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ABSTRACT

This course of study is aligned with the California State Science Framework and provides students with the physics content needed to become scientifically and technologically literate and prepared for post-secondary science education. Framework themes incorporated into the course of study include patterns of change, evolution, energy, stability, systems and interaction, and scale and structure. The course of study is divided into four sections. The first section provides an overview of the course and includes a course description, representative objectives, a time line, and the sequence of instructional units. The second section presents the course's five instructional units and enumerates the required concepts and skills to be taught. The first unit on mechanics is covered in the first semester. The four units for the second semester include heat and thermodynamics; electricity, magnetism, and electromagnetism; light and optics; and modern physics. The third section on lesson planning discusses various teaching strategies that foster scientific ways of thinking and encourage student creativity and curiosity. Five sample lesson plans identifying specific objectives, instructional activities, practice formats, individual learner differences, and evaluation methods are provided. Twenty-six experiments concerning concepts covered in the five units are included. The fourth section contains three appendices: a list of 37 resources; a list of the standards for Physical Science from the "Model Curriculum Standards, Grades Nine through Twelve"; and a statement on physics preparation expected of entering freshman in the State of California. (MDH)

PHYSICS AB

A COURSE OF STUDY

Los Angeles Unified School District
Office of Secondary Instruction
Publication No. SC-953

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ADDITIONAL EXPERIMENTS (Cont.)

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FOREWORD

Physics AB is designed to provide students with the knowledge and skills to become scientifically and technologically literate citizens while preparing them for post-secondary science education. In Physics AB, students learn that science is (1) relevant to every aspect of contemporary society (2) a process used to understand what happens in the universe, and (3) a body of knowledge of interconnected principles, laws, and theories that explain the known universe and our relationship to it. The study of physics emphasizes physical matter and energy in the areas of dynamics, light, heat, electricity, magnetism, sound, and atomic structure.

This course of study is aligned with the California State Science Framework and provides the content of physics and incorporates the larger themes and ideas which permeate all science content areas. Framework themes incorporated in the course of study include patterns of change, evolution, energy, stability, systems and interaction, and scale and structure.

Physics teachers have the responsibility of teaching scientific and technological literacy by focusing on the interrelationships among science, mathematics, technology, and contemporary society. Scientific ways of thinking should be fostered; motivational aspects of the laboratory experience should be emphasized; and the development of problem-solving skills should not be limited to mathematical solutions, but should be based on observations, experience, demonstrations, and laboratory investigations. Effective teaching strategies in Physics AB include introducing topics with questions about phenomena or experiences, rather than answers to be learned. Teachers are expected to actively engage students in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes.

This course provides teachers with the opportunity to foster scientific curiosity and creativity as students journey on the road to scientific and technological literacy.

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GERALD GARNER
Secondary Science Specialist
Office of Secondary Instruction

ROSALYN S. HEYMAN
Assistant Superintendent
Office of Secondary Instruction

APPROVED:

PAUL M. POSSEMATO
Associate Superintendent
Instruction

INTRODUCTION

This course of study is divided into four sections. Section I provides an Overview of Physics AB which includes a course description, representative objectives, a time line, and the sequence of instructional units.

Section II, Instructional Units, provides teachers with all of the required concepts and skills to be taught for Physics AB. Preceding the five instructional units, which are organized by content topics, is an introductory unit entitled "Skills and Concepts to be Developed and Incorporated into all Units of Physics AB." The skills and concepts in the introductory unit are to be incorporated into each of the five instructional units. Topics preceded by an asterisk are included to enrich the basic curriculum. These topics are particularly appropriate for an honors course.

Section III provides teachers with strategies for lesson planning and the delivery of the Physics AB curriculum. Included in this section are sample lesson plans for each of the five instructional units.

Section IV, the Appendices, provides a bibliography containing resources for additional experiments, and includes sample demonstrations, curriculum guides, video sources, computer simulation software, and professional organizations and meetings for physics teachers. Appendices B and C enable the teacher to relate the goals and objectives of Physics AB to corresponding listings in the State of California Model Curriculum Standards, Grades Nine Through Twelve: Physical Science, 1985 and the UC and CSU "Statement on Physics Preparation Expected of Entering Freshmen in the State of California, 1986."

SECTION I

OVERVIEW

COURSE DESCRIPTION AND REPRESENTATIVE OBJECTIVES

PHYSICS AB (Annual Course--Grades 11-12. Prerequisites: Algebra 2AB, Biology AB or equivalent, Chemistry AB or equivalent. Emphasis: Physical Science)

36-15-01 Physics A
36-15-02 Physics B

Course Description

The major emphasis of this course is to develop scientific attitudes and skills used in critical thinking, and the use of general principles in solution of problems through laboratory investigation. Meets the grade 9-12 District physical science requirement. Meets the University of California entrance requirement for one year of laboratory science.

Representative Objectives

According to his or her present capacities, the student grows in the ability to:

- Assemble and use laboratory apparatus, tools, and materials skillfully, with attention to safety precautions.
- Use empirical and mathematical relationships to solve quantitative problems in physics.
- Demonstrate manipulative skills in laboratory work that results in data.
- Interpret data and draw conclusions based on data and calculations.
- Identify the nature and effects of forces and formulate relationships between forces and motion.
- Interpret a pattern of wave transfer and energy.

Application of Basic Skills

Provides an opportunity for students to demonstrate basic skills in areas of speaking and listening, writing, reading, and computation. Examples of these skills are:

Speaking and Listening

- Gather information from the instructor and from audiovisual media by watching and listening.
- Participate in group discussions.
- Gather information from the community for classroom presentations and discussions.

Writing

- Examine and evaluate major concepts.
- Write a scientific paper using the scientific method.
- Draw inferences from the content.
- Apply data from reading to practical problems.
- Make and substantiate hypotheses and generalizations.

Reading

- Identify main ideas.
- Become familiar with technical vocabulary.
- Read symbols, abbreviations, and formulas.
- Understand and interpret graphs and tables.
- Follow directions in laboratory work.
- Organize ideas from reading.
- Utilize sources to locate materials.

Computation

- Calculate solutions to problems using the basic operations of mathematical skills.
- Use a calculator when appropriate.
- Use the cognitive process necessary to solve problems.

Performance Skills

The student will:

- Gather needed information which has been generated by others from a variety of sources appropriate to his or her ability level.
- Record observations accurately and organize data and ideas in ways that improve their usefulness.
- Communicate with others in a manner that is consistent with knowledge.
- Use the metric system effectively.
- Apply appropriate mathematical concepts and skills in interpreting data and in solving problems.

Instructional Units

Unit One:	Mechanics
Unit Two:	Heat and Thermodynamics
Unit Three:	Electricity, Magnetism, and Electromagnetism
Unit Four:	Light and Optics
Unit Five:	Modern Physics

TIME LINE AND SEQUENCE OF UNITS

FIRST SEMESTER		NUMBER OF DAYS
UNIT ONE	MECHANICS	
Topic A	Metric System and Measurements	5
Topic B	Proportion and Scaling	5
Topic C	Kinematics in One Dimension, Vectors	10
Topic D	Kinematics in Two Dimensions	8
Topic E	Dynamics	13
Topic F	Motion in the Heavens/Universal Gravitation	5
Topic G	Conservation of Energy	12
Topic H	Linear Momentum Conservation	12
Topic I	Angular Momentum Conservation*	5
Topic J	Harmonic Motion/Resonance*	5
Topic K	Fluids*	5
Topic L	Mechanical Waves	5
	Total	90

SECOND SEMESTER		NUMBER OF DAYS
UNIT TWO	HEAT AND THERMODYNAMICS	
Topic A	Heat and Temperature	3
Topic B	Heat Exchange and Transfer	3
Topic C	Gas Laws	3
Topic D	Kinetic Theory	3
Topic E	Laws of Thermodynamics*	3
UNIT THREE	ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM	
Topic A	Static Electricity/Coulomb's Law	5
Topic B	Electric Fields/Electric Potential	4
Topic C	Current/Simple Circuits/Ohm's Law	5
Topic D	Capacitance*	5
Topic E	Magnetism	4
Topic F	Electromagnetic Induction	10
Topic G	Electromagnetic Waves	2
UNIT FOUR	LIGHT AND OPTICS	
Topic A	Ray Optics	6
Topic B	Wave Nature of Light	10
Topic C	Color and Spectra	4
UNIT FIVE	MODERN PHYSICS	
Topic A	Special Relativity*	7
Topic B	General Relativity*	7
Topic C	Quantum Physics	3
Topic D	Nuclear Structure/Particle Physics*	2
Topic E	Radioactivity/Fission/Fusion	1
	Total	90

*Recommended for inclusion in an honors course, for enrichment, or at the discretion of the teacher depending on the background of the teacher or of the students.

SECTION II

INSTRUCTIONAL UNITS

SKILLS AND CONCEPTS TO BE DEVELOPED AND INCORPORATED INTO ALL UNITS OF PHYSICS AB

GOALS FOR ALL UNITS

Students will:

- Apply scientific methods and utilize higher levels of thinking skills in solving everyday problems.
- Learn to apply mathematical procedures to solve physics problems.
- Perform laboratory experiments carefully and safely.
- Prepare laboratory reports.
- Recognize the role of physics in human affairs.
- Understand applications of physics principles to our daily lives.

TOPICS COVERED IN ALL UNITS

A. Physics problem solving-skills
B. Scientific method
C. Laboratory skills
D. Science and human affairs

SKILLS AND CONCEPTS TO BE DEVELOPED AND INCORPORATED INTO ALL UNITS OF PHYSICS AB

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
A. Physics Problem-Solving Skills	
	-Recognize the physical variables associated with an observed phenomenon. -List and organize given information. -Where possible, diagram the situation depicted in a given problem. -Attempt to identify the physics principles, laws, ideas, definitions, etc., that may be involved in a given problem. -Interpret graphical information. -Apply appropriate mathematical concepts and skills in solving problems. -Make ballpark estimates within one order of magnitude.
B. Scientific Method	
	-Clearly state the problem under investigation. -Develop hypotheses. -Test the hypotheses by gathering and recording data and subsequently analyzing that data. -Based on the analysis of data, make conclusions as to the validity or nonvalidity of the original hypotheses. -Test the conclusions. -Modify or discard the original hypotheses.
C. Laboratory Skills	
	-Assemble and use laboratory apparatus, tools, and materials. -Accept responsibility for the safe and careful handling of laboratory materials and equipment. -Generate data by observing, measuring, recognizing, and identifying. -Use simple instruments to aid the senses in collecting data. -Distinguish between trial and error and controlled investigations. -Accept the need to repeat observations as a means of improving reliability.

SKILLS AND CONCEPTS TO BE DEVELOPED AND INCORPORATED INTO ALL UNITS OF PHYSICS AB

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
	-Organize observed data and display it so that it may be examined for relationships. -Interpret tabulated data and graphical information. -Apply appropriate mathematical concepts and skills in interpreting data. -Transfer spatial information to other forms (e.g., make the connection between an oscilloscope display and the voltage it represents). -Prepare laboratory reports.
D. Science and Human Affairs	
	-Be aware of the impact of physics laws, principles, and concepts on everyone (and everything) in our society. -Assess the various political, military, environmental, and health issues in a scientifically literate manner.

UNIT 1: MECHANICS

GOALS FOR THIS UNIT

Students will:

- Understand how and why objects move.
- Understand and apply Newton's Laws.
- Gain an appreciation of the significance of Newton's Laws.
- Explain motion on the basis of conservation of linear momentum, conservation of energy (and conservation of angular momentum*).
- Appreciate the application of mathematics to a complete understanding of motion.
- Demonstrate knowledge and understanding of the concepts outlined in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.
- Exhibit the skills described in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.

TOPICS COVERED IN THIS UNIT	NUMBER OF DAYS
A. Metric System and Measurements	5
B. Proportion and Scaling	5
C. Kinematics in One Dimension, Vectors	10
D. Kinematics in Two Dimensions	8
E. Dynamics	13
F. Motion in the Heavens/Universal Gravitation	5
G. Conservation of Energy	12
H. Linear Momentum Conservation	12
*I. Angular Momentum Conservation	5
*J. Harmonic Motion/Resonance	5
*K. Fluids	5
L. Mechanical Waves	5
Total	90

*Topics preceded by an asterisk are those which may not necessarily need to be included in a standard course of Physics AB. They may be included at the option of the teacher to enrich the students' backgrounds in the specific topics, depending on the text in use and the particular interests of the teacher. These topics may be included in an honors course.

UNIT 1: MECHANICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
A. METRIC SYSTEM AND MEASUREMENTS	**(5 Days)**
1. Fundamental units	-Name the fundamental SI units (International System of Units) for length, time, and mass. -Describe the fundamental SI units in terms of their relationship to units commonly used in everyday life.
2. Derived units	-Distinguish between fundamental and derived units.
3. Orders of magnitude scientific notation	-Use orders of magnitude and scientific notation to describe physical data. -Make order of magnitude estimates and approximations.
4. Significant figures, accuracy, measurements	-Correctly apply the rules for significant figures and accuracy. -Use scientific notation, significant figures, and accuracy considerations as a means of stating the precision of measurements. -Measure lengths, masses, and time intervals with minimal error. -Calculate percent error and percent differences in length, mass, and time measurements.
5. Unit analysis, dimensional analysis	-Use unit and dimensional analysis to test the validity of formula, the solutions of problems, and so forth.
B. PROPORTION AND SCALING	**(5 Days)**
1. Direct and indirect relationships and proportions	-Recognize direct and inverse mathematical relationships among physical variables. -Recognize direct and inverse relationships on graphs. -Predict mathematical relationships by graphing functions of physical variables which yield straight lines through the origin.

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SUGGESTED RESOURCES AND ACTIVITIES

NOTE: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

A3 Experiment 1: Size of a Molecule, page 111.

B1 Experiment 2: The Analysis of an Experiment, page 113.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
2. Scaling laws, Area α Length^2, Volume α Length^3 Mass α Length^3	-Employ scaling relationships to calculate area, volume, mass, and weight ratios of similar geometric shapes.
Weight α Length^3 Strength α Cross-Sectional Area α Length^2, Strength to Weight ratio	-Calculate the relative strengths of structures and strength to weight ratios to determine size limits of objects and living things.
C. KINEMATICS IN ONE DIMENSION, VECTORS	**(10 Days)**
1. Distance, position, displacement, speed, velocity, acceleration	-Distinguish among the kinematic variables: distance, position, displacement, speed, velocity, acceleration.
2. Average velocity, average acceleration, instantaneous velocity, instantaneous acceleration	-Define and calculate average velocity and average acceleration of moving bodies. -Distinguish between instantaneous velocity and average velocity; instantaneous acceleration and average acceleration.
3. Graphs of distance vs. time, velocity vs. time, acceleration vs. time	-Analyze motion by graphing distance vs. time, velocity vs. time, acceleration vs. time. -Interpret the physical meaning of the slope of d vs. t graphs and v vs. t graphs. -Interpret the physical meaning of the area under v vs. t graphs and a vs. t graphs.
4. Vectors and scalars	-Represent physical quantities using vectors and scalars. -Distinguish between scalar and vector quantities. -Add and subtract vectors geometrically. *-Add and subtract vectors analytically. -Multiply vectors by scalars. -Resolve vectors into components. *-Utilize unit vectors. *-Evaluate dot and cross products of vectors.

SUGGESTED RESOURCES AND ACTIVITIES

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C4 Physics - Teach to Learn, Module 4: "Vectors"; teacher-directed computer simulations; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
5. Kinematic equations $x = v_0t + \frac{1}{2}at^2$ $v = v_0 + at$ $v^2 = v_0^2 + 2ax$	-Apply the kinematic equations of motion for uniformly accelerated objects. *-Derive the kinematic equations from previously learned basic definitions of average velocity and acceleration.
6. Free fall	-Apply the kinematic equations for objects accelerating near the surface of the earth where: $a = -g = -9.8\ m/s^2$, in vacuum.
D. KINEMATICS IN TWO DIMENSIONS	**(8 Days)**
Projectile motion	-Describe the path of a projectile near the surface of the earth. -Apply the kinematic equations to the problem of a projectile's motion near the surface of the earth. -Recognize the independence of the vertical and horizontal components of the motion of a projectile. -Qualitatively describe the affects of air resistance on the path of a projectile.
E. DYNAMICS	**(13 Days)**
1. Inertia, mass	-Define inertia. -Define mass as a measure of the inertia of an object at rest.
2. Principle or Law of Inertia (Newton's First Law)	-State and give examples of the Law of Inertia. -Place Galileo and the concept of inertia in historical context.
3. Force	-Define force.
4. Newton's Second Law $\vec{F} = m\vec{a}$	-Recognize that a net, unbalanced force acting on an object produces an acceleration in the same direction as that force. -Identify the SI and English units of force. -Demonstrate an understanding of the vector nature of forces and the meaning of net force.

SUGGESTED RESOURCES AND ACTIVITIES

NOTE: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

C5 Sample Lesson 1: Kinematic Equations, page 101.

C5 Experiment 3: Constant Acceleration: Galileo's Inclines, page 115.

C5 Physics - Teach to Learn, Module 2: "Kinematics"; teacher-directed computer simulations; see Appendix A.

C5 The Mechanical Universe High School Adaptation: "The Law of Falling Bodies"; demonstrations, video, activities, evaluation; see Appendix A.

C6 Physics - Teach to Learn, Module 3: "Free Fall"; teacher-directed computer simulations; see Appendix A.

D Experiment 4: Projectile Target, page 117.

D Physics - Teach to Learn, Module 5: "Projectile Motion"; teacher-directed computer simulations; see Appendix A.

E1 Physics - Teach to Learn, Module 1: "Inertia in Curvilinear Motion"; teacher-directed computer simulations; see Appendix A.

E1 - E2 The Mechanical Universe High School Adaptation: "Inertia"; demonstrations, video, activities, evaluation; see Appendix A.

UNIT 1: MECHANICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
5. Mass, weight	-Define weight. -Distinguish between mass and weight.
6. Kg, slugs N, pounds	-Contrast the SI and English units for weight and mass.
7. Action and Reaction (Newton's Third Law) $\vec{F}_{1,2} = -\vec{F}_{2,1}$	-State and provide examples of the law of action and reaction. -Identify action-reaction pairs of forces and recognize that they operate on pairs of bodies.
* 8. Static and kinetic friction, $f = \mu N$, coefficient of friction	-Distinguish between static and kinetic friction. -Recognize the empirical nature of friction.
9. Newton's Laws of Motion	-Predict the motions and changes in motions of objects using Newton's three laws of motions. -Place Newton and his laws within historical context. -Apply Newton's Laws of Motion to the following specific systems: a. masses on inclines, without friction (and with friction.*) b. bodies in elevators. c. objects in equilibrium. d. Atwood's machines. e. bodies moving at terminal velocity.
10. Hookes' Law $F_{spring} = - kx$	-State Hookes' Law and apply it to the case of a mass oscillating on a spring.
11. Uniform Circular Motion (UCM), centripetal force, centrifugal force $a_c = v^2/R = 4\pi^2R/T^2$ $F_c = ma_c$	-State and explain the conditions for UCM. -List and apply the equations which govern UCM. *-Derive the equations for centripetal acceleration. -Describe the relationships among the radius, velocity, and acceleration vectors in UCM. -Distinguish between the terms centripetal and centrifugal forces and accelerations.
*12. Frames of reference, inertial and accelerated	-Relate centripetal and centrifugal forces and acceleration to the concept of frames of reference. -Distinguish between an inertial and a noninertial (accelerating) reference frame.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

E7 The Mechanical Universe High School Adaptation: "Newton's Laws"; demonstrations, video, activities, evaluation; see Appendix A.

E8 Experiment 6: Static and Kinetic Friction, page 121.

E9 Physics - Teach to Learn, Module 6: "Dynamics"; teacher-directed computer simulations; see Appendix A.

E11 Experiment 5: Centripetal Force and Acceleration, page 119.

E11 The Mechanical Universe High School Adaptation: "Motion in Circles"; demonstrations, video, activities, evaluation; see Appendix A.

E11 Physics - Teach to Learn, Module 7: "Circular Motion--Dynamics"; teacher-directed computer simulations; see Appendix A.

E12 Film: "PSSC Frames of Reference"; see Catalog of Films for Secondary and Adult Levels, Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
	-Recognize that the descriptions of motion differ when viewed from different frames of reference.
*13. Torque $\tau = r_{\perp}F = rF_{\perp}$ $*\vec{\tau} = \vec{r} \times \vec{F}$	-Define torque and identify its SI units. *-Define torque as a vector cross product. -Identify situations where torques are acting. -Solve problems involving rotational equilibrium.
*14. Simple machines	-Describe and predict the functions of simple machines such as levers as illustrations of Newton's Laws.

F. MOTION IN THE HEAVENS/UNIVERSAL GRAVITATION **(5 Days)**

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
1. History	-Describe the contributions of Plato, Aristotle, Ptolemy, Copernicus, Brahe, Kepler, and Galileo to the development of astronomy and physics.
2. Kepler's Laws R^3/T^2 = constant	-State Kepler's three laws of planetary motion. -Use Kepler's Third Law tq predict time periods and average orbital radii for planets around the sun or any orbiting object around a central body.
3. Newton's Law of Universal Gravitation $F = Gm_1m_2/r^2$ $* \vec{F} = Gm_1m_2/r^2 \hat{r}$	-State and apply Newton's Law of Universal Gravitation in scalar (and unit vector form.*) -Discuss the inverse square nature of Newton's Law of Universal Gravitation. -Describe orbital motion in terms of the laws of universal gravitation and inertia. -Calculate the orbital speed and period of motion of a satellite around a central body. -Calculate the mass of a central body being orbited. -Show how Newton derived Kepler's Third Law. -Relate the fall of an apple on earth to the motion of the moon around earth. -Assess the significance of Newton's Law of Universal Gravitation.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

F2 Experiment 7: Planetary Harmony, page 123.

F2 The Mechanical Universe High School Adaptation: "Kepler's Laws"; demonstrations, video, activities, evaluation; see Appendix A.

F2 Physics - Teach to Learn, Module 19: "Kepler's Laws"; teacher-directed computer simulations; see Appendix A.

