Rankine, (William John) Macquorn

(1820–1872)

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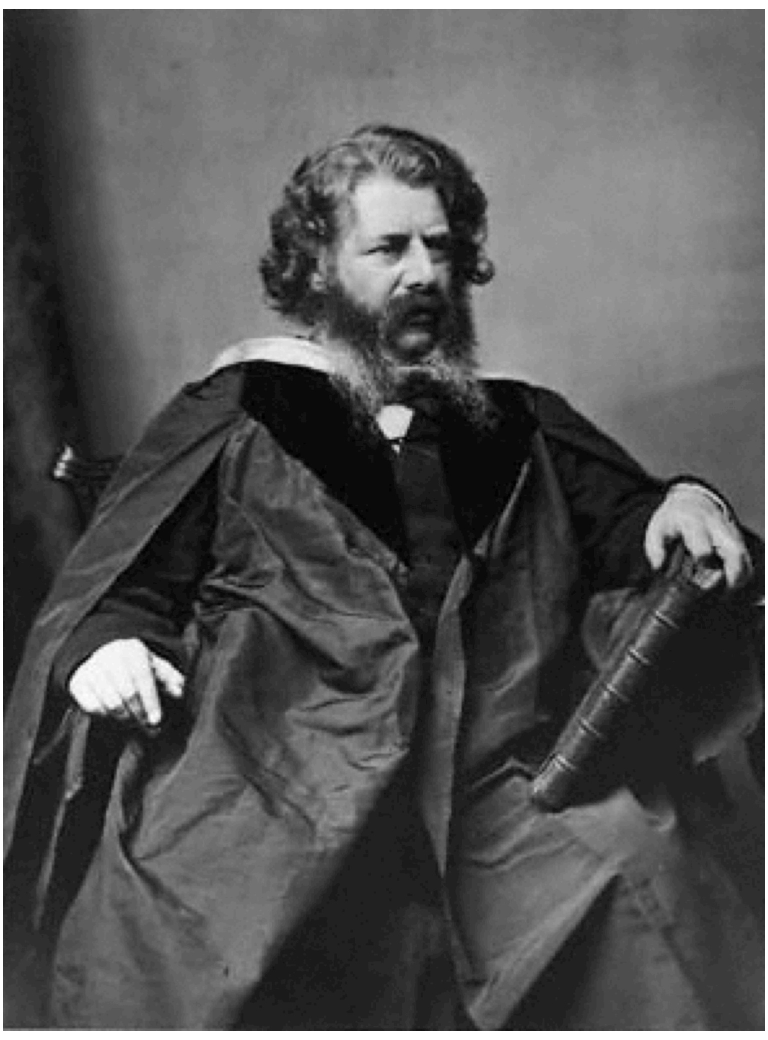

(William John) Macquorn Rankine (1820–1872)

by Thomas Annan, pubd 1871

Rankine, (William John) Macquorn (1820–1872), civil engineer and physicist, was born in Edinburgh on 5 July 1820, the second son of David Rankine (*d*. 1870), rifle brigade lieutenant and civil engineer, and his wife, Barbara (*d*. 1871), the elder daughter of Archibald Grahame (or Graham), a Glasgow banker. Tracing his ancestry to Robert the Bruce, Rankine could claim to be a Scot of Scots. His only sibling, David, died young. In early childhood Rankine's parents guided his religious education; his father taught him arithmetic and elementary mechanics. Between 1828 and 1829 he studied at Ayr Academy; in the autumn of 1830 he briefly attended Glasgow grammar school; later he studied geometry with George Lees in Edinburgh. During prolonged periods of confinement due to illness Rankine was privately educated. He exhibited a keen interest in the theory of music and read deeply in higher mathematics, including number theory. In December 1834 his uncle Archibald Graham gave him Newton's *Principia* in Latin: Rankine devoured the book, citing it later as the foundation of his natural philosophy.

