Lesson Title	Scientific Inquiry: Periodic Motion
Length of Lesson	1 Day
Created By	Jed Leggett, Dustin Spayde, William Funderburk
Subject	Physics
Grade Level	11-12 (Physics)
State Standards	Physics: 1 c, d, f; 2 d
DOK Level	DOK 3
DOK Application	Investigate, Draw Conclusions
National Standards	9-12: A(inquiry);
Graduate Research Element	Isolation of Independent Variables

Student Learning Goal:

Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific investigations: (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development); (d) Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs) draw conclusions and make inferences; (f) Formulate and revise scientific explanations and models using logic and evidence (data analysis).

2. Develop an understanding of concepts relatated to forces and motion: (d) Apply the effects of the universal gravitation law to graph and interpret the force between two masses, acceleration due to gravity, and planetary motion – Oscillatory Motion.

National Science Education Standards of Content 9-12

A (Inquiry): Design and conduct scientific investigations. Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.

Materials Needed (supplies, hand-outs, resources):

Materials to construct a simple pendulum, mass on a spring, or any other example of periodic motion (lab posts, string, masses, springs, etc), Access to a personal computer with spreadsheet and word processing software

Lesson Performance Task/Assessment:

In this lesson, students will choose a simple system that exhibits periodic motion (e.g. simple pendulum, mass on a spring) and design an experiment to look for factors that affect the period. Students will formulate a proposed mathematical relationship between each chosen factor and the period of the system.

Lesson Relevance to Performance Task and Students:

Through the investigation of a simple system with a clearly defined dependent variable (period), students will move past the simplistic conception of science as merely following a given method and develop the more robust conception of science as a complicated process of inquiry.

Anticipatory Set/Capture Interest:
The teacher will have a few quotes on the board as students enter the room that challenge the notion that science is just the application of the scientific method. Example:

Isaac Newton: "*I have not as yet been able to discover the reason for these properties of gravity from phenomena, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction.*" - Philosophiae Naturalis Principia Mathematica, General Scholium. Third edition, page 943 of I. Bernard Cohen and Anne Whitman's 1999 translation, University of California Press ISBN 0-520-08817-4, 974 pages.
Students may need to be reminded that in Newton's time what we now call Science was referred to as experimental philosophy.

Numerous examples may also be found in the book *Against Method* by Paul Feyerabend.

Guided Practice:
The teacher will lead a brief guided inquiry at the beginning of class concerning the nature of scientific investigation. The teacher will then break the students into groups of 3-4 and instruct the students to choose a system that exhibits periodic motion and design an experiment to investigate factors that might affect the period of the system. The teacher should then move from group to group encouraging the students to think about other possible factors, consider the concept of control, and point out possible sources of error. However, the teacher should only give advice when it is clear that students are overlooking a vital part of the investigation. Students should always be given ample time to discover problems on their own. The goal of the lesson is to teach inquiry, not for the students to determine the correct formula governing the period of a particular system.

Independent Practice:
Students will break into groups of 3-4 and choose a system that exhibits periodic motion. Students should be encouraged to think outside of the box when choosing their system, however the simple pendulum or mass on a spring can always be used if students can't think of anything else. Students will then brainstorm as a group to identify possible factors that might affect the period of the system. Students will then design an experiment to test the various factors they have identified. Students should try to develop

a mathematical relationship between the period of the system and at least 1 of the factors they chose from data taken during their experiment.

Remediation and/or Enrichment:
Remediation: individual IEP; partner help throughout lesson

Enrichment/Extension: Students can develop a presentation of the results of the experiment that they designed.

Check(s) for Understanding:
Were there any factors that you did not consider or decided not to test? How could you have made your experiment better? How does your data support the mathematical relationship you found? What are some possible sources of error in your experiment?

Closure:
The teacher can model the results of their own experiment in which they investigated the motion of the pendulum. The teacher should be very explicit concerning their thought process as they chose factors to investigate and designed their experiment.

Possible Alternate Subject Integrations:
*Math – Students can perform curve fitting on their data.

Teacher Notes:
If students do not have access to a PC, data can be recorded on paper and graphed by hand.