**Chapter 1: Introduction to Leaving Cert Physics**

*Physics is like sex: sure, it may give some practical results, but that's not why we do it.*

Richard Feynman

This is a textbook like no other.

I used to think that it was just me who thought this. But then I started to come across others who felt equally frustrated (I think ‘cheated’ is a more appropriate term).

Take the following quotes for example:

Science only adds to the mystery and the awe of the natural world . . .

***Wonder is part and parcel of what science is about, yet this rarely features in our education***

*The most beautiful experience we can have is the mysterious - the fundamental emotion which stands at the cradle of true art and true science.*

Albert Einstein. Quote taken from 'Living Philosophies', 1931

*The goal is for the public to appreciate the order and beauty of the abstract and natural worlds which is there, hidden, layer-upon-layer. To share the excitement and awe that scientists feel when confronting the greatest of riddles. To have empathy for the scientists who are humbled by the grandeur of it all.*

[Charles Simonyi Professorship in the Public Understanding of Science](http://www.simonyi.ox.ac.uk/index.shtml)

*Students today are often immersed in an environment where what they learn is subjects that have truth and beauty embedded in them but the way they’re taught is compartmentalised and it’s drawn down to the point where the truth and beauty are not always evident.*

*It’s almost like that old recipe for chicken soup where you boil the chicken until the flavour is just . . . gone.*

David Bolinsky

*I devour popular science, finding its history and its wonder a constant delight. . . . It is a mystery how so many science teachers can be so bad at their jobs that most children of my acquaintance cannot wait to get shot of the subject. I am tempted to conclude that maths and science teachers want only clones of themselves, like monks in a Roman Catholic seminary.*

Simon Jenkins

*We are deprived by our stupid schooling system of most of the wonders of the world, of the skills and knowledge required to navigate it, above all of the ability to understand each other. Our narrow, antiquated education is forcing us apart like the characters in a Francis Bacon painting, each locked in our boxes, unable to communicate.*

George Monbiot

Murray Gell-Mann, the Nobel prize-winning scientist who ‘discovered’ quarks thought that Physics at high school was “the dullest course I had ever taken”, and he only applied to study physics at university “to please my father”.

We educators take this incredibly exotic jungle of knowledge called Science and distil it until all the wonder and context has been boiled off and we are left with nothing but the uncomfortable union of cold facts and equations lying in a bed of sludge. We use this residue to form the basis of our syllabus and textbooks and then force our students to learn it ‘off by heart’ so that it can all get vomited back up once more come exam time.
And then we wonder why so many young people don’t like science.

It’s really such a shame that *the wonder of Science* only seems to be celebrated by artists, poets and writers. Why do scientists and science teachers (and in particular those who are responsible for drafting the science syllabi) hide from it so much?

Would they not accept that by acknowledging and then highlighting the wonder that lies at the heart of the subject we might actually engage the students a little more?

Science is a source of *infinite* wonder. More than what you will ever find in any circus or magic show. A magician would be booed offstage if he made half the claims that we make in Science.

Humans have evolved from single-celled organisms? ‘Rubbish’!

We are almost completely empty space and this notion of solidity is an illusion? “Don’t be ridiculous”!

It turns out that - to quote a scientist from the eighteen century – the universe is not only queerer than we suppose; it is queerer than we *can* suppose.

Where in Accounting or Business Studies or Religion are you likely to come up with a concept as mind-blowing as the following?

*Hold up your hand: You are looking at stardust made flesh. The iron in your blood, the calcium in your bones, the oxygen that fills your lungs each time you take a breath – all were baked in the fiery ovens deep within stars and blown into space when those stars grew old and perished. Each one of us was quite literally made in heaven. Modern science has shown us that we are more intimately connected to the stars than anyone dared to guess.*

Carl Sagan

My job is to undo some of the damage. Enjoy the ride.

**Science education is not even particularly good at educating students about science.**
But don’t take my word for it. Here’s somebody who might know a thing or two about a thing or two:

*One had to cram all this stuff into one’s mind for the examinations, whether one liked it or not. This coercion had such a deterring effect on me that, after I had passed the final examination, I found the consideration of any scientific problems distasteful to me for an entire year.*

Einstein

*Conservatives say teaching sex education in the public schools will promote promiscuity. With our education system? If we promote promiscuity the same way we promote math or science, they’ve got nothing to worry about.*Beverly Mickens

*Science is built up of facts as a house is of stones, but a collection of facts is no* *more a science than a pile of stones is a house.*

Henri Poincare, *La Science et l’Hypothese* (1908)

The irony is that our Science education is not even remotely successful in what it sets out to do. Research has shown that many students actually know *less* Science after they finish their schooling than before they began.

