PHYSICS

The Kilogram Makeover

Finally a better standard for the fundamental unit of mass

The kilogram is a 127-year-old relic. It is the last remaining standard of measurement in the International System of Units that is still based on a physical object—a single, golf ball-sized cylinder of platinum and iridium that sits in a vault just outside Paris. It is kept under lock and key—and secured underneath three vacuum-sealed, glass bell jars—in a temperature-controlled room in the International Bureau of Weights and Measures. The slightest amount of dust, moisture, oil from fingerprints, or contraction or expansion could alter the mass of the cylinder. In fact, the so-called *Le Grand K* is so well protected that caretakers remove it only every 40 years so that other prototypes from around the world can be compared with it. Even then, it is impossible to tell if changes are caused by the fact that *Le Grand K* lost mass or that one of its copies gained some from contamination.

This is a serious problem for modern science, given that many technologies depend on an accurate measurement of the kilogram, says Stephan Schlamminger, a physicist at the National Institute of Standards and Technology. That is why scientists, for decades now, have wanted to redefine the kilogram in terms of constants found in nature—an achievement that would provide a more stable (and accessible) unit of measurement.

Schlamminger and his team recently reported that they have paved the way for such a feat by using Planck's constant, a mathematical value that describes the link between the energy of a photon and its frequency and that can be related to mass through Einstein's famous equation $E = mc^2$. As detailed in the *Review of Scientific Instruments,* the NIST team measured Planck's constant with a high-tech scale called a watt balance.

The researchers placed a known mass on one end of the scale and then counterbalanced it by sending an electric current through a movable coil of wire suspended in a magnetic field. They then used that electromagnetic force to measure

CASPAR BENSON *Getty Images*

A BRIEF HISTORY OF THE INTERNATIONAL SYSTEM OF UNITS

1799

The metric system was created at the time of the French Revolution. Two platinum standards representing the meter and the kilogram were chosen in an effort to standardize trade.

1889

The first General Conference on Weights and Measures sanctioned international prototypes for the meter and the kilogram. Along with the second as a unit of time, these became the three base units of measurement.

1954

The 10th conference added the kelvin to the system of units as a measure of temperature.

1960

The 11th conference replaced the physical meter with a definition based on the radiation of krypton 86. This was later changed (in 1983) to the distance light travels in a given time.

Planck's constant down to an accuracy of 34 parts per billion.

Before the world redefines the kilogram based on Planck's constant, however, multiple teams must publish independent measurements by July 2017. At the 2018 General Conference on Weights and Measures, the data from each group will then be evaluated, including a constant calculated by counting the atoms in a silicon sphere. A complex computer program will subsequently sift through the numbers to arrive at a final value. Only then may *Le Grand K* be retired to the Louvre, next to the old meter and other artifacts. —*Knvul Sheikh*

BY THE NUMBERS

$6.626\ 069\ 83 \times 10^{-34}$ kg m²/s

Planck's constant as measured using the NIST-4 watt balance

$0.000\ 000\ 22 \times 10^{-34}$ kg m²/s

(or 34 parts per billion)

Level of uncertainty in the measurement by Stephan Schlamminger's team

230 miles

Driving distance between Washington, D.C., and New York City

0.5 inch

Level of uncertainty in the measurement of distance that is comparable to 34 parts per billion

SOURCE: NATIONAL INSTITUTES OF HEALTH

1967

The 13th conference changed the definition of a second from 1/86,400 of an average solar day to a particular number of periods of radiation produced by a cesium 133 atom.

2018

The year in which the physical kilogram is set to be replaced by a definition based on Planck's constant.