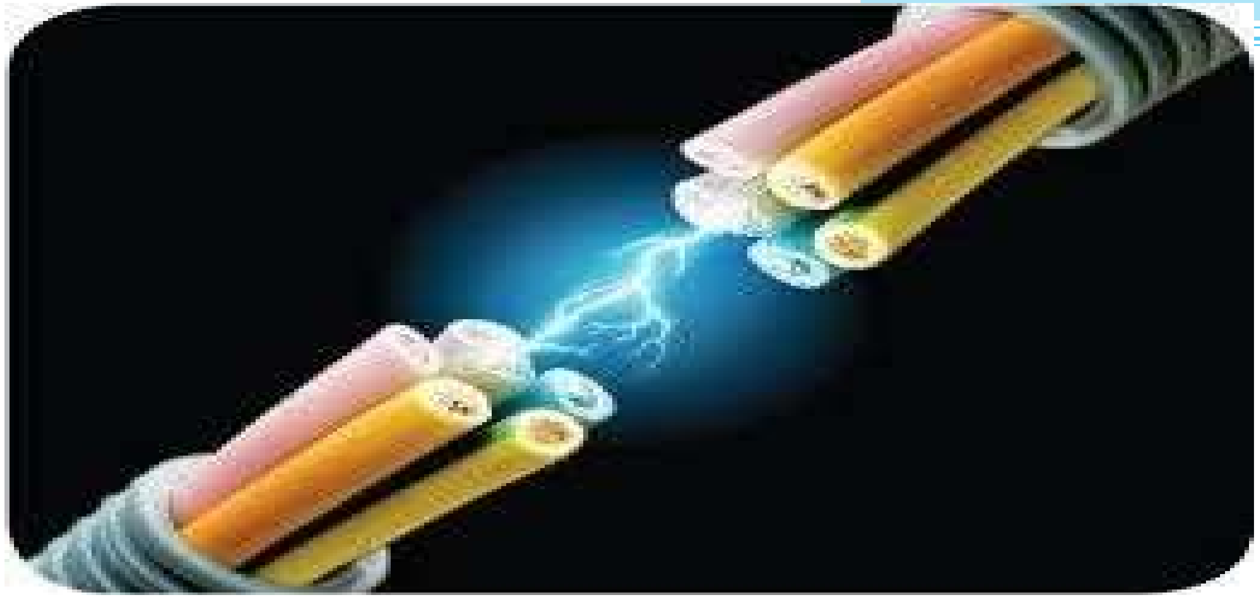
Unit-1
Basic Electrical Terms and Units

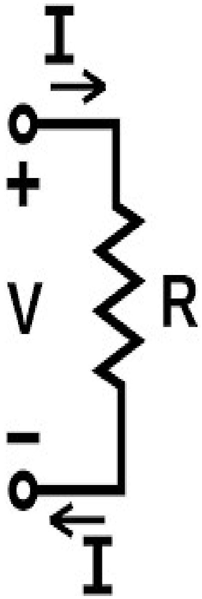
Prepared by:
Dr.Dharmesh Dabhi
M & V Patel Department of Electrical Engineering
CHARUSAT
dharmeshdabhi.ee@charusat.ac.in



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 <u>set</u> during manufacturing and ***cannot be changed***.
    - ***variable resistors***

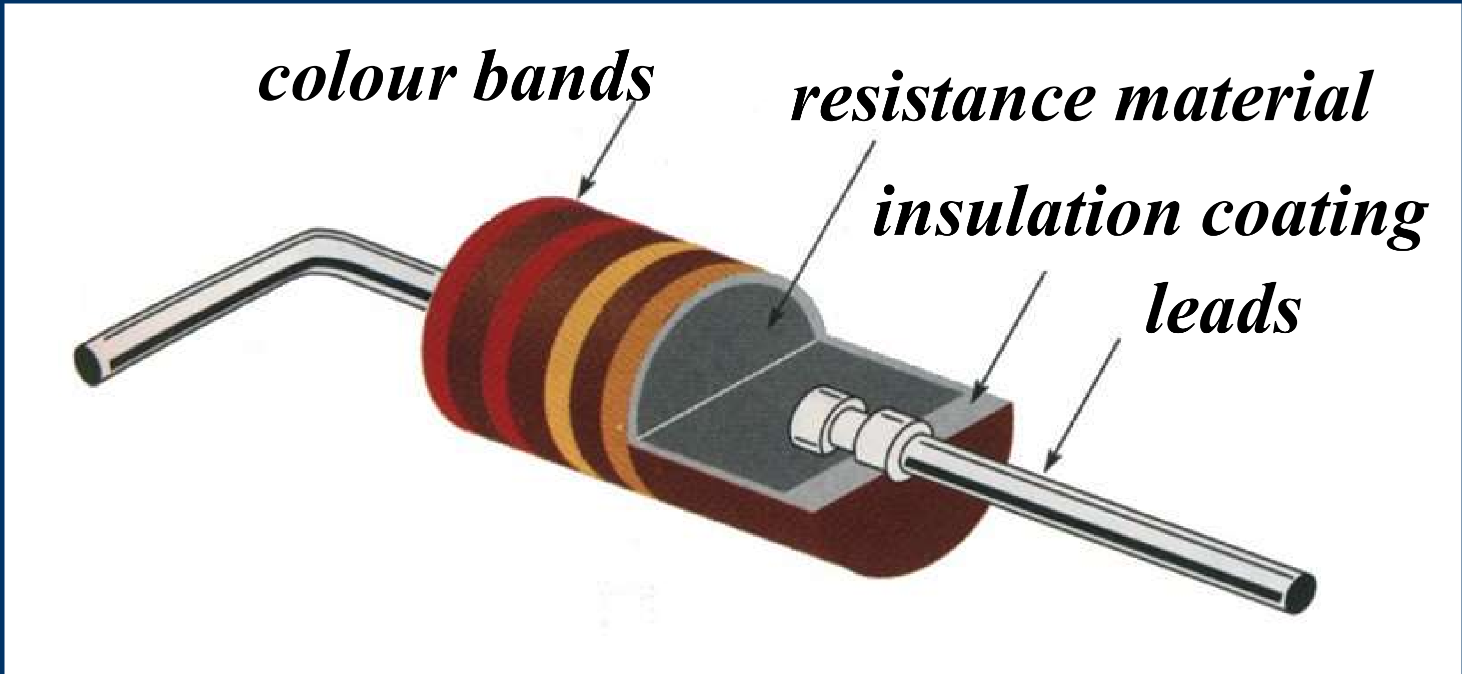
      - resistance values ***can be changed*** easily with a manual or an automatic <u>adjustment</u>.

