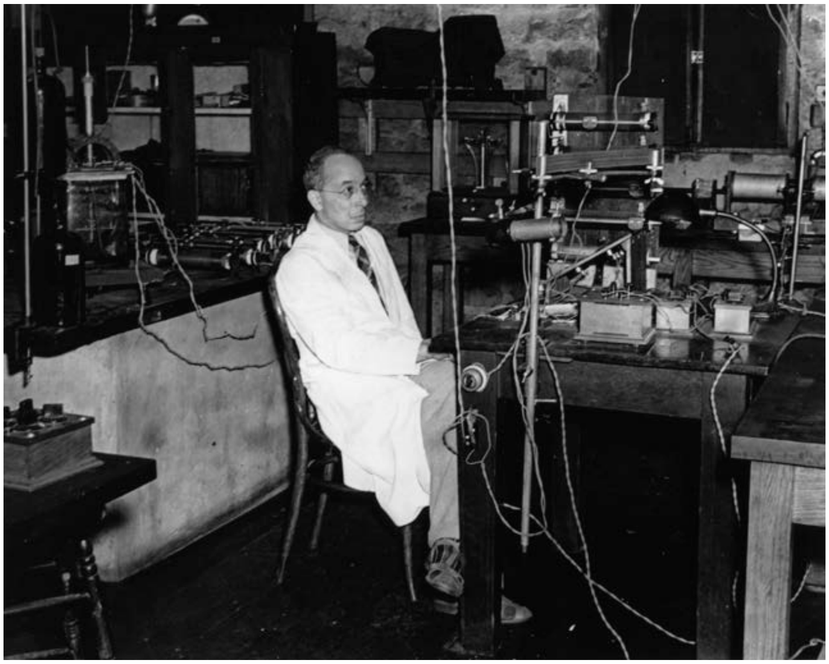
Lesson Plan
Dr. Elmer Imes and Spectroscopy



Portrait of Elmer Imes working in a laboratory,
Image from Fisk University, Nashville, courtesy AIP Emilio Segré Visual Archives.

Grade Level(s): 9-12	**Subject(s): History, Physics**

In-Class Time: 60-80 min	**Prep Time: 15-20 minutes**

Materials

- AIP Handout on Elmer Imes and Fisk University (see Supplemental Materials)
- Clear prism
- Colored light source
- Focused white light source (flashlight, etc.)
- Video capabilities (projector, etc.) to show Elmer Imes and Spectroscopy PowerPoint (found in Supplemental Materials). Or:
- **Optional:**
  - o Diffraction glasses
  - o Gas discharge/spectrum tubes
  - o Gas discharge/spectrum tube power source
  - o Society of Physics Students 2014-15 SOCK supplemental activity, “Excited gases”

Objective

In this lesson plan, students will learn about Dr. Elmer Imes, the second African-American to receive a Ph.D. in physics in 1918 and a physics professor at Fisk University. Students will learn about Imes' experimental work on spectroscopy and how it was a turning point in modern applied physics. Afterward, students will learn about the principles of spectroscopy. This lesson explores Imes' personal history and scientific work in spectroscopy, and provides a hands-on activity demonstrating refraction and spectra. **Note**: this lesson works very well alongside the AIP Teaching Guide "Physicist Activist: Dr. Elmer Imes and the Civil Rights Case of Juliette Derricotte," which explores a historical tragedy that Elmer Imes became involved in.

Introduction

For information on Elmer Imes' life and work, refer to the AIP Handout on Elmer Imes and Fisk University (found in Supplemental Materials).

Infrared Spectroscopy

At the University of Michigan, Imes worked in Randall's laboratory designing and building high-resolution infrared spectrometers and detectors. **Infrared spectroscopy** is the study of how molecules absorb and emit infrared light. By examining how this occurs, we will not only learn about how infrared radiation is absorbed, but we will also learn about molecular structure and how the study of infrared spectroscopy can provide information about the structure of organic molecules. An infrared spectrum of a chemical substance is very much like a photograph of a molecule. However, unlike a normal photograph which would reveal the position of nuclei, the infrared spectrum will only reveal a partial structure. It is the purpose of this lesson to provide you with the tools necessary to interpret infrared spectra successfully.

The term "spectroscopy" refers to the study of spectra. A **spectrum** is the range of wavelengths, or radiating energy, given off by an energy source. For example, a typical light bulb emits white light. The **white light** you see is actually a combination of different colors of light. The light that creates these different colors is composed of photons, and each photon has its own energy, frequency and wavelength that corresponds to its particular color. When white light is split into individual wavelengths, the full spectrum of colors becomes visible: violet, blue, green, yellow, orange and red.

In addition to the colors of light in the visible spectrum, there is radiation that is not visible. Radiation beyond the violet end of the spectrum is known as ultraviolet, while radiation beyond the red end of the spectrum is known as infrared. Although humans cannot see it with our eyes, scientists can detect electromagnetic radiation with these wavelengths using spectrometers.