F3 The Mechanical Universe High School Adaptation: "The Apple and the Moon"; demonstrations, video, activities, evaluation; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
G. CONSERVATION OF ENERGY	**(12 Days)**
1. Work	-Define work in the proper scientific sense. -State the SI units of work.
$W = F_{\parallel} d$	-State the conditions for using the work definition: $W = F_{\parallel}d$.
* $W = \vec{F} \cdot \vec{d}$	*-Define work as a vector dot product. -Calculate work from the area under a F vs. d graph.
2. Kinetic energy	-Define kinetic energy and state the SI units. -Give examples of kinetic energy.
3. Potential energy	-Define potential energy. -Give examples of potential energy. -Recognize that work is done when energy is transferred from one system to another.
4. Gravitational potential energy: near earth: $\Delta U = mgh$	-Use the equations for computing changes in gravitational energy near the surface of the earth and in general for any distance from earth's center out, to infinity.
in general: $U = -Gm_1m_2/r$	-Recognize the arbitrary nature of the zero level or base of gravitational potential energy.
5. Energy stored in a linear spring $U = kx^2/2$	-Calculate the potential energy stored in a compressed or extended spring.
6. Conservation of Energy	-State and apply the law of conservation of energy.
$E = mc^2$	-Use the Einstein relationship $E=mc^2$ to include matter in the law of conservation of energy. -Include other forms of energy such as heat, sound, and light in the conservation of energy consideration. -Recognize that it is changes or transformations in energy that are important rather than energy alone. *-Relate the Law of Conservation of Energy to conserving resources.
* 7. Gravitational binding energy, escape velocity	-Compute the gravitational binding energy for an object at distance r from the center of the earth (or other central body). -Compute the gravitational binding energy for an object in an orbit of radius r about the earth (or other central body). -Calculate escape velocities.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

G6 Experiment 8: Potential and Kinetic Energies for a Swinging Weight, page 125.

G6 The Mechanical Universe High School Adaptation: "Conservation of Energy"; demonstrations, video, activities, evaluation; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
* 8. Navigation in space, transfer orbit, launch opportunity, launch window, gravity assist	-Explain and justify the use of transfer orbits for interplanetary travel. -Describe how launch opportunity is related to planetary geometry. -Diagram and distinguish between launch windows to inner and outer planets. -Describe the use of a gravity assist in space travel.

H. LINEAR MOMENTUM CONSERVATION (12 Days)

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
1. Linear momentum	-Define linear momentum and state its SI units. -Identify the vector nature of momentum.
2. Impulse = $F_{ave}\ \Delta t$	-Define impulse and contrast its technical definition with its colloquial usage.
3. Force vs. time graph	-Explain the conditions under which impulse can be computed by $F\Delta t$. -Explain the meaning of the area under a F vs. t graph; calculate the area by approximation.
4. $\vec{F}\ \Delta t = \Delta \vec{p} = m\ \Delta \vec{v}$	-Demonstrate the equivalence of impulse to the change in momentum.
5. A. $\vec{p}$ = constant if $\vec{F} = 0$ B. $\vec{F} = \Delta \vec{p} / \Delta t$ C. $\Delta \vec{p}_{1,2} = - \Delta \vec{p}_{2,1}$	-Restate Newton's Three Laws of Motion in terms of momentum.
6. Conservation of linear momentum, center of mass, closed system	-State and explain how Newton's Laws are really a statement of conservation of linear momentum. -Define center of mass and discuss the relationship of momentum conservation to the motion of the center of mass of a system. -Identify what is meant by a closed system. -Recognize that the total momentum of a closed system is constant though the momenta of bodies within that system may be changing.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

G8 <u>The Mechanical Universe High School Adaptation</u>: "Navigating in Space"; demonstrations, video, activities, evaluation; see Appendix A.

H6 Experiment 9: Conservation of Linear Momentum: An Explosion, page 127.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
7. Elastic collisions and inelastic collisions in one and two dimensions	-Identify the conditions necessary for an elastic collision. -Compare and contrast elastic and inelastic collisions. -Apply conservation of linear momentum and conservation of kinetic energy to one- and two-dimensional elastic collisons. -Predict the final velocities for colliding objects. -Assess the significance of the study of collisions to our understanding of the structure of matter and the forces involved.

I. ANGULAR MOMENTUM CONSERVATION (5 Days)

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
1. Rotational inertia (moment of inertia)	-Define rotational inertia. -Explain how rotational inertia is analogous to mass (inertia) but also incorporates how the mass is distributed in the body relative to some axis of rotation.
2. Angular velocity, angular acceleration	-Define angular velocity and angular acceleration.
* 3. Vector cross products	-State the definition of a cross product.
* 4. Right hand rule	-Compute vector cross products and identify the direction of the resulting vector using the right hand rule.
* 5. Torque $\vec{\tau} = \vec{r} \times \vec{F}$ $\tau \times I\alpha$	-Define torque and state its SI units. -Identify torque as a cross product. -Show that torque can be expressed as $I\alpha$.
6. Angular momentum $\vec{L} = \vec{r} \times \vec{p}$ $L = I\omega$	-Define angular momentum and state its SI units. *-Identify angular momentum as a vector cross product. -Show that angular momentum can be given by $I\omega$.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

H7 The Mechanical Universe High School Adaptation: "Conservation of Momentum"; demonstrations, video, activities, evaluation; see Appendix A.

H7 Physics - Teach - to Learn, Module 8: "Collisions"; teacher-directed computer simulations; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
7. Newton's Laws for rotation 1. $\vec{L}$ = constant 2. $\vec{\tau} = \Delta\vec{L}/\Delta\vec{t}$ 3. $\Delta\vec{L}_{1,2} = -\Delta\vec{L}_{2,1}$	-State Newton's three laws for rotation and demonstrate how they are analogous to Newton's three laws expressed in terms of linear momentum.
8. Conservation of angular momentum	-Explain how Newton's Laws for rotation are really a statement of the conservation of angular momentum. -State examples of angular momentum conservation such as: 1. planetary motion. 2. bathtub and hurricane vorticies. 3. helicopters. 4. spinning ice skaters. 5. shape and motion of the galaxy.

J. **HARMONIC MOTION/RESONANCE** **(5 Days)**

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
1. Harmonic motion	-Identify examples of harmonic motion in nature.
2. Simple harmonic motion	-Define simple harmonic motion.
3. Mass on spring, Hooke's Law	-Describe the motion of a mass on a spring. -Analyze the direction of displacement and force on a mass oscillating on a spring. *-Use F = ma and Hooke's Law to deduce and/or recognize the sine or cosine wave nature of simple harmonic motion.
4. Period of mass/spring system $T = 2\pi\sqrt{(m/k)}$	-Relate the period of the motion of a mass on a spring to the mechanical properties of the mass/spring system.
5. Simple harmonic motion and uniform circular motion	-Recognize simple harmonic motion as uniform circular motion viewed edgewise.
6. Simple pendulum	-Describe the motion of a simple pendulum as being (very nearly) simple harmonic.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

I8 Mechanical Universe High School Adaptation: "Angular Momentum"; demonstrations, video, activities, evaluation; see Appendix A.

J5 Physics - Teach to Learn, Module 16: "Simple Harmonic Motion"; teacher-directed computer simulations; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
7. $T = 2\pi\sqrt{(l/g)}$	-Relate the period of a pendulum to the length of the pendulum.
8. Resonance	-Describe the phenomenon of resonance as nature's response to twanging a vibrating system. -Recognize the factors involved in establishing resonance in a system. -Provide examples of resonating systems such as: 1. a child on a swing. 2. aeolean harp. 3. shattering a wine glass. 4. Tacoma Narrows bridge. 5. sound box on a musical instrument. 6. buildings in earthquakes.
K. FLUIDS	(5 Days)
1. Pressure $P = F/A$	-Give a macroscopic definition of pressure. -Calculate pressure and demonstrate knowledge of the SI and other common pressure units.
2. Barometer	-Explain the construction and operation of a barometer.
3. Liquid pressure $P = P_0 + \rho gh$	-Calculate the pressure at depth in a liquid.
4. Pascal's Principle	-State and apply Pascal's Principle.
5. Archimedes' Principle, buoyancy	-Define buoyant force. -State and apply Archimedes' Principle.
6. Bernoulli's Principle	-Provide everyday examples of Bernoulli's Principle in action, such as: 1. operation of a perfume atomizer. 2. lift of an airfoil. 3. tacking a sailboat against the wind. 4. circulation of air in a gopher hole
7. Bernoulli's Equation $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$	-Explain how Bernoulli's Equation is really a statement of conservation of energy. -Apply Bernoulli's Equation.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

J7 Experiment 10: Pendulum, page 129.

J8 Mechanical Universe High School Adaptation: "Harmonic Motion"; demonstrations, video, activities, evaluation; see Appendix A.

K1 Experiment 11: Pressure vs. Force: The Weight of a Car, page 130.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
L. MECHANICAL WAVES	**(5 Days)**
1. Mechanical waves	-State the definition of a mechanical wave and list various wave phenomena in nature. -Recognize that a mechanical wave passes through a medium without any net motion of the particles of the medium. -Describe how mechanical waves may be created and how they transfer energy.
2. Transverse, longitudinal waves	-Categorize waves as transverse and longitudinal and distinguish between them.
3. Frequency, wavelength, amplitude, speed	-Define and describe wave properties of frequency, wavelength, speed and amplitude.
$\lambda f = v$	-Relate the speed of mechanical waves to their frequencies and wavelengths. -Compute wave speeds, frequencies, and wavelengths.
4. Sound waves, speed of sound, range of human hearing, sound intensity	-Describe how sound waves are longitudinal, mechanical waves. -Cite factors, which affect the speed of sound. -Experimentally determine the speed of sound. -Express the approximate frequency range for sound audible to humans. -Express sound intensity in decibels.
$dB = 10 \log I/I_0$	-Cite experimental evidence that sound energy is transferred by waves.
5. Principle of Superposition, standing waves, musical tones	-State and apply the Principle of Superposition of waves. -Demonstrate and explain the creation of standing wave patterns. -Related musical tones to standing and superimposed waves. -Describe the behavior of strings and columns of air when they produce musical sounds.
6. Doppler Effect for mechanical waves	-Explain the cause of the Doppler Effect -Describe situations in which the Doppler Effect occurs.
$f = f_s(v/(v \pm v_s))$	*-Use the Doppler Effect equations.
7. Shock waves, sonic booms	-Explain the conditions for production of shock waves. -Describe the production of a sonic boom

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

L3 The Mechanical Universe High School Adaptation: "Introduction to Waves"; demonstrations, video, activities, evaluation; see Appendix A.

L3-L4 Experiment 12: The Speed of Sound in Air, page 131.

L5 Physics - Teach to Learn, Module 9: "Superposition and Reflection of Pulses"; teacher-directed computer simulations; see Appendix A.

L5 Physics - Teach to Learn, Module 10: "Superposition and Reflection of Waves"; teacher-directed computer simulations; see Appendix A.

L6-L7 Physics - Teach to Learn, Module 17: "Doppler Effect and Shock Waves"; teacher-directed computer simulations; see Appendix A.

UNIT 2: HEAT AND THERMODYNAMICS

GOALS FOR THIS UNIT

Students will:

- Recognize that heat is a form of energy, the least usable form, which must be included in applying the conservation of energy principle.
- Understand how temperature is a measure of the average molecular motion (kinetic energy) of a sample of material.
- Become familiar with the absolute temperature scale.
- Appreciate the application of mathematics to a complete understanding of heat and thermodynamics.
- Demonstrate knowledge and understanding of the concepts outlined in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.
- Exhibit the skills described in the Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.

TOPICS COVERED IN THIS UNIT	NUMBER OF DAYS
A. Heat and Temperature	3
B. Heat Exchange and Transfer	3
C. Gas Laws	3
D. Kinetic Theory	3
*E. Laws of Thermodynamics	3
Total	15

*Topics preceded by an asterisk are those which may not necessarily need to be included in a standard course of Physics AB. They may be included at the option of the teacher to enrich the students' backgrounds in the specific topics, depending on the text in use and the particular interests of the teacher. These topics may be included in an honors course.

UNIT 2: HEAT AND THERMODYNAMICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
A. **HEAT AND TEMPERATURE**	**(3 Days)**
1. Heat, temperature	-Distinguish between heat and temperature.
2. Temperature scales, absolute zero	-Demonstrate familiarity with Fahrenheit, Celsius, and Kelvin temperature scales. -Recognize the Kelvin temperature scale as the true scale which measures from true or absolute zero.
3. The mechanical equivalent of heat, calories, joules	-Describe Joule's experiment for determining the mechanical equivalent of heat. -Express heat energy in calories and joules.
B. **HEAT EXCHANGE AND TRANSFER**	**(3 Days)**
1. Specific heat, latent heats, and phase changes	-Define specific heat and use it to calculate heat energy exchanges. -Define latent heats (fusion and vaporization) and state values for water. -Calculate heat energy transfers through latent heats. -Discuss the energy consideration which must be involved to explain changes in phase.
C. **GAS LAWS**	**(3 Days)**
1. Boyles $P \alpha 1/V$	-State and apply the gas laws of Boyles, Charles, and Gay-Lussac, and the Ideal Gas Law.
2. Charles $V \alpha T$	-Discuss the empirical nature of the gas laws.
3. Gay-Lussac $P \alpha T$	-Experimentally verify the relationships contained in the gas laws.
4. Ideal $PV = nkT$	-Determine absolute zero from extrapolation of data from gas laws experiments.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

A3 Sample Lesson 2: The Mechanical Equivalent of Heat, page 103.

A3 Experiment 13: The Mechanical Equivalent of Heat, page 132.

C1-C4 The Mechanical Universe High School Adaptation: "Temperature and the Gas Laws"; demonstrations, video, activities, evaluation; see Appendix A.

C2-C3 Experiment 14: Absolute Zero, page 133.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
D. KINETIC THEORY	**(3 Days)**
1. States of matter	-Describe the four states of matter.
2. Kinetic theory of matter, of gases	-List the assumptions of the kinetic theory of matter, gases.
3. $KE_{ave} = 3/2\ kT$	-Use Newton's Laws, the macroscopic definition of pressure, and the ideal gas law to obtain the relationship of absolute temperature and average kinetic energy of the molecules in a sample of gas.
4. Pressure, temperature	-Explain the phenomonen of pressure and temperature in a gas in terms of the kinetic theory.
5. Internal energy	-Recognize the average kinetic energy of molecules as one form of internal energy. (Another form is rotational energy of the molecules, which does not contribute to temperature changes.)
E. LAWS OF THERMODYNAMICS	**(3 Days)**
1. Laws of Thermodynamics	-State the Laws of Thermodynamics.
2. First Law of Thermodynamics, conservation of energy	-Recognize the first law of thermodynamics as a restatement of the law of conservation of energy.
3. Second Law of Thermodynamics: entropy	-Define entropy.
4. Heat engine, refrigerator, efficiency	-Explain the main point of the second law of thermodynamics. -Diagram a model of a basic heat engine and of a refrigerator. -Contrast the basic heat engine and the refrigerator with reference to the laws of thermodynamics. -Explain how a refrigerator can operate by expanding a gas. -Define efficiency of a basic heat engine. -Relate efficiency to the laws of thermodynamics.

SUGGESTED RESOURCES AND ACTIVITIES

UNIT 3: ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM

GOALS FOR THIS UNIT

Students will:

- Describe simple electrostatic phenomena in terms of electric fields and the effects the fields have on electric charges placed in them.
- Diagram, construct, and utilize simple electrical circuits.
- Describe how the magnetic properties of matter are ultimately linked to electricity.
- Understand the phenomenon of electromagnetic induction and appreciate that its utilization is the foundation of our modern society.
- Apply conservation of energy and conservation of charge to the overall explanation of electricity, magnetism, and their interaction.
- Appreciate the application of mathematics to a complete understanding of electricity and magnetism.
- Demonstrate knowledge and understanding of the concepts outlined in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.
- Exhibit the skills described in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.

TOPICS COVERED IN THIS UNIT		NUMBER OF DAYS
A. Static Electricity/Coulomb's Law		5
B. Electric Fields/Electric Potential		4
C. Current/Simple Circuits/Ohm's Law		5
*D. Capacitance		5
E. Magnetism		4
F. Electromagnetic Induction		10
G. Electromagnetic Waves		2
	Total	35

*Topics preceded by an asterisk are those which may not necessarily need to be included in a standard course of Physics AB. They may be included at the option of the teacher to enrich the students' backgrounds in the specific topics, depending on the text in use and the particular interests of the teacher. These topics may be included in an honors course.

UNIT 3: ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
A. **STATIC ELECTRICITY/ COULOMB'S LAW**	**(5 Days)**
1. Charge; law of charges	-Identify the two types of charge that exist in nature and explain the forces between like and unlike charges. -Describe charging by friction and identify the charge on a plastic rod rubbed with fur and a glass rod rubbed with silk.
2. Conservation of charge	-Incorporate the conservation of charge into the explanation of charging of materials.
3. Grounding	-Discuss and explain the phenomenon of grounding.
4. Electroscopes	-Explain the behavior of an electroscope.
5. Leyden jars	-Use a Leyden jar to store charge.
6. Lightening	-Demonstrate that charge will flow from areas of high to areas of low charge concentration. -Explain the phenomenon of lightening.
7. Millikan Experiment, quantization of charge	-Describe the Millikan Experiment. -Explain the method used by Millikan to determine the elementary charge. *-Perform the Millikan Experiment or a simulation of it. -Explain how the results of Millikan's experiment established the fact that charge is quantized.
8. Units of charge	-Name the SI unit of electric charge and define it in terms of the charge of an electron or a proton.
9. Coulomb's Law $F = K_e q_1 q_2 / r^2$ *$\vec{F} = K_e q_1 q_2 / r^2 \ \hat{r}$	-State and apply Coulomb's Law of Electric Force for point charges in scalar form and unit vector form. -Recognize the inverse square nature of Coulomb's Law. -Compare and contrast Coulomb's Law to the Law of Universal Gravitation. -Experimentally verify Coulomb's Law.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

A7 The Mechanical Universe High School Adaptation: "Millikan's Experiment"; demonstrations, video, activities, evaluation; see Appendix A.

A9 Film: "PSSC Coulomb's Law"; see Catalog of Films for Secondary and Adult Levels, Appendix A.

A9 Experiment 15: Coulomb's Law, page 135.

UNIT 3: ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
B. ELECTRIC FIELDS/ELECTRIC POTENTIAL	(4 Days)
1. Electric field, electric field strength $\vec{E} = \vec{F}/q$	-Define an electric field. -Discuss the concept of the electric field. -Mathematically express and calculate electric field strength for simple point charge distribution. -Illustrate the electric field patterns between parallel conducting plates and other simple charge geometries.
2. Electric potential energy, electric potential difference, voltage	-Define electric potential energy and electric potential difference (voltage) and identify the SI units of each.
C. CURRENT/SIMPLE CIRCUITS/ OHM'S LAW	(5 Days)
1. Current, conventional current	-Define current and conventional current -Identify the SI units of current.
2. Conductors, insulators, semiconductors	-Describe the characteristics of conductors, insulators, and semiconductors.
3. Resistance, resistivity $R = \rho l/A$	-Define resistance and identify its SI units. -List factors that affect resistance in a cylindrical conductor of length l, cross-sectional area A, and resistivity ρ.
4. Ohm's Law $V = IR$	-State and explain Ohm's Law. -Recognize that Ohm's Law is not a basic law of nature, but rather an empirical relationship for metallic conductors and certain other materials such as carbon resistors.
5. Simple DC circuits	-Diagram and construct simple DC circuits using appropriate circuit symbols and locating meters correctly. -Demonstrate knowledge and skill in the use of ammeters and voltmeters.
6. Resistors in series, resistors in parallel $R = R_1 + R_2 + \ldots + R_n$ $1/R = 1/R_1 + 1/R_2 + \ldots + 1/R_n$	-Apply Ohm's Law to solve for currents, voltages, and resistances in simple DC circuits. -Determine the equivalent resistances for resistors in parallel, in series, and combinations of these.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

B1 The Mechanical Universe High School Adaptation: "Electric Forces and Fields"; demonstrations, video, activities, evaluation; see Appendix A.

B1-B2 Physics - Teach to Learn, Module 17: "Charged Particles in Electric Fields"; teacher-directed computer simulations; see Appendix A.

B2 The Mechanical Universe High School Adaptation: "Equipotentials and Fields"; demonstrations, video, activities, evaluation; see Appendix A.

C6 Sample Lesson 3: Simple Circuits, page 105.

C6 Experiment 16: Simple DC Circuits, page 137.

C6 The Mechanical Universe High School Adaptation: "Simple DC Circuits"; demonstrations, video, activities, evaluation; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
* 7. Kirchoff's Rules	-Apply Kirchoff's Rules to the solution of more complicated arrangements of resistors in DC circuits.
8. Electric power	-Define electric power.
$P = IV$	-Derive the equations for calculating electric power.
$P = I^2R = V^2/R$	-Calculate the power delivered to a circuit and the power lost (Joule heating) in the resistances in the circuit.
9. Kilowatt hours (kwh)	-Define the kwh as a unit of energy = 3.6×10^6 and determine the cost of that energy.

D. CAPACITANCE (5 Days)

1. Capacitors, capacitance	-Name the parts of a capacitor and describe how varying geometry of plates affects the capacitance. -Identify a Leyden jar as a capacitor. -Describe how a capacitor stores electric charge.
$Q = CV$	-Define capacitance as the ratio of the magnitude of the charge on a plate to the voltage across the plates.
2. Capacitors in parallel and series	-Compute the equivalent capacitance of capacitors in series and in parallel.
$C = C_1 + C_2 + \dots + C_n$	
$1/C = 1/C_1 + 1/C_2 + \dots + 1/C_n$	
* 3. RC circuits	*-Describe how the charge, voltage, and current vary with time in the charging and discharging of a capacitor in an RC circuit.

E. MAGNETISM (4 Days)

1. Magnets	-List and qualitatively describe the magnetic aspects of lodestones, permanent magnets, bar magnets, and compass needles. -Make a permanent magnet.
2. N pole, S pole, law of magnetic poles	-Define a magnetic pole. -State the law of magnetic poles.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

E1-E14 The Mechanical Universe High School Adaptation: "Magnetic Fields"; demonstrations, video, activities, evaluation; see Appendix A.

UNIT 3: ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
3. Magnetic field, magnetic force $*F = K_m p_1 p_2 / r^2$	-Define and discuss the concept of a magnetic field in analogy with gravitational and electric fields. -Draw the fields of bar magnets and horseshoe magnets. -State the magnetic force law and compare it to those of gravity and electric forces.
4. Magnetic field strength, B, Tesla	-Represent the magnetic field strength as a vector quantity symbolized by B and identify the SI unit as tesla.
5. Oersted's discovery	-Describe Oersted's experiment and explain its significance.
6. B fields for a line of charge, ring of charge, a solenoid	-Describe the nature of and draw the B field of a straight line of charge, a ring of charge, and a solenoid.
7. Right hand rule	-Use the right hand rule to determine either current or direction of the field in a wire given one or the other.
8. Electromagnets	-Construct an electromagnet.
9. Ultimate source of magnetism	-Relate the existence of magnetic fields to moving charges or currents.
10. Dipoles, monopoles	-Explain that single magnetic poles (monopoles) are not observed in nature. Poles occur in N-S pairs called dipoles.
11. Earth's magnetic field	-Describe the nature of the earth's magnetic field. -Explain why the magnetic pole in our northern geographic hemisphere is actually a south magnetic pole and vice versa. -Explain auroual phenomenon.
12. Magnetic force on a line of current in an external magnetic field $F = IlB_{\perp}$	-Predict the magnitude and direction of the deflecting force on a wire carrying current across an external magnetic field.
$*\vec{F} = I\vec{l} \times \vec{B}$	*-Express the magnetic force on a current line as a cross product.
13. Magnetic force on a moving charge in an external magnetic field $F = qvB_{\perp}$	-Predict the magnitude and direction of the deflecting force on a charged object moving across an external magnetic field.
$*\vec{F} = q\vec{v} \times \vec{B}$	*-Express the magnetic force on a moving charge as a cross product.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

E6-E9 Experiment 17: The Magnetic Field of a Long, Straight, Current-Carrying Wire, page 138.

