PHYS 1441 – Section 001
Lecture #12

Thursday, June 25, 2020

Dr. Jaehoon Yu

CH 26

- That one example problem!
- Kirchhoff's Rules
- EMFs in Series and Parallel
- RC Circuits

CH 27: Magnetism and Magnetic Field

- Electric Current and Magnetism
- Magnetic Forces on Electric Current
- About Magnetic Field

Announcements

- We will have a mid-term grade discussion today ➔ We will have a class till 11:30am, followed by the discussion on zoom
  - Will use breakout rooms, one student in each room (must stay connected to zoom!)
  - Last name A – K:11:30 – 12:00
  - Last name L – Z: 12:00 – 12:30
- Quiz #3 on Quest
  - Beginning of the class coming Monday, June 29
  - Covers CH25.4 – what we finish today (CH26.5?)
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the exam
  - No derivations, word definitions, figures, pictures, arrows, or setups or solutions of any problems!
  - No additional formulae or values of constants will be provided!
  - Must send me the photos of front and back of the formula sheet, including the blank, no later than 10am tomorrow
    - Once submitted, you cannot change, unless I ask you to delete some part of the sheet!

Reminder: Special Project #4

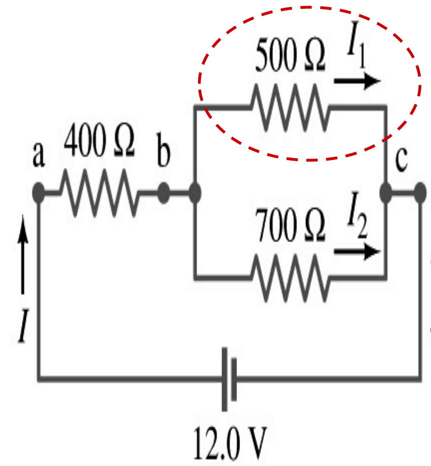
- Make a list of the power consumption and the resistance of all electric and electronic devices at your home and compile them in a table. (10 points total for the first 10 items and 0.5 points each additional item.)
- Estimate the cost of electricity for each of the items on the table using your own electric cost per kWh (if you don't find your own, use $0.12/kWh) and put them in the relevant column. (5 points total for the first 10 items and 0.2 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. (8 points)
- Due: Beginning of the class Tuesday, June 30
  - Scan all pages of your special project into the pdf format
  - Save all pages into one file with the filename SP4-YourLastName-YourFirstName.pdf
  - Send me the file in an email with the subject SP4 Submission

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

Resistor and Capacitor Arrangements

- Parallel Capacitor arrangements $$C_{eq} = \sum_i C_i$$
- Parallel Resistor 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 Resistor arrangements $$R_{eq} = \sum_i R_i$$

Example 26 – 5



Current in one branch. What is the current flowing through the 500-Ω resistor 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: $\frac{1}{R_P} = \frac{1}{500} + \frac{1}{700} = \frac{12}{3500}$ $\quad R_P = \frac{3500}{12}$

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 $V_{bc} = IR_P = 17 \times 10^{-3} \cdot 292 = 4.96V$

The current flowing across 500-Ω resistor is therefore

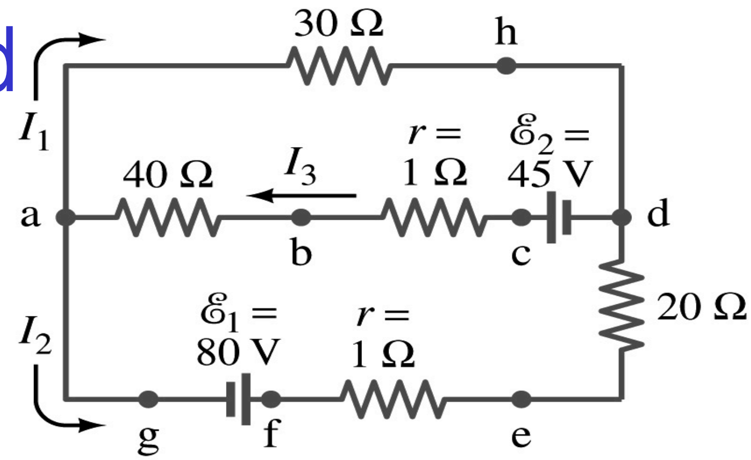
$$V_{bc} I_{500} = \frac{V_{bc}}{R} = \frac{4.96}{500} = 9.92 \times 10^{-3} = 9.92mA$$

What is the current flowing 700-Ω resistor?

