Lecture 2

Resistance

Introduction to Electricity

Resistance

All materials have resistance. Conductors have little resistance. Insulators provide a lot of resistance. Some electronic components (resistors) have a specific resistance. These are often needed to reduce current in order to protect other components or to adjust the amount of current that goes to other components.

Unit of Resistance Ohms

Symbol of Resistance (R)

Introduction to Electricity

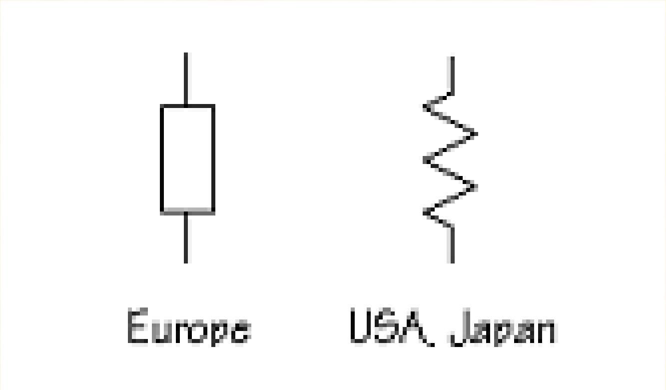
Material resistance

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

ρ = resistivity of material

L = length

A = cross-sectional area



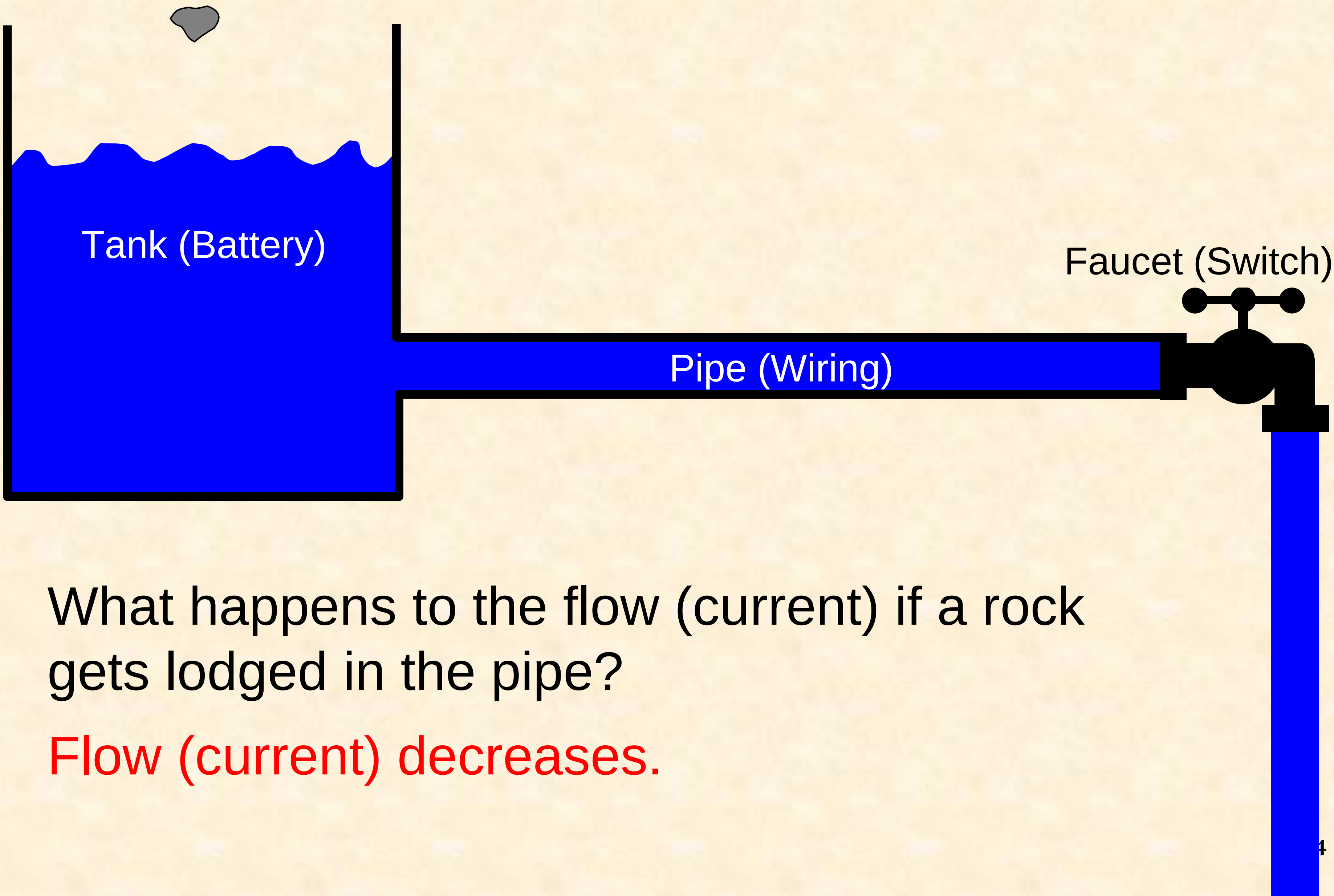
Symbol of Resistance

Measured in Ohms (Ω)

Resistance properties

1- Opposes flow of current.
2- Depends upon type of material, area & length.
3- Produces heat when current flows through it.
4- Fixed and variable resistor (potentiometer).

Resistance



What happens to the flow (current) if a rock gets lodged in the pipe?

Flow (current) decreases.

Introduction to Electricity

Resistor Applications

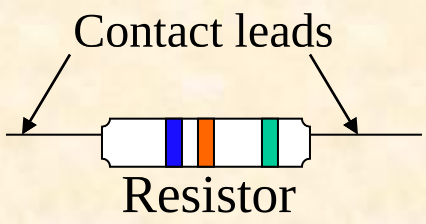
1- Limiting current in electric circuits.

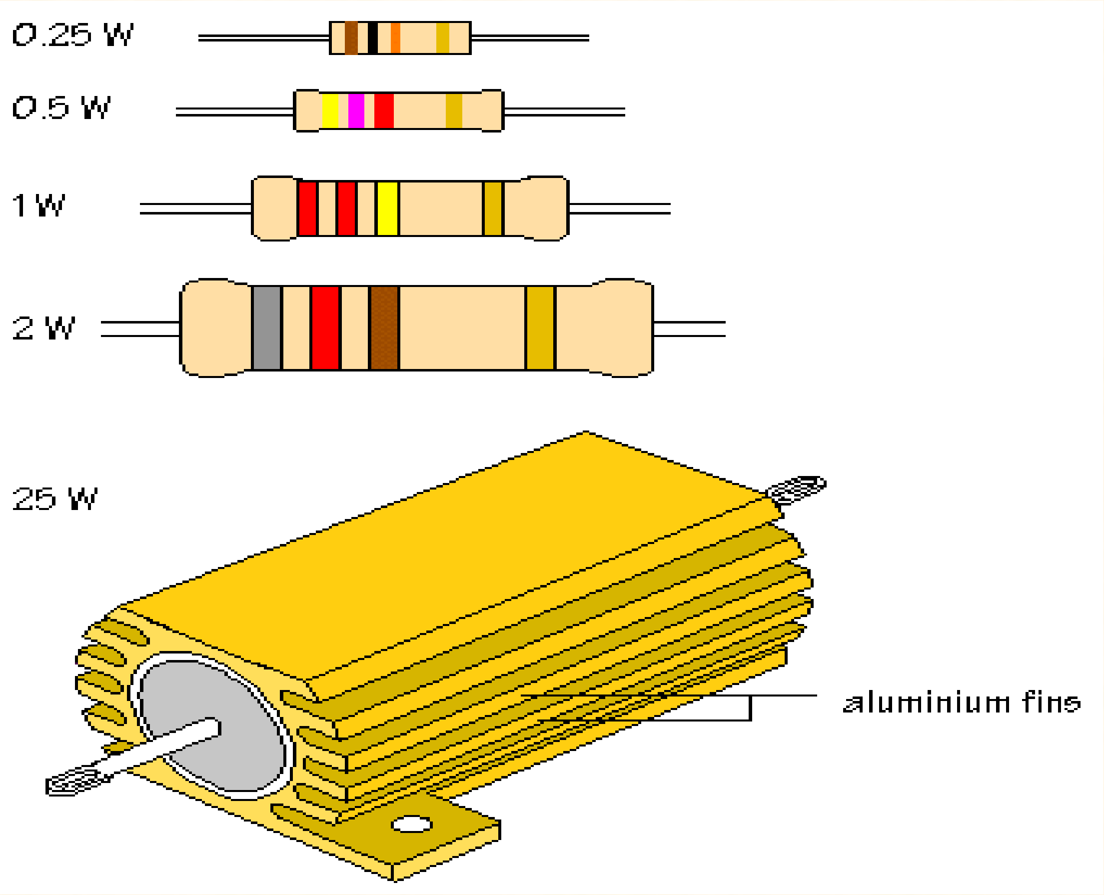
2- Lowering voltage levels in electric circuits (using voltage divider).

3- As a sensor (e.g., photoresistor detects light condition, thermistor detects temperature condition, strain gauge detects load condition, etc.).

4- In electronic circuits, resistors are used as pull-up and pull-down elements to avoid floating signal levels.

Resistor Examples





The resistance wire depends on:

1- A metals structural resistance to electron flow (Resistivity)

Resistivities at 20°C	
Material	**Resistivity** ($\Omega \cdot m$)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	$150. \times 10^{-8}$
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

Which metals have low resistance?

Silver and Copper

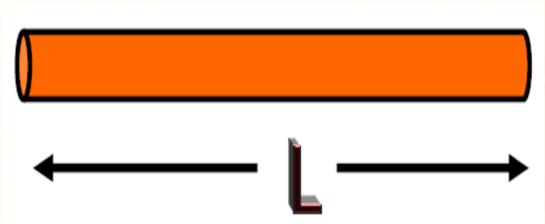
Which metals have high resistance?

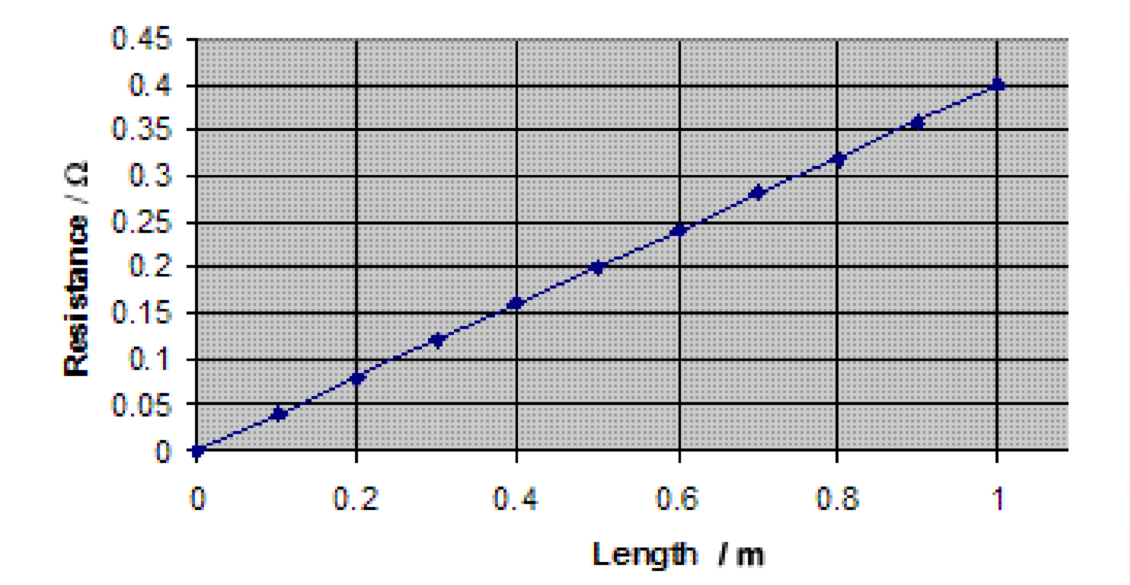
Nichrome and Tungsten

The resistance wire depends on:

2- Length of the wire

The shorter the wire the less resistance there is

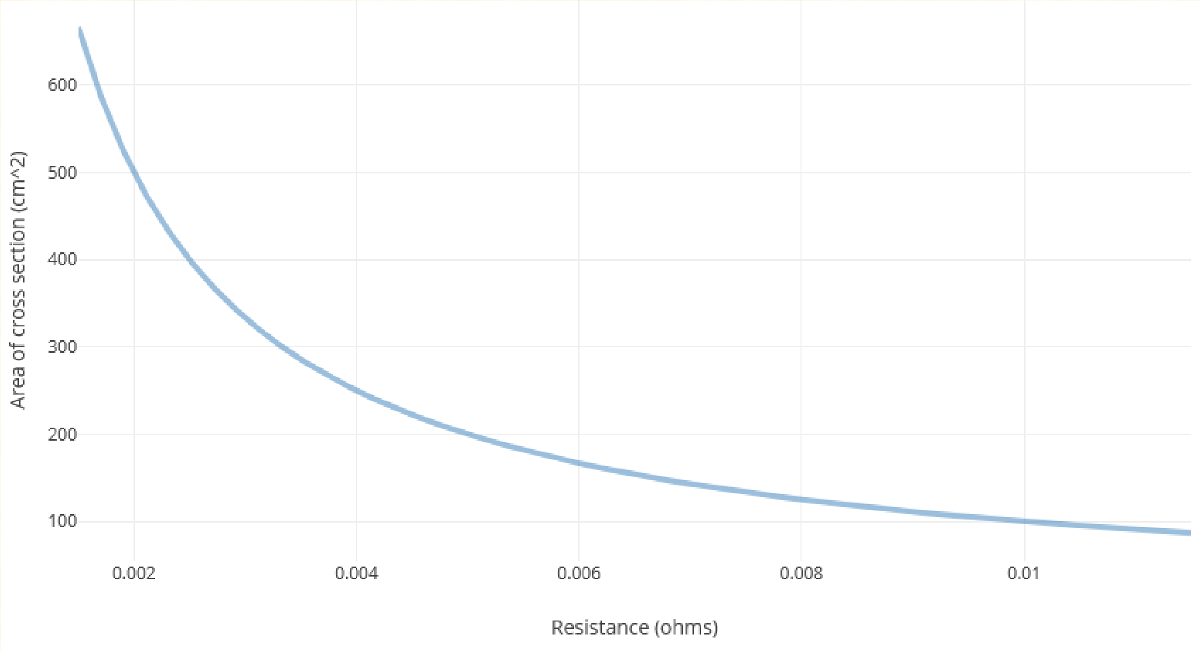




The resistance wire depends on:

