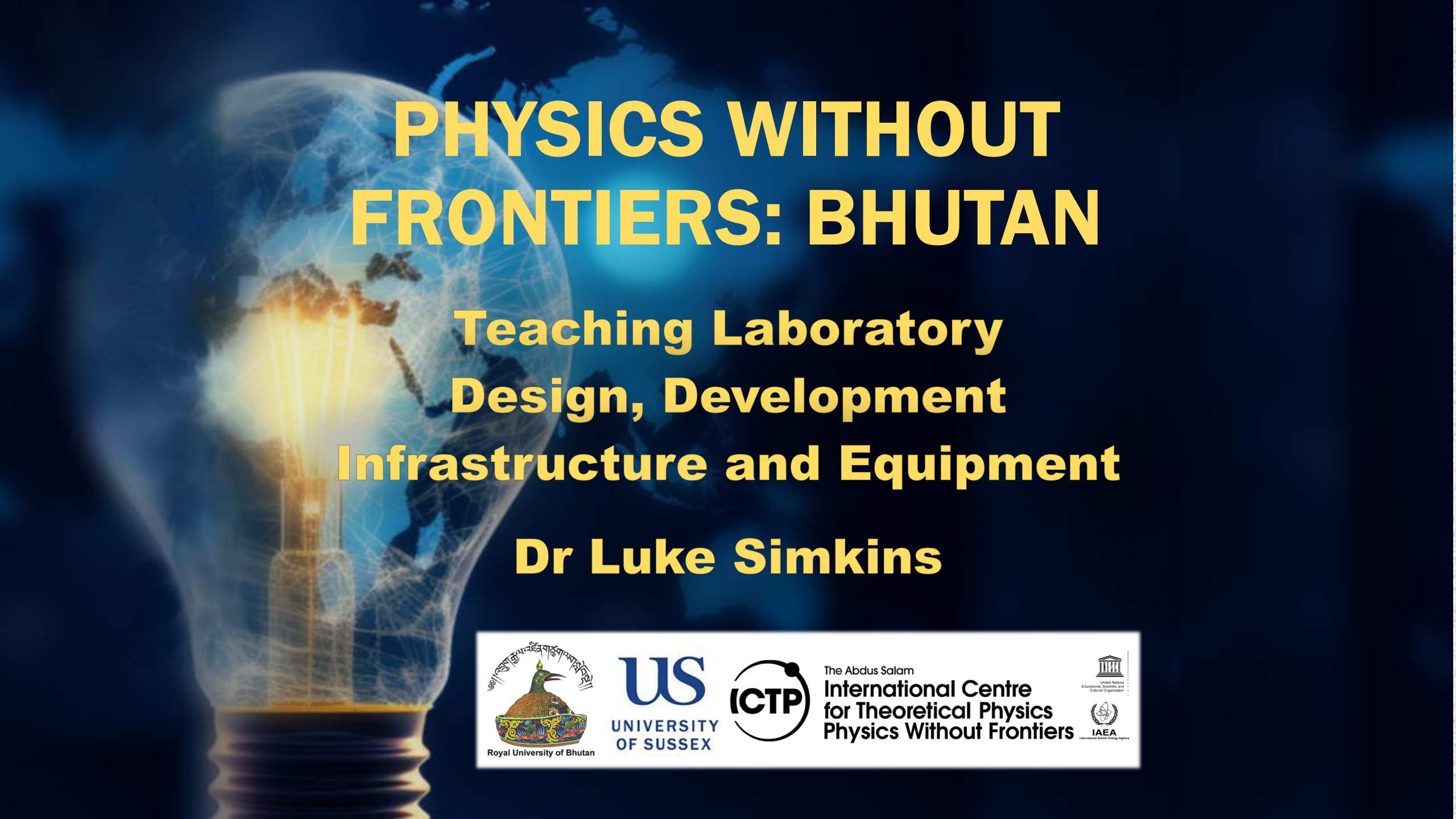

PHYSICS WITHOUT FRONTIERS: BHUTAN

Teaching Laboratory Design, Development Infrastructure and Equipment

Dr Luke Simkins

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The Abdus Salam International Centre for Theoretical Physics
Physics Without Frontiers

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

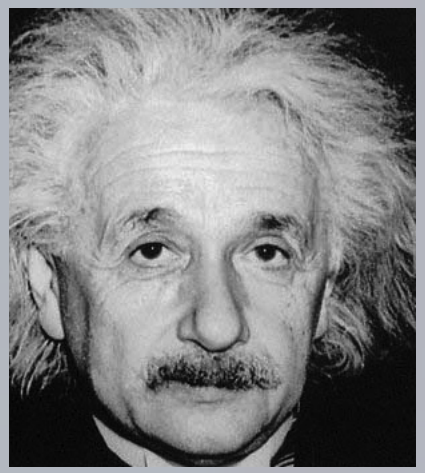
Teaching Laboratory, Design, Development Infrastructure and Equipment

- Pedagogy – focus on experiment and physics of reality
- Overview of physics labs at Sussex:
  - Foundations, PIP
  - Undergrad, 1st year Lab, 2nd year Lab
  - Mphys Lab
- Infrastructure – IT, Equipment, Consumables, Gas, LN2 and Maintenance
- Safety and managing risk
- Experimental Design – Infrastructure and Safety informed design
- Equipment – Designing for learning outcomes
- Development, changes in technology,

Pedagogy

- Quote “Insanity is doing the same thing over and over again but expecting different results”

