PHYS2326
Lecture #14

Prof. Fabiano Rodrigues

Department of Physics
The University of Texas at Dallas

Goals for the lecture

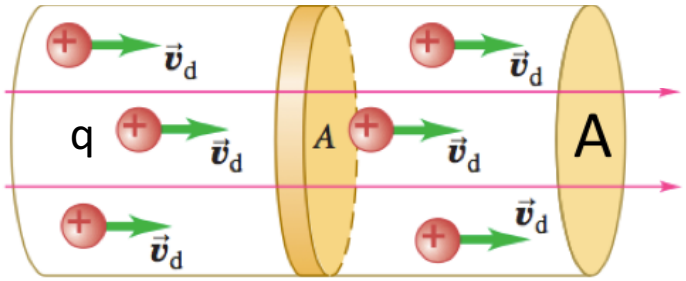
- Review and finish our analysis of Ohm's Law
- Resistors in series and parallel (Sec. 26.1)
- Electric Meters: Voltmeter and Ammeter
- The Electromotive Force (EMF)

Chapter 25 + 26.1

Charges in Motion

Electric Current: Definition

- Electric current (I) is the amount of charge flowing through an specific cross section area per unit of time.



$$I = \frac{dQ}{dt}$$

$$I_{avg} = \frac{\Delta Q}{\Delta t}$$

Direction of Electric Current

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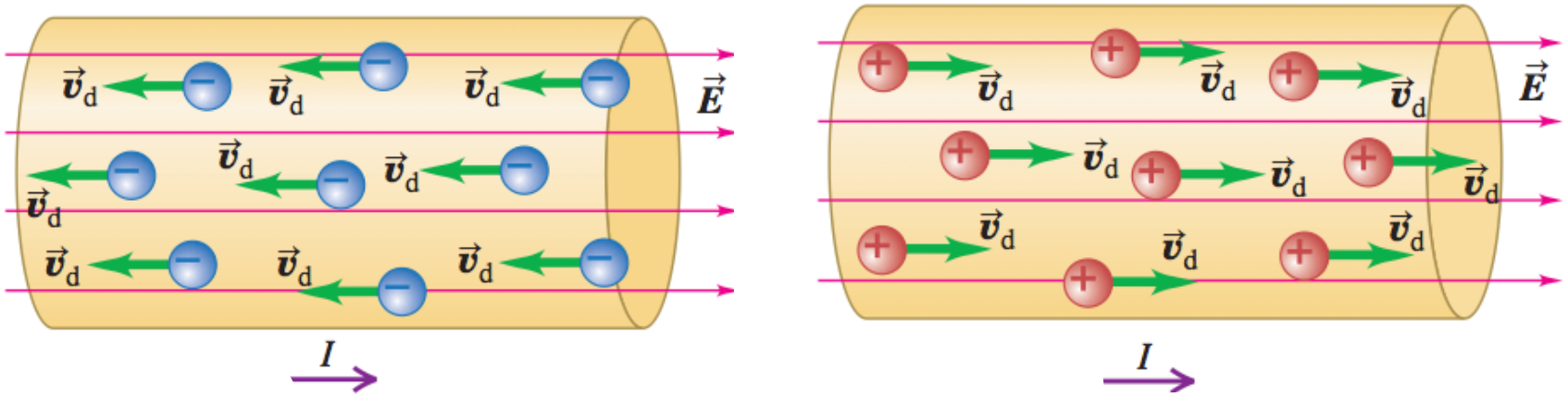

- **Direction of current:** Convention is that current points in the direction that positive charges would flow.

Electric Current Density (J)

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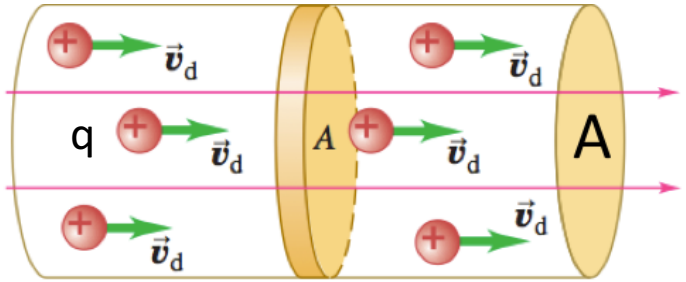
$$J = \frac{I}{A} = |q|nv_d$$

Vector current density:

$$\vec{J} = qn\vec{v}_d$$

$Units: C/(m^2 s) = A/m^2$

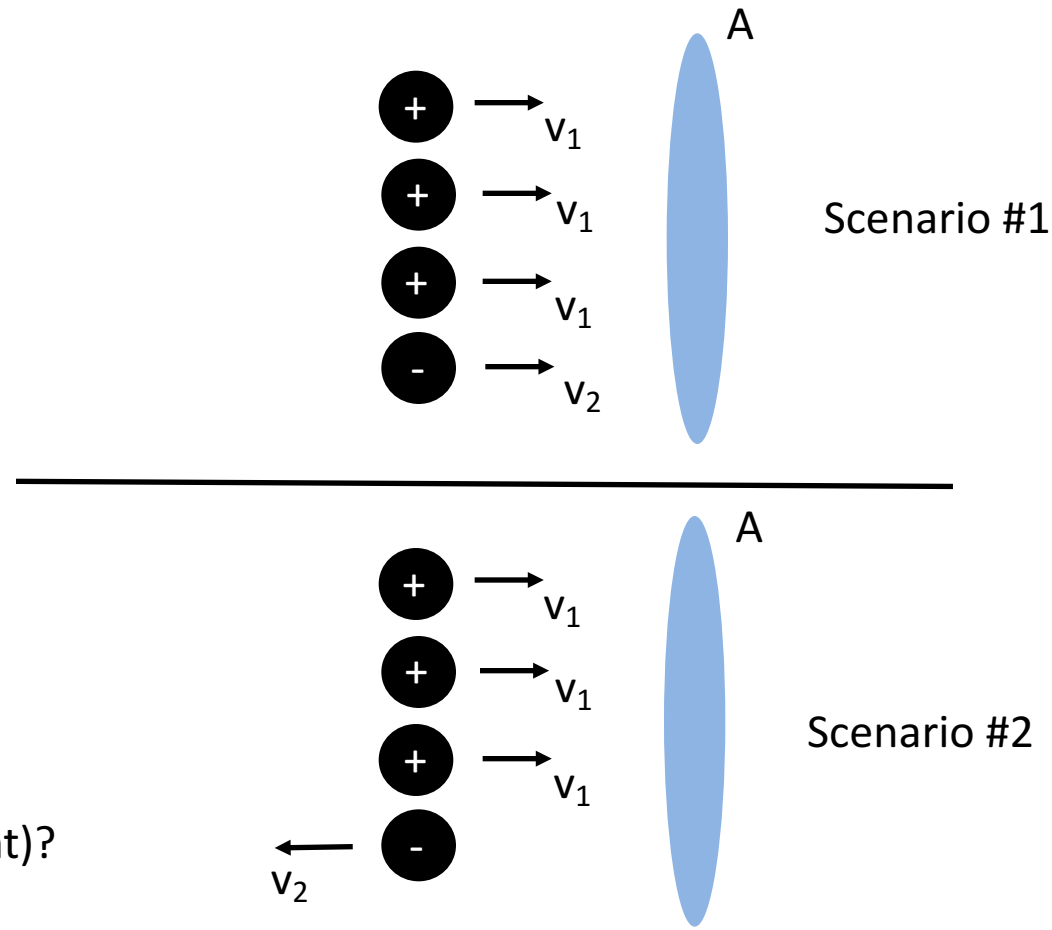


$A = cross - section\ [m^2]$
$v_d = drift\ velocity\ [m/s]$
$q = charge\ [C]$
$n = volume\ charge\ density\ [m^{-3}]$

Analysis: Current

$$\vec{J} = qn\vec{v}_d$$

$$\vec{J} = \sum_{i=1}^{N} q_i n_i \vec{v}_{d,i}$$



What scenario illustrates a larger current density (or current)?

