Technician License Course
Chapter 3
Electricity and Circuits

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Fundamentals of Electricity

Electric Charges can be Positive or Negative.

- Electrons are negatively charged atomic particles.
- Protons are positively charged particles.
- Ions are atoms with a charge which may be positive or negative.

Electric current is the rate that charges flow through a conductor. (charges per second)

For practical purposes in most cases, current is the movement of electrons.

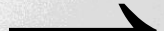
Conductors (and Insulators)

A conductor is a material that allows charges or electrons to move with relative freedom within the material.

- Metals – most are good conductors
- Liquids with dissolved salts

An insulator is any non-conductor.

- Glass, Ceramic, Plastic, Rubber, and others
- Insulators may breakdown and become a conductor.



Fundamentals of Electrical Circuits

In electronics and radio, we control currents and voltages to make things happen.

- Control is accomplished by component devices.
- Devices are connected together by conductors to make an electrical circuit.
  - A circuit is a path where charges can move.
  - A circuit includes a force to cause charges to move.

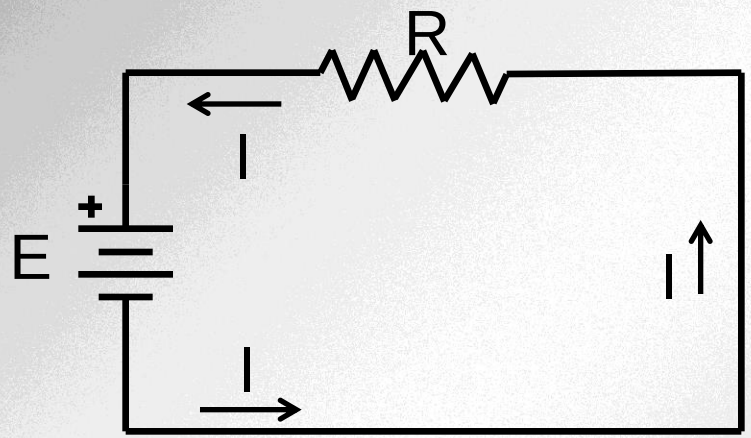
Properties of an Electrical Circuit

There are four primary parts of an electrical circuit:

- Voltage – The force
- Current – The charges
- Resistance – The opposition or losses
- Circuit – The Path

Some other electrical properties will be discussed later: Power, Capacitance, Inductance, Rectification

Elementary Electrical Circuit



A voltage E and resistance R connected by conductors.

- Current I is the direction of electron movement.
- Current I is the same at all points.

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Voltage and Current are related

Voltage is an **ElectroMotive Force (EMF)**. It must be present to have a Current in a circuit.

The ratio of Voltage (E) to Current (I) in the circuit is called Resistance (R).

The resistance ratio is mathematically expressed in Ohm's Law: R = E/I or E = IR

The unit of resistance, the Ohm, is defined such that one Volt causes a current of one Amp through a resistance of one Ohm. Symbol is Ω

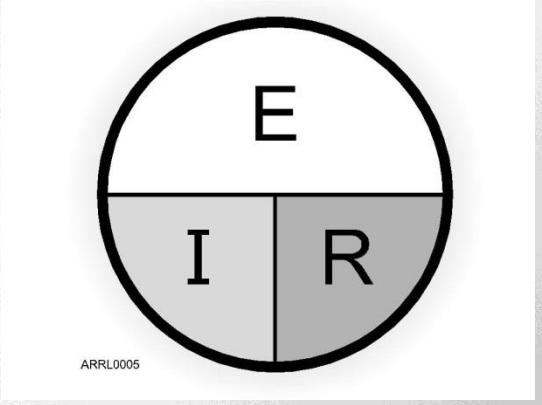
Ohm's Law Circle

E is voltage in Volts.

I is current in Amperes or Amps.

R is resistance in Ohms.

One Volt and one Ohm → one Amp



Cover the variable that you need to find.