  – Einstein



Pedagogy

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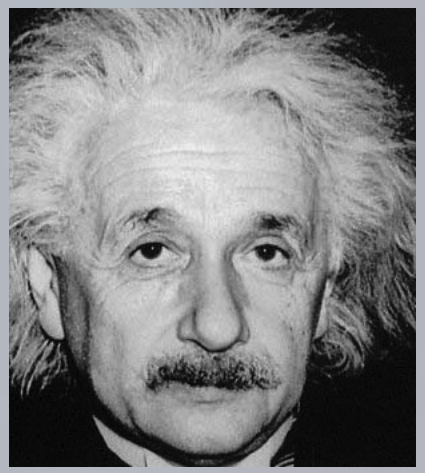

Pedagogy

- Quote “Insanity is doing the same thing over and over again but expecting different results”
  - – Rita Mae Brown Mystery writer

    paraphrasing an existing phrase

Pedagogy

- Quote “Insanity is doing the same thing over and over again but expecting different results”

- Experimental physics we use the fact that: how many measurements it takes to see a different result, inform us how certain we can be about a measurement.

Pedagogy

- Uncertainty is a key concept in science and the key learning outcome of Laboratory work.
- Measurements have an uncertainty and quantities must have units
- Give experience with the equipment and instrumentation required to perform experimental work.
- Record keeping, writing observations and measurements in a logbook
- Give experience in performing analysis, performing weighted fits
- Lab allows students to link theory with physical reality
- Key to understanding experimental results is not just the physics of the system under investigation but the physics of the instrumentation used for experimentation

Achieved with documentation, tutors, and through the marking scheme

alongside resources such as videos guides, and in future virtual experiments

Overview of physics labs at Sussex Foundation Year Laboratory

- A physics laboratory module exclusively for Foundation year students, with basic experiments investigating classical mechanics, thermodynamics, optics, electricity and magnetism
- Students must:
  - Demonstrate familiarity with simple scientific instruments.
    - Such as rulers, stopwatches, vernier callipers, multimeters, function generators, oscilloscopes
  - Make accurate measurements and keep records of observations.
    - Write a logbook to record data and observations while performing experiments
  - Analyse and interpret data, including evaluating uncertainties.
    - Basic data analysis, error propagation, line fitting (unweighted) using Excel
  - Make a high-quality oral presentation of an experiment
  - Write journal style report

Overview of physics labs at Sussex Foundation Year Laboratory

The Simple Pendulum
The Spiral Spring
Young's Modulus
Moment of Inertia of a Flywheel
Boyle's Law
Equivalence of Heat and Energy
Specific Heat Capacity of a Metal
Free Fall in a Gravitational Field
Latent Heat of Water
Measurement of Capacitance
Logic Circuits
Acoustic Resonance
Interference and Diffraction
Properties of a Thin Lens
Variation of Resistance with Temperature
Introduction to Operational Amplifiers
Collisions in One Dimension
Magnetic Forces

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Overview of physics labs at Sussex
PIP

An introductory physics module, with a mixture of lectures and computer workshops with a few basic experiments, focusing on the statistics and concepts required for experimental physics

Students must:

- Demonstrate an understanding of data analysis techniques and error propagation.
- Analyse and critically assess experimental data.
- Demonstrate understanding of some electronic elements and circuits.
- Communicate experimental results and theoretical ideas by written report and oral presentation.
- Demonstrate basic programming skills
  - Using python

Overview of physics labs at Sussex 1st year

- Students must:
  - Keep detailed, transferable records
    - Write a logbook to record data and observations while performing experiments
  - Use common experimental equipment.
    - Such as rulers, stopwatches, vernier callipers, multimeters, function generators, oscilloscopes
  - Analyse measurement data to extract physics
  - Estimate uncertainties and apply these estimates in an error analysis
  - Present in written form, measurement procedures, analyses and results