Ohm’s Law: Resistivity and Resistance

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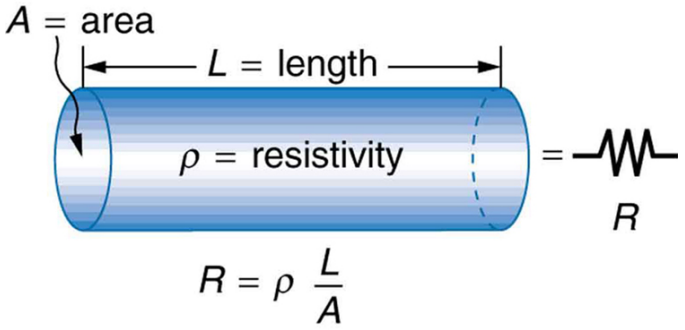
$$\vec{\mathrm{E}} = \rho\vec{J}$$

$$V = RI$$



$$\rho = resistivity\ [\Omega \cdot m\ or\ ohm \cdot m]$$

$$R = \rho\frac{L}{A} = resistance\ [\Omega]$$

Resistors

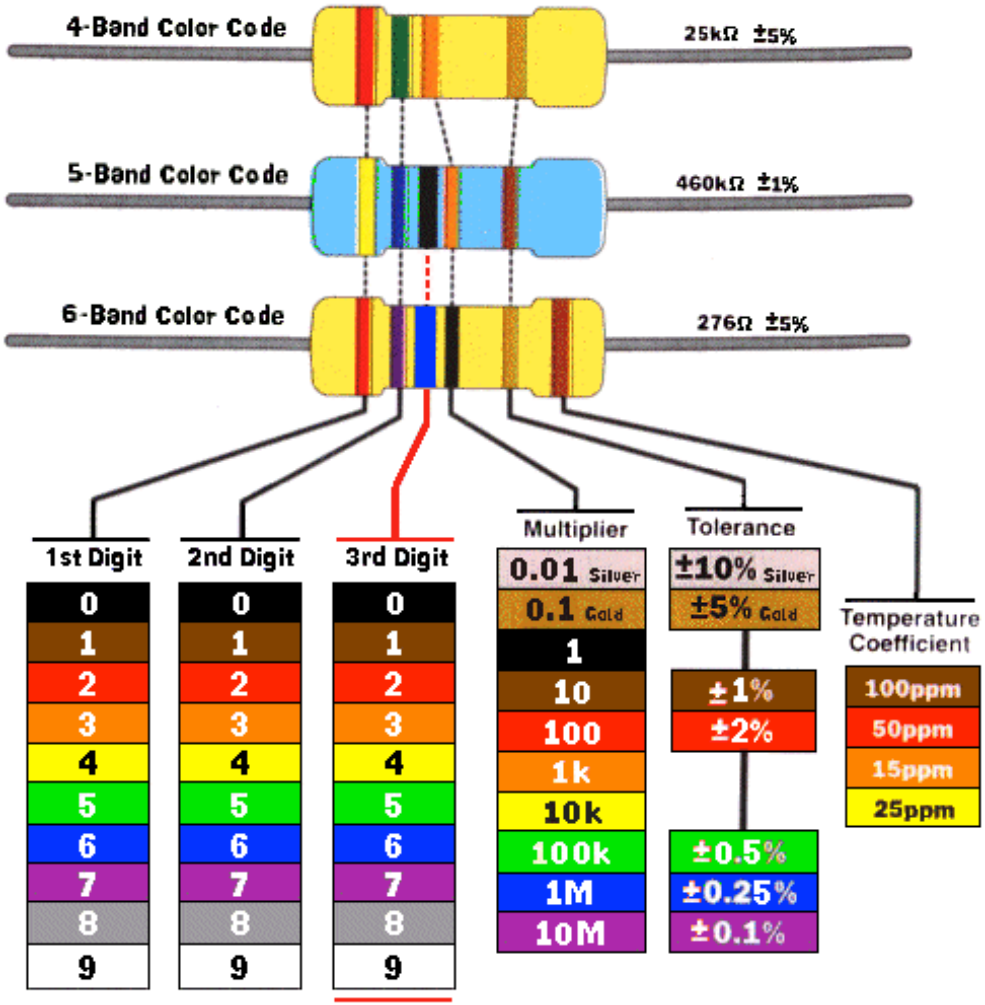
- Resistors are electric circuit devices made with a specific value of resistance.

- Symbol:

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

- Unit: Ω (ohm)

Resistors



ppm/°C (parts per million per ^{o}C)
Example: 15 ppm
It will not change more than
$15 \times 10^{-6} \Omega$ / ^{o}C from value at 25^{o}C

Example: The current in a wire varies with time according to the relation:
$I = 55\ A - (0.65\ A/s^2)t^2$.
How many coulombs of charge pass a cross section of the wire in the time interval between t=0 and t = 7.5 s ?

$$I = \frac{dq}{dt}$$

$$|\vec{J}| = \frac{|\vec{E}|}{\rho}$$

$$V = \left(\frac{\rho L}{A}\right) I$$

$$R = \frac{\rho L}{A}$$

$$V = RI$$

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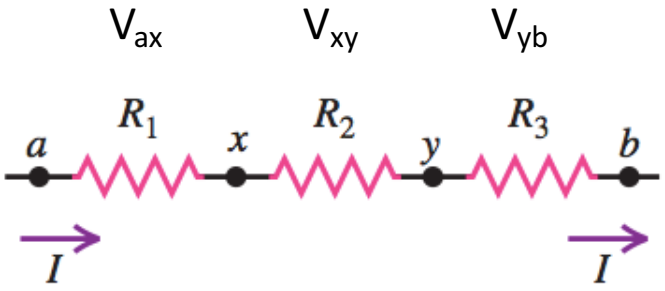
Resistors in Series and Parallel

Resistors in Series

- Resistors share the same current (I)
- Resistors have distinct potential differences (V)



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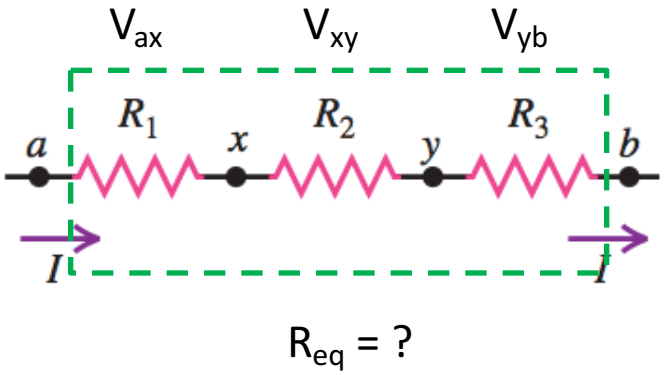

R_{eq} = ?

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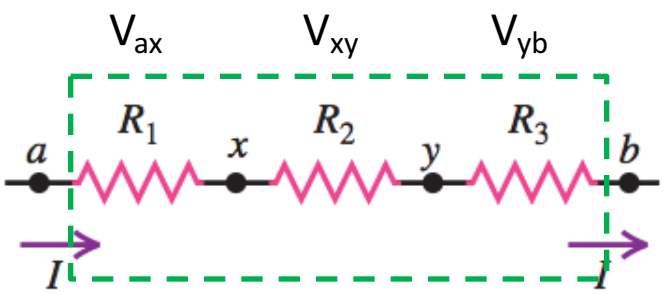

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$$V_{ab} = V_{ax} + V_{xy} + V_{yb}$$

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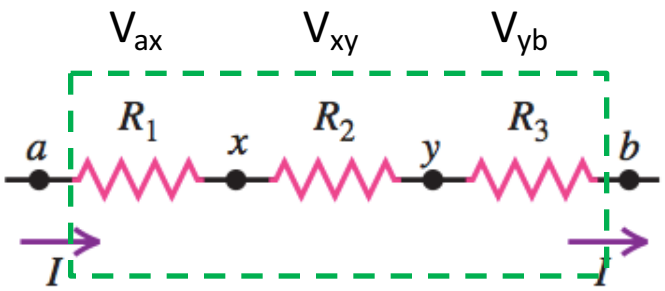

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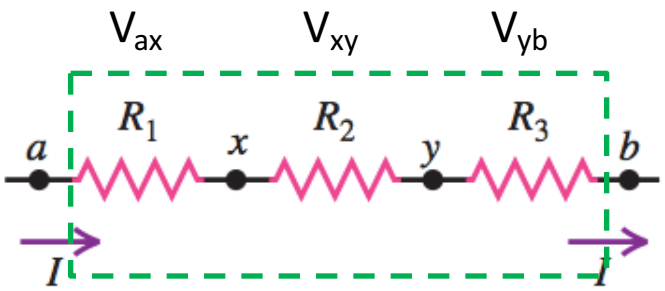

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$$\frac{V_{ab}}{I} = R_1 + R_2 + R_3$$

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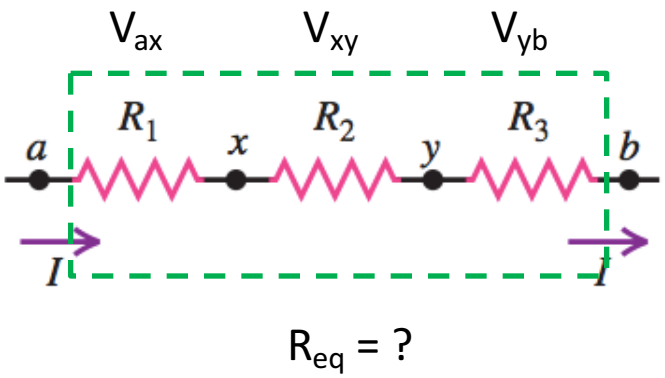

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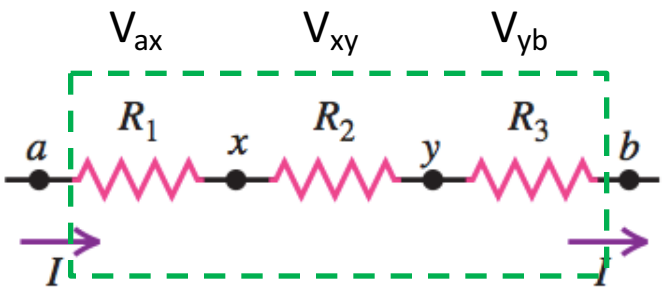

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$$\frac{V_{ab}}{I} = R_1 + R_2 + R_3$$

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

$$R_{eq} = R_1 + R_2 + R_3 + \ldots + R_N$$

$$R_{eq} = \sum_{i=1}^{N} R_i$$

Resistors in Parallel

- Resistors share the same potential difference (V_{ab})
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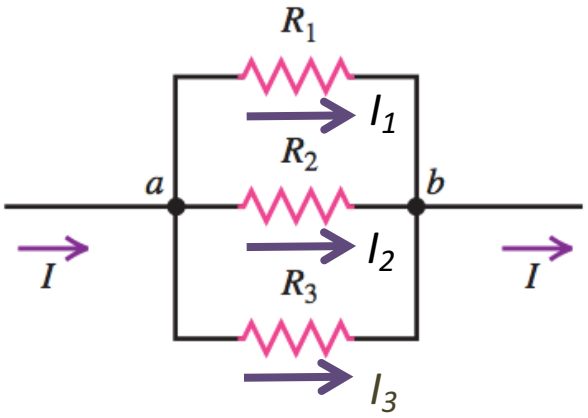

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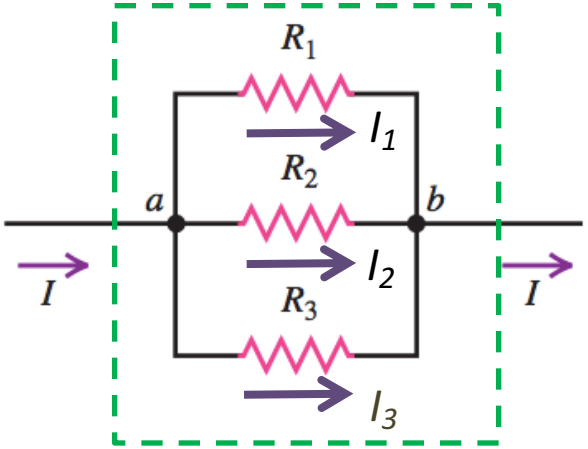

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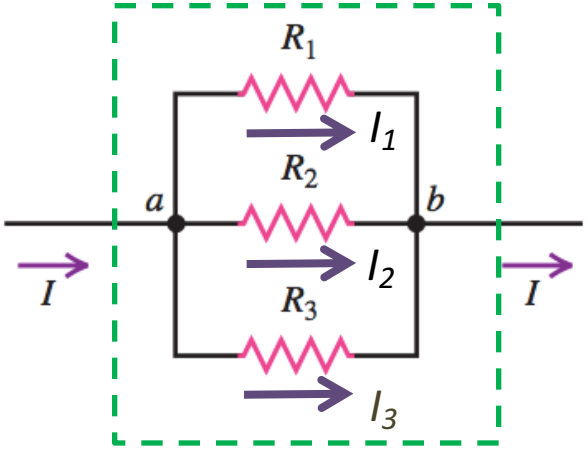

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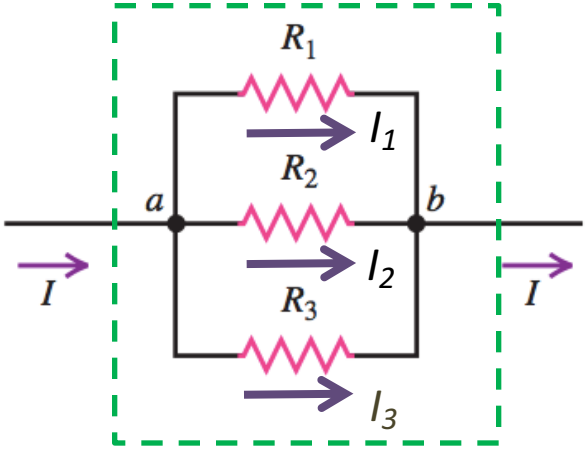

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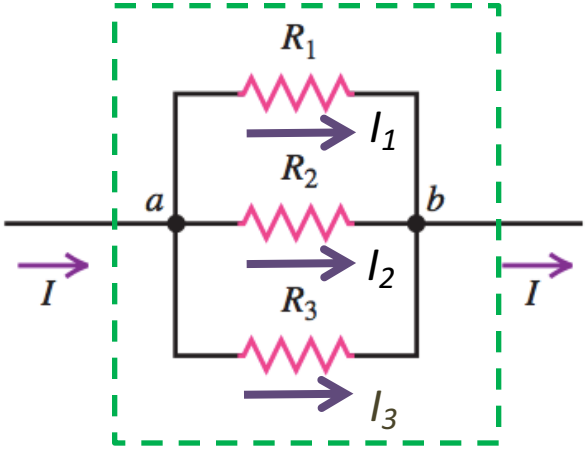

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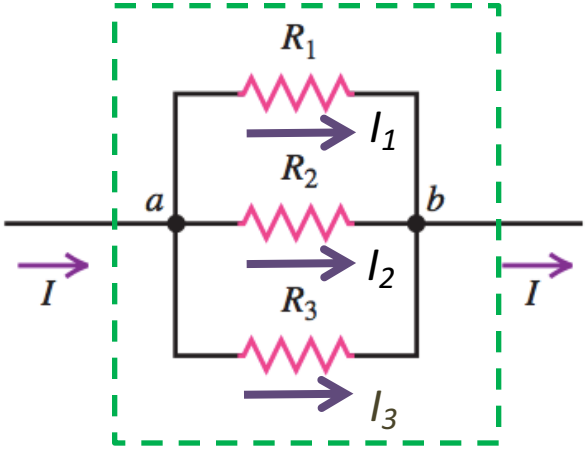

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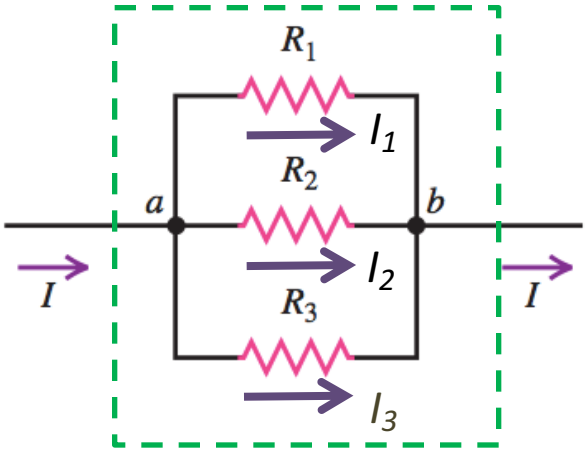

R_{eq} = ?

