Unit 1350

Keeping it Safe: An Electrical Security System

Summary

In this lesson, teams of three or four students will apply their knowledge of electric charge, energy sources, and series and parallel electric circuits to design and construct a working model of an alarm system to protect a car. The completed model, with storage building, fence, and security system, must be scaled to fit on a 1-m × 1-m platform. The security system must include a minimum of one complete series circuit with three lightbulbs (resistors); a DC energy source (battery); necessary wires, switches, and fasteners; and one parallel circuit with a minimum of two lightbulbs and an alarm. Students will plan their model and create a poster of their design, using correct electric circuit symbols for the components. Using their drawing as their guide, the team will construct a working model. Each team will give a 5- to 10-min presentation of their working security system, along with an explanation of how it works and what energy transformations occur within the system. Students should also answer this question: What important factors make their model function as an efficient security system?

Estimated duration

Allow one week of class time for projects (students may also work on these at home) followed by one or two days of presentations. This may vary due to other classroom factors and schedules, as well as student readiness.

Total: Allow six to seven class periods for project planning, designing, building, and presenting.

Teacher Content Background

Static electricity is an unbalanced charge on the surface of a non-conducting object. The unbalanced charge is caused by either an excess or loss of electrons by the object. It is usually caused when surfaces of non-similar objects touch each other, causing charges to become separated. (Example: Brushing hair transfers electrons from the hair to the brush. The brush then has an unbalanced negative charge after gaining electrons, and the hair has an unbalanced positive charge after losing electrons.)

Electric current occurs when electrons flow continuously through a conductor or conductors. There must be an energy source and a complete path to and from the energy source for the electrons to move. These conducting pathways are referred to as electric circuits.

Atoms are the basic unit of all matter. Atoms combine to form molecules of matter (such as water) or crystalline structures of matter (such as sodium chloride—table salt).

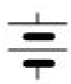
Atomic structure Atoms consist of a nucleus and outer electrons. The nucleus is made up of positively charged protons and neutrons that have no charge. The nucleus makes up most of the mass of an atom. Moving around the positive nucleus are negatively charged electrons. An electron has very little mass. Because opposite charges attract, the positive nucleus tends to pull on the negative electrons. However, some kinds of atoms have many electrons, some orbiting far from the nucleus. The farther the electron is from the nucleus, the weaker the attraction. Under certain conditions, outer electrons are able to move rather freely within the matter. This is generally why the electrons in metals are somewhat free to move. With energy supplied by a source (for example, a battery), the metals' electrons can produce an electric current through a closed circuit.

Energy is needed to apply a force. In the case of the direct current (DC) circuits featured in this lesson, the energy source is a battery. The chemical reactions within a battery provide the energy to move electrons through the circuit as an electric current.

Circuit drawing (schematic) basic symbols:

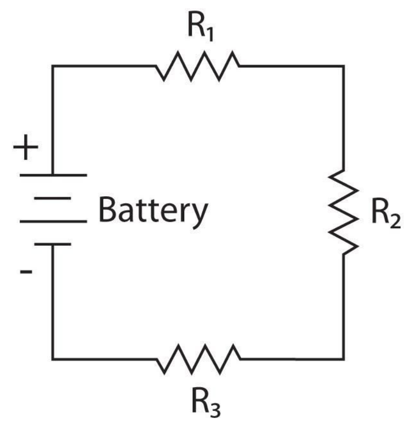
 resistor

 switch

 battery

______________________ wire

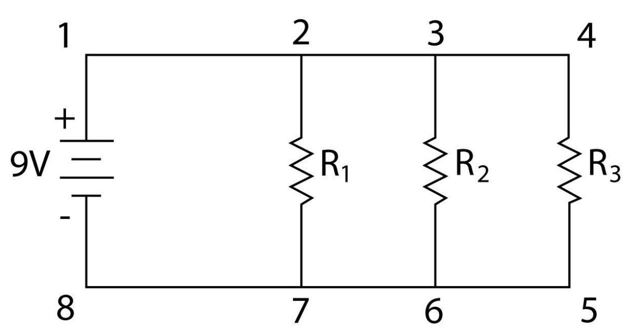
Simple series electric circuit drawings (schematic) show the conventional schematic symbols for any type of resistor (lightbulbs, buzzers, heating coils, and many other devices included in various electric circuits).



