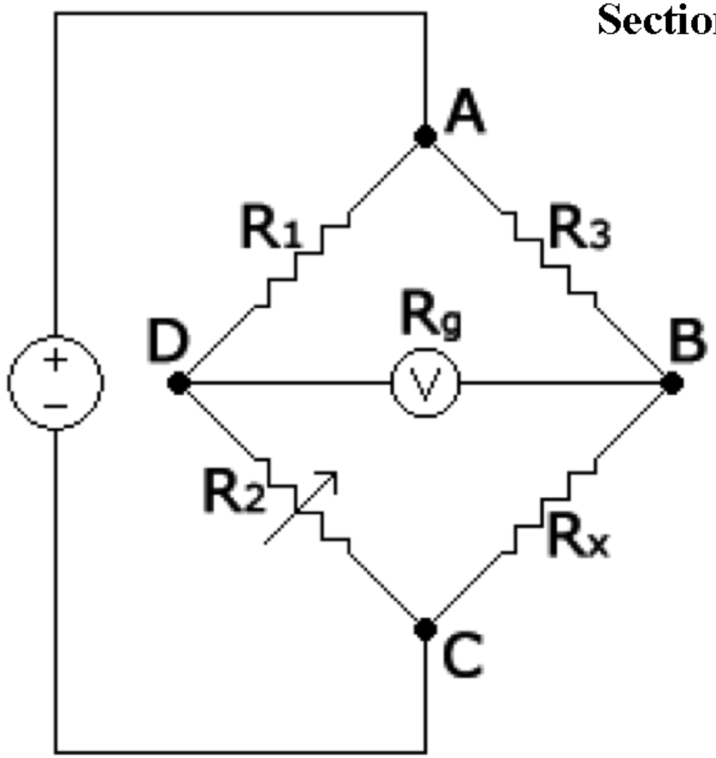
Section 2.1: Ohms LAW Review

Beckwith Chaps. 6 & 7 Various Sections



Ohm's Law Review (1)

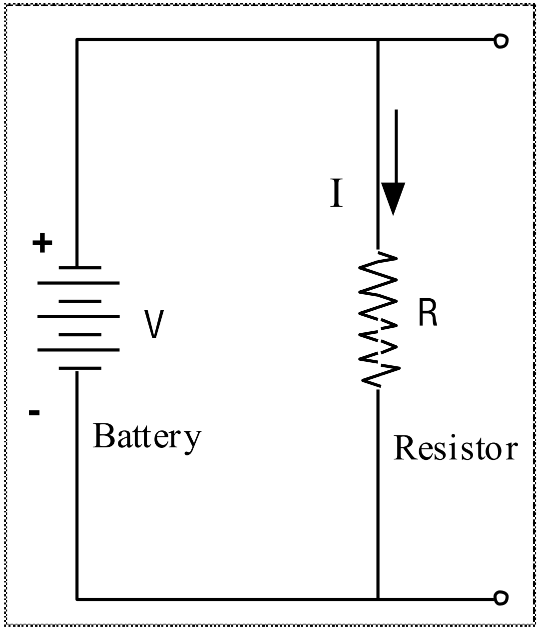
• ***Ohm's Law*** deals with the relationship between voltage and current in an ideal conductor.

--- potential difference (voltage) across an ideal conductor is proportional to the current through it.

--- Voltage//current proportionality --> "resistance", ***R***.

--- Ohm's Law is given by:

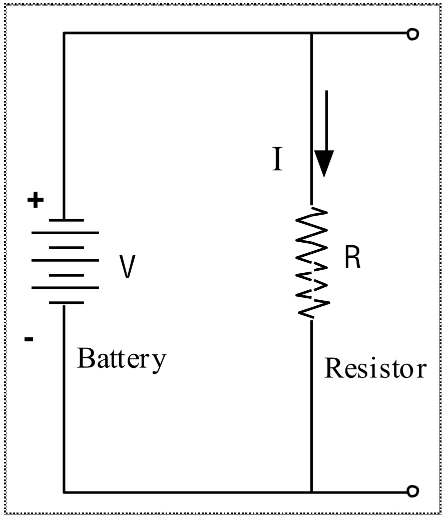
$$V = I R$$



--- V (sometimes called E) is the potential difference between two points which include a resistance ***R***. ***I*** is the current flowing through ***R***.

--- Units of resistance "Ohms" Ω

Ohm's Law Review (2)



Quantity	Name of Unit	Symbol	Expression in terms of SI base units	Expression in terms of other units
Electrical capacitance	farad	F	$m^{-2}\ kg^{-1}\ s^{4}\ A^{2}$	C/V
Electrical charge	coulomb	C	A s	
Electrical conductance	siemens	S	$m^{-2}\ kg^{-1} s^{3} A^{2}$	A/V
Electrical inductance	Henry	H	$m^{2}\ kg\ s^{-2}\ A^{-2}$	
Electrical potential	volt	V	$m^{2}\ kg\ s^{-3}\ A^{-1}$	W/A
Electrical resistance	ohm	w	$m^{2}\ kg\ s^{-3}\ A^{-2}$	V/A

- **Resistors**

Dissipate electrical Energy as heat

- ***P = I²R***

- ***Power***

dissipated by resistor

$$P = I^2 R = I \cdot V$$

$$\rightarrow A \cdot \frac{m^2\, kg}{s^3\, A} = \frac{\left(\frac{kg \cdot m}{s^2} \cdot m\right)}{\text{sec}} = \frac{Nt \cdot m}{\text{sec}} = \frac{J}{\text{sec}} = Watts$$

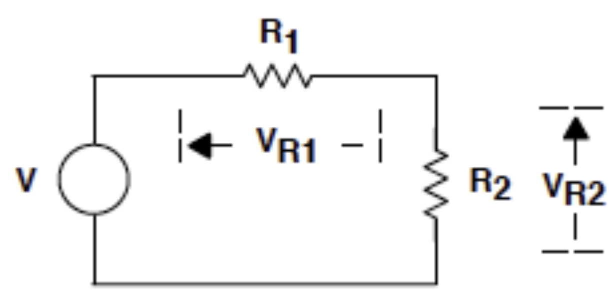
Kirchoff's Laws

- **Kirchoff's Voltage Law: Sum of the Voltage Sources Around a Loop Must Equal the Sum of the Voltage Drops**

Kirchoff's Voltage Law

$$\sum V_{SOURCES} = \sum V_{DROPS}$$

Example: $V = V_{R1} + V_{R2}$



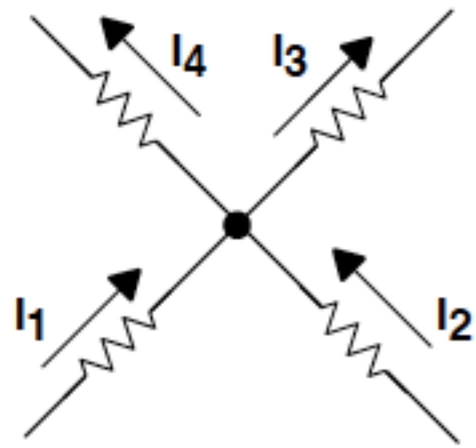
Kirchoff's Laws (2)

- **Kirchoff's Current Law: Sum of the currents entering a junction equals the sum of the currents leaving a junction.**

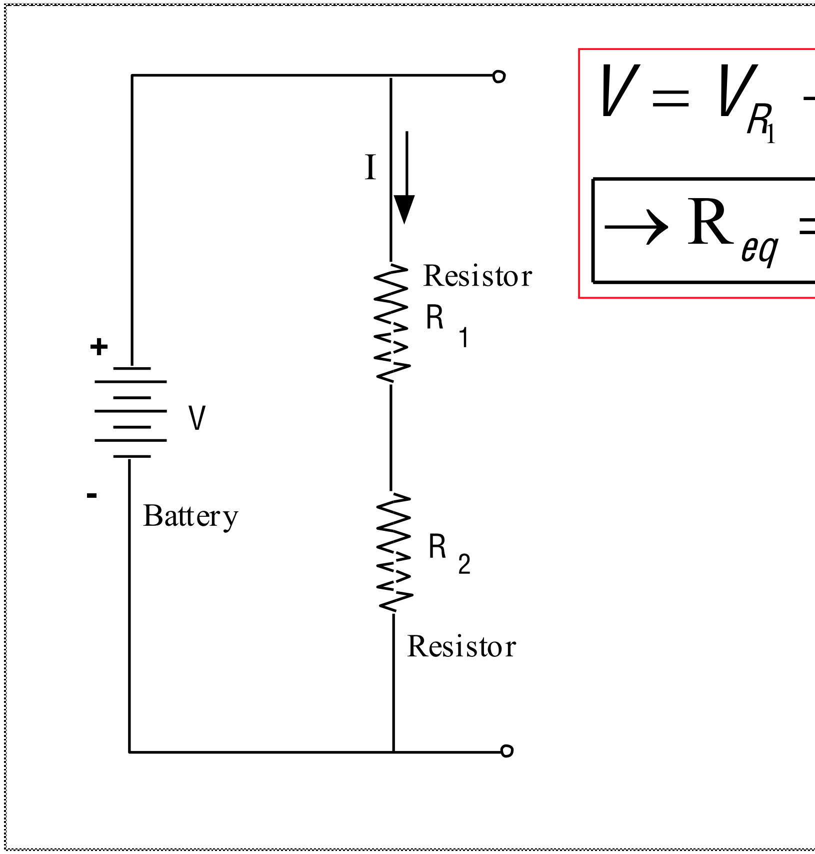
Kirchoff's Current Law

$$\sum I_{IN} = \sum I_{OUT}$$

$$I_1 + I_2 = I_3 + I_4$$



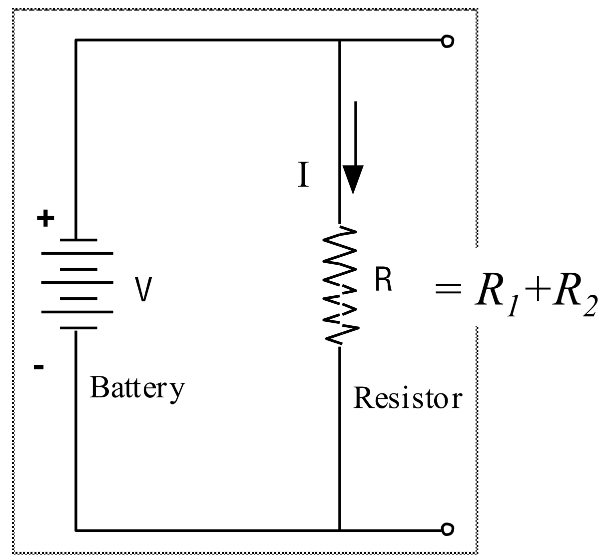
Resistors in Series (1)



