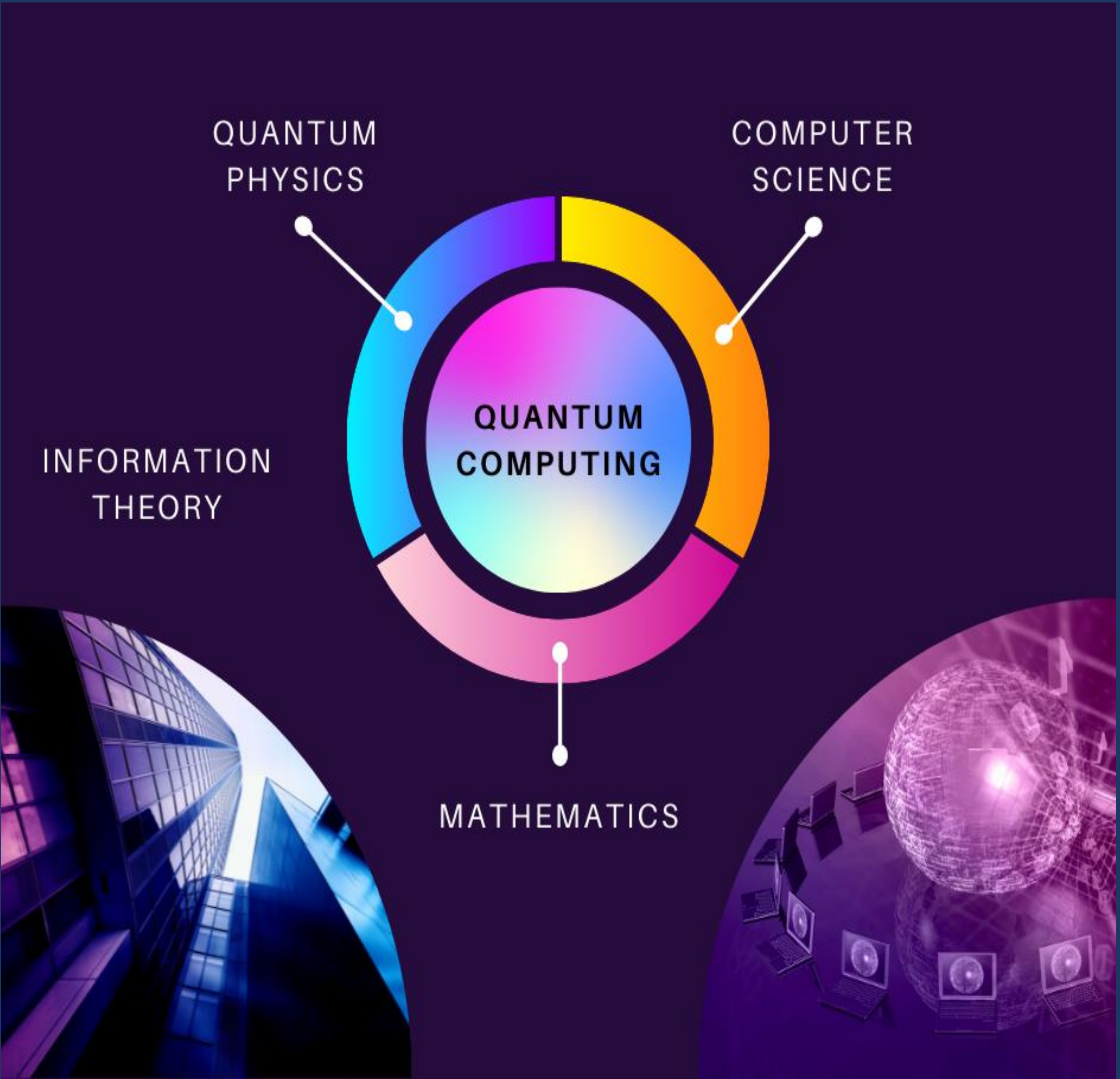
Quantum Computing

Quantum computing is a beautiful fusion of quantum physics and computer science, incorporating some of the most stunning ideas from twentieth-century physics into an entirely new way of thinking about computation.

Reference: Quantum Computing for Everyone

- Chris Bernhardt



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Quantum Computing

Why Quantum Computing is Future

According to the Report titled "Quantum Technology Market by Computing, Communications, Imaging, Security, Sensing, Modeling and Simulation 2022 – 2027", We can observe global and regional forecasts as well as the outlook for quantum technology's impact on embedded hardware, software, applications, and services from 2022 to 2027.

- Overall global quantum technology market will reach $42.4 billion by 2027
- Quantum computing will lead the market at $16.1 billion by 2027 and 39.4% CAGR
- North America will be the biggest regional market for quantum technologies overall
- China will lead the APAC quantum technology market at $5.41 billion by 2027 with a 38.5% CAGR
- Germany will lead the European quantum technology market at $3.6 billion by 2027 with a 33.1% CAGR
- The global quantum dots market will reach $13.25 billion by 2027, growing a 25.1% CAGR and led by displays
- The quantum sensing market will reach $989 million globally by 2027, nearly twice the size of the quantum imaging market
- The quantum magnetometer market will reach $925 million globally by 2027, led by superconducting quantum interference devices