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

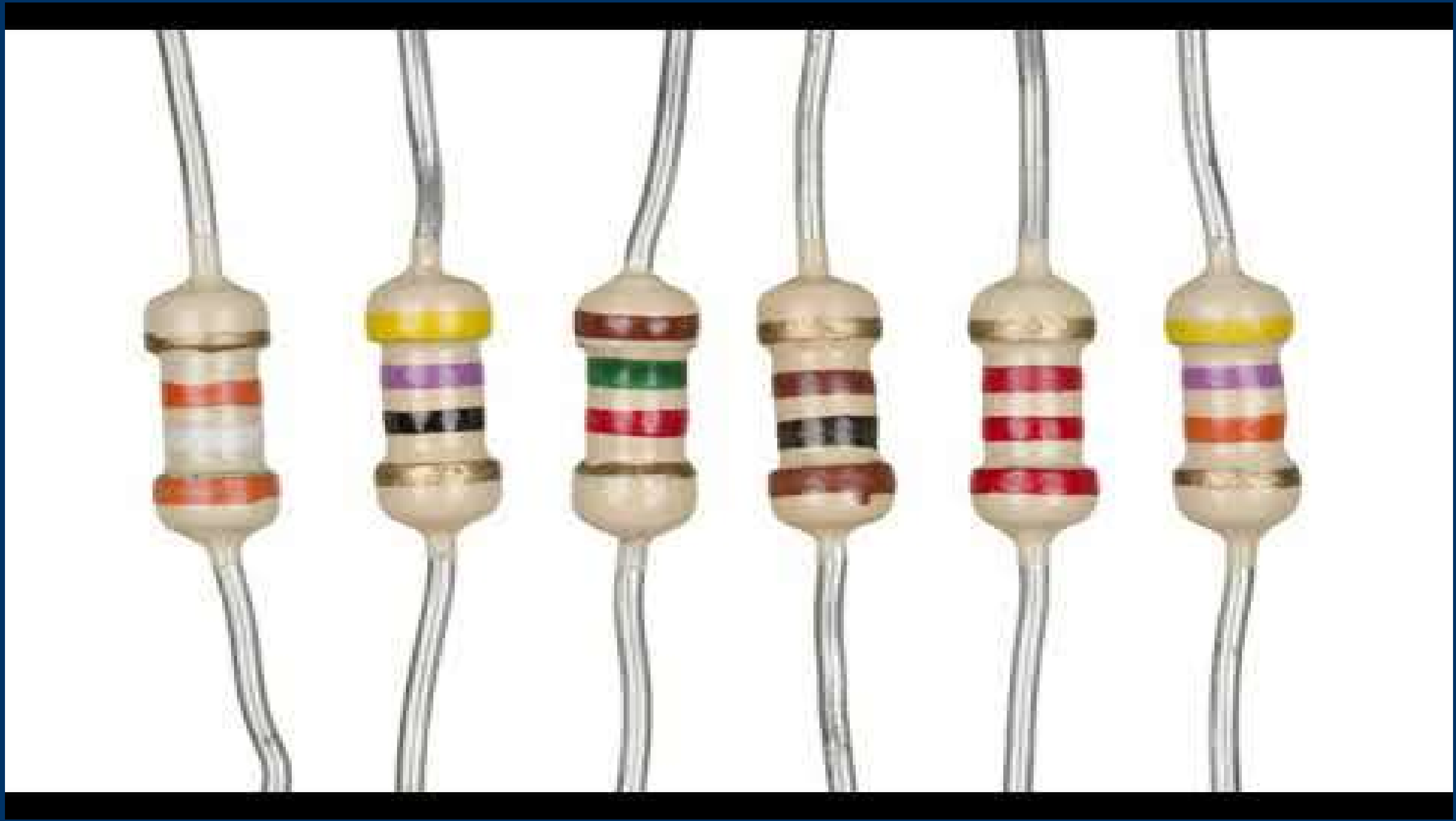


Fixed Resistors

- 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

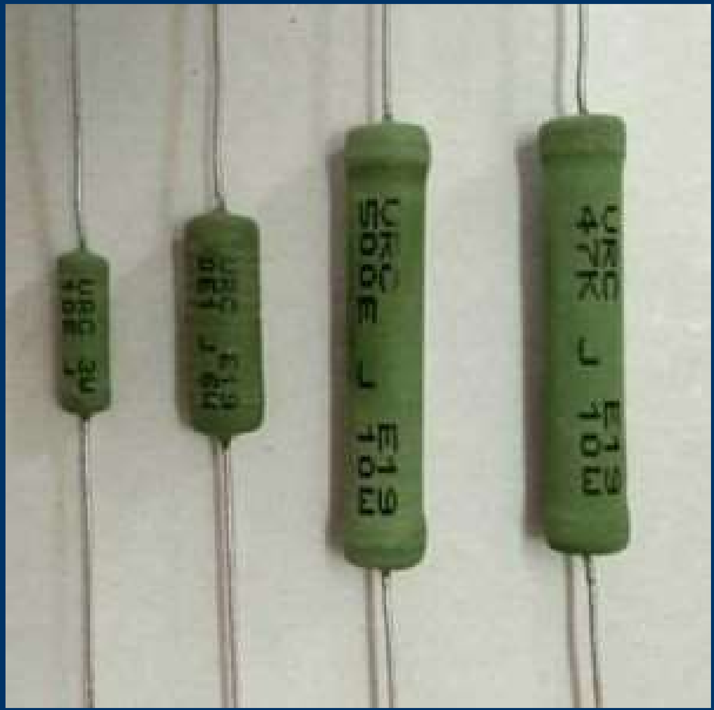


Fixed Resistors

- 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

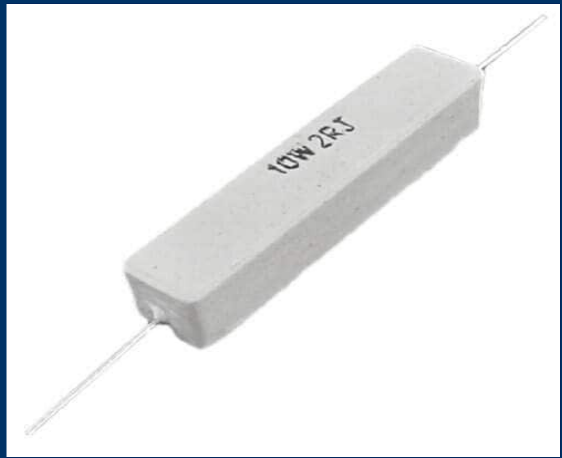
Wire-wound resistors



low power rating

high power rating

mid power rating

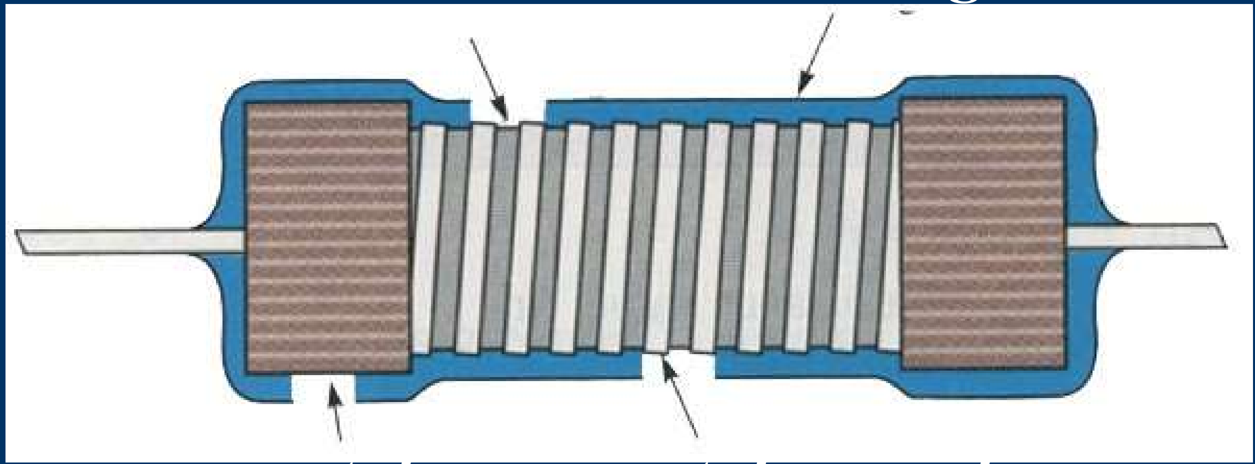


Fixed Resistors

- 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.

