METROLOGY

standards
and
references

The seven base units

Length (meter) (1983)

Time (second) (1967)

Mass (kilogram) (1889)

Electric current (ampere) (1948)

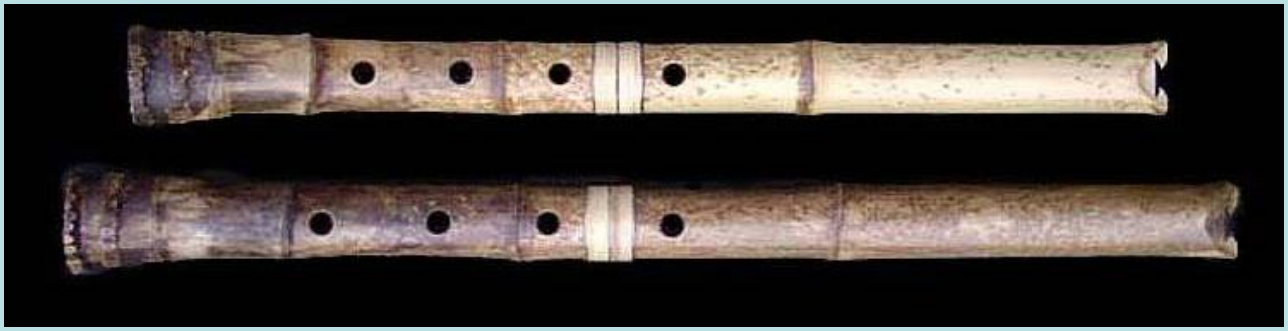
Thermodynamic temperature (kelvin) (1967)

Luminous intensity (candela) (1979)

Amount of substance (mol) (1971)

standard length: history

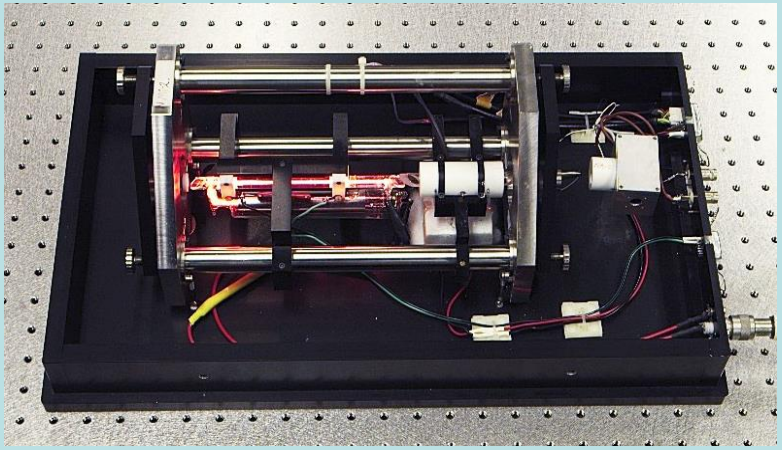
- China: bamboo flute
- Japan: shakuhachi (1 shaku = 30,3 cm)



- Egypt: royal cubit (= 7 palms = 52.3 cm)

length: 1 meter

90% platinum
10% iridium



1983: The **meter** is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second

mass: history

Egypt: seeds of the quirat tree; stone weights

India: stones in a binary series: 1, 1/2, 1/4, 1/8, 1/16, 1/32 (13.7 gram)

mass: history (2)

Greek: talents

Romans: libra (pound); uncia (ounce)

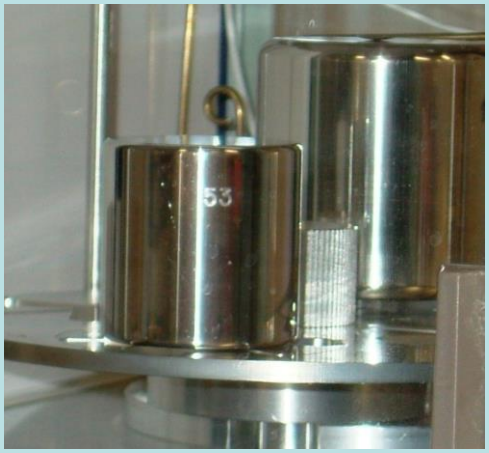
mass: history (3)

Europe, 18th century

1 kilogram (1889-2011)

The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram

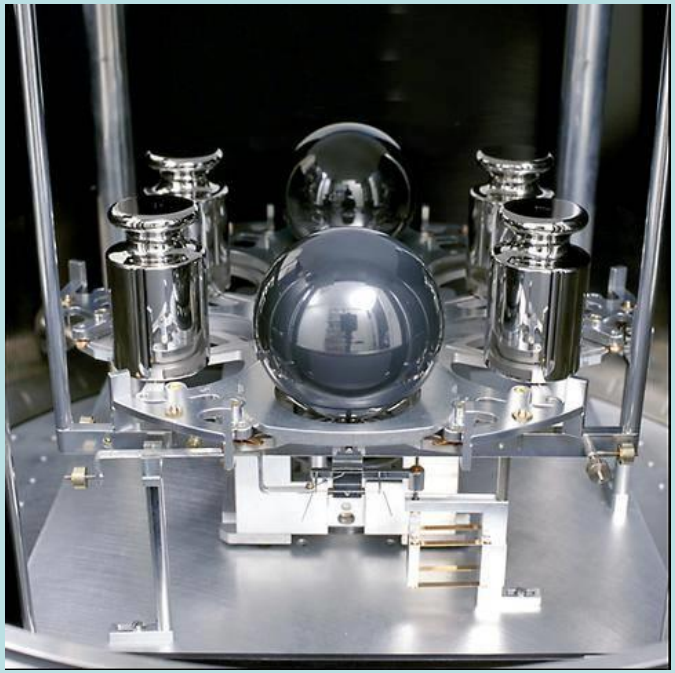
International prototype “Grand K“



Dutch kilogram: PtIr no. 53

1 kg + 146 mg ± 10 mg

A new kilogram (2011?)



sphere of pure silicon

diameter 93.6344 mm

time: history

- ca 1500 before Christ: sun clock
- 1656: pendulum clock by Christiaan Huygens

Oldest sundial in the Netherlands: Utrecht, 1463

time: second (1967)

- The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom

time standard

Electric current

The **ampere** is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 x 10-7 newton per meter of length.

