

Conceptions of Quantization and the Photon of Students at various Educational Levels

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Objectives

- **To identify the preconceptions about quantization that students bring to the introductory physics course**
- **To determine the extent to which these conceptions exist within the student population**
- **To determine if and to what extent these preconceptions adversely impact upon the student's ability to understand contemporary physics concepts.**

Assumptions

- Students have notions that influence how they think about physics
- These notions grow with age and experience
- Quantization is a fundamental centerpiece of 20th century physics
- We can use the student's ability to talk about the photon to gain insight into their grasp of quantization

“Interviews” done

73

Colleagues	7
Middle School Teachers	42
Graduate Students	6
High School Students	7
Undergraduates	11

These interviews formed the basis for the questionnaire given to a sample of undergraduates in physics courses.

The Survey

on quantization and the photon

Four items are multiple choice

Three multiple choice items have a confidence indicator.

Forty-two items are currently being tested as distractors/answers by use of a Likert scale response, which also includes a “don’t know” option.

We currently intend to make the final questionnaire in multiple choice format.

We invite you to fill in the survey for us as “experts,” and mail it in to us. We would appreciate your help.

What we've found so far:

- **Students in the nonengineering courses are more likely to give an answer when the questions are in multiple choice format, even if they lack confidence in their answers, than if they can choose “don't know” as an option.**
- **Many introductory students have heard the word photon, but few have a clear mental image of one.**
- **Few introductory students have heard the word quantization at all.**
- **Even graduate students and physicists struggle with mental images.**

When you hear the word “photon,” what are the images that come to mind?

Circle all that apply; more than one answer could be correct.

grad student,
lab prep

	Physics 132 N = 4	Physics 132E N = 54	Physics 107 N = 11	"experts" N = 3
a particle	4	43	5	0
a wave	4	32	0	1
a packet of energy	2	42	5	3
a small, round, positively charged object	1	9	4	0
a high-energy bullet	2	17	1	0
quanta of electromagnetic radiation	3	21	0	2
an extremely small particle in an atom	1	14	4	0
beams of light	1	39	4	0
something very small	2	31	4	0
a ball of light	2	18	2	0
a disk about the size of a dime	0	0	1	0
rod-shaped particles	0	1	1	0
a ball of some kind that's always white in color	0	3	0	0
other (please explain): _____				

Which of the following physical characteristics do you MOST FREQUENTLY use to describe a photon?

Circle all that apply; more than one answer could be correct.

	N = 4	N = 54	N = 11	N = 3
wavelength	1	27	5	2
frequency	0	20	1	1
energy	4	50	8	3
mass	0	10	2	0
none of above; photons too "small"	0	1	0	0
uncertain	2	17	2	1
confident	1	13	2	1
certain	1	18	5	0
no response	0	6	2	1

Which of the following BEST describes the size of a photon?

Circle all that apply; more than one answer could be correct.

	N = 4	N = 54	N = 11	N = 3
photons have no size	2	18	2	2
the size of an atom	0	1	2	0
the size of a nucleus	0	1	1	0
the size of an electron	0	12	1	0
smaller than an atomic nucleus	2	17	3	1
photons come in a variety of "sizes"	0	12	1	1
uncertain	1	26	8	2
confident	2	14	2	0
certain	1	9	0	1
no response	0	5	1	0

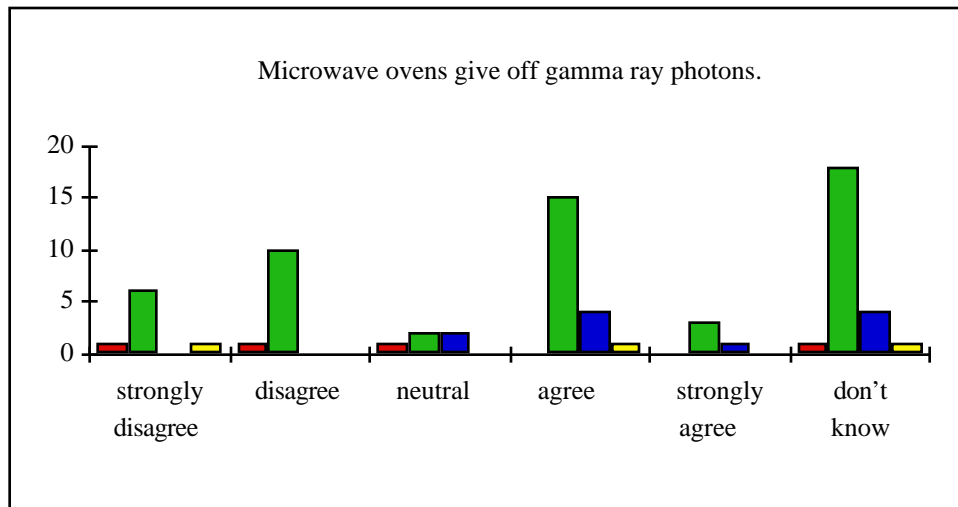
Which of the following has/have to do with the size of a photon?

