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

Plan for Lecture 10 (Review Chapters 26-28):

1. Capacitance
2. Resistance
3. Voltage

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)*			
	03/15/2012	*No class (Spring Break)*			
14	03/20/2012	Induction and AC circuits	32.1-32.6		

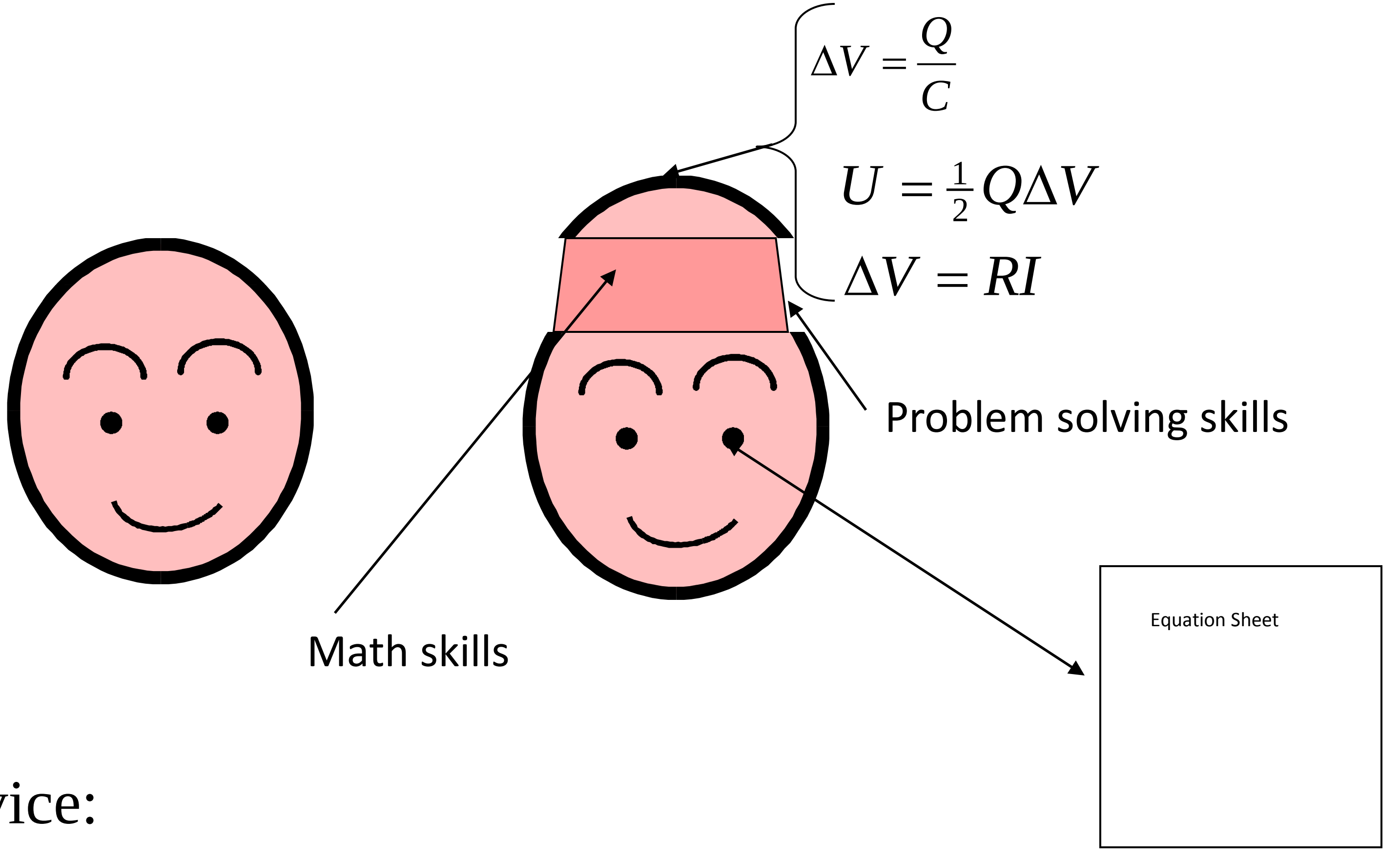
Remember to send in your chapter reading questions…

Professor George Holzwarth (gholz@wfu.edu)
will administer the exam on 2/28/2012
and will lecture on magnetic fields, electric motors, etc. on 3/1/2012.

Reminder:

Second exam – Tuesday, February 28, 2012 – covering Chapters 26-28.

- ~5 problems – show your work and reasoning for possible partial credit.
- Should bring 1 8½” x 11” sheet of paper to the exam (to be turned in with your exam papers).
- Should bring calculator for numerical work. Must not use cell phones or computers during the exam.
- There will be assigned seating in Olin 101 for the exam.



Advice:

1. Keep basic concepts and equations at the top of your head.
2. Practice problem solving and math skills
3. Develop an equation sheet that you can consult.

Problem solving steps

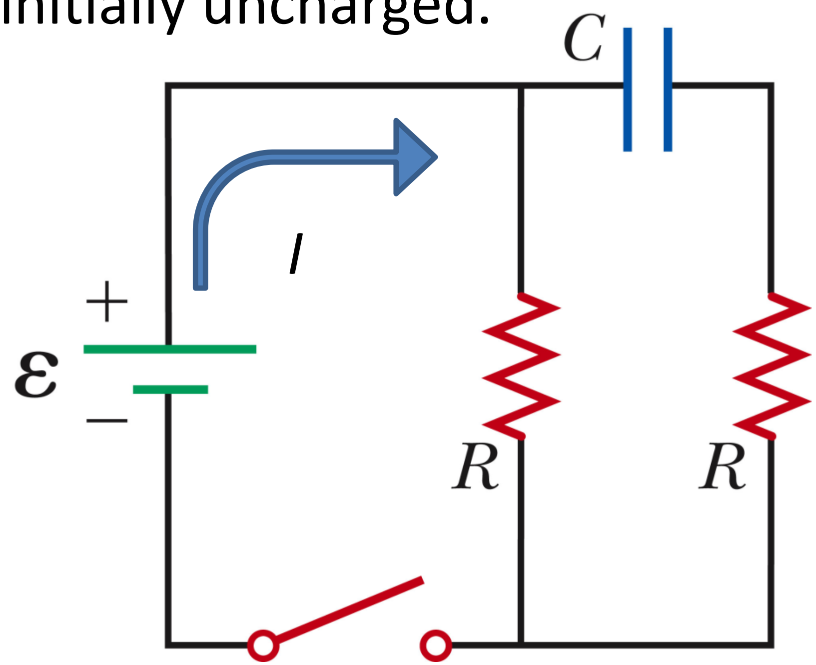
1. Visualize problem – labeling variables
2. Determine which basic physical principle(s) apply
3. Write down the appropriate equations using the variables defined in step 1.
4. Check whether you have the correct amount of information to solve the problem (same number of knowns and unknowns).
5. Solve the equations.
6. Check whether your answer makes sense (units, order of magnitude, etc.).

