Professor Tait. By Lord Kelvin.

(Read December 2, 1901.)

When Professor Tait last February resigned the chair of Natural Philosophy in the University of Edinburgh, we hoped that the immediate relief from strain and anxiety regarding his duty might conduce to a speedy recovery from the severe illness under which he was then suffering. I was indeed myself sanguine in looking forward to an unbroken continuation of the friendly intercourse with him which I had enjoyed through forty-one years of my life. A slight abatement of the graver symptoms, and a cheering return to some mathematical work left off six months before, gave hope that a change from George Square to Challenger Lodge in June, on the invitation of his friend and former pupil Sir John Murray, might be the beginning of a recovery. But it was not to be. Death came suddenly on the 4th of July, and our friend is gone from us.

Peter Guthrie Tait was born at Dalkeith on 28th April 1831. After early education at Dalkeith Grammar School, and Circus Place School, Edinburgh, he entered the celebrated Edinburgh Academy, of which he remained a pupil till 1847, when he entered the University of Edinburgh. After a session there under Kelland and Forbes, he entered Cambridge in 1848 as an undergraduate of Peterhouse, and in 1852 he took his degree as Senior Wrangler and First Smith's Prizeman, and was elected to a Fellowship of his College. He remained officially in Peterhouse as mathematical lecturer till 1854, when he was called to Queen's College, Belfast, as Professor of Mathematics. This was a most happy appointment for Tait. It made him a colleague of, and co-worker on the electrolytic condensation of mixed oxygen and hydrogen and on ozone with Andrews, the discoverer of a procedure producing continuous change in a homogeneous substance, from liquid to gaseous and from gaseous to liquid condition. Through Andrews it introduced him to William Rowan Hamilton, the discoverer of

the principle of varying action in dynamics, and the inventor of the captivatingly ingenious and beautiful method of quaternions in Mathematics. It gave him six years of good duty in Queen's College, well done, in teaching Mathematics; and for some time also Natural Philosophy, in aid of his colleague Stevelly. During those bright years in Belfast he found his wife, and laid the foundation of a happiness which lasted as long as his life.

In 1860 he was elected to succeed Forbes as Professor of Natural Philosophy in the University of Edinburgh. It was then that I became acquainted with him, and we quickly resolved to join in writing a book on Natural Philosophy, beginning with a purely geometrical preliminary chapter on Kinematics, and going on thence instantly to dynamics, the science of Force, as foundation of all that was to follow. I found him full of reverence for Andrews and Hamilton, and enthusiasm for science. Nothing else worth living for, he said; with heart-felt sincerity I believe, though his life belied the saying, as no one ever was more thorough in public duty or more devoted to family and friends. His two years as "don" of Peterhouse and six of professorial gravity in Belfast had not wholly polished down the rough gaiety nor dulled in the slightest degree the cheerful humour of his student days; and this was a large factor in the success of our alliance for heavy work, in which we persevered for eighteen years. "A merry heart goes all the day, Your sad, tires in a mile-a." The making of the first part of "T and T′" was treated as a perpetual joke, in respect to the irksome details of interchange of drafts for "copy," amendments in type, and final corrections of proofs. It was lightened by interchange of visits between Greenhill Gardens, or Drummond Place, or George Square, and Largs, or Arran, or the old or new College of Glasgow; but of necessity it was largely carried on by post. Even the postman laughed when he delivered one of our missives, about the size of a postage stamp, out of a pocket handkerchief in which he had tied it, to make sure of not dropping it on the way.

One of Tait's humours was writing in charcoal on the bare plaster wall of his study in Greenhill Gardens a great table of living scientific worthies *in order of merit*. Hamilton, Faraday, Andrews, Stokes, and Joule headed the column, if I remember

right. Clerk Maxwell, then a rising star of the first magnitude in our eyes, was too young to appear on the list.

About 1878 we got to the end of our "Division II." on "Abstract Dynamics"; and, according to our initial programme, should then have gone on to "properties of matter," "heat," "light," "electricity," "magnetism." Instead of this we agreed that for the future we could each work more conveniently and on more varied subjects, without the constraint of joint effort to produce as much as we could of an all-comprehensive text-book of Natural Philosophy. Thus our book came to an end with only a foundation laid for our originally intended structure.