E6-E9 Experiment 18: Tangent Galvanometer, page 140.

E13 Physics - Teach to Learn, Module 15: "Charged Particles in Magnetic Fields"; teacher-directed computer simulations; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
14. Mass spectrometer	-Describe the basis of operation of a mass spectrometer.
F. ELECTROMAGNETIC INDUCTION	**(10 Days)**
1. Magnetic flux $\Phi = B_{\perp}A = BA_{\perp}$	-Define magnetic flux.
2. Faraday's Law, Lenz's Law $\varepsilon = -\Delta\Phi/\Delta t$	-State and explain Faraday's Law of Induction and Lenz's Law.
3. Induced current Induced voltage (emf)	-Define emf. -Describe the conditions necessary for the induction of an emf and a current in a conducting loop. -Given either the induced current direction or the action of the inducing field, determine the other.
4. AC and DC generators, motors	-Diagram and list the parts of an AC and a DC generator and describe the function of each part. -Compare and contrast generators and motors. -Draw graphs of Φ vs. t, ε vs. t, and I vs. t for AC and DC generators. -Use Faraday's law to understand and interpret graphs of induced voltage, induced current, and induced electric field as a function of time. -Explain and assess the significance of Faraday's Law.
5. AC transformers	-Diagram and describe the AC transformer -Explain the function of the AC transformer in terms of Faraday's Law. -Explain the primary coil to secondary coil ratio effect on voltage and current in solving transformer problems
6. Power generation, AC vs. DC	-Discuss the Edison-Tesla conflict regarding AC vs. DC power generation. -Describe the stages in a large scale electric transmission and distribution network. Include a description of the roles of transformers. -Explain the advantages of AC power transmission over DC power transmission

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

F5 The Mechanical Universe High School Adaptation: "Electromagnetic Induction"; demonstrations, video, activities, evaluation; see Appendix A.

F6 The Mechanical Universe High School Adaptation: "Alternating Currents"; demonstrations, video, activities, evaluation; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
7. AC frequency, peak and rms voltages, rms currents	-Compare and contrast AC power generation in the U.S. and European and Central and South American countries with regard to frequency. -Distinguish between peak and rms voltages and currents. -State and calculate peak and rms voltages for the U.S. and other countries.

G. ELECTROMAGNETIC WAVES (2 Days)

1. Accelerated charges, electromagnetic waves	-Outline the historical context of Maxwell's conception of EM waves. -Describe the generation of EM waves by accelerated charges. -Discuss the generation of EM waves in terms of an antennae/receiver system. -Describe light as arc EM disturbance using E and B vectors. -List the characteristics of CM waves, i.e. frequency, speed, wavelength, and transverse nature.
2. Electromagnetic spectrum	-Identify the commonly named regions of the electromagnetic spectrum.
3. Polarization	-Explain the phenomenon of polarization of electromagnetic waves. -Using H-sheet or polaroid material, polarize light.

SUGGESTED RESOURCES AND ACTIVITIES

UNIT 4: LIGHT AND OPTICS

GOALS FOR THIS UNIT

Students will:

- Understand how light can exhibit both wave and particle behavior.
- Use simple optical instruments and understand how the reflection, refraction, and diffraction properties of light explain their functioning.
- Recognize that light is ultimately a form of electromagnetic energy emitted by accelerated charges.
- Become aware of the existence of the electromagnetic spectrum and familiar with the properties of the various regions within it.
- Understand and appreciate the synthesis of electricity, magnetism, and optics that results in our modern understanding of light.
- Appreciate the application of mathematics to a complete understanding of light and optics.
- Demonstrate knowledge and understanding of the concepts outlined in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.
- Exhibit the skills described in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.

TOPICS COVERED IN THIS UNIT	NUMBER OF DAYS
A. Ray Optics	6
B. Wave Nature of Light	10
C. Color and Spectra	4
Total	20

UNIT 4: LIGHT AND OPTICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
A. RAY OPTICS	**(6 Days)**
1. Light rays	-Diagram the path of light beams using rays.
2. Reflection	-Demonstrate how the path of a beam of light may be changed by reflection. -Distinguish between diffuse and specular reflection.
3. Law of Reflection $\theta_i = \theta_R$	-State and apply the Law of Reflection. -Trace the path of a ray of light as it reflects from plane mirrors and curved surfaces.
4. Mirror images, real and virtual	-Experimentally and theoretically predict the location of the images formed using plane and parabolic mirrors. -Define what is meant by a real or virtual image. -Identify whether an image in a mirror is a real or a virtual image.
5. Refraction	-Demonstrate how the path of a beam of light may be changed by passing from one medium into another and identify this phenomonen as refraction.
6. Snell's Law, index of refraction $n_1\sin\theta_1 = n_2\sin\theta_2$	-State and apply Snell's Law of refraction. -Experimentally determine the index of refraction of transparent materials such as water and glass.
7. Total internal reflection, critical angle	-Investigate and explain the phenomenon of total internal reflection. -Calculate critical angles. -Use and discuss the use of fiber optics as an application of the phenomenon of total internal reflection.
8. Lenses; converging and diverging lenses, real and virtual images	-Trace the path of a ray of light through a single lens and through a combination of lenses. -Locate the images formed by lenses. -Identify whether a lens image is real or virtual. -Distinguish between converging and diverging lenses.
9. Near- and far-sightedness	-Relate the use of converging and diverging lenses to remedy vision problems such as near- and far-sightedness.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

A1-A7 Film: "PSSC Introduction to Optics," see Catalog of Films for Secondary and Adult Levels, Appendix A.

A5 Sample Lesson 4: Reflection and Refraction, page 107.

A5 Experiment 19: Reflection and Refraction, page 142.

A6 Physics - Teach to Learn, Module 11: "Speed of Light in Different Media"; teacher-directed computer simulations; see Appendix A.

A8-A14 Experiment 20: Lenses and the Refracting Telescope, page 145.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
*10. Thin lens equation $1/f = 1/o + 1/i$	-Apply the thin lens equation.
11. Prism dispersion	-Explain the phenomenon of dispersion in a prism. -Recognize that dispersion is really refraction where different colors of light refract differently.
12. ROYGBIV	-Identify the colors of the rainbow as the result of dispersion of white light. -Explain the production of a rainbow. -Observe and explain how any light source may be analysed as to its component colors using a prism.
*13. Scattering	-Recognize the phenomenon of scattering of light and explain why the sky is blue and sunsets are red.
14. Telescopes, microscopes	-Trace the path of light through a simple refracting telescope and through a Newtonian reflector. -Diagram, construct, and observe the images in a simple refracting telescope. -Compare and contrast reflecting and refracting telescopes. *-Describe the nature of the abberations and other image problems in telescopes. -Explain the operation and construction of a simple optical microscope.

B. WAVE NATURE OF LIGHT **(10 Days)**

1. Historical	-Discuss the historical development of a wave description of light behavior.
2. Mechanical wave analogies to light	-Observe and investigate reflection and refraction of one-dimensional waves on ropes or springs and relate to the behavior of light. -Observe and investigate the wave properties of light by comparing with two-dimensional water waves in ripple tanks.
3. Huygens constructions	-Explain the reflection and refraction of water (and light) waves using Huygens wave constructions.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

B1-B4 Physics - Teach to Learn, Module 12: "Refraction"; teacher-directed computer simulations; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
4. Refraction, Snell's Law $\sin\theta_1/\sin\theta_2 = \lambda_1/\lambda_2 = v_1/v_2$	-Observe the analogy of the passage of water waves from deep to shallow regions with the passage of light waves from less dense to more dense media. -Observe and recognize that refraction results in a change in the wavelength, not the frequency, of the refracting waves.
5. Interference, Young's Experiment, nodal lines	-Describe Young's double-slit experiment. -Explain how Young's Experiment provides incontrovertable evidence for the wave nature of light. -Identify nodal lines in an interference pattern. -Draw, observe, calculate, and predict the interference patterns produced by passing light of known wavelength through two slits of given separation. -Calculate unknown wavelengths by appropriate experimentation using interfering water waves and light waves.
6. Diffraction, gratings	-Define diffraction. -Experimentally observe interference of water waves in ripple tanks and of monochromatic light using various slit arrangements. -Compare and contrast the diffraction patterns in single and double-slit arrangements.

C. COLOR AND SPECTRA (4 Days)

1. Sources of light	-Identify light sources as luminous or nonluminous.
2. Spectra, emission, absorption, continuous	-Observe and distinguish among absorption, emission, and continuous spectra.
3. Color	-Describe how the color an object appears depends on the light it reflects. -Explain how a change of light source incident on an object can change the apparent color of that object.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

B5 Experiment 21: A Young's Type Experiment, page 146.

B5-B6 Physics - Teach to Learn, Module 13: "Interference"; teacher-directed computer-simulations; see Appendix A.

B5-B6 Experiment 22: Interference of Waves in a Ripple Tank, page 148.

B6 Experiment 23: Wavelength of Laser Light, page 150.

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TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
C. COLOR AND SPECTRA	**(4 Days)**
4. Primary colors, secondary colors	-List the three primary colors of light and describe how their various combinations produce secondary colors and white light. -List the three primary colors of pigments and explain how they mix to produce other colors.

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SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

C4 The Mechanical Universe High School Adaptation: "The Wave Nature of Light"; demonstrations, video, activities, evaluation; see Appendix A.

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UNIT 5: MODERN PHYSICS

GOALS FOR THIS UNIT

Students will:

- Appreciate the usefulness of classical physics in interpreting our world but understand its limitations in quantum and relativistic realms.
- Understand why atoms exist.
- Recognize that the conservation laws are the foundation of all realms of physics.
- Appreciate their knowledge and understanding of radioactivity, nuclear structure, and nuclear changes.
- Apply the scientific principles associated with nuclear changes to informed understanding of, and decisions about, technological developments.
- Appreciate the application of mathematics to a complete understanding of relativity, quantum, and nuclear physics.
- Demonstrate knowledge and understanding of the concepts outlined in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.
- Exhibit the skills described in Skills and Concepts to be Developed and Incorporated Into All Units of Physics AB.

TOPICS COVERED IN THIS UNIT		NUMBER OF DAYS
*A. Special Relativity		7
*B. General Relativity		7
C. Quantum Physics		3
*D. Nuclear Structure/Particle Physics		2
E. Radioactivity/Fission/Fusion		1
	Total	20

*Topics preceded by an asterisk are those which may not necessarily need to be included in a standard course of Physics AB. They may be included at the option of the teacher to enrich the students' backgrounds in the specific topics, depending on the text in use and the particular interests of the teacher. These topics may be included in an honors course.

UNIT 5: MODERN PHYSICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
***A. SPECIAL RELATIVITY**	**(7 Days)**
1. Michelson-Morley Experiment	-Explain the intent and outcome of the Michelson-Morley Experiment.
2. Postulates of Special Relativity; inertial reference frame	-State Einstein's Postulates of Special Relativity. -Define what is meant by an inertial reference frame.
3. Simultaneity	-Discuss the concept of simultaneity in light of Enstein's Postulates of Special Relativity.
4. Time dilation $t = t_0/\sqrt{(1 - v^2/c^2)}$	-Discuss the phenomenon of time dilation as a consequence of the postulates of special relativity. *-Derive and use the equation for time dilation.
* 5. Space-time diagrams	-Use space-time diagrams to predict the order of a series of events from the point of view of different inertial observers. -Use space-time diagrams to predict the relativity of clock measurements and lengths from the point of view of different inertial observers.
6. Length contraction $l = l_0 \sqrt{(1 - v^2/c^2)}$	-Discuss the phenomenon of length contraction as a consequence of the postulates of special relativity and use the equation for length contraction.
7. Mass increase $m = m_0 /\sqrt{(1 - v^2/c^2)}$	-Discuss relativity of mass and use the equation for mass increase.
8. Speed limit of the universe = c	-Discuss the concept of c being the unattainable speed limit for any particle of matter as a consequence of special relativity.
9. $E = mc^2$	-State Einstein's equation for the equivalence of matter and energy.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

A1 The Mechanical Universe High School Adaptation: "The Michelson-Morley Experiment"; demonstrations, video, activities, evaluation; see Appendix A.

A1-A9 The Mechanical Universe High School Adptation: "Special Relativity"; demonstrations, video, activities, evaluation; see Appendix A.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
B. GENERAL RELATIVITY	**(7 Days)**
1. Inertial, gravitational mass	-Distinguish between inertial and gravitational mass.
2. Principle of Equivalence	-State Einstein's Principle of Equivalence. -Explain why the principle of equivalence requires that light "bend" when it passes by a mass.
3. Gravity, space-time	-Compare and contrast Newton's classical view of gravitation with Einstein's concept of it. -Explain Einstein's concept of gravity as "warped space-time."
4. Inertia	-Compare and contrast the classical principle of inertia with the relativistic concept of an object moving inertially.
5. Black holes	-Trace the connection between the General Theory of Relativity and our understanding of black holes.
C. QUANTUM PHYSICS	**(3 Days)**
1. Stability of atoms	-Explain why Newton's mechanics and Maxwell's electromagnetic wave theory cannot account for the prolonged existence of atoms.
2. Rutherford's α particle scattering experiments	-Describe the setup of Rutherford's α particle scattering experiments. -Detail the view of atomic structure revealed by Rutherford in his α scattering experiments.
* 3. Thermal radiation	-Describe the thermal radiation of a glowing body such as an incandescent filament. *-Explain how Planck attempted to explain thermal radiation in terms of quantized energy modes of oscillation of the atom.
4. Photoelectric effect, Einstein's interpretation of the photoelectric effect, work function, photons $E = hf$	-Observe and describe the photoelectric effect. -Relate how classical physics could not account for the photoelectric effect. -Explain how Einstein explained the photoelectric effect. -Recognize that the energy of a particle of light called a photon is given by $E = hf$.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

B1-B5 The Mechanical Universe High School Adaptation: "Curved Space and Black Holes"; demonstrations, video, activities, evaluation; see Appendix A.

C1-C13 The Mechanical Universe High School Adaptation: "Wave Particle Duality"; demonstrations, video, activities, evaluation; see Appendix A.

C1-C13 The Mechanical Universe High School Adaptation: "Models of the Atom"; demonstrations, video, activities, evaluation; see Appendix A.

UNIT 5: MODERN PHYSICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
$E = \Phi + KE$	-Define work function. -Use Einstein's photoelectric effect equation.
5. Absorption, emission, continuous spectra	-Describe absorption, emission, and continuous spectra. -Explain how spectra cannot be explained by classical physics. -Observe and measure wavelengths of atomic spectra. *-Explain how spectra can be used to tell about the temperature, composition, rotation rate, pressure, and magnetic conditions on stars.
6. Coherent light, lasers, holograms	-Discuss coherent light and the operation of lasers. -Observe and describe a hologram.
7. Bohr model of the atom	-Describe how Bohr's model of the atom explains atomic spectra.
8. deBroglie's equation $\lambda = h/p = h/mv$	-State deBroglie's wave-particle equation. -Explain how deBroglie modified Bohr's model using the idea of standing waves. -Discuss how deBroglie's standing waves provided an explanation for the discret energy transition in Bohr's atom.
9. Quantization of atomic energies	-Describe how the Frank-Hertz Experiment established the quantization of atomic energy levels.
10. Wave particle duality	-Describe and give other examples of wave particle duality such as electron diffraction. -Compute the "wavelengths" of ordinary objects and of atomic particles. -Explain why we don't notice the particle nature of matter in our macroscopic world.
11. Heisenberg Uncertainty Principle $\Delta x \Delta p \geq h/2\pi$	-State Heisenberg's Uncertainty Principle and recognize that it is a consequence of wave particle duality.
12. Quantum mechanics, waves of probability, ψ the wave function	-Give an historical sketch of the development of quantum mechanics. -Qualitatively describe the probability context of the quantum mechanics. -Recognize that the "wave nature of matter" is manifested as "waves of probability" in the quantum mechanics. -Recognize ψ as a quantity related to "waves of probability."

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

C5 Experiment 24: Spectra of Elements, page 151.

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
13. Electron cloud model	-Express the present day model of the atom as the "electron cloud" model. -Describe the features of the electron cloud model of the atom in terms of quantum mechanics, the wave nature of matter, and the Uncertainty Principle. -Compare the electron cloud model with the Bohr-Rutherford model.
D. NUCLEAR STRUCTURE/ PARTICLE PHYSICS	**(2 Days)**
1. Collision experiments, cross section, quantized energy levels	-Define what is meant by the cross section of a scattering or collision experiment. -Describe how neutron capture experiments result in nuclear spectra which contain discrete lines (energy levels). -Contrast the energy scales of atomic and nuclear energy levels. -Predict the relative strengths of atomic and (Coulombic) forces vs. nuclear forces.
2. Classification of subatomic particles	-Describe the classification of subatomic particles as baryons, mesons, leptons, and bosons.
3. Fundamental forces: gravitational, electromagnetic, weak nuclear, strong nuclear	-List, compare, and contrast the four basic interactions (forces) between particles of matter. -Recognize the attempts of physicists to reduce the fundamental forces to one force which presumably manifested itself at the time of the "big bang."
4. Elementary particles, quarks, unified field theories	-Describe recent developments in the search for quarks and ~~the~~ unified field theories.
5. Conservation laws	-Describe how conservation laws relate to and are the foundation of particle physics.
E. RADIOACTIVITY/FISSION/FUSION	**(1 Day)**
1. X rays and radioactivity	-Recount the discoveries of X rays and radioactivity.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

D1 Experiment 25: Simulated Nuclear Cross Section, page 152.

D3 The Mechanical Universe High School Adaptation: "Fundamental Forces"; demonstrations, video, activities, evaluation; see Appendix A.

UNIT 5: MODERN PHYSICS

TOPICS	REPRESENTATIVE OBJECTIVES STUDENT OUTCOMES
2. Isotopes, ${}^{A}_{Z}X$ notation	-Define isotopes. -Describe the nature of the three isotopes of hydrogen. -Utilize the ${}^{A}_{Z}X$ notation.
3. α, β, γ, α and β decay	-Distinguish among α, β, and γ radiation. -List properties of α, β, and γ rays. -Explain the changes that occur in a radioactive nuclide which undergoes α or β decay. -Predict the products of α and β decay for particular isotopes. -Define and utilize the concept of half life.
4. Half-life	-Plot half-life graphs. -Predict amounts and times from half-life graphs.
5. $E = mc^2$, mass defect, and nuclear binding energy	-Use Einstein's mass energy equation to calculate the nuclear binding energy of atoms. -Describe the relationship between nuclear binding energy and mass defect. -Graph nuclear binding energy per nucleon vs. mass number and interpret the information contained therein.
6. Fission, chain reaction	-Define fission. -Describe and diagram a typical fission chain reaction. -Explain the basic components of fission power generators. -Assess the risks and benefits associated with fission power.
7. Fusion	-Define fusion. -Compare and contrast fission and fusion -Relate fission and fusion to the structure of the graph of nuclear binding energy per nucleon vs. mass number. -Describe how stars are fusion powered. -Describe the current status of fusion research.
* 8. Radiation and health, Roentgens, RAD, REM	-Describe the characteristic effects of radioactive nuclides on living tissue. -Explain how exposure to radioactivity is measured. -Contrast Roentgen's, RAD's, and REM's.

SUGGESTED RESOURCES AND ACTIVITIES

Note: A complete bibliography of outside resources (films, videos, lab manuals, etc.) appears in Appendix A.

E4 Experiment 26: Half-life, page 153.

E4 <u>Physics - Teach to Learn</u>, Module 18: "Radioactive Dating"; teacher-directed computer simulations; see Appendix A.

SECTION III

LESSON PLANNING

SAMPLE LESSON PLANS AND SAMPLE LABORATORY EXPERIMENTS

Samples of teacher-directed instructional sequences or lesson plans are provided on the following pages. One sample plan is included for each of Units 1-5.

The lesson plans follow the format of the seven-step, teacher-directed instructional sequences which are in District use. The questions below need to be addressed when the teacher is designing these sequences.

- What is the specific objective? How will it be presented to the students?
- What is the value in achieving the objective?
- What learning activities must be modeled, explained, or illustrated for students?
- What guided group practice will be provided for the students?
- What independent practice or activity will be provided for the students?
- What provisions will be made for individual differences in learning styles?
- How will the lessons be evaluated?

Following the lesson plans are 26 sample laboratory experiments. It is not intended that any or all of these specific experiments are required, but with careful planning and reasonable stores of equipment, 20-30 labs can and should be incorporated into a "standard" Physics AB course. Those contained in this outline are offered as possibilities. Many other possible experiments are referenced in Appendix A.

QUESTIONS AND COMMENTARY FOR TEACHING DECISIONS

1. What is the specific objective and how will it be presented to the students?

   The specific objective tells what students will be able to do by the end of the lesson. It should be a refinement of the broader representative objective selected for the lesson from the course description in the Guidelines for Instruction or from the required course of study.

2. What is the value to students in achieving the objective?

   The teacher explains to the students the importance of achieving the objective and how it relates to past or future learning or their total development. The teacher motivates the students by providing a rationale for achieving the objective.

3. What learning activities are suitable for the students involved and for the specific objective being taught?

   The teacher selects or designs initial learning activities--such as a demonstration, a film, a text selection, a lecture, a class or small-group discussion, or questions followed by student answers--which fit the ability levels or learning styles of the students. Similarly, the teacher develops initial learning activities which constitute the most efficient means for putting across the particular specific objective.

4. What guided group practice will be provided for the students?

   The teacher has the class perform some of the steps leading toward mastery of the specific objective to determine if the students understand the concepts well enough to perform the tasks independently. Student responses give the teacher feedback on the students' degree of understanding.

5. What independent practice or activity will be provided for the students?

   The teacher gives the students the opportunity to perform the task stated in the objective with little or no teacher assistance.

6. What are the provisions for individual differences in style of learning?

   a. Remedial or Alternatives: The teacher provides other kinds of learning activities for students requiring alternative opportunities to practice the task.

   b. Enrichment or Supplemental Activities: The teacher provides learning activities for students who were successful and can profit from probing the subject to a greater depth or by extending the subject to other areas.

7. How will the lesson be <u>evaluated</u>?

To plan learning activities for future lessons, the teacher assesses students' mastery of the skill or skills of the present specific objective.

