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## ***Musimathics: The Mathematical Foundations of Music***

Bradley Lehman

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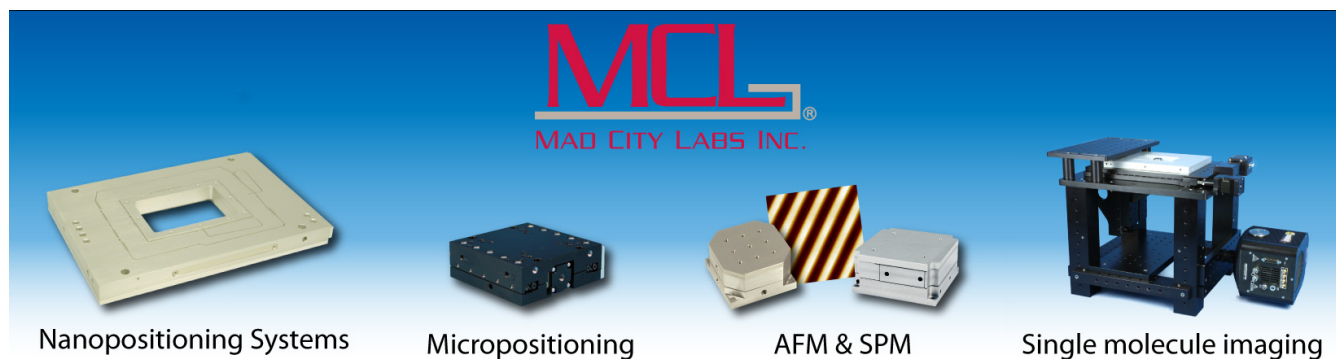
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The advertisement features the MCL logo (Mad City Labs Inc.) at the top center. Below the logo, four distinct pieces of equipment are displayed, each with a label underneath:

- Nanopositioning Systems**: A large, light-colored, square-shaped device with a central square cutout.
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- Single molecule imaging**: A complex, dark-colored mechanical system with a large, flat, rectangular component mounted on a frame, and a smaller, dark rectangular component to its right.

# Sound that doesn't sound so simple

## Musimathics

### The Mathematical Foundations of Music

**Gareth Loy**

**Volume 1**

MIT Press, Cambridge, MA, 2006.

\$52.00 (482 pp.).

ISBN 978-0-262-12282-5

**Volume 2**

MIT Press, Cambridge, MA, 2007.

\$52.00 (562 pp.).

ISBN 978-0-262-12285-6

Reviewed by Bradley Lehman

In the preface of volume 1 of *Musimathics: The Mathematical Foundations of Music*, Gareth Loy assures readers that the two-volume set presumes no advanced background in calculus or trigonometry. The text of volume 1 can serve as a good general primer of Newtonian physics, and Loy develops the mathematical principles with lucid explanations. The second and more challenging volume presents a comprehensive development of mathematical models that apply to music, sound, recording, synthesis, and acoustics; it completes an excellent set. Every chapter of *Musimathics* has a welcome summary at the end that bypasses the calculations to reiterate the concepts. The material in both volumes is well focused, interrelated, and admirably concise throughout more than 1000 pages.

Loy is a musician, composer, and president of Gareth Inc, a company that provides software engineering and consulting services internationally. He is an interdisciplinary thinker with fine pedagogical instincts. Some of the material in volume 2 is so abstruse that it would take a year or two of expert, professorial guidance and commitment to follow through all the derivations. It is not the author's fault that the modeling equations really *are* that complicated;

they describe complicated phenomena. The systematic sequence of material will serve not only experts as an invaluable desk reference but also instructors for a university course—I'd estimate about two semesters per volume.

Loy's approach, as presented in the preface of volume 2, is refreshing: "I believe that enlightened common sense and inference are the whole of mathematics and that inference itself flows from enlightened common sense." Accordingly, he uses enlightening analogies and excellent illustrations. He uses the measuring of tides via water moving through pipes as a model for digital sampling. The algebra of complex numbers gives us a gumdrop on a rotating turntable, which represents a phasor function. Flashlights project the gumdrop's shadows onto two perpendicular screens; the traces give the shapes of sine and cosine waves. A device resembling a pantograph shows another way to draw sinusoid graphs with a pen, while  $e$  raised to imaginary powers spins us through transforms. A piston demonstrates resistance and inductance. A 1913 snapshot of a race car, visually distorted by the era's photographic technology, illustrates convolution.

What would I put on my wish list for Loy's intellectual voyage? At the top would be a CD or an extensive set of web downloads to demonstrate exactly what those interesting-looking waves and filters do for us. Listening to the sound would allow me to understand, as a practicing non-electronic musician, why I should care about or memorize any formulas from the books. The second volume illustrates triangular waves (page 375), phase modulation (page 399), flanging (page 429), and the Indian instrument *rudra vina* (page 442). What do the formulations and instrument sound like, beyond the calculations and visual aids? Loy mentions white noise (page 34), but I could not find an explanation in either volume for the "pink noise" calibration button on my equalizer or for other colors of noise, such as blue, brown, red, and gray.

A website gives a detailed outline of both volumes and includes a list of errata to be corrected in later printings (<http://www.musimathics.com>); Loy responds cordially and quickly to submitted suggestions. Both volumes and another website (<http://www.musimat.com>) present Loy's free MUSIMAT programming language, which resembles C++ or C# and contains some built-in data types and methods for musical applications. Such a language for experimentation is welcome, and I feel ungracious in rejecting a free tool, but I disagree with too many of the MUSIMAT details. The programming language reflects the first volume's pervasive misuse of the term "rhythm." I would rename its "Rhythm" data type either "Duration" or "Meter," because the main purpose of that type is apparently to subdivide a regular bar.

"Rhythm" broadly includes repeated or varied patterns, articulation, accentuation, rests, and more. To play something rhythmically can be profoundly expressive; to play merely metrically, as machines do, is usually dull and too predictable.

There are also some inaccurate and unfortunately misleading points in Loy's coverage of pitch and intonation. For example, in both volumes Loy defines "glissando" and "portamento" incorrectly as each other. The biggest conceptual predicament is providing appropriate names for all the notes. Historically, correct diatonic spelling has been vital in tonal music because it affects both sound and musical expression. Twentieth-century theory and practice have oversimplified about 28 common-practice notes—naturals, sharps, flats, double sharps, and double flats—down to the "Western scale" (Loy's term) of only 12 frequencies per octave, with glibly interchangeable pitch-class names. According to 18th-century textbooks, however, sensitive musicians were alert to fine nuances in everyday practice: for example, performing B-flat about one-ninth of a tone higher than A-sharp. The instruments



**Bradley Lehman** works for Angel.com, based in McLean, Virginia, where he designs and produces automated telephone systems. A performing musician and composer, he holds a doctoral degree in harpsichord. His current research involves an unequal tuning system he deduced from Johann Sebastian Bach's music and pedagogy (<http://www.larips.com>).

sometimes had separate holes, keys, or fingering charts to play the different notes accurately. MUSIMAT says those several notes are simply identical by definition (page 440, volume 1). The “Pitch” data type does not concern either intonation or pitch perception, as its name suggests. Perhaps it should be called “PianoKey” instead, as the data type evidently only assigns ordinal numbers to the 88 available notes on a piano. MUSIMAT has a “PitchList” data type to offer some melodic transposition features, but it naively obliterates the musical distinction between chromatic versus diatonic semitones. Therefore, according to the printed example of the musical couplet “Shave and a Haircut” (page 442, volume 1), it yields enharmonically wrong notes.

Loy’s musical assumptions as a composer and writer are understandably oriented toward synthesizer players and digital technology mavens, not music historians or expert players of conventional instruments. *Musimathics* will draw in physicists and engineers at the risk of alienating ordinary musicians who seek straightforward answers to practical questions. The indexing of both volumes and the website’s outline do not serve, for example, the likely interests of a cellist—finding sections about string vibrations, tone production, the friction and velocity of the bow, and so forth. Why are the higher notes closer together on the fingerboard? What are the comparative acoustical properties of steel, gut, or wound strings? I could not find anything about the double reeds of oboes or bassoons. A harpsichord builder studying plucking points or soundboard resonances would have to page carefully through both volumes side by side, seeking the topics of nodes and modes. My own favorite “musimathic” topic, the history and theory of unequal tuning methods, gets only a thin and long-outdated treatment in volume 1. But, to keep everything in broader perspective, any of those topics slighted in musical mathematics could by themselves require 1000 pages. Loy’s generalist approach is excellent for sparking curiosity.

*Musimathics* and its subtitle suggest that everything springs from “mathematical foundations,” through intense calculation and careful modeling. Yet I lose the sense that most of those musical and acoustical ideas were already commonly practiced before the mathematics came along to measure them. The mathematical modeling is not necessarily a foundation; rather, it describes accurately some of the things we

recognized and enjoyed first for non-intellectual reasons. Whether the mathematical structure is the foundation, the framework, or only the external scaffolding, Loy demonstrates that it has its own abstract beauty. That beauty, as he states in volume 1, was a gift he encountered by his own precocious inquisitiveness at age 11. Thus Loy suggests an alternative subtitle for *Musimathics*: “Everything I wanted to know about music when I was eleven.” If I were 11 years old again, these well-organized volumes would seem totally awesome and inspiring.

# Radiation Oncology

## A Physicist’s-Eye View

**Michael Goitein**  
 Springer, New York, 2008. \$129.00  
 (330 pp.). ISBN 978-0-387-72644-1

The title of Michael Goitein’s book *Radiation Oncology: A Physicist’s-Eye View* is a play on words. The concept of “beam’s-eye view” in radiation-therapy treatment planning was developed by Goitein himself to describe the radiographic view of a patient’s anatomy, as