Addressing the Skills Shortage in Experimental Physics

*Changes Implemented in the First Year Labs in **Durham***

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First Year Lab pre 2004

- Experiments not changed since …..
- Experiments assumed both knowledge of physics and experimental skills
  - Designed to 'teach' physics concepts using experiments as the medium
  - Contained within other Physics Modules

Old Format….

- Students cycled through a series of individual experiments over 16 weeks
- Worked through detailed scripts individually
- Only interaction with demonstrator when stuck
- Self-selecting assessment - the student selected experiment per term to write up in a formal report.

Problems!

First year students were interviewed about their experience of practical physics at University and school

- Lack of experimental experience from school
  - Either watching a demonstration or filling in the box. Wide variation in experience (A, AS, IB…)
- Confusing scripts and inconsistent feedback
- Error analysis a key problem
  - Poorly taught at school
  - Not properly addressed in laboratory

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Perceptions

- Student feedback poor
  - Disillusioned students
  - Lack of coherent focus
  - Lack of dynamism
  - Students not ready for second year
- Staff Issues
  - Unmotivated staff
  - Little interaction with students
    - (demonstrating vs. teaching)
  - Stagnant work environment
  - Issues of data reporting and error analysis in final year projects

New Module Structure

Discovery Skills in Physics

- Laboratory sessions form a separate and contained module
  - Development of experimental complexity
  - Coherent approach
- A few introductory lectures
  - report writing
  - error analysis
- Both supported with web-based resources
- To be implemented with minimal cost

Experimental Ethos I

- Assume no prior knowledge
- Reinforce key skills throughout module
  - All scripts involve fitting a straight line
- Use lab scripts which are more 'student friendly' and accessible.
- Stress error analysis, data presentation, error propagation, fitting and reporting
- Use spreadsheets and computers to do data analysis
- Develop holistic skills such as keeping of logbook and writing reports

Experimental Ethos II

Prime aims are:

- to teach experimental physics
- develop experimental skills
- learn about errors and data fitting
- prepare students for further studies

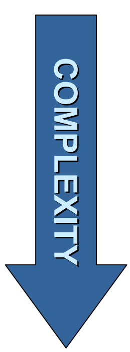
Experiments no longer tied to particular concepts in specific lecture courses.

Re-enforce Key Skills

Error Analysis

1. The best estimate of a parameter is its mean,
2. The error is the standard error on the mean, α
3. Round up the error to the correct number of significant figures
4. Match the number of decimal places in the mean to the standard error
5. Include Units

New Structure



- 5 Skills Experiments
  - 4 laboratory based
  - 1 report writing
- 4 Discovery Experiments
- 8 Full Experiments

Experiments performed in week 1 are very different from those performed in the second term.

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New Mechanics

- Students work in pairs (randomly assigned)
- Task based lab scripts marked in real time
  - Feedback given in real time
  - Marks for experiment tasks, preliminary task and holistic lab-book keeping
- Reduced number of experiments allow for whole room / group teaching
  - in groups of
    - 16 Skills
    - 8 Discovery
    - 4 full

Skills Sessions

1. Ohm's Law and Potential dividers
2. Simple a.c. RC circuits and using an oscilloscope
3. *Projectiles*
4. *Dimensional analysis and coupled pendulum*
5. Report writing on model data (decay of a capacitor)

Ohm's Law

Learning Outcomes, to have:

- Understood how voltage and current are divided in a circuit
- Built simple electrical circuits
- Practiced plotting and fitting straight line graphs

Key Skills

- Understanding basic circuits
- Using a digital multimeter
- Performing error analysis and propagation
- Drawing a straight line graph
- Introduction to least squares fitting
- Using significant figures

Example Tasks I

Task 2: Resistance of Wires
All circuits connect their elements with wires. Most wires are made of copper. What would the resistance be of 1 meter of wire with a diameter of 0.2mm if the resistivity of copper is $\rho = 1.7\times10^{-8}\,\Omega m$ *?*

Stresses the importance of:

- Significant figures
- Units

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Example Tasks II

Task 4: Using Ohm's Law to Measure R

Connect the circuit you drew in task 1 using the box with the d.c. power supply set to give 5Volts. Before you predict any readings, use Ohm's law to predict what current you expect to flow. Use this information to choose an appropriate scale for measuring current. Use the multi-meters to measure V and I, and estimate the voltage being delivered from the power supply, E, using its display. What values do you record for V, I and E? What are the errors on these values?
Use Ohm's law to determine the resistance R.
Using your errors in your current and voltage measurements, what is the error on R?

Example Tasks III

Task 6: Curve Fitting:

Use EXCEL and plot your data using the computer. Ensure that you know how to incorporate the error bars on your graphs, and how to produce a line of best fit. ***If in doubt, ask your demonstrator for help****. Use the LINEST function to calculate the least squares error on the gradient. Print out the graph, with the best fit line, and stick it into your lab book. Propagate your error in the gradient through an error in the resistance.*

Which method gives the best value for the resistance *R*?
Make observations in your lab book as to why you think this is.

Example Task IV

Task 7: Measurement of the resistance of R

By finding some suitable wires, measure the resistance R using the hand-held multimeter.
What is the value of its resistance and its error? Does the value of the resistance you record using this method, agree within error, to that found in the tasks above? Which method gives the best value of R?