No international standard

Electric standard is based on standards for voltage and resistance

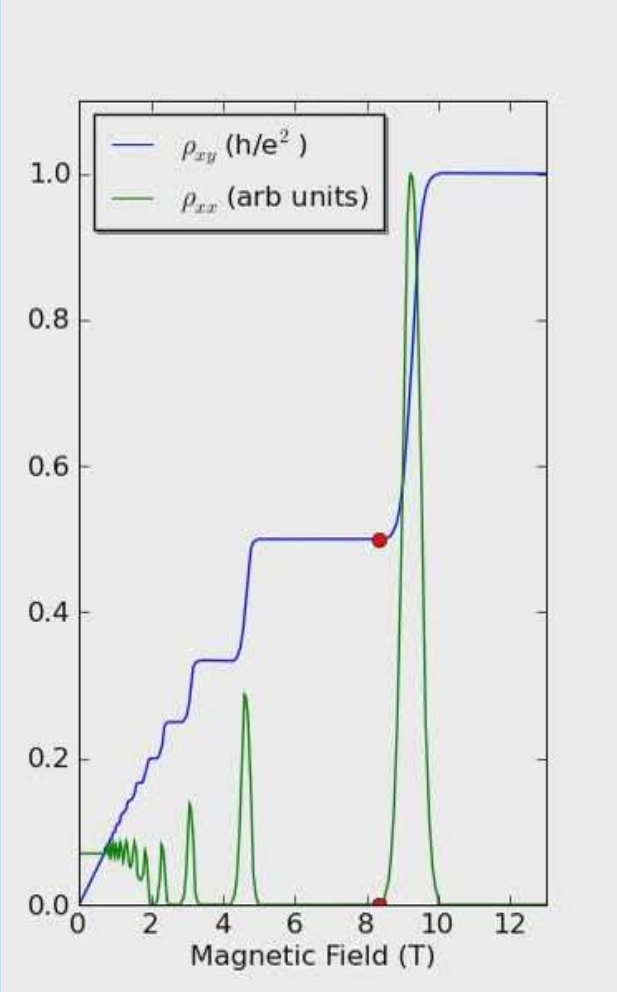
Electric resistance

Basis: Quantum Hall effect

$$R_H(i) = \frac{V_H(i)}{I} = \frac{R_k}{i}$$

Klitzing constant: $R_k = h/e^2$

$$R_{H-90} = 25812.807 \quad \Omega$$

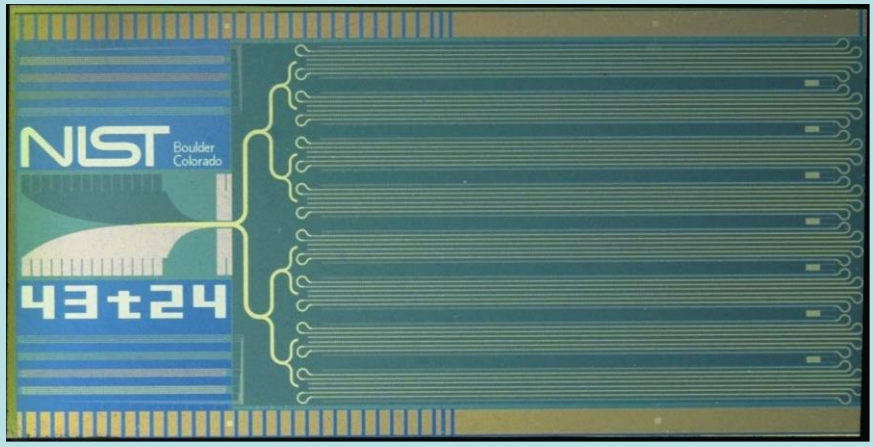


Voltage

Basis: Josephson junction

$$V_j(N) = \frac{N \cdot f}{K_j}$$

$$K_j = \frac{2e}{h}$$



$$K_{j-90} = 483597.9 \quad \text{GHz/V}$$

Temperature

The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

light intensity: history

A foot-candle, abbreviated fc, lm/ft^2, is a non-SI unit of illuminance or light intensity widely used in photography, film, television, conservation lighting, and the lighting industry.

light intensity: candela

1967: The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 THertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

1948: (candle) unit of luminous intensity, defined as 1/60 of the intensity of a black body, or ideal radiator, at the temperature at which platinum solidifies (2,046 degrees Kelvin).

amount of substance

1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol."
2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

Tracebility: example

PtIr53 (NMi)
1 kg ± 0,010 mg

Reference standards (NMi)
1 kg ± 0,026 mg

Working standards (NMi)
1 kg ± 0,150 mg

Mass standards (RvA laboratories)
1 kg ± 0,500 mg

Mass standards/scales (industry)
1 kg ± 1,50 mg t/m 500 mg