How many times did you use your equation sheet during the last exam?

A. 0
B. 1
C. 2
D. >2

Example 28.5 :

Assume the capacitor is initially uncharged.



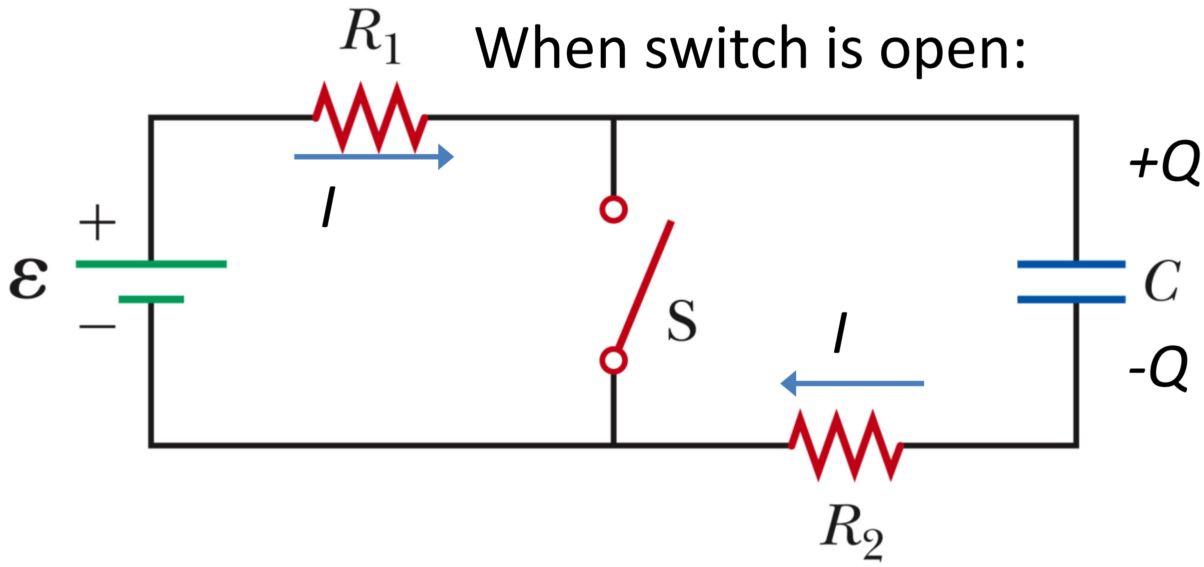
What is the current *I* flowing through the battery just when the switch is closed?

A. 0
B. $\mathcal{E}$/2R
C. $\mathcal{E}$/R
D. 2$\mathcal{E}$/R

What is the current *I* flowing through the battery after the switch has been closed for a long time?

A. 0
B. $\mathcal{E}$/2R
C. $\mathcal{E}$/R
D. 2$\mathcal{E}$/R

When switch is open:



$$\mathcal{E} - IR_1 - \frac{Q}{C} - IR_2 = 0$$

$$I\left(R_1 + R_2\right) = \mathcal{E} - \frac{Q}{C}$$

$$\frac{dQ}{dt}\left(R_1 + R_2\right) = \mathcal{E} - \frac{Q}{C}$$

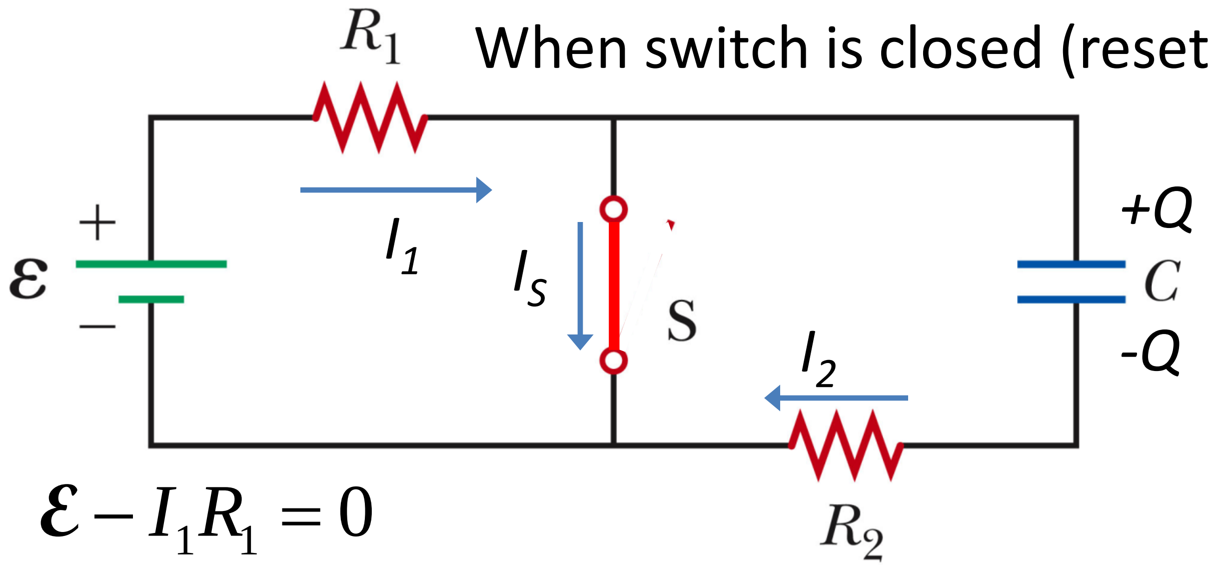
$$\frac{dQ}{dt} = -\frac{1}{\left(R_1 + R_2\right)C}\left(Q - C\mathcal{E}\right)$$

$$Q(t) = C\mathcal{E}\left(1 - e^{-t/\tau}\right) \quad \text{where } \tau \equiv \left(R_1 + R_2\right)C$$

$$\text{For } t >> \tau: \quad Q(t \to \infty) = C\mathcal{E}$$

$$I(t \to \infty) = \frac{C\mathcal{E}}{\tau} e^{-t/\tau}\Big|_{t \to \infty} = 0$$

