Your Comments

I wish we had a day off for exams that would be fantastic

WE SHOULD NOT HAVE HAD CLASS TODAY!!!!! BOOOOOOOo!!!

I have three midterms this week; specifically, two tomorrow. I am studying for chemistry and calculus tonight.

The concept seemed easy but the applications seemed rather hard.

i'm really having trouble grasping the pre-lecture problem asking about the current between points a and b.

The charges flowing in clockwise direction made my head spin for a while, the signs changing is confusing.

Can you explain the blue wire and how you can tell the current across it?

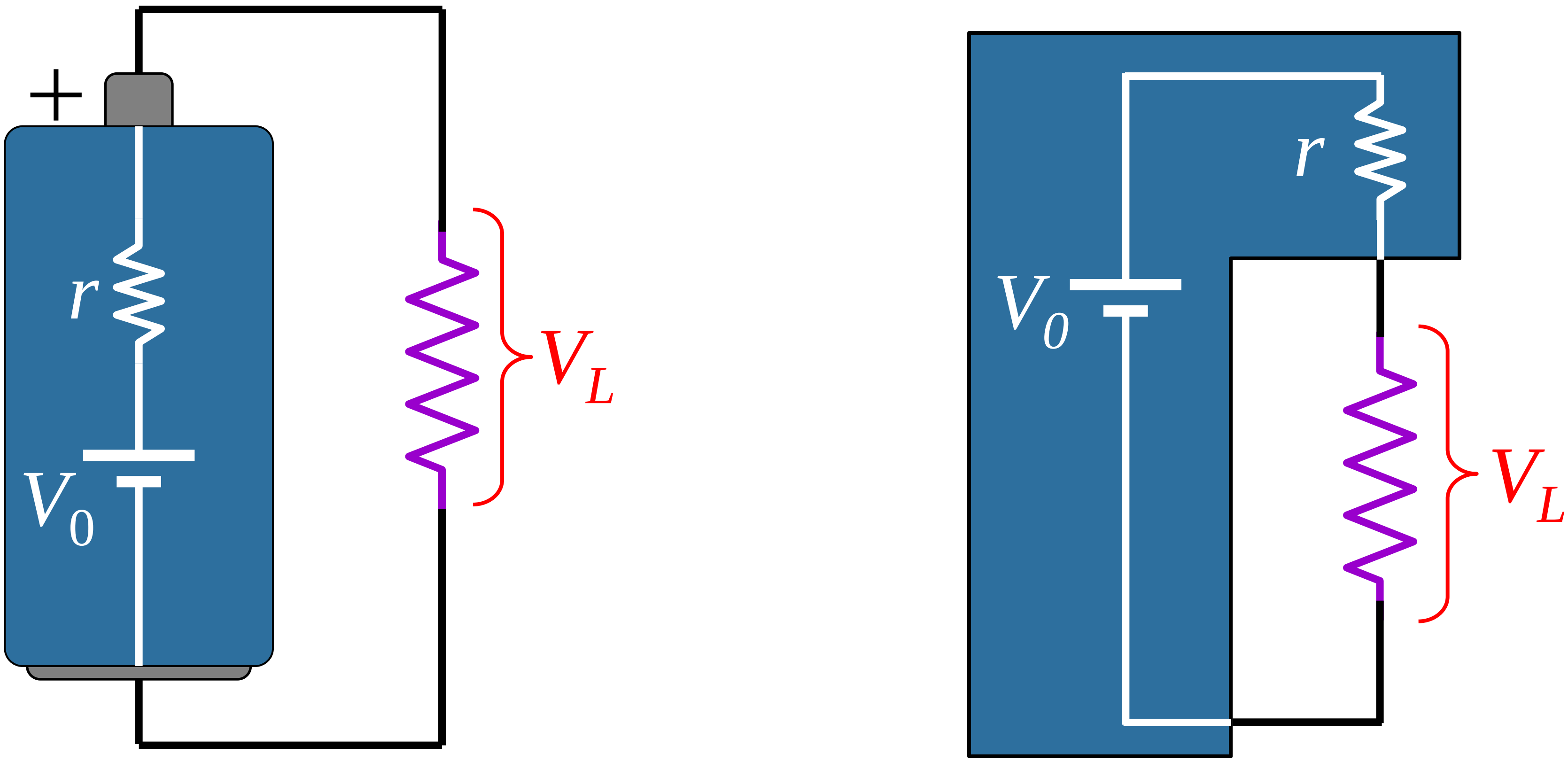
You know Watt? The Current amount of electricity puns is Shockingly low. We need to Amp it up. Yes, there will be Resistance to such tom-foolery, some may even be reVolted by its childishness, but there's no reason for assault and Battery on their part. Come on, I believe we Conduit.

Physics 212
Lecture 10

Today's Concept:

Kirchhoff's Rules

Model for Real Battery: Internal Resistance



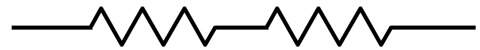
Usually can't supply too much current to the load
without voltage "sagging"

Last Time

Resistors in series:

Current through is same.

Voltage drop across is IR_i

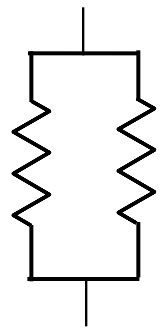


$$R_{effective} = R_1 + R_2 + R_3 + \ldots$$

Resistors in parallel:

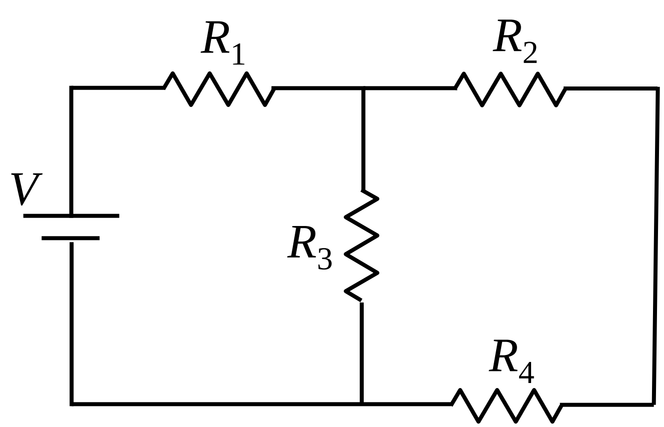
Voltage drop across is same.