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

$$\frac{1}{R_{eq}} = \sum_{i=1}^{N} \frac{1}{R_i}$$

$$I = I_1 + I_2 + I_3$$

$$\frac{V_{ab}}{R_{eq}} = \frac{V_{ab}}{R_1} + \frac{V_{ab}}{R_2} + \frac{V_{ab}}{R_3}$$

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Describing Circuits

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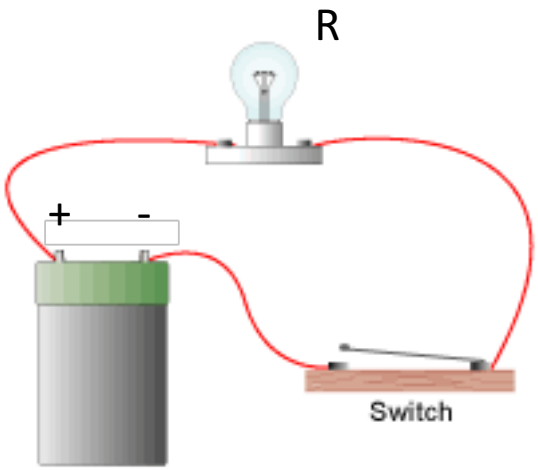

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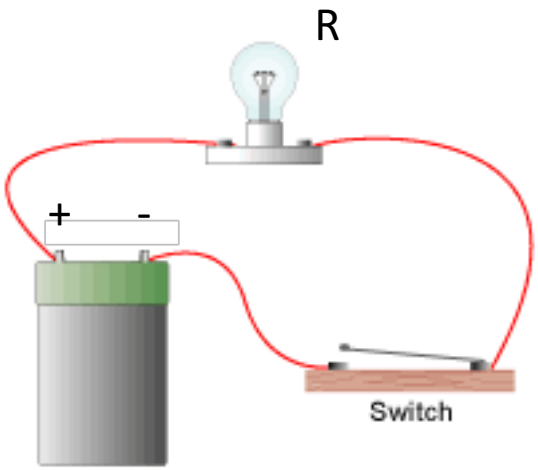
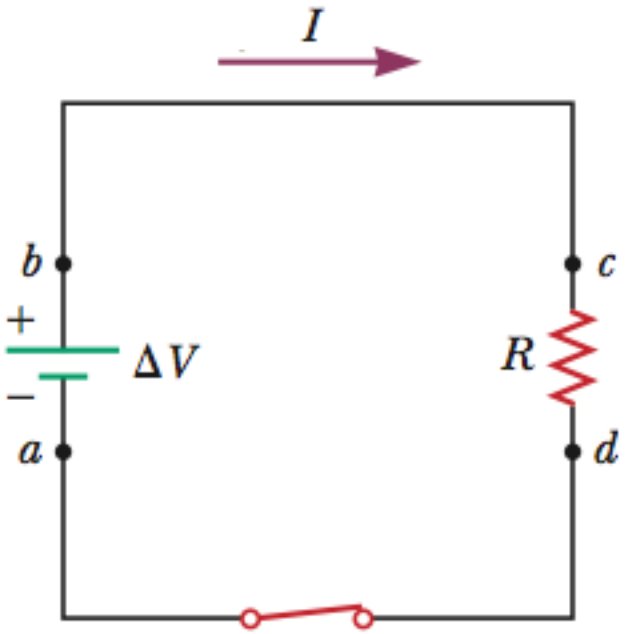
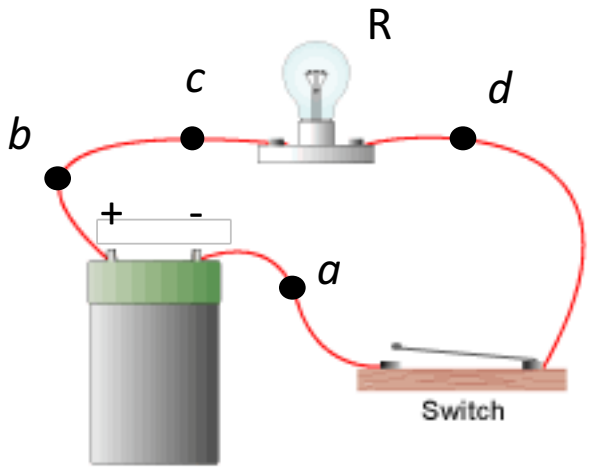
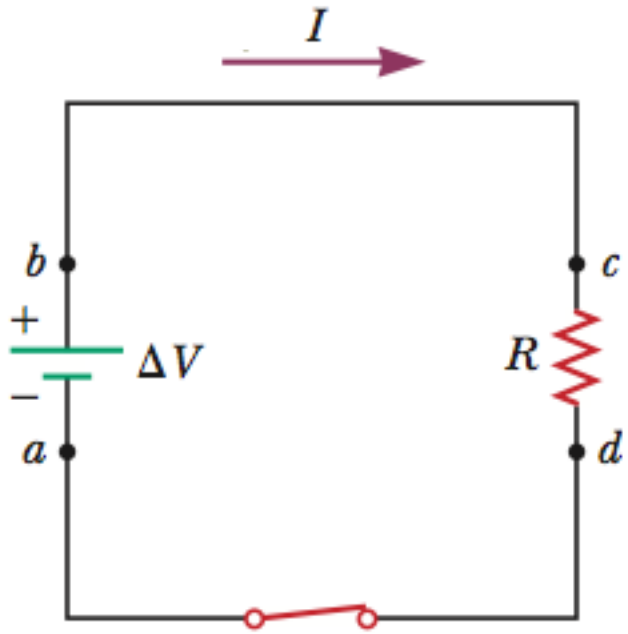




switch

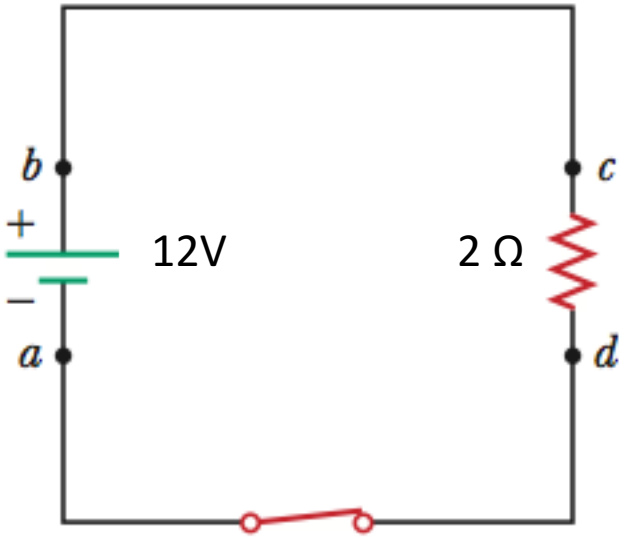
Describing Circuits





switch

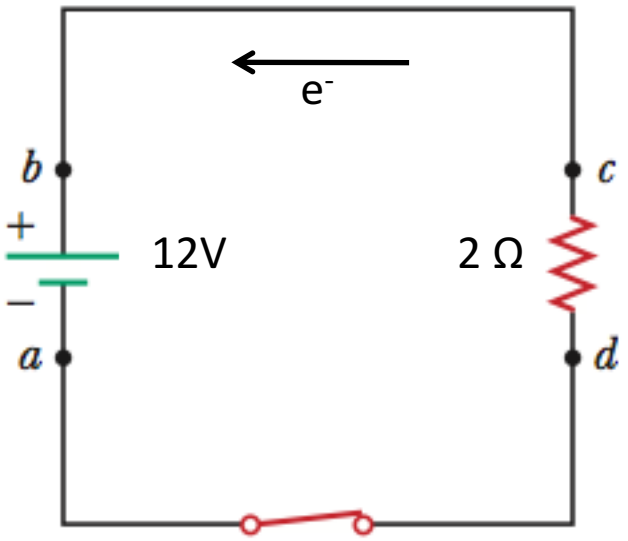
Example: Ohm's Law



Consider the circuit shown :

(a) What is the direction of the current?

