NPL
National Physical Laboratory

UP
EPSRC Centre for innovative manufacturing in ultra precision
UNIVERSITY OF CAMBRIDGE
Cranfield UNIVERSITY

Fundamentals of Metrology

NPL Module for Cambridge / Cranfield Masters course

MRes Module offered to the Cambridge / Cranfield students from the EPSRC CDT in Ultra Precision

Delivery date: 26 – 29 January 2016 (45-60 minute lectures, on site at NPL, Teddington)

Syllabus

The following subject headings to be covered over the 4 day course:

	Metrology basis & International metrology	Speaker
1.	International cooperation on standards – why it matters?	Mr Robert Gunn
2.	NMI partnership basis for maintaining worldwide standards (EURAMET, CIPM, BIPM, ISO)	Dr Kamal Hossain
3.	Traceability: linking results to the SI with uncertainties	Dr Stephanie Bell
4.	The New SI: the future of metrology based on fundamental constants	Dr Ian Robinson
	Dimensional Metrology	
5.	Fundamentals of interferometry – achieving length traceability	Dr Andrew Lewis
6.	Practical realisation of metre (lasers, ions, combs)	Dr Geoffrey Barwood
7.	Fundamental principles & techniques of dimensional measurements	Mr Ben Hughes
8.	Examples of dimensional metrology systems and applications	Mr David Flack
9.	Traceable Nanometrology : the Metrological AFM – and why is it needed	Dr Andrew Yacoot
10.	Beyond nanometrology : the X Ray interferometer – and why it is needed	Dr Andrew Yacoot
	Thermal Metrology	
11.	Fundamentals – the kelvin and primary measurement (focus on acoustic thermometry, but to include other primary standards)	Dr Michael De Podesta
12.	Definition of the temperature scale (history of temperature scales, ITS 90 and PLTS – 2000)	Prof. Graham Machin
13.	Realisation and dissemination of the ITS-90	Dr Jonathan Pearce
14.	Practical temperature sensing – I : thermocouples (practical realisation of fixed points, platinum resistance thermometers, calibration, other dissemination e.g. dry block calibrators)	Dr Jonathan Pearce
15.	Practical temperature sensing – II : radiation thermometry, thermal imaging	Ms. Helen McEvoy
16.	Thermometry at extremes (Combustion, explosion, surfaces in high background radiance)	Dr Gavin Sutton
17.	Humidity and moisture measurement : primary standards to practical applications	Dr Stephanie Bell
	Mass Metrology	
18.	Fundamentals of mass metrology	Dr Stuart Davidson
19.	Realisation and implementation of a new kilogram definition	Dr Ian Robinson
20.	Practical dissemination of the mass scale and realisation of derived SI units	Dr Stuart Davidson
21.	Force standards and applications	Mr Andy Knott
22.	Practical static and dynamic pressure measurements	Dr Stephen Downes

Suggested daily schedule

Day 1: 26 January	9:30am – 4:30pm	Day 3: 28 January	9:00am – 4:30pm
Day 2: 27 January	9:00am – 4:30pm	Day 4: 29 January	9:00am – 3:30pm

Course Descriptor

RATIONALE

The module will provide a detailed grounding in theoretical and practical aspects of metrology (measurement science) applicable to the subject of Ultra Precision in science & engineering. Following an introduction to the principles and international framework for the bases of measurement, lectures will concentrate on the key aspects of achieving high accuracy measurements of dimensions and temperature, with traceability to the internationally accepted SI system of units.

OBJECTIVES/LEARNING OUTCOMES/COMPETENCES

After successfully completing the module, students should be able to:

1. Understand why international agreement on measurement standards is important and know which international and national organisations they will encounter when considering making traceable measurements and how these organisations relate to one another.

2. Understand the basis of worldwide measurement – the SI, how it is defined and how it is evolving and is about to be re-defined and what this means in practical terms.

3. Understand that no measurement is traceable (i.e. valid) without a statement of the uncertainty of the result and how to calculate uncertainties and achieve traceability.

