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The value of useless studies

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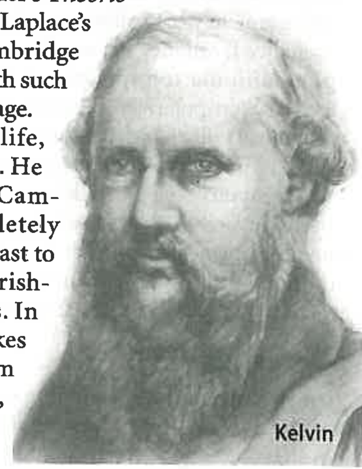
This lecture is is a celebration of two men from the extreme Western fringe of Europe, in fact two Irishmen– Lord Kelvin and George Francis Fitzgerald. My title is taken from a letter to Nature by Fitzgerald in 1892. It sticks persistently in my mind and provokes a lot of questions about the the meanings of "value" and "useless" and hence in which pure and applied physics interact with each other, as they did in the lives of these two men.

These people appeal to me because, while they lived in a bygone age, I have no difficulty at all in understanding them. Their life-spans include that period in which physics emerged as a distinct professional discipline, and they played their part in shaping it. Its value is under question today. This debate is not a new one: it goes right back to the very dawn of our Western culture, in Greece, and it was certainly active in the time of Kelvin and Fitzgerald. The value of useless studies has always been questioned, but rarely more than today.

Kelvin was born was born as William Thomson in 1824, of the Scottish Covenanter stock that had settled in Northern Ireland in the 17th century. His father James, who taught mathematics in Belfast, was a talented and industrious man. William and his brother James both inherited their father's academic ability and he fostered this assiduously, both before and after the family moved to Glasgow University, where the father took up the Chair of Mathematics.

From an early age James and William were tutored by their father and they attended lectures at the university while still very young, surpassing all the other students.So when William went to Cambridge at the age of sixteen he had already been fully immersed in university education at Glasgow, and had devoted his previous summer to Fourier's *Théorie Analytique de la Chaleur* and Laplace's *Méchanique Céleste*. Few Cambridge Freshmen can have arrived with such heavyweight intellectual baggage.



Kelvin enjoyed college life, including athletic pursuits. He formed an attachment to Cambridge but was not completely seduced by it. This is in contrast to his good friend and fellow Irishman George Gabriel Stokes. In later life he was to warn Stokes that he should move away from "London and Cambridge, those great Juggernauts under which so much potential

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energy for original discovery is crushed". But Stokes—a famously shy man, remained cocooned in his college for life. Their lifelong friendship—when Stokes was buried Kelvin said that his heart was in the grave with him—was an attraction of opposites. Stokes was a classic example of the dedicated, distracted, introverted but admirable professorial type. JJ Thomson praised the clarity of his lectures and his enthusiasm, which in 1898 after fifty years of lecturing, sometimes led him to forget the time and go on uninterruptedly for as much as three hours. Rayleigh recalled something similar from his undergraduate days: if the sun was shining and Stokes able to use its rays for demonstrations, he would ignore the clock and the timetable. But his audience forgave him: "With complete ease and accuracy and with the expenditure of about two pence he performs the most valuable and decisive demonstrations of his theories. His astonishing faculty for doing without costly apparatus must be a heaven-sent gift to the impoverished university."Stokes even got carried away writing a letters to his fiancée, and provided her with many pages of explanation of the details of his mathematical research. He almost lost her. *I regularly advise graduate students not to do this.*

A year after his graduation in mathematics, in which he somehow managed to come only second in the list, Kelvin returned to Glasgow as Professor of Natural Philosophy, and refused all offers (including the Cavendish chair in Cambridge, three times) to move south again. He had already published twenty scientific papers.

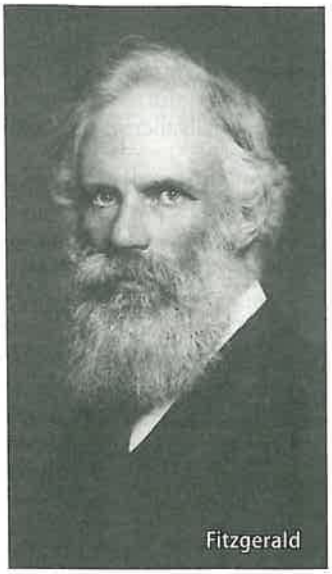
At this point one wonders what to say about the vast range of his accomplishments over his entire career. It ranges across all of physics, and from the fundamental to the applied, His output of more than 600 papers and many books and patents was spread evenly over his long life, rising smoothly like the parabolic trajectory of a projectile, from a few papers a year in his late teens to more than ten a year in mid career and declining again to a few every year in his eighties. Let us mention thermodynamics, optics, elasticity, electricity and magnetism, hydrodynamics, navigation, geophysics and the properties of materials. He was surely the last great classical physicist, and he's sometimes portrayed as a conservative figure in his later years. Which of us will not be so, if we make it to the age of 83? It is true that he declared airplanes to be a complete impossibility, but that did seem to be the clear prediction of theory at the time.

