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WILLIAM H. C. BARTLETT

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BY

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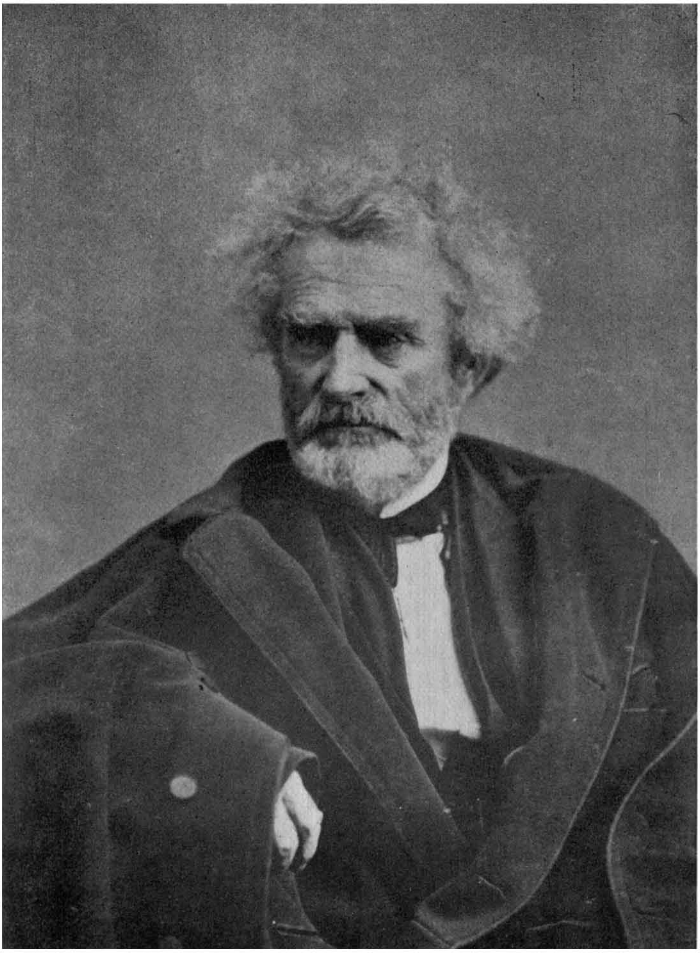

Wm H. C. Bartlett
Profr. Nat. & Expt. Phi.

WILLIAM H. C. BARTLETT.

WILLIAM H. C. BARTLETT was born in Pennsylvania in September, 1804. He died at Yonkers, New York, on February 11, 1893, aet. 89. His parents moved from Pennsylvania to Missouri, and settled there while he was yet an infant. His early education is said to have been meagre, but his natural abilities attracted the attention of his fellow-townsmen, and in 1822, at the age of 17 years, he was appointed a cadet at West Point. It is said that his appointment was at least partly due to the friendly offices of Senator Thomas H. Benton.

From 1822 onwards his career is well recorded. The following is summarized from General Cullum's Biographical Register of the Officers and Cadets of the U. S. Military Academy, with a few additions.

WILLIAM H. C. BARTLETT; Class of 1826; born in Pennsylvania, 1804; appointed from Missouri, 1822; graduated No. 1 in a class of 41 members. Among his classmates were General Thomas Jefferson Cram; General Albert Sidney Johnston (C. S. A.); General Samuel P. Heintzelman; General Augustus J. Pleasanton; General Amos B. Eaton; and General Silas Casey. He was in the corps of cadets at the same time with the classes of 1823, 1824, 1825, 1826, 1827, 1828, and 1829, and was thus associated with the following named officers, among many others: Major Alfred Mordecai, General George S. Greene; General Lorenzo Thomas; General Hannibal Day; General E. B. Alexander (C. S. A.); Professor Dennis H. Mahan; Robert P. Parrott; Alexander Dallas Bache; General Daniel S. Donelson (C. S. A.); General Benjamin Huger (C. S. A.); General Robert Anderson; General Charles F. Smith; General William Maynadier; Bishop and General Leonidas Polk (C. S. A.); General Gabriel J. Rains (C. S. A.); General Philip St. G. Cooke; Professor Albert E. Church; Professor W. W. Mather; President Jefferson Davis (C. S. A.); Charles Mason; General Hugh W. Mercer (C. S. A.); General T. F. Drayton (C. S. A); General Robert E. Lee (C. S. A.); General James Barnes; Professor Charles W. Hackley; William R. McKee; General Joseph E. Johnston (C. S. A.); General Albert G. Blanchard (C. S. A.); Professor and General Ormsby McK. Mitchel; General Sidney Burbank; General William Hoffman; General Seth Eastman; General Thomas Swords; Professor James Clark, S. J.; General Benjamin W. Brice; and General Theophilus H. Holmes (C. S. A.).

