

Table of Contents

Pre-Assessment		2-8
Introduction		9-16
Chapter One	Introduction to the MR Board	17-24
Chapter Two	Basic Principles and Components of Electronics	25-31
Chapter Three	Series vs. Parallel Circuits	32-37
Chapter Four	Introduction to Resistance and the Color Code	38-41
Chapter Five	Introduction to Potential Difference and Circuits	42-49
Chapter Six	Introduction to Current and Switches	50-57
Chapter Seven	Ohm's Law Introduction	58-66
Chapter Eight	Introduction to Kirchhoff's Voltage Law	67-70
Chapter Nine	Introduction to Kirchhoff's Current Law	71-74
Chapter Ten	Basic Capacitor Circuits	75-78
Chapter Eleven	Analog vs Digital Electronics	79-84
Chapter Twelve	Binary Counting and the ASCII System	85-89
Chapter Thirteen	Truth Tables and Timing Diagrams	90-94
Chapter Fourteen	Logic Gates: AND, OR, & NOT	95-102
Chapter Fifteen	NAND & NOR GATES	103-108
Chapter Sixteen	XOR & XNOR GATES	109-115
Chapter Seventeen	De Morgan's Theorems	116-123
Chapter Eighteen	Duality of Logic	124-132
Chapter Nineteen	Boolean Expressions for Digital Circuits	133-143
Chapter Twenty	Logic Simplification	144-149
Post-Assessment		150-156
Teacher Answers		157-163

Name: _____

Date: _____

Period: _____

Electronics Pre-Assessment

Basic Demographics

Age: _____

Grade Level: _____

Gender: Male or Female

Ethnicity (optional): African American/Black Hispanic Asian Caucasian/White Pacific Islander

Other _____

First Spoken Language: _____

Opinions about the importance and study of electronics:

Use the rating scale to record your opinion regarding the following questions. Circle the statement the best describes how you feel.

1. I am excited about the study of electronics.	Not True	Sometimes True	Mostly True	Completely True
2. I think understanding electronics will be important for my future.	Not True	Sometimes True	Mostly True	Completely True
3. I will benefit from knowing about electronics.	Not True	Sometimes True	Mostly True	Completely True
4. I believe that there is an important link between electronics and video games.	Not True	Sometimes True	Mostly True	Completely True
5. Understanding how to turn a switch on and off is all the understanding that I need.	Not True	Sometimes True	Mostly True	Completely True
6. In the future I see myself in a career that requires no knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
7. In the future I see myself in a career that requires a basic knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
8. In the future I see myself in a career that requires an advanced knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
9. I spend some time each day thinking about how different electronic devices work.	Not True	Sometimes True	Mostly True	Completely True
10. I believe that there is an important link between electronics and computer	Not True	Sometimes True	Mostly True	Completely True

programming				
11. I think that electronics is confusing.	Not True	Sometimes True	Mostly True	Completely True
12. I think that studying electronics is very difficult.	Not True	Sometimes True	Mostly True	Completely True
13. I spend some time each week thinking about how different electronic devices work.	Not True	Sometimes True	Mostly True	Completely True
14. I think electronics is boring.	Not True	Sometimes True	Mostly True	Completely True
15. It is necessary to understand electronics to understand robotics.	Not True	Sometimes True	Mostly True	Completely True
16. I think that binary logic is an important part of electronics.	Not True	Sometimes True	Mostly True	Completely True
17. Studying electronics is something that is difficult for me.	Not True	Sometimes True	Mostly True	Completely True
18. I use electronics devices several times a day.	Not True	Sometimes True	Mostly True	Completely True
19. I believe there is a connection between electronics and science.	Not True	Sometimes True	Mostly True	Completely True

1. Do you think that an understanding of electronics principles is important for the average person? (Explain)

2. Would you like to study electronics more in school? Why would this be important?

3. Have you been taught electronics in your past? Yes No If yes, explain:

Electronics Content Knowledge

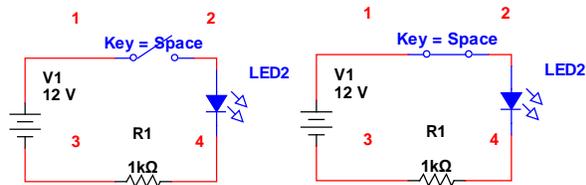
Solve the following questions to the best of your ability:

1. What will happen to the brightness of a light bulb if you reduce the voltage in electrical circuit it is in?

2. Explain your answer for the above question?

3. Do you know what a series circuit is? Yes No If yes please explain.

4. Which of the following examples is a complete circuit? (circle your answer)



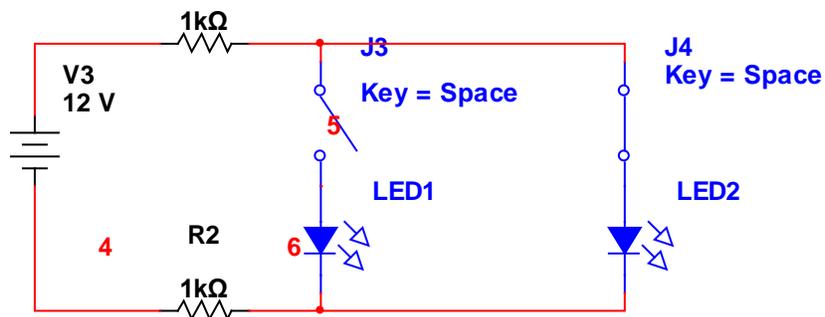
5. Why did you choose your answer for the above question?

6. Do you know what a parallel circuit is? Yes No If yes please explain.

7. Do your best to draw a series circuit containing a power source, LED, resistor, and switch in the space below.

8. Do your best to draw a parallel circuit containing a power source, 2 LEDs, and two resistors in the space below. The light bulbs should be able to function independently.

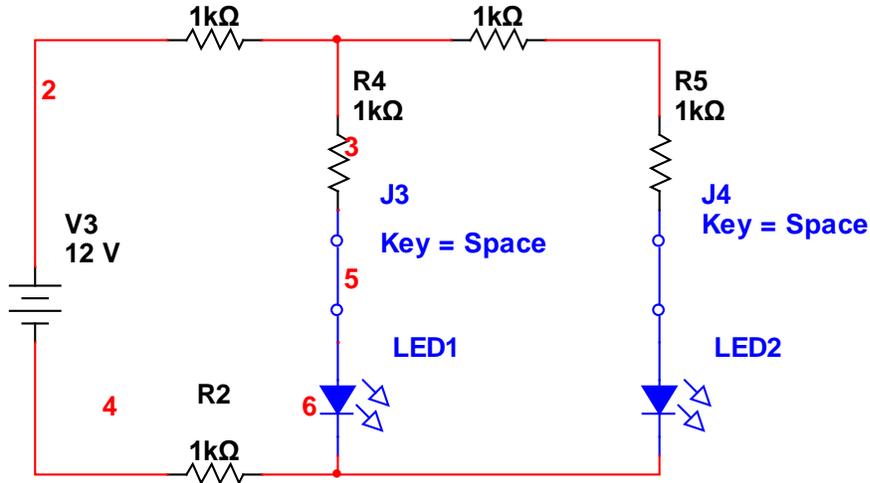
9. Describe what happens in the circuit below when J3 is opened.



10. Explain the purpose of a switch in an electrical circuit.

11. Explain how to measure resistance across a single component in an electrical circuit.

12. Which circuit below will have the brightest LED?



13. Explain your answer for the above question?

14. If a 5kΩ resistor has 4mA of current flowing through it, what is the voltage drop across it?

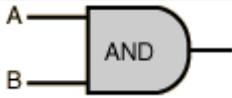
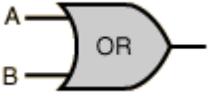
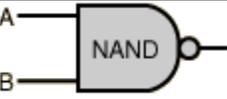
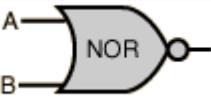
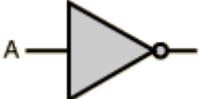
15. Explain how you figured out the answer to number 14.

16. What will be the sum of voltage drops in a circuit with a 12V power source? Explain.

17. What does a timing diagram show?

18. What is the difference between an analog and a digital circuit?

19. Complete the following table.

Gate	Logic Symbol	Boolean Equation	Truth Table		
			Inputs		Output
			B	A	Q
AND		AB	0	0	
			0	1	
			1	0	
			1	1	
OR		$A + B$	0	0	
			0	1	
			1	0	
			1	1	
NAND		\overline{AB}	0	0	
			0	1	
			1	0	
			1	1	
NOR		$\overline{A + B}$	0	0	
			0	1	
			1	0	
			1	1	
XOR		$A \oplus B$	0	0	
			0	1	
			1	0	
			1	1	
XNOR		$\overline{A \oplus B}$	0	0	
			0	1	
			1	0	
			1	1	
NOT		\overline{A}	-	0	
			-	1	

Future Ambitions

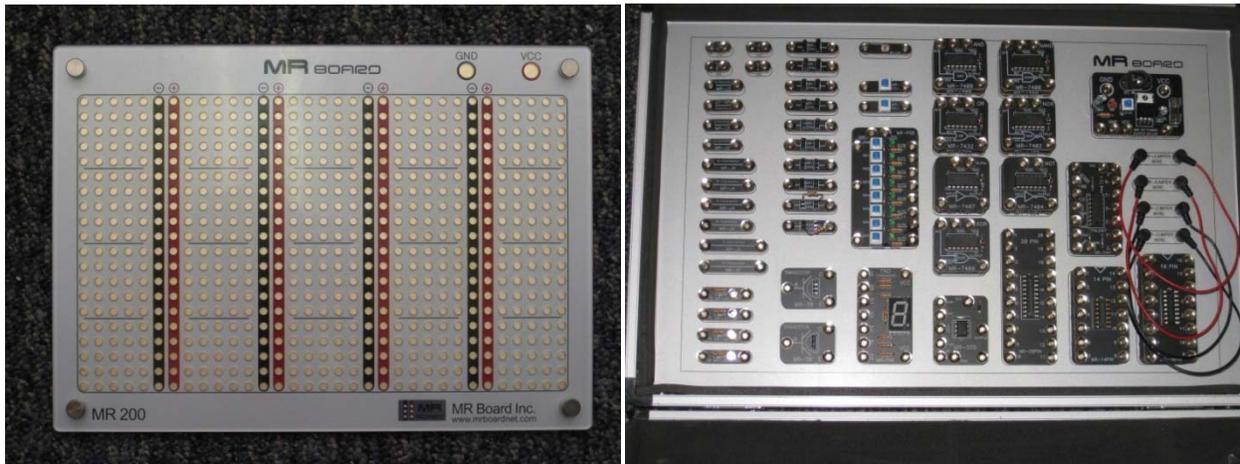
What interests you the most as an area for your future career?

- Business (What kind _____)
- Medical (What kind _____)
- Construction (What kind _____)
- Science (What kind _____)
- Engineering (What kind _____)
- Teaching (What kind _____)
- Law (What kind _____)
- Other

List the career options above that would be benefitted by an understanding of electronics.

What was your opinion of this survey? (was it difficult, frustrating, easy, fun, etc.) Explain.

THE MR BOARD



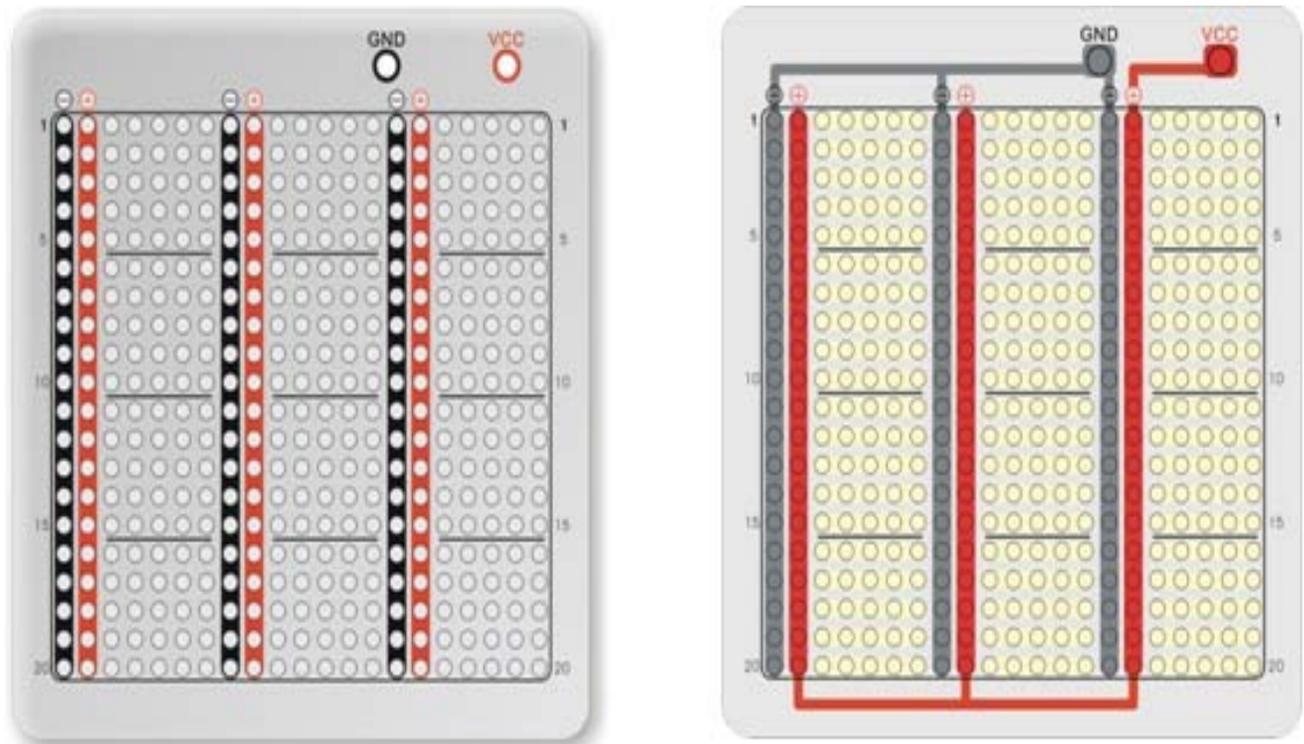
MAGNETOELECTRONIC REVOLUTION KIT FOR ANALOG AND DIGITAL ELECTRONICS

Introduction

The MR Board is a reusable magnetic breadboard device that eliminates the need to solder or strip wires when constructing an electronic circuit. By using components that connect through magnetic attraction to the board students are able to quickly check and expand their ideas regarding electronics concepts.

[Back to Table of Contents](#)

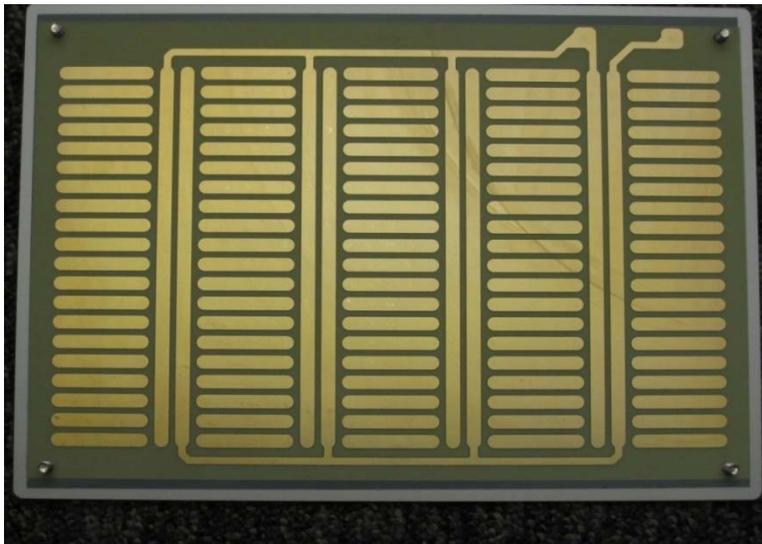
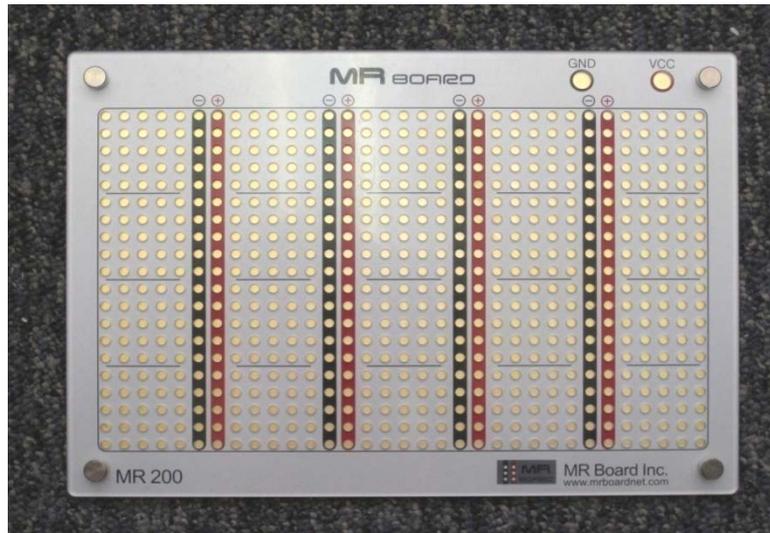
How it Works



The VCC (positive) and GND (negative), positioned at the top-right side of the board, are connected to holes of red lines and holes of black lines, respectively.

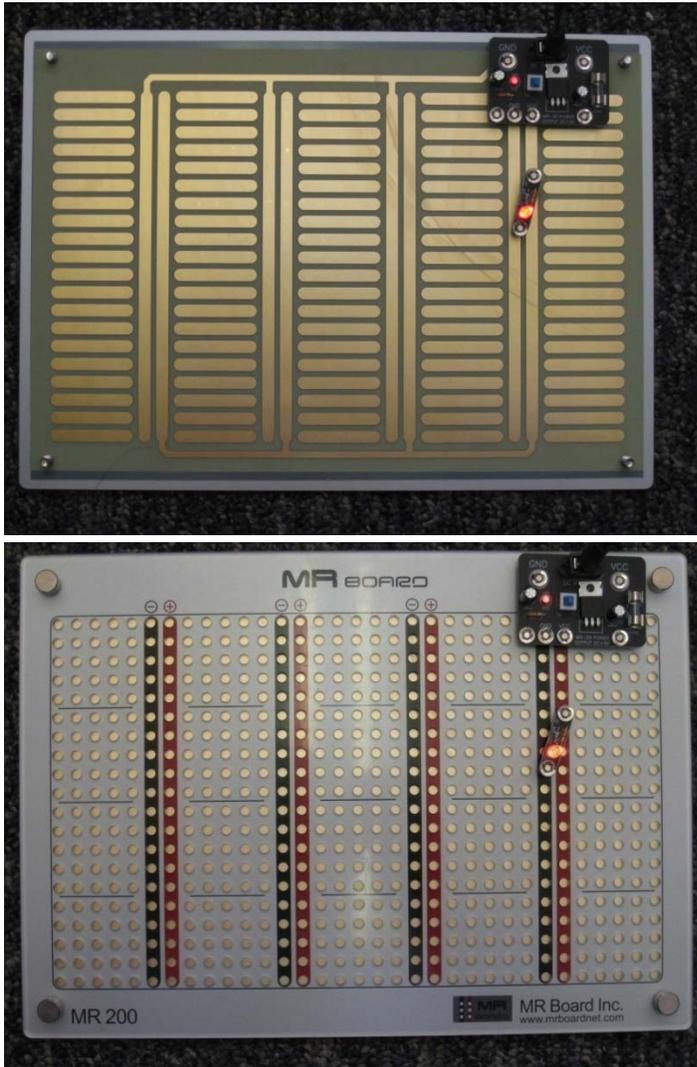
The power source to the Board is provided by connecting a DC 9V source to VCC and ground to GND. Therefore, once a source is connected to VCC and GND power is provided to all red vertical lines.

A Look Inside

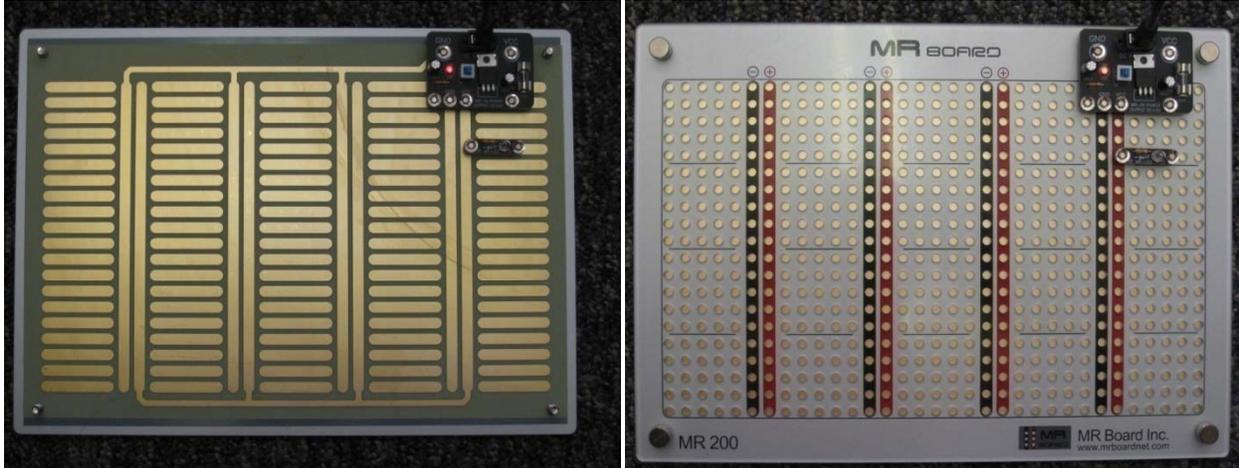


As shown above, there are sets of five holes horizontally in between a set of black and red vertical lines. The sets of five horizontal holes are connected by a conducting gold-coated metallic strip. If a signal is connected to one of the five holes, the other four will have the identical signal. These holes are used to connect different electronic MR components on the board.

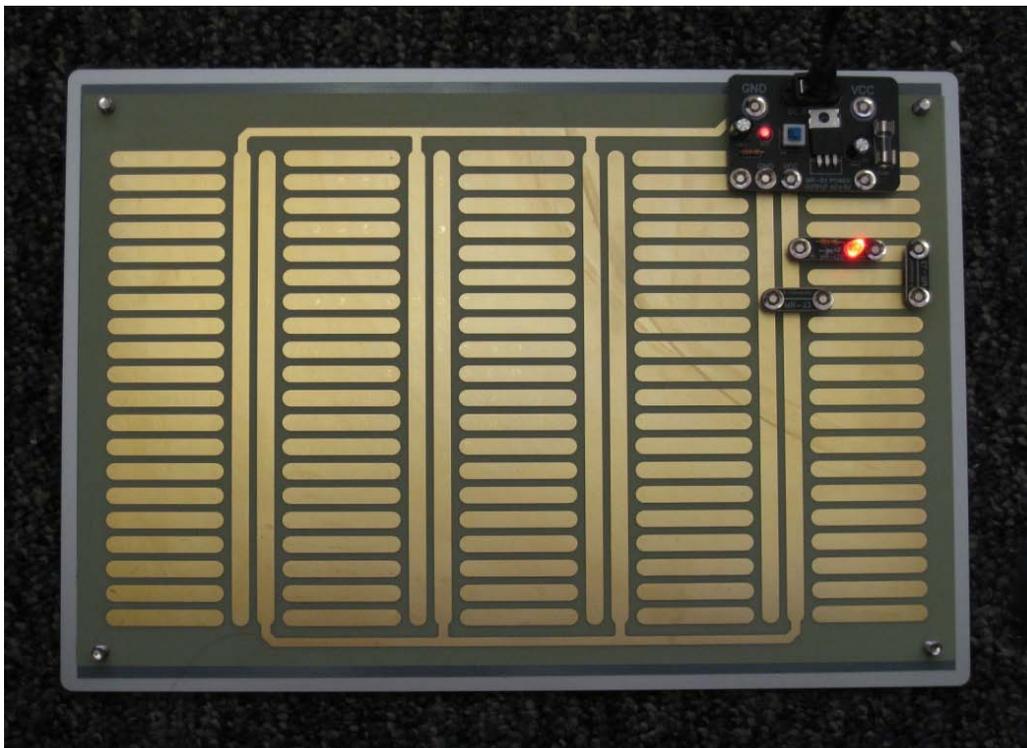
Simple Circuit Examples

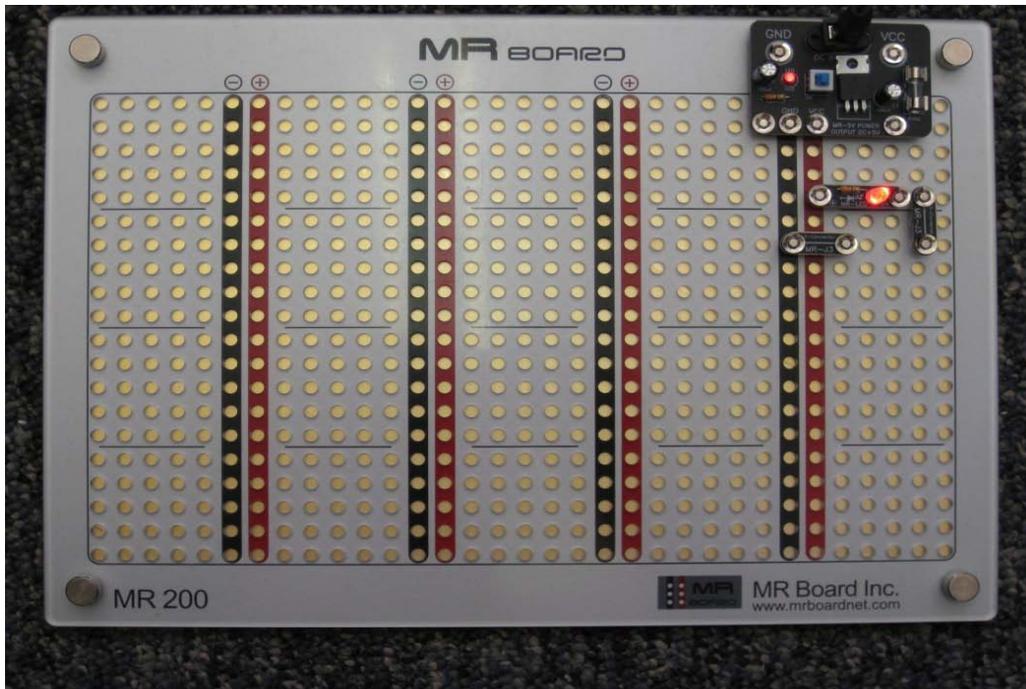


A circuit can be made on the MR Board by simply connecting the VCC to GND. Notice the picture above without the cover plate. Getting students to recognize the layout of the MR Board is the topic of the first lesson and is an essential foundational piece to build their knowledge upon. The same circuit is shown with the cover plate in place.



In this example the LED will not light up because there is no connection to ground. The following example will show how to complete the circuit.





Notice how the vertical lines are used to complete the circuit.

Taking Care of the MR Board

Due to the nature of the board, dust can settle into the connections sites. To make sure that an optimal connection is maintained periodic cleaning of the MR Board is necessary. It is appropriate to remove the cover and use a standard window cleaner to wipe down the conducting surface.

Note from the Author

Education is a lifelong pursuit. It happens every day in every situation. Students' formal education will help them throughout their life in ways they might never imagine. It is my job as a teacher to show students practical applications of the lessons they are being taught through activities that are relevant to the real world. The usefulness of what I teach depends on my students seeing the connection between life and what goes on in the classroom. I am responsible to help students make that connection. The MR Board is an incredibly valuable and versatile tool that facilitates creative thinking and allows students to explore their own ideas. It is a constant challenge and goal to find or create open ended inquiry activities that provide the scaffolding necessary to lead students toward a "discovery" of important concepts. The lessons contained in this manual are my best attempts to use the MR Board in reaching this goal.

The MR Board facilitates the learning of electronics concepts in a relevant way that provides students with the building blocks to construct their own knowledge. Students from elementary to college will benefit from the functionality and adaptability of this valuable tool.

We live in an age in which scientific and technological advances are common place and often taken for granted.

Students today need to be well versed in the language of technology in order to be wise consumers, responsible citizens, and participants in ongoing innovations of technology. That language is electronics. I give my full endorsement and recommendation to using the MR Board for the teaching and learning of basic and advanced analog and digital electronics.

Sincerely,

Matthew T. Smith
Science Teacher
Salt Lake Center for Science Education



Special Acknowledgments:

I would like to give thanks to Larry Madden and Ken O'Brien for their mentorship and helping to make this project possible. Niki Hack, and the staff at the Salt Lake Center for Science Education for their support and willingness to collaborate. Thanks also goes to the University of Utah, College of Education for offering suggestions and reviewing material associated with this curriculum.

Chapter One

Introduction to MR Board

[\(Back to Table of Contents\)](#)

Objectives

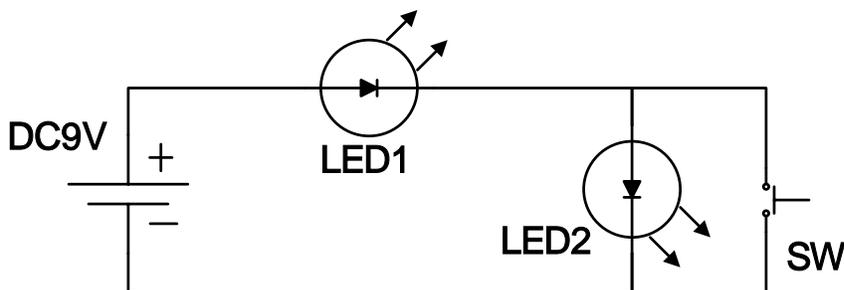
- Familiarize students with MB Board
- Improve students thinking skills
- Ease apprehensions regarding the MR Board
- Through experimenting with the MR Board students will gain an understanding of how to construct a series circuit with and without the cover on the MR Board

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



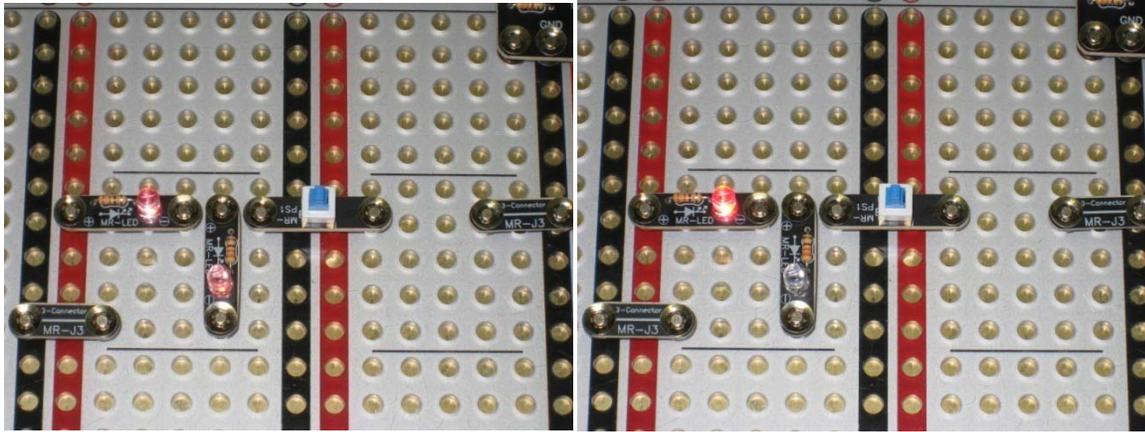


Figure 1: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

In this inquiry activity groups of up to three students will use a digital multimeter to discover how the dots are connected under the cover of the MR Board. The multimeter will allow student teams to investigate which dots have infinite resistance (not connected between) and which have conductivity (connection between dots). Using this information, students will draw solid lines through the dots that are connected. After students have had a chance to map out the internal connections of the MR Board the teacher will give instructions regarding how to remove the boards cover. Students will then be allowed to make adjustments to their connection maps in a different color if needed.

To further familiarize students with the MR Board instruct them on how to connect the power adapter then challenge them to use two connectors and an LED to make a complete circuit with the cover off of the MR Board. After completing this challenge students will replace the cover and create the circuit again.

Examples:

Ideal Student Investigation Results



Figure 2: Possible student map of MR Board connections.

Possible Circuits



Figure 3: Simple circuit example using two connectors and an LED. (cover off)

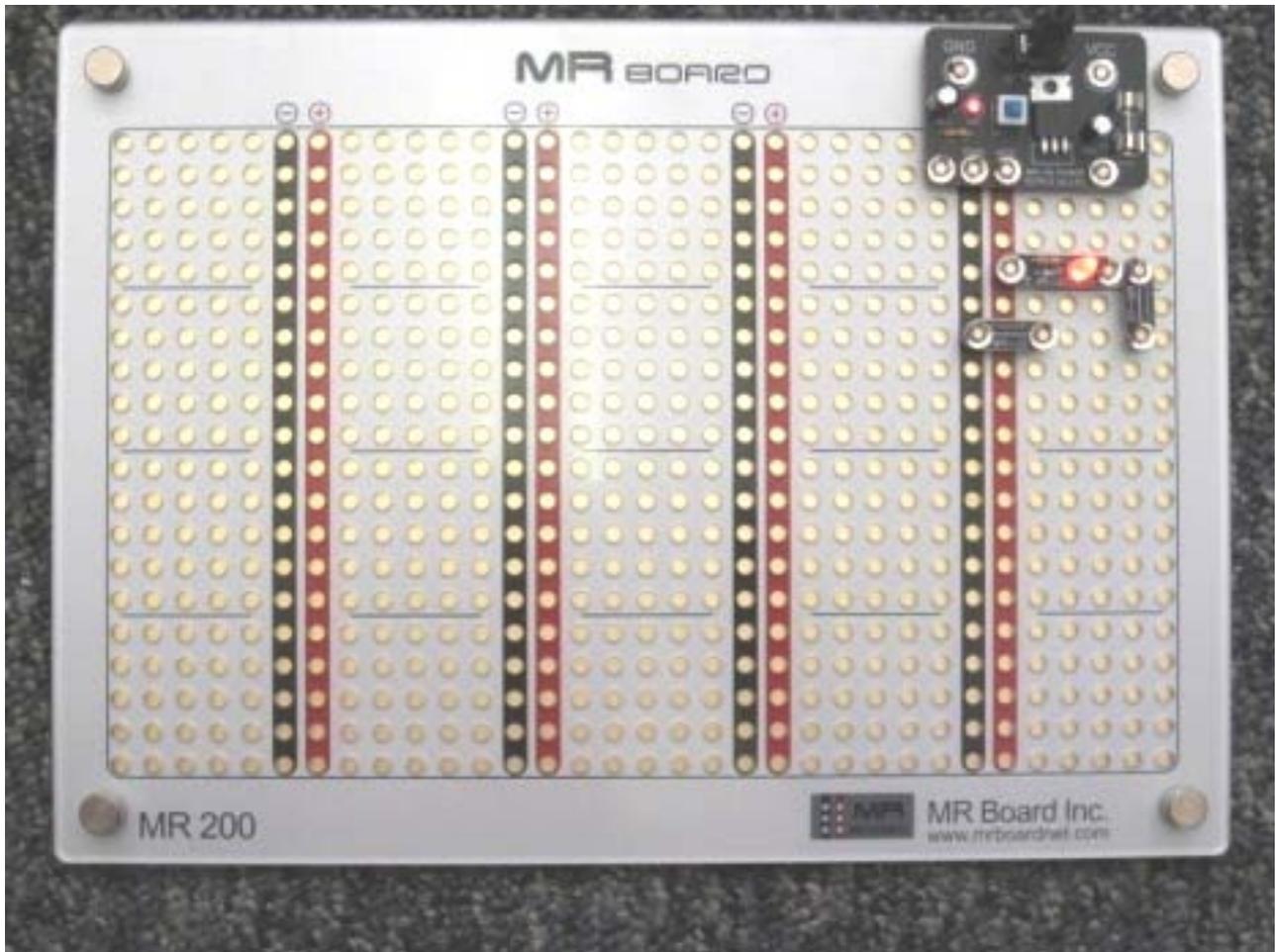
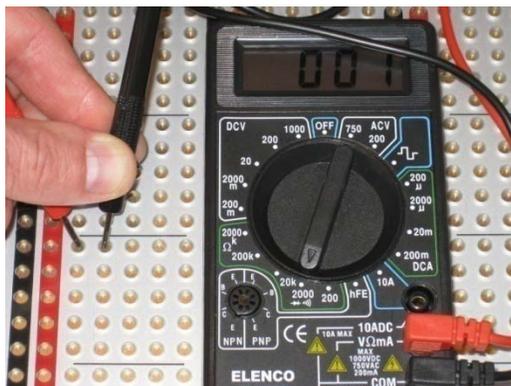


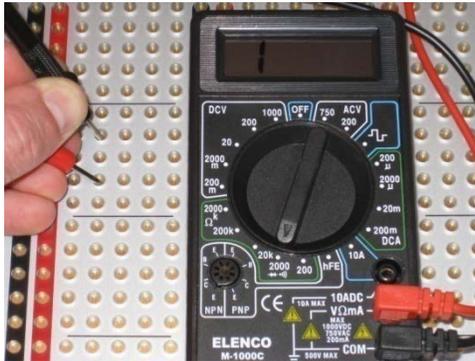
Figure 4: Simple circuit example using two connectors and an LED. (cover on)

Procedures:

1. The teacher will instruct students on the use of a multi-meter and introduce them to the MR Board. The picture below shows the proper setting on the multi-meter for checking conductivity. When there is a connection between two holes the meter will make a high pitched beep and show zero or near zero.