*I know nothing more terrible than the poor creatures who have learned too much . . . What they have acquired is a spider’s web of thoughts too weak to furnish sure supports, but complicated enough to produce confusion.*

Ernst Mach (Mach was a major influence on Albert Einstein and it is after him that the term *Mach Number* is named).

**So what is Science?**

**Science is *a cultural activity* – it is an integral part of what it means to be human**

I see Science not as an accumulation of facts but as being part of our culture; it tells us as much about where we have come from as it does about the world we inhabit. This must not be downplayed. In this context *psychology* is probably the most important of all the sciences. So naturally there is no reference to psychology in any of the science syllabi or textbooks at Junior Cert or Leaving Cert level. Go figure.

*The awed wonder that science can give us is one of the highest experiences of which the human psyche is capable… to rank with the finest that music and poetry can deliver.*

Richard Dawkins

**Science is *Maths***

Strange as it may seem, most of the progress in Physics over the past few centuries have required the language of mathematics. It would be an interesting exercise to try and see where we would be today without it. The picture you get of Physics from this syllabus is very much a ‘dumbed-down’ version, and if you choose to take Physics at third-level prepare yourself for a serious shock.

But if it’s any consolation, Einstein had trouble with maths too.

**Science is *a tool used by the powerful to subjugate the weak***

Science is many things, but one on which you definitely won’t be told about in this course is that it is a tool used to maintain the inequality between the first and third world. It is an instrument used to develop the military technology which enforces this inequality and which in turn is fed by the unequal distribution of the world’s resources.

One of the ‘strengths’ of Science lies in its refusal to acknowledge its role in this. Indeed the mere questioning of this can label the critic as an ‘outsider’ and consequently negate the message or its potential validity. Look no further than the manner in which the role played by war has influenced so many developments in Science, and note how it has conveniently been downplayed or ignored completely for the sake of a more sanitised and noble picture which you find in your school science text-book.

**Science is a *Story***

Science is a story. It is traditionally said to have begun as the middle ages ended (in fact it played a large part *in* the ending of The Middle Ages and the beginning of The Renaissance period in Europe). It actually began 2000 years before that, and then in the dark ages when questioning anything was frowned upon, much of the knowledge was kept and developed by the Muslim world.

**Scientists are not secular saints**

Great scientists in the past have been painted as being great people; it is as though Science needed its secular saints to counteract Religion’s.

But scientists are human and have all the human flaws that the rest of us have. Isaac Newton may indeed have been a wonderful scientist, but he was also a mad bastard – he actually spent more time trying to date the Earth using biblical references than he ever spent on Science.

And if you think Einstein was so cool, just ask his wife (the first one).

How about Crick and Watson (they won the Nobel prize for discovering the structure of DNA)? Turns out they stole some of the crucial information from a colleague.

Not only would including the bigger picture be a more accurate account of events; it would also make for a more interesting and therefore memorable story. And the ‘facts’ may not seem quite so isolated as a spider’s web of thoughts alluded to earlier.

**Science is a way of generating knowledge different from all others**

“How do you know that?” is perfectly valid question in Science; the answer should ultimately lead to the results of an experiment. Appeals to authority are useless, referring to deities or faith are equally invalid. And that’s why we do experiments in Science. Unfortunately however the experiments we do are experiments in name only – they are no more real experiments than baking a cake is. Real experiments occur when you don’t know the outcome or even the best way to carry it out. In school however we follow a procedure laid down as in a cookbook. But it’s (slightly) better than nothing.

**Science is *not* about Certainty**

*We are all deeply conscious today that the enthusiasm of our forbearers for the marvellous achievements of Newtonian mechanics led them to make generalisations in this area of predictability which, indeed, we have generally tended to believe before 1960, but which we now recognise were false. We collectively wish to apologise for having misled the general educated public by spreading ideas about the determinism of systems satisfying Newton’s laws of motion that, after 1960, were to be proved incorrect.*

Sir James Lighthill (<http://thinkforyourself.ie/2009/01/07/an-interesting-quote/>)

*We dance around a ring and suppose, But the secret sits in the middle and knows.*

Robert Frost

*The last century was defined by physics. This was a century that began with the certainties of absolute knowledge and ended with the knowledge of absolute uncertainty.*

Jim Baggott (*The Quantum Story: A history in 40 moments)*

**Physics is cool**

For a long time it was *not* cool to study Science, or Physics in particular. But this has changed in recent years. It’s difficult to attribute this change to any one factor, but television shows like *The Big Bang Theory* and *Mythbusters* probably played a part.

