DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

CHAPTER 19: DC CIRCUITS

LSN 19-1: EMF AND TERMINAL VOLTAGE
LSN 19-2: RESISTORS IN SERIES AND IN PARALLEL

Reading Activity Questions?

Big Idea(s):

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- The interactions of an object with other objects can be described by forces.
- Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding(s):

- Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.
- Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.

Enduring Understanding(s):

- At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
- The energy of a system is conserved.
- Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.

Essential Knowledge(s):

- Electric charge is conserved. The net charge of a system is equal to the sum of the charges of all the objects in the system.
  - An electrical current is a movement of charge through a conductor.
  - A circuit is a closed loop of electrical current.

Essential Knowledge(s):

- There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
  - Like-charged objects and systems repel, and unlike-charged objects and systems attract.

Essential Knowledge(s):

- The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
  - The magnitude of the elementary charge is equal to 1.6 ×10–19 coulombs.
  - Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron.

Essential Knowledge(s):

- Matter has a property called resistivity.
  - The resistivity of a material depends on its molecular and atomic structure.
  - The resistivity depends on the temperature of the material.

Essential Knowledge(s):

- Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
  - Electric forces dominate the properties of the objects in our everyday experiences. However, the large number of particle interactions that occur make it more convenient to treat everyday forces in terms of nonfundamental forces called contact forces, such as normal force, friction, and tension.
  - Electric forces may be attractive or repulsive, depending upon the charges on the objects involved.

Essential Knowledge(s):

- For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.

Essential Knowledge(s):

- A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
  - The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.]

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- The student is able to make claims about natural phenomena based on conservation of electric charge.
- The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.

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- The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.
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- The student is able to choose and justify the selection of data needed to determine resistivity for a given material.
- The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges.

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- The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
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Emf (ε)

- Emf sources
  - battery - converts stored chemical energy into electrical energy
  - generator – converts mechanical energy into electrical energy
  - thermocouple – converts thermal energy into electrical energy
  - photoelectric material – converts solar energy into electrical energy

Emf (ε)

- Charges will not move in a conductor unless there exists an electric potential created by an <u>*electromotive force (emf)*</u> providing the energy
  - Resistance
  - Superconductors are an exception
- Since the electrons must be 'pushed' from the positive terminal to the negative terminal, work must be done on the electrons

Emf (ε)

- Electromotive force (emf, **ε**) is equal to the total work done in moving a unit charge completely around a circuit

$$\varepsilon = \frac{W}{q}$$

- Unit for emf is the volt (V, J/C)

Emf (ε)

- Emf can also be defined as the total power generated by the voltage source per unit current

$$\varepsilon = \frac{W}{q}$$

$$P = \frac{W}{t}, Pt = W$$

$$\varepsilon = \frac{Pt}{q}$$

$$I = \frac{q}{t}, \frac{1}{I} = \frac{t}{q}$$

$$\varepsilon = \frac{P}{I}$$

Emf (ε)

- Chemicals inside the battery create a small amount of resistance (r) which is the ***internal resistance*** of the battery
- The total emf is reduced by the internal resistance of the battery, thus the potential of the battery is $V = \varepsilon - IR$
- Thus, the potential of a battery is always less than the emf of the battery

Review Video: Resistance 2

Electric Resistance and Ohm's Law

- Electric resistance of a conductor is defined as the potential difference across its ends, divided by the current flowing through it:

$$R = \frac{V}{I}$$

- The unit for resistance is the Ohm (**Ω**) and is equal to 1 V/A

Potential Drop (Voltage)

$$R = \frac{V}{I}$$

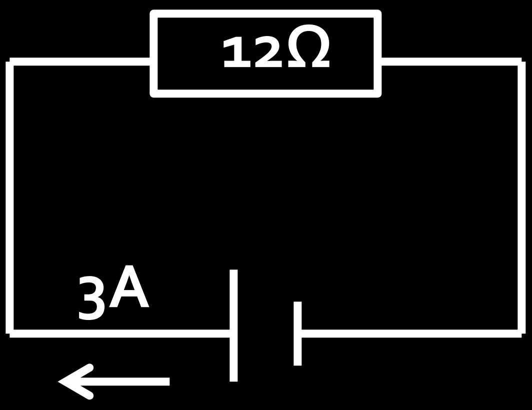
$$V = IR$$

- **This derivation tells us that for current to flow through a resistor, there must be a potential difference (V) across the resistor.**
- **In a circuit, the voltage is said to "drop" across each resistor**
- **If we assume the resistance of the conductor (wire) and the battery are negligible, the total voltage drop and potential difference will be the same**

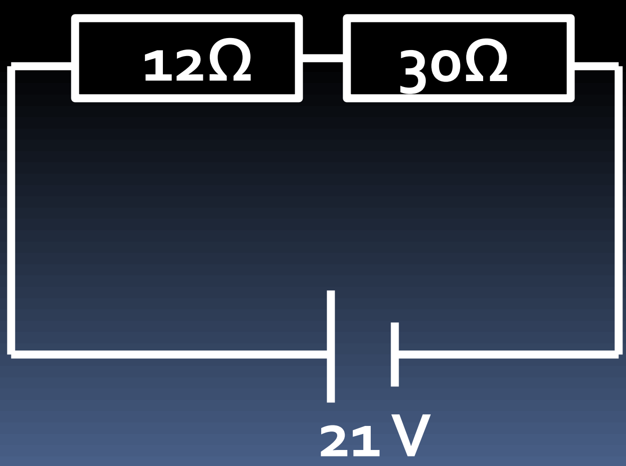
Potential Drop

- **Examples:**

A



B



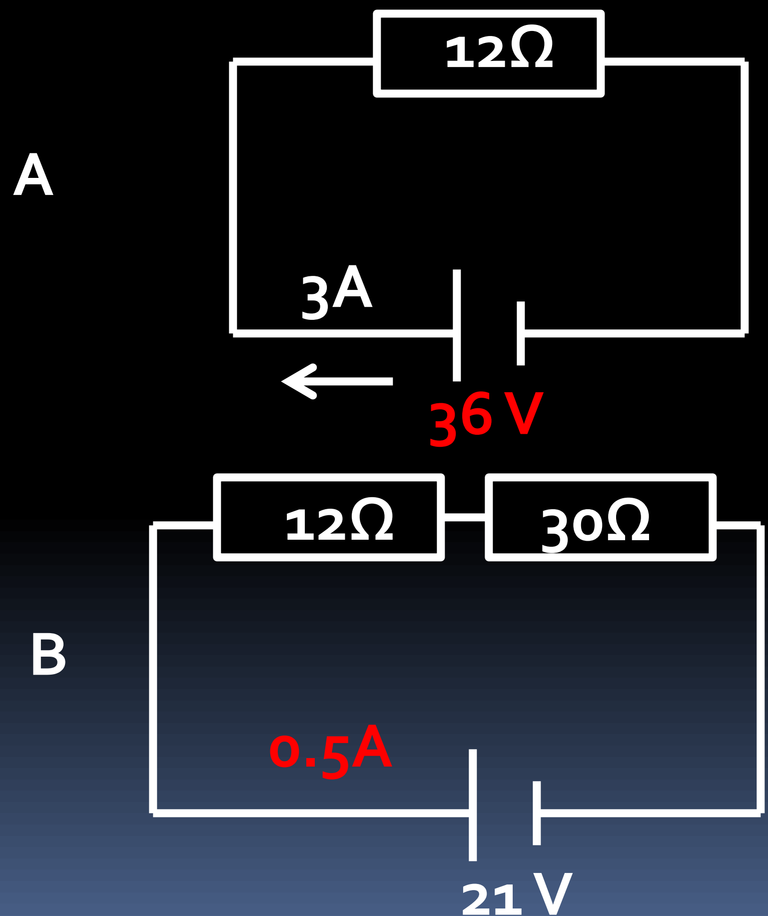
$$R = \frac{V}{I}$$

$$V = IR$$

$$I = \frac{V}{R}$$

Potential Drop

- **Examples:**



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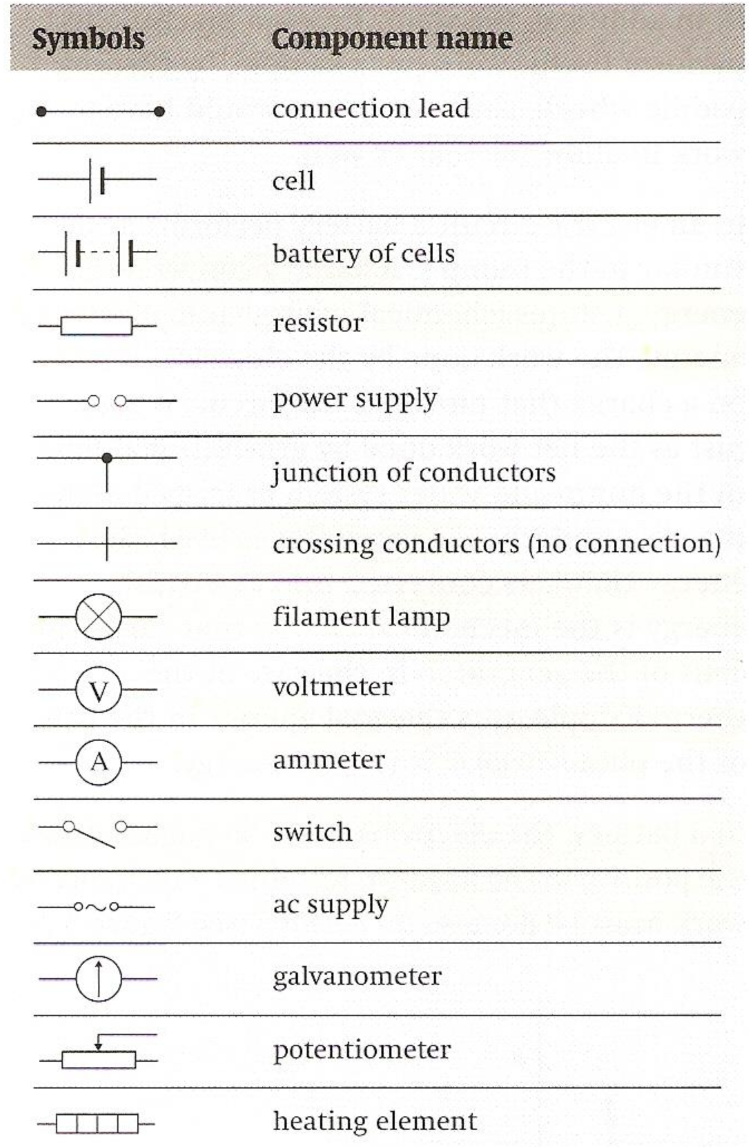
Simple DC Circuits

