Week 4

Physics 1409/1430 – Physics 2

Hello and Welcome to the weekly resources for PHY 1409/1430 – Physics 2!

This week is Week 4 of classes, and typically in this week of the semester, your professors are covering these topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to take a look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.

If you have any questions about these study guides, group tutoring sessions, private 30-minute tutoring appointments, the Baylor Tutoring YouTube channel or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours, M-Th 9am-8pm on class days, at 254-710-4135.

Keywords: Electric Current, Ohm's Law, Kirchoff's Rules

Important Notes

Important Conventions

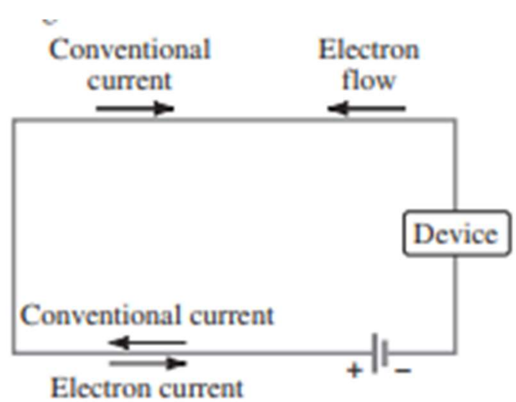
Topic of the Week : Electric Circuit

Highlight 1: Electric Current:

The flow of charges in the wire is referred to as electric current. It is the net amount of charge that is passing through a cross section of the wire in at any point of the circuit per unit time.

$$I = \frac{\Delta Q}{\Delta t}$$

The SI unit for current is Ampere (A). For a circuit to be considered complete, there has to be a continuous conducting path between the positive and negative terminal of the battery. If the circuit is not complete, no current can flow through it. One common thing you will notice is that most of the conventions based around electricity rotate around the effects on positive charges. When these conventions were first laid down, it was believed that electricity was the flow of positive charges. But it was later discovered that electricity consisted of negative charges. But the only thing it changed was the directions and signs for the conventions



and mathematics that was laid down for electricity, so physicists decided to keep the old conventions and keep in mind that the reality is the flow electrons. So current that is defined by what you learn this semester is the conventional current. But, electrons flow the opposite way.

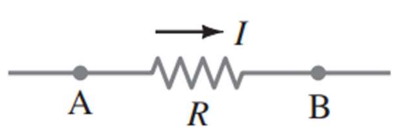
Highlight 2: Ohm's Law

For current to flow in a circuit, there must be a difference in potential. Charges leave the battery with the highest potential and move through the circuit losing their potential as they pass through wires and devices. Once the get to the negative end of the battery, they are at their lowest potential. The battery takes those charges and brings them back to the high potential so that they can continue the process. This idea is being stressed because it is extremely important later in the semester.

The magnitude of the current therefore is directly related to the voltage. The proportionality factor between them is called resistance. From that, we derive ohm's law as

$$V = IR$$

The resistance is more than just a proportionality constant. Resistance is the property that causes a drop in voltage because its impedes the flow of current. Think of the flow of current as a river and resistance as rock in the river. The water that interacts with the rocks is slowed down by the rocks. The more rocks there are, the slower the river flows. The same idea applies to resistance and current. The larger the resistance, the bigger the voltage drop in the circuit path. In the picture above, the device is the resistor. All electronic devices are resistors in a circuit. Resistors are represented as follows in a circuit. The SI unit of resistance is Ohms(Ω).



Example:

A 4.5 V battery is connected to a bulb whose resistance is 1.3 Ω. How many electrons leave the battery per minute?

Solution: (Note: Always Draw the circuit for better visualization)

V = IR (note: this is the most heavily used formula this semester)

4.5 = I (1.3)

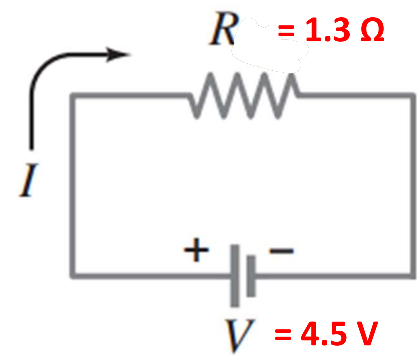
I = 4.5 / 1.3

I = 3.46 A (Note: I = Q/t)

Q/t = 3.46

Q / 60 = 3.46

Q = 207.6 C



Highlight 3: Resistivity:

Resistance is a property all materials possess. Resistance of conductors and insulators are what set them apart. Conductors are just really bad resistors whereas insulators are really good resistors. Resistance of a resistor is unique and can be changed by changing its physical characteristics. The resistance of a wire is directly proportional to the length of the wire and inversely proportional to the cross section area of the wire. The proportionality constant for the relation is resistivity. As an equation, it is as follows

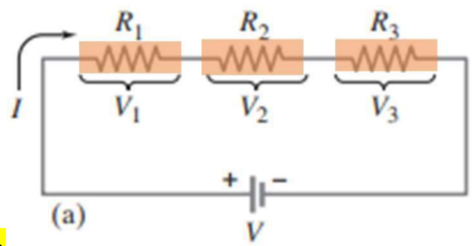
$$R = \rho \frac{\ell}{A}$$

Resistivity is the characteristic that is unique to each substance. It can only be affected by the temperature of the material. The resistance of a resistor can be changed by making the appropriate changes to the length and cross-section area of the resistor.

Highlight 4: Resistors in Series and in Parallel

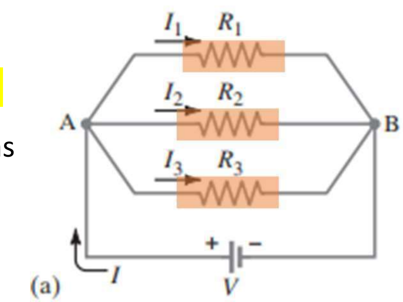
So far, you have looked at simple circuits involving only one resistor. But what happens when you put in multiple resistors in a circuit? There are rules to how you must analyze a circuit whenthis happens. The goal while working with complex circuits is to break it down to the simplest form and then working through the math. Resistors can be added to circuits in two ways.

The first way is in series. When resistors are in a series, they are placed on the same path. This is depicted on the right in the diagram. What we do when we have multiple resistors is that we combine the resistance of all the resistors in the circuitinto a equivalent resistor, which represents all the resistors in the circuit. When the resistors are in series, the equivalent resistance is calculated simply by adding the resistors in the circuit.



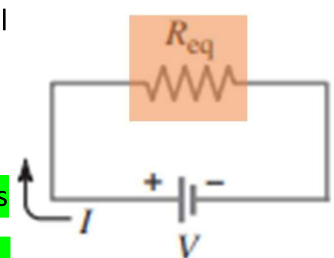
$$R_{eq} = R_1 + R_2 + R_3$$

The second way is in parallel. When resistors are in parallel, they are placed on different paths which are formed by junctions. The junctionbreaks into as many paths as the resistors in parallel. To find the equivalent resistance for resistors in parallel, you calculate it by adding up the reciprocal of each resistor individually.



$$1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 \ldots$$

There is one special thing about each type of resistor placement that is essential to know. For resistors in series, the current across the all the resistors is the same. For resistors in parallel, the voltage across the junctions is the same (between A and B in the second diagram, which also means it is the same across R_1, R_2 and R_3). These characteristics are highly important to always keep in mind. It makesanswering concept questions much easier.



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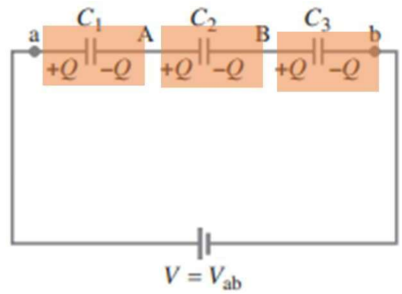
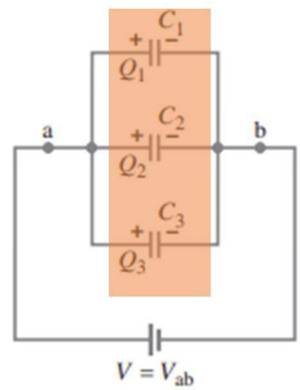
Capacitors in Series and in Parallel



Much like how resistors play a role in a circuit, capacitors are also placed in circuits. Capacitors can also be placed in parallel and in series but therules for breaking them down to the equivalent capacitors is the oppositeof what you see in resistors. For capacitors in series

$$C_{eq} = [(1/C_1) + (1/C_2) + (1/C_3) \ldots]^{-1}$$



For capacitors in parallel,

$$C_{eq} = C_1 + C_2 + C_3 \ldots$$

Highlight 5: Kirchhoff's Rules

Kirchhoff's are an essential tool for analyzing loops and paths in the circuit. It consists of two rules my high school physics teacher liked to call the duh rules of circuits.

1. At any junction point, the sum of all currents entering the junction equals the sum ofall currents leaving the junction.
2. The sum of the changes in potential around any closed loop of a circuit must be zero.

These rules are seemingly obvious, but their iteration is very important.Especially when you look at the circuit shown on the right. To better understand what is happening in the circuits, use these two rules to analyze the movement of the current and the changes in potential from one point to another.

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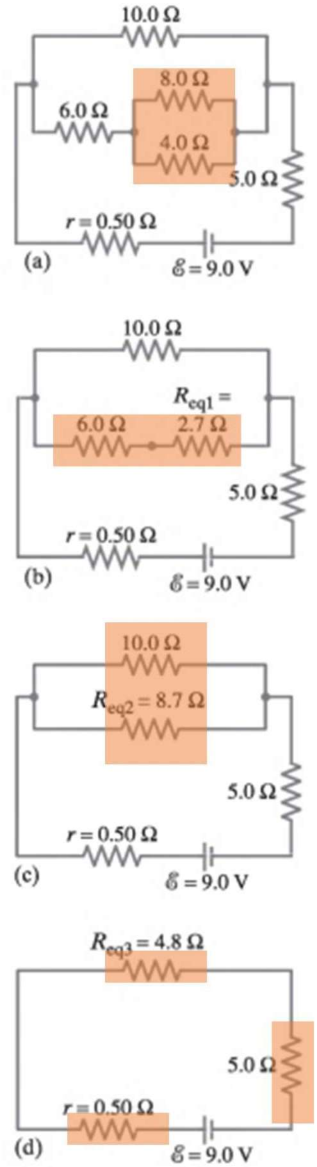
Example

A 9 V battery whose internal resistance r is 0.5 Ω is connected in the circuit shown in the figures. (a) How much current is drawn from the battery? (b) What is the terminal voltage of the battery? (c) What is the current in the 5 Ω resistor?



Solution

With questions like this, the first goal is to reduce the number of resistors, as shown in the diagram.

$R_{eq1} = [(1/4)+(1/8)]^{-1} = 2.7\ \Omega$

$R_{eq2} = 2.7 + 6 = 8.7\Omega$

$R_{eq3} = [(1/8.7) + (1/10)]^{-1} = 4.8\ \Omega$

$R_{eq4} = 4.8 + 0.5 + 5 = 10.3\Omega$

Now that we have R_{eq} for the circuit, we can calculate the I for the circuit

$V = I R$

$I = (9/10.8) = 0.87$ A

$V_{ab} = \mathcal{E} - Ir = 9 - (0.87)(0.5) = 8.6$ V

Notice that the 5Ω resistor is in series with the other complex of resistors. In the circuit, it is a series resistor. Hence, the current flowing in the overall circuit is the current flowing in that resistor. Hence

$I_{5\Omega} = 0.87$ A

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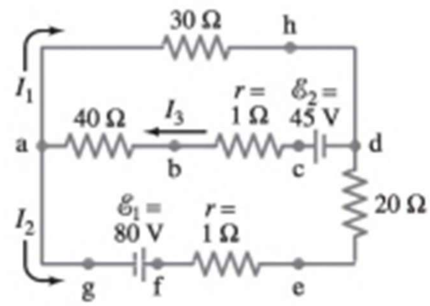
CHECK YOUR LEARNING

1. A 5 V battery is connected to a bulb whose resistance is 2 ohms. How many electrons leave the battery per minute?
2. Three 25 ohm lightbulbs and three 35 ohm lightbulbs are connected in series with a 100 V power source. What is the total resistance? What is the current in the circuit? What is the total resistance if the 25 ohm resistors in parallel are connected in series with the 35 ohm resistors also in parallel? What is the current across the 25 ohm and 35 ohm resistors?
3. Suppose you have a resistor in a simple circuit. Which of the following changes will increase the resistance by a factor of 4?
   a. Apply 4 times the voltage
   b. Apply 2 times the voltage
   c. Increase the cross-section area of the resistor by 4
   d. Decrease the cross-section area of the resistor by 1/4
4. Calculate the currents I_1, I_2, I_3 in the three branches of the circuit in the Figure.



THINGS YOU MAY STRUGGLE WITH

1. Remember ohm's law and memorize the formula. It is one of the most important equations this semester. The law not only applies to the entire circuit but also across individual resistors.
2. Remember the rules of finding the equivalent resistance and capacitance and the rules for the combination. The rules for the series and parallel connections for both are reversed. They can be easily confused so remember to practice using the rules with problems from the textbook
3. Much like capacitance, resistance is a physical property. It cannot be affected by changing the voltage in a circuit or across the resistor. It can only be changed by altering the cross-section area, the length of the resistor or the material for the resistor to a material with the desired resistivity.
4. Kirchoff's rules are difficult to use for circuits with multiple batteries. It will be most useful when you have multiple loops with more than one battery. Otherwise, ohms law should suffice for the circuit. Practice working on such circuits that require using Kirchoff's rule, they tend to be the most challenging.

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resource: www.baylor.edu/tutoring ! Answers to check you learning questions are below!

Answers: 1) 9.38×10^{20} electrons 2) 180 ohms, 0.56A, 5 A, 1.67 A and 1.67 A 3) D 4) $I_1 = -0.87A$, $I_2 = 2.6A$, $I_3 = 1.7A$

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