- Cover E → E = I * R
- Cover I → I = E **Over** R
- Cover R → R = E **Over** I

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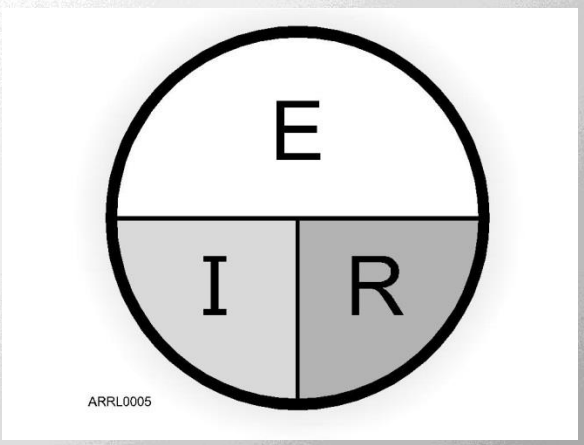
Using Ohm's Law

E	R	I
1 Volt	1 Ohm	?
?	100 Ohm	0.25 Amp
70.7 Volts	?	1.414 Amps
5 Volts	1 Kohm	? mAmp
12.6 Volts	?	50 mAmp
?	56 Ohm	0.160 Amp



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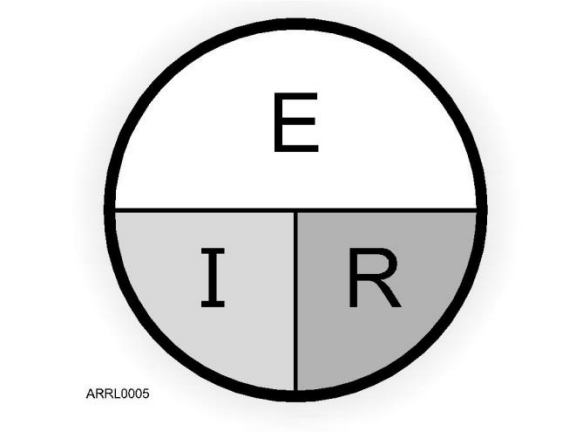
Using Ohm's Law

E	R	I
1 Volt	1 Ohms	1 Amp
25 Volts	100 Ohms	0.25 Amp
70.7 Volts	50 Ohms	1.414 Amps
5 Volts	1 Kohms	5 mAmp
12.6 Volts	252 Ohms	50 mAmp
8.96 Volts	56 Ohms	0.160 Amp



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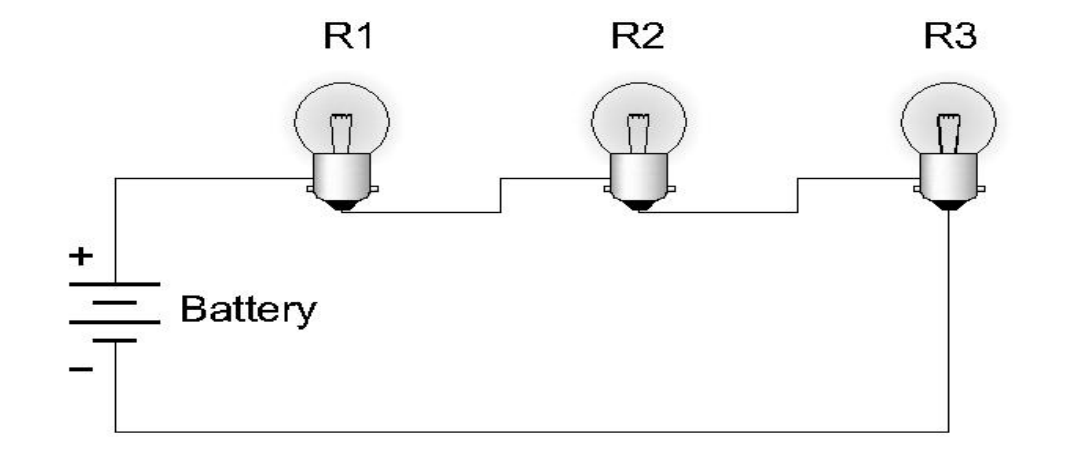
Series Circuits

Series circuits provide only one path for current flow.



