MEMOIR

OF

WILLIAM CHAUVENET.

1820–1870.

BY

J. H. C. COFFIN.

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BIOGRAPHICAL MEMOIR OF WILLIAM CHAUVENET.

MR. PRESIDENT AND GENTLEMEN:

A single decade has just closed since the organization of our Academy, yet sixteen of the original fifty members have passed from us. Some of these had long been laborers and leaders in the promotion of science and scientific investigations, and all have contributed to the advancement of science and to arousing the interest of others in scientific pursuits, and have been recognized by their works and merits, as fittingly worthy of membership in our limited band.

I have now, in accordance with our rules and by your selection, to present a tribute to the memory of WILLIAM CHAUVENET, at the time of his death Vice President of the Academy. By his election to this office, you have yourselves endorsed his selection for membership; and the American Association for the Advancement of Science has added its verdict by electing him in 1869 as its president for the session of the following year. As his friends feared, when the time came, his health had become far too feeble to allow of his attendance. Years before this he had been elected into the American Philosophical Society and the American Academy of Arts and Sciences. In 1860 St. John's College, Annapolis, Maryland, one of the oldest colleges in the United States, conferred upon him the merited degree of LL.D.

His father, William Marc Chauvenet, was born in Narbonne, France, in 1790. Left an orphan while yet a boy, his education was undertaken by two older brothers, then residing in Italy, and with considerable wealth. As secretary to one of these, at the time a chief commissary in Napoleon's army in Italy, he lived in that country during a part of his youth and early manhood. There he found abundant means and time to cultivate a natural taste for music and literature. Prof. Chauvenet often remarked that his father was his severest musical critic. At the downfall of Napoleon he was forced to look elsewhere for means of support, and came first to Boston, then to New York, as a partner in a

silk importing and manufacturing company. But this enterprise failed and nearly ruined him financially. Previous to this he had married Miss Mary B. Kerr, of Boston. He now gave up business. Fancying, from early association with one of his brothers, who was a somewhat noted agriculturist near Milan, that he would like a similar occupation, he purchased a farm near Milford, in Pike Co., Penn. A brief trial convincing him that he could not succeed in this enterprise, he removed to Philadelphia in 1821, engaging there in business, and this time with fair success. On the removal of the Naval School to Annapolis, in 1845, he accompanied his son, and, as that institution developed into its present form, he was appointed Assistant Professor of French. This position he held until his death, in 1855. He was endeared to those about him by a refined taste, the amenities of social life, the singular gentleness and purity of his character, and the consistency and earnestness, without obtrusiveness, of the religious faith for which he was noted. He was much esteemed and beloved, and his pupils, ofttimes very troublesome to their instructors of foreign birth, had not the heart to vex or trouble him.

To his father Prof. Chauvenet owed his love of music and literature. From his mother he appears to have inherited the logical exactness and methodical reasoning powers which are the basis of mathematical ability. She was noted for her excellent sound judgment, rarely, if ever, at fault, which, combined with tact and efficiency, and a kindly, unselfish disposition, rendered her invaluable as a neighbor and a friend. From her many estimable traits of character, she was much esteemed and beloved by those who were brought into association with her.

It was during their brief residence at Milford that their son, William Chauvenet, was born on the 24th of May, 1820. As an only child, he was carefully nurtured and cared for in Philadelphia, his home until after reaching the age of manhood. The best schools were selected for his instruction. As a boy he devoted himself but little to out-door sports, chiefly from the little opportunity afforded by a city life. But he early manifested a decided mathematical ability and a mechanical knack in his pastimes; "his kites always flew well, his fire balloons never failed." Later, "mechanical exhibitions of legerdemain would always set him

at work to reason out and finally reproduce the feats he had seen performed, and almost invariably with success."

His teacher for some years previous to his entering college was Dr. Samuel Jones, then conducting what at that time was considered the best boys' school in Philadelphia. One of his pupils thus speaks of him: "In his capacity to develop his pupils' powers, in fact to educate, he certainly was a remarkable man."