Overview of physics labs at Sussex 1st year

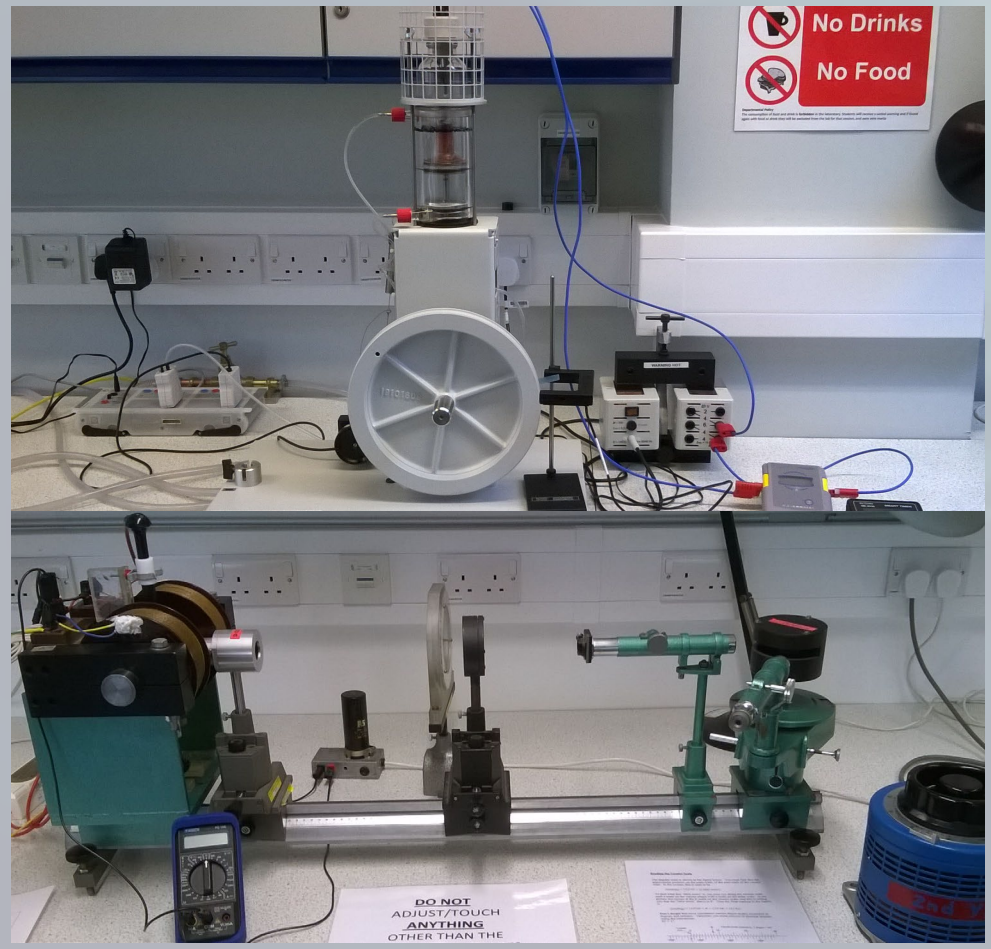
Speed of Sound Experiment
Index of Refraction of Gases
Millikan Oil Drop Experiment
Charge/Mass of the Electron
Photoelectric Effect
Introduction to Electronics
RC and RL Circuits
RC High and Low Pass Filter
RCL Circuits
AC Resonance Circuit

Overview of physics labs at Sussex 2nd year

- Students must:
  - Operate a range of instruments used in physical measurements to obtain meaningful data.
  - Deduce an overall uncertainty in the numerical result obtained from an experiment.
  - Report clearly, in written form, on the results obtained and the conclusions drawn from a particular experiment.
  - Be able to apply to experiments the basic laws of Physics such as Maxwell's equations, thermodynamic principles and basic quantum physics.

Overview of physics labs at Sussex 2nd year

- Transmission lines
- Transistors
- LEDs and Photodiodes
- Doppler effect
- Sterling engine
- Zeeman effect
- Superconductivity
- Hall effect

