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Quantum Concepts for High School and College

Jessica Rosenberg, Nancy Holincheck, Ben Dreyfus

QSEC

Quantum Science & Engineering Center

Who does Industry Expect to Hire?

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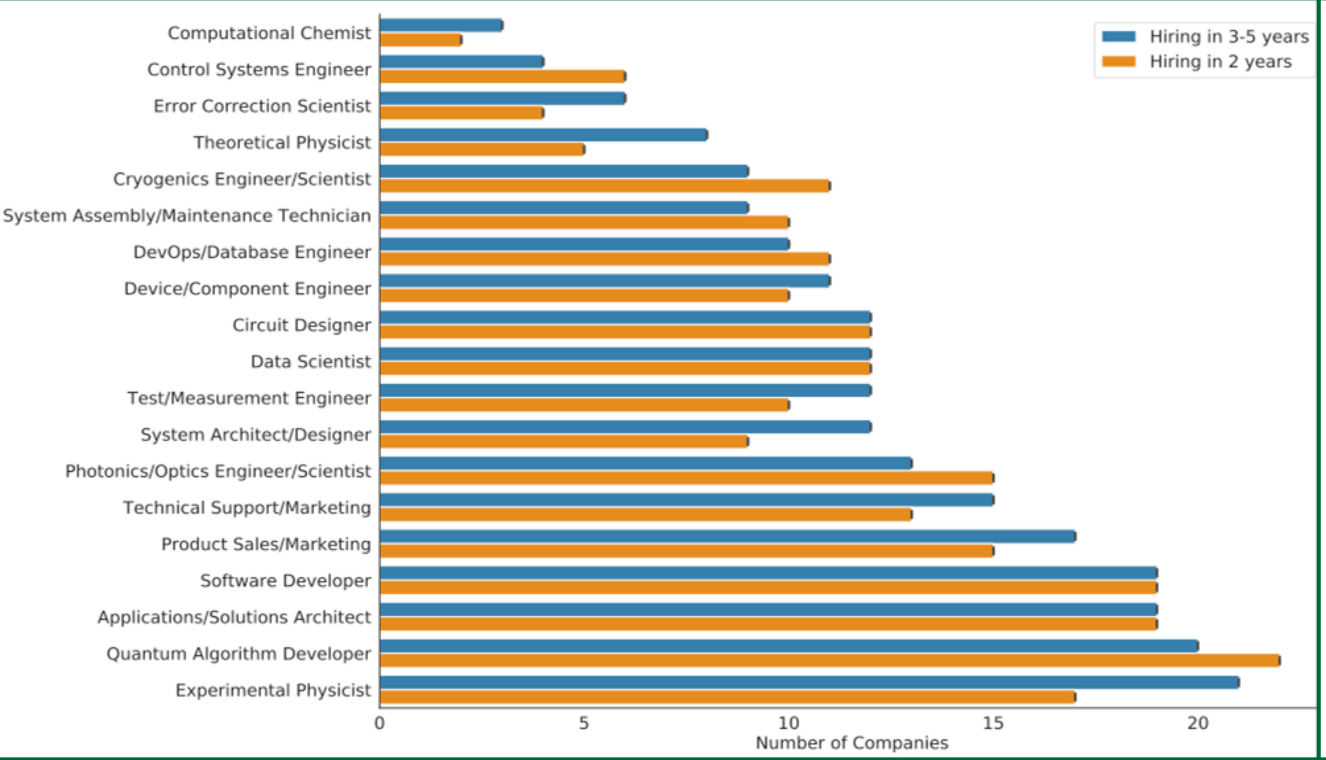

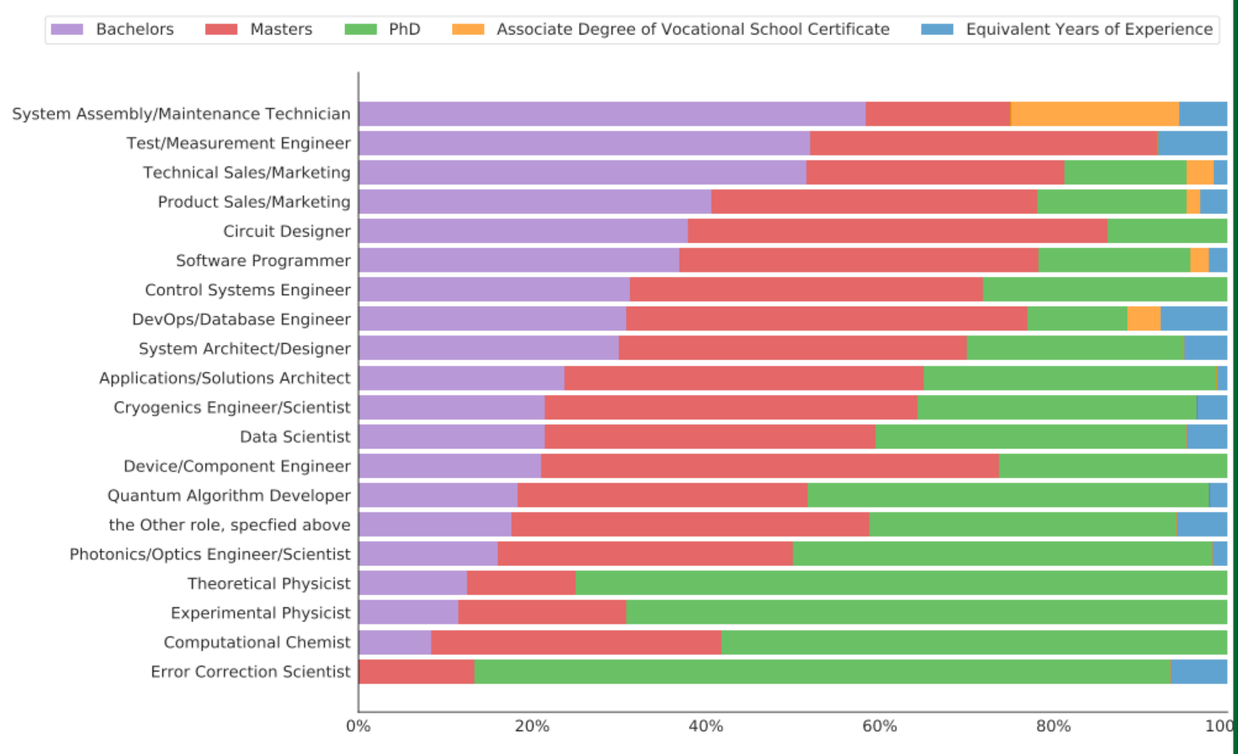

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Hughes et al 2021, http://arxiv.org/abs/2109.03601

