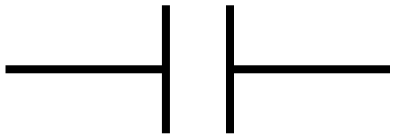
Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Circuit Components

Quick Overview of Electric Circuit Components.



Capacitor – stores charge and potential energy. $\Delta V = Q/C$.

Battery – generates a constant electrical potential difference (ΔV) across it.

Resistor – resists flow of charge due to scattering; dissipates energy. $\Delta V = IR$.

Power Dissipation

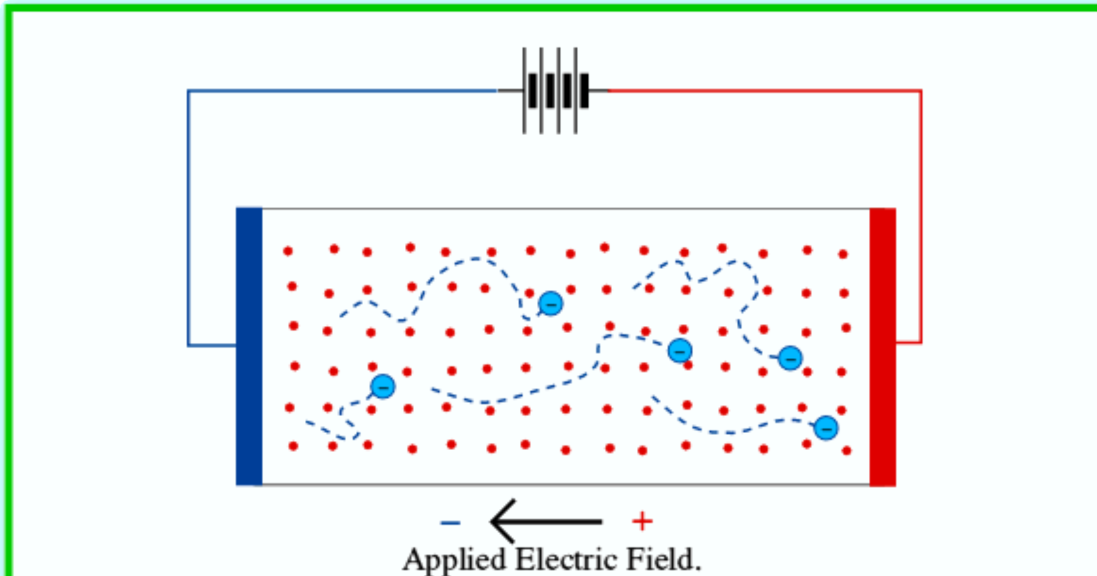
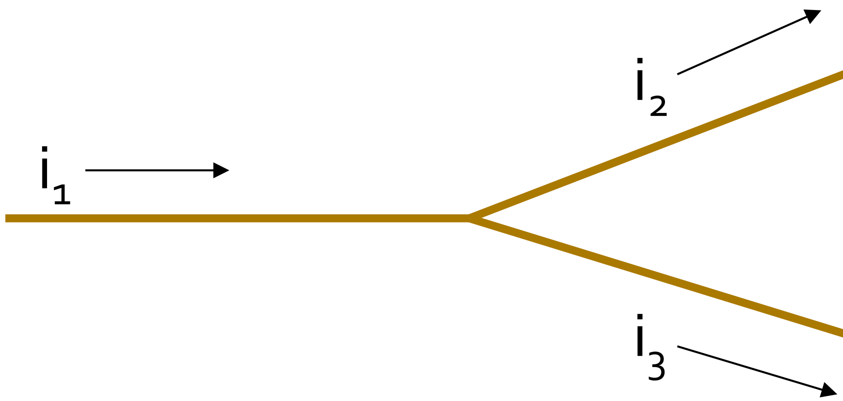


Figure 2.2 Electrons squeezing their way through a resistor.

$$P = VI = \frac{V^2}{R} = I^2 R$$

Junction Rule

Junction Rule



$$i_1 = i_2 + i_3$$

In a steady state, must have $i_{(in)} = i_{(out)}$ at any junction, otherwise charge is building up somewhere, which cannot happen in steady state [Capacitors charging up are non-steady-state].