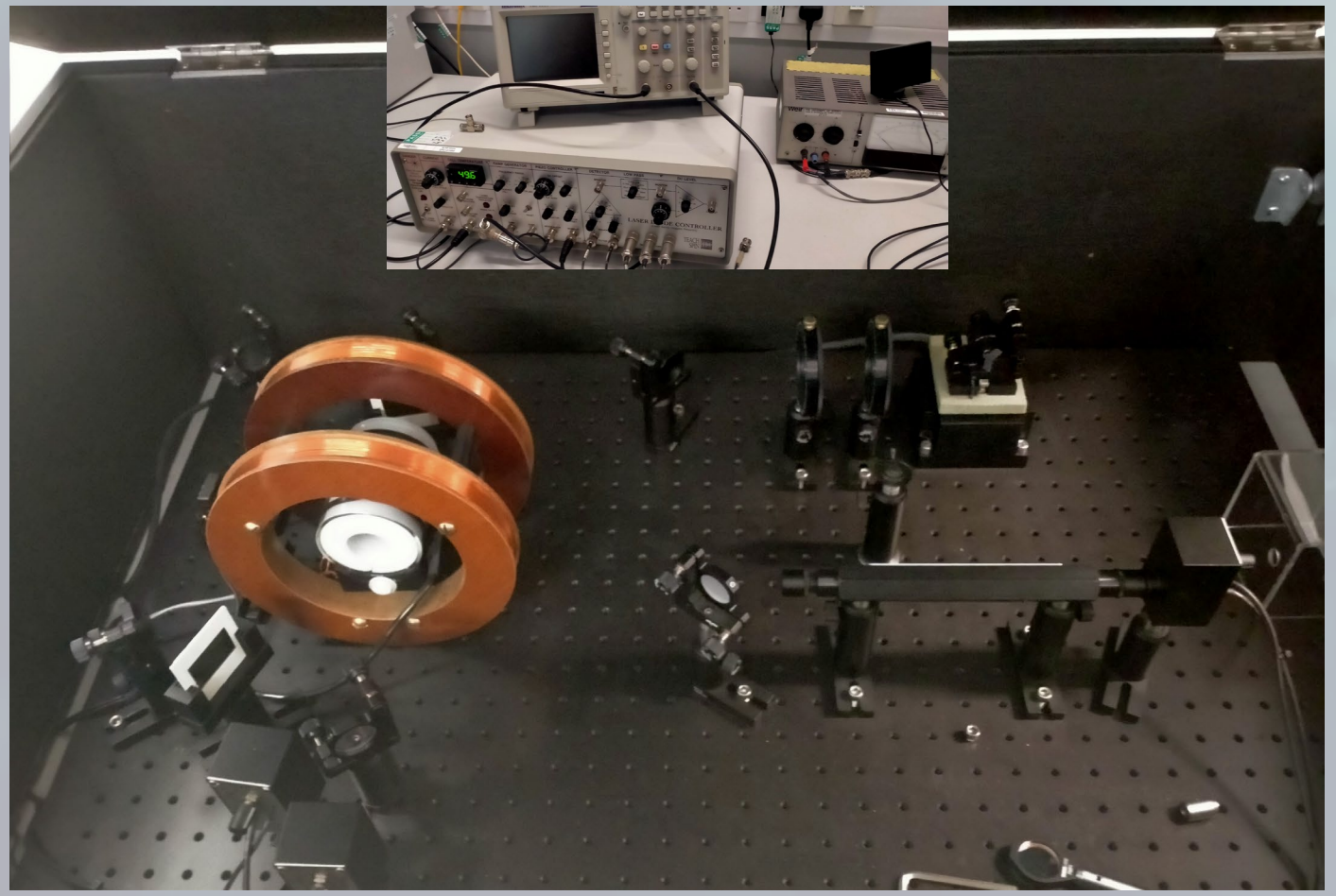


Overview of physics labs at Sussex
Advanced physics (MPhys) Lab

- Students must:
  - Write a short proposal, including health and safety assessment.
  - Perform and record an advanced physics experiment independently
  - Demonstrate an understanding of the working of the apparatus and the physics behind the experiment
  - Obtain meaningful data and analyze it.
  - Report on their project work in a long report
  - Understand general experimental techniques relevant to the experiments.

Overview of physics labs at Sussex
Advanced physics (MPhys) Lab

Laser spectroscopy
Optical spectroscopy
Optical pumping
Pulse NMR
HPGe detector
NaI detector
Muon lifetime
Optical telescope
Radio telescope



Overview of physics labs at Sussex
Advanced physics (Mphys) Lab

Laser spectroscopy
Optical spectroscopy
Optical pumping
Pulse NMR
HPGe detector
NaI detector
Muon lifetime
Optical telescope
Radio telescope

Infrastructure – IT, Equipment, Consumables, Gas, LN2 and Maintenance

- Reliance on external providers
  - For consumables - BOC gas and LN2
  - For supplies for maintenance
- Reliance on internal providers
  - IT infrastructure

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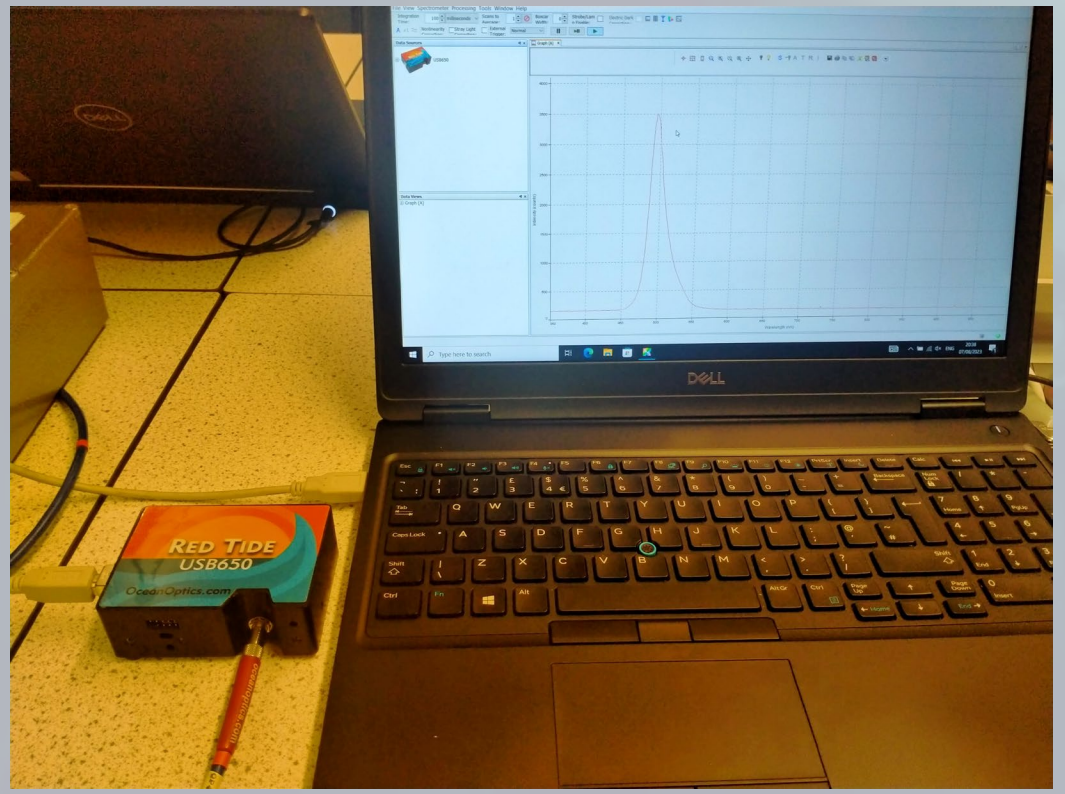
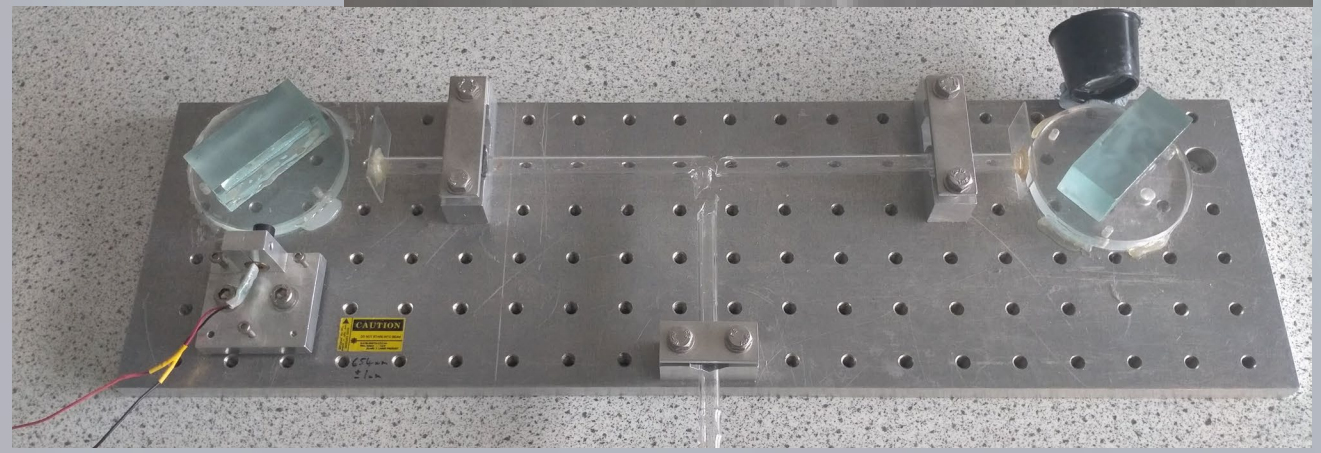


