Homework #5 due next Tuesday at 11:59PM

COME DOWN AND PLAY WITH THE RC SINGLE LOOP CIRCUIT
In Fig. 27-41, the ideal batteries have emfs $\mathcal{E}_1 = 10.0 \, \text{V}$ and $\mathcal{E}_2 = 0.500 \mathcal{E}_1$, 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?
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, $R_1 = 100$ $\Omega$, $R_2 = 200$ $\Omega$, and $R_3 = 300$ $\Omega$. 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 $\varepsilon = 30.0 \, \text{V}$, and the resistances are $R_1 = R_2 = 14 \, \Omega$, $R_3 = R_4 = R_5 = 6.0 \, \Omega$, $R_6 = 2.0 \, \Omega$, and $R_7 = 1.5 \, \Omega$. What are currents (a) $i_2$, (b) $i_4$, (c) $i_1$, (d) $i_3$, and (e) $i_5$?

Fig. 27-70  Problem 72.

Look for resistors in series or in parallel
In Fig. 27-70, the ideal battery has emf \( \varepsilon = 30.0 \text{ V} \), and the resistances are \( R_1 = R_2 = 14 \Omega \), \( R_3 = R_4 = R_5 = 6.0 \Omega \), \( R_6 = 2.0 \Omega \), and \( R_7 = 1.5 \Omega \). 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 \( R_4 \).
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

can’t always reduce the two-terminal box to a single
resistor using series/parallel rules alone
35. In Fig. 27-46, \( \varepsilon = 12.0 \text{ V} \), \( R_1 = 2000 \ \Omega \), \( R_2 = 3000 \ \Omega \), 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) \( V_A - V_C \)?

Fig. 27-46  Problem 35.
**Ammeter:** device that measures current (amperes)

Two-terminal device
Insert into the circuit so that the current to be measured passes through the ammeter
“in series” - watch and count the charges going by

Insert an additional device – a different circuit
change currents and voltages in the rest of the circuit? resistance should be as LOW as possible

Single loop circuit: EXAMPLE: $E$ and $R$. Insert ammeter with resistance $r$. Current changes from $E/R$ to $E/(R+r)$. The smaller $r$ is, the less the current changes.
**Voltmeter:** device that measures potential difference (volts)

Two-terminal device
Connected between the two points between which you want to measure the potential difference
“in parallel”

Insert an additional device – a different circuit
change currents and voltages in the rest of the circuit?
resistance should be as HIGH as possible

Single loop circuit: $E$ and two resistors $R$. Connect voltmeter with resistance $r$ across one of the resistors. $V$ across the resistor in absence of the voltmeter is $E/R$. With the voltmeter, $r$ is in parallel and $V'$ is $E(rR/(r+R))/(R+rR/(r+R)) = E(r/(r+R))/(1+r/(r+R)) = E(1/(1+R/r))/((2+R/r)/(1+R/r)) = E(1/(2+R/r))$ so want $r>>R$
Introduction to time-varying circuits

Release the steady-current condition a little bit
Allow current to depend on time $i(t)$
Charge on capacitor(s) to change with time $Q(t)$

The rules we learned for time-independent circuits are still true:
**Take a snapshot at time $t$**
The voltage change through each circuit element is computed the same way as before
Loop rule and junction rule hold at each time $t$
a single-loop circuit with a battery $\mathcal{E}$, a resistor $R$ and capacitor $C$

**STEADY CURRENT CONDITION:**
NO CURRENT FLOWS $i = 0$
Charge on capacitor $q = C \mathcal{E}$
a single-loop circuit with a battery $E$, a resistor $R$ and capacitor $C$

Charge on capacitor $q(t)$
$V_C(t)$ across the capacitor is $q(t)/C$
$V_R(t)$ across the resistor is $E - V_C(t)$
i(t) is $(E - V_C(t))/R$
a single-loop circuit with a battery $\mathcal{E}$, a resistor $R$ and capacitor $C$

Charge on capacitor $q(t)$

$V_C(t)$ across the capacitor is $q(t)/C$

$V_R(t)$ across the resistor is $E - V_C(t)$

$i(t)$ is $(\mathcal{E} - V_C(t))/R$

One more important fact

$i(t) = dq/dt$
In the circuit shown, $\mathcal{E}$ is 20 V and $q(t)$ on the 100 nF capacitor is 1 $\mu$C at $t=2.0$ s. What is the current through the 5.0 $\Omega$ resistor at $t = 2.0s$?

(a) 20 A  
(b) 3.0 A  
(c) 2.0 A  
(d) 1.0 A  
(e) I have no idea how to do this
Switch closed to “a” position at $t=0$
Initial $q = 0$

$$\mathcal{E} - iR - \frac{q}{C} = 0.$$  

$$i = \frac{dq}{dt}.$$  

$$R \frac{dq}{dt} + \frac{q}{C} = \mathcal{E}.$$  

$$q = C\mathcal{E}(1 - e^{-t/\tau_{RC}}).$$  

$$i = \frac{dq}{dt} = \left(\frac{\mathcal{E}}{R}\right)e^{-t/\tau_{RC}}.$$

A capacitor that is being charged initially acts like ordinary connecting wire relative to the charging current. A long time later, it acts like a broken wire.
RC circuits

\[ i = \frac{dq}{dt} = \left(\frac{\mathcal{E}}{R}\right)e^{-t/RC} \]

\[ \tau = RC \]

the time it takes for the current to decrease by a factor of e “time constant”

RC ln 2 = the time it takes for the current to decrease by a factor of 2

Fig. 27-15  When switch S is closed on a, the capacitor is \textit{charged} through the resistor. When the switch is afterward closed on b, the capacitor \textit{discharges} through the resistor.