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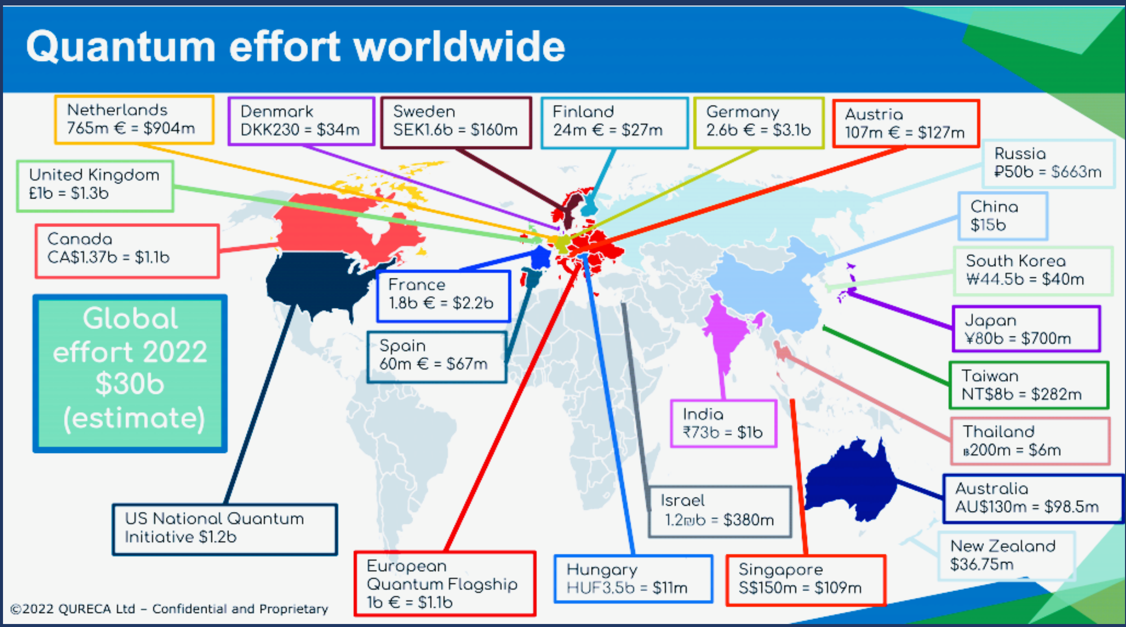
Quantum Computing is a trending technology and has been widely adopted by various countries. The global quantum effort leading to research and innovation in quantum science and technology is continually rising with current worldwide investments reaching almost $30 billion.

Overview of public funding in quantum technologies



Insights of Country-wise Details

India:

- In 2020, The Indian government has introduced an NM-QTA (National Mission on Quantum Technologies and Applications) with a total budget of INR 8000 crores (approximately $1 billion) over five years.
- Finance Minister Nirmala Sitharaman stated that a lot of commercial applications are expected to emerge from theoretical constructs developing in quantum technology.
- Indian Institute of Science has a dedicated research area for quantum technology.
- The Initiative on Quantum Technology explores many areas such as superconducting qubit devices, single-photon sources and detectors for quantum communications, integrated photonic quantum networks, and quantum sensors.

Quantum Computing

China:

- China is believed to be one of the leading nations in quantum information science, as the country began investing in quantum research and development very early on, by the end of the 90s.
- Over the past two decades, quantum information science has received significant recognition in China, as the First Prize of National Natural Science of China in 2013 and 2015 has been awarded to this field.
- By 2030, the country aimed to expand its national quantum communications infrastructure, by developing a general quantum computer prototype and constructing a practical quantum simulator.

Canada:

- Canada is considered one of the world's leading nations in quantum research. It has invested more than $1 billion in quantum research over the past decade.
- It has a growing private sector impact, outstanding research expertise, and extensive government commitments to innovation.
- Canada is in a very strong position to drive quantum technology development.
- As of April 2021, a further $360 million investment to launch a National Quantum Strategy was announced by the Canadian Government.
- Quantum Algorithms Institute will receive $2.2 million from the Canadian Government to accelerate innovation and commercialization in quantum technologies.

Japan:

- Its total investment for quantum information science and technology is around ¥30 billion.
- The main funding agencies have been the Japan Science and Technology Agency, the National Institute of Information and Communications Technology, the Japan Society for the Promotion of Science, and the Cabinet Office of the Government of Japan.
- For example, the Japanese Government launched the Q-LEAP initiative in 2018 to invest in R&D projects in three fields of quantum technology:

1. Quantum simulation and computation,
2. Quantum sensing,
3. Ultrashort pulse lasers.

- New Japanese initiatives have recently been launched in 2018 to advance quantum information science and technology to the next phase.
- The Moonshot Project is expected to invest around ¥15-20 billion to achieve its goal of creating a fault-tolerant universal quantum computer by 2050.

Quantum Computing

France

- France has been investing 60 million € in quantum technologies every year.
- In 2020, plan they announced the strategic recommendations.

1. Deploy cutting-edge quantum computing infrastructure for research and industry.
2. Launch an ambitious technological development program.
3. Implement a program for supporting the development of applications.
4. Create an effective environment for innovation.
5. Deliver a tailored economic security strategy.
6. Establish effective governance.

Many such initiatives can be seen in various fields and sectors throughout the world. Still, if anyone thinks Quantum is future technology, then they are wrong.

This year IBM plans to release a 433-qubit processor called Osprey. Osprey features a smaller chip that ensures more logical qubits that don't sacrifice performance.

In 2023, IBM plans to release a 1,121-qubit processor called Condor to succeed Osprey. By the time Condor is released, IBM believes they will be close to a "quantum advantage", the point at which quantum computers outperform classical computers.

Quantum Computing

Importance of Quantum Computing

One classical machine learning approach optimized a portfolio in 33 hours; hybrid quantum annealing produced similar results in three minutes.

- **Konstantinos Karagiannis**

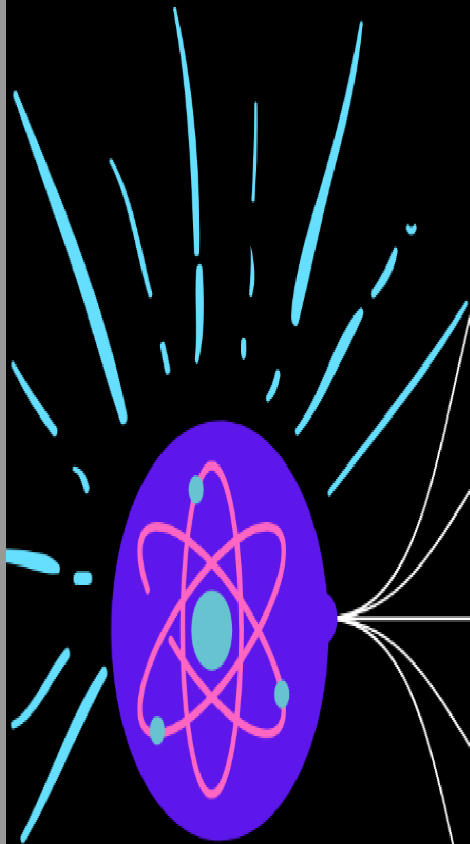
(Associate Director with Quantum Computing Services at Protiviti)

Quantum will soon reach a tipping point when quantum revolutionizes information security, fraud detection, logistics, and other optimization- and simulation-friendly activities.

Sooner or later organizations will struggle to find and hire the quantum talent they need. The first wave is already underway, it is imperative for organizational leaders to understand what quantum computing is, which activities it is best suited for right now, and the challenges and enablers that must be addressed to facilitate its use and advancement in this area.