If the dots are not connected the meter will max out showing infinite resistance.



2. The teacher will go over the student sheet with the class and answer any questions that do not undermine the inquiry. It is important that students find the connections and create the circuits their self.

Name: _____

Date: _____

Period: _____

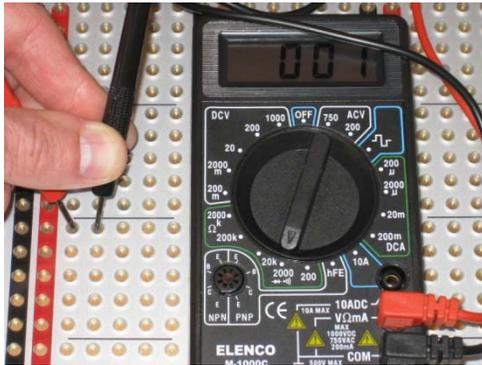
Introduction to the MR Board Student Sheet

Introduction:

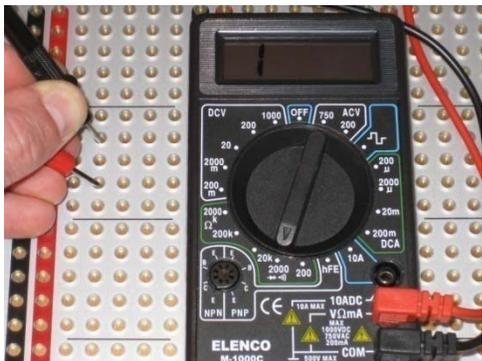
MR Board is a reusable magnetic breadboard device. By using components that connect through magnetic attraction to the board you will be able to quickly check and expand your ideas regarding electronics concepts. In this learning activity you will explore the functions of the MR Board, discover how the technology works, and use the components to build a simple circuit.

Procedures:

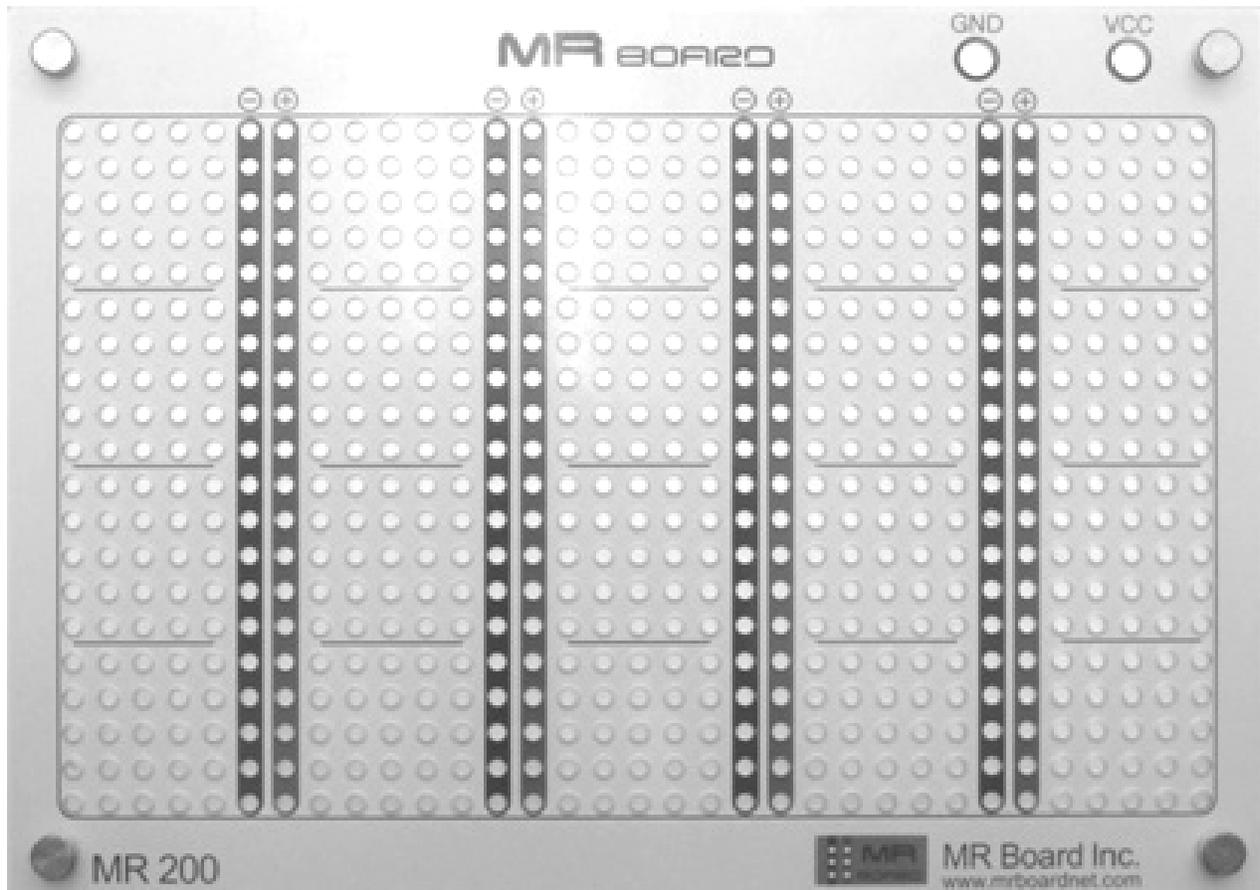
You and your group will investigate the MR Board using a digital multimeter. You will be checking for the amount of resistance between the dots on the MR Board. If the dots are connected the meter will show zero, or near zero, resistance and make a high pitched beep.



If the dots are not connected the meter will max out showing infinite resistance.



When you find that two dots are connected you should draw a line between them showing the connection. You are to repeat this process until you have completely mapped out the connections on the MR Board. You'll then be instructed on how to remove the cover plate and check your work. If you have made mistakes correct them at this time with a colored pencil. **Don't remove the cover plate until instructed to do so.**

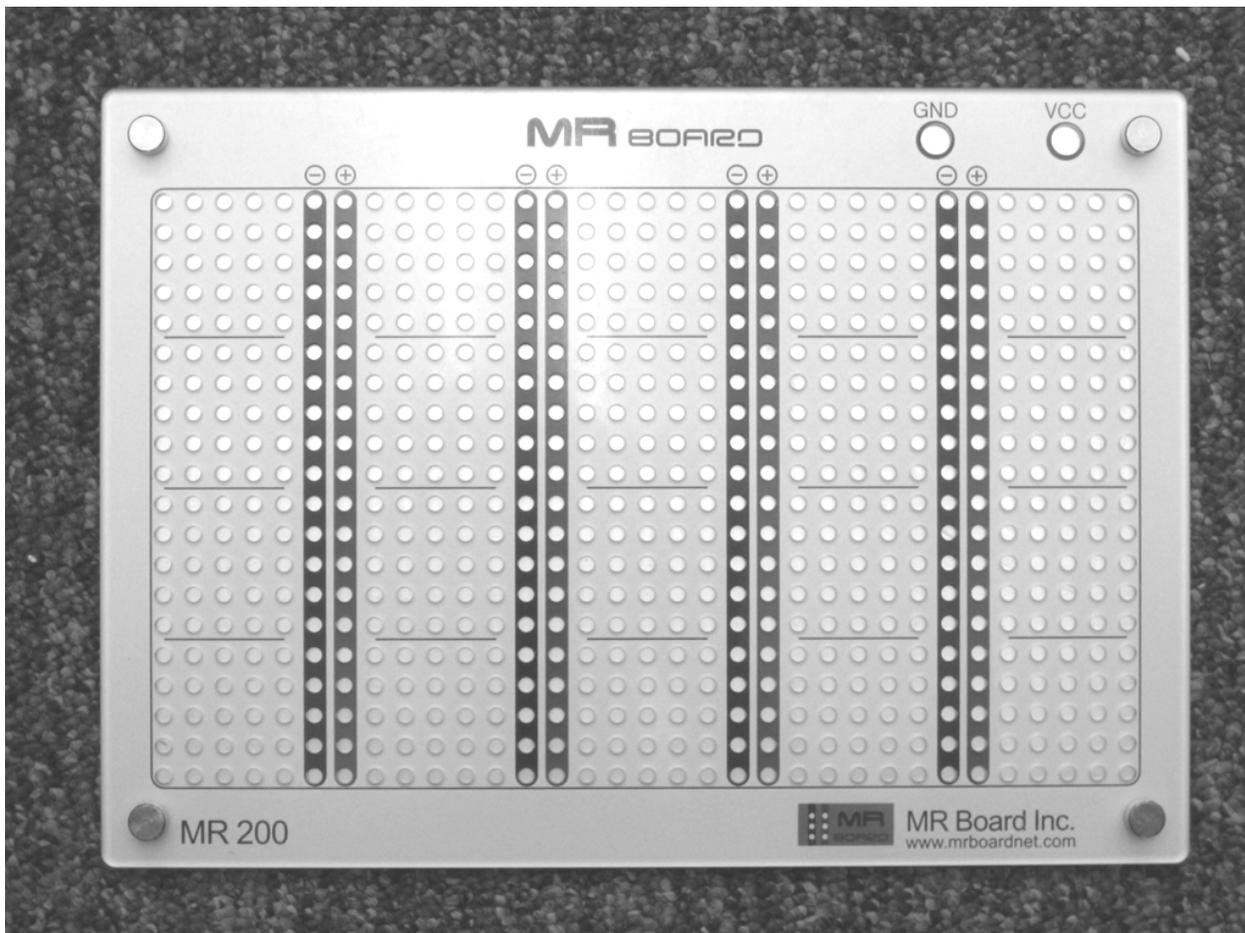


Now that we know a little bit about the MR Board and how it works let's plug it in. Your task is to create a simple circuit using two connectors and an LED. Make this Circuit with the cover off. Draw the circuit below.

Replace the cover on the MR Board and recreate the circuit.

Analysis Questions:

1. Could the LED be connected in any direction? Try it if you haven't yet.
2. Could you have built your circuit in other places on the MR Board? If so, how many?
3. Draw four examples of where your circuit could have been built?



Chapter Two

Basic Principles and Components of Electronics

[Back to Table of Contents](#)

Objectives

- To learn basic principles of electronics
- To distinguish between DC and AC
- To understand the concept of current, voltage, resistance, and capacitance
- To identify the schematic symbols for a battery, a voltage source, a current source, and a resistor

Basic Electric Variables

- Current
 - Current is the traveling or movement of electrons through a conducting pathway
 - Current is conventionally described as flowing from positive to negative which is the opposite direction that electrons move (negative to positive). This is because of an incorrect conjecture made by Ben Franklin regarding the direction of charge flow from smooth wax to rough wool. He set the convention that is still used today even though we now know that electrons are the packets of charge and that they move in the opposite direction that Franklin predicted (from the wool to the wax). By the time this understanding came to be, the nomenclature had been well established and no effort was made to change it. The terms used to describe current flow are merely human inventions and have no absolute meaning other than scientific description.
 - Unit of current: Ampere or Amp, represented by the letter A and symbol [I]
- Voltage (Potential Difference)
 - Potential energy that pushes electrons from an area of high concentration to an area of low concentration
 - The positive side of a battery is considered to have the potential to accept electrons and the negative side is considered to have the potential to donate electrons.
 - The greater the potential difference between the two sides the greater the voltage
 - Unit: Volt, represented by the letter V or E and the symbol [V]

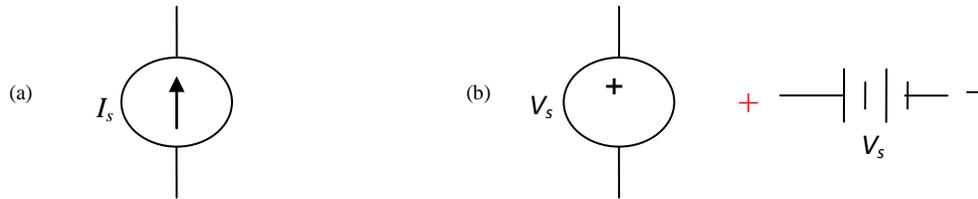


Figure 1: Schematic symbols for (a) a DC current source and (b) two DC voltage sources.

- Resistance

- Resistance is a friction against the flow of current.
- One volt can push 1A of current through 1 ohm of resistance. Thus, the current flow can be controlled by resistors in a circuit.
- Unit: ohm, represented by the letter R, and the symbol Ω .

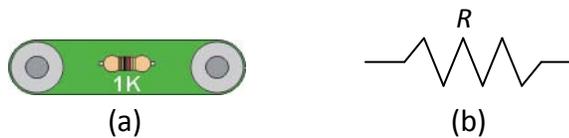


Figure 2: (a) MR module of a resistor (b) Schematic symbol for a resistor

- Capacitance

- Capacitance is a measurement of the amount of electrical charge a device can store for a certain electric potential.
- A capacitor is an electrical component or device used for the storage of charge.
- Unit: farad, represented by the letter C, and the symbol F.
- The millifarad (mF), the microfarad (μF), the nanofarad (nF), and the picofarad (pF) are the subunits of capacitance that are commonly used. The farad (F) is too large a value in a circuit.

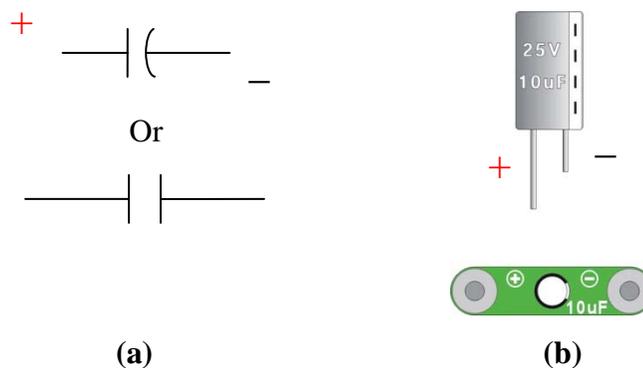


Figure 3: a) Schematic symbol for a capacitor. b) MR module of a capacitor

Lesson Progression

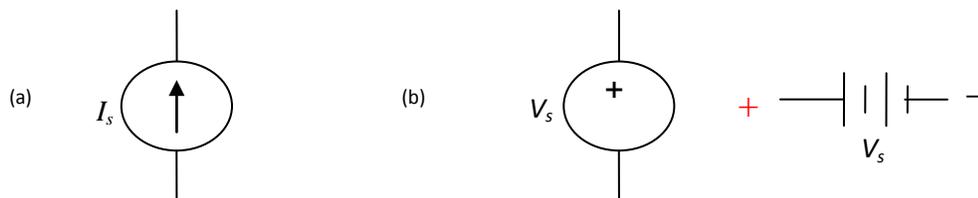
1. The teacher will explain to students that they are each going to be responsible for teaching a portion of today's lesson.
2. Students will be placed into groups of four and students in each individual group will be numbered from one to four.
3. The teacher will explain that the group students are currently in (teaching group) will be the group that they teach to after becoming and "expert" on one of the electronic variables from the lesson.
4. Students will then be placed in their expert group. This is the group in which students will learn about and discuss the electronic variable they have been assigned. Groups will be made using the numbers assigned in step 2. That is to say that the ones from each teaching group will be working together as an expert group. The twos will be together and so on.
5. Each expert group will be given the handout related to the four electronic variables. Students will be required to complete the section of the table that pertains to their assigned variable. They will write the definition of the variable in their own words, draw a picture that relates to the meaning of the variable (i.e. they could draw a picture of a river flowing a higher elevation to a lower elevation to represent current flowing from a higher electric potential to a lower electric potential), and write a question about the variable with an answer.
6. Expert groups will be given time to review the information in their handout and come up with a strategy for teaching the information to their teaching group. The teacher will circulate between groups during this time and ask questions to assess understanding.
7. After expert groups have prepared students will be placed back into their teaching group where they will take turns presenting their information. Students will complete the remainder of their handout within their teaching group.
8. When teaching groups have finished their task the teacher will facilitate a class discussion during which students will complete the Basic Principles and Components of Electronics handout.
9. Students will be given a short quiz regarding the four electronics variables covered in the lesson.

Current

- Current is the traveling or movement of electrons through a conducting pathway
- Current is conventionally described as flowing from positive to negative which is the opposite direction that electrons move (negative to positive). This is because of an incorrect conjecture made by Ben Franklin regarding the direction of charge flow from smooth wax to rough wool. He set the convention that is still used today even though we now know that electrons are the packets of charge and that they move in the opposite direction that Franklin predicted (from the wool to the wax). By the time this understanding came to be, the nomenclature had been well established and no effort was made to change it. The terms used to describe current flow are merely human inventions and have no absolute meaning other than scientific description.
- Unit of current: Ampere or Amp, represented by the letter A and symbol [I]

Voltage (Potential Difference)

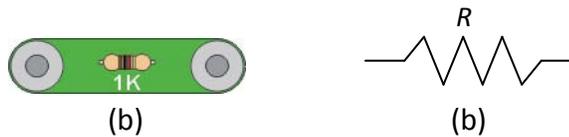
- Potential energy that pushes electrons from an area of high concentration to an area of low concentration
- The positive side of a battery is considered to have the potential to accept electrons and the negative side is considered to have the potential to donate electrons.
- The greater the potential difference between the two sides the greater the voltage
- Unit: Volt, represented by the letter V or E and the symbol [V]



Schematic symbols for (a) a DC current source and (b) a DC voltage source.

Resistance

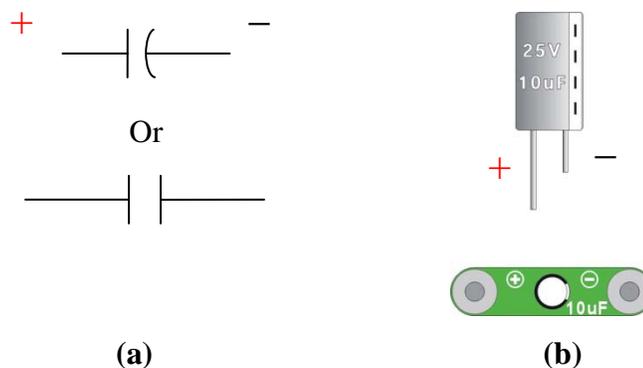
- Resistance is a friction against the flow of current.
- One volt can push 1A of current through 1 ohm of resistance. Thus, the current flows can be controlled by resistors in a circuit.
- Unit: ohm, represented by the letter R, and the symbol Ω .



(a) MR module of a resistor (b) Schematic symbol for a resistor

Capacitance

- Capacitance is a measurement of the amount of electrical charge a device can store for a certain electric potential.
- A capacitor is an electrical component or device used for the storage of charge.
- Unit: farad, represented by the letter C, and the symbol F.
- The millifarad (mF), the microfarad (μF), the nanofarad (nF), and the picofarad (pF) are the subunits of capacitance that are commonly used. The farad (F) is too large a value in a circuit.



a) Schematic symbol for a capacitor. b) MR module of a capacitor

Name: _____

Date: _____

Period: _____

Basic Principles and Components of Electronics Student Sheet

Instructions: Expert groups will complete their assigned section of the following table. After returning to their teaching group students will finish the remainder of the table based on what they are taught by the other group members.

Electronics Variable Table

Variable	Definition	Visual Interpretation	Question With Answer
Current			
Voltage			
Resistance			
Capacitance			

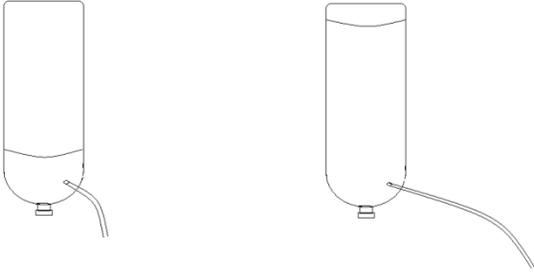
Name: _____

Date: _____

Period: _____

Quiz: Basic Principles and Components of Electronics

Use the following diagram to answer the first seven questions:



1. In the picture above what electronic variable does the size of the whole in the bottles represent?

2. Explain your answer to question number one.

3. In the picture above what electronic variable does the water level in the two bottles represent?

4. Explain you answer to question number three.

5. In the picture above what electronic variable does the water exiting the two bottles represent?

6. Explain you answer to question number five.

7. Circle the bottle above that has more electric Potential. Explain how you know. -

8. If you were building a circuit and need to store a charge which of the electronic variables would help you?

Chapter Three

Series and Parallel Circuits

[Back to Table of Contents](#)

Objectives

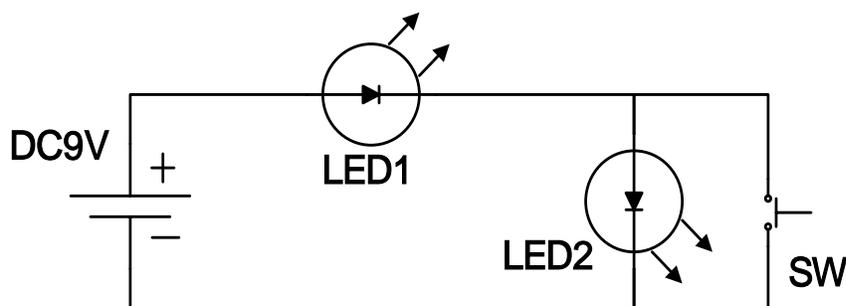
- Students will become further familiarize with the MB Board
- Students will demonstrate their understanding regarding topics covered in lesson two
- Improve students thinking skills
- Introduce students to series and parallel circuits

Materials

- MR Board Kit for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



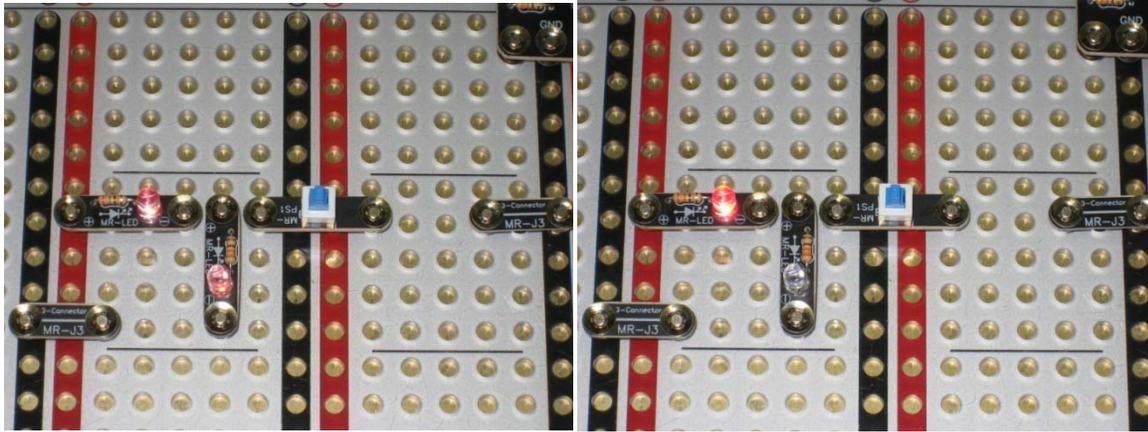


Figure 2: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Big Ideas and Important Concepts

- Series Circuit
 - A circuit with components connected in a way that provides a single path for electrons to flow through

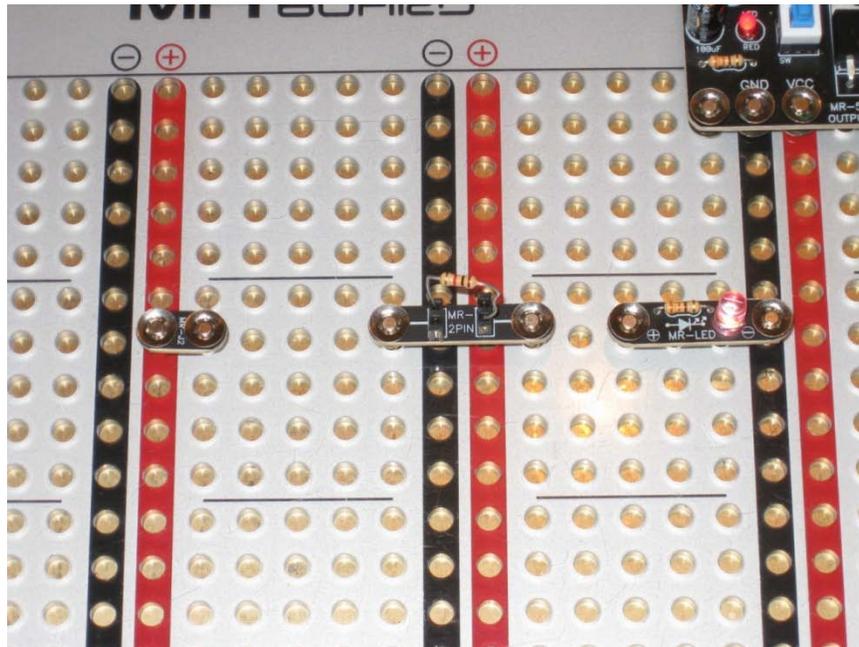


Figure 3: Example of a Series Circuit

- Parallel Circuit
 - A circuit with components connected in a way that provides multiple pathways for electrons to flow through.

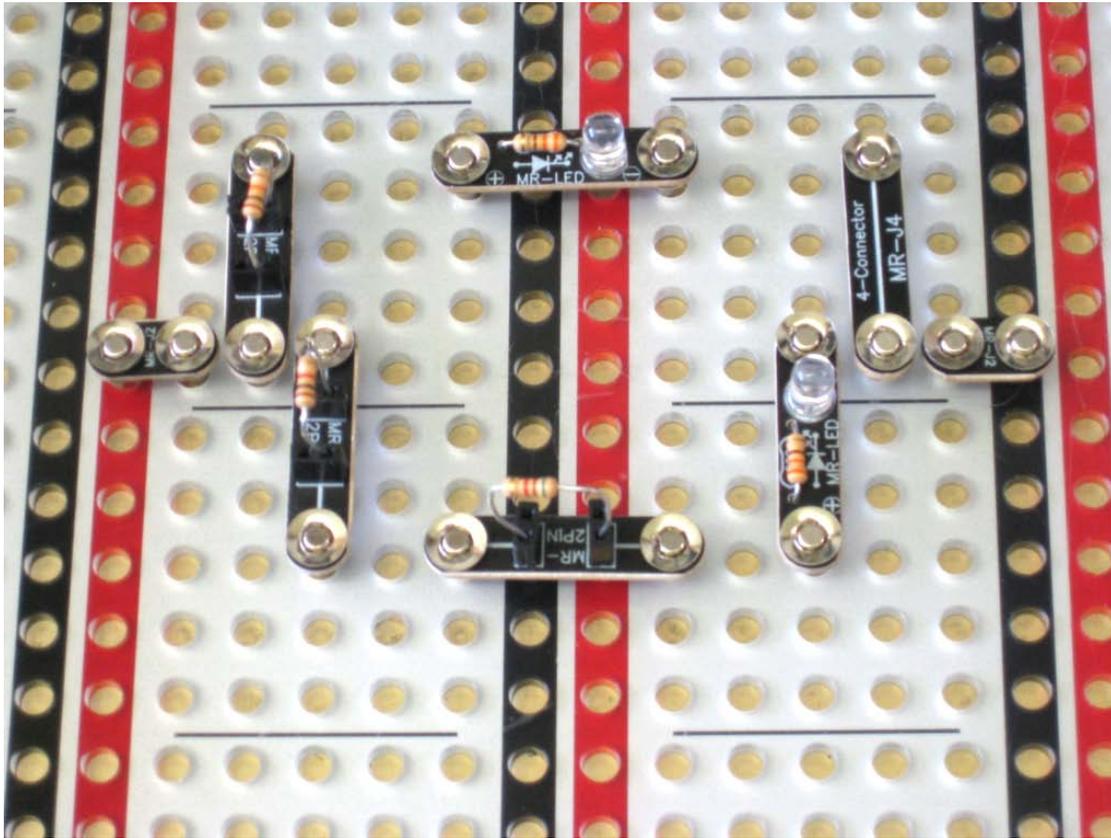


Figure 4: Example of a Parallel Circuit

Lesson Progression

1. The teacher will hand out the student sheet and read through the instructions making sure they are understood by students.
2. Students or student groups will construct two circuits. Each circuit must be made using 2 LEDs and 2 two hole connectors. The first circuit should be constructed in a way that allows one LED to remain on when the other LED is removed (this is a parallel circuit). In the second circuit the remaining LED will turn off when the other is removed (this is a series circuit). See circuit examples below.

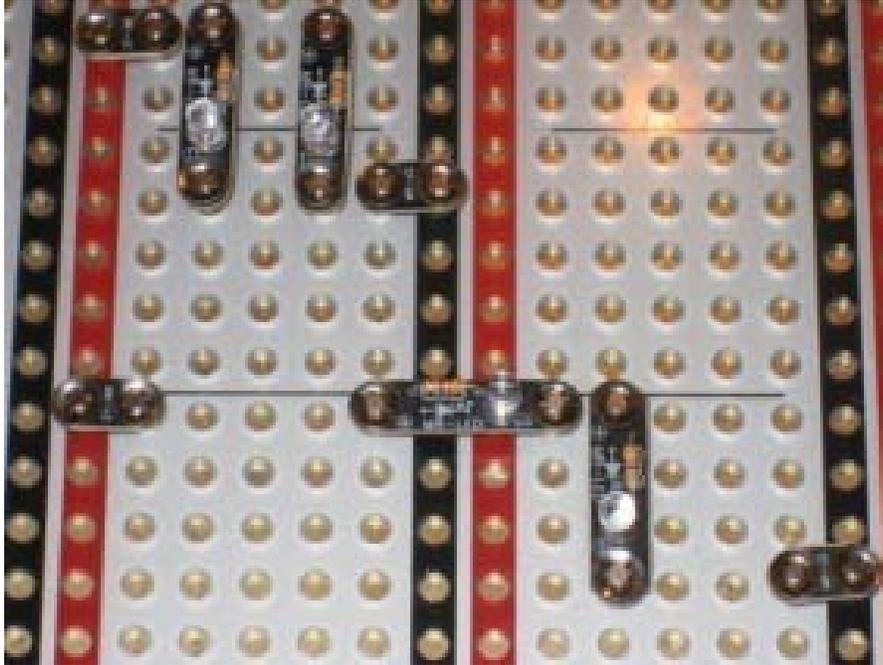


Figure 5: The top circuit is connected in parallel and the bottom circuit is connected in series

3. The teacher will circulate throughout the room and check for student understanding as groups work together to make the circuits. The teacher should not tell groups how to build the circuits. It is desirable for students to struggle a little as they figure out how to make the circuits work.
4. After students have completed the inquiry the teacher will help them use their observations to create definitions for series and parallel circuits.
5. Students will then sketch their circuits and trace where they think the electrons are going in each case.

Name: _____

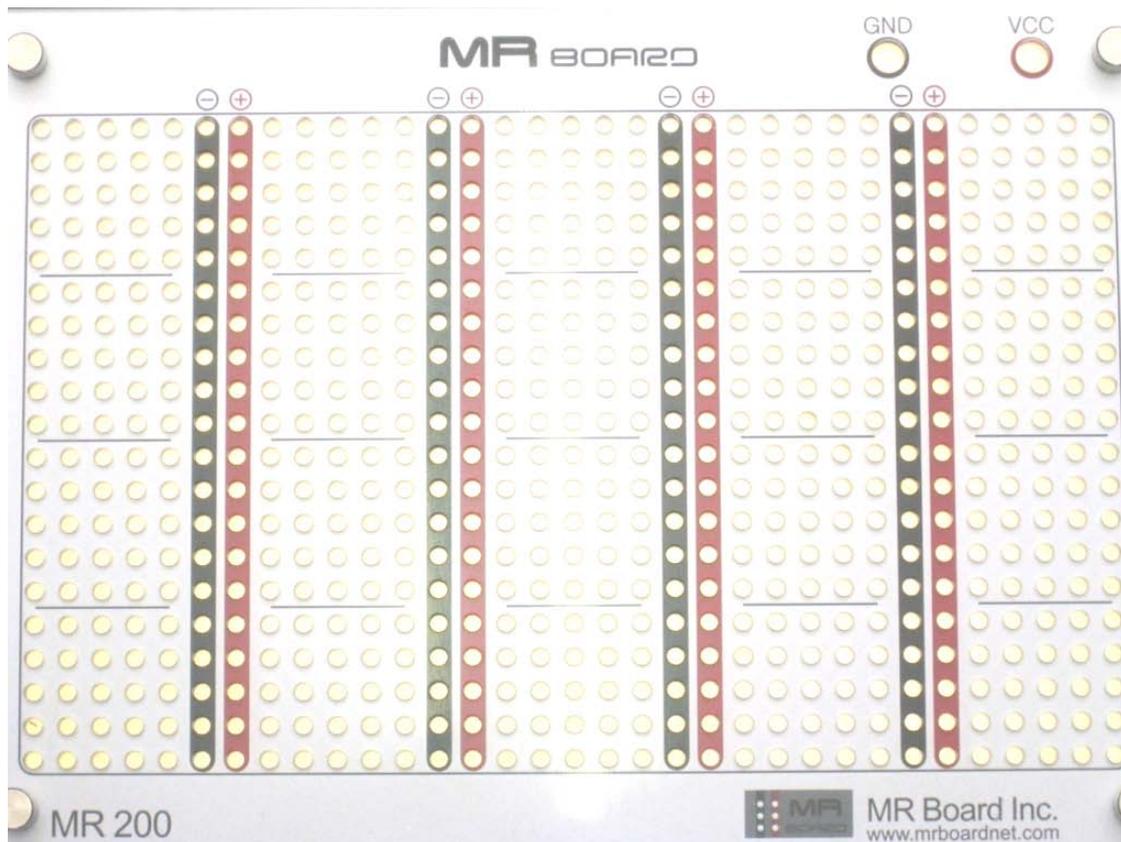
Date: _____

Period: _____

Introduction to Series and Parallel Circuits Student Sheet

In this learning activity you will discover the difference between series and parallel circuits. Along with your team members, you will design and construct two circuits. The first circuit should be constructed in a way that allows one LED to remain on when the other LED is removed (this is a parallel circuit). In the second circuit the remaining LED will turn off when the other is removed (this is a series circuit).

1. Sketch your circuits on the picture below after they are working as described.



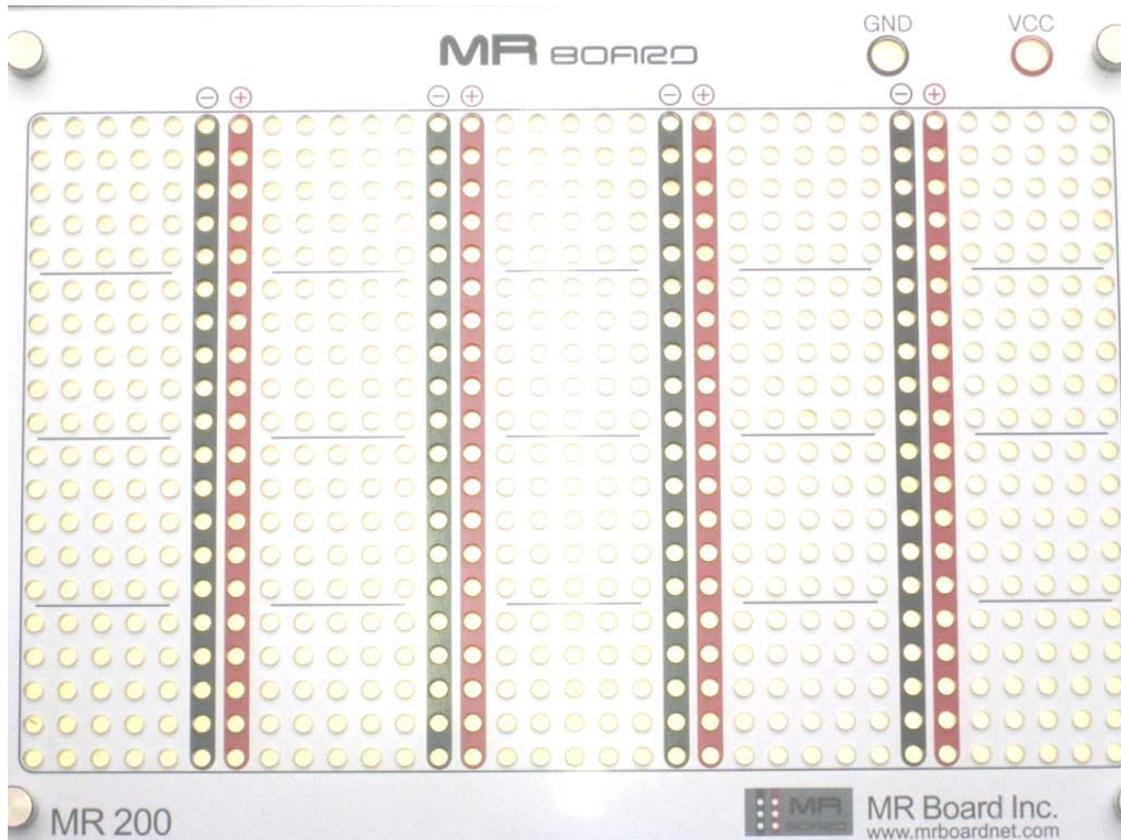
2. Looking at your circuits and thinking of how electrons might flow through them try to come up with a definition for series and parallel circuits.

a. Series Circuit: A circuit that

b. Parallel Circuit: A circuit that

3. Use a colored pencil to trace over you sketches showing where you think electrons flow.

4. On the picture below draw a series and a parallel circuit that each use 3 LEDs.



Chapter Four

Resistance and the Color Code

[Back to Table of Contents](#)

Objectives

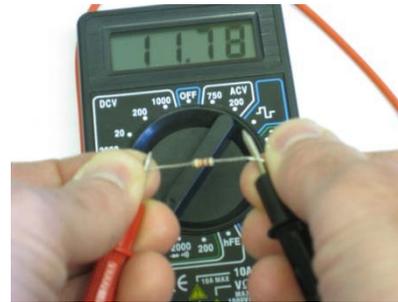
- Students will review information covered in lesson three
- Students will be introduced to the concept of resistance
- Students will learn how to use the color code to calculate the value of resistors

Materials

- The loose resistors included with the MR Board
- Digital Multimeter for each student group

Lesson Progression

1. The teacher will lead a discussion reminding students what a resistor does. After the discussion the teacher will ask the students to observe two different resistors and describe their differences and similarities.
2. Once students have identified the different color bands the teacher will explain that the bands are a code that tells the value or magnitude of resistors.
3. Students will need to be taught how to use a multimeter for measuring resistance. Each MR Board Kit comes equipped with $1k\Omega$, $10k\Omega$, $27k\Omega$, and $100k\Omega$ resistors. Students will remove three resistors with different values to run their initial tests. With the meter in the $20k\Omega$ position (see picture below) students will hold the black meter probe on one side of a resistor and the red meter probe on the other side of the resistor. The sensitivity of the meter may need to be adjusted depending on the value of the resistor being measured. After measuring the resistance students will record their results and draw the resistor on the student sheet. They will repeat this process for all three resistors.



