UNDERSTANDING OF CLASSICAL PHYSICS WHEN LEARNING QUANTUM MECHANICS: STUDENTS' PERSPECTIVE

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INTRODUCTION

Quantum mechanics is becoming more relevant, not only for future physicists, but also for technologists, chemists, and biologists. Quantum mechanics is crucial in a wide number of domains, notably photonics, mesoscopic architecture, and diagnostic medicine. As a consequence, it's unexpected that quantum mechanics is already being presented to a growing number of high school pupils. On the other hand, quantum mechanics is difficult and abstract. Additionally, a working grasp of certain classical concepts is required for effective understanding of quantum systems. The goal of this article is to describe the study's results about the influence of students' knowledge of classical concepts on their quantum mechanics learning. We describe students' difficulties under the classical domain and how these difficulties seem to impede students' acquisition of quantum concepts in each setting. We briefly discuss how these impediments could be addressed. Obviously, the examples in this work are not exhaustive. Rather than that, we are pursuing two objectives. The first is to highlight the vital need of a strong conceptual basis for advanced physics courses. The second objective is to emphasise the crucial necessity of studying student learning on a consistent and rigorous basis using physics education research approaches.

KEYWORD: Quantum mechanics, future physicists, quantum systems, student learning, quantum ideas

PHYSICS RESEARCH

The findings in this article are the outcome of comprehensive examinations into how students learn physics. Classroom observations, free answer and multiple-choice diagnostics, recorded and transcribed individual demonstrations interviews, and a variety of other techniques are used in research. Due to space constraints, we will summarise the findings of a few research and give sources for further information. A recent edition of Physics Today has an overview of the topic of physics educational psychology (Redish & Steinberg, 1999).

FROM PHYSICAL OPTICS TO PHOTONS

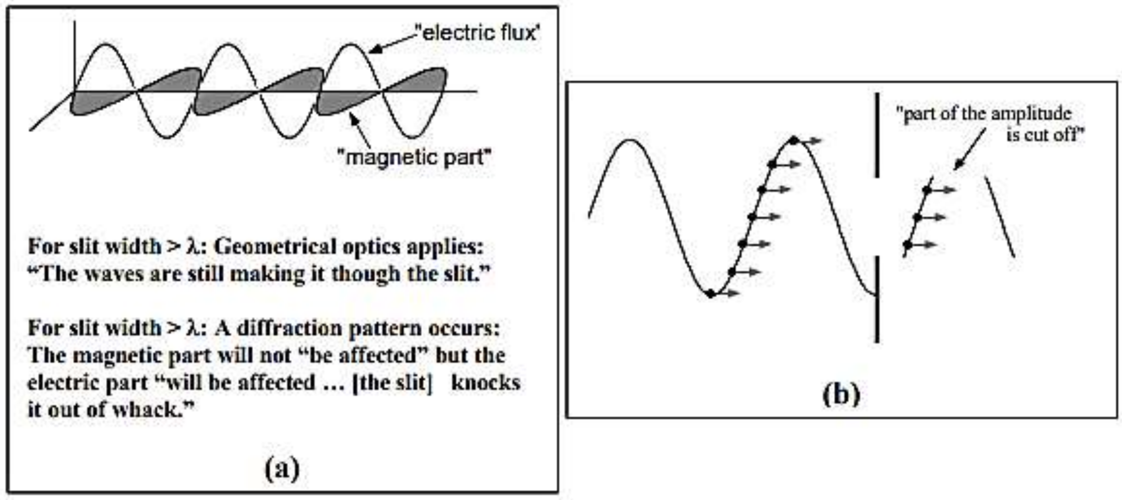
Students often begin their studies of contemporary physics and quantum mechanics by studying electromechanical waves and then mechanical optics. The justifications for this are reasonable. Without an understanding of superposition, wave representations, and diffraction, the wave characteristics of matter, quantum physics duality, and atomic spectroscopy make no sense. We demonstrate in this section how student confusion about the wave nature of light might spread when they are exposed to the idea of a photon.

STRUGGLE WITH PHYSICAL OPTICS

Students have been noted to struggle with learning light models (Ambrose et al., 1999). Clearly, the majority of pupils do not construct a credible wave model of light's behaviour. For instance, about half of students who had just finished an introductory calculus-based physics course thought that the amplitude of a light wave was spatial (as opposed to electromagnetic). Many students use the term "fitting" or "not fitting" waves when attempting to explain diffraction. Fig. 1a illustrates a student answer to a question on the behaviour of light travelling through a small slit during an interview. His answer was typical.

