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Computational Physics in the New Physics Degrees at Portsmouth

Chris Dewdney
Director of Undergraduate Studies
Reader in Theoretical Physics

Chris.Dewdney@port.ac.uk

Physics at Portsmouth?

- *Physics delivered at Portsmouth since the 1960's*
- *New BSc Applied Physics – started 2010*
- *MPhys Applied Physics, MPhys/BSc Physics, Astrophysics and Cosmology starting September 2015*

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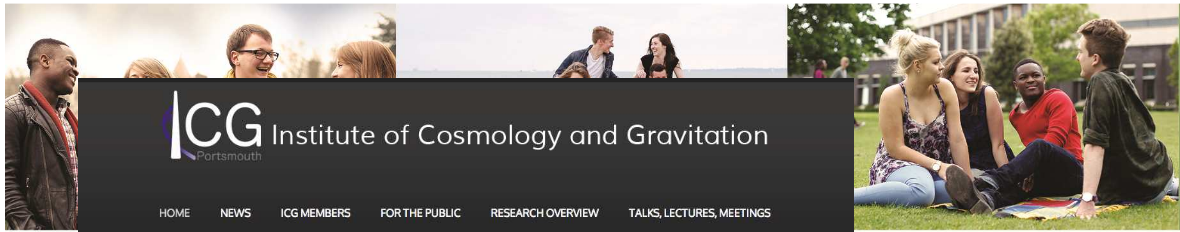

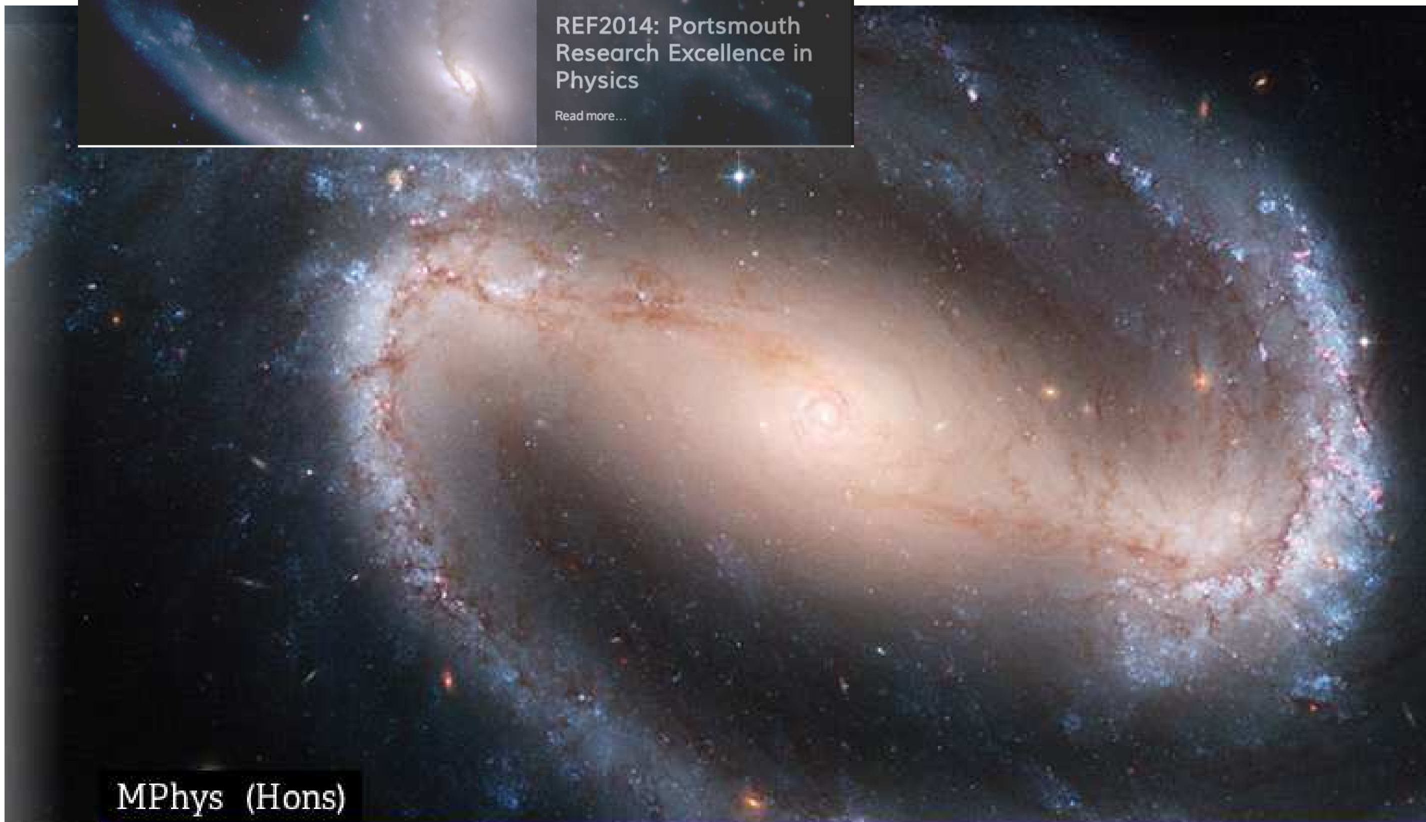

TUTOR'S VIEW

Prof Claudia Maraston
Physics, Astrophysics and Cosmology

“Did you know that 95% of the Universe is in a form we do not understand? And did you know that a supermassive black hole in the centre of our Galaxy regulates the formation of new stars? If you are curious about the most extreme among natural sciences, 'Modern Astrophysics' will teach you the fundamental physics in Astrophysics and Cosmology and inform you about the latest discoveries and technologies.”

MPhys (Hons)

PHYSICS, ASTROPHYSICS AND COSMOLOGY

Study the physical world from the sub atomic scale to the whole Universe.

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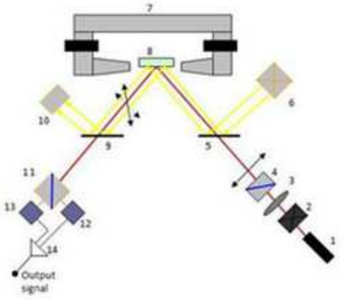

Applied Advanced Materials Research

The research undertaken focuses on the preparation of multi-functional materials and development of novel materials characterisation metrologies. Areas of applicability of our research include sensor technologies, data storage, energy harvesting and solid state cooling technologies.

MPhys (Hons)

APPLIED PHYSICS

Apply physics to real world issues.

New labs - £900,000 investment

TUTOR'S VIEW

Dr Melvin M Vopson
Applied Physics

“The MPhys degree in Applied Physics offers you the opportunity to acquire unique practical skills in synthesis of smart nano-materials and advanced measurement techniques, preparing you for a wide range of career options including high-tech engineering and scientific research.”

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Applied Physics

"Physics-based businesses directly contribute 8.5% of the UK's economic output, more than £77 bn per year."