3- Thickness (Cross Sectional Area) of the wire

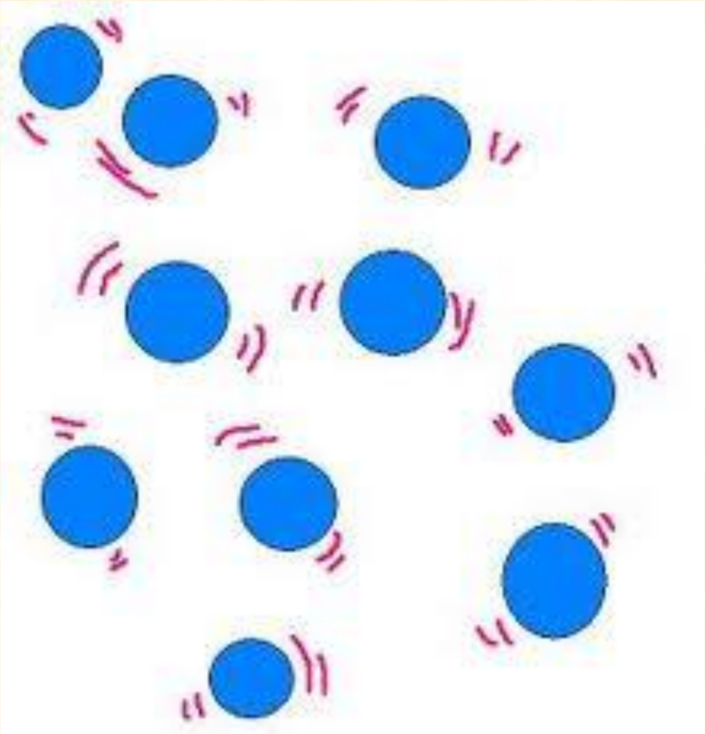
The wider the wire the less resistance

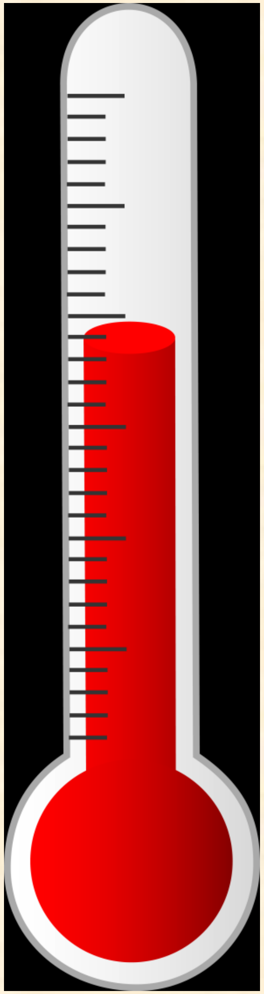


The resistance wire depends on:

4- Temperature:

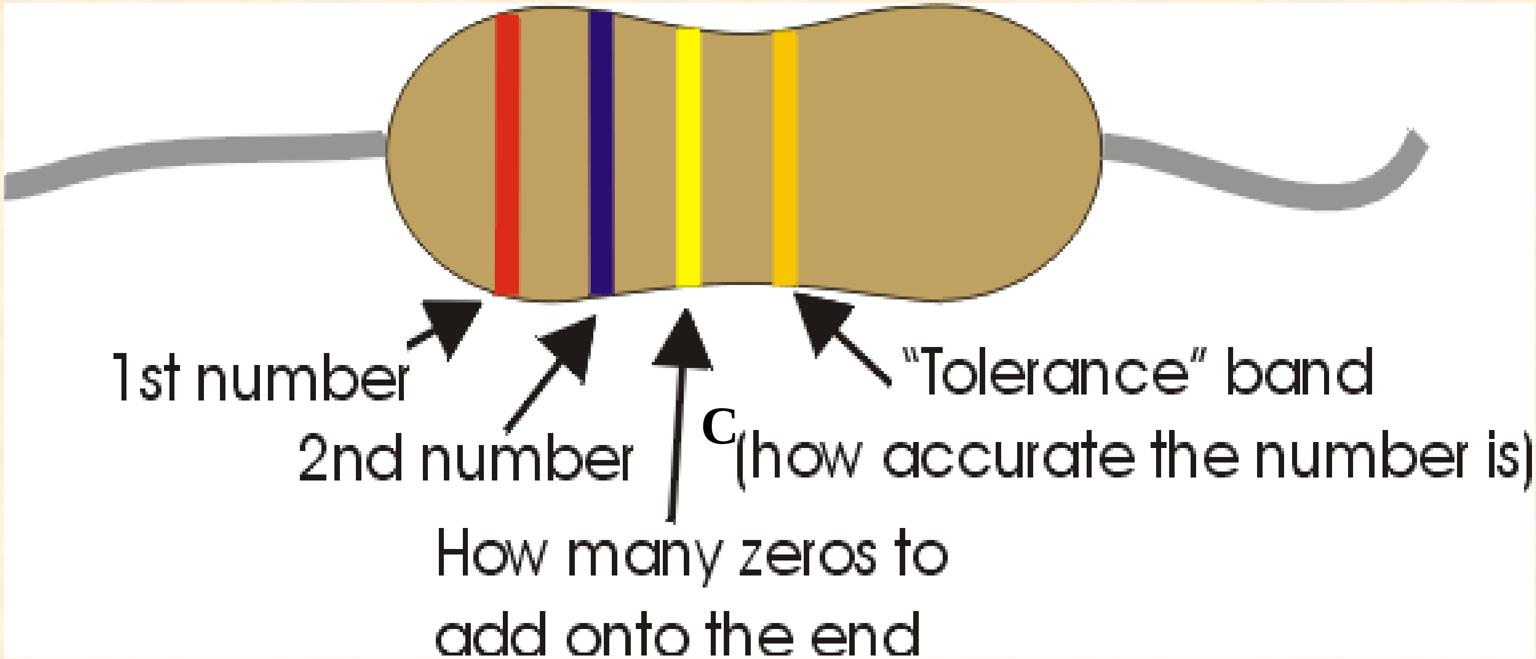
The colder wire it is the less resistance



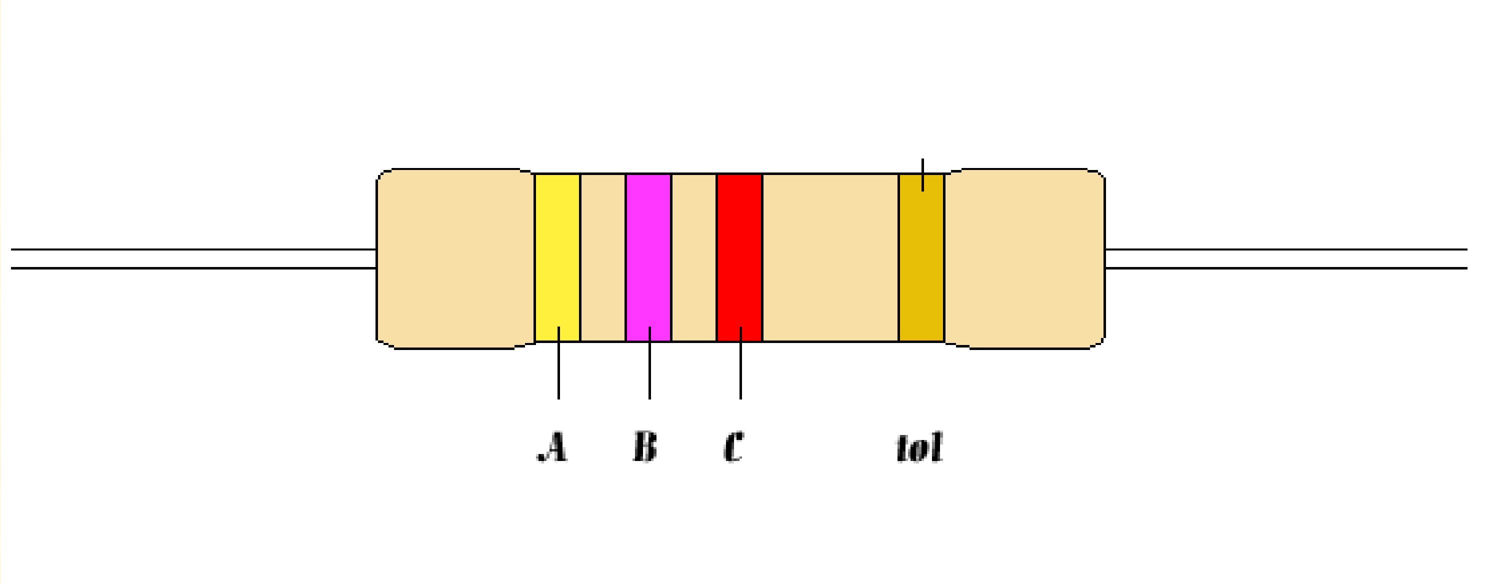


Resistor Labels

- A majority of resistors have color bars to indicate their resistance magnitude.
- There are usually 4 to 6 bands of color on a resistor. As shown in the figure below, the right most color bar indicates the resistor reliability, however, some resistor use this bar to indicate the tolerance. The color bar immediately left to the tolerance bar (C), indicates the multipliers (in tens). To the left of the multiplier bar are the digits, starting from the last digit to the first digit.



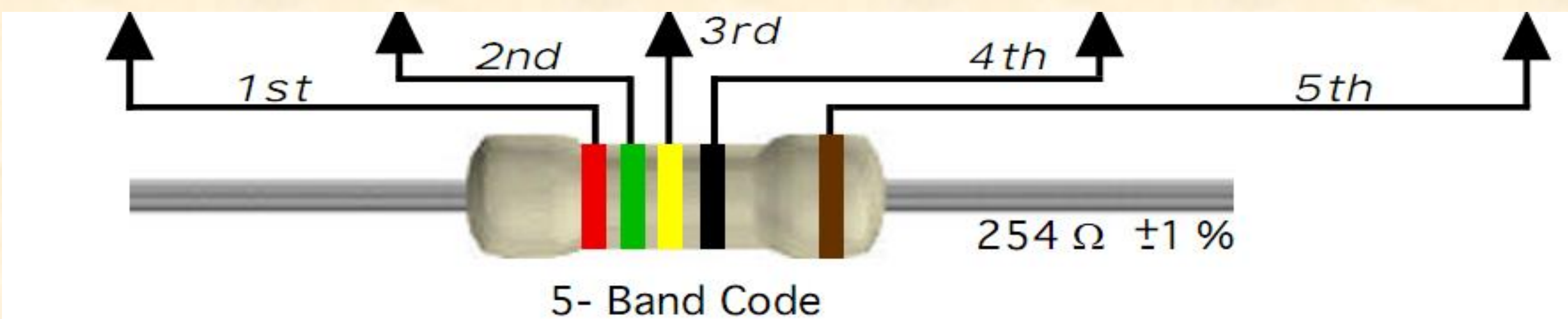
Resistor Labels



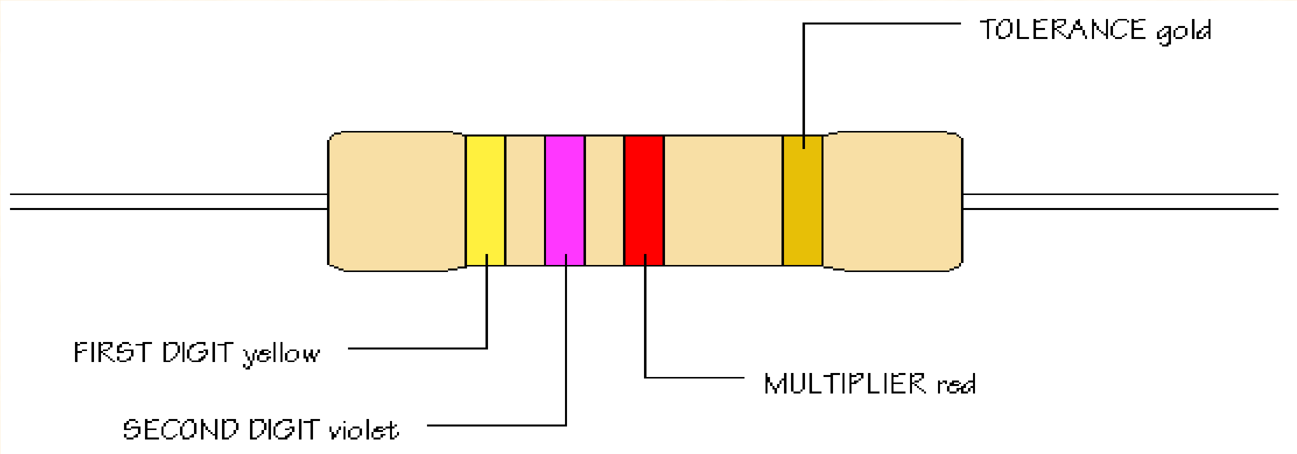
Resistor value = $AB \times 10^{C} \pm tol\%(\Omega)$

Resistor Color Codes

Color	1st Band	2nd Band	3rd Band	Decimal Multiplier		Tolerance
Black	0	0	0	1	1	
Brown	1	1	1	10	10	± 1 %
Red	2	2	2	100	100	± 2 %
Orange	3	3	3	1K	1,000	
Yellow	4	4	4	10K	10,000	
Green	5	5	5	100K	100,000	
Blue	6	6	6	1M	1,000,000	
Violet	7	7	7	10M	10,000,000	
Gray	8	8	8		100,000,000	
White	9	9	9		1,000,000,000	
Gold					0.1	± 5 %
Silver					0.01	± 10 %
None						± 20 %



Example

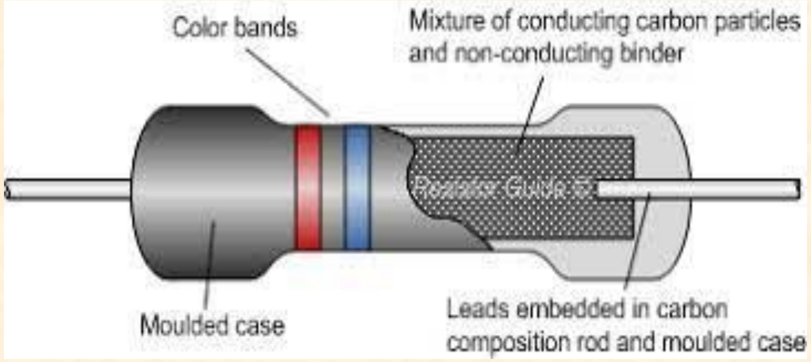


Resistor value = $AB \times 10^{C} \pm tol\%(\Omega)$

- The first band is yellow, so the first digit is 4
- The second band is violet, so the second digit is 7
- The third band is red, so the multiplier is 10^{2}
- Resistor value is $47 \times 10^{2} \pm 5\%(\Omega)$

Type of fixed resistors

Carbon Composition Resistors



made of carbon clay composition covered with a plastic case. The lead of the resistor is made of tinned copper

Available in as low as 1 Ω value and as high as 22 MΩ value.

