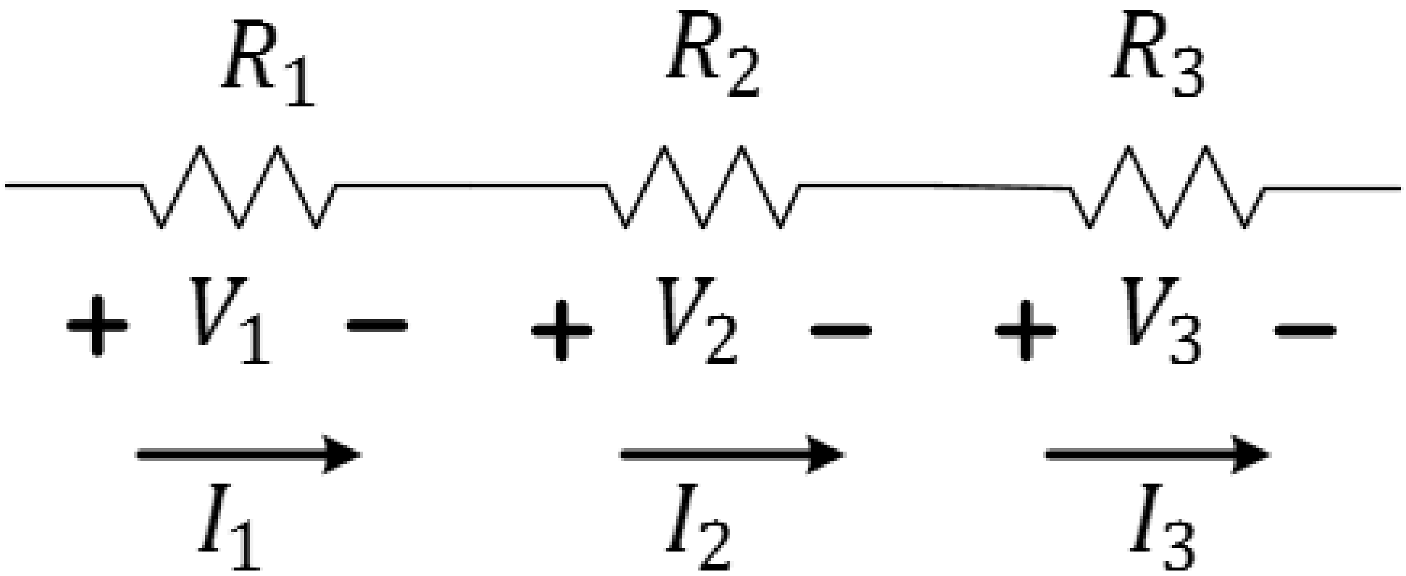
Lecture 7: Circuit Tools

- Equivalent Resistance Defined
- Voltage Divider
- Current Divider
- Power Dissipation in Series and Parallel Resistive Loads
- Example Problems and Practice