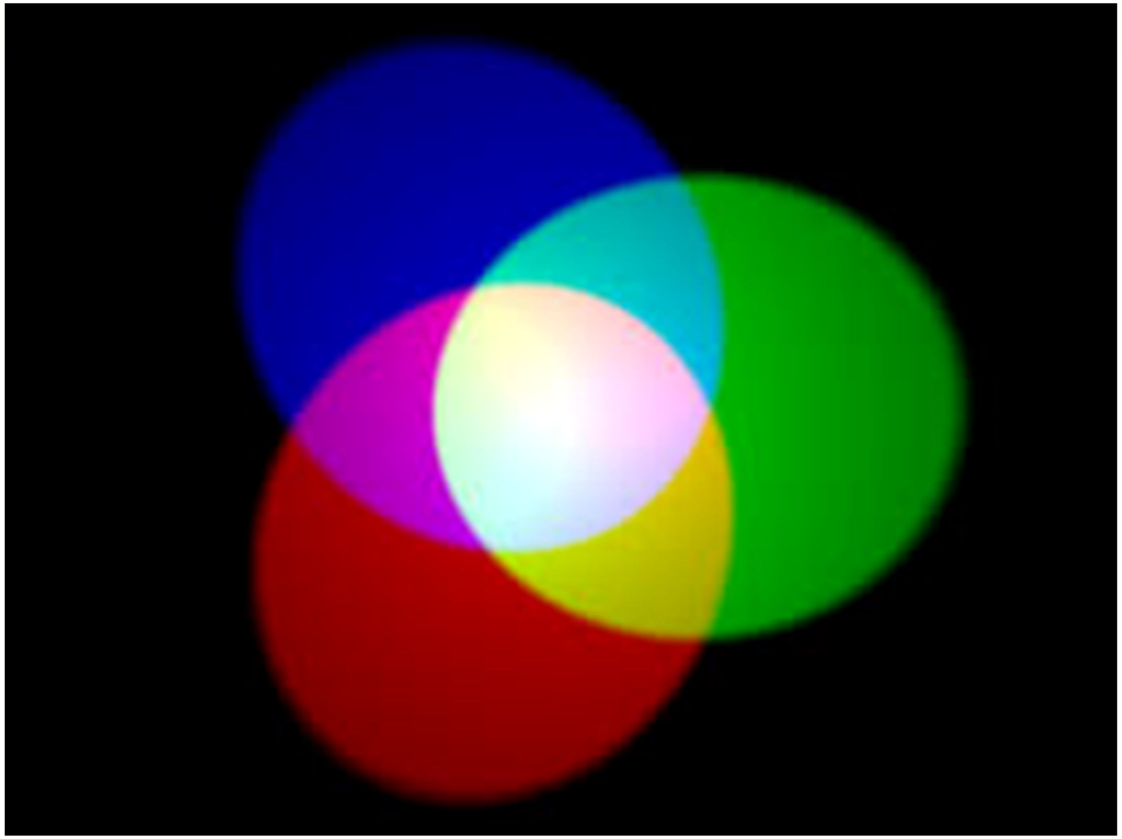
The Importance of Physics to the UK Economy (October 2012)

Download the full report (PDF, 4 MB)

- *Physicists contribute a vast amount to the economy. Physics-based industry alone employs over 1.79 million people in the UK and contributes over £130bn in export value to the UK economy.*

2006 –
The Independent

Physics



Theory – Experiment – Computation

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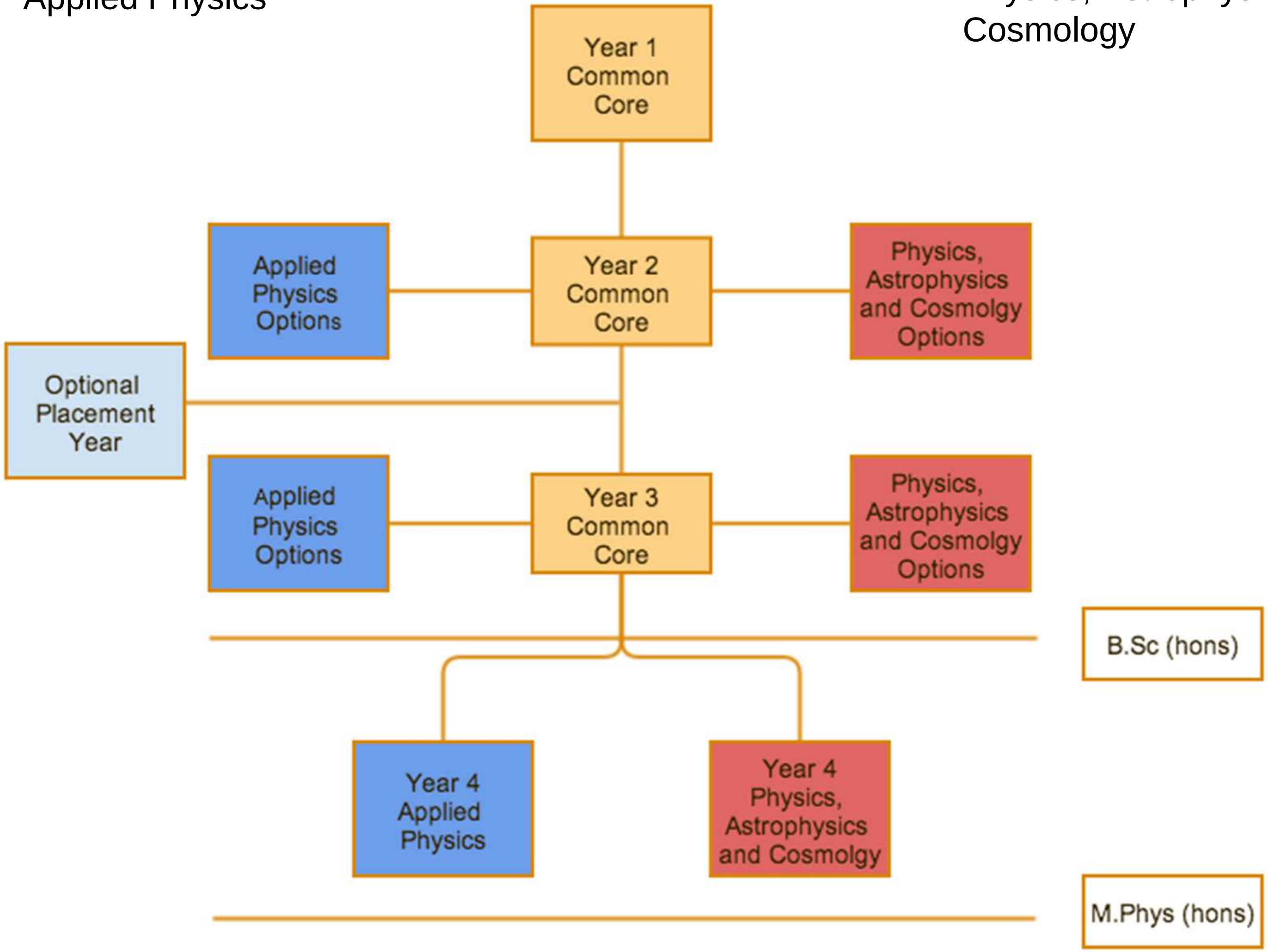
Applied Physics

Physics, Astrophysics and Cosmology



Informed by Employers – Industry, Defence, Health Care and Commerce

Adoption of Good Practice in HE (HEG,IOP, HESTEM,HEA)

- Vital participation of industry (Industrial Advisory Board)
- Embed employability skills
- Develop students as independent and cooperative learners
- Integrate understanding principles of physics with mathematical/computational modelling laboratory work through problem-based learning.
- Develop professional practice

