PHYS 1441 – Section 002
Lecture #14

Monday, Oct. 29, 2018

Dr. Jaehoon Yu

- Chapter 26 – DC Circuit
  - Resisters in Series and Parallel
  - Kirchhoff's Rules
  - EMFs in Series and Parallel
  - RC Circuits – Charging and Discharging
- Chapter 27: Magnetism and Magnetic Field

Today's homework is #10, due 11pm, Monday, November 12!!

Announcements

- Reading Assignments: CH26.5, 6 and 7
- Quiz #3
  - At the beginning of the class Monday, Nov. 5
  - Covers CH25.5 to what we learn this Wednesday
  - Bring your calculator but DO NOT input formula into it!
    - Cell phones or any types of computers cannot replace a calculator!
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants
  - No derivations, word definitions or solutions of any kind!
  - No additional formulae or values of constants will be provided!

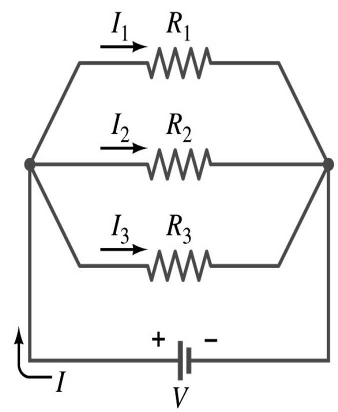
Reminder: Special Extra Credit #4

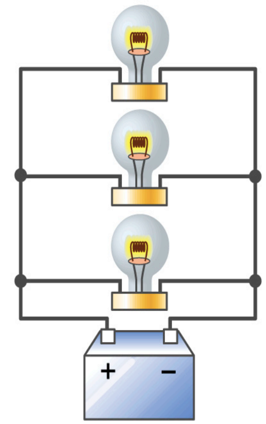
- **Election Participation Exercise**
- For those with legal voting rights: You can submit three “I Voted” stickers for 20 points total – one your own and two others who voted and the remainder 2 points each
- For those without legal voting rights: You can submit for the first four “I Voted” sticker for 20 points total and the remainder 2 points each
- Be sure to tape one side of the stickers on a sheet of paper with your name on it.
  - Write the precinct number the vote was cast, the full name of the person voted and the signature of the voter next to the relevant sticker
- None of the stickers can be from the same person on someone else’s extra credit or on your own. All of those with any of the identical persons on your extra credit sheet will get 0 credit.
- Deadline: Beginning of the class Wednesday, Nov. 7

These are acceptable!

Resisters in Parallel

- Resisters are in parallel when two or more resisters are connected in separate branches
  - Most the house and building wirings are arranged this way.





- What is common for the devices in a parallel circuit?
  - The voltage is the same across all the resisters in the same circuit
  - The total current that leaves the battery is, however, split.
- The current that passes through every element is
  - $I_1=V/R_1$, $I_2=V/R_2$, $I_3=V/R_3$
- Since the total current is I, we obtain
  - $I=V/R_{eq}=I_1+I_2+I_3=V(1/R_1+1/R_2+1/R_3)$
  - Thus, $1/R_{eq}=1/R_1+1/R_2+1/R_3$

$$\frac{1}{R_{eq}}=\sum_i \frac{1}{R_i}$$

Resisters in parallel

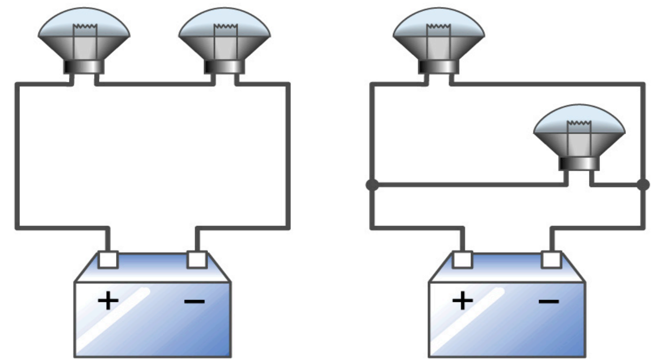
When resisters are connected in parallel, the total resistance decreases and the current increases.

Resister and Capacitor Arrangements

- Parallel Capacitor arrangements $$C_{eq} = \sum_i C_i$$
- Parallel Resister arrangements $$\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i}$$
- Series Capacitor arrangements $$\frac{1}{C_{eq}} = \sum_i \frac{1}{C_i}$$
- Series Resister arrangements $$R_{eq} = \sum_i R_i$$

Example 26 – 2

Series or parallel? (a) The light bulbs in the figure are identical and have identical resistance R. Which configuration produces more light? (b) Which way do you think the headlights of a car are wired?



(a) What are the equivalent resistances for the two cases?

Series $R_{eq} = 2R$ Parallel $\frac{1}{R_{eq}} = \frac{2}{R}$ So $R_{eq} = \frac{R}{2}$

The bulbs get brighter when the total power transformed is larger.