Proficiency level	Area (I)	Area (II)	Area (III)
A1 Awareness	**Reproduce** basic q. concepts & terminology	**Reproduce** basic functionalities of a QT facet	**Recognize** potential of QT
A2 Literacy	**Describe** fundamental q. concepts	**Perform** basic tasks on a QT facet	**Identify** value of QT
B1 Utilization	**Apply** quantum methods to problems	**Modify/apply** a QT facet	**Classify** available QT applications/approaches
B2 Investigation	**Analyze** problems with quantum	**Analyze** performance, improve QT	**Analyze** QT market and opportunities
C1 Specialization	**Refine** and extend quantum methods	**Conceptualize** integrated QT systems	**Advise** on QT appl. selection or strategies
C2 Innovation	**Develop** innovative solutions	**Develop** new QT facet	**Develop** and assess QT (product) strategies

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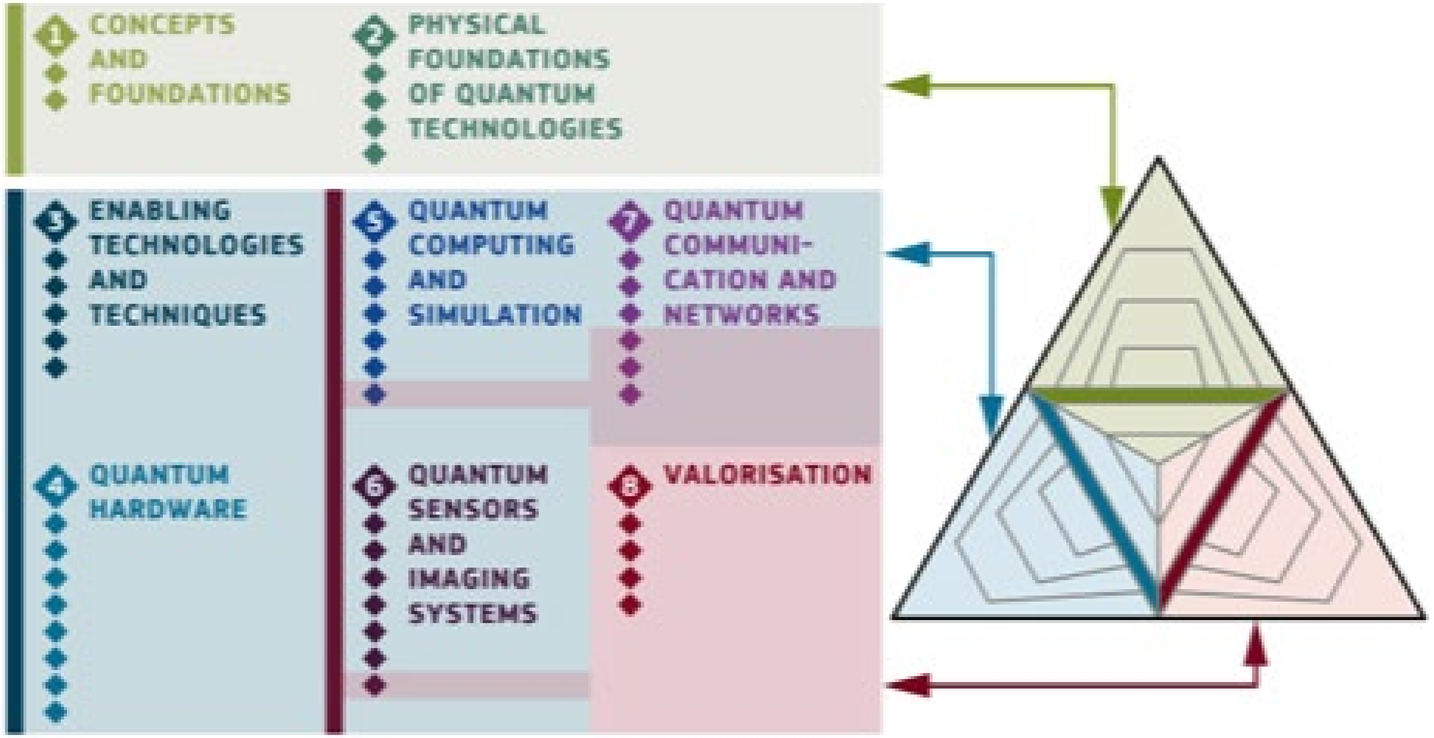
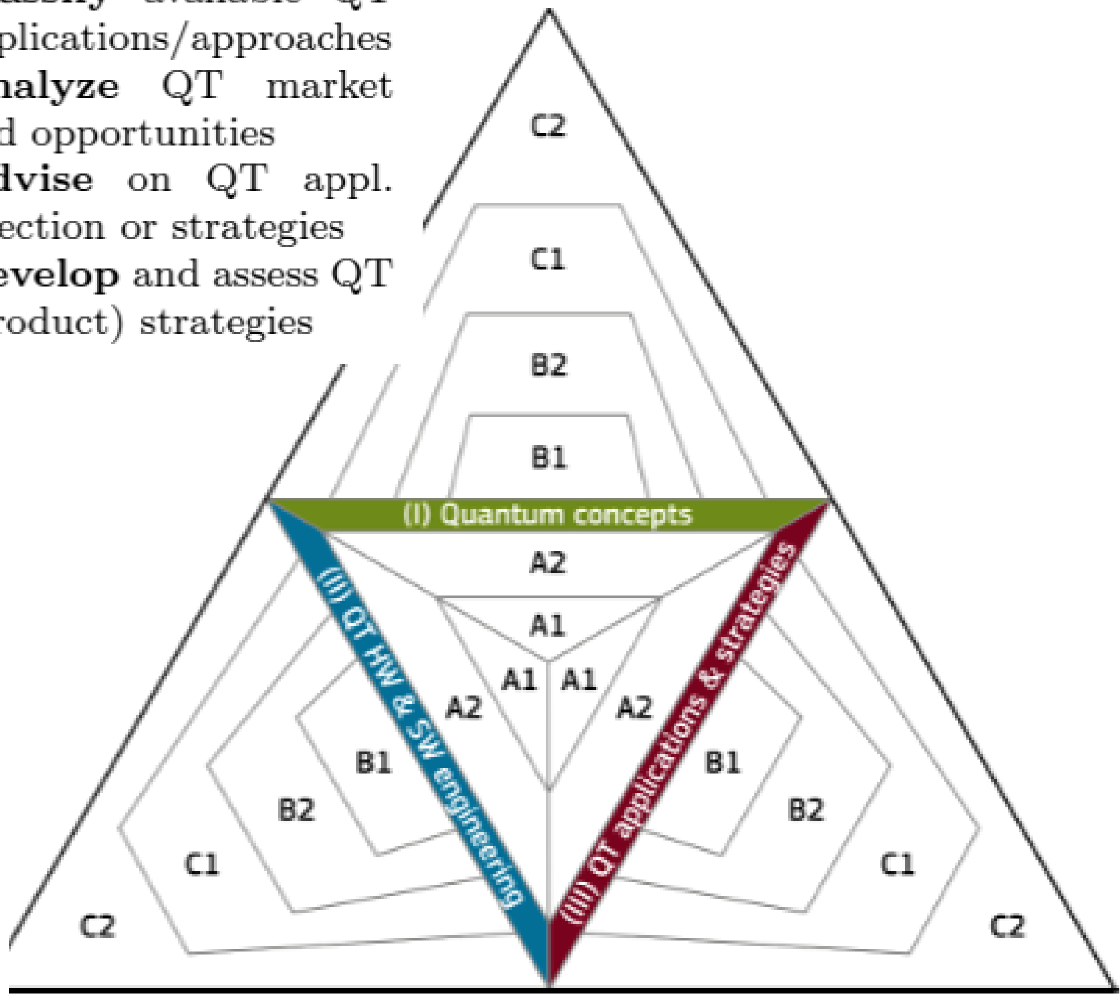
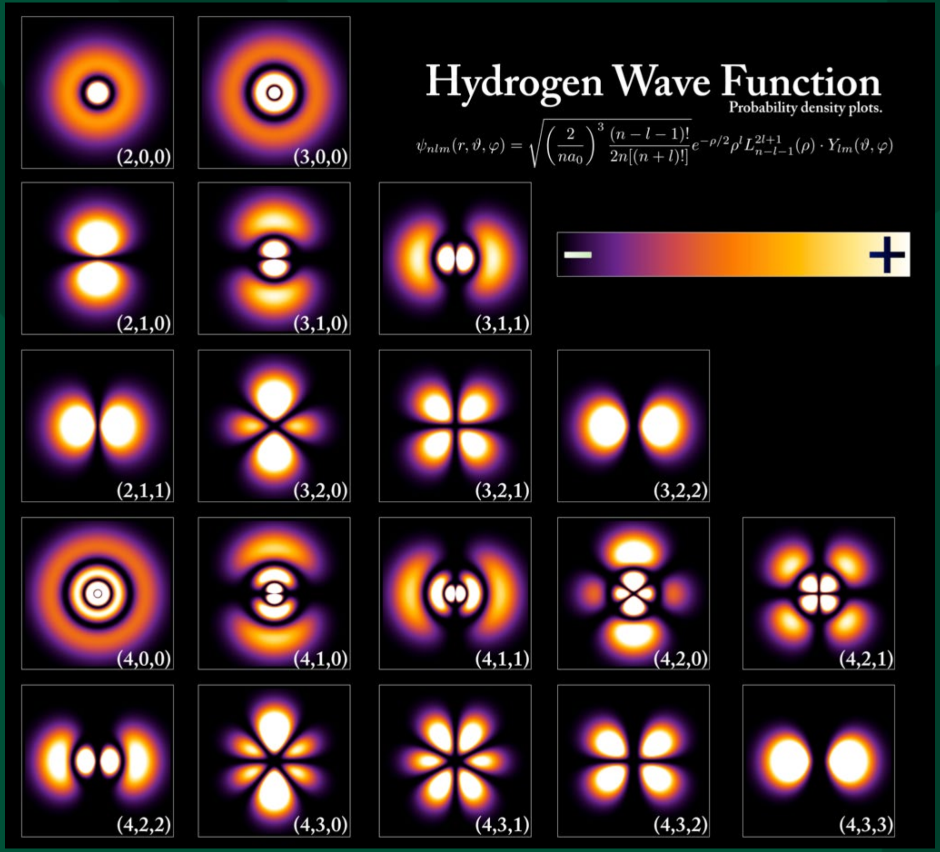