QUANTUM COMPUTING

Career Opportunities



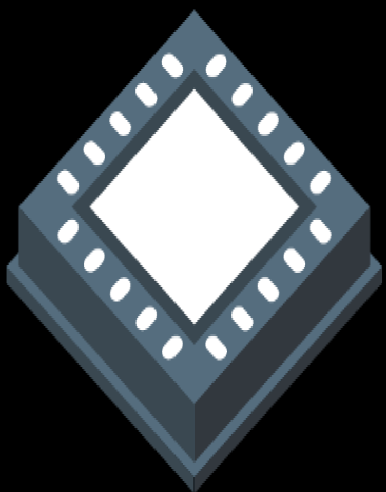
01 Superconducting Qubit Researchers

02 Quantum Control Researchers

03 Quantum Error Correction Researchers

04 Quantum Computer Architects

05 Quantum Complexity Theorists



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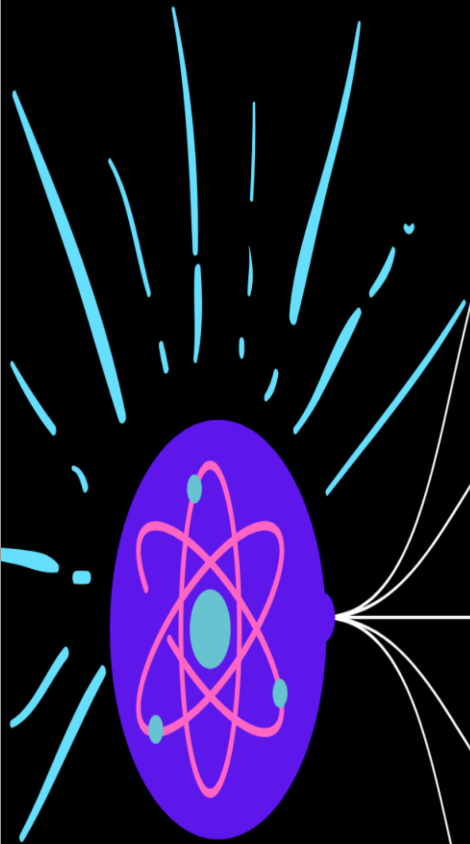
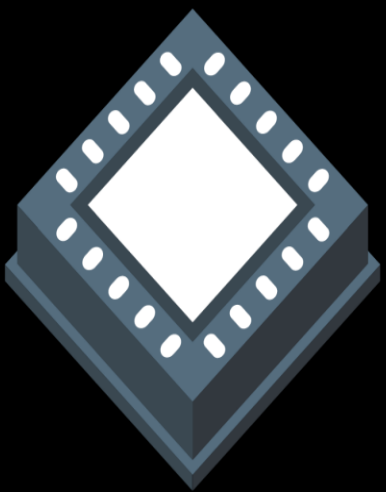
Career Opportunities



6. Quantum Algorithms Researchers
7. Quantum Cryogenic Engineers
8. Quantum Microwave Engineers
9. Quantum FPGA Engineers
10. Quantum Software Developers



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.

- **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.

- **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.

• **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.

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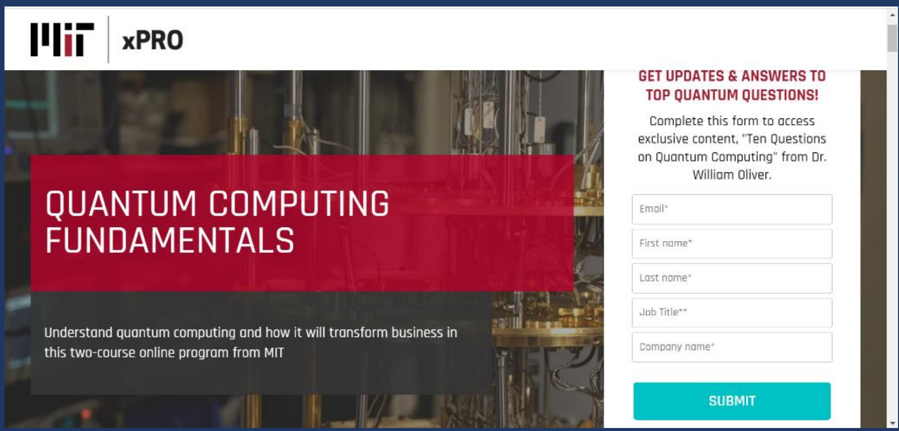
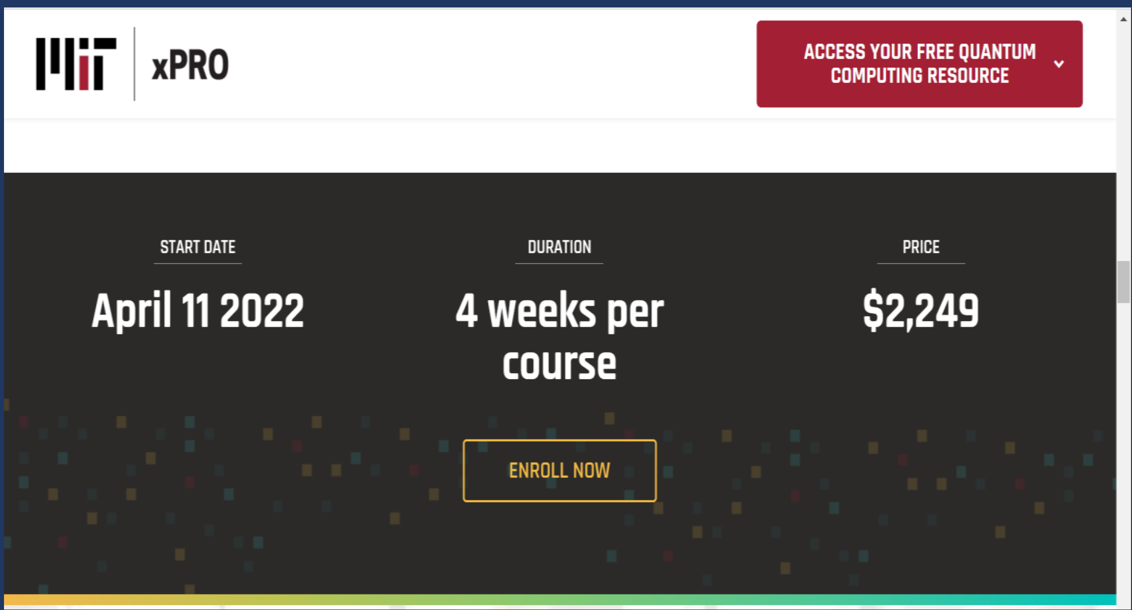
Course Expenditure