Simple Electric Circuits

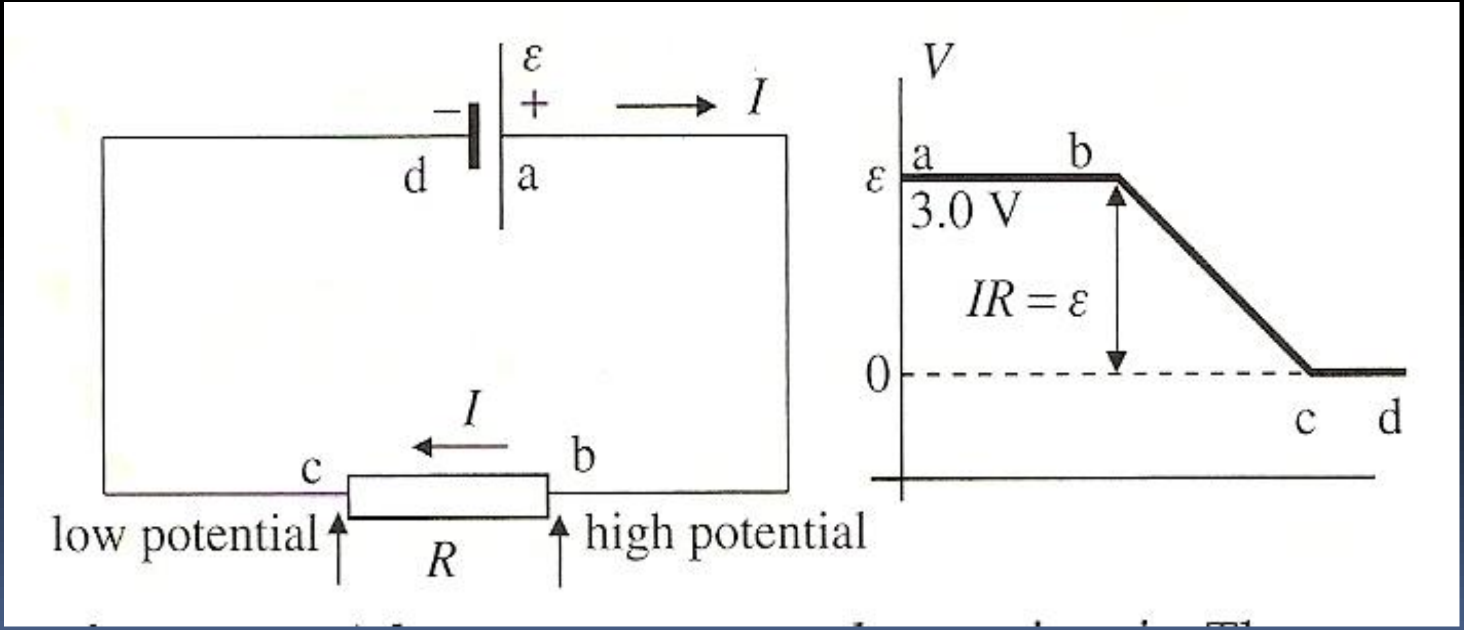


Symbols	Component name
	connection lead
	cell
	battery of cells
	resistor
	power supply
	junction of conductors
	crossing conductors (no connection)
	filament lamp
	voltmeter
	ammeter
	switch
	ac supply
	galvanometer
	potentiometer
	heating element

Table 5.1 Names of electrical components and their circuit symbols.

Simple Electric Circuits

- **Example: Find the current in the simple circuit below with negligible internal resistance, ε = 3.0V, and R = 1.5 Ω.**



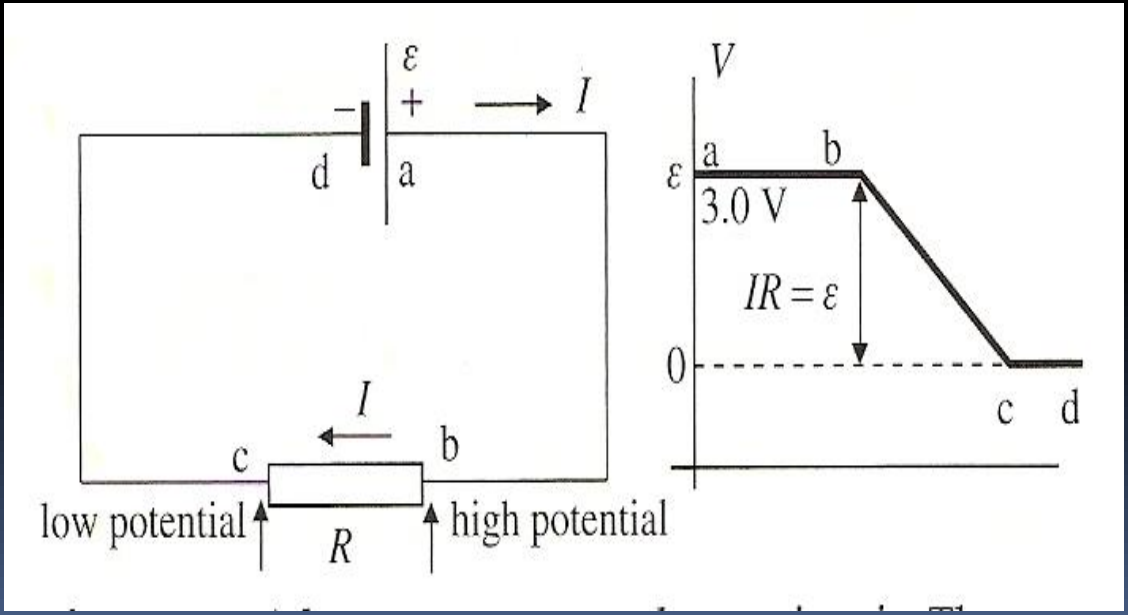
Simple Electric Circuits