The civil engineer

Between 1836 and 1838 Rankine attended classes in natural philosophy, natural history, and botany at the University of Edinburgh. He had matriculated but did not register for a degree. Outside the university he studied chemistry with David Boswell Reid. James David Forbes awarded Rankine gold medals for prize essays on the wave theory of light (1836) and on methods in physical investigation (1838). At college Rankine read widely in empiricist and Scottish common-sense philosophy, explored French and German scientific literature, but did not attend mathematics classes, or progress to the exacting Cambridge mathematical tripos. Opting, instead, for the fashionable profession of the engineer, Rankine helped out on the new Leith branch (1837–8) of the Edinburgh and Dalkeith Railway which his father superintended. In 1838 he became a pupil of John Benjamin MacNeill, a prominent engineer with extensive commitments in the north of Ireland and a clutch of talented apprentices including Le Fanu and Bazalgette. Between 1839 and 1841 Rankine learned his trade implementing river improvements, waterworks and harbour works in Ireland. At work on MacNeill's Dublin and Drogheda Railway (1841) he developed ‘Rankine's method’ for setting out curves.

Back in Edinburgh Rankine published a series of investigations conducted with his father as *An experimental inquiry into the advantages attending the use of cylindrical wheels on railways* (1842). He dedicated the work to his former teacher Forbes, a vociferous advocate of science applied to practice. In December 1842 Rankine became a fellow of Edinburgh's Royal Scottish Society of Arts. In July 1843 he entered the Institution of Civil Engineers (ICE) in London as an associate. During 1843 he read papers to the institution: one explained the fracture of axles by referring to molecular structure; others developed David Rankine's suggestions or publicized his mechanical contrivances; some received prizes, including a premium of the institution's president James Walker. Between 1844 and 1848 Rankine worked for Locke and Errington constructing the Clydesdale Junction Railway and on projects sponsored by the Caledonian Railway Company, of which his father had become secretary. In 1845–6 he projected the Edinburgh and Leith Waterworks, only to have the scheme defeated by the Edinburgh Water Company. In 1848 the Institution of Civil Engineers showed itself wary of Rankine's programme to reform the practice of sea defence construction, and of engineering practice generally, as an inductive science.

Thermodynamics

Rankine made his scientific début in 1840 with a neat and topical mathematical analysis of the cooling of the earth. In 1842, after reading Clapeyron's discussion of Carnot's heat theory, Rankine started to write on molecular physics, elasticity, and, especially, the mechanical action of heat. From July 1849 he published results linking the temperature, pressure and density of gases, vapours (especially steam), and liquids, much encouraged by the close agreement between his theoretical deductions and Regnault's new experimental data. Rankine became a fellow of the Royal Society of Edinburgh in 1849. Shortly thereafter, in February 1850, he matched William Thomson's account of Carnot (1849) with an idiosyncratic theory of the mechanical action of heat. Here Rankine considered heat not as Carnot's indestructible caloric but, following Joule, as motion equivalent to work.

During the early 1850s Rankine, Thomson, and Rudolf Clausius elaborated a new thermodynamics which supplemented Joule's first law with a second law characterizing the potential efficiency of engines and, later, the order and decay of physical systems. Rankine's work had two distinguishing features. First, he quickly perceived and elaborated the links between the new science and thermodynamic engines, especially the ubiquitous steam engine, and its serious contemporary rivals like the air engine. By April 1851 he had constructed a simple law governing the potential efficiency of any heat engine in terms of its upper and lower working temperatures. Here was a perfect theoretical standard against which actual engine economy and the efficient practice of the engineer were to be assessed. Between 1853 and 1857 Rankine collaborated with the Glaswegian shipbuilder James Robert Napier in the development of a marketable hot-air engine (with regenerator), convinced on theoretical grounds that its efficiency would be greater than the maximum attainable by any condensing steam engine. Despite initial hopes that air would supersede steam they abandoned their patent when practical problems proved insurmountable. Second, rather than treat macroscopic phenomena, Rankine exploited what Maxwell termed scientific imagination to create a complex mechanical model of the unobservable whirling motions in which he believed heat to consist. He had designed this versatile hypothesis of molecular vortices to unify the study of heat, elasticity, light, and, ultimately, electromagnetism. Although Rankine was fêted by contemporaries as a founder of thermodynamics, Maxwell, Thomson, and others questioned his tenacious adherence to a hypothesis beyond the test of direct observation, accused him, not without justification, of obscurity in his statements of the second law, and claimed that the phrase 'molecular vortices' was of far greater import than the detail of the model itself (published December 1851).

