Chapter 5

Series Circuits

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Series Circuits

- Two elements in a series
  - Connected at a single point
  - No other current-carrying connections at this point
- A series circuit is constructed by connecting various elements in series

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Series Circuits

- Normally
  - Current will leave the positive terminal of a voltage source
  - Move through the resistors
  - Return to negative terminal of the source

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Series Circuits

- Current is similar to water flowing through a pipe
  - Current leaving the element must be the same as the current entering the element
- Same current passes through every element of a series circuit

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Series Circuits

- The laws, theorems, and rules that you apply to DC circuits
  - Also apply to AC circuits

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Kirchhoff's Voltage Law (KVL)

- The algebraic sum of the voltage that rises and drops around a closed loop is equal to zero
- $$E_T - V_1 - V_2 - V_3 - \cdots - V_n = 0$$

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Kirchhoff's Voltage Law (KVL)

- Another way of stating KVL is:
  - Summation of voltage rises is equal to the summation of voltage drops around a closed loop

$$V_1 + V_2 + V_3 + \cdots + V_n = E_T$$

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Resistors in Series

- Most complicated circuits can be simplified
- For a series circuit
  - $V_1 + V_2 + V_3 = E$
  - $IR_1 + IR_2 + IR_3 = E$
  - $I(R_1 + R_2 + R_3) = E$
  - $I(R_1 + R_2 + R_3) = IR_{total}$ (Note: I's cancel)

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Resistors in Series

- Total resistance in a series circuit is the sum of all the resistor values

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Power in a Series Circuit

- Power dissipated by each resistor is determined by the power formulas:

$$P = VI = V^2/R = I^2R$$

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Power in a Series Circuit

- Since energy must be conserved, power delivered by voltage source is equal to total power dissipated by resistors

$$P_T = P_1 + P_2 + P_3 + \cdots + P_n$$

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Voltage Sources in Series

- In a circuit with more than one source in series
  - Sources can be replaced by a single source having a value that is the sum or difference of the individual sources
- Polarities must be taken into account

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Voltage Sources in Series

- Resultant source
  - Sum of the rises in one direction minus the sum of the voltages in the opposite direction

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Interchanging Series Components

- Order of series components
  - May be changed without affecting operation of circuit
- Sources may be interchanged, but their polarities can not be reversed
- After circuits have been redrawn, it may become easier to visualize circuit operation

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The Voltage Divider Rule

- Voltage applied to a series circuit
  - Will be dropped across all the resistors in proportion to the magnitude of the individual resistors

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The Voltage Divider Rule

- Voltage dropped across each resistor may be determined by the voltage across any other resistor (or combination of resistors) by using the voltage divider rule expressed as:

$$V_x = \frac{R_x}{R_y} V_y$$

- The subscripts must match (x and y)

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Voltage Divider Rule Application

- If a single resistor is very large compared to the other series resistors, the voltage across that resistor will be the source voltage
- If the resistor is very small, the voltage across it will be essentially zero

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Voltage Divider Rule Application

- If a resistor is more than 100 times larger than another resistor
  - Smaller resistor can be neglected

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Circuit Ground

- Ground
  - Point of reference or a common point in a circuit for making measurements
- One type of grounding is chassis ground
- In this type of grounding
  - Common point of circuit is often the metal chassis of the piece of equipment

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Circuit Ground

- Chassis ground
  - Often connected to Earth Ground
- Earth ground
  - Physically connected to the earth by a metal pipe or rod

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Circuit Ground

- If a fault occurs within a circuit, the current is redirected to the earth
- Voltages are often measured with respect to ground

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Double Subscripts

- For the circuit shown, we can express the voltage between any two node points (*a* and *b)* as V_{ab}.
- If *a* is at a higher potential than *b*, then V_{ab} is positive

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Double Subscripts

- If *b* is at a higher potential than *a*, then V_{ab} is negative
- In this case, V_{ab} would be negative

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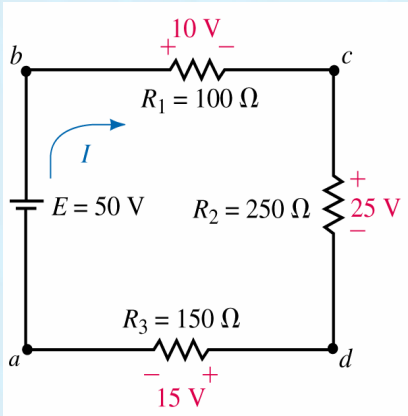
Double Subscripts



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Double Subscripts

- To determine correct polarity
  - Calculate all voltage drops across all components
  - Assign polarities
- As you go around a circuit, add the gains and subtract the drops

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Double Subscripts

- Be sure to take the sign of the polarity on the same side of the source or element as you go around the circuit

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Single Subscripts

- In a circuit with a ground reference point
  - Voltages may be expressed with respect to that reference point
- V_a
  - Voltage at point *a* with respect to ground
  - Ground represents a point of zero reference potential

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Single Subscripts

- Any voltage with a single subscript is with respect to ground
- This is the same as $V_{a(0)}$

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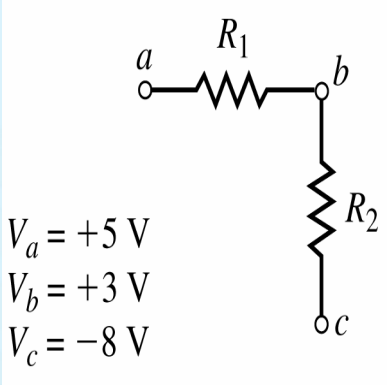
Single Subscripts

- If voltages at various points in a circuit are known with respect to ground, then the voltage between points is easily determined
- $V_{ab} = V_a - V_b$



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Point Sources

- Voltage source given with respect to ground
  - May be represented by a voltage at a single point (node) in the circuit
  - This voltage may be referred to as a point source

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Point Sources

- Voltages at these points represent voltages with respect to ground, even if ground is not shown
- Point sources simplify representation of a circuit

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Internal Resistance of Voltage Sources

- Ideal sources have no internal resistance
- In an ideal source
  - Terminal voltage does not change when the load changes
- For a practical source
  - There is internal resistance

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Internal Resistance of Voltage Sources

- As the load changes
  - Drop across the internal resistance changes
  - Terminal voltage changes

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Ammeter Loading Effects

- An ammeter is placed in a circuit to make a measurement
  - Resistance will affect the circuit
- Amount of loading is dependent upon the instrument and the circuit

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Ammeter Loading Effects

- If resistance of the meter is small compared to the resistance of the circuit, the loading effect will be small

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