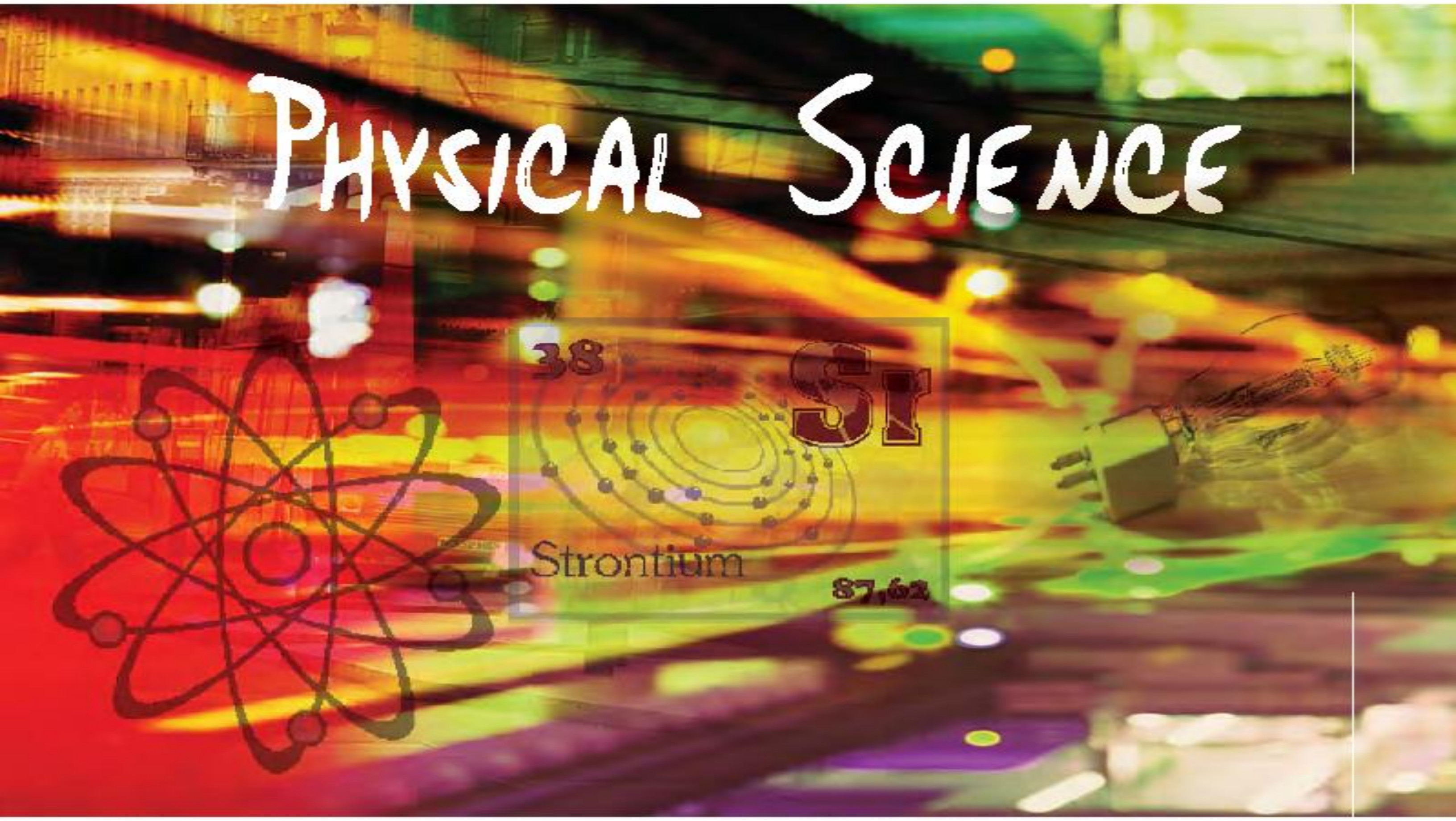
Miami-Dade County Public Schools



H.O.T. Science Labs

(High Order Thinking Science Labs)

Curriculum and Instruction

Division of Mathematics, Science, and Advanced Academic Programs

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Introduction

The purpose of this document is to provide Physical Science teachers with a list of basic laboratories and hands-on activities that students in a Physical Science class should experience. Each activity is aligned with the Physical Science Curriculum Pacing Guide and the Next Generation Florida Sunshine State Standards (NGSSS).

All the information within this document provides the teacher an essential method of integrating the Science NGSSS with the instructional requirements delineated by the Course Description published by the Florida Department of Education (FLDOE). The information is distributed in three parts:

(1) A list of the course specific benchmarks as described by the FLDOE. The Nature of Science Body of Knowledge and related standards are infused throughout the activities. Specific Nature of Science benchmarks may have been explicitly cited in each activity; however, it is expected that teachers infuse them frequently in every laboratory activity.
(2) Basic resources to assist with laboratory safety, organization of groups during lab activities, and scientific writing of reports.
(3) Hands-on activities that include a teacher-friendly introduction and a student handout. The teacher introduction in each activity is designed to provide guidelines to facilitate the overall connection of the activity with course specific benchmarks through the integration of the scientific process and/or inquiry with appropriate questioning strategies addressing Norman Webb's Depth of Knowledge Levels in Science.

All the hands-on activities included in this packet were designed to cover the most important concepts found in the Physical Science course and to provide the teacher with sufficient resources to help the student develop critical thinking skills in order to reach a comprehensive understanding of the course objectives. In some cases, more than one lab was included to cover a specific standard, benchmark, or concept. In most cases, the activities were designed to be simple and without the use of advanced technological equipment to make it possible for all teachers to use. However, it is highly recommended that technology, such as *Explorelearning Gizmos* and hand-held data collection equipment from *Vernier*, *Texas Instruments*, and *Pasco*, is implemented in the science classrooms.

This document is intended to bring uniformity among the science teachers that are teaching this course so that all can work together, plan together, and rotate lab materials among classrooms. Through this practice, all students and teachers will have the same opportunities to participate in these experiences and promote discourse among learners, which are the building blocks of authentic learning communities.

Acknowledgement

M-DCPS Curriculum and Instruction Division of Mathematics, Science, and Advanced Academic Programs would like to acknowledge the efforts of the teachers who worked arduously and diligently on the preparation of this document.

Next Generation Sunshine State Standards (NGSSS)

1. **LACC.910.RST.1.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
2. **LACC.910.RST.1.3:** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
3. **LACC.910.RST.2.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.
4. **LACC.910.RST.2.5:** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
5. **LACC.910.RST.3.7:** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
6. **LACC.910.RST.4.10:** By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.
7. **LACC.910.WHST.1.2:** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (1) Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. (2) Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. (3) Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts. (4) Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers. (5) Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing. (6) Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
8. **LACC.910.WHST.3.9:** Draw evidence from informational texts to support analysis, reflection, and research.
9. **MACC.912.F-IF.3.7:** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (1) Graph linear and quadratic functions and show intercepts, maxima, and minima. (2) Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions. (3) Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior. (4) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior. (5) Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

10. **MACC.912.N-Q.1.1:** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
11. **MACC.912.N-Q.1.3:** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
12. **SC.912.L.17.16:** Discuss the large-scale environmental impacts resulting from human activity, including waste spills, oil spills, runoff, greenhouse gases, ozone depletion, and surface and groundwater pollution.
13. **SC.912.L.17.19:** Describe how different natural resources are produced and how their rates of use and renewal limit availability.
14. **SC.912.L.17.20:** Predict the impact of individuals on environmental systems and examine how human lifestyles affect sustainability.
15. **SC.912.L.18.12:** Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.
16. **SC.912.N.1.1:** Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: (1) pose questions about the natural world, (2) conduct systematic observations, (3) examine books and other sources of information to see what is already known, (4) review what is known in light of empirical evidence, (5) plan investigations, (6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), (7) pose answers, explanations, or descriptions of events, (8) generate explanations that explicate or describe natural phenomena (inferences), (9) use appropriate evidence and reasoning to justify these explanations to others, (10) communicate results of scientific investigations, and (11) evaluate the merits of the explanations produced by others.
17. **SC.912.N.1.2:** Describe and explain what characterizes science and its methods.
18. **SC.912.N.1.3:** Recognize that the strength or usefulness of a scientific claim is evaluated through scientific argumentation, which depends on critical and logical thinking, and the active consideration of alternative scientific explanations to explain the data presented.
19. **SC.912.N.1.4:** Identify sources of information and assess their reliability according to the strict standards of scientific investigation.
20. **SC.912.N.1.5:** Describe and provide examples of how similar investigations conducted in many parts of the world result in the same outcome.
21. **SC.912.N.1.6:** Describe how scientific inferences are drawn from scientific observations and provide examples from the content being studied.
22. **SC.912.N.1.7:** Recognize the role of creativity in constructing scientific questions, methods and explanations.
23. **SC.912.N.2.1:** Identify what is science, what clearly is not science, and what superficially resembles science (but fails to meet the criteria for science).
24. **SC.912.N.2.2:** Identify which questions can be answered through science and which questions are outside the boundaries of scientific investigation, such as questions addressed by other ways of knowing, such as art, philosophy, and religion.

25. **SC.912.N.2.3:** Identify examples of pseudoscience (such as astrology, phrenology) in society.
26. **SC.912.N.2.4:** Explain that scientific knowledge is both durable and robust and open to change. Scientific knowledge can change because it is often examined and re-examined by new investigations and scientific argumentation. Because of these frequent examinations, scientific knowledge becomes stronger, leading to its durability.
27. **SC.912.N.2.5:** Describe instances in which scientists' varied backgrounds, talents, interests, and goals influence the inferences and thus the explanations that they make about observations of natural phenomena and describe that competing interpretations (explanations) of scientists are a strength of science as they are a source of new, testable ideas that have the potential to add new evidence to support one or another of the explanations.
28. **SC.912.N.3.1:** Explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have to offer.
29. **SC.912.N.3.2:** Describe the role consensus plays in the historical development of a theory in any one of the disciplines of science.
30. **SC.912.N.3.3:** Explain that scientific laws are descriptions of specific relationships under given conditions in nature, but do not offer explanations for those relationships.
31. **SC.912.N.3.4:** Recognize that theories do not become laws, nor do laws become theories; theories are well supported explanations and laws are well supported descriptions.
32. **SC.912.N.3.5:** Describe the function of models in science, and identify the wide range of models used in science.
33. **SC.912.N.4.1:** Explain how scientific knowledge and reasoning provide an empirically-based perspective to inform society's decision making.
34. **SC.912.N.4.2:** Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.
35. **SC.912.P.10.1:** Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
36. **SC.912.P.10.2:** Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
37. **SC.912.P.10.3:** Compare and contrast work and power qualitatively and quantitatively.
38. **SC.912.P.10.4:** Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter.
39. **SC.912.P.10.5:** Relate temperature to the average molecular kinetic energy.
40. **SC.912.P.10.7:** Distinguish between endothermic and exothermic chemical processes.
41. **SC.912.P.10.10:** Compare the magnitude and range of the four fundamental forces (gravitational, electromagnetic, weak nuclear, strong nuclear).

42. **SC.912.P.10.11:** Explain and compare nuclear reactions (radioactive decay, fission and fusion), the energy changes associated with them and their associated safety issues.
43. **SC.912.P.10.12:** Differentiate between chemical and nuclear reactions.
44. **SC.912.P.10.14:** Differentiate among conductors, semiconductors, and insulators.
45. **SC.912.P.10.15:** Investigate and explain the relationships among current, voltage, resistance, and power.
46. **SC.912.P.10.18:** Explore the theory of electromagnetism by comparing and contrasting the different parts of the electromagnetic spectrum in terms of wavelength, frequency, and energy, and relate them to phenomena and applications.
47. **SC.912.P.10.21:** Qualitatively describe the shift in frequency in sound or electromagnetic waves due to the relative motion of a source or a receiver.
48. **SC.912.P.12.2:** Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
49. **SC.912.P.12.3:** Interpret and apply Newton's three laws of motion.
50. **SC.912.P.12.4:** Describe how the gravitational force between two objects depends on their masses and the distance between them.
51. **SC.912.P.12.7:** Recognize that nothing travels faster than the speed of light in vacuum which is the same for all observers no matter how they or the light source are moving.
52. **SC.912.P.12.10:** Interpret the behavior of ideal gases in terms of kinetic molecular theory.
53. **SC.912.P.12.11:** Describe phase transitions in terms of kinetic molecular theory.
54. **SC.912.P.12.12:** Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.
55. **SC.912.P.8.1:** Differentiate among the four states of matter.
56. **SC.912.P.8.2:** Differentiate between physical and chemical properties and physical and chemical changes of matter.
57. **SC.912.P.8.4:** Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
58. **SC.912.P.8.5:** Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.
59. **SC.912.P.8.7:** Interpret formula representations of molecules and compounds in terms of composition and structure.
60. **SC.912.P.8.8:** Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.
61. **SC.912.P.8.11:** Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.

Resources

Materials

1. **What Not To Do**
   - ☐ Handout

2. **Drops on a Coin**
   - ☐ 1 coin (penny or nickel)
   - ☐ 1 eye dropper or glass dropper
   - ☐ Plenty of paper towels.
   - ☐ One 50-ml Beaker
   - ☐ Clean tap water
   - ☐ Safety goggles

3. **Speed and Velocity**
   - ☐ meter stick
   - ☐ stop watch

4. **Speed and Acceleration**
   - ☐ Stack of books
   - ☐ Masking tape
   - ☐ Meter stick
   - ☐ Ramp (about 50 cm long)
   - ☐ Toy cars
   - ☐ Stopwatch

5. **Momentum**
   - ☐ Dynamics Cart with Mass
   - ☐ Collision Cart
   - ☐ Dynamics Cart Track
   - ☐ Meter Stick
   - ☐ Mass Balance

6. **Exploring Newton's Laws**
   - ☐ 3 masses, 1 kg each
   - ☐ Beaker
   - ☐ Coin, such as a quarter
   - ☐ Cord
   - ☐ Dynamics cart with spring mechanism
   - ☐ Human-figure toy or doll
   - ☐ Water
   - ☐ Index card
   - ☐ Paper towels
   - ☐ Rubber band
   - ☐ Set of masses, 20g-100g
   - ☐ Stopwatch
   - ☐ Track with pulley
   - ☐ Dynamic cart
   - ☐ String
   - ☐ 16 washers
   - ☐ Hook
   - ☐ Pulley
   - ☐ Timer
   - ☐ Ruler

7. **Bouncing Ball Gravity Lab**
   - ☐ Ball.
   - ☐ Stopwatch.
   - ☐ Meter stick.

8. Kinetic and Potential Energy and Their Work

- Different masses (objects)
- Balance
- Metric ruler
- Spring scale
- Ramp

9. Mechanical Advantage of an Inclined Plane

- Ramp (long enough to drag the chosen masses)
- (3) blocks with different masses
- Spring scale
- Balance
- Meter stick
- Books (to incline the ramp)

10. Static Electricity

- Rubbing materials
- Foam board
- Aluminum foil
- Paper pencil
- Plastic rods
- Swivel
- Metal rod

11. Phase Changes

- Hot plate
- 250 mL beaker
- Water
- Thermometer
- balance
- Graph Paper
- Ruler
- Stirring Rod
- Ring Stand
- Thermometer Clamp
- Timer
- Heat Proof Gloves
- Safety Goggles

12. Boyle's Law

- safety goggles
- Boyle's law apparatus
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors

13. Models of Atomic Structure

- White paper and colored paper
- Markers
- Pencils
- Tape or Glue
- Compass
- Scissors
- Colored dots labels for the electron (can be made using a hole-puncher to create dots from peel off labels)
- Atom template (see next page)

14. Alien Periodic Table

- ☐ Blank *Alien Periodic Table*
- ☐ Periodic table from text (used for reference)
- ☐ Colored pencils

15. A Bagged Chemical Reaction

- ☐ Lab notebook
- ☐ Safety goggles
- ☐ Calcium Chloride pellets
- ☐ Sodium Bicarbonate (Baking Soda)
- ☐ Phenol Red solution
- ☐ Graduated cylinder
- ☐ (2) plastic teaspoons
- ☐ (1) Gallon ziplock bag
- ☐ (2) twist ties or rubberbands
- ☐ water
- ☐ permanent marker (black)

16. Factors Affecting Reaction Rates

- ☐ duct tape
- ☐ 50 mL beaker
- ☐ paper towel 1 dropper
- ☐ test tube with stopper
- ☐ Hot plate
- ☐ Beaker
- ☐ Timer
- ☐ Waste Beaker
- ☐ (6) effervescent Tablets
- ☐ Room temperature water
- ☐ mortar and pestle (small)
- ☐ filter paper

17. Half-Life

- ☐ 100 pennies
- ☐ opaque rectangular container with lid (shoebox)
- ☐ timer

18. Solubility Curve of KCl

- ☐ potassium chloride (KCl)
- ☐ distilled water
- ☐ balance
- ☐ evaporating dish (or 100-ml beaker)
- ☐ 25-ml graduated cylinder
- ☐ watch glass
- ☐ 250 or 400 ml beaker
- ☐ hot plate or burner with ring stand, 2 rings & wire gauze
- ☐ test tube (18X150 mm)
- ☐ utility clamp
- ☐ glass stirring rod
- ☐ thermometer or temperature probes
- ☐ funnel
- ☐ cotton wadding
- ☐ tongs &/or hot mitts
- ☐ graph paper

Laboratory Safety

Rules:

- Know the primary and secondary exit routes from the classroom.
- Know the location of and how to use the safety equipment in the classroom.
- Work at your assigned seat unless obtaining equipment and chemicals.
- Do not handle equipment or chemicals without the teacher's permission.
- Follow laboratory procedures as explained and do not perform unauthorized experiments.
- Work as quietly as possible and cooperate with your lab partner.
- Wear appropriate clothing, proper footwear, and eye protection.
- Report to the teachers all accidents and possible hazards.
- Remove all unnecessary materials from the work area and completely clean up the work area after the experiment.
- Always make safety your first consideration in the laboratory.

Safety Contract:

I will:

- Follow all instructions given by the teacher.
- Protect eyes, face and hands, and body while conducting class activities.
- Carry out good housekeeping practices.
- Know where to get help fast.
- Know the location of the first aid and firefighting equipment.
- Conduct myself in a responsible manner at all times in a laboratory situation.

I, ________________________, have read and agree to abide by the safety regulations as set forth above and also any additional printed instructions provided by the teacher. I further agree to follow all other written and verbal instructions given in class.

Signature: _____________________________ Date: ____________________

Lab Roles and Their Descriptions

Cooperative learning activities are made up of four parts: group accountability, positive interdependence, individual responsibility, and face-to-face interaction. The key to making cooperative learning activities work successfully in the classroom is to have clearly defined tasks for all members of the group. An individual science experiment can be transformed into a cooperative learning activity by using these lab roles and responsibilities:

Project Director (PD)
The project director is responsible for the group.
- Reads directions to the group
- Keeps group on task
- Is the only group member allowed to talk to the teacher
- Assists with conducting lab procedures Shares summary of group work and results with the class

Materials Manager (MM)
The materials manager is responsible for obtaining all necessary materials and/or equipment for the lab.
- Picks up needed materials
- Organizes materials and/or equipment in the work space
- Facilitates the use of materials during the investigation
- Assists with conducting lab procedures
- Returns all materials at the end of the lab to the designated area

Technical Manager (TM)
The technical manager is in charge of recording all data.
- Records data in tables and/or graphs
- Completes conclusions and final summaries
- Assists with conducting the lab procedures
- Assists with the cleanup

Safety Director (SD)
The safety director is responsible for enforcing all safety rules and conducting the lab.
- Assists the PD with keeping the group on-task
- Conducts lab procedures
- Reports any accident to the teacher
- Keeps track of time
- Assists the MM as needed.

When assigning lab groups, various factors need to be taken in consideration:
- Always assign the group members, preferably trying to combine in each group a variety of skills. For example, you can place an "A" student with a "B", "C", and a "D" and or "F" student.
- Evaluate the groups constantly and observe if they are on task and if the members of the group support each other in a positive way. Once you realize that a group is dysfunctional, re-assign the members to another group.

Writing in Science

A report is a recap of what a scientist investigated and may contain various sections and information specific to the investigation. Below is a comprehensive guideline that students can follow as they prepare their lab/activity reports. Additional writing templates can be found in the District Science website.

Parts of a Lab Report: A Step-by-Step Checklist

Title (underlined and on the top center of the page)

Benchmarks Covered:
- A summary of the main concepts that you will learn by carrying out the experiment.

Problem Statement:
- Identify the research question/problem and state it clearly.

Hypothesis(es):
- State the hypothesis carefully, logically, and, if appropriate, with a calculation.
  1. Write your prediction as to how the independent variable will affect the dependent variable using an ***IF-THEN-BECAUSE*** statement:
     i. **If** (state the independent variable) is (choose an action), **then** (state the dependent variable) will (choose an action), **because** (describe reason for event).

