Quantum Computing: Understanding Its Learning Path And Career Choices

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Intro

- IBM Researcher Jay Gambetta observes that the interest in quantum computing is coupled by a broadening of entry paths and R&D, which has sparked an interest in the field. However, graduates in India often struggle to understand what the requisite amount of knowledge is required to make a career in this buzzing field.
- According to Debdeep Ghosal a PhD researcher at the University of Basel, one needs to understand that quantum computers, as opposed to digital computers, are based on transistors and that they use the principle of superposition of states to encode the quantum bits instead of binary digits. In a nutshell, quantum mechanics and computational physics along with the knowledge of algorithms like integer factorisation are very helpful in this field.

Here's How MIT Breaks It Down - Here is a list of prerequisites before diving into quantum computing:

- **Physics**: In Physics, it is highly recommended to beef up the basics about quantum mechanics and at a more advanced level, learn about the quantum information overlap with AMO, condensed matter and high energy.
- **Maths**: In Maths, beef up knowledge of linear algebra and probability. One should also learn group and representation theory, random matrix theory and functional analysis.
- **Computer Science:** In computer science, topics such as information theory, machine learning, error-correcting codes, optimisation and complexity are important.
- Must
  1. **Basic quantum mechanics**
  2. **Linear algebra**
  3. **Basic group theory (and generally basic abstract algebra)**
  4. **Basic probability and stochastic processes**
  5. **Fourier transforms**
  6. **And basic algorithms and analysis of algorithms**
- Students interested in learning about quantum information theory — a subtopic, prior knowledge of probability theory and classical information theory is a must. According to one Redditor, knowledge of basic quantum information processing, quantum noise modelling and quantum error correcting codes is also a must.

A Mix And Match Combination Of These Skills Is Ideal - Online Learning Resources

- There are three different majors or specialisations which can lead to a career in quantum computing. For example, a Physics major can be particularly helpful if he/she is interested in building a quantum computer. A Physics major with theoretical Computer Science focus can help one in designing algorithms for a quantum computer. If one is interested in Quantum Mechanics, then a major in computer science and a minor in Maths with a focus on abstract linear algebra is required to build a foundation in quantum computing. From the above, we can ascertain that knowledge of computational physics/science and quantum mechanics is crucial for this field.
- We list down the most recommended list of online resources for:
- Written material

1. A Modern Physics course by Michael Fowler, University of Virginia.
2. Also check out Quantum Mechanics PDF by Richard Fitzpatrick, University of Texas
3. Quantum Physics PDF from a UCSD course
4. In addition to this, there is Quantum Computation Lecture Notes & Homework Assignments, 2006
5. Check out older John Preskill's lecture notes on Quantum Computation
6. One of the most highly recommended books on quantum computing — Quantum Computation and Quantum Information by Nielsen and Chuang aimed at students who do not have prior experience with quantum mechanics or computer science and introduces them to quantum information science.

Job roles in Quantum Computing: & Conclusion

- Gambetta, an IBM researcher lists down some of the job roles and entry paths for quantum enthusiasts. The ongoing research in quantum computing, especially in companies like IBM, Microsoft and Google have opened clear career pathways for developers, engineers and researchers. He lists down some of the top job roles that students can explore in quantum computing. Among them, the most popular ones are Quantum Computer Architects, Quantum Algorithms Researchers and Quantum Software Developers.

- **Conclusion**
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The Hitchhiking Cat's Guide to Getting a Job in Quantum Computing– https://medium.com/qiskit/the-hitchhiking-cats-guide-to-getting-a-job-in-quantum-computing-da7e3bb9ff64

- While traveling around to give talks about quantum computing, I've noticed two things — the enthusiasm of our growing community, and the frequency of the following question: "I don't know much about quantum physics, but can I get into quantum computing?" The answer I give today is very different from what it was several years ago. When I finished my PhD in theoretical quantum physics, the path to working in quantum computing was narrow, but now that single path has broadened and branched into a set of many entry paths. These paths involve specialties that include various types of researchers, architects, theorists, developers, designers, and community builders.
- For me, quantum computing has evolved from exploring the fundamental science of quantum information to, more recently, showing that it's possible to build a quantum computer and make it available for free via the cloud. We refer to this as the *transition from quantum science to quantum ready*. One shouldn't take this to mean that we have now entered an *engineering phase*. Nor does this mean that there is no science left to do (quite the contrary is true!) Rather, there are now many reasonably defined parts of the system that need a rigorous focus to come together.
- This broadening of entry paths into quantum computing, combined with the transition from *quantum science*into *quantum ready*, opens the door for lots of opportunities to contribute to the future of quantum computing. Here are some ways to get involved:

Get involved in the open source community (and become known!)