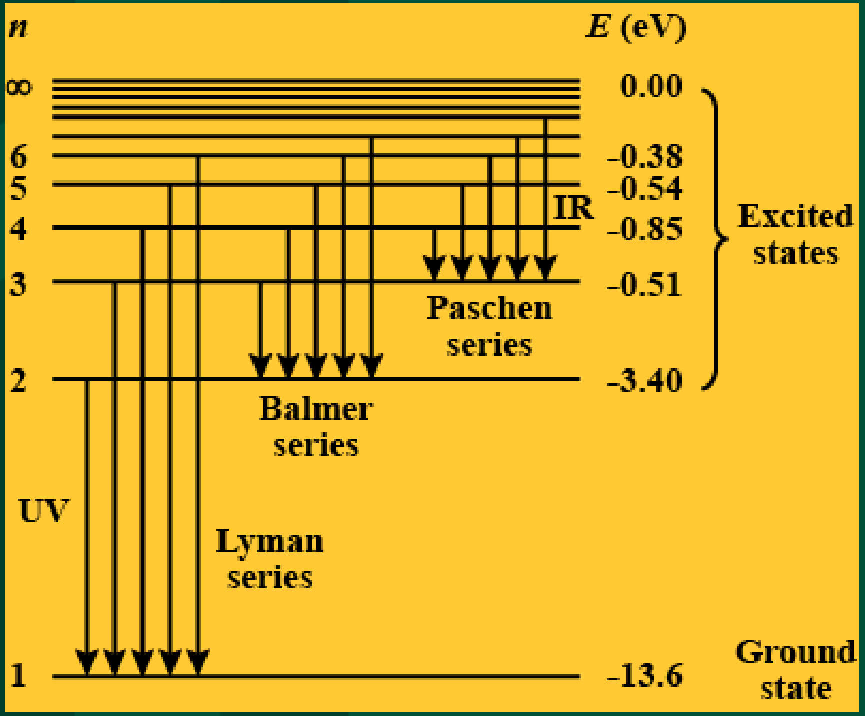


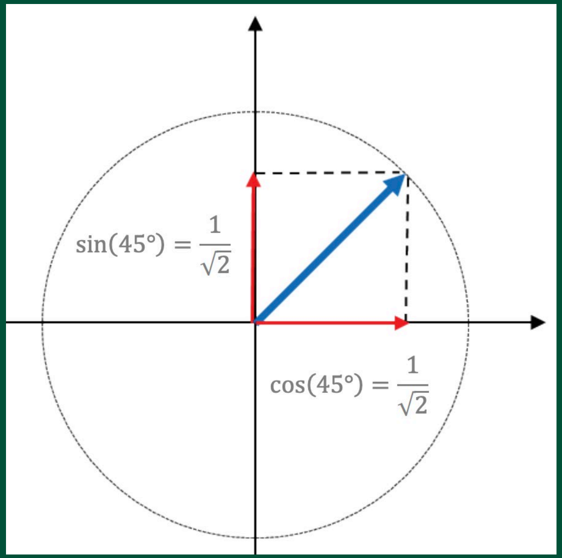
Greinert et al. 2024, arXiv.2410.07692

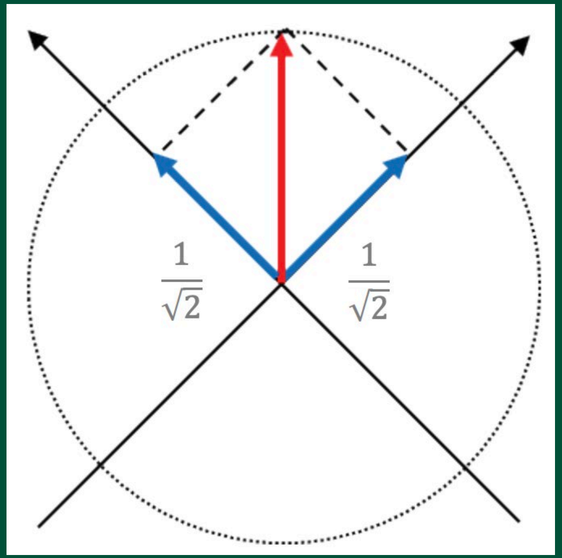
Quantum State:

A quantum state is a mathematical representation of a physical system, such as an atom, and provides the basis for processing quantum information.









Quantum Professional Learning and Curriculum Development for Secondary Teachers

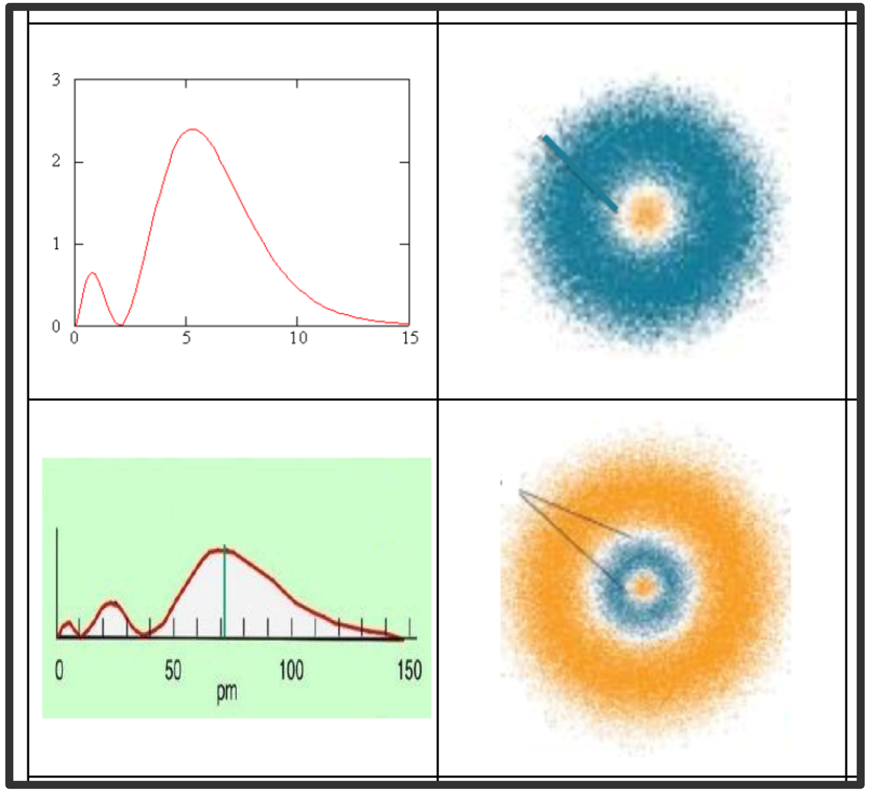
K-12 Teachers: Quantum in Your Classroom

- Recruited 14 chemistry, physics, and computer science computer science teachers from across the DC-MD-VA region
- Teachers engaged in professional learning around quantum concepts and applications
- Teachers worked in disciplinary groups to develop curricular resources to use in their teaching

Christina Cameron

Bishop Ireton HS

Quantum in Chemistry



Lesson Plan
Find the electron game

George Mason University's Quantum Science & Engineering Center's K-12 Quantum Initiative

I. LEARNING OBJECTIVES

- SWBAT state that orbitals are 90% accurate with the location of an electron
- SWBAT relate quantum numbers with the types and shapes of orbitals of an atom.
- SWBAT explain families of elements, and the variation of orbital size and geometry will be related to periodic properties.
- SWBAT understands that orbitals are not orbits.