Materials and activity set up:
- List and describe the equipment and the materials used. (e.g., A balance that measures with an accuracy of +/- 0.001 g)
- Provide a diagram of the activity set up describing its components (as appropriate).

Procedures:
- Do not copy the procedures from the lab manual or handout.
- Summarize the procedures that you implemented. Be sure to include critical steps.
- Give accurate and concise details about the apparatus (diagram) and materials used.

Variables and Control Test:
- Identify the variables in the experiment. There are three types of variables:
  1. Independent variable (manipulated variable): The factor that can be changed by the investigator (the cause).
  2. Dependent variable (responding variable): The observable factor of an investigation resulting from the change in the independent variable.
  3. Constant variable: The other identified independent variables in the investigation that are kept or remain the same during the investigation.
- Identify the control test. A control test is the separate experiment that serves as the standard for comparison and helps identify effects of the dependent variable

Data:
- Ensure that all observations and/or data are recorded.
  1. Use a table and write your observations clearly. (e.g., color, solubility changes, etc.)
  2. Pay particular attention to significant figures and make sure that all units are stated.

Data Analysis:

- Analyze data and specify method used.
- If graphing data to look for a common trend, be sure to properly format and label all aspects of the graph (i.e., name of axes, numerical scales, etc.)

Results:

- Ensure that you have used your data correctly to produce the required result.
- Include any errors or uncertainties that may affect the validity of your result.

Conclusion and Evaluation:

- **First Paragraph:** Introduction
- What was investigated?
  1. Describe the problem.
- Was the hypothesis supported by the data?
  1. Compare your actual result to the expected (from the literature, or hypothesis) result.
  2. Include a valid conclusion that relates to the initial problem or hypothesis.
- What were your major findings?
  1. Did the findings support (or not) the hypothesis as the solution to the problem?
  2. Calculate the percentage error from the expected value.

- **Middle Paragraphs:** Discuss the major findings of the experiment.
- How did your findings compare with other researchers?
  1. Compare your result to other students' results in the class.
     a. The body paragraphs support the introductory paragraph by elaborating on the different pieces of information that were collected as data.
     b. Each finding needs its own sentence and relates back to supporting or not supporting the hypothesis.
     c. The number of body paragraphs you have will depend on how many different types of data were collected. They should always refer back to the findings in the first paragraph.

- **Last Paragraph:** Conclusion
- What possible explanations can you offer for your findings?
  1. Evaluate your method.
  2. State any assumptions that were made which may affect the result.
- What recommendations do you have for further study and for improving the experiment?
  1. Comment on the limitations of the method chosen.
  2. Suggest how the method chosen could be improved to obtain more accurate and reliable results.
- What are some possible applications of the experiment?
  1. How can this experiment or the findings of this experiment be used in the real world for the benefit of society?

Hands-on Activities

What Not To Do

(with permission from www.labsafety.org)

NGSSS:
There are no benchmarks that pertain directly to Lab Safety, however, appropriate safety procedures should be introduced and reinforced throughout the length of the course.

Purpose of Lab/Activity: Students will review safety procedures and behaviors necessary to conduct laboratory experiments.

Prerequisite: Prior to this activity, the teacher should make sure that students:

- Have a working knowledge of the practice of science and the characteristics of the scientific process.
- Understand the dangers inherent to a laboratory experiment (equipment, behaviors, etc.).

Materials (individual or per group):

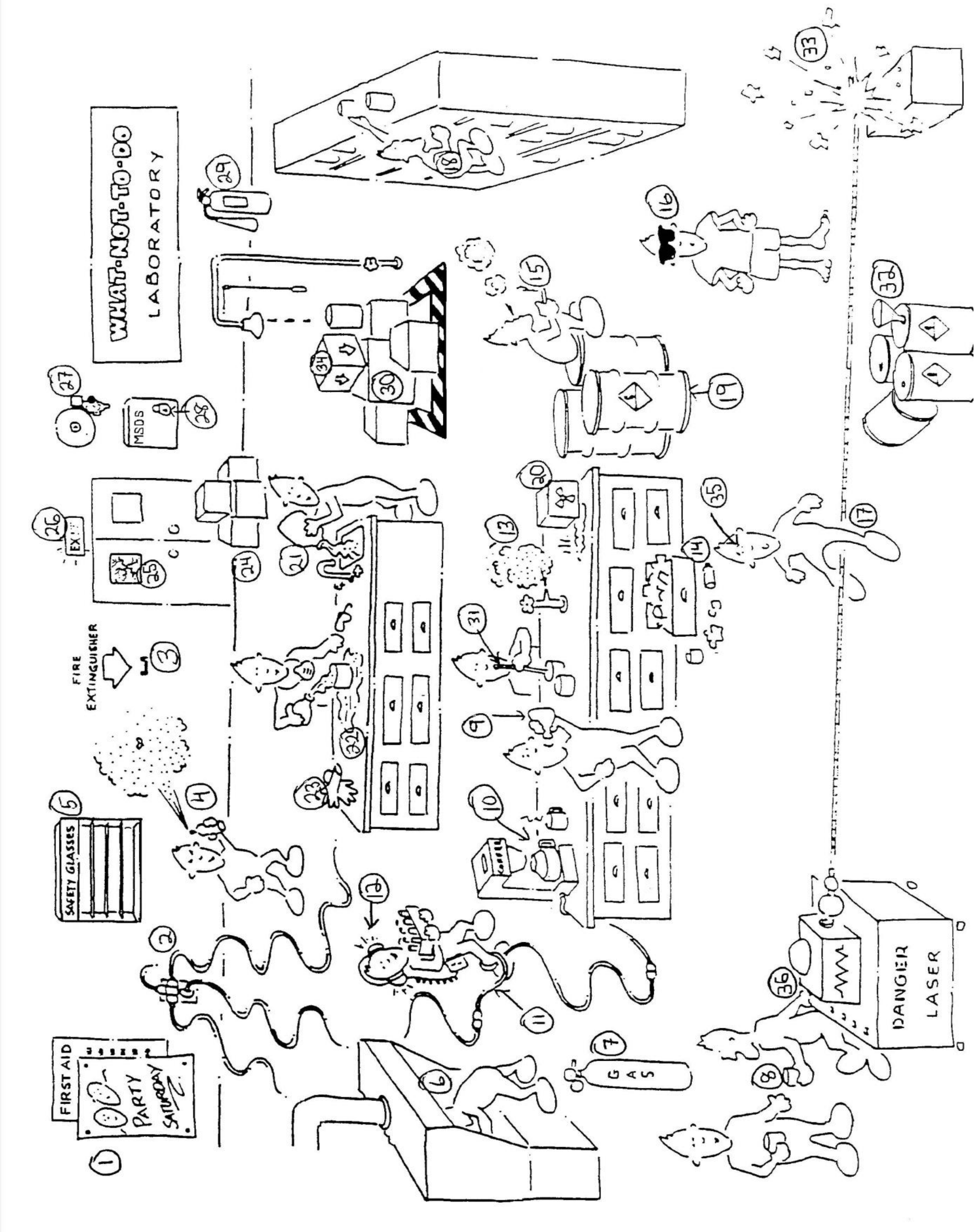
- Handout

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Discuss the importance of conducting safety practices in a laboratory setting, including a classroom setting with lab equipment and materials. b. Address misconceptions regarding proper behavior in a laboratory setting, including a classroom setting with lab equipment and materials.
During activity:	**What the teacher will do:** a. As students work on the worksheet/handout, ask to compare their worksheet to activities they have done in the past. b. Monitor student progress as the worksheet is completed, and ask questions that engage students' understanding of the safety concerns described in the worksheet/handout: 1. Why is it wrong to cover first aid information? 2. What could happen if too many plugs are used in a single electrical outlet? 3. Ask students to provide explanations that support their description of each safety concern
After activity:	**What the teacher will do:** a. Review student understanding of each safety concern and discuss their explanations. b. Probe for probable misconceptions as to their reasoning for safety concerns.

Extension:
Discuss various areas of your classroom and the associated safety concerns. Describe future lab activities and ask students to describe possible safety issues with equipment and materials.

What Not To Do (with permission from www.labsafety.org)



Student

What is wrong with the picture? On a separate sheet of paper: a) describe each event (1-36), b) provide an explanation that addresses the safety concern, and c) describe the necessary steps that should be followed in order to avoid an accident.

Teacher

Drops on a Coin

NGSSS:

SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Purpose of Lab/Activity: Students will apply their understanding of scientific processes and habits of mind to solve problems.

Prerequisite: Prior to this activity, the teacher should make sure that students:
- Have a working knowledge of the practice of science and the characteristics of the scientific process.
- Understand each step in the scientific process.
- Are able to explain the vocabulary words linked to the scientific method.

Materials (individual or per group):
- 1 coin (penny or nickel)
- 1 eye dropper or glass dropper
- Plenty of paper towels.
- One 50-ml Beaker
- Clean tap water
- Safety goggles

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** c. Prepare the appropriate lab materials according to the number of students or groups. d. Review the scientific processes with the students and clarify why we are about to do this lab. e. Address misconceptions regarding hypothesis, prediction, the different types of variables, data analysis, theory, scientific law. f. Problem Statement: Which side (head or tail) of the penny will hold more water? Why? Have the students come up with their own hypothesis using the format: **IF** (independent variable, action verb) - **THEN** (dependent variable, action verb) – **BECAUSE** (reason, description). g. Discuss the lab safety and the directions related to this experiment. h. Have the students gather into groups of 2 or 3 and pick up the required materials for the group. i. Define the role of each group member?
During activity:	**What the teacher will do:** c. Why do we use only the same coin at a time for the experiment? d. Explain why do we have to do more than one trial on each side?

	e. What are the benefits of doing many trials? f. Identify the independent and the dependent variables, the control. g. Related to the students' hypothesis, what do you observe? h. After drying one side of the coin at the end of the first trial, ask the students how many drops do they expect for the second trial on the same side? Why? i. Walk around and make sure that the students follow directions and record their data during the activity. j. Make sure that the students analyze the data through table and graphs and draw a conclusion.
After activity:	**What the teacher will do:** c. Create a class data so the students can compare their results (individual trial and average) with the other groups. Why are there any discrepancies? d. Provide at least 2 possible reasons for the similarities or differences. e. Why did we have a difference on the number of drops after each trial? f. What effect on the results, if any, if we use soap water vs simple water? Old vs new coins? Explain. g. What could have been done for every group to have the same results? h. Have students write a lab report using the *"Power Writing Model 2009."*

Extension:
Explain the concept of Cohesion and Surface Tension to the students.
Cohesion: water molecules are attracted to other water molecules. The oxygen end of water has a negative charge and the hydrogen end has a positive charge. The hydrogens of one water molecule are attracted to the oxygen from other water molecules. This attractive force is what gives water its cohesive properties, the water's ability to "stick to itself".
Surface Tension: the cohesion of water molecules at the surface of a body of water. The cohesion of water molecules forms a surface "film" or "skin." Some substances may reduce the cohesive force of water, which will reduce the strength of the surface or "skin" of the water. Surface tension can be measured and observed by dropping water (drop by drop) onto a penny. The number of water drops that can fit on a penny will surprise you.

a. How does the coin's cleanliness affect the result?
b. How does soap affect the water's surface tension?
c. How does sugar affect the surface tension of water?

Student

Drops on a Coin

NGSSS:
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Background: Scientists daily apply scientific method in their activities. This activity introduces students to the inquiry of the scientific process.

Purpose or Problem Statement: Which side (head or tail) of the penny will hold more water?

Safety: The only safety concern is the water:
- Wash your hands before and after the experiment.
- Do not let student play with the water.
- Clean up spills immediately.
- Clean up the lab materials after the experiment and place them back into their proper location.

Vocabulary: Prediction**,** Independent or Manipulated Variable, Dependent or Responded Variable, Controlled Variable or Constant, Hypothesis, Data analysis, Conclusions, Theory, Law, Surface Tension, Cohesion.

Materials (individual or per group):
- 1 penny or coin
- 1 dropper or glass dropper
- Plenty of Paper Towels.
- One 50-ml Beaker
- Clear water
- Gloves
- Safety goggles
- Lab Notebook

Procedures:
1- Use a flat surface to put the coin. Use the coin as is.
2- Pour about 20 ml of tap water in the beaker.
3- Prepare the lab data table like the one below in your lab notebook.
4- Use the dropper to get water from the beaker.
5- Place drops of water **one at a time** on one side of the penny until water runs over the edge of the coin.
6- Record your observation and the number of drops during this trial.
7- Dry the coin side completely and repeat steps 4 to 6 for trial 2 and 3.

Student

Observations/Data:

Coin side	Trial 1	Trial 2	Trial 3	Average	Observations
Head					
Tail					

Observation/Data Analysis:

- Analyze your data through the data table,
- Determine the best format for the data and present visual summaries such as the utilization of graphs (line, bar, histograms….) to interpret the data.
- Explain the data outcome. How can you describe the difference in the number of drops for each trial on the same side?

Results: Analyze not only your individual or group data but also the class data and engage classroom discussion with teacher oriented questions with higher ordered thinking to explore concept understanding and application.

a. In the class data, compare your results (individual trial and average) with the other groups. Why are there any discrepancies?
b. Provide at least 2 possible reasons for the similarities or differences.
c. Why did we have a difference on the number of drops after each trial?
d. What effect on the results, if any, if we use soap water vs simple water? Old vs new coins? Explain.
e. What could have been done for every group to have the same results?

Conclusion: Write *a Lab Report using the "Power Writing Model 2009".*

Teacher

Speed and Velocity

NGSSS:
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Purpose of Lab/Activity: To give the students practices in measuring average speeds, and to get their thinking about average and instantaneous speed. This activity has two parts. First, you will calculate some average speeds. Then, you will use these calculated average speeds to determine an unknown distance.

Prerequisite: Prior to this activity, the student should be able to:

- Apply the definition of distance traveled to a specific case.
- Apply the definition of interval of time to a specific case.
- Apply the definition of Average speed as Total distance traveled divide by the time interval.

Materials (individual or per group):

- meter stick
- stop watch

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Explain to the students they will be working in a group of 3-4 students, but **this is not a group activity**. You will decide the event for your group and you will collect your own data, and make your own calculations. Each student will submit their own results and conclusions. b. Assess students' prior knowledge and skills using the students' prerequisites to guide a class discussion and to clarify any misconception. The teacher will review using questions as: 1. What do you need to measure average speed? (Guide the discussion to review the definition and the mathematical equation, they will use). 2. What are the units of average speed? (Use the equation to review the units of average speed (m/s)). 3. How could you measure the distance traveled? (Guide the discussion to review the definition as Final Position minus Initial Position - $\Delta \mathbf{d} = \mathbf{d_f} - \mathbf{d_i}$).

	4. How could you measure the time? If it is necessary explain the use of the stop watch. 5. The teacher will draw an example of the data table the students need to record the data. c. Inform the students that they must write a Lab Report based on accepted models ("Parts of the Lab Report" or "Power Writing Model 2009", Found in web links cited in this document).
During activity:	**What the teacher will do:** k. Supervise the "event" selected for the students and ensure the safety during performance of the chosen action. l. The teacher will settle any disagreements that cannot be settle among the participants. m. To keep the students working with the concept of average speed ask questions related to the same. Such as: Does the value of the average speed change if you increase the distance traveled or the length of the experiment? n. Is the starting point a variable in this experiment? o. In the 2nd Part of the Lab, provide the students with different value of "unknown distance".
After activity:	**What the teacher will do:** a. Discuss the different average speed obtained, and compare them with the event performed. b. Request the students to list the possible errors they cannot avoid in performing the experiment. c. Assess student understanding of the result of the experiment and the analysis of the data by asking the following questions: 1. Does the value of the speed calculated in each trial have a large discrepancy? 2. Could you consider that the events performed were at constant speed? 3. How could you identify constant speed in a position vs. time graph? 4. What information can be inferring the shape of the distance vs. time graph give? d. The students will make graphs of distance vs. time using the data obtain from the lab (plot the time in the horizontal axis).

Student

Speed and Velocity

NGSSS:
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Background: Velocity is a rate that tells how much distance is covered in a unit of time. It can be expressed by the formula

$$V = d/t$$

Where v is the velocity or speed (in m/s), d = distance traveled (in meters), and t = time (in second).

Purpose or Problem Statement: This activity will give you practice in measuring average speeds, and to get you thinking about average speed and instantaneous speeds.

Safety:
- It is more important to move at a consistent (and safe) speed than it is to go fast.
- There are no prizes for "winning" these events!
- If a person in your group suggests an activity that you think is unsafe, degrading, or will get your clothes dirty, you have the right to insist that they pick some other "event".
- The teacher will settle any disagreements that cannot be settled among the participants.

Vocabulary: distance, time, average speed, system of reference.

Materials (individual or per group):
- Meter stick
- Stop watch

Procedures:
Part 1 - Calculating Average Speed:
1. You need to decide on an "event" for the students in your group to participate in. This event could be walking, running, walking backwards, walking heel-to-toe, hop, skip, crawl, whatever (HINT: The other students in your group will be planning an event for YOU, too...)

Student

2. It is your job to determine the average speed for each student in your group for your event. Think about what you need to measure to determine the average speed, and how you will go about making the calculations. Then construct a data table to record your data and display your results. Be sure to label the columns and indicate the units of measurement for each quantity. You should allow for 2 to 3 trials for each person in your event.

Observations/Data:
Data Table Part 1 – Calculating Average Speed

Distance = ________ meter

Person	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Speed (m/s)

1. Supervise your event, and record your data. Each person in your group (except you) will "run" in your event, and you will participate in the event of every other person in your group.

Part 2 - Calculating an Unknown Distance:

When you have finished Part 1, report to your teacher. It is not necessary that your calculations be complete.

1. Your teacher will show you an "unknown distance". Time your participants in your event over this distance. Record the results in a data table.
2. Use your average speed calculation from Part 1 and the time required to cover the "unknown distance" to calculate the "unknown distance". Put your results in the data table.
3. Measure (and record) your "unknown distance" with a meter sticks, so you can judge the accuracy of your calculation in number 2.
   i) Part 2. Measuring and Unknown Distance

Person	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)	Speed (m/s)	Distance (m)

Student

Observation/Data Analysis:
Make a distance vs. time graph using the data obtained.

Results/Conclusion:

1. How do your measured and calculated values for the "unknown distance" compare? If there is a large discrepancy, why do you think it occurred?
2. How is the average speed of a person related to the total distance covered and the total time taken?
3. If the average speed of a person was 1.2 meters/second, does this mean that their speed was exactly 1.2 meters/second the whole time? Is the average speed related to the maximum or minimum speed of the person? Explain why you think so.

Teacher

Speed and Acceleration

NGSSS:
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Purpose of Lab/Activity: Students will apply their understanding of the Kinematic concepts of speed, distance, and acceleration to the motion of a toy car.

Prerequisite: Prior to this activity the student should be able to:
- Differentiate between the distance traveled and the displacement.
- Calculate the speed of object using the appropriated equation.
- Calculate the acceleration of object using the appropriated equation.
- To observe and record the times of the moving object.

Materials (individual or per group):
- Stack of books
- Masking tape
- Meter stick
- Ramp (about 50 cm long)
- Toy cars
- Stopwatch

Procedures: Day of Activity

Before activity:	**What the teacher will do:** a. Assess previous knowledge through a class discussion (Prerequisites). b. Review terminology (vocabulary) c. Conduct Lesson Lead-In; ask students: “describe in words the motion of the car after it leaves the ramp”. d. Show a demo, if necessary, and emphasis in: 1. That all motion is relative to the frame of reference selected 2. That there is no absolute frame of reference. These concepts are very important and although they may seem easy to comprehend, they will trouble students every time measurements must be made 3. It is imperative to remind students to mind their frame of reference and select the same starting point per each trial 4. Remind to the students that the initial velocity have to be zero. 5. The use and reading of the stopwatch. e. Inform the students that they must write a Lab Report based on accepted models (“Parts of the Lab Report” or “Power Writing Model 2009”, found in

	web links cited in this document).
During activity:	**What the teacher will do:** a. As the class continues, ask questions that pertain to the lab such as: 1. How can you determine the distance traveled? 2. Why is important to use the same car in all the trials? 3. How can you determine the time in each trial if more than one student records the time? 4. Why is important to be sure that the initial velocity of the cart is zero? 5. Why the velocity of the car is slowing down?
After activity:	**What the teacher will do:** Discuss with the students the result obtained: a. Students will have different data and their numbers may differ, but overall the acceleration of the car should be constant, ask questions about this facts like: 1. Was there a significant difference between the values of the acceleration obtained from trial to trial? If there was, explain why? b. Why the velocity should be decreasing? c. Does the friction between the floor and the cart will be slowing down the velocity?

Student

Speed and Acceleration

NGSSS:
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.

Background:
Acceleration is the rate of change of velocity. Since velocity includes both speed and direction, when either value changes, velocity changes. To find the change in velocity, subtract the initial velocity from the final velocity:

$$\Delta V = V_f - V_i$$

To calculate average acceleration, divide the change in velocity by the time in which the velocity changes:

$$a = \frac{\Delta V}{\Delta t}$$

Purpose or Problem Statement: The purpose of this activity is to find a relationship between the changes in velocity and the acceleration of a toy car.