4. The teacher will explain that today's lesson focuses on using the resistor color code. The teacher will then pass out the student sheet and then circulate throughout the room as students complete the exercise. It may be beneficial to go through the color code example on the student sheet with the class.

Name: _____

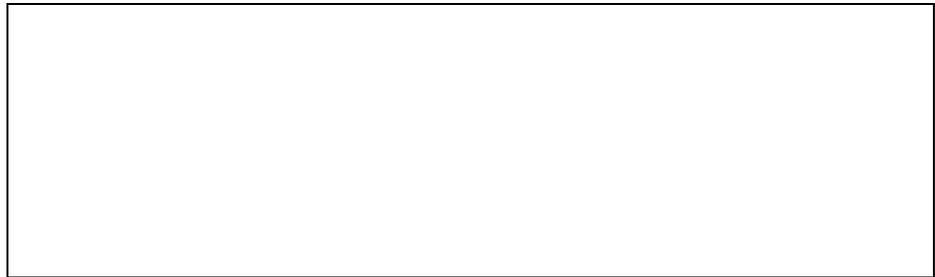
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Introduction to Resistors Student Sheet

Measuring Resistance: Pick three resistors from your MR Board Kit and measure the resistance of each. After measuring the resistance draw the resistor in detail (pay close attention to the color of the bands around the resistor).

Resistor 1 =
_____ Ω



Resistor 2 =
_____ Ω



Resistor 3 =
_____ Ω



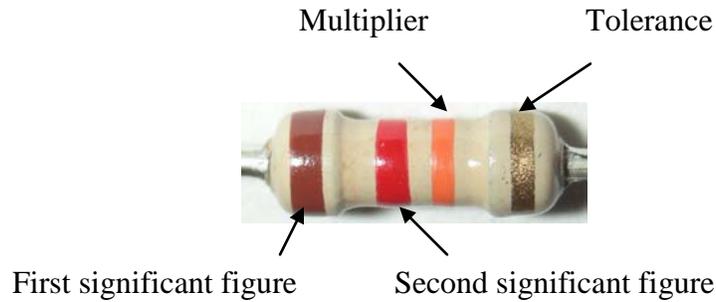
Using the Resistor Color Codes:

Table 1. This code will enable you to find resistance of a resistor without a meter.

Color	Band 1	Band 2	Band 3 (Multiplier)	Band 4 (Tolerance)
Black	0	0	1	-
Brown	1	1	1 X 10	1%
Red	2	2	1 X 100	2%
Orange	3	3	1 X 1000	-
Yellow	4	4	1 X 10000	-
Green	5	5	1 X 100000	0.5%
Blue	6	6	1 X 1000000	0.25%
Violet	7	7	1 X 10000000	0.1%
Gray	8	8	1 X 100000000	0.05%
White	9	9	1 X 1000000000	-
Gold	-	-	1 X 0.1	5%
Silver	-	-	1 X 0.01	10%
No Color	-	-	-	20%

Procedure Examine color bands of a resistor and identify each band color on the resistor.

1. Determine what colors are Band 1 and Band 4.
2. Read the color band from band 1 to Band 4.
3. Calculate the amount of value of the resistor and find out the tolerance value.

Example

- Calculate the amount of resistance value of the resistor Above
- The first significant band, the closest to the left end of the resistor is brown. The color band order is Brown-Red-Orange-Gold.
- The brown color tells that the digit is 1 in the table 1. The next band is red and the digit is 2. Band 3 is violet (Multiplier) is 3. You can multiple by 1,000 to the number 12 and the value of the resistor is 12,000 Ω or 12 k Ω .
- The last band is gold and the tolerance is 5%. Thus, the actual value of the resistor is plus or minus of 5% of the value and it could actually be anywhere between 11,400 Ω and 12,600 Ω The value can be confirmed by using a multimeter.

Self Test

1. Identify the value of resistance below color bands and tolerance

A) Brown-Black-Orange-Gold

Resistance Value:

Tolerance:

B) Sliver-Orange-Brown-Red

Resistance Value:

Tolerance:

2. How can you know the value of a resistor if the colors cannot be read?

3. Are the actual measured values of the three resistors above the same as the values you would get for them using the color code table? Explain.

Chapter Five

Introduction to Potential Difference and Connected (Closed) vs. Disconnected (Open) Circuits

[Back to Table of Contents](#)

Objectives

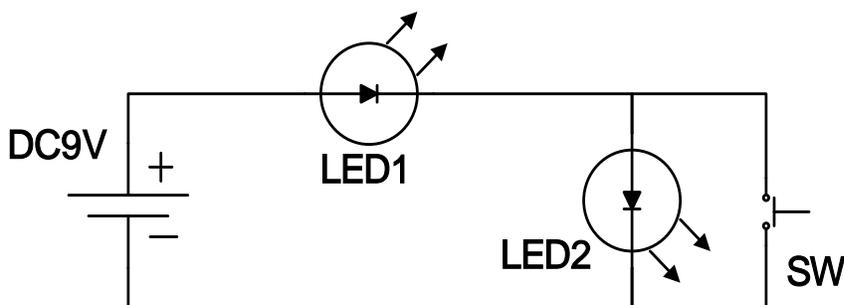
- Further Familiarize students with MB Board
- Review information covered in lesson four
- Check for understanding regarding topics covered in lesson four
- Improve students thinking skills
- Introduce students to the concept of potential difference
- Introduce students to the concept of open and closed circuits and relate this concept to that of potential difference

Materials

- MR Board Kit for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



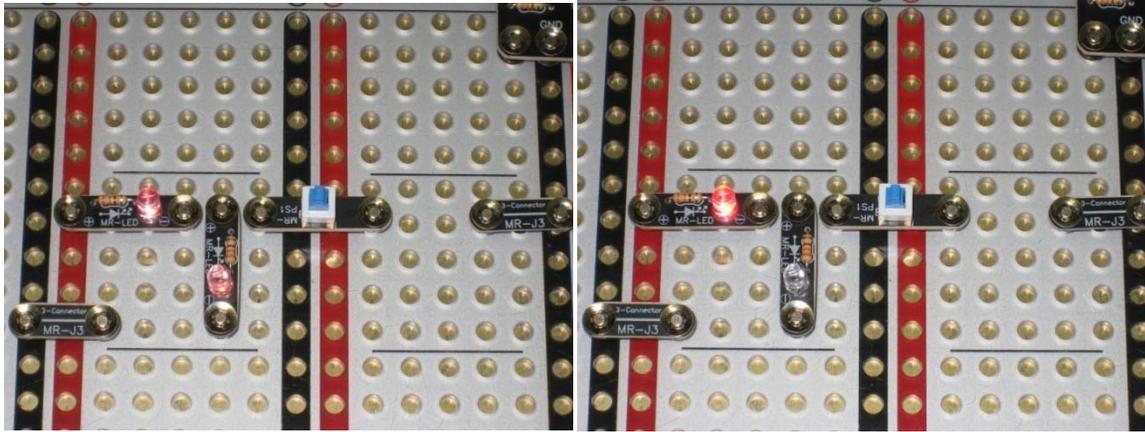


Figure 6: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Big Ideas and Important Concepts Covered in Lesson Two

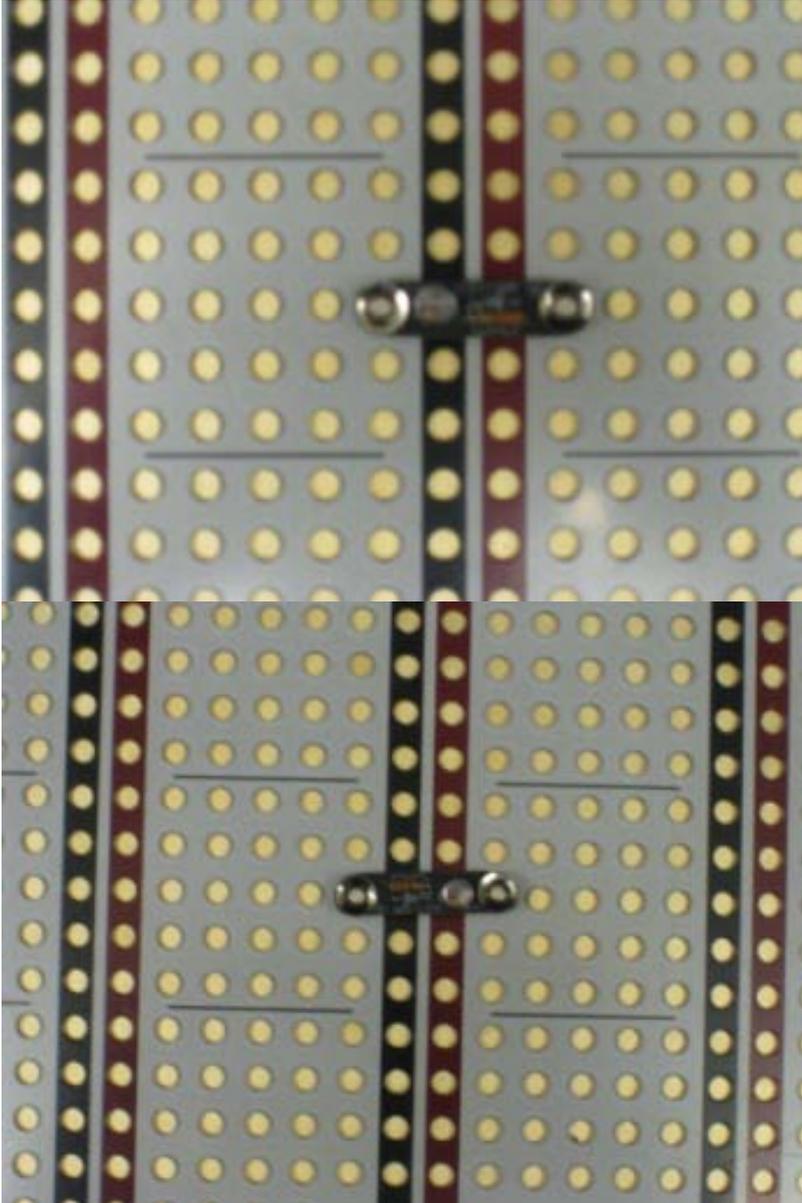
- Potential Difference
 - Potential energy that pushes electrons from an area of high concentration to an area of low concentration
 - The positive side of a battery is considered to have the potential to accept electrons and the negative side is considered to have the potential to donate electrons.
 - The greater the potential difference between the two sides the greater the voltage
 - Unit: Volt, represented by the letter V or E and the symbol [V]
- Connected and Disconnected Circuits
 - An open circuit does not have a potential difference therefore there is no potential energy pushing the electrons. Electrons are not flowing. Theoretically there is “infinite” resistance, in other words there is no where for the electrons to go. It is analogous to water held in a reservoir. If there is no outlet to the reservoir then the water will does not have anywhere to go. In introducing open circuits to students it is more intuitive to use the term disconnected circuit. This term fits better with their understanding and helps them understand examples of disconnected circuits such as a broken or cut wire.

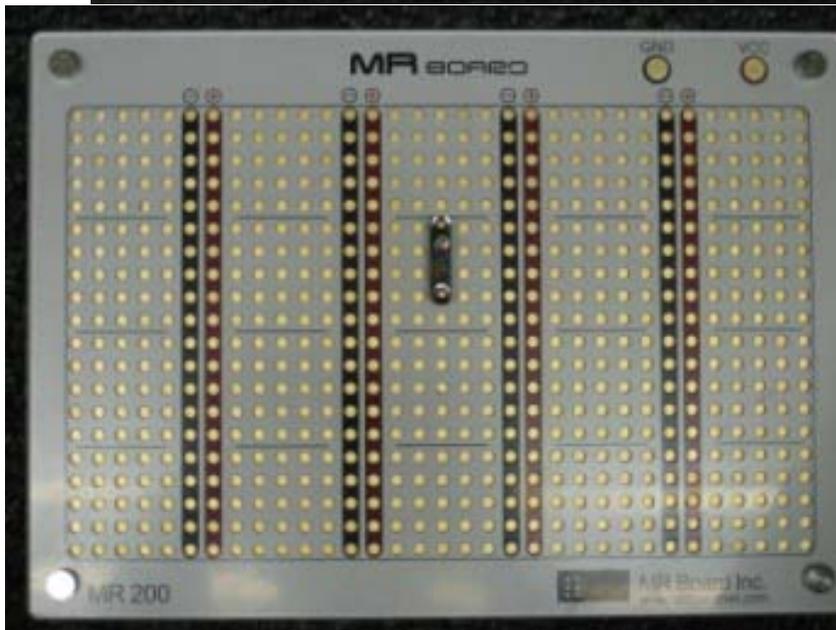
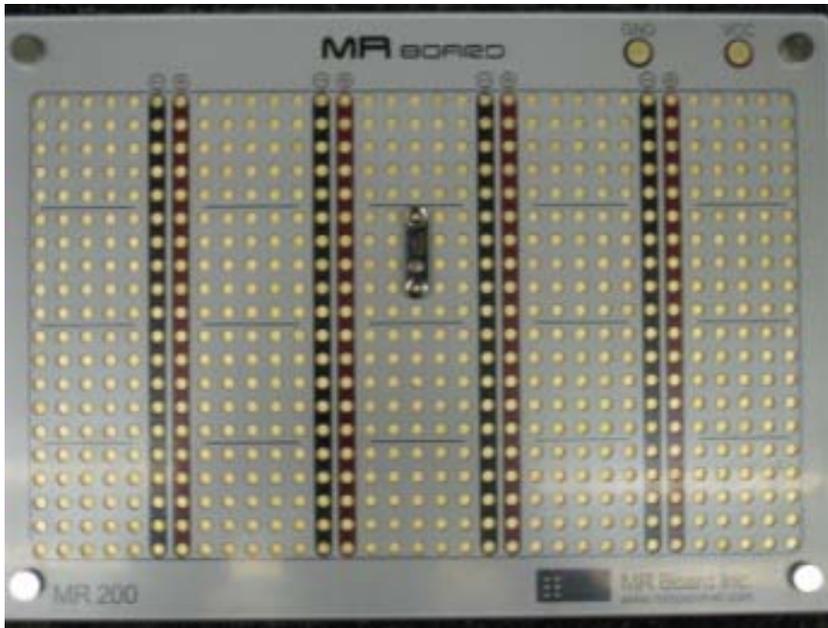
- In a closed circuit there is a connected pathway between areas of differing potential. This is to say that there is potential energy pushing the electrons and that they do have a pathway to travel. Similar to water in a reservoir being released from the spillway. Using the term connected circuit to replace closed circuit during instruction will help students understand that there is a pathway provided through which electrons may travel.

Lesson Progression

1. Students will be asked clarifying questions regarding the previous lesson. Questions will be related to how the MR Board functions. The teacher should consider removing the cover plate to remind students of the way the conducting filament is constructed.
2. The teacher will outline the objectives of the lesson as described above and tell students that there will be a short quiz at the end of class.
3. Teacher will demo disconnected and connected circuits using a battery. This will help students tie the lesson to their background knowledge.
4. The Instructor should be sure to discuss the process of making connections on the MR Board. Specifically, possible complications such as debris getting on the conducting filament or the electronics components being attached crookedly and not making adequate contact with the filament.
5. Students will be split into teams of three and asked to solve circuit challenges using the MR Board as a manipulative. The following are examples of circuits that could be used for challenges: (The challenges focus on the principles of open and closed circuits. Show students the position of the LED and ask them to make it light up in multiple ways.)

Make sure the students recognize that LEDs are directional.





6. A representative from several groups will explain the group's logic regarding their solution
 - a. Teachers should be strategic when choosing groups and when deciding which student from each group will present
 - i. Lower ability students could be asked to present if the pedagogical objective is for them to receive help from their group and the rest of the class (if this is the case the presenting student should be told before hand and maybe given some hints so as to ease their anxiety and help them feel prepared.

- ii. Higher ability student could be asked to present if the pedagogical objective is for them to provide instruction to their group and the rest of the class.
7. The teacher will facilitate a discussion on disconnected and connected circuits being sure to guide students towards the topics covered in the “Big Ideas...” section above.
8. The teacher will ask clarifying questions checking for student’s comprehension of the lessons “Big Ideas”.
9. Students will take a quiz assessing their understanding of lesson topics. (See quiz below)

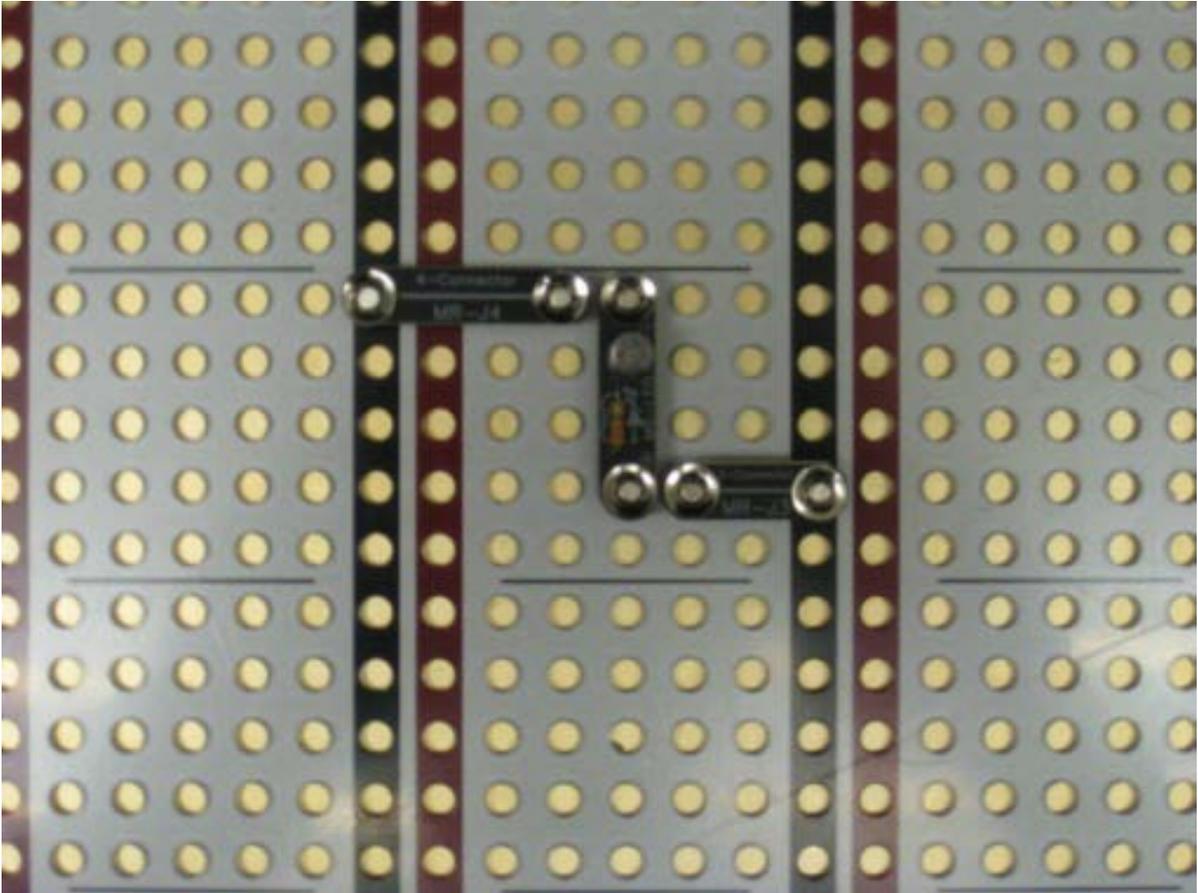
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Period: _____

MR Board Lesson Five Quiz

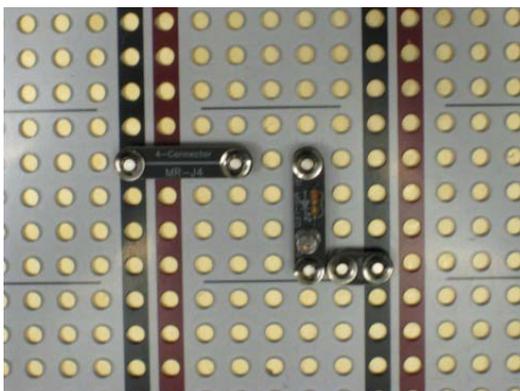
1. Look at the following circuit and say whether it is disconnect or connected.



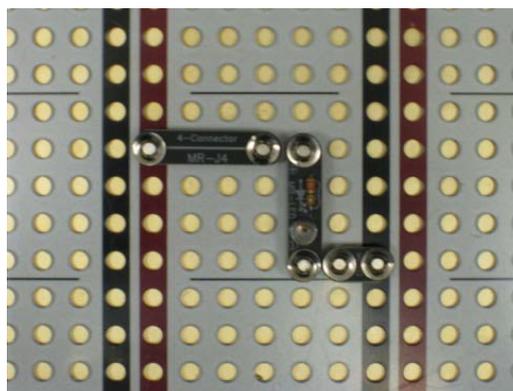
2. Explain your answer to question #1.

3. Will the LED in the circuit above light up? Why or why not?

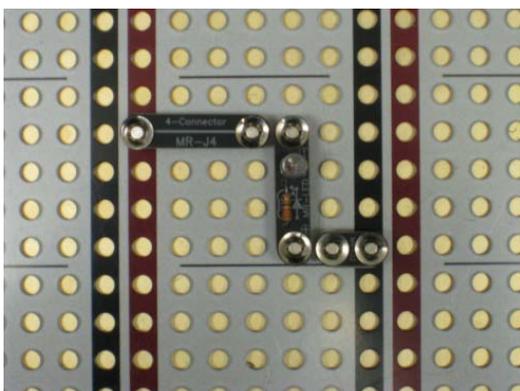
4. Circle the circuit below that is connected. (There could be more than one correct answer)



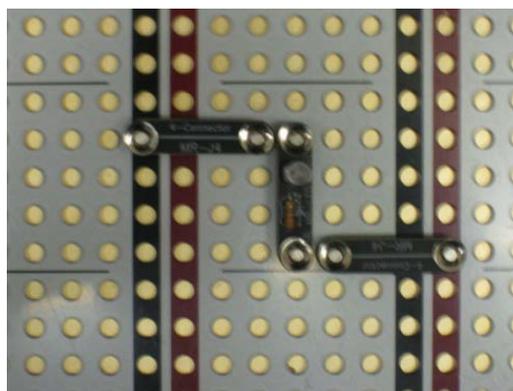
(a)



(b)



(c)



(d)

5. Compare and contrast the disconnected and connected circuits from question #4.

Chapter Six

Introduction to Current and Switches

[Back to Table of Contents](#)

Objectives

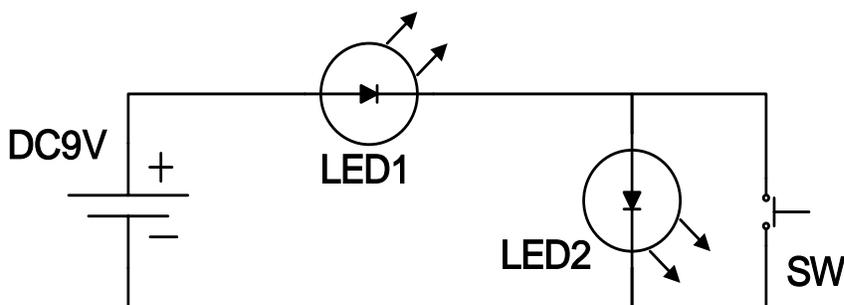
- Further Familiarize students with MB Board
- Review information covered in lesson five
- Check for understanding regarding topics covered in lesson five
- Improve students thinking skills
- Introduce students to the concept of Current
- Introduce students to the use of switches
- Students will learn how to use a multimeter to measure current

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



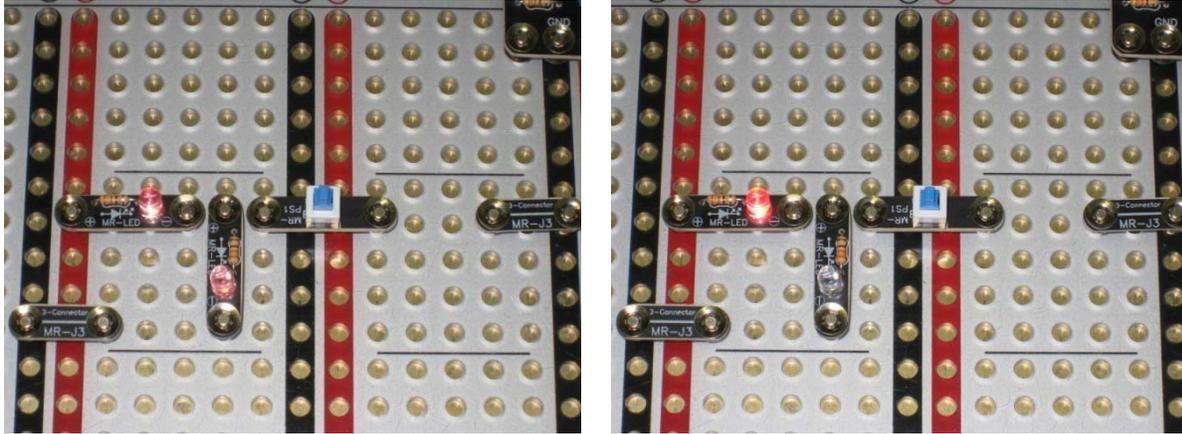


Figure 7: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

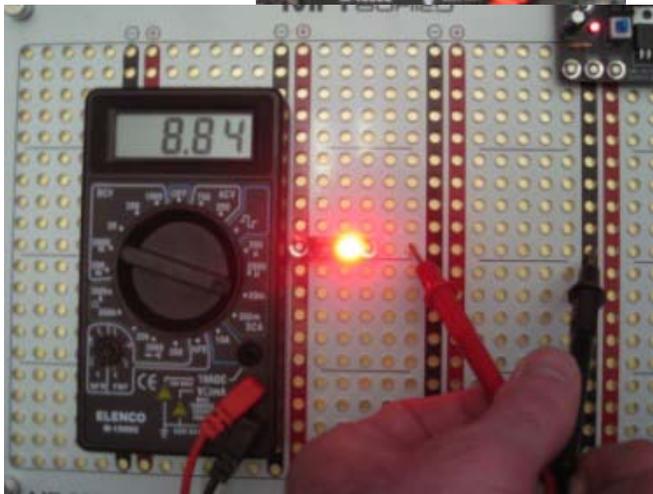
Big Ideas and Important Concepts

- Current
 - Current is the traveling or movement of electrons through a conducting pathway
 - Current is conventionally described as flowing from positive to negative which is the opposite direction that electrons move (negative to positive). This is because of an incorrect conjecture made by Ben Franklin regarding the direction of charge flow from smooth wax to rough wool. He set the convention that is still used today even though we now know that electrons are the packets of charge and that they move in the opposite direction that Franklin predicted (from the wool to the wax). By the time this understanding came to be, the nomenclature had been well established and no effort was made to change it. The terms used to describe current flow are merely human inventions and have no absolute meaning other than scientific description.
 - Unit of current: Ampere or Amp, represented by the letter A and symbol [I]
 - The current in a series circuit will be the same throughout the circuit (the electrons will travel through each component at the same rate).
 - Current splits in a parallel circuit. We will cover more specific information about how current splits in a parallel circuit in a future lesson. For now it is sufficient for students to recognize that it splits.
- Switch

- A device that has an on/off position that connects or disconnects the circuit's path.
- Common types of switches are a knife, toggle, push button, and slide.

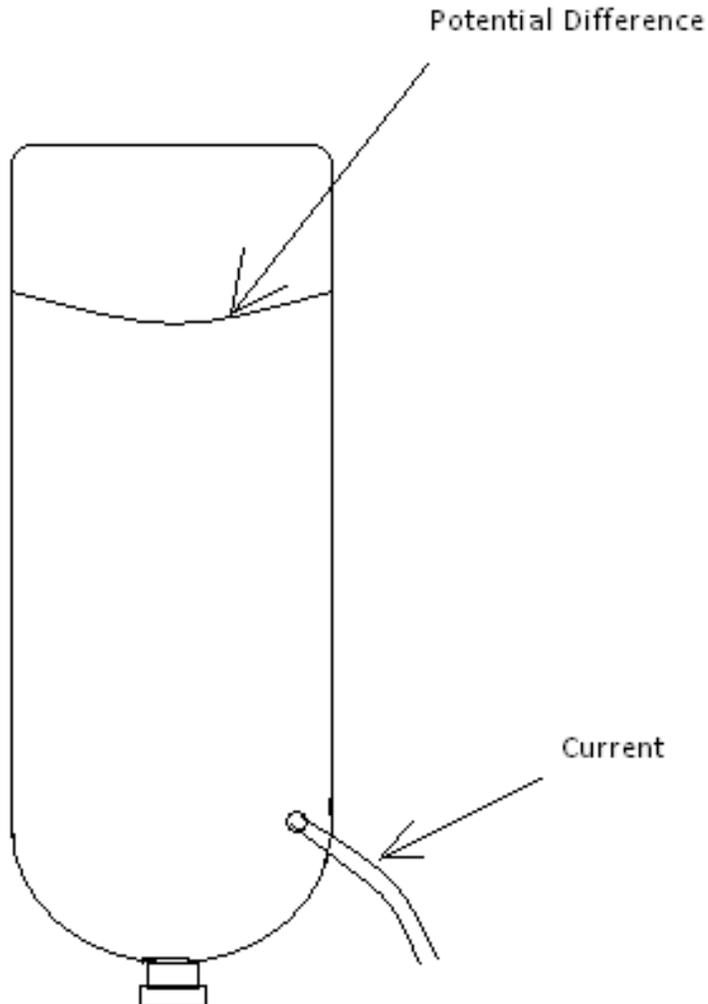
Lesson Progression

1. Students will need to be taught how to use a multimeter for measuring current. With the meter in the 20 mA position students will integrate the meter into the circuit forcing current to travel through the meter to get to ground.



2. Students will be asked clarifying questions regarding the previous lesson. Questions will be related to potential difference and connected/disconnected circuits. Review hydrodynamic analogies.

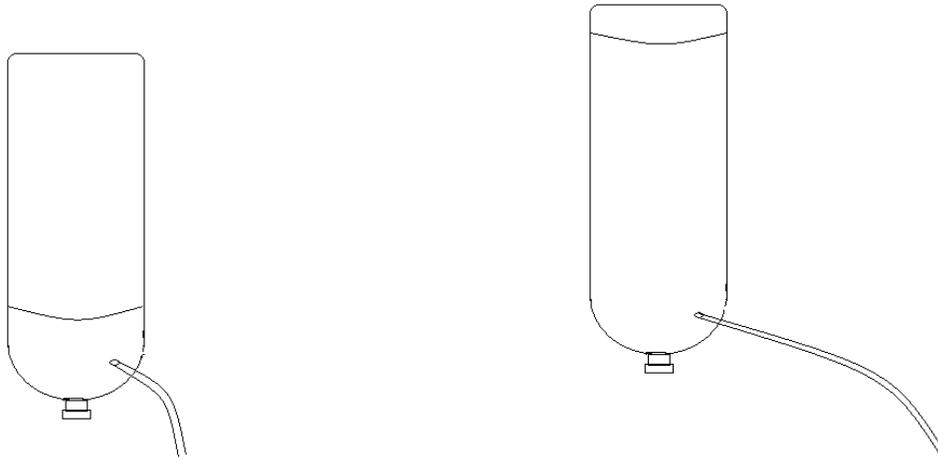
3. The teacher will outline the objectives of the lesson as described above and tell students that the assessment of their understanding will be based on their responses to question on the student sheet.
4. The teacher will demonstrate/model current as water being drained from a bottle with a hole in it. See diagram and demonstration explanation below.



In this demonstration the **height** of water in the bottle represents the potential difference, or voltage, that the circuit possesses. The amount of water that flows out of the bottle in a given amount of time (per second) represents the current. In other words, the rate of water flowing out of the bottle is likened to the rate of electrons flowing through a circuit. Through the demonstration students can see that as the potential difference increases (higher water level) the current increases (more water leaves the bottle in a given amount of time). The hole through which water leaves the bottle can be compared to resistance. A switch can be demonstrated by placing a finger over the hole.

