Energy and Empire

A biographical study of Lord Kelvin

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Lord Kelvin caricatured by *Vanity Fair Album* in 1897. Classing him as one of its 'Statesmen', *Vanity Fair* published the accompanying eulogy of the seventy-two-year-old peer.

LORD KELVIN

His father was Professor of Mathematics at Glasgow. Himself was born in Belfast seventy-two years ago, and educated at Glasgow University and at St Peter's, Cambridge; of which College, after making himself Second Wrangler and Smith's Prizeman, he was made a Fellow. Unlike a Scotchman, he presently returned to Glasgow – as Professor of Natural Philosophy; and since then he has invented so much and, despite his mathematical knowledge, has done so much good, that his name – which is William Thomson – is known not only throughout the civilised world but also on every sea. For when he was a mere knight he invented Sir William Thomson's mariner's compass as well as a navigational sounding machine, that is, unhappily, less well known. He has also done much electrical service at sea: as engineer for various Atlantic cables, as inventor of the mirror-galvanometer and siphon recorder, and much else that is not only scientific but useful. He is so good a man, indeed, that four years ago he was ennobled as Baron Kelvin of Largs; yet he is still full of wisdom, for his Peerage has not spoiled him.

He has been President of the Royal Society once, and of the Royal Society of Edinburgh three times. He has been honoured by nine universities – from Oxford to Bologna; he is the modest wearer of German, Belgian, French, and Italian Orders; and he has been twice married. He knows all there is to know about Heat, all that is yet known about Magnetism, and all that he can find out about Electricity. He is a very great, honest, and humble Scientist who has written much and done more.

With all his greatness, he remains a very modest man of very charming manner.

[*Vanity Fair Album* (1897)]

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A biographical study of Lord Kelvin

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and

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Any one may commence the writing of a book,
but what may be its extent, or the time of its completion,
no one can tell . . .

Dr James to William Thomson, 9th April, 1843.

The right of the University of Cambridge to print and sell all manner of books was granted by Henry VIII in 1534. The University has printed and published continuously since 1584.

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Preface

Addressing the British Association for the Advancement of Science from the presidential chair in 1871, Sir William Thomson expressed his enthusiasm for intellectual capitalism:

> Scientific wealth tends to accumulation according to the law of compound interest. Every addition to knowledge of properties of matter supplies the naturalist with new instrumental means for discovering and interpreting phenomena of nature, which in their turn afford foundations for fresh generalizations, bringing gains of permanent value into the great storehouse of [natural] philosophy.[1]

Literally as well as metaphorically, scientific knowledge meant wealth for Thomson. In his pioneering Glasgow physical laboratory he had united the pursuit of scientific and industrial wealth through precision measurements on the properties of matter, measurements which he judged equally fundamental to science-based industry and to science itself.

Twentieth-century commentators have not been generally sympathetic to William Thomson's industrial vision, which is so closely associated with his elevation to Lord Kelvin. In his Royal Society obituary notice, the Lucasian professor of mathematics at Cambridge, Sir Joseph Larmor, regarded Kelvin's commercial interests as distractions from the proper intellectual concerns of a natural philosopher, most notably the constitution of matter and ether.[2] Larmor's remarks reflect a traditional Oxbridge disdain for economic man, a disdain also manifest in the character of much twentieth-century British physics, as dominated by the Cavendish Laboratory in Cambridge.

An even less sympathetic, but better known, commentary on the Kelvin style is that of Pierre Duhem. Duhem found the evil of the industrial spirit pervading textbooks of British physics: 'It has penetrated everywhere,' he said, 'propagated by the hatreds and prejudices of the multitude of people who confuse science with industry, who, seeing the dusty, smoky, and smelly automobile, regard it as the triumphal chariot of the human spirit.' Sir William Thomson's Baltimore Lectures supplied Duhem with numerous illustrations of the factory mentality of British physics, epitomized, as he saw it, in the use of mechanical models.[3]

[1] PL, 2, 175–6. [2] JL, iii, liv.
[3] Pierre Duhem, *The aim and structure of physical theory*, P.P. Wiener (ed.) (New York, 1962), pp. 71, 93. Originally published in 1906 from articles of 1904–5.

J.G. Crowther also saw in Kelvin's commercial interests the contamination of his science, which he severely criticized in comparison to the purer pursuits of James Clerk Maxwell:

> He [Kelvin] was the leading symbol of the scientific ideology of the British nineteenth-century governing class . . . He was an intellectual colossus who saw one-half of the aspects of material nature with unsurpassed clarity and power, but was blind to the other half. His great personality was an expression, in the realm of ideas, of the power and of the blindness of capitalism.[4]

Crowther maintained that physical nature is there to be discovered, finally and objectively, but that Kelvin's capitalist blinkers prevented him from grasping its deeper truths, despite his great scientific powers.

These three commentators approached Lord Kelvin's work from very different cultural and social perspectives: Larmor as elite Cambridge mathematician, heir to Isaac Newton, and staunch upholder of the political unity of Britain and Empire; Duhem as conservative French Catholic and apologetic defender of orthodox Christianity; Crowther as early twentieth-century Marxist, hostile to nineteenth-century capitalism but committed to knowledge as power. Nevertheless, in their common recognition of Kelvin's industrial orientation, his critics offered perceptive insights into the character of his activities.

To recognize that William Thomson related his physics to a vision of industry and empire, however, does not engage the question of how his science expressed that vision. In this biographical study our primary object has been not simply to recount the ideology and activities of a Victorian scientific entrepreneur, but rather to analyze the practices through which that ideology was realized in Thomson's best work, in his instruments and patents certainly, but also in his mathematical physics. By contrast to Larmor, who regarded Thomson's ventures as distractions from his science, we show that the scientific and industrial pursuits were essential to one another. It was therefore not merely a case of science applied to industry, but of industry applied to science, for Thomson's industrial vision thoroughly permeated his understanding of the natural world and the theoretical and experimental research which he pursued.

Again, Thomson's approach was not merely a matter of metaphysical predisposition, but of the making and doing of mechanics, thermodynamics, and electromagnetism, of problem solutions, models, measurements, and absolute values. We do not argue, however, that Thomson's social context determined the content of his science. Rather, we show that he drew extensively on conceptual and material resources available in his industrial culture and, with motivations structured by that culture, arrived at rational explanations of physical phenomena and at means of controlling those phenomena. Thus we

[4] J.G. Crowther, *British scientists of the nineteenth century* (London, 1935), p. 256.

seek to show, concretely and in detail, how the science that Thomson produced was inseparably integrated with the industrial culture that he represented.

Of overriding importance to his intellectual achievement were particular objects of the material culture. The steam-engine, electric telegraph, and vortex turbine, which he drew upon for model solutions of the most fundamental problems of natural philosophy, were constitutive of his thermodynamics, electrodynamics, and cosmology. And just as such artefacts served Thomson as generators of scientific theory, they also served him as guarantors of the reality, or validity, of theoretical entities. Machines, in short, represented the industrial culture to natural philosophy and natural philosophy to the industrial culture. By embodying the idea of work, for example, the steam-engine translated between the fundamental concept of labour value in political economy and the fundamental concept of energy in natural philosophy.

In analyzing Thomson's life and work we have employed a set of labels for interrelated aspects of his political, religious, and scientific ideology. The most general term is 'whig'. In the political sense it refers not to the Whig party as such, but to a liberal, progressive, reforming stance imagined to be above party affiliation. Its religious correlate is 'latitudinarian', connoting an anti-sectarian (if also anti-Catholic and anti-fundamentalist) point of view, and opposed to nothing so much as to perceived authority and dogma in theological matters.

In scientific methodology, the labels are 'non-hypothetical' and 'anti-metaphysical'. As in the political and religious spheres, these words must not be understood to mean that Thomson succeeded in developing a science without hypotheses and without metaphysics. Metaphysics, for him, carried the odour of idealism and *a priori* knowledge, while hypotheses lacked what he regarded as direct empirical evidence. His proscription of both sources of error expressed his view that truth in natural philosophy is based on direct sensory perception rather than mental construction.

Finally, and most ubiquitously, we use the term 'practical'. Thomson himself employed it from the beginning to the end of his career. Though covering a wide spectrum of meanings, it suggests the all-pervasive spirit of engineering and industry that we elaborate in his life and work.

