the SPS Observer

Volume LVII, Issue 2

FALL 2023

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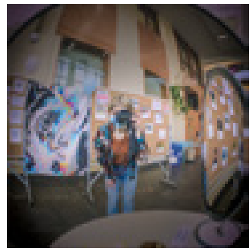
DEPARTMENTS

The American Institute of Physics is a federation of scientific societies in the physical sciences, representing scientists, engineers, educators, and students. AIP offers authoritative information, services, and expertise in physics education and student programs, science communication, government relations, career services, statistical research in physics employment and education, and history of the physical sciences. AIP publishes *Physics Today*, the most closely followed magazine of the physical sciences community, and is also home to the Society of Physics Students and the Niels Bohr Library & Archives. AIP owns AIP Publishing LLC, a scholarly publisher in the physical and related sciences. For details visit www.aip.org.



ON THE COVER
In spring of 2022, the University of the Sciences SPS chapter hosted an exhibit-style event called Trickery of the Eye: The Physics of Optical Illusions. More than 100 attendees explored the many demonstrations, games, and optical illusions. Here, SPS chapter president Nell Grabowski demonstrates the distortion of light by a convex lens. Photo by Grabowski.

GradSchoolShopper
This issue was produced in partnership with GradSchoolShopper.com.

As You Look Ahead, Embrace Your Love of Learning

LEFT: At the 2022 Physics Congress festival, Earl and Marguerite Blodgett (center)—dressed as Pierre and Marie Currie—pose with students. Photo by SPS.

by Earl Blodgett, Historian, SPS and Sigma Pi Sigma Executive Council and Physics Professor Emeritus, University of Wisconsin - River Falls

You have finally settled on your major and are happily working on all those fun classes. Everything seems under control. But then your advisor ruins it by asking, "So, what are you planning on doing after graduation?" You aren't looking much farther ahead than your next semester break! Or perhaps you are a planner, and you've laid out every course you will take until graduation—but what's after that? Graduate school? A job?

Wherever you are on the "planner spectrum," this issue will be a useful resource for exploring and taking your next steps. The SPS community is great at sharing experiences and tips from diverse perspectives; you are sure to find something that will speak to you. You will hear from near-peers, recent graduate school alums, and grizzled veterans. I'm one of the grizzled veterans, with 35 years of experience mentoring undergraduate students.

When discussing whether to attend graduate school, I advise my students not to go simply because they expect to earn more money with a higher degree. That can be true, but you can also make good money with an undergraduate degree. I've had many students whose salaries topped mine within a few years of earning their undergraduate degree in physics or astronomy. A good long-range plan is to find a job you greatly enjoy while making enough money to support your other goals in life.

If you aren't doing it for the money, then why spend several more years in school to earn an advanced degree? Do it only if you find it fascinating. Do it because you love learning everything you can about a subject. Do it because you can't imagine doing anything else. Then find a program that feels right to you, where you will be supported and encouraged.

If those reasons don't resonate with you, don't default to graduate school. There are so many opportunities out there for creative problem solvers, critical thinkers, and logical reasoners who understand data and work from basic principles. Identify what excites you and what you love to learn, then explore your options.

Whatever you decide to do, find a balance between flexibility and dogged determination. As an undergraduate studying physics or astronomy, you know the value of determination. But don't let yourself get stuck in a situation that prevents you from being happy while you pursue your goals.

One of my former students decided to go to graduate school in physics because he enjoyed his upper-level physics courses, had good grades, and wasn't ready to jump into a job. He got into a prominent program, did fine in the courses, and enjoyed being a teaching assistant. However, he was not enjoying the experience. Wisely, after one year of physics graduate study he took a gap year. Not a hiking around the world gap year, not a laying on the beach gap year, and not even a working in a random job gap year. He intentionally explored other options while working part time.

His exploration included studying Latin at the University of Minnesota, and in the process, he discovered medieval literature. He found a graduate program in the field, learned Old Norse so that he could read original manuscripts of *Beowulf*, and absolutely loved it! He wound up with a PhD in medieval literature and embarked on a career that gives him the personal satisfaction he didn't find in physics. Don't be afraid to change your plans! Be flexible! The skills you learn as a physics or astronomy major will serve you well in a variety of pursuits and careers.

One of the plenary speakers at the 2012 Physics Congress was Freeman Dyson, a famously creative, respected, and iconoclastic figure in physics for decades. He accomplished much in his long and varied physics career, despite never getting around to finishing his doctorate degree. As he put it, interesting opportunities kept presenting themselves, and he never saw the need to go back for a piece of paper. He told the crowd of students that planning is overrated, because you may be reluctant to seize an unexpected opportunity.

Dyson had a flair for drama and a lifelong commitment to being contrary, but he made a good point. You do need to be flexible—don't stick with a plan solely because you are stubborn. If you start a graduate program or job that you don't enjoy, *you can change course*! Explore! Continue learning and growing your entire life, regardless of whether you get a degree or a fat paycheck. If you choose to pursue an advanced degree, do so because it's an enjoyable and fulfilling way to facilitate your love of learning. Then all the hard work that goes with it will be worth the effort.

You can continue that learning right now by reading this issue. Enjoy! //

From Curious Kid to Medical Physicist and Educator

Q&A with Julianne Pollard-Larkin, plenary speaker at the 2022 Physics Congress

Interview by Addison Hild, Alex Pantoja, and Caleb Robinson, SPS Reporters, Texas Lutheran University

Julianne Pollard-Larkin is the physics section chief of thoracic service in the Department of Radiation Physics – Patient Care, Division of Radiation Oncology, at The University of Texas MD Anderson Cancer Center.

What got you into physics?

Remember the first questions you asked as a little kid? "Why?" Those are the questions I had in my formative years, just like all of us human beings. I grew up in a family full of educators. When I would ask a question, my dad would say, "Julie, you want to know why? Look at that Britannica, figure it out, and tell me what you read." Then he'd go to work. My parents fed my curiosity. They helped me expand my world. I give all credit to my parents for my staying with science.

Did you join any organizations while you were in college?

I joined the same one that you are in—yes to the SPS! I went to college at the University of Miami in Coral Gables, Florida. When it came to SPS, there was no one who really wanted to lead the chapter. So here comes Julie . . . I'm already standing out because, first of all, I'm a girl. When you're in university classes with hundreds of people and you're one of maybe 10 girls, you feel that pressure. To be chocolate [Black] on top of that . . . Going through that crucible at that young age, I figured why not get connected and join SPS? Then, when nobody wanted to lead the meetings, why not help run the chapter?

I was happier than the traditional physics student. SPS got me connected. That experience gave me my first taste of leadership. SPS was my avenue, and I am so grateful for what I got when I was at your stage in life.

What or who inspired you to join the field of medical physics?

In 2000, while doing a summer internship, I got the call that nobody wants. My mom was diagnosed

ABOVE: Julianne Pollard-Larkin inspires the Physics Congress crowd. Photo by SPS.

ABOVE RIGHT: Texas Lutheran University SPS reporters pose with Julianne Pollard-Larkin (center) and SPS council member Sylphrena Kleinsasser (left) at PhysCon. Photo courtesy of the SPS reporters.

with breast cancer. I finished everything and went back home. I was there for her first surgery and her radiation therapy treatment. Before that, I had no clue what radiation therapy meant.

At her first radiation appointment, people were explaining the treatment and showing my mom the vault where patients are treated, the linear accelerator, and everything else in the room. Then lo and behold, a man in a white lab coat comes out from behind a wall that shields people from the linear accelerator. He had been playing with something in the back—maybe some wiring—and checking numbers on a screen. He sees us and says, "Oh, don't worry, I'm going to get out before the treatment. I'm just a physicist, I'm not going to get in the way."

As a physics major, I turn to my mom and say, "Mom, why is there a physicist in your wall?"

He answers, "I help with your mom's treatment." When I ask how and he finds out I'm a physics major, he says, "This is a linear accelerator, right? Don't you need one for quality assurance and everything? Haven't you heard of AAPM?"

I now know that AAPM is the American Association of Physicists in Medicine. But as an undergrad, I hadn't heard of it. None of my professors were in medical physics or talked about the field, if they even knew about it.

After that interaction, my real research began—understanding who and what my purpose was, as a scientist. I eventually identified that this is where my heart is.

What is your day-to-day job like?

I'm the manager of a physics team in the hospital. I'm at work before everybody else, getting everything set up for scheduling. I make sure there are no issues, all the machines are running, and nobody's sending desperate pages asking for assistance. Patients usually come in around 6:50 or 7:00 am. And then it's all patient care and dealing with high-dose, short fractionation treatments where an error or accident could be deadly—I'm here to make sure that doesn't happen. I do a lot of troubleshooting. That's my job until about noon.

The afternoon is my academic time. I meet with graduate students, MD residents, physics residents, and others who I'm teaching or are related to my committee work for professional organizations. I also work on my research goals during that time.

What are the most rewarding parts of your job?

I love meeting people, encouraging them to go into the field, and nurturing their talents and gifts. Coming from a space where nobody really encouraged me to study physics, I decided to be a nurturing educator. I want to encourage the best in everybody, indiscriminately.

I have spent my time opening doors, making bridges, and not burning them once I get across. I can't leave behind an obstacle just because I got over it: I want to make sure you don't have that same one. I will take all the licks so that you can come out brilliant and amazing, because the world needs our talent, and I want to make sure it's better for you. And I truly love and appreciate the interactions I have with patients.

What has been the hardest part of your career?

As a scientist, you always have the pull to do research. I do primarily clinical work. I have a passion for flash radiotherapy research, but at the end of the day, I don't have time to go at it hard. That's a difficult thing to navigate, but I'm much better person-to-person than I am in the lab.

How has the representation of minorities in the field changed since you entered physics, and how can we do better in the future?

I am excited about where our field is compared to when I started. There was a lack of awareness and internet then. We didn't have pictures showing what people in the field really looked like—when I wanted to see representation, I would look in the mirror. With social media, physics students can see that representation now.

There's a way of finding your niche, finding your community within physics and every organization. And if it doesn't exist, make it. We have agency, we have voices, we deserve to be here, and we're being recognized. There are wonderful, powerful stories happening in every single city. //

This interview has been edited for length and clarity.

LEARN MORE ABOUT MEDICAL PHYSICS

- American Association of Physicists in Medicine (AAPM): aapm.org
- AAPM's public education site: medicalradiationinfo.org
- GradSchoolShopper's Pathways to Medical Physics: gradschoolshopper.com/pathways-to-medical-physics.html

Members of SPS are eligible for free membership in AAPM, for details see spsnational.org/about/membership.

The Fundial: A Sundial for Live Streaming

by Jeffrey Creager, Jeffrey Korbitz, Kierra Pendill, and Jordan Werner, SPS and American Chemical Society (ACS) Club Members, Benedictine University

Many of us have heard the warning, "Let's not reinvent the wheel here." This saying implies that recreating objects or techniques that were developed in the past is foolish. But that conclusion could not be further from the truth—especially when, rather than the wheel, it's the sundial that's being reinvented.

Sundials are a significant and ancient technology. Using the motion of earth relative to the sun, they produce shadows that can be used to measure time. The earliest known sundial dates back to approximately 1500 BCE in ancient Egypt.[1] The Greeks and Romans improved their precision, while ancient Babylonian, Chinese, and Mayan civilizations developed similar solar timekeeping technologies. The sundial was critical to many cultures, as it was one of the earliest clocks and the first to be powered by nothing more than the sun and mathematics.

At Benedictine University, we are in the process of building a sundial on campus to serve the same purposes as historical sundials—to keep time and be a gathering place. We will also do outreach with our sundial, sharing the fascinating physics and mathematics governing it with the community. Finally, thanks to modern technology, we'll live stream the sundial so that we can reach out to a global audience.

Elements of a sundial

At its core, a sundial consists of a gnomon—the thing that casts a shadow, the base upon which the shadow is cast, and markers that correlate the shadow's position to time. If you know the latitude and longitude of your location and utilize the equation of time for the current season and month, you can accurately read a sundial.[2]

Sundials force us to reconnect with nature, with the rising and setting of the sun. They remind us that the sun gets higher and lower in the sky throughout the year and that the sunlit day varies in length.

Building our sundial

The first step to any construction project is choosing a good location. We decided to build the Benedictine University "Fundial" in the center of campus for all members of the Benedictine community to see. It will be surrounded by our community gardens, baseball field, and art building.

We started by identifying a central point and outlining a circle 2 meters in diameter around that point. Then, working as a chapter, we excavated the top 6 inches of the circle. We poured a layer of sand on top of the soil to create a smooth base and placed a hand-welded metal ring around the circumference. After adding rebar to make the base more durable, we poured concrete into the circle.

We then attached a steel gnomon to the center of the sundial and used a compass to align markers for the local meridian line. Next, we added numbers to show the hours. And finally, we purchased a solar-powered camera with Bluetooth connectivity and set up a live stream of the sundial. If all goes as planned, we'll be ready to stream the sundial in late 2023. Keep an eye on benedictinesundial.com.

We're looking forward to seeing this project come to life. We hope the Fundial will serve as a gathering place for members of the Benedictine community and help us reconnect with nature and the motions of the planets, especially our own. And we hope that people on campus and around the world will enjoy seeing our sundial and learning the science behind this timepiece via our live stream.

LEFT: SPS members break ground for the Fundial.

ABOVE: SPS members mark the future location of the Benedictine Fundial with a prototype. Photos courtesy of the chapter.

Our club has already learned a lot about the sun and how to predict its motion during the day and throughout the year—and about basic construction! The project has inspired us to study the mathematics of the earth's motion and why we see shadows of particular lengths at particular times. We're excited to be merging this ancient device with modern technology by making the sundial visible to anyone, anywhere. //

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1. "Short History of Sundials," European Association for Astronomy Education, eaae-astronomy.org/projects/find-a-sundial/short-history-of-sundials.
2. J. Vincent, "The Mathematics of Sundials," *Australian Senior Mathematics Journal* 22, no. 1 (2008).

GET MONEY FOR CHAPTER RESEARCH PROJECTS

SPS Chapter Research Awards provide up to $2,000 for physics and astronomy research projects deemed imaginative and likely to contribute to the strengthening of the SPS program, like the Fundial. Applications are due November 15. Learn more at spsnational.org/awards/chapter-research.

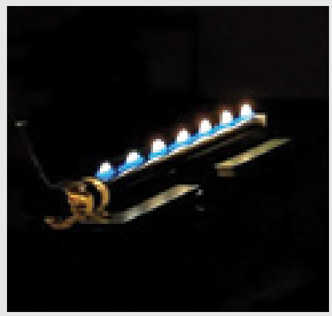
Spring Brings Doves, Dandelions, and Demos

by Andrew Ybarra, SPS Chapter Secretary, University of New Mexico

Spring is back! And with it comes a wonderful influx of warm weather. The birds are singing and the flowers are blooming. But those aren't the only signs of spring. For those of us in the SPS chapter at the University of New Mexico (UNM), spring means demos. Once again, this spring we held a physics demo show on campus to share our favorite subject with others.

We hold demo shows twice a year to show UNM students and our local community the wonders of physics. The topics range from Newtonian mechanics to superconductivity, anything covered in our introductory sequence of physics classes. This spring our demos included a Tesla coil, human gyroscope, Rubens tube, rocket car, and a giant Newton's cradle, among many others. And, like always, we finished with a bang—generated by an imploding barrel!

Audiences love our shows, but they're not the only ones. Participating SPS members are always grinning ear to ear after this fun evening. "It was a great production," says Ethan Sloan, SPS chapter president, when reflecting on our recent show. "We had a lot of fun! I'm looking forward to future performances." //



LEFT: SPS presenters illustrate classical mechanics using a rocket car.

RIGHT: A Rubens tube steals the show. Photos courtesy of the chapter.

GET MONEY FOR CHAPTER OUTREACH EVENTS

Marsh White Awards of up to $500 are available for chapter programs or events that promote an interest in physics or astronomy among students or the general public. Applications are due November 15. Learn more at spsnational.org/awards/marsh-white.

Future Faces of Physics Awards of up to $500 are available for chapter programs or events that promote physics and astronomy across cultures. Applications are due November 15. Learn more at spsnational.org/awards/future-faces.

Don't Leaf Me Hanging![1]

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma

If you leaf near a forest or in a relatively wet climate, you know how big a task it can be to rake up all the leaves that fall in people's yards each fall. Well, not all the leaves, as it's good to leave some leaves around, but most people rake up most leaves each season.[2] We're so excited to see the leaves change color each year—and so much less excited to clean them up. As I spent the last 20 hours raking the leaves of only seven trees, it got me thinking about a new Fermi question…

FERMI QUESTION:

If I raked up all the leaves on earth, would I have a literal mountain of leaves?

The physics of how materials like leaves make piles or stacks is extremely complicated—more mathematically complicated than Introductory Quantum Mechanics (as I've taught that class for many years, I can make a pretty solid claim). As "proof" I'll reference XKCD comic #1867 in Fig. 1.

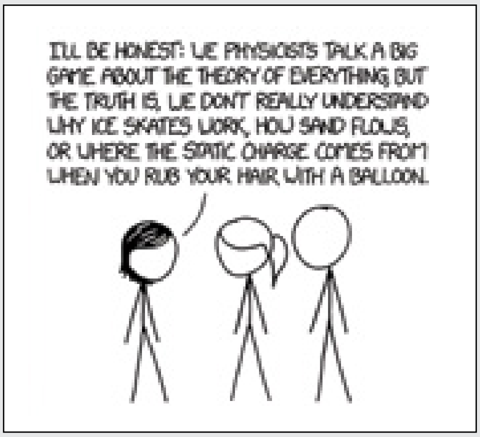


Figure 1. The flow (and stacking) of granular materials such as sand, leaves, and even food is significantly different from that of a liquid and a solid, but the flow is not exactly known. Credit: XKCD, xkcd.com/1867.

To solve most Fermi problems like this, we first need to reframe it in terms of questions we can try to answer. It's even better if we can break it down into smaller problems. There are, as always, lots of ways to try to get a handle on this question, but here's how I went about it.

Break it up!

I propose we break this problem down into three separate questions:

1. How many trees are there?
2. How many leaves are created by these trees that need to be raked?
3. How big of a pile can we make with that many leaves?

How many trees?

The world is a really big place. I remember how big it is from a favorite professor of mine: Within a small margin of error, the

$$r_{EARTH} \approx 2\pi \cdot 1000\,\mathrm{km}$$
$$A_{SPHERE} = 4\pi \cdot r_{EARTH}^2$$
$$\%\,\mathrm{LAND} \sim 33\%$$
$$A_{TREE} \sim (10\,\mathrm{m})^2 = 100\,\mathrm{m}^2$$
$$\#\mathrm{TREES} = \frac{A_{SPHERE} \cdot \%\,\mathrm{LAND}}{A_{TREE}} = \frac{4\pi r_{EARTH}^2 \cdot 1/3}{100\,\mathrm{m}^2} \cong 5 \times 10^{11}\ \mathrm{TREES}$$

Figure 2. A calculation of the number of trees on earth using order-of-magnitude estimates. This calculation gives an area for earth of about 5 x 10^{14} m^2. Assuming the earth is one-third land, the land is one-third trees by area, and each tree has a canopy area of 100 m^2, we arrive at 5 x 10^{11} trees.

$$\#_{TREES} \sim 5 \times 10^{11}$$
$$1\ \text{TREE} \rightarrow 10\ \text{Bags}$$
$$V_{BAG} \sim 1\text{m} \cdot 0.5\text{m} \cdot 0.5\text{m} \sim 0.25\text{m}^3$$

$$V_{TOTAL} = \#_{TREES} \cdot 10\ \text{Bag}/\text{TREE} \cdot 0.25\ \text{m}^3/\text{Bag} = 5 \times 10^{11} \cdot 10 \cdot 0.25\ \text{m}^3 \sim 1 \times 10^{12}\ \text{m}^3 \text{ of LEAVES}$$

Figure 3. A calculation of the volume of leaves 5 x 10^{11} trees produce. Luckily, the leaves are compacted pretty heavily in the bags, so that helps to make it more accurate. We are left with about 1 x 10^{12} m^3 bags. That is a HUGE amount!

radius of the earth is 2π–4000 km, or about 6,400 km. We know that the earth is about two-thirds water, so let's pick one-third. It's a guess, but it's probably not that far off—that's a key method of solving Fermi problems. If you're within a factor of 2 or 3, you are doing well. Let's also estimate that each tree has a footprint of 100 m^2. That leaves us with (I'm trying to make as many leaf puns as possible in this article) Fig. 2.

How many leaves?

I'll be honest. I first tried to guess how many leaves were on an average tree, but it got pretty complicated. (I later found an article from *The Physics Teacher* that has a pretty neat way of estimating it.[3]) Complicated can be fun, but let's not for this one. Instead, let's think about this: If all the leaves from a tall tree fell, how many big bags would I need? Remembering my 20-hour comment for only seven trees, it's definitely more than one bag and less than 100. I'd say it's much closer to 10 bags. Each bag is about 1 m tall, 0.5 m wide, and 0.5 m deep, or 0.25 m^3 in volume. So, putting all those numbers together brings us to Fig. 3.

How big a pile?

Since we are piling together so many bags of leaves, I'm going to guess they will stack as a 45° cone. I don't have a good sense for whether this is right, but I think it would be at least 30° and less than 60°. From high school geometry, remember that the volume V of a right circular cone is $V=(h\pi r^2)/3$. Solving for the height leads us to Fig. 4.

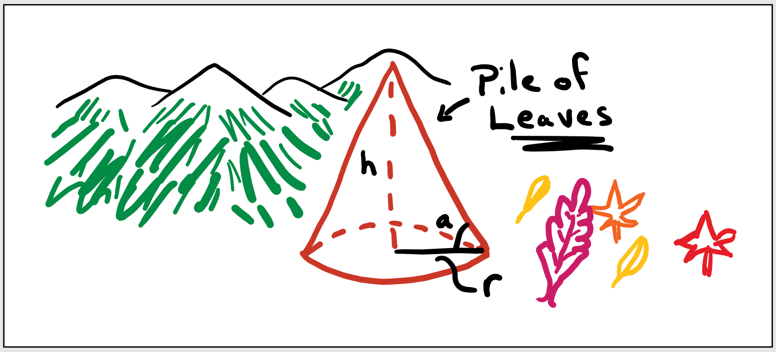


Figure 4. A pile of leaf bags with height h, base r, and angle a. For this problem we are assuming h and r are the same. Unless otherwise noted, all images by Conrad.