- **Example: Find the current in the simple circuit below with negligible internal resistance, ε = 3.0V, and R = 1.5 Ω.**

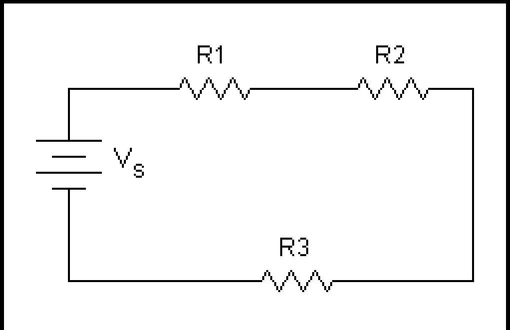
$$V = IR$$

$$I = \frac{V}{R}$$

$$I = \frac{3.0}{1.5} = 2A$$



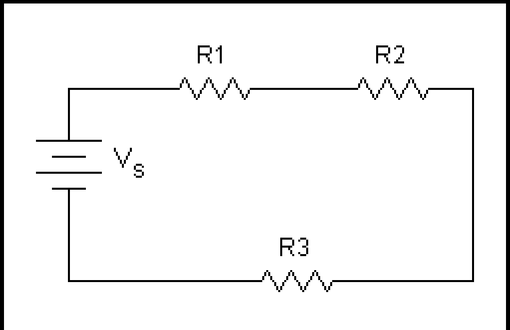
Series Circuits



- Circuits are said to be "in series" when the same current runs through them as if they were connected end to end
  - The potential drop across each resistor is, $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

$$V = IR_1 + IR_2 + IR_3$$
$$V = I(R_1 + R_2 + R_3)$$
$$V = IR_{Total}$$
$$R_{Total} = R_1 + R_2 + R_3$$