Safety and managing risk

- University must comply with legal regulations
- Department must comply with University policies
- Risk assessment of experiments
- Must assesses sources of harm,

their impact and likelihood

  - Ionising Radiation
  - Laser radiation
  - Slips, trips and falls



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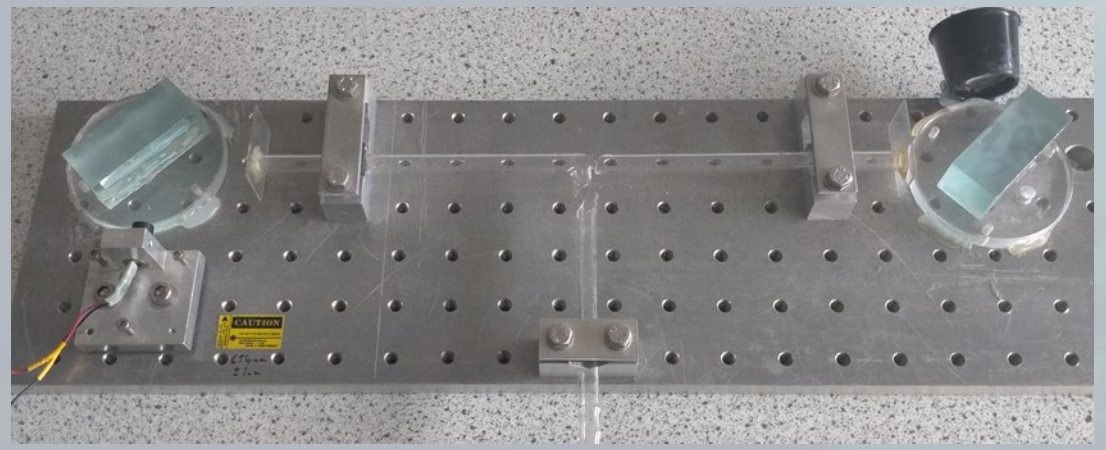
Experimental Design – Infrastructure and Safety informed design

- Choice of experiment / parameter are dependent on available infrastructure.
- Safety must inform design



Example: index of refraction of gas

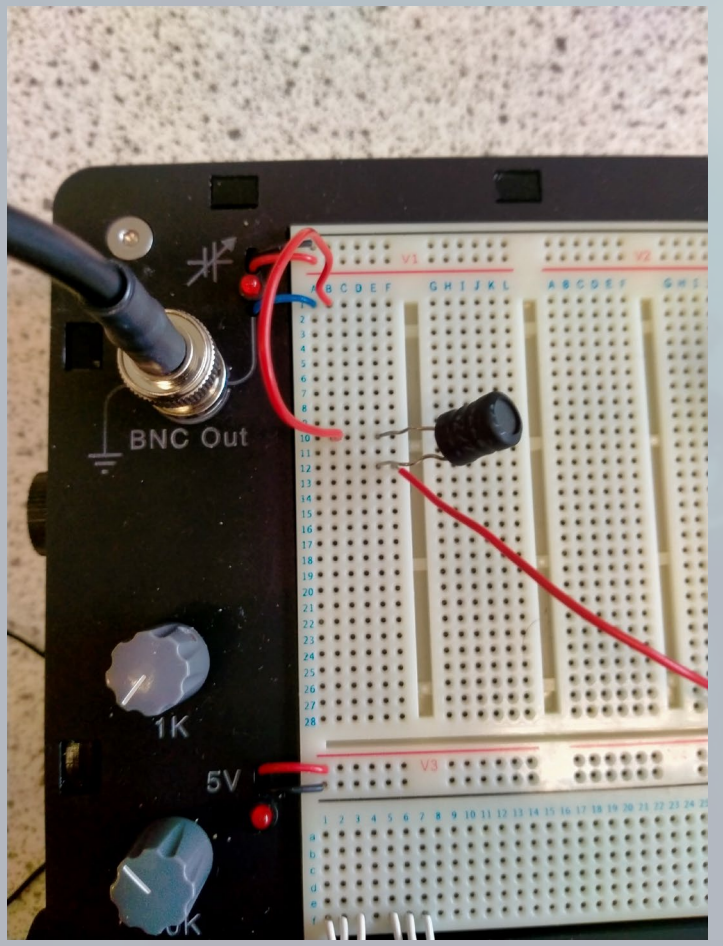
- Requires infrastructure for gases
- Requires safety systems of gases
- Laser required – could use of low power laser, but may require a dark area
- Enclosed to ensure only diffused reflection of beam is viewed