All of these terms together – whig, latitudinarian, non-hypothetical, anti-metaphysical, and practical – label Thomson's commitments rather than any fully articulated or particularly consistent philosophy. They evoke the motivations which operated, sometimes implicitly and sometimes explicitly, in his everyday life. As such we use them, leaving their definitions somewhat elastic, subject to expansion and contraction in the specific contextual instances of their application. In Chapter 13, however, under 'The methodology of look and see' and 'Mephistopheles' we have attempted to articulate more fully the differences between metaphysical ideality, which he despised, and practical reality, which he worshipped.

A problem of constant concern to us has been the fact that, although the major Kelvin archives in Cambridge and Glasgow contain many thousands of letters, very few of those letters reveal William Thomson's innermost thoughts or his emotional responses to major crises, such as the death of his father. His relation to his first wife, who was ill virtually from their marriage to her death over seventeen years later, remains obscure. Thus we have had to choose between psychological speculation on meagre evidence and restricting Thomson's personality largely to its professional and public side. We have chosen the public side, first because there is so much of it and because of its historical importance, and secondly because we suspect that many sources of a personal nature have been destroyed, leaving a distorted sample. From William's Cambridge diary of 1843, for example, small and large pieces have been excised, while his brother James's surviving papers in Belfast contain no family correspondence. In dramatic contrast, a few letters from William in a separate regional archive offer a glimpse of an intense but unrequited love, prior to his marriage. These letters are unlike anything in the 'official' archives, suggesting that the latter conceal what they do not reveal. The truly private Thomson must remain a veiled figure.

Thomson's career covers a wide variety of subjects, each with a coherence of its own and each carrying an appeal to a different group of readers. We have therefore arranged our four-part study thematically rather than chronologically. In Part I we locate the young William and his close-knit family within their local context in the 1830s and 1840s. Pivotal is the dynamic city of Glasgow, destined to become, with its growing reputation for reliable and economic steamships, the shipyard of the Empire and its Second City during his maturer years. We explore Thomson's political, religious, and economic context in relation to the first major phase of his career, which saw him advance from Glasgow University student and Cambridge undergraduate to Cambridge Fellow and ultimately to Glasgow professor at the early age of twenty-two.

Part II concerns the development of Thomson's mathematical physics. Here we aim at portraying, through the activities of a single individual, one of the major 'revolutions' in the history of science. From 1840 to 1870 Thomson played a starring role in the birth-dramas of electromagnetic field theory and thermodynamics, as well as in the transformation of mechanics, such that classical physics could no longer bear the epithet 'Newtonian'. Energy and extremum principles replaced force as the foundation of dynamical explanation; temporal development became as essential to physical systems as to biological ones; and for the basis of material reality, British natural philosophers looked to structures of motion in a universal plenum, rather than to hard atoms. Thomson sometimes imagined himself the modern Newton. We attempt to show why, giving as much conceptual content as possible. A modicum of mathematics is required. Later parts of our study can nevertheless be read without extensive reference to this one.

Thomson's construction of a system of the world is the subject of Part III. Concerned here with his cosmological and geological theories, we discuss them less in terms of their general scientific and popular impact through the question of the earth's age – the focus of previous studies – and more in relation to debates with his colleagues in natural philosophy, most notably G.G. Stokes and Hermann von Helmholtz. Drawing heavily on engineering systems, Thomson constructed his economy of nature in accordance with the laws of energy. These laws ruled the material world. But he also devoted much thought to the nature of mind, to free-will, and to the relation of mind to matter, as well as to the origin of life on earth. An analysis of the latter problems concludes Part III.

Part IV takes us from a study of Thomson's involvement in the grandest of all Victorian engineering projects, the Atlantic telegraph cable which earned him his knighthood, through his profitable business and industrial activities, to his elevation to the British peerage as Baron Kelvin of Largs. Part I located him within a developing Scottish city of heavy industry. Now we see the mature professor and entrepreneur reaping the social prestige and economic wealth of a physics perceived to serve the needs of all Britain. It was a physics which offered qualitative improvements to the new telegraphic and maritime communications so fundamental to the physical unity and political identity of the Empire on which the sun never set.

This book originated in a manuscript written by Crosbie Smith some ten years ago. At his invitation Norton Wise joined the project in 1980. In the drafting and redrafting that has gone on since then our individual contributions have become highly mixed. Although primary responsibility for Parts I, III, and IV (Thomson's early years, his system of the world, and his entrepreneurial activities) has rested with Crosbie Smith, and for Part II (Thomson's mathematical physics) with Norton Wise, many chapters (4, 5, 9, 10, 18, 19), and numerous sections of other chapters, are fully coauthored. Above all, the book's unifying themes are the product of frequent and lively discussion between us, leading to a full integration of our separate ideas and original expertise.