Advantages

easily available in local market in very low cost and they are very durable too.

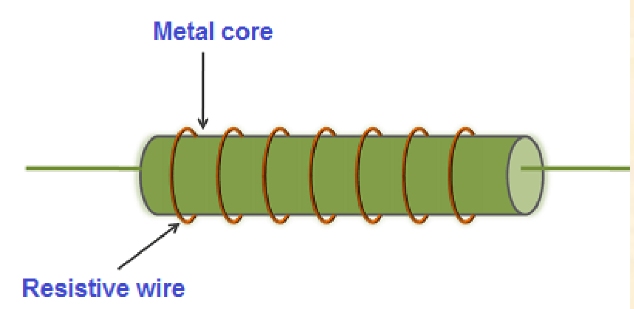
Disadvantages

1- very much temperature sensitive.
2- Tendency of electric noise due to passage of electrical current from one carbon particle to other

Type of fixed resistors

Wire-wound resistors

The wire wound resistor is made by winding the metal wire around a metal core.



A Nichrome or manganin is commonly used as the metal wires, core materials include plastic, fiberglass, or ceramic.

values varies from 1 Ω to 1 MΩ.

Advantages

1- Different sizes and ratings can easily be achieved by using different lengths and diameters of the wire.
2- They can be used for high power applications of 5 to 200 W dissipation ratings.

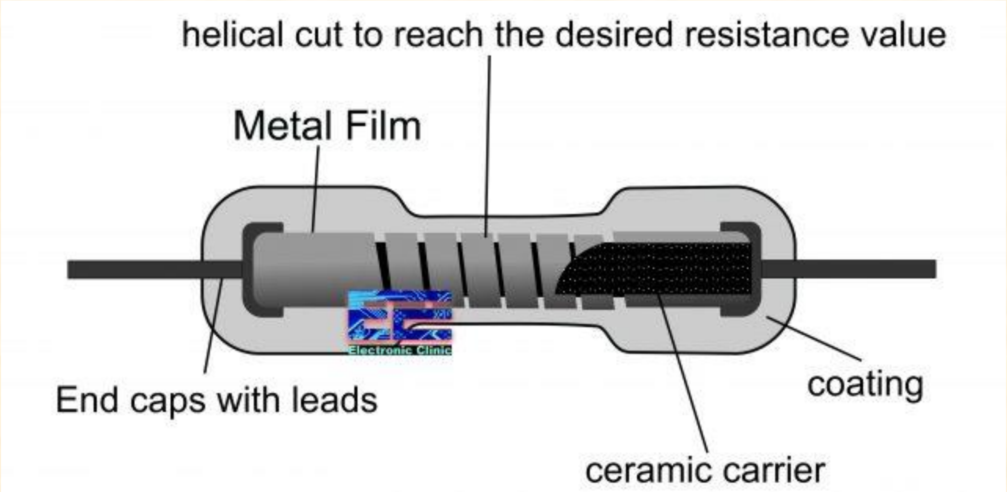
Disadvantages

The cost is much higher than carbon resistor.

Type of fixed resistors

Thin Film Resistors

constructed by means of film deposition technique; deposition a thin film of resistible material such as pure carbon or metal on to an insulating core.



Types of thin film resistors.

Metal Film Resistor.

Carbon Film Resistor

Advantages

can be made up to a value of 10,000 MΩ

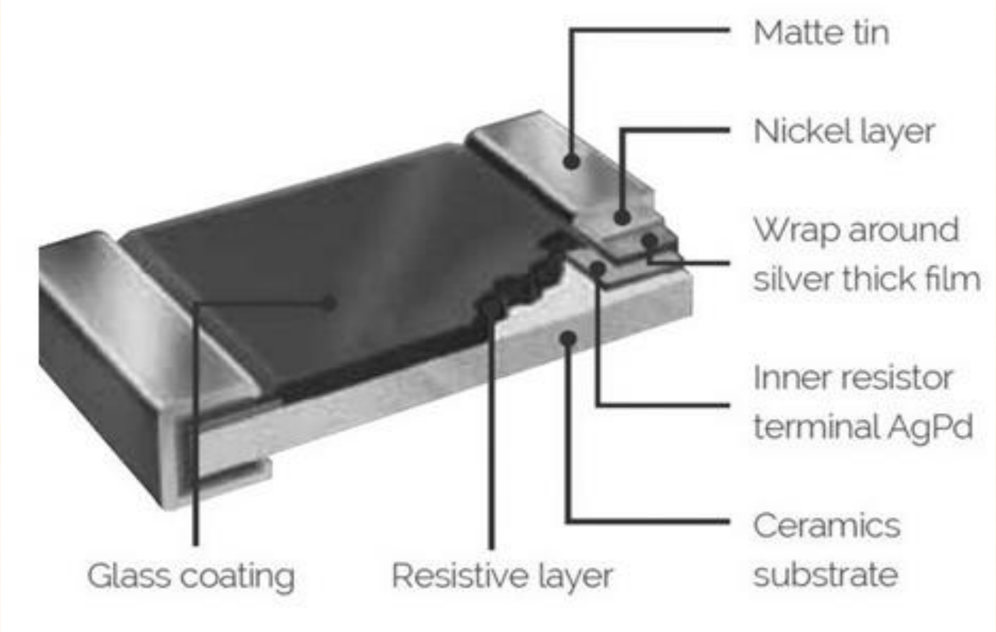
size of this type of resistor is much smaller than wire wound resistor.

lower resistor temperature coefficients, have lower noise.

Type of fixed resistors

Thick Film Resistors

same like thin film resistors, but the difference is that there is a thick film instead of a thin film or layer of resistive material around.



Types of thin film resistors.

Metal Oxide Resistors

Cermet Oxide Resistors

Fusible Resistors

Ohm’s Law

What is Ohm’ s Law?

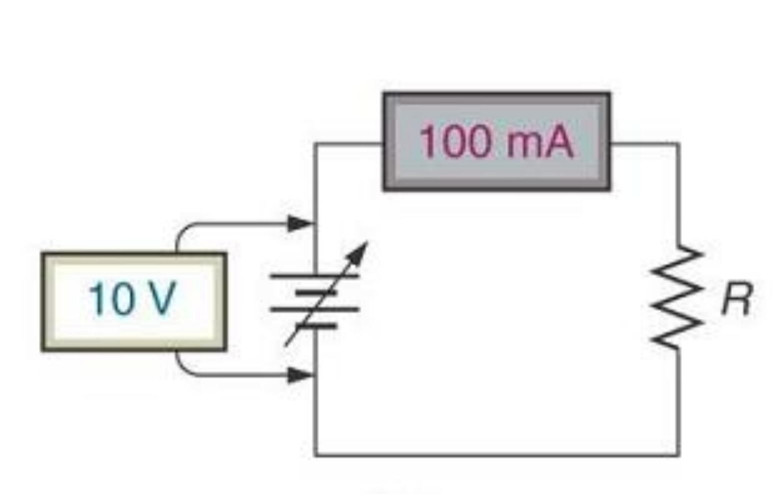
Ohm's Law states that, at constant temperature, the electric **current** flowing in a conducting material is directly proportional to the applied **voltage**, and inversely proportional to the **Resistance**.

Why is Ohms Law important?

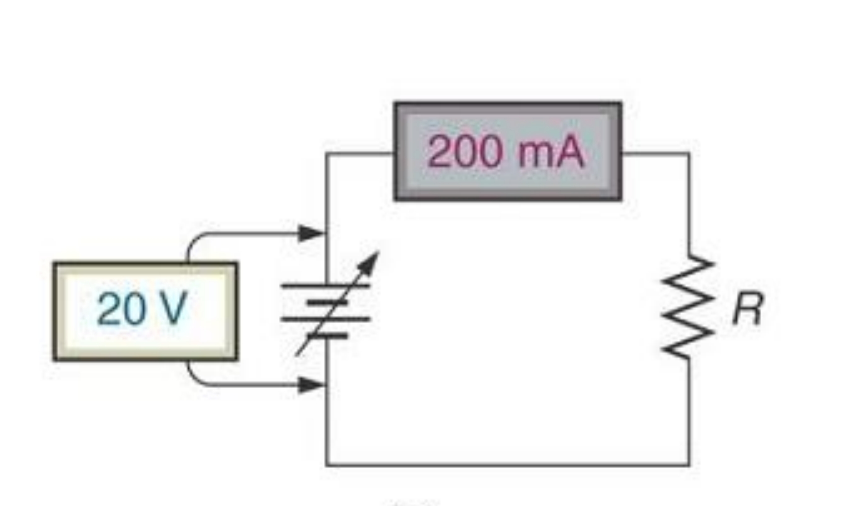
Ohm’s Law is the relationship between power, voltage, current and resistance. These are the very basic electrical units we work with. The principles apply to alternating current (ac), direct current (dc), or radio frequency (rf) .

Ohm's Law

The relationship between current and voltage



(a)

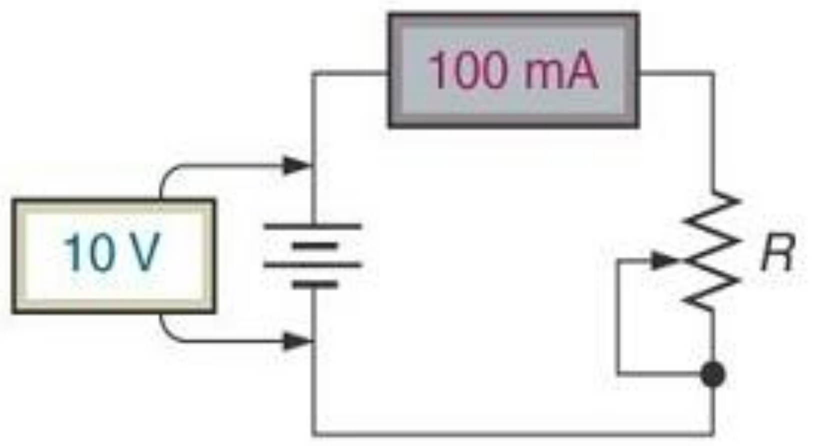


(b)

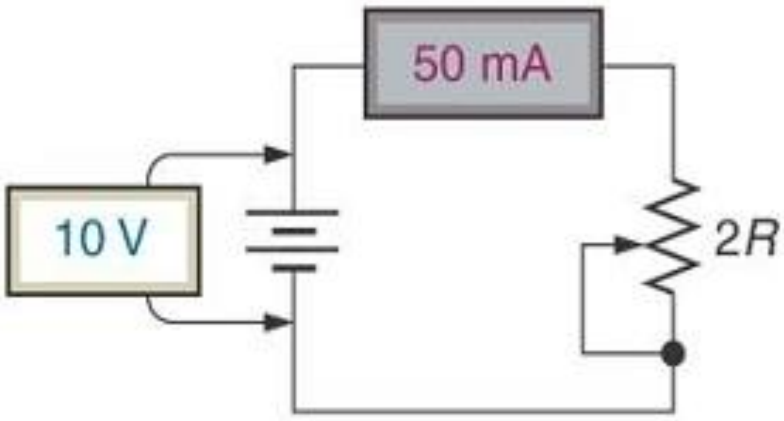
As voltage increases, current also increases

Ohm's Law

The relationship between current and resistance



(a)



(b)

As resistance increases, current decreases

Ohm's Law

If you know 2 of the 3 quantities,
you can solve for the third.

Quantities	Abbreviations	Units	Label
Voltage	V or E	Volts	V
Current	I	Amperes	A
Resistance	R	Ohms	Ω

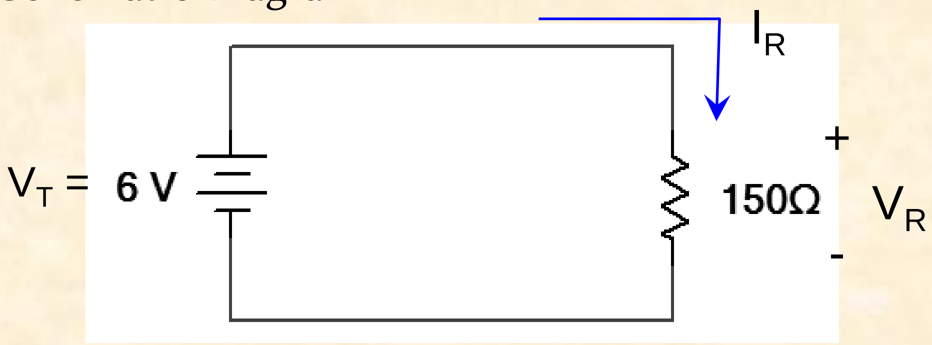
$V=IR$ $I=V/R$ $R=V/I$

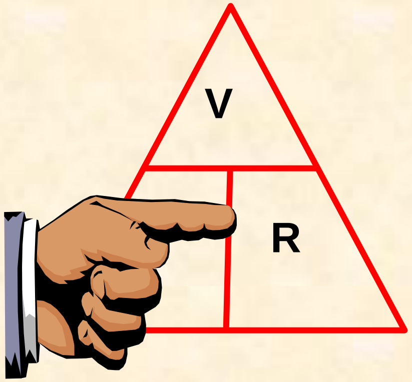
Ohm's Law

Example:

The flashlight shown uses a 6 volt battery and has a bulb with a resistance of 150 Ω. When the flashlight is on, how much current will be drawn from the battery?