The evaluator can be a student, a group of students, or the teacher. An objective test, a subjective test, or a performance test can be used to assess students' ability to perform the objective.

TEACHER RESPONSIBILITIES

The teacher is responsible for creating, maintaining, and fostering a classroom environment and a climate for learning which encourage instructional excellence and achievement. In order to maintain such an environment successfully, the teacher is responsible for:

1. Providing students and parents with a clear statement of instructional objectives, overall goals, and standards of expected progress and achievement.

2. Providing instruction which incorporates a diagnostic-prescriptive program for learning all required skills and concepts.

3. Following the time line as closely as possible, preparing instructional activities for the entire class period, and assisting students in striving for mastery of content and process skills.

4. Having evidence in the classroom of lesson planning to meet the educational needs of the students and the goals of the instructional program.

5. Providing regular instruction and practice in preparing students to take and succeed on tests and other measures of achievement.

6. Maintaining well-defined and consistent classroom standards for academic achievement, citizenship, and work habits.

7. Providing regularly assigned homework designed to reinforce classroom instruction.

8. Providing students and parents with an explanation of the standards used for assigning marks.

9. Providing prompt feedback to students on the results of quizzes, homework, and other class assignments.

10. Recognizing individual student progress and exceptional achievements; displaying student accomplishments and products in the classroom.

11. Recording a minimum of one grade per week in the rollbook for each student.

12. Keeping parents regularly informed of the educational progress and achievement of the student.

13. Informing parents of outstanding progress and accomplishment.

14. Notifying parents of any signs of significant academic decline in student effort or achievement.

15. Providing parents with suggestions on how to help the student study and complete homework assignments.

16. Communicating with administrators, the department chairperson, and fellow teachers to keep them informed of classroom happenings and concerns.

It is desirable to invite administrators, the department chairperson, and fellow teachers to visit the classroom and participate in a sharing of effective and innovative lessons.

THE AGENDA

An agenda, or schedule of class activities, prominently displayed in the classroom, gives immediate directions to the students and prepares them for the day's classwork. The agenda should include an objective, a dispatch activity, scheduled class activities, and a homework assignment. The agenda may be written on the chalkboard. Some teachers, particularly teachers who travel from classroom to classroom, prefer to use chart paper that can be easily taped or pinned to a board and quickly removed to be used in a new location. A good way to evaluate an agenda is to ask the question, "If a student were absent, could he or she read the agenda and know what happened in the classroom today?"

The dispatch activity is an essential part of the agenda. It should be a short, written, timed exercise that students start as soon as the period begins. Students should be able to complete the dispatch without teacher assistance. The dispatch is used to:

- review and reinforce concepts and ideas previously studied
- start students working immediately upon arrival in class
- preview or introduce new work
- establish a routine
- allow the teacher an opportunity to take care of attendance responsibilities

Below is a sample agenda as it would be written on the board:

AGENDA

Teacher's Name
Physics AB, Period 1
September 25, 1989

Objective:	Students will hypothesize regarding the properties which may affect the period of pendulum. Their hypotheses will be tested in an experiment.
Dispatch:	Referring to instructions on the board or handout, write a statement giving reasons why the mass of the pendulum bob, angle of release, or length will affect the period of a pendulum. Construct data tables to record laboratory data providing for three masses, three angles of release, and five pendulum lengths.
Classwork:	Discuss the importance of pendulums, both historically and in our lives. Discuss the written student statements and the characteristics of well-designed data tables.
Independent Work:	Perform Experiment 10 in Section III of this Course of Study.
Homework:	Read and report on Galileo and the pendulum and the Foucault pendulum.

GUIDELINES FOR ASSIGNMENT OF HOMEWORK*

Homework, which is a necessary part of each student's educational program, is purposeful when it provides the student with time to complete or expand upon assignments begun in class; develops good work habits and a sense of responsibility for completing tasks on time; and provides opportunities for the student to engage in creative projects, self-directed activities, and research in the area of his or her developing interests. Furthermore, purposeful homework is related to classwork and the objectives of the course, emphasizes quality rather than quantity, is consistent with the grade level and maturity of the student, and should be reflected in the subject mark.

1. Daily homework assignments are important resources for teachers in helping students learn.

2. Homework assignments should be reasonable in content, length, and resources required. Books and other materials required for assignments should be provided or easily obtainable.

3. Homework for all students should be purposeful and clear and should be based on the needs of the class. It should be modified for students with special needs. It should never be assigned as a punishment.

4. Homework may be scheduled over an extended period of time that may include weekends and vacations. If homework is assigned over an extended period, regular checks on progress should be made by the teacher.

5. Homework should be directly related to the content and objectives being taught. Students should not be given homework assignments they have not been taught how to do. Homework should be assigned to reinforce and enrich student knowledge or extend abilities. The assignment should always be stated in terms of the skill or concept being reinforced rather than in terms of the chapter, unit, or page number in a given text.

6. Homework assignments and due dates should be thoroughly explained by the teacher in advance and thoroughly understood by the student and parents. The written description of the goals and subject content provided to parents at the beginning of the course should include homework requirements and [illegible]

7. When appropriately assigned and explained by the teacher, homework becomes the responsibility of the student to understand, complete, and return by the expected due date.

8. Completed homework assignments should be acknowledged and recorded by teachers in a timely manner and reviewed with students.

9. Parents should be notified when students do not complete homework assignments or show signs of significant decline in effort or achievement.

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*Adapted from the Office of the Associate Superintendent, Instruction, Bulletin No. 22 (REV.), April 30, 1990, "Homework and Makeup Assignments for School Absences in Grades K-12."

TEACHING STRATEGIES

A variety of instructional strategies can enhance the students' growth in both concept and skill development. Examples of these instructional strategies include:

- Teacher-directed lessons with the class investigating the same problem.

- Teacher demonstration with the class observing and recording observations and data.

- Independent study. Students conduct independent research and study concept or process areas. When completed, such individual work provides a basis for class learning projects.

- Team learning situations wherein two to four students function together as a laboratory investigation group. Interaction within and among groups acts both as a stimulus and an information-sharing aid to learning.

- Grouping of lower achieving students with those achieving at a higher level. This permits peer tutoring and interaction which can benefit the less motivated or less successful individuals.

- Contract between student and teacher which outlines and prescribes specific tasks to be performed by the student for the fulfillment of certain course requirements and relates levels of achievement to marks earned.

- Self-paced learning designed for mastery. Assessment is conducted as each student concludes each unit, and the results indicate whether a student is ready to advance to the next unit or experience--a repeated opportunity for the instructor to use a new strategy. Student's mark is based on number of units mastered.

- Library research studies wherein many of the principles learned in laboratory and class activities can be applied to a class, small group (team), or individual project.

- Class presentations by individual or laboratory teams on the outcomes of laboratory investigations which are shared with the class.

- Design and formulation of research projects. Individuals or teams apply the methods, materials, and techniques learned to a real experimental investigation.

- Activities such as simulation of a legislative hearing to give students practice in making decisions after collecting scientific information to answer questions arising from real-world problems related to Science, Technology, and Society (STS).

HIGHER LEVELS OF THINKING

Because questioning is the primary tool in achieving educational goals, teachers will want to be sure their questions are appropriate for the ability level of students and challenge students to higher levels of thinking.

Bloom* classifies six levels of thinking. They are:

- Knowledge (recognition or recall of previously learned material)
- Comprehension (translation or interpretation of data)
- Application (application of past learnings to a new situation)
- Analysis (emphasis on the breakdown of material into constituent parts, the detection of relationships, and the organization of parts)
- Synthesis (organization of separate elements in a new creative structure)
- Evaluation (arrival at value judgments about a material or work)

The levels of thinking are sequential. In other words, each category of thinking is different and builds on lower categories. The categories are arranged from simple to complex and from concrete to abstract.

It is important that all students have many opportunities to answer questions involving every level of thinking. Within each category of thinking there are both simple and complex questions for slow and rapid learners.

Questioning is particularly important during guided group practice in the teacher-directed lesson. Carefully constructed questions using various levels of thinking will help the teacher determine the students' comprehension of new material and assess their readiness to move on to independent practice. Individualization of instruction and remedial or alternative work can be achieved by constructing questions of varying levels of complexity.

Verbs alone do not necessarily determine the level of thinking. A given question may not represert the same task to all students. What may be an analysis question to one student may be a knowledge question to a student who has already read and received an explanation of the material. The level of a question depends on how much information the student has already received. If a student is expected to answer a "why" or "how" question by restating an answer provideu in the textbook or from the teacher's lecture, the level of thinking is knowledge. If, however, the student has to figure out the answer, not simply remember it, the student is working on a higher level of thinking, such as analysis, synthesis, or evaluation.

*Benjamin S. Bloom: Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain, (Longman Inc., New York, 1956).

Six categories of thinking and suggested verbs for teachers are provided below. Teachers will find these helpful in constructing questions and planning lessons. For further classification of learning levels in the affective and psychomotor domains, teachers are referred to <u>Reaching Higher Levels of Thought</u>, Los Angeles Unified School District, Office of Secondary Instruction, Publication No. X-118, 1982.

MAJOR CATEGORIES AND SUGGESTED VERBS FOR USE IN STATING COGNITIVE OUTCOMES

KNOWLEDGE	COMPREHENSION	APPLICATION	ANALYSIS	SYNTHESIS	EVALUATION
define	translate	interpret	distinguish	compose	judge
repeat	restate	apply	analyze	plan	appraise
record	discuss	employ	calculate	propose	evaluate
list	describe	use	experiment	design	rate
recall	recognize	demonstrate	test	formulate	revise
name	explain	dramatize	compare	arrange	score
relate	express	practice	contrast	assemble	assess
underline	identify	illustrate	criticize	collect	estimate
	locate	operate	diagram	construct	choose
	report	schedule	inspect	create	measure
	review	shop	debate	set up	select
	tell	sketch	inventory	organize	value
			question	manage	
			relate	prepare	
			solve		
			examine		
			categorize		

THE PROCESSES OF SCIENCE

The learning and application of the processes and special skills required in science are essential for a complete course. Together with basic skills, knowledge, and attitudes, they provide the foundation for understanding the objectives and content of the course as well as addressing the general societal need for scientific and technological literacy. Students cannot understand the interrelationships of science, technology, society, and individuals without understanding how science happens.

In order to learn the processes and special skills required in science, it is essential that the students participate in content-related, hands-on laboratory investigations. This is the only way to achieve a balance between process and content learning in science.

The processes listed are descriptions of the more important ones. The processes are sequential. Each successive level cannot be accomplished unless the one before has occurred.

PROCESSES		DESCRIPTIONS
Observing	. Seeing . Hearing . Feeling . Tasting . Smelling	The main route to knowledge is through observing, using all the senses. This process is a distinct one by which people come to know about the characteristics of objects and their interactions.
Communicating	. Silent . Oral . Written . Pictorial	Objects are named and events are described by people so that they can tell others about them. Communicating is a fundamental human process that enables one to learn more about a greater range of information than could be learned without this process.
Comparing* (includes measuring)	. Sensory comparisons . Relative positive comparisons . Linear comparisons . Weight comparisons . Capacity comparisons . Quantity comparisons	Comparing is a distinct process by which people systematically examine objects and events in terms of similarities and differences. By comparing the known to something unknown, one gains knowledge about the unknown. All measurements are forms of comparing.

PROCESSES		DESCRIPTIONS
Organizing*	. Data gathering . Sequencing . Grouping . Classifying	Knowledge of principles and laws gained only through the systematic compiling, classifying, and ordering of observed and compared data. Bodies of knowledge grow from long-term organizing processes.
Relating*	. Using space-time relationships . Formulating experimental hypotheses . Controlling and manipulating variables	Relating is a process by which concrete and abstract ideas are woven together to test or explain phenomena. Hypothetical-deductive reasoning, coordinate graphing, the managing of variables, and the comparison of effects of one variable on another contribute to the attainment of the major concepts of science.
Inferring*	. Synthesizing, analyzing . Generalizing . Recognizing and predicting patterns; stating laws . Formulating explanatory models and theorizing	The process of realizing ideas that are not directly observable is the process of inferring. The process leads to predictive explanations for simple and complex phenomena.
Applying*	. Using knowledge to solve problems . Inventing (technology)	Use of knowledge is the applying of knowledge. Inventing, creating, problem-solving, and determining probabilities are ways of using information that lead to gaining further information.

*These processes include the application of mathematical concepts and skills in interpreting data and solving problems.

LEARNING MODALITIES

The learning modalities are the sensory channels by which students receive information. The three learning modalities are visual, auditory, and kinesthetic. Classroom instruction should include all three modalities.

A student's dominant modality is the channel through which instruction is processed most efficiently. Teachers can capitalize on learning strengths by determining the students' dominant modalities. Teachers should also assess their own learning styles, since research indicates that teachers tend to teach in their preferred modalities. An awareness of different learning styles will assist the teacher in planning a variety of instructional activities.

Some of the materials and techniques listed below have proved highly effective in designing lessons based on learning modalities.

Visual Learners	Auditory Learners	Kinesthetic Learners
Flash cards	Tapes	Tracing activities
Matching games	Music	Tactile experiences
Puzzles	Rhymes	Felt pens
Dictionaries	Clapping/keeping time	Math manipulatives
Card files	Language master	Plays, art
Overhead projector transparencies	Puppet conversations	Puppet actions
Charts	Rhythm instruments	A-V equipment monitoring
Pictures	Poetry	Demonstrator of tasks
Written directions	Reading aloud	Role playing
Instructional books	Talking about the skills to be learned	Pantomime

EVALUATION PROCEDURES

The evaluation of instruction is an integral part of the educational process. It provides information on what has been accomplished and where to go next. The first phase of evaluation should be diagnostic. The teacher should assess what students know before instruction, and then plan an appropriate course of instruction based on students' knowledge and abilities. In addition to diagnostic pretesting, ongoing evaluation during instruction provides teachers with a record of student progress and indicates the instructional changes that may have to be made in order to plan for maximum achievement. Post-testing assesses how well students have met the objectives at the end of the unit or course.

The selection or construction of appropriate instruments of evaluation is critical to the measurement process. Test items must measure and reflect instructional objectives. Tests of achievement and problem-solving skills often require advanced reading skills. Therefore, it is recommended that diagrams, graphs, and pictures also be used to evaluate student progress and achievement.

Various measures of evaluation can be used in all phases of science education. Achievement tests assess science knowledge and comprehension. Problem-solving measures are useful for measuring higher cognitive skills such as analysis, synthesis, and evaluation. Motor skills and skill in the application of scientific knowledge can be evaluated in the laboratory setting. Observation and interview techniques are useful in the assessment of such laboratory skills as manipulating materials, setting up experiments, handling and caring for live specimens, and employing safety practices. These measurement techniques allow for immediate feedback to students.

Suggested assessment procedures include the following: teacher-prepared tests; commercially-prepared tests; departmental tests; informal and formal assessment of individual and group activities in oral work and discussion; student-prepared test items which provide reinforcement and the opportunity to apply course content; and student projects.

TIPS FOR PARENTS

The following are some of the important ways in which parents can provide the proper guidance, motivation, assistance, and nurturing home environment for their student's success and learning in science.

1. Show an active interest in your student's learning activities.

   Be a good observer and a good listener. Discuss interests and questions. This will help you learn more about your student's interests, study skills and habits, thinking and reasoning abilities, values, and attitudes.

2. Provide (designate) a quiet work and study area.

   Help your student develop a routine that allows time for homework and study activities.

3. Provide materials for learning.

   For example, try to have related books, magazines, newspapers, dictionaries, encyclopedias, maps, and a globe available for home study. Not only do these help students complete class assignments, but they also motivate and enhance learning and provide opportunities to experience the satisfaction of independent inquiry and discovery.

4. Read, review, and discuss homework and other class assignments.

   Commend efforts and achievements. Make suggestions for improvement, if necessary.

5. Learn together.

   Encourage questions and discussion. Plan activities which provide opportunities for practicing and applying science skills and concepts. For example, help your student learn to withhold judgments until sufficient evidence has been secured, to challenge sources of information, and to be open-minded. These efforts will help lead students toward developing essential critical-thinking and reasoning skills as well as toward guiding and preparing them to become humane, rational, understanding, and participating citizens in a democratic society.

6. Share interests and experiences.

   In order to assist your student to develop a curiosity and interest about science, discuss with him or her science-related articles and television specials.

7. Encourage use of public as well as school libraries.

   Help your student obtain an up-to-date library card and use the library's resources on a regular basis.

8. Plan and make trips and visits to study-related places.

   For example, plan visits to museums, open houses at universities, and industrial agencies.

9. Become familiar with the teacher's procedures, routine, and expectations.

   It is important to know and understand the teacher's and the school's standards regarding homework, grades, citizenship, behavior, and attendance.

10. Discuss student's progress with the teacher.

    Meet and discuss with the teacher, on a regular basis, such concerns as your student's progress and achievement level, his or her specific learning needs which can be met through home study, and how your student might receive individualized help if needed.

11. Become familiar with the school's instructional materials and resources.

    Consult with the teacher and librarian about the selection of related books, magazines, newspapers, and other materials available for reading. Also, learn about the variety of other instructional resources used by the school.

12. Learn about the school's academic program.

    Parental support of the school program is an essential factor in shaping positive attitudes toward education.

13. Become a resource person.

    You may wish to offer your services as a community resource person or suggest other community or business resources which may be of service and enrichment to the school's instructional program.

14. Most of all, care.

    It is only through the combined and cooperative efforts of school, parents, and community that the necessary support, strength, enrichment, and continued excellence of our public schools will be sustained.

SAFETY IN THE SCIENCE LABORATORY

Science laboratory investigations are a significant part of science instruction. Every District-approved science course includes laboratory investigations. These investigations enable the student to develop process skills which transcend the facts of science; to integrate the content and laboratory learning; to obtain data which when analyzed, leads to an improved understanding of scientific principles; and to gain an appreciation of science as a process for obtaining and organizing information. The realization of these goals will lead not only to improved science learning but also to an improved understanding of the interrelationships of science and society.

Laboratory experiences are essential in science courses. As with all activities where materials are manipulated, experience has shown that potential hazards exist. It is not suggested that all potentially hazardous materials be removed from school laboratories, rather that teachers must become aware of hazards associated with specific chemicals and equipment and take proper safety precautions. Safety is an integral part of science instruction. Only qualified science instructors trained in laboratory procedures and familiar with the potential hazards associated with the substances used in the school's science program should be assigned to teach science courses. Teachers must have sufficient information to use their own judgment about the degree of precaution necessary for using and storing each chemical. Chemicals in any form can be safely stored, handled, or used if the physical, chemical, and hazardous properties are fully understood and the necessary precautions, including the use of proper safeguards and personal protective equipment, are taken.

Chemicals must never be stored alphabetically except within designated categories. Although protective barriers should be present to prevent containers from tumbling from shelves, large, heavy, or breakable containers should be stored near the floor.

Both eye protective devices and chemical resistant aprons should be available. Approved goggles must protect from splash hazard and include only unventilated ones and those with baffled ventilators. Spectacle type eye-protection is not approved. Face shields should be used only with goggles. The wearing of contact lenses in the laboratory is not recommended.

Sections 32030 through 32033 of the California Education Code deal with devices to protect the eyes.

32030. DUTIES REGARDING EYE PROTECTIVE DEVICES

It shall be the duty of the governing board of every school district, and community college district and of every county superintendent of schools, and of every person, firm, or organization maintaining any private school, in this state, to equip schools with eye protective devices as defined in Section 32032, for the use of all students, teachers, and visitors when participating in the courses which are included in Section 32031. It shall be the duty of the superintendents, principals, teachers or instructors charged with the supervision of any class in which any such course is conducted, to require such eye protective devices to be worn by students, teachers, or instructors and visitors under the circumstances prescribed in Section 32031.

32031. COURSES IN WHICH DEVICES TO BE USED; SUBSTANCES AND ACTIVITIES DANGEROUS TO EYES

The eye protective devices shall be worn in courses including, but not limited to, vocational or industrial arts shops or laboratories, and chemistry, physics or combined chemistry-physics laboratories, at any time at which the individual is engaged in, or observing, an activity or the use of hazardous substances likely to cause injury to the eyes.

Hazardous substances likely to cause physical injury to the eyes include materials which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition or other means as defined in the California Hazardous Substances Labeling Act.[1]

Activity or the use of hazardous substances likely to cause injury to the eyes includes, but is not necessarily limited to, the following:

1. Working with hot molten metal.
2. Milling, sawing, turning, shaping, cutting, grinding, and stamping of any solid materials.
3. Heat treating, tempering, or kiln firing of any metal or other materials.
4. Gas or electric arc welding.
5. Repairing or servicing of any vehicles, or other machinery or equipment.
6. Working with hot liquids or solids or with chemicals which are flammable, toxic, corrosive to living tissues, irritating, strongly sensitizing, radioactive, or which generate pressure through heat, decomposition, or other means.

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[1] Health and Safety Code, Sections 28740 et seq.

32032. STANDARDS FOR DEVICES

For purposes of this article the eye protective devices utilized shall be industrial quality eye protective devices which meet the standards of the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection" (Z87.1--1968), and subsequent standards that are adopted by the American National Standards Institute for "Practice for Occupational and Educational Eye and Face Protection."

32033. SALE OF DEVICES AT COST TO PUPILS AND TEACHERS

The eye protective devices may be sold to the pupils and teachers or instructors at a price which shall not exceed the actual cost of the eye protective devices to the school or governing board.

LESSON PLAN FORMAT

Subject or Course: Teacher:

Representative Objective:

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing___ Reading___ Listening___ Thinking___

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Synthesis___ Analysis___ Application___ Evaluation___

1. Specific Objective and How Presented to Students:

2. Value to Students in Achieving the Objective:

3. Initial Instructional Activity to Teach Objective to Students:

4. Guided Group Practice:

5. Independent Practice or Activity:

6. Provision for Individual Differences in Ways of Learning:

    a. Remediation or Alternative Activities:

    b. Enrichment or Supplemental Activities:

7. Evaluation:

    a. Summary:

    b. Homework:

SAMPLE LESSON 1: KINEMATIC EQUATIONS

Subject or Course: Physics AB Teacher:

Representative Objective: Students will understand how objects move.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading___ Listening X Thinking___ Problem Solving X Explaining X Laboratory X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Synthesis___ Analysis X Application X Evaluation___

1. Specific Objective: The students will apply the kinematic equations of motion for uniformly accelerated objects.

2. Value to Students in Achieving the Objective: The students will solve problems involving constant acceleration using appropriate mathematical concepts first developed by Galileo. They will be able to check the validity of the kinematic equations through laboratory investigations.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will have provided instruction on the concepts and definitions of distance, speed, velocity, and acceleration and will have derived the kinematic equations and explained how Galileo first discovered this concept. Examples of applying the equations will be given with particular emphasis given to cases where $a = -g = -9.8\ m/s^2$. The instructor will provide various demonstrations of falling objects (see references Appendix A) and may wish to present The Mechanical Universe High School Adaptation, video segment "The Law of Falling Bodies."