Equipment – Designing for learning outcomes

- Component selection allow for minimising technical requirements of equipment,

Example : AC resonance

- Choice of inductor determines high frequency requirement of function generator and oscilloscope
- Learning outcomes are not dependant on this frequency but can represent a cost saving of equipment



Development, changes in technology,

Legacy can determine choices of equipment

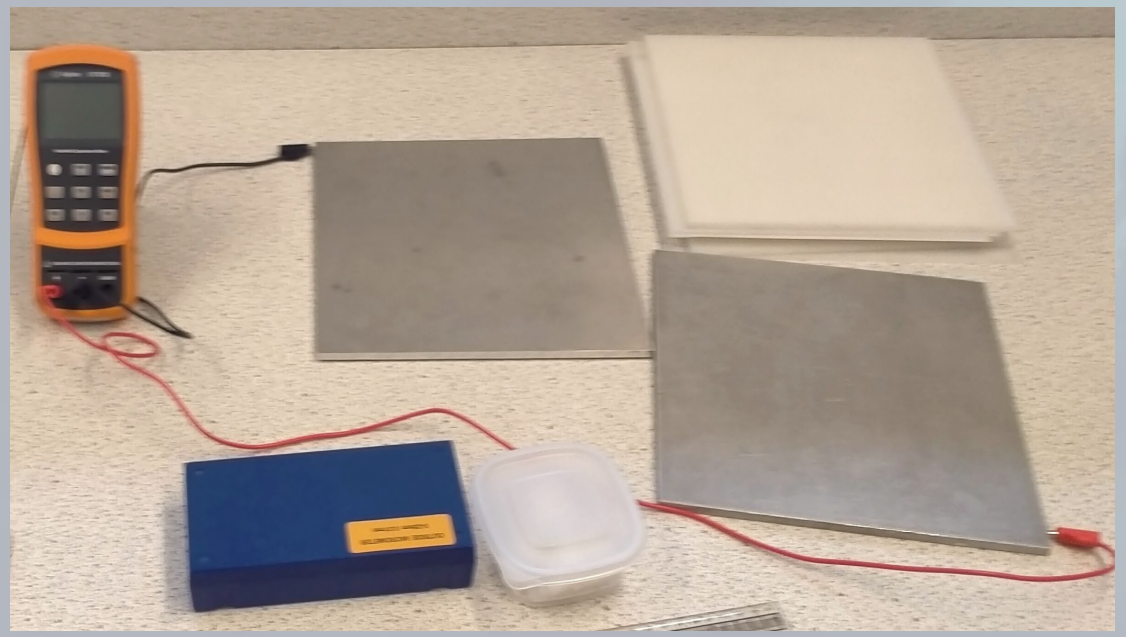
2009 WD 500GByte
Hard disk drive
Current price 1Tb ~£40

2021 WD 500GByte
Solid state drive
Current price 1Tb ~£40
Faster and smaller

Development, changes in technology,

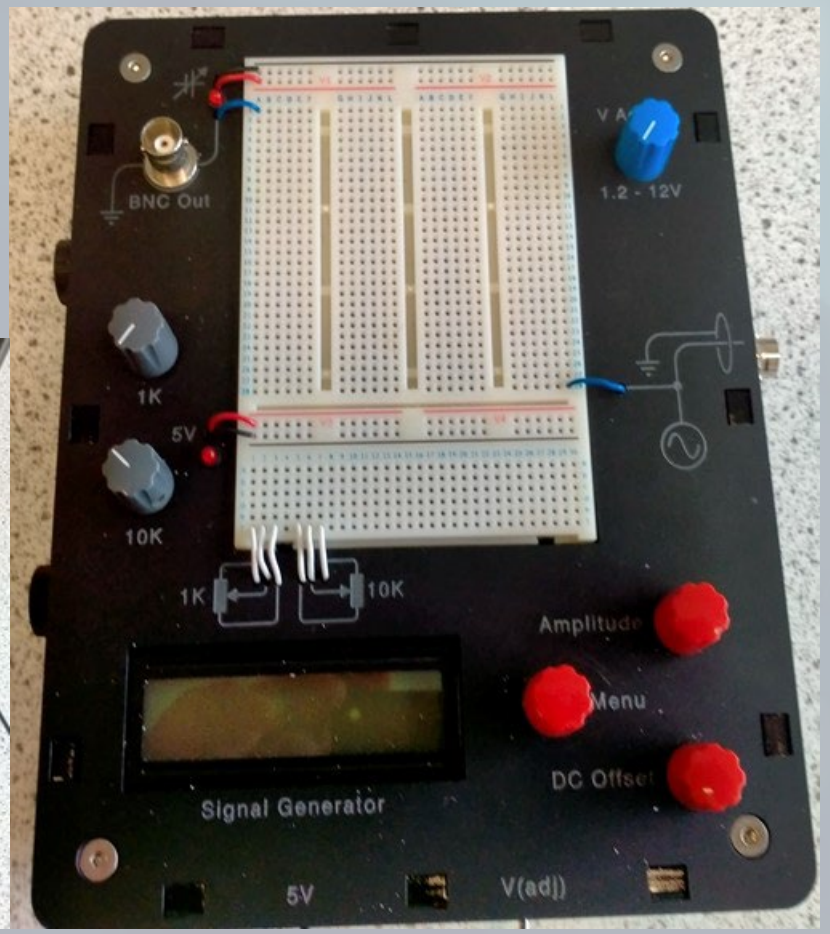
Legacy can determine choices of equipment; we must reassess choices when technological development can reduce cost

