Quantum Measurements Generating Forces with Heisenberg's Uncertainty Principle. An Alternative Understanding of Quantum Mechanics by Using Concepts From Thermodynamics, Special, and General Relativity.

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Abstract

According to Heisenberg's uncertainty principle, changing the uncertainty in a particle's position through measurement changes the particle's momentum. Newton's second law states that a changing momentum is due to a force on the particle. Therefore, changing the uncertainty in a particle's position through measurement changes the particle's momentum and generates a force on the particle. Understanding the consequences of measurements creating forces requires a conceptual derivation using thermodynamics and relativity concepts.

Motion is not absolute; a quantum particle requires a second particle to provide a relative position and momentum. A measurement generates a force and creates a non-inertial reference frame. Without a measurement, velocity, momentum, and position are undefined. The particle occupies every possible allowed state simultaneously until a measurement defines the observables, increases entropy, and collapses the wavefunction.

Many quantum mechanics interpretations use the complex wavefunction to obfuscate the underlying mechanics. Interpretations describe observable particle properties as consequences of ideas which science cannot falsify. It is impossible to measure imaginary numbers experimentally. The Heisenberg uncertainty principle eliminates the need for the Born rule, as it already contains the squared wavefunctions. Applying oscillating uncertainties provides a logical mechanism for forces and extends into the spherical harmonics of atomic physics.

The theory of quantum mechanics accurately describes experiments and observations. At the heart of the theory are cognitive dissonances and many difficult concepts to grasp:

- Measurement and observation.
- Nonlocality.
- Indeterministic probabilities.
- The wavefunction's collapse.
- The ontology of the wavefunction.
- Uncertainty principles.
- Understanding forces.

Being in a state of cognitive dissonance is exceptionally unpleasant. The theory is correct, but the consensus is that quantum mechanics is hard to conceptualize. Cognitive dissonances resolve when using the postulates and concepts of relativity and thermodynamics. I hope to provide the reader with relief that quantum mechanics is behaving as expected.

Relativistic, Thermodynamic, and Probability Concepts:

- Motion is not absolute.
- The twin paradox is resolved by using non-inertial reference frames.
- The simultaneity of events is not absolute. The order of events is relative.
- Nonlocal phenomena happen when causality is missing.
- Entropy increases.
- The thermodynamic arrow is the arrow of time.
- A particle is equally likely to be in any of its microstates.
- Absolute zero cannot be reached.
- There are uncertainties between some observables.
- The uncertainty principle can replace the wavefunction and eliminate other quantum interpretations.
- Changing uncertainties generates forces.

1 Relativity Concepts

1.1 Motion is not absolute. Motion is relative.

In the vacuum of space, an astronaut floating alone cannot determine their velocity and position because there is no background frame of reference. With two astronauts, there is a sense of relative motion and position with respect to each other. Measuring these observable properties at any scale is only possible based on their relative properties.

In quantum physics, the order of magnitudes are so small that there is no possible way for a background of photons to continuously provide any sense of relative motion and position. In quantum physics, a second particle measuring the isolated quantum particle provides the relative motion between the two particles. The velocity of the isolated quantum particle is undefined without a second particle's measurement to provide a relative velocity.

The relative motion concept still applies when multiplying the particle velocities by a scalar mass value to obtain the particle's relative momentum. For massless photons, the velocity is known to be the speed of light in any rest frame. The relative momentum between a particle with mass or without mass is still uncertain. The photon's momentum, measured by the isolated quantum particle, depends on the quantum particle's rest frame. The quantum particle and the measuring device agree on the speed of light but will disagree on the photon's momentum. From the quantum particle perspective, it cannot tell the momentum of itself, only the momentum of a photon in its rest frame. Without a measurement, the momentum can be anything.

A measurement without a background is possible by detecting the measuring particle after the two particles collide and scatter. Like when a photon measuring an electron undergoes a momentum change due to Compton scattering. If the initial and final states of the photon's momentum are known, then it is possible to deduce more about the momentum of the quantum particle under observation. Finding the quantum particle's momentum requires colliding the photon with the quantum particle. This collision changes where the original particles are in the quantum system. Changing the quantum particle's momentum changes its position. This idea is formalized in Heisenberg's Microscope to show a fundamental uncertainty between knowing a particle's position and momentum with arbitrary accuracy.

Quantum Postulate. A measurement of a particle defines the observables of position and momentum. The observables are undefined until there is a measurement.

Quantum Postulate. A measurement of momentum and position has a minimum uncertainty between them, given by Heisenberg's uncertainty principle.

1.2 The twin paradox from special relativity is resolved by using non-inertial reference frames in general relativity.

In the twin paradox, one twin leaves the other behind and travels at a velocity close to the speed of light. The paradox is to determine which twin is older when they are reunited because both twins appear to be moving in the other twin's rest frame.

In inertial reference frames, it is impossible to tell which twin underwent movement and deduce which twin is older. Each twin appears to be moving in the other twin's rest frame. The resolution of the paradox is to find which twin experiences acceleration. The twin who experiences a force is younger than the twin who does not experience a force. The twin who experiences a force and the accompanying non-inertial reference frame is the twin who accelerates and is in motion. General relativity resolves the twin paradox by incorporating non-inertial reference frames instead of only the inertial frames of special relativity.

In quantum physics, two entangled twin particles are impossible to distinguish until measuring them. The particles and their entangled observables exist in inertial frames. Applying a force to measure the particles pushes one particle into a non-inertial frame. Only one of the particles experiences the non-inertial frame, distinguishing one twin particle from the other particle.

In physics, Newton's second law defines the force as a change of momentum. An example of a force in a measurement is when a particle enters the magnetic field of a Stern-Gerlach experiment and is deflected either up or down based on its spin. Measurement and observations are nebulous concepts, but measurement imposes forces on particles. Even light passing through a polarizer changes its momentum and energy. In the astronaut example, each astronaut visually inspects the other astronaut's velocity. There are not enough particles to do this instantaneously on a quantum scale. A single particle cannot measure another particle without creating an uncertainty between momentum and position. Each particle is measured by being subjected to a non-inertial reference frame, a force, the change in momentum, like in a collision between two particles.

Quantum Postulate. A measurement or observation of a particle requires applying a force to the particle.

1.3 The simultaneity of events is not absolute. The order of events is relative.

Two observers traveling at different velocities observe events occurring at different times. The classic example is picturing someone standing beside a train track while a speeding train passes them. The stationary observer sees two simultaneous lightning strikes on opposite horizons. A train passenger traveling exceptionally fast past the stationary observer sees the lightning strike on the horizon they are traveling towards before the lightning strike on the horizon they are moving away from.

In a quantum system, if the momentum is undefined until a measurement provides a relative momentum, then events cannot be in any order in any reference frame. Assigning causality such that event A happens before event B is impossible. The order of events is undefined. Pure imaginary numbers have no order because they do not satisfy the number theory order axioms. Complex numbers on a complex plane are also not ordered. Ordering complex numbers requires complex conjugates used either with the wavefunction itself or with the wavefunction measuring them. This measurement creates real numbers on the real number line satisfying the order axioms.

Quantum Postulate. Different events cannot be ordered in time until a measurement provides defined observables.

1.4 If a particle travels faster than the speed of light then causality is violated.

Suppose someone on Pluto receives a radio message about an event on Earth and can send the information back to Earth faster than the speed of light. Then, information will go into Earth's past light cone, where the information can prevent the event from occurring. A ship traveling faster than the speed of light appears in multiple places simultaneously in all reference frames. An observer would see the light from the ship's final position before the light from the initial position faded. The speed of light and causality are linked. Violating the speed of light violates causality.

In quantum, without a defined momentum and a way to order events, a quantum particle appears to violate causality locally. The quantum particle seems to break the speed of light and is nonlocal until a measurement. The quantum particle occupies every position and state spanned by the wavefunction simultaneously until a measurement collapses the wavefunction.

Quantum Postulate. If there is no causality because there is no order of events, then the only possible events are those events that can occur simultaneously and independently of the rest frame. The particle appears to occupy every possible allowed state at the same time.

Quantum Postulate. Measurement creates local causality in a quantum system.

2 Thermodynamic Concepts

2.1 Entropy increases.

The entropy of an isolated system must increase until it reaches its maximum entropy. The second law of thermodynamics is a statistical argument that depends on the law of large numbers. Understanding entropy in terms of microstates, macrostates, and multiplicity using a simple example makes it easier to understand how a wavefunction can collapse through an observation or measurement. The collapse of the wavefunction is analogous to the entropy of mixing.