Circle all that apply; more than one answer could be correct.

	N = 4	N = 54	N = 11	N = 3
energy	4	43	5	2
wavelength	2	28	3	0
mass	1	17	5	0
frequency	1	20	2	0
amplitude	1	19	2	0
uncertain	3	28	7	1
confident	0	14	1	0
certain	1	7	1	0
no response	0	5	2	2

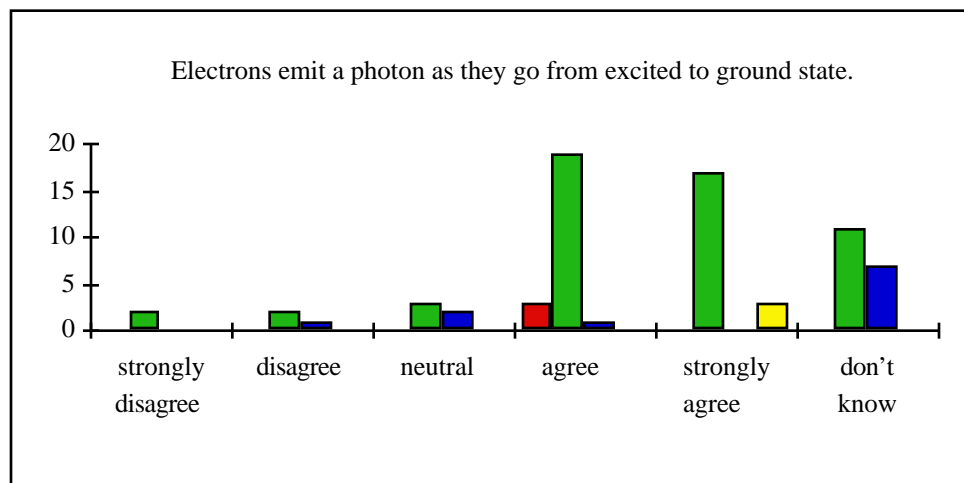
Item 8: Microwave ovens give off gamma ray photons.

	N = 4	N = 54	N = 11	N = 3
strongly disagree	1	6	0	1
disagree	1	10	0	0
neutral	1	2	2	0
agree	0	15	4	1
strongly agree	0	3	1	0
don't know	1	18	4	1



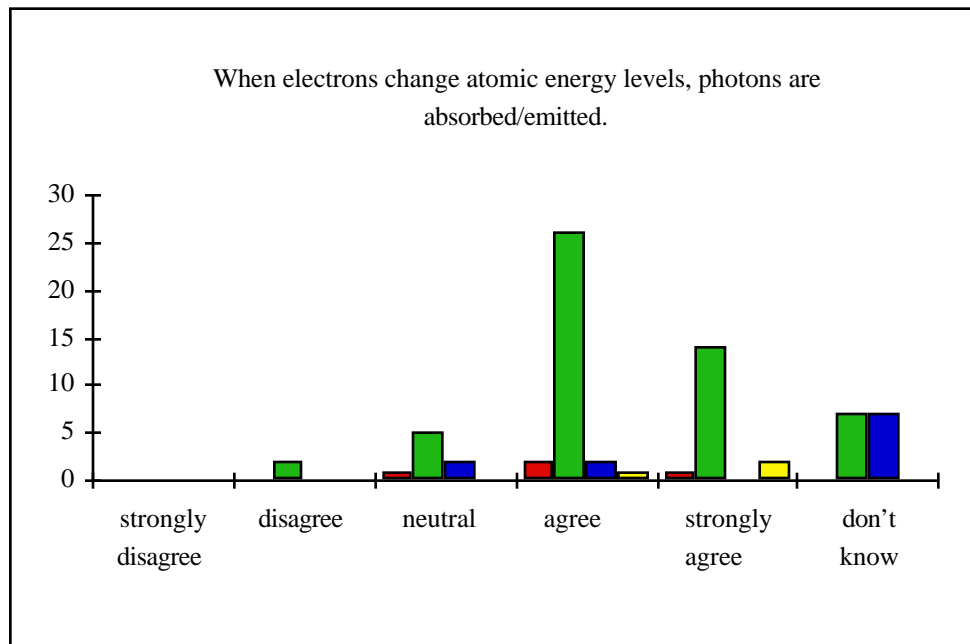
Item 18: Excite atoms and let them deexcite. As the electrons go back from the excited state closer to the ground state they will emit a photon.