Lower potential difference = less current

Higher Potential Difference = More Current



5. Students will conduct a series of investigations using their student sheet to guide them toward an understanding of the way current behaves in an electrical circuit.
6. Students will be split into teams of three and asked make measurements and record data as instructed on the student sheet. They will use their data and observations as a resource in answering the questions that follow.
7. A representative from several groups will explain the group's logic regarding their data interpretation and the way they answered the questions.
 - a. Teachers should be strategic when choosing groups and when deciding which student from each group will present
 - i. Lower ability students could be asked to present, if the pedagogical objective is for them to receive help from their group and the rest of the class. If this is the case the presenting student should be told before hand and maybe given some hints to ease their anxiety and help them feel prepared.
 - ii. Higher ability student could be asked to present, if the pedagogical objective is for them to provide instruction to their group and the rest of the class.
8. The teacher will facilitate a discussion on current being sure to guide students towards the topics covered in the "Big Ideas..." section above.
9. The teacher will ask clarifying questions checking for student's comprehension of the lessons "Big Ideas".
10. The class will have a discussion regarding the student sheet. **Make sure students discover that current in a series circuit will be the same throughout the circuit and that current splits in a parallel circuit.**

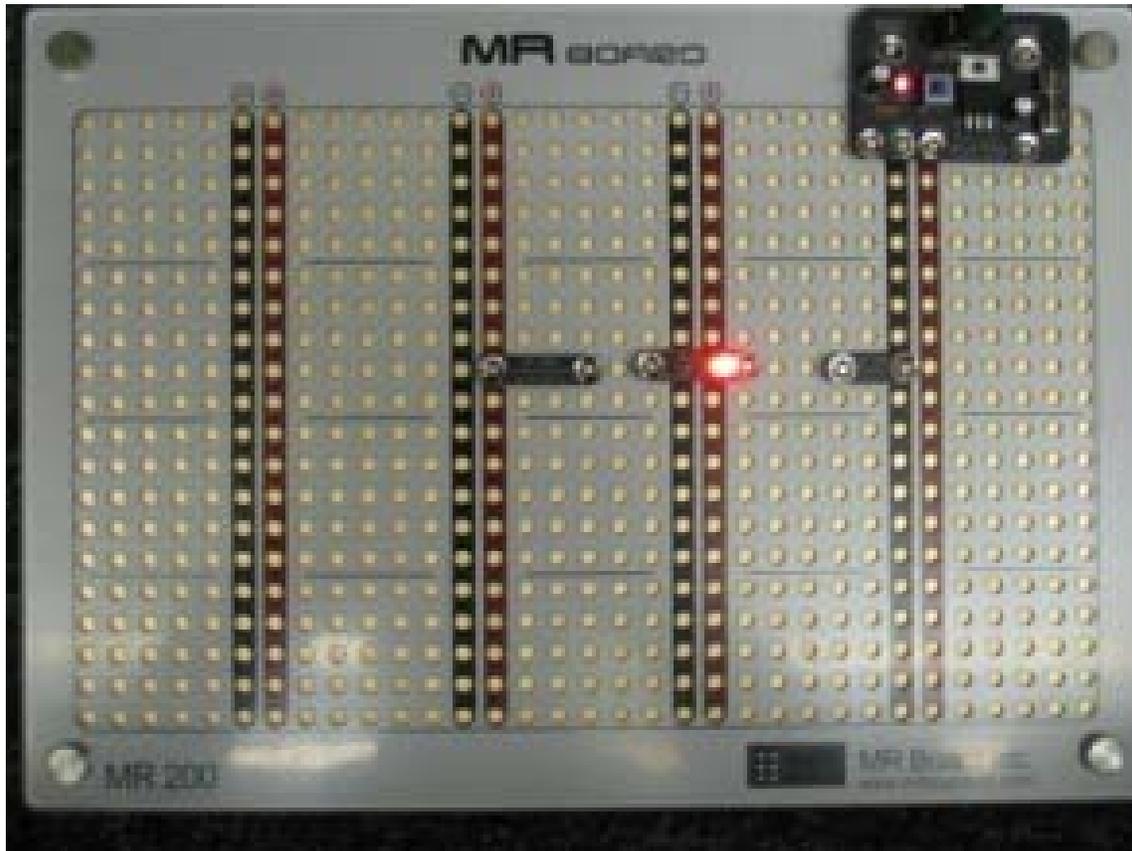
Name: _____

Date: _____

Period: _____

Chapter Six Student Sheet: Current and Switches

1. Measure the current in the following circuit:

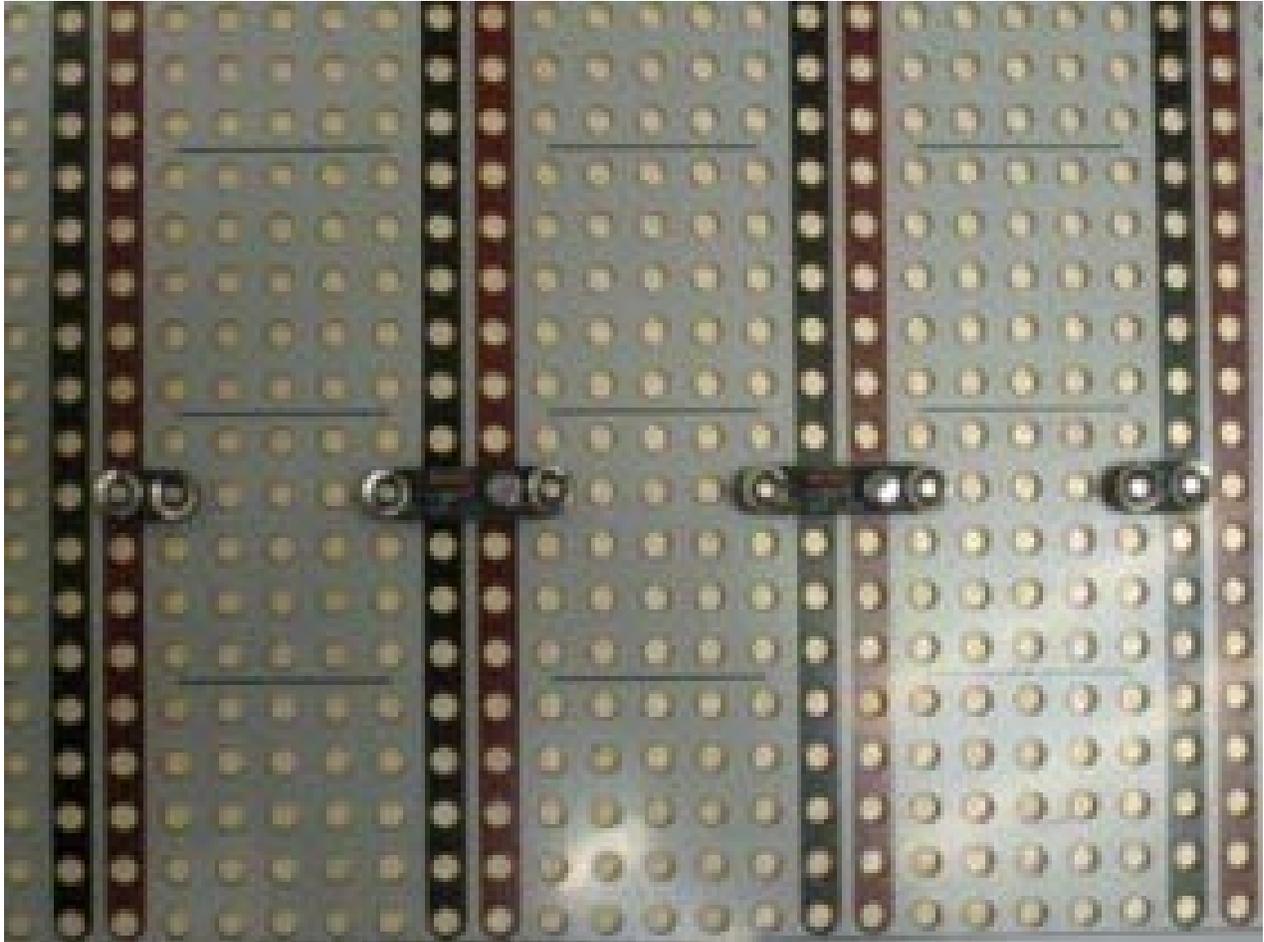


Record your data here. $I = \text{_____} \text{ A}$

What happens to your current if you reverse the placement of the multimeter's red and black probes?

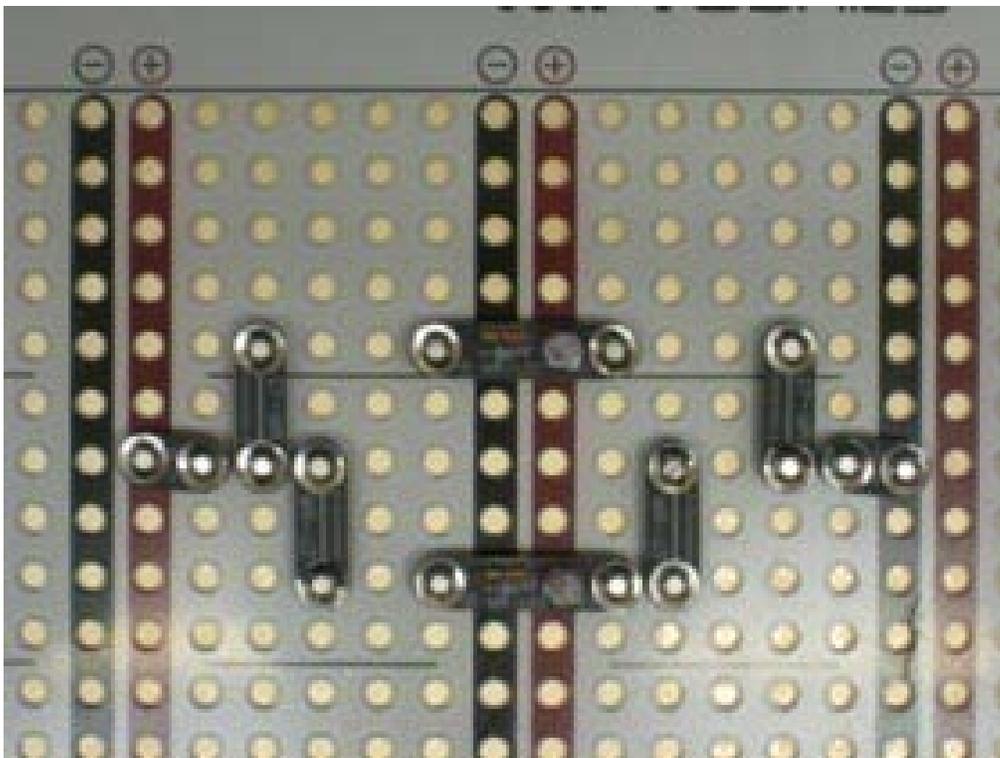
True or False This tells us that current travels in a specific direction.

2. Build the following circuit



Take various measurements of current. Describe your observations including where you measured and what current was at those specific locations.

3. Build the following circuit



Take various measurements of current. Describe your observations including where you measured and what current was at those specific locations.

4. Looking at your data and observations what conclusions can you come to regarding current?

Chapter Seven

Ohm's Law Introduction

[Back to Table of Contents](#)

Objectives

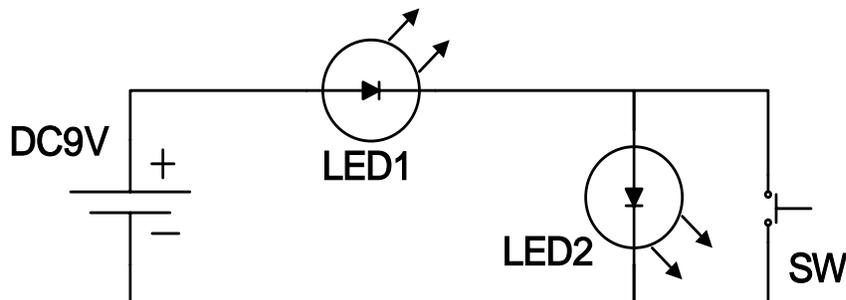
- Students will review information covered in lesson six.
- Students will learn how to measure voltage and be reminded how to measure resistance in an electrical circuit.
- Students will investigate the relationship between voltage, current, and resistance (Ohm's Law).
- Students will learn how to draw a simple circuit.

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



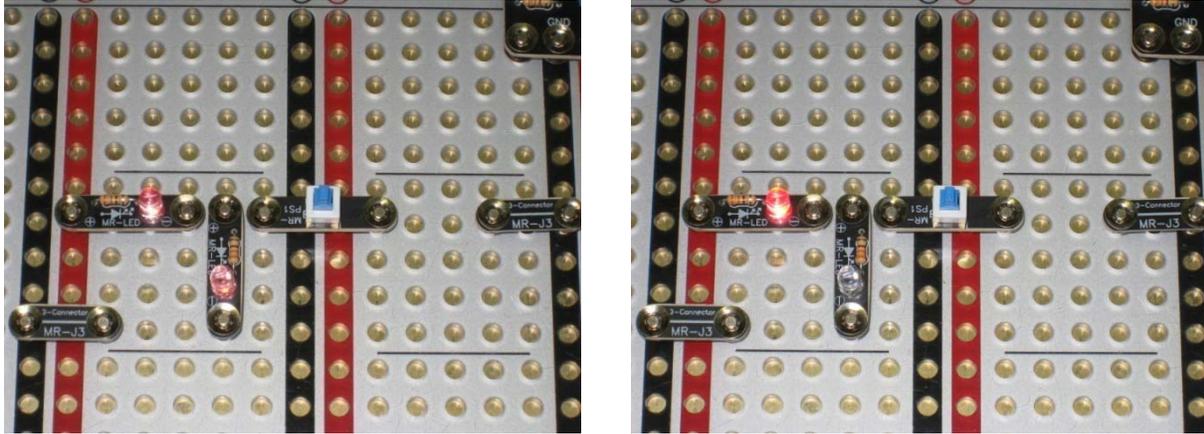


Figure 8: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

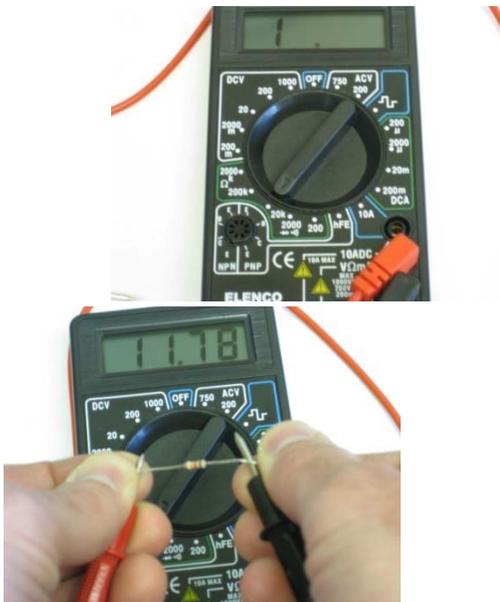
Big Ideas and Important Concepts Covered in Lesson Four

- Resistance
 - Resistance is a friction against the flow of current.
 - Unit: ohm, represented by the letter R, and the symbol Ω .
 - One volt can push 1A of current through 1 ohm of resistance. Thus, the current flows can be controlled by resistors in a circuit.
- Ohm's Law
 - Ohm's Law is the relationship between voltage, current, and resistance in an electrical circuit.
 - Ohm's Law: Voltage equals the product of current and resistance. $V=IR$, Here V is voltage (volts), I is current (amps), and R is resistance (ohms).
 - Using Ohm's Law you can calculate one parameter (voltage, current, or resistance) when you know the other two parameters (i.e. if voltage and current are known, resistance can be calculated by rearranging the equation to isolate R on one side, $R=V/I$).

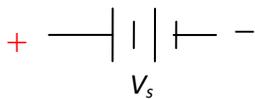
Lesson Progression

1. The teacher will refer to the hydrodynamic analogy demonstrated in Lesson Six and ask students to make a prediction in their journal regarding what the effect would be of increasing or decreasing the size of the hole through which the water flows out of the bottle.

2. The teacher will facilitate a discussion about the topic of resistance using the student's predictions.
3. Students should be reminded how to use a multimeter for measuring resistance. Each MR Board Kit comes equipped with a variety of resistors. Students will remove three resistors to run their initial tests. Students should first be required to use the color code for determining the value of each resistor then check their calculations with the multimeter. With the meter in the 20kΩ position (see picture below) students will hold the black meter probe on one side of a resistor and the red meter probe on the other side of the resistor. The sensitivity of the meter may need to be adjusted depending on the value of the resistor being measured.



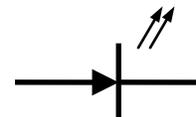
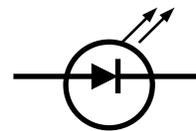
4. Students will draw the following symbols and record the description of the symbols in their notebooks.



The electrical circuit symbol for a power source.

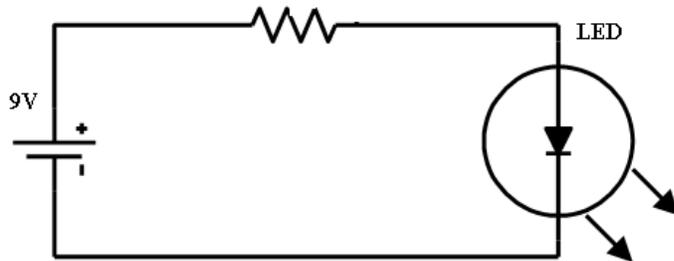


The electrical circuit symbol for a resistor.

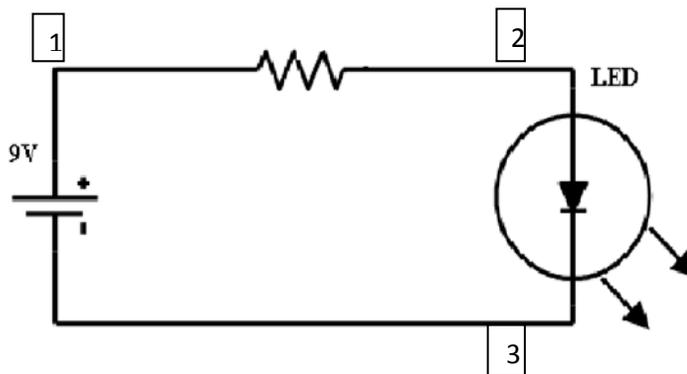


The electrical circuit symbol for an LED.

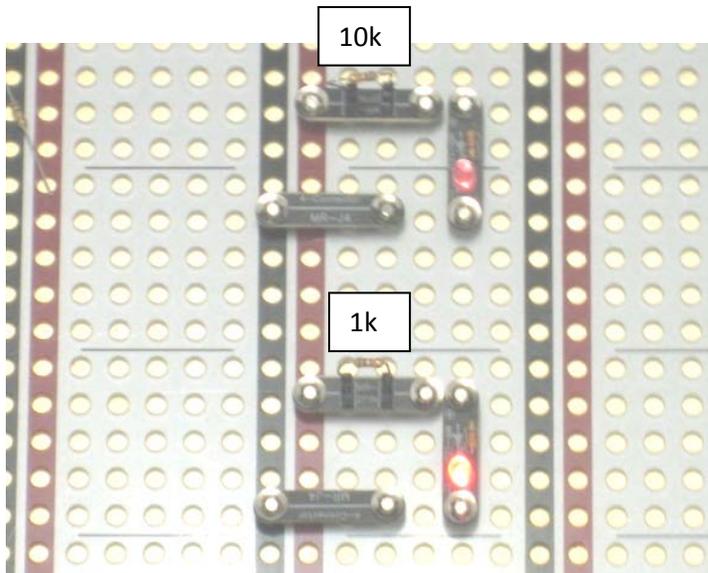
5. Students will construct the following circuit using one of the three resistors measured above. This will be labeled circuit 1.



6. Students will be taught how to measure voltage using their multimeter using the diagram below as a guide. To measure the voltage drop across the resistor place the meter's red probe at position 1 and the black probe at position 2. To measure the voltage drop across the LED place the meter's red probe at position 2 and the black probe at position 3. To measure the voltage drop across the entire circuit place the meter's red probe at position 1 and the black probe at position 3.
7. Students will discuss their observations regarding these measurements.



8. The teacher will demonstrate the following circuits (the circuit on top will be referred to as circuit 2 and the other will be called circuit 3:



9. The teacher will ask students to observe the LEDs, explain their observations to each other, and record these observations on their student sheet. Students will make a prediction as to why the LED in the top circuit is dimmer.
10. Students will construct the demonstrated circuits and take measurements to compare voltage, current, and resistance in the circuits.
11. The teacher will ask guiding questions to lead students toward a derivation of Ohm's Law (the mathematical relationship between voltage, current, and resistance).
12. Discuss the lesson and assign students the rest of the student sheet as homework.

Name: _____

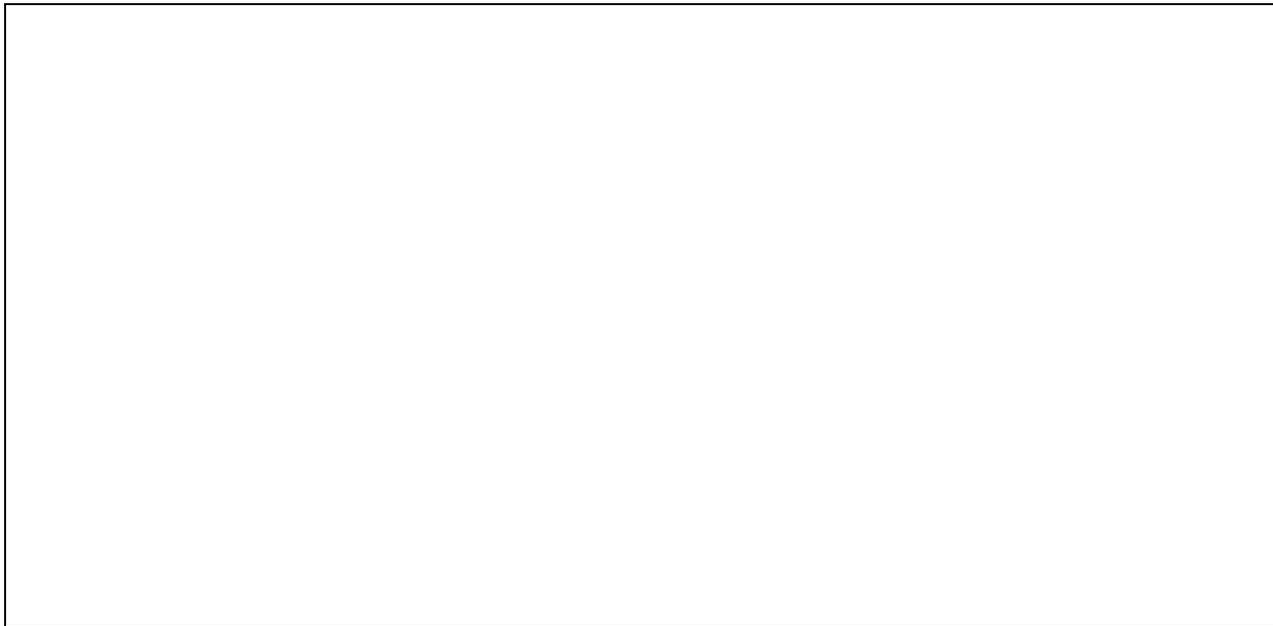
Date: _____

Period: _____

Chapter Seven Student Sheet
Resistors and Ohm's Law Introduction

Data Collection for Circuit 1:**Resistor Values:**A. Calculated using color code = _____ Ω , Measured with meter = _____ Ω B. Calculated using color code = _____ Ω , Measured with meter = _____ Ω C. Calculated using color code = _____ Ω , Measured with meter = _____ Ω

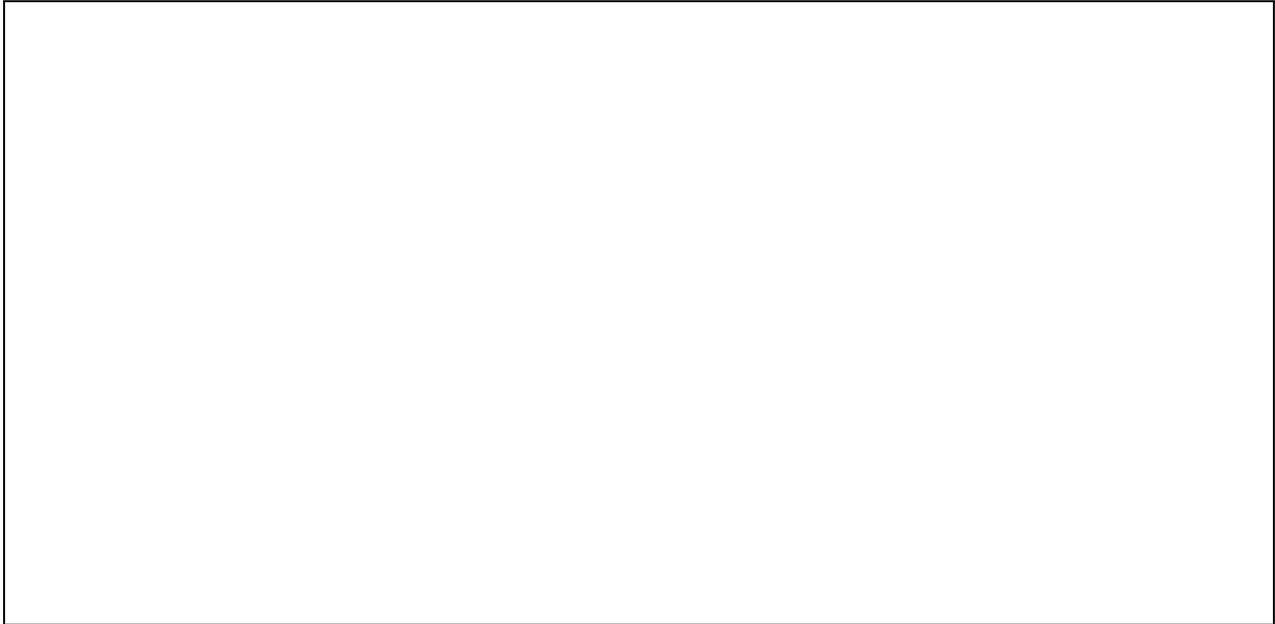
Is there a difference between the calculated and measured value on each resistor? If so, why?

Drawing of Circuit 1: (Be sure to include the value of the resistor used.)**Voltage Drops in Circuit 1:**

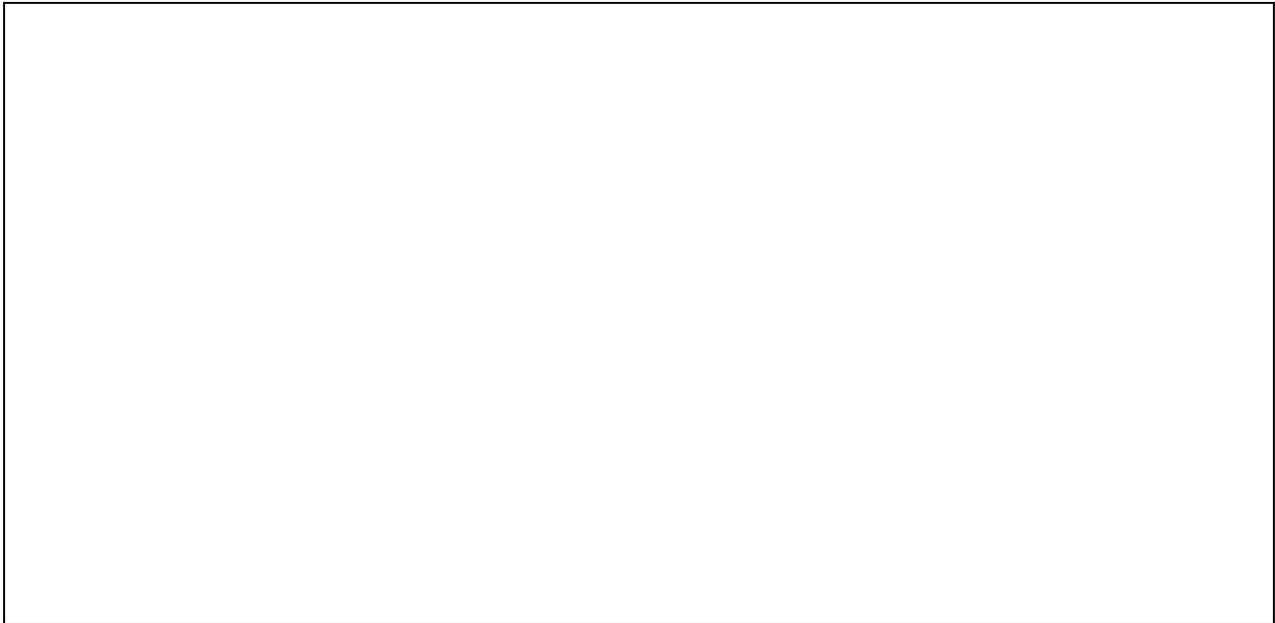
Change in V across the resistor = _____ V

Change in V across the LED = _____ V

**Teacher Demonstrated Circuits:
Drawing of Circuit 2**



Drawing of Circuit 3



Observations of Circuits 2 & 3

Explanation of Observations

Data Collection for Circuits 2 and 3:

	Voltage	Current	Resistance
Circuit 2			
Circuit 3			

How do the values of voltage, current, and resistance relate to each other? (Is there a mathematical relationship?)

Definition of Ohm's Law:

Answer the following questions (show your work!):

1. What is the voltage drop across a resistor that has a current of 10 mA going through it and whose resistance value is 500Ω ?
2. Consider a circuit with resistor that has 5 mA of current going through it and has a drop of 20 volts going across it. What will be the value of that resistor?
3. If a 5k resistor has a voltage drop of 15 V, how much current is going through it?

Find the missing value in the problems below (show your work!):

4. $R = 10k$, $I = \underline{\hspace{2cm}}$, and $V = 2V$

5. $R = \underline{\hspace{2cm}}$, $I = 12 \text{ mA}$, and $V = 4 \text{ V}$

6. $R = 3k$, $I = 0.7 \text{ mA}$, and $V = \underline{\hspace{2cm}}$

Write three problems related to Ohm's Law in the space below and explain how to solve them.

Problem one:

Explanation:

Problem two:

Explanation:

Problem Three:

Explanation:

Chapter Eight

Kirchhoff's Voltage Law

[Back to Table of Contents](#)

Objectives

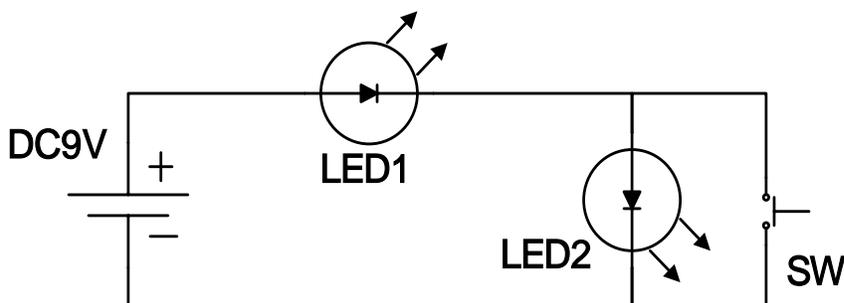
- Students will review information covered in lesson seven
- The teacher will check for student's understanding regarding topics covered in lesson three
- Students will be introduced to Kirchhoff's Voltage Law
- Students will investigate the relationship between the algebraic sum of voltage drops in a circuit and sum of the voltage sources in a complete circuit

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



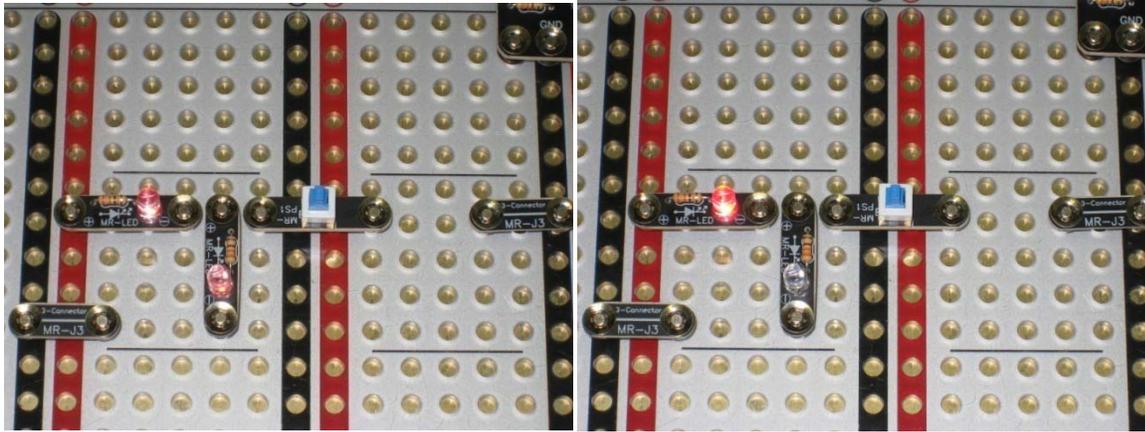


Figure 9: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

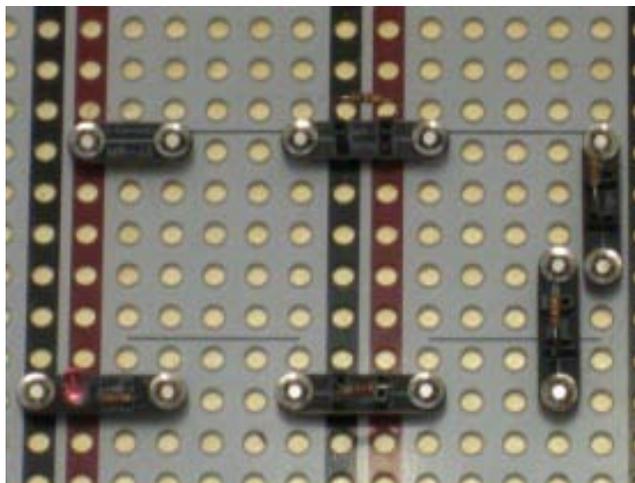
- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Big Idea and Important Concept Covered

- Kirchoff's Voltage Law
 - The algebraic sum of voltage drops of each resistor is equal to the algebraic sum of the voltage source in a complete circuit .

Lesson Progression

1. Student will be asked to build the following circuit (Circuit 1). The value of the resistors in the circuit is not critical but it will make assessment of student work easier if each group builds the exact same circuit. Make sure students record the value of each resistor in their drawing in their notes.



2. Students will measure the voltage drop across each component in the circuit and then analyze the drops looking for a mathematical relationship. (They should discover that the sum of the drops equals the voltage of the power source.) The teacher will give groups time to discuss their analysis but should not give them any clues at this point.
3. The teacher will ask groups to change the resistor values in Circuit 1. This new circuit will be called Circuit 2. Students will draw Circuit 2 in their notes.
4. As in a previous lesson a representative from several groups will explain the group's analysis regarding their observations of voltage drops.
 - a. Teachers should be strategic when choosing groups and when deciding which student from each group will present
 - i. Lower ability students could be asked to present if the pedagogical objective is for them to receive help from their group and the rest of the class (if this is the case the presenting student should be told before hand and maybe given some hints so as to ease their anxiety and help them feel prepared.
 - ii. Higher ability student could be asked to present if the pedagogical objective is for them to provide instruction to their group and the rest of the class.
5. The teacher will facilitate a discussion regarding the group presentations being sure to guide students towards Kirchhoff's Voltage Law.
6. Students will take a short quiz regarding Kirchhoff's voltage Law.

Name: _____

Date: _____

Period: _____

Quiz: Kirchhoff's Voltage Law

1. Consider a complete circuit with a 12V power source and three resistors. If the voltage drop across the first resistor is 6V and the drop across the third resistor is 2V, what is the drop across the second resistor? (show your work)

2. Explain why you answered question 1 the way that you did.

3. Consider a complete circuit with a 9V power source and four resistors. If the voltage drop across the first resistor is 6V and the drop across the second resistor is 2V, what is the sum of drops across the third and fourth resistors? (show your work)

4. Explain why you answered question 3 the way that you did.

Chapter Nine

Kirchhoff's Current Law

[Back to Table of Contents](#)

Objectives

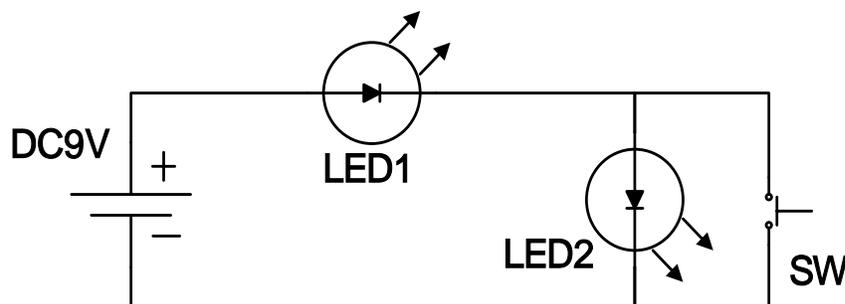
- Students will review information covered in lesson eight
- The teacher will check for student's understanding regarding topics covered in lesson eight
- Students will be introduced to Kirchhoff's Current Law
- Students will investigate the relationship between the algebraic sum of voltage drops in a circuit and sum of the voltage sources in a complete circuit

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



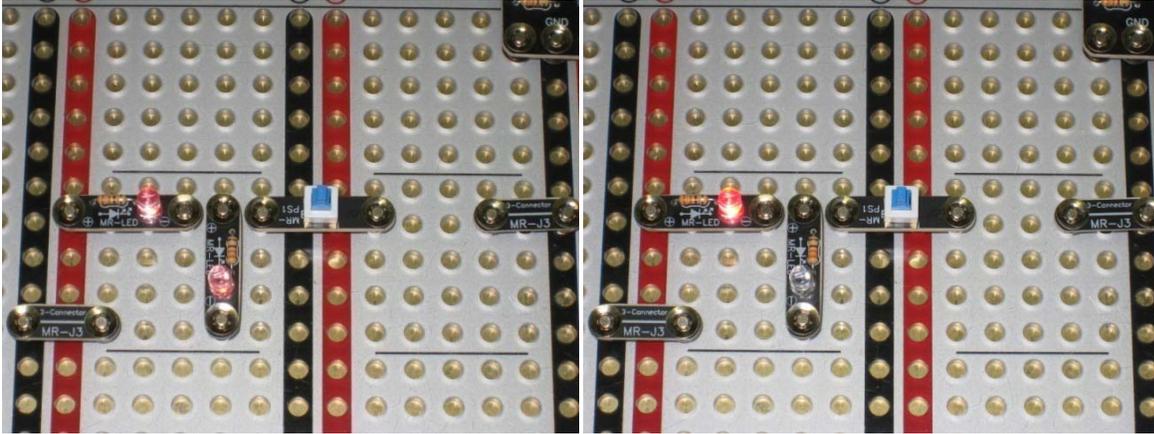


Figure 10: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

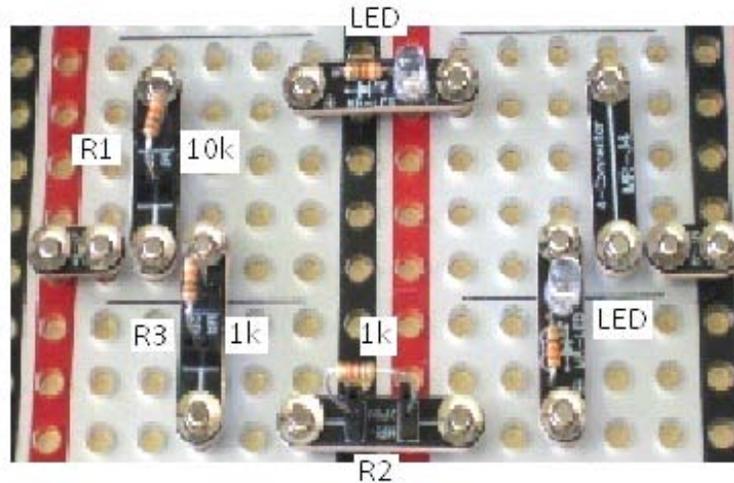
- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Big Idea and Important Concept Covered

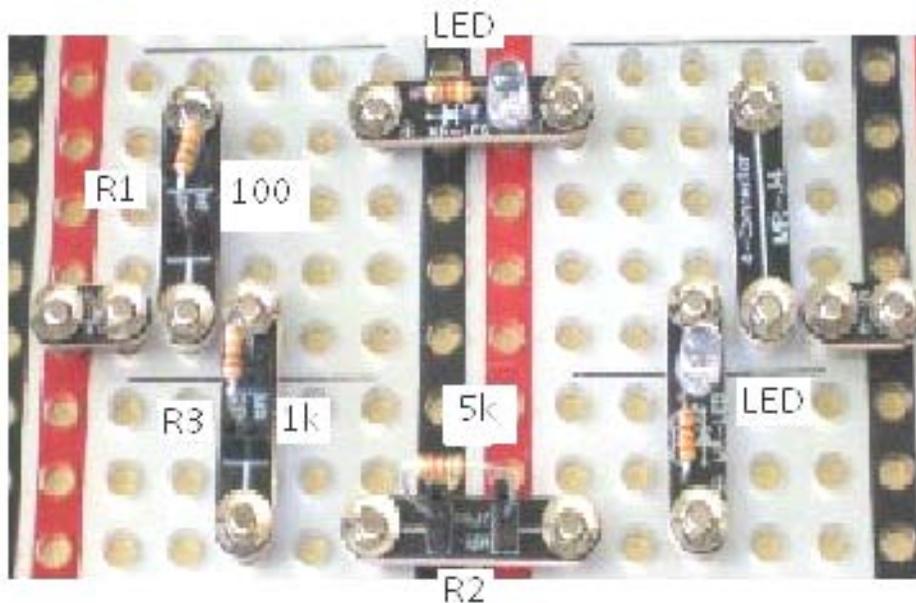
- Kirchhoff's Current Law
 - The algebraic sum of currents flowing into a node equals the current flow out of the node in a closed circuit.
- Node
 - A node is a junction in a circuit (current splits or comes together at a node).

