Curriculum Development at UoS

Iacopo Vivarelli

The Abdus Salam International Centre for Theoretical Physics
Physics Without Frontiers

United Nations Educational, Scientific and Cultural Organization

IAEA
International Atomic Energy Agency

UNIVERSITY OF SUSSEX

Drivers

UNIVERSITY OF SUSSEX

The UoS
Physics degrees

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Drivers

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IOP Institute of Physics

Sets requirements for a physics degree in the UK

The UoS Physics degrees

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Government policy

UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME

Our ten-year plan to make Britain a global AI superpower

Over the next ten years, the impact of AI on businesses across the UK and the wider world will be profound - and UK universities and startups are already leading the world in building the tools for the new economy. New discoveries and methods for harnessing

UK Research and Innovation

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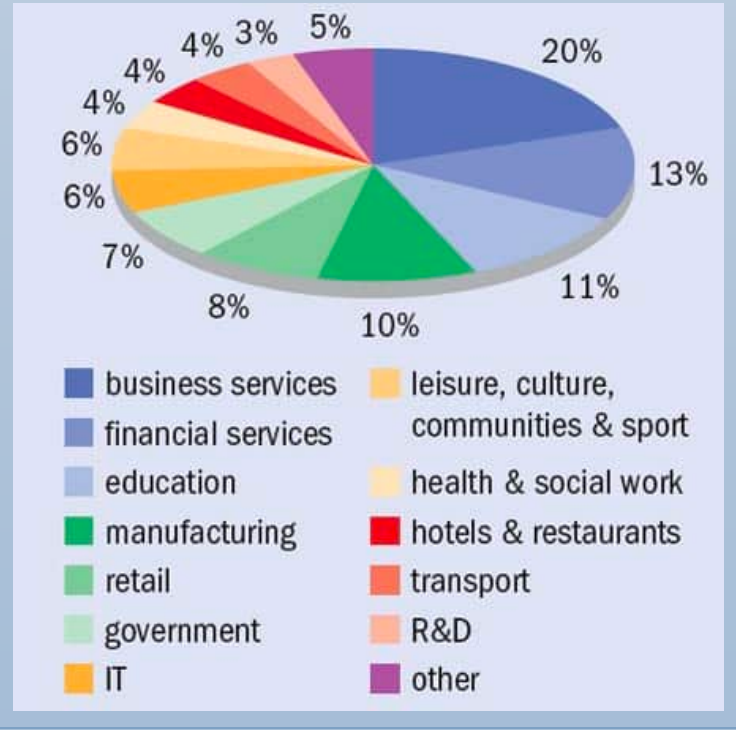
The job market



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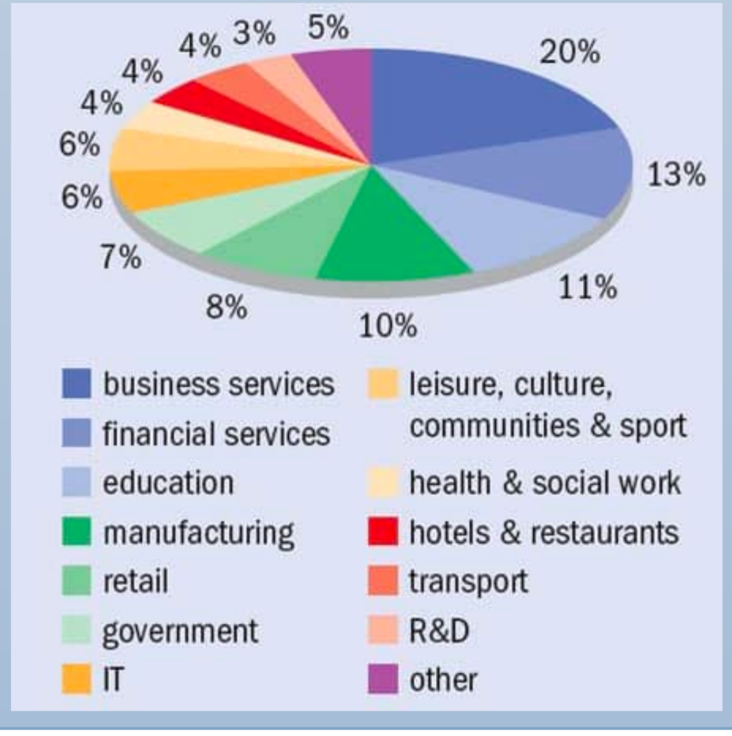