4. Guided Group Practice: Students will work in pairs and perform Experiment 3. Students may form small groups, and each group will decide upon an answer and an explanation of the question posed in the "Everyday Connections and Other Things to Discuss" in the The Mechanical Universe High School Adaptation, module "The Law of Falling Bodies."

5. Independent Practice or Activity: Students will perform an additional experiment on free fall. (See references Appendix A.)

6. Provision for Individual Differences in Ways of Learning:

   a. Remediation or Alternative Activities: Students who had difficulty grasping the concepts will be given an additional worksheet. They will also reread the appropriate sections in their text and view the Mechanical Universe video tape a second time.

   b. Enrichment or Supplemental Activities: Students will work individually with a computer tutorial on this material. Students may complete "computerized g" experiment. (See How to Build a Better Mousetrap, Appendix A.)

7. <u>Evaluation</u>: The instructor will mark students' laboratory reports and assess the group's work on the questions.

SAMPLE LESSON 2: THE MECHANICAL EQUIVALENT OF HEAT

Subject or Course: Physics AB Teacher:

Representative Objective: Students will recognize that heat is a form of energy.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading___ Listening X Thinking___ Problem Solving X Explaining X Laboratory X

Thinking Level or Cognitive Level: Knowledge___ Comprehension X Synthesis___ Analysis X Application___ Evaluation___

1. Specific Objective: The students will distinguish between heat and temperature and experimentally determine a value for the ratio of work units to heat units.

2. Value to Students in Achieving the Objective: The experiment performed by students affords them a good opportunity to analyze for error since their values should noticeably vary from the expected value of 4.186 J/cal.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will have provided instruction on the concepts of heat and the units in which each is measured. Discussion of the caloric theory of heat and a historical overview of Joule's famous experiment would be appropriate. The Mechanical Universe High School Adaptation, video segment "Conservation of Energy" could be referenced in this regard.

4. Guided Group Practice: Students will work in pairs and perform Experiment 13.

5. Independent Practice or Activity: Students may wish to perform a similar experiment at home and compare the results.

6. Provision for Individual Differences in Ways of Learning:

   a. Remediation or Alternative Activities: Students who had difficulty grasping the concepts will be given an additional worksheet. They will also reread the appropriate sections in their texts.

   b. Enrichment or Supplemental Activities: Students may research a report on Joule's experiment to measure the mechanical equivalent of heat. They may present the report to the class in lieu of a lecture by the instructor.

7. Evaluation: The instructor will mark students' laboratory reports.

SAMPLE LESSON 3: SIMPLE CIRCUITS

Subject or Course: Physics AB   Teacher:

Representative Objective: Students will diagram, construct, and use simple electrical circuits.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading___ Listening X Thinking___ Problem Solving X Explaining X Laboratory X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Synthesis___ Analysis X Application X Evaluation___

1. Specific Objective and How Presented to Students: The students will apply Ohm's Law to solve for currents, voltages, and resistances in simple DC circuits using appropriate circuit symbols and locating meters correctly.

2. Value to Students in Achieving the Objective: Students will demonstrate and recognize the value of knowledge of simple parallel and series circuits construction and operation. They will be able to apply this knowledge to future course work and to real-life situations.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will have provided instruction on the concepts of electric current, voltage and resistance, the appropriate SI units, and open and closed circuits. He or she will explain and provide examples of simple circuits and derive the expression for equivalent resistance in series and parallel circuits. Appropriate demonstrations of circuit features and construction, including the use of ammeters and voltmeters will have been given. The Mechanical Universe High School Adaptation, video "Simple DC Circuits" will be shown.

4. Guided Group Practice: Students will share ammeter and voltmeter or combination meters and practice reading them correctly. They will complete a worksheet on simple circuits and Ohm's Law.

5. Independent Practice or Activity: Students will perform Experiment 16.

6. Provision for Individual Differences in Ways of Learning:

   a. Remediation or Alternative Activities: Students who need further help will reread the section on circuits in their books. They will take notes and redraw diagrams of the circuits in the experiment. They will then construct the circuits with the assistance of other students who understand the concepts.

b. Enrichment or Supplemental Activities: Students may wish to go further into circuit theory. They can obtain advanced texts dealing with more complicated arrangements of resistors, etc., and apply Kirchoff's Rules to their solutions. Students may use a more sophisticated voltmeter such as an oscilloscope in their circuit measurements.

7. Evaluation: The instructor will mark students' laboratory reports and worksheets and may test individual students for their ability to use and read meters. The Mechanical Universe High School Adaptation, module "Evaluation Questions" provides a good quiz on the material.

SAMPLE LESSON 4: REFLECTION AND REFRACTION

Subject or Course: Physics AB   Teacher:

Representative Objective: Students will use simple optical devices and investigate how reflection and refraction of light explain their functioning.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing_X_ Reading___ Listening_X_ Thinking___ Problem Solving _X_ Explaining _X_ Laboratory _X_

Thinking Level or Cognitive Level: Knowledge___ Comprehension_X_ Synthesis___ Analysis_X_ Application_X_ Evaluation___

1. Specific Objective: Students will demonstrate how the path of a ray of light may be changed by reflection and refraction. They will apply Snell's Law and the thin-lens equation.

2. Value to Students in Achieving the Objective: Students will experience and verify natural laws of optics. They will construct a simple telescope using these laws and appreciate how a seemingly complex optical device can be rendered understandable through the application of physics.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will have provided instruction in the study of ray optics, reflection, refraction, total internal reflection, mirrors, and lenses. He or she will have demonstrated ray diagrams associated with plane and parabolic mirrors, converging and diverging lenses. Appropriate demonstrations of the above phenomena will be performed. Depending on the sequence in the course, the instructor may wish to utilize all or part of The Mechanical Universe High School Adaptation module on optics: "The Wave Nature of Light."

4. Guided Group Practice: Students will perform Experiments 18 and 19 singly or in groups of two or three under the supervision of the teacher.

5. Independent Practice or Activity: Students will analyze their data at home to prepare a written lab report.

6. Provision for Individual Differences in Ways of Learning:

   a. Remediation or Alternative Activities: The students will reread the section in the text about mirrors and lenses. They will construct and label a ray diagram for both a converging and diverging lens. They will explain, in written form, the difference between a real image and a virtual image.

   b. Enrichment or Supplemental Activities: The students may write a brief research paper on how lenses are used in the human eye, to correct vision problems, in a microscope, in a reflecting telescope, or in a camera. Class members may draw and label diagrams to show how light is refracted in each kind of instrument.

7. Evaluation: Laboratory exercises will be evaluated by the teacher.

SAMPLE LESSON 5: HALF-LIFE

Subject or Course: Physics AB   Teacher:

Representative Objective: The students will gain in knowledge and understanding of radioactivity, nuclear structure, and nuclear changes.

Sending and Receiving Skill(s) Emphasized: Speaking___ Writing X Reading___ Listening X Thinking___ Problem Solving X Explaining X Laboratory X

Thinking Level or Cognitive Level: Knowledge___ Comprehension___ Synthesis___ Analysis X Application___ Evaluation___

1. Specific Objective: The students will demonstrate the rate at which radioactive atoms decay.

2. Value to Students in Achieving the Objective: The students will have greater insight and understanding when assessing nuclear related issues.

3. Initial Instructional Activity to Teach Objective to Students: The teacher will introduce the concept of radioactive half-life and may use the chalkboard, overhead transparencies, filmstrips, etc., to help explain this concept. (See references Appendix A.) He or she should instruct the students how to tabulate their data and how to record the data in graphical form.

4. Guided Group Practice: The students may work in groups of two or three and perform Experiment 26 under the supervision of the teacher. They will also work as a class with the simulations dealing with radioactivity in the *Physics - Teach to Learn* materials. (See reference page 159.)

5. Independent Practice or Activity: Students will each plot natural decay series on a graph of A vs. Z, indicating the type of decay (α or) and the half-life of each nuclide in the series.

6. Provision for Individual Differences in Ways of Learning:

   a. Remediation or Alternative Activities: Students will reread and outline the section on radioactivity in their text.

   b. Enrichment or Supplemental Activities: The students will write a library research paper on the beneficial uses of radioactivity or nuclear issues. They may want to research the effects of radioactivity on cancer treatments or the usefulness of radioactive isotopes in chemical research.

7. Evaluation: Independent practice papers and laboratory exercises will be evaluated by the teacher.

UNIT 1A - EXPERIMENT 1: THE SIZE OF A MOLECULE

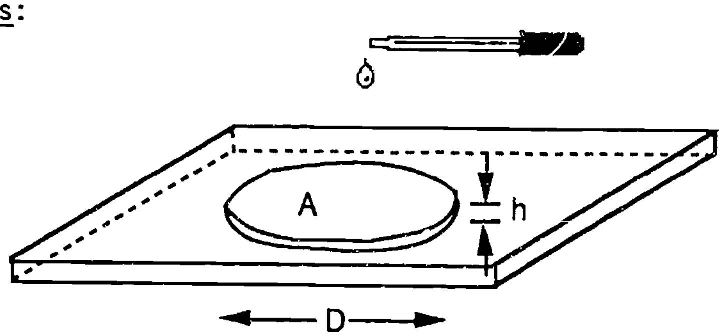
Purpose:

To obtain a ballpark or order of magnitude measurement for the size of a molecule of oleic acid. To use simple measuring instruments to extend our senses. To appreciate how we can use physics to measure seemingly immeasurable quantities.

Materials:

tank of water (ripple tank or other tank about 2' x 2')
5% solution of oleic acid
Lycopodium powder
10 mL graduated cylinder
dropper
soap
meter stick

Procedure and Notes:



1. Have students fill the tank about ½ full with water and let it come to rest. Place the tank where no air currents will disturb the still water.

2. Count out 100 drops of the dilute oleic acid into a graduated cylinder. Calculate the volume of one drop of dilute oleic acid.

   (Remember 1 mL = $cm^3 = 10^{-6}\ m^3$.)

   Calculate the volume of the oleic acid in the drop (volume of one drop x .005) (Note: prepare the dilute oleic acid by dissolving 450 mg of oleic acid in 100 mL of alcohol).

3. Sprinkle Lycopodium powder on the surface of the still water in the tank, so that it forms a light, uniform layer.

4. Drop one drop of the dilute acid onto the center of the tank. Observe the drop expanding into a roughly circular shape, pushing the powder out.

5. After waiting approximately 30 seconds, when the drop has spread to its maximum (about 20-30 cm), measure the diameter at two or three places and calculate an average diameter. Calculate the area, $A = \pi D^2/4$.

6. Calculate the thickness of the molecule. Express the answer in meters.

$$h = \frac{\text{volume of oleic acid in 1 drop}}{\text{area}}$$

7. Round the value for h to the nearest order of magnitude.

Explanation:

This experiment is an excellent introduction to physics. It allows the student to see part of the range of physics--the study of the very small--and how our senses are too limited to directly measure such values. It provides a method of measuring the size (thickness) of a molecule by indirect means, using only simple measuring tools such as a meter stick and a graduated cylinder to extend the senses. Since the diameter and volume measurements are only approximate, the student can appreciate the usefulness of order of magnitude estimates. (Note: It is assumed that the oleic acid spreads out to be one molecule thick. Explain to students that the number they obtain really represents an upper limit to the size of the molecule and that an assumption is made that the molecule is a sphere.)

Alternative:

As a preparation for the above experiment or as an alternative, use dry hard beans (lima, pinto, kidney).

Measure out 100 cm^3 of the beans. Pour out the beans on a flat surface and form into a compact circle, one bean thick. Measure the diameter, determine the area, and calculate the thickness, which is equal to the volume divided by the area.

UNIT 1B - EXPERIMENT 2: THE ANALYSIS OF AN EXPERIMENT

Purpose:

To recognize mathematical relationships among the height of water (h), diameter of the drain hole (d), and time to drain (t) for water draining from a can with a hole in the bottom.

To deduce a law, stated mathematically, among h, d, t by graphing functions of these variables which yield straight lines through the origin.

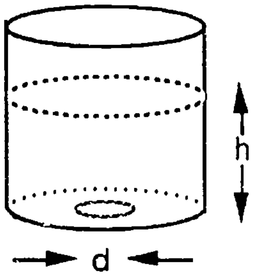
Materials:

Can be done as a "dry lab"

Procedure and Notes:

1. Give the students the data from an experiment where data was taken for the times required for water standing at different heights to drain from a hole in a can.

d \ h	30	10	4	1
1.5	73.0	43.5	26.7	13.5
2	41.2	23.7	15.0	7.2
3	18.4	10.5	6.8	3.7
5	6.8	3.9	2.2	1.5



2. Graph t vs. d for h = 30. On the same graph, plot for h = 10, 4, 1. What type of relationship seems to exist between t and d? (Inverse, i.e., $t \alpha 1/d^n$.) Plot t on the abscissa and and $1/d^n$ on the ordinate for whatever value of n yields a straight line through the origin. (n = 1, $t \alpha 1/d$.)

3. Graph t vs. h for d = 1.5. On the same graph plot for d = 2, 3, 5. What type of relationship seems to exist between t and h? (Direct, i.e., $t \alpha h^m$.) Plot t vs. h for whatever value of m yields - straight line through the origin.

   $(m = \frac{1}{2},\ t \alpha \sqrt{h})$

4. Deduce the law governing this situation involving all three variables.

   $$t = \frac{k\sqrt{h}}{d^2}$$

5. Graph t vs. $\sqrt{h}/d^2$ to determine k, the slope.

6. Predict the time for draining for d = 4, h = 20.

Explanation:

This experiment is adopted from the PSSC physics laboratory program. It is an excellent one to use to enable students to practice recognizing direct and indirect relationships among physical variables through graphing. It provides a good illustration of a method of data analysis, i.e., graphing of variables, used throughout a course in physics. Students should be able to derive the law:

$$t = \frac{k\sqrt{h}}{d^2} \quad \text{where } h \approx 30 \text{ sm.}^{-3/2}$$

1:2

UNIT 1C - EXPERIMENT 3: CONSTANT ACCELERATION: GALILEO'S INCLINES

Purpose:

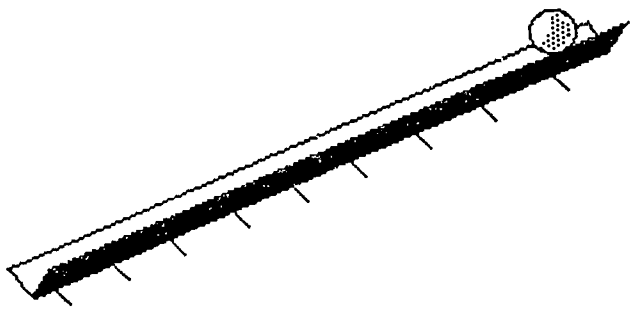
To generate data involving distances traversed by a ball rolling down an incline and the times required to travel those distances.

To analyze that data to determine if Galileo's relationship, $d \alpha t^2$ holds true.

Materials:

V shaped metal bar 3-4 meters long (optional: air track)
poles
clamps
pole stands
meter sticks
stopwatch (optional: photogate timers)

Procedures and Notes:



1. Students repeatedly roll a ball, from rest, down tne ramp (or release a cart on the air track) which has distances marked every 0.40 m.

2. Students time the ball (cart) at 0.40, 0.80, 1.20 m, etc.

3. Students calculate the average times at each position using data from the entire class. Record the data in a table.

   Include a column for t^2 and d/t^2 in the table.

d(m)	t(s)	t^2	d/t^2
.40			
.80			
1.20			
etc.			

4. Students plot d vs. t^2.

Explanation:

Students can examine data for relationships. They should determine that $d \alpha t^2$ or d/t^2 = constant, thus verifying Galileo's kinematic equation, $x = at^2/2$ for an object released from rest. Common variations include actually calculating the acceleration and comparing it to $g = 9.8\ m/s^2$ since on an incline $a = g \sin\theta$. For the ball rolling on the incline, not accounting for rotational motion causes the value of g so obtained to be much smaller than the actual value since the ball's rotational motion is not accounted for. Using an air track and more accurate timing methods yields a value of g closer to $9.8\ m/s^2$.

UNIT 1D - EXPERIMENT 4: PROJECTILE TARGET

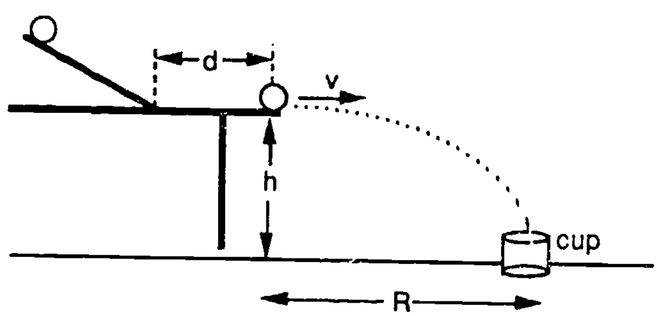
Purpose:

To predict the range of a projectile, a ball, launched horizontally from the table top.

Materials:

large steel ball bearing or marble
plastic ruler with center groove
stopwatch
meter stick
paper cup

Procedure and Notes:



1. Assemble the ramp as shown and release the ball from rest, timing the distance, d, traveled. Catch the ball as it comes off the end of the table. This should be repeated five times to obtain an average time. The ball should always be released from the same position on the ramp.

2. Measure h.

3. Use the d, t, h information to calculate R, the range. Let students derive the equation for R.

   (Using $h = gt^2/2$, $v = d/t$, $R = vt$, one obtains $R = v(2h/g^{\frac{1}{2}}))$.

4. Place the cup at the expected R position and let the ball roll down into it.

Explanation:

Students seem to delight in getting the ball into the cup. They will discover that the height of the cup may require them to move it a bit forward of their predicted position so that the ball lands in the cup.

UNIT 1E - EXPERIMENT 5: CENTRIPETAL FORCE AND ACCELERATION

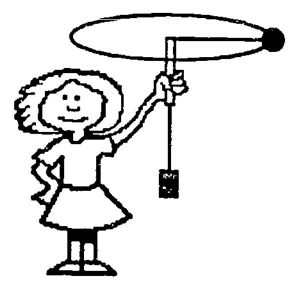
Purpose:

To verify the equation $F = 4\pi^2 Rm/T^2$ for an object undergoing centripetal motion.

Materials:

10 cm of fire polished glass tubing
#4 or #5 two-hole rubber stopper
weight set
stopwatch
nylon string
masking tape
metal washers

Procedure and Notes:



1. Wrap 10 cm of fire polished glass tubing in masking tape for safety, in case the glass breaks.

2. Tie about two meters of strong nylon string through the holes of the stopper. Thread the other end through the glass tubing and tie a loop to that end.

3. (Caution: This procedure can be dangerous if a classroom full of students performs it.) Whirl the stopper around in a horizontal circle of given radius when the appropriate weight is hung on the end of the string. Time ten revolutions to find the period of motion. Measure m, the mass of the stopper.

4. Utilize $F = 4\pi^2 Rm/T^2 = Mg$, the weight on the end of the string, to investigate any or all of the following relationships:

   A. How does R affect T when F, m are held constant? Choose R = 1.0, 0.75, 0.50, 0.25 m when F = 2.0 N.

   B. Find R/T^2 in each case and compare to $F/4\pi^2 m$.

   C. Plot R vs. T and R vs. T^2. Interpret the graph. What does the slope represent?

   D. How does F affect T when R, m are held constant? Choose F= 1N, 2N, 3N, 4N when R = 1.0 m.

   E. Find T^2F in each case and compare to $m4\pi^2R$.

   F. Plot F vs. T and 1/F vs. T^2. Interpret the graph.

Explanation:

This lab gives practice in examining relationships among physical variables by graphical analysis. In steps 4 A-C, since

$$F = 4\pi^2 Rm/t^2$$

$$R/T^2 = F/4\pi^2 m = \text{constant}$$

and so a graph of R vs. T^2 should yield a straight line through the origin whose slope = $F/4\pi^2 m$.

In steps 4 D-F, $T^2F = 4\pi^2 mR$ = constant and so a graph of 1/F vs. T^2 should yield a straight line through the origin.

As a third investigation ask students how they could check the dependence of m and T.

UNIT 1E - EXPERIMENT 6: STATIC AND KINETIC FRICTION

Purpose:

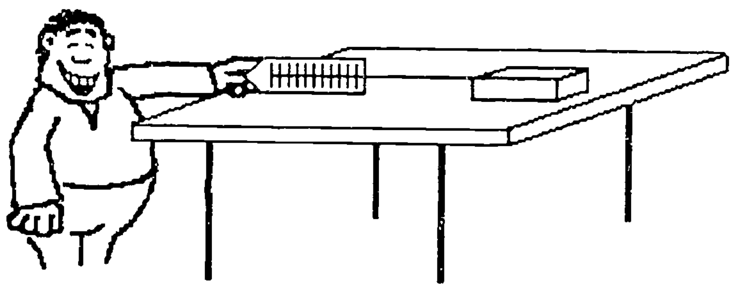
To distinguish between static and kinetic friction. To determine and compare coefficients of static and kinetic friction. To see if the amount of surface area in contact affects the coefficient of friction.

Materials:

brick (wrapped in butcher paper to prevent grit from crumbling off the brick) or other rectangular block
table or other surface such as a wooden plank which can be set at an incline
weight sets
spring scales
string
protractor
two-pan balance

Procedure and Notes:

Part I: Perform this part of the experiment on a level table.



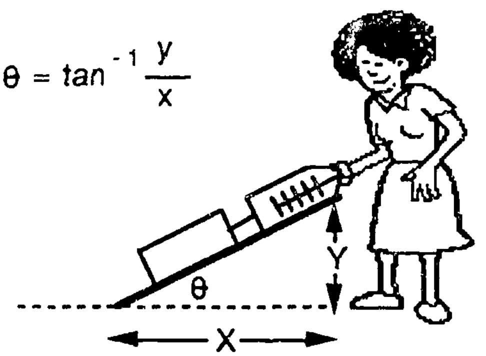
1. Tie a string around the brick and attach the string to the spring scale.
2. Drag the brick along the table or plank using the largest area of the brick. Use just enough force to get it moving. Record that force.
3. Once moving, record the force needed to keep the brick moving at a constant speed.
4. Measure the mass of the brick and calculate the coefficient of static and kinetic friction, recalling $f = \mu N = \mu mg$.
5. Repeat using a smaller area of the brick in contact with the table or plank.

6. Represent all the data and results in a table as shown:

Area	F_s	F_k	m	N	μ_s	μ_k
large						
small						

7. Students compare the results for the large and small areas to determine if area is a factor in friction.

Part II: Perform this part of the experiment on an inclined surface.



1. Using the large area side of the brick and table or plank, tilt the table or plank until the block just barely begins to slide. Measure the angle the table or plank makes with the horizontal with a protractor or measure x and y as shown.