Among these selected names there are three corporators of the National Academy of Sciences: Bartlett, Bache, and Mahan. The names of distinguished military commanders in the war with Mexico and in the Civil War will be familiar. Bishops, ministers of the gospel, priests, presidents and professors of colleges, and judges are there enumerated. Some of the pillars of our Coast and Geodetic Survey are named, with others who surveyed the boundary lines of our country. To those who are familiar with the early history of railways in America some of these distinguished names will recall the builders, engineers, managers, directors, and presidents of our first railway lines.

I am tempted to set down in order the names belonging to this latter group because the memory of the great services of graduates of the Military Academy in this respect is growing faint, and because this should not be so. Among the cadets of the years 1823–29, who were at West Point with Bartlett, the following were closely connected with the beginnings and with the development of our railway system or with water works and canals. Only those who served in civil capacities are named; none who were in the active army, and none except those of the seven classes of 1823–29:

G. S. Greene, canals, Croton water works; G. W. Long, chief engineer of the Alton Railroad, Illinois, etc.; J. M. Fessenden, chief engineer of the Boston and Worcester Railroad, etc.; R. E. Hazzard, engineer of the Baltimore and Ohio Railroad; J. N. Dillahunty, engineer of the Baltimore and Ohio Railroad; W. B. Thompson, chief engineer of the Goldsboro Railroad, etc.; T. S. Brown, chief engineer of the Erie Railroad, etc., consulting engineer to the St. Petersburg and Moscow Railroad, etc.; A. H. Brisbane, chief engineer of various railroads in Georgia; E. B. White, engineer of railroads in South Carolina and North Carolina; John Childe, engineer of the Baltimore and Ohio, Mobile and Ohio, and many other railroads; A. J. Center, superintendent of the Panama Railroad, etc.; R. C. Tilghman, harbor improvements on Lake Erie, etc.; Edmund French, engineer of the Croton dam, Hudson River Railroad, etc.; Charles Mason, president of the Burlington and Northwestern Railroad Company, etc.; James Barnes, chief engineer of the Seaboard and Roanoke Railroad, etc.; W. R. McKee, engineer of the Charleston and Louisville Railroad, etc.; O. McK. Mitchel, chief engineer of the Ohio and Mississippi Railroad, etc.; T. A. Davies, engineer on Croton aqueduct, etc.; A. G. Blanchard, chief of survey of the New Orleans and Opelousas Railroad, etc.; A. Snyder, engineer of the Reading Railroad, etc.

These twenty ex-officers, graduated between the years 1823 and 1829, held the chief positions in the railways of the United States. Together with many others, not here named, they made the preliminary surveys of the early American railways, located them, built them, and managed them. The first railways of Cuba, Mexico, South America, and Russia were their work.

Cullum's Biographical Register shows that no less than 49 graduates between 1802 and 1902 have been *chief* engineers of railways, and 22 have been presidents of railroad companies. In the period of 1802–1900 no less than $383,000,000 have been expended by engineer officers (all graduates) on the improvement of rivers and harbors; from the time of Bonneville (U. S. Military Academy, 1815) they have been pre-eminent as explorers, surveyors of boundaries, of the routes for the Pacific railways; the Coast Survey was founded by a professor from West Point, and brought to its highest efficiency under Bache, a graduate of 1825; the Lake Survey was created by Comstock (U. S. Military Academy, 1855); the 40th Parallel Survey (King) and the Surveys West of the 100th Meridian (Wheeler) were executed under the direction of the engineer department; the lighthouses of the United States have all been constructed by graduates; no less than 16 graduates have been members of the National Academy of Sciences.

To resume the official record of Bartlett, after this digression: He was graduated and promoted in the army to be second lieutenant in the Corps of Engineers July 1, 1826, and served in this capacity to April 20, 1836, on which date he was appointed to be professor of natural and experimental philosophy in the Military Academy, in succession to Prof. Edward H. Courtenay. On February 14, 1871, he was retired from active service, on his own application, "after (more than) forty years of continuous service."

He served at the U. S. Military Academy as assistant professor of engineering from August 30, 1826, to April 21, 1827, and as principal assistant professor in the same department to August 30, 1829; as assistant engineer in the construction of Fort Monroe, Virginia, in 1828; and of Fort Adams, Newport, Rhode Island, 1829-32; as assistant to the chief engineer at Washington, D. C., 1832-34; and as acting professor of natural and experimental philosophy at the Military Academy from November 22, 1834, to the date of his appointment as full professor, April 20, 1836.

He received the degree of A. M. from the College of New Jersey (Princeton) in 1837; and of LL. D. from Hobart College (Geneva, N. Y.) in 1847. He was a member of the American Academy of Arts and Sciences (Boston) and of the American Philosophical Society (Philadelphia), and one of the corporators and original members of the National Academy of Sciences in 1863.

Bartlett's work at Fort Adams was under the immediate direction of Colonel J. G. Totten. Difficulties that arose in the laying of the coping of the stone walls of this fortification led to an investigation of the expansive coefficients of various building stones in the years 1830 and 1831. The results are printed in the American Journal of Science, Vol. 22, 1832, pp. 136–140. The methods employed seem to be simple and direct and the results of sufficient exactness.