Series Connection

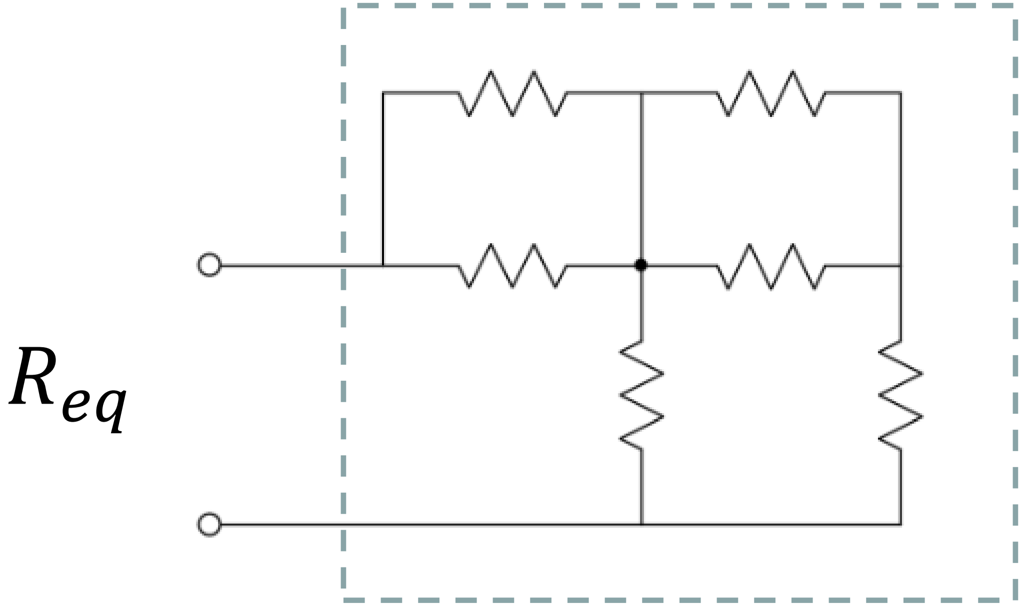
Series connections share the same current



$I_1 = I_2 = I_3$ because of KCL

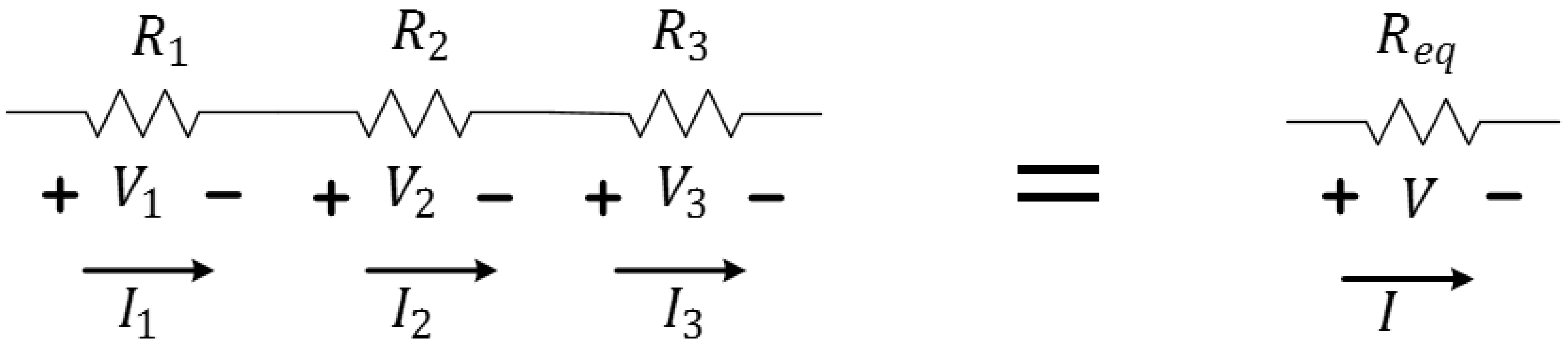
Equivalent Resistance

Equivalent Resistance is the resistance value you get when you place an entire resistive network into a (virtual) box and characterize it as an Ohmic device (a new resistor).



