

# Achievements with quantum electrical effects and report from the CCEM

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**Bureau**  
International des  
Poids et  
Mesures



# Electrical measurements in daily life



Sustainable  
society



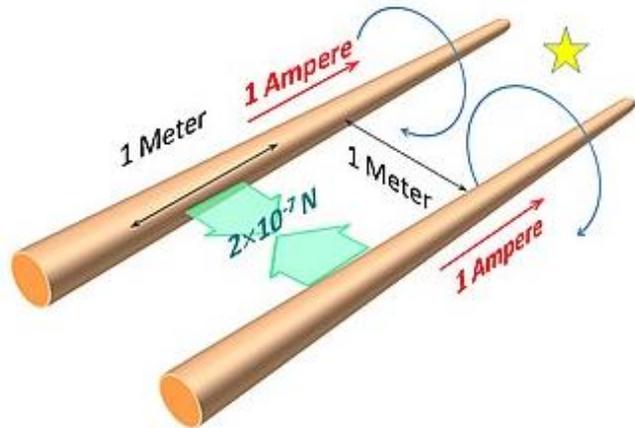
Fair trade



Innovation

# Present definition of the ampere

*“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 metre apart in vacuum, would produce between these conductors a force equal to  $2 \times 10^{-7}$  Newton per metre of length.”*



- ◆ The ampere will never be better than the IPK  
⇒ CCEM scientific challenge is to improve this!

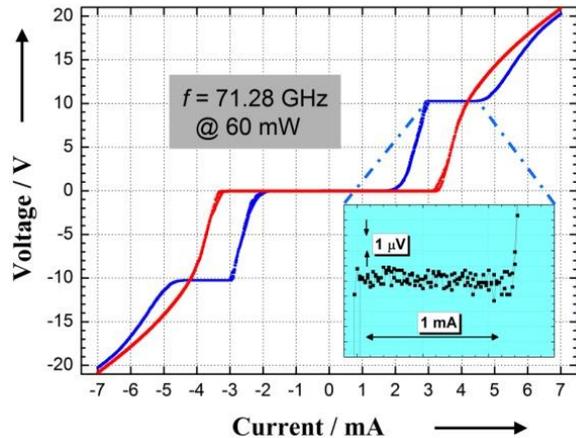
# Introducing the CCEM community

- ◆ 25 members
- ◆ CENAM - new member
- ◆ SCL, NIS - new observers
  
- ◆ Meetings: 2015, 2017
- ◆ WGLF, GTRF,  
WGKG, WGSJ,  
WGRMO



# Global forum for progressing the state-of-the-art

## Quantum standards for voltage and resistance:

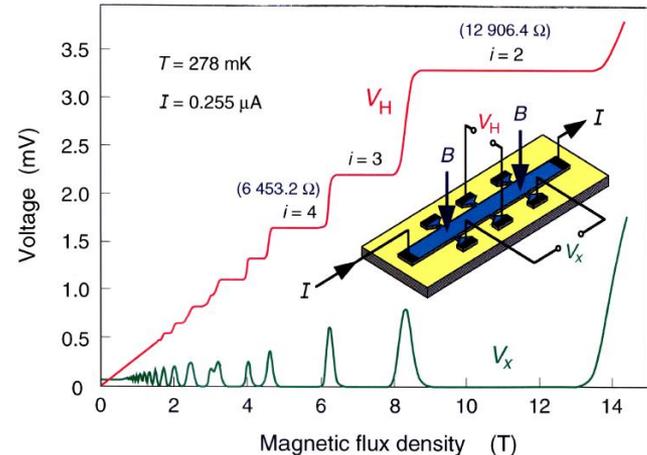


$$V = n \cdot (h/2e) \cdot f$$

$\swarrow K_{J-90}$

$$R = (h/e^2) \cdot 1/n$$

$\swarrow R_{K-90}$



- ◆ Conventional 1990 values.
- ◆ Link to SI “only at  $10^{-7}$  level”, internal agreement at  $< 10^{-9}$  level
- ◆ Recent developments: AC JAVS, graphene QHE



# Kibble balance – paving the way to the revised SI

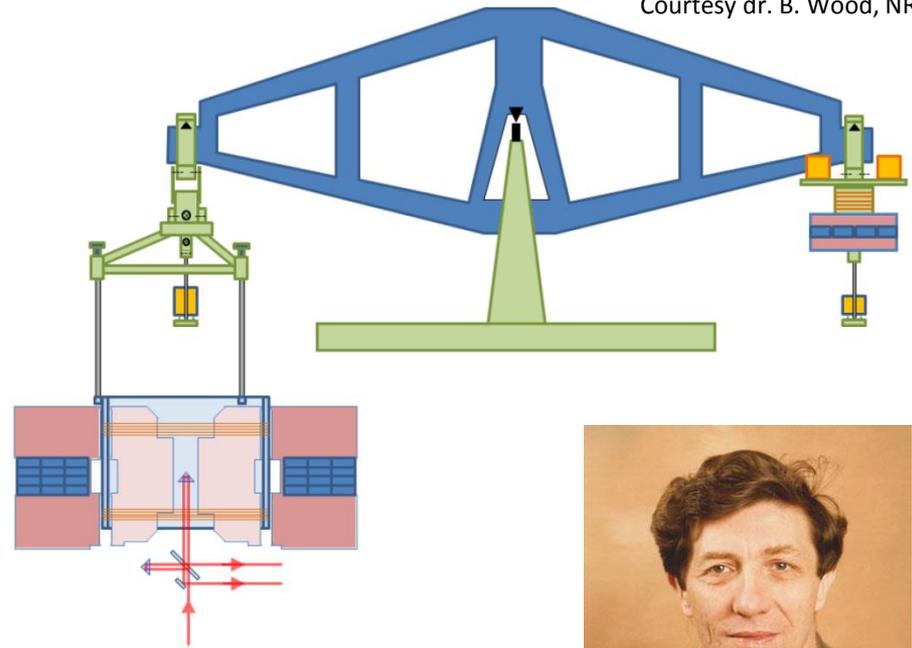
Combining 2 steps:

1. Weighing:  $M \cdot g = B \cdot L \cdot I_w$
2. Moving:  $V_m = v \cdot B \cdot L$

Comparing electrical and mechanical Watt:

$$\Rightarrow M \cdot g \cdot v = V_m \cdot I_w \propto h$$

$$\text{Josephson, QHE: } V \propto h/2e, R \propto h/e^2 \Rightarrow V \cdot I = V^2 / R \propto h$$



Courtesy dr. B. Wood, NRC

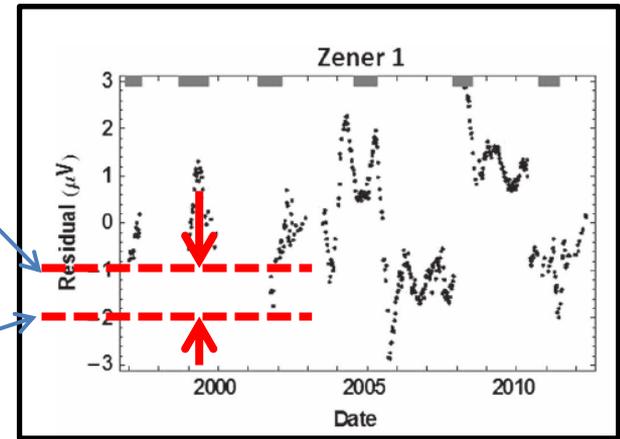
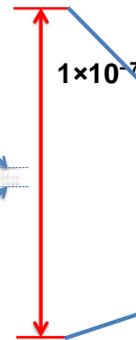
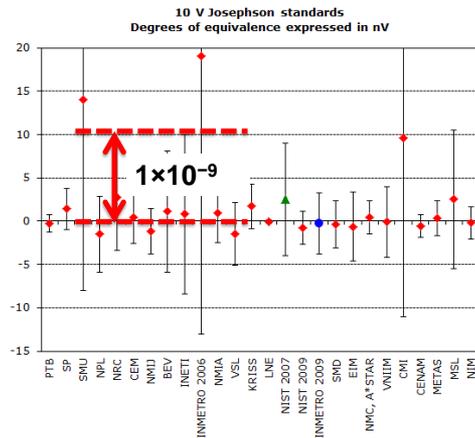
# Impact of the revised SI on EM quantities

- ◆ By fixing values of  $h$  and  $e$ , CCEM will be “back in the SI”

However...

- ◆ Final values of  $h$ ,  $e$  do not perfectly align with 1990 values

⇒ CCEM is the only CC with a step change!



# Facilitating dialogue NMs and stakeholders

- ◆ Knowledge transfer to industry in operating quantum standards
- ◆ Revised SI support

## CCEM Guidelines for Implementation of the 'Revised SI'

Consultative Committee for Electricity and Magnetism

### Electrical Units in the New SI: Saying Goodbye to the 1990 Values

Nick Fletcher, Gert Rietveld, James Olthoff, Ilya Budovsky, and Martin Milton

### Other 'outreach' activities:

- ◆ Future challenges workshop
- ◆ Support for CCRI

# Global comparability of measurements

- ◆ Quantum standards and 1990 conventional values of  $R_K$  and  $K_J$  greatly increased comparability of EM measurements worldwide
- ◆ CIPM MRA was a significant second step in enhancing worldwide acceptance of measurement results



# Global comparability of measurements

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CCEM has been very active in making the CIPM MRA more effective and efficient:

- ◆ KC's now strategically planned
- ◆ Reduction of number of CMCs via introduction of matrices
- ◆ Effective CMC review process (“selective review”)

BIPM provides crucial support to CCEM via comparison of quantum standards, calibration services, and efficient performance of other comparisons (e.g. capacitance)

# Outlook

CCEM is continuously working on its key objectives via

- ◆ *Advancing measurement science:*
  - Quantum Technologies
  - Bio- and nanoscience
  - Applied science for societal challenges (e.g. energy)
- ◆ *Enhancing impact to society:* new challenges (e.g. DC charging), increased stakeholder interaction (workshop)
- ◆ *Increased comparability of measurement results:* ‘run’ the CIPM MRA as smoothly and effectively as possible

Please: say



to the  
revised SI...



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