Introduction to the Introduction to Fusion Energy and Plasma Physics Course

Arturo Dominguez
Head of the Science Education Department
First, a bit about myself

- From Bogotá, Colombia
- Started studying physics at the National University of Colombia at Bogota.
- Transferred to University of Texas at Austin where I finished undergrad (HOOK’EM HORNS!)
- Did my graduate work at MIT, in Boston on **fusion plasmas** (GO BEAVERS!)
- Now I’m at the Princeton Plasma Physics Lab (GO TIGERS!)
PPPL is one of 17 Department of Energy national laboratories
PPPL is one of 17 Department of Energy national laboratories
- ~600 employees
- 19 faculty (Princeton)
- ~22 post-docs
- ~40 grad students
- Operated by Princeton U.
- ~600 employees
- 19 faculty (Princeton)
- ~22 post-docs
- ~40 grad students
- Operated by Princeton U.
Lyman Spitzer started PPPL (originally Project Matterhorn) in 1951...Birthplace of US fusion

Inventor of the Stellarator

Founder of the lab

Made countless advances in plasma physics (his name is everywhere)

Proposed telescopes in outer space (hence the Spitzer Space Telescope)
The Laboratory has three major missions:

1. **Fusion:** To develop the scientific knowledge and advanced engineering to enable fusion to power the U.S. and the world

2. **Plasma Manufacturing:** To advance the science of nanoscale fabrication for industries of the future

3. **Frontiers of Plasmas:** To further the scientific understanding of plasmas from nano- to astrophysical-scales
History of the Intro to Fusion/Plasma Course

- Originally started in 1992 by Prof. Nat Fisch and former assistant director (and former congressman) Rush Holt, as part of the National Undergraduate Fellowship (NUF).
Changes during the pandemic

• Fully Remote

• 2 weeks long, but 4.5 hours a day

• Shorter talks (50+10 minutes, vs. 90 minutes)

• Many more talks (27 speakers vs. 15 in the past)!

• Many more participants!

• Broader scope, covering the full spectrum of topics under the Fusion Energy Sciences and Plasma Physics umbrella
All lectures are free to watch and will be posted

• All lectures will be streamed via Zoom Webinar. No registration is needed.

• Enrollees, i.e. those who filled out the google form on the site and which we could fit, will have a Zoom-Brady-Bunch-Square, will get priority for questions, join the hallway discussions, and will join the networking events.

• Webinar participants can ask questions using the ask/chat feature.

• ALL written questions should be directed at the hosts and we will hold them for the Q/A portion.

• As has been done since 2015, the course lectures and the speaker videos will be posted on the site.
We had way more submissions than we could handle!

- We were pleasantly surprised by the number and breadth of enrollment submissions (almost 1000)!
- Submissions included undergraduate students, grad students, postdocs, researchers, professors and general public.
- Because of technical limitations, we could only enroll ~300 participants so priority has been given to undergraduates conducting fusion/plasma research.
Y’all are all over the world!
Y’all are all over the world! Except Australia 😊
A birds-eye view of the undergrads

Undergraduate enrollees are based in the US and in many other countries, including: Mexico, India, Nigeria, Colombia, UK, and many more!

Many enrollees are conducting internships/summer research. Some of the programs are:

- Science Undergraduate Laboratory Internship Program (SULI) and Community College Internship (CCI), run by DOE.
- Students doing internships at their own colleges
- Private companies developing fusion
- Plasma and Fusion Undergraduate Research Opportunities (PFURO) program
WHAT TO EXPECT IN THE NEXT COUPLE OF WEEKS
Today (6/13) we’ll begin with introductions

<table>
<thead>
<tr>
<th>Eastern Time</th>
<th>Day 1 (6/13/22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 PM</td>
<td>Introduction to the Course</td>
</tr>
<tr>
<td></td>
<td>Dominguez</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>1:30 PM</td>
<td>Introduction to fusion</td>
</tr>
<tr>
<td></td>
<td>Hartwig</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Introduction to Plasmas I</td>
</tr>
<tr>
<td></td>
<td>Schaffner</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

- After this intro, Prof. Zach Hartwig (MIT) will present the promise and challenges of fusion energy

- Prof. David Schaffner (Bryn Mawr) will introduce plasmas and highlight the wide breadth of the field.
Tomorrow (6/14) we continue with Plasmas

- Prof. Jeremiah Williams (Wittenberg) will discuss different models for dealing with plasmas (single-particle/fluid)

- Prof. Steffi Diem (Wisconsin-Madison) will present the variety of waves in plasmas, and how they can be used in various plasma systems

