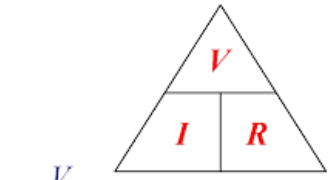
AP Phys 2 Unit 3.C.3 Notes - Ohm's Law

3.C.3 Ohm's Law

$$V = I\,R$$



$$I = \frac{V}{R} \qquad R = \frac{V}{I}$$

Ohm's Law Review

Voltage, current, and resistance are unified through Ohm's Law, named after Georg Simon Ohm, a German physicist and mathematician, who discovered this relation in the early 1800's.

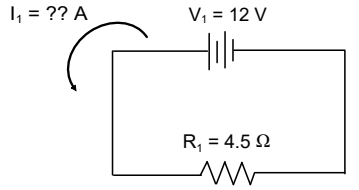
$I = \frac{\Delta V}{R}$ AP Equation	I = Current (A) V = Volts (V) R = Ohms (Ω)

See circle Resource P. 6.

Often, it's written V = IR.

1. Current Example

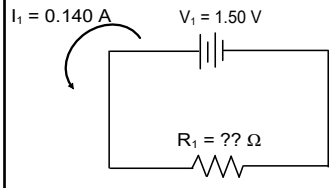
Calculate the current in the following circuit:



$$I = \frac{\Delta V}{R} = \frac{12V}{4.5\Omega} = 2.7\,A$$

2. Resistance Example

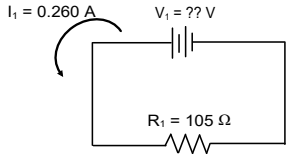
Calculate the resistance in the following circuit:



$$R = \frac{V}{I} = \frac{1.50V}{0.140\,A} = 10.7\,\Omega$$

3. Voltage Example

Calculate the voltage in the following circuit:

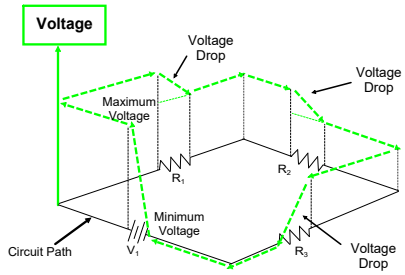


$$V = IR$$
$$= 0.260\,A \bullet 105\,\Omega$$
$$= 27.3\,V$$

Voltage Drops

Voltage can be thought of as "electrical pressure:" highest at the positive end of a battery, and zero at the negative end.

Voltage drops over each component, until it is zero.



AP Phys 2 Unit 3.C.3 Notes - Ohm's Law

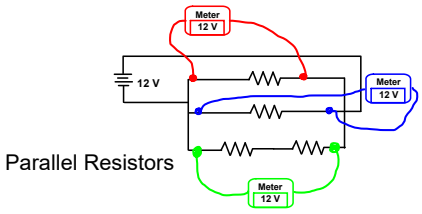
Determining Voltage Drops

Three ways:
1. Direct measurement with meter. (Demo - You Do!)
2. Ohm's Law Method.
3. Ratio Method.

Regardless of method, voltage drops are proportional to resistance.

Ohm's Law Method

Fundamentals:
1. Voltage drops across parallel resistors are the same (but current through each can vary).
2. Current through resistors in series is the same (but voltage drops over each can vary).



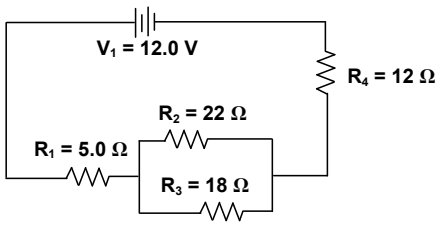
Parallel Resistors

Ohm's Law Method

Simple process (can be tedious):
1. Determine resistance over parallel sections.
2. Find total resistance, then calculate current through circuit.
3. Use Ohm's Law (V = IR) to calculate voltage over resistors in series (or reduced parallel sections).
4. Check: sum of voltage drops should equal battery voltage.

4. Ohm's Law Method Example

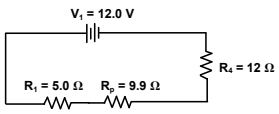
Find the voltage drop over each resistor.



Ohm's Law Method Answer 1

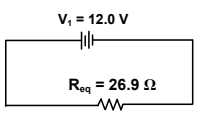
Find parallel resistance:

$$R_p = \left(22\Omega^{-1} + 18\Omega^{-1}\right)^{-1}$$
$$= 9.9\Omega$$



then total resistance:

$$R_{eq} = 5.0\Omega + 9.9\Omega + 12\Omega$$
$$= 26.9\Omega$$



finally, current: $I = \frac{V}{R} = \frac{12.0V}{26.9\Omega} = 0.45A$

Ohm's Law Method Answer 2

Using Ohm's Law, find voltage drops over sections:

R_1: $V_1 = IR = 0.45A \cdot 5.0\Omega = 2.25V$

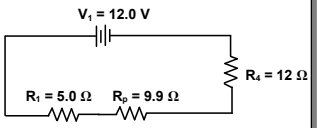
R_p: (same for both resistors) $V_{2\,and\,3} = IR = 0.45A \bullet 9.9\Omega = 4.46V$

R_4: $V_4 = IR = 0.45A \bullet 12\Omega = 5.4V$

Check: Do individual voltages add up to 12.0 V?

