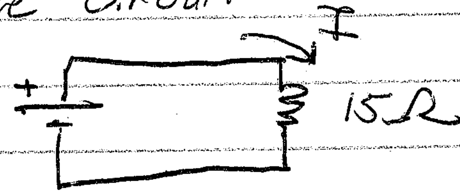
① Phys 1402 2017-09-21 Lec 6

Recall Simple Circuit

$V = IR$

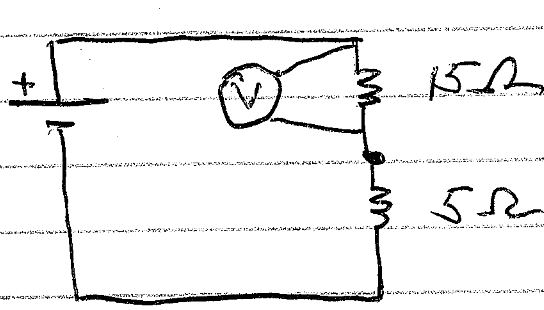
$V = 3.0\ V$



Current: $I = \frac{V}{R} = \frac{3.0\,V}{15\,\Omega} = 0.2\ A$

Power: $P = VI = (3.0\,V)(0.2\,A) = 0.6\ W$

Let's Add a Resistor in Series:



After Solving for I:

$V_{15} = (0.15)(15) = 2.25$

$V_5 = (0.15)(5) = 0.75\ V$

We know $I_{Batt} = I_{15} = I_5$

In Series, Voltage Adds.

$V_{Tot} = V_{15} + V_5$ $\quad V = IR$

$= I(15\,\Omega) + I(5\,\Omega)$

$= I(15\,\Omega + 5\,\Omega)$

$(3.0\,V) = I\,(20\,\Omega)$ ← Looks like Ohm's Law

$0.15\,A = I$

In Series $R_{eq} = R_1 + R_2 + \ldots$

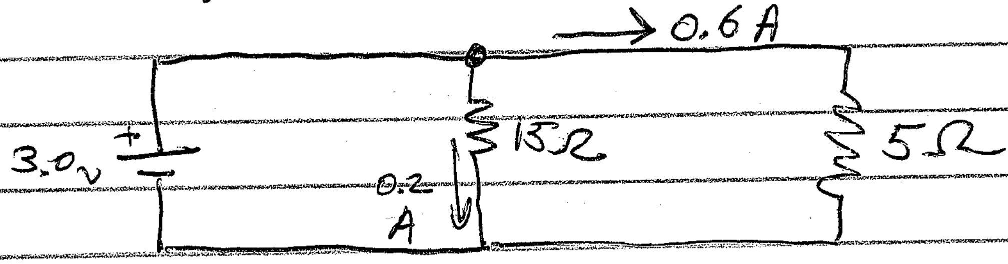
R_{eq} is bigger than any individual R_i

Adding a resistor in series reduces the current.

(Assuming same V_{Batt})

(2)

Instead, Let's Add the 5Ω in parallel.



In parallel, each component has the same voltage.

$$I_{15} = \frac{3.0\,V}{15\,\Omega} = 0.2\,A$$

$$I_5 = \frac{3.0\,V}{5\,\Omega} = 0.6\,A$$

$$I_{Batt} = 0.2A + 0.6A = 0.8\,A$$

Equivalent Resistance for parallel

$$I_{Tot} = \frac{V}{R_1} + \frac{V}{R_2} + \dots$$

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2} + \dots\right)$$

$$I_{Tot}\left(\frac{1}{R_1} + \frac{1}{R_2} + \dots\right)^{-1} = V = I_{Tot} R_{eq}$$

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \dots\right)^{-1}$$

Note: $\left(\frac{1}{2} + \frac{1}{4}\right)^{-1} = \left(\frac{3}{4}\right)^{-1} = \frac{4}{3}$

This is not $2+4=6$.