Here a parallel plate experiment uses a respected brand capacitance meter bought many years ago. Expanding the number of apparatus could purchase more on these meters at a cost of ~£240 each.
However newer cheaper options are available
replacing with a functionally similar, but cheaper device costing ~£20 each.
Such devices may not offer the same degree of calibration and accuracy, but their precision is sufficient to perform the experiment. This can benefit learning outcomes as students need to understand that no measurement device is perfect, and must be calibrated to a standard



Development, changes in technology,

Advances in technology and systems for development are allowing new approaches to creating and maintaining apparatus



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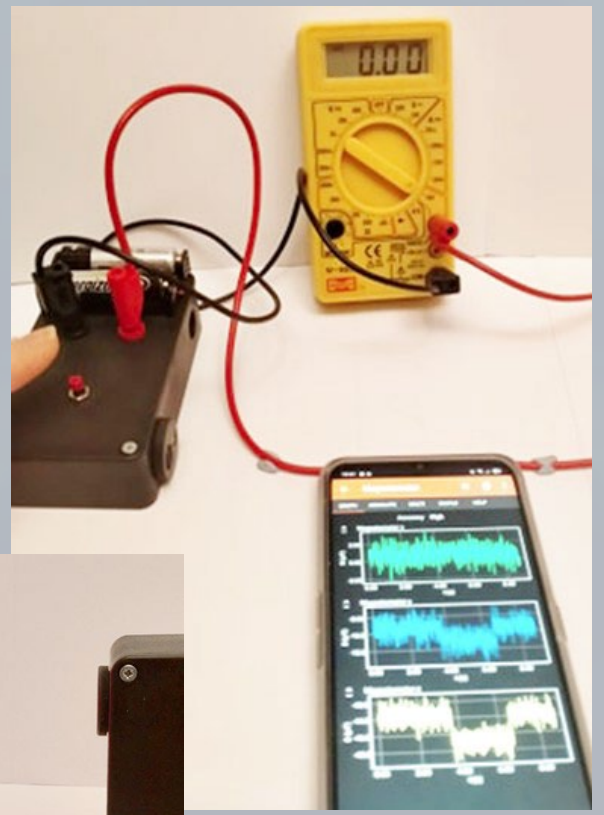