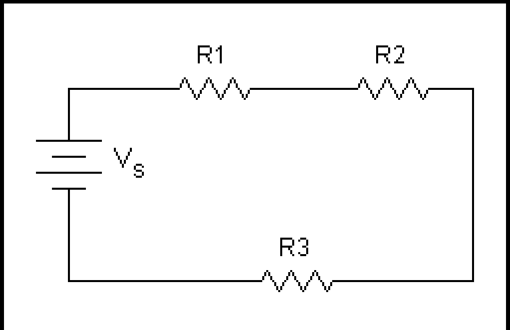
Series Circuits



- For resistors in series, it is the same as replacing all resistors with one that has the total value of all in series.
- For resistors in series, the same current flows through all resistors and the potential drop across the resistors is equal to the drop across the series.

$$R_{Total} = R_1 + R_2 + R_3$$

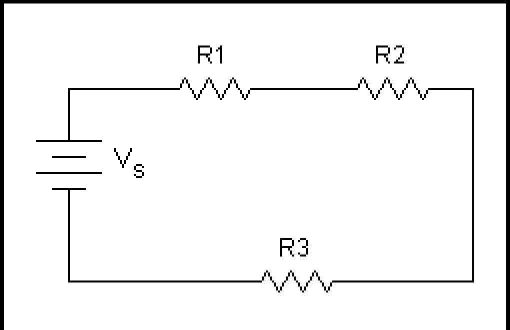
Series Circuits



- **<u>EXAMPLE:</u> If resistors of 2Ω, 3 Ω, and 7 Ω are connected in series in a circuit with a current of 2.5 amps what will be the emf in a source with negligible resistance?**

$$R_{Total} = R_1 + R_2 + R_3$$

Series Circuits



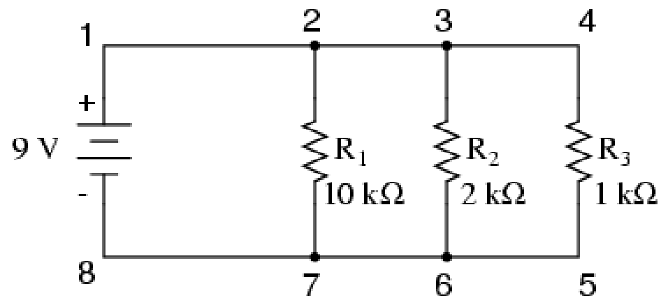
- **<u>EXAMPLE:</u> If resistors of 2Ω, 3 Ω, and 7 Ω are connected in series in a circuit with a current of 2.5 amps what will be the emf in a source with negligible resistance?**

