Begin by reading Section 3 through Section 6 of *The Economist's* 2017 article "Quantum Technology is Beginning to Come into Its Own."

This article addresses the past, present, and future of quantum computing, and includes perspectives from Prof. Aram Harrow and Prof. David Kaiser from MIT, among many others in the business, engineering, science, and technology fields. The four sections you are to read discuss quantum communications, quantum computation, software for quantum computers, and the uses of quantum technology.

Prepare responses (300-500 words) for each of the following questions below.

1. **According to the article, how do ambitions for quantum networks differ across nation-states around the world, and why? Include your own convictions about what role quantum networks should play.**

   Scoring criteria
   (2 pts) Complete: *Compared the ambitions of at least* ***three*** *nation-states around the world. Commented on the difference between them. Mentioned the importance of quantum networks for the development of the quantum internet. Gave one personal opinion about the role of quantum networks.*
   (1 pt) Partially Complete: *Compared the ambitions of* ***two*** *nation-states around the world. Commented on the difference between them. Gave one personal opinion about the role of quantum networks.*
   (0 pts) Incomplete/Not attempted*: Did not compare the ambitions of nation-states. Gave one personal opinion about the role of quantum networks.*

2. **Give four reasons why corporations and governments believe "the time for investment, all agree, is now" for quantum computation, according to the article. Comment on which of the reasons you believe are most convincing.**

   Scoring criteria
   (2 pts) Complete: *Given the information presented in the article, provided* ***four*** *reasons on why corporations and governments believe they should invest in quantum computing now. Discussed the most convincing reason.*
   (1 pt) Partially Complete: *Given the information presented in the article, provided* ***two or three*** *reasons on why corporations and governments believe they should invest in quantum computing now. Discussed the most convincing reason.*
   (0 pts) Not attempted: *Given the information presented in the article, provided one reason why corporations and governments believe they should invest in quantum computing now.*

3. **The article quotes IBM vice president Dario Gil saying, "The power of quantum computing is rediscovering all the problems that computers cannot solve, and having a path to solving them." Discuss three ways "quantum software" addresses this idea, and argue whether one should believe Dr. Gil's statement (or not).**

   Scoring criteria
   (2 pts) Complete: *Discussed* ***three*** *ways in which the article addresses the phrase: "The power of quantum computing is rediscovering all the problems that computers cannot solve, and having a path to solving them." Discussed the accuracy of the phrase.*
   (1 pt) Partially Complete: *Discussed* ***two or three*** *ways in which the article addresses the phrase: "The power of quantum computing is*

rediscovering all the problems that computers cannot solve, and having a path to solving them." Did not discuss the accuracy of the phrase.
(0 pts) Incomplete/Not attempted: *Discussed one way in which the article addresses the phrase. Did not discuss the accuracy of the phrase.*

4. **The article states "subjects that used to be mere footnotes to physics will rule, and engineers (and perhaps even consumers) will have to learn to speak quantum." How is this point presented in the article (cite corporate and government examples), and can you give examples from your own experience?**

   Scoring criteria
   (2 pts) Complete: Summarized at least **three** corporate and government examples given in the article. Explained why engineers will need to learn about quantum computing. Using personal experiences provided **one or more** examples on the need to learn quantum computing.
   (1 pt) Partially Complete: Summarized **two** corporate and government examples given in the article. Explained why engineers will need to learn about quantum computing.
   (0 pts) Incomplete/Not attempted: Summarized one corporate and government example given in the article.

Answer to question 1:

The quantum network is similar to a regular network, but it can send quantum states and establish entanglement. The main advantages of quantum networks are speed and security. To build a full-scale quantum network is very challenging and to establish it every country has its own ambitions. The most ambitious countries dedicated to the invention are Singapore, Austria, the USA, the Netherlands, the UK, Australia, China, Japan, South Korea, Switzerland, etc.

China is one of the most prominent countries in the sphere of quantum networks. The proof is the central government investment was made to connect the metro network over 70 square kilometers with the aim of connecting senders and receivers with switchboards. The main customers were financial institutions, which points out China's ambitions in the aspect of a quantum network is to build a secure banking system. Another example of engagement is the Micius, a QKD enabled satellite, meaning that it can be further used as a trustful relay to connect any two points on Earth for high-security key exchange. By these actions, China showed that its main goal is to surpass the US and become the global high-tech leader. China's investments in quantum communications are much more than the US's, with all these steps China aims to become technologically self-sustaining. We also can notice Quantum research is a part of a long-term strategy for China. Additionally, China makes promising announcements to improve its records.

The second notable country in the sphere is America with the aim of increasing national and financial security, patient privacy, drug discovery, and the design and manufacturing of new materials. All the ambitions are of governmental level and to build a quantum network is the way to keep the nation secure.

The third eminent country in the aspect of building a quantum network in Switzerland. The article points out that the ambitions of the Swiss government is to make the elections secure. Although the most apparent ambition is the aim of building a secure financial system, as long as Switzerland is considered to be the financial center of the world. So, private banks do not save efforts to reach the goal. Id Quantique, a Swiss company, has installed quantum links, which is another attempt by Switzerland. Obviously, as Switzerland is a non-military country, its ambitions are not to build security at the state level(although every country aims it in any case) in contrast to China and the US.

I mentioned the countries which have different ambitions depending on their political, economical, and social needs.

A quantum network in which the processors are located at different geographical locations is called a quantum internet. While the quantum network enables the exchange of quantum bits between any of the connected quantum processors.

Quantum processors can also be connected into a quantum network in order to assemble a large quantum computing cluster, which is called networked quantum computing and offers a natural path towards scalability. Combining a quantum internet and a networked quantum computer finally allows remote users/providers to perform secure quantum computing “in the cloud”.

In my opinion, the aim of having the most secure infrastructures makes the countries focus on establishing a quantum network. The countries seeking to have the most secure banking system will initiate the establishment of quantum networks. State applications such as military service are also triggering nations to have a quantum network as soon as possible. Briefly, this is for everyone who has an urgent need to keep things secret via rules of physics. Overall, the leading country in quantum computing will gain significant scientific advances, but it will also gain a substantial military quantum advantage.

Answer to question 2:

The new vision of solving problems that are hard for people and also for classical computers gave birth to a new computational branch – quantum computing. The idea was a breakthrough in science and is challenging till now since everything was theoretical and no one knows how to build hardware. Despite the advances in the branch, there are people that do not believe in the success of quantum computers, many of them do not know why to invest in it and why corporations and governments invest now. In contrast, the other part of the people believes that “the time for investment is now”. Here are some reasons why is it so

1. As it is mentioned in the article, “even the smaller and less capable machines that will soon be engineered will have the potential to earn revenue ”. Additionally, there is mentioned that the very first applications will be “quantum simulators” that mimic nature. There are examples of using revenue even now (D-Wave’s quantum annealer). Startups and consulting firms are now trying to match problems to small quantum computers trying to face the difficulties of quantitative finance, pharmacy, oil, and gas.
2. Whenever, and by whomever, this is accomplished, it will launch an era of small-scale machines offering quantum-enhanced solutions and services. The first publicly accessible one, IBM’s Quantum Experience, may be an

indication that the machines' future will be in the cloud. Most users have no more need for one at home as they have access to a supercomputer.

3. What makes the idea of quantum computers so attractive is not so much that they will work faster than traditional computers—they may for some applications but not for others—but that they will work fundamentally differently. Three intuition-defying concepts play a role.
4. But in a clear indication that quantum computing is getting closer, names familiar from traditional computing are increasingly getting involved. Hewlett-Packard is trying to build its own machine. Intel's global quantum investments include $50m going into work at QuTech, the Netherlands' national quantum-technology hub. Intel's global quantum investments include $50m going into work at QuTech, the Netherlands' national quantum-technology hub. Microsoft's topological quantum approach, if it works, will be much less error-prone. The quantum-computing startup scene is also becoming increasingly vibrant. Researchers from Yale and the University of Maryland have spun off companies, and physicists who had worked at IBM and America's Department of Energy have started their own firms.
5. Paolo Bianco, who heads the quantum-technology research team at Airbus, a big European aerospace firm, says that quantum-simulating a new material such as a stiffer or lighter alloy for use in airplanes or satellites would be much faster and cheaper than manufacturing and then testing the material itself. "The promise of quantum technologies", he says, "is in engineering terms a step up in performance—not of 20%, but of a couple of orders of magnitude." Google is aiming to use its own machinery, a so-called gate-model quantum computer of the sort most groups are pursuing, to achieve "quantum supremacy", whereby a quantum computer performs a calculation faster than any known computer could. Google researchers have laid out an ambitious plan which may let them achieve that feat this year.

In my opinion, the most convincing reason is the first one. Revenue always played a role in the development and progress of science. I believe that quantum computers will be so revolutionary that will help a lot of branches of science. It will give a chance to the government and private sector to develop the infrastructure and make life easier.

Answer to question 3:

As time passes, the fact that quantum computers will be built is becoming closer. When a machine is invented a software is needed to run the machine. The other aim should be to develop algorithms, to make the computers work as it is intended to do. Dario Gil said that the power of quantum computing is rediscovering the problems that are unsolvable for classical computers and have a path to solve those problems. The following points are about what Dario Gil addressed

1. One of the most promising areas is in machine learning and deep learning. The applications are in searching through vast data to find the pattern, such as in image recognition, cybersecurity as well as algorithms that crunch numbers to those that mimic atoms. All these quantum algorithms call for some means of cataloging the data. In my opinion, quantum computers will give a chance to two aspects of artificial intelligence by rediscovering it from another angle and giving another way of a solution such as storing data by types. Here, consumers and academia can gain from the speed of quantum computers to solve the problems that are hard to do on classical ones.
2. “Stephen Jordan invented a taxonomy of 59 mathematical families suited to particular kinds of problems or breaking down problems in a particular, quantum-friendly way. All these algorithms are even-better emulators for eventual machines, and the most interesting branch is finance in this respect”, as it is mentioned in the article. There are lots of problems that classical computers cannot solve, hence Stephen Jordan invented the mentioned algorithms to run on quantum machines.
3. “Companies such as QxBranch and 1Qbit play a new role of middleman between the quantum experts and industry, examining whether and how a given firm’s business might be improved by quantum methods, for example optimizing trading strategies or supply chains, or monitoring network activity to spot cyber-attacks. Landon Downs, a co-founder of 1Qbit, says that can lead to solutions which can already be put to use”, says Landon Downs in the article, also he mentioned that in the search of the best algorithm on quantum computers, the scientist can find a better solution for the classical ones as well. In this case, we see an impact on classical computing also, which is obviously a great advantage.

In all these examples where the author points out the saying given above, we see that the found software is the power of quantum computers, but would we go to that

algorithm if there wasn't speed and security in communications? I assume, no, as the main advantage led to the inventions occurring today in science is the wish of having faster computers. Though the author gives very big importance to quantum algorithms considering it as the power of quantum computing, yes it is correct, but I think that all the components that will make quantum computers work are of very high importance, the hardware also plays a huge role, as quantum computers are a way of looking at nature in another way, from the sight of quantum weirdness.

Answer to question 4:

At the beginning of the last century, quantum computing was considered to be mere footnotes to physics, but the situation has changed. Now, a large scale of investments is done to develop and spring up quantum computing. Furthermore, the author of the article mentioned the fact that "subjects that used to be mere footnotes to physics will rule, and engineers(and perhaps even consumers) will have to learn to speak quantum". There are a lot of examples that prove the justification of the statement. They are the following

1. The authors of the article pointed out, " The first of sensitive magnetic-field sensors was developed in 1964 at Ford Research Laboratory, the American carmaker's blue-skies research facility. Now they are widely used, for example in MRI machines. In the early 1980s, researchers at IBM turned the quantum effect of tunneling, in which particles seem to pass straight through impenetrable barriers, into a way to see the microscopic world with staggering resolution." This is a corporate example of the statement about the growing importance of quantum computing.
2. Element Six, a subsidiary of De Beers, a diamond giant, has carved out a niche selling diamonds with bespoke "nitrogen vacancies"—flaws that turn them into sensors. Silicon carbide is tipped to be just as quantum-amenable as those diamonds, but so far expertise with it is thin on the ground.
3. Intel aims to build qubits into silicon, in order to piggyback on existing fabrication infrastructure. But that will require the material to be produced to a much higher purity. To that end, Intel has joined forces with Urenco and Air Liquide, two materials firms.
4. "We certainly expect there are many additional things that we'll be able to do with quantum beyond the things we know of," We had no idea of all the

> things we'd be able to build with the transistor, and we see the same thing with quantum", says Tim Polk of the White House Office of Science and Technology Policy.

The government and corporations understand that the future is for quantum computers. The companies that are investing in science understand the significance of quantum computers. Speaking quantum will be a new highly-demanded skill for engineers. Additionally, looking at statistics will give an overview of the quick growth of Quantum Computation.

In my personal example, I wished to study quantum computation regarding the abstraction quantum computation has. Quantum computers will be speedy, secure, which are the facts attractive for engineers, but the weirdness is the most significant thing Quantum Computation has. Now QC is becoming trendy, making interest in every engineer, I am also witnessing some examples that good professionals switch from one field to QC. This is bringing us to a new tech revolution.