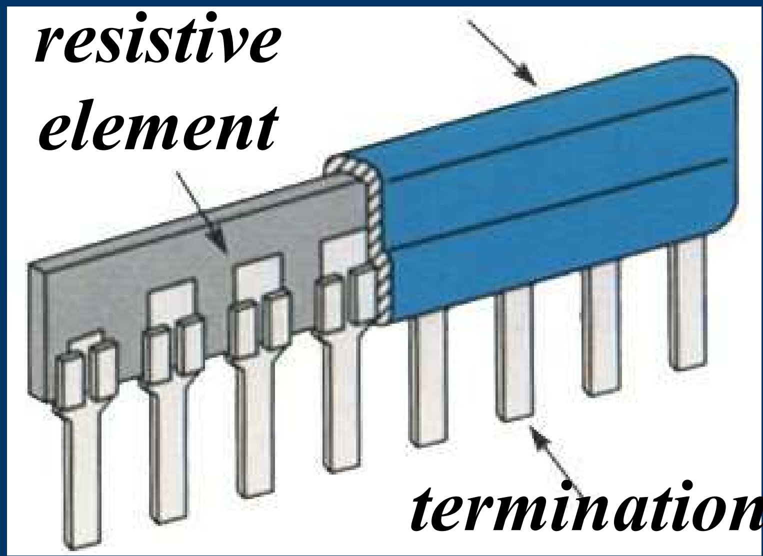
Fixed Resistors

- **Film resistors** (spiraling technique)



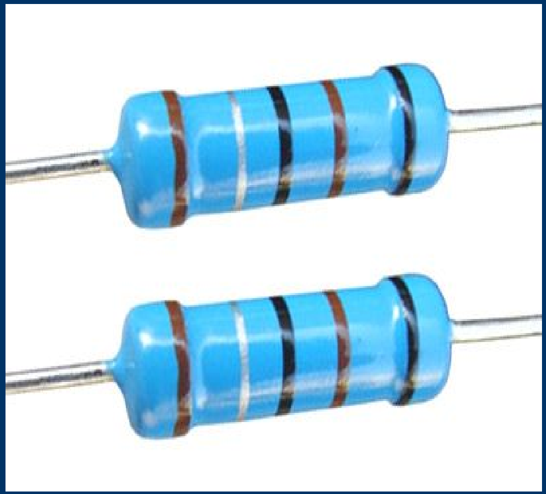
Fixed Resistors

- **Film resistors** (resistor network)



Fixed Resistors

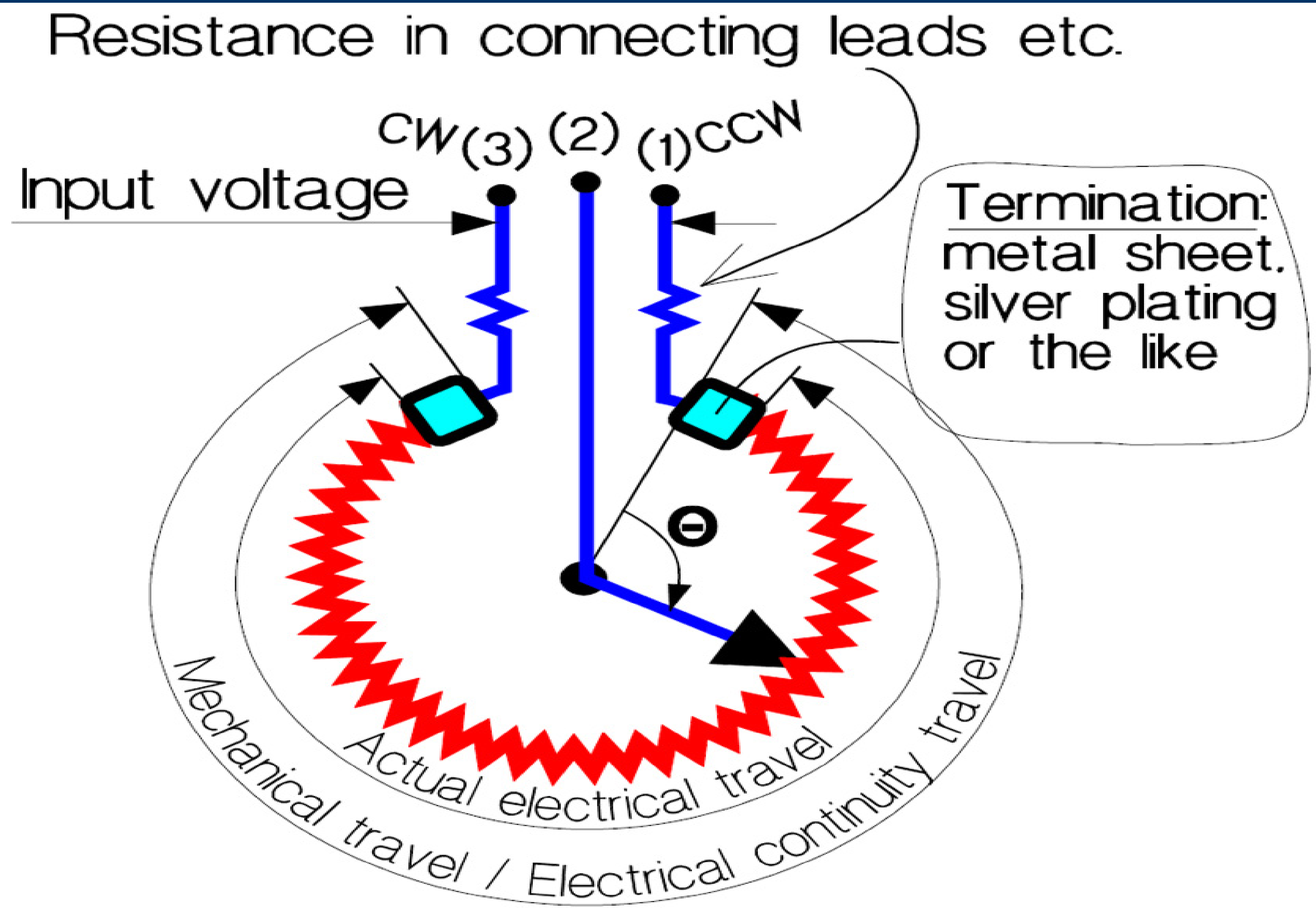
- Film resistors



Variable Resistors

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

Variable Resistors



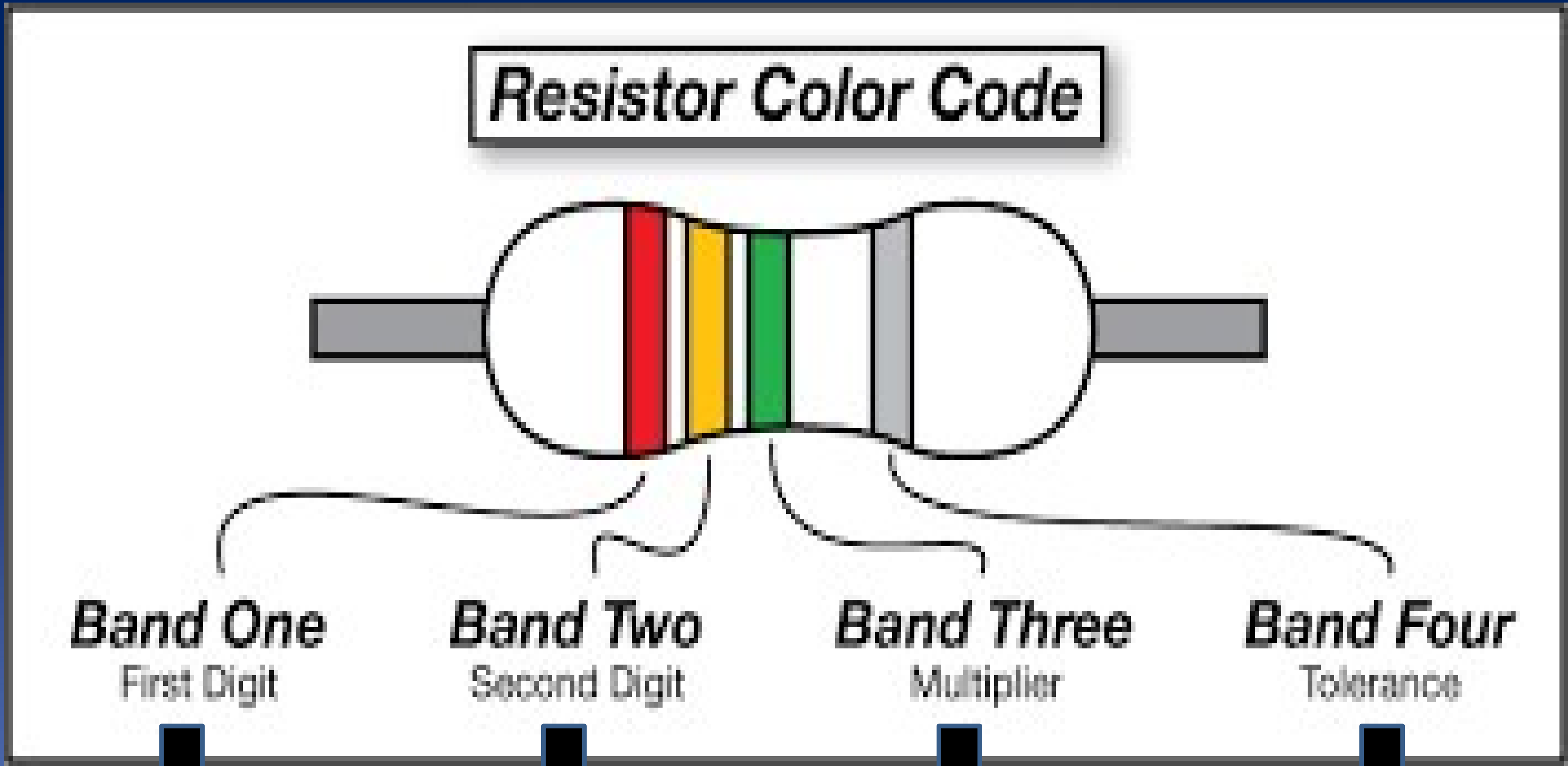
Resistance in connecting leads etc.
CW (3)
(2)
(1) CCW
Input voltage
Termination: metal sheet, silver plating or the like
Θ
Actual electrical travel
Mechanical travel / Electrical continuity travel