It was during his service at Fort Adams that Bartlett married (February 4, 1829) Miss Harriet Whithorne, daughter of Samuel Whithorne, a merchant of Newport. Eight children were born of the marriage, of whom three sons and two daughters were living with their mother at the time of his death, in 1893.*

In the year 1840 Professor Bartlett applied to Colonel J. G. Totten, Chief Engineer of the Army and Inspector of the U. S. Military Academy, for permission to go abroad to inspect the astronomical observatories and establishments of Europe. He was absent from West Point from July 1 to November 20, 1840, and his manuscript report of 52 pages (now in the library of the U. S. Military Academy) was submitted on February 16, 1841. He visited the observatories of Greenwich, Oxford, Cambridge, Dublin, Armagh, Edinburgh, Paris, Munich, and Brussels; and the workshops of Troughton and Simms, Dolland, Jones, Grubb, Gambey, Ertel, Merz, and others. His report is general in its nature, but details are given of devices and arrangements that seemed important.

This visit led to the equipment of the observatory of West Point, whose instruments were ordered on the recommendation of Bartlett, set up, and used by him and his assistants, notably by his son-in-law, afterwards Lieut. General John M. Schofield.

WEST POINT OBSERVATORY

1843–1871.

Professor Loomis' volume, The Recent Progress of Astronomy, Especially in the United States (New York, 1851), con-

* Scharf, J. T. History of Westchester County, New York, Vol. I, p. 622.

tains an excellent description of the observatory of the U. S. Military Academy. The first equatorial had an objective, by Lerebours, of six inches aperture. It was replaced in 1856 by a 9¾-inch objective by Fitz. A transit instrument by Ertel (5¼ inches aperture), with a Hardy sidereal clock, occupied the east tower. A mural circle by Simms (5 feet in diameter, with a telescope of 4 inches aperture) occupied the west tower. Professor Loomis remarks (p. 170): Professor Bartlett "has made a good many observations with the meridional instruments which have not yet (1851) been published. He is at present engaged in a regular series of observations on the stars enumerated in the notes to the British Association catalogue, and also on the planet Neptune."

The manuscript records of these observations I saw in 1872–73, and formed the project of reducing and publishing them in honor of my old teacher, and of my Alma Mater, especially as my examination showed the work to be of high quality. I regret that the leisure to carry out my youthful project has never come in the course of a long and busy life.

In the reconstruction of the building and the removal of the observatory to a new site (1879–1883, or later) the manuscripts were lost, and have not yet been found. For that reason no further reference can be made to them here, except to give my personal recollection, based on computation, that the precision of Bartlett's work with the mural was of the same order as that of that prince of observers, Professor J. H. C. Coffin, whose work I was then studying.

OBSERVATIONS AND ORBIT OF THE COMET OF 1843.

In March, 1843, the equatorial telescope (objective of 6 inches by Lerebours; mounting by Grubb) was the only instrument fully mounted at West Point. It was utilized by Bartlett to observe the Comet of 1843 on four nights of March and April (the weather being unfavorable on other nights).

In a communication read to the American Philosophical Society,* Bartlett gives the reduction of his observations as well as the elements of the comet derived from places obtained

*Proc. American Philos. Soc., Vol. 3, p. 151.

on March 25, March 29, and April 2, together with the results of measures of the diameter of the nebulous envelope of the head. The original paper was accompanied by drawings and a description of the new observatory, then nearly completed.

COMAS AND TAILS OF COMETS.

In 1859 Bartlett printed in the American Journal of Science, Vol. 29, pp. 62–64, a short paper on the comas and tails of comets. It is very general in form and seeks to give mathematical expressions for the circumstances of the relative motion of the material elements of any aggregation of molecules—a comet, for instance—immersed in the ether of space and acted on by light-rays from the sun. He first shows how the forces from the sun and from the elements of the comet may produce light waves in the ether and render it *self-luminous*. And next it is shown how the internal motions of the material elements of the comet's head, influenced by the light-rays from the sun, may render the comet itself *self-luminous*.

He concludes that the comet's head can have no phases, and altogether denies the presence of cometary material in the coma and in the tail. These appendages are to be regarded, he says, as but phenomena due to the reciprocal action of the ethereal and cometary molecular forces. The coma and tail are, as it were, but parts of a luminous shadow and have no objective existence. Applying the same principles to the zodiacal light, he makes the deduction that the component molecular motions inside the sun are greater in the direction of the solar axis than in any other.

BARTLETT AS A PURE MATHEMATICIAN.

In this paper, as in another on polarization that will be cited, it appears to the writer that Bartlett looks on the phenomena he is discussing with the eyes of a pure mathematician, and this in spite of the fact that he expressly states the cometary problem to be not one of mathematics, but of physics. By physics it would seem that Bartlett meant mathematical molecular physics, and that he rested in his conclusions without the slightest temptation to test them by appeal to observation or to experiment. Both papers suggest that Bartlett was entirely satisfied as to the validity of his results so soon as he was sure that his analytic expressions were correctly deduced. The anxiety of a physicist about the data introduced, and respecting the comprehensiveness of his formulas, did not seem to affect him in any marked degree.*

Somewhere in Bartlett's book on Optics there is a conclusion like the following: k is small, and therefore we can hear, but cannot see, round a corner. This is the view of the pure mathematician. The enunciation should be: Since we can hear, and not see, round a corner, k *must* inevitably be small, as it turns out to be in the formula.