For N identical coins tossed simultaneously, each coin is equally likely to land as heads or tails. If half the coins land heads, then its macrostate is half heads. But with this information, the microstate and the exact order of the coins that landed heads are unknown that generate the half heads macrostate. Many different microstates can generate an identical macrostate. The multiplicity is the number of microstates that can create an identical macrostate. The logarithm of the multiplicity is called the entropy.

Occasionally, a few coins are in a macrostate with zero heads, but the zero-head state is improbable in an experiment with many coins. There is only one microstate for this macrostate of zero heads, therefore this macrostate is extremely unlikely. If any coins land heads, then it is in a different macrostate. If we increase the number of coins, there is still only one microstate for the zero-head macrostate. But increasing the number of coins now means the probability of the half-heads macrostate has significantly increased due to the larger number of microstates. The multiplicity or entropy has increased, and the system is in its maximum entropy state, which is the most likely macrostate.

Increasing the entropy forces many macrostates to be inaccessible, while a small number of other macrostates are overwhelmingly likely. The probability function collapses into a single macrostate when systems mix. Entropy is why heat flows from a hot object to a cold object and why nature abhors a vacuum, but it is a subtle statistical argument. The microstates and macrostate probabilities never vanish. But some macrostates become so unlikely that they are ignored and assumed to be zero in the irreversible mixing process.

Quantum systems are much smaller, and the law of large numbers previously assumed in the argument for the second law of thermodynamics becomes essential and nuanced. Nonetheless, combined quantum systems increase the total entropy and force the probabilities to collapse into a single definite state.

Quantum Postulate. A measurement increases entropy, making one state overwhelmingly more likely than other states. Increasing entropy collapses the wavefunction.

2.2 The fundamental postulate of statistical mechanics: an isolated system in equilibrium is equally likely to occupy any of its accessible microstates.

In quantum mechanics, many consider the probabilistic interpretation of the theory to be unnatural. The equation describing the wavefunction is the deterministic Schrodinger equation. In classical mechanics, particles and their trajectories are entirely deterministic. In quantum, assigning a probability for each possible state for a particle is controversial with some physicists.

In statistical mechanics, this indeterministic interpretation is not controversial. The number of microstates in a macrostate, the multiplicity, creates probability coefficients with different weights that act like partition functions. Some macrostates are more likely than others. Accepting that the fundamental postulate applies to a single particle due to relativistic concepts of relative observables and causality means a single particle can be in any of its microstates. A single particle in all of its microstates simultaneously until a measurement satisfies the fundamental postulate of statistical mechanics.

The particle can be anywhere inside the wavefunction over any distance as long as the wavefunction has spanned the distance. The nonlocal properties do not violate relativity because the wavefunction spreading rate is slower than the speed of light. This postulate explains why quantum mechanics is a theory of probabilities because it is the small-scale application of statistical mechanics.

Quantum Postulate. Quantum mechanics describes the probability of a particle or ensemble of particles simultaneously in many different possible states.

2.3 The arrow of time and thermodynamic arrow are the same.

Entropy increases, which is why the past differs from the future. The past has a lower entropy than the future. Entropy increases on larger classical scales and creates an irreversible process. On a smaller scale without a background, when two particles collide and ricochet, they look the same, forwards and backward in time. The direction of time forward and backward seems the same until entropy increases and creates a local thermodynamic arrow. Entropy increasing locally builds classical local causality.

Increasing entropy for a quantum system requires measurements to provide a local arrow of time and create local causality. Without local causality, we cannot say where a particle started or finished or the path the particle takes between two points. The particle in a reference frame without causality must appear everywhere until a measurement and increasing entropy provide causality.

Quantum Postulate. The time evolution of the wavefunction looks the same forwards and backward in time until a measurement increases entropy and collapses the wavefunction.

2.4 Absolute zero cannot be reached.

The third law says that the entropy of a closed system at thermodynamic equilibrium approaches a constant value when its temperature approaches absolute zero. The third law says reaching a temperature of absolute zero is impossible. The temperature of a material is related to the velocity of its atoms and molecules. Holding a particle still in a closed system at thermodynamic equilibrium is impossible. The particle is going to change its position.

After a measurement collapses the wavefunction, a second fast measurement finds the same value with certainty. A third delayed measurement will see the uncertainty begin to spread out according to the deterministic Schrodinger equation, and now the particle can be in other states and values. The measurement is a fleeting interaction. A measurement is like temporarily combining a single coin with 50 others and observing a half-head macrostate. Removing the added coins makes it more likely to find our single coin in the lower-probability macrostate. The wavefunction diffuses like the temperature function diffuses in the nearly identical Poisson heat equation. The more energy the system has, the faster it will diffuse. In a quantum system, the particle that measured it may not stay nearby and become irreversibly mixed with the system. The new quantum state jostles around from other random interactions measuring it. In this thermodynamic equilibrium, it eventually approaches a constant state, the ground state, and its lowest energy state as the wavefunction diffuses.

Quantum Postulate. After the wavefunction collapses from measurement, it spreads out and dissipates the change in its energy from the force that measured it into the rest of the quantum system.

Quantum Postulate. The rate at which the wavefunction spreads is proportional to the total change in energy during the measurement until it reaches a thermodynamic equilibrium that depends on the size of the boundaries that define the system.

Quantum Postulate. Energy is conserved in quantum systems, and the lowest possible energy state is the ground state.

Quantum Postulate. A particle with mass will never receive enough energy to dissipate its wavefunction faster than the speed of light.

3 Probability Theory

3.1 There are uncertainties between some observables.

In probability theory, there is a need to find data set averages and the data distribution above and below the average. Half of the values might be below average and half above average. This is the standard deviation. Data can also be negative and positive, like when analyzing debts and savings. If half the data is negative and half is positive, then the average may be zero. A more reliable way to compare data and different data sets is to use a three-step method. First, square each data point in the "A" data set which is A^2, this transforms all the negative numbers into positive numbers, and find the average of their squared values $\langle A^2 \rangle$. Second, find the average value using raw unsquared numbers, $\langle A \rangle$, and then square the average, $\langle A \rangle^2$. Lastly, find the data spread by taking the square root of the difference between the average of the squared data points, $\langle A \rangle^2$, and the square of their average, $\langle A \rangle^2$, this is the standard deviation of A denoted as, ΔA.

$$\Delta A = \sqrt{\langle A^2 \rangle - \langle A \rangle^2}$$

The value is zero if there is no spread in the data when everything is equal to the average value. If two different averages of different properties, called random variables, do not influence each other, they are called mutually exclusive and independent. In that scenario, the value is zero when we multiply the standard deviation of one with the other, then multiply them in the opposite way, and take the difference, $\Delta A \Delta B - \Delta B \Delta A = 0$, the values A and B commute. The random variables do not influence each other, and measuring them without any uncertainties between the data sets is possible. If the random variables are dependent and not mutually exclusive, then they do not commute, $\Delta A \Delta B - \Delta B \Delta A \neq 0$, and there is a minimum uncertainty between the two random variables.

Quantum Postulate. Observables in quantum that commute can be measured to any accuracy simultaneously because they are mutual exclusive and independent random variables.

Quantum Postulate. Observables in quantum that do not commute cannot be measured simultaneously to arbitrary degrees of accuracy because they are not mutual exclusive and independent random variables.

3.2 The uncertainty principle can replace the wavefunction.

Squaring averages and averaging squares provide important information about the spread of random variables around their averages. Similarly, a wavefunction is squared to find a random variable's probability density, ρ, and the spread of possible values around its average value. The square of the wavefunction is the complex conjugate, $i^*i = i(-i) = 1$, of the wavefunction, $\psi^*\psi = \langle\psi|\psi\rangle = |\psi^2| = \rho$. Using a wavefunction without taking the complex conjugate that also yields a probability density would make it impossible to use alternative interpretations of quantum physics. A real wavefunction is physically real.

The Copenhagen interpretation defines the wavefunction as a mathematical object because the wavefunction is not real. The wavefunction uses imaginary numbers, which experimentalists cannot measure physically in a lab. Scientists measure energy and momentum with real numbers. The wavefunction in the Copenhagen interpretation is used to calculate predictions and does not represent something physically real. However, the forces are still dependent on the phase evolution of the wavefunction, which the interpretation denies exists but requires it to exist to make accurate predictions.

