Your comments

Having taken ece 110 made it easy for me to grasp most of the concepts.

I think it is silly that we say that the current/charges move in the opposite direction as the actual electrons move... Is this Thomas Edison's fault or does it go back further?

WE WERE GOING TO USE THE TIME MACHINE TO PREVENT THE ROBOT APOCALYPSE, BUT THE GUY WHO BUILT IT WAS AN ELECTRICAL ENGINEER.

What are resistors made of?

JOIN THE RESISTANCE!!!

Current Density. And also the relationship between the equations of capacitors and resistors.

Is there a systematic way to calculate I, V, and Q, because it seems like guess and check stumble around right now?

Can you tell us more about the vdrift? What is that?

If the v_drift in conductors is so slow, how come information can be sent along wires so quickly?

Exam Logistics

1) **EXAM 1: WED September 24th at 7pm**
    - Sign Up in Gradebook for Conflict Exam
    - MATERIAL: Lectures 1 – 8, HW 1 - 4, Disc 1 - 4, Lab 1 - 2

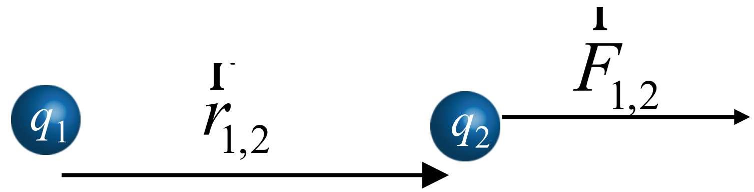
2) **EXAM 1 PREPARATION**
    - Study HW, Discussion, Checkpoints
    - Old Exams are a good way to assess what you need to know
    - Prelecture of Fall 2010 solutions available

3) **Extra Office Hours** (Tuesday 8am-3pm, 5pm-8pm; Wednesday 8am-5pm)

A Big Idea Review

Coulomb's Law
Force law between point charges

$$\vec{F}_{1,2} = \frac{kq_1q_2}{r_{1,2}^2}\hat{r}_{1,2}$$



Electric Field
Force per unit charge

$$\vec{E} \equiv \frac{\vec{F}}{q}$$

Electric Field
Property of Space
Created by Charges
Superposition

Gauss' Law
Flux through closed surface is always proportional to charge enclosed

$$\int \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$$

Gauss' Law
Can be used to determine E field → Spheres, Cylinders, Infinite Planes

Electric Potential
Potential energy per unit charge

$$\Delta V_{a\to b} \equiv \frac{\Delta U_{a\to b}}{q} = -\int_a^b \vec{E} \cdot d\vec{l}$$

Capacitance
Relates charge and potential for two conductor system

$$C \equiv \frac{Q}{V}$$

Electric Potential
Scalar Function that can be used to determine E

$$\vec{E} = -\vec{\nabla} V$$

Applications of Big Ideas

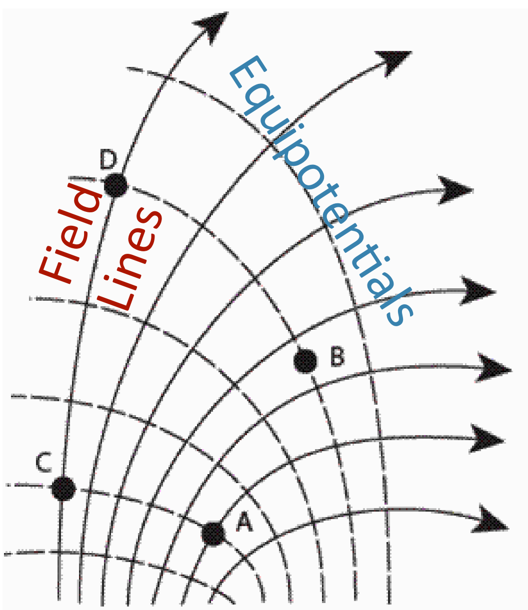
Conductors
Charges free to move → What Determines How They Move? → They move until $E = 0$!

↓

$E = 0$ in conductor determines charge densities on surfaces

Gauss' Law → Spheres, Cylinders, Infinite Planes

Field Lines & Equipotentials



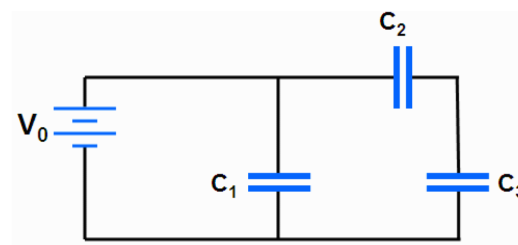
Work Done By E Field

$$W_{a\to b} = \int_a^b \vec{F}\cdot d\vec{l} = \int_a^b q\vec{E}\cdot d\vec{l}$$

Change in Potential Energy

$$\Delta U_{a\to b} = -W_{a\to b} = -\int_a^b q\vec{E}\cdot d\vec{l}$$

Capacitor Networks



Series:

$$(1/C_{23}) = (1/C_2) + (1/C_3)$$

Parallel

$$C_{123} = C_1 + C_{23}$$

Electric Current

Physics 212
Lecture 9

Today's Concept:

Ohm's Law, Resistors in circuits

Current and Resistance

Key Concepts:

1) How resistance depends on A, L, s, r

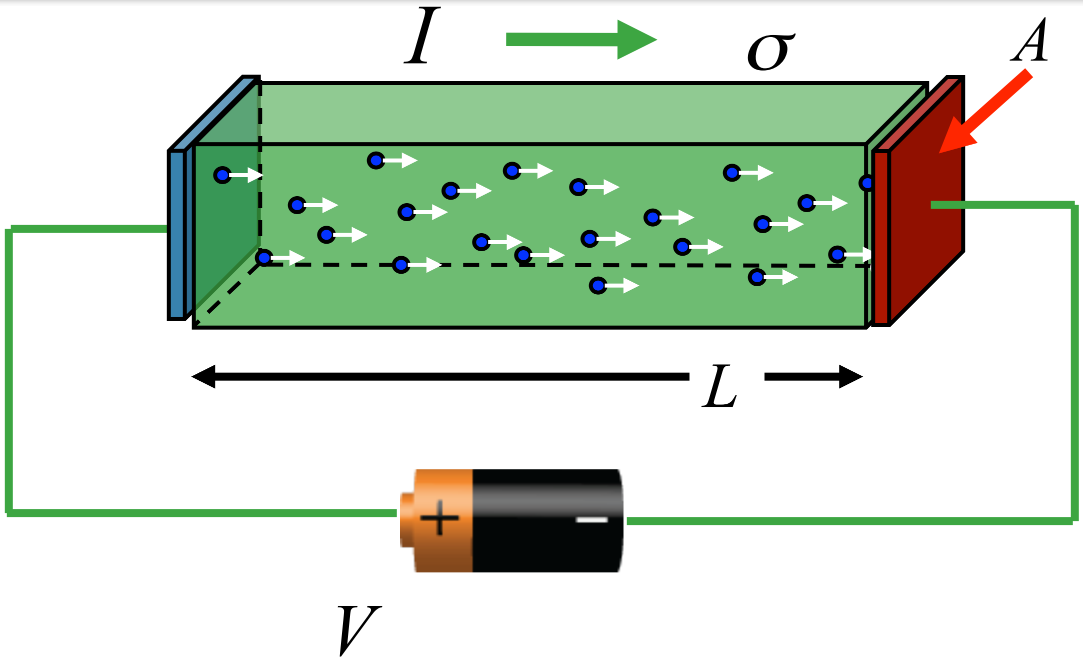
2) How to combine resistors in series and parallel