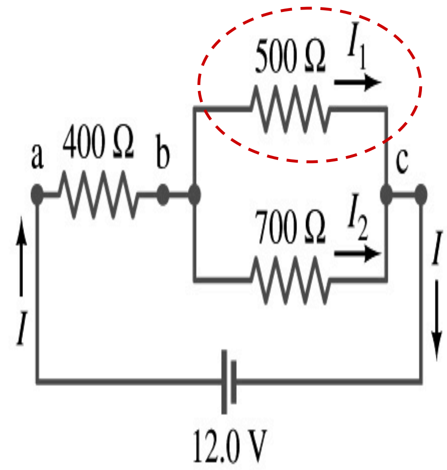
series $P_S = IV = \frac{V^2}{R_{eq}} = \frac{V^2}{2R}$ parallel $P_P = IV = \frac{V^2}{R_{eq}} = \frac{2V^2}{R} = 4P_S$

So parallel circuit provides brighter lighting.

(b) Car's headlights are in parallel to provide brighter lighting and also to prevent both lights going out at the same time when one burns out.

So what is bad about parallel circuits? Uses more energy in a given time.

Example 26 – 5



Current in one branch. What is the current flowing through the 500-Ω resister in the figure?

What do we need to find first?

We need to find the total current.

To do that we need to compute the equivalent resistance.

R_{eq} of the small parallel branch is: $\frac{1}{R_P} = \frac{1}{500} + \frac{1}{700} = \frac{12}{3500}$ $R_P = \frac{3500}{12}$

R_{eq} of the circuit is: $R_{eq} = 400 + \frac{3500}{12} = 400 + 292 = 692\Omega$

Thus the total current in the circuit is $I = \frac{V}{R_{eq}} = \frac{12}{692} = 17mA$

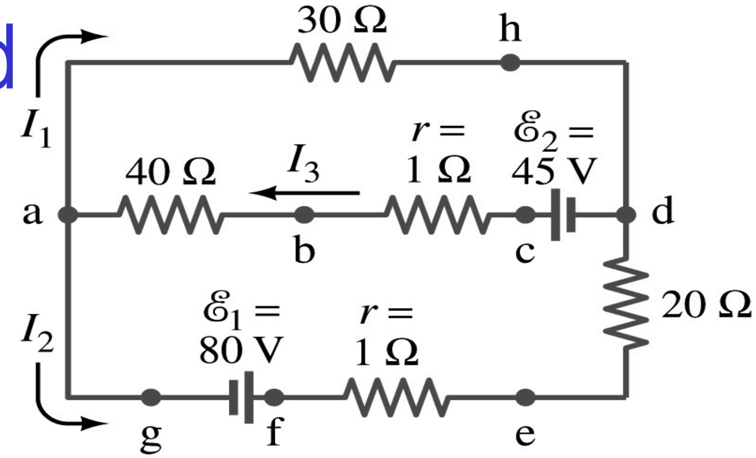
The voltage drop across the parallel branch is $V_{bc} = IR_P = 17\times10^{-3}\cdot 292 = 4.96V$

The current flowing across 500-Ω resister is therefore

$$V_{bc} I_{500} = \frac{V_{bc}}{R} = \frac{4.96}{500} = 9.92\times10^{-3} = 9.92mA$$

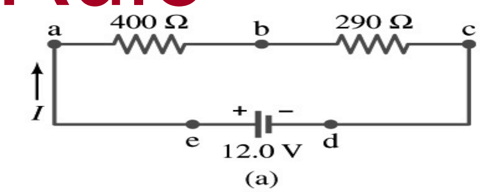
What is the current flowing 700-Ω resister? $I_{700} = I - I_{500} = 17 - 9.92 = 7.08mA$

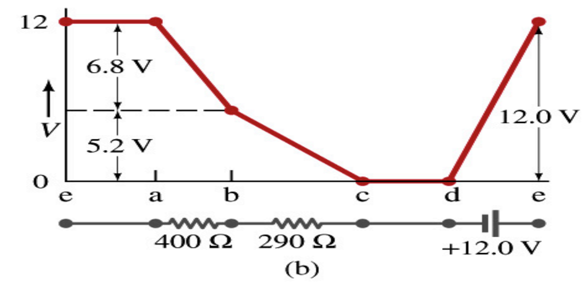
Kirchhoff's Rules – 1st Rule



- Some circuits are very complicated to do the analysis using the simple combinations of resisters
  - G. R. Kirchhoff devised two rules to deal with complicated circuits.
- Kirchhoff's rules are based on **conservation of charge and energy**
  - Kirchhoff's 1st rule: The junction rule, **charge conservation**.
    - At any junction point, the sum of all currents entering the junction must be equal to the sum of all currents leaving the junction.
    - In other words, what goes in must come out.
    - At junction *a* in the figure, I_3 comes into the junction while I_1 and I_2 leaves: $I_3 = I_1 + I_2$