II. BACKGROUND INFO FOR TEACHERS (teacher notes)

Focus of the Lesson

Students will use their understanding of quantum numbers, orbitals and subshells to predict where the electron(ball) is hidden in the grid.

Quantum concepts

- The quantum number (n) relates to the energy level of the atomic (row of the periodic table)

Connect with the curriculum

Students explore and are able to draw the BOHR model for various elements, by exploring how the quantum model (and numbers) relate, they will be able to extend their thinking into producing and understanding how quantum models are related.

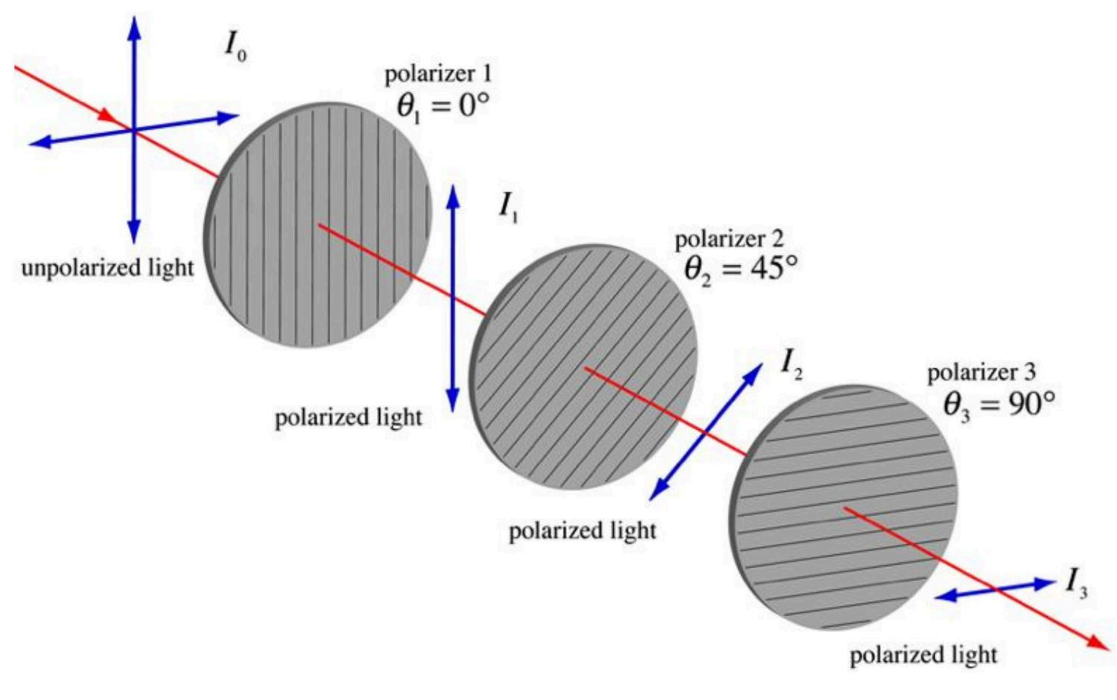
III. CONNECT TO STANDARDS

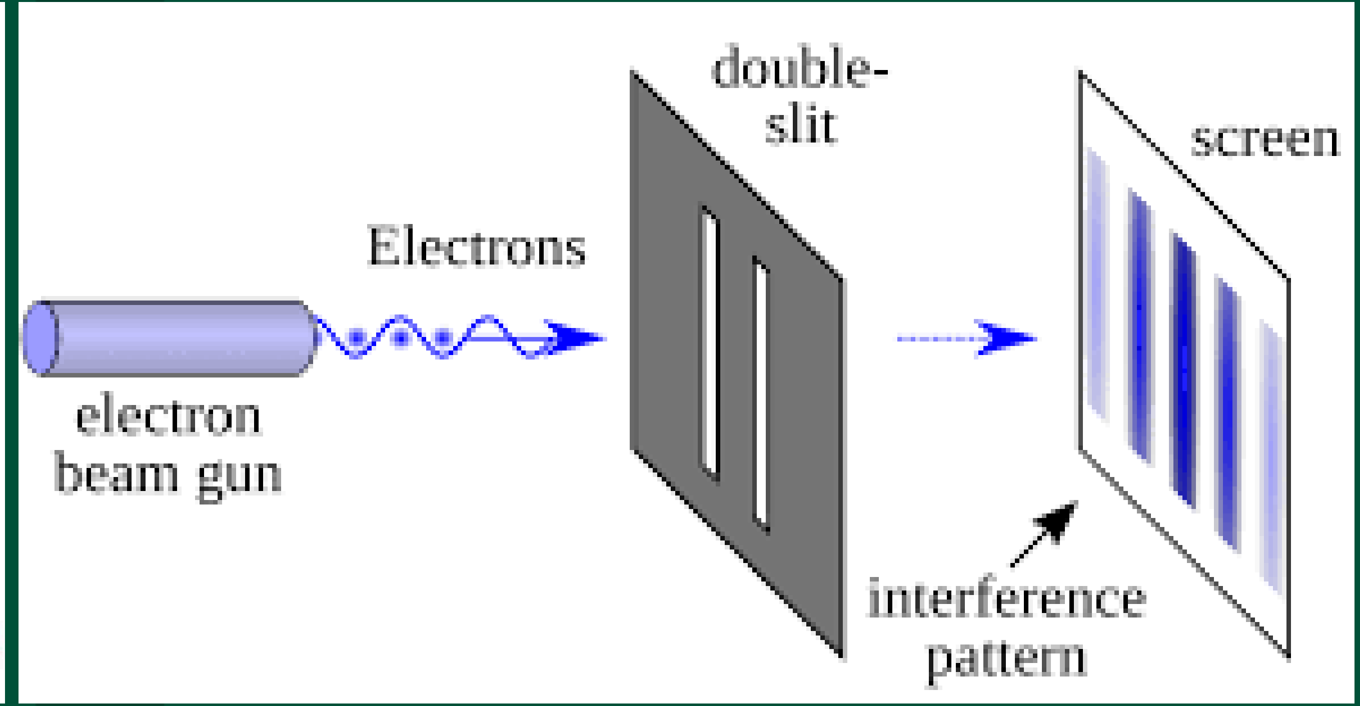
HS-PS1-1

Matter and Its Interactions. Students who demonstrate understanding can: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

Quantum Measurement

How do we know… quantum edition





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Let's play another game!

