
# Technician License Course
# Chapter 3
# Electricity and Circuits

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# Fundamentals of Electricity

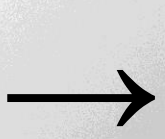
Effects of Electric Charge are observable.

Charges can be Positive or Negative.

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

Electric Current is the rate that charges flow through a conductor. (# of charges per second)





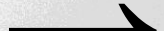
# Conductors (and Insulators)

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 the flow of electrons 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

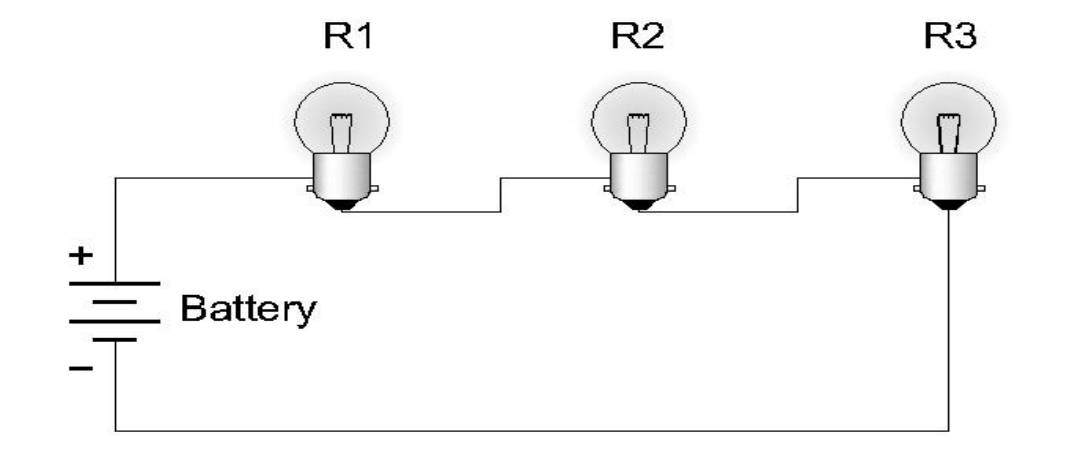
There are four primary parts of an electrical circuit:

- Voltage – The **Electromotive Force** – EMF
- Current – The moving charges
- Resistance – The opposition or losses
- Circuit – The Path

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


# Series Circuits

Series circuits provide only one path for current flow.




The current is the same through all lamps but the voltage is divided.

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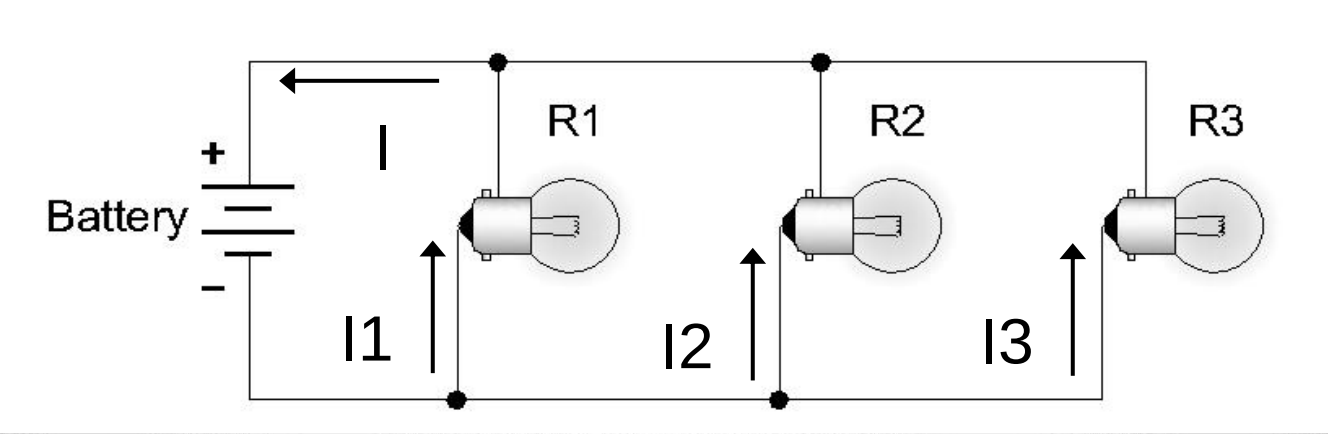
# Parallel Circuits

Parallel circuits provide more than one path for current flow.

