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SECTION 3

BASIC AUTOMATIC CONTROLS

UNIT 12

BASIC ELECTRICITY AND MAGNETISM

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Unit Objectives

- Describe the structure of an atom.
- Identify atoms with a positive charge and atoms with a negative charge.
- Explain the characteristics that make certain materials good conductors and others good insulators.
- Describe how magnetism is used to produce electricity.
- State the differences between alternating current and direct current.
- List the units of measurement for electricity.
- Explain the differences between series and parallel circuits.

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Unit Objectives

- State ohm's law.
- State the formula for determining electrical power.
- Describe a solenoid.
- Explain inductance.
- Describe the construction of a transformer and the way a current is induced in a secondary circuit.
- Describe how a capacitor works.
- Describe a sine wave.

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Unit Objectives

- State the reasons for using proper wire sizes.
- Describe the physical characteristics and the function of several semiconductors.
- Describe procedures for making electrical measurements.

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Atomic Structure (1 of 6)

- Matter made up of atoms
- Smallest quantity of a naturally occurring element
- Protons
  - Positively charged particles
- Electrons
  - Negatively charged particles
- Neutrons
  - Neutrally charged particles
- Like charges repel each other
- Opposite charges attract each other

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Atomic Structure (2 of 6)

• Opposite charges attract each other.

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Atomic Structure (3 of 6)

• Like charges repel each other.

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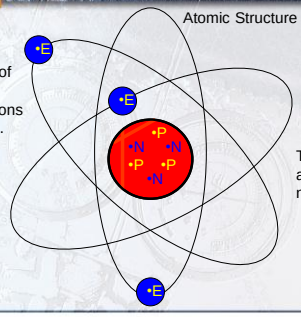
Atomic Structure (4 of 6)

The nucleus of the atom contains protons and neutrons.



The electrons orbit around the nucleus.

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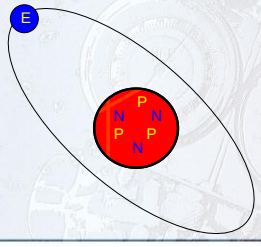
Atomic Structure (5 of 6)



Good conductors of heat and electricity are made of atoms that have only 1 or 2 electrons in the outer shell.

- Gold
- Silver
- Copper
- Aluminum

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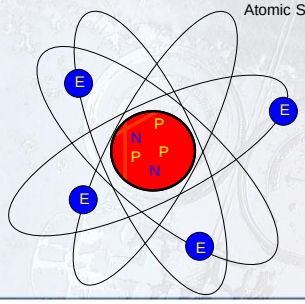
Atomic Structure (6 of 6)



Poor conductors of heat and electricity are called insulators.

– The atoms of insulators have several electrons in the outer shell.

- Glass
- Rubber
- Plastic

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Electricity Produced from Magnetism (1 of 2)

- Magnets have poles designated as north and south.
- Magnets have lines of force called magnetic flux.
- Like poles repel, opposite poles attract.
- When the lines of flux are cut with a conductor, electrical current is generated.

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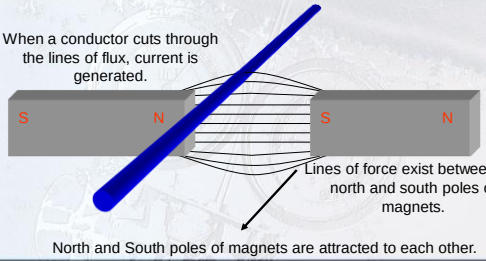
Electricity Produced from Magnetism (2 of 2)

When a conductor cuts through the lines of flux, current is generated.



Lines of force exist between the north and south poles of magnets.

North and South poles of magnets are attracted to each other.

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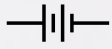
Direct Current

- Current travels in one direction.
- Negatively charged electrons flow to atoms with positive charges.
- It flows from negative to positive.
- Direct current is typically found in circuits powered by batteries.
- The electrical symbol for a battery is



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Alternating Current (AC)

- Continually reverses direction as power source is changing
- Most commonly used power source
- Electron flow changes direction
- More economical to produce than direct current
- Electrical symbol for an alternating power source is

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Electrical Units of Measurement

- Voltage
  - Electrical pressure or electromotive force (emf)
  - Indicated by the difference in potential between 2 points
  - Measured in volts, indicated by V or E
- Current
  - Measures the amount of electron flow per unit time
  - Measured in amperes, or amps, indicated by A or I
- Resistance
  - Opposition to electron flow
  - Measured in ohms, Ω, indicated by R
  - Good conductors have low resistance

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The Electric Circuit

- Power source
  - Provides the voltage for the circuit
  - Can be alternating current (AC) or direct current (DC)
- Load
  - Device that uses electric power
  - Can be resistive or inductive
- Switch
  - Controls the operation of the load
- Conductors
  - Provides a path for the current

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Making Electrical Measurements

- Voltage readings can be taken across loads, switches, and power sources.
- Amperage readings are often taken with a meter that clamps around a conductor.
- Resistance readings are taken on circuits that are de-energized.