The ensemble interpretation argues the wavefunction is real and represents the possible states of an ensemble of particles. This interpretation looks eerily similar to thermodynamics' partition functions and entropy equations. Some believe a conscious observer is required to collapse the wavefunction. Many cosmologists want a deterministic theory without the indeterminism of quantum mechanics. This is the many-worlds interpretation where each possible quantum state branches off into a separate universe.

The wavefunction is imaginary, and we are trying to do probability theory and apply ontologies to imaginary numbers. The strange interpretations of quantum physics depend on using imaginary numbers in the wavefunction. Imaginary numbers represent the evolution of a system where causality, the arrow of time, and relative observables are undefined.

Getting the results of squared wavefunctions is possible by using the observable's standard deviation without directly working with their imaginary wavefunctions. Doing quantum physics with real numbers removes the need for interpretation. The uncertainty between momentum and position is defined by Heisenberg's uncertainty principle.

$$\Delta P = \sqrt{\langle P^2\rangle - \langle P\rangle^2} = \sqrt{\int P^2\psi(p)^*\psi(p) - \left(\int P\psi(p)^*\psi(p)\right)^2} = \sqrt{\int P^2|\psi(p)|^2 - \left(\int P|\psi(p)|^2\right)^2}$$

$$\Delta X = \sqrt{\langle X^2\rangle - \langle X\rangle^2} = \sqrt{\int X^2\psi(x)^*\psi(x) - \left(\int X\psi(x)^*\psi(x)\right)^2} = \sqrt{\int X^2|\psi(x)|^2 - \left(\int X|\psi(x)|^2\right)^2}$$

$$\Delta X\Delta P \geq \frac{[\Delta X\Delta P - \Delta P\Delta X]}{2i} \geq \frac{\hbar}{2}$$

Quantum Postulate. Using the standard deviation to find quantum probability densities is equivalent to squaring the wavefunction.

Quantum Postulate. A real wavefunction eliminates the need for quantum interpretations.

4 Conclusions

4.1 Oscillating Uncertainties Generate Forces.

Forces are an afterthought in quantum physics. In quantum, describing forces requires using a particle's stationary initial and final energy states represented by a Lagrangian, the kinetic energy minus the potential energy. This particle Lagrangian plugs into the Euler-Lagrange equation. The output of the Euler-Lagrange equation describes the force by modeling the most likely action between the initial and final energy states. The fundamental forces are then reduced to abstract symmetries and Lie algebras. All the standard unitary groups describe the relationships of observables that are not commuting between allowed energy states. The equations describe forces in terms of uncertainties.

Framing physics problems in a different conceptual way often simplifies them. One way is to think of the massive nucleus of the proton, which means it has a large momentum and, therefore, the proton's position occupies a smaller volume of space. The momentum and position relationship still satisfies Heisenberg's uncertainty principle. The electron has a much smaller mass and smaller momentum than the proton. The electron's position must be in a larger volume of space than the volume needed for the proton's position. The uncertainty principle explains why the electron is in a cloud around the massive and small nucleus. Describing forces in quantum physics should use a similarly simple concept.

If I attempt to hit a ball by throwing another ball while blindfolded and miss, I have reduced the uncertainty of where the target ball is located in space. In quantum physics, this experiment means the uncertainty in the momentum changes, and it must become larger as the particle's position is more certain. The particles do not need to collide to change uncertainties; they only need to eliminate possible allowed states of the particle. A change in momentum is a force by Newton's second law, $F = dp/dt$. A change in the uncertainty of the momentum in one direction changes the momentum's average value in that direction and acts like a force on the particle.

When exchanging a photon, two particles, like an electron and a proton, constantly change their relative momentum and position uncertainties and generate a force between them. If both particles' position uncertainty reduces in the direction facing each other, then the uncertainty and the average momentum value are also greater in the direction toward the other particle, creating an attractive force between them.

4.2 Simple Harmonic Motion

As the uncertainty in one observable decreases, the uncertainty in the other increases. This oscillating change in uncertainty between position and momentum has simple harmonic motion properties. The oscillating uncertainties of the two observables are coupled together with Planck's constant. In two dimensions, simple harmonic motion, like a speaker oscillating a membrane to create sound waves, is described by Bessel functions. In three-dimensional spherical coordinates, a point source with simple harmonic motion has stationary energy states determined by spherical harmonics. Similarly, the quantum mechanical wavefunction solutions in spherical coordinates produce the atomic electron energy levels and quantum numbers.

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