Fourth Conference on Laboratory Instruction
Beyond the First Year of Physics

California State University Chico

July 12-14

Welcome to Chico, CA, for the Fourth Conference on Laboratory Instruction Beyond the First Year of Physics (BFY4)! The theme of this conference -- "Advanced Labs: Transformative Hubs for STEM Careers" -- builds on the themes of the 2015 and 2018 BFY conferences, and we hope that you leave here with ideas of for constructing great laboratory experiences for your students that help them develop skills that they can take to graduate school or the STEM workforce. The conference programming is designed to provide hands-on learning experiences and to stimulate dialog and idea-generation that you can ultimately implement in your lab curricula to help students develop a range of transferrable skills and deepen their understanding of physics and laboratory practices.

Another important aspect of this conference is community building. ALPhA is committed to providing a diverse, inclusive, and welcoming community where scientific and educational innovation, especially related to the advanced lab, can thrive. And it is this community, from the members of the organizing committees to the presenters and workshop leaders to the vendors to all of the participants, that makes the BFY conferences successful. As a community, we can keep the discussions going and work together to support and strengthen advanced lab experiences for all of our students. Enjoy your time here at Chico and take time to connect with others in the advanced lab community.

-- Daniel, Eric, and Joe

Fourth Conference on Laboratory Instruction

Beyond the First Year of College

Cal State Chico
July 12-14, 2023

Advanced Labs: Transformative Hubs for STEM Careers

ALPhA Advanced Laboratories

www.advlab.org/

BFY 4

Keep the conversations going at the AAPT Summer Meeting July 15-19 in Sacramento!

Organizing Committee

Eric Ayars, CSU Chico (co-chair)

Daniel Borrero Echeverry, Willamette U. (co-chair)

Joseph Kozminski, Lewis University (co-chair)

Ernie Behringer, Eastern Michigan University

Jake Bobowski, University of British Columbia

Tori Borish, University of Colorado Boulder

Sara Callori, CSU San Bernardino

Shantanu Chakraborty, Valdosta State University

Natasha Holmes, Cornell University

Mary Lowe, Loyola University Baltimore

John Mann, Pepperdine University

Rachael Merritt, University of Colorado Boulder

Christopher Nakamura, Saginaw Valley State University

Kosta Popovic, Rose-Hulman Inst. of Technology

Nathan Powers, Brigham Young University

Michael Ray, CSU Sacramento

Timothy Roach, College of the Holy Cross

Jeremiah Williams, Wittenberg University

Thanks also to:

Lyle Barbato (AAPT / ComPADRE), Merideth Fray (Sarah Lawrence College / ALPhA Secretary), Bruce Mason (University of Oklahoma / ComPADRE), Heather Quilici (CSU Chico, Professional Development Programs & Events Manager), Sean Robinson (MIT / ALPhA Treasurer), and the Demo Show Organizers Daniel Davis (Harvard), Sam Sampere (Syracuse University) and David Sturm (University of Maine)

Thank you to…

Our host institution:

Vendors who are presenting workshops:

Sponsors:

ALPhA's Statement on Diversity

The Advanced Lab Physics Association (ALPhA) recognizes that scientific and educational excellence and innovation are best achieved in a diverse, inclusive community where different perspectives can be shared and integrated. Therefore, ALPhA is committed to increasing access to advanced laboratory experiences and the development of transferable skills throughout the laboratory curriculum for all physics students regardless of race, ethnicity, age, gender identity or expression, ability status, personal appearance, sexual

orientation, national origin, immigrant status, religion, medical condition, ancestry, marital status, political affiliation, educational background, and military or veteran status.

Wednesday, July 12

Registration		**7:45-8:30 a.m.** **Colusa Hall**
Opening Remarks *Eric Ayars (CSU Chico), Daniel Borrero Echeverry (Willamette University) & Joe Kozminski (Lewis University), BFY4 co-chairs*		**8:30-8:45 a.m.** **Colusa Hall 100B**
Session I: Plenary Session		**8:45-9:45 a.m.** ~~**Knott Hall B03**~~
Invited Talk: "Sustainable laboratory experiences spanning the physics curriculum to address diverse students and career preparation" *Laura Clarke (North Carolina State University)*	8:45-9:15 a.m.	
Invited Talk: "Sustainable Interdisciplinary Research to Inspire Undergraduate Success: Integrating Course-based Undergraduate Research Experiences (CUREs) and Authentic Learning Experiences (ALEs) across the curriculum" *Enid Orta-Gonzalez (California State University, Sacramento)*	9:15-9:45 a.m.	
Coffee Break		**10:00-10:30** **Science Building**
Session II: Breakout Discussions		**10:30 -11:15 a.m.** **Science Building** **Various Locations**
Lunch Sponsored in part by Spectrum Techniques		**11:30 a.m. – 12:30 p.m.** **Colusa Hall 100A**
Session III: Workshops		**12:45 – 2:20 p.m.** **Science Building** **Various Locations**
Workshop 1	12:45-1:25 p.m.	
Workshop 2	1:40-2:20 p.m.	
Coffee Break		**2:20-2:50 p.m.** **Science Building Atria**
Session IV: Workshops		**2:50 – 4:25 p.m.** **Science Building** **Various Locations**
Workshop 3	2:50-3:30 p.m.	
Workshop 4	3:45-4:25 p.m.	
Coffee Break		**4:25-4:55 p.m.** **Donnelly Atrium**
Session V: Workshops		**4:55 – 6:30 p.m.** **Science Building**

Workshop 5	4:55-5:35 p.m.	**Various Locations**
Workshop 6	5:50-6:30 p.m.	

Dinner **6:45 p.m.**

On your own in Chico. Meet at 6:45pm (location) in the Science Building if you would like to go to dinner with other attendees from your ALPhA Region

Thursday, July 13

Session VI: Plenary Session **8:00-9:30 a.m.**
Colusa Hall 100B

Invited Panel: "Looking forward: what skills should we be teaching in advanced labs" 8:00-8:30 a.m.
Alexis Knaub (AAPT), Wolfgang Losert (University of Maryland)

Invited Talk: "Incorporating quantum information science into the undergraduate curriculum" 8:30-9:00 a.m.
Justin Perron (California State University, San Marcos)

Invited Talk: *""* 9:00-9:30 a.m.
Kiko Galvez (Colgate University)

Session VII: Workshops		**10:00 – 11:35 a.m.**
		Science Building
Workshop 7	10:00-10:40 a.m.	**Various Locations**
Workshop 8	10:55-11:35 a.m.	

Lunch **11:35 a.m. – 1:00 p.m.**
On your own. Food Trucks available on campus

Session VIII: Workshops		**1:00 – 2:35 p.m.**
		Science Building
Workshop 9	1:00-1:40 p.m.	**Various Locations**
Workshop 10	1:55-2:35 p.m.	

Session IX: Posters Session / Coffee and Snacks **2:45 – 3:45 p.m.**
Science Building
4th Floor

Session X: Demo Show **4:00 – 5:00 p.m.**
Performing Arts Center
134

Session XI: Workshops		**5:20 – 6:55 p.m.**
		Science Building
Workshop 11	5:20-6:00 p.m.	**Various Locations**
Workshop 12	6:15-6:55 p.m.	

Friday, July 14

Coffee and Networking	**8:00-8:30 a.m.** **Colusa Hall 100B**
Session XII: Plenary Session	**8:30 -9:45 a.m.** **Colusa Hall 100B**
Invited Talk: "Development of Project-Based Learning Models Relevant to Semiconductor Manufacturing" *Jason Keleher (Lewis University)*	8:30-9:00 a.m.
Invited Talk: "More than technical support: Professional contexts of physics instructional labs" *Lauren Dana (Worcester Polytechnic Institute), Benjamin Pollard (Worcester Polytechnic Institute), Sarah Mueller (Brown University)*	9:00-9:30 a.m.
Invited Talk: "Preparing Physics Students for 21st Century Careers: The PHYS21 Report" *Paula Heron (University of Washington)*	9:30-10:00 a.m.
Closing Remarks	10:00-10:15 a.m.
Session XIII: Breakout Discussion	**10:30 – 11:15 a.m.** **Science Building** **Various Locations**
Boxed Lunch	**11:15 a.m. – 12:00 p.m.** **Science Building**
Conversations with Vendors	**12:00 – 3:00 p.m.** **Science Building** **Various Locations**

Session II: Breakout Discussions

Wednesday, July 12
Science Center
10:30 – 11:15 a.m.