Prof. Chauvenet often said that the country needed more teachers like him. It was at the earnest solicitation of this worthy gentleman, that Mr. Chauvenet, who intended his son for a line of business similar to his own, consented to send him to Yale College. His preparation in mathematical studies was not only completed, but before admission he had already mastered the whole college course in that department. At the age of fifteen he had no knowledge of Latin or Greek, yet in one year he finished his preparation in these languages, with such success that he passed readily the examinations for admission, and at the end of his first college year took the first prize for Latin composition. During his last years at college he was the only one of a class of nearly 100 who took the special optional course in mathematics.

Entering college at the age of sixteen, he graduated in 1840 with high honors, due nearly as much to his classical as to his mathematical attainments.

Afterwards, in speaking of his college life, he remarked that it was sometimes a disadvantage to a boy to be too well fitted for college, and that in his own case this led him to neglect the study, which he could always command for the use of the day at sight, so that when he graduated he felt confident he knew less of mathematics than when he entered college.

Yet in his case we need not regret the opportunity afforded for other studies. A familiarity with classical and general literature, and with the entire range of the college course, and the subsequent symmetry of his intellectual development, were valuable results.

Soon after leaving college he was selected by Prof. Bache to assist in the series of magnetic observations undertaken at Girard College in Philadelphia. The friendship here formed between them was an enduring one. In such high esteem did

Prof. Chauvenet hold this friend's judgment, that later in life he often consulted him, and was more than once guided by his advice. Many of us look back upon the friendly influence and goodly counsels of this distinguished man, imparting his own interest in scientific labors and guiding and assisting in their pursuit, as also to his continued friendship, as among the valued reminiscences of the past.

And here let me allude to another, who at that time was contributing so largely in awakening on this side of the Atlantic the interest in astronomy which resulted in the establishment of observatories, and from which have grown the many valuable observations and astronomical discussions which have given a high repute to American astronomers. At the time of which I speak, the astronomical observatory at the Philadelphia High School was established through the labors and under the direction of Mr. Sears C. Walker. To him Prof. Chauvenet, in common with others, attributed the direction of his studies to this department of science, and to the vast fund and characteristic features of German mathematical and astronomical literature.

In 1841 he was appointed a professor of mathematics in the navy, and for a few months served on board the U. S. steamer Mississippi. A brief trial so well convinced him of the uselessness, both to himself and to the midshipmen whom he was expected to instruct, of the plan of teaching on ship-board, subject to the many inconveniences and interruptions of alternate life at sea and in port, that he decided to resign his appointment.

Midshipmen were then appointed, many of them as mere boys with but little schooling; sea-life first, intellectual development afterwards, was the naval maxim then, and with some officers is even now. Five or more years at sea, with or without instructors, as the case might be, and eight months' study at a school on shore, afforded all the required preparation for examination for promotion.

The naval schools at the three principal navy yards had in 1839 been concentrated at the Naval Asylum in Philadelphia, under the charge of Professor David McClure. His death occurring in 1842, Prof. Chauvenet was appointed to succeed him, and was thus retained in the navy for the valuable services he subsequently rendered in developing the present Naval Academy from this small beginning.

Young as he was, younger than many of his pupils, he inspired them with respect, and awakened an interest in their studies, so that something more than a practical acquaintance with the rules in Bowditch's Navigator was attempted by a few better educated or abler than the rest. A course of mathematical study was arranged, and obtained the sanction of the secretary of the navy. In one of his letters, prepared for an historical account of the Naval Academy, Prof. Chauvenet speaks in some detail of the almost ludicrously insufficient appliances and accommodations of the school, adding: "I found, however, that it was only necessary to ask for the necessary appliances to have them liberally granted."

