

PHYS 1442 – Section 001

Lecture #8

Monday, June 17, 2013

Dr. Jaehoon Yu

- Chapter 18
 - Superconductivity
 - Electric Hazards
- Chapter 19
 - EMF and Terminal Voltage
 - Resistors in Series and Parallel
 - Energy losses in Resistors
 - Kirchhoff's Rules
 - EMFs in Series and Parallel
 - Capacitors in Series and Parallel
 - RC Circuit

Monday, June 17, 2013



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Announcements

- Mid-term exam
 - This Wednesday, June 19
 - Comprehensive exam
 - Covers CH16.1 – what we finish tomorrow, Tuesday, June 18 plus Appendices A1 – A8
- Quest payment of \$25 each
 - Deadline is June 28.
 - If not paid, your homework access will be disabled.
- Will have a mid-term grade discussion
 - Between 2 – 3:30 pm this Friday, June 21
 - In Dr. Yu's office (CPB342)



Special Project #3

- 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 Thursday, June 20

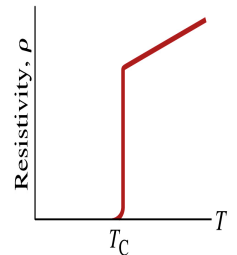
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Superconductivity

- At the temperature near absolute 0K, resistivity of certain material becomes 0Ω .
 - This state is called the “superconducting” state.
 - Observed in 1911 by H. K. Onnes when he cooled mercury to 4.2K (-269°C).
 - Resistance of mercury suddenly dropped to 0Ω .
 - In general superconducting materials become superconducting at the transition temperature or critical temperature.
 - The highest temperature superconductivity seen is 160K
 - First observation above the boiling temperature of liquid nitrogen is in 1987 at 90k observed from a compound of yttrium, barium, copper and oxygen.
- Since much smaller amount of material can carry just as much current more efficiently, superconductivity can make electric cars more practical, computers faster, and capacitors store higher energy



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Electric Hazards: Leakage Currents

- How does one feel shock by electricity?
 - Electric current stimulates nerves and muscles, and we feel a shock
 - The severity of the shock depends on the amount of current, how long it acts and through what part of the body it passes
 - Electric current heats tissues and can cause burns
- Currents above 70mA on a torso for a second or more is fatal, causing the heart to function irregularly, “ventricular fibrillation”
- A dry human body between two points on opposite side of the body is about 10^4 to $10^6 \Omega$.
- When wet, it could be $10^3 \Omega$.
- A person in good contact with the ground who touches 120V DC line with wet hands can get the current:
 - Could be lethal

$$I = \frac{V}{R} = \frac{120V}{1000\Omega} = 120mA$$

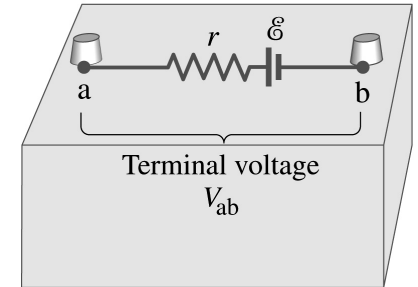


EMF and Terminal Voltage

- What do we need to have current in an electric circuit?
 - A device that provides a potential difference, such as a battery or a generator
 - They normally convert some types of energy into electric energy
 - These devices are called source of the electromotive force (emf)
 - emf does NOT refer to a real “force”.
- Potential difference between terminals of an emf source, when no current flows to an external circuit, is called the emf ($\mathcal{E}$) of the source. What is the unit of the emf? V
- Battery itself has some **internal resistance** (r) due to the flow of charges in the electrolyte
 - Why does the headlight dim when you start the car?
 - The starter needs a large amount of current but the battery cannot provide charge fast enough to supply current to both the starter and the headlight



EMF and Terminal Voltage



- Since the internal resistance is inside the battery, we can never separate them out.
- So the terminal voltage difference is $V_{ab} = V_a - V_b$.
- When no current is drawn from the battery, the terminal voltage equals the emf which is determined by the chemical reaction; $V_{ab} = \mathcal{E}$.
- However when the current I flows naturally from the battery, there is an internal drop in voltage which is equal to Ir . Thus the actual **delivered** terminal voltage of a battery in a circuit is $V_{ab} = \mathcal{E} - Ir$.