When switch is closed (reset t=0):



$$\mathcal{E} - I_1 R_1 = 0$$

$$-\frac{Q}{C} - I_2 R_2 = 0$$

$$I_2 = \frac{dQ}{dt} \quad \Rightarrow Q(t) = Q_0 e^{-t/\tau}$$

$$\tau \equiv R_2 C \quad \text{and} \quad Q_0 \equiv C\mathcal{E}$$

$$I_2 = \frac{dQ}{dt} = -\frac{C\mathcal{E}}{\tau} e^{-t/\tau} = -\frac{\mathcal{E}}{R_2} e^{-t/\tau}$$

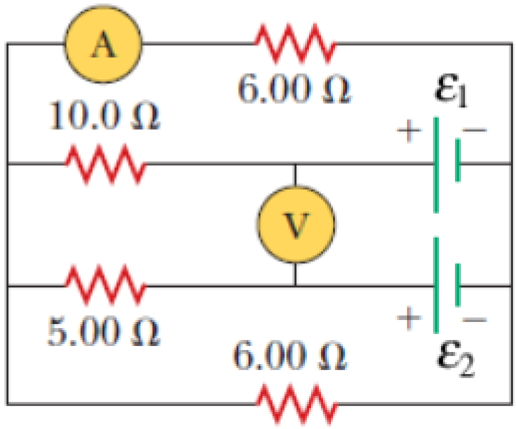
Current through switch :

$$I_1 = I_2 + I_S = 0$$

$$I_S = I_1 - I_2 = \frac{\mathcal{E}}{R_1} + \frac{\mathcal{E}}{R_2} e^{-t/\tau}$$

From webassign:

Consider the following figure, where $\mathcal{E}_1$ = 6.6 V and $\mathcal{E}_2$ = 2.9 V.

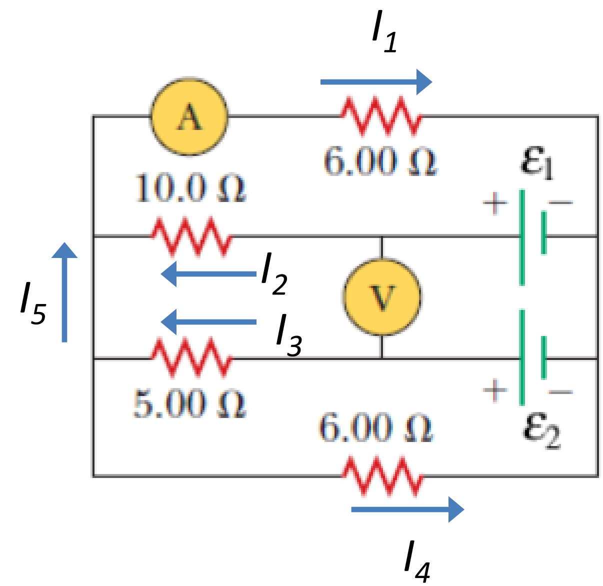


(a) What is the expected reading of the ideal ammeter?

A

(b) What is the expected reading of the ideal voltmeter?

V



$$V - \mathcal{E}_1 + \mathcal{E}_2 = 0 \quad \Rightarrow V = 3.7V$$

$$\mathcal{E}_1 - 10I_2 - 6I_1 = 0$$

$$\mathcal{E}_2 - 5I_3 - 6I_4 = 0$$

$$I_1 = I_2 + I_5 \qquad I_1 = I_4$$

$$I_3 = I_5 + I_4$$

$$V - \mathcal{E}_1 + \mathcal{E}_2 = 0 \quad \Rightarrow V = 3.7V$$

$$\mathcal{E}_1 - 10I_2 - 6I_1 = 0$$

$$\mathcal{E}_2 - 5I_3 - 6I_4 = 0$$

$$I_1 = I_2 + I_5 \qquad I_1 = I_4$$

$$I_3 = I_5 + I_4$$

$$2I_1 = I_2 + I_3$$

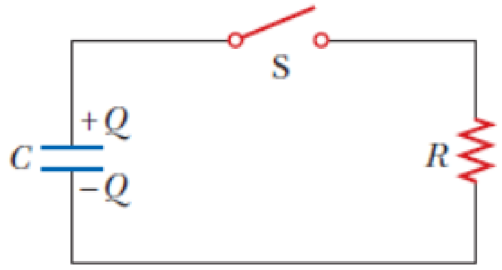
$$\mathcal{E}_1 - 10I_2 - 6I_1 = 0$$

$$2\left(\mathcal{E}_2 - 5I_3 - 6I_4 = 0\right)$$

$$\Rightarrow \mathcal{E}_1 + 2\mathcal{E}_2 - 20I_1 - 18I_1 = 0$$

$$I_1 = \frac{\mathcal{E}_1 + 2\mathcal{E}_2}{38} = 0.33A$$

A charged capacitor is connected to a resistor and switch as in the figure below. The circuit has a time constant of 0.800 s. Soon after the switch is closed, the charge on the capacitor is 80.0% of its initial charge.



(a) Find the time interval required for the capacitor to reach this charge.

s

(b) If R = 200 kΩ, what is the value of C?

μF

$$Q(t) = Q_0 e^{-t/\tau}$$

$$\text{If} \quad \frac{Q(t)}{Q_0} = 0.8 = e^{-t/\tau}$$

$$\Rightarrow \ln\left(e^{-t/\tau}\right) = -\frac{t}{\tau} = \ln 0.8 = -0.223$$

$$t = 0.8\ s \cdot 0.223 = 0.18\ s$$

Review of Chapters 26-28

General formulation of capacitance

Ignoring sign: $Q = C\ \Delta V$

Charge on + and – terminals of capacitor

Depends on geometry and material composition of capacitor

Voltage drop across capacitor terminals

Units: $$C = \frac{\text{Coulombs}}{\text{Volt}} \equiv \text{Farad}$$

For parallel plate capacitors in vacuum (or air):

