

On Surprising Connections in Physics

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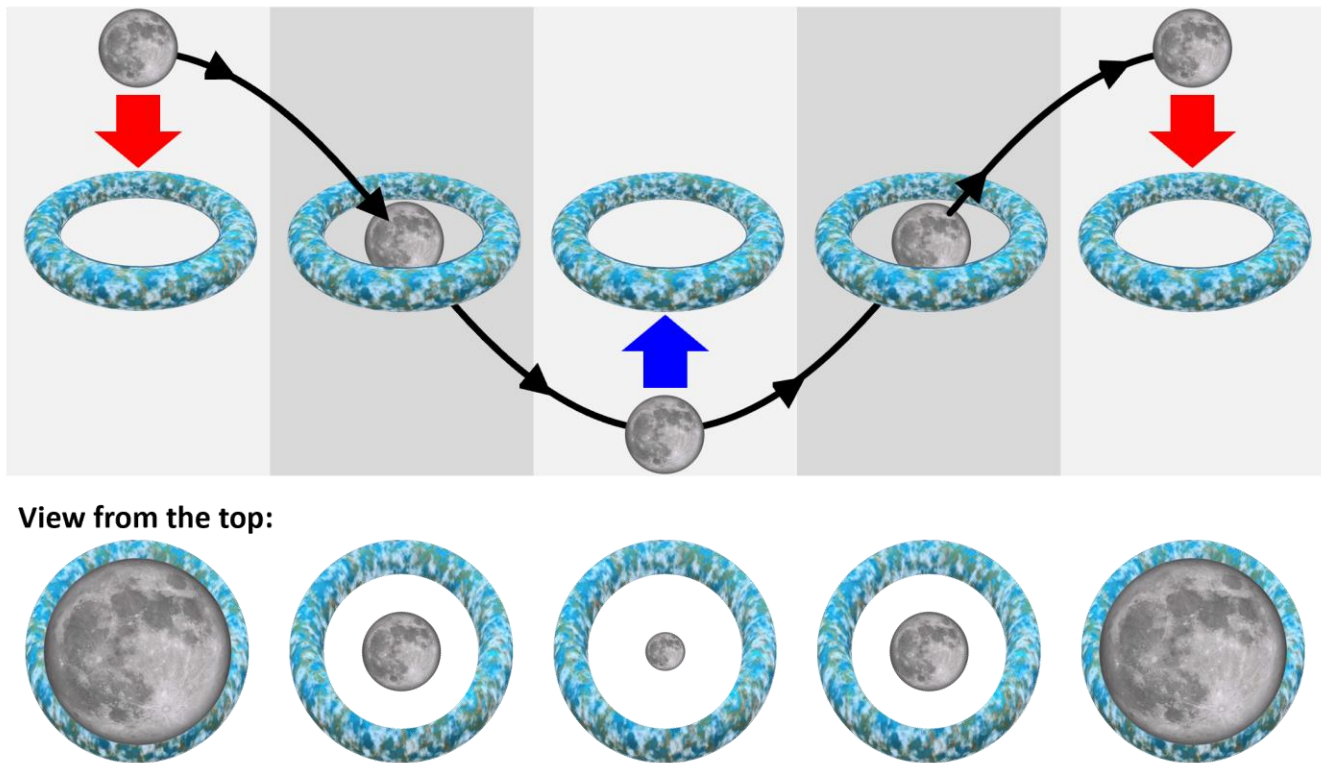


Figure 1. *The Moon in a Zero-Angular-Momentum Orbit Around a Donut Earth*
(Terry Bollinger, my work, CC BY 4.0, Oct 13, 2026).

First, A Bit of Fun with Astronomy

You can already see where this one is heading, just from the intro figure (Fig. 1)! But there's a surprise toward the end, one that is not obvious from this starting point.

First, the obvious question: Could a planet shaped like a (or bagel, or “toroid”) really exist? Surprisingly, this idea not only has been discussed, but is considered a real physical possibility. Such a planet could, perhaps, exist somewhere in the universe.

Is it likely? No! But is it possible, according to the laws of gravity and angular momentum? Yes! And that leads to some interesting possibilities when you add in the Moon.

If you've ever heard that an “orbit” is what happens when a moon or satellite moves sideways fast enough to pass by its planet before it can fall to the ground, it turns out that this is only part of the full picture. There is one very special type of orbit that can only happen when the planet has a hole through it. That special orbit is the one shown in the intro figure: A repeating up-and-down fall without any sideways motion at all!

