

Why Energy Can Never Truly Be Destroyed

Published April 24, 2026 · 13 min read · <https://thesleepyphysicist.com>

There is a version of this idea that most people encounter in school and immediately file away as settled, uninteresting, done. Energy is conserved. Fine. Move on. But the more carefully you look at what that actually means, the stranger and more profound it becomes. It is not simply a rule that nature happens to follow. It is a mathematical consequence of something deeper, something that touches the nature of time itself. And understanding why energy is conserved, not just that it is, changes how the entire physical world looks.

The Candle That Never Really Goes Out

Start somewhere ordinary. A candle burns down on a table. The wax disappears. The flame goes out. Everything about the experience suggests that something has been used up, spent, finished. This is the natural reading of a hundred everyday observations: things slow down, cool off, burn out. The world appears to be running down.

What is actually happening is different. The wax does not vanish. It converts. Carbon and hydrogen atoms combine with oxygen from the air, forming carbon dioxide and water vapor, and the difference in bond energy between the starting materials and the products is released as heat and light. Every joule that was stored in the chemical bonds of the wax is accounted for in the warmth of the room, the infrared radiation absorbed by the walls, the slight heating of the air above the flame.

The room is measurably warmer after the candle burns. Not by much, from a single candle over an hour. But the accounting is exact. Joule by joule, the energy that was in the wax is now distributed through the surrounding environment. It is not gone. It is just no longer in a form that looks like a candle.

This is the first law of thermodynamics, expressed not as an equation but as an observation. The total energy of an isolated system does not change. It only moves.

The candle does not go out. It becomes the room.

What Joule Actually Proved

In the 1840s, James Prescott Joule ran a series of experiments that most people would consider almost painfully tedious. He built a container of water with a paddle wheel inside it, attached the wheel to a falling weight via a cord, and measured how much the water warmed when the weight fell. He did this over and over, changing the weight, the height, the paddle design, the volume of water. He used thermometers calibrated to one two-hundredth of a degree Fahrenheit.

He was looking for the mechanical equivalent of heat: the precise conversion rate between mechanical work and thermal energy. What he found was that the rate was fixed and consistent regardless of the method. One calorie of heat always required the same amount of mechanical work to produce. Always. Whether the work came from falling weights, compressed air, or electrical resistance, the ratio was the same.

This seems like a modest result. It is not. What Joule demonstrated was that motion and heat are not different categories of physical reality. They are different forms of the same underlying quantity. When a moving object slows down due to friction, its kinetic energy does not disappear. It converts into the disordered thermal motion of the molecules in the surfaces involved. The surfaces get warmer by exactly the amount the kinetic energy decreased.

Friction, which for centuries looked like the mechanism by which motion was destroyed, turned out to be the mechanism by which motion becomes heat. Nothing is cancelled. Everything is redirected.

The value Joule measured, approximately 4.184 joules per calorie, has been confirmed to extraordinary precision by every subsequent experiment. It appears in the definition of the joule itself. The unit of energy is named after a brewer from Salford who refused to stop measuring things until the numbers made sense.^[1]

The Equation That Changed Everything

For most of the nineteenth century, conservation of energy and conservation of mass ran as parallel but separate laws. Mass was conserved. Energy was conserved. Both were confirmed by extensive experiment. Neither suggested it had anything to do with the other.

In 1905, Einstein showed they were the same law.

The relationship is expressed in the most recognized equation in science:

$$E = mc^2$$

Where E is energy, m is mass, and c is the speed of light, approximately 3×10^8 metres per second. The speed of light squared is approximately 9×10^{16} joules per kilogram. This means that one kilogram of any material, completely converted to energy, would release approximately 90 petajoules, which is roughly the energy released by 21 megatons of TNT.

What the equation says, underneath the numbers, is that mass is not a different thing from energy. Mass is energy in a particular configuration, energy that has settled into the stable structure of matter and is sitting there, patient, waiting. When nuclear reactions occur, a small fraction of that mass converts to other forms of energy. In fusion, four hydrogen nuclei combine to form one helium nucleus, and the helium weighs slightly less than the four hydrogens did separately. The missing mass, approximately 0.7 percent of the original, becomes photons, kinetic energy, neutrinos.