$$V = V_{R_1} + V_{R_2} = I \cdot R_1 + I \cdot R_2 = I(R_1 + R_2)$$

$$\rightarrow \mathrm{R}_{eq} = R_1 + R_2$$

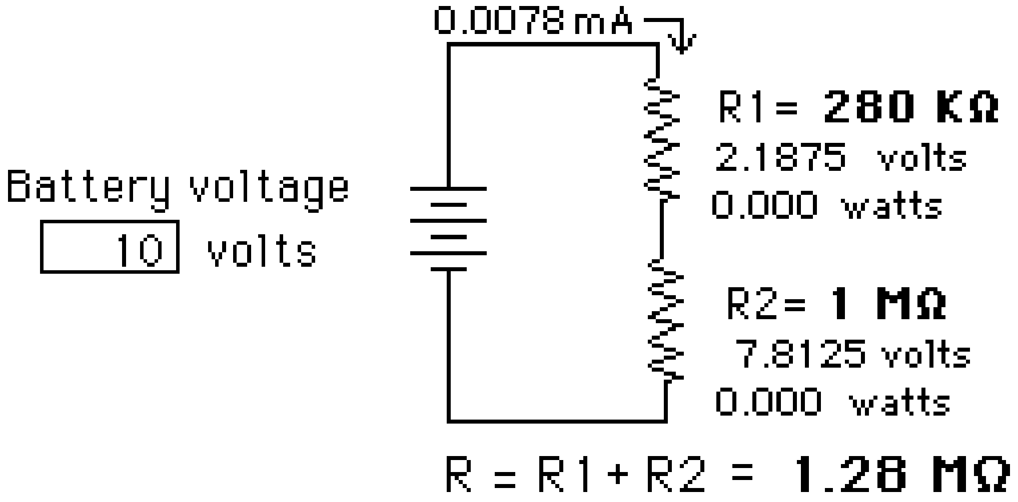
Resistors in series add linearly



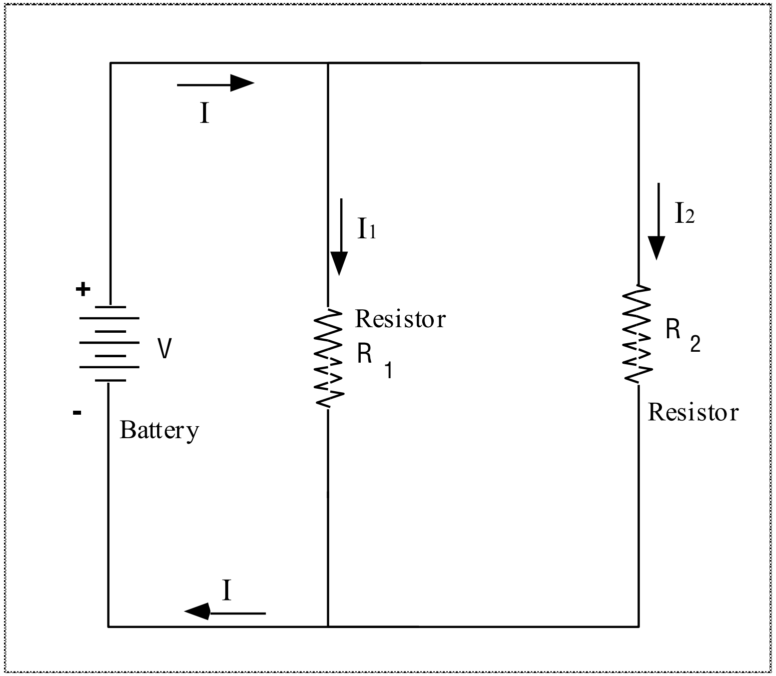
Equivalent Circuit

Resistors in Series (2)

- Numerical Example



Resistors in Parallel (1)



- Analyze Circuit Using Kirchoff's law
- Voltage drop across both Resistors Is same $=V$
- *Currents sum at branch*

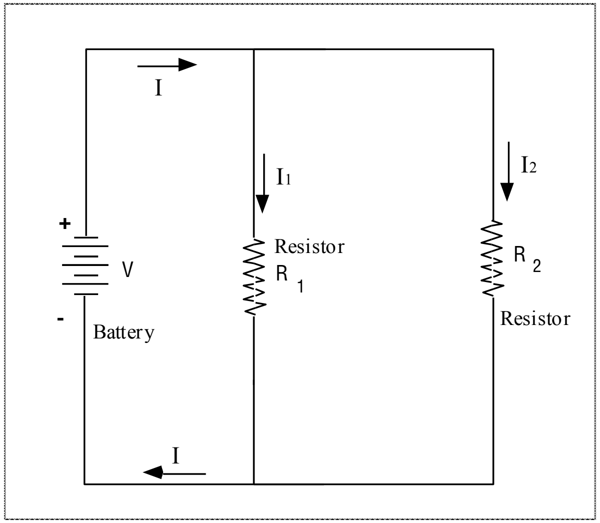
$$\boxed{V = V_{R_1} = V_{R_2}} \rightarrow \boxed{I_1 \cdot R_1 = I_2 \cdot R_2}$$

$$(I - I_2) \cdot R_1 = I_2 \cdot R_2 \rightarrow I \cdot R_1 = I_2 (R_1 + R_2) \rightarrow \boxed{I_2 = \frac{I \cdot R_1}{(R_1 + R_2)}}$$

$$\boxed{I = I_1 + I_2} \rightarrow$$

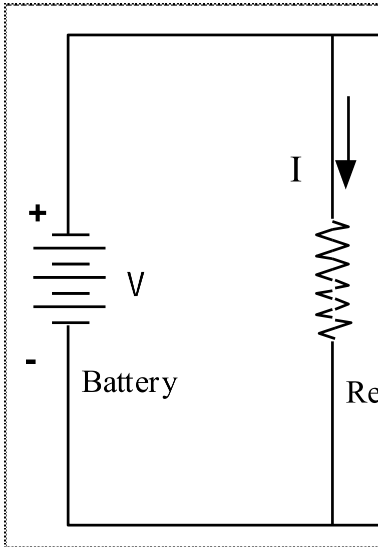
$$(I - I_1) \cdot R_2 = I_1 \cdot R_1 \rightarrow I \cdot R_2 = I_1 (R_1 + R_2) \rightarrow \boxed{I_1 = \frac{I \cdot R_2}{(R_1 + R_2)}}$$

Resistors in Parallel (2)



$$R_{eq} \equiv \frac{V}{I} = \frac{I_1 \cdot R_1}{I_1 + I_2} = \frac{\frac{I \cdot R_2}{(R_1 + R_2)} \cdot R_1}{\frac{I \cdot R_1}{(R_1 + R_2)} + \frac{I \cdot R_2}{(R_1 + R_2)}} =$$

$$\frac{R_1 \cdot R_2}{(R_1 + R_2)} \frac{1}{\frac{R_1}{(R_1 + R_2)} + \frac{R_2}{(R_1 + R_2)}} = \frac{R_1 \cdot R_2}{(R_1 + R_2)} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$



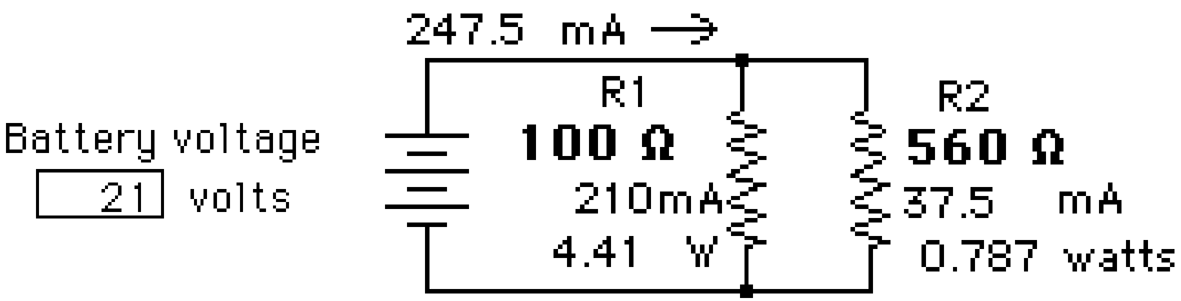
$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Resistors in parallel add as reciprocals

Equivalent Circuit

Resistors in Parallel (3)

- Numerical Example



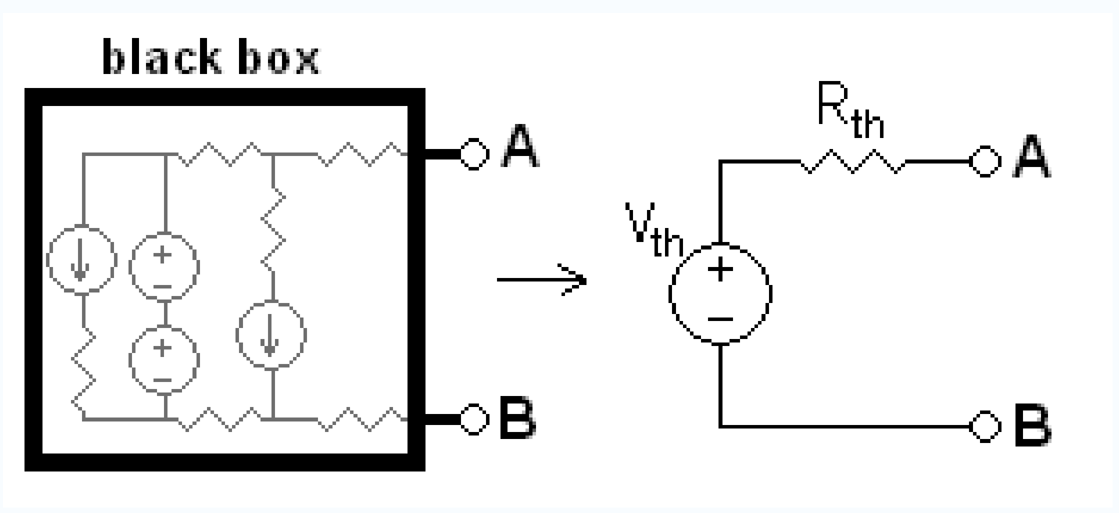
$$R = \frac{1}{\frac{1}{R1}+\frac{1}{R2}} = 84.848485\ \Omega$$

Equivalent Circuit

Thevenin's Equivalent Circuit (1)

• Any combination of batteries and resistances with two terminals can be replaced by a single voltage source V_{eq} and a single series resistor R_{eq}.

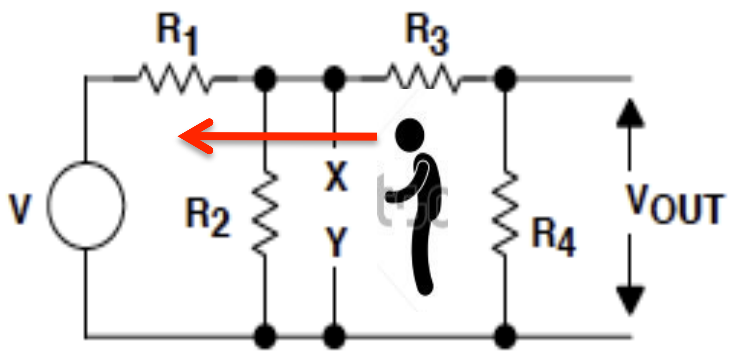
• The value of V_{eq} is the open circuit voltage at the terminals, and the value of R_{eq} is V_{eq} divided by the current with the terminals short circuited.