1. MIT xPro Quantum Computing Fundamentals



Cost

Expenditure:



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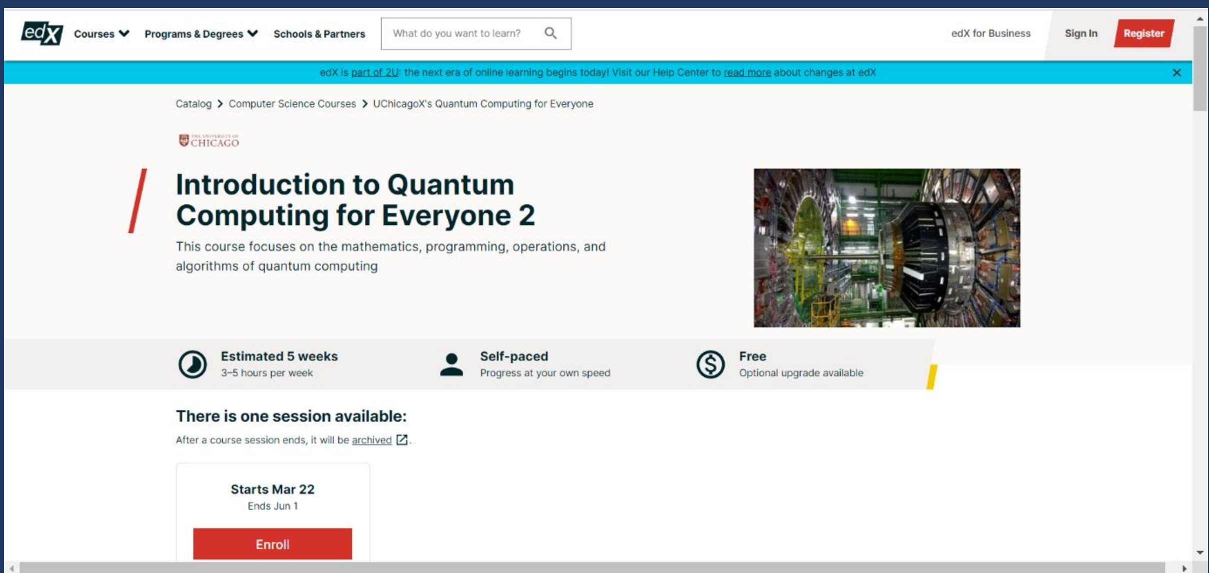
Course Syllabus / Outcome

2. UChicago - [Introduction to Quantum Computing for Everyone 2]



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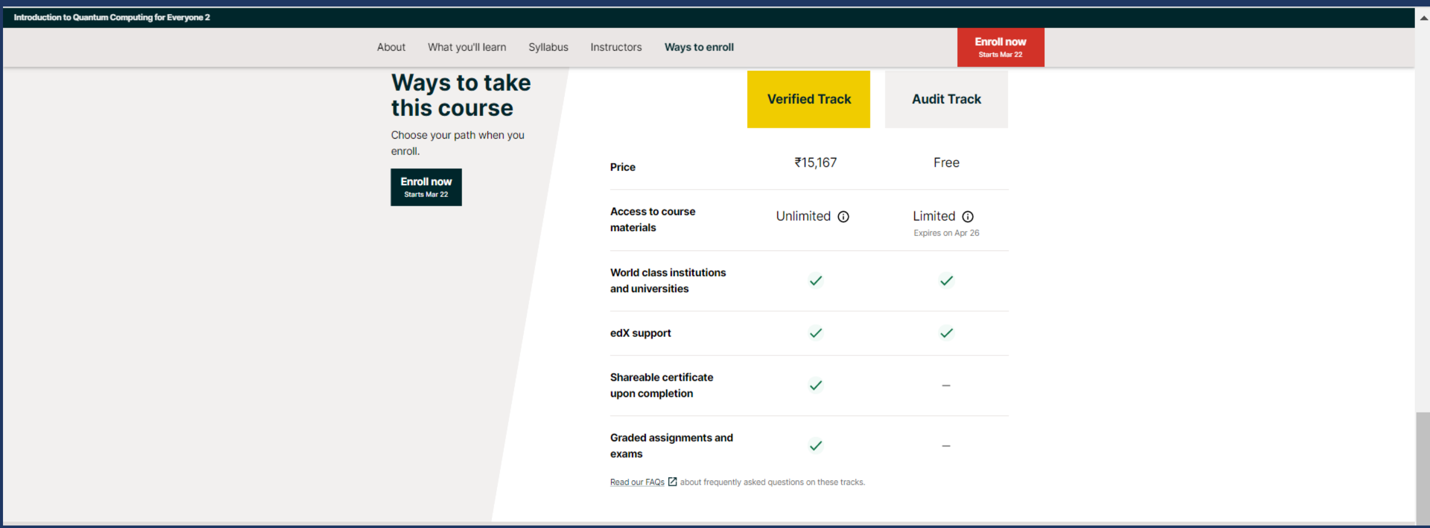
Expenditure :



Introduction to Quantum Computing for Everyone 2

About | What you'll learn | Syllabus | Instructors | Ways to enroll | Enroll now Starts Mar 22

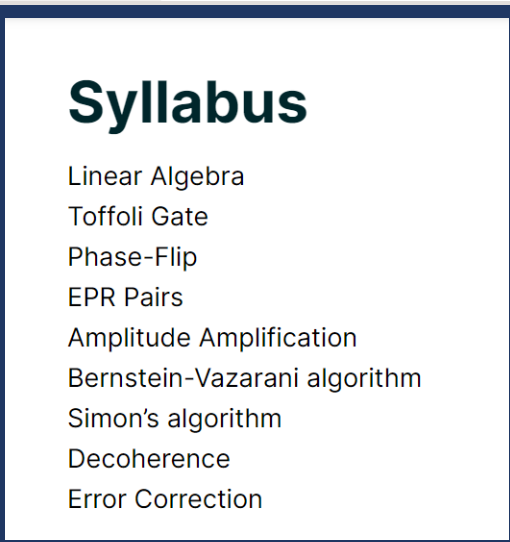
Ways to take this course

Choose your path when you enroll.