The current is the same through all lamps but each lamp may have a different voltage.

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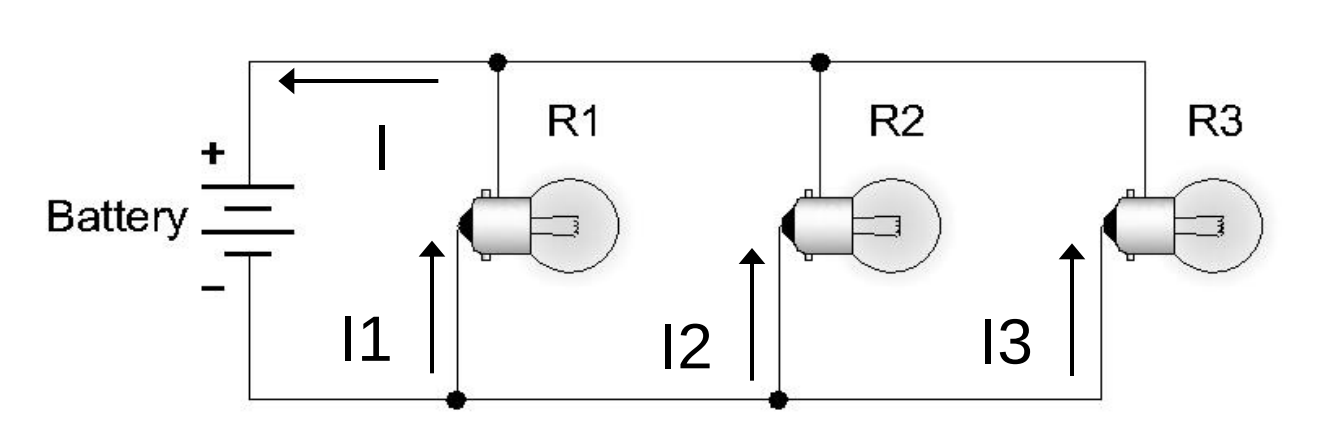
Parallel Circuits

Parallel circuits provide independent paths for current flow.



The voltage is the same for all lamps but the currents may be different.

Kirkoff's Law => $I = I1 + I2 + I3$

Faults in Circuits

Faults caused by component failures:

- Open Circuit – Zero or Low Current.
- Short Circuit – Higher than normal Current.
- Components with changed values.
- Mis-wiring and poor soldering.

Opens in Circuits

Open circuits may be caused by:

- Broken wires
- Burned out parts, especially resistors.
- Tarnished or corroded switch contacts.

Use Voltmeter to look for missing voltage.

Use Ohmmeter to find high resistance.

Switch contacts may be cleaned with chemicals or a burnishing tool.

Shorts in Circuits

Short circuits may be caused by:

- Broken, Burned, or worn-out insulation.
- Burned out parts, especially capacitors.
- Metal shielding.

Use Voltmeter to look for low voltage.

Use Ohmmeter to find low resistance.

Energy, Work, and Power

Energy is the potential to do work. When energy is expended to move or accelerate something, work is performed and energy is converted to a different form.

When electrons are accelerated, energy is converted to heat or fields.

Power is the rate that energy is converted.

Power is measured in the units of Watts (W).

One Watt is one Volt causing one Amp.

Power Formulas

Power is defined as the Rate at which Energy is being converted by a system or device to do work.

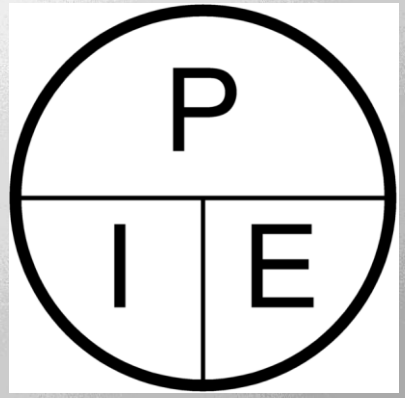
One Amp, one Volt, one Watt

$P = I * E \rightarrow E = P/I \rightarrow I = P/E$

Substitute Ohm's Law for E and I:

$P = (E/R) * E = \mathbf{E^2 / R}$

$P = I * (I * R) = \mathbf{I^2 * R}$



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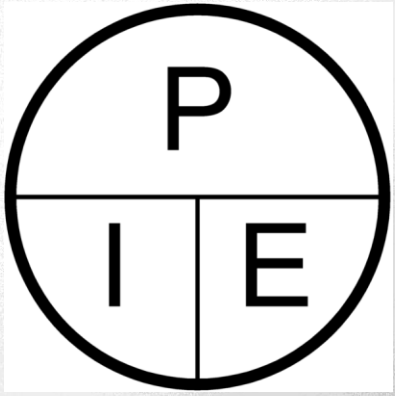
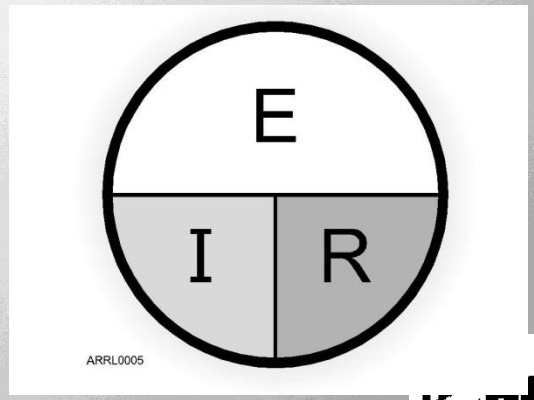
1 Volt	1 Amp	1 Ohm	? Watt
12.6 Volts	10 Amps	? Ohms	? Watts
70.7 Volts	? Amps	50 Ohms	? Watts
? Volts	5 Amps	4 Ohms	? Watts
117 Volts	? Amps		1 KW
? Volts	0.707 Amps	100 Ohms	? Watts
? Volts		600 Ohms	1 mW





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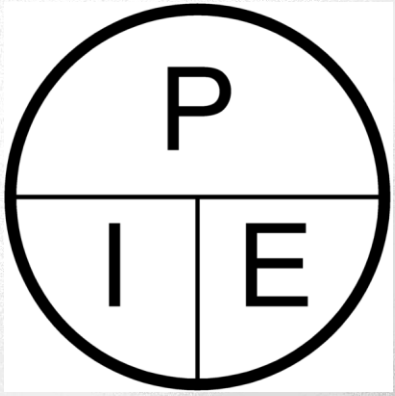
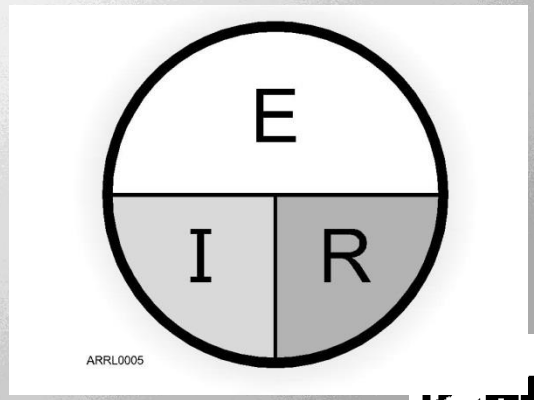
1 Volt	1 Amp	1 Ohm	1 Watt
12.6 Volts	10 Amps	1.26 Ohms	126 Watts
70.7 Volts	1.414 Amps	50 Ohms	100 Watts
20 Volts	5 Amps	4 Ohms	100 Watts
117 Volts	8.55Amps		1 KW
70.7 Volts	0.707 Amps	100 Ohms	50 Watts
0.774 Volts		600 Ohms	1 mW





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Two Basic Kinds of Current

When current flows in only one direction, it is called direct current (DC).

- Batteries are a common source of DC.
- Most electronic devices need DC.

When current flows alternately in one direction and then in the opposite direction, it is called alternating current (AC).

- Common source of AC is rotating alternators.
- Your household power is AC at 60 Hz.
- RF in a conductor is AC at radio frequencies.