Example: Ohm's Law



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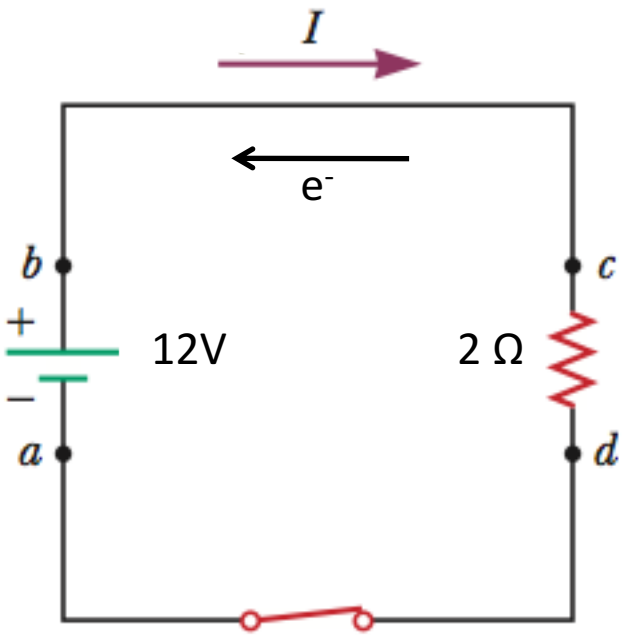

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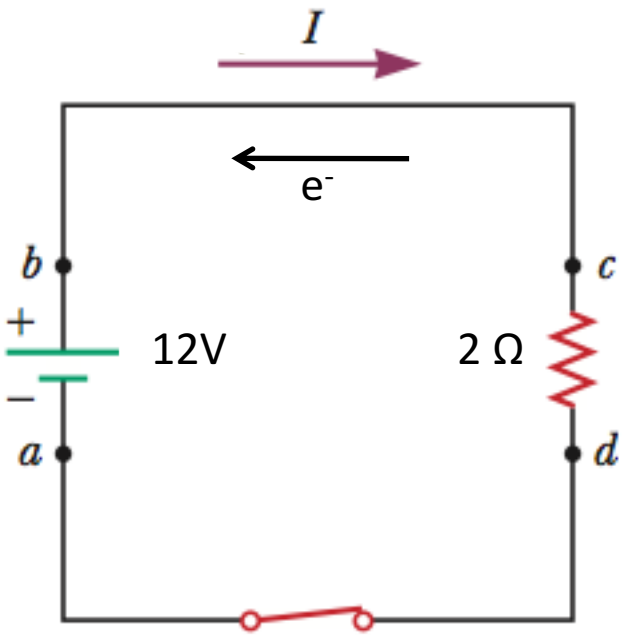
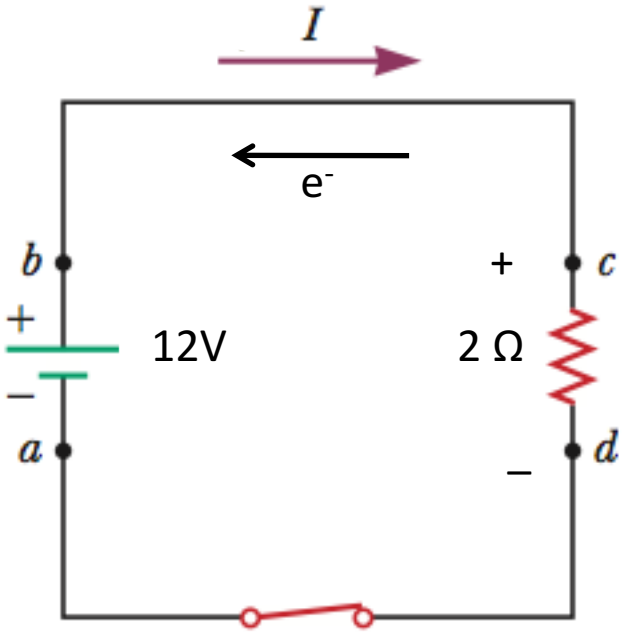


Consider the circuit shown :

(a) What is the direction of the current?

(b) $V_c > V_d = ?$

Example: Ohm's Law



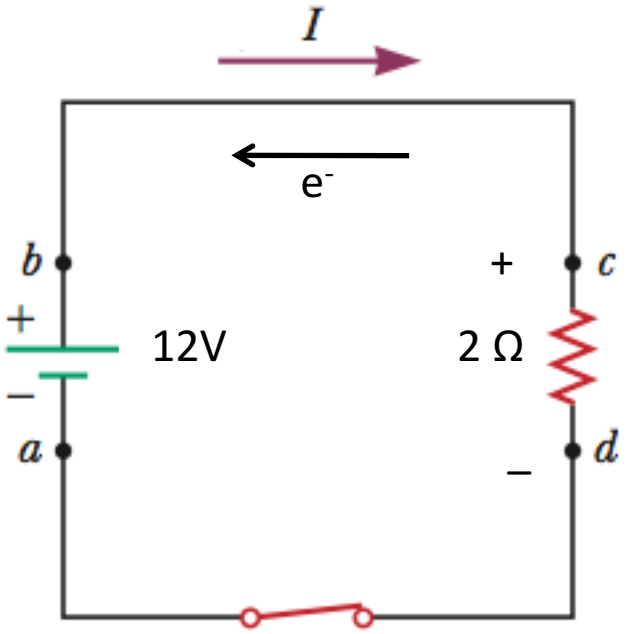
Consider the circuit shown :

(a) What is the direction of the current?

(b) $V_c > V_d = ?$

(c) What is the magnitude of the current?

Example: Ohm's Law



Consider the circuit shown :

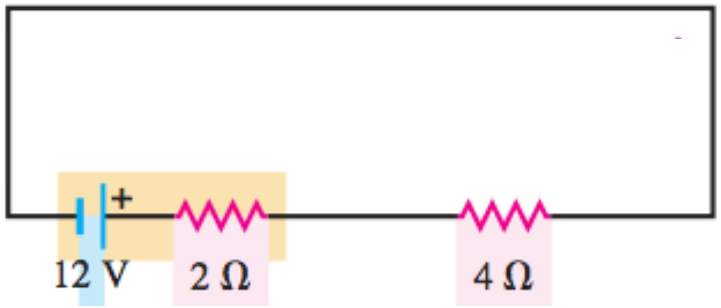
(a) What is the direction of the current?

(b) $V_c > V_d = ?$

(c) What is the magnitude of the current?

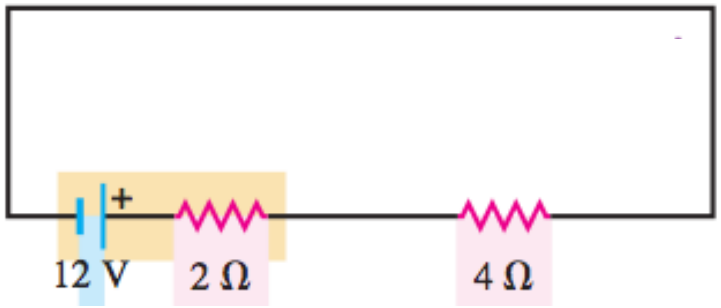
$$I = \frac{\Delta V}{R} = \frac{12V}{2} = 6A$$

Potential Changes Around a Circuit



$$\Delta V = RI$$

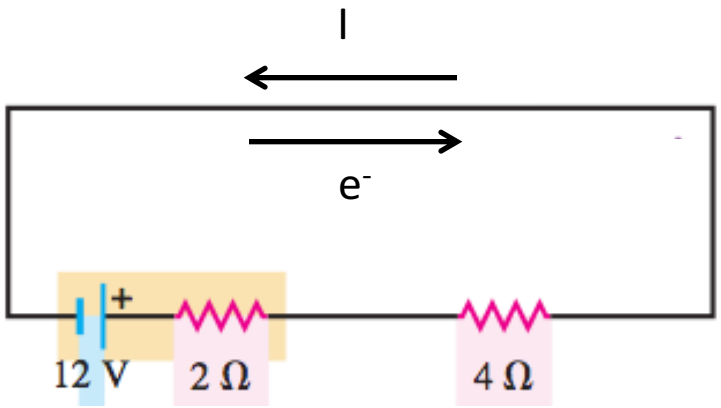
Potential Changes Around a Circuit



Direction of current?