Enroll now Starts Mar 22

	Verified Track	Audit Track
Price	₹15,167	Free
Access to course materials	Unlimited	Limited Expires on Apr 26
World class institutions and universities	✓	✓
edX support	✓	✓
Shareable certificate upon completion	✓	–
Graded assignments and exams	✓	–

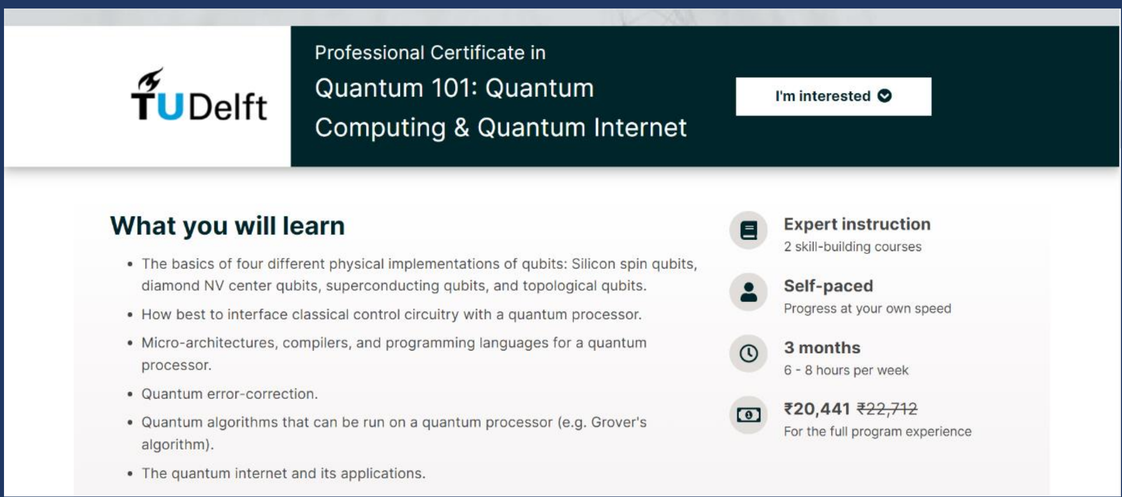
Read our FAQs about frequently asked questions on these tracks.



Syllabus

Linear Algebra
Toffoli Gate
Phase-Flip
EPR Pairs
Amplitude Amplification
Bernstein-Vazarani algorithm
Simon's algorithm
Decoherence
Error Correction

3. Delft: Quantum 101: Quantum Computing & Quantum Internet



TU Delft

Professional Certificate in
Quantum 101: Quantum Computing & Quantum Internet

I'm interested

What you will learn

- The basics of four different physical implementations of qubits: Silicon spin qubits, diamond NV center qubits, superconducting qubits, and topological qubits.
- How best to interface classical control circuitry with a quantum processor.
- Micro-architectures, compilers, and programming languages for a quantum processor.
- Quantum error-correction.
- Quantum algorithms that can be run on a quantum processor (e.g. Grover's algorithm).
- The quantum internet and its applications.

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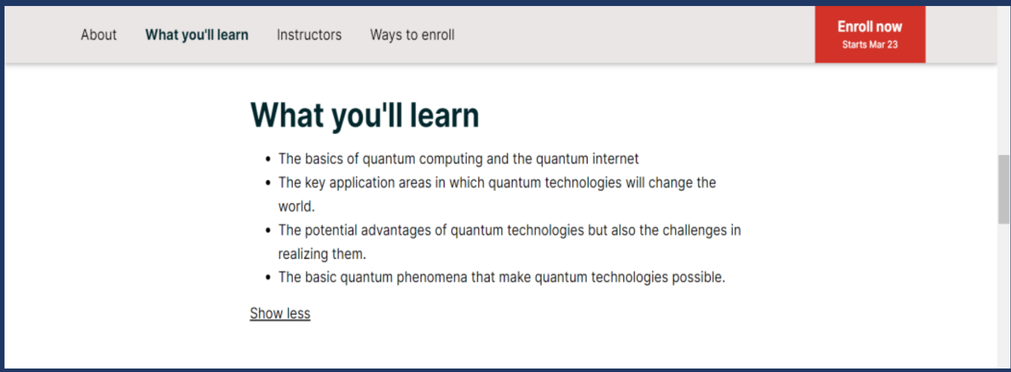
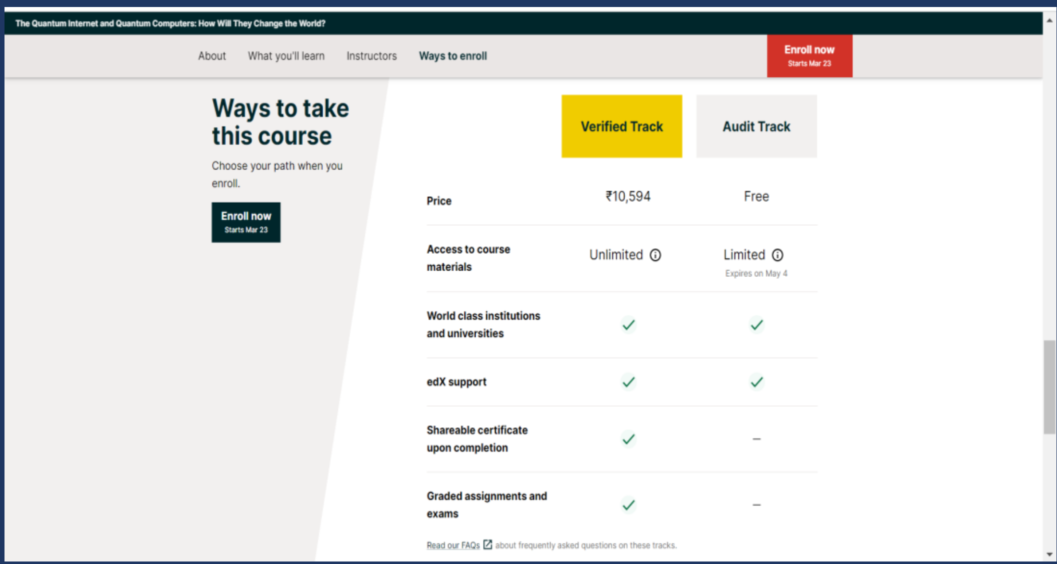
Quantum Computing

4. Delft: The Quantum Internet and Quantum Computers: How Will They Change the World?




The Quantum Internet and Quantum Computers: How Will They Change the World?