B01 **Advanced Labs on a Budget** *(SCI 243)* – Ernest Behringer (Eastern Michigan University) presiding

B02 **Advanced Labs and Writing/Science Communication** *(SCI 216)* – Catherine Herne (SUNY New Paltz) presiding

B03 **Making Labs more Welcoming/Accessible** *(SCI 241)*– Sara Mueller (Brown University) presiding

B04 **Computation in Advanced Labs** *(SCI 242)* – Kirstin Purdy Drew (Penn State University) presiding

B05 **Assessment in Advanced Labs** *(SCI 2nd Floor Landing)* – Sara Callori (California State University San Bernardino) presiding

B06 **CUREs/ALEs in Advanced Labs** *(SCI 250)* – Enid González-Orta (California State University Sacramento) presiding

B07 **The Quantum Initiative and Advanced Labs** *(SCI 247)* – Justin Perron (California State University San Marcos) presiding

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Session IX: Poster Session

Thursday, July 13
4th Floor, Science Center
2:45 – 3:45 p.m.

P01 **Taylor-Couette Flow: A Versatile Platform for Fluid Dynamics Experiments**
Daniel Borrero-Echeverry, Anna E. Hornbeck, Alicia E. Robbins (Willamette University)

P02 **Making Nuclear Magnetic Resonance Resonate with Students: Integrating NMR into the Undergraduate Science Curriculum**
Merideth Frey, Colin Abernethy (Sarah Lawrence College), David Gosser (City College of New York)

P03 **Realizing the Fourier Series**
Michael Braunstein (Central Washington University)

P04 **Using numerical Laplace transforms and a lossy transmission line model to replicate the measured transient response of coaxial cables**
Jake Bobowski, Takamitsu Koyano, (University of British Columbia)

P05 **Experiment control: a Python course**
Annelies Vlaar (Vrije Universiteit Amsterdam)

P06 **Visualizing NMR: Some Lessons with VPython**
David B. Pengra (University of Washington)

P07 **Birefringence and polarization experiments using calcite crystals in optical tweezers**
Catherine Herne (SUNY New Paltz)

P08 **Exploration of fluid mechanics with low-cost experiments**
Irene Dujovne, Varghese Mathai (University of Massachusetts Amherst)

P09 **Cloud-based Bose-Einstein Condensation (BEC) Experimental Access for All**
Heather Lewandowski, Victoria (Tori) Borish (University of Colorado)

P10 **Student perspectives about seeing quantum effects in experiments**
Victoria Borish, Heather Lewandowski (University of Colorado Boulder and JILA)

P11 **More than technical support: the professional contexts of physics instructional labs**
Benjamin Pollard, L M Dana (Worcester Polytechnic Institute), Sara Mueller (Brown University)

P12 **Bridging the disconnect between the classroom lab and the research lab**
Ashley Carter, Daniel Oo, Victoria D. Kuntz, Alejandra Velasquez (Amherst College)

P13 **Implementation of a course-based, authentic learning experience in upper- and lower-division laboratory classes**
Michael Ray, Mikkel Herholdt Jensen, Eliza J. Morris (California State University, Sacramento)

P14 **Integrating Short Laboratory Activities into an Upper-Division Lecture Course on Laser Physics**
Christopher M. Nakamura (Saginaw Valley State University)

P15 **Designing Writing Intensive Upper Division Laboratories in Physics**
Sara Callori (California State University San Bernardino)

P16 **On the use of a meta-report as instruction for how to write a lab report**
Lars Hellberg (Chalmers University of Technology, Sweden)

P17 **Seeking Feedback for Project Labs**
Lauren Dana (Worcester Polytechnic Institute)

P18 **Experimental physics instruction beyond the first year at the University of Alberta**
Mark Freeman, Adam Cunningham, Katryna Fast, Michael Dunsmore (University of Alberta)

P19 **Online Advanced Labs in Physics**
Peter Bennett (Arizona State University)

P20 **Branching Out: Measuring Model-Based Reasoning in Upper-Division Physics Labs with MAPLE**
Rachael L. Merritt (University of Colorado Boulder/JILA), Michael F. J. Fox (Imperial College London), Heather J. Lewandowski (University of Colorado Boulder/JILA)

P21 **Representational differences in how students compare measurements**
Gayle Geschwind, Michael Vignal, Heather J. Lewandowski (University of Colorado Boulder & JILA)

P22 **ALPhA's Laboratory Immersions: Impacts and Adaptations**
Lowell McCann (University of Wisconsin - River Falls)

Session XIII: Breakout Discussions

Friday, July 14
10:30 – 11:15 a.m.
Science Center

B08 **Advanced Lab and Undergraduate Research** *(SCI 247)* – Meredith Frey (Sarah Lawrence College) presiding

B09 **Not in a Vacuum: Course Design in the Advanced Lab** *(SCI 250)* – Chris Nakamura (Saginaw Valley State University) presiding

B10 **Non-tenured Advanced Lab Practitioners** *(SCI 216)* – Benjamin Pollard (Worcester Polytechnic Institute) and Sara Mueller (Brown University) presiding

B11 **AI and Advanced Labs** *(SCI 242)* – Ramón Torres-Isea (University of Michigan) presiding

B12 **Career Readiness and the Advanced Lab** *(SCI 241)* – Gabe Spalding (Illinois Wesleyan) presiding

B13 **Emerging Topics** *(SCI 2nd Floor Landing)* – Rachael Merritt (University of Colorado Boulder/JILA) presiding

Workshops

Wednesday, July 12
Thursday, July 13
Science Center

W01 **Coherent imaging (Phase contrast/Dark-field/CDI)** (*SCI 245*)
Nathan Powers, Brigham Young University

W02 **Measuring properties of coaxial transmission lines** (*SCI 247*)
Michael Braunstein, Central Washington University

W03 **Intuitive Understanding of the Nyquist Rate with Arduino** (*SCI 243*)
Kathryn Ledbetter, Harvard University

W04 **Real-time quantitative measurement of a Stirling engine PV diagram** (*SCI 250*)
Jake Bobowski, University of British Columbia

W05 **Modern Eddington Experiment**(*SCI 242*)
Toby Dittrich, Portland Community College

W06 **Making Nuclear Magnetic Resonance Resonate with Students** (*SCI 243*)
Merideth Frey, Sarah Lawrence College

W07 **Faraday Rotation** (*SCI 131*)
R. Seth Smith, Francis Marion University

W08 **Unlock the Power of Data Analysis with Tailor - A Hands-On Workshop** (*SCI 247*)
David Fokkema, Vrije Universiteit Amsterdam

W09 **Phase-sensitive detection with a low-cost microcontroller** (*SCI 243*)
Jerome Fung, Ithaca College

W10 **An Affordable Starter Lab for Intermediate Optics** (*SCI 245*)
Ernest Behringer, Eastern Michigan University

W11 **Open Source Microscopy in the Advanced Lab: Einstein, Boltzmann, fluorescence and more** (*SCI 131*)
Douglas Martin, Lawrence University

W12 **FPGA-Based Positron Emission Tomography** (*SCI 218*)
Kevin Van De Bogart, University of Chicago

~~W13 **A Low-Cost Muon Telescope** (*SCI 250*)~~
~~Ian Berden, Niels Bohr Institute, University of Copenhagen~~

W14 **Surface Mount Electronics How-To** (*SCI 218*)
Eric Ayars, California State University Chico

W15 **Fully-Online Advanced Labs** (*SCI 131*)
Peter Bennett, Arizona State University

W16 **Demonstration of a simple setup for cosmic muon lifetime measurements and presentation of a possibility for measurements of the magnetic moment of cosmic muons** (*SCI 243*)
Damir Bosnar, University of Zagreb

W17 **Cosmic Ray Muon Telescopes** (*SCI 131*)
Brett Fadem, Muhlenberg College

W18 **Index-Matched Computer Tomography** (*SCI 242*)
Mark Paetkau, Thompson Rivers University

W19 **Fluid physics laboratory experiments** (*SCI 131 (back)*)
Varghese Mathai, University of Massachusetts Amherst

W20 **Miniature Tesla Coil Teaching Lab** (*SCI 250*)
Nathan Tompkins, Wabash College

~~W21 **Disappearing Slides** (*SCI 250*)~~
~~Sam Sridhar, North Carolina State University~~

W22 **Fourier analysis of audio signals for investigation of resonances** (*SCI 242*)
Timothy Roach, College of the Holy Cross

W23 **Microscopy projects** (*SCI 250*)
Ashley Carter, Amherst College

W24 **Z-axis Tunneling Microscope Experiments** (*SCI 131*)
Joshua Veazey, Grand Valley State University

W25 **Room temperature Superconductors! It's almost here! Experiment with superconductors and magnetic levitation** (*SCI 126*)
Boaz Almog, Quantum Experience Ltd.