Our own research:

- CERN/LHC, Particle Physics, Astrophysics, Cosmology, Quantum computing, Condensed State Physics, etc.

A range of 3- or 4-year degree courses

There are 4 entry levels into physics degree courses at Sussex:

Foundation year: aimed at those who don't quite get the grades they need. Leads on to one of …

BSc: 3-year course that gives you a broad range of knowledge and skills.

MPhys: 4-year course for those who want to go on to further research or a specialist career in physics.

MPhys (Research Placement): 4-year course with opportunity to apply for **paid** research placements over the summer.

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All our degrees are **fully accredited** by the Institute of Physics.*

*Accreditation process of Physics with Data Science ongoing

Successful completion on the **Foundation Year** gives you access to any of our other Physics programmes.

You can switch between **BSc and MPhys** at any time up until the end of your second year.

Core physics and diversification

All our degrees contain the **same core material**.

Choose the course that best suits your interests:

- **Physics** – maximum choice of options, including electives/pathways from other subjects.
- **Theoretical Physics** – no labs, more mathematical in nature.
- **Physics with Astrophysics** – specialist astrophysics options.
- **Astrophysics** – specialist astrophysics options, plus guaranteed astrophysics project.
- **Physics with Data Science** – emphasis on theoretical and practical aspects connected with large-scale data analysis.

In addition, you can add in:

- **Industrial Placement** – a year in industry, in the penultimate year of study.
- **Year Abroad** – either as an additional year, or integrated (MPhys only).

Physics BSc/MPhys modules – Y1&2

- **Core modules**

Year 1
Mathematical Methods for Physics 1 & 2
Mechanics and Relativity
Physics in Practice
Oscillations, Waves & Optics
Physics Year 1 Laboratory

Year 2
Electrodynamics
Mathematical Methods for Physics 3
Physics Year 2 Laboratory
Applying Physics Skills
Quantum Mechanics 1
Thermal and Statistical Physics

Optional modules

You choose one option per semester
- 2 options per year

Year 1
Introduction to Quantum Physics
Introduction to Astrophysics
Electives / Pathway

Year 2
Scientific Computing, Galaxies and the Cosmos
Theoretical Physics
Electives / Pathway

Physics BSc modules – Y3

Year 3

Core

Atomic Physics
Condensed State Physics
Nuclear and Particle Physics

Options (may vary)

Communicating STEM
BSc Final Year Project
Advanced Condensed State Physics
Lasers and Photonics
Particle Physics
Quantum Mechanics 2
Researching STEM
Stellar and Planetary Physics

Physics Mphys modules – Y3+4

Year 3

Core

Advanced Physics Laboratory A & B
Atomic Physics
Condensed State Physics
Nuclear and Particle Physics
Quantum Mechanics 2

Options

Advanced Condensed State Physics
Lasers and Photonics
Particle Physics
Researching STEM
Stellar and Planetary Physics

Year 4

Core

MPhys Final Year Project

Options

Atom Light Interactions, Cosmology
Data Analysis Techniques, Further Quantum Mechanics
General Relativity,
Quantum Field Theory 1, Quantum Optics and Quantum Information
Advanced Cosmology, Astrophysical Processes, Electrons, Cold Atoms & Quantum Circuits, Frontiers in Particle Physics
Introduction to Nano-materials and Nano-characterisation, Monte Carlo Simulations, Particle Physics Detector Technology
Practical Quantum Technologies