The need of an institution for the education of officers of the navy, similar to that which had long been provided at West Point for those of the army, had, almost from the foundation of our present government, been urged on the attention of Congress and secretaries of the navy. Officers of high standing and of several grades were earnestly pleading for it, and some of the professors of mathematics had represented in strong terms the utter inefficiency of instruction at sea. But our secretaries of the navy were not all to blame for their apparent want of interest and neglect of so important a matter. The plans presented, many of them crude and imperfect, and almost as various as the individuals who offered them, could hardly be digested into a system by one in so laborious an office. With some exceptions these plans required the action of Congress. The idea that such an institution might be a growth, instead of a creation, was entertained by few.

Prof. Chauvenet did not stop with the slight advance which a limited eight months' course allowed. He drew up a plan for the expansion of the existing school into a regularly organized institution, in which all the subjects regarded as indispensable in the education of a navy officer were to be taught under competent instructors. He represented to the several successive secretaries (there were many in a few years) that they had the same power to send to the school several of the professors under their command, as only one, and other officers who might be willing to engage in instruction. "The first object was to initiate a successful course of study, and then to ask Congress to support it."

Prof. Bache entered earnestly into his views, and succeeded

in awakening an interest in the matter at the Navy Department. But to place midshipmen at a naval school before going to sea was too radical a change to be at once adopted. A two years' course, subsequent to sea-service, was all that was formally sanctioned, to go into effect in October, by Secretary Henshaw, but only to be revoked by one of his successors. The precedent, however, was established, and early in 1845 these views were effectively pressed on the new secretary, Hon. George Bancroft; and, the asylum at Philadelphia being needed for the veteran seamen, for whom it was intended, the naval school was removed to Fort Severn, at Annapolis, Maryland. A board of officers entered only so far into the views of its youngest member, that a plan was adopted of two years' instruction at the school, a service at sea of two or three years, and a final course of two years at the school. But even this advance was rescinded by a new secretary within a year. The old term of eight months was restored; but with great improvement in the course, not only in mathematics, but in providing better instruction in seamanship, and gunnery, and a little mechanics.

Undiscouraged by these failures, he still persisted, but it was not until 1851 that a four years' course before sea-service was adopted, and the Naval Academy in its present form was commenced. And yet it was an imperfect development of his plans. The arithmetic of whole numbers, with reading, writing, and spelling, were, and even for several years after his leaving the Academy, the only requisities for admission, and only within the last two years have the school studies of arithmetic, English grammar, and geography, which occupied the greater part of the first year, been remitted to the preparatory schools. It fell far short of the ideal for which he had been so long laboring. This required a much higher standard of admission, a more extended course; and, beyond this, that the chief instructors should be of recognized ability and attainments in their several departments, and that the graduates should be brought back, nominally as assistant instructors, but to give them opportunities for further studies; and moreover that the Academy, by its appliances, means, and aids for professional studies, should offer inducements to graduates to resort to it for further prosecution of any of the subjects which enter into their profession. In his own department he provided for this by the erection of a small observatory,

in which were an equatorial and a meridian circle by Repsold, the latter constructed much after his own plans, and manifesting in many of its arrangements the mechanical tact which had characterized him in early life. There were others who sympathized with his views and aided his efforts. But his was the guiding mind. The Naval Academy is more indebted to him than to any other for its development and organization. He availed himself of the opportunities which his position afforded, and proved to be the right man at the right time in the right place.

At first as professor of mathematics and astronomy, later of astronomy, navigation, and surveying, he was always the most prominent of the academic staff. The Academy derived reputation from his recognized ability. His sound judgment and just appreciation of all branches of instruction and all the wants of the institution gave to his opinions a controlling weight in the counsels of the academic board.

In a term of sixteen years, a large number of officers came in successive classes under his instruction. His intellectual abilities, his thorough knowledge of the subjects of instruction, the wide range of his attainments, a just appreciation of merit, an unwavering integrity, a uniform disposition, never disturbed by passionate excitement, and a kindly interest in those with whom he was associated, gained the esteem and respect of all. In naval circles his memory is revered.

In the recitation room he was noted for logical exactness, and for that peculiar tact, in which many fail, of promptly detecting what is in the mind of the student, and guiding his logical processes without being engrossed by his own.

