Explorations of the Sun

Deborah Yager
Stanford Solar Center, Stanford University
IISME Summer 2009

Subject Area: Science Grades: 10-12

Abstract:

Solar emissions blast the Earth in many different forms. This lesson introduces waves, electromagnetic radiation, quantum theory and spectroscopy and teaches how to build a simple spectroscope that is used to study light emissions.

Students can also study the effects of solar energy on Earth's ionosphere by installing and using a SuperSID monitor at their high school. Spectroscope kits and SuperSID monitors are available at low cost from the Stanford Solar Center.

Alignment with Standards:

California State Science Standards: Grades Nine through Twelve (Chemistry)
Atomic and Molecular Structure

1. The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure. As a basis for understanding this concept:
   j.* Students know that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship $E=hv$).

National Board Standards:
IV. Engaging the Science Learner
Accomplished Adolescence and Young Adulthood/Science teachers spark student interest in science and promote active and sustained learning, so all students achieve meaningful and demonstrable growth toward
learning goals.

For SuperSID Extension:
California State Science Standards: Grades Nine through Twelve (Chemistry)
Investigation and Experimentation Standards

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:
   a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
   b. Identify and communicate sources of unavoidable experimental error.
   c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.

d. Formulate explanations by using logic and evidence.

Description:

In chemistry, we study both the classical wave nature and quantum particle nature of light. While most students can relate their common experience of electromagnetic radiation (i.e. radio waves, microwaves and visible light) to classical wave properties (amplitude, frequency, wavelength), most find it challenging to understand the quantum nature of light. Quantum behavior can be quantitatively studied by spectroscopy, where light resulting from the interaction of radiation with gaseous matter (atoms, ions and molecules) is separated into a spectrum of component colors. This information can be used to identify the chemical composition of unknown gases, as well as the surface temperature and relative velocities of distant stars. A well-designed PowerPoint presentation will not only provide important background information about electromagnetic radiation and spectroscopy, beautiful spectroscopic images will inspire student learning. Students will then build their own individual spectroscope from first principles and use them to study light from incandescent and fluorescent light bulbs, as well as spectrum bulbs filled with known gases and a large-scale flame test demonstration (Goblets of Fire). Students will then learn the basics of light diffraction and use this understanding to calibrate the grating inside their spectroscopes. These spectroscope kits are available from the Stanford Solar Center for the cost of shipping. The presentation continues with an explanation of how absorption and emission lines are created, beginning with a hands-on activity involving the Bohr model of the hydrogen atom. It concludes with an introduction to the uses of spectroscopy in astronomy, including determination of stellar temperature, composition, radial velocity and magnetism.

While there are many laboratory investigations in a chemistry classroom, few are open-ended and capable of teaching the basics of real scientific research. Stanford's Solar Center provides low-cost space weather monitors to school sites to inspire and support student-based solar research projects using hands-on "real" scientific instruments and data. With assistance, students can set up and use a Stanford-donated SuperSID (sudden ionospheric disturbance) monitor that will introduce them to space weather and collecting, analyzing and interpreting scientific data. Students can share their data with other SuperSID investigators around the world via the web. I will help students set up one of the first SuperSID monitors at my high school.

About the SuperSID Space Weather Monitor Instruments

SuperSID is a new, second-generation space weather monitor designed, built and distributed by Stanford's Solar Center as part of their educational outreach program. Two hundred and thirty one of its predecessor, SID, have been distributed for student use to high schools and universities around the world, including countries throughout Europe, South America, Africa and Asia. SID monitors detect changes in Earth's ionosphere by recording very low frequency (VLF) transmissions from one VLF transmitter as they bounce off the ionosphere. SuperSID monitors are less expensive to produce and detect ionospheric changes by monitoring several VLF stations simultaneously, making it more versatile. SuperSIDs are being distributed through the Society of Amateur Radio Astronomers (SARA) and can be ordered by sending email to: supersid@radio-astronomy.org

Objectives:

At the conclusion of this plan, students will be able to:

1. Identify radiation types (radio, microwave, infrared, visible, ultraviolet waves, x-rays, gamma rays etc) based on wave characteristics (frequency and wavelength) and recognize that visible light is one small part of the electromagnetic spectrum

2. Know the basic design and uses of a spectroscope and build a simple spectroscope
3. Use a spectroscope to study emissions from bulbs of known types
4. Understand the basics of diffraction and calibrate a diffraction grating
5. Understand how emission and absorption spectra are produced and how they are used in astronomy