There's a technical term for describing this concept of an orbit without any sideways motion: It is an orbit with zero angular momentum. That is, of course, just a slightly fancier (but also more precise) way of saying "the satellite or Moon has no sideways motion at all relative to the Earth."

Let's Shrink Everything

So far, so good. But the goal here is not just to describe zero angular momentum orbits in astronomy, but also to ask an odd question: Might they also exist on much smaller scales?

To explore this line of questioning thoroughly, I need to give you a couple of remarkably powerful conceptual tools. The first of these tools is unexpected, but also one of the most thoroughly proven concepts in all of physics: Mass is a clock.

Nobel Laureate Richard Feynman said it most precisely in his famous Lectures on Physics [1]:

"There are three different ways of specifying the energy: by the frequency of an amplitude, by the energy in the classical sense, or by the inertia. They are all equivalent; they are just different ways of saying the same thing."

Most folks have heard of Einstein's famous equivalence of energy to mass, so when Feynman talks about the "energy" of something, he also means the mass. That is why he brings up the issue of inertia, which is a way of measuring mass.

But what is this "frequency of an amplitude" all about? What is an amplitude?

Here's something you may or may not have encountered: Every particle in the universe is way more like a clock than you probably realized. It has a little hand, and that hand is its amplitude. Like any clock hand, this amplitude hand spins at a regular rate. The number of times it completes one round per second is its frequency. The more combined mass and energy the particle has, the faster it spins. That is why Feynman says that this clock-like spin is identical to the concept of the inertial (or gravitational) mass of the particle.

These frequencies are incredibly fast! Yet they are also used to create some of the most precise clocks in the universe, such as atomic clocks.

Remarkably, this process scales up for anything in which such particles are bound to each other. The individual particles keep their own clocks, but they also all contribute to this larger, faster clock that defines the total mass of the combined particles.

The Moon, of course, is such a combined mass, and it has a clock rate that defines that total mass. So let's take a look at very different ways of representing the zero-angular-momentum orbit of the Moon and a Donut Planet, which is to view the Moon as a clock that keeps track of time, and thus has a particular hand position as it falls (Fig. 2).

The first thing to notice about this Moon-As-A-Clock figure is that I've assumed an extremely lightweight Moon! I mean, the silly thing can't even complete one cycle during its downward fall, ending up only at about 6 PM. Clearly, this is not our real Moon, which has a mass frequency so large that's not a number you are likely to encounter.

But that's okay, because the goal here is to search for the existence of smaller — and thus, perhaps more plausible — examples of zero-orbital-momentum orbits.



