CG1111: Engineering Principles and Practice I

Electrical Circuit Principles

NUS
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What We'll Learn

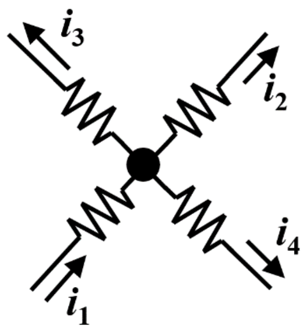
- Kirchhoff's Current Law (KCL)
- Kirchhoff's Voltage Law (KVL)
- Resistances in Series
- Resistances in Parallel
- Voltage Division Principle
- Current Division Principle

Kirchhoff's Current Law (KCL)

Sum of all currents entering a node
=
Sum of all currents leaving the node

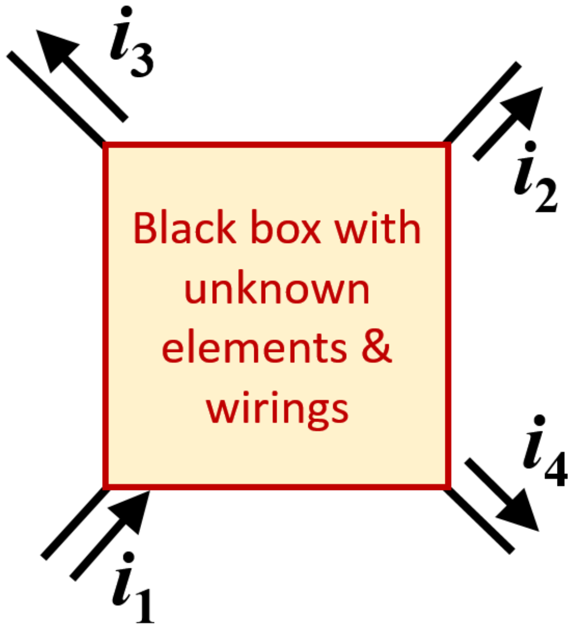
- Based on conservation of charges
- Recall: current = rate of flow of charges
- Since charges cannot be created nor destroyed, the net flow of charges into or out of a node must be 0

$$i_1 = i_2 + i_3 + i_4$$



Applying KCL to a “SuperNode”

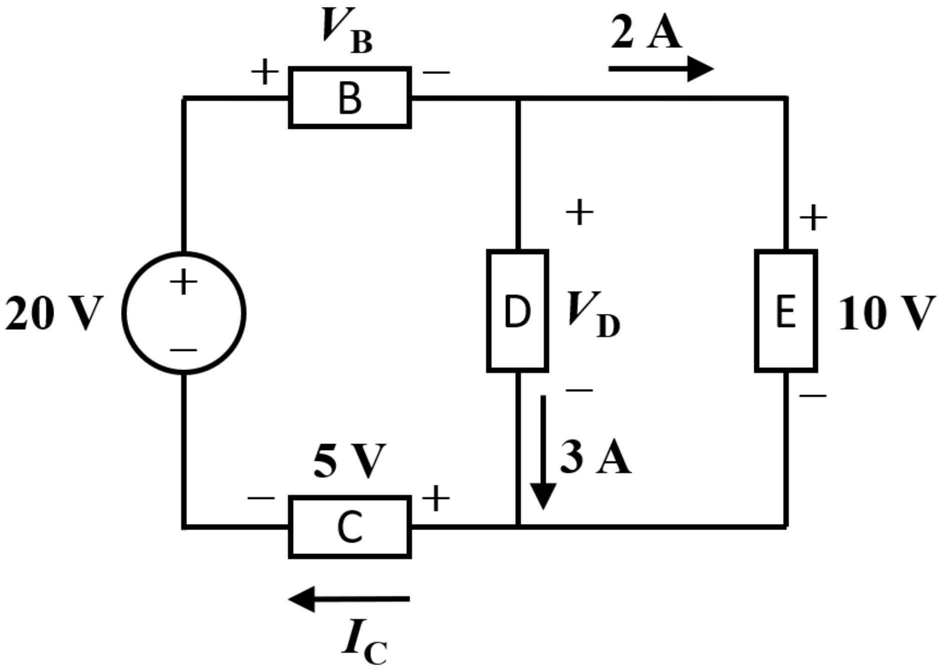
- The “supernode” can be any enclosed portion of the circuit