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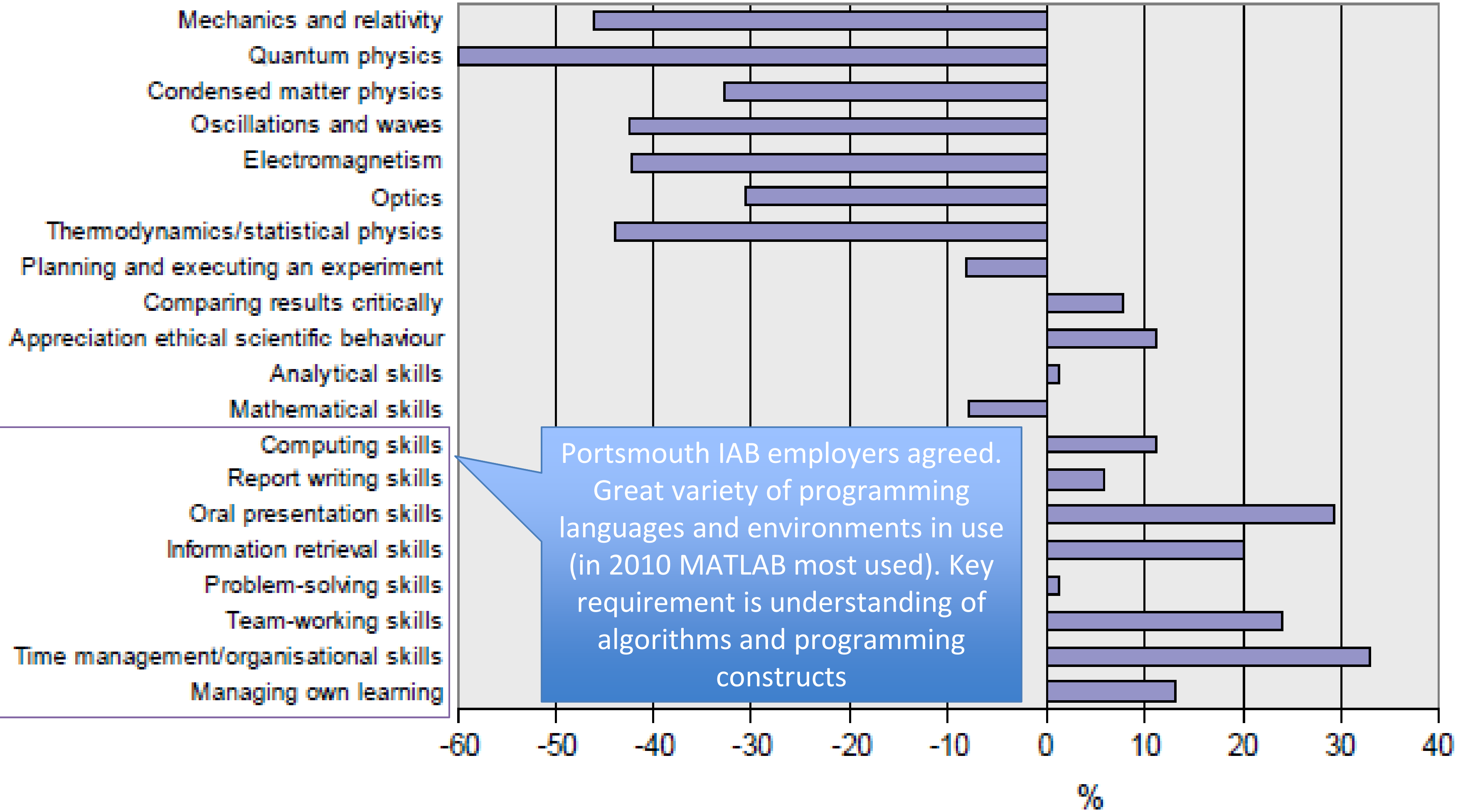

University of Hull/IOP employed graduate survey 2.5 years after graduation

Figure 11: 'Development deficits' for all graduates

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Industry Projects

Final year (40-credit) joint university-industry projects integrating experimental, theoretical and computational skills and knowledge to design, plan, implement and evaluate a project that addresses specific problems that arise in the industrial, research and field context.

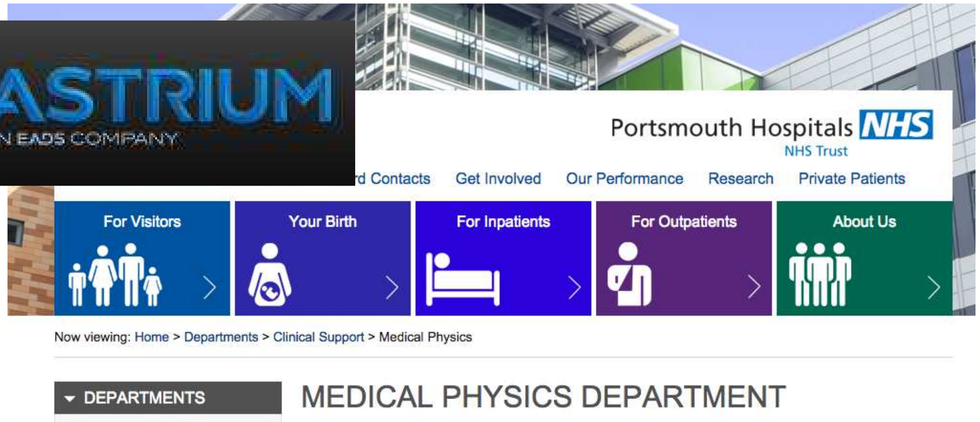
ired

QinetiQ

Defence Academy of the United Kingdom

[dstl]

ASTRIUM
AN EADS COMPANY



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For physics · For physicists · For all

IOP Institute of Physics

- IOP support
  - Higher Education Group
  - New Degrees Group (Liverpool, Portsmouth, Salford, Leicester, Bradford, St Mary's(Twickenham))
  - Industry Group Projects

- HESTEM
  - Curriculum Development Group
  - Mathematical Modelling and Problem Solving Group (Mike Savage, Leeds)
  - Problem-based Learning Laboratories Adopters (Derek Raine, Leicester)

Language Learning

- Learn language syntax and grammar in depth
- When mastered attempt communication
- What do you want to say?

VS

- Incremental learning driven by needs
- Learn in specific contexts
- Use immediately to achieve specific ends
- Progressively develop more sophisticated means of expression.