As an extension:
1. Set up a SuperSID monitor, including building a radio antenna
2. Use a SuperSID monitor to collect data related to ionization of the ionosphere
3. Determine the sunrise and sunset signatures for a SuperSID monitor
4. Compare their SuperSID data with data collected from other SID and SuperSID monitors worldwide, as well as with data from the GOES satellite

Identification of Resources:

- Computer with digital projector capable of showing PowerPoint presentations
- Stanford Solar Center/Lockheed Martin spectroscope kits (including diffraction gratings) available online for the cost of shipping at:
  http://solar-center.stanford.edu/posters/posters_spec_bulk.html
- Fluorescent (CFL bulbs are ideal) and incandescent light bulbs with corresponding electrical sockets
- Spectrum tubes filled with helium, sodium, neon and argon gases (or any other single element gases) with associated power supply. Spectrum tube power supply available at Ward's Natural Science for $187; spectrum tubes for $33-47 each.

For SuperSID installation:

- SuperSID space weather monitor with associated documentation and software (free and all included with shipment; available online at http://solar-center.stanford.edu/SID/)
- Computer capable of running Windows XP (Pentium 4, 2GHz, 512MB Ram, 40GB hard drive)
- Materials and tools needed to build antenna: An antenna frame can be built of almost anything, from PVC tubes to wood to broomstick handles. Several example antenna designs with required materials are included in the SuperSID documentation. You will need common tools: electric drill, hammer, clamps, measuring tape.
- Place to set up antenna that is as far away as possible from sources of electronic noise; this must be determined for each installation site. It is best to place the antenna away from power lines, generators, any source of electrical interference. A rooftop or outdoor location can be ideal, so long as the antenna is secured and protected from lightening.

Teacher Notes and Documents:

1. "Fingerprints in Starlight: Spectroscopy of Stars" PowerPoint presentation that covers electromagnetic radiation, particle and wave natures of light, quantum theory, basics of spectroscopy, how to build a simple spectroscope, atomic emission and absorption spectra, uses of spectroscopy in astronomy. Notes for most slides are included in presentation.
2. Directions for how to make Stanford Solar Center/Lockheed Martin spectroscope: http://solar-center.stanford.edu/activities/cots.html
3. "Fingerprints in Starlight: Spectroscopy of Stars Inquiry Questions" worksheet and answer sheet

For SuperSID extension:
1. SuperSID Documentation (included with shipment of SuperSID and available online):
   - Space Weather Monitors: SuperSID Manual (in progress; should be available 9/2009)

Check: http://solar-center.stanford.edu

- Space Weather Forecast: A Space Weather Curriculum for High School Students
  http://solar-center.stanford.edu/SID/Distribution/expanded_files/SpaceWeatherForecast-v.070507.doc
- Research with Space Weather Monitor Data
  http://solar-center.stanford.edu/SID/Distribution/expanded_files/ResearchGuide.doc

2. SuperSID system: preamplifier, 90 MHz sound card and computer software (free)
3. Documentation, software and SuperSID system are available at little to no cost (for educators)and take approximately one week to receive once ordered. The only additional costs are the materials needed to build a simple antenna ($10-50, depending on design).

Student Documents:

1. Directions for how to make Stanford Solar Center/Lockheed Martin spectroscope: http://solar-center.stanford.edu/activities/cots.html
2. Spectra Worksheet
3. “Fingerprints in Starlight: Spectroscopy of Stars Inquiry Questions” worksheet

Assessments:

1. “Mystery Star” questions near middle of PowerPoint presentation
2. Multiple choice questions at end of PowerPoint presentation
3. “Fingerprints in Starlight: Spectroscopy of Stars Inquiry Questions” worksheet

Implementation:

Once you have covered atomic structure, electron orbital configurations, the electromagnetic spectrum and basic quantum theory in class, students will perform the Flame Test Lab. Then present the “Fingerprints in Starlight: Spectroscopy of Stars” PowerPoint presentation in three parts:

- We will build spectroscopes and study light emissions from different bulb types, as well as observe the “Goblets of Fire” demonstration, during a block day class session.
- Discussion of diffraction and calibration of diffraction gratings will take place during an after school Science Club meeting.
- Discussion of emission and absorption spectra, including their uses in astronomy, and Spectra Worksheet activity will take place during a second after school Science Club meeting.