PHYS 1444 – Section 002
Lecture #15

Monday, Oct. 30, 2017

Dr. Jaehoon Yu

- Chapter 26
  - Resistance in series and parallel
  - Kirchhoff's Rules
  - EMFs in Series and Parallel

Today's homework is homework #9, due 11pm, Monday, Nov. 6!!

Announcements

- Reading assignments
  - CH26.5, 6 and 7
- Mid-term exam results
  - Class average: 70.5/96
    - Equivalent to 73.4/100
    - Previous exam: 50.1/100
  - Top score: 96/96
- Quiz #3
  - At the beginning of the class Monday, Nov. 6
  - Covers CH25.5 to what we learn this Wednesday, Nov. 1
  - BYOF

Valid Planetarium Shows

- Regular running shows
  - Stars of Pharaoes – Saturdays at 6:00pm
  - Astronaut – Sundays at 1:30pm
- Shows that need special arrangements
  - Black Holes (up to 2 times)
  - Bad Astronomy, Cosmic Origin, Experience the Aurora
  - From Earth to the Universe, IBEX, Ice Worlds, Magnificent Sun
  - Mayan Prophecies, Nanocam, Phantom of the Universe
  - Two Small Pieces of Glass, Unseen Universe: The Vision of SOFIA
  - Violent Universe, We are Astronomers
- How to submit for extra credit?
  - Obtain the ticket stub that is signed and dated by the planetarium star lecturer at the show
  - Collect the ticket stubs
  - Tape all of them on a sheet of paper with your name and ID written on it
  - Submit the sheet at the beginning of the class Nov. 29

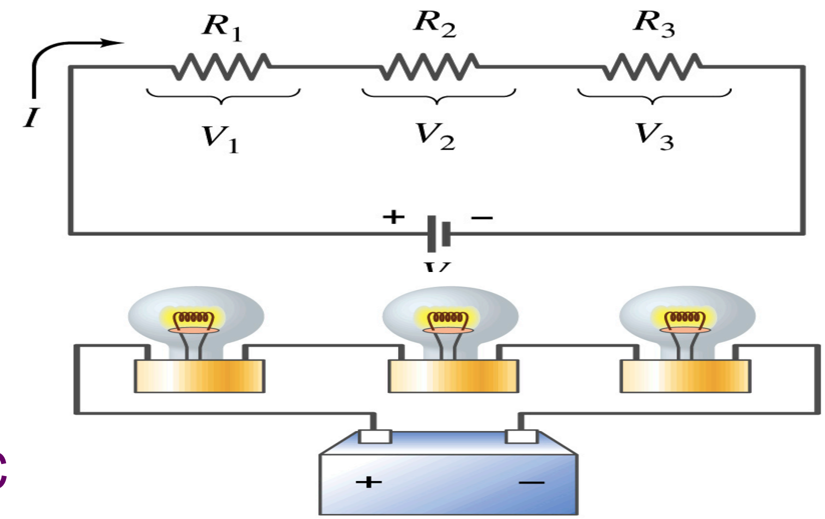
Reminder: Special Project #5

- Make a list of the power consumption and the resistance of all electric and electronic devices at your home and compiled them in a table. (5 points total for the first 10 items and 0.25 points each additional item.)
- Estimate the cost of electricity for each of the items on the table using your own electric cost per kWh (if you don't find your own, use $0.12/kWh) and put them in the relevant column. (2 points total for the first 10 items and 0.1 points each additional items)
- Estimate the the total amount of energy in Joules and the total electricity cost per day, per month and per year for your home. (6 points)
- Due: Beginning of the class this Wednesday, Nov. 1

Item Name	Rated power (W)	Number of devices	Number of Hours per day	Daily Power Consumption (kWh)	Energy Cost per kWh (cents)	Daily Energy Consumption (J).	Daily Energy Cost ($)	Monthly Energy Consumption (J)	Monthly Energy Cost ($)	Yearly Energy Consumption (J)	Yearly Energy Cost ($)
Light Bulbs	30	4									
	40	6									
	60	15									
Heaters	1000	2									
	1500	1									
	2000	1									
Fans											
Air Conditioners											
Fridgers, Freezers											
Computers (desktop, laptop, ipad)											
Game consoles											
Total				0		0	0	0	0	0	0

Resisters in Series

- Resisters are in series when two or more resisters are connected end to end
  - These resisters represent simple resisters in circuit or electrical devices, such as light bulbs, heaters, dryers, etc



- What is common for devices in a series circuit?
  - Current is the same through all the elements in series
- Potential difference across every element in the circuit is
  - $V_1=IR_1$, $V_2=IR_2$ and $V_3=IR_3$
- Since the total potential difference is V, we obtain
  - $V=IR_{eq}=V_1+V_2+V_3=I(R_1+R_2+R_3)$
  - Thus, $R_{eq}=R_1+R_2+R_3$

