Lesson Title	X-Ray Diffraction (XRD)
Length of Lesson	3 Days
Created By	Jed Leggett, Dustin Spayde, William Funderburk
Subject	Physics
Grade Level	11-12 (Physics)
State Standards	Physics: 1a, g; 4a, e; 6b
DOK Level	DOK 4
DOK Application	Apply Concepts, Analyze
National Standards	9-12: A(inquiry); B (physical); E (technology)
Graduate Research Element	Identifying Crystalline Content in Samples

Student Learning Goal:
Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific investigations: (a) Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic; (g) Collect, analyze, and draw conclusions from data to create a formal presentation using available technology (e.g., computers, calculators, SmartBoard, CBL's, etc.)
4. Discuss the characteristics and properties of light and sound: (a) Describe and model characteristics and properties of mechanical waves; (e) Investigate and draw conclusions about the characteristics and properties of electromagnetic waves.
6. Analyze and explain concepts of nuclear physics: (b) Defend the wave-particle duality model of light, using observational evidence.

For student to practice authentic scientific processes in the field to collect data; to analyze the data collected; and to create a product to reflect their understanding of the physics standards that focus on relationships among wave characteristics such as velocity, period, frequency, amplitude, phase, and wavelength.

National Science Education Standards of Content 9-12
A (Inquiry): identify questions and concepts that guide scientific investigations.
B (Physical): interactions of energy and matter; **structure and properties of matter. The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.**
E (Science and Technology): abilities of technological design; understanding about science and technology

Materials Needed (supplies, hand-outs, resources):
Samples (i.e. rock salt, sandy soil, etc.), access to a personal computer with WebTOP installed (available for free from http://webtop.msstate.edu/), access to personal presentation software (Powerpoint, Impress, etc.), and access to an x-ray diffractometer (see Teacher notes below for SEM resources, or check with your state university)

Lesson Performance Task/Assessment:
In this lesson, students will apply their understanding of the properties of electromagnetic waves to investigate the molecular structure of matter. Students will work a problem set in which they calculate either the lattice spacing of a crystal or the wavelength of incident x-rays using Bragg's Law and given information. Students will also collect and prepare samples to be analyzed using an x-ray diffractometer.

Students will demonstrate their ability to collect and present scientific data by preparing a presentation that will be critiqued by student peers.

Lesson Relevance to Performance Task and Students:
Using real world data collection techniques, students will gain experience with scientific practices used by working scientists. These activities will give the students a clearer picture of how science is applied in the real world and inspire confidence in students that they have the abilities to become a scientist.

Anticipatory Set/Capture Interest:
As students enter the room on Day 1, the teacher will have a WebTOP module running that exhibits some complicated behavior. Students will be asked to write a short paragraph explaining what is occurring in this module.

Guided Practice:
Day One:
The teacher will demonstrate the capabilities of the various WebTOP modules focusing on interference effects.

The teacher will model several example quantitative problems in order to provide the students with a framework for approaching their problem set.

Day Two:
The teacher will give a brief presentation about the lab where students' samples will be analyzed and explain the sample preparation process for the particular XRD that will be used. This presentation will give students an idea of what samples will be appropriate for analysis.

Day Three:
The teacher will observe and provide feedback on student presentations. However, the teacher should keep their own feedback to a minimum and encourage the students to critique the presentations of their peers.

Independent Practice:
Day One: The students will spend 20-30 minutes exploring relevant WebTOP modules. Students should focus special attention on the N-slit interference module and the effect of varying the slit separation. This activity will give students an intuitive idea of how changes in lattice spacing affect the x-ray interference pattern.

Day Two: The students will collect and prepare samples for the x-ray diffractometer. If students finish their sample collection early, they can begin work on the assigned problem set.

Day Three: Students will deliver their in class presentations.

Remediation and/or Enrichment: individual IEP; partner help throughout lesson; shorten parts of assignment; focus upon smaller elements of the process

Enrichment/Extension:

1. Set up a seminar which includes students from other science classrooms as an audience for the student team design presentations.
2. Samples relevant to other subjects may be analyzed in order to create an inter-disciplinary project.

Check(s) for Understanding:

Day One: 1. What does it mean to say that two waves interfere with each other? 2. How does the interference pattern depend on the position of the sources (slit separation, lattice spacing)?

Day Two: 1. How does an x-ray diffractometer work? 2. Why did you choose your particular samples? 3. What do you expect the diffraction to look like for each of your samples?

Day Three: 1. What was the conclusion of your presentation? 2. How might this information be used in the real world?

Closure:
Day One: Have the students work one problem as a group that is similar to an example problem.

Day Two: Have the students write a brief outline for their presentation, even though they do not have any data.

Day Three: Have the students list at least one thing that they wish they would have included in their presentation.

Possible Alternate Subject Integrations:
*Math – can manipulate mathematical expressions to isolate needed variables

*Language Arts – can use PowerPoint to deliver a public presentation of an engineering design

Teacher Notes:

Possible places to look for x-ray diffraction (XRD) machines:

NATIONAL LABS:
Department of Energy: links to national laboratories:
http://www.er.doe.gov/National_Laboratories/
Ames Laborator: http://www.ameslab.gov/
Argonne National Laboratory: http://www.anl.gov/
Brookhaven National Laboratory: http://www.bnl.gov/world/
Lawrence Berkeley National Laboratory: http://www.lbl.gov/
Oak Ridge National Laboratory: http://www.ornl.gov/
Oak Ridge National Laboratory, Center for Nanophase Material Sciences:
http://www.cnms.ornl.gov/
Pacific Northwest National Laboratory: http://www.pnl.gov/

MISSISSIPPI SEM RESOURCES
Mississippi State Universlty Electron Microscope Center: http://emcenter.msstate.edu/
University of Mississippi of Mississippi Medical Center, Department of Biochemistry:
http://biochemistry.umc.edu/
Jackson State University, Department of Physics: http://msp.jsums.edu/