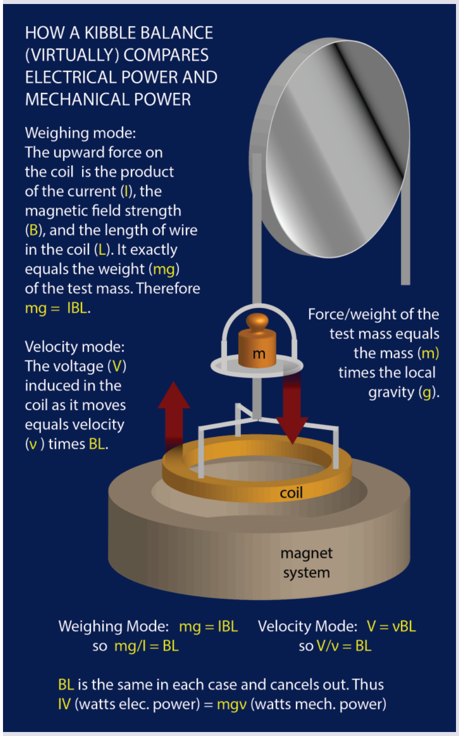
THE EXACT MASS OF A KILOGRAM: THE ELECTRIC KILOGRAM

In 1999, a group of NIST scientists began exploring the use of a Kibble's balance in order to assign a fixed value to Planck's constant, which was precise enough to be useful in redefining the kilogram.

A Kibble (or NIST-4 watt) balance is a sophisticated and extremely sensitive set of scales that provides extremely precise electrical measurements of mass. It can act in two modes – a weighing (or force) mode, and a velocity (or calibration) mode. It is used in:



The Kibble balance equates electrical and mechanical power to calculate mass.

Credits: Adapted from National Institute of Standards and Technology. URL: https://www.nist.gov/siredefinition/kilogram-kibble-balance. License: CC-BY.

- Weighing mode to measure the force acting on a mass in terms of the current a coil in the Kibble balance produces to counteract it.
- Velocity mode to calculate the velocity of the coil and the voltage it generates once the mass is removed and the coil moves through a uniform magnetic field.

The mass is measured by equating the mechanical power in the weighing mode with the electrical power in the velocity mode.

How do these measurements help arrive at a more precise value of Planck's constant? The current the coil in the Kibble balance produces in weighing mode is measured in terms of a physical constant called the von Klitzing constant. The voltage the coil in the Kibble balance generates in the velocity mode is measured in terms of another physical constant called the Josephson constant. Both these constants – von Klitzing and Jospehson – are defined in terms of Planck's constant (and, the charge of an electron). Therefore, obtaining precise measurements of the current and voltage produced by a one kilogram standard in the Kibble balance could be used to arrive at an extremely precise value for Planck's constant.

For a more detailed explanation of how V and I are expressed in terms of Planck's constant, see: https://www.youtube.com/watch?v=Oo0jm1PPRuo.

A team of seven NIST researchers, headed by S. Schlamminger, used this approach to obtain a measurement of Planck's constant that had an uncertainty of 13 parts per billion. Subsequently, this balance has been used to arrive at three other measurements which were precise enough to meet the standards set by the International Committee for Weights and Measures, one of which has an error margin as low as 9.1 parts per billion.

When will the kilogram be redefined? Find out on page 94.

Siddharth Setlur is a Grade XII student & founder of the non-profit peer-to-peer learning platform (www.vlearn.xyz) who aims to pursue an academic career in theoretical physics and mathematics. He can be contacted at: siddharth.setlur@gmail.com.

Chitra Ravi works at Azim Premji University, Bengaluru.

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