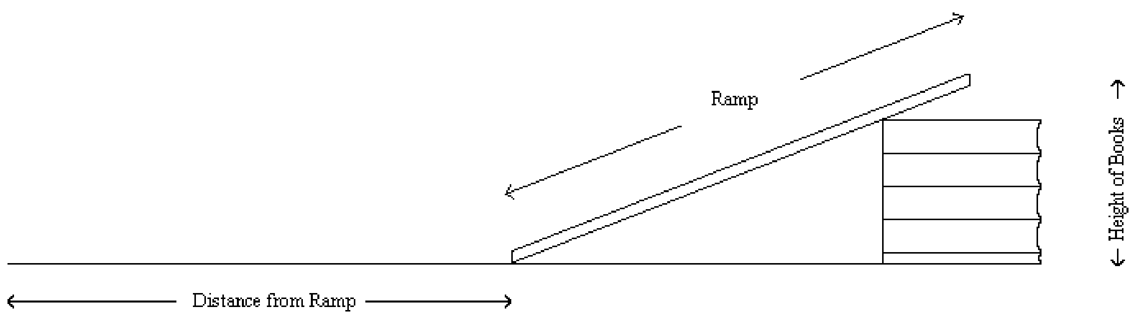
Safety: There are not specific safety concerns for this activity.

Vocabulary: speed, velocity, acceleration, distance, time.

Materials (individual or per group):
- Stack of books
- Masking tape
- Meter stick
- Ramp (about 50 cm long)
- Toy cars
- Stopwatch

Procedures:
Part A - Average Speed
1. At one end of a runway area, set up a launching ramp. Put one end of ramp on the stack of books (approximately 20 cm tall) and the other end on the floor. You will launch the toy car on its test runs from the top of the ramp.

2. Place a masking tape marker where the ramp touches the floor. Label this marker 0.0 m and place similar markers at 1.0 m, 2.0 m, 3.0 m, 4.0 m, and 5.0 m from the bottom of the ramp.
3. Launch the toy car down the ramp several times. Observe the car's motion and path. Add or remove books from the ramp so that the car travels a distance of 5.0 meters. Remember that the 5.0-meter distance begins at the bottom of the ramp.
4. Measure the time that the car takes to travel the 5.0 meters. Record the time and distance in the data table. Measure and record the time in 2 more trials.



Part B - Deceleration (acceleration in the opposite direction of the initial velocity)

1. Repeat sending the car down the ramp. Now measure the time required for the toy car to pass each marker. You may require several practice runs to be able to observe and record the times quickly. One lab partner can keep track of the time while the other records the data.
2. Complete three trials and record the time and distances in the data table.

Observations/Data:

Trial	Time to 1.0 m	Time to 2.0 m	Time to 3.0 m	Time to 4.0 m	Time to 5.0 m
1					
2					
3					
Average time					
Average speed					
Acceleration					

Observation/Data Analysis:
Part A – Average speed

1. Calculate the average time for the three trials. Record the results on your table.

2. Calculate the average speed of the toy car by dividing the distance by the average time.

Student

Distance = _____________m   Car's average speed = ________________m/s

Part B - Deceleration

1. Calculate the average time the car needed to travel each distance for the three trials. Record the results in the data table.

2. Calculate the average speed of the toy car as it passes each marker. Record the result to the nearest 0.1 m/s in the data table.

3. Make a graph to compare the average speed of the toy car (y-axis) to the distance of each marker (x-axis).

Results/Conclusions:

1. Describe the motion of the car as it moved across the floor.
2. What caused the car to slow down and stop?
3. Did the toy car travel at a constant speed? How do you know this?
4. How could you change this experiment to make the toy car decelerate at a faster rate?
5. How could you change the experiment to make the car accelerate at a faster rate?
6. Think about the 5.0 meters that the car traveled. What conditions are necessary for the car to have no acceleration or deceleration?

Teacher

Momentum

NGSSS:
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.
SC.912.P.12.5 Apply the law of conservation of linear momentum to interactions, such as collisions between objects.

Purpose of Lab/Activity: The purpose of this experiment is to demonstrate conservation of momentum for two carts pushing away from each other.

Prerequisite: Prior to this activity, the student should be able to:

- Explain the definition of momentum.
- Define velocity
- Apply the conservation of momentum to a specific situation.
- Recognize when an External Force is acting upon the system.
- Define the System Reference

Materials (individual or per group):

- Dynamics Cart with Mass
- Collision Cart
- Dynamics Cart Track
- Meter Stick
- Mass Balance

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess previous knowledge through a class discussion using the prerequisite guide. 1. What is the definition of momentum? Review the equation of momentum ($p = mv$) 2. What are the units of momentum? Kg m/s 3. Define the system being studied? The student must define the system of the two interacting carts. 4. Are the forces acting between the carts internal forces? The students must identify as internal forces.

	5. What is the meaning of a “Conservation Law”? 6. When is the momentum conserved? When no external forces acting on the system. b. Consider a head-on collision between two billiard balls. One is initially at rest and the other moves toward it. Is momentum conserved in this collision? Yes, this is an elastic collision. c. Inform the students that they must write a Lab Report based on accepted models (“Parts of the Lab Report” or “Power Writing Model 2009”, Found in web links cited in this document).
During activity:	**What the teacher will do:** a. Ask the following questions as students perform the activity: 1. Is the friction force an external force? Yes, but in this lab, the friction force is too small and does not affect the conservation of the momentum. 2. Why the masses of the carts are not affecting the velocity after the collision? 3. Why is this collision elastic? 4. Why is the kinetic energy conserved in this collision? 5. Did you select the same initial position in all trial?
After activity:	**What the teacher will do:** a. Explain how to calculate the ratio between two values and assess student understanding by asking additional questions: 1. Does the ratio of the distances equal the ratio of the masses in each of the cases? In other words, is momentum conserved? 2. When the carts with unequal masses push away from each other, which cart has more kinetic energy? Why? 3. When the carts with unequal masses push away from each other, which cart has more momentum? Explain

Student

Momentum

NGSSS:
SC.912.N.1.1 Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1) pose questions about the natural world, 2) conduct systematic observations, 3) examine books and other sources of information to see what is already known, 4) review what is known in light of empirical evidence, 5) plan investigations, 6) use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7) pose answers, explanations, or descriptions of events, 8) generate explanations that explicate or describe natural phenomena (inferences), 9) use appropriate evidence and reasoning to justify these explanations to others, 10) communicate results of scientific investigations, and 11) evaluate the merits of the explanations produced by others.
SC.912.P.12.2 Analyze the motion of an object in terms of its position, velocity, and acceleration (with respect to a frame of reference) as functions of time.
SC.912.P.12.5 Apply the law of conservation of linear momentum to interactions, such as collisions between objects.

Background: When two carts push away from each other and no net external force exist, the total momentum of both carts is conserved, in other words the momentum before the push is equal to the momentum after. Because the system is initially at rest, the final momentum of the carts must be equal in magnitude and opposite in direction so the resulting total momentum of the system is still zero.

$$\rho = m_1\bar{v}_1 - m_2\bar{v}_2 = 0$$

Therefore, the ratio of the final speeds of the carts is equal to the ratio of the masses of the carts.

$$\frac{v_1}{v_2} = \frac{m_2}{m_1}$$

To simplify this experiment, the starting point of the carts at rest is chosen so that the two carts will reach the end of the track simultaneously. The speed, which is the distance divided by the time, can be determine by measuring the distance traveled since the time traveled by each cart is the same.

$$\frac{v_1}{v_2} = \frac{\frac{\Delta x_1}{\Delta t}}{\frac{\Delta x_2}{\Delta t}} = \frac{\Delta x_1}{\Delta x_2}$$

Thus the ratio of the distances is equal to the ratio of the masses:

$$\frac{\Delta x_1}{\Delta x_2} = \frac{m_2}{m_1}$$

Student

Purpose or Problem Statement: The purpose of this experiment is to demonstrate conservation of momentum for two carts pushing away from each other.

Safety: There are not specific safety concerns for this activity.

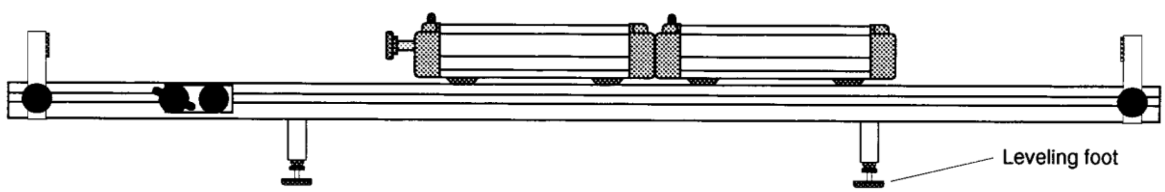
Vocabulary: velocity, time mass, distance, ratio, momentum, system.

Materials (individual or per group):

- Dynamics Cart with Mass
- Collision Cart
- Dynamics Cart Track
- Meter Stick
- Mass Balance

Procedures:

1. Level the track the track by setting a cart on the track to see which way it rolls. Adjust the leveling feet to raise or lower the ends until a cart placed at rest on the track will not move.



2. For each of the following cases, place the two carts against each other with the plunger of the Dynamics cart pushed completely in and latched in its maximum position (See Figure).
3. Push the plunger release button with a short stick and watch the two carts move to the ends of the track. Experiment with different starting positions until the two carts reach their respective ends of the track at the same time. Then weigh the two carts and record the masses and the starting position in Table 1.
   i). CASE 1: Carts of Equal Mass (Use the two carts without any additional mass bars)
   ii). CASE 2: Carts of Unequal Mass (Put one mass bar in one cart, none in the other)
   iii). CASE 3: Carts of Unequal Mass (Put two mass bars in one cart, none in the other)
   iv). CASE 4: Carts of Unequal Mass (Put two masses bars in one cart, one mass bar in the other)

Observations/Data:

Mass 1	Mass 2	Position	X_1	X_2	X_1/X_2	M_2/M_1

Table 1

Student

Observation/Data Analysis:

1. For each of the cases, calculate the distances traveled from the starting position to the of the end of the track. Record the result in Table 1.
2. Calculate the ratio of the distances traveled and record in the table.
3. Calculate the ratio of the masses and record in the table.

Results:

1. Does the ratio of the distance equal the ratio of the masses in each of the cases? In other words, is momentum conserved?
2. When carts of masses push away from each other, which cart has more momentum?
3. When the carts of unequal masses push away from each other, which cart has more kinetic energy?
4. Is the starting position dependent on which cart has its plunger cocked? Why?

Conclusion

The students must write a Lab Report based on accepted models ("Parts of the Lab Report" or "Power Writing Model 2009", Found in web links cited in this document).

Teacher

Exploring Newton's Laws

NGSSS:
SC.912.E.5.6 Develop logical connections through physical principles, including Kepler's and Newton's Laws about the relationships and the effects of Earth, Moon, and Sun on each other.
SC.912.P.12.4 Describe how the gravitational force between two objects depends on their masses and the distance between them.

Purpose of Lab/Activity: The purpose of this lab is to explore the factors that cause a change in motion of an object, make conclusions about the relationship between mass and acceleration, graph data and investigate the acceleration of two objects acting on one another.

Prerequisite: Prior to this activity, the student should be able to
- Newton's Law
- Acceleration
- Time

Materials (individual or per group):
- 3 masses, 1 kg each
- Beaker
- Coin, such as a quarter
- Cord
- Dynamics cart with spring mechanism
- Human-figure toy or doll
- Water
- Index card
- Paper towels
- Rubber band
- Set of masses, 20g-100g
- Stopwatch
- Track with pulley
- Dynamic cart
- String
- 16 washers
- Hook
- Pulley
- Timer
- Ruler

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess previous knowledge through a class discussion using the prerequisite guide. 1. Using Newton's three laws of motion, we can describe the relationship between the motion of objects found in our everyday world and the forces acting on them, in others words explain the causes of the motion of the objects. The three laws of motion are simple and sensible: ask questions that pertain to the Newton's Law such as: b. What is the Law of Inertia or Newton's 1st Law? 1. The first law states that a force must be applied to an object in order to change its state of motion. Refer that all objects have the property to resist the change of its state of motion force. 2. What is Newton's Law? c. The second law states that the net force on an object is directly proportional to its acceleration: 1. What is the equation that relates force and acceleration? $\mathbf{F}_{net} = m\mathbf{a}$ 2. Is the acceleration in the same direction to the resultant or net force?

	3. Could a single Force act alone? d. The third law states that do not exist one force along, the forces acting on pair. Any action force has a reaction force with the same intensity, but opposite direction. e. Inform the students that they must write a Lab Report based on accepted models ("Parts of the Lab Report" or "Power Writing Model 2009", Found in web links cited in this document).
During activity:	**What the teacher will do:** a. During the first and second activities (Part A and Part B), guide the analysis of the demonstration into the property of the object to try to keep the state of motion after the external interaction, questions such as: 1. What is the state of motion of the object? 2. What do you expect will happen if we remove suddenly the index card? 3. If we remove the index card slowly, does the coin fall into the water? b. During the third activity, Part C, guide the analysis of the lab with questions such as: 1. How you can measure the time? 2. Explain to the students that they can start record the time when they see the car start moving and stop the timer when they hear the impact of the washers with the floor. 3. How you can calculate the average time for every trial? 4. Is the interval of time proportional with the increment of the number of washers? 5. What is the force that causes the motion of the car? 6. How you can increase the value of the force applied? c. Graph the data. Plot Total Mass (in kg) on the horizontal axis versus Average Acceleration (in m/s^2) on the vertical axis.
After activity:	**What the teacher will do:** a. The teacher will guide instruction and encourage discussions by asking the following questions: 1. What is the relationship between mass and acceleration? Using the equation of the straight line on the student plot of Acceleration versus the inverse of the Mass, the teacher can explain linearization and find that acceleration varies inversely with mass. ($y= mx + b$, identify the slope m = force; $a=F/m$, identify the x variable $x= 1/m$) 2. Does this agree with what you have read about Newton's law of motion? Explain. The equation associated with Newton's 2^{nd} Law is $F=ma$. 3. Do the results of this experiment fit this equation and agree with the inverse relationship between mass and acceleration? 4. Which is easier to accelerate, a sport car or a moving truck? Why? A sport car is easier to accelerate than a moving truck because it has less mass.

Student

Exploring Newton's Laws

NGSSS:
SC.912.E.5.6 Develop logical connections through physical principles, including Kepler's and Newton's Laws about the relationships and the effects of Earth, Moon, and Sun on each other.
SC.912.P.12.4 Describe how the gravitational force between two objects depends on their masses and the distance between them.

Background: Using Newton's three laws of motion, we can describe the relationship between the motion of objects found in our everyday world and the forces acting on them. The three laws of motion are simple and sensible:

a. The first law states that a force must be applied to an object in order to change its state of motion.
b. The second law states that the acceleration varies inversely proportional with mass. The equation that describe this law is net force on an object equals the object's mass times its acceleration.
c. The third law states that whenever we push on something, it pushes back with equal force in the opposite direction.

Newton's laws, together with his invention of calculus, opened avenues of inquiry and discovery that are used routinely today in virtually all areas of mathematics, science, engineering, and technology. These accomplishments are considered among the greatest achievements of the human mind.

Purpose or Problem Statement: In this lab you are to test one of the fundamental laws of nature: that the greater the force, the larger the acceleration under which the object will move. Another purpose of this lab is to explore the factors that cause a change in motion of an object, graph data and investigate the acceleration of two objects acting on one another.

Safety: There are not specific safety concerns for this activity.

Vocabulary: acceleration, mass, force, inertia

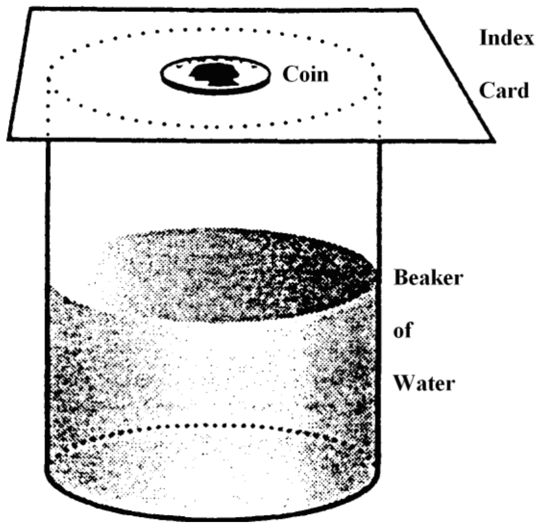
Materials (individual or per group):

- 3 masses, 1 kg each
- Beaker
- Coin, such as a quarter
- Cord
- Dynamics cart
- Dynamics cart with spring mechanism
- Human-figure toy or doll
- Water
- Index card
- Dynamic cart
- String
- 16 washers
- Hook
- Pulley
- Timer
- Ruler
- Paper towels
- Rubber band
- Set of masses, 20g-100g
- Stopwatch
- Track with pulley

Student

Part A: An Object at Rest
Procedures:

1. Carefully fill the beaker about half-full with water. Wipe the lip and the outside of the beaker with a paper towel.
2. Place an index card on top of the beaker so that the card covers the opening of the beaker. Place the quarter on top of the card.
3. Remove the index card by pulling it quickly away. Make sure you pull the card perfectly horizontally.

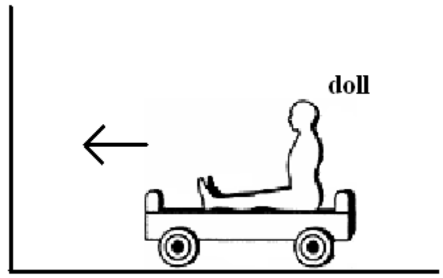


Analysis:

1. What happened to the coin when the card was pulled out from underneath?
2. Is this what you expected to happen? Explain why or why not.
3. What would happen to the coin if the card were pulled out very slowly? Try it, and compare your results.

Part B: An Object in Motion
Procedures:

1. Choose a location where you can push a dynamics cart so that it rolls for a distance without hitting any obstacles or obstructing traffic and then hits a wall or other hard surface.
2. Place the toy or doll on the cart, and place the cart about 0.5 m away from the wall.
3. Push the cart and doll forward so that they run into the wall. Observe what happens to the doll when the cart hits the wall.
4. Place the cart at the same starting place, about 0.5 m away from the wall. Return the doll to the cart, and use a rubber band to hold the doll securely in the cart.
5. Push the cart and doll forward so that they run into the wall. Observe what happens to the doll when the cart hits the wall.
6. When you are finished, return the cart to the table or storage place. Do not leave the cart on the floor.

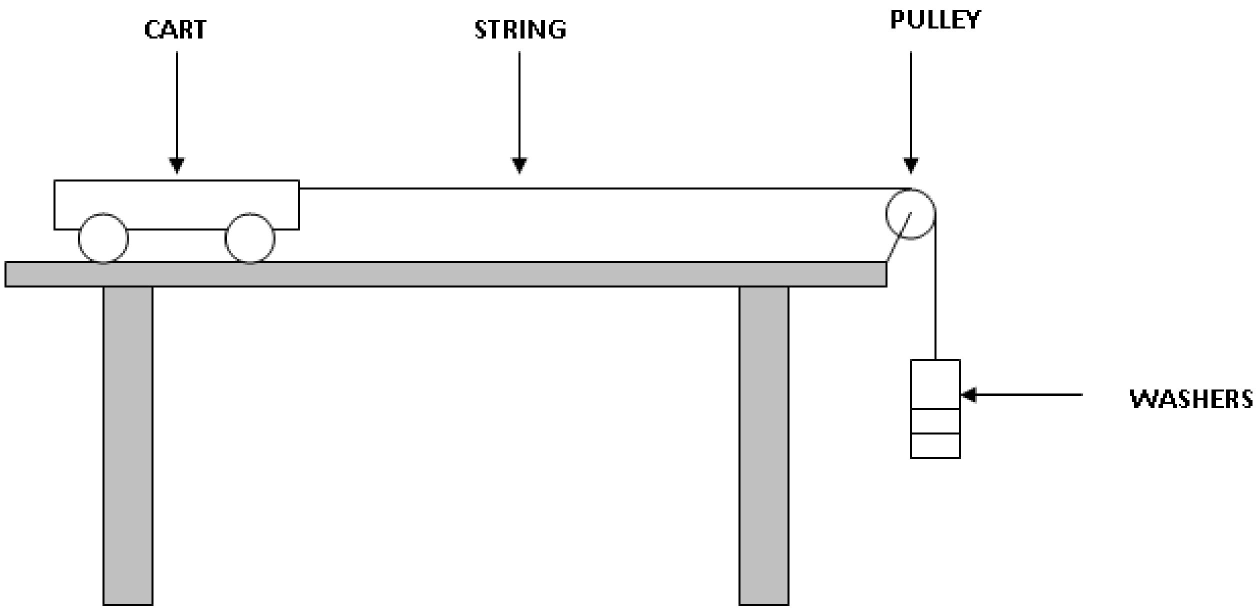


Analysis:

1. What happened to the unsecured doll when the cart hit the wall?
2. What happened to the doll secured with the rubber band when the cart hit the wall?
3. How could you change the result of the experiment?
4. Compare the experiment with the doll and cart with the experiment with the card and coin. Explain how the results of the two are similar.