Equivalent Resistance of Series Resistors

Resistances in series add up



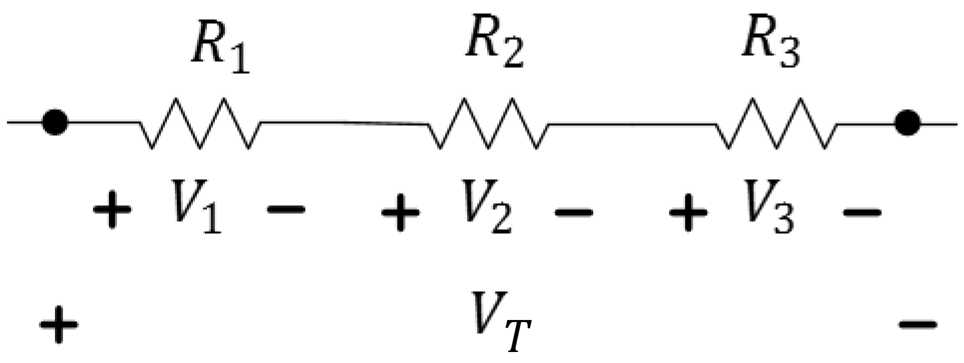
$$R_{eq} = R_1 + R_2 + \cdots + R_N$$

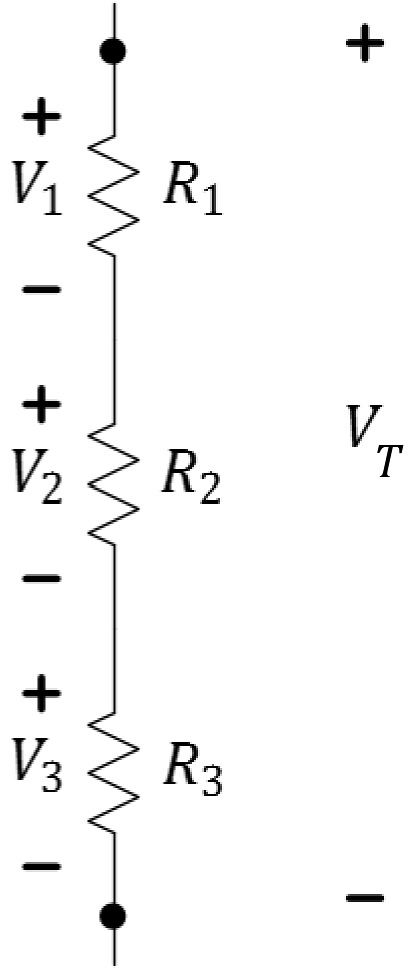
This can be intuitive: think of telegraphy wires in series.

Voltage Divider Rule (VDR)

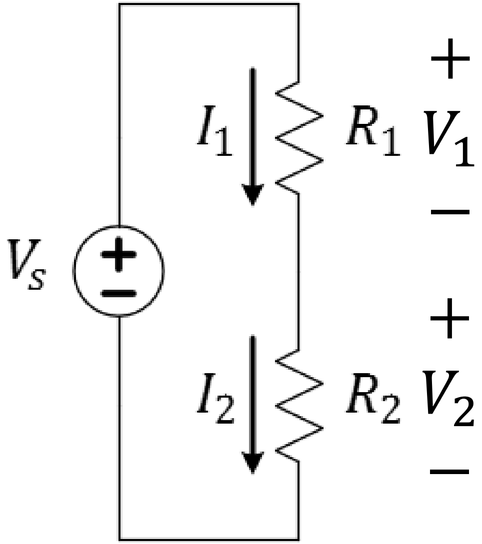
When a voltage divides across resistors in series, more voltage drop appears across the largest resistor.

$$V_k = \frac{R_k}{R_{eq}} \cdot V_T$$



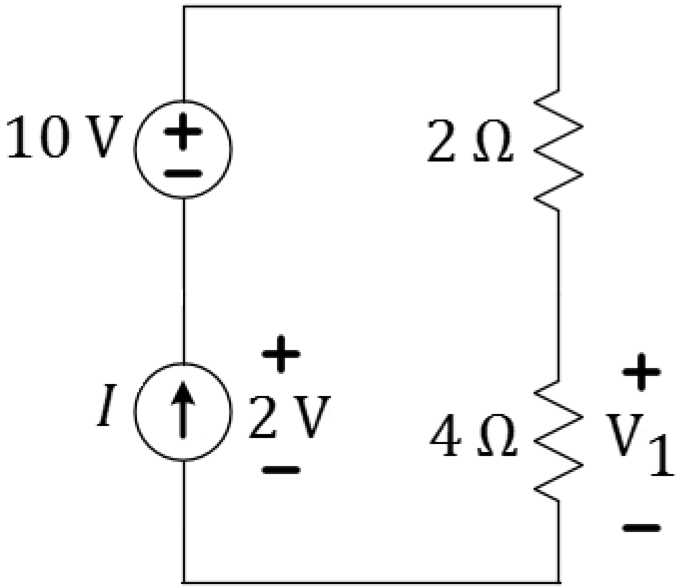


Q: If $R_1 < R_2$, which of the following is true?