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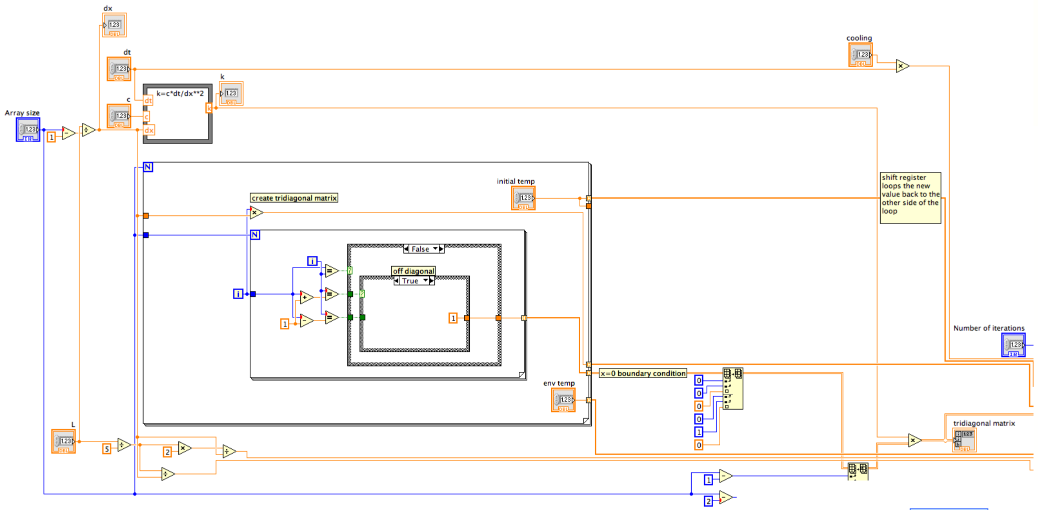
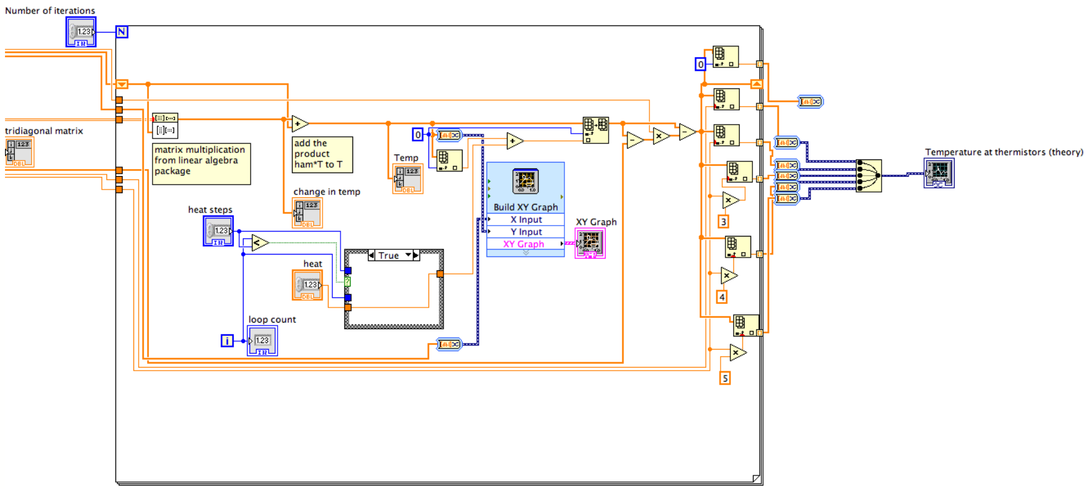
Computing Options Considered

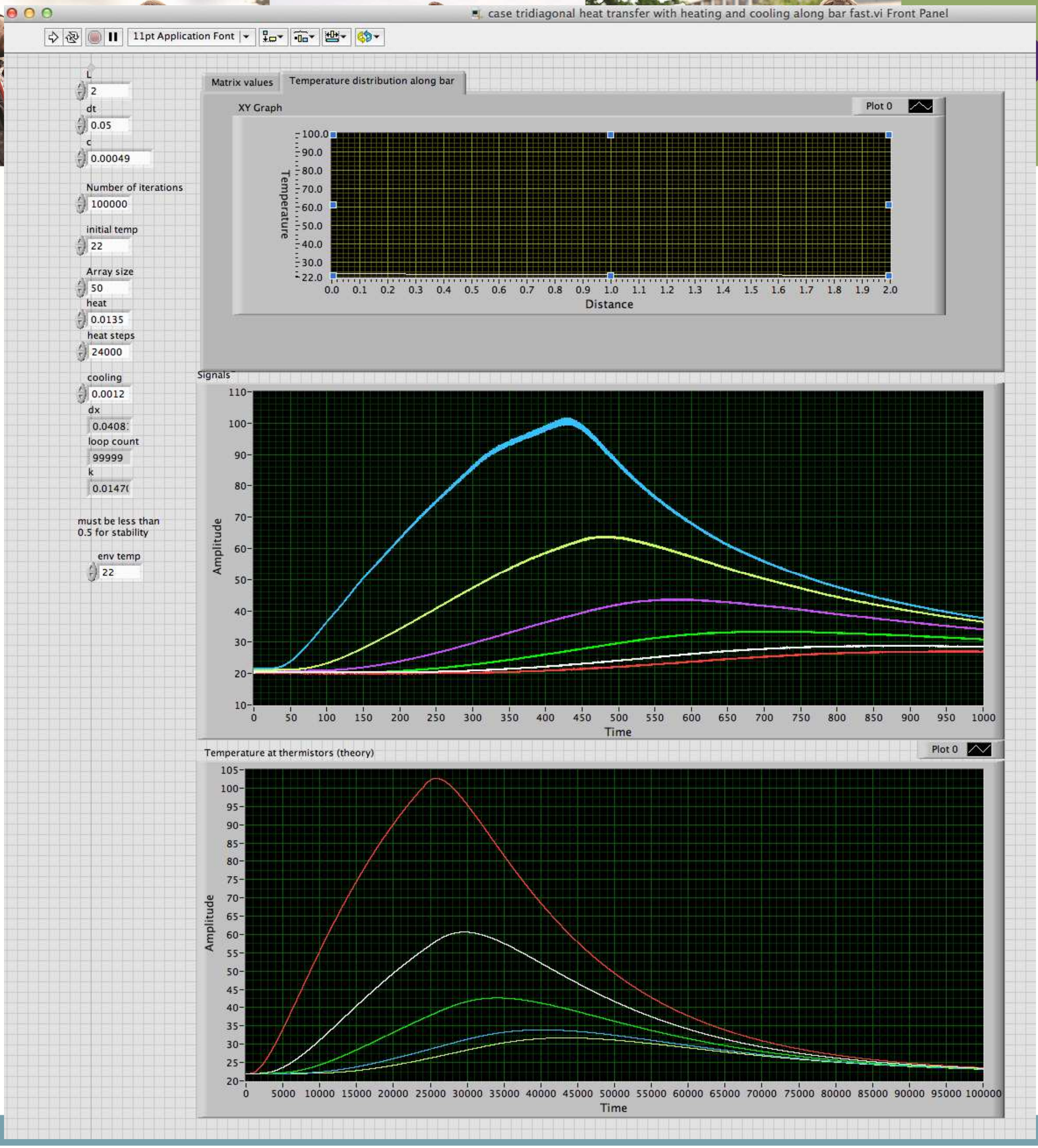
- LabVIEW: data acquisition, virtual instrument construction – express VI's and Visual Progamming – quick and easy in the lab – graphical programming not best for even relatively simple computations.
- MATLAB: High level, ease of entry, complete environment, many custom modules but introduces dependence, matrix based – (alternative GNU OCTAVE)
- EXCEL: Good for introducing techniques? e.g. Finite difference methods? Limited computationally. Good for data analysis and presentation and obviously spreadsheets.
- Visual Basic: Easy construction of GUI's – VBA in Excel – very slow for computations – now dropped
- C++, Java – not the easiest to start with – possibly introduce later.
- Maple/Mathematica: not a panacea for poor mathematical skills! Need strong maths basis to use effectively.
- PYTHON: free – increasing usage (since 2009) – reconsidering now.

LabVIEW: Heat Diffusion numerical solution



Hard to review!