DC series circuit, three resistors (usual schematic symbols)

An electric energy source for DC circuits would most commonly be a battery (as in a flashlight or car) or an AC-to-DC converter device (sometimes available in science laboratories).

Parallel electric circuit: If R_1 is a device that “burned out” (turned off), R_2 and R_3 could remain turned on because they maintain continuous pathways, completing the circuit.



DC parallel circuit, three resistors (usual schematic symbols)

⚠ All projects involving working electric circuits must involve use of only DC (battery-powered) circuits. AC plug-in (for example, wall or workbench) circuits are not safe for experimentation, electric circuit design, or electric circuit model-building.

Connecting wires (conductors) are available in various diameters and may be made of a variety of materials. Some examples of electric conductors are silver, gold, copper, aluminum, iron, steel, brass, bronze, graphite, and salt water. Some of these materials (silver and gold) conduct electricity better than others (bronze and graphite). Generally shorter and/or thicker wires conduct better (offer less resistance) and produce less thermal energy (are less likely to overheat) than long and/or thin wires.

A resistor, such as the thin wire filament inside an incandescent lightbulb, is actually designed to get “glowing hot” to give off light. But there is a considerable amount of wasted energy because of the thermal energy it produces. Items we connect to an electric circuit are resistors, and all produce thermal energy. Sometimes this thermal energy is useful, as in a toaster, electrical oven, clothes iron, and electrical heater. However, in many cases the thermal energy is wasted (and sometimes harmful) when given off as heat. Examples include most incandescent lightbulbs, radios, televisions, computers, refrigerators, and fans.

⚠ When working with an electric circuit project, avoid handling the connected wires or resistors in a circuit that is “on.” Components, including the wires, in a current-carrying circuit may be hot.

Energy transformations in electric circuits may include potential, kinetic, thermal, electric, chemical, light, and sound energy. In a DC circuit the battery’s chemical potential energy is converted to the kinetic energy of the electrons moving in the circuit. Within the circuit, the kinetic energy of the electrons can be converted by various resistors to thermal energy, sound energy, light energy, and other kinetic energy (such as vibrations of a buzzer). In AC circuits (in houses, schools, and business buildings), mechanical energy is transformed to electric energy by a generator. Generators rotate magnets, giving them mechanical energy that is converted to electric energy. These generators provide electric current to operate devices that can then convert the electric energy to thermal energy, sound energy, light energy, and so on.

Before You Begin:

1. Help students understand the basics of electric currents and circuits. Review atomic structure and the role of electrons in electric current; the drawing symbols to use for circuit drawings (series and parallel design drawing features); and symbols for resistors, source (battery), and switches.
2. Help students understand the energy transformations that should occur in the circuits they design and construct. Chemical energy transforms to kinetic

energy, which transforms to electric energy, which transforms to sound, thermal, and light energy.

3. Students must be informed of relevant safety issues and precautions when working with an electric current. Inform students about the relatively safe use of DC (battery powered) electric circuits, as compared to the much more dangerous AC circuits wired into our houses, schools, and most other buildings.

4. Create a list of vocabulary terms. Examples include: *electric circuits, electric energy, atom, atomic structure, series circuit, parallel circuit, kinetic* and *potential energy, thermal energy, energy transformations, resistors, switches, and connecting wire.* These terms should be used correctly and often in classroom conversations as well as in student writings and drawings.

5. Give examples of common series and parallel circuits. A flashlight is a series circuit, as are many holiday lights. There are no other current-carrying pathways in the circuit. When there is a break in a series circuit (or the switch is turned off), all the items in the circuit turn off. In a parallel circuit, there are several pathways for the current to follow. Our houses, schools, and most other buildings are wired in parallel circuits. For example, if a computer is turned off (switch is open), the lights and ceiling fan in the room will stay on because the room is wired in a parallel circuit.