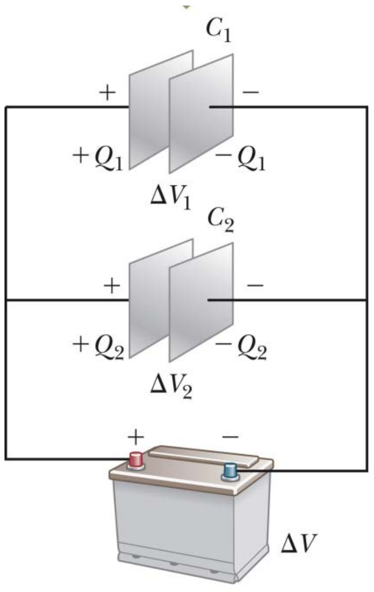
$$C = A\varepsilon_0 / d$$

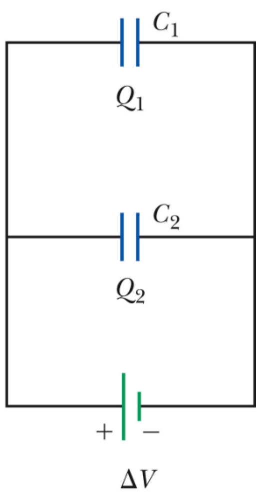
For parallel plate capacitors in dielectric medium:

$$C = A\kappa\varepsilon_0 / d$$

$\kappa \equiv$ dielectric constant (typically $\kappa > 1$)

More complicated circuits –
Capacitors connected in parallel



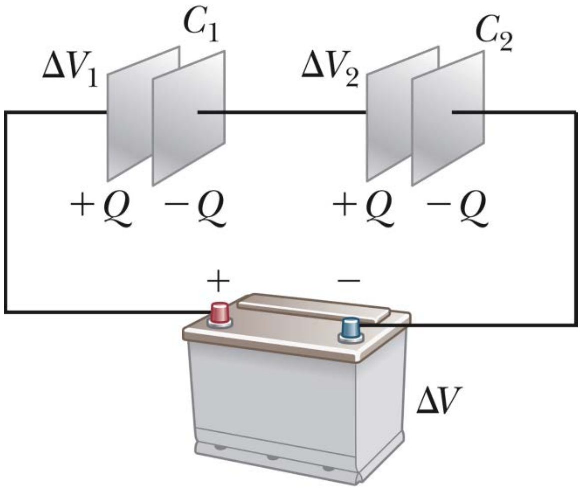


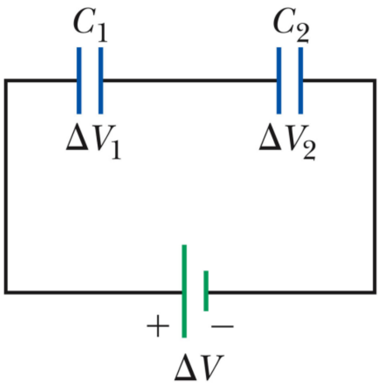
$$\Delta V = \frac{Q_1}{C_1} = \frac{Q_2}{C_2} \equiv \frac{Q_{tot}}{C_{eq}}$$

$$Q_{tot} = Q_1 + Q_2 = C_1\Delta V + C_2\Delta V$$
$$= \left(C_1 + C_2\right)\Delta V$$

