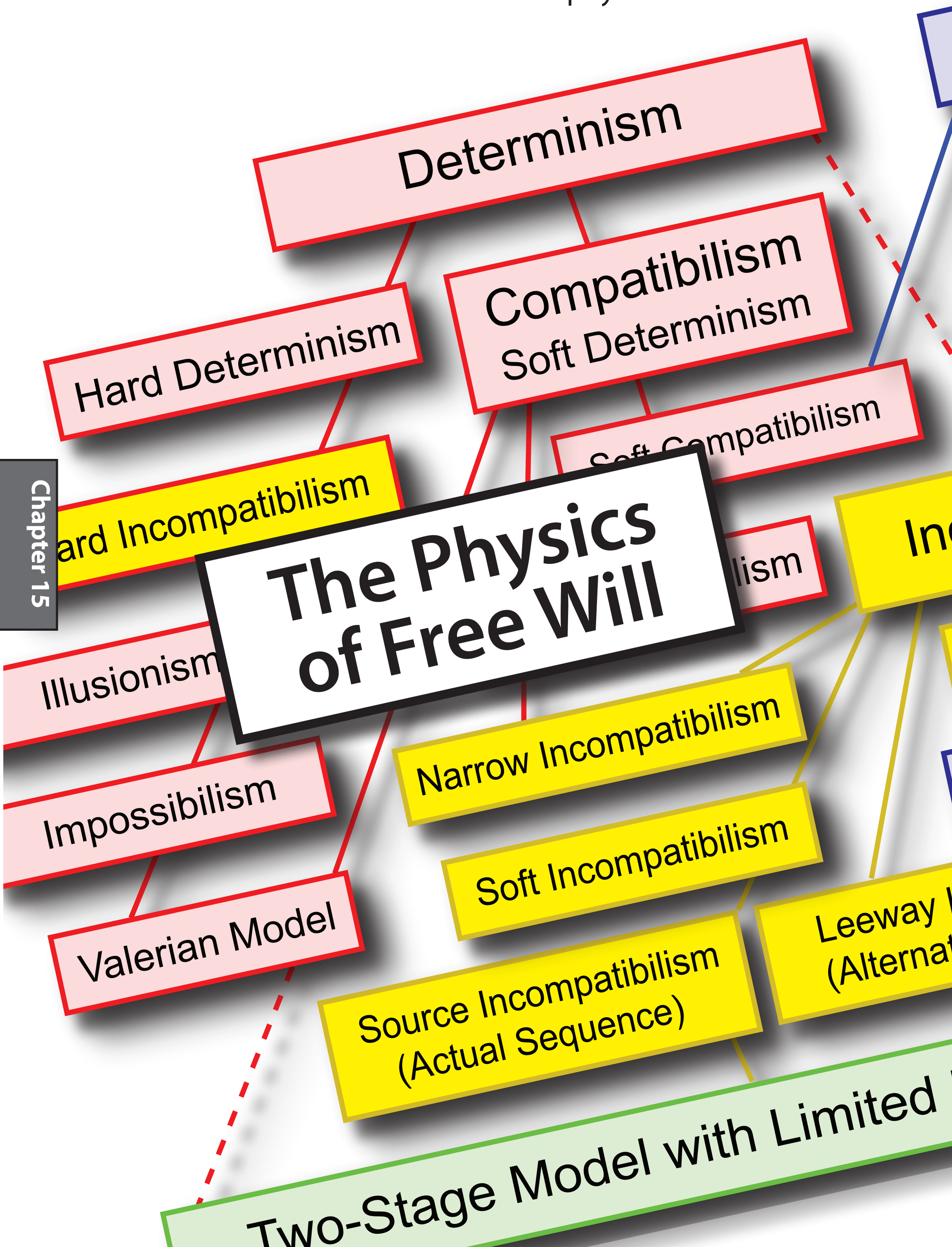
The Physics of Free Will



This chapter on the web
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The Physics of Free Will

Does physics, or more generally as philosophers describe the problem, do the causal "laws of nature" put limits on human freedom? The goal of information philosophy and information physics is to provide you with the current state of physical knowledge, to help you decide for yourself whether there are any such limits.

For information philosophy, the classical problem of reconciling free will with physical **determinism** (this reconciliation is accepted by all compatibilists) is now seen to have been the easier half of the free will problem. The more difficult half is reconciling free will with the physical **indeterminism** in the first stage of a **two-stage model**.