W26 **Quantum Control** (*SCI 126*)
David Van Baak, TeachSpin, Inc.

W27 **Some Extensions To The Quantum Analogs Experiment** (*SCI 126*)
David Lee, TeachSpin, Inc.

W28 **Quantum Optics Kit** (*SCI 243A*)
Micheal King, Thorlabs, Inc.

W29 **Fourier Optics Kit** (*SCI 126*)
Micheal King, Thorlabs, Inc.

W30 **Quantum Cryptography** (*DS 253*)
Micheal King, Thorlabs, Inc.

W31 **Gamma-Gamma Coincidence and Half Life Determination** (*SCI 126*)
Richard Love, Spectrum Techniques

W32 **Single Photon Counting Module demo** (*SCI 126*)
Kurt Gibbings, Pacer USA

ALPhA Community Standards of Ethical and Professional Conduct

1. Introduction

The Advanced Laboratory Physics Association ("ALPhA") seeks to foster an atmosphere that encourages open dialogue and exchange of scientific ideas in all venues,virtual or in person. ALPhA supports equality of opportunity and treatment for all participants. ALPhA is dedicated to providing a safe and productive experience for the ALPhA community (including for members/non-members at ALPhA sponsored events) regardless of identity - including gender, gender identity or expression; race; color; national or ethnic origin; religion or religious belief; age, marital status; sexual orientation; disabilities; veteran status; immigration status, and any other basis protected or not currently protected by applicable federal or state laws or local ordinances.(See also ALPHA's Statement on Diversity)

All ALPhA members and those attending ALPhA events are expected to treat others with respect and consideration. ALPhA does not tolerate discrimination, or any form of harassment, and is committed to enforcing these community standards (the "Standards"). ALPhA aims to achieve an inclusive and welcoming environment. Harassment, sexual or otherwise, is a form of misconduct that undermines the integrity of ALPhA meetings, Immersions, and other gatherings and communications, and will not be tolerated.

2. General Expectations

ALPhA values high-quality research, education, professional practice, and service *combined with* highly professional, ethical and inclusive conduct, as fundamental to excellence and integrity of ALPhA. These values require the following community standards of conduct ("Standards"). ALPhA requires compliance with the Standards by all participants, staff, guests, and vendors, within the ALPhA community, regardless of membership status.

These Standards are in effect for ALPhA activities. This includes but is not limited to conferences, meetings, meeting breakout sessions, tours, social events, and electronic communication, as well as at all ALPhA related events that are expressly sponsored or promoted by ALPhA, whether held in public or private facilities (each may be referred to herein as an "Event" or collectively, as the "Events").

3. Standards

ALPhA encourages all participants to:

- Practice respectful, equitable and inclusive conduct and treatment of all those engaged or contemplating engagement in ALPhA's community, as well as others in the field, including actively rejecting (and not practicing) sexual and other bases of harassment and discrimination (i.e., on the basis

of, e.g., gender, race, ethnicity, nationality, religion, sexual orientation, identity and expression, disability, and other identities), including intersections of these identities;
- Not retaliate against any person(s) who raises a conduct concern (including but not limited to under Title IX as applicable), or who assist in any way to investigate or resolve it;
- Pay attention to the safety of ALPhA event and community participants, both physical and emotional;
- Participate in the advancement of the ability of individuals, groups and entities to pursue and share the full range of scientific ideas, popular and not, including bolstering creativity, discovery and service via robust and open exchange of scientific ideas and encouraging multiple perspectives to be voiced by a diversity of individuals;
- Follow ALPhA's policies relevant to professional and ethical conduct (these "Standards" and Harassment guidelines below);

4. Harassment and Prohibited Conduct

Harassment Defined

Harassment includes verbal, physical, and visual conduct that creates an intimidating,
offensive, or hostile environment, as perceived by others. Harassing conduct can take many forms and includes, but is not limited to: slurs, epithets, derogatory comments, insults, degrading or obscene words, jokes, demeaning statements, offensive gestures, or displaying derogatory or demeaning pictures, drawings, or cartoons based upon an individual's gender identity, race, color, personal appearance, national origin, religion, age, ability status, medical condition, ancestry, marital status, sexual orientation, or any other basis.

Sexually harassing conduct in particular includes all of these prohibited actions, as well as other
unwelcome conduct, such as unwanted physical advances, whether or not the participant
submits to the invitation; lewd propositions or innuendos; leering; making sexual gestures;
making sexually suggestive or graphic comments or engaging in
sexually-oriented conversation;
sexually suggestive objects, graphics, pictures, or posters, whether physically displayed in-person or accessed over the Internet; making or using derogatory comments, epithets,
slurs or jokes; the touching or display of one's own body; or physical touching or assault, as
well as impeding or blocking movements.

Sexually harassing conduct can be by a person of any gender identity and toward a person of any gender identity. Conduct that begins as consensual in nature may become harassment if one party withdraws their consent. Sexual or other harassment is unacceptable and will not be tolerated.
The list presented herein of what may be deemed sexual or other harassment

is not all-inclusive. It is impossible to define every action or word that could be interpreted as harassment. Harassment is defined by the perception of the victim. ALPhA has a "zero tolerance" policy toward discrimination and all forms of harassment and reserves the right to sanction individuals who engage in inappropriate conduct within the ALPhA community, even if it is not specifically referred to in this Code or is not actionable as sexual or any other form of harassment.

Prohibited Conduct

Prohibited conduct within the ALPhA community includes, but is not limited to:
1. harassment based on gender identity, race, color, personal appearance, national origin,
religion, age, ability status, medical condition, ancestry, marital status, sexual orientation,
or any other basis protected by federal or applicable state laws or local ordinances;
2. demeaning comments or harassment about a person's professional status or qualifications;
3. sexual harassment, as defined above,
4. abusive conduct that has the purpose or effect of unreasonably interfering with another
person's ability to benefit from and enjoy or participate in the Event, including social
events related to the Event and sponsored by ALPhA;
5. undue interruption of any Event, speaker, or session; and
6. violence or threats of violence.

Retaliation for complaints of inappropriate conduct or harassment are also considered
harassment and will not be tolerated. Retaliatory behavior in connection with the ALPhA community will be investigated in a similar manner to initial complaints.

5. Reporting an Incident

Event participants or other individuals who witness or experience inappropriate conduct within the ALPhA community should report such conduct immediately. The individual may report the conduct to an ALPhA officer or board member (https://advlab.org/Contact). Anyone experiencing or witnessing behavior that constitutes an immediate or serious threat to public safety is advised to report it immediately to relevant law enforcement or security. The victim or witness is not required or expected to discuss the concern with the alleged offender.

ALPhA cannot address claimed inappropriate conduct or harassment unless the claims are
brought to the attention of ALPhA leadership. Participants are encouraged to report any
incidents as quickly as the participant feels safe to do so. This will help ALPhA decrease incidents of harassment by increasing awareness and allowing for appropriate follow-up action.
ALPhA is committed to taking all reasonable steps to prevent harassment and prohibited
conduct within the community, and will make every reasonable effort to promptly and completely

address and correct any prohibited conduct that may occur.

The following guidelines for witnesses or victims of harassment or other prohibited conduct are provided to help with an investigation. ALPhA will make every effort to maintain the confidentiality of reporters and/or of any supporting documentation.

- If possible, record as many details as possible surrounding the event. This includes, but is not limited to: time(s), place(s), nature of the incident, comments made or actions encountered.
- If possible, save any written documentation associated with the violation, including but not limited to emails, notes, or images.
- In documenting the incident, observers and victims are encouraged to be detailed as possible.

ALPhA can only investigate situations that arise within ALPhA events and communications. If inappropriate conduct or harassment occurs at the participant's own or another institution, at a place of work, at a research facility, or online but not via ALPhA -sponsored channels, the appropriate office at that location or the individual's home institution who handles such issues should be contacted.

6. Follow up for Reported Incidents

Investigation

A designated ALPhA representative will promptly and impartially investigate the facts and circumstances of any claim of inappropriate conduct or harassment related to ALPhA communications or within the ALPhA community, after securing approval and cooperation of the individual(s) who experienced harassment (at any time the individual(s) who experienced harassment, whether or not they brought the report to ALPhA, can choose to end the investigation). ALPhA will make every effort to keep the reporting individual's concerns confidential and will not deliberately share personal information other than to the investigator(s); however, confidentiality cannot be guaranteed in all cases.