$$i_1 = i_2 + i_3 + i_4$$

KCL Example

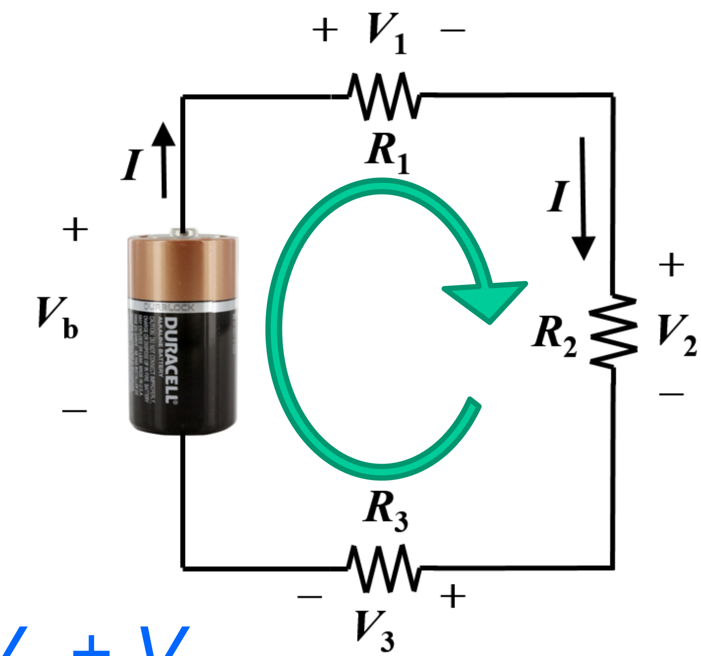
- Find I_C:



Kirchhoff's Voltage Law (KVL)

Around any closed loop:

Sum of voltage rises
=
Sum of voltage falls

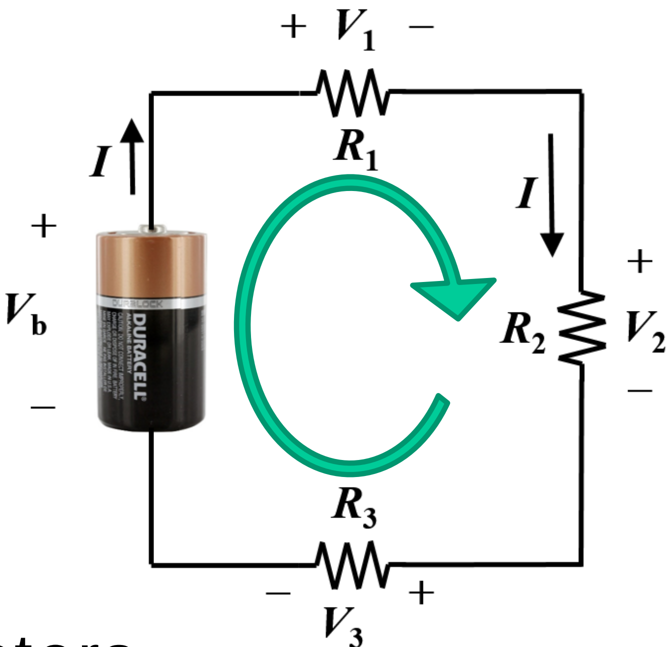


$$V_b = V_1 + V_2 + V_3$$

- Voltage rises when we go from negative polarity to positive polarity
- Voltage falls when we go from positive polarity to negative polarity

KVL is Derived from the Principle of Conservation of Power

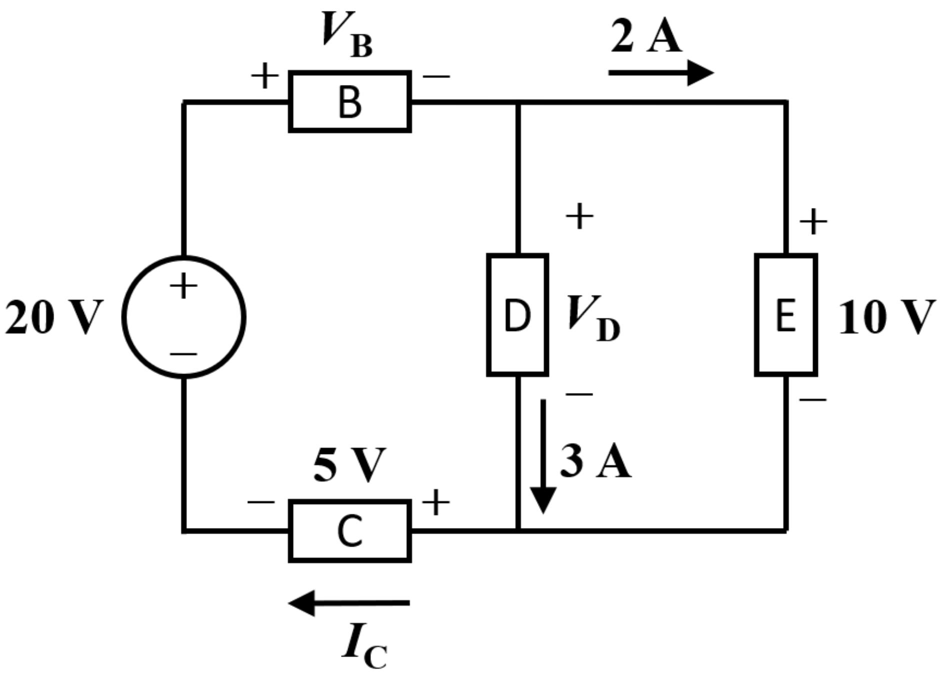
$$V_b = V_1 + V_2 + V_3$$



- Total power consumed by resistors $= V_1\, I + V_2\, I + V_3\, I = I\,(V_1 + V_2 + V_3)$
- Power supplied by battery $= V_b\, I$
- By the principle of conservation of power, $V_b\, I = I\,(V_1 + V_2 + V_3)$
- Hence, $V_b = V_1 + V_2 + V_3$

KVL Example

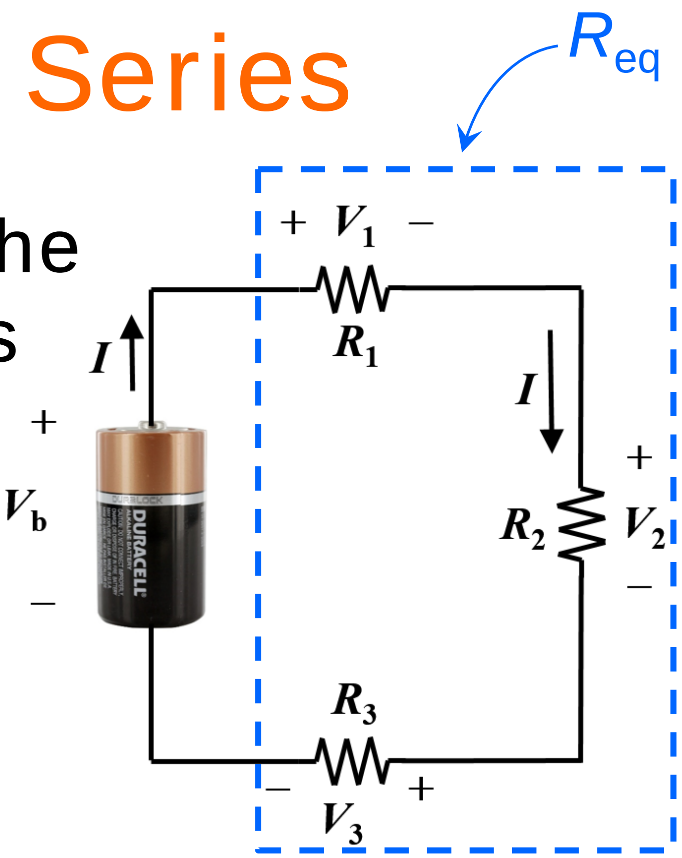
- Find V_B and V_D:



Resistances in Series

- From KCL, we know that the currents in all the resistors in series will be identical
- From KVL & Ohm's Law,

$$V_b = V_1 + V_2 + V_3$$
$$= R_1 I + R_2 I + R_3 I$$
$$= (R_1 + R_2 + R_3) \times I$$

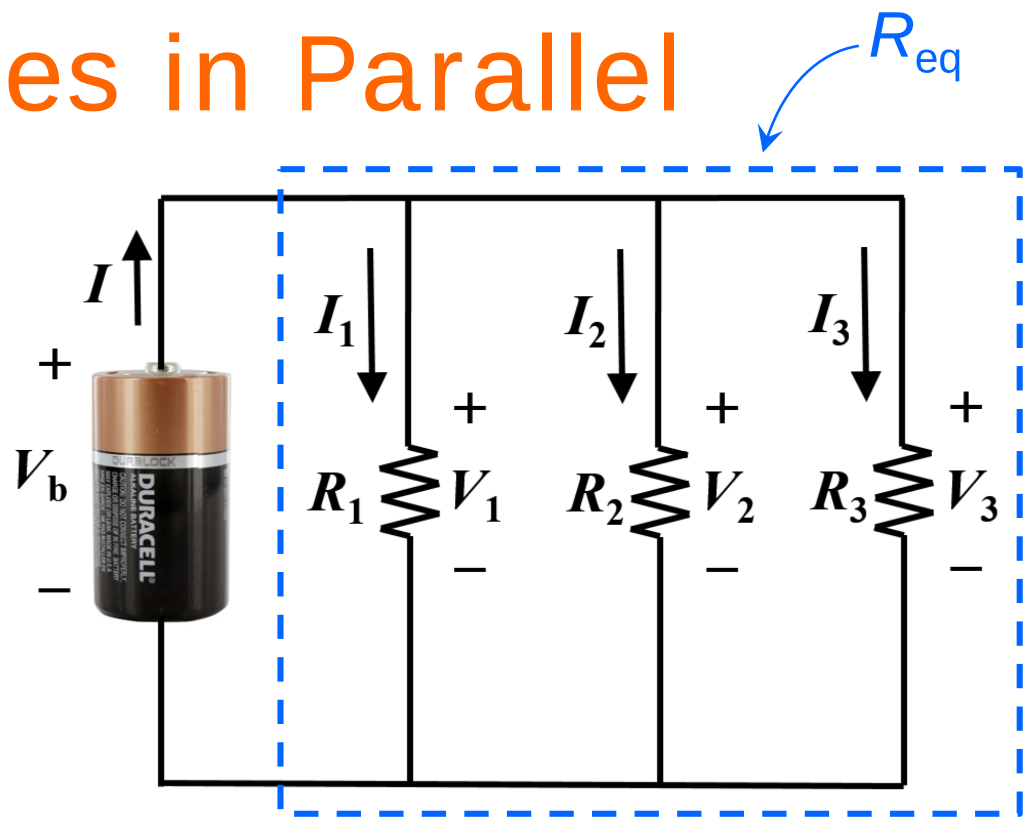


- Since V_b is also given by $R_{eq} \times I$, therefore, the equivalent resistance is

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

Resistances in series lead to increased resistance

Resistances in Parallel



- $V_1 = V_2 = V_3 = V_b$
- From KCL,

$$I = I_1 + I_2 + I_3$$
$$= \frac{V_b}{R_1} + \frac{V_b}{R_2} + \frac{V_b}{R_3}$$
$$= V_b\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

Since $I = \frac{V_b}{R_{eq}}$, we have $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Since $\frac{1}{R_{eq}} > \frac{1}{R_i}$ for any $i = 1,2,3$, $\therefore R_{eq} < R_i$

Resistances in parallel lead to reduced resistance

Resistances in Parallel: Special Cases

- Two resistances in parallel:

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

- Two <u>equal</u> resistances in parallel:

$$R_{eq} = \frac{R}{2}$$

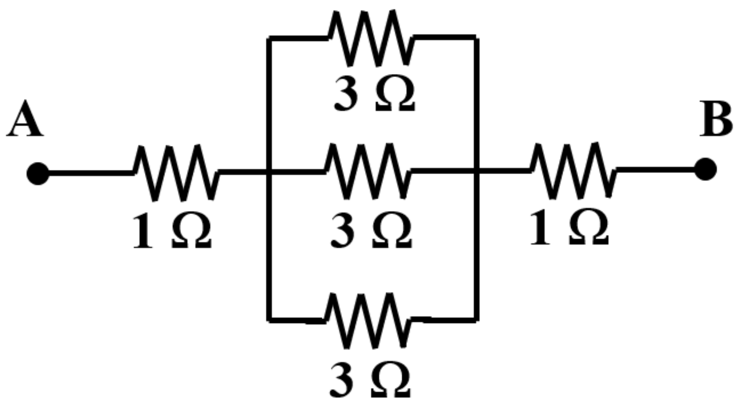
- *N* <u>equal</u> resistances in parallel:

$$R_{eq} = \frac{R}{N}$$

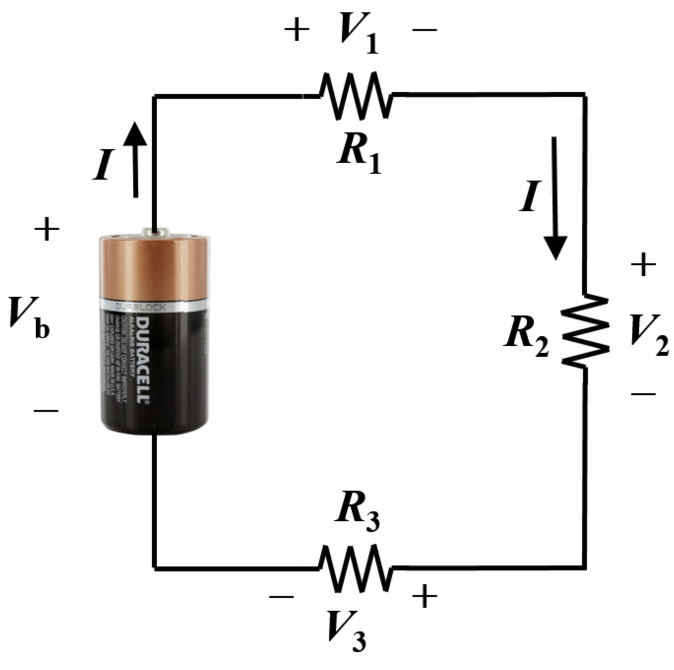
Network Analysis Using Series & Parallel Equivalents

- A resistive circuit can be solved by repeated simplification through application of series & parallel equivalents

- Example:
  - –Find equivalent resistance between A & B:



Voltage Division Principle



$$I = \frac{V_b}{R_1 + R_2 + R_3}$$

$$V_1 = I \times R_1 = \frac{R_1}{R_1 + R_2 + R_3} V_b$$

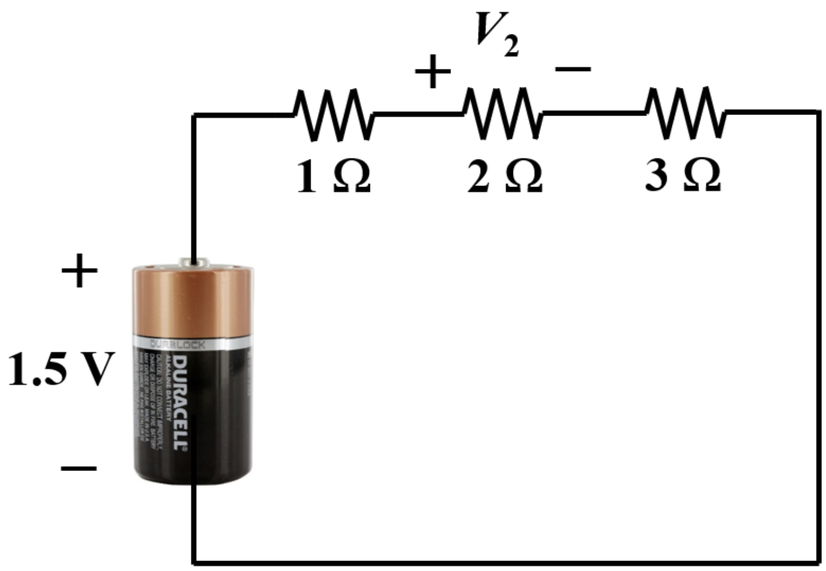
$$V_2 = I \times R_2 = \frac{R_2}{R_1 + R_2 + R_3} V_b$$

$$V_3 = I \times R_3 = \frac{R_3}{R_1 + R_2 + R_3} V_b$$

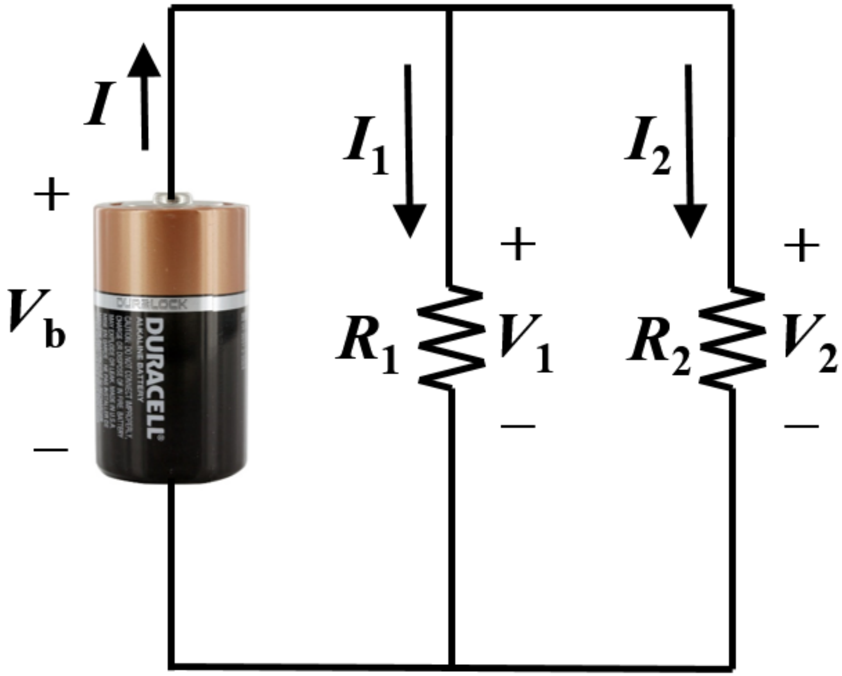
In series circuit, the voltage across each resistance is a fraction of the total voltage, equal to the ratio of the concerned resistance to the total resistance

Example Using Voltage Division Principle

- Find voltage V_2:



Current Division Principle



$$V_b = (R_1 \parallel R_2)I = \frac{R_1 R_2}{R_1 + R_2} I$$

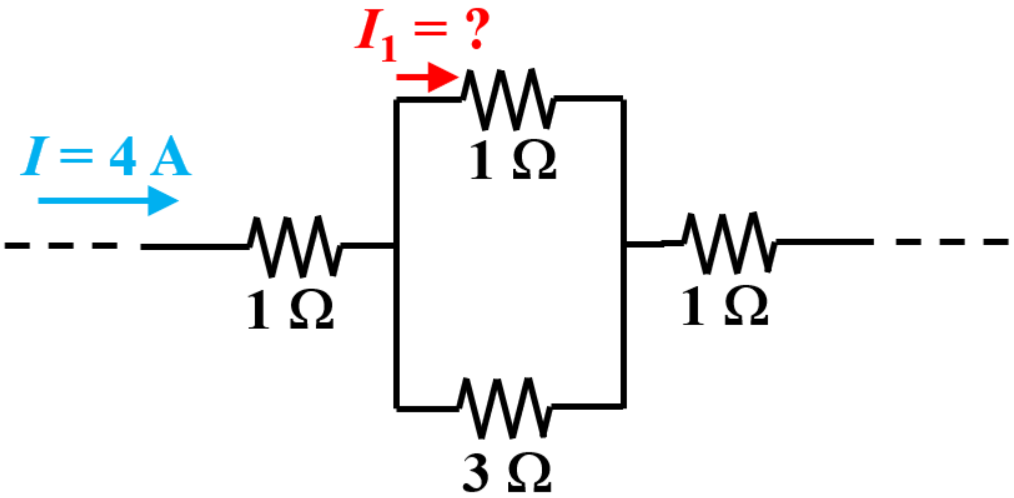
$$I_1 = \frac{V_1}{R_1} = \frac{V_b}{R_1} = \frac{R_2}{R_1 + R_2} I$$

$$I_2 = \frac{V_2}{R_2} = \frac{V_b}{R_2} = \frac{R_1}{R_1 + R_2} I$$

For two resistances in parallel, the current flowing in each resistance is a fraction of the total current, equal to the ratio of the other resistance to the sum of both the resistances

Example Using Current Division Principle

- Find current I_1:



THANK YOU