Loop Rule

- LOOP RULE: The algebraic sum of the changes in potential encountered in a complete traversal of any loop of a circuit must be zero.
  - These changes in potential include those across an EMF device, and those across any electrical components [resistors, capacitors, etc]

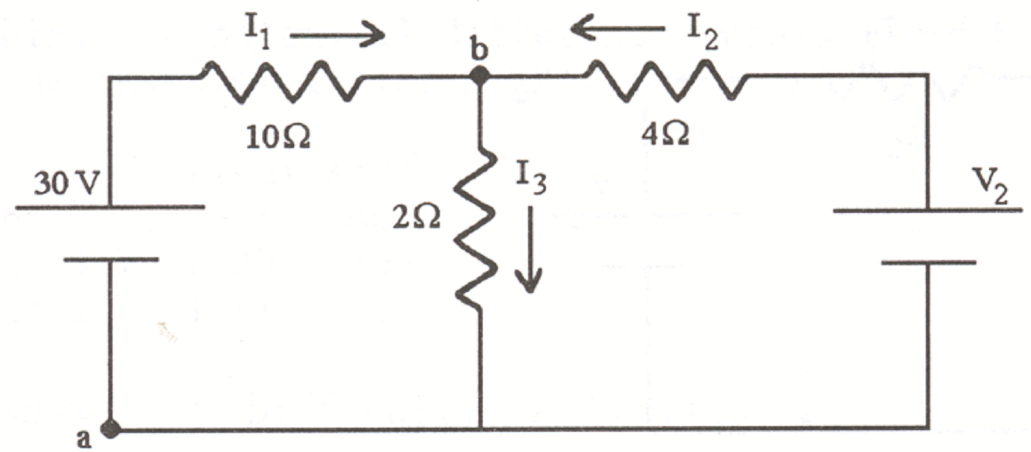
$$\sum_{loop} \Delta V_{rises} = \sum_{loop} \Delta V_{drops}$$

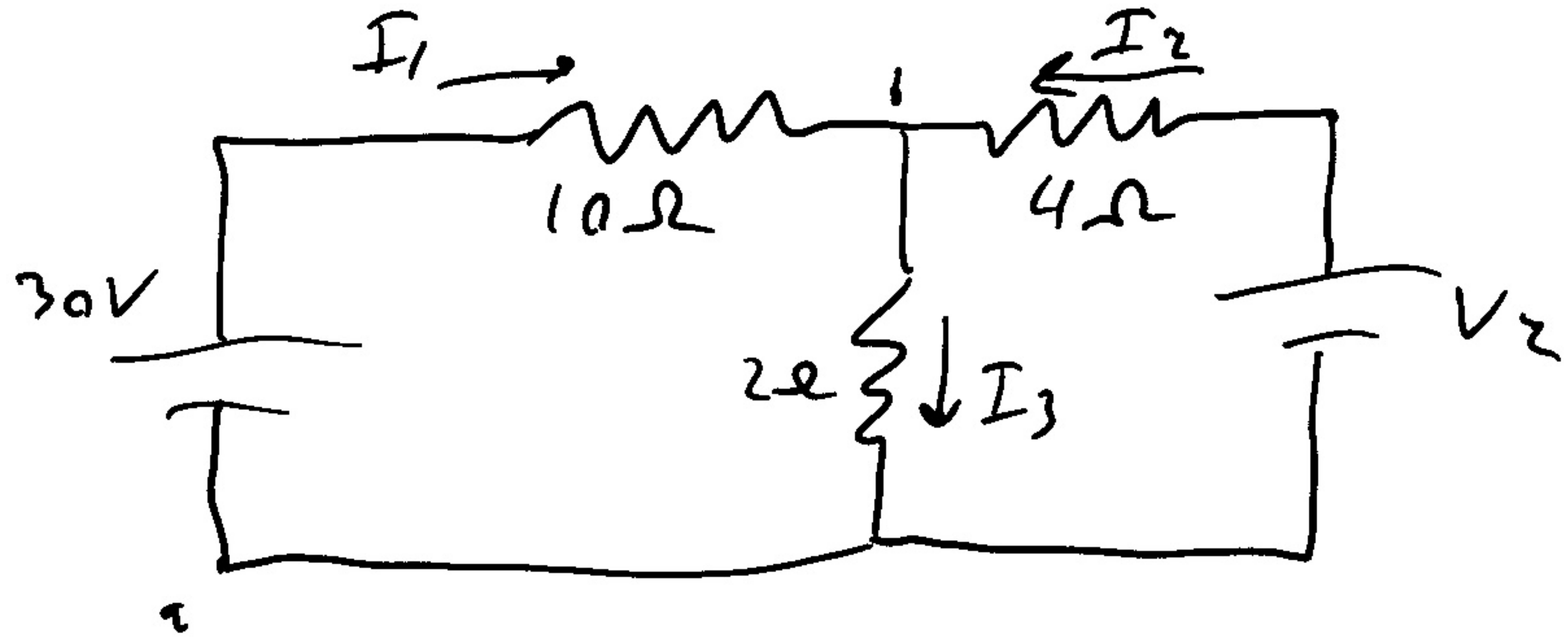
"Conservation of Energy (per Charge)"