His paper, On the direction of molecular motions in plane polarized light (American Journ. Sci., Vol. 30, 1860, pp. 361–366), seems to the writer to exhibit the same purely mathematical point of view, and to suggest that it may have been characteristic.

Bartlett first discusses the living force and the quantity of motion in a plane polarized wave, and next their resolution by deviating surfaces. By transformations which seem to the writer to be ingenious, he arrives at simple formulas which he interprets as demonstrating that the vibrations of the molecules in a plane polarized wave must be parallel to the plane.

The writer is not competent to detect the fallacy in this conclusion, but it is certain, according to Lord Kelvin, that this result is to be denied.†

ON THE SOLAR ECLIPSE OF 1854, MAY 26.

In the Astronomical Journal (No. 77, November 10, 1854) Bartlett had an important paper on the partial solar eclipse of 1854. He measured the distance between cusps during the eclipse with a double-image micrometer and noted the corresponding times. But his work is important for another reason. For the first time in America photography was util-

*The formula in the middle of page 64 should read: R. N. sin (etc.), and not as printed.

† Chwolson: Physique—l'énergie rayonnante; Chap. XV, page 729, where Kelvin's Baltimore lecture (No. XVIII) is cited.

ized for astronomical measurements. During the eclipse Mr. Victor Prevost, of New York, assisted Bartlett in obtaining photographs of the solar disk; the distances separating the cusps were subsequently measured on the glass negatives. The telescope employed was of six-inch aperture and the solar focal length was eight feet. A small camera was attached to the eye end; the plates must have been wet plates, and the exposures were practically instantaneous. The solar image was about ⅞ of an inch in diameter. Nineteen photographs were taken and accurately timed.

ASTRONOMICAL PHOTOGRAPHY.

The very first essay in astronomical photography was that of Prof. John Henry Draper, of New York, who in the year 1840 took a satisfactory daguerreotype of the moon. The experiments of Draper were repeated by George Bond at the Harvard College Observatory, in 1850, and a lunar daguerreotype made by him was exhibited in London at the Crystal Palace in 1851, where it attracted great attention. Solar daguerreotypes were first taken by Foucault and Fizeau in Paris, in 1845, on the advice of Arago. A small but excellent daguerreotype of the total solar eclipse of July 28, 1851, was taken by Busch at Königsberg. Up to this time photography had not been utilized in measurement, and Bartlett was, I think, the first to so employ it.

The first daguerreotype of a star was taken by George Bond in 1850, and the first photograph of a star in broad daylight was made by the writer at the Lick Observatory in 1889 to test a theory of photographic vision. The first photograph of a nebula was made by Dr. Henry Draper and M. Janssen in 1881. Sir David Gill first photographed a comet in 1882 The earliest photograph of a star-spectrum showing measurable lines was made by Henry Draper in 1872, though Huggins had obtained an *image* of the spectrum of Sirius as early as 1863. The first photographs of the inner corona were made by De la Rue in 1860.

All these data refer to ancient history, and the results obtained are insignificant compared to the magnificent negatives of today. Still they have their place in the history of astronomy, and for Bartlett it may be claimed, I believe, that he was the first to obtain quantitative results from astronomical photography.

BARTLETT AS A TEACHER (1836–1871).

Professor Bartlett is best known to the general public by his series of text-books on Acoustics, Optics, Astronomy, Mechanics, and Molecular Physics.

They were used at many schools and colleges and gave him a definite standing among his fellows. Of the Astronomy I can say that, while it has distinct merits, it is not so directly useful for the purpose of training an army officer for practical work in the field as the contemporary text-books of Loomis. Still it must be remembered that this volume gave their only preliminary training in astronomy to a long line of engineer officers whose work on the Coast Survey, the Lake Survey, the Mississippi River Survey, and on many boundary surveys has been distinguished for accuracy and precision. The basis laid by the book and the teacher was sound.

Of the other text-books of Professor Bartlett, the Analytical Mechanics is the most important. Its first edition was dated in 1853; the ninth in 1874. Regarding it I will quote a paragraph by Bartlett himself, taken from his testimony before a commission appointed by Congress to inquire into the affairs of the U. S. Military Academy, Hon. Jefferson Davis, chairman,* and parts of a memoir of Bartlett written by his pupil and successor in the professorship at West Point, Colonel P. S. Michie.†

Professor Bartlett's own testimony is:

The text-books in natural and experimental philosophy have been prepared expressly for the cadets of the Military Academy. They have a threefold purpose—mental discipline, a corresponding knowledge of the subjects of which they treat, and a confirmation, in the minds of the students, of their previous mathematical course. The text on mechanics, the groundwork of the whole, begins with the simplest elements of physics, and such general facts in regard to the action of forces as are

* 36th Congress, 2d session, Senate Misc. Doc. No. 3, pp. 350.