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 quantity is the same for resisters in a circuit connected in series?

- Current is the same through all the elements in series

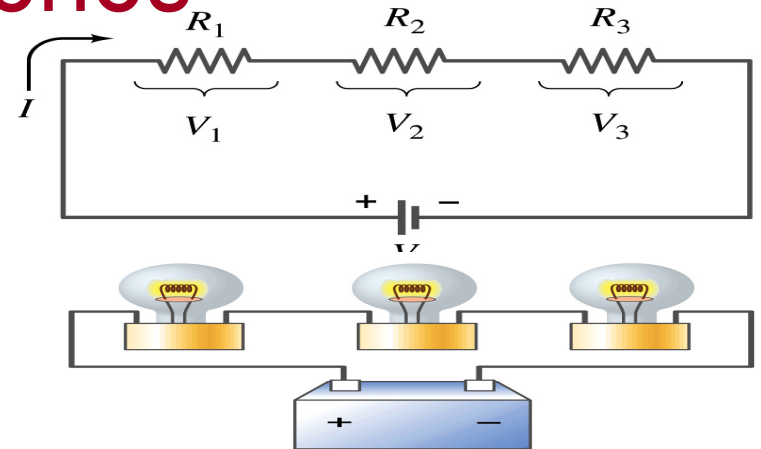
- Potential difference across every element in the circuit is

- $V_1=IR_1$, $V_2=IR_2$ 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, $R_{eq}=R_1+R_2+R_3$



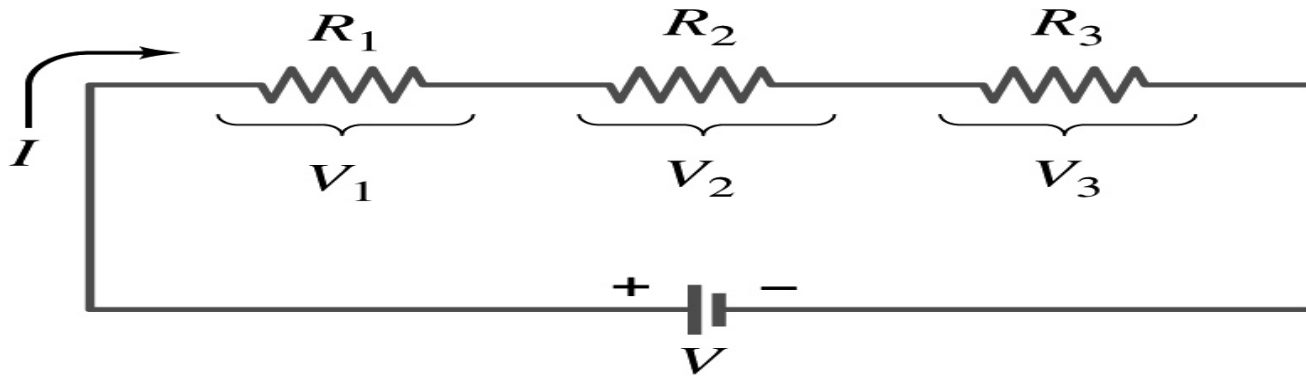
$$R_{eq} = \sum_i R_i$$

Resisters
in series

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

Energy Losses in Resistors

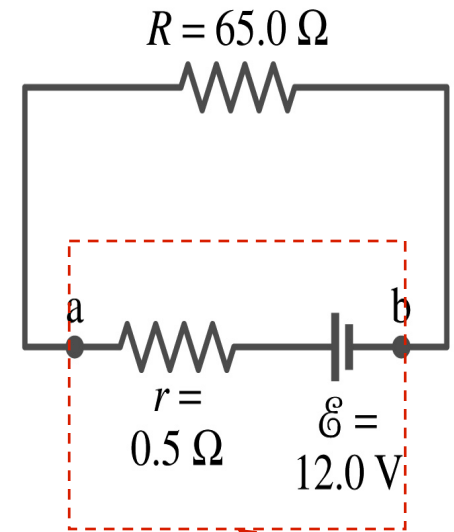
- Why is it true that $V=V_1+V_2+V_3$?