Concept Check

Q27) If in the diagram below, $I_1 = 2$ A, what is the potential difference between points a and b, and which point is at the higher potential?

1) 50 V; point a
2) 50 V; point b
3) 10 V; point a
4) 10 V; point b





- To answer, use loop rule

$$30 - I_1 \cdot 10 - I_3 \cdot 2 = 0$$
(left loop)

so $V_b - V_a = I_3 \cdot 2$
$= 30 - I_1 \cdot 10$
$= 30 - 2 \cdot 10$
$= 10\ V$

- What if we didn't know I_1?
  - Look at right loop and go ccw
    $$V_2 - I_2 \cdot 4 - I_3 \cdot 2 = 0$$

  - Look @ outer loop and go CW
    $$30 - I_1 \cdot 10 + I_2 \cdot 4 - V_2 = 0$$

  - solve first two $30 - 10 I_1 = 2 I_3$
    $V_2 - 4 I_2 = 2 I_3$

    subtract to get $30 - 10 I_1 + 4 I_2 - V_2 = 0$

    $\Rightarrow$ outer loop gives redundant info.

- If we didn't have I_1

$$30 - 10 I_1 - 2 I_3 = 0$$
$$V_2 - 4 I_2 - 2 I_3 = 0$$
$$I_3 = I_1 + I_2$$

- 3 eqs. in 4 unknowns
- need to know one of I_1, I_2, I_3, V_2

Now to solve:

$$I_3 \cdot 2 = 10 V$$
$$\Rightarrow I_3 = 5 A$$

$$I_3 = I_1 + I_2$$
$$\Rightarrow I_2 = 3 A$$

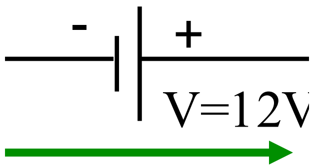
$$V_2 - 4 I_2 - 2 I_3 = 0$$
$$\Rightarrow V_2 = 4 \cdot 3 + 2 \cdot 5$$
$$= 22 V$$

Check: $30 - 10 I_1 + 4 I_2 - V_2 = 0$ ✓

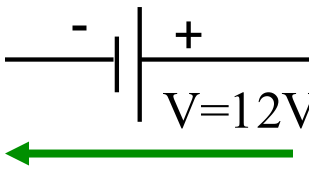
$30 - 20 + 12 - 22 = 0$

Voltage Drop Across Battery

<u>**Critical Sign Convention!**</u>



If your loop goes through a battery from – to + the Voltage <u>increases</u> (e.g. ΔV = +12 V)



If your loop goes through a battery from + to – the Voltage <u>decreases</u> (e.g. ΔV = -12 V)

Voltage Drop Across Resistors

- If your loop goes in the direction of current, the voltage drop across a resistor is negative
- If your loop goes opposite to the direction of current, the voltage drop across a resistor is positive

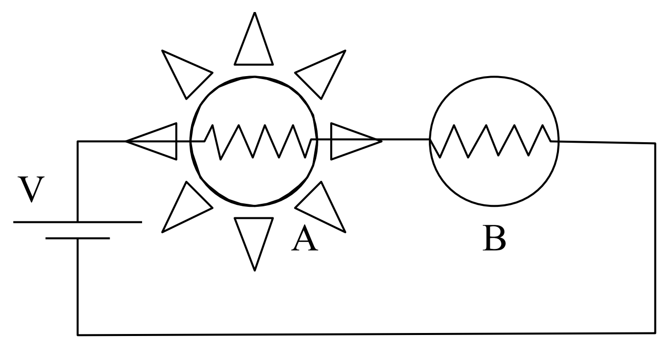
Concept Check

Two light bulbs, A and B, are in series, so they carry the same current. Light bulb A is brighter than B.