Resistor Color Coding

Resistor

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 **<u>left side</u>**.



Copy the digit

Copy the digit

Number of zero/s

Minimum and Maximum Value

ACTUAL VALUE

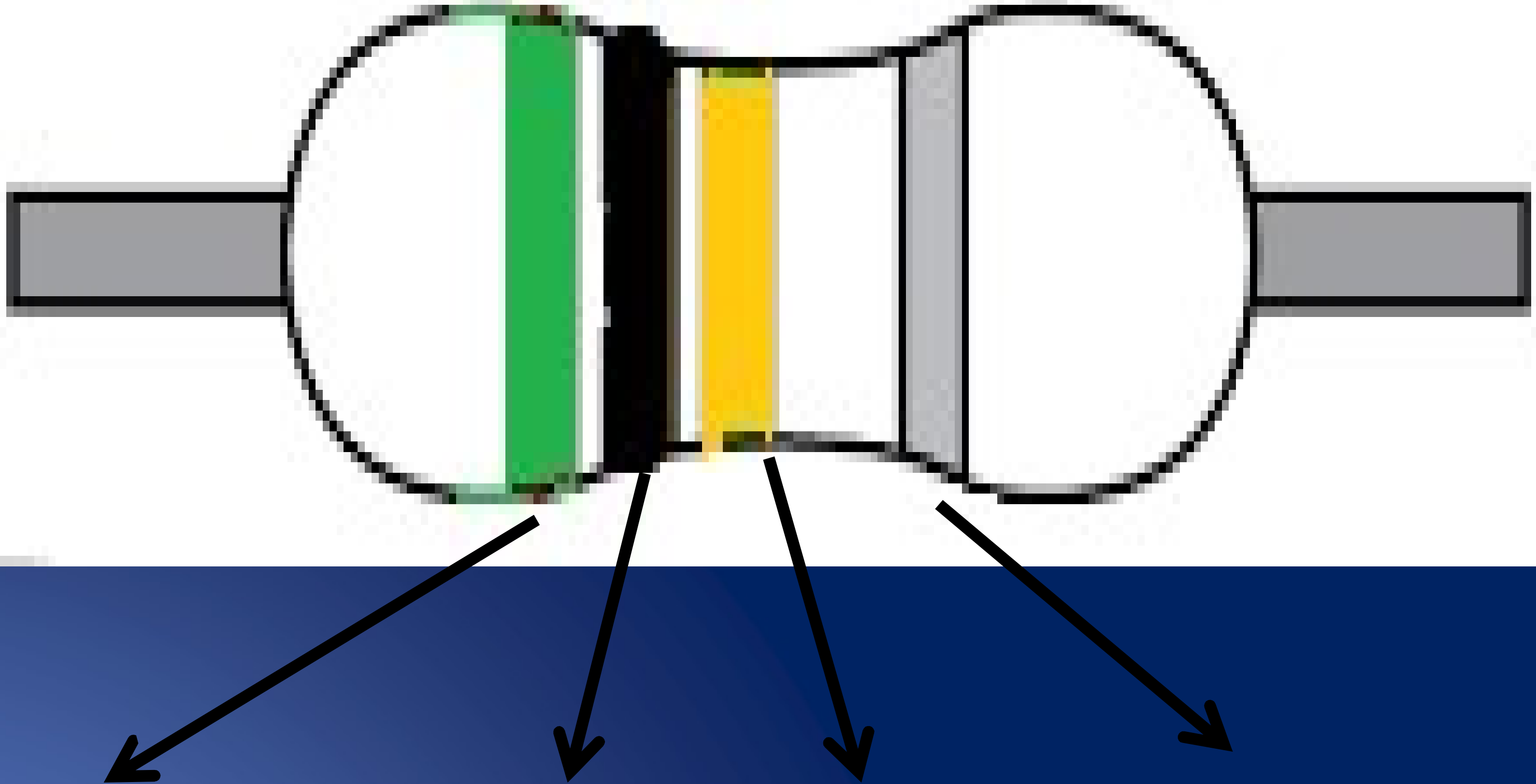
TROUBLESHOOTING

COLOUR	1ST BAND	2ND BAND	3RD BAND	4TH 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%

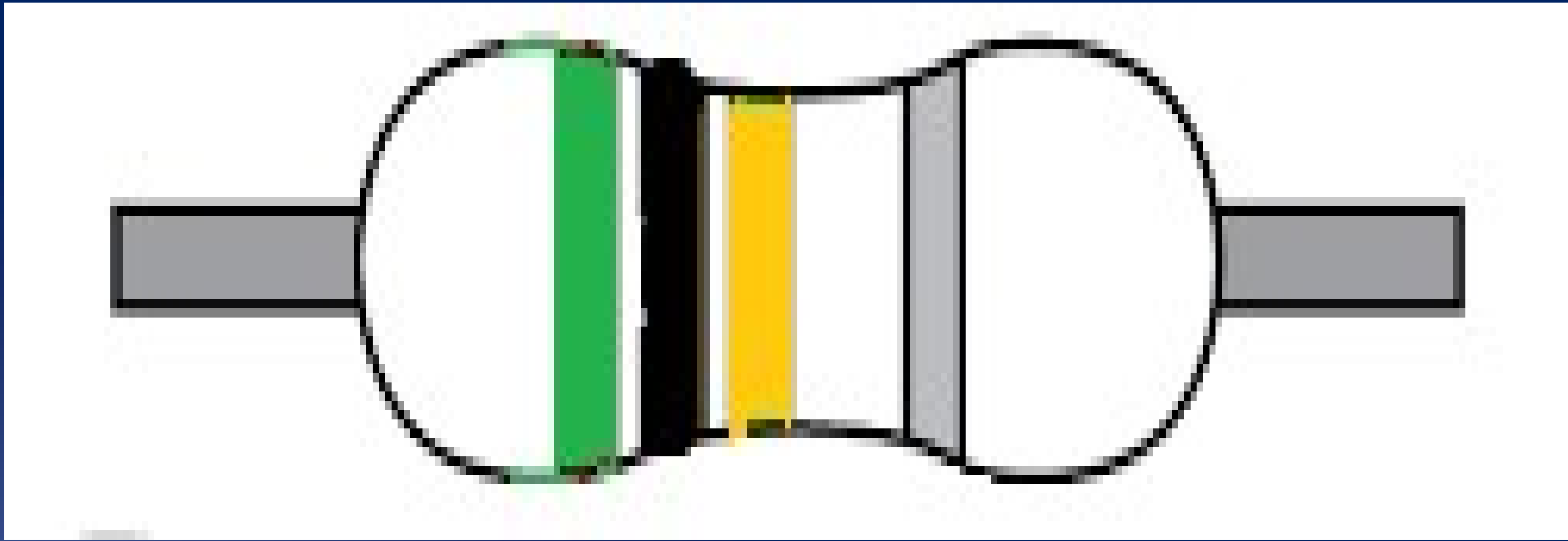
NOTE:

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 ±10%

REVERSE

VALUE → COLOR BANDS

350 OHMS **±5%**

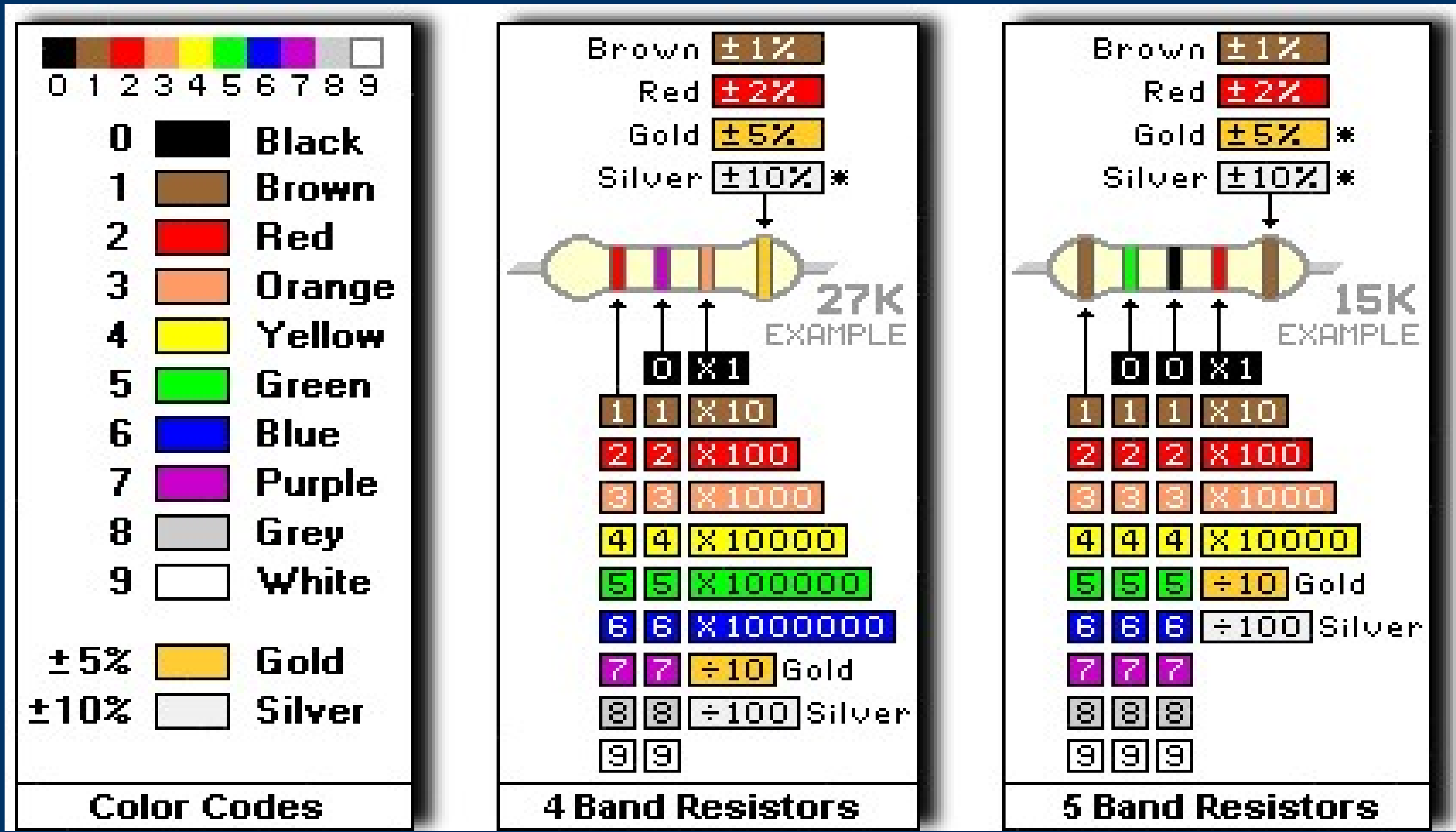
Orange

Green

Brown

Gold

Resistor Colour Code



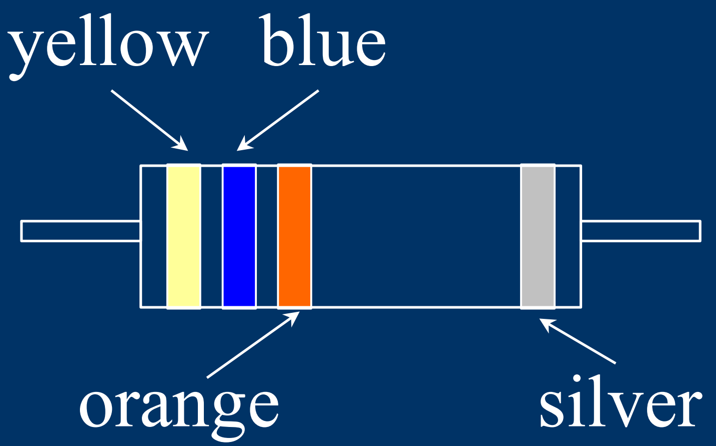
Resistor Colour Code

- **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



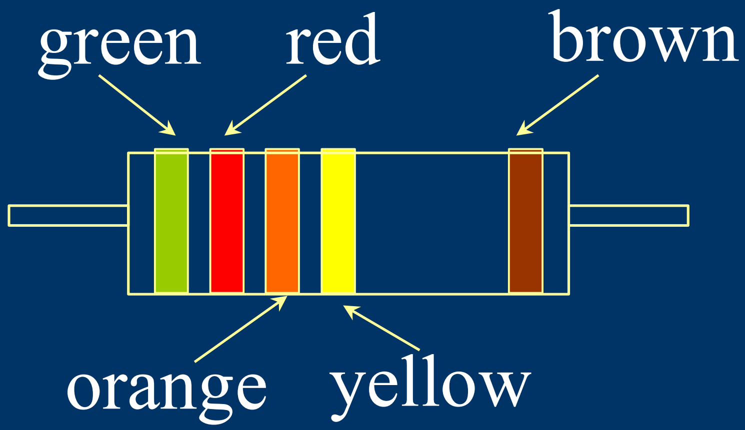
yellow = 4
blue = 6
orange = 10^3
silver = 10%

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

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

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

Example 2



green = 5
red = 2
orange = 3
yellow = 10^4
brown = 1%

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

$tolerance = 1\%\ of\ 5.23\ M\Omega = 0.0523\ M\Omega$

$R = (5.23\ M\Omega - 0.0523\ M\Omega)\ to\ (5.23\ M\Omega + 0.0523\ M\Omega)$

$= \mathbf{5.177\ M\Omega\ \ to\ \ 5.2823\ M\Omega}$

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. 10Ω ± 5%
2. 850,000 Ω ± 10%
3. 70,000,000 Ω ± 5%

Ans.1-BROWN,BLACL,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.