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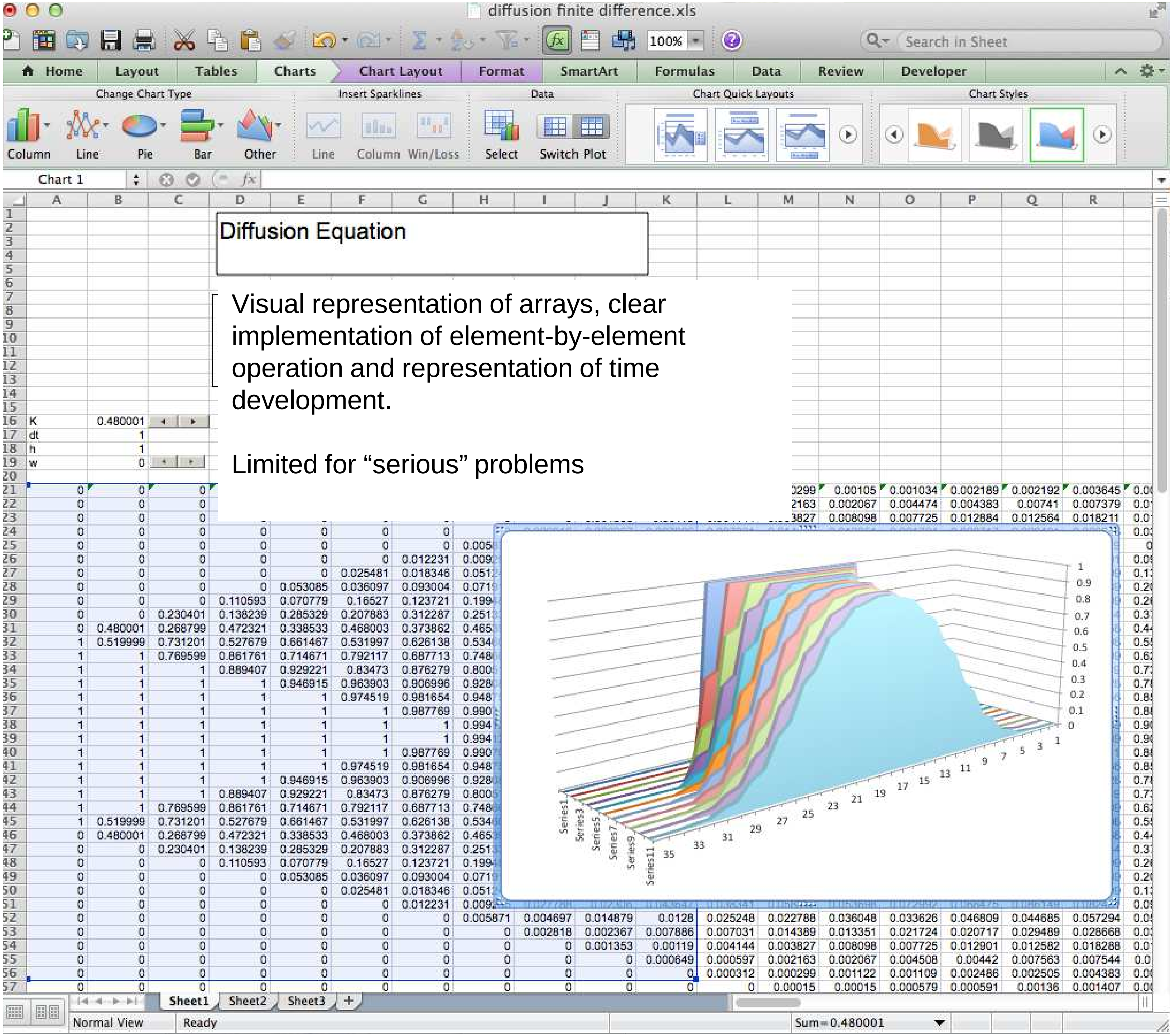
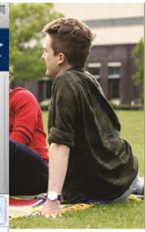
Easy to create GUI – virtual instruments integrating numerical simulation with real-time data acquisition.

Excel



Visual representation of arrays, clear implementation of element-by-element operation and representation of time development.

Limited for “serious” problems



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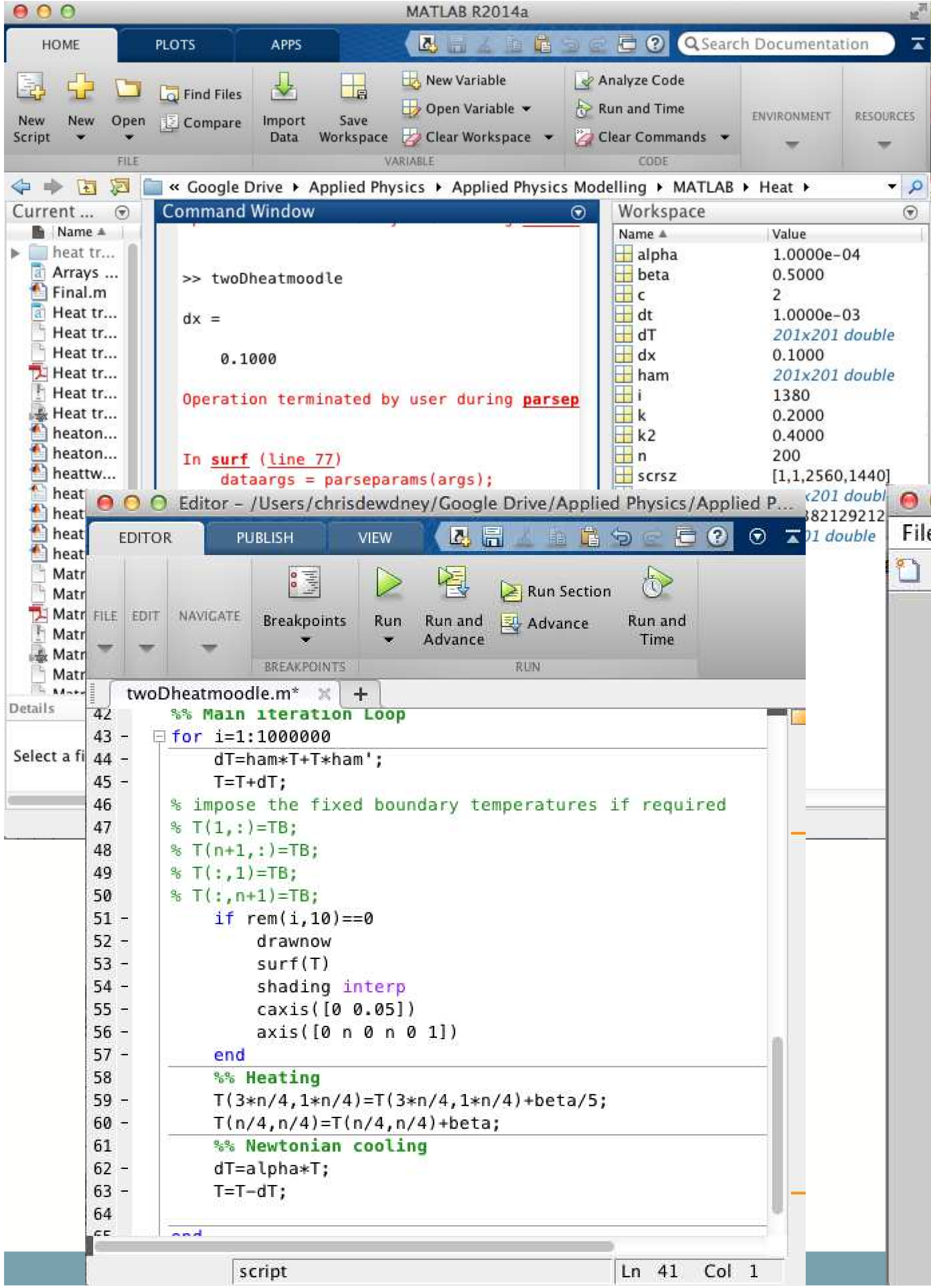
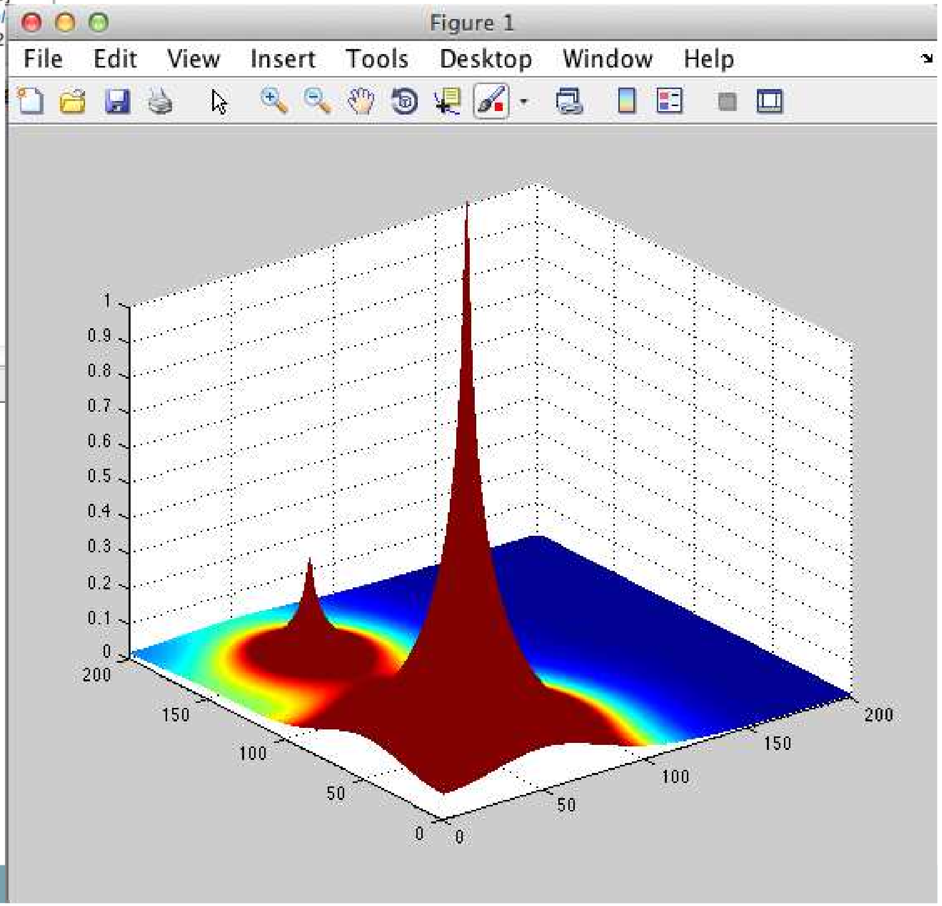
MATLAB