Current through is V/R_i



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

Solved Circuits



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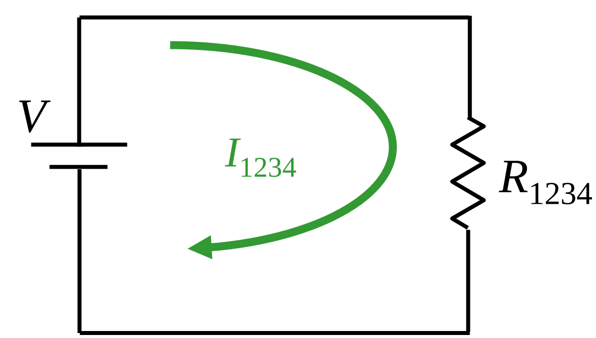
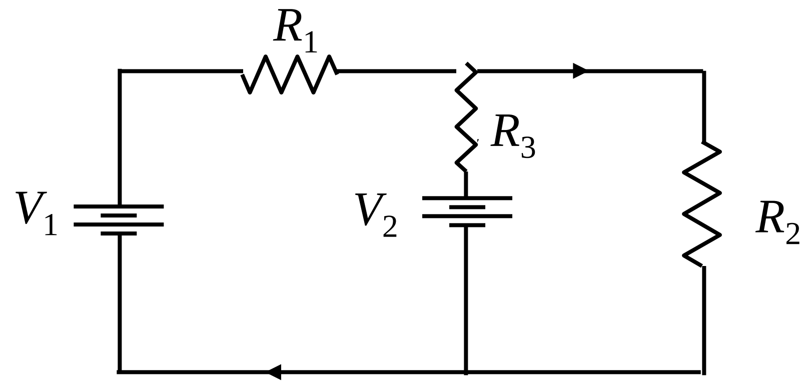
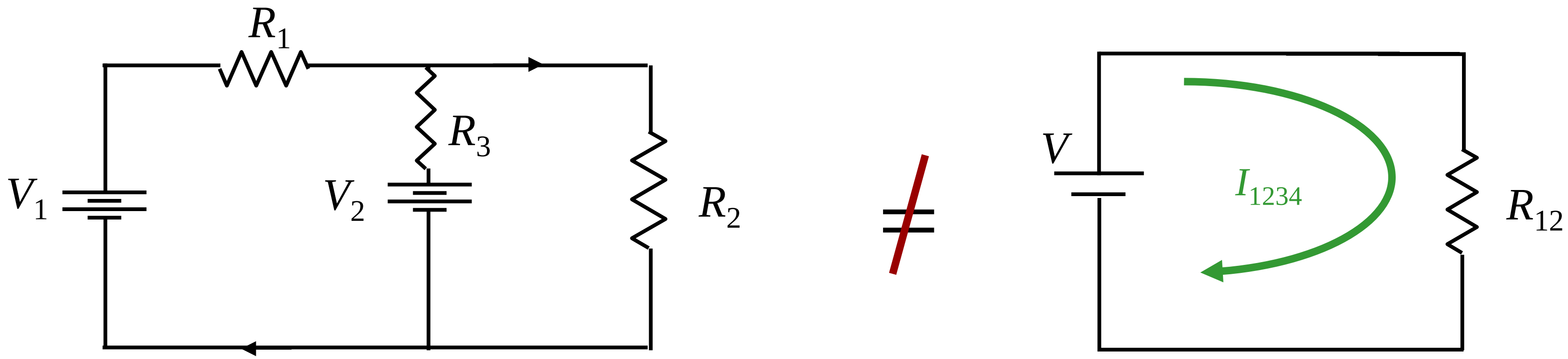


New Circuit



How Can We Solve This One?



THE ANSWER: Kirchhoff's Rules

Kirchhoff's Voltage Rule

$$\sum \Delta V_i = 0$$

Kirchhoff's Voltage Rule states that the sum of the voltage changes caused by any elements (like wires, batteries, and resistors) around a circuit must be zero.

WHY?

The potential difference between a point and itself is zero!

Kirchhoff's Current Rule

$$\sum I_{in} = \sum I_{out}$$

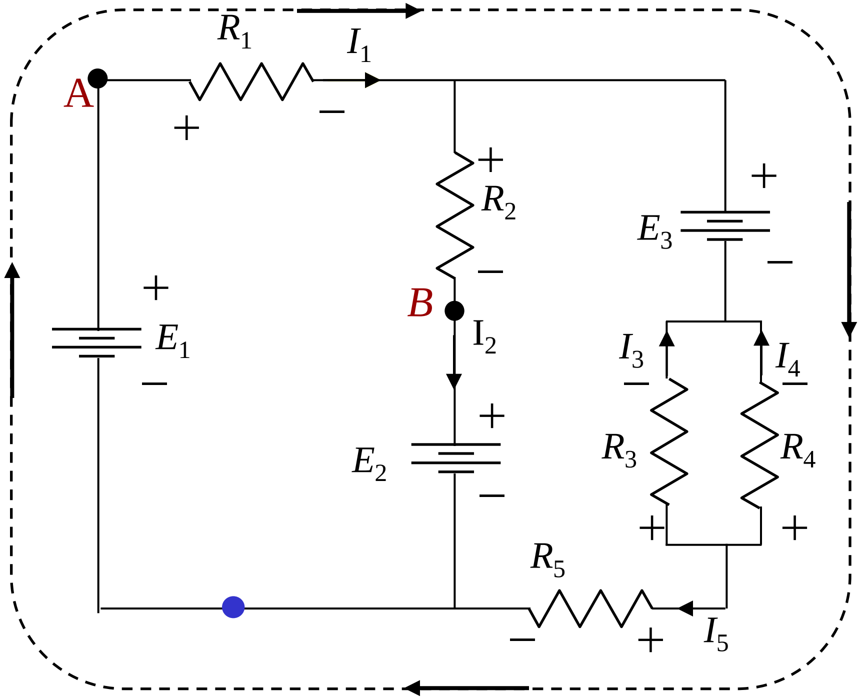
Kirchhoff's Current Rule states that the sum of all currents entering any given point in a circuit must equal the sum of all currents leaving the same point.