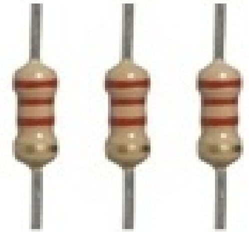
1. 12 ± 5%
2. 47 ± 5%
3. 100 ± 10%
4. 37, 000 ± 5%
5. 22, 000, 000 ± 10%

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

¼ Watt Resistors



½ Watt Rersistors

1 Watt Resistors

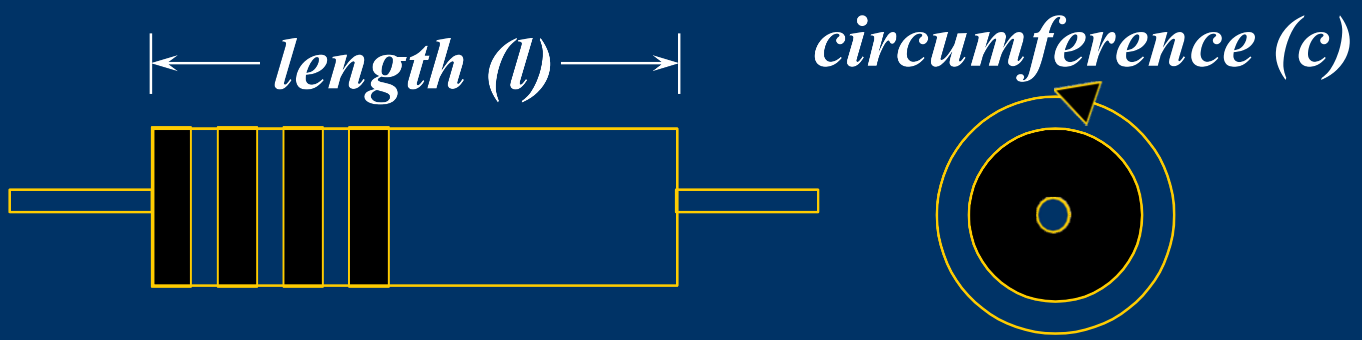
2 Watt Resistors

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 = $(l \times c)$



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).

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

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
➢ 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*e-8 ohm.m behave as conductor. ➢ E.g. Silver, Copper, Aluminium, Carbon and almost all metals.	➢ 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 know as insulators. ➢ All materials with resistivity above 10*e5 ohm.m behave as insulator. ➢ E.g. Mica, Porcelain, Glass, oil, rubber, etc.	➢ 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 10e-8 and 10e5 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

$$\Delta R = R_t - R_0$$

I. directly proportional to its initial resistance, and

II. directly proportional to the change in temperature.

- Thus,

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

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

Continue....

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

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

- 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), $R_t = R_0 * [1 + \alpha_0 * t]$

$$\alpha_0 = \frac{R_t - R_0}{R_0 \times t}$$

= Increase in resistance/ohm original resistance/°C rise in temperature

Hence **temperature co-efficient of resistance** *of a conductor is the increase in resistance per ohm original resistance per °C rise in temperature.*

A little reflection shows that unit of α will be ohm/ohm°C *i.e.*/°C. Thus, copper has a temperature co-efficient of resistance of 0.00426/°C. It means that if a copper wire has a resistance of 1 Ω at 0°C, then it will increase by 0.00426 Ω for 1°C rise in temperature *i.e.* it will become 1.00426 Ω at 1°C. Similarly, if temperature is raised to 10°C, then resistance will become 1 + 10 × 0.00426 = 1.0426 ohms.

Resistance at different temperatures

- If at a standard temperature of '0' degree Celsius a material has a resistance of R0 ohms,

➢ at t1 degree Celsius resistance of R1 ohms and

➢ at t2 degree Celsius resistance of R2 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_{t1} and t_1 degree Celsius and the unknown resistance R_{t2} and t_2 degree Celsius can be found as follows:

R_{t1}= resistance at t_1 degree Celsius

R_{t2}= resistance at t_2 degree Celsius

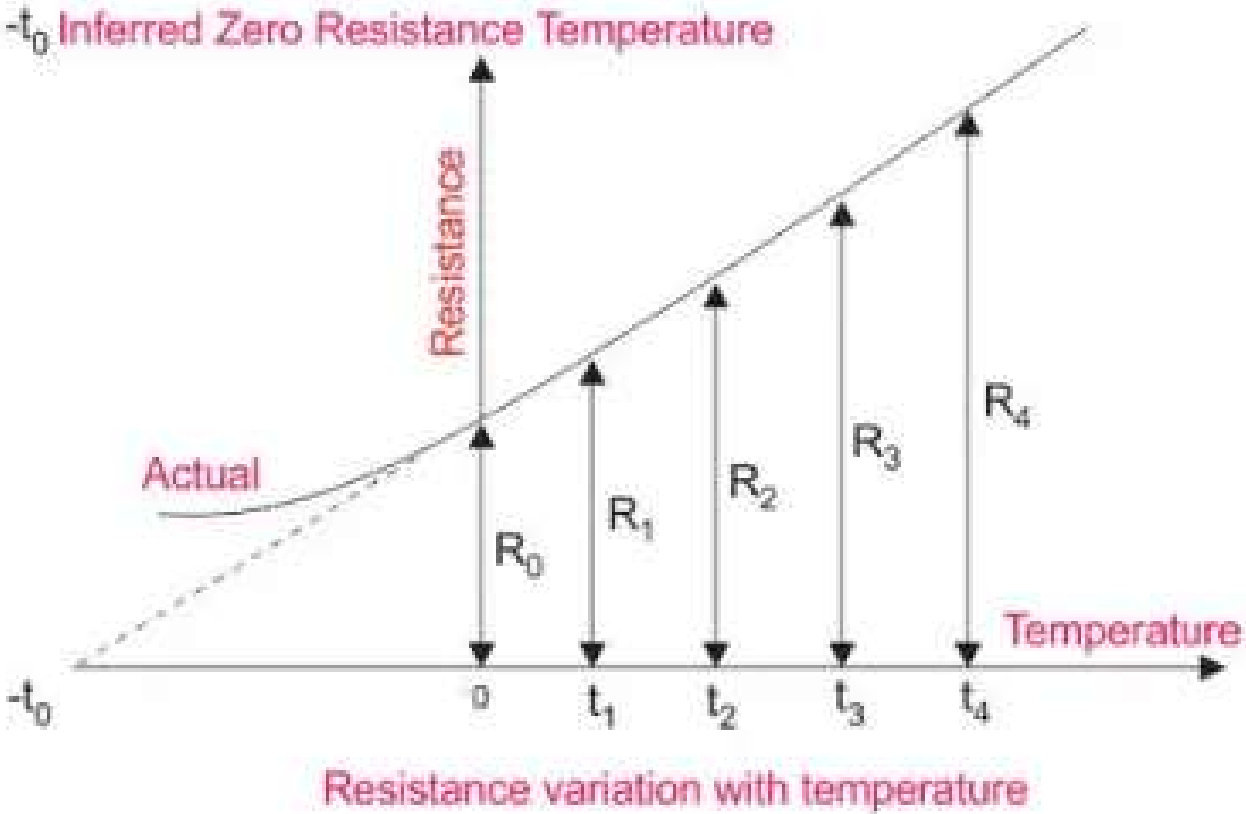
- Suppose,

α_{t1}= temperature co-efficient of resistance at t_1 degree Celsius

$$\alpha_{t1} = \text{Slope of the graph / resistance at } t_1 \text{ degree Celsius}$$

$$\text{Slope of the graph} = \alpha_{t1} * R_{t1}$$

What is Resistance Variation with Temperature?