STUDYING PHOTONS

Students seem to carry issues such as the one seen in Fig. 1a with them while learning more sophisticated areas in physics that follow physical optics. This may result in incorrect interpretations of, for example, the quantum nature of light (Steinberg, Oberem, & McDermott, 1996). Rather of revising their flawed model of light, many students integrate the new physics they are learning into it. Many beginning students consider the amplitude of light to be a spatial quantity. When these pupils learn of the particle nature of light, it looks as if they merely have photons travelling along sinusoidal trajectories. Fig. 1b illustrates how a youngster who had just studied photons characterises light's behaviour as it travels through a slit. Other students experimented with photons going up and down a sinusoidal route.



For slit width > λ: Geometrical optics applies: "The waves are still making it though the slit."

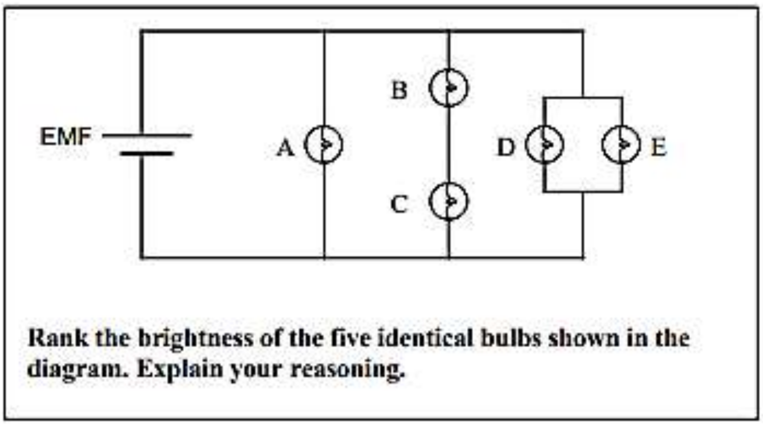
For slit width > λ: A diffraction pattern occurs: The magnetic part will not "be affected" but the electric part "will be affected … [the slit] knocks it out of whack."

Figure 1. Typical student descriptions of light passing through a narrow slit: (a) Diagram and explanation given by a student who just completed introductory calculus-based physics. (b) Diagram drawn by student who just studied the photon.

FROM CIRCUITS TO BAND DIAGRAMS

Instructors often presume that their students have a decent concept of conductivity when teaching introductory quantum mechanics, band diagrams, and the intriguing features of semiconductor devices. After all, what good is a MOSFET if pupils do not grasp the fundamentals of current and voltage? In this part, we will discuss some of the issues that many students have when studying current and voltage in an university physics class and how these difficulties might hinder students' grasp of more sophisticated conductivity models.

learning current and voltage



Rank the brightness of the five identical bulbs shown in the diagram. Explain your reasoning.

Figure 2. Part of an examination question given to introductory calculus-based physics students after they had finished studying dc circuits. Only 16% of the 94 students in the class gave the correct ranking (A=D=E>B=C).

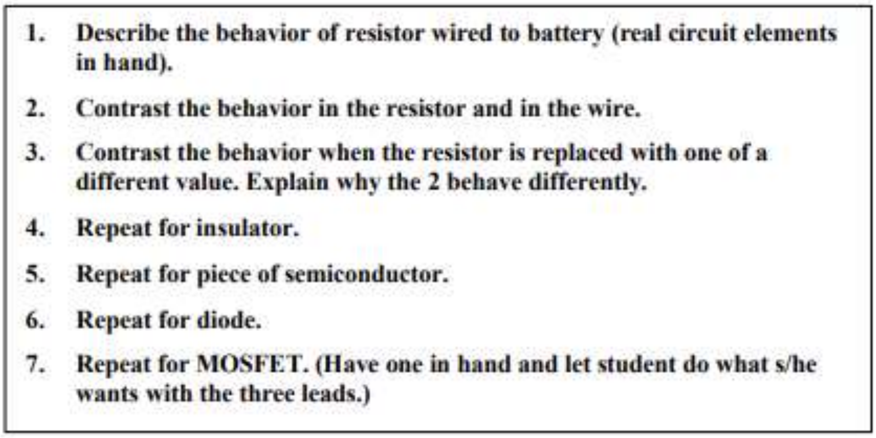
McDermott and Shaffer (1992) demonstrated the problems students face in college physics while studying current and voltage. They discovered that many students lack a conceptual knowledge of a full circuit, lack a model for current as a flow, and lack a functional comprehension of voltage. We replicated similar results at the University of Maryland in an introductory calculus-based physics class dominated by sophomore engineering majors (many of them in electrical engineering). For example, only 16% of students successfully answered the final test question presented in Fig. 2 after studying dc circuits, approximately equal resistance, Ohm's law, and Kirchoff's equations. The challenges encountered by students, such as current being "used up" in bulb B before it could be utilised in bulb C, were basically identical to those documented by McDermott & Shaffer.

