PHY 114 A General Physics II
11 AM-12:15 PM TR Olin 101

Plan for Lecture 8 (Chapter 28):

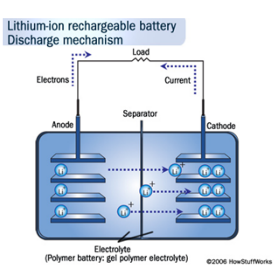
1. **Direct-current circuits**
2. **Voltage and resistor circuits**
3. **Kirchhoff's rules**

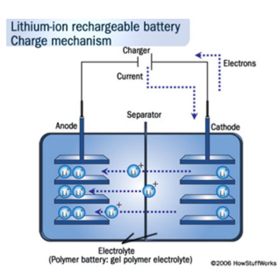
2	01/24/2012	Electric field	23.4-23.7	23.22,23.20,23.61a	01/26/2012
3	01/26/2012	Gauss's Law	24.1-24.3	24.22a,24.23,24.40	01/31/2012
4	01/31/2012	Electric potential	25.1-25.4	25.12,25.23,25.34,25.01	02/02/2012
5	02/02/2012	Electric potential	25.5-25.8	(Review for exam)	
	02/07/2012	Exam			
6	02/09/2012	Capacitance and dielectrics	26.1-26.7	26.4,26.13,26.30	02/14/2012
7	02/14/2012	Current and resistance	27.1-27.6	27.3,27.12,27.29	02/16/2012
8	02/16/2012	Direct current circuits	28.1-28.2	28.3,28.7,28.19	02/21/2012
9	02/21/2012	Direct current circuits	28.3-28.5	28.23,28.25,28.34	02/23/2012
10	02/23/2012	Review	26.1-28.5	(Review for exam)	
	02/28/2012	Exam			
11	03/01/2012	Magnetic fields	29.1-29.6	29.5,29.12,29.47	03/06/2012
12	03/06/2012	Magnetic field sources	30.1-30.6		
13	03/08/2012	Faraday's law	31.1-31.5		
	03/13/2012	*No class (Spring Break)*			

Remember to send in your chapter reading questions…

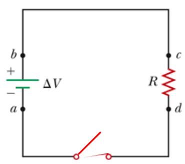
Comment on Direct current versus Alternating current
http://www.pbs.org/wgbh/amex/edison/sfeature/acdc.html

Example – Li ion rechargeable battery
http://electronics.howstuffworks.com/everyday-tech/lithium-ion-battery1.htm

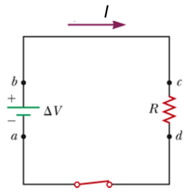




Switch open, no current flowing, battery storing energy



Switch closed, current flowing, battery discharging



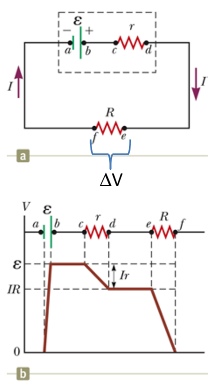
Equivalent circuit for $\mathcal{E}$

$$\mathcal{E} - Ir - IR = 0$$

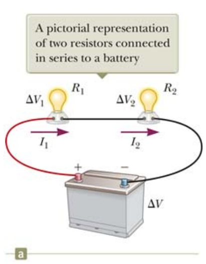
$$I = \frac{\mathcal{E}}{r + R}$$

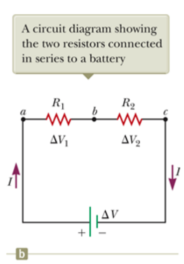
$\mathcal{E}$=12V, r=0.1Ω, R=9.9Ω;
what is ΔV?

A. $\Delta V = \mathcal{E}$
B. $\Delta V < \mathcal{E}$
C. $\Delta V > \mathcal{E}$



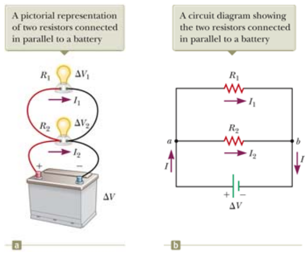
Resistors in series:





$$\Delta V - IR_1 - IR_2 = 0 \qquad I = \frac{\Delta V}{R_1 + R_2} \qquad R_{series} = R_1 + R_2$$

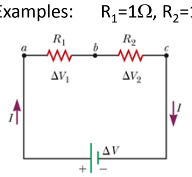
Resistors in parallel

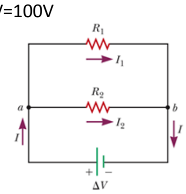


$$\Delta V - I_1 R_1 = 0$$
$$\Delta V - I_2 R_2 = 0$$
$$I = I_1 + I_2 = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2}$$
$$\Delta V = I \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \equiv IR_{Parallel}$$

$$R_{Parallel} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Examples: R_1=1Ω, R_2=100Ω, ΔV=100V



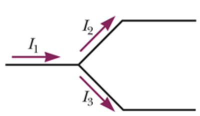


$$\Delta V - IR_1 - IR_2 = 0$$
$$I = \frac{\Delta V}{R_1 + R_2} = \frac{100}{101} = 0.99A$$
$$\Delta V_1 = IR_1 = 0.99V$$
$$\Delta V_2 = IR_2 = 99.01V$$

$$\Delta V - I_1 R_1 = 0$$
$$\Delta V - I_2 R_2 = 0$$
$$I_1 = \frac{\Delta V}{R_1} = \frac{100}{1} = 100A$$
$$I_2 = \frac{\Delta V}{R_2} = \frac{100}{100} = 1A$$
$$I = I_1 + I_2 = 101A$$