That 0.7 percent is what powers the sun. It is what has powered it for 4.6 billion years and will continue to power it for roughly 5 billion more. The mass that goes missing in the solar core becomes the light that warms every surface on Earth, drives every act of photosynthesis, powers every ecosystem. Every photon that has ever reached this planet from the sun was once a small quantity of hydrogen mass that became energy in a stellar core.

Conservation of energy and conservation of mass became, with relativity, a single unified law: conservation of mass-energy. The total of the combined quantity does not

change. It only transforms.

The Missing Energy That Wasn't Missing

In the 1920s, conservation of energy appeared to break down.

In a process called beta decay, certain radioactive nuclei emit an electron. Physicists measured the energy of the emitted electrons and found a continuous spectrum, a spread of energies ranging from nearly zero to a maximum value, rather than a single fixed energy. Since the initial and final nuclear states had fixed energies, the electron should carry a specific, predictable amount. Instead, it carried variable amounts, and the amounts were consistently less than expected.

The deficit was real. It was not experimental error. The numbers simply did not add up, and the missing energy had nowhere obvious to go.

Niels Bohr, one of the founders of quantum mechanics, suggested seriously and in print that conservation of energy might be statistical rather than exact at the quantum scale. That it might hold on average across many events without holding for each individual event. This was a coherent position. It was also incorrect.

Wolfgang Pauli took a different view. In a letter written in 1930, he proposed that a second particle was being emitted alongside the electron, a particle electrically neutral, with very little or no mass, that passed through matter without interacting and therefore escaped every detector then in existence. He called it, tentatively, the neutron. Enrico Fermi later renamed it the neutrino, the little neutral one.

Pauli reportedly expressed regret at having proposed a particle that could not be detected. He called it a terrible thing to have done. A particle invented purely to make an accounting equation balance felt, to many physicists, like something closer to theology than physics.

It took twenty-six years.

In 1956, Clyde Cowan and Frederick Reines detected antineutrinos experimentally using a nuclear reactor as a source and a large tank of water and cadmium chloride as

the detector.^[2] The signal was unambiguous. Pauli was sent a telegram. The neutrino was real. The energy had never been missing. It had been carried away by a particle that passed through everything without leaving a trace, and no instrument had been sensitive enough to catch it until then.

Conservation of energy had been confirmed by its own apparent violation. The deficit was not evidence that the law was wrong. It was evidence that something was hiding.

The Reason It Has to Be True

Everything so far is experimental. It describes what has been observed to happen in every physical system ever studied. But there is a deeper question: why is energy conserved? Is it a rule the universe happens to follow, a brute fact about physical reality with no further explanation? Or is there a reason?

In 1918, a mathematician named Emmy Noether published a theorem that answered this question completely.

Noether's theorem states that every continuous symmetry of a physical system corresponds to a conserved quantity. This is not a heuristic or an analogy. It is a mathematical proof, derived from the calculus of variations, that applies to any system described by a Lagrangian function.

The relevant symmetry here is time-translation symmetry: the fact that the laws of physics are the same today as they were yesterday. An experiment run now produces the same result as the same experiment run last week. Physics does not drift. The equations do not age.

Noether's theorem says that this time symmetry directly and necessarily implies conservation of energy. Not as a consequence that happens to follow in most cases, but as a mathematical certainty. If the laws of physics are time-symmetric, then energy is conserved. The two statements are equivalent.

$$\frac{dH}{dt} = 0 \quad \text{if} \quad \frac{\partial L}{\partial t} = 0$$

Where H is the Hamiltonian (the total energy of the system) and L is the

Lagrangian. If L does not explicitly depend on time, then H is conserved.

Conservation of energy is not a fact about energy. It is a fact about time.

This reframes everything. Asking why energy is conserved is the same as asking why the laws of physics are stable across time. And that question opens into something physics cannot fully answer about itself. The stability can be tested, verified to extraordinary precision, confirmed in every experiment. But why the universe is the kind of place where Tuesday's physics is Monday's physics is a question that sits at the edge of what the framework can say about its own foundations.