†Annual of the Association of Graduates, U. S. Military Academy, for 1893.

furnished by experience, and which comprehend all special cases of nature. These are fully discussed, and a mathematical formula, an expression of the laws by which forces are connected with matter, is deduced. From this point the work is purely deductive, and presents to the student a connected discussion, instead of a series of detached propositions, as in most texts upon the same subject. This formula is made a never-failing source whence may flow, through the channel of mathematical analysis, and in the natural order of sequence, all the laws of matter, and the rationale of all physical phenomena. The method is natural, simple, and comprehensive, and it saves to the student a great deal of useless labor, by avoiding the necessity of new statements and demonstrations on the presentation of new cases and new data. It requires, to be sure, more labor from the student at the beginning; but that labor is rewarded by ample returns in the increasing ease with which he may progress, after mastering first principles, and in the facility with which the text may be reviewed.

The totally new aspect given, within a few years, to that branch of natural philosophy embracing what were formerly called the 'imponderables,' viz., light, heat, and electricity, made it necessary, in my judgment, to add to the mechanics of solids and of fluids, that of molecules; and it is proposed to replace the present text-book on acoustics and optics by another, embracing, in addition, heat and electricity, which shall be purely deductive, and little else than corollary to this new branch of mechanics.*

Professor Michie, Bartlett's successor, thus summarizes the text-books prepared by his predecessor and used by himself for many years:

Professor Bartlett, on assuming the duties of his department, continued the text-books and methods of his own predecessor, until he was able to make suitable modifications more advantageous to his pupils. Mechanics was taught from Courtenay's translation of Boucharlat until September, 1850, when it was replaced by Bartlett's Synthetical Mechanics. Some opposition having developed against this work, on the ground that it was of too elementary a character for students familiar with the calculus, he prepared his Analytical Mechanics to replace it, and the latter was adopted as a text-book August 29, 1853. His Treatise on Optics, the first of his text-books to be prepared, was introduced into the course February 16, 1839, and it continued to be used until it was superseded by his less difficult, but more comprehensive work, Acoustics and Optics, September 27, 1852. Bartlett's Spherical Astronomy, adopted by the academic board September

* Report of the Commission to Examine the Military Academy at West Point, 1860, pp. 110–111.

5, 1855, was the last of his series of scientific text-books. While all of these works were of a high grade, clearly and concisely written, and valuable contributions to the higher scientific education, his lasting fame will rest more solidly upon his Analytical Mechanics. This work passed through nine editions and was used in many institutions of well established scientific reputation. He always expressed a just pride in the success he had attained in its preparation, and it exhibits in a marked degree the special tendency of his own talent for generalization. He distinctly perceived that all natural phenomena are nothing more than particular exhibitions of a great general law, but yet capable of being most simply expressed by a single formula. His perception of this great truth is thus eloquently expressed in his preface:

"The design of the author is to give to the classes committed to his instruction, in the Military Academy, what has appeared to him a proper elementary basis for a systematic study of the laws of nature. The subject is the action of force upon bodies—the source of all physical phenomena—and of which the sole and sufficient foundation is the comprehensive fact, that all action is ever accompanied by an equal, contrary, and simultaneous reaction. Neither can have precedence of the other in point of time, and from this comes that character of permanence, in the midst of endless variety apparent in the order of nature. A mathematical formula which shall express the laws of this antagonism will contain the whole subject, and whatever of specialty may mark our perceptions of a particular instance will be found to have its origin in corresponding peculiarities of physical condition, distance, place and time, which are the elements of this formula. Its discussion constitutes the study of Mechanics. All phenomena in which bodies have a part are its legitimate subjects, and no form of matter under extraneous influences is exempt from its scrutiny. It embraces alike, in their reciprocal action, the gigantic and distant orbs of the celestial regions, and the proximate atoms of the ethereal atmosphere which pervades all space, and establishes an unbroken continuity upon which its Divine Architect and Author may impress the power of His will at a single point and be felt everywhere. Astronomy, terrestrial physics, and chemistry are but its specialties; it classifies all of human knowledge that relates to inert matter into groups of phenomena, of which the rationale is in a common principle; and in the hands of those gifted with the priceless boon of a copious mathematics it is a key to external nature."

Professor Bartlett's own preface to the ninth edition of his Analytical Mechanics may be quoted here to give his last word on a subject near to his heart:

Twenty years ago, the course of Mechanics taught, for several previous years, to classes in the United States Military Academy, was published in the first edition of this work.

In that edition the following assertion was made:

"All physical phenomena are but the necessary results of a perpetual conflict of equal and opposing forces, and the mathematical formula expressive of the laws of this conflict must involve the whole doctrine of mechanics. The study of mechanics should, therefore, be made to consist simply in the discussion of this formula, and in it should be sought the explanation of all effects that arise from the action of forces."

