2 Project Plan

2.1 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project. At minimum, this section should have a task dependence graph, description of each task, and a justification of your tasks with respect to your requirements. You may optionally also include sub-tasks.

Required tasks needed to complete in order for successful completion of project:

1. **Research vast amounts of information related to quantum computing, quantum mechanics, and qubit design.**
    a. **There are several terms we need to fully understand in order to move forward onto the next step such as:**
        i. **Coherence time, entanglement, Rabi frequency and it's relationship with wavelength, quantum transconduction, quantum memory, quantu sensing**
    b. **We also need a solid amount of knowledge acquired relating to rare earth's (RE)**
        i. **For this project, we will be using a RE dopant with a suitable host (most likely also RE) to design a qubit with a coherence time of ~1 second.**
2. **After the research stage, we need to begin and develop our simulator to test for coherence time. This will be done in Python, and in order for it to work we need to really understand how the math works and relates to what we are trying to accomplish.**
3. **Once we build the simulator, we need to test different RE's based on its atomic properties and likelihood of being able to manipulate electrons.**
4. **Depending on how far we can get, our client wants us to write some sort of paper detailing our findings/discoveries.**

2.2 Project Management/Tracking Procedures

Which of agile, waterfall or waterfall+agile project management style are you adopting. Justify it with respect to the project goals.

Our project management style most aligns with the "waterfall" methodology. This is because our project has very distinct goals:

1. **Research and gather information regarding quantum mechanics, quantum computing, design of a qubit, and knowledge on rare earth dopants.**
2. **Develop a simulation that can test the coherence time of our proposed qubit design**

3. **Test different compounds to see which dopant and host yields a coherence time of ~ 1 second**

What will your group use to track progress throughout the course of this and the next semester. This could include Git, Github, Trello, Slack or any other tools helpful in project management.

For the mean time, we have been importing our research into a google drive folder, along with all of our assignments/presentations. We have also been using Discord to communicate and share helpful links.

Our projects proposed milestones and evaluation criteria are going to differ slightly from some of the other product-focused projects that other groups are working on.

The majority of the first semester is going to consist of mainly researching the quantum field and learning everything we can in order to develop a fundamental understanding of the physics and chemistry behind the quantum systems and materials we are working with

our mission statement, or purpose, is to Design a qubit with a coherence time of 1 second using a RE dopant and suitable host, which is the very definition of "easier said than done"

Our first task is to perform ongoing literature reviews to gather insight about the physics and chemistry of the materials we are working with and the equations that define their performance and material characteristics.

There are numerous factors we need to consider in order to develop a host-dopant system that yields the result we are pursuing.

Once a fundamental understanding is reached, we can then begin to develop python code that, when given the characteristics of a material, will be able to produce an estimated coherence time; the preface to this is that we work to ensure that the system will even work in the first place at a chemical and physics level.

the actual sequence of events we are uytilizing is similar to a sprint based approach, where we will research and develop a theory on what system will work, manipulate eth python code tosimulate that system and produce some characteristics, and then analyze those results to determine if we need to repeat the process or not

The ultimate goal of this semester is to obtain a fundamental understanding of how these quantum systems work and develop some amount of ideas of what to simulate. In addition to this, we hope to have at least some shell code that outlines howthe simulation is going to operate. It is likely that we will be able to produce a document containing a compilation of everything we have learned, and a clear direction of how to move forward.

2.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

What are some key milestones in your proposed project? It may be helpful to develop these milestones for each task and subtask from 2.1. How do you measure progress on a given task? These metrics, preferably quantifiable, should be developed for each task. The milestones should be stated in terms of these metrics: Machine learning algorithm XYZ will classify with 80% accuracy; the pattern recognition logic on FPGA will recognize a pattern every 1 ms (at 1K patterns/sec throughput). ML accuracy target might go up to 90% from 80%.

In an agile development process, these milestones can be refined with successive iterations/sprints (perhaps a subset of your requirements applicable to those sprint).

Our project is quite different from most of the senior design projects this semester. Most of this semester will be dedicated to learning/researching the quantum field and gaining a strong grasp of understanding how the physics/math/chemistry works.