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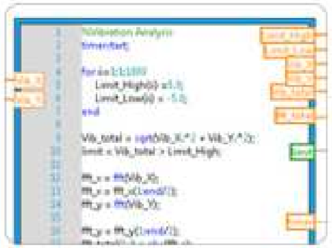
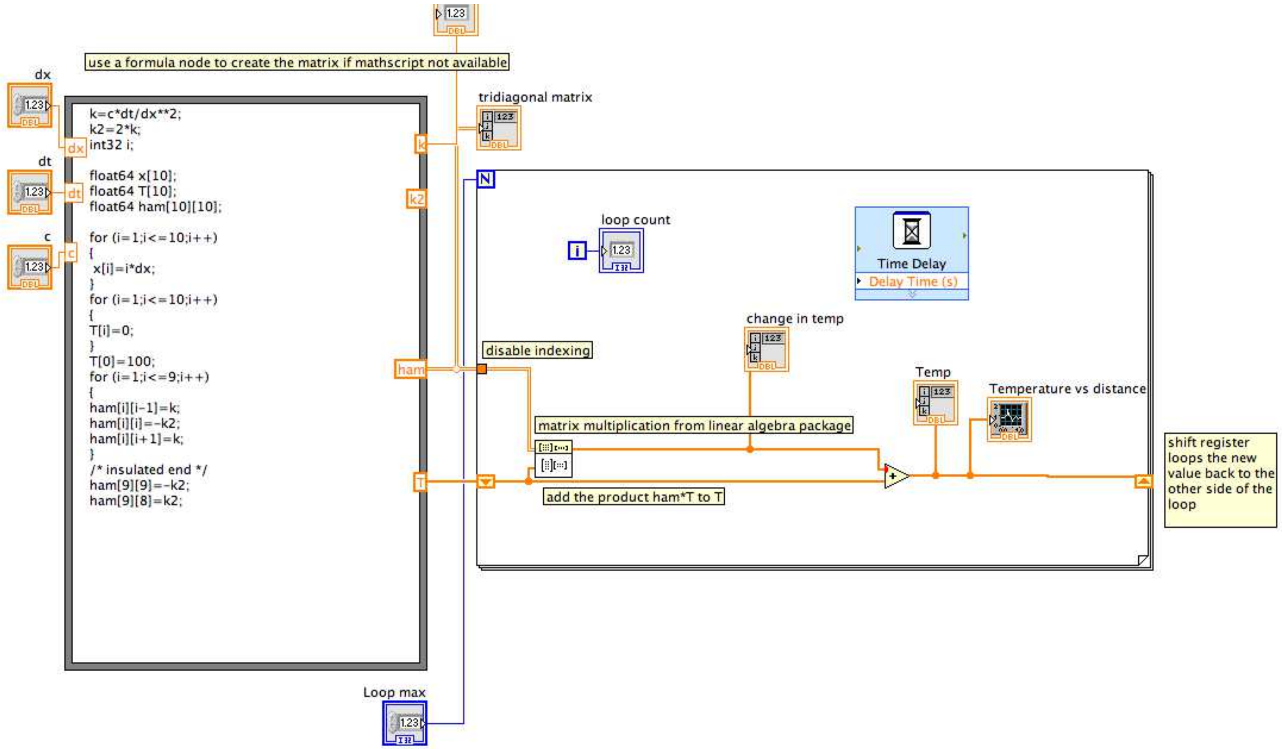
LabVIEW MathScript RT Module



The NI LabVIEW MathScript RT Module adds textual math to the LabVIEW development environment with a native compiler for the .m files you have developed in MATLAB® or GNU Octave software. You can blend textual and graphical approaches for algorithm development, signal processing, control design, and data analysis tasks. Easily deploy your .m code to real-time hardware without extra code-generation steps.

Download Evaluation

Buy



Computational Units and Integration in the Curriculum

- Level 4 Introduction to Computational physics
- Level 5 Computational Physics
- Level 7 (MPhys) Advanced Computational Techniques (2018-2019)

Level 4 “Bottom-up” approach

- Excel – introduce simple concepts – data manipulation – graphics.
- Variables and implementation of iterative processes in intuitive and straightforward contexts. Algorithms developed without initial mention of DE’s.
- Limitations of Excel soon encountered.

- MATLAB – introduce environment – basic text-based programming constructs
- Variables and implementation of iterative processes in intuitive and straightforward contexts. Algorithms developed without initial mention of DE’s.
- Limitations of Excel soon encountered.

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Level 4 “Bottom-up” computing lab approach

Excel

Use the Steps in Computational Modelling and Problem SolvingFile to develop a solution to the following “coffee cooling” problem. The Excel workbook should be used to address each one of the seven steps in the problem solving process (insert a text box or embed a word doc, use more than one sheet as you see fit). You need to create a well-formatted Excel Workbook and marks will be given for clarity of presentation.

Evaluation should be quantitative and also discuss limitations of the model itself and the errors inherent in your numerical method.

Part 1

Coffee cooling

The problem is to find out how long it takes for a cup of coffee that has just been made to cool to a drinkable temperature. You need to model the cooling process numerically using a suitable algorithm to calculate how the temperature varies with time. You may assume that Newton’s law of cooling applies: *The rate of cooling is proportional to the temperature difference between the object and the ambient temperature.*

No mention of differential equations

Part 2

Adding cream

The cooling process can be aided by adding a fixed amount of cream. When exactly is the optimum time to add the cream to make the coffee the right temperature for drinking in the shortest time interval?