During an investigation, the designated ALPhA representative or a designated independent consultant subject to obligations of confidentiality, will generally proceed as follows to determine
appropriate action(s):

- document the nature of the complaint;
- interview the complainant;
- conduct further interviews as necessary, with witnesses or, at an appropriate time, the alleged offender;
- document ALPhA's findings regarding the complaint;
- document recommended follow-up actions and remedies, if warranted; and
- inform the complainant of ALPhA's findings.

A specific timeline for the investigation cannot be predicted in advance, as it may depend upon the nature of the allegations and the investigation process. Every effort will be made to act

upon the investigation in a prompt and timely manner. Upon completion of the investigation,
ALPhA will take corrective measures against any person who has engaged in conduct in
violation of this policy, if ALPhA determines such measures are necessary.

Notwithstanding, ALPhA reserves the right, upon receipt of a complaint, to remove an individual without undertaking an investigation as described herein, if in ALPhA's reasonable discretion, the nature of such complaint requires the immediate removal of an individual in order to ensure that an event may proceed safely and without undue interruption,.

Sanctions

If, after a thorough investigation, the designated ALPhA representative determines that an individual has engaged in prohibited conduct, the representative shall determine the appropriate action to be taken, which may include, but is not limited to:

- private reprimand;
- removal from an event without warning or refund;
- implementation of conditions for attendance at future ALPhA events;
- restriction from attendance at future ALPhA events;
- or revocation of ALPhA membership.

ALPhA may, but is not required to, report any incident to proper authorities, including but not
limited to law enforcement, if in ALPhA's sole discretion such reporting is advisable or
necessary. If ALPhA determines that an individual has engaged in prohibited conduct at an
ALPhA event or within the ALPhA community, and such individual is an ALPhA member, ALPhA may consider suspension or termination of ALPhA membership solely in compliance with any member disciplinary or termination procedures adopted by ALPhA that provide the member, at a minimum, the rights of notice, a hearing, and a right to appeal any adverse decision.

Adapted from the American Association of Physics Teachers (AAPT) Event Participation Code of Conduct and with guidance from the Societies Consortium on Sexual Harassment in STEMM. Draft version to be adopted by the ALPhA Officers and Board of Directors.

ABSTRACTS / DESCRIPTIONS

Session I: Plenary Abstracts

Sustainable laboratory experiences spanning the physics curriculum to address diverse students and career preparation

Physics careers require diverse skills: working on a team, design and testing, technical writing, and project management. In contrast, physics undergraduate programs primarily focus on content knowledge, with potentially detrimental consequences. Students with strong professional skills and interest in real world applications sometimes leave physics. Students who "fit well" with physics undergraduate education may struggle in transitioning to jobs. Since 2012, NC State Physics has experimented with adding short (1-2 week) career-focused, hands-on activities occurring frequently in freshman-junior years capped by a term-long senior design course intended as a bridge to the workplace. Mini-labs introduce real-world applications for freshman and later add an experimental component (a single lab innately associated with the course content) to theory-only classes. Physics senior design is a mock-work experience where small groups of students design and construct a scientific apparatus for a sponsor in 10 weeks, while weekly presenting their progress to a rotating group of observers. Graduate tracking provides detailed pertinent career information for students. I will discuss implementation and assessment of these innovations.

Laura Clarke (North Carolina State University)

Sustainable Interdisciplinary Research to Inspire Undergraduate Success: Integrating Course-based Undergraduate Research Experiences (CUREs) and Authentic Learning Experiences (ALEs) across the curriculum

Course-based Undergraduate Research Experiences (CUREs) represent opportunities for students to engage in research through an institution's course curricula, thus increasing access to, and eliminating barriers associated with, extra-curricular undergraduate research experience (UREs). Our institution responded to URE inequities with the Sustainable Interdisciplinary Research to Inspire Undergraduate Success (SIRIUS) Project, a multi-disciplinary program to design and integrate CUREs across the curricula of diverse STEM departments. SIRIUS I resulted in the re-design of 16 laboratory courses across the Biological Sciences, Chemistry, Environmental Studies and Geology, all addressing a local and relevant problem - the health of the American River ecosystem. SIRIUS II expanded the program to include 10 STEM disciplines at Sacramento State and four nearby community colleges with a focus on research and authentic learning experiences (ALEs) related to Northern California's water resources. For both, we have employed a multi-year Faculty Learning Community (FLC) to train and support faculty as they collaboratively develop and implement their SIRIUS curricula.

Course-based undergraduate research experiences engage students in scientific practices, discovery with broad relevance, collaboration, iteration, and communication/dissemination (often referred to as the critical design elements). In the **CUREs/ALEs in Advanced Labs** participants will 1) discuss the critical design elements of CUREs,/ALEs distinguishing between

inquiry-based and research-based curricula, and 2) identify potential challenges associated with specific CURE elements in individual courses.

Enid Orta-Gonzalez (California State University, Sacramento)

Session II: Breakout Discussion Descriptions

B01. Advanced Labs on a Budget

Funding for advanced lab equipment and supplies can often be challenging to secure. Creative methods can lead us to high-quality advanced labs that don't have to break the budget. Participants in this session are invited to share their strategies for deploying Beyond-the-First Year lab work at low cost for all types of institutions.

Moderator: Ernest Behringer (Eastern Michigan University)

B02. Advanced Labs and Writing/Science Communication

The ability to convey technical outcomes in both formal and informal settings is an important skill that laboratory courses can help students develop. Participants in this session will share and discuss methods for incorporating writing and scientific communication in advanced lab courses.

Moderator: Catherine Herne (SUNY New Paltz)

B03. Making Labs more Welcoming/Accessible

Creating advanced lab environments that are accessible and welcoming to all students is essential for promoting equity and diversity in physics. However, there are many challenges to achieving this goal, including concerns about accommodating students with disabilities, addressing biases and stereotypes, and fostering a sense of community among lab participants. In this session, we will discuss successful practices that we are implementing in our labs and brainstorm solutions to issues we may currently be troubleshooting.

Moderator: Sara Mueller (Brown University)

B04. Computation in Advanced Labs

Computation has become an integral part of most physics experiments. In this session, participants will share and discuss different possible ways to structure computation into advanced lab courses that could include topics such as basic programming to run lab equipment, data analysis techniques, simulations to compare with experimental data, or computational essays presenting the results from a lab.

Moderator: Kirstin Purdy Drew (Penn State University)

B05. Assessment in Advanced Labs

Advanced Lab classes often focus on the process of doing science as much as on the products that result and this can be difficult to evaluate. In this session we will share and discuss assessment

strategies for advanced lab courses and how course design can be used to support student learning and skill building in addition to providing feedback on experimental outcomes.

Moderator: Sara Callori (California State University San Bernardino)

B06. CUREs/ALEs in Advanced Labs

Course-based undergraduate research experiences (CUREs) and authentic learning experiences (ALEs) have been shown to have numerous positive outcomes for students. However, these approaches are more commonly used in other STEM disciplines, such as biology and chemistry, than in physics. In this session, we will discuss opportunities and challenges of using CUREs and ALEs in physics.

Moderator: Enid González-Orta (California State University Sacramento)

B07. The Quantum Initiative and Advanced Labs

The US government and others around the world have recently been investing a lot of money into the field of quantum information science and technology, and many educators are thinking about how best to educate students for this new workforce. This session will be a discussion about how we can utilize lab courses to help teach students the skills and knowledge necessary for quantum jobs both in industry and academia.

Moderator: Justin Perron (California State University San Marcos)

Session VI: Plenary Abstracts

Incorporating quantum information science into the undergraduate curriculum

Quantum information science and technology (QIST) is expected to have a substantial impact on the economy. To fulfill that promise, we need a quantum capable workforce that is conversant with the core aspects of quantum technologies and is large enough to meet the anticipated demand. Although the majority of recent QIST job postings require graduate level degrees, workers with bachelor's level degrees meet the requirements for roughly one third of posted positions. Furthermore, as the industry matures and its focus transitions from predominantly research and development towards deployment, the need for bachelor's level employees will grow. Thus, there is an increasing need for bachelors educated workers with knowledge, skills, and experience relating to QIST. In this talk I will discuss many challenges associated with incorporating QIST into undergraduate curricula, strategies and approaches to overcoming some of these challenges, and finally introduce some resources that can be adapted for use in existing courses to help introduce these concepts.

Justin Perron (California State University, San Marcos)

Experimental education to prepare students for the second quantum revolution

The second quantum revolution has driven an increased need for quantum proficient STEM graduates. To address this need, there are many new educational programs and degrees being developed that are often focused on computational or conceptual knowledge around quantum. However, there has been a lack of work understanding how laboratory courses and experiments contribute to undergraduate quantum education. One particular set of quantum optics labs (often called single-photon labs) are used widely across the US due to support from the Advanced Lab Physics Association (ALPhA). Through their equipment purchasing and faculty professional development programs, they have supported over 100 institutions engaged with these experiments.

