21.7: Combinations of resistors: in series or in parallel

\[ 4\Omega \quad 7\Omega \quad 1\Omega \quad 2\Omega \]
Resistors connected in series

What’s $R_{eq}$ in terms of $R_1$ and $R_2$?

$$\Delta V = IR_{eq}$$
Resistors connected in series

Note: Current is the same in $R_1$ and $R_2$.

$\Delta V_1 = IR_1$

$\Delta V_2 = IR_2$

$\Delta V = \Delta V_1 + \Delta V_2$

$\Delta V = IR_1 + IR_2 = I(R_1 + R_2)$

$\Delta V = IR_{eq}$

$R_{eq} = R_1 + R_2$

For $N$ resistors in series:

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

Note that $R_{eq}$ is larger than any one individual $R$ value.
Resistors connected in series

Find $R_{eq}$:

$R_{eq} = 4\Omega + 7\Omega + 1\Omega + 2\Omega = 14\Omega$
Understanding the Series Law

\[ R = \rho \frac{L}{A} \]

means \( R \) is prop. to \( L \)

Total \( R \) is prop. to \( (L_1 + L_2) \)
Resistors in Parallel
What happens at a junction?

Initial current $I_{\text{tot}}$ splits up:
$I_1$ through $R_1$ and $I_2$ through $R_2$

**Charge is conserved:** $I_{\text{tot}} = I_1 + I_2$

More charge will be able to travel through the path of least resistance

If $R_1 > R_2$, then $I_2 > I_1$
Resistors in Parallel

Note: $\Delta V$ across each resistor is the same

$I = I_1 + I_2 = \Delta V / R_1 + \Delta V / R_2 = \Delta V (1/R_1 + 1/R_2)$

$\Delta V = I / (1/R_1 + 1/R_2)$

$\Delta V = I R_{eq}$

$R_{eq} = 1 / (1/R_1 + 1/R_2)$

$1/R_{eq} = (1/R_1 + 1/R_2)$

For $N$ resistors in parallel:

$1/R_{eq} = 1/R_1 + 1/R_2 + \ldots + 1/R_N$
Understanding the parallel law

\[ R = \rho \frac{L}{A} \]

- R is prop.to 1/A
- \( A_{\text{tot}} = A_1 + A_2 \)
- \( A_{\text{tot}} \) prop.to 1/R_1 + 1/R_2
- \( R_{\text{tot}} \) prop.to 1/A_{\text{tot}}
- 1/R_{\text{tot}} prop.to 1/R_1 + 1/R_2
Example:

Find the current in each resistor.
\[ I_1 = \frac{\Delta V}{R_1} = \frac{18 \text{ V}}{3 \Omega} = 6 \text{ A} \]
\[ I_2 = \frac{\Delta V}{R_2} = \frac{18 \text{ V}}{6 \Omega} = 3 \text{ A} \]
\[ I_3 = \frac{\Delta V}{R_3} = \frac{18 \text{ V}}{9 \Omega} = 2 \text{ A} \]
(Total \( I = 11 \text{ A} \))

Find the power dissipated in each resistor:
\[ P_1 = I_1 \Delta V = 6 \text{ A} \times 18 \text{ V} = 108 \text{ W} \]
\[ P_2 = I_2 \Delta V = 3 \text{ A} \times 18 \text{ V} = 54 \text{ W} \]
\[ P_y = I_3 \Delta V = 2 \text{ A} \times 18 \text{ V} = 36 \text{ W} \]

Total \( P = 198 \text{ W} \)
Example:

Find $R_{eq}$:

\[
\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{(3\,\Omega)} + \frac{1}{(6\,\Omega)} + \frac{1}{(9\,\Omega)} = \frac{11}{(18\,\Omega)}
\]

$R_{eq} = (18/11)\,\Omega = 1.64\,\Omega$

Find the power dissipated in the equivalent resistor:

\[
P = (\Delta V)^2/R_{eq} = (18\,V)^2/1.64\,\Omega = 198\,W
\]

Also, $P = I\Delta V = 11A \times 18V = 198W$
Comparing resistors and capacitors

Resistors in series are like capacitors in parallel. Resistors in parallel are like capacitors in series.

\[ R \propto L \quad \text{and} \quad C \propto \frac{1}{L} \]

\[ R \propto \frac{1}{A} \quad \text{and} \quad C \propto A \]
Find $R_{eq}$ through multiple steps:
1. Connect in series
2. Then connect in parallel
3. Repeat #1-2 as needed

What happens when you have resistors in series AND in parallel?
The next 3 slides cover quick quizzes 21.5-21.7; I did not have time to review them in lecture Tuesday
Quick Quiz 21.5

Use a piece of conducting wire to connect points b & c, bypassing $R_2$.

What happens to the brightness of Bulb 2?
It goes out.

What happens to the brightness of Bulb 1?

$$\Delta V = I_{\text{orig}}(R_1+R_2)$$

$$\Delta V = I_{\text{new}}(R_1)$$

$I_{\text{new}} > I_{\text{orig}}$

Brightness of Bulb 1 increases due to increased power due to increased current.
Quick Quiz 21.6:
Current $I_{\text{orig}}$ is measured in the ammeter with the switch closed. When the switch is opened, what happens to the reading on the ammeter?

Initially, all current flows through switch, bypassing $R_2$. \[ \Delta V = I_{\text{orig}}R_1 \]

When switch is opened, all current is forced through $R_2$; we have a circuit with two resistors in series. \[ \Delta V = I_{\text{new}}(R_1 + R_2) = I_{\text{new}}(R_{eq}) \]

$R_{eq} > R_1$ and $\Delta V$ remains fixed, so $I_{\text{new}} < I_{\text{orig}}$. (current decreases)
Quick Quiz 21.7

Initially: switch closed, no current through R2. Current in R1, measured with ammeter. When the switch is opened, current begins to flow through R2. What happens to the reading on the ammeter?

Initially, \( \Delta V = I_{\text{init}} R_1 \)

Then, \( \Delta V = I_{\text{final}} R_{\text{eq}} \)

For R’s in parallel, \( R_{\text{eq}} \) is < individual R’s.

So \( I_{\text{final}} > I_{\text{init}} \)