Rankine nevertheless established himself as a significant scientific voice. As secretary of section A of the British Association for the Advancement of Science (BAAS) from 1850 he met Cambridge mathematical physicists like George Gabriel Stokes. He was president of section A in Newcastle (1863). Countering William Thomson's universal dissipation of the energy available to humanity, Rankine proposed in November 1852 a cyclic cosmology in which energy might be reconcentrated. Rankine had joined the Glasgow Philosophical Society early in 1852 and soon became prominent on its council. In January 1853 he presented the society with a set of general laws of the transformation between 'actual' and 'potential' forms of energy. This Aristotelian dichotomy engineered a succinct statement of an empirical law of energy conservation. Rankine's penchant for patenting scientific constructs expressed itself in many such coinages: some ('stress', 'strain', 'adiabatic') endured; others ('actual energy') fell into disuse or were so cumbersome ('platythliptic') as to cause mirth among tongue-tied colleagues.

Shortly after his election to the Royal Society of London (2 June 1853) Rankine refashioned the science of thermodynamics in geometrical terms: his diagram of energy (a theorized indicator diagram) linked the science of energy and heat-engine practice in a visual form ideal for teaching. In March 1854 the Royal Society of Edinburgh awarded him its Keith prize for his work on heat. In May 1855 he outlined the science of energetics in which he treated the laws of physical energy in an abstract and general manner, eschewing mechanical complexities and, in particular, treating heat phenomenologically. Positivists would subsequently champion Rankine's suggestion that energy—rather than matter—constituted a secure ontology for all physics. But Rankine had not abandoned the hypothesis of molecular vortices. As president of the Glasgow Philosophical Society (elected November 1861) he drew upon Scottish common-sense philosophy to argue for the legitimacy and probability of his model by virtue of its predictive capacity and its use of mechanical analogy. Having increasingly relaxed the conditions of the model, Rankine finally claimed that all that he required was a steady circulation of streams. Nevertheless scientists abandoned the hypothesis on which his claim to scientific originality largely rested in preference for a new orthodoxy of Maxwellian statistical physics.

The Glasgow engineering chair

From 1849 Rankine balanced a burgeoning scientific career with engineering commitments. By the beginning of 1851 he had transferred his Scottish base from Edinburgh to Glasgow. There he worked at the core of the Glasgow Philosophical Society, establishing himself as an engineer concerned to promote the city's improvement. In partnership with John Thomson, son of medical professor Dr William Thomson, Rankine surveyed the Glasgow College grounds, promoted a submarine telegraph between Britain and Ireland, and, jointly with the professor of natural philosophy, lodged a patent for improvements in telegraph conductors (1854). Their most ambitious project (1852) revived the audacious scheme of Lawrence Hill and Rankine's friend the engineering professor Lewis Gordon to bring water to Glasgow from Loch Katrine.

Although Glasgow was to be the centre of Rankine's scientific and engineering business, in 1853 and 1854 he frequented Gordon's Westminster offices. Their proximity provided the opportunity to plan the relaunch of the all but abandoned engineering chair. The year 1855 saw these plans in operation: an appointment as visitor of the Edinburgh observatory enhanced Rankine's scientific status; from January to April Rankine lectured to aspirant civil engineers on applied mechanics and the science and practice of heat engines; they left the classroom with commercially valuable results. In September the British Association visited Glasgow, responding to the invitation of Rankine, the Philosophical Society, and other local bodies. Gordon resigned his commission during the meeting; Rankine used his address as president of section G (mechanical science) to make a thinly concealed bid for the chair.

On 7 November 1855 Rankine succeeded Gordon in the regius chair of civil engineering and mechanics, despite eleventh-hour attempts by some incumbent professors to have the government endowment of £275 per annum redirected. Rankine allied himself with a reforming whig faction in the college, including anatomy professor Allen Thomson. His widely reported inaugural address espoused the harmony of theory with practice in mechanics, and outlined a tripartite theory of knowledge—theory, practice, and the application of theory to practice—which left room for a new breed of engineering scientists to bridge theoretical and practical domains. A second introductory address (November 1856) likened the Christian's quest for spiritual perfection to the sacred duty of the engineer to perfect himself in the liberal and noble art of engineering.