Noether herself never held a permanent paid academic position. She was blocked from a faculty appointment at Gottingen because she was a woman, lectured under Hilbert's name without pay for years, and was eventually expelled by the Nazis in 1933. She died in 1935 at age 53. Einstein called her the most significant creative mathematical genius thus far produced in the history of mathematics.^[3]

The End of the Universe, and Why the Books Still Balance

The second law of thermodynamics does not contradict the first. It adds something the first law does not address.

The first law says the total energy of an isolated system does not change. The second law says that energy tends to spread out, to move from concentrated states to diffuse ones, from ordered configurations to disordered ones. Entropy, the measure of this disorder, always increases or remains constant in an isolated system.

$$\Delta S \geq 0$$

Where ΔS is the change in entropy. The relationship between entropy and the number of available microstates is given by the Boltzmann equation:

$$S = k_B \ln \Omega$$

Where k_B is Boltzmann's constant and Ω is the number of microstates. More microstates means higher entropy. The spread-out, disordered state has overwhelmingly more available configurations than the concentrated, ordered state,

which is why energy spontaneously disperses and never spontaneously concentrates.

This is why a hot cup of coffee cools. The heat flows from the coffee into the room because there are vastly more ways for the energy to be distributed across the room's air molecules than concentrated in the coffee. The first law is satisfied throughout: every joule that leaves the coffee arrives somewhere in the room. The second law is also satisfied: the entropy of the system increases as the heat spreads.

Taken to its cosmological extreme, the second law points toward a final state called heat death. Over timescales measured in googols of years, 10^{100} years and beyond, all temperature differences in the universe will flatten. Stars will have long since stopped forming and burning. Black holes will have evaporated via Hawking radiation, returning their mass-energy to the universe as thermal photons. The remaining particles and radiation will approach perfect thermal equilibrium.

No energy will have been destroyed. Every joule present at the beginning will be present at the end. The universe will simply have reached a configuration so uniform that no gradient remains to drive any further process. The accounting will be exactly as it has always been. There will just be nothing useful left to spend.

What We Actually Know

Conservation of energy is one of the most thoroughly tested principles in all of science. It has been confirmed in mechanical systems, thermal systems, electromagnetic systems, nuclear systems, and quantum systems. Every apparent violation has ultimately revealed something new: the neutrino, the photon, the deeper unity of mass and energy. The law has never been revised downward. Each revision has expanded what counts as energy to include something previously overlooked.

The deepest version of what we know comes from Noether's theorem. Energy is conserved not because we have checked enough cases, but because the laws of physics do not change with time. If they ever did, energy conservation would break down in exactly the way the theorem predicts, and we would be able to measure the violation. No such violation has ever been observed.

The total energy of the universe right now, in whatever units you choose to measure it, is the same as it was at the beginning. It has been distributed differently, transformed through an extraordinary variety of forms, concentrated into stars, scattered into photons, locked into matter, released as radiation. But the total has not changed.

Nothing that has ever happened has made it smaller. Nothing that will ever happen can.

^[1] Joule's most precise experiments achieved an accuracy within approximately 1 percent of the modern accepted value of 4.1868 joules per calorie. His 1845 paper "On the Mechanical Equivalent of Heat" was initially rejected by the Philosophical Magazine before being published in an abbreviated form. The unit of energy, the joule, was named in his honour by the British Association for the Advancement of Science in 1882.

^[2] The Cowan-Reines experiment used the Savannah River nuclear reactor in South Carolina as a neutrino source. The detection relied on inverse beta decay: an antineutrino interacting with a proton to produce a positron and a neutron, with both particles producing detectable signals in the cadmium-loaded water tank. Reines received the Nobel Prize in Physics in 1995 for this discovery; Cowan had died in 1974. Their telegram to Pauli announcing the detection reportedly prompted Pauli to reply that everything comes to those who know how to wait.

^[3] Einstein's tribute to Noether appeared in the New York Times on May 5, 1935, four days after her death. He wrote that her work in the realm of algebra was the most significant creative mathematical genius thus far produced. Hermann Weyl, who had worked alongside her at Gottingen, wrote that she was not only the greatest woman mathematician who had ever lived, but the greatest mathematician, regardless of sex, in her era at Gottingen.