**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.*

Quantum networks make the transmission of information in the form of qubits between physically disjointed processors possible. That’s an important infrastructure needed to connect senders and receivers.

* China is the leading nation-state that has created the most ambitious quantum network in the world to date. China’s quantum network connects Beijing and Shanghai via Jinan and Hefei.Jivan has a metro network of over 70 square kilometers with 50 “nodes”, and Hefei with 46 nodes network. These numbers are huge *compared with* other countries, their capacities and work done so far towards creating a quantum network.
* South Korea’s government is funding a 250km link to join existing metro quantum networks.
* Britain will create a network between the cities of Bristol and Cambridge via London, which *compared with* China is less ambitious , but will have a similar length as South Korea’s network.
* *Compared* with other countries, Australia is building a closed government network in the capital, Canberra. It should be mentioned that the length of the network is also a challenge.

Though China is on the same list with these countries it’s role and engagement is incomparable. China has launched Micius, a quantum-key-distribution-enabled satellite backed by tech companies including Huawei and Lenovo.

The government-industry connection brings more opportunities for the development of a network and a technology in general. In all these countries the key role plays the government as it supports the development of quantum networks. We believe, quantum networks with quantum-enabled satellites will create a baseline and a strong ground for the development of the quantum internet, which will bring new opportunities for quantum enhanced security. We believe that if more countries start working toward these goals, the faster the development of the technology will be. The quantum internet will solve major problems that people, companies, organizations and governments face nowadays connected with privacy. We think that it is firstly the priority of governments to work and invest towards creating a quantum internet with potential to establish more trustworthy communications in means of privacy.

**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. Even small and not yet advanced quantum computers are able to solve problems that are not solvable with classical computers. This brings new horizons, perspectives and new ways to commercialize the technology and earn revenue. Already, startups and consulting firms are creating ways to match prospective small quantum computers to problems faced in sectors including quantitative finance, drug discovery and oil and gas.
2. Quantum simulators can help to design and create room-temperature superconductors, which will allow electricity to be transmitted without losses, or with investigating the nitrogenase reaction used to make most of the world’s fertiliser. Quantum simulators are computers that mimic real physical systems.
3. Fintech: Hyder Jaffrey, head of Strategic Investments and Fintech Innovation at UBS Investment Bank, says he prioritises quantum computing as he does it with artificial intelligence and blockchains, “all these evolving technologies with the potential to change markets”. So here comes a factor of competition, if one bank uses quantum computing and starts to benefit, others should start to. They work with QxBranch startup which uses quantum algorithms in foreign-exchange trading and arbitrage.
4. Strategic reasons: The founder of quantum-technology institute of Netherlands states “We don’t want to risk the scenario that we have invested all this money for years and in the end the money is going to be made in the US or China,” she says. She emphasizes the case of defence applications, where she believes security plays a role too: “If you have to buy it off the shelf, it’s not just an economic disadvantage, it’s also dangerous.” We think the first one is the most convincing. Investments are worth the money if and only if investors have an idea how their investment will pay off. Most research funding comes from two major sources: corporations and the government. Companies have a goal to create products that will be compatible, useful and will solve a real problem, a problem, which solution will help them earn more money. Governments on the other hand have goals to make the countries economy more stable, stronger and compatible with other countries, in the case of quantum computing the government has also a goal to create networks for the development of quantum internet (refer to the first question). Blue-chip companies including Intel, Hewlett-Packard, Google and Microsoft all have research programmes. Last year IBM released Quantum Experience, which lets all interested people play and experiment with a crude quantum computer over the internet.

**3. The article quotes** [**IBM vice president Dario Gil**](https://researcher.watson.ibm.com/researcher/view.php?person=us-dgil) **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. In the article we see that Dr Shor was the first scientist who showed that a quantum computer would be able to work out the prime numbers that, multiplied together become a significantly large number. The fact that this “decomposition” is mathematically very hard is the basis of cryptographic protocols which are used nowadays. Starting from that, researchers have come up with a lot of problems for which quantum computers can be way better and can be superior to the best supercomputers. Also they come up with many algorithms, or sets of steps, to break down problems in such a way that quantum computers can crunch through them.

