"A PAER ON THEORETICAL VS PRACTICAL PHYSICS"

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ABSTRACT

The most famous physicists are all theorists who stayed well grounded in experiment, e.g. Newton, Einstein, Maxwell, Boltzmann, and the founders of QM. The great experimentalists in physical science before quantum physics are today remembered as chemists and engineers; Rutherford is an example of someone who considered himself an experimental physicist and is today mostly remembered as a chemist. Saying "Who ordered the theorist?" is like saying "Who ordered Matter waves?"(De Broglie), "Who ordered anti-matter?" (Dirac), "Who ordered QED?"(Feynman et al), "Who ordered Bose condensates?", "Who ordered W and Z?", etc or more fundamentally "Who ordered calculus?", "Who order probability and statistics?" (gee i dunno, is Gauss more of an experimentalist, or a theorist?). I don't see a need to fight, and I am not saying "who ordered the experimentalist?" but if choosing between extremes I prefer mathematics to the short-sighted empirical method as a way of gaining knowledge, but we should all agree that combining these two into the scientific method has been a great success. Edit: The "Who needs.." article is dishonest because it is written in 2000 and is talking about the J/Psi and prior events, but it is a well known fact that the standard model (a theory) has predicted every observation since the J/Psi in the 1970s. Hopefully the discovery of super symmetry of even relatively large extra dimensions at the LHC would boost the status of theoretical physics

INTRODUCTION

All preoccupations of physicists are channeled towards the investigation and study of the physical properties of the universe; the interactions and interrelations of matter and energy at different scales - from atomic scale (Quantum Physics), human scale (Classical Physics) and cosmic scale (Cosmology & Astrophysics).

Theoretical Physicists spend their time, energy and resources to conceive and develop models (*usually conceptual, philosophical and thoroughly mathematical) in order to describe observable or non-observable physical phenomena and also the laws governing the interactions and interrelations of matter and energy at all scales.

Experimental Physicists on the other hand spend their time, energy and equipment (resources) performing tests and experimentation on models and theories. Experimental Physicists could be very practical in the sense that they are more inclined to become Engineers using physical principles, laws and models to invent technologies - of the present and of the future.

Both Theoretical and Experimental Physics seem like imperatives for investigating the universe or studying physics. They are the Yin and Yang of the discipline.

As regards physics as a profession, the job responsibilities separates both imperatives. The professional responsibility of a Theoretical Physicist include:

- Building conceptual models of the physical properties of the complex universe (through Thought Experiments mostly)
- Making mathematical analyses and predictions about these 'concepts' relating to the complex phenomena we experience and observe.
- Writing papers and debating about right or wrong theories like Bohr–Einstein debates (This is so cool, it made me fall in love with Theoretical Physics)

The professional responsibility of an Experimental Physicist include:

- Testing the models and theories made by Theoretical Physicist (* just like those guys who tested Einstein's hypothesis about the quantum world — quantum entanglement, spooky actions, and the 'to be or not to be' scenario)
- Developing ways to use the properties of matter and energy in industry applications (very cool)
- The models created by Theoretical Physicists needs data - lots of them - hence, Experimental Physicists observe, record and analyze data for the efficiency and utility of the models.

The interactions of matter and energy are studied by all physicists. Experimental physicists test ideas about how these interactions take place at the atomic level and their work has applications to medicine and nuclear technologies. Theoretical physicists use mathematics to create models which explain all the factors governing the interactions of matter and energy.

Responsibilities of a Theoretical Physicist vs. an Experimental Physicist

The equipment used by each type of physicist is a big difference between these two professions. Theoretical physicists may require large computers for computation and modeling or they may only require the mathematical tools of calculus and trigonometry. On the other hand, an experimental physicist must use powerful tools such as particle accelerators, lasers, telescopes and radiation monitors. Both types of physicists collect and analyze data to draw their conclusions about the interactions of matter and energy.

Theoretical Physicist

The nature of the universe is the primary focus of theoretical physicists. Gravity, the nature of time and the origin of the universe are all topics these scientists explore, but these professionals typically specialize in an area of interest. Their work is published in scientific journals and they are usually employed by universities. Federal agencies such as NASA may also employ theoretical physicists. Most of their work is in an office and involves using mathematics to describe observations about the basic laws and principles of the universe. Albert Einstein was a theoretical physicist.

Job responsibilities of a theoretical physicist include:

- Modeling physical properties of the universe using computers
- Comparing their mathematical analyses with those made by peers
- Making predictions about complex natural phenomena
- Presenting papers at scientific conferences

Experimental Physicist

Atomic structure, properties of light, superconductors and nuclear energy are all topics explored by experimental physicists. They design experiments to test theories about the interactions of matter and energy in specific ways using sophisticated equipment. Applications of their research are important in medicine, manufacturing, alternative energy technologies and in the military. Most of their work is in a laboratory setting although many have to spend time writing proposals to get funding for their work. Experimental physicists are employed by medical research companies, universities and the federal government.

Job responsibilities of an experimental physicist include:

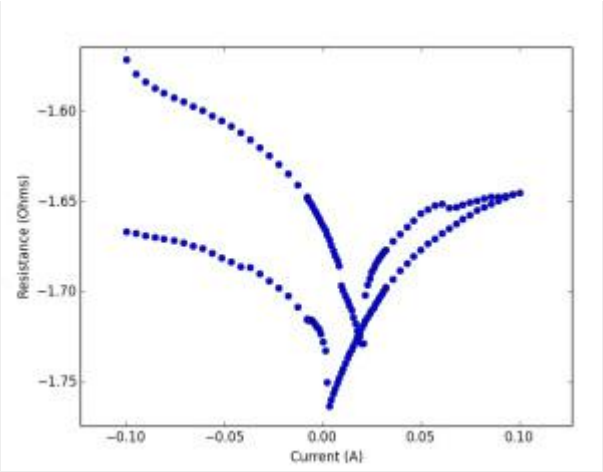
- Developing ways to use properties of matter and energy in industry
- Monitoring and assessing radiation levels where nuclear technologies are used
- Analyzing data on the efficiency of specific instrumentation

- Establishing physical standards for materials used in aeronautics

EXPERIMENTAL OR THEORETICAL PHYSICS

Like every undergraduate physicist I started out doing lab work at least once a week. All these had a work sheet we had to follow and were heavily experimental. Honestly, I didn't really enjoy them all that much but as I progressed though my degree I was able to choose what I wanted to work on. By the time I started my Masters project I was only interested in theoretical projects. I really enjoyed them. I loved creating simulations and I knew when something went wrong it was something I'd done. And you always got some lovely looking data! (If you compare the first 2 images in the post you will see what I mean!)

Then came the time to decide what to do with my life. I knew I wanted to pursue a PhD so I started applying to various universities. Unsurprisingly, four out of the five projects focused on computational simulations. However, I picked the only one which had an experimental element, the Condensed Matter Physics CDT in Bristol and Bath. I had fallen in love with Condensed Matter Physics (CMP), especially magnetism, by the end of my Masters and I wanted to understand it better. I wanted to be able to read papers and know how the experimental techniques worked and how this related to their results and impacted my potential future research.



Experimental data from my first project in the CMP-CDT. Copyright Emma Gilroy 2016. All rights reserved.

My plan was to try everything and learn as much as I could in the first year, then I would choose a theoretical PhD project. I picked a wide variety of Physics Techniques modules (short introductory training modules into a range of techniques important in CMP) so I could try lots of new and interesting things. I got to use the clean room at Bath, design and etch circuit boards, use an electron microscope as well as a variety of other things. For my first longer research project in the CDT I decided to stick with something I felt comfortable with. I was looking at magnetic proximity effects from iron in uranium. The theory was something I had a little knowledge about so I had no idea what to expect from the experimental side. I had to learn how to attach 25 micrometer diameter gold wire from a contact pad to the sample we were looking at. It was fiddly and frustrating, very frustrating! And then there were the actual magneto-resistance measurements… These consisted of turning on a current source to create a magnetic field, then waiting 20 minutes and pressing a button to take the field back to zero, then another 20 minutes and switching the polarity of the field…and so on. Each measurement took close to an hour and a half to complete where we just had to sit and wait in order to press one button! However, some of the results were very interesting, which made the whole thing worth it in the end.

Somehow, even with all the things that frustrated me I chose to stick with experimental physics a little while longer. I took on a placement with one of the Partners of the CDT-CMP in Nijmegen at the High Field

Magnet Laboratory. I got to learn how to create a working experimental probe and how to take low temperature measurements. The more I did it the more I enjoyed it.

Then just at the end of February we were given the list of potential PhD project choices. Would you believe it? – I decided to continue with my first long research project in the CDT. All the labs and projects I did throughout the year really opened my eyes to what experimental physics was really like. Yes, there was a lot of waiting around and different bits and pieces were always breaking down but it was a lot of fun! It is so rewarding when you spend a long time preparing your measurements and then they finally work; I can't wait to see where my PhD takes me and what other skills I will end up learning by taking on an experimental project. Maybe, I'll even be able to use some of the skills learned in my theoretical adventures to make my PhD as interesting as possible.

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