- Dr. Ken Hammond (PPPL) will introduce the first of the magnetic fusion concepts, the stellarator.
On Wednesday (6/15) we will focus on magnetic and inertial fusion (with a turbulent detour)

<table>
<thead>
<tr>
<th>Eastern Time</th>
<th>Day 3 (6/15/22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 PM</td>
<td><strong>Tokamaks Wilks</strong></td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>1:30 PM</td>
<td><strong>Plasma Turbulence Francisquez</strong></td>
</tr>
<tr>
<td>2:30 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>3:00 PM</td>
<td><strong>Inertial Confinement Fusion Kraus</strong></td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

- Dr. Theresa Wilks (MIT) will present on the most widely studied magnetic fusion devices, the tokamak.
- Dr. Manaure Francisquez (PPPL) will discuss how turbulence arises in plasma systems and its physics.
- Dr. Brian Kraus (PPPL) will focus on another approach to fusion, inertial confinement.
Thursday (6/16) we will concentrate on plasmas...in space!

- Prof. Jan Egedal (Wisconsin) will discuss magnetic reconnection, ubiquitous in astrophysical plasmas.
- Dr. Yeimy Rivera (Harvard Smithsonian CFA) will touch upon plasmas within the solar system.
- Prof. Weichao Tu (West Virginia) will relate basic plasma physics concepts to the plasmas of the Van Allen belts.
Thursday (6/16) will also feature the first networking session

- Day 4 will also feature the first of two network sessions in which the group will be divided into groups of ~10-20 and will meet with current graduate students in the field. This is a space to ask questions about grad schools, the grad experience, the field, etc.
Friday (6/17) Princeton and PPPL will be observing Juneteenth – NO COURSE

• **Juneteenth is a holiday commemorating the emancipation of enslaved people in the US.**

• It commemorates the day in 1865 when enslaved people of Texas, then the most remote region of the Confederacy, finally learned slavery had been abolished.

• In observance of **Juneteenth**, Princeton U and PPPL will be closed on Friday, June 17th.

• We welcome you to take some time to learn about Juneteenth and about ongoing systemic racism in the US and in your own country.
Saturday and Sunday, we rest
On Day 5 (6/20) we touch on astrophysical plasmas, fusion technology and alternative configurations

- Prof. Matt Kunz (Princeton) will discuss plasmas at astrophysical scales and their unique qualities.
- Dr. Erica Salazar (CFS) will present high-temperature superconductors, the technological innovation that is revolutionizing fusion.
- Dr. Eli Parke (TAE) will present on the innovative alternative fusion approaches that haven’t been discussed yet.
On Day 6 (6/21) we will quantify success towards fusion and tackle the physics at the edge

<table>
<thead>
<tr>
<th>Eastern Time</th>
<th>Day 6 (6/21/22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 PM</td>
<td>Physics of Core-Edge Casali</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>1:30 PM</td>
<td>Quantifying progress towards fusion energy gain: the Lawson criterion Wurzel</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Plasma-surface interactions: Interplay between the plasma and solid wall components Lasa</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>

- Prof. Livia Casali (UTK) will begin discussing the way the core of the plasma relates to the edge physics and vice-versa

- Sam Wurzel (ARPA-E) will connect the fusion talks by introducing the Lawson criterion and how it can be generalized to various fusion approaches

- Dr. Ane Lasa (UTK) will focus on the physics interactions between the plasmas at the edge and the materials at the wall of the reactors.
Day 7 (6/22): Focus on Low-Temperature Plasmas

- Day 8 will start with a broad overview of the physics of low-temperature plasmas given by Prof. Marien Simeni-Simeni (Minnesota).

- Prof. Katharina Stapelmann (NCSU) will present on how low-temperature plasmas can be used in biomedical applications.

- Prof. Steven Shannon (NCSU) will expand on the applications of low-temperature plasmas, by discussing their industrial uses.

- The day will conclude with the second networking session event.

<table>
<thead>
<tr>
<th>Eastern Time</th>
<th>Day 7 (6/22/22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 PM</td>
<td>Physics of Low-Temperature Plasmas Simeni-Simeni</td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>1:30 PM</td>
<td>Biomedical Plasmas Stapelmann</td>
</tr>
<tr>
<td>2:30 PM</td>
<td>Break/Hallway Discussion</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Industrial Plasma Applications Shannon</td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Networking Hour</td>
</tr>
<tr>
<td>5:00 PM</td>
<td>Adjourn</td>
</tr>
</tbody>
</table>
Day 8 (6/23): Heat removal, neutronics and computation

- Prof. Lane Carasik (Virginia Commonwealth U) will continue the edge issues discussed on day 6 by presenting on the challenges of removing the heat from the first wall.