So here we see that researchers and scientists are working towards rediscovering all the problems that computers cannot solve, through quantum computers and new algorithms based on prior discoveries.

Also, there are even problems that are not solvable with help of classical computers, and if a computer big enough to do what Dr Shor has envisioned, will be useful for that problems as well.

1. We would like to citate these words of Tim Polk of the White House Office of Science and Technology Policy from the article below:

“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.”

There are problems that classical computers cannot solve, also there are problems that classical computers do solve but not quite effectively. Here we see the third type of problems which can be solved with the help of quantum computers. Tim Polk refers to it and we agree with the idea that sole solutions can bring to other ones and nowadays we cannot fully imagine the scope of solutions that quantum computers and technologies will bring.

1. *Security and Development of post-quantum ciphers.* The idea of post-quantum ciphers is the challenge and idea is to create ciphers that future quantum computers will be unable to crack. It has a goal to identify a way of data encryption that is difficult to break without needing too much memory or computation to implement. Nowadays the standard is RSA, which could be made hard enough to break, but the cryptographic keys would have to be a terabyte long which is an impracticable option. For example elliptic-curve cryptography keys are just 32 bytes long; any post-quantum solution needs to be sufficiently secure.

So this article both describes the challenges of security and networks but also the challenges connected to post-quantum ciphers.

The phrase is accurate, as quantum computing brings new challenges, new solutions and new problems connected with possible solutions. We do agree with that statement. The only thing that is arguable is that there are comparably more problems without clear paths to solve them then there are actual paths for solutions (find our ideas below each point).

1. **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?**1. To a great extent, quantum weirdness escaped the lab, as on account of the superconducting quantum interference device, a stunningly sensitive magnetic field sensor. The first of these was created in 1964 at Ford Research Laboratory, the American carmaker's blue-skies examine office. And now we can see it’s use today as they are generally utilized, for instance in MRI machines. That’s why it is very important to make more research on new quantum theories and usage so that we can use it in our ordinary life in the future, after developing it for some time.  
   2.However there might be a big danger coming from realesing a lot of quantum knowledge and tools in the masses. But quantum technologies will not pass into the wider world in the same way as the global positioning system, which was developed with copious government funding behind closed doors and then handed over as a public good. “It’s just not like that today,” says Neil Stansfield, formerly of the British government’s Defence Science and Technology Laboratory. “We’re not the big kid on the government block, and certainly not on the global block.”. IMagine giving knowledge of utilizing atom to everyone, in hope that they will make a energy sources from it, and not Atmoic bombs.  
   3. But also there is a beauty in the unknown.ob Wisnieff, a manager at IBM’s microelectronics-research labs, says that “we’re not that far from being capable…of building quantum computers that will do things we cannot predict exactly.” John Preskill, a quantum expert at the California Institute of Technology, who coined the phrase “quantum supremacy”, has said that “a quantum computer can simulate efficiently any physical process that occurs in nature. Maybe. We don’t actually know for sure.”. And it is very important to discover new things to enlarge our knowledge in science and have a opportunity in future that we can’t imagine now. If Edison did not invented the light bulb, there would be no LED lights today. It is very important to start teaching about quantum computing to wide masses, as the need of it arises, more and more. Even I had an experience were, in my job place, we needed to secure our information with very secure way, and I someone suggested the quantum cryptography, however at that time nobody knew about it, so we just declined it, now reflecting back on it I think it would be much better if we knew about quantum computing long ago.

**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.

1. These are three experimental demonstrations of quantum simulations. Noting its relative date of publication, describe your chosen paper's impact in the business trade press. Do you feel it had the largest influence of the three? Why or why not?  
  