Firmly ensconced in the college, Rankine promulgated a programme of engineering science in three interrelated ways. The first was institutional. Rankine was appointed consulting engineer to the Highland and Agricultural Society of Scotland (1865) and elected to bodies like the American Academy of Sciences (1856) and the Royal Academy of Sweden (1868). But the institution which gave him greatest scope for immediate action was closer to home. In 1856 Rankine supported a Glaswegian association temporarily constituted to host a summer meeting of the Institution of Mechanical Engineers. Collaborating thereafter with Walter Neilson and J. R. Napier, Rankine built upon the successes of the summer to create a permanent professional body for Scottish engineers independent of the Institution of Civil Engineers. Recently honoured with the degree of LLD from Trinity College, Dublin (1857), Rankine resigned his associateship of the Institution of Civil Engineers—never having been granted full membership—and was elected president (1857–9) of a new and dynamic Institution of Engineers in Scotland. The institution encouraged engineering science and practice in and beyond the Glaswegian 'metropolis of mechanics', worked closely with the Philosophical Society, and brought together academics, engineers, shipbuilders, and ironmasters like William Baird and Henry Dunlop.

No less important was the dissemination of Rankine's engineering science in literary form. Building upon the recent technical pedagogy of Moseley, Willis, and Whewell, Rankine repeatedly developed in his lectures new analytical techniques. His 'reciprocal diagrams' of frames and forces (1856) allowed an engineering designer more scope in studying the stresses in structures. Rankine issued lithographs of lecture notes in 1855 and 1856. Thereafter he arranged with Richard Griffin in Glasgow to publish a series of exhaustive manuals suitable for teaching and reference alike. The central pillar—*A Manual of Applied Mechanics* (1858)—had been extensively sketched in the *Encyclopaedia metropolitana*. The *Steam Engine and other Prime Movers* (1859) extended an article on the mechanical action of heat in Nichol's *Cyclopaedia* and offered a typically anglocentric historiography of thermodynamics; contemporaries applauded this work as the first systematic treatise of the new science. *Civil Engineering* (1862) put Rankine's applied mechanics to work in engineering practice. Completing the best-selling series with *Machinery and Millwork* (1869), Rankine wrote with the authority of an experienced juror of 'machinery in general' at the London International Exhibition (1862). With a companion volume of *Useful Rules and Tables* (1866) the manuals were standard texts. Some remained in print well into the twentieth century. Rankine's former student and assistant in his final years, E. F. Bamber, completed the *Mechanical Textbook* (1873) as a much-needed light introduction to the weighty matter of the manuals.

Rankine structured his books to suggest that engineering knowledge had its roots in scientific principle: he stated a general problem, solved it, and only then treated the special cases encountered in practice. Where no principles were yet accessible he was a natural historian of an artefactual world, provisionally collecting the data of engineering with the ultimate intention of subsuming them under scientific law. Consequently his works were exhaustive rather than elegant and they were hard reading for the bulk of the profession. Contemporaries nevertheless recognized a rare combination of practical sense, scientific breadth, original investigation, and literary workmanship in a permanent *Principia* of engineering. In order to respond to topical matters—from the stability of chimneys to the dynamics of the new velocipede—Rankine made almost weekly contributions to *The Engineer* from 1858. Even in popular works Rankine channelled his energies to promote or reflect practical and especially scientific engineering. A keen cellist, pianist, and vocalist, his one published composition was a piano accompaniment to a song entitled the 'Iron Horse'; as a British Association red lion, hailed as lion-king in 1871, he penned quirky and humorous poems like 'The Mathematician in Love' and 'The Three-Foot Rule' (a protest against the metric system). These *Songs and Fables* (1874) appeared posthumously with illustrations by Jemima Blackburn, wife of Glasgow College's mathematics professor. Thus his model of a systematic and responsive body of engineering theory escaped the Glasgow classroom to endure in literary form and, through his college students, in practice.

Finally, Rankine increased the purchase of engineering science by, quite literally, raising the profile of the university and of his own subject within it. From the late 1860s he worked to raise funds for the new college buildings—a cathedral of science—at Gilmorehill. Although in 1855 engineering was not recognized as a subject qualifying for a degree, and the university commissioners disallowed Rankine's suggestion (approved by senate in 1859) that college engineers be granted diplomas, by 1862 Rankine had at last ensured that a systematically educated Glasgow engineer could leave the university with a certificate of proficiency in engineering science. Rankine seriously considered moving to Edinburgh and its chair of engineering in 1868, and the following year admitted his aspirations to succeed Thomas Graham, a distant relation, as master of the Royal Mint. But he remained in Glasgow to press for a full degree in engineering. In 1872 the university began to offer the degree of BSc for science subjects, including engineering.

The science of the ship

In July 1859 Rankine had taken a leading part in raising and organizing the second Lanarkshire, or Glasgow University corps, of the rifle volunteers. He attended a course at Hythe to qualify himself to instruct the corps in musketry. He became captain (October 1859) and then major of the corps (May 1860–June 1864). Later Rankine was the first convenor of the Glasgow University senate committee on the education of candidates for commissions in the army.

