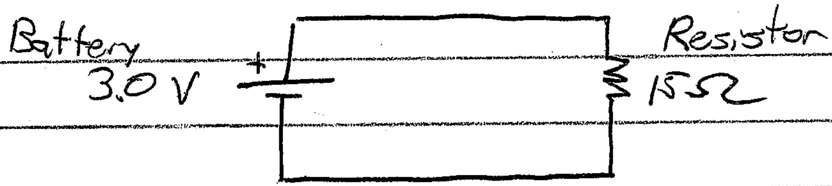
① Phys 2426 2017-09-21 Lec 6

Basic DC Circuit



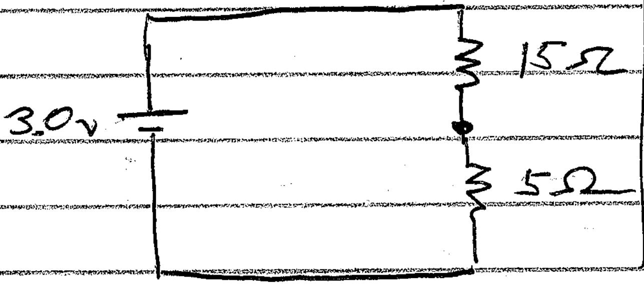
$V = IR$

$P = VI$

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

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

Let's add a 5Ω resistor in series



After knowing I:

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

$= 2.25\,V$

$V_5 = (0.15)(5)$

$= 0.75\,V$

Conservation of Charge: Same I everywhere

Cons. of Energy: $P_{batt} + P_{15} + P_5 = 0$

(All $\oplus$ = generated)

generated $\Rightarrow P_{Batt} = P_{15} + P_5 \leftarrow$ used

$I\mathcal{E} = IV_{15} + IV_{5}$

$\mathcal{E} = V_{15} + V_5$ Voltage Adds in Series

For each resistor, $V = IR$

$$(3.0V) = V_{Batt} = I(15\Omega) + I(5\Omega)$$
$$= I(15\Omega + 5\Omega)$$
$$3.0V = I\ 20\Omega$$
$$\frac{3.0V}{20\Omega} = I = 0.15A$$

Looks like $V = IR$

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

Equivalent Circuit : 3.0V Batt
20 Ω Res.

For the battery, this is identical.

Compare to original basic (15Ω) circuit.
- R_{eq} is larger.
- Current is smaller (for same $\mathcal{E}$)

Power Balance:

Generated: $P = IV = (3.0V)(0.15A) = 0.45$

Used : $P_{15} = (2.25V)(0.15A) = 0.3375$

$P_{5} = (0.75V)(0.15A) = 0.1125$

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Power Generated: $P = \mathcal{E} I_{Batt}$
$= (3.0v)(0.8A) = 2.4W$

Used: $P_{15} = (3.0v)(0.2A) = 0.6W$
$P_{5} = (3.0v)(0.6A) = 1.8W$

In parallel, R_{eq} is smaller than any R_i.
Total Current is more (w/ ideal $\mathcal{E}$)
The current I_{15} is the same as by itself.
(Because V_{15} didn't change.)

Practical Battery:

$$\underset{\text{Generated}}{\mathcal{E}} = \underset{\text{Usable}}{V_{Term}} + \underbrace{IR_{int}}_{\text{Wasted}}$$

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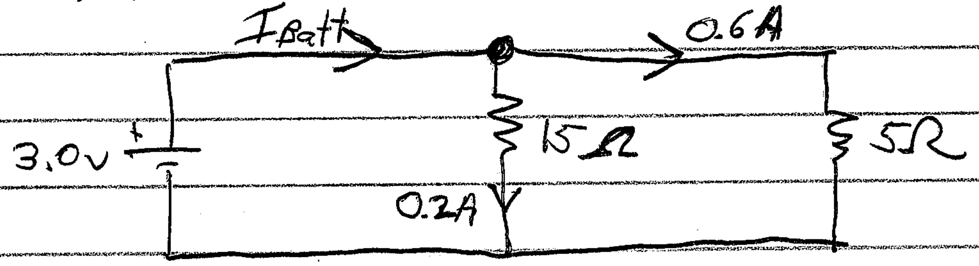
Instead, place the 5Ω in parallel.



In parallel, each component has the same voltage.

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

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

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

Equivalent resistance for parallel

$$I_{tot} = \frac{V}{R_1} + \frac{V}{R_2} + \cdots$$

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

$$I_{tot} = \frac{V}{R_{eq}}$$

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

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

$$R_{eq} = \left(\frac{1}{15} + \frac{1}{5}\right)^{-1} = \left(\frac{4}{15}\right)^{-1} = \frac{15}{4} = 3.75\,\Omega$$

Kirchoff's Laws - summarize the series & parallel voltage & current rules.

Kirchoff's Current Law (KCL)

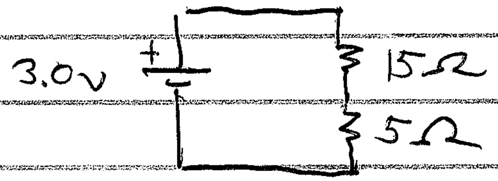
What goes in must come out.

For a junction: $\sum I_{in} = \sum I_{out}$

Kirchoff's Voltage Law (KVL)

What goes up must come down.

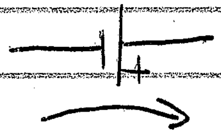
For any loop: $\sum \Delta V = 0$

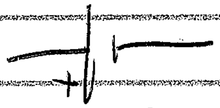


Batt, 15Ω, 5Ω

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

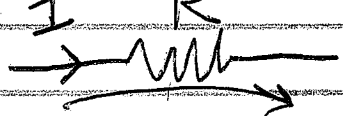
Battery:

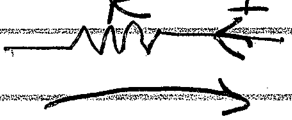




$\Delta V = \mathcal{E}$ $\Delta V = -\mathcal{E}$

Resistor:





$\Delta V = -IR$ $\Delta V = IR$

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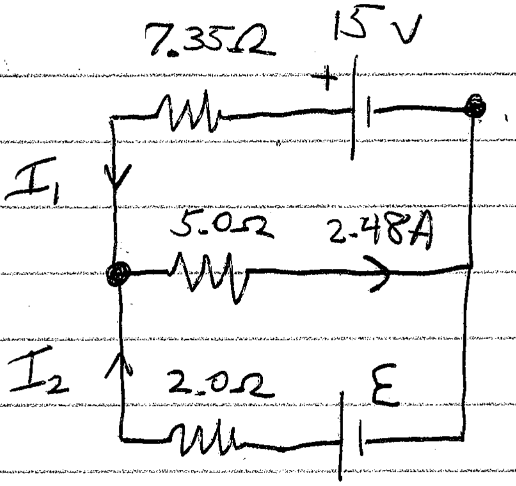


Label Unknown Currents

KCL:

$$I_1 + I_2 = 2.48\ A$$ ⊛

Choose a Loop for KVL:

- Strategy: Follow the currents. ⊛

Top Loop, CCW: $0 = +(15\,V) - I_1(7.35\,\Omega) - (2.48A)(5.0\Omega)$

Bottom Loop, CW: $\mathcal{E} - I_2(2.0\Omega) - (2.48A)(5.0\Omega) = 0$ ⊛

Wolfram Alpha: $x + y = 2.48$

$15 - x * 7.35 - 2.48 * 5 = 0$

$z - y * 2 - 2.48 * 5 = 0$

By hand: $15 - 7.35 I_1 - 12.4 = 0$

Voltage of the 7.35 resistor $\rightarrow$ $2.6 = 7.35 I_1$

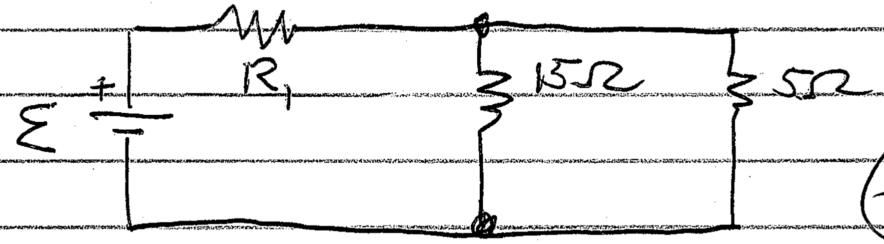
$I_1 = (0.354\ A)$

$I_2 = 2.48 - I_1 = (2.13\ A)$

$\mathcal{E} - 2I_2 - 12.4 = 0$

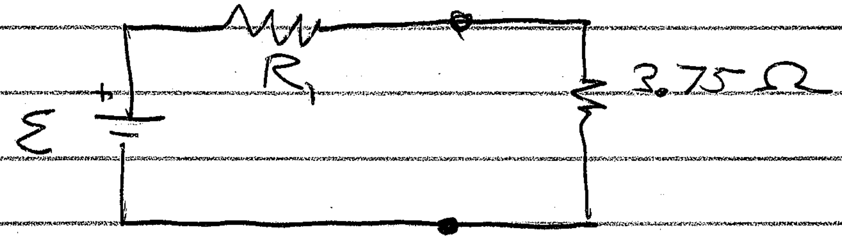
$\mathcal{E} = (16.7\ V)$

Using Equivalent Resistances



$$\left(\frac{1}{15}+\frac{1}{5}\right)^{-1}$$

$$R_{eq} = 3.75\,\Omega$$



Unchanged parts: Same V's and I's

Parallel Equiv: $V_{eq} = V_2 = V_3$

Series Equiv: $I_{eq} = I_1 = I_2$

Measuring Voltage:

- Voltmeter is in parallel
- Voltmeter has high resistance = no current.

Measuring Current:

- Ammeter is in series = break to include
- Ammeter has low resistance = no voltage drop.