$$\Rightarrow C_{eq} = C_1 + C_2$$

More complicated circuits –
Capacitors connected in series



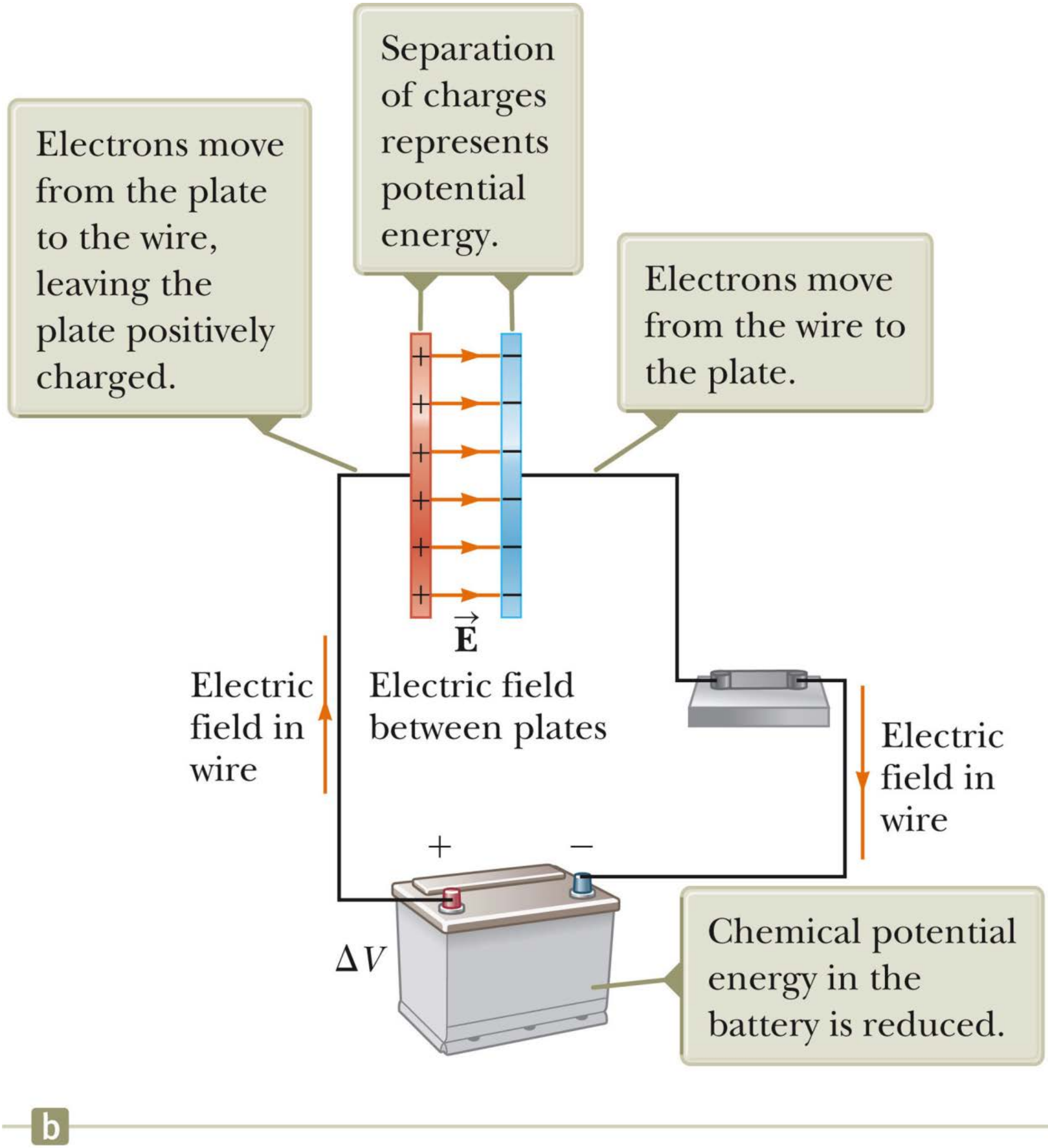


$$\Delta V = \frac{Q_1}{C_1} + \frac{Q_2}{C_2} \equiv \frac{Q_{tot}}{C_{eq}}$$

$$Q_{tot} = Q_1 = Q_2 = C_{eq}\Delta V$$

$$\Rightarrow C_{eq} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$

Energy storage within a capacitor



$$dU = \frac{q}{C}\,dq$$

$$U = \int_0^Q \frac{q}{C}\,dq = \frac{1}{2}\frac{Q^2}{C}$$

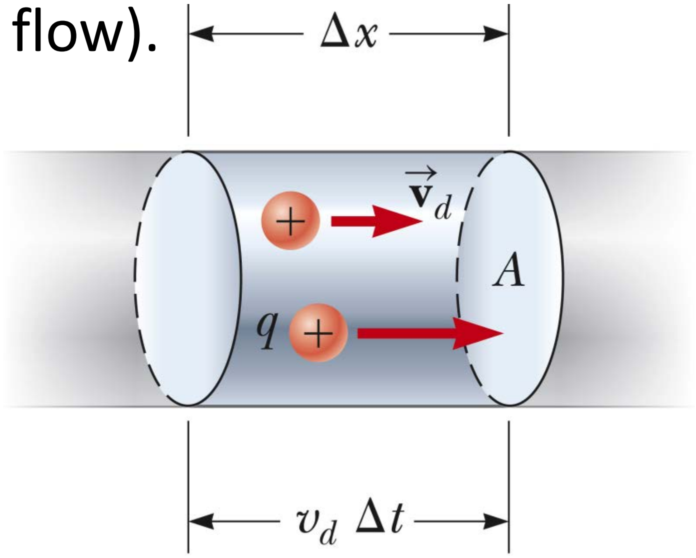
$$U = \frac{1}{2}C(\Delta V)^2$$

Up to now, we have been considering equilibrium configurations of charges -- electrostatics. Now we will consider steady-state motions of charges.

Electrical current

$$I = \frac{dQ}{dt} \quad \text{units}: \frac{\text{Coulomb}}{\text{second}} \equiv \text{Ampere (A)}$$

➔By convention *+I* denotes the direction of positive charge flow (or the opposite direction of negative charge flow).



drift velocity

$$I = nqv_d A$$

charges/volume

Model to describe drift velocity

$$\text{Newton's law:}\quad m_e\frac{dv}{dt} = -eE - \frac{m_e v}{\tau}$$

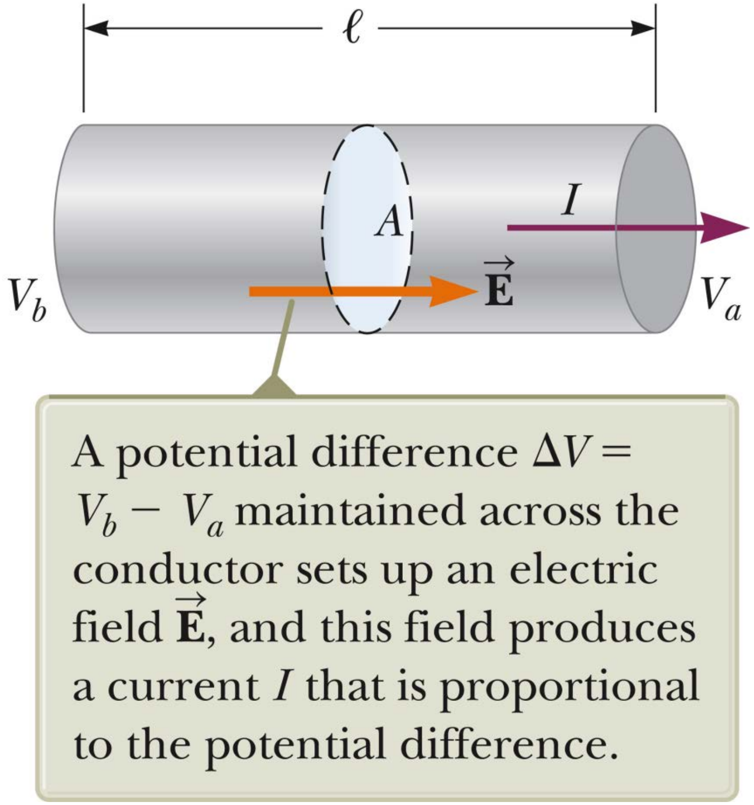
term representing collisions on a time scale of τ

$$\text{Under steady-state conditions:}\quad \left\langle m_e\frac{dv}{dt}\right\rangle = 0 = -eE - \left\langle\frac{m_e v}{\tau}\right\rangle$$

$$\Rightarrow \langle v(t\to\infty)\rangle \equiv v_d = \frac{-eE\tau}{m_e}$$

$$\text{Corresponding current:}\quad I = n(-e)v_d A$$

$$I = \frac{ne^2\tau}{m_e}AE$$



ΔV=E ℓ

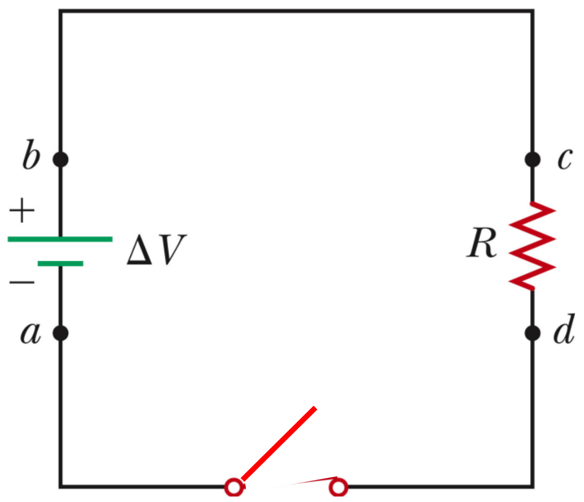
$$I = \frac{ne^2\tau}{m_e} AE = \frac{ne^2\tau}{m_e} \frac{A}{\ell} \Delta V$$

