PHYSICS

Goals

Physics, the most fundamental of the natural sciences, is quantitative in nature and uses the language of mathematics to describe natural phenomena. Inquiry is applied to the study of matter and energy and their interaction. The following topics are "uncovered" in this curriculum:

- Conservation of mass and energy.
- Conservation of momentum.
- Waves.
- Interactions of matter and energy.

The following section introduces the teacher to the program strands and unifying concepts. During instruction, these concepts should be woven through the content goals and objectives of the course. Supplemental materials providing a more detailed explanation of the goals, objectives, and strands, with specific recommendations for classroom and/or laboratory implementation are available through the Department of Public Instruction's Publications Section.

Unifying Concepts

The following unifying concepts should unite the study of various physics topics across grade levels.

- Systems, Order and Organization.
- Evidence, Models, and Explanation.
- Constancy, Change, and Measurement.
- Evolution and Equilibrium.
- Form and Function.

Nature of Science

This strand includes the following sections: Science as a Human Endeavor, Historical Perspectives, and the Nature of Scientific Knowledge. These sections are designed to help students understand the human dimensions of science, the nature of scientific thought, and the role of science in society. Physics is rich in examples of science as a human endeavor, its historical perspectives, and the development of scientific understanding.

Science as a Human Endeavor

Intellectual honesty and an ethical tradition are hallmarks of the practice of science. The practice is rooted in accurate data reporting, peer review, and making findings public. This aspect of the nature of science can be implemented by designing instruction that encourages students to work collaboratively in groups to design investigations, formulate hypotheses, collect data, reach conclusions, and present their findings to their classmates.

The content studied in physics provides an opportunity to present science as the basis for engineering, electronics, computer science, astronomy and the technical trades. The diversity of physics content allows for looking at science as a vocation. Scientist, artist, and technician are just a few of the many careers in which a physics background is necessary.

Perhaps the most important aspect of this strand is that science is an integral part of society and is therefore relevant to students' lives.

Historical Perspectives

Most scientific knowledge and technological advances develop incrementally from the labors of scientists and inventors. Although science history includes accounts of serendipitous scientific discoveries, most development of scientific concepts and technological innovation occurs in response to a specific problem or conflict. Both great advances and gradual knowledge-building in science and technology have profound effects on society. Students should appreciate the scientific thought and effort of the individuals who contributed to these advances. Galileo's struggle to correct the misconceptions arising from Aristotle's explanation of the behavior of falling bodies led to Newton's deductive approach to motion in The Principia. Today, Newton's Law of Universal Gravitation and his laws of motion are used to predict the landing sites for NASA's space flights.

Nature of Scientific Knowledge

Much of what is understood about the nature of science must be explicitly addressed:

- All scientific knowledge is tentative, although many ideas have stood the test of time and are reliable for our use.
- Theories "explain" phenomena that we observe. They are never proved; rather, they represent the most logical explanation based on the currently available evidence. Theories become stronger as more supporting evidence is gathered. They may be modified as new data are gathered or existing data are interpreted in different ways. They provide a context for further research and give us a basis for prediction. For example, the Theory of Relativity explains the

behavior of objects accelerating at velocities approaching the speed of light.

- Laws are fundamentally different from theories. They are universal generalizations based on observations of the natural world, such as the nature of gravity, the relationship of forces and motion, and the nature of planetary movement.
- Scientists, in their quest for the best explanations of natural phenomena, employ rigorous methods. Scientific explanations must adhere to the rules of evidence, make predictions, be logical, and be consistent with observations and conclusions. "Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific." (National Science Education Standards, 1996, p 201)

Science as Inquiry

Inquiry should be the central theme in physics. It is an integral part of the learning experience and may be used in both traditional class problems and laboratory work. The essence of the inquiry process is to ask questions that stimulate students to think critically and to formulate their own questions. Observing, classifying, using numbers, plotting graphs, measuring, inferring, predicting, formulating models, interpreting data, hypothesizing, and experimenting all help students to build knowledge and communicate what they have learned. Inquiry is the application of creative thinking to new and unfamiliar situations. Students should learn to design solutions to problems that interest them. This may be accomplished in a variety of ways, but situations that present a discrepant event or ones that challenge students' intuitions have been successful.

