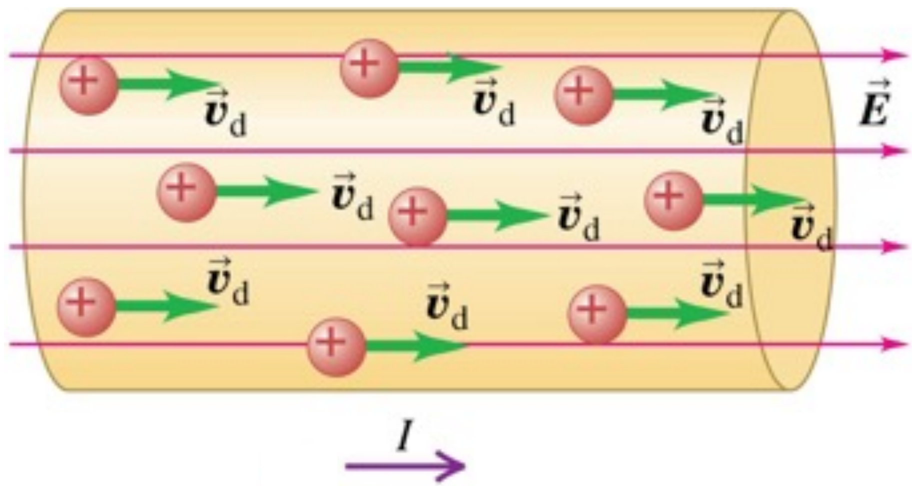
Lecture 23

PHYC 161 Fall 2016

Current

- A **current** is any motion of charge from one region to another.



Rate at which charge flows through area

$$I = \frac{dQ}{dt} = n|q|v_d A$$

Current through an area

Concentration of moving charged particles

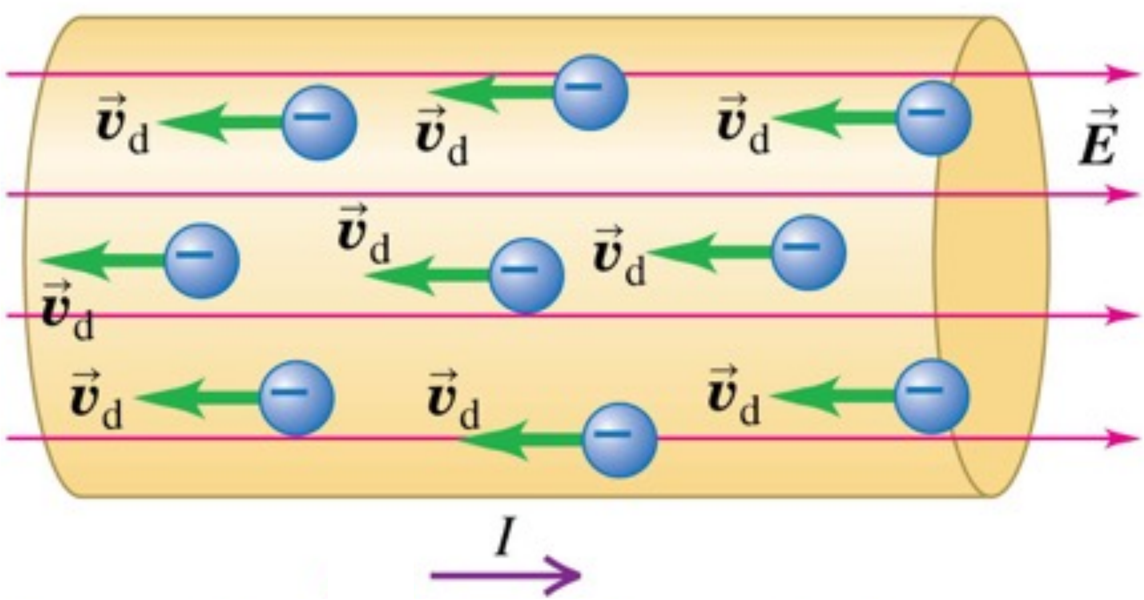
Drift speed

Cross-sectional area

Charge per particle

Direction of current flow

- A current can be produced by positive or negative charge flow.
- *Conventional current* is treated as a flow of positive charges.
- In a metallic conductor, the moving charges are electrons — but the *current* still points in the direction positive charges would flow.



Current density

- We can define a *vector* current density that includes the direction of the drift velocity:

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

Vector current density → $\vec{J}$; Concentration of moving charged particles → n; Charge per particle → q; Drift velocity → $\vec{v}_d$

- The vector current density is always in the same direction as the electric field, no matter what the signs of the charge carriers are.

Resistivity

- The **resistivity** of a material is the ratio of the electric field in the material to the current density it causes:

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

Resistivity of a material → ρ
E ← Magnitude of electric field in material
J ← Magnitude of current density caused by electric field

- The *conductivity* is the reciprocal of the resistivity.
- The next slide shows the resistivity of various types of materials.