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Slope of the graph=AB/BC

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

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

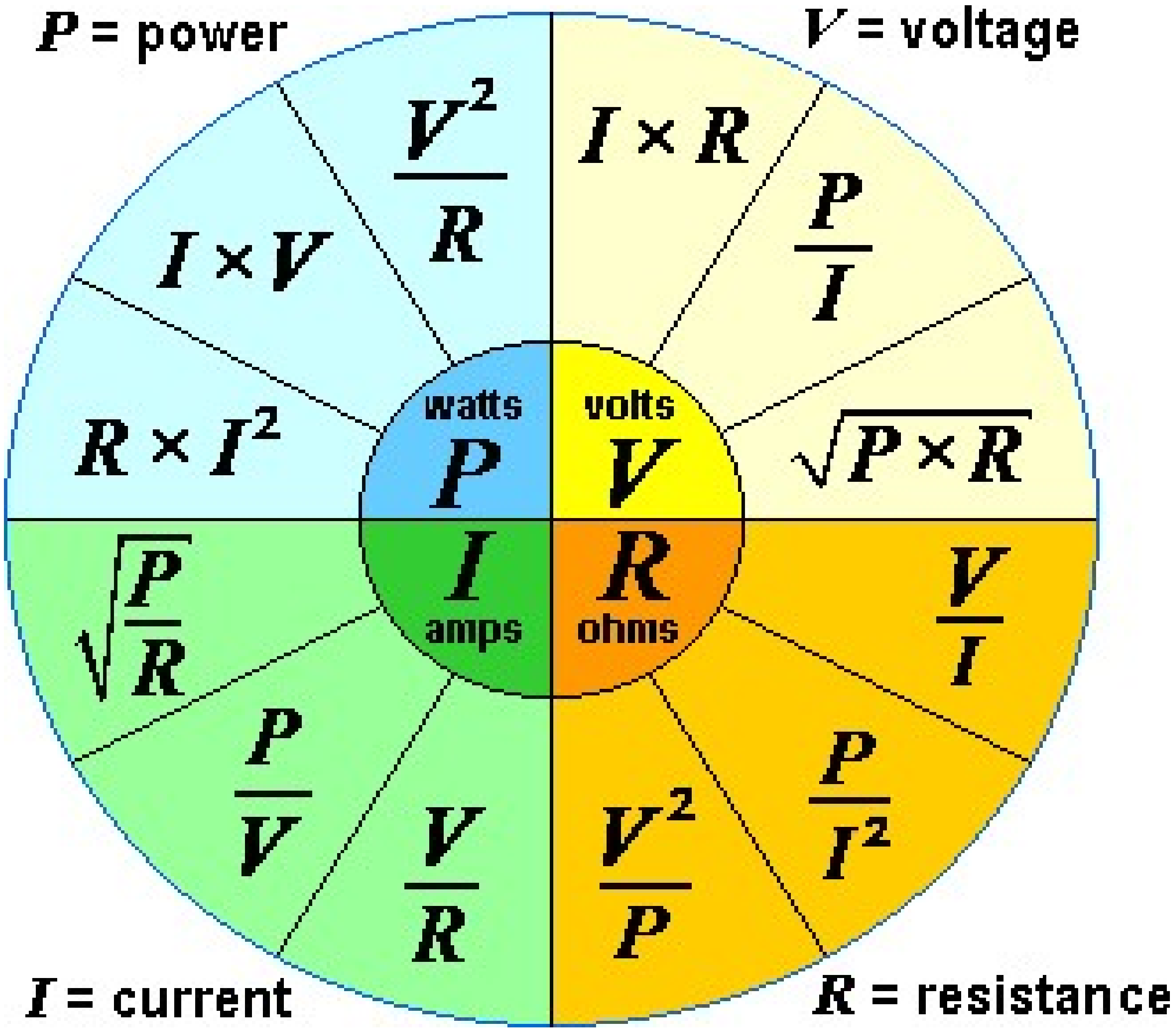
$$R_{t2} - R_{t1} = \alpha_{t1} * R_{t1} * (t_2 - t_1)$$

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

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

Effect of temperature on Resistance

Metals	Alloys	Insulators, Semi-Conductors & Electrolytes
➢ 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	➢ 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	➢ 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



P = power
V = voltage
I = current
R = resistance
watts
P
volts
V
I
amps
R
ohms
$\frac{V^2}{R}$
$I \times V$
$R \times I^2$
$I \times R$
$\frac{P}{I}$
$\sqrt{P \times R}$
$\sqrt{\frac{P}{R}}$
$\frac{P}{V}$
$\frac{V}{R}$
$\frac{V}{I}$
$\frac{P}{I^2}$
$\frac{V^2}{P}$

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

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

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

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

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

By stretching the wire, volume remains unchanged

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

In other words

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

Now $R_1 = 2\ \Omega \qquad l_2 = 3\ l_1$

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

$$= 2\ (3)^2$$

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

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*10e^-8 ohm*m. If the wire is drawn out to three times its original length, find out new resistance.

Solution:

$$l = 100\ m$$

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

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

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

=500 ohm

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

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

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

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

$\therefore$ R α l^2

As length is increased 3 times

$l_2 = 3\, l_1$

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

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

R2=9*500=4500 ohm

3. **A resistance wire of 10 m long and cross section area 10 mm^2 at '0' degree Celsius passes a current of 10 A when connected to a D.C. supply of 200Volts. Calculate:**

I. **Resistivity of the material**

II. **Current which will flow through the wire when the temp. rises to 50 degree Celsius.**

Given α_0 = 0.0003 per degree Celsius.

Solution:-

$l = 10$ m. $\quad a = 10\ mm^2 = 10 \times 10^{-6}\ m^2$

$I_0 = 10$ A. $\quad V = 200$ V, $\quad \alpha_0 = 0.0003$

$\rho = ?$ $\quad I_{50} = ?$

At 0°C. $\quad I_o = \dfrac{V}{R_o}$

10=200/R0

R0=20 OHM

$\therefore \quad R_o = 20\ \Omega$

$R_o = \dfrac{\rho_o l}{a}$ $\qquad \therefore \quad 20 = \dfrac{\rho_o \times 10}{10 \times 10^{-6}}$

$\therefore \quad \boxed{\rho_o = 20 \times 10^{-6}\ \Omega m}$

Now resistance will increase with the increase in temperature

$R_t = R_0 (1 + \alpha_0 t_1)$

$R_{50} = 20 (1 + 0.0003 \times 50)$

$= 20.3\ \Omega$

$I_{50} = \dfrac{V}{R_{50}} = \dfrac{200}{20.3} = 9.85\ A$

$\therefore \quad \boxed{I_{50} = 9.85\ A}$

4. A copper coil has a resistance of 12.2 ohm at 28 degree Celsius and 14.4 ohms at 44 degree Celsius, find:-

I. Temperature co-efficient of resistance at 0 degree Celsius

II. Resistance of coil at 0 degree Celsius

III. Temperature co-efficient of resistance at 60 degree Celsius

IV. Resistance of coil at 75 degree Celsius

Solution:-

$R_1 = 12.2\ \Omega$ $\qquad t_1 = 28°C$

$R_2 = 14.4\ \Omega$ $\qquad t_1 = 44°C$

(i) $$\frac{R_2}{R_1} = \frac{1 + \alpha_0 t_2}{1 + \alpha_0 t_1}$$

$$\frac{14.2}{12.2} = \frac{1+\alpha_0 \times 44}{1+\alpha_0 \times 28}$$

$$1.18 + 33\ \alpha = 1 + 44\ \alpha_0$$

$$11\ \alpha_0 = 0.18$$

$$\alpha_0 = \boxed{0.016\ ^\circ C^{-1}}$$

(ii) $$R_t = R_0\ (1 + \alpha_0\ t_1)$$

$$R_0 = \frac{12.2}{1 + (0.016 \times 28)}$$

$$= \frac{12.2}{1.448}$$

$$R_0 = \boxed{8.425\ \Omega}$$

(iii) $\alpha_t = \dfrac{\alpha_0}{1 + \alpha_0 t}$

$$= \frac{0.016}{1 + (0.016 \times 60)}$$

$$\alpha_t = \boxed{0.0082 \ ^\circ C^{-1}}$$

(iv) $R_t = R_0 (1 + \alpha_0 t)$

$$= 8.425 (1 + 0.016 \times 75)$$

$$R_t = \boxed{18.54 \ \Omega}$$

... ... (1.14.4)

Example 1.14 : The resistance of a coil embeded in a large transformer is 12 Ω at 25 °C. After the transformer has been in operation for several hours, the resistance of the coil is found to be 13.4 Ω. Find the temperature of the transformer core. Take $\alpha_{20} = 0.00393\ ^{\circ}C^{-1}$.