Modern physics sees the physical world as fundamentally undetermined. The universe began in a state of chaos and remains chaotic and random at the atomic scale (as well as some macroscopic regions of the cosmos). So the challenge presented by physics for free will is - how can anything at all be **adequately determined** with all this microscopic chaos and indeterminism?

We now know that even for very large objects, the laws of physics are only statistical laws. We have known this since Ludwig Boltzmann's work in 1877. Statistical physics was brilliantly confirmed at the level of atomic collisions by Max Born in 1926, and by Werner Heisenberg in 1927, with his quantum mechanical uncertainty principle. Unfortunately, "antipathy to chance"[1] has led many prominent physicists, then and even some now, to deny indeterminism and cling to a necessitarian deterministic physics.

Biologists knew about chance even earlier, from Charles Darwin's work in 1859. Chance is the driver for evolution and so chance must be a real part of the universe. Indeed, it is known that quantum collisions of high-energy cosmic rays with macromolecules carrying genetic information create the mutations that produce variation in the gene pool.

1 William James' characterization. James (1884) p. 153.

Charles Sanders Peirce, strongly influenced by Darwin, was the greatest philosopher to embrace chance, and he convinced his friend William James of it. James described the role of chance in free will in his essay, *The Dilemma of Determinism*.

Information philosophy has identified the cosmic creative processes (I call them "ergodic") that can overcome the chaotic tendency of indeterministic atomic collisions and create macroscopic, information-rich, structures. When these emergent structures are large enough, like the sun and planets, their motions become very well ordered and incredibly stable over time.

Even small macromolecular systems can have incredible stability, thanks to quantum mechanics. DNA has maintained its informational stability for nearly four billion years by adding error detection and correction processes ("proof reading" when replicating).

Early Greeks like Anaximander saw the universe as a "cosmos" and imagined laws of nature that would explain the cosmos. Later the Stoic physicists identified these laws of nature with laws of God, proclaimed nature to be God, and said both were completely determined.

For the Greeks, the heavens became the paradigm of perfection and orderly repetitive motions without change. The sublunary world was the realm of change and decay. When, two thousand years later, Isaac Newton discovered dynamical laws of motion for the planets that appeared to be perfectly accurate theories, he seemed to confirm a deterministic universe. But as Newton knew, and as Peirce and later Karl Popper were to argue, we never have observational evidence to support the presumed perfection. The physical laws had become a dogma of determinism.

This is epitomized in the super-intelligence of **Laplace's demon,** for whom the complete past and future are implicit in the current universe.

For most scientists, this determinism of classical physics has been invalidated by quantum mechanics. Statistical laws give us only **adequate determinism**. But some determinist philosophers doubt that current quantum theory is the last word. And others look to special relativitistic physics (also a classical theory) to prove determinism, as we will see below.

Quantum Physics

There is little doubt that there will be improvements in quantum theory in the future. Quantum mechanics has been made consistent with special relativity, but not yet with gravity and general relativity. The grand unification of the forces of nature may change something about the way we do quantum mechanics. But only if the predictions of the improved theory are as good or better than the current quantum theory, which is at this time the most accurate theory of physics, good to 15 significant figures or one part in 10^{15}.

The essential difference between classical physics and quantum physics is unlikely to change. Paul Dirac[2] identified the essential properties of quantum mechanics as **indeterminacy** and the *superposition* of quantum states.[3] The interference of probability-amplitude wave functions (shown in the two-slit experiment) is impossible for classical systems. Predictions of experimental outcomes are at best probabilistic and confirmable only statistically.

The decay of a radioactive particle is a good example. In a sample of radioactive material, it is impossible to predict when an electron will be ejected as one of the nuclei decay, but it is highly likely that after the "half-life" of the material, half of the radioactive nuclei will have decayed. In the language of the **Cogito model** of free will, the time to the next decay is **indeterminate**, but the number decayed after the half-life is **adequately determined**.

Special Relativity and the Block Universe

Einstein might have been surprised to find that several philosophers use his theory of special relativity to prove determinism, but he would not have been surprised to learn that they fail.

2 Dirac (2001), ch. 1.
3 See informationphilosopher.com/solutions/experiments/dirac_3-polarizers for a discussion.

Einstein was as strong a believer in determinism as any scientist. If he thought his special theory of relativity could be used to prove determinism, he surely would have done so.

Since the 1960's, several philosophers have thought that they could prove that determinism is true because of the special theory of relativity. They include J. J. C. Smart, C.W. Rietdijk, Hilary Putnam, Roger Penrose, Michael Lockwood, and Michael Levin. [4]

The basic idea behind using the special theory of relativity to prove determinism is that time can be treated mathematically as a fourth dimension. This gives us excellent results for experiments on moving objects. It predicts the strange Lorentz contraction of objects in space and dilations of clock speeds for observers in fast moving frames of reference (coordinate systems).