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Ohm's Law

- Relationship between voltage, current, and resistance
  - Voltage = Current x Resistance
  - Current = Voltage ÷ Resistance
  - Resistance = Voltage ÷ Current
- Ohm's law holds for direct current circuits that contain resistive loads.

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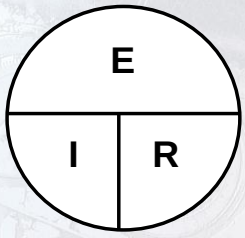
I = E/R

R = E/I

E = I x R



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The Series Circuit

- Electric current has only one path to take.
- The current is the same at all points in the circuit.
- The total circuit resistance is the sum of all resistances in the circuit.
- The voltage is divided across all circuit loads.
- Any interruption in the circuit will stop current flow through the entire circuit.

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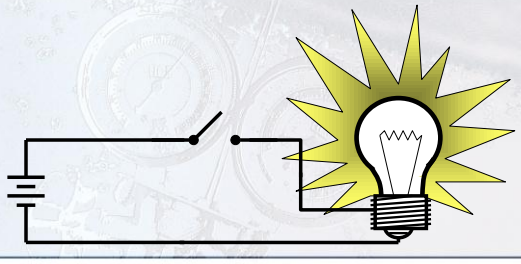
A Simple Series Circuit



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Series Circuit Rules

$I_T = I_1 = I_2 = I_3$

$R_T = R_1 + R_2 + R_3$

$E_T = E_1 + E_2 + E_3$

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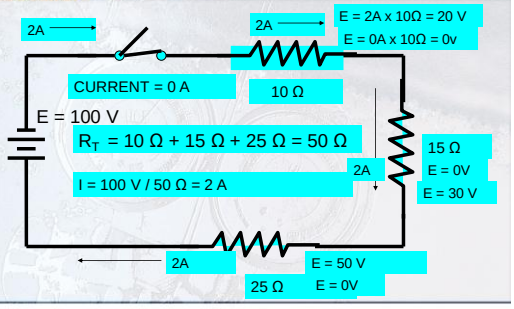

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The Parallel Circuit

- The current can take more than one path.
- Each branch circuit is unaffected by the other branches.
- The supply voltage is the same in all branches.
- The current is divided between the branch circuits.
- The total circuit resistance drops as more branch circuits are added.
- Most circuits are configured as parallel circuits.

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Parallel Circuit Rules

$$I_T = I_1 + I_2 + I_3$$

$$E_T = E_1 = E_2 = E_3$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

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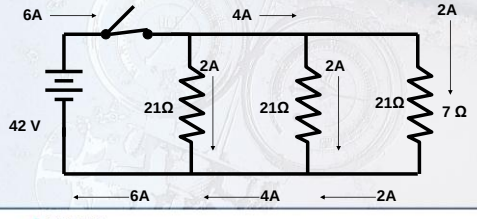
Parallel Circuit Example (1 of 2)

I = E/R = 42V/7Ω = 6A



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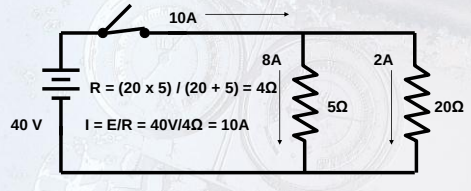
Parallel Circuit Example (2 of 2)



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Electrical Power

- Measured in watts
  - 746 watts = 1 horsepower
  - 1,000 watts = 1 kilowatt (1 kw)
  - Watts = Voltage x Current (DC circuits)
- Consumers charged by kilowatt usage

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Magnetism

- When current flows in a conductor, a magnetic field is generated around the conductor.
- Creating coils of wire increases the strength of the magnetic field.
- Coils of wire are referred to as solenoids.
  - Solenoids are used to open and close electrical contacts, valves, and other controls.

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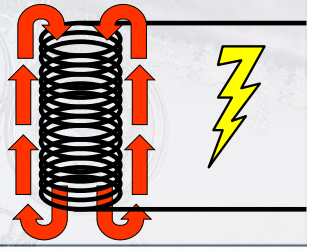
When current flows through a conductor, a magnetic field is generated.

The strength of the magnetic field is determined by the amount of current flow.

By forming wire into a coil or solenoid, the strength of the magnetic field is increased.

The magnetic field can then be used to open or close electrical switches, valves other components.



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Inductance

- When alternating current is generated, the magnetic field constantly builds up and collapses.
- Voltage is induced when the magnetic field cuts the conductor.
  - The induced voltage opposes the original voltage.
  - Inductive reactance is created.