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	2	0	0
disagree	0	2	1	0
neutral	0	3	2	0
agree	3	19	1	0
strongly agree	0	17	0	3
don't know	0	11	7	0



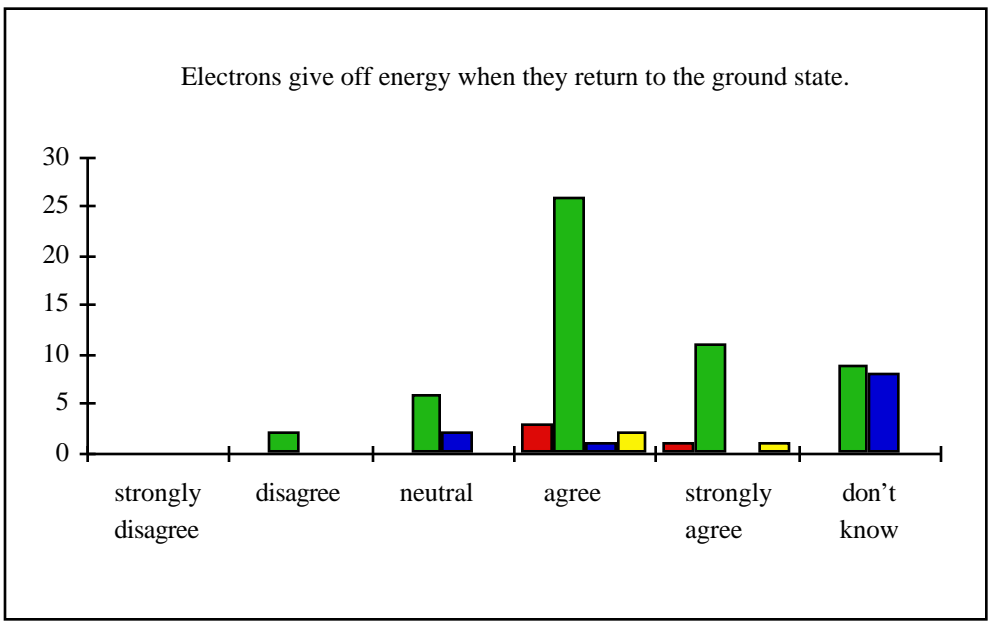
Item 32: When electrons change their energy levels in an atom, photons are being absorbed or emitted.

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	0	0	0
disagree	0	2	0	0
neutral	1	5	2	0
agree	2	26	2	1
strongly agree	1	14	0	2
don't know	0	7	7	0