Kirchhoff's Rules – 2nd Rule



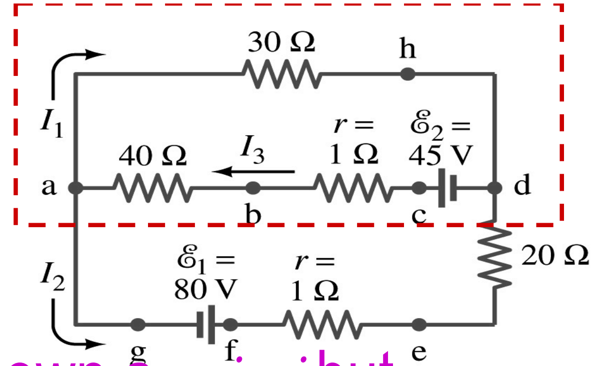


- Kirchoff's 2nd rule: The loop rule, uses **conservation of energy**.
  - The sum of the changes in potential in any closed path of a circuit must be zero.
- The current in the circuit in the figure is I=12/690=0.017A.
  - Point e is the high potential point while point d is the lowest potential.
  - When the test charge starts at e and returns to e, the total potential change is 0.
  - Between point e and a, no potential change since there is no source of potential nor any resistance.
  - Between a and b, there is a 400Ω resistance, causing IR=0.017*400 =6.8V drop.
  - Between b and c, there is a 290Ω resistance, causing IR=0.017*290 =5.2V drop.
  - Since these are voltage drops, we use negative sign for these, -6.8V and -5.2V.
  - No change between c and d while from d to e there is +12V change.
  - Thus the total change of the voltage through the loop is: -6.8V-5.2V+12V=0V.

How to use Kirchhoff's Rules??

1. Determine the flow of currents at the junctions and label each and everyone of the currents.
   - It does not matter which direction, you decide but keep it!
     - You cannot have all current coming in or going out of a junction, though!
   - If the value of the current after completing the calculations are negative, you just need to flip the direction of the current flow.
2. Write down the current equation based on Kirchhoff's 1st rule at various junctions.
   - Be sure to see if any of them are the same.
3. Choose closed loops in the circuit
4. Write down the potential in each interval of the junctions, keeping the proper signs as you decided in step 1 above.
5. Write down the potential equations for each loop.
6. Solve the equations for unknowns.

Example 26 – 9



Use Kirchhoff's rules. Calculate the currents I_1, I_2 and I_3 in each of the branches of the circuit in the figure.

The directions of the current through the circuit is not known a *priori* but since the current tends to move away from the positive terminal of a battery, we arbitrarily choose the direction of the currents as shown.

We have three unknowns so we need three equations.

Using Kirchhoff's junction rule at point *a*, we obtain $I_3 = I_1 + I_2$

This is the same for junction *d* as well, so no additional information.

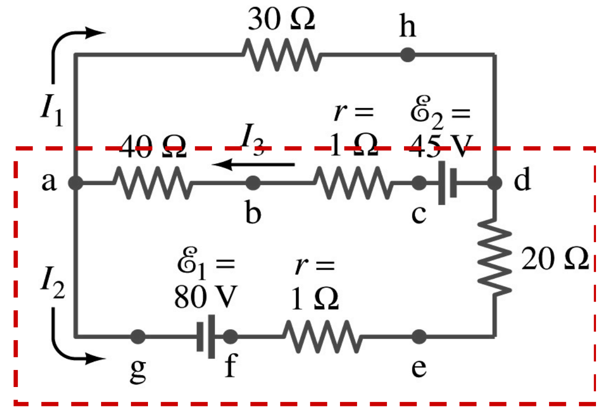
Now the second rule on the loop *ahdcba*.

$$V_{ah} = -I_1 30 \qquad V_{hd} = 0 \qquad V_{dc} = +45 \qquad V_{cb} = -I_3 \qquad V_{ba} = -40 I_3$$

The total voltage change in the loop *ahdcba* is.

$$V_{ahdcba} = -30I_1 + 45 - 1 \cdot I_3 - 40I_3 = 45 - 30I_1 - 41I_3 = 0$$

Example 26 – 9, cnt'd



Now the second rule on the other loop *agfedcba*.

$$V_{ag} = 0 \quad V_{gf} = +80 \quad V_{fe} = -I_2 \cdot 1 \quad V_{ed} = -I_2 \cdot 20$$

$$V_{dc} = +45 \quad V_{cb} = -I_3 \cdot 1 \quad V_{ba} = -40 \cdot I_3$$

The total voltage change in loop *agfedcba* is. $V_{agfedcba} = -21I_2 + 125 - 41I_3 = 0$

So the three equations become

$$I_3 = I_1 + I_2$$

$$45 - 30I_1 - 41I_3 = 0$$

$$125 - 21I_2 - 41I_3 = 0$$

We can obtain the three current by solving these equations for I_1, I_2 and I_3.

Do this yourselves!!