t1} * (t_2 - t_1)]$$

Effect of temperature on Resistance

| Metals | Alloys | Insulators, Semi-Conductors & Electrolytes |
|--|--|--|
| <ul style="list-style-type: none">➤ Resistance of pure metals increases with the rise in temperature.➤ The increase in resistance is large and regular.➤ Metals have a positive temperature co-efficient of resistance.➤ E.g. Copper, Aluminium | <ul style="list-style-type: none">➤ Resistance of alloys increases with the rise in temperature.➤ But the increase in resistance is irregular and small.➤ Alloys have a very low value of positive temperature co-efficient of resistance.➤ E.g. Nichrome | <ul style="list-style-type: none">➤ Resistance of Insulators, Semi-Conductors & Electrolytes decreases with the rise in temperature.➤ As temperature is increased, many free electrons are created.➤ So there is a drop in the value of the resistance.➤ Hence they have a negative temperature co-efficient of resistance.➤ E.g. Rubber, Oil, Plastic |



1. A wire has a resistance of 2 ohms. It has been stretched to the length 3 times that of original, what will be the resistance of wire?

Solution:-

We know that

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

$$= \frac{\rho \times l}{a} \times \frac{l}{l} \quad (\because \text{Multiply and divide by 'l'})$$

$$= \frac{\rho l^2}{a l}$$

$$= \frac{\rho l^2}{V} \quad [\because V = a l]$$

By stretching the wire, volume remains unchanged

$$\therefore R \propto l^2$$

In other words

$$\frac{R_2}{R_1} = \left(\frac{l_2}{l_1} \right)^2$$

$$\text{Now } R_1 = 2 \, \Omega \quad l_2 = 3 \, l_1$$

$$\therefore R_2 = 2 \left(\frac{3 \, l_1}{l_1} \right)^2$$

$$= 2 (3)^2$$

$$\boxed{= 18 \, \Omega}$$

2. Calculate the resistance of 100 m length of a wire having a uniform cross section area of 0.1 mm^2 if the wire is made of Manganin having a resistivity of $50 \times 10^{-8} \text{ ohm} \cdot \text{m}$. If the wire is drawn out to three times its original length, find out new resistance.

Solution:

$$l = 100 \text{ m}$$

$$a = 0.1 \text{ mm}^2 = 0.1 \times 10^{-6} \text{ m}^2$$

$$\rho = 50 \times 10^{-8} \Omega \text{m}$$

$$(i) \quad R = \frac{\rho l}{a}$$

$$= 500 \text{ ohm}$$

$$(ii) \quad R = \frac{\rho l}{a}$$

$$= R = \frac{\rho l}{a} \times \frac{l}{l} \quad (\text{multiply by } l \text{ to the numerator and denominator})$$

$$= \frac{\rho l^2}{V} \quad (\because V = a \times l)$$

As wire is drawn its length l and cross section a may vary but the volume remains constant.

$$\therefore R \propto l^2$$

As length is increased 3 times

$$l_2 = 3 l_1$$

$$\therefore \frac{R_2}{R_1} = \left(\frac{l_2}{l_1} \right)^2 = \left(\frac{3}{1} \right)^2$$

$$\therefore \boxed{R_2 = 9 R_1}$$

$$R_2 = 9 \times 500 = 4500 \text{ ohm}$$