Tait's first published work was undertaken in conjunction with a Peterhouse friend, Steele, who was his second in the University both as Wrangler and Smith's Prizeman. They commenced their work together immediately after taking their degrees; but Steele died before more than two or three chapters had been written, and Tait finished it alone, and published it four years later under the title "Tait and Steele's Dynamics of a Particle" (1856). It has gone through many editions, and still holds its place as a text-book.

Tait's second published book, "Elements of Quaternions," was commenced under the auspices of Hamilton; but, in deference to his wish, not published till 1867. It has gone through three editions, and is, I believe, the text-book for all those who wish to learn the subject.

Tait also produced several valuable *Treatises*, short, *readable*, interesting, and useful, on various subjects in physical science:—

"Sketch of Thermodynamics" (1867).

"Recent Advances in Physical Science" (1876).

"Heat" (1884, 2nd edition 1892).

"Light" (1884, 3rd edition 1900), based on article in *Encyclopædia Britannica.*

"Properties of Matter" (1885, 4th edition 1899).

"Dynamics" (1895), based on article "Mechanics" in *Ency. Brit.*

Among smaller articles contributed to the *Ency. Brit.* are "Quaternions," "Radiation and Convection," and "Thermodynamics," all reprinted in the collected papers. A small 50-page book on "Newton's Laws of Motion" is a remarkably concise

statement of the foundations of dynamical science. It is Tait's last published work, primarily intended as a help to medical students attending his special three months' course of lectures for them on Natural Philosophy.

In the Royal Society of Edinburgh we all know something of how Tait has enriched its Proceedings and Transactions by his interesting and varied papers on mathematical and physical subjects from year to year since 1860, when he came to Edinburgh to succeed Forbes as Professor of Natural Philosophy in the University. Nearly all of these are now collected, along with a considerable number of other scientific papers which he brought out through other channels, arranged in order of time, from 1859 to 1898; one hundred and thirty-three articles in all; republished by the Cambridge University Press in two splendid quarto volumes of 500 pages each; a worthy memorial of a life of laborious whole-hearted devotion to science.

The "Scientific Papers" collected in these two volumes abound in matter of permanent scientific interest; and literary interest too, as witness the short articles on "Hamilton," "Macquorne Rankine," "Balfour Stewart," "Clerk Maxwell," and "The Teaching of Natural Philosophy." Of all the mathematical papers in the collection, one of those which seem to me most fundamentally important is Part IV. of "Foundations of the Kinetic Theory of Gases," in which we find the first proof (and, I believe, the only proof hitherto given) of the theorem enunciated first by Waterston and twelve years later independently by Clerk Maxwell, asserting equal average partition of energy between two sets of masses larger and smaller, taken as hard globes to represent the molecules of two different gases thoroughly mixed together. The collection contains also papers describing valuable experimental researches made by Tait through many years on various subjects: Thermo-electricity; Thermal Conductivity of Metals; Impact and Duration of Impact; Pressure Errors of the Challenger thermometers; Compressibility of Water, Glass, and Mercury (contributed originally to the "Physics and Chemistry" of H.M.S. Challenger). His work for the Challenger Report was a splendid series of very difficult experimental researches carried on for about nine years (1879 to 1888), with admirable scientific inventiveness, and no less admirable

zeal and perseverance. One little scientific bye-product of extreme interest I cannot refrain from quoting. Referring to a hermetically sealed glass tube under tests for strength to resist great water pressure, "I enclosed the glass tube in a tube of stout brass, " closed at the bottom only, but was surprised to find that it was " crushed almost flat on the first trial [when the glass tube broke]. " This was evidently due to the fact that water is compressible, " and therefore the relaxation of pressure (produced by the break- " ing of the glass tube) takes time to travel from the inside to the " outside of the brass tube; so that for about 1/10000th of a " second that tube was exposed to a pressure of four or five tons " weight per square inch on its outer surface, and no pressure on " the inner. The impulsive pressure on the bottom of the tube " projected it upwards so that it stuck in the tallow which fills " the hollow of the steel plug. Even a piece of gun-barrel, which " I substituted for the brass tube, was cracked, and an iron disc, " tightly screwed into the bottom of it to close it, was blown in. " I have since used a portion of a thicker gun-barrel, and have had " the end welded in. But I feel sure that an impulsive pressure " of ten or twelve tons weight would seriously damage even this. " These remarks seem to be of interest on several grounds, for they " not only explain the crushing of the open copper cases of those " of the Challenger thermometers which gave way at the bottom " of the sea, but they also give a hint explanatory of the very " remarkable effects of dynamite and other explosives when fired " in the open air. (It is easy to see that, *ceteris paribus*, the " effects of this impulsive pressure will be greater in a large " apparatus than in a small one)."