2. Repeat 1 but adjust the angle of the table or plank so that once moving, the brick moves at a constant speed down the incline.

3. Represent all the data and results in a table as shown, where $N = mg\cos\theta$, $f = mg\sin\theta$, and $\mu = f/N = \tan\theta$.

	θ	W	N	F	μ
static					
kinetic					

Explanation:

It is hoped that students will note that in all cases $\mu_k < \mu_s$ and that surface area has no effect on the results.

UNIT 1F - EXPERIMENT 7: PLANETARY HARMONY

Purpose:

To deduce the relationship between the average radius of a planet's orbit around the sun, and the time to make one orbit.

Materials:

This is a dry lab.

Procedure and Notes:

1. Give students the following data table of time periods and average radii for the planets.

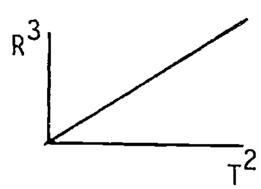
Planet	T (yr)	R (AU)
Mercury	.241	.387
Venus	.615	.723
Earth	1.00	1.000
Mars	1.88	1.524
Jupiter	11.8	5.203
Saturn	29.5	9.534
Uranus	84.0	19.18
Neptune	165	30.06
Pluto	248	39.44

2. Ask the students to plot R vs. T and to plot the functions of R and T which yield a straight line through the origin.

Explanation:

This dry lab can be used on two levels. First, if students do not already know Kepler's Third Law, deriving the correct powers of R and T can be quite challenging.

If they already anticipate $R^3 \alpha T^2$, the lab can still be a good verification of this relationship. In either case they should obtain



where the slope of the graph is numerically equal to 1.00 AU^3/yr^2. As an extension, have them convert this number to its appropriate value using meters and seconds.

UNIT 1G - EXPERIMENT 8: POTENTIAL AND KINETIC ENERGIES FOR A SWINGING WEIGHT

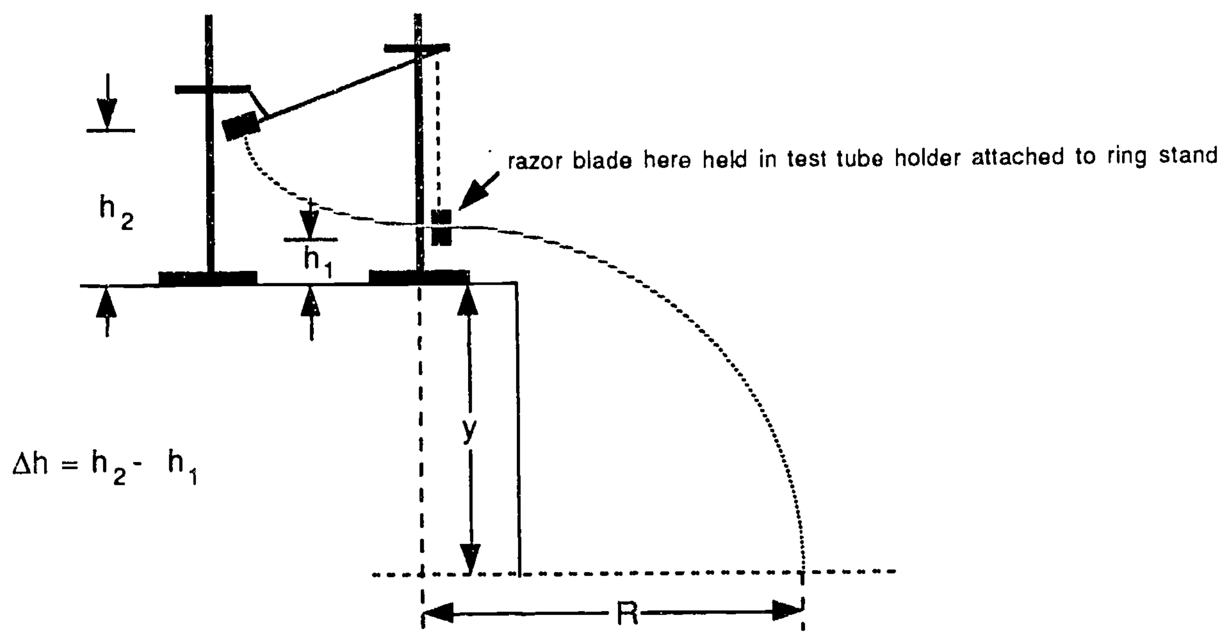
Purpose:

To confirm the conservation of energy principle.

Materials:

string
ring stands
c clamps
meter stick
matches
razor blade
carbon paper
utility clamp
metal ball or other suitable weight to be used as pendulum bob
thread

Procedures and Notes:



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1. Suspend a weight with string from a ring stand. Measure the height, h_1, to the table top. Raise the weight to a new height, h_2 and tie it with thread to another ring stand. Measure h_2.

2. Fix a razor blade so that when the thread is burned, the string holding the swinging weight will be cut at the bottom of its swing.

3. Record the position where the weight hits the floor with an upside-down piece of carbon paper on top of a sheet of notebook paper. Measure y and R. Determine the velocity the weight had as it was cut from the string.

4. Calculate the gravitational potential energy the weight started out with and the kinetic energy it had as it was cut by the razor.

5. Repeat the entire procedure using a new value for h_2.

Explanation:

Students should be able to confirm that:

$$\Delta U_g = \Delta E_k$$

or that mg $\Delta h = mv^2/2$ where v is determined from kinematic equations

$y = gt^2/2$ and $R = vt$.

UNIT 1H - EXPERIMENT 9: CONSERVATION OF LINEAR MOMENTUM: AN EXPLOSION

Purpose:

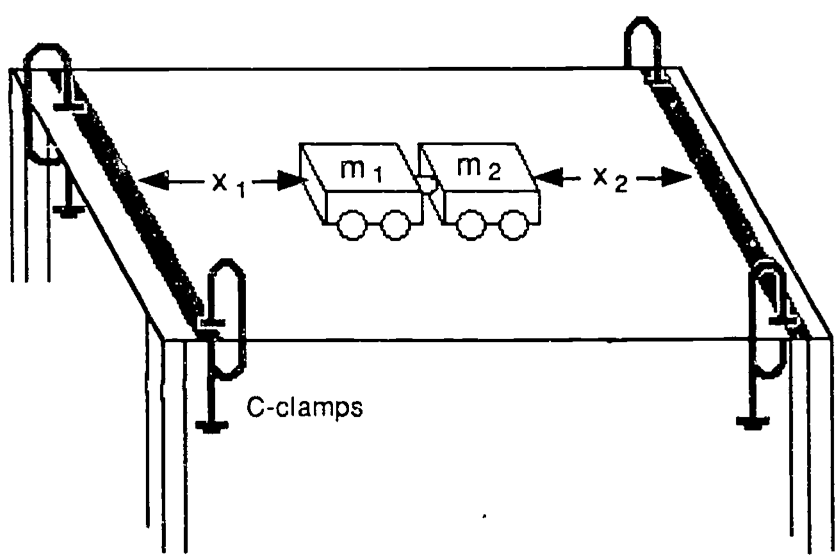
To observe and verify the law of conservation of linear momentum in a situation involving two "exploding" lab carts.

Materials:

2 lab carts (PSSC type) of the same mass--one with a spring-loaded plunger mechanism
bricks or other suitable weights
weight sets
meter stick
wooden sticks to act as bumpers
stopwatch
masking taping

Procedure and Notes:

1. Arrange the two carts together with the plunger mechanism cocked and ready to go. Place the carts at the position on the table where they will reach the two bumpers at the same time. Mark that position with masking tape. Students must listen to determine that both hit at the same time.



2. Measure x_1 and x_2 and the mass of each cart.

3. Verify whether momentum was conserved in the explosion.

4. Repeat but make one of the carts heavier by loading it with two bricks.

Explanation:

$$p_1 = p_2$$

$$m_1v_1 = m_2v_2$$

$$m_1x_1/t = m_2x_2/t$$

$$\therefore m_1 X_1 = m_2x_2$$

since the times are the same.

UNIT 1J - EXPERIMENT 10: PENDULUM

Purpose:

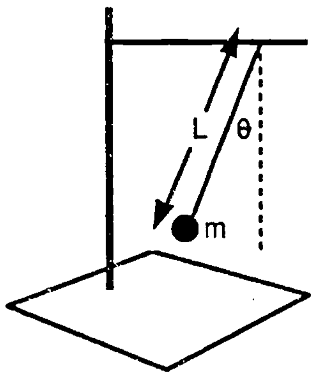
To determine which if any properties of a pendulum (length, angle of release, mass of pendulum bob) affect its period.

Materials:

hooked weights to serve as pendulum bobs
string
poles
platforms
pendulum clamp
C clamp
protractor
meter stick
stopwatch or other timing mechanism

Procedure and Notes:

1. Construct pendula of varying masses, lengths, and angles of release by varying one factor while keeping the other two fixed, and measuring the time for 50 complete swings. Calculate the period.



2. If the correct relationship, $T \propto \sqrt{L}$ is not already known by the students, have them plot:

   T vs. L and T vs. L^m until they can determine values for m which yield a straight line through the origin.

   Determine the slope of this line. (Alternative step 2: If it has already been studied that $T = 2\pi\sqrt{L/g}$, experimentally confirm this by plotting t vs. $\sqrt{L}$ and determine the slope. Compare this value to $2\pi/\sqrt{g}$.

Explanation:

Students should discover (or verify if previously known) that the correct graph is T vs. $\sqrt{L}$. The slope should be numerically equal to $2\pi/\sqrt{g}$. Students will discover that the angle of release and the mass should not affect the period. (Note: Keep the angles small, $\leq 15°$-- otherwise there may be some noticeable variation.)

UNIT 1K - EXPERIMENT 11: PRESSURE VS. FORCE: THE WEIGHT OF A CAR

Purpose:

To distinguish between pressure and force; to determine the weight of a car.

Materials:

a car
tire pressure gauge
graph paper

Procedures and Notes:

(The experiment is to be carried out at school or home under the supervision of an adult.)

1. Rub dirt or ink onto the tread of one of the car's tires.
2. Roll the car onto the paper. Trace the outline of the tire where it contacts the paper. Roll the car back off the paper.
3. Compute the contact area and, as accurately as possible, determine what percent of the area was actually in contact with the paper by estimating what percent of the tire is tread. Calculate the actual area in contact.
4. Measure the pressure in the tire.
5. Calculate the force in the tire and multiply by 4.
6. Compare this value to the "known" weight of the car (check owner's manual).

Explanation:

Be sure students account for possible errors in the "known" value of the car's weight.

$F = P/A_{actual}$ and Weight = 4F.

Have students determine pressures in lb/in^2 and N/m^2 and forces in pounds and Newtons.

UNIT 1L - EXPERIMENT 12: THE SPEED OF SOUND IN AIR

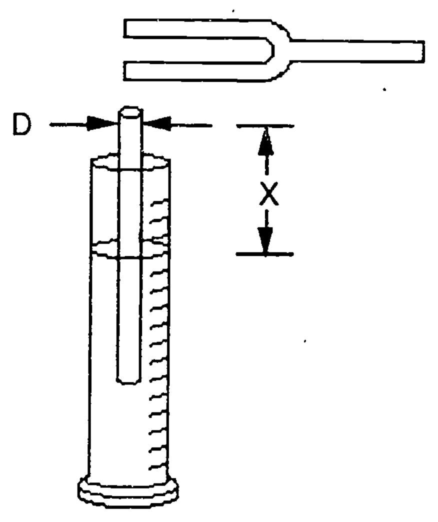
Purpose:

To determine the speed of sound in air.

Materials:

large 500 mL or 100 mL graduated cylinder
2 tuning forks (256 Hz or above)
hollow metal tube
meter stick

Procedure and Notes:



1. Add water until the graduated cylinder is about 3/4 full.

2. Strike the tuning fork, place it as shown and raise and lower the tube until the sound is best reinforced.

3. Measure x. Calculate $x_{corrected} = x + .4D$.

   Calculate $\lambda = 4x_c$ and $v = \lambda f$ where f is the frequency of the tuning fork.

4. Measure the room temperature T in °C. Calculate the expected value for the speed of sound in air from $v_{expected} = 332 + .6\ T$.

   Compare to the calculated value for the speed. Determine the % error.

5. Repeat using two other tuning forks of different frequencies.

Explanation:

The loudest sound waves heard occur when the tuning fork pushes the air column at just the right frequency to start the air column vibrating sympathetically. The continued vibration of the fork establishes a resonance condition where x is approximately $\lambda/4$ for the fundamental note.

UNIT 2A - EXPERIMENT 13: THE MECHANICAL EQUIVALENT OF HEAT

Purpose:

To obtain a value for the ratio of work units (Joules) to heat units (calories), the mechanical equivalent of heat.

Materials:

a long cardboard tube (mailing or packing type)
lead shot
solid rubber stoppers for ends of tube
beaker
thermometer

Procedure and Notes:

1. Cool 1-2 kg. of small lead shot in a beaker to about 5°C below room temperature. Record the temperature.

2. Quickly but carefully pour the shot into the open end of the cardboard tube whose other end has already been stoppered.

3. Insert the second stopper securely and invert the tube so that the lead shot falls the full length of the tube. Repeat this quickly 100-200 times.

4. Immediately pour the shot out into the beaker again and measure its temperature.

5. Compute the mechanical equivalent of heat.

Explanation:

The work done by dropping the shot is $W = Nmgh$, where N is the number of inversions, m is the mass of the shot, h the distance the shot falls each time. The heat gained by the shot is $H = mc\,\Delta T$ where c is the specific heat of lead, which is 1.3×10^{-4} J/Kg/°C and ΔT is the change in the temperature. The mechanical equivalent of heat is:

$W/H = Nmgh/Mc\,\Delta T = Ngh/c\,\Delta T$ and should be about 4.18 J/cal. (Note: You may wish to have the students mass the lead shot and calculate W and H explicitly before finding their ratio.)

UNIT 2C - EXPERIMENT 14: ABSOLUTE ZERO

Purpose:

To extrapolate a value for absolute zero using Charles' Law and Gay-Lussac's Law.

Materials:

Erlenmeyer flask with 1-hole stopper
large beaker
graduated cylinder
fish tank
bunsen burner
ring stand
ring
wire gauze (or hot plate)
masking tape
thermometer
pressure gauge connected to a closed container of gas
ice
dry ice

Procedure and Notes:

A. Charles' Law

1. Note the room pressure and record.

2. Place the stoppered flask containing air in boiling water and hold at a boil for a few minutes. Note the temperature of the water, [T_1].

3. Cover the hole in the stopper with your protected finger. Remove it from the water bath and place the flask upside down in the 3/4 full fish tank, allowing water (but not air) to flow into the flask.

4. Lower the flask until the water inside the flask is at the same level as that on the outside. (The pressure is thereby the same as atmospheric pressure.) Record the temperature of the tank water, T_2.

5. Put your finger back over the hole and remove the flask from the tank. Place a piece of masking tape at the location of the bottom of the stopper or the flask and remove the stopper. Pour the water from the flask into a graduated cylinder and record its volume, V_{H_2O}.

6. Similarly determine the total volume of the flask by filling water to the tape mark and measuring its volume, V_{flask}.

   Note: $V_2 = V_{flask} - V_{H_2O}$

7. Correct V by accounting for the vapor pressure of water at T_2:

$$P_{air}/P_{\substack{water\\vapor}} = V_{air}/V_{\substack{water\\vapor}}$$

and

$$V_{2\ corrected} = V_2 - V_{\substack{water\\vapor}}$$

8. Plot (T_1, V_1) and $(T_{2\ corrected}\ V_2)$ on a V vs. T graph.

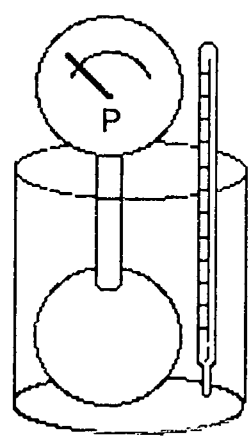
   Extrapolate to where V = 0 to find absolute zero.

B. Law of Gay Lussac:

1. Place the pressure gauge-gas container absolute zero demonstration device in water at various temperatures (ice water to boiling water) and record the pressures and temperatures.

2. Crush dry ice and bury the gas container in a beaker of it. Record pressure and temperature.

3. Plot P vs. T and extrapolate to where P = 0 to find absolute zero.



Explanation:

Charles' Law indicates V α T for constant pressure and constant number of molecules and for T measured in degrees Kelvin. The Gay-Lussac Law indicates P α T for constant volume and constant number of molecules when temperature is in degrees Kelvin. Both graphs should be straight lines (through the origin if T in degrees Kelvin is plotted or with some P-intercept if °C is plotted).

UNIT 3A - EXPERIMENT 15: COULOMB'S LAW

Purpose:

To verify the inverse square nature of Coulomb's Law.

Materials:

approximately 1 cm diameter styrofoam ball coated with graphite, suspended on 250 cm of nylon thread
another ball of the same diameter mounted on an insulating rod
rods
platforms
C-clamp
utility clamp
two clothespins
charging mechanism such as Van de Graff Generator
electrophorus or fur and vinyl strips
Leyden jar

(Note: A commercial Coulomb's Law Apparatus is available.)

Procedures and Notes:

1. Suspend the ball so that it is free to swing.

2. Arrange the light source so that a sharp shadow of the balls appears on the wall behind. Mark the initial positions of the balls on the graph paper.

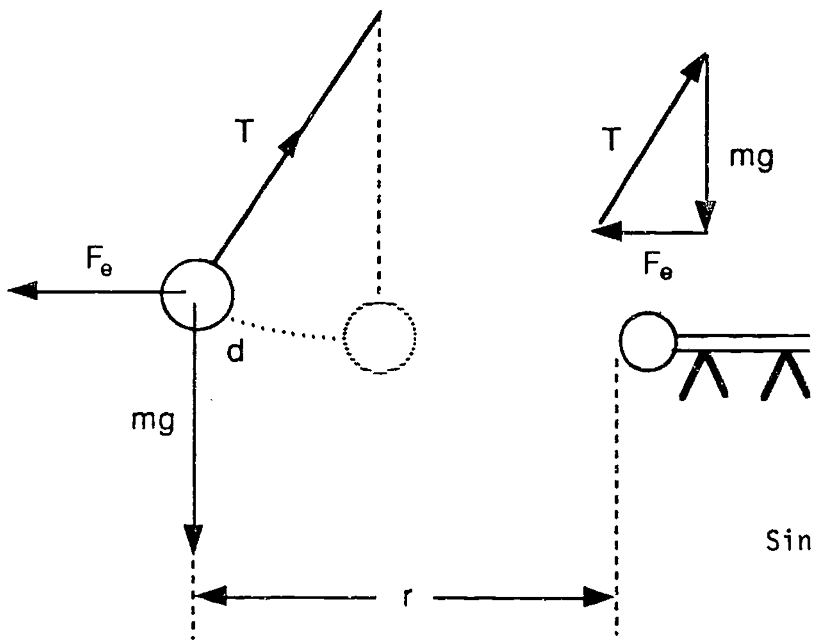
3. Charge both the balls using Leyden jars charged from a Van de Graff or by some other means.

4. Vary r and mark both r and d for each value of r.

5. Plot d vs. r and d vs $1/r^2$. Interpret the graphs.

Explanation:

The following figure depicts the physics of this lab.



$F_e/mg \approx d/L$

$F_e = mgd/L \propto 1/r^2$

Since $F_e \propto d$, then $d \propto 1/r^2$

Measuring d in effect measures F_e, thus verifying the inverse square law.

UNIT 3C - EXPERIMENT 16: SIMPLE DC CIRCUITS

Purpose:

To utilize Ohm's Law. To gain experience in constructing simple DC circuits. To gain experience in the use of voltmeters and ammeters.

Materials:

2 flashlight bulbs and sockets
1.5 volt battery (dry cell or flashlight type in a holder)
2 carbon 47Ω resistors
voltmeter
ammeter of 10A-1μA range (or combination meter)
connecting wires

Procedure and Notes:

For each of the following, ask students to draw the circuit involved before setting it up. You or your teacher assistant should check each circuit prior to final hookup to the battery. Be sure students have ammeters connected in series and voltmeters across (in parallel) with the circuit elements under study.

1. Connect one bulb to the battery. Measure the voltage across the bulb; measure the current. Find R_{eq}.

2. Connect two bulbs in series to the battery. Measure the voltage across each bulb, measure the current. Find R_{eq}.

3. Connect two bulbs in parallel. Measure the voltage across each bulb. Measure the current in the main branch. Find R_{eq}.

4-6. Repeat steps 1-3 using an unknown (to the student) carbon resistor. Ask students to note the color band sequence of the resistor.

7. Connect two bulbs in parallel in series with one of the unknown resistors. Measure the voltage across each element of the circuit; measure the current in the main branch. Calculate R_{eq}.

Explanation:

The bulbs may range from 5-15Ω each.

In series $R_{eq} = R_1 + R_2$; in parallel $R_{eq} = 1/R_1 = 1/R_2$.

Students will note that two bulbs in series are more dimly lit than when in parallel. Also, they may presume zero current if a bulb is not lit, when in fact the current is just too low to light the filament.

(Note: Due to the circuit checking, this lab will probably require two or three fifty-minute periods.)

UNIT 3E - EXPERIMENT 17: THE MAGNETIC FIELD OF A LONG, STRAIGHT, CURRENT-CARRYING WIRE

Purpose:

To verify the circular nature of the magnetic field of a line of current. To determine how the strength of the field varies with radial distance from the wire.