In Britain it’s not uncommon to hear people talk of the *Professor Cox effect*, named after the popular television presenter (and former pop singer) Brian Cox. YouTube has also played a large part.

Channels like Veratasium, IFLScience (“I f@\*king love Science”), VSauce all have hundreds of thousands of subscribers and their uploaded videos regularly get over one million views. One thing which they all share in common is that they latch on to the concept of wonder and feed off it in the same way that we try to do here.

Facebook also offers students a nice way to communicate with each other, sharing videos and cartoons and quietly encouraging the formation of informal science ‘clubs’ within schools.

*I’m interested in elementary particles, any spare time I have, I bury my head in a physics textbook. The elements at the atomic and subatomic level make up everything. You, me, the buildings, our souls, our minds. I’m reading a lot about Einstein. I like theories. I want to understand string theory. I’m dying for someone to explain quarks to me!*

Actress Anne Hathaway

*A while ago I was reading an interview with the actress Cameron Diaz in a movie magazine. At the end the interviewer asked her if there was anything she wanted to know, and she said she’d like to know what E = mc2 really means. They both laughed, then Diaz mumbled that she’d meant it, and then the interview ended.*

David Bodanis, author of  *E = mc squared; A biography of the world’s most famous equation*

*I have no special talent. I am only passionately curious.*

Albert Einstein

**Science is counter-intuitive**



<http://smbc-comics.com/index.php?db=comics&id=2088#comic>

We give the impression that we know everything that needs to be known about Science and that all this information is summed up in textbooks. Nothing could be farther from the truth. It wouldn’t be stretching the truth a whole lot to say that ‘the more we know the more we know we know nothing’.

Here are just some of the small details things that we don’t understand.

1. **Mass**
For starters it turns out that we have two separate concepts of mass, both of which we deal with on this course, but both of which are completely different. They are known as ‘inertial mass’ and ‘gravitational mass’ but have so little do with each other that they should have completely different names. Unfortunately they even have the same unit (kg). They only thing they do have in common is that you can put the value for one type into a formula for the other type and still get the right answer. We do this all the time in Leaving Cert Physics, but there is no mention of this being in anyway strange, when in fact it couldn’t get any stranger.

And nobody (and I mean nobody) knows why this works.

1. **Energy**

*It is important to realize that in physics today, we have no knowledge what energy is.*

Richard Feynman

A biologist once wrote that nothing in Biology makes sense except in the light of evolution (bear in mind there is no mention of the word ‘evolution’ in Junior Cert Science, and it only gets a token chapter in Leaving Cert Biology). The same could be said for the concept of Energy, except in this case it is not just Biology but also Chemistry and Physics that it rules over with an iron fist. And yet Energy is presented as being just another concept to learn off. Admittedly we do need to know the *principle of conservation of energy* but not its significance, or more importantly, as alluded to above, the reason *why* it’s so mysterious.

1. **Magnetism**

*“Nobody knows* how a magnet can move a piece of metal without touching it . . .more astonishing still, nobody seems to care.”
Bruno Maddux

And yet kids care. Magnetism fascinates kids. And it fascinated Einstein; he admitted that it was the starting point into his fascination of how the world works. And it continues to fascinate folk of all ages. But in many ways our familiarity with magnetism has masked our wonder into the mechanisms of *how* it works. In this course we deal a little with the rules governing magnetisms influence on other objects, but note that we never actually explain what magnetism is or how it works. Not because it’s too difficult (it’s not) but because that would be drifting dangerously into the world of wonder. And we daren’t go dare. There be dragons.

1. **Gravity**
See above
2. **The atom**
Science doesn’t get any stranger than the astonishing world of the atom. But I can’t summarise it here because I simply wouldn’t even know where to begin
3. **The electron**

*‘The electron is a theory we use; it is so useful in understanding the way nature works that we can almost call it real.’*

Richard Feynman

See above

I tend to quote Feynman a lot – he’s a righteous dude.