About · What you'll learn · Instructors · Ways to enroll · Enroll now (Starts Mar 23)

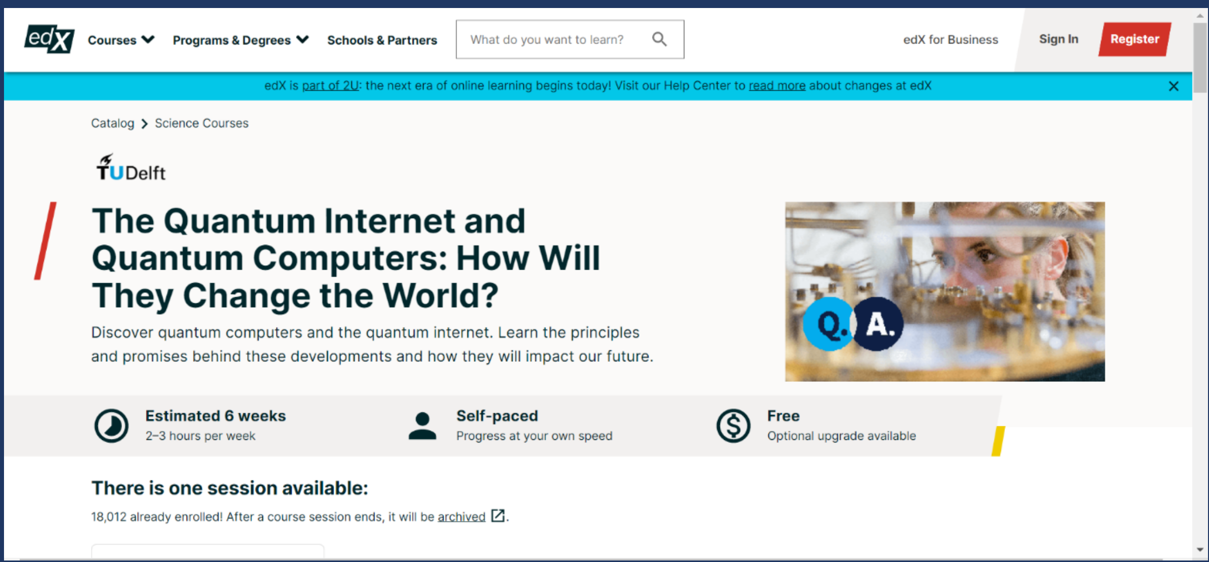
Ways to take this course

Choose your path when you enroll.

Enroll now
Starts Mar 23

	Verified Track	Audit Track
Price	₹10,594	Free
Access to course materials	Unlimited	Limited (Expires on May 4)
World class institutions and universities	✓	✓
edX support	✓	✓
Shareable certificate upon completion	✓	–
Graded assignments and exams	✓	–

Read our FAQs about frequently asked questions on these tracks.



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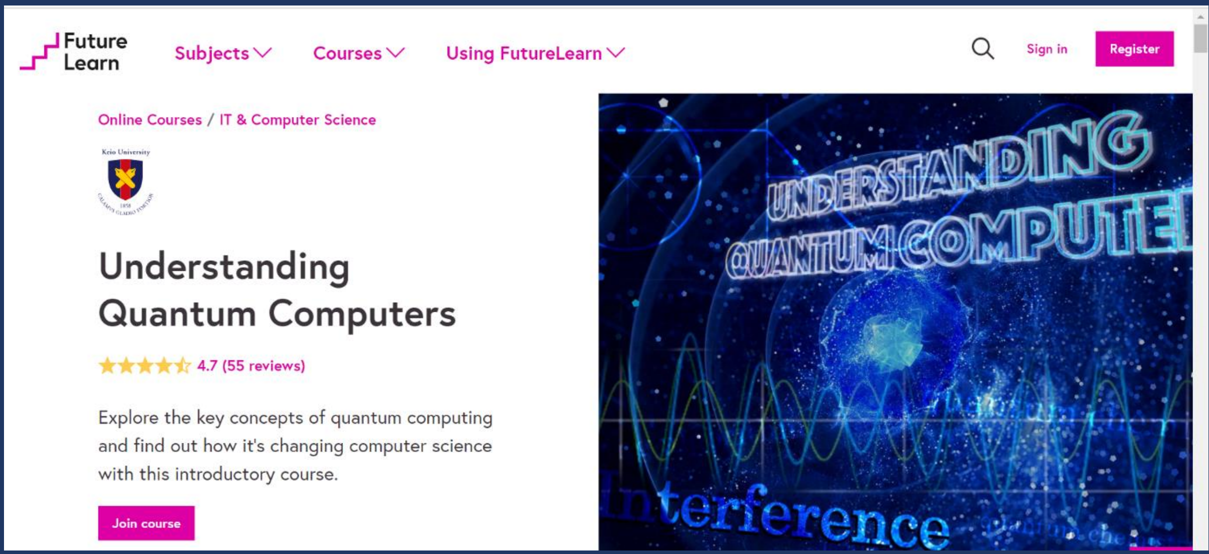
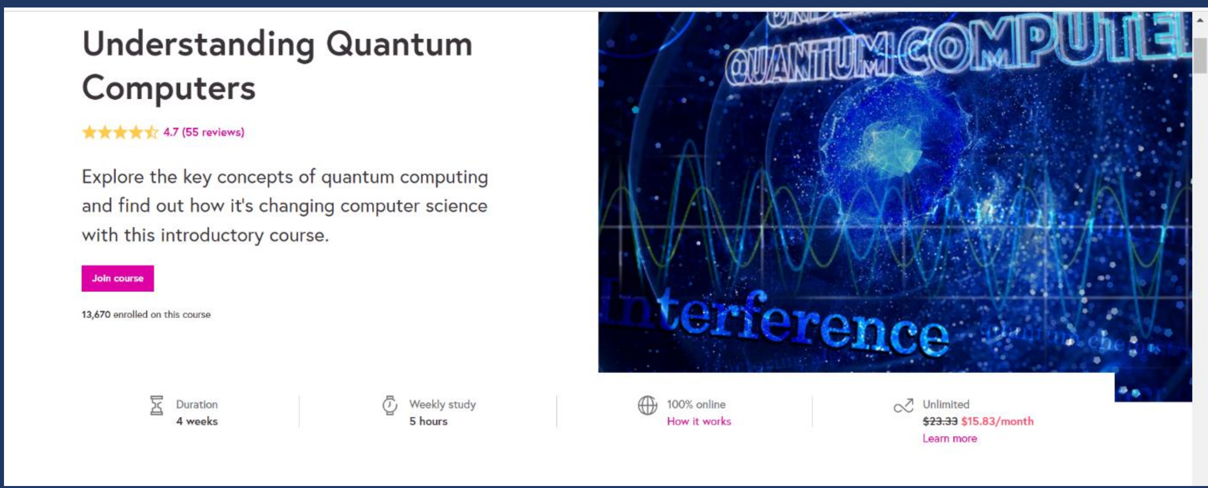
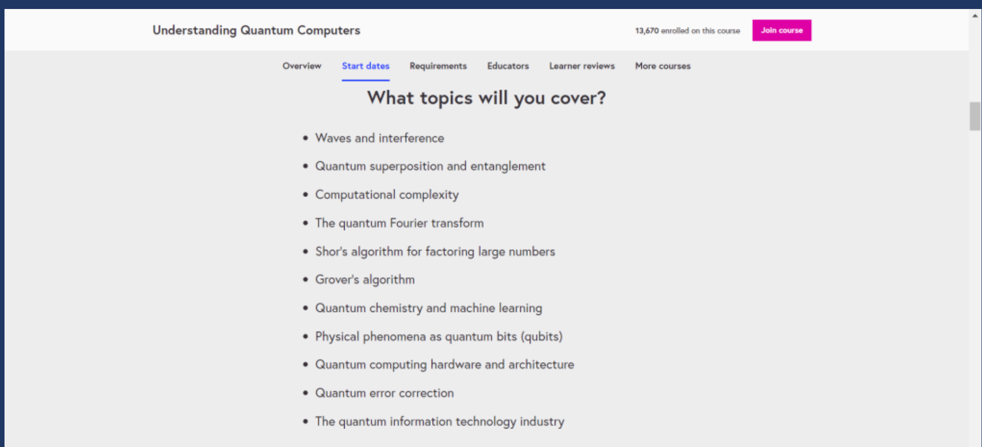
5. Future Learn: Understanding Quantum Computing







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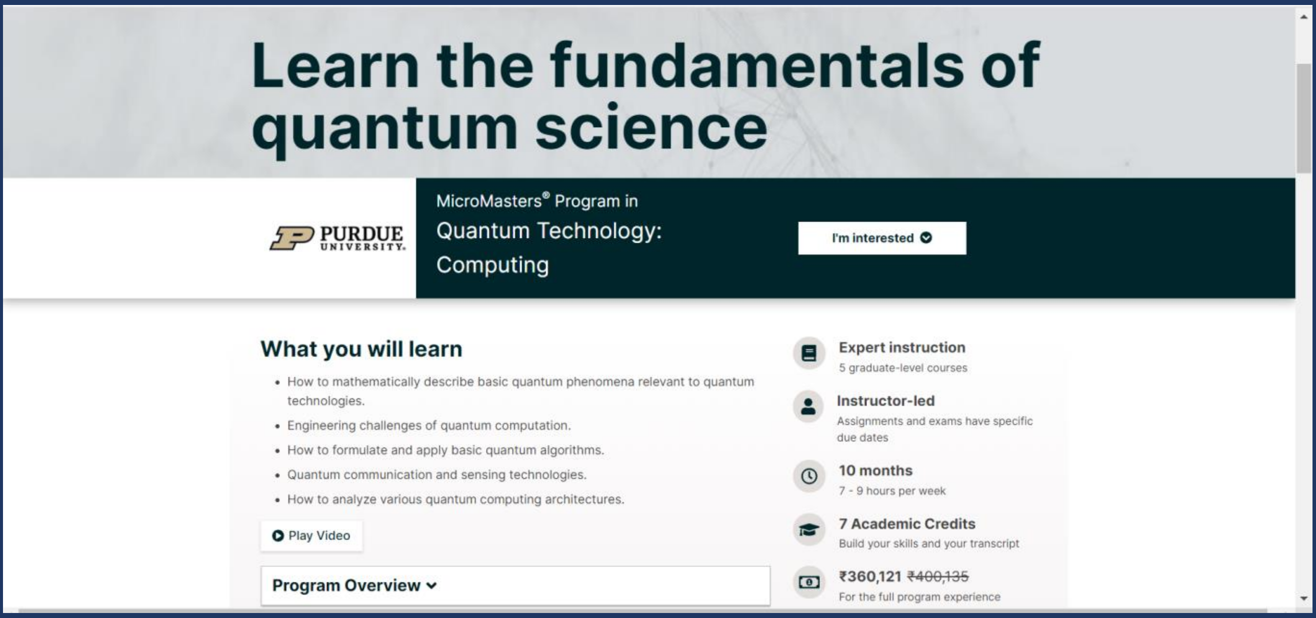
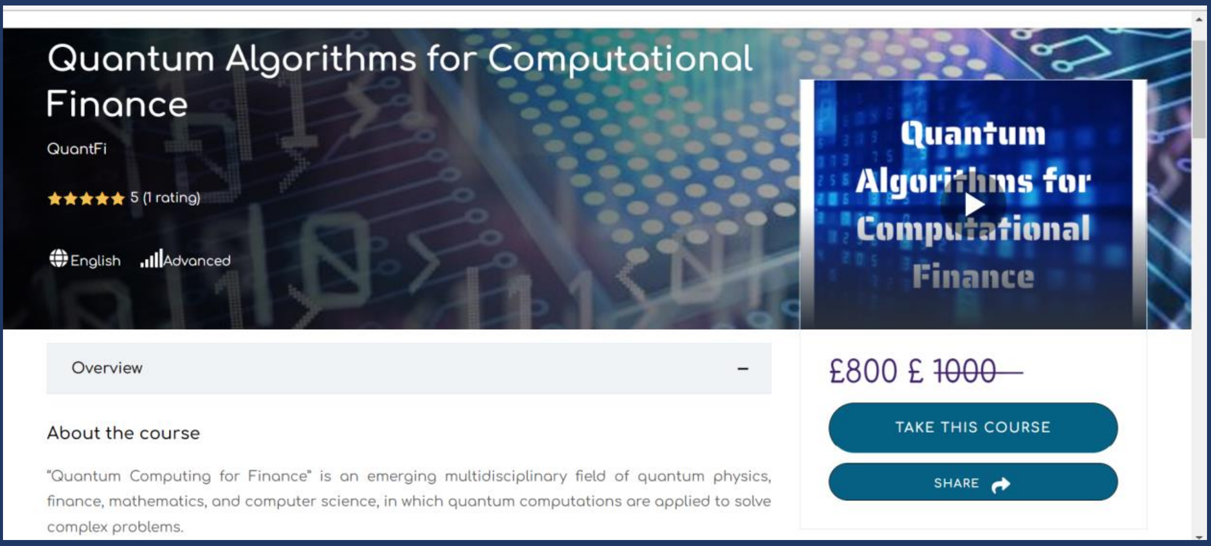
6 . Perdue: [Quantum Technology: Computing Micromasters]