3) Understanding resistors in circuits

Today's Plan:

1) Review of resistance & preflights

2) Work out a circuit problem in detail



I
σ
A
L
+
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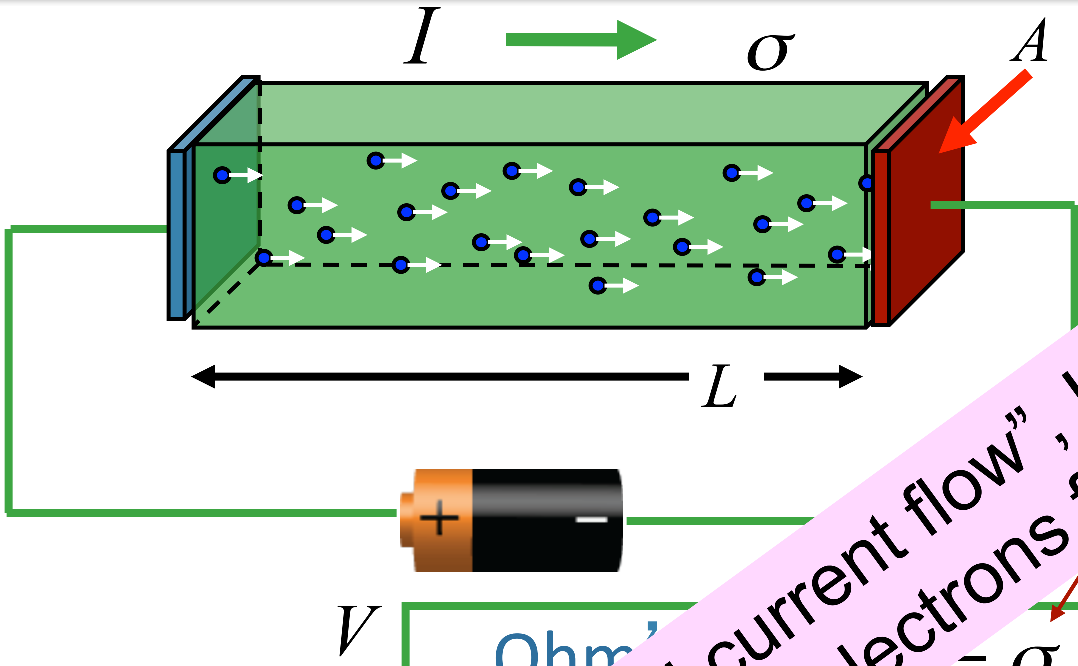
V



Note: "Conventional current flow", I, is opposite to direction electrons flow

...nductivity – high for good conductors.

$\boxed{\text{Ohm'}\ldots = \sigma E}$

Observables:

$V = EL$

$I = JA$

$\ldots A = \sigma V/L \rightarrow I = V/(L/\sigma A)$

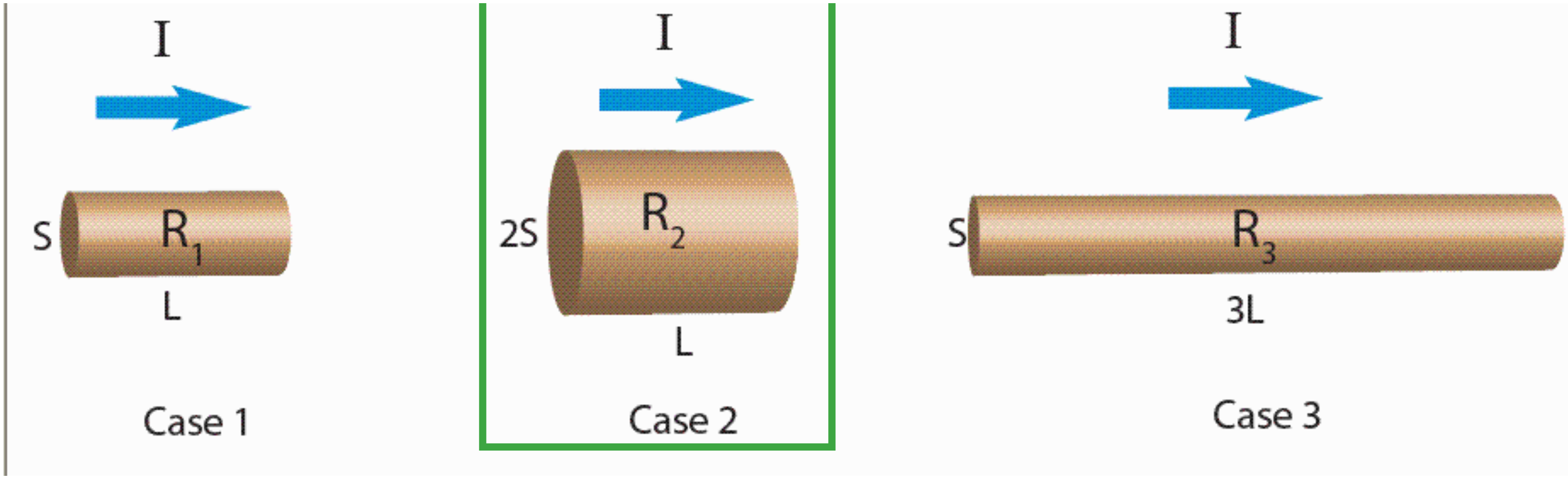
...esistance

$\rho = 1/\sigma$

$\boxed{I = V/R} \leftarrow R = \dfrac{L}{\sigma A}$

CheckPoint 3

The SAME amount of current I passes through three different resistors. R_2 has twice the cross-sectional area and the same length as R_1, and R_3 is three times as long as R_1 but has the same cross-sectional area as R_1.

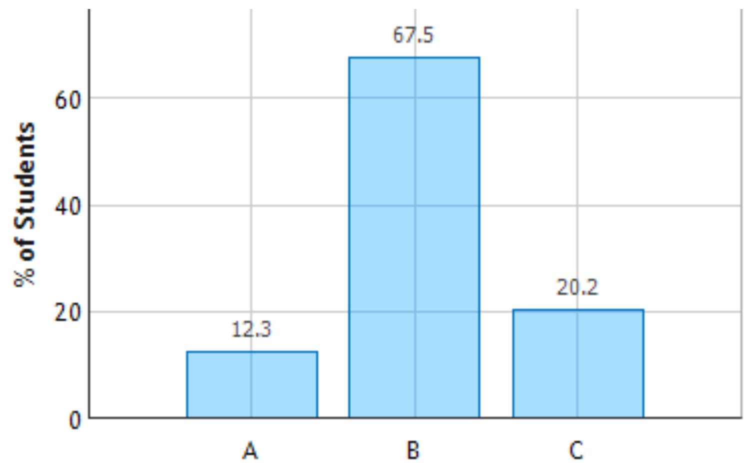


In which case is the CURRENT DENSITY through the resistor the smallest?

A. Case 1 ***B.*** Case 2 ***C.*** Case 3

$$J \equiv \frac{I}{A} \quad \longrightarrow \quad J_1 = J_3 = 2J_2$$

Same Current $\longrightarrow$ $J \propto \dfrac{1}{A}$



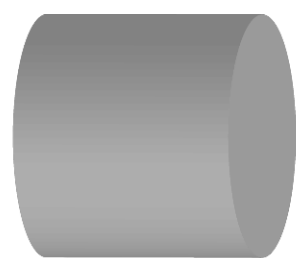
This is just like Plumbing!