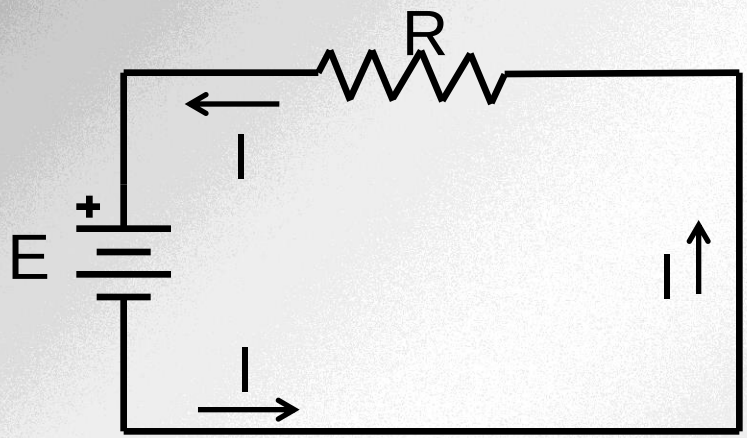



The voltage is the same for all lamps but the current from the battery divides. The currents can be different.

*I = I1 + I2 + I3 .* This is **Kirkoff's Law**.



# Elementary Electrical Circuit




A voltage E and resistance R connected by conductors.

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



# Voltage And Current Are Related

The ratio of Voltage to Current in the circuit is called Resistance.

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

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



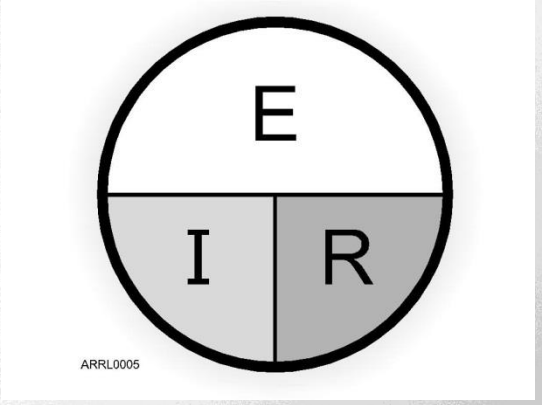
# Ohm's Law Circle

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**

Remember: "The Eskimos skate over the Icey River."

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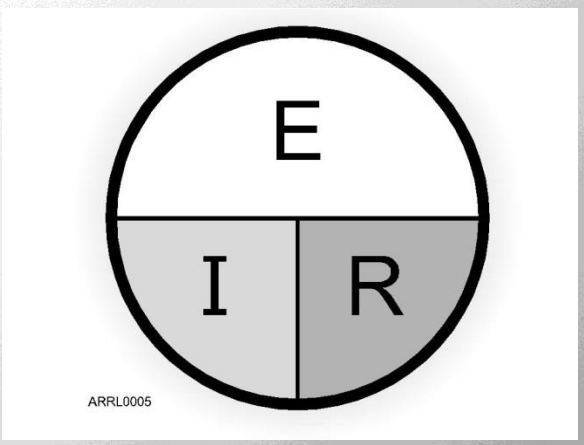
# Using Ohm's Law

| 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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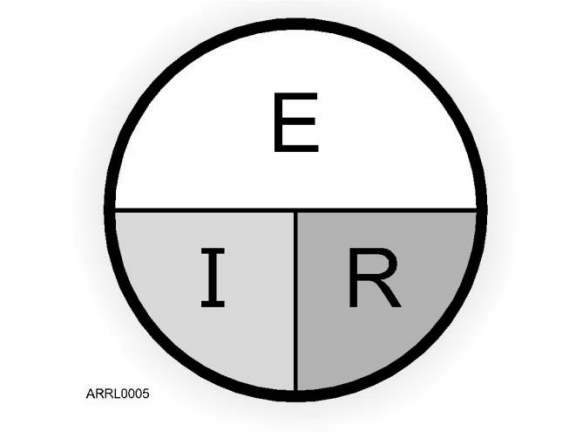
# Using Ohm's Law

| 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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# 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.