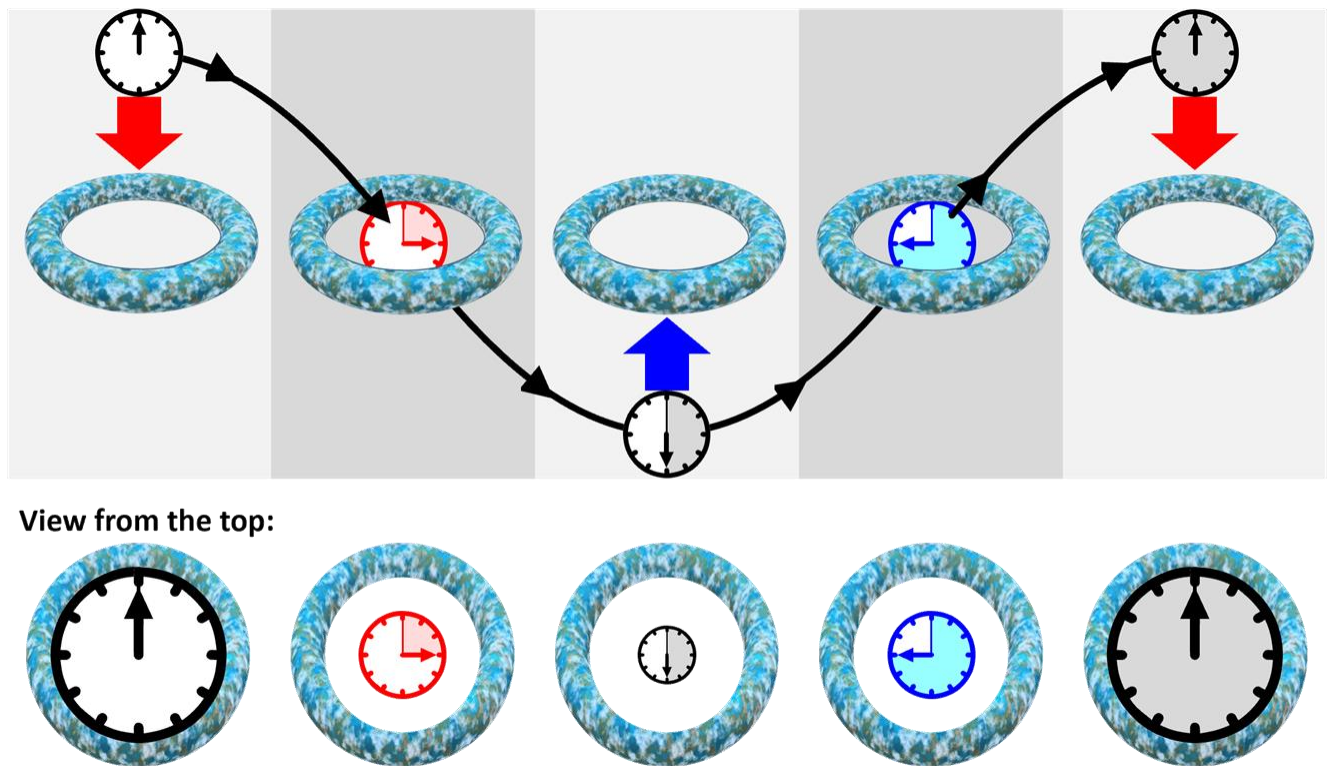


Figure 2. *The Moon as a Ticking Clock (Terry Bollinger, my work, CC BY 4.0, Oct 13, 2026).*

Tracking Hand Positions

The next thing to notice about Moon Clocks — which should not be confused with Moon Pies, which are smaller and much tastier — is that the position of their hands over time traces out an interesting arc or series of arcs, as shown in the third figure (Fig. 3).

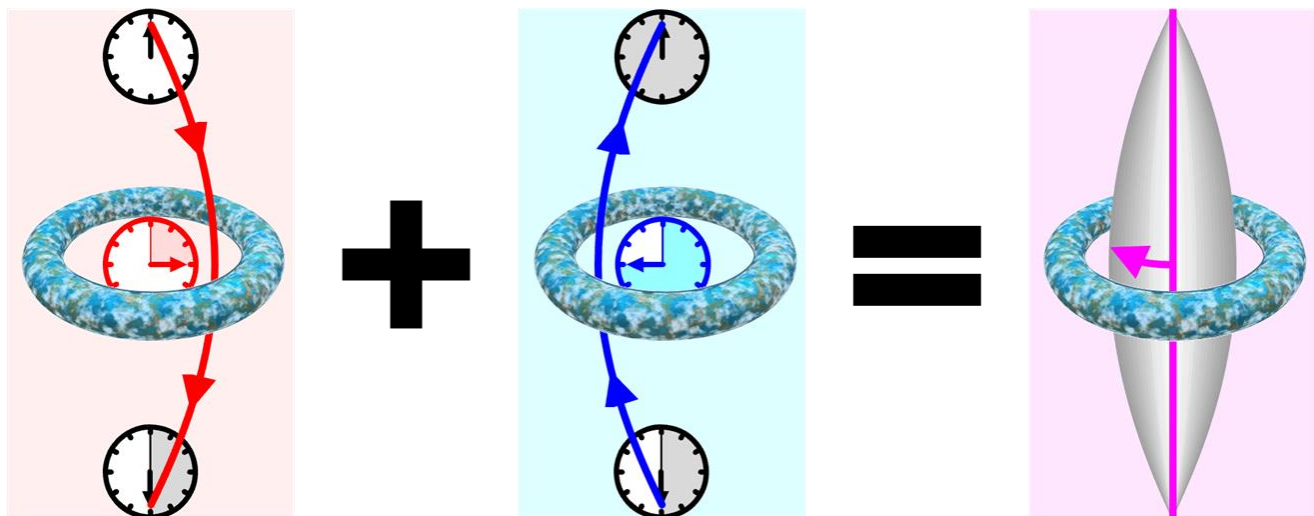


Figure 3. *The Simplest Possible Moon-As-A-Clock Orbits (Terry Bollinger, my work, CC BY 4.0, Oct 13, 2026).*

Assuming the lightest Moon possible gives the next figure, in which each downward and upward fall of the mood traces out only one half of a loop. The two half-loops differ in direction — one is the Moon falling down (red), and the other is the Moon falling up (blue) — but they share one feature: The clock always rotates clockwise. (Incidentally, in physics they prefer to use counterclockwise for such figures. Same idea, just a different choice of conventions.)

