Does Physics Give us Freedom?

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October 2022

1 Introduction

Freedom could be understood as having multiple possible choices or being able to direct one's future; physics, as a fundamental subject, plays a significant role in our concept of freedom. This essay is going to investigate the idea of freedom from a physicist's point of view.

2 Newtonian Physics

2.1 Free Particles are not Free

Forces have two different effects: to constrain a motion or to change a motion. The restriction of motion is achieved by *constraints*. If the motion of a particle or system is constrained by one or more conditions, then the number of different ways to move the particle freely is reduced. Such restrictions are called constraints [3]. For example, a particle attached to a string cannot go infinitely far away as the string will pull the particle back. This shows that forces reduce the degrees of freedom. In order to obtain more freedom or become totally unbounded, we need to endeavour to remove all forces. In this ideal state, we become a *free particle*, a particle that is not bound by an external force[2]. Such a particle, according to Newton's First Law, will move in a straight line at a certain speed. This is not what we normally consider to be freedom as nobody likes walking along a corridor at a given speed without being able to turn back or to reach either side.

2.2 The Paradox of Constraints

External forces acting on a particle can change its motion. For instance, an object that experiences gravity in free fall is accelerated downward; a pendulum that experiences tension from the string is allowed to swing back and forth. As such, we can conclude that forces are required to change or start a motion.

If we try to have the physical freedom - to travel to multiple places in a short time - we need help from forces. First, we need an external force to accelerate us until we gain speed. Meanwhile, we also need a force to adjust the direction of our motion; otherwise, we may crash into a wall. Nevertheless, forces are considered to be constraints. Conterintuitively, if we attempt to achieve conventional freedom, we need to apply constraints.

Figure 1: Constraint

2.3 Laplace Demon: Determinism

The seventeenth century saw the development of classical mechanics, which profoundly altered scientists' views on nature[10] and started a new era where all motion can be described by equations: a set of starting conditions leading to a definite consequence. This means if we know velocities and positions of all particles at a particular moment, a computer can help us simulate the future since the current state is the consequence of the past, and the cause of the future. In 1814, without a computer, Laplace proposed an intellect which could do the same, namely the *Laplace Demon*[8].

The Laplace Demon reinforces a preexisting philosophical idea: *determinism*, which denies freedom. Determinism entails that a person makes a certain decision or performs a certain action. In other words, it is never true that people could have decided or acted otherwise than they actually did[4]. We may expend this idea to the whole universe: the universe behaves as clockwork with all gears governed by the laws of motion. By adjusting the time, we can see the predictable and definite future.

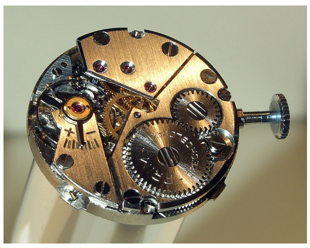

Figure 2: Clockwork

3 Quantum Physics

That classical mechanics leaves no space for freedom really frustrates us; however, there are areas where classical physics is forbidden. Quantum physics, being conterintuitive, may surprisingly provide us with freedom.

3.1 Wave Function: God Does Play Dice

In 1924 de Broglie theorised that under the right conditions particles can behave like waves[6], and in 1926 Schrödinger introduced the *wave function* into the theory. In the same year, the wave function was interpreted as the probability distribution of a particle, which has become a backbone of physics[5].

In quantum physics, a particle's properties are described by its wave function. This shows the indeterminacy, for the wave function only tells us the probability of where to find a particle[7]. For example, if we put an electron in a box, and the electron doesn't experience any force, we can only know that it is relatively likely to be present at a place or impossible to be found at another place. Now, if we are trying to locate this electron, we need to measure its position and direction. At this time, its wave function collapses, and the particle reverts to its particle nature. This raises an interesting question: where is the particle before we look for it? The orthodox quantum interpretation suggests that the particle is everywhere, and the act of measurement causes the particle to choose a particular place to stand. This matches our understanding of freedom: the future is not determined and we can choose one from a range of given options.

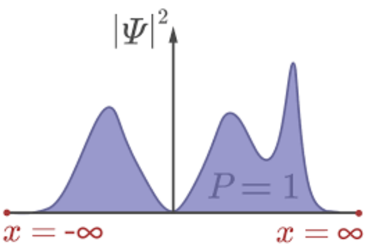

Figure 3: Wavefunction

3.2 Uncertainty: Don't Panic

Other than the wave function, the *uncertainty principle* is considered as another pillar in quantum mechanics. Formulated by Werner Heisenberg in 1927, the uncertainty principle states that we cannot know both the exact position and momentum (therefore velocity) of a particle; the more we nail down the particle's position, the less we know about its velocity and vice versa.[1]. The uncertainty principle means that the simulation of the real world will be different from the real case, which occurs due to the uncertainty of the initial state of the particles. Different outcomes of simulations oppose the idea of determinism and open a window for freedom.

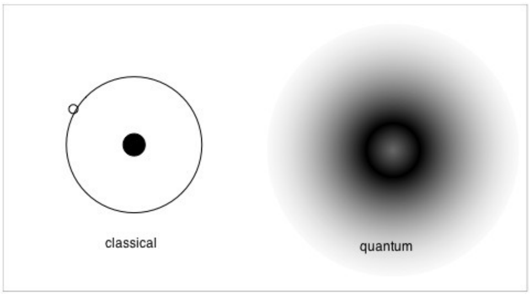

Figure 4: Classical vs Quantum

4 Conclusion

So far, we have examined the idea of freedom according to two main branches of physics, while the result is contradictory: classical mechanics suggests the determinancy of our world and offers one possible future, while quantum mechanics points out the indeterminancy and provides infinitely many possible futures in which we may have agency[9].

Unfortunately, we live in the classical world, in which the quantum effects are not manifest. Nonetheless, there is a bridge joining the classical world and the quantum world: our brain. The small size of our brain system enables the quantum effects, especially indeterminancy, to appear, which can then have an impact on the classical world through the actions of our body. However, whether we can obtain freedom with the aid of indeterminancy is still disputable since indeterminancy is a necessary but not sufficient condition for freedom[11].

References

[1] What is the uncertainty principle and why is it important? *Caltech Science Exchange*.

[2] Free particle. *Wikipedia* (2022).

[3] Chourasiya, S. Constraints in motion (classical mechanics). *M-Physics Tutorial* (2022).

[4] Duignan, B. Determinism. *Encyclopædia Britannica* (Mar 2022).

[5] Gao, S. Meaning of the wave function. *International Journal of Quantum Chemistry 111*, 15 (2011), 4124–4138.

[6] Gregersen, E. De broglie wave. *Encyclopædia Britannica* (Sep 2022).

[7] GRIFFITHS, D. J., and SCHROETER, D. F. *INTRODUCTION TO QUANTUM MECHANICS*, 3rd ed. Cambridge University Press, 2018.

[8] Hawking, S. Does god play dice. *Stephen Hawking: Academic Lecture* (1999).

[9] Herzenberg, C. Why our human-sized world behaves classically, not quantum-mechanically: A popular non-technical exposition of a new idea. *arXiv preprint physics/0701155* (2007).

[10] Larry, B. Laplace's demon. *Chaos Fractals* (2022).

[11] López-Corredoira, M. Quantum mechanics and free will: counter-arguments. *NeuroQuantology 7*, 3 (2009).