**Scoring Criteria**  
***(2 pts) Complete:*** *For chosen paper, enumerated the number of business press related to it and classified the variety of impacted audience. Identified the magnitude of business opportunities related to each technology. For* ***both other papers****, classified the variety of impacted audience and identified the magnitude of business opportunities related to each technology.*

We have chosen the second article, [Scalable Quantum Simulation of Molecular Energies](https://ai.google/research/pubs/pub44815), which was published in 2016. We have read a number of articles connected to this one and others and came to a conclusion that quantum simulation of molecular energies is able to impact a bigger scale of audience and has a much wider magnitude of business opportunities nowadays than others. We have researched having a focus in mind to nowadays problems and how those researches and technologies can impact and solve those. Nowadays one of the biggest challenges businesses, governments and the world in general faces is the challenge to create a vaccine for CVOD-19. The question that arises is what does the simulation of molecular energies do with the research needed to find the vaccine. Viruses are big molecules as they are made of carbon, hydrogen, nitrogen and etc. The problem arises when the active parts of those molecules start to interact with human bodies and the cells in it, by creating negative changes and harming human health. With simpler words, the idea behind vaccines and drugs is a creation of the combination of other molecules that can interact with the molecules of the virus and disable it with interacting with human molecules and cells. The challenge here is to try to find those molecules, but it’s a time consuming and quite hard challenge, because most importantly there should be clinical trials as well to prove it’s effectiveness and safety. This cannot be done on humans, as the cost is too high (human health and lives). This should be done with help of simulators. Here come quantum simulations. This is a great business opportunity and not only, of course. Countries will be more than happy to pay for the research and implementation. Quantum computing can help to lessen the time required for the simulation of big molecules. This is more about perspectives and works/articles/researches done on it. But talking about dates and direct connection with the article and the content int, in the 2017 in the Chemical and Engineering News had a headline: “[Chemistry Is Quantum Computing’s Killer App](https://cen.acs.org/articles/95/i43/Chemistry-quantum-computings-killer-app.html). It was directly connected to the use of quantum machines as a dool to develop new drugs and materials. Also, a [2018 report by the Boston Consulting Group](https://www.bcg.com/en-us/publications/2018/coming-quantum-leap-computing.aspx) suggested that a huge $20-billion quantum pharmaceutical industry could emerge by 2030. So these are business opportunities we came across with and think can be promising for upcoming years. We used this sources:

[*https://physics.aps.org/articles/v12/112*](https://physics.aps.org/articles/v12/112)[*https://advances.sciencemag.org/content/6/19/eaat9488*](https://advances.sciencemag.org/content/6/19/eaat9488)[*https://www.sciencenews.org/article/quantum-computers-are-about-get-real*](https://www.sciencenews.org/article/quantum-computers-are-about-get-real)[*https://www.enterpriseai.news/2020/04/21/chemical-discovery-at-industrial-medical-companies-aided-by-carnegie-mellons-neural-network-tool/*](https://www.enterpriseai.news/2020/04/21/chemical-discovery-at-industrial-medical-companies-aided-by-carnegie-mellons-neural-network-tool/) [*https://thenewleam.com/2020/05/mapping-possible-solutions-to-the-covid-19-pandemic-the-urgency-of-an-interdisciplinary-approach/*](https://thenewleam.com/2020/05/mapping-possible-solutions-to-the-covid-19-pandemic-the-urgency-of-an-interdisciplinary-approach/)Regarding the first article, it also had an impacted audience which is both scientists, researchers, and startups. "Quantum simulations are widely believed to be one of the first useful applications of quantum computers," says Alexey Gorshkov, NIST theoretical physicist and co-author of the study. "After perfecting these quantum simulators, we can then implement quantum circuits and eventually quantum-connect many such ion chains together to build a full-scale quantum computer with a much wider domain of applications." In the first article below it is shown and discussed in detail the atomic advantage based on our first article. And having perspectives to implement quantum circuits and quantum computers, will bring a huge domain of applications, hence business perspectives. <https://physics.aps.org/articles/v10/95> <https://advances.sciencemag.org/content/5/8/eaax1568> <https://www.sciencedaily.com/releases/2017/11/171129131434.htm> Regarding the third article. With future quantum processors with much bigger volume will be able to explore the approach described in the article for many complex molecules, which classical computers are unable to explore. Which means that the new opportunities are connected with the ability to simulate chemical reactions accurately. If so, the business perspectives that it will allow to create new drugs, fertilizers and even new sustainable energy sources. This is more than one industry. Sources: <https://phys.org/news/2017-09-molecule-energy-quantum.html> <https://physics.aps.org/articles/v12/112> <https://venturebeat.com/2019/03/27/ibms-quantum-computation-technique-mitigates-noise-and-improves-accuracy/>

2. Two of the papers employ superconducting qubits, and were from research at large corporations, while one paper describes research using atomic qubits, performed at a research university. Based on how these results were received in the news press, can you see how the technology, and the research institution, made a difference in expectations for future developments?  
  