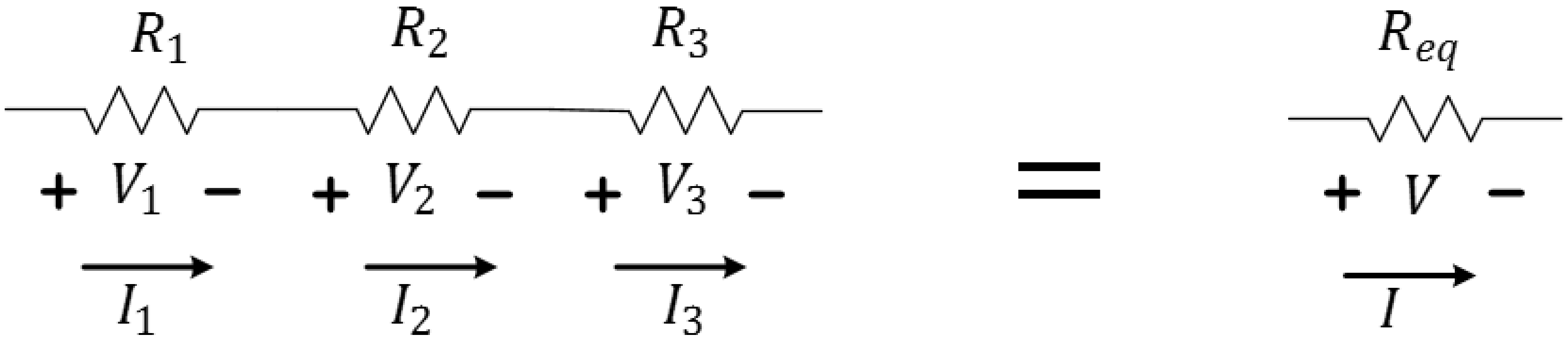
A. $V_1 < V_2$ and $I_1 < I_2$
B. $\boxed{V_1 < V_2 \text{ and } I_1 = I_2}$
C. $V_1 = V_2$ and $I_1 = I_2$
D. $V_1 > V_2$ and $I_1 = I_2$
E. $V_1 > V_2$ and $I_1 > I_2$

Q: Use VDR to find V_1.