$2.25V + 4.46V + 5.4V = 12.1V$

Close Enough!



Ratio Method

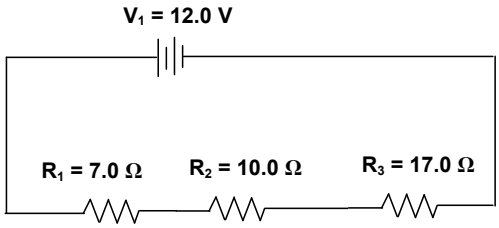
1. Find total resistance of circuit.
2. Multiply battery voltage by fraction of each serial (or reduced parallel) resistor.

$V_n = V_T \frac{R_n}{R_T}$	n = resistor of interest T = Total

3. Check that voltage drop sum equals total voltage.

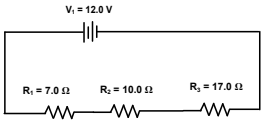
5. Ratio Method Example

What's the voltage drop over each resistor?

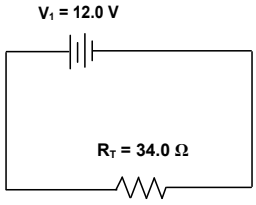


Ratio Method Answer

1. Find the total resistance first:



$$R_T = 7.0\Omega + 10.0\Omega + 17.0\Omega = 34.0\Omega$$



Ratio Method Answer

2. Using ratios, find voltage drop across each resistor:

R1: $V_1 = V_T \frac{R_1}{R_T} = 12.0V \bullet \frac{7\Omega}{34\Omega} = 2.47V$

R2: $V_2 = V_T \frac{R_2}{R_T} = 12.0V \bullet \frac{10\Omega}{34\Omega} = 3.53V$

R3: $V_2 = V_T \frac{R_2}{R_T} = 12.0V \bullet \frac{17\Omega}{34\Omega} = 6.00V$

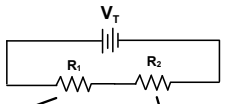
3. Check: Do added individual voltages equal total?

$$V_T = 2.47V + 3.53V + 6.00V = 12.0V$$

Yes.

Ratio Method Shortcut (Lab Prelude)

A faster comparison exists, especially if one resistor is unknown (two resistor example):



$$V_1 = V_T \frac{R_1}{R_T} \qquad V_2 = V_T \frac{R_2}{R_T}$$

$$1 = \frac{V_T \frac{R_1}{R_T}}{V_1} \longrightarrow \frac{V_T \frac{R_1}{R_T}}{V_1} = \frac{V_T \frac{R_2}{R_T}}{V_2} \longleftarrow 1 = \frac{V_T \frac{R_2}{R_T}}{V_2}$$

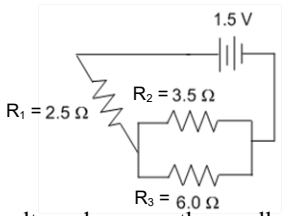
$$\boxed{\frac{R_1}{V_1} = \frac{R_2}{V_2}}$$

6. Last Example (Use Ohm's Law)

Three resistors are connected across a 1.5 V battery.

A. What is the voltage drop across each resistor?

B. What is the current through each resistor?

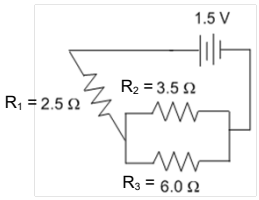


Note: the voltage drop over the parallel resistors is the same.

Last Example Answer

1. Resistance, parallel first:

$$R_p = (3.5\Omega^{-1} + 6.0\Omega^{-1})^{-1} = 2.2\Omega$$



Total resistance:

$$R_T = R_1 + R_P$$
$$= 2.5\Omega + 2.2\Omega = 4.7\Omega$$

Last Example Answer

2. Total current:

$$I = \frac{V}{R_T} = \frac{1.5\,V}{4.7\,\Omega} = 0.32\,A$$

3. Use Ohm's Law:

V_1: $V_1 = I \bullet R_1 = 0.32\,A \bullet 2.5\Omega = 0.8V$

Over parallel section:

$$V_p = I \bullet R_p = 0.32\,A \bullet 2.2\Omega = 0.7V$$

Does the sum of individual voltages equal the total?

$$0.7V + 0.8V = 1.5V$$

Last Example Answer

B. Use Ohm's Law to find the current:

R_1: already done: 0.32 A

R_2: $I_2 = \frac{V_P}{R_2} = \frac{0.7\,V}{3.5\,\Omega} = 0.20\,A$

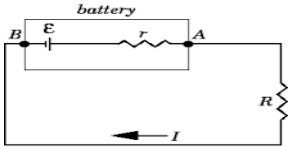
R_3: $I_3 = \frac{V_P}{R_3} = \frac{0.7\,V}{6.0\,\Omega} = 0.12\,A$

Does the current through the parallel section equal the current through the serial resistor?

Terminal Voltage & Internal Resistance

Batteries aren't perfect conductors: some power is lost within the battery due to internal resistance (ever felt a hot battery?)

This gives rise to terminal voltage: the voltage measured at the terminals of a battery (duh);
BUT, when internal resistance is accounted for, maximum optimal voltage is larger (but not usable).



Homework

3.C.3 Problems
Due: Next Class