Solving for the h, we get a height of about ~11,000 m. For comparison, Mount Everest is 8,848 m tall. We should expect a whole lot of compression, as the weight of that many leaves will be immense, but even if it compresses by a factor of 4, it's still a very tall mountain. So, the answer is yes. If I took all the leaves, I'd be able to make a literal mountain.

But... there is always one more problem to solve. I *leaf* you with this (I got one more pun in).

CHALLENGE FERMI QUESTION:

If I jumped from a plane and landed on the pile, would the mountain (or hill) of leaves save me? //

References

1. For some reason, my original wording of the title, "How Many Leaves Fall in Fall?" didn't quite *leaf* the right impression.
2. Brooke Franklin, "This Fall, Leave the Leaves!," US Department of Agriculture (blog), October 17, 2022, usda.gov/media/blog/2022/10/17/fall-leave-leaves.
3. Larry Weinstein, "Solutions for Fermi Questions," *Phys. Teach*. 56 (October 2018): A489–A489, doi:10.1119/1.5055310.

Amanda Williams Eiting

BS in Physics, Weber State University

What she does

I am a ninth-grade physics teacher at a Utah charter school in the Salt Lake City area. Working at a charter school, I get to have some freedom with the curriculum, and we have an ecosystem that encourages experiential learning for all our students. We include lots of labs and field trips to get them excited about science, making every day different from the next. I am also working on earning my teaching certificate through a three-year program.

How she got there

I haven't always been a math or science-y person, and in middle school I really did not see myself studying either subject later in life. But everything changed when my high school physics teacher showed me that math can be useful by applying it through physics. After that, I decided to pursue my love of physics at Weber State University (WSU) in Utah as a first-generation college student. The WSU physics and astronomy department was so awesome! I felt very supported, and that made me feel like I could succeed.

I knew I had found my niche when my mentor at WSU helped get me involved in outreach, teaching, and mentoring on campus. I was able to further develop my science communication and outreach skills by working as a Science Outreach Catalyst Kit (SOCK) intern in the SPS Summer Internship Program. After graduation, I worked in multiple science outreach–based positions at places like AstroCamp in California and the Boys & Girls Club of Greater Salt Lake. When this teaching position opened up, my outreach mentor from WSU helped me get a foot in the door!

Most challenging part of her job

The most challenging part of my job is making sure that I do not let "perfect" be the enemy of "good." Working with young people is rewarding, and also demanding! I've put a lot of pressure on myself because I want to do right by every student. It can be overwhelming. I'm learning patience really is a virtue. Good teaching is a craft, and takes time. With any new career, you have to give yourself grace.

It's good to take a step back and realize that good really is enough. There is always going to be more to do, but you need to find a sustainable process that works for you. Setting an unrealistic pace and getting burnt out isn't good for you, your friends and family, or the students you're trying to teach.

Her advice to physics and astronomy students

Doing science in college is hard, especially if you're coming in as a first-generation college student like I did. I didn't have it all together, but I built an amazing support system for myself. Support is really the key to my success—and hard work. If you look for ways to collaborate productively with your classmates and learn from them, as well as your professors, you will start building a network of support. Those people will have your back and vice versa. Not only is school more enjoyable this way, but those connections will certainly pay off for you in the long run. //

ABOVE: Amanda Williams Eiting.

INTERESTED IN TEACHING PHYSICS?

Check out the American Association of Physics Teachers (AAPT) at aapt.org. Members of SPS are eligible for free membership in AAPT. For details visit spsnational.org/about/membership/free-ms-membership.

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Science Outreach Catalyst Kits (SOCKs) are free science outreach kits designed for SPS chapters. New SOCKs are created each summer by SPS interns. Request a SOCK for your chapter at spsnational.org/programs/outreach/science-outreach-catalyst-kits.

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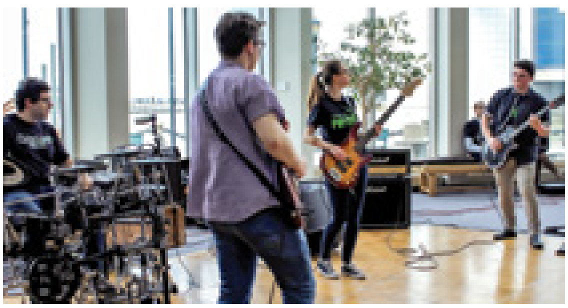
SPECIAL FEATURE

Top 5 Reasons to Get Involved in SPS

by Samantha Tietjen, SPS Alum and Barn Manager and Instructor, Lilac Thyme Stables

I'm a bit of a poster child for SPS—I was chapter president for a few years, published multiple articles in the *SPS Observer* and *Radiations*, and received SPS Travel Awards and an SPS Leadership Scholarship—but when I started college I had no idea that the organization existed. Thankfully, on a whim, I attended a meeting of my local chapter at Cleveland State University. Being involved in SPS was hugely beneficial for me, both personally and professionally.

Here are my top five reasons why YOU should get involved in your local SPS chapter. If you're not already an SPS member, you can learn more about SPS and join at spsnational.org, or reach out to the chapter or department chair at your school. If you're a member but haven't jumped all the way in yet, give it a try. I suspect you'll never look back.



1. COMMUNITY

Cleveland State is a large school with a tiny physics department. Physics majors take mostly prerequisites and general education courses in their first year, and almost every STEM major takes introductory physics. Because of this, I didn't meet another physics major until my fourth semester! And that was only because we asked our teaching assistant about the upcoming SPS meeting at the same time.

That meeting was my first peek into any sort of community within the major that I'd been committed to for nearly two years already. It was a turning point. I'd finally met the people I'd sit next to in class for the next two years.

As we progressed into advanced classes, these friends became an essential support system. We studied, hung out, and trudged on toward graduation together. That first meeting helped me establish a local support system that only spread out as we moved on to graduate school and employment. This is no doubt my strongest network, even today.

While SPS has "physics" in its name, its doors—and its community—are open to all students interested in physics or astronomy.

TOP: Samantha Tietjen (far right) leads a demo during an outreach event. Photos courtesy of Tietjen.

LEFT: Samantha Tietjen (second from right) jams with fellow SPS members at Cleveland State's Physics of Rock and Roll event, hosted by the Great Lakes Science Center.

2. SELF-DISCOVERY

SPS is a society for and led by students. While each chapter has a faculty or staff advisor, most of the leadership is in the hands of students. This presents many opportunities for growth. I went from being a behind-the-scenes person to taking on several SPS officer roles in my chapter—including chapter president.

For multiple years I led our chapter's outreach team, and I had an amazing time learning to teach children from many different backgrounds and age groups. I wasn't planning to teach, but here I am, working as an equestrian riding instructor, relying on my outreach experience and understanding of mechanics to teach people the safest and most physically stable way to ride.

SPS gave me a forgiving space to explore my leadership and teaching skills and test my independence. Through outreach, trips to conferences, and running programs with many moving parts, I learned so much about myself from being part of SPS.

3. NETWORKING

As someone who left high school a little bit socially awkward and a lot bit anxious, SPS helped me realize that what seemed like one of the most intimidating parts of professional development—networking—was far simpler than I'd imagined.

Networking is about making meaningful connections. You can network with peers by simply talking to them during SPS chapter meetings and working alongside them during outreach events or other chapter activities. Attending a local conference and making friends from a different school is another step. By the time you hit a national conference, where you're swimming through a world of professionals, networking often looks like socializing between sessions or at meals.

Through professional development opportunities, internships, the Careers Toolbox, chapter gatherings, and regional meetings, SPS teaches students how to network and provides opportunities for applying that skill in a friendly environment.

THE CAREERS TOOLBOX

Learn networking and other professional skills with the Careers Toolbox, designed especially for physics and astronomy undergraduates. Go to spsnational.org/sites/all/careerstoolbox.

GET FUNDING FOR CONFERENCE TRAVEL

Applications for SPS Travel Awards and Reporter Awards are accepted on a rolling basis. Learn more at .

4. TRAVEL

SPS encourages undergraduates to attend conferences and offers $300 in travel assistance to students presenting their research at or reporting on one of many physics and astronomy conferences. SPS Travel Awards helped me fund trips to four national meetings in four great cities—San Francisco, Los Angeles, Boston, and Providence.

My first conference was the 2016 Physics Congress held in San Francisco, California. I went as an SPS reporter, which means that SPS helped fund my travel and I wrote an article about my experience for SPS to share. That conference set a fire under me to pursue research and present my own work at future meetings, which I did!

Conferences are a great introduction to research, new fields of study, and the professional science community. They provide excellent networking and résumé-building opportunities, and usually time to explore the local area.

5. PERSPECTIVE

Many students enter physics and astronomy programs thinking they already know the research and career they want to pursue, but that often changes wildly as they learn more. SPS introduced me to areas of science and applications of physics that I didn't even know existed, through conferences, talks at SPS chapter meetings, and articles in the SPS Observer.

I walked into Cleveland State planning to be an astrophysicist, did research in lasers and imaging, and left wanting to be an art conservationist. A visit to the Woods Hole Oceanographic Institute had me briefly flirting with oceanography and climate science. After touring CalTech during an American Physical Society March Meeting, I had visions of working in particle physics.

There is so much out there beyond what your campus offers, and SPS is a great way to learn about your options. Its resources can be a game changer for physics and astronomy students! //

ABOUT THE AUTHOR

Samantha Tietjen graduated from Cleveland State University in Ohio with a bachelor's degree in physics, minors in biology and mathematics, and a master's degree in physics. For being so active in her local SPS chapter, she was inducted into Sigma Pi Sigma, the physics and astronomy honor society, postgraduation.

The Grad School Issue: Start Here

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma

Thinking about what comes after your bachelor's degree can be a lot. *Like, a lot*. Graduate school is a common next step and might be an ideal step toward launching your dream career or even saving the world. Then again, it might not be. Going right into the workforce is a common next step too, and might launch you into your world-saving, dream career. Physics and astronomy set the stage for so many exciting career paths. But exploring the breadth of options and deciding whether to go to grad school can feel overwhelming.

Should I go to grad school? For what? Where? How?

This issue of the *SPS Observer*, created in collaboration with GradSchoolShopper.com, will help you select some boundary conditions and turn these questions into solvable problems that optimize your needs and future career goals. You'll learn about many of the career pathways that open up to students like you through grad programs. You'll read about who pays for grad school and the wide variety of program options. You'll find out what admissions committees look for in applicants and how to demonstrate those qualities in your application package. And you'll get excellent advice on how to find programs that are a good fit for you.

One of the best ways to learn about your options is to hear from those who've been in your shoes. You'll find many such stories in this issue, from Div Chamria's application advice (p. 55) to Paul McKinley's reflection on doing an energy technology engineering grad program abroad (p. 47). One of the stories in this issue may be the spark that helps you envision your future.

If you decide to go to grad school, know that there isn't just one "right" program for you—there are probably dozens that could help you reach your career goals. As a physics or astronomy major, the most important skill you learn is how to solve problems without a known solution. This allows you to work in diverse teams, conquer unknown technical problems, and use first principles to simplify complex problems. Physicists and astronomers plug into a diverse and exciting set of grad programs across all of STEM.

Careers are not destinations but journeys with twists and turns and surprises. As you choose your adventure, do some soul-searching about what makes you happy and how your career can make the world a better place. Break down the process into small, digestible chunks.

ABOVE: Brad Conrad.

ABOVE: Credit: XKCD, xkcd.com/1346.

If you read through this issue and decide that grad school isn't for you, that's time well spent. Turn your attention to exploring the *many* career options that don't require a grad degree. To learn more about them, check out the SPS Careers Toolbox at spsnational.org/sites/all/careerstoolbox and SPS Jobs at jobs.spsnational.org.

Figuring out your next step isn't easy, but a little planning can go a long way. Feeling overwhelmed? You don't have to have it all figured out today! The Society of Physics Students, Sigma Pi Sigma, and GradSchoolShopper.com are rooting for you and are here to help you along the way. //

The Right Path is Your Path

by Madison Swirtz, Graduate Student in Physics Education Research, University of Utah

▌ ABOVE: Madison Swirtz.

I thought I did my undergrad wrong. I was passionate about my community and did too much service work. My CV is stacked with proof that I know and care about equity issues, but not nearly as much traditional physics research.

I wanted to be connected to queer issues in physics, but that was the one issue my department wouldn't talk about. So I sought out queer spaces in the broader physics community. That's where I learned about queer research happening in physics education research. I met my current advisor right as I was applying to graduate school and feel incredibly lucky that I am pursuing "queer physics" in a research capacity within a physics department.

I've been meeting many new people recently, and when they ask what I do for a living it becomes a bit of a monologue. "I'm a graduate student" usually covers me for a quick acquaintance, but if they want any more detail, I explain: "I'm a physicist in a physics PhD program. My subfield is physics education research, but I don't do education at all and don't like teaching. My research is on the social networks and career trajectories of LGBT+ physicists. More broadly, I apply queer theory in a physics context." Explaining this can make me feel like an outsider in my own field, but everyone replies similarly: "I'm glad there are people doing this work, and it's awesome that you can do something you're so passionate about."

I did my undergrad wrong. And I'm probably doing grad school wrong. But by not following the "correct" path, I ended up pursuing the research I always wanted to do. //

Trust Your Gut

by Karthik Rao, Physics Graduate Student, Rice University

My life is the result of a series of decisions I made based primarily on gut feelings.

I decided to major in physics when I was a junior in high school. To accomplish this, I chose not to stay in India for college, where I would likely have become an engineering major, and instead applied to schools in the United States. This was based on a gut feeling that it would work out; my family did not have the finances to pay international student tuition rates, but I hoped I would somehow get enough scholarships to attend a US college and become a physicist. It worked out amazingly well. I attended Texas A&M University, and my undergrad experience culminated in a fantastic internship at the National Institute of Standards and Technology (NIST) through an SPS summer internship. It was based on that same gut feeling that I decided to pursue a physics PhD.

I'm currently a second-year graduate student at Rice University, working in Prof. Emilia Morosan's lab, and thus far, my experience has been extraordinary. I've had incredible opportunities to travel, present my research, and network with people in my field, and I've learned so much from working on my research projects. But grad school has been more than just research and classes. I've gained valuable leadership experience by participating in student organizations, volunteered at physics outreach events, and developed lifelong friendships.

If you are on the fence about attending graduate school, I advise you to go for it! It is the perfect place to get "real-world" job experience while also having the freedom to explore and decide what you truly want to spend the rest of your life doing. Good luck! //

ABOVE: Karthik Rao.

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I Traded Grad School for Life Without WiFi

by Victoria Catlett, Software Engineer, Green Bank Observatory

I had planned to be in graduate school right now. Instead, I'm in a place where WiFi is illegal and the nearest Walmart is an hour away. My phone stays in airplane mode—there's no cell service. I wouldn't want to be anywhere else.

I graduated last year from the University of Texas at Dallas (UTD), where I earned bachelor's degrees in physics and mathematics. While there I spent a lot of energy making sure that I was doing the exact right things to get into a good graduate school. I planned to get a PhD and then… well, I'd have at least five or six more years to figure that out. But when I stared at the blank graduate school application forms, I couldn't bring myself to commit to more schooling.

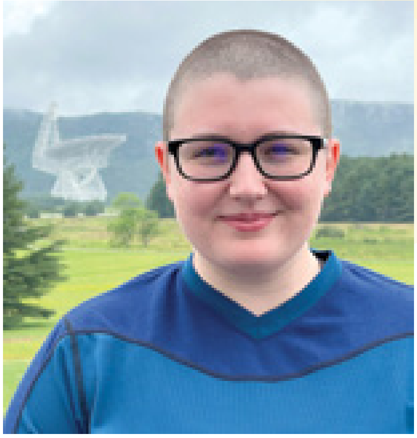
I liked the coding I'd done in classes and research, so I started looking for software jobs. I doubted I'd get a job in a field I didn't have a degree in, but I tried anyway.

Then, in January of my senior year, I got the offer that brought me here: a software engineering position at the Green Bank Observatory in West Virginia, home of the world's largest fully-steerable radio telescope.

The observatory, and the surrounding area, has strict rules prohibiting radio-emitting devices because they interfere with the telescope's sensitive observing work (and that of the nearby National Security Agency site)—hence the lack of WiFi and cell service.

Green Bank seemed like a strange place to live, and the job didn't match my major, but I accepted because it sounded like a fun challenge. It ended up being the perfect move for me! I help with all sorts of groundbreaking science while learning new skills and drawing from my existing skill set.

My experience is actually quite common. According to the American Institute of Physics (AIP), about half of the physics and astronomy majors in the United States go directly into the workforce after earning their bachelor's degrees. And most of their jobs don't have "physics" or "astronomy" in the title!

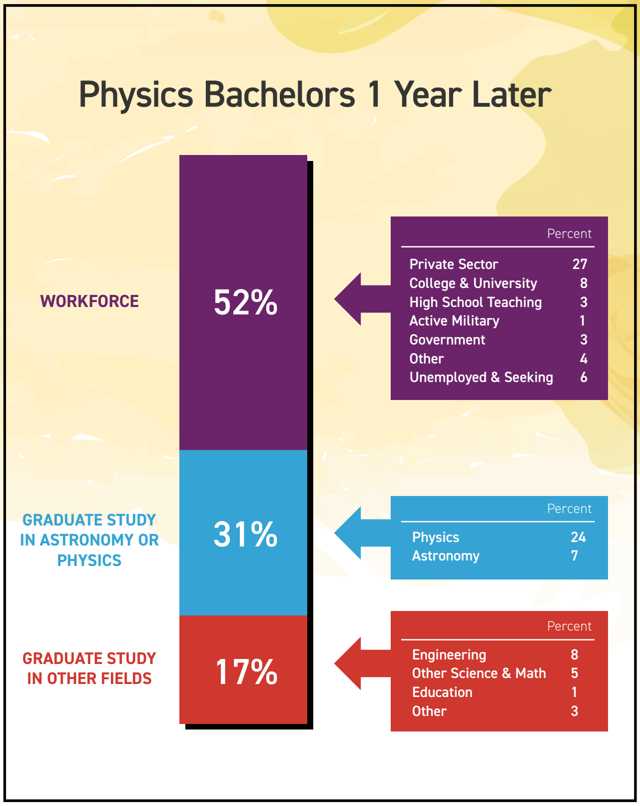


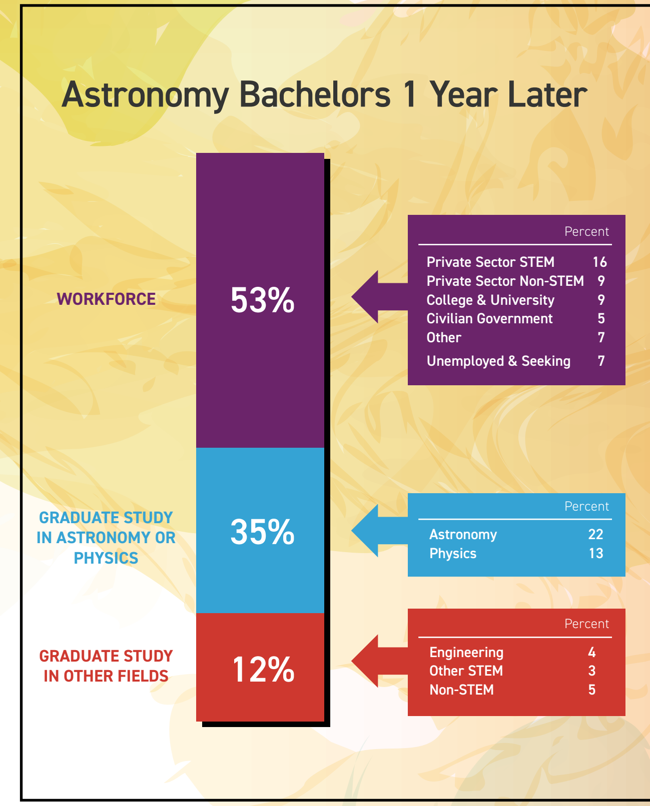
ABOVE: Victoria Catlett on the grounds of Green Bank Observatory; the 100-meter Robert C. Byrd Green Bank Telescope looms in the background. Photo credit: NSF/GBO.

LEFT: Green Bank Observatory. Photo by Jill Malusky, credit NSF/GBO 20.

The problem-solving skills physics and astronomy students learn are transferable to a wide variety of fields. That's one of the great things about the degree. Most jobs rely heavily on on-the-job learning, and many employers want to hire people who know how to break down problems into their constituent components.

I'm sharing my story with the hope that I can help others find the right path, like I did. The last year of college can be incredibly stressful, with advanced classes, deciding what to do next, applying for programs or jobs, and awaiting your fate. In physics and astronomy, many majors don't know a lot about options beyond graduate school.





ABOVE LEFT: The status of those who received physics bachelor's degrees in 2019 and 2020, one year later. This does not include respondents who reported leaving the United States. Credit: The American Institute of Physics, aip.org/statistics.

ABOVE RIGHT: The status of those who received astronomy bachelor's degrees in 2018, 2019, and 2020, one year later. This does not include respondents who reported leaving the United States. Credit: The American Institute of Physics, aip.org/statistics.

Here are some resources that can help you figure out what's next:

— **SPS Careers ToolBox:** The Careers Toolbox contains helpful information and practical tools for undergrads who are considering going right into the workforce after college. Check it out at spsnational.org/sites/all/careerstoolbox or use the QR code below.

— **Common Job Titles for Physics Bachelors:** The AIP Statistical Research Center compiles a list of common job titles held by physics bachelor's degree recipients. Browse the list at aip.org/statistics/common-job-titles-physics-bachelors.

— **Job listings from professional organizations:** Most large professional societies maintain lists of active job openings relevant to people in their fields, including SPS (jobs.spsnational.org), AIP (through *Physics Today*, jobs.physicstoday.org), and the American Astronomical Society (AAS, jobregister.aas.org). They're helpful for exploring the possibilities and job hunting.

— **Who's Hiring Physics Bachelors?** If you know where you'd like to live, check out this state-by-state listing of employers who recently hired new physics bachelor's degree recipients, aip.org/statistics/whos-hiring-physics-bachelors.