- One great way to get on the radar of hiring managers in various quantum groups at IBM is to contribute to Qiskit Terra and Qiskit Aqua:
- ● Qiskit Terra is the code foundation for composing quantum programs at the level of circuits and pulses.
- ● Qiskit Aqua contains libraries for building algorithms and applications.
- There are many different ways to help out, including implementing quantum algorithms, maintaining vertical applications (chemistry, optimization, machine learning, finance), making performance improvements, and improving core infrastructure. Some very quick but valuable contributions include improving documentation, and writing blog posts about getting started with Qiskit. These will help the community and build your reputation. We have plans in the works to better reward our community members for their contributions, so stay tuned!
- The best way to start is to go to https://github.com/Qiskit/, pick a repository, and pick a “Good first contribution” label in the issues. Jump right in and start asking questions… we are happy to help.

Apply for an opportunity in a quantum group at IBM

- A quantum computer can only emerge from a family of *researchers*, *engineers*, *developers*, *designers* and*builders in the community* united by a challenge that is, at its very core, a fundamental part of harnessing nature. These roles are many and each is interconnected with and vital to the others. Diversity of thought and experience will be equally important, resulting in opportunities for internships and professionals with varying years of experience. Exciting roles certainly abound at IBM in quantum computing:
- ● **Superconducting Qubit Researchers** study the fundamental element: the *qubit*. At IBM, we work on superconducting qubits. Although remarkable progress has been made in coherence and thermalization, these metrics must continue to improve. As systems grow ever larger, we need to engineer extensible components for the full quantum hardware system. Superconducting qubit processor improvement is primarily driven by physicists with expertise in condensed matter physics working in close collaboration with quantum engineers. The physical processors themselves are made by researchers and technicians with backgrounds in device design and layout, micro-fabrication, and process integration, with a fair bit of transferable knowledge from semiconducting chip integration.
- ● **Quantum Control Researchers** study the problem of making high fidelity quantum gates. Qubits operate chorally, as part of bigger systems, and the intricacies of their interactions make precisely isolating ideal qubit operations extremely challenging. With superconducting qubits, one typically uses carefully shaped microwave pulses. A researcher in this area needs an understanding of optimal control, Hamiltonian modeling, dynamical decoupling and microwave hardware expertise. The latter expertise is required for conditioning and processing the classical microwave signals used to control and readout the superconducting qubit processor.

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- ● **Quantum Error Correction Researchers** study codes and protocols for reliable information storage, processing, and transmission of quantum information. One of the central problems is to devise efficient methods for computing in the presence of realistic rates of control errors, decoherence, and other noise and imperfections. These fault-tolerant quantum computing protocols influence the long-term design and architecture of quantum computers.
- ● **Quantum Computer Architects** help design the software stack that enables near-term explorations and scientific experiments with quantum computers. They define the abstraction layers for the different pieces of software, and design an overall system for efficiency and scalability. This includes optimizing quantum programs, defining user interfaces, and benchmarking an evolving software framework. They also define the connections between classical systems and the new quantum systems.
- ● **Quantum Complexity Theorists** study the fundamental strengths and limitations of quantum computing as a model of computation. Complexity theorists are interested in precise classes of problems that can be solved efficiently, and classes of problems that are unlikely to ever have efficient solutions. One recent direction is to understand limited computing models inspired by near-term devices, such as computations that are restricted to circuits with shallow depth.
- ● **Quantum Algorithms Researchers** explore computational problems that can be solved more efficiently by harnessing quantum effects such as quantum randomness and entanglement. They develop basic subroutines for quantum programs and identify new application areas for quantum computers. Of particular interest are polynomial-time quantum algorithms that are believed to be the most powerful form of computation permitted by the laws of physics. An ideal quantum algorithms researcher will therefore help us design and implement new quantum algorithms and advance the research on existing algorithms. The researcher will also collaborate with our industrial partners to address domain-specific problems in a growing number of disciplines.