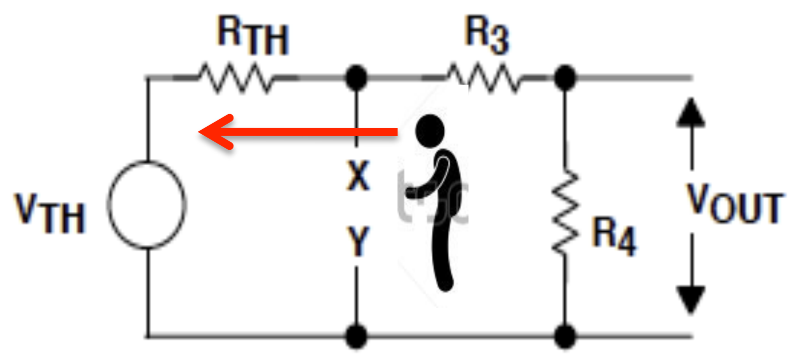
• ***Thevenin's Theorem***

Simple Thevenin Example

• "Stand" on the terminals *"X-Y"* with back to output circuit … Calculate Observed Voltage, V_{TH}



(a) The Original Circuit



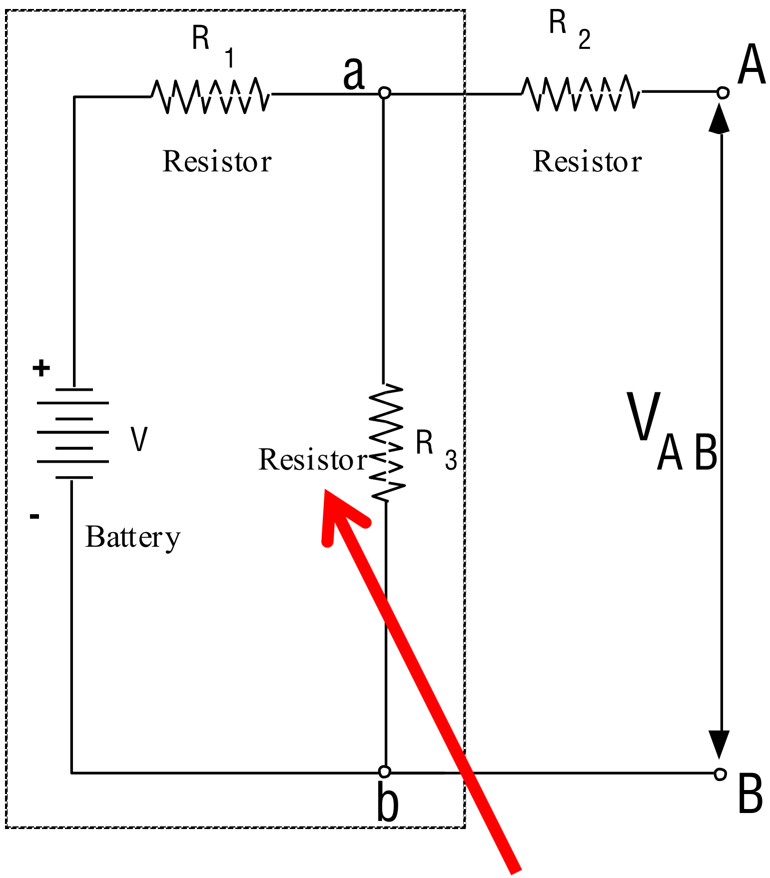
(b) The Thevenin Equivalent Circuit

$$V_{TH} = V \cdot \frac{R_2}{R_1 + R_2}$$

$$R_{TH} = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

A More Complex Example

Thevenin's Equivalent Circuit (2)



Parallel resistances

$$V_{ab} = I \cdot R_3$$

$$\downarrow$$

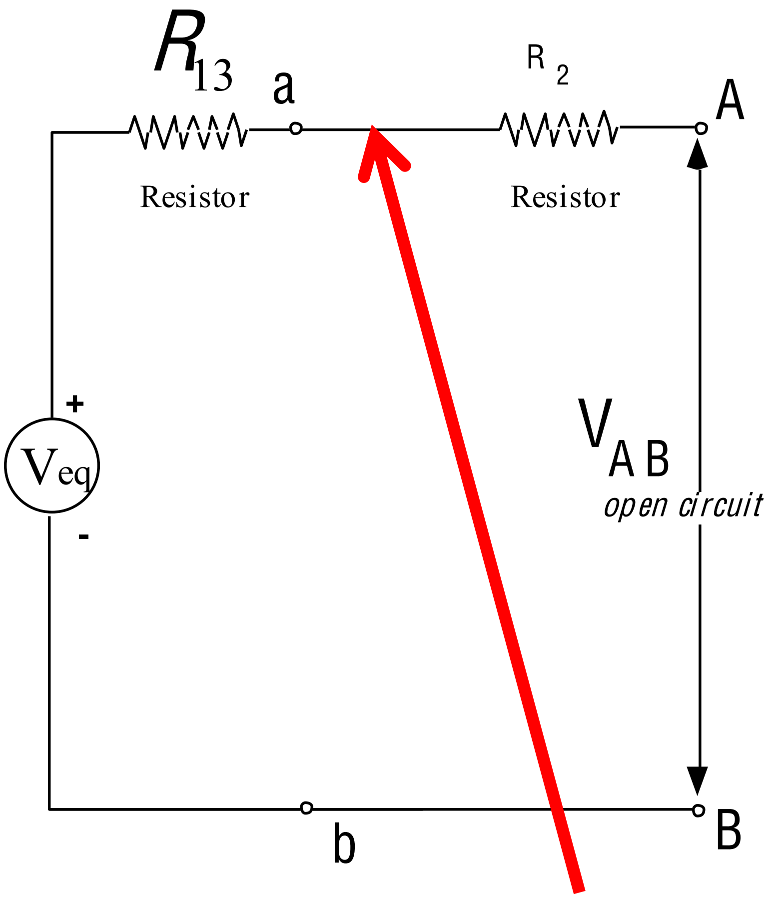
$$I = \frac{V}{(R_1 + R_3)}$$

$$\downarrow$$

$$V_{eq} = V_{ab} = V \cdot \frac{R_3}{(R_1 + R_3)}$$

- ***Replace with Thevenin Equivalent Circuit***

Thevenin's Equivalent Circuit (3)



Serial resistances

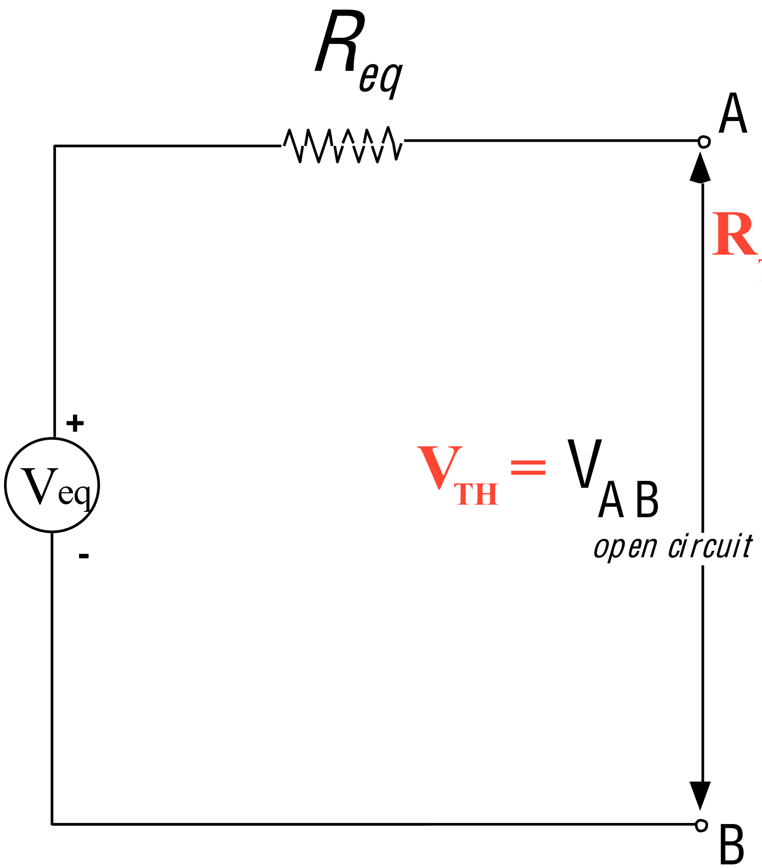
$$V_{eq} = V \cdot \frac{R_3}{(R_1 + R_3)}$$

$$R_{13} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_3}} = \frac{R_1 R_3}{(R_1 + R_3)}$$

- ***Replace again with Thevenin Equivalent Circuit***

Thevenin's Equivalent Circuit (4)

$$V_{eq} = V \cdot \frac{R_3}{(R_1 + R_3)}$$

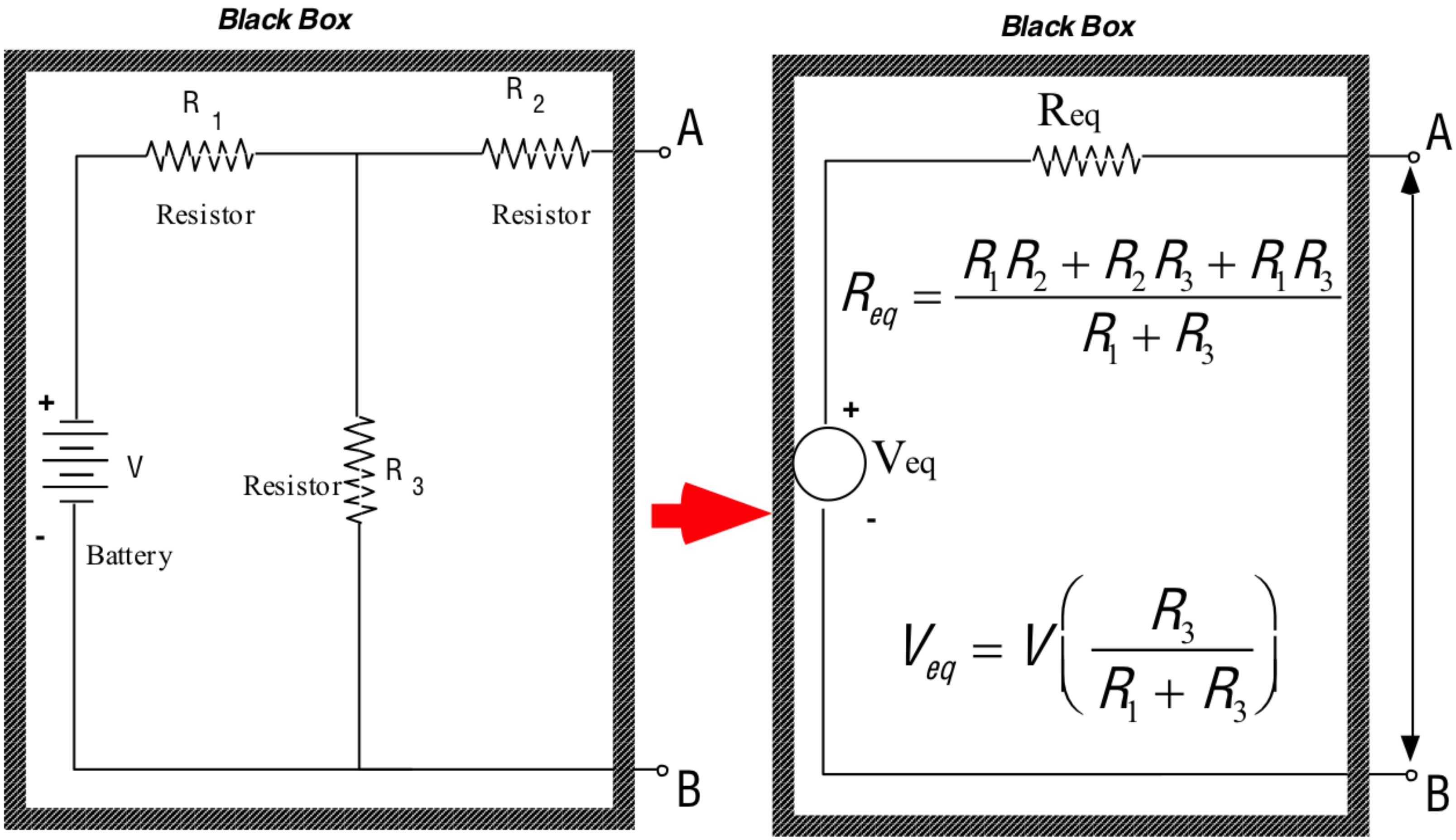


$$R_{TH} = R_{eq} = R_2 + \frac{1}{\frac{1}{R_1} + \frac{1}{R_3}} = R_2 + \frac{R_1 R_3}{(R_1 + R_3)}$$

