Lesson Title	Polarization and Optics (introduction optical mineralogy)
Length of Lesson	30 minuets - 1 hour
Created By	Henry Stauffenberg IV
Subject	Physics and Geology
Grade Level	9-12 (Physics/Geology)
State Standards	Physics: 1 a, b, c, e, f, g; 4 a, c, d, e; Geology: 1 g, d
DOK Level	Physics: 4; Geology: 4
DOK Application	Investigate, compare, inquire, interpret, connect, analyze, design, draw conclusions, apply concepts, prove
National Standards	9 – 12 A: Inquiry; B: Physical Science; E: Science and Technology
Graduate Research Element	Thin section analysis, use of microscopes, and applied knowledge using basics into optical mineralogy

Student Learning Goal:

The purpose of this lesson is to promote understanding of polarization/optics through application of knowledge in real life activity. This lesson proceeds after a lecture, or a lab, about polarization and optics. Students will learn how to use a microscope (with the addition of polar films) for thin section analysis of metamorphic and fossil rich rocks. Students will gain hands on experience identifying minerals and fossils using polar film and optical lens standard to optical mineralogy. Students will connect what they have learned in class and be able to describe how a microscope, with polar film, works with respect to light waves passing through lens and thin section mineral. Furthermore, through clever crafting and design they will learn how to make a simple microscope (x10, x20 magnification with bottom light source) work similar to a 10,000 dollar advanced mineral optics microscope. Also, students will have fun seeing rainbow color changes, shadow extinction of light, and other optical properties of metamorphic minerals under polarized light. This will promote intrigue and inquiry suitable for college level. Connecting graduate level design and application of microscopes.

<u>Mississippi State Standards</u>

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; (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; (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 light waves; (c) Explain the laws of reflection and refraction and apply Snell's law to describe the relationship between the angles of incidence and refraction; (d) Use ray tracing and the thin lens to solve real-world problems involving object distance from lenses; (e) Investigate and draw conclusions about the characteristics and properties of electromagnetic waves.

Geology: 1: (a) Conduct a scientific investigation demonstrating safe procedures and proper care of laboratory equipment, safety rules and symbols, proper use and care of the compound light microscope, slides, chemicals; (b) Formulate questions that can be answered through research and experimental design. 2: (h) Research and describe different techniques for determining relative and absolute age of the Earth (index of fossils) and identification of minerals that make up earth mantle and crust.

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: Interactions of energy and 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.
- Waves, including sound and seismic, waves on water, and light waves, have energy and can transfer energy when they interact with matter.
- Each kind of atom or molecule can gain or lose energy only in a particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify specific substances.

E: Science and Technology: Understanding about science and technology using a optical microscope

- 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):

A geologist or geology major graduate student, access to metamorphic and fossil thin sections (university lab or professor collection), Regular microscope with bottom light source (at least x10 or x20 zoom), microscope setup instructions, small foam plates for tray that holds mineral thin section, large sheet of polarized film that can be cut into squares, stand with vertical metal rod, 2 clamps that can attach to vertical metal rod, metal O ring (like a clamp but for beakers), hand samples of rocks and fossils that go with thin sections (see student or professor), discussion handout, worksheet handout, optional: a few optical mineralogy and fossil identification textbooks with pictures to show what to look for with mineral/fossil identification and correlation tables of rock ages to index fossils.

Lesson Performance Task/Assessment:

- Completion of lab activity and ability to inquire about what they analyzed
- Able to explain how a microscope works by drawing a picture using light rays, lens, and polar films
- Ability to explain polarization of light and useful applications
- Ability to demonstrate proper use of microscopes
- Using resources to correlate identified fossils to rock ages
- Ability to connect and discuss optics and light and apply what they learned in classroom to real world problems

Lesson Relevance to Performance Task and Students:

- To gain lab practice and experience using microscopes and thin sections
- Using available resources to fabricate a working mineral optics microscope without paying 10,000 dollars
- To promote inquiry about what is analyzed through microscopes applying what they learned about optics/light
- Using index fossils to grasp geologic time scale (age of rocks)
- Understanding how a microscope with polar films works (more than just handling)
- Connecting what they learned about polarization to practical application in optical mineralogy; insight into one college earth science path

Anticipatory Set/Capture Interest:

Tell students they are about to see something not many people outside of the geosciences get to see. Let them jump right into microscopes and polar films (after quick intro into proper lab handling) withholding explanation lecture until after they are awe struck by mineral rainbow effects, light extinction effects, and many other optical properties beyond what they know. It is the teacher's responsibility to tease out/filter questions from class that stay within what they learned about polarization and optics. Only after the main connections are made does the geologist satisfy geology oriented questions explaining more in depth into what the students just analyzed.

Guided Practice:

Refer to microscope setup handout. Give students worksheet and instruct to focus on question 1 and that question 2 will be answered in discussion. Make sure they draw pictures last after everyone rotates to each microscope station (which each group will build...maybe). Teacher can setup microscopes for them before class into several stations

(one for each mineral section) because students tend to be clumsy. Again see microscope setup handout. Have students cut hole in center of small foam plates, hole needs to be just big enough to allow all light to shine through and thin section not to fall through hole. Then have them cut two squares out of large sheet of polar film. Have students clamp one polar square just below magnification lens and clamp other polar square just above light source (or have film rest over light source). Make sure both polar films rotated 90 degrees to one another. Clamp the O ring between the polar films for plate and thin section. Have students delicately place thin section over center of plate (or have geologist do this to avoid risk of breaking sections) and place on O ring. Turn on microscopes. Rotate upper polar clamp away from lens and allow students to look at minerals under plain polarized light. Then move upper polar back under lens to polarize the light, the colors and light extinction should now be visible. Be sure to have students rotate and move plate with thin section. In this way they can see different areas and light effects on thin section in plain polarized light and polarized light. Note: The stronger (more intense) the light source the better the colors. Most standard light up microscopes will do great, finding one with a better light source makes things even better.
They will see fun things happen but the geologist will know what is happening to the minerals under polarized light. For those who are not geologists see discussion handout that will explain in detail what is going on in simple physics and geology terms.
In short the two cross polars are placed to filter out all light in single direction known as plain polarized, hence the bottom polar over light. With just the light (both upper and lower polars oriented 90 degrees) you will see black becuase no lights gets through to lens. When a mineral sample is introduced (if colors are visible) the light is being split into two rays that do not get filtered by upper polar because polar set to filter only specific single direction light. Any mineral that is black means that the light is unchanged going through mineral and upper polar filters single direction light as designed.
After students observe, inquire, and take notes from microscope activity have everyone gather for discussion. Use the discussion handout. Have them work in groups with guided questions such as draw out how a microscope works? or just give a brief interactive lecture on what they just analyzed and how it ties into what they learned. They will ask questions you will have to answer about physics and geology. You in turn will ask questions to them and gauge their level of understanding and promote constructive inquiry.

Independent Practice:
Students working with microscopes and recording observations.

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 microscope and how mineral interacts with light.

Enrichment: Just go into more advanced mineral optics such as explaining how the thickness of a mineral slows down ray paths and how the light rays become in phase or out of phase as a result.

Check(s) for Understanding:

- Tell me in general how a microscope works?
- What is polarization? How is it useful?
- Why did you setup the microscopes the way you did? What happens to the light rays that go through particular thin sections?
- Based on the resources in front of you what fossils did you (or we) identify? How and why could they be useful for determining a rocks age?
- Explain how optics works?
- What is reflection, refraction, and diffraction?
- What is the importance of clever/resourceful designing?

Closure:
End discussion with lesson relevance and connection to graduate school/college.

Possible Alternate Subject Integrations:

Ecology: connecting thin section fossils to living ecosystem with respect to geologic time scale.

Teacher notes:

- Thin sections are fragile and expensive. Don't smudge them and handle with delicate care. Take the time to explain to students proper handling of samples and microscope.