Clockwise
Counter-clockwise

Potential Changes Around a Circuit



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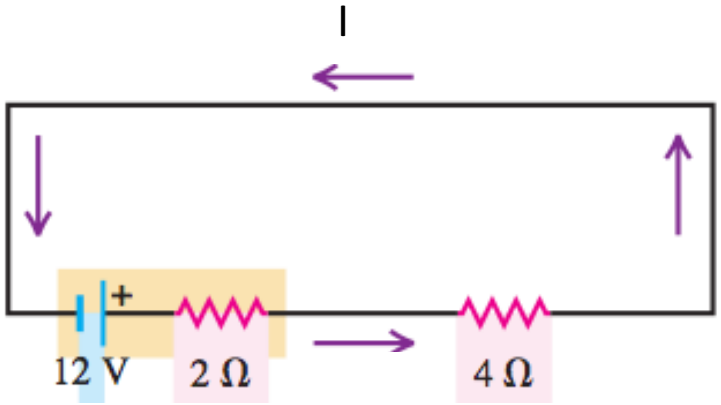
Counter-clockwise

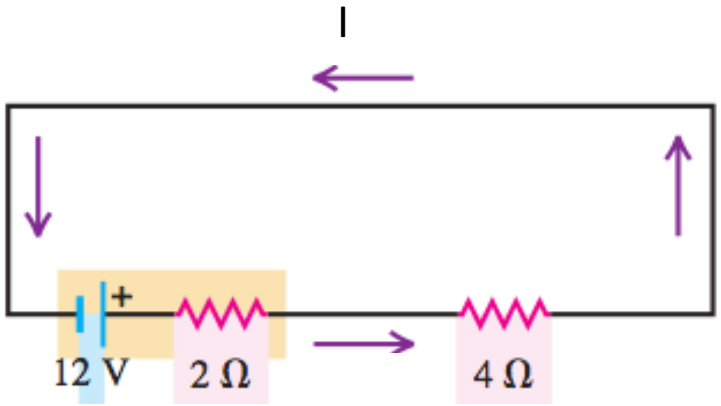
Potential Changes Around a Circuit



Direction of current?

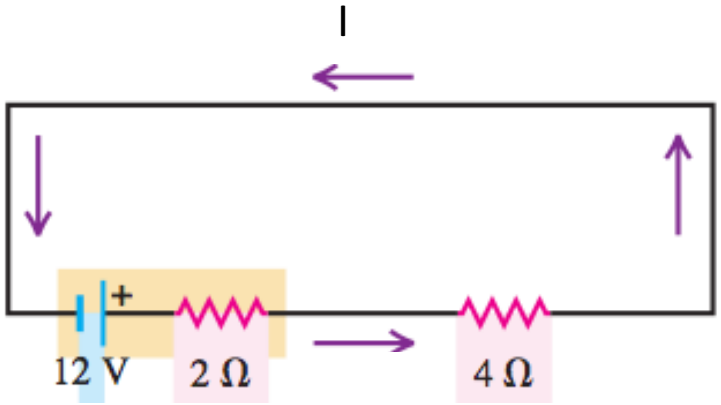
Clockwise
Counter-clockwise

Potential Changes Around a Circuit



Magnitude of current?

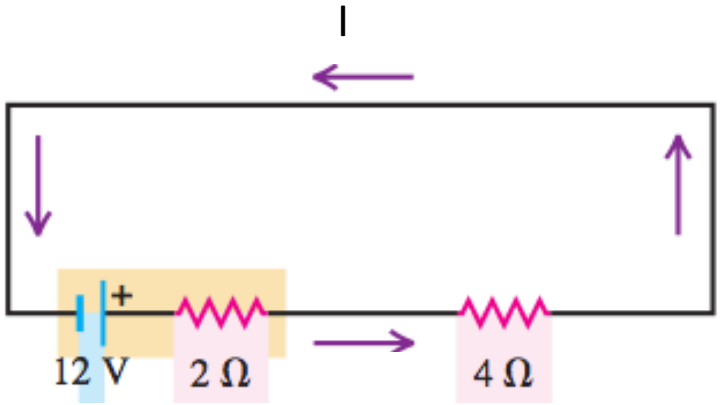
Potential Changes Around a Circuit



Magnitude of current?

$\Delta V = RI$

Potential Changes Around a Circuit

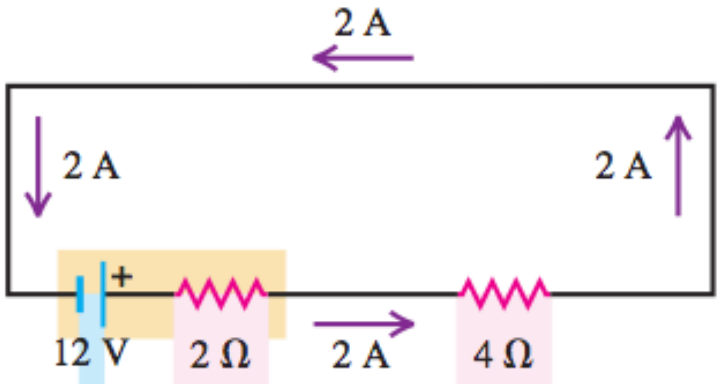


Magnitude of current?

$$\Delta V = RI$$

$$I = \frac{\Delta V}{R} = \frac{12}{2+4} = 2\ A$$

Potential Changes Around a Circuit



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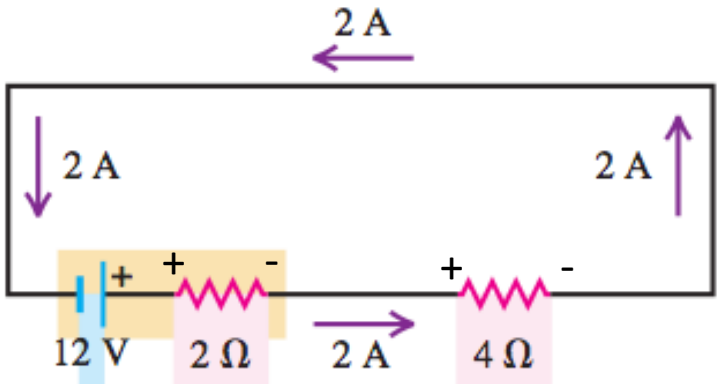

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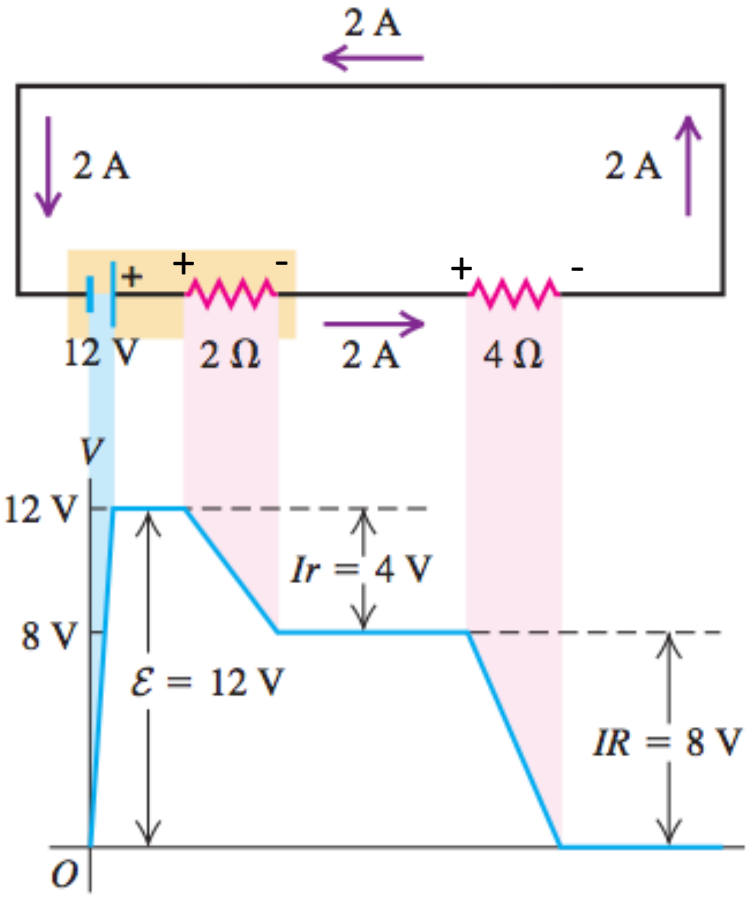

Magnitude of current?