Resistivities at room temperature (20°C)

	Substance	$\rho\ (\Omega \cdot m)$
Conductors ↕	Copper	1.72×10^{-8}
	Gold	2.44×10^{-8}
	Lead	22×10^{-8}
Semiconductor:	Pure carbon (graphite)	3.5×10^{-5}
Insulators ↕	Glass	$10^{10} - 10^{14}$
	Teflon	$>10^{13}$
	Wood	$10^{8} - 10^{11}$

Q25.1

Two copper wires of different diameter are joined end to end, and a current flows in the wire combination. When electrons move from the larger-diameter wire into the smaller-diameter wire,

A. their drift speed increases.

B. their drift speed decreases.

C. their drift speed stays the same.

D. either A or B is possible, depending on circumstances.

E. any of A, B, or C is possible, depending on circumstances.

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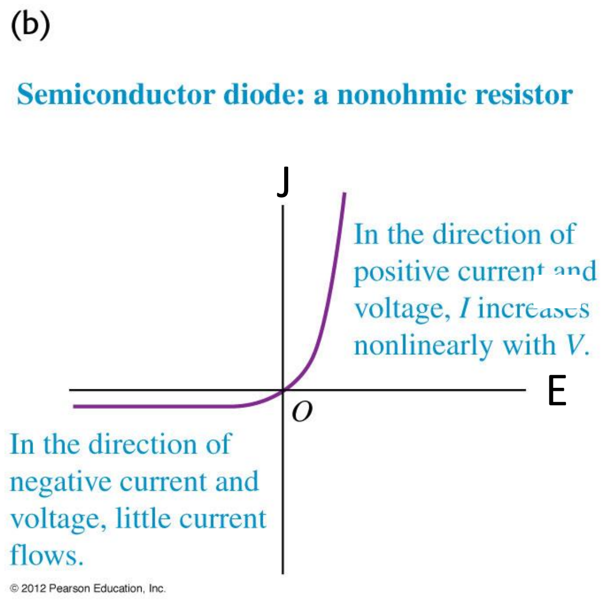
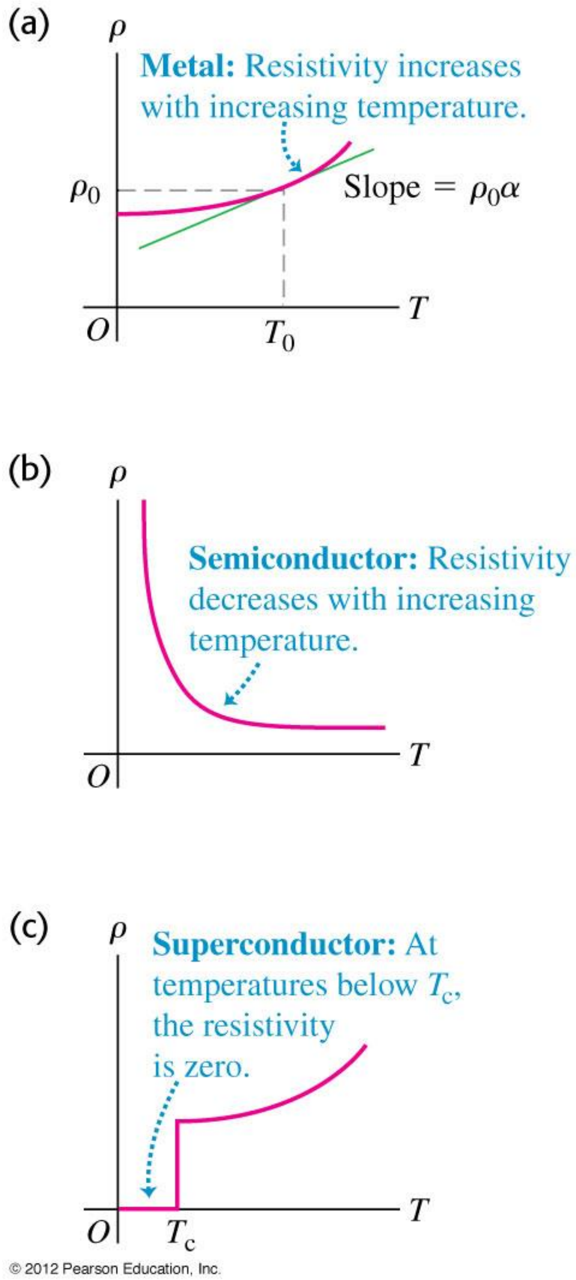
Caveats