Physics with Data Science – an overview

Data Science-specific modules

Year 1
Foundations of Data Analysis
Data Structures and Algorithms

Year 2
Scientific Computing
Fundamentals of Machine Learning

Year 3
Linear Statistical Models
Statistical Inference

Year 4
Options
Algorithmic Data Science
Quantum Computing
Wider Topics in Data Science
Machine Learning
Applied Natural Language Processing
Monte Carlo Simulations

The key expectations

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Full expectations for accreditation of a physics course by the institute of physics available at this link

Key expectations (KE) for accreditation			BSc	IM	MSc
Breadth and depth of knowledge	KE1	Evidence that students study the fundamental areas of physics at appropriate times in the course	✓	✓	
	KE2	Evidence that students study the application of the fundamental principles to an appropriate selection of areas of physics relevant to the degree title	✓	✓	
	KE3	Students can demonstrate that they can apply their physics knowledge across topic boundaries and in unrehearsed contexts	✓	✓	✓
	KE4	Students can demonstrate the ability to use mathematics to model, describe and predict phenomena in the real world	✓	✓	✓
	KE5	The content builds on undergraduate knowledge of physics in areas appropriate to the degree title			✓
	KE6	Programmes allow students to demonstrate an appreciation of recent developments in physics	✓	✓	
	KE7	Students can demonstrate the ability to evaluate current research at the forefront of the discipline		✓	✓
Practical skills	KE8	Programmes provide an experience of the practical nature of physics and equip students with a range of practical skills necessary to plan, execute investigations and analyse data	✓	✓	
Investigative and project work	KE9	Programmes must include elements of independent investigative work of an open-ended nature	✓		
	KE10	Programmes must include a substantial project of an open-ended nature		✓	✓
Physics skills	KE11	Students can demonstrate the ability to formulate and tackle problems in physics	✓	✓	✓
Transferable and professional skills	KE12	Programmes must provide training in a broad range of transferable skills and their use should be demonstrated throughout the programme	✓	✓	✓
	KE13	Students can demonstrate appropriate professional skills	✓	✓	✓

Emphasis on what the **students can do**, rather than on **what we teach them.**

Skills

Emphasis on what “the students can do” means **skills and knowledge**

From [this website]

Skills

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Python:

Introduced in Physics in Practice, then applied in Physics Year 1 & 2 Laboratory (and other modules too)

Communication skills:

Oral presentation in Physics in Practice, repeated in Advanced Physics Labs and for Final Year Project

Problem solving:

Everywhere, but in particular in “Applying Physics Skills”

Team work:

A dedicated group project in year 3 as part, where students have to research a problem and produce a poster

Careers:

Write a CV, write a cover letter, prepare for a job interview, all covered as part of a dedicated submodule.

(Autonomous) research:

Part of the students’ final year project

Example: python programming

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What do you need:

- PCs with internet connections (possibly some IT person to make sure they stay functional).
- One or more faculties that know (or are willing to learn) the language.

An almost infinite amount of learning resources are already available online!

…..Including the ATLAS Open Data

Then you get this:

```
[1]: import uproot
     import pandas as pd
     import time
     import math
     import numpy as np
     import matplotlib.pyplot as plt
     import matplotlib.patches as mpatches # for "Total SM & uncertainty" merged legend handle
     from matplotlib.lines import Line2D # for dashed line in legend
     from matplotlib.ticker import AutoMinorLocator,LogLocator,LogFormatterSciNotation # for minor ticks
     import scipy.stats
     import os

     import HZZSamples
     import HZZCuts
     import HZZHistograms
     import infofile

     class CustomTicker(LogFormatterSciNotation):
         def __call__(self, x, pos=None):
             if x not in [1,10]:
                 return LogFormatterSciNotation.__call__(self,x, pos=None)
             else:
                 return "{x:g}".format(x=x)
```

Exercises

Total marks available = 10, breakdown in [. . .].