$$\sigma \equiv \frac{1}{\rho}$$

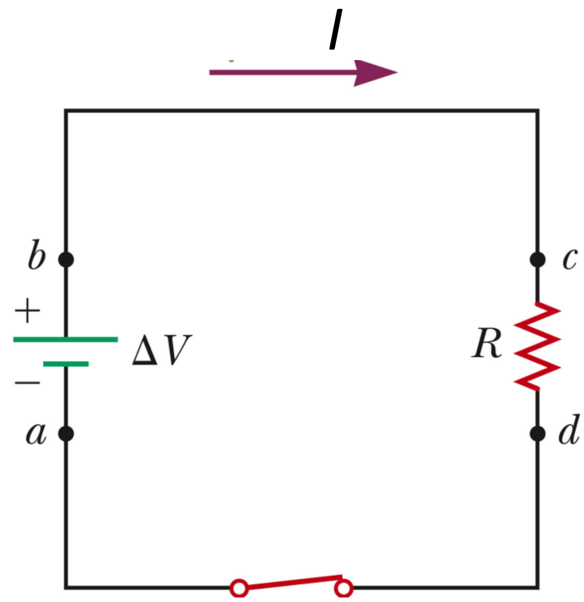
$$I = \frac{1}{R} \Delta V$$

$$R = \rho \frac{\ell}{A}$$

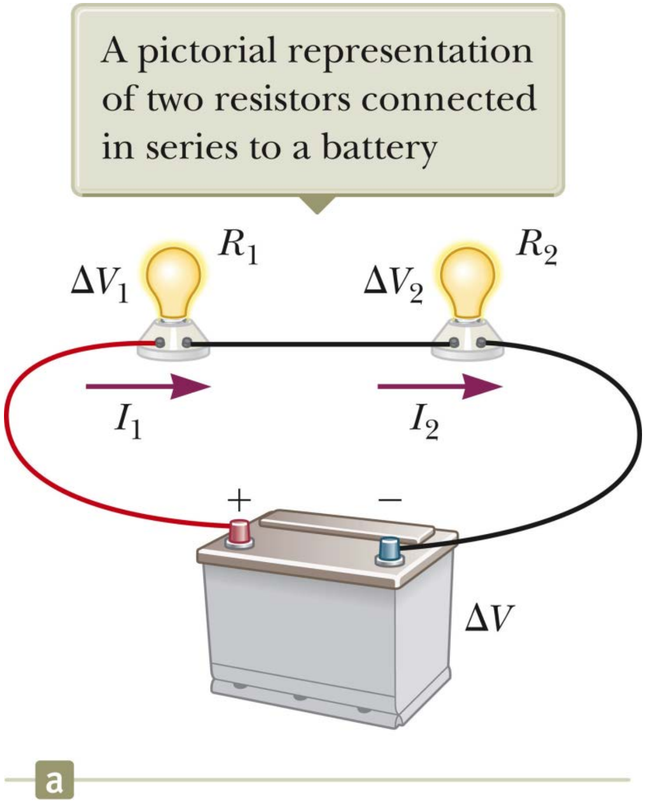
Switch open, no current flowing, battery storing energy

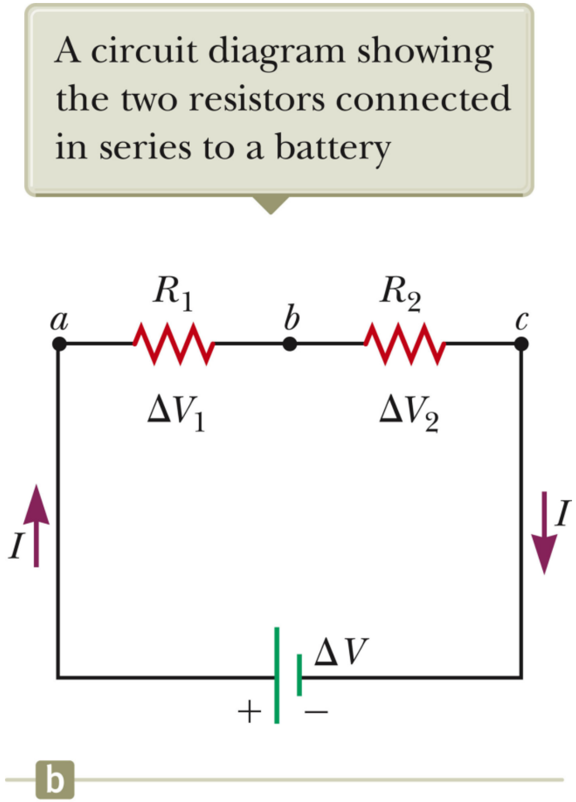


Switch closed, current flowing, battery discharging



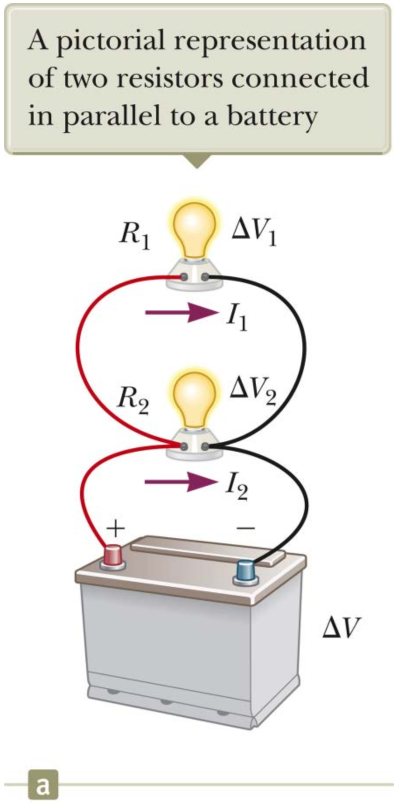
Resistors in series:

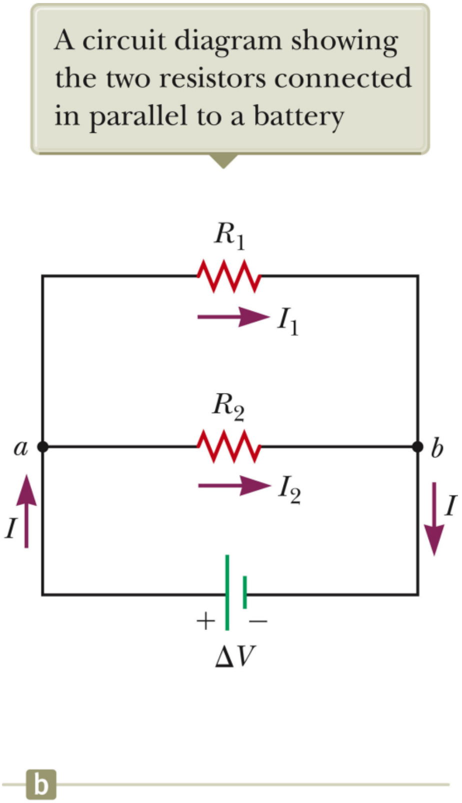




$$\Delta V - IR_1 - IR_2 = 0 \qquad I = \frac{\Delta V}{R_1 + R_2} \qquad R_{series} = R_1 + R_2$$

Resistors in parallel





$$\Delta V - I_1 R_1 = 0$$

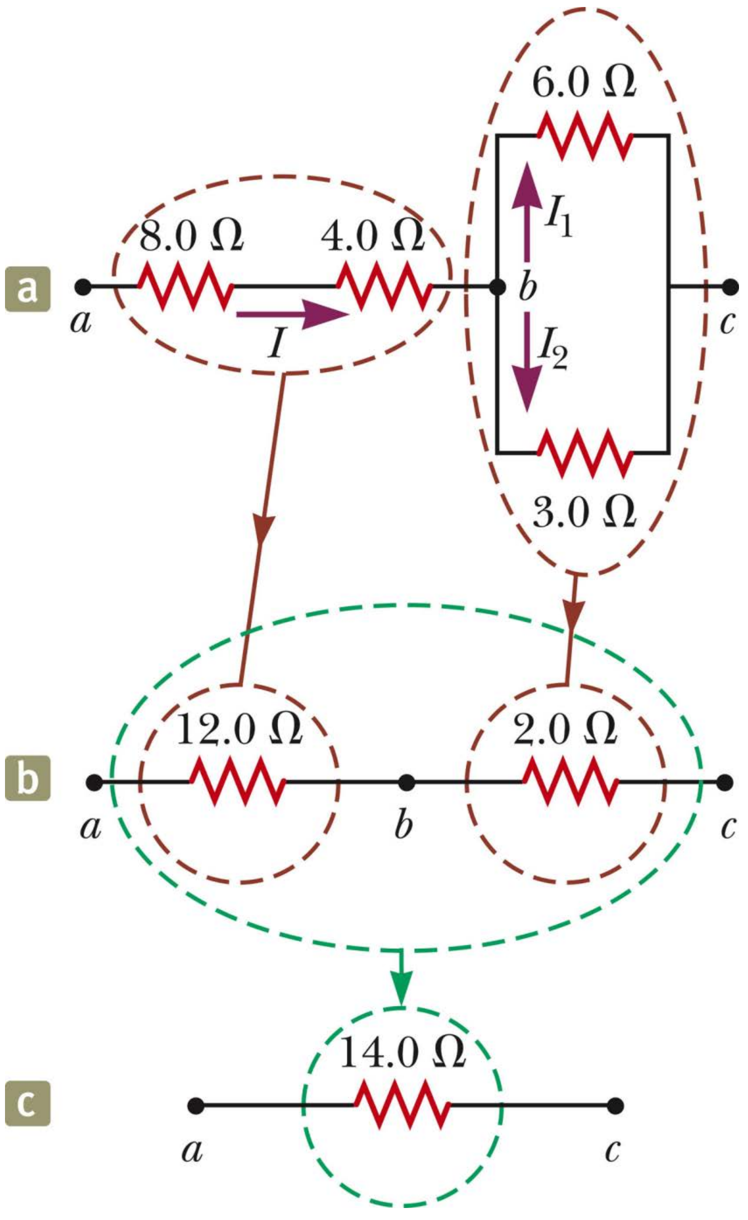
$$\Delta V - I_2 R_2 = 0$$

$$I = I_1 + I_2 = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2}$$

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

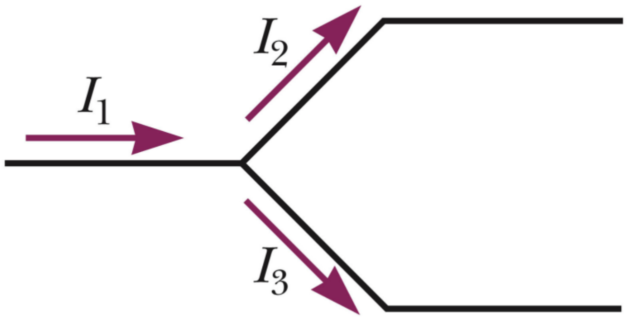
$$R_{Parallel} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Step-by-step reduction of resistor circuit to its equivalent



Circuit analysis – Kirchhoff's rules

Conservation of charge (current) at a junction:

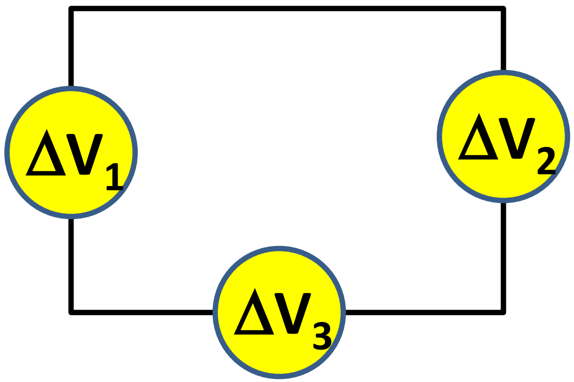


$$\sum_{junction} I = 0$$

$$I_1 - I_2 - I_3 = 0$$

Circuit analysis – Kirchhoff's rules

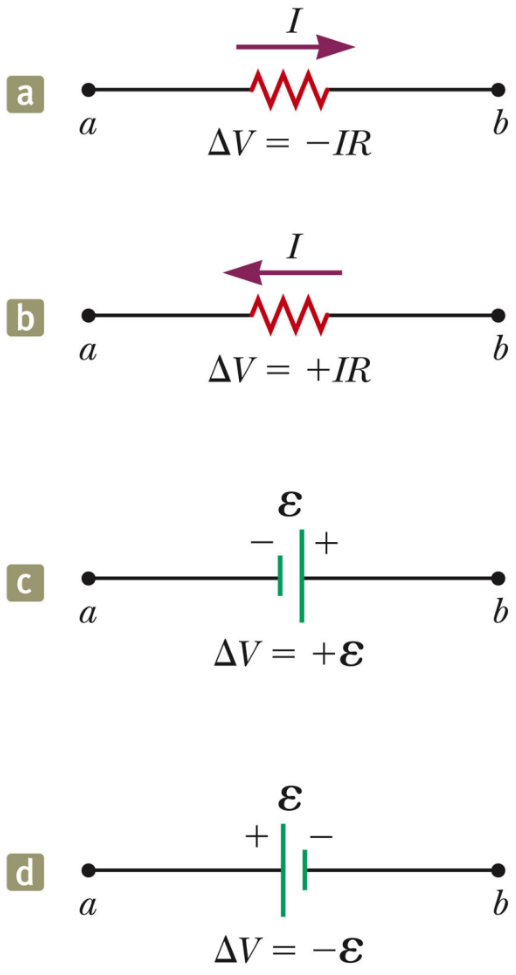
Conservation of potential around a closed circuit:



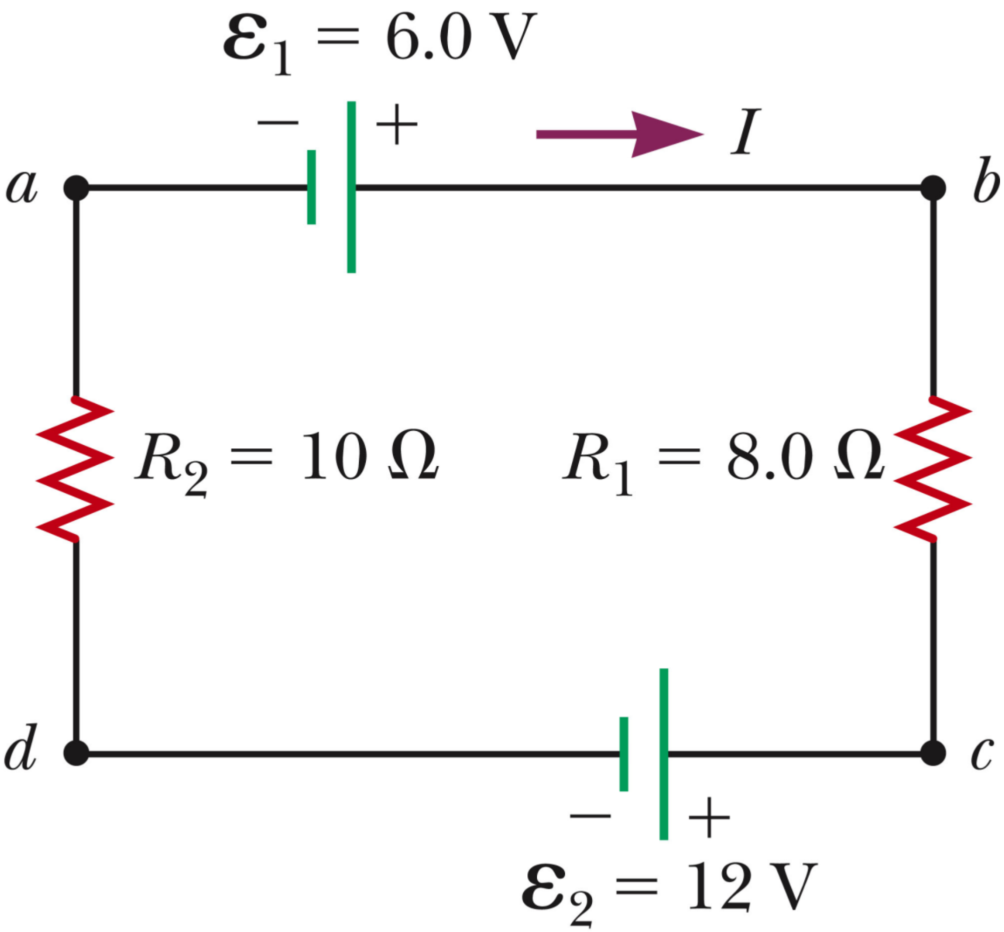
$$\sum_{closed\ \ loop} \Delta V = 0$$

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

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



Example:



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

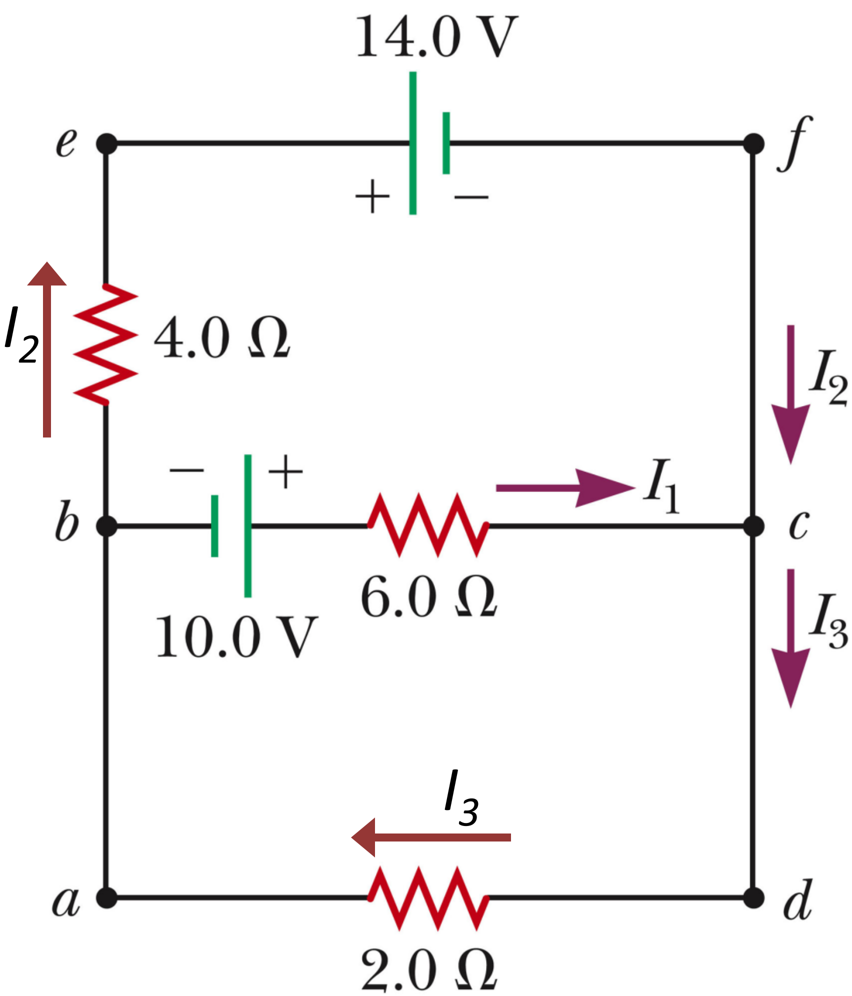
Solve for I :

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

I<0 means:

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

Example:



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

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