6. Clarify how students should keep a record of their work in a science journal. The journal should include items such as notes about the team's planning, design sketches and discussions, to-do lists, a time line, and team member tasks.

7. Help students think through a materials list. Determine what will be available in the classroom and how to obtain other possible items.

8. Collect the following basic project supplies for students' use: electrical wire, duct tape, hammers, nails, screws, screw drivers, metersticks, a selection of heavy cardboard boxes and wood pieces, scissors, rubber bands, string, twist ties, empty boxes, batteries, electric circuit switches, alligator clips (for connecting wires and devices in the circuit), flashlight bulbs, lightbulb sockets, wire cutters, and so on.

9. Prepare information about safety. Tell students to keep in mind to avoid accidents or injuries. Consider the specific features in your classroom, as well as class size. Be clear about proper use of tools and materials, as well as

consideration for others in the room. If any part of the lesson is given as homework, discuss safety expectations for that scenario.

Student Performance Guidelines: Oral Presentation and Demonstration

____ Demonstrate operation of your security system. Explain how the system and its components work.

____ Describe and explain the system and its components as related to safety, design, energy transformations, and effectiveness.

____ Use *series circuits, parallel circuits, resistors, conductors, energy transformations,* and related terminology correctly.

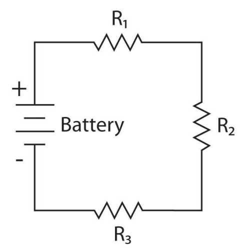
____ Make certain that each team member participates in the presentation and that the presentation is well-planned and presented "professionally."

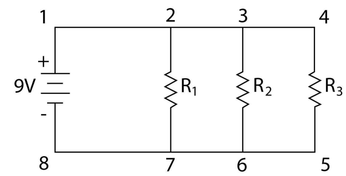
____ Remember to keep safety in mind.

____ Ensure that the presentation is scientifically accurate, indicates use of mathematical skills, shows evidence of design-engineering and construction, includes correct circuit schematics (symbols) in the planning poster, and indicates use of technology.

Day One

1. The working model will include at least one series circuit and one parallel circuit, at least two lightbulbs, and a buzzer. Students will use a favorite toy car of their choice that is of appropriate size for this project.
2. During the last day or two of the activity, each team will demonstrate and explain their working model and display their poster to the class.
3. Discuss safety issues and expectations related to the project.
4. Allow students to choose teams, or have a method for assigning teams of three to four students per team.
5. Administer the Pre-Assessment (Attachment A). Allow 15 to 20 minutes. Explain that it is not for a grade, but to determine what students know.
6. Following the Pre-Assessment, allow a few minutes for student comments and questions.
7. Remind students to be prepared to keep a daily science journal of work on their project.
8. For homework/study-center time, assign an internet search and report for simple security systems and/or designing simple series and parallel circuits using direct current (DC, battery operated). Illustrations of series and parallel circuits may be useful in helping students to visualize the lesson concept:





Day Two

1. Use classroom computers or an interactive whiteboard to provide examples of systems that involve series and parallel circuits to perform a task. There are examples of suitable resources on the Internet. You might search terms such as *building DC circuits, car storage, lightbulbs in simple circuits,* and *buzzer devices in simple circuits.* Ask students to share reports from the prior day's homework. What useful information or hints did they find in their searches?
2. Follow up with information and instructions related to the weak areas of essential knowledge as revealed in yesterday's Pre-Assessment results.
3. The students will get into their teams for about half the period. They should:
   - organize their science journals (Each should keep a science journal, but they should work as a team.)
   - discuss and record how they will begin this project together
   - brainstorm a design process (Ultimately they will need to design drawings for both the building and fence enclosure, as well as the security circuit system for the lights, buzzer, switches, wiring, and so on.)
   - determine what supplies are available in the classroom and what else is needed
   - determine where they can get the other needed supplies and who will get them
   - have a plan for how to move along during the next class

Day Three

1. Check to see how the teams are coming along with research, brainstorming, planning, designing, and obtaining supplies.
2. Provide opportunities for questions and answers and encourage sharing with other teams, as appropriate.
3. Keep in mind that the lesson and details of the project should be treated as a learning experience.
4. As students work on their project designs, monitor productivity and listen for engineering, mathematical, scientific, and technological language.
5. Students should continue to plan, design, make science journal entries, and construct the model.