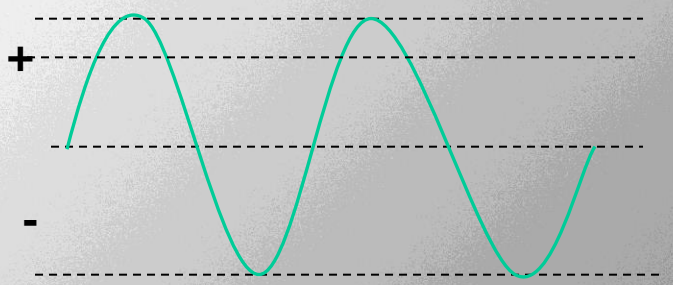
Some circuits may have a combination of AC and DC.

Fundamentals of AC

When current flows alternately in one direction and then in the opposite direction, it is called alternating current (AC).

An Alternating Current is caused by an Alternating Voltage. Term AC is used for both voltage and current.

- AC has a Frequency.
- AC has Peak Values.
- AC has Effective Values.
- AC has a Waveform.



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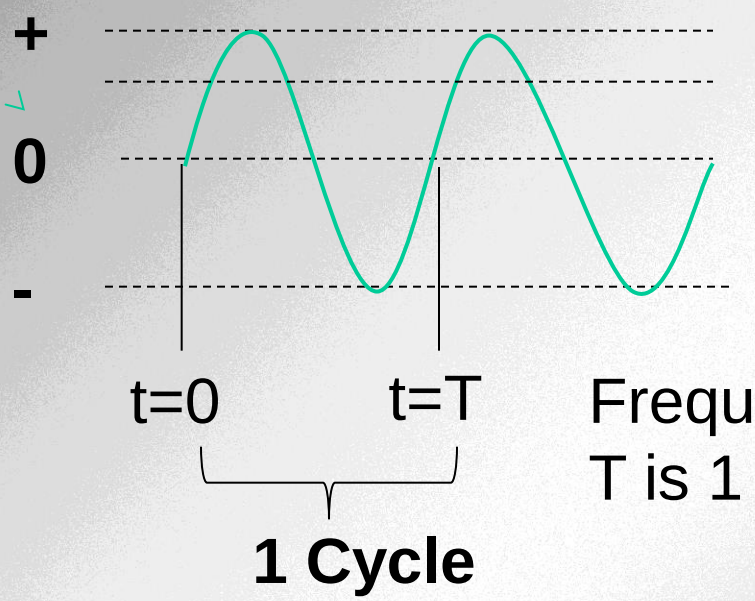
Fundamentals of AC Waveform



Vpk +

V_{RMS} (Effective Value)

Vpk -

Frequency is 1 divided by T.
T is 1 divided by Frequency.

The effective value V_{RMS} is 0.707 * Vpk (for a sinewave)
Frequency F is number of cycles per second.
Time for one cycle is T seconds. T = 1/F and F = 1/T

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Measuring Voltages

A Voltmeter is used to measure voltage.

- Analog – Moving needle or Bar Graph
- Digital – Alphanumeric Display

Voltmeters are connected across the circuit or components. (In Parallel)

Start analog meters with highest range to avoid damage to moving needle. Digital VM may have Auto-Ranging.

In high voltage circuits, turn off power while making connections.

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Measuring Currents

An Ammeter is used to measure current.

- Sense voltage across a shunt resistor – DC or AC
- Sense magnetic field around a wire – AC
- Some ammeters clamp around a wire.

Ammeters are inserted in series with the components.

- The circuit may have to be opened to insert the ammeter. Cut or unsolder components.
- Safety: Turn off power while making connections.

The ammeter should match range of current. Start with highest range to avoid damage.

Measuring Resistance

An Ohmmeter is used to measure resistance.

- Analog – Position of pointer on scale.
- Digital – Digits on numeric display.

Ohmmeters are connected in parallel with the circuit or components.

- Check for parallel resistance paths.
- Reading across capacitor increases as it charges. From short to open.

Circuit power may cause meter damage or error. Turn OFF.