Which bulb has higher resistance?

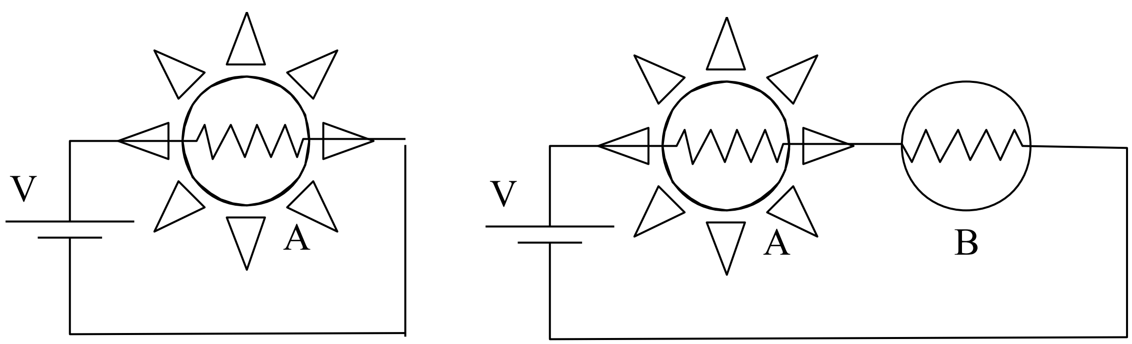
A) A B) B C) Same resistance.

Answer: Bulb A has higher resistance. Since the resistors are in series, they have the same current I. According to $P = I^2 R$, if I = constant, then higher R gives higher P.



Concept Check

We start with the left circuit with one lightbulb (A). The brightness of the bulb directly reflects the power. If we add a second bulb (B) as shown on the right, what happens to the bulbs?



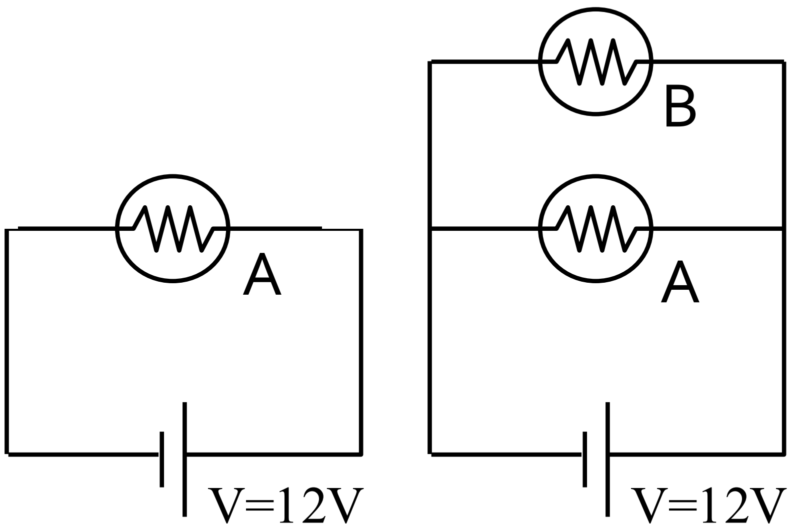
A) Bulb A is equally bright.

B) Bulb A is dimmer than before

C) Bulb A is brighter than before

Concept Check

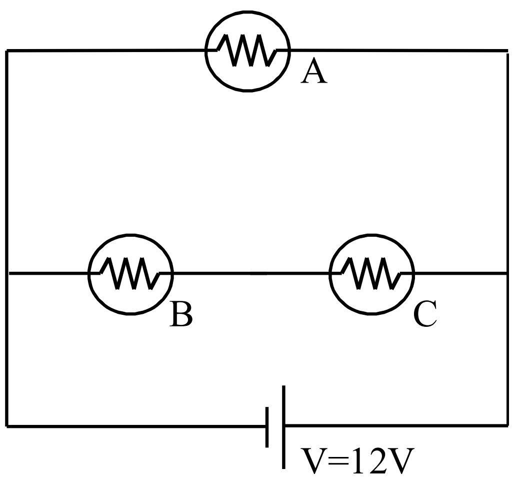
We start with the left circuit with one lightbulb (A). The brightness of the bulb directly reflects the power. If we add a second bulb (B) as shown on the right, what happens to the bulbs?