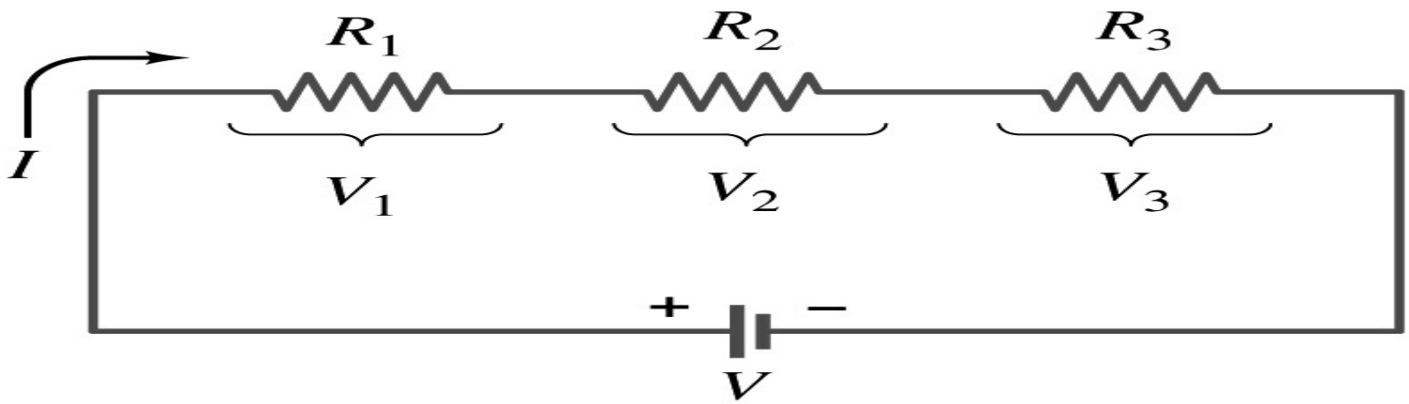
$$R_{eq} = \sum_i R_i$$

Resisters in series

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

Energy Losses in Resisters

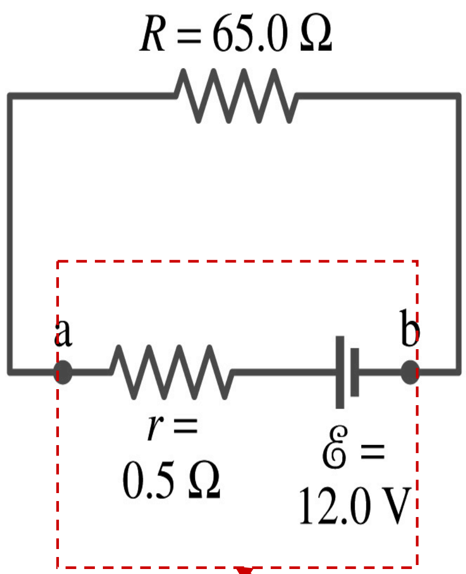
- Why is it true that $V=V_1+V_2+V_3$?



- What is the potential energy loss when charge q passes through resisters R_1, R_2 and R_3
  - $\Delta U_1=qV_1$, $\Delta U_2=qV_2$, $\Delta U_3=qV_3$
- Since the total energy loss should be the same as the total energy provided to the system, we obtain
  - $\Delta U=qV=\Delta U_1+\Delta U_2+\Delta U_3=q(V_1+V_2+V_3)$
  - Thus, $V=V_1+V_2+V_3$

Example 26 – 1

Battery with internal resistance. A 65.0-Ω resistor is connected to the terminals of a battery whose emf is 12.0V and whose internal resistance is 0.5-Ω. Calculate (a) the current in the circuit, (b) the terminal voltage of the battery, V_{ab}, and (c) the power dissipated in the resistor R and in the battery's internal resistor.



What is this?

A battery or a source of emf.

(a) Since $V_{ab} = \varepsilon - Ir$ We obtain $V_{ab} = IR = \varepsilon - Ir$

Solve for I

$$I = \frac{\varepsilon}{R+r} = \frac{12.0V}{65.0\Omega + 0.5\Omega} = 0.183A$$

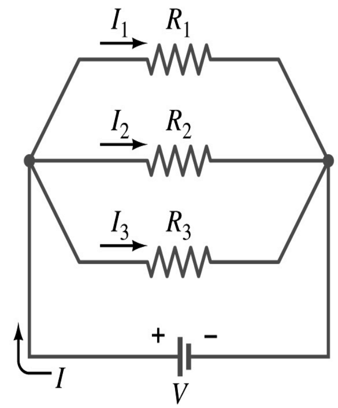
(b) The terminal voltage V_{ab} is $V_{ab} = \varepsilon - Ir = 12.0V - 0.183A \cdot 0.5\Omega = 11.9V$

