1 Conclusion

In this report, we've explored the basic concepts behind quantum computing - starting from the simplest case of building a code that can make quantum measurements (i.e expectation values of various gates) and the implementation of the quantum gates and quantum qubits, which serves as the building blocks for a quantum computing algorithm. As seen in the results sections, we were succesful in performing Bell measurements (see figure **??**) on our system, and also successfully performed the Hadamard gate on this Bellstate, resulting in the measurement presented in figure **??**. With this in mind, we can conclude that our initial, simplest quantum implementation worked as intended.
We then moved our focus on implementing the Variational Quantum Eigensolver (VQE) algorithm, and used this to compute the ground state energies of firstly, two simple Hamiltonian, both for single- and two-qubit system. We saw, as presented in figure (**??**), that our VQE algorithm managed to capture the complex nature of the Hamiltonian, namely the entanglement, and gave us a good estimate of the ground state energy. Since it should "turn around" at the avoided crossing we see in the figure (**??**), we can be certain that our VQE implementation for the simplest system was a success.

This was also the case for the two-qubit system, where we saw that the VQE algorithm managed to capture the entanglement between the qubits, and gave us a good estimate of the ground state energy.

In the study of the Lipkin model, using the encoding schemes presented in the article, and the code we've developed through the report, the VQE algorithm for the single-qubit system was able to compute the ground state energies extremely well (see figure (**??**)). For the more complex two-qubit system we see that, even though the VQE algorithm captures somewhat the entanglement properties of the system, it does fail to accurately compute the ground state energy for the highest levels of interaction. This shows room for improvement in our otherwise successful VQE implementation, and is a good starting point for further work.

In conclusion, we have successfully implemented a simple quantum computing algorithm, the VQE algorithm, and used this to compute the ground state energies of two simple Hamiltonians, and the Lipkin model.