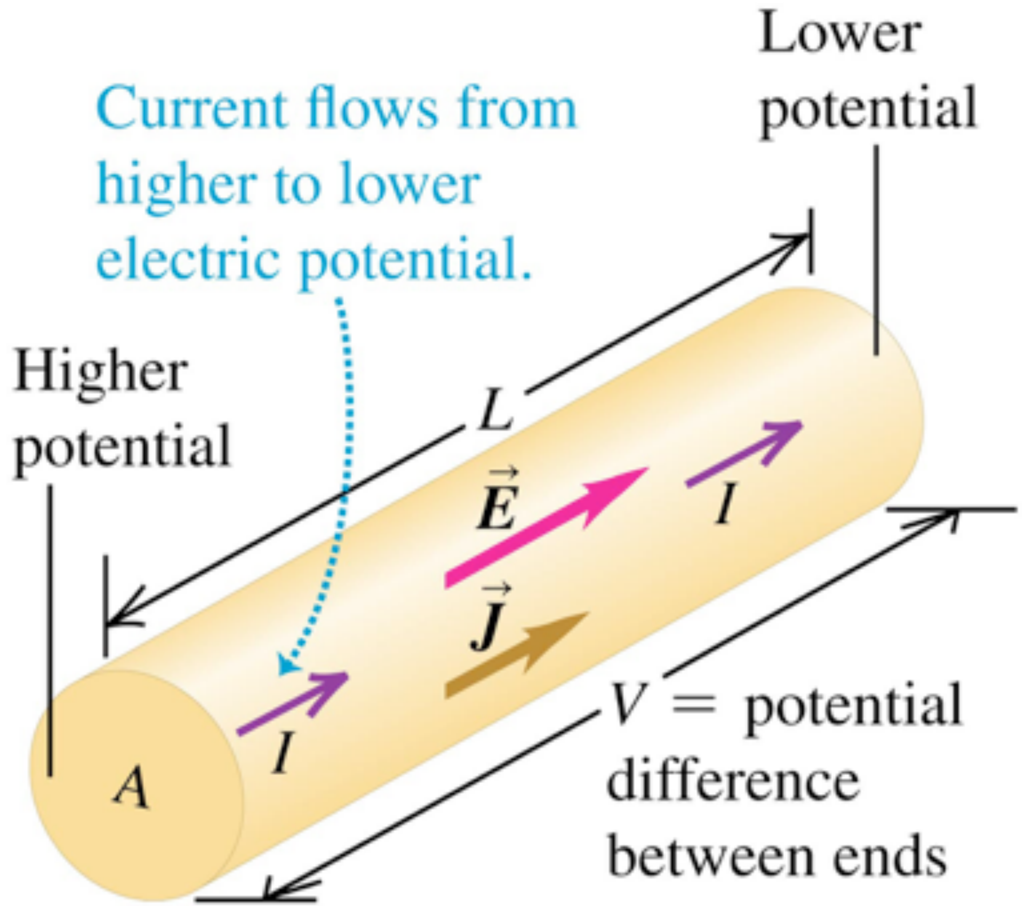
- The resistivity of materials in general depends on temperature.
- Not all materials are ohmic.





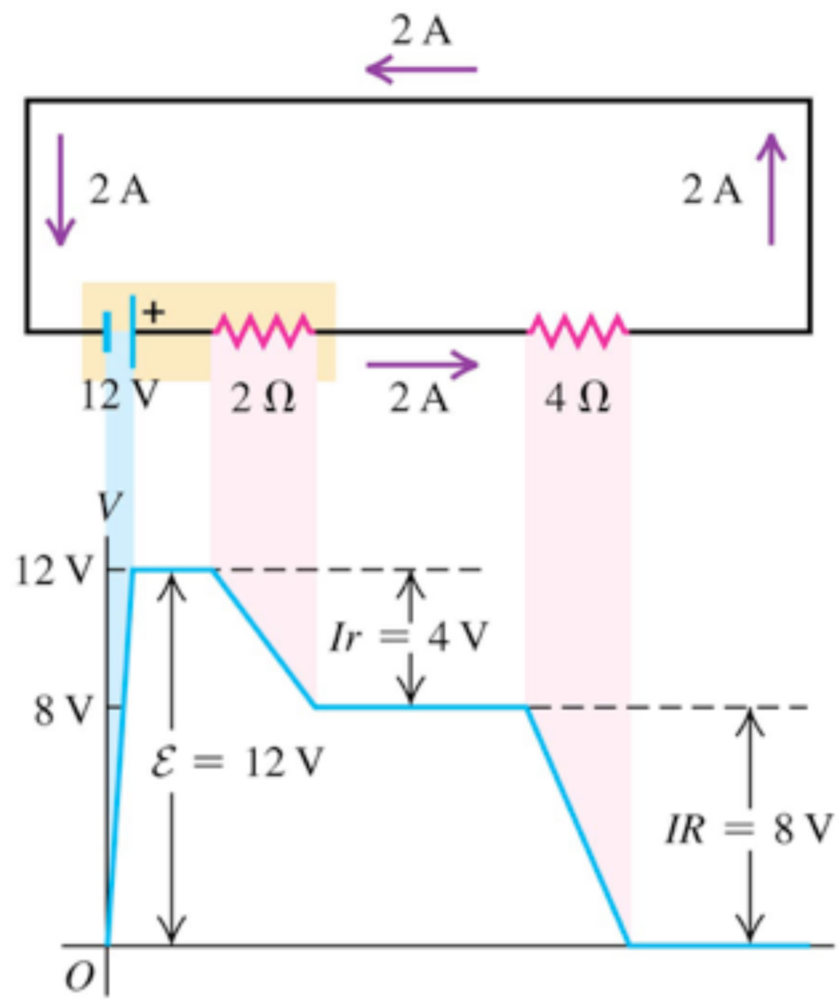
Resistance and Ohm's law

- The *resistance* of a conductor is $R = \rho L / A$.
- The potential across a conductor is given by Ohm's law: $V = IR$.



Potential changes

- The figure shows how the potential varies as we go around a complete circuit.
- The potential rises when the current goes through a battery, and drops when it goes through a resistor.
- Going all the way around the loop brings the potential back to where it started.