***Scoring criteria******(2 pts) Complete:*** *Compared which organization has more social and business impact: The university or the two large corporations. Gave an opinion about why the difference between them.*

Third article on [Hardware-efficient Variational Quantum Eigensolver for Small Molecules and Quantum Magnets](https://www.nature.com/articles/nature23879) is from IBM, one of the leading corporations in the sphere of quantum computing. And like the second article supported by the big corporation, these two had more non-scientific articles based on them with different perspectives of use and development of the technology in the context of business opportunities and problems that they are going to solve. We agreed that both organizations have an impact, but we would rather say that large corporations have bigger opportunities to apply research to solving real industry problems, aslo let’s bring this example: back when this research article was posted (2017) Google, had a nine-qubit computer and had huge plans to scale up to 49 qubits. IBM, like Google, also had huge plans. In March of 2017, the company announced it would build a 50-qubit computer in the next few years and make it available to be among the first adopters of the technology. Of course those numbers and the bar are much higher now, but the important thing is that both companies had a vision to create quantum computers which can be used in business perspectives and have a big capacity. Both three have social impact, but again we would say that big corporations have bigger social impact as well, as for example IBM creates enormous opportunities for scientists, new comers, everyone interested in quantum computing, also IBM are pushing their quantum computers to users via the Web. “A lot of these companies are realizing that they need people to start playing around with these things,” Devitt says. Same cannot happen in universities, they don’t have similar power, access to data hence similar impact. We think that the main difference is the core of motivation. Big corporations have a goal to be the first one in the market, hence develop everything as fast as possible and focus on things that will make quantum computers more effective and give that computers available among the first adopters of the technology. So here comes the motivation, goals and importance of timing. Also, the bigger impact you have, the stronger your organization is.

3. Imagine that you are responsible for investing the money of a company or a funding agency interested in the further development of quantum computation. Would you invest your money in your chosen paper's project? Why or why not?  
  
**Scoring Criteria  
(2 pts) Complete:** Gave **three** arguments on why they would or would not choose their chosen paper’s particular project to invest.  
**(1 pt) Partially Complete:** Gave **two** arguments on why they would or would not choose their chosen paper’s particular project to invest.  
Prepare a response for each of the following prompts below (300-500 words overall).

**1:** There is a whole scientific community interested in providing an indisputable proof that nature violates Bell's inequality. Explain why the Big Bell Test assures that they closed all the loopholes and what does it imply for our understanding of the universe.

John Bell,changed Einstein's vision of realism and now it is called “local realism.” With this mathematical description, he proved that Einstein’s view is incompatible with quantum mechanics. That means that there are experiments for which quantum mechanics gives one prediction which contradicts Einstein's prediction Bell’s work thus made it possible to test in the laboratory what had previously been a philosophical question. he Bell inequality must be satisfied by mutual cross-correlations of these data. This leads to the ultimate loophole in the Bell theorem: mutual cross-correlations of measured or predicted quantum data for three/four variables must satisfy a Bell inequality.At the same time there exists freedom of choice loophole which states that “the variables a and b can be considered as free or random” and if the setting choices “are truly free or random, they are not influenced by the hidden variables. Then the resultant values for a and b do not give any information about λ” . That’s why Big Bell Tests aims to get rid of freedom of choice loophole to support Bell’s vision and push forward quantum mechanics.

***Scoring criteria  
(2 pts) Complete:*** *Defined the concept of loophole in Bell's inequality context. Described the freedom of choice loophole. Summarized the arguments of the Big Bell Test collaboration about why they are closing the freedom of choice loophole.****(1 pt) Partially Complete:*** *Defined the concept of loophole in Bell's inequality context. Described the freedom of choice loophole.****(0 pt) Incomplete:*** *Defined the concept of loophole in Bell's inequality context.*

**2:** Gamification is a powerful tool that can be used in several contexts, such as marketing and generation of products. Explain how The Big Bell Test experiment utilized gamification for generating random numbers and imagine and discuss other possible applications of gamification in quantum computing.