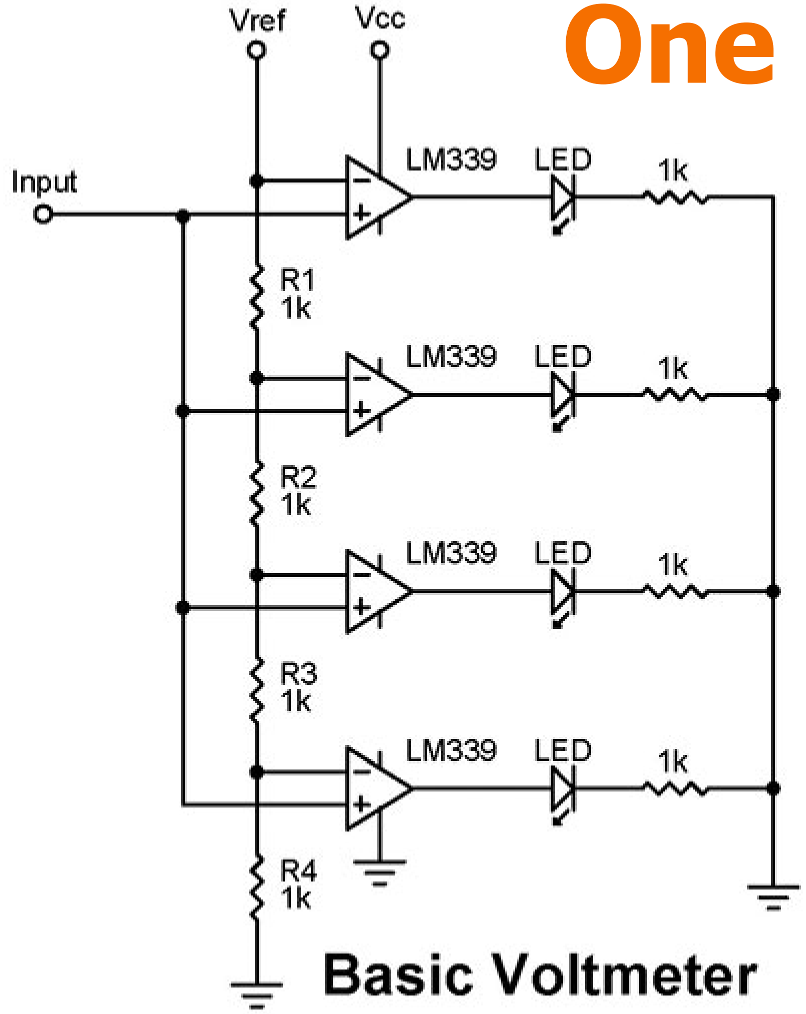
A. $V_1 \leq -6\ V$
B. $-6 < V_1 \leq -2\ V$
C. $-2 < V_1 \leq 2\ V$
D. $2 < V_1 \leq 6\ V$
E. $\boxed{6\ V < V_1}$

VDR Derivation



Since $I = I_k$, $\quad \dfrac{V}{R_{eq}} = \dfrac{V_k}{R_k}$ by Ohm's Law. So, $\quad V_k = \dfrac{R_k}{R_{eq}} \cdot V$

One VDR Application

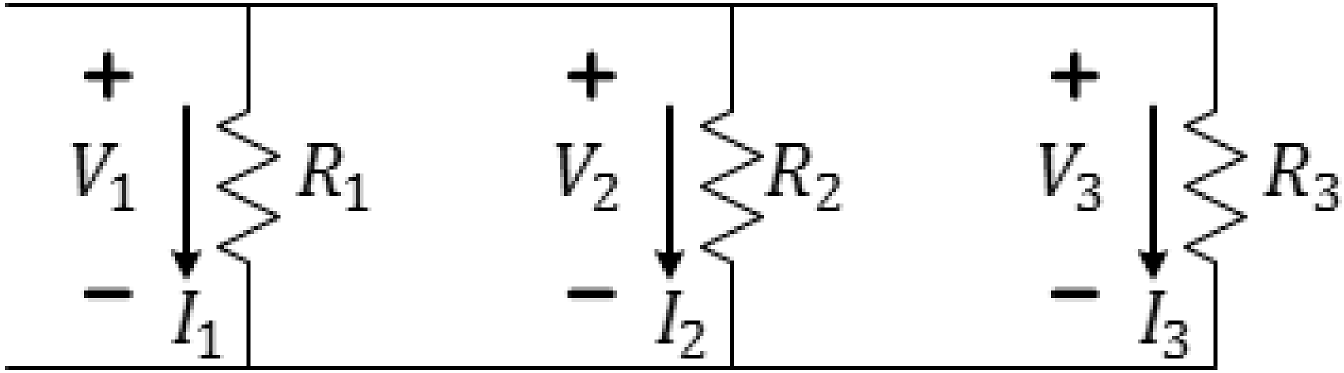


- Compares the input voltage to known voltages.
- Uses “voltage dividers” and “comparators”
- This is stuff we will understand through ECE110!

