Lesson Title	Understanding an X-ray defractometer and introduction of Bragg's law
Length of Lesson	1 Day
Created By	Henry Stauffenberg IV
Subject	Physics
Grade Level	9-12 (Physics)
State Standards	Physics: 1 a, b, c, d, e, f, g; 4 a, c, e
DOK Level	Physics: 4
DOK Application	Organize, graph, compare, interpret, investigate, calculate, connect, analyze, assess, draw conclusions, apply concepts
National Standards	9 – 12 A: Inquiry; B: Physical Science; E: Science and Technology
Graduate Research Element	Quantitative treatment and analysis of data using a X-ray defractometer (XRD) which is an essential tool for thesis/scientific work projects.

Student Learning Goal:
The purpose of this lesson is to promote student skill proficiency with a X-ray defractometer (XRD) and provide them an understanding in how it works through a field trip and a lab exercise. They will apply concepts learned in the classroom (about waves and properties of matter) to investigate how an XRD works and how to interpret the data graphed from XRD analysis using unknown samples. Along with graphical data the students will learn how to utilize the Jade program to manipulate data and results from XRD scan. Overall, students will be able to analyze and interpret real world data to calculate the "d spacing" values to complete the missing data using Bragg's law and be able to connect Bragg's law to how the XRD operates/resultant graphs. They will also know how to identify major and minor peaks on XRD graphs and be able to utilize all available resources in identifying two unknown samples (halite and sand).

Mississippi State Standards
Physics: 1: (a) Use current technologies to explore current research related to a specific topic; (b) Clarify research questions and design laboratory investigations; (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations; (d) Organize data to construct graphs; (e) Evaluate procedures, data, and conclusions to critique the scientific validity of research; (f) Formulate and revise scientific explanations and models using logic and evidence (data analysis); (g) Collect, analyze, and draw conclusions from data to create a formal presentation using available technology. 4: (a) Describe and model the characteristics and properties of mechanical waves; (c) Explain the laws of reflection and refraction and apply Snell's law and Bragg's law to describe the relationship between angles of incidence and refraction (e) Investigate and draw conclusions about the characteristics and properties of electromagnetic waves.

National Science Education Standards of Content 9 – 12

A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science: structures and properties of matter with respect to spectrophotometric analysis

- 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: Understanding about science and technology using a spectrophotometer.

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

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

Fieldtrip to lab with working XRD, two mineral samples (one pure and one complex) ex: halite and sand, XRD operations handout pdf, Jade software operations handout pdf, XRD problem set handout pdf (data table with all values for each peak of each graph with d space values erased for students to calculate later using Bragg's law), XRD peak graphs of both minerals printed out or saved to file (accompany with problem set handout), Folder of mineral XRD fingerprints (optional but useful for graph overlay and comparison for mineral identification), and finally use attached **power point presentation** (explains everything and introduces lab after field trip)

Lesson Performance Task/Assessment:

- Completion of fieldtrip and successful identification of unknown mineral samples using applied knowledge
- Ability to calculate d space values using Bragg's law in order to connect and further investigate mineral samples
- Validate/Invalidate hypothesis about what the unknown samples could be before XRD analysis
- Ability to explain and connect their real world data/applied knowledge to how an XRD operates; as well as, explain XRD significance and application
- Citation of other sources (more than one) used in data analysis

Lesson Relevance to Performance Task and Students:

- To gain lab practice and experience using a XRD and Jade software

- To understand application and importance of XRD for substance identification
- To connect and apply Bragg's law/classroom knowledge with real time XRD data provided in handouts
- Practice of scientific method with hypothesis creation followed with testing using XRD and available resources
- Resume building activity: to be able to know and explain how an XRD operates, what it is used for, and where it fits into the big picture in graduate schooling and working world
- Utilization of multiple sources which shows good research skills and mastery of finding information useful in all practices

Anticipatory Set/Capture Interest:
Tell students they are going on a field trip to a very advanced research laboratory and mention that this is something that they might be doing in college. Any opportunity to get out of classroom will intrigue students. Also, mention how expensive the XRD is and the dangers involved with using this machine when at the labs. This will break the ice and start guiding questions that will lead to how an XRD operates.

Guided Practice:
Introduce two unknown mineral samples (one pure substance and other mixed) and have students make a hypothesis about what the substances could be using only basic observation and what little they may already know. Many students think the salt is sugar or quartz until they taste it. Then tell students that they are going to test their hypothesis's using an XRD in a college laboratory. Take students on field trip and have them prepare the samples for XRD scan. While in lab explain how, what, and why about XRD. Also, make time for questions and have a technician present if possible. Either on trip or before trip give the XRD and Jade program pdf handouts which briefly explain how the XRD works/operations manual. Walk students through XRD operation and Jade program data manipulation. Let students play around with Jade program.
In classroom present attached power point (in materials) to explain how to interpret their XRD results and solidify how an XRD works. The lab will also be presented in power point and resources are given to help students interpret results and validate/invalidate hypothesis's. Everything is step by step and easy to follow, make sure students have access to power point. Give students printout or electronic files of XRD problem set and peak graphs (mentioned in materials). Also, give students folder of XRD mineral fingerprints but that is optional.
Make sure to have students only calculate the d spacing for major peaks only using Bragg's law. Make sure that the table of data they are working with have the d space values erased so they can calculate them. Some scans will have more than 40 major/minor peaks and don't tell students to do all peaks, just select a few. With a teacher master copy compare d space values calculated by Jade program with that of the student calculations. The answers should be close if not exact depending on significant digits used.

Have students create formal lab write with works cited page using more than one resource in addition to XRD resultant graphs.

Independent Practice:
Students will work to calculate d space values using power point, handouts, and Bragg's law. They will take these values to further investigate identification of their minerals and validation of their hypothesis's. Research and formal write up is all independent.

Remediation and/or Enrichment:
Remediation: individual IEP, partner with helpful student, shorten assignment(s), make lesson more walk through intensive. Focus on introducing with less detailed explaining about the XRD and walk through lab calculations.

Enrichment: Have students calculate other values that you cross of from data table. Use more challenging minerals to identify and ask more in depth questions for them to answer such as; why won't organic material work? or who can use this device, give multiple real world examples? What specifically is going on with X-ray interaction into substance on molecular level, tell me more than just the basics?

Check(s) for Understanding:
In addition to completion of performance tasks and discussion

- Tell me in general how a XRD works?
- How do I use the Jade program?
- Prove to me why the substance is salt and not quartz
- What is a major and minor peak? Why they important?
- How do I interpret this graph?
- Explain Bragg's law
- Connect what you learned in class with the lab, what do you see?
- Why is XRD analysis important?
- Where can I go to find more information about the minerals you have identified?

Closure:
Inform students that the XRD is based on physics but useful in many other disciplines and trades. Make it clear that the students who go to college will probably see this machine again and the knowledge they have gained today will serve them well in the pursuit of the sciences. Also let them know that not many high schools get this opportunity and what they did on par with the graduate students, a taste what is to come with higher education.

Possible Alternate Subject Integrations:

Geology: Mineral identification (a must know for advanced techniques)
Algebra and Calculus: Linear regression, tables and graphs, using Beer's law.

Teacher notes:

- A few days before lab take two mineral samples and run them for 1.5 hours each in the XRD and print out results similar to pdf handouts
- READ all the handout/supplement material with this lesson. They explain everything (especially the power point)
- If you are not a geologist stick to simple minerals such as salt, clay, sand, see power point for mineral website (mindat.org)
- Make sure minerals you select are in mineral database in Jade program (every university is different)