Part C: Acceleration and Force: Newton's Second Law

Set up the experiment according to the following sketch.



Theory:

According with to Newton's Second Law, **F= ma**; **F** is the net force acting on the object of mass **m,** and **a** is the resulting acceleration of the object.

For a cart of mass m_1 on a horizontal track with a string attached over a pulley to a mass m_2 (see figure), the net force **F** on the entire system (cart and hanging mass) is the weight of hanging mass, $F_{net} = m_2g$, assuming the friction is negligible.

According to Newton's 2nd Law, this net force should be equal to **ma,** where **m** is the total mass that is being accelerated, which in this case is $m_1 + m_2$. This experiment will check to see if m_1g **is equal to** $(m_1 + m_2)a$ when friction is ignored.

Student

To obtain the acceleration, the cart will be started from rest and the time (**t**) it takes for it to travel a certain distance (**d**) will be measured. Then since d= (½)at^2, the acceleration can be calculated using the equation **$a = 2d / t^2$** (assuming the acceleration is constant)

Procedures

1. Level the track by setting the cart on the track to see which way it rolls. Adjust the leveling feet to raise or lower the ends until the cart placed at rest on the track will not move.
2. Use the balance to find the mass of the cart and record in the table
3. Attach the pulley to the end of the track as shown in Figure. Place the dynamics cart on the track and attach a string to the hole in the end of the cart and tie a mass hanger on the other and of the string. The string must be just long enough so the cart hits the stopping block before the mass hanger reaches the floor.
4. Pull the cart back until the mass hanger reaches the pulley. Record this position at the top of Table 1. This will be the release position for all the trials. Make a test run to determine how much mass is required on the mass hanger so that the cart takes about 2 second to complete the run. Because of reaction time, too short of a total time will cause too much error. However, if the cart moves too slowly, friction causes too much error. Record the hanging mass in the Table
5. Place the cart against the adjustable end stop on the pulley end of the track and record the final position of the cart in Table 1.
6. Measure the time at least 5 times and record these values in the Table1.
7. Increase the mass of the cart and repeat the procedure.

Initial release Position = ______________________________

Final Position = ______________________________

Total distance = ______________________________

Cart Mass	Hanging Mass	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average time

Table 1

Observation/Data Analysis:

1. Calculate the average times and record in Table 2
2. Calculate the total distance traveled by taking the difference between the initial and final positions of the cart as given in Table 2.
3. Calculate the accelerations and record in Table 2.
4. For each case, calculate the total mass multiplied by the acceleration and record in Table 2.
5. For each case, calculate the net force acting on the system and record in Table 2.
6. Calculate the percent difference between **F_{net}** and **$(m_1 + m_2)a$** and record in Table 2.

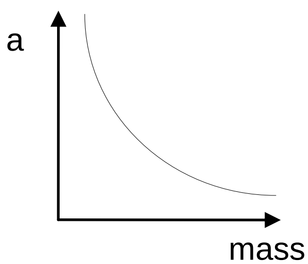
Student

Cart Mass	Acceleration	$(m_1 + m_2)$	$F_{net} = m_2g$	% Difference

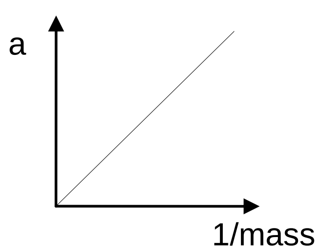
Table 2

Results:

Original Graph: **Acceleration vs. Mass**



Linearize Graph: **Acceleration vs. 1/Mass**



Linearize graph using the equation y = mx + b, where b=0

$a = F\frac{1}{mass}$ or $a = \frac{F}{mass}$ or $F = ma$

Conclusion:

1. Did the results of this experiment verify that **F = ma?**
2. Considering frictional forces, which force would you expect to be greater: the hanging weight or the resulting total mass times acceleration? Did the results of these experiments consistently show that one was larger than the other?
3. Why is the mass in **F = ma** not just equal to the mass of the cart?
4. When calculating the force on the cart using mass times gravity, why isn't the mass of the cart included?

Teacher

Bouncing Ball Gravity Lab

NGSSS:
SC.912.E.5.6 Develop logical connections through physical principles, including Kepler's and Newton's Laws about the relationships and the effects of Earth, Moon, and Sun on each other.
SC.912.P.12.4 Describe how the gravitational force between two objects depends on their masses and the distance between them.

Purpose of Lab/Activity: The students will calculate from the experiment the value of the acceleration of gravity.

Prerequisite: Prior to this activity, the student should be able to:
- Observe and record the interval of times of the moving object.
- Use kinematics equation to calculate acceleration.
- Apply the definition of velocity to a specific case.
- Apply the definition of distance to a specific case.

Materials (individual or per group):
- Ball.
- Stopwatch.
- Meter stick.

Procedures: Day of Activity:

<table>
<tr><td>Before activity:</td><td>What the teacher will do:
a. Explain to the students they will be working in a group of 2-3 students, but this is not a group activity. You will collect your group data, and make your own calculations. Each student will submit their own results and conclusions.
b. Assess previous knowledge through a class discussion using the prerequisite guide.
1. Review terminology (vocabulary).
2. Ask:
i) What is the initial velocity in the experiment if the student has to drop the ball?
ii) What equation can we use if we know the distance traveled, the interval of time, and the initial velocity?
$\Delta x = V_i t + \frac{1}{2} a t^2$, where V_i is the initial velocity, t is the interval of time, Δx is the height, and a is the acceleration of gravity that we can write $a = g$
iii) Ask the students to absolute the variable g, if we know that the initial velocity is equal to zero.
$$g = \frac{2\Delta x}{t^2}$$
c. Explain how the students will measure the height, using as a reference frame, marks on the wall made with different colors or electrical tapes to designate specific height.
d. Inform the students that they must write a Lab Report based on accepted</td></tr>
</table>

	models ("Parts of the Lab Report" or "Power Writing Model 2009", Found in web links cited in this document).
During Activity	**What the teacher will do:** a. Each team needs to assign one student to measure the s will be at the floor and other student to register the height the ball reach in each bounce. b. Each student needs to record the data in the data table. c. The teacher supervise that the student drop the ball (initial velocity equal zero) d. Be sure that a student remains at ground level to avoid hitting anybody passing by.
After activity:	**What the teacher will do:** a. Discuss the different average acceleration obtained, and compare them with the event performed. b. Request the students to list the possible errors they cannot avoid in performing the experiment. c. The teacher assess student understanding of the result of the experiment and their analysis of the data such as: Does the value of the gravity calculated in each trial have a large discrepancy? Could you consider that the events performed were at constant acceleration? Explain. d. Additional activity: The students will make graphs of distance vs. time using the data obtain from the lab (plot the time in the horizontal axis). The graph will be a curve of distance proportional to the time square.

Student

Bouncing Ball Gravity Lab

NGSSS:
SC.912.E.5.6 Develop logical connections through physical principles, including Kepler's and Newton's Laws about the relationships and the effects of Earth, Moon, and Sun on each other.
SC.912.P.12.4 Describe how the gravitational force between two objects depends on their masses and the distance between them.

Background:
During the early part of the seventeenth century, Galileo experimentally examined the concept of acceleration. One of his goals was to learn more about freely falling objects. Unfortunately, his timing devices were not precise enough to allow him to study free fall directly. Therefore, he decided to limit the acceleration by using fluids, inclined planes, and pendulums. In this lab you will find experimentally the value of the acceleration of gravity.

The acceleration to the gravity is the acceleration that an object experiences because of gravity when it falls freely close to the surface of a massive body, such as a planet. Also known as the **acceleration of free fall**, its value can be calculated from the Universal Law of Gravitational Forces, which describes the forces between masses and is represented as

$$F = G\,\frac{m_1 m_2}{r^2}$$

Where G is the gravitational constant (= 6.6742×10^{-11} N·m^2/kg^2), m_1 and m_2 represent the masses and r is the distance between the masses, we can rewrite this equation as:

$$F = \quad G\frac{M}{r^2} \quad m$$

or

$$F = g \; m$$

There is a direct relationship between gravitational acceleration and the downwards weight force experienced by objects on Earth (F = mg).
In which g is:

$$g = \frac{GM}{(R + h^2)}$$

where *M* is the mass of the gravitating body (such as the Earth), *R* is the radius of the body, *h* is the height above the surface, and *G* is the gravitational constant. If the falling object is at, or very nearly at, the surface of the gravitating body, then the above equation reduces to:

$$g = \frac{GM}{R^2}$$

Student

Earth's gravity, denoted **g**, refers to the acceleration that the Earth imparts to objects on or near its surface. In SI units this acceleration is measured in m/s^2 (meter per second per second, equivalently written as $m \cdot s^{-2}$). It has an approximate value of 9.81 m/s^2, which means that, ignoring air resistance, the speed of an object falling freely near the Earth's surface increases by about 9.81 meter per second every second. This quantity is informally known as little g (contrasted with G, the gravitational constant, known as big G).

The precise strength of the Earth's gravity varies depending on location. The nominal "average" value at the Earth's surface, known as **standard gravity** is, by definition, 9.80665 m/s^2. This quantity is denoted variously as g_n, g_e (though this sometimes means the normal equatorial value on Earth, 9.78033 m/s^2), g_0, gee, or simply g (which is also used for the variable local value).

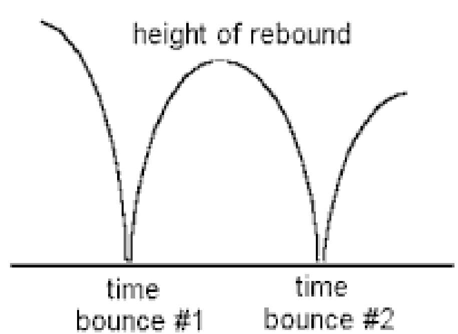
Purpose or Problem Statement:
Through experimentation confirm that the value of the acceleration of gravity is 9.81 m/s^2

Safety: Be sure that a student remains at ground level to avoid hitting anybody, maybe passing by.

Vocabulary: gravity, free fall, acceleration, force, mass, distance, time,

Materials (individual or per group):
- Ball.
- Stopwatch.
- Meter stick.

Procedures:
Two students form a team. The first student will use a stop watch to time the number of seconds between bounces and the second student will be the observer of how high the ball bounces. When the designated student drops the ball, the student with the stop watch listens for the sound of the first bounce, starts the stop watch, and then listens for the sound of the second bounce, when he stops timing. The second student observes how high the ball bounces against the backdrop of the marked wall, using, as a reference, the marks on the wall with different colors or electrical tapes to designate specific height. The height and times are recorded in the data chat, as your observations. The experiment needs to be repeated for a total of five trials.



Student

Observations/Data:
Calculate the acceleration due to gravity by using the kinematics equation:

$$\Delta x = v_i t + \frac{1}{2} a t^2$$

and any given information that isolate the second half of the golf ball's bounce:
- $V_i = 0$
- s = height of bounce
- t = ½ (the total time on your stopwatch)
- $g = \frac{2\Delta x}{t^2}$

Place the results of these calculations in the last column.

Trial	Time between bounces (s)	Height (m)	Experimental 'g' (m/s^2)
1			
2			
3			
4			
5			

Observation/Data Analysis:
1. Calculate the average experimental value for "g" base in all 5 trials.

   Avg. gravity = _____________

2. Why should your average experimental value actually only be express with a maximum of 2 significant digits?
3. Using your average experimental value for "g" calculate a percent of error against the accepted value, 9.8 m/s^2.

Results:
1. Compare the result obtained by your team with the result of other teams.
2. Which aspect of the data collection had the last precision: the timing or the ball's height measurement? Support your choice.

Conclusion:
1. How close to the actual value was your experimental result?
2. Was there a large difference? Explain the probable cause of the error.
3. Students should write a report, *"Parts of a Lab Report" or "Power Writing Model 2009"*, or answer a set of questions designed to engage higher ordered thinking through concept understanding and application)

Kinetic and Potential Energy and their Work

NGSSS:
SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
SC.912.P.10.3 Compare and contrast work and power qualitatively and quantitatively.
SC.912.P.10.6 Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.

Purpose of Lab/Activity: The student will calculate the Kinetic Energy ($\mathbf{E_K}$) and the Gravitational Potential Energy ($\mathbf{E_g}$) of a system and find a relationship to Work (**W**).

Prerequisite: Prior to this activity, the student should be able to:
- Differentiate the Potential Energy from the Kinetic Energy
- Calculate the Gravitational Potential energy using the equation: PE=mgh
- Calculate the Kinetic Energy of the object using the equation: $KE=½mv^2$
- Calculate the work using the equation: W=Fd

Materials (individual or per group):
- Different masses (objects)
- Balance
- Metric ruler
- Spring scale
- Ramp

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess previous knowledge through a class discussion using the prerequisite guide. Ask the following questions: 1. What form or forms of energy does the "mass" have while momentarily at rest at the top of the ramp? Gravitational Potential Energy 2. How could you calculate work? **Work = F d**, where F is the force applied, and d is the length of the ramp. 3. What is the distance you will use to calculate the work? Length of the ramp 4. What is the mathematical equation to calculate Potential Energy gained by an object as it climbs an incline? Direct the question to **Potential Energy = mgh**, where **m** is the mass of the cart, g is the acceleration due to gravity, and h is the vertical height the cart is raised. 5. What form or forms of energy does the object have while it is moving with constant velocity to the top of the ramp? Gravitational Potential Energy, due the height reached, and Kinetic Energy due the motion of the object. b. Inform the students that they must write a Lab Report based on accepted models ("Parts of the Lab Report" or "Power Writing Model 2009", Found in web links cited in this document).

Teacher

During activity:	**What the teacher will do:** a. Explain to the students they will measure the work needed to move an object up the ramp at constant speed. As the teacher demonstrates by moving a cart, elicit student participation and understanding by asking the following questions: 1. Why does the object move with constant speed? To guarantee that the Force Applied is constant and the resultant force acting on the object is zero, then you can measure the magnitude of the force applied that is equal to the friction force between the object and the ramp.(Remember that **W = Fd** only when the applied force is constant.) 2. What is the value of the resultant (net) force, when the object is moving with constant speed? The resultant or net force is zero, because the friction force is opposite and with the same size or intensity to the force applied on the object. 3. What is the value of the resultant force while you are moving the object up the ramp, at a constant velocity? (Move cart up the ramp as you ask this question). The resultant force is zero. 4. Are you doing work on the object? Yes, you are applying a force in the direction of motion for a certain distance. 5. Does the object have energy? What kind of energy? Explain. Yes, by moving the object, Kinetic Energy. By moving the cart to certain height, with respect to its original position, Gravitational Potential Energy. 6. Is the object gaining energy? Yes, Gravitational Potential Energy 7. What is the value of the force you are applying? What is the value of the friction force? They are the same, because the object is moving with constant velocity. 8. How can you calculate Gravitational Potential Energy? Potential Energy = mgh
After activity:	**What the teacher will do:** a. Ask questions to engage student thinking after activity, such as: 1. Lift a book straight up from the floor to the table. Did you do work? Yes, work was done to lift the book. Both the force applied and the displacement is upward. 2. Could you lift the book with constant force? Since the book moves with constant velocity, the force the student applied is equal in magnitude to the book's weight. 3. Holding one end still, stretch a rubber band. Did you do work on the rubber band? To answer this question, consider whether you applied a force parallel to the displacement of the moving end of the rubber band. Yes, it takes work to stretch the rubber band. The force applied and the displacement of the end of the rubber band are both in the same direction. 4. Is the force you apply constant when you stretch the rubber band? If not at what point in the stretch is the force the least? At what point is the force the greatest. The force needed to stretch a rubber band is small at first, and then increases as the band stretches.

Student

Kinetic and Potential Energy and their Work

NGSSS:
SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
SC.912.P.10.3 Compare and contrast work and power qualitatively and quantitatively.
SC.912.P.10.6 Create and interpret potential energy diagrams, for example: chemical reactions, orbits around a central body, motion of a pendulum.

Background: Work is a measure of energy transfer. In the absence of friction, when positive work is done on an object, there will be an increase in its kinetic or potential energy. In order to do work on an object, it is necessary to apply a force along or against the direction of the object's motion. If the force is constant and parallel to the object's path, work can be calculated using the formula:

$$W = F \cdot X$$

where **F** is the constant force and **x** is the displacement of the object.

Another relation used to compare how the energy of a system is converted to other forms through application of forces is explained in the work-energy theorem:

$$W = \Delta E_K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

where **W** is the work done on an object, thus transferring energy and changing the state of the object, and $\mathbf{\Delta E_K}$ is the change in kinetic energy, which means that the object (of mass **m**) has changed position through a change in velocity (**v**). In this experiment, you will investigate the relationship between work, potential energy, and kinetic energy.

Purpose or Problem Statement: In this Lab you will investigate the relationship between work, potential energy, and kinetic energy.
Safety: (begin here)

Vocabulary: Force, Distance, Work, Energy, Kinetic Energy, Potential Energy, Gravitational Potential Energy, Velocity, Mass

Materials (individual or per group):
- Different masses
- Balance
- Metric ruler
- Spring scale
- Ramp

Procedures:
1. Place the ramp on top of some books (like in figure 1).

Student

2. Measure the length and height of the ramp; be accurate to the nearest tenth of a centimeter.
3. Measure masses in kg and enter this in the data table.
4. Hook the spring scale to one of the masses and pull the mass (at a constant velocity) up to the top of the ramp placed at specified height.
5. Repeat for two other masses and record the constant force used to pull each mass.
6. Calculate the work done by pulling each mass to the specified height using the inclined plane.
7. Calculate the potential energy of each mass at the specific height used in the previous procedures.
8. Repeat 2 - 5 for two other heights.

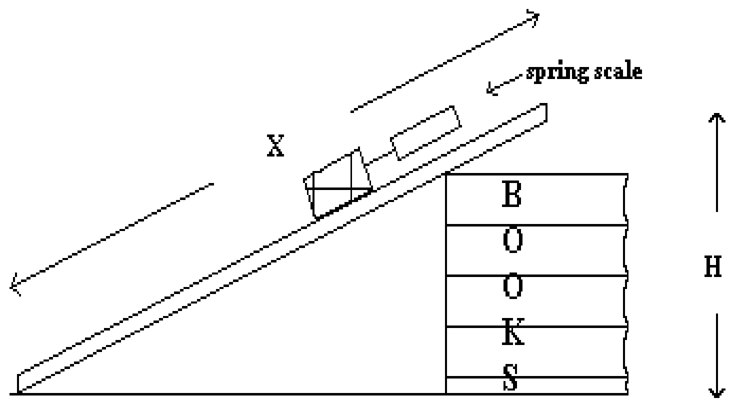


Figure 1

Observation/Data:

Ramp I

Height = m	Mass 1 = kg	Mass 2 = kg	Mass 3 = kg
Force (N)			
Work (J)			
Potential Energy (J)			

Ramp II

Height = m	Mass 1 = kg	Mass 2 = kg	Mass 3 = kg
Force (N)			
Work (J)			
Potential Energy (J)			

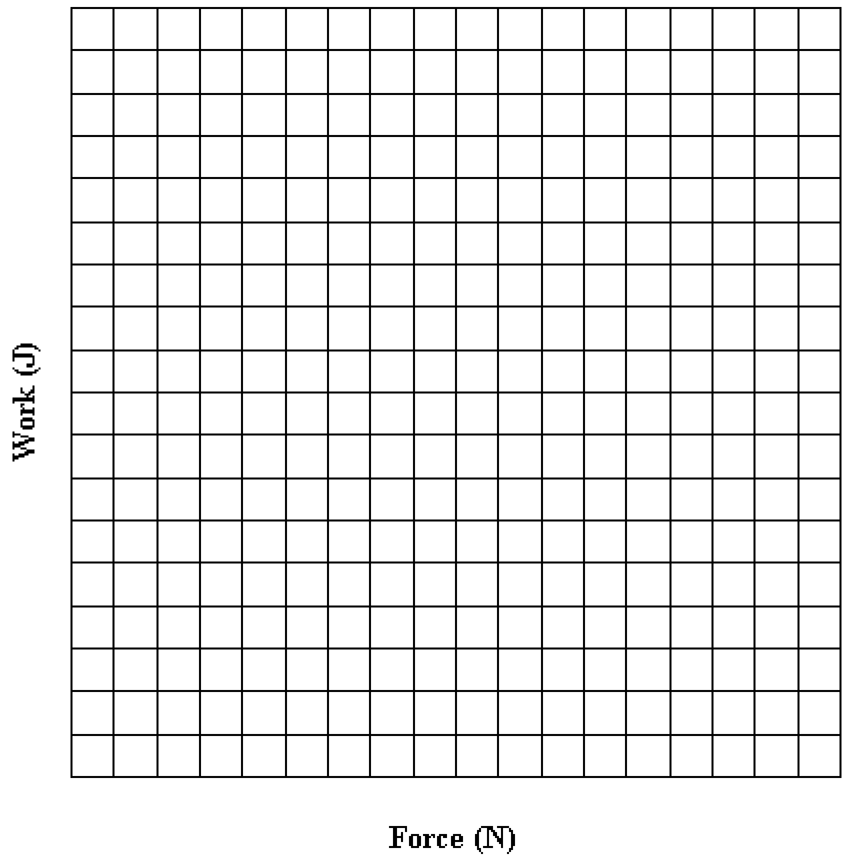
Ramp III

Height = m	Mass 1 = kg	Mass 2 = kg	Mass 3 = kg
Force (N)			
Work (J)			
Potential Energy (J)			

Student

Observation/Data Analysis:

1. Show all the calculations required for the information on the table.
2. Graph Work versus Force for each setup. Is there a relation between these two variables?



Results:

1. Does mass affect the force applied? Explain.
2. Is Potential Energy related to Force? Work? Explain.
3. Taking into account conservation of energy, but ignoring friction, what would be the Kinetic Energy of the mass at the halfway point if it slid down from the top of the ramp? (Calculate the value of EK at this point for each setup.)
4. Make connections between the type of energy studied in this activity and the energy that shape the Earth such as the wind energy that causes weathering, the ocean energy and rain energy that cause erosion, and the energy in biological processes.

Conclusion:

Students should write a report, *"Parts of a Lab Report" or "Power Writing Model 2009"*, or answer a set of questions designed to engage higher ordered thinking through concept understanding and application.

Teacher

Mechanical Advantage of an Inclined Plane

NGSSS:
SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
SC.912.P.10.3 Compare and contrast work and power qualitatively and quantitatively.

Purpose of Lab/Activity: The purpose of this activity is to calculate the mechanical advantage of an inclined plane and find its relationship to Work.

Prerequisite: Prior to this activity, the student should:
- Understand the relationship between weight and mass.
- Know how to calculate both mechanical advantage and ideal mechanical advantage.
- Know how to calculate the percent of efficiency of a machine.

Materials (individual or per group):
- Ramp (long enough to drag the chosen masses)
- (3) blocks with different masses
- Spring scale
- Balance
- Meter stick
- Books (to incline the ramp)

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Review pertinent vocabulary as given in student section. b. Ask an essential question: Why do you think that the ramp which extends from a moving van is usually more than two-thirds of the length of the van? The longer the ramp is, the lower the angle, and the “easier” it is to walk up the ramp and move something into the van. c. Write the Problem Statement on the board: Does an inclined plane really reduce the amount of Work you must perform in order to raise an object to a certain height? d. Tell the students: Formulate a hypothesis in response to the given problem statement. (Ex: I believe an inclined plane does reduce the amount of work needed to lift an object because it allows you to move the object to the desired height without actually lifting it.) At this time, the teacher may choose to check and initial each hypothesis. e. Model lab steps as a dry run without using any reactants. f. Review sample calculations associated with the lab, listed in the student background section, on the board for the students.
During activity:	**What the teacher will do:** a. As students begin to work on the lab, ask the following questions: 1. Is it important to maintain the same ramp height (angle) throughout the trials for both masses? Explain why. 2. Why is it important to try to drag the masses up the ramp using as constant a speed as possible?

	3. What is the manipulated (independent) variable in this lab? 4. What is the responding (dependent) variable in this lab?
After activity:	**What the teacher will do:** a. Review student understanding by asking: 1. Was there a difference between the weight you calculated and the measured weight using the spring scale? If there was, what types of errors may be responsible for this discrepancy? 2. Would the mechanical advantage of the ramp be affected if the ramp was covered with sandpaper instead of being smooth? 3. Would the sandpaper surface affect efficiency? Explain b. Tell the student that they must write a lab report based on accepted models ("Parts of a Lab Report" or "Power Writing Model 2009") cited in this document.

Student

Mechanical Advantage of an Inclined Plane

NGSSS:
SC.912.P.10.1 Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity.
SC.912.P.10.3 Compare and contrast work and power qualitatively and quantitatively.

Background: Machines are tools designed to reduce the amount of force needed to perform a given activity. For example, an elevator is designed to lift you up, say 10 floors, with a simple push of a button. This is definitely easier and requires less force than walking 10 floors up a set of stairs. If we consider the energy requirements for performing such tasks, we would have to measure how many calories we would lose during the exercise and compare it to the energy required in operating the elevator. A comparison can be made with a simple relation:

$$\text{work}_{\text{in}} = \text{work}_{\text{out}}$$

$$F_{\text{in}} \cdot d_{\text{in}} = F_{\text{out}} \cdot d_{\text{out}}$$

An ideal machine converts all the energy put in and uses it in its output force. In other words, an ideal machine is 100% efficient. Unfortunately, in the real world machines are not so efficient, and mechanical advantages and efficiencies must be calculated in order to make sure the machines produced are cost-effective. Therefore, to help you understand some of these concepts, in this experiment, you will use a spring scale to measure the force needed to lift an object to a determined height and to pull the same object up an inclined plane to the same height. Then you will be able to calculate and compare the energies (work done) in both cases. An inclined plane is a slanted surface used to raise objects. The sloping floor of a theater, a road over a mountain, and a ramp into a building are examples of inclined planes. An inclined plane is an example of a simple machine.

$$\text{Mechanical Advantage} \quad \text{MA} = \frac{\text{output force } (F_{\text{out}})}{\text{input force } (F_{\text{in}})}$$

$$\text{Efficiency } (\%) = \frac{W_{\text{out}}}{W_{\text{in}}}$$

<u>For an inclined plane:</u>

$$\text{Ideal Mechanical Advantage} = \frac{\text{length of ramp}}{\text{height of ramp}} \text{ x } 100$$

Problem Statement: Does an inclined plane really reduce the amount of Work you must perform in order to raise an object to a certain height?

Student

Safety: There are no specific safety concerns for this activity.

Vocabulary: Actual mechanical advantage, Ideal mechanical advantage, Efficiency, Output force, Input force

Materials (individual or per group):

- Ramp (long enough to drag a mass)
- (2) blocks with different masses
- Spring scale
- Balance
- Meter stick
- Books (to incline the ramp)

Procedures:

3. Place the ramp on top of some books (like in figure 1).
4. Measure the length and height of the ramp; be accurate to the nearest tenth of a centimeter.
5. Measure the mass of each object with the balance. Calculate the weight of each object.
6. Measure the weight of each object with the spring scale.
7. Attach the spring scale to one of the masses and drag it up the ramp at a constant speed. Record the force reading on the scale as Input Force. Repeat for the second mass. Try to be accurate to the nearest tenth of a Newton (depending on the accuracy of the spring scale).
8. Record all data in steps 1-5 in Table 1.
9. Calculate the Work done in lifting each block to the height of the ramp without using the ramp.
10. Calculate the Work done in lifting each block to the height of the ramp, using the inclined plane.
11. Calculate the Ideal Mechanical Advantage (IMA) and the Actual Mechanical Advantage (AMA) for each object.
12. Record all your results from steps 7-9 in Table 2.

Observations/Data:

	Mass (kg)	Calculated Weight (N)	Measured Weight (N)	Input Force (N)
Object 1				
Object 2				

Table 1

	Length of Ramp (m)	Height of Ramp (m)	Work w/out Ramp (J)	Work with Ramp (J)	AMA	IMA
Object 1						
Object 2						

Table 2

Student

Observation/Data Analysis:
Show the required calculations for objects 1 and 2 using the formulas given above on a separate sheet.

Results/Conclusion:
The following questions should be addressed in the conclusion of your lab report.

1. Multiple trials with each mass would increase the accuracy of the data obtained. Would this new level of accuracy significantly affect your final conclusion?
2. Explain why.
3. What general statement can be made about the relationship between friction and the efficiency of a machine?
4. Did your results support your hypothesis? Explain why they did or did not.

Teacher

Static Electricity

NGSSS:
SC.912.P.10.13 Relate the configuration of static charges to the electric field, electric force, electric potential, and electric potential energy.
SC.912.P.10.14 Differentiate among conductors, semiconductors, and insulators.

Purpose of Lab/Activity: Learn how to explain the interactions of charged and uncharged objects.

Prerequisite: Prior to this activity, the student should:

- Describe how electric charges exert forces on each other.
- Distinguish between conductors and insulators.
- Explain how objects become electrically charged.

Materials (individual or per group):

- Rubbing materials
- Foam board
- Aluminum foil
- Paper pencil
- Plastic rods
- Swivel
- Metal rod

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess previous knowledge through a class discussion using the prerequisite guide. 1. Define static electricity 2. Review the concept of the Coulomb's Law. 3. The electrostatic force is directly proportional to the charges and inversely proportional to the square of the distance between them. b. Inform the students that they must write a Lab Report based on accepted models ("Parts of the Lab Report" or "Power Writing Model 2009", found in web links cited in this document).
During activity:	**What the teacher will do:** a. As students perform the lab activity assess conceptual understanding by asking the following questions: 1. Why would electrons move from one object to another? 2. When the teacher rubs the plastic rod, does it create electric charges? 3. Does a neutral object repel electric charges?
After activity:	**What the teacher will do:** a. Review and assess student understanding by asking additional questions, such as 1. Was the charge conserved in this experiment? 2. How many types of electric charge exist? 3. What does it mean to say that charge is conserved? 4. Is humidity in the room a concern in this experiment? Why or why not? 5. As time passes, the plastic rod loses the excess charge. Where does it go?

Teacher

Extension:

- Gizmo: Coulomb Force (Static)

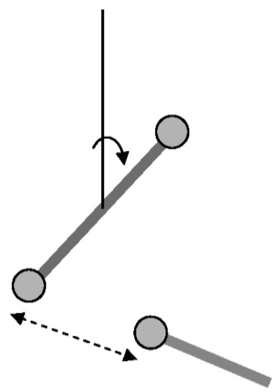
Student

Static Electricity

NGSSS:
SC.912.P.10.13 Relate the configuration of static charges to the electric field, electric force, electric potential, and electric potential energy.
SC.912.P.10.14 Differentiate among conductors, semiconductors, and insulators.

Background: Charles Coulomb used the apparatus shown below to measure the force that one charged metal ball exerts on another charged ball. The magnitude of the force can be inferred from the angle at which the string twists when a charged object approaches another charged object.

Coulomb's goal was to find how the force between two electrically charged objects depends on the magnitudes of the charges and on their separation. At Coulomb's times people could not measure the absolute magnitude of the electric charge on the metal balls but they knew from observations that if you touch a charged metal ball with an identical uncharged metal ball, both will have the same charge equal to half of the original. Thus Coulomb could divide the charge on metal balls in half and he could also measure the magnitude of the force that the balls exerted on each other.



Purpose or Problem Statement: The purpose of the experiment is to learn how to explain the interactions of charged and uncharged objects, and to find how the intensity of electric interactions depends on the distance between electrically charged objects.

Safety: No specific safety concerns for this Lab.

Vocabulary: Static electricity, Law of Conservation of Charge, Conductor, Insulator, Charging by contact.

Materials (individual or per group):
- Rubbing materials,
- Foam board,
- Aluminum foil
- Paper pencil
- Plastic rods
- Swivel
- Metal rod

Student

Procedures:

I. Observation experiment (qualitative): How does electric force depend on the distance?

You have two rods: one rod is on a swivel and the other one is a free rod. Vigorously rub one end of each rod with felt. Then slowly bring the rubbed end of the free rod closer and closer to the rubbed end of the rod on the swivel.

Observations/Data:

Describe your observations.
What can you infer from these experiments about how the electric force between charged objects depends on the distance between them?

II. Observation experiment: Interactions of a charged object with an uncharged object.

Part 1:

Rub one end of a plastic rod (rod 2) with felt or fur and bring it close to the rod (rod 1) on a swivel that has not been rubbed. Repeat, but this time rub another rod with a different material (rod 3) and bring it near the end of unrubbed rod 1 which is placed on the swivel.
a) Record in words and by drawing a picture what you observed.
b) Devise an explanation involving a possible internal structure of the material of the rods that might explain why the rubbed rod attracts the unrubbed rod.

Part 2:

Rub one end of a plastic rod 2 with felt or fur and bring it close to the end of a metal rod 1 on a swivel (metal rod has not been rubbed). Repeat, but this time rub another rod with a different material and bring it near the end of the metal rod 1 on the swivel.
a) Record what you observed in words and by drawing a picture.
b) Devise an explanation involving a possible internal structure of the metal rod that might explain why the rubbed rods attract it.

Part 3:

Tear off small pieces of paper, place them on a foam board and bring a plastic rod rubbed with felt or fur close to the pieces. Record your observations.
a) Repeat the experiment but this time use small pieces of aluminum foil instead of paper. Record your observations.
b) Compare and contrast the outcomes of a) and b). Explain the outcomes and the differences in the outcomes if there were any.

Observation/Data Analysis:

a) Draw a picture of the apparatus
b) Describe your observations in words

Conclusion:

Students should write a report, *“Parts of a Lab Report” or “Power Writing Model 2009”*, or answer a set of questions designed to engage higher ordered thinking through concept understanding and application.

Teacher

Phase Changes

NGSSS:
SC.912.P.8.1 Differentiate among the four states of matter
SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.
SC.912.P.10.4 Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter.
SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.
SC.912.P12.11 Describe phase transitions in terms of kinetic molecular theory.

Purpose of Lab/Activity: The purpose of this lab is to understand the energy changes in water when temperature is increased through a period of time and to find the thermal energy needed to boil and evaporate the water.

Prerequisites: Prior to this activity, the student should be able to
- Use and read a Celsius thermometer
- Identify the various phase changes and the types energy transfers associated with each in terms of particle motion.
- Graph data within a coordinate plane
- Safely operate a hotplate

***Materials (individual or per group):**
- Hot plate
- 250 mL beaker
- Water
- Thermometer
- balance
- Graph Paper
- Ruler
- Stirring Rod
- Ring Stand
- Thermometer Clamp
- Timer
- Heat Proof Gloves
- Safety Goggles

*Note: This lab can also be performed using a CBL unit with a temperature probe and a TI Graphing Calculator if these are available.

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Review pertinent vocabulary as given in student section. b. Write on the board: Problem Statement: Can you add thermal energy to a substance, in this case water, without increasing its temperature? c. Tell the students: Formulate a hypothesis in response to the given problem statement. (Ex: If the substance is changing phase then the energy is being used for that process, because of this during the phase change there will not be any excess energy to cause a change in temperature.) d. At this point the teacher may choose to check and initial each hypothesis before beginning the lab. e. If working in groups remind students that each student should be active and performing a specific role. f. g. Warn students to minimize their movement around the lab do to hot surfaces and boiling liquids present.

Teacher

<table>
<tr><td>During activity:</td><td>What the teacher will do:
a. Tell students, while performing this lab to note any gain or loss of energy during and before each change in phase.
b. As students perform the lab, ask the following questions:
1. As energy is added to the water what do you think is happening to the water molecules in terms of movement?”
2. What do you think is the purpose of stirring the water before every reading?
3. Why does the thermometer have to be suspended so as to avoid the bottom and sides of the beaker?</td></tr>
<tr><td>After activity:</td><td>What the teacher will do:
a. Assess student understanding by asking additional questions or asking students to explain additional applications, for example:
1. Though it was not directly studied in the lab, during the process of ice melting into the liquid state infer and trace the changes in terms of potential and kinetic energy of the water molecules, and the subsequent temperature changes which occur.
b. Verify that the students turned off their hot plates.
c. Tell students that a lab report must be submitted in a standard format. (“Parts of a Lab Report” or “Power Writing Model 2009” cited in this document.)
d. Instruct students to answer the questions under the results and conclusion section of the lab report, using complete answers with supportive observations and data.
e. After collecting the lab reports have a class discussion of the answers to the assigned questions and the reasoning behind them.</td></tr>
</table>

Student

Phase Changes

NGSSS:
SC.912.P.8.1 Differentiate among the four states of matter
SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes of matter.
SC.912.P.10.4 Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter.
SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.
SC.912.P12.11 Describe phase transitions in terms of kinetic molecular theory.

Background: A substance usually undergoes a change in temperature when its energy is transferred with its environment. In some cases, however, the transfer of energy doesn't result in a change in temperature. This can occur when the physical characteristics of the substance change from one form to another, commonly referred to as a **phase change**. Some common phase changes are solid to liquid (melting), liquid to gas (boiling), and a change in the crystalline structure of a solid. Any such phase change involves a change in the internal energy but **no change in the temperature**.

Purpose: The purpose of this lab is to understand the energy changes in water when temperature is increased through a period of time and to find the thermal energy needed to boil and evaporate the water.

Safety:
- Students should minimize movement around the lab and be careful working around the hot plate.
- The beaker of water should not be moved while boiling it should be allowed to cool down before being moved.
- When the hot beaker has to be moved heat proof gloves should be used.
- Goggles should be worn at all times.

Vocabulary: Phase changes, Heat transfer, Boiling, Vaporization, Condensation, Melting, Freezing, Sublimation, Heat curve, Kinetic energy, Potential energy.

Materials (individual or per group):
- Hot plate
- 250 mL beaker
- Water
- Thermometer
- Graph Paper
- balance
- Ruler
- Stirring Rod
- Ring Stand
- Thermometer
- Clamp
- Timer
- Heat Proof Gloves
- Safety Goggles

Procedures:
1. Pour about 150mL of the water into a 250-mL beaker.
2. Place the thermometer in a clamp attached to a ring stand so its height can be adjusted at will.

Student

3. Turn your hot plate to high setting (or as recommended by your teacher).
4. Allow a few minutes for the plate to heat up.
5. Place the beaker on the hot plate and lower the thermometer so that it extends approximately 2/3 of the way into the water. Suspend the thermometer so that it does not touch the sides or the bottom of the beaker.
6. Immediately measure the initial temperature of the water in the beaker and record it in the table at 0 seconds. Leave the thermometer suspended in the water.
7. Record the temperature every 30s. Remember to carefully stir the water before taking each temperature reading.
8. When the water starts boiling, continue recording the temperature for an additional three minutes.
9. Carefully remove the beaker from the hot plate. Turn the hot plate off.

Observations/Data:
Sample data table copy to lab report and expand as needed to accommodate data.

Time (sec)	Temp (^{0}C)

Observation/Data Analysis:

1. Using the data you obtained, make a graph of temperature (Y-axis) vs. time (X-axis).
2. Label your graph using the following terms: liquid water, water vapor, boiling or vaporization, increase in kinetic energy and increase in potential energy, temperature increase and no temperature change, wherever applicable.
3. Using your data, find the thermal energy given to the water to change it to steam during the experiment. Solve and show your work.
   i). Use $q = m\,C\,\Delta T$; where C is the specific heat of water, m is mass, and ΔT is the change in temp.
   ii). Specific heat of water is 1 calorie/gram °C = 4.186 joule/gram °C

Results:
Summarize the lab results using the following chart. The first phase change melting of ice, which was not included in the actual lab, was given to you as an example.

Description of Phase Change	Term for Phase Change	Heat Movement (absorbed or released)	Temperature Change?
Solid to liquid	Melting	Heat absorbed	None

Student

Conclusion:

1. What is occurring to the potential and the kinetic energy of the water during the horizontal or flat portion of your graph? Explain.
2. What is occurring to the potential and the kinetic energy of the water during the diagonal or sloped portion of your graph? Explain.
3. What are the melting and boiling points for water as determined by your lab results?
4. Compare your results to the actual values for the melting and boiling points of water. If there are discrepancies what do you attribute them to?
5. The phase change from liquid water to ice requires what in terms of energy transfer? Would such a change be exothermic or endothermic in nature?
6. What is generally required to bring about a phase change in a substance?

Teacher

Boyle's Law

NGSSS:
SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.
SC.912.P.12.10 Interpret the behavior of ideal gases in terms of kinetic molecular theory.
SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Purpose of Lab/Activity: To examine the idea of pressure and its relationship to volume.

Prerequisite: Prior to this activity, the student should be able to:
- State Boyle's law in their own words.
- Use the kinetic molecular theory to describe how particle behavior is related to Boyle's law.
- Describe the change of pressure with respect to elevation.
- Give all the units for pressure and explain their origins.
- Explain pressure in terms of force and area.
- Derive the standard units for force, area and volume.
- Compare the use of a barometer to a manometer.