Gamification is a very good mechanism not only in marketing but also in collecting data. Using gamification we can gather useful information, without our participant knowing about it. It gives us a better understanding of his/her real thought because if he/she knew about the experiment the outcome may differ. The same technique is implemented in the Big Bell Test Game. Participants played in 2 steps, in first one they inputted bits as fast as they could , and then they played a little predicting game. Each human-generated bit used in the experiment was thus the result of a unique and conscious decision process and that’s why it was a completely random generated number. The Gamification method will be useful for quantum computing as there are a lot of details, and theories that should be somehow tested. And gamification gives us opportunity to have a very big pool of random data, as then analyse it.

***Scoring criteria  
(2 pts) Complete:*** *Described how the Big Bell Test Game works. Explained the process done by the Big Bell Test collaboration for generating random numbers. Gave one possible application of gamification in quantum computing.****(1 pt) Partially Complete:*** *Described how the Big Bell Test Game works. Explained the process done by the Big Bell Test collaboration for generating random numbers.****(0 pt) Incomplete:*** *Described how the Big Bell Test Game works.*

**3:** Choose two of the thirteen nodes of the Big Bell Test experiment and compare their physical system, degree of freedom measured, rate of bits consumed and total number of bits, how where the bits used, how long the experiment took, and the distance between Alice and Bob.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Name | Physical system | Degree of Freedom | rate of bits consumed | total number of bits | how where the bits used | how long the experiment took | distance between Alice and Bob |
| Shanghai | Photons | Polarization | 1kbps | ~80M bits. | The bits were used to choose the measurement settings | two days | Around 87 meters |
| Buenos Aires | photon pair created from a single input photon | Photon polarization | 1.02bps | 33920. | Retreived bits from the server were used to rotate two half-waveplates, located at Alice and Bob’s setups | nine hours | 3.5 meters. |

**Scoring criteria  
(*2 pts) Complete:*** Compared the physical system and degree of freedom that each node used, and also compared the rate of bits consumed and total number of bits. Described how bits were used, how long the experiment took and the distance between Alice and Bob.  
***(1 pt) Partially Complete:*** Compared the physical system and degree of freedom that each node used, and also compared the rate of bits consumed and total number of bits.  
***(0 pt) Incomplete:****Compared the physical system and degree of freedom that each node used.*

### Which modality do you think would be the first to support a functional quantum computer?

Respond to questions 1 and 2 (300 words each)

1. Why do you think your chosen modality will be the first one in supporting a functional quantum computer? Compare at least three modalities.
2. Think about the second modality that might be also a good candidate and answer the same as above.

First of all I want to discuss 3 modalities that in my opinion are going to be more or less dominant, in the quantum computing future. These are superconducting qubits, trapped ions and linear optics quantum computing. I Want to talk about them in this specific order as I believe that the biggest future is behind superconducting qubits.This modality holds a promise for the longer-term goal of building large scale and error free quantum computers. While continued work on many aspects of this technology is certainly necessary, the pace of both conceptual and technical progress in the last years has been immersive.The fact that quantum computer should be scalable the superconducting qubits offer a lot of positive stats, and also they starting to make much more progress in fulfilling DiVincenzo criteria.  
Second one is trapped ions. Promising schemes in development to scale the system to arbitrarily large numbers of qubits made trapped ions one of the main approaches of creating quantum computers. Trapped ions' main scheme is transporting ions to spatially distinct locations in an array of [ion traps](https://en.wikipedia.org/wiki/Ion_traps), building large entangled states with photonically connected networks of remotely connected ios, and combinations of these two ideas. This and also the fact that ,as superconducting qubits, trapped ions are progressing in DiVincenzo criteria fulfillment, is why they are having a very big popularity and are one of favorites in terms of building large scale quantum computers,  
And a third one is linear optical quantum computing, where the activeness or absence of a photon comprises the qubit. Quantum data is prepared utilizing linear optical parts. Viable non-direct instructions are accomplished using single photon sources, photo-detectors, and so forth.The primary issue with linear optical quantum computing is that it's extremely difficult to make photons interact with each other.  
***Scoring Criteria******(2 pts) Complete:*** *Compared and discussed three or more modalities, and the arguments are completely consistent with the theory.   
Justified answer for the second chosen modality, explained assumptions and reasons. Arguments are completely consistent with the theory.****(1 pt) Partially Complete:*** *Compared and discussed three or more modalities, but the arguments are partially consistent with the theory.  
Justified answer for the second chosen modality, explained assumptions and reasons, but arguments are partially consistent with the theory* ***(0 pt) Incomplete:*** *Compared and discussed three modalities, but the arguments are not consistent with the theory.  
Justified answer for the second chosen modality, explained assumptions and reasons, but arguments are not consistent with the theory.*