I is like flow rate of water
V is like pressure
R is how hard it is for water to flow in a pipe

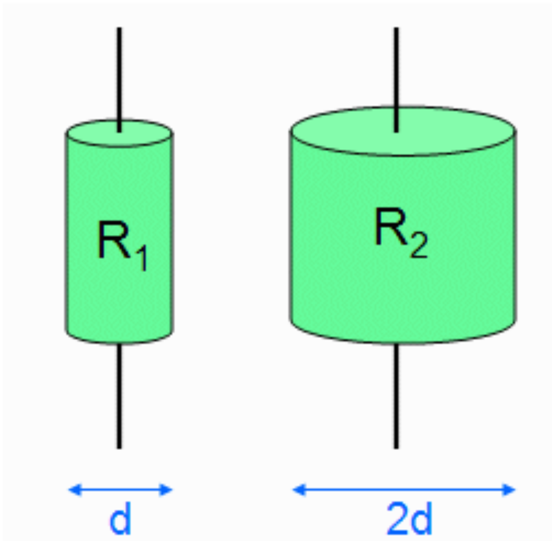
$$R = \frac{L}{\sigma A}$$

To make R big, make L long or A small

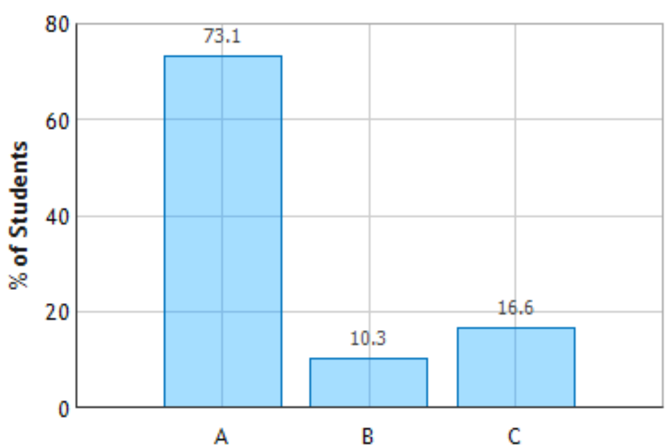
To make R small, make L short or A big



CheckPoint 1a



$V_1 > V_2$ $V_1 = V_2$ $V_1 < V_2$



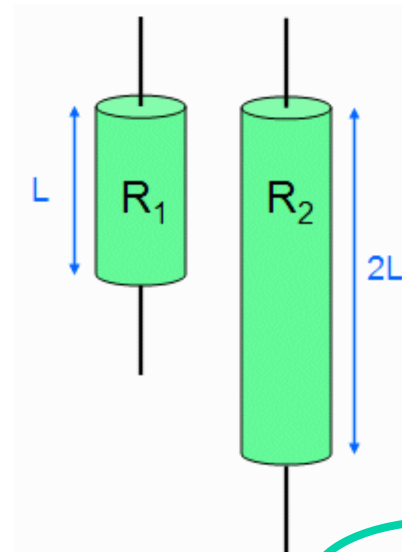
Same current through both resistors

Compare voltages across resistors

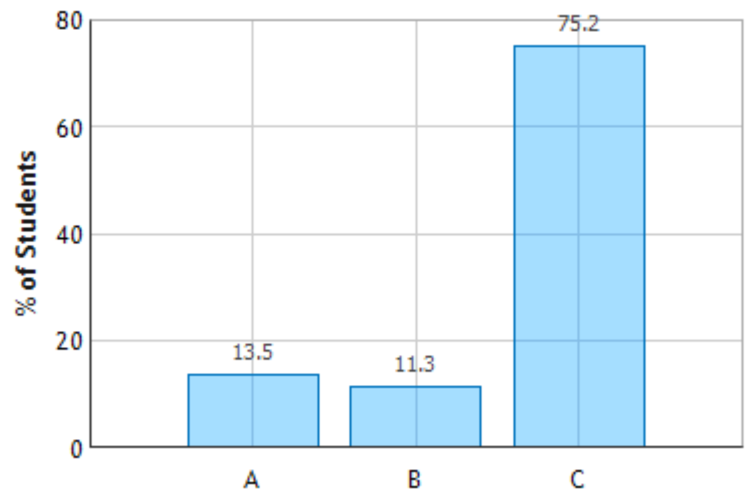
$$R \propto \frac{L}{A}$$

$$V = IR \propto \frac{L}{A}$$

CheckPoint 1b



$V_1 > V_2$ $V_1 = V_2$ $V_1 < V_2$



Resistor Summary

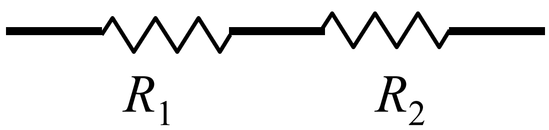
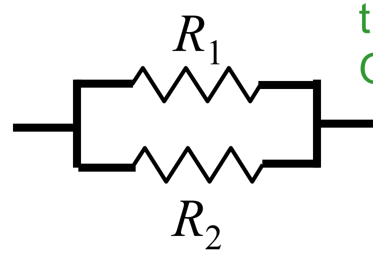
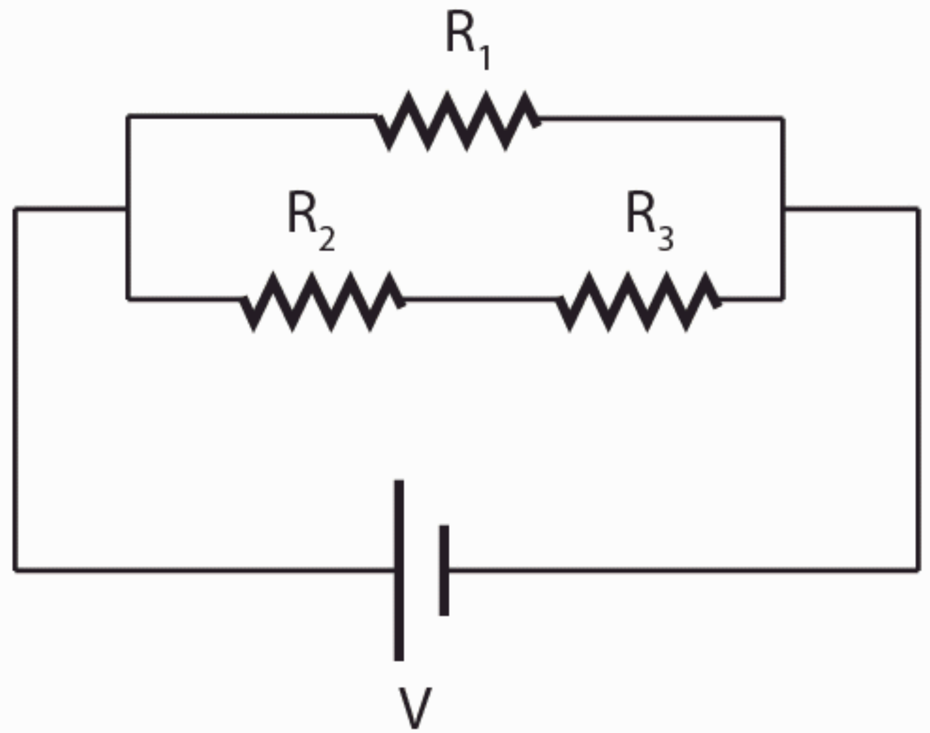
	Series	**Parallel**
	Every loop with R_1 also has R_2	There is a loop that contains ONLY R_1 and R_2
		