Schematic Diagram



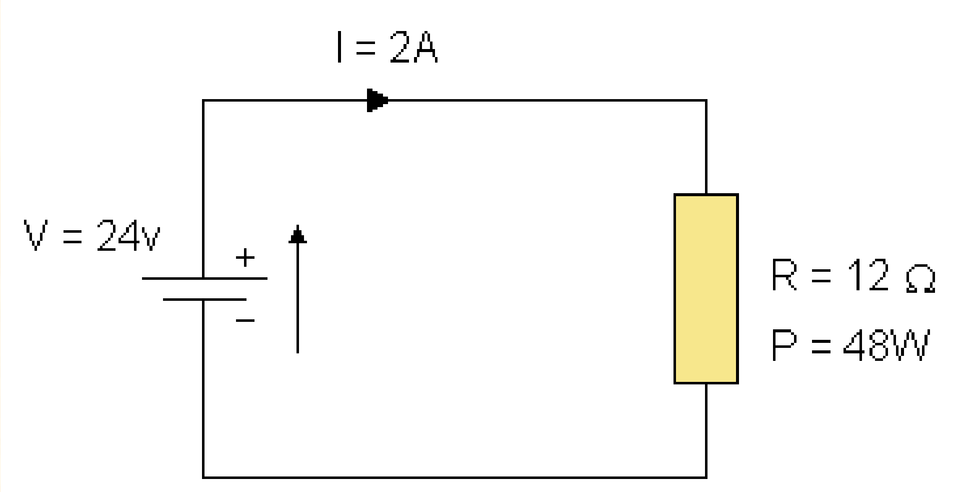


$$I_R = \frac{V_R}{R} = \frac{6\ \mathrm{V}}{150\ \Omega} = 0.04\ \mathrm{A} = 40\ \mathrm{mA}$$

Power rating of resistor

The power rating of a resistor is the amount of electrical power absorbed by resistance as it is the product of voltage and current with some resistances converting this power into heat

The power rating of a resistor is the specification given with a resistor that serves to tell the maximum amount of power that the resistor can withstand.



$P = I * \mathrm{V}$ $\qquad$ $P = I^2 * \mathrm{R}$

$I = 2\ A$ $\qquad$ $R = 12\ ohm$

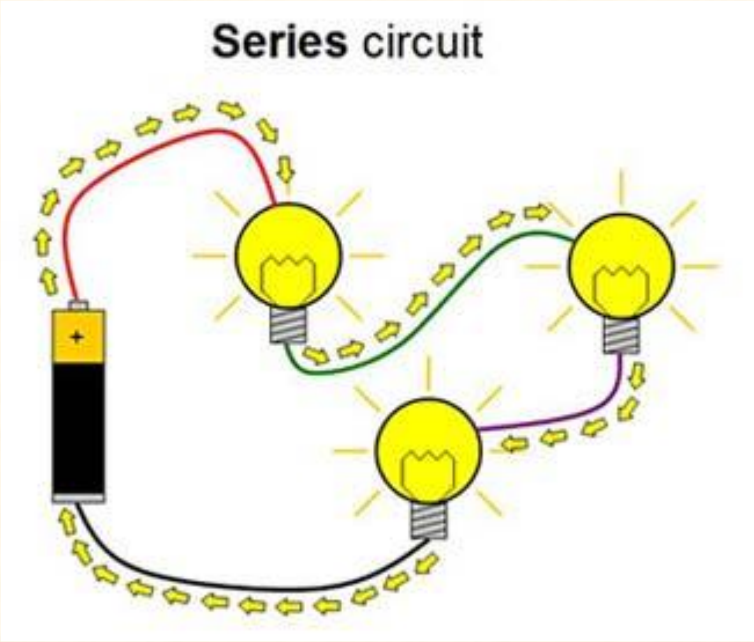
$$P = 2^2 * 12$$

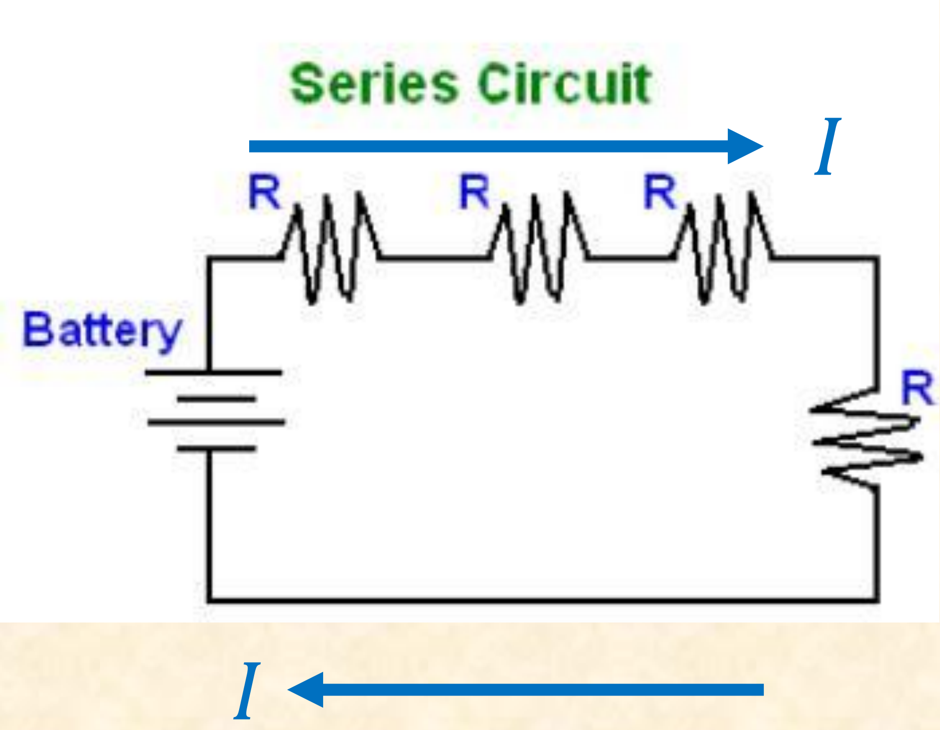
$$P = 48\ W$$

Resistors in Series and in Parallel

Resistors in Series

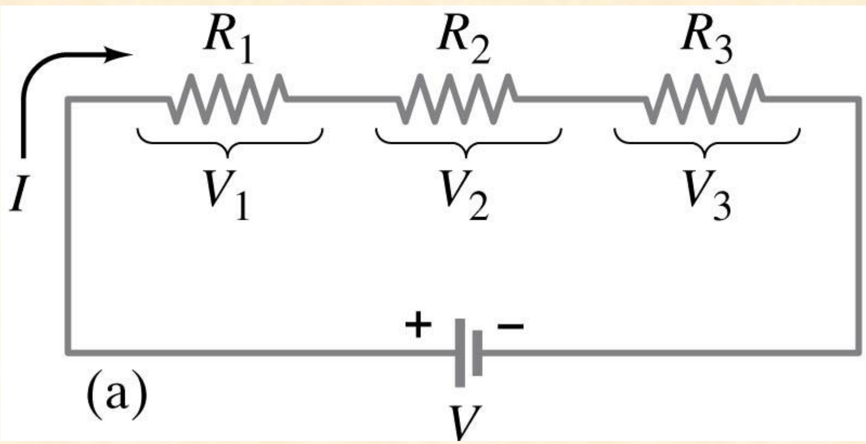
When components are connected in series, the same electric current flows through them

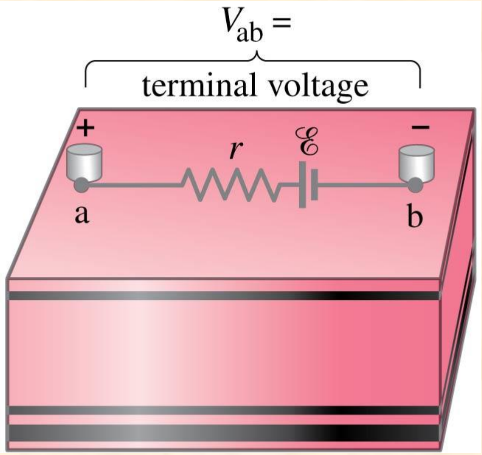




Resistors in Series and in Parallel

A series connection has a single path from the battery, through each circuit element in turn, then back to the battery.





$$V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$

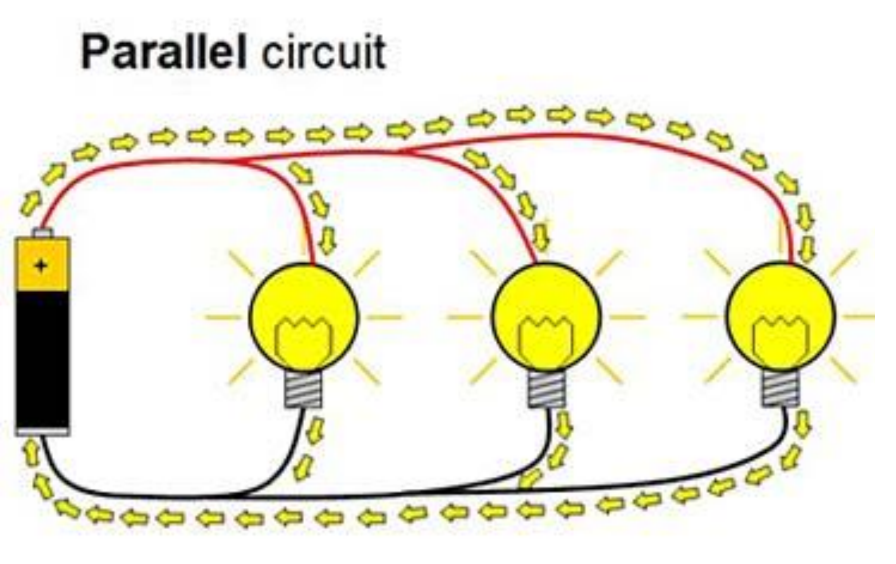
$$\boxed{R_{eq} = R_1 + R_2 + R_3.}$$

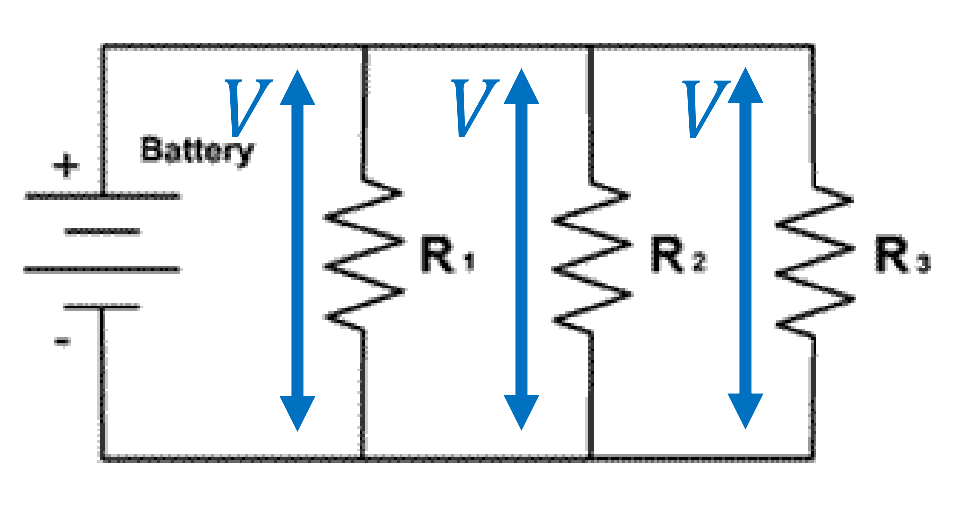
$$\mathbf{R_{eq} = R_1 + R_2 + \ldots + R_N}$$

Resistors in Series and in Parallel

Resistors in parallel

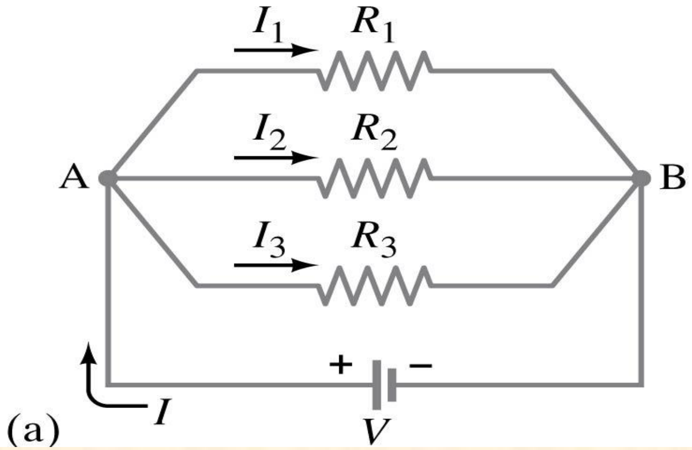
A parallel connection splits the current; the voltage across each resistor is the same:

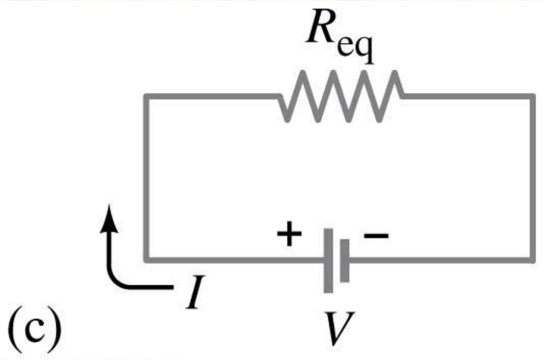




Resistors in Series and in Parallel

Resistors in parallel





$$I = \frac{V}{R_{eq}}$$

$$I = I_1 + I_2 + I_3,$$

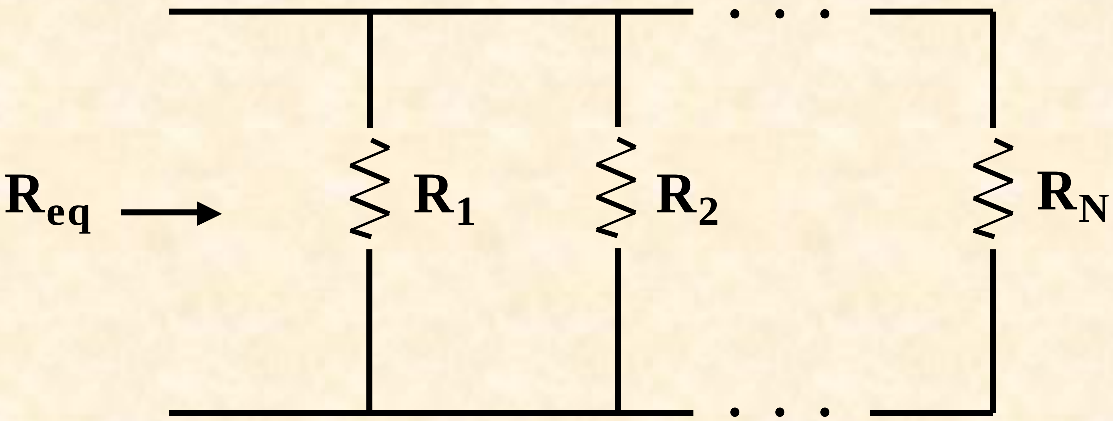
$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