Materials (individual or per group):
- safety goggles
- Boyle's law apparatus
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Review the basic principles of the kinetic molecular theory. b. Derive the standard units for pressure, force, and area. c. Explain the use of a barometer and the principle underlying the measurement of pressure. d. Relate pressure to elevation and its subsequent implications. e. Review the use of graphs in evaluating variables as a basic tool of the scientific method. f. Review the use of a piston as a measurement of PV work g. Discuss the chemical composition of air.
During activity:	**What the teacher will do:** a. Supervise the safe use of the piston b. Provide directions for reading the syringes accurately. c. Confirm the dependent variable is assigned as the volume. d. Ask the students, "why is the pressure considered the independent variable for this experiment?"
After activity:	**What the teacher will do:** a. Have the students construct the mathematical relationship between pressure and volume. b. Have students discuss the behavior of the particles using the kinetic molecular theory.

Teacher

	c. Discuss the shape of the graphs and compare to initial predictions. d. Have students calculate the PV constant for the piston using the appropriate units. e. Have students establish Boyle's law in their own words based on their experimental observations.

Extension:

- Interactive Boyle's Law Apparatus
- Gizmo: Boyle's Law and Charles' Law

Student

Boyle's Law

NGSSS:
SC.912.P.10.5 Relate temperature to the average molecular kinetic energy.
SC.912.P.12.10 Interpret the behavior of ideal gases in terms of kinetic molecular theory.
SC.912.P.12.11 Describe phase transitions in terms of kinetic molecular theory.

Background Information:
In this investigation, you will observe the behavior of a gas, using a device called a Boyle's law apparatus. The apparatus consists of a graduated syringe with a movable piston. Initially, the syringe is adjusted to trap a volume of gas at the same pressure as its surroundings. The piston then does not move because the pressure exerted by the gas in the syringe equals the pressure of the atmosphere pushing on the piston. If the piston is pushed downward, it compresses the gas trapped in the syringe. If the pressure on the piston is then decreased, the pressure of the trapped gas will push the piston up.

In order to read the volume of trapped gas correctly, you must always read the measurement on the side of the piston that is in contact with the gas. Because air is a mixture of gases-mostly nitrogen and oxygen-that behaves physically as a single gas, the data from this lab can be treated as data for a single gas. As the pressure of the air changes, you will monitor and collect data on the resulting changes in volume. You can then use your data to find the atmospheric pressure and determine how closely your results agree with Boyle's law

Purpose of Lab/Activity: Determine the relationship between pressure and volume.

Safety Precautions:
- Wear appropriate safety goggles.
- Don't let the students aim the pressurized syringe at anyone as the syringe tip cap could shoot off.
- Note: *The increasing load of books on the piston may become unsteady. Falling books can injure the person measuring the gas volumes and damage the Boyle's law apparatus. Steady the books by resting them slightly against the ring or by nudging them into balance as you would with wooden building blocks*.

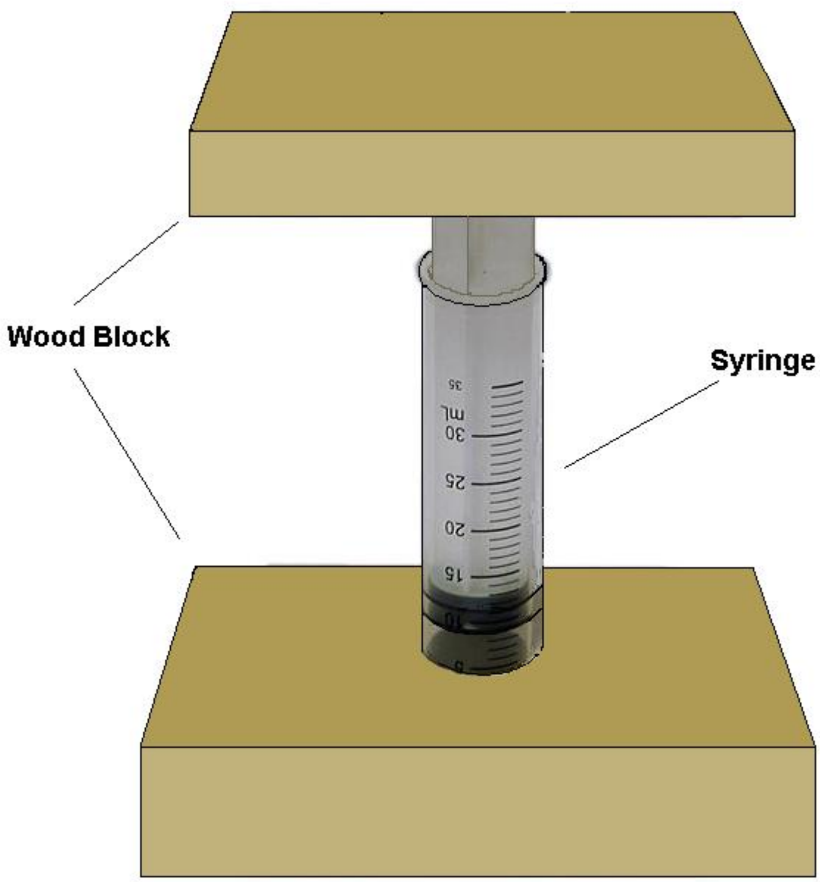
Vocabulary: Force, area, pressure, barometer, manometer, gases, altitude, elevation, density, torr, psi (pounds per square inch- Ibs/in^2), N/m^2, mmHg, atm, volume

Materials (individual or per group):
- safety goggles.
- Boyle's law apparatus.
- ring stand clamp
- 5 chemistry textbooks
- 2 pens or pencils of different colors.

Student

Procedures:

1. Work with a partner so that one person operates the apparatus (see figure below) while the other steadies the books and keeps track of the procedural steps.
2. Put on your safety goggles. Secure the Boyle's law apparatus with a ring stand and clamp. Adjust the initial volume (about 30 ml) to atmospheric pressure as directed by your teacher.
3. Test the apparatus by pushing down on the piston with your hand slowly and steadily until the volume of the trapped gas is reduced to 15 ml. Release the piston and note whether it returns to initial volume. If not, check and adjust the seal at the syringe opening.(Note: if red tip seals are too loose try replacing it with a small rubber stop with a small indentation).
4. Place the apparatus on a flat, steady surface, such as a sturdy table or the floor. Record the initial volume at 0 books of pressure in the data table.
5. Place one book on the piston and record the resulting volume of trapped gas in the data table. Add a second book and record the gas volume. Continue adding books and recording the resulting volumes until all 5 books are resting on the piston. Remember to steady the books, especially when the apparatus is being read.
6. Remove all the books from the piston and reset the apparatus to the initial volume recorded in Step 2.
7. Repeat Step 5 and 6 two more times, remembering to reset the apparatus between sets of trials.
8. Clean up your work area.



Student

Observations/Data:

Data Table 1- Volume and Pressure Relationship

Pressure (#books)	V_1 (ml)	V_2 (ml)	V_3 (ml)	V_{avg} (ml)	$1/V_{avg}$ (ml^{-1})	P_{atm}	P_{total}	(P_{total}) x (V_{avg})

Data Analysis and Results:

1. Find the average of each set of three volumes and record these averages in the data table.
2. For Graph #1 plot the pressure (in books) on the horizontal axis, and the average volume, V_{avg} on the vertical axis. Draw a smooth line through the points. Make sure the graphs are titled, axes clearly labeled with units, and scales properly sequenced.
3. According to Boyle's law, pressure and volume have an inversely proportional relationship. If this idea is correct, you should obtain a linear relationship (straight line) when you plot pressure versus the corresponding inverse of the average volume. Calculate the inverse, $1/V_{avg}$, of each volume and record these values in the appropriate column of the data table.
4. For Graph #2, plot the corresponding $1/V_{avg}$ values versus pressures in units of "books" on the horizontal axis. Note: the graph of Pressure vs $1/V_{avg}$ is also "linear", yielding a slope of m = PV; furthermore the y = mx + b equation will confirm that the *y-intercept* is the initial atmospheric pressure when 1/V = 0 (no books initially present).
5. The line obtained for the second plot crosses the vertical axis of the graph above the origin, which tells you that there is pressure on the gas even when there are no books on the piston. Consider that 1/V = 0 only when the total pressure on the gas is zero (and the volume is infinitely large). The additional pressure is the atmospheric pressure. To find this pressure in units of books, extend the plot of $1/V_{avg}$ versus $Pressure_{books}$ on Graph #2 to the point where it intersects the horizontal axis. At this point, $1/V_{avg} = 0$. The scale distance from this point to the origin is the atmospheric pressure measured in books. Using your graph, determine this value (See Sample Graph 2 below).
6. Record the value of P_{atm} in each row of the table in the proper column.
7. Add the value you found for atmospheric pressure (P_{atm}) to pressure in books (P_{books}) for each trial and record these values of P_{total} in the table.

$$P_{total} = P_{books} + P_{atm}.$$

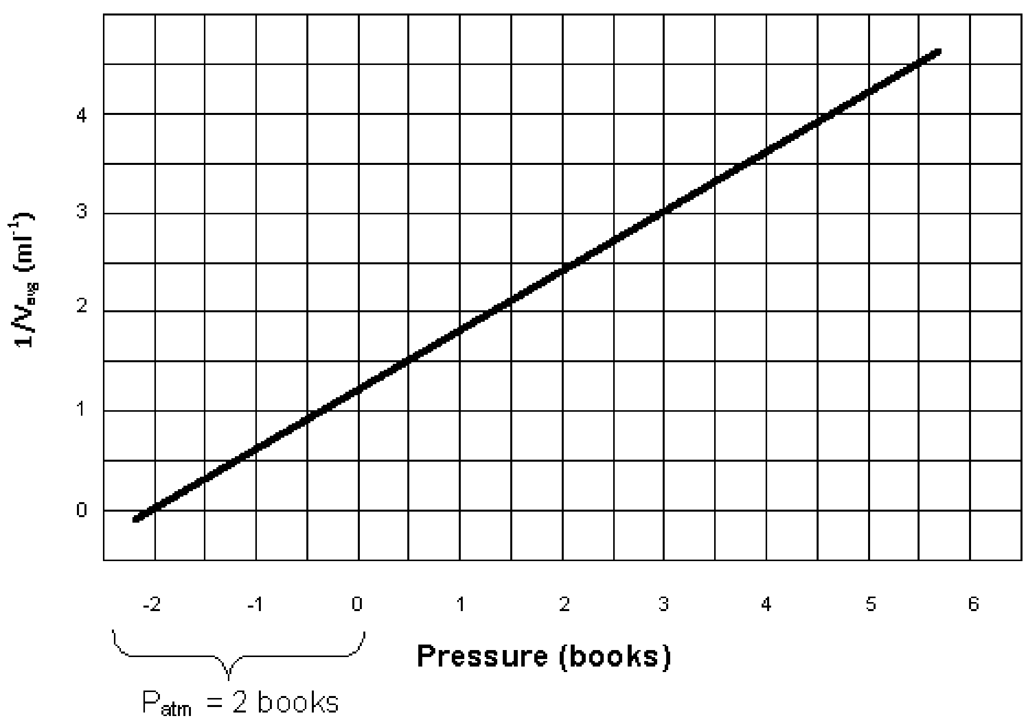
8. Calculate the product of P_{total} x V_{avg} for each trial and record these values in the data table.

Student

Conclusions:

1. What is the benefit of repeating the measurements 3 times?
2. Explain the relationship between pressure and volume shown in Graph#1.
3. Describe the results shown in Graph #2.
4. Look at the values you calculated in the last column of the data table. How do they compare?
5. State Boyle's Law.
6. How do the pressure and volume values relate in terms of Boyle's law?
7. Will this pressure/volume relationship hold true for solids and liquids? Why or why not?
8. When the plunger was compressed, it got more and more difficult to push the plunger in. Explain, using the kinetic molecular theory, why this happens.
9. Solve the following problems: 1) For an initial volume of 5.20-L and a pressure of 103 kilopascals, at what pressure in atmospheres will the volume of the gas expand to 12.00-L? 2) A gas at 700.0 milimeters mercury occupies volume of 200.0 milliliters, at how many atmospheres will it occupy 0.950-Liter?

Sample Graph



Extension for Advanced Students:

1. If the gas had behaved non ideally, what would have been the effect on the results of the experiment? (Hint: There will be a negative and a positive deviation away from the expected behavior- research the molecular origin of these effects).
2. When you use a bicycle pump to inflate a tire you push on the pump and air moves into the tire. In order for the pump to work, air pressure must be greater in the pump than in the bicycle tire. The air will move from the pump to the tire, causing inflation. How does the principle of Boyle's law come into effect in the operation of bicycle pump?

Teacher

Models of Atomic Structure

NGSSS:
SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.
SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.
SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.
SC.912.P.10.10 Compare the magnitude and range of the four fundamental forces (gravitational, electromagnetic, weak nuclear, strong nuclear).

Purpose of Lab/Activity: In this activity, students will create models of atoms to learn about the structure and properties of an atom. Using the information provided in the periodic table, they will be able to represent protons, neutrons, and electrons of the first twenty atoms. They will discover the similarities in electron structure and the physical and chemical properties of each atom.

Prerequisite: Prior to this activity, the teacher should make sure that each student should be able to

- Comprehend the periodic table: periods, families or groups, Noble Gases.
- Understand the electronic configuration or structure of an element.
- Relate the atomic number to the number of protons.
- Relate the atomic mass to the number of protons and neutrons.
- Determine the number of protons, neutrons and electrons based on the atomic number and atomic mass.
- Describe the changes that occur in atomic energy levels as you move down the periods in the Periodic table.
- Describe the changes that occur in atomic energy levels as you move across a period in the Periodic table.

Materials (individual or per group):

- White paper and colored paper
- Tape or Glue
- Colored dots labels for the electron (can be made using a hole-puncher to create dots from peel off labels)
- Atom template (see next page)
- Markers
- Pencils
- Compass
- Scissors

Teacher

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess prior knowledge about Atomic structure and address misconceptions concerning atomic number, protons, electrons, and neutrons, families /groups. b. Essential question: What is a model? What are some examples of using models in a science class? c. Discuss the advantages and limitations in the use of models to represent real objects. d. Discuss the lab safety and the directions related to this experiment.
During activity:	**What the teacher will do:** a. To engage student thinking during activity, ask them to describe the structure of an atom and the location of the different particles. b. Ask student to explain how to find out the atomic number, the number of protons, electrons, and neutrons of each of the 20 elements? c. What happens to an element as you move down a family/group? d. What happens to the reactivity of an element as you move more to the left side of the periodic table? Why? e. Walk around and make sure that the students follow directions and record their data during the activity. f. Make sure that the students analyze the data through table and graphs and draw a conclusion.
After activity:	**What the teacher will do:** a. Have students complete the lab data table and answer the analysis questions. b. Assign each student to research the physical and chemical properties of their element, and how the similarities of this element to others have been studied and used for scientific or practical purposes. c. Have them make a short presentation to the class. As each student presents, the others should take notes on a blank Periodic Table. Once the presentations are finished, lead a discussion in analyzing the similarities in chemical and physical properties within the elements of each family. d. The assessment activity should include what they have done in class, the conceptual connections and its applications, therefore, based on the similarities among elements students must conduct research to make connections of real life applications of this concept and extend their knowledge.

Extension:

1. Create a large classroom Periodic Table with the models constructed by each of the students. Paste the students' atomic models on colored papers coded for each family and have the students arrange these in the order of the Periodic Table. You can secure each model to the others with string or wire.
2. Have the students create two additional squares per element family. On the first square, label the group number and family name, and place these above the models for each group. Use the second square to summarize the properties per group, and add these to the bottom of the models.
3. Hang the student created Periodic Table on the wall and use for future reference.

Teacher

4. Assign one element to each student (it could be the same one that they used for the lab or a new element) and ask them to conduct research on the properties of the elements, their practical uses and similarities with any other element in the Periodic Table.

Student

Models of Atomic Structure

NGSSS:
SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.
SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.
SC.912.P.8.6 Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces.
SC.912.P.10.10 Compare the magnitude and range of the four fundamental forces (gravitational, electromagnetic, weak nuclear, strong nuclear).

Background: Building a model of an atom structure can help you understand how a complex system operates. Something as simple as observing and releasing an inflated balloon can give you information about the forces involved in launching rockets. Building and using a model for an atom can help you understand how the main parts of an atom relate to each other. A model helps us understand something we cannot see directly, usually because it is too large or too small.

The atom consists of a positively charged center, or nucleus, surrounded by negatively charged particles called electrons. The two major kinds of particles in the nucleus are protons and neutrons. The number of protons, or atomic number, in a neutral atom is equal to the number of electrons. Electrons move around the nucleus in a region called electron cloud. Within the electron cloud, electrons have energy. The energy differences of the electrons can be described by energy levels.

Purpose of this activity: Learn how models facilitate the understanding of scientific phenomena. Construct a model of an atom and analyze similarities in electron structure and physical and chemical properties between elements of the same group or family.

Problem Statement: What is a model? What are some examples of using models in a science class? How can an atomic structure of an element explain the physical and chemical properties between elements?

Safety: There is no safety concern; be sure that you use blunt scissors.

Vocabulary: model, atom, protons, neutrons, electrons, energy levels, electron, configuration, chemical and physical properties.

Student

Materials (individual or per group):

- White paper and colored paper
- Tape or Glue
- Colored dots labels for the electron (can be made using a hole-puncher to create dots from peel off labels)
- Atom template (see next page)
- Markers
- Pencils
- Compass
- Scissors

Procedures:

1. Make a table like the one shown below. List the elements with atomic numbers of 1 through 20. Determine the number of each kind of particle needed to make up an atom of the element. Write your results in the table.
2. Working in teacher assigned groups, use the atom template pattern provided to create a model of the assigned elements. Use a marker or pen to write the number of protons and neutrons in the center circle. This represents the nucleus of the atom. The number of neutrons (**n**) is equal to the atomic number (number of protons, **p**) subtracted from the mass number or the atomic mass (**M**):

$$\#n = M - \#p$$

3. In the outer circles, arrange the colored dots to represent the electrons within the energy levels around the nucleus. Use as many of these electrons as you need for your element. Paste or stick the electrons in their places pairing the electrons to represent filled orbitals.
4. Repeat steps 2 and 3 for the other elements in your assigned group.

Observations/Data:

As you fill out the table, write your observations as you determine the atomic number, the number of protons, the number of neutrons, and the number of electrons.

Element name	Number of protons	Number of neutrons	Number of electrons
Etc.			

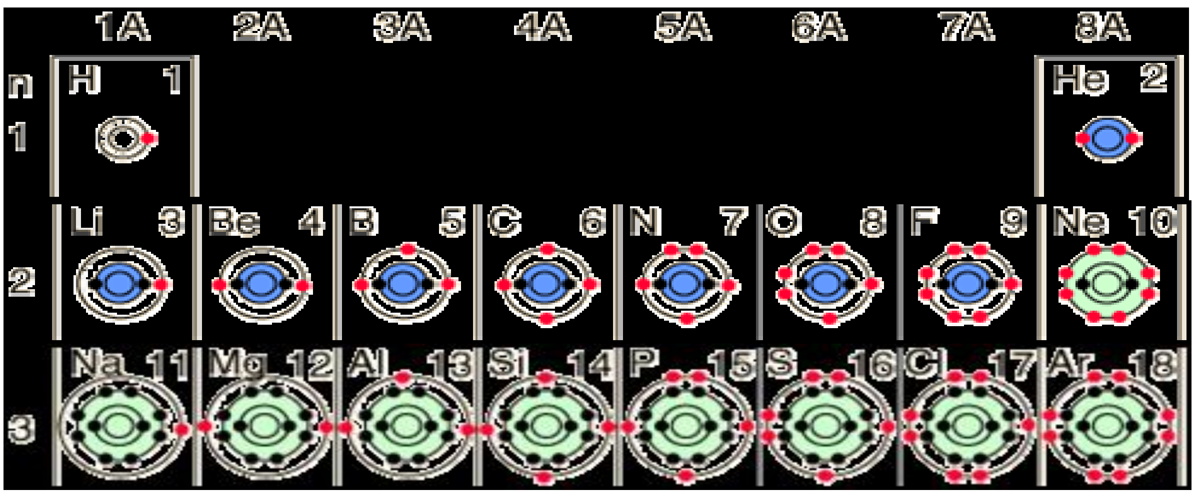
Student

Observation/Data Analysis:
Analyze your data through the data table. Explain the data outcome. What do you notice?

1. In a neutral atom, which particles will always be present in equal numbers?
2. Hypothesize what you think would happen to the charge of an atom if one of the electrons was removed from the atom.
3. Except for hydrogen, how many first-level electrons did each atom contain?
4. How is the Bohr model of an atom similar and different to an actual atom?
5. What would you do to make a better model of an atom? Explain using relative sizes of each subatomic particle and location.
6. Classroom discussion: Analyze the similarities in chemical and physical properties within the elements of each family and how the similarities of this element to others have been studied and used for scientific or practical purposes.