All molecules are composed of at least two atoms, and all atoms contain subatomic particles called protons, neutrons and electrons. The center of an atom, the nucleus, contains protons and possibly neutrons. Electrons move in particular configurations around the nucleus. With **infrared spectroscopy**, **Imes** could determine the energy levels of **electrons** within a **molecule** (which can describe the positions of electrons in the electron cloud).

In order for an electron to jump between energy levels, it needs to absorb a specific amount of energy. Sometimes photons with the correct amount of energy (a specific wavelength/frequency) come close enough to interact and be absorbed by the electron. If a photon does not have the correct amount of energy, it will not interact with the electron. After the electron has been excited (given enough energy to jump up to a higher energy level) it has become unstable and so it wants to jump back down to a lower energy level. To do this, it releases a photon of the corresponding energy amount that it needs to lose. The direction that the photon entered the electron from and the direction that it leaves from are unrelated and can vary widely.

By analyzing the spectrum of light produced by a particular molecule, Imes could understand the position and energy levels of the electrons within its atoms. Imes could also calculate interatomic distance, or the distance between atoms in molecules. Imes' research enabled scientists to identify unknown substances and to better understand the known chemical elements. His innovative methods for examining molecules had a significant impact on the advancement of **quantum theory** which states that energy can only exist in specified amounts.

When Imes began his work on infrared spectroscopy in 1918**,** quantum theory was regarded with skepticism by many scientists, as it was still fairly new. Imes' research proved to scientists around the world that quantum theory could be used to gather information about phenomena that physics could not explain without it. His work also helped show that quantum theory could be used to study and solve a wide range of scientific problems.

Imes was correct in thinking that quantum theory had general use in scientific research. Since his lifetime, quantum theorists have answered questions about the creation of the universe, harnessed nuclear energy, and helped develop the first computer.

Instructions/Activities

Engage: 5-10 Minutes

Teachers will introduce (or re-introduce) students to Dr. Elmer Imes via a short lecture based on the AIP Handout on Elmer Imes and Fisk Univeristy (found in Supplemental Materials).	
What is the teacher doing? Distribute copies of the Elmer Imes Handout (from the Supplemental Materials) to the class. Give a short lecture on Elmer Imes' life and work. Discuss his childhood, education, and professional career. Conclude by focusing on his work in spectroscopy, introducing and defining the field.	**What are the students doing?** Receive and read the Handout on Dr. Elmer Imes, while also listening to the lecture about his life and work.

Explore: 10-15 Minutes

Teachers will introduce students to an aspect of spectrometry and spectroscopy by refracting light through a prism. Students will observe and discuss their observations. Teachers will conclude by discussing the field of spectroscopy.	
What is the teacher doing? 1. Write ROY G BIV on the board. Ask the student what they know about what this means. This is an acronym for the colors	**What are the students doing?** 1. Explain the acronym ROY G BIV.

of the rainbow: red, orange, yellow, green, blue, indigo, violet.	
2. Direct students to draw how rainbows are formed in their notebooks. Light is being refracted by water droplets in the atmosphere.	2. Draw or describe how rainbows are formed (hint: light refracts through water droplets).
3. Tell students it is possible to create a rainbow without water and sunlight in the classroom.	
4. Turn off lights. Shine a white light through a prism, ensuring the light exiting it shines on a screen or board.	
5. Ask the students what they observe. The light exits at a different angle than it entered, and becomes a color spectrum.	5. Explain what is observed as light passes through the prism. Be sure to note the colors observed, as well as the angle of the light as it exits the prism.
6. Explain that light is being refracted by the prism as it travels through, and white light is composed of all the colors of the rainbow, each of which represents a specific wavelength of light. As white light passes through a prism, different wavelengths are refracted at different angles, so the individual colors can be observed.	
7. Tell students to predict what will happen if a colored light is used instead of a white light. Shine colored light through prism and tell students to compare their predictions with the results. The colored light should exit at a different angle than the white.	7. Predict what will happen if a colored light is shined through the prism. Compare predictions with observations once the teacher shines the colored light through.
8. Shine white light through the prism again. Place poster paper where the light is refracted. Have students use corresponding markers to draw where each color of light begins and ends.	8. One student should put poster paper where the light shines as it exits the prism. Other students should use corresponding colored markers to mark where each color begins and ends.

Explain: 5 Minutes

Teachers will explain the principles behind spectroscopy and the devices used to practice it, as well as elaborating on observations from the preceding demonstration. Also, teachers will remind students of Elmer Imes and his work in the field.	
What is the teacher doing? Explain spectroscopy, its principles, practice, and technology involved. Consult the AIP Handout on Elmer Imes and Fisk University if further information on the subject is needed. Remind	**What are the students doing?** Listen to the teacher's explanation of spectroscopy, and remember Dr. Elmer Imes, and his contributions in the field of infrared spectroscopy.

students of Elmer Imes and his pioneering work in infrared spectroscopy once more.	