Once you have an idea of what you want to do, this is what I suggest:

— **Write (and maintain) a CV:** A curriculum vitae (CV) is essentially a long version of a résumé detailing your academic and professional experiences. When you have everything in one place, you can easily send prospective employers the entire CV (if they ask for it) or create a custom, single-page résumé by plucking out the most relevant information.

— **Tailor your online presence:** Your online presence isn't just about your public social media accounts, although you should make sure they are professional. The internet gives you options to cultivate your image in ways that are more flexible than a résumé. For example, if you've done programming, make a few clean, well-documented GitHub repositories of your work.

— **Learn from real people:** The day-to-day work of a job is almost certainly not what you envision. Talk to people who took various paths—those you're interested in and those you're not! You might be surprised about the realities of certain paths.

Figuring out the next step in your life can be scary, but armed with the right information, you'll do just fine. Be open to possibilities outside of your plan, and you may find exactly where you're supposed to be. //

SPS Careers Toolbox

Now You Know: Grad School Edition

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma

As you consider your future, it's helpful to know some foundational facts, figures, and statistics about grad school in physics, astronomy, and engineering.

Getting started

— Most people switch schools for grad school. It's even preferred by some grad programs.
— Most grad programs begin in the fall semester, few allow students to start in the spring.
— Most programs accept international students, but some funding options may be limited to US citizens.
— Many programs let accepted students defer their admittance for one year. The longer you wait to apply, the less likely you are to do so.

Financial support for PhDs

— Almost all new physics and astronomy PhD students are fully supported:

53% **by teaching assistantships (avg. salary ~$25,000)**

20% **by research assistantships (avg. salary ~$31,000)**

26% **by fellowships and scholarships**

— Almost all new engineering PhD students are fully supported:

14% **by teaching assistantships (avg. salary ~$28,000)**

52% **by research assistantships (avg. salary ~$30,000)**

34% **by fellowships and scholarships**

Master's versus PhD programs

— Many more students enroll in physics and astronomy PhD programs than master's programs. In engineering, the reverse is true.
— Eighty percent of physics and astronomy PhD students graduate in 6 ± 1 year.
— Most master's programs take two years.
— Master's programs usually have lower stipends than PhD programs (if any) and may not have tuition waivers.

Research topics

— Most new grad students don't come in with a thesis topic.
— Students can change research fields within a program.
— The ratio of theory to experimental dissertation research varies with topic. In physics and astronomy, it breaks down like this:

Materials science, nanoscience, surface physics: ~88% experimental

Astronomy, astrophysics, cosmology: ~40% observational

Relativity, gravity: ~90% theoretical

Condensed matter physics: ~68% experimental

In most PhD programs in physics and astronomy...

— Students who are research or teaching assistants get regular paychecks.
— Research and teaching asisstants usually don't pay tuition.
— Health insurance is offered to grad students.
— Students work all year, including summers.
— Most students don't apply for loans because tuition is waived and they are paid.
— Students focus primarily on classes for the first two years.
— Students focus solely on research after finishing classes.

What comes after a PhD?

— Fifty-two percent of those who earned physics or astronomy PhDs in 2019 and 2020 became postdocs, 38% took potentially permanent positions.
$ Avg. starting salary for postdocs: $55,000–$70,000.
$ Avg. starting salary for private-sector positions: > $115,000.

The data is important, but it's not the whole story. Advanced degree programs are great if you love research or if the degree will take you someplace you love, but they're tough. Don't go to grad school just because you don't know what else to do. And if you decide to go for a PhD, consider individual research advisors, not school names. Look for programs with multiple advisors you'd want to work with—options are essential. You'll spend most of your time doing research with your advisor. //

Most of the data referenced in this article is from studies by the American Institute of Physics (AIP) Statistical Research Center. Use the QR code or go to aip.org/statistics to explore more.

FOR MORE ON...

- Master's and PhD programs, see page 26
- Paying for grad school, see page 30
- Selecting an advisor, see page 50

Graduate Programs 101

Physics and astronomy majors are qualified for *many* educational pathways

by Ben Perez, Contributing Writer

There is no one-size-fits-all grad program, even in a field like astronomy or physics. Most programs are classified by the highest degree they offer, master's degree or PhD, but there are variations even within those categories. And having a physics or astronomy major doesn't mean you're limited to physics and astronomy grad programs. You're qualified for many physics-adjacent grad programs and professional degree programs too.

Master's programs

A typical master's program in physics, astronomy, or engineering takes two years to complete. You may have to pass a qualifying exam, present a thesis, or simply pass the necessary classes. The requirements vary from program to program, so read the fine print on programs that interest you.

Master's programs can be terminal (the end of the line) or earned on the way to a PhD. Terminal master's programs are more common in engineering than physics and astronomy. However, physics and astronomy students who start a PhD program and then realize it's not a good fit usually have the option to leave with a master's degree after two years. Some transfer to a PhD program elsewhere, while others enter the workforce. These are sometimes called combined master's/PhD programs.

If you're undecided about pursuing a PhD or want to develop more skills first, a master's-to-PhD bridge program may be the way to go. These programs typically include more mentoring, research experience, and academic support than a traditional master's degree program, and the end result is the same degree. Students in bridge programs can apply to PhD programs or enter the workforce with their degrees.

Another option offered by some departments is the "4+1" program. The departments count dual-listed undergrad courses toward a master's degree, so a fourth-year student (or equivalent) only needs one additional year of graduate coursework to finish the master's degree.

A master's degree is a great way to dive deeper into a topic and position yourself for more independent work and leadership roles. When deciding which type of program to apply to, keep in mind that terminal master's programs often have less financial support than combined programs.

PhD programs

A PhD program is the older sibling of a master's program. Progress through the program can vary between schools, but typically you focus on taking classes and starting independent research for the first two years. That research may or may not become your thesis project, but you'll learn valuable research skills.

During this time, many programs require students to pass a qualifying exam to show mastery over the core subject. Qualifying exams vary by program but may consist of one or a combination of measures such as a written exam, oral exam, research presentation, or thesis proposal.

After you complete the majority of your coursework, your focus shifts to research and preparing a thesis proposal (if that wasn't part of the qualifying exam). A thesis proposal describes what you plan to explore with original research and demonstrates your ability to think about a subject, find a gap in existing knowledge, and outline the steps needed to fill that gap.

Once the proposal is approved, it's time to narrow in on that topic—researching, publishing papers, and presenting in that niche area. This usually takes a few years.

ABOVE: Contributing writer Ben Perez has a bachelor's degree in physics and a PhD in materials science.

In the final steps of a PhD program, you write and defend your thesis—your original research and its results. The format can vary, but it's common for a defense to consist of two parts. The first is a public session where you present your thesis to a thesis committee (a select group of faculty members) and the general public. The second is a closed session where the committee asks you questions about the research, possible holes in your work, and moving the project forward.

You'll also need to submit a written version of your thesis to the committee. The committee provides feedback and helps you wrap up loose ends so it's ready to be published. Then it's the home stretch! The last thing to do is walk the stage in a cap and gown.

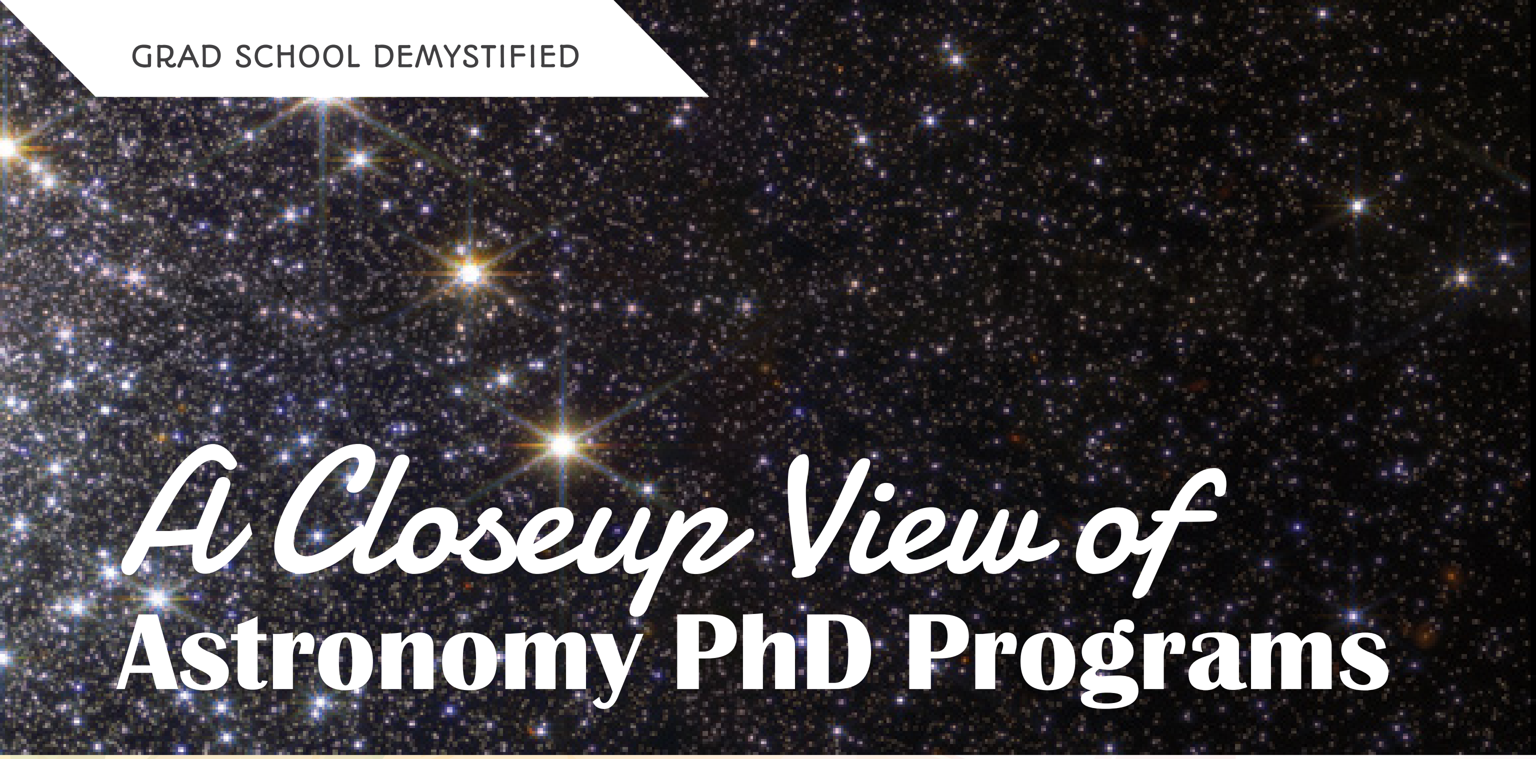
People with PhDs can become teaching or research faculty, lead research projects at industrial and national labs, consult, and enter a variety of other positions in the public and private sectors.

Professional degree programs

While many physics and astronomy undergraduates choose to pursue a master's or PhD in physics, astronomy, or a related field, those aren't the only postgraduate degree options. Physics and astronomy undergraduates have gone on to earn many professional degrees: doctor of medicine (MD), juris doctor (JD, for a career in law), master of education (EdM), doctor of dental surgery (DDS), master of business administration (MBA), and more.

Professional degrees vary greatly in cost and aren't always as well-funded as PhD programs in physics, astronomy, and related fields. Grants and tuition reimbursement programs sometimes supplement the cost, but you may need to self-fund.

Having a physics and astronomy background gives you a great foundation to pursue these degrees. Many of the critical thinking, problem-solving, learning, and deductive skills you've gained will help you transition to a new field. Your background is a ball of clay that you can mold into what you want to become. //



A Closeup View of Astronomy PhD Programs

by Tom Rice, Education and Mentoring Specialist, American Astronomical Society, and Assistant Research Professor of Physics, George Washington University

Note from the author: *In this article astronomy and astrophysics are used as synonyms, following their everyday use in the professional community. Additionally, this guidance pertains to US-based programs; international programs will have important differences.*

So you think you'd like to earn a PhD in astronomy?

Astronomy is one of the most exciting branches of natural science—we deal with the search for life in the universe (and life's origins), the nature of black holes and other extreme objects, the formation and dynamics of galaxies, the beginning of time, and the ultimate fate of the cosmos. In my research I use infrared and radio observatories to study young, still-forming planetary systems.

I applied to astronomy PhD programs in 2011 and earned my PhD from the University of Michigan in 2019. Some things have changed since then: astronomy programs have gotten ever more competitive, and there has been a movement to change graduate admissions requirements to improve equity (e.g., by removing the physics GRE requirement). But many things have stayed the same—hopefully my insight can help guide your way!

Qualifications: What background do I need for an astronomy graduate program?

Typically, graduate programs in astronomy are accessible to anyone with a physics major, a physics- and math-rich astronomy major, or a major in a related field (e.g., chemistry, mathematics, computer science) who has completed substantive training in physics or astrophysics (at least a minor or a relevant research experience). Just like a PhD program in physics, strong quantitative preparation is required, and undergraduate research experience is highly desirable.

If you're coming from a pure physics undergraduate background, don't worry—many students make the leap into astronomy only when they begin their PhDs, and the first two years of astronomy graduate coursework are often designed to be accessible to someone with solid physics foundations, perhaps with some extra self-study.

Programs: What does a strong astronomy PhD program look like?

Astronomers often specialize as observers, theorists, numericists, or some combination

TOP: This JWST image shows part of M92, a cluster of thousands of stars located 27,000 light-years away from us. Credit: NASA, ESA, CSA, A. Pagan (STScI).

ABOVE: Tom Rice.

of the three. This somewhat parallels the situation between experimentalists and theorists in physics, with the key difference that the astronomy theorist community is typically much more integrated into the observer community.

A strong astronomy PhD program will help you acquire the resources you need to succeed as an astronomer: data (for observers) or computer resources (for numericists), as well as professional connections.

Astronomical data comes from many sources. While some of the most prominent astronomy departments have dedicated access to world-class telescopes, in the modern era, you don't need institutional access if you can work with a large collaboration, use open-access data from telescope archives, or successfully write small, focused telescope proposals as a principal investigator (PI).

Having a supportive PhD advisor and other mentors is key to gaining access to data and the professional community with whom you will share your scientific work.

Departments: What kind of departments should I consider applying to?

You can get a PhD in astronomy from a standalone department of astronomy. You can also get one through a joint department of physics and astronomy, some of which have separate astronomy and physics PhD programs. The astronomical community also has many people with PhDs in physics from departments of physics, whose dissertation research focused on astronomy questions. Because astronomy shares so much technique and history with "mainstream" physics, these distinctions are often permeable.

Advice: What else should I know?

Applying to graduate programs can be expensive; I come from a working-class family and needed to take out loans to cover the cost of my PhD applications. Some institutions now offer fee waivers for students with financial needs or from historically underrepresented groups; ask ahead of time—some fee waiver deadlines are several weeks before the formal application deadlines.

Successful astronomers come from many different backgrounds and life paths; this is something our community is working toward celebrating. I always encourage students to let their strengths shine in their application and apply broadly. Give yourself the best odds of finding a champion on an admissions committee who can see the incredible value you'll bring to the astronomy community. //

ABOUT AAS

The American Astronomical Society (AAS, aas.org) is an international organization of professional astronomers, astronomy educators, and amateur astronomers. AAS hosts the largest regularly held conference in the astronomical sciences worldwide, publishes astronomy journals, and provides resources on astronomy education, careers, and more. Members of SPS are eligible for free membership in AAS; for details see spsnational.org/about/membership/free-ms-membership.

ADDITIONAL RESOURCES

Much of my thinking on PhD programs has been shaped by these resources. You might want to check them out too!

—Tom Rice

Applying to Graduate School in Astro/Physics by Chanda Prescod-Weinstein

Applying to PhD Programs in Computer Science (pdf) by Mor Harchol-Balter

Syllabus for PhD Students by Eric Gilbert

How to Decide which Grad School to Attend (Twitter thread) by Nicole Cabrera-Salazar

Who Pays for Grad School?

PhD Programs

by Kendra Redmond, Editor

In physics and astronomy PhD programs, the department typically covers tuition and related expenses for its graduate students, or the university waives these expenses. Most students never see a bill—or if they do, it has a zero balance.

To cover the cost of living, graduate students typically earn a stipend—a fixed amount paid as a salary. The typical stipend is less than what you might earn in the workforce, but it offers some breathing room along the way to a PhD. Stipends can be paid by the university through teaching or research assistantships, or paid by the department or an external source through a fellowship.

Teaching assistants (TAs)

Universities fund TA positions to facilitate their undergraduate classes. TAs are usually assigned to work with an undergraduate course in their department. They may be responsible for leading discussion or problem sessions, teaching labs, holding office hours, grading homework, and proctoring exams, among other activities. It's common to spend about 20 hours each week on TA duties.

In most physics PhD programs in the United States, first-year students receive teaching assistantships unless they've already lined up a research assistantship or fellowship, are not proficient in speaking English, or decline financial assistance. Students may continue to work as a TA in later years if they don't have research funding or simply wish to continue teaching. Some astronomy PhD programs follow a similar model, while others have students begin research immediately and TA in later semesters.

Research assistants (RAs)

RAs get paid for doing research. RA positions are typically funded by individual labs and sometimes by the department. They enable students to focus on doing research toward their thesis. Money for RAs often comes from research grants, so the number of positions in a particular lab often depends on its current funding situation. RAs may get paid a little more than TAs. Some programs, especially astronomy programs, may help you line up an RA before you start. Physics programs will often let you come in as an RA if you've worked out the details with a researcher in advance.

Fellowships

Graduate students supported by fellowships receive a stipend that isn't tied to teaching or research in a particular lab. Fellowships can be for one or more years. Students entering a program with a fellowship can typically spend more time on their coursework during the first two years since they don't have to be a TA or RA. Fellowships also give students more flexibility in their research, as they can work in a lab without needing financial support from that lab. National fellowships are offered by foundations, nonprofits, corporations, and government agencies. Many follow the awardee to whatever school they choose and if they transfer programs. Fellowships are competitive, and application deadlines for incoming grad students can be *up to a year before you even start a program*. It's never too early to start looking. Some departments provide internal fellowships as well.

A PhD can take many years to complete, so it's essential to consider the financial aspects of this path. When comparing stipends for different programs, be sure to factor in the local cost of living and healthcare. Virtually all programs offer graduate students healthcare plans, but coverage and costs can differ significantly. Extras such as transportation assistance, access to staff daycare facilities, or affordable graduate student housing options can also reduce your living expenses.

Don't let low stipends limit your options right from the start. Apply to higher-paying fellowships and reach out to departments of interest—if you're a good fit, they may be able to help you secure a grant or fellowship that can make all the difference. //

This article is adapted from an earlier version that appeared in the 2022 issue of GradSchoolShopper *magazine.*

CAVEATS AND CONSIDERATIONS

- **US PhD programs in many other scientific disciplines have a similar approach to supporting grad students, but the amount and number of stipends vary with research funding and other factors.**
- **Some financial support—even in physics and astronomy PhD programs—may be available to US citizens only.**
- **Look carefully at the financial support packages typically offered by any program that interests you, and read the fine print in any offers you receive.**

> **"A big part of what my National Science Foundation (NSF) fellowship did for me was give me freedom. It made me feel like it wasn't required of me to do everything that was asked of me by my advisor and by the institution because they were no longer paying me. I was getting paid by the NSF, and if I picked up and left, the NSF was still going to pay me. Finding my own funding was so empowering for me."**
>
> ***–Simone Hyater-Adams, Founder, MEGA Imagination LLC***

PHYSICS
COLORADO STATE UNIVERSITY

PHYSICS GRADUATE PROGRAM

Application due: January 15, 2024

Apply: https://bit.ly/3KdE6Gy

Degree(s): PhD, MS

Fields offered include:
AMO, Condensed Matter, HEPPA, theoretical

Questions: physics_grad_admissions@mail.colostate.edu

- Average stipend per academic year of **$21,015**
- **3:1** student to faculty ratio
- **100%** of graduate students are receiving assistantship support

Fort Collins, Colorado
www.physics.colostate.edu/future-students/future-grad-students

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

PHYSICS AND ASTRONOMY

Application due: December 12, 2023

Apply: https://bit.ly/3pXxODR

Degree(s): PhD, MS

Questions: mejensen@email.unc.edu

- **99** total grad students
- **30%** of grad students are women
- **Special research equipment:** TUNL: Premier Nuclear Physics Lab, Biomedical Imaging Research Labs, Multiple Astronomical Instrumentation Labs

Chapel Hill, North Carolina
www.physics.unc.edu

Master's and Professional Degree Programs

by Ben Perez, Contributing Writer

The cost of many master's programs and professional programs falls upon the student. That means you could be responsible for paying your tuition, fees, and living expenses.

Many students offset these costs by applying for scholarships, grants, and loans. Doing well on entrance exams (e.g., MCAT, LSAT, or GRE), earning a high GPA, and having valuable work experience may help you receive more financial aid.

Some people work and pay for a graduate degree through their employer's tuition reimbursement program. Many US companies offer this to employees who meet certain eligibility requirements, such as having worked at the company for a certain number of years or earning a degree related to their position or career track. This is common with MBAs but applies to other degrees as well.

Don't have tuition reimbursement? Some people work and pay for school as they go. And some can get a TA, RA, or fellowship in their department—opportunities vary by university and field.

If you'd like to get a master's degree in physics, astronomy, or a related field, but none of these financial options appeal to you, then a combined master's degree and PhD program may be a better fit. You might spend more time doing research, but as a part of your RA, TA, or fellowship, your tuition will likely be paid in full and you'll earn a stipend. You can stick around for a PhD if you'd like, or exit the program once you've met the requirements for a master's degree. Caution: Not all PhD programs support this approach or offer master's degrees, so find out the details *before* you apply to programs. //

HELPFUL RESOURCES

- **The Economic Policy Institute's Family Budget Calculator is one of many online tools for estimating the cost of living in a specific location: epi.org/resources/budget.**
- **The University of Arizona's national fellowship list for physics graduate students: w3.physics.arizona.edu/graduate-studies/fellowships-and-scholarships.**
- **A national fellowship list for astronomy graduate students compiled by Astrobites: astrobites.org/2018/04/27/list-of-major-us-fellowships-for-astronomy-students.**

Doing Grad School Part Time

by Jack Moody, Officer, US Army, and Graduate Student in Applied and Computational Mathematics, Johns Hopkins University

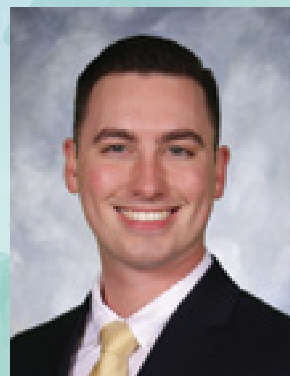
In 2021 I graduated with a physics bachelor's degree from the University of Massachusetts Amherst. Now I'm an active US Army officer and part-time graduate student at Johns Hopkins University, where I study applied and computational mathematics. If going to grad school part time sounds interesting, here are some things to consider.