$$R_{Total} = R_1 + R_2 + R_3$$

$$R_{Total} = 3 + 2 + 7 = 12$$

$$V = IR = 2.5x12 = 30V$$

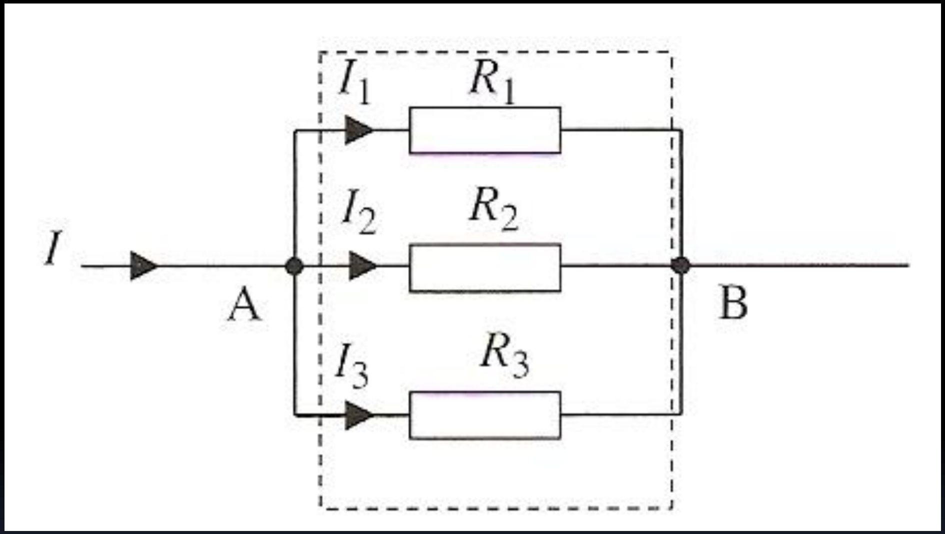
Parallel Circuits



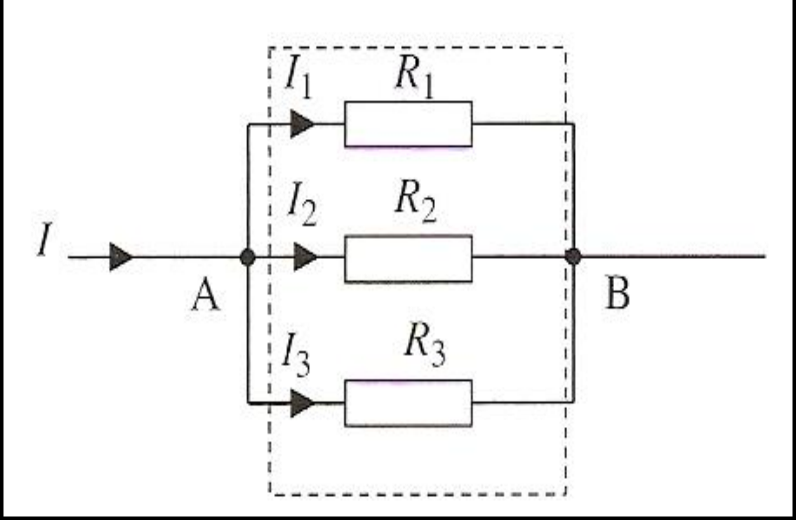
- In parallel circuits, the current splits and flows through two or more resistors
- The current that enters the split must equal the current that exits the split
- The sum of the split currents must equal the current in and out
- The same potential exists across each resistor that is connected in parallel
  - That is what determines the current

Parallel Circuits

- Consider the circuit below



Parallel Circuits



$$V = IR$$

$$I = \frac{V}{R}$$

$$I_{Total} = I_1 + I_2 + I_3$$

$$I_{Total} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$I_{Total} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{I_{Total}}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$R_{Total} = \frac{V}{I_{Total}}$$

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Series Circuits

$$R_{Total} = R_1 + R_2 + R_3 + \bullet\bullet\bullet$$

Parallel Circuits

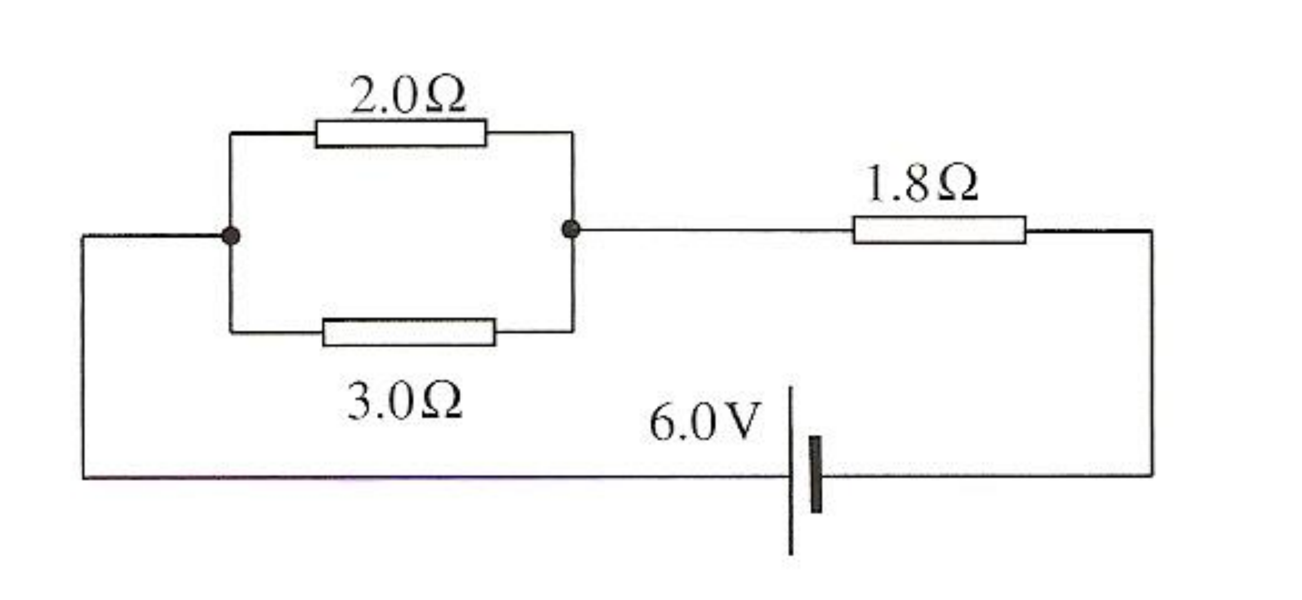
$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \bullet\bullet\bullet$$