In Figure 15-1, observers A and B are moving toward one another at high speed. At the current time, they are at events A_0 and B_0. B_1 is an event that is in B's future. It is in a timelike separation from B_0. Special relativity says that A sees the event B_1 as happening "now" in A's fast-moving frame of reference. A_0 and B_1 are happening at the same time. But notice that, like the current events A_0 and B_0, the two events that A thinks are happening "now" are in a spacelike separation. There can be no causal connection from A_0 to B_1.

Similarly, B sees the event A_1 as synchronous with the event B_0 by his clocks. But any "influence" of B_0 on A_1 would have to move faster than the speed of light, which is impossible.

These philosophers jump to the unacceptable conclusion that the time dimension is like space and so the "future is already out there." Any event that is going to happen has already happened,.

This is a special relativistic version of Diodorus Cronus' ancient notion of actualism, only what actually will happen could ever happen.

4 See informationphilosopher.com/freedom/special_relativity.html

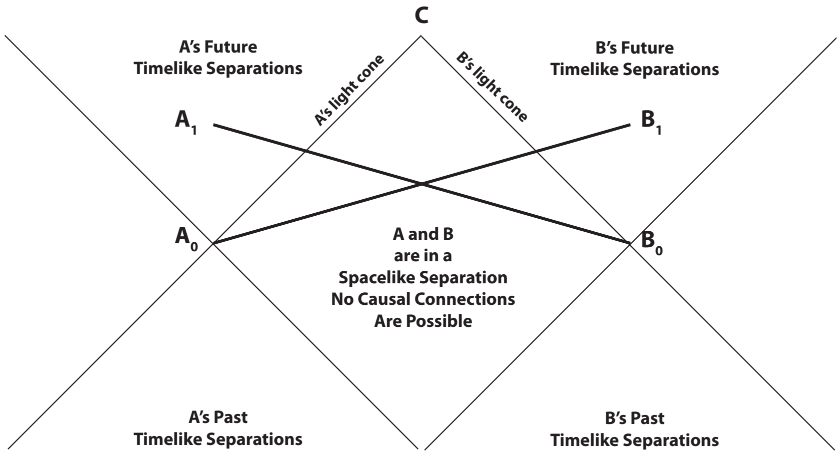

Figure 15-1. Space-time diagram for observers fast approaching one another.

But just because an event is placed on a space-time diagram, it is not made actual. It is still in the future.

Quantum mechanics has eliminated the kind of physical determinism that Laplace's demon might have used to connect present events causally with events in the future.

But despite quantum mechanics, Albert Einstein remained a confirmed determinist. He might have been surprised to learn that so many philosophers have used his theory of special relativity in an attempt to prove determinism.

Einstein believed in determinism as much any scientist. He very likely did not develop this argument from his special theory of relativity because he knew it is absurd and knew it would fail.

But Einstein's special relativity has one more role to play in the free will problem. Nonlocality and entanglement are apparent violations of Einstein's limit on things traveling faster than the speed of light. Some philosophers and scientists think that the mysteries of nonlocality and entanglement can help solve the mysteries of consciousness and free will.[5]

5 E.g., Roger Penrose, John Conway, Simon Kocher, Nicolas Gisin, Antoine Suarez. See informationphilosopher.com/freedom/nonlocality.html

Nonlocality and Entanglement

Albert Einstein never liked Werner Heisenberg's indeterminacy principle in quantum mechanics, although it was the direct result of his own early confirmation of Max Planck's idea that nature is discrete and quantized.

Einstein also did not like the apparent fact that when the probability-amplitude wave function collapses, the values of the wave function change instantly over large distances, suggesting that the probability is traveling faster than the speed of light.[6] This violated Einstein's sense of "local" reality. He said that nature seemed to have non-local behaviors.

It is not clear which was worse for Einstein, the quantum **indeterminacy** that made physics indeterministic, or the faster-than-light implications of the Einstein-Podolsky-Rosen experiment and Bell's Theorem.

Einstein disliked indeterminism, famously saying that "The Lord God does not play dice." But he was also opposed to what he called the "spooky action at a distance" implied by the "nonlocal reality" of quantum mechanics.