6. If time is short, help teams arrange for any necessary outside-of-class work.

Day Four

1. Use class time to continue the processes of improving designs, recording in journals, collaborative drawing, and constructing. Continue to stress safety.
2. Use of class time is much the same as on day three. Students should also devise a team presentation plan. How will they demonstrate their finished security system? Who will do what in the presentation? Will they need props other that the working system and poster? Do they need a script? How will they have the right timing for the demonstration/presentation? *(The limit is approximately 10 minutes.)* Assist students with questions and help them stay on schedule.

Day Five

1. Teams should be finishing their presentations and posters. They may have had to redesign, as difficulties may have occurred. Their science journals should be up-to-date. Make sure students are aware of the scoring guide for the performance assessment. They should strive for a quality display of thoughtful practices in engineering design, collaborative work, measurements, calculations, data organizing and record-keeping, productive use of technology, and clear communication.
2. Student should be ready to present to the class on day six.

Day Six

Student teams present their security systems and posters to you and the class. (Ideally there is time near the end of the period for questions and answers.)

Day Seven (If needed)

Student teams present their security systems and posters to you and the class. (Ideally there is time near the end of the period for questions and answers.)

Differentiated Instruction

- Students who physically struggle with handling tools and construction materials could focus on the design illustrations, planning input, and verbal explanations instead of the actual model building.
- Students who have difficulty organizing information (such as notes and journal entries) could be supplied with graphic organizers (Attachment F).
- Students who struggle with reading or listening to instructions could be given a simplified step-by-step chart or list (Attachment G).

- Students who have not learned or cannot recall previous related content could be assisted by you and/or classmates in discussing the illustrations, instructions, and descriptions in this lesson (Attachments A, B, and C).

Extension

Provide opportunities for teams (or individuals from each team) to modify and improve the initial security system they presented to the class. (See Attachment E for suggestions.)

Home Connections

Encourage students to study examples of different circuits and energy transformations in home electric systems, and to determine how many things in their home depend on electric energy. This also provides an opportunity for students to think of ways they could efficiently use electric energy in their homes to save money and natural resources.

STEM Connections

- Collect, understand, and apply relevant scientific evidence.
- Use evidence-based reasoning to arrive at creative and innovative solutions to problems and issues.
- Use mathematical applications to measure, gather data, and construct scale drawings and devices.
- Complete relevant computations.
- Make use of technology tools to do a task, seek information, compute, and gather and organize data.
- Work cooperatively and collaboratively as a team.
- Apply engineering principles to design procedures and/or devices to accomplish specific tasks. (The example in this activity is to design and construct working models of series and parallel DC circuits, with specific components included in the circuits.)

Career Opportunities

electrical engineer, computer engineer, industrial systems engineer, research scientist, mathematician, electrician, environmentalist, computer systems developer/manager, energy commission member, home-repair servicer

Attachments

Attachment A: Pre-Assessment and Scoring Key with Possible Student Answers

Attachment B: Teacher Review Sheet and Planning Reminders with Suggestions

Attachment C: Sample Illustrations for Students

Attachment D: Post-Assessment Performance Assessment

Attachment E: Evaluating and Improving Your Security System Model

Attachment F: Journal Graphic Organizer

Attachment G: Step-by-Step Graphic Organizer

Attachment A

Pre-Assessment

1. All matter is made up of particles called _______________.
2. Electrons, protons, and neutrons are the three main parts of a(n) _______________.
3. The electric charge on a proton is _______________.
4. The electric charge on an electron is _______________.
5. The electric charge on a neutron is _______________.
6. Make a schematic drawing of a series electric circuit.

7. a. What is the purpose for including a battery in a flashlight?

   b. How does a battery work to serve that purpose?

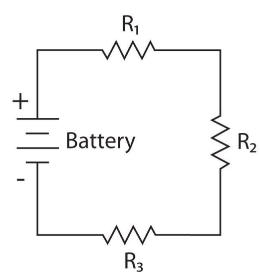
8. What do the terms *electric conductor* and *electric insulator* mean?