Analyzing Circuits

- The reason we have learned how to combine resistors that are in series or in parallel is that it gives us a means for analyzing circuits

Analyzing Circuits

- **EXAMPLE: Find the current through each resistor and the potential difference across each resistor in the circuit below:**

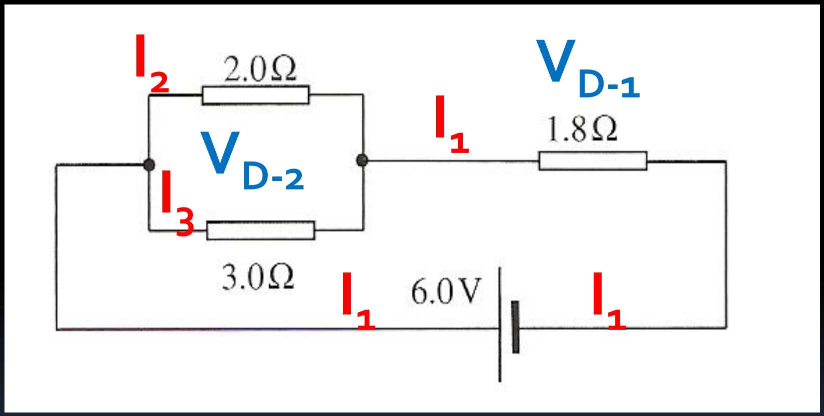


- *In series resistors, the current through each resistor is the same and the potential difference (drop) is different.*

- *In parallel resistors, the potential difference (drop) is the same and the current through each resistor is different.*

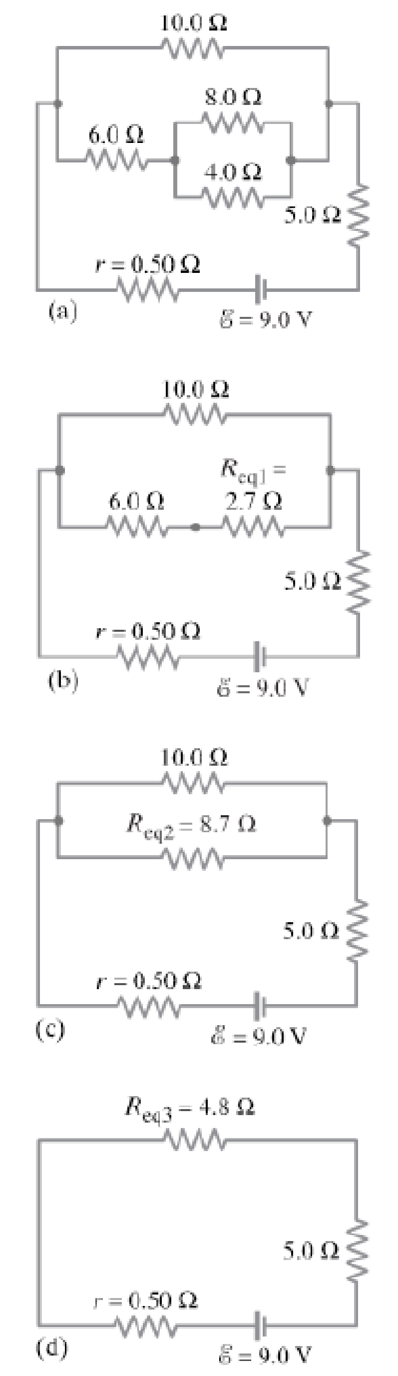
Analyzing Circuits

- **EXAMPLE: Find the current through each resistor and the potential difference across each resistor in the circuit below:**