One of the reasons Rankine resigned his commission in 1864 was the increasing burden of work related to naval architecture. From the mid-1850s Rankine collaborated closely with men like J. R. Napier and the partners John Elder and Charles Randolph who combined craft skills with an overtly scientific approach to marine engineering and shipbuilding. In the autumn of 1857 Napier provided Rankine, in confidence, with a body of raw data from experiments relating engine power, size, shape, and speed of steamships. By December 1857 Rankine had deduced a general formula for the resistance of ships of the designs usually given to steamers. Unable to divulge a result which was commercially sensitive and, in Napier's *Admiral*, practically proven, Rankine published a letter in the *Philosophical Magazine* (September 1858) disguising the formula as an anagram.

Thereafter Rankine was ubiquitous on British Association committees, gathering and reducing data on the design, propulsion, and resistance of ships in commercial practice, and thereby seeking to remould shipbuilding as an exact science. He was a member of the Institution of Naval Architects from 1862. In 1864, in order to gather data on sea waves and the rolling of ships, he made observations in the Western Isles. He lectured to the Royal School of Naval Architecture in the years 1865–8 and was an examiner at the school. Rankine worked with Isaac Watts, chief constructor of the navy, Frederick K. Barnes of the controller's department, and Napier as corresponding editor and principal contributor to *Shipbuilding, Theoretical and Practical* (1866).

Rankine's numerous papers in hydrodynamics usually deployed his favoured strategy of stating simple principles and then following even the most difficult of investigations through with elementary mathematics. The topics he chose were almost invariably of practical relevance: he developed a theoretical description of waves of finite height (sea waves) on the surface of deep water; he applied his theory of streamlines to find good forms of lines for real ships; he investigated the causes of and remedies for ship resistance; in 1865 he produced a theory of the propeller. In these writings, always undertaken in dialogue with men of practice like Napier, Rankine successfully combined considerations of the fluid flow and the geometry of actual ships with engine propulsion, hull resistance, and, most importantly, work: that is, he had found a new practical object for energy physics in a science, jointly developed with William Froude and others, of naval dynamics. As a recognized expert, in December 1870 he accompanied William Thomson on a scientific sub-committee of the government committee on designs for ships of war, created after the loss of the *Captain*.

The death of John Elder precipitated Rankine once again into the presidency of the Institution of Engineers in Scotland (1869–70). Drawing upon his experience as co-editor and contributor in the area of engineering, mathematics, and natural philosophy to *The Imperial Dictionary of Universal Biography* (3 vols., 1857–63) Rankine wrote in 1870 and published in 1871 a memoir of his intimate friend and confidant. In May 1872, at the end of the university session, Elder's widow significantly enhanced the value of Rankine's professorship with a donation of £5000. Although in August 1872 Rankine was fit enough to work with Stevenson Macadam on a study of an explosion at the Tradeston Flour Mills, he did not teach again. Failing sight proved to be a symptom of deeper illness (possibly heart disease). Rankine's health deteriorated rapidly in October; during his last days he lost the power of speech and then of motion on his right side. He died, unmarried, at 59 St Vincent Street, Glasgow, on 24 December 1872 and was buried at Sighthill cemetery, Glasgow, four days later after a public service in the university chapel. The city mourned a chameleon—engineer, natural philosopher, and engineering scientist—who had brought the minute and orderly habits of a businessman to science and practice alike, worked to create a new science of thermodynamics, and fostered the philosophical reform of commerce and industry in the second city of the empire.

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Likenesses

- group portrait, photograph, 1870 (with the Glasgow University Senate), repro. in Channell, *William John Macquorn Rankine*
- T. Annan, carte-de-visite, pubd 1871, NPG [see illus.]
- statue, 1950, Virginia Polytechnic Institute, Blackburg, department of engineering
- T. Annan?, photograph, Mitchell L., Glas.
- Crawford (after photograph by Annan), Institution of Engineers and Shipbuilders in Scotland
- bust replica (after Ewing), U. Glas., Hunterian Library
- engraving, repro. in *Popular Science Monthly*, 12 (1877–8), facing p. 129
- portrait, repro. in Millar, ed., *Miscellaneous scientific papers*, frontispiece
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Wealth at Death

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