1. Define a tuple of the basic matplotlib colours, as given in Table 8.2 of the Python Lab Book (use the full names, not the 1-letter abbreviations). Print out 5 colours at random from the tuple using a loop. (Note: duplicate names accepted, i.e. you don't have to remove a name after it is randomly selected). [2]

2. Plot a graph of
$$y = x\cos\left(x - \frac{\pi}{2}\right)$$
with limits of $[-5, 5]$ on the x-axis and $[-6, 4]$ on the y-axis. Label the x and y axes, and add a title. Graph must be visually smooth. [2]

3. In this question, you will make a plot that demonstrates that the expansion of the Universe is accelerating. The supplied data file contains two catalogues (*Gold* and *Silver*) of type Ia supernovae, which act as 'standard candles' in cosmology, with approximately constant peak intrinsic luminosity, corresponding to an absolute magnitude $M \approx -19.3$.

   (a) Download the file supernovae.csv from Canvas to the same folder as your python notebook. Read the data into a Pandas dataframe — no path should be specified, as the file should be in the current folder. [1]

   (b) Plot the magnitude (along with its error) against redshift for each supernova. Use red symbols for the *Gold* data, blue symbols for *Silver*; do not connect the symbols. Hint: look at the contents of the CSV file in Canvas to find the relevant column names. [3]

   For full marks, make sure that the plot is large enough that most of the *Silver* sample points are distinguishable from each other, that both axes are labelled, and that the *Gold* and *Silver* samples are labelled in the figure legend.

Applying physics skills (year 2 module)

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Target: develop problem solving skills

How?

- Students are divided into groups of 5.
- They meet weekly with one faculty. They are presented a physics problem tehy have never seen before.
- They have 1h to discuss among them and with the faculty to get to the quantitative answers.
- The problems are such that they have to dig into their phsyics background to be able to find the relevant information to tackle the problem.

What do you need?

- Some time to prepare the problems.
- A significant amount of faculty time.

Secondments/placements

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Key for our university: its networks

- We are part of the so-called SEPNet (South-East Physics Network):
  - Boost our teaching offers to areas we are not very equipped for.
  - Offers summer placements for our own students in companies or public sector
    - Wonderful opportunity to develop skills in a real working environment while still at t he university.
- Through connections built with research and networking:
  - Offer “industrial placement” year on top of the usual course duration. Partner companies in the private sector develop early relations with students (sometimes students ger hired by the company when they graduate).
  - Research labs around the globe: CERN is a primary example.

JRA/research placement

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The University and the School of Mathematics and Physical Sciences run a research excellence programme:

- Junior Research Associate: students are paid to work with a research group for a summer. The funds are allocated on a competitive basis (students present a research project).
- Research placement: similar, but funded by the school. Best students are offered this.

Key to foster a healthy competition between students and a strive fo high achievement

Very helpful for the research groups as well, as tehy get to know the best students ahead of their graduation.

Feedback

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We have several mechanisms to receive feedback on the quality of our teaching:

We receive feedback from:

- Students, through surveys (on each module, and on the course overall).
- University, through stats (retention rates, average graduation grades, intake ets.)

Reacting on this feedback is a significant part of the work of the school/department management

- It is crucial (especially with students) to close the loop and present them with the actions that followed the feedback.

A healthy education system is one where there are systems in place to collect the feedback, and bodies in place to act on it.

Summary

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Curriculul developed as it has because of:

The **drivers**: what are we required to do, and which parties (stakeholders) play a role? What type of graduate do we want to produce?

- Skills in data science, AI and quantum technologies are the push from the government

The steer in the last few years has been focused on **skills** more and more:

- It is not enough anymore to **teach** to student: the stakeholders want us to demonstrate that they have **learnt.**
- Focus is on programming/data science, communication, team working, problem solving.

Networking has been (and is) key:

- It helps taming our weaknesses and value our strengths.

Feedback on the teaching (from students and external bodies) is also key.