In fact, he was as fond of speculation as anybody, and his many wild ideas about atoms and the ether exhibit as much *chutzpah* as the more imaginative writers of Phys Rev Letters today.

He gathered a long list of honours, including foreign membership of the Hungarian Academy of Sciences, awarded in the same year that Eotvos Lorand was admitted—1873. But as he became Sir William Thomson and then Baron Kelvin, he did not let it propel him into too many other activities—that was the advantage as he saw it, of staying in his remote fastness in Glasgow. He could even retreat to the palatial property that he built on the coast, or his yacht, to contemplate his latest challenge in peace. There and indeed everywhere else, he could jot down fresh thoughts all the time in his many notebooks, which now rest in Cambridge.

Kelvin was an adept mathematician but, as Fitzgerald said, "his mathematics is for the sake of the result and not for the sake of the mathematics." He himself said, together with PG Tait, in the preface to their textbook (Thomson and Tait, known at the time as "T and T prime"): 'Nothing can be more fatal than too confident reliance on mathematical symbols: for the student is only too apt to take the easier course, and consider the formula and not the fact to be the physical reality'.

When he did have recourse to mathematics he was eager to see its results in a tangible form. When he produced an ideal cell for foam as a model for the ether, he had a wire model made immediately, and a stereo picture for viewing—and he even got his wife to make a pincushion of the required shape. Kelvin always brought his work home, indeed his house is said to have been the first in the world to have a full domestic electric lighting system.



Fitzgerald

This idea that physics has to be something that you *feel* with your hands is a robust and valuable tradition can be associated with British natural philosophy in general, and set against the more formal and abstract approach of many French mathematical physicists such as Poincaré. There is still a contrast today, *et vive la différence*. Kelvin said that model-making was to be regarded as more than a "rude mechanical illustration" of a physical effect—it was a sort of consistency test of a theory, based partly on the notion that physics was the same on all length scales. Not that he was uninterested in mechanical illustrations —he performed them with dramatic effect for his classes, using for example a muzzle-loading elephant gun for demonstration of momentum conservation.. He was particularly fond of the trick with two eggs, one boiled and the other not, which behave so differently when you spin them on a surface.

At times Kelvin took his down to earth approach too far—he was unhappy with Maxwell's theory, in particular, and right to the end of his days he saw the ether as a "real thing" (to be fair, so did Maxwell!). This material ether might be a jelly as Stokes had suggested— he wrote to Stokes to say that his *chocolat au lait* in a Paris café had congealed into something like the jelly that Stokes had been talking about. His own conception of ether was as a foam. (Incidentally Osborne Reynolds, yet another Irishman, thought it was a granular material, like sand—and both granular and foam models are mentioned in the latest conceptions of space-time on the Planck scale today, in an ironic twist of history, which I much enjoy and would enjoy better if I could understand quantum gravity...).

At the opposite pole of speculation on ether was Larmor—yes, yet another Irishman—who took field theory to the extreme of trying to describe the electron as no more than a singularity in a very mathematical sort of ether, of the kind Kelvin found distasteful.

So Kelvin was a mathematician who became a physicist—and then an engineer. What else are we to call a man whose seventy practical patents had a profound effect on the advance of technology. Let me quote Fitzgerald:

"If one were asked to point out a typical example of the kind of intellect that has changed the face of society so that our whole industrial system has been utterly revolutionised and with it the conditions of life of the majority of civilized nations, the first name that would occur would be that of Lord Kelvin"

So when we teach the second law of thermodynamics, and struggle with entropy (a word he did not like to use himself—I suppose because he could not feel it with his hands) and the absolute scale of temperature, we should tell our students that the same man that debated and helped to originate these concepts can also be said to have invented the heat pump, air cooling by refrigeration and other useful tricks that depend on the laws of thermodynamics. But his most prolific area of invention was electricity. In the dusty corridors of older physics department, glass cases still contain the many instruments that he designed. Incidentally there is now an excellent museum devoted to him in Glasgow.

Out of this came his climactic achievement in the field of telegraphy—*not* startlingly original—important inventions do not have to be so, and they usually are not.

In its time the telegraph was as exciting as the Web is today. Almost overnight, it was said, the world was shrunk to a global village. The masters of the arcane knowledge of telegraphy had high salaries, there was tension between private investment and government regulation, there was concern over security, a rush to invent peripheral devices (Edison made his first fortune from a ticker tape machine), and many investors got their fingers burned.