For permission to use unpublished material, we are especially indebted to Cambridge University Library, where the main part of the Kelvin archive is deposited. The staff of the Manuscripts Room have been always helpful over a long period of research. Our special thanks go also to Dr Nigel Thorp and his colleagues in the Special Collections Department of Glasgow University Library, which holds substantial amounts of Kelvin material. We are further indebted to Rex Whitehead and to the late J.T. Lloyd in the Department of Natural Philosophy at Glasgow for their personal interest and for such invaluable services as directing us to Thomson's annotated copy of Maxwell's

Treatise on electricity and magnetism. The staff of Queen's University Library, Belfast, have been most helpful in providing access to the James Thomson papers. We thank the Strathclyde Regional Archives for the use of Archibald Smith's family papers, St Andrew's University Library for J.D. Forbes's correspondence, and the Salisbury Collections, Hatfield, as well as the Devonshire Collections, Chatsworth, for important correspondence cited in our final chapter.

Among very many colleagues who have supported us in our task, we are especially grateful to David Gooding and Geoffrey Cantor for critically reviewing the entire manuscript. We are similarly indebted to Nancy Cartwright and Robert Westman for their comments on large sections, and to Alex Dolby and Tim Lenoir for critical insights in the course of informal discussions. Norton Wise recognises the continuing value of concrete methodological lessons learned long ago from Tom Kuhn. David Wilson has relieved our research task immeasurably by giving us access to his fully edited typescript of the immense Stokes–Kelvin correspondence. To other colleagues we owe specific intellectual debts for interpretative insights: Simon Schaffer on J.P. Nichol's science of progress (ch. 4); Joan Richards on British algebra (ch. 6); David Gooding on Faraday's field theory (chs. 7 and 8); Menachem Fisch on Whewell's mechanics (ch. 11); Sam Schweber on political economy and optimization conditions in relation to biology and physics (ch. 11); Jed Buchwald and Bruce Hunt on Maxwellian electromagnetic theory (ch. 13); Jack Morrell on John Phillips (ch. 16); Ted Porter on Maxwell's statistical physics (ch. 18); and David Cannadine on the nineteenth-century Devonshires (ch. 23). On the ideas of all of these scholars our own work is built.

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Crosbie Smith acknowledges a debt for the enduring support of his family, and in particular for that of his late father who introduced him at a very early age to the beautiful Firth of Clyde around Largs and to the fascinating city of Glasgow while it was still the Second City of the Empire. Without such youthful inspiration, he would scarcely have undertaken this project.

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Footnote abbreviations

BAAS Report *Report of the British Association for the Advancement of Science.*
BL William Thomson, *Notes of lectures on molecular dynamics and the wave theory of light* (Baltimore, 1884).
DNB *Dictionary of national biography*
DSB *Dictionary of scientific biography*, C.C. Gillispie (ed.) (16 vols., New York, 1970–80).
E&M William Thomson, *Reprint of papers on electrostatics and magnetism* (London, 1872).
James Thomson, *Papers* James Thomson, *Collected papers in physics and engineering*, Sir Joseph Larmor and James Thomson (eds.) (Cambridge, 1912).
JL Sir Joseph Larmor, 'William Thomson, Baron Kelvin of Largs. 1824–1907' (obituary notice), *Proc. Royal Soc.*, [series A], 81 (1908), i–lxxvi.
MPP William Thomson, *Mathematical and physical papers* (6 vols., Cambridge, 1882–1911).
MSP W.J.M. Rankine, *Miscellaneous scientific papers*, W.J. Millar (ed.), (London, 1881).
PL William Thomson, *Popular lectures and addresses* (3 vols., London, 1889–94).
QUB Thomson papers, Queen's University Library, Belfast.
SPT S.P. Thompson, *The Life of William Thomson, Baron Kelvin of Largs* (2 vols., London, 1910).
ULC Kelvin Collection, Add. MS 7342, University Library, Cambridge. Kelvin letters in the Stokes Collection, Add. MS 7656, University Library, Cambridge are listed as Stokes correspondence, ULC.
ULG Kelvin Collection, University Library, Glasgow.