Cathleen Morawetz: The Mathematics of Waves

An applied mathematician, she is at the top of her field and one of the very few women of her generation to succeed in mathematics

Cathleen Morawetz is an applied mathematician at New York University's Courant Institute. She is one of the few women to attain eminence in mathematics, a field in which many other women have become discouraged. According to Mary Gray of American University in Washington, D.C., only a handful of women of Morawetz's age actually did (or do) mathematical research. And her work is of high quality. "She does excellent, first-rate work," says Michael Reed of Duke University.

This is the fourth of a series of occasional articles about mathematics as seen through the eyes of its most prominent scholars.

Morawetz's large, airy office is on the 13th floor at the top of the Courant Institute, a modern brown brick building on the edge of the Bowery. Her quiet office seems sheltered from the bustling city. For Morawetz, the institute has been a professional as well as a physical haven. "I've led a protected life at the Courant Institute and I know it," she says.

As Morawetz tells it, her choice of career was almost accidental. Her father is the well-known applied mathematician John L. Synge, but she says that he did not push her to follow in his footsteps. "My father's attitude was that I had talent but that I was not willing to work hard enough," she explains. And she was at first put off by the idea of becoming a mathematician because, observing her father, she decided that the life was an isolated one. She now realizes that mathematicians need not be isolated, that they can be in constant contact with colleagues if they choose. "I could do with a bit more isolation," she says.

After finishing high school in Toronto, Morawetz won a scholarship in mathematics to the University of Toronto on the basis of her performance on regional exams, and this led her to study mathematics in college. She concentrated in applied mathematics because she found it esthetically appealing to use mathematics to describe natural phenomena. She then went to the Massachusetts Institute of Technology, where she studied for a master's degree and married Herbert Morawetz, a chemist.

After MIT, Morawetz moved with her husband to the New York area, where he had a job. It was 1946, and when Morawetz inquired about working at Bell Laboratories, she was told that her name would be put in a pool with those of the women applicants who had bachelor's degrees. This was such a discouraging prospect that she decided not to apply. Then, by a fortunate connection, she got a job at New York University.

It happened that her father and the world-renowned mathematician Richard Courant, who was at NYU, were comparing the problems their daughters were having in getting professional jobs. Courant said to Synge, "You can't do anything for my daughter [who was a biologist] but maybe I can do something for yours." He offered Morawetz a job soldering connections for a computer. When she arrived, however, the job had been taken by someone else. So she was asked to edit the book *Supersonic Flow and Shock Waves*, written by Courant and Kurt Friedrichs.

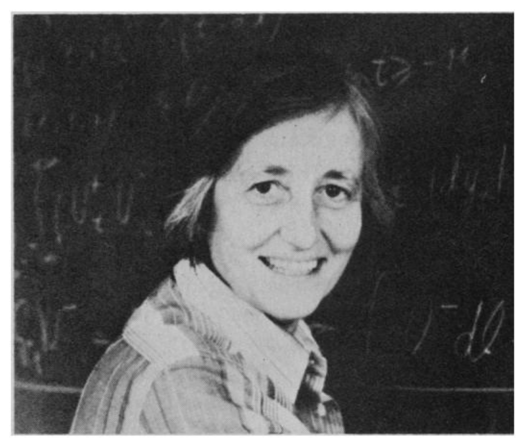
The editing job proved a fascinating one. "I learned the subject that way. It was the best instruction I ever had," she explains. She then went on to take courses at NYU. Although she does not remember ever officially entering as a graduate student ("it probably was a formality after the fact," she says), she eventually wrote a Ph.D. thesis with Friedrichs on imploding shock waves.

After her thesis Morawetz spent several years working part-time at NYU, supported by Navy contracts, and finally received an offer of an assistant professorship at NYU, which she accepted. Morawetz has never left NYU since then. She is currently a full professor and a director of the Courant Institute.

Her research interests are focused mainly on two types of problems. First is the mathematics of transonic flow, where, she explains, "the exciting problem has been connected to the study of flow past an airfoil, such as the wing of an airplane." If a plane flies very fast, shock waves will develop and will increase the drag on the aircraft.

Engineers designing wings have put considerable effort into reducing the likelihood that shock waves will develop. It is known that different wing shapes are associated with different sized shocks and shocks at different speeds. But for many years, everyone wondered whether it was possible to design a wing that would never cause a shock wave and, if not, why. In numerical models of transonic flow past an airfoil, shocks were not seen. But these models used too coarse a grid; they smoothed over the discontinuities of the shocks.

Morawetz explains that this problem was a rare instance in which engineers came to mathematicians for an existence proof. Generally, engineers complain that mathematicians work out the theoretical foundations for problems to which the engineers already know the answers.



In the 1960's, Morawetz analyzed the equations of transonic flow and showed that, in general, a shock wave must occur if a plane goes fast enough, no matter how the wings are designed. "This result was interpreted by some people in too extreme a way," she says. "It is possible to have airfoils with small shocks and this is what engineers settle for now." Still, she says, there continue to be lots of unanswered questions involving the mathematics of transonic flow.

Morawetz's major current interest is the mathematics of the scattering of waves. Scattering arises in all sorts of situations. When a wave—which can be electromagnetic, sound, or elastic—hits a barrier, it interacts with the barrier. The wave can be reflected, absorbed, or transmitted, depending on such things as the wave frequency and the properties of the barrier. The problem in scattering theory is to analyze how the interaction takes place and what can be observed from a distance.