Although significant resources (time and money) have been dedicated to implementing these experiments in undergraduate labs, there is little research into what students are gaining from these experiences and how that might be improved. Through interviews with instructors and interviews and clinical observations of students working with these experiments, we are beginning to understand what goals instructors have for these labs and how students are achieving these goals.

Heather Lewandowski (University of Colorado Boulder)

Panel Discussion on Quantum in the Lab

Kiko Galvez (Colgate University)
Heather Lewandowski (University of Colorado Boulder)
Justin Perron (California State University, San Marcos)

Session X: Poster Session Abstracts

P01. Taylor-Couette Flow: A Versatile Platform for Fluid Dynamics Experiments

Taylor-Couette flow is the flow of a viscous fluid sheared in the gap between two rotating coaxial cylinders. Sometimes called the "hydrogen atom of hydrodynamics," Taylor-Couette flow has a rich phenomenology and has long been a testbed for new ideas in fluid mechanics and an important tool in the development of nonlinear dynamics. We present examples of laboratory activities that can be conducted using inexpensive equipment to introduce students to fluid mechanics topics not typically covered in the physics curriculum. By using flow visualization to measure the velocity profile in the gap, to demonstrate Reynolds similarity, and to examine the transition to turbulence, students not only gain insight into fluid behavior but also develop practical skills in scientific image acquisition and digital image/signal processing.

Primary Contact: Daniel Borrero-Echeverry (Willamette University) <dborrero@willamette.edu>
Co-authors: Anna E. Hornbeck (Willamette University) and Alicia E. Robbins (Willamette University)

P02. Making Nuclear Magnetic Resonance Resonate with Students: Integrating NMR into the Undergraduate Science Curriculum

Despite the prevalence of nuclear magnetic resonance (NMR) as an essential research tool across a wide variety of STEM fields, there has historically been an inequality of access to this important piece of laboratory equipment due to its high cost and maintenance requirements. Fortunately, the recent development of inexpensive benchtop NMR spectrometers offers great opportunities for predominantly

undergraduate institutions to give their students relevant hands-on learning and research skills with this essential tool in the modern STEM workforce. Through the support of an NSF-IUSE grant, we have established an interdisciplinary and cross-institutional team to develop, assess, and disseminate curricular material that integrates NMR into the undergraduate science curriculum. We are currently developing and testing curricular materials consisting of twenty-five lab modules and associated instructional guides and online resources. In the future, we hope to assess the implementation of these materials and their effectiveness in different institutional environments, with or without direct access to an NMR system. If you or any faculty colleagues may be interested in implementing any of our materials, please scan the QR code on the poster for the contact form!

Primary Contact: Merideth Frey (Sarah Lawrence College) <mfrey@sarahlawrence.edu> Co-authors: Colin Abernethy (Sarah Lawrence College) and David Gosser (City College of New York)

P03. Realizing the Fourier Series

Using simply an inexpensive three component electronic band-pass filter, a function generator, and an oscilloscope, students can realize the Fourier series through interactions with a physical system and measurements. As an exercise in our upper division physics labs, we have students assemble and perform measurements with an RLC band-pass filter circuit, demonstrating resonant and other phenomena with sinusoidal waveforms. The differential equation for the circuit is a good context for introducing or reviewing the Fourier series for periodic functions and its application in linear differential equations. After the introduction/review, we have students apply both square and triangle waveforms as inputs to the filter. By adjusting the frequency of these waveforms so that harmonics correspond with the measured resonant frequency of the filter, a very clear qualitative confirmation of the Fourier series is obtained. Measurements of signal amplitudes can also be performed and shown to be consistent with the terms obtained by the usual analytic method of the Fourier series.

Primary Contact: Michael Braunstein (Central Washington University) <michael.braunstein@cwu.edu>

P04. Using numerical Laplace transforms and a lossy transmission line model to replicate the measured transient response of coaxial cables

We have measured and modeled the transient response of a length of coaxial transmission line to both voltage steps and narrow rectangular pulses. We first considered the case of an ideal (lossless) transmission line and showed that, while the calculated response captured many of the features found in the experimental measurements, there were also clear differences. We attempted to account for these non-ideal features by incorporating both conductive and dielectric losses into our transmission line model and including the non-ideal characteristics of the signal generator and oscilloscope used in the experimental setup. This work was initiated in our advanced undergraduate lab course and then further explored as an experimental directed-studies course.

Primary Contact: Jake Bobowski (University of British Columbia) <jake.bobowski@ubc.ca>
Co-authors: Takamitsu Koyano (University of British Columbia)

P05. Experiment control: a Python course

Experiment Control: A Python Course (ECPC) is an advanced undergraduate laboratory program that teaches the development of Python applications for data acquisition. The course begins with an exploration of the characteristics of a Light Emitting Diode (LED), with students measuring current over a voltage

range. This introductory experiment serves as a foundation for learning the essentials of experiment control. Students then apply their skills to a more complex experiment, investigating the behavior of a solar panel by varying the load resistance.

During ECPC, students with a basic understanding of Python programming are led through the process of controlling an Arduino device and collecting experimental data. They learn to follow programming etiquette by breaking down their Python code into logical components using the Model-View-Controller (MVC) design pattern. They also learn to use GitHub for version control and Poetry for dependency management, which enables them to combine their code into a single, installable package. Additionally, students learn how to create a useful application by developing a Command Line Interface (CLI) that enables users to interact with the device, perform data analysis, and store data. In the final part of the course, they design a Graphical User Interface (GUI) to simplify the control of the experiment.

ECPC provides students with valuable experience in programming, data acquisition, and software engineering. In this poster presentation, we will discuss the course's design and implementation, present data on student performance, and share feedback from student surveys.

Primary Contact: Annelies Vlaar (Vrije Universiteit Amsterdam, The Netherlands) <a.m.vlaar@vu.nl>

P06. Visualizing NMR: Some Lessons with VPython

The Bloch equations, and their extension by Hahn to treat an ensemble, form the foundation of the phenomenology of nuclear magnetic resonance. The understanding of NMR measurements in terms of these equations presents the student with a challenge in geometric imagination: to see in the mind's eye the "spins" (magnetic moments with angular momentum) evolve under the influence of static and dynamic fields (including pulsed fields), and relaxation. By making use of computational tools such as VPython, one can aid the imagination with animated simulations. I show a few selected lessons using interactive VPython programs that illustrate the spin dynamics predicted by the Bloch equations and how they predict measurements made by the TeachSpin PS1 NMR spectrometer. Some examples: Switching between the lab and rotating reference frame; Continuous excitation with a weak RF field; Off-resonance versus on-resonance; Spin echos and Hahn's pi/2 - pi/2 "eight-ball;" The Carr-Purcell sequence and the Meiboom-Gill correction for pulse-width error; Off-resonance spin echos; Measuring T1 with the inversion-pulse sequence versus a rapid pi/2 sequence. In addition, the simulations reveal an interesting and beautiful geometry to evolution of spin ensembles, with the appearance of organized states ("internal echos") that do not produce a signal due to their symmetry.

Primary Contact: David B. Pengra (University of Washington) <dbpengra@uw.edu>

P07. Birefringence and polarization experiments using calcite crystals in optical tweezers

Single-crystal calcite is a perfect medium for demonstrating principles of birefringence, polarization, and the angular momentum carried by light. In this poster we illustrate two experiments demonstrating the interaction of polarized light with birefringent calcite crystals. The first experiment involves trapping and levitating stationary calcite crystals with linearly polarized light; the crystals orient themselves relative to the beam axis and the direction of polarization. Our understanding of this stationary orientation is based on equilibrium positions, which are found by examining the induced polarization in the crystal. The second

experiment is to rotate trapped and levitated crystals with circularly or elliptically polarized light. The theory of rotation of these crystals can be quite complex, but at a basic level can be described with the change in angular momentum of light passing through the crystal. We also explain the precipitation process for growing calcite crystals using chemicals commonly found in a chemistry stockroom. This set of advanced lab experiments can be successfully performed with a rudimentary optical tweezer apparatus and access to common chemicals. The learning outcomes of the experiments include implementing optical tweezers, understanding polarization and birefringence, and applying electromagnetic theory to the propagation of light in crystals.

Primary Contact: Catherine Herne (SUNY New Paltz) <hernec@newpaltz.edu>

P08. Exploration of fluid mechanics with low cost experiments

Fluid mechanics is a topic not generally covered in undergraduate physics courses. We present two experiments designed for a senior lab that explore fluid mechanics and are simple to implement. We have observed that, for some students, this is the only time in their undergraduate studies that they would be exposed to these topics.