STUDYING SEMICONDUCTOR PHYSICS

At certain institutions, faculty members are examining students' grasp of microscopic models of conductivity after their completion of numerous more advanced courses, including fundamental undergraduate electrical engineering. After instance, it is sometimes considered that students overcome their challenges by repeated exposure to the same ideas in more complex situations. We chose to conduct one-on-one interviews following the approach shown in Fig. 3. We believed that this was an appropriate selection of questions for this group of pupils. Regrettably, none of the about 12 students we have interviewed so far have a model for current that is capable of accounting for the distinctions between conductivity, insulators, and semiconductors. For instance, about half of the students defined conductivity in a manner comparable to the student shown in Fig. 4. When describing conduction in a wire, one student said that a "minimum voltage" is required for any current to flow. (Note the phenomenological similarities between this and the photoelectric effect, which removes electrons from metals.) Unfortunately, current "kicks in" initially when a finite voltage is present, and there is no way to account for semiconductor physics in this model. Other pupils define conductivity disparities in terms of the size of the physical confinements that electrons must traverse at the atomic level. Few students questioned mentioned the drift speed mechanism, charge carrier concentration, or band diagram. This is especially concerning because many of them had spent considerable time studying the operation of diodes and transistors.

RESEARCH BASED CURRICULUM DEVELOPMENT

At the beginning level, research in physics education has aided in the creation of curricula and teaching methodologies, with positive results (e.g. Redish & Steinberg, 1999). For instance, requiring students to work through materials in which they can construct their own models, reinforce their conceptual understanding, and practise their reasoning skills has resulted in significant improvements in teaching in all physical optics (Ambrose et al., 1999) & simple circuits (Shaffer & McDermott, 1992). We are currently using this similar concept to the development of quantum materials. Our first findings are positive (e.g., Steinberg & Oberem, 1999).



1. Describe the behavior of resistor wired to battery (real circuit elements in hand).
2. Contrast the behavior in the resistor and in the wire.
3. Contrast the behavior when the resistor is replaced with one of a different value. Explain why the 2 behave differently.
4. Repeat for insulator.
5. Repeat for piece of semiconductor.
6. Repeat for diode.
7. Repeat for MOSFET. (Have one in hand and let student do what s/he wants with the three leads.)

Figure 3. Brief outline of interview protocol administered to students who had finished introductory calculus-based physics and at least one more advanced course in physics or electrical engineering. In qbout a dozen 45-minute interview, we often have not gotten past question 3 and have never gotten to question 6.

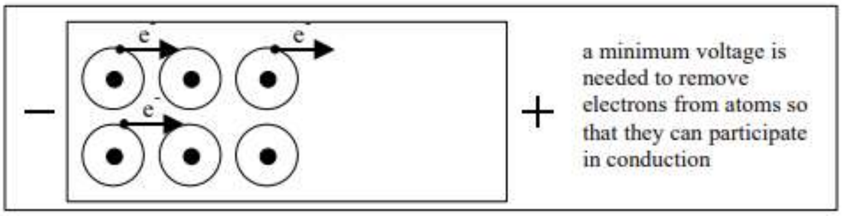


Figure 4. Typical student explanation about conductivity in the wire. This student explains that at some "minimum voltage" the electron is removed from the atom and contributes to conduction. The student was notable to contrast the behavior of conductors, insulators, and semiconductors using his model.

CONCLUSIONS

Clearly, there are very compelling reasons to educate a large audience about quantum physics. The objective, however, is not to reduce this teaching to a vocabulary lesson or a maths exercise for the kids. Rather than that, it is feasible to make quantum mechanics training considerably more relevant. We have attempted to demonstrate in this study how identifying students' comprehension of key classical notions and how they gain an understanding of quantum topics may help guide education.

REFERENCES

1. Ambrose, B.S., Shaffer, P.S., Steinberg, R.N., & McDermott, L.C. (1999). An investigation of student understanding of single-slit diffraction and double-slit interference. American Journal of Physics 67, 146-155.
2. McDermott, L.C., & Shaffer, P.S., "Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding," American Journal of Physics
3. 60, 994-1003 (1992); erratum, ibid. 61, 81 (1993).
4. Redish, E.F. & Steinberg, R.N. (1999). Teaching physics: Figuring out what works.
5. Physics Today, 52(1), 24-30.
6. Shaffer, P.S., & McDermott, L.C., "Research as a guide for curriculum development: An example from introductory electricity. Part II: Design of an instructional strategy," American Journal of Physics 60, 1003-1013 (1992).
7. Steinberg, R.N., Oberem, G.E., & McDermott, L.C. (1996). Development of a computer-based tutorial on the photoelectric effect. American Journal of Physics, 64, 1370-1379.
8. Steinberg, R.N., & Oberem, G.E., (1999). Research based instructional software in modern physics. To be published.