Scientists Propose a Better Definition for the Kilogram

How much is a kilogram?

It turns out that nobody can say for sure, at least not in a way that won't change ever so slightly over time. The official kilogram – a cylinder cast 118 years ago from platinum and iridium and known as the International Prototype Kilogram – has been losing mass, about 50 micrograms at last check.

That's not so good for a standard the world depends on to define mass.

Now, two U.S. professors say it's time to define the kilogram in a new and more elegant way that will be the same today, tomorrow and 118 years from now. They proposed redefining the kilogram as the mass of a very large – but precisely-specified – number of carbon-12 atoms.

"Our standard would eliminate the need for a physical artifact to define what a kilogram is," says Ronald F. Fox, a Regents' Professor Emeritus in the Georgia Tech School of Physics. "We want something that is logically very simple to understand."

Their proposal is that the gram – 1/1,000th of a kilogram – would henceforth be defined as the mass of exactly $18 \times 14{,}074{,}481^3$ carbon 12 atoms.

The proposal, made by Fox and Theodore P. Hill – a Professor Emeritus in the Georgia Tech School of Mathematics – first assigns a specific value to Avogadro's constant. Proposed in the 1800s by Italian scientist Amedeo Avogadro, the constant represents the number of atoms or molecules in one mole of a pure material – for instance, the number of carbon 12 atoms in 12 grams of the element. However, Avogadro's constant isn't currently known exactly; it's a range of values that can be determined experimentally, but not with enough precision to be a single number.

Spurred by Hill's half-serious question about whether Avogadro's constant was an even or odd number, in the fall of 2006 Fox and Hill submitted a paper to *Physics Archives* in which they proposed assigning a specific number to the constant. The authors pointed out that a precise Avogadro's constant could also precisely redefine the measure of mass, the kilogram.

Their proposal drew attention from the editors of *American Scientist*, who asked for a longer article that was published in March 2007. The proposal drew five letters, including one from Paul J. Karol, chair of the Committee on Nomenclature, Terminology and Symbols of the American Chemical Society. Karol added his endorsement to the proposal and suggested making the number divisible by 12 – which Fox and Hill did in an addendum by changing their number's final digit from 8 to 6. So the new proposal for Avogadro's constant became $84{,}446{,}886^3$, still consistent with the best mean value and estimated uncertainty determined by the U.S. National Institute of Standards and Technology (NIST).

Fast-forward to September 2007, when Fox read an Associated Press article about the mass disappearing from the International Prototype Kilogram. While the AP said the missing mass amounted to no more than "the weight of a fingerprint," Fox argues that the amount could be significant in a world that is measuring time in ultra-sub-nanoseconds and length in ultra-sub-nanometers.

So Fox and Hill fired off another article, this one proposing to redefine the gram as 1/12th the mass of a mole of carbon 12 – a mole long being defined as Avogrado's number of atoms. They now hope to generate more interest in their idea for what may turn out to be a competition of standards proposals leading up to a 2011 meeting of the International Committee for Weights and Measures.

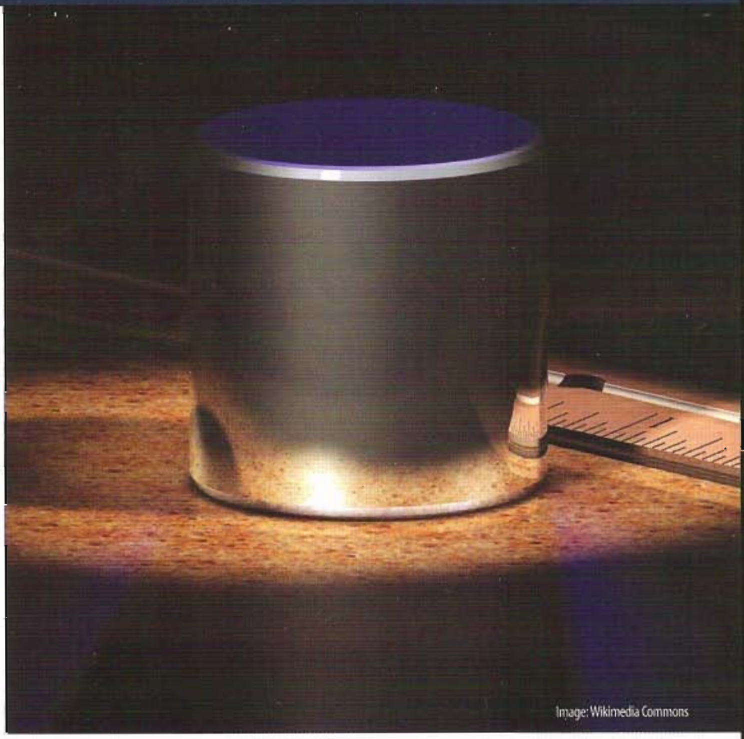

Image: Wikimedia Commons

A computer-generated image of the International Prototype Kilogram, which is made from an alloy of platinum and iridium. Researchers have proposed a new kilogram definition that would replace this physical artifact.

At least two other proposals for redefining the kilogram are under discussion. They include replacing the platinum-iridium cylinder with measurements using spheres of pure silicon atoms, and using a device known as the "watt balance" to define the kilogram using electromagnetic energy. Both would offer an improvement over the existing standard – but not be as simple as what Fox and Hill have proposed, nor be exact, they say.

"Using a perfect numerical cube to define these constants yields the same level of significance – eight or nine digits – as in those integers that define the second and the speed of light," Hill says. "A purely mathematical definition of the kilogram is experimentally neutral – researchers may then use any laboratory method they want to approximate exact masses."

The kilogram is the last major standard defined by a physical artifact rather than a fundamental physical property. In 1983, for instance, the distance represented by a meter was redefined by how far light travels in 1/299,792,458 of a second – replacing a metal stick with two marks on it.

– John Toon

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