Gould and Tobochnik

Develop computational skills in parallel with the mathematical physics skills – no DE’s until TB2

Understanding of derivatives through finite differences.

Steps in Computational Modelling and Problem Solving

Step 1: **Problem analysis.** Develop an understanding of the nature of the problem. What are the factors that should be taken into account? What software tools are available? What are the key variables and constants? What factors have an influence but will not be used in the model?

Step 2: Problem statement. Develop a detailed statement of the mathematical model that is to be used to solve the problem developed. Diagrams may useful.

Step 3: Processing scheme. Define the inputs required and the outputs to be produced by the program.

Step 4: Algorithm. Design the step-by-step procedure using the top-down design process that decomposes the overall problem into subordinate problems/tasks. This list of tasks is the structure plan; it is written in pseudocode. The goal is to design a plan that is understandable and easily translated into a computer language.

Step 5: Program algorithm. Translate or convert the algorithm into a computer context (e.g. Excel Spreadsheet, Maple worksheet, MATLAB program) and debug the syntax errors until the tool executes successfully.

Step 6: Evaluation. Test all of the options and conduct a validation study of the computer program, accuracy and e.g. other programs, experimental data, theoretical predictions.

Step 7: Modification and Revision

Based on: Hahn, B and Valentine, D.T. (2006) Essential Matlab for Engineers and Scientists. Elsevier

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Level 4 "Bottom-up" approach

Heat transfer –

There are many applications on all scales (microchips to large machines) in which equipment must be cooled. One way of achieving this is through the use of shaped metal conductors in thermal contact with the device that needs cooling.

The problem is to investigate the process of heat transfer in a conductor. The aim is to construct a computer program to simulate the processes involved. In the first approach a simple one-dimensional model can be assumed.

1. Problem analysis
   a. What are the physical processes involved?
   b. How can the processes be calculated?
   c. What assumptions must be made?

Develop computational skills in parallel with the mathematical physics skills – no DE's until TB2

- Level 4 units develop knowledge, confidence and understanding of physics in industry and research:
  - Electricity and Magnetism
  - Space Science and Applications of Physics
  - Mathematical Physics (1&2): incorporates Newtonian mechanics
  - Introduction to Laboratory physics
  - Introduction to Computational Physics (1)

- Coordinated approach across separate units: example
  - Oscillations: mechanical and electrical
    - Laboratory investigations (Pasco data acquisition -> LabView systems. Mini PBL.
    - Excel then MATLAB "bottom up" simulation
    - Theory of Ordinary Differential Equations in Dynamics "top down"
  - Different Physical Situations - same algorithm – same solution

Group Project: Use of Excel/MATLAB, Wiki's and Modelling process in PBL environment (TB1)

Felix set the world record for skydiving an estimated 39 kilometres, 14 October 2012, and became the first person to break the sound barrier without vehicular power on his descent.

- Use the 7-step modelling process (see Moodle site) to solve the problem of finding the motion of Felix Baumgartner as he jumped from 39km.
- Develop a group wiki to present your work. Each step in the modelling process should have its own wiki page – see Moodle document for how to work with wikis

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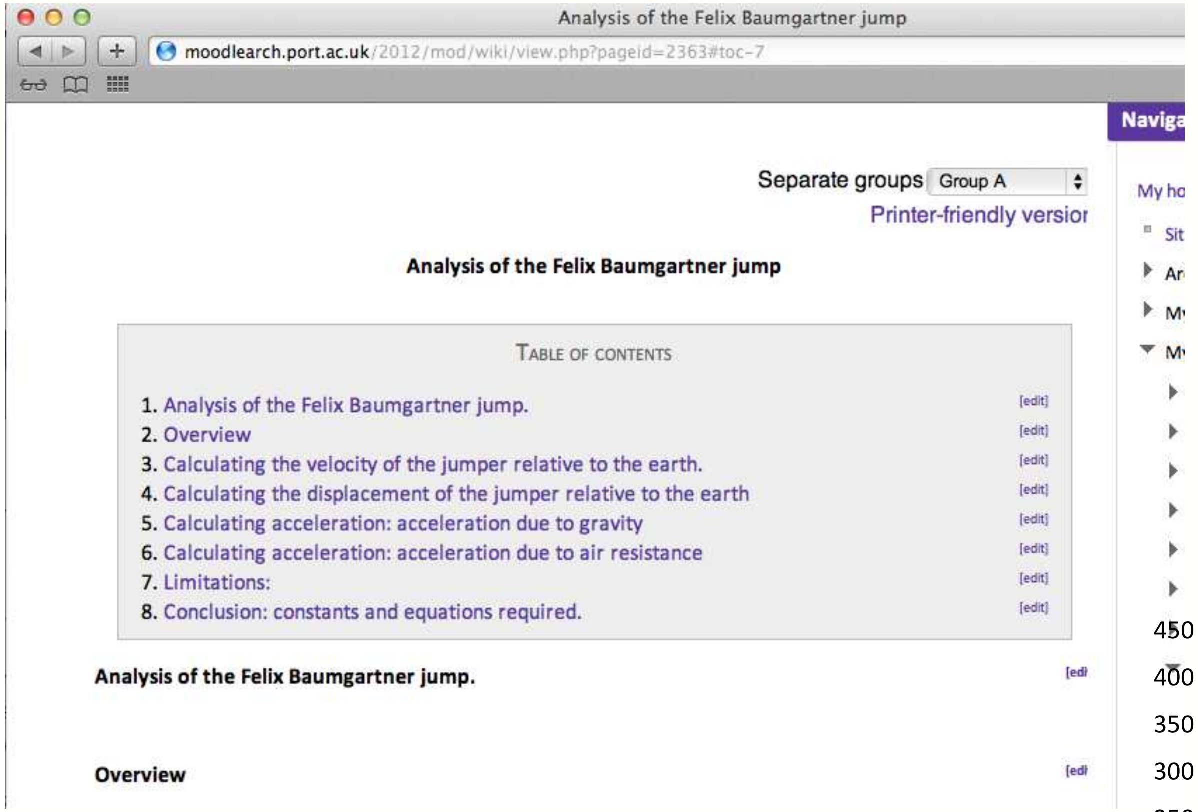
National HE STEM Programme



Analysis of the Felix Baumgartner jump

moodlearch.port.ac.uk/2012/mod/wiki/view.php?pageid=2363#toc-7

Separate groups Group A

Printer-friendly version

Analysis of the Felix Baumgartner jump

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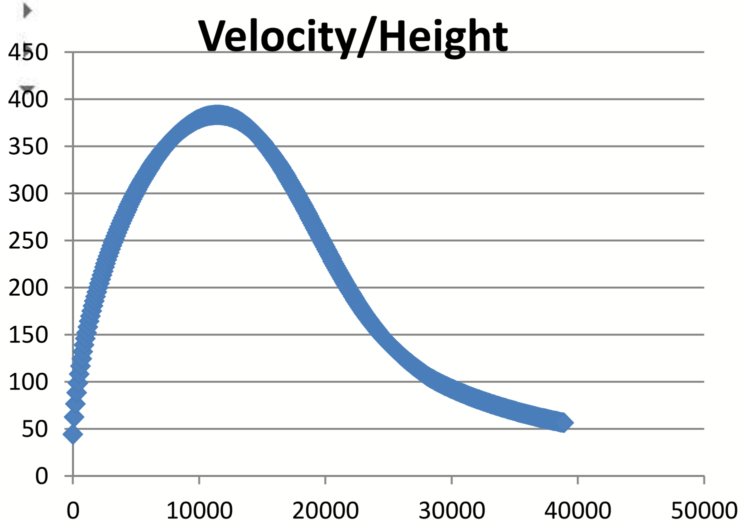
Analysis of the Felix Baumgartner jump.