9. Identify at least two safety precautions that should be followed when working with an electric current.

Attachment A (Continued)

Pre-Assessment
Scoring Key with Possible Student Answers

1. All matter is made up of particles called _____*atoms*_____.
2. Electrons, protons, and neutrons are the three main parts of a(n) _____*atom*_____.
3. The electric charge on a proton is _____*positive (+)*_____.
4. The electric charge on an electron is _____*negative (−)*_____.
5. The electric charge on a neutron is _____*neutral (no charge)*_____.
6. Make a schematic drawing of a series electric circuit.



7. **a.** What is the purpose for including a battery in a flashlight?

   A battery provides the energy needed to push electrons through the flashlight electric circuit so that there is a current to light the bulb.

   b. How does a battery work to serve that purpose?

   The battery's chemical energy transforms to the kinetic energy of the electrons moving in the conducting wires of the circuit. This provides the current needed to light (light energy) the bulb.

8. What do the terms *electric conductor* and *electric insulator* mean?

   electric conductor: a material that allows its electrons to easily move along a pathway (for example, metals) *electric insulator: a material that won't allow its electrons to easily move along a pathway (for example, glass)*

9. Identify at least two safety precautions that should be followed when working with an electric current.

   1) Experiment only with DC, not AC, current. 2) Know that wires may be hot, and it may not be safe to touch them.

Attachment B

Teacher Review Sheet and Planning Reminders

1. An atom is the basic particle of all ________________________.
2. To exert a force, ________________ is required.
3. In a direct current (DC) circuit, the most common energy source is a _________________.
4. Draw an atom. Label *protons, nucleus, electrons,* and *neutrons,* showing the type of electric charge on each.

5. Draw and describe what a simple series circuit would look like (using conventional circuit symbols) if it included connecting wires, a battery, and three resistors. Describe how a switch could also be added to the circuit.

6. What are some examples of energy transformations within electric circuits?
7.

Explain the scientific meaning of the following terms:
a) electric charge **b)** voltage **c)** series circuit **d)** force **e)** thermal energy
f) kinetic energy **g)** DC current **h)** parallel circuit **i)** resistance

8. Give examples of common everyday electrical devices that would be considered resistors in a circuit.

9. Students should keep records of their learning activities in journals. These records should include:

10. Brainstorm a list of materials that will be needed for your students' projects.

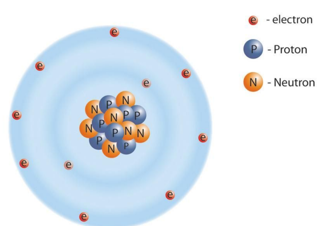
11. Determine and list which needed materials will be available in the classroom for student use.

12. Some essential safety precautions related to this assignment are:

Attachment B

Teacher Review Sheet and Planning Reminders with Suggestions

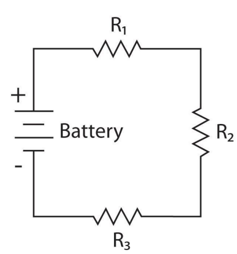
1. An atom is the basic particle of all ______*matter*______.
2. To exert a force, ______*energy*______ is required.
3. In a direct current (DC) circuit, the most common energy source is a ______*battery*______.
4. Draw an atom. Label *protons, nucleus, electrons,* and *neutrons,* showing the type of electric charge on each.



P&N cluster in the center is the nucleus. Protons +1, electrons −1, neutrons no charge.

5. Draw and describe what a simple series circuit would look like (using conventional circuit symbols) if it included connecting wires, a battery, and three resistors. Describe how a switch could also be added to the circuit.

It would be a closed loop of wire with the three resistors wired in line with each other—no side loops and no gaps in the circuit. The battery would also be in the same loop. It would look like this:



If a switch were added, it would be inserted in the loop—just as the battery and resistors are. It could be opened (create a gap in the circuit) to turn the circuit off, or closed (fill the gap) to turn the circuit on.