Q25.3

A source of emf is connected by wires to a resistor, and electrons flow in the circuit. The wire diameter is the same throughout the circuit. Compared to the *potential energy of an electron* before entering the *resistor*, the *potential energy of an electron* after leaving the *resistor* is

A. greater.

B. less.

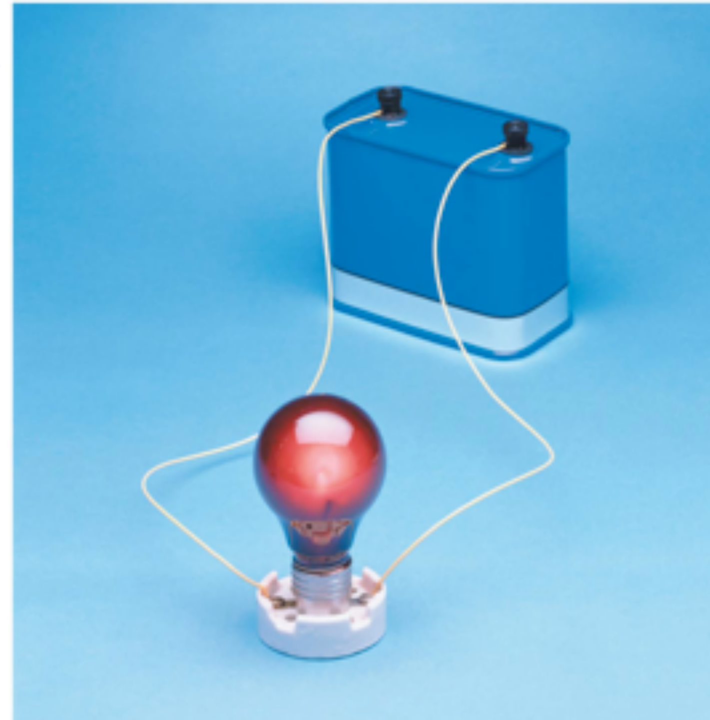
C. the same.

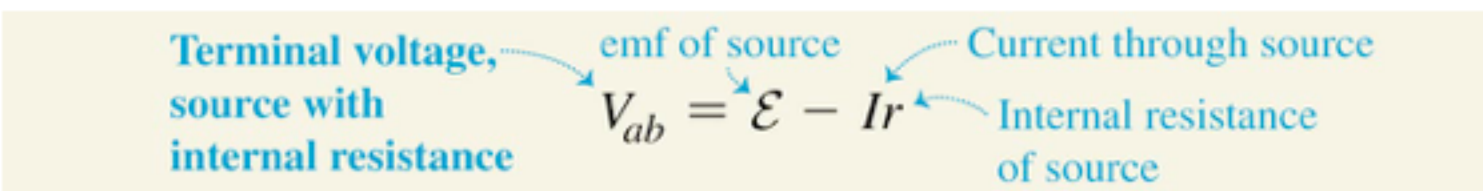
D. either A or B depending on circumstances.

E. any of A, B, or C depending on circumstances.

Internal resistance

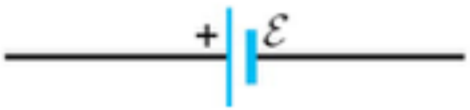
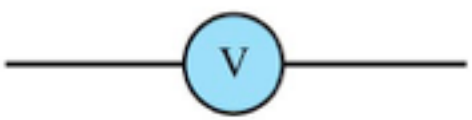
- Real sources of emf actually contain some **internal resistance** *r*.
- The **terminal voltage** of the 12-V battery shown at the right is less than 12 V when it is connected to the light bulb.





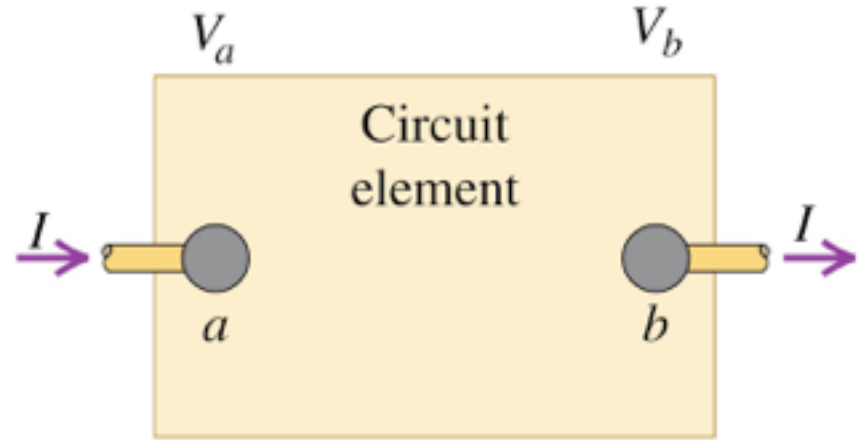
$$V_{ab} = \mathcal{E} - Ir$$

Table 25.4 — Symbols for circuit diagrams

	Conductor with negligible resistance
	Resistor
	Source of emf (longer vertical line always represents the positive terminal, usually the terminal with higher potential)
 or 	Source of emf with internal resistance *r* (*r* can be placed on either side)
	Voltmeter (measures potential difference between its terminals)
	Ammeter (measures current through it)

Energy and power in electric circuits

- The box represents a circuit element with potential difference $V_{ab} = V_a - V_b$ between its terminals and current I passing through it in the direction from a toward b.



