

Department of Mechanical Engineering

This was a good year for the Department of Mechanical Engineering (ME). *U.S. News and World Report* once again ranked ME the number one department in the field, and our students and faculty continue to be recognized, both nationally and internationally, for their originality, their impact on research and education, and their leadership in the field of mechanical engineering.

This year we made offers to four new faculty members, who have agreed to join the department next year. They are Rohit Karnik (PhD, Berkeley, microfluidics), Evelyn Wang (PhD, Stanford, energy), Maria Yang (PhD, Stanford, design), and Pierre Lermusiaux (PhD, Harvard, ocean sciences). These appointments will simultaneously strengthen our core and expand our research activities into exciting new application areas. Next year we expect to conduct searches for two additional faculty members.

In May 2006, we opened the new Pappalardo Laboratory for Micro/Nano Engineering, a 5,000-square-foot facility housing a suite of laboratories focused on energy, bioengineering, instrumentation, design, and manufacturing, all at the small scale. This laboratory was made possible by the continuing generosity of Jane and Neil Pappalardo, and it will house the research of seven faculty members and their students and postdoctoral fellows, working on science, engineering and technology at the micro and nano scales. The laboratory also includes an educational laboratory for new classes being developed in this field.

The field of micro/nano engineering is increasingly interdisciplinary, and many engineering departments at MIT work at these very small scales. As a consequence, ME faculty members today participate in many different communities that transcend traditional disciplinary boundaries. At the same time, we recognize the distinct focus of mechanical engineering within this interdisciplinary activity—in other words, the centrality of mechanical and thermal phenomena. Mechanical and thermal phenomena provide the focus for our models and methodologies, the inspiration for our processes and products, the medium for our engineering and technological innovation, and the examples with which we develop engineering and problem-solving skills in our students. Even in this exciting new field of micro/nano engineering, the focus of mechanical engineering is what it has always been: the sciences of mechanics, thermodynamics, and transport, with a steadfast aim toward the responsible development of products, processes, and power.

A new initiative we began working on this year is a discussion of *how* we teach (rather than *what* we teach). We hosted many guest speakers and have had many departmental discussions on this topic. We have also engaged with industry, and are planning the development of an innovation studio to emphasize the creative aspects of engineering, both in education and as a topic for research.

A second initiative we started this year is the MIT Women's Technology Program (WTP) in Mechanical Engineering, a summer program for high school juniors. A small group of female ME graduate students conceived, developed, and taught the program. Twenty

female high school students came to MIT for four weeks to take classes, work on design, and build Rube Goldberg machines. The program was intended for young women who are good at math and science but intimidated by technology. It was a great success and we plan to continue it in the future.

We have continued to institute various programs and activities to strengthen the merger of the Department of Ocean Engineering with the Department of Mechanical Engineering. In particular, this year we called for proposals for the joint development of curricula between the two faculty groups. We also had a very successful two-day retreat at Cape Cod to discuss and develop research synergies, preceded by a half-day visit to the Woods Hole Oceanographic Institution (WHOI).

The students in the Naval Construction and Engineering Program held their annual Ship Design and Shipbuilding Technology Symposium in May. Student teams presented both conversion and new concept ship designs. One of the design project reports, which concerned surface-effect unmanned vehicle host ships for littoral operations, was subsequently accepted for publication and presentation at three conferences: the American Society of Naval Engineers, June 2006, in Crystal City, VA; Maritime Systems and Technology, September 2006, in Nice, France; and the Royal Institute of Naval Architects, October 2006, in London, UK. This program had its first civilian student in many years. He is supported by the Lockheed Martin Corporation and studies the sea-keeping performance of a nonconventional hull design.

Three giants of the department passed away this year: Professors Robert W. Mann and Ernest Rabinowicz in 2006, and Professor Nathan H. Cook in late 2005. They were all extraordinary leaders in their respective fields: Bob in design and biomedical engineering, Ernie in tribology, and Nate in manufacturing. They will be sorely missed, though their legacies will last forever.

Research Highlights

As can be inferred from the awards received by the faculty, the department has many thriving and vibrant research programs. A few research projects, selected randomly, are described below:

—Professor Carol Livermore's group in Area 7 has been creating microelectromechanical systems (MEMS) for a new application: MEMS-based chemical lasers. Their designs and modeling show that scaling key features to the microscale allows for more compact, efficient systems than are possible at the macroscale. In particular, they have designed, built, and demonstrated a miniature chemical reactor, which creates an excited species of oxygen to power the laser. The reactor creates nearly seven times more excited oxygen per unit reactor volume than the best macroscale systems.

—Professor Yang Shao-Horn of Area 4 and our Electrochemical Energy Laboratory has revealed the mechanism of platinum activity loss in proton exchange membrane fuel cells during operation. The activity loss of the platinum catalyst is the prime reason for the reduction of fuel cell efficiency and lifetime. Current platinum degrades by two

processes: coarsening of platinum nanoparticles by Ostwald ripening, and platinum dissolution and precipitation of inactive crystals. Current work involves the design of active and stable catalysts with less platinum.

—Professor John Leonard of Area 3 is leading an initiative for the Office of Naval Research to implement advanced feature-based navigation algorithms for US Navy autonomous underwater vehicles performing mine-hunting and surveillance missions.

—Professor Thomas Peacock's group in Area 1 has been advancing a new experimental technique, synthetic schlieren, for the first laboratory investigations of internal-wave generation by deep-ocean topography. This is a very active research topic because of recent recognition of its important role in deep-ocean mixing. His advanced wave tank and visualization facilities allow investigations in otherwise inaccessible, nonlinear regimes, supporting the development of next-generation models. Research is closely tied to ocean-going investigations; group members recently returned from field studies in the North Pacific.

—Professor Martin Culpepper of Area 2 has created a scalable robotic system for six-axis positioning of parts and probes in nanomanufacturing applications. Six-axis positioners set the limits on mankind's ability to precisely measure, understand, and manipulate at the nano-scale. Culpepper's design makes it possible to miniaturize positioners so that they may measure and manipulate at the speeds required for high-rate nanomanufacturing. He has created the first practical MEMS six-axis positioner (thousands of cycles per speed) and is working on assembling nano-scale positioners (millions of cycles per speed) from six molecules; that is, six carbon nanotubes.

Education Highlights

Our educational programs remain strong. Our subjects continue to be popular and their contents are continually updated and revitalized. A number of new subjects have been developed in the past couple of years, a few of which are mentioned below:

—Professors Nicolas Hadjiconstantinou, George Haller, Nick Patrikalakis, and Tom Peacock have developed the new subject 2.003J Dynamics and Control I. This sophomore-level subject provides students with a strong background in the fundamentals of rigid body motion, with applications taken from vehicle dynamics, structural dynamics, sports, ocean engineering, and other areas. Responding to recent needs for more advanced undergraduate subjects, the new 2.003 subject includes a thorough treatment of stability theory, analytical mechanics, and multi-degree-of-freedom vibrations. In addition, the subject includes a systematic introduction to MATLAB, a numerical software package broadly used both in MIT subjects and by the industry.

—Professor Todd Thorsen has created subject 2.371 Microscale Fluid Mechanics. There has been a growing interest in the implementation of micro/nanoscale fluidic devices for diverse applications, ranging from biomedical lab-on-a-chip type devices to microchemical reactors to fuel cells. Engineering these devices not only requires skills in design and manufacture, but also a fundamental understanding of the underlying fluid

mechanics operating in these systems. This course supports the long-range vision of the micro/nano research core in the Department of Mechanical Engineering, introducing students to the underlying physics of pressure-driven flows in microfluidic devices, as well as the electrochemical technologies used for manipulating ultrasmall fluid volumes in microconduits.

—Subject 2.72 Elements of Mechanical Design is an upper-level undergraduate elective covering mechanical components (such as gears, cams, bearings) and their use in design of systems (for example, automobiles and manufacturing equipment). In spring 2006, 2.72 was substantially revised to more firmly link the topic to the engineering core and to enable students to make better use of computation in support of design. For example, students developed mathematical models of mechanisms and programmed computers to synthesize systems to perform desired functions. Students work in small teams to apply these skills to design and build equipment for the handicapped, for developing countries, and for public educational broadcasting.

—Professor Ahmed Ghoniem introduced 2.60 Fundamentals of Advanced Energy Conversion in fall 2004, in collaboration with Professors Kazimi, Shao-Horn, and Tester. This cross-disciplinary subject covers the fundamentals of thermodynamics, chemistry, and transport phenomena required to analyze the performance of energy conversion systems, including power plants, engines, fuel cells, hydrogen, and other fuel production, using fossil, nuclear, solar, or biomass sources, with an emphasis on efficiency and environmental impact. This integrated approach focuses on the complexity of modern energy systems and introduces students to rigorous analysis tools. Students from the departments of Mechanical Engineering, Chemical Engineering, Nuclear Science and Engineering, Materials Science and Engineering, Aeronautics and Astronautics, and Physics, the Engineering Systems Division, the Sloan School of Management, and from Harvard all take this class.

Undergraduate Program

Undergraduate Enrollment in Mechanical Engineering and Ocean Engineering (OE figures in parentheses), Academic Years 2002–2006

	AY2002	AY2003	AY2004	AY2005	AY2006
Sophomores	83 (3)	76 (6)	113 (8)	126 (4)	130 (4)
Juniors	91 (5)	81 (5)	72 (6)	105 (6)	126 (5)
Seniors	118 (7)	107 (6)	91 (5)	105 (8)	122 (5)
5th-yr students				13 (0)	
Total	292 (15)	264 (17)	276 (19)	349 (18)	378 (14)
Total ME & OE	307	281	295	367	392

The following honors and prizes were awarded to our undergraduate students:

- Department Service Award for Outstanding Service to the Department of Mechanical Engineering: Nicoli Ames, Sungyon Lee, Rosalind Takata, and Dawn Wendell

- Society of Naval Architecture and Marine Engineering Award for Outstanding Undergraduate in the Marine Field: Seth Clark
- Robert Bruce Wallace Academic Prize for Academic Excellence and Outstanding Potential for Professional Leadership in Ocean Engineering: Nina Young
- Alfred A. H. Keil Ocean Engineering Development Fund Award for Excellence in Broad-based Research in Ocean Engineering: Evan Karlick
- Carl G. Sontheimer Prize for Creativity and Innovation in Design: Mark Cote
- John C. and Elizabeth J. Chato Award for Excellence in Bioengineering: Brendan Harley
- Padmakar P. Lele Student Award for Outstanding Research and Thesis: Dr. Namik K. Yilmaz
- Outstanding Undergraduate Assistant in Subject 2.007 Design and Manufacturing I: Shutsu Chai, Brendan Englot, Sam Jewell, Vivian Li, Jesse Marsh, and Mika Tomczak
- Luis de Florez Award for Outstanding Ingenuity and Creativity: Josiah Rosmarin, 1st Place, and Alexander H. Slocum, Jr., 2nd Place
- Peter Griffith Prize for Outstanding Undergraduate Thesis: Josef L. Miller and Christopher Rhodes
- AMP Inc. Award for Outstanding Performance in Subject 2.002 Mechanics and Materials II: Patrick Barragan, Batya Fellman, Logan Munro, and Martin Segado
- Whitelaw Prize for Originality in Subject 2.007 Design and Manufacturing I Design and Contest: Ilan Moyer and Howard Kellogg
- International Design Competition for Subject 2.007 Design and Manufacturing I: Gina Angelosanto, Shane Colton, Gregory Schroll, and Orian Welling
- Wunsch Foundation Silent Hoist and Crane Award for Outstanding Teaching Assistants in Subject 2.007 Design and Manufacturing I: Liang Xue
- Outstanding Performance in Subject 2.008 Design and Manufacturing II: Allen Reyes and Sachin Tandon
- Outstanding Teaching Assistant in Subject 2.007 Design and Manufacturing I: Hongshen Ma
- Outstanding Thesis in Fluid Mechanics: Randy Ewoldt
- Most Creative Design in the International Competition: Adrianna Hee

Graduate Program

Our graduate program continues to be strong, with a total of 479 students. Of the 244 students in the master's program, 27 percent are international, 18 percent are women, and 7 percent are persons of color. Our students were supported by research assistantships, 11 National Science Foundation fellowships, 36 Department of Defense fellowships, and 84 fellowships from other sources (including National Aeronautics

and Space Administration, WHOI, DuPont, Bill and Melinda Gates Foundation, and Lemelson).

**Graduate Enrollment in Mechanical Engineering and Ocean Engineering
(OE figures in parentheses), Academic Years 2001–2006**

	AY2001	AY2002	AY2003	AY2004	AY2005	AY2006
Master's	220 (70)	189 (81)	170 (73)	180 (81)	194 (87)	174 (70)
Doctoral	161 (36)	179 (26)	181 (28)	178 (29)	190 (37)	200 (35)
Total	381 (106)	368 (107)	351 (101)	358 (110)	384(124)	374(105)
Total ME & OE	487	475	452	468	508	479

This past year, 831 students applied for admission to our graduate programs; 27 percent of them were offered admission. Of these 27 percent, 60 percent matriculated.

The following honors and prizes were awarded to our graduate students:

- Meredith Kamm Memorial Award for the Outstanding Mechanical Engineering Woman Graduate Student: Sarah Hupp
- Hatsopoulos \$50,000 Innovation and Thesis Award: Chulmin Joo

Faculty Notes

George Barbastathis, Nicolas Hadjiconstantinou, and Sang-Gook Kim were awarded tenure, while Marty Culpepper, Dan Frey, Anette Hosoi, and Alexandra Techet were named associate professors without tenure.

Other awards and prizes presented to ME faculty:

- Junior Bose Award: Anette Peko Hosoi and Dan Frey
- Joel and Ruth Spira Award for Teaching Excellence: John Brisson
- Baker Prize: David Wallace
- Fellow, American Society of Mechanical Engineers: Gang Chen and Woodie Flowers
- Knopf "Programming the Universe" Award: Seth Lloyd
- Academy Gold Medal of Honor from the Academy of Transdisciplinary Learning and Advanced Studies: Nam Suh
- Nicolau Award, College International pour la Recherche en Productique (CIRP): Nam Suh
- Warren and Townley Rohsenow Chair: Gang Chen
- Ford Professor: Tony Patera
- School of Engineering Professor of Teaching Innovation: Linda Griffith, Gareth McKinley

- Joseph Keenan Award for Innovation in Undergraduate Education: Ely Sachs and Dave Trumper

School of Engineering Awards

- Infinite Mile Award: Deborah Alibrandi and Angela Mickunas
- Infinite Mile Team Award: Joe Cronin, Robert Gertsen, Stephen Haberek, and Robert Nuttall

Rohan Abeyaratne
Department Head
Quentin Berg Professor of Mechanics
MacVicar Faculty Fellow

More information about the Department of Mechanical Engineering can be found at <http://meche.mit.edu/>.