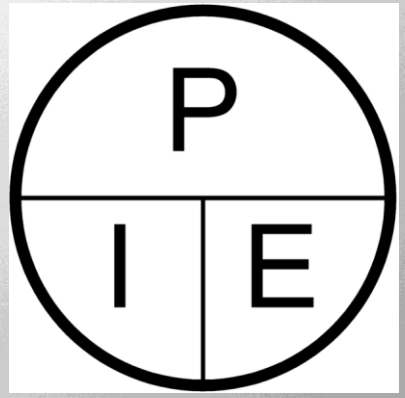
One Amp, one Volt, one Watt

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

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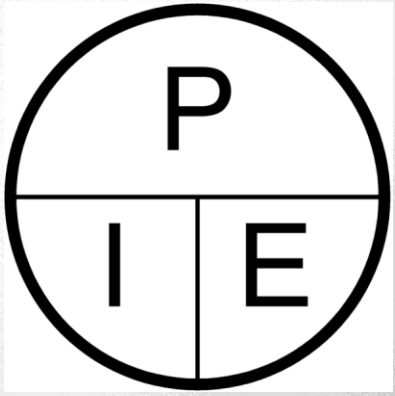
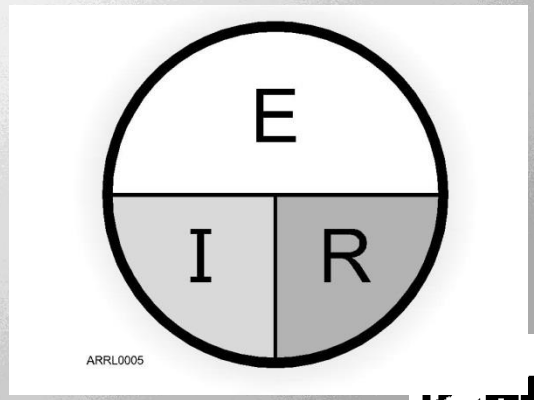
| 1 Volt | 1 Amp | 1 Ohm | ? Watt |
|---|---|---|---|
| 12.6 Volts | 10 Amps | ? Ohms | ? Watts |
| 70.7 Volts | ? Amps | 50 Ohms | ? Watts |
| ? Volts | 5 Amps | 4 Ohms | ? Watts |
| 117 Volts | ? Amps | | 1 KW |
| ? Volts | 0.707 Amps | 100 Ohms | ? Watts |
| ? Volts | | 600 Ohms | 1 mW |

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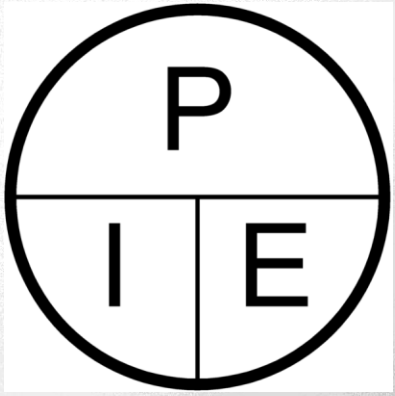
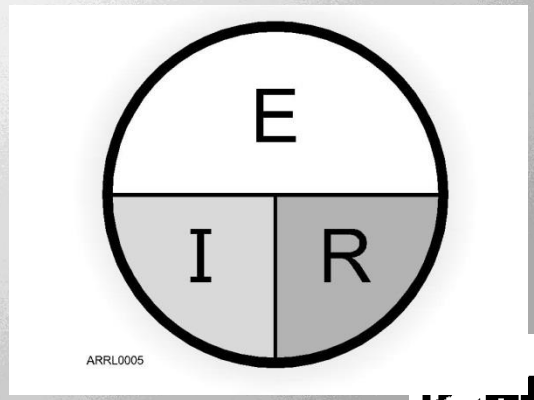
| 1 Volt | 1 Amp | 1 Ohm | 1 Watt |
|---|---|---|---|
| 12.6 Volts | 10 Amps | 1.26 Ohms | 126 Watts |
| 70.7 Volts | 1.414 Amps | 50 Ohms | 100 Watts |
| 20 Volts | 5 Amps | 4 Ohms | 100 Watts |
| 117 Volts | 8.55Amps | | 1 KW |
| 70.7 Volts | 0.707 Amps | 100 Ohms | 50 Watts |
| 0.774 Volts | | 600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