Classical experiments such as measuring inertia and the speed of falling bodies need not be excluded. Rather, they should be a prelude to open-ended investigations in which students have the chance to pose questions, design experiments, record and analyze data, and communicate their findings. For example, after measuring the relationships among force, mass, and acceleration of falling bodies, students might investigate the phenomenon of "weightlessness."

Although original student research is often relegated to a yearly science fair project, continuing student involvement in research contributes immensely to their understanding of the process of science and to their problem-solving abilities. Physics provides much potential for inquiries. "Would it be easier to identify the location of a sound source in water or in air?" Why?" "Would the passengers in a head-on collision between two automobiles be safer if the cars bounced off of each other or if they stuck together?" "Why?" The processes of inquiry, experimental design, investigation, and analysis are as important as finding the correct answer. Students will master much more than facts and acquisition of manipulative skills; they will learn to be critical thinkers.

A solid conceptual base of scientific principles, as well as knowledge of science safety, is necessary for inquiry. Students should be given a supportive learning environment based on how scientists and engineers work. Adherence to all science safety criteria and guidelines for classroom, field, and laboratory experiences is imperative. Contact the Science Section at DPI for information and professional development opportunities regarding North Carolina specific Science Safety laws, codes, and standards. The Science Section is spearheading a statewide initiative entitled *NC-The Total Science Safety System*.

Science and Technology

It is impossible to learn science without developing some appreciation of technology. Therefore, this strand has a dual purpose: (a) developing students' knowledge and skills in technological design, and (b) enhancing their understanding of science and technology.

The methods of scientific inquiry and technological design share many common elements - objectivity, clear definition of the problem, identification of goals, careful collection of observations and data, data analysis, replication of results, and peer review. Technological design differs from inquiry in that it must operate within the limitations of materials, scientific laws, economics, and the demands of society. Together, science and technology present many solutions to problems of survival and enhance the quality of life.

Technological design is important to building understanding in physics. Telescopes, lasers, transistors, graphing calculators, personal computers, and photo gates, for example, have changed our lives, increased our knowledge of physics, and improved our understanding of the universe.

Science in Personal and Social Perspectives

This strand is designed to aid students in making rational decisions in the use of scientific and technological understanding. "Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges." (NSES, p. 199). The *NSES* emphasizes that students should understand the appropriateness and value of basic questions 'What can happen?' - 'What are the odds?' and 'How do scientists and engineers know what will happen?'" (NSES, p. 199).

Students should understand the causes and extent of science-related challenges. They should become familiar with the advances that proper application of scientific principles and products have brought to environmental enhancement, better energy use, reduced vehicle emissions, and improved human health.

PHYSICS - Grades 9-12

Physics, the most fundamental of the natural sciences, is quantitative in nature and uses the language of mathematics to describe natural phenomena. Inquiry is applied to the study of matter and energy and their interaction. Learners will study natural and technological systems. The program strands and unifying concepts provide a context for teaching content and process skill goals. All goals should focus on the unifying concepts:

- Systems, Order and Organization
- Evidence, Models, and Explanation
- Constancy, Change, and Measurement
- Evolution and Equilibrium
- Form and Function

Strands: The strands are: Nature of Science, Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives. They provide the context for teaching of the content Goals and Objectives.

COMPETENCY GOAL 1: The learner will develop abilities necessary to do and understand scientific inquiry.

Objectives

1.01 Identify questions and problems that can be answered through scientific investigations.

1.02 Design and conduct scientific investigations to answer questions about the physical world.
- Create testable hypotheses.
- Identify variables.
- Use a control or comparison group when appropriate.
- Select and use appropriate measurement tools.
- Collect and record data.
- Organize data into charts and graphs.
- Analyze and interpret data.
- Communicate findings.

1.03 Formulate and revise scientific explanations and models using logic and evidence to:
- Explain observations.
- Make inferences and predictions.
- Explain the relationship between evidence and explanation.

1.04 Apply safety procedures in the laboratory and in field studies:
- recognize and avoid potential hazards.
- safely manipulate materials and equipment needed for scientific investigations.

1.05 Analyze reports of scientific investigations of physical phenomena from an informed scientifically literate viewpoint including considerations of:
- Adequacy of experimental controls.
- Replication of findings.
- Alternative interpretations of the data.