### When do you think the first functional quantum computer will be created?

Respond to questions 3 and 4 (300 words each)

1. Why do you think it will take the time that you chose to create the first functional quantum computer? Argue at least two reasons.

First of all let me state that there are several important factors for creating a fully functional quantum computer.  
1. Well-characterized quantum two-level systems that can be employed as qubits.

2. An ability to initialize the qubits.

3. A set of quantum operations on the qubits, known as “quantum gates,” that is universal for

quantum computation.

4. An ability to measure quantum bits one by one, without disturbing the others.

5. Decoherence times that are long enough to be able to carry out the computation or error

6. Ability to interconvert stationary and flying qubits

7. Ability to transmit flying qubits faithfully between two locations

First of all we need a system where our qubits can be measured and kept. But for that we need a system with around -273 Celsius degree, so that we can stabilize our qubit and measure it. Keeping that degree constantly so that we can measure our qubit constantly is very hard, and a pricey task. Secondly it is very important to understand that if we are planning to make commercial computers, we will need millions of qubits, we can have physical systems that are a few hundred to a thousand qubits, however, it’s unclear exactly what types of software or applications that we’ll be able to run. There are two paths for growing the size of the system: One is to add more qubits, which would take up more physical space which can cause problems if we are talking and considering 1 million qubit computers..The other path is to shrink the inner dimensions of the integrated circuit, but that approach is unlikely with a superconducting system. The other path is to shrink the inner dimensions of the integrated circuit, but that approach is unlikely with a superconducting system, which tends to be large. So that’s why I think we should not concentrate on making the quantum system scalable, but we should take a scalable process — silicon manufacturing — and make it quantum. Also Since quantum programs are different from programs for classical computers, research and development is needed to further develop the software tool stack. Because these software tools drive the hardware, contemporaneous development of the hardware and software tool chain will shorten the development time for a useful quantum computer. In fact, using early tools to complete the end-to-end design (application design to final results) helps elucidate hidden issues and drives toward designs with the best chance for overall success, an approach used in classical computer design. I believe considering that technology is growing exponentially, in around 20-25 years we can have scalable and ready for use computers.

1. Think about the time frame of the second modality that might also be a good candidate. Argue at least two reasons.  
   We made a long point in the last question because we believe it will affect any kind of quantum computer and it is general issue, however concerning our chosen 2nd modality, trapped ions, we will discuss modal specific issues. FIrst of all there decoherence in the ion trap system. Decoherence in the ion trap system can probably be substantially reduced over what has been obtained in experiments so far. How far this reduction can be carried is an issue which must be resolved experimentally.Also there is another issue. Rabi rate for any operation is limited to approximately the motional frequency. An obvious direction to pursue is to make smaller traps with higher trapping potentials; however, this aggravates the problem of addressability, and will increase the coupling of the ions to the electrodes thereby increasing decoherence Thus taking that all into account we can state that these are mostly ion trap specific issues which should be solved to create first quantum computer. In my opinion those issues may be solved after a big step up of science not only in quantum computing field but also overall. Thus we can approximate around 25-30 years, so that the science and technology we be enough developed to create mass production for quantum computers.  
     
   ***Scoring criteria******(2 pts) Complete:*** *Justified answer for both chosen modalities, explained assumptions and reasons. Arguments are completely consistent with the theory. Argued at least two reasons.****(1 pt) Partially Complete:*** *Justified answer for both chosen modalities, explained assumptions and reasons, but arguments are partially consistent with the theory. Argued at least two reasons.* ***(0 pt) Incomplete:*** *Justified answer for both chosen modalities, explained assumptions and reasons, but arguments are not consistent with the theory. Argued at least two reasons.*