Resistance

Ω

Conductivity in Materials

Some materials have a lot of Free Valence Electrons.

A cubic centimeter of copper has about 10^{23} Free Electrons.

Free Electrons move easily in an Electrostatic Field or when pushed by a Magnetic Field.

Materials in which Electrons move easily are called Conductors.

Silver, Copper, Gold, Aluminum, Zinc, and most metals to some degree are conductors.

Insulation

Some Materials have very few to No Free Electrons. All the electrons are bound tightly to the atomic structure, and are unable to flow in even strong electrostatic fields.

These materials are called Insulators.

Glass, Mica, Quartz, Ceramics, Cellulose, Polyethylene and other Plastics, Waxes, Rubber, Most Organic Fluids, and thankfully Air.

Semiconductors

Atoms with Four Valence Electrons are tightly bound only in pure crystal form.

Impurities with five valence electrons in the crystal create excess electrons which can move.

Impurities with three valence electrons create “holes” into which electrons can move.

Semiconductors are used to create Diodes, Transistors and Integrated Circuits.
Carbon, Silicon, Germanium, Gallium- Arsenide, Indium-Antimony.

Resistance

Some materials conduct electrical current, but poorly. The electrons bump into the atoms and give up electrical energy as heat.

This "friction" to current flow, an impediment to charge movement, is called Resistance.

For any fixed value of Voltage an increase of Resistance will cause a Decrease of Current.

Resistance symbol is R, measured in Ohms.

The Ohms symbol is the Greek *Omega* Ω.

The Resistance of a conductor is dependant upon the type of Material.

Silver	$1.645 \times 10^{-8}\ \Omega\text{–m}$
Copper	$1.723 \times 10^{-8}\ \Omega\text{–m}$
Gold	$2.443 \times 10^{-8}\ \Omega\text{–m}$
Aluminum	$2.825 \times 10^{-8}\ \Omega\text{–m}$
6061-T6	$4.066 \times 10^{-8}\ \Omega\text{–m}$
Tungsten	$5.485 \times 10^{-8}\ \Omega\text{–m}$
Iron	$12.30 \times 10^{-8}\ \Omega\text{–m}$
304 SS	$68.97 \times 10^{-8}\ \Omega\text{–m}$
316 SS	$74.96 \times 10^{-8}\ \Omega\text{–m}$
Nichrome	$99.72 \times 10^{-8}\ \Omega\text{–m}$
Carbon	$3500 \times 10^{-8}\ \Omega\text{–m}$

Length Of Conductor

The Resistance of a Conductor is directly proportional to the length of the conductor.

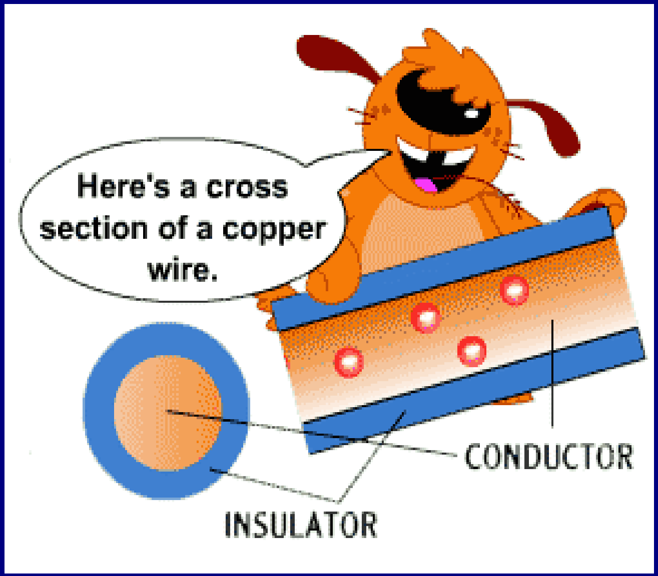
The longer a wire is the more material the current has to go through. Double the wire length and you double the resistance.

Think of it as more distance the current has to go for a given amount of energy.

Conductor Cross Sectional Area

The Resistance of a Conductor is Inversely Proportional to the Cross Sectional Area of the conductor.

With more area to fly through the electrons are able to flow more easily, with less loss.