Image from https://www.nutsvolts.com/questions-and-answers/led-voltmeter

Parallel Connection

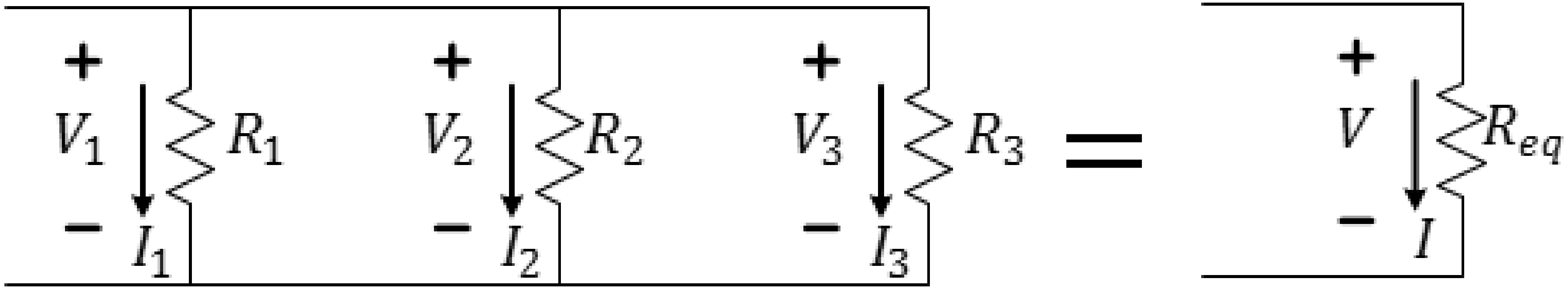
Parallel connections share the same voltage potentials at two end nodes (shared by the elements)



$$V_1 = V_2 = V_3 \text{ because of KVL}$$

Q: Are appliances in your house/apartment connected in A. series or B. $\boxed{\text{in parallel?}}$

Equivalent Resistance of Parallel Resistors



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

If $N = 2$, $$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Q: Which statement is true in general?