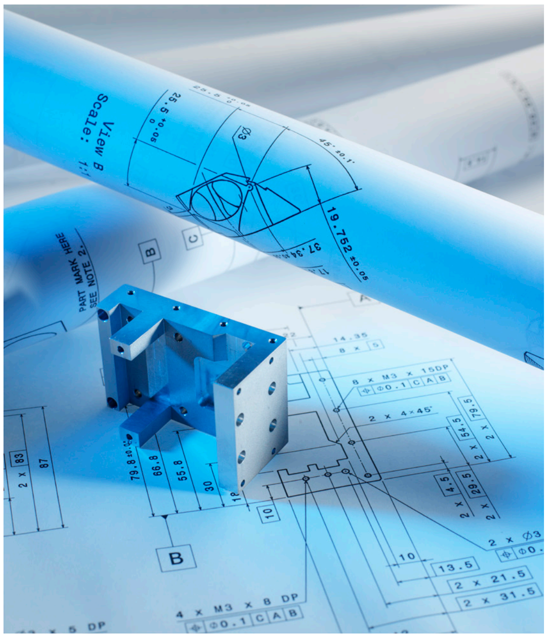
4. Understand the basic principles of making measurements of: mass, force, pressure, temperature, humidity and dimensions in the context of achieving high precision.

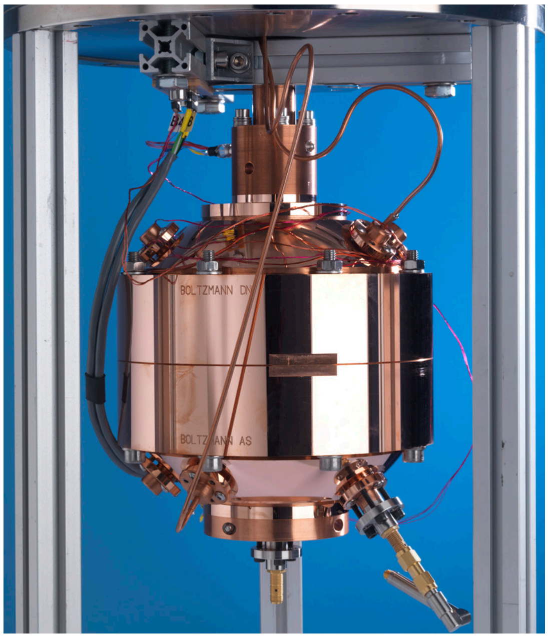
5. Communicate how the SI base units of mass, length, temperature and related units of force, pressure and humidity are realised in a practical sense from their definitions.

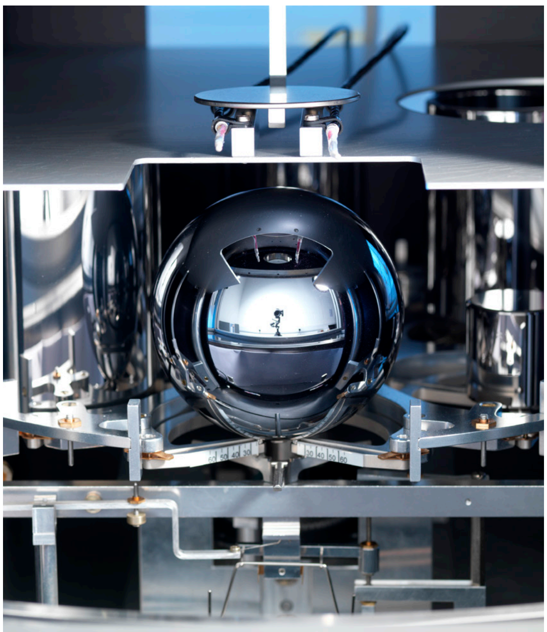
6. Understand the techniques used to perform measurements at the highest level of accuracy, including: interferometry using lasers and X-rays, acoustic thermometry, radiation thermometry, thermal imaging, dynamic pressure sensing, fringe sub-division, mass comparators, force balances.

7. Explain and utilise best practice techniques to minimise measurement errors including: reversal processes, precision alignment, refractive index and thermal compensation, elimination of Abbe offset, buoyancy correction, substitution methods, multilateration approaches.

8. Use their knowledge to design new experiments and improve existing experimental designs to achieve better precision and generate results which will be accepted by the international community at the highest levels.







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