InterActions

across physics and education

September/October 2007

Focal Point

Physicists at Work

Inside:

Career Paths, Profiled

Physics Majors, Uncovered

Writing About Science

and introducing "Homer Dodge's Notebook"

InterActions
across physics and education

About INTERACTIONS

Interactions is a general-interest magazine about physics education. Our mission is to inform and stimulate diverse conversations on teaching and learning by publishing thought-provoking news, analysis, and commentary on the people, programs, and policies that interact to influence scientific practices and knowledge—and, ultimately, human destiny.

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The editors welcome your response. Send comments, questions or suggestions to interactions@aapt.org or mail letters to Interactions Forum, One Physics Ellipse, 5th Floor, College Park, MD 20740. Please include your full name, mailing address, and daytime contact information. Space is limited and all published comments are subject to editing.

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On the Cover

Graduates toss their mortar boards high into the air during graduation ceremonies hoping they are prepared for the real world.
Photo courtesy www.photos.com.

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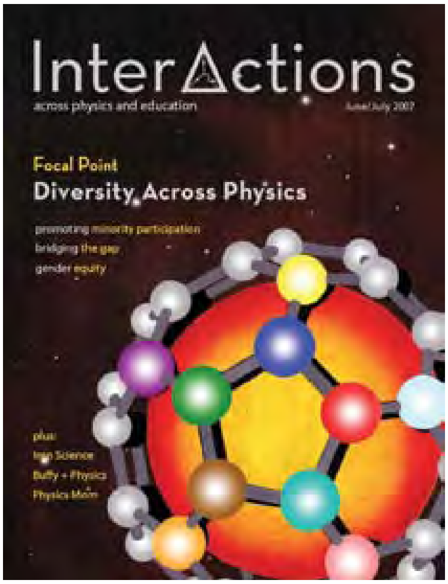

Debate on I.D. Continues

In the June/July 2007 issue of *Interactions*, letter writer Greg Fazzari claims to be arguing against bias in science while sprinkling his own bias throughout his letter (Fear Not Intelligent Design). First of all, where did "fear" enter into the discussion? The idea of intelligent design as an alternative to biological evolution has too little merit to generate fear. Not once in the letter is there a statement of what could be taken for an objective theory of intelligent design or how it might even in principle be tested.

A major oddity was the personalization of Fazzari's arguments. In addition to writing about specific people, he identifies two of them as "atheistic." Is the point that atheists can't do science without bias or that Fazzari is biased against atheists? Also, contrary to this labeling, Stephen J. Gould was by his own account not an atheist. He identified himself as an agnostic.

Fazzari claims that the "evolution debate has been raging within the scientific circles for years." This refers to the debate between the hypothesis of punctuated equilibrium and the modern synthesis. To the best of my knowledge, and I've been following the various debates for over 30 years, the biggest debate is about whether these two ways of thinking about biological evolution are no different, slightly different or very different. Also, most biologists don't seem to spend a lot of time worrying about this, and I get no sense of anything "raging."

The implication that what was found in the Burgess shale suggests a sudden appearance of new phyla that can't possibly be explained by the modern synthesis seemed to make some sense many years ago, but later finds in Southern China and elsewhere have made it clear that there was a considerable period during which precursors of the organisms fossilized in the Burgess shale were abundant. The "sudden appearance" myth was a result of incomplete information.

Finally, Fazzari keeps suggesting that if we all studied ID along with evolutionary theory without bias, the former would look much better and we would see that the latter is not even science. So much for lack of bias. In any case I've done the studying, and I'm still looking for even an objective statement of what can be deduced from ID. No objective statement implies no theory.

On the other hand, in the case of biological evolution we have very detailed fossil records of evolution of horse and whale lines, and there are even more detailed fossil records of foraminifera. We now even have direct measurements of evolution rates, as indicated in *The Beak of the Finch*, and these have shown that evolution can occur much more rapidly than had been expected—even when each individual step is very small. Δ

Robert J. Reiland
Pittsburgh, Pennsylvania

Concerning the letter in the [June/July 2007] *Interactions* by Greg Fazzari: He says, "The evolution debate has been raging within the scientific circles for years."

Well, yes, just as the nuclear theory debate and the high-temperature superconductivity debate and the supersymmetric particle debate all have raged within scientific circles for years. But there is no genuine debate at all over the validity of the core findings of nuclear theory and solid-state theory and particle theory and evolutionary theory.

In all of these cases there is such a mass of interconsistent observations, successful experimental manipulation of the relevant systems, and diverse theoretical perspectives that although all science is tentative, the core facts of all these disciplines are now extremely well established. Just as general relativity and quantum mechanics did not throw out Newton's explanation of tides, it is essentially impossible that future understanding will throw out the established fact that biological systems evolve through replication with variation plus selection.

Concerning [Stephen Jay Gould] and punctuated equilibrium: The estimable Daniel Dennett, a Tufts [University] philosopher who has immersed himself deeply in evolutionary biology, in his superb book *Darwin's Dangerous Idea: Evolution and the Meanings of Life* (Simon & Schuster 1995) comments:

"In my own work over the years, I have often appealed to evolutionary considerations, and have almost as often run into a curious current of resistance: my appeals to Darwinian reasoning have been bluntly rejected as discredited, out-of-date science by philosophers, psychologists, linguists, anthropologists, and others who have blithely informed me that 'I have got my biology all wrong—I haven't been doing my homework, because Steve Gould has shown that Darwinism isn't in such good shape after all. Indeed, it is close to extinction.' This is a myth, but a very influential myth, even in the halls of science."

There is not room in a letter even to summarize the issues, but there is room for one comment. Punctuated equilibrium, the notion that species remain unchanged for long periods, then experience brief episodes of rapid change, is little more than an issue of grain size. What is "long"? What is "rapid"? Gould's proposal evoked useful argument among evolutionary biologists, but it is not an attack on Darwinian evolution.

Fazzari asserts that evolutionary theory doesn't explain various observations. Dennett discusses in some detail the logical flaw in assuming that just because someone (or even all living humans) cannot at this time explain some particular data, these data can never be explained using current theory, so the existing theory is wrong. In his Klopsteg lecture at the AAPT [National Meeting] in Greensboro, N.C. (Summer 2007), the astrophysicist Neil DeGrasse Tyson pointed out that Newton couldn't prove the stability of the Solar System and invoked a supernatural cause for the observed long-term stability. Later Laplace invented perturbation theory and was able to prove that Newtonian mechanics predicted a stable Solar System. A healthier stance by Newton would have been to say, "At this time I don't see how to prove that the Solar System is stable, but perhaps later research will clarify this issue."

The wiggle room for objections to the heart of Darwinian evolution gets smaller every year. For many years the objection was "missing links," finally laid to rest by a lot of hard work that found the intermediate fossil forms. Intelligent design is another flavor of this: "I can't figure out how evolution would produce the vertebrate eye, or flagella, therefore evolutionary theory must be wrong."

But given these challenges, biologists have stopped what they were doing and responded with solid evidence for evolution having produced eyes and flagella, though these clarifications have studiously been ignored by the critics. Many people are so uncomfortable with Darwin's inconvenient truth that there may be no mechanism for scientists to establish satisfactorily for the critics the validity of Darwinian evolution. Δ

Bruce Sherwood
North Carolina State University

Greg Fazzari (June/July 2007) defended intelligent design by presenting Darwinian evolution and punctuated equilibrium as being opposing concepts. I have a background in science and have been in education for over three decades, teaching math, biology, chemistry and physics. I have also heard Niles Eldridge and have extensively read Stephen Jay Gould's works. Rather than refuting Darwinian evolution, punctuated equilibrium merely modifies it.

Gould has repeatedly pointed out that one of the biggest problems in this controversy is the difference between the vernacular and scientific definitions of theory. In the scientific community, Gould has noted that rather than being "imperfect facts" theories are "structures of ideas that explain and interpret facts." They are supported by extensive observations and evidence. Einstein's theories did not erase Newton's—they merely specified differences under certain conditions. The same is true in this case.

Darwin's theory of evolution refers to change as being continuous and gradual. If conditions do not change, evolutionary modifications do not offer any advantage and are absorbed into the larger population, in effect being erased. This is why fossil records show long periods without apparent change.

However, if stress is introduced, a species may not survive. In an isolated population, those that carry a genetic variation that is suddenly favorable may survive. What was an aberration becomes an asset. Given time, a new species can evolve and, when reintroduced to the larger population, it will be distinct.

Fazzari ignores the time scale expressed in punctuated evolution. Evolutionary change occurs over thousand or tens of thousands of years. In the fossil record, this is very brief, being perhaps 0.0002 percent of Earth's history and, as Gould estimates, far less than one percent of the 10-million-year lifespan of an invertebrate species, which is what he studied. Combined with the fact that this occurs in a limited population, it is not in any way surprising that this does not show up in the fossil record.

This addresses the question raised in intelligent design of how life change occurs quickly and then stops. The change is only "quick" in geological terms and the change doesn't stop. It is continuous, but it is absorbed in a population unless environmental conditions favor such change.

This adds to the need to educate everyone to understand what science is and its limitations, as these perceptions can influence decisions that can all too easily affect our future. Δ

Avi Ornstein, Ed.D.
New Britain, Connecticut

The Importance of Conceptual Physics

Stewart Brekke wrote (June/July 2007, page 4): "Physics First is…a nonmathematical approach to introductory physics. Therefore, the students… are really not prepared to take an AP course…in the way a third-year mathematical physics student is prepared, especially if he uses [a standard math-based physics textbook]."

I disagree. The essential, and only, preparation needed for an AP course or any other math-based physics course is a good conceptual physics (meaning no algebra) course. In fact, the College

Board's Advanced Placement course description emphasizes that the math-based AP physics courses should "build on the conceptual understanding attained in a first course in physics." It describes this first course as a "physics course aimed at developing a thorough understanding of important physical principles and that permits students to explore concepts in the laboratory," and explains that such a course "provides a richer experience in the process of science and better prepares them for the more analytical approaches," (The College Board, 2007).

Physics education research confirms that students in courses that place primary emphasis on problem solving rather than on underlying concepts come away with little conceptual understanding of physics. They can work formula-based problems, but ask them a simple conceptual question about the forces involved when a truck rams a Volkswagen, and you soon discover that they don't understand Newton's third law. To put it succinctly: In a first physics course, algebra gets in the way of the conceptual understanding that students must have if they are to really understand a future math-based course. Thus, a conceptual course provides better preparation for a future AP or college course then does a math-based course.

Furthermore, since we surely want all students to learn something of the physical universe, the first physics course should be designed for non-scientists as well as future scientists. In my 35 years of teaching, it's become clear that we should avoid algebra entirely when teaching non-scientists. Why do they need to be able to calculate how long it takes a block to slide down an inclined plane? A first physics course should be numerate (graphs, units, powers of ten, proportionalities), but not algebraic.

There are two further reasons why the first physics course should be conceptual. Math-based, high school courses concentrate on Newtonian mechanics and 19th century electromagnetism, while hardly mentioning our current view of the physical universe. Many of our future biology, medicine, engineering, and other students will never take a course that presents the central concepts of quantum physics and relativity, not to mention contemporary cosmology and high-energy physics.

Second, there is no time in traditional math-based courses for such crucial social topics as scientific methodology or the environment. Yet it has become obvious that industrialized democracies cannot survive unless its citizens are literate in such topics. In the absence of a broad conceptual physics course, our future physicists, physicians, and engineers will probably never encounter such topics in the classroom. Δ

Art Hobson
Fayetteville, Arkansas

Women and Physics

Physics courses, in high school and particularly at the university, must provide more laboratory experience for women and be particularly careful that the women [are] required to use the tools and to set up and operate the lab equipment.

Next, women should always expect to have to take leave from their job for about five years to raise their children to the age where they can attend some kind of school; it took my wife that long before our twin sons could enter kindergarten. Therefore, women have to expect to be treated as I was treated. In July, after I had been awarded my Ph.D. in physics in June, I received my orders to active duty teaching physics and physics of aviation at the U.S. Naval Academy for the next four and a half years. When I returned to inactive duty and applied for a position as a research physicist, I was treated by every firm I approached as if I were a newly minted Ph.D., and [was] paid as such. Thereafter, I was always five years behind my peers because they had received deferments during the war for doing essential work. Whenever you make a comparison between women and men for position or salary you must take this factor into account.

[Finally, women] shy away from academia and government positions and instead go into industry because only industries provide family leave. Academia is especially hard on women with its rules for advancement [even] from assistant professor to associate professor.

I believe that women see this situation more clearly than you think, especially during their freshman year as they become acquainted with academia, and that is one of the reasons they don't major in physics in the first place. Δ

Arthur S. Jensen
Parkville, Maryland

Share Your Opinion

The mission of *Interactions* is to foster an open discussion on any issue of particular interest to the physics education community.

Send comments to: interactions@aapt.org.

Careers of Physicists

BY JOHN S. RIGDEN

The purpose of education is to open the mind to all that life offers. The centerpiece of an education is determined and shaped by a student's choice of a career. Instructors at every level—grades K–20—influence students' educational programs and career choices. Because of this, instructors might remember two things. First, suppose I spent 50 hours/week on the job, 50 hours/week sleeping, and 14 hours/week eating, leaving 51 waking-hours each week for me to spend as I choose. This accounts for almost one-third of a person's life. An education should prepare a student to use this "leisure" time in a fulfilling and productive fashion.

Second, many students agonize over how they want to spend their working life. Physics instructors might suggest to students that this agony is largely unnecessary. In conversations with many working physicists, they acknowledge that their careers have taken many twists and turns that they did not or could not plan for. The telephone rings, a letter comes, a door opens and suddenly there is a new career opportunity awaiting a response.

A student needs to make broad decisions—science vs. non-science, physical science vs. life science. Then, instead of thinking about a working life, students should think a few years ahead, decide what they want to do in those few years, design their education accordingly and, this I believe is important, design their education so that it provides a base that will give them the intellectual flexibility to move in unanticipated directions as career opportunities arise. A bachelor's degree in physics provides such a base; of course, a graduate degree in physics strengthens that base.

The evidence that supports this claim is available for all to see. Examine the lives of working physicists, and the evidence mounts: Physicists pursue a wide range of careers and do so with great success.

I emphasize the bachelor's degree for two reasons: I regard a person with a baccalaureate in physics as a physicist; second, it is after the baccalaureate that the career paths of physicists begin to diverge. For instance, a few years ago, I organized a one-hour physics course that each week featured a non-academic physicist as a guest speaker. All these physicists had at least a physics baccalaureate, but from there the differences abounded. Over a period of 26 weeks, I had 26 physicists with different career-types ranging from medicine, government, management, life sciences, history, engineering, consulting, entrepreneurial, computer sciences, NASA, industry (large, medium, and small), national laboratories, the military, journalism, and the list goes on. Almost every guest speaker, on his or her own initiative, identified their physics education as an asset, and many said that their problem-solving skills set them apart from their co-workers. (Two human resource directors have told me that they call their physicists their "problem solvers.") Therefore, a baccalaureate in physics is a good base for a variety of successful careers.