Wiring	Each resistor on the <u>same</u> wire.	Each resistor on a <u>different</u> wire.
Voltage	<u>Different</u> for each resistor. $V_{total} = V_1 + V_2$	<u>Same</u> for each resistor. $V_{total} = V_1 = V_2$
Current	<u>Same</u> for each resistor $I_{total} = I_1 = I_2$	<u>Different</u> for each resistor $I_{total} = I_1 + I_2$
Resistance	<u>Increases</u> $R_{eq} = R_1 + R_2$	<u>Decreases</u> $1/R_{eq} = 1/R_1 + 1/R_2$

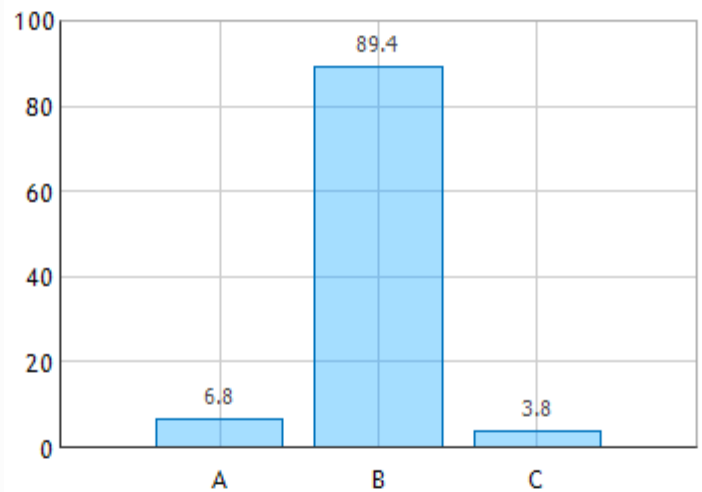
Figure 1 labels: R_1, R_2

Figure 2 labels: R_1, R_2

CheckPoint 2a

Three resistors are connected to a battery with emf V as shown. The resistances of the resistors are all the same, i.e. $R_1 = R_2 = R_3 = R$.





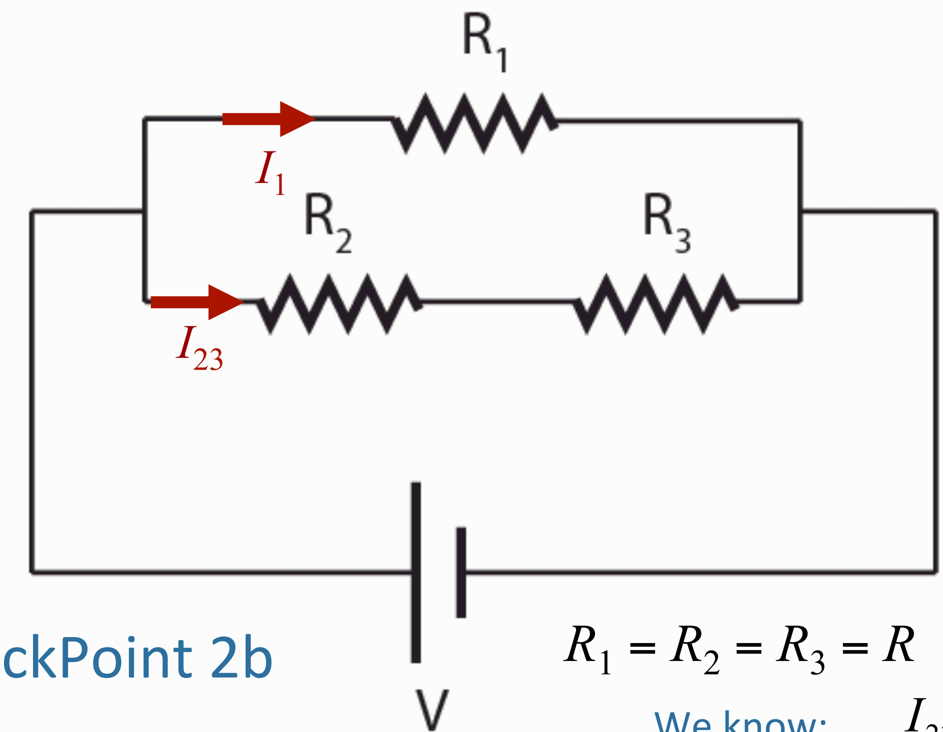
Compare the current through R_2 with the current through R_3:

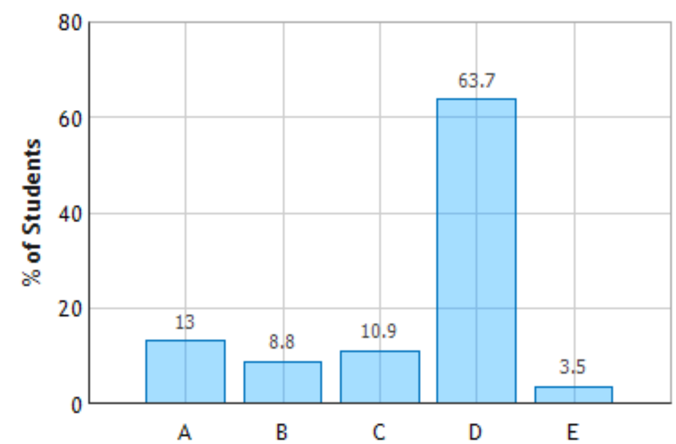
A. $I_2 > I_3$ ***B.*** $I_2 = I_3$ ***C.*** $I_2 < I_3$