6. What are some examples of energy transformations within electric circuits?

chemical to kinetic (battery), electric to thermal (incandescent bulb), electric to light (incandescent bulb), electric to sound (buzzer, radio, motor), or kinetic to electric (moving electrons providing electric current)

7. Explain the scientific meaning of the following terms:
   a) electric charge **b)** voltage **c)** series circuit **d)** force **e)** thermal energy **f)** kinetic energy **g)** DC current **h)** parallel circuit **i)** resistance

a) *Electric charge is a fundamental property of matter specific to the protons and electrons of an atom. Protons have a positive charge and electrons have a negative charge.*
b) *Voltage is the amount of energy used to move one coulomb of electrons through an electric circuit.*
c) *A series circuit is an electric circuit with only one closed path for an electric current to follow*
d) *Thermal energy is the sum of the kinetic energy and the potential energy of the particles that make up an object produced when the particles (molecules and/or atoms) within a substance gain kinetic energy.*
e) *Kinetic energy is energy of motion.*
f) *DC current is "direct current" in a circuit. The energy source for DC is generally a battery. Note: AC current (alternating current) is the main type of current in circuits in most schools, houses, and other buildings and is generally much higher voltage than DC. Commonly, large electrical generators at power plants produce AC current, which is then transported through high-power lines to our houses and other buildings. AC circuits are much more dangerous to handle and investigate than DC circuits.*
g) *Parallel circuits contain several pathways for electric current to pass through. The advantage to parallel circuits is that, unlike single-loop series circuits where one portion (or loop) of the parallel circuit goes out, the rest of the loops can continue to carry current.*
h) *Resistance in a circuit is the tendency for materials to resist (or hold back) the movement of electrons that provide electric current in the circuit. Even the best conductors offer some resistance in a circuit. This is because as electrons move ("flow") in the conductors, they bump into each other and into the atoms of the material.*

8. Give examples of common everyday electrical devices that would be considered resistors in a circuit.

lightbulbs, radios, televisions, kitchen stoves, refrigerators, clocks, computers, water pumps, fans, and hair dryers

9. Students should keep records of their learning activities in journals. These records should include:

procedures, discussion notes, materials lists, names of team members, important explanatory drawings, to-do lists, individual job assignments, data gathered, goals, and time lines for completing assignments

10. Brainstorm a list of materials that will be needed for your students' projects.

Lists will vary but will likely include: wires; lamp sockets and bulbs; wood, plastic, or cardboard for the platform on which to build the model; materials to construct the storage building and fence; toy car; battery; buzzer; switch; wire cutters; scissors; tape; and wire connectors such as alligator clips.

11. Determine and list which needed materials will be available in the classroom for student use.

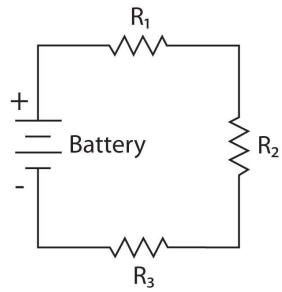
Lists will vary. Assess classroom materials in order to provide students with a list of items that are already available.

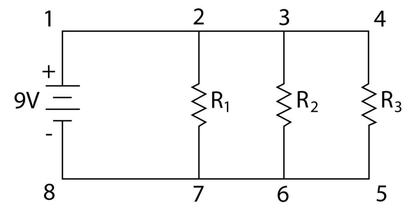
12. Some essential safety precautions related to this assignment are:

Precautions to be emphasized include safe practices with electric current; proper use of batteries, tools, and materials; consideration for others in the room; and other precautions, as appropriate.