This gives the equivalent resistance:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

Resistors in Series and in Parallel

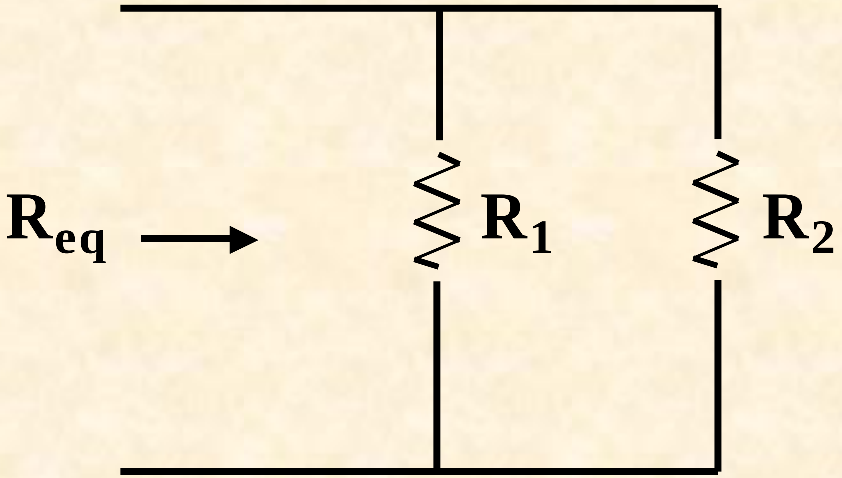
Equivalent Resistance:



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_N}$$

Resistors in Series and in Parallel

Equivalent Resistance For the **special case** of two resistors in parallel:

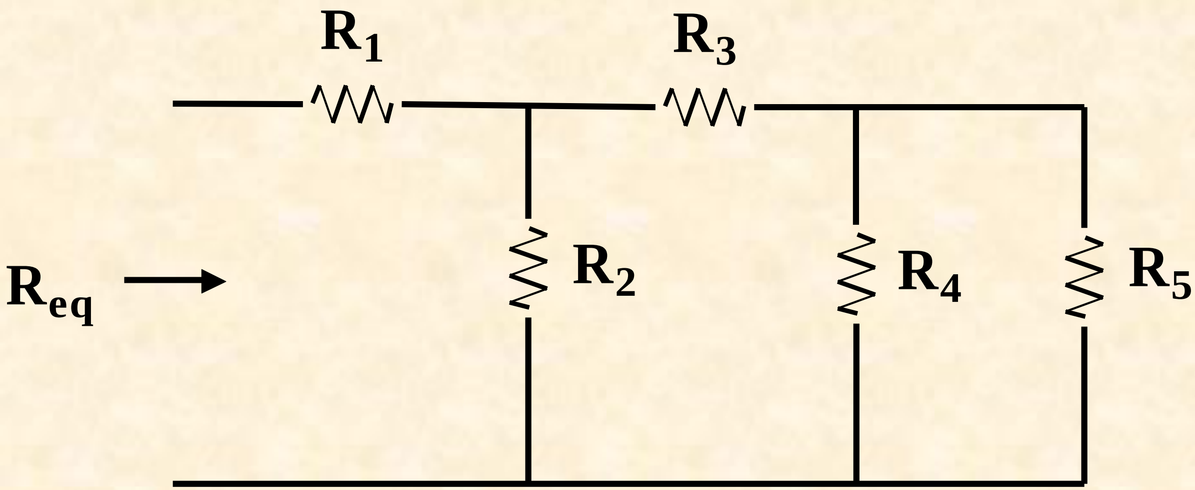


$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Resistors in Series and in Parallel

Resistors in combination.

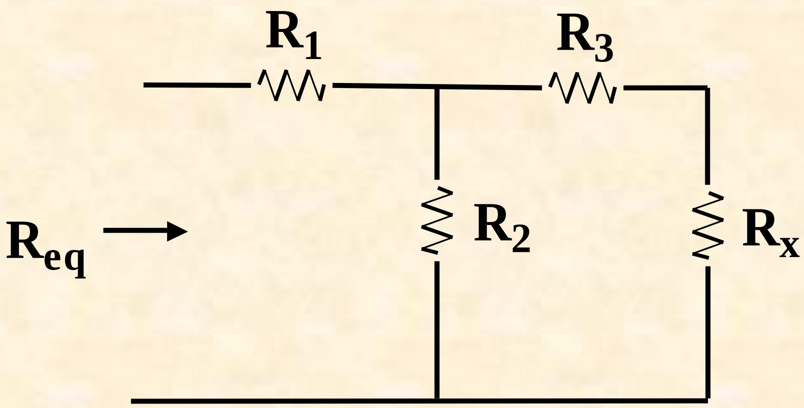
By combination we mean we have a mix of series and Parallel. This is illustrated below.



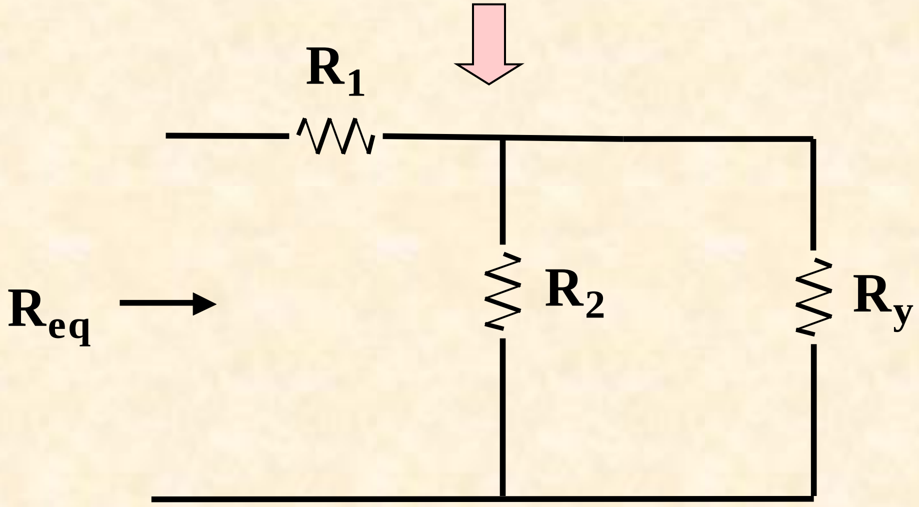
To find the equivalent resistance we usually start at the output of the circuit and work back to the input.

Resistors in Series and in Parallel

Resistors in combination.



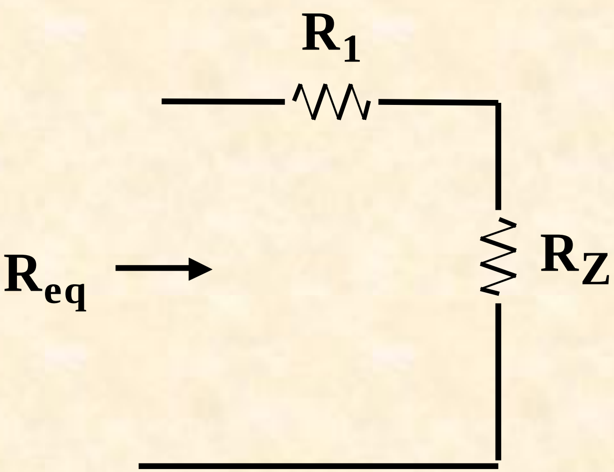
$$R_x = \frac{R_4 R_5}{R_4 + R_5}$$



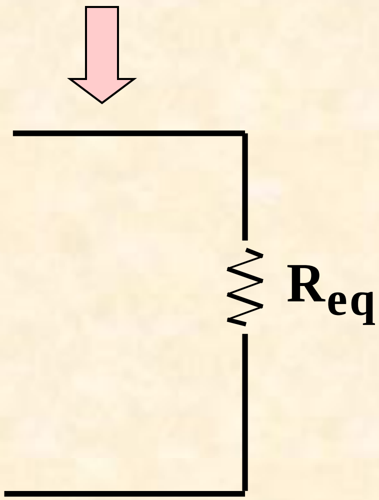
$$R_y = R_x + R_3$$

Resistors in Series and in Parallel

Resistors in combination.



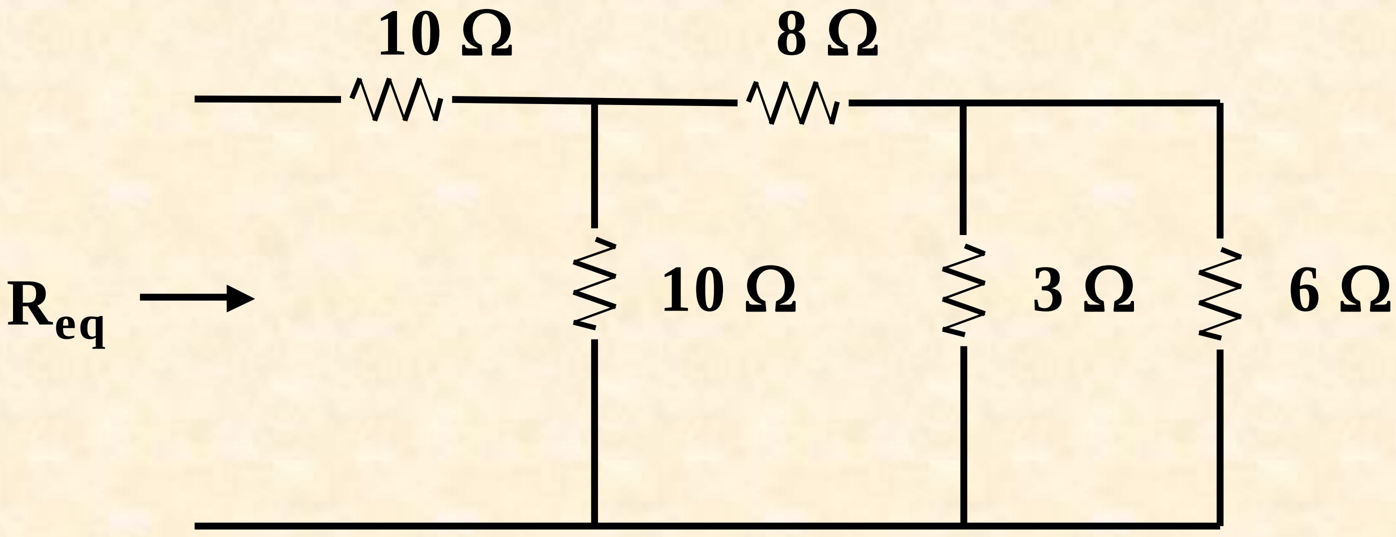
$$R_Z = \frac{R_2 R_Y}{R_2 + R_Y}$$



$$R_{eq} = R_Z + R_1$$

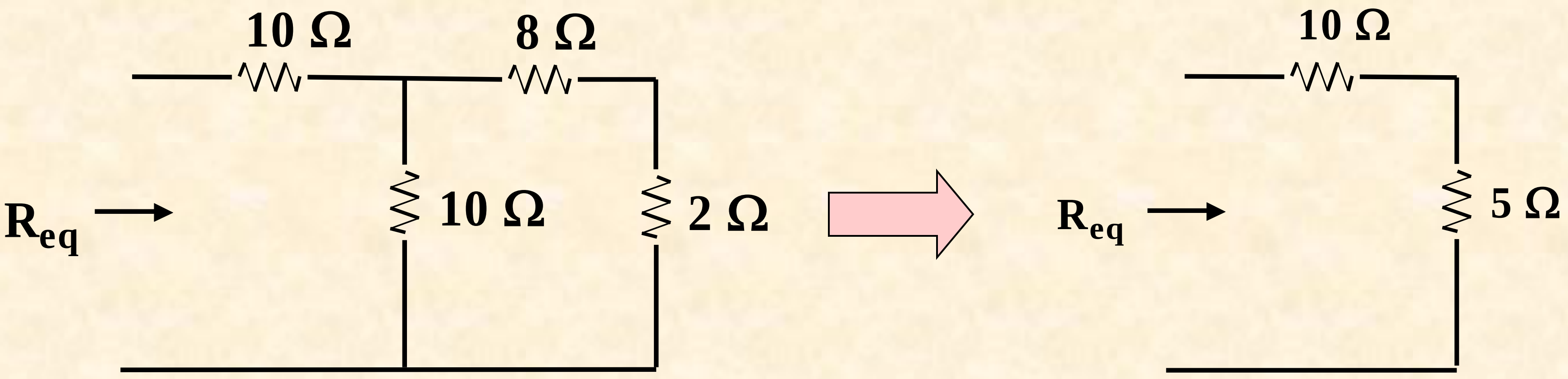
Resistors in Series and in Parallel

Example : Given the circuit below. Find R_{eq}.



Resistors in Series and in Parallel

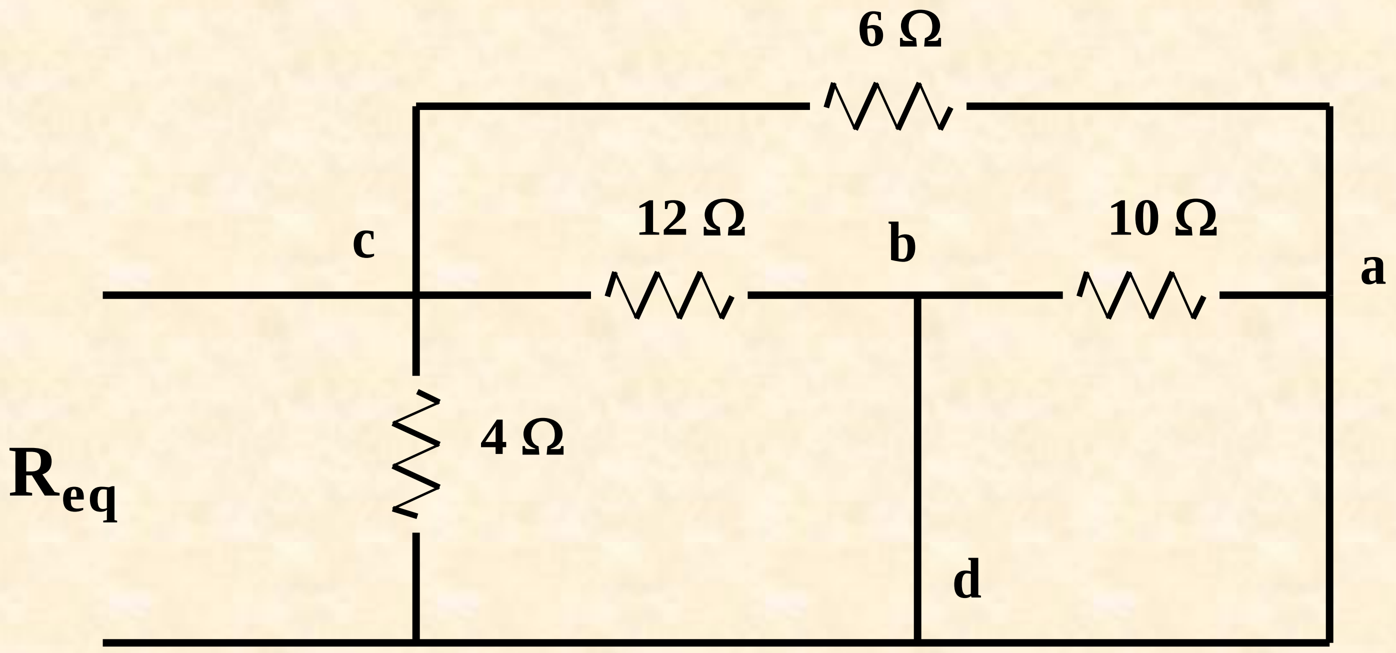
We start at the right hand side of the circuit and work to the left.