Lesson Progression

1. Students will be asked to build the following circuit.



2. The students will measure the current passing through each component in the circuit and then discuss their observations within their group. The teacher may need to ask guiding question to lead groups toward the observation that the current entering the node equals the current leaving the node.
3. Students will change the resistors in the circuit they have built as shown below.



4. Students will measure the current going into the circuit and the current going through the top half of the circuit after the node. The teacher will then ask groups to make a prediction as to what the current will be going through the bottom half of the circuit. (The current through the bottom half will be equal to the current going into the circuit minus the current going through the top half of the circuit.)
5. Students will measure the current going through the bottom half of the circuit to confirm their predictions.

- The teacher will facilitate a discussion regarding the predictions being sure to guide students towards Kirchhoff's Current Law.
- Students understanding of Kirchhoff's Current Law will be assessed with a paper pencil quiz.

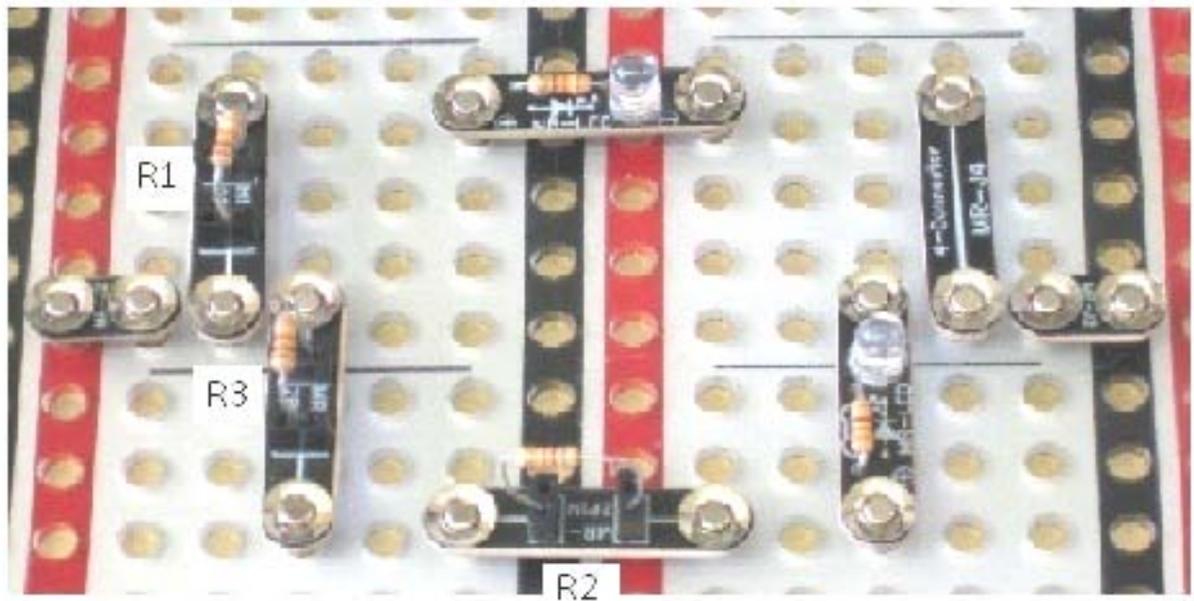
Name: _____

Date: _____

Period: _____

Quiz: Kirchhoff's Current Law

- Consider the following circuit:



If $R1=10k$, $R2=2k$, and $R3=2k$, will more current go through the top half or the bottom half of the circuit? Explain.

2. Label the nodes in the circuit above.
3. Consider a parallel circuit similar to the one pictured above. If the current before the node is 2.8mA and the current through the bottom half of the circuit is 0.7mA, what will the current be through the top half of the circuit? Explain.
4. What will the current be just before entering ground in the circuit described in number three? Explain.

Chapter Ten

Basic Capacitor Circuits

[Back to Table of Contents](#)

Objectives

- Review information covered in lesson nine
- Check for understanding regarding topics covered in lesson nine
- Improve students thinking skills
- Introduce students to the concept of capacitance in electronic circuits

Materials

- MR Board Kit for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher
- The MR Board uses electricity at a low voltage, care should still be taken
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.

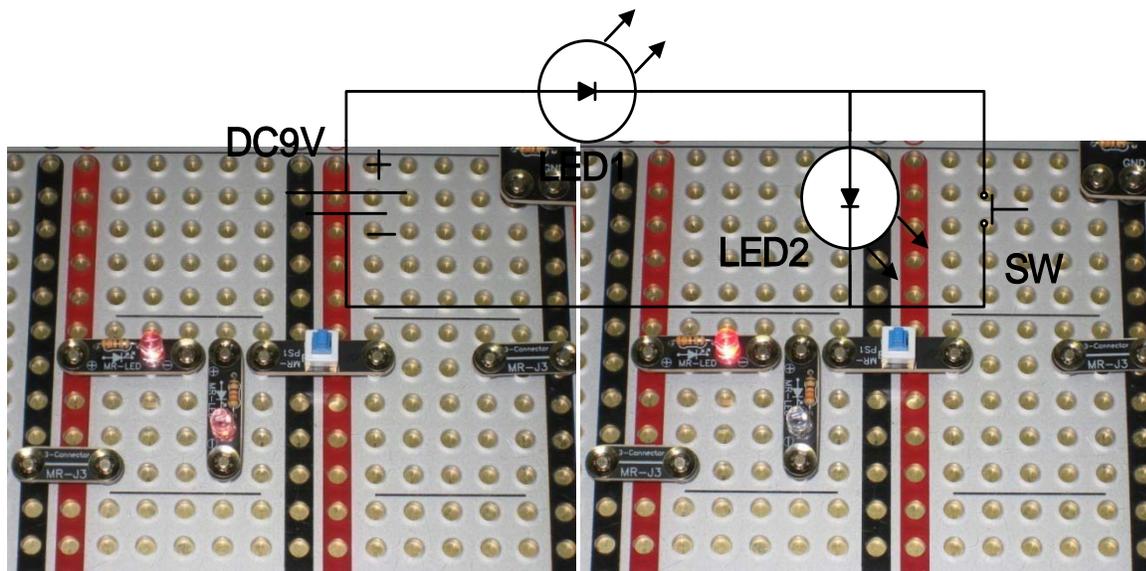
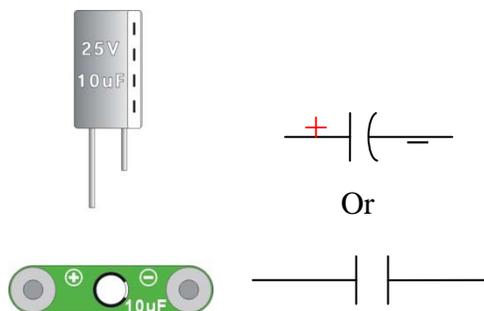


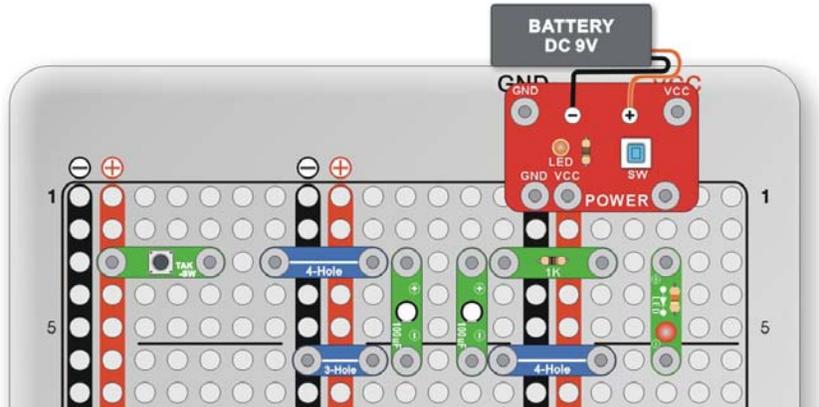
Figure 11: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

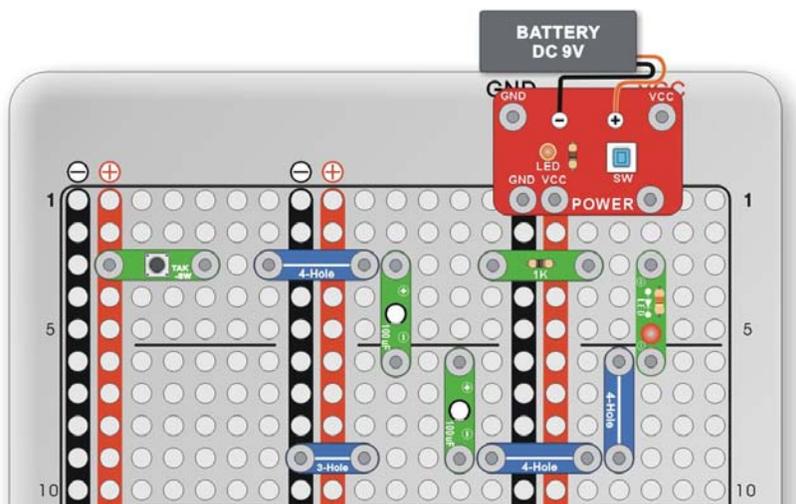
Big Ideas and Important Concepts Covered

- **Capacitance**
 - Measurement of the amount electrical charge a device can store for a given electric potential energy.
 - A capacitor is an electrical component used for storing charge.
 - Unit: farad, represented by the letter C, and the symbol F.
 - Because a full farad is too large a value in a circuit, the millifarad (mF), the microfarad (μF), the nanofarad (nF), and the picofarad (pF) are the most common subunits of capacitance used.





Circuit A



Circuit B

Lesson Progression

1. Students will construct the circuits shown above and then measure the voltage and current from the power source with a multimeter.
2. Students will make observations and take various measurements to explore the circuit with the switch in the on and off position.
3. Students will discuss observations in their group.
4. The teacher will guide students toward the observations listed below.
5. The teacher will ask students the “Self Study” questions and hand out the Post Assessment.

Observations

- The LED light goes slowly out when a parallel capacitor circuit is used.
- The 1 k Ω resistor slows down the discharges
- The LED light is on when the pushbutton switch is ON. The LED light slowly dims when the switch is turned OFF.

Self Study

1. What is “charged” and “discharged” on the capacitor?
2. How can you do if you want to increase the capacity of capacitance when you have 3 different values of capacitor?

Chapter Eleven

Analog vs Digital Electronics

[Back to Table of Contents](#)

Objectives

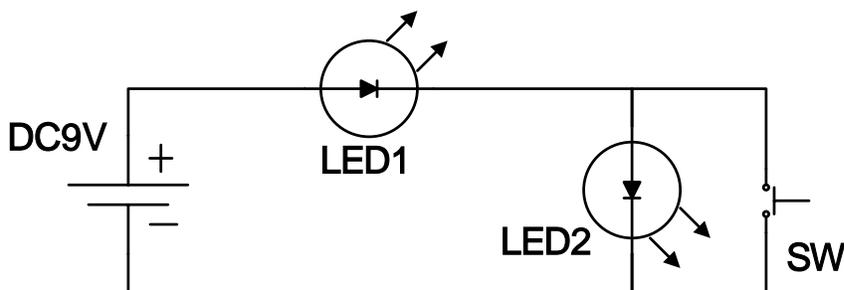
- Familiarize students with digital vs. analog signals
- Improve students thinking skills
- Through experimenting with the MR Board students will gain an understanding of the difference between analog and digital circuits based on their inputs and outputs

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



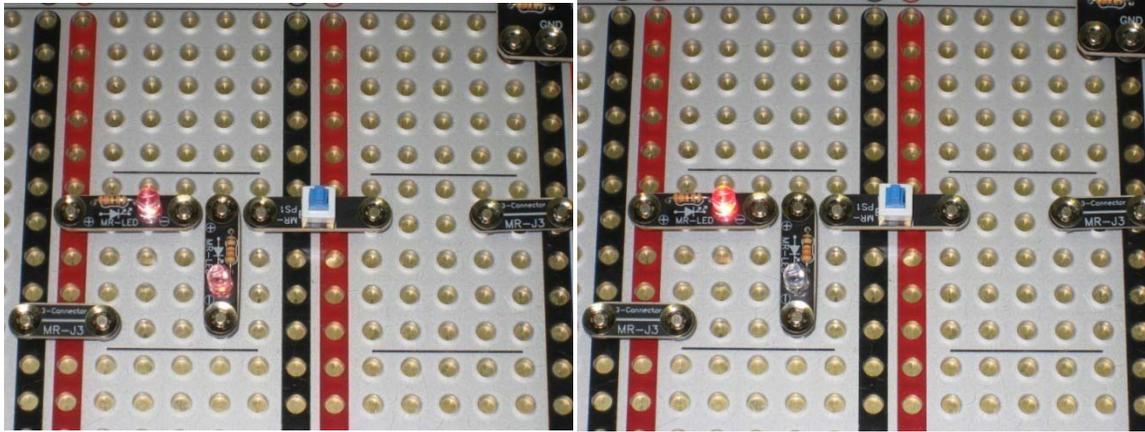


Figure 12: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

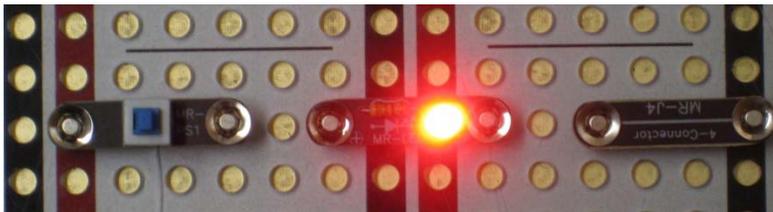
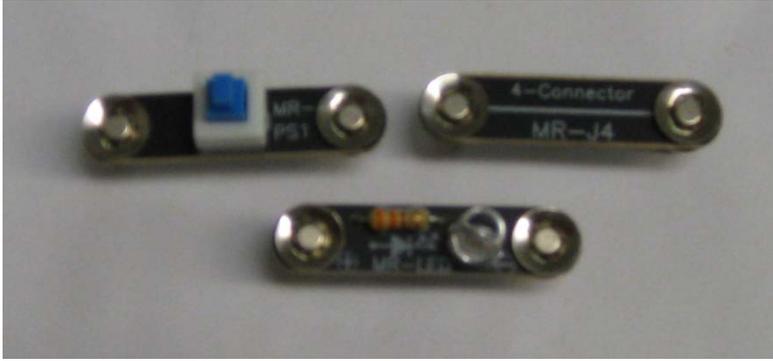
Digital Signal: The input and output of a digital circuit is either on (indicated by the number 1 in digital logic) or off (indicated by the number 0 in digital logic). This simple principle of a circuit having an input and output that is on (1) or off (0) is a very powerful tool in electronics. It is the basic principle upon which computing is built. In this introductory lesson on digital electronics students will experiment with switches and logic gates to determine the meaning of terms used to describe the eight common logic gate types.

Analogue Signal: In an analog circuit the input and output are not defined as being either on or off. Analogue signals can vary between on and off.

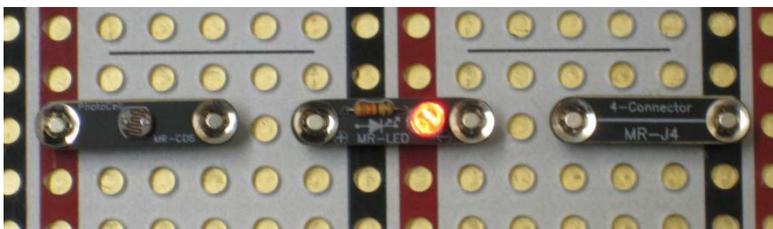
The focus of this chapter is for students to identify digital and analog circuits by analyzing the inputs and outputs.

Procedures:

3. Students will be asked to design a circuit on the MR Board that uses a switch, an LED, and one connector. (circuit one)



4. Students will analyze the circuit using the multimeter and record their measurements on the student sheet.
5. Students will be asked to design a circuit on the MR Board that uses a photocell, an LED, and an on connector.



6. Students will analyze the circuit using the multimeter and record their measurements on the student sheet.
7. The teacher will facilitate a class discussion regarding the circuits built and the measurements taken. The teacher should make sure that the differences between the two circuits are talked about, specifically that the output of the first circuit is either on or off with no signal in between and that the output of the second circuit varies depending on the amount of light that is allowed to reach the photocell.
8. Students will be told that the first circuit is a digital circuit and the second circuit is an analog circuit then they'll be ask to come up with a definition for both circuit types.
9. Each student group will choose a representative to explain their definition to the class.
10. The teacher will facilitate a discussion to guide the class to a consensus on the definitions. The definitions agreed upon by the class will be recorded at the end of the student sheet and in the student's notebook.

Name: _____

Date: _____

Period: _____

Chapter Eleven Student Sheet: Analog vs. Digital Electronics

Introduction: Digital electronic devices have become a part of our society, they are all around us. Cell phones, smart phones, pda's, computers, mp3 players, digital voice recorders, digital video recorders the list goes on and on. So how do digital devices work? This activity will provide you with a foundation for your understanding of digital electronics.

Design a circuit on the MR Board that uses a switch, an LED, and one connector. (Circuit one)
Sketch of Circuit One:

Design a circuit on the MR Board that uses a photocell, an LED, and one connector.
Sketch of Circuit Two:

Use a multimeter to measure the output of the two circuits. Check the output on circuit one with the switch in the on and off position. Check the output on circuit two with the photocell uncovered, partially covered, and completely covered. Record your observations below.

Circuit	Observations
One	
Two	

Student Definitions:

The first circuit gives a digital output. Use your observations of circuit one to write a definition for digital circuits.

The second circuit gives an analog output. Use your observation of circuit two to write a definition for analog circuits.

Class Definitions:**Analog Circuits:**

Digital Circuits:

Chapter Twelve

Binary Counting and the ASCII System

[Back to Table of Contents](#)

Objectives

- Familiarize students with binary numbers, the binary counting system, and the mechanism through which key strokes are converted in binary numbers.
- Improve students thinking skills
- Students will gain an understanding of the use of binary numbers in digital electronics

Materials

- Internet access

Introduction

Unlike the decimal number system, which is based on numbers 0 through 9, the binary number system uses two numbers, 1 and 0, to represent numerical values. The binary number system is used for the input and outputs of circuits in digital electronics, and is the internal counting system used in modern computers.

Like counting in the decimal system (using symbols 0 through 9) you begin with a single digit and proceed through each symbol in increasing order. The difference is that in binary counting the only symbols used are 0 and 1.

Example of decimal counting:

Symbols for the first number increases stepwise from 0-9. When the symbols for the first digit are used up, the digit to the left is incremented and counting at the first digit starts over at 0:

0
1
2
3
4
5
6
7
8
9
10

When the symbols for the second left most digit are used up, the digit to the left is incremented, and counting at the second digit starts over at 0:

95
96
97
98

99
100
101

This pattern continues.

In decimal, after the exhaustion of symbols 0-9 in a particular digit an increment resets it to 0 but also causes an increment of the digit to the left. Counting in binary follows the same format as in digital except that only the two symbols 0 and 1 are used. After a digit reaches 1 in binary it is reset to 0 and an increment of the digit to the left begins:

0000
0001
0010
0011
0100
0101
0110
1000
1001...

And so on.

Counting in Decimal	Counting in Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

Binary counting, or a sequence of 1s and 0s, is how information is stored and manipulated in modern computing. When we type a word on the keyboard the letters we type are converted into binary numbers. The **American Standard Code for Information Interchange or ASCII code is the character coding scheme that accomplishes the conversion.**

Procedure

1. The teacher will give students instruction regarding the binary counting system. It is important that students be able to relate the process of counting in binary to the process of counting in decimal as outlined in the introduction to the lesson. This will provide them with a reference frame for understanding the two digit system since it is possibly the first exposure to binary students have had.
2. After explaining the binary system the teacher will ask students to work with the student sitting next to them to write the next four binary numbers in a sequence starting with 1111 (15 in the decimal system as seen in the table above). **Answer: 10000, 10001, 10010, and 10011.**
3. Teacher will ask a student pair to put their answer on the board and explain to the class how they arrived at it.
4. After making sure that the class members are able to successfully count using the binary system the teacher will discuss the importance of the binary system in modern computing and digital electronics. **Everything is controlled by 1 and 0.**
5. The teacher will direct students to the following website and explain the ASCII conversion system to them:
http://www.micron.com/k12/lessonplans/binary_converter.aspx
6. The teacher will hand out and assign the student sheet.
7. While students are working, the teacher will circulate throughout the room and check for student understanding.

Name: _____

Date: _____

Period: _____

Student Sheet: Binary Numbers and the ASCII System

Introduction

Binary counting, or a sequence of 1s and 0s, is how information is stored and manipulated in modern computing. When we type a word on the keyboard the letters we type are converted into binary numbers. The **American Standard Code for Information Interchange or ASCII code is the character coding scheme that accomplishes the conversion. This sheet will check your understanding of the binary counting system and familiarize you with the conversion of text into binary numbers using the ASCII system.**

Binary Counting: For the following binary numbers write the three binary numbers that would follow.

Ex. 101010, 101011, 101100, 101101

1.) 100001, _____, _____, _____

2.) 011111, _____, _____, _____

3.) 101100, _____, _____, _____

4.) 110011, _____, _____, _____

5.) 111000, _____, _____, _____

ASCII System: Follow the directions on the Micron Binary Converter website

(http://www.micron.com/k12/lessonplans/binary_converter.aspx). Show your converted name to your teacher and use the space below to write the letters of your first name in binary numbers.

Letter	Binary Code

Chapter Thirteen

Truth Tables and Timing Diagrams

[Back to Table of Contents](#)

Objectives

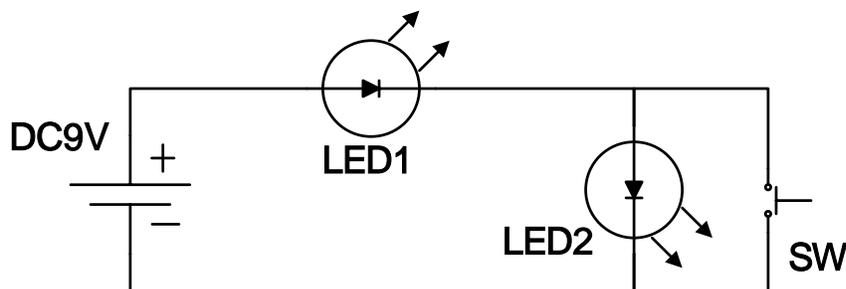
- Familiarize students with the terms associate with digital electronics
- Improve students thinking skills
- Through experimenting with the MR Board and class discussion students will gain an understanding of function of truth table and timing diagrams

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



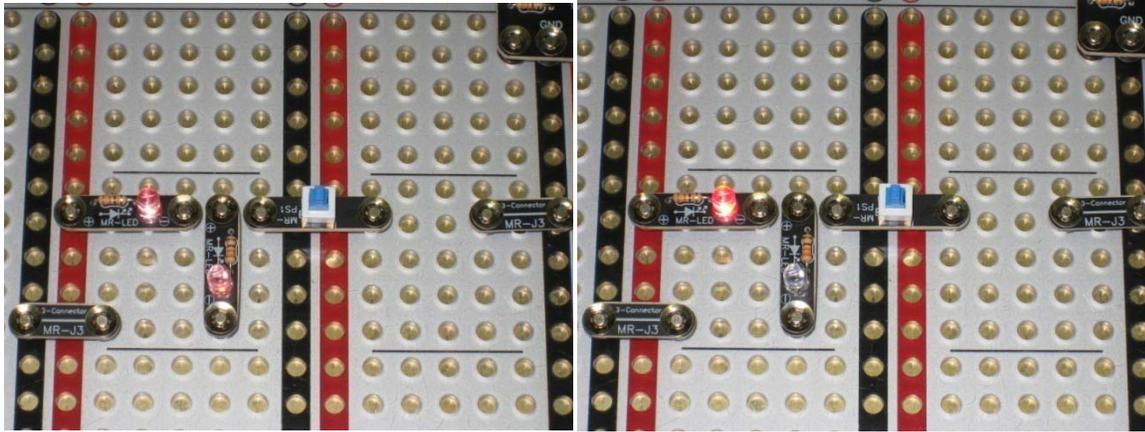


Figure 13: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

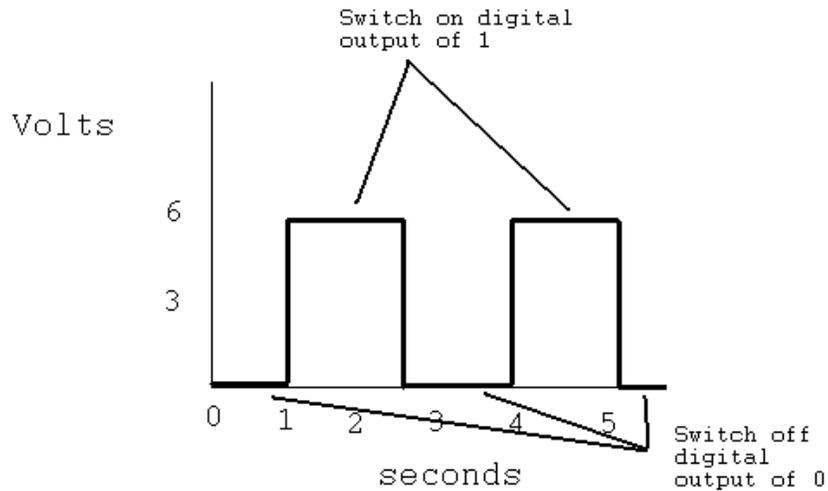
The terms and symbols associated with digital electronics will be unfamiliar to students. This lesson will help students to begin building a foundation for understanding the language of digital electronics.

Important Concepts

- Truth Table: A table that compares the inputs and output of a digital circuit.
 - ie. A circuit consisting of a switch, an LED, and a power source would have the following truth table.

Switch (input)	LED (output)
ON	1 (light is on)
OFF	0 (light is off)

- Timing Diagram: A diagram or graph of the output of a digital circuit that plots voltage vs. time. The high points correspond to the output of the circuit being on and the low points correspond to the output of the circuit being off. See below.



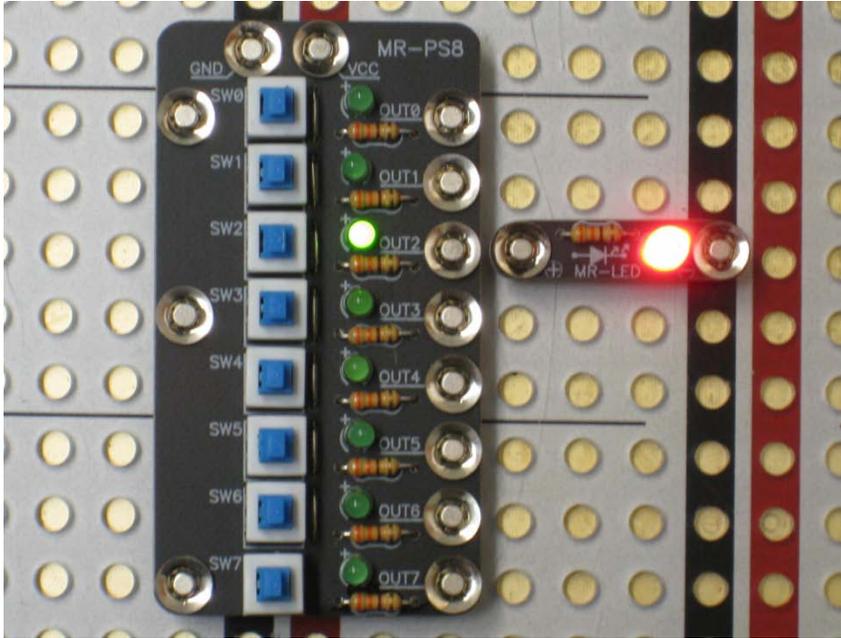
Procedures

1. The teacher will lead a class discussion on truth tables. Following the discussion the teacher will challenge students to complete a simple truth table for a circuit containing a switch and an LED.

Truth Table Example (students should not be shown the text in red)

Switch (input)	LED (output)
ON	1 (light is on)
OFF	0 (light is off)

2. The teacher will ask student how they could use a switch to manually control a circuit that would give an output that would repeat the cycle of being on (1) for 2 seconds then off (0) for 5 seconds.
3. The students will build the circuit that accomplishes the task outlined in step two. Students should use the digital switchboard for their circuit. This will give them a chance to see how it works in a simple situation.



4. Students will then take the measurements of voltage at the given time intervals and graph these measurements versus time.
5. The teacher will choose a student to explain their results then facilitate a class discussion on timing diagrams.

Name: _____

Date: _____

Period: _____

Chapter Thirteen Student Sheet: Truth Tables and Timing Diagrams

1. Truth Table:

2. Complete the following truth table for a series circuit that contains a switch and an LED:

Switch (input)	LED (output)

3. How can you use a switch to manually control a circuit that would give an output that would repeat the cycle of being on (1) for 2 seconds then off (0) for 5 seconds?

4. Use the space below to sketch your circuit:

5. Use the following table to record your circuits output:

Time (s)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Output (V)																					

6. Graph your results in the space below:

7. How is your graph similar to a timing diagram?

Chapter Fourteen

Logic Gates: AND, OR, & NOT

[Back to Table of Contents](#)

Objectives

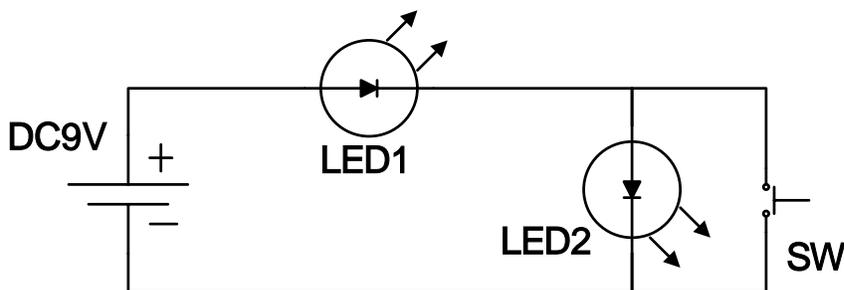
- Familiarize students with the terms associate with digital electronics
- Improve students thinking skills
- Through experimenting with the MR Board and class discussion students will gain an understanding of what logic gates are and specifically how AND, OR, & NOT gates function

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



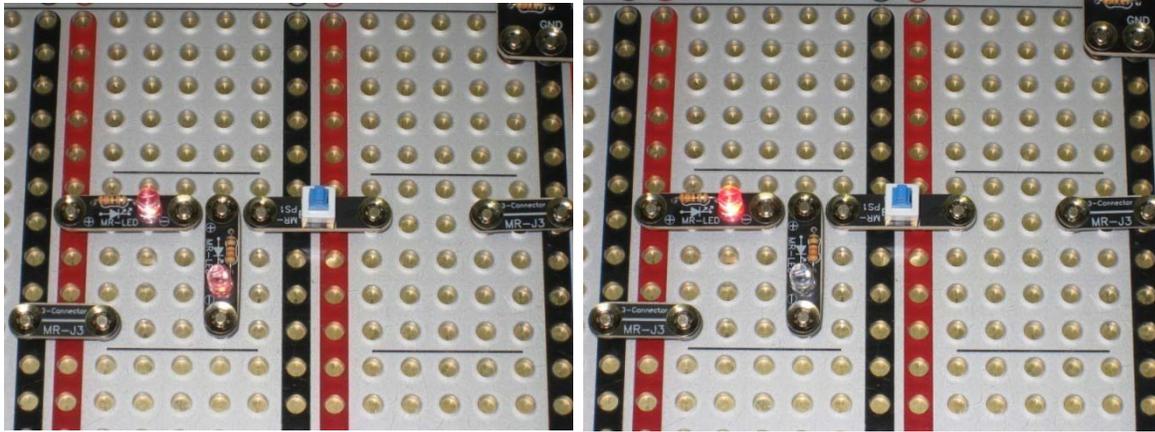


Figure 14: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

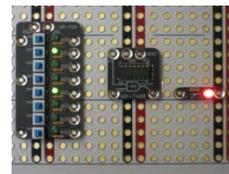
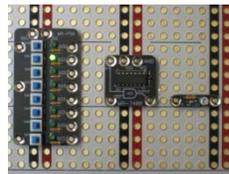
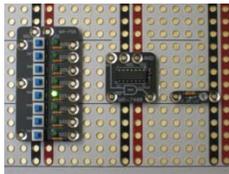
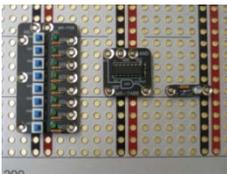
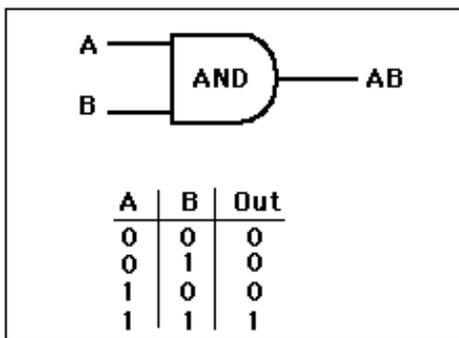
Introduction

Binary Logic (when the output of a circuit is hi or low, 1 or 0 respectively) is fundamental to digital Electronics. An understanding of logic gates is essential for students to gain a conception of how information is transferred using ones and zeros.

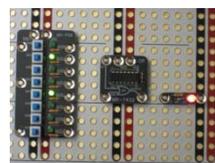
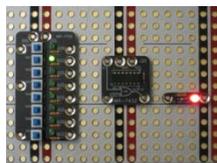
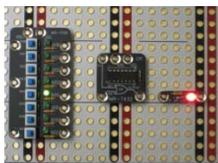
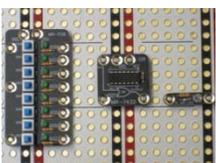
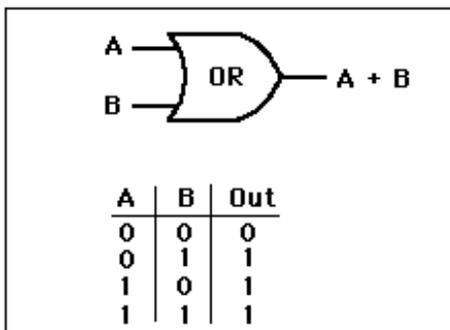
- Logic Symbols: Symbols that represent various logic commands in binary or Boolean logic systems. This lesson will focus on three fundamental gates (AND, OR & NOT). Logic gate symbols with explanatory truth tables for AND, OR & NOT gates are found below. **Don't show students these truth tables until after the activity.**
- AND Logic Gate: A logic gate with an output that will be on (digital signal of 1) when the two inputs are both on. If one or both of the inputs is off then the output of an AND gate will be off. See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.) It may be helpful to talk about analogies to logic gates. A possible analogy is a gender specific restroom that requires a key such as those at gas stations. In order for an individual to get into the restroom there are two conditions and they must both be true. The individual must be of the appropriate gender for the specific restroom and they must have a key. This is similar to AND gates which have two inputs that must both be high (digital 1) in order for the output to be high (digital 1).

Girls Restroom that Needs a Key

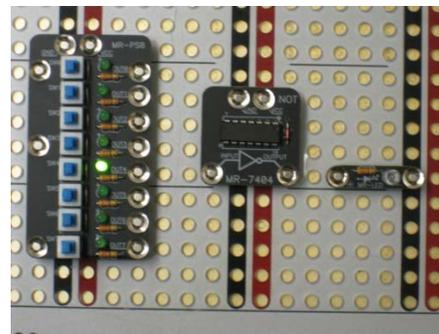
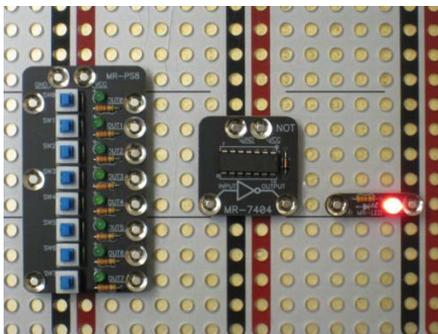
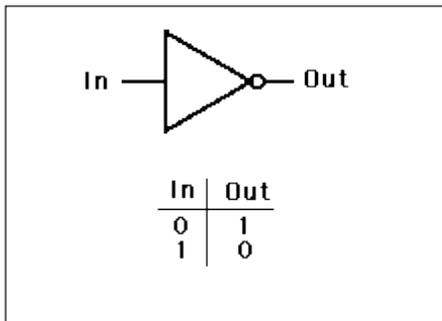
Is a girl	Has a key	Can use restroom
0	0	0
0	1	0
1	0	0
1	1	1



- OR Logic Gate: A logic gate with an output that will be on when one or both of the inputs is on. If both inputs are off then the output is off. See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.)