What do you want from a graduate program? Do you want to study something that makes you better at your job, something you're passionate about, or both? These are vital aspects of deciding *what* and *where* to study. If you're interested in pursuing research or a PhD in the future, note which programs offer these tracks versus course-based degrees.

How can you do both? Time management is crucial when you're juggling multiple pursuits. Schedule study time throughout the entire week (including weekends), and stick to that plan! It's helpful if your supervisor supports your schooling and gives you the flexibility to attend office hours, study groups, and other school events.

How will you pay tuition? Most US graduate programs don't cover tuition or give stipends to part-time students. However, some employers will pay for their employees to take specific classes or even earn a degree. There may be stipulations—all companies are different, so check with your employer. As a part-time student, you can also pay out of pocket and apply for scholarships and loans.

How can you make the most of grad school? It can be tempting to just answer homework questions and move on, but take the time to meet with professors during office hours and with other students during group study sessions. This will help you retain more information and cultivate a meaningful network. //



ABOVE: Jack Moody.

George Mason University

DEPARTMENT OF PHYSICS & ASTRONOMY

Application due: January 1, 2024

Apply: https://bit.ly/3DF45ml

Degree(s): PhD, MS

Fields offered:
Many research areas available

Questions: gadvphys@gmu.edu

- Average stipend per academic year of **$24,000**
- **80** total graduate students
- **70** faculty members

Fairfax, Virginia
physics.gmu.edu

Georgia Tech College of Sciences
School of Physics

SCHOOL OF PHYSICS

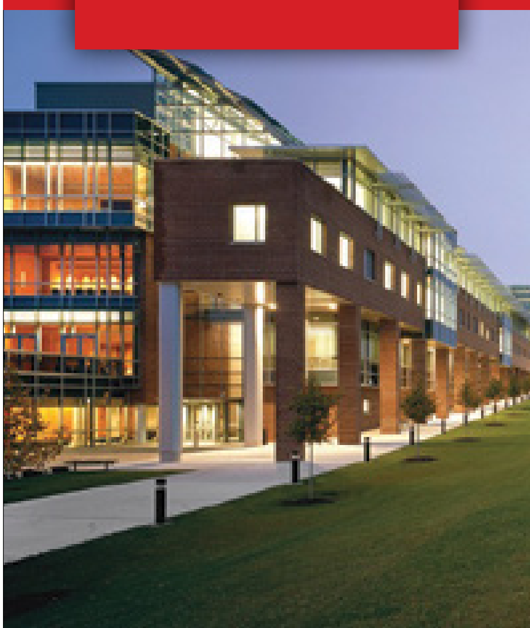
The School of Physics at Georgia Tech focuses on six areas of research: Astrophysics, Atomic, Molecular and Optical Physics, Condensed Matter and Material Sciences, Non-linear Systems, Physics of Living Systems and Soft Matter. The graduate curriculum in the School of Physics provides the background and training needed to conduct and complete high quality, world-recognized research, allowing graduate students from diverse backgrounds to develop into creative physicists who can function effectively in educational, industrial or government laboratory settings.

physics.gatech.edu

Phone: 404-894-5201 • Email: gradinfo@physics.gatech.edu
School of Physics, Georgia Institute of Technology. 837 State Street. Atlanta, GA 30332

Rensselaer
School of Science

DEPARTMENT OF PHYSICS, APPLIED PHYSICS, AND ASTRONOMY



Ph.D. or M.S. in Physics, M.S. in Astronomy

Careers of graduates: Nobel laureate, university faculty, researchers at national laboratories, leaders in industry and technology

Apply: https://bit.ly/3YfkkA7

Research Areas

- Astrophysics and Astronomy: Galactic structure, large astronomical surveys, nature of dark matter
- Particle Physics: Neutrinoless double beta decay, lattice QCD
- Energy Research: Energy harvesting, solid-state lighting, complex systems and networks
- Nanoscience and Nanomaterials: Nanoelectronics, nanodevices, nano-bio interfaces
- Optical Physics: Plasmonic structures, light-matter interactions, terahertz spectroscopy, quantum optics and entanglement
- Condensed Matter and Statistical Physics: Molecular electronics, quantum molecular dynamics, semiconductor materials and devices, thin film devices, machine learning for materials

Phone: (518) 276-6310 • Email: gradphysics@rpi.edu
110 8th Street, Troy, NY 12180-3590

science.rpi.edu/physics

You're Not Limited to Physics and Astronomy
More Fields to Explore

by Ben Perez, Contributing Writer

Did you know physics and astronomy majors are often qualified for master's and PhD programs in other fields? This isn't a comprehensive list of them, but it should get you thinking more broadly about your options.

Acoustics and acoustical engineering deal with sound and vibrations. People in the field work on designing, analyzing, and controlling sound for applications such as noise dampening, ultrasound imaging, underwater communication, audio productions, and aircraft design. Learn more from the Acoustical Society of America, acousticalsociety.org.

Aeronautics and aerospace engineering encompass the subject of how objects move through the air. Most typically the fields are associated with planes, satellites, and spacecraft, but they also play an integral part in the design of products ranging from cars to golf balls to defense equipment.

Biophysics is the study of biological phenomena using physics approaches and methods. People in this field often analyze and interpret data from molecular and organism studies for medical applications, industrial applications, or basic research. Biophysics often overlaps with fields like physical chemistry, bioengineering, computational biology, and nanotechnology.

Computer science focuses on designing or using hardware, software, or software systems to solve problems—skills common among physics and astronomy majors. Computer scientists work in areas such as artificial intelligence, cybersecurity, hardware and software design, and data analysis.

Data science uses statistics, algorithms, and the scientific method to gain insights from unstructured or complex data sets. Data scientists often write and develop code. This path may be a good option for students with programming skills who are interested in machine learning, artificial intelligence, and statistics.

Earth science relates to how and why the earth functions the way it does. The field encompasses geology, oceanography, atmospheric science, climate change, and more. Programs may be standalone (e.g., oceanography) or fall under an earth sciences umbrella. Earth scientists work in areas like alternative energy, environmental science, mining, and civil engineering.

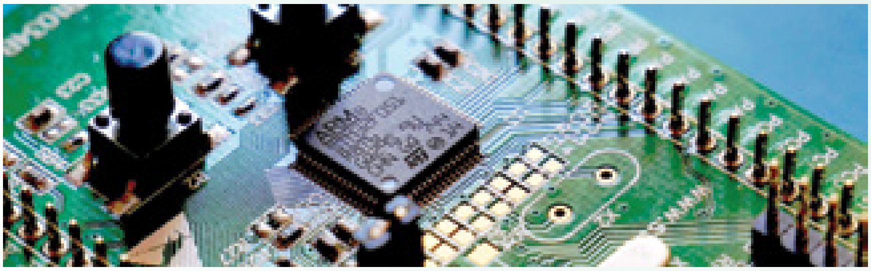
Energy science includes the renewable and nonrenewable forms of energy we use for power generation. If you want to develop more sustainable and cost-effective ways to produce or store energy, this may be the field for you. Grad degree programs are offered in many areas: renewable energy, sustainable energy, energy engineering, nuclear engineering, energy technologies, petroleum engineering, and others.

Materials science and engineering is a broad discipline that seeks to understand materials and engineer them to exhibit certain characteristics for various applications. Materials scientists work in areas from semiconductors to nanotechnology, 3D printing, and everything in between.

Mechanical engineering is the study of physical machines and motion. Mechanical engineers design machines or analyze their movement and forces to optimize the system for functionality, aesthetics, or manufacturability. Career areas range from automotive to aerospace to robotics.

Medical physics aims to prevent, diagnose, and treat human diseases using physics applications. Medical physicists work in areas like medical imaging, radiotherapy for cancer treatment, cardiology, and medical research. To learn more, check out "Pathways to Medical Physics" from *GradSchoolShopper* at GradSchoolShopper.com/pathways-to-medical-physics.html.

Optics and photonics explore the fundamental properties of light and how to utilize them for practical applications. People in optics and photonics commonly work in communications (e.g., optical fibers), medicine (e.g., imaging techniques), displays (e.g., cell phone screens), and sensor design (e.g., monitoring environmental conditions or contents). Learn more from Optica, optica.org. //



TOP: Photo by Vishnu Mohanan on Unsplash.

ABOVE: Photo by American Public Power Association on Unsplash.

Georgia State University

PHYSICS AND ASTRONOMY

Application due: January 15, 2024
Apply: https://bit.ly/3QrvwW7
Degree(s): PhD Astronomy, PhD Physics
Fields offered include:
Astrophysics, Nuclear, Condensed Matter, and more
Questions: rwhite31@gsu.edu (Astronomy), msar@gsu.edu (Physics)

- **Special research equipment:** Operating the CHARA interferometric array (CA), access to Apache Point Observatory 3-5m telescope (NM), access to Cerro Tololo Inter-American Observatory (Chile), collaborations with Brookhaven National Lab (NY) and Jefferson Lab (VA).
- **78** total grad students
- **100%** of grad students are receiving assistantship support

Atlanta, Georgia
physics-astro.gsu.edu

LEHIGH UNIVERSITY

Bethlehem, Pennsylvania
physics.cas.lehigh.edu

PHYSICS AND ASTRONOMY

Application due: January 15, 2024
Apply: https://bit.ly/3tGbPjC
Degree(s): PhD, MS
Questions: alh422@lehigh.edu

- **5 years** to completion
- **100%** of graduate students receive support through sixth year
- **2.3 students** per faculty member

INDIANA UNIVERSITY
BLOOMINGTON

Bloomington, Indiana
physics.indiana.edu

DEPARTMENT OF PHYSICS

Application due: January 1, 2024
Apply: https://bit.ly/3Kpyl8C
Degree(s): PhD, MS
Fields offered include:
All subfields, experiment and theory
Questions: gradphys@indiana.edu

- **90** total graduate students
- **100%** of graduate students are receiving assistantship support
- **Special research equipment:** Interdisciplinary centers include Center for Exploration of Energy and Matter (CEEM), Center for Spacetime Symmetries (CSS), and Quantum Science and Engineering Center (QSEc)

Northeastern College of Science

PHYSICS

Application due: December 1, 2023
Apply: https://bit.ly/3YiGzFv
Degree(s): PhD, MS
Fields offered include:
Biophysics, Condensed Matter, Particle
Questions: gradphysics@northeastern.edu

- **$41,535** average stipend per academic year
- **35+** research groups and growing
- **Over $53 million** in department research funding

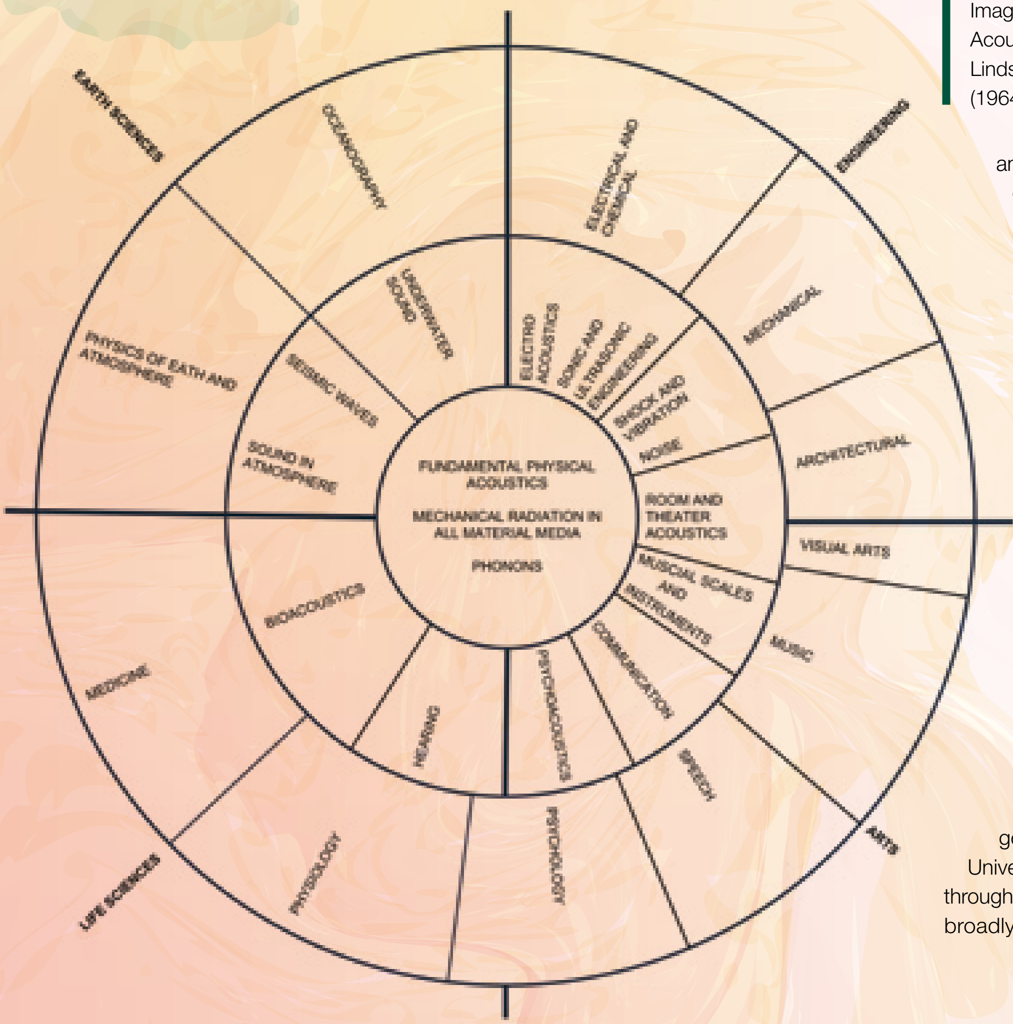
Boston, Massachusetts
cos.northeastern.edu/physics

Pathways to a Career in Acoustics

by Keeta Jones, Education and Outreach Coordinator, Acoustical Society of America, and Noah Jenkins, Senior Engineer, Systems & Technology Research (STR)

Many people mistakenly limit acoustics to musical or architectural applications, but acoustics includes the production, control, transmission, reception, and effects of sound. This means that no matter what you're interested in, there is likely a related field of acoustics.

A bioacoustician might research bird populations to determine if human-made noise disrupts their behavior. An architectural acoustician could model the reverberation times of an opera house. An engineer could work to reduce noise caused by trains. An underwater acoustician might design sophisticated sonar hardware to explore the ocean floor, while an acoustician interested in ultrasound could develop medical equipment to destroy kidney stones. This is just a small sample of what acousticians do!



TOP: Keeta Jones.

BELOW LEFT: Lindsay's Wheel of Acoustics demonstrates how acoustics relates to the arts, earth sciences, engineering, and life sciences. Image reproduced with permission of the Acoustical Society of America from R. Bruce Lindsay, "Wheel of Acoustics," *JASA* 36, no. 11 (1964): 2242.

Because of this variety, there is no single pathway to a career in acoustics. The path that will get you there depends on what field of acoustics you want to pursue. The best degree to prepare you for animal bioacoustics is not the same as the one for musical acoustics. Additionally, a lot of people end up studying very different fields in graduate school than they did in undergrad.

If a career in acoustics sounds intriguing, look at "Lindsay's Wheel of Acoustics" while exploring programs and searching school catalogs. The word "acoustics" might not be in the title or description, but often topics in physics, aerodynamics, engineering, speech and hearing, and anatomy will provide good foundational knowledge for acoustics. Universities may offer acoustics-related courses through different departments, so be sure to search broadly. While some institutions offer graduate degrees in acoustics, you may need to seek out different degree programs based on your interest, such as oceanography, biology, engineering, or physics, to name a few.

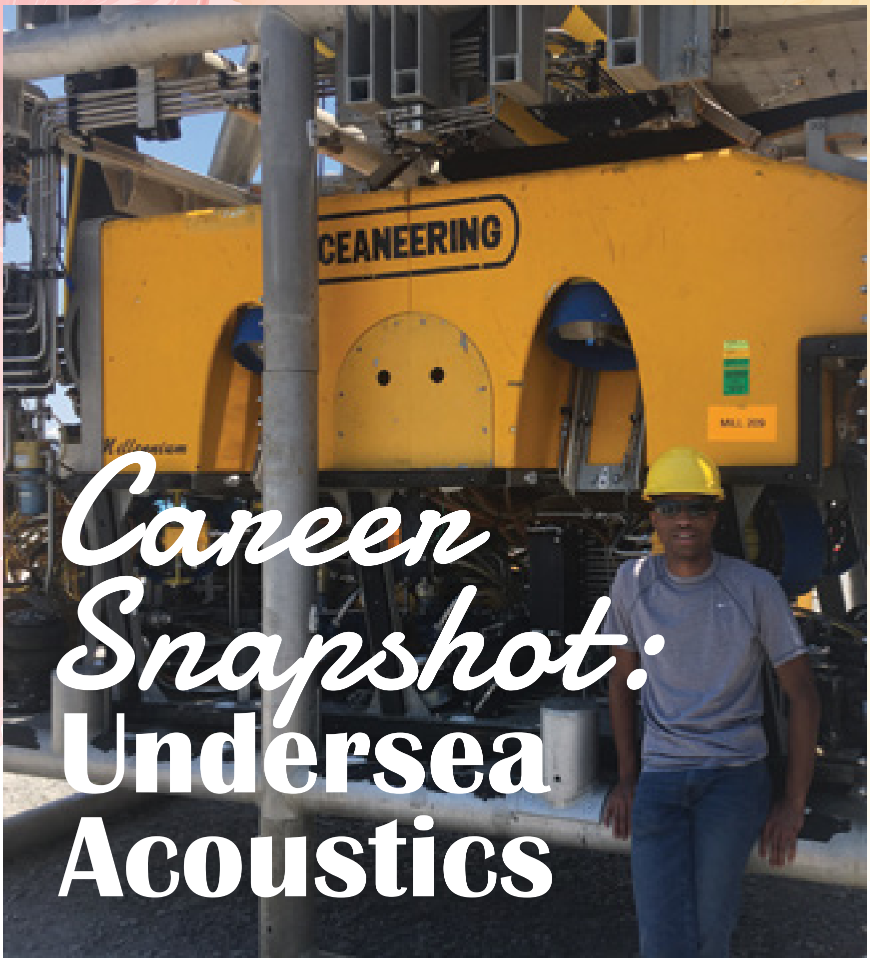
Many large companies employ acousticians to study the acoustics and vibrations of the systems or products that the company develops, maintains, or studies. Acousticians can also be found in consulting companies that provide services in building acoustics and noise and vibration control. In the United States, the National Institute for Occupational Safety and Health (NIOSH), the National Oceanic and Atmospheric Administration (NOAA), and the military employ acousticians. With a graduate degree in acoustics, you could also teach or conduct research at a college or university.

Since there are so many different fields of acoustics, there are many kinds of acousticians and career opportunities. A good approach is to find people doing work you would like to do and see what their educational paths look like. Where can you find them? Consider attending an Acoustical Society of America (ASA) meeting to meet acousticians, learn more about the field, and discover exciting possibilities for your future. Meeting information is available at acousticalsociety.org. //

ABOUT ASA

The Acoustical Society of America (ASA, acousticalsociety.org) is a professional society that aims to increase and diffuse the knowledge of acoustics and promote its practical applications. ASA members are both academic and professional acousticians. The society hosts meetings, publishes the *Journal of the ASA*, and provides resources for acoustics education, among other activities. Members of SPS are eligible for free membership in ASA. For details see spsnational.org/about/membership.

ASA
ACOUSTICAL SOCIETY
OF AMERICA



Career Snapshot: Undersea Acoustics

LEFT: Noah Jenkins stands in front of a remotely operated vehicle (ROV) prior to its deployment for an undersea experiment. Photo courtesy of Jenkins.

by Noah Jenkins, Senior Engineer in the Undersea Systems and Acoustics Group, Systems & Technology Research (STR)

Why is undersea acoustics important?

An Introduction to Underwater Acoustics by Xavier Lurton, an invaluable reference book for those in the field, provides a nice summary of the practical uses of acoustic waves underwater:

— Detecting and localizing obstacles and targets. This is the main function of sonar (**so**und **na**vigation and **r**anging), which is used primarily for military applications such as antisubmarine warfare.

— Measuring characteristics of the marine environment. For example, you can use acoustics to map seafloor topography.

— Transmitting signals. This includes applications such as transmitting data acquired by underwater scientific instruments.

Taking advantage of these practical applications requires designing and building undersea acoustic systems tailored to meet specific needs. For example, the US government collaborates with industry companies to design and build high-performance, long-range sonar systems for naval applications. Undersea acoustics also has a strong presence in academic and research domains, such as universities and navy research labs. Undersea acousticians have successful careers in all of these environments.

Someone with a career in undersea acoustics may be disguised with a title other than "undersea acoustician," which speaks to how interdisciplinary the field is. The pathway to a career in this area—and the training for working in this space—can vary significantly from person to person. I was initially exposed through an internship at a small company that specialized in developing undersea acoustic systems. The technical staff included people with bachelor's degrees in engineering, physics, and mathematics. Some also held graduate degrees in those fields.

After completing a bachelor's degree in applied mathematics, I was hired as an engineer at General Dynamics Applied Physical Sciences. Today, I am a senior engineer in the Undersea Systems and Acoustics Group at Systems & Technology Research (STR). I design, analyze, and implement sonar signal processing algorithms for high-performance systems. These algorithms allow us to extract useful information about an underwater object of interest from signals generated by electromechanical acoustic sensors called hydrophones.