- What is the potential energy loss when charge q passes through the resistor 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 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 19 – 1

Battery with internal resistance. A $65.0\text{-}\Omega$ resistor is connected to the terminals of a battery whose emf is 12.0V and whose internal resistance is $0.5\text{-}\Omega$. 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.



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

Solve for I

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

What is this?

A battery or a source of emf.

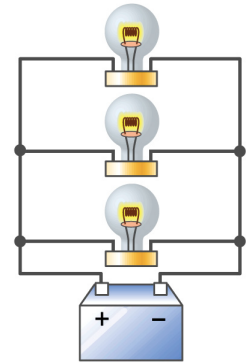
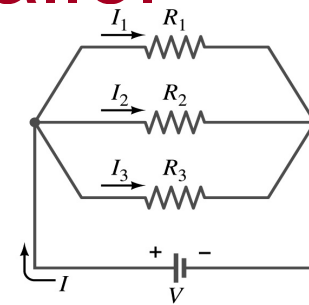
(b) The terminal voltage V_{ab} is $V_{ab} = \mathcal{E} - Ir = 12.0\text{V} - 0.183\text{A} \cdot 0.5\Omega = 11.9\text{V}$

(c) The power dissipated in R and r are $P = I^2 R = (0.183\text{A})^2 \cdot 65.0\Omega = 2.18\text{W}$

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

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 quantity is the same for the resisters in a circuit connected in parallel?
 - The voltage is the same across all the resisters.
 - The total current that leaves the battery, is however, split through the branches.
- 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, $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3$



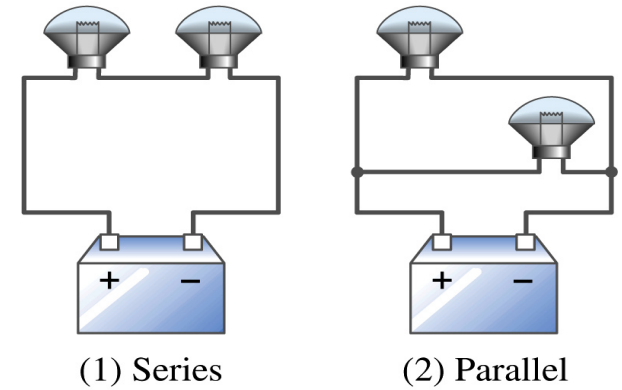
$$\frac{1}{R_{eq}} = \sum_i \frac{1}{R_i}$$

**Resisters
in parallel**

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

Example 19 – 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?

$$\begin{array}{ccc} \text{Series} \rightarrow & R_{eq} = 2R & \text{Parallel} \rightarrow \frac{1}{R_{eq}} = \frac{2}{R} \quad \text{So} \rightarrow R_{eq} = \frac{R}{2} \end{array}$$

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

$$\begin{array}{ll} \text{series} & P_S = IV = \frac{V^2}{R_{eq}} = \frac{V^2}{2R} \\ \text{parallel} & P_P = IV = \frac{V^2}{R_{eq}} = \frac{2V^2}{R} = 4P_S \end{array}$$

So parallel circuit provides brighter lighting.

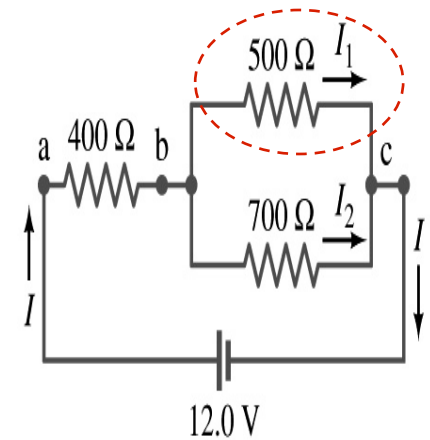
(b) Car's headlights are in parallel to provide brighter lighting and also to prevent both lights going out at the same time when one burns out.