A class of open problems in scattering theory is the inverse scattering problems: You know what wave was sent in, you have some data on how it was scattered, and you would like to find out what the wave hit to cause the disturbance. Morawetz explains that the classical x-ray diffraction problem was the first of the inverse scattering problems to be completely explored. More recently, an inverse scattering problem was solved in connection with x-ray tomography.

Now there is great interest in acoustic waves, especially waves of lower frequencies. Mathematical analyses of high-frequency waves are the basis of techniques used in medicine, to visualize internal organs and to see the fetus within the uterus, as well as in geology, to search for oil fields. In general, high-frequency waves are more easily analyzed than those of medium frequencies because they bounce straight off their targets. But at times, such as when they are bouncing off objects with complicated shapes, it can be quite hard to calculate what the waves hit. Many researchers believe that, in these cases, it may be easier to use medium-frequency waves.

The methods previously developed to study high-frequency waves are asymptotic theories, which means that some parameter—in this case the wave frequency— is treated as infinite. Morawetz and her associate Gregory Kriegsman of the University of Nebraska are now working on ways to solve the problems numerically and are trying to devise methods that will work for waves of any frequencies. Already they have shown that their techniques agree with the asymptotic methods at high frequencies.

In the past decade, Morawetz has worked with Walter Strauss of Brown University to solve two famous problems involving the mathematics of waves. The first, which they solved in 1972, involved equations of great interest to elementary particle physicists. The techniques he and Morawetz used were "very interesting, very tricky." What they had to show was that the amplitude of a certain nonlinear wave goes to zero if you wait a long time. They knew that there was a sequence of discrete times approaching infinity at which the amplitude approached zero. They had to fill in the gaps of this sequence and show that the amplitude approached zero at the in-between points as well. The proof was complicated. "We were hoping for a simple proof but no one has come up with one," he says.

Morawetz also collaborated with Strauss and with James Ralston of the University of California at Los Angeles to solve a famous problem involving a light wave bouncing off a mirror with indentations. The problem was to decide what sort of indentations the mirror must have for the light to be trapped, bouncing from one spot on the mirror to another. In collaborating with Morawetz, Strauss was struck by what he describes as her tremendous insight and her seemingly endless stock of new ideas. He says it is very unusual for a mathematician to have so many new ideas for solving problems. "She approaches each problem in an original way, from scratch," he observes.

Everyone who knows her work agrees that Morawetz has an inborn talent for mathematical thinking. Yet, as Morawetz herself is the first to admit, she is not ranked with the greatest talents of this century. Almost never, in fact, has a woman been one of the superstars of mathematics, and some psychologists postulate that women are inherently less capable than men of mathematical reasoning. "On the level of learning the amount of mathematics that I think ordinary human beings should know, I don't think there's any difference between men and women," Morawetz remarks.

She believes that although it is possible that superlative mathematical talent is more common among men, no one has proved that it is. She says she has met "few young women with the kind of single-minded devotion to mathematics that you find in the best men"; but she points out that she has met relatively few women mathematicians, so her sample is too small to allow conclusions to be drawn. Her own experience has led her to believe that social conditions discouraged most talented women from becoming mathematicians.

These social conditions were more apparent in the past than they are now, Morawetz says, and she was able to buck them partly because of her upbringing and her husband's support and partly because of being at the Courant Institute. In her day, she explains, the main problem for a woman professional was to get any kind of job near where her husband was employed and then, at the same time, to manage her house and care for her children. She quotes Suzanne Keller, a professor of sociology at Princeton, as saying, "It is very difficult to be mother, maid, and Madame Curie." Today, she says, the social pressures on women are easing, with the result that "women are now allowed to be ambitious."

Unlike most of her contemporaries, Morawetz was encouraged by her husband to succeed. He came from a well-to-do Czechoslovakian family where servants were part of everyday life. Thus he encouraged Morawetz to hire housekeepers to cook, clean, and help care for their four children. When their children were growing up, Morawetz explains, it was extremely rare for American men to encourage their wives to work outside their homes and not expect them to do domestic chores as well.

She was also extremely fortunate in her protected environment at the Courant Institute. There she was respected from the start and was treated especially well by Courant himself. When her first child was born, for example, he gave her a raise to enable her to afford a babysitter and thus return to work sooner.

This is not to say that Morawetz never experienced social pressure to stay home with her children. She tells, for example, of a time in the early 1950's when her husband was offered a job by General Electric. Morawetz, who had a Ph.D. at the time, applied for a job there also. She was told, "GE wives don't work." She recalls, "I always remember that phrase. It had such a euphonious ring to it." When her children were young, people often asked her whether she didn't worry about them when she was at work. Her reply was, "No, I'm much more likely to worry about a theorem when I'm with my children."

But, in general, the course of Morawetz's career has been surprisingly smooth. She has won professional recognition and has been asked to fill administrative positions. For 4 years she was a member of Princeton's board of trustees. For the past year she has been a director of the large computer firm NCR. She has also chaired an American Mathematical Society committee on women in mathematics and compiled a roster of women mathematicians. "I think my strong point in administrative work is my common sense," she says.

Of course, Morawetz's success is due to her talent and personality as well as to good connections. She is in a currently fashionable field of mathematics and this is a time when women mathematicians are in vogue. But for years, applied mathematicians were looked down on by the mathematics community and women mathematicians were, blatantly or subtly, frowned upon. But Morawetz survived those years quite well. "She is just a strong woman and very capable," Joseph Keller of Stanford University explains. As a result, she has earned her position as a leader in her field of mathematics.—Gina Bari Kolata