Indeed the first Transatlantic cable did not survive much beyond the exchange of greetings between Queen Victoria and the President. These messages were not as peremptory as is sometimes said. The Queen sent one of 99 words. It took 16 $^1/_2$ hours to transmit it. No wonder that early telegraphic technologists were already very interested in compression; many codes were invented to achieve it. In one of these the single word GNAPHALIO meant "Please send supply of light clothing".

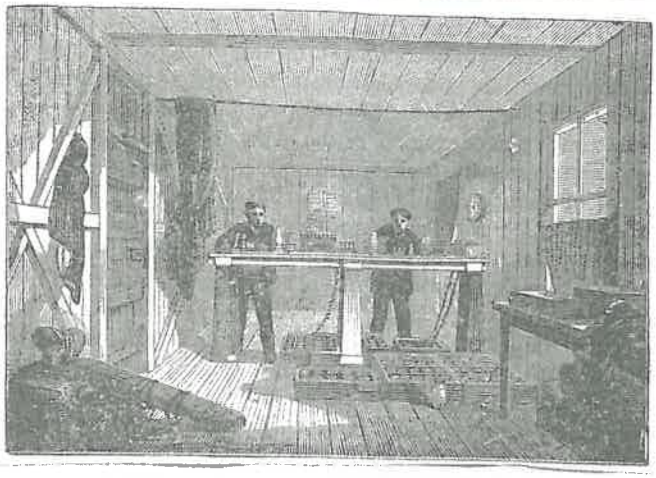
The rapid failure of the first Atlantic cable was a commercial disaster and the improvement of its technology a demanding imperative. It suffered from electrical breakdown. Kelvin made a rapid diagnosis and recommendation for the second attempt, which included using lower voltages than proposed, thicker cables, and more sensitive detection. For this he developed a sensitive mirror galvanometer, very like the ones that were used in university teaching labs until not very long ago. I hope you have not thrown all of them out!

The compelling force of his personality overcame the opposition of the ignorant and the amateurs, and a new system based on his ideas worked wonderfully well in 1866. It made the amazing sum of one thousand pounds on its first day of operation. So he became rich and famous...

Towards the end he described his career as a failure, which is quite preposterous. Admittedly the piece of physics that he took most pride in—his estimate of the age of the earth—went badly wrong, on account of the unknown effects of radioactive decay. I suppose he shared some of the feelings expressed in Russell MacCormmach's *Night Thoughts of a Classical Physicist*, that his beloved classical physics was incomplete.

There are many parallels in the career of George Francis Fitzgerald, although we shall see that this symmetry was eventually broken. He too was born into an academic family, and rose to become Professor of Natural Philosophy at an early age in a provincial capital—in his case Dublin. Both were athletic, and were said to be superb lecturers and fond of demonstrations. Both made important advances in the introduction of laboratory classes : Kelvin's were certainly among the earliest in the world—1848—and Fitzgerald, having improvised a student laboratory, fought for modern facilities up to his death. The indirect effect of their practical teaching must have been immense: one example of a Kelvin student is Gerard Philips, who founded the Philips lighting company. Fitzgerald's protege Lyle founded the first physical laboratory south of the equator, in Melbourne.

To continue with the search for symmetry: both men were very prominent in the British Association and both were Editors of Philosophical Magazine. Fitzgerald, like Kelvin, was mathematically gifted, and he too preferred realistic physics to formal theory, and gradually developed strong interests in the industrial applications of physics. Both had powerful personalities, Fitzgerald's even the more so perhaps.



▲ The receiving station of the Atlantic telegraph at Valentia in Ireland.

There is however a stark contrast in the directly measurable output of the two men. Fitzgerald published only a few dozen significant papers, and no books. He fostered an inventive spirit among his protégés but he himself did little in applied physics. He could be accused of being a mere dabbler, as when he flew (if only just) the Lilienthal glider in the university grounds—the first one to do this in the British Isles. He seems to have lost interest in it thereafter, or taken fright.

Even his theoretical work was often left tentative and incomplete, as when he conjectured that length contraction could account for the Michelson-Morley experiment, sent a brief letter to an obscure American journal and forgot about it until Lorentz published something similar several years later. It took a long time for historians to work out that Fitzgerald's idea, which came to him while sitting in Oliver Lodge's house in Liverpool, was not just a wild guess but had its roots in the mathematical expression of electromagnetic theory, on which he was conducting an extensive correspondence.

Through that correspondence Fitzgerald's indirect influence was immense, and his reputation grows with every retelling of his period by the historians of science, especially in the book *The Maxwellians*, by Bruce Hunt. Often in incidental remarks in his letters and writings he showed extraordinary insight and he offered it freely to everyone. For example when writing a review in praise of Boltzmann he speculated on the nature of gravity, to the effect that it was probably a change in the structure of the ether, what we would just call space today, produced by the presence of matter. Another example: when asked what would happen when velocity exceeded the speed of light and the already familiar expression in maxwellian theory—square root of one minus v over c squared—ceased to exist as a real number, he said that it might well be that the velocity of light was the limit to the velocity of a body. And so on.