In this issue, a wide range of physicists and careers are featured:

- Jason Coleman, a computer game designer and co-owner of Big Huge Games, a computer game development company;
- William R. Hendee, a medical physicist, academic administrator;
- James N. Hollenhorst, a physicist at a large tech company called Agilent Laboratory;
- Helge Kragh, a writer and historian of science;
- Dennis Overbye, science reporter for *The New York Times*;
- Gregory Rigden, a physicist for a small tech firm called Electro Magnetic Applications, Inc.;
- Peter Wanderer, a physicist for a national Laboratory; and many others.

Each one has an interesting story to tell. Also, you will notice that there is no academic type among them. This, of course, was a deliberate choice. I assume that after spending 16 or 20 years sitting in a classroom, watching physics instructors, and talking to them, many *Interactions* readers will have an abundance of first-hand knowledge about an academic career. For those of you wondering, I can say, after almost 30 years as a professor, that a career in academe is very satisfying. I loved it. Throughout those 30 years, however, I had very little idea about what the vast majority of physicists did after they received their baccalaureate. I hope the array of physicists featured in this issue of *Interactions* gives a sense, albeit limited, of the rich opportunities open to physicists. Δ

John S. Rigden, Washington University in St. Louis.

People

Mother and Son Team Earn Physics Degrees

Suzanne Buckley's unstinting dedication to ensuring her son Robert received an undergraduate physics degree earned her an honorary sheepskin of her own.

University of Texas at San Antonio

Thanks to an honorary degree awarded to physics major Robert Buckley's mother, Suzanne, graduation in May 2007 at the University of Texas at San Antonio was a family affair.

Along with his bachelor's degree in physics from the University of Texas at San Antonio this past May, Robert Buckley achieved perfection—perfect attendance and a perfect grade point average of 4.0.

Buckley earned his high grades thanks to his own formidable brain power. His flawless attendance, however, must be attributed in part to the indefatigable efforts of his nurse/chauffeur/personal assistant, Suzanne Buckley, who also happens to be his mother. Diagnosed with muscular dystrophy at 18 months, Buckley, now 22, has relied on a wheelchair since age seven and breathed with the aid of a ventilator since his sophomore year of high school.

To reward her for her tireless devotion to her son's education, the UTSA physics department made the May ceremony a twofer, awarding Suzanne Buckley an honorary degree in physics.

"Really, my condition doesn't pose much of a challenge for me as far as school goes," Buckley said. "It has a bigger effect on my mom, who sits in on all of my classes."

The framed document reads "Honorary Degree, Bachelor of Science in Physics." "It is truly an honorary degree, as I am definitely not qualified to use it," Suzanne said. "I cannot pass a physics exam."

In high school, the local school district provided a nurse to care for Buckley while attending classes. But by the time he enrolled at UTSA, the Buckley's health insurance would not cover the cost. So Suzanne became her son's constant companion. She trundled a cart of books, papers and various school and medical supplies alongside Robert's motorized wheelchair. She ferried Robert to and from class and labs in the family van. She sat behind Robert in class and administered respiratory therapy treatments as needed, often several times a day. After earning an honors-level degree in physics and completing an undergraduate thesis on the Brownian motion of stationary objects, Buckley immediately embarked on graduate work—and his mother will be by his side when he needs her.

Always the academic overachiever, Robert Buckley graduated as valedictorian of his senior class at Sandra Day O'Connor High School in San Antonio. In addition to his attendance and academic performance at UTSA, physics professor Dhiraj Sardar praised Buckley for his intense focus. "His attention to the details of physics problems is unmatched," Sardar says.

"He is the single best student I've ever had in my teaching career," said Liao Chen, who has taught in the UTSA physics department since 1994. "He is not satisfied with good grades, though he earned perfect grades all the time … his curiosity is not momentary but perpetual."

Buckley's earliest interest in physics came via a childhood fascination with astronomy. "Black holes, pulsars, galaxy clusters, supernovae—the sheer scale of these kinds of things is awe-inspiring: enormous masses, extreme energies, and unfathomable distances," he mused.

Buckley later derived inspiration "for obvious reasons" in the work of famous physicist Stephen Hawking (Amyotrophic Lateral Sclerosis, or ALS, more commonly known in the United States as Lou Gehrig's disease, keeps Hawking confined to a wheelchair). He also gives credit to Jeff Nordine, a high school physics teacher now working toward a doctorate in science education at the University of Michigan. "His classes were extremely entertaining and usually humorous without detracting at all from the educational value," Buckley recalled.

"I really enjoy learning about how the universe works, the physical laws and principles that govern the motions of this intricate dance of particles and energy and information that constitutes our world," he said.

He hopes one day to pursue research in theoretical physics and is confident his disability will never pose an obstacle to his academic pursuits.

"I've never felt excluded because of my condition," he said.

—Steve Davolt

Retiring Utah Physics Demo Wiz Goes Out With a Bang

Ziggy Peacock, a living legend among physics laboratory demonstrators, bids the University of Utah adieux with a grand finale.

It was a grand finale worthy of a virtuoso. On June 22, University of Utah physics demonstrator Zigmund "Ziggy" Peacock gave a farewell performance for a standing-room-only crowd. Peacock regaled an estimated audience of 250 in the university's James Fletcher Building with two hours of his trademark demonstrations.

The event marked the end of 28 years of service for Peacock, whose official job title is Lecture Lab Demonstration Specialist but who is more often referred to as lecture demo "guru" or "wizard." Peacock presided over one of the largest physics demonstration shops in the country. The University of Utah's 3,700-square-foot facility houses some 4,000 demos, many of which Peacock built himself, designing and manufacturing the equipment in the department's machine shop. According to students and faculty, Peacock's lively demonstrations, sense of humor, and avuncular warmth have made him one of the Utah campus's most beloved personalities. He received an AAPT Distinguished Service Citation in 2006.

"Ziggy is equally adept at dealing with faculty and students," physics professor Brian Saam said. Saam, who has taught at the university for nine years, said he quickly came to rely on Peacock for concrete illustrations of his lectures. He said Peacock's patience and friendliness made him a favorite personality around the campus.

Peacock's inquisitive nature and dexterity made him a natural for the job, Saam said. "In another life, Ziggy might have been a famous inventor."

"His demos are always a big success with the students," said Paolo Gondolo, another member of the physics faculty.

Gondolo recalls a crowd-pleasing demo from the past school year. In the "monkey shoot," a stuffed primate is dropped vertically while a 10-inch wooden bullet is launched at it from across the lecture hall to show that both objects fall at the same rate despite the forward momentum of the projectile. On at least one occasion, Peacock replaced the monkey with a toy cougar emblazoned with the letters "BYU," the mascot of the University of Utah's sworn rival, Brigham Young University.

Ziggy Peacock's physics demonstrations were always hair-raising experiences.

A U.K. native, Peacock landed in Utah in the late 1960s when a spinal ailment forced his father to relocate to a warm, arid climate. He took the job at the University of Utah in 1979.

After nearly three decades on the job, Peacock still marvels at many of the demonstrations. "Some are rather plain Jane, but they still delight you because you realize how much physics is involved," he says.

In addition to coordinating on-campus demonstrations, Peacock often takes his physics show on the road to area schools and organizations, part of a community outreach effort strongly encouraged by the department. Although his farewell party marked the end of his official duties at the university, he will continue to put on off-campus shows and devise new apparatus for the department during the coming year.

"The most thrilling moment for me is when a student walks up to me and says, 'You know, I came to one of your demos in grade school and now I'm here,' studying physics or engineering or whatever."

Peacock said there are some aspects of full-time teaching he won't regret leaving behind. "I won't miss strolling through the door at 6:30, 7 in the morning because we have a demo for an early class," Peacock said.

Adam Beehler, who has been under Peacock's tutelage for much of the past year, took over as physics demonstrator June 1. Beehler recounted the most important lesson Peacock impressed upon him: "I'm in charge of the demos. You have to know when to tell the faculty to shut up and take charge."

Despite whatever heat-of-the-moment friction may occur in the lecture hall, Peacock said he will miss the camaraderie in the department. "I've developed some close friendships," he said. "During 28 years on the job, you kind of grow up together."

The sentiment seemed to be mutual. "We have a successor in Adam Beehler, but Ziggy is irreplaceable," said Paolo Gondolo.

–S.D.

BYU Program Bolsters Ranks of Physics Teachers

At a time when teaching programs across the country are struggling to catch up to the ambitious math and science goals set by No Child Left Behind, Brigham Young University has turned itself into a veritable factory for physics teachers. During the 2006-2007 school year, the Provo, Utah-based, Mormon Church-sponsored university graduated 16 students certified to teach high school physics, or about 5 percent of the national estimate of 300 new physics teachers.

BYU's disproportionate success in molding physics teachers is the result of a unique collaboration between the colleges of education and physical sciences. Three years ago the McKay College of Education transferred responsibility for science teacher training to the College of Physical and Mathematical Sciences.

"Both deans share a common desire to provide the best possible preparation for future teachers in general and specifically for critically needed physics and mathematics teachers," said Robert Beck Clark, a BYU physics professor and president of AAPT in 1986-87.

Clark gives a lion's share of the credit for the program's success to Duane Merrill, a veteran physics teacher recruited by BYU three years ago to oversee training of science educators. Merrill taught high school physics in Utah for 20 years, 18 of them at Emery High School in Castle Dale, before moving to BYU.

"Having a battle-scarred master physics teacher to design and conduct the program makes all the difference," Clark said. "Duane really cares about each student and is there for them 24 hours a day, seven days a week."

Old-fashioned mentoring lies at the heart of the teacher training program, which garnered attention in a June 1 *Science* article on science educators. "The fact that I was a high school physics teacher myself for 20 years carries a lot of validity with the students," Merrill said.

Merrill leads off the program by teaching Introduction to Science Teaching, in which students observe 48 hours of actual classroom instruction. Taking an incremental approach, the BYU program gradually prepares teacher candidates for their own debut as student teachers in local schools.

The physics faculty attributes much of the program's success to the culture and environment of BYU, summed up by a motto at the campus's main entrance: "Enter to learn. Go forth to serve." Many of the school's 300 undergraduate physics majors, as well as faculty and staff, volunteer for two years of public service or missionary work around the world.

That missionary zeal encapsulates the desire to teach for Brad Moser, a 2007 graduate of the physics teacher training program at BYU. "You do it because it's a passion," Moser said. "I like preparing lessons, helping people have their 'a-ha' moments. At this point, I'm still having mine, so I relate better to the students."

Moser wasted no time in putting his recent pedagogical training into practical application, landing a job teaching high school physics this year in Webb City, Missouri. But he already knows he wants to return to the university for graduate work—in physics education research. "There's a lot of different educational approaches, tools, techniques. I'd like to do research to determine what's really effective in the classroom," he said.

The BYU physics faculty has become adept at promoting teaching as an alternative to the predominant research track. That philosophy held a strong appeal for Heather McKnight, who also graduated this year from BYU with a certificate to teach physics. McKnight started her academic career as a physics major at Carnegie Mellon University in Pittsburgh, but transferred to BYU. At CMU and during internships, McKnight was turned off of research after seeing physicists scrambling after research funding, living grant to grant.

"I knew I didn't want to do that," she said. "I knew I wanted to be helping people some way."

A two-year public-service mission in Spain continued to nudge McKnight toward a teaching vocation and she entered physics teacher training after her return to BYU. She now teaches high school physics in Littleton, Massachusetts, near Boston.

Meanwhile, Duane Merrill will be turning more attention to adapting BYU's success in minting physics teachers to other STEM disciplines. If he succeeds in replicating the results thus far, the university will have done more than its share to bolster the ranks of a new generation of science educators.

—S.D.

Teachers' Zero-Gravity Flights Give Lessons a Lift

What these science teachers experience 32,000 feet in the air also serves as a lesson to their students.

Science teachers across the United States attempted to break the law and couldn't wait to tell their students. To better understand the "law of gravity" 400 mostly middle-school science teachers will fly aboard a modified Boeing 727 to an approximate altitude of 32,000 feet before dropping in free-fall to experience the sensation of weightlessness.

A program known as Weightless Flights of Discovery and created by a partnership between defense contractor Northrop Grumman and Zero Gravity Corp., a privately held space tourism company in Ft. Lauderdale, Fla., allows teachers to experience so-called low- and no-gravity environments. "We believe that by making space and microgravity concepts more accessible to educators and students, we will help inspire tomorrow's explorers," said Peter Diamandis, CEO and co-founder of Zero Gravity Corp.

Diamandis is known in aerospace circles as the founder of the X Prize, the $10 million award to the first private-sector team to fly a manned aircraft to the threshold of outer space, claimed in 2004 by aircraft designer Burt Rutan and Microsoft co-founder Paul Allen.

Northrop Grumman Foundation established the Weightless Flights of Discovery program in 2006 in response to President Bush's American Competitiveness Initiative, intended to spur academic interest and excellence in STEM disciplines. The program took some 250 teachers aloft aboard five flights in its first year.

Teachers aboard "G Force One" await the steep descent that will render the modified Boeing 727's cabin a gravity-free zone.

Between August and September of this year Weightless Flights launched missions in Dallas, Baltimore, New Orleans, Los Angeles, Washington, D.C., Bethpage, N.Y., Newport News, Va., and Colorado Springs, Colo. Each flight is preceded by a workshop in which teachers learn about the physics of weightlessness and prepare microgravity experiments to conduct during the flight. "You can't truly describe weightlessness until you've experienced it," said Jeff Klein, who teaches physics to freshmen and juniors at Gilmour Academy, a K-12 Catholic school in Gates Mills, Ohio. "Even if you're a hang-glider or bungee jumper, you've come close but you had the air friction."

Klein flew with 20 other teachers from Cleveland's Hopkins Airport in the inaugural year of the program. Klein incorporates his weightless experience into classroom instructions on Newton's laws and kinematics. "Only then do you get a true sense of the difference between inertia and mass and weight," Klein said. "Now in the classroom, when I'm talking about force versus inertia, I can make the difference crystal clear."

The weightless flights deploy a customized plane christened "G Force One," in pre-approved air space 10 miles wide and 100 miles long. The plane flies in steeply ascending and descending parabolas during which simulated low gravity (the lunar and Martian equivalents) and no gravity are achieved about 15 times. G Force One climbs to altitudes between 24,000 and 32,000 feet to sustain weightless periods of 20-24 seconds. Astronauts, subjected to similar training exercises have dubbed such flights the "vomit comet."

Matt Gelon, who teaches conceptual and AP physics at Barrington High School in Illinois, took his space walk aboard the same Cleveland-based flight as Klein. "The video clips of these experiences are priceless in the classroom," Gelon said. "The students really wanted to understand how the airplane could produce the zero G effect. At first, some of the students were convinced that the plane actually reaches space for about 25 seconds then comes back down. After working through how the airplane's parabolic path produces the feeling of weightlessness, it wasn't hard to show why the occupants of the space station felt weightless in a vehicle that is doing the exact same thing at a higher altitude."

Gelon explained that some of the experiments conducted aboard G Force One involved studying the surface tension of water droplets floating midair, the stability of a gyroscope constructed from a bicycle wheel, and the varying periods of a pendulum in different gravitational fields. Weightless fliers also tossed some of their smaller counterparts about the gravity-free cabin.

Classroom presentations back on Earth are enhanced when teachers wear the flight suit issued for their weightless voyage, a souvenir that gets teachers equally "psyched." And, says Jeff Klein: "I even wore it on Halloween."

–S.D.

Inventors' Web Portal Ups Its Physics Ante

InnoCentive, a Web site that pays cash rewards for R & D solutions to a global network of problem solvers, adds more physics-related challenges.

INNOCENTIVE®

InnoCentive, an eBay-like hub that farms out scientific problems posed by corporate entities to an international corps of problem solvers will soon include more physics problems.

InnoCentive is an innovative e-business concept that offers cash rewards up to $100,000 for solutions to problems posed by "seeker" companies. Think of the Internet as the modern-day equivalent to the Wild West—InnoCentive is where you'd tack the wanted posters.

The Andover, Mass.-based company (www.innocentive.com) boasts a registered network of potential "solvers" that includes some 125,000 professional and amateur scientists from 175 countries. Seeker companies, who pay a fee to post their queries to the Web site, have included prominent corporations as Boeing, BASF, Dow Chemical, Procter & Gamble, and the Rockefeller Foundation.

In the past, many of the problems posted by InnoCentive overlapped multiple disciplines or skewed toward R&D challenges peculiar to chemical manufacturing. But new Web pages specifically for engineering and the physical sciences, slated for launch sometime in September (at the time this issue went to press), will post challenges directly related to nanotechnology, and plasma, material, and solid-state physics.

Launched by pharmaceutical giant Eli Lilly & Co. in 2001, InnoCentive was spun off as an independent entity in 2005. When it came to models for InnoCentive, Alpheus Bingham, a Lilly executive who helped found the venture, said, "There was a lot of DNA out there." Bingham cites HelloBrain.com, a short-lived venture from Silicon Valley where freelance engineers and programmers bid for projects.

Bingham even sees a commonality between InnoCentive and Linux, the "open source" computer code posted on the Internet by its inventor, Finnish computer programmer Linus Torvald. The InnoCentive model isn't confined to the Internet, however. Real world examples abound. U.S. federal agencies routinely offer percentage-based awards to civil servants who devise proven cost-saving efficiencies. Office supply titan Staples has fielded thousands of customer suggestions for new products. In perhaps what is the supreme problem-solving challenge, the X Prize Foundation paid $10 million to the design team that launched the first commercial manned spacecraft.

The irony of a business that relies on a collectivist model for profit has not gone unnoticed. When Bingham was in China on business, a government official remarked to him, "What an interesting model. I can't decide if it's the perfect expression of capitalism or socialism."

–S.D.

Philly Science Magnet Draws Crowd, Praise

Following a well-received first year, the Science Leadership Academy, a STEM-oriented high school in Philadelphia's Center City, returned to class this fall with heightened expectations and twice as many students. One of four small magnet schools launched by former schools chief Paul Vallas to invigorate the city's education system, SLA opened its doors Sept. 7, 2006, amid considerable buzz and fanfare.

By all accounts, the school, which is supported by a partnership with Philadelphia's Franklin Institute, logged some auspicious outcomes in its maiden year. Launched with 110 ninth-grade students, SLA achieved 95 percent attendance, a 96 percent course passing rate, and 97 percent retention. All students returned this year with the exception of two: one who relocated and a single student who elected not to attend.

"For the ninth grade in an urban setting, those statistics are on the level of unheard of," said SLA Principal Chris Lehmann.

But Lehmann, who came to SLA from Manhattan's progressive Beacon School, said it is not just the numbers that spell success for the school. He points to students staying late for an open house, cheering for teachers introduced during an assembly "as if they were rock stars," and volunteering for more volunteer work than is available.

"From a curricular and cultural standpoint, this year went better than we had any right to expect," Lehmann said.

The Science Learning Academy got its start when then-CEO of the School District of Philadelphia Paul Vallas spearheaded an effort to create four small academically focused high schools centrally located in the city. Aside from SLA, Philadelphia inaugurated the high-tech, paperless High School of the Future, the National Constitution Center-sponsored Constitution High School, and The Academy at Palumbo, a spin-off of Philadelphia's academically first-rate Central High School.

The scientific spirit

According to its mission statement, SLA is founded on a scientific philosophy that embraces five core values of inquiry, research, collaboration, presentation, and reflection. The school, which began with just a ninth-grade class and will add a grade level each year, will introduce physics to its junior class next year. SLA's founders believed that by grounding students in biology and chemistry first, they gained a firmer basis from which to delve into the principles of physics.

"The thinking is there is no one right way to design a science sequence," Lehmann said.

SLA's curriculum is based on an inquiry-driven, project-based ethos that encourages students to learn by doing. Courses are integrated in a way intended to discourage isolating subjects in their own silos and promote interdisciplinary understanding. The culminating event of the school year was a science fair in which every student participated.

A powerful partnership

The Science Leadership Academy benefits from a founding partnership with The Franklin Institute, a nationally acclaimed science museum. Although the school is primarily funded by the school district, The Institute contributes to curriculum development and supports the school with material and informational resources.

Museums of The Franklin Institute's stature rarely lend their imprimatur to a single school, but Vallas persuaded Institute President Dennis Wint the relationship would prove symbiotic. SLA would flourish under The Institute's aegis, and The Institute would be cultivating the kind of citizenry dedicated to supporting the museum.

"It is unique for an institution on the scale of The Franklin Institute to make such an investment and long-term commitment to a school," said Janet Porter, regional superintendent for Center City.

SLA is housed in a renovated office building on 22nd Street, about two blocks from the museum. "We believe geography is destiny," said Carol Parsinnen, a Franklin Institute senior vice president who has developed programs for the city's schools for 25 years. "We wanted the kids to be able to walk to the museum."

"It's a terrific opportunity to show we can dissolve the barrier between formal education and informal, free-choice education," she added.

The museum has launched two formal programs thus far for SLA students. Four-week mini-courses link instruction to some facet of museum operations. The courses can focus on everything from special exhibits, such as the traveling Tutankhamen artifacts the museum hosted this year, to something as ordinary as facilities management. The Institute also christened its SLA Ambassadors, well-placed Philadelphians who grant kids access to resources and help them cultivate budding networking skills. Current ambassadors include the president of the Moore College of Art, the head of Philadelphia's teacher union, and the dean of Drexel University, who arranged for SLA students to take dual credit courses at the university.

Student engagement

Like most magnet schools, SLA imposes a gauntlet of special-admission requirements. A panel of admissions officers reviews grades and test scores, after which students present a project of their choice and orally defend it before the panel.

The school also makes liberal use of educational technology. Every student is issued a laptop. Students form and participate in online communities and networks. There's even an online student newspaper.

Will Richardson, author of *Blogs, Wikis, Podcasts and Other Powerful Web Tools for Classrooms*, dropped by SLA for a three-hour tour last December. Richardson lauded the students' use of computers and the Internet to build class Web sites and online portfolios. “But what’s neat is that students are taking real ownership over what happens at the school,” he wrote on his blog, Weblogg-ed. Richardson noted that SLA students were chatting online about goings-on at that school months before the doors opened.

New schools routinely encounter resistance. “You’re building a culture from the ground up,” explained the Institute’s Parsinnen. “You have to convince parents to take the kids out of established schools and send them to this new institution.”

Evidently, parents and students were convinced. In its first year, SLA attracted students from 58 schools throughout the metropolitan area. This year the school received 2,000 applications for its 220 seats.

As the Science Leadership Academy builds toward becoming a full-fledged secondary school, it has its work cut out for it in maintaining the performance standards of its auspicious first year. But so far, so good.

“We’re building a culture that is vibrant, caring and rigorous,” Principal Lehmann said. “Students are reacting powerfully and passionately to this model.” Δ

—S.D.

Policy

U.S. Bows Out of International Test

In the wake of the passage of the America COMPETES Act, which authorized tens of billions of dollars for STEM education over the next several years, the U.S. Department of Education announced in early August it was bowing out of an international science and math test for high-school students. The Trends in Math and Science Study Advanced 2008 is designed to gauge the academic performance of 12th graders taking advanced math and physics around the world.

Initial reports cited budget constraints as the rationale for the decision not to participate, but considerations beyond tight purse strings prompted the pullout of the TIMSS Advanced testing.

“There were questions raised as to whether the study would be truly internationally representative,” said Mark Schneider, commissioner of the Education Department’s National Center for Education Statistics, whose office administers the test for U.S. students. With the November 2007 deadline looming, only nine countries had signed up to date: Armenia, Iran, Italy, Lebanon, the Netherlands, Norway, Russia, Slovenia, and Sweden.

“There were questions raised about the quality of the assessment and the degree to which the TIMSS Advanced accurately reflected the U.S. physics curriculum,” Schneider continued. Physics educators on a TIMSS review board pointed out that sequencing of courses within the physics curricula of other countries doesn't match that of the United States.

Schneider also questions the results of the first TIMSS test in 1995. Of the 16 countries that signed up to participate, six did not meet reporting standards and another five cited exceptions that skewed their results.

"We have to keep our eye on the ball," said Gerald Wheeler, executive director of the National Science Teachers Association. "As a nation, we have to stay focused on our education goals and priorities. Participation in [TIMSS Advanced] is not a priority."

"The number one thing we need to be concerned with is that our kids are not getting a sufficient science education," Wheeler said.

Both Schneider and Wheeler highlighted the main TIMSS tests for fourth- and eighth-grade students, and the Programme for International Student Assessment (PISA) as useful instruments for international comparisons. The results of the 2006 version of the triennial PISA, which tested the science literacy of 15-year-olds from nearly 60 countries, including the United States, will be released December 4, 2007.

Critics of the TIMSS Advanced stipulate several major obstacles to an accurate comparison, from the length of time students in respective countries receive compulsory education to the different ages at which such education is terminated.

William Schmidt, a Michigan State University statistician who was National Research Coordinator for the TIMSS 1995 testing, conceded there were inequitable bases of comparison in the first study. In one example Schmidt offered, the tests of college preparatory students in some countries were measured against students of Germany, where a large percentage of secondary students attend vocational and trade schools. "You had the tests of college-bound students compared to those of carpenter's apprentices," Schmidt said.

According to Schmidt, from a perspective of national policy, the testing was valid.

"If the participating countries consider these students the equivalent of secondary advanced students, then that's what they are," Schmidt said

While some educators and policymakers support the decision, others question whether the decision in fact ignores the primary problem with K-12 science education in the United States. Toufic Hakim, Executive Officer of the American Association of Physics Teachers [the publisher of this magazine], remarked: "If the real issue is how well, or how badly, our students might fare, compared with their international peers, then we are, in effect, admitting our collective failure to prepare these students adequately in physics." Δ

Steve Davolt is assistant editor of Interactions.

"Why is it not generally realized that physics has much to contribute to industry? In the first place, much that is physics goes by other names."
— Homer Dodge, AAPT founding member (1930)

Conference Targets Two-Year College Teachers

On the list of loneliest occupations, teaching physics at a two-year college should rank between fire lookout and lighthouse keeper, because an estimated 60 percent serve as the sole physics faculty member at their respective institution.

Two-year college physics faculty will have an opportunity to overcome their state of isolation at the New Faculty Training Conference for Two-Year College Physics Faculty being held March 6-8, 2008, at Delta College, in University Center, Mich.

The conference features crash courses on effective teaching methods for introductory physics informed by Physics Education Research. AAPT joins Delta College, Estrella Mountain Community College, Lee College, and the National Science Foundation as event sponsors.

On the first day, participants are introduced to three approaches well-suited to teaching physics in a two-year setting. On successive days, instructors take an all-day course in two of the three approaches. The courses offered include instruction on utilizing microcomputer-based laboratory (MBL) tools to convert collected data on-the-spot into easily grasped graphics; CD-based modules called Introductory College Physics/Twenty-First Century, which incorporate some of the latest applications in industry and medicine; and Instructional Strategies in Introductory Physics, an array of practices and strategies such as modeling, classroom management, and conceptual exercises.

Armed with knowledge of effective teaching methods, participants return to their institutions ready and able to implement the tools and techniques learned at the conference. A 15-month assessment is slated for June 2009, in Ann Arbor, Mich., immediately before the AAPT National Meeting.

For further information on the conference, contact Thomas L. O'Kuma, ATE Program for Physics Faculty Project, Lee College, Baytown, Texas, at tokuma@lee.edu or (281) 425-6522. ∆

Thawing 'Frozen' Curriculum With Computation

The "frozen curriculum" was a hot subject at the topical conference on computational physics at Davidson College, North Carolina, July 27–28, and during the July 31 meeting of AAPT's Committee on Undergraduate Education at the national meeting in Greensboro.

Some physics teachers fault the traditional undergraduate physics curriculum for failing to keep pace with changes in how physics is practiced in the real world. "My impression is that there is a general feeling that the core curriculum is stagnant and doesn't reflect the excitement of new fields within physics," said Ernest Behringer, chair of the undergraduate committee.

Physics educators also are taking issue with the insular way in which various branches of physics continue to be taught to undergraduates. In an email response to the frozen curriculum discussion at the committee meeting, North Carolina State University physics professor Bruce Sherwood argued that the present curriculum fails to reflect interdisciplinary realities. "There is little crosstalk between courses, with compartmentalization that is the antithesis of the contemporary physicist's view of the discipline," Sherwood wrote.

A report from the computational physics conference at Davidson College suggested: "One broadly applicable

Matt Payne

way to modernize the teaching of the subject is by including computation throughout the undergraduate curriculum." The conference underscored that the existing power of computers and maturity of computational tools is now sufficient to include computational physics throughout the curriculum.

Committee chair Behringer added: "Because computation enables the study of authentic, cutting-edge problems, computation is an integral aspect of the contemporary practice of physics."

"This integration will require changes to the undergraduate curriculum, thereby 'unfreezing' the entire undergraduate curriculum, and will help to better prepare students for post-baccalaureate employment as well as graduate study."

Following the topical conference, recommendations were drafted for integrating computational physics into the upper-level undergraduate curriculum. Key recommendations include providing students with a wide range of tools (computers, software, etc.) and resources for learning computational physics, revising textbooks to integrate computational physics, and directly assessing the effectiveness of computational tools and methods. At press-time, the undergraduate education committee was completing a proposal to present to AAPT in September 2007. ∆

InterActions
across physics and education

We wish to thank the readers and contributors for your understanding and valued support during this development phase.

Look for the official debut of Interactions with "Physics Education Across the Globe."
Coming January 2008. —Editors

New Faculty Training for Two-Year College Physics Faculty Conference (NFTC)

March 6–8, 2008
Delta College, University Center, MI

This conference is designed to equip new faculty members with knowledge of active learning techniques that are both based on Physics Education Research (PER) and that have been successfully implemented at two-year colleges across the country. Led by experienced two-year college physics instructors, this conference will empower a new faculty member as they embark on the important mission of developing critical thinking skills in their students and developing the future technological workforce for this country.