In 1855, he was offered the professorship of mathematics in Yale College, but he was not ready then to relinquish his work at the Naval Academy; and again the professorship of astronomy and natural philosophy in 1859. This recognition by his Alma Mater was a gratifying and appreciated honor. At the same time, he was elected to the chair of mathematics in Washington University, then recently established in St. Louis by the munificence of its citizens.

Weighing well the claims of each, and considering all the circumstances of a connection with either, he decided in favor of St. Louis. It was with him mainly a choice, though there were other inducements, between an institution recognized as one of

the highest, oldest, and of most repute, and one just beginning life, but organized on plans and with a liberal scope which he approved, and where conscious usefulness would be his best reward.

But he found it necessary to regard the welfare of his family. The west seemed to offer a better field for the future of his sons, from whom during their education he did not wish to be separated. His long and patient labors in introducing into the navy an education deserving of the name, except in the estimation in which he was held, had received no fitting reward. At the Naval Academy he had not the means of providing for the education of his children, who were advancing to an age requiring higher and better schools than the neighborhood afforded. The fruitlessness of repeated efforts of himself and associates (they had but little aid, and even incurred opposition, from others) left little hope for the future. He felt a strong reluctance to sever old ties and associations, and left with regret the field to which he had devoted the best portion of his life. It is to the discredit of the Naval Academy, or rather of those who controlled its interests, that he was suffered to depart without any effort to retain him. But his loss was deeply felt by all who had the best interests of the Academy at heart. A few years later, when it was restored to its old moorings, from which it had been driven at the commencement of the war, and had suffered from want of proper appliances and unfavorable circumstances of its location in Newport, and many consequent irregularities, and the process of restoration had been successfully commenced, he was solicited to return. It needed one of his reputation to restore it to its former repute. But as long as the Naval Academy exists, his memory will not be forgotten.

Entering with characteristic energy in his new field, he gained at once the confidence and high esteem of those with whom he was associated. And in 1862, on the death of Chancellor Hoyt, he was chosen Chancellor of the University. His inaugural address in the following year, on the trite subject of education, evinces a breadth of philosophic thought, and a just appreciation of all departments of inquiry in which the human mind can enter, which render it well worthy of attention. In the organizing and superintending the several schools of instruction, and in his own special department, his memory claims and receives a lasting

tribute of gratitude from the friends and supporters of that important and rising institution.

Unhappily, in the spring of 1864 his health gave way, and, travelling in Wisconsin and Minnesota with hope of restoration, he was suddenly recalled to St. Louis by the death of his mother. The following winter and spring were spent in Minnesota, and he was so far restored that he was able to attend the meeting of our Academy at Northampton in August 1865, and in the fall to resume his duties at the University. The trustees had showed their appreciation of his worth by not accepting his previous resignation.

He devoted himself assiduously to his duties; but, his health again failing, he was obliged in 1869 again to relinquish them and resign his position. Passing the summer in Colorado and Minnesota, and the following winter in Philadelphia, in the spring, by the advice of his physicians, he went to Aiken, S. C. But it was too late to derive benefit from that benign climate. Returning to St. Louis, and thence to Minnesota, where he had previously been so much benefited, he finally closed a laborious, useful life at St. Paul, Minnesota, on the 13th December, 1870, in the 51st year of his age.

In developing and giving character and reputation to two distinguished educational institutions, he had done a noble work.

His professional duties were at all times arduous. At the Naval Academy, ofttimes four, and sometimes six hours a day, were required in the recitation room; yet he found time to prepare a work on trigonometry, published in 1850, which has been justly spoken of as "an important addition to our mathematical literature, being the most complete treatise on trigonometry extant in the English language.[1] While it contains everything useful to the mathematician and astronomer, the more elementary portions of the work are easily distinguished by the large type in which they are printed, and form of themselves a connected treatise, adapted to the wants of the young student." Yet it pursued the subject to its higher developments, supplying almost every want in astronomy and geodesy, and of those who required trigonometrical analysis in its varied forms as an instrument of investigation. It introduced the American stu-