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- ● **Quantum Cryogenic Engineers** study and develop the tools for keeping our systems cold. The infrastructure for a quantum computing system is very different from traditional mainframes and other classical computation hardware. In the case of superconducting qubits, this includes low-temperature (~15mK) physics know-how for cryogenic dilution refrigerator operation. The engineer will have experience with thermometry techniques and low-temperature engineering/thermalization and familiarity with thermal modeling.
- ● **Quantum Microwave Engineers** develop the packaging and microwave hygiene that makes high fidelity operation of these devices possible. They need extensive experience in modeling and simulating complex structures operating in the microwave frequency regime, and developing electrical circuits for quantum computing processors. Expertise with electromagnetic modeling tools, such as HFSS, Microwave Office, or other microwave simulation tools are a must to better understand quantum hardware control and packaging. Familiarity with how to quantize a microwave circuit into a quantum Hamiltonian is an added bonus.
- ● **Quantum FPGA Engineers** develop the tools for running more complex experiments. As these experiments get bigger we have to more processing near the device. To work in this are have extensive VHDL experience and are capable of working with FPGAs to control and readout microwave signals for qubit control is a must. The ability to also work on analog microwave hardware design would complete the skill set.
- ● **Quantum Software Developers** A few years ago, my colleague and friend Jerry Chow decided to put a quantum computer on the web. We would take what we did in the lab and put it online — how hard could it be? Totally underestimating the complexity of software, I signed up, thinking “no problem.” That endeavor has been one of the most challenging things I have ever done, and it would have been impossible without the input of a software developer. Early on in the project, I was lucky enough to encounter Ismael Faro, who had no quantum experience — and with his collaboration, our quantum computer in the cloud has been a success with now over 100,000 users. While we as researchers may know what we want to do, I know now that making sure it is usable, maintainable, and modular is not so simple. It requires the intellect and creativity of a really good developer. We need developers who want to build some of the more critical parts of this quantum revolution, from the user interfaces, open source SDKs, cloud services, and APIs, down to the systems software. Our developers apply all aspects of classical computer engineering in a fast-paced DevOps environment to optimize and connect the classical and quantum worlds.

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- ● **Quantum Community Builders** work to make sure that our technology meets the needs of the people. It's important that we must value people first, technology second. Our work is only as relevant as the world we share it with . Because of this, creating authentic and vibrant communities around our technology has to become a way of life. Community builders are the glue that help our team meaningfully connect with and teach people about quantum computing. No matter how many new people I meet, many are not aware that IBM has for 2 years made our 5 and 16 qubit devices available for anyone to use, and have been building out our Qiskit software in open source on Github for almost as long. One of the main reasons we chose to do this in the open was the desire to connect with the community.
- ● **Quantum User Experience Designers** bridge between the quantum community, technical requirements, data driven user research, and conceptual ideas by creating experiences that bring value to the people they serve. They start with a hypothesis and then by working with the users (students, researchers, professors, industry clients) determine how to design the experience and make sure a product is built for its users. Without our design team working with research and development, we would have never created the first IBM Quantum Experience.
- **Reach out and talk to a quantum expert**
- We've made it easy to learn more about positions or submit your resume by writing to quantum@us.ibm.com. Your message will be reviewed IBM Q technical leaders, including me. Since we're hiring for so many types of positions, this is a great way to express your interest and tell us a little bit about yourself. It is certainly better than starting with the daunting process of finding and applying for a position online! Whether or not you see a listing on the IBM Careers website, the IBM Q team is always actively looking for talent. We are also excited to be announcing some new internship programs for undergraduate and graduate students soon
- Liz Durst, our community manager, is a great resource. As our quantum outreach expert, she is connected with our entire team and can match you to the right hiring manager relevant to your skills. Liz and I, as well as all of the quantum computing folks at IBM, are excited about the contributions that you'll make in moving quantum computing into the future!

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