Elaborate: 30-35 Minutes

Students will look at the emission spectra of different elements. They will learn about the different tools that allow them to view these spectra.	
What is the teacher doing? Review what the students know about atomic emission and absorption. Have the students explain what is being represented on the Atomic Absorption/Emission slide of the PowerPoint (see supplemental materials). Address any questions or points of misunderstanding that may arise.	**What are the students doing?** Look at and explain the Atomic Absorption/Emission (first) slide of the PowerPoint. Ask the teacher any remaining questions/clarify points of confusion.
If spectrum tubes, a power source and diffraction glasses are available: Set up the spectrum tubes and power source. Give the students diffraction glasses. Turn on the power source and let the students observe the emission spectrum. Show them multiple gases, if possible. Provide students with & lead them through the Spectroscopy Discussion Questions. For further instruction on how to lead this activity, please see the Society of Physics Students 2014-15 SOCK supplemental activity, "Excited gases". **If spectrum tubes, a power source and diffraction glasses are not available:** Project the spectrum viewing slide. Provide students with & lead them through the Spectroscopy Discussion Questions.	**If spectrum tubes, a power source and diffraction glasses are available:** Observe the emission spectra of various gases. Participate in the discussion about what is seen. (PowerPoint slide can be used to explain what's happening in the experimental setup). Answer the Spectroscopy Discussion Questions **If spectrum tubes, a power source and diffraction glasses are not available:** View the slide about spectra viewing. Describe how spectra are produced and how we can view them for study. Answer the Spectroscopy Discussion Questions.

Evaluate: 10-15 Minutes

Teachers will provide students with the Discussion Questions (found in the Supplemental Materials). Students will answer them, and submit their answers to the teacher for evaluation. Students may answer the Questions individually or in their small groups.

Required/Recommended Reading and Resources

- AIP Handout on Fisk University and Elmer Imes

Center for History of Physics

Discussion Questions

Discussion Questions can be found as a Handout with a corresponding Answer Key in the Supplemental Materials to this lesson plan.

On Elmer Imes:

1. Where was Imes from and where did he go to school?
2. Why did Dr. Imes study infrared spectroscopy?
3. What was significant about Dr. Imes research? What was going on in the history of physics?

On Spectroscopy:

1. What do you see?
2. What do you think the diffraction glasses are doing to the light?
3. What do you think is causing the bright lines by the spectral tube?
4. Do you think that those bright lines would change if there was a different gas inside of the tube?

Further Reading and Additional Resources

- George Hutchinson, *In Search of Nella Larsen: A Biography of the Color Line* (Cambridge, MA: Belknap Press of Harvard University Press, 2006). Contains significant information on Elmer Imes.
- Thadious M. Davis, *Nella Larson, Novelist of the Harlem Renaissance* (Baton Rouge, LA: Louisiana State University Press, 1994). Contains significant information on Elmer Imes.
- Ronald E. Mickens, "Elmer Samuel Imes — Scientist, Inventor, Teacher, Scholar," in *Edward Bouchet: The First African-American Doctorate* (River Edge, NJ: World Scientific Publishing, Co., 2002), 101-107.

Extensions

Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:

- Physicist Activist: Dr. Elmer Imes and the Civil Rights Case of Juliette Derricotte
- Spectra and Margaret Huggins

Society of Physics Students (SPS) Science Outreach Catalyst Kits (SOCKS): SOCKS are modular kits that include exploratory science and physics activities designed to facilitate outreach at SPS chapters. Information about requesting kits can be found at:
https://www.spsnational.org/programs/outreach/science-outreach-catalyst-kits

- "Light: A Spectrum of Utility" (2014):
  - from the SOCK description: "The 2014-15 SOCK celebrates the International Year of Crystallography (2014) and the International Year of Light (2015). Through a variety of activities it brings the concept of **Light: A Spectrum of Utility** to life. Users explore ways that we use light on a daily basis, and what it can tell us about matter and its structure. Activities range from using a laser to determine the structure of a CD to creating "stained glass" masterpieces through polarization."
    https://www.spsnational.org/programs/outreach/science-outreach-catalyst-kits/2014/light-spectrum-utility

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

History/Social Studies	
CCSS.ELA-LITERACY.RH.9-10.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.
CCSS.ELA-LITERACY.RH.11-12.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.
Science & Technical Subjects	
CCSS.ELA-LITERACY.RST.9-10.2	Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
CCSS.ELA-LITERACY.RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
CCSS.ELA-LITERACY.RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information
Dimension Two: Crosscutting Concepts	1. Patterns 2. Cause and effect 4. Systems and system models 5. Energy and Matter 6. Structure and function
Dimension Three: Disciplinary Core Ideas	Core Idea PS1: Matter and Its Interactions Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer