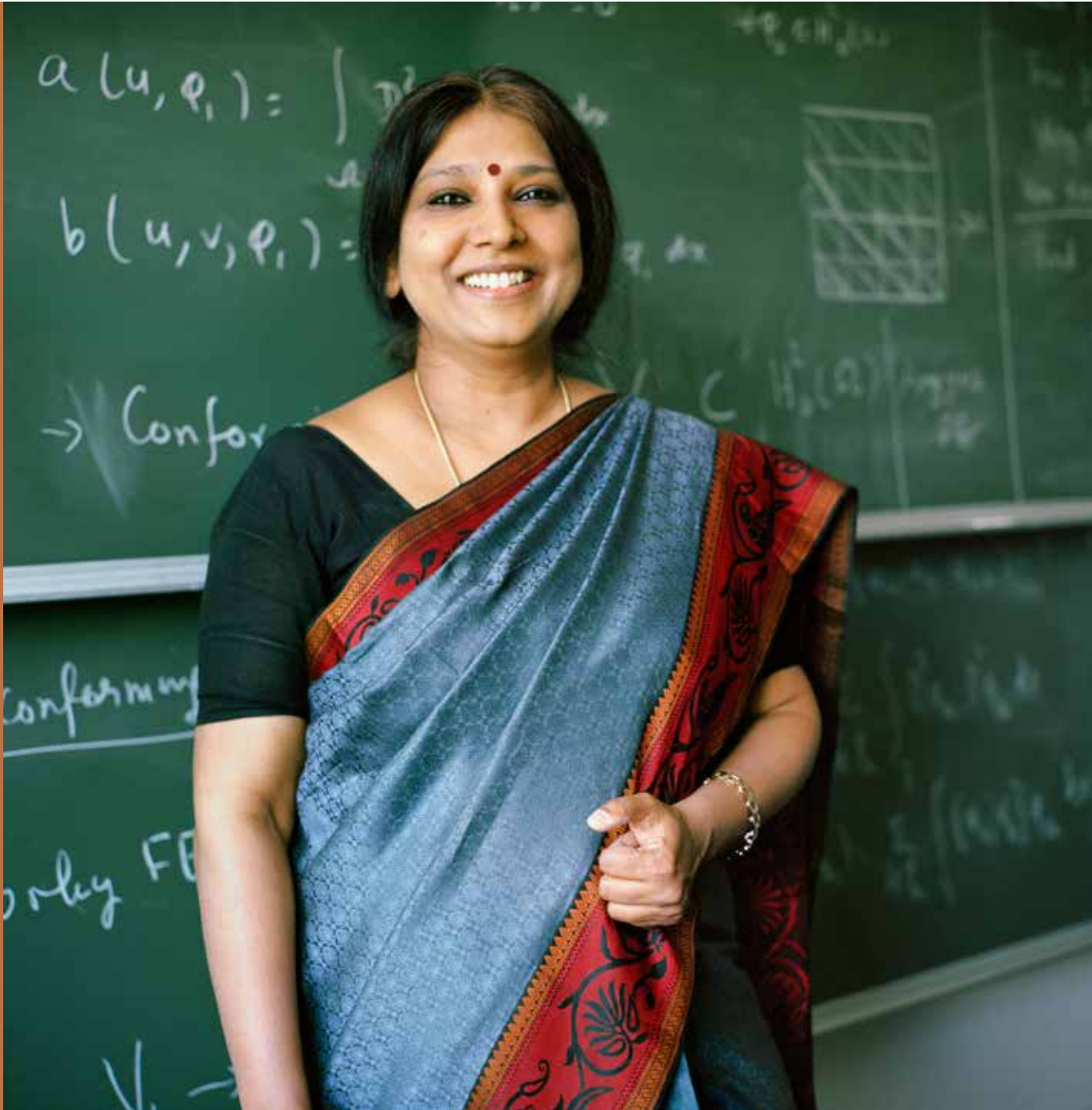


Neela Nataraj

$$\left. \begin{aligned} \Delta^2 u &= [u, v] + f \\ \Delta^2 v &= -\frac{1}{2} [u, u] \end{aligned} \right\} \text{ in } \Omega$$
$$u = v = 0 \quad \text{on } \partial\Omega$$
$$\frac{\partial u}{\partial n} = \frac{\partial v}{\partial n} = 0 \quad \text{on } \partial\Omega$$

Neela Nataraj obtained her Ph.D. in 1998 from IIT Delhi under the supervision of Prof. P.K. Bhattacharyya. She was appointed a faculty member in the Department of Mathematics at the same institute in 1999. She moved to IIT Bombay in 2003 and became a full professor in 2014. Presently, she is an Institute Chair Professor in the Department of Mathematics of IIT Bombay. She has also been serving as the Dean (Faculty Affairs) of IIT Bombay for the past two years. For her exemplary teaching, Neela Nataraj was conferred the Indian National Science Academy Teachers Award in 2019. She became an elected Fellow of the National Academy of Sciences in 2019 and a Fellow of the Indian Academy of Sciences in 2021. She has been featured in the film 'Journeys of Women in Mathematics (2018),' produced by the International Mathematical Union Committee for Women in Mathematics. She is a member of the editorial boards of ESAIM: Mathematical Modelling and Numerical Analysis, Computational Methods in Applied Mathematics, and Computers & Mathematics with Applications.

- Research topics:**
- Numerical analysis
 - Finite element methods
 - Applied mathematics



Golm, Germany, 2019

How and when did you choose to do mathematics?

I studied in several schools (1st to 10th grade) since we often moved because my father was a bank employee. I started my schooling in Bombay and then went to schools at several places in Kerala, a Southern state of India. I changed schools five to six times in all. During the lower grades of school, I was scared of mathematics. At some stage during the tenth to twelfth grades, a few excellent teachers made a difference and boosted my self-confidence, which probably helped me decide to study mathematics. After school, I never planned to pursue Ph.D. In fact, it was not a common thing to choose to do Ph.D. three decades ago, more so given the family background that I come from. The thought of Ph.D. dawned and the motivation to pursue the same happened at a summer school during my Masters. Well, I never planned anything when I started - my career path came as it came. All I was clear about right from my childhood was that I wanted to teach. Anything beyond that I considered a bonus.

Were you encouraged by your family, friends or other people around you?

I come from a very conservative and traditional South Indian

family where women were expected to settle down soon in life, which meant marriage and possibly a stable job. My mother had a Ph.D. in Botany from Bombay University but had quit her job as a Professor to take care of her two children, my younger sister and myself. The child-care centers did not exist back then, so she could not expect help. As a result, she left an academic career, yet I don't think my mother ever regretted having given up her career to raise us. Irrespective of the situation, she made the best of her life, and was always happy and positive. These have been great and very important lessons for me. Her positive attitude towards life was always an inspiration. She was very passionate about teaching and in a situation where she could not work, she offered private lessons to students who needed help in their studies. When my younger sister and I were less dependent on her, she began to work as a principal in a school. My father was a genuinely kind person to support my decisions, but he was not into academics. He was always concerned about my settling down in life, my financial stability, and autonomy. My sister, Deepa Venkitesh, who is five years younger than me, and now a faculty member Indian Institute of Technology (IIT) Madras, considers me a role model.

After I received my Master's degree from Kerala University, I moved to IIT Delhi to pursue my Ph.D. degree, thanks to the efforts of my maternal aunt for getting me the application form and encouraging me to apply and try for admission to IIT Delhi! My Ph.D. was funded by a fellowship from National Board for Higher Mathematics. I got married in the very first year of my Ph.D. at the age of 23. I had full support from my husband Nataraj and parents-in-law to continue a Ph.D., which I think was crucial. The family adopted me as a daughter. I would give full credit to my husband's family for encouraging me to continue with my work for the Ph.D. degree, which extended over a long period of time due to various personal problems that I had to face. My son was born when I was 25. In Delhi, we were living initially at my parents-in-law's home, in a small place with a lot of people. It was a phase of abundant love and fun. I could not do focus on studies at home. However, at all times in my life, my immediate and extended family members were and are still very affectionate. They admire the fact that I am working and doing well, although they don't quite fully understand what I am doing. The very fact that the family, especially my husband and son, supports me and values whatever I do is very

gratifying and is an important boost even today. I consider myself fortunate to have had the opportunities of interacting with some very inspirational, scientifically eminent and encouraging people, both national and international, and mathematicians and non-mathematicians. A very important and essential source of support has been from the collaborators and mentors. Personally, work collaborations keep me going; the excitement of sharing new ideas, working together and learning constantly new things make me happy. One important person who changed the course of my life is my Ph.D. supervisor, Professor P. K. Bhattacharyya (IIT Delhi), a very strict but understanding teacher and mentor. He was a very soft person but was rather tough in terms of work and quality, more importantly. Indian Ph.D. programs include course work, somewhat like in the USA. Starting Ph.D. for me was starting from scratch. As I mentioned earlier, I had to face many personal problems. During this period, my father passed away from a heart-attack when he was only 60 years, and my mother had been diagnosed with liver cirrhosis. This meant that I had to travel many times to my parental home to attend to exigencies. The regular breaks, sometimes for long periods of time, delayed



k formulation for VKE

$v \in H_0^2(\Omega)$ st

$$a(u, v, \varphi_1) + b(u, v, \varphi_1) + b(v, u, \varphi_1) = (f, \varphi_1) \quad \forall \varphi_1 \in H_0^2(\Omega)$$

$$a(u, u, \varphi_2) - b(u, u, \varphi_2) = 0 \quad \forall \varphi_2 \in H_0^2(\Omega)$$

$$a(u, \varphi_1) = \int_{\Omega} D^2 u : D^2 \varphi_1 \, dx$$

$$b(u, v, \varphi_1) = -\frac{1}{2} \int_{\Omega} [u, v] \varphi_1 \, dx$$



conforming FE $V_h \subset H_0^2(\Omega)$ Argyris FE

Plate bending problems

Thick plates

Thin plates

Very thin plates

Von Karman Plates

Find u, v such that

$$\Delta^2 u = [u, v] + f \text{ in } \Omega$$

$$\Delta^2 v = -\frac{1}{2} [u, u] \text{ in } \Omega$$

$$u = v = \frac{\partial u}{\partial n} = \frac{\partial v}{\partial n} = 0 \text{ on } \partial \Omega$$

length to thickness ratios

$$\Delta^2 = \frac{\partial^4}{\partial x^4} + \frac{\partial^4}{\partial x^2 \partial y^2} + \frac{\partial^4}{\partial y^4}$$

$[u, v] \rightarrow$ Monge

Ampere bracket

$u, u_x, u_y, u_{xx}, u_{xy}, u_{yy}$

conforming FE $V_h \subset H_0^2(\Omega)$

FE



$h \rightarrow$ Morley FE spec (+BC)

$$a_h(u_h, \varphi_{1h}) + b_h(u_h, v_h, \varphi_{1h}) + b_h(v_h, u_h, \varphi_{1h}) = (f, \varphi_{1h}) \quad \forall \varphi_{1h} \in V_{1h}$$

$$a_h(v_h, \varphi_{2h}) + b_h(u_h, u_h, \varphi_{2h}) = 0 \quad \forall \varphi_{2h} \in V_{2h}$$

$$a_h(u_h, \varphi_{1h}) = \sum_{T \in \mathcal{T}_h} \int_T D^2 u_h : D^2 \varphi_{1h} \, dx$$

$$b_h(u_h, v_h, \varphi_{1h}) = \sum_{T \in \mathcal{T}_h} \int_T [u_h, v_h] \varphi_{1h} \, dx$$

$$h = \max_{T \in \mathcal{T}_h} h_T$$

$$\text{As } h \rightarrow 0, \begin{cases} u_h \rightarrow u \\ v_h \rightarrow v \end{cases}$$

$$\|x\|_1 = a(x, x)$$

the Ph.D. Also, there were a few years when I was without any financial support/fellowship. I got strong encouragement from my advisor, a very good human being, in the toughest phases of my life. Although he was uncompromising scientifically, he was very patient. Let me quote a concrete example: I asked him for a month's leave for my wedding in the first year of my Ph.D., which he granted happily. The course on Finite Element Methods that he was teaching began in July and ended in November, and I got married in August that year. I missed classes for a month, yet managed an excellent grade in the exam. He nevertheless asked me to take the course and the exam again the following year. His argument was that since I was absent for the classes, I was missing the knowledge and the understanding, which are really crucial. I think he was right!

After my Ph.D. at IIT Delhi, I worked as a faculty member in IIT Delhi for a few years and then moved to IIT Bombay in 2003. This was the phase when my son was growing up and I wanted to spend more time with him. At IIT Bombay, where I still am now, I met a colleague, Professor Amiya K. Pani, who warmly welcomed me to the Numerical Analysis group of IIT Bombay. We collaborated in supervising Ph.D. students

and wrote joint projects and research papers. During that phase of life, research pace slowed down a bit as I was trying to balance teaching, research, and family life. I would also say that the international community has been extremely supportive. I would like to mention two collaborators who have really made a difference in my research career and helped me learn a lot. Professor Carsten Carstensen at the Humboldt University in Berlin, a brilliant mathematician, has played a very important role as a research mentor. He is an excellent collaborator, who has been always very encouraging about new ideas and research directions. Also, Jérôme Droniou (Monash University) is a very enthusiastic and intelligent mathematician; he has terrific energy when it comes to research work. We supervise Ph.D. students jointly through the IITB-Monash Research Academy. The interactions with my collaborators keep the research aspect of my life very lively. I am really fortunate to have these very knowledgeable, meticulous collaborators, who impress me each time with their swift thinking! In India, once you have a permanent job, stability is ensured. It is then important to have someone to talk to about the emergent areas. The Indian Numerical Analysis community is

particularly small and there are only very few members in the country. All my collaborators and several others contribute to keeping my motivation levels high, learning new things, and staying abreast of new directions in research.

Did you come across obstacles in pursuing your career as a mathematician?

At every stage in life, you face obstacles. It totally depends on you whether you choose to view them as challenges to overcome or as difficulties that act as debilitating deterrents. It all depends on how you want to find ways to overcome them and bounce back. It depends on how passionate you are about the work and the mathematics you want to do.

As I mentioned, while I was doing my Ph.D., my mother was diagnosed with liver cirrhosis, she lived 10 years with this illness. She had to quit work for a few years after she had been diagnosed. Yet, she would call in students, whenever her health permitted, to help them with their studies. She also helped me with my son when he was growing up. Even with the illness, she was very positive and unstoppable, which I think has had a strong influence on my attitude toward life and problems.

In retrospect, are you happy to have chosen mathematics or do you have some regrets? What are for you the joys of mathematics? What are for you the hardships of mathematics?

No regrets on anything, I just enjoy my life however it comes. Joy lies in learning, eureka moments, and collaborations. I enjoy learning new things and am happy to work hard. Learning and working keep me going always. I try to choose collaborators who work better than me so that I can improve myself. I am not being modest, this is the truth. I always get inspired by smarter people than me and I admire them. My personal set of friends is totally different, and is rather minimal, because I don't have the time and am basically a shy person in the social context. Due to my work priorities, all the social relations are compromised. I would consider myself to be selfish, very selfish in that aspect. Simple philosophy: if you want to enjoy what you are doing, maximize the time for it! Of course, you have to make compromises and choices since the time one has is finite. I have been involved in administrative activities for the past ten years, which take up a lot of my time. It is very hard for me to say no to a task, especially when assigned by my very supportive institute. My supervisor had this philosophy that the

time you invest in something sincerely is not wasted time. Collecting different types of experiences, and facing different types of problems forges your personality, and improves your expertise and logical capacity. You have to do it to experience it. A few examples are the Headship of the department and the activities that concern IMU CWM and IWM. I think I know my strengths and my limitations very well. At this stage of my life, I at least try to invest some time in activities around women and mathematics, as I consider it as one form of service to society. I would be most happy if it helps a young person consider mathematics as a career.

For a woman, there is a phase in a life dedicated to raising one or more children. This phase does not come back. I would like the fact that I am a mother of one son and have spent quite a lot of time with him when he was growing up. This, of course, takes time off from your research, but I don't regret it. I believe that women should enjoy this phase in their lives, and bringing up children ensures some kind of balance in one's personality. If you want to have children, you should go ahead and not let mathematics prevent you from having them. There are age bounds and if one crosses them, it makes it difficult to go back and do what





one wished to. This can deter the progress in research to a certain extent, but then one can always come back if one is backed with passion and fire to pursue.

What would you recommend a young woman in your country wanting to start a career in mathematics?

