CSE 470N B

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26th January 2023

Lecture notes from the 2023 undergraduate course Quantum Computing, given by Professor James D Kiper at Miami University at Benton Hall in the academic year 2022-2023. This course covers introductory quantum computing concepts. Credit for the material in these notes is due to Professor James D Kiper, while the structure is loosely taken from the in-class lectures. The credit for the typesetting is my own.

Disclaimer: This document will inevitably contain some mistakes–both simple typos and legitimate errors. Keep in mind that these are the notes of an undergraduate student in the process of learning the material, so take what you read with a grain of salt. If you find mistakes and feel like telling me, I will be grateful and happy to hear from you, even for the most trivial of errors. You can reach me by email, in English, at sayahie@miamioh.edu.

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Thu, 26 January 2023, 2:50pm – 4:10pm

Lecture 1: Week 1, Thursday

Definition 1.1

A *bit* is a binary digit that can take on one of two values, 0 or 1.

Definition 1.2

A *qubit* is analogous to a bit in a quantum computer, but can take on a superposition of the values 0 and 1–it can be in a state of 0 and 1 at the same time.

Definition 1.3

The *planetary model of the atom* is a model of the atom in which the electrons orbit the nucleus in a circular orbit. The planetary model of the atom was developed by Niels Bohr in 1913.

The Stern-Gerlach experiment, first successfully performed in 1922, demonstrated that the magnetic field of an electron can be used to separate the electron into two different states, one with a magnetic field pointing up and one with a magnetic field pointing down. Silver atoms with random spatial orientations were sent straight between two magnets, with the atoms hitting a detector on the other side. The detector was able to detect which direction the atoms were moving in, and the results showed that the atoms were split into two groups, one with a magnetic field pointing up and one with a magnetic field pointing down–'the magnetism was quantised'. This was not expected–the initial hypothesis was that the atoms would form a continuous pattern instead of falling onto two points on the detector, as the spatial orientations were random.

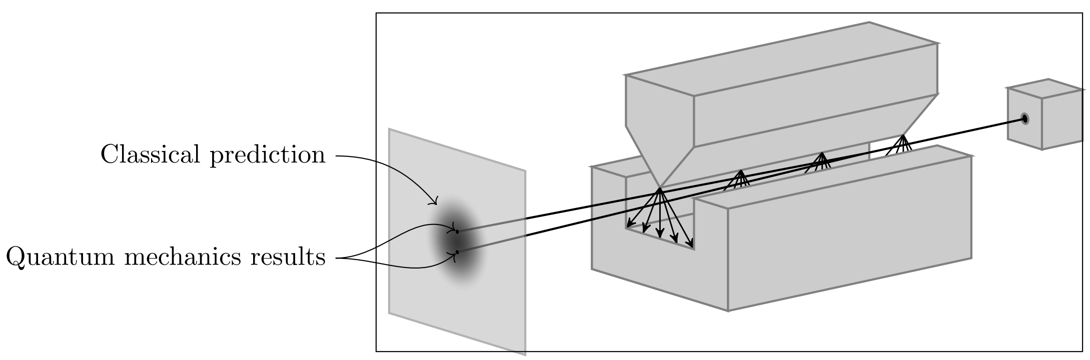

Figure 1: Stern-Gerlach Experiment

Figure 1 designed by Clemens Koppensteiner

Note:-

An electron orbiting in a circular orbit generates a magnetic field.

Particles have some properties, such as 'colour' (with two possible values: black or white), and 'hardness' (with two possible values: soft, hard). We can build detectors that, when given many particles, show a long-run probability of detecting a particle with a certain property. These detectors can be repeated (eg, a colour detector followed by another colour detector) without the probability changing. These detectors demonstrate that the properties are also probabilistically independent (as in, the results are not correlated between a particle's colour, hardness, etc).

Definition 1.4

The *uncertainty principle* states that the probability of detecting a particle with a certain property is inversely proportional to the probability of detecting a particle with a different property. This is demonstrated in Figure 2. In other words, the more certain we are of detecting a particle with a certain property, the less certain we are of detecting a particle with a different property.

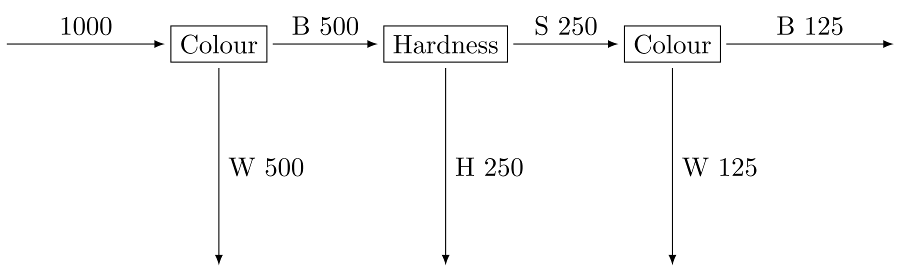

Figure 2: Repeated detectors that detect colour and hardness, demonstrating the uncertainty principle. By measuring the hardness, we became uncertain of the colour.

Notes