In sonar systems, a typical signal processing chain consists of the following modules: bandpass filtering, beamforming (array processing), detection and clustering, tracking, and finally, classification. Robustly implementing each of these modules requires a strong understanding of the sound propagation physics in the area where the sonar is deployed. To help get this information, we utilize numerical models to simulate how sound propagates in the ocean under assumed environmental parameters. In addition to designing operational algorithms, I sometimes do research to better understand a problem our system needs to address.

There is significant research on undersea acoustics going on, primarily driven by its importance to naval applications. For example, researchers in academia or industry might investigate how a particular ocean phenomenon affects sound propagation or how to exploit the feature of an ocean waveguide to transmit sound very far away.

What I enjoy most about working in undersea acoustics is the breadth of technical fields it intersects with. I work with and learn from people with a variety of technical backgrounds and skill sets. Additionally, many of the projects I work on require at-sea testing and experiments—this has afforded me the opportunity to travel to new coastal and offshore destinations. Working on the unique, challenging problems in this field is both enjoyable and rewarding. //

FLORIDA INTERNATIONAL UNIVERSITY

GRADUATE PROGRAM IN PHYSICS

The Graduate Program in Physics at FIU offers talented students the opportunity to pursue a Ph.D. in several areas of experimental and theoretical physics such as theoretical and experimental nuclear/particle physics, biophysics, atomic molecular optics, nanophysics and condensed matter physics, astrophysics, physics education, and medical physics. Ph. D. students are offered assistantships that include stipends, matriculation waivers, and health insurance. Entering students typically have a Bachelor's degree in physics or a related field. Applications are due by the 5th of February.

case.fiu.edu/physics
Email: physicsgrad@fiu.edu
11200 SW 8th Street, CP 204, Miami, FL 33199

SAN DIEGO STATE UNIVERSITY

MASTERS IN PHYSICS, MASTERS IN MEDICAL PHYSICS

Application due: May 2, 2024

Apply: https://bit.ly/3oviU3r

Degree(s): PhD, MS

Fields offered include: Optics, CMP, TheorNP, MedPhys, BioPhys

Questions: fweber@sdsu.edu

- **$15,360** average stipend per academic year; **$4164** part time in-state tuition waiver
- **10:1** student to faculty ratio
- **90%** of grad students are receiving assistantship support

San Diego, California
physics.sdsu.edu

UNIVERSITY OF WYOMING

Laramie, Wyoming
www.uwyo.edu/physics/graduate-program

GRADUATE PROGRAMS IN PHYSICS

Application due: January 20, 2024

Apply: https://bit.ly/3s64ETI

Degree(s): PhD, MS

Fields offered include: astronomy and condensed matter physics

Questions: physics@uwyo.edu

- Total graduate students: ***40***
- Women graduate students: ***16***
- Number of faculty: ***15***

UAB THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

DEPARTMENT OF PHYSICS

UAB Physics conducts high impact research on ***Materials Under Extreme & Non-equilibrium Environments***, building on the convergence of Physical and Digital Sciences with Engineering and Medicine. Now hosted in a new Science & Engineering Complex, our research programs and MS concentrations on Materials, Computational, Instrumentation, and Laser Physics focus on materials emergent properties and ultrafast responses, https://www.uab.edu/cas/physics/. Student training includes x-ray, neutron, and computational resources at National Laboratories, with many of our Ph.D. graduates employed by industry.

uab.edu/cas/physics
Phone: (205) 934-4736 • Email: physics@uab.edu
1720 2nd Avenue South, Campbell Hall 310, Birmingham, AL 35294-1170

So You Want to Go to GRADUATE SCHOOL

by Matthew J. Wright, Associate Physics Professor and Chair, Adelphi University

Graduate school can be one of the most rewarding and exciting opportunities in your life. It can be transformative.

The training that you receive in the process of obtaining a PhD puts you at the forefront of human knowledge and technology while simultaneously exposing you to the deeper workings of the universe. You'll develop confidence and the ability to solve nearly impossible problems.

Pursuing a master's degree expands your subject knowledge and prepares you for independent projects and leadership roles, while a professional degree, such as a JD or MD, is essential for some career paths.

A graduate degree can open up an array of career opportunities that were once inaccessible to those outside of an elite social and economic background, such as finance, management consulting, and faculty. Sounds amazing, right?

Get on the grad school path

If you're considering graduate school, here's my most important advice: Get out and meet people! Even if you're a sophomore or junior, now is the time.

Many undergraduates in physics, astronomy, and related fields apply for summer research opportunities during their second or third year. Summer research is an excellent way to see what graduate school is like—you are paid to work on an amazing research project, develop relationships with experts who can give advice and write letters of recommendation for you, and get a peek into the lives of the graduate students in your lab.

Research opportunities are somewhat competitive, so apply to lots of external programs, such as Research Experiences for Undergrads (REUs), programs at national labs (e.g., the Department of Energy's SULI program), international labs (e.g., CERN), the SPS Summer Internship Program, and any others that interest you. Also, ask about summer research opportunities at your school—sometimes there is nothing available until you ask! Applications for summer programs are often due in January.

Professional meetings are another great place to find out about graduate programs. Each year the American Physical Society and American Astronomical Society host big meetings with graduate school fairs. Attend, if you're able, and talk to all of the representatives. The Physics Congress, coming next in 2025, is another fantastic conference for undergraduates that features a large graduate school fair. But you don't need a grad school fair to find out about grad schools. Ask the people you meet where they went to graduate school and what it was like. Ask current graduate students about their programs, ask fellow undergraduates where they are planning to apply, and ask professors where they teach.

If traveling long distances is difficult, there are likely local and regional meetings, such as SPS zone meetings and APS section meetings, that can introduce you to graduate school options and potential mentors. If you want to go to graduate school in another field, check out the key meetings in that field. Talk to everyone, and ask tons of questions!

ABOVE: Matthew Wright.

If you're interested in programs that aren't represented at meetings or you have specific questions, simply email the graduate program coordinators.

At the same time you're looking for a great place to go to school, schools are looking for great students. Graduate students do vital work for universities, and they are always looking to bring in wonderful students (hint, that's you) who are a great fit for them. So, while it might sound intimidating to attend a graduate school fair or email a graduate coordinator, programs are eager to hear from you. In fact, they're hoping you'll reach out.

Find programs for you

After you've explored lots of programs, it's time to figure out how many and which programs you should apply to. This may not be easy. PhD programs take about six years, sometimes more, so think about location and quality of life as you consider your options. Here are some other factors you might want to consider:

— **Field of study.** Apply to schools that focus on the area you're interested in, or if you have several interests, apply to those with many options.

DON'T MISS THE 2025 PHYSICS CONGRESS

Hosted by SPS and Sigma Pi Sigma, the next Physics Congress will be October 30–November 1, 2025, in Denver, Colorado. Keep an eye on the SPS website for details, spsnational.org.

- **Advisors.** Most professors appreciate hearing from students interested in working with them. If you find an advisor whom you trust and want to work for, that could be a great reason to apply to a particular school.
- **Your long-term career goals.** These can be hard to define, but start asking yourself questions like, Can I envision a pathway to my desired career from this program? What are the barriers to success?

The quality of a school's research in your field is more important than the name of the school. Don't just apply to the big names. Find schools that are a good fit for you, and cast a wide net. I applied to six graduate schools, but I have students who've applied to ten or more.

Craft successful applications

If you're considering graduate school in physics, I advise taking the general GRE and physics GRE during the spring of your junior year or fall of your senior year. Not all graduate schools require or accept them, but some do. You don't have to report your scores. And, arguably most importantly, the process of studying for the physics subject exam will be a beneficial review of the field. You'll want to look up the exam dates and start studying early.

As part of your application, you'll need to write essays. Think through what you are going to write for each school and be direct—address why *that* program should accept you. Have more than one set of eyes proofread your drafts, such as your school's writing center and a professor. The writing center can help you smooth out your essays, and your professor can make sure they will resonate with admissions committees.

You'll also need three letters of recommendation. Choose people you trust and have had good experiences with. Most of your letters should come from research advisors and professors in the field; however, it's okay for one letter to come from a coach, boss, or nonscience professor with whom you have a strong history. Don't feel bad asking professors to recommend you—they expect and enjoy writing letters of recommendation for their students. At least I do.

Wrap it up—for now

After your applications are in, it's time to relax and wait. It's common not to hear back for a couple of months. This can be stressful, but luckily, you'll have plenty of exams and homework to keep you busy!

Working toward my PhD was one of the most powerful experiences of my life. I became an expert in diode lasers, published papers, and walked out of the lab a professional—trust me when I say that I didn't start there. The process transformed me! And I've seen it transform many of my former students too.

For now, talk to people and find out as much information as you can, take time to make your applications perfect, and meet the deadlines. You got this! //

GET FUNDING FOR CONFERENCE TRAVEL

SPS offers travel support to undergraduates presenting research at or reporting on national physics and astronomy meetings. Applications for SPS Travel Awards and Reporter Awards are accepted on a rolling basis. Learn more at spsnational.org/awards/individual-awards.

WHY CHOOSE TEMPLE UNIVERSITY FOR YOUR PHYSICS PhD?

FACULTY

Research active—across nuclear, particle, condensed matter, atomic and molecular physics—with funding from NSF, DOE Office of Science and W.M. Keck Foundation

LOCATION

Convenient East Coast location close to top research partners and Brookhaven and Jefferson labs, hubs for the next generation of nuclear physics research with the Electron-Ion Collider

FOCUS

Strength in high-performance computing, data science and computational physics

FUNDING

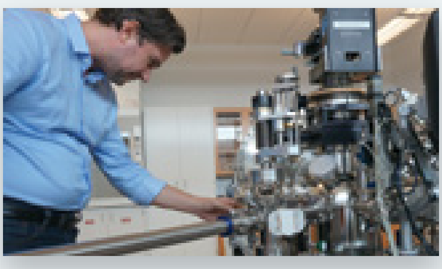
First-year summer guaranteed and University Fellowships available for competitive applications

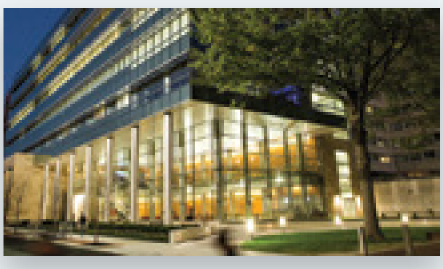
FACILITIES

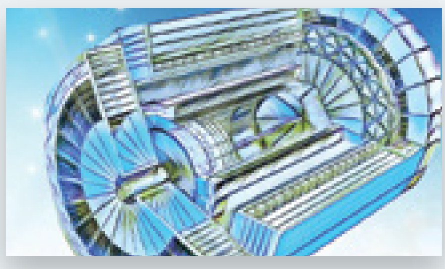
Science Education and Research Center with advanced research labs, collaborative spaces, clean rooms and a low-vibration scanning tunneling microscope facility

LIFESTYLE

Philadelphia offers varied housing options, world-class urban amenities and easy access to parks and outdoor activities







Learn more about the department and PhD program at **phys.cst.temple.edu** or contact:

Prof. Martha Constantinou
Physics Graduate Admissions Director
physgrad@temple.edu

Temple University
College of Science and Technology

SPS SUMMER Internship Program

Internships are **10-week-long positions** in science policy, communication, research, education, and outreach.

All internships **include paid housing, a competitive stipend, a commuting allowance, and transportation** to and from the Washington, DC area.

For more information, view the previous work and journal entries of SPS interns at **spsnational.org/programs/internships**.

Applications due January 15

AIP

SPS

GRAD SCHOOL APPLICATION TIMELINE

A sample schedule for weighing options and applying to programs

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma

Learning about graduate schools and applying to programs is a time-consuming process, but working on it a little at a time can make it a lot less stressful. Below is a suggested timeline based on a four-year undergraduate experience that transitions right into a graduate program, though 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 to work for you. And if you're in your final year of college, no need to panic! Just jump in where you can.

Years 1-2

— Get started on research! Talk to professors, advisors, and classmates to find opportunities, and apply for summer research experiences (e.g., REUs) and internships.
— Find out what schools your department's alum attended and what they're up to today.
— Attend career fairs and department colloquia to learn about career options.

Year 3

— Talk to current and recent graduate students about their experiences.
— Identify what you're looking for in a program: size, location, department culture, research specialties, financial assistance, etc.
— Browse GradSchoolShopper.com, and visit program websites.
— Look into fellowships and scholarships that offer financial and professional support to grad students, like the NSF GRFP and the Hertz Fellowship. Their deadlines are often *one year before* you start grad school, and the awards follow you wherever you decide to go.
— Start a list of programs that interest you.
— Check program prerequisites to make sure your coursework is on track.
— Check the financial packages offered by the programs on your list to make sure they'll meet your needs.
— Check whether those programs require entrance exams. If so, look up the details, decide when to take the exams, request fee waivers if applicable, register, and create study plans.
— Take entrance exams, if applicable.

Summer before year 4

— Decide where to apply. Many students submit 6–12 applications.
— Look at the application essays required by each program. Draft a personal statement, research statement, and responses to all prompts. Draft a résumé or CV. Ask faculty members and mentors for feedback on everything.
— Plan for application-related expenses. Most application fees are $60–$120. Entrance exams and official transcripts often have fees too. If cost is a barrier, request waivers and consider asking your department or lab for support.

Year 4, fall semester

— Make a spreadsheet to track the status of each program's application requirements and deadlines.
— Take entrance exams, if applicable.
— Request transcripts, exam scores, and letters of recommendation early. Ask letter writers at least four weeks before the due date.
— Finalize your personal statement and essays for each program. Finalize your résumé. Ask the writing center or a friend to proofread everything.
— Submit your applications, and make sure your letters are submitted too.
— Take a well-deserved break!

Year 4, spring semester

— Confirm that your applications were received.
— Prepare for and participate in interviews and site visits, if applicable.
— Consider your options and decide what's next for you!
 ş If you accept an offer, decline others immediately.
 ş If you don't receive offers, know that you're not alone. Explore nontraditional routes such as bridge programs, which often have later application deadlines, and talk to your professional network about other possibilities.
— Thank all those who helped you. Your professors and mentors can be a source of support and collaboration for years to come. Let them know your plans, and keep in touch. //

This article is adapted from an earlier version that appeared in the 2021 issue of GradSchoolShopper *magazine.*

FINDING GREAT Grad Programs for You

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma

The most important thing to know about searching for a grad program is that there isn't just one "right" program for you•there are likely many places where you could thrive and excel. The key is to identify what is best *for you* and *your goals*. Keep in mind that the overall purpose of attending graduate school isn't to get another degree, or even to get a job in a specific field, but to further your career and life goals. There are probably many pathways and many programs, degrees, and advisors—sometimes wildly different ones—that can help you achieve your goals. The following questions highlight some factors to consider while exploring programs. The more honest you are about your needs, preferences, and goals, the easier it will be to identify programs that will help you be successful.

Questions for you

Physical location

- Would a coastal, midwestern, or mountain location be best?
- City, rural, or suburbia?
- Warmer or colder climate?
- How far from home are you willing to go?

Department culture and vibe

- Would you prefer a larger or smaller program?
- Which of the following are non-negotiable for you in a program?
  - ş Diverse student body
  - ş Outreach opportunities
  - ş Active grad student group
  - ş Close-knit community
  - ş Diversity, equity, and inclusion efforts
  - ş Interdisciplinary research
  - ş Industrial partnerships
  - ş Accessible faculty

Research

- What kind of research would you like to do?
- Would you like a larger or smaller research group?
- Would you work best with a hands-on advisor? A results-driven advisor?
- How often do you want to see your advisor?
- Would you like to work with a national lab, industry lab, or observatory?

Your future

- What do you hope your life looks like in ten years?
- What kinds of programs could get you there?
- Where would you like to work after graduating?

Questions related to programs

Exams and research

- What percentage of students who start the program finish?
- When do students have to select an advisor?
- Are there opportunities to partner with industry, other disciplines, or government labs?
- Is there a qualifying exam? If so, when is it given? What percentage of students pass?
- How is the department addressing diversity, equity, and inclusion?
- What kind of career preparation services are available to students?
- How are struggling graduate students supported?

Financials

- Are fellowship, teaching, or research positions available?
- How much are the stipends? For how many years is funding guaranteed?
- Are tuition and fees waived?
- Is there health insurance? How much does it cost?

Questions for potential advisors

Overall

- What is your work style?
- How often do you travel?
- Do you have funding for additional students?
- How often do you meet with students individually and as a group?
- Could you connect me to some alumni from your lab?

Expectations for students

- How much time do your students spend in the lab each week?
- Do students typically work nights, weekends, or holidays?
- How long does it take students in your lab to graduate?
- How often do your students travel?

Questions for grad students in the program

Overall
- How much time do you spend each week on homework? Research?
- What do you like best about the department? What would you change?
- What do you wish you had known before you started?
- If you could do it over, would you choose the same program?
- Is there a graduate student group?
- Are graduate students unionized?

Research
- How do students find out about research openings?
- Is it common for students to change research groups?
- Can students work with faculty outside the department?
- Can students do research at national labs or observatories?
- Who are the advisors to avoid?

Life outside the program
- How expensive is housing?
- Where do grad students typically live? How long is the commute?
- What do grad students usually do on weekends?
- Do students study together? Hang out together?
- Is the stipend enough?
- Do I need a car? Are there parking fees?

This list is far from exhaustive, but I hope it helps you think about what you want out of your graduate program—this is all about you and your future. Happy grad school searching! //

This article is adapted from an earlier version that appeared in the 2021 issue of GradSchoolShopper *magazine.*

Lessons from GRADUATE SCHOOL ABROAD

by Paul McKinley, Graduate Student in Energy Technology Engineering, University of Cambridge

ABOVE: Paul McKinley.

I enjoyed studying physics during college, but I was most interested in the applications it unlocked for understanding the energy sector and decarbonization. I had missed the opportunity to study abroad due to COVID-19 and didn't feel ready to undertake a PhD, so I applied to international master's programs during my senior year. I'm now in a master's of philosophy (MPhil) program in energy technology engineering at the University of Cambridge.

MPhil programs are usually one year and serve as preparation for a PhD program, although many graduates pursue other paths. My first term was exciting, challenging, and wholly different from my undergraduate experience. Lectures are longer and faster paced, but the coursework can be more interesting and in-depth compared to weekly homework sets.

The MPhil curriculum covers a range of topics in the energy sector, from renewable power generation systems to combustion processes and electricity market design. It's focused on engineering, but my physics and math background has been helpful (you can actually use some of those headache-inducing derivations beyond undergrad).

Living in Cambridge is exciting. It's exhilarating and deeply humbling to walk through a campus shared at various points in time by pioneering figures not only in science, but in all academic fields. Beyond the picturesque grounds and cobblestone streets, I'm fortunate to have found supportive communities in my academic program, residential college, and the university cross country team.

At times, the single-year duration of the program feels punishingly short. There is so much information and so little time to absorb it! As I write this, a little over halfway through my degree, I'm reflecting on some lessons I've already learned: Starting grad school can reveal how interesting a field is while also reminding you how much you don't yet know, supportive communities are critical for weathering the inevitable periods of stress and frustration, and British scones and American scones are fundamentally different pastries. //

MAKING YOUR LIST

GradSchoolShopper.com: A search tool for physics and astronomy programs

by Kendra Redmond, Editor

Searching through graduate programs can be overwhelming—there are lots of options! It's often helpful to talk to professors, research advisors, and alumni from your department, but if you want a broader view, check out GradSchoolShopper.com (GSS).

GSS is a free online resource for browsing, sorting, and comparing hundreds of graduate programs in physics, astronomy, and related fields. It's hosted by the American Institute of Physics, home to the Society of Physics Students.

The backbone of GSS is an extensive collection of program profiles relevant to physics and astronomy majors. Each profile includes research specialties and contact information, and many programs provide more details: application requirements, department descriptions, quick links to relevant web pages and social networking pages, and even videos and photos.

What can you do on GradSchoolShopper.com?

— Search programs by school, specialty, or keywords.
— Browse programs by more than 50 research specialties.

GradSchoolShopper presented by AIP Empowering Physical Scientists

— Sort programs by degrees offered, campus setting, acceptance rate, or application deadline.
— Narrow your options by state or country (most programs are in the United States).
— Create an optional free account to save your favorite programs and download search results.
— Browse *GradSchoolShopper* magazine, the precursor to this issue of the *SPS Observer*, to learn more about all things grad school.
— Find links to quality resources like physics bridge programs, data on physics and astronomy graduate education, and the Women+ of Color Project. //

YOUR GUIDE to Grad School Visits

by Ben Perez, Contributing Writer

You can learn a lot about a graduate program through online research, but nothing compares to an in-person visit. It's a great way to see the campus, talk to faculty members, and hear from current graduate students before you commit to a program. In general, graduate school visits fall into two broad categories: preapplication visits and postacceptance visits.

Preapplication visits

These visits are a great way to explore schools before you apply. They aren't always convenient, but you can learn a lot and eliminate schools that aren't the right fit early. You usually have to arrange these visits yourself, although some undergraduate programs and conferences will take groups of students on grad school tours. It's worth asking!

Before you go

— Do your research on the program and write down your questions.
— Identify three to five professors whose research interests you.
— Reach out to the graduate student coordinator and possibly the admissions coordinator, administrative specialist, or chair about visiting. Ask how you should proceed, and follow up on any recommendations.
— Email professors whose research interests you—introduce yourself and request a meeting or tour. No response? Follow up until you get one.
— Set up a campus tour and time to chat with current graduate students.
— Write down questions for everyone you'll meet.

During the visit

— Be punctual—it shows respect and responsibility.
— Get to know the professors and let them get to know you.
— Find out what the program is really like from current graduate students.
— Wander around and enjoy!

When you get home

— Send thank you emails to reinforce your newly established relationships and leave a good impression.
— Write down your thoughts and key details. Can you see yourself thriving there? Would the program help you reach your goals? Do you want to apply?
— If you apply, tell the faculty members you met—they may advocate for your acceptance.

Postacceptance visits

Grad schools want those they've accepted to say yes, so most will host visit weekends in early spring. They'll often cover travel and lodging for accepted students coming from within the United States. If you get invited, go! Go even if you've already visited. Visit weekends are designed just for you and your prospective classmates, so they're informative and fun. And you'll have another chance to impress potential research advisors.

Before you go

— RSVP. Do we even have to say it?
— Plan your travel according to the guidelines you receive.
— If you haven't already, identify three to five professors whose research interests you. Let the department know you'd like to meet with them.
— Come prepared with questions about the program and for potential research advisors.

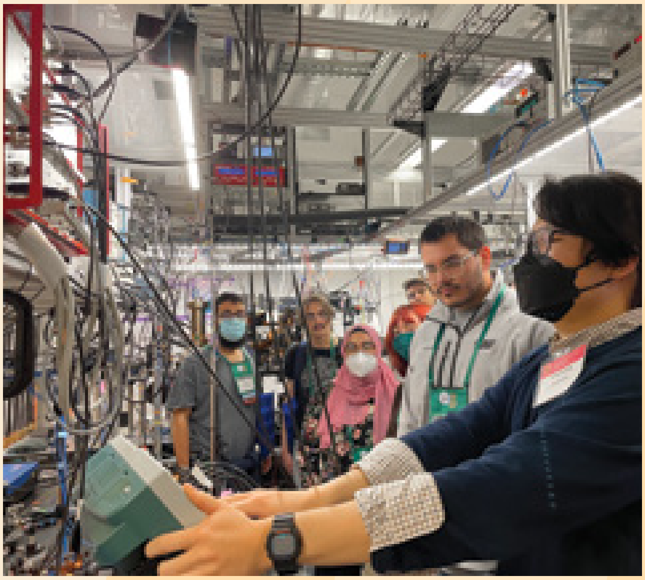
During the visit

— Be yourself. If you don't feel accepted for who you are, that's probably not the place for you.
— Talk to people and ask tons of questions.
— Have fun! (But not so much fun that you can't get out of bed the next day.)

When you get home

— Send thank you emails to everyone, especially the people whose labs you might want to join.
— Evaluate your visit. Write down your impressions and talk with friends and mentors. Does it feel like a good match?

After your postacceptance visits, it's decision time. What feels right? What excites you? Where do you feel comfortable? Consider what you want and what will help you thrive. Keep in mind that there aren't bad choices, only choices. And then send in that acceptance form. //



ABOVE: Undergraduates attending the 2022 Physics Congress tour one of the labs at the University of Maryland, College Park. Photo courtesy of Donna Hammer.

Selecting the Right PHD ADVISOR FOR YOU

by Molly McDonough, Materials Science and Engineering PhD Student, Penn State University

Deciding to pursue a PhD is a big deal—you're committing to one place for the next five to seven years of your life.

Even more important than deciding *where* to attend is deciding *who* will be your thesis advisor, the principal investigator (PI). This may be the only time in your career that you get to choose your boss, and since it's a long-term commitment and your advisor will have a direct impact on when you graduate and your career path, you definitely want one who's a good fit for you.

I've learned from personal experience that taking these steps can help you identify a good match.

1. Know yourself first

Consider what kind of research interests you. Experimental, theoretical, computational, or a mix of all three? What subfields do you find fascinating? What kind of career do you want? What research can help you get there?

2. Connect with potential advisors and their students

Once you narrow down your research interests, look for professors working in that area. Aim to identify three to five for each program you're considering applying to. Get a sense of their research and lab culture. Google their names and see what comes up. Then email those who could be a good match. Ask if they have space for new graduate students in the current application cycle and, if so, whether they can meet with you. If they aren't local, consider a Zoom call.

During the meeting, ask about their research, funding status, management style, travel schedule (some PIs are rarely on campus), group members, and work expectations. Here are a few questions to get you started:

— What kind of funding do you have for new graduate students?
— What are your research and publishing expectations?
— Do group members typically work evenings and weekends?
— What is your management style?
— How long does it take for your students to graduate? Where do they go?

Next, find out what it's really like working for those on your shortlist. Most PIs have a group website that lists current students and alum—reach out to them. Most will be happy to share their experience with you.

3. Consider your options

By now you've been accepted. Congratulations! It's time to seriously weigh your options for advisors. Consider programs with at least two PIs you'd like to work with—there are no guarantees. Also, consider the prestige of the advisors and the pros and cons of working in a prestigious lab. Here are some:

Pros:
— Your group may publish frequently in high-impact journals.
— You may get a leg up in the academic job market.
— You may get impactful letters of recommendation for future positions.

Cons:
— You may face unreasonable expectations.
— You may be in a highly competitive environment.
— The lab may be run by postdocs or graduate students if the advisor frequently travels.

4. Go get your PhD!

Hopefully you'll have an excellent advisor, but you don't have to suffer if things aren't working. Talk to your advisor if you think it might help, and reach out to your graduate student coordinator, mentors, or trusted classmates about unresolved issues. If you can't find a solution, you're not stuck. You can always change advisors, departments, and even programs. This is *your* PhD, and you deserve to be happy with your research topic and advisor. **//**

ABOVE: Molly McDonough.

A CAUTIONARY TALE [with a Happy Ending]

by Brittney Hauke, PhD Candidate in Materials Science and Engineering, Penn State University

When I started graduate school the first time, I did what the other students in my research group had done their first year—took four classes and did research. That was a mistake. I would never recommend taking four grad classes at once, especially in your first semesters!

Fast-forward a year. I had severe anxiety about meeting with my advisor, struggled to connect with my lab mates, worked all the time with nothing to show for it, and felt like I couldn't do anything right. During one meeting my advisor suggested that I not get a PhD. A few months later my funding was pulled due to lack of progress. I decided to finish a master's degree and leave.

Not long after, I decided to pursue a PhD elsewhere in a different field. This time I'm having a totally different experience. I get along really well with my advisor, have a supportive lab group, do research I enjoy, and have a good work–life balance.

I see now that I missed some warning signs in my first go-around. I'm sharing them here so you can learn from my experience:

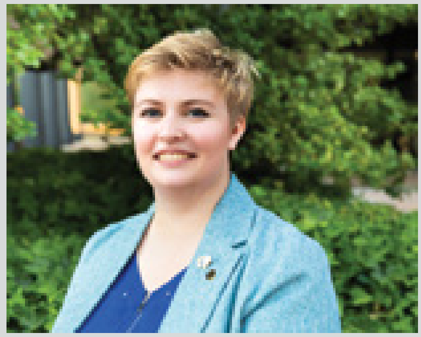
In a research group:

- Students take much longer to graduate than average.
- People work all week and most weekends and holidays.

In a program:

- Many grad students are weeded out via classes or the qualifying exam.
- Professors don't talk, collaborate, or really like one another.
- The department isn't receptive to grad student feedback.
- Grad student funding is inflexible or not guaranteed.

The presence of one or two red flags might be fine, but be on alert if you see several. Graduate school is really hard, but it shouldn't be traumatic. If you ever feel like it is, take action—there are so many great opportunities out there for you! **//**



ABOVE: Brittney Hauke.

This article is adapted from an earlier version that appeared in the 2021 issue of GradSchoolShopper *magazine.*

Department of Physics & Astronomy

Public night at DU's historic Chamberlin Observatory (operated by the Department of Physics & Astronomy).

UNIVERSITY OF DENVER

Why study physics and astronomy at DU?

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PHYSICS

Application due: January 5, 2024

Apply: https://bit.ly/44QmzfA

Degree(s): PhD, MS

Fields offered include:
Particle Physics and Condensed Matter Physics

Questions: gradphys@vt.edu

- ***100*** total graduate students
- ***40*** faculty members
- ***100%*** of graduate students are receiving assistantship support

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Department of Physics

PHYSICS

Application due: January 8, 2024

Apply: https://bit.ly/3093iNW

Degree(s): PhD, MS

Fields offered include: Biophysics, condensed matter physics, gravitation

Questions: salsbufr@wfu.edu

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Winston-Salem, North Carolina
www.physics.wfu.edu

DEPARTMENT OF PHYSICS AND ASTRONOMY

The Department of Physics and Astronomy at Texas Tech University offers M.S. and Ph.D. degrees in the following research areas: astrophysics, biophysics, condensed matter physics, high energy physics, and physics education. We have collaborations with research centers like CERN, NASA, Fermi, Los Alamos, and Sandia National Labs, and the alumni of our programs are employed in academia and industry. The department offers several forms of financial assistance, like the teaching and research assistantships. To be nominated for additional fellowships students are encouraged to accept offers of admission prior to February 15.

depts.ttu.edu/phas

Phone: 806.742.3767 • Email: physics.academic.advising@ttu.edu

Department of Physics & Astronomy, Box 41051, Lubbock, TX 79409-1051

PHYSICS

Ongoing rolling admission (no due date)

Apply: https://bit.ly/3tG1Vi2

Degree(s): PhD, MS

GRE Subject Test: Required

Questions: graduate@stevens.edu

- **$29,003** average stipend per academic year
- **17** faculty members
- **96%** of grad students are receiving assistantship support

Hoboken, New Jersey

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Application due: January 15, 2024

Apply: https://bit.ly/3HrSVm5

Degree(s): PhD, MS

Fields offered include:
Condensed matter, nuclear, quantum

Questions: grad@physics.illinois.edu

- **91** grad students are women
- **95%** degree completion rate
- **100%** of grad students receive assistantship or fellowship support

Urbana, Illinois

physics.illinois.edu

Make Your Applications Count

by Brad R. Conrad, Director of SPS and Sigma Pi Sigma, and Matthew J. Wright, Associate Physics Professor and Chair, Adelphi University

When admissions committees review your grad school applications, they'll consider many factors: your letters of recommendation, personal statement, academic record, research experience, accomplishments, desired research area, and personal characteristics. Together they'll decide, based on that picture, whether you're likely to be a good fit and succeed in their program. We've helped many students get into research-based physics and astronomy graduate programs in the United States and Canada—here's what we've learned along the way.

TARGET SCHOOLS THAT FIT YOU

Before applying anywhere, think about your goals, what you want from a graduate degree, what you'd like to do after you finish, and your ideal work and living environments. What do you want your life to look like in 10 years? Apply to programs that are a good fit for you, not just those ranked highly by some website.

Make a list of programs that spark your interest as you explore GradSchoolShopper.com and program websites, and talk to peers, mentors, and professors. Get *lots* of opinions. Once you have a list, here are some ways to decide whether a program should stay on your shortlist:

- Revisit your goals. Would this program help you reach them?
- Revisit your preferences. Are you really okay with living there?
- Find out about the department and grad student community. Could you see yourself being happy there?
- Email professors you're interested in working with and get to know them. Could you see yourself working with any of them?
- If you have many interests, consider whether the program has a sufficient breadth of research fields and opportunities for you.

Students often apply to multiple programs—6 to 12 is not uncommon—but apply only to those that truly fit you, your interests, and your needs.

PERSONALIZE EACH APPLICATION

A personalized application is much more likely to impress an admissions committee than a generic one. As you work on your applications, consider what you can bring to each program. Then tailor your application, including your personal statement (aka statement of purpose), to *each program*.

- If there are any prompts in the application, answer them directly.
- In your personal statement, highlight why you're a good match for *that* program. Name-drop research projects and potential advisors that interest you and otherwise demonstrate that you're familiar with *that* program.
- If you've visited the department or met with any of its faculty members, say so.
- Double-check your files before uploading them. Since you'll have different versions of your personal statement, make sure you send the correct one to each program!

Let your passion, personality, grit, and perseverance shine through. Graduate programs want to admit students who truly wish to be there and are likely to attend if admitted.

MAKE YOUR RECOMMENDATION LETTERS COUNT

Programs typically ask for three letters of recommendation. Request letters from those who can speak to who you are and your likelihood to succeed in grad school. Ideally, ask research mentors and faculty members in the field who know you well.

Give your letter writers plenty of advanced notice and a copy of your résumé or CV. Remind them about projects you worked on together, your contributions to their classes, and the skills they've seen you develop. The more personal information letter writers have and remember about you, the stronger your letter will be.

DON'T LET PERCEIVED BARRIERS STAND IN YOUR WAY

Many qualified students don't apply to graduate school because of lower grades or GRE scores, lack of research experience, feelings of self-doubt or inadequacy, financial barriers, or other factors. If you're on the fence, share your concerns with trusted professors and mentors who know you well. They can offer honest assessments of your readiness, suggestions for strengthening your skills or preparation, and recommendations for programs.

If your academic track record or lack of research experience has you worried, talk to the graduate school coordinator at programs that interest you. They may be more flexible than you think. In addition, briefly address any extenuating circumstances that account for problematic aspects of your application in your personal statement.

If application costs are a barrier, request fee waivers for financial hardship. Many programs will grant them. Ask around on campus too; sometimes research groups, departments, and student organizations will help with graduate school–related expenses.

START EARLY AND BE ORGANIZED

Some programs accept applications as much as one year in advance. Carefully track the due dates of required materials for each program so that you don't miss anything. And if you have any questions about a program or application, don't hesitate to ask the program's graduate coordinator for guidance. //

This piece is adapted from an article published in the Fall 2019 issue of the SPS Observer.

COMMONLY REQUIRED APPLICATION MATERIALS

- Application form
- Résumé or CV
- Written essays (e.g., personal statement or research statement)
- College transcripts
- Letters of recommendation
- GRE and English proficiency test scores (if applicable)

Managing Grad School Applications During a Busy Senior Year

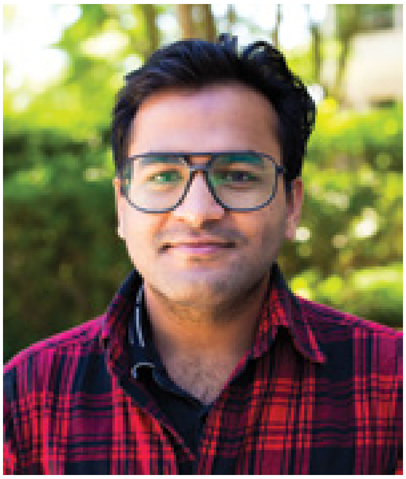
by Div Chamria, PhD Student in Materials Science and Engineering, University of Illinois Urbana-Champaign

I applied to 13 PhD programs during my senior year, so I was working on coursework, research, exams, essays, and interviews at the same time. Applying felt like a full-time job. How did I manage? I had a plan. And I stuck to it (for the most part).

Researching your options is crucial. I recommend making a spreadsheet of all the programs that interest you in the summer before your senior year. I started off with a relatively long list and narrowed it down based on research areas, potential research advisors, and factors such as location and program size. This can be pretty time-consuming, but it allows you to make an informed choice on where to apply.

The main application materials you'll need to work on are your CV or résumé and your statement of purpose. I used mine to highlight my research experience and explain why I was pursuing a graduate degree. Once you have a draft of your statement, I recommend asking advisors, friends, and professors for feedback.

None of the programs I applied to required the GREs. If you take them, I recommend preparing for them during your junior year—studying can take up a significant chunk of time.



ABOVE: Div Chamria.

If you are accepted into programs, choosing one can be difficult as there are so many factors to consider, such as location, cost, reputation, research opportunities, faculty–student ratio, and campus culture. Talking to current students or alum about their experiences can provide valuable insight, but there is no perfect formula for making the "right" decision. Do your research, visit schools, and choose the program that feels right. //

What Grad Programs Look For

Interviews by Kendra Redmond, Editor

Q&A with Abdelkader Kara and Daniel Britt from the University of Central Florida

Abdelkader Kara is a professor and the graduate program director in the Department of Physics at the University of Central Florida (UCF). Daniel Britt is a professor and the program director for planetary science in the Department of Physics at UCF. The department offers the following graduate degrees: master of science (MS) in physics (standard); MS in physics (MS to PhD bridge program); MS in physics, planetary sciences track; PhD in physics; and PhD in physics, planetary sciences track.

Q Your department has two tracks. How are the physics and planetary sciences grad programs related?

A *Kara:* We admit 20-something students each year to the physics graduate program. They are mainly PhD students, with some master's degree students.

A *Britt:* Planetary sciences is a separate degree program with a different admissions process, but it's in the physics department. Depending on availability, we admit maybe three to five graduate students per year.

Q What do you look for in potential graduate students?

A *Kara:* We're always looking for great students. We use a rubric to determine admissions for the physics MS and PhD programs. Applicants receive points for a number of factors, such as GPA, research experience, strong letters of recommendation, teaching experience, and outreach activities. We don't require the general GRE, and the physics GRE is optional. Instead, we do a course-by-course evaluation to see what people have taken and whether they seem to be improving, and we allot points accordingly. Then the scores are compiled and ranked for admission.

A *Britt:* In the planetary sciences program, we don't use a rubric. We mostly look at letters of recommendation, GPA, research experience, and qualities such as motivation and initiative. We also consider an applicant's research interest and how it matches faculty research. The university has a GPA cutoff of 3.0 for admission to graduate programs, but we don't really admit people with GPAs in the B range.

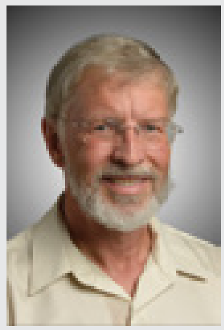
Q What commonly missed opportunities or mistakes do you see in applications?

A *Kara:* You can tell us that you want to live in Florida because it's warm or because your family lives close, and we will sympathize, but there is no place for that in the rubric. We want to know who you are and your research interests. It's a mistake not to include the areas of physics you're interested in, and it's even better to mention specific professors you would like to do research with. Not discussing this hurts your application, especially if we're on the fence.

A *Britt:* There's a difference between people who want to do planetary sciences and people who are capable. We turn down many people who would like to do it but who we don't think are good matches for our faculty and the program's rigor. Also, make sure you're interested in the kind of research our faculty is doing before you apply—reach out to them about their research in advance.

Q What advice would you give to students who plan on applying to physics graduate programs soon?

A *Kara:* Take it seriously. Complete your application before the deadline. Pay attention to everything. Prepare yourself and think ahead. Initiate research if you haven't already, and get involved in mentoring, teaching, or outreach related to physics. When you apply to a particular department, tailor at least one part of your personal statement to that place—it's a big mistake to submit a generic application. Tell us about yourself and your activities. If you have a low GPA, address it, and we may still consider you. If your GPA is low because you're a first-generation college student working two jobs to pay for school—let us know. We're looking for the person behind the paper.



TOP: Abdelkader Kara.

ABOVE: Daniel Britt.

Q&A with Raja GuhaThakurta from UC Santa Cruz

Puragra (Raja) GuhaThakurta is a professor and former chair of the Department of Astronomy and Astrophysics at the University of California, Santa Cruz. The department offers a PhD, and students may earn a nonterminal master's degree along the way.

Q Do most of your grad students have bachelor's degrees in physics or astronomy?

A It's a pretty good mix right now. It used to be the case that almost every student had a physics background because astronomy bachelor's degrees were rare. But now, probably more than 50 percent of our students were astronomy majors or received significant astronomy or astrophysics training as undergraduates. Some students come in with a master's degree; usually they're international students.

Q What do you look for in potential graduate students?

A We pay a lot of attention to applicants' essays and letters of recommendation. We pay some attention to transcripts. We look at how the student has done in the classes that matter in graduate school. We also look for gradients—when a student struggles early on but improves.

We're not simply interested in how much an applicant has achieved. That would be easier. We're interested in predicting how well an applicant will do when they get to our department, given our resources. To gauge that, we try to determine what the student achieved as an undergraduate given the resources they had.

We don't look at GRE scores at all. We think those are far-from-perfect indicators of success in graduate school.

We interview a short list of applicants before we send out offers. We ask about their favorite research project and the broader context of the project. We also let them ask us questions, which tells us whether they are interested in our program. In the end, we're looking for a good match.

Q What do you look for in personal statements and other essays?

A We look for perseverance. We look for grit. And we look for signs that the student went above and beyond what was easily available. If a student has overcome a significant obstacle, we want to hear about that.

It's tempting to pick the applicants with the most papers, but there are pitfalls in using this as a metric. First, we don't know what opportunities each applicant had to write papers. Second, it's a metric that students and faculty are gaming. If I know—as a student—that I'll get my name on a paper if I join a project about to be written up, I may decide to join that project. Then I'll have a paper, but I didn't experience the grind that is the essence of research. Every admissions committee has to watch out for this.

We also look for passion. Graduate school is such a hard grind that it can be hard to succeed unless you're really excited about what you're doing. But just saying that you're passionate isn't enough—show us your passion through your journey.

ABOVE: Raja GuhaThakurta.

Q What commonly missed opportunities or mistakes do you see in applications?

A It's very hard to make these decisions. This last cycle we had 360 applicants and made 15 offers. It's become brutal. We're not just looking at good versus not-so-good applications. We could have admitted 150 of those 360 students, and we'd have been perfectly happy. We say no to people on very flimsy grounds in hopes that they will get in somewhere else, and it will be our loss, not theirs.

Q What advice would you give to students who plan on applying to astronomy and astrophysics programs soon?

A Be sure you really want this because graduate school isn't everything it's made out to be. For example, graduate students are often not paid well, and it can be hard to afford rental prices near the school. This is a common story for graduate students around the world.

If you really want this, apply to multiple schools and have backup plans. It doesn't matter how strong your portfolio is; that's just the reality of the numbers. It's important to be realistic.

If you apply to many places and don't get in, that doesn't mean you're not fit to do research. It just means that the committees didn't see your potential amidst the glare of the hundreds of other students applying to the same program. It doesn't mean that you're not capable. Not at all.

PHYSICS AND ASTRONOMY BY THE NUMBERS

The American Institute of Physics Statistical Research Center is your source for data on education, careers, and diversity in physics, astronomy, and other physical sciences. Explore the data at aip.org/statistics.

Q&A with Diyar Talbayev from Tulane University

Diyar Talbayev is a professor and graduate physics advisor in the Department of Physics and Engineering Physics at Tulane University. The department offers the following graduate degrees: MS in physics, MS in materials science and engineering, PhD in physics, PhD in materials physics and engineering.

Q What do you look for in potential graduate students?

A Ultimately, we look for people who can complete the program. There are two major hurdles before the thesis defense: coursework and the qualifying exam. At a minimum, we want graduate students who can pass them. There's no perfect way to judge who will be successful, but we look for good grades in relevant coursework. We look for applicants who want to work in science and are motivated to work toward their goals. We read their personal statement and letters of recommendation to get insight into what the applicant has already done to illustrate this desire. For example, if a student has had a summer research experience, that's a great indicator that they want to pursue a research career. We don't require the general or physics GRE.

Q What commonly missed opportunities or mistakes do you see in applications?

A The main missed opportunity is in the letters of recommendation. Sometimes letters can be insightful and helpful, but sometimes not. We use the letters to judge a student's interest, experience, and nonacademic qualities, like motivation and collegiality.

Q What advice would you give to students planning to apply to physics graduate programs soon?

A If you can, participate in hands-on research to see whether you like it and if it fits you. It can be theoretical or in the lab. If it lights a fire in your belly, write about that in your application. //

Responses have been edited for length and clarity.

ABOVE: Diyar Talbayev.

HEAR FROM MORE DEPARTMENTS

See how representatives from Penn State, University of Alabama, and University of Maryland, College Park answered similar questions in the 2022 issue of *GradSchoolShopper* magazine.

> "The article from 2022 is very good, indeed, very similar to what I would have said."
>
> *–Joshua Winn, Professor and Director of Graduate Studies, Department of Astrophysical Science, Princeton University*

How to Write an Effective Statement of Purpose

ABOVE: Ritchie Patterson.

Q&A with J. Ritchie Patterson from Cornell University

Interview by Kendra Redmond, Editor

Ritchie Patterson is a professor in the Department of Physics at Cornell University. She has been the director of graduate studies, chaired the Graduate Admissions Committee, and advised students at and beyond Cornell on applying to graduate school.

Q What do you look for in a personal statement/statement of purpose?

A A personal statement is a narrative that pulls together information that's not in your transcript or letters of recommendation. It is the main place to describe any research you've conducted. We're interested not just in your research title or who you worked for, but how you talk about your research. What were the big picture goals? What did the research group hope to learn about nature? What did you work on? Be very specific about your particular tasks, for example, "I tested hundreds of readout boards," or "I wrote a LabVIEW program that provided data on new samples."

We also want to hear about research obstacles and how you overcame them. As you were testing all those boards, maybe you learned that the solder joints were weak and suggested a new test process. Be as specific as you can about what you did, the obstacles you encountered, and how you showed initiative to overcome them—whether that meant reaching out to an expert, reviewing the literature, or even asking your research supervisor for advice. Science never works the first time.

And finally, tell us about the lasting impact or an outcome of your work. Maybe you presented your work at a conference, or people are still using the software you wrote, or you studied an effect and showed that it was so tiny it didn't need to be considered. Then relate that outcome back to the big picture. If you made one tiny cog in a detector, what were people able to learn about nature thanks to the fact that your tiny cog was there?

Sometimes students worry because they want to do one kind of research in graduate school but did a different kind as an undergraduate. Don't worry about that. We know that students knock on dozens of doors and write multiple applications to get a research position. The research that you end up doing as an undergraduate can be a crapshoot. We don't expect a coherent evolution from one project to another, so don't set that bar for yourself. Just write about what you've done.

If you've had an extraordinary hardship, tell us that in your statement too. If you had to work full time on the family business and couldn't fit in research, let us know. Maybe you have a strong academic record in general but tanked one semester. If there's a reason—you had mono, there was an upset in your family, or you were working from home during the pandemic and had to share a computer with siblings—let us know. Don't go into a long story, just address it with a couple of sentences. To some extent, the statement of purpose is an opportunity to provide connective tissue, the explanation that underlies your transcript and experiences.

> **"In the personal statement we look to see if you've mentioned particular faculty members whom you might want to work with. This shows that you have a genuine interest in our program. And if there's something unusual in your application, please tell us about it in your statement. A brief explanation can go a long way."**
>
> *–Steven Rolston, Professor and Chair, Department of Physics, University of Maryland, College Park*

Q What if a student hasn't done any research?

A Most students manage to do research at their school or in one of many programs such as Research Experience for Undergraduates (REU) or Science Undergraduate Laboratory Internships (SULI). If not, maybe you've taken a lab course or done a class project or independent study that you can discuss in the same way. What was the overall goal? What were you hoping to discover about nature? Why was the topic scientifically interesting? What specifically did you do? And then talk about some kind of outcome, like writing up a report or giving a presentation.

You can also talk about projects that are not science related, but where you showed initiative or determination to get something done. Show the committee that you see the big picture and convey your contribution.

Q **What kind of structure do you recommend for a statement of purpose?**

A I expect an opening paragraph, which can be brief, and then one to two paragraphs for each research project or independent study you've done. Then you can add a paragraph on your outreach activities, if the program seems interested in that. And finally, a paragraph that identifies the area or areas that you'd like to pursue in grad school and explains how the university is a good fit.

The last paragraph should be different for each application. You'll want to learn what individual faculty members are doing at each school and name several whose research interests you. It's okay if you don't know exactly what you want to do, but if you don't see anyone whose research interests you, that may be a sign that you should apply elsewhere. Every now and then we get an application from somebody who's absolutely determined to work in a niche in physics that we don't offer at our university. And that's the end of that application—the student should go somewhere else.

Sometimes students think it's impressive to say they want to do theory. The reality is that universities often have more openings in experiment than theory, so anyone who limits themself to theory has extra tough competition. Flexibility in your interests is not a bad thing, and it may mean there are more opportunities for you. So narrow it down a little, but not too much.

Q **Is there room for creativity, or do you recommend sticking to the structure you outlined?**

A It's usually best to stick to the template, but I do remember reading an application from a world-class rock climber. Someone with that background has determination and the ability to overcome challenges, which are characteristics needed in grad school, so telling us about it in the statement worked in their favor. It would be a mistake to replace the other things I mentioned with a discussion of rock climbing, but you can include things that reveal your relevant skills and traits.

Q **Do you have any tips on writing style?**

A Some students worry about bragging, but bragging isn't needed if you instead focus on the science: "My job was to test hundreds of electronics boards. The boards allowed us to read out detectors that measured the energy of photons produced in collisions at the Large Hadron Collider. That's important because the Higgs boson decays into photons, so the boards enable detection of the Higgs." All of a sudden your work is sounding pretty great, even though you didn't talk about yourself.

Framing the sentences around the science also avoids the pitfall of using many "I" sentences, such as "I did …" or "I was excited to do…"

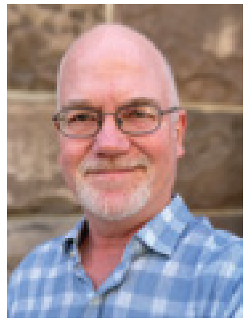
Sometimes students think that we want to know their personal story from childhood; others think we are looking for a set of skills such as multiple programming languages. We're not looking for either of those things. We want to know that you have the traits to learn, persist, and succeed in graduate school. Talk about the science and we'll learn that you're passionate about it; describe your innovations and we'll learn that you're creative; mention the obstacles and we'll learn that you're persistent. //

Responses have been edited for length and clarity.

"If you've done research, your statement of purpose should describe that research. You should demonstrate a clear understanding of the goals of your research project, your specific contribution to the project, and the results. If you don't have research experience, include other relevant experiences in your statement of purpose, such as programming, observing, or lab experiments, even those outside your current area of interest."

–Preethi Nair, Professor and Director of Graduate Recruiting and Admissions, Department of Physics and Astronomy, University of Alabama

How to Build a Strong CV and Résumé



ABOVE: Bodhi Rogers.

Q&A with Michael "Bodhi" Rogers from the University of Colorado Denver

Interview by Kendra Redmond, Editor

Bodhi Rogers is chair of the Department of Physics at the University of Colorado Denver. He created and teaches a series of one-credit professional development seminars for physics majors.

Q Many graduate programs require a résumé or curriculum vitae (CV). Why?

A Your transcript is an official record of your courses, the grades you earned, your major and minor, and the degree you received. All of this information is useful for graduate selection committees, but it only reveals one aspect of your academic accomplishments.

On a résumé, the entire contents of your transcript will typically be reduced to a few lines in the education section stating your type of degree, major and minor, the date the degree was awarded, and your GPA (if you choose to include it). The rest highlights your cocurricular activities, such as leadership roles, research, presentations, publications, and work history, and the skills and abilities you gained during your undergraduate career. Together, your résumé and transcript give the selection committee a more complete view of your accomplishments and abilities.

Q What's the difference between a résumé and a CV?

A A résumé is typically short, a couple of pages at most, and highlights your experiences, accomplishments, and skills relevant to the job or program you're applying to. I think of a CV as an uber-résumé that contains *every* accomplishment and highlight of your career. This definition is typical in North American academia, although in other usages the term CV may be interchangeable with résumé.

Q Which one should students write?

A I encourage you to create a comprehensive CV (the uber-résumé). Then, when you're applying to something, just remove the irrelevant lines. I created my CV using LaTex, which makes it super easy to comment out the entries I don't want on my résumé.

Your CV should include your education; work, research, teaching, and leadership experiences; awards and honors; professional society memberships; presentations; and publications. You should also include your skills and proficiency level, even if it's hard to classify. The takeaway message is to include *everything* on your uber-résumé.

Q How can students strengthen their CV and résumé?

A I teach a professional development seminar to students midway through their undergraduate careers. They build a résumé, look at their successes, and identify any gaps. Then they develop an individualized plan for filling out their résumé over the next few semesters. This might include presenting at an upcoming conference, publishing in the *Journal of Undergraduate Reports in Physics* (JURP), or taking on a leadership role in SPS. The students also build a calendar of deadlines related to their plan—graduation comes fast!

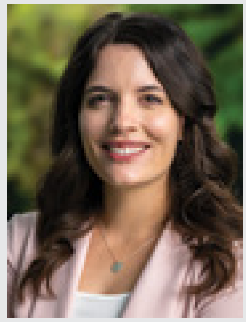
Q What are some emerging ways students can convey their accomplishments?

A A *comprehensive learner record* (CLR) is similar to a transcript but includes cocurricular accomplishments, such as being a club officer, winning an award, or presenting at a university symposium. Some schools are piloting the use of CLRs to capture and convey more complete pictures of their students.

Using *badging* to record accomplishments is also becoming popular. You can get a badge by attaining an assessed competency or participating in a workshop or event. LinkedIn's skill assessments feature is an example. How well do you know how to program using Python? The badge you earn conveys your skill level to others. //

Responses have been edited for length and clarity.

How to Create a Compelling Highlight Reel (aka Résumé)



ABOVE:
Lindsay Buettner.

Q&A with Lindsay Buettner from Argonne National Laboratory

Interview by Kendra Redmond, Editor

Lindsay Buettner leads the university student programs at Argonne National Lab (ANL). She is a certified professional résumé writer and frequently teaches science students how to write résumés.

Q What's the best way to approach writing a résumé?

A A résumé is a sales pitch highlighting the skills, experience, and accomplishments that make you a great candidate. The goal is simply to create enough interest that the reader wants to know more about you. Think about your résumé as a one-page highlight reel.

People are drawn in by a résumé (or not) in 10 to 15 seconds, so grab their attention. Instead of a template, use tools like bold text, bullet points, action verbs, and keywords to keep the reader's eyes moving and direct them to key information. Throw English 101 out the window and use sentence fragments. White space is your friend. You can infuse your personality with the stylistic and formatting choices you make, but make sure that someone outside of your field can comprehend most of your résumé within two minutes.

Write yours now, even if you're not applying for anything yet. You never know when unexpected opportunities will pop up. As you gain new experiences and accomplishments, just add them to your existing résumé—make it a living document.

Q What should students convey in their résumé?

A A résumé has a professional summary at the top—a couple of sentences summarizing the rest of the page. This is followed by relevant sections such as education, work experience, research experience, and skills. Think of the sections as puzzle pieces; you can move entire sections up and down based on what's most relevant to individual programs or positions.

You want to highlight your successes in work and academic environments. If you haven't had relevant jobs or research experiences, that's okay. Focus on the transferable soft skills (e.g., program management) and technical skills (e.g., Python) that you've gained from other experiences. Then demonstrate your impact with quantitative descriptors.

Let's say you work at a library. It's tempting to write, "I help people check out books and find resources." Instead, use numerical details such as "provide customer service to 3,000 patrons" or "cataloged new collection of 1,000 books" to convey a sense of scale and impact.

Q Should students include their political or religious involvement?

A Like at the family dinner table, it's usually good to keep those topics out of your résumé. But if they're related to an experience or achievement that you're really proud of, consider these questions before you decide:

- Do I feel so strongly about this that I'm okay with not getting selected because of it?
- Does the graduate school feel strongly about this?

Q What common mistakes do you see in student résumés?

A Sometimes students think their résumé should be chronological, but you're really streamlining a highlight reel. Make sure that your biggest accomplishments are at the top of the page.

I also see students describe their job or academic program instead of what they accomplished or learned there. Focus on what you achieved, the transferable skills you strengthened, and how that experience prepared you to take this next step.

Q What is your best résumé advice?

A Don't undersell yourself or downplay your achievements. Avoid words like "only," "just," and "basic understanding." I get it. Imposter syndrome is at its peak when you're applying to graduate school or your first research internship. But every scientist has started out exactly where you are now. Be proud of what you've accomplished! //

Responses have been edited for length and clarity.

How to Tackle Physics GRE Questions

Q&A with Robert Brown from Case Western Reserve University

Interview by Kendra Redmond, Editor

Robert "Doc" Brown is a professor in the Department of Physics at Case Western Reserve University. He teaches a physics GRE seminar and developed a series of physics GRE flashcards used by thousands of students to prepare for the exam.

ABOUT THE GREs

Grad programs sometimes require applicants to submit their scores on the standardized Graduate Record Examination (GRE) General Test, which covers verbal reasoning, quantitative reasoning, and analytical writing. In addition, some require the subject-based physics GRE. The number of programs requiring the physics GREs has been declining, and many departments dropped all GRE requirements with the onset of COVID-19. Check carefully with programs before you apply—right now there is a mixture of programs that require GREs, will not accept scores, and that accept scores but don't require them.

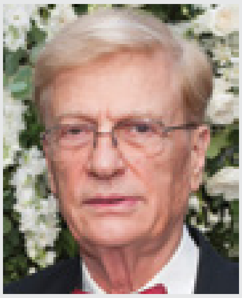
Q Since many graduate programs don't require the physics GRE right now, is it even worth taking?

A If you have good grades, great letters of recommendation, lots of research, and a publication, and you're not applying to any programs that require the physics GRE, you probably don't need to take it. Although a good GRE score could strengthen your application at places where it's optional.

Now suppose you want an extra edge or you're a little worried that your record won't set you apart. Take the physics GRE. You don't have to report your score, and you can take the exam multiple times if you can afford it.

Q How hard are the physics GRE questions?

A However we might criticize the GRE, it has beautiful little problems. Sometimes I'll give students questions from the physics GRE (which are multiple choice) along with typical free-form problems. They'll do amazingly well on the free-form problems but just bomb the GRE questions. There are a bunch of reasons why I think that's the case. First, in physics we don't require students to remember anything. Second, many students don't read carefully. Third, students can get partial credit on free-form questions. And fourth, students have a hard time getting the numbers right without a calculator. Students right now are as smart as ever, as capable as ever, but our field has put them in a situation where memorizing and arithmetic are lost skills.



LEFT: Doc Brown.

Q What's the best way to study?

A There are seven past tests out there, so go over them to build up your muscles. The older tests have much longer problems, so do them without worrying about time. That really helps.

A lot of students like the book *Conquering the Physics GRE*. The questions sometimes have a little different feel than the GRE questions, but they're very good. And taking sample exams gives you practice doing problems quickly and reading questions carefully.

Also, you need to memorize some things for the exam. Most people can remember something better if they understand where it comes from: You can understand all the interference phenomena in waves just by knowing that light can travel in different paths and when the waves come back together, they can be in phase or out of phase. Such a fundamental story can help you remember the formulas, and that's where flashcards come in. Several years ago, we developed a set of physics GRE flashcards that cover all 14 topics on the physics GRE. A few minutes of practice each day makes a big difference. All of the cards are in an online app now. To request free access, go to physics.case.edu/flashcards and complete the form. //

Responses have been edited for length and clarity.

LEARN MORE

General GRE:
ets.org/gre/score-users/about/general-test

Physics GRE:
ets.org/gre/score-users/about/subject-tests

Fee waivers:
ets.org/gre/score-users/reducing-barriers/fee-reductions

Physics GRE flashcards:
physics.case.edu/flashcards

PHYSICS GRE CHANGES

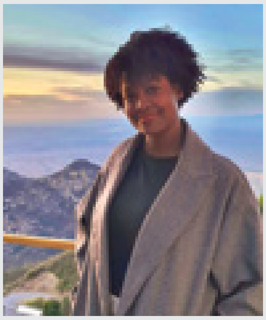
Beginning in fall 2023, the physics GRE will move from paper to computer format. Check the GRE website for registration information and testing dates as early as one year before you plan to take the test.

Conquering the Physics GRE was written by Yoni Kahn and Adam Anderson. Read an interview with them on physics GRE questions and how to study at GradSchoolShopper.com.

GRE COSTS

As of spring 2023, registering for the general GRE is $220 and the subject test is $150. There is an additional fee for sending your scores to more than four programs. Partial fee waivers are available—visit the GRE website for details.

How to Get Great Letters of Recommendation



ABOVE: Osase Omoruyi.

Q&A with Osase Omoruyi from Harvard University

Interview by Kendra Redmond, Editor

Osase Omoruyi is a graduate student in the Department of Astronomy at Harvard University. Since 2020 she's led workshops for the Women+ of Color Project on getting great letters of recommendation for grad school.

Q What role do letters of recommendation play in the admissions process?

A Graduate schools want to hear about your potential to succeed in the program. For research-based programs, that means knowing whether you can complete a research project. Letters are an opportunity for your research advisors, professors, or supervisors to speak to this as well as your work ethic, passion for research, and potential to contribute to the field.

Programs also want to hear about your academic accomplishments. Through letters, professors or academic advisors can speak to your growth and capacity to learn in a way that might not be reflected in your transcripts.

Lastly, programs want to hear about you as a person. Letters can highlight the qualities, abilities, and skills—such as maturity, grit, and leadership—that demonstrate your likelihood to thrive in the program and beyond.

Q Who should applicants ask to write their letters?

A If you're applying to a research-based program, your most important letters will be from research supervisors. If you haven't done a lot of research, letters from professors who have supervised you during lab classes or hands-on class projects can also speak to your potential.

It's good to have one or more letters from classroom professors or academic advisors who know you well and have seen you grow and improve over the years. If you've been out of school for a while, try to get a letter from the supervisor at your most recent and most impactful job.

Q What can students do to make sure their letters are personal and meaningful?

A Send each recommender your CV, personal statement, and a page highlighting your relationship. For a research advisor, this might include when you did research together, the project, your contributions, the equipment you used, and related presentations or papers. For a class professor or academic advisor, this might include the classes you took from them, your grades, notable projects or presentations, and growth in your academic performance. In both cases, note experiences and personal characteristics you'd like the writer to reference in the letter.

Q What's a good timeline for requesting letters?

A Send an email a few months before your application deadline and ask, "Would you feel comfortable writing me a very strong letter of recommendation for graduate programs?" If they say yes, great! If not, ask someone else. You only want letters from those interested in your success.

About four weeks out, send your letter writers a list of the programs you're applying to and the deadlines. Also include your personal statement, résumé or CV, and the page highlighting your relationship. Send reminders about a week before the deadline, if necessary. Then send thank yous and keep your writers updated on your success.

Q What else should students know?

A Even if you have excellent letters of recommendation, things may not go your way. Someone with okay letters whose advisor knows someone on the admissions committee may have an edge over you. You can do everything right and still not get in, unfortunately. The important thing is to give it your best effort and make sure nothing is left in your court. //

This piece is adapted from an article published in the 2022 issue of GradSchoolShopper *magazine.*

The Women+ of Color Project provides a platform for women of color to interact and learn best practices for applying to graduate school, surviving graduate school, maintaining research productivity, and growing their academic careers. For more information visit thewocproject.org.

Get more tips on letters of recommendation in the full-length version of this article, available on GradSchoolShopper.com.

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So You Heard Back. Now What?

by Matthew J. Wright, Associate Physics Professor and Chair, Adelphi University

I remember the anticipation I felt every time I checked my mailbox, waiting to hear if I had been accepted to graduate school (that was before email). I checked the mail three to four times a day. A friend informed me that the mail was only delivered once a day, but I still checked it multiple times. There was a *lot* of anticipation.

Today, students usually start to hear back from schools by email in February. It can be an exciting or excruciating time, depending on the news. There are typically three scenarios: you're accepted, you don't hear anything, or you're not accepted. Let's go through each possibility.

SCENARIO 1: YOU'RE ACCEPTED

If you are accepted into a grad program, you'll typically receive an offer letter by email that indicates how much funding you'll receive during your first year and what you need to do for that funding (e.g., be a teaching assistant or research assistant). Typically, you have until April 15 (Tax Day) to decide whether you will accept an offer, so students accepted into multiple programs will need to do a careful analysis of their options in early April.

PhD programs often invite accepted students to visit campus for a weekend in March. If you're accepted by multiple programs, you may be invited to visit all of them—making for a busy month. The schools usually, but not always, pay for your travel. There will be campus and lab tours and opportunities to meet with professors and graduate students. This is an excellent time to dive in, do some research, and network. Chat with the professors, and ask yourself if you would be interested in working for them. It's been 24 years since I started working with my PhD advisor, and he is still an active part of my life.

During your visits, talk to graduate students—especially after the official events are over for the day and you're hanging out at a bar or another informal setting. Ask questions like: What is it like working at the university? What is it like to work with this advisor? Are the graduate students happy? Are they bitter? Are there graduate students in their tenth year? (Note: The national average is 6.5 years.) Is this an environment in which you can grow and be successful?

Most graduate programs in physics, astronomy, and related fields require students to pass an exam or a series of exams before getting too far along in the program. Qualifying exams can be scary, and it's a good idea to ask whether there is a qualifier, what it's like, how it's used, and what the pass rate is during a visit weekend. A difficult qualifying exam doesn't have to be a deal breaker. Some departments offer prep classes or give students multiple tries to pass. Looking back, I relish studying for my qualifying exams and all of the physics I learned over a short period of time. I complained very loudly at the time, but I see now that it benefited my career.

If a school doesn't have a visit weekend or if you can't attend, I still highly recommend visiting the campus before deciding whether to attend. Selecting a graduate program can be tough for students and their families. It is a personal decision that takes time and effort.

Pro tip: If you are in a serious relationship and your partner would likely be moving with you, bring them along on these visits—especially if they aren't familiar with the location.

SCENARIO 2: YOU DON'T HEAR BACK IN FEBRUARY OR MARCH

The process of selecting graduate students is complicated. Typically, there are two evaluation processes for each university, one by the graduate school admissions office and one by the specific program.

If you don't hear back from a program in February or March, this could mean that you are on the waiting list. After accepted students let programs know whether they will attend (by that April 15 deadline), graduate programs evaluate whether they can accept additional students. If so, they'll go down their wait list, sending out additional acceptance letters. Schools handle this differently, and there are no rules for how the process goes. There's not much you can do other than wait and check in with the program coordinator periodically.

LEARN MORE

- **Find links to physics and astronomy bridge programs, the AIP Careers Toolbox, and many other useful resources at GradSchoolShopper.com/grad-school-resources.html.**
- **Check out "Who's Hiring Physics Bachelor's" at aip.org/statistics/whos-hiring-physics-bachelors.**

SCENARIO 3: YOU'RE NOT ACCEPTED

Not being accepted can make you feel like you don't have what it takes to get the degree, but take heart. It's hard to get into grad school. The program may not have had a spot available in the kind of research you want to do, it may have received so many applications that very little separated accepted and rejected applicants, or your application package may not have accurately conveyed your likelihood of success.

If you are rejected by all the programs you applied to, take a step back and talk with your mentors and professors. How can you strengthen your applications for the next cycle, if you try again? Should you revise your program choices? What are your options for the coming year? Many people work for a year or more before going to graduate school.

If you were applying to PhD programs, you might consider applying to bridge programs. Bridge programs provide amazing opportunities for students to prepare for PhD programs. Students take courses to strengthen their academic preparation, develop research skills, and receive mentoring. By the end of the one- or two-year program, graduates have a master's degree and a stronger PhD program application. Many bridge programs have late application deadlines so that they can accept students who didn't get into PhD programs. Similar terminal master's programs can be a great launching point into a PhD program or career as well.

If you're not up for reapplying, turn your attention to other opportunities. There are plenty! Talk to your network, visit the career center on campus, find out which companies hire physics bachelors through AIP's "Who Hires Physics Bachelors?" resource, and check out the Careers Toolbox to see what else is out there. Your value is not tied to whether you get into graduate school!

The unfortunate reality is that not everyone who wants to go to graduate school will be accepted. While rejection may be difficult to handle, know that physicists are in high demand in the job market. For example, there is a shortage of high school physics teachers and high-tech professionals. Gaining experience outside of academia can strengthen your application for graduate school in the future, or lead to an amazing career you hadn't considered before.

WHATEVER YOU HEAR, TAKE A DEEP BREATH

As your college years wind down, figuring out your next step can be exciting and stressful. There are so many career options available, and everything looks wonderful at 50,000 feet. Give yourself time to carefully evaluate each option, talk to as many people as possible, and have confidence that you will make the right decision for yourself. And if you don't? That's okay—you can always retool and try something else. Physicists work on different and exciting projects all over the place! //

Three Tips for Staying Grounded in Grad School

by Kendra Redmond, Editor

It takes a special kind of grit to sign up for another year, two, or six after already completing some 17 years of schooling. But pushing the boundaries of knowledge and discovery can be immensely alluring and rewarding. Grad school is a natural way to continue down that path, but it's a challenging one. The difficult classes, demanding lab schedule, meager stipend, and pressure to measure up, succeed, pass, publish, and land a good job takes a toll on many grad students. Here are three tips to help you keep perspective and prioritize yourself and your future.

FIND COMMUNITY

After studying in three major cities in different countries, arriving in the small town of Ithaca, New York, was a culture shock for Xiangkun (Elvis) Cao. Although it was 2016, there was no Uber or Lyft, he recalls. "You had to call a number to get a cab." As a first-generation, international student in the middle of nowhere, Cao felt especially isolated. A strict US visa policy for many Chinese students in STEM made it difficult for him to travel home, and during a lab rotation, he witnessed an advisor ridicule an international graduate student for mispronouncing English words. After just three months, Cao was ready to leave.

Simone Hyater-Adams knows isolation too. She went from historically Black Hampton University to the "hyper-White space" of the University of Colorado Boulder (CU) for a PhD program in physics education research. She immediately jumped in—doing research, running an afterschool program, TAing, and taking classes. But her confidence started to waver when she didn't have the math background needed for a class. And she waited a long time before telling anyone. "If you don't trust that [people in the department] will know what you need and really give it to you, then you're not going to want to tell them," she says. "They have the power to take what you have away." Burned out and feeling inadequate, she contemplated leaving.

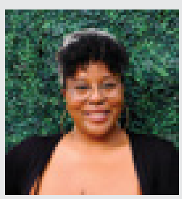
Why did Cao and Hyater-Adams stay? In part because they found communities that gave them a sense of belonging. With the help of his program's graduate student advisor, Cao changed principal investigators (PIs) and went to a lab where he was valued and supported. Hyater-Adams took classes in ethnic studies, dance, and education and joined groups for people of color in those departments. "What made things really great for me while I was at CU is that I had little communities all over campus," she says. Those groups were more affirming of her physics identity than the physics department.

The bottom line: Find communities inside and outside your department where you're supported, valued, and free to be yourself. When research or life gets challenging (and both will), these communities will be a lifeline.

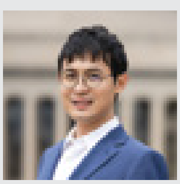
ABOUT THE CONTRIBUTORS

Photo by Vincent Boisot, 2022.

Zachary Murguía Burton is an adjunct lecturer in earth and planetary sciences at Stanford University and cocreator of *The Manic Monologues* (theManicMonologues.org), an award-winning play sharing the stories of people touched by mental illness. Murguía Burton was in his second year of a geological and environmental sciences PhD program when suicidality and psychosis landed him in the hospital for several weeks. He is a vocal advocate for disrupting the stigma of mental health.



Simone Hyater-Adams is the founder of MEGA Imagination LLC, an arts and STEM education and research firm. As a physicist, artist, educator, researcher, and consultant, she applies her unique skill set to increase opportunities for students, especially students of color. As she transitioned from a historically Black university to a physics education research PhD program at a predominately White institution, imposter syndrome took hold, and she nearly quit the program. Now she shares her story and expertise in physics identity to help others navigate and change the culture of physics.



Xiangkun (Elvis) Cao is a Schmidt Science Fellow at MIT who works on carbon capture and utilization at the intersection of technology, policy, and business. Three months into a mechanical engineering PhD program, he was on the verge of quitting due to isolation and a toxic lab environment. Among his many efforts, he now calls on universities to provide mental health resources for graduate students and better training and accountability for PIs (see references). You can learn more about his work and get in touch at ElvisCao.com.

WORK FOR A SUPPORTIVE ADVISOR

During the worst of her isolation and self-doubt, a supportive advisor made all the difference to Hyater-Adams. "There was a semester where I kind of quit," she says. "I was still in school, but I was just doing very, very little." With her advisor's blessing, she didn't TA and only took one class—dance. "I don't think I would have stayed in grad school if I hadn't taken that semester," she says. And that's the semester her dissertation was born.

Cao knows what working with advisors on both ends of the spectrum is like. "I think the advisor–student relationship is one of the greatest reasons students have mental health issues during grad school," he says. "A lot of students suffer because of a toxic relationship there."[1]

When Zack Murguía Burton's mental health declined to a life-threatening level, he didn't have to worry about losing his grad student status or funding. His advisor told him to return whenever he felt ready to reengage with the program. And Murguía Burton did. "What was so critical to being able to reenter my PhD program and then take my qualifying exams in October, five months after being hospitalized, was the support of my PhD advisor," he says.

To increase the odds that you'll select a good advisor, Murguía Burton suggests talking to potential advisors, the grad students currently in their labs, and group alum. This can give you a good understanding of the group dynamics, he says. Although it shouldn't be a student's responsibility to find a good advisor—advisors should be trained and held accountable—given the current system, Murguía Burton advises students to do their due diligence.

Despite your best efforts, you could end up with an advisor that isn't a good fit for you. Know that you're not stuck. Plenty of grad students change advisors and research projects. Some even change programs or schools. Others leave grad school altogether. None of those choices signify failure. It's your life. Do whatever you need to keep yourself grounded mentally and emotionally, says Hyater-Adams.

The bottom line: Invest the time to find a supportive advisor who's on your side. That person will have a significant impact on your life and well-being.

Continue reading on next page ->

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.

- **988 Suicide and Crisis Lifeline:** Call or text 988 from anywhere within the United States for free and confidential help with a mental health crisis.
- **Wikipedia's list of international suicide crisis lines:** Visit Wikipedia's list of suicide crisis lines by country at en.wikipedia.org/wiki/List_of_suicide_crisis_lines.
- **Crisis Text Line:** Text "HOME" to 741741 anytime for free crisis counseling.
- **Grad Resources, National Grad Crisis Line:** Call (877) GRAD-HLP, and find resources for free counseling and more on the website gradresources.org.
- **Support on Social Media:** The 988 Suicide and Crisis Lifeline will help you contact social media platforms directly if you're concerned about a friend's social media postings: 988lifeline.org/help-someone-else/safety-and-support-on-social-media/.
- **Thrive Lifeline:** Text (313) 662-8209 to access support from qualified crisis responders in STEMM (science, technology, engineering, mathematics, and medicine). Learn more at thrivelifeline.org.
- **Veterans Crisis Line:** Call (800) 273-TALK (8255) and press 1, or text to 838255 for a free, confidential resource that connects veterans with trained responders, 24 hours a day, seven days a week.

Tip: Save a picture of these resources on your phone so they're always within easy reach.

SET UP YOUR MENTAL HEALTH FOR SUCCESS

If you have mental health challenges, establish a local medical care team (e.g., doctor, psychiatrist, therapist) when you arrive in your new location—or better yet, in advance. Look at resources offered by the school and providers covered by the health insurance you'll get. Then reach out so you're not at the bottom of a long waiting list when you need care.

TREAT YOURSELF AS A PERSON, NOT A LAB RAT

With the pressure to get research results and publish, grad students often think they should be in the lab 60+ hours a week. But that's not sustainable, healthy, or good work–life balance. Embrace student orientation events and community events, says Murguía Burton. Continue doing the nonacademic things you love—chess club, cooking classes, or playing a sport.[2]

"Grad school is the perfect time for you to explore," Cao says.[3] There are not nearly enough professorships for everyone who earns a PhD, so use that time to investigate different career options, he says. Explore the career support your school offers outside of academia, join a management consulting club on campus, or take a summer internship. The opportunities are there, but you'll have to talk to your advisor and graduate school staff and probably go outside your department.[4]

As PhD students, "It can feel like we're just so specialized and have no skills that are applicable beyond doing this very narrow scope of research," Murguía Burton says. But using grad school as a time to explore interests and career possibilities can help you escape that mindset, he says. "There are so many opportunities and possibilities out there and so many ways to bridge to other disciplines."

Hyater-Adams was revitalized by exploring her interest in dance and ethnic studies, and she eventually integrated them into her research on physics identity. Cao secured his current fellowship in part due to a policymaking opportunity he pursued in grad school. Murguía Burton is both an academic and a playwright helping to destigmatize mental illness. "Ultimately, it's absolutely about our own mental health, our own wellbeing, our own happiness," he says.

The bottom line: Grad school doesn't define you. Exploring your other interests can keep you grounded and add richness, perspective, and new opportunities to your life. //

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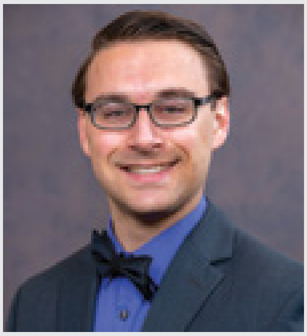
Choosing a Supportive Research Group

by Joseph Tibbs, Bioengineering PhD Student, University of Illinois Urbana-Champaign

Choosing a research group can feel daunting. It's important to be passionate about the research you do, but passion isn't enough to keep you going if you aren't supported in the lab. I'm fortunate to be in a great lab and do research I care about, but that isn't always the case.



ABOVE: Joseph Tibbs.

What does it take to feel supported? For me, clear communication and a network of people inside and outside of the lab who I can turn to when research life gets tough.

One of my professors told our class that there's no such thing as a *perfect* model, only a *useful* one. I reflect on that sometimes when I think about choosing a research group. Before I committed to the program, I had questions. What is the group like? How many people? How cutting-edge is the research? How hands-on is the professor? Will I be supported or be on my own? These questions had no *perfect* answers, just answers that were best for me.

When you're considering a research group, learn what you can from the students already in that group—many will be willing to answer emails or have a quick Zoom call. Then think about what is important to you and whether this research group will give you the support you need.

Learning and adapting is part of grad school. Be willing to set boundaries and goals, and review your progress with your advisor regularly. If something isn't working, address it. Get help if you need it. Graduate department coordinators can be a great resource. Starting grad school is a big transition, but it gives you the freedom to determine how you want to work and learn—take advantage of that! //

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physics.sciences.ncsu.edu

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Fields offered include: Astrophysics, Biophysics, Quantum physics, Condensed Matter Physics, Experimental Nuclear Physics, Nuclear and Particle Physics

Questions: py-grad-program@ncsu.edu

- **24%** of grad students are women
- **98%** of grad students are receiving assistantship support
- **Special research equipment:** IBM QHub, Tristar reactor, NCSU NNF and AIF, Genome Sciences Laboratory, ORNL, JLab, SLS

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physics.ucmerced.edu

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Application due: January 15, 2024

Apply: https://bit.ly/47khPkc

Degree(s): PhD

Fields offered include: astro, AMO, biophys, cond mat, soft matter

Questions: dstrubbe@ucmerced.edu

- Average stipend per academic year: **$36,000**
- Graduate students who are women: **14**
- University founded in **2005**

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Medford, Massachusetts
as.tufts.edu/physics/academics/graduate-programs

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sciences.ucf.edu/physics

PHYSICS AND ASTRONOMY

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Degree(s): PhD
Fields offered include:
physics.nd.edu/research
Questions: lorifuson@nd.edu

- **33%** of grad students are women
- **60** faculty members with ~20 postdocs
- **100%** of grad students are receiving assistantship support

Notre Dame, Indiana
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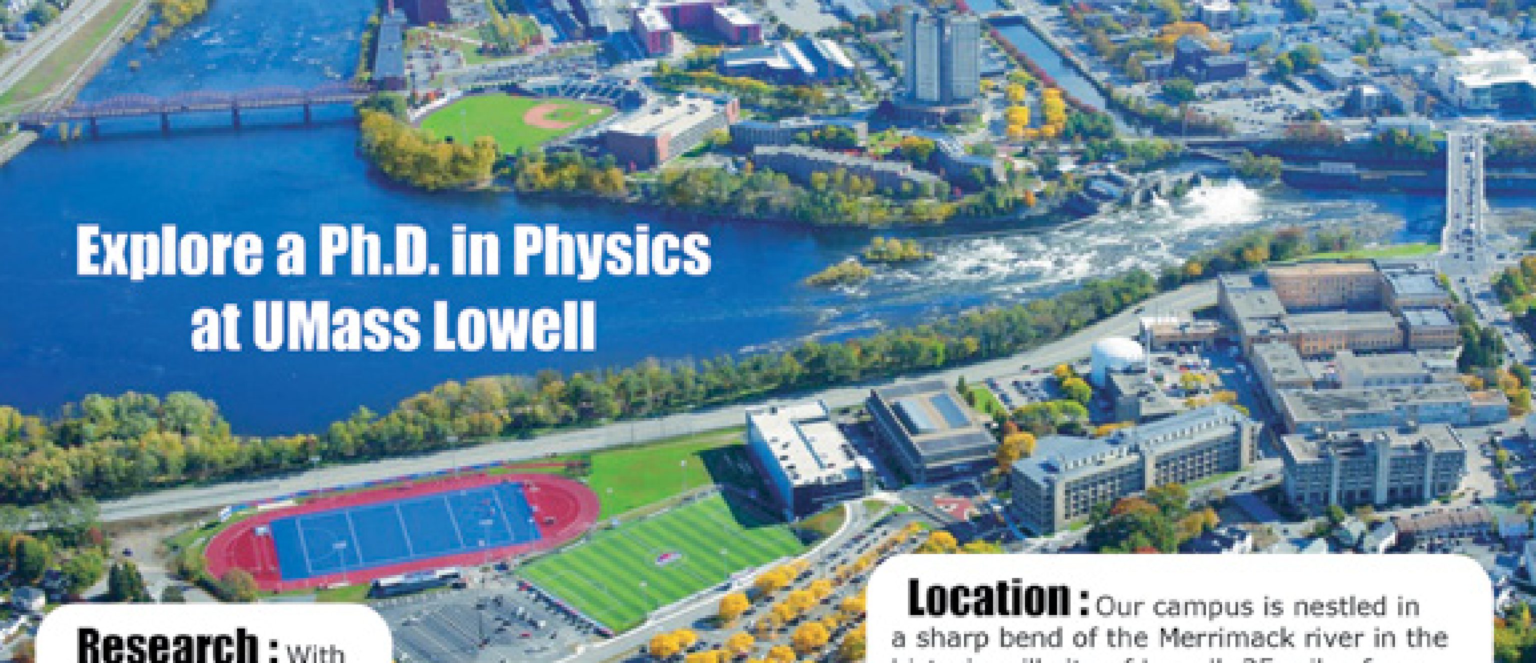

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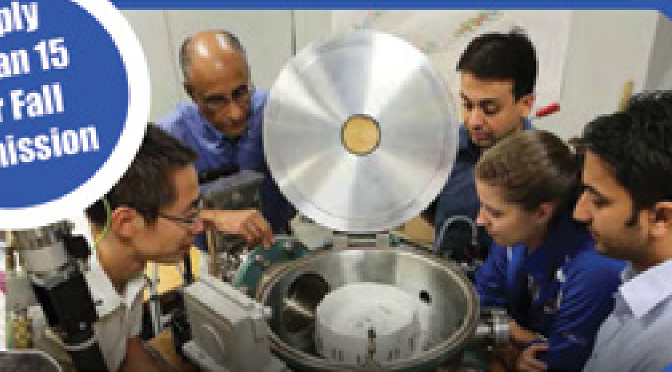
Apply by Jan 15 for Fall admission



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UMASS LOWELL

Department of Physics and Applied Physics
Kennedy College of Sciences

www.uml.edu/physics

www.uml.edu/physics/graduate

2023 Individual Award and Scholarship Recipients

The Society of Physics Students congratulates this year's recipients and thanks the generous Sigma Pi Sigma (ΣΠΣ) and SPS donors whose support makes these awards possible.

SCHOLARSHIPS

Multiple awards are given by SPS and ΣΠΣ each year, ranging in value from $2,500 to $6,000, to individuals showing excellence in academics, SPS participation, and additional criteria. Learn more about the scholarships and recipients at spsnational.org/awards/scholarships.

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SSAI Academic Scholarship

Sponsored by Science Systems and Applications, Inc.

Megan Loh
Stanford University

SSAI Underrepresented Student Scholarship

Sponsored by Science Systems and Applications, Inc.

Cecilia Ochoa
Georgetown University

SPS AWARD FOR OUTSTANDING UNDERGRADUATE RESEARCH

Awards are made to individuals for outstanding research conducted as an undergraduate. Winners are awarded $1,800 to present their research at an AIP Member Society meeting and receive $500 for themselves and $500 for their SPS chapter. Learn more at spsnational.org/awards/outstanding-undergraduate-research.

Maya Hendija
University of San Diego

Hyo Jung Park
Smith College

ABOVE: The 2023 SPS summer interns pose for a group photo during orientation at the American Center for Physics. Photo by SPS.

2023 SPS SUMMER INTERNS

The SPS summer internship program offers 10-week positions for undergraduate physics and astronomy students in science research, education, outreach, and policy with organizations in the greater Washington, DC, area. Students are placed in organizations that use the interns' skills to engage with the community and promote the advancement of physics and astronomy.

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Radford University
AIP Science Policy News Intern (FYI)

Melissa Cano
University of Texas at El Paso
AAPT Teacher Professional Development Intern

Gizem Dogan
Bowdoin College
NIST Policy Intern

Daniil Ivannikov
Florida Polytechnic University
NIST Research Intern

MJ Keller
University of Rochester
AIP Center for History of Physics/Niels Bohr Library & Archives Intern

Devin Kodsi
University of Alabama
APS Education & Diversity Intern

Tiffany Liou
University of California, San Diego
Space Telescope Science Institute Research Intern

Clayton Markech
Carthage College
NIST Research Intern

Hannah Means
Bowling Green State University
Physics Today Science Writing Intern

Colin Myers
Millersville University
NIST Research Intern

Emily Pavasars
Valparaiso University
SPS SOCK Intern

Eva Rissanen
Appalachian State University
NIST Research Intern

Brynn Schierenbeck
Cornell College
Society of Rheology/Soft Matter Kitchen Intern

Jaden Sicotte
George Washington University
APS Careers Intern

Janessa Slone
Embry-Riddle Aeronautical University - Prescott
NIST Research Intern

Jenna Tempkin
Lafayette College
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Ruthie Vogel
University of Maryland, College Park
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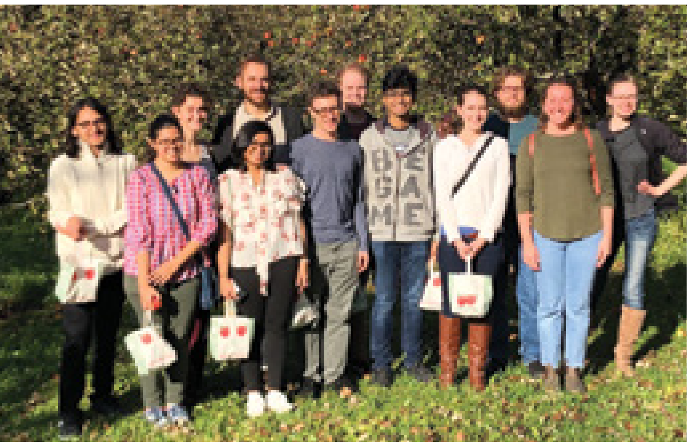
Graduate Programs in Physics

at the University of Wisconsin–Madison



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