Ans: $R_{eq} = 15\,\Omega$

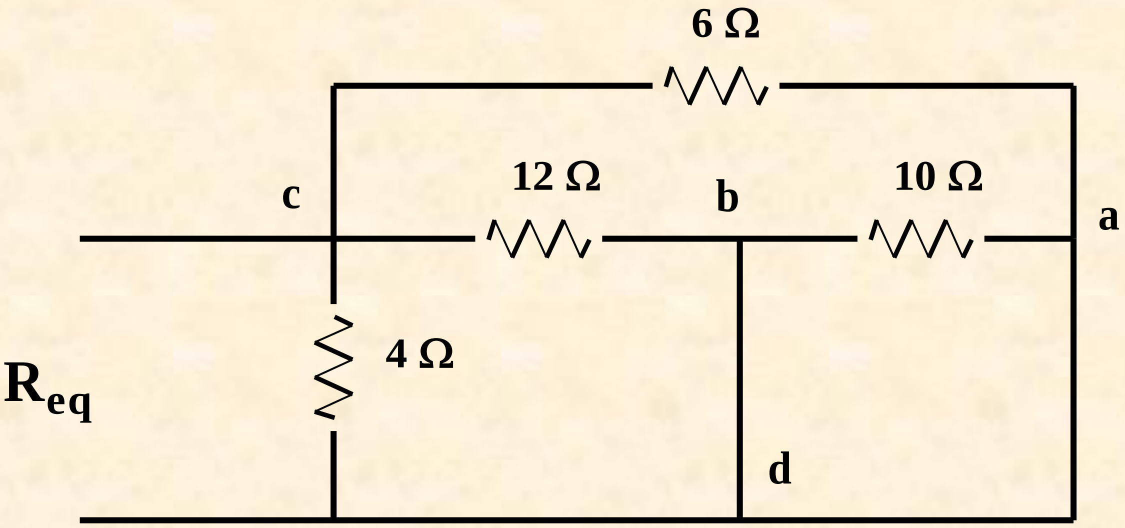
Resistors in Series and in Parallel

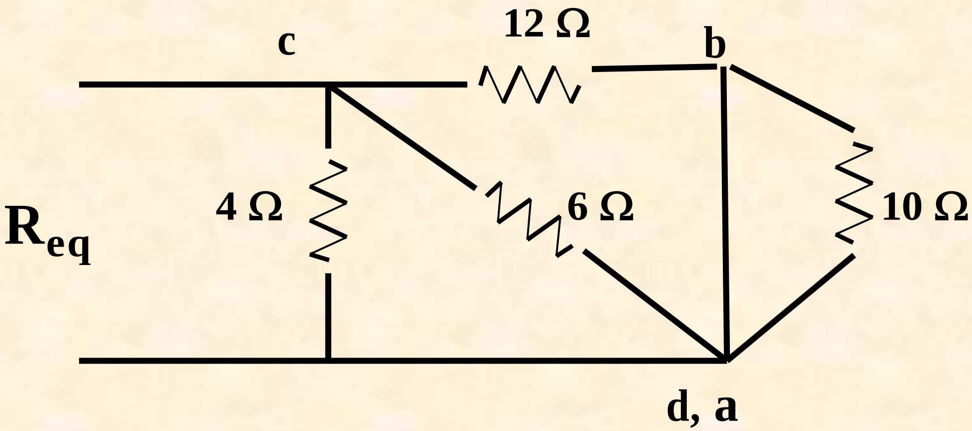
Example : Given the circuit below. Find R_{eq}.



Resistors in Series and in Parallel

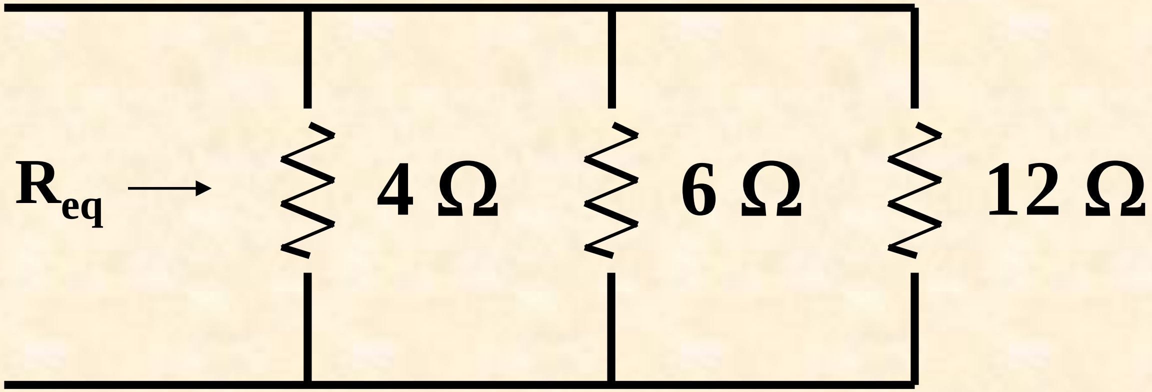
Reduction steps.





10 Ω resistor shorted out

Resistors in Series and in Parallel

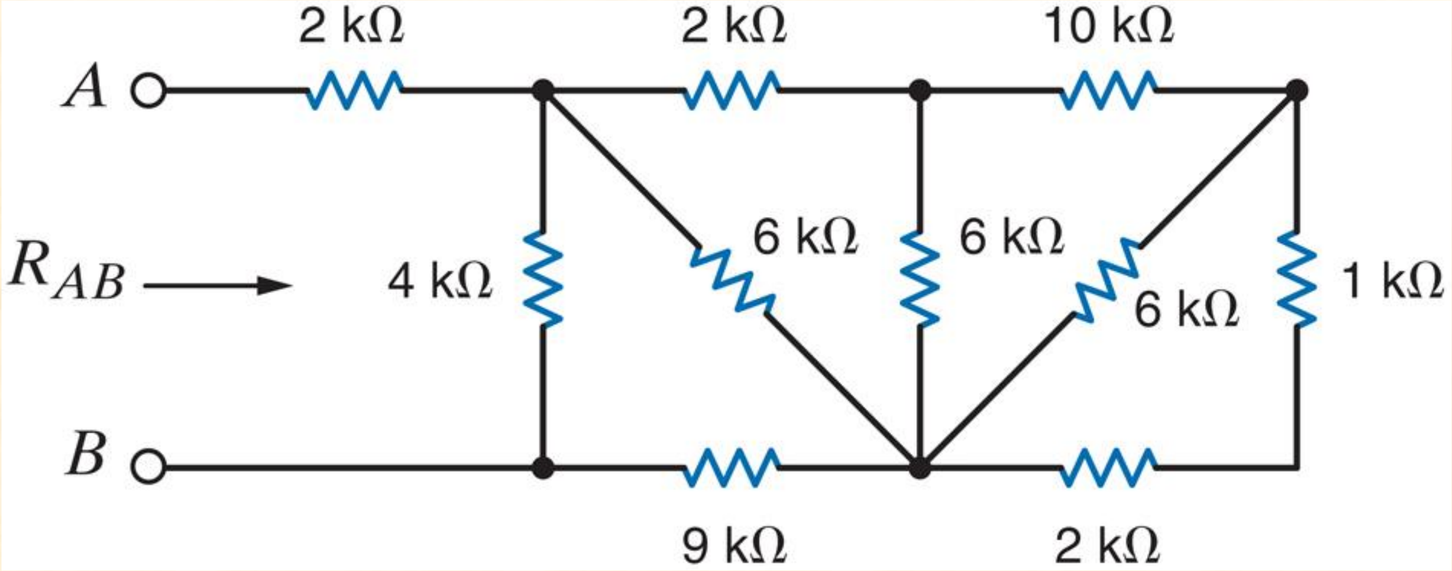


$$\frac{\mathbf{1}}{\mathbf{R_{eq}}} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{1}{2}\ \mathbf{\Omega}$$

$$\mathbf{R_{eq}} = 2\ \mathbf{\Omega}$$

Resistors in Series and in Parallel

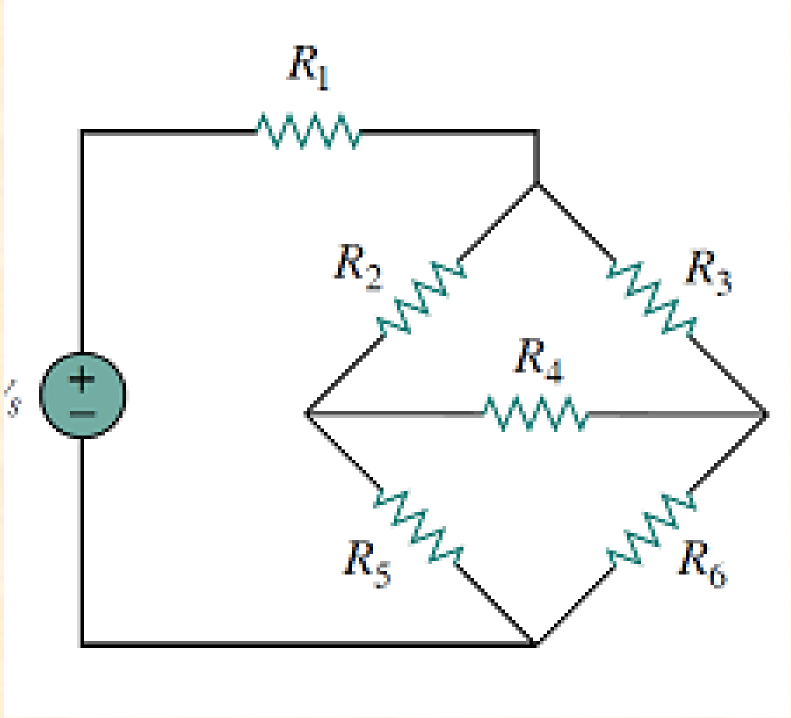
Example : Given the circuit below. Find R_{AB}.



$\boxed{5k\Omega}$

Resistors in Series and in Parallel

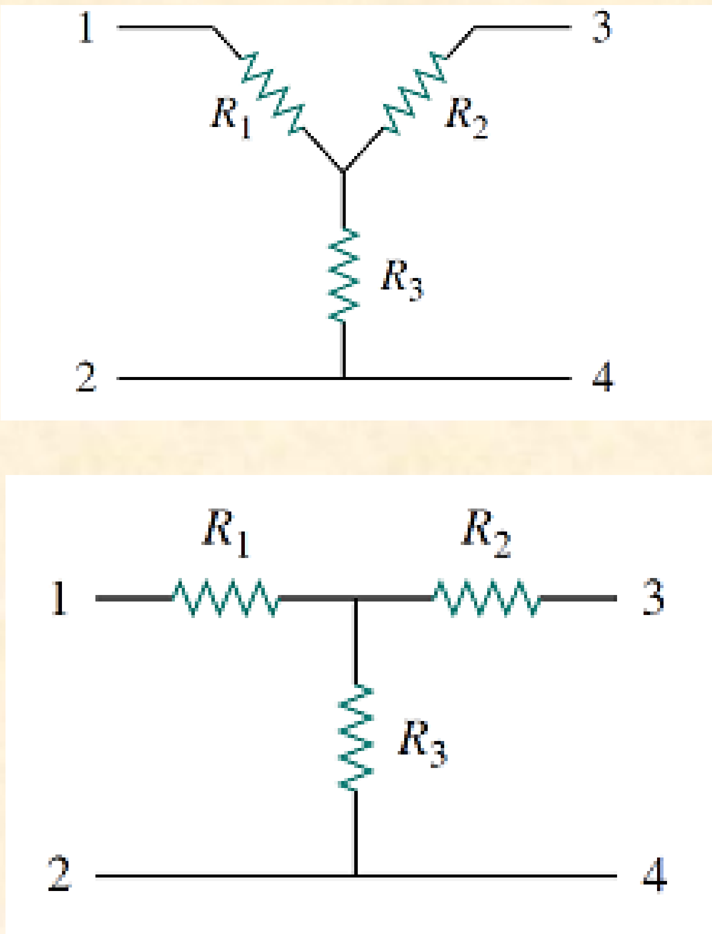
Wye and Delta (Y – Δ) circuit:



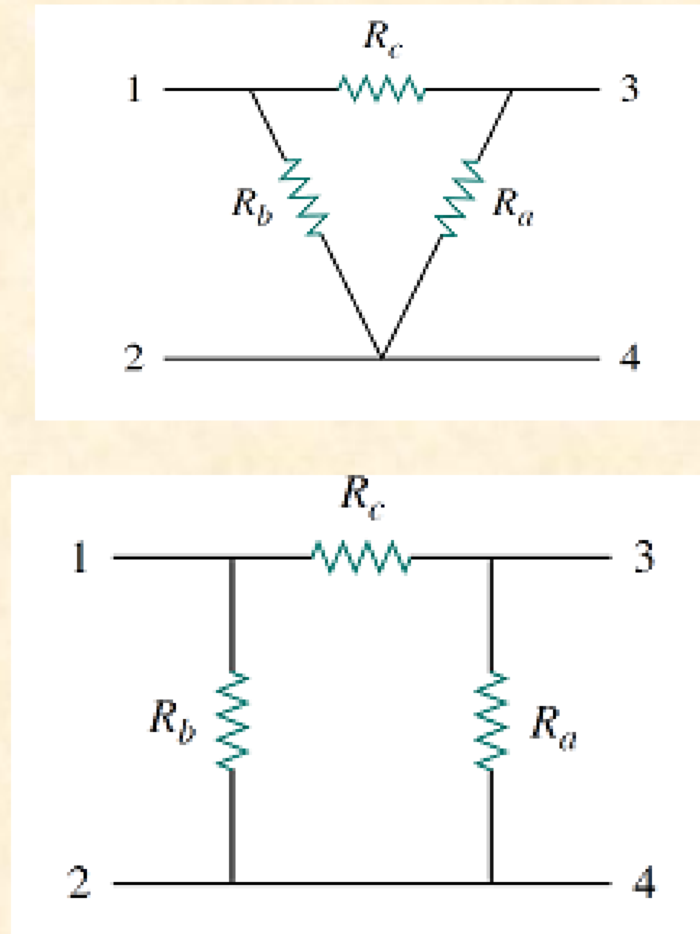
This circuit has no resistor series or parallel