From the single fundamental formula thus referred to, the whole of analytical mechanics was then deduced.

That formula was no other than the simple analytical expression of what is now generally called *the law of the conservation of energy*, which has since revolutionized physical science in nearly all its branches, and which at that time was little developed or accepted.

It is believed that this not only was the first, but that it even still is the only treatise on analytical mechanics in which all the phenomena are presented as mere consequences of that single law.

And in offering to the public this new edition, which has been most carefully revised and in many parts rewritten, one of the principal objects sought has been to render it more worthy of use, by making it what it ought to be in view of the great progress achieved during the last twenty-five years, in consequence chiefly of the more general recognition and acceptance of the grand law of work and energy, by Newton called that of action and reaction. (Yonkers, New York, 1874.)

I add a few reflections of my own upon the earlier book of Bartlett, namely: Elements of Natural Philosophy, I: Mechanics, by W. H. C. Bartlett, LL. D., 2d edition, New York, 1851, 1 vol., 8vo, pp. 632. The first edition of this book was published in 1850. The preface states that the book was written with constant reference to the works of Poncelet, and that much valuable assistance was derived from Peschel.

No detailed examination of the volume has been made by the present writer, but such examination as has been made seems to show that this text-book was very well suited, indeed, to the cadets of the academy. Its explanations and proofs are clear and not too brief. Each paragraph has a rubric in the margin summarizing its contents; diagrams are freely used, and numerical examples are worked throughout the text. The book has no collection of unworked problems so necessary for students, but problems were given out by the professor (if we may judge by his subsequent practice in this respect). The excellent fashion of presenting many unworked problems in a text-book had not then been set by the English text-books, written to prepare students for test examinations.

As I turn over the pages it appears to me somewhat regrettable that this excellent volume was not made the basis of the course in mechanics at the U. S. Military Academy, supplemented, as required, by a higher treatise in which the subject was treated analytically for the use of the upper men in each class—the engineer, ordnance, and artillery officers of the future. I think it is the judgment of a very large number of graduates that their study of mechanics, and especially of molecular mechanics, from the text-books of Bartlett and similar treatises, has been less profitable and of less practical use in their military careers than it might have been. The ideal of the mathematical studies at the academy is to create *power* by means of *useful* knowledge. There is no science or art so practical as war, and all our training must be directed toward giving, *first,* power—mental and moral—and toward giving it, *second,* through useful, available, practical knowledge.

Perhaps the result of Bartlett's training upon the mass of his pupils might have been even more fruitful than it was if his first judgment had been followed, and if he had not been obliged to revise it to conform to the views of his colleagues. The revision itself was admirably done, and those who were ready to profit by his teaching profited exceedingly.

Perhaps this is an appropriate place to point out that the U. S. Military Academy is not, and never has been, a school of pure science. It is a technical school for war. Pure science is taught as a means of mental discipline, but still more as a basis for the application of science to the military art. This is the fact, and it ought always to be so. The conditions of the country were such in the years 1802 to 1860 that the scientific education at West Point was the best then attainable, particularly when one remembers that invaluable moral training which comes from discipline, a high sense of honor, and a simple unquestioning devotion to duty.

The atmosphere of the École Polytechnique is very different from that at West Point. There was no such stimulating criticism for the members of its academic board as surrounded their contemporaries in Paris. It is for this reason, I think, that Bartlett, and his colleagues as well, were not as keen to follow the progress of their sciences as they certainly would have been had they lived in an intellectual atmosphere like that of Paris. They conscientiously prepared the texts from which cadets were taught, and laboriously and minutely corrected and improved them year by year. Their chief interests were in the teaching of their sciences, not in advancing them. This was as it should be. The object of the academy is to produce competent officers equipped for instant work, not primarily to add to science itself.

The alert and vigorous mind of Bartlett would, I think, have developed very differently under different conditions. Whenever his interest was excited his work was of a high order. Witness his investigation of the strains in rifled ordnance (Memoirs Nat. Acad. Sci., Vol. I) for his friend and neighbor, R. P. Parrott, and his photographs of the solar eclipse of 1854 (the first made in America), and his researches as actuary of the Mutual Life Insurance Company of New York. His daily life at West Point was filled with routine duties, all performed in the most conscientious and best manner. Lacking the stimulus of intellectual equals in his own pursuits, he led a life of easy usefulness, contented with achievements not fully commensurate with his great powers. Under different circumstances of stimulus, criticism, and approval he would have become a still more shining light among his fellows. The Military Academy gained where science lost.