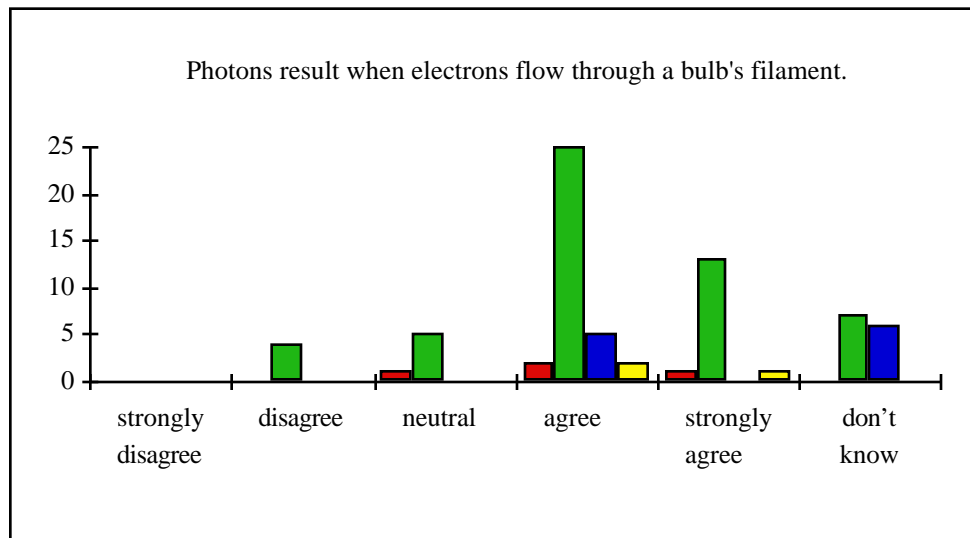
Item 40: When electrons in atoms come back down to the ground state, it gives off that energy in the form of photons

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	0	0	0
disagree	0	2	0	0
neutral	0	6	2	0
agree	3	26	1	2
strongly agree	1	11	0	1
don't know	0	9	8	0



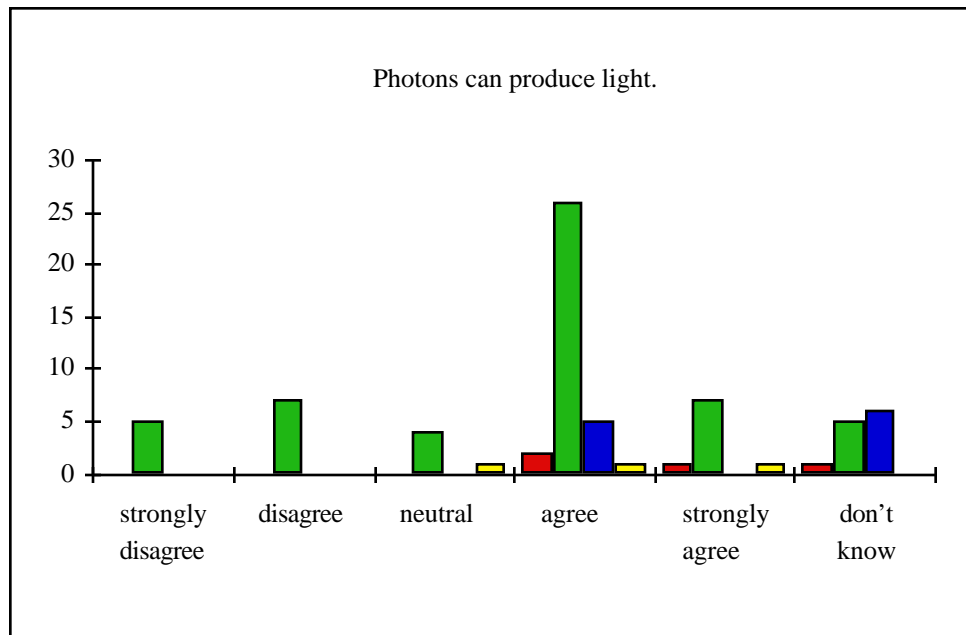
Item 24: When electrons flow through a filament inside a bulb, photons are created .

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	0	0	0
disagree	0	4	0	0
neutral	1	5	0	0
agree	2	25	5	2
strongly agree	1	13	0	1
don't know	0	7	6	0



Item 31: Photons can produce light.

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	5	0	0
disagree	0	7	0	0
neutral	0	4	0	1
agree	2	26	5	1
strongly agree	1	7	0	1
don't know	1	5	6	0



Item 33: The photon is not real, it is only a way of thinking about light and energy.

	N = 4	N = 54	N = 11	N = 3
strongly disagree	0	7	1	1
disagree	2	13	3	1
neutral	1	8	0	0
agree	0	11	0	0
strongly agree	1	2	0	0
don't know	0	13	8	1

