E is for energy

"Energy, power, 101 FM!" This radio jingle is driving me to distraction. Why are DJs convinced that energy and power are the same thing? Is there some history to this? I do wish the jingle writers would consult an encyclopedia before going public.

Ah, energy. Such a little word, so often misunderstood, yet such a wonderfully useful concept – and surely the most ubiquitous quantity in physics. "Energy is the capacity to do work" we tell hapless students in their introductory physics courses. It is probably the first abstract concept they encounter, but most find it intuitively easy to understand – as in "I hadn't the energy to get out of bed". Then they learn of kinetic and potential energy, and of the law of conservation of energy, before going on to calculate the landing velocity of boys falling off cliffs. These are simple ideas but deep (my favourite type). The conservation of energy, for example, arises from the translational symmetry of time, which is an example of Noether's theorem – not something that generally arises in a first physics course.

As the student progresses in physics, the ubiquity of energy becomes apparent. From mechanics to heat, from optics to electrostatics, energy just keeps on turning up. The history of how energy spread through physics is an interesting one; apparently the word *energeia* was first used by Aristotle, but the concept of energy in the modern sense had to wait the late 1600s, when Leibniz defined *vis viva* as the mass of an object multiplied by its velocity squared. And it was not until the 19th century that scientists discovered that heat is simply a form of energy – a discovery that paved the way for the laws of thermodynamics and all that followed.

The ubiquity of energy continues into modern physics. Consider special relativity. For all its startling predictions of time dilation and length contraction, it is the discovery of the equivalence of mass and energy that is the theory's crowning achievement. Mass is a hidden form of potential energy, no less. Even the sacred law of conservation of energy becomes a law of conservation of mass–energy.

This brings us to $E = mc^2$. Much has been written on the fame of this equation, but for my money, it is all in the E. Anyone can guess that E stands for energy, so it is easy to grasp the excitement of an equation that predicts a whole new form of energy (especially if the equation is accompanied by a picture of an atomic bomb). That said, friends tell me the humble c^2 also gives a certain pizzazz to the equation. Incidentally, "ee is mc two" is how the equation is pronounced by the younger generation, apparently. Sigh.

Energy plays an even more important role in the general theory of relativity, since the curvature of space–time on one side of the equations is related to the density of matter–energy on the other. (Or something like that.) Sounds completely mad until you remember that effects such as time dilation in a gravitational field have been verified beyond doubt.

And what about quantum theory, that other pillar of modern physics? It is not long before one encounters the Schrödinger equation – the starting point for almost any problem in quantum physics. Written as $H\psi = E\psi$, this is just another energy equation. While students struggle with the true meaning of the wavefunction ψ (don't we all), that

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Any surfer will tell you that tides are a damn sight more reliable than wind or wave

energy operator H makes life a good deal simpler – thanks to the Irish physicist William Rowan Hamilton.

Actually, my favourite sort of energy turns up in the quantum world: the energy of the vacuum. According to the Heisenberg uncertainty principle ($\Delta E \Delta t \geq \hbar/2$), particles can borrow energy to come into existence as long as they are quick enough about it – a pretty neat trick, if a bit short-lived. This vacuum energy is particularly important in cosmology, as it is thought to be responsible for the current acceleration of the expansion of the universe (the so-called dark energy).

Come to think of it, just about all of Big Bang cosmology can be stated succinctly in terms of energy: an ultra-hot and ultra-dense universe gradually cooling and expanding is surely one great conversion of potential to kinetic energy, from beginning to end. How about that for a brief history of time?

That was a quick ramble through physics, but of course the concept of energy is used throughout science. For the public, the most familiar example is surely renewable energy. Plenty has been written in this issue on the potential of renewables to simultaneously address the twin challenges of energy supply and carbon emissions. I am no expert, but speaking as a surfer, my money is on tidal energy: if you have a moon and oceans, then you have a highly periodic and reliable free lunch, no? Any surfer will tell you that tides are a damn sight more reliable than wind or wave.

But wait, wait! Why do we speak of wave *power* but tidal *energy*? No wonder our friends in the media are confused. Time for some standardization, people. I suggest we stick with energy...and while we are at it, let's change that jingle to "Wave energy, tidal energy, 101 FM".

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