In a communication on "Charcoal Vacua" to the Royal Society of Edinburgh of July 5, 1875, imperfectly reported in *Nature* of July 15 of that year, the true dynamical explanation of one of the most interesting and suggestive of all the scientific wonders of the nineteenth century, Crookes' radiometer, was clearly given. The phenomenon to be explained is that in highly rarefied air a disc of pith or cork or other substance of small thermal conductivity, blackened on one side, and illuminated by light on all sides, even the cool light of a wholly clouded sky, experiences a steady measurable pressure on the blackened side. Many naturalists, I

believe, had truly attributed this fact to the blackened side being rendered somewhat warmer by the light; but none before Tait and Dewar had ever imagined the dynamical cause,—the largeness of the free path of the molecule of the highly rarefied air, and the greater average velocity of rebound of the molecules from the warmer side. *Long free path* was the open sesame to the mystery.

The Keith Medal of the Royal Society of Edinburgh was awarded to Professor Tait in the year 1869, and again in 1874; and one of the Royal Medals of the Royal Society of London was awarded to him in the year 1886. The Gunning Victoria Jubilee Prize of the Royal Society of Edinburgh was awarded to him in 1890.

Enthusiast as he was in experimental and mathematical work, he never allowed this to interfere with his University teaching, to which, from beginning to end of the forty years of his Professorship, he devoted himself with ever fresh vigour, and with unremitting faithfulness, as his primary public duty. How happily and usefully and inspiringly he performed it, has been remembered with gratitude by all who have ever had the privilege of being students in his class.

With not less devotion and faithfulness during all these years he has worked for the Royal Society, of which he was elected a Fellow when he came to Edinburgh as Professor. At the commencement of the following session he was elected a Member of Council; and in 1864 he became one of the Secretaries to the ordinary meetings. In 1879, in succession to Professor Balfour, he was elected to the General Secretaryship; and he held this office till the end of his life.

His loss will be felt in the Society, not only as an active participator in its scientific work, but also as a wise counsellor and guide. It has been put on record that "The Council always felt that in "his hands the affairs of the Society were safe, that nothing would "be forgotten, and that everything that ought to be done would be "brought before it at the right time and in the right way." In words that have already been used by the Council, I desire now to say on the part, not only of the Council, but of all who have known Tait personally, and of a largely wider circle of scientific men who know his works,—"We all feel that a great man has

" been removed ; a man great in intellect, and in the power of using " it, and in clearness of vision and purity of purpose, and therefore " great in his influence, always for good, on his fellowmen ; we feel " that we have lost a strong and true friend."

After enjoying eighteen years' joint work with Tait on our book, twenty-three years without this tie have given me undiminished pleasure in all my intercourse with him. I cannot say that our meetings were never unruffled. We had keen differences (much more frequent agreements) on every conceivable subject,—quaternions, energy, the daily news, politics, *quicquid agunt homines*, etc., etc. We never agreed to differ, always fought it out. But it was almost as great a pleasure to fight with Tait as to agree with him. His death is a loss to me which cannot, as long as I live, be replaced.

The cheerful brightness which I found on our first acquaintance forty-one years ago remained fresh during all these years, till first clouded when news came of the death in battle of his son Freddie in South Africa, on the day of his return to duty after recovery from wounds received at Magersfontein. The cheerfulness never quite returned. The sad and final break-down in health came after a few weeks of his University lectures in October and November of last year. His last lecture was given on December 11, 1900.