To get only one half-arc in each direction, the mass of this Moon needs to be tiny indeed. It would also help things along if the force used was a lot stronger than gravity, such as the attraction between negative and positive electrical charges. But the principle remains the same, and the intuition provided by thinking of the mass of the Moon as a clock remains the same.

Pixelation Versus Superposition

The third figure (Fig. 3) doesn't end with two paths, however. I show these two paths as having some sort of a “sum,” shown in purple, that somehow represents both paths.

If you know anything about quantum mechanics, you are likely thinking you know where this is going: The purple path is a “superposition” of the two possibilities, that is, of the Moon falling down and the Moon falling up. It contains both states, and represents both at the same time. If you've heard explanations of quantum computing, you've very likely heard the same idea there: That “superposition” computing — computing with two states at the same time — is part of how quantum computers are faster than ordinary ones.

But this is where I want you to consider another, simpler explanation: Pixelation due to insufficient storage. In particular, when you crank down the speed of the Mass Clock to the point where it just barely finishes one half-loop on the way down, the problem is that the Moon no longer has enough memory to remember which way it's going. It has only enough memory to recall its momentum, but it “lost” the additional bits of memory that tell it which way that momentum was going. Its momentum is stripped down to its absolute minimum, one in which even time — the time needed to go up or down — no longer applies in any meaningful way.

The effect is much like the pixelation blurring you sometimes see in digital systems, and it happens for similar reasons. However, this form of pixelation is uncomfortably fundamental, since it implies that our usual concepts of space and time as infinitely precise “givens” don't really apply for these very minimal orbits. Those are only added later, when additional energy or mass becomes available to add more details — to remove the pixelation.

I should also point out that the pixelation interpretation does not change the equations involved in such events. It only affects their interpretation, but in ways that can be significant if you are trying to understand reality at a deeper level. Superposition assumes that a potentially infinite number of infinitely precise orbital states can all exist at once, implying in turn that one would need a truly enormous amount of storage to track all those states at once. Pixelation does the exact opposite in terms of resources: It assumes that only enough bits exist to capture the basics of what an orbit is, and no more. The handful of bits constrains the future in ways that give rise to exactly the same solutions as superposition, but only creates them on a case-by-case basis.

The result is that in the pixelation interpretation of adding the up and down Moon orbits, what really happens is that you lose track of which way it is going — and that's all. No more energy is needed, but the idea that “infinite precision” underlies every such path ceases to exist. It becomes more of a principle that exists for its own sake, rather than to explain what actually happens.

So, if the states of superposition view are not energetically real, what does happen?

It's pretty simple: The system never contains more energy than is needed to represent an extremely stripped-down orbit. And all you have to give up is the idea that space and time are fundamental. :) In their place, you get little



ledger books that each particle — each tiny Moon, in this case — uses to keep track of what must be kept even after the ordinary concepts of time and separation disappear.

The purple line in the third figure thus is not so much a sum as a simplification, though the math stays the same. It is the simplest, most minimal representation of “something” that is still an orbit.

The Inspiration of Skip Ropes

So, if all that is left of the Moon orbit is the single, neither-up-nor-down curved line, how does that behave?

Here’s the surprise: It behaves in a remarkably intuitive fashion, which is like a skip rope.

The fourth and last figure (Fig. 4) shows how this works. The purple orbit, now shown as red to help keep track of an issue called “phase,” can continue as a single half-loop. Or, by rotating it harder and faster — by adding more energy, and thus enough additional bits to create more lasting structure — you can make it break up into more than one loop.

