THE KIBBLE BALANCE

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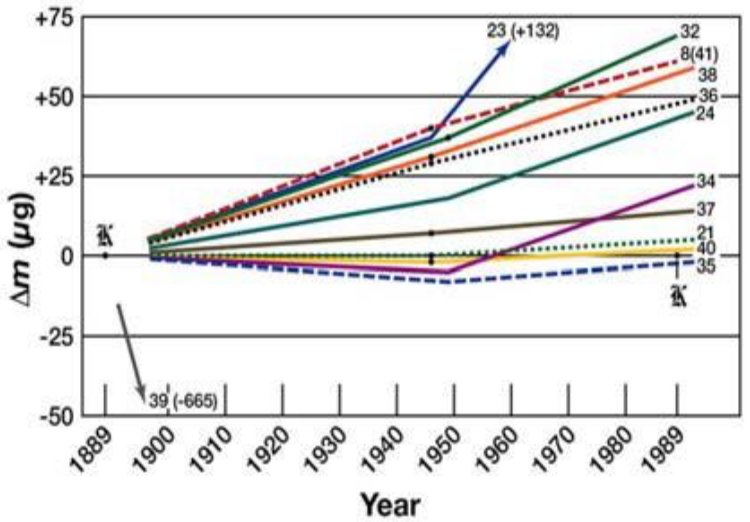
Introduction

- The IPK has been the definition of kilogram since 1889.
- The International prototype kilogram, which is a lump of Platinum-iridium metal cylinder which is located in Paris.
- The problem with the prototype is that it doesn't always weigh the same. Accumulation of the fine dust particles affects its mass.
- So we need a new definition for kilogram that is based on a fundamental constant which is invariant over time.
- The constant is Planck's constant: a number that relates a photon's energy to its frequency.



https://en.wikipedia.org/wiki/Kilogram

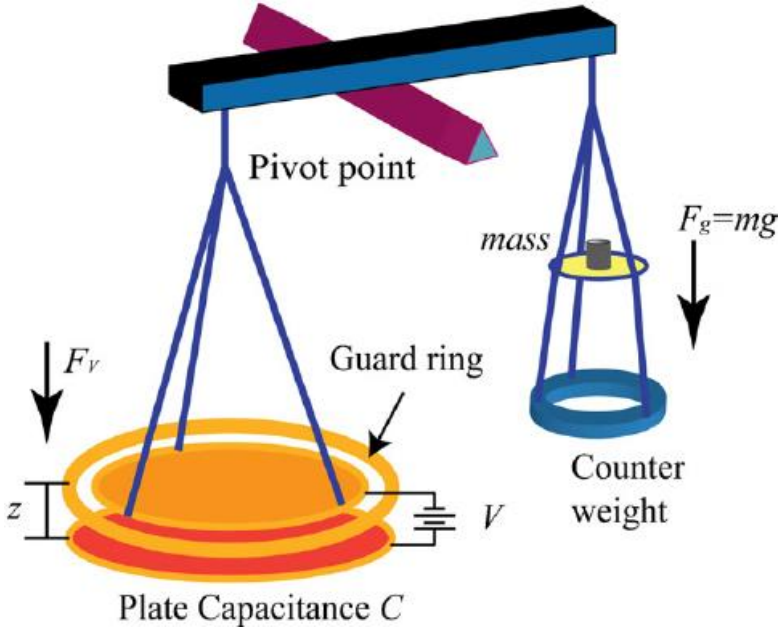
A replica of the International Prototype Kilogram at the BIPM

The Kibble balance

- Kibble balance is an apparatus that can determine the Planck's constant by comparing gravitational force with the electromagnetic force.

- An ordinary beam balance works by adjusting the amount of mass on one side of the beam so that its weight exactly balances the weight of the test mass on the other side.

Beam balance



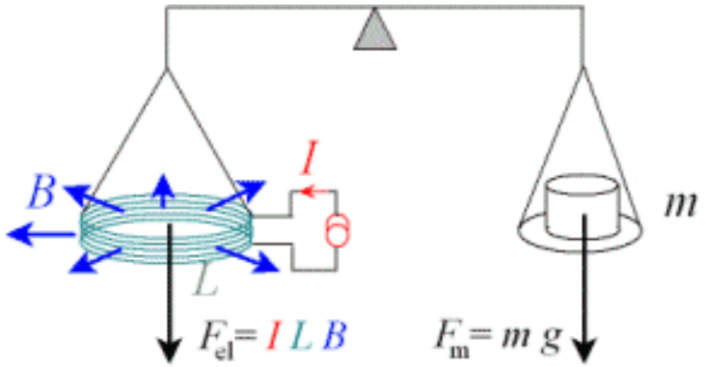
Kibble Balance

Principle and working of the Kibble balance

- In **weighing mode**, a test mass is placed on a pan that is attached to one arm of the balance which experiences a downward force.

- The current applied to the coil is then adjusted until the upward force on the coil precisely balances the downward force of the weight. When the system reaches equilibrium, the current is recorded.

→ **Weighing experiment**



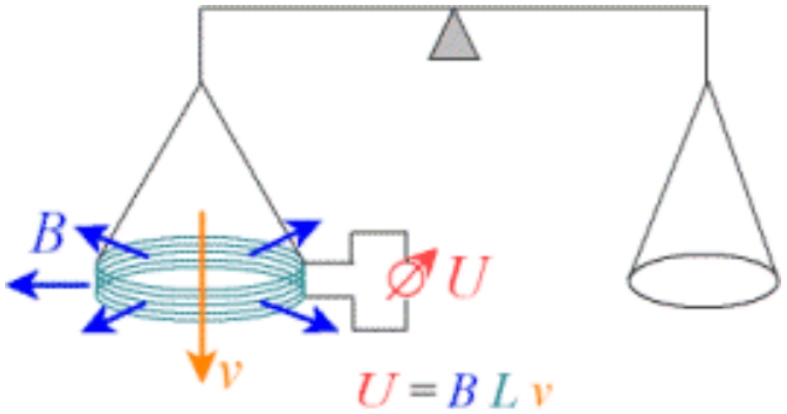
In the weighing experiment, a mass and a coil are suspended from a balance. The coil (wire length *L*) is placed in a magnetic field of flux density *B*. The gravitational force on the mass *m* is balanced by an equal and opposite electromagnetic force on the coil by sending a current *I* through it:

$$m\,g = I\,L\,B$$

https://www.bipm.org/en/bipm/mass/watt-balance/wb_principle.html

- In **velocity mode**, the test mass is removed from the pan.
- The coil is then moved through the surrounding field at a carefully controlled constant velocity. The resulting induced voltage is measured.

→ **Moving experiment**



In the moving experiment, the coil is moved at a vertical speed *v* through the magnetic field so that a voltage *U* is induced:

$$U = B\,L\,v$$

https://www.bipm.org/en/bipm/mass/watt-balance/wb_principle.html

Mass and the Planck's constant

- If the properties of the coil and the magnetic field, *L* and *B*, and their alignment, do not change between the two experiments,

$$U\,I = m\,g\,v$$

- To establish a link between the macroscopic mass m and the Planck's constant h, the electrical quantities voltage and current are measured by using two macroscopic quantum phenomena, the Josephson effect and the quantum Hall effect.

$$U = \frac{Nhf}{2e}$$

Josephson effect

$$I = \frac{V}{R} \qquad R = \frac{h}{ne^2}$$

Hall effect

Thank You