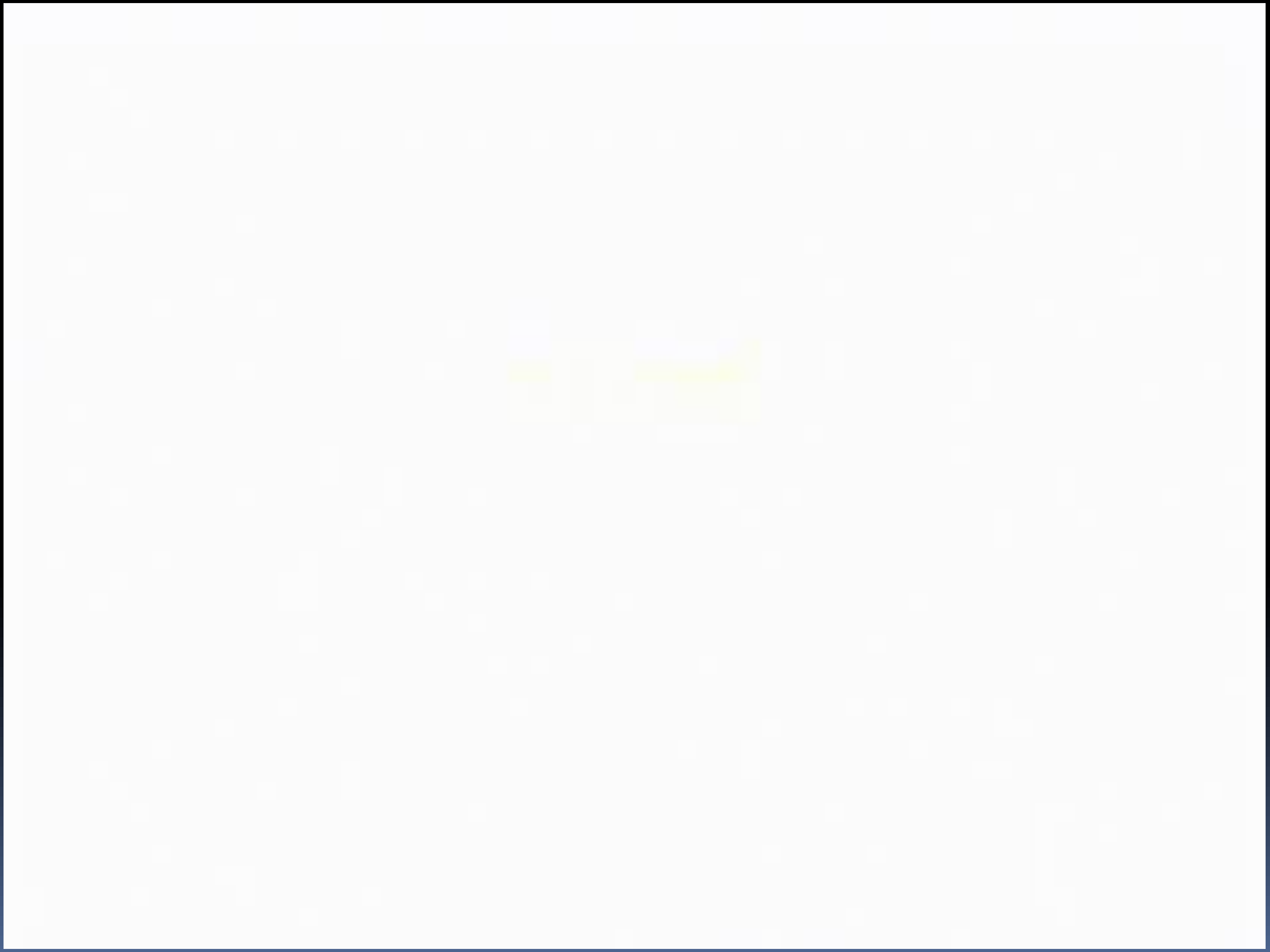


- Find total resistance
- Find current in/out of battery
- Find voltage drop across series resistor
- Find voltage drop across parallel circuit
- Find current through each parallel resistor

Figure 19-10


10.0 Ω
8.0 Ω
6.0 Ω
4.0 Ω
5.0 Ω
r = 0.50 Ω
(a)
ℰ = 9.0 V
10.0 Ω
R_eq1 = 2.7 Ω
6.0 Ω
5.0 Ω
r = 0.50 Ω
(b)
ℰ = 9.0 V
10.0 Ω
R_eq2 = 8.7 Ω
5.0 Ω
r = 0.50 Ω
(c)
ℰ = 9.0 V
R_eq3 = 4.8 Ω
5.0 Ω
r = 0.50 Ω
(d)
ℰ = 9.0 V

Electrical Circuits - Ohm's Law - Summary



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QUESTIONS?

Homework

#1-18

STOPPED HERE 4/21/15