Think large diameter pipe vs small pipe, or six lanes of highway vs one lane of parking lot.

Wire is catorgorized in American Wire Gauge, AWG, or by it's diameter in millimeters.

Component : Resistors

Resistors are used to limit the flow of Current.

Resistors come in many sizes, shapes, and values.

Resistor Ratings

Resistors are rated by:

Resistance in Ohms ... Ω

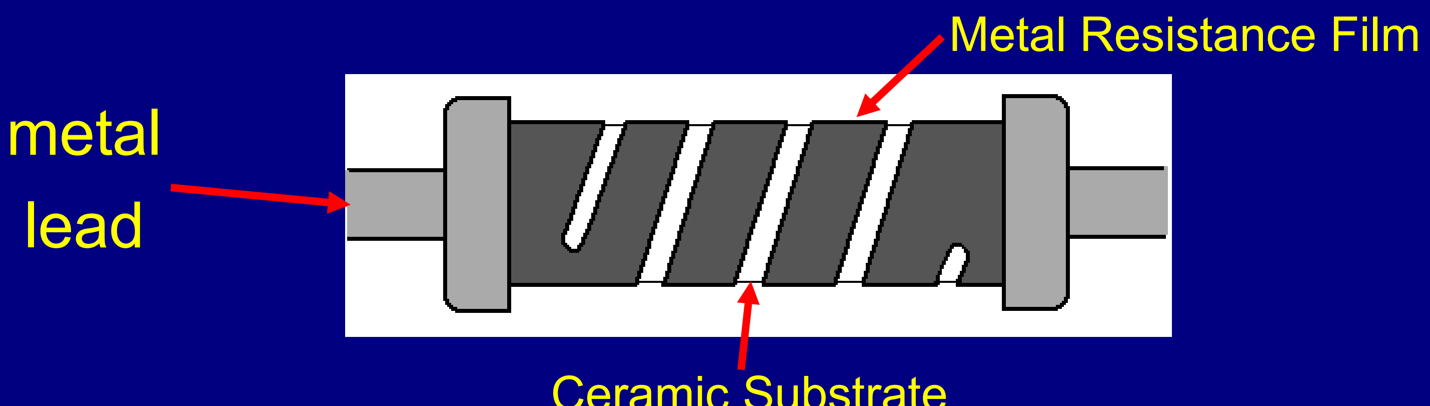
Power Dissipation in Watts ... W

Tolerance in Percent ... %

Sometimes: Reliability in % failures per 1000 hours

Maximum safe Operating Voltage

Noise



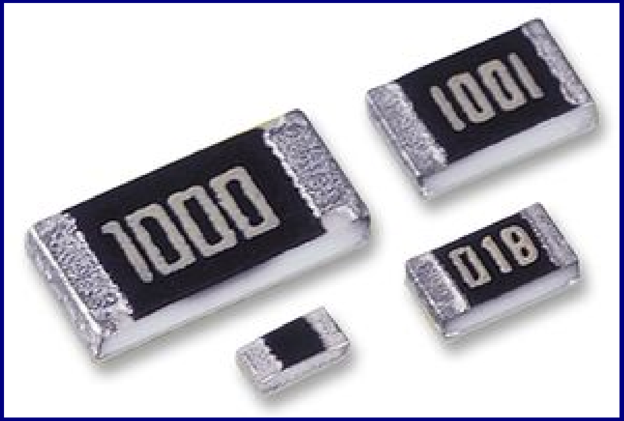
Resistor Physical Size

Large Resistors are able to Dissipate more Power than small Resistors can.

Standard Resistors are available in sizes:
1/8, 1/4, 1/2, 1, 2, 3, 5, 10, 15, 20, 25, 30, 50W

Surface Mount resistors:

0201	.5mm x .25mm	1/20 W
0402	1mm x .5mm	1/16 W
0603	1.5mm x .8mm	1/10 W
0805	2mm x 1.27mm	1/8 W
1206	3mm x 1.5mm	¼ W
2010	5mm x 2.5mm	½ W
2512	6.35mm x 3mm	1 W



5% Resistor Standard Values

5% Standard Decade Value Resistors from 0.1 ohm to 20 million ohms are:

10	11	12	13	15	16	18	20
22	24	27	30	33	36	39	43
47	51	56	62	68	75	82	91

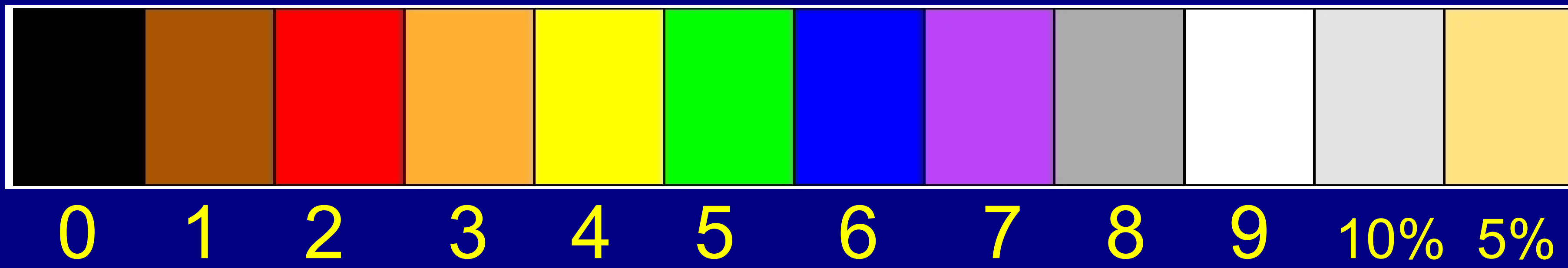
eg: 0.33Ω, 2.4Ω, 10Ω, 47Ω, 150Ω, 270Ω, 560Ω, 1.2kΩ, 3kΩ, 15kΩ, 82kΩ, 130kΩ, 200kΩ, 330kΩ, 510kΩ

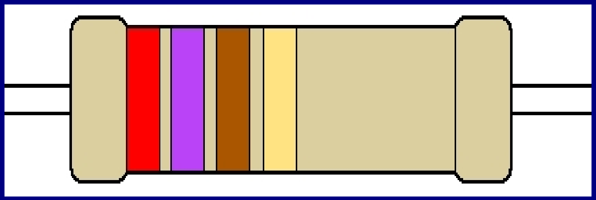
1% Precision Standard Values

1% resistors from 1 ohm to 2.2 million ohms are:

10.0	10.2	10.5	10.7	11.0	11.3	11.5	11.8	12.1
12.4	12.7	13.0	13.3	13.7	14.0	14.3	14.7	15.0
15.4	15.8	16.2	16.5	16.9	17.4	17.8	18.2	18.7
19.1	19.6	20.0	20.5	21.0	21.5	22.1	22.6	23.2
23.7	24.3	24.9	25.5	26.1	26.7	27.4	28.0	28.7
29.4	30.1	30.9	31.6	32.4	33.2	34.0	34.8	35.7
36.5	37.4	38.3	39.2	40.2	41.2	42.2	43.2	44.2
45.3	46.4	47.5	48.7	49.9	51.1	52.3	53.6	54.9
56.2	57.6	59.0	60.4	61.9	63.4	64.9	66.5	68.1
69.8	71.5	73.2	75.0	76.8	78.7	80.6	82.5	84.5
86.6	88.7	90.9	93.1	95.3	97.6			