Conference Leaders:

Scott Schultz, Delta College, University Center, MI
Todd Leif, Cloud County Community, Concordia, KS
Sherry Savrda, Seminole Community College, Sanford, FL
Dwain Desbien, Estrella Mountain Community College, Avondale AZ
Tom O'Kuma, Lee College, Baytown, TX

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Physicists Among Us

BY STEVE DAVOLT

A university physics education might best be regarded as a high-grade, adult version of the "thinking cap," that imaginary chapeau that an elementary school teacher bid us don to magically deflect distractions so we can concentrate all our brain power on the matter at hand. Like a thinking cap, a physics education fosters the cognitive skills that allow us to focus and think clearly about a problem.

A physics education is invisible and, like a thinking cap, worn by people all around us who forsook a career founded on physics to pursue other vocations—writers, musicians, politicians, businesspeople, and computer programmers, to name a few. In the great diasporas that come after earning an undergraduate degree some migrate from physics to myriad other fields. Some seek an avocation, such as religion or politics, while physics continues to be their "day job." The following profiles proudly expose some of those physicists among us who have parlayed their physics major into success in a diversity of careers.

From Protons to Politics

In mid-July 2007, Mike Fortner was feeling the onus of his responsibilities as a freshman state senator. Though the Illinois General Assembly was scheduled to adjourn on May 31, Gov. Rod Blagojevich and the state legislators were at a stalemate on a budget. It was six weeks into summer with no relief in sight.

The political impasse presented a welter of logistical problems for Fortner. As long as the opposing sides remained deadlocked, he had to shuttle between Springfield and Northern Illinois University in Dekalb, where he was teaching an introductory physics course during the summer term. Fortner's home in West Chicago and the university are near one another, but both are a good two-hour drive to Springfield. Furthermore, his research as part of the "D Zero" collider team at Fermilab in Batavia, Ill., was temporarily on hold.

After moving to West Chicago in 1987, Fortner joined the physics faculty at Northern Illinois. Not long afterward he entered politics by taking a seat on an historic preservation committee. Over time, he gradually ratcheted up his political activities, joining a planning commission and other committees, then becoming an alderman. "I became more and more interested in different aspects of city government," Fortner says.

His hometown political career culminated in 2001 when he was elected mayor. He was into his second term when he ran for state senator and won a November 2006 election.

Fortner credits his physics background for being an able-minded politician. "Physics gives you the ability to analyze a complex problem, to break it down into its essential parts that are solvable," says Fortner. Being a physicist is also an advantage when he's analyzing the kind of data that inform policy decisions. According to Fortner, "Physicists have no fear of numbers."

His years of classroom experience imbued him with the ability to communicate complex issues, a skill that applies as much to deciphering the abstruseness of legislation as to explaining the theory of relativity.

Fortner doesn't expect his colleagues to run for civic office, but he does enjoin physicists to become more engaged politically: "Physicists can use their training to give the public a greater comfort level with science and scientists."

Although he won't rule out running for national office—after all, one former Illinois state senator, named Barack Obama, is a presidential candidate—Fortner must first convince himself he can serve better than from where he sits currently. "I'm pretty content where I am now." ∆

A Singular Clarity

When Mike Long moved from his native Missouri to Washington, D.C., in 1996 to become a speechwriter for Sen. Fred Thompson, it marked a major turning point in his career. Long had spent a decade as a systems analyst, but had long since exhausted his enthusiasm for working with computers. So he turned to one of his first loves—writing.

That his college education has been in physics might have made writing seem a less than likely profession. Long received a bachelor's degree in physics from Murray State University in Kentucky. He did a year of post-graduate work at Vanderbilt University before abandoning academia.

"A physics education was perfect training for becoming a writer," Long says. "Many writers tend to be dreamy, romantic types. But physics is a fact-based discipline that teaches you to see a problem in its most elementary form. It gives you the ability to strip down a situation and impose upon it a singular clarity."

He counters the frequent criticism that such a technical approach deprives writers of a voice: "You learn to write as clearly as you can, then your voice or style comes through as an expression of your personality."

Long had gravitated toward science since his high school days in the tiny town of Matthews, Mo., where his first love was biology—genetics, in particular. But he discovered that physics was more conducive to his "mechanistic" way of looking at the world. "I wanted things to make sense," Long says. "Physics at its core level expresses how the world works."

When it came to making the transition to becoming a working writer, Long discovered that many of the writers he admired were pundits, critics, and speechwriters. He began contacting successful wordsmiths to find out how to break into the business. Two in particular—arts critic Terry Teachout, currently the drama critic for the *Wall Street Journal*, and Andrew Ferguson, a journalist who covered U.S. presidential elections for the *American Standard*—were exceedingly helpful by merely taking his phone calls and doling out advice.

After two years on Capitol Hill, Long spent several years picking up an assortment of political writing gigs. In 2004, he joined the White House Writers Group, a boutique communications firm founded by veterans of the Reagan and the George H.W. Bush administrations. WHWG writers pen articles, policy papers, and speeches for government, corporate, and nonprofit clients.

A Washington speechwriter with a physics education is such a rarity that his degree has become a sort of "calling card." According to Long there is a demand in D.C. for someone who understands technology and can write. About half his clients these days hail from the technology sector.

Aside from his day job, Long is a frequent contributor to the political newsweeklies *Weekly Standard* and *National Review Online*. His writing even garnered a "Best of the Web" distinction from the *Wall Street Journal*. ∆

A Harmonic Divergence

You might never suspect that Amelia Kaplan set out to be anything other than a musician and composer until you notice in her oeuvre a work for solo violin titled "The Heisenberg Uncertainty Principle." For Kaplan, a professor of music composition at Oberlin Conservatory of Music in Ohio, the juxtaposition of music for a stringed instrument and quantum mechanics epitomizes the duet that physics and music have played in her life.

From an early age, both vied for her attention. In her eighth-grade science class, Kaplan was captivated with how electrical forces, or bonds, cause substances composed of the same elements to have different properties. "My science teacher told me that was physics—although it's also chemistry. I decided at that point I would be a physicist," Kaplan recalls.

Her primary extracurricular activity was music. She began taking piano lessons at age nine, later adding clarinet, oboe, and saxophone. She would play for many youth and community orchestras, usually as first-chair clarinet.

When the time came to choose a career, however, practical considerations steered her toward science. Kaplan majored in physics at Princeton University, but almost immediately misgivings arose. Kaplan says the rigor of the required math was daunting; she also wasn't enjoying it, but sheer doggedness saw her through. "I'm pretty stubborn, so I don't tend to give up things until it's past a reasonable point."

She received a bachelor's in physics in 1985 and went to work for Bell Communication Research in Morristown, N.J. (formerly part of Bell Labs). Kaplan continued to take piano lessons and in her spare time performed with Princeton's New Music Group. "I realized then that I absolutely had to try to make a go at it in music, or I would regret it forever," she says.

Kaplan began driving into New York City once a week for composition lessons from a professor at the Julliard School. Later, she won a full scholarship to the University of Chicago, where she earned a Ph.D. in music composition in 1998.

Asked why music is often referred to as the most mathematical and scientific of arts, Kaplan replies, "I suspect it has to do with pattern recognition and quantitative thinking common to both. Both involve recognizing connections between sets of abstract objects, be they numbers or pitches or rhythmic structures."

Her own worst critic, Kaplan believes her best work as a composer is still to come. "Unlike some of my colleagues, who could use some humility, I am quite ready to pronounce something a piece of crap," she acknowledges. "Let's just say that I hope to have some notable achievements as a composer but haven't got there yet." Δ

Riding the Waves

It was one of those scenarios for which the ancient Greeks coined the term "irony." As a geophysicist, J. Ernest "Sunny" Breeding, Jr., stalked ocean waves for three decades before one named Katrina finally caught up with him. She reached all the way up to Slidell, La., on the north side of Lake Pontchartrain, flooding his home with four feet of water and nearly wiping his travel agency off the map.

Sunny Breeding started World Class Travel & Tours after a long, successful career with the Naval Research Laboratories. An expert on wave mechanics, he studied how the wavelength, speed, and direction of ocean waves were influenced by meteorological change and ocean floor topography. His research was critical in projecting their effect on sea-going vessels and coastal areas.

Breeding was of draft age during much of the Vietnam War, but the Navy asked the local draft board to exempt him from active duty. "[The Navy] said I was more valuable to national security as a civilian than as a soldier," Breeding explains.

Breeding first began thinking about the nature of waves as an adolescent in his native Iowa. A ham radio hobbyist at the time, he contemplated the radio signals oscillating across the cornfields. The rigorous certification process required to get a ham radio operator's license sealed his destiny as a scientist.

He earned a bachelor's degree in physics from Drake University in Des Moines, Iowa, later earning his Ph.D. in geophysics and physical oceanography from Columbia University, where he conducted research at Columbia's Lamont-Doherty Earth Observatory. "At Lamont-Doherty I had the privilege of studying with one of the great pioneers of geophysics, Maurice Ewing," Breeding says.

Breeding has taught undergraduate physics at the University of Tennessee-Knoxville, Florida State University, and the Florida Institute of Technology. His extensive collection of physics texts, fond relics of his teaching days, was among the property lost to Katrina.

After more than thirty years working as a physicist, Breeding made a career change after budget cuts at the Naval Research Laboratory at Mississippi's Stennis Space Center.

Breeding and his wife, Rebecca, a math major with a minor in physics, had started World Class Travel & Tours in 1994, at a time when Rebecca's employment situation was uncertain. Rebecca eventually landed another job, so Breeding, newly unemployed, devoted his full attention to the travel agency, where he has occasion to draw on his knowledge of waves to advise his clients. "If someone is prone to motion-sickness, I can tell them which cabins to book on a cruise ship to experience the least amount of movement," Breeding says. Δ

Returning to Earth

Like many schoolchildren who lived through the post-Sputnik zeitgeist, David Larson was lured into science by a combined sense of patriotism and adventure. "The space program was in full swing, and the race to the moon was a pretty romantic notion," Larson says.

How would rockets work in space? Could a space vehicle safely convey a man to the moon? Larson says these were huge questions that had to be answered. "This was pure science fiction."

Like nearly all wannabe space travelers, Larson was destined to remain grounded. He enrolled in the physics program at Washington University in St. Louis "not really knowing what I'd do with the degree," he recalls, but after a change of heart, he set his sights on a business career.

Although easy to assume, Larson didn't abandon physics because the stars in his eyes had been replaced by dollar signs. "Once you get to college you realize there's this whole world out there," Larson explains. "So much of physics involves working in a lab, in isolation. I was getting the idea that I wanted to be more actively involved with people."

Fortunately, the university offered a "three-two" program, which allowed students to work toward their undergraduate and master's degree simultaneously. Larson earned a bachelor's in physics and an M.B.A. He soon found, however, that the earthbound world of business is light years from his star-struck dream of working on space projects.

"When I started studying business I had no idea what a liability or an asset is," says Larson, whose bank holds more than $2 billion in assets. "Once I learned the terminology, I found that what physics taught me about problem solving gave me an advantage."

According to Larson, the scientific process physics students learn applies to problems in other fields. After physics, the math of accounting and finance came easy. This "competitive advantage" helped Larson quickly ascend to leadership positions. "Because physics is a problem solving discipline, it allows you to think about strategy," he said.

After a couple of marketing stints with Fortune 500 companies, Larson broke into banking and financial services, climbing rapidly through the ranks at Citibank. During the 1990s he helped bring financial services to the Internet with companies such as Mortgage.com and Monetrics, a car loan broker. He returned to traditional banking in 2006 as CEO of Birmingham, Ala.-based New South Federal Savings and Loan. Δ

Physics and Faith

In an era when science is argued to be the antithesis of religion, however shall the twain meet? Answer: Father Cyril Opeil, physicist and Jesuit priest. An assistant professor of physics at Boston College, Father Cyril reconciles faith and science on a daily basis.

Father Opeil was a young engineer working on aircrafts for Westinghouse in Baltimore in the 1980s before being called to the priesthood. He chose the Jesuits because of their well-known scholarly tradition and spiritual devotion. "It was a wonderful combination that the Jesuits offered," Opeil says. "I could have a profession, and be a priest and live a ministerial life."

Such a creed offered the scholar in Opeil the perfect opportunity to devote himself monastically to his work. A few years after his ordination, Opeil taught chemistry and physics at Gonzaga High School, a distinguished Jesuit school in Washington, D.C. His provincial, Rev. Edward Glynn, recognized his scientific aptitude and suggested he pursue doctoral studies.

Opeil earned a Ph.D. in physics at Boston College. He then accepted a two-year post-doc, becoming the first Jesuit priest to work at Los Alamos National Laboratories.

While at Los Alamos, Opeil attached himself to the tiny parish of Chimayo, which is tucked away in the Sangre de Cristo Mountains. Although encouraged by his superiors to exempt himself due to his research schedule, he took on a full range of ministerial duties—saying Masses, hearing confessions, conducting weddings and baptisms.

The heart of the parish is the Sanctuaria de Chimayo, a small chapel also known as the "Lourdes of America," where pilgrims come to carry away small amounts of the red earth to which they ascribed healing properties.

Founded in 1534 by Ignatius of Loyola, the Society of Jesus boasts a long history of scholarly and intellectual achievement. The Jesuit scientists that Opeil counts among his precursors include the polymath Athanius Kircher, the German astronomer Christopher Clavius, and the French paleontologist Teilhard de Chardin. Opeil point outs that 23 lunar craters are named after Jesuits. "We were the people mapping the moon."

"It was the idea of our founder, Ignatius, to educate and nurture the whole person, to care for the soul, not just to make sure people are meeting certain requirements," Opeil says.

Much of his research involves studying electrons in uranium. Opeil unifies the supposed dichotomy of his two callings through the Jesuit motto, "To find God in all things," as he unlocks the mysteries of the smallest components of the natural order. Says Father Opeil, "Science is a way of looking at how the Creator manifests himself in the world." Δ

THE GAMER

What Do We Not Know?

JASON COLEMAN

Video game developer, VP of Software, and founding partner of Big Huge Games.

Degree: Master's in Physics, University of North Carolina at Chapel Hill

The Latest: Lead programmer for Rise of Nations (2003) and Rise of Legends (2006).

When I was five or six years old, my Dad, a physicist (just how many people enter physics without a physicist role-model?), would joke that he knew everything there was to know. At that age, I believed him. For me though, it seemed that all the interesting stuff is in the gaps. What do we not know? How do we apply well-developed theories to unsolved problems? How does a faucet work with all the simple yet subtle forces? And when you get down to it, what the heck is time?

In order to have any hope of answering questions of that type, I, like most people, needed to learn a reasonable amount of what is already known. I concentrated my studies on physics. However, I was borderline bad at picking up the pieces that had already been established; it was difficult for me to follow someone else's line of reasoning. My goal became learning how I as an individual could understand the world in a way that would be meaningful to me specifically. Physics became a journey in "Learning How to Learn."

I learned to attack an idea on multiple fronts, gathering as many different sources as I could find. I learned to skim through and start with a broad understanding, then start filling in the missing pieces. Textbooks tend to present ideas as a series of proofs but a major goal for me was to develop an intuitive feel. I learned that it takes time and constant reassessment of my comfort level with a particular idea.

My second year of graduate school I started to feel like I knew what I was doing. I had developed a confidence that anything is learnable. If I understood a derivation, I could jump nimbly through those steps to arrive at an answer (my random-access memory is not so good). These skills have influenced my approach throughout work and how I view the world.

But there I was finishing my second year of graduate school with a Master's Degree and, as far as I was concerned, I should have started all the introductory physics classes again. I felt that I was lacking a sufficient understanding of some basic concepts. I took a part time job doing research for an India-based thermos company. The task: make a better thermos. While I had been leaning toward the theoretical, I loved many aspects of experimentation; I'm a bit of a tinkerer at heart. Unfortunately, I loathed some key aspects of the process. I was getting great and new results, but I found robustly explaining it all—a significant part of the job—to be tedious.

At that point, my wife and I moved to Baltimore for her work, and I applied and was accepted at a university in Maryland with the idea of completing a Ph.D. in Physics. A good friend from my undergraduate years suggested I take a temporary job for the summer testing (yes, I said testing) computer games at a software company where he worked. Though I didn't tell anyone at the time, I made up my mind on the very first day that it was the industry for me. I deferred a year from graduate school. Six months later, I let the university know they could stop holding my spot.

In those six months, I leveraged what I learned from programming physics simulations in FORTRAN and taught myself enough C++ to land a job there as a programmer. I left to join a startup game company and then, two years later, left to join three partners in starting our own game company, Big Huge Games. Big Huge Games is currently a 100-person company consisting of programmers, artists, designers, audio technicians, production, and support. We make games for the mass market on platforms including the PC, Microsoft's XBOX 360, Sony's Playstation 3, and Nintendo's Wii.

So what's the appeal? It's many of the things that appealed to me in physics: the problems are never-ending and constantly changing, and you get to work with insanely smart, interesting people. Initially, it had the appeal of being something I could jump into right away in its full form whereas, in physics, I had many years of graduate school remaining before the next phase. Practically, it solved the key problem I was facing in my physics studies; I knew how to learn but I felt I had a lot of catching up to do in physics. In programming, past experience is useful but the base of knowledge changes so rapidly from year to year, it's relatively easy to become an expert in some useful sense and jump into the pool.

The business-side of what I do has proven fascinating and, surprisingly, I call into play my physics education here too. As the mysteries of code get peeled away one by one, solving various business problems occupies the majority of my free thinking. Sometimes decisions have to be made with incomplete information—how incomplete is a matter of degree. Some of those decisions, while not the life-in-hand decisions of a NASA launch, do have profound implications for people's lives. My approach is to try to find the underlying system that approximates reality, and then update the system as we pull in new information. The trick is to have some reasonable confidence in your view of the world while striving to update it with new data. At Big Huge Games, we use the term "Intellectual Honesty" with the formal definition, "Keeping one's convictions in line with the evidence." That sounds a lot like the scientific method to me. It also leads to a steady stream of surprises; we are constantly improving processes to the point of wondering how things ever worked before. Game development is still in the early stages, and I often draw an analogy to filming a movie at the same time you're creating the camera, the lighting, the set, and even the actors. And these days, the investments are similar so there's a lot that can go wrong, and there is always room for improvement.

In matters of scale, physics and computer science have a lot in common. While not a requirement, it's been said that having the ability to hold both the large and small in your head simultaneously suits a programmer well. Physics, with scales ranging from sub-atomic to galactic, certainly gears the mind toward that way of thinking.

And then, of course, there's the actual physics. When I started in the games business, we mostly dealt with two-dimensional visuals and worlds that were guided without much of a nod at the actual universe. Now physics simulations are bound to show up in a surprising array of games. A set of problems games have tried to solve is collectively known as "inverse kinematics." This is where we have certain constraints such as where a foot on a character must be placed and certain aspects of his pose, and we must then figure out the rest of the motion according to physical laws. All of that linear algebra which seems to get glossed over in many undergraduate courses is a key component of 3D graphics. And we're inching closer to solving fundamental lighting equations in real-time (at 60 frames per second). Numerically solving these problems efficiently is a big problem and a major focus of modern game development.

Physics satisfied my need to learn how things work. In the process, it taught me new ways of seeing the world and a set of skills that can be applied to anything. That's neat.

THE WRITER

Like Leaving the Family Farm

DENNIS OVERBYE

Science writer for
The New York Times

Degree: B.S. in Physics, Massachusetts Institute of Technology

Author: *Einstein in Love: A Scientific Romance*, Viking (2000)

My literary career ended in the ninth grade, when I was kicked off the junior high newspaper—which I had founded a year before—for being after school without permission in a room in which erasers were thrown. There were also mutterings about a conspiracy to subvert the student government somehow.

Luckily another career choice had already opened up. Sputnik had been launched a year before, propelling the world into what my science-fiction-reading friends and I had already presumed would be the future. We spent our time arguing about whether the universe was Big Bang or Steady State and devouring the stories of Arthur C. Clarke, Robert Heinlein, Isaac Asimov, Ray Bradbury and many many other names I can still fondly recall.

Four years later I wound up at MIT, then a factory for training particle physicists. Within a week of entering the place I had forgotten why I had ever been interested in physics or science, for that matter. I soldiered through on the grounds that it was better than being drafted into the army. What I remember most now are courses on existentialist literature taught by Hubert Dreyfus, eastern religion by Huston Smith, and the junior physics lab, in which students sacrificed Saturday mornings and sometimes their fingers redoing classic adventures like the Millikan oil-drop experiment—the main point of which seemed to be to teach us to do error analysis. At least I have never forgotten that, and although we don't always quote the formal errors in *New York Times* articles, I always look for the error bars when some allegedly scientific result is announced.

After graduating, all I wanted to do was live a bohemian life in some cozy Back Bay brownstone, but in the interest of remaining out of the army, and Vietnam, I embarked on a series of jobs in the defense industry, most notably with EG&G studying the effects of high-altitude nuclear explosions. In spite of my miserable MIT grades I got in graduate school at UCLA to study astronomy only to succumb immediately to a fiction writing workshop taught by the late novelist and screenwriter Bernard Wolfe. It was one of the revelations of my life that I was able to even to get into his workshop.

I dropped out again and pursued a novel, funded by 65 weeks worth of unemployment compensation and my wife's salary as a kindergarten teacher. I spent too much time trying to be Thomas Pynchon and not enough time being myself and the project eventually slogged to a halt under the weight of its own ambitions. In desperation in 1976 I wrote letters to every publisher listed in the Boston phone book. As a result *Sky and Telescope* offered me a part-time typesetting and proofreading job at the stunning rate of $6 an hour. Charley Federer, the magazine's founder, told me on my first day to keep my salary a secret because they would never pay me so much full time, although I later learned that I was being called "the six-dollar man" behind my back.

True to their word, when they hired me full time a few months later, I had to take an hourly pay cut. I had barely worked my way back up to that level four years later when Time Inc. offered me three times as much to come down to New York in 1980 and help them start *Discover*, the "newsmagazine of science."

It was like leaving the family farm. In those days everybody at the magazine did everything; after writing or editing the articles, we all did our own layouts, artwork and photography. Most of what I know about astrophysics and cosmology I learned there carving out a niche as the local expert or fanatic on black holes, the Big Bang and assorted exotic mysteries—mutating neutrinos, multiple universes, and quantum gravity.

I caught a wave being one of the first people to write about Stephen Hawking. When I first met him, rolling down the aisle at an astrophysics conference, the so-called Texas Symposium, in the Copley Plaza in 1976, I knew something dramatic was happening. I never dreamed that 30 years later I would watch him roll into the Great Hall of the People in Beijing, like an emperor from another planet.

The people doing this work were some of the same people I'd sat next to at MIT—the ones who actually took notes and did the problem sets. Aided by a certain familiarity with their world, an ability to pass, conferred by MIT and a rigorous re-education at *Sky and Telescope*, I've been happily following and writing about them ever since, at *Discover* and now *The New York Times*.

I've come to think of them as my own Yoknapatawpha county, the fictional locale where William Faulkner's characters lived. It's a community as rich in passion, adventure, personality and ideas as any you would find. You couldn't make up—you wouldn't dare make up—characters like Stephen Hawking or David Schramm or Allan Sandage. You certainly wouldn't dare to make up string theory or the accelerating universe.

My first book, "Lonely Hearts of the Cosmos," was an attempt at a sort of group portrait of this generation that went from Sputnik to dark matter and dark energy. It was published in 1991 and my most prized memento of that time is a fan letter I got from Arthur C. Clarke—talk about coming full circle. He liked the book, but hated the title.

In 1998, as I was finishing my second book, "Einstein in Love," which I thought of as a prequel to Lonely Hearts (they made fun of that title too), *The New York Times* whistled me down from Woodstock, where I was living, to become the deputy science editor.

It was fun suddenly working at the center of the news universe and having people to talk to during the day, but I wasn't a very good editor of other people's stuff and there was no time to write my own. My creativity was limited to crafting headlines every Monday for the next day's science section. So after a couple of years I stepped away from the "dark side"—as we refer to editors here—to become, as I sometimes refer to myself, the cosmic affairs correspondent. My official title according to my paycheck is "domestic correspondent."

In February I will have been at the *Times* for 10 years, which is by far the longest I have ever been able to hold a job. Luckily, it's a good one. The scientific life is in many ways the last unexplored continent of popular culture. I've been privileged to live and report from there, even if I didn't really throw those erasers. I swear.

THE MEDICAL PHYSICIST

Doing Well by Doing Good

WILLIAM R. HENDEE

Internationally-renowned radiation physicist

Degree: Ph.D. in Physics, University of Texas - Austin and Dallas

Scholarly Works: Authored or co-authored more than 370 scientific articles and 25 books, and is editor of *Medical Physics*, a leading journal of biophysics.

Medical physics has and continues to be a highly stimulating and rewarding discipline for me. I would like to see more physicists enter the profession, especially since there is a shortage of individuals with physics backgrounds working in particular areas of medical physics. I can think of no field in physics where using one's knowledge and experience can directly lead to improvements in the care patients with many different diseases and disabilities receive.

After receiving an undergraduate degree in physics from Millsaps College and doing graduate work at Vanderbilt University, The University of Texas offered me a scholarship in medical physics (formally called radiological physics). In addition to taking several courses in radiation and nuclear physics, I completed two years of medical school. My medical training has been an invaluable part of my career because I am able to understand the many technical challenges from the physician's perspective.

After receiving my Ph.D. in 1962, I taught physics at my alma mater, Millsaps College. In 1965 I officially entered the medical physics profession when I accepted a position as the sole medical physicist in radiation oncology at the University of Colorado.

Medical physics focuses primarily on research and clinical applications of physics and engineering in medical imaging and radiation oncology. Medical physicists are involved in all of the imaging modalities in medicine: X-ray, nuclear medicine (imaging of internally distributed radionuclides), computed tomography, ultrasound, magnetic resonance imaging, magnetoencephalography, and emerging technologies such as optical and impedance tomography. In radiation oncology, physicists are at the forefront of new technologies such as image-guided therapy, high dose-rate brachytherapy, stereotactic radiosurgery, intensity-modulated conformal X-ray therapy, and evolving fields such as radiation therapy using protons and heavy ions. Physicists are responsible for the development, calibration, quality control, and the safe and effective use of all of these technologies.

In the mid-1960s nearly all treatment plans designed for patients receiving radiation therapy were created manually using transparent overlays of radiation charts. With assistance from two medical students and access to a computer owned by the Denver-Rio Grande Railroad, I developed software that made possible computer-based treatment planning. The program was used first at my hospital and subsequently at hospitals throughout Colorado and in several other states via a teletype communications network.

By the mid-1970s radiological physics had expanded within the University of Colorado. The Division of

Radiological Physics was created consisting of a graduate program, several faculty, and postdoctoral fellows. In 1976 I accepted an invitation to serve as acting chair of the radiology department. In 1978 I was appointed the chair. As probably the only medical physicist to serve as a radiology chair in the United States, I was responsible for a major research program in medical imaging, radiation oncology, and radiation biology as well as clinical services at three large area hospitals.

One of the more rewarding aspects of my job is the many, productive medical physicists—including four former presidents of the American Association of Physicists in Medicine (AAPM)—who have started their careers at the University of Colorado.

In 1985 I accepted the position of Vice President for Science and Technology at the American Medical Association in Chicago—a rewarding experience that extended my understanding of medicine well beyond radiology and radiation oncology. Still, I missed academia and the time it affords for research and contemplation. So in 1991 I joined the Medical College of Wisconsin as Senior Associate Dean for Research and Professor of Radiology.

Over the next several years I took on additional administrative responsibilities, from Dean of the Graduate School of Biomedical Sciences to Vice Chair of Radiology. Of all my responsibilities at the Medical College, by far the most satisfying was working with graduate students. There were 102 graduate students when I became dean in 1992, and 365 students when I left in 2006.

Since my retirement as an administrator at the Medical College, I have more time to devote to medical physics, which delights me because the profession has been so good to me over these many years. I presently serve as editor of Medical Physics, the foremost scientific journal in the field and published by AAPM.

I am heavily involved in efforts around the world to improve the education of medical physicists and physicians in the use of physics and engineering for developing new technologies in medicine. Working with physicists from diverse institutions and countries is a wonderful way to complete a career devoted to physics.

Through my experience I have learned a few valuable lessons worth sharing. The adage "doing well by doing good" perfectly fits medical physics. To be a good medical physicist, you must first be a good physicist; thus, it is essential you acquire a solid physics background. Medical physics being a very dynamic field, a commitment to life-long learning is also essential for those entering the profession.

The well-being and safety of patients depend on the work and ability of physicists. We should demonstrate our competence to work in a clinic through certification by the American Board of Radiology. Finally, every physicist should contribute his or her time and energy to the profession's member organizations as a way to at least partially earn the privilege to serve individual patients as well as society as a medical physicist.

Primer on How To Develop a Career in Medical Physics

BY MAHADEVAPPA MAHESH

The path towards a career in medical physics starts with a sound undergraduate degree in physics or other engineering science.

At present, the three dominant areas in medical physics are radiation therapy, diagnostic radiology and nuclear medicine.

A career in medical physics is quite rewarding, not only in remuneration but also in terms of the level of respect obtained from medical colleagues. There is a fairly high demand for qualified medical physicists, and the future appears advantageous, as many practicing medical physicists of the baby-boom generation will be soon retiring.

There are often debates about which type of undergraduate degree best prepares an individual for a career in medical physics. Although the debate continues, my feelings are that an undergraduate degree in physics provides a solid foundation over other specialties. With the looming changes in the requirements for those who want to obtain certification in medical physics, it is best to get in touch with a practicing medical physicist to establish a mentor relationship sooner, rather than later.

The Four Steps to Medical Physics:

1. Undergraduate degree in physics.
2. Graduate degree in medical physics from a program accredited by the Commission on Accreditation of Medical Physics Educational Programs (CAMPEP).
3. Residency in one of the medical physics specialties (e.g., radiotherapy physics, diagnostic radiology physics, etc.) at a CAMPEP-accredited institution.
4. Certification in the particular medical physics specialty by an appropriate certification body (e.g., American Board of Radiology (ABR), Canadian College of Physicists in Medicine (CCPM)).

For a high school student who is interested in a medical physics career or merely curious to learn more about medical physics, I offer the following advice:

- **Visit the American Association of Physicists website (www.aapm.org).** It is the best place to start with general questions about careers in medical physics. AAPM is a good source to obtain contact information for local medical physicists, information on summer fellowships for undergraduates, CAMPEP accredited graduate programs in medical physics (www.campep.org), and suggestions for selecting a mentor.
- **Contact medical physicists in your local area** and arrange a visit to spend part of the day at their facility.
- **Apply for a summer research fellowship through AAPM.** This is a 10-week fellowship for students in undergraduate programs to work with medical physicists on specific research topics.

Finally, good luck on your journey towards a rewarding career in medical physics.

Mahadevappa Mahesh, MS, Ph.D., FAAPM, (mmahesh@jhmi.edu), Johns Hopkins University School of Medicine, Baltimore, MD

THE HISTORIAN

Not Merely a Scientist Doing Historical Work

HELGE KRAGE

Professor of history of science and technology, University of Aarhus, Denmark

Born: 13 February 1944, Fredericksberg in Copenhagen, Denmark

Degree: Cand.scient., major in physics and minor in chemistry, University of Copenhagen.

Few historians of science have identical career patterns so my path to becoming an historian of science may not be representative, but it is instructive nonetheless.

When I began studying physics and chemistry at Copenhagen University in 1962, the Danish physicists and Nobel Laureate Niels Bohr was alive—and though he died a few months later, I am unaware of any causal connection. Like most physics students, I was ambitious and confident that I would make a career as a research physicist, preferably in elementary particle physics.

Unfortunately my talents did not match my ambitions, and after graduation I ended up teaching physics and chemistry at a Danish gymnasium (more or less equivalent to a high school). This was not the job I desired, but I learned to like it and have never regretted those many years as a teacher of students 16 to 19 years old. I pride myself on having an experience in teaching that has given me the ability to express myself clearly and with more clarity than many of my colleagues. Moreover, while teaching I became seriously interested in the history of physics. I not only incorporated elements of science history in my teaching, I also contributed to the field with scholarly articles on the historical development of atomic and quantum theory.

Based on this work I was fortunate enough to be appointed an associate professor of history of science at Cornell University. My position at Cornell was quite unusual—I was hired jointly by the physics department and the history department, thus I was able to experience directly the difference between the two academic cultures. My office in the physics department also happened to be next to the office of Hans Bethe.

After two fruitful years at Cornell, having now completed the transformation into a professional historian of science, I returned to Europe and was eventually appointed curator at the Steno Museum in Aarhus, Denmark, a museum devoted to the history of science and medicine. When the University of Oslo, Norway, created a history of science chair, I was appointed as the country's first professor in the field.

As I continued my work in the history of post-1850 physics, I gradually extended my research interests to cover the history of chemistry and astronomy. After a couple of years in Oslo, I accepted a professorship at the University of Aarhus, meaning I became part of a small department for the history of the exact sciences.

History of science is typically associated with philosophy of science and the sociology of scientific knowledge and established within a Faculty of Arts or another interdisciplinary program. There are advantages to keeping history of science institutionally close to the natural sciences, but there are also disadvantages—science students rarely have any interest in or knowledge of the past.

It is worth mentioning that my formal education has consisted entirely of physics and chemistry. I have never followed a course in history, philosophy or the social sciences; yet, I have never felt I am at a serious disadvantage. Most historians of science agree that history of science is primarily a branch of history. It goes without saying that it requires a great deal of historical insight, knowledge of historical methods and historiographical traditions—subjects that one can learn through independent study. This is how I became a historian of science and not merely a scientist doing historical work.

History of science is a small and somewhat fragile academic field. On the other hand, its approach is very broad, interdisciplinary, and intellectually challenging, requiring competences in the natural sciences as well as in the humanities and social sciences. Many historians of science have a background in mathematics or natural science, but there are those who insist that competence in the sciences is not necessary, indeed, too much knowledge may be a detriment. I, however, emphatically disagree.

Although training in physics, or some other science, may be avoidable or irrelevant for certain parts of the history of science, it is indispensable for studying most primary sources contained in the research literature. Certainly, had I not been trained in physics I would never have been able to appreciate Bohr's atomic theory or reconstruct how Schrödinger arrived at his famous wave equation for the hydrogen atom or become interested in the history of modern cosmology, which can only be understood if you have some knowledge of Einstein's general theory of relativity.

History of science is both a cultural and scientific study, neither in conflict with the other. It includes as a central component reconstructing the work of past scientists; the historian must be able to think like Newton, Maxwell or Heisenberg. To do so, knowledge of physics is necessary, though not sufficient.

History of science is primarily aimed at understanding the past, but it possesses the extra bonus that knowledge of the past may well put you in a better position to understand science in the present, both epistemically and socially. I will even go as far as to claim that a physicist with a proper historical perspective of his or her science will make a better physicist than the one who cares little about the historical development of physics. Although a sound knowledge of modern physics does not imply a correspondingly sound knowledge of its historical roots, it does help. A few times I have come across non-trivial mistakes made by physicists of the past, some being quite important. Would I have been able to spot such mistakes if I had not been trained in physics? Of course not.

History of physics is an attractive field. One reason is it spans the infamous gulf between the "two cultures"—the literary-humanistic and the technical-scientific. Another attractive feature is its conduciveness to scientific insight. The serious researcher of the history of physics will not only learn to understand how physicists thought in the past, he or she will also learn a great deal about physics. Although I have forgotten much of the physics I was taught during my studies at Copenhagen University, I have been more than compensated by the physics I pick up studying the history of science.

THE TECHIE

Embracing and Enjoying Change

JAMES N. HOLLENHORST

Senior Director of Intellectual Property Strategy for Agilent Laboratories

Degree: Ph.D. in Physics, Stanford University

Latest Project: Keynote speaker, Research Review Day at the Baskin School of Engineering

On the face of it, my Ph.D. training in low temperature astrophysics would hardly seem to qualify me for a career as a physicist in the business world. In retrospect, it was excellent training, and thanks to the enlightened hiring practices of Bell Labs, I was able to get my first job in spite of a dearth of experience solving problems of direct relevance to AT&T's business.

Although initially planning to be a theoretical physicist, I was attracted to the experimental group of Bill Fairbank while studying for the Ph.D. at Stanford University. Bill's students were very independent and Bill's genius was to get funding for outlandish experiments, like searching for gravity waves and free quarks, or measuring the free-fall of positrons to see if they fell up. My own work was part of the gravity wave search, investigating the sensitivity limits of superconducting quantum interference devices and the quantum limits on detection of classical forces.

When it came time to find a job, I was torn between the default academic path, and getting a job in business. With lots of encouragement from my wife, Mary, I took the latter course seriously. At the time, a job at Bell Labs was considered every bit as prestigious as a job in academia, so when Bell Labs made an offer, I gladly took it, thinking it would be a good place to work for a couple of years until I figured out what I really wanted to do with my life. During the interview, I remember Joe Geusic explaining that in industry you could choose to be an expert in one area, just like in Academia, or dabble in many different areas over one's career. Joe was one of the early laser inventors, the first to develop a Nd-YAG laser. Part of Joe's hiring practice was to find young Ph.D.s who he thought had great potential, paying less attention to whether or not they had specific skills in the problem at hand. Unfortunately, I have found this to be a rare practice in industry, where the pressures of solving the latest development problem typically dominate the hiring decisions.

I joined Bell Labs to work on superconducting devices for digital computers. It soon became clear that we could not keep up with the rapid advances in silicon integrated circuits and our project was cancelled. Some of us in our little Josephson group started reading up on semiconductor device physics as we searched elsewhere in Bell Labs for another job. After spending six months as a silicon IC designer, my boss Barney De Loach (inventor of the IMPATT diode and a superb human being) offered me a job as a Project Manager.

Perhaps the most difficult decision of my career was whether or not to choose the path of manager or individual contributor. For as long as I can remember, I wanted to be a scientist and never had any desire to supervise others. I decided to take the plunge and quickly found that I was now thinking mainly about people instead of thinking mainly about things. It was not something I was trained for, nor felt competent at, but I adapted and ultimately learned to take great pride in the things that other people did under my leadership. I led work on photodiodes and lasers and was able to develop my technical expertise as a semiconductor device physicist and experience the satisfaction of seeing our work deployed to improve worldwide communications and provide a livelihood for many other employees of AT&T.

As AT&T's lightwave business became increasingly troubled and, after 11 years of Bell Labs, I decided to move back to California and take a job with a company I greatly admired, Hewlett-Packard. I was attracted by the opportunity to work with two great men, Len Cutler, and John Moll. Both of them had a passion for science, like me, and they combined it with distinguished careers as scientists and business leaders. Len was responsible for hiring many great scientists and engineers into HP Labs and its successor, Agilent Labs. I also had the opportunity to work for Gary Baldwin, a great leader and mentor. HP Labs had a wonderful collaborative spirit and a tremendous record of contribution to the business that made it immediately attractive to me. I had the opportunity to continue to learn many new areas of technology and, ultimately to lead Electronics Research for Agilent and later Life Science and Chemical Analysis research.

Let me conclude with some observations about life as a physicist in business. In the academic world, you have the freedom and the mandate to become the world expert in a small area of science or technology. In business this can occur, but it is more likely that you will have to change fields many times within your career. This is exciting and enriching for someone who embraces and enjoys change. You are also unlikely to be identified primarily as a physicist. Corporate research labs no longer have a "Physics Department" or "Solid-State Physics Lab". The work is often organized along product lines and not technology. Your job title may be Scientist, Engineer, or Manager, but is typically not Physicist. You will work in interdisciplinary teams and do work that is not easily classified among academic disciplines. You will learn to appreciate that other disciplines are just as deep and equally hard. You will make mistakes that, unlike those of practitioners of softer disciplines, will be immediately evident, like your new computer program that crashes or your new transistor that has no gain. This makes physicists acutely aware of human fallibility and breeds a healthy skepticism. Finally, you will discover that the most important learning from your physics training is not how to solve Maxwell's or Schrödinger's equations. You will bring a quantitative mindset and be adept at approximations and back-of-the-envelope estimates. You will need to understand why and apply your skill at breaking a complex problem down into simpler problems. Your designs and inventions will be based on a firm scientific understanding rather than the quicksand of pure empiricism. Most importantly you will bring an attitude, the conviction that hard problems can be solved by hard work, an invaluable trait in the business world.

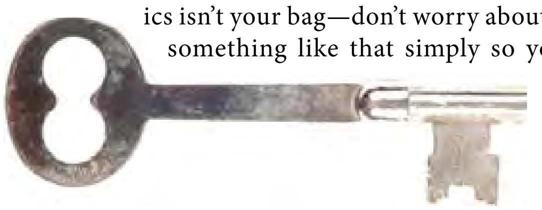
Keys to Success

BY DAVID McMAHON

As spring approaches and new graduates will begin their job search, once again we are hearing alarm bells ringing about the risk of getting a degree in physics and then facing the unemployment line. It is true that getting a physics degree is less of a sure thing than, say, becoming an electrical engineer. This is because electrical engineering is something that gives you a specific skill set that is in demand by industry, while physics could be said to be a degree that creates a generalist with a lot of problem solving skills. However, rather than panic or lament having studied a pure science, there are steps that students can take to ensure they will be employable both inside and outside of academia. Having spent many years working in industry and the national laboratories, I have come up with 7 keys to success with a physics degree that I believe will help graduating physicists maintain employability.

1. NOBODY CARES WHAT YOUR DEGREE IS IN, THEY CARE ABOUT WHAT YOU CAN DO

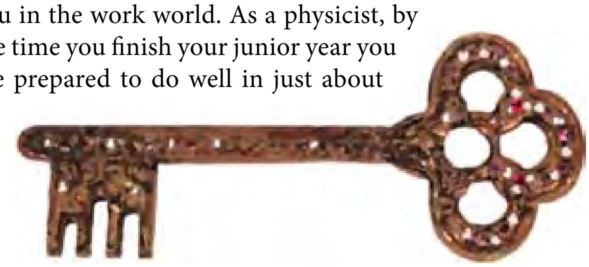
The first thing I have noticed in the "real world" is that the bottom line is WHAT you get your degree in isn't all that important. Now let's not to carry this too far, getting a Ph.D. in English is certainly not viewed as equivalent to getting a Ph.D. in nuclear engineering. What I am saying is that basically, it doesn't matter all that much if you get your degree in math, physics, or engineering unless you're hot on some specific niche career. So, if learning MRI or condensed matter physics isn't your bag—don't worry about doing something like that simply so you can



get a job after graduation. What people really care about is what type of skill set you have. Many skills you can learn in school can be applied in a wide variety of areas. This leads us to key number two.

2. DIVERSIFY YOUR ACADEMIC BACKGROUND

While in school, students are primarily focused on completing their degree requirements and getting out as soon as possible. This is a mistake. While satisfying degree requirements and making sure you complete that physics degree in a timely manner is important, you should take advantage of the fact that you are in school and therefore have access to a wide pool of knowledge that can help you in the work world. As a physicist, by the time you finish your junior year you are prepared to do well in just about



any technical discipline. Take advantage of this fact to learn at least two subject areas related to physics that are of use in industry. For example, you might consider taking a look at the electrical engineering department and taking focused courses in a particular subject area, such as signal processing, optics, or semiconductors. Let's consider signal processing. A student could take courses in signals and systems, digital signal processing, random signal processing, and circuit analysis. Then take courses in Fourier analysis and wavelets in the math department—making sure to take a course that included some study of Fourier analysis and wavelets using a computational tool like MatLab. As another example, instead of taking a minor in math, take a minor in mechanical engineering. Heat transfer and fluid dynamics aren't required for a physics degree, but take an extra semester and take them anyway.

There are also several options right in the physics department that students interested in astronomy or theoretical physics might be avoiding. Take courses in optics, laser physics, and computational physics. Do some laboratory work in optics. By taking courses like these, the student will put him or herself in a position where they are viewed as worth hiring in industry "despite" having a physics degree—even if you specialize in something as esoteric as quantum field theory or astrophysics.

Get Computer Skills!

3. LEARN COMPUTER MODELING PACKAGES

No matter where I have worked, whether it's been at Sandia National Labs or in industry, doing some sort of computer modeling has always been part of the job. If you start to learn this while in school, you will have a leg up in your employment search and add to your skill set making you more secure. The first step is to learn how to do computational math. MatLab and MathCad are the most widely used tools, so while in school you should get very comfortable with using them. Don't just dabble—make sure you master them. Start by learning how to enter equations and do plots, how to solve differential equations and how to do linear algebra computationally. It is also a good idea to get familiar with Mathematica.

However, these computational math packages are only the start. There are many modeling programs that are in wide use in industry that basically solve the equations behind the scenes. Your job as a working physicist is to design models and interpret the results, and suggest new

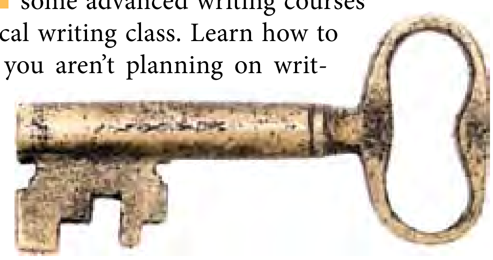
approaches based on those results. In short you are conducting experiments on the computer. One popular package that models electromagnetic phenomena is OPERA, a very impressive package sold by Vector Fields. While working on the ITER fusion project and while doing ion engine design I used this package extensively to model experimental scenarios. CF Design is a widely-used package to study fluid dynamics. FEMLAB is a more general modeling tool that can be used to study everything from quantum phenomena to heat transfer. Find out who is using OPERA or a similar package at your university—this probably means going to the engineering departments. Learn how to use a CAD or drawing program like CATIA. Take courses where learning these packages is part of the class.

4. LEARN A COMPUTER LANGUAGE

This is related to step #3. In this day and age, it is vitally important to learn how to code—and to do so beyond an introductory level. This doesn't mean you need to become a computer scientist, it just means you need to be able to write, successfully compile, and debug programs. You don't want to make yourself so diverse that you're paper thin shallow, rather what you're interested in doing is complementing your physics degree. If you ask the question "how would a physicist be more useful in industry," one answer is going to be: know how to code scientific and mathematical algorithms in C/C++ or FORTRAN. So we aren't talking about learning how to design Web pages or write Java. Instead, as a trained scientist, it is important to know how to code numerical algorithms. Pick up a copy of Numerical Recipies—and yes—learn FORTRAN. It is still used in many large codes because it's lean and mean—and therefore very useful for getting numerical results.

5. LEARN HOW TO WRITE

Writing up reports and documents is going to be an important part of your job. Take some advanced writing courses including a technical writing class. Learn how to use Latex even if you aren't planning on writing a scientific paper in the near future. Familiarize yourself with the correct way to put together a bibliography.



6. GET A SUMMER INTERNSHIP IN INDUSTRY

While working in the neutrino lab over the summer might be exciting, you might be better off spending at least one summer working in industry. Chances are your first job won't amount to much. The honest truth is I haven't seen students being given many substantial tasks. But the important thing is to start to build a resume and to begin making contacts. In the real world or in the academic world for that matter, whom you know is going to be as important as what you know.

In the real world or in the academic world for that matter, whom you know is going to be as important as what you know.

You'll be in much better shape if you are able to put a three month internship at NASA or at Intel on your resume—and you will be able to call on people you worked for as future references.

7. STAY FOCUSED AND DON'T DESPAIR When all is said and done, we aren't talking about abandoning your dream of becoming a string theorist. Rather, if you take the steps outlined in this article, you can do that string theory thesis and not worry about a thing—because you know that, while you have mastered string theory, you also know how to work with several computational modeling packages and have that on your resume you've prepared for industry just in case those post-doc jobs aren't coming. Finally, keep in mind that getting your foot in the door at a lab can be the first step to doing some interesting physics. So while taking a job in modeling shock waves from explosions might not be your thing—keep in mind that once you get on as a staff member, later on you might be able to work on say, quantum computing. Good luck! ∆

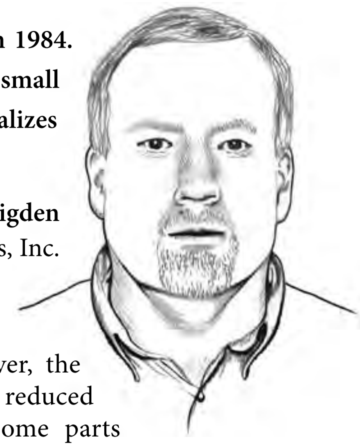
David McMahon is a physicist consulting with Sandia National Labs. He has written books on quantum mechanics, relativity, and mathematics.

The editors welcome your feedback. Send comments, questions, or suggestions to interactions@aapt.org.

Physicists at Work

INTERVIEW BY DARYL MALLOY

Gregory Rigden received a Master's in Physics from the University of Colorado at Boulder in 1984. After a year working as a teaching assistant at the University of Colorado at Denver, he joined a small company in Albuquerque, N.M., called Electro Magnetic Applications, Inc. (EMA), which specializes in analysis of electromagnetic phenomena such as electrostatic discharge, electromagnetic interference, and nuclear electromagnetic interference. Today, Rigden works in Denver along with eight to ten other EMA employees.



Gregory Rigden
Electro Magnetic Applications, Inc.

Malloy: Soon after receiving your Master's in physics, you taught at the University of Colorado at Denver. What course(s) did you teach?

Rigden: I was a teacher's assistant (TA) at UCD while enrolled in graduate school. I started out as a TA at the University of Colorado at Boulder (CU), but UCD needed TAs so I volunteered to work there during my last year of school. This mainly involved the teaching of physics lab and recitation courses. I continued on in this capacity after receiving my degree but also became involved in the Inroads Education program that was offered through the university. Within this program I taught beginning physics courses consisting of mechanics and electromagnetism.

Malloy: How difficult was the transition from academia to industry?

Rigden: I was not involved in academia long enough to become particularly acclimated to it. I always wanted to be in industry and never really had a desire to remain in academia. I only considered my time there as a stepping stone. When the right opportunity was presented, I quickly made myself available.

Malloy: Are the problem-solving skills you learned in a physics classroom useful to your day-to-day work?

Rigden: The problems encountered in the classroom were almost always analytical in nature—usually involving equation manipulation or the solving of complex integrals or differential equations. The physics problems encountered at EMA are usually electromagnetic interaction problems associated with real world geometries, materials, and configurations.

Such problems almost always require some sort of numerical computation followed by an assessment of the associated accuracy. Oftentimes, however, the numerical problem can be reduced in complexity by solving some parts analytically or by using analytical solutions to simplify the larger complex problem. The exercises performed in the classroom were a definite benefit when trying to understand and simplify those encountered in industry.

Malloy: You are currently working on a project for NASA. What can you say about it?

Rigden: The project involves electromagnetic effects on the Orion Crew Exploration Vehicle. These effects include the impact of electromagnetic hazards such as lightning and HIRF. I am presently enhancing some of our in-house software to help deal with the complexities involved in this problem. One such enhancement includes the integration of a multi-conductor, multi-shielded, multi-branched cable code with a three-dimensional full-wave solver to provide a strongly coupled, self consistent solution. The computation of electromagnetic responses throughout the vehicle can then be augmented by the inclusion of individual wire pin voltages at equipment box connectors. Unfortunately, I am not able to divulge much more than this at the present time.

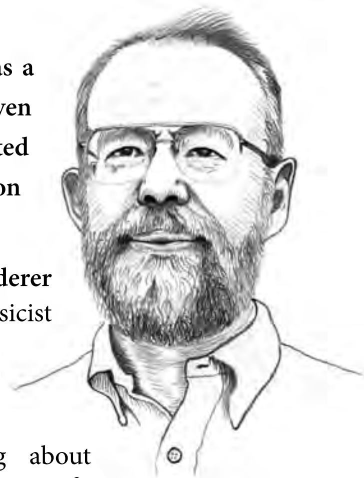
Malloy: Would you consider ever returning to teaching physics?

Rigden: I have been involved in commercial industry for many years. For a long time I never really considered returning to academia. For the most part, this is probably still the case. However, as time evolves, I have come to recognize the advantages inherent within academia. The opportunity to have a positive impact on young minds is a desirable situation. I would also enjoy the exposure to novel ideas and being at the forefront of developing technology.

Thank you.

Matt Payne

Peter Wanderer received a Ph.D. from Yale University in 1970. The focus of his research was a search for the Intermediate Vector Boson. In 1975 Wanderer accepted a position at Brookhaven National Laboratory, splitting his time between tracking the status of experiments conducted at the Alternating Gradient Synchrotron and working with a team to build a proton-proton collider called Isabelle. Wanderer has helped build magnets for Brookhaven's Relativistic Heavy Ion Collider and other magnet projects.



Peter Wanderer
National Laboratory Physicist

Malloy: Your doctoral research at Yale focused on experimental elementary particle physics. What effect did that work have on your career choices?

Wanderer: At the time I finished graduate school, one was expected to have a broad knowledge of elementary physics and the critical issues in the field, especially on the experimental side. One was also expected to be familiar with one or two experimental techniques (e.g., wire chambers, scintillation counters) and have reasonable skill with Monte Carlo simulations. Students at present are still expected to have a good overview of the field, but are much more specialized (e.g., simulation or devices, but probably not both).

In terms of career choices, students who are experts at simulation can find jobs in simulating financial markets or in crossover fields such as biophysics. Students who are experts at electronics can find jobs in this field. There is a general awareness that one can attract better students if they know they will learn skills which are marketable outside elementary particle physics.

Malloy: Given your post-doctoral experiences at Cornell University's Wilson Synchrotron and at Fermilab, how important are post-docs for physics Ph.D.s?

Wanderer: Post-docs are important for people who want to continue in the same field, because they allow the new Ph.D. to broaden his/her range of experience before applying for a tenure-track position at a university or a job with industry or the government. They are also important for new Ph.D.s who want to change fields. For example, a good friend of mine realized during his Ph.D. studies that he did not want to continue in experimental elementary particle physics because the groups were larger than he wanted. He applied for a post-doc in oceanography and read about the field on his own. He was hired as a post-doc at Woods Hole, and went on to a successful career in oceanography.

Malloy: What is the distinction between an applied physicist and a theoretical physicist in terms of their respective roles in a nonacademic setting?

Wanderer: For my setting, a [Dept. of Energy] lab, I would add experimental physicist to the list. Theoretical physicists search for new descriptions of nature. They may spend significant effort on developing computer simulations. Some of the descriptions are phenomenological. Experimental physicists test existing laws and look for expected and unexpected phenomena. They may develop phenomenological descriptions of their measurements. In thinking about applied physics, I refer to one of my colleagues, who has a degree in applied physics. During his career he has become an expert in writing control software for measurements of the performance of superconducting devices. His expertise includes detailed knowledge of the performance of the instrumentation we use and the properties of superconductors.

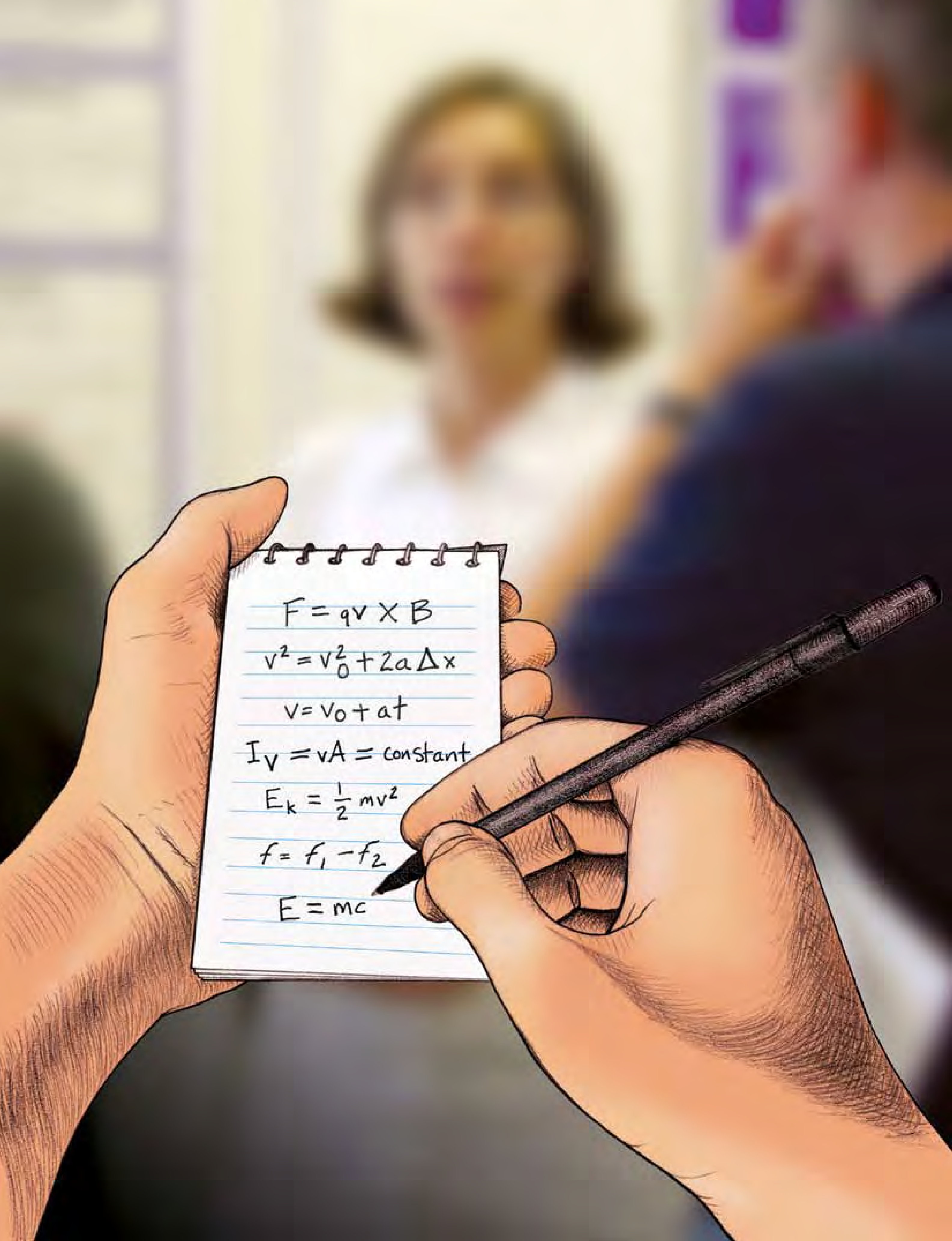
Malloy: In your opinion, what is more difficult: a physicist learning on the job to be an engineer or an engineer learning physics on the job?

Wanderer: If one is talking about learning a basic set of skills, my experience is that good engineers are capable of learning the skills needed to make good physics measurements and good experimental physicists can learn the main points of engineering (e.g., economy of design). I think that it is easier for a physics major to learn engineering than vice versa because a good undergraduate curriculum covers the basic concepts that underlie the engineering disciplines, so that the groundwork has been laid for studying engineering. Nonetheless, my experience is that one can't retrain a good, experienced professional (engineer or physicist) to the same high level of competence in another profession because of the large body of practical knowledge acquired during work in the field.

Malloy: Do you ever think about returning to the classroom as a physics teacher?

Wanderer: Yes, as something that I might do at the end of my present career. I think the best option would be to teach at a small college, where research would be expected to involve the undergraduate majors. I suspect that such positions would be hard to find. There is certainly a demand for teaching physics in high school, but the prospect of teaching five classes a day and learning the names of 150 students is daunting. To put it another way, good high school physics teachers are special. As for teaching at the junior college level, I have the impression that the supply exceeds the demand where I live (Long Island, N.Y.). Often, adjunct positions are used to limit the size of the permanent faculty. In any event, teaching requires careful thought and preparation.

Thank you.



$F = qv \times B$
$v^2 = v_0^2 + 2a\Delta x$
$v = v_0 + at$
$I_V = vA = \text{constant}$
$E_k = \frac{1}{2}mv^2$
$f = f_1 - f_2$
$E = mc$

Physicists as Journalists

A background in physics has given many journalists an advantage in the rewarding field of science writing.