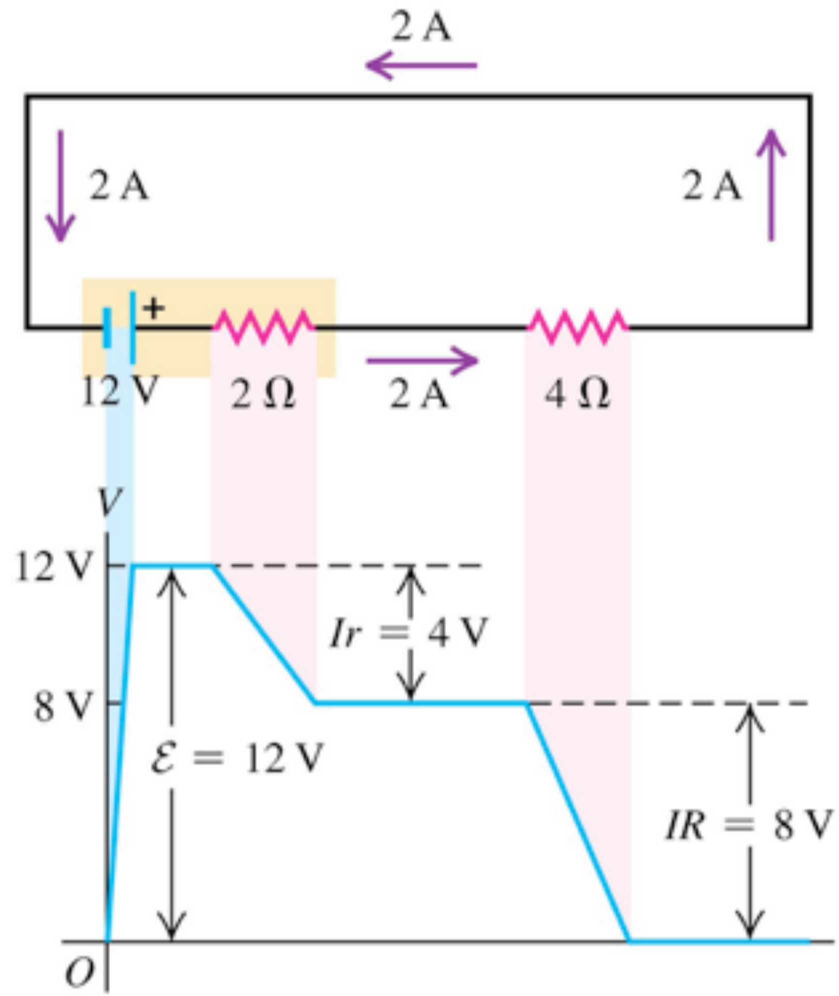
- If the potential at a is lower than at b, then there is a net transfer of energy out of the circuit element.
- The time rate of energy transfer is power, denoted by P, so we write:

$$P = V_{ab} I$$

Power delivered to or extracted from a circuit element → P; Voltage across circuit element → V_{ab}; Current in circuit element → I

Potential changes

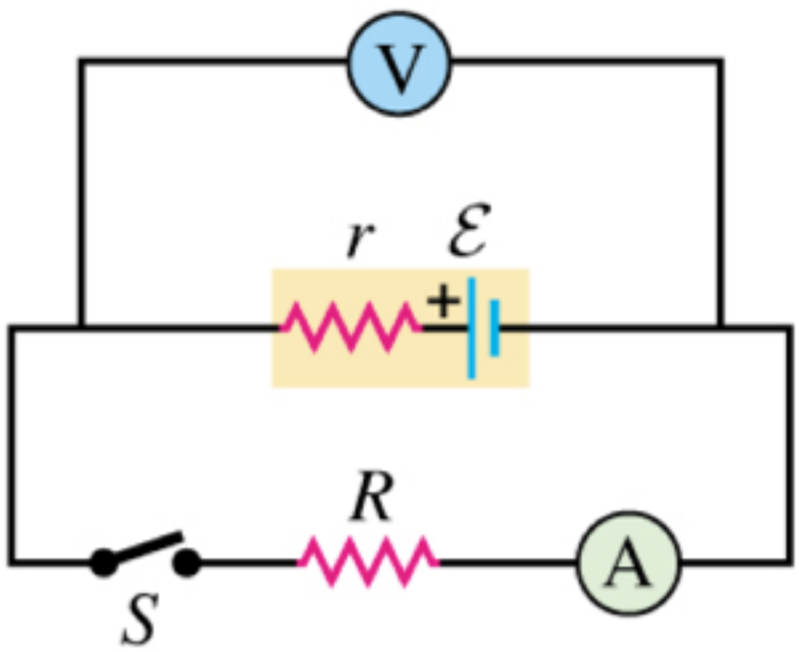
- The figure shows how the potential varies as we go around a complete circuit.
- The potential rises when the current goes through a battery, and drops when it goes through a resistor.
- Going all the way around the loop brings the potential back to where it started.



25.29

When switch S in the figure (Figure 1) is open, the voltmeter V of the battery reads 3.13 V . When the switch is closed, the voltmeter reading drops to 2.95 V , and the ammeter A reads 1.70 A . Assume that the two meters are ideal, so they don't affect the circuit.