1. **Light**
*All the fifty years of conscious brooding have brought me no closer to the answer to the question, What are light quanta? Of course, today every rascal thinks he knows the answer, but he is deluding himself.*

Einstein

*Sometimes I think I’d gladly be locked up in a dungeon ten fathoms below ground, if in return I could find out one thing: What is light?*

Galileo, from the play *Life of Galileo*, by Bertolt Brecht

This I love.

We can demonstrate that light is a wave (and students have to know the demonstration). This means, among other things, that it is spread out; part of the light-wave can be here and part of it can be over there.

But . . .

We can demonstrate that light is a particle (and students have to know the demonstration). This means, among other thing, that it can’t be spread out; either all of it is here and none of it is over there, or vice versa.

Confused? You’re in good company – read the quotes above again and this time note that we are no closer to making sense of this now than we were one hundred years ago when we first discovered ‘the problem’. Admittedly I’m being a bit generous in the use of the word ‘we’ here.
There is no reference to this conundrum in the syllabus or textbooks (even though you do need to be able to describe the demonstrations, as mentioned above).

Light just keeps on getting stranger, and this is just meant to be enough of an introduction to whet your appetite.

But let me throw out one more nugget on Light before we go; in the equation E = mc2 E is energy, m is mass and c represents the speed of light. What does the speed of light have to do with connecting energy and mass?

1. **Time** (Mr Deity)

I’m tired now.

Just watch this: <http://youtu.be/K2ujpzdeolA>

**Science is not a bus-tour; you need to get out and experience the culture for yourself.**

*I will begin each chapter with a question (or series of questions) for which I will not provide answers.*

Science is solving a mystery with limited clues and if the answer is all you seek then you can google your way out of trouble. But then the information becomes merely an item of trivia. A much more valuable skill is the ability to solve mysteries (problem solving) based on the information supplied in the chapter. But beware; the answer may not be simple (or we may not even know the answer. The important thing is that you *think* about it (by getting off the bus).

**Science is mad.** **Physics is mad.**

**Science is NOT about you getting an A in your leaving cert.**

Well maybe it is - just a little.

You getting an ‘A’ in your leaving cert is not my concern – it is yours. I will facilitate your learning in so far as I can. I will put all the material that you need into a form that makes it relatively straightforward for you to understand. I will explain concepts as best I can and do likewise for all your questions.

I do not intend to motivate you. If I am doing my job correctly then most of you will want find out as much as you can about this world so and you will end up taking responsibility for your own learning.

If on the other hand your intention is to do as little as possible then congratulations – this class will be like a dream come true for you. Once you don’t disrupt anybody around you then we’ll get on just fine.

I do however need to keep record of your performance over time, and as with all students an email will go home after every exam detailing your result. But once everybody is okay with this then we’ll all get along just tickety boo. I must admit however that over the years very, very few characters fit into this category.

Because I tend to digress in class, I have teaching aids in the form of class notes to bring me back on track. They contain all that you need to know, and finish with the relevant extract from the syllabus so you get to keep track of me. They also act as a useful checklist for yourself.

I then include 15 years of questions from past papers. These are deliberately broken up into bite-size chunks to make the task easier initially. If you want to challenge yourself at any stage you can find the full questions in the ‘Revision’ section of the website under ‘long questions’. Each section here begins with Ordinary Level questions and then proceeds to Higher Level questions. We usually don’t cover this in class until Sixth Year, but if you want to challenge yourself in Fifth Year then this is the perfect way to do it.

Both the short questions at the end of each chapter and the long revision questions have solutions provided.

Feel free to contact me at any stage if you need further assistance.

The website contains an extensive ‘Revision’ section.

The main features are the booklets for Section A, the Long Questions mentioned above, the Short Questions and the Revision Booklet. I give these out in Sixth Year, but as I say, if you are looking for a top grade then you should be tackling them yourself as you cover the topics in Fifth Year.

One other part worth mentioning is the ‘Extra Credit’ section in the class notes. These originally featured as explanatory notes in the body of the notes themselves but over time they began to bulk this section too much, so now I have them at the back, with an asterisk beside each topic which is elaborated on at the end. This elaboration may be in the form

Hopefully your memory of this Physics class, and more importantly of Physics itself, will be a happy one.

So strap in.

Welcome to the ride.