Circuit analysis – Kirchhoff's rules

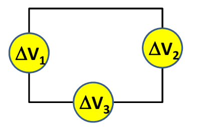
Conservation of charge (current) at a junction:



$$\sum_{junction} I = 0$$
$$I_1 - I_2 - I_3 = 0$$

Circuit analysis – Kirchhoff's rules

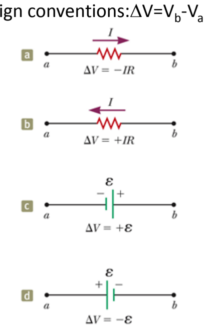
Conservation of potential around a closed circuit:



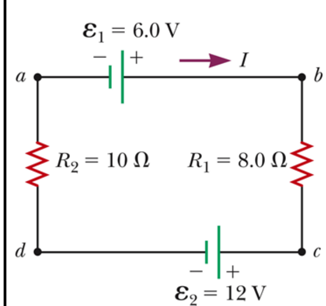
$$\sum_{closed\ loop} \Delta V = 0$$

$$\Delta V_1 + \Delta V_2 + \Delta V_3 = 0$$

Sign conventions: $\Delta V = V_b - V_a$



Example:



$$\mathcal{E}_1 - IR_1 - \mathcal{E}_2 - IR_2 = 0$$

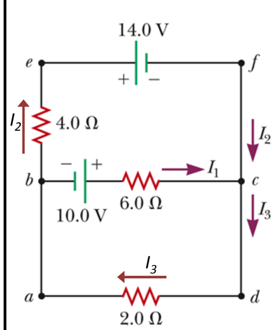
Solve for I:

$$I = \frac{\mathcal{E}_1 - \mathcal{E}_2}{R_1 + R_2} = \frac{6-12}{8+10} = -0.33A$$

$I<0$ means:

A. The circuit is wrong (cannot exist or will blow up).
B. The current flows opposite the arrow.

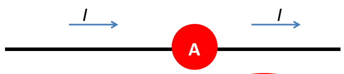
Example:



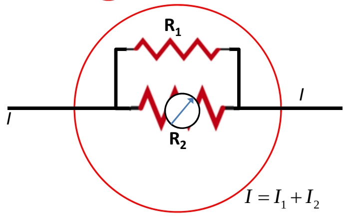
$$-14 - 2I_3 - 4I_2 = 0$$
$$10 - 6I_1 - 2I_3 = 0$$
$$I_1 + I_2 = I_3$$

$$I_1 = 2A$$
$$I_2 = -3A$$
$$I_3 = -1A$$

How to measure current



Inside ammeter:

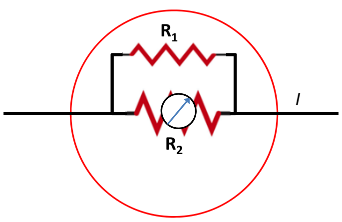


$I = I_1 + I_2$

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

$I_1 \equiv$ "shunt" current; $R_1 << R_2$

$I_2 \equiv$ device current; $I_2 << I_1$



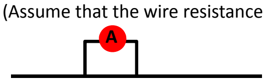
Suppose that :

$I = 10\,A,\ R_1 = 0.01\Omega,\ R_2 = 100\,\Omega$

$$I_2 = \frac{I}{1 + \frac{R_2}{R_1}} = \frac{10}{10001}\,A = 0.001\,A$$

➔Current that drives measurement device.

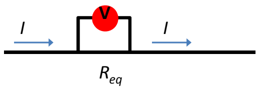
What if the ammeter were connected in parallel to the wire? (Assume that the wire resistance is R_w=0.001Ω.)



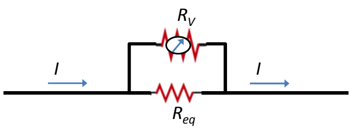
A. The measurement would be identical to series result.
B. The measurement would be less than the series result.
C. The measurement would be greater than the series result.

$$I_2 = \frac{I}{1 + \frac{R_2}{R_1} + \frac{R_2}{R_w}} = \frac{10}{110001}\,A = 0.0001\,A$$

How to measure voltage



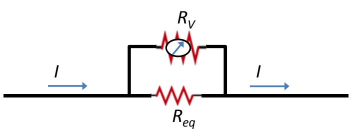
Total equivalent circuit:



$$I_V R_V = \frac{IR_{eq}}{1+\frac{R_{eq}}{R_V}}$$

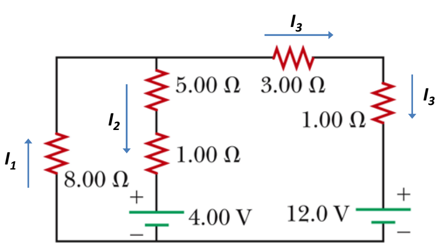
$\Rightarrow$ Works well if $R_V >> R_{eq}$

Total equivalent circuit: Suppose I=10A, R_{eq}=10Ω, R_V=100Ω



$$I_V R_V = \frac{10\times 100}{1+\frac{10}{100}} = 909.1$$

$$\frac{IR_{eq} - I_V R_V}{IR_{eq}} = 9\%$$



3 unknowns ➔ need 3 equations

$I_1 = I_2 + I_3$

$-8I_1 - 6I_2 - 4 = 0$

$-4I_3 - 12 - 8I_1 = 0$

$-4I_3 - 12 + 4 + 6I_2 = 0$