Resistor Standard Marking





First Band: Most Significant Digit

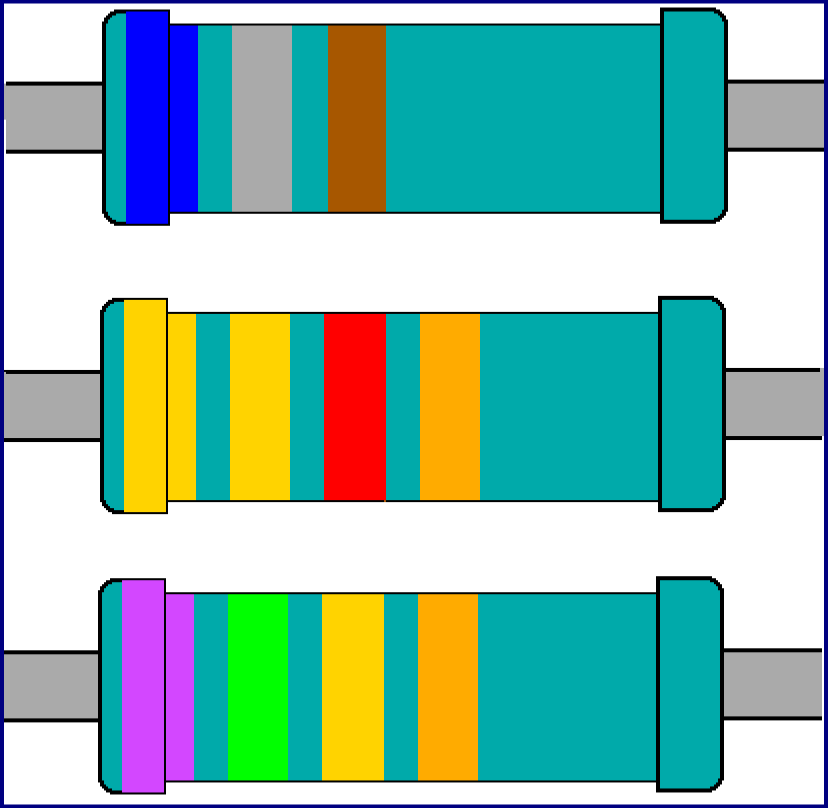
Second Band: Second Significant Digit

Third Band: Multiplier

Forth Band: Tolerance

No forth band? 20% tolerance.

What's the Value?



680Ω 20%

3300Ω 5%

75,000Ω 5%

Tolerance

A 1000Ω 5% resistor can be any value between 950Ω and 1050Ω.

A 1000Ω 20% resistor is still "in tolerance" anywhere between 800Ω and 1200Ω. Early vacuum tube radios were "good enough" with 20% resistors, as tubes are highly variable.

Modern analog circuits often make use of 1% resistors for their precision and stability.

What is the expected resistance range of a 2700Ω 5%?

5% of 2700Ω is 135Ω, so range is 2565Ω to 2835Ω.

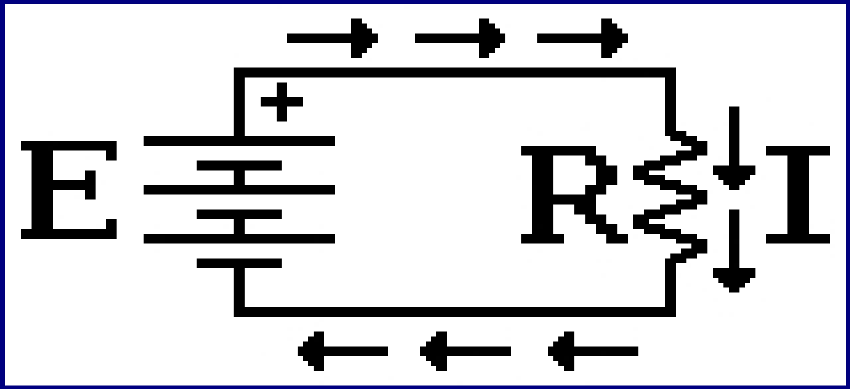
OHM's LAW RULES!

Ohm's Law

Current in a Resistive Circuit is Directly Proportional to Voltage and Inversely Proportional to Circuit Resistance.

$$I = \frac{E}{R}$$

Whatsdatmean?



$$I = \frac{E}{R}$$

For a Fixed Resistance:

Increase Voltage and Current Increases.

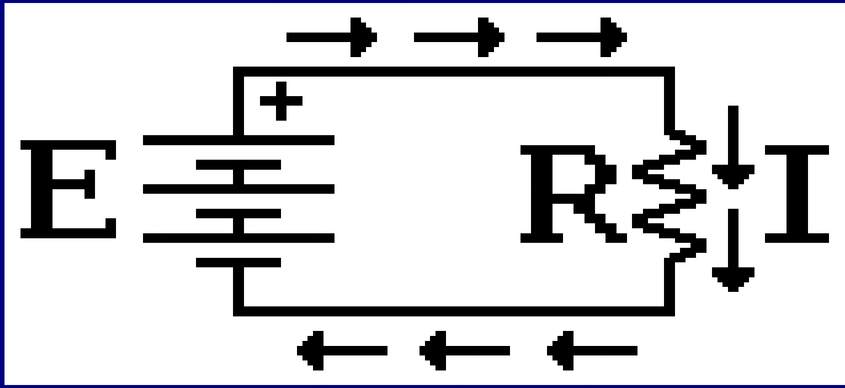
Decrease Voltage and Current Decreases.