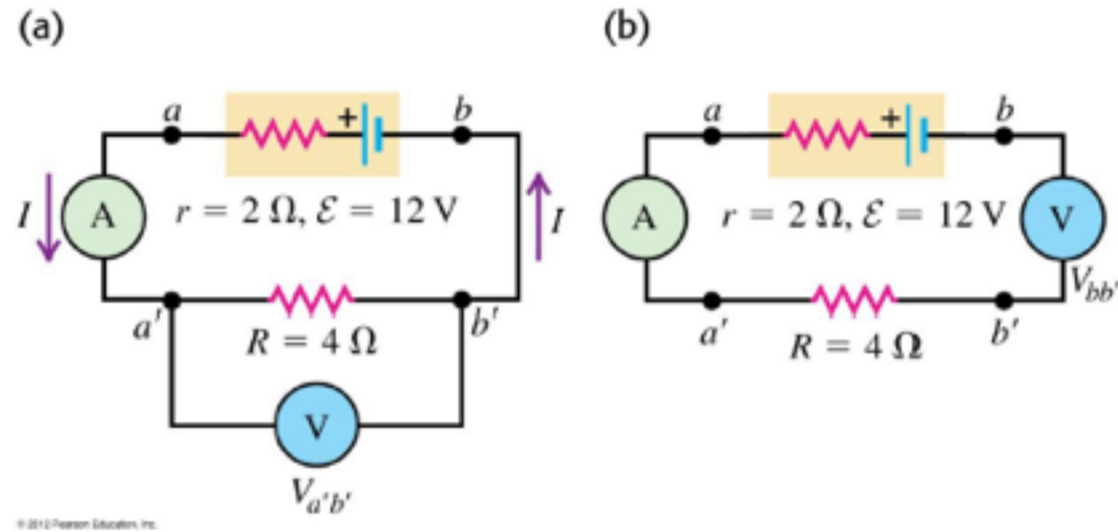
Figure 1 of 1



Find $\mathcal{E}$ and r

CPS 23-2

In diagram a, the ammeter reads 2A and the voltmeter reads 8V. What are the readings in diagram b?



A. 2A and 8V.

B. 2A and 0V.

C. 0A and 12V.

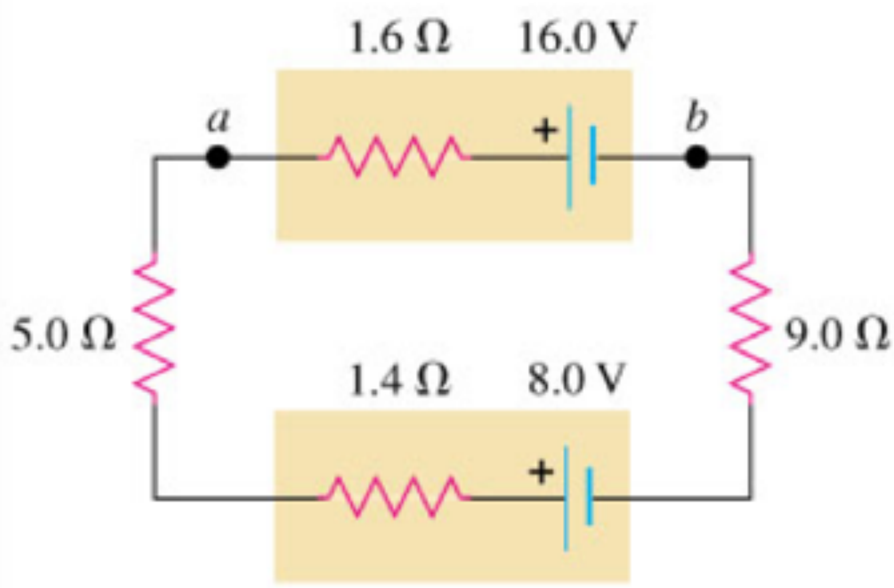
D. 0A and 0V.

E. 2A and 12V.

Exercise 25.33

The circuit shown in the figure (Figure 1) contains two batteries, each with an emf and an internal resistance, and two resistors.

Figure 1 of 1

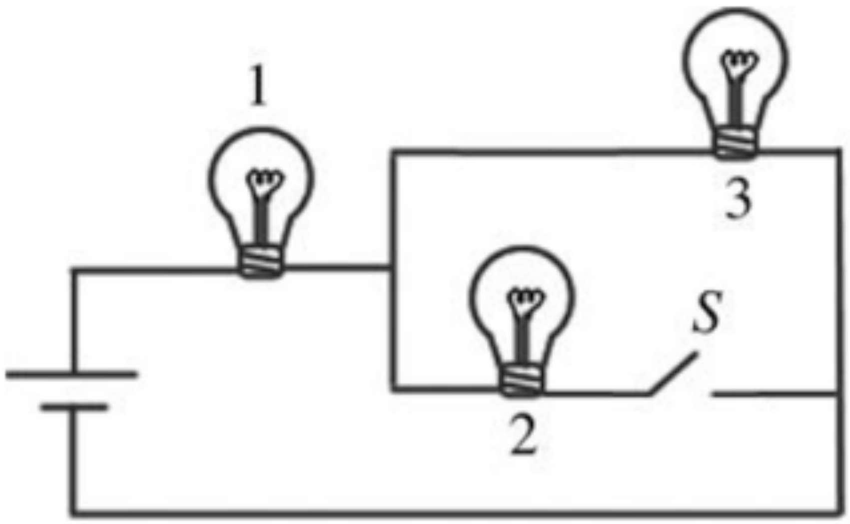


Find the direction of the current?

