# PhysicsQuest [2025]: Bits v Qubits

Date - Revised:

| Title: Bits v Quibits**Subtitle:** The advantages to quantum computing - an Augment Reality approach Developed by - Michele McColgan - Siena College | | | |
| --- | --- | --- | --- |
| **Total Time:** 3 class periods  **Audience:** High School Physics and Computer Science Teachers  **Education Level:** Grades 10-12 | | | |
| **Content Area:** Quantum Computing  **Educational topic:**  **Key Question:** What are the properties of qubits? How do they compare to classical bits? How are qubits used in quantum computers to store and transmit data?  **Objectives:**  **Module 1:** I can understand and describe the similarities and differences between bits and qubits and how they are used to store numbers and data.  **Module 2:** I can understand the differences in electron spin  **Module 3:** I can understand how gates can be used to change the state of a qubit and prepare it for use in algorithms. | | | |
| Quantum computing is not in the Next Generation Science Standards, however after the passage of the US National Quantum Initiative Act in December 2018 [1], the National Science Foundation and the White House Office of Science and Technology Policy (WHOSTP) assembled an interagency working group who designed the QIS K-12 Key Concepts Framework, an initial set of expectations and learning goals, which will be useful to curriculum developers and teachers seeking to develop physics lessons and activities for teaching QIS K-12 Key Concepts.  [**QIS Key Concepts**](https://q12education.org/wp-content/uploads/2023/12/MS-QIS-Key-Concepts-FINAL-12-7-2023.pdf)**:**  High School Physics   * 1. Quantum information science (QIS) exploits quantum principles to transform how information is acquired, encoded, manipulated, and applied. Quantum information science encompasses quantum computing, quantum communication, and quantum sensing, and spurs other advances in science and technology. * 4. The quantum bit, or qubit, is the fundamental unit of quantum information, and is encoded in a physical system, such as polarization states of light, energy states of an atom, or spin states of an electron. * 7. Quantum computers, which use qubits and quantum operations, will solve certain complex computational problems more efficiently than classical computers.   High School Computer Science:  See QIS K-12 CS Key Concepts for CS Classes [here](https://q12education.org/wp-content/uploads/2025/01/Jan2025-v2-Key-Concepts-for-CS-Classes.pdf). | | | |
| **Materials** | * Smartphone * Copy of Merge Cube [printout](https://mergecube.com/paper-pdf) (teacher must photocopy and print on cardstock (if possible) for each student - original found in kit) * MARVLS: Quantum Computing App   + To install: Scan QR Code below   + Follow prompts to install.     Apple App Store Google Play Store | | |
| **Overview:**  View augmented reality models of quantum computing concepts through your phone. You'll need a Merge Cube (link included to download). Click on a button to navigate to different topics. Tap the camera icon and point your camera towards the Merge Cube to visualize and interact with our MARVLS. Topics include bits, qubits, superposition, entanglement, electron spin, and logic gates. | | | |
| **Teacher Background:**  Physics teachers, computer science teachers, and physical science teachers have the background to guide their students through these lessons. The lessons are designed so that students can find the answers to the questions in the lessons by recording what they see when they use the App, interact with the Merge cube, and recording what they observe. Teachers can refer to the answer key to guide students through the lessons. An answer key is provided. | | | |
| **Key Terms (used or presented after the activities - see Foreword for details)** | | | |
| **Teacher’s Guide** | | | |
| **Objectives:**  – \*   * Define bits and show students how numbers are represented in binary. * Define qubits and show students how qubits are similar to bits and how they are different. * Describe a qubit’s superpower - superposition. Introduce the Bloch sphere and how it is used to visualize superposition. * Describe entanglement and how qubits are entangled. * Describe how and why using qubits increases computational power. * Show students how quantum gates are used to make calculations. * Show students how probing electrons with lasers of a special frequency changes the state of a qubit from zero to one, one to zero, and a superposition state. * Help students create qubit circuits starting with one qubit and then extending to circuits with two qubits.   \*It is important to understand that student goals may be different and unique from the lesson goals. We recommend leaving room for students to set their own goals for each activity. | | | |
| **Before the Experiment:** | | 1. We invite you to watch a [brief video demonstration](https://www.youtube.com/watch?v=V4m4V4MLxX8&list=PLgxD9DiwxLGp_3vj3biSPG88gIyU6Vzpz&index=12) of the developer conducting the experiment you’ll be facilitating with your students. 2. Consider exploring XXX’s narrative using the lessons ideas detailed on the Introduction found in your materials kits. 3. Print a Merge cube for each student or student group 4. Have students download the MARVLS app from the App Store or Google Play Store using the QR codes above. 5. Ask students what they know or think they know about    1. classical computers and how they work    2. quantum computers and how they work    3. The differences between the two | |
| **Setting Up** | | 1. Construct the Merge cube 2. Download the student guide to your Google Classroom, LMS, learning platform or print the student activity guide for each student or student group. They will follow the instructions using the MARVLS app and their Merge cube to complete the activity and answer questions towards understanding. | |
| **During the Experiment** | | **-Collecting Data**   1. Students will follow and complete the student guide using the MARVLS app and the Merge cube.   **-Teacher Tips:**   1. Suggested [STEP UP Everyday Actions](https://engage.aps.org/stepup/curriculum/everyday) to incorporate into activity  * When pairing students, try to have male/female partners and invite female students to share their ideas first * As you put students into groups, consider having female or minority students take the leadership role. * Take note of female participation. If they seem to be taking direction and following along, elevate their voice by asking them a question about their experiment.  1. Consider using white boards so students have time to work through their ideas and brainstorms before saying them out loud. 2. As students experiment, roam around the room to listen in on discussion and notice experiment techniques. If needed, stop the class and call over to a certain group that has hit on an important concept. 3. \*\*\*Consider using the [RIP protocol](https://drive.google.com/file/d/1XPZvBRBMgUD9U3cvrRO9_-I7yKfA5vlk/view?usp=sharing) (Research, Instruct, Plan) for lab group visits and conferring. 4. \*\*\*Consider [culturally responsive tools and strategies](https://www.nciea.org/blog/a-culturally-responsive-classroom-assessment-framework/) and/or [open ended reflection questions](https://www.cde.state.co.us/standardsandinstruction/es-student-reflections-mc) to help push student thinking, evidence tracking, and connections to their lives. Look for \*\*\* below to find suggested places to add. | |
| **Conclusion** | | 1. Students will answer all questions in student guide 2. Teacher answer key found [here](https://drive.google.com/file/d/1JgCEnFF60NP7PQj0mPqbo2FlNIbOCHqg/view?usp=sharing). 3. Ask students to reflect on their pre-activity answers and add, change, amend answers to the question, What do they know about    1. classical computers and how they work    2. quantum computers and how they work    3. The differences between the two | |
| **Student’s Guide** | | | |
| [Download or print](https://drive.google.com/file/d/1jVGzD4OU85N7N1w6sV66Qmkm_coUrt-N/view?usp=sharing) the student activity guide | | | |
| **Additional Resources:** | | | |
| **Assessment/Extension activities\*\* (optional to extend thinking after the lesson):**   * Real world connections -   + Sign up for [Physicists To-Go](https://www.aps.org/programs/outreach/physiciststogo.cfm) to have a scientist talk to your students. * Suggestions for drawing, illustrating, presenting content in creative ways * Engineering and design challenges connected to the content   + if engineering challenges have a time constraint, students are allowed to keep iterating and developing their ideas outside of class time and continue to participate in the challenge at a later date   \*\*Real world situations/connections can be used as is, or changed to better fit a student’s own community and cultural context. | | | |