The mission statement for our project is simply put: Design a qubit with a coherence time of 1 second using a RE dopant and suitable host.

However, that is not as easy as it sounds, since we haven't had a lot of exposure to quantum mechanics/computing outside of EE332 (semiconductor physics). And even from that course, we are learning that relating semiconductor physics to quantum computing is not as easy as we'd hope, forcing us to dive deep into reading material.

Building our simulator is also something we need to be extremely knowledgable about how the math relates to coherence time along with our chosen dopant and host. Before we are fully aware of this, it is hard to predict how our simulator will work and what important aspects need to be incorporated into it. There are several quantum terms that will need to be inputted such as: Rabi frequency, T1 and T2 times, quantum memory, quantum transconductance, etc.

2.4 Project Timeline/Schedule

• A realistic, well-planned schedule is an essential component of every well-planned project

• Most scheduling errors occur as the result of either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly complete the activity

• A detailed schedule is needed as a part of the plan:

– Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text.

– Annotate the Gantt chart with when each project deliverable will be delivered

• Project schedule/Gantt chart can be adapted to Agile or Waterfall development model. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.

Month	Task

Month 1	Research: Learning from our client, diving deep into research articles related to designing a qubit, and trying to understand complex quantum terms and definitions.
Month 2	Research: Learning from our client, diving deep into research articles related to designing a qubit, and trying to understand complex quantum terms and definitions.
Month 3	The beginning of the third month will still most likely be dedicated towards continuing research. About halfway through this month (maybe more near the end) we hope to begin building our simulator in Python.
Month 4	This month will be dedicated to finalizing our simulator and making sure all constraints and features required to know the coherence time of our qubit are correctly implemented.
Month 5	Test different RE dopants and hosts in the hopes we can find a successful pair that gives us a coherence time of 1 second. If this happens sooner than later, we will begin writing our paper (but that is unlikely to happen this semester due to the complexity of this project.)

2.5 Risks And Risk Management/Mitigation

Consider for each task what risks exist (certain performance target may not be met; certain tool may not work as expected) and assign an educated guess of probability for that risk. For any risk factor with a probability exceeding 0.5, develop a risk mitigation plan. Can you eliminate that task and add another task or set of tasks that might cost more? Can you buy something off-the-shelf from the market to achieve that functionality? Can you try an alternative tool, technology, algorithm, or board?

(Task 1) Research: There is zero to no risk in this stage of the project. The main outcome is to just put in a lot of time reading information related to our project. The hardest part of this section is purely just understanding the material. Our client has told us on many instances that it's highly unlikely that we are going to understand this material right away, and it is important to just keep re-reading until something starts to click.

(Task 2) Building simulator: This part of the project will most likely have the highest risk of success. In order for it to work, we need to have a strong understanding of what mathematical modeling is most important in determining our coherence time, along with the simulator being able to take information about our dopant and host material to

formulate a coherence time. Since we are still in the research phase, we will have to add more to this section on the risk which will be hard to truly know until we begin developing it.

(Task 3) Testing different RE dopants and host materials: This section also has a decent amount of risk that goes into it. In order for the simulator to actually work, it will need to know a lot of the chemical and physical properties in order to determine how it would react on the atomic level. We can definitely have a better idea of a dopants success from reading articles related to qubit design, but it will still take lots of trial and error until we hopefully find a suitable candidate.

2.6 Personnel Effort Requirements

Include a detailed estimate in the form of a table accompanied by a textual reference and explanation. This estimate shall be done on a task-by-task basis and should be the projected effort in total number of person-hours required to perform the task.

This project's largest task by some margin is found in the research, both for creating our simulator and for identifying promising compounds to simulate. We estimate that during the research period, we will be spending roughly 150 hours this semester, including the time already spent this semester.

Creating a simulator should take about 15 hours, once all the information required has been required.

This semester no simulations will take place, although actual simulation time once the simulator has been completed should be approximately 8 man hours.

Meetings are expected to take another 30 hours total this semester, although some less formal meetings may be classified in research.

2.7 Other Resource Requirements

Identify the other resources aside from financial (such as parts and materials) required to complete the project.

This project's output will be simulated compounds and a simulator, and so the only resources required are computers and information on compounds, which fortunately can be found online.