The Kilogram – Redefined

It Started in 1889 and Changed in 2019

A chunk of platinum and iridium known as “Le Grand K” defined the mass of a kilogram since 1889. That is until May 20, 2019, World Metrology Day, when scientists officially changed the definition of the kilogram to one based on physicist Max Planck’s constant. The new definition is evidence of metrology’s shift from physical artifacts to physical constants.

Take, for example, 1 m = the distance light travels in a vacuum in 1/299,792,458 of a second. That definition has an uncertainty three to five orders of magnitude more precise than prior physical artifacts. (The definition of a second is a further four orders of magnitude more precise).

The kilogram is now characterized by the redefinition of the Planck constant using a Kibble balance (or a watt balance, because it measures the current and voltage required to generate the force that balances the mass being measured).

Le Grand K: State of the Art … for the 19th Century

Le Grand K, a cylinder of platinum-iridium alloy, sat for years in a vault outside Paris. Over time, and as carefully as scientists handled it, the cylinder lost atoms, an estimated 50 micrograms over its lifetime.

With the redefinition, scientists now get to measure the kilogram against Planck’s constant. With physical constancy, the kilogram corresponds to the mass of a precise number of photons, or particles of light, of a particular wavelength. What this does is define the kilogram in terms of seconds and the meter, which are physical constants and more reliable than a fabricated object.

Planck’s constant connects the amount of energy carried by a photon to the frequency of its electromagnetic wave. A photon’s energy is equal to its frequency multiplied by Planck’s constant.

Take a look at the seven units of the metric system and their fundamental constants:

- **Meter**: length, or the distance traveled by light in a vacuum in 1/299,792,458 of a second
- **Second**: time, or exactly 9,192,631,770 cycles of radiation of an atom of caesium-133
- **Kilogram**: mass; Planck’s constant divided by 6.626,070,15 × 10^{-34} m²s⁻¹
- **Mole**: the amount of substance; the Avogadro constant, or 6.02214076 × 10^{23} elementary entities
- **Candela**: luminous intensity; a light source with monochromatic radiation of frequency 540 × 10^{12} Hz and radiant intensity of 1/683 of a watt per steradian
- **Kelvin**: temperature; the Boltzmann constant, or a change in thermal energy of 1.380649 × 10^{-23} joules
- **Ampere**: current, equal to the flow of 1/1.602176634 × 10^{-19} elementary charges per second
Planck’s constant, symbolized by $h$, relates the energy in one quantum (photon) of electromagnetic radiation to the frequency of that radiation. In the International System of Units (SI), the constant equals approximately $6.626176 \times 10^{-34}$ joule-seconds.