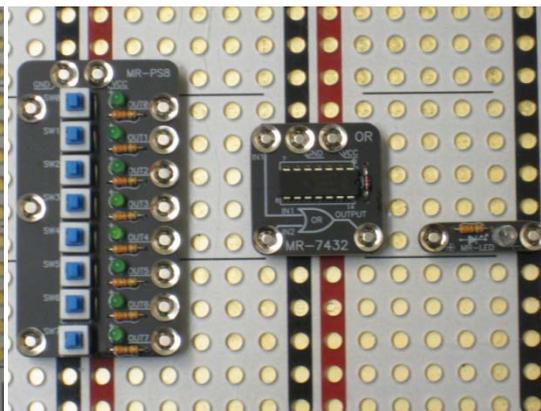
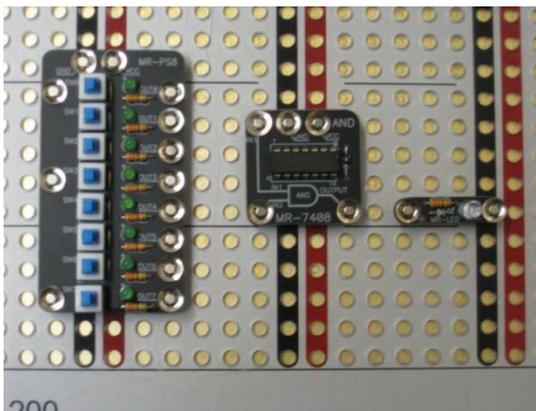


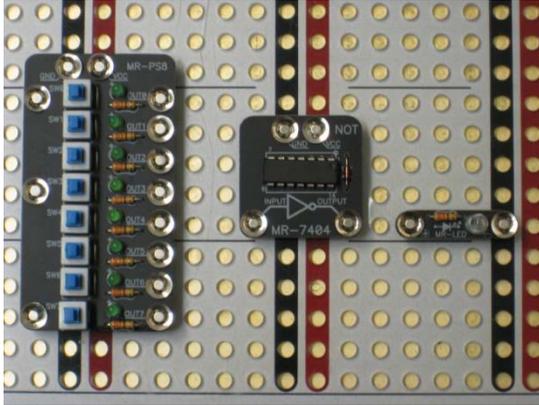
- NOT Logic Gate: A logic gate whose output is the opposite of its input. It is a logic inverter.



Procedures

1. In this learning activity students will construct three circuits. One with an AND gate, one with an OR gate, and one more using a NOT gate. Each of the three circuits will use the digital switch board in the MR Board kit to control the inputs and an LED to display the output. Allow the students to experiment with different ways to set up the circuits. They should end up creating circuits pictured below.





2. Once a student groups have successfully built the appropriate circuit the teacher will challenge the groups to create a truth table that describes the logic of their circuit. This process will continue until all groups have built and discovered the truth table for all three circuits.
3. As students are manipulating the inputs of the circuits and observing the affect on the output the teacher will circulate through the room and ask the groups questions to help them recognize any mistakes they have made or to reinforce the data they have successfully interpreted.
4. When all groups have created the appropriate truth tables (see examples above) students will be challenged to use their tables to come up with a definition for AND, OR, & Not gates. Definitions should be similar to those given in the introduction section of this lesson.
5. After students have completed the activity portion of the lesson and the accompanying student sheet the teacher will pass out the quiz on truth tables, timing diagrams, and AND, OR, & Not gates.

Name: _____

Date: _____

Period: _____

**Chapter Fourteen Student Sheet:
AND, OR, & NOT Logic Gates**

Circuits: You will need to construct three circuits. One with an AND gate, one with an OR gate, and one more using a NOT gate. Each of the three circuits will use the digital switch board in the MR Board kit to control the inputs and an LED to display the output. Use the space provided below to draw your three logic circuits.

Truth Tables: Complete the following truth tables by experimenting with the digital switch board that determines the inputs to your logic gates.

AND

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

OR

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

NOT

Input	Output
0	
1	

Definitions: Use the results of your experimenting recorded in the truth tables above to come up with a definition for AND, OR, & Not gates.

AND Gate:

NOR Gate:

Not Gate:

Name: _____

Date: _____

Period: ____

Quiz: Truth Tables, Binary Numbers, Timing Diagrams, and AND, OR, NOT Logic Gates

1. Draw a timing diagram for a circuit whose output is on at 5V for 2 seconds, then off at 0V for 3 seconds. Repeat the cycle three times.
2. What is 7 in the binary number system? Show how you got your answer.
3. What would the output of a circuit be whose inputs go into an AND gate that is followed by a NOT gate? Complete the truth table to show your answer.

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

4. What would the output of a circuit be whose inputs go into an OR gate that is followed by a NOT gate? Complete the truth table to show your answer.

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

Chapter Fifteen

NAND & NOR Logic Gates

[Back to Table of Contents](#)

Objectives

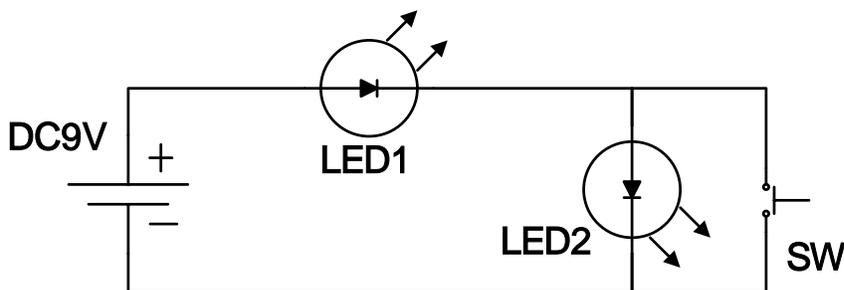
- Familiarize students with the terms associate with digital electronics
- Improve students thinking skills
- Through experimenting with the MR Board and class discussion students will gain a deeper understanding of what logic gates are and specifically how NAND, NOR, & Buffer gates function

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



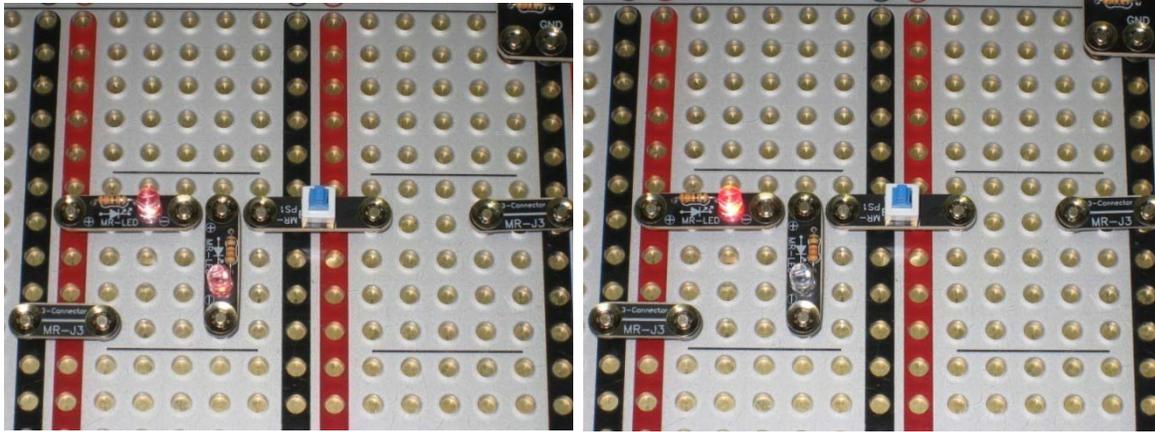


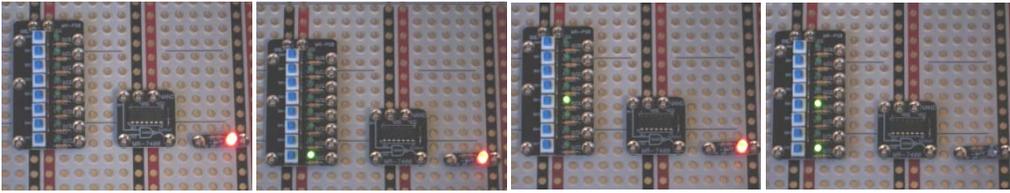
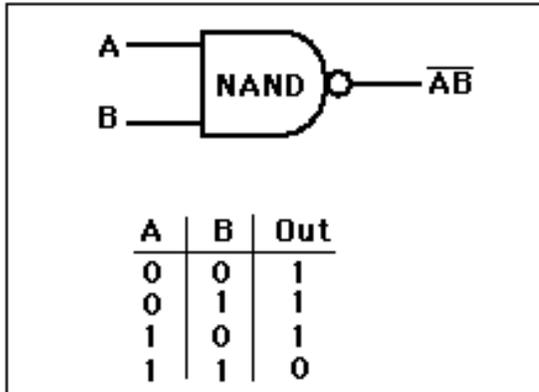
Figure 15: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

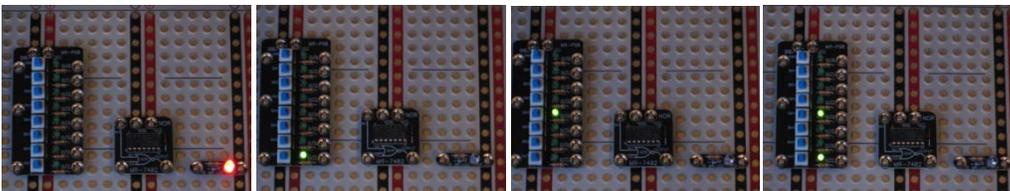
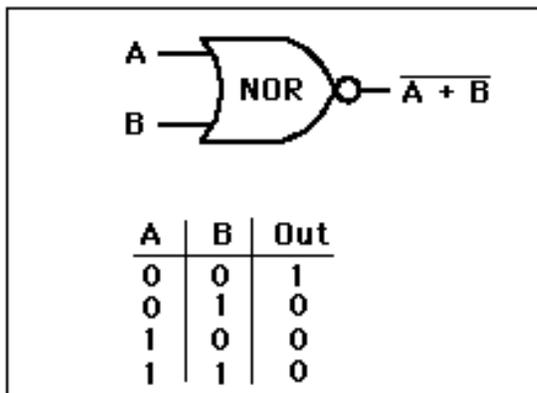
Introduction

Binary Logic (when the output of a circuit is hi or low, 1 or 0 respectively) is fundamental to digital Electronics. An understanding of logic gates is essential for students to gain a conception of how information is transferred using ones and zeros.

- Logic Symbols: Students should remember that logic symbols are symbols that represent various logic commands in binary or Boolean logic systems. This lesson will focus on two fundamental gates (NAND & NOR). Logic gate symbols with explanatory truth tables for NAND & NOR gates are found below. **Don't show students these truth tables until after the activity.**
- NAND Logic Gate: A NAND logic gate is a gate that can be modeled by putting a NOT gate on the output of an AND gate. It is a logic gate with an output that will be on (digital signal of 1) when the one or both of the two inputs are off (digital signal of 0). If both of the inputs is on then the output of an NAND gate will be off. See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.)



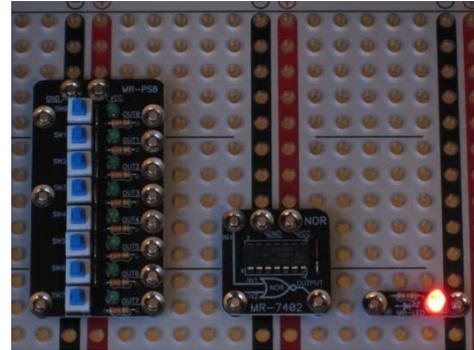
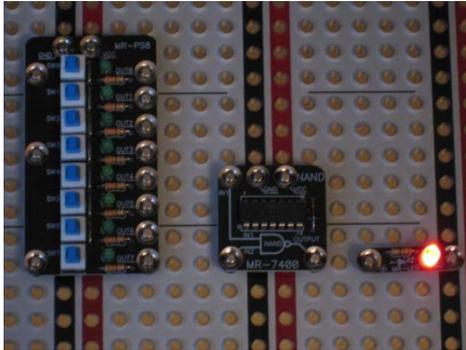
- NOR Logic Gate: A NOR logic gate is a gate whose logic can be modeled by putting a NOT gate on the output of an OR gate. It is a logic gate with an output that will be on when both of the inputs are off. If one or both of the inputs are on then the output is off. See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.)



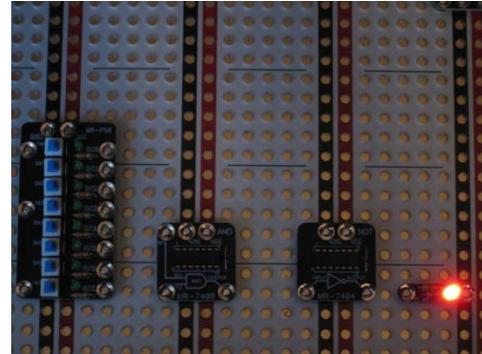
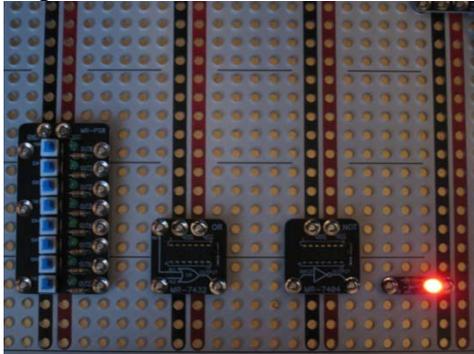
Procedures

1. This learning activity begins with students being asked to construct two circuits. One with an NAND gate and one with an NOR gate. Both of these circuits will use the digital

switch board in the MR Board kit to control the inputs, the appropriate gate, and an LED to display the output. Allow the students to experiment with different ways to set up the circuits. They should end up creating circuits pictured below.



2. Once a student groups have successfully built an appropriate circuit the teacher will challenge the groups to create a truth table that describes the logic of their circuit. This process will continue until all groups have built and discovered the truth table for both circuits.
3. The teacher will then instruct student groups to build two more circuits. They will build one circuit that contains an AND gate with a NOT gate on the output and another with an OR gate that has a NOT gate on the output. Both of these circuits will be made using the digital switch board, the gates mentioned and an LED (the LED indicates the logic on the output).



4. After completing the second set of circuits, student groups will complete the Student Sheet by comparing the truth tables of all four circuits and describing the function of a NAND and NOR logic gate. Their descriptions should be similar to those given above.
5. After students understand the logic of NAND and NOR gates the teacher will explain that these gates are extremely important in that they can be used to create the logic of any of the other gates. This is a way to cut costs in the manufacturing process. The methods used to simplify logic will be covered in later lesson.

Name: _____

Date: _____

Period: _____

Chapter Fifteen Student Sheet: NAND & NOR Logic Gates

Circuits: You will need to construct two circuits. One with an NAND gate and one with an NOR gate. Both of these circuits will use the digital switch board in the MR Board kit to control the inputs, the appropriate gate, and an LED to display the output. Use the space provided below to draw your logic circuits.

Truth Tables: Complete the following truth tables by experimenting with the digital switch board that determines the inputs to your logic gates.

NAND

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

NOR

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

AND with NOT on output

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

OR with NOT on output

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

Circuit Descriptions: Compare the logic gates above and describe the function of NAND and NOR logic gates.

Definitions

NAND Gate:

NOR Gate:

Why is it valuable to know that a NOR gate has the same logic as an OR gate followed by a NOT gate and a NAND gate has the same logic as an AND gate followed by a NOT? Think about how this knowledge is important to manufacturers.

Chapter Sixteen

XOR & XNOR Logic Gates

[Back to Table of Contents](#)

Objectives

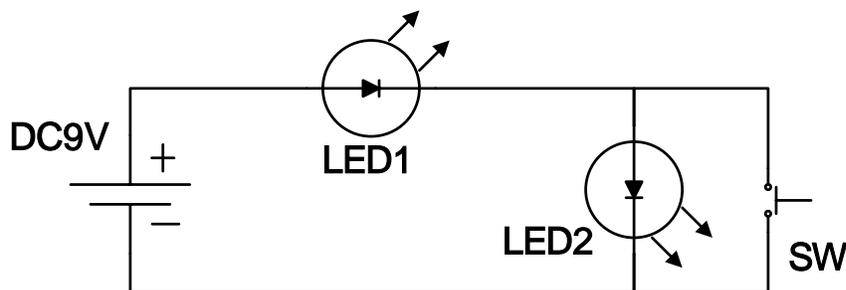
- Familiarize students with the terms associate with digital electronics
- Improve students thinking skills
- Through experimenting with the MR Board and class discussion students will gain a deeper understanding of what logic gates are and specifically how XOR & XNOR logic gates function

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



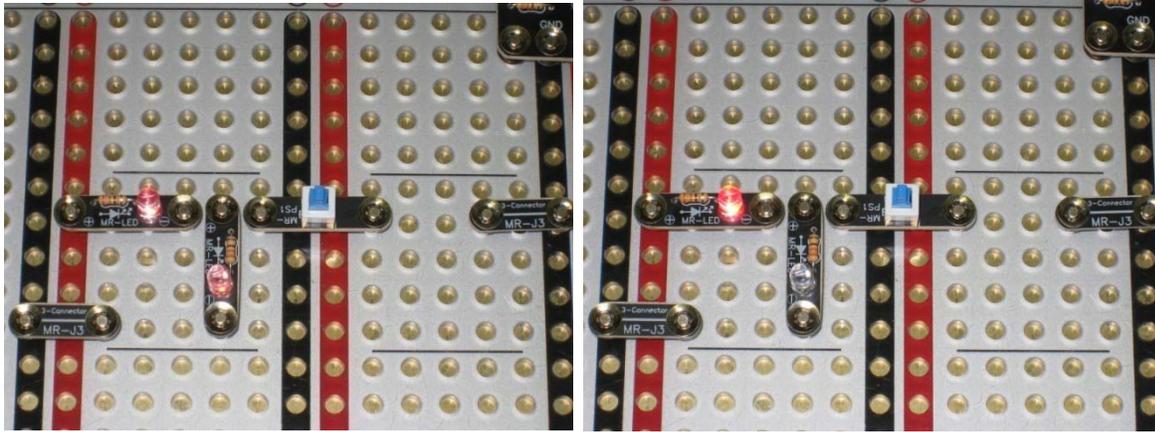


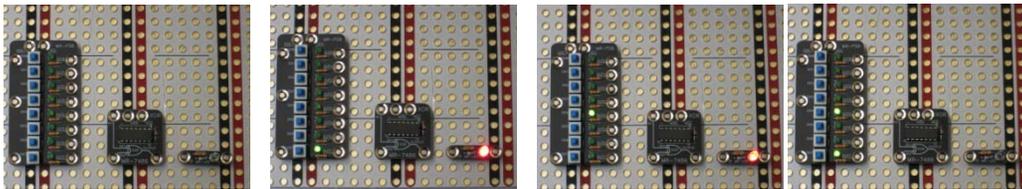
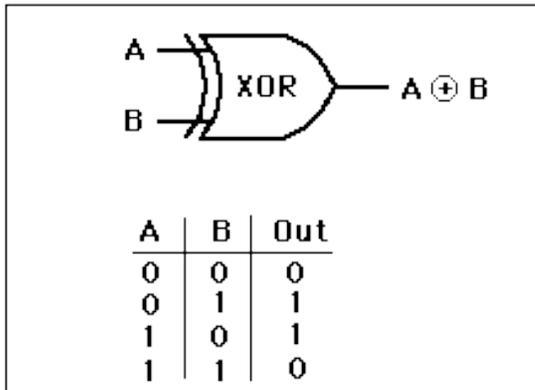
Figure 16: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

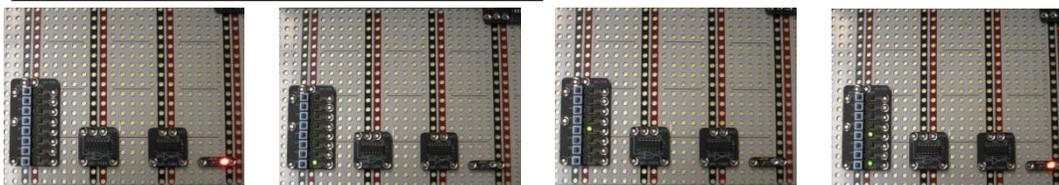
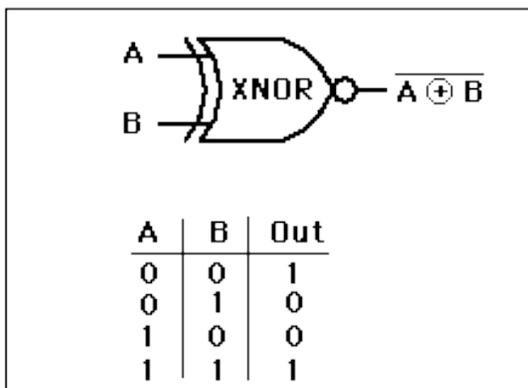
Introduction

Binary Logic (when the output of a circuit is hi or low, 1 or 0 respectively) is fundamental to digital Electronics. An understanding of logic gates is essential for students to gain a conception of how information is transferred using ones and zeros.

- Logic Symbols: Students should remember that logic symbols are symbols that represent various logic commands in binary or Boolean logic systems. This lesson will focus on two fundamental gates (XOR & XNOR). Logic gate symbols with explanatory truth tables for XOR & XNOR gates are found below. **Don't show students these truth tables until after the activity.**
- XOR Logic Gate: An XOR (Exclusive OR) logic gate is a gate whose output is on (digital signal of "1") only when one of the inputs is on and the other is off. If both inputs are on or both inputs are off the output signal is off (digital signal of "0") See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.)



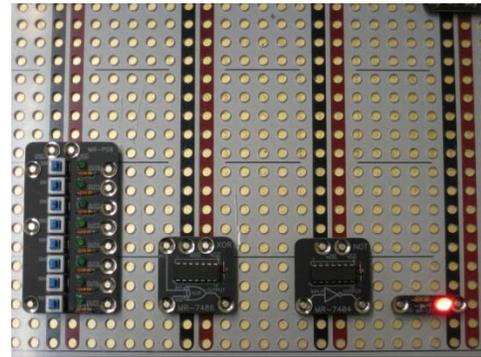
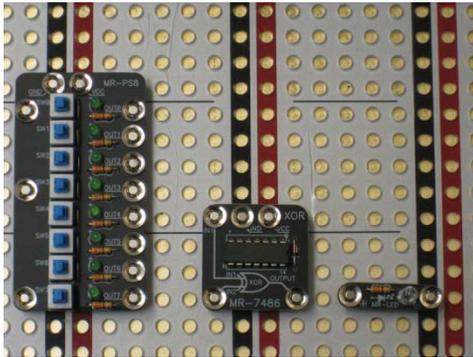
- **XNOR Logic Gate:** An XNOR, or inverted XOR logic gate, is a gate whose logic can be modeled by putting a NOT gate on the output of a NOR gate. It is a logic gate with an output that will be on when the inputs have shared logic. That is to say that the output of an XNOR gate is on when both inputs are off or when both inputs are on. If one of the inputs is on then the output is off. See the truth table and images below. (To preserve the inquiry in this activity, students should not be given this information.)



Procedures

1. This learning activity begins with students being asked to construct two circuits. One with an XOR gate and one with an XNOR gate. Both of these circuits will use the digital switch board in the MR Board kit to control the inputs, the appropriate gate, and an LED to display the output. The XNOR will also require a NOT gate. Allow the students to

experiment with different ways to set up the circuits. They should end up creating circuits pictured below.



2. Once a student groups have successfully built an appropriate circuit the teacher will challenge the groups to create a truth table that describes the logic of their circuit. This process will continue until all groups have built and discovered the truth table for both circuits.
3. After completing the truth tables for their circuits, student groups will complete the Student Sheet by comparing the truth tables and describing the function of a XOR and XNOR logic gate. Their descriptions should be similar to those given above.
4. After students understand the logic of XOR and XNOR gates and have completed the student sheet the teacher will assign the Logic Gate Performance Assessment.
5. After students have completed the Performance Assessment the teacher will call attention to the Boolean Expressions listed on the table for each logic gate. The teacher will lead a discussion to familiarize students with these Boolean Expressions. Boolean Expression will be covered in more depth in chapter nineteen.

Name: _____

Date: _____

Period: _____

Chapter Sixteen Student Sheet: **XOR & XNOR Logic Gates**

Circuits: You will need to construct two circuits. One with an XOR gate and the other with an XNOR and a NOT gate. Both of these circuits will use the digital switch board in the MR Board kit to control the inputs, the appropriate gate, and an LED to display the output. Use the space provided below to draw your logic circuits.

Truth Tables: Complete the following truth tables by experimenting with the digital switch board that determines the inputs to your logic gates.

XOR

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

XNOR

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

Circuit Descriptions: Compare the logic gates above and describe the function of NAND and NOR logic gates.

NAND Gate:

NOR Gate:

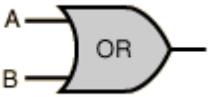
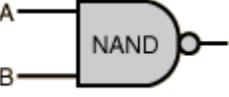
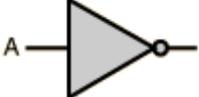
Name: _____

Date: _____

Period: ____

Logic Gate Performance Assessment

Use the MR Board to complete the following truth table.

Gate	Logic Symbol	Boolean Equation	Truth Table		
			Inputs		Output
			B	A	Q
AND		AB	0	0	
			0	1	
			1	0	
			1	1	
OR		$A + B$	0	0	
			0	1	
			1	0	
			1	1	
NAND		\overline{AB}	0	0	
			0	1	
			1	0	
			1	1	
NOR		$\overline{A + B}$	0	0	
			0	1	
			1	0	
			1	1	
XOR		$A \oplus B$	0	0	
			0	1	
			1	0	
			1	1	
XNOR		$\overline{A \oplus B}$	0	0	
			0	1	
			1	0	
			1	1	
NOT		\overline{A}	-	0	
			-	1	

Chapter Seventeen

De Morgan's Theorems

[Back to Table of Contents](#)

Objectives

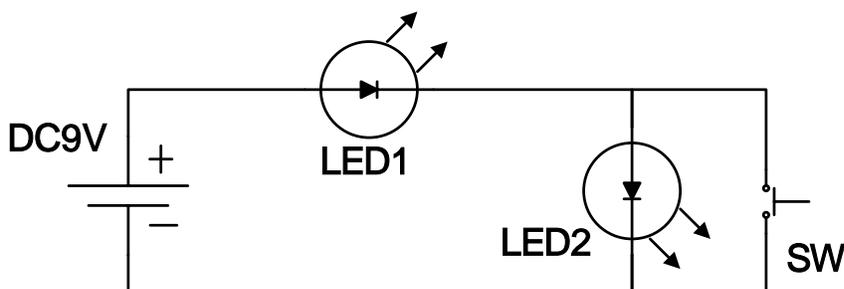
- Familiarize students with De Morgan's Theorems
- Improve students thinking skills
- Through experimenting with the MR Board students will gain an understanding of the use of NOT gate in creating equivalent logic with AND and OR gates

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.



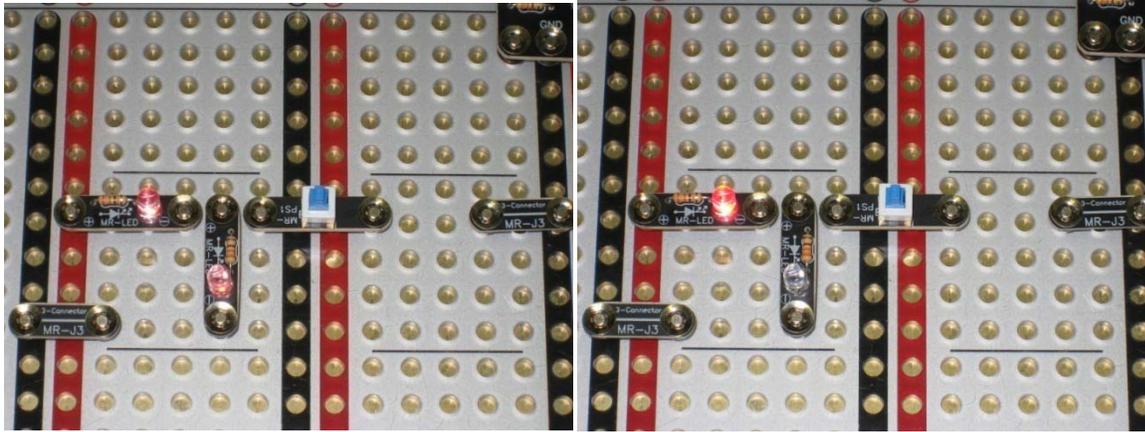


Figure 17: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

De Morgan's Theorems are rules that show the equivalent logic of AND and OR gates when they are combined with inverters (NOT gates). A circuit made with NOT and AND gates can have the same output logic as a circuit made with NOT and OR gates. **Do not show truth tables until student have created their own.**

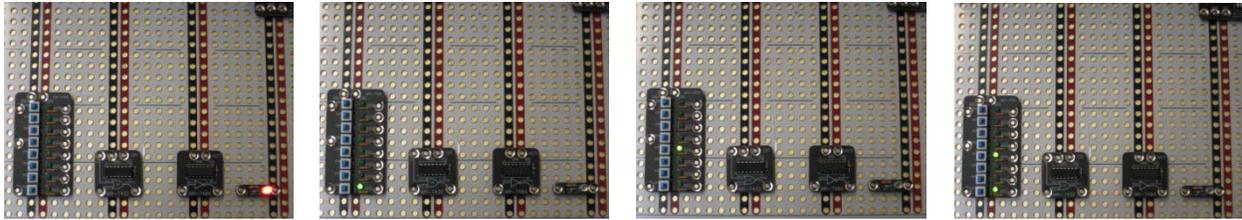
Example:

$$\text{NOT (A OR B)} = (\text{NOT A}) \text{ AND } (\text{NOT B})$$

$$\text{NOT (A AND B)} = (\text{NOT A}) \text{ OR } (\text{NOT B})$$

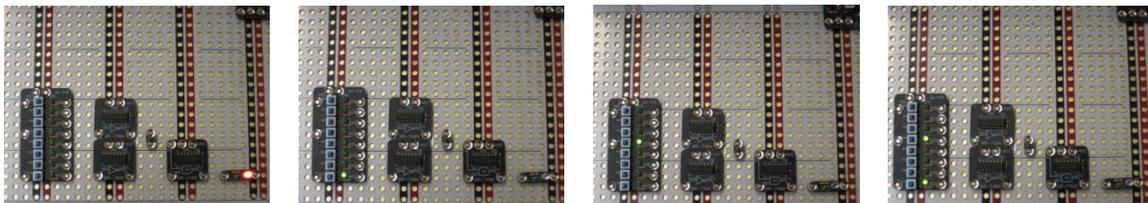
NOT (A OR B)

Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0



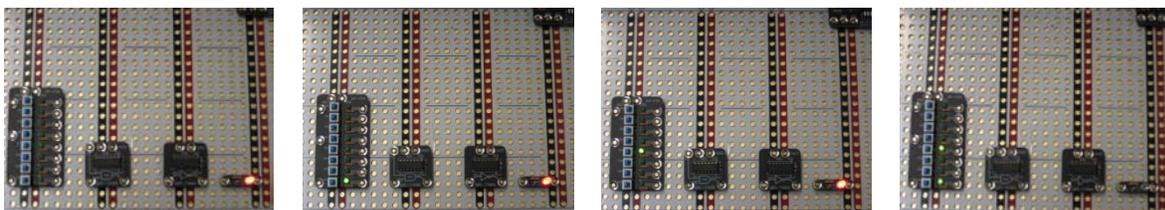
(NOT A) AND (NOT B)

Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0



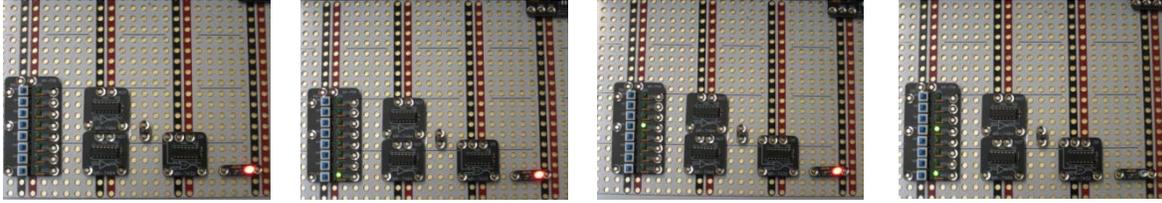
NOT (A AND B)

Input A	Input B	Output
0	0	1
0	1	1
1	0	1
1	1	0

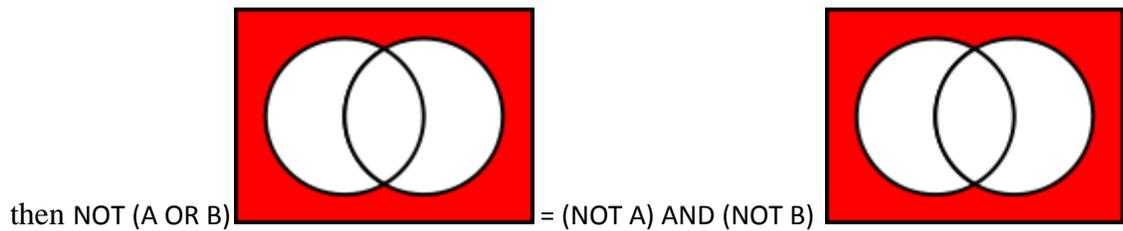
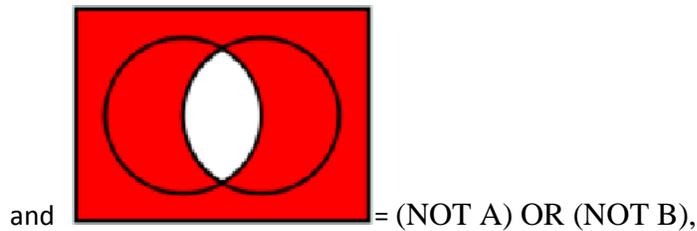
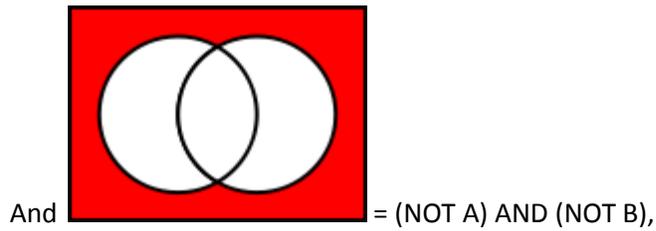
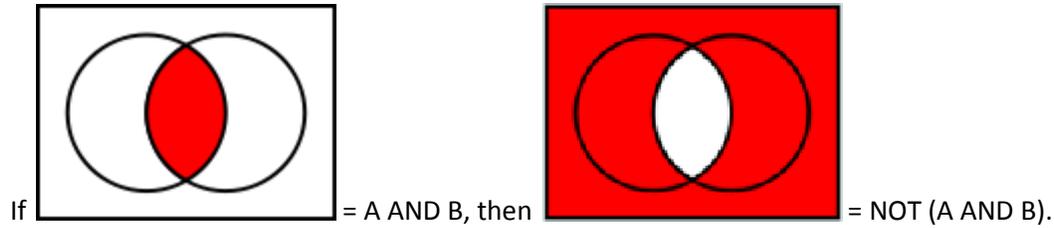
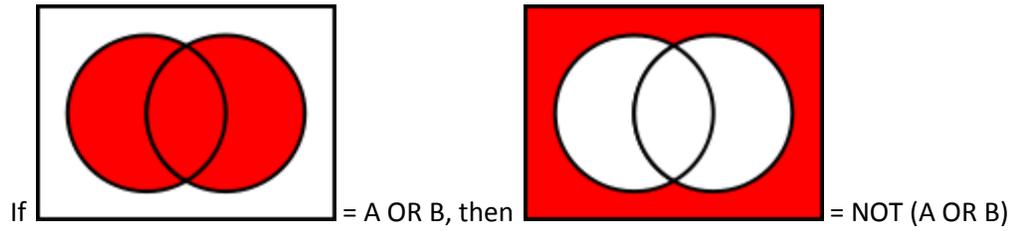


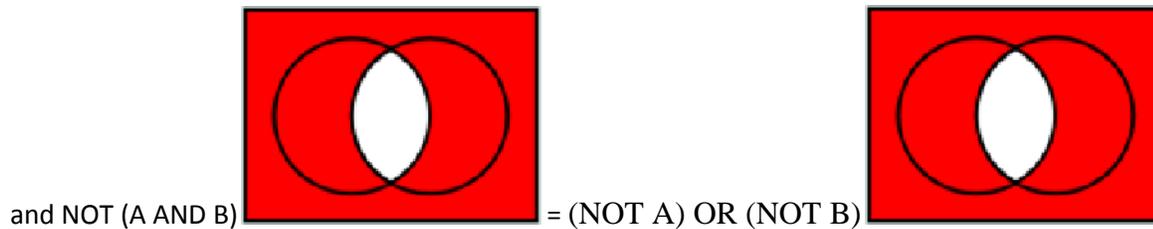
(NOT A) OR (NOT B)

Input A	Input B	Output
0	0	1
0	1	1
1	0	1
1	1	0



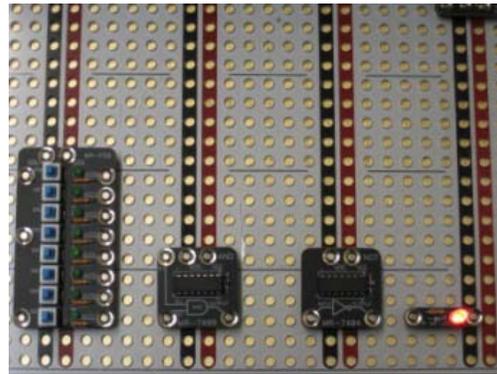
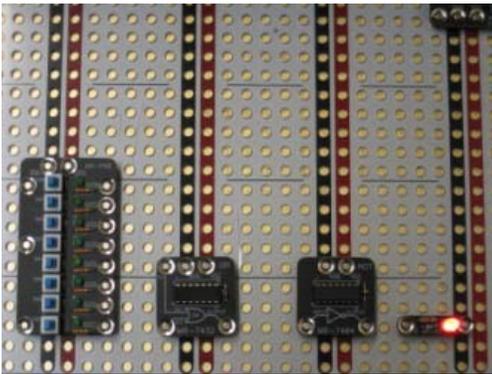
- The equivalencies can be shown using Venn Diagrams as follows: (Red = True and White = False)



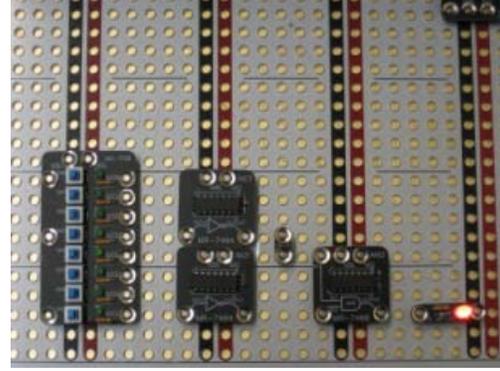
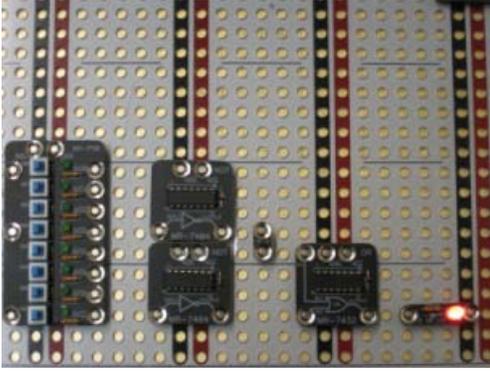


Procedures

1. This learning activity begins with students being asked to construct two circuits. One with an OR gate followed by a NOT gate [NOT (A OR B)] and another with an AND gate followed by a NOT gate [NOT (A AND B)]. Both of these circuits will use the digital switch board to control the logic before the gates, the appropriate gates, and an LED to display the logic of the output. They should end up creating the circuits pictured below.