He was the acknowledged leader of an international team—what we would today call an invisible college—calling themselves the Maxwellians—the subject of Hunt's splendid book. So unlike Kelvin he was a devoted and visionary disciple of Maxwell. The Maxwellians included Oliver Lodge, Joseph Larmor, Oliver Heaviside, and Heinrich Hertz, with others such as JJ Thomson on the fringes. Hertz in particular complained that Maxwell was

◂ Applied physics: Fitzgerald prepares to fly the Lilienthal glider before his admiring students.

not readily accepted by conservative German physicists, so he eagerly joined the list of Fitzgerald's correspondents.

Fitzgerald above all others saw the full, dramatic implications of Maxwell's theory, as redrafted by the extraordinarly eccentric and self-effacing Oliver Heaviside and others. (It was Heaviside that first wrote Maxwell's Equations, not Maxwell himself, and his contributions went largely unrecognised, because of his reclusive nature. Fitzgerald, although he had met him only once, was responsible for getting him a state pension to save him from poverty, by petitioning the Prime Minister.)

He still felt some need for some interpretation of the nature of the ether, even though he expressed the hope that a material ether could be dispensed with. So he built a mechanical model to show how Maxwell's theory worked in the ether. Alas, my Department seems to have lost this precious icon in the 1950's: I still harbour a faint hope that it may turn up.

In one of his most significant insights, Fitzgerald foresaw the generation of electromagnetic waves of longer wavelength than light by electrical circuits, publishing a characteristically brief note on this. When, some years later, Hertz announced his experimental results, Fitzgerald was exultant (although he must have felt foolish for not doing such an experiment himself)

He described the achievement of the young German to the British Association on 1888.

It was a great step in human progress when man learnt to make material machines,

When he used the elasticity of his bow and the rigidity of his arrow to provide food and defeat his enemies.

It was a great advance when he used the chemical action of fire: when he learnt to use water to float his boats and air to drive them: when he used artificial selection to provide himself with food and domestic animals.

For two hundred years he has made heat his slave to drive his machinery.

*Fire, water, earth and air have long been his slaves; but it is only within the last few years that man has won the battle lost by the giants of old, has snatched the thunderbolt from Jove himself, and enslaved **the all-pervading ether.***

Unlike Kelvin, Fitzgerald never quite got down to consistently applying his insights, as in this instance. He complained bitterly about the government's ignorance and inappropriate application of funds for science. "A company can be promoted with a capital of a hundred thousand pounds for almost any conceivable object, but it is quite hard to get ten or twenty to try experiments. I look forward to the time when eager capitalists and energetic government departments will importune inventors to be allowed to work out their discoveries." One cannot escape the conclusion that the fault lay partly with himself, and he recognised his own tendency to flit around from topic to topic: "I admire from a distance those who contain themselves till they worked to the bottom of their results but as I am not in the very least sensitive to having made mistakes I rush out with all sorts of crude notions in hope that they may set others thinking and lead to some advance."

He really should have played a greater part in the development and commercial exploitation of radio, especially since Marconi did such crucial work in Ireland. It may have been the intense hostility of the Maxwellian Oliver Lodge towards Marconi that kept Fitzgerald out of the action.I had intended to admit to you frankly at this point that Marconi was certainly *not Irish*, but to my surprise I find that he was, or at least almost so, for he was the son of an aristocratic Irish lady and married another one!

But there is no hint of jealousy in his praise of Kelvin's success in Fitzgerald's praise for him on the 50th anniversary of his professorship:

"He has advanced civilization by making the all-pervading ether available to us, by enabling us to measure its properties, and by teaching us how to lay the nerves of civilization in thedepths of the oceans. He has helped to unify humanity, to modify competition by co-operation, to push forward the federation of the world."

There is a hint here of his strong sense that science has a positive moral content. Here he is again, in a speech in which he advocated the setting up of industrial laboratories, not to be governed by the decisions by "mere officials" but by scientific advisers in touch with scientific advance and enthusiastic believers in it.

"Hope is the great incentive to exertion. Without it a nation is dead. Without it we lose all belief in the possibility of improvement, and improvement at once becomes impossible. The history of electrical engineering, the utilization of the all-pervading ether for the service of man, should strengthen our hope and belief in the possibility of improvement. For has it not revolutionized society and enabled high and low, rich and poor to lead better lives, by making life less hard and grimy, and this improved the well-being of man both materially and, what is more important, morally as well?"

This confident sense of the power for their work for the common good, founded on traditional religion reconciled with science, is another symmetry between the two. Differences of personality and circumstances led to one being highly successful in realising the direct applications of science, and the other not. Both deserve to be better recognised: their lives demonstrate the value of "useless" studies.

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