Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Historia Mathematica ●●● (●●●●) ●●●–●●●
HISTORIA MATHEMATICA
www.elsevier.com/locate/yhmat

Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950

David E. Zitarelli *

Temple University, Philadelphia, PA 19122, USA

Abstract

This paper weaves two interlocking histories together. One piece of the puzzle traces the development of the American mathematician Joseph B. Reynolds from a peripheral player to an active contributor to mathematics, astronomy, and engineering and to the founding of a sectional association of mathematicians. The other piece describes the evolution of his institution, Lehigh University, from its founding in 1865 to a full-fledged research department that began producing doctorates in 1939. Both Reynolds and Lehigh straddled the line between the pre- and post-Chicago eras in American mathematics.

Zusammenfassung

In dieser Arbeit werden zwei ineinander greifend Geschichten dargestellt. Einen Teil der verflochtenen Geschichte bildet die Entwicklung des amerikanischen Mathematikers Joseph B. Reynolds von einer Randerscheinung sowohl zu einem aktiven Autor mathematischer und astronomischer Arbeiten sowie solcher aus den Ingenieurswissenschaften als auch zu einem Begründer einer sektionalen mathematischen Gesellschaft. Der andere Teil der Geschichte betrifft die Gründung seiner akademischen Einrichtung, der Lehigh University, von ihrer Gründung 1865 bis zu einer reifen Forschungsabteilung in den 1939 Jahre Promotionen aufweisen konnte. Sowohl Reynolds als auch die Lehigh University können als Scharnier zwischen der Vor- und Nach-Chicagoer Ära in der amerikanischen Mathematik betrachtet werden.

MSC: 01A70; 01A73; 01A60

Keywords: Reynolds; Lehigh; American mathematics; Engineering

1. Introduction

J.B. Reynolds (1881–1975) and R.L. Moore (1882–1974) were contemporaries who contributed to the emerging American mathematical community in vital ways, yet their contributions reflect entirely different strata within this community. Moore is well known for his eponymous teaching method and pivotal role in the development of topology. He is regarded today as a figure who towered above the American mathematical landscape in the first half of the 20th century [Zitarelli, 2001a, 619–623]. Within the past few years, a biography has detailed many aspects of his

* Fax: (215) 553 5705.
E-mail address: zit@temple.edu.

0315-0860/$ – see front matter
doi:10.1016/j.hm.2006.10.005

life and times [Parker, 2005], while two historical papers have analyzed his mathematical exploits [Lewis, 2004; Zitarelli, 2004]. Reynolds, on the other hand, is virtually unknown, although his role in the evolving community was sketched in a recent article [Zitarelli, 2005]. Unlike Moore, he had little direct contact with the leading figures of the day, none during his formative years, but he was a productive scholar whose output exceeded that of most American mathematicians in the first half of the 20th century.

We exhume Reynolds's record because of his varied productivity in pure and applied mathematics, astronomy, and sundry fields of engineering. Along the way we strive to portray his human side by drawing from his professional writings and diaries, as well as interviews and correspondence with surviving family members. And for the historian it is always refreshing to find a mathematician with an abiding interest in history. Not only did he sign his book on genealogy "Jos. B. Reynolds, Family Historian" [JBR, 1940a], but his 75-yr history of mathematics at Lehigh is a major resource for the early development of that department [JBR, 1941a].[1] In this paper we describe his education, interests, publications, and professional activities with a view toward presenting him as a transitional figure straddling two entirely different worlds of mathematics in the United States. The dividing line between these two worlds may be taken to be the establishment in the 1890s of the University of Chicago with its primary emphasis on research mathematics. In the case of Reynolds the pre-Chicago paradigm can be seen in his rearing and early schooling (reflecting life on the plains), higher education (with strong ties to astronomy), onerous teaching load, and participation in a general science organization (the Pennsylvania Academy of Science). On the other hand, post-Chicago elements appear in a reduced load that afforded time to write books and papers (in a striking array of journals in pure and applied mathematics, astronomy, and engineering) and to engage actively in a specialized organization (the Mathematical Association of America).

Reynolds spent all but one year of his academic life at Lehigh, where changes that took place in the 1920s typify the struggle that many American universities endured while attempting to replicate successful programs at the country's top-ranked institutions. The histories of the mathematics departments at most of the latter institutions have been fairly well documented, but not those at emerging departments, so we sketch the history of Lehigh through the first half of the 20th century. (For instance, the three-volume *A Century of Mathematics in America* [Duren, 1989] contains accounts of Harvard, Yale, Chicago, Princeton, Stanford, Berkeley, NYU, Columbia, MIT, Michigan, and Texas.)

At the turn of the 20th century dramatic changes in higher education transformed the mathematical landscape in the United States from an educational backwater to a legitimate enterprise. The groundbreaking book by Parshall and Rowe [1994] discusses these developments in detail for the period 1876–1900, singling out the contributions of major players (the Englishman J.J. Sylvester, the German Felix Klein, and the American E.H. Moore) at leading universities (Johns Hopkins, Göttingen, and Chicago, respectively). But it also cites work by mathematicians outside this exclusive group. We document the life and work of one of these rank-and-file figures, as well as the transformation of his university, showing how both emerged with a strong research agenda.

2. Early education

Joseph Benson Reynolds was born on May 17, 1881, in Skidmore, near New Castle, the county seat for Lawrence County, located in western Pennsylvania near the border with Ohio. He was the seventh of eight children born to Peter Stafford and Lydia Ann (Kemp) Reynolds, who married in 1865 and lived in a log cabin. In 1872 the family moved into a brick farmhouse they built themselves, where they became expert in farming and stock raising. Deeply held religious beliefs formed the core of their daily existence, with values transmitted to their children so thoroughly that none ever touched a drop of liquor. As another indication, every mention of a Saturday night social event in Reynolds's diaries finds him leaving in time to arrive home by midnight; there is never any mention of frivolity on the Sabbath and only on rare occasions a hint of work, including grading papers or conducting research.

Reynolds received his early education at the one-room Painter Hill School and then New Castle High School. His contemporary R.L. Moore also attended a one-room school. Reynolds, however, could only take classes in winter during nonfarming seasons, so he turned 22 just before receiving his diploma in 1903, the first person in his family to graduate from high school. The previous year he earned a Teachers Provisional Certificate for "being a person of good moral character" and passing examinations in 12 subjects, including mental arithmetic, written arithmetic, algebra,

[1] References in the form [JBR, 1941a] refer to the corresponding publication by Joseph B. Reynolds in the Appendix.

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

and the theory of teaching, which suggests plans to become a high-school teacher. It is unknown whether he harbored loftier ambitions at the time.

This brief survey provides the first sign of Reynolds' straddling posture. His farming roots and secondary education reflect an earlier period in American mathematics, but his higher education was a product of emerging trends. He enrolled at Lehigh University on a full scholarship based on superior performance on the entrance examination in eight subject areas, including algebra, plane geometry, Greek, and Latin. It is natural to ask why Reynolds left his close-knit family for a school located in the eastern part of Pennsylvania, some 350 miles away. After all, the University of Pittsburgh was within 50 miles and in the midst of an exciting period inspired by the grand opening of the Hotel Schenley, while Slippery Rock University was located just 16 ms away. An interview with his nonagenarian daughter, Mrs. Jane Parsons, revealed that Reynolds detested farm work and was anxious to get as far away from it as possible.[2] His diaries disclose, however, that he returned to New Castle to help with farmstead chores for many summers after he had moved to Bethlehem.

As a mature student, Reynolds fared very well at Lehigh. He was listed as honorable mention in a university contest conducted toward the end of his freshman year, with grades in mathematics courses of 9.7 (out of 10) in spherical geometry, 8.4 in algebra, and 7.8 in trigonometry. In his sophomore year his grades included a 9.8 in physics, 8.4 in analytic geometry, and 8.6 in calculus. In his final two years, the only mathematics courses he took were least squares and determinants, though he elected related courses in astronomy, analytical mechanics, and physics. As a result of his outstanding performance, he graduated with first honors, a $10 prize for first honors in mathematics, election to Phi Beta Kappa, and selection as salutatorian of the class. Lehigh required all candidates for the A.B. degree to produce a thesis. Reynolds wrote his on "The temperature compensation of the Bond sidereal clock of Sayre Observatory at Lehigh University," a topic that portended his abiding professional interest in applications of mathematics [JBR, 1907].

3. Lehigh history

Lehigh University offers a prime example of second-tier departments that initiated plans for graduate programs in the 1920s but did not see them blossom until after World War II. We recount its founding and compare it with two others that emerged contemporaneously, Johns Hopkins and Cornell. We also describe the mathematics curriculum, which was influenced strongly by that of the United States Military Academy at West Point. We then trace the development of upper-level offerings during the 45 years Reynolds was associated with the department, emphasizing the radical change in its mission from his student days at the beginning of the 20th century to the time of his retirement in 1948.