Resistors in Series and in Parallel

Wye and Delta (Y – Δ) circuitos:



Wye circuit



Delta circuit

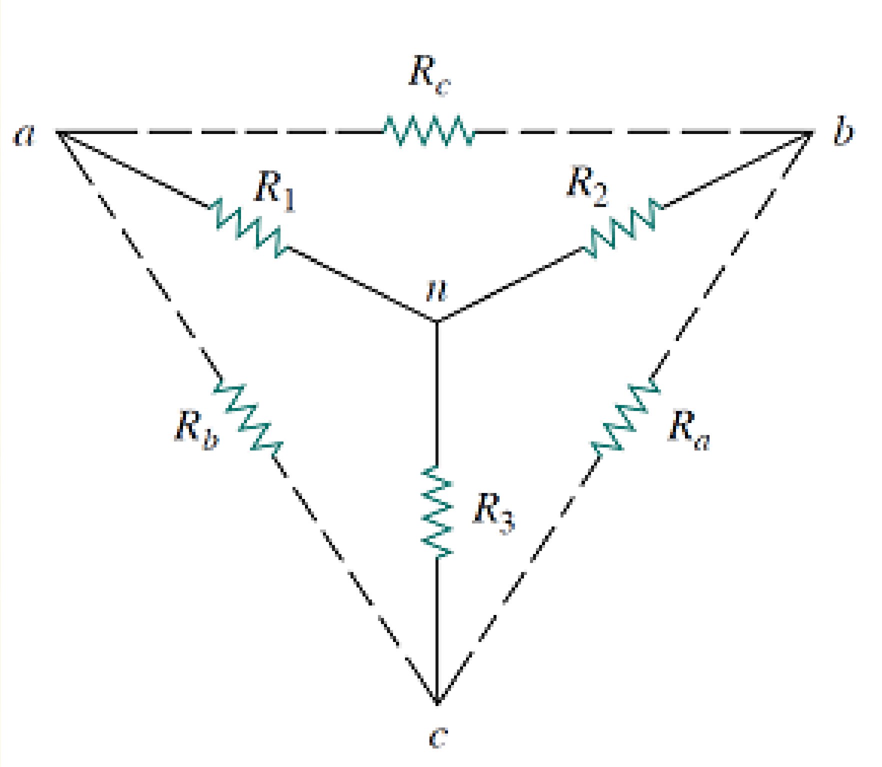
Resistors in Series and in Parallel

Wye to Delta Transformation:

$$R_a = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

$$R_b = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

$$R_c = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$



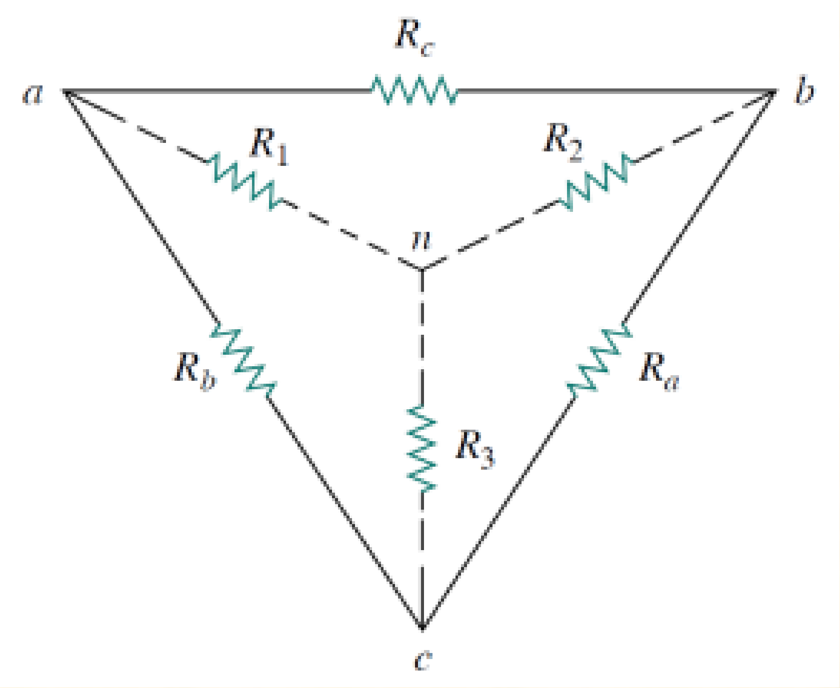
Resistors in Series and in Parallel

Delta to Wye Transformation:

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

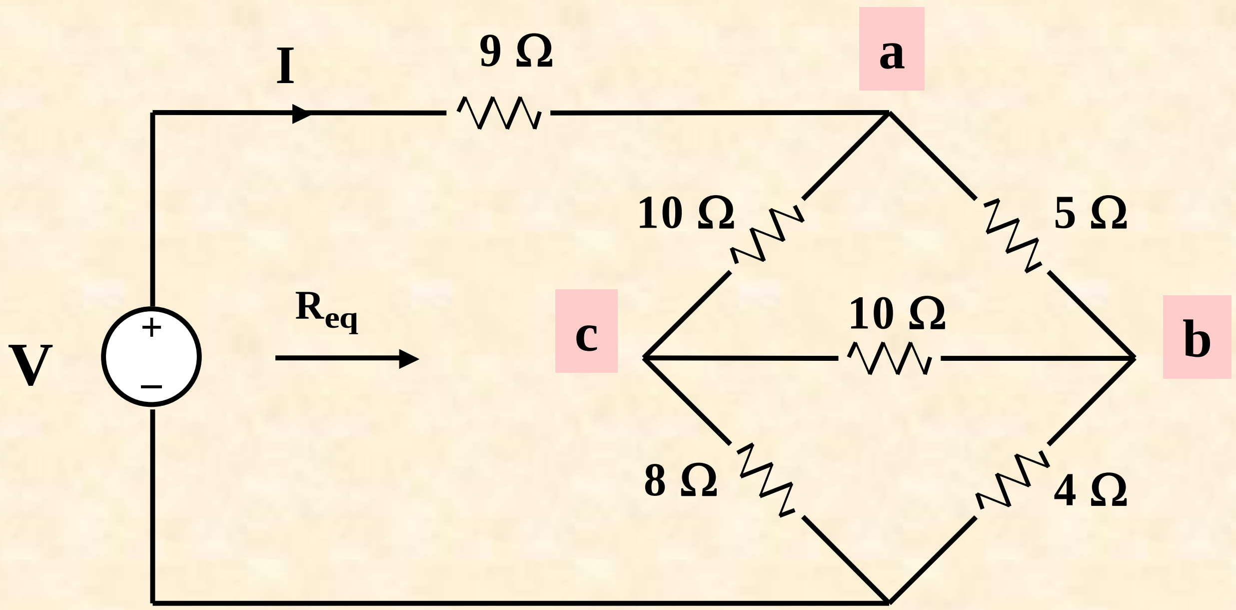
$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$



Resistors in Series and in Parallel

Example : Given the circuit below. Find R_{eq}.



Convert the delta around a – b – c to a wye.

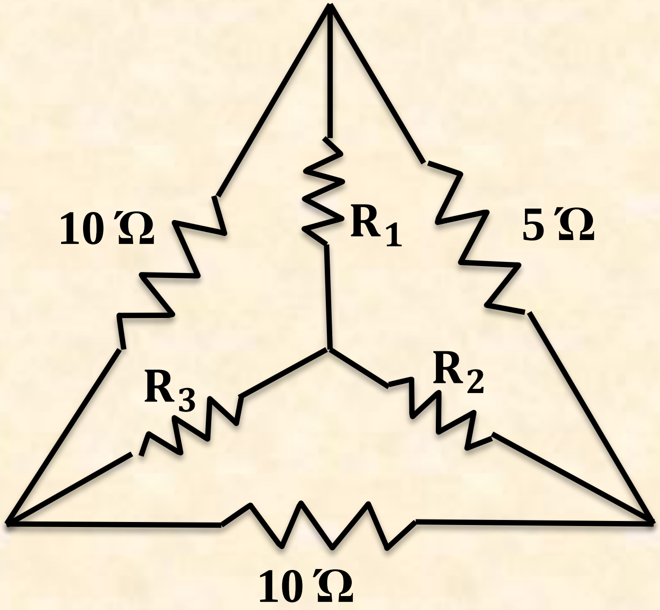
Resistors in Series and in Parallel

Delta to Wye Transformation:

$$\mathbf{R_1} = \frac{\mathbf{5} * \mathbf{10}}{\mathbf{10 + 10 + 5}} = \mathbf{2}\,\Omega$$

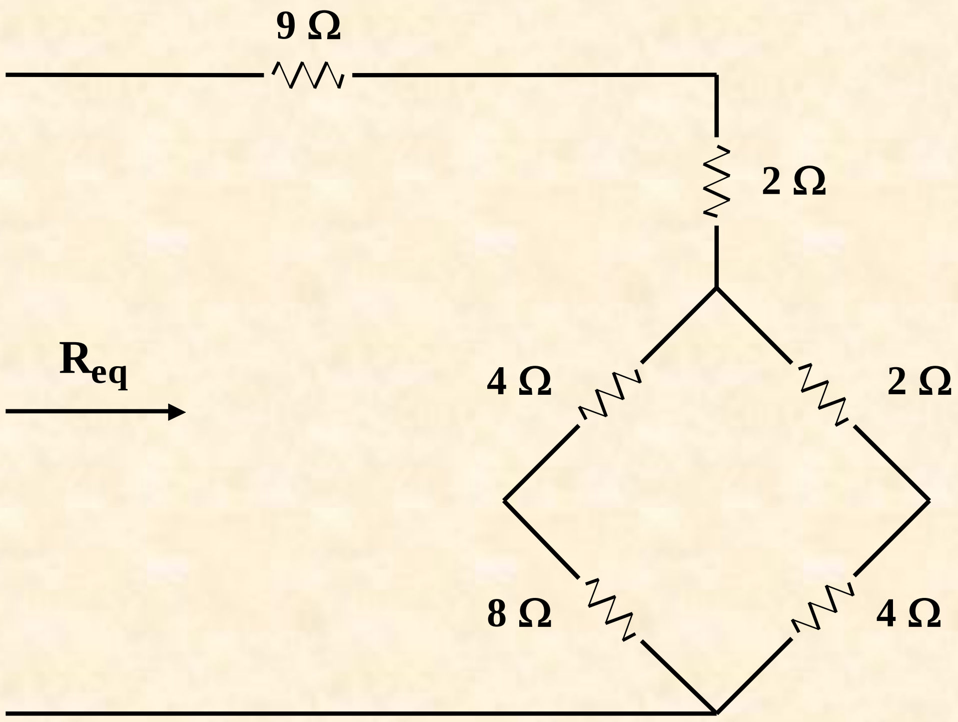
$$\mathbf{R_2} = \frac{\mathbf{5} * \mathbf{10}}{\mathbf{10 + 10 + 5}} = \mathbf{2}\,\Omega$$

$$\mathbf{R_3} = \frac{\mathbf{10} * \mathbf{10}}{\mathbf{10 + 10 + 5}} = \mathbf{4}\,\Omega$$



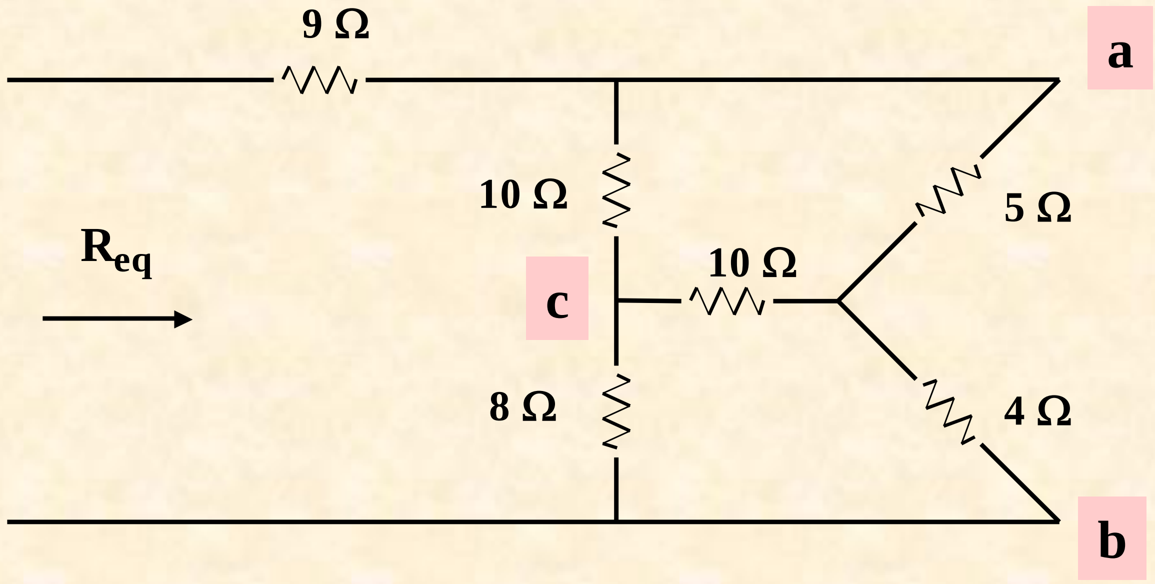
Resistors in Series and in Parallel

$R_{eq} = 15\ \Omega$



Resistors in Series and in Parallel

Example : Given the circuit below. Find R_{eq}.



Convert the wye around a – b – c to delta.