Nonlocality shows up best in two-particle experiments like that proposed by Einstein and his Princeton colleagues, where measurements that detect a particle in one place instantly determine the properties (position, momentum, spin, etc.) of another "entangled" particle that can be at a very great distance from the first.[7]

Einstein might have been pleased to learn that many physicists and philosophers are still trying to confirm his notion of "local" reality. They using "hidden variable" theories to explain how a particle at point A can determine the properties of another particle far away at point B.

John Bell's famous theorem, if confirmed experimentally, could prove Einstein to be correct, restoring both determinism and local reality. Unfortunately, three decades of experiments continue to

6 See informationphilosopher.com/solutions/experiments/wave-function_collapse for an animated visualization

7 See informationphilosopher.com/solutions/experiments/EPR for an explanation and visualization of the Einstein-Podolsky-Rosen experiment.

show that Bell's theorem is violated and the nonlocality of quantum physics has been confirmed.

Information philosophy and physics can explain the mystery of "faster than light" effects in nonlocality and entanglement. The proper explanation is that only abstract information appears instantly over vast distances.

Information is neither matter nor energy. It needs matter for its embodiment and energy for its communication, but in its abstract form it can appear to travel at supraluminal speeds, even in non-quantum events. Consider a horse race.

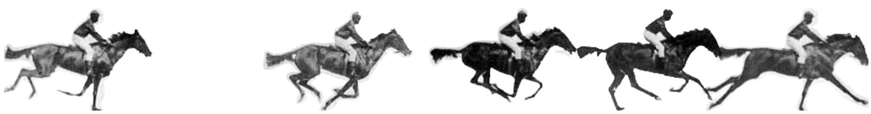

Figure 15-2. Information about probabilities is instantaneous,

Moments before the winning horse's nose triggers the photo finish, there is still some probability that horses far behind might win the race. The other horses might collapse.

But at the instant the lead horse wins, the probability of horses at the rear winning falls to zero, faster than the speed of light. No signal travels faster than light. We can now see how this also explains nonlocality in the EPR experiment.

In figure 15-3, two electrons are entangled in the center with total spin equal zero. One electron must have spin up and the other spin down. But electrons are identical interchangeable particles. We cannot know which has which spin until we measure them. And until we measure them, we cannot label them either.

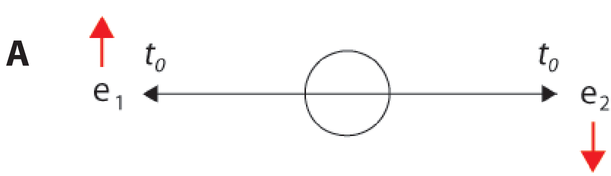

Figure 15-3. Electrons prepared with total spin = 0 at the center.

Let's now say that an observer A makes a measurement and finds an electron with spin up. We can now label that electron 1, and instantly we know that the other electron, now called 2, is an equal but opposite distance from the center and has been **determined** by A's measurement to have spin down.

But note that this was not **pre-determined** before A's measurement. This is the logical and physical mistake that you will find in most accounts of nonlocality. In the horse race, the horses are already numbered. But with quantum particles, we don't know their identity until we find them.

Note that because B and A have a spacelike separation, we know from the special relativity analysis above that observer B might have measured "first" at t_0 in his own frame of reference,

In the case of a single particle wave-function collapse, all the probability appears instantly at one point. In the two-particle case, the abstract probability information collapses instantly to two points, one for each particle. Those points are located so as to conserve the momentum, energy, and angular momentum (spin).

Despite exaggerated claims that nonlocality and entanglement introduce new quantum mysteries, there is actually nothing new beyond the fundamental mystery of wave-function collapses, except that we now have two particles.

These exaggerations have misled philosophers to make claims that nonlocality and entanglement can *explain* free will.

The Free Will Theorem

The mathematician John Conway (well-known for his cellular automata and the Game of Life) and his Princeton colleague Simon Kochen use the EPR experiment[8] and tests of Bell's Inequality to show what some science writers have argued is "free will" for elementary particles.

Conway and Kochen's argument is that if

> "experimenters have sufficient free will to choose the settings of their apparatus in a way that is not determined by past history, then the particles' responses are also not determined by past history...
>
> "Since this property for experimenters is an instance of what is usually called "free will," we find it appropriate to use the same term also for particles." [9]

8 See informationphilosopher.com/freedom/free_will_theorem.html
9 Foundations of Physics 36 (10): 1441

What Conway and Kochen are really describing is the indeterminism that quantum mechanics has introduced into the world. While my **two-stage model** makes indeterminism a necessary precondition for human freedom, it is insufficient by itself to provide free will.