Gomoku / Five-in-a-Row - Quantum Entanglement Edition

Object of the Game

- Be the first player to achieve five stones of one's own color in a row, wherein said row may be vertical, horizontal, or diagonal.
- For every five stones placed by a single player, the player must entangle at least twice.

Challenge:

- Combine both versions of the game! All rules apply! Each turn will need both a decision about measurement and a decision about entanglement. Good luck!

Photoelectric effect: Demonstration

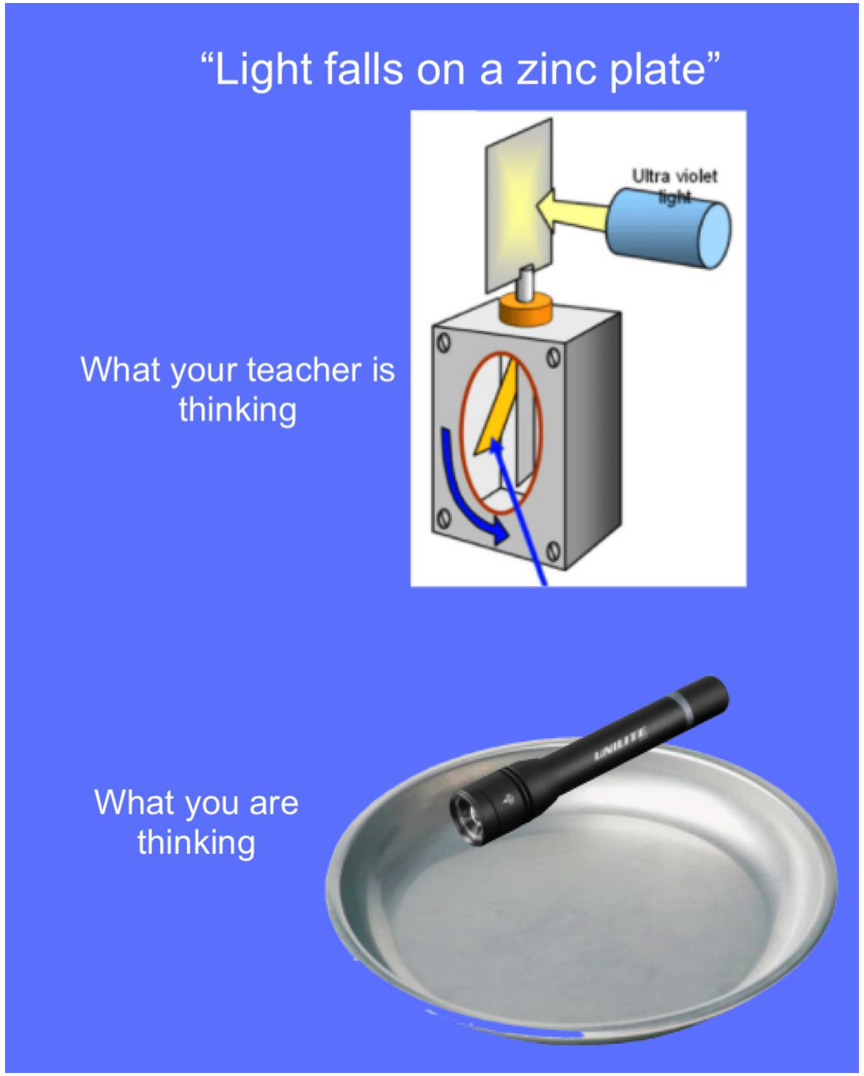
Guiding question: What is (are) the factor(s) affecting the photoelectric effect?

Demonstration:

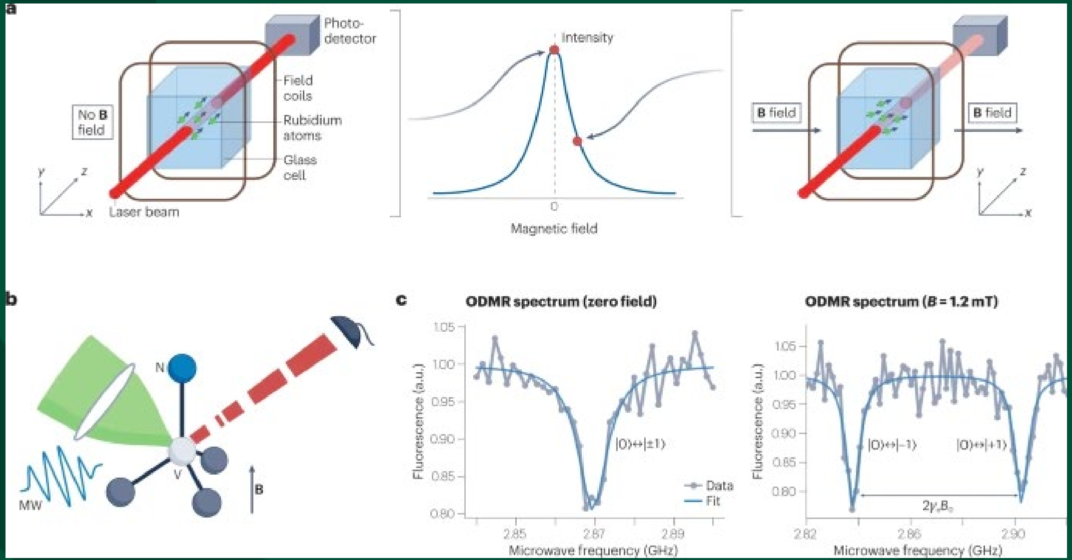
Different types of light will be used on the top plate of a negatively charged electroscope:

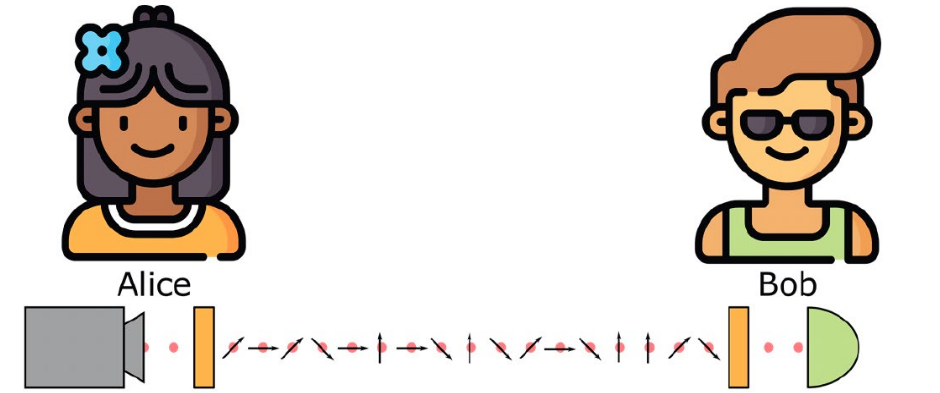
White light (with different intensities), UV-A light (Black light), UV-C light (germicide light)

For each sources of light, observe the motion of the arm of the charged electroscope, if any.

