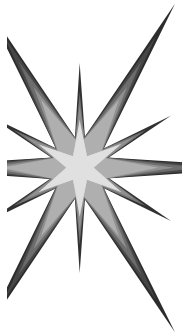


Student Conceptions of Quantization and the Photon

**Physics Education
Research Group**
Ohio State University

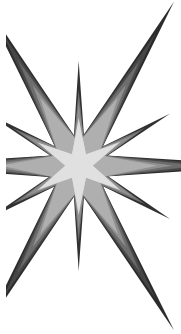
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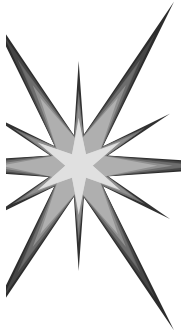
Objectives

- * To identify the conceptions about quantization that students bring to introductory physics courses.
- * To determine the extent to which these conceptions exist within the student population.
- * To determine the extent to which these conceptions affect a student's ability to understand other modern physics concepts.



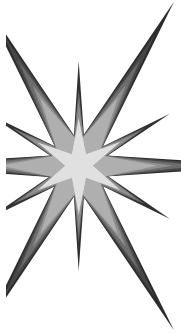
Assumptions

- * Quantization is a fundamental concept of modern physics.
- * Students have notions that influence how they think about physics, which grow with age and experience.
- * We can use the students' ability to talk about the photon to gain insight into their grasp of quantization.



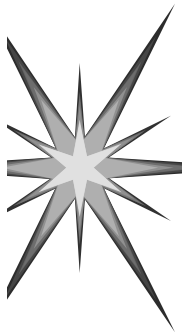
What we are doing

- * We have interviewed high school students, undergraduates, graduate students, middle school teachers, physics professors.
- * We have developed interview protocol.
- * We plan to develop paper/pencil survey (questionnaire).
- * We plan to use the survey with a large number of students and others.



Interview Protocol

- * [Demonstration: showcase bulb on a dimmer switch]
How dim can the bulb get? Explain what you see when you look at it through this diffraction grating.
- * Have you ever heard of the term “photon?” If so, where?
- If yes, proceed. If no, use “light” questionnaire.
- * When you hear the term “photon” used, what mental image comes to mind?
- * Describe a photon to me. Tell me what it does.
- * If you can, please draw a photon the way you think it looks.
- * Does the word “quantization” have any meaning for you?

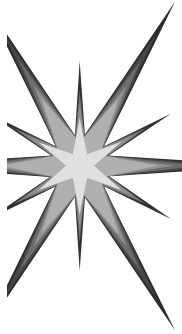


Protocol (continued)

- * How would you know that a photon exists?

Follow-up questions:

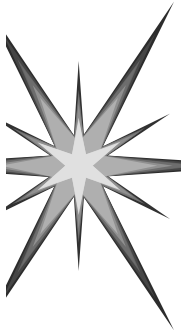
- * Does a photon have mass?
 - * Does a photon have size?
 - * Can you distinguish between photons?
 - * Does a photon have speed? (How fast?)
 - * Can a photon exert a force?
 - * Does a photon have energy?
 - * How is a photon produced?
-
- * Explain why you think of a photon as “real” or why not.
 - * If you were to try to explain what a photon is to a 9-year-old, what would you say?
 - * [Demonstration: excited mercury vapor] What do you see? Explain what you see when you look at it through this diffraction grating. How is it the same or different from the showcase bulb?



Protocol (continued)

- * What is a shadow and how is it formed? How could photons be related to shadows?

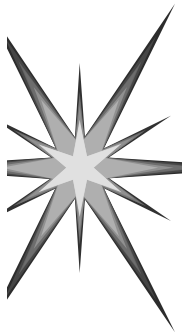
- * Are photons related to any of the following items? How?
 - * fluorescent lamps
 - * CAT scans
 - * TV remote controls
 - * X-ray machines



Initial Observations

mental image question

1. “A little ball of light or packet of light, traveling in a continuous wave motion.”
2. “Small particles (rod shape) that are part of light.”
3. “Little high energy bullets flying out of a collision.”
4. “A particle smaller than an atom—or the parts of an atom.”
6. “The carrier of energy.”
7. “A particle of light coming from the sun and traveling through space.”



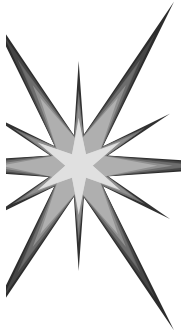
Interviews

Interviews are taped.

The tapes are used to produce transcripts.

We have chosen to try Dragon Software's Naturally Speaking™ to transfer the tapes to the transcripts.

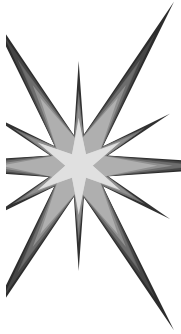
Small success so far, though the program is over 95% successful at recognizing "trained" voices. Problems include cheap tape recorders, background hum, inability to send tape to computer electronically.



Initial Observations

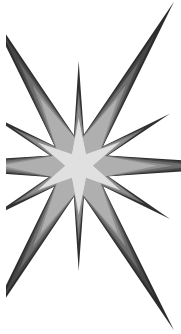
(continued)

8. “Very small, extremely impossible to see.”
9. “Like a squiggly arrow, like a little sine wave with an arrow at one end.”
10. “The atom’s nucleus - several little circles or balls.”
11. “Something real small, real, real small, spherical. And it’s bright.”
12. “Squiggly lines from Feynman diagrams.”
13. “Little white dots.”



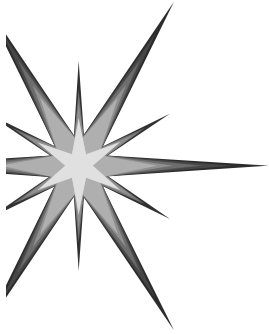
Preliminary Guesses

- * Many students of introductory physics have heard the word “photon,” but few have a clear mental image of it.
- * Those images they do have are diverse.
- * Graduate students and physicists also struggle with mental images, but the images they have are generally more elaborate than those of high school students and undergraduates.



Common mental images

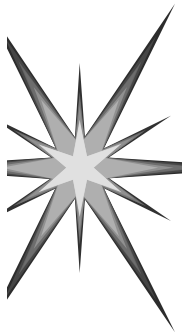
- * Ball or packet of light.
- * Wave, or something that moves in a wave-like pattern.
- * “Photon” being confused with “proton” or with atom’s nucleus.
- * “Photon” being confused with the rod-shaped cells in eyes?



Interpreting the transcripts

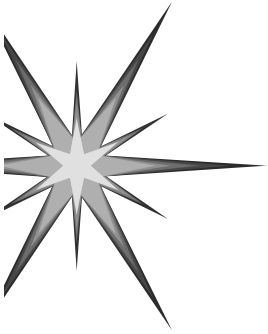
Use of the software package NUD*IST to interpret transcripts.

The software does not do the analysis itself, but it helps in organizing the common threads in various ways (as shown in the example in the next transparency).



The next step: developing the survey

- * Identify student conceptions of photon properties and of quantization.
- * Create multiple-choice questions that identify mental images, conceptions of photon properties, and understanding of quantization.
- * Administer the survey and perform member checks by interviewing survey respondents.
- * Revise the survey and iterate.



Summary

We have learned interesting things about visualization of the photon, both among physicists and students.

We have learned that we were correct: few recognize quantization directly.

We are beginning to analyze the transcripts for common ideas.

We will produce a questionnaire.