WHY?

Electric Charge is Conserved

Applying Kirchhoff's Laws in 5 easy steps

$-E_1 + I_1R_1 + E_3 - I_4R_4 + I_5R_5 = 0$



1) Label all currents

Choose any direction

2) Label +/– for all elements

Current goes + ⇒ – (for resistors)

Long side is + for battery

3) Choose loop and direction

Must start on wire, not element.

4) Write down voltage drops

First sign you hit is sign to use.

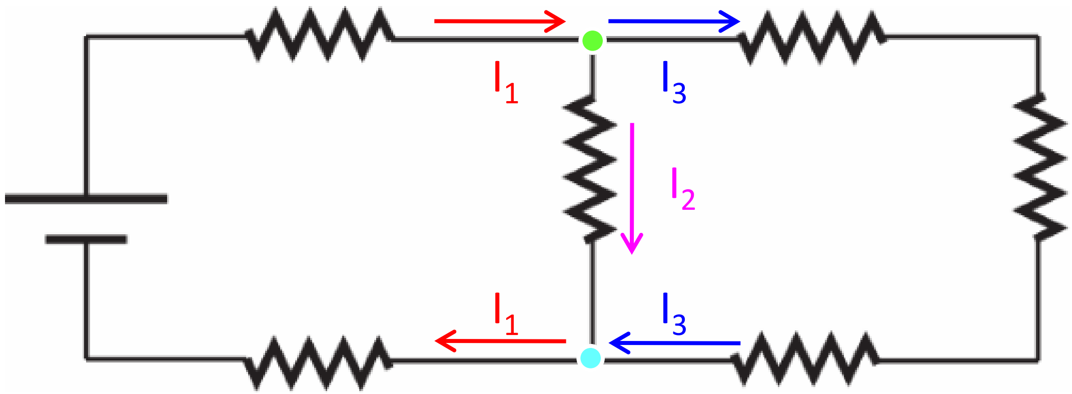
5) Write down node equation $I_{in} = I_{out}$

We'll do calculation today

It's actually the easiest thing to do!

Check Point 1

How many potentially different currents are there in the circuit shown?



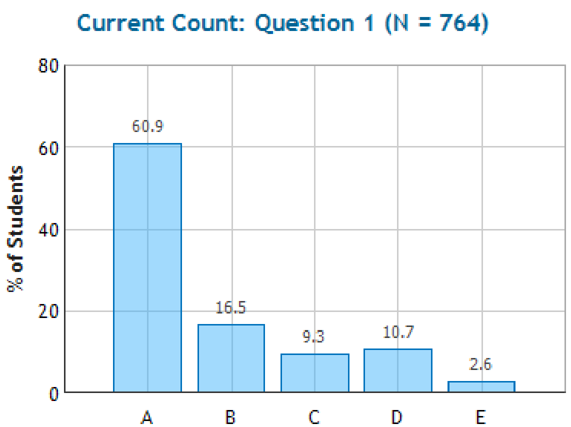
A. 3 ***B.*** 4 ***C.*** 5 ***D.*** 6 ***E.*** 7

Look at the nodes!

Top node: I_1 flows in, I_2 and I_3 flow out

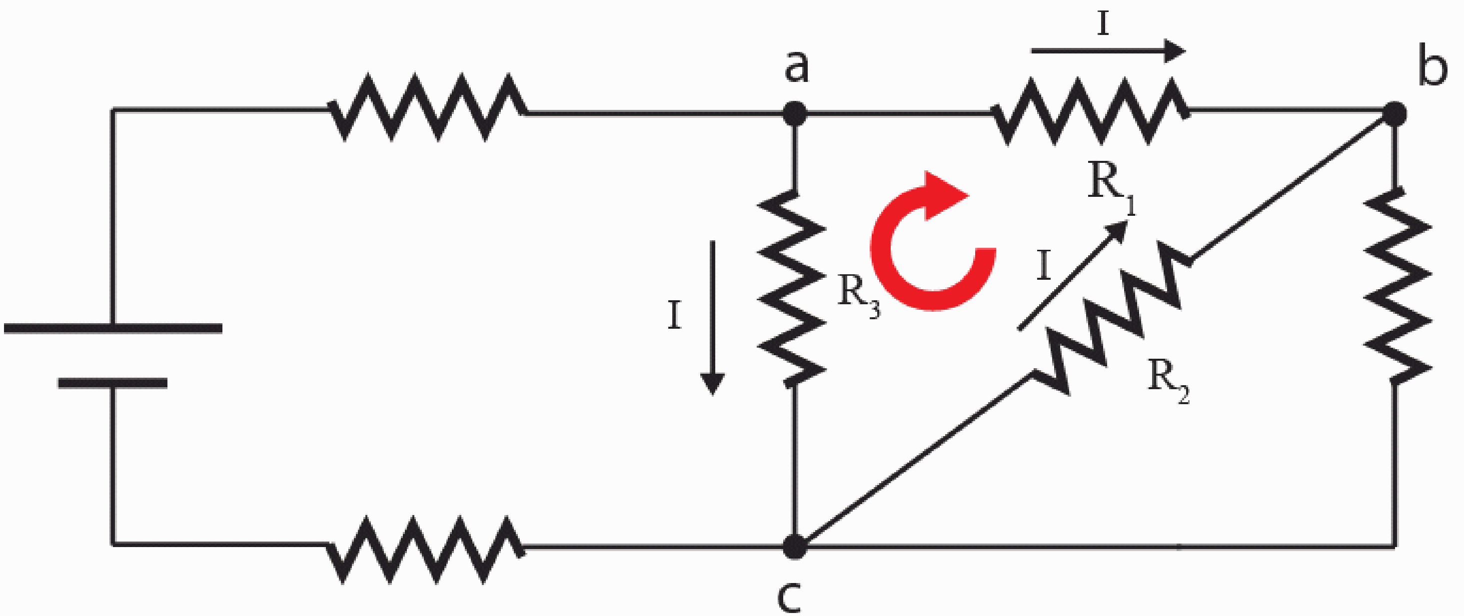
Bottom node: I_2 and I_3 flow in, I_1 flows out

That's all of them!