From my own recollections I can say that he was an accomplished teacher—luminous, exact, suggestive, inspiring—more particularly for the upper sections of the class; apt to become nervous and impatient with slower or duller minds, yet, I think, fundamentally just, fair, and kind to all. The systematic teaching at West Point ordinarily kept us closely to the text of each lesson, but there were memorable occasions when it seemed to him worth while to add to the expositions of the book developments entirely unforeseen, leading us on and on and opening vistas wholly unsuspected. It was done with a neat precision of method, so simply as to produce a delighted surprise when we suddenly found the somewhat arid formulas of the text leading straight to broad and general views. In our daily work we were kept closely to our allotted tasks, and it was always easy to see that he was able, but it was on such exceptional occasions that we knew that he was great. And it was then that we had our first knowledge of the meaning of science, its insights and previsions. A teacher of this power is a light to his pupils, and they owe him a deep gratitude. I think this power of his was felt by all as great, even when it was not fully comprehended or appreciated. His weight and authority as a teacher were measured by his highest powers, not by the average of every day.

It is a privilege to quote a paragraph from a letter of Gen. Henry L. Abbot, Corps of Engineers, U. S. A., a pupil of Bartlett in the class of 1854. General Abbot writes:

> He was one whose influence upon the older graduates of the academy had few equals and whom we all remember with profound respect. His professional writings did honor to West Point. Personally I have never forgotten his interest in promoting my efforts to establish a suitable Engineer School of Application at Willets Point. He loaned me a full set of instruments for our little astronomical observatory from among those that had been replaced at the academy, and gave me much good advice about how to supplement the instruction received at the Military Academy. His interest in his pupils followed them in their life work.

LIFE AT WEST POINT.

An intimate picture of the simple life at West Point in the years 1840–1856 is given by Mrs. Théophile D'Orémieulx in the Bulletin of the Association of Graduates, U. S. Military Academy, No. 3, 1903, pp. 39–46. Captain D'Orémieulx was instructor of the French language at the academy for many years, an intimate friend of General Scott and a man of birth and culture. He was one of the founders of the West Point Army Mess, a social center; of an amateur orchestral club (where Beethoven's trios, and even Schumann's quintette, were played), and of other clubs and societies. Many of the officers' families kept but one servant at that time, or at most two—a cook at $8 per month and a maid at $4 or a little more. The Thanksgiving turkey cost 12½ cents per pound, eggs 23 cents a dozen, partridges 63 cents a brace (this was in 1853, the golden age). All lived under the same rule; there was no attempt at show; all were on the same social level, though the superintendent (then General Robert E. Lee) and the academic board of professors were older, of higher rank, and were naturally deferred to. Official and personal visits were punctiliously paid.

The river was crossed by rowboat, or on the ice, or not at all. New York was reached by the Hudson River Railway or by steamboat. The social life was necessarily confined to the post, and to the neighboring villages of Garrison, Highland Falls, and Cold Spring. At Cold Spring Mr. Gouverneur Kemble lived, and once a week, on Saturdays, he kept open house for the professors and higher officers, and for distinguished guests from all over the country. Regularly every Saturday Professors Mahan, Bartlett, and Church crossed in a rowboat to Cold Spring, there to dine, to play whist, and to return at night. No one of the academic board was a member of the Century Club, as most now are. New York was too far away. These details throw some light on the simple and dignified life at West Point. It was not an idle life by any means. All the preparation for lessons and lectures that is exacted of professors and instructors at colleges was part ot the daily work here, besides an infinity of details relating to the conduct and proficiency of cadets (the marking system is an integral portion of West Point methods). This was the atmosphere in which Bartlett lived for so many years. There was plenty of work, but little competition. Thoroughness was the essence of the instruction given. The justice of the discipline was absolute, or at least was so regarded by the cadets and officers of my own time (1866–73). We were, if not all a happy family, at least a self-respecting one.

THE MEMOIR ON RIFLED GUNS (1866).

In Ordnance Notes, Nos. 148 and 291, February 8, 1881, and April 18, 1883, Major George W. McKee, Ordnance Department, has papers under the title "The practical application of Bartlett's formulas to problems in gun construction," in which Professor Bartlett's analysis of the Parrott system of rifling is extended to cover the system then in use. Several of Bartlett's deductions are confirmed by calculation from data not available to him in 1866, and his practical suggestion as to the shape of the cutting tool in Benton's pressure gauge has been adopted in the Department.

Through the kindness of Brigadier-General William Crozier, Chief of Ordnance, Major Edward P. O'Hern, of the Department, has made a complete analysis of Bartlett's memoir in the light of all our present knowledge, which is printed in what follows. It must be borne in mind that the forty-five years that have elapsed since the appearance of Bartlett's memoir have been filled with the most elaborate researches on the subject, both theoretical and practical, at the hands of experts all over the world.

SUMMARY OF PAPER BY PROFESSOR WILLIAM H. C. BARTLETT, U. S. MILITARY ACADEMY, ENTITLED "RIFLED GUNS," PUBLISHED IN MEMOIRS OF THE NATIONAL ACADEMY OF SCIENCES, VOL. I, 1866; BY MAJOR EDWARD P. O'HERN, ORDNANCE DEPARTMENT, U. S. ARMY.