Overview



3.1) The best part of the unit is:

the use of skills that are real skills that some of the physics Jobs will really favour.	Using and learning another skill, that will be used throughout the degree.
Learning to use new computer programmes.	I am now able to code basic programmes. something that previously I was unable to do so. I have learnt a skill for life

- Level 5 Core:
  - Laboratory-based PBL
  - Thermodynamics and Statistical Physics
  - Computational Physics
  - Quantum, Atomic and Nuclear
  - Mathematical Physics
  - Waves and Optics

- Heat transfer
  - Laboratory investigations LabView systems. PBL.
  - MATLAB "bottom up" simulation – finite difference
  - Theory of Ordinary Differential Equations in Dynamics "top down"

- Solving problems in QM using Maple

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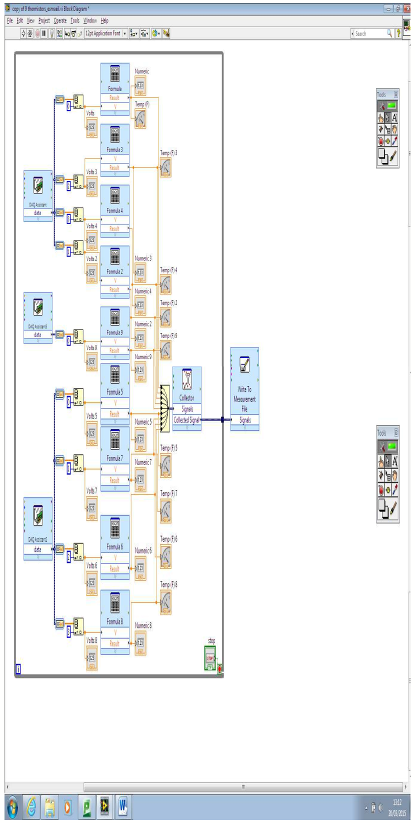
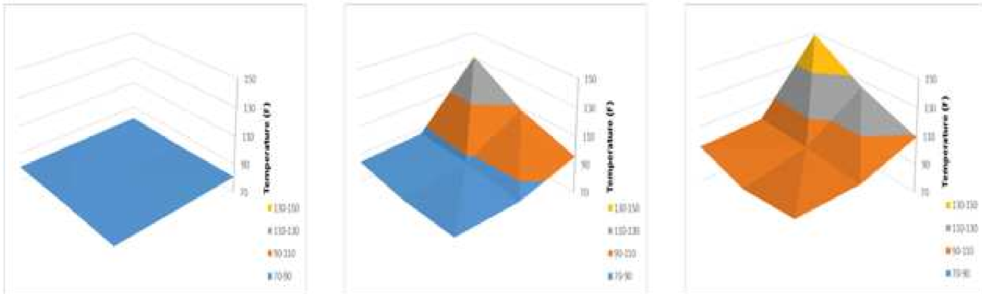
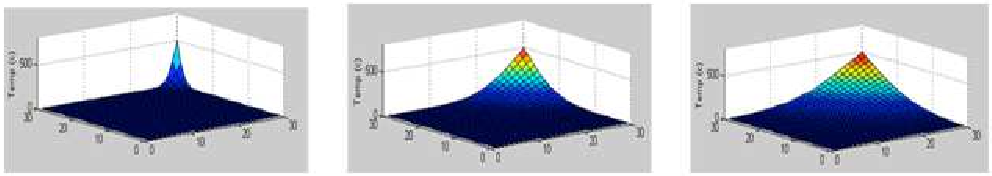
Level 5: Laboratory Physics – Problem-based Active Learning: Integrated Theory, Experiment and Computer Simulation







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I enjoy the more independent work in this unit and alot of the magnetic practicals are very interesting. I've enjoyed the EBC work and how helpful the lecturers at giving insight into some problems.	We are told way in advance what we need to do to be successful, and how to do it. Some fun experiments too..
Problem based learning - I get to use my problem solving skills to carry out my own research.	Testing concepts that we have learnt on the course and seeing them work in a practical environment. The experiments are interesting.
Practical application of theory, helps learning in other units.	Everything
The ability to work ~~independantly~~ independantly.	The freedom we get to learn on our own but with the benefit of help should we need it

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Level 7 – Advanced Computational techniques (for the future 2018-2019 introduction) – “top-down approach”

Abstract
Computational techniques now rank equal in importance with theoretical and experimental methods for the development of physics. This unit builds on skills developed at level 4 and 5. Common methodologies and algorithms are studied and implemented within the context of either advanced materials or astrophysical and cosmological systems. Specific methodologies for applied physics or astrophysics and cosmology will be developed in autonomous project work.

Aims (10 max.)	
1	To develop an understanding of advanced computational techniques and their implementation in physics.
2	To build advanced skills in the implementation, and critical evaluation of the limitations, of computational techniques to model and predict the behaviour of physical systems from first principles
3	To give students an appreciation of the forefront of computational techniques in their particular specialism within physics.

Syllabus (10 max.) – The topics covered will be chosen, inter alia, from:	
1	Use of an appropriate third generation programming language (C, Python for example) in the development of computational models.
2	Use of computer algebra systems (Maple or Mathematica, for example) to carry out advanced mathematical manipulations using tensor calculus with applications in materials physics and general relativity.
3	Dynamics of complex systems using various methods for N-body simulations, including, for example, particle-in-cell, particle-mesh, smooth particle dynamics and molecular dynamics, and applications in evolution of stellar systems and multilayer solid state materials.
4	Advanced MonteCarlo methods with applications in materials physics and astrophysics.
5	Data visualization and analysis techniques.
6	Special topics in computational astrophysics, cosmology or materials physics.

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Effectiveness and Evaluation?

- Need a systematic assessment and evaluation
  - Excel -> Matlab ?
  - Problem-based approach – a diversion from learning computing techniques systematically?
  - Integrated maths/labs/physics/computing PBL's?
- Perhaps a basis for a collaborative project?

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PHYSICAL REVIEW SPECIAL TOPICS - PHYSICS EDUCATION RESEARCH **8**, 010115 (2012)

Mapping university students' epistemic framing of computational physics using network analysis

Madelen Bodin*

Department of Physics, Umeå University, Umeå, Sweden

(Received 4 October 2011; published 10 April 2012)

Solving physics problem in university physics education using a computational approach requires knowledge and skills in several domains, for example, physics, mathematics, programming, and modeling. These competences are in turn related to students' beliefs about the domains as well as about learning. These knowledge and beliefs components are referred to here as epistemic elements, which together represent the students' epistemic framing of the situation. The purpose of this study was to investigate university physics students' epistemic framing when solving and visualizing a physics problem using a particle-spring model system. Students' epistemic framings are analyzed before and after the task using a network analysis approach on interview transcripts, producing visual representations as epistemic networks. The results show that students change their epistemic framing from a modeling task, with expectancies about learning programming, to a physics task, in which they are challenged to use physics principles and conservation laws in order to troubleshoot and understand their simulations. This implies that the task, even though it is not introducing any new physics, helps the students to develop a more coherent view of the importance of using physics principles in problem solving. The network analysis method used in this study is shown to give intelligible representations of the students' epistemic framing and is proposed as a useful method of analysis of textual data.

DOI: 10.1103/PhysRevSTPER.8.010115 PACS numbers: 01.40.Fk, 01.40.Ha, 01.50.H−