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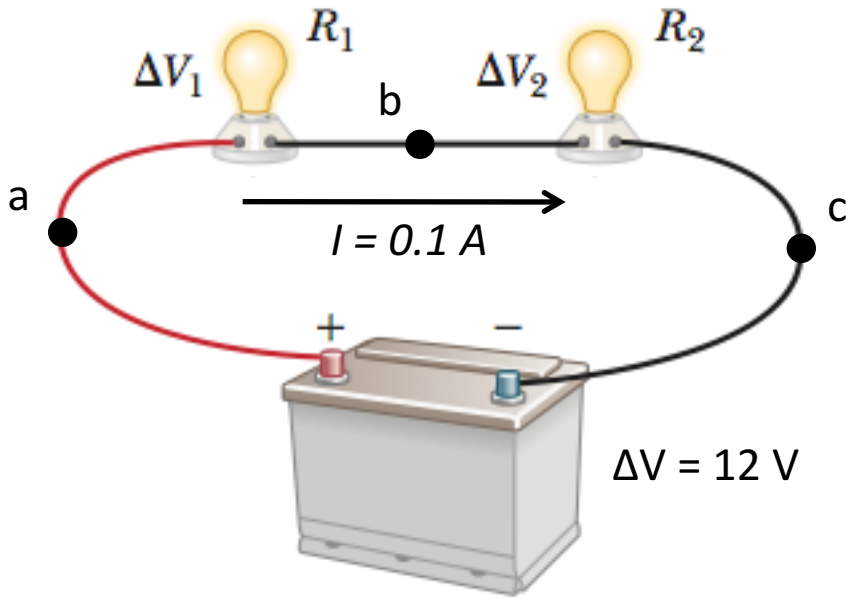
Example: If a battery provides a potential difference of 12 V, the current is 0.1 A and R_1 = 40 Ω and R_2 = 80 Ω. What potential difference would you measure (a) between points a and b, and (b) between points b and c?



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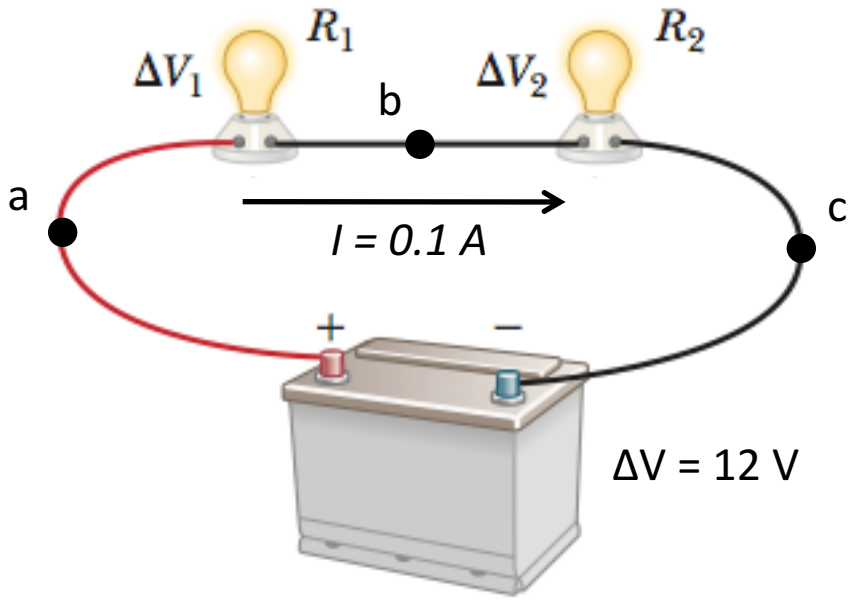

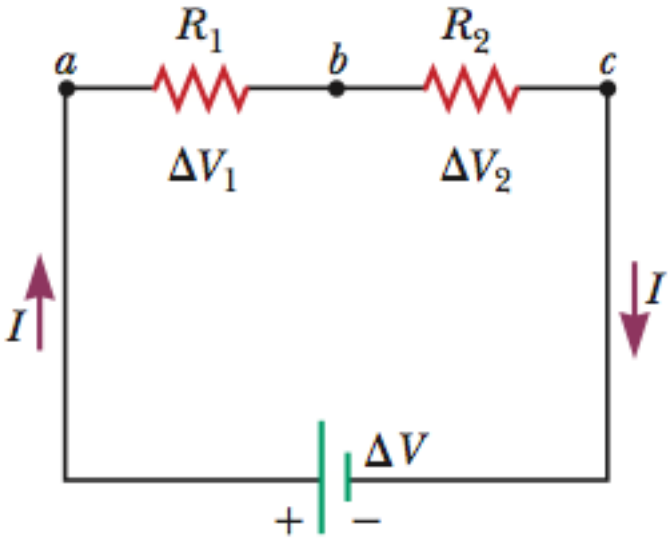

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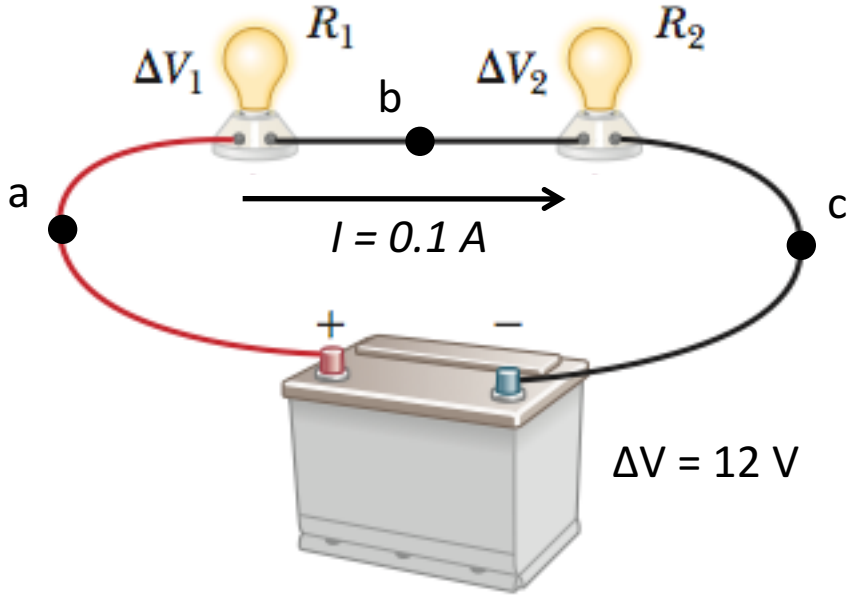
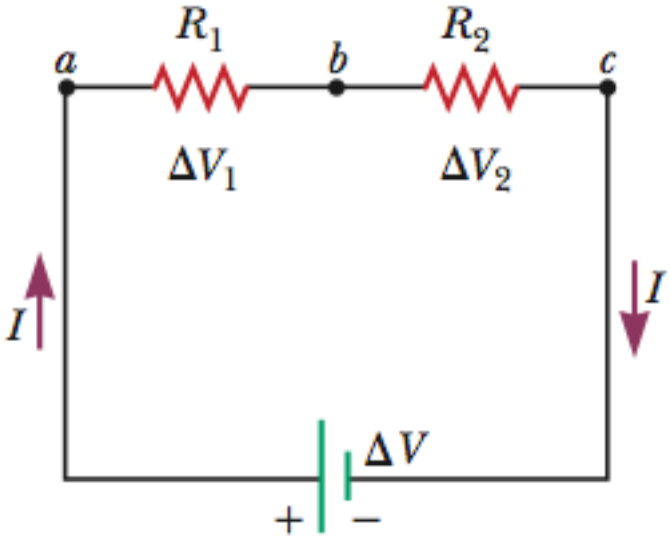