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Transformers (1 of 2)

- Produce an electric potential in a secondary circuit by electromagnetic induction
- Primary coil, secondary coil, and a core
- Voltage applied to the primary induces a voltage in the secondary
  - The amount of induced voltage is related to the number of turns in the primary and secondary windings.
- Often used to create the 24-volt power source for control circuits
- Rated in volt-amperes, or VA

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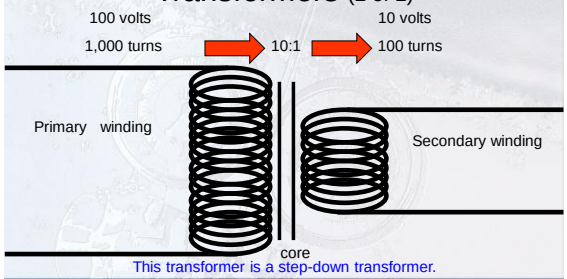
Transformers (2 of 2)



This transformer is a step-down transformer.

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Capacitors

- Store an electric charge
- Made up of two plates separated by an insulator
- Capacitors are rated in microfarads, μF
- Run capacitors used to increase motor running efficiency
- Start capacitors used to increase starting torque
- The electrical symbol for a capacitor

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Impedance

- It is the total effect of resistance, capacitive reactance, and inductive reactance in a circuit.
- When there is only resistance, the voltage and current are in phase with each other.
- The voltage leads the current in an inductive circuit.
- The current leads the voltage in a capacitive circuit.
- Inductive and capacitive reactance can cancel each other out in a circuit.

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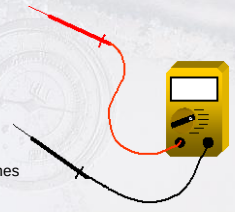
Electrical Measuring Instruments

- The volt-ohm-millameter (VOM)
  - Can measure AC and DC voltages
  - Can measure resistance and continuity
  - Can measure small amperages although not a commonly used feature
  - Equipped with function and range switches



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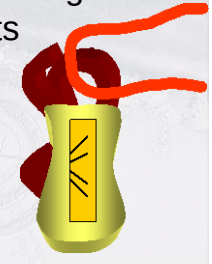
Electrical Measuring Instruments

- Clamp-on ammeters
  - They measure amperage by clamping the meter around one of the conductors in an electric circuit.
  - The higher the circuit amperage, the stronger the magnetic field generated around the circuit conductors.



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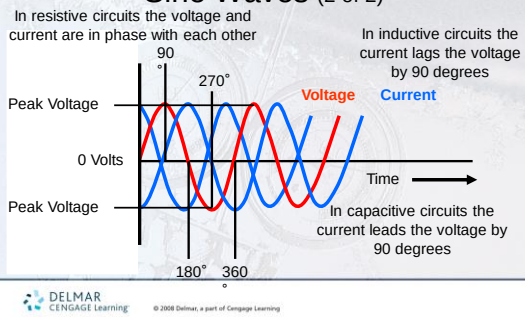
Sine Waves (1 of 2)

- Graphically represents alternating current through 360 electrical degrees
- Represents the voltage generated as a conductor is rotated within a magnetic field
- Shows peak to peak voltage values
- Effective voltage is RMS value (root, mean, square)
  - RMS value equal to 0.707 times the peak voltage

Sine Waves (2 of 2)



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Wire Sizing

- Conductors and wires have resistance.
- Resistance is affected by the material, cross sectional area, and length of the conductor.
- Lower resistance permits higher current flow.
- Larger diameter wire has more current carrying capability than smaller diameter wire.
- American Wire Gauge, AWG
  - Larger wire gauges indicate smaller diameter wire.

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Circuit Protection Devices

- Circuits must be protected from excessive current.
- Fuses
  - Plug, element, cartridge
  - One-time devices
- Circuit breakers
  - Can be reset
- Ground Fault Circuit Interrupters (GFCI)
  - Senses small current leaks to ground

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Semiconductors

- Components found on solid state boards
  - Diodes
  - Rectifiers
  - Silicon-controlled rectifiers
  - Diacs and triacs
  - NPN transistors
  - PNP transistors
  - Thermistors
  - Heat sinks

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Unit Summary (1 of 2)

- Atoms contain protons, neutrons, and electrons.
- Opposite charges attract; like charges repel.
- Good conductors allow electrons to flow freely.
- Electrical characteristics include voltage, current, resistance, and power and are related by Ohm's law.
- Circuits can be wired in either series or parallel.
- A magnetic field is generated when current flows.
  - The magnetic field is used in solenoids, transformers, and to measure electrical values.

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Unit Summary (2 of 2)

- Power sources can be alternating or direct current.
  - Alternating current (AC) power sources follow a path resembling a sine wave.
- Common instruments used to measure electrical characteristics are the VOM and clamp-on ammeter.
- Wires are sized according to the current requirements of the circuit.
- Circuits can be protected by fuses, circuit breakers, and ground fault circuit interrupters.