[1] Journ. Frank. Inst., vol. xx., 3d series, p. 215.

dent to the methods of the German school, noted for the rigor and generalization and exhaustive character of its discussions, and to many topics wanting in all the text-books in the highest colleges in this country and in England, and found by our mathematical students only in German, French or Latin. The Gaussian equations, the finite variations and differentials of trigonometric expressions, the solution of the general spherical triangle, and the development of several functions into series of multiple angles, are instances most readily noted. What was found in many books was digested into a connected treatise, remarkable for its symmetry, its thorough exactness, and the clearness, conciseness, and purity of language of every expression. It is the only text-book in any branch, I have ever used, which I never criticized or found fault with. After the writings of Cagnoli, Gauss, Bessel, and others, it was hardly to be expected that anything new could be developed. Yet there are not a few topics which are new, and others in which he improved the discussions of these great masters.

At the time of its publication trigonometry in many of our colleges was restricted to the simple cases of plane and spherical triangles, by the trammelling geometric processes. Analytical trigonometry was but little known except to those engaged in astronomical or geodesic work. This book supplied a pressing need of the times, and, as a classic and complete work on the subject of which it treats, it will be long before it is superseded.

His manual of Spherical and Practical Astronomy was commenced at Annapolis, but completed at St. Louis, and, through the commendable liberality and appreciation of his friends in that city, published in 1863. In spherical astronomy it embraces all the topics which come up in the work of an observatory, or in astronomical work on land or at sea, and each is treated with the exhaustive generality and mathematical rigor of the German school. The whole is wrought into a symmetrical treatise, remarkable for its clearness and simplicity, and which could only be the work of a master mind, fully conversant with the subjects which it discussed. As has been aptly said by one well able to judge, "It represents astronomy in its most modern and perfected forms of research. Many of its investigations are either wholly or in part original, such, for example, as some of the

formulæ for latitude and eclipses, occultations of planets, improved method of lunar distances, etc."

The second volume on Practical Astronomy evinces the same completeness and thoroughness of analysis. It discusses, in an elaborate and exhaustive manner, all the best instruments used for astronomical observations, whether in the higher observatories, or in the more modest work in the field or at sea. An appropriate chapter on the method of least squares is added, in which the subject is treated with a perspicuity, and freedom from the mystery in which it has been shrouded, found nowhere else.

Each chapter is a monograph by itself, but here treated in unison with the rest, and with a noted symmetry. The theory of each instrument is admirably discussed, with all its needful appendages. It is not a minute description of a particular instrument, with its peculiar arrangements, but of its essential parts, while, as also in the first volume, there are many valuable suggestions and examples, illustrating what is needed and what is best in practice. It may need extension, as many subsequent improvements demand, but as yet it stands far above all others in the subjects of which it treats.

It is deeply to be regretted that failing health prevented his taking up another department of practical astronomy, which relates to the orbits and perturbations of the various bodies of our solar system. But another of our associates, Prof. J. C. Walton, with the exhaustive processes of the same school, has supplied this want.[1]

It is a marked evidence of the advancing progress of science among us, that each of these works, published as a hazardous experiment and with the supposition that few copies only would be required, has met with an increasing demand from year to year. The Astronomy is called for as much abroad as here. Both works exhibit a rare combination of the able mathematician, the skilled observer, and the expert instructor, fully appreciating the wants of the student.

In his early years at Philadelphia (1843), he published a work on the theory of logarithms, far more extensive and elaborate than what is found in our college text-books. It manifests the

[1] Am. Journ. of Sci. and Arts, xxxvi., 2d Series.

same thoroughness and exactness which are conspicuous in his later writings.

Several papers, chiefly on trigonometrical and astronomical problems, appeared at various times in the scientific journals. The most noted is on lunar distances, subsequently incorporated in his Astronomy, which, while equally rigorous with that of Bessel, was adapted to the usual tables in the British and American Ephemerides, and so simply and admirably arranged, that the non-mathematical navigator could use his method with almost equal facility as the imperfect processes usually employed.

In 1854 he devised and had constructed a "great circle protractor," by which at sea the course in a great circle could be determined with almost as much ease, as on a rhumb-line by a Mercator chart; and spherical triangles could readily be solved to the nearest quarter of a degree. This drew largely on his pecuniary resources, from which, a long time after, he was only partially relieved by its purchase by the hydrographic office.

At Philadelphia, in the last winter of his life, and when physical failing might well excuse from intellectual labor, he occupied himself with completing and publishing a work on the Elements of Geometry. It would seem as though an addition to the numerous books of this class was hardly needed, and could offer nothing new. Yet, following the system of Legendre, he wrote the whole in his own clear, precise style, improving wherever improvements could be made, and occasionally introducing a new proposition or a new mode of solution, and enlarging the limits of this fundamental branch. The addition of judiciously selected problems to be solved by the pupil supplied a needed want. Excellent as are some of the books on this subject which preceded it, it is an improvement on them all. It is more that it was the closing labors of his life that I speak of it here; but let us not forget, that, next to those who are directly laboring to extend and advance science, they contribute to its progress who prepare fitting aids to the young beginner, and remove the difficulties in his way.

In his youth he had become an expert performer on the piano, and, even up to the time of his leaving college, the strongest of all his tastes was for music; and he pursued its study, with characteristic earnestness and thoroughness, with the idea of devoting himself to it as a profession. Happily he was dissuaded from

this, and mathematical studies became his life work. But his love for music continued, and his enthusiasm and interest in it were marked characteristics up to the close of life. As only hours of recreation could be devoted to it, he confined himself to that which was of a classical character. Becoming acquainted with the works of Beethoven, he studied the interpretation of them with such success, that his rendering of them was always listened to in social circles with a silence which few others could command. Many declared that they never understood or appreciated these noble compositions until they heard them as rendered by him. As a musical critic, mere execution never satisfied him. It was not the artistic skill of the performer, of however high an order, but the music itself which roused his enthusiasm. In a letter not long before his death, after listening to Adelaide, a song by Beethoven, as sung to his accompaniment, he says, "It was tame as moonlight, where it should burn like a mid-day sun. I have never yet heard this song sung, except in my own soul. *Can* it be sung by the voice?" Again, after hearing a violin and piano sonata of the same great composer, he writes: "It was another revelation to me of Beethoven's many-sided nature. The Scherzo has haunted me ever since, and as I write, my pen will move only to the rhythm of it. Another played from Chopin and Mendelssohn, but everything pales before Beethoven's glorious effulgence."

In the various social circles in which he moved at different times, his society was always prized. The charm of his power of musical entertainment was fully supplemented by the wide range of subjects in which he was at home, for whatever he read, he read thoroughly and well, so that it became his own. In the more limited circle of intimate friends, his warm heart and affectionate interest, and judicious counsels, when needed, made him an invaluable associate, and there are many who have deeply deplored his loss. Charitably overlooking their faults, he constantly and unconsciously set before them an example of a life governed by elevated principle, and exhibiting a constant uniformity of disposition, never yielding to impulses and passions, and rarely if ever at fault. Such a one could have no enemies.

In his family the warmest traits of his character were constantly exhibited. In 1842, soon after taking charge of the naval school in Philadelphia, he married Miss Catherine Hemple,

of that city. It was a union of affection, which continued through his life, and, according to their religious faith, is not ended yet. He was devoted to his children, even in most laborious days, finding time in their childhood to join in their sports and contribute to their amusement, and in after years to guide their reading and studies and direct their tastes. He was their companion and friend.

Besides his wife, a daughter and four sons survive him. The former inherits his musical taste and ability, one of his sons is devoting himself to chemistry, and is state chemist of Missouri; the others, still young, are promising careers of usefulness. They all have our earnest sympathy in the loss they have sustained.

With his parents, he was a reader of Swedenborg and a believer in his doctrines. But a Swedenborgian in the sense of a belief in Swedenborg as the only guide of faith, he certainly was not. He admired his writings, and found in them a breadth and extent of philosophic and scientific thought, which accorded well with his earnest character. *Nullius jurare in verba magistri* was a maxim of his life, and he brought all religious thought to the test of the written word. He never obtruded the peculiarities of his faith on those who differed from him. But, in his constant unswerving religious life, he manifested his earnest faith in the religion which he professed.

In his inaugural address, already referred to, he says: "All education must have reference to man's destiny as an immortal being. If there is no future life, if all man's future hopes and aspirations are bounded by the finite horizon of this material existence, there is nothing left us but to enjoy the greatest amount of physical and intellectual happiness possible; and the only education desirable is that which teaches us the condition and limitation of human enjoyment." "If man is immortal, the education which he receives here must be but the first step of an indefinite progress. We are not to think of him as becoming immortal *after death*, but as immortal here and now." This close linking of our life here with that hereafter, and our intimate connection with the spiritual world, characterize the school of religious thought which he had embraced. This was his firm belief, and his whole life was consistent with such elevated and elevating faith. And in this he saw nothing inconsistent with the highest development of our mathematical, physical or natural science, but that it pre-

sented a different field of thought and sentiment. Those and other teachings of the sacred Scriptures he regarded as adapted to man's spiritual nature, and necessary to his highest wants. Can we afford to ignore them, constituted as we are by our Creator? He has passed from earthly life, with firmly grounded hope and aspirations for that higher life.

I append the following list of his published works and papers:—

Binomial Theorem and Logarithms for the use of the Midshipmen at the Naval School, Philadelphia. *Philadelphia*, 1843, pp. 92.

Solution to a Case of Sailing. *Amer. Journ. Sci. and Arts*, xlvi, 1844.

On the Method of Determining the Geographical Latitude by Altitude of the Moon. *Amer. Journ. Sci. and Arts*, liii, 1849.

On Lunar Distances. *Proc. Amer. Association*, 1850.

A Treatise on Plane and Spherical Trigonometry. *Philadelphia*, 1850, pp. 256.

On Unlimited Spherical Triangles and their Solution. *Gould's Art. Journ.*, i, 1851.

On the Employment of the Theorem, "Small Angles are Proportional to their Sines." *Gould's Art. Journ.*, i, 1851.

On a New Method of Correcting Lunar Distances for Parallax and Refraction. *Gould's Art. Journ.*, ii, 1852.

Tables for Correcting Lunar Distances. *Amer. Ephemeris and Nautical Almanac*, 1855; 1852.

Improved Method of Finding the Error and Rate of a Chronometer by Equal Altitudes. *Amer. Ephemeris and Nautical Almanac*, 1856; *Proc. Amer. Association*, 1853.

Some New Formulas of Spherical Astronomy. *Gould's Art. Journ.*, iii, 1854.

Note on the Solution of some Trigonometrical Equations by Series. *Gould's Art. Journ.*, iii, 1854.

A Simple Method of Correcting the Common Nautical Method of Double Altitudes of the Sun, Moon, or a Planet for the Change of Declination between the Observations. *Proc. Amer. Association*, 1856.

On a Method of Determining the Latitude of a Place from the Observed Times, when two known Stars arrive at the same Altitude. *Proc. Amer. Association*, 1856.

On the Method of Finding the Longitude of a Place by Transits of the Moon and a Star over the same Vertical Circle. *Gould's Art. Journ.*, v, 1858.

Note on the Projection of a Great Circle of a Globe on a Mercator Chart. *Math. Monthly*, i, Cambridge, 1860.

On the Locus of Perpendicular Tangents to any Conic Section. *Math. Monthly*, ii, Cambridge, 1860.

A Manual of Spherical and Practical Astronomy, vol. i, Spherical Astronomy, pp. 708; vol. ii, Theory and Use of Astronomical Instruments. Method of Least Squares, pp. 632. *Philadelphia*, 1863.

A Treatise on Elementary Geometry, with Appendices containing a Collection of Exercises for Students and an Introduction to Modern Geometry, pp. 368. *Philadelphia*, 1870.