BY ROBERT IRION

As an undergraduate at the Massachusetts Institute of Technology I survived the infamous "8.03"—one in a series of brutal physics courses at MIT designed expressly (or so it seemed) to put students through the intellectual wringer. They have names—8.03 is Physics III: Vibrations and Waves—but at MIT students simply spit out the number: "8.01" instead of Classical Mechanics or "8.02" for Electricity and Magnetism, and so on. By the time I got to 8.07 and 8.08 I had grave doubts about whether I was cut out to be a scientist. And when my senior research project in astronomy became a horrendous slog of data analysis, I knew I couldn't face five years of graduate school to earn that Ph.D. in astrophysics I'd always thought I would pursue. Fortunately, an enlightened instructor named Rae Goodell steered me toward a new path during my last semester: science writing.

In Goodell's writing course, Science Journalism, she asked us to interview MIT researchers doing interesting work that no one knew about. I approached this assignment by wandering the hallways of the physics and chemistry lab buildings until I came upon a poster on utilizing lasers to study how proteins in the eye bind to form cataracts. The research team was happy to talk to me, and to my amazement my story made the pages of an MIT research newsletter—a published article on my first try.

Nonetheless, I wondered whether I could possibly combine my costly training in science with my love of writing—a passion that had started in junior high school. Professor Goodell and her guest lecturers, editors and reporters from around the country, assured me that I could. By semester's end, my cloudy vision of the future had become clear.

I worked for two years as a general-assignment reporter at a weekly newspaper near Boston, then I enrolled in a graduate program in science writing at the University of California, Santa Cruz. In the 20 years since, I have found continued challenges and rewards in science journalism. I've published articles on topics in astronomy and beyond, including magazine cover stories about matter clashing with antimatter following the Big Bang, microbes in Arctic sea-ice providing clues to possible life on Jupiter's icy moon Europa, and the influence of giant black holes at the centers of galaxies. I've interviewed Nobel laureates and young scholars who, prior to talking to me, had never spoken to a reporter. I've gotten "fan mail" from readers convinced they have the final word on alien life, alternative theories of gravity, and traveling faster than the speed of light. Indeed, this career I happened to stumble upon—while grimly journeying through the physics curriculum at MIT—has never been boring.

Academic programs that focus on training scientists and science-interested students in the art and craft of science journalism arose in the 1980s at Boston University, New York University, UC Santa Cruz, and elsewhere. (For a list of the most prominent such programs today, and a link to all science-writing courses at U.S. universities, see the sidebar "Graduate Programs in Science Journalism.") Since then, the ranks of the reporting profession have swollen with writers sporting Bachelor's Degrees in science, or Master's Degrees, or even Ph.D.s. These journalists draw upon their knowledge of the working lives of scientists to write rich stories about the research enterprise, not just news about the hottest new cure or the latest climate scare.

Former physicists are part of this cadre of writers. But the balance is skewed: Most science-trained journalists studied the life sciences earlier in their careers. The UC Santa Cruz program—which I now direct—usually has just a couple of physical scientists in each year's class of 10 students. This tilt toward biology and medical writers—also reflected in informal figures from other programs—makes talented physics writers in high demand by editors worldwide.

When *Interactions* asked me to write about journalism as a possible career choice for physics majors, I had a great excuse to quiz some of my writing colleagues around the country about their pasts. I wanted to know about their transition from scientists to writers and editors for newspapers, magazines, and research organizations. Although some dove into the uncertain waters of science writing sooner than others, no one has looked back with regret. Here are some of their tales.

The magazine industry

Scientific magazines must cater to a targeted niche of readers. For instance, *Popular Science* offers a wide variety of research

Matt Payne

and technology content for nonscientists, while *Nature*, a leading science journal, plumbs the rich depths of science and policy primarily for an academic audience. Former physics students play central roles as writers and editors at both magazines.

In 1998 a team of astrophysicists at the University of California, Berkeley, produced the first convincing evidence that "dark energy" causes the cosmos to expand at an accelerating rate. Michael Moyer was an undergraduate research assistant on that team. While Moyer enjoyed explaining the research findings and its "weird" implications to friends and family, the work was high-pressured and hectic, due to an intense competition with a rival team. Furthermore, he loathed the many hours of elaborate computer coding.

Not yet ready to abandon academia completely, Moyer enrolled in Columbia University's master's program in philosophical foundations of physics as a trial run for a possible career in academia. But then Moyer attended a job fair in New York City that led to a writing internship at *Popular Science*. "As the person on staff who understood physics," recalls Moyer, "I was a great asset to them."

Moyer later became a full-time department editor at *Popular Science* for articles on new products and gadgets. He is now the magazine's executive editor—a post he landed just six years after first arriving as an intern.

Geoff Brumfiel also turned away from graduate school in physics research, but for a different reason. As an undergraduate at Grinnell College in Iowa, Brumfiel majored in both physics and English. During summer research programs, his mentors seemed unhappy with their work as graduate students. Instead, another option caught Brumfiel's attention: writing seminars at Johns Hopkins University, advertised on a poster.

Brumfiel enrolled at Johns Hopkins intent on earning a Master's Degree in creative writing. His goals changed yet again once he got an internship at *Physical Review Focus*, an online news service published by the American Physics Society (APS). His editor, David Ehrenstein, who has a Ph.D. in physics, demands that writers understand a scientific study thoroughly before trying to write about it. "He always wanted more details," Brumfiel says. "It was a great place to learn persistence as a reporter."

After the internship at APS and several rejection letters, Brumfiel landed a job as a correspondent in the Washington, D.C., office of *Nature* magazine, where he covers science and politics. He is moving to London to continue this work in the home office of *Nature*.

Science at *The New York Times*

Kenneth Chang also is no stranger to rejection letters. He estimates that he opened about 50 such notices when he applied for newspaper writing internships during the mid-1990s. But today, through dogged persistence, he works as a science reporter at *The New York Times*.

Chang studied physics as an undergraduate at Princeton and spent seven years in the graduate program at the University of Illinois. But during his doctoral research on controlled chaos, Chang felt his grasp of physics slipping away as he focused on the minutiae of one project. He turned to a position at the *San Francisco Chronicle* as a Mass Media Fellow—an annual program sponsored by the American Association for Advancement of Science that gives scientists exposure to the working world of journalism. Chang wrote 30 articles during a 10-week stint at the *Chronicle*. "That was the first time I realized I could combine writing and science," he says.

While enrolled in the science writing program at UC Santa Cruz, Chang met guest lecturer Cornelia Dean, who at the time was deputy science editor at *The New York Times*. Dean read his *Chronicle* clips, and she encouraged him to keep in touch. Chang worked at a few other newspapers and at ABCNews.com, but after five years of correspondence with Dean his persistence paid off. After Chang endured numerous interviews with editors, *The New York Times* created a position for him to cover the beats of other science writers when they were away.

Today Chang writes and reports on subjects ranging from geology and chemistry to solid-state physics and the space program. When he conducts interviews, he doesn't volunteer that

GRADUATE PROGRAMS IN SCIENCE JOURNALISM

by Robert Irion

Many graduate schools offer courses that focus on writing about science, health, or the environment as part of a broader curriculum in journalism. A website maintained by the University of Wisconsin (www.journalism.wisc.edu/dsc) provides a comprehensive directory.

Graduate programs specializing in science journalism:

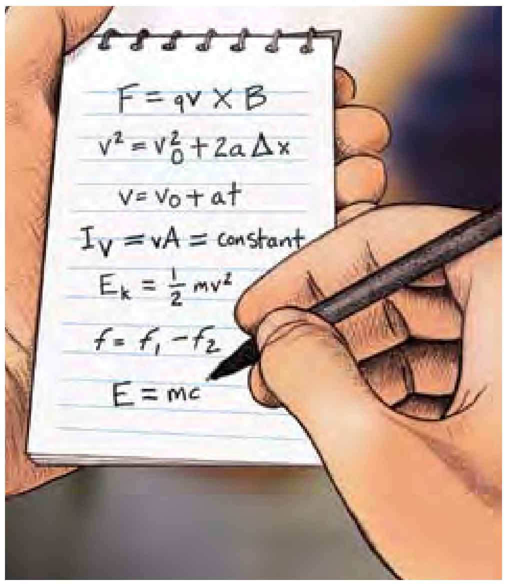
Boston University
Degree program: Master's (1.5 years)
Website: www.bu.edu/com/jo/science

he has a physics background. "When asked," Chang explains, "I say, 'Yes, but assume I don't.' " The main advantage of his training in physics is knowing how to judge the reliability of research results, he says.

Physics and Public Affairs

The slide in newspaper readership and corresponding revenues has made Chang's career path rarer in recent years. However, writers with physics training continue to prosper at scientific institutions that promote research directly to the public.

The Stanford Linear Accelerator Center in California, for example, produces *SLAC Today*, an electronic daily publication featuring news and information by and about the SLAC community. "It's just like working at a newspaper," says Kelen Tuttle, *SLAC Today's* editor. "The pace is absolutely insane."



Moreover, Tuttle has been pleasantly surprised at the lack of "spin" demanded. Specifically, no one exerts pressure to hide news that could cast a negative light on the U.S. Department of Energy facility, Tuttle says.

Her path to SLAC started at Carleton College in Minnesota, where she studied physics, astronomy, and English. But it was her summer work experiences that foreshadowed what career lay ahead. She far preferred writing for the Association for Women in Science, located in Washington, D.C., to conducting astrophysics research at the University of Wisconsin, Madison. Accordingly, Tuttle enrolled in the master's program in science journalism at Boston University. In 2005 she started work at *SLAC Today*—just days after completing her degree in Boston.

As head of public information at the Fermi National Accelerator Laboratory in Illinois, Kurt Riesselmann works in a setting similar to Tuttle's. But for years earlier in his career, he was a working physicist. Riesselmann, a Fulbright scholar, studied at the University of Oldenburg in Germany, and earned his Ph.D. at the University of Wisconsin. His doctoral work focused on devising theoretical calculations of the Higgs boson. But Riesselmann faced an uncertain future when the U.S. Congress axed funding for the Superconducting Super Collider (SSC) just as he was finishing his doctorate.

Riesselmann returned to his native Germany and landed a postdoctoral position at the Zeuthen branch of the DESY particle physics lab. At the end of his postdoc, he accepted an invitation to coordinate the lab's public outreach program.

Two years later, Fermilab hired Riesselmann for its public affairs office, where he now edits the online newsletter *Fermilab Today* and the joint Fermilab-SLAC magazine *symmetry*.

In a twist of fate the search for the Higgs boson has heated up at Fermilab. So, does Riesselmann miss the science? No, he confesses, [because] "I'm right in the middle of it."

Ben Stein also is in the midst of national physics, by virtue of his 16 years at the American Institute of Physics (AIP) in College Park, Maryland. Stein serves as manager of media relations for AIP's member societies, including the Acoustical Society of America, the American Association of Physicists in Medicine, and the AAPT (publisher of *Interactions*).

Stein worked in a condensed-matter lab while an undergraduate at Binghamton University in New York. While struggling through his senior research project, he visited the campus career office "out of desperation." Stein had been editor of a campus magazine; so, he recalls, "The counselor asked if I had thought

Johns Hopkins University
Degree program: Master's (One year)
Website: web.jhu.edu/writingseminars

New York University
Degree program: Master's (1.5 years)
Website: journalism.nyu.edu/prospectivestudents/coursesofstudy/serp

Massachusetts Institute of Technology
Degree program: Master's (One year)
Website: web.mit.edu/sciwrite

University of California, Santa Cruz
Degree program: Certificate (One year)
Website: scicom.ucsc.edu

about science writing." He decided to enroll in the writing program at New York University, where he had the distinction of being the only physicist in his class. His first internship offer came from AIP, and he liked the work well enough to stay.

Life as a Freelance Writer

Like Stein, Don Monroe distinguished himself at New York University's journalism school, but for a different reason: Monroe, who had earned his bachelor's and doctorate at the Massachusetts Institute of Technology and had worked as a physicist for nearly 20 years, was also the oldest student in his class.

Starting in 1985, Monroe devoted his working hours to integrated circuits and optoelectronics at the famous Bell Labs in New Jersey. However, progress on his research stalled when Lucent Technologies, the parent company of Bell Labs, spun out its microelectronics research into a separate company called Agere Systems in 2002.

"Once you get into research, it's hard to do something else," Monroe recalls. But an appointment onto a panel investigating charges of scientific misconduct against a Bell Labs researcher and the opportunity to write part of the report on the panel's findings "planted the psychological seeds of being a writer."

At NYU, Monroe initially found the pace of producing a news story daunting, but his confidence rose after only a few classes on the basics of news writing and reporting. "I got the hang of [shaping] a story out of a bunch of interviews and facts. I began to feel like a journalist."

Indeed, by the time he finished at NYU, he was confident enough to branch out on his own as a freelance writer. Today, his clients include the New York Academy of Sciences, a magazine on supercomputing published by the Department of Energy called *SciDAC Review*, and a newspaper for biologists called *The Scientist*.

"I'm making significantly less than I did as a full-time scientist, but I learn so much more now, about so many different things," Monroe says. "And the flexibility of choosing when to work is wonderful."

For Monroe and for many others, science journalism has been an appealing path. The profession does take a relentless drive to tell others about science, as well as a natural talent for writing. Scientists can contribute to society's understanding of science in many other ways (see sidebar, "Physicists and the Public"). But for those with a yen to devote their lives to the written word, journalism can shape those years of scientific training into a satisfying new career. Δ

Robert Irion directs the Science Communication Program at the University of California, Santa Cruz. He has written about physical sciences for Science, Discover, New Scientist, Smithsonian, *and other magazines, and he is coauthor of* One Universe: At Home in the Cosmos *(Joseph Henry Press, 2000).*

PHYSICISTS AND THE PUBLIC:
HOW TO MAKE A DIRECT CONNECTION

You don't need to change careers to make an impact on the public understanding of science. Indeed, there are many ways for physicists and physics teachers to reach audiences beyond the classroom. Some are old-fashioned; others rely on the new era of Web 2.0. If you care about how our society perceives physics, try some of the following approaches:

- **Contribute to an "Ask a Physicist" column online. Magazine readers love to send questions for experts to address, from the obvious to the obscure. Many departments now create ties with their communities by posting such queries on their Web sites. It's a kick for faculty and grad students to reply.**
- **Design your Web site for a lay audience. Most federal grants now require an "Education and Public Outreach" program to describe the research to taxpayers and students. University labs should do this routinely, with text and photos. High-school classes can post news about field trips, science fairs, and cool videos of kids learning how the world works.**
- **Write op-eds about issues in science. Opinion editors at local newspapers seek fresh voices and perspectives on news stories. Your expertise will draw readers into a well-written column. Tackle pseudoscience, deflate misconceptions about global warming, or (if you dare) explain why the quest for nature's basic laws is worth billions of dollars.**
- **Blog about physics or science in general. Current or former researchers write some of the most widely read blogs in science. The technology is a snap, but be warned that a blog only gains readers with regular and topical postings.**
- **Host or speak at lectures and science book clubs. The Web is wonderful, but a live talk is still the best way to excite an audience. Seek out community groups that might value your insights for an evening, or start one of your own. It will grow with time, and it's a great way to keep in touch with popular opinions about life, the universe, and everything.**