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

- ***Final Thevenin Equivalent Circuit***

Thevenin's Equivalent Circuit (5)



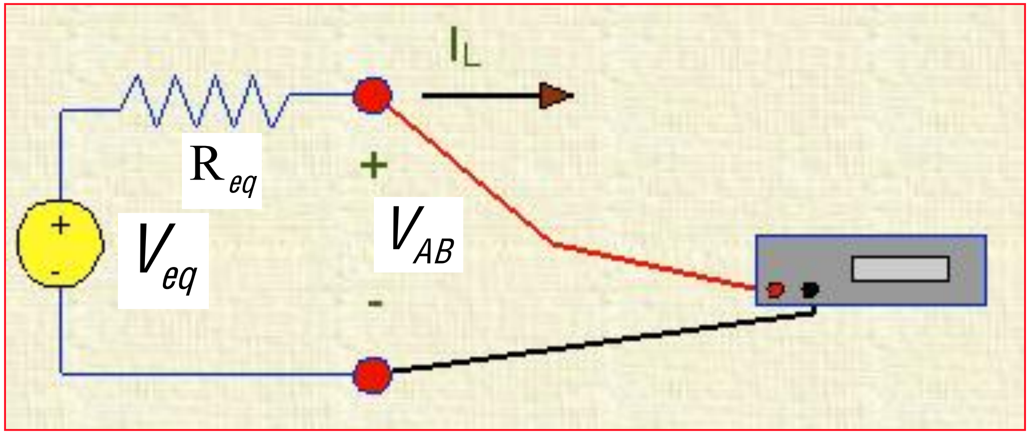
$$R_{eq} = \frac{R_1 R_2 + R_2 R_3 + R_1 R_3}{R_1 + R_3}$$

$$V_{eq} = V\left(\frac{R_3}{R_1 + R_3}\right)$$

- ***Allows Circuits of Components to be Simplified for Modeling and analysis***

Second Circuit Simplier … "but equivalent"

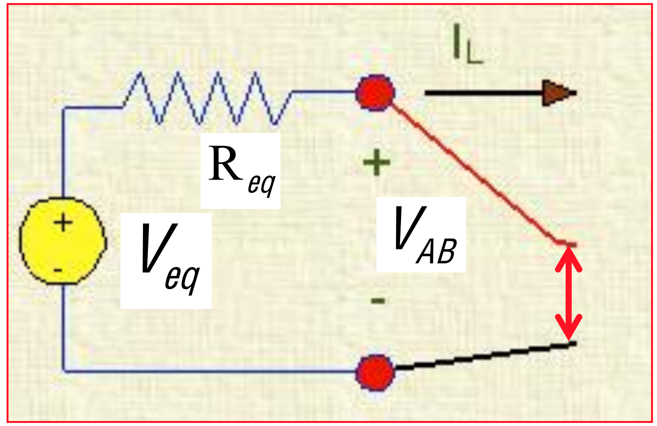
Thevenin's Equivalent Circuit (6)



- V_{eq}, is the voltage measured when no load is attached (open circuit voltage)

- If you just attach a voltmeter to the output terminals - and didn't attach anything else, the voltmeter woud read V_{eq}.

Thevenin's Equivalent Circuit (7)

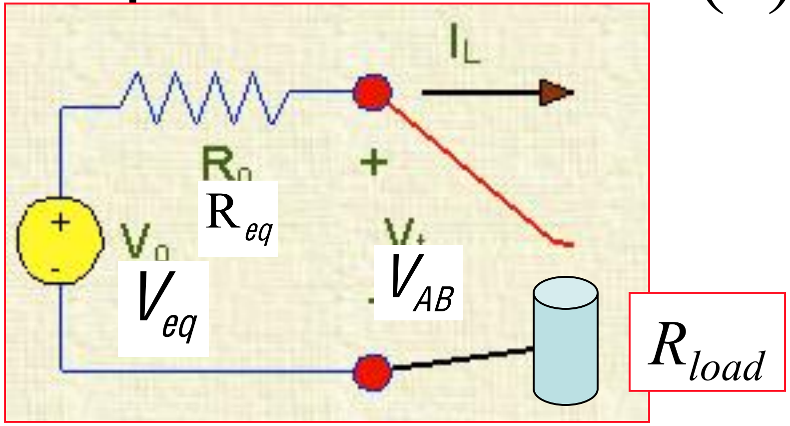


- For this component is a definite limit to how much current this source can supply to a load.

- If we short the terminals - the current is:

$$I_{max} = \frac{V_{eq}}{R_{eq}} = \frac{V\left(\frac{R_3}{R_1 + R_3}\right)}{R_2 + \frac{R_1 R_3}{R_1 + R_3}} = V\left(\frac{R_3}{R_2\left(R_1 + R_3\right) + R_1 R_3}\right)$$

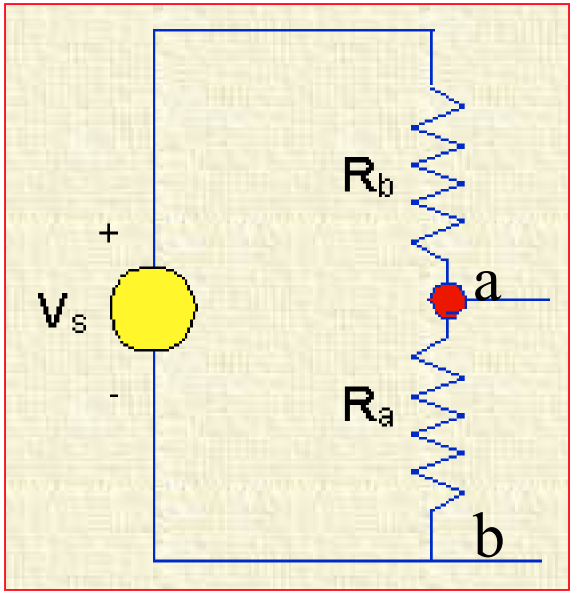
Thevenin's Equivalent Circuit (8)



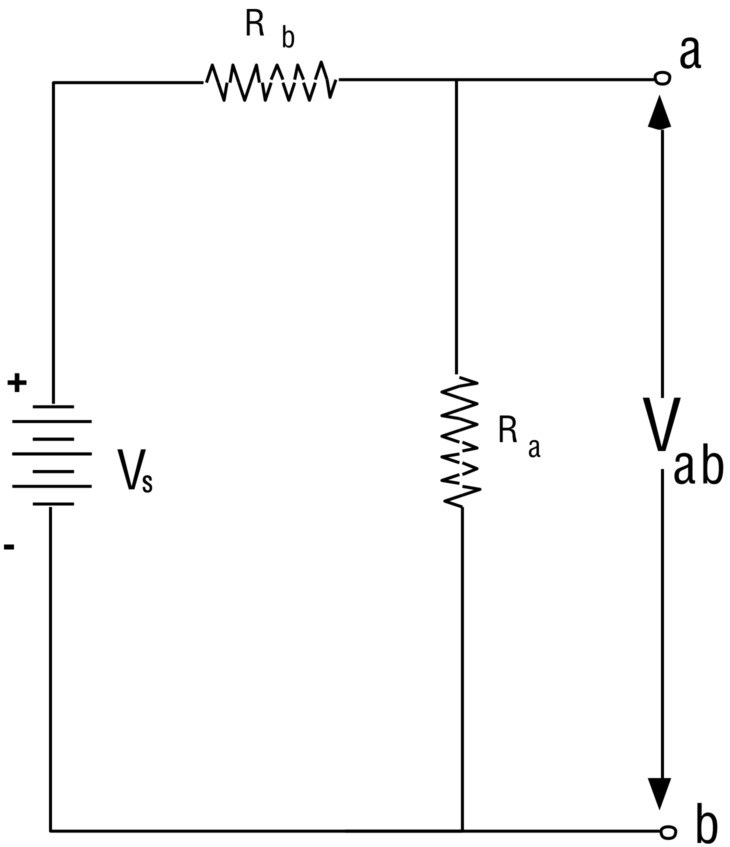
• If we attach a Load with Impedance …. R_{load} .. Then the current drawn is

$$I_{load} = \frac{V_{eq}}{R_{eq} + R_{load}} = \frac{V\left(\frac{R_3}{R_1 + R_3}\right)}{R_2 + R_{load} + \frac{R_1 R_3}{R_1 + R_3}} = V\left(\frac{R_3}{(R_2 + R_{load})(R_1 + R_3) + R_1 R_3}\right)$$

Example 2: Voltage Divide Circuit (1)

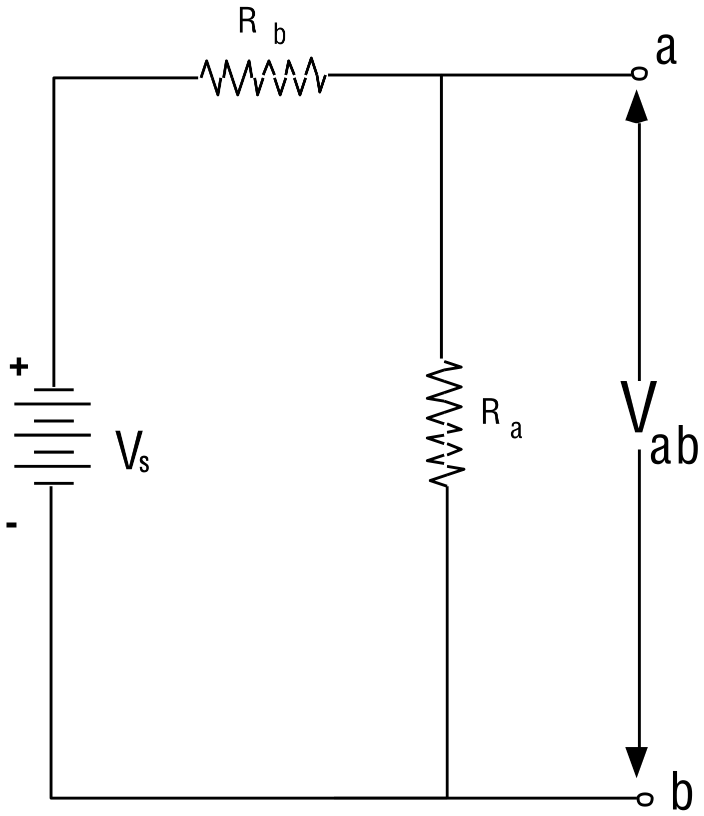


Redraw in more familiar Form …..