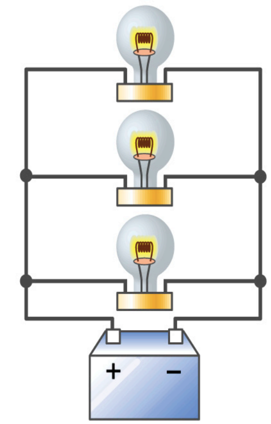
(c) The power dissipated in R and r are

$$P = I^2 R = (0.183A)^2 \cdot 65.0\Omega = 2.18W$$

$$P = I^2 r = (0.183A)^2 \cdot 0.5\Omega = 0.02W$$

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.
  - 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, $1/R_{eq}=1/R_1+1/R_2+1/R_3$

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

Resisters in parallel

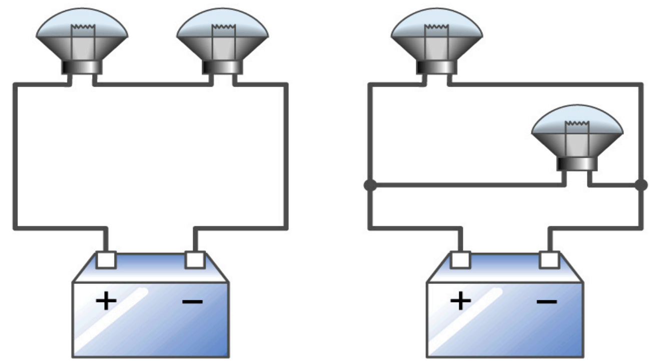
When resisters are connected in parallel, the total resistance decreases and the current increases.

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?



(1) Series (2) Parallel

(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.

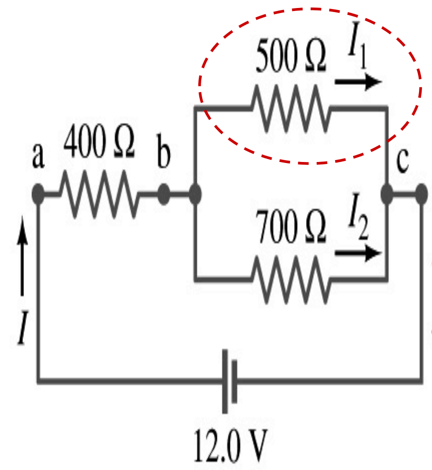
series $P_S = IV = \frac{V^2}{R_{eq}} = \frac{V^2}{2R}$ parallel $P_P = IV = \frac{V^2}{R_{eq}} = \frac{2V^2}{R} = 4P_S$

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: $$\frac{1}{R_P}=\frac{1}{500}+\frac{1}{700}=\frac{12}{3500} \qquad R_P=\frac{3500}{12}$$

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 $$V_{bc}=IR_P=17\times10^{-3}\cdot 292=4.96V$$

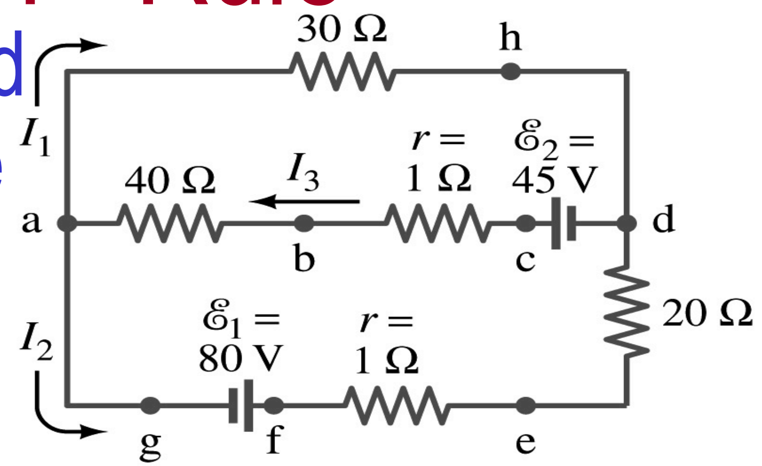
The current flowing across 500-Ω resister is therefore

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

What is the current flowing 700-Ω resister?

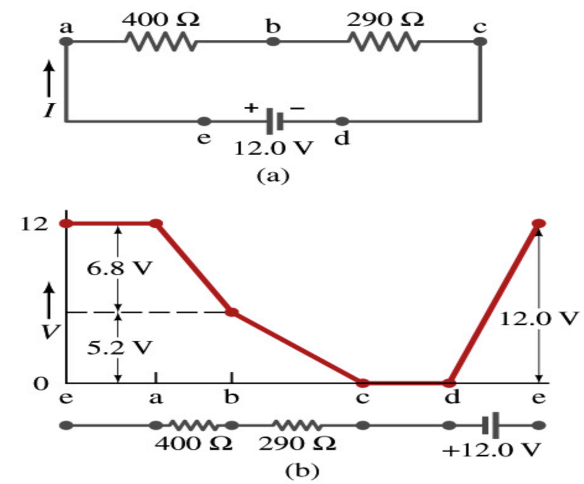
$$I_{700}=I-I_{500}=17-9.92=7.08mA$$

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.