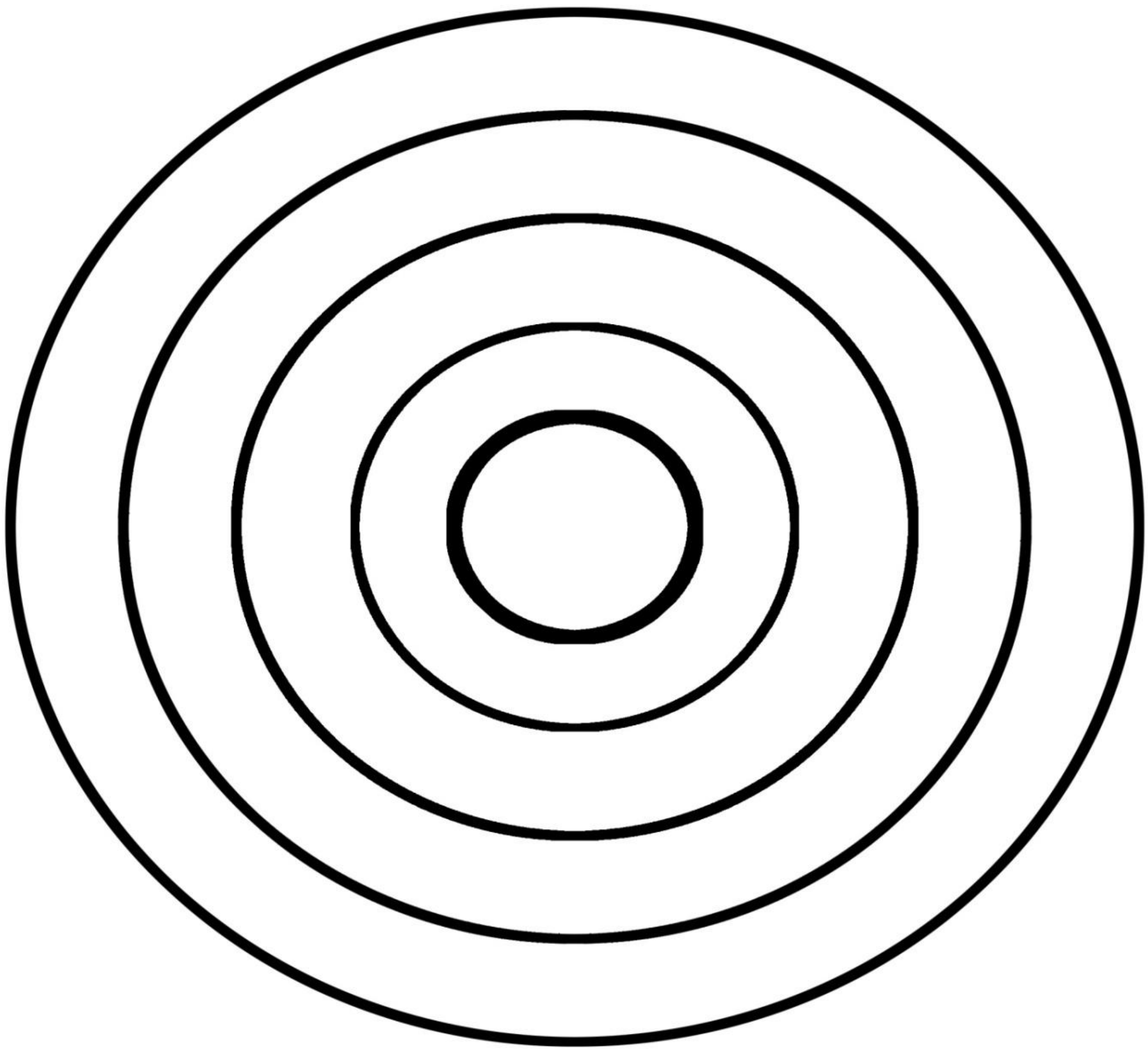
Results / Conclusion:
The assessment activity should include what you have done in class, the conceptual connections and its applications. Therefore, to extend your knowledge, conduct research to make connections of real life applications of this concept based on the similarities among elements.

Table for extended activities



IMPORTANT: Cut 1 inch outside of the outer circle. Label with pencil the name of the atom in the back and save these atomic models for Lab Activity entitled Periodic Trends.

Student



Teacher

Alien Periodic Table

NGSSS:
SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.
SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

Purpose of Lab/Activity: Students will apply their understanding of the Periodic Table to predict characteristics of unknown elements.

Prerequisite: Prior to this activity the student should be able to…

- Label the parts of the Periodic Table: periods, families or groups, Noble Gases.
- Identify an element as being a metal, nonmetal, or metalloid.
- Recognize carbon as the element of life.
- Identify those elements which occur as diatomic molecules.
- Using the Periodic table, recognize which metals are more reactive than others.
- Relate the atomic number to the number of protons.
- Relate the atomic mass to the number of protons and neutrons.
- Determine the number of protons, neutrons and electrons based on the atomic number and atomic mass.
- Describe the changes that occur in atomic energy levels as you move down the periods in the Periodic table.
- Describe the changes that occur in atomic energy levels as you move across a period in the Periodic table.
- Describe ionic and covalent bonds.
- Relate ionic and covalent bonds to an atom's electron requirements.
- Relate physical and chemical properties to atomic structure.

Materials (individual or per group):

- Blank *Alien Periodic Table*
- Periodic table from text (used for reference)
- Colored pencils

Procedures: Day of Activity

Before activity:	**What the teacher will do:** a. Make copies of the blank Alien Periodic table. b. Review the structure of the Periodic Table emphasizing: 1. periods, families/groups, Noble Gases. 2. metals, nonmetals, or metalloids. 3. carbon as the element of life. 4. diatomic molecules. 5. reactivity of substances.

	6. calculations of protons, neutrons and electrons based on the atomic number and atomic mass. 7. ionic and covalent bonds. c. Assess prior knowledge and ask the following questions: 1. Does the Periodic Table follow universal laws? Guide students to a “yes” answer. 2. If laws are universal, then would they apply to even the elements found on an alien planet?
During activity:	**What the teacher will do:** a. As a class guided activity, answer the first set of unknown elements on the Alien Periodic Table, modeling how to apply the logic required to complete the lab. b. As the lab progresses monitor student work and understanding by asking: 1. How can you determine the number of protons in an element? 2. How can you determine the number of electrons in an element? 3. How can you determine the number of neutrons in an element? 4. How does the physical size of an atom change as you move down a family (column)? 5. How does reactivity change as you move more to the left side of the periodic table?
After activity:	**What the teacher will do:** a. Lead a class discussion in order to find out which clues the students found most helpful, which clues were the most difficult, and what would the students change about the clues. b. Tell students they just applied the scientific theory of atoms (also known as atomic theory) by making predictions regarding unknown elements by using their knowledge of the structure of atoms.

Answer Key – Conclusions

1. Students will create a table with the following information:

Atomic #	Element	Alien Name
1	Hydrogen	Pfsst
2	Helium	Bombal
3	Lithium	Chow
4	Beryllium	Doggone
5	Boron	Ernst
6	Carbon	Floxxit
7	Nitrogen	Goldy
8	Oxygen	Nuutye
9	Fluorine	Apstrom
10	Neon	Logon

Atomic #	Element	Alien Name
11	Sodium	Byyou
12	Magnesium	Zapper
13	Aluminum	Yazzer
14	Silicon	Highho
15	Phosphorus	Magnificon
16	Sulfur	Oz
17	Chlorine	Kratt
18	Argon	Jeptum
19	Potassium	Quackzil
20	Calcium	Rhaatrap

Atomic #	Element	Alien Name
31	Gallium	Doadeer
32	Germanium	Terribulum
33	Arsenic	Sississ
34	Selenium	Urrp
35	Bromine	Vulcania
36	Krypton	Wobble
37	Rubidium	Xtalt
38	Strontium	Pie
49	Indium	Anatom
50	Tin	Eldorado

2. Student answers will vary.
3. Student answers will vary.
4. Generally, atomic mass also increases as you increase in atomic number.

Teacher

5. Rare Earth Metals, Transition Metals
6. Yes, these groups exist on Earth and the many of the other elements are man-made.
7. Student answers will vary.
8. They are the most reactive due to their electron configuration; each of the elements listed in procedure #2b have one valance electron and are likely to react with other elements.
9. Atoms are more stable when their energy levels are filled with electrons. There are three types of bonds associated with chemical bonding: covalent bonding, ionic bonding, and metallic bonding. In covalent bonding, two elements share electrons. In ionic bonding, two elements that are oppositely charged are held together. In metallic bonding, outer electrons are shared and move freely around the atom.

Student

Alien Periodic Table

NGSSS:
SC.912.P.8.3 Explore the scientific theory of atoms (also known as atomic theory) by describing changes in the atomic model over time and why those changes were necessitated by experimental evidence.
SC.912.P.8.4 Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.
SC.912.P.8.5 Relate properties of atoms and their position in the periodic table to the arrangement of their electrons.

Background: Imagine that scientists have made radio contact with life on a distant planet. The planet is composed of many of the same elements as are found on Earth. But the inhabitants of the planet have different names and symbols for the elements. The radio transmission gave data on the known chemical and physical properties of 30 that belong to Groups 1, 2, 13, 14, 15, 16, 17, and 18. You need to place the alien elements into a blank periodic table based on these properties.

Problem Statement: Where do alien elements fit into a periodic table using information based on universal atomic properties?

Safety: There are no specific safety concerns for this activity.

Vocabulary: Periodic table, Atom, Element, Atomic number, Atomic mass, Proton, Electron, Neutron, Reactivity, Metal, Nonmetal, Metalloids, Nobel gases, Periods, Family/Group

Materials (individual or per group):
- Blank *Alien Periodic Table*
- Periodic table from text (used for reference)
- Colored pencils

Procedures:
1. Obtain the blank periodic table.
2. Listed below are the data on the chemical and physical properties of the 30 elements. Place the elements in their proper position in the blank periodic table.
   a. The noble gases are bombal (Bo), wobble (Wo), jeptum (J), and logon (L). Among these gases, wobble has the greatest atomic mass and bombal the least. Logon is lighter (in mass) than jeptum.
   b. The most reactive group of metals are xtalt (X), byyou (By), chow (Ch), and quackzil (Q). Of these metals, chow has the lowest atomic mass. Quachzil is in the same period as wobble.
   c. Apstrom (A), vulcania (V), and kratt (Kt) are nonmetals whose atoms typically gain or share one electron. Vulcania is in the same period as quackzil and wobble.
   d. The metalloids are Ernst (E), highho (Hi), terribulum (T), and sississ (Ss). Sississ is the metalloid with the greatest atomic mass. Ernst is the metalloid with the lowest atomic

mass. Highho and terribulum are in Group 14. Terribulum has more protons than highho. Yazzer (Yz) touches the zigzag line, but it's a metal, not a metalloid.

e. The lightest element of all is called pfsst (Pf). The heaviest element in the group of 30 elements is eldorado (El). The most chemically active nonmetal is apstrom. Kratt reacts with byyou to form table salt.
f. The element doggone (D) has only 4 protons in its atom.
g. Floxxit (Fx) is important in the chemistry of life. It forms compounds made of long chains of atoms. Rhaatrap (R) and doadeer (Do) are metals in the fourth period, but rhaatrap is less reactive than doadeer.
h. Magnificon (M), goldy (G), and sississ are all members of Group 15. goldy has fewer total electrons than magnificon.
i. Urrp (Up), oz (Oz), and nuutye (Nu) all gain 2 electrons when they react. Nuutye is found as a diatomic molecule and has the same properties as a gas found in Earth's atmosphere. Oz has a lower atomic number than urrp.
j. The element anatom (An) has atoms with a total of 49 electrons. Zapper (Z) and pie (Pi) lose two electrons when they react. Zapper is found in planet Earth's crust.

3. Use all of the provided information to complete the blank alien periodic table provided.
4. Color-code the table to indicate each family of elements.

Observations/Data: Fill in attached Alien Periodic Table

Data Analysis: Use descriptions of alien elements atomic structures and qualities found in Procedures section to identify and determine placement in Alien periodic table.

Conclusion:

1. Complete the table below indicating the Earth name that corresponds to the 30 alien elements.

Atomic #	Element	Alien Name
1	Hydrogen	
2	Helium	
3	Lithium	
4	Beryllium	
5	Boron	
6	Carbon	
7	Nitrogen	
8	Oxygen	
9	Fluorine	
10	Neon	

Atomic #	Element	Alien Name
11	Sodium	
12	Magnesium	
13	Aluminum	
14	Silicon	
15	Phosphorus	
16	Sulfur	
17	Chlorine	
18	Argon	
19	Potassium	
20	Calcium	

Atomic #	Element	Alien Name
31	Gallium	
32	Germanium	
33	Arsenic	
34	Selenium	
35	Bromine	
36	Krypton	
37	Rubidium	
38	Strontium	
49	Indium	
50	Tin	

2. Explain which alien elements you were able to place on the blank periodic table with just a single clue and how that one clue assisted in the placement.
3. Why did you need two or more clues to place other elements? Explain using examples.
4. Why could you use clues about atomic mass to place elements, even though the table is now based on atomic number?
5. Which groups of elements from Earth's periodic table are not included in the alien periodic table?

Student

6. Do you think it is likely that an alien planet would lack the group of elements mentioned in question #5? Explain.
7. The procedures are written in (a,b,c) format for each of the alien elements. Did you follow the order or was it necessary to skip some sections to make progress in completing the table?
8. Explain why the groups of metals mentioned in procedure #2b are the most reactive on the periodic table.
9. Procedures #2c and #2i both discuss electron movement. Explain how you know which elements typically gain, lose, or share electrons.

Student

ALIEN PERIODIC TABLE

	1	2	13	14	15	16	17	18
1								
2								
3								
4								
5								

Teacher

A Bagged Chemical Reaction

NGSSS:
SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.
SC.912.P.8.8 Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity
SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Purpose of Lab/Activity: To observe any changes which take place during the interaction of several substances and identify those changes which indicate a chemical reaction is taking place.

Prerequisite: Prior to this activity, the student should …

- Be familiar with phenol red solution and its use as a PH indicator.
- Be able to identify those changes which indicate a chemical reaction has taken place.
- Be able interpret a chemical equation and identify its reactants and products.
- Be familiar with the terms "endothermic" and "exothermic" as they apply to energy transfer during chemical reactions.

Materials (individual or per group):

- Lab notebook
- Safety goggles
- Calcium Chloride pellets
- Sodium Bicarbonate (Baking Soda)
- Phenol Red solution
- Graduated cylinder
- (2) plastic teaspoons
- (1) Gallon ziplock bag
- (2) twist ties or rubberbands
- water
- permanent marker (black)

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Assess students' prior knowledge and skills using the student prerequisites to guide a class discussion and to clarify any misconceptions. b. Write the equations representing some of the reactions involved in this lab on the board. c. Review pertinent vocabulary as given in student section. d. Depending on the activity, the teacher should inform students that they must write a lab report based on accepted models, *"Parts of a Lab Report" or "Power Writing Model 2009"*, or answer a set of questions designed to engage higher ordered thinking through concept understanding and application. e. Model lab steps as a dry run without using any reactants. f. Ask the following questions: 1. How many chemical reactions can you identify which occur every day around us?

	2. How do you know they are chemical reactions and not just physical changes? g. Review the specific safety concerns associated with this lab as outlined in the student section. h. Provide a container for the safe disposal of the lab bags.
During activity:	**What the teacher will do:** a. Write the equations representing some of the reactions involved in this lab on the board as shown below: 1. $NaHCO_3(s) + CaCl_2(s) \rightarrow CaCO_3(s) + NaCl(aq) + HCl(aq)$ 2. $NaHCO_3(s) + HCl(aq) \rightarrow H_2O(l) + CO_2(g) + NaCl(aq)$ b. As students perform the lab, tell them to "use all of their senses when gathering data during this lab", and to "be specific when recording your observations."; then ask the following questions: 1. Why is it important to continue being observant during the interaction of the reactants even after an obvious sign of chemical interaction has taken place?" 2. Identify the reactants, products, and their states from the chemical equations given for some of the reactions in this lab. **Note**: Stress the importance of noting any change observed during the interaction of the reactants no matter how insignificant it may seem at the time.
After activity:	**What the teacher will do:** a. In order to review and assess student understanding , ask the following questions: 1. Why would the outside of the bag get cold if the reaction inside it is endothermic (heat absorbing) one? 2. How would the bag feel if the reaction inside was an exothermic (heat releasing) one? b. Instruct students to answer the questions under the results and conclusion section of the lab, using complete answers with supportive reasoning and data. c. After collecting the lab reports have a class discussion of the answers to the assigned questions and the reasoning behind them.

Student

A Bagged Chemical Reaction

NGSSS:
SC.912.P.8.7 Interpret formula representations of molecules and compounds in terms of composition and structure.
SC.912.P.8.8 Characterize types of chemical reactions, for example: redox, acid-base, synthesis, and single and double replacement reactions.
SC.912.P.10.2 Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity
SC.912.P.10.7 Distinguish between endothermic and exothermic chemical processes.

Background: Chemical reactions occur when molecules come together to form new products. In our bodies and environments, chemical reactions occur continuously to help run our lives. During a reaction, chemical bonds are broken and remade. Usually, color changes, gases being released, changes in temperature, and/or formation of solute characterize chemical reactions. These events describe changes in energy or solubility of the compound, meaning new products were produced.

Chemical reactions can be defined by a chemical equation in which reactants and products are characterized by chemical symbols. All chemical reactions areaccompanied by a change in energy. Some reactions release energy to their surroundings (usually in the form of heat) and are called **exothermic**. For example, sodium and chlorine react so violently that flames can be seen as the exothermic reaction gives off heat. On the other hand, some reactions need to absorb heat from their surroundings to proceed. These reactions are called **endothermic**. A good example of an endothermic reaction is that which takes place inside of an instant "'cold pack." Commercial cold packs usually consist of two reacting compounds - in separate containers within a plastic bag. When the bag is bent and the inside containers are broken, the two compounds mix together and begin to react. This reaction is endothermic.

Purpose or Problem Statement: To observe any changes which take place during the interaction of several substances and identify those which would indicate a chemical reaction is taking place.

Safety:
1. Remind students that there is NO eating or drinking during the lab.
2. A gas is produced in the bags. Make sure the area is well-ventilated before releasing all the gas.
3. Do not let students ingest baking soda or calcium chloride. Avoid contact with eyes or mouth.
4. Watch for bags exploding. Ensure the students shake the bag away from their faces and clothes.
5. Once bags get tightly filled with gas, vent the CO2 gas by opening the one corner of the bag carefully. If it does explode, all the products are non-toxic and can be washed off.
6. The bags can be disposed of in the trash receptacle provided by the instructor because all products are non-toxic.

Student

Vocabulary: endothermic, exothermic, basic, acidic, neutral, precipitate.

Materials (individual or per group):

- Lab notebook
- Safety goggles
- Calcium Chloride pellets
- Sodium Bicarbonate (Baking Soda)
- Phenol Red solution
- Graduated cylinder
- (2) plastic teaspoons
- (1) Gallon ziplock bag
- (2) twist ties or rubberbands
- water
- permanent marker (black)

Procedures:

1. Place 2 teaspoons calcium chloride pellets into one corner of the bag.
2. Twist off the corner to separate the calcium chloride from the rest of the bag. Follow teacher instructions and use either a rubber band or twist tie to secure.
3. Place two teaspoons of baking soda into the opposite corner of the bag.
4. Twist off the corner to separate the baking soda from the rest of the bag. Follow teacher instructions and use either a rubber band or twist tie to secure.
5. Fill a cup with about 10 ml of water and phenol red solution.
6. Pour the phenol red solution into the bag.
7. Carefully remove as much air as possible and close the bag.
8. Carefully untwist the two corners (if you used a rubber band, use scissors to cut the rubber band, but be careful not to cut the bag).
9. Hold the two corners of the bag apart. One partner may hold both corners, or each partner may hold one side.
10. Quickly observe any immediate changes in both corners and record them in your data table.
11. Release the calcium chloride and baking soda allowing the liquid to mix with the two substances.
12. Observe the reaction until it comes to a complete stop. Record all your observations in your data table.

Observations/Data:

Observed Changes	Calcium Chloride + Phenol Red (aq) Solution (A)	Sodium Bicarbonate + Phenol Red Solution (B)	Mixture of Solution A + B
Color			
Temperature			
Precipitate			
Gas Production			
PH			
Other			

Student

Results / Conclusions

1. If some type of temperature change was detected:
   i). Which reaction(s) would you characterize as exothermic? Why?
   ii). Which reaction(s) would you characterize as endothermic? Why?
2. Based on the balanced chemical equations for some of the reaction(s), Identify
   i). The gas which was produced in your bags?
3. Is it possible to determine the total number of chemical reactions which took place during the interaction of the substances exactly based on the number of changes observed? Explain why or why not.
4. What was the function of the phenol red in the experiment besides indicating PH? What else did it indicate?

Teacher

Factors Affecting Reaction Rates

NGSSS:
SC.912.P.12.11 Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.
SC.912.P.12.12 Explain the concept of dynamic equilibrium in terms of reversible processes occurring at the same rates.

Purpose of Lab/Activity: The purpose of this lab is to determine experimentally how the temperature and surface area of the reactants affect the reaction rate of a chemical reaction.