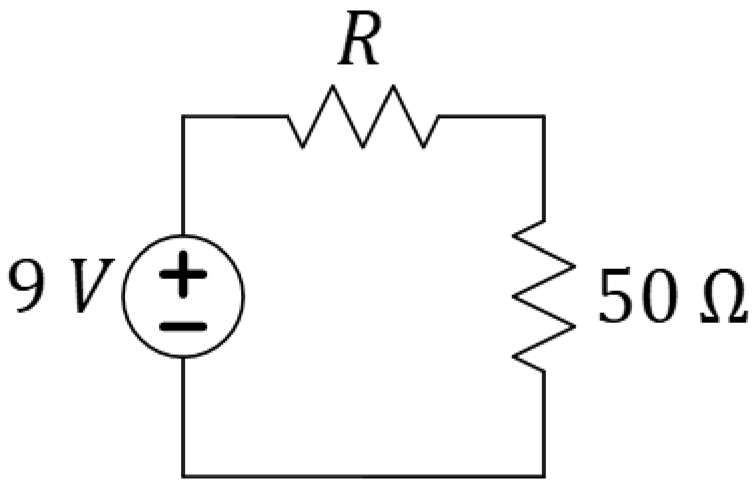
A. $R_{eq} \approx R_1$

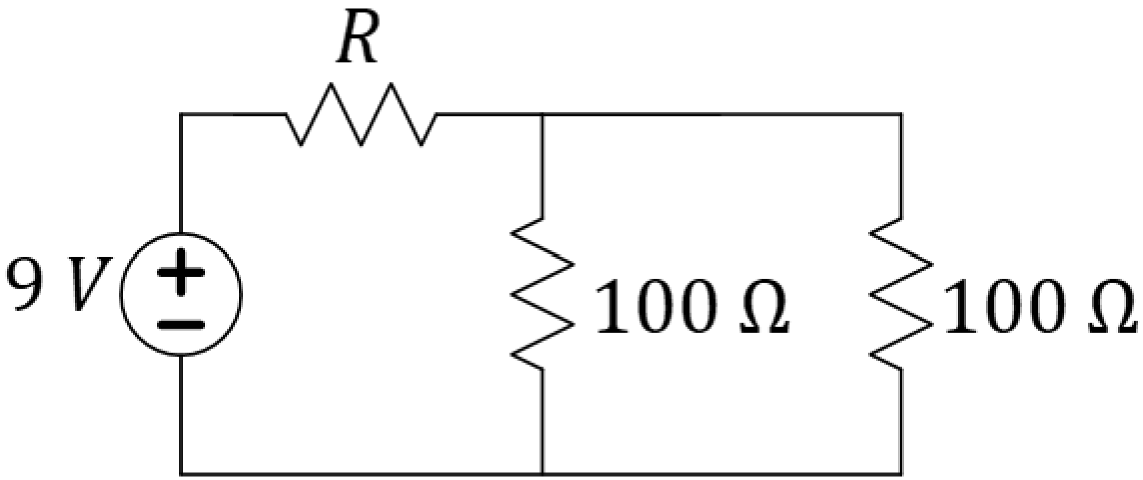
B. $R_{eq} < R_1$

C. $R_{eq} > R_1$

D. None of these is true

Resistors and Power Ratings





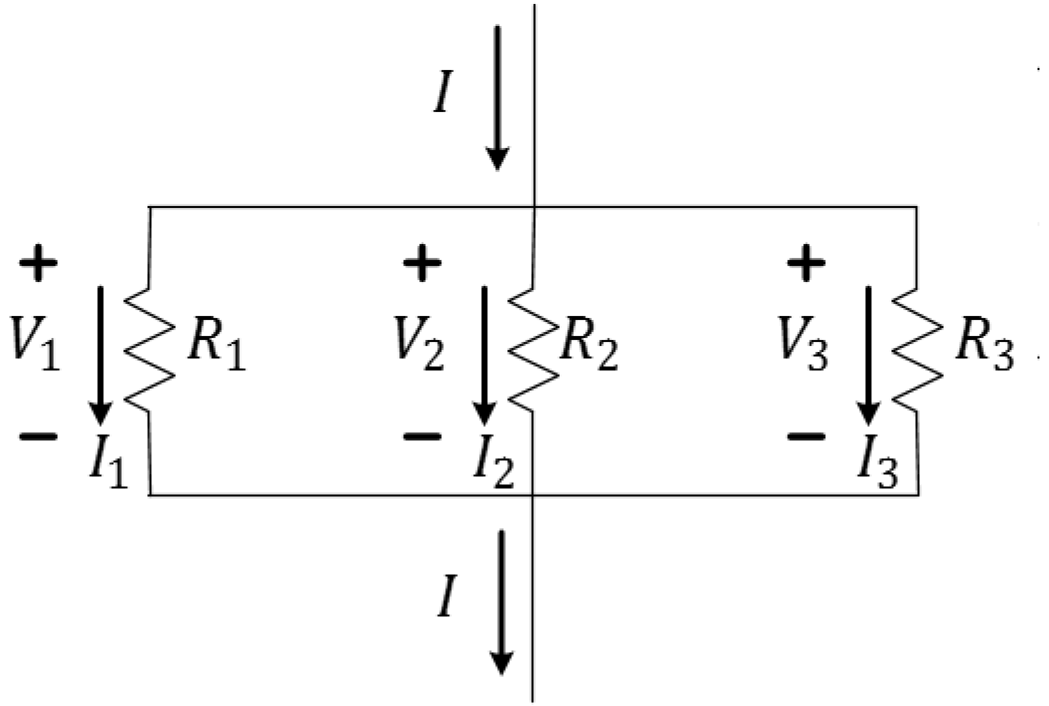
Q: Which statement is true regarding a single 50-Ohm resistor vs two 100-Ohm resistors, each of which is rated ¼ -watts, used as shown above in the same circuit?

