Lesson Title	Energy Dispersive Spectroscopy (EDS)
Length of Lesson	3 Days
Created By	Dustin Spayde, Jed Leggett, William Funderburk
Subject	Physics
Grade Level	11-12 (Physics)
State Standards	Physics: 1a, g; 6b
DOK Level	DOK 4
DOK Application	Apply Concepts, Analyze
National Standards	9-12: B (physical); E (technology)
Graduate Research Element	Identifying Sample Material Purity

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. Quantum energy and emission spectra.

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 atomic binding energies and high energy emission spectra.

National Science Education Standards of Content 9-12
A (Inquiry): identify questions and concepts that guide scientific investigations.
B (Physical): structure of atoms; structure and properties of matter; **interactions of energy and matter**. **Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.**
E (Science and Technology): abilities of technological design; understanding about science and technology

Materials Needed (supplies, hand-outs, resources): Copper sample of acceptable purity (a penny); incandescent light bulb filament (tungsten); access to a scanning electron microscope w/ x-ray detector (see Teacher notes below for SEM resources, or check with your state university)

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Lesson Performance Task/Assessment:
Students will learn about electron binding energies and how they vary for each element. Using this information, students will then calculate the wavelengths of the characteristic X-rays emitted from different elements (including copper and tungsten).
Finally, samples of copper and tungsten will be placed inside a scanning electron microscope (SEM) with an attached X-ray collector to show this concept being used in a real world application. Students will then compare their work with the output of the SEM analysis.

Lesson Relevance to Performance Task and Students:
Energy Dispersive Spectroscopy (EDS) is a method of elemental analysis or chemical characterization of a sample of matter. This technique can be used in many fields from material engineering to crime scene investigation.

Anticipatory Set/Capture Interest:
Have a relevant question written on the board class before the class enters.
Example: "Someone has just hit your parked car and the impact has left some of their paint on your vehicle. How can you use the paint sample to find out more about the car that hit you? What technologies can you think of to use?"

Guided Practice:
Day One: Student teams are determined by the instructor and the calculations are modeled using data gathered from the internet or textbook. The necessary theory is as follows:

The electron binding energies of each element are unique. The values associated with each element have been discovered and are readily available online at a variety of websites. When an electron penetrates the shells of an atom, electrons begin to shift from an outer shell down to another. This downward shift emits characteristic X-rays at wavelengths based on the difference in binding energies between shells. The binding energies can be related to the wavelength of the characteristic X-rays through the following equations.

$$\Delta E = h \cdot f$$

$$c = f \cdot \lambda$$

Where ΔE is the difference in the binding energies between the shell, an electron moves from to the new shell it occupies; h is the Planck constant; f is the frequency of the characteristic X-ray; c is the speed of light; and λ is the wavelength of the characteristic X-ray.

Day Two: Students will be brought to a lab with a scanning electron microscope with a X-ray detector. Here the students will place samples of copper and tungsten into the microscope for analysis. They will use the results of this analysis to verify the analytical work.

Independent Practice:
Day One: Students will solve for the different wavelengths of the characteristic X-rays for copper and tungsten. A problem set may also be assigned.

Day Two: Students will use the results of the SEM EDS analysis to compare and verify analytical work.

Day Three: Student groups will present on their finding and comparisons to the class and a panel of teachers (if available).

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

Enrichment/Extension: Set up a seminar which includes students from other science classrooms as an audience for the student team design presentations.

Check(s) for Understanding:

Day One: Do students know how to look up the electron binding energies for each element and understand their meaning? Can students calculate the wavelength of a characteristic X-ray for copper and tungsten?

Day Two: Can students explain the process of what is happening inside the SEM during the EDS analysis and how it relates to the previous day’s work?

Day Three: Do the students know how to employ PowerPoint to relate the process or method they used to generate their data and to present their results?

Closure:

Day One: Have the students compare their work with other students in their group.

Day Two: Have the students explain the basic process of what is happening inside the SEM during the EDS analysis.

Day Three: Have a panel of teachers offer suggestions for improvement for student presentations.

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:
NATIONAL LABS:
Department of Energy: links to national laboratories:
http://www.er.doe.gov/National_Laboratories/
Ames Laboratory: 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 University 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/

There are many other options available most areas such as universities and colleges in your area.