2. Once a student groups have successfully built an appropriate circuit the teacher will challenge the groups to create a truth table that describes the logic of their circuit. This process will continue until all groups have built and discovered the truth table for both circuits.
3. The teacher will then instruct student groups to build two more circuits. They will build one circuit that has a NOT gate on both inputs of an AND gate [(NOT A) AND (NOT B)] and another that has a NOT gate on both inputs of an OR gate [(NOT A) OR (NOT B)]. Both of these circuits will use the digital switch board to control the logic before the gates, the appropriate gates, and an LED to display the logic of the output. They should end up creating the circuits pictured below.



4. After completing the second set of circuits, student groups will complete the Student Sheet by comparing the truth tables of all four circuits and describing the equivalencies in De Morgan's theorems. Their descriptions should be similar to those given above.
5. The final question on the student sheet is designed to guide students to a recognition that a NOR and NAND gate could be used instead of the OR followed by a NOT and the AND followed by a NOT.

Name: _____

Date: _____

Period: _____

Chapter Seventeen Student Sheet: De Morgan's Theorems

Circuits: You will construct two circuits. One with an OR gate followed by a NOT gate [NOT (A OR B)] and another with an AND gate followed by a NOT gate [NOT (A AND B)]. Both of these circuits will use the digital switch board to control the logic before the gates, the appropriate gates, and an LED to display the logic of the output. Use the space provided below to draw your logic circuits.

Truth Tables: Complete the following truth tables by experimenting with the digital switch board that determines the inputs to your logic gates.

NOT (A OR B)

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

NOT (A AND B)

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

You will build two more circuits. They will build one circuit that has a NOT gate on both inputs of an AND gate $[(\text{NOT } A) \text{ AND } (\text{NOT } B)]$ and another that has a NOT gate on both inputs of an OR gate $[(\text{NOT } A) \text{ OR } (\text{NOT } B)]$. Both of these circuits will use the digital switch board to control the logic before the gates, the appropriate gates, and an LED to display the logic of the output. Use the space provided below to draw your logic circuits.

 $(\text{NOT } A) \text{ AND } (\text{NOT } B)$

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

 $(\text{NOT } A) \text{ OR } (\text{NOT } B)$

Input A	Input B	Output
0	0	
0	1	
1	0	

1	1	
---	---	--

De Morgan's Theorems: Which circuits have the same output logic? Analyze the truth tables above to find the equivalencies. These equivalencies are De Morgan's Theorems. Write a definition of De Morgan's Theorems.

How could the circuits in this activity have been simplified using NOR and NAND gates? What could they have replaced?

Chapter Eighteen

Duality of Logic

[Back to Table of Contents](#)

Objectives

- Familiarize students with the Duality of Logic
- Improve students thinking skills
- Through experimenting with the MR Board students will gain an understanding of the use of NOR and NAND gates in creating logic equivalent to AND, OR, & NOT

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.

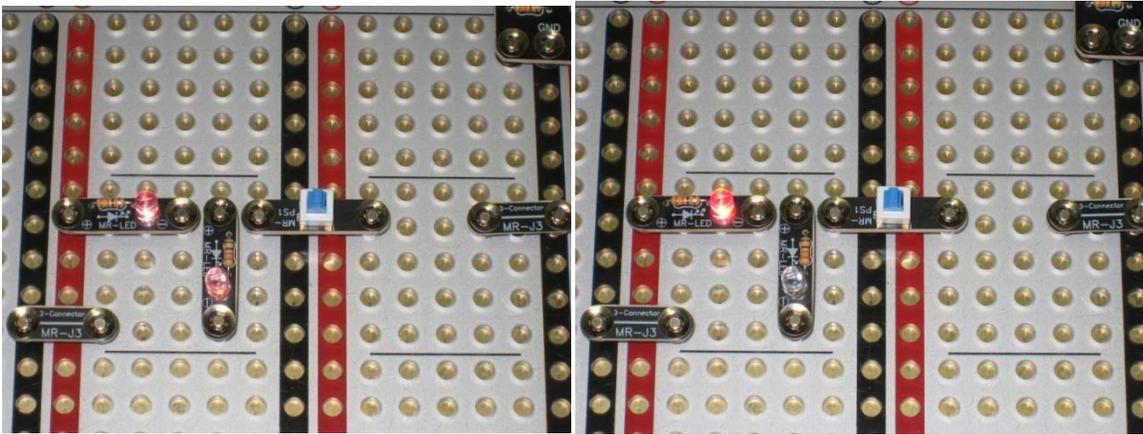
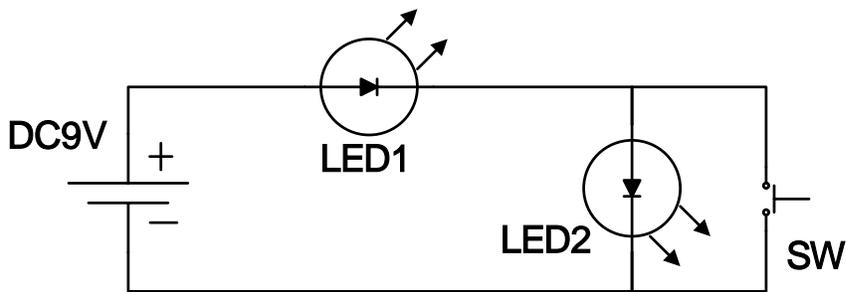


Figure 18: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

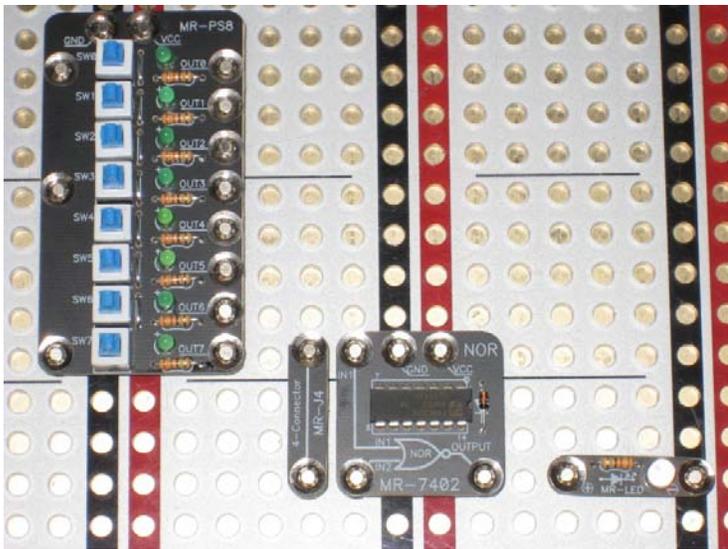
- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

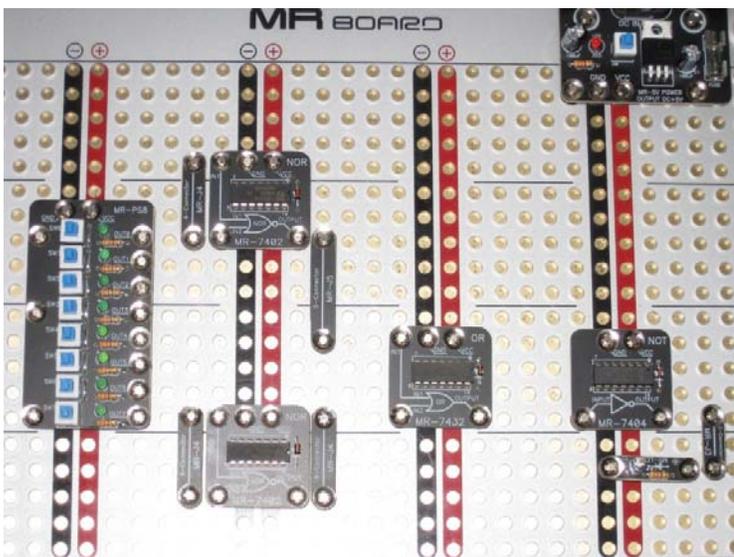
NOR gates are very versatile in that they can be used to make AND, OR, and NOT gates. This versatility provides for the simplification of circuits and a reduction in the cost of manufacturing. In this lesson students will simulate the logic of AND, OR, AND NOT gates.

Procedures

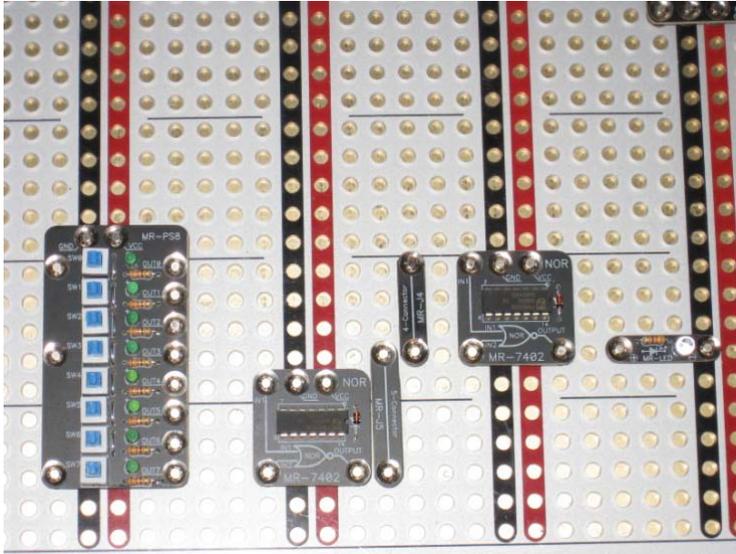
1. Students will construct the following circuit with a NOR gate (simulating a NOT gate) and use the output logic to complete Truth Table 1 on the student sheet.



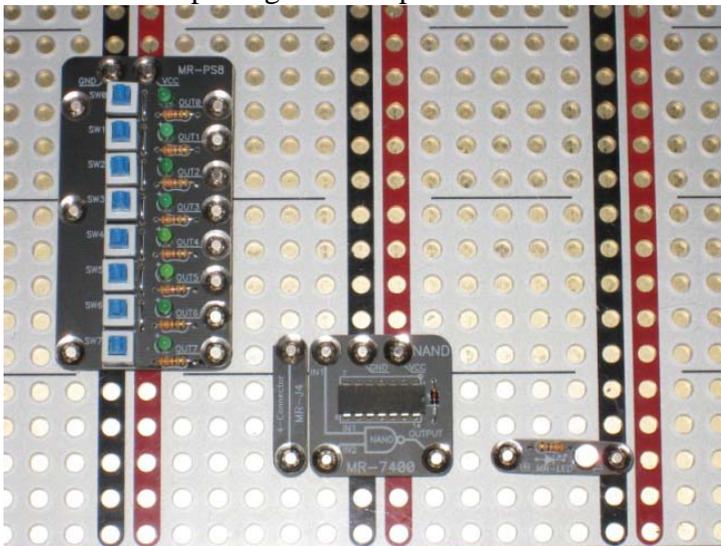
- Students will construct the following circuit (simulating an AND gate) and use the output logic to complete Truth Table 2 on the student sheet.



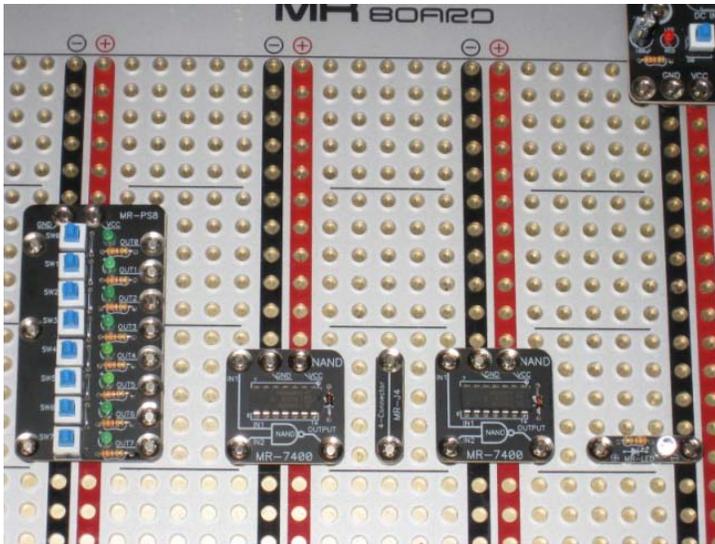
- Students will construct the following circuit with NOR gates (simulating an OR gate) and use the output logic to complete Truth Table 3 on the student sheet.



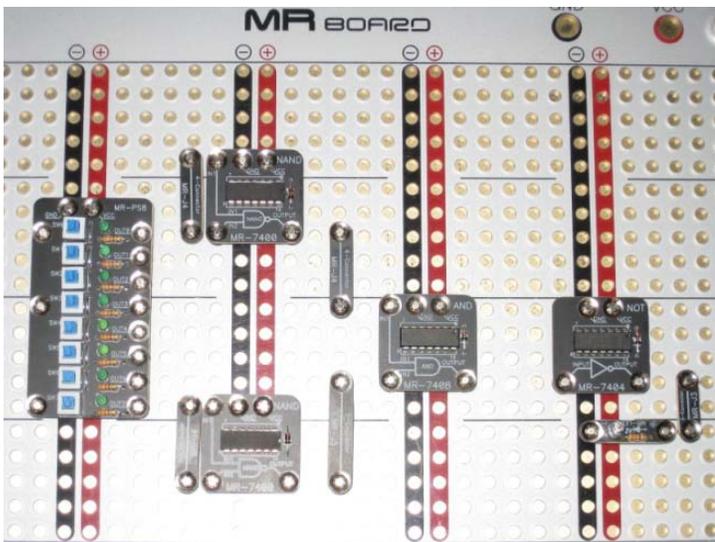
4. Students will construct the following circuit with NAND gates (simulating a NOT gate) and use the output logic to complete Truth Table 4 on the student sheet.



5. Students will construct the following circuit with NAND gates (simulating an AND gate) and use the output logic to complete Truth Table 5 on the student sheet.



6. Students will construct the following circuit with NAND gates (simulating an OR gate) and use the output logic to complete Truth Table 6 on the student sheet.



7. Students will use the data in their truth tables to identify the gates simulated by the NOR and NAND gates.
8. The teacher will make sure students were able to correctly simulate the logic and then facilitate a class discussion about the reasons the duality of NOR and NAND gates is important.

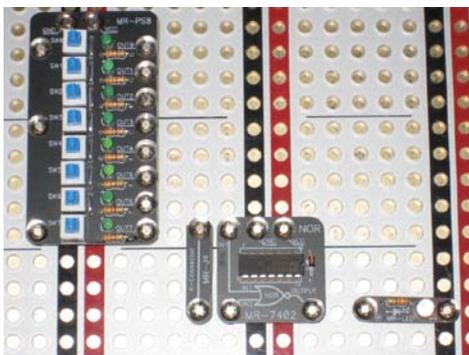
Name: _____

Date: _____

Period: _____

Chapter Eighteen Student Sheet: Duality

Construct the following circuit with a NOR gate and use the output logic to complete Truth Table 1.

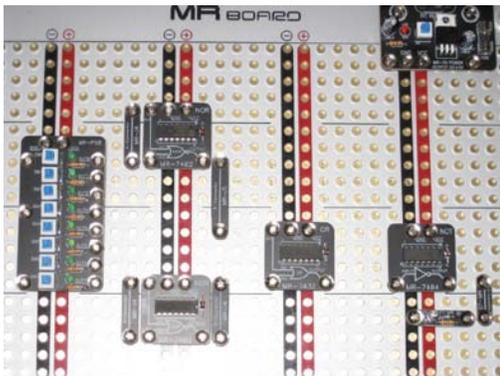
**Truth Table One**

Input A	Input B	Output
0	0	
0	1	
1	0	

1	1	
---	---	--

1. What basic gate has logic that matches the output data in Truth Table One?

Construct the following circuit and use the output logic to complete Truth Table 2.

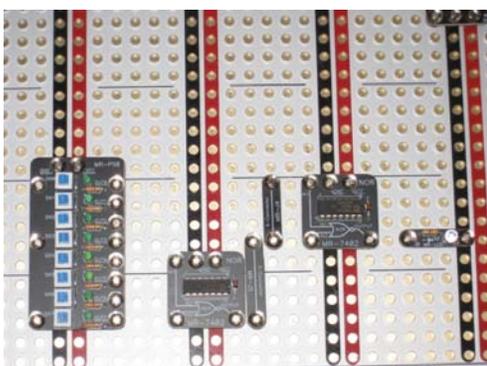


Truth Table Two

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

2. What basic gate has logic that matches the output data in Truth Table Two?

Construct the following circuit and use the output logic to complete Truth Table 3 on the student sheet.



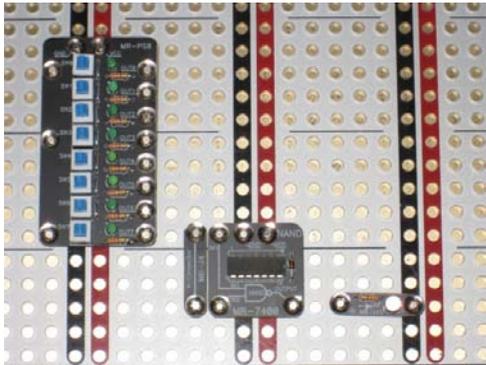
Truth Table Three

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

3. What basic gate has logic that matches the output data in Truth Table Three?

Construct the following circuit and use the output logic to complete Truth Table 3 on the student sheet.

Construct the following circuit and use the output logic to complete Truth Table 4 on the student sheet.

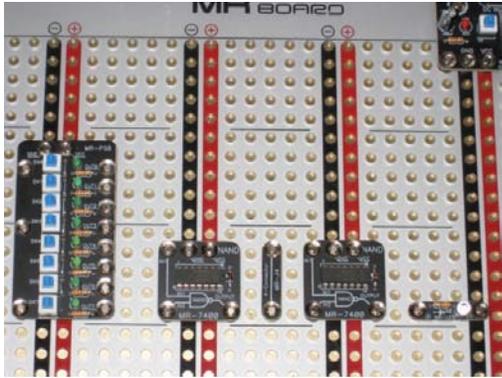


Truth Table Four

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

4. What basic gate has logic that matches the output data in Truth Table Four?

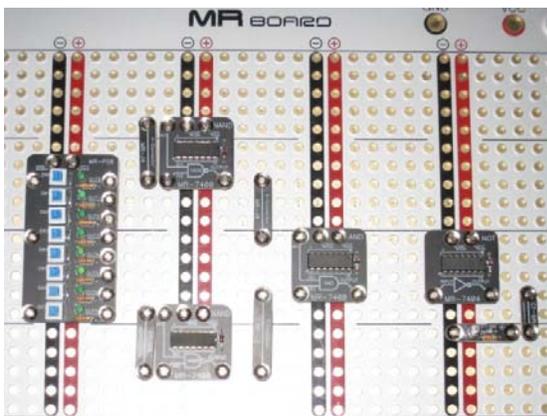
Construct the following circuit and use the output logic to complete Truth Table 5 on the student sheet.

**Truth Table Five**

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

5. What basic gate has logic that matches the output data in Truth Table Five?

Construct the following circuit and use the output logic to complete Truth Table 6 on the student sheet.

**Truth Table Six**

Input A	Input B	Output
0	0	
0	1	
1	0	
1	1	

6. What basic gate has logic that matches the output data in Truth Table Six?

Why do you think the duality of NOR and NAND gates is important in building digital circuits?

Chapter Nineteen

Boolean Expressions from Digital Circuits

[Back to Table of Contents](#)

Objectives

- Familiarize students with Boolean Expressions and the formats (sum-of-products, product-of-sums) in which they can be written
- Improve students thinking skills
- Through experimenting with the MR Board students will derive a Boolean Expression and truth table from a logic circuit, they will also construct a logic circuit from a Boolean Expression.

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse

to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.

- The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.

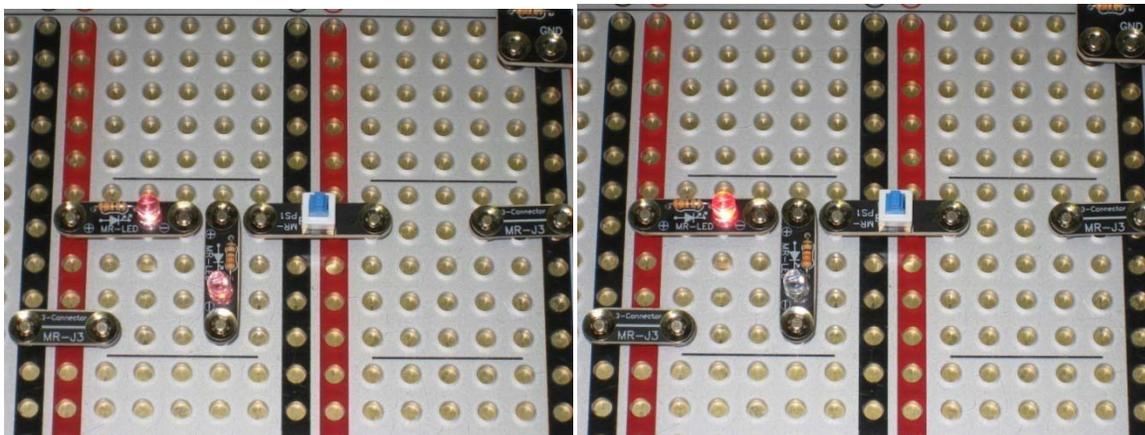
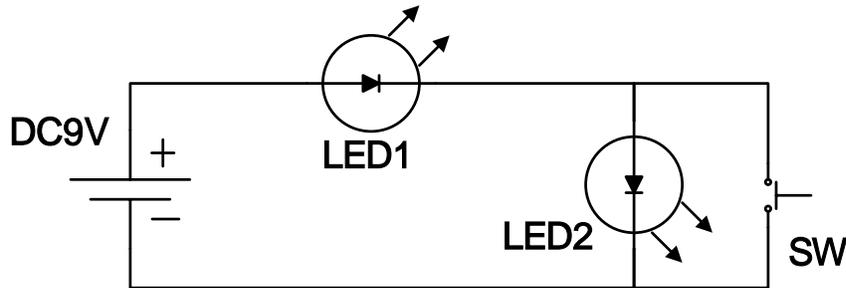


Figure 19: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

Each logic gate or combination of logic gates has an accompanying Boolean Expression. We can derive a Boolean Expression and truth table from a logic circuit. We can also create a logic circuit from a

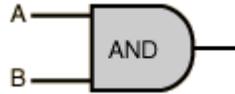
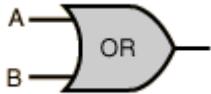
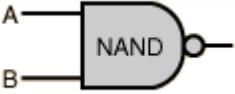
Boolean Expression. In this lesson students will learn both of these skills. Students will also learn the two formats in which Boolean Expressions can be written.

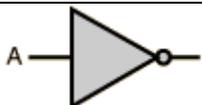
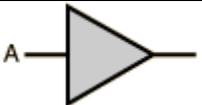
Boolean Expressions can be written to two formats

- Sum-of-Products or minterm expressions format implements OR gates to combine the outputs of AND gates
- Product-of-Sums or maxterm expressions format uses AND gates to combine the outputs of OR gates

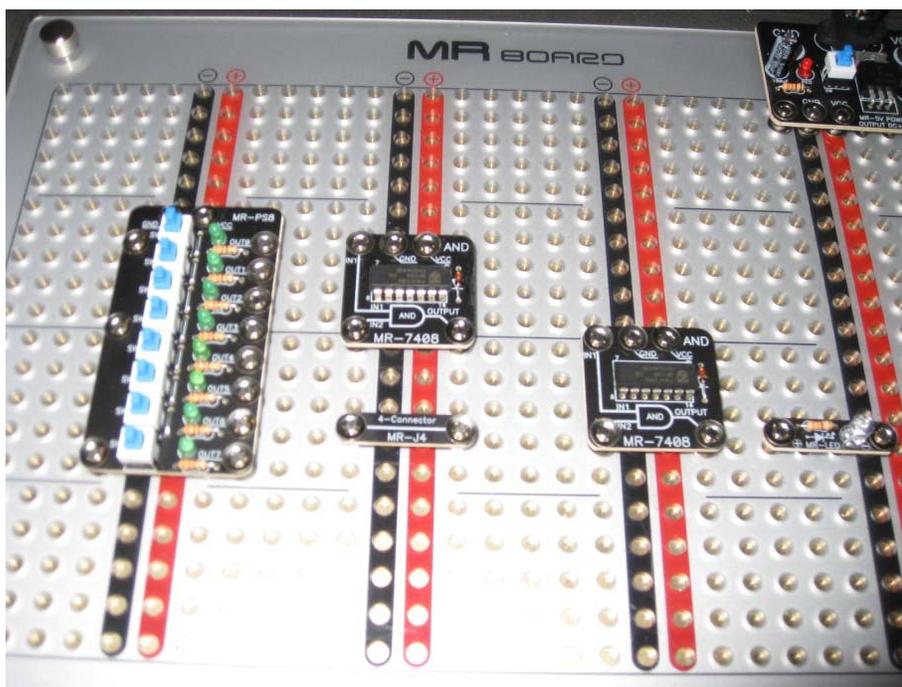
Procedures

1. The teacher will review Boolean Expressions introduced in chapter sixteen for the standard logic gates.

Gate	Logic Symbol	Boolean Equation	Truth Table		
			Inputs		Output
			B	A	Q
AND		AB	0	0	0
			0	1	0
			1	0	0
			1	1	1
OR		$A + B$	0	0	0
			0	1	1
			1	0	1
			1	1	1
NAND		\overline{AB}	0	0	1
			0	1	1
			1	0	1
			1	1	0
NOR		$\overline{A + B}$	0	0	1
			0	1	0
			1	0	0
			1	1	0
XOR		$A \oplus B$	0	0	0
			0	1	1
			1	0	1
			1	1	0
XNOR		$\overline{A \oplus B}$	0	0	1
			0	1	0
			1	0	0
			1	1	1

			1	1	1
NOT		\bar{A}	-	0	1
			-	1	0
YES		A	-	0	0
			-	1	1

- Students will construct the circuit (circuit 1) below (they should do so without power connected to the board so they are not tempted to check the logic before their analysis of the arrangement of the gates).



- After completing the circuit, students will analyze it and complete a prediction of the truth table on the student sheet without testing the logic.
- The teacher will choose a group to present and explain their prediction.
- Students will then test the logic of circuit 1 and make any needed corrections to their truth table predictions. The correct truth table is shown below.

Inputs are identified alphabetically from the top down on the digital switch board

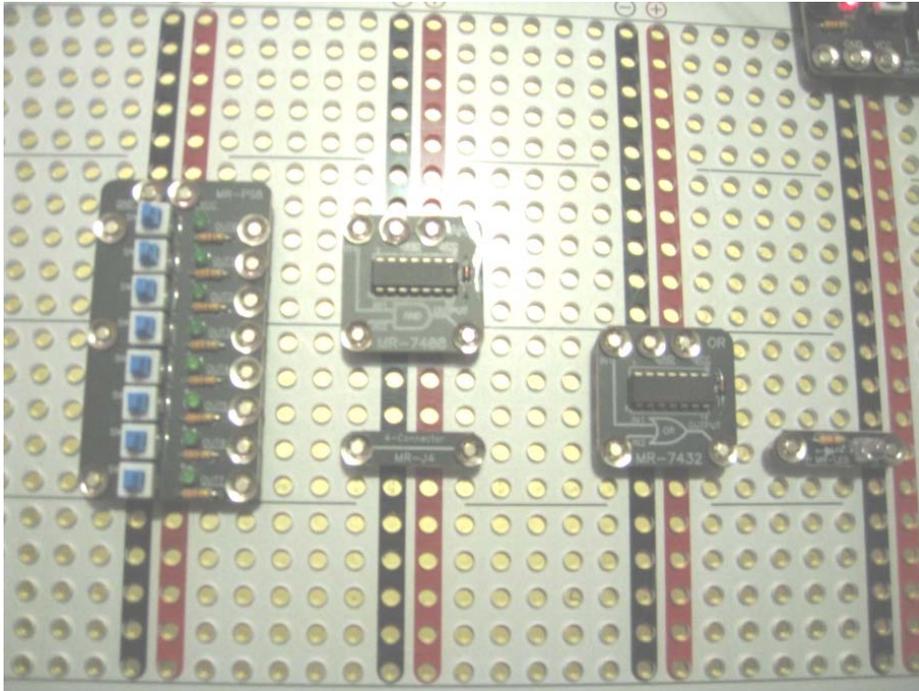
Input A	Input B	Input C	Output
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0

1	1	0	0
1	1	1	1

6. Through an analysis of the truth table, groups will work together to derive the Boolean Expression for circuit 1. See Boolean Expression below.

$$\text{Output} = ABC = (A \text{ AND } B \text{ AND } C)$$

7. Students will construct the circuit (circuit 2) below.



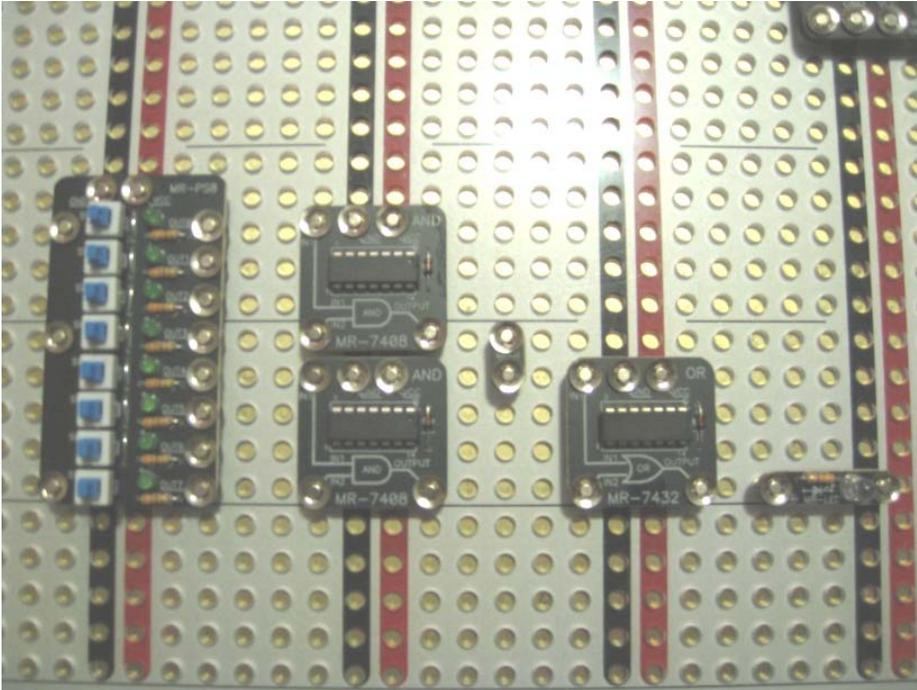
8. Students will repeat steps 3 through 6 for circuit 2. The proper truth table and Boolean Expression for circuit 2 are shown below.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

$$\text{Output} = AB + C = (A \text{ AND } B \text{ OR } C)$$

9. Students will construct the circuit (circuit 3) below.



10. Students will repeat steps 3 through 6 for circuit 3. The proper truth table and Boolean Expression for circuit 3 are shown below.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Input D	Output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

$$\text{Output} = AB \text{ OR } CD = ((A \text{ AND } B) \text{ OR } (C \text{ AND } D))$$

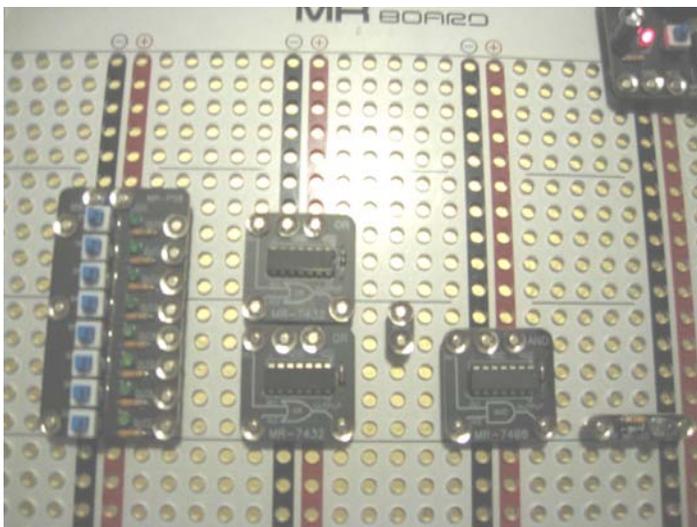
11. Through analyzing the following truth table and Boolean Expression student groups will design and construct a matching logic circuit.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Input D	Output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

$$\text{Output} = (A+B)(C+D) = ((A \text{ OR } B) \text{ AND } (C \text{ OR } D))$$

12. As student groups are constructing their circuits the teacher will circulate through the room and ask guiding questions regarding the output logic in order to lead struggling groups toward the appropriate circuit.
13. The circuit matching the truth table and Boolean Expression given in step 11 is shown below.



