# Chapter 4

## Series Circuits

## Objectives

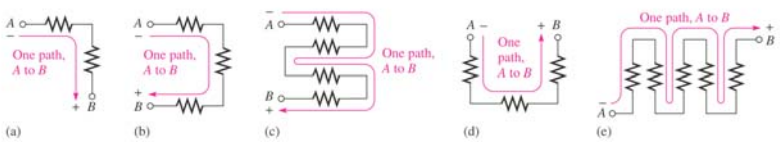
- Identify a series circuit
- Determine the current in a series circuit
- Determine total series resistance
- Apply Ohm’s law in series circuits
- Determine the total effect of voltage sources in series

# Objectives

- Apply Kirchhoff's voltage law
- Use a series circuit as a voltage divider
- Determine power in a series circuit
- Determine and identify ground in a circuit

# Resistors in Series

- A series circuit provides only one path for current between two points so that the current is the same through each series resistor

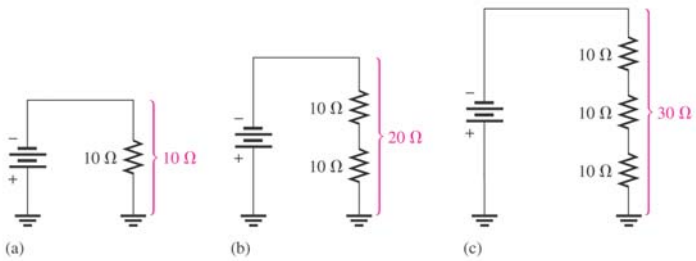


# Current in a Series Circuit

- The current is the same through all points in a series circuit
- The current through each resistor in a series circuit is the same as the current through all the other resistors that are in series with it
- Current entering any point in a series circuit is the same as the current leaving that point

# Total Series Resistance

- The total resistance of a series circuit is equal to the sum of the resistances of each individual series resistor



## Series Resistance Formula

- For any number of individual resistors connected in series, the total resistance is the sum of each of the individual values

$$R_T = R_1 + R_2 + R_3 + \ldots + R_n$$

## Ohm's Law in Series Circuits

- Current through one of the series resistors is the same as the current through each of the other resistors and is the total current
- If you know the total voltage and the total resistance, you can determine the total current by using: $I_T = V_T/R_T$
- If you know the voltage drop across one of the series resistors, you can determine the current by using: $I = V_R/R$

## Ohm's Law in Series Circuits

- If you know the total current, you can find the voltage drop across any of the series resistors by using: $\mathbf{V_R = I_T R}$
- The polarity of a voltage drop across a resistor is positive at the end of the resistor that is closest to the positive terminal of the voltage source
- The resistor current is in a direction from the negative end of the resistor to the positive end

## Ohm's Law in Series Circuits

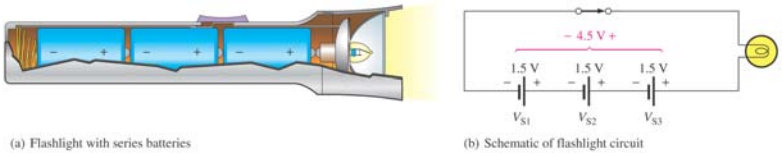
- An open in a series circuit prevents current; and, there is zero voltage drop across each series resistor
- The total voltage appears across the points between which there is an open

# Voltage Sources in Series

- A voltage source is an energy source that provides a constant voltage to a load
- Batteries and electronic power supplies are practical examples of dc voltage sources

# Voltage Sources in Series

- When two or more voltage sources are in series, the total voltage is equal to the the algebraic sum (including polarities of the sources) of the individual source voltages



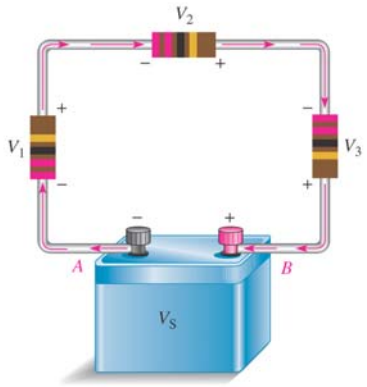

(a) Flashlight with series batteries

(b) Schematic of flashlight circuit

# Kirchhoff's Voltage Law

- The algebraic sum of all the voltage drops around a single closed loop in a circuit is equal to the total source voltage in that loop