A. The 100-Ohm parallel combination has twice the power rating.
B. The 100-Ohm parallel combination has a resistance of 200 Ohms.
C. The 100-Ohm parallel combination has twice the probability of failure.
D. None of these are true.
E. All of these are true.

Current Divider Rule (CDR)

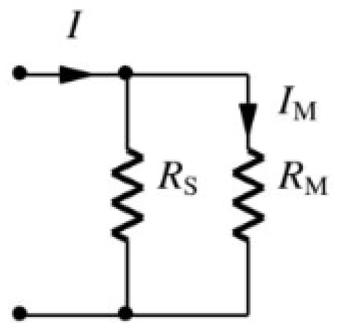
When a current divides into two or more paths, a greater amount of current will go down the path of lower resistance.

$$I_k = \frac{R_{eq}}{R_k} \cdot I$$



One CDR Application

- High-current Ammeter
- Use a high-power shunt resistance R_S to carry most of the current
- Measure the current through R_M (the meter resistor) using a galvanometer.



Q: Which is true in this application?

A. $R_S \ll R_M$

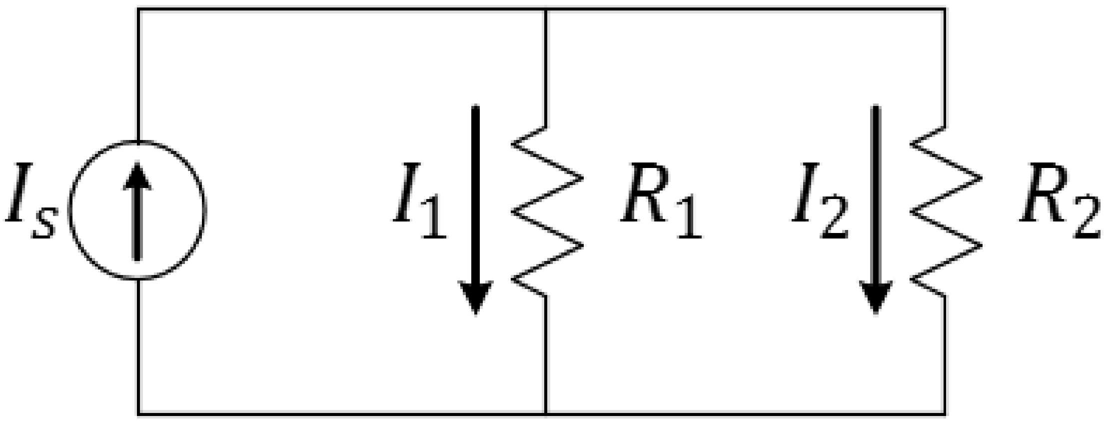
B. $R_S \gg R_M$

C. $R_S \approx R_M$

Q: Give the formula for I (the current we want measured) in terms of I_M (the current we did measure).

$$I = \frac{R_k}{R_{eq}} I_M = \cdots = \frac{R_S + R_M}{R_S} I_M$$

Q: If $R_1 < R_2$, which of the following is true?



A. $I_1 < I_2 < I_s$
B. $I_1 < I_s < I_2$
C. $\boxed{I_2 < I_1 < I_s}$
D. $I_2 < I_s < I_1$
E. $I_s < I_2 < I_1$

Q: In a parallel connection, does a smaller (A.) or larger (B.) resistor absorb more power?

L7 Learning objectives

a. Identify series and parallel connections within a circuit network
b. Find equivalent resistance of circuit networks
c. Compute power ratings of resistor networks
d. Estimate resistance by considering the dominant elements
e. Apply rules for current and voltage division to networks
f. Apply conservation of energy to components within a circuit network