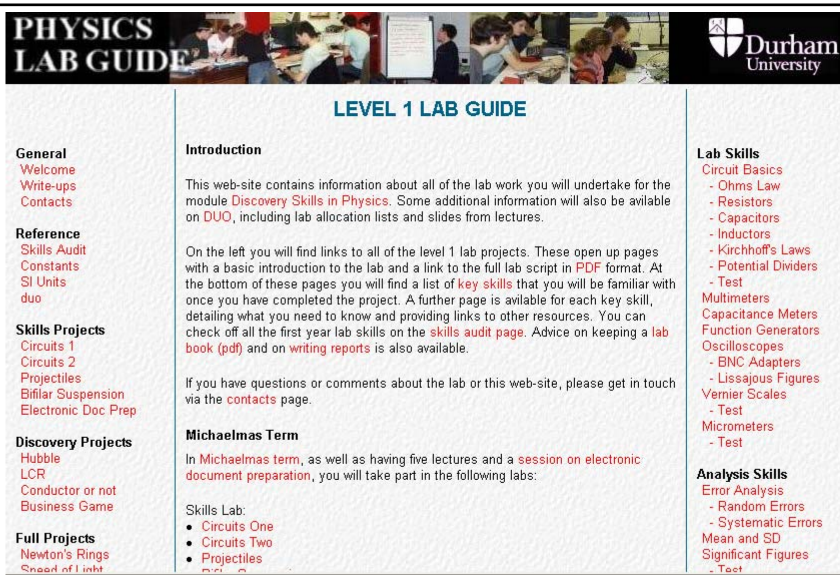
Use all your experimentally determined values of the resistance to determine your **best estimate of *R* and its error**

Ohm's Law Experiment

- An experiment designed to introduce a range of introductory skills
  - Not dependent on prior knowledge
  - Experienced students will still learn new skills
  - Facilitates group discussions

Web-based Support

- Provide skills support outside of the laboratory
- Enables student to refresh knowledge
- Familiarisation with new equipment though Java applets (e.g. link to virtual oscilloscope)
- Instrument reading skills (with links to web pages with an opportunity to read digital meters, analogue meters, vernier scales etc.)
- Report writing skills (guidelines for common tasks – inserting figures and using equation editors as well as examples of good practice and marking pro-forma).



http://level1.physics.dur.ac.uk/general/index.php

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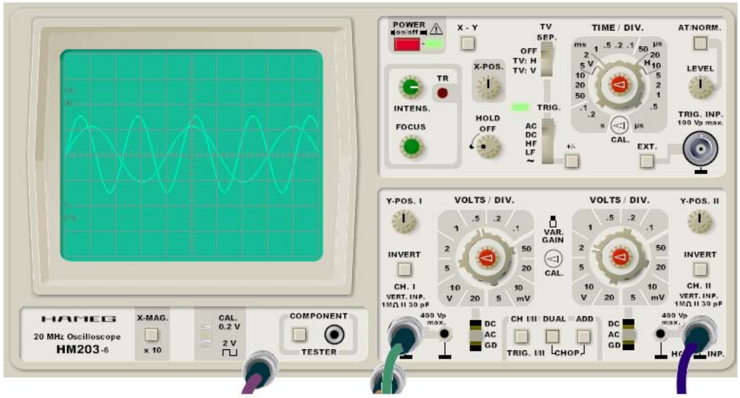
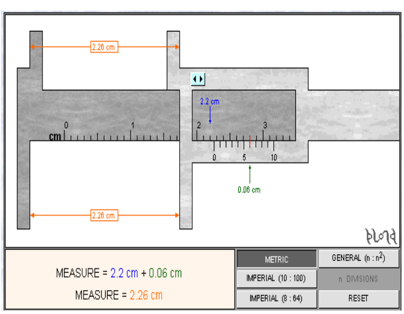
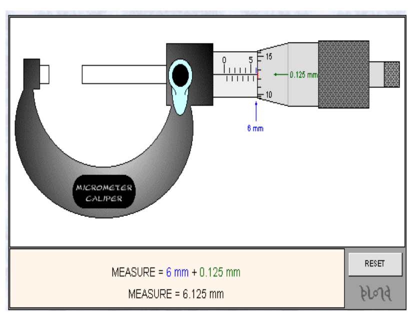
Web-based Support for Key Skills



http://www.virtual-oscilloscope.com/simulation.html#

External Java Applets





http://members.shaw.ca/ron.blond/index.html

Continuing Developments

• Preparatory tasks introduced 2006

Preparatory Task :
Read the entire script; familiarise yourself with the learning outcomes and skills required. If you are not confident in having acquired the skills you will be using today, make use of the web resource where you can gain further practice. Look up and record in your lab book using suitable references the currently accepted value of Boltzmann's constant, and the temperature of dry-ice. [1 Mark]

• Writing answers on the Board

Through peer interaction / pressure the 5 Golden Rules are quickly adopted! After 2 sessions we no longer see 1.1±0.134, or 3.14 (3 sig. fig.) as answers. Carried through to other years.

Perceptions of New Module

- Student feedback excellent
  - Engaged students
  - Coherent focus
  - Dynamism and excitement during laboratory sessions
  - Marked improvement in second year and beyond

- Staff Issues
  - Motivated staff
  - A lot of interaction with students, group teaching
    - Tiring!!
  - Dynamic work environment with new experiments being developed and implemented
  - Significant improvement in data reporting and report writing in final year projects

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