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

Example 19 – 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: $\frac{1}{R_P} = \frac{1}{500} + \frac{1}{700} = \frac{12}{3500}$ $R_P = \frac{3500}{12}$

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

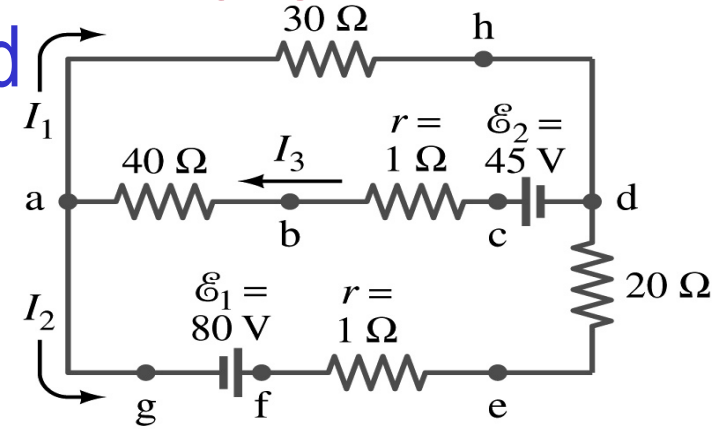
$$I_{500} = \frac{V_{bc}}{R} = \frac{4.96}{500} = 9.92 \times 10^{-3} = 9.92mA$$

What is the current flowing thru 700- Ω resistor?

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

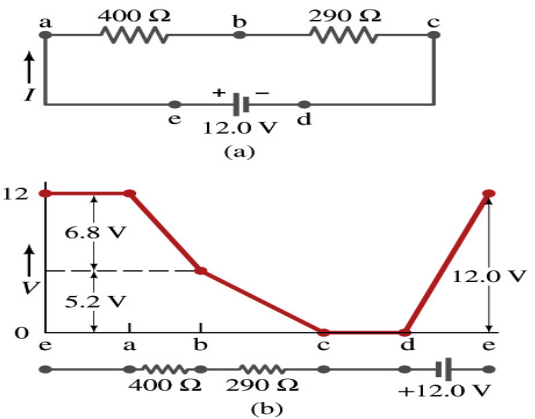
Kirchhoff's Rules – 1st Rule

- Some circuits are very complicated to analyze 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: 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 – 2nd Rule

- Kirchoff's 2nd rule: Loop rule, uses conservation of energy.
 - The sum of the changes in potential around any closed path of a circuit must be zero.



- The current in the circuit in the figure is $I=12/690=0.017\text{ A}$.
 - Point e is the highest 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 or any resistance to drop potential.
 - Between a and b , there is a $400\ \Omega$ resistance, causing $IR=0.017 \times 400 = 6.8\text{ V}$ drop.
 - Between b and c , there is a $290\ \Omega$ resistance, causing $IR=0.017 \times 290 = 5.2\text{ V}$ drop.
 - Since these are voltage drops, we use negative sign for these, -6.8 V and -5.2 V .
 - No change between c and d while from d to e there is $+12\text{ V}$ change.
 - Thus the total change of the voltage through the loop is: $-6.8\text{ V} - 5.2\text{ V} + 12\text{ V} = 0\text{ V}$.

Using Kirchhoff's Rules

1. Determine the flow of currents at the junctions.
 - It does not matter which direction of the current you choose.
 - If the value of the current after completing the calculations are negative, you just 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 independent closed loops in the circuit
4. Write down the potential in each interval of the junctions, keeping the signs properly.
5. Write down the potential equations for each loop.
6. Solve the equations for unknowns.

