Q1: Which modality do you think would be the first to support a functional quantum computer?
C1: 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.

A1: Qubits are essential building blocks of any quantum computer. Researchers have different approaches to creating the physical manifestation of qubits. Big companies that invest heavily in quantum computing (e.g. Google, IBM, Intel) are focused on creating quantum computers powered by superconducting qubits, which, simply put, are electrical circuits acting as atoms.
Another variation of the physical qubit implementation is trapped ion qubits, which are being researched by research centers like the one in the University of Maryland. This technique is based on the same concept that was used in the creation of the world's most accurate atomic clocks.
Next variation of qubit technology is based on electron spins. Quite recently, researchers at Princeton University presented a result, which establishes this modality as a strong opponent to the rest of the competition.
One of the common grounds to compare the modalities is using the DiVincenzo criteria, which consists of 7 components that cover most of the aspects and requirements of a functional quantum computer. For most of the criteria trapped ions and superconductors are at the same level, that is it has been demonstrated that it is possible to scale them 100 qubit levels. However, each modality has its advantages and disadvantages properties, which impacts their prospects to become the first technology to power quantum computers.
The popular front runners in this are superconducting and trapped ion qubits. Other disadvantages of other modalities pose strong challenges to their development. If we consider different variations of electron spin qubits for example, we will notice that while it leverages an existing silicone technology, there are some strong shortcomings. In most variations, a 3D integration is required to make them work. In phosphorus doped silicon technology, the dopants must be placed to each other extremely close, to ensure sufficient qubit coupling. Moreover, the precision requirement with which the dopants must be placed is very high, which is again an outstanding challenge.
Considering the aspects that are known about modalities, we think that the first modality to support a functional quantum computer will be the superconducting qubits, for several reasons.
The first advantage it has over the competitors is the gate speed. It has the best gate speed for 1 and 2 qubit gates among all the competitors, while also maintaining a considerable advantage in fidelity against **some** competitors. In terms of DeVincenzo criteria, this modality is on par with all of the competitors, only being second to trapped ions in terms of coherence, which will be discussed later.
Another major advantage for this modality is the existing resources. The resources needed for the implementation heavily rely on the semiconducting technology that is present and is being used today, which makes it way more appealing for the investors.
Last but not least, this technology is being led by the "heavy hitters" of the tech world. Having a backing like this attracts more research and more funds towards this problem, accelerating the

development process and making the superconducting qubit based quantum computers that much more realistic. While this modality also has some limiting factors, such as the strict temperature requirements, gate connectivity limitations and short coherence, the reasons mentioned above make us bet on this modality to reach the finish line first.

As for the second modality, we believe that it will be the trapped ion technology for qubits. This modality holds some major technical advantages over the superconducting qubits.

The first advantage, as mentioned above, is better coherence. These qubits tend to hold on to information significantly longer, as long as they are undisturbed. Fidelity wise, these are the best in the competition, both for 1-qubit and 2-qubit gates.

Another advantage over superconducting qubits is the maintainability. These do not have the near absolute zero temperature requirements, which decreases the overhead significantly.

Also, trapped ion qubits are better connectivity wise. While the superconducting qubits support adjacent-only connectivity, trapped ion qubits have significantly better all-to-all connectivity to other qubits.

Of course, this modality also comes with its disadvantages. In terms of gate speed, it is well behind superconducting qubits, silicon quantum dots and electron spins.This is one area on which the future success of the method depends.

Another disadvantage is scalability. The lasers that used to make these quantum computers operational, are considered difficult to scale. But successful scaling of this, will bring us very close to trapped ion powered computers.

Taking all of this into account, while we believe that the superconducting technology will bring us the first operational quantum computer, the achievement of the trapped ion powered quantum computers will give us a more stable and reliable solution.

Q2: When do you think the first functional quantum computer will be created?
Why do you think it will take the time that you chose to create the first functional quantum computer? Argue at least two reasons.
Think about the time frame of the second modality that might also be a good candidate. Argue at least two reasons.

C2: Justified answer for both chosen modalities, explained assumptions and reasons. Arguments are completely consistent with the theory. Argued at least two reasons.

A2: There are a lot of speculations going around about when the first functional quantum computers will see the light of day. Every research group has their own understanding and expectations about this. For instance, Hartmurt Neven, the director of the Quantum Artificial Intelligence Lab at Google claimed that quantum computers follow a faster growth rate than the ordinary ones. If Moore's law claimed that the number of transistors in circuits doubles every ~2 years, Neven suggests that quantum computers are scaling at double exponential rate (2^{2^n}). This claim is not shared by other researchers, who even though believe that the progress is happening at great speed, but the double exponential rate is an overestimation.
As we mentioned, we believe that the first functional quantum computers will be powered by superconducting qubits. The rough estimation on when it will happen, according to us, is around some time around 2040's. To understand the estimation, let's look at the timeline of superconducting qubits. It was first shown in 1999 that superconducting circuits can act as qubits. Almost a decade later, the first demonstration of the CNOT gate using a pair of superconducting qubits was presented. It took another decade to create the first quantum error correction code using 4 qubits. After 2015, things started to pick up speed. In a matter of 5 years, we went from single digit qubits to more than 50 qubit quantum computers, and the number keeps growing. However, to make this functional (solve a real world problem like breaking the RSA1024), we would need 5 orders of magnitude more qubits and 2 orders of magnitude better error rate. There are many claims that quantum computing growth follows an exponential trend. If we analyze the growth rate as a power function, we will see that the fitted curve reaches the desired amount of gates somewhere around the 2040's.
One of the major flaws of superconducting qubits is their temperature requirements. Fortunately, this problem is not quantum computing specific, as physicists were researching the issue of reaching to near-absolute zero for years. And by looking at the achievements in this field, we could see that there is significant progress. While the current world record of low temperature was set in 1999 of 100pK, some alternative solutions yield much better results. In 2017, researchers managed to reach a temperature of 1pK in a space based lab, for more than 20 seconds. Also, considering the growing communication with space, if we interpolate the achievements to the future, we will see that in about 20 years (or even sooner) we will be able to achieve colder temperatures, which will reduce the error rate of superconducting qubits.
For trapped ion qubits, the picture is a bit different. As we believe that it will come later than the superconducting qubit based quantum computers, we're looking well into the future and making any assumptions about 50 years from now will be short sighted. But still, based on some

assumptions we estimate that the arrival of trapped ion powered functional quantum computers will be available in 2060's.
Again, we should examine the timeline of trapped ion qubit technology, to see where it is coming and where it is headed in the future. The first evidence of their potential to be used as physical manifestation of qubits came about 5 years later than for superconducting qubits. The first material results were announced in 2014, where a group of researchers demonstrated a quantum computer with 7 qubits. Fast forward to 2018, where the startup IoniQ presented a programmable 60 two-qubit gates commercial quantum computer. And looking at other achievements around this time, we have some samples of points in time, which could help us interpolate to the future. Again, we should take into consideration that the rate of growth for quantum computers is exponential. With this assumption, again, a fitted power function curve shows us our desired qubit count in some time around mid 2060's.
Also, we should consider the potential slowdowns that could happen. This technology is primarily researched by the non-corporate scientific world, so it depends a lot on government funding. And the funding is heavily dependent on the results. And as the growth rate for this technology is somewhat smaller, the results may not come as fast. This would result in decrease of government funding, which could slow down the growth of this technology, compared to the privately funded superconducting qubit research.