What is the current, I?

Which brings us to resistor networks

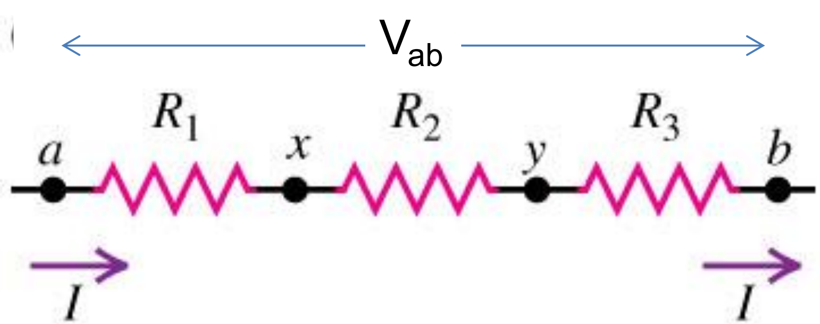
7) The figure shows three identical light bulbs connected to a battery having a constant voltage across its terminals. What happens to the brightness of light bulb 3 when the switch S is closed?

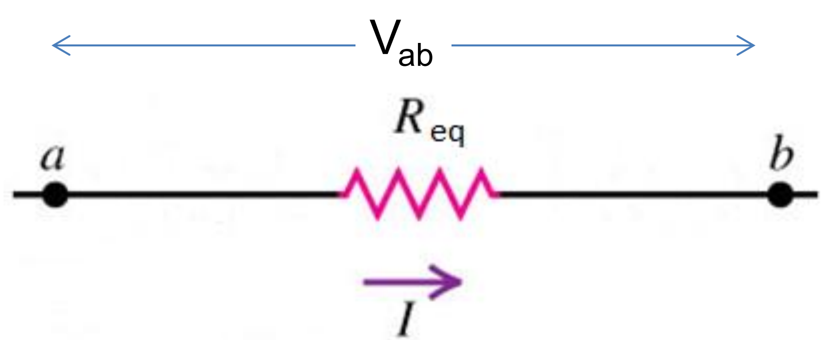


Series Resistors

- Since the current through each resistor is the same,

$$
\begin{aligned}
V_{ab} &= IR_1 + IR_2 + IR_3 \\
&= I\left(R_1 + R_2 + R_3\right) \\
&= IR_{eq} \Rightarrow \\
R_{eq} &= R_1 + R_2 + R_3
\end{aligned}
$$





Parallel Resistors

- For resistors in parallel, the voltage across each is the same, so,

$$V_{ab} = I_1R_1 = I_2R_2 = I_3R_3$$

$$and$$

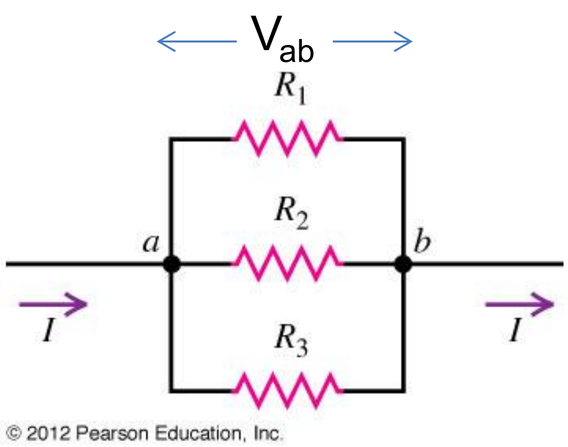
$$I = I_1 + I_2 + I_3$$

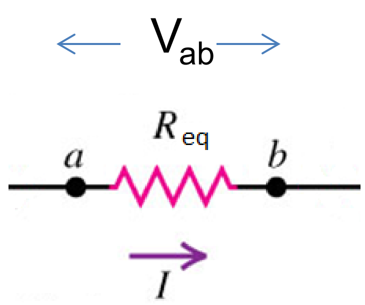
$$V_{ab} = IR_{eq} \Rightarrow$$

$$\frac{V_{ab}}{R_{eq}} = I = I_1 + I_2 + I_3$$

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

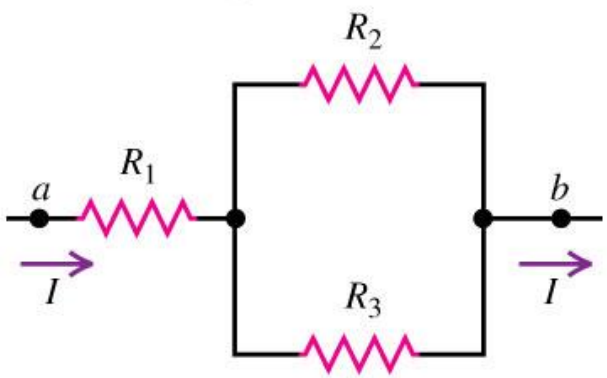
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