Lehigh was founded in 1865 by Judge Asa Packer (1805–1879) to educate "men learned in ... careful and exact thought by a due study of the dead languages and mathematics" [Stevens, 1869, 22]. Women were not permitted to take classes until 1916, and only then at the graduate level; women entered undergraduate ranks only in 1971. Right from the start, Lehigh's emphasis was on engineering and science but not at the expense of a classical education, because all curricula (then called "schools") required grounding in the classics. Packer provided a $500,000 endowment he hoped would provide free tuition forever. He was not alone in this desire. The Baptist minister Russell Conwell and the philanthropist Leland Stanford founded Temple and Stanford Universities in 1884 and 1891, respectively, with the goal of charging no tuition, based on donations from parishioners at Baptist Temple and a sizable endowment at Stanford [Royden, 1989, 238–239]. But that policy was soon reversed at all three institutions, with Lehigh reinstating tuition in 1891.

While the founding of Cornell was supplemented by funds from the Morrill Land Grant Act of 1862, neither Lehigh nor Johns Hopkins benefited directly from the act. Unlike Johns Hopkins and Cornell, Lehigh was not named after its benefactor, but the most significant difference was the influence of West Point on staffing and curriculum. Lehigh's first president, Henry Coppée (1821–1895), was an 1845 graduate of the Military Academy who served in the army during the Mexican War and taught at West Point and the University of Pennsylvania before moving to Lehigh in 1866. Besides administrative duties, Coppée taught classes in history, logic, rhetoric, political economy, and Shakespeare, and wrote several elementary textbooks, including one on logic.

[2] The interview was conducted 15 July 2005 in the house Reynolds had bought initially as a summer cottage in Sugar Run, Pennsylvania. It became his permanent home upon retirement.

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

Table 1
Mathematics curriculum at Lehigh by 1920

Year/semester	Fall	Spring
Freshman	Analytic geometry (5) Elementary mechanics (5)	Differential calculus (5) Elementary mechanics (5)
Sophomore	Integral calculus (5)	Differential equations (5) Analytic mechanics (2)
Junior	General astronomy (3)	Practical astronomy (3)
Senior	Elective in geodesy	

Faculty appointments of West Point graduates ensured that mathematics would play a central role. The initial Lehigh faculty consisted of five professors, with one in mathematics, mechanics, and engineering (MM&E) and another in physics and astronomy. The first MM&E professor, Edwin Wright Morgan (1814–1869), taught there from the time classes began in the fall of 1866 until his death three years later. An 1837 West Point graduate, he was superintendent of a military institute in Kentucky before coming to Lehigh. Morgan was replaced by Hiero Benjamin Herr (1842–1920; USMA 1866), who had taught at West Point the two previous years. The mathematics and physics departments underwent a dramatic change in 1871, when MM&E became mathematics and astronomy, and physics joined with mechanics. The first professor of physics and mechanics was Lorenzo Lorain (1831–1882; USMA 1856). But Herr remained at Lehigh for only 5 yr, being succeeded by Charles Leander Doolittle (1843–1919), who chaired the department 1874–1895. Doolittle, with no apparent connections to West Point, had received a C.E. degree from the University of Michigan a few months before accepting the Lehigh offer. Known affectionately as "Poppy Doo" by his students, he strengthened the curriculum during his 21-yr tenure, in which five of the six instructors he hired were Lehigh graduates and both of his sons served as instructors after receiving their bachelor degrees. Doolittle left in 1895 for the University of Pennsylvania, where he became the Flower Professor of Astronomy the following year. He was succeeded by Charles Lewis Thornburg (1859–1944), who had earned four degrees (B.S., B.E., C.E., and Ph.D.) in four consecutive years (1881 through 1884) at Vanderbilt University, culminating in a dissertation on the transit of Venus. Thornburg became quite ill during his first autumn on campus and tendered his resignation, but the administration refused to accept it, so he returned the next fall in full health and set about modernizing the curriculum.

The first two years of the Lehigh curriculum had remained basically the same for all students from 1866 until 1896, requiring courses in mathematics, physics, and chemistry as well as composition and literature, history, drawing, and languages (Latin and German both years, plus Greek the first and French the second); a thesis was required for graduation. By the time Reynolds enrolled in 1903 his texts in geometry, algebra, and trigonometry no longer reflected West Point, earlier popular editions having been replaced by more modern versions. The new model was Chicago, not the Military Academy. The change in mathematics offerings under Thornburg resulted in the curriculum shown in Table 1, where numbers in parentheses denote the number of class meetings—one hour each—per week; these classes met from 9 a.m. until 4 p.m. weekdays and until noon on Saturdays. This change did not alter the practice of mathematics classes meeting every day of the week during the first 2 yr, however. It is noteworthy that knowledge of astronomy remained the major goal of the new mathematics curriculum.

A popular tradition known as the Calculus Cremation tells how Lehigh students felt about their experience in mathematics. It began in the mid-1870s with students hiring bands to play songs set to well-known tunes with lyrics they themselves had composed, but by the next decade it grew into an elaborate torch parade through the streets of Bethlehem, with printed programs distributed to crowds numbering in the thousands. When the parade reached campus, a trial was conducted on an effigy of Calculus, which was dragged into court, confronted by witnesses dressed like professors, and sentenced to death by fire, resulting in a blazing bonfire of calculus books. Unfortunately during the 1890s the affair turned into a drunken orgy and the administration replaced it with a more respectable program restricted to campus. Not surprisingly, student interest waned. An attempt was made during Reynolds's undergraduate days to revive the tradition but the revival never took root and the Calculus Cremation was interred during World War I.

The initial fuel for the fire was the popular text by Charles Davies (1798–1876), *Elements of Analytical Geometry and the Differential and Integral Calculus*. Initially intended for cadets at West Point, it was "the first commercially

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

successful calculus text written by an American" [Rosenstein, 1989, 83]. In 1891 Lehigh replaced it with *Differential and Integral Calculus with Examples and Applications* by George Abbott Osborne (1839–1927), who, ironically, taught at the Naval Academy. Unlike Yale, which then adopted texts by their own faculty members, Lehigh eschewed *Differential and Integral Calculus for Technical Schools and Colleges* by Preston Albert Lambert (1862–1925) even though he was a Lehigh graduate (B.A. 1883, M.A. 1891) who had joined the faculty in 1884, spent 1892–1893 studying in Germany, and became the university's first research mathematician. (See [JBR, 1925c] for details of Lambert's career.)

Lehigh graduate offerings experienced a checkered history. As early as 1873, alumni could remain as "resident graduates" to attend lectures in any department over the next three years free of charge. An 1879 announcement that the university would award master's, Ph.D., and Sc.D. degrees showed the influence of Johns Hopkins, but whereas Hopkins president Daniel Coit Gilman conducted an international search for researchers to lead new programs, Lehigh presidents Henry Coppée and John McDowell Leavitt sought personnel within the Lehigh family. This attempt was clearly misguided. By 1896 only two Ph.D.s had been granted, neither in mathematics, so all doctoral programs were unceremoniously terminated. Nonetheless, the 1879 announcement prodded faculty to offer advanced courses, as reflected in the 1895 catalog description of a 2-yr program in mathematics consisting of six graduate courses:

- First year: spherical astronomy, methods of least squares, numerical calculus.
- Second year: celestial mechanics, interpolation and quadrature, and computation of orbits and perturbations.

Clearly the focus was on astronomy and applied mathematics. However, the foundation for a modern program evolved between 1900 and 1925, during which time the department developed seven graduate courses. Reynolds himself complained that "The teaching of graduate courses was seldom encouraged" [JBR, 1941a, 53] and taught only one such course during this period.

4. Advanced degrees and career

Although P.A. Lambert's calculus book was never adopted by his home institution, he spent his entire career at Lehigh after receiving his bachelor's degree. So did Reynolds. He was hired as an instructor in 1907 by department head C.L. Thornburg, who appointed only 6 Lehigh graduates among the 17 new faculty members hired during his 30-yr tenure (1895–1925). Although Reynolds complained mildly in his diary about the burden of teaching an 18-h load, he managed to pursue advanced courses and obtain an M.A. degree in 1910. His transcript shows that between 1907 and 1910 he took only three formal courses, none in mathematics: theoretical astronomy (four credits), practical astronomy (two), and theoretical mechanics (nine). The introduction to his thesis, "The determination of the elements of the orbit of a minor planet: Taunton no. 94, 'Lehigh,' " describes the nature of his work and the naming of the asteroid (then called a "minor planet") [JBR, 1910a]:

> Early in Dec., 1909, the Rev. Joel Metcalf of Taunton, Mass., discovered a minor planet. It was nearing opposition at the time and he estimated its magnitude at 12.5. Its position was photographed at four different dates ... After Feb. 1, it was lost in the Milky Way.
>
> The measurements of the positions on the plates for these four dates together with the B.D. minutes of the comparison stars were sent to Prof. John H. Ogburn of Lehigh University and under his direction the author has deduced the following elements of the planet's orbit. By the kind permission of Mr. Metcalf the planet has been named "Lehigh."
>
> Our thanks are due Prof. Doolittle of the Flower Observatory of the University of Pennsylvania for the A.G. (1875.0) positions of the comparison stars.

Regarding the name of the asteroid, J.H. Ogburn offered to compute its orbit in return for naming rights but Reynolds actually carried out the calculations. Reynolds proceeded to study the asteroid's movement for the next 3 yr, resulting in his first three publications, each presenting an ephemeris of the planet in the weekly *Astronomical Journal*. The first paper was lifted directly from his thesis [JBR, 1910b], making good on a suggestion that appeared on the official transcript from 6 June 1910, which read, "May publish thesis results under Prof. Thornburg's supervision."

The two subsequent papers established the planet's correct magnitude as 13.4 [JBR, 1911, 1912]. These publications undoubtedly contributed to his promotion to assistant professor in 1913.[3]

Although Reynolds seemed to be on course for a career in astronomy, his interest in mathematics had not waned, as he took a 1-yr course in differential equations (and another in theoretical mechanics) during 1910–1911, the year after receiving his master's degree. The dearth of offerings in mathematics in the Lehigh Valley at that time surely limited his opportunities, yet he showed no interest in pursuing graduate work at the University of Pennsylvania (unlike J.R. Kline, who graduated from nearby Muhlenberg College in 1912, entered Penn the next year, and became R.L. Moore's first Ph.D. student in 1916). Reynolds was unable to take any mathematics courses during 1911–1912 but the next year he enrolled in the second year of the theoretical mechanics sequence. Happily, Lehigh reduced teaching loads uniformly in 1915 to 12 h (or 13 for those who, like him, taught a 4-h course in mechanics), although class size averaged 20 during the period of higher teaching loads but increased beyond 30 afterwards.

The reduction afforded Reynolds time for independent study, which he devoted to vector analysis. There is no clue in his diary to this sudden change in primary interest from astronomy, but the end result was a doctoral dissertation, "The application of vector analysis to plane and space curves, surfaces, and solids" [JBR, 1919]. No copy of this work remains at Moravian College, where it was submitted in 1919. The only extant version is a 252-page handwritten work shelved in the archives at nearby Lehigh, and fragmentary evidence suggests that this was the original copy. For one, Reynolds's diary entry from 3 April 1919 reads, "Moravian College faculty voted my Ph.D. this morning. Got my thesis and notebooks back." For another, all geometrical figures are drawn with precision, demonstrating an impressive ability to render precise curves by hand. His wife and he would later hook rugs that still cover the floor in their Sugar Run home with geometrical patterns resembling these curves. Precise drawings can be seen in the first section (of five) of the dissertation, where he used numerous plane curves of a sort in vogue at the time to solve several *Monthly* problems. We list three of the curves, along with the intriguing names he attached to them.

- The dumbbell: $a^4y^2 = a^2x^4 - x^6$ [JBR, 1919, 17].
- The bowknot: $x^4 = (x^2 - y^2)ay$ [JBR, 1919, 17].
- The devil: $y^4 - x^4 - a^2y^2 + b^2y^2 = 0$ [JBR, 1919, 18].

In a later section Reynolds introduced a vector notation to succinctly express formulas for conoids that theretofore required long and involved forms [JBR, 1919, 103]. Figure 1, which reproduces page 18 from the dissertation, demonstrates the precise rendering of the graph of the devil and shows an earlier use of vector equations.

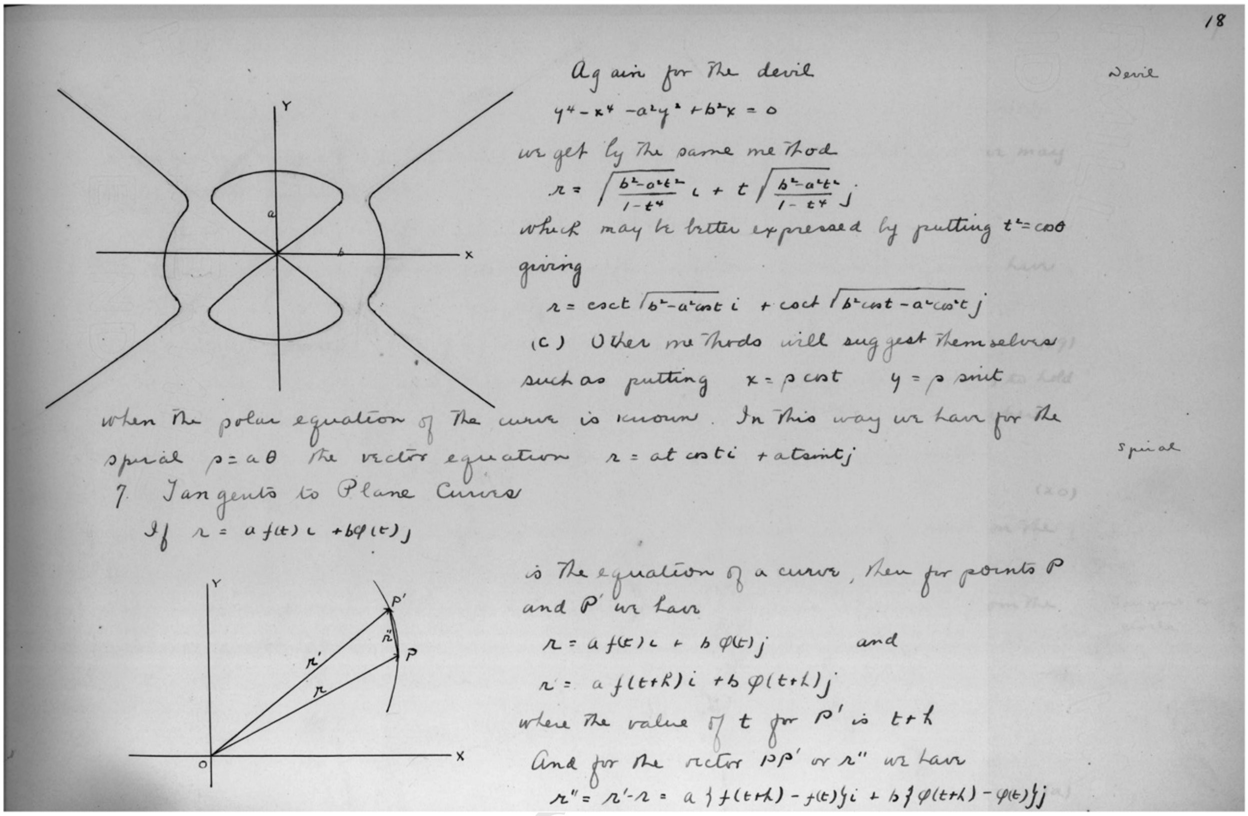
The practice of awarding doctorates by small colleges is practically nonexistent today, but it thrived up to about 1920. Founded in 1742 as separate boys' and girls' schools, Moravian College did not grant advanced degrees for over a century. A history of the institution states that in 1863 Moravian was "authorized to award a variety of earned degrees, including the doctor of philosophy and the master of arts. In the course of its history about a dozen of the former were granted, mostly to members of the teaching staff" [Weinlick, 1977, 47]. The requirements were spelled out in the college's catalogs: "The degree of Doctor of Philosophy may be conferred on College graduates who, after having taken a Bachelor's degree, shall have devoted themselves for not less than two years to advanced studies under the direction of the Faculty, passed examinations in them, and presented a dissertation embodying the result of original investigation on some topic previously approved by the Faculty. Candidates for this degree must spend at least one of the two years in study in attendance at the College." After 1921 Moravian catalogs no longer mention Ph.D. degree requirements.

Reynolds devoted the minimum amount of time to the program. According to faculty minutes from 18 October 1917, his proposal listed four areas of investigation beyond work he had completed for his master's degree:

(a) A study of Richter's *Advanced Rigid Dynamics*.
(b) A study of Love's *Theory of Elasticity*.
(c) A course in differential geometry offered at Lehigh University.
(d) A dissertation titled "The application of vector analysis to plane and space curves, surfaces and solids."

[3] Unlike today, assistant professors were not granted full faculty rights. Reynolds's diary for 12 May 1919 stated, "Received notice that asst prof are invited to faculty meetings from now on." Three weeks later he proudly announced, "Attended my first faculty meeting today."

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005


18

Again for the devil — Devil

$y^4 - x^4 - a^2y^2 + b^2x = 0$

we get by the same method

$r = \sqrt{\frac{b^2-a^2t^2}{1-t^4}}\, i + t\sqrt{\frac{b^2-a^2t^2}{1-t^4}}\, j$.

which may be better expressed by putting $t^2 = \cos\theta$

giving

$r = \csc t\sqrt{b^2 - a^2\cos t}\; i + \cot t\sqrt{b^2\cos t - a^2\cos^2 t}\; j$

(c) Other methods will suggest themselves

such as putting $x = \rho\cos t$ $y = \rho\sin t$

when the polar equation of the curve is known. In this way we have for the

spiral $\rho = a\theta$ the vector equation $r = at\cos t\, i + at\sin t\, j$ — Spiral

7. Tangents to Plane Curves

If $r = af(t)i + b\varphi(t)j$

is the equation of a curve, then for points P and P' we have

$r = af(t)i + b\varphi(t)j$ and

$r' = af(t+h)i + b\varphi(t+h)j$

where the value of t for P' is $t+h$

And for the vector PP' or r'' we have

$r'' = r' - r = a\{f(t+h) - f(t)\}i + b\{\varphi(t+h) - \varphi(t)\}j$

Fig. 1. A page from Reynolds's dissertation. Courtesy of Lehigh University Archives.

The book cited in (a) probably refers to *Über die Bewegung eines Körpers auf einer Horizontalebene* (1887) by Max Richter; it is known that Reynolds was fluent in German.[4] Augustus Edward Hough Love's *A Treatise on the Mathematical Theory of Elasticity* was first published in 1892. The course in (c) paid immediate dividends, with his dissertation making critical use of "the usual formulas of differential geometry" [JBR, 1919, 153].

The Moravian faculty minutes concluded, "The work is to cover two years. The charges are to be 25.00 per year and the diploma fee is to be 10.00." Minutes from 3 April 1919 confirm that Reynolds satisfied all requirements within 2 yr:

> It was reported that Mr. Jos. B. Reynolds, an instructor at Lehigh University and candidate for the PhD degree at this institution, had completed his major work on Differential Geometry and his minor work in analytical mechanics, as well as his thesis "The Application of Vector Analysis to Curves Surfaces and Solids." This work being submitted for approval and having been found satisfactory by the professor in charge, it was on motion accepted and the degree is to be conferred at the commencement exercises.

Not until the turn of the 20th century did it became widespread practice for doctoral recipients in the U.S. to acknowledge a dissertation supervisor. For instance, at the University of Pennsylvania, Edwin Schofield Crawley (1862–1933) was awarded a doctorate in 1892 with a dissertation composed of papers already published, and he was listed as the supervisor for a dissertation the following year. That turned out to be the only such attribution at Penn in the years 1893 to 1902, but during 1903 to 1924, 16 of the 20 dissertations cited a supervisor. The last one lacking such mention was completed by Perry A. Caris (1890–1966) in 1925. (See the booklet [Penn, 1999] for a history

4 His diary from 1919 records an interest in learning Chinese from Lehigh student T.Y. Tseng. Several slips of paper with Chinese characters and words are inserted into that year's diary.

of the mathematics department at Penn and [Zitarelli, 2001b, 32 and 36] for biographical information on Caris and Crawley, respectively.)

Reynolds's dissertation does not list a supervisor but his diary entry from 8 March 1919 records, "Turned in my work for Ph.D. degree this afternoon. Dr. Rau much pleased with thesis." Albert George Rau (1868–1942), dean of Moravian College from 1909 until his death, was a polymath with a B.S. degree from Lehigh (1888) and Ph.D. from Moravian (1910) in economic sociology. He published books on the history of 19th-century Europe (1898) and on music by American Moravians (1938), as well as many monographs on colonial history. He and Reynolds became charter members of the Mathematical Association of America (MAA) when it was formed in late 1915. They both solved *Monthly* problems and attended a few sectional MAA meetings. Rau presented the paper "The teaching of mathematics in the Pennsylvania German schools" at one such gathering in 1935. (See [Zitarelli, 2001b, 68] for an account of his lecture and additional biographical information.) Overall, Reynolds's dissertation consisted of original research, a 20th-century development, but the topic and granting institution were firmly rooted in the preceding century. He maintained an affinity for Moravian College throughout his life, representing the MAA at the inauguration of its president 30 yr later, in 1949.

Degree in hand, and already 38 years old, Reynolds set about establishing academic credentials. He had published but one paper, in the *Monthly* [JBR, 1917], so he was relatively unknown when he attended the annual AMS–MAA meeting at Columbia University in late December 1919. Among the 143 in attendance was a mathematician who would turn out to be an important force in Reynolds's career, Albert A. Bennett (1888–1971), then at the army's ordnance department in Washington, DC (on leave from the University of Texas). Two years later Reynolds published a paper in the *Mathematics Teacher*, which had just become the official journal of the nascent National Council of Teachers of Mathematics [JBR, 1921]. This record hardly warrants promotion by today's standards, yet regarding the milieu at Lehigh up to this time he wrote, "Heavy teaching rosters and lack of atmosphere pretty thoroughly squelched attempts at research" [JBR, 1941a, 54]. Nonetheless, he was promoted to associate professor that year.

Reynolds's production increased markedly from 1923 to 1927 as the result of a critical event that occurred when Charles Russ Richards, Dean of Engineering at the University of Illinois, assumed the Lehigh presidency in 1922. Richards sent word to the faculty at once that "there was going to be a change and that we could expect to leave off being a small college and become a university; that members of the Faculty would be expected to do research work" [JBR, 1941a, 65]. It took over 2 yr for this radical change in mission to affect the mathematics department, but its implementation exacted a heavy toll. C.L. Thornburg was the first casualty, being removed as chair in February 1925. Ironically the man credited with modernizing the curriculum over his 30-yr tenure was now charged with opposing meaningful change aimed at thrusting Lehigh into the ranks of research universities. But tragedy struck when acting head P.A. Lambert drowned just 2 wk later in a freak accident, whereupon Reynolds became acting chair for the remainder of what he termed "a demoralizing year" [JBR, 1941a, 65]. Fortunately two events that fall enabled the turbulent year to end on a resounding note, both involving Albert A. Bennett, whom Reynolds had met 6 yr earlier. First, Bennett was appointed chair, an excellent choice to carry out President Richards's announced research agenda because he was a Princeton graduate (Ph.D. 1916 under Oswald Veblen) who had been a colleague of R.L. Moore at the University of Texas. The decision to hire an outside head initially left Reynolds unsure of his status in the department. However, on 15 January 1926 he recorded in his diary, "Bennett ... told me today that there was a place here for me at L.U. and Dr. Richards expected to advance me so I need not look for another position." Thus reassured, Reynolds took advantage of the occasion to spend the year 1926–1927 on sabbatical leave at Princeton. By the time he returned in the summer of 1927 he had been promoted to full professor, yet the department had another new chair, Tomlinson Fort (1886–1970)—the fifth within three years—his close friend Bennett having accepted an offer to return to his *alma mater*, Brown University. Fort arrived with a Harvard Ph.D. and additional studies in Paris and Göttingen, so his credentials for carrying out the announced research mission were impeccable. He would remain at Lehigh until 1945, steadying the department and establishing its first legitimate Ph.D. program in 1936. The awarding of degrees began sporadically, with three granted during 1939–1941 and another three during 1949–1951, but it was 1958 before the department awarded Ph.D. degrees regularly.[5]

The other notable event from the fall of 1925 linking Reynolds with Bennett, as well as J.R. Kline, was the founding of an MAA section. A recent paper [Zitarelli, 2005] posited that Reynolds was responsible for the idea of forming a

[5] The first doctorate was awarded to E.S. Kennedy, a well-known historian of mathematics at the American University of Beirut who spent every third or fourth year at Brown, where he established a thriving school of historians of Islamic science.

section of the MAA, and two sources unknown at the time of the writing of this paper provide proof for that assertion. A footnote in the history of the Lehigh department reads: "While acting head of the department Reynolds initiated a movement to establish a Lehigh Valley Section of the Mathematical Association of America. This developed under Bennett's management into the establishment of the Philadelphia Section of the Association" [JBR, 1941a, 72]. One might view such an assertion as self-aggrandizement since Reynolds is the author, but a letter in the Lehigh Archives affirms its veracity. On 3 July 1925, MAA secretary–treasurer W.D. Cairns wrote:

> I should apologize very deeply for neglecting to reply to your letter recd some weeks ago ... The plan of a Lehigh Valley Section is a fine one; I am only wondering whether an Eastern Pa. Section would be more valuable ... Would it not be feasible for those in the eastern half of the state to get together at one place once each year?

This letter confirms the vital role that Reynolds played in a section that was formed at an organizational meeting held at Lehigh on the Saturday following Thanksgiving in 1926; it was called the Philadelphia Section even though its dominion stretched throughout eastern Pennsylvania, Delaware, and southern New Jersey.

The years 1922 to 1927 were critical for Lehigh and for Reynolds's career. His work before then put him in league with those mathematical enthusiasts who filled 19th-century journals with small papers and contributed vigorously to their problem sections. But he adapted well to the charge set out by President Richards, as can be seen in a key diary entry from 2 February 1925 that encapsulates the president's view of professionalism and Reynolds's stature within that view:

> Dr. Richards and I discussed education and he told me what he felt was needed further to improve me. He said a good university man should be first a good teacher, second a good faculty man, third a productive man, fourth a broadly acquainted and educated man. He said in the first three my qualifications were fine and I had played the game since he came about the best of any on the faculty, that I was a good teacher, a good conscientious committee man, a writer of articles, but he felt my education was too local and I ought to spend a year broadening it when the opportunity offered and he said he would get me a leave at half pay.

In short, Reynolds was satisfactory in teaching, service, and publication, but lacking in exposure to modern, higher education.

Richards was a man of his word, and a year later Reynolds was on his way to Princeton as guest professor. The experience in upper-level graduate courses offered by world-class scientists would affect Reynolds deeply for the rest of his life. One can only wonder what he might have accomplished if he had been afforded such an educational opportunity at age 20 instead of 45. Interestingly, Reynolds thrived in the engineering courses, notably one from the fall of 1926 conducted by George Erle Beggs (1883–1939), a civil engineer who applied his method for predetermining stress resistance to the construction of the Arlington Memorial Bridge and the towers of the Golden Gate Bridge. He also studied spectroscopy under Henry Norris Russell (1877–1957), whose pioneering use of atomic physics for analyzing stars played a principal role in laying the foundations for modern astrophysics. The following spring Reynolds took a course on the theory of X-rays with Arthur Holly Compton (1892–1962), who would be awarded the Nobel Prize in physics that fall for his experiments on the intensity of X-ray reflection from crystals, resulting in what is known in quantum physics today as the "Compton effect" or "Compton scattering." While Reynolds found these courses stimulating, his experience in mathematics was somewhat disappointing. On the one hand, his diary contains regular complaints about the obscurity of Wedderburn's lectures on algebra, as well as occasional gripes about the inaccessibility of Veblen's seminar on differentiable geometry. Fortunately guest lectures to the mathematics club by such luminaries as Herman Weyl, Alfred Haar, and Dirk Struik provided a helpful counterbalance, so overall Reynolds found Princeton exhilarating and rewarding.

Richards was delighted with Reynolds's performance at Princeton and promoted him to Professor of Mathematics and Theoretical Mechanics. That position came with new responsibilities, however, one of which took effect immediately upon his return to campus in June 1927, when he taught a 6-wk course in mathematical surveying to a group of engineering students that involved living in a tent at a camp on mountains about 2 h from Lehigh. As he had done at Princeton, Reynolds commuted in his new Essex car every Monday morning and Friday afternoon.

Beginning in the fall of 1927 Reynolds put his Princeton experience to good use in investigations that resulted in numerous papers and books in mathematics and engineering. His work at the interface of engineering and mathemat-

Table 2

Chair	Term
E.W. Morgan	1866–1869
H.B. Herr	1869–1874
C.L. Doolittle	1874–1895
C.L. Thornburg	1895–1925
A.A. Bennett	1925–1927
T. Fort	1927–1945
J.B. Reynolds	1945–1948
G.E. Raynor	1948–1960
A.E. Pitcher	1960–1978

ics soon resulted in an invitation to present his views at a distinguished conference.[6] In June 1934, Cornell hosted a two-day conference on "Advanced courses in mathematics for engineering students," in cooperation with the annual meeting of the Society for the Promotion of Engineering Education (SPEE). Thirteen papers were delivered, most of them by industrial engineers representing the Packard Motor Company, Westinghouse Electric and Manufacturing Company, General Electric Company, and the Air Force, but Reynolds was a panelist along with three other academicians. His former colleague and section founder A.A. Bennett began the program by describing opportunities available to mathematicians for industrial consulting. Next, J.B. Scarborough (Naval Academy) listed mathematical topics necessary for understanding developments in engineering that had arisen during the preceding 30 yr, and I.S. Sokolnikoff (University of Wisconsin) proceeded to describe post-calculus courses that would address these topics. When it came time for Reynolds to speak, the usually conservative mathematician proffered surprising advice, as the tone from minutes of the conference suggests [Weaver, 1934, 487]:

> Professor Reynolds seems to think that, in general, there is no place for advanced courses in mathematics in existing engineering curricula and that there is not much hope of their being included in such curricula. His solution is the establishment of a curriculum in general engineering with specialization in mathematics. This curriculum would stress careful analytical thinking in a few fundamental mathematics courses rather than in a number of specialized courses.

The curriculum that Reynolds recommended never materialized, perhaps because its reliance on careful analytical thinking smacked of "proofs," and the proper role of mathematics in engineering education remains fluid to this day.

Reynolds continued to publish in both mathematical and engineering journals from the time of the Cornell conference up to World War II. Given his practical bent and engineering expertise, it is somewhat surprising that he never participated directly in either world war, unlike Bennett, for example, who volunteered in both. In 1945 the 64-year-old Reynolds was appointed head of the department, a position he held for 3 yr until his retirement. Minutes from a meeting of the Pi Mu Epsilon student chapter held a couple of months before his retirement state that he was the guest of honor and that he "gave an account of the progress and amusing events he has seen take place in the more than forty-one years he has been associated with Lehigh University" [Vogelsong, 1949, 127]. Table 2 presents a list of all eight department chairs during Lehigh's first century.

Following retirement, Reynolds moved to Sugar Run, PA, a rural town located 115 miles northwest of Bethlehem. He remained there until his death in December 1975, a fact not recorded in the *Monthly* for another 4 yr, when the notice read "date not known" and listed his residence erroneously as Erie, PA [Haeder, 1979, 327]. The lack of accuracy is not surprising because by age 94 he had lost touch with the mathematical community, though 10 yr earlier he had attended an MAA summer meeting where he was honored along with 17 other living charter members. That same year the *Monthly* printed the solution to the last problem he submitted, bringing full circle a lifetime of problem-solving activity he had begun 50 years earlier. We turn to this activity in the next section.

In 1908 Reynolds married the former Chloey Bessie Graham (1881–1971), a high-school graduate who had been a teacher in New Castle. They had three children: Peter Graham (1909–1995), Jane Niblock (b. 1913; married Rev. William A. Parsons in 1938), and Joseph Benson Jr. (1920–1992). (See Fig. 2.) In 1936 Reynolds purchased a summer

[6] A contemporary mathematician working at the interface of mathematics and engineering was Reynolds's former colleague Morris Knebelman (1890–1972), who held a similar position at Princeton 1929–1939 after receiving a Ph.D. under Oswald Veblen and Luther Eisenhart.

Fig. 2. J.B. Reynolds with children and wife. Photograph courtesy of Ruth Parsons.

home along the Susquehanna River in a remote part of northeastern Pennsylvania called the "endless mountains" with funds that survived the stock crash and resulting depression. He attributed his financial success in the market to patience, a virtue he went to great lengths to teach his children. His daughter Jane recalled that he would often take her to campus and make her wait for him while he conducted classes. One day, however, he became distracted after class and walked home without her, not realizing his mistake until reaching the house, whereupon he returned two miles to campus to find his child diligently waiting in the hallway. Many years later, in 1971, Jane and Bill Parsons moved into the Sugar Run house where Reynolds had lived since his retirement in 1948, in order to care for him after his wife of 63 years had died. The Parsonses were given the house when Reynolds died 4 yr later at age 94.

5. Problemist

Problems played a central role in almost every 19th-century mathematics journal in America. The only such journal still flourishing today, *The American Mathematical Monthly*, carried the subtitle, "Devoted to the solutions of problems in pure and applied mathematics, papers on mathematical subjects, biographies of noted mathematicians, etc." In his review of its problems departments during 1894–1954, Charles Trigg wrote, "At its inception, the *American Mathematical Monthly* was essentially a problem journal ... Finkel advocated the educational value of a good senseless problem as against that of the so-called practical problem which is so insisted upon by some modern educators" [Trigg, 1957, 3]. Reynolds proposed and solved both types of problems, although there was no hint of such activity until 1915, when the *Monthly* included two he had proposed:

- Problem 309. The tangent at one cusp of a vertical, three arched hypocycloid is horizontal, and a particle will just slide under gravity from the upper cusp to this cusp. Find the equation which the coefficient of friction must satisfy.
- Problem 384. In what time will a sum of money double itself at 6 per cent interest per annum if compounded at indefinitely short intervals?

Problem 309 combines two of Reynolds's specialties—analytic geometry and mechanics. Problem 384 is a typical exercise in many textbooks today when introducing exponential functions.

Reynolds was smitten by the problems bug. Later issues in 1915 acknowledge correct solutions to three problems, with one proposed by Finkel appearing in print. The next year, when the *Monthly* became the official journal of the MAA, he proposed three problems and solved another. But his banner year was 1917, when 7 of the journal's 10 issues contained at least one entry, amounting to 19 altogether (four printed solutions, seven solutions listed under "Also solved by," six problems proposed, and two solutions of problems he had proposed). Although some problems dealt with astronomy and mechanics, most concerned mathematics proper. He solved one problem that year that had been proposed by Bennett, whom he did not know at the time.

Those who regard problems as lowly exercises would probably assign Problem 384 to this lot, but Problem 309 is of a different ilk. Cajori wrote, "This solving of problems is very beneficial at first, but it becomes a waste of time if one confines himself to that sort of work" [Cajori, 1890, 284]. This statement rings true for many of the towering figures in mathematics, beginning with E.H. Moore, who furnished solutions to six problems in the *Analyst* from the fall of his senior year at Yale (1882) through the fall of his first year in graduate school (none was chosen for publication). By contrast, Reynolds continued to solve and propose problems in the *Monthly* throughout his lifetime, an activity that warranted inclusion in the famous *Otto Dunkel Memorial Problem Book*, which listed him among six problemists who "upon becoming emeritus found continued problem-solving an effective weapon against vegetation" [Trigg, 1957, 8]. Moreover, one entry was selected among the 400 "best problems" proposed from 1918 to 1950 [Eves and Starke, 1957, 22].

6. Publications

If Reynolds's claim to fame was only as a section organizer and problemist, there would be little reason to profile his contributions to American mathematics. We regard him, however, as an accomplished mathematician who served as liaison with the engineering community in the first half of the 20th century. It is important to emphasize that he was not a first-class research mathematician; he neither published in a major research journal nor presented a paper at an AMS meeting. Even participation in MAA affairs was with the section he helped found and not the national association. However, he presented invited papers at a national engineering society, which places him again at the interface of mathematics and engineering.

Reynolds's original investigations in several different fields display an impressive versatility, beginning with the period 1910–1921. This can be seen in a small note in the *Monthly* that is suitable today as an exercise in a calculus course [JBR, 1917], as well as the paper "Vectors for beginners" in the *Mathematics Teacher* [JBR, 1921], which extended results from his doctoral dissertation. He also published a paper in the journal *Engineering Record* that improved computations from an earlier article on the design of sand boxes by a Lehigh civil engineer [JBR, 1916]. Reynolds commented, "There occurred to me a simple method of solving the equation graphically," one that was based on a clever construction of a triangle that enabled him to confirm values the author had obtained in convoluted fashion [JBR, 1916, 630]. Another work displayed a budding interest in history when he traced his genealogical roots back to England and published his findings with support from a Reynolds family group [JBR, 1914]. The pursuit of history ultimately bore fruit in a booklet on the history of his specific branch of the family tree [JBR, 1940a] and three other historical accounts related to Lehigh [JBR, 1925c, 1934b, 1941a]. Overall, his record through 1921 was meager, but these three works anticipated fields he would pursue in later investigations—mathematics, engineering, and history.

The transitional period 1922–1927 saw Reynolds's output increase substantially. In 1923 two *Monthly* papers continued his work on vector analysis [JBR, 1923a, 1923b]. The following year he was invited to review the book *Vector Analysis* by the Göttingen applied mathematician Carl Runge, which had just been translated into English. The contents were quite advanced (an introduction to the mathematical theory of relativity in terms of tensors, and applications to hydromechanics, electromagnetic theory, elasticity, and the lattice structure of crystals), yet Reynolds concluded, "This book is ... comprehensive and meaty yet not too formidable" [JBR, 1924b, 244]. His selection as reviewer of a work by such an eminent mathematician suggests a growing reputation. But this did not mark the end of his activity with vector analysis. In 1926 he delivered a paper at the inaugural meeting of the Pennsylvania Academy of Science and published the abstract in its *Proceedings* [JBR, 1926b]. Details of this talk can be found in his final paper on this topic, which appeared in the *Tôhoku Mathematics Journal* [JBR, 1928d].

A paper from 1925 foreshadowed an interest in methods of calculating area and volume, adopting clever methods for computing volumes of pyramids, spheres, and surfaces of revolution using limits intuitively but no other concepts from calculus [JBR, 1925a]. Two subsequent papers addressed this theme, one of which developed a formula for volumes of revolution that generalized a classical result attributed to Pappus [JBR, 1928b]. The other is of interest mainly for what it tells us about the source of Reynolds's research topics: "To some students applications of a subject or method outside of those found in the text studied is a never-failing stimulus to renewed thought and effort. The beginning of a life of research is frequently to be found in such small revelations" [JBR, 1928c, 197]. Two other papers dealt with evolutes of a parabola, one in the *Proceedings of the Pennsylvania Academy of Science* [JBR, 1926c] and the other in the *Monthly* [JBR, 1927]. By this time Lehigh was sponsoring weekly research seminars, and his diary records several occasions where he vetted results before submitting them for publication. The two remaining items from the transitional period paint a vivid contrast with the foregoing papers on serious mathematical subjects—a short piece in the *Pennsylvania School Journal* [JBR, 1924c] and a local newspaper article on an eclipse of the sun [JBR, 1925b]. The latter two pieces are reminiscent of times when mathematical practitioners wrote articles on education for school journals and on popular astronomy for newspapers.

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

Reynolds engaged in none of these lower sorts of publication after his sabbatical. From the time he returned to Lehigh in June 1927 until he retired 21 yr later, he published 12 papers on mathematical topics, 13 in engineering, and 5 textbooks on calculus and mechanics, one of which ran to three editions. The remainder of this section presents a chronological overview of his contributions in each of these realms—mathematics, engineering, and textbooks.

Within mathematics, Reynolds published five papers in the *Monthly*, three in *National Mathematics Magazine*, two in the *Proceedings of the Pennsylvania Academy of Science*, and one each in the *Mathematics Teacher* and *Tôhoku Mathematics Journal*. These works appeared in three separate periods: six in 1928–1933, one in 1938, and five in 1944–1948. We have already cited his three mathematics papers from 1928 on volumes and vector analysis. Three others distinguish him as one of the few American-born mathematicians who investigated applied topics before World War II. The first involved the Archimedean problem of determining the positions that certain homogeneous prisms would assume as a function of their specific gravity. He concluded, "The results of the analysis in this article can be verified by floating prisms of differing specific gravities in water or other liquids" [JBR, 1931a, 112]. Another article derived two differential equations that describe the motion of a flexible, inextensible chain that slides down a curve, with or without a portion of the chain initially hanging vertically over the lower edge of a plane [JBR, 1933b].

Reynolds wrote only two papers in pure mathematics in the 1930s. One was a *Monthly* piece on summing series using Fourier expansions [JBR, 1932a] and the other a brief note in the forerunner of today's *Mathematics Magazine* [JBR, 1938c] on a method of integration. Just as the invitation to review Runge's important book in 1924 helped establish Reynolds's reputation in vector analysis, two reviews in 1938–1939 validated his standing in other specialties. The review of a book of tables bears relevance today because it shows interest in tables of mathematical formulas, a topic then closely connected with computing machinery [JBR, 1938e]. A diary entry from 19 March 1926 addressed this issue over a decade earlier: "Practiced a bit on our new computing machine today. It is quite a marvelous device." In another review requested by the *Bulletin*, Reynolds bemoaned the fact that his beloved fields of vector analysis and mechanics were losing their luster in mathematics: "Apparently the trend in technical schools is rather away from heavy courses in mechanics than towards them. The teacher finds himself forced to do the best he can with the usual preparation in calculus, no matter how desirable a knowledge of vector analysis may be in a study of analytical mechanics" [JBR, 1939c, 346].

The *Monthly* and *National Mathematics Magazine* also served as the outlets for the five papers he wrote from 1944 to 1948. The first dealt with methods for solving differential equations he claimed were appropriate for "every student who is trained for engineering or other scientific work" [JBR, 1944a, 578]. The second presented geometrical interpretations of the formula for the statistical mean [JBR, 1944b], while the third derived an equation of an ellipse to explain the workings of a machine built by precision-tool manufacturers for cutting nuts (for bolts) in the shapes of various regular polygons [JBR, 1945]. His final two papers were written during his three years as chair of the department; one derived techniques for integrating certain functions using the method of undetermined coefficients [JBR, 1947], the other proved the rule for double roots in linear differential equations [JBR, 1948].

Reynolds's contributions to engineering were remarkably varied, featuring numerous works in fields developing in the 1930s, some co-authored with colleagues in various departments and others with industrial engineers. By contrast, all of his writings in mathematics were solitary efforts. His collaborative efforts in engineering were foreshadowed by two papers in the 1920s that highlight his ability to publish in nontraditional venues. The short "How to find the contents of storage tanks" was coauthored with a Lehigh chemical engineer, which explains why it appeared in *Chemical and Metallurgical Engineering* [JBR, 1924a]. Two years later "Relation of surface area to fineness modulus," written with a Lehigh civil engineer, was published in the journal *Concrete* [JBR, 1926a]. In the period 1930–1941 he carried out collaborative research on various applied topics, concentrating on mechanical engineering. He co-authored with a mechanical engineer a two-part article in the *Transactions of the American Society of Mechanical Engineers* (ASME) that was based on papers that had been presented at an ASME meeting held in New York City [JBR, 1932b, 1932c]. A related work in a periodical called *Iron Age* was not by Reynolds, but a report about a two-year investigation on the eccentricity of spiral springs under compression carried out with a Lehigh research associate and based on a paper delivered at another ASME meeting [JBR, 1933a]. He also published a joint work with two Lehigh chemical engineers called "Studies in the drying oils" [JBR, 1934c]. It too was based on an address given at a national gathering, this time an annual meeting of the American Chemical Society held in St. Petersburg, FL. Finally, the paper "Chain links under cross forces" appeared in the *Journal of Applied Mechanics*, which encouraged readers to comment on its articles [JBR, 1939b]. Criticism by a Cornell professor of machine design warranted a brief rejoinder from the

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

Table 3

Books by J.B. Reynolds	Year
Elementary Mechanics	1928
Analytic Mechanics	1929
Analytic Geometry and the Elements of Calculus	1930
Forty Lessons in Analytic Mechanics	1939
Elements of Mechanics	1943

author [JBR, 1940b]. Ironically 10 yr earlier Reynolds signaled expertise in mechanical engineering with a similar commentary [JBR, 1930a].

Reynolds's remaining papers concerned topics in automotive, agricultural, chemical, and civil engineering. One on stresses endured by truck frames was written with the engineer in charge of trailers at Mack Trucks, a subsidiary of International Motor Corporation [JBR, 1931b]. Another calculated the strength of cylinders subject to internal and external stresses based on earlier experiments carried out in ordnance labs with a Lehigh physicist [JBR, 1934d]. The next year Reynolds offered a five-page commentary on the mathematical theory of twisting I-beams, responding to an earlier article by a civil engineer at Columbia University, a topic that had been on his agenda for at least 9 yr [JBR, 1935]. Finally, a paper from *Science* on the causes of falling chimneys was based on experiments he had conducted to determine the strength of certain materials and the stresses they can withstand [JBR, 1938a]. It corrected an earlier piece by a different author.

A diary entry from 4 June 1926 notes the difficulty all scholars face when attempting to publish outside their immediate specialty. Reynolds reports that he asked a colleague "where to send [my] paper on twisted drills that the *American Machinist* thought too mathematical for its readers." Perhaps this explains why no paper on engineering after that time was a solitary effort. For instance, an article about spoked wheels on automobiles appeared in *Agricultural Engineering* and was written with F.L. Ehasz, a research fellow in civil engineering [JBR, 1936]. Five years later Reynolds also served on Ehasz's doctoral examining committee for a Ph.D. in civil engineering. Reynolds's final paper in engineering dealt with welded girders and was written with two Lehigh civil engineers [JBR, 1941b]. For unknown reasons, his work in applied mathematics and engineering came to an abrupt halt in 1941, with only a textbook on mechanics appearing after that time.

This book was the last of the five texts Reynolds wrote, four of them on mechanics. (See Table 3.) His first textbook, *Elementary Mechanics*, was written at the request of fresh department head Tomlinson Fort to be the text for a new freshman course offered by the department [JBR, 1928a]. That course met 3 h a week and included a mandatory 3-h study session as well. The text was revised and enlarged (from 250 pp. to 336) [JBR, 1934a] and then reprinted [JBR, 1937]; it remained popular well into the 1940s. The second book, *Analytic Mechanics* [JBR, 1929a], was used as the text in the upper-level mechanics course for 10 yr, when it was replaced by *Forty Lessons in Analytic Mechanics* [JBR, 1939a]. Reynolds's final book, *Elements of Mechanics* [JBR, 1943], written with colleague George Emil Raynor (1895–1975), was produced only in lithoprint form.[7]

Reynolds wrote one other text, a standard calculus book co-authored with his Allentown-born colleague Frank Mark Weida (1891–1977) that was adopted at Lehigh for a short while [JBR, 1930b]. Weida was one of three new hires in the department in 1925 along with Norman Taylor and department head A.A. Bennett. None remained at Lehigh long: Bennett moved after two years to Brown, while Taylor became chair at George Washington University after only 1 yr and hired Weida three years later.

7. Conclusion

Joseph Benson Reynolds was 22 yr old when he graduated from high school and 38 when he was awarded a doctorate from Moravian College, hardly the typical background of a successful research mathematician. After his doctorate he initially seemed content with being a mathematical enthusiast who savored problem solving and applications to engineering. However, in 1922 his institution, Lehigh, brought in a new president with a charge to transform the institution from a college to a university, a radical change that required faculty members to publish as well as teach.

7 Raynor had received a Ph.D. from Princeton in 1923 with a thesis on Dirichlet's problem.

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

Reynolds adapted particularly well to the transformation, which is especially impressive in view of his limited formal education. Yet it was his exposure to world-class scientists during a sabbatical year at Princeton—at the educationally advanced age of 45—that profoundly influenced the rest of his life. Until this point, Reynolds had taken only four courses beyond calculus, two at the undergraduate level (least squares, determinants) and two in graduate school (differential equations, differential geometry), all at Lehigh. But the research initiatives of the mathematicians Veblen and Wedderburn, the engineer Beggs, the astrophysicist Russell, and the physicist Compton stimulated him to write 12 papers in mathematics, 13 co-authored works in engineering, and 5 textbooks over the 20 yr of his career. All the while he engaged in *Monthly* problems, his last appearing at age 84.

It is difficult to characterize Reynolds within the history of mathematics in the United States in the first half of the 20th century. His case is not as simple as, say, R.L. Moore's, who spent the first part of his career as a researcher and the second as a mentor. Moore, and his doctoral students, published in the leading journals (even in Europe), presented invited papers at national meetings, and held the highest offices in the AMS and MAA. Reynolds certainly does not fit this mold. He published no papers in mathematics research journals (at least one was rejected by the *Annals*); he produced no Ph.D. students (Lehigh awarded only three before he retired); and his only presentations to, as well as offices held in, mathematics organizations were at the MAA sectional level. Our account has portrayed him as a pure mathematician (earning some renown as a problem solver), an applied mathematician (astronomy, mechanics, and a broad range of engineering sciences), an amateur historian, an able administrator, and a founder of an MAA section. These exploits earned him listings in *Who's Who in American Education* and *Who's Who in Engineering*.

Reynolds's work in mathematics followed an evolutionary path, even if his university, Lehigh, radically reinvented itself. Likewise, his contributions to mechanics evolved from classroom assignments that began in 1915 and continued to World War II. His engineering papers were written with many coauthors across a range of disciplines, most resulting from regular contact with colleagues in various departments, a common occurrence in midsize universities. In this way Reynolds emerged as a sort of mathematical consultant for engineers, reminiscent of T.H. Gronwall, who was portrayed in this role so convincingly in [Gluchoff, 2005]. But Reynolds's stable home life and academic position, which stand in stark contrast to Gronwall's personal and professional problems, allowed him to cap a fulfilling career with a 3-yr term as chair before retiring in 1948. Significantly, all but one of his papers in the 1940s dealt with traditional mathematical topics.

In attempting to characterize Reynolds, it is useful to adapt Nathan Reingold's [1976] classification of early American scientists (into cultivators, practitioners, and researchers) by assigning separate categorizations for each of the distinct periods of his career. During 1910–1921 Reynolds can be viewed as a mathematical *enthusiast* engaged in problem solving and writing a few small notes. When Lehigh reinvented itself, however, he rose to mathematical *practitioner* during the critical period 1922–1927. But it was his sabbatical year at Princeton that propelled him into the rank of productive *scholar* in mathematics and its applications to engineering during his final period, 1928–1948. Few American mathematicians in the first half of the 20th century achieved the level of leading international research figures. Most devoted all of their time to teaching, and of those who published after receiving their doctorates, the primary outlets were the *Monthly* and *Mathematics Magazine*. Reynolds stands as a leading representative—perhaps even a paragon—of this underrepresented group.

Acknowledgments

The author gratefully acknowledges the help he received from Lehigh curators Philip A. Metzger and Ilhan Citak, Lehigh registration assistant Judith Petrick, and Moravian archivist Jan Ballard. He is very appreciative for the interviews he was able to conduct with Reynolds's daughter Jane Parsons and her children Ruth and David. He is indebted to Mrs. Parsons for providing him unrestricted access to her father's diaries and to Ruth Parsons for serving as tour guide to the family's home in Sugar Run. Finally, the author extends sincerest thanks to Joseph H. Reynolds, grandson of our Joseph B. Reynolds, for providing much personal information about his paternal grandfather.

References

Cajori, F., 1890. The Teaching and History of Mathematics in the United States. Government Printing Office, Washington.

Duren, P. (Ed.), 1989. A Century of Mathematics in America. Am. Math. Soc., Providence, RI.

Eves, H., Starke, E.P. (Eds.), 1957. The Otto Dunkel Memorial Problem Book. American Mathematical Monthly, vol. 64 (No. 7, Part 2). Mathematical Association of America, Menasha, WI.
Gluchoff, A., 2005. Pure mathematics applied in early twentieth-century America: The case of T.H. Gronwall, consulting mathematician. Historia Mathematica 32, 312–357.
Haeder, P.A., 1979. News and notices. American Mathematical Monthly 86, 325–327.
Lewis, A.C., 2004. The beginnings of the R.L. Moore school of topology. Historia Mathematica 31, 279–295.
Parker, J., 2005. R.L. Moore: Mathematician and Teacher. Mathematical Association of America, Washington, DC.
Parshall, K.H., Rowe, D.E., 1994. The Emergence of the American Mathematical Research Community, 1876–1900: J.J. Sylvester, Felix Klein, and E.H. Moore. Am. Math. Soc., Providence, RI.
Penn, 1999. Centennial Celebration. University of Pennsylvania, Philadelphia, PA.
Reingold, N., 1976. Definitions and speculation: The professionalization of science in America in the nineteenth century. In: Oleson, A., Brown, S. (Eds.), The Pursuit of Knowledge in the Early American Republic: American Scientific and Learned Societies from Colonial Times to the Civil War. Johns Hopkins Univ. Press, Baltimore, MD, pp. 33–69.
Rosenstein, G., 1989. The best method. American calculus textbooks of the nineteenth century. In: [Duren, 1989, vol. 3, pp. 77–109].
Royden, H., 1989. The history of the mathematics department at Stanford. In: [Duren, 1989, vol. 2, pp. 237–278].
Stevens, W.B., 1869. The Lehigh University, Its Origin and Aims: An Historical Discourse, Delivered in the Chapel of Packer Hall, on University Day, June 24th, 1869. A.C. Bryson & Co., Philadelphia, PA.
Trigg, C.W., 1957, The Monthly problem departments, 1894–1954. In: [Eves and Starke, 1957, pp. 3–8].
Vogelsong, J.H., 1949. Pi Mu Epsilon: Lehigh University. American Mathematical Monthly 56, 127.
Weaver, J.H., 1934. Mathematics conference of the S.P.E.E. American Mathematical Monthly 41, 485–487.
Weinlick, J.R., 1977. Twentieth Century Moravian College Challenge and Response. Alumni Association of Moravian College, Bethlehem, PA.
Zitarelli, D.E., 2001a. Towering figures of American mathematics, 1890–1950. American Mathematical Monthly 108, 606–635.
Zitarelli, D.E., 2001b. EPADEL: A Semisesquicentennial History, 1926–2000. Raymond-Reese Book Co., Elkins Park, PA.
Zitarelli, D.E., 2004. The origin and early impact of the Moore Method. American Mathematical Monthly 111, 465–486.
Zitarelli, D.E., 2005. In the shadow of giants: A section of American mathematicians, 1925–1950. Mathematics Magazine 78, 175–191.

Appendix

Listed below are the majority of works by Joseph B. Reynolds. The list is complete for papers published in mathematics journals but may be missing some items from engineering journals that we are unaware of.

JBR, 1907. The temperature compensation of the Bond sidereal clock of Sayre Observatory. Lehigh University, Bethlehem, PA (bachelor's thesis).
JBR, 1910a. The determination of the elements of the orbit of a minor planet: Taunton No. 94, "Lehigh". Lehigh University, Bethlehem, PA (master's thesis).
JBR, 1910b. Elements of the minor planet. J. G. Astron. J. 26, 1461910.
JBR, 1911. Ephemeris of the minor planet, Lehigh (691). Astron. J. 26, 1861911.
JBR, 1912. Oppositions—ephemeris of minor planet Lehigh. Astron. J. 27, 661912.
JBR, 1914. Genealogy of the Henry of Chichester Line Reynolds Family. Reynolds Family Assoc. of Amer.
JBR, 1916. Design of sand boxes to lower arch centers. Engineering Record 74, 630.
JBR, 1917. Relating to a curve with unusual properties. Amer. Math. Monthly 24, 343–344.
JBR, 1919. The application of vector analysis to plane and space curves, surfaces, and solids. Moravian College, Bethlehem, PA (doctoral dissertation).
JBR, 1921. Vectors for beginners. Math. Teacher 14, 355–361.
JBR, 1923a. The area of ruled surfaces by vectors. Amer. Math. Monthly 30, 185–189.

JBR, 1923b. Vector analysis of a surface. Amer. Math. Monthly 30, 374–382.
JBR, 1924a. How to find the contents of storage tanks. Chemical and Metallurgical Engineering 31, 665–668 (with S. Cottrell).
JBR, 1924b. Review of "Vector Analysis". Amer. Math. Monthly 31, 242–244.
JBR, 1924c. What would you do?. Pennsylvania School J. 72, 612.
JBR, 1925a. Some applications of algebra to theorems in solid geometry. Math. Teacher 18, 1–9.
JBR, 1925b. The total eclipse of the sun, Jan. 24, 1925, as seen at Avoca, Pa. Bethlehem Times and South Bethlehem Globe, Jan. 26.
JBR, 1925c. Professor Lambert, His Life and His Works. Lehigh University, Bethlehem, PA.
JBR, 1926a. Relation of surface area to fineness modulus. Concrete 29, 32–34 (with M.O. Fuller).
JBR, 1926b. A discussion of helicoids and helices by vectors (abstract). Proc. Penn. Acad. Sci. 1, 81.
JBR, 1926c. The evolutes of the parabola. Proc. Penn. Acad. Sci. 1, 108–112.
JBR, 1927. The evolutes of a certain type of symmetric plane curves. Amer. Math. Monthly 34, 415–419.
JBR, 1928a. Elementary Mechanics. Prentice Hall, New York.
JBR, 1928b. A new formula for volume. Amer. Math. Monthly 35 (1928), 175–178.
JBR, 1928c. Finding plane areas by algebra. Math. Teacher 21, 197–203.
JBR, 1928d. A discussion of equal-slope surfaces and helices by vectors. Tôhoku Math. J. 29, 401–406.
JBR, 1929a. Analytic Mechanics. Prentice Hall, New York.
JBR, 1929b. The coal pile problem. Lehigh Brown and White, Feb. 8.
JBR, 1930a. Discussion of a paper by A.M. Wahl. Trans. Amer. Soc. Mech. Eng. 51, 220.
JBR, 1930b. Analytic Geometry and the Elements of Calculus. Prentice Hall, New York (with F.M. Weida).
JBR, 1931a. Floating positions of homogeneous square prisms. Proc. Penn. Acad. Sci. 5, 106–112.
JBR, 1931b. Stresses in truck frames from dead load, acceleration and oscillation can be predicted. Automotive Industries 65, 1–4 (with H.A. Soulis).
JBR, 1932a. The summation of certain series by Fourier expansions. Amer. Math. Monthly 39, 473–476.
JBR, 1932b. Design and investigation of a spring in which all coils nest simultaneously. Trans. Amer. Soc. Mech. Eng. 54, 197–202 (with O.B. Schier).
JBR, 1932c. Design and investigation of conical springs with coils of a constant slope. Trans. Amer. Soc. Mech. Eng. 54, 203–212 (with O.B. Schier).
JBR, 1933a. Eccentricity of load in helical springs. Iron Age 132, 31.
JBR, 1933b. Inextensible chains of fixed plane curves. Proc. Penn. Acad. Sci. 7, 92–98.
JBR, 1934a. Elementary Mechanics, revised ed. Prentice Hall, New York.
JBR, 1934b. Twenty-five years out. Proc. Penn. Acad. Sci. 8, 73–76.
JBR, 1934c. Studies in the drying oils. Industrial and Eng. Chem. 26, 864–876 (with J.S. Long and J. Napravnik).
JBR, 1934d. A mathematical theory for auto-frettaged cylinders. Tôhoku Math. J. 38, 162–178 (with D.L. MacAdam).
JBR, 1935. Discussion: "Structural beams in torsion" by I. Lyse and B. Johnston. Proc. Amer. Soc. Civil Eng., 512–516.
JBR, 1936. Loaded spoked vehicle wheels. Agricultural Engineering 17, 155–161 (with F.L. Ehasz).
JBR, 1937. Elementary Mechanics, reprint of revised ed. Prentice Hall, New York.
JBR, 1938a. Falling chimneys. Science 87, 186–188.
JBR, 1938b. Growing up?. Lehigh U. Alumni Bull. 25 (March), 12–13.
JBR, 1938c. On Euler's forms. Nat. Math. Mag. 12, 294–295.
JBR, 1938d. Review of "Manual of Mathematics and Mechanics". Amer. Math. Monthly 45 (1938), 383–384.
JBR, 1938e. Review of "Segmental Functions, Text and Tables". Amer. Math. Monthly 45, 384.
JBR, 1939a. Forty Lessons in Analytic Mechanics. Edwards Bros., Ann Arbor, MI.
JBR, 1939b. Chain links under cross forces. J. App. Mech. 6, A171–A176.
JBR, 1939c. Review of "Theoretical Mechanics: A Vectorial Treatment". Bulletin Amer. Math. Soc. 45, 346.
JBR, 1939d. On wheels. Lehigh U. Alumni Bull. 26 (Feb.), 12–13, 20.
JBR, 1940a. The Peter Reynolds Family of Lawrence County, Pennsylvania. Edwards Bros., Ann Arbor, MI.
JBR, 1940b. Author's closure: Chain links under cross forces. J. App. Mech. 7, A88.
JBR, 1941a. A Seventy-Five Year History Department of Mathematics. Lehigh University, Bethlehem, PA.
JBR, 1941b. Welded girders with inclined stiffeners. J. Amer. Welding Soc. 20, 33–45 (with C.D. Jensen and C.M. Antoni).

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005

JID:YHMAT AID:2566 /FLA [m3SC+; v 1.67; Prn:1/12/2006; 9:03] P.18 (1-18)

JBR, 1943. Elements of Mechanics. Edwards Bros., Ann Arbor, MI (with G.E. Raynor).
JBR, 1944a. Reversion of series with applications. Amer. Math. Monthly 51, 578–580.
JBR, 1944b. On interpreting a formula. Nat. Math. Mag. 19, 37–39.
JBR, 1945. The mathematics of a nut cutter. Nat. Math. Mag. 19, 159–162.
JBR, 1947. Undetermined coefficients in integration. Amer. Math. Monthly 54, 37–38.
JBR, 1948. Teaching note on repeated roots in linear differential equations. Amer. Math. Monthly 55, 494.

Please cite this article as: D.E. Zitarelli, Straddling centuries: The struggles of a mathematician and his university to enter the ranks of research mathematics, 1870–1950, Historia Mathematica (2006), doi:10.1016/j.hm.2006.10.005