CheckPoint 2

In the following circuit, consider the loop abc. The direction of the current through each resistor is indicated by black arrows.

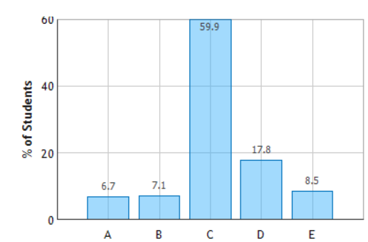


If we are to write Kirchoff's voltage equation for this loop in the clockwise direction starting from point a, what is the correct order of voltage gains/drops that we will encounter for resistors R1, R2 and R3?

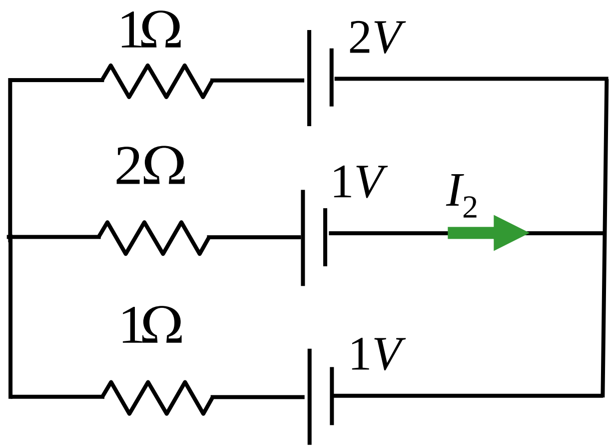
A. drop, drop, drop
B. gain, gain, gain
C. drop, gain, gain
D. gain, drop, drop
E. drop, drop, gain

With the current → VOLTAGE DROP

Against the current → VOLTAGE GAIN



Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

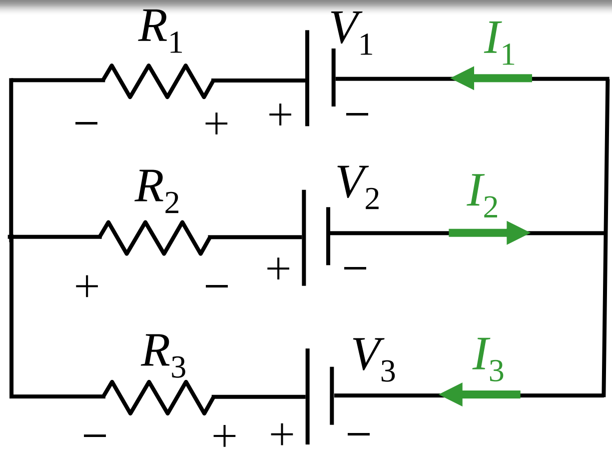
Conceptual Analysis:

- Circuit behavior described by Kirchhoff's Rules:
  - KVR: $\Sigma V_{drops} = 0$
  - KCR: $\Sigma I_{in} = \Sigma I_{out}$

Strategic Analysis

- Write down Loop Equations (KVR)
- Write down Node Equations (KCR)
- Solve

Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

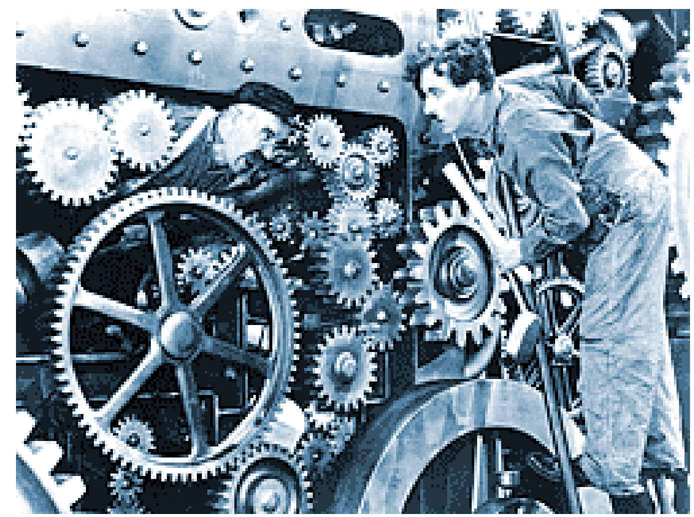
1) Label and pick directions for each current

2) Label the + and – side of each element

This is easy for batteries Long side is +

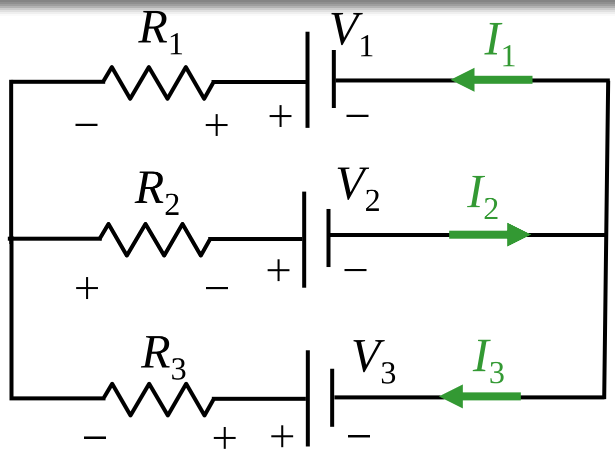
For resistors, the "upstream" side is +

Now write down loop and node equations



Just turn the crank.

Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

How many equations do we need to write down in order to solve for I_2?

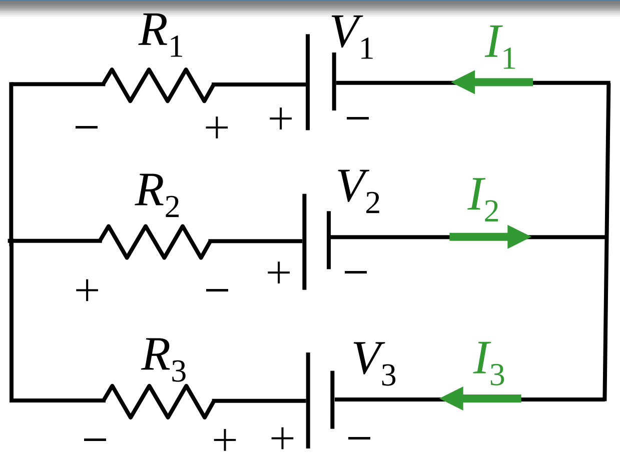
A) 1 B) 2 **C) 3** D) 4 E) 5

Why?