Attachment C

Sample Illustrations for Students





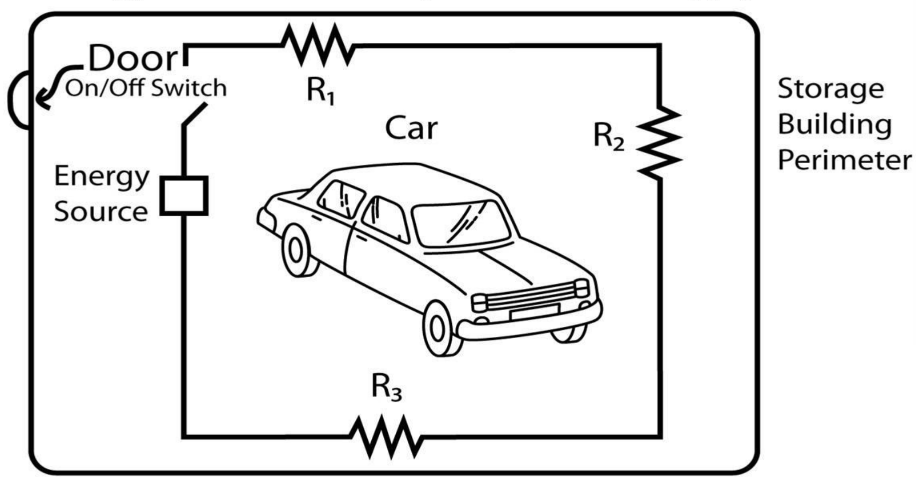
Energy Transformations in an Electrical Security System

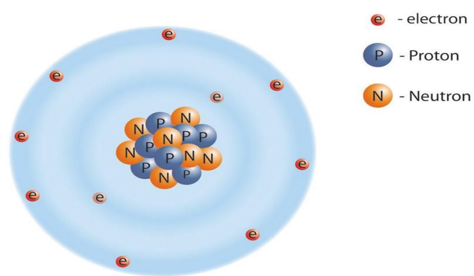
Energy Source = Battery or DC Power Supply

R_1 & R_3 = Light socket and bulb

R_2 = Buzzer

Energy Source = Battery or DC Power Supply




e - electron
P - Proton
N - Neutron

Attachment D

Post-Assessment Performance Assessment

Each student team will demonstrate and explain to the teacher and class the operation of their working model of an electric circuit security system for protecting their “classic car” in storage. Presentations will include their poster display and explanation of a basic electric circuit security system.

Security System Specifications and Grading Guide:

___The security system must not exceed the size that would fit into a 1-m × 1-m platform (base).

___The security system must be capable of emitting lights and buzzer warning signals when an “intruder” enters the premises.

___The system must include at least one series circuit component and one parallel circuit component.

___The system operation will be started manually by the entering “intruder.” However, once started, no external energy source or force may be used to complete the operation.

___The electric energy source used in the system can be only size D or smaller batteries. (No higher volt batteries, capacitors, or wall plug-ins for electricity.)

___Students will explain how the system protects the car.

___The security system must be durable enough to withstand several demonstrations.

___The system must be visible and audible to the observer. That is, during the presentation, observers must be able to see the entering “intruder,” circuit, and lights turn on, and also hear the buzzer warning.

Attachment E

Evaluating and Improving Your Security System Model

If time permits, have students proceed with this extension.

1. Identify the features in your initially presented security system that could be improved, such as

a) visual attractiveness of the model;
b) ease of operation of the model;
c) reliability and effectiveness of the model;
d) cost of the model (while still considering its necessary features);
e) other:

2. Describe and create a design plan and drawing showing how your team will improve the features you have identified above.

3. List and explain relevant safety precautions and practices that your team must be aware of as you modify your security model.

4. List and collect materials needed to complete the improvement of your security system model.

5. Complete the planned model improvements. Test the improved model to assure that it is operational and better meets the requirements of such a system.

6. Follow up by discussing the advantages and disadvantages of your initial and your improved model. As a team, write a summary of the work done to improve the model

and the team's evaluation of the results. Submit this summary, along with a brief improved-model demonstration, to your teacher.

Attachment F

Journal Graphic Organizer

Topic: Systems and Poster Project; Simple Electric Circuits and Security System

What Did We Discuss?	What Do We Want to Accomplish?	What Did We Learn? What Needs to be Done? Who Will Do It?	How Can We Learn More? What Supplies Do We Need?
Additional information we need:			

Attachment G

Step-by-Step Graphic Organizer

Title of project: ____

Team members: ____

*Description of project:

*Pre-planning *Getting started *Projected schedule to complete:

*How are we doing? *Progress and problems (with possible solutions):

*Comments on completed project and presentation *Questions to consider *Possible future redesign: