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The Student Guide to Grad School in Physics, Astronomy, and Related Fields

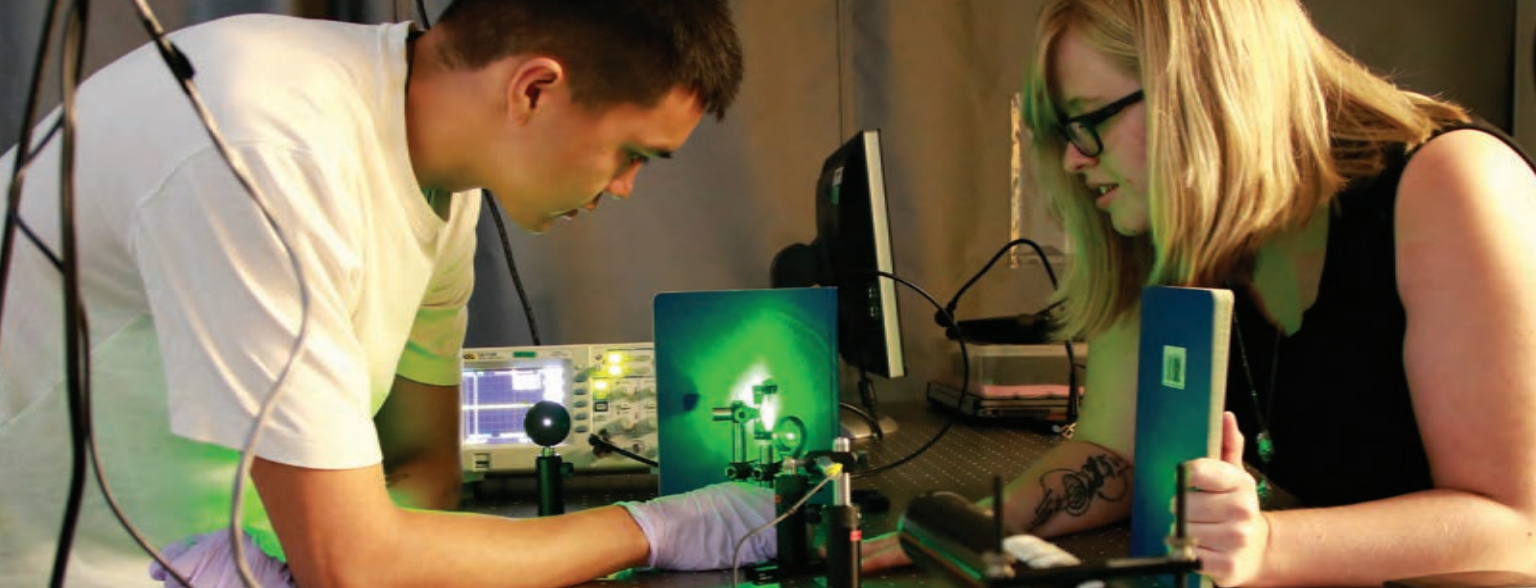
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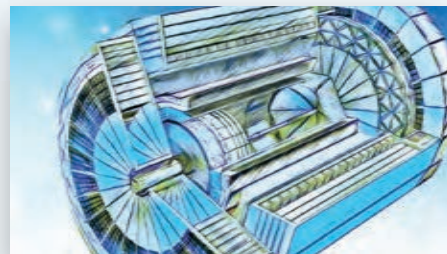
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From the Front Line

- 9 **Lexxi Reddington** on the Job Versus Grad School Decision
- 11 **Mary Ann Mort** on the Application Process
- 25 **Camille Coffie** on Taking the Bridge Program Route
- 32 **Amandeep Gill** on Finding the Right Fit
- 33 **Simon Patané** on Choosing a Path
- 33 **Cabot Zabriskie** on Prospective Student Visits
- 39 **Letrell Harris** on Doing Applications Right
- 58 **Ben Perez** on Graduate Advisers

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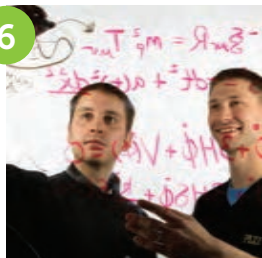
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Other member organizations

- Sigma Pi Sigma Physics Honor Society
- Society of Physics Students
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TABLE OF CONTENTS

6



6 The Graduate School Path

- Thinking About Graduate School?
- Taking Your Physics Bachelor's Degree to Grad School
- Time is Relative, Deadlines Aren't
- Simplify Your Grad School Search with GradSchoolShopper.com
- Considering a Career in Research?
- The Path to a Physics PhD
- The \$\$ Aspect of Grad School

24



24 Finding the Right Program for You

- Bridging Students from Physics Bachelor's to PhD
- Andrew's Story: Why I Went to Grad School
- Elon's Story: A Path Shaped by Conferences, Community, and Mentoring
- A Guide to Choosing the Right Grad Program
- Farrah's Story: Is There a Place for Me in Grad School?
- Find Your People and Grad Program at the 2022 Physics Congress

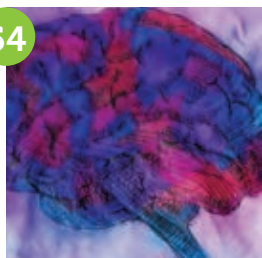
38



38 Crafting Successful Applications

- Standout Applications
- Applying to Grad School with a COVID-19 Transcript
- Real Talk: GRE Scores and Physics Graduate Programs
- Make a Statement with Your Personal Statement
- Tools for Making Your Career Dreams a Reality
- Don't Limit Yourself

54



54 Navigating Graduate School and Beyond

- Mental Health Matters in Grad School
- PhD Student-Adviser Pairing is Critical, but in US Physics Departments it's Often Haphazard
- Brittney's Story: Navigating the "Worst Case Scenario" in Grad School
- The Employment Landscape for New Physics Degree Recipients
- Katherine's Story: Physics Lessons for Life

About GradSchoolShopper

This issue of *GradSchoolShopper* is published annually by the American Institute of Physics in collaboration with the Society of Physics Students and PHYSICS TODAY. The companion website, GradSchoolShopper.com, is the only global online graduate program network dedicated exclusively to physics, astronomy, and other fields within the physical sciences. The site features several hundred graduate programs in a searchable, sortable format—many with additional data relevant to students researching their options. The site is free for students, and more information about its functionality can be found on page 12. Departments wishing to list or advertise their graduate program are encouraged to contact info@gradschoolshopper.com for more information on options in both print and online.

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The Society of Physics Students (SPS) is a professional association designed for students and their advisers. Membership, through collegiate chapters, is open to anyone interested in physics. Housed within SPS is Sigma Pi Sigma, the national physics honor society, which elects members on the basis of outstanding academic achievement. This unique two-in-one society operates within the American Institute of Physics, an umbrella organization for 10 other professional science societies.

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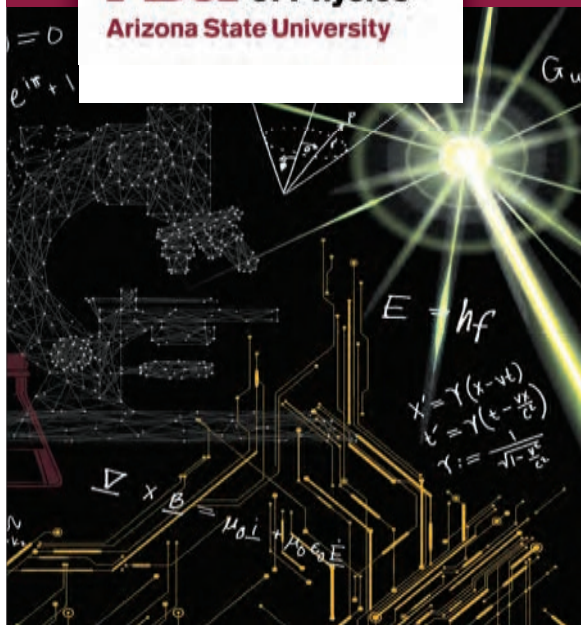


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Brad R. Conrad, director, Society of Physics Students and Sigma Pi Sigma

Thinking About Graduate School?

#Howtogradschool

Brad R. Conrad



Brad R. Conrad

You have options! A physics degree is wonderful because it can lead to so many different types of disciplines, careers, and jobs. But that same fact can make it challenging to figure out what to do after a bachelor's degree.

To help orient yourself, one of the best things you can do is to check out the data on what physics majors do upon graduation.¹ In summary, the data show that lots of students go into the workforce and lots of them go into graduate programs. Of the latter, many go into PhD programs in physics, astronomy, and related fields, as you might expect. You might not know, however, that many other students enter programs in another discipline (e.g., engineering, materials science, and other fields related to physics), specialize in a facet of physics (like acoustics or optics), or enter a master's degree program. As the data show, a physics degree gives you some really useful skills² that make you valuable in a variety of fields. Graduate study doesn't have to mean getting a PhD in physics or astronomy; physics majors excel in all kinds of graduate programs.

If you are just starting your search for a graduate program or considering whether graduate school is for you, I recommend thinking about what you are truly passionate about. What do you love to learn about? At the same time, think about the kind of problems you want to help solve. You might not have the opportunity to work on that specific issue, but giving it some thought can help you choose a discipline or even a subfield to pursue.

I advise potential graduate students to start exploring programs just over a year before they graduate. It takes time to sort through what you might want to do and which programs would be the best fit for you. Browse GradSchoolShopper.com. Reach out to programs of interest. Talk to people about their research. Conduct informal interviews with professors and graduate students to get a feel not just for their research, but for the department atmosphere and group dynamics.

One strategy that can help is to break down the decision on where to apply into smaller questions. How many programs do you want to apply to? Where in the world do you want to live for 5 to 7 years? What kind of adviser best suits your style? What do you need outside the department to thrive as a whole person? This is all about you, and it's okay to lean into that.

Once you've narrowed down the options, do your homework. If you can, visit the location and the program in person. Take the time to learn about the faculty, research areas, and

MYTH BUSTERS

There are many widespread myths about going to graduate school. Here's the reality.

- ▶ In the vast majority of situations, programs will pay you to go to school for a PhD.¹
- ▶ Many programs don't weigh GRE scores heavily, or even at all. You are not one exam score.
- ▶ Many students are unsure of the field they want to study when they apply to graduate school, and they still get in.
- ▶ It's not uncommon to change subfields after you've started a program.
- ▶ You can go back to school after a break.
- ▶ You can study similar problems in different programs and fields.
- ▶ Different programs can lead to similar jobs or career pathways.
- ▶ If you are in a PhD program, most of your time will be spent doing research, not taking classes.
- ▶ Many jobs don't require a PhD—they require skills you can learn in the process of earning a PhD.

References

1. P. Mulvey, A. M. Porter, and S. Nicholson, "First-year graduate students in physics and astronomy: Characteristics and background," American Institute of Physics, November 2019, www.aip.org/statistics/reports/first-year-graduate-students-physics-and-astronomy-characteristics-and-background.


people you'd be interacting with. Knowing a lot about a program and who you'd like to do research with can really help your chances of getting in.

You don't have to have it all figured out before you apply. When I applied to graduate programs, I had a pretty good idea of some areas I loved—and some areas I was not super excited about—and in the end I got my PhD in a subfield I never anticipated (probably because I didn't know it existed when I applied). What I recommend most strongly is that you spend time learning about which programs would be a good fit for you and why.

In the end, realize that just like people, educations and careers are not made overnight. They are journeys. Being well informed is an important first step. Do a little self-searching to help narrow down the topics you might want to study. Break the big question of where to apply down into smaller, easier questions. Learn about the programs and advisers you are considering. A little planning can go a long way in helping you achieve your goals.

The main takeaway: Don't panic. You don't need to have all the answers today. Or tomorrow. We hope that this grad school guide will be a helpful resource along your journey.

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1. American Institute of Physics, "Employment and careers in physics," April 2020, www.aip.org/statistics/reports/employment-and-careers-physics.
2. P. Mulvey and J. Pold., "Physics doctorates: Skills used and satisfaction with employment," American Institute of Physics, August 2020, www.aip.org/statistics/reports/physics-doctorates-skills-used-satisfaction-employment-1516. 



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Toni Sauncy, past director, Society of Physics Students; physics professor and department chair, Texas Lutheran University

Taking Your Physics Bachelor's Degree to Grad School

Toni Sauncy



Toni Sauncy

Earning a bachelor's degree in physics or astronomy signals to the world that you can learn! On average, about half of the more than 9,000 physics bachelor's degree recipients in the US go straight into graduate programs.¹ And many of those who enter the workforce right after earning a bachelor's earn a graduate degree at some point down the road.

Students (and faculty) are often surprised to learn about the broad range of advanced degree options available to physics bachelor's degree recipients. While pursuing an advanced degree in physics or astronomy is the obvious choice, physics graduates are assets in many other fields of study.

In the fall of 2019, the American Institute of Physics Statistical Research Center (SRC) reported that for the classes of 2017 and 2018 combined, about 29% of all physics bachelor's graduates went to grad school and chose physics or astronomy degree programs.² This means that about 20% pursued graduate studies in fields outside the "typical" choices. Where did they go?


Engineering graduate programs are a frequent pick, spanning a wide range of subfields from more common ones like mechanical, electrical, and civil engineering to specialized fields like materials, space, and computer engineering. Physics students often seek advanced degrees in closely related sciences as well, such as medical physics, biophysics, materials science, optics, atmospheric sciences, earth science, chemistry, computer science, and data science.

Remarkably, or perhaps not, physics students do very well on the admissions exams for medical school (MCAT) and law school (LSAT)³; it's not uncommon for them to become physicians and attorneys. Interested in policy or science communication? Physics graduates have excellent graduate school op-

tions for pursuing those areas as well. You'll also find physics graduates with business administration degrees (MBA), dental degrees (DDS or DDM), and others that might surprise you.

The point is this: Physics students are well prepared to take on the challenges of a wide range of advanced degree programs and to become productive, contributing members of those fields. If you think grad school is in your future, a great time to start exploring programs is well before your final year of undergrad. Use your alumni network to connect with students who have gone to grad school, explore the programs on GradSchoolShopper.com, talk to graduate recruiters and faculty from programs that pique your interest, and read publications like *PHYSICS TODAY*, *The SPS Observer*, and *Radiations* to find out more about the broad range of options at your fingertips.

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1. American Institute of Physics, "Physics bachelor's one year later," *AIP Physics Trends*, fall 2019, www.aip.org/sites/default/files/statistics/physics-trends/fall19-Bach1yrlater-p.pdf.
2. Ibid.
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Lexxi Reddington on the Job Versus Grad School Decision

I remember feeling immense stress as I was finishing my senior year as a physics major, simultaneously completing degree requirements and trying to determine what to do next. I was considering graduate school but also applying to jobs. My job hunt included frequent participation in career fairs, and much to my amazement, a lead from one fair led to a full-time job offer as a research scientist.



Lexxi Reddington

I would have taken that job if I hadn't heard about my university's graduate teaching assistant positions available for master's degree students in the computer science department. As a graduate teaching assistant I'd earn a stipend, tuition would be waived, I'd have numerous mentoring opportunities, and I'd get to choose my courses based on what interested me.

This was a turning point for me. I could envision myself pursuing the degree more easily than jumping into a career, and I had a strong desire to expand my computer science skill set. It has been two years since I made the decision to continue my education, and I can confidently say that it was the right one for me!

Lexxi Reddington recently graduated with a computer science master's degree from the University of Denver.



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Time is Relative, Deadlines Aren't

A sample timeline for weighing your options and applying to programs

Brad R. Conrad

Doing some work on your applications well before they are due will make the process much smoother! This timeline assumes a four-year undergraduate experience that transitions right into a graduate program, but lots of successful graduate students don't follow that path. There is no one-size-fits-all approach when it comes to planning your future, so adapt this timeline to work for you. Also note that individual program deadlines vary and that for some tasks you may need more or less lead time than indicated here.

First and Second Year

► Get started on research!

Talk to your professors and mentors for help finding labs that are looking for students and take advantage of summer research experiences, independent studies, internships, and research courses.

► Explore a wide variety of career possibilities.

Find out where graduates from your department have gone and what they're up to today. Attend career fairs and department colloquia to learn about career options for physicists.

Summer before Fourth Year

► Decide which programs you're going to apply to.

Students usually submit 4 or more applications.

► Prepare your essay-based application materials.

Craft your responses to any prompts in the applications and request critical feedback on them from your professional network.

► Register for the GREs.

October is usually the last month the physics GRE is offered before applications are due.

Third Year

► Learn about graduate school life.

When you have the opportunity, talk to current and recent graduate students about their experiences.

► Research graduate programs.

Identify what you're looking for in a program. Consider factors such as size, location, department culture, research specialties, and financial assistance. Talk to your professional network, browse GradSchoolShopper.com, and visit program websites. Make a list of programs that interest you.

► Check the prerequisites.

Most physics and astronomy programs require the same courses you're already taking as a physics or astronomy major, but fields like medical physics or engineering may have different requirements.

► Prepare for the GRE and physics GRE, if applicable.

Find out when and where the tests are offered, decide when to take them, and start studying.

► Plan your finances.

Plan for the GRE and application fees. Some departments will, on request, waive the application fee in cases of financial hardship. Most science PhD students have tuition waivers and are financially supported by their program, but not all graduate programs have these benefits. If applicable, look into external funding sources and financial aid packages.

● Fourth Year: Fall

▶ Finalize your personal statements.

Your statements should be tailored to each program and its prompts.

▶ Request application materials from external sources.

In early fall, input application requirements and deadlines into a spreadsheet for tracking and request materials that need to be sent directly to programs, e.g. transcripts, GRE scores, and letters of recommendation. Give writers 4 to 6 weeks to write and submit their letters.

▶ Take the GREs.

▶ Send reminders to your letter writers.

When the deadline is near, confirm that letters are completed and submitted.

▶ Submit your applications!

● Fourth Year: Spring

▶ Confirm that your application packages were received.

▶ Participate in interviews and site visits, if applicable.

Not all graduate programs have interviews or sites visits, but some do. If you're invited to do either, spend time preparing and writing down your questions.

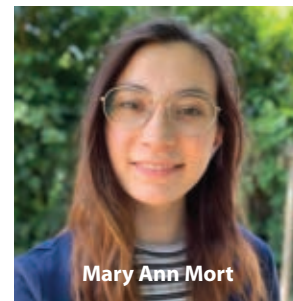
▶ Consider your options and decide what's next for you!

If you accept an offer, notify any other programs of your decision. If you don't receive any offers, explore nontraditional routes such as bridge programs, which often have later deadlines, and talk to your professional network about other possibilities for the coming year.

▶ Thank all of those who helped you.

Your professional network can be a source of support and collaboration for years to come. Let them know your plans and keep in touch. GSS

Mary Ann Mort on the Application Process



Mary Ann Mort

After working in the energy industry for a year, I decided to apply to graduate programs. I had toyed with the idea while completing my bachelor's degree in applied physics but only really considered attending when I realized I'd be taken more seriously and be better utilized at work. So began the process of taking the GRE, condensing everything I'd ever done into a statement of purpose, and figuring out where to apply.

My major considerations when choosing programs were location, GRE requirements, financial assistance, and energy-related research opportunities. I used GradSchoolShopper.com to identify schools that fit my criteria. For each school, I looked into a variety of graduate programs: physics, electrical engineering, mechanical engineering, materials science, geophysics, and more. I compiled requirements, due dates, and the names of faculty members whose research piqued my interest.

Take my advice and make sure you have everything you need well in advance—official transcripts take time to process and get where they need to go. I wasn't able to apply everywhere I intended to because I didn't allot enough time for this. But, in the end, everything worked out and I'm now well on my way to a PhD in electrical engineering.

Mary Ann Mort is an electrical engineering PhD student at the University of California, Davis.



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Simplify Your Grad School Search with GradSchoolShopper.com

A resource for students interested in physics, astronomy, and related fields

Kendra Redmond

Searching for the right grad program can be time consuming, but it doesn't have to consume you! GradSchoolShopper.com (GSS) is a free resource for sorting, browsing, and comparing graduate programs in physics, astronomy, and related fields within the physical sciences. GSS is a product of the American Institute of Physics and an official partner of PHYSICS TODAY and the Society of Physics Students.

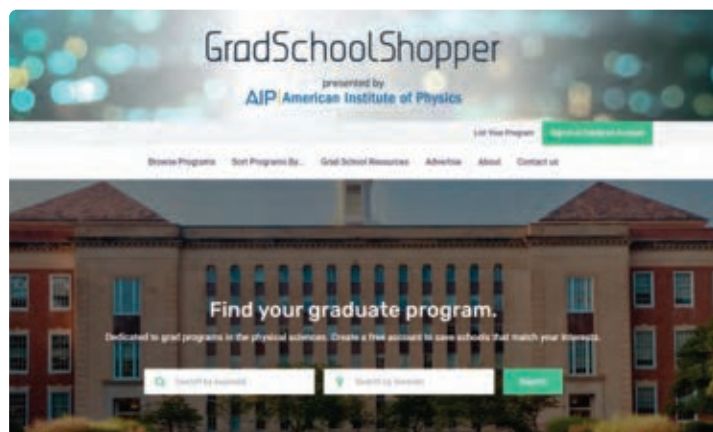
The site includes hundreds of graduate program profiles sortable by degree(s) offered, specialty, campus setting, acceptance rate, and application deadline. You can also search by keyword and location. Not sure what you're looking for? Use the browse feature to explore what's out there by state or by one of 50-plus research specialties.

Each program profile includes, at minimum, a list of research specialties and contact information. Many programs have enhanced profile pages that provide an overview of the program, application requirements, quick links to relevant web pages and social networking pages, and even videos and photos.

You don't need an account to access all of the resources on GSS, but creating one is a helpful way to keep track of interesting

programs. It's quick and easy to do, and once you're logged in, you can bookmark the programs you like and revisit them anytime through the "favorites" list in your profile.

While you're on the site, be sure to explore the "Resources" tab for tips on applying to grad school, advice on navigating financial aid options, personal stories on the grad school experience, and more—all geared to undergraduate physics and astronomy students. GSS was created for you by the physics community, so come find your future at www.GradSchoolShopper.com! **GSS**



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Considering a Career in Research?

Contemplate your desired approach—from computational to theoretical, experimental, and applied

Kendra Redmond

For many undergraduate physics and astronomy students, especially those in small departments with few faculty members, research opportunities on campus are fairly limited. You can expand your exposure to different fields, tools, and techniques by pursuing research experiences and internships both on and off campus, reading about the latest developments in physics, and going to research talks and professional physics meetings. However, it can still be hard to decide what type of research you would like to pursue in graduate school (although not all research jobs require a PhD, many of them do) and as a career.

For example, if you're interested in studying gravitational waves, before approaching potential research advisers you might consider questions like these: Do you want to study gravitational waves on location at an existing observatory? Work on plans for a new gravitational wave detector? Analyze data? Predict what gravitational wave signals will look

in more than one approach, but thinking about how well each one aligns with your passion, personality, and skills may help you focus your research interests. Most undergraduate physics students are familiar with the experimental approach but have less exposure to other three. To introduce them, we asked three scientists to share their stories.

like from various sources? Characterize, operate, or design equipment? Study the sources of gravitational waves?

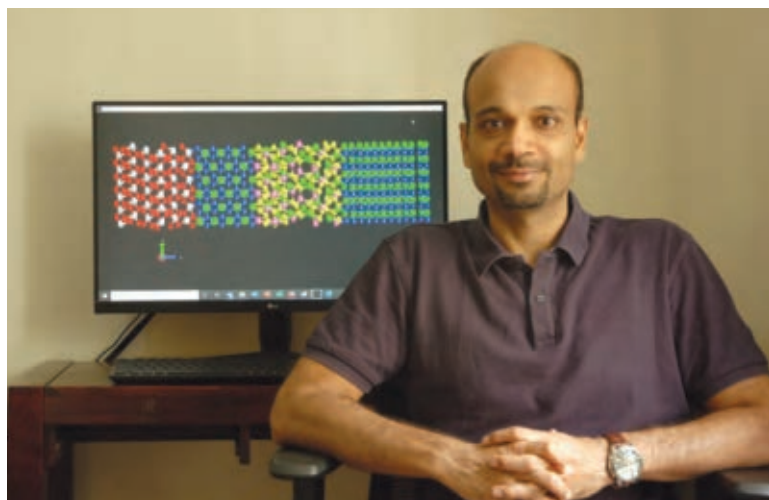
One way to break down the options is to categorize research approaches as computational, theoretical, experimental, and applied. The lines between these approaches can be blurry and researchers can be experts

Computational physics

By Rajesh Sathiyarayanan, deputy engineering director, Applied Materials

I had never seriously considered pursuing a career in physics until halfway through college. In the late 1990s in India, people who were good at math and science mostly went into an engineering track. Fortunately, my college provided the option of double majoring, an unusual opportunity in India, so I ended up studying physics and computer science. This naturally paved a way for me to go into the field of computational physics later. Although I was initially inclined toward working on theoretical cosmology in graduate school, funding scenarios and job prospects in that field made me change my mind. After talking to faculty members from different research groups, I decided to specialize in computational materials science.

Broadly speaking, computational physicists use simulations to provide a reasonably accurate description of systems that are either too complex for a purely theoretical treatment or require considerable cost and time to study through experiments. For instance, the question "How do atoms arrange



Computational physicist Rajesh Sathiyarayanan. His monitor displays a typical high-k metal gate stack, made out of multiple metal/oxide thin films (each a few nanometers thick). Such metal gates form part of the transistors in all laptops and phones released in the last 10 to 12 years. Photo by Uma Ramanathan.

themselves at the interface when two solids are brought together?" can be answered relatively easily through a computational approach. In computational materials science, simulations help users evaluate different materials to identify the ones with desirable properties. Simulations are also being used to design materials with desired properties. As a result, this field has found applications in a lot of industries, ranging from aerospace to fabrics.

After my PhD and a short postdoctoral stint, I got a research position suited to my background in the semiconductor industry. For the past several decades, Moore's law, i.e., that transistor density doubles approximately every two years, has been the guiding principle in the semiconductor industry. Of late, materials innovation has played a huge role in helping semiconductor technologists keep up with Moore's law. My job in-

volves performing simulations to screen materials that could lead to better semiconductors.

There are multiple options in industry for people who want to pursue a career in computational physics research. Physicists are a highly sought-after group, mainly due to their strong mathematical training and analytical skills. A little bit of coding knowledge further enhances one's job prospects. This does not require much extra effort, as most data collection and analysis work in graduate school involves writing scripts—a great way to hone your coding skills.

Across industries, I see an increasing reliance on computer simulations to understand and verify ideas before building actual prototypes, and I think it is a great time to get into the field of computational physics, especially if one is interested in a career outside academia.

Theoretical Physics

By Bret Underwood, chair and associate professor of physics, Pacific Lutheran University

"H mm . . . What now?" It's a familiar feeling, being stumped on a physics problem, not sure what to do next. But this was a different type of problem. As a college junior majoring in physics, I was strongly considering graduate school. I enjoyed studying physics and had some research experience as an undergraduate. But I was a little intimidated by the graduate school application process. What field should I study?

I read about current research areas on faculty web pages and in journals like *PHYSICS TODAY* and realized I was most excited about particle physics and cosmology. However, I was not particularly confident about my laboratory skills (perhaps my instructors felt the same way), so I felt theoretical physics was a better fit. I talked with my faculty mentors about graduate school and the application process, and I discussed my sketched-out plans with my fellow students. I learned that graduate school was not just going to be more physics classes; it would also require me to take a much more active role in creating new science. I thought that sounded pretty cool, so I chose some graduate schools that were doing things I was excited about and submitted my applications.

In graduate school, I began studying problems like a theoretical physicist, refining the same skills I used in my graduate school decision-making: reading, learning new ideas and techniques, and discussing with others. For example, my first research project involved studying the aftermath of a string theory model of a period of the early universe that underwent a very brief, rapid expansion called inflation. In order to understand this model, I had to learn general relativity, string theory, and relativistic field theory, as well as the more specific topics of inflation, D-branes, Kaluza–Klein modes, and post-inflationary reheating. If you don't know what most of these things are, that's okay—I didn't either at the time. Stacks of books and journal articles covered my desk as I read, reproduced calculations, talked with my adviser and other students, and generally tried to figure out what calculations of my own I could do.

One of my vivid memories of starting graduate school in



Theoretical physicist Bret Underwood (right) and former student Auberry Fortuner (B.S., 2013) explore the physics that gave rise to the expansion of the universe. Photo by John Froschauer, Pacific Lutheran University.

theoretical physics is attending a research seminar in my first year and (mostly) following the speaker's description of their research. Midway through the talk, there was a disagreement about the physics between the speaker and the faculty, postdoctoral researchers, and graduate students whom I regarded as experts. I remember realizing, with a start, that I had found the frontier of physics: If the experts needed to talk out the physics together in order to make sense of it, perhaps I could join that community and have something to add. Eventually, with guidance from my adviser, I found a way to contribute my own ideas to this community working at the boundaries of our knowledge.

Today, as a professor at a liberal arts college, I still use the skills of a theoretical physicist, whether I'm working on a research project or revising my teaching. Reading the literature, learning new ideas and methods, and conferring with colleagues are essential techniques for me anytime I'm facing that familiar question: "Hmmm . . . Now what?"

Applied Physics

By Jasmine Oliver Graham, medical physicist,
Moffitt Cancer Center

I was introduced to medical physics at South Carolina State University at a summer orientation for incoming freshmen. I was going to major in biology and planned to attend medical school until a talk on medical physics piqued my interest. After the orientation I mulled over my options for the remainder of the summer. When I returned in August, I was a physics major. I reasoned that a physics degree could work for either medical school or medical physics, and by the beginning of my senior year at SC State, I'd decided that medical physics was the field for me. Fast-forward through graduate school in medical physics, a postdoctoral fellowship, and a medical physics residency at the Orlando Health UF Health Cancer Center, and I am now a medical physicist at the Moffitt Cancer Center in Tampa, Florida.

Medical physics falls into the subdiscipline of applied physics, in which physics principles are applied in practical situations. For example, as a medical physicist I apply physics concepts to treat cancer patients with radiation. Applied physics can be thought of as a bridge between physics and engineering. Pure physics research forms the fundamental basis for applied physics research, which is applied in real time for practical use.



Medical physicist Jasmine Oliver Graham stands in front of a clinical CT scanner. Photo courtesy of Graham.



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Although the work environment is different, there are many similarities between applied and experimental physics. Both are hands-on disciplines that commonly require scientists to calibrate, operate, and troubleshoot equipment. Both fields value people who can assess data quickly and solve problems creatively. The ability to work well with others on a common goal is essential, whether that be most effectively treating a patient or detecting gravitational waves.

If you are interested in pursuing a career in applied physics research, here's my advice. Do your research (no pun intended). Look up various physics subdisciplines and talk with people in those fields, if possible. Even better, make an effort to shadow these professionals or at least visit their labs. Apply for internships and research experiences in your top fields. Be sure to consider salary, work/life balance, job availability, and location of available positions in your decision-making process.

Begin developing the necessary skills for your future position now. Take as many math, physics, lab, and related courses as possible. Expose yourself to as much knowledge as possible, and look for connections between disciplines. In my experience, areas of physics that I can connect with other science disciplines (e.g., chemistry) are easier to fully comprehend. Begin thinking and acting like a scientist/researcher now. Analyze situations and challenge yourself to creatively solve problems using the resources you have on hand.

This piece is an updated version of an article published in the winter 2018 issue of The SPS Observer, www.spsnational.org/the-sps-observer.

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PHYSICS AND ASTRONOMY

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Chan Kyaw recently earned his PhD in physics from Howard University and is now a process engineer. His responses have been edited for length and clarity.



Chan Kyaw shows off his PhD diploma on graduation day at Howard University. Photo courtesy of Kyaw.

The Path to a Physics PhD

A Q&A with Chan Kyaw on grad school classes, milestones, and setting one's own timeline

I almost went for a PhD in EE at Howard. I thought I would have better job prospects, but for a technical reason I ended up in the physics program. Now I've realized that no matter what field you get a PhD in, your research project will define your career opportunities. I'm happy I ended up with a PhD in physics. It's what I did as an undergrad and I enjoy it. Plus, it would have been a lot harder academically to learn new EE design programs and prepare for the EE qualifying exam.

Q You have a master's in electrical engineering (EE) from Colorado State University and a PhD in optics from Howard University. What was your grad school experience like?

A I started out in an EE master's program. Looking back, I think I focused too much on the classes. I've realized that graduate classes don't really matter that much; you just need to pass them so you can focus on the research. I learned very early exactly what research I needed to do to get my master's, and that helped me progress.

When I joined my physics PhD program, I knew classes weren't top priority. I wanted to finish as fast as possible and I knew that meant getting a good idea of the metrics my research adviser would use to judge whether I was ready to graduate. There was a postdoc in the group who was very helpful in getting me up to speed and publishing quickly, and that helped me on my journey.

Q What were some of the differences between grad school in electrical engineering and in physics?

A The courses that you take in a physics graduate program are the same that you take as an undergrad—electricity and magnetism, quantum mechanics, etc.; they're just at a higher level. The learning curve can be steeper if you go into a different field.

Q What did you like most about graduate school?

A In grad school you mostly set your own time. You're given project parameters to accomplish, but unless your adviser is really micromanaging you, you can decide what to do on what day. There is no one breathing down your neck. As an undergraduate you take classes all the time. In graduate school classes are a means to an end, to passing the qualifier and getting to your research. You only take classes for one or two years and then decide what to do with the rest of your time.

Q What are the big milestones along the path to earning a physics PhD?

A The first year or two is really focused on classes. After you finish your classes, you take a qualifying exam. The qualifier covers a lot of topics, all of your required classes, and you need to pass to move on in the program. The questions are not necessarily structured like they are on class exams or in homework, so to prepare you should do a lot of questions on each topic—even if you did really well in your classes.

After you pass the qualifier, you usually do a proposal defense. You write a proposal that describes the research you plan to do for your thesis and defend it before a committee. In some sense it's a formality because you don't have to have any results. It's more about forming a committee and telling them what research you want to do and the methods you're going to use.



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Once your proposal is approved, you collect results and write your dissertation. If you've already published some papers, like I had, that reduces the writing time. But you have to allot time to write introductory materials, make modifications to existing material, write conclusions, and bring it all together.

During your thesis defense you orally present your results to your committee and they review your written dissertation. This is the last step in earning a PhD. There's a lot of nervousness surrounding the thesis defense, but if you've been communicating with your committee members, you should know the temperature of what they're thinking and whether you're going to pass.

Q What advice do you have for students considering a physics PhD?

A Having a good mentor in your research group will be a great help on your journey. Otherwise, you'll be figuring things out by yourself, and sometimes that can take weeks or months when a good mentor could help you fix the issue in five minutes. It's not just how much they know in terms of research skills and knowledge, but also how helpful they are and how much time they can give you.

Also, remember that going to grad school doesn't necessarily mean you have to work in academia. There are options. You're not closing any doors by going to grad school. GSS



GRADUATE STUDIES IN PHYSICS

The department, located in Las Cruces, fifty miles north of the large metropolitan area of El Paso, TX, conducts rigorous research in experimental and theoretical high-energy nuclear physics, solid-state physics, optics, and geophysics, in close collaboration with a number of national labs, in and outside the state of New Mexico. The program is truly international, with students from more than half a dozen countries.

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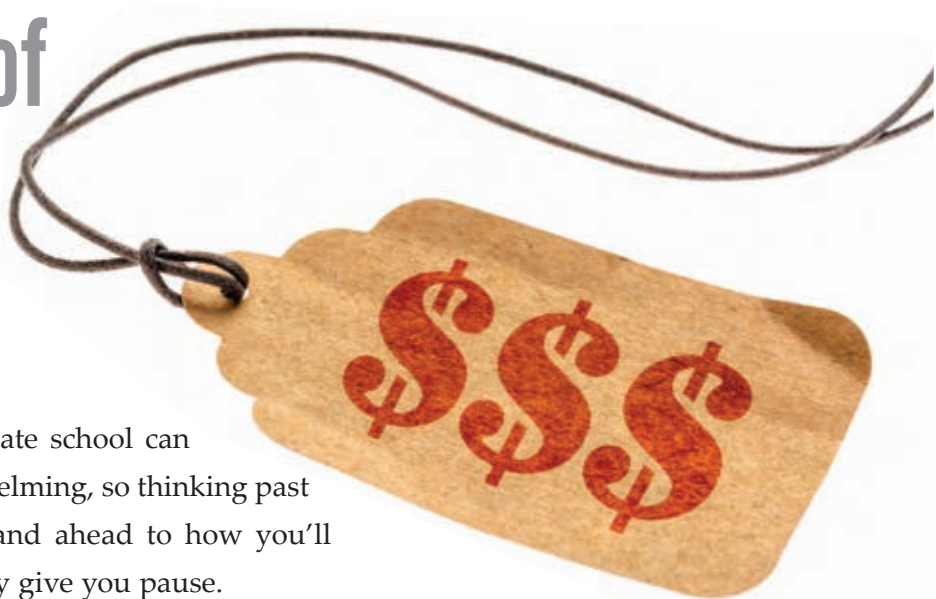
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Anashe Bandari, science writer,
American Institute of Physics

The \$\$ Aspect of Grad School

Anashe Bandari

Simply applying to graduate school can be expensive and overwhelming, so thinking past the application process and ahead to how you'll fund the degree itself may give you pause.



The good news is that in the United States, most physics and astronomy doctoral programs are funded. In other words, your academic department will generally cover all enrollment expenses, including tuition, or your university will waive these altogether.

The vast majority of physics graduate students also receive a stipend for the work they contribute to their department. Though the size of the stipend varies and may take into account factors like the local cost of living, it should be enough to cover textbooks and supplies, rent, food, and—if you're lucky—a little bit of fun.¹

You're likely wondering what the department expects from you in return for your stipend. Early graduate students are typically paid through teaching assistantships, which can entail running laboratory classes or physics problem sessions for undergraduates. As you progress, you'll likely receive a research assistantship that will pay you directly for the research work you're doing toward your thesis, rather than requiring you to be a teaching assistant. Beyond these standard funding sources, graduate students can qualify for external and internal fellowships and grants that supplement or replace assistantships.

Going straight into a doctoral program—or going into a physics or astronomy doctoral program at all—isn't for everyone. Pursuing a master's degree or enrolling in a bridge program are viable alternatives, but funding packages and expectations for these vary from program to program. For students hoping to transfer from physics into a different field, figuring out how to pay for their education is a different challenge.

Daniel Klein, a third-year emergency medicine resident, went to medical school after a short break following his physics bachelor's degree. He says federal forgiveness plans are a great option for people considering this route, but he emphasizes that forgiveness programs are not guaranteed, and students considering this path should carefully weigh their funding options.

KNOW YOUR TERMS

Stipend: Graduate students typically earn a stipend, a fixed amount paid as a salary in exchange for working for the department as a teaching or research assistant.

Teaching Assistant: Teaching assistants are usually assigned to an undergraduate class in their department. They may lead discussion or problem sessions, teach labs, hold office hours, grade homework, and proctor exams, among other activities. At most schools in the United States, first-year physics and astronomy graduate students are offered teaching assistantships unless they've already lined up a research assistantship or fellowship, they are not proficient in speaking English, or they decline financial assistance.

Research Assistant: Rather than earning a stipend in exchange for teaching duties, research assistants receive a stipend from the lab in which they are doing research. Research assistantships enable students to focus on doing research toward their thesis instead of teaching. In general, the number of research assistantships offered by a particular lab depends on its funding situation. If you want to enter graduate school with a research assistantship, you'll need to discuss the possibility with the researchers you're interested in working with as early as possible.

Fellowship: Graduate students with fellowships receive a stipend without having to teach or do research in support of the department—although there may be other requirements. Fellowships can be internal to the department or from external sources such as foundations, nonprofits, corporations, or government agencies. Fellowships are typically competitive and require lead time, so it pays to seek them out early.

Therese Jones, senior director of policy at the Satellite Industry Association, experienced both worlds by leaving an astrophysics graduate program to pursue public policy. A master's degree in public policy would have required out-of-pocket costs, but Jones opted for a PhD. Even so, she says, public policy programs pay less than physics programs, and the admission offers she received varied by \$10,000. The work she was paid to do was also different—rather than requiring a single, large-scale research goal, her program allowed her the flexibility to work on multiple, shorter-term projects.

Regardless of the road you take, it pays to look into fellowships, grants, and the typical financial packages offered by the programs that you're interested in. Most programs are happy to share this information with prospective students, and some even have this information on their websites and their GradSchoolShopper.com profiles.

NOTES

1. According to the most recent numbers from the American Institute of Physics, the median stipend for first-year physics doctoral students was \$20,000 for those without fellowships and \$26,000 for those with fellowships for the combined academic years of 2014–2015 and 2015–2016. The numbers are slightly higher in astronomy programs. For details, see P. Mulvey, A. M. Porter, and S. Nicholson, "First-year graduate students in physics and astronomy: Characteristics and background," American Institute of Physics, November 2019, www.aip.org/sites/default/files/statistics/graduate/1styeargradrpt-1516.pdf. GSS



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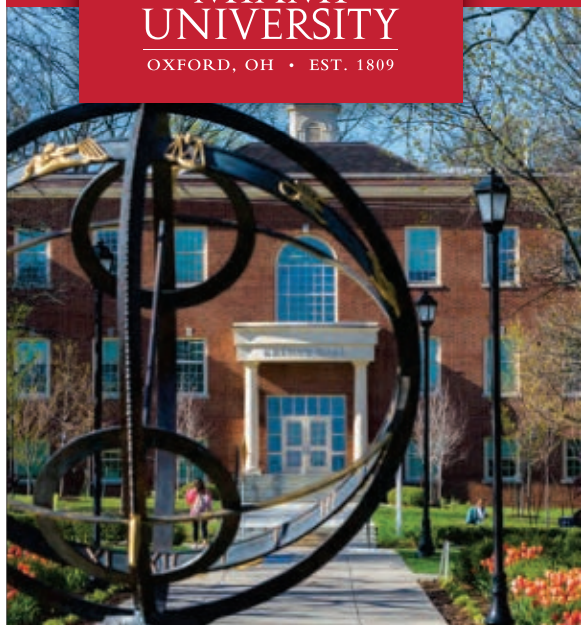
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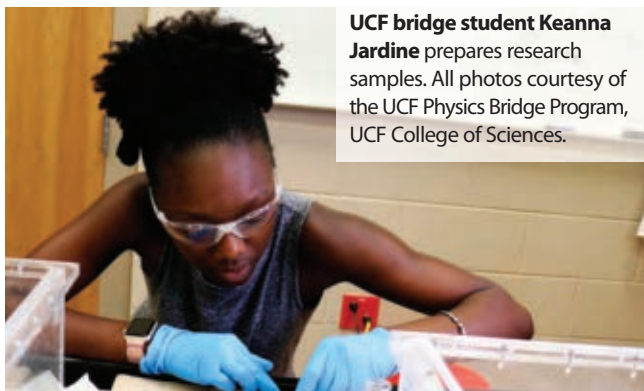


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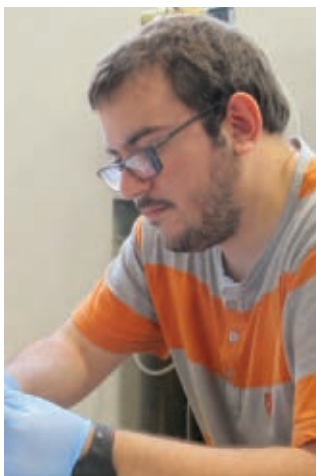
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UCF bridge student Keanna Jardine prepares research samples. All photos courtesy of the UCF Physics Bridge Program, UCF College of Sciences.



UCF bridge student Fernand Torres-Davila works with 2D catalysts.



UCF bridge student Christopher Sims prepares to do spectroscopy.

Q What is a bridge program?

A Sometimes students finishing their undergraduate degrees find themselves in a situation where pursuing direct admission to a PhD program may not be the right choice. For some, personal or academic challenges, financial constraints, lack of access to information, or lack of research experience may be deterrents; in other cases, lack of mentoring may prevent students from putting together a competitive application.

Bridge programs provide a one- or two-year pathway that allows recently graduated physics students to strengthen their training in preparation for a PhD program. Bridge programs have developed academic, research, and more holistic mentoring communities to support the needs of students with high potential and help them develop the foundation for a successful career in STEM.

Some bridge programs are independent while others are centralized. The University of Central Florida's physics department is one of five bridge sites established through the APS Bridge Program.² Other programs, such as the Fisk-Vanderbilt Masters to PhD Bridge Program and those at Columbia University and the University of Chicago, predate the APS initiative and remain independent.

This Q&A was conducted with members of the bridge program team at UCF.¹ It was facilitated by **Laurene Tetard**, associate professor in the Nanoscience Technology Center and bridge program site leader in the physics department at UCF. Responses have been edited for length and clarity.

Bridging Students from Physics Bachelor's to PhD

A Q&A with University of Central Florida (UCF) faculty and staff on bridge programs and the extra support they offer students

Q Who should apply?

A Students who would like to pursue a higher degree after earning their physics bachelor's and have a strong interest in research but find themselves unsure about their readiness for a PhD should consider applying. Most bridge programs give preference to students from underrepresented groups in physics, who are often disproportionately deterred from applying to physics graduate programs.

Q If a student accepts an offer from a bridge program, are they committed to earning a PhD from that specific program?

A The main goal of bridge program sites is to train students so that they eventually earn a PhD. We like to retain the students that we admit through the bridge program at UCF, but students are free to apply for admission to other physics PhD programs. Getting a PhD is a personal journey in addition to being an academic one. It is important for students to find an environment that they feel comfortable in and connected to and a research project that they are passionate about.

Q In what ways is a bridge program experience different from the traditional first year or two of physics graduate school at UCF?

A Bridge programs have now spread over many institutions, and they take a variety of approaches. At UCF, students who are admitted in the bridge program have flexibility in their choice of courses. For instance, students could choose to retake one or more undergraduate courses. However, students who are ready to take all graduate courses during their first year have an experience that is very similar to a traditional first year of graduate school.

Our bridge team offers mentoring, especially during the transition period. During the second semester we discuss choosing a research adviser in preparation for summer research. In addition, now that our program has been in place for several years, students who have been admitted to our PhD program after the bridge program remain active in the department and organize meetings and events for current bridge students.

Our bridge program is tightly integrated in the physics department. UCF is a metropolitan university and has a very diverse student population. Thanks to the program, our department now reflects to a greater extent the diversity in our university and in the Central Florida region. Students are engaged in a variety of research topics, from computational physics to experimental biophysics.

Q **What is the application process like?**

A The application process for APS Bridge Program sites is centralized and since 2020 has been regulated by the Inclusive Graduate Education Network (IGEN), so students upload their application to the IGEN platform. The application period traditionally runs from mid-December until March. Sometime in mid-April all IGEN-affiliated graduate programs can access the documents and organize interviews. In a way, this is a chance for students' applications to be seen by many departments with no application fee.

There are also independent bridge sites that have their own application systems. The application deadlines may be earlier or later.

Q **What advice would you give to students interested in applying?**

A If you're interested, apply! Students often forgo applying because they lack confidence, but admissions committees can see potential in an application even when the applicant doesn't see it yet. Letters of recommendation are important, especially from research mentors.

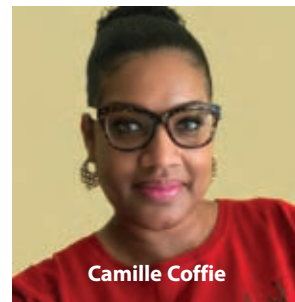
It may be helpful to talk to a mentor about what details to include in your personal statement. In general, personal statements and essay questions provide you the opportunity to describe the

LEARN MORE AND APPLY

For details on the APS Bridge Program sites, and to apply, visit www.aps.org/programs/minorities/bridge/students.cfm.

The University of Maryland GRAD-MAP team has compiled a list of physics and astronomy bridge programs, including independent programs, at www.umdgradmap.org/bridge-programs.

Camille Coffie on Taking the Bridge Program Route



I decided to return to grad school to study physics after working for many years in the aerospace industry and public education. My desired career required an advanced degree, so I sought out schools that did physics education research (PER). Many of these schools mentioned the APS Bridge Program on their website, so I became curious and looked it up. I liked the idea of being able to have my application viewed by several institutions at once, including some of my top choices. Also, as a nontraditional student, I appreciated the opportunity to take some advanced physics classes to refresh my memory and get research experience before starting a PhD program.

I was interviewed by a few bridge program schools and chose the University of Central Florida, the one that made me feel the most comfortable and was the most supportive of my goals. In addition, my prospective research adviser at UCF, Jackie Chini, was very welcoming and encouraging toward me, and that solidified my decision to attend.

My top two priorities when looking for a grad school were finding one with PER and being able to work with a good adviser and research group. The sunny weather in central Florida was an added bonus.

Camille Coffie is a physics grad student at the University of Central Florida.

context of any less-than-satisfactory academic performances or notable gaps in your training. Admissions committees that adopt a holistic approach to reviewing applications like to see details of the research you've done, challenges that arose, and the steps you took to overcome the challenges.

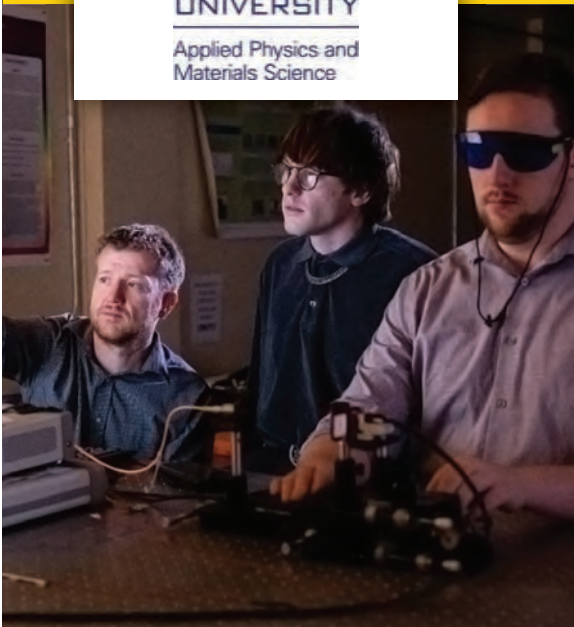
In addition to explaining your research, background, and any challenges you've encountered, use the personal statement to describe your research interests in detail and how open (or not) you are to various fields. You should also include any outreach, mentoring, and teaching experiences you've had. Members of the department don't want to know only if you can succeed in the program; they want to make sure they can provide a research environment in which you'll flourish.

NOTES

- Contributors include the following UCF physics department faculty and staff: Eduardo Mucciolo, professor; Michael Chini, associate professor; Adrienne Dove, associate professor; Abdelkader Kara, graduate program director, graduate admission chair, and professor; Laurene Tetard, bridge program associate site leader and associate professor; Talat S. Rahman, UCF bridge program founder and site leader and professor; and Esperanza Soto, physics graduate admissions coordinator.
- The APS Bridge Program is now under the umbrella of the Inclusive Graduate Education Network (IGEN). IGEN aims to help Black, Latinx, and Indigenous applicants who are unable to gain admission to physical science PhD programs through the traditional process or unable to complete the traditional admissions process for any reason. For details and application information, visit <https://igenetwork.org>. **IGEN**



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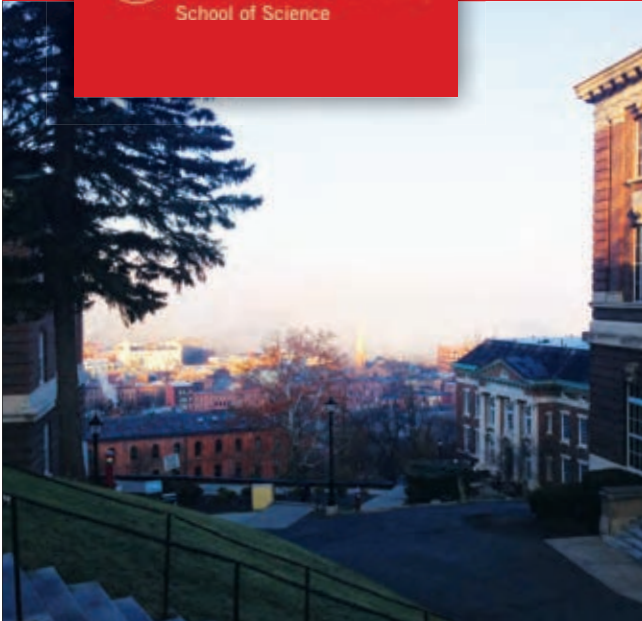
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ANDREW'S STORY

Why I went to graduate school

Like many of my peers, I spent a lot of time thinking about going to graduate school while I was in college. I worked in process development at a startup company along with doing university research, so I was definitely aware of the realities of both academia and industry.

However, more information isn't always better. I had to ask myself what I wanted for my life and career.

I liked the research and development aspect of both science and industry, so R&D was a "must have." After talking to people with careers that interested me, it was clear that to engage in R&D would require a graduate degree, regardless of whether I was in academia or industry.

So, one dilemma solved, but that opened up an array of questions: Master's or PhD? What kind of research? What program? What adviser? From my conversations with researchers at my university and in industry, I was pretty sure I wanted to stay in physics, which meant a PhD over an MS (for engineering, a master's is usually the better choice); plus, it's usually possible to opt for a master's while in a PhD program. The big question was what kind of research I wanted to do.

To discover research topics, I read a lot of books, magazines, and accessible journals; reading *PHYSICS TODAY* cover to cover every month really helped. As I found interesting topics, I would explore them more thoroughly, looking at related articles and the authors' research websites.

Looking back, I could have made things easier on myself by engaging more people around me in the process of identifying my passion. I was interested in too many topics and could have used an outside perspective. I talked with a mentor, and we had a good conversation about research and graduate school, but I wish we had talked three months sooner; he helped me figure out the core of my research interests. A trusted adviser is a huge benefit.

The same goes for graduate school, by the way. If there was just one piece of advice I could give to prospective graduate students, it would be to carefully select an adviser; it makes or breaks the graduate school experience. At every school I visited, I made sure not only that I would have a good relationship with the adviser I wanted, but also that I could envision myself working with at least two other faculty members. Life is unpredictable, and you never know when a "sure thing" will fall through. I sat down with potential advisers to talk with them about their research interests, along with my own, and tried to imagine working with them for the next five years.

Andrew P. Proudian earned a PhD in physics from the Colorado School of Mines and is now an engineer at Excelitas Technologies.



When I met Jeramy Zimmerman, an associate professor of physics at the Colorado School of Mines (CSM), it was clearly a good fit. He eventually became my adviser.

Andrew Proudian doing his PhD coursework at the Colorado School of Mines. Photo courtesy of Proudian.

I am now an engineer at Excelitas Technologies, helping to produce optics that span the deep ultraviolet into the infrared, and I use the skills and experience I gained while pursuing my PhD every day. Looking back, my time in the PhD program at CSM set me up for a successful career not only because of the education, but also because of the amazing people I met along the way.

*This piece is an updated version of an article published in the fall 2017 issue of The SPS Observer, www.spsnational.org/the-sps-observer. **GSS***

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Elon Price is a physics PhD student at Auburn University.

ELON'S STORY

A path shaped by conferences, community, and mentoring



Elon Price

When I started working toward an undergrad degree in physics, I wasn't sure what I was in for. My family and I didn't know much about astrophysics as a career, and we didn't know of any Black, female astrophysicists at the time either. My dad told me it would probably be a white- and male-dominated field. My parents warned me that I might feel isolated sometimes and experience discrimination, but that made me only more determined.

After a few years of working toward a physics bachelor's degree, I started to feel constantly overwhelmed by the various stressors in my life—including more responsibilities at work and harder courses. One day I got an email from a professor about a conference of the National Society of Black Physicists (NSBP)¹ that offered free travel and lodging to students who wanted to attend. I had no idea this kind of thing even existed, or that there were many Black physicists out there. I decided to attend.

During that NSBP conference, I experienced the value of networking and connecting to the broader physics community. I finally started to feel a sense of belonging in physics. Other conferences presented unique opportunities too, one even led me to a Society of Physics Students summer internship. Participating in that internship taught me a lot about physics professional societies and the myriad of physics careers and research areas.

During my undergrad years, I also found time to serve as a mentor. I volunteered for many summer sessions with Imhotep Academy, a program that teaches elementary and middle school students from underrepresented groups about careers in STEM. As an alumna, it meant a lot to me to give back to the program that first exposed me to laboratory research. My experiences with Imhotep over the years taught me the importance of mentor-mentee relationships and the impact they can have on a student's education and career.

When the time came for me to apply to graduate schools, I had a lot of resources but was still nervous. I was knowledgeable about physics and had a clear picture of my career goals, but I also knew about the increased underrepresentation of minority students in physics at the graduate school level. And I understood the importance of belonging and effective mentoring. As I learned more about the many bridge programs that support underrepresented minority students in the transition from undergraduate degree to physics

PhD program, I was inspired to apply.

Ultimately I enrolled in the Fisk University–Vanderbilt University Master's-to-PhD Bridge Program, and I recently completed a master's degree at Fisk. The experience only reinforced my career goals. The support I received boosted my confidence and affirmed my physics identity, and in the positive, encouraging environment, my coursework and overall understanding of physics improved. The skills I gained have prepared me well for obtaining a physics PhD, which I'm doing now at Auburn University.

My advice to students planning their physics career is to use networking to your advantage. Obstacles will arise, and it's reassuring to have an established network you can rely on for guidance. Mentoring is important, and mentors can come from many places, including conferences, internships, research experiences, and department faculty, among others. Ultimately, your mentors and community can help you make solid career choices that align with your interests.

NOTES

1. To learn about the National Society of Black Physicists, visit <https://nsbp.org>. Student members of the Society of Physics Students are eligible for free membership in NSBP; for details, visit www.spsnational.org/about/membership/joint-memberships. **GSS**

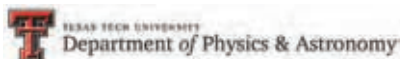


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A Guide to Choosing the *Right* Grad Program

By Brad R. Conrad, director, Society of Physics Students and Sigma Pi Sigma

The key to determining the graduate program that's right for you is to understand where you are likely to succeed, your personal preferences for community, and where each program can take you. I stress the word *you* because your preferences really matter. The overall aim isn't to get a degree from a specific institution or even to get a job in a specific field, but to achieve your career and life goals.

There are likely many pathways to your specific goals, and often many programs—sometimes wildly different programs—can help you achieve them. So, before you begin, realize that you are choosing among great opportunities, not “good” or “bad” ones.

The more honest you are with yourself about your needs, preferences, and goals, the easier it'll be to pick the program that's right for you. Here are some of the many factors you might consider.

1 THE PHYSICAL LOCATION

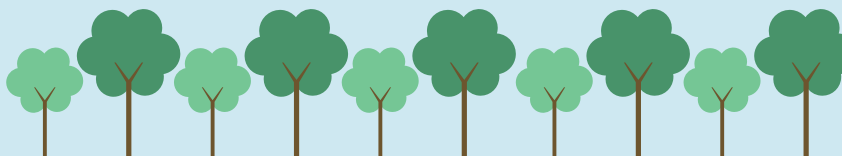
- Would you prefer a city, suburban, or rural location?
- Do you want a large or small school?
- Does a warmer or a colder climate appeal to you?
- Would a coastal, midwestern, or mountain location be best?
- Are there other centers of science nearby?

2 THE FINANCIALS

- Is there a stipend?
- What is the stipend amount versus the cost of living in that location?
- Would you have a research, teaching, or fellowship position?
- Do you need to pay tuition or semester fees?
- Does the program provide health care?
- Do you need to budget for parking or commuting fees?
- Would the stipend allow you to live comfortably?

3 LIFE OUTSIDE THE LAB

- Do you want a house, shared apartment, or campus housing?
- Would you rather drive, bike, or walk to the lab and classes?
- What is there to do in the area besides schoolwork?
- Do students often live together? Do they have a social life?
- Are there community organizations that reflect your interests and/or values?



4

DEPARTMENT CULTURE

- Do you want a large, diverse incoming class or a small, personal one?
- Would you prefer a collaborative or competitive student culture?
- Who teaches the courses?
- Do you need to take any labs as a graduate student?
- Is there a foreign language requirement?
- Are interdepartmental projects common?
- Can you work outside the university with national labs and researchers?
- Are there closely related departments (e.g., astrophysics, applied physics, chemical physics) that would expand your opportunities?
- Is there a qualifying exam? If so, what percentage of students pass?
- Is there a graduate student group?
- Are graduate students unionized?
- How inclusive and diverse is the department?
- Are students expected to be working all the time?
- What percentage of students who start the program finish?

5

POTENTIAL ADVISERS

- Are there multiple potential advisers you'd be excited to work with? How many?
- Do potential advisers have work styles that are compatible with yours?
- How often would you be expected to travel?
- How much of the time would your adviser be traveling?
- Does your potential adviser have research funding?
- Would you need to be a teaching assistant in your later years?

6

STUDENT SATISFACTION

- What's it like being a student there?
- Are the students happy?
- What do they do for fun?
- What do they think is the worst part of being a student there?
- The best part?
- What do current students wish they had known before they started?
- If they could do it over, would they choose the same program?
- Is the stipend enough?
- Are students involved in the local community?
- Do students like the department? Is it cohesive and supportive?

This list of questions is far from exhaustive. It's meant to get you thinking about the things that are important to you in graduate school.

While courses and the broader department culture matter most during your first two years, your adviser and research group matter most for the remaining years in graduate school. So make sure you research both aspects: classes and department culture plus individual advisers and research groups.

One often overlooked item is that your social and emotional well-being is just as important as your academic life. If you choose the perfect school for your career but you aren't happy there, it can be very difficult to succeed. Conversely, if you are at a school that matches your style but you aren't happy with your academic options, this can be an issue as well. Many students do not consider life issues and personal preferences when choosing their graduate programs, and this can diminish their chances of success.

Above all else, realize that there is most likely not just one perfect school but many schools that can work for you. So do your grad school research well and ask the hard questions. If you do, you'll likely end up in the place that's best for you. Good luck! //

This piece is an updated version of an article published in the winter 2018 issue of The SPS Observer, www.spsnational.org/the-sps-observer.

Farrah Simpson is a physics PhD candidate at Brown University and leads the Student Council of the National Society of Black Physicists.

FARRAH'S STORY

Is there a place for me in grad school?

I think often about how close I was to not going to graduate school, even though I really wanted to.

I'm from Jamaica. I went to high school there and moved to the US for college. My first undergrad physics class was taught by a professor who did high-energy experimental research at CERN. He would always go on tangents talking about his research and his experiences as a physicist. It excited me and was something that I was interested in, but I didn't know if being a physicist was feasible for me.

During my junior year, two of my professors encouraged me to apply to PhD programs. I still wasn't sure. I decided to take a gap year to think about what I wanted to do for the rest of my life and that's when I met Stephon Alexander, a physics professor at Brown University. He was the first Black physicist I had ever met. He's Trinidadian—so he's Caribbean, like me—and as I talked to him, I realized that what was holding me back from applying to a physics PhD program wasn't just that it's a hard field and a hard path. It was also that I didn't see myself fitting in with what it meant to be a scientist.

The more I talked to Professor Alexander and felt supported by him, the more I realized I would actually be supported in the Brown physics PhD program. I met a few more professors in the program. I visited twice. I got into schools that were higher-rated than Brown, but my top concerns were "Where am I going to thrive? Where am I going to be supported? Where am I going to be able to achieve what I want to achieve?" The department had a culture of supportiveness, and that was very important for me because I'd had a difficult time as an undergrad. I had felt very isolated, very alone. My decision was really about finding a program that fit me and that I felt supported in, and also having a mentor who made me believe that a physics PhD program was something I could do.

I remember telling Professor Alexander that I couldn't do high-energy experimental research—even though that's what I really wanted to do—because I didn't have any experience in that field. He responded, "We're going to make this happen." Now I'm doing high-energy experimental research with the CMS group.

If you don't think you'll fit into a graduate program, it's



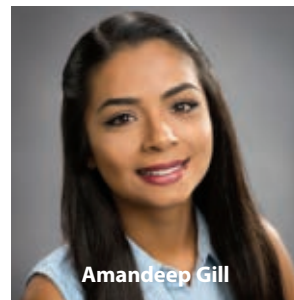
Farrah Simpson

important to critically think about why. Often it's not about abilities or achievements; it's other people or society telling us that we don't belong. Know that you can achieve this and you are capable. The thing about grad school is that everyone is starting from a different place. There are people with so much more research experience and people with so much more teaching experience—everyone is bringing their own unique background. There is a place for you in grad school, if that's what you want to do.

GSS

Amandeep Gill on Finding the Right Fit

My graduate school journey began in my last year as a physics undergraduate. I loved the subject but didn't have the confidence to apply to physics graduate programs. Instead, I applied to physics-adjacent programs, seeking a terminal master's degree.



Amandeep Gill

I began such a program the next fall, after spending the summer as a physics outreach intern. On day one of classes, I realized the program was not for me. I can't pinpoint what turned me away, but the field was very male-dominated, the city was too hectic, and I missed physics. I tried to make it work but in the end decided to leave.

Leaving was absolutely the best thing for me. I was able to explore life outside academia, substitute teach, intern for the governor of California, and reconsider my graduate-school future. From this messy time in my life, I emerged with the confidence and drive to pursue a PhD in physics. I am now in my last year of such a program and very happy—my experiences outside academia have only helped me succeed. It hasn't been easy, but it has felt right.

Amandeep Gill is a physics PhD candidate at the University of Nevada, Reno.

Simon Patané on Choosing a Path

I didn't want to pursue a traditional physics or astronomy PhD in graduate school, but I found it hard to settle on a path. While my peers compared physics and astronomy programs at a variety of schools, I searched through programs spanning aerospace engineering, engineering physics, and systems engineering, and I investigated opportunities in science policy.

I felt tremendous anxiety and uncertainty while deciding on a path, so I reached out to prospective faculty advisers in different programs. They were all more than happy to answer my questions and share their experiences. Many connected me with current students who also offered their perspectives. The grad school application process really is a two-way street.

Ultimately, I chose a systems engineering program with a focus on spacecraft design and program management. I was worried that I might not be adequately prepared, but I was. Anyone who's survived the rigors of a physics bachelor's will have no issue thriving in an engineering graduate program. The first-principles problem-solving approach foundational to physics is, not surprisingly, just as applicable to engineering.

Simon Patané has an engineering master's degree from the University of Michigan and works for Made In Space, Inc.



Simon Patané

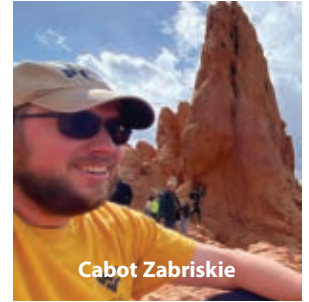
Cabot Zabriskie on Prospective Student Visits

Selecting a physics PhD program was daunting. All I knew was that I wanted to focus on applied research that could lead to a nonacademic job. To narrow down where to apply, I talked with people I trusted, explored GradSchoolShopper.com, and googled promising programs.

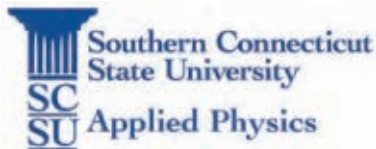
Going on prospective student visits was key in deciding what offer to accept. PhD programs often bring in accepted students for a weekend to see campus, tour labs, meet graduate students, and learn about the program (at their expense, not yours). These visits are where you really get a sense of the program and the area.

During the visits I took every opportunity to spend time with current students, including brewing beer and playing darts. I asked lots of questions, especially when professors weren't around. I also made sure there were at least two labs I could see myself working in. When all was said and done, I trusted my gut and decided to attend West Virginia University. It was a good choice—I received my PhD there in 2019, and even learned how to brew beer along the way.

Cabot Zabriskie has a physics PhD from West Virginia University and works for Apple Inc.



Cabot Zabriskie



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Samantha Pedek, graduate student,
University of Iowa; co-chair, Physics
Congress 2022 Planning Committee

Find Your People and Grad Program at the 2022 Physics Congress

Join hundreds of physics undergrads, grad school reps, and physics luminaries

Samantha Pedek

Networking is one of the most important aspects of being a young professional. We've all heard the spiel about how networking can have positive impacts on future educational and career-related opportunities, but many of us struggle with making the initial contact that can lead to lasting connections.

In 2016 I attended the Physics Congress (PhysCon), the largest gathering of undergraduate physics students in the United States. Every few years, PhysCon brings together students, alumni, and faculty members for three days of frontier physics, interactive professional development workshops, and networking. It is hosted by Sigma Pi Sigma, the physics honor society, and anyone interested in physics can attend.

Networking at PhysCon was unlike any other professional development experience I had as an undergraduate physics student. The sheer number of like-minded people was daunting—hundreds of physics and astronomy undergraduates, representatives from graduate schools and summer research programs, employers from all over the country, and well-established pro-



Samantha Pedek

fessionals at the height of their careers were all under one roof for three days.

PhysCon has continued growing in attendance, scope, and opportunities, and you won't want to miss the next one! In celebration of the 100th anniversary of Sigma Pi Sigma, an extra-special PhysCon is planned for October 6–8, 2022 in Washington, DC. With a little preparation, you'll have the chance to narrow down your graduate school search, meet potential employers, and make lasting connections with people heading down similar career paths.

The most direct opportunity to meet with representatives from physics and astronomy grad programs and potential employers occurs during the Expo, which encompasses both a grad school fair and a career fair. During the Expo, attendees can visit booths to learn more about a program, company, or undergraduate research experience as well as get tips and advice on applying. When I attended, seeing the wide variety of vendors enabled me to start thinking about my life after col-

NETWORKING TIPS

Before you attend a networking event, craft and practice your **elevator pitch**—a 30-second narration of who you are professionally, what you've accomplished, and where you hope to go in the future.

If you're attending an in-person event as a prospective student or employee, **business cards** (or contact cards) show that you're serious about your future and make it easy for new contacts to connect with you.



The Physics Congress is a high-energy, hands-on weekend designed explicitly for undergraduate physics students.
Photo courtesy of SPS National.

BE AN SPS INTERN

The Society of Physics Students summer internship program offers 10-week, paid positions for undergraduate physics students in science research, education, communication, and policy with various organizations in the Washington, DC, area.

www.spsnational.org/programs/internships.

lege, and I was blown away by the versatility that a degree in physics can provide.

A more subtle opportunity to build your network as a young professional is to engage with attendees you don't already know, between events or at meals. Shuffling between workshops, plenaries, and banquets will be hundreds of people with lived experiences similar to yours. Be adventurous and sit at a meal or workshop table with strangers! You might find yourself next to a professor from a graduate school you're interested in, or even from a school you didn't realize you should be interested in. A quick conversation can leave a lasting impression.

A straightforward way to meet students and professionals is to go to the poster sessions, as a presenter or an attendee. These are excellent opportunities to have one-on-one interactions with others and to learn about new topics. Seeking out posters in subfields you're doing research in or interested in studying in grad school is a great way to form connections and learn about current research in the field. My favorite question to ask a presenter is "Can you tell me more about your re-



2019 Physics Congress attendees visit one of the many graduate school booths in the exhibit hall to learn about the program and check out physics demonstrations. Photo courtesy of SPS National.

search?" They likely have an answer prepared, which can be a bridge to more natural conversation.

The physics and astronomy community is quite small, so if you meet people at PhysCon, you're likely to run into them again. Almost a year after I attended PhysCon 2016, I was a Society of Physics Students intern. Of the 14 of us, over half had met previously, largely at PhysCon. Having that shared experience helped me connect with the other interns right from the start. We even looked back at old PhysCon photos and tried to spot one another in the background, which was wildly entertaining.

Attending PhysCon is the networking gift that keeps giving. I have met others who attended in different years and we're still able to bond over our shared experiences. You are bound to find someone with similar interests and goals in a sea of over a thousand physics students, mentors, and advisers. Preparation is the key to successful networking, so practice your elevator pitch, make business cards, and I'll see you in 2022! GSS



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The Muon g-2 experiment at the Fermi National Accelerator Laboratory. Credit: Fermilab

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Standout Applications

Tips for getting your application to the top of the pile

Brad R. Conrad and
Matthew Wright

Note that our experience is primarily with physics and astronomy programs in the United States and Canada, but the application processes for other fields and for programs in other countries are often similar.

Graduate program admissions committees generally examine lots of documents and consider many factors during the application process: letters of recommendation, personal statement(s), course performance, quality of undergraduate preparation, research experience, research areas of interest, and personal characteristics. Ultimately admissions committees are looking for students who will excel, be outstanding researchers for their faculty, raise the profile of the university, and contribute to the department. Departments want students who will interact well with others in the department, have resolve, can teach undergraduate courses, and can pass any qualifying exams into candidacy.

Here are our thoughts, roughly ordered in terms of importance, about how you can increase your odds of standing out and being accepted. Keep in mind that our suggestions are just that—suggestions. The more people you consult, the better.

Where to apply

Apply to the schools that are best for you, not just the ones you've heard of or those whose rankings you like. When you take the time to learn about a program, consider what you can bring to that program, and tailor your application to that program, you increase your odds of getting in.

Spend some time thinking about what your goals are, what you hope to get from the degree, what you would like to do

Brad R. Conrad, director, Society of Physics Students and Sigma Pi Sigma, and **Matthew Wright**, associate professor and department chair, Adelphi University



Coauthor Matthew Wright (right) does optics research with then-undergraduate Tara Peña. Peña is now a graduate student at the University of Rochester. Photo by Statia Grossman.

when you finish, and your ideal work and living environment. Narrowing down programs can be tricky, but you can learn a lot from GradSchoolShopper.com, program websites, research group papers, and your professional network. Get lots of opinions, and ask the hard questions.

The people side of the equation is important too. Find out what the graduate student community is like at the places that interest you. Consider individual professors you could wind up working with and reach out to them. Discuss work styles, expectations, graduation timelines, funding, and research interests. If you're undecided on a research specialization, consider the breadth of research fields and opportunities available within programs. Then, once you're sold on a few programs and ready to apply, personalize each application package to show why you're a good fit for that program.

GPA

Most schools have a minimum GPA requirement to receive financial support, with a 3.0 average being a common cutoff. Pragmatically, you should aim for a higher GPA to be competitive. Admissions committees will look at what courses you've taken and your grades in those courses. These factors often matter more than your undergraduate institution. They want

to know if you are prepared and what you may need to work on.

If you are worried about your GPA or potential gaps in your undergraduate preparation, there are several ways to address this. Talk with the graduate program administrator about your situation and ask if the program can work with you. Discuss obstacles that hindered your academic progress in your personal statement, if appropriate. Don't be afraid to speak with specific advisers you might want to work with. Many programs will have flexibility with students who show interest, grit, and perseverance, even if their grades or preparation aren't ideal. You might also explore the physics bridge programs that help students hone their research and academic skills in preparation for physics PhD programs.

Personal statement

Most admissions committees spend a good deal of time reading personal statements, as they can be a clear window into many of the factors committees consider. Rather than using a generic statement, directly answer any prompts they provide, and avoid including a laundry list of research areas of interest. Instead, highlight why you're a good fit for that particular program and why it's a good fit for you. Customize your application to the specific program, faculty, and research areas you're focusing on. Keep in mind that your personal statement will most likely be read first and could impact how your other materials are viewed.

One of the most important factors committees look for is an applicant's ability to conduct guided and independent research. Highlight the skills and experiences that show the committee you are prepared to do these activities as a graduate student. Diving into one or two specific examples of your research is typically better than providing a long list of activities. It doesn't matter if your undergraduate research aligns with the subject that you want to study in graduate school. The project depth and skills acquired are what matter. Be sure to highlight your contributions to the project, not just the project as a whole. Additionally, highlight when your work has been featured in publications, presented at conferences, or recognized with an award.

Many of the people applying to a given school could succeed academically there; thus graduate programs want to admit students who truly wish to be there and will accept a spot if one is offered. To truly stand out in your application, let your passion and personality shine through.

Letters of recommendation

Many schools ask for multiple letters of recommendation, and for good reason. Some consider these to be the most important part of the application. Request letters from people who can provide a well-rounded picture of who you are and why you would succeed in graduate school. Make sure they can speak to your coursework performance and your research skills and address how you worked (or would work) in a research environment. Faculty members who have taught you in multiple courses and those you've done research under are ideal. Always provide letter writers with a copy of your CV to help

Letrell Harris on Doing Applications Right

Here are five essential takeaways from my recent graduate school application experience.

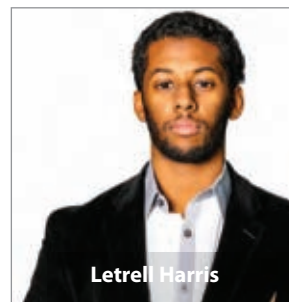
1. Request your letters of recommendation (LOR) as early as possible. Ultimately, you want the authors of your LORs to portray the qualities that make you an exceptional candidate for your desired graduate program(s), so diversify your LOR pool to go beyond research advisers. You might include the department chair and professors you studied with, as well as individuals who can attest to your character outside the laboratory and/or classroom. Also, be sure to request more than the minimum number of LORs your graduate applications require; this way, if one of your LOR authors drops the ball, you will still have enough LORs for a complete application.

2. Request fee waivers if financial barriers are preventing you from applying everywhere you want to. I applied to eleven graduate schools. I know what you're thinking: "Eleven graduate schools? That sounds expensive!" However, it wasn't. Many of my application fees were waived because I was a McNair Scholar and others were waived by the department. In the end, I paid for only three applications.

3. Don't sell yourself short. Apply to as many schools as you'd like; you never know which programs are looking for you. If you never apply, you've already rejected yourself. Don't tell yourself you are not qualified enough to be accepted by a graduate program. Let the program decide.

4. DO YOUR RESEARCH! Make a list of important dates and deadlines for the graduate programs you're applying to, and submit your applications early.

5. Most important, build genuine relationships with the departments you are applying to. Reach out to the professors whose research most interests you, and get to know them. Networking is key!



Letrell Harris is a first-year physics graduate student at Michigan State University.

them discuss your accomplishments, and give them plenty of time before the deadline.

General GRE and subject test

Graduate programs usually require the standardized GRE general test and sometimes the physics subject test as well. A poor performance on one or both does not mean you won't do well in a graduate program, but it may limit your options. Check the requirements of the programs you're interested in and the dates and locations where the GREs are offered, and begin studying as early as possible. A good strategy is to mimic the testing atmosphere with practice tests.

Other considerations

Many qualified students decide not to apply to graduate school because of a wide variety of barriers. These might include application costs, the perception that grades and/or GRE scores aren't high enough, impostor syndrome (recurring feeling of self-doubt or inadequacy), or lack of research experience, among others.



Photo by Sharon McCutcheon on Unsplash

Before you make a decision not to apply, consider that while admissions committees consider a variety of metrics, they are ultimately looking for people who will succeed in their program and connect well with their faculty. If you have extenuating circumstances that account for less-than-stellar grades,

poor test scores, gaps in your education, or another potentially problematic aspect of your application, consider addressing that in your personal statement, or ask your mentors whether it makes sense to mention it in your letters of recommendation. Remember, grit and the ability to overcome challenges matter to lots of admissions committees.

Some programs accept applications as much as one year before matriculation, so start early. Keeping track of due dates and required materials for each program of interest is vital. It usually costs money to apply to a program, but you can sometimes get the fee waived by contacting the graduate department and asking. Students who are serious about the process often apply to multiple programs—5 to 10 is not uncommon—but apply only to those programs that truly fit you, your interests, and your needs.

Remember, talk to faculty and other professionals about their experiences and recommendations, as subfields and departments will vary. If you have questions about a program, don't be afraid to ask the graduate program coordinator or a faculty member. When writing your personal statement, focus on communicating to faculty within the department you are applying to. Keep in mind that what makes you stand out to one program might not be as noteworthy to another. Your best course of action is to personalize each application to showcase who you are and what makes you a good fit for that specific program.

This piece is adapted from an article published in the fall 2019 issue of The SPS Observer, www.spsnational.org/the-sps-observer.

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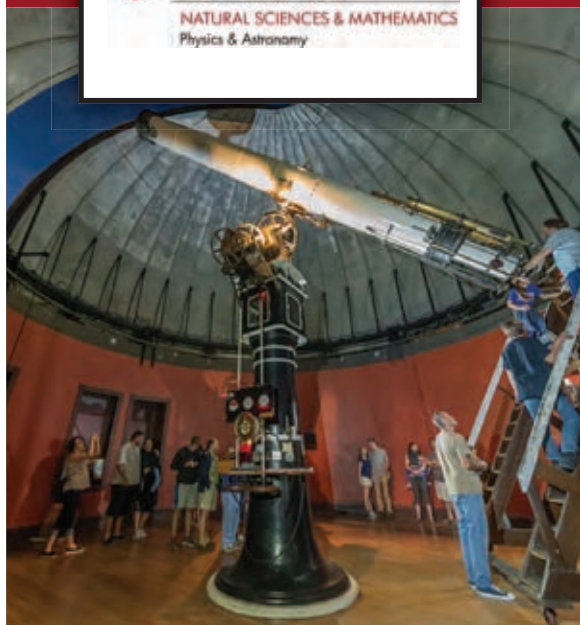
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Robert Riehn, associate director of graduate programs, department of physics, North Carolina State University

Applying to Grad School with a COVID-19 Transcript

Robert Riehn

When an admissions committee examines applications, it looks at two things:

1) Proven successes—From completed courses and research experiences, the committee assesses whether a student will be able to complete the classwork and research requirements to graduate.

2) Potential to excel—From research experience, resilience, and demonstrated skills, the committee tries to judge whether a student will be a successful researcher. We look for students who put their heart into a project or an activity that mattered to them, even if they didn't have access to the best resources as undergraduates.

Because of the uncertainty in how courses were conducted during the COVID-19 outbreak, the grades of today's applicants are harder to interpret. For example, GPAs were influenced by distance learning in undetermined ways, and some institutions switched to satisfactory/unsatisfactory grading systems. In addition, we received essentially zero physics GRE scores. They are one of many factors we normally consider because, after accounting for systematic biases, they can help people from schools whose transcripts are hard to interpret.

Given these blind spots, we've had to put more emphasis on research promise. A cohesive research story, as told in the student's personal statement and letters of recommendation, has become very important. This year we've admitted people who might need more academic work but had such a great documented research record that everything fit together.

My best advice is to address your research preparation. Make sure you have letters of recommendation from research advisers, and spend time on your personal statement—it's considerably more important than a homework assignment. In your statement, identify which researcher(s) you would like to work with, why, and how your experience is relevant to their research area. If the pandemic shaped your research direction—if you had to switch from experimental to theoretical or computational research when labs were shuttered, or if a research opportunity was canceled—you may want to include this in your statement as well.



Robert Riehn

If you've been involved in other activities and leadership opportunities as an undergraduate, we want to know about them, too. At the end of the day, we want self-motivated students who have a passion for research and will succeed in the program—even if some of their semesters were extra challenging because of the pandemic. **GSS**



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Casey Miller is the associate dean for research and faculty affairs at the Rochester Institute of Technology. His responses have been edited for length and clarity.



Casey Miller

Real Talk: GRE Scores and Physics Grad Programs

A Q&A with Casey Miller on how well the GREs predict success

As part of the admissions process, many graduate programs in the United States require students to take the standardized Graduate Record Examination (GRE) General Test. The general GRE includes sections on verbal reasoning, quantitative reasoning, and analytical writing, and test takers receive a numerical score in each area. Many physics graduate programs also require students to take the standardized, subject-based physics GRE. Physics GRE test takers receive a single numerical score.

But what do the scores actually mean? If you score low on the

physics GRE, should you start applying to jobs instead of graduate programs? If you score high, does that mean you'll be a tenured physics faculty member in no time? A team led by Casey Miller, a PhD physicist and associate dean at the Rochester Institute of Technology, analyzed 10 years' worth of student data to find out whether GRE scores—verbal reasoning, quantitative reasoning, or physics—predict successful completion of a physics PhD. Their results were published in the journal *Science Advances*.¹

Q What is the bottom-line finding of your study?

A GRE scores do not predict success in physics PhD programs very well.

Q What should physics students know about the GREs?

A A GRE score does not reflect your potential to be a PhD-level scientist. There is much more to graduate education. As a result, students who score low can, and often do, become excellent scientists. Students who score high can also make excellent scientists—but not always.

Q Some physics grad programs used GRE scores as admissions criteria. Why is this so problematic?

A The main problem is when programs use the scores in unenlightened ways to select who gets to do the science of the future. For example, some require a minimum score for admission. This is not in line with how the test maker says to use the test. This

practice significantly biases who is deemed “acceptable,” and it is especially damaging to the representation of applicants who identify as female, Hispanic, Native American, African American, and US citizens.² Combine that with our results that question the tool's utility, and you have a serious systematic problem.

Q What would you say to a student who takes the physics GRE and does poorly?

A Your score is not necessarily related to your ability to do PhD-level physics or to become a PhD-level scientist. Because of the misuse of GRE scores in the admissions process, you will be overlooked by certain programs—at their loss—while other programs will evaluate your overall potential based on multiple factors.³

Q What would you say to a student who takes the physics GRE and does well?

A Your score is not necessarily related to your ability to do PhD-level physics or to become a PhD-level scientist. Completing a PhD requires numerous skills that cannot be measured

by such tests. In fact, most students leave graduate school for nonacademic reasons.

Q What advice would you give to students applying to physics grad programs?

A Consider programs based on multiple dimensions, including non-science-specific issues such as culture and location, to make a best guess about how well they might fit your life.

NOTES

1. C. W. Miller et al., "Typical physics Ph.D. admissions criteria limit access to underrepresented groups but fail to predict doctoral completion," *Science Advances* 5(1), 2019 Jan. 23, DOI: 10.1126/sciadv.aat7550.
2. As noted in the paper, "Although the best evidence suggests that faculty are well intentioned when selecting students, many are unaware of demographic patterns in GRE scores and they carry out admissions according to inherited practices that include using cutoff scores. Programs using the [physics GRE] as an integral part of their admissions process may be unwittingly selecting against underrepresented groups and U.S. citizens."
3. If you find yourself in this situation and would still like to be considered by a program that uses a cutoff, you can retake the general and physics GREs. GRE prep materials may help improve your score. Alternatively, you may want to focus on the growing number of programs that do not require the physics GRE.

This article was originally published in the fall 2019 issue of The SPS Observer, www.spsnational.org/the-sps-observer. GSS



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Robert Riehn is the associate director of graduate programs in the physics department at North Carolina State University. His responses have been edited for length and clarity.



Photo by Andrew Neel on Unsplash.

Make a Statement with Your Personal Statement

A Q&A with Robert Riehn on what admissions committees want to know

Q How do you write a good personal statement, statement of purpose, or cover letter?

A Show us, the graduate admissions committee, your strengths through a narrative. Many students have a wide variety of strengths, and it is hard to provide such a diverse group with a prompt that effectively encompasses this range of strengths.

Good letters provide a compelling narrative and highlight the applicant in a unique way. Students have diverse interests when applying to graduate school, and so you have to explain to us why you believe you will be a good researcher and why you are well suited for a challenging program. Many students provide a narrative of how they decided to go to graduate school. If you do this, know that we are looking for the ability to present this as a path with reasoned steps.

The strongest essays prove that the applicant is a suitable student and a good researcher and that our school is a good fit for them. It's important to state why you're interested in our institution and relate your interests to our program. From the cover letter we can also judge how well you write, which is very important to us since writing is a large part of completing a PhD.

Q How does a student stand out as an applicant?

A Achievements. Students often lower the impact of their application by writing about things they did but not identifying why their contribution to the field is unique and why their work is significant. When you write your story, your narrative, in terms of achievements and with context, that is a strong indication that you can write and that you are aware of where you stand in the world.

Q If students have done research, should they discuss that?

A Research is a very important part of being a graduate student. If a student has a research background, we look for an explanation of that research, the findings, and the student's contribution to the field of research. We expect all strong applicants to identify who they would want to work with within the program, why they want to work with those specific groups, and why they believe they are specifically suited to that work. Make sure that your letter has this piece and that it fits into the broader narrative.

Additionally, if you have overcome significant hurdles in your life, provide a description of how you approached and overcame these hurdles. How people overcome hurdles tells the committee a lot about how they will address challenges as a researcher.

Q In an application, how many labs should a student mention being interested in working with?

A I suggest mentioning three. Research groups are often 3 to 5 students per faculty member, but in many fields there are multiple professors and researchers working on overlapping projects. It's totally possible that a specific group will not have space for you in a given year but that there is space in a different group in the same field that collaborates with your first choice. If you identify three faculty members, you usually can find a research home, even if it is not with the one person you identified first in your application.

Interestingly, about 50% of students decide to join a PhD adviser they didn't foresee working with when they started their program. This typically happens when students arrive on campus, take classes, and discover a new field of research that lights a fire for them. I recommend listing not too many potential advisers, and if you can't decide on whom to list, it's best to be honest about it. Authenticity is an important aspect of an application—write what you mean.



What other advice would you give to students applying to graduate programs?



Contact the graduate program if you have any questions at all. If you are not clear on something—required grades, tests, or groups you could work with—contact the program. If you don't have all of the required preparation, some schools will work with you on a way to complete the coursework necessary to succeed.

If you have a transcript from a well-known school, admissions staff will be able to judge your transcript easily. If your transcript is from a less well-known school, ask if there is anything the admissions committee is interested in seeing, such as a textbook list or syllabi. If you are a mathematician or a computer scientist or an engineer and you discovered your passion for physics late, departments can still work with you. If you are worried about your application, ask if there is anything the committee would like to know about you. Programs want applications that help them understand you at a deep level.

Many professors are willing to start a conversation with you before you apply. They may be able to tell you the kinds of skills they are looking for and whether you may be a good match. You could find a research adviser even before joining the graduate program. Be sure you do your homework before writing that first email—the more you know, the better your email, and the more likely you are to engage the professor in a conversation.

This is an excerpt from an article published in the fall 2020 issue of The SPS Observer, www.spsnational.org/the-sps-observer. GSS



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GSS



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LaNell Williams

LaNell Williams is a physics PhD candidate at Harvard University and founder of the Women+ of Color Project. Her responses have been edited for length and clarity.

Don't Limit Yourself

A Q&A with LaNell Williams on applying with confidence and the Women+ of Color Project

Q What did the grad school application process look like for you?

A I'm technically a nontraditional student. I took some time to do a master's at Fisk University and really solidify my knowledge of physics before I applied to PhD programs. I was a McNair Scholar when I was an undergrad, and that was really helpful when I was applying to graduate school the first time. A good amount of what I learned about applications and GREs was from the McNair program, but I also learned from experience and getting feedback from people on my essays the second time I applied.

Q Tell us about the Women+ of Color Project.

A The project started because someone ticked me off by saying that women of color don't like physics, they don't always have the qualifications, and if we spend time recruiting them, we should be doing it for other groups too. I was really upset and decided to build something. It was supposed to be a Google Doc with the application information and resources I'd used. I was going to send it to a bunch of Black and Brown women and encourage them all to apply to Harvard that year. I wanted to flood the application pool and hopefully increase the chances of some of them getting in.

The effort grew into the Women+ of Color Project through the support of Harvard physics professor Jenny Hoffman and because the Heising-Simons Foundation offered to fund a workshop. The project aims to improve the pipeline of underrepresented racial minority women+ who pursue graduate school in STEM. We share best practices for applying to graduate school and thriving in graduate school through an online portal and in-person workshops. It was supposed to be a one-time workshop, but this October we'll be doing our third.

Q What are some of the common mistakes that you see students make in their applications?

A A lot of times students are not able to sell themselves to schools. Students underplay their accomplishments; they don't talk about things that are important—like research—on their applications. They spend too much time on the personal part instead of on what graduate school is about, the research.

The biggest mistake I see is that students don't know the difference between a personal statement and a statement of purpose. Think about your research experience and what you can do as the meat of the essay, and think about your personal experience and who you are as the seasoning. This can help you tie it all in so that you have a cohesive story.

The other mistake I see is students not applying at all because of their GPA or GRE scores. Know that you have options. You can still apply; I've seen students who struggled with their GPA still get into graduate school. You can also take a slightly less traditional route like applying to bridge programs, going into a master's program first, or working for a while as you build up your skills.

Q What are some of the additional challenges faced by women of color in the grad school application process?

A Women of color are capable of completing the application process; the barrier is that people are always discouraging them from doing it. There is a sort of a negative light over applying to the Ivy League institutions. Places like Harvard and Stanford are

THE WOMEN+ OF COLOR PROJECT

The Women+ of Color Project provides an open platform for women of color to communicate about best practices for applying to graduate school, surviving graduate school, maintaining research productivity, and growing their academic careers. To connect with the project and find information on upcoming workshops, visit <https://thewocproject.org/>.

seen as reserved for those who are “more qualified,” like white and Asian men. That’s a narrative that a lot of us know.

Q What advice would you share with physics undergraduates considering graduate school?

A Get into a lab and, if you can, get your name on a paper. If you can’t get into research it’s not the end of the world; there are other options. But if you can, do it early. Research is what graduate school is really about.

Prepare for the physics GRE early, if you can, but know that whatever happens, happens. If you can afford it or can get your program to pay for it, hire a tutor. Use the few study resources that are available. Carve out the time, do your best, and then move it to the side and focus on the main things: your research, your recommendations, and your personal statements.

Start being strategic about your letters of recommendation early. The strongest recommendations come from research advisers. Ask if they can give you a strong letter of recommendation, and give them bullet points of what you’ve done, including what you’ve done with them specifically. Send them your personal statement and your CV. Make the recommendation writing process easy for them.

When you apply, let the program know what kind of research you want to do. Speak to what skills you can bring to the program in addition to your interests.

Finally, balance your application pool to include extremely competitive programs, some in the middle, and some safety programs as well. Apply to where you want to go; don’t limit yourself as a result of what others say. **GSS**



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Kendra Redmond, editor, and **Brad R. Conrad**, director, Society of Physics Students and Sigma Pi Sigma

Mental Health Matters in Grad School

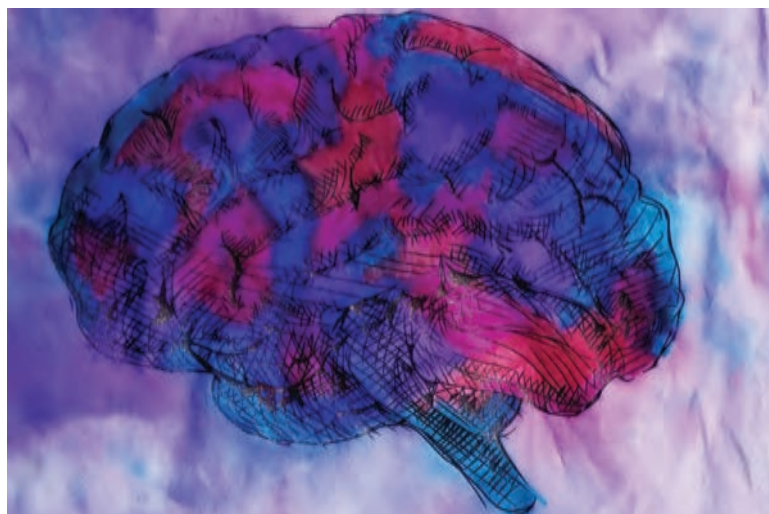
Kendra Redmond
and Brad R. Conrad

Graduate school is an amazing opportunity to immerse yourself in learning, discovering, growing, and, in the case of science PhD programs, contributing to our knowledge of the universe. Grad school is also challenging, even under ideal conditions. The high pressure to achieve can be accompanied by unhealthy work demands, less than ideal mentoring, isolating environments, insufficient resources, or even crippling feelings of inadequacy. Compounding all of this are intense time constraints and, for many, entirely new surroundings to adjust to.

If you're a physics or astronomy student, you're no stranger to challenges—you probably thrive under them—but you also know that research means something. Recent studies have shown that mental health issues such as depression, anxiety, burnout, suicidal thoughts, and post-traumatic stress disorders are prevalent among PhD students.¹ The incidence rates for many of these conditions are higher among PhD students than for average populations and other highly educated populations.²

As you embark on your graduate school journey, it's important to prioritize and protect your mental well-being. As former football player and coach Chuck Pagano famously said, "If you don't have your health, you don't have anything." One way to set yourself up for success is to cultivate a broad support network—including your undergraduate professors, mentors, former classmates, family, and friends—that will be there for you no matter where you go to school. Let them know your plans, and stay in touch.

When considering graduate programs, examine how well they support their students. Do they encourage collaboration or competition among students? Do they have procedures in place to support those who need extra help, academic or otherwise? What percentage of students who begin the program complete their degree? One of the best ways to find answers is by talking to grad students currently in the programs you're interested in.



Artwork from a "Love Your Brain" event at Notre Dame University cosponsored by the Society of Physics Students chapter there. Photo courtesy of the chapter.

GET HELP NOW

If you or someone you know is in a mental health crisis, please seek help. The following resources are free and available 24/7 from the comfort of your home. Call 911 in an emergency.

- » **US National Suicide Prevention Lifeline:** Call (800) 273-8255 for free and confidential help.
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- » **Thrive Lifeline:** Text (313) 662-8209 to access support from qualified crisis responders in STEM (science, technology, engineering, mathematics, and medicine), <https://thrivelifeline.org>.
- » **Grad Resources, National Grad Crisis Line:** Call (877) GRAD-HLP, and find more at <https://gradresources.org>.
- » **7 Cups:** Caring listeners for free emotional support, www.7cups.com.
- » **Suicide Prevention Lifeline:** <https://suicidepreventionlifeline.org/help-someone-else/safety-and-support-on-social-media>. The organization will help you contact social media platforms directly if you're concerned about a friend's social media updates.

PATHS TO RESILIENCE AND SUCCESS

By Soonhee Lee, assistant director/training director, Counseling Center, University of Maryland, Baltimore County; Susan Han, associate director for outreach, Counseling Center, Johns Hopkins University; and Bruce Herman, director of health and counseling, University of Maryland, Baltimore County

School is a time of academic, personal, and social development. You may experience a wide range of emotions, including excitement, nervousness, sadness, or happiness. In addition, up to 82 percent¹ of successful people experience impostor syndrome (feeling like a fake or fraud), and it is not uncommon to feel intimidated by seemingly smarter peers and professors. BIPOC people (Black, Indigenous, and People of Color) in predominantly White environments are more likely to experience impostor syndrome.²

These are all normal emotional experiences. But knowing that these emotional ups and downs are normal doesn't necessarily make them easier to deal with. Resilience, in particular, has been shown to be positively related to mental well-being, academic success, and retention.³ Here are some specific resilience-building strategies that you can practice.

Get involved with friends and organizations. First-year college students' sense of social belonging was found to predict their academic and health-related outcomes over three years.⁴ It takes time to develop close relationships, so be patient! Also, remember that participation in clubs and organizations, affinity groups, leadership positions, and immersion in the community all contribute to a sense of belonging and empowerment in your life.

Accept that no one is perfect. Rigid and too-high standards can take an emotional toll on students, leading to feelings of guilt, shame, or anxiety. And while it can seem motivating to compare yourself with someone who does better than you, it can also dampen your spirit or sense of hope. Keep in mind all of the things you already

do well, accept that it is okay to be human, and don't be afraid to make mistakes.

Embrace your anxiety. Anxiety is a part of life and necessary for survival. Its effect on us takes the shape of a bell curve: We do best when we experience a moderate level of it. There are different strategies—techniques such as mindfulness, cognitive flexibility, or relaxation—that can help you reduce anxiety when it is too high, but you should also try to motivate yourself when it is too low. Embrace your anxiety rather than fight or suppress it.

Nurture your body. Our minds and our bodies are intricately connected, and to be well we need to take a holistic view of health. Healthy eating habits, regular exercise, and restful sleep are just as important as other aspects of self-care and study breaks. For academic success, nurture your mind and your body.

Ask for help and guidance. Whenever you face a new opportunity or challenge, don't be afraid to ask questions, get advice, and learn from others' experiences. Schools provide a wealth of services and resources that are intended to guide you, and there's no reason to feel embarrassed to ask for help when you need it. Taking steps early can prevent problems in the future!

Get to know the mental health resources on campus. It can be helpful to talk to a mental health professional before, during, and after periods when your stress or anxiety levels start to impact your academic, social, or personal functioning. Many schools have a counseling center or offer various mental health services, including individual or group counseling, skills-based workshops, or psychi-

atric care. The staff are trained to work with students and can help you develop a plan for the future. In addition, many schools offer crisis services or referrals for students who are in need of more immediate care. Make sure you are aware of these resources, for yourself or for your friends and peers who may be in need.

These strategies can help you as you navigate your way through school. As you practice resiliency-building skills, you may find yourself feeling better able to face new challenges and persist despite barriers. Remember that the staff and faculty at your school are on your side and want to see you thrive. Make the most of the resources that are provided to you and enjoy the experience!

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This piece is an updated version of an article published in the fall 2018 issue of The SPS Observer, www.spsnational.org/the-sps-observer.

When starting a program, familiarize yourself with the support resources available on campus; it's best to have this information before you need it. Prioritize finding community, ideally both within and outside the department, through clubs, interest groups, or other organizations. If you're moving to a new area, ask members of your support network if they have friends or colleagues in the area and establish local connections. Having people awaiting your arrival can make a place feel a lot more like your new home.

Once you're on campus, join or lead efforts to create an inclusive, supportive community among your peers. Participate in study groups and make an effort to engage in social events. It might be hard at first, but the connections you make in grad school can last a lifetime—these are your future colleagues and collaborators. The more we in the science community look out for and support one another, the better the environment will be for everyone. This also extends into the research lab. Choose a research adviser with care, and seek out men-



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torship in multiple places, not just the lab in which you're working. It's not uncommon to work with a few advisers before you find a good fit, and it's not the end of the world to change advisers.

Most important, don't let the grad school environment fool you into thinking that your worth is defined by achievements and research results. Graduate students are first and foremost humans, and your health, humanity, happiness, and well-being are worth protecting.

NOTES

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Toni Feder, science writer, PHYSICS TODAY,
American Institute of Physics

PhD Student–Adviser Pairing Is Critical, but in US Physics Departments It’s Often Haphazard

Toni Feder

Back when Dan Stamper-Kurn, now a physics professor at the University of California (UC), Berkeley, headed to graduate school at MIT, he got two bits of advice that were “right on.” A researcher with whom he had explored the effects of urban heat islands on energy use told him to work “in the most fundamental science” possible so as to gain a strong foundation. The other piece of advice came from a graduate student who told him, “Don’t work for a jerk.”

Since then Stamper-Kurn, whose research focuses on ultracold atoms, has mentored dozens of PhD students. Choosing an adviser is the most important decision a graduate student will make, he says. The relationship continues after the student gets their PhD. It is personal. It has a power dynamic. And both parties need each other for their careers.

Yet adviser–advisee relationships tend to form with minimal information. The process involves institutional structures, funding, individual initiative, trial projects to sample research interest and work styles, and compatibility. “There is no formula,” says Stamper-Kurn. “I have to think it will be possible to turn [the student] into a kick-ass scientist.”

Open houses and pizza lunches

At many US universities, the admissions process paves the way for pairing faculty with PhD students. Faculty members are polled to see who wants to take on new students, and applicants are asked to list their areas of interest. The aim is to engineer an incoming class whose interests roughly line up with the available research spots.

Prospective students and advisers meet during campus vis-



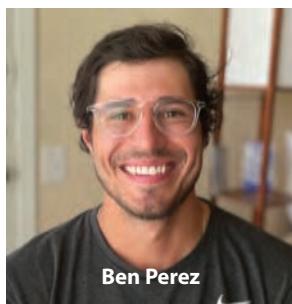
Prospective graduate students at the Louisiana State University physics department’s 2017 open house, which coincided with a local St. Patrick’s Day parade. Now working on their physics PhDs at LSU are Tej Poudel Chhetri (far left), Thomas Ruland (red shirt), Frank McKay (light blue shirt), and Scott Mullen (maroon shirt). Madeleine Miora (second from right) earned her master’s at LSU; the other students went to other universities. Photo by Ilya Vekhter.

its. That’s how Rachel Nguyen, now a second-year graduate student in dark-matter theory at the University of Illinois at Urbana-Champaign (UIUC), found her adviser. “I had a large list of universities I was interested in, and for each one that I was accepted to, I tried to identify several professors that I thought I would be happy working with,” she says. As it turned out, the person who became her adviser was not on her spreadsheet—he was a new hire and was not yet featured on the department’s website. “His interests matched mine, so the department put him on my schedule for visitors’ weekend,” she says. Afterward he followed up with email messages and a Skype call.

Rachel Malecek didn’t know what research area she wanted to pursue. At the Louisiana State University (LSU) physics department’s open house in spring 2017, she attended talks by several professors and chatted with them and their students. “I’d never considered nuclear as an option because I hadn’t had

Ben Perez on Graduate Advisers

If I had to give one piece of advice to prospective grad students, it would be this: Find a research adviser whom you like, who will work with you to achieve your goals, and who is authentic. Not all research advisers have the same funding, time, and mentoring approach.



Ben Perez

As a new graduate student, I expected a certain level of mentorship, guidance, and attention. I envisioned working alongside my adviser, asking questions, and meeting regularly. I definitely expected to see my adviser more than once a year! But my experience hasn't really matched my expectations. I am funded, I have free time, and I have the freedom to explore my own research ideas, but I would have benefited from an adviser with more availability.

Do your due diligence and figure out what it would be like to work under someone before you make a selection. Be picky. Don't fall for charisma or prestige. Find the right fit for you. This is your life, and you deserve to be in the situation that is most beneficial for you.

Ben Perez is a materials science and engineering PhD candidate at the University of Texas–Dallas.

a class as an undergraduate," she says. "But from the short talks, it sounded cool. The nuclear-physics group seemed like a nice, tight-knit group." Malecek later sent an email to one of the nuclear physicists and asked if he was looking for graduate students. He was, and she joined his group.

Once students are accepted to UC Berkeley, Stamper-Kurn reaches out to those who express interest in atomic, molecular, or optical physics. "I encourage them to come to our open house. I show them around the labs and talk to them about Berkeley and our group." At Berkeley and other state schools, departmentally funded fellowships are scarcer than at some of the private schools that the students may be looking at, he says. "One tool I have in my arsenal is to offer students a spot in my group right off." If they want to do research and not have to work as a teaching assistant, he says, "that can be a powerful incentive."

Faculty members who want to take on students typically present departmental talks. For first-year students in the Yale University physics department, for example, Friday pizza lunch is a de facto required class. "Students learn about potential advisers, and it gives them a sense of research in the department," says Sarah Demers, an associate professor whose group focuses on using muons and tau leptons to investigate physics beyond the standard model. "It's a great recruiting opportunity."

Some departments offer rotations, in which students join different research groups for up to a semester each. Official rotation programs are rare in physics—they are common in biology and chemistry—but often students can create their own rotation schedules. The physics department at UC Berkeley, for

example, encourages students to do that. Heather Gray is an assistant professor there who studies the Higgs boson. "In high-energy physics, we work in enormous collaborations," she notes. "The rotations are an opportunity to see if the personalities work together. The PhD is long, and there is no purpose in being in a group where you are unhappy."

"Motivation any day"

So what do faculty look for in advisees? Passion and excitement about the specific research topic are often critical. "I don't look for just experience and talent," says MIT's Nergis Mavalvala, who works on the Laser Interferometer Gravitational-Wave Observatory. "I look for interest. I can teach students the tools of my trade, but I can't teach them to be excited about what I do."

Professors also look for dedication, motivation, creativity, a willingness to ask questions, and the ability to recognize when a line of inquiry hits a wall. Frank Würthwein of UC San Diego searches for new high-energy phenomena at the Large Hadron Collider. "Each faculty member has a different set of criteria," he says. Theorists are more interested in what students know, he observes, while experimentalists are typically more interested in what skills they have. He pays attention to the questions students ask and to whether they are self-critical.

Würthwein likens his group to a small business, in which his investment in students should pay off. "There is real money in the game," he says. "I want to make sure students are productive."

David Gerdes, physics chair at the University of Michigan, asks prospective students, "What are your goals? What is your perfect day?" Some students are software oriented, some like analyzing data, some want to fiddle with lasers or other hard-



Group dynamics can be an important factor in choosing a research adviser. At the University of Illinois at Urbana-Champaign, Jessie Shelton (right) and other professors in high-energy theoretical physics hold joint group meetings. Photo by Brian Stauffer, University of Illinois at Urbana-Champaign.

ware, some like higher-level interpretation. Sussing out a student's interests is important when matching them with a project, Gerdes says. "There's an axis of skills and abilities, and an axis of motivation, persistence, and enthusiasm. Ideally, someone has both. But if I have to pick, I'd pick motivation any day."

A common approach for faculty is to invite students to work with them on a provisional basis so both parties can test the fit. Lars Bildsten, director of the Kavli Institute for Theoretical Physics at UC Santa Barbara, says that to onboard students he works with them intensely, usually after their first year of graduate school. "By the end of the summer, I'll say, 'Yes, great' or 'No, this isn't working.'" A no is better earlier than later, he notes, and usually it's no surprise to the student. "If they don't have that fire in the belly for the specific research problem, it comes through quickly," says Bildsten. Usually, he adds, the student goes on to find a research area, adviser, and group that are a better fit.

James Sethna, a Cornell University theorist in statistical physics, says he works with students for a summer or semester before committing to take them on for their PhD. "It's not just how smart they are, or how much overlap of interest we have. It's also personal chemistry." Theory tends to attract more students than departments can support, he notes, so student initiative is important. "The ones who are aggressive end up getting more attention." But Sethna says he avoids snap judgments. He recalls one student whose persona was very unassuming. "You didn't find out how really amazingly smart she was until you worked with her for a while. I was really pleased I didn't make the decision right away. I grew to appreciate how talented she was."

Elements of style

Professors, for their part, have different mentoring styles. They can be hands-on or let students flounder. They may insist that students be in the lab on weekends and evenings. "It's fascinating to see how people gravitate to work with one sort of professor or another," says Melissa Franklin, a Harvard professor who studies proton-proton collisions at the Large Hadron Collider. In looking for a good fit, she says, "I ask students, 'What book are you reading now?' You can get a sense of who they are intellectually."

Group dynamics is a key issue, says Yale's Demers. "Graduate school is a challenge, and the relationships among students, postdocs, and myself have to be functional." And, she adds, "I want students who are kind and respectful. I don't want arrogant or overconfident. I want someone who sees doing a PhD as not a waste of time, regardless of what they end up doing."

Whisper networks

For students, talking to other students can be helpful in selecting a research adviser and group. LSU's Malecek says senior graduate students "gave me the inside scoop on their advisers." Karmela Padavić-Callaghan, who recently earned her PhD in condensed-matter theory at UIUC, says she knew when she entered graduate school that she wanted to be a theorist, and she knew the field was male dominated and competitive. "I didn't want to work with someone who would make me feel small if I didn't know things," she says. She chatted with graduate students because "they don't have a reason to lie. They warn you, and if you ignore those warnings, it's not ideal." She

sought out a research group mainly on the basis of topic, but it was also important to find a female adviser "for the shared lived experience."

"I had spoken to graduate students who seemed burned out," says Mariel Pettee, who will graduate next spring from Demers's group at Yale. "I wanted to pick a place where I could be happy as a whole adult."

Sergio Cantu, an American of Mexican heritage, works with Vladan Vuletić, an MIT professor who creates and studies entangled many-body states. He joined Vuletić's lab after spending a year at MIT in a bridge program that helps students from underrepresented groups transition to graduate school. "I shopped around," says Cantu. "But I kept going back to him because he was welcoming. And once I started working in his lab, I noticed he would say things like 'your lab' and 'your experiment.' That gave me ownership and made me feel empowered."

When it doesn't work out

No reliable statistics exist, but several faculty members interviewed for this story estimated that 10–20% of PhD students end up switching groups. The main reasons are that they find a topic they are more excited about, they clash with their adviser, or their adviser runs out of funding. When the switch happens relatively early—say by the end of the second year—it tends to go smoothly, students and faculty members report. Switching later is trickier, and it often adds time to finishing a degree.

*This piece is adapted from an article published in the October 2020 issue of PHYSICS TODAY, <https://doi.org/10.1063/PT.3.4588>. **GSS***



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Brittney Hauke is a materials science and engineering PhD student at Penn State University.

BRITTNEY'S STORY

Navigating the “worst-case scenario” in grad school

As a physics undergraduate, I remember hearing that changing advisers was one of the worst things you could do in graduate school, so picking the right one was the most important part of choosing a program.

There is a lot of great advice out there on questions to ask prospective advisers and their students, but it's difficult to determine if you can work well with someone after, at most, only a handful of interactions. And no one tells you what to do if the worst-case scenario happens: You and your adviser don't get along, or you find yourself in a toxic lab environment for another reason. Luckily for you, I've been there, and I'm here to offer some thoughts and highlight some red flags.

First, some background. I started graduate school (the first time) at Arizona State University in a new field and a completely new research area. I did what all the other students in my group did in their first year and took four classes on top of my lab work. This was the first mistake I made: I would never suggest any graduate student take four classes at once, especially in their first year! In addition to adjusting to a new environment (I moved almost halfway across the country), you're also trying to fit in with a new lab group and navigate a new lab. This, along with classes and the actual lab work, was simply too much for me. My grades suffered, and I was not making sufficient progress in my lab, at least according to my adviser's standards.

Fast-forward about a year, and I was not happy in my lab group. Meetings with my adviser caused severe anxiety, I



Brittney Hauke

struggled to really connect with my lab mates, I was overworking with nothing to show for it, and it felt like I couldn't do anything right. During one meeting my adviser suggested that I not get a PhD. A few months later my funding was pulled due to lack of progress.

Once I realized it was not going to work out between me and my adviser, I had a few options: Ride it out with him and seek mentorship elsewhere, switch to a different adviser in the same department, switch to a different department at the same school, transfer to another school, or “master out”—earn a master's degree and be done.

I chose the last option but considered all of them. I struggled to connect with most of the other professors, which made finding mentorship or another adviser in the department challenging. The one I did connect with wasn't sure he would have funding for me, which was a key issue in all of this. Originally I wanted to transfer to another school, but again funding and timing became an issue. Finally, I didn't have any reason to stay in Arizona. Together, these factors cemented my decision to stay for one more semester and leave with a master's degree.

That was more than two years ago. After leaving the pro-

gram, I decided that if I was going to pursue a PhD again, I wanted it to be in the field I'd enjoyed so much as an undergrad. I am now a PhD student in materials science and engineering at Penn State with an adviser I get along with really well, a supportive lab group, research I enjoy, and a good work/life balance! Graduate school is really hard, but it shouldn't be traumatic.

I thought I knew what questions to ask potential advisers and their students the first time around, but there were some red flags I wish I'd been more aware of. Some of these are subjective, and one or two don't necessarily make or break a department or research group, but take it from me: You might

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Switching Grad Schools & PhD Advisers: A Story of Perseverance, Networking, & Luck
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want to reconsider your options if you see too many of them.

1. Lots of students in the lab group have been there way longer than the program takes on average.

2. The adviser and grad students in the lab don't have a good work/life balance; they work almost all weekends and holidays. (Yes, you will probably have to work occasional weekends, but doing it all the time without taking other days off to compensate is not healthy.)

3. The department puts a heavy emphasis on weeding graduate students out via classes or exams. Lots of programs have qualifying exams of some type, but if the school prides itself on a high percentage of students failing, that could be a toxic environment. On the flip side, some programs offer faculty-led study sessions to help students pass their qualifiers, or the graduate students all help one another prepare.

4. The professors in the department don't seem to talk to one another, collaborate, or even really like one another.

5. Funding is inflexible or not guaranteed. Make sure you get a funding commitment in writing, and ask if there are flexible funding opportunities in case you need coverage for an extra semester or year.

Not all departments and lab groups are equal. Many schools will try to entice you with a "standard blueprint" for what your graduate school experience will be like, but it's important to keep in mind that everyone is different, and things that work for others may not work for you. The worst-case scenario isn't changing advisers or even changing schools; it's staying in a toxic situation that erodes your confidence and well-being. **GSS**



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Patrick J. Mulvey, research manager, and
Anne Marie Porter, survey scientist, Statistical
Research Center, American Institute of Physics

The Employment Landscape for New Physics Degree Recipients

Patrick J. Mulvey and Anne Marie Porter

The career paths of physics degree recipients vary greatly, influenced by personal circumstances, interests, degree(s), and economics. This article explores the initial outcomes of physics degree recipients at the bachelor’s, master’s, and PhD levels. The data come from surveys of physics graduates from the classes of 2017 and 2018 conducted by the Statistical Research Center (SRC) of the American Institute of Physics (AIP). The data were collected from new graduates in the winter following the academic year in which they received their degree.

Physics bachelors

The number of students receiving physics bachelor’s degrees from US institutions has been increasing for more than two decades, reaching almost 9,200 in 2019.

New physics bachelors follow one of two initial post-degree paths: they enter the workforce or enroll in graduate school. For the classes of 2017 and 2018, about half (48%) indicated they were enrolled in a graduate program in the winter following the year they received their degree. Of these, the majority were studying physics or astronomy (figure 1).

The other half (52%) of new physics bachelors were employed in the workforce or seeking employment. They held positions in a variety of economic sectors, with the private sector employing by far the largest proportion (67%). Within the private sector, physics bachelors were most commonly working in engineering (38%) and computer or information systems (26%). About a fifth were working in non-STEM positions, although the majority of these were regularly called on to solve technical problems. Very few respondents (3%) indicated that they were working in physics or astronomy. About a third of the employed physics bachelors indicated they were planning to enroll in a graduate program in the future.

Exiting physics masters

Exiting masters refers to those who earn a master’s degree from a US physics department and leave that department to enter

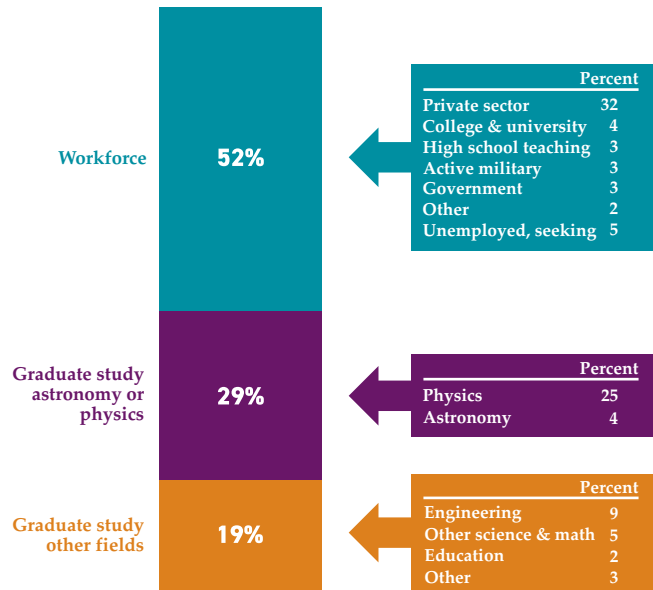


Figure 1. The status of physics bachelor’s recipients one year after degree for the classes of 2017 and 2018 combined. Two percent of respondents indicated they had left the United States to pursue employment or graduate study and are not included in the data. All figures by the American Institute of Physics, Statistical Research Center.

the workforce or pursue another graduate degree elsewhere. Physics departments in the US conferred about 900 physics master’s degrees in 2019.

Survey data for the classes of 2017 and 2018 showed that US citizens exiting with master’s degrees generally tended to follow a post-degree path different from that of non-US citizens (figure 2). The majority of those with US citizenship entered the workforce or remained in positions they held prior to receiving their degrees. The most common outcome for non-US citizens was continuing graduate study at another department or institution.

Regardless of citizenship, the majority of those continuing their graduate studies were enrolled in a physics or astronomy program at another US institution. The most commonly cited “other field” of graduate study was engineering.

Similar to the physics bachelors, more than half (57%) of the employed exiting masters were working in the private sector. The next-largest employment sector was two- and four-year colleges and universities (20%). Eight percent of the physics masters were working as high school teachers, of whom almost all indicated that they were teaching STEM subjects.

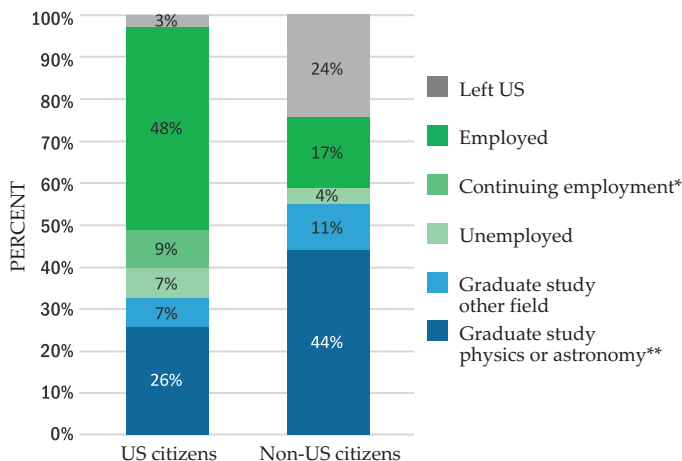


Figure 2. Status of exiting physics master's recipients one year after degree, by citizenship. Data are for the classes of 2016, 2017, and 2018 combined. *Continuing Employment refers to working with the same employer for more than two years; i.e., employment began more than one year prior to earning the master's degree. **Graduate Study-Physics or Astronomy refers to being enrolled at an institution different from the one where the master's degree was obtained.

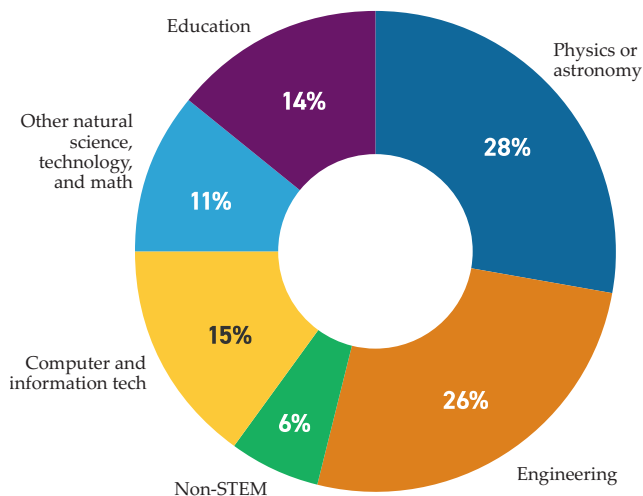


Figure 3. The field of employment for new physics master's recipients one year after degree. Data are from the classes of 2016, 2017, and 2018 combined. The figure includes physics masters employed in the United States, including those who were employed part-time (7%) and those who were continuing in positions they held while pursuing their degrees (16%).

Physics masters secured employment in a diverse set of fields, confirming the notion that physicists have the skills and training to work in many areas of the economy (figure 3). Almost equal proportions of exiting physics masters were employed in the fields of “physics or astronomy” or “engineering,” comprising more than half of those in the workforce. Six percent indicated they were working in a non-STEM field, most commonly finance. Many (12%) of the new physics masters in the workforce hoped to return to graduate school in the future.

Physics doctorates

During the 2018–19 academic year, US physics departments conferred about 1,900 physics PhDs. Although this number was relatively unchanged from the previous year, the total has risen 75% since a recent low in 2004. New physics PhD recipients generally enter a postdoctoral fellowship (postdoc), work

in a potentially permanent position, or accept a non-postdoctoral temporary position (figure 4). For most of the past two decades, the most prevalent employment outcome has been a postdoc, but this is no longer true. In the physics PhD class of 2018, an almost equal portion of PhDs accepted a potentially permanent position.

Again, the results for the classes of 2017 and 2018 reflect differences between US citizens and non-US citizens. A considerably greater proportion of non-US citizens than US citizens accepted postdocs, 51% versus 40%, respectively. The reverse was true for potentially permanent positions, with 47% of the US citizens and 35% of the non-US citizens accepting such a position.

Of those who accepted a potentially permanent position, the majority (74%) were employed in the private sector by companies ranging from the smallest startups to the largest corpo-

A NOTE ON POSTDOCS AND MID-CAREER OUTCOMES

Postdoctoral fellowships are temporary, mentored research positions that provide new PhDs with an opportunity to improve their research skills and publish findings. They are typically two-year positions and are frequently renewable. The majority of postdocs (~75% historically) are in a university setting, with most of the remainder at government labs. Although these positions provide valuable experience and are almost a prerequisite for PhDs seeking an academic position, they are not a necessary step for many career paths.

The data in this article address initial post-degree outcomes. Most people change jobs over the course of their careers—some many times. A resource from the National Science Foundation using data from its Doctorate Recipients Survey provides information on the proportion of mid-career physicists working in different employment sectors. In 2013, about half of physics PhDs who had earned their degree 10–14 years earlier were working in the private sector (51%), with fewer working in academia (43%) or government (6%).¹

Reference

1. National Science Board, “Science, engineering, and health doctorates in the workforce, 1993–2013,” www.nsf.gov/nsb/sei/infographic2/#main (accessed January 2021).

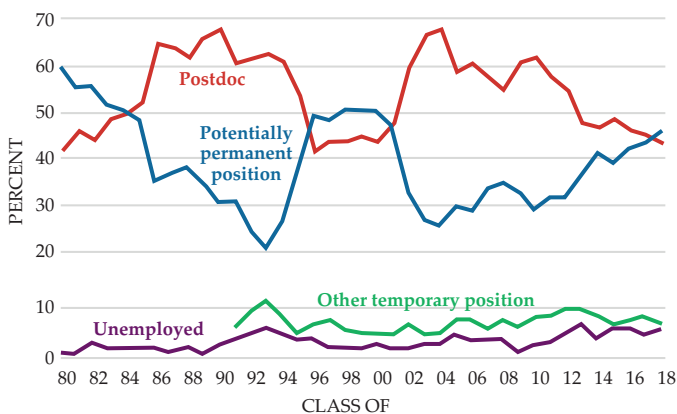


Figure 4. The initial employment of physics PhD recipients over the years 1980 to 2018. The data include only PhDs who earned their degrees from a US university and remained in the United States.

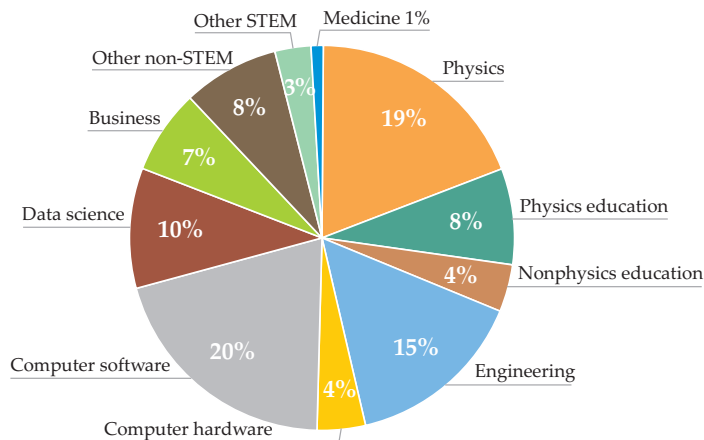


Figure 5. The field of employment for physics PhD recipients in potentially permanent positions. Data are from the classes of 2017 and 2018 combined.

rations. Those in potentially permanent positions were working in a variety of fields, with physics, computer software, engineering, and data science accounting for two-thirds of the employment fields (figure 5).

Less than 10% of the positions held by new PhDs were in non-postdoctoral temporary positions. These were primarily in academia (70%) and came with titles of visiting professor, guest lecturer, or research scientist.

What does the future hold?

While the graduates of 2017 and 2018 entered a strong and growing economy, the economic realities of today are somewhat different. Recessions in the US are nothing new and typically occur at least every 10 years or so. Data show that new

degree recipients who enter the workforce during a recession, regardless of degree field or degree level, encounter a challenging job market.

Regardless of when the economy recovers, there are some things we know are true now and will be in the future. Private sector employers will need to fill positions, government research labs will continue to need staff, and schools and universities will continue to hire faculty. Physics degree recipients are adept at learning and problem solving and have strong mathematical and analytical skills, making them attractive to a variety of employers even in the midst of a recession.

*This article was originally published in the spring 2021 issue of Radiations, www.sigmapisigma.org/sigmapisigma/radiations. **GSS***

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Katherine Zaunbrecher is a teacher-adviser at Compass Community Collaborative School.

KATHERINE'S STORY

Physics lessons for life

No one said it would be easy. In fact, people kept telling me that getting a physics degree would be very difficult. That's why I chose it for my major. I wanted to prove to them—and to myself—that I could succeed in my studies. And I did.

Since graduating with my bachelor's degree in physics, I have moved across the United States, completed graduate school, worked at a national laboratory, and given talks around the country and the world. Now I'm teaching physics, mathematics, and so much more to middle and high school students who make my often challenging work very rewarding. And that's just the career-related side. I am not quite sure what my future endeavors will be, but I know that whatever is in store for me, I am well equipped to handle any challenge, thanks to my education.

Studying physics provides much more than the opportunity to obtain a wide variety of jobs or earn a higher degree. It allows you to develop tools that will be useful throughout life, both in your career and otherwise. These tools are not merely intellectual and academic. Thanks to the late nights spent working on problem sets and trying to understand concepts that might one day seem simple, I was taught perseverance, how to effectively communicate and work with others, and how to be comfortable with not always knowing the answer. Going through a rigorous academic program that emphasized strengthening one's critical thinking skills gave me the ability to readily face challenges. It also developed my intellect and confidence to tackle difficult problems.

Another important—and not-so-obvious—tool that comes with a degree in physics is the ability to manage transitions well. Even though the future often felt very uncertain for me as I began looking into graduate schools and, later, jobs, studying physics helped prepare me for many of the major and minor life changes that followed. Although I knew that I was not at the top of my class and would most likely not be producing groundbreaking research in my field, I had the confidence to believe that I could succeed at anything I wanted to pursue. That meant being able to handle the stress of graduate school on my own, admitting when I could not handle it, and asking for help when I needed



Katherine Zaunbrecher

It also meant embracing the uncertainty I felt after completing my PhD as I transitioned into a research position. Additionally, it helped ease my mind when, almost three years into that job, I decided that a long-term career in academia or research was not for me. The time I had between research and a new teaching job gave me room to reflect and mentally prepare myself for what I knew would probably be the biggest transition I had yet to make.

Teaching physics and mathematics has been a joy. It is stressful and difficult at times, but the challenges are different from those I encountered as a researcher. Yet, I was more than prepared. Being solid in my content, which is more than many other high school physics and math teachers can say,¹ has meant that I can focus more time and energy on developing other skills that are useful to managing a classroom, building curricula, and motivating and engaging students. While I still struggle with the occasional onset of imposter syndrome—even the best of us do—I have been well equipped with the tools necessary to succeed. I owe many of my successes, as well as my desire and willingness to try different things, to my education and training as a physicist. I hope that you, too, are able to recognize the many wonderful opportunities that being a physicist gives you.

NOTES

Less than half of high school physics teachers in the United States have a major or minor in physics or physics education, according to the most recent analysis. For details, see S. White and J. Tyler, "Who teaches high school physics?" AIP Statistical Research Center, December 2014, www.aip.org/sites/default/files/statistics/highschool/hs-whoteaches-13.pdf.

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