Materials:

6 meters of 18-20 gauge wire
poles and clamps
brick
2 long, narrow pieces of wood
6-12 volt DC power supply, capable of 8-10 amps of current
1-10 amp ammeter
about 30 cm x 30 cm piece of cardboard
blank graph paper
compass

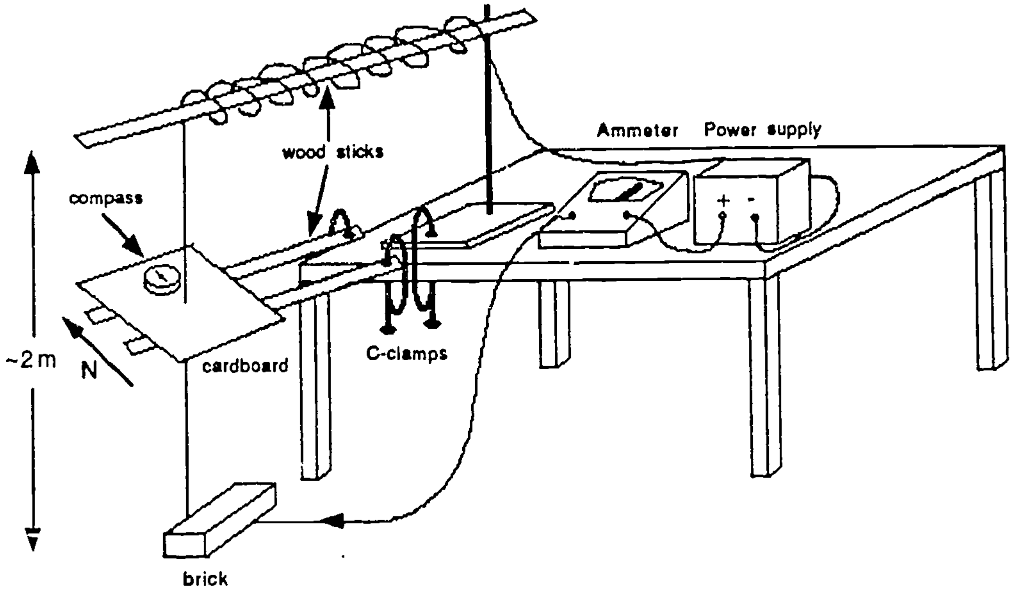
Procedure and Notes:

1. Arrange the apparatus as shown. Thread the wire through the center of the cardboard and the graph paper.

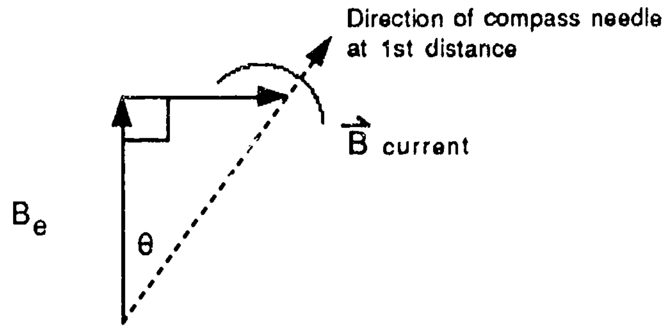
2. With no current flowing, determine the direction of the earth's magnetic field, B_e.

3. Be sure there are no iron objects within 50 cm of the sheet of graph paper.

4. With about five amperes flowing, measure the angular deflection of the compass needle from north at various distances along the N-S line. Choose 3, 5, 7, 9, 12, and 15 cm distances.



5. The following should show how to anlyze the data. Choose a length for B_e, such as 2 cm.



Indicate the direction of the needle and draw $B_{current}$. Repeat for all distances.

6. Ask students to plot $B_{current}$ vs. distance from the wire.

7. Ask them to find the relationship between $B_{current}$ and distance

   (They should plot B_c vs. 1/distance and get a straight line.)

   They should conclude $B_c \alpha 1/d$ by plotting B_c vs. d^m choosing m

   so that a straight line through the origin is obtained.

Explanation:

The graph of B_c vs. d should yield an inverse graph. Plotting B_e vs. 1/d will produce a straight line enabling students to conclude $B_c \alpha 1/d$.

UNIT 3E - EXPERIMENT 18: TANGENT GALVANOMETER

Purpose:

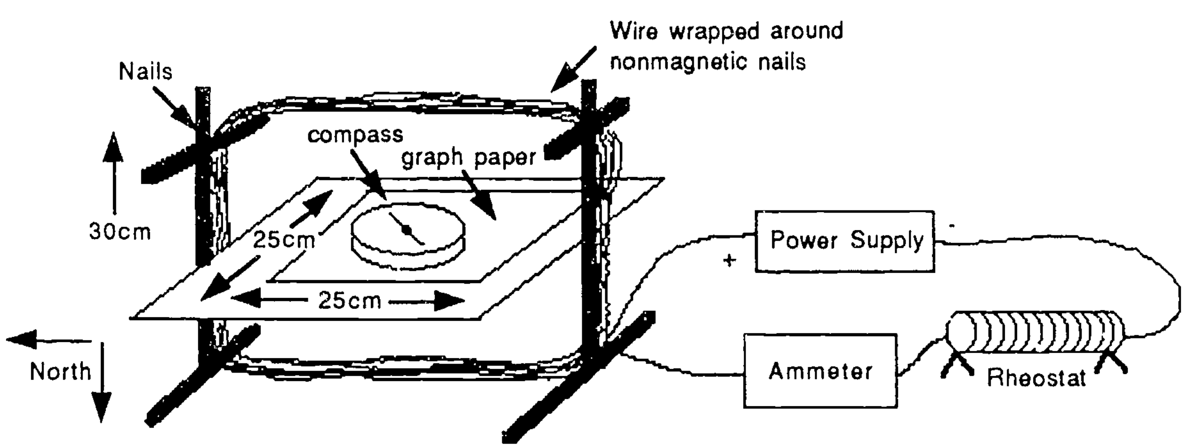
To construct an arrangement of current loops to produce a galvanometer.

Materials:

6-8 meters of 18-20 gauge wire
compass
nonmagnetic metal (or wood)
tangent galvanometer apparatus (purchase or construct as shown below)
6-12 volt DC power supply
27 ohm rheostat
1-10 amp ammeter
graph paper

Procedure and Notes:

1. Purchase or construct the tangent galvanometer apparatus shown.



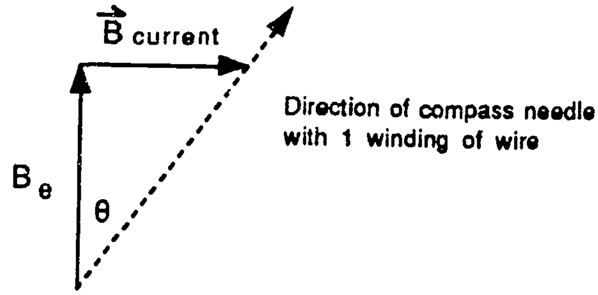
Non magnetic Platform and Stands

2. Have students align the apparatus so that the plane formed by the wire loop is in the N-S direction.

3. With one loop of wire wrapped around the nails and a current flowing, measure the angular deflection of the compass needle from north.

4. Repeat for 2, 4, 6, 8 loops of wire. This represents twice, four times, etc., the amount of current.

5. The following is used in the analysis of the data. Choose a length for B_e, such as 2 cm.



Indicate the direction of the needle and draw B_c. Repeat for all number of windings.

6. Ask students to plot B_c versus the number of windings (i.e., amount of current).

7. Ask students to explain how this setup can be used as a galvanometer.

Explanation:

The graph of B_c vs. the number of loops or current should yield a straight line.

The unit can serve as a galvanometer since the deflection of the compass can be calibrated to correspond to various values of current.

UNIT 4A - EXPERIMENT 19: REFLECTION AND REFRACTION

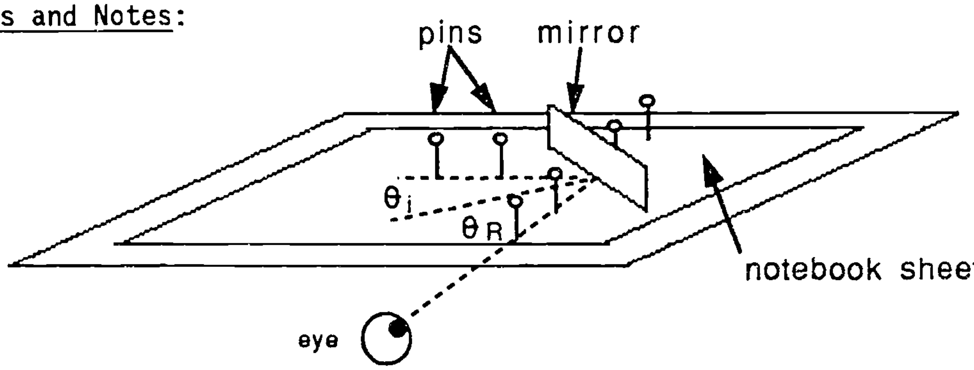
Purpose:

To verify the Law of Reflection. To use Snell's Law to compute indices of refraction.

Materials:

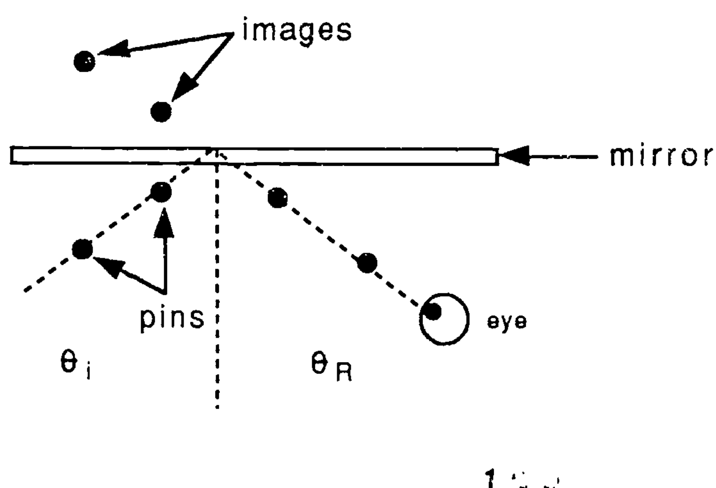
cardboard box sides (about 8½ x 11 inches)
small plane mirrors (1 x 3 inches)
semicircular clear plastic boxes
hatpins
glass blocks (2 x 2 inches)
plastic blocks
protractor

Procedures and Notes:



1. Support a mirror vertically on top of a piece of the mirror on the paper. Place two pins at a large angle (greater than 45°) relative to the normal mirror surface and move the head around until you see the images of both pins lined up with no parallax. Place two more pins in line with this view.

   Measure θ_i and θ_R and verify the law of reflection



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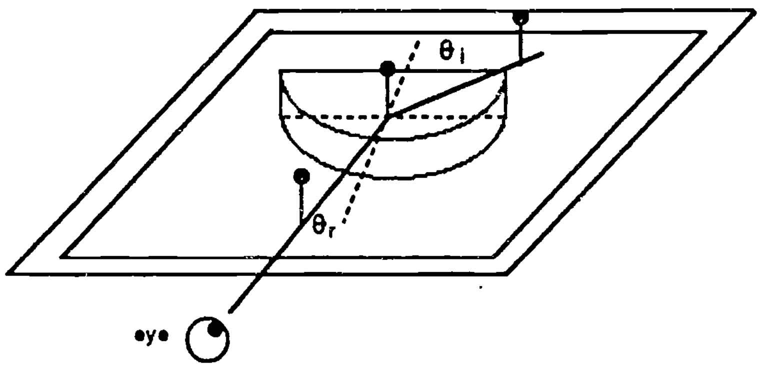
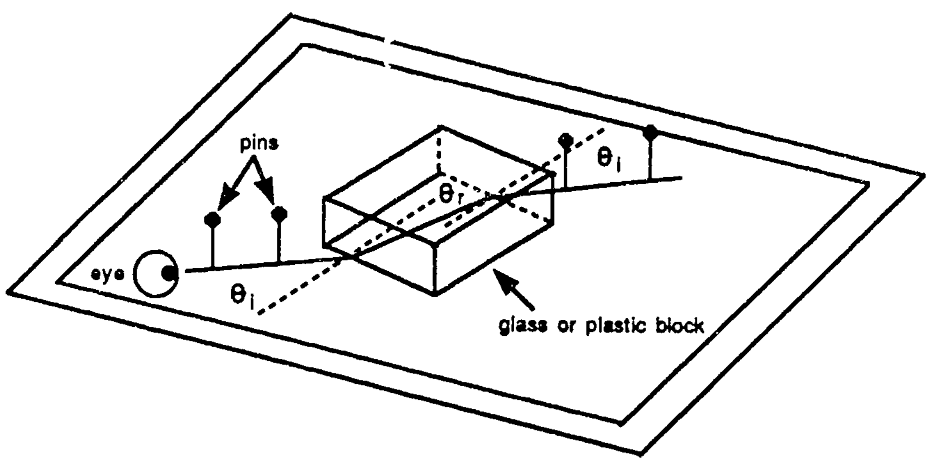
2. Place and trace a water-filled semicircular transparent plastic box on the cardboard with notebook paper. Place a pin at the center of the circle and another out and over to establish a line of sight. Looking through the round end simulates being under water. Place another pin in line with where the two other pins seem to line up without parallax. Measure θ_i and θ_r.



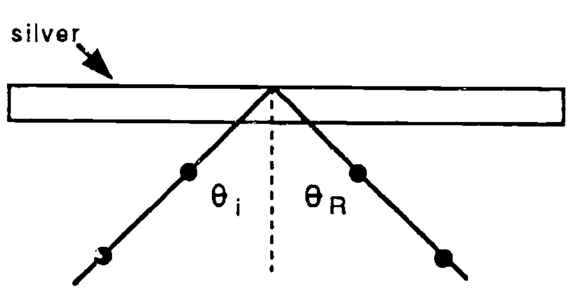
Use Snell's Law to determine the index of refraction of the water.

3. Place and trace a glass block and/or plastic block as in step 2. Use pins to establish the line of sight in air. Using Snell's Law, determine the index of refraction of the glass/plastic.

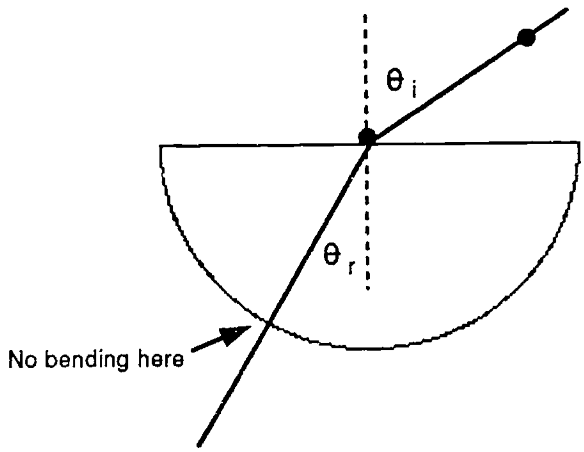


Explanation:

Comment to students that the mirror surface is actually on the back of the glass mirror. The lines should intersect there and not at the front of the glass.



Placement of one pin at the center of the semicircular disk results in no bending of the light through the circular side; hence the effect of being under water.



UNIT 4A - EXPERIMENT 20: LENSES AND THE REFRACTING TELESCOPE

Purpose:

To gain experience in using simple lenses and observing their optical properties. To verify the relationships among image distance, object distance, and focal length for converging lenses. To construct a simple refracting telescope.

Materials:

converging lenses of various focal lengths (5 cm - 30 cm)
lens holders for meter sticks
meter sticks
1.5 volt battery
flashlight bulbs and sockets
connecting wires
unfrosted 150 W incandescent light source

Procedure and Notes:

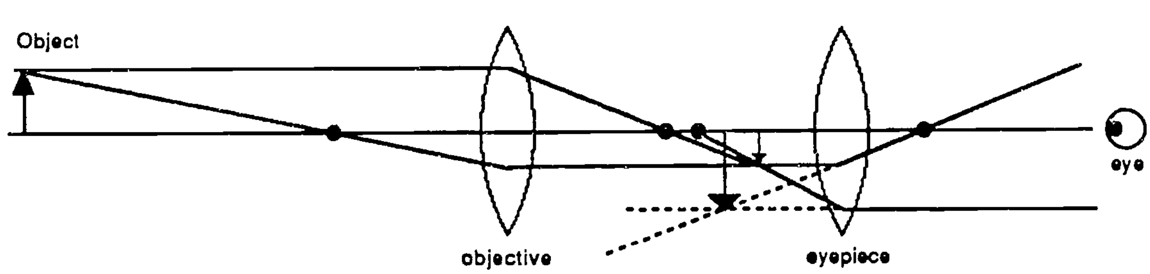
1. Select 2 converging (double convex) lenses of differing focal lengths. Place each in lens holders on a meter stick and observe the light source across the room (at a large enough distance to be considered infinite!). Using a piece of paper, locate the position of the sharpest image of the bulb and measure this distance on the meter stick. This is the focal length.

2. Place the lit flashlight bulb as an object 20 cm beyond the focal point of one of the lenses. Locate and measure the position of the image using a paper screen. Calculate the expected position and compare it to the experimentally determined position.

3. Construct a simple refracting telescope using both lenses. The eyepiece should be the lens with the smaller focal length. Observe an object across the room (down the hall, etc.). Make a ray diagram of the situation. Calculate the magnification of the telescope.

Explanation:

In the second step, students should use the lens formula $1/f = 1/i + 1/o$ to solve for i and compare to the experimental value of i. For the telescope the diagram should resemble the following:



The magnification is $m = f_o / f_e$.

UNIT 4B - EXPERIMENT 21: A YOUNG'S TYPE EXPERIMENT

Purpose:

To observe the interference of light waves using a double-slit arrangement.
To calculate the wavelength of the light source.

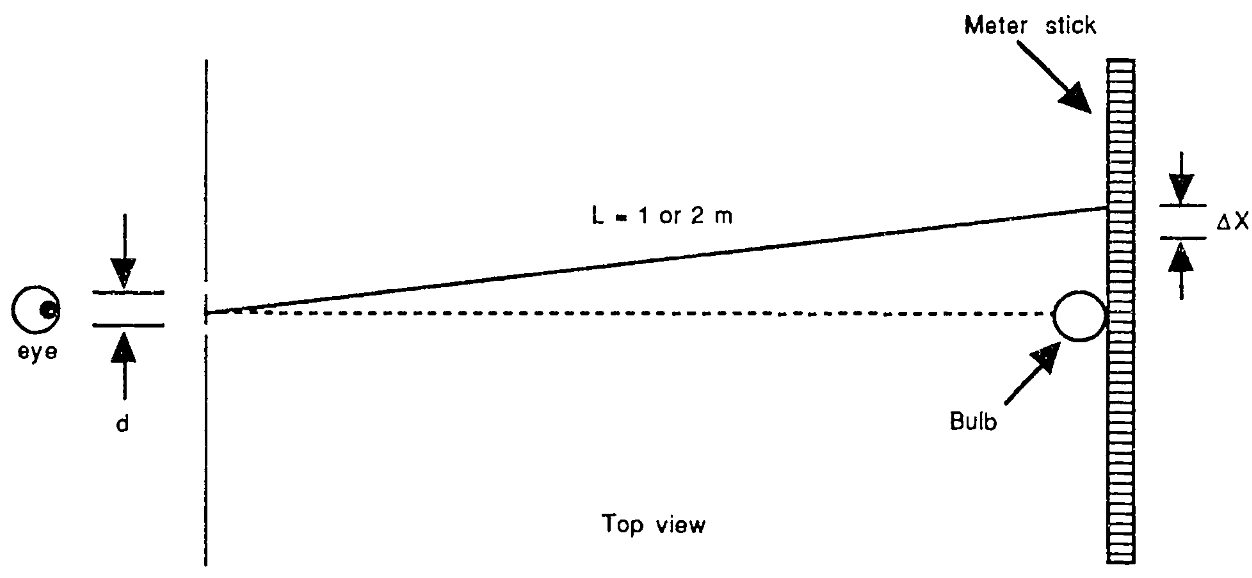
Materials:

Cornel Slit film or other suitable commercially available or homemade double-slit arrangement*
showcase lamp
red and blue cellophane
rubber bands
meter stick
poles
platform
clamps

*See Appendix A: Laboratory Guide PSSC Physics for instructions on construction.

Procedure and Notes:

1. Arrange the materials as shown.



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2. Observe the red filtered light through the double-slit arrangement along the meter stick.

3. Note and diagram the interference pattern.

4. Measure the distance between one dark line and the next (Δx) by measuring 10 Δx's and dividing by 10. Measure L; note d. Calculate the wavelength.

5. Repeat using the blue cellophane filter.

6. See if the values for the blue and red light fall within the wavelength range for each given in a textbook.

Explanation:

Referring to the diagram the wavelength is calculated from:

$$\lambda = d \ \Delta x / L$$

UNIT 4B - EXPERIMENT 22: INTERFERENCE OF WAVES IN A RIPPLE TANK

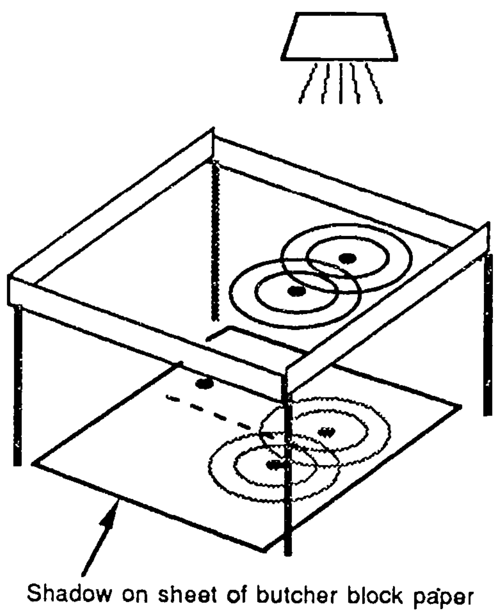
Purpose:

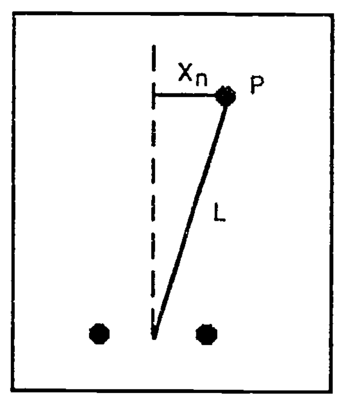
To observe the interference patterns of two in-phase point sources in a ripple tank. To calculate the wavelength of the waves produced and compare to the measured value.

Materials:

ripple tank and accessories including two-point source wave generator
hand-held stroboscope
meter stick

Procedure and Notes:





1. Observe the nodal lines and lines of reinforcement for two interfering point sources in the ripple tank. Trace the pattern on the sheet.

2. Choose a point on the nth nodal line far from the sources and mark its location. Also draw in X_n and L. Calculate the wavelength.

4. Stop the pattern using the hand-held stroboscope and place the meter stick in the shadow to measure the wavelengths (from one bright area to the next along a line of reinforcement).

5. Compare the measured and calculated values and find the percent difference.

Explanation:

Depending on the textbook in use, the wavelengths can be calculated using

$\lambda = dX_n/L(n - \frac{1}{2})$

if n = 1, 2, 3 ... for 1 = first nodal line beyond the center

or $\lambda = dX_n/L(n - \frac{1}{2})$

if n = 0, 1, 2, 3 ... for 0 = first nodal line beyond the center.

UNIT 4B - EXPERIMENT 23: THE WAVELENGTH OF LASER LIGHT

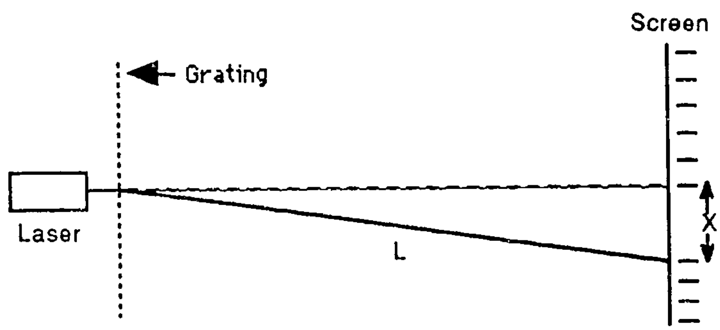
Purpose:

To observe the diffraction pattern of the light from a HeNe laser and indirectly measure its wavelength.

