Homework #5 is due tonight, Tuesday 16 Oct at 11:59PM
Homework #6 is due next Tuesday 23 Oct at 11:59PM

Office hour today after class (3-4PM) in Serin 283 tea room

Make sure your clickers are out and ready before class starts
Circuits
- principles
- formulas and rules for analyzing circuits

steady currents

Circuit elements and rules
- battery
- resistor
- capacitor
Ideal battery maintains specified voltage $\mathcal{E}$ between + and – terminal. The same no matter how much current $i$ flows through the battery.
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Charges arrive at small terminal at rate given by current $i$

Battery does work $q \mathcal{E}$ on charges to place them at + terminal.

Rate of energy delivery by battery $= i \mathcal{E}$
Ideal battery maintains specified voltage $\mathcal{E}$ between + and – terminal.

Charges arrive at small terminal at rate given by current $i$. The battery does work $q \mathcal{E}$ on charges to place them at + terminal.

Rate of energy delivery by the battery = $i \mathcal{E}$

Current $i$ can flow in either direction.

Charges can move from + terminal to – and lose energy, which goes to “recharge” the battery.
Resistor: Current $i$ flows from + to – potential

If resistor has resistance $R$: $i = \frac{V}{R}$
rate of energy loss: $i \cdot V = \frac{V^2}{R} = i^2R$
Capacitor in **steady current conditions**: 
Q is constant in time 
i is zero through capacitor 
\( V = \frac{Q}{C} \)
All capacitors have capacitance 6 mF and all the batteries have an emf of 10V. What is the charge on capacitor C?
All capacitors have capacitance 6 mF and all the batteries have an emf of 10V. What is the charge on capacitor C? First, what is the voltage across C?
All capacitors have capacitance $6 \, \mu\text{F}$ and all the batteries have an emf of $10\text{V}$. What is the charge on capacitor C? First, what is the voltage across C?
Analyzing circuits

Voltage change across each circuit element:
Battery: $+\mathcal{E}$ from small plate (-) to large plate (+)
Resistor: decreases by $iR$ in direction of current arrow

LOOP RULE: total voltage change around loop is ZERO
Single loop: all circuit elements are connected in series
All have same current $i$
What does the arrow show?
What does the arrow show?
NOT the direction of the current
BUT the direction in which the current flows when $i$ is positive
If the potential at point P is 100 V, what is the potential at point Q?
Energy delivered / lost by each circuit element

50 V battery is charging
A real battery

The voltage difference between the terminals decreases as the current through the battery increases.

Behaves like an ideal battery $\mathcal{E}$ in series with internal resistor $r$. 
Analyze a circuit with a real battery
Analyze a circuit with a real battery

Compare $i$ and voltage across the terminals if $R = 2.0 \ \Omega$
a single-loop circuit
with a battery $V$, a resistor $R$ and capacitor $C$
a single-loop circuit with a battery $V$, a resistor $R$ and capacitor $C$

NO CURRENT FLOWS
Charge on capacitor $Q = CV$
Simplest multiloop: emf with elements in parallel

Voltage across elements is the SAME

Equations for $i_1$, $i_2$ and $i_3$
Upper loop / lower loop / big loop
Junction rule

![Diagram of a multiloop circuit with elements in parallel]
Multiloop circuits

**Junction rule**: net current into a junction is ZERO

**Loop rule** applies to every loop
In Fig. 27-41, the ideal batteries have emfs $\varepsilon_1 = 10.0 \, \text{V}$ and $\varepsilon_2 = 0.500 \varepsilon_1$, and the resistances are each $4.00 \, \Omega$. What is the current in (a) resistance 2 and (b) resistance 3?
Solving systems of equations: how to do that easily?
You need to find your own best fail-proof way
All resistors have capacitance 6 Ω and all the batteries have an emf of 4V. What is the current through resistor R?
Circuits with connection to ground gives a reference for specifying potential.

In Fig. 27-47, $\varepsilon_1 = 6.00$ V, $\varepsilon_2 = 12.0$ V, $R_1 = 100$ Ω, $R_2 = 200$ Ω, and $R_3 = 300$ Ω. One point of the circuit is grounded ($V = 0$). What are the (a) size and (b) direction (up or down) of the current through resistance 1, the (c) size and (d) direction (left or right) of the current through resistance 2, and the (e) size and (f) direction of the current through resistance 3? (g) What is the electric potential at point $A$?
An automobile gasoline gauge is shown schematically in Fig. 27-74. The indicator (on the dashboard) has a resistance of 10 Ω. The tank unit is a float connected to a variable resistor whose resistance varies linearly with the volume of gasoline. The resistance is 140 Ω when the tank is empty and 20 Ω when the tank is full. Find the current in the circuit when the tank is (a) empty, (b) half-full, and (c) full. Treat the battery as ideal.

note that current can flow from/to ground
Equivalent resistance **CONCEPT**
Useful for analyzing complex circuits
Can I put this resistor network in a box with two terminals?

Series and parallel combinations are the simplest examples
Works for any resistor network

Need to be able to go back and answer questions about
Individual resistors
In Fig. 27-70, the ideal battery has emf $\mathcal{E} = 30.0$ V, and the resistances are $R_1 = R_2 = 14$ Ω, $R_3 = R_4 = R_5 = 6.0$ Ω, $R_6 = 2.0$ Ω, and $R_7 = 1.5$ Ω. What are currents (a) $i_2$, (b) $i_4$, (c) $i_1$, (d) $i_3$, and (e) $i_5$?

Note: Easy to see that $R_5$ and $R_6$ are in parallel. Also $R_1$ and $R_2$ are in parallel, as well as $R_3$ and $R_4$. 
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can’t always reduce the two-terminal box to a single
resistor using series/parallel rules alone
In Fig. 27-46, $V = 12.0 \text{ V}$, $R_1 = 2000 \ \Omega$, $R_2 = 3000 \ \Omega$, and $R_3 = 4000 \ \Omega$. What are the potential differences (a) $V_A - V_B$, (b) $V_B - V_C$, (c) $V_C - V_D$, and (d) $V_A - V_C$?