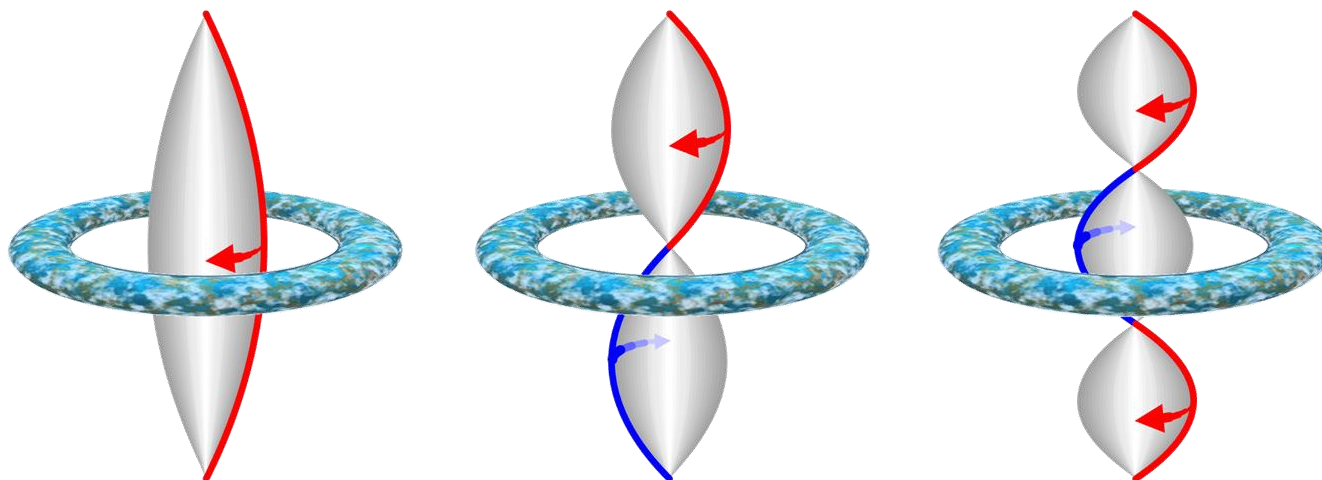


Figure 4. *The First Three Skip-Rope-Like Moon Orbits*
(Terry Bollinger, my work, CC BY 4.0, Oct 13, 2026).

Now, here’s the kicker. Recall how I said that the concept of time gets blurry when you simplify to the point where up and down travel no longer apply? Well, a similar thing happens to location: You can no longer say, with certainty, where the Moon shows up if you poke it by adding more energy.

In fact, there’s a strikingly simple rule for figuring out where the Moon may be: It’s the volume of those loops, with the likelihood of the Moon showing up increasing as the skip-rope looks gets wider. For the simplest single-half-loop case, the Moon is most likely to show up in the middle of the torus. But for the second two-half-loop case, something non-intuitive happens: The chance of finding the Moon in the middle becomes almost zero, even though that is where the attraction of Donut Earth is strongest. In the final, most energetic case, the Moon again picks up a good chance — about a one-in-three chance — of showing up in the middle of the donut. But it comes at a cost, since two other “never here” points appear. The idea that the moon travels in an uninterrupted line simply does not exist anymore, and the space in which it can exist becomes lumpy and granular.

The Hydrogen Surprise

I promised an unexpected physics connection at the end of this discussion of mostly astrophysics, and here it is: If you followed (not necessarily agreed with, but followed) what I've just said about minimal Moon orbits, you now understand all of the critical concepts for understanding the quantum mechanics of hydrogen atoms in their ground, first, and second excited states. You may not know all of the math notations, but you have the concepts down — and that is incredibly important for understanding the math.

The simplest possible state of the electron in a cold hydrogen atom is called the 1s state, where the “s” stands for “spherical.” Unlike classical orbits, these states have zero angular momentum — sound familiar? The absence of a simple model for classical zero-angular-momentum states often makes these perfectly spherical states difficult to imagine.

“But Terry!”, you say. “There’s absolutely nothing spherical about what you just described! It’s more like a chimney!”

Yep. But do you also recall what I said about pixelation and the loss of all but the most essential elements of an orbit, giving up ordinary concepts of time and space?

Pixelation also applies to orientation. That is, even if this chimney-like arrangement looks and behaves like a straight line from the perspective of an electron, the idea of a “direction” of that straight line turns out to be fully optional. To the outside world, at least until you poke it hard and insert enough new energy to add a direction, the 1s or “up and down Moon” orbital looks perfectly spherical.

Pixelation of space also explains how the electron gets by the proton, which is most definitely not shaped like a donut! Lack of sufficient spatial detail causes the electron to go around the proton without ever getting close enough to “see” the proton well enough to interact with its complicated interior. That can change, however, with some heavy elements in which K or L shell electrons do acquire enough energy to “see” and interact with the nucleus.

Physics is Connected, Always

Physics is connected at every scale, even when those scales tempt us to see related effects as completely different phenomena. Thus, remarkably, the orbital of a single electron in a hydrogen atom still manages to sketch out the deepest, most fundamental details of what makes an orbit an orbit. All increasing the masses and scales does is add enough additional information storage to produce the far more precise levels of detail that we like to call “classical” physics.

What a remarkable thing that is!

References

- [1] R. Feynman, *Lectures on Physics*, Volume III, Section 1-1, Paragraph 6. April 29, 1963.
https://www.feynmanlectures.caltech.edu/III_07.html#Ch7-S1-p6