7. Qureca: [Quantum Algorithms for Computational Finance]



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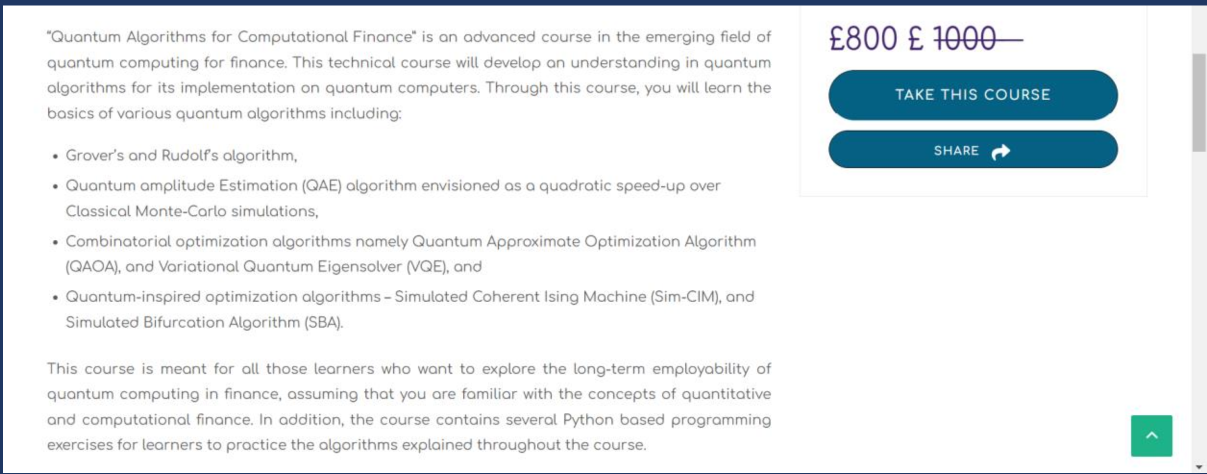

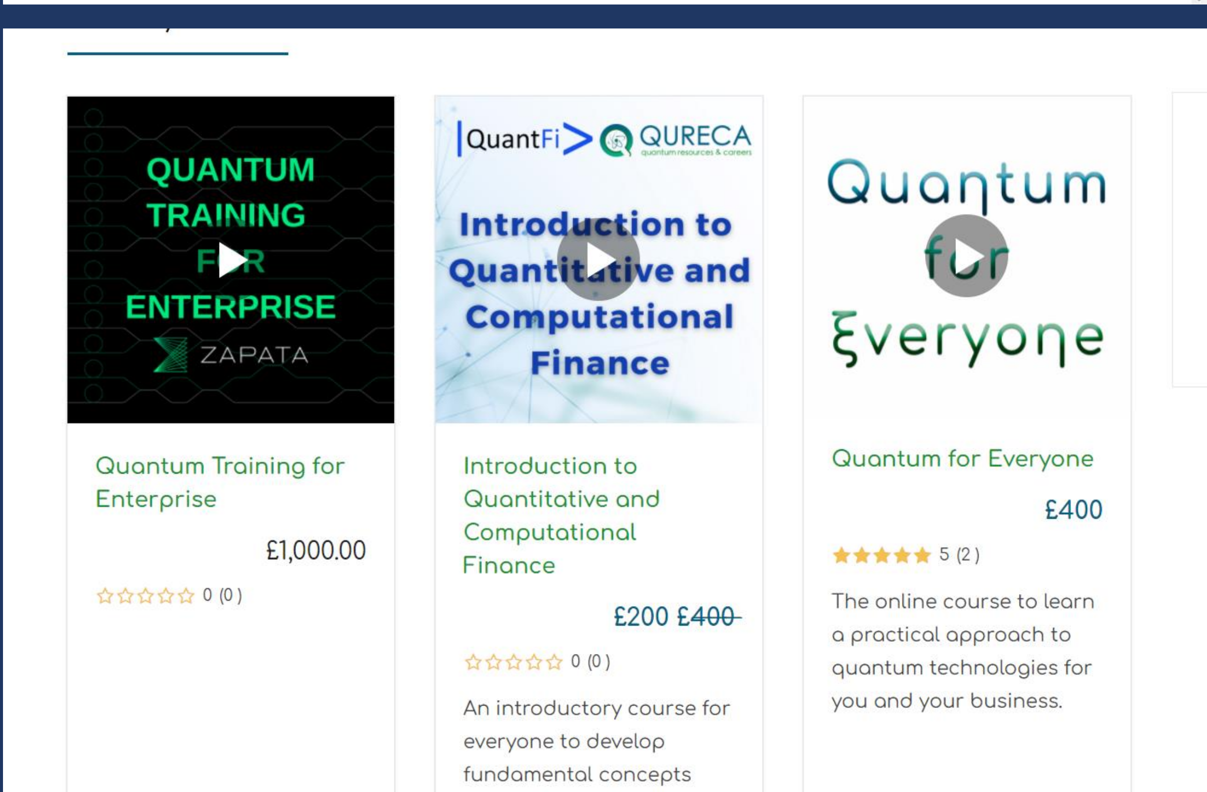

From above details you can observe the Cost estimation to learn Quantum Computing offered by various institutes and online platforms.

Sooner or later, every industry will start moving towards Quantum Computing, by seeing this **Mr. Vimal Daga** sir started a mission to make India's future-ready in "Quantum Computing" along with the **#13** community.

Quantum Computing

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