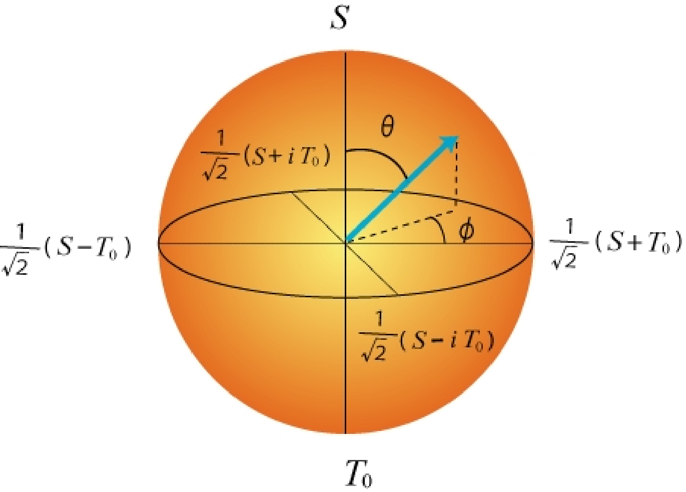
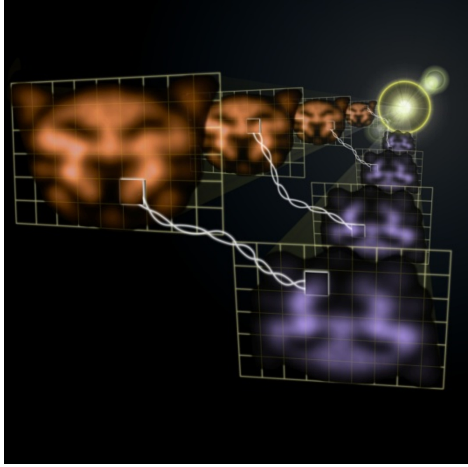




Setting the Stage: Is a Big G Consortium the Right Way?

Carl J. Williams, Chief

Quantum Measurement Division

Quantum Measurement Division

Quantum Measurement Division (QMD)

- **QMD is at the center of the redefinition of the "Quantum SI"**
  - Mohr, Taylor, and E. Williams instrumental in basic idea
  - CODATA (Committee on Data for Science and Technology) recommended values will be basis for fixing the constants
- **QMD realizes electrical, mass, and force units**
  - Reorganization creates a *unique* opportunity for the mise-en-pratique for mass!
  - Quantum based measurements provides foundation for advances in all units including beyond the standard quantum limit

INSTITUTE OF PHYSICS PUBLISHING METROLOGIA
Metrologia 43 (2006) 227–246 doi:10.1088/0026-1394/43/3/006

Redefinition of the kilogram, ampere, kelvin and mole: a proposed approach to implementing CIPM recommendation 1 (CI-2005)

Ian M Mills[1], Peter J Mohr[2], Terry J Quinn[3], Barry N Taylor[2] and Edwin R Williams[2]

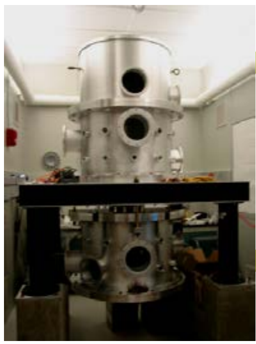
2010 CODATA RECOMMENDED VALUES OF THE FUNDAMENTAL CONSTANTS OF PHYSICS AND CHEMISTRY NIST SP 959 (Dec 2012)

Values from: P. J. Mohr, B. N. Taylor, and D. B. Newell, *Rev. Mod. Phys.* **84**, 1527 (2012) and *J. Phys. Chem. Ref. Data* **41**, 043109 (2012). The number in parentheses is the one-sigma (1 σ) uncertainty in the last two digits of the given value.

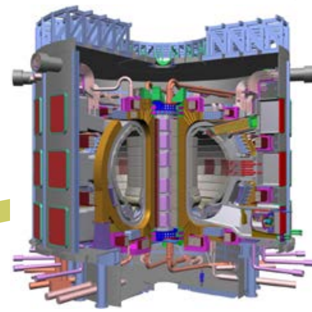
Quantity	Symbol	Numerical value	Unit
speed of light in vacuum	c, c_0	299 792 458 (exact)	m s^{-1}
magnetic constant	μ_0	$4\pi \times 10^{-7}$ (exact)	N A^{-2}
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817... \times 10^{-12}$	F m^{-1}
Newtonian constant of gravitation	G	$6.673\,84(80) \times 10^{-11}$	m^3 kg^{-1} s^{-2}
Planck constant	h	$6.626\,069\,57(29) \times 10^{-34}$	J s
$h/2\pi$	$\hbar$	$1.054\,571\,726(47) \times 10^{-34}$	J s
elementary charge	e	$1.602\,176\,565(35) \times 10^{-19}$	C
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	$7.297\,352\,5698(24) \times 10^{-3}$	
inverse fine-structure constant	α^{-1}	137.035 999 074(44)	
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 539(55)	m^{-1}
Bohr radius $\alpha/4\pi R_\infty$	a_0	$0.529\,177\,210\,92(17) \times 10^{-10}$	m
Bohr magneton $e\hbar/2m_e$	μ_B	$927.400\,968(20) \times 10^{-26}$	J T^{-1}