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# Two Kinds of Current

When current always flows in one direction, it is called direct current (**DC**). “DC” can mean current or voltage.

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

When current flows alternately in one direction and then in the opposite direction, it is called alternating current (**AC**). “AC” can mean current or voltage.

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

Some circuits may use a combination of AC and DC.

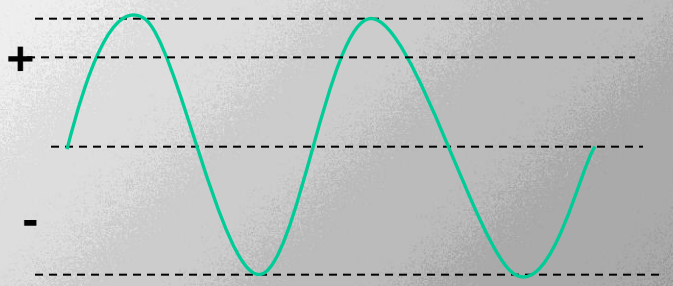


# Fundamentals of AC

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. The 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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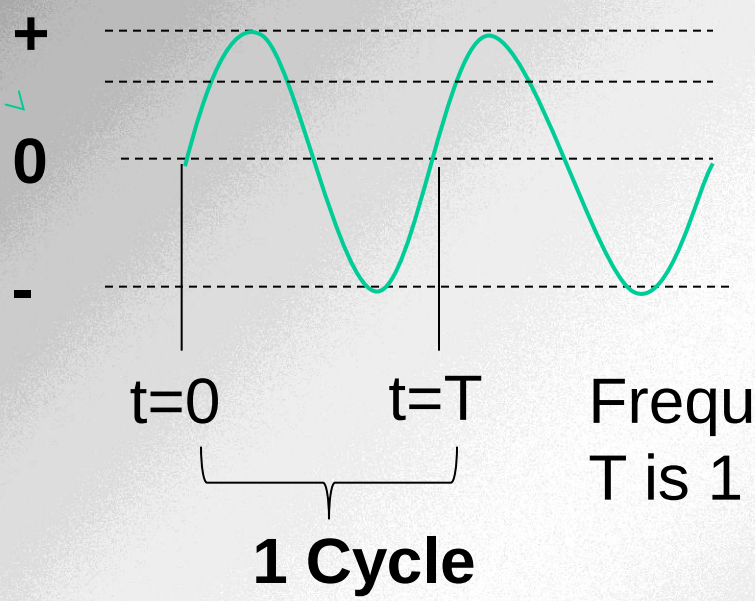
# Fundamentals of AC Waveform




Vpk +

$V_{RMS}$ (Effective Value)

Vpk -

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

$V_{RMS}$ is the effective value (0.707 * Vpk for a sinewave)
Time for one cycle is T seconds.
Frequency is number of cycles per second.

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# Measuring Voltages

A Voltmeter (VM) 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.



# 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.
- 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 – usually measures a current.
- Digital – usually measures a voltage.

Ohmmeters are connected in parallel with the circuit or components.

- Check for parallel resistance paths.
- Large capacitors will charge up slowly.

Turn off circuit power while measuring to:

- Avoid damage to ohmmeter.
- Ensure an accurate reading.