- We have 3 unknowns: I_1, I_2, and I_3
- We need 3 independent equations to solve for these unknowns

3) Choose Loops and Directions

Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

Which of the following equations is NOT correct?

A) $I_2 = I_1 + I_3$

B) $-V_1 + I_1 R_1 - I_3 R_3 + V_3 = 0$

C) $-V_3 + I_3 R_3 + I_2 R_2 + V_2 = 0$

D) $-V_2 - I_2 R_2 + I_1 R_1 + V_1 = 0$

4) Write down voltage drops

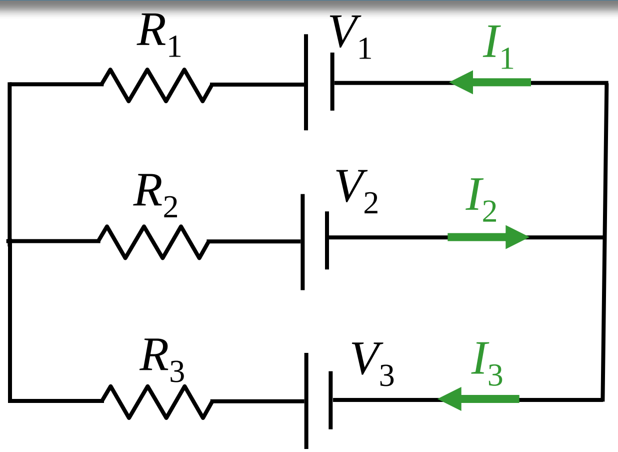
5) Write down node equation

Why?

- (D) is an attempt to write down KVR for the top loop
- Start at negative terminal of V_2 and go clockwise

$V_{gain}\ (-V_2)$ then $V_{gain}\ (-I_2R_2)$ then $V_{gain}\ (-I_1R_1)$ then $V_{drop}\ (+V_1)$

Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

We have the following 4 equations:

1. $I_2 = I_1 + I_3$
2. $-V_1 + I_1R_1 - I_3R_3 + V_3 = 0$
3. $-V_3 + I_3R_3 + I_2R_2 + V_2 = 0$
4. $-V_2 - I_2R_2 - I_1R_1 + V_1 = 0$

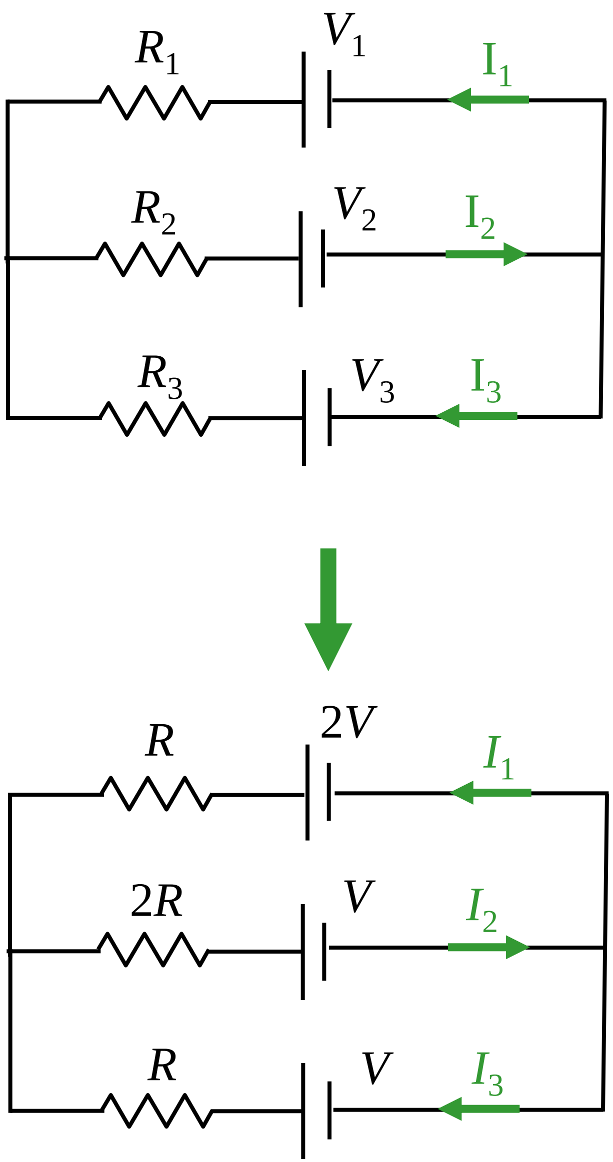
We need 3 equations:
Which 3 should we use?

A) Any 3 will do
B) 1, 2, and 4
C) 2, 3, and 4

Why?

- We need 3 INDEPENDENT equations
- Equations 2, 3, and 4 are NOT INDEPENDENT
  $\text{Eqn } 2 + \text{Eqn } 3 = -\text{Eqn } 4$
- We must choose Equation 1 and any two of the remaining (2, 3, and 4)

Calculation



In this circuit, assume V_i and R_i are known.

What is I_2 ?

We have 3 equations and 3 unknowns.

$$I_2 = I_1 + I_3$$
$$V_1 + I_1 R_1 - I_3 R_3 + V_3 = 0$$
$$V_2 - I_2 R_2 - I_1 R_1 + V_1 = 0$$

Now just need to solve ☺

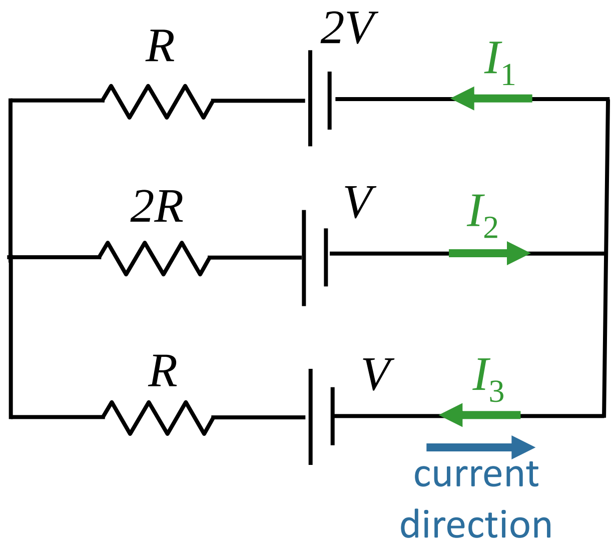
The solution will get very messy!

Simplify: assume $V_2 = V_3 = V$

$$V_1 = 2V$$
$$R_1 = R_3 = R$$
$$R_2 = 2R$$

Calculation: Simplify

In this circuit, assume V and R are known. What is I_2 ?



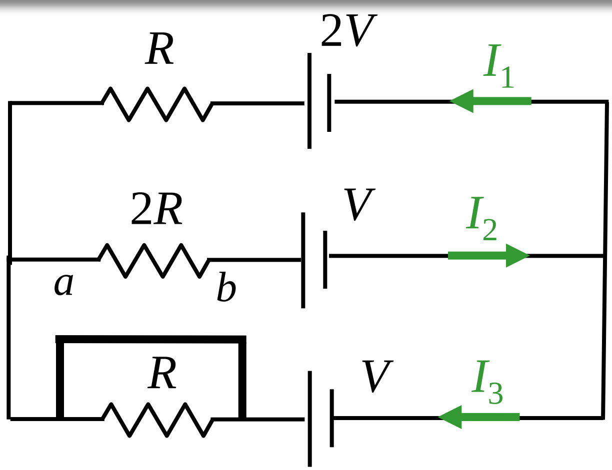
We have 3 equations and 3 unknowns.

$$I_2 = I_1 + I_3$$
$$-2V + I_1R - I_3R + V = 0 \quad \text{(outside)}$$
$$-V - I_2(2R) - I_1R + 2V = 0 \quad \text{(top)}$$

With this simplification, you can verify:

$$I_2 = (1/5)\ V/R$$
$$I_1 = (3/5)\ V/R$$
$$I_3 = (-2/5)\ V/R$$

Follow Up



We know:

$I_2 = (\ 1/5)\ V/R$

$I_1 = \ (\ 3/5)\ V/R$

$I_3 = (-2/5)\ V/R$

Suppose we short R_3: What happens to V_{ab} (voltage across R_2?)

A) V_{ab} remains the same

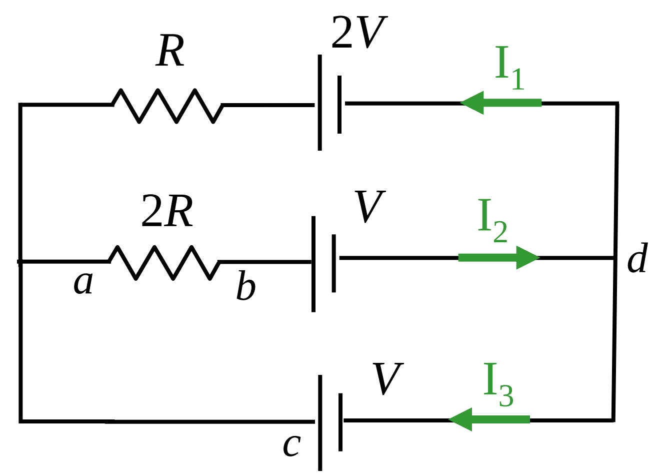
B) V_{ab} changes sign

C) V_{ab} increases

D) V_{ab} goes to zero

Why?

Redraw:



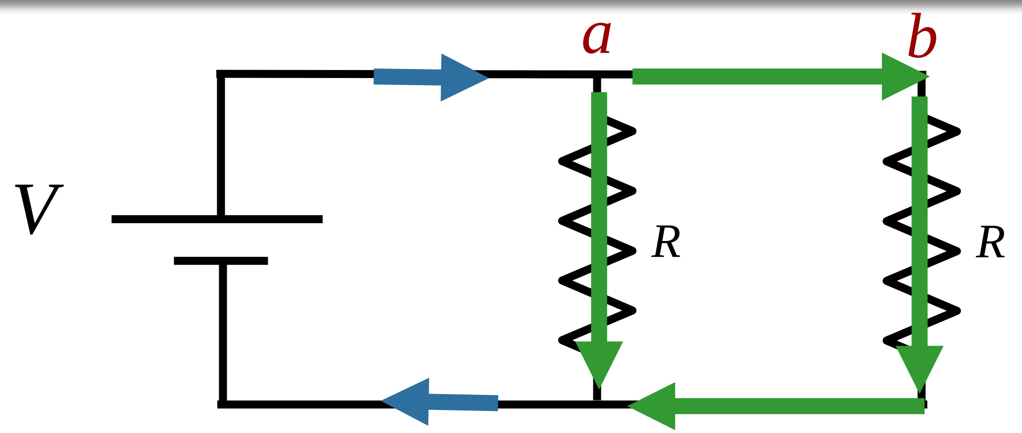
Bottom Loop Equation:

$$V_{ab} + V - V = 0$$

$$\downarrow$$

$$V_{ab} = 0$$

CheckPoint 3 Warm up



Is there a current flowing between a and b ?

A) Yes
B) No

a & b have the same potential

No current flows between a & b

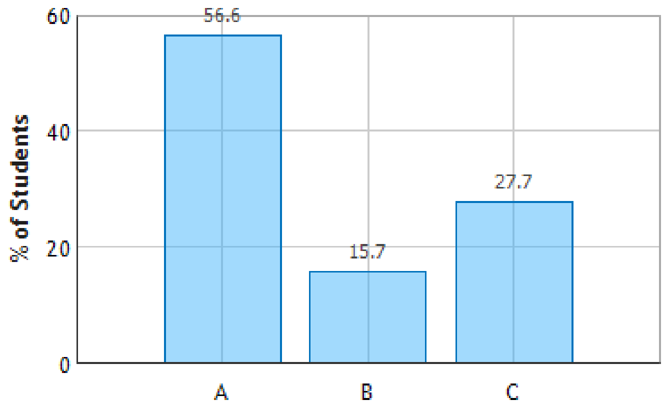
Current flows from battery and splits at a

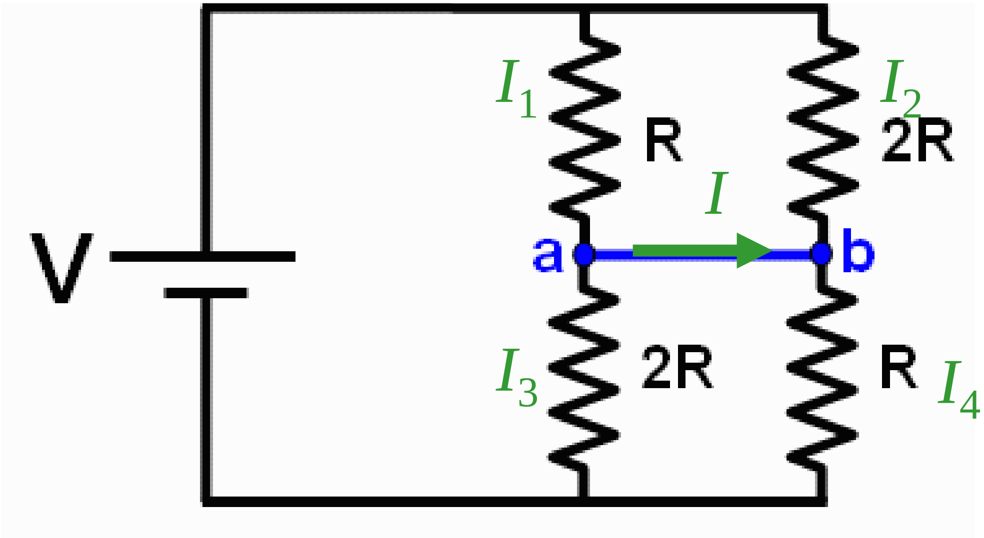
Some current flows down

Some current flows right

CheckPoint 3a

Consider the circuit shown below. Note that this question is *not* identical to the similar looking one you answered in the prelecture.





Which of the following best describes the current flowing in the blue wire connecting points **a** and **b**?

A. Positive current flows from *a* to *b*

B. Positive current flows from *b* to *a*

C. No current flows between *a* and *b*

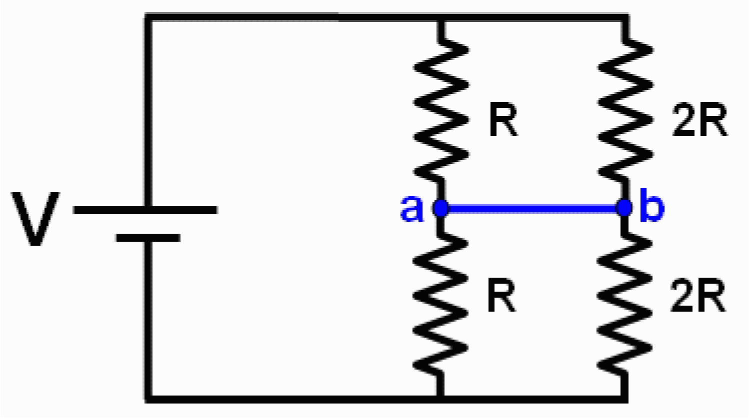
$I_1R - I_2\,(2R) = 0 \;\rightarrow\; I_2 = ½\; I_1$

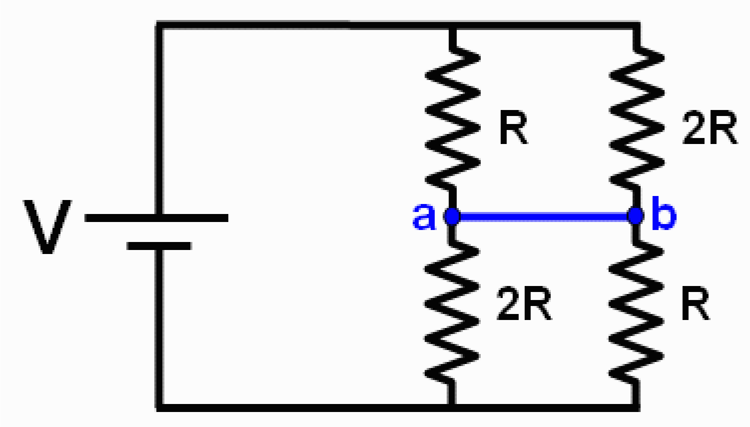
$I_4R - I_3\,(2R) = 0 \;\rightarrow\; I_4 = 2\; I_3$

$I = I_1 - I_3$

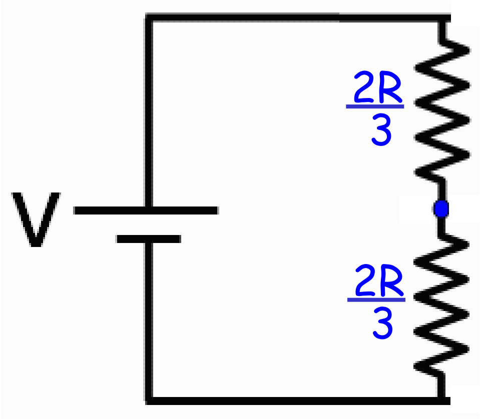
$I + I_2 = I_4 \;\rightarrow\; I_1 - I_3 + ½\; I_1 = 2I_3 \;\rightarrow\; I_1 = 2I_3 \;\rightarrow\; I = +I_3$