Work hard! Networking and collaboration help motivate but ultimately you have got to sit down and work. Networking and academic friends don't lead to a tangible output in research

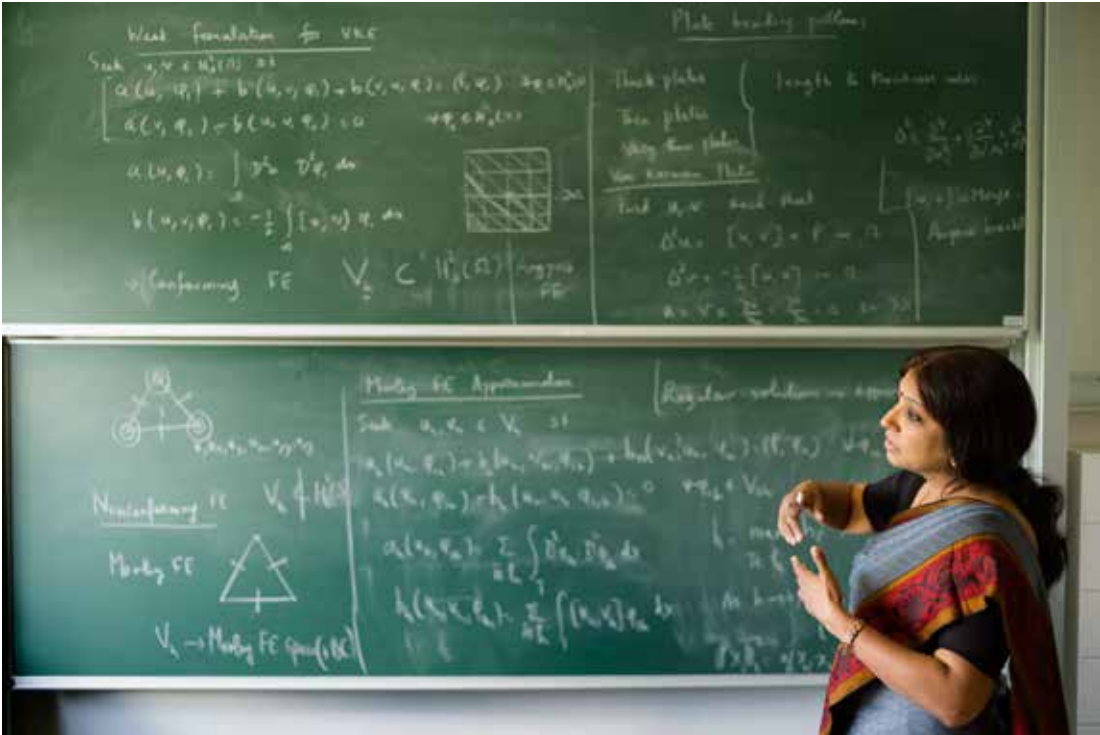
unless you make important contributions. You can be a nice person, and you can have good skills, but to be a co-author of a paper and to have a long-term collaboration going, there are no substitutes for sincerity and hard work. For my students, I am always there. I try to understand their difficulties. I will, however, not compromise with work quality and quantity.

Could you describe your favourite personal achievement in mathematics?

It is the joy of teaching. Nothing makes me happier than going

into a class and teaching the students. The feeling one has when leaving the lecture hall is the most satisfactory feeling that cannot be substituted with anything else. The smarter the students that you teach, the better you enjoy.

I love all the research projects I am doing but what makes me most happy and contented is teaching. I wouldn't mind a pure research position if I could still teach and train the Ph.D. students. I know that I am not doing path breaking research that would change the world I



give my 100 % to whatever I am doing.

I am also proud of my Ph.D. Mathematics keeps me going during the tough periods of my life. I am happy with the share of family responsibilities that I have and enjoy that. Family is the primary reason for why I never thought of staying outside India for a longer period of time, even for a postdoctoral stint.

Could you describe your field of mathematics in simple words?

I work on many problems in applied mathematics, engineering, economics/finance, biology, etc. that come under the broad area of Numerical Analysis. My investigations lead to mathematical models that are described by partial differential equations. Solving them exactly is an impossible task in most situations, and one has to resort to efficient numerical techniques that work differently for different problems. My work

is concerned with applying different numerical techniques to several problems in applications and obtaining efficient numerical solutions that are heavily dependent on mathematical analysis of the methods. As a matter of fact, my Ph.D. supervisor and Carsten are engineers, who became mathematicians. Currently, I am trying to understand and work on mathematical problems related to liquid crystals with collaborators with expertise in these areas.