The two experiments are "Levitation of balls in a Jet" and "Vortex toroid of magnetic stirrer in a liquid [PIV Challenge]". The first one consists of balls of different diameters and weights that are placed on the air stream produced by a hair dryer that is provided with different diameter nozzles. The PIV experiment is based on the observation of the movement of tracer particles moving under sheet illumination.
While the first experiment is quite open and students have to design the experiment according to which variables they choose to focus on, the second experiment is more directed and students get exposed to a completely new technique (PIV).

Primary Contact: Irene Dujovne (Department of Physics, University of Massachusetts Amherst) <dujovne@umass.edu>
Co-authors: Varghese Mathai (Department of Physics, University of Massachusetts Amherst)

P09. Cloud-based Bose-Einstein Condensation (BEC) Experimental Access for All

As we aim to better prepare our students to contribute to the Second Quantum Revolution, providing access to current technology used in the quantum industry is critical. Through an industrial partnership with Infleqtion, we are developing research-based instructional materials for a new remotely controllable BEC apparatus. The experiment resides in Colorado at Infleqtion, but has a web interface where students and researchers can control various parameters and receive the resulting data after the experimental run. We are hoping this system will allow students to interact with research-grade quantum matter systems at all intuitions regardless of intuitional resources.

Primary Contact: Heather Lewandowski (University of Colorado) <lewandoh@colorado.edu>
Co-authors: Victoria (Tori) Borish (University of Colorado)

P10. Student perspectives about seeing quantum effects in experiments

Quantum mechanics is a field often considered very mathematical and abstract. To make quantum more concrete, some instructors expose their students to fundamental quantum phenomena in an experimental setting. This can be done in undergraduate instructional labs with a sequence of quantum optics experiments referred to as the single-photon experiments. Here, we present results from an interview study

about what it means to both instructors and students to see quantum effects in experiments. Focusing on student experiences with the single-photon experiments, we find that students believe they are observing quantum effects and achieving related learning goals. Although it is not possible to see the quantum phenomena directly with their eyes, students point out different aspects of the experiments that contribute to them observing quantum effects. There is also variation across student achievement of related learning goals, ranging from many of the students being excited about these experiments and making a connection between the mathematical theory and the experiments to only some of the students seeing a connection between these experiments and quantum technologies. This work can help instructors consider the importance and framing of quantum experiments.

Primary Contact: Victoria Borish (University of Colorado Boulder and JILA)
<victoria.borish@colorado.edu>
Co-authors: Heather Lewandowski (University of Colorado Boulder and JILA)

P11. More than technical support: the professional contexts of physics instructional labs

Physics lab instructors, both faculty and staff, are instrumental to student learning in instructional physics labs. However, the faculty-staff dichotomy belies the complex, varied, and multifaceted landscape of positions that lab instructors hold in the fabrics of physics departments. We present the results of a mixed methods study of the people who teach instructional labs and their professional contexts. Recruiting physics lab instructors across the US, we collected 84 survey responses and conducted 12 in-depth interviews about their job characteristics, professional identities, resources, and experiences. Our investigation reveals that lab instructors vary in terms of their official titles, job descriptions, formal duties, personal agency, and access to resources. We also identified common themes around the value of instructional labs, mismatched job descriptions, and a broad set of necessary skills and expertise. Our results suggest that instructors often occupy overlapping roles that fall in between more canonical jobs in physics departments. By understanding the professional contexts of physics lab instructors, the rest of the physics community can better promote and engage with their critical work, improving laboratory learning both for students and for the lab instructors who teach and support them.

Primary Contact: Benjamin Pollard (Worcester Polytechnic Institute) <bpollard@wpi.edu>
Co-authors: L M Dana (Worcester Polytechnic Institute), Sara Mueller (Brown University)

P12. Bridging the disconnect between the classroom lab and the research lab

If you ask an undergraduate at my institution, did your physics lab courses prepare you for work in a research lab, the answer is a resounding no. What is the disconnect? Why can't we train students for research science? I recently taught a sophomore/junior level laboratory to three of my research students and saw first hand that my efforts in the classroom lab did not translate. One issue is that the nature of the science that we do in the classroom laboratory is fundamentally different from the nature of the science in the research lab. Here, I will describe these fundamental differences--which surround steps for i) how to start a lab project, ii) how to take data, iii) how to collaborate with other scientists, and iv) how to communicate data. I will also discuss some updates to the course that have had varying success.

Primary Contact: Ashley Carter (Amherst College) <acarter@amherst.edu>
Co-authors: Daniel Oo, Victoria D. Kuntz, Alejandra Velasquez (Amherst College)

P13. Implementation of a course-based, authentic learning experience in upper- and lower-division laboratory classes

We designed and implemented a course-based authentic learning experience (ALE) in which upper-division students design and build instruments to monitor water quality of the American River, which runs by our campus and is important to the local ecology. Students in a lower-division, introductory course then characterize and test the instruments for eventual deployment in the river. The project bridges the upper- and lower-division classes while providing all students with a great example of how physicists can contribute to environmental and societal issues. We will discuss our first implementation of the project and its benefits to students, along with our long-term implementation plans for the ALE.

Primary Contact: Michael Ray (California State University, Sacramento) <ray@csus.edu>
Co-authors: Mikkel Herholdt Jensen (California State University, Sacramento),
Eliza J. Morris (California State University, Sacramento)

P14. Integrating Short Laboratory Activities into an Upper-Division Lecture Course on Laser Physics

Laser physics is applicable to a wide range of careers in science and technology. Learning to work with optical equipment is an important part of studying the discipline. While pairing a lecture and lab is a natural choice, resource and logistic constraints, particularly at smaller, or undergraduate-focused institutions may not allow for that. Here we discuss short laboratory activities designed to be integrated into a lecture course to provide a hands-on experimental supplement to the theoretical work being done in other course components. The lab activities focus on using common laser lab tools to observe important phenomena such as laser beam profile, laser cavity modes and fluorescence lifetime. This work is part of a larger goal of implementing a 3-D course design in which theoretical, computational and experimental tasks are integrated into one course, and students use all three modes of inquiry to understand the course content from multiple perspectives.

Primary Contact: Christopher M. Nakamura (Saginaw Valley State University) <cnakamur@svsu.edu>

P15. Designing Writing Intensive Upper Division Laboratories in Physics

"Communicating Physics" forms part of the AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum, and writing falls squarely within this domain. Over the last several years, our department has revised our upper division laboratory curriculum to meet our university's Writing Intensive designation. Here, I will share the architecture of our third- and fourth-year lab courses and strategies used to introduce and discuss aspects of scientific writing into these courses. This includes a focus on having students practice professional forms of writing, such as journal articles, experimental proposals, and peer review. Class time is also dedicated to introducing students to ways that science can be communicated to non-expert audiences and the role that writing plays in how physics is "done".

Primary Contact: Sara Callori (California State University San Bernardino) <sara.callori@csusb.edu>

P16. On the use of a meta-report as instruction for how to write a lab report

This contribution describes a method to help students in a project-based physics lab course in the second year of a physics major program at the university to write reports according to the IMRAD model. The usual situation is that there is a separate description of what the different sections, for example the abstract or the method section, of a (technical) report should contain. Our experience is that it is often peculiarly

difficult for the students to interpret these instructions, which leads to a lot of questions regarding the report writing itself to us teachers. Instead, we have created a Meta Report according to the IMRAD model where the various IMRAD sections do not contain any physics but only detailed information about what is expected to be found in the IMRAD sections of the actual student reports. This may seem like a subtle difference compared to the previous separate instructions, but the Meta Report method has resulted in a clear reduction in the number of the questions we get from students regarding the writing of the reports. In fact, they have largely ceased.
N.B. The same content will presented at the AAPT Summer Meeting 23

Primary Contact: Lars Hellberg (Chalmers University of Technology, Sweden)
<lars.hellberg@chalmers.se>

P17. Seeking Feedback for Project Labs

While we often ask our students to incorporate our feedback to make their reports and talks stronger, we so rarely are afforded the same opportunity. I would love to submit a poster soliciting feedback from other lab instructors on a new lab we have developed and deployed in the last year.
This past year we transitioned the labs associated with our Waves and Oscillations sophomore-level course to focus on experimental design, with an emphasis on iteration. To that end we offer 3 set labs. Then in the fourth lab students develop their own experiment. We provide a list of supplies, including several demo setups, and ask students to write a motivation, experimental method, and collect and process at least one dataset.
They then pass those three deliverables off to another student group, normally in the same lab section, who then performs that lab for the fifth and final lab. Those students then provide written feedback to the students who wrote the lab, who then submit a final lab guide that includes all of the above information, and a theoretical introduction.
My questions for the community are manifold, and I welcome comments outside of these questions, but here are some of my initial questions
Is there specific scaffolding I should be focusing on?
Do the deliverables for the first seem enough, or should I be modifying them?
Are there learning goals associated with asking students to perform as both student and lab instructor?
I also wish to acknowledge the privilege inherent in taking up space in this manner, and if anyone wants feedback on any labs I would be happy to provide some. My email is ldana@wpi.edu, and I understand what it is to exist where most of the feedback one receives is that either "did not like it, but nothing specific to say" (students) or "looks fine" (professors).