- Prof. Martin Nieto-Perez (Penn State) will continue on the fusion technological challenges by presenting on the issue of neutronics in fusion devices.
Day 8 (6/23): Computational workshop

- The computational workshop will be a “hands-on” event organized by the PlasmaPy team, led by Dr. Nick Murphy and Dr. Peter Heuer.

- This workshop will require you to have the Anaconda Python environment installed in your computer.

- In order to ensure the time is spent on the content and not on the setup, we’ve put together this document laying out the steps for installation.
Day 9 (6/24): Computational methods + HEDP and closing

- Dr. Ammar Hakim (PPPL) will follow the computational workshop with a discussion on computational methods used in plasma physics.

- Dr. Sophia Rocco (LLNL) will switch topics to high-energy density plasmas (HEDP) to discuss various approaches in this field.

- To close the HEDP section (and the course) Dr. Félicie Albert (LLNL) will explore one extreme realm in plasma physics, relativistic plasmas.

- I will conclude with some closing remarks.
We’ve started a Discord server for the incoming fusion/plasma community!

- Summer of 2020, we created a venue to let the participants of this course, and, in general, undergrads and grads just starting out in the road of fusion and plasma physics, talk to each other and learn about summer opportunities. Conversations continued beyond the summer.

- With the help of Nigel DaSilva and Louise Ferris, we’ve created and maintained a Discord server for this purpose. Enrollees were all invited to join.

Nigel DaSilva, 2020 PPPL SULI
Current Columbia grad student

Louise Ferris, 2020 LANL SULI
Current UW-Madison grad student
Continue the conversations with the speakers!

- Some speakers will be able to stick around after their talks to continue discussions. We will share a “Hallway Discussions” zoom link with enrollees. We will announce if speakers will be available and when.

- We will also have Discord channels for each topic to continue discussions and we’re inviting the speakers to join (we’ll also send them the questions that arise there).
• The American Physical Society Division of Plasma Physics (APS-DPP) meeting is scheduled for the week of October 17-21 in Spokane, WA. The conference will be held as a hybrid in-person/remote event. Visit the meeting website for up to date information.

• As with every year, undergraduates are invited to present their research at a dedicated poster session. There were more than 100 undergraduate posters at the 2021 APS-DPP meeting!

• All poster abstract submissions are due July 1st and can be submitted on the meeting website

• Registration and APS membership is free for undergrads!
These are not normal times and we should acknowledge this

• The reason the course is remote is because we are living during a pandemic.

• All talks are recorded and will be posted, so practice self-care. Take rests, sit out when you’re exhausted, stretch, stay hydrated, etc.

• YOUR HEALTH AND WELL BEING ARE THE PRIORITY!
A healthy culture of diversity, equity and inclusion is needed for the future of fusion energy and plasma physics

- The US fusion energy and plasma physics community has a poor record on diversity, equity and inclusion, as evidenced by the few women and underrepresented minorities in the field as compared to other physics and engineering fields.

- Recent community-wide strategic plans have, for the first time, acknowledged these problems and put forth initial plans to address them. But an inclusive climate is the only way to start.
Code of conduct

Since this is a public forum we ask speakers and participants to:

• Make participation in our community a harassment-free experience for everyone

• Act in ways that contribute to an open, welcoming, diverse, inclusive, and healthy community

• We align with the Contributor Covenant Code of Conduct
Code of conduct: Unacceptable Behaviors

• The use of sexualized language or imagery, and sexual attention or advances of any kind

• Trolling, insulting or derogatory comments, and personal attacks

• Public or private harassment

• Other conduct which could reasonably be considered inappropriate in a professional setting
Code of conduct: Positive Behaviors

• Demonstrating empathy and kindness
• Being respectful of differing opinions and experiences
• Giving and gracefully accepting constructive feedback
• Accepting responsibility and apologizing to those affected by our mistakes, and learning from the experience
Code of conduct: Positive Behaviors

• Respect the pronouns of others
• Recognize that intent is not equal to impact
• **Self-Care is revolutionary!**
Thanks to the folks that make this happen

This course is a massive effort that requires many folks behind the scenes, both at PPPL and beyond. I’d like to especially thank:

Deedee Ortiz
Harry Tsamutalis Jr
Louise Ferris
Britt Albucker
Matt Parsons
Anthony Pizzo
Finally, of course, thanks to all of the speakers!