Materials:

1 HeNe laser
meter stick or metric tape measure
diffraction grating (13,400 slits per inch)
(Optional: Use a double slit and proceed as in Experiment 20.)

Procedure and Notes:



1. Observe the diffraction pattern of laser light using a diffraction grating.

2. Measure l, x for the first "dot" beyond the central one.

3. Compute and compare to the known value for the laser light

   (6.328×10^{-7}m).

Explanation:

The formula $\lambda = dx/l$ applies where d must be calculated knowing the line spacing for the grating:

1 in/13,400 lines (2.54×10^{-2}m/in).

UNIT 5C - EXPERIMENT 24: SPECTRA OF ELEMENTS

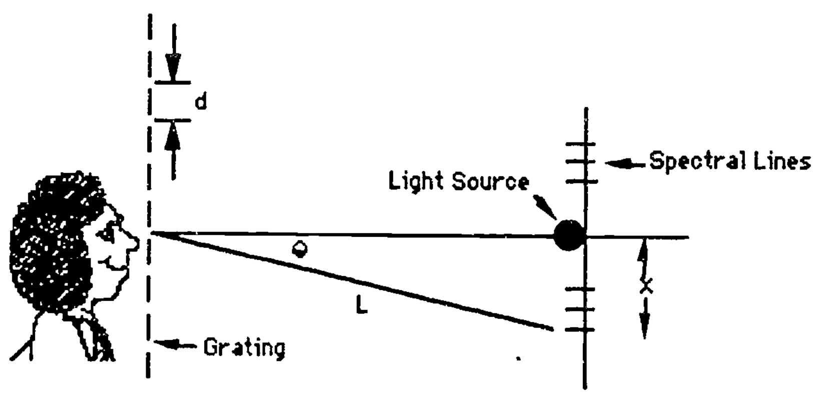
Purpose:

To observe the emission spectral lies of various glowing gaseous elements using a diffraction grating. To calculate wavelengths of Hydrogen's Balmer lines and of unknown elements.

Materials:

meter stick
diffraction grating (13,400 slits per inch)
gaseous discharge tubes for hydrogen, helium, mercury, neon, etc.
chart of emission spectra

Procedure and Notes:



1. Observe the Balmer lines of hydrogen (3 can easily be seen in a dark room) through the grating. Let L be 1-2 m.

2. Measure L, x for each line.

3. Compute λ for each line and compare to the known values on a chart of spectral lines.

4. Repeat with the most prominent lines of at least one other unknown gas and try to determine its identity using the chart.

Explanation:

We know that a diffraction grating will disperse the various wavelengths in luminous gases. The formula $d \sin\theta = m\lambda$ applies where $m = 0, 1, 2...$, the so-called order of the spectra. In this experiment measurements of the first order ($m = 1$) diffraction pattern for the various lines are used. From the diagram $d \sin\theta = \lambda = dx/L$.

UNIT 5C - EXPERIMENT 25: SIMULATED NUCLEAR CROSS SECTION

Purpose:

To measure indirectly the "size" of an object as an analog to the measurement of the cross section of a nuclear target in a nuclear collision experiment.

Materials:

40 coins (nickels are a good size)
pencil
sheet of notebook paper
masking tape

Procedure and Notes:

1. Lay out the coins randomly but more or less uniformly on the sheet of paper taped to the floor.
2. Drop the pencil from 2 m onto the sheet of paper 50 times and count those shots that hit a coin. (Some rearrangement may be necessary between drops. Ignore all shots that miss the paper.)
3. Calculate the area of a target coin.

Explanation:

The probability that a hit occurs can be expressed as the ratio of the total coin area, nA_c, where n is the number of coins, to the area of the paper A_p:

$$P = nA_c/A_p$$

The probability is also the ratio of the number of hits to the number of drops:

$$P = H/D = nA_c/A_p$$

So, the area of a coin can be calculated:

$$A_c = HA_p/nD$$

This experiment shows how we can infer the size of something such as a nucleus, without having measured it directly. Knowing the number of nuclei in a given area of target (which is possible via Avogadro's number) we can find the area of the nucleus or its cross section.

UNIT 5E - EXPERIMENT 26: HALF-LIFE

Purpose:

To simulate the decay of a radioactive nuclide. To plot a "half-life" graph for this simulated decay.

Materials:

shoe box with lid
200 pennies (or other objects with distinct sides)
graph paper

Procedure and Notes:

1. Shake up the pennies in the closed box for 15 seconds. Then open the box and remove all the pennies that are heads up. These represent decayed atoms. Record the number removed and the number remaining.

2. Repeat step 1 until all the pennies have been removed.

3. Record the data in a table similar to the following:

Trial Number	# Pennies Removed	# Pennies Remaining
1		
2		
3		
etc.		

4. Graph the number of pennies remaining (N_R) vs. the trial number (t).

Explanation:

This exercise simulates the decay of a given amount of radioactive nuclide. The "half-life" here is represented by the trial number.

As an added exercise encourage students with knowledge of logarithms and exponentials to plot a graph of:

N_R vs. t^m

choosing m so that a straight line through the origin is obtained. A computer graphing program may be helpful.

SECTION IV:

APPENDICES

APPENDIX A - RESOURCES

AAPT Guidelines for High School Physics Programs, American Association of Physics Teacher (AAPT), College Park, MD. Latest edition.

American Association of Physics Teachers (AAPT), 5112 Berwyn Road, College Park, MD 20740. (301) 345-4200. Publications, national conventions, committees, and workshops are among the benefits of membership.

American Association of Physics Teachers (AAPT), Southern California Section. This is the regional arm of the AAPT. It sponsors two meetings at various Southern California locations (university, high school, industry) in fall and spring.

Audiovisual Materials Resource List, Secondary Schools Edition. Latest Revision. Los Angeles Unified School District, Audiovisual Services Section.

Blueprint for Bulletin Boards. Los Angeles Unified School District, Office of Secondary Instruction, Publication No. SC-824, 1983.

Catalog of Standard Supplies and Equipment for Elementary, Secondary, and Adult Schools. Latest Revision. Los Angeles Unified School District, Purchasing Branch.

Catalog of Films for Secondary and Adult Levels. Latest Revision. Los Angeles Unified School District, Audiovisual Services Section.

Conceptual Physics Laboratory Manual. Robinson, P., Addison-Wesley Publishing Company, Inc., Menlo Park, CA. 1987 or latest edition. This is a source of labs and lab type activities, many of which are very simple and easy to do. This publication also incorporates optional computer interfacing in many of the experiments.

Conservation of Energy, Suggested Activities for Pupils. Los Angeles Unified School District, Instructional Planning Division, Publication No. EC-448. Available from Regional Science Center.

Course Content in High School Physics. AAPT, College Park, MD. 1988 or latest edition.

A Demonstration Handbook for Physics. Freier and Anderson, American Association of Physics Teachers (AAPT), College Park, MD. Latest edition. This is a collection of demonstrations for almost every physics concept with diagrams and brief descriptions.

Guidelines for Instruction: Secondary School Curriculum, Science. Los Angeles Unified School District, Office of Instruction, Publication No. SC-863.19, 1985.

How to Build a Better Mousetrap. Vernier, D. Latest edition. Vernier Software, 2920 SW 89th Street, Portland, Oregon 97225. This publication contains ideas for constructing interfacing gadgets and using Vernier's inexpensive interfacing software.

Laboratory Guide PSSC Physics. Haber-Schaim, DC Heath and Co., Lexington, MA. 1986 or any edition. Classic PSSC experiment guide with open-ended, high conceptual level experiments.

Laboratory Physics. Murphy, Merrill Publishing Co., Columbus, Ohio. Latest edition. This is a set of laboratory experiments in a more traditional format, (i.e., not so open-ended as the PSSC Guide.)

List of Authorized Textbooks, Junior and Senior High Schools and Community Adult Schools. Latest Revision. Los Angeles Unified School District, Textbook Services Section, Publication No. 426.

The Mechanical Universe High School Adaptation. (MUHSA), Quads I-VII, Southern California Consortium, 1-800-LEARNER, 1985-89. This material is based upon work supported by the National Science Foundation and is also disseminated through the National Diffusion Network. It was excerpted from the college television course, The Mechanical Universe and re-edited specifically for use in the high school curriculum. It consists of seven "quads," each containing four video programs of approximately fifteen minutes duration, and a complete curriculum guide featuring objectives, demonstrations, student activities, everyday connections, teacher background resources and evaluation questions. Each LAUSD high school had the opportunity to obtain some or all of the series through a grant from the Department of Water and Power.

Model Curriculum Standards Grades Nine Through Twelve. California State Department of Education, 1985 or latest edition. See Appendix B for a reprint of the section on physical science.

Occidental Physics Teachers' Meeting. This annual meeting usually takes place in January or February at Occidental College, Eagle Rock, California. Considered by many to be the best meeting of its kind for high school physics teachers, it features short presentations, demonstrations, etc., on the art and science of teaching physics.

Office of the Associate Superintendent, Instruction, Bulletin No. 22 (REV.), April 30, 1990, "Homework and Makeup Assignments for School Absences in Grades K-12."

Office of the Associate Superintendent, Instruction, Bulletin No. 23 (REV.), May 16, 1990, "Marking Practices and Procedures in Secondary Schools."

The Physics Teacher. American Association of Physics Teachers (AAPT), College Park, MD. This journal is published monthly except June, July, and August and is provided as part of a membership in the AAPT and contains new demonstrations, teaching suggestions, reviews of new apparatus, books, software, etc.

Physics - Teach to Learn. Curriculum Package. Los Angeles Unified School District, Office of Secondary Instruction, Publication No. SC-930, revised edition, 1989. This package contains teacher-directed computer simulation modules which address common student misconceptions of various physics principles. It was developed by physics teachers in LAUSD and has since became a National Diffusion Network validated dissemination project. It requires an Apple IIe, IIc, or IIGS and large classroom monitor and comes complete with an instructors guide containing notes, pre- and post-tests and floppy disks.

A Potpourri of Physics Teaching Ideas. Berry, Donna, American Association of Physics Teachers (AAPT), College Park, MD. Latest edition. It contains selected reprints of demonstrations, labs, and classroom activities from The Physics Teacher.

Precautions With Chemicals. Los Angeles Unified School District, Office of Instruction, Publication No. SC-865, 1984.

Project Physics Handbook. Rutherford, Holt, Reinhart and Winston. Latest edition.

Project Physics Resource Book. Rutherford, Holt, Reinhart and Winston. Latest edition. Both handbook and resource book contain experiments, demonstrations, activities, background notes, filmloop notes, and tests developed specifically for the Project Physics Course but useful to any physics course.

Reaching Higher Levels of Thought. Los Angeles Unified School District, Office of Instruction, Publication No. X-118, Stock No. 463320.

Resource Kit for the New Physics Teacher. American Association of Physics Teachers (AAPT), College Park, MD. 1985 or latest revision. This kit provides new physics teachers with information and materials that will help them actively involve their students in the process of learning physics during the first few weeks of school.

The Role, Education, and Qualifications of the High School Physics Teacher. American Association of Physics Teachers (AAPT), College Park, MD. Latest edition.

Science and Technology in Society (SATIS), Volumes 1-10, 1981. Holman, John. The Association for Science Education (distributed by the American Chemical Society).

Science Materials Center Catalog and Loan Equipment List for Senior High Schools, Order Forms and Other Information. Revised annually. Los Angeles Unified School District, Office of Instruction.

Science Safety Handbook for California High Schools. California State Department of Education, 1987.

Statement on Preparation in Natural Science Expected of Entering Freshmen. Academic Senates of California Community Colleges, CSUS and UC, California State Department of Education, 1986. See Appendix C for statement on physics preparation.

String & Sticky Tape Experiments. Edge, R.D., American Association of Physics Teachers (AAPT), College Park, MD. Latest edition. Meaningful experiments and activities put together with the simplest, least expensive materials.

Test-Taking Procedures and Techniques for Secondary School. Los Angeles Unified School District, Office of Instruction, Publication No. X-116, Stock No. 463897.

Use Metric. Los Angeles Unified School District, Office of Secondary Instruction, Publication No. SC-726, Stock No. 464000.

APPENDIX B

MODEL CURRICULUM STANDARDS, GRADES NINE THROUGH TWELVE: PHYSICAL SCIENCE. CALIFORNIA STATE DEPARTMENT OF EDUCATION, 1985

The following is a list of the standards for Physical Science which pertain to physics from the Model Curriculum Standards, Grades Nine through Twelve: Physical Science. California State Department of Education, 1985.

Individuals are referred to the entire document as it contains additional information including suggested activities which exemplify each standard.

1. Students understand the three basic phases of matter on earth and the role temperature and pressure play in the change of phase. Students will be able to relate the kinetic theory model to matter around them. (MCS PS-3)

2. Students learn to define, measure, and calculate various physical characteristics of substances (e.g., mass, weight, length, area, volume, and temperature). (MCS PS-5)

3. Students understand the basic concepts of nuclear science, including elementary particles, fission, fusion, plasma, radioactivity, half-life, and nuclear chain reactions. (MCS PS-8)

4. Students understand forces and their effects upon matter. (MCS PS-9)

5. Students understand that energy has been described as the ability to do work and that energy appears in many forms that can neither be created nor destroyed but only exchanged among various bodies or converted from one form to another in a quantitative and reproducible way. (MCS PS-10)

6. Students understand mechanics, including the interrelationships of force, mass, distance, and time. (MCS PS-11)

7. Students understand that motion is a movement of an object from one place to another, that acceleration is a rate of change in the velocity and or direction of motion, and that inertia is the resistance manifested by all matter to alteration of its state of motion. (MCS PS-12)

8. Students understand the nature of waves (electromagnetic [including light], sound, fluid), sources, propagations, and interactions. (MCS PS-13)

9. Students describe the characteristics of the electromagnetic spectrum (with reference to the nature of the surfaces and materials they are incident upon). (MCS PS-14)

10. Students understand heat, heat transfer, specific heat, and the differences between heat and temperature and their implications for calculating heat loss in isolated systems, converting heat into work. (MCS PS-15)

11. Students understand and appreciate the nature and role of electricity and electronics in the natural and the technological world. (MCS PS-16)

12. Students understand the relationship of magnetic forces and electrical currents and investigate magnetic polarity, electromagnetic induction, and the common uses of magnetism. (MCS PS-17)

13. Students understand certain principles of astronomy. These will include a study of stars, galaxies, the solar system, and the interactions of the moon and earth. (MCS PS-23)

APPENDIX C

STATEMENT ON PHYSICS PREPARATION EXPECTED OF ENTERING FRESHMAN IN THE STATE OF CALIFORNIA* COURSE CONTENT - PHYSICS

Introduction

The study of physics provides a systematic understanding of the fundamental laws that govern physical, chemical, biological, terrestrial, and astronomical processes. Physics is the root science. The basic principles of physics are the foundation of most other sciences and of technological applications of science. Physics is also part of our culture and has had enormous impact on technological developments. Many issues of public concern, such as energy, nuclear power, national defense, pollution, and space exploration involve physical principles that require some understanding for informed discussion of the issues. Thus comprehending physics is important for a rational, enlightened citizenry to participate responsibly in decisions on public policy regarding complex technological issues.

Physics is not just for physicists. In fact, few people who study the fundamentals of physics actually become physicists. Many enter related fields, such as engineering or other sciences, and many pursue nonscientific careers. For this reason, precollege physics should be taught at a general level and should demonstrate the general principles of the science.

Physics is an experimental science in that every statement of physical law is subject to verification and should be taught with this in mind. The relevance of physics to present and future technology should be made apparent.

The course content list that follows is offered as a best estimate of what should be included in the high school physics course for college-bound students. It is hoped the list will serve as a starting point for continuous discussion regarding the nature and scope of the course.

Mathematics: The physics course can be taught well with various levels of mathematical preparation. In fact, physics lends itself well to introducing students to the mathematical aspects of science. Physics is easy to describe mathematically, but it should not be inferred that physics can be easily learned mathematically. An overemphasis on mathematical analysis will disenfrancise many capable students from studying physics at the high school level. Ideally, a balance must be struck between the conceptual and mathematical aspects of physics with neither predominating. Physics teachers should make reasonable adjustments in their presentations to ensure this balance and to keep the scientific level compatible with the mathematical preparation of their students. Prerequisites consistent with the Statement on Competencies in Mathematics Expected of Entering Freshmen are Algebra I and geometry with a corequisite of Algebra II.

From "Statement on Preparation in Natural Science Expected of Entering Freshmen," issued by the Academic Senates of the California Community Colleges, The California State University, and The University of California. California State Department of Education, July 1986.

Topics for a One-Year Course in Physics

The topics are grouped under five main classifications: Mechanics, Heat and Thermodynamics, Electricity and Magnetism, Light and Optics, and Modern Physics. Specific concepts are grouped in relation to the topics within which they may best be covered. It is assumed that basic concepts of the nature of science have been covered at an earlier stage either in other science courses or, preferably, at a pre-secondary level. Basic to an understanding of science would be an appreciation of:

- the nature of scientific evidence
- strengths and limitations of science as a way of "knowing"
- the objective process of scientific inquiry
- accuracy and predictability of scientific knowledge

There are other topics that should be covered in introductory science courses, such as climate, weather, and weather predictions; plate tectonics; descriptive astronomy. Additional coverage of weather behavior (not just prediction) and plate tectonics (and the consequences of plate motion), while based in physics, is the domain of earth science.

The topics marked with a single asterisk (*) are also listed under the chemistry curriculum. The topics marked with a double asterisk (**) are considered to be special or advanced topics.

A. Mechanics

1. The Metric System of Units for Length, Time, and Mass*

   - estimates and approximations
   - metric units:
     their relation to units commonly used in everyday life
     dimensions
     measurement and error
     scientific notation

2. Concepts of Velocity and Acceleration

   - falling bodies:
     in vacuum (constant acceleration)
     in air
     in viscous fluids (terminal velocity)

3. Projectile Motion in a Vertical Plane

   - trajectories

4. Newton's Three Laws of Motion

   - law of inertia
   - Newton's second law:
     gravity of Earth
     springs
     viscosity
     friction
   - Newton's third law

5. Gravity (Newtonian)

   - universal gravitation:
     on Earth (law of falling bodies)
     beyond (orbits)

6. Concepts of Torque, Center of Mass, Equilibrium

   - levers
   - tension
   - center of mass and torque
   - machines (mechanical advantage)

Comment: The fundamentals of simple machines (lever, wheel, pulley, etc.) and mechanical advantage should be addressed in this segment as these discussions have been largely displaced from the college curriculum.

> "Give me somewhere to stand, and I will move the Earth."
> Archimedes, in reference to the lever.

7. Concepts of Work, Energy, and Power; Conditions for the Conservation of Energy

   - work
   - kinetic energy
   - gravitational potential energy
   - other potential energy

8. Linear Momentum; Conditions for Conservation of Linear Momentum

   - conservation of momentum
   - collisions and other applications

9. Circular Motion

   - centripetal force
   - centrifugal force
   - speed, acceleration

10. Rotational Motion and Angular Momentum

   - conservation of angular momentum
   - gyroscopes
   - Kepler's second law**

11. Fluids; Statics and Dynamics

    - fluid statics (Archimedes' principle)
    - energy in fluid flow (Bernoulli's principle)**

12. Harmonic Motion

    - springs
    - pendulums (time-keeping)

13. Waves in Linear Media; Principle of Superposition; Sound

    - waves (water waves, sound waves)
    - wave properties (speed, frequency, wavelength, standing waves, propagating waves)
    - resonance**

B. HEAT AND THERMODYNAMICS

1. Temperature and Heat

    - heat
    - heat and temperature
    - thermometers; F, C, K scales
    - heat as a kinetic phenomenon

2. Thermal Equilibrium and Heat Transfer

    - spread of heat
    - conduction
    - convection
    - radiation

3. Mechanical Equivalent of Heat

4. Change of State*

    - state of matter
    - phase transitions

5. Thermal Expansion of Matter

    - thermal coefficient of expansion

6. The Ideal Gas Law*

7. Kinetic Theory of Matter

    - ideal gas law as a kinetic phenomenon*

8. First and Second Laws of Thermodynamics

    - Carnot engine**
    - absolute temperature*
    - cryogenics**

C. ELECTRICITY, MAGNETISM, AND ELECTROMAGNETISM

1. Coulomb's Law

   - charge
   - charge conservation
   - Coulomb's law

2. Electric Field and Electric Potential

   - potential energy and voltage
   - electric field

3. Ohm's Law

   - electricity in matter
   - conductors and insulators
   - current
   - batteries
   - Ohm's law
   - simple circuits
   - power and heat

4. Capacitance

   - capacitors
   - typical values of voltage, charge, and energy
   - electrostatics machines and devices

5. The Magnetic Field; Magnetic Forces

   - force on a moving charge
   - atomic magnetism (magnetic materials)**
   - permanent magnets
   - planetary magnetism**

6. Electromagnetic Induction

   - principle of electromagnetic induction
   - transformers

7. Energy of Electric and Magnetic Fields

8. Alternating Current

   - AC generators; motors
   - AC transmission lines (reason for)

9. Electromagnetic Waves

D. LIGHT AND OPTICS

1. Light and Color

2. Reflection and Refraction

   - prism spectrometer (observation and discussion of)
   - refraction; Snell's law
   - colors

3. Mirrors and Lenses

   - lenses and images
   - telescopes and microscopes
   - fiber optics**

4. Diffraction and Polarization

   - grating spectrometer (observation and discussion of)
   - wave nature of light; diffraction
   - the electromagnetic spectrum
   - polarization

5. Coherent Light

   - lasers (holograms)**

E. MODERN PHYSICS

1. Special Relativity**

   - the Michelson-Morley experiment
   - time dilation and space contraction
   - relativistic mass:
     $E = mc^2$
     gravitational and inertial mass
     principle of equivalence
     curved space and black holes

2. The Heisenberg (Indeterminacy) Principle**

   - quantum physics
   - the photoelectric effect; waves are particles
   - electron diffraction; particles are waves
   - Heisenberg principle of uncertainty (indeterminacy)

3. Atomic Theory and Structure (introductory)

   - electricity: nature of atoms, solids and liquids
   - x-ray diffraction**
   - transistors**
   - integrated circuits and computers**

4. Nuclear Structure (introductory)**

   - elementary particles, quarks, etc.

5. Radioactivity; Fission; Fusion**

   - stability of nuclei
   - fission, fusion
   - nuclear decay, lifetimes
   - nuclear reactors; health-physics concerns

F. SCIENCE AND HUMAN AFFAIRS

   - public participation in scientific undertaking
   - using knowledge to reach informed decisions
   - careers and avocations in science