$\mathbf{V_S = V_1 + V_2 + V_3 + \ldots + V_n}$



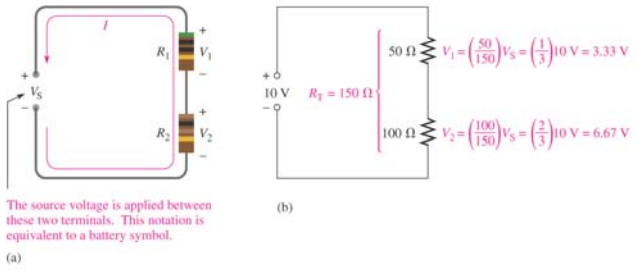

# Another Way to state Kirchhoff's Voltage Law

- The algebraic sum of all voltages (both sources and drops) around a closed path is zero

$$V_S - V_1 - V_2 - V_3 - \ldots - V_n = 0$$

# Voltage Dividers

- Since each resistor has the same current, the voltage drops are proportional to the resistance values



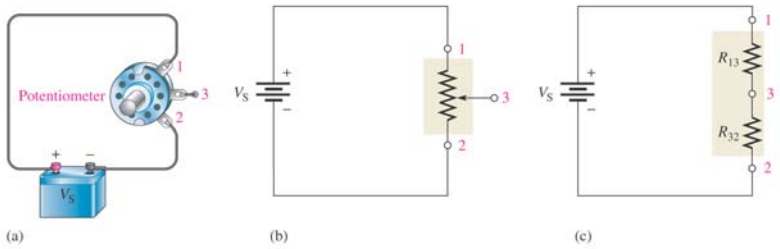

# Voltage-Divider Formula

- The voltage drop $V_x$ across any resistor or combination of resistors in a series circuit is equal to the ratio of that resistance value $R_x$ to the total resistance $R_T$, multiplied by the source voltage $V_S$

$$V_x = (R_x/R_T)V_S$$

# Potentiometer as an Adjustable Voltage Divider

- The potentiometer shown below is equivalent to a two-resistor voltage divider that can be manually adjusted
- The two resistors are between terminals 1 & 3 and 2 & 3




# Power in a Series Circuit

- The total amount of power in a series resistive circuit is equal to the sum of the powers in each resistor in series

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

## Power in a Resistor

- The amount of power in a resistor is important because the power rating of the resistor must be high enough to handle the expected power in the circuit

## Circuit Ground

- Voltage is relative
- The voltage at one point in a circuit is always measured relative to another point
- This reference point in a circuit is usually the ground point

## Measuring Voltages with Respect to Ground

- When voltages are measured with respect to ground in a circuit, one meter lead is connected to the circuit ground, and the other to the point at which the voltage is to be measured

## Measuring Voltage Across an Ungrounded Resistor

- Voltage can normally (as long as the meter is isolated from the power line ground) be measured across a resistor even though neither side of the resistor is connected to circuit ground
- The reading will be the voltage drop across the resistor

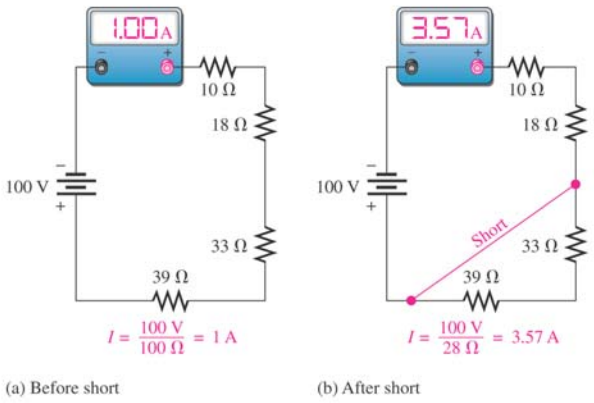
## Open Circuit

- The most common failure in a series circuit is an **open**
- When an open occurs in a series circuit, all of the source voltage appears across the open

## Short Circuit

- When there is a **short**, a portion of the series resistance is bypassed, thus reducing the total resistance
- A short in a series circuit results in more current than normal through the circuit
- The voltage across a shorted series component (or circuit) is 0 volts

# A Short in a Series Circuit




# Summary

- Current is the same at all points in a series circuit
- The total resistance between any two points in a series circuit is equal to the sum of all resistors connected in series between those two points
- Voltage sources in series add algebraically
- Kirchhoff's voltage law (KVL): **The sum of all the voltage drops around a single closed loop in a circuit is equal to the total source voltage in that loop**

## Summary

- Alternative KVL: The algebraic sum of all voltages (both sources and drops) around a closed path is zero
- The voltage drops in a circuit are always opposite in polarity to the total source voltage
- Current is out of the negative side of a source and into the positive side
- Current is into the negative side of each resistor and out of the positive side

## Summary

- A voltage divider is a series arrangement of resistors
- A voltage divider is so named because the voltage drop across any resistor in the series circuit is divided down from the total voltage by an amount proportional to that resistance value in relation to the total resistance
- A potentiometer can be used as an adjustable voltage divider

# Summary

- The total power in a resistive circuit is the sum of all the individual powers of the resistors making up the series circuit
- Ground is zero volts with respect to all points referenced to it in the circuit
- The voltage across an open series element equals the source voltage
- The voltage across a shorted series component is 0 volts