A) Bulb A is equally bright.
B) Bulb A is dimmer than before
C) Bulb A is brighter than before

Concept Check

The three light bulbs A, B, and C are identical. How does the brightness of bulbs B and C together compare with the brightness of bulb A?

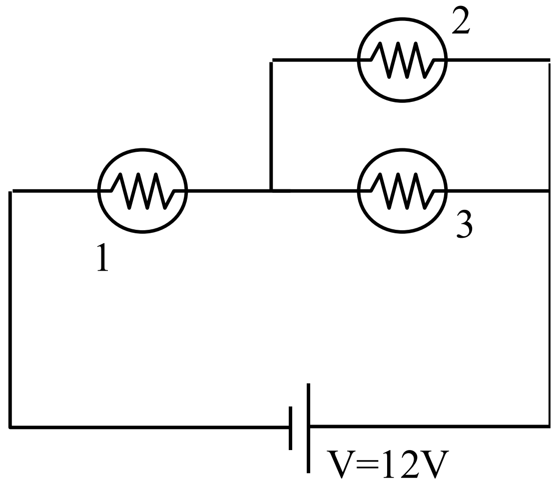


A) Total power in B+C = power in A.
B) Total power in B+C > power in A.
C) Total power in B+C < power in A.

Answer: Use $P = V^2/R_{tot}$ For bulbs B and C, $R_{tot} = 2R$.
Total power in B+C < power in A.

Concept Check

In the circuit below, what happens to the brightness of bulb 1, when bulb 2 burns out? (When a bulb burns out, its resistance becomes infinite.)



A) Bulb 1 gets brighter

B) Bulb 1 gets dimmer.

C) It's brightness remains the same.

(Hint: What happens to the current from the battery when bulb 2 burns out.)

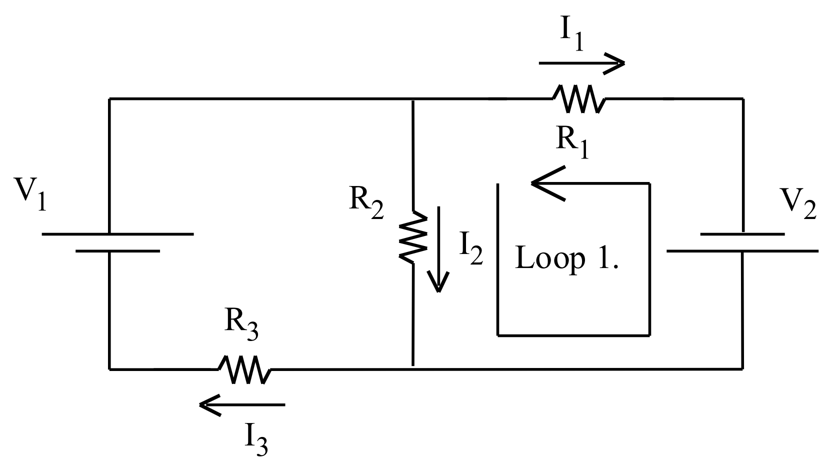
Concept Check

A circuit with two batteries is shown below. The directions of the currents have been chosen (guessed) as shown.

Which is the correct current equation for this circuit?

A) $I_2 = I_1 + I_3$ B) $I_1 = I_2 + I_3$ C) $I_3 = I_1 + I_2$

D) None of these.



Concept Check

Which equation below is the correct equation for Loop 1?

A) $-V_2 + I_1R_1 - I_2R_2 = 0$

B) $V_2 + I_1R_1 - I_2R_2 = 0$

C) $-V_2 - I_1R_1 + I_2R_2 = 0$

D) $V_2 + I_1R_1 + I_2R_2 = 0$

E) None of these.

Answer: $-V_2 + I_1R_1 - I_2R_2 = 0$