For a Fixed Voltage:

Increase Resistance and Current Decreases.

Decrease Resistance and Current Increases.

Evaluating Electromagnetic Potential!



$$E = I \times R$$

Voltage is a Product of Current & Resistance

For a Fixed Current:

Increase Resistance and Voltage Increases.

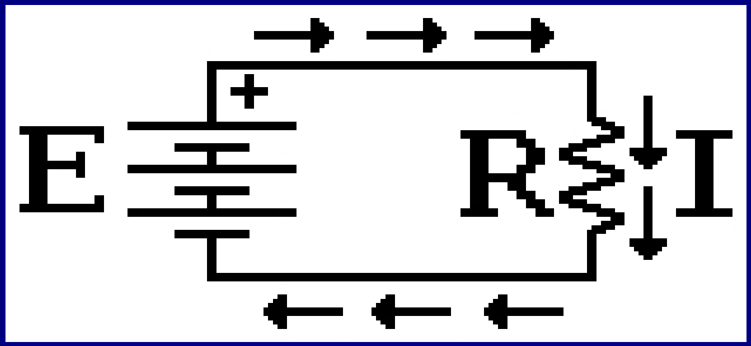
Decrease Resistance and Voltage Decreases.

For a Fixed Resistance:

Increase Current and Voltage Increases.

Decrease Current and Voltage Decreases.

Calculating Resistance



$$R = \frac{E}{I}$$

Resistance is Directly Proportional to Voltage and Inversely Proportional to Current.

For a fixed Current:

Increase Voltage and Resistance increases.

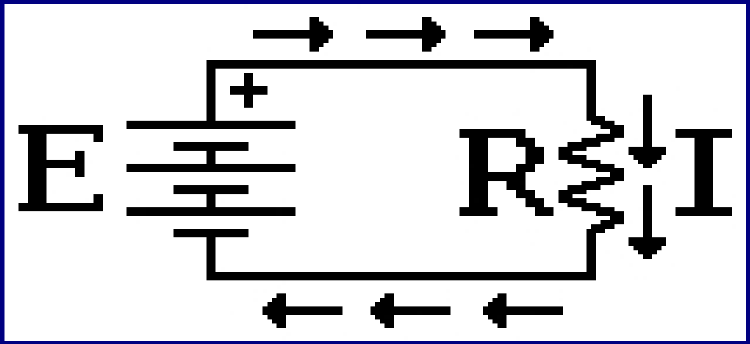
Decrease Voltage and Resistance decreases.

For a Fixed Voltage:

Increase Current and Resistance decreases.

Decrease Current and Resistance increases.

Calculating Values



Given Any Two of E, I, or R, Calculate the Third.

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

$$E = I \times R$$

Energy & Power

We learned that One Volt of Potential is the movement of One Coulomb through One Joule of Energy.

$$V = \frac{W}{Q}$$

We also learned that One Coulomb of flow in One Second is One Ampere.

$$I = \frac{Q}{t}$$

Energy & Power

When One Coulomb of Charge flows through a potential of One Volt in One Second, then One Joule of Energy is dissipated in One Second.

$$\frac{Q}{t} \times \frac{W}{Q} = \frac{W}{t} = P$$

One Joule of Energy dissipated in One Second is One Watt.

Power is Energy Over Time

One Ampere flowing through a Potential of One Volt dissipates One Watt of Power

$$P = I \times V$$

Power is the Rate of doing Work: $P = \frac{W}{t}$

Additional Power Formula

Given $$P = E \times I$$

And $$E = I \times R$$

Then $$P = I \times R \times I = I^2 R$$

Or $$I = \frac{E}{R}$$

So $$P = E \times \frac{E}{R} = \frac{E^2}{R}$$

Other Forms

Frequently Other forms of these formula are required.