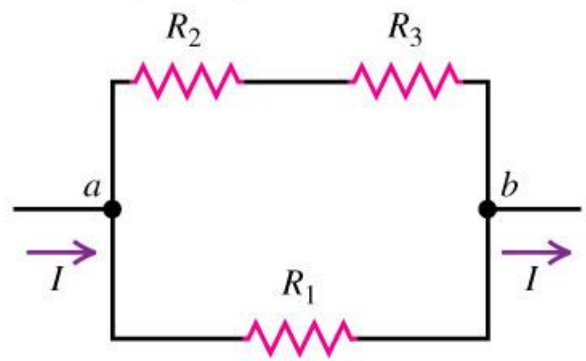


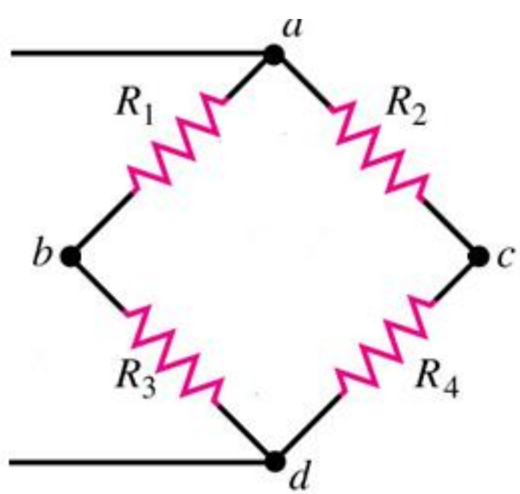
Mixed Resistors

(c) R_1 in series with parallel combination of R_2 and R_3



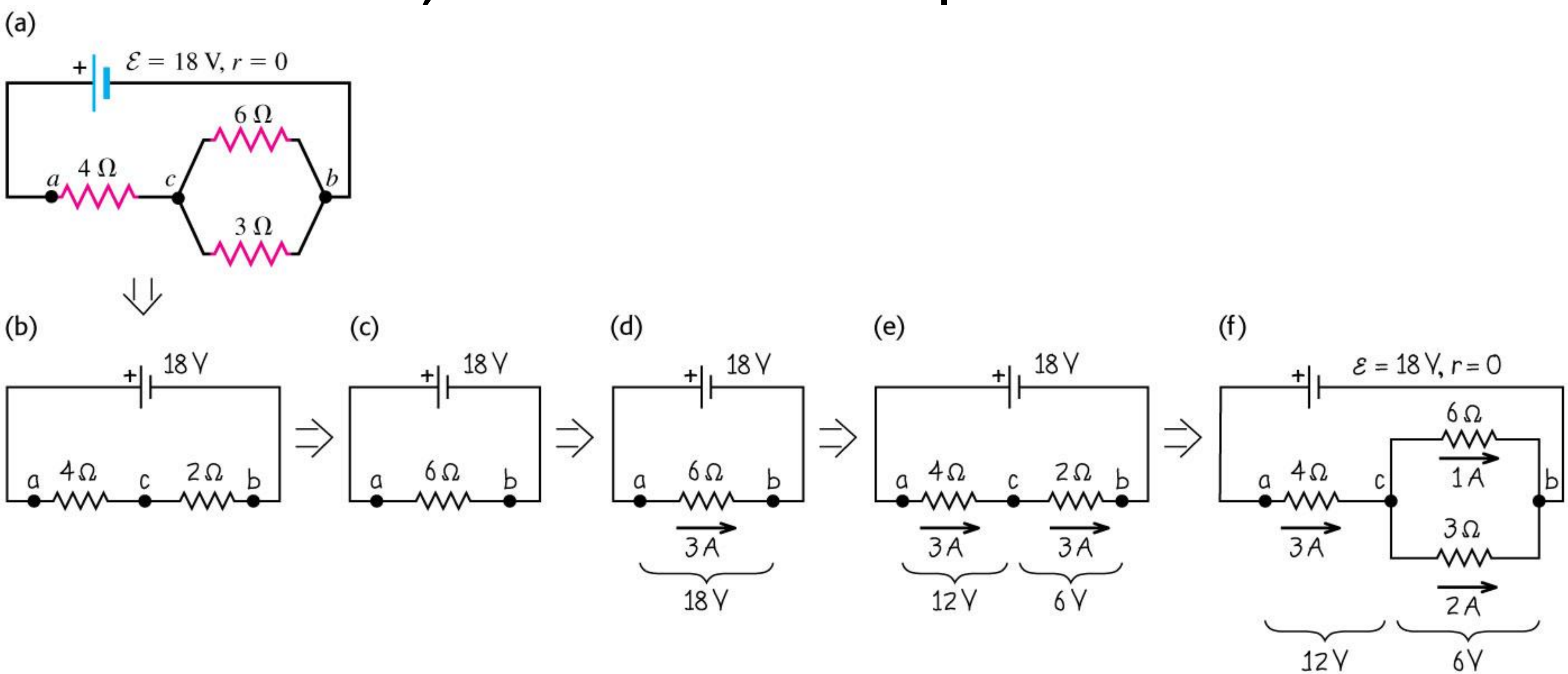
(d) R_1 in parallel with series combination of R_2 and R_3





Analysis Steps

- If you are asked to determine the current through and potentials across several resistors in a circuit, follow these steps:



Caution!

- Not all circuits can be analyzed in this way.
- In the diagram below, the resistors are neither in series or in parallel.
- We will develop another method for this analysis.