Power for parallel Circuit $P = VI$

$P_{15} = (3.0\,V)(0.2\,A) = 0.6\,W$ used

$P_{5} = (3.0\,V)(0.6\,A) = 1.8\,W$ used

$P_{batt} = (3.0\,V)(0.8\,A) = 2.4\,W$ supplied

In parallel, R_{eq} is Less than any R_i.
Individual Currents can be found separately.
(15 Ω unaffected by parallel resistor)
The Battery has to supply more current.

- If there is internal resistance, the "Lost voltage" will be more.

$$\mathcal{E} = V_{Term} + I R_{int}$$

$\mathcal{E}$ ← Generated

V_{Term} ← Usable

$I R_{int}$ ← Lost or Wasted

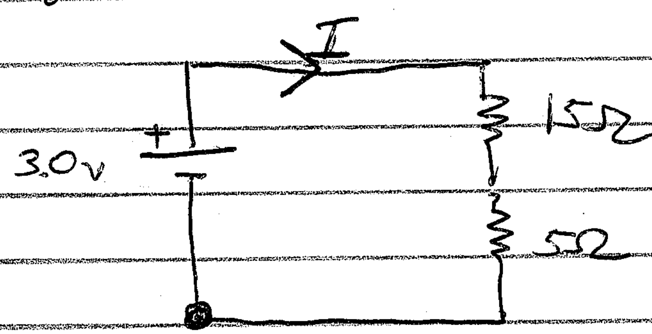
- This is why the headlights dim when you crank the starter.

Kirchoff's Laws summarize the series & parallel rules in two compact equations.

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

"What goes in must come out."

Voltage: $\sum \Delta V = 0$ along a loop



For a CW Loop: $\Delta V_{Batt} + \Delta V_{15} + \Delta V_{5} = 0$

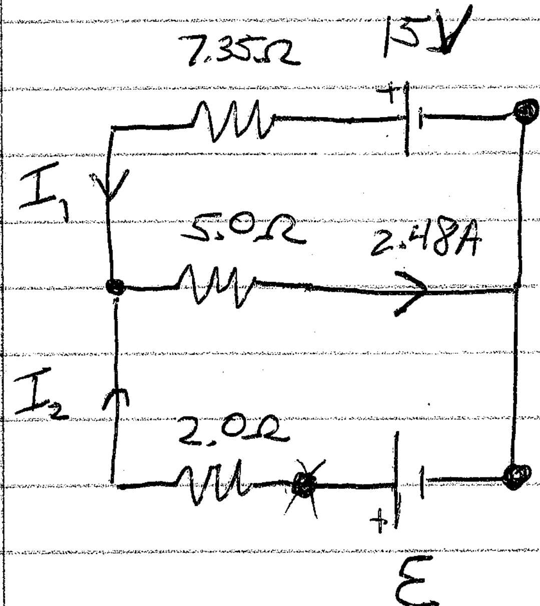
$$(3.0\,V) - I(15\,\Omega) - I(5\,\Omega) = 0$$

Travel across battery, ⊖ to ⊕: $\Delta V = +3\,V$

Travel across 15Ω, with I, there is a voltage drop: $\Delta V = -I(15\,\Omega)$

$\Delta V = -I(5\,\Omega)$

(3)



Label every current.

KCL:

$$I_1 + I_2 = 2.48 A$$ (*)

With known I_1:

$$0.354 + I_2 = 2.48$$
$$I_2 = 2.13 A$$

KVL, Top Loop, CCW:

$$+(15 V) - 7.35 I_1 - (5)(2.48) = 0$$ (*)

Can solve:

$$15 - 7.35 I_1 - 12.4 = 0$$
$$15 = 12.4 + 7.35 I_1$$

Voltage of 7.35Ω Resistor $\rightarrow$ $2.6 = 7.35 I_1$

$$I_1 = 2.6/7.35 = 0.354 A$$

KVL, Bottom Loop,

$$\mathcal{E} - (2.0\Omega) I_2 - (5.0\Omega)(2.48A) = 0$$ (*)
$$\mathcal{E} - (4.26 V) - 12.4 V = 0$$
$$\mathcal{E} = 16.7 V$$