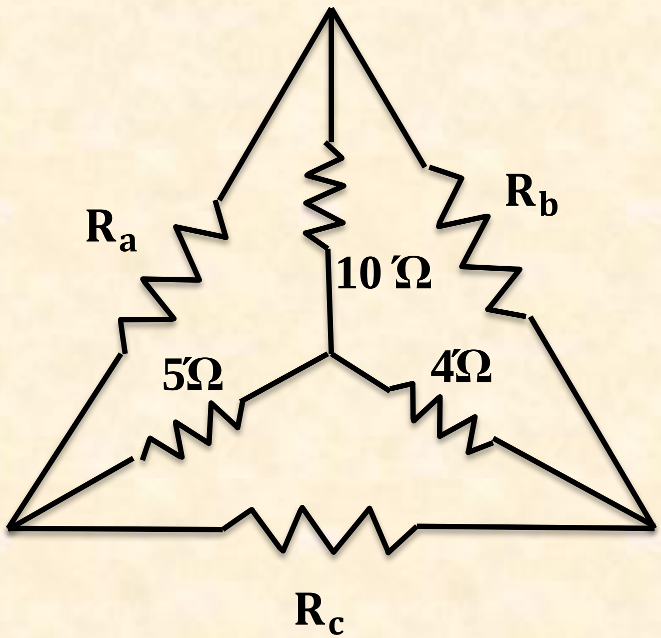
Resistors in Series and in Parallel

Wye to Delta Transformation:

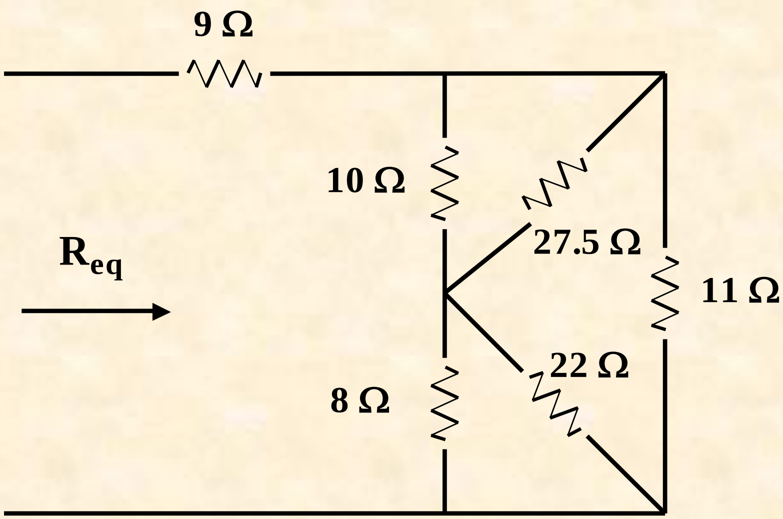
$$\mathbf{R_a = 5 + 10 + \frac{5 * 10}{4} = 27.5\ \Omega}$$

$$\mathbf{R_b = 10 + 4 + \frac{4 * 10}{5} = 22\ \Omega}$$

$$\mathbf{R_c = 5 + 4 + \frac{5 * 4}{10} = 11\ \Omega}$$

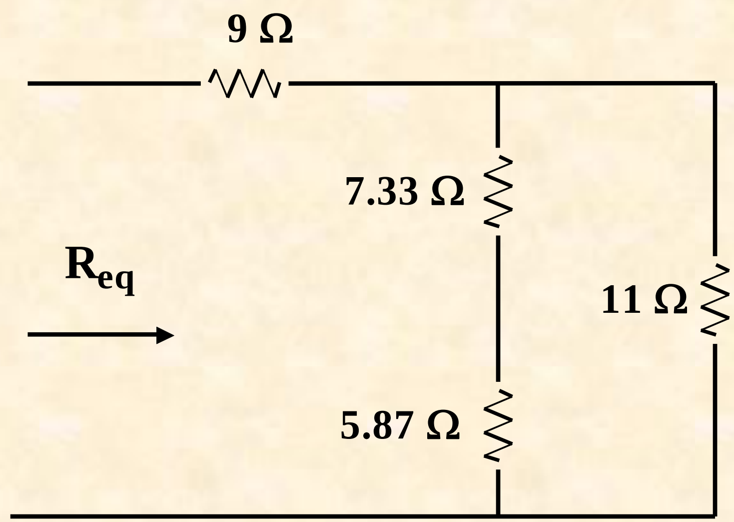


Resistors in Series and in Parallel



$10\ \Omega \parallel 27.5\ \Omega$

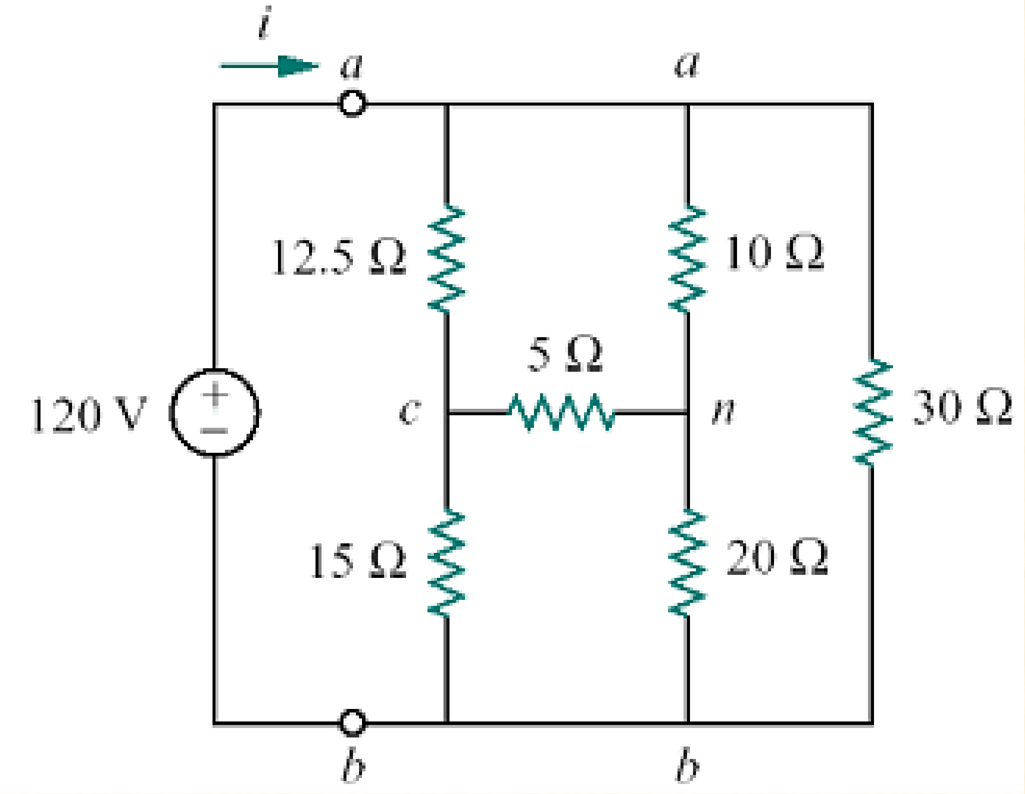
$8\ \Omega \parallel 22\ \Omega$



$R_{eq} = 15\ \Omega$

Resistors in Series and in Parallel

Example : Obtain the equivalent resistance R_{ab} for the given circuit and find current i.



Convert the delta around a – b – c to a wye.

Resistors in Series and in Parallel

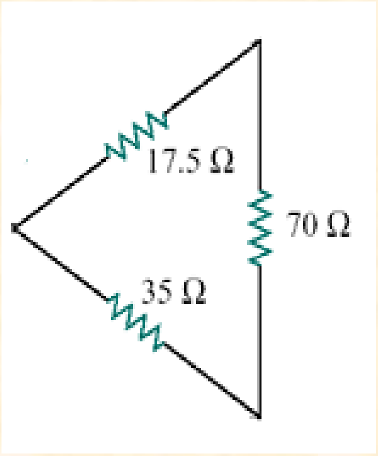
Convert the wye around a – b – c to delta.

$\mathbf{R_1 = 10\ \Omega}$ $\mathbf{R_2 = 20\ \Omega}$ $\mathbf{R_2 = 5\ \Omega}$

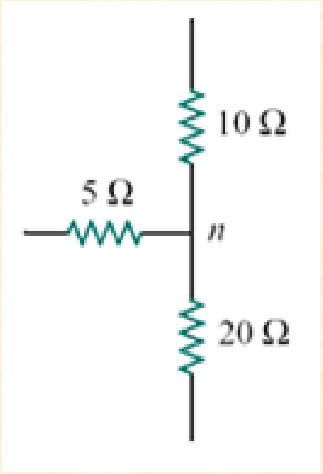
$$\mathbf{R_a = 5 + 10 + \frac{5 * 10}{20} = 17.5\ \Omega}$$

$$\mathbf{R_b = 5 + 20 + \frac{5 * 20}{10} = 35\ \Omega}$$

$$\mathbf{R_c = 10 + 20 + \frac{10 * 20}{5} = 70\ \Omega}$$

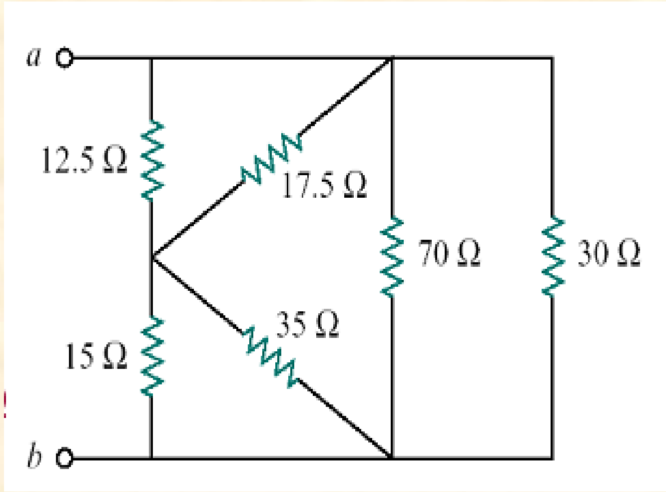


=



Resistors in Series and in Parallel

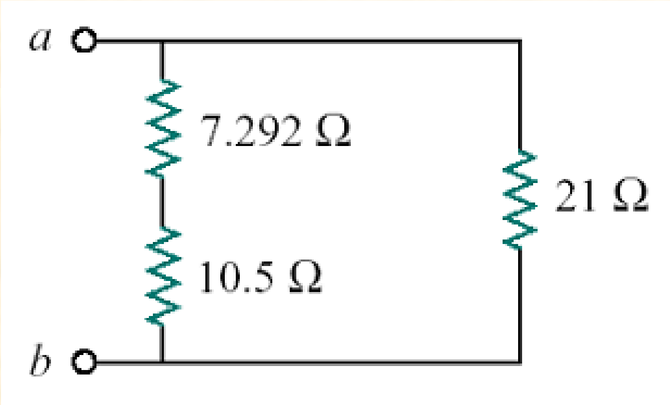
Combining the three pairs of resistors in parallel, we obtain



$$30\,\Omega \,//\, 70\,\Omega = \frac{70 * 30}{70 + 30} = 21\,\Omega$$

$$12.5\,\Omega \,//\, 17.5\,\Omega = \frac{12.5 * 17.5}{12.5 + 17.5} = 7.29\,\Omega$$

$$15\,\Omega \,//\, 35\,\Omega = \frac{15 * 35}{15 + 35} = 10.5\,\Omega$$

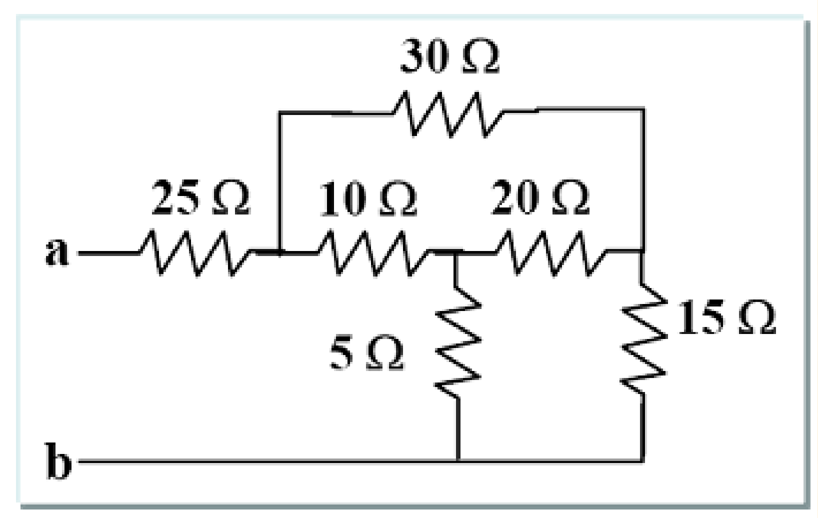


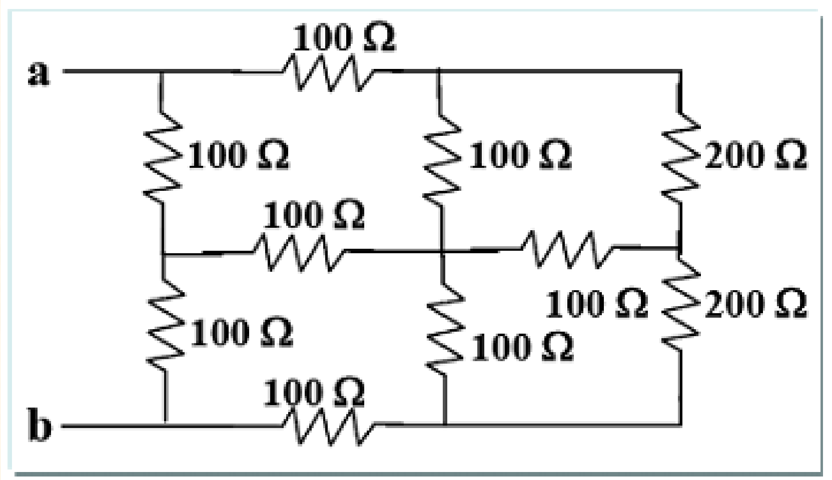
$$\mathrm{R_{eq}} = \frac{17.79 * 21}{17.79 + 21} = 9.6\,\Omega$$

$$\mathrm{I} = \frac{V}{\mathrm{R_{eq}}} = \frac{120}{9.6} = 12.4\,A$$

Resistors in Series and in Parallel

Exercise: Obtain the equivalent resistance at the terminals a-b for the given circuit.





R_{eq} = 36.25 Ω

R_{eq} = 125 Ω