- ***We've seen this before …***

Example 2: Voltage Divide Circuit (2)



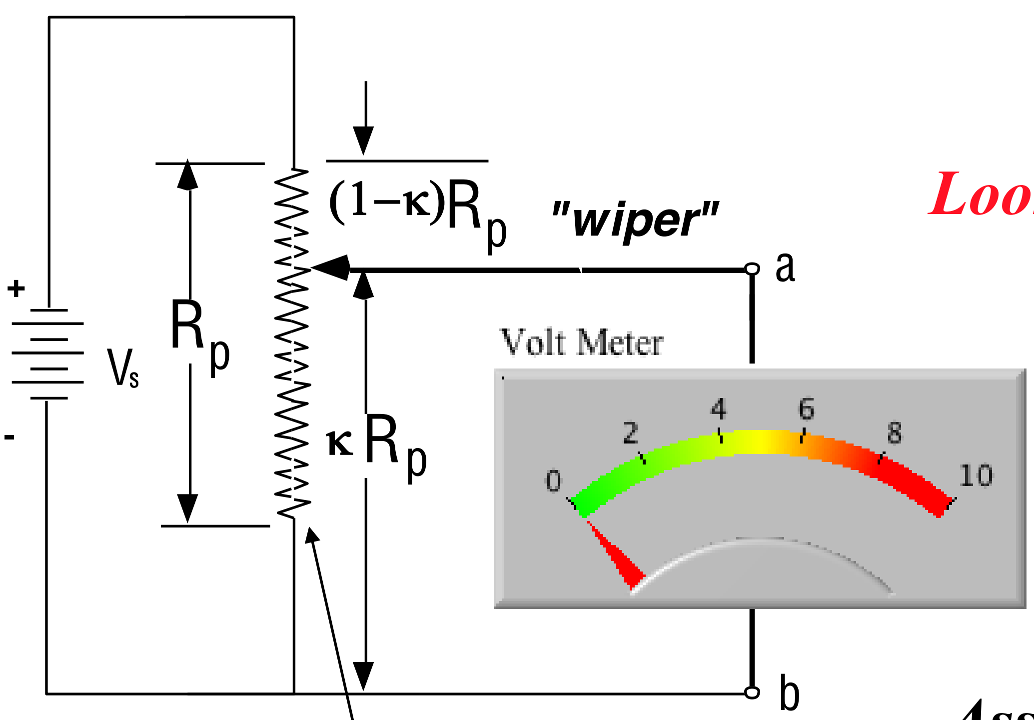
$$V_{ab} = I \cdot R_a$$

$$I = \frac{V}{(R_a + R_b)}$$

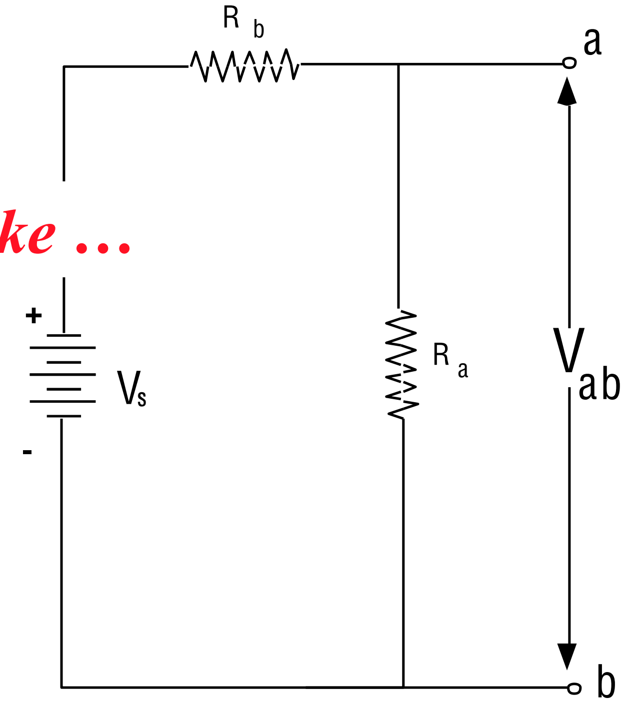
$$V_{ab} = V \cdot \frac{R_a}{(R_a + R_b)}$$

"Voltage Divider" …
Takes original voltage and
Reduces its magnitude

Voltage Dividing Rehostat



Looks like …

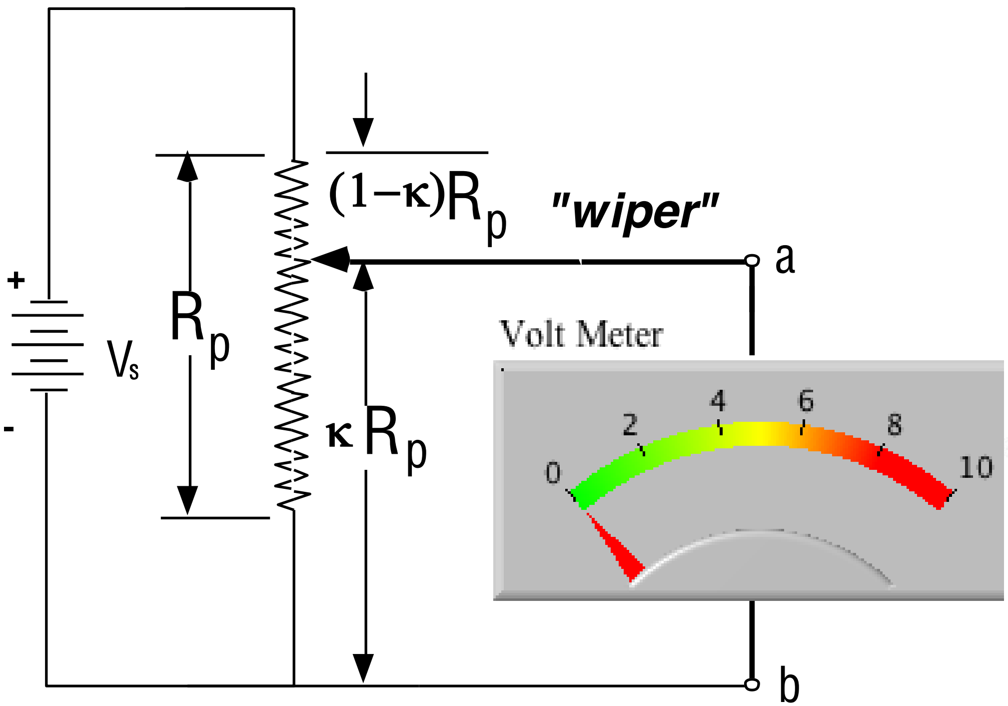


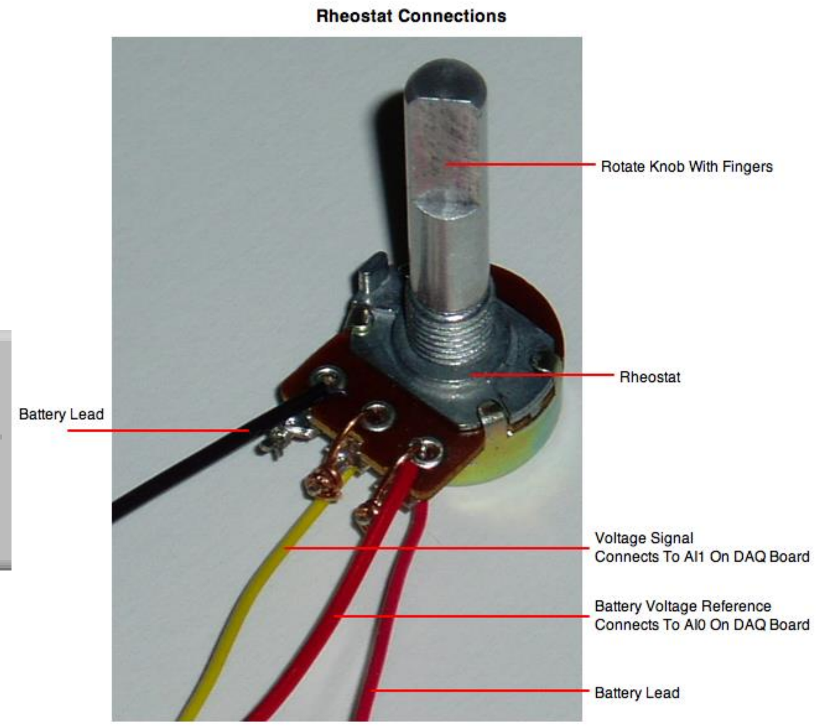
- from Thevenin

Assuming voltmeter has Nearly infinite impedance

$$V_{ab} = V \cdot \frac{\kappa R_p}{(\kappa R_p + (1-\kappa) R_p)} = \kappa \cdot V$$