Prerequisite: Prior to this activity, the student should:
- Be familiar with the collision theory.
- Be familiar with the factors which can affect the reaction rate of chemical reactions.

Materials (individual or per group):
- duct tape
- 50 mL beaker
- paper towel 1 dropper
- test tube with stopper
- Hot plate
- Beaker
- Timer
- Waste Beaker
- (6) effervescent Tablets
- Room temperature water
- mortar and pestle (small)
- filter paper

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Review pertinent vocabulary as given in student section. b. Ask the essential question: Exploding fireworks are instantaneous and violent while digestion in humans is a gradual and more subtle process. These are examples of chemical reactions, why are they so different in nature? (Ex: They are different because there are factors present in each case which control the rates of the reactions.) c. Write the problem statement on the board d. Provide a waste receptacle in which to discard materials as the lab progresses. e. Model lab steps for the students as a dry run without using any reactants.
During activity:	**What the teacher will do:** a. Circulate among the students to make sure they understand the activity and are following proper lab procedures. b. As students work on the lab activity, ask the following questions: 1. What visible indication(s) can you describe that would suggest that a chemical reaction is taking place? 2. What acted as the control in this experiment? 3. What is the purpose of taking the average of the trials? 4. What is the independent variable in this lab? The dependent variable in this lab? 5. List at least 3 possible sources of error in this lab. 6. Ask students to make suggestions as to how these sources of error

	could be minimized or eliminated?
After activity:	**What the teacher will do:** a. In order to review and assess student understanding, ask the following questions: 1. Consider the collision theory and use it to explain how heating the water affects the reactants' molecules and consequently their rate of reaction? b. How did finely crushing one of the reactants affect the reaction rate? Explain why. c. Ask students to design a lab investigation using the same materials to explore the effects of varying the concentration of the reactants. Students should include their suggested procedure in their lab report. d. All the typical parts of a lab should be identified. e. Tell students: A lab report must be submitted in a standard format. (*"Parts of a Lab Report"* or *"Power Writing Model 2009" cited in this document.)*

Student

Factors Affecting Reaction Rates

NGSSS:
SC.912.P.12.11 Explain how various factors, such as concentration, temperature, and presence of a catalyst affect the rate of a chemical reaction.
SC.912.P.12.12 Explain the concept of dynamic equilibrium in terms of reversible processes occurring at the same rates.

Background: Chemical reactions occur when the molecules of two or more elements or compounds, called the reactants, collide and recombine to form a new compound, which is called the product. According to the collision theory, these colliding molecules must first reach the reaction's activation energy for the reaction to occur. Activation energy is the level of energy required for the molecules to collide with enough force to recombine and form a new product. The rate of reaction describes how fast reactants form products in a chemical reaction. Chemical reactions can be sped up or slowed down by altering the surface area, concentration, and temperature of the reactants.

Purpose: The purpose of this lab is to determine how the temperature and surface area of the reactants affect the reaction rate of a chemical reaction.

Safety: Students should cover top of test tube with their hand or a paper cup indoors.
If the activity is being done outdoors remind students to the aim test tube away from their faces and those of others while the chemical reaction is taking place
Students must not try to hold the stopper in while the reaction is taking place the test tube could rupture
Students must wear goggles at all times

Vocabulary: Collision Theory, Activation energy, Surface area, Rates of reaction, Catalyst (Enzyme), Concentration.

Materials (individual or per group):
- duct tape
- 50 mL beaker
- paper towel 1 dropper
- test tube with stopper
- Hot plate
- Beaker
- Timer
- Waste Beaker
- (6) effervescent Tablets
- Room temperature water
- mortar and pestle (small)
- filter paper

Procedures:
1. Prepare 12 half –tablets by scoring the back of each tablet and breaking into two equal pieces. (A pill splitter could be used.)
2. Dry fit the stopper into the test tube just tight enough to make a good seal. (Do not push the stopper in too tightly.)
3. Right below the end of the stopper, wrap your test tube once all the way around with duct tape. This will be the guide every time the stopper is reinserted for each trial.
4. Add approximately 20 ml of water at room temperature into your test tube and drop half a tablet.
5. Cap the test tube immediately and begin timing the reaction.

6. Stop the timer when the stopper pops off, record the time.
7. Dispose of the used solution in the test tube into your waste beaker.
8. Before beginning each trial be sure to rinse the test tube and dry off the stopper bottom and the test tube lip.
9. Perform 3 trials in total.
10. Repeat steps 4 through 9 using hot water. Record your data in the table.
11. Repeat the procedure steps 3 thru 7, but this time crush the half tablets into powder using the mortar and pestle provided. Use a folded piece of filter paper to funnel the powder into the test tube.

Observations/Data:

Water (room temperature)	**Tablet Form**	**Time (sec)**
Trial 1	Whole ½ tablet	
Trial 2	Whole ½ tablet	
Trial 3	Whole ½ tablet	
	Avgerage Time	

Water (hot)	**Tablet Form**	**Time (sec)**
Trial 1	Whole ½ tablet	
Trial 2	Whole ½ tablet	
Trial 3	Whole ½ tablet	
	Avgerage Time	

Water (room temperature)	**Tablet Form**	**Time (sec)**
Trial 1	Crushed ½ tablet	
Trial 2	Crushed ½ tablet	
Trial 3	Crushed ½ tablet	
	Avgerage Time	

Water (hot)	**Tablet Form**	**Time (sec)**
Trial 1	Crushed ½ tablet	
Trial 2	Crushed ½ tablet	
Trial 3	Crushed ½ tablet	
	Avgerage Time	

Student

Results/Conclusion:

1. After collecting the students' lab reports, the teacher will have students demonstrate their procedures for exploring the effect that varying the concentration of the reactants can have on a chemical reaction's rate.
2. The class will discuss how effective their various procedures are and point out any areas in them which could introduce error(s) into their labs. Suggestions will be made as to how to minimize those errors.
3. The class will then choose the lab procedure they decide is the most effective and the teacher will perform it as a demonstration. If time allows more than one procedure may be tested.
4. After discussing the results the class will come to a general conclusion about the effect that concentration has on the rate of chemical reaction.

Half-Life

NGSSS:
SC.912.P.10.11 Explain and compare nuclear reactions (radioactive decay, fission and fusion), the energy changes associated with them and their associated safety issues.
SC.912.P.10.12 Differentiate between chemical and nuclear reactions.

Purpose of Lab/Activity: To model the process of radioactive decay and use it to determine the half-life of an imaginary isotope.

Prerequisite: Prior to this activity, the student should:
- Be able explain the basic structure of atoms and their isotopes.
- Understand the concept of stable and unstable isotopes
- Be able to interpret data and graph it in a coordinate plane

Materials (individual or per group):
- 100 pennies
- opaque rectangular container with lid (shoebox)
- timer

Procedures: Day of Activity:

Before activity:	**What the teacher will do:** a. Review the vocabulary as given in student section. b. Ask the Essential question: The decaying isotopes within the Earth liberate energy scientists believe may explain Earth's molten layers. Do you believe this is possible? (Ex: I believe it is possible because the effect of all that energy being released is a cumulative one.) c. The teacher will model the lab procedure for the class.
During activity:	**What the teacher will do:** a. Circulate among the students to make sure proper procedures are being followed. b. As students perform the lab activity, ask the following questions in order to monitor understanding: 1. What is the purpose of taking the average of the trials and combining the data from all the groups? 2. Why is it important to maintain consistency in the timing when shaking the box?
After activity:	**What the teacher will do:** a. Assess student understanding and ask additional questions: 1. Where does most of the energy released during radioactive decay come from? 2. Do you think that overall this lab is an adequate model of radioactive decay? Where is it deficient? 3. Have the class brainstorm on how it could be improved. b. Inform the students that they must write a lab report based on accepted models (*"Parts of a Lab Report" or "Power Writing Model 2009"* cited in this document.) c. Instruct the students to answer the questions at the end of the lab handout,

	using complete answers with supportive reasoning and data. d. After collecting the work have a class discussion of the answers to the assigned questions and the reasoning behind them. e. Take time to clear up conceptual misconceptions the students may still have.

Student

Half-Life

NGSSS:
SC.912.P.10.11 Explain and compare nuclear reactions (radioactive decay, fission and fusion), the energy changes associated with them and their associated safety issues.
SC.912.P.10.12 Differentiate between chemical and nuclear reactions.

Background: Isotopes are atoms of the same element with different atomic masses. These different masses are a result of having different numbers of neutrons in their nuclei. Isotopes can be stable or unstable (radioactive). Radioactive isotopes have unstable nuclei that break down in a process called radioactive decay. During this process, the radioactive isotope is transformed into another, usually more stable, element. The amount of time it takes half the atoms of a radioactive isotope in a particular sample to change into another element is its half-life. A half-life can be a fraction of a second for one isotope or more than a billion years for another isotope, but it is always the same for any particular isotope.

Purpose: To model the process of radioactive decay and use it to determine the half-life of an imaginary isotope.

Safety: This lab does not present any significant safety issues.

Vocabulary: Isotope, Unstable isotopes, radioactive decay, half life.

Materials (individual or per group):
- 100 pennies
- opaque rectangular container with lid (shoebox)
- timer

Procedures:
1. Place 100 pennies, each head-side up, into the container. Each penny represents an atom of an unstable isotope.
2. Place the lid securely on the container. Holding the container level, shake it vigorously for 20 seconds.
3. Set the container on the table and remove the lid. Remove only pennies that are now in a tails-up position (decayed nuclei).
4. Count the pennies you removed and record this number in Table 1 under Trial 1. Also record the number of heads-up pennies that are left (undecayed nuclei).
5. Repeat steps 2 through 4 until there are no pennies left in the container.
6. Repeat steps 1 through 5 and record your data in Table 1 under Trial 2.
7. Calculate the averages for each time period and record these numbers in Table 1
8. Graph the average data from Table 1. Graph the number of heads-up pennies remaining on Y-axis (undecayed atoms or nuclei) against time (on X-axis) using a symbol such as X, O.

Student

Observations/Data:
Table 1: Group Data (H = heads; T = tails)

	Trial 1	Trial 2	Averages			
	A	B	C	D		
Shaking Time	Number of Heads-up Remaining	Number of Tails-up Removed	Number of Heads-up Remaining	Number of Tails-up Removed	Columns A and C (H)	Columns B and D (T)
At 0 s	100	0	100	0	100	0
After 20 s						
After 40 s						
After 60 s						
After 80 s						
After 100 s						
After 120 s						
After 140 s						

Table 2: Class Data (H = heads; T = tails)

	Group	I	II	III	IV	V	VI	VII	VIII	Total	Average
0 s	H	100	100	100	100	100	100	100	100	800	100
	T	0	0	0	0	0	0	0	0	0	0
20 s	H										
	T										
40 s	H										
	T										
60 s	H										
	T										
80 s	H										
	T										
100 s	H										
	T										
120 s	H										
	T										
140 s	H										
	T										

Student

Observation/Data Analysis:

1. Copy the averages from Table 1 into Table 2 under Group I.
2. Record the averages obtained by other groups in your class in Table 2.
3. Determine the totals and then averages for the combined data from all groups and record in Table 2.
4. Graph the average class data for undecayed nuclei on your graph using a different symbol in the same way as you graphed your individual group's data.

Results / Conclusions:

1. In this model, what was the half-life of the pennies? Explain how you determined this.
2. Did your graph reflect the general trend you would expect in radioactive decay? Explain.
3. What can you generally conclude about the total number of atoms that decay during any half-life period of the pennies?
4. If your half-life model had decayed perfectly, how many atoms of the radioactive isotope should have been left after 80 seconds of shaking?
5. If you started with 256 radioactive pennies, how many would have remained undecayed after 60 seconds of shaking?

Teacher

Solubility Curve of KCl

NGSSS:
SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.
SC.912.P.8.11 Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.
SC.912.L.18.12 Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.

Purpose of Lab/Activity:

- To study the effect of temperature on solubility
- To understand the process of solubility and saturation at the particle level
- To experimentally construct a solubility curve
- To use a solubility curve to find the solubility of a solute at different temperatures

Prerequisite: Students should have clear model on how the solution process works. Most important is for them to realize that solids dissolve and disappear from view as the particles of the solid are separated by the solvent. Students should also know that temperature is a measure of the kinetic energy of the particles in a system. Basic laboratory safety and techniques are expected due to the nature of this experiment.

Materials (per group):

- potassium chloride (KCl)
- distilled water
- balance
- evaporating dish (or 100-ml beaker)
- 25-ml graduated cylinder
- watch glass
- 250 or 400 ml beaker
- hot plate or burner with ring stand, 2 rings & wire gauze
- test tube (18X150 mm)
- utility clamp
- glass stirring rod
- thermometer or temperature probes
- funnel
- cotton wadding
- tongs &/or hot mitts
- graph paper

Procedures: Day of Activity

Before activity:	**What the teacher will do**: a. Gather all materials and set up the students into groups b. Ask students about their experience with solutions. Sugar in lemonade or iced tea is usually an event most students are familiar with. c. Introduce the difference in solubility at different temperatures by asking whether more sugar will dissolve in hot tea or iced tea. d. Explain the procedure to students e. Assign a different temperature to each group (i.e., room temperature, 30 ^oC, 40 ^oC, 50 ^oC, 60 ^oC, 70 ^oC, 80 ^oC, and 90 ^oC). Adjust temperature assignment according to the number of groups. Warn students not to allow the water bath to boil.
During activity:	**What the teacher will do**: a. Make sure students are working safely and diligently.

	b. The most difficult part of this lab is to keep the temperature of the water bath constant. Assist students with this task and make sure that they are reading the thermometers correctly. c. Visit each group individually and ask them questions about what steps they are completing and why. d. Point out to students that given the initial amount of KCl added (about 10 grams) they should not expect all the salt to ever dissolve. Ask them if they expect the amount of solute dissolved in the solvent to be constant at different temperatures and why. e. Set up a space in the room for groups to post their results. The quality of the graph will depend on the individual group results so great care must be taken if good results are desired.
After activity:	**What the teacher will do**: a. Students should gather data from the whole class and construct their solubility curve b. After all groups build their graph, bring them together for a whole class discussion and analysis of results c. The class discussion should have two main goals: First, to help students develop a particle level model of solubility and how temperature affects it. Second, for students to know how to read their chart and answer questions such as the ones in the conclusion section of the student procedure. d. Have students explain orally how water dissolves KCl. They should say that in the solid state, the ions of potassium and chlorine are attracting each other in a crystal lattice structure. All the ions together amount to a visible quantity of salt. When water is added the water molecules surround the ions and separate them from the lattice. Now the ions are in the aqueous state and invisible. e. Once this is established, ask why temperature affects this process. Lead students to see that at higher temperatures the water molecules have more energy and are moving faster. At the same time, the potassium chloride lattice has more energy as well. The extra energy makes is easier for the water molecules to separate the potassium and chloride ions. Therefore, fewer water molecules are needed to separate the particles and the amount of solute dissolved increases. f. Turn now to the analysis of the solubility curve that the students produced. Ask students what the solubility line represents. This is the combination of temperature and amount of solute at saturation. Below the line the solution is unsaturated. Above the line the solution is saturated and there are visible undissolved solids. One of the conclusion questions addresses extrapolation of the curve by asking students for solubility at temperatures outside of the range of data collected. Students may have difficulty understanding how the units in the vertical axis in the chart. The units are grams of solute (KCl) per 100 grams of solvent (water). A question in the student section addresses this understanding by checking on other amounts of solvent. Another question in the conclusion section addresses calculating how much solute precipitates if a solution is cooled down. Feel free to add more questions such as this which enforce graphical analysis. g. Two extension questions are given at the end for students to apply their

	understanding of the situation to real life applications. One deals with the solubility of gases - carbon dioxide in soda. The question begins by telling students that the opposite trend is observed when dealing with the solubility of gases. Explain to students that gases would rather escape the liquid and they are lightly attracted to the solvent particles. Increasing the temperature will help the particles escape the attraction and leave the liquid phase.

Extension:

- Gizmo: Solubility and Temperature

Student

Solubility Curve of KCl

NGSSS:
SC.912.P.8.2 Differentiate between physical and chemical properties and physical and chemical changes.
SC.912.P.8.11 Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH.
SC.912.L.18.12 Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.

Background: A homogeneous mixture of a solute in a solvent is called a solution. If the solute is originally a solid, the solvent is able to separate the particles of the solid to the point that the solid disappears from view. An unsaturated solution is capable of dissolving additional solute for a given amount of solvent because there are free solvent molecules available to do the dissolving. Molecules of the solvent surround particles of the solute as they separate them. When all the solvent particles are "busy" surrounding solute particles no more solute can dissolve. This is called a saturated solution. Any additional solute added to a saturated solution will collect on the bottom of the container and remain undissolved. Think of adding sugar to lemonade. At the beginning all the sugar will dissolve but at some point no more sugar will dissolve and the extra sugar just sits in the bottom. The amount of solute that can be dissolved in a given amount of solvent at a specific temperature and pressure is defined as the solubility of the solute. Solubility is dependent upon temperature. You can dissolve more sugar in hot lemonade than in cold lemonade. In this activity, you will determine the solubility of a salt at different temperatures and will plot a solubility curve for the solute.

Purpose of Lab/Activity:
- To determine the solubility of a solute, potassium chloride (KCl), in water as the temperature of the solution is changed.

Safety:
- Always wear safety goggles and a lab apron.
- Never taste any substance used in the lab.
- Test tube and evaporating dish may be cause burns
- Use caution around hot items.

Vocabulary: Solubility, solution, saturated, unsaturated, homogeneous, solubility curve, supersaturated.

Materials (per group):
- potassium chloride (KCl)
- distilled water
- balance
- evaporating dish (or 100-ml beaker)
- 25-ml graduated cylinder
- watch glass
- 250 or 400 ml beaker
- hot plate or burner with ring stand, 2 rings & wire gauze
- test tube (18X150 mm)
- utility clamp
- glass stirring rod
- thermometer
- funnel
- cotton wadding
- tongs &/or hot mitts
- graph paper

Student

Procedures:

1. Your teacher will assign your group a temperature between 20ºC and 90ºC.
2. Determine the mass of a clean, dry evaporating dish (or 100 ml beaker) with watch glass cover. Set aside.
3. Fill the large 250 or 400 ml beaker with water ½ way and place on hot plate to heat.
4. Put 15 ml of distilled water in the test tube and add about 10 g of KCl. Immerse the test tube in the large (250 ml) beaker.
5. Place the thermometer in the large beaker and heat the water until it reaches your assigned temperature. Maintain this temperature for 10 minutes, stirring every few minutes and rechecking the temperature.
6. Set up a funnel for filtering the solution, using a small wad of cotton instead of filter paper, placing the previously weighed evaporating dish (or 100 ml beaker) below the funnel.
7. Remove the test tube from the water bath, being careful that any solid at the bottom of the test tube is undisturbed. Decant about half of the solution into the funnel.
8. Weigh the evaporating dish, watch glass, cover and contents when filtering is complete.
9. Evaporate the water from the solution by heating rapidly at first and then more slowly. Start the evaporation without the watch glass and then cover the evaporating dish with the watch glass to prevent loss of KCl by spattering.
10. After the evaporating dish has cooled, measure the mass again. Reheat until the mass changes by less than 0.02 g.
11. Cleanup and Disposal:
    a. Turn off the hot plate and allow it to cool.
    b. Make sure all glassware is cool before emptying the contents.
    c. Dissolve all the KCl with plenty of water and flush down the drain
    d. Return all lab equipment to its proper place.
    e. Clean up your work area.

Observations/Data:

1. Record your data calculation answers in Table 1.
2. Record class data in Table 2
3. Make a line graph of the solubility of KCl in grams KCl/100 g water (Y-axis) versus the temperature in ºC (X-axis).

Table 1 - Individual Group Data

Assigned Temperature	
Mass of evaporating dish and cover	
Mass of evaporating dish and cover plus KCl solution	
Mass of KCl solution	
Mass of evaporating dish and cover plus dry KCl	
Mass of dry KCl	
Mass of water that was in solution	
Grams KCl in one g water	
Grams KCl in 100 g water	

Student

Table 2 - Class Data

Temperature (ºC)	Mass of KCl per 100 g water

Conclusion:

1. Describe your findings on the effect of temperature on the solubility of KCl.
2. Explain, at the particle level, why changes in temperature affect solubility?
3. Using the plot you made, predict the solubility of KCl in water at 15°C and 95°C
4. A saturated solution of potassium chloride in 50 g of water at 70°C is cooled to 30°C. How much solute will precipitate out of the solution?
5. If you wish to fully dissolve 500 grams of KCl in a liter of water, at what temperature should the solution be?
6. In a dishwasher, the temperature of the water is very hot. Explain why it is better to use hot water in a dishwasher rather than cold water.
7. Unlike solids for which solubility in a liquid generally increases with increasing temperature, the solubility of a gas in a liquid usually decreases as the temperature increases. Knowing this, explain why you should never heat a can containing a carbonated soft drink.

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