R_2 in series with R_3 → Current through R_2 and R_3 is the same

$$I_{23} = \frac{V}{R_2 + R_3}$$

Checkpoint 2b





CheckPoint 2b

Compare the current through R_1 with the current through R_2

A $I_1/I_2 = 1/2$

B $I_1/I_2 = 1/3$

C $I_1/I_2 = 1$

D $\boxed{I_1/I_2 = 2}$

E $I_1/I_2 = 3$

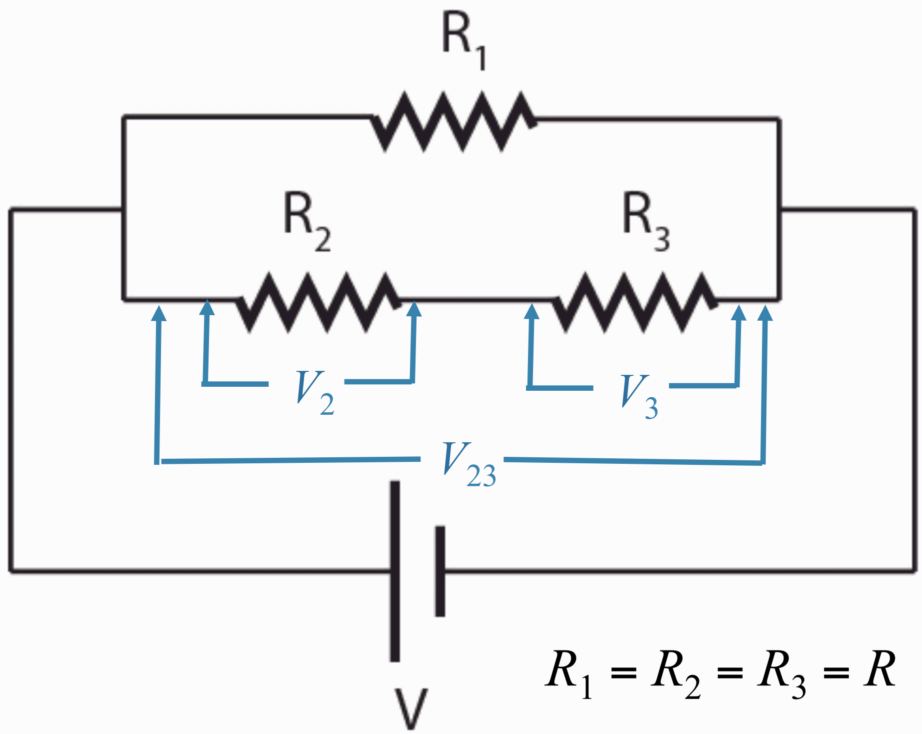
$$R_1 = R_2 = R_3 = R$$

We know: $I_{23} = \dfrac{V}{R_2 + R_3}$

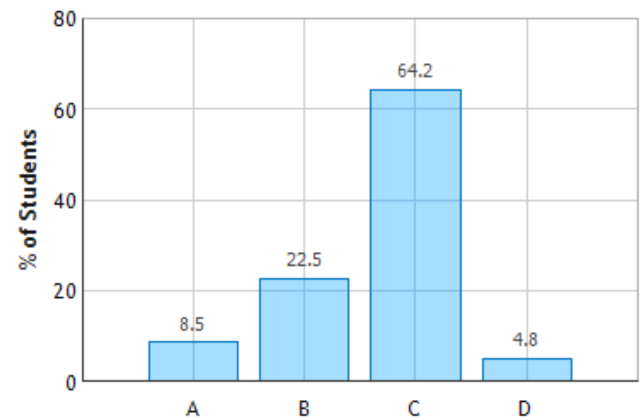
Similarly: $I_1 = \dfrac{V}{R_1}$

$$\rightarrow \quad I_1 = I_{23}\frac{R_2 + R_3}{R_1}$$

$$\frac{I_1}{I_{23}} = \frac{R_2 + R_3}{R_1} = 2$$



$$R_1 = R_2 = R_3 = R$$



CheckPoint 2c

Compare the voltage across R_2 with the voltage across R_3

A $V_2 > V_3$

B $V_2 = V_3 = V$

C $\boxed{V_2 = V_3 < V}$

D $V_2 < V_3$

$$V_2 = I_2 R_2$$

$$V_3 = I_3 R_3$$

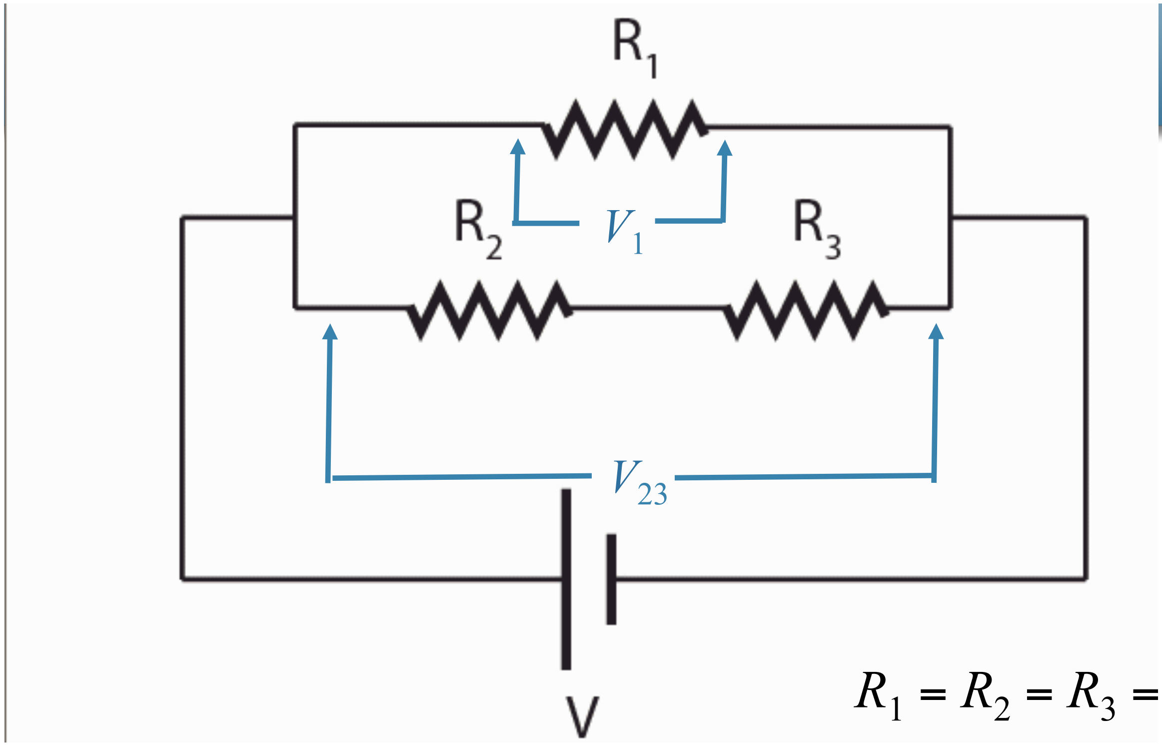
$I_2 = I_3$ (Series)
$R_2 = R_3$ (Problem statement)

$$V_2 = V_3$$

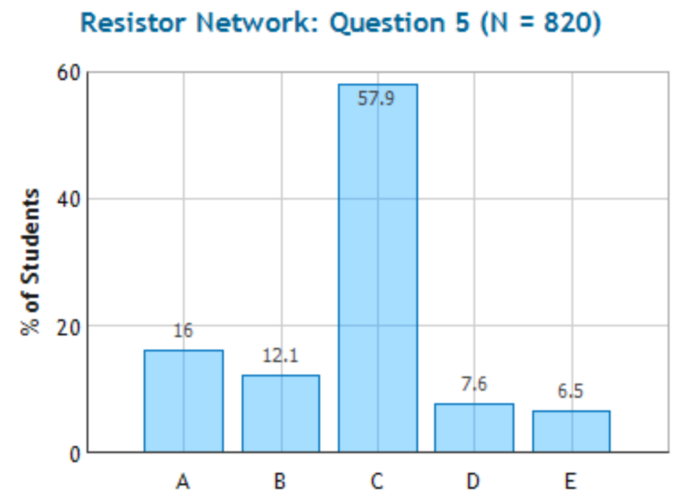
$$V_{23} = V$$

$$V_{23} = V_2 + V_3$$

$$V_2 = V_3 = \frac{V}{2}$$



$R_1 = R_2 = R_3 = R$



CheckPoint 2d

Compare the voltage across R_1 with the voltage across R_2

A $V_1 = V_2 = V$

B $V_1 = ½\, V_2 = V$

C $\boxed{V_1 = 2V_2 = V}$

D $V_1 = ½\, V_2 = 1/5\ V$

E $V_1 = ½\, V_2 = ½\ V$

R_1 in parallel with series combination of R_2 and R_3

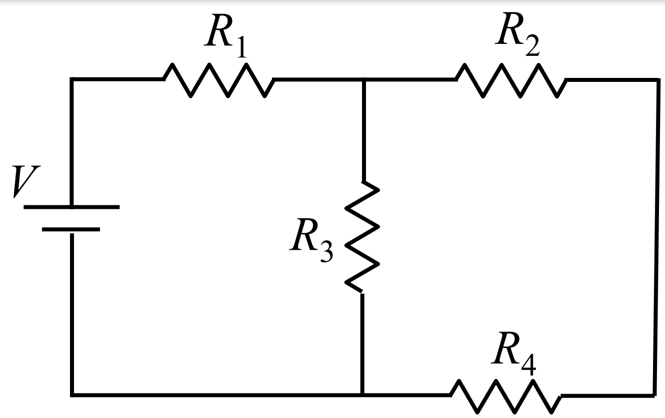
$$V_1 = V_{23}$$

$$R_2 = R_3 \Rightarrow V_2 = V_3$$

$$V_{23} = V_2 + V_3 = 2V_2$$

$$\longrightarrow \quad V_1 = 2V_2 = V$$

Calculation



In the circuit shown: $V = 18V$,
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.

What is V_2, the voltage across R_2?

Conceptual Analysis:

Ohm's Law: when current *I* flows through resistance R, the potential drop V is given by: $V = IR$.

Resistances are combined in series and parallel combinations

$$R_{series} = R_a + R_b$$
$$(1/R_{parallel}) = (1/R_a) + (1/R_b)$$

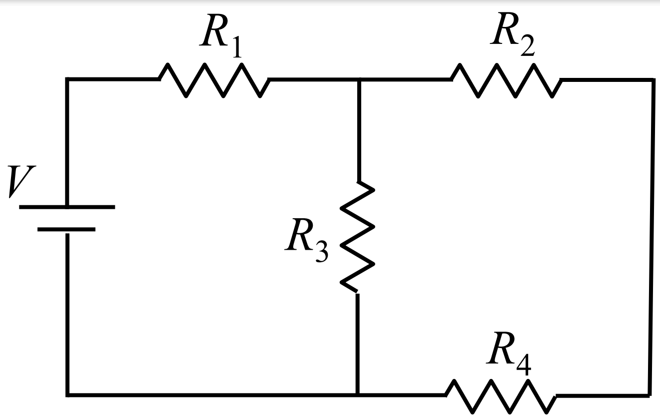
Strategic Analysis:

Combine resistances to form equivalent resistances

Evaluate voltages or currents from Ohm's Law

Expand circuit back using knowledge of voltages and currents

Calculation



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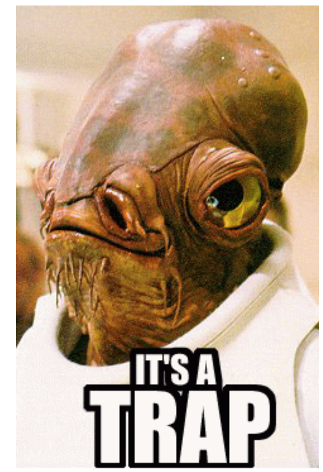


Combine Resistances:

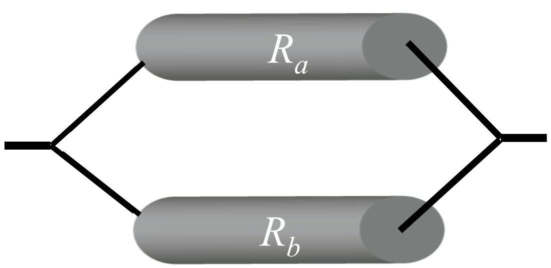
R_1 and R_2 are connected:

A) in series

B) in parallel

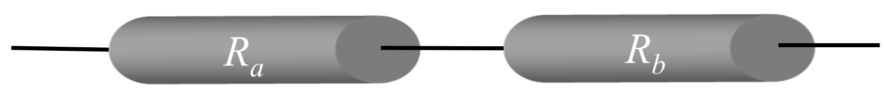
C) neither in series nor in parallel

Parallel Combination



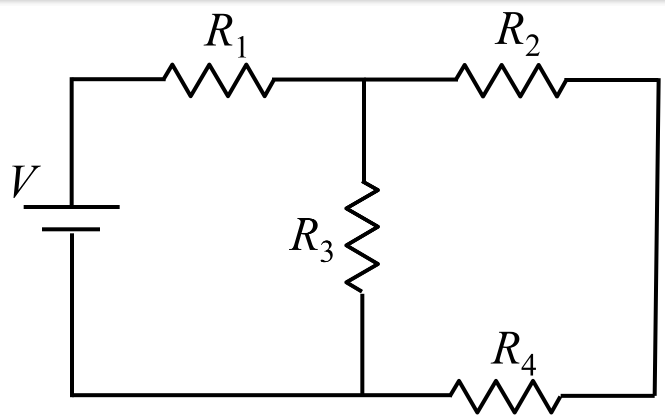
Parallel: Can make a loop that contains only those two resistors

Series Combination



Series : Every loop with resistor 1 also has resistor 2.

Calculation



In the circuit shown: $V = 18V$,
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.

What is V_2, the voltage across R_2?

We first will combine resistances R_2, R_3, R_4:
Which of the following is true?

A) R_2, R_3 and R_4 are connected in series

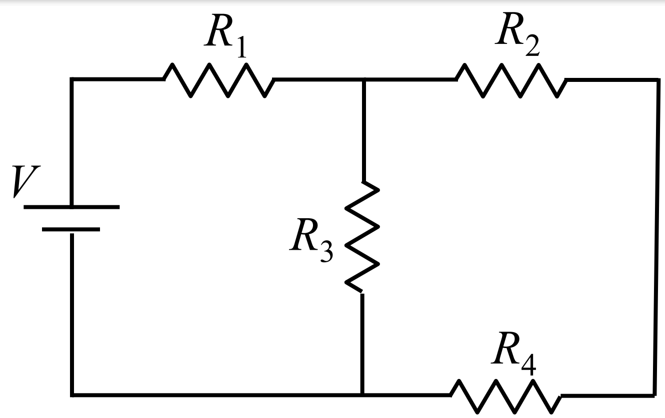
B) R_2, R_3, and R_4 are connected in parallel

C) R_3 and R_4 are connected in series (R_{34}) which is connected in parallel with R_2

D) R_2 and R_4 are connected in series (R_{24}) which is connected in parallel with R_3

E) R_2 and R_4 are connected in parallel (R_{24}) which is connected in parallel with R_3

Calculation

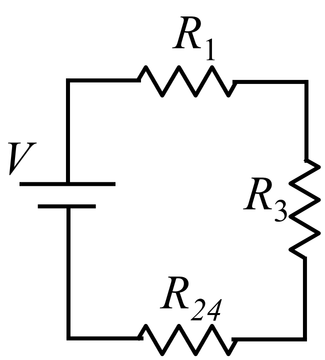


In the circuit shown: $V = 18V$, $R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.

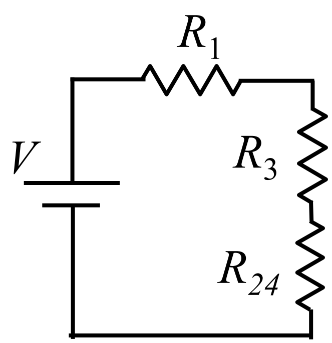
What is V_2, the voltage across R_2?

R_2 and R_4 are connected in series (R_{24}) which is connected in parallel with R_3

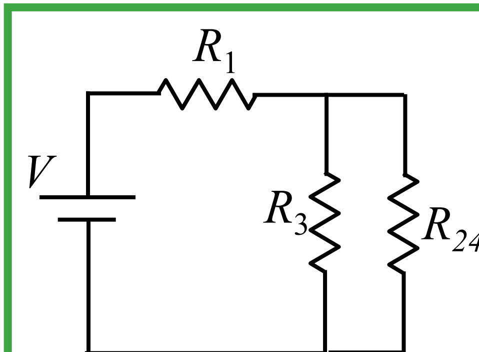
Redraw the circuit using the equivalent resistor R_{24} = series combination of R_2 and R_4.



(A)

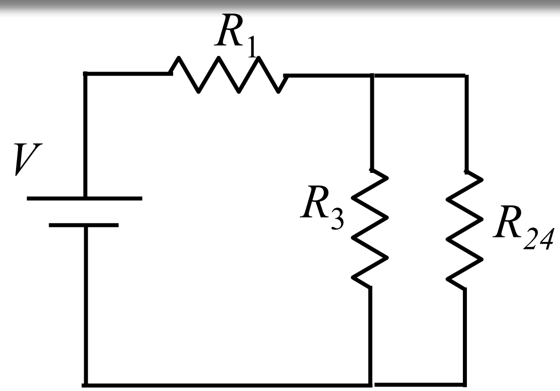


(B)



(C)

Calculation



In the circuit shown: $V = 18V$,
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.

What is V_2, the voltage across R_2?

Combine Resistances:

R_2 and R_4 are connected in series = R_{24}
R_3 and R_{24} are connected in parallel = R_{234}

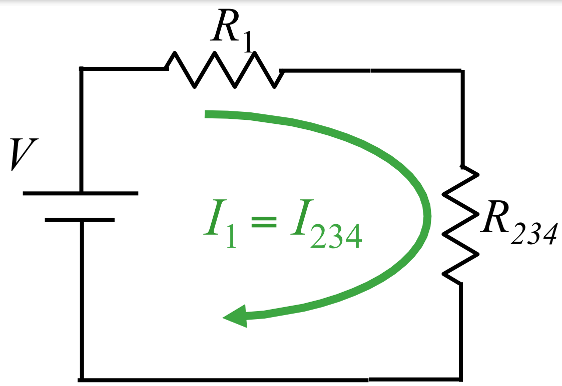
What is the value of R_{234}?

A) $R_{234} = 1\ \Omega$ B) $\boxed{R_{234} = 2\ \Omega}$ C) $R_{234} = 4\ \Omega$ D) $R_{234} = 6\ \Omega$

R_2 and R_4 in series → $R_{24} = R_2 + R_4 = 2\Omega + 4\Omega = 6\Omega$

$(1/R_{parallel}) = (1/R_a) + (1/R_b)$ → $1/R_{234} = (1/3) + (1/6) = (3/6)\ \Omega^{-1}$ → $R_{234} = 2\ \Omega$

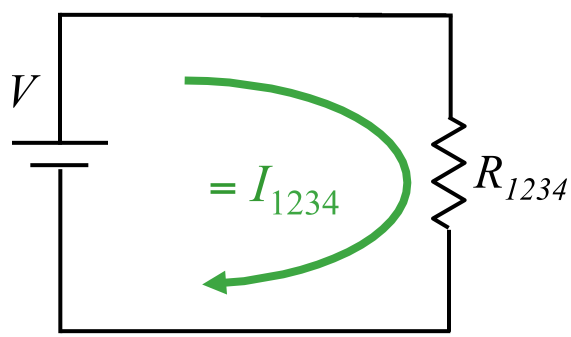
Calculation



In the circuit shown: $V = 18V$,
$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.
$R_{24} = 6\Omega$ $R_{234} = 2\Omega$
What is V_2, the voltage across R_2?

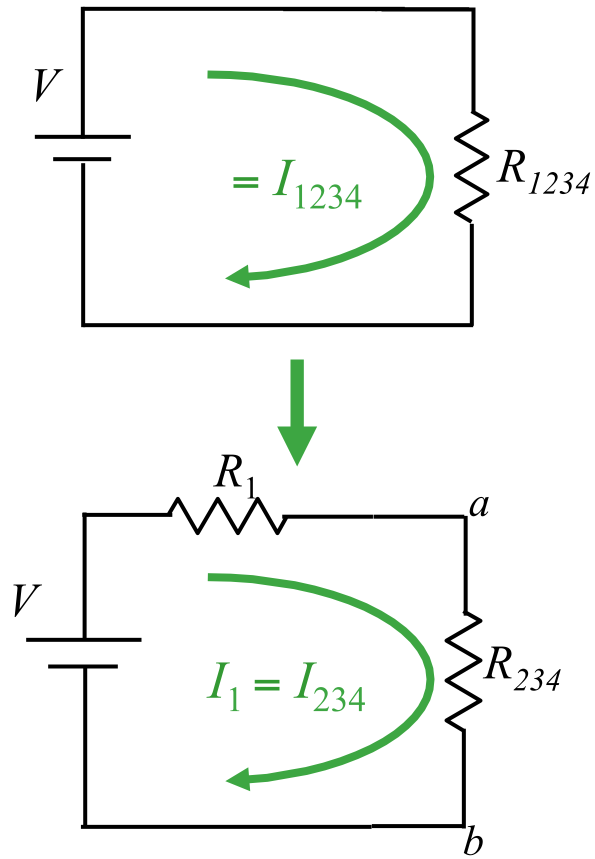
R_1 and R_{234} are in series. $R_{1234} = 1 + 2 = 3\ \Omega$

Our next task is to calculate the total current in the circuit



Ohm's Law tells us: $I_{1234} = V/R_{1234}$
$= 18 / 3$
$= 6$ Amps

Calculation



In the circuit shown: $V = 18V$,

$R_1 = 1\Omega$, $R_2 = 2\Omega$, $R_3 = 3\Omega$, and $R_4 = 4\Omega$.

$R_{24} = 6\Omega$ $\quad R_{234} = 2\Omega$ $\quad I_{1234} = 6\ A$

What is V_2, the voltage across R_2?

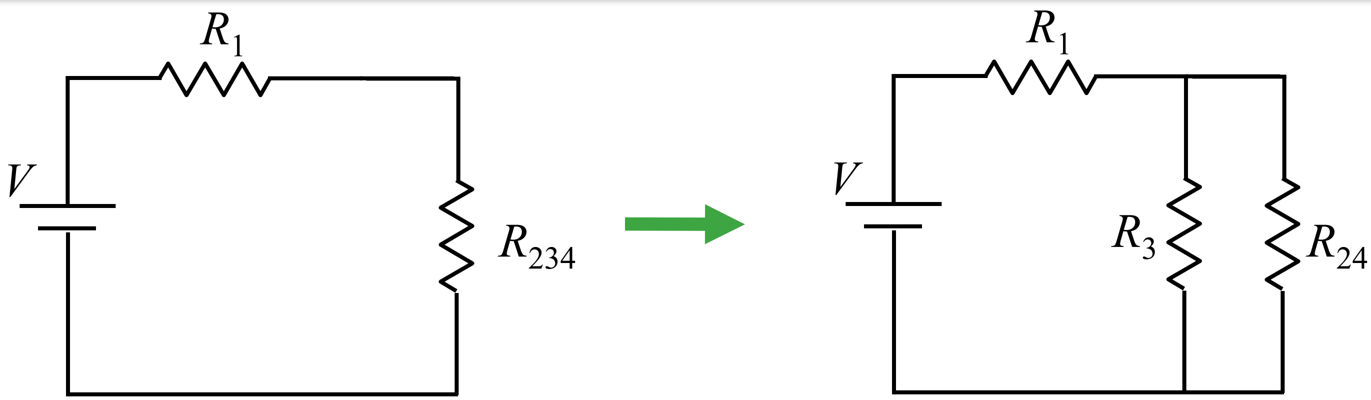
$I_{234} = I_{1234}$ Since R_1 in series with R_{234}

$$V_{234} = I_{234}\ R_{234}$$
$$= 6 \text{ x } 2$$
$$= 12 \text{ Volts}$$

What is V_{ab}, the voltage across R_{234} ?

A) $V_{ab} = 1\ V$ B) $V_{ab} = 2\ V$ C) $V_{ab} = 9\ V$ D) $\boxed{V_{ab} = 12\ V}$ E) $V_{ab} = 16\ V$

Calculation



$V = 18V$
$R_1 = 1\Omega$
$R_2 = 2\Omega$
$R_3 = 3\Omega$
$R_4 = 4\Omega$
$R_{24} = 6\Omega$
$R_{234} = 2\Omega$
$I_{1234} = 6$ Amps
$I_{234} = 6$ Amps
$V_{234} = 12V$
What is V_2?

Which of the following are true?

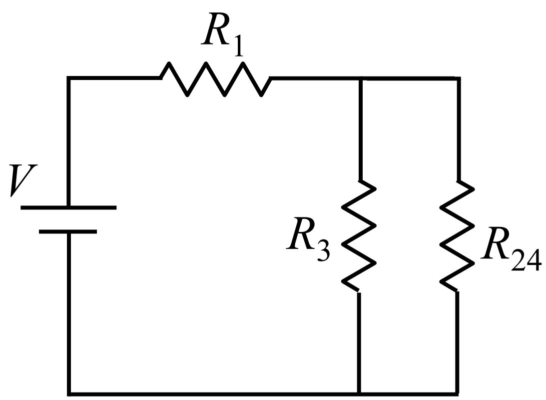
A) $V_{234} = V_{24}$ B) $I_{234} = I_{24}$ C) Both A+B D) None

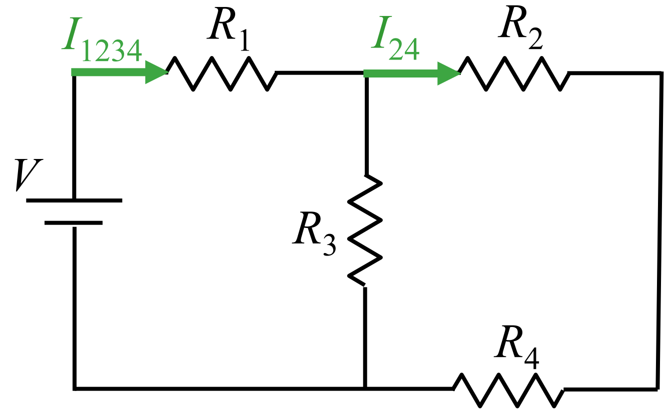
R_3 and R_{24} were combined in parallel to get R_{234} → Voltages are same!

Ohm's Law

$$I_{24} = V_{24} / R_{24}$$
$$= 12 / 6$$
$$= 2 \text{ Amps}$$

Calculation





$V = 18V$
$R_1 = 1\Omega$
$R_2 = 2\Omega$
$R_3 = 3\Omega$
$R_4 = 4\Omega.$
$R_{24} = 6\Omega$
$R_{234} = 2\Omega$
$I_{1234} = 6$ Amps
$I_{234} = 6$ Amps
$V_{234} = 12V$
$V_{24} = 12V$
$I_{24} = 2$ Amps
What is V_2?

Which of the following are true?

A) $V_{24} = V_2$ B) $I_{24} = I_2$ C) Both A+B D) None

R_2 and R_4 where combined in series to get R_{24} → Currents are same!

The Problem Can Now Be Solved!

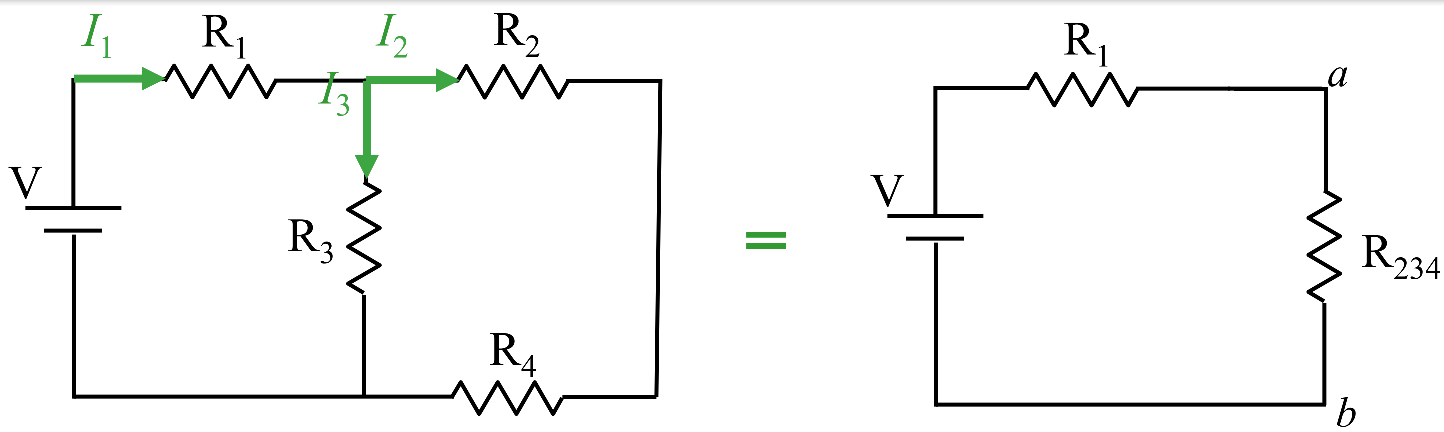
Ohm's Law

$V_2 = I_2 \ R_2$

$= \ 2 \times 2$

$= 4$ Volts!

Quick Follow-Ups



$V = 18V$
$R_1 = 1\Omega$
$R_2 = 2\Omega$
$R_3 = 3\Omega$
$R_4 = 4\Omega$
$R_{24} = 6\Omega$
$R_{234} = 2\Omega$
$V_{234} = 12V$
$V_2 = 4V$
$I_{1234} = 6$ Amps

What is I_3 ?

A) $I_3 = 2\ A$ B) $I_3 = 3\ A$ C) $\boxed{I_3 = 4\ A}$

$V_3 = V_{234} = 12V \rightarrow I_3 = V_3/R_3 = 12V/3\Omega = 4A$

What is I_1 ?

We know $I_1 = I_{1234} = 6\ A$

NOTE: $I_2 = V_2/R_2 = 4/2 = 2\ A \rightarrow I_1 = I_2 + I_3$ Make Sense?