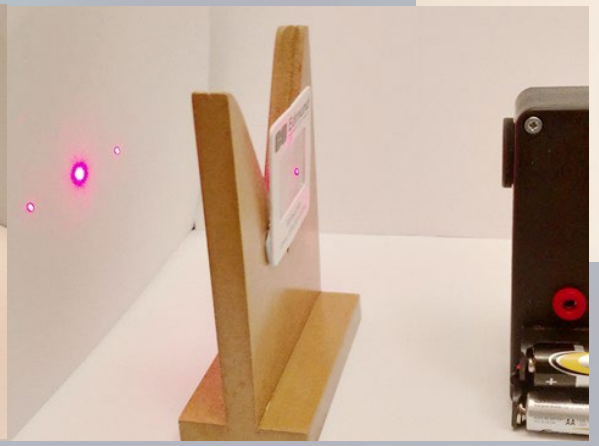

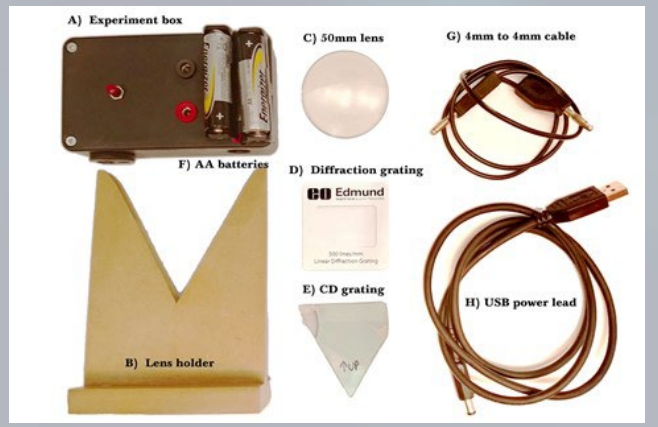

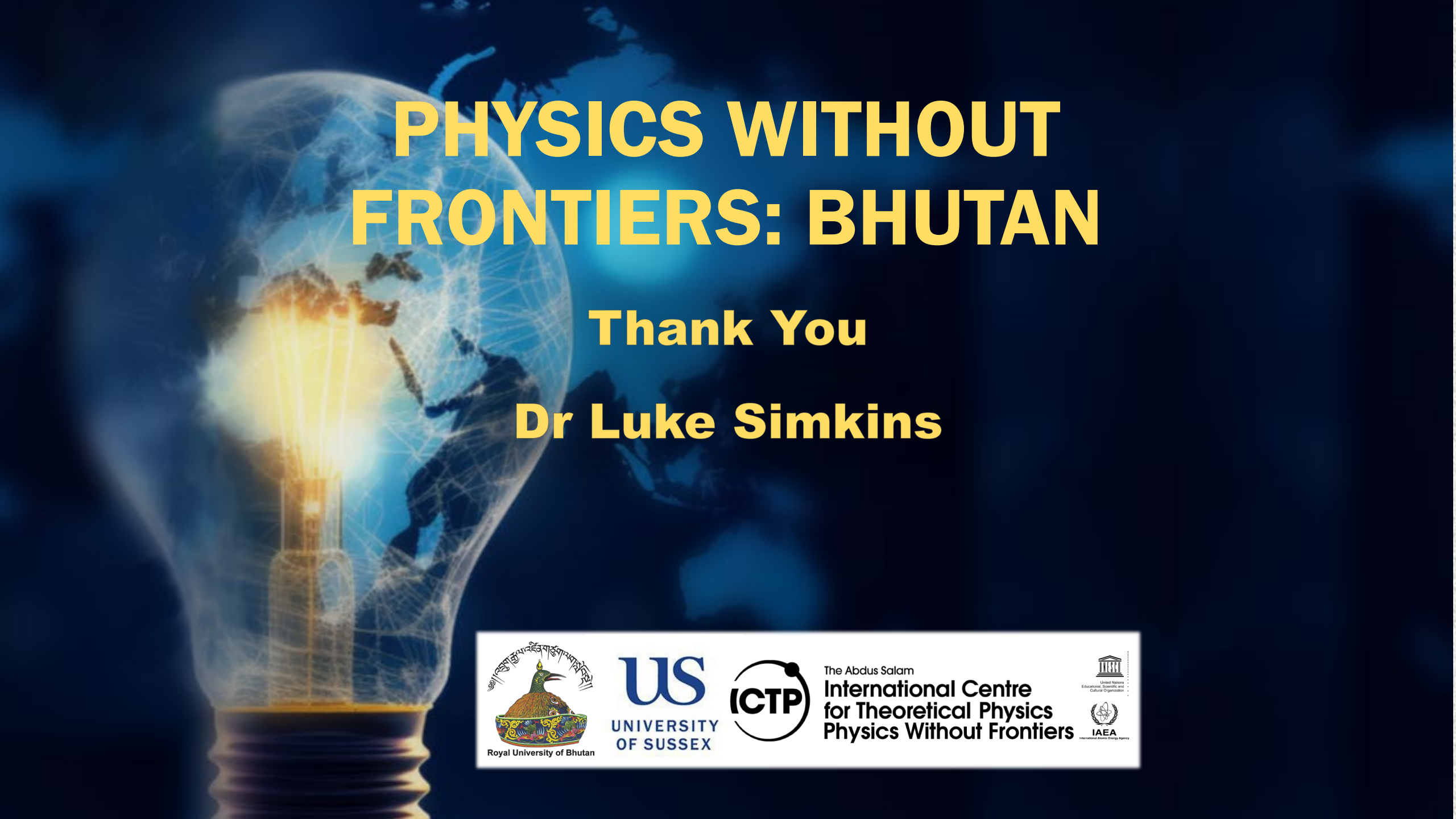

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Thank You

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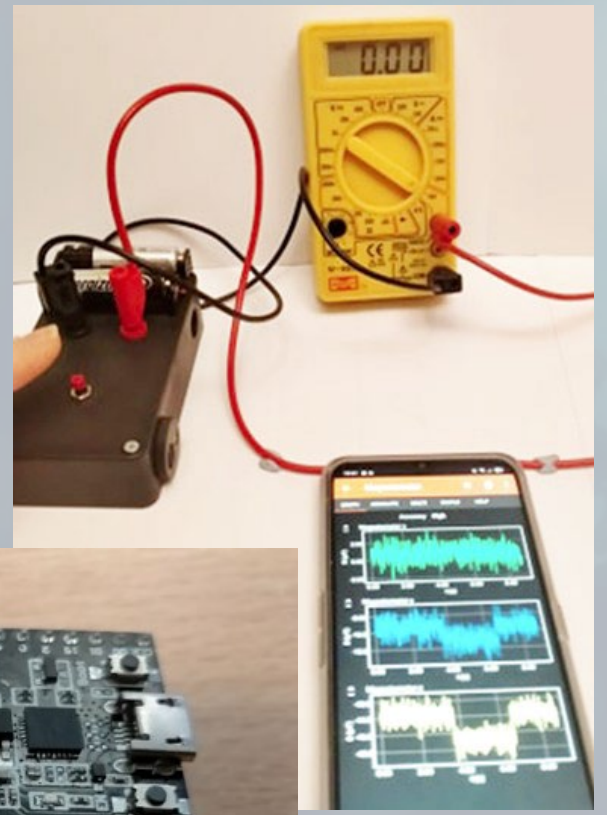
Designing for inclusion -

Inclusion requires education experience to be tailored to each students needs can include issues that are both personal and circumstantial

In the west there has been a large focus on direct discrimination due to gender and race, but institutional discrimination effects also occur without direct discrimination due to survival bias and effect a wide range of people.

Issues related to poverty, physical and mental attributes as well as things like expectations (both personal and external) effect outcomes.



Use of new approaches can aid in tacking these issues and improve overall student performance.
Lab beyond the lab - virtual labs, compact resource for home labs can be used to help when access to facilities or physical use of equipment is restricted.
Resources to different learning modes aid neurodivergent students
Use of varieties of assessment types can help correctly identify student ability and understanding