Primary Contact: Lauren Dana (Worcester Polytechnic Institute) <ldana@wpi.edu>

P18. Experimental physics instruction beyond the first year at the University of Alberta

Experimental physics for majors at the University of Alberta is taught through a sequence of three, one-semester courses in the sophomore and junior years. The teaching and learning goals of the courses are fundamental skills for experimentation, data analysis, and scientific communication (written and oral). Over the past decade we have made Python a requirement for data analysis, introduced coaching in the development of numerical models for experiments, and opened a small makerspace where students can create small parts and extend their hands-on skills. Students completing the full sequence have opportunities for creativity and immersion in a topic reminiscent of the experience of physics research.

The poster outlines these courses and summarizes, from our perspectives as recent course participants in the roles of instructor, TAs, and student, both what works and where there is clear room for improvement. We look forward to discussions with other BFY4 attendees and their ideas for delivering the greatest benefit to the most students.

Primary Contact: Mark Freeman (Department of Physics, University of Alberta) <mark.freeman@ualberta.ca>
Co-authors: Adam Cunningham (Department of Physics, University of Alberta),
Katryna Fast (Department of Physics, University of Alberta), Michael Dunsmore (Department of Physics, University of Alberta)

P19. Online Advanced Labs in Physics

At Arizona State University we have developed a fully online BS degree in Physics. A key component of the curriculum is a set of Advanced Lab courses, which include a suite of Nobel-Prize-winning experiments such as Interferometry, Zeeman effect, Cavendish Balance, Quantum Entanglement, etc. I will review the structure of these online Advanced Lab courses, and show examples of the custom-built simulator, overview videos, student worksheets, lab notebook and formal reports.

Primary Contact: Peter Bennett (Arizona State University) <peter.bennett@asu.edu>

P20. Branching Out: Measuring Model-Based Reasoning in Upper-Division Physics Labs with MAPLE

Many undergraduate physics labs have students engage in modeling, the iterative process of constructing, testing, and refining models of experimental physical and measurement systems. Model-based reasoning is an important skill for undergraduate physics students to develop. Lab courses, particularly upper-division courses, provide students with the opportunity to develop their modeling skills. The Modeling Assessment for Physics Laboratory Experiments (MAPLE) is a research-based assessment instrument designed to measure student proficiency with modeling in experimental physics in upper-division electronics and optics courses. The MAPLE surveys consist of two parts. Part 1 is a 'choose your own adventure' activity which probes students' larger-scale approaches to modeling. Part 2 uses coupled multiple response questions to examine students' modeling competency and reasoning. Assessing students' modeling proficiency and growth is valuable to instructors for informing course development and improvement.

Primary Contact: Rachael L. Merritt (University of Colorado Boulder/JILA)
<rachael.merritt@colorado.edu>
Co-authors: Michael F. J. Fox (Imperial College London), Heather J. Lewandowski (University of Colorado Boulder/JILA)

P21. Representational differences in how students compare measurements

Measurement uncertainty - an essential concept in introductory physics labs - plays a critical role in ensuring the accuracy and reliability of experimental results. An assessment tool called the Survey of Physics Reasoning on Uncertainty Concepts in Experiments (SPRUCE) aims to evaluate students' ability to handle a variety of concepts related to measurement uncertainty. This assessment includes two isomorphic questions, one presented numerically and the other pictorially, with diagrams illustrating error bars and means. Interestingly, despite the questions being identical, students answer them in different ways, indicating that they rely on distinct modes of representation to make sense of measurement uncertainty and

comparisons. Unfortunately, even though instructors emphasize the importance of understanding measurement comparison, students frequently struggle with these questions. Notably, students score much higher on the pictorially represented item, showing a gap in ability to compare numerical measurements.

Primary Contact: Gayle Geschwind (University of Colorado Boulder & JILA) <gayle.geschwind@jila.colorado.edu>
Co-authors: Michael Vignal (University of Colorado Boulder & JILA), Heather J. Lewandowski (University of Colorado Boulder & JILA)

P22. ALPhA's Laboratory Immersions: Impacts and Adaptations

This poster will review the impacts ALPhA's Laboratory Immersions program has had on physics departments and faculty since its inception in 2010. We will also examine the changes to the program made over the years, and what changes are in store in the near future.

Primary Contact: Lowell McCann (University of Wisconsin - River Falls) <lowell.mccann@uwrf.edu>

Session XII: Plenary Abstracts

Development of Project-Based Learning Models Relevant to Semiconductor Manufacturing

Following the CHIPS Act of 2022 making $53 billion available for semiconductor manufacturing and R&D, the focus has shifted to educating the next-generation of domestic semiconductor workforce. Leading semiconductor companies are looking for individuals with skillsets at the interface of chemistry, physics, material science and engineering to further populate the workforce pipeline. Preparing the future innovators/leaders of the semiconductor industry can begin at the undergraduate level via the development of integrated curriculum that minimizes disciplinary boundaries and enhances critical thinking skills. This presentation will provide a model rooted in the fundamental sciences/engineering while providing hands-on opportunity for exploring the semiconductor manufacturing eco-system. An example set of interdisciplinary laboratory experiences will be presented with an emphasis placed on critical areas of manufacturing such as lithography, chemical mechanical planarization, and electroplating.

Jason Keleher (Lewis University)

More than technical support: Professional contexts of physics instructional labs

Physics lab instructors, both faculty and staff, are instrumental to student learning in instructional physics labs. However, the faculty-staff dichotomy belies the complex, varied, and multifaceted landscape of positions that lab instructors hold in the fabrics of physics departments. We present the results of a study of the people who teach instructional labs and their professional contexts. We collected survey responses and conducted interviews with lab instructors across the US. Our investigation revealed that lab instructors vary in terms of their official titles, job descriptions, formal duties, personal agency, and access to resources. We also identified common themes around the value of instructional labs, mismatched job descriptions, and a broad set of necessary

skills and expertise. Our results suggest that instructors often occupy overlapping roles that fall in between more canonical jobs in physics departments.

Lauren Dana (Worcester Polytechnic Institute), Benjamin Pollard (Worcester Polytechnic Institute), Sarah Mueller (Brown University)

Preparing Physics Students for 21st Century Careers: The PHYS21 Report

Undergraduate physics programs tend to treat preparation for graduate school as the default, and pay relatively little attention to informing students about, and preparing them for, other careers. However, most physics graduates are employed outside of academia. With support from the NSF, the AAPT and APS formed a Joint Task Force on Undergraduate Physics Programs (JTUPP) to identify the skills and knowledge that undergraduate physics degree holders need to be well prepared for a diverse set of careers. The Task Force reviewed employment data, surveys of employers, and reports generated by other disciplines. We also met with physicists in selected industries to get their views on the strengths and weaknesses of physics graduates, commissioned a series of interviews with recent physics graduates employed in the private sector, and identified exemplary programs that ensure that all of their students are well prepared to pursue a wide range of career paths. The resulting report "PHYS21: Preparing Physics Students for 21st Century Careers" contains recommendations intended to help departments and professional associations support student career preparation.

Paula Heron (University of Washington)

Session XIII: Breakout Discussions Descriptions

B08. Advanced Lab and Undergraduate Research

Part of the purpose of advanced lab courses is to help prepare students for future research. In what ways do our advanced lab classes do a good job of preparing students for undergraduate research opportunities? How could we change them to better prepare students for more authentic research projects? In this session, participants will discuss and share ways to structure advanced lab courses as a stepping stone to undergraduate research.

Moderator: Meredith Frey (Sarah Lawrence College)

B09. Not in a Vacuum: Course Design in the Advanced Lab

Advanced Lab courses don't exist in a vacuum. How can we best structure our Advanced Lab courses? How can we foster connections with introductory labs, and with other upper-division courses in the curriculum? Participants in this session will discuss curriculum design with an eye to structures that can help students get more out of their undergraduate physics studies.