Vertically Integrated Measurements and Services within the Quantum Measurement Division

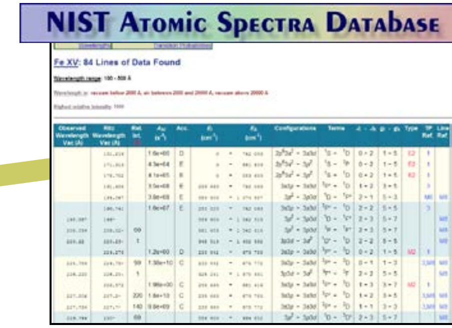
Research to Support *Mise-en-pratique*



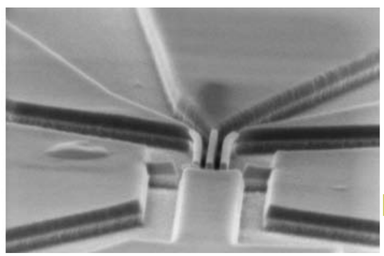
Research for Advanced Technology



Standards Dissemination



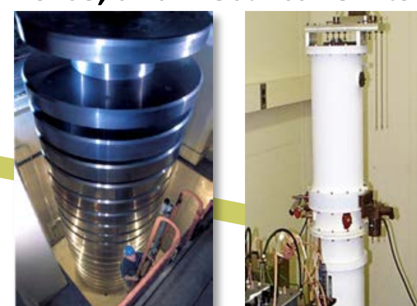
Calibration Services and Data Dissemination



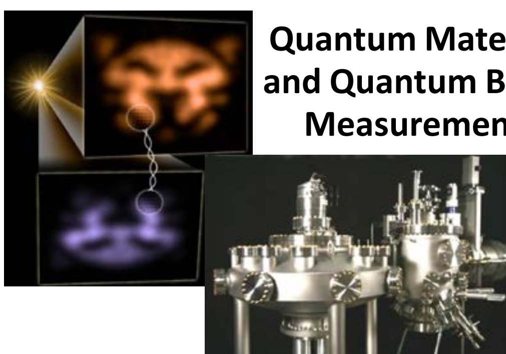
Measurement Science Research

Device Physics and Concept Demonstration

Realization of Mass, Force, and Electrical Units



Quantum Materials and Quantum Based Measurements



Precision Measurements

2010 CODATA RECOMMENDED VALUES OF THE FUNDAMENTAL CONSTANTS OF PHYSICS AND CHEMISTRY NIST SP 959 (Dec 2012)

Values from: P. J. Mohr, B. N. Taylor, and D. B. Newell, *Rev. Mod. Phys.* 84, 1527 (2012) and *J. Phys. Chem. Ref. Data* 41, 043109 (2012). The number in parentheses is the one-sigma (1 σ) uncertainty in the last two digits of the given value.

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Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 539(55)	m^{-1}
Bohr radius $\alpha/4\pi R_\infty$	a_0	$0.529\,177\,210\,92(17) \times 10^{-10}$	m
Bohr magneton $e\hbar/2m_e$	μ_B	$927.400\,968(20) \times 10^{-26}$	J T^{-1}

Fundamental Constants/CODATA

Quantum SI

Why are we here?

- We have a problem with "G"
- As described at the Royal Society meeting the current discrepancy suggests that one more measurement doesn't help.
- Well a much better measurement could resolve the discrepancy at least until the 2nd improved measurement showed up!
- General Questions:
  - Do we need an advisory board?
  - Do we want a consortium?

NIST and G

- Paul Heyl measures G with a torsion balance:
  - 1930: 6.670(5) x 10^{-11} $m^3/kg/s^2$
  - 1942: 6.673(3) x 10^{-11} $m^3/kg/s^2$
- Gabe Luther & William Towler use a torsion balance: 1982: 6.6726(5) x 10^{-11} $m^3/kg/s^2$
- Joshua Schwartz *et al.* (Faller) measure G in free fall: 1998: 6.6873(94) x 10^{-11} $m^3/kg/s^2$
- Harold Parks & Jim Faller use a simple pendulum: 2010: 6.67234(14) x 10^{-11} $m^3/kg/s^2$

How to move ahead?

1. Do nothing – just wait
2. Form a consortium (NIST concept on this is on the next slide)*
3. Wait pending new results and then revisit the question
4. Other ideas for solution

* If we agree on this choice, NIST Is prepared to consider designing and building one or more instruments as a "Hub member" of a consortium

Why a consortium?

- Numerous measurements
- More ways to look for systematics
  - Instrument Design
  - Operator Expertise
  - Data Analysis
  - *Undiscovered* physics

Our Concept of the Approach

- 3 methods – 2 copies each …
- "Hub members" – willing to design and build multiple instruments
- Members – willing to make independent measurements using an instrument provided
- Lead Members – willing to make measurement on a non-transportable instrument

Problems and Issues

- Avoid group think
- Avoid intellectual phase locking (double/triple blind measurements)
- How do we do this blind?
- Do we want multiple offsets?
- Blind measurements are they really good?

International Support Exists

- **Decision CIPM/103-23** The CIPM would welcome the presentation of a formal proposal on the creation of an advisory board on *G* experiments at its next meeting.
- **IUPAP** is willing to accept a proposal as well.
  This may end up under **Commission C2 – SUNAMCO:** (Commission on Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants)

Questions