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

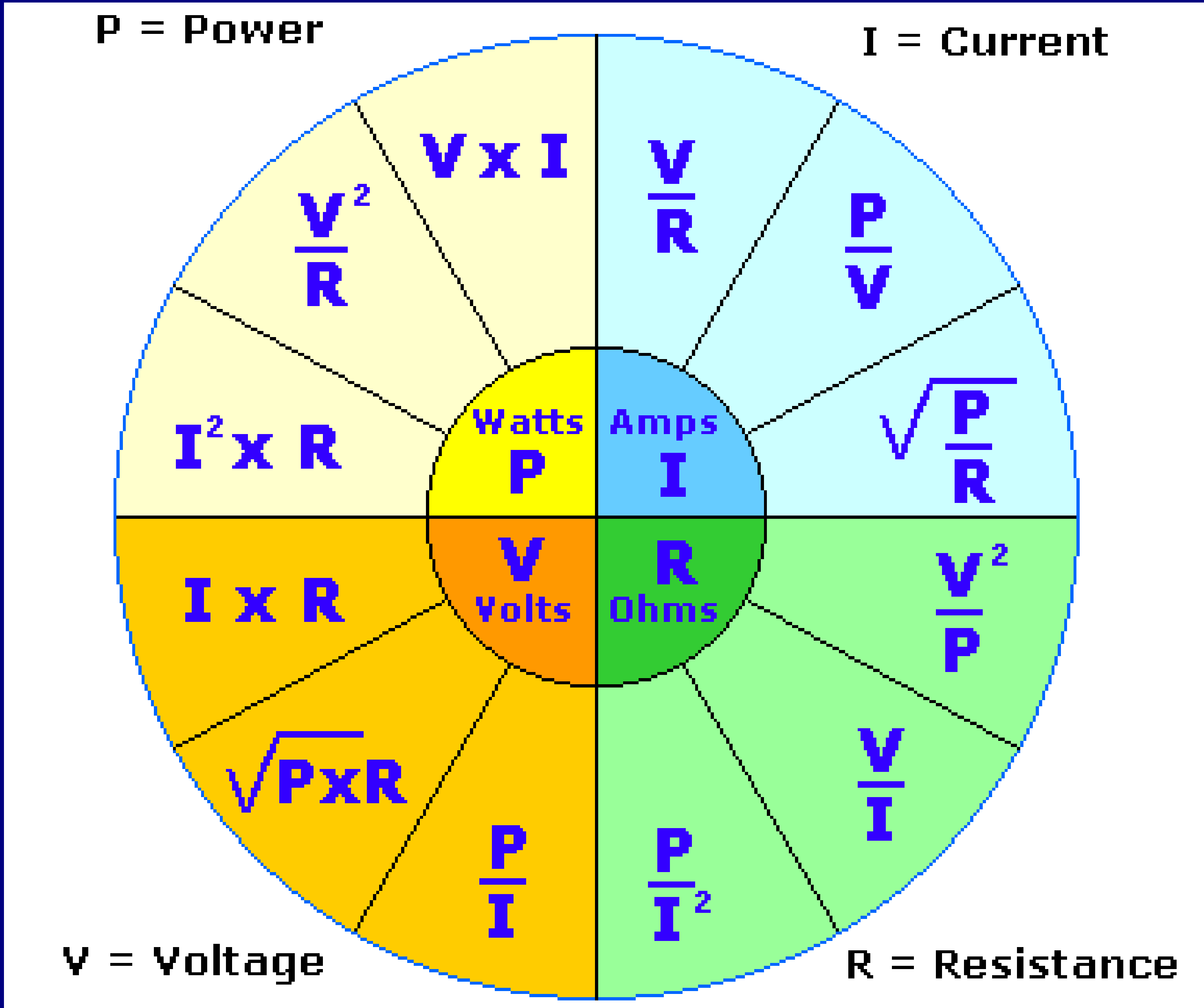
$$V = \sqrt{P \times R}$$

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

$$P = I^2 \times R$$

$$I = \sqrt{\frac{P}{R}}$$

$$R = \frac{P}{I^2}$$


P = Power
I = Current
V = Voltage
R = Resistance
Watts
P
Amps
I
V
Volts
R
Ohms
V x I
V² / R
I² x R
V / R
P / V
√(P / R)
I x R
√(PxR)
P / I
V² / P
V / I
P / I²