14. Students will record their work and complete the questions on the student sheet.

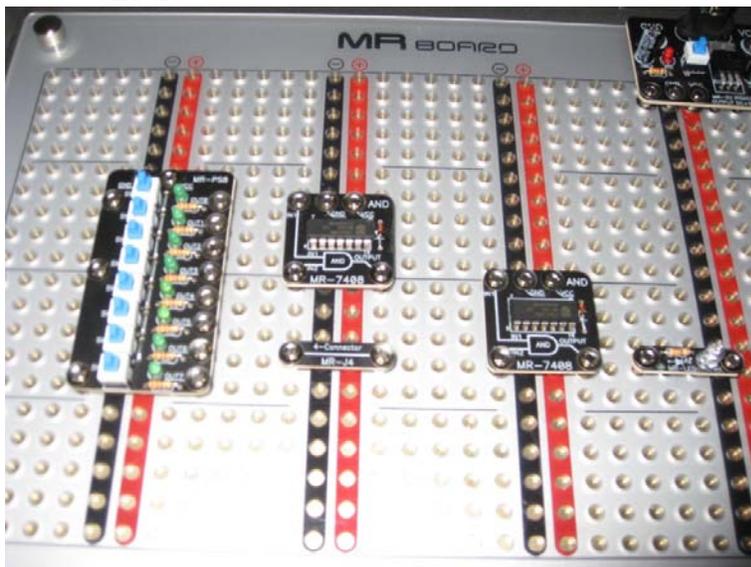
Name: _____

Date: _____

Period: ____

Chapter Nineteen Student Sheet: Digital Expressions

1. Build the circuit shown below (circuit 1) and predict the truth table without testing the circuit.

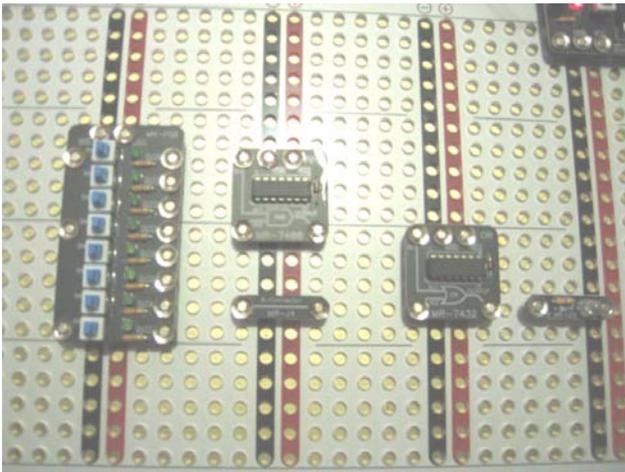


Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	
0	0	1	

0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

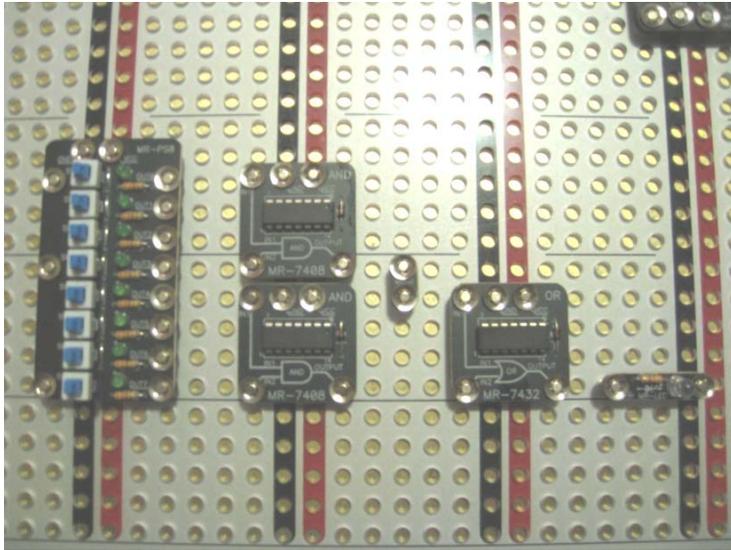
2. What is the Boolean Expression that describes circuit 1? _____
3. Build the circuit shown below (circuit 2) and predict the truth table without testing the circuit.



Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

4. What is the Boolean Expression that describes circuit 2? _____
5. Build the circuit shown below (circuit 3) and predict the truth table without testing the circuit.



Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

6. What is the Boolean Expression that describes circuit 3? _____
7. Through analyzing the following truth table and Boolean Expression design and construct a matching logic circuit. Use the space below to show your design. Make sure you check that your logic matches that in the truth table.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Input D	Output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1

1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

Output = $(A+B)(C+D)$, $((A \text{ OR } B) \text{ AND } (C \text{ OR } D))$

8. Boolean Expressions can be written in two formats
- Sum-of-Products or minterm expressions format implements OR gates to combine the outputs of AND gates
 - Product-of-Sums or maxterm expressions format uses AND gates to combine the outputs of OR gates
- What format is circuit 1 written in? _____
9. What format is circuit 2 written in? _____
10. What format is circuit 3 written in? _____

Use the following truth table and Boolean Expression to guide you in the design and construction of a matching logic circuit.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Input D	Output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1

1	1	1	1	1
---	---	---	---	---

$$\text{Output} = (A+B)(C+D) = ((A \text{ OR } B) \text{ AND } (C \text{ OR } D))$$

Use the space below to draw your logic circuit.

11. What is the format (Sum-of-Products or Product-of-Sums) for the circuit you designed?

Chapter Twenty

Logic Simplification

[Back to Table of Contents](#)

Objectives

- Familiarize students with the laws and rules of Boolean Algebra
- Improve students thinking skills
- Through experimenting with the MR Board students will simplify Boolean Expressions and verify the truth tables of the simplified circuits

Materials

- MR Board Kit for each student group
- Digital Multimeter for each student group

Safety Concerns

- Students should never put any part, component, piece of the MR Board in their mouth or use them in any way that is not outlined in the lesson or instructed by their teacher.
- The MR Board uses electricity at a low voltage, care should be taken.
- Students should be instructed as to what a short circuit is and warned not to construct one. A short circuit is created when current is provided a pathway of little to no resistance that is different from the one intended. Teachers need to watch for students making direct connections from voltage to ground. While the MR Board is equipped with a safety fuse to avoid danger, making a short circuit is a bad habit that can damage electronics equipment and potentially cause a fire. Not to mention having to replace popped fuses.
 - The schematic below shows a possible construction of a short circuit. This circuit is not dangerous because LED 1 provides a load even when LED 2 is shorted out. Students should recognize the tendency of current to follow the path of least resistance.

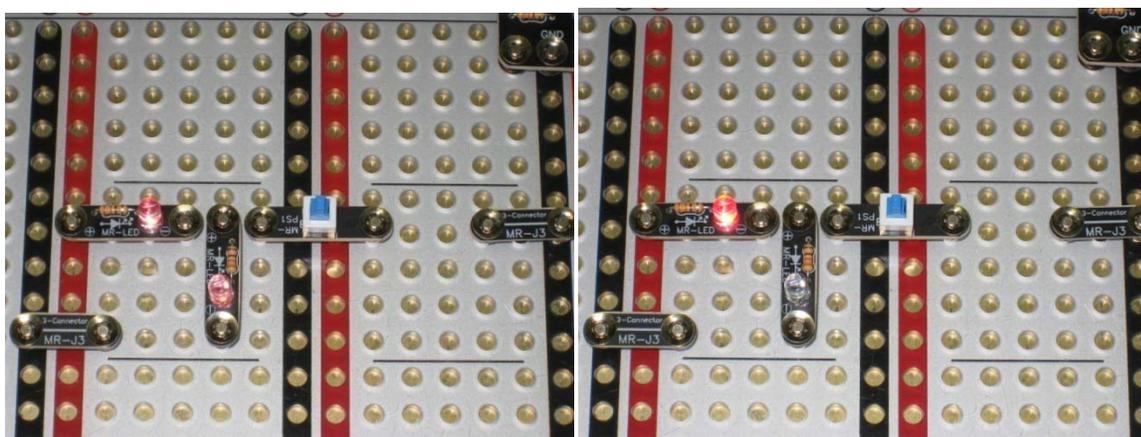
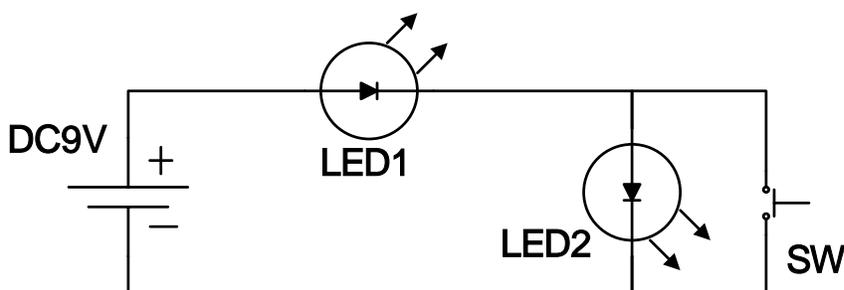


Figure 20: The picture on the left shows the circuit with the switch turned off. Notice that electricity flows through both LED's. In the picture on the right the switch is turned on allowing electricity to flow through it to ground, bypassing the second LED. This particular short circuit is not dangerous due to the load provided by the first LED. If the first LED were to be replaced by a connector then current would have a path directly from VCC to GND creating the unwanted situation described above.

- Students should not eat or drink near or while working with the MR Board
- Teachers should make certain that the power adapter included in the MR Board Kit is the only power adapter used (9V 1Amp or 5V 2Amp DC output adapter).

Introduction

Boolean Algebra is the mathematical language of digital electronics. The rules and laws of Boolean Algebra can be used to simplify the expressions used to create digital circuits. In this lesson students will learn the laws and rules of Boolean Algebra. They will then simplify the logic of a digital circuit and verify the truth table of their simplified circuit.

Laws of Boolean Algebra

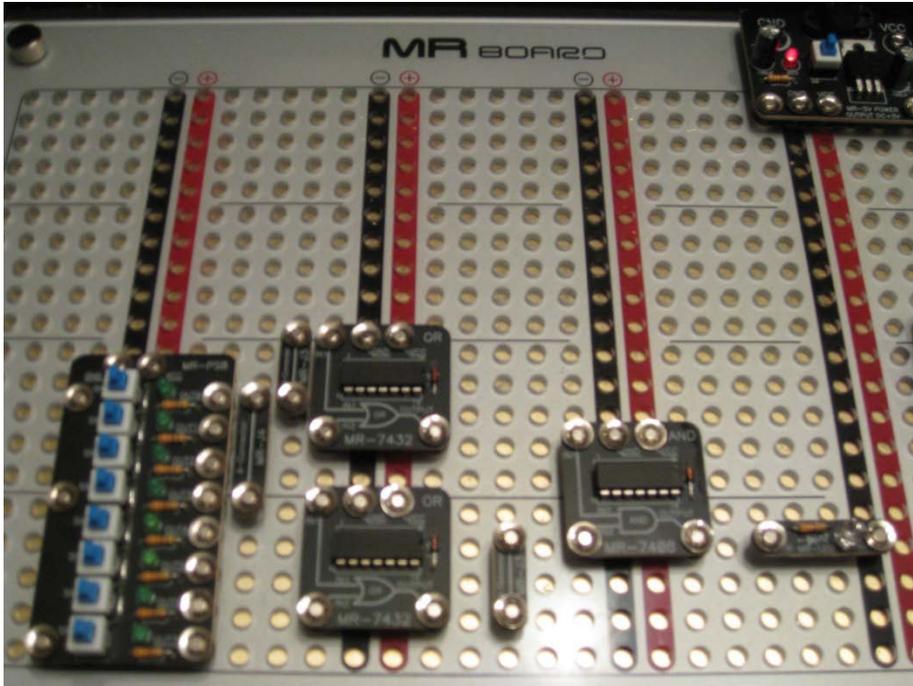
Law	Expression
Commutative	Addition: $A + B = B + A$ Multiplication: $AB = BA$
Associative	Addition: $A + (B + C) = (A + B) + C$ Multiplication: $A(BC) = (AB)C$
Distributive	$A(B + C) = AB + AC$

Rules of Boolean Algebra

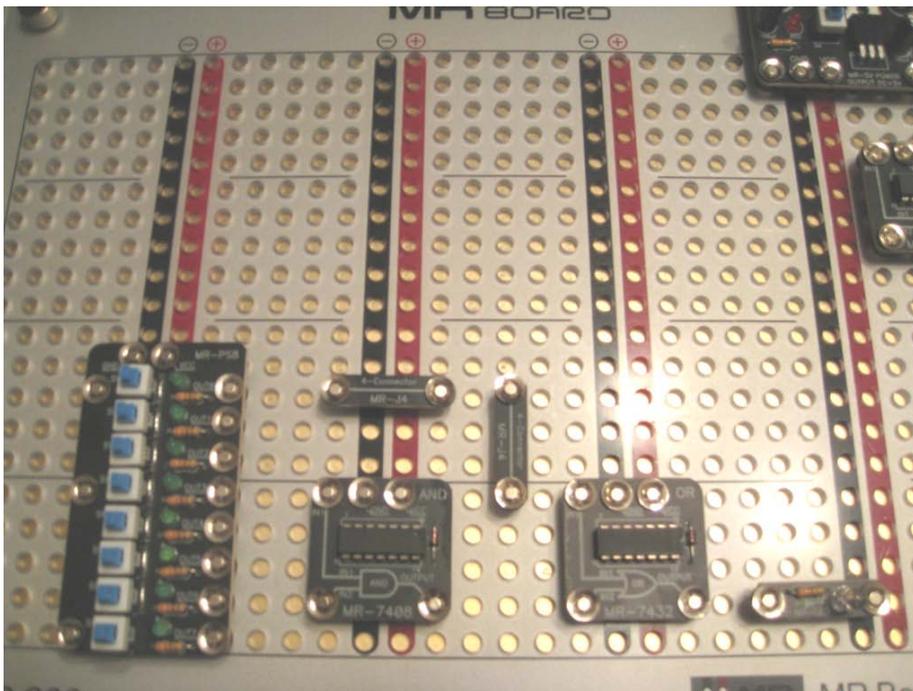
Rule Number	Boolean Expression
1	$A + 0 = A$
2	$A + 1 = 1$
3	$A \cdot 0 = 0$
4	$A \cdot 1 = A$
5	$A + A = A$
6	$A + \bar{A} = 1$
7	$A \cdot A = A$
8	$A \cdot \bar{A} = 0$
9	$\bar{\bar{A}} = A$
10	$A + AB = A$
11	$A + \bar{A}B = A + B$
12	$(A + B)(A + C) = A + BC$

Procedures

1. Students will be taught the laws and rules of Boolean Algebra. Each student will copy these laws and rules as their teacher explains them and writes them on the board.
2. Students will build and test the following circuit (circuit 1) to create its truth table.



- Students will build and test the following circuit (circuit 2) to create its truth table.



- Students will compare the logic in the truth tables for the 2 circuits and write the Boolean Expression for each.
- Students will identify the Boolean Algebra Rule that states the equivalency of the two circuits

- Students will then design circuits that for the purpose of proving the truthfulness of one Boolean Algebra Law and one Boolean Algebra Rule. These circuits will be checked by the teacher.

Name: _____

Date: _____

Period: ____

Chapter Twenty Student Sheet: Logic Simplification

Draw Circuit 1 in the space below and complete its truth table.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	

1	1	1	
---	---	---	--

Draw Circuit 2 in the space below and complete its truth table.

Inputs are identified alphabetically from the top down on the digital switch board

Input A	Input B	Input C	Output
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

- How are circuits 1 and 2 similar to each other?

- What are the Boolean Expressions that describe the two circuits?

a. Circuit 1: _____

b. Circuit 2: _____

- Which rule of Boolean Algebra is modeled through circuits 1 & 2? _____

- Design two circuits to demonstrate the truthfulness of a Law of Boolean Algebra of you choosing.

a. Which law are you modeling? _____

b. Use the space below to draw your circuits and their accompanying truth tables.

5. Design two circuits to demonstrate the truthfulness of a Rule of Boolean Algebra of you choosing.
- Which rule are you modeling? _____
 - Use the space below to draw your circuits and their accompanying truth tables.

Name: _____

Date: _____

Period: _____

Electronics Post-Assessment

[Back to Table of Contents](#)

Basic Demographics

Age: _____

Grade Level: 7th or 8th

Gender: Male or Female

Ethnicity (optional): African American/Black Hispanic Asian Caucasian/White

Pacific Islander

Other _____

First Spoken Language: _____

Opinions about the importance and study of electronics:

Use the rating scale to record your opinion regarding the following questions. Circle the statement the best describes how you feel.

1. I am excited about the study of electronics.	Not True	Sometimes True	Mostly True	Completely True
2. I think understanding electronics will be important for my future.	Not True	Sometimes True	Mostly True	Completely True
3. I will benefit from knowing	Not True	Sometimes True	Mostly True	Completely True

about electronics.				
4. I believe that there is an important link between electronics and video games.	Not True	Sometimes True	Mostly True	Completely True
5. Understanding how to turn a switch on and off is all the understanding that I need.	Not True	Sometimes True	Mostly True	Completely True
6. In the future I see myself in a career that requires no knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
7. In the future I see myself in a career that requires a basic knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
8. In the future I see myself in a career that requires an advanced knowledge of electronics.	Not True	Sometimes True	Mostly True	Completely True
9. I spend some time each day thinking about how different electronic devices work.	Not True	Sometimes True	Mostly True	Completely True
10. I believe that there is an important link between electronics and computer programming	Not True	Sometimes True	Mostly True	Completely True
11. I think that electronics is confusing.	Not True	Sometimes True	Mostly True	Completely True
12. I think that studying electronics if very difficult.	Not True	Sometimes True	Mostly True	Completely True
13. I spend some time each week thinking about how different electronic devices work.	Not True	Sometimes True	Mostly True	Completely True
14. I think electronics is boring.	Not True	Sometimes True	Mostly True	Completely True
15. It is necessary to understand electronics to understand robotics.	Not True	Sometimes True	Mostly True	Completely True
16. I think that binary logic is an important part of electronics.	Not True	Sometimes True	Mostly True	Completely True
17. Studying electronics is something that is difficult for me.	Not True	Sometimes True	Mostly True	Completely True
18. I use electronics devices several times a day.	Not True	Sometimes True	Mostly True	Completely True
19. I believe there is a connection between electronics and science.	Not True	Sometimes True	Mostly True	Completely True

1. Do you think that an understanding of electronics principles is important for the average person?
(Explain)

2. Would you like to study electronics more in school? Why would this be important?

3. Have you been taught electronics in your past? Yes No If yes, explain:

Electronics Content Knowledge

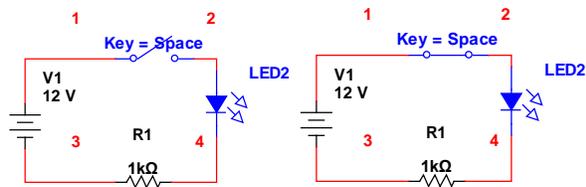
Solve the following questions to the best of your ability:

1. What will happen to the brightness of a light bulb if you reduce the voltage in electrical circuit it is in?

2. Explain your answer for the above question?

3. Do you know what a series circuit is? Yes No If yes please explain.

4. Which of the following examples is a complete circuit? (circle your answer)



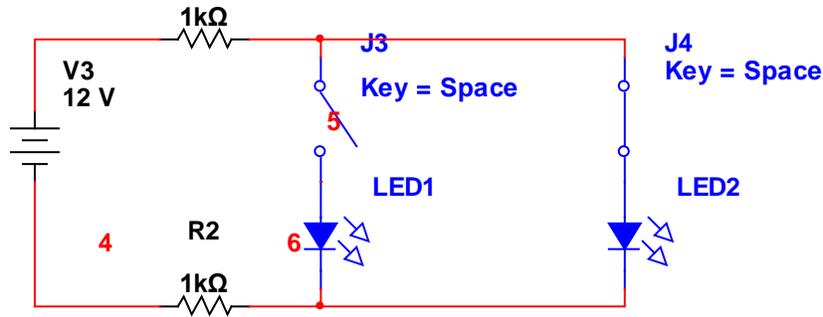
5. Why did you choose your answer for the above question?

6. Do you know what a parallel circuit is? Yes No If yes please explain.

7. Do your best to draw a series circuit containing a power source, LED, resistor, and switch in the space below.

8. Do your best to draw a parallel circuit containing a power source, 2 LEDs, and two resistors in the space below. The light bulbs should be able to function independently.

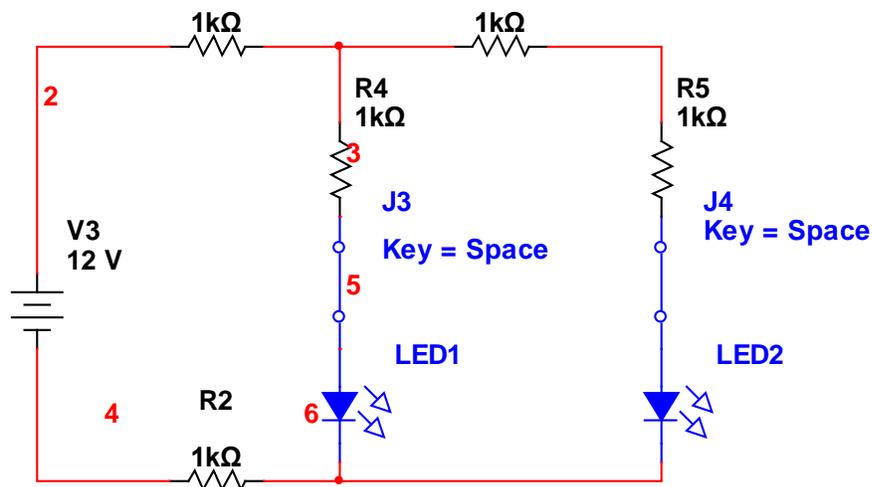
9. Describe what happens in the circuit below when J3 is opened.



10. Explain the purpose of a switch in an electrical circuit.

11. Explain how to measure resistance across a single component in an electrical circuit.

12. Which circuit below will have the brightest LED?



13. Explain your answer for the above question?

14. If a $5k\Omega$ resistor has 4mA of current flowing through it, what is the voltage drop across it?

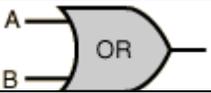
15. Explain how you figured out the answer to number 14.

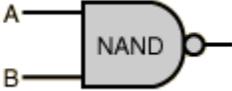
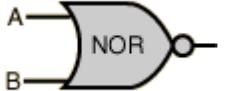
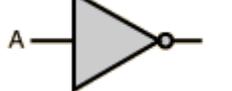
16. What will be the sum of voltage drops in a circuit with a 12V power source? Explain.

17. What does a timing diagram show?

18. What is the difference between an analog and a digital circuit?

19. Complete the following table.

Gate	Logic Symbol	Boolean Equation	Truth Table		
			Inputs		Output
			B	A	Q
AND		AB	0	0	
			0	1	
			1	0	
			1	1	
OR		$A + B$	0	0	
			0	1	

			1	0	
			1	1	
NAND		\overline{AB}	0	0	
			0	1	
			1	0	
			1	1	
NOR		$\overline{A+B}$	0	0	
			0	1	
			1	0	
			1	1	
XOR		$A \oplus B$	0	0	
			0	1	
			1	0	
			1	1	
XNOR		$\overline{A \oplus B}$	0	0	
			0	1	
			1	0	
			1	1	
NOT		\overline{A}	-	0	
			-	1	

Future Ambitions

What interests you the most as an area for your future career?

- Business (What kind _____)
- Medical (What kind _____)
- Construction (What kind _____)
- Science (What kind _____)
- Engineering (What kind _____)
- Teaching (What kind _____)
- Law (What kind _____)
- Other

List the career options above that would be benefitted by an understanding of electronics.

What was your opinion of this survey? (was it difficult, frustrating, easy, fun, etc.) Explain.

Teacher Answer Sheets

[Back to Table of Contents](#)

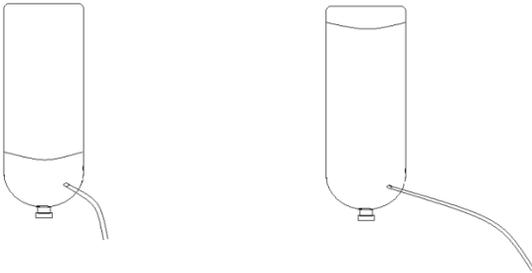
Name: _____

Date: _____

Period: _____

Quiz: Basic Principles and Components of Electronics

Use the following diagram to answer the first seven questions:



- In the picture above what electronic variable does the size of the hole in the bottles represent? **Resistance**
- Explain your answer to question number one. **The size of the hole restricts the water flowing out of it in a way similar to how a resistor restricts the flow of electrons.**

- In the picture above what electronic variable does the water level in the two bottles represent? **The water level in the two bottles represents voltage.**
- Explain your answer to question number three. **The water level provides a potential that pushes water out of the hole similar to how voltage pushes electrons through a wire.**

- In the picture above what electronic variable does the water exiting the two bottles represent? **The water exiting the two bottles represents current.**
- Explain your answer to question number five. **The water leaving the bottles is flowing from an area of high potential to an area of low potential similar to the way current flows.**
- Circle the bottle above that has more electric Potential. Explain how you know. Students should circle the bottle on the right. **That bottle has a higher water level to push the water out with more force**
- If you were building a circuit and needed to store a charge which of the electronic variables would help you? Explain. **You would want to use a capacitor because a capacitor is an electronic device used for storing charge.**

Name: _____

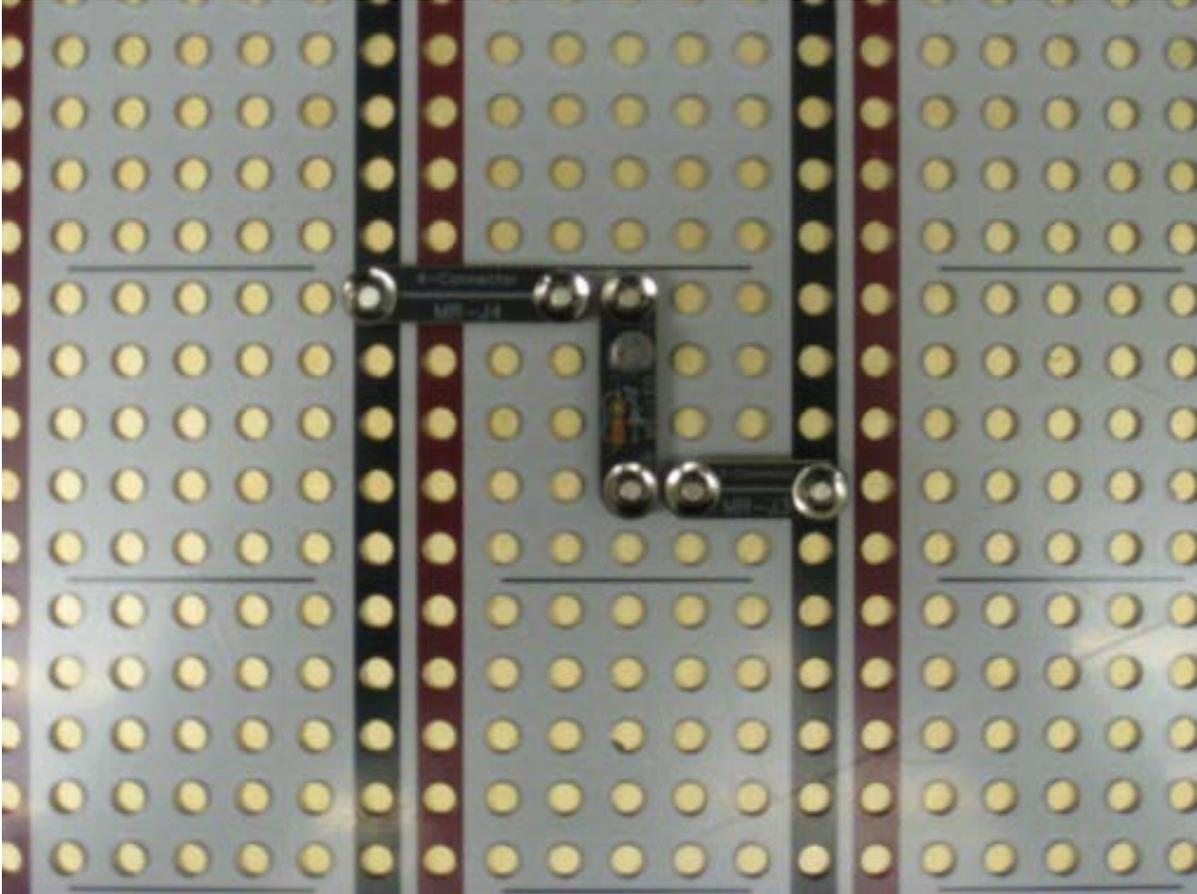
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MR Board Lesson Five Quiz

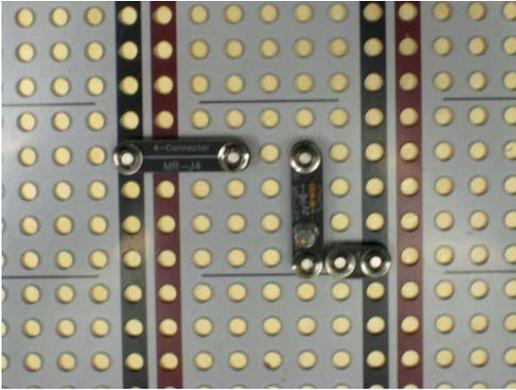
1. Look at the following circuit and say whether it is disconnect or connected.

Disconnected

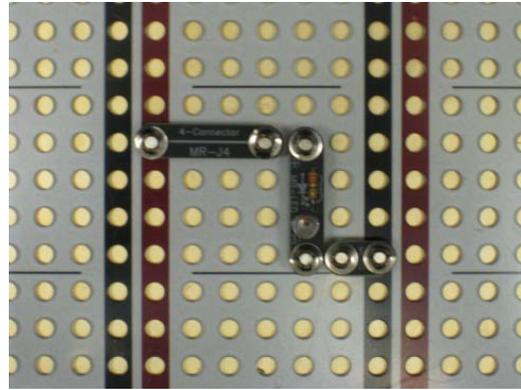


2. Explain your answer to question #1. Both ends of the circuit are connected to ground so there is no potential difference to cause electrons to flow.

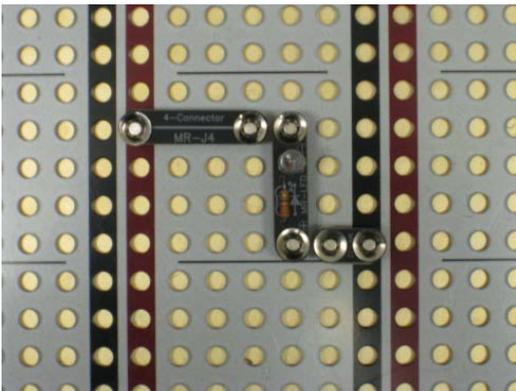
3. Will the LED in the circuit above light up? Why or why not? The LED in the circuit above will not light up because the circuit is disconnected and has no current flowing through it.
4. Circle the circuit below that is connected. (There could be more than one correct answer)



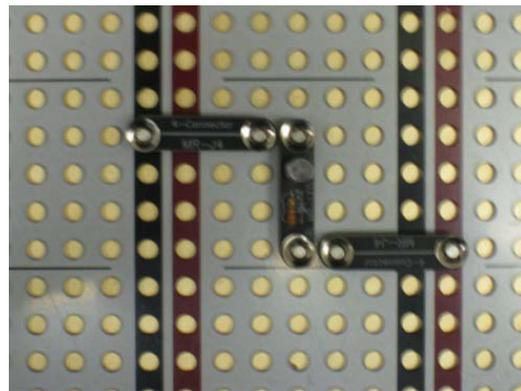
(a)



(b)



(c)



(d)

Students should circle circuits (b) and (d).

5. Compare and contrast the disconnected and connected circuits from question #4.
- (a) Both ends of circuit are connected to ground so there is no potential difference. The circuit is disconnected.
 - (b) There is a potential difference between VCC and GND and the LED is in the correct direction. The circuit is connected.
 - (c) There is a potential difference between VCC and GND but the LED is not in the correct direction. The circuit is disconnected.
 - (d) There is a potential difference between VCC and GND and the LED is in the correct direction. The circuit is connected.

Name: _____

Date: _____

Period: _____

Quiz: Kirchhoff's Voltage Law

1. Consider a complete circuit with a 12V power source and three resistors. If the voltage drop across the first resistor is 6V and the drop across the third resistor is 2V, what is the drop across the second resistor? (show your work)

The voltage drop across the second resistor is 4V.

2. Explain why you answered question 1 the way that you did.

The circuit has a 12V power source and the sum of voltage drops must be equal to the voltage of the power source. $6V+2V=8V$, $12V-8V=4V$

3. Consider a complete circuit with a 9V power source and four resistors. If the voltage drop across the first resistor is 6V and the drop across the second resistor is 2V, what is the sum of drops across the third and fourth resistors? (show your work)

The sum of voltage drops across the third and fourth resistors is 1V.

4. Explain why you answered question 3 the way that you did.

The circuit has a 9V power source so the sum of voltage drops across each component in the circuit must equal 9V. The voltage drop sum of the first two resistors is 8V therefore the remaining resistors must have voltage drops that add up to 1V.

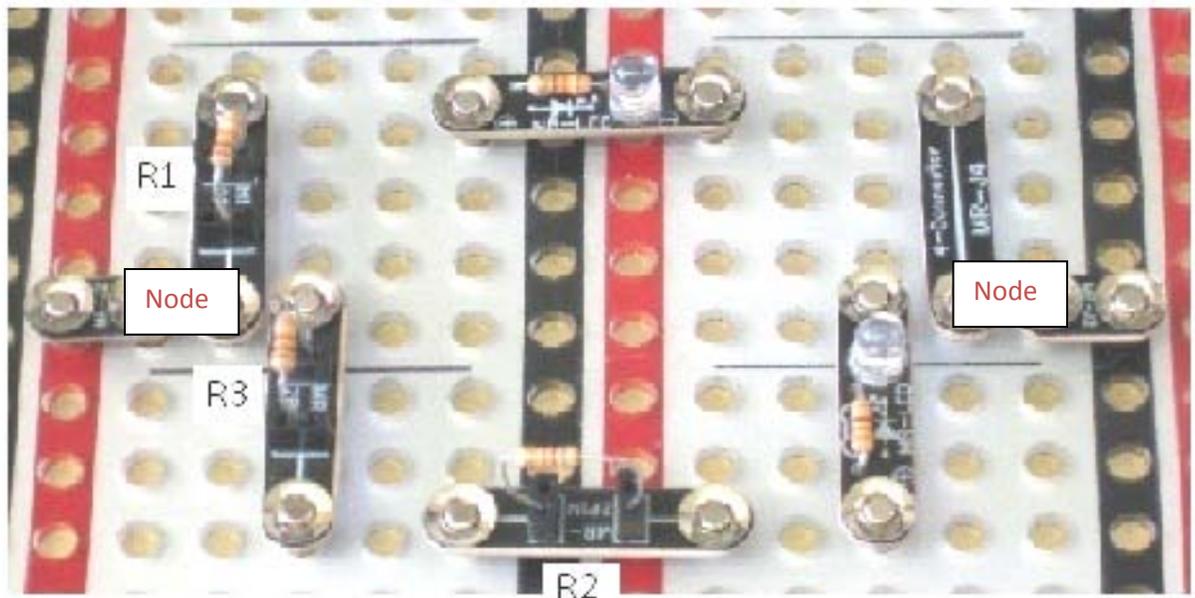
Name: _____

Date: _____

Period: ____

Quiz: Kirchoff's Current Law

1. Consider the following circuit:



If $R1=10k$, $R2=2k$, and $R3=2k$, will more current go through the top half or the bottom half of the circuit? Explain.

More current will go through the bottom half because there is less resistance.

2. Label the nodes in the circuit above. See picture.
3. Consider a parallel circuit similar to the one pictured above. If the current before the node is $2.8mA$ and the current through the bottom half of the circuit is $0.7mA$, what will the current be through the top half of the circuit?
The current through the top half of the circuit will be $2.1mA$.
4. What will the current be just before entering ground in the circuit described in number three? Explain.
The current will be $2.8mA$ because it must be equal to the current before the node.

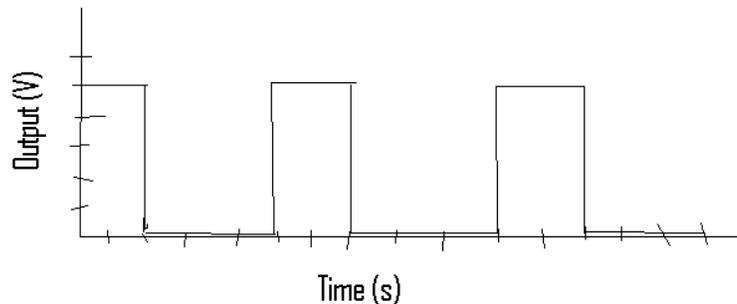
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Date: _____

Period: _____

Quiz: Truth Tables, Binary Numbers, Timing Diagrams, and AND, OR, NOT Logic Gates

1. Draw a timing diagram for a circuit whose output is on at 5V for 2 seconds, then off at 0V for 3 seconds. Repeat the cycle three times.



2. What is 7 in the binary number system? Show how you got your answer.

$$7 = 0111$$

$$1=0001, 2=0010, 3=0011, 4=0100, 5=0101, 6=0110, \text{ and } 7=0111$$

3. What would the output of a circuit be whose inputs go into an AND gate that is followed by a NOT gate? Complete the truth table to show your answer.

Input A	Input B	Output
0	0	1
0	1	1
1	0	1
1	1	0

4. What would the output of a circuit be whose inputs go into an OR gate that is followed by a NOT gate? Complete the truth table to show your answer.

Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0

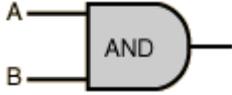
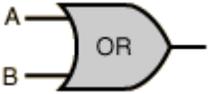
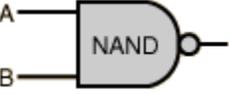
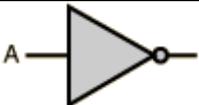
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Date: _____

Period: ____

Logic Gate Performance Assessment

Use the MR Board to complete the following truth table.

Gate	Logic Symbol	Boolean Equation	Truth Table		
			Inputs		Output
			B	A	Q
AND		AB	0	0	0
			0	1	0
			1	0	0
			1	1	1
OR		$A + B$	0	0	0
			0	1	1
			1	0	1
			1	1	1
NAND		\overline{AB}	0	0	1
			0	1	1
			1	0	1
			1	1	0
NOR		$\overline{A + B}$	0	0	1
			0	1	0
			1	0	0
			1	1	0
XOR		$A \oplus B$	0	0	0
			0	1	1
			1	0	1
			1	1	0
XNOR		$\overline{A \oplus B}$	0	0	1
			0	1	0
			1	0	0
			1	1	1
NOT		\overline{A}	-	0	1
			-	1	0