Prelecture CheckPoint

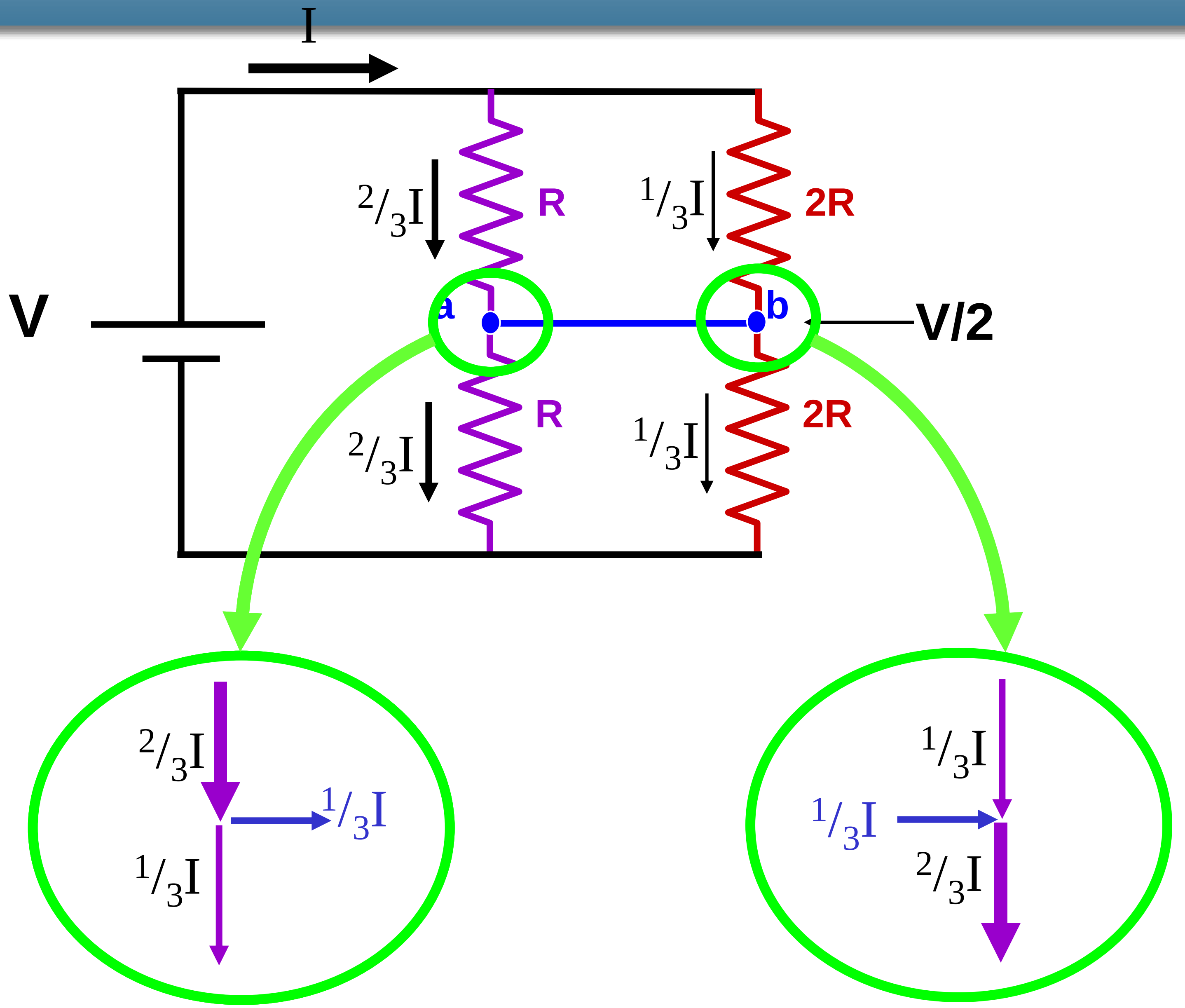




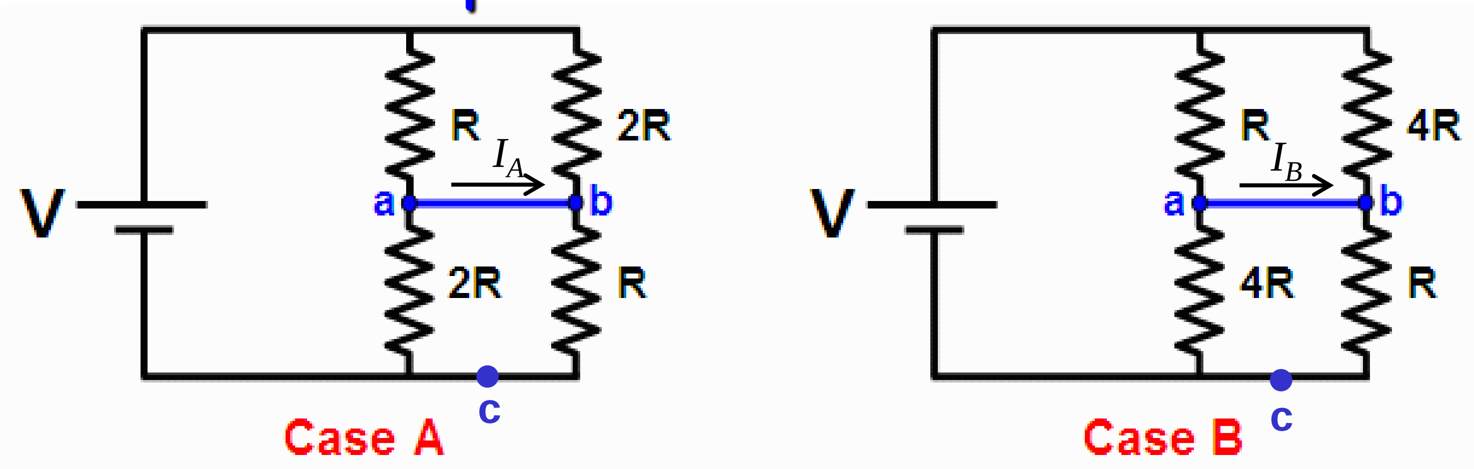
What is the same? Current flowing in and out of the battery.



What is different? Current flowing from a to b.


I
V
R
2R
R
2R
a
b
V/2
2/3I
1/3I
2/3I
1/3I
2/3I
1/3I
1/3I
1/3I
1/3I
2/3I

Checkpoint 3b



which case is the current flowing in the blue wire connecting points **a** and **b** the largest?

A. Case A

B. Case B

C. They are both the same

Current will flow from left to right in both cases.

In both cases, $V_{ac} = V/2$

$$I_{2R} = 2I_{4R}$$

$$I_A = I_R - I_{2R}$$
$$= I_R - 2I_{4R}$$

$$I_B = I_R - I_{4R}$$