Another way of looking at their work is to say that if determinism is true, then all the experimental tests might have been predetermined (e.g., by a deceiving God) to convince us that quantum mechanics is correct and that indeterminism exists, but that the real underlying nature of the universe is deterministic. Even Einstein could not go this far.

The Free Will Axiom

Philosophers and scientists from René Descartes to those who today are leaders in experimental tests of Bell's Theorem have all assumed that free will is necessarily axiomatic.[10]

Descartes wrote in 1644, "The freedom of the will is self-evident." In his 1874 book *Principles of Science*, the great logician and economist William Stanley Jevons is unequivocal that scientists have a freedom to hypothesize. In a section entitled Freedom of Theorizing, he declares,

> "The truest theories involve suppositions which are most inconceivable, and no limit can really be placed to the freedom of framing hypotheses."

In 1880, the founder of two-stage models credited Jevons with explaining the **creativity** of the genius as dependent on random hypotheses. James said,

> "To Professor Jevons is due the great credit of having emphatically pointed out how the genius of discovery depends altogether on the number of these random notions and guesses which visit the investigator's mind. To be fertile in hypotheses is the first requisite, and to be willing to throw them away the moment experience contradicts them is the next." [11]

10 See informationphilosopher.com/freedom/free_will_axiom.html

11 James (2007)

John Searle said in 2005 that

> "The special problem of free will is that we cannot get on with our lives without presupposing free will. Whenever we are in a decision-making situation, or indeed, in any situation that calls for voluntary action, we have to presuppose our own freedom."[12]

The Swiss scientist Nicolas Gisin, winner of the first John Stewart Bell prize, who recently confirmed the violations of Bell's Inequality over a distance of 19km in Geneva, says:

> "I know that I enjoy free will much more than I know anything about physics. Hence, physics will never be able to convince me that free will is an illusion. Quite the contrary, any physical hypothesis incompatible with free will is falsified by the most profound experience I have about free will." [13]

The Contribution of Quantum Mechanics

Why is quantum indeterminacy involved in the shaking together (*co-agitare*) of our agenda items, the real **alternative possibilities** for thought or action that allow us to say we "could have **done otherwise**?" There are three important reasons:

- Before quantum indeterminacy, many philosophers, mathematicians, and statistical scientists argued that chance was just a name for our ignorance of underlying deterministic processes. They denied the existence of real, objective chance in the universe. They thought that chance was epistemic and subjective, a result of the ignorance of finite minds.
- As soon as quantum mechanics was established in the 1920's, first scientists and then philosophers began claiming that quantum indeterminism could explain free will. Chapter 12 looked at some of their ideas. After a few years thought, most scientists qualified their enthusiasm or reported admissions of failure. Only a few libertarian philosophers, mostly those following Robert Kane, have been reluctant to give up on quantum indeterminism. Among determinists, Ted

12 Searle (2007) p.11.
13 Gisin (2010) p.

Honderich has taken it very seriously, but Daniel Dennett has denied its significance, as we shall see. [14]

• Quantum uncertainty remains the best explanation for breaks in the causal chain of strict determinism. But attempts to use the strange non-intuitive aspects of quantum mechanics - such as unpredictable quantum jumps between energy levels, "collapse" of the wave function in physical measurements, non-local behavior of particles that have become "entangled," spontaneous decay of "metastable" states, etc. - as models for the decision process have been hopeless failures.

The **Cogito** model of Chapter 13 identified the critical aspect of quantum mechanical **indeterminacy** that makes an "intelligible" contribution to human freedom, while preserving **adequate determinism** and **moral responsibility**. It is simply noise.

As we will see in the next chapter, molecular biologists have doubted we could ever locate a randomness generator in the brain. Such a generator would need to be small enough to be susceptible to microscopic quantum phenomena, yet large enough to affect macromolecular structures like neurons, which may contain as many as 10^{20} atoms.

Proposed amplifier mechanisms have been bizarre failures.[15]

The Cogito model simply identifies the source of randomness as the inevitable **noise**, both thermal noise and quantum noise, that affects both proper storage of information and accurate retrieval of that information at later times.

These read/write errors are an appropriately random source of unpredictable new ideas and thoughts that provide **alternative possibilities** for action. Noise is ever present, yet suppressible by the macroscopic brain.

We need not look for tiny random-noise generators and amplifiers located in specific parts of the brain. They are no more necessary than the Cartesian Theater homunculi sometimes evoked by philosophers to parody a tiny internal free agent inside the mind.

14 Honderich in Chapter 23, Kane in 24, and Dennett in 25.

15 See informationphilosopher.com/freedom/free_will_mechanisms.html