COMPETENCY GOAL 2: The learner will build an understanding of linear motion.

Objectives

2.01 Analyze velocity as a rate of change of position:
- Average velocity.
- Instantaneous velocity.

2.02 Compare and contrast as scalar and vector quantities:
- Speed and velocity.
- Distance and displacement.

2.03 Analyze acceleration as rate of change in velocity.

2.04 Using graphical and mathematical tools, design and conduct investigations of linear motion and the relationships among:
- Position.
- Average velocity.
- Instantaneous velocity
- Acceleration.
- Time.

COMPETENCY GOAL 3: The learner will build an understanding of two-dimensional motion including circular motion.

Objectives

3.01 Analyze and evaluate projectile motion in a defined frame of reference.

3.02 Design and conduct investigations of two-dimensional motion of objects.

3.03 Analyze and evaluate independence of the vector components of projectile motion.

3.04 Evaluate, measure, and analyze circular motion.

3.05 Analyze and evaluate the nature of centripetal forces.

3.06 Investigate, evaluate and analyze the relationship among:

- Centripetal force.
- Centripetal acceleration.
- Mass.
- Velocity.
- Radius.

COMPETENCY GOAL 4: The learner will develop an understanding of forces and Newton's Laws of Motion.

Objectives

4.01 Determine that an object will continue in its state of motion unless acted upon by a net outside force (Newton's First Law of Motion, The Law of Inertia).

4.02 Assess, measure and calculate the conditions required to maintain a body in a state of static equilibrium.

4.03 Assess, measure, and calculate the relationship among the force acting on a body, the mass of the body, and the nature of the acceleration produced (Newton's Second Law of Motion).

4.04 Analyze and mathematically describe forces as interactions between bodies (Newton's Third Law of Motion).

4.05 Assess the independence of the vector components of forces.

4.06 Investigate, measure, and analyze the nature and magnitude of frictional forces.

4.07 Assess and calculate the nature and magnitude of gravitational forces (Newton's Law of Universal Gravitation).

COMPETENCY GOAL 5: The learner will build an understanding of impulse and momentum.

Objectives

5.01 Assess the vector nature of momentum and its relation to the mass and velocity of an object.

5.02 Compare and contrast impulse and momentum.

5.03 Analyze the factors required to produce a change in momentum.

5.04 Analyze one-dimensional interactions between objects and recognize that the total momentum is conserved in both collision and recoil situations.

5.05 Assess real world applications of the impulse and momentum, including but not limited to, sports and transportation.

COMPETENCY GOAL 6: The learner will develop an understanding of energy as the ability to cause change.

Objectives

6.01 Investigate and analyze energy storage and transfer mechanisms:
- Gravitational potential energy.
- Elastic potential energy.
- Thermal energy.
- Kinetic energy.

6.02 Analyze, evaluate, and apply the principle of conservation of energy.

6.03 Analyze, evaluate, and measure the transfer of energy by a force.
- Work.
- Power.

6.04 Design and conduct investigations of:
- Mechanical energy.
- Power.

COMPETENCY GOAL 7: The learner will develop an understanding of wave motion and the wave nature of sound and light.

7.01 Analyze, investigate, and evaluate the relationship among the characteristics of waves:
- Wavelength.
- Frequency.
- Period.
- Amplitude.

7.02 Describe the behavior of waves in various media.

7.03 Analyze the behavior of waves at boundaries between media:
- Reflection, including the Law of Reflection.
- Refraction, including Snell's Law.

7.04 Analyze the relationship between the phenomena of interference and the principle of superposition.

7.05 Analyze the frequency and wavelength of sound produced by a moving source (the Doppler Effect).

COMPETENCY GOAL 8: The learner will build an understanding of static electricity and direct current electrical circuits.

Objectives

8.01 Analyze the nature of electrical charges.

- Investigate the electrical charging of objects due to transfer of charge.
- Investigate the conservation of electric charge.
- Analyze the relationship among force, charge and distance summarized in Coulomb's law.

8.02 Analyze and measure the relationship among potential difference, current, and resistance in a direct current circuit.

8.03 Analyze and measure the relationship among current, voltage, and resistance in circuits.

- Series.
- Parallel.
- Series-parallel combinations.

8.04 Analyze and measure the nature of power in an electrical circuit.