Voltage Dividing Potentiometer



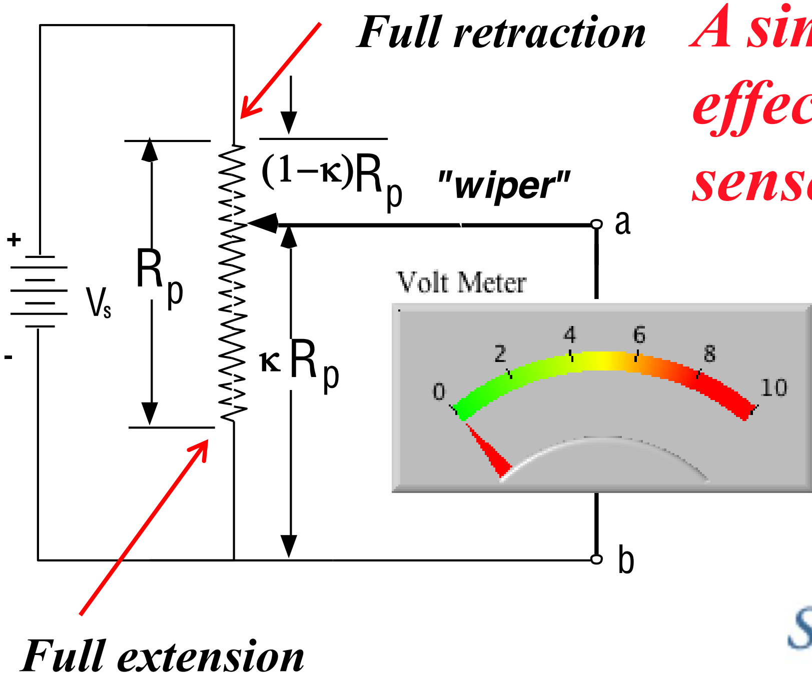


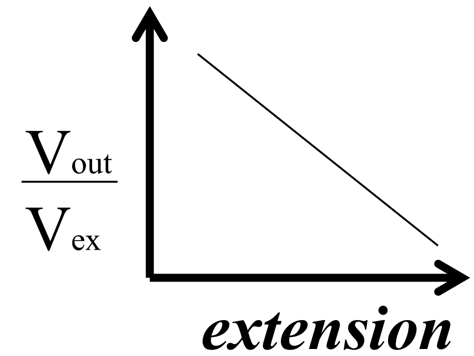
- Like a Rheostat, Only Smaller

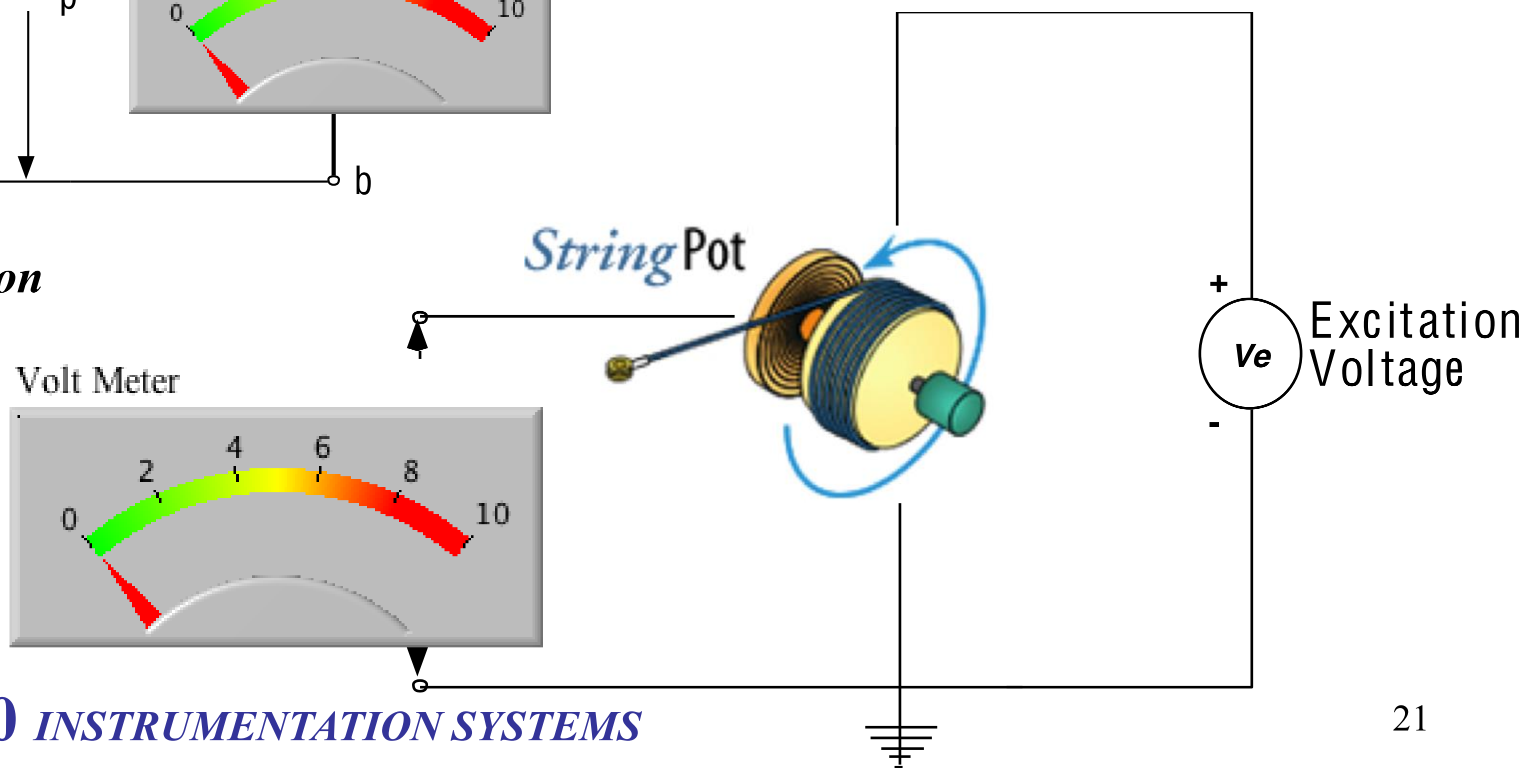
$$V_{ab} = V \cdot \frac{\kappa R_p}{\left(\kappa R_p + (1-\kappa) R_p\right)} = \kappa \cdot V$$

Voltage Dividing Potentiometer (2)

A simple but effective position sensor

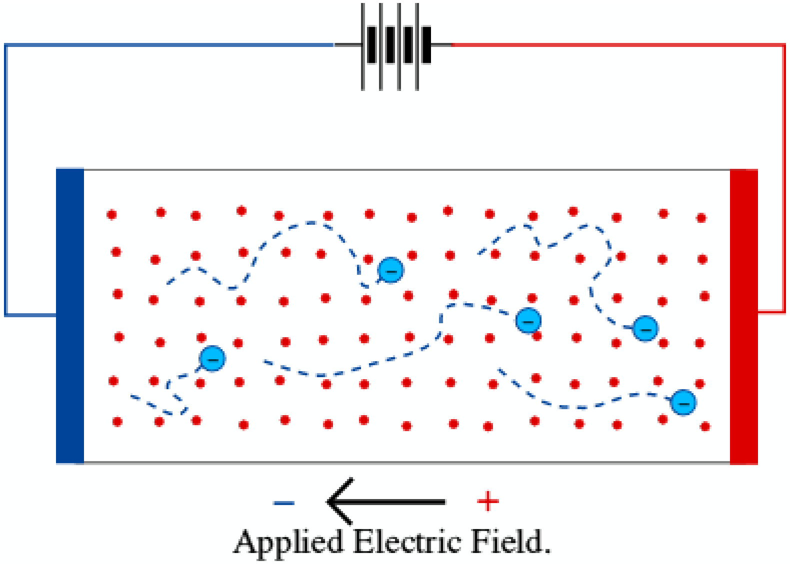






Power Dissipation in a Resistor

As current flow through a resistor, the drop in Voltage (potential) causes energy to be dissipated as heat …



Electrical Resistance Heater Element

- The electrical potential (V) forces electrons through the resistor substrate
- Energy of a single electron is one "Electron volt" $q_e V$
- As an electron strikes an atom in the resistor substrate is releases its kinetic energy
- Rate of energy dissipation (power) for n electron collisions is

$$P = \frac{dE}{dt} = n \cdot \frac{dq_e}{dt} \cdot V = I \cdot V$$

Power Dissipation in a Resistor (2)

Electrical Resistance Heater

$$P = I \cdot V$$

$$I = V / R \rightarrow \boxed{P = \frac{V^2}{R}}$$

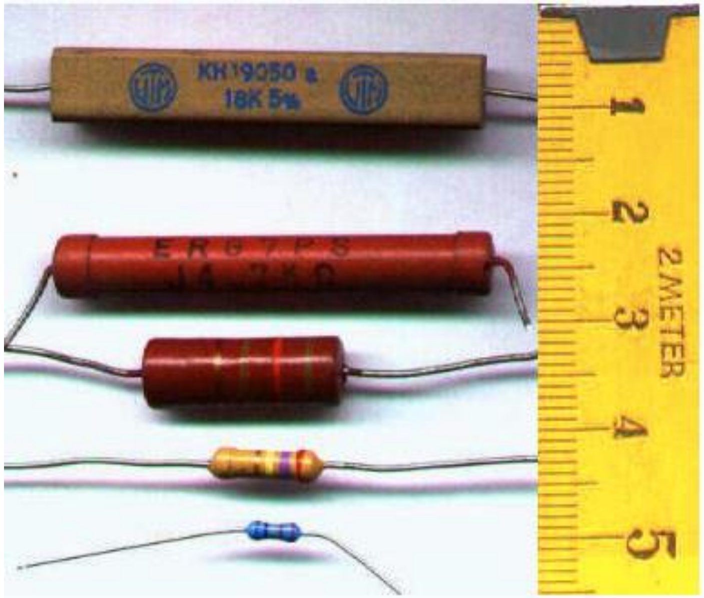
$$V = I \cdot R \rightarrow \boxed{P = I^2 R}$$

Check Units?

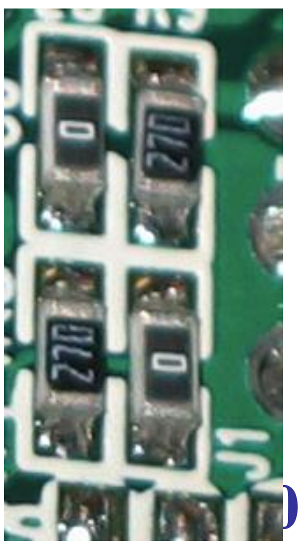
$$\begin{bmatrix} P \sim A^2 \cdot \Omega \\ \Omega \sim \dfrac{m^2 \cdot kg}{s^3 \cdot A^2} \end{bmatrix} ...see...slide...3$$

$$\rightarrow P \sim A^2 \cdot \frac{m^2 \cdot kg}{s^3 \cdot A^2} = \frac{m}{s} \cdot \frac{kg - m}{s^2} = \frac{N - m}{s} = \frac{J}{s} = W$$

Types of Resistors (1)



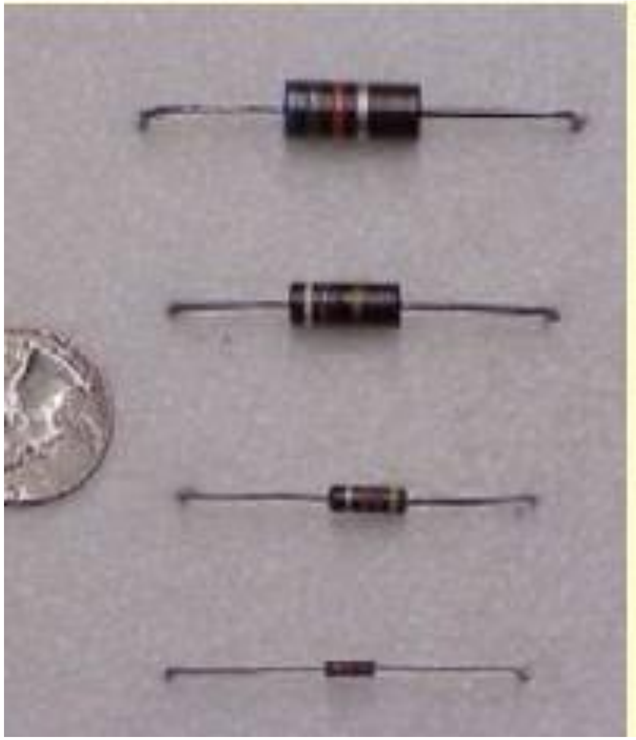
Fixed resistors



Surface Mount Resistors

Type	Properties
Carbon Composition	Carbon mixed with a binder. Molded and baked. Ratio of carbon to binder determines resistance. Most common. Tolerances 10%
Carbon Film	Blend of carbon and an insulator deposited on a ceramic form. Tolerances from 2%-5%.Better temperature stability than Carbon composition.
Metal Film	A thin metal film is deposited on an insulating substrate. Good stability with tolerances around 1%
Wirewound	A conducting wire is wound on a ceramic form. Tend to be physically large. Low resistances. High power capability. Tolerances around 1%. Figure 1-8 shows some wire wound resistors.
Metal Oxide	A metal oxide (e.g.. Tin oxide) film is deposited on a substrate. Excellent temperature stability.

Types of Resistors (2)

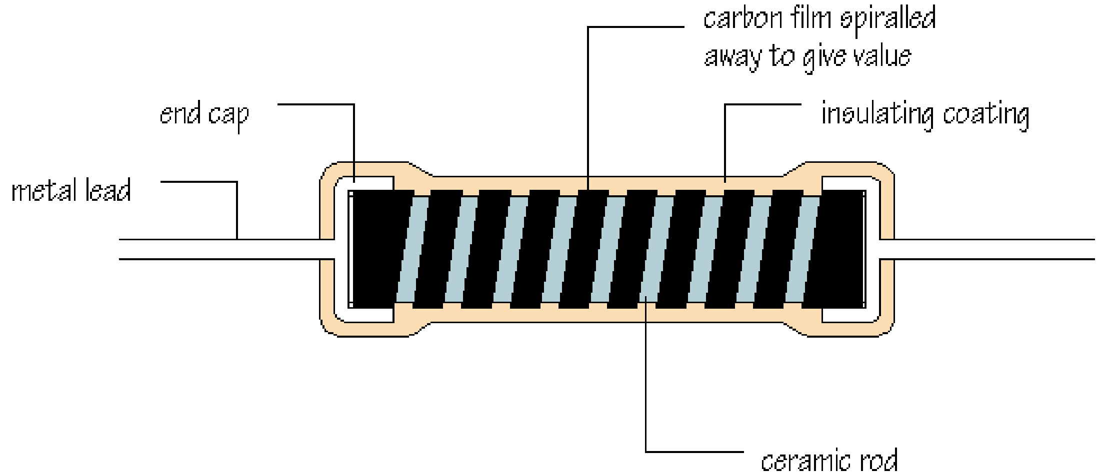


- *Carbon composition* resistors consist of a solid cylindrical resistive element with embedded wire leadouts or metal end caps to which the leadout wires are attached.

- Resistive element is made from a mixture of finely ground (powdered) carbon and an insulating material (usually ceramic). The mixture is held together by a resin.

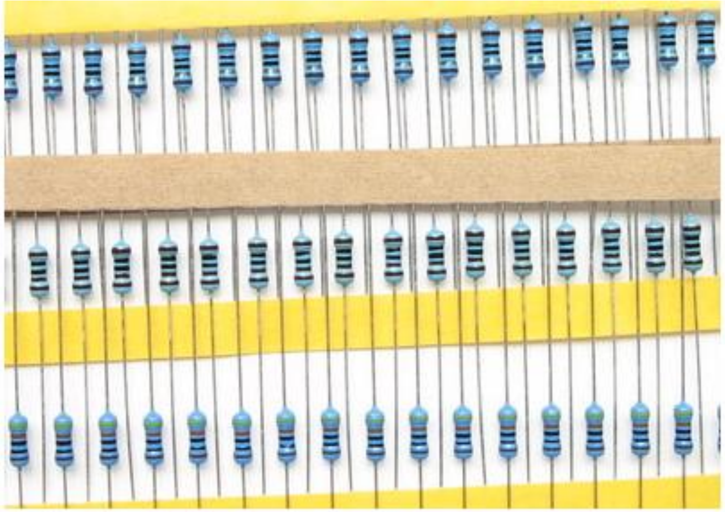
- Resistance is determined by the ratio of the fill material (the powdered ceramic) and the carbon.

Types of Resistors (3)



- *Carbon film resistors* are cheap and easily available, with values within 10% or 5% of their marked, or 'nominal' value.
- During manufacture, a thin film of carbon is deposited onto a small ceramic rod.
- Resistive coating is peeled away in an automatic machine until resistance between ends rod is within tolerance
- Metal leads and end caps are added and resistor is covered insulating coating and painted with colored bands to indicate the resistor value.

Types of Resistors (4)



Metal Film resistors

- *Metal-film resistor is a* common type of *high precision axial resistor* today is referred to as a
- Metal Film resistors are usually coated with nickel chromium (NiCr)
- Resistance value is determined by cutting a helix through the coating rather than by etching.
- The result is a reasonable tolerance (0.5, 1, or 2%).

Types of Resistors (5)

Wirewound resistors

- *Wirewound resistors* are commonly made by winding a metal wire around a ceramic, plastic, or fiberglass core.
- The ends of the wire are soldered or welded to two caps, attached to the ends of the core.
- The assembly is protected with a layer of paint, molded plastic, or an enamel coating baked at high temperature.
- For higher power wirewound resistors, either a ceramic outer case or an aluminium outer case on top of an insulating layer is used.

Types of Resistors (6)

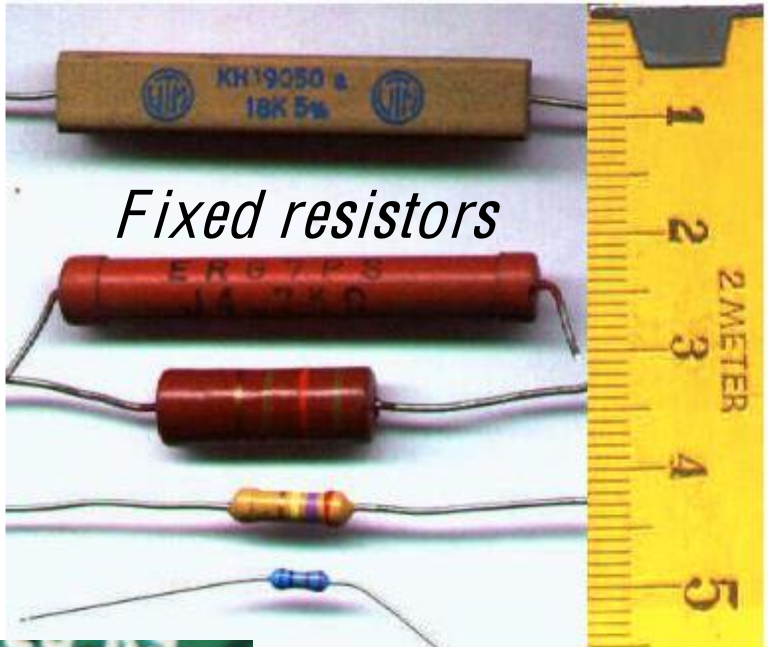
Metal Oxide resistors

- *Metal Oxide resistors* are non-inductive and substitute for carbon comp in most cases.

- They have a resistance element formed by the oxidation reaction of a vapor or spray of tin chloride solution on the heated surface of a glass or ceramic rod.

- The resulting tin-oxide film is adjusted to value by cutting a helix path through the film.

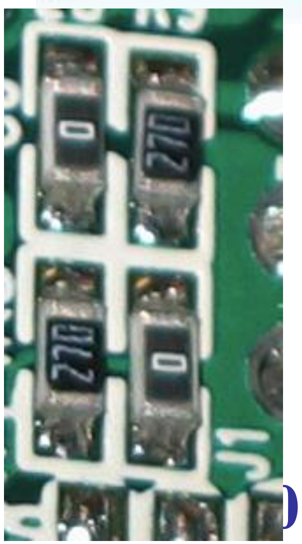
Types of Resistors (7)



• Resistors are manufactured in values from a few milliohms to about a Gigaohm

• Only a limited range of values from the IEC 60063 preferred number series are commonly available.

• These series are called E6, E12, E24, E96 and E192. The number tells how many standarized values exist in each decade (e.g. between 10 and 100, or between 100 and 1000).



Surface Mount Resistors

• So resistors confirming to the E12 series, can have 12 distinct values between 10 and 100, whereas those confirming to the E24 series would have 24 distinct values.

Types of Resistors (8)

• E12 preferred values: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 Ohms

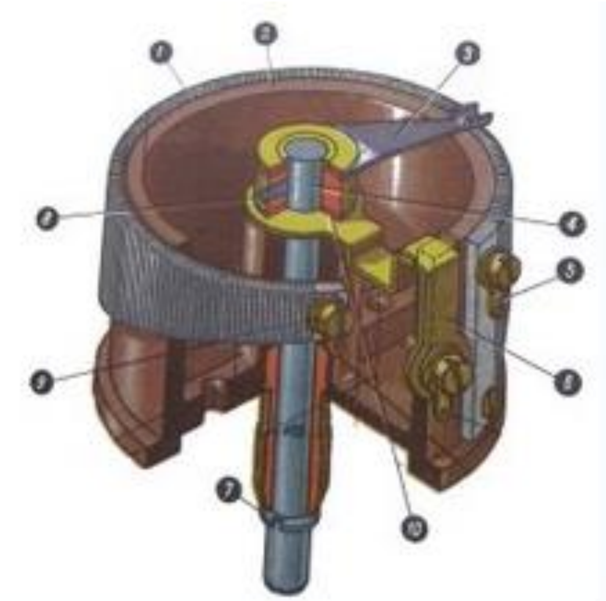
• Multiples of 10 of these values are used, … 0.47 Ω, 4.7 Ω, 47 Ω, 470 Ω, 4.7 k Ω, 47 k Ω, 470 k Ω, and so on ….. .

• E24 preferred values, includes E12 values and: 11, 13, 16, 20, 24, 30, 36, 43, 51, 62, 75, 91 Ohms

• In practice, the discrete component sold as a "resistor" is not a perfect resistance, as defined above. Resistors are often marked with their tolerance (maximum expected variation from the marked resistance).

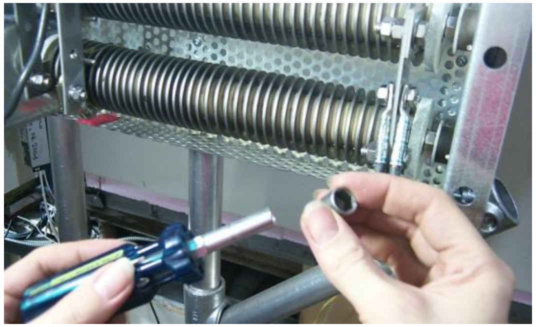
Types of Resistors (9)

Variable resistors



Construction of a wire-wound variable resistor. The effective length of the resistive element (1) varies as the wiper turns, adjusting resistance.

- *Rheostat*: variable resistor with two terminals, one fixed and one sliding. It is used with high currents.



- *Potentiometer*: a common type of variable resistor. One common use is as volume controls on audio amplifiers and other forms of amplifiers.

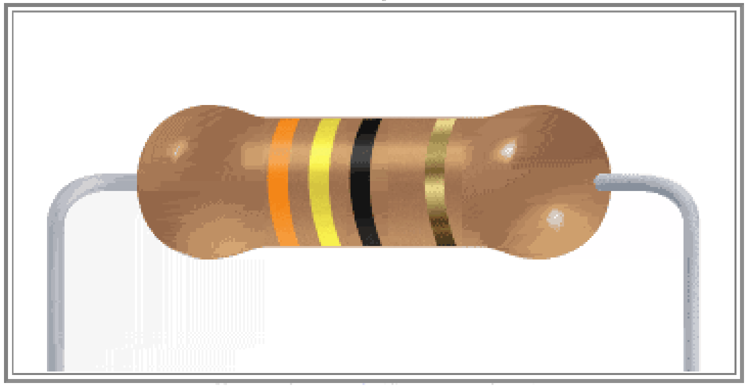
Resistor Color Code (1)

• A resistor is device whose **only** purpose it is to offer resistance to current flow.

• Nominal resistance of a resistor is printed onto the resistor in code.

• Pattern of colored rings is used.

• Most resistors have three rings to encode the value of the resistance, and one ring to encode the tolerance (uncertainty) in percent.



Resistor Color Code (2)

• Ring Colors are internationally defined to as integers 0 -- 9.

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

• First band is the band closest to one end of the resistor.

• First and second band together make a two-digit integer number.

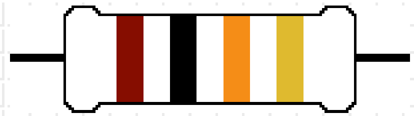
• Multiply number represented by the color of the first band by 10 and add the number represented by the color of the second band.

• Result is a two-digit integer number.

Resistor Color Code (3)

- Ring Colors are internationally defined to as integers 0 -- 9.

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9



- Number represented by the color of the third band is the number of zeroes that must be appended to the number obtained from the first two bands to get the resistance in Ohms.

- (If this number is 1, you add one zero, or multiply by 10^1, if the number is 2, you add two zeroes, or multiply by 10^2, etc.)

Resistor Color Code (4)

- Ring Colors are internationally defined to as integers 0 -- 9.

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

- The next band, (i.e. the fourth band), is the tolerance band -- typically either gold or silver.

- A gold tolerance band indicates actual value will be within 5% of the nominal value.

- A silver band indicates 10% tolerance.

Resistor Color Code (5)

- Ring Colors are internationally defined to as integers 0 -- 9.

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

- If the resistor has one more band past the tolerance band it is a quality band.

- Read the number as the % failure rate per 1000 hours, assuming maximum rated power is being dissipated by the resistor.

Resistor Color Code (6)

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

23 Mohms, +/-5%

RESISTOR COLOR CODES

Color	1st & 2nd Significant Figures	Multiplier	Tolerance
Black	0	1	--
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	--
Blue	6	1,000,000	--
Violet	7	10,000,000	--
Gray	8	100,000,000	--
White	9	--	--
Gold	--	0.1	±5%
Silver	--	0.01	±10%
No Color	--	--	±20%

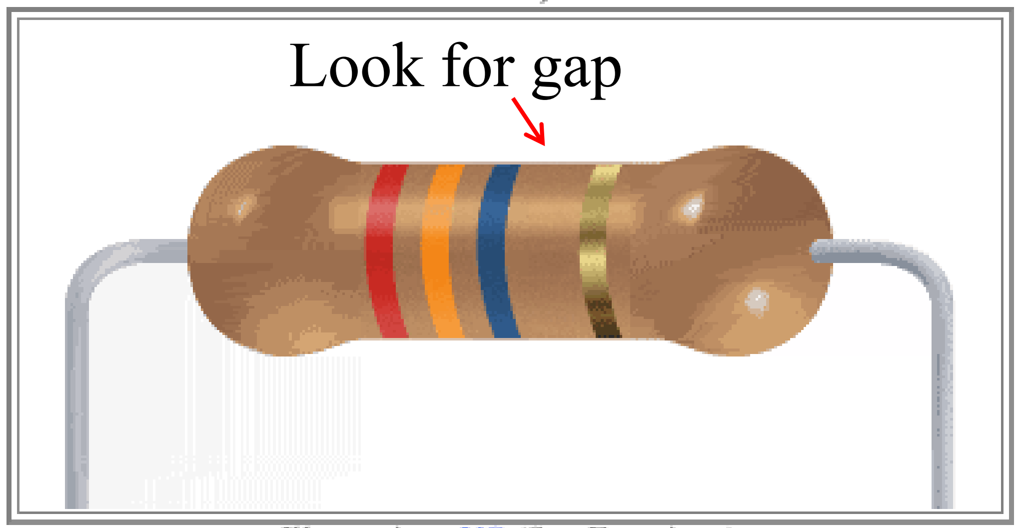
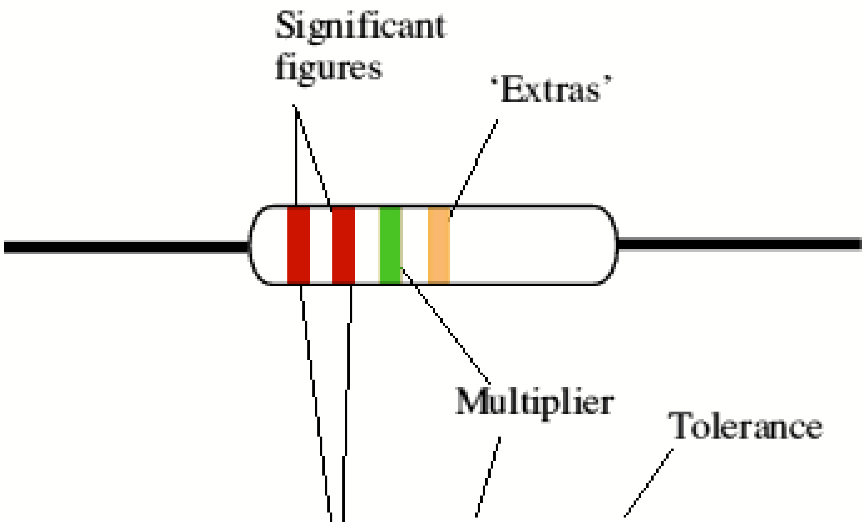


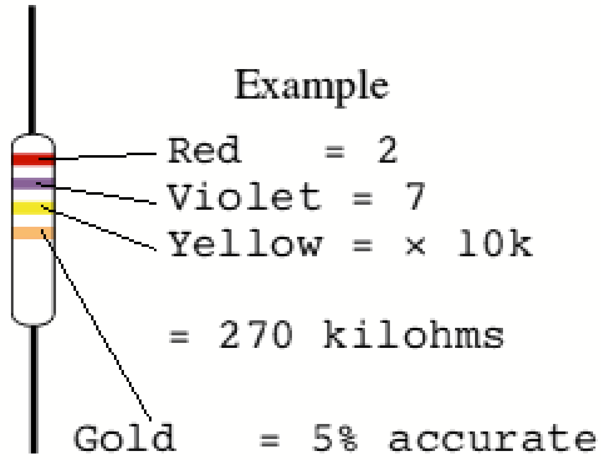
Illustration: YO (San Francisco)

$$(2 \cdot 10 + 3) \cdot 10^6 \pm 5\% = \left(23 \pm 1.15\right) M\Omega$$

Resistor Color Code (7)



Silver		0.01	10%
Gold		0.1	5%
Black	0	1	
Brown	1	10	1%
Red	2	100	2%
Orange	3	1k	
Yellow	4	10k	
Green	5	100k	0.5%
Blue	6	1M	
Violet	7	10M	
Grey	8		
White	9		



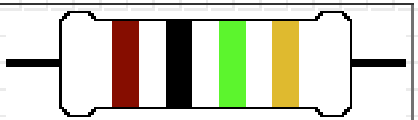
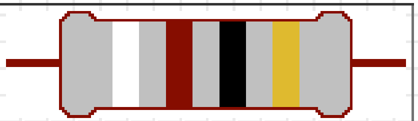
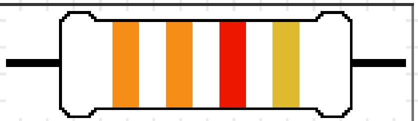
- ***Another Color Coding Example***

Precision Resistor Coding

- 5-band axial resistors5-band identification is used for higher tolerance resistors (1%, 0.5%, 0.25%, 0.1%), to notate the extra digit. The first three bands represent the significant digits, the fourth is the multiplier, and the fifth is the tolerance.

Color Code Quiz

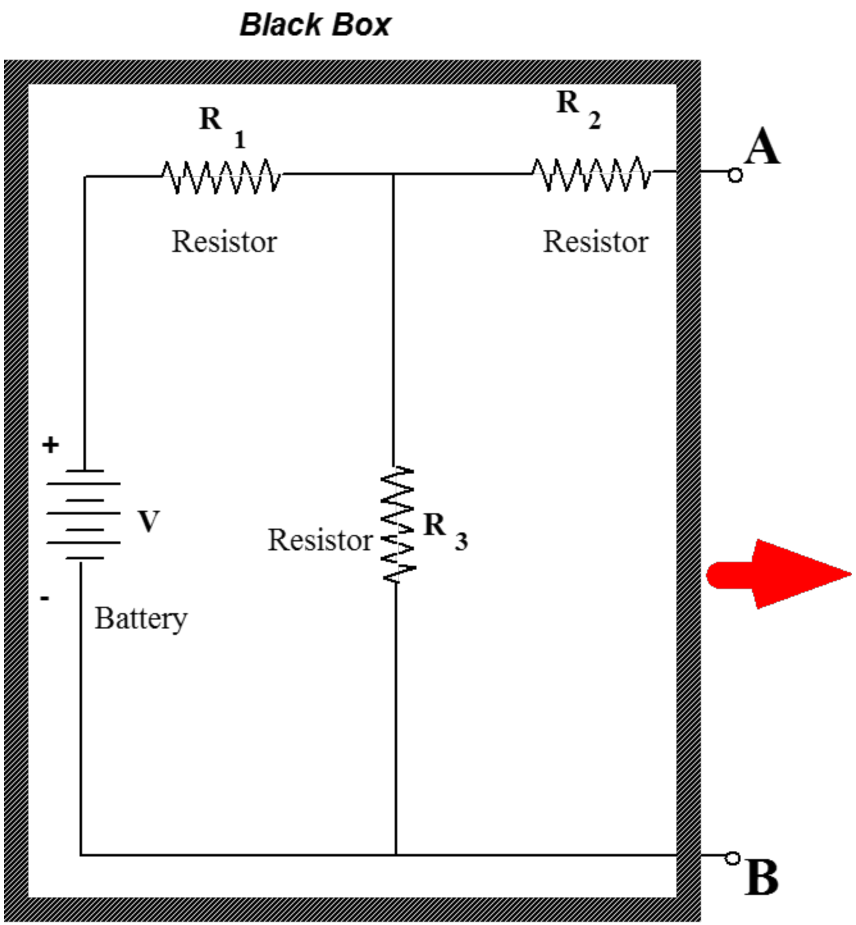
Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White
0	1	2	3	4	5	6	7	8	9

Resistors	Nominal R Ω	Tolerance %
R_1 	10^6	5%
R_2 	91	5%
R_3 	3300	5%

RESISTOR COLOR CODES

Color	1st & 2nd Significant Figures	Multiplier	Tolerance
Black	0	1	--
Brown	1	10	±1%
Red	2	100	±2%
Orange	3	1,000	±3%
Yellow	4	10,000	±4%
Green	5	100,000	--
Blue	6	1,000,000	--
Violet	7	10,000,000	--
Gray	8	100,000,000	--
White	9	--	--
Gold	--	0.1	±5%
Silver	--	0.01	±10%
No Color	--	--	±20%

Homework 2: Due in Lab Week of Jan. ~~20-24~~. Feb 1-5



For:

$V = 12\ Vdc$
$R_1 = 120\ \Omega$
$R_2 = 200\ \Omega$

Calculate R_3 so that

$V_{AB} = 4\ Vdc$

How Much Current will be Drawn Through *AB* (R_2) when circuit is closed across *AB* *with no load*