Given : $R_{t_1} = 12\ \Omega \qquad t_1 = 25\ ^{\circ}C$

$R_{t_2} = 13.4\ \Omega \qquad t_2 = ?$

$\alpha_{20} = 0.00393\ ^{\circ}C^{-1}$

Now, we know that

$$\alpha_t = \frac{\alpha_0}{1+\alpha_0 t}$$

Taking $t = 20\ ^{\circ}C$

$$\alpha_{20} = \frac{\alpha_0}{1+\alpha_0 \times 20}$$

$$\therefore \quad 0.00393\ (1 + 20\alpha_0) = \alpha_0$$

$$0.00393 + 0.0786\alpha_0 = \alpha_0$$

$$\therefore \quad 0.9214\ \alpha_0 = 0.00393$$

$$\therefore \quad \alpha_0 = \frac{0.00393}{0.9214} = 0.00426\ ^{\circ}C^{-1}$$

We know that,

$$\frac{R_{t_2}}{R_{t_1}} = \frac{1 + \alpha_0 t_2}{1 + \alpha_0 t_1}$$

$$\therefore \quad \frac{13.4}{12} = \frac{1 + 0.00426 \times t_2}{1 + 0.00426 \times 25}$$

$$\therefore \quad 1 + 0.00426\, t_2 = 1.23559$$

$$\therefore \quad t_2 = 55.3\ ^{o}C$$

5. **A 100 W, 200 V bulb is connected in series with a 100 W, 250 V bulb ,across it 250 V supply is connected . Calculate**

(i) Circuit current

(ii) Voltage across each lamp.

Assume bulb resistance to remain unchanged.

Solution:-

(i) Circuit current

Resistance of bulb 1,

$$R_1 = \frac{V_1^2}{P_1}$$

$$= \frac{(200)^2}{100}$$

$$= 400\ \Omega$$

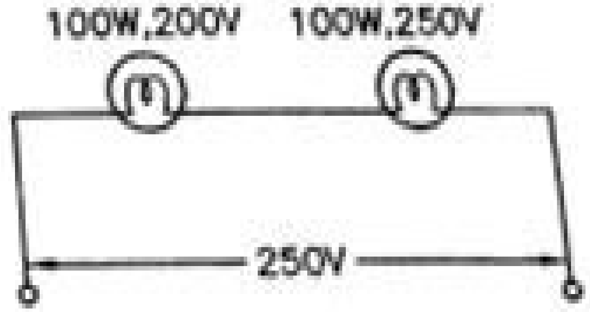


FIG. 1.17

Similarly resistance of bulb 2,

$$R_2 = \frac{V_2^2}{P_2}$$

$$= \frac{(250)^2}{100}$$

$$= 625\ \Omega$$

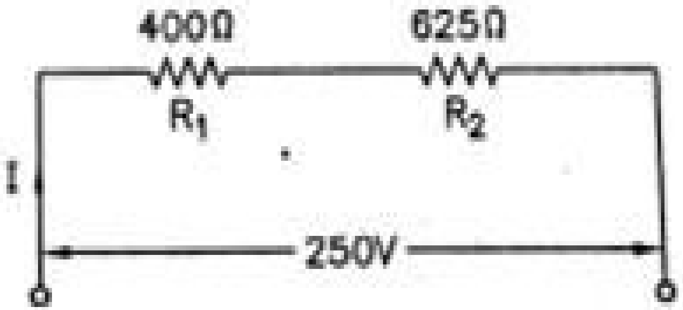


FIG. 1.18

Total resistance = 400 + 625 = 1025 Ω

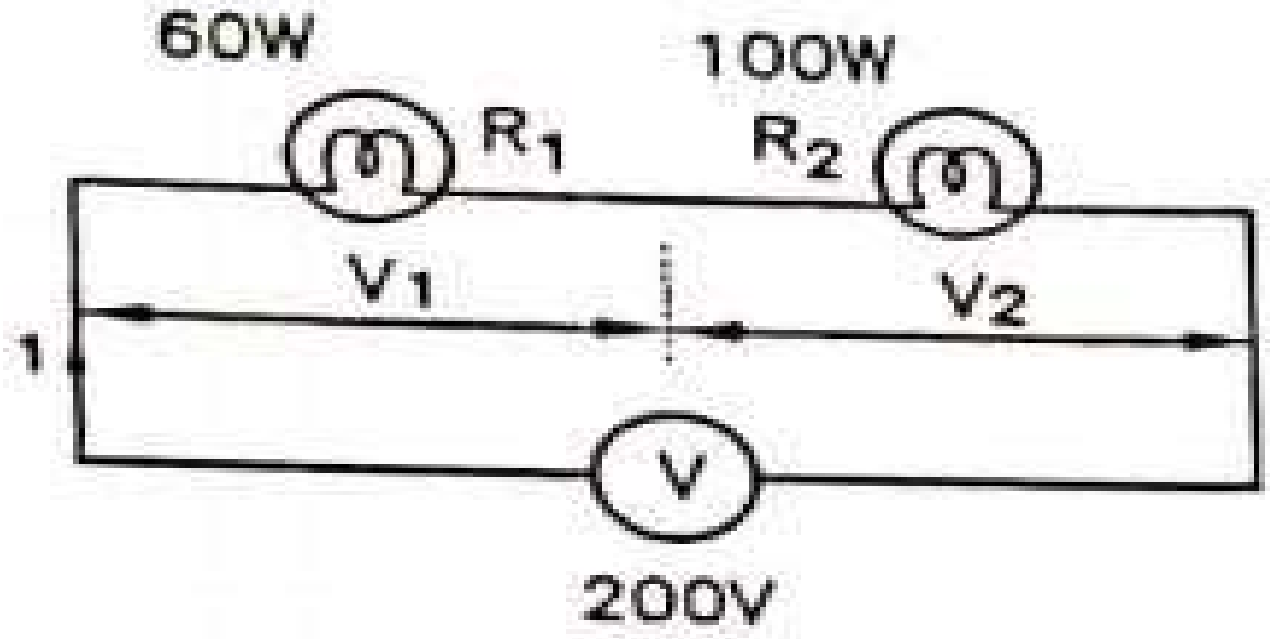
Current $I = \frac{V}{R} = \frac{250}{1025} = \boxed{0.244\ \text{A}}$

(ii) Voltage across each lamp.

- Voltage across 200 V bulb:- IR1= 0.244*400= 97.6 V

- Voltage across 250 V bulb;- IR2=0.244* 625= 152.5 V

6. Two bulbs rated 250 V, 60 W and 100 W respectively are connected in series across 200 V. Find voltage across each bulb.



Resistance of bulb–1

$$R_1 = \frac{V^2}{P}$$

$$= \frac{(250)^2}{60}$$

$$= 1041.66\ \Omega$$

Resistance of bulb–2

$$R_2 = \frac{V^2}{P}$$

$$= \frac{(250)^2}{100}$$

$$= 625\ \Omega$$

The bulbs are in series, so the current is same. Hence the voltage across each bulb is proportional to its resistance

$$\therefore \frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$\therefore \frac{V_1}{V_1 + V_2} = \frac{R_1}{R_1 + R_2}$$

$$\therefore V_1 = \left(\frac{R_1}{R_1 + R_2}\right) V \qquad [\because V = V_1 + V_2]$$

$$= \left(\frac{1041.66}{1041.66 + 625}\right) \times 200$$

$$= 125 \text{ V}$$

$$\therefore V_2 = V - V_1 = 200 - 125$$

$$= 75 \text{ V}$$