Primary Goal: ***All students should have access to supportive, excellent, education in science, mathematics, engineering, and technology, and all students should learn these subjects by direct experience with the methods and processes of inquiry.***
"Shaping the Future, National Science Foundation Report."

Content Area: Physics

A. The student will know and apply the concepts and laws of physics (at the level of standard calculus-based physics textbooks, see note below) to understand and explain the behavior of the physical world as listed on page 2.

B. The student will know and be able to apply mathematics of calculus through multivariate calculus and one full semester course in differential equations.

C. The student will have experiences in the physics classes with activity-based learning consistent with current methods of teaching physics at high schools.

D. The student will have familiarity with experimental physics and have experience with the collection and analysis of data from experiments on physical systems.

E. Scientific computing is strongly recommended.

F. The student is strongly recommended to have a well-rounded background in science and should consider taking other science courses from areas such as chemistry, earth sciences, astronomy, geology, or biology.

Note: Examples of standard calculus-based introductory level physics text books (including modern physics) are:

a. *Fundamentals of Physics* by Halliday, Resnick & Walker
b. *Physics for Scientists and Engineers* by Serway & Beichner
c. *Physics for Scientists and Engineers* by Tipler & Mosca
d. *Physics for Scientists and Engineers with Modern Physics* by Giancoli
e. *University Physics* by Young & Freedman
f. *University Physics* by Reese
g. *Understanding Physics* by the Physics Education Group

Content Knowledge

1. **Mechanics:**
    a. **vectors and scalars**
    b. **kinematics**
    c. **statics and dynamics**
    d. **work and energy**
    e. **energy and momentum conservation laws**
    f. **simple harmonic motion**
    g. **rotational dynamics**
    h. **gravitational fields**
    i. **fluid mechanics**
2. **Electricity and magnetism:**
    a. **static electricity**
    b. **electric forces, potentials, and fields**
    c. **electrical and magnetic properties of materials**
    d. **AC and DC circuits and circuit components**
    e. **magnetic forces and fields**
    f. **electromagnetic induction**
    g. **electromagnetic radiation**
    h. **Maxwell's equations**
3. **Optics and waves:**
    a. **transverse and longitudinal waves and their properties and characteristics**
    b. **refraction, reflection and superposition of waves**
    c. **applications to light and sound**
    d. **geometric and physical optics**
4. **Heat and thermodynamic:**
    a. **temperature, heat, heat capacity and heat transfer**
    b. **kinetic molecular theory**
    c. **phase changes**
    d. **laws of thermodynamics with applications such as heat engines**
5. **Modern physics:**
    a. **atomic models and their experimental bases**
    b. **structure of the atoms and molecules**
    c. **nuclear reactions and radioactivity**
    d. **special relativity**
    e. **photoelectric effect**
    f. **wave-particle duality**
    g. **introduction to quantum mechanics**
6. **Experimental Physics**
    a. **experimental uncertainty and error propagation**
    b. **comparison of data and theory**
    c. **modeling**
    d. **experimental design**

Outcomes

"Assessment Type" and "Sample Assessment Tasks" are not meant to be definitive, but rather guides to the reader. Examples have been provided to represent the wide range of assessments that can be used to demonstrate students' attainment of outcomes. These are also included to emphasize that demonstrating understanding of physics goes beyond problem-solving. Institutions are encouraged to add to this list of examples, which is by no means complete.

Outcomes	Indicators	Assessment Type	Sample Assessment Tasks
1. Teacher candidates will know the vocabulary and mathematical language associated with each content knowledge area listed above.	a. select, define, and recall terms b. use terms in context c. describe and classify terms d. translate word problems into proper mathematical expressions or diagrams	• completion • multiple choice • matching • short response (one sentence answer, list examples) • classification • extended response (written paragraph, problem solution)	• A newton is a unit of ________. • Give an example of work used in everyday language that fits the physics definition of work. • Give an example of a transverse wave. • Rank the following in order of smallest to largest frequency: x-ray, visible light, microwaves, radio waves, gamma rays.
2. Teacher candidates will understand the concepts, relationships, and principles of each content knowledge area listed above and the interrelationships between related content areas.	a. explain concepts and use them to describe physical phenomena b. use graphical representation when appropriate c. describe relationships among concepts	• short response • extended response	• Use Newton's laws to explain the motion of a person in a car speeding up, moving at a constant velocity, slowing down, and making a right turn. • A ball is thrown vertically into the air. Sketch graphs of position, velocity, and acceleration as a function of time. Label the portions of the graph where the ball is on its way up, at the top, and on the way down. • Compare and contrast series and parallel circuits.

Outcomes	**Indicators**	**Assessment Type**	**Sample Assessment Tasks**
3. Teacher candidates will apply concepts and relationships to qualitative problems and quantitative problems in each content knowledge area listed above.	a. solve a simple problem or break a complex problem into manageable parts b. apply appropriate concepts, mathematical techniques (algebra, graphing, and calculus), and technology tools to the problem c. synthesize the results d. critically assess solutions to determine if they are valid and reasonable e. effectively communicate orally and in writing the explanation of a problem solution and results f. apply dimensional analysis and order of magnitude analysis to check answers	• higher-order multiple choice (using multiple concepts) • short response • extended response • single-concept problem solving • multiple-concept problem solving	• As more identical resistors R are added to the parallel circuit shown (insert diagram) here, the total resistance between points P and Q (choose one) increases, remains the same, or decreases. Explain. • A student has a part time job and is asked to bring a steel rod of length 85.0 cm and diameter 2.8 cm from the stock room to the machinist. Will the student need a cart? Provide justification. • A sled starts from rest at the top of a frictionless hemispherical snow-covered hill of radius R. As it descends, at what angle does it leave the hill? Show all critical aspects of the solution and present the solution to the class.

Outcomes	Indicators	Assessment Type	Sample Assessment Tasks
4. Teacher candidates will investigate a classical physical system experimentally (in at least each of the broad content knowledge areas 1 – 4 listed above) and apply the experimental physics content knowledge (content knowledge area 6).	a. design an investigation to explore a concept or test the validity of a hypothesis in a statistically meaningful way b. carry out the experiment designed in part a, collect data, and display the results appropriately c. use data acquisitions software and equipment (for example MBLs or CBLs) for collecting data d. use computer spreadsheets for plotting and analyzing data e. apply appropriate mathematical techniques and technology tools to the investigation f. analyze experimental error and apply a least-squares fit to compare theory and data g. draw appropriate conclusions from the investigation h. effectively communicate orally and in writing the results of an investigation	• extended response • performance assessment (successful task completion, ability to successfully complete experiment)	• Using the phenomena of diffraction, design and carry out an experiment, using available equipment, to determine the average thickness of human hair, determine if thickness is related to hair color, and aggregate the class results and compare individual results to the class aggregate. Present a written or an oral report of the results.

Outcomes	**Indicators**	**Assessment Type**	**Sample Assessment Tasks**
5. Teacher candidates will work individually and cooperatively in teams on investigations and/or problem solutions.	a. identify functions of different roles in a team b. set goals and objectives c. be aware of and be able to access resources d. function in each of the roles e. assess the effectiveness of the group process	• multiple choice • extended response • performance assessment	• Determine the relationship between the length and period of a pendulum in a group of four students. Identify four appropriate roles for the members of your team. Describe each role in terms of their functions. Set goals and objectives for each member of the group and for the group as a whole in order to carry out the investigation. Acquire the equipment and supplies necessary to carry out the experiment. Read background information in the textbook related to this phenomenon. Carry out an assigned role. On a scale of 0 to 5 (with 0 = low and 5 = high) assess individual performance in the group process and justify ratings. On a scale of 0 to 5, assess the group's effectiveness and performance and justify ratings.

Outcomes	**Indicators**	**Assessment Type**	**Sample Assessment Tasks**
6. Teacher candidates will have experience with activity-based learning consistent with current methods of teaching physics at high schools. This outcome will require collaboration between the physics and education faculty.	a. display competency in setting up, collecting and analyzing data with an automatic data collection system b. identify the objectives and scope of current programs that implement methodologies based on physics education research such as *Workshop Physics, Physics by Inquiry, Castle Project*, etc. and are familiar with initiatives supported by Physics Teaching Resource Agents (PTRA) c. observe high school physics classes that use activity-based learning techniques d. display competency with web-based teaching resources such as simulations, school web sites, text book web sites, applets, physlets, etc.	• extended response • performance assessment	• Using a commonly available MBL system, set up a motion detector and analyze the graphically-displayed data to calculate acceleration of an object. • Maintain a portfolio that includes readings on current physics education research and activity-based curricula. • Maintain a portfolio that documents observations of high school physics classes, and include reflections on effective learning techniques with evidence of metacognitive awareness of personal learning experiences.

Outcomes	Indicators	Assessment Type	Sample Assessment Tasks
7. Teacher candidates will develop a historical perspective of the development of physics at the level presented in the introductory textbooks and be knowledgeable of current areas of research in physics. This outcome may require collaboration between the physics and education faculty.	a. identify the discoveries and development of major concepts of physics, relate them to one another and place them in a historical context b. identify the experimental evidence supporting major concepts in physics c. place major technological advances that are based on discoveries in physics into a historical and societal perspective d. identify areas of physics that are actively being investigated	• completion • matching • multiple choice • short response • extended response	• Which physicist did not contribute directly to our current understanding of the structure of the atom: Thomson, Rutherford, Chadwick, Maxwell, or DeBroglie? • Place the following events in chronological order: French Revolution, Galileo's experiments on Motion, Newton theory of universal Gravitation, Franklin's experiments on electric charge, Splitting the atom. • Name six discoveries or ideas that significantly altered the course of physics and explain why they did. • Describe two areas of current research in physics and their potential impact on science and society. • Maintain portfolio items that document an understanding of a historical perspective and current areas of physics research.

In creating this document we were guided by PRAXIS II, NCATE, NSTA Standards, Maryland State Performance Standards: Science Core Learning Goal documents, feedback from 2-year and 4-year schools in Maryland, and the collective experience and wisdom of the Secondary AAT Physics Outcomes Writing committee.