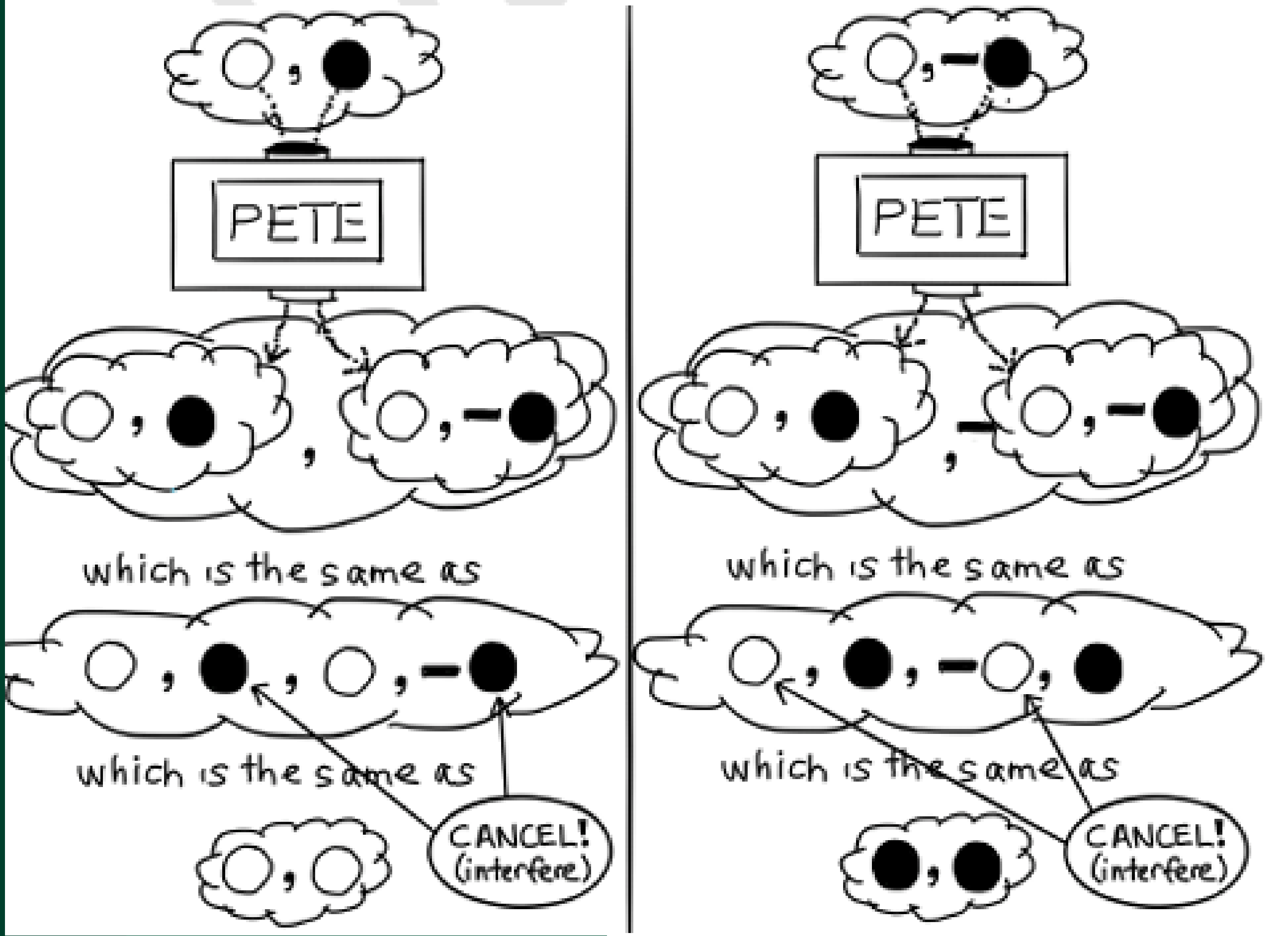


Quantum Applications: Sensing, Communications, Computing





Institute for Quantum Computing, U. Waterloo

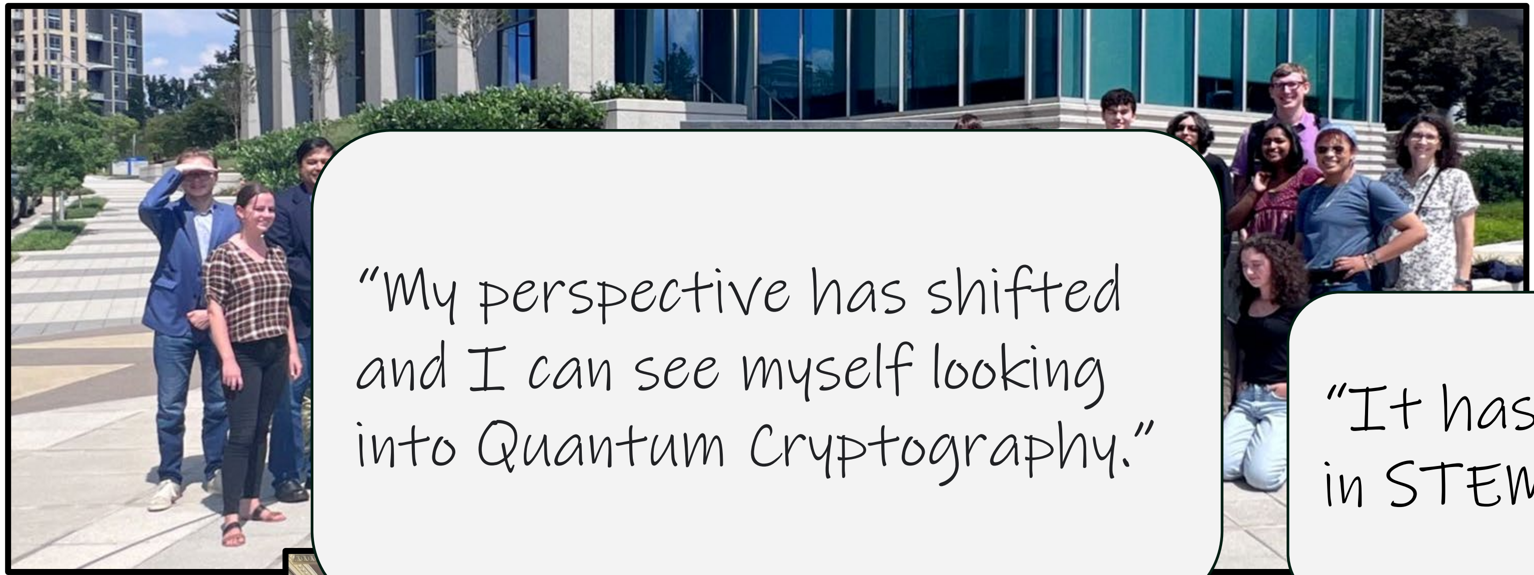


Q is for Quantum, Terry Rudolph

Quantum Immersion for High School Students

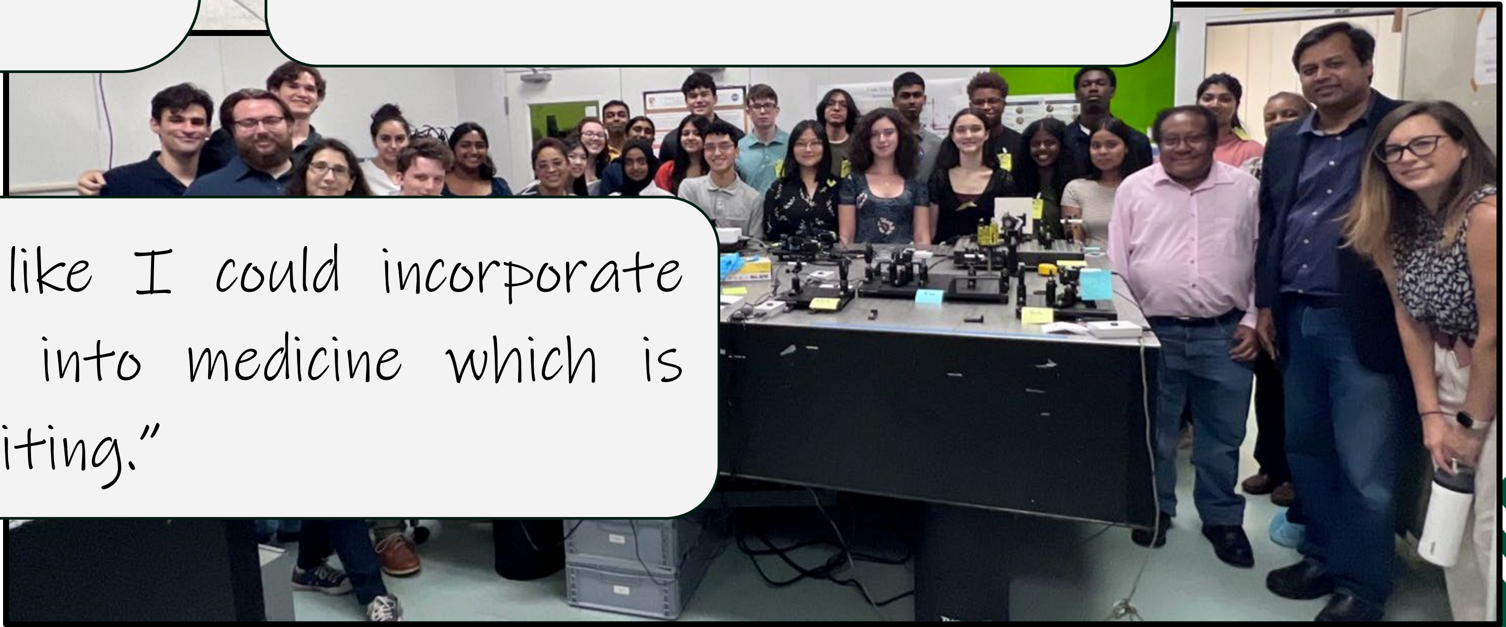
2 weeks online learning key concepts and about careers and applications

1 week immersive career-focused in-person



"My perspective has shifted and I can see myself looking into Quantum Cryptography."

"It has deepened my interest in STEM"



"I feel like I could incorporate quantum into medicine which is really exciting."

Why do we care... quantum edition

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Attempts at Quantum Supremacy in the Analysis of Particle Systems

Detection of Dark Matter with Quantum Sensing

Improving Awareness of Space Debris through Quantum Sensing and Quantum Computing

Quantum Internet and Future Uses

QRYPT HAVEN: A Post-Quantum Cryptography Company

Quantum Teleportation and its Applications in Communication

Quantum Corners: Improving Emergency Response with Smart Traffic Management and Quantum Sensors

Personalizing Cancer Treatment with Quantum Machine Learning

Can Quantum Sensor Solve Patient with PTSD in Sleep?

Quantum Testbeds for Machine Learning Algorithms

Pollution in our Oceans: Applications of Quantum Sensing

Sustainable Climate: Taking Action with Renewable Energy

Conclusions

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- Students need to understand how we know about quantum
- For the most part, a first discussion of the technologies does not require a lot of math
- Students need to see how quantum science is being applied to communications, sensing, and computing
- Students can think about the applications of these technologies to important problems
- Digging into a question that is interesting to them gets students more engaged and interested

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