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

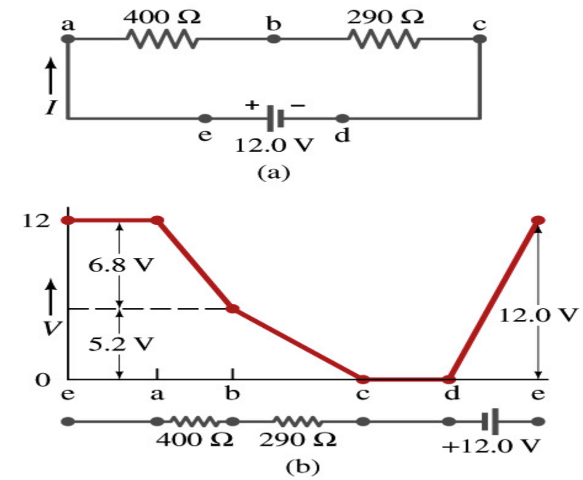
Kirchhoff's Rules – the 1st Rule

- Some circuits are very complicated to do the analysis using the simple combinations of resistors
  - 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 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 – the 2nd Rule

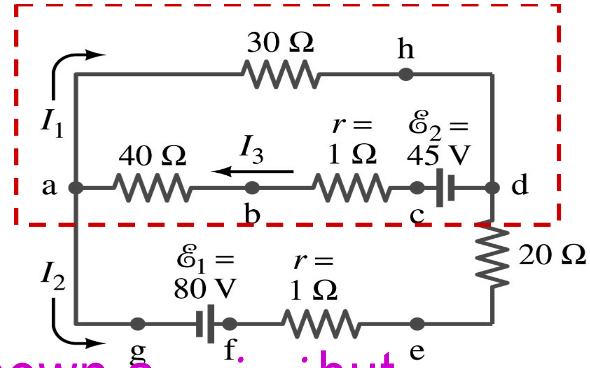


- Kirchoff's 2nd rule: The loop rule, **Conservation of energy**. (poll13)
  - The sum of the changes in potential in any closed path of a circuit must be zero.
- The current in the circuit in the figure is I=12/690=0.017A .
  - Point *e* is the high potential point while point *d* is the lowest potential.
  - 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 .

Using Kirchhoff's Rules

1. Determine direction of 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!
   - 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 equations are the same.
3. Choose closed loops in the circuit
4. Write down the potential in each interval of the junctions, keeping the sign properly.
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.

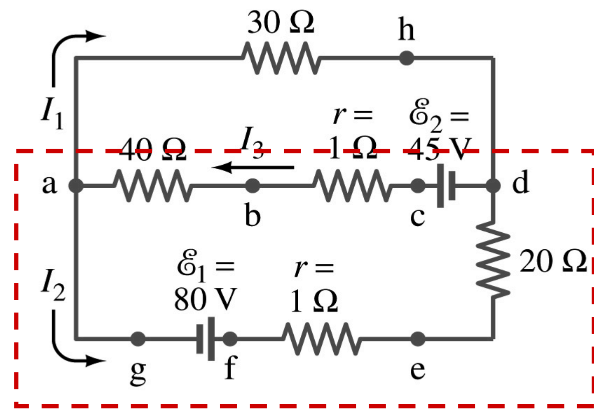
Now the second rule on the loop *ahdcba*.

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

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

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

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!!