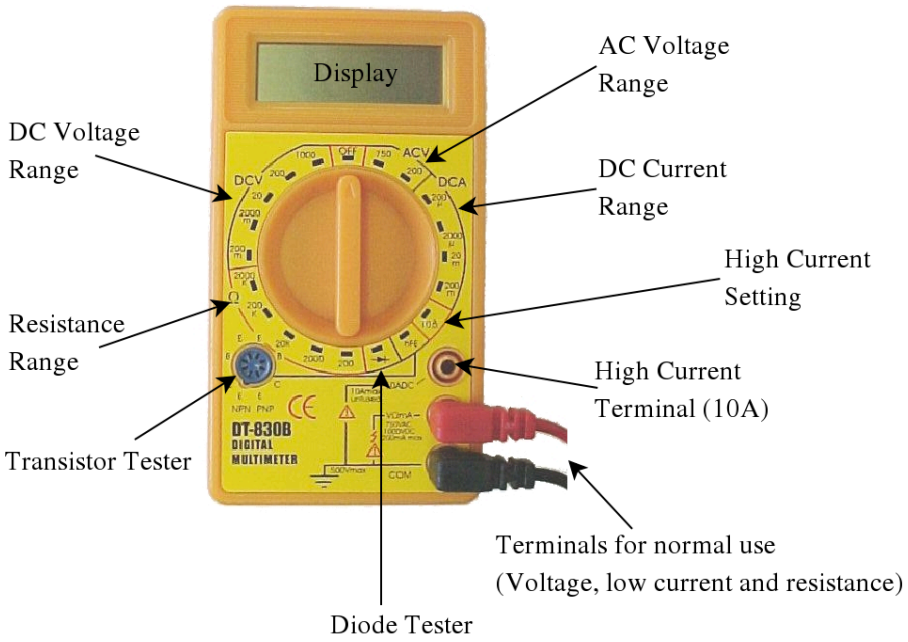
$$\Delta V = RI$$

$$\Delta V_1 = R_1 I = (40)(0.1) = 4 \ V$$

$$\Delta V_2 = R_2 I = (80)(0.1) = 8 \ V$$

Meters

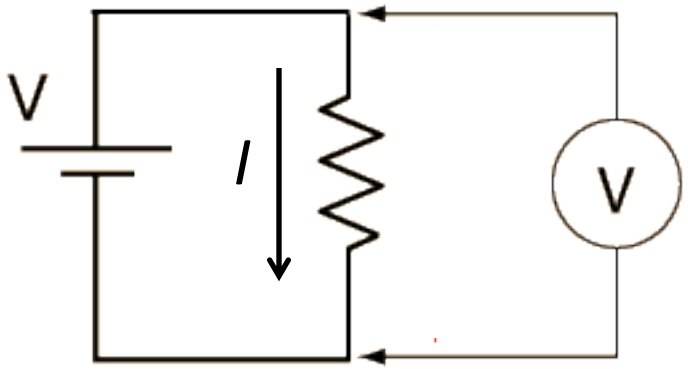
Meters



- Voltmeter: Measures the potential difference between two points in a circuit.

- Ammeter: Measures the electric current trough a portion of a circuit.

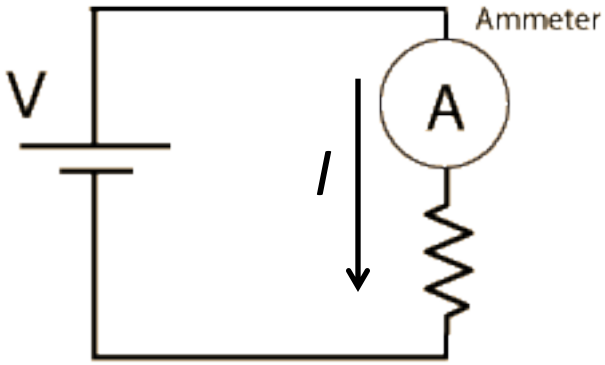
Voltmeter



- A voltmeter is placed in parallel with the circuit element whose voltage is to be measured.

- A voltmeter has high resistance so that all the current goes through the circuit element.

Ammeter

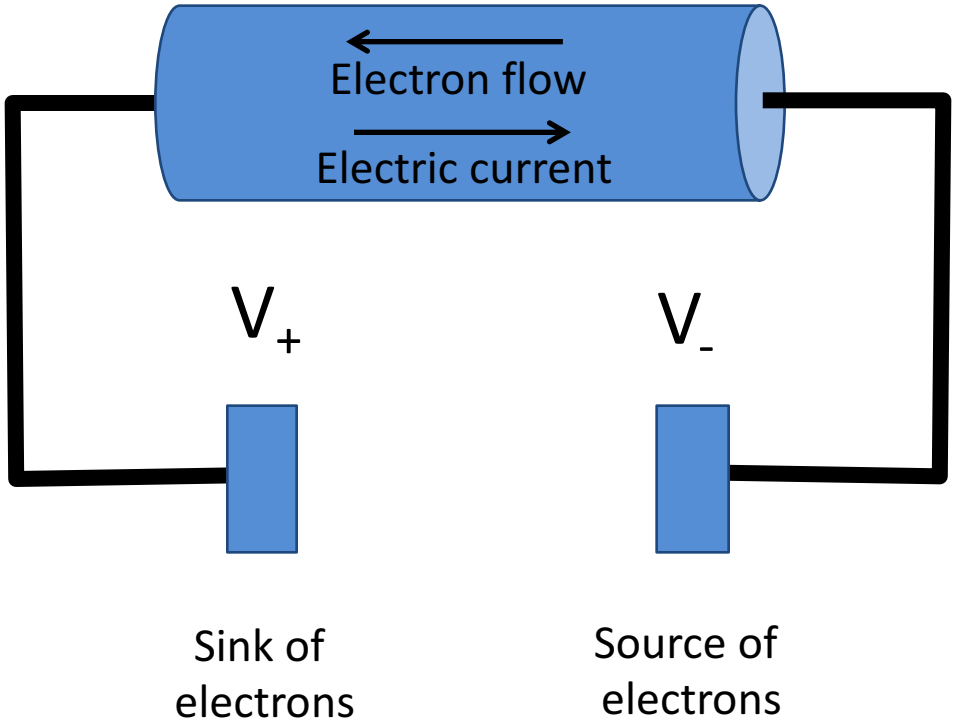


- Ammeter is placed in series with the circuit element whose current going through is to be measured.

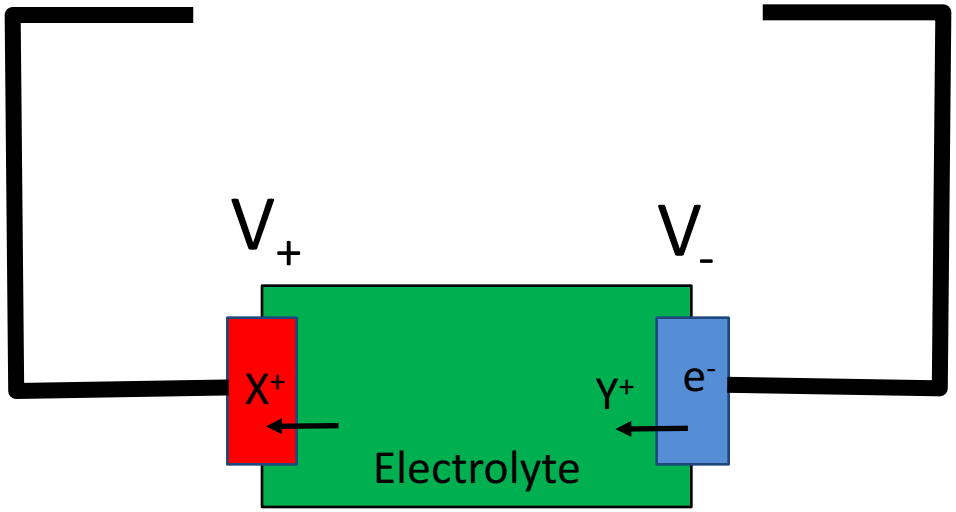
- Ammeter has low resistance so that it does not affect the current going through element.

Electromotive Force

Electromotive Force



Electromotive Force



Electromotive Force