Quantum Physics

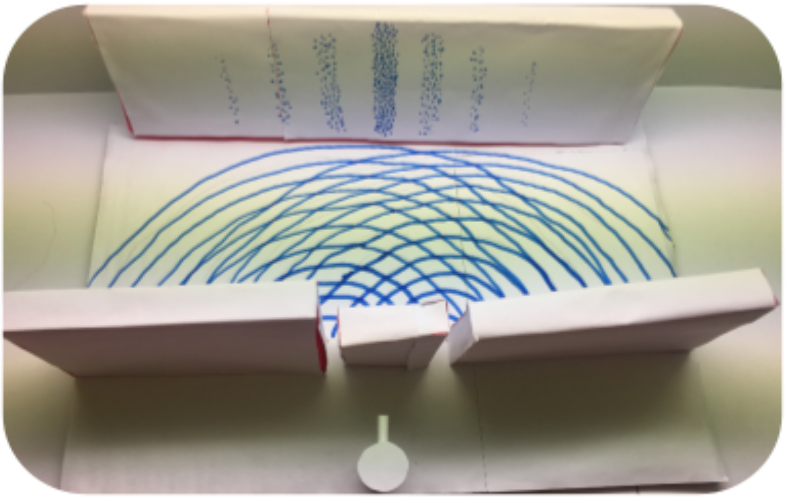
Quantum physics is a hypothetical theory that explains the properties of matter and energy at the subatomic level. It attempts to predict the behavior of molecules and atoms and their components such as quarks and leptons. These particles behave strangely, and often contradict with real life notions and the theory of relativity.

Wave Particle Duality

Wave particle duality introduces the idea that particles can act like particles and waves. This behavior was first observed with photons and electrons in the double slit experiment.

The wave particle duality is only seen in subatomic particles, and is a quantum principle. In everyday life, we see waves (sound waves, ocean waves) and particles (ball, car, earth, sun) all the time and we know they are two separate things. However, in quantum mechanics, a particle can act as both waves and particles. This is proven with the famous "Double Slit Experiment," first conducted by Thomas Young in the early 19th century. In this experiment, photons (light particles) are shot at a barrier with two slits, and the places they land are marked on the screen behind it. If we conduct this experiment with life-size objects, they will either pass through one of the holes and land on the area directly behind the hole, or they will be stopped by the barrier. But when we used photons or electrons, they created the wave intersection pattern on the screen as shown below. The blue dots indicate the probability of particles landing in that area. If the lines are thick, the probability of particles landing in that area is high, but if the lines are thin, the probability is less. Erwin Schrodinger wrote an equation that can be used to calculate the probability of finding a particle in a certain location. But he also stated that the more accurately we know a particle's position, the less accurately we know its momentum and vice versa, making it hard to detect them. This may be because of the particle's wave like behavior.

Small particles, the size of electrons and photons, have the ability to act like waves and particles. When an electron is in the form of a wave, we can only predict the probability of finding it in a specific location at a specific time interval but we'll never know with certainty where it actually is.



This is the Double slit experiment that proves particles can act like waves. Instead of passing through the two slits or getting stopped by the barrier, the particles created the interference pattern only seen in waves.

Entanglement

Quantum entanglement is a physical phenomenon where the properties of a particle cannot be determined independently of its partner. Even when separated by a whole universe, these particles are connected and can communicate and change their features accordingly.

Entanglement, also known as ‘spooky action at a distance’ is the connection between two or more particles. If you affect one of them, you will affect the other. For example, if one entangled particle is measured and is found to be spin up, its entangled partner should be spin down no matter where it is. The reason this was named ‘spooky action at a distance’ by Einstein is because these pairs seem to be communicating at speeds greater than the speed of light across great distances, contradicting the theory of relativity. To help you imagine, pretend you have two spinning wheels with two colors red and green with a 50% chance of landing on green and red. When one wheel stops on the color green, the other is guaranteed to stop on red. Albert Einstein found this very disturbing, so instead, he thought these two entangled particles had a definite spin and there was no communication between the two particles. He proposed that entangled particles were like a pair of gloves. Let’s imagine we separated two gloves and put a right hand glove in the first box and a left hand glove in second box and sent them to different places. If a person looks at one box and finds a left hand glove, the person knows that the other box contains a right hand glove even when nobody looked inside the box. Although this idea is more intuitive, it isn’t accurate in the microscopic realm.

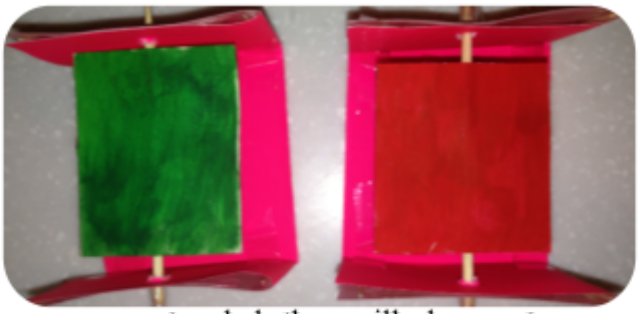
In the 1960s, Irish scientist John Bell thought of an experiment to find out who was right Einstein or Quantum Mechanics. The first Bell experiment was conducted in the year

1981 by Alain Aspect's team. In this experiment, a machine measured hundreds of entangled particle pairs to see if entanglement existed. It turned out 5 out of every 9 entangled pairs were actually entangled. But these tests were inaccurate, since there were detection and communication loopholes. The detection loopholes were caused, since only some of the photons were detected and 80% of them were lost during the experiment. The communication loophole was caused since the photons were close enough to communicate with each other. To solve these problems, Ronald Hanson of Delft University of Technology created a new technique: entanglement swapping. In this experiment, the researchers started with two separate atoms each in a diamond chip and entangled them to two separate photons. The atoms were placed 1.3 kilometers apart from each other. The two photons were zapped to a third location and they became entangled, so all four subatomic particles became entangled. Using this technique for a duration of nine days, the team generated 245 entangled pairs, which were easy to monitor and far enough to prevent communication. This team used entangled particles to detect eavesdroppers. The first particles of entangled pairs were sent to one user, and the second particles were sent to the other user. These photons were used to make a cryptographic image that only the users knew. If somebody tries to eavesdrop, the properties of the photons will change, setting off an alarm.

Entanglement can also be used to teleport elements. Scientists have already succeeded in sending the quantum state of a photon 6.2 km across Calgary, Canada and 14.7 km across Shanghai, China. In these experiments, there were two entangled particles. The first entangled particle copied information of the photon that'll be teleported and sends the information to its entangled pair. While information is being sent, the original photon gets destroyed and the second entangled pair becomes an exact copy of the photon. Today, this technique can't be used on big objects or humans, since there is too much information to send, and during the process the original gets destroyed.

Entanglement is a phenomenon where the properties of a particle are connected to another particle. They seem to be able to communicate and act in accordance of each other.

Superposition



If these two spinners were entangled, they will always stop on opposite colors no matter how far they are. In quantum mechanics, the particle's colors aren't the opposite, but the spin is.

Superposition is a principle in quantum physics describing particles' ability to reside in multiple places at the same time. It introduces a complicated reality that an object can be here and there at the same time, and a "quantum" cat can be both alive and dead at the same time.

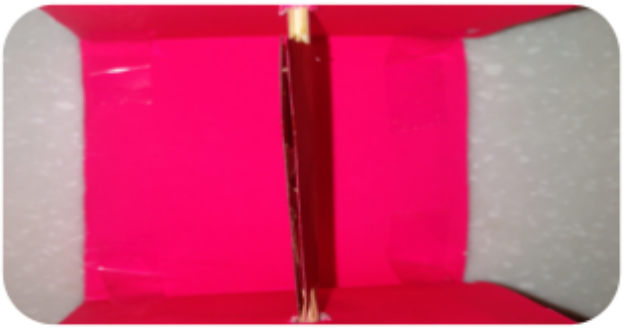
Superposition states that a subatomic particle can be in all the possible places at the same time. Only when we measure it, we force it to choose a specific location and all the possibility and uncertainty disappears. To understand this strange principle, Erwin Schrodinger made a theoretical thought experiment about a cat. Let's imagine we put a cat in a steel box with a deadly acid in a vial and a radioactive substance. When a single atom of this radioactive substance decays, it affects a hammer to move, break the vial with acid, and kill the cat. However, we don't know when the substance will decay, making it impossible to know if the cat is dead or alive. So in quantum mechanics, the cat is both dead and alive. The only way to know is to open the box and see the cat. This experiment indicates that the act of observation forces the 'quantum' cat to choose between dead or being alive.

The double slit experiment has also been used to prove superposition. When we are not observing, the photons that enter through the slits act as a wave of probability and create the wave's interference pattern on a screen. To further explore superposition, scientists decided to observe the electrons to see how they acted. But when observed, the photons acted like life size objects, remained in one position and created two lines, directly behind the two slits. But when the scientists didn't observe the particles, they acted like waves. To prove their theory, scientists tried observing the particles after they entered the two slits but before they touched the screen. At first, it acted like a wave. But since we decided to observe it, the photons created the pattern with two lines. Scientists came to a conclusion that when we

observe the particles, we send photons that somehow affect the particles and force them to choose one position.

Superposition is also used in quantum computers. These computers can solve problems much faster than normal computers, since they have cubits that can be in multiple places at the same time, go through obstacles, and share information. Cubits are bits that can be 1, 0, or both. This increases the quantum computer's speed and accuracy. Today, these computers are huge and need lots of energy, but the results are promising.

Superposition proves that electrons can be everywhere at the same time. Only when we measure its position, the superposition collapses and the particle chooses a location.



Superposition in Quantum Mechanics is the ability to reside in different places at the same time, or have different properties at the same time In the picture above, when the spinner is spinning, it's color is both green and red.

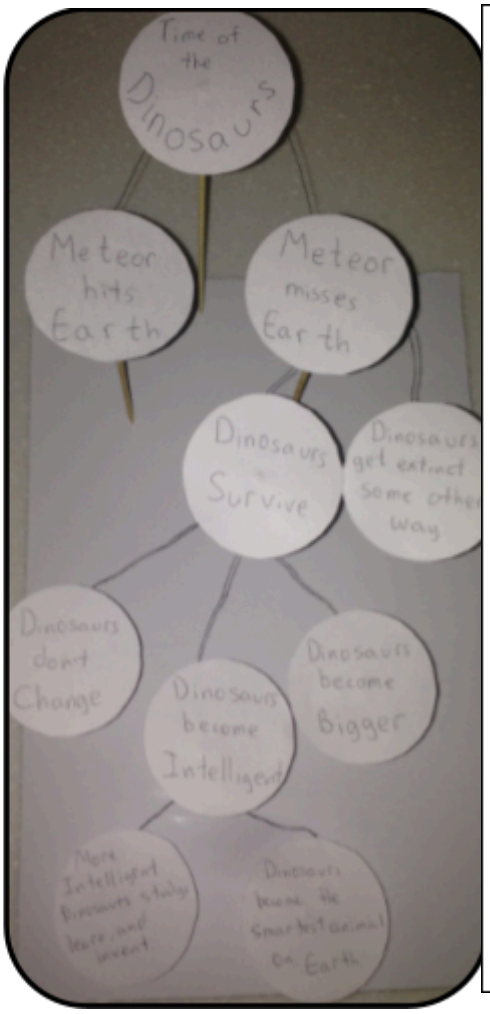
Multiverse

The multiverse suggests that there are different universes, each wih different outcomes. These changes and differences may be drastic, or minor.

By using the many worlds theory, scientists believe there are many universes, and everything possible happened. In those universes, there might be extreme differences such as different physical laws, different life species, etc. and there might be small differences such as people having different lifestyles or characters. But if the multiverse principle is true, all the possibilities mentioned above and more are happening at this instance. For example, if you had a choice, even a small one such as kicking the ball in a soccer tournament as opposed to missing the ball, the universe separates into two different worlds. In the first one, perhaps you got lucky and scored a final score and got in first place, and in the second one, you didn't kick the ball so you didn't score and you got in second place instead. This is merely a minor choice that has minor effects. But some decisions and changes may have huge consequences. For example, if the pull of gravity was less after the big bang, maybe the universe wouldn't have formed at all.

Scientists have theorized four different universe possibilities, which include: Infinite universes, Bubble universes, Parallel universes, and Daughter universes. Infinite universes are believed to continue forever. Since scientists predict our universe to have existed for 13.7 billion years, that's how much time light had to expand. Therefore, the universe is expanding all the time. But ahead of the universe's boundaries, there are other universes growing just like our own. But even though universes may continue forever, there are limited amounts of ways particles can exist in space and time. So it is possible that each person has an infinite amount of twins. Some of these twins may be exactly the same as us, others may be living a different life than us, and others may have different personalities than us. Another theory is the bubble universes. This was invoked by the idea of eternal inflation. It is believed that universes expanded by inflating greatly right after the big bang. This idea was first proposed by cosmologist Alexander Vilenkin, who believed some universes, continued to inflate, while others stopped, creating a massive ocean of bubble universes. In our universe, inflation has ended or slowed down, which gave stars and complex bodies to form. In other bubbles, there might be a minor change in the conditions that caused a vast amount of different physical laws, celestial objects, and life. Parallel universes suggest that instead of forming bubbles, like the bubble theory implies, these universe float slightly above or below each other. Most of the time, these other universes are out of reach for us, but when they slam into each other, they cause a big bang, creating a new, different universe. Finally, there are daughter universes. These universes are said to be created when the universes split into the different number of probabilities each time somebody makes a choice.

The multiverse theory suggests that there are different universes and each of them is different.



The multiverse daughter universes theory suggests that when there are two or more possibilities, the universe splits in two or more number of different universes where the outcomes are different. In this example, there are 6 possible outcomes.

- Meteor hits earth and the dinosaurs get extinct
- Dinosaurs get extinct in some other way
- Dinosaurs remain the same.
- Dinosaurs become bigger and scarier
- Dinosaurs become intelligent like humans
- Dinosaurs become the smartest animals on Earth.

Tunneling

Tunneling in quantum mechanics makes it possible for subatomic particles to disappear and appear in different places. This is made possible due to the wave like behavior.

Tunneling in quantum mechanics is the ability to go through barriers and jump from one position to another without travelling through the distance in between. This is detected when electrons jump to different orbitals and when the hydrogen atoms in the sun fuse together to create energy. Due to the wave properties of a particle, there is a chance of finding a particle on the other side of the barrier or in a different position. In the sun, there is a slim chance of two hydrogen atoms fusing and creating energy. The many hydrogen atoms in the sun create enough energy for it to continue to burn. In the quantum leap, electrons jump up and down to different orbitals and create light energy in indivisible amounts, called quanta.

The principle of quantum leap is used to make a laser. The word laser is an acronym for light amplification by stimulated emission of radiation. In stimulated emission, an atom will get excited, which means it gets energy from a photon with a specific amount of energy that influences the atom to emit light. In doing so, the atom emits two identical photons with

the same wavelength, direction, and energy. When these two photons encounter two other atoms, they will get excited and will emit four identical photons creating a chain reaction. For this reaction to continue, the atoms always need to be in the excited state, so they don't use the energy from the photons for absorption. This action is called optical pumping that makes population inversion possible to continue the reaction. These photons and atoms will be put in a case with a mirror on one side and a semitransparent mirror on the other side. The photons will bounce back and forth and the light will be amplified. Only when the photons reach a specific energy level, will they be released through the semitransparent mirror.

Tunneling is a quantum principle that gives subatomic particles the ability to go to different places. This effect allows electrons to create specific colors, and enables the sun to burn.

Time traveling

Time travelling can be caused by time dilation, worm holes, or the difference of time for stationary and moving objects. It can be done by humans, particles, and machines.

Life size objects can time travel as well using the effects of time dilation. Time travels slower for astronauts who fly around the earth compared to people on earth. This scenario is known as time dilation, where time acts differently for a person travelling at great speeds in a rocket, compared to a person on earth. The greatest time traveller is Russian astronaut Sergei Krikalev, who time travelled into his future by 0.02 seconds by spending 308 days 9 hours, and 39 minutes in space and traveling at 17500 miles per hour. In the 20th century, Einstein did a thought experiment to further understand time. He imagined a man named Jack on a train, dribbling a ball. Jack sees the ball going up and down, but a woman named Jill, who's sitting outside the train sees it travel in a triangular direction, for a longer distance, but saw it moving faster. But if Jack had two mirrors that were bouncing a beam of light, Jack and Jill cannot disagree on the time. If the speed is the same and the distance is different, time taken should be different, indicating time travel. This also works for people. If Jack and Jill both had synchronized watches before Jack boarded the train, and compared the watches afterward, Jack travelled faster, and spent less time. In the 1970s, scientists boarded a rocket with highly accurate watched, synchronized with the scientists left on Earth. After traveling around the world, the clocks of the scientists left on Earth showed a longer time, and the scientists who boarded the plane spend less time. This time dilation affects machines, such as the clocks of the Global Positioning System satellites. When measured accurately, the clocks on the GPS satellite disagree with the clocks on earth by 7 millionths of a second every day. This may seem small after one day, but after a longer period of time, this will cause GPS to

loose accuracy. But this is for objects moving with a small speed. If we can make machines that can travel to speeds closer to the speed of light, we can time travel into the distant future. If we board on a rocket that can move 99.9999% of the speed of light, ten years on the plane will be equal to approximately 7000 years on planet Earth.

But there are several different ways we may be able to time travel: spending time near a black hole, travelling through wormholes and riding on the fabric of space and time. The immense pull of gravity of a black hole causes space to warp. If space and time are connected, this will also affect time and slow it. If we manage to spend time near a black hole, we might be able to travel to the future while aging less. Another possible way is to ride on warp space. If we can make space expand behind the spaceship and shrink in the front, we might be able to create a warp bubble that travels at the speed of light. Today, this may be impossible to create, but in the future, we may be able to create warp bubbles and use them to travel through space and time. But these techniques for time travel take time. For a rapid travel, we should consider going through a wormhole. Wormholes are passageways in space with varying lengths and sizes. They can be found in space, but are very small, mostly the size of atoms. In the future, we might need to grow these wormholes to bigger sizes before we can use them.

Today, time travelling seems like science fiction, but in the future it may become a reality.

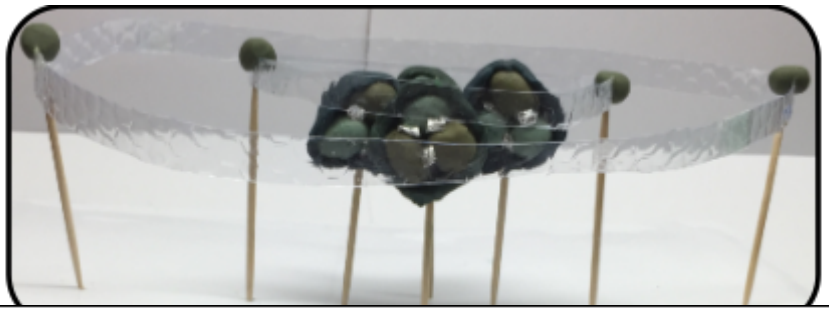
Fermions and Bosons

All matter and energy is created with fermions and bosons. Fermions include quarks and leptons and bosons include Gauge bosons and Higgs bosons.

Fermions create matter (quarks and leptons) and bosons are force carriers (Gauge bosons and Higgs bosons). There are six different ‘flavors’ of quarks: up, down, strange, charm, top, and bottom and there are six leptons: electron, muon, tau, electron neutrino, muon neutrino, and tau neutrino. Protons and neutrons are made up of three quarks each. The protons are made of two up and one down quark and the neutron is made of two down and one up quark. Strangely, the spin for the down quark is -⅓ and the spin for the up quark is ⅔, making a neutron neutral and a proton positively charged. There is the Higgs boson and five different types of Gauge bosons: gluon, photon, W, Z, and graviton that create four different types of forces: strong, electromagnetic, weak, and gravity. The Higgs boson connects together to make the Higgs field, that give matter their mass. The gluon carries the strong force that keeps the quarks in the proton and neutron and the protons and neutrons together in the nucleus. The photon is light energy. It is used to hold the electrons in the atom. The W

and Z forces are the weak forces. The weak force causes nuclear fission and decay and plays a role in how the sun burns. This force is actually stronger than gravity, but is called weak since it is only effective for short distances. Lastly, the graviton is the force of gravity. This force is almost the exact opposite of the weak force. In reality, it is weak but can be felt across great distances.

The fundamental parts of the universe are made of atoms and forces, which are made of fermions and bosons.



In this picture, the dark blue hemispheres are protons and the dark green hemispheres are neutrons making the nucleus. The little grey spheres are up quarks and the little green spheres are down quarks. Lastly, the dark green spheres surrounding them are the electrons.

QCraft

QCraft is a special minecraft mod that incorporates some quantum physics principles to the game. It gives players a basic understanding of the quantum world through interesting blocks and properties.

QCraft is a special mod that can be downloaded onto minecraft and teaches children some properties of quantum physics and their uses. These properties include: observational dependency, superposition, and entanglement. Observational dependency shows that observing a particle changes it. So this property can be used to make a block that looks like it's made from different substances when you look at it from different angles. In minecraft, it's possible to use this property on large scale objects and can even make them invisible. Superposition of a block means it can become different substances randomly. In minecraft, this can be used to make a block that is both gold and diamond. This can also work on bigger objects, like a wall that has a doorway and doesn't have a doorway at the same time. It can be used to trick people into thinking it's just a wall, but can have a doorway depending on when and how you observe it. Entanglement is the connection between two or more blocks that can communicate and change their property according to their entangled pair. In minecraft, it can

be used to make two or more light bulbs that all light up when you look at one of them and turn off when you look at it from a different angle. These properties can be used in many different ways such as teleporting, making invisible buildings with hidden surprises, and more.

QCraft is a great tool that helps players understand the properties of subatomic particles and incorporate them to teleport objects, make disappearing buildings, traps, and more.

Conclusion

Quantum mechanics is the study of the properties of atomic and subatomic particles. Particles can act as waves, they can go through solid objects, two entangled particles can share information over great distances, particles can have multiple different spins at the same time, and quantum theory suggests that we might live in one universe among a collection of universes.

Matter is made of fermions and the forces are made from bosons. There are two different type of fermions: quarks (up, down, top, bottom, strange, and charm) and leptons (electron, muon, tau, electron neutrino, muon neutrino, and tau neutrino) and two different types of bosons: Higgs bosons and Gauge bosons (photon, graviton, gluon, Z, and W). The Higgs boson creates the Higgs field, which give objects their mass. A photon is a light particle and graviton is the force of gravity. Gluon is the strong force that keeps the quarks in the protons and neutrons and the protons and neutrons in the nucleus. Z and W are the weak forces that are actually strong and are called weak, since they are only effective for short distances (billionth of a meter). These particles act differently than life size objects and have physical rules of their own.

Particles aren’t limited to a specific place, time, or universes. They can be in multiple places with their superposition, in different times, and possibly different universes. Whenever we aren’t looking at or observing these particles, they may reside in multiple different places in a haze of probability, so it can be here, there, and everywhere. Only when we measure it, the particle will decide on a specific position and the wave will collapse. Bigger objects can’t be in multiple different places at the same time, since there are thousands to trillions of atoms, connected as one whole which stops its ability to act as waves. Using this property, particles can go through solid objects. This is possible, since a small end of the wave is on the other side of the object, making it possible to be there when somebody measures it.

Entanglement is when two particles are mysteriously “connected” and can constantly share information with each other. For example, if one of these particles is measured to be a

spin up, its pair is sure to be spin down and vice versa. Using large amounts of entangled pairs, scientists can create an eavesdropper catcher. The first particle of the pairs is sent to the first user and the second is sent to the second user. These users each create a cryptographic key which they can use to enter the information. When an unauthorized person tries to see the information, the property of the entangled pairs change. Entangled particles can also be used to teleport particles. If a scientist wants to teleport a photon, they will first make the photon interact with the first particle. That particle collects information about the photon and sends it to its pair. During the process, the photon gets destroyed and the second entangled particle becomes an exact copy of that photon.

The multiverse theory suggests there are different universes each with different forces and laws, and together, everything which has a possibility of happening did happen. These universes may be separated by distance, borders, and dimensions. If universes are infinite, and there are only a finite number of particles, atoms, and objects, they should overlap. This suggests there are an infinite number of everyone, even you and me. But our "twins" are living a slightly different life than us. If the universes are separated by dimensions, it means somewhere, there is a universe with two dimensions, four dimensions, five dimensions, and so on. But, each of these universes is different and the objects, planets, and stars are different as well.

QCraft is a minecraft mod that uses the quantum properties to make interesting objects, buildings, traps, and inventions that seem to be possible only in science fiction. It uses the properties such as entanglement, superposition, and observational dependency to teleport objects, make disappearing buildings, traps, and random events. The observational dependency can be used to make an object look like gold from the north side, diamond from the east side, wood from the south side, dirt from the west side, nothing from the top, and emerald from the bottom. This can be used to make a door that can only open when looked at from a particular position or a bigger object, such as a building change shape depending on the angle you observe it from. Superposition is similar to this, but it's much more random. It doesn't matter which side you look at an object, since the change is irregular. Entanglement can be used to make many different blocks change form depending on one block. Maybe all the lights turn on only when one of them is affected. If the quantum computer is entangled to another quantum computer, it can be used to teleport objects, and even buildings.

Reflection

After researching about Quantum Physics, I believe we can use the properties mentioned above to go to other universes and understand them like we understand our own. To do this, we need to understand wave particle duality, tunneling, entanglement, and superposition. Researching about the wave particle duality principle to comprehend it at a deeper level might give us the knowledge to control it. This will make it possible for us to influence molecules and atoms in an object to become a wave. Through entanglement, the waves can connect with each other to act as one. This might make tunneling possible for more than one atom or molecule. When we can use this to travel around the world, it would be much quicker and effective, sort of like teleportation. Bringing it to a different perspective, tunneling may be useful to travel to different universes where there are different physical laws, conditions, and lives. By understanding superposition at a deeper level, we may be able to live in multiple different universes at the same time. By entangling all our bodies and minds, we should be able to share thoughts, ideas, and information. It might be like living different lives at the same time. These are just thoughts, but they might become a reality in the future.

This picture shows me with my models after completing them.

Bibliography:

"Can a Game Teach Kids Quantum Mechanics?" *Quantum Frontiers*, Spiros, 29 Oct. 2013, quantumfrontiers.com/2013/10/17/can-a-game-teach-kids-quantum-mechanics/.

Coolman, Robert. "What Is Quantum Mechanics?" *LiveScience*, Purch, 26 Sept. 2014, www.livescience.com/33816-quantum-mechanics-explanation.html.

DovBaron. "What Is Quantum Physics?" *YouTube*, YouTube, 17 Sept. 2010, www.youtube.com/watch?v.

Fermilab. "Fermion and Bosons ." *YouTube*, YouTube, 13 Jan. 2017, www.youtube.com/watch?v.

LondonCityGirlMag. "Quantum Mechanics for Dummies." *YouTube*, YouTube, 14 May 2015, www.youtube.com/watch?v=JP9KP-fwFhk&t=131s.

"Physics for Kids." *Ducksters Educational Site*, Ducksters, www.ducksters.com/science/physics/elementary_particles_quarks.php. "QCrafting Episode "Quantum Physics For Kids." *Real World Physics Problems*, www.real-world-physics-problems.com/quantum-physics-for-kids.html.

Scientific Documentaries. "Quantum Universe and Entanglement Science Documentary." *YouTube*, YouTube, 19 July 2015, www.youtube.com/watch?v=5o_oRRREPFM.

TEDEducation. "Is Time Travel Possible? - Colin Stuart." *YouTube*, YouTube, 21 Oct. 2013, www.youtube.com/watch?v=7H3ksmxwpWc

Worldsciencefestival. "The Invisible Reality: The Wonderful Weirdness of the Quantum World." *YouTube*, YouTube, 22 Aug. 2014, www.youtube.com/watch?v=IxRfDtaot5U.

WorldScienceU. "What Is Entanglement, or 'Spooky Action'?" *YouTube*, YouTube, 21 July 2014, www.youtube.com/watch?v=Fz42YkX7HLw.

1Veritasium. "Quantum Entanglement & Spooky Action at a Distance." *YouTube*, YouTube, 12 Jan. 2015, www.youtube.com/watch?v=ZuvK-od647c.

2.1: Quantum Teleporters ." *YouTube*, YouTube, 17 Oct. 2013, www.youtube.com/watch?v.

Advexon. "Quantum Theory - Full Documentary HD." *YouTube*, YouTube, 25 May 2014, www.youtube.com/watch?v=CBrsWPCp_rs.