Professor Bartlett's paper entitled "Rifled Guns" is divided into two general parts. Part I discusses the strains to which rifled guns are subjected and Part II discusses the materials and dimensions of guns. The paper was published soon after the general introduction of rifled guns, and is probably one of the earliest scientific discussions and determinations of the stresses due to the introduction of the rifling. By the application of his formulas to a concrete example of the form of rifling then in use he demonstrated that the additional stresses due to the rifling were of a minor character in comparison with those that existed independently of the rifling.

Part I comprises a statement of the benefits derived from the introduction of rifled guns, a discussion of the additional strains due to the rifling, and of the fundamental principles that should govern in the design and use of guns, and a plea for the adoption of a uniform and safe system of artillery.

The general discussion is followed by the deduction of the formulas and by their application to specific problems.

The equation of the rifling curve for the twist used in the Parrott rifles, the most common type then in use in the U. S. service, is deduced in a clear, simple manner. This is followed by a very skillful mathematical deduction of two equations expressing the relation between the linear and the angular accelerations in terms of the velocity of the projectile, and of the elements of the rifling curve. By means of these equations the total longitudinal and torsional stresses due to the presence of the rifling may be computed. From a third equation may be computed the total stress tending to rupture the gun tangentially.

The formulas are applied in a number of interesting examples. The first is the determination of the total tangential, torsional, and longitudinal strains to which a 100-pounder Parrott gun was subjected in firings under certain specified conditions. In that determination there are certain errors whose presence is a little difficult to understand. The most serious of these is that the tangential stress was computed not at the time of the maximum powder pressure, but after the projectile had traveled one-third the distance down the bore, at which point the pressure was assumed to be one-third the maximum pressure. Having thus obtained the total values of the forces, a direct comparison of their amounts was made without inviting attention to the fact that the areas of metal engaged in resisting the forces were different in the case of the tangential stress as compared with the others. In deducing the equation for the longitudinal strains and in his discussions and application thereof, Professor Bartlett makes no reference to the very important stresses due to the acceleration of recoil. This omission can be explained on the ground that he was discussing only the additional stresses due to the use of the rifling, but the failure to refer to the existence of the other stress appears remarkable in view of the fact that the gun to which he applied his formulas was mounted so as to recoil.

In the computation of the work with which the projectile and powder charge leave the gun there is an error in assuming that the center of mass of the gas moves with the same velocity as the projectile; whereas until the projectile has left the bore it moves with approximately one-half the velocity of the projectile, and after that instant moves with much higher velocity, usually assumed as approximately twice the velocity of the projectile.

Computation of the work of friction is seriously in error in failing to include therein the friction on the driving edge of the lands, and the friction between the rotating band and the bore due to the action of the powder pressure in expanding a lip on the band, or in forcing forward the band on a coned surface in order to expand it into the rifling, as was necessary with muzzle-loading rifles.

Professor Bartlett proves by a mathematical analysis that on account of the energy of the moving parts the pressures registered by the crusher gauge then in use were probably much higher than the true values. His conclusions have since been fully verified by experiment, and have led to modifications in pressure gauges with a view to avoiding that source of error.

Part I concludes with a discussion of the friction developed between a projectile and its bursting charge and the resulting tendency to cause a premature burst by the ignition of the bursting charge.

Part II is a skillful mathematical analysis of the laws of transmission through the walls of a gun of the stresses resulting from the powder pressures. Professor Bartlett demonstrates that with the quickly acting black powders then in use the maximum pressure might be developed so quickly that the interior of the gun would be damaged before receiving proper assistance from the outer parts. The deduction was based upon the assumption that the velocity of transmission of the molecular resistance was the same as the velocity of sound transmission in the gun metal. He reaches the conclusion that a gun having its dimensions adjusted to slow powder might fail under the action of quicker powder, and recommends the use of slow powders.

His conclusion and recommendation are very sound. He fails, however, to mention the important advantage of the slower powder, in that the same muzzle velocity may be secured with a less maximum pressure, due to the greater movement of the projectile before the time of the maximum.

ACTUARIAL DUTIES (1870-1893).

In the last years of Professor Bartlett's service at the Military Academy (1870-71) his attention was invited to actuarial questions then interesting the authorities of the Mutual Life Insurance Company of New York City. With the assistance of his colleague, Professor Church, Bartlett made an investigation and report upon these matters which led to the proposal on the part of the company that he should retire from active duty at West Point to become actuary of the company at a salary (one that was, I believe, subsequently increased) more than double his army pay. After some hesitation, Bartlett consented to break away from old associations and ties and to begin at the age of 67 years an entirely new life of labor and responsibility.

He was most successful in his new office, and to the surprise and pleasure of his friends took on a new lease of life and vigor. He continued as actuary of the company until 1889, when he retired at the age of 85, and lived happy and honored till his death, at his home in Locust Hill avenue, Yonkers, in 1893, aet. 89. Some of his actuarial work was printed by the company, but when, on taking charge of the academy library in 1901, I sought for a complete collection of the printed works of my old teacher, it was found to be impossible to obtain all of them, even from the officials of the company. The library contains only his interest tables, a quarto volume. Much of his work was, of course, never printed, as it was of a confidential nature.

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