Moderator: Chris Nakamura (Saginaw Valley State University)

B10. Non-tenured Advanced Lab Practitioners

Many of the instructors and managers who design and teach advanced lab courses are non-tenured faculty. This session will provide a space to discuss their experiences and the challenges they have faced and allow others in the community the opportunity to learn more about their experiences.

Moderators: Benjamin Pollard (Worcester Polytechnic Institute) and Sara Mueller (Brown University)

B11. AI and Advanced Labs

From long-used machine learning algorithms to the recent buzz of Chat GPT we know that artificial intelligence is changing how we do science and impacting education. Participants in this session will discuss opportunities and challenges associated with AI in the Advanced Lab.

Moderator: Ramón Torres-Isea (University of Michigan)

B12. Career Readiness and the Advanced Lab

The Advanced Lab can be the perfect place to develop skills students need for their careers, but does that happen in your course deliberately and intentionally or is it just a random walk? Participants in this session will discuss strategies to build career-relevant skills into their Advanced Lab courses and how to discover and highlight career-relevant skills developed in the Advanced Lab that might be going unnoticed.

Moderator: Gabe Spalding (Illinois Wesleyan)

B13. Emerging Topics

This session will provide a space to discuss advanced lab topics that have emerged this week that are not represented in other breakout sessions.

Moderator: Rachael Merritt (University of Colorado Boulder/JILA)

Workshop Descriptions

W01: A laboratory for teaching coherent imaging principles and techniques

We demonstrate our approach to teaching coherent imaging principles and techniques in the advanced lab using basic optical equipment. Starting from a single lens imaging setup, we introduce simple adjustments that allow the user to create dark-field and phase contrast images of optically transparent objects with subwavelength variations in optical path length. The dark-field imaging technique uses a wire to block the focus of the beam while the phase contrast imaging technique uses a phase line or phase dot. To understand these imaging techniques, students are introduced to Fourier imaging principles. We also demonstrate a simple way to introduce the concept of Coherent Diffraction Imaging using a similar setup. We start by imaging the diffraction pattern created by a pair of small pinholes. ImageJ is used for post-processing and analyzing the data. We discuss how phase retrieval techniques are used to retrieve an image of the pinholes from the diffraction pattern.

Primary Contact: Nathan D. Powers, Brigham Young University <ndp5@byu.edu>
Co-authors: David D. Allred and Richard L. Sandberg

W02: Laboratory Investigation of Distributed Electronic Circuits: Coaxial Transmission Lines

Laboratory investigation of the phenomena and physics of signals propagating in coaxial transmission lines is a useful and relatively simple pathway for introducing intermediate level physics students, students who to that point in the curriculum may have largely considered and worked with only lumped electronic circuit models and systems, to the broader phenomena of distributed electronic/electromagnetic systems. In this workshop, participants will have the opportunity to work through a short laboratory exercise that we apply in that context. The response of coaxial transmission lines to signal pulses is measured and related to the physics governing their behavior. Using a function generator and a high pass RC filter, electronic pulses are applied to one terminal of a coaxial transmission line for which the other terminal can be subject to different electronic conditions. The length of the transmission line is sufficient so that multiple reflections of the pulse from the terminals can be resolved on an oscilloscope, and this condition places the behavior of the system in the realm of distributed electronic circuits. The primary activity for students is developing an experimental method to accurately measure the effective impedance of the coaxial transmission line by understanding and then exploiting the relationship between signal amplitudes measured at both terminals and the impedance properties of the components of the system (i.e., not simply using the impedance matching condition). These measurements can be compared to results from electromagnetic theory and component specs. Beyond this primary activity, there are additional experimental activities that can be performed with the apparatus associated with electromagnetic signal propagation and component impedance.

Primary Contact: Michael Braunstein, Central Washington University <michael.braunstein@cwu.edu>

W03: Intuitive Understanding of the Nyquist Rate with Arduino

This workshop is based on a two-session lab from a lab skills class, Physics 113: Electronics for Physicists, which targets sophomore and junior physics majors to prepare them for research experience (and the advanced lab course). In the first session of the lab, students focus on technical skills: how to use serial communication to control a digital-to-analog (DAC) converter from an Arduino microcomputer, and how to use interrupts to control timing from an external clock. In the second session of the lab, students use their setup to investigate the Shannon-Nyquist sampling theorem by sampling an incoming analog signal and trying to reproduce it with the DAC output. By driving a speaker with the output of the DAC, students develop a visceral understanding of aliasing, and connect what they hear to the Nyquist limit. The use of

audible frequencies helps students think in frequency space, and provides practice in thinking about the frequency spectrum of a signal.

Primary Contact: Kathryn Ledbetter, Physics Department, Harvard University kledbetter@fas.harvard.edu>

W04: Real-time quantitative measurement of a Stirling engine P-V diagram

This workshop will demonstrate a real-time measurement of a Stirling engine P-V diagram. The experiment uses an inexpensive gamma-type Stirling engine. The only modifications required to the as-purchased engine are a single hole drilled in the top plate to accommodate a pressure sensor and attaching circular choppers to the flywheel. The outer chopper is completely transparent except for a single narrow black line which is positioned such that it is at the top of the flywheel when the internal volume of the Stirling engine is a minimum. The inner chopper, on the other hand, has 100 equally-spaced divisions and is used to track the orientation of the flywheel. The P-V diagram is constructed using electronics and a dual photogate that were designed inhouse. The outer chopper is used to reset a counter and the inner chopper increments the count. A digital-to-analog converter converts the binary output of the counter to a voltage between -3.14 V to +3.14 V (i.e., a voltage that spans 2π) which can then be used to calculate the gas volume. Our system allows a calibrated P-V diagram to be displayed on oscilloscope while the Stirling engine is running. We are also able to observe the phase shift between the pressure and volume oscillations as well as how the P-V diagram changes when friction is applied to the flywheel. Finally, we can run the Stirling cycle in reverse to demonstrate refrigeration. A rotary tool with a felt attachment is used to rotate the flywheel while the temperature difference that develops across the top and bottom plates of the engine is monitored using a differential thermocouple.

Primary Contact: Jake Bobowski, University of British Columbia <jake.bobowski@ubc.ca>
Co-authors: Nikolai Lesack, University of British Columbia

W05: Modern Eddington Experiment

History was made and Einstein became famous in 1919 when Eddington and Dyson measured the Einstein Coefficient. Between 1919 and 1957 several additional experiments were performed with varying success, but the images obtained were entirely beyond twice the radius of the sun, and the data was very limited (7 stars for 1919 and only a total of about 100). At this distance the gravitational deflection is very small and lies out in the tail of the hyperbolic curve (1/r) for photon deflections. This makes a curve fit verification questionable. After no experiments being performed until 2017, two experiments were successful one by Don Bruns and one by Dittrich/Berry (involving four undergraduate students who became the first to ever measure the curvature of space). The modern CCD cameras used captured hundreds of images. For the April 2024 eclipse, Professor Dittrich has organized more than 10 teams using new CMOS cameras that will be able to capture hundreds of thousands of images, many between R = 1-2 solar radii. This will enable the creation of the first ever adequate curve fit verification of Einstein's hyperbolic deflection relationship. This Modern Eddington Experiment will involve many colleges and undergraduates as well as amateur astronomers from around the world. This workshop will discuss the MEE2024 project.

Primary Contact: Toby Dittrich, Portland Community College <tdittric@pcc.edu>

W06: Making Nuclear Magnetic Resonance Resonate with Students

This workshop introduces a set of labs developed as part of an NSF-IUSE grant to help integrate nuclear magnetic resonance (NMR) into the undergraduate science curriculum. These modular labs were developed to cover the theory, practice, and applications of NMR in a truly multidisciplinary way as well as have the flexibility for use in a variety of different courses, classroom environments, and institutions. The developed materials take advantage of the growing capabilities of lower-cost benchtop NMR spectrometers available

on the market but are also designed so that the materials can still be useful for faculty and students who do not have direct access to a benchtop NMR spectrometer. We will explore some of these lab modules and discuss how faculty could potentially implement these materials into their own lab courses.

Primary Contact: Merideth Frey, Sarah Lawrence College <mfrey@sarahlawrence.edu>
Co-authors: Colin Abernethy, Sarah Lawrence College and David Gosserm, City College of New York

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W07: Pulsed Faraday Rotation

Faraday Rotation is a phenomenon showing that magnetism and light are related, in that the polarization properties of a medium are affected by the presence of a static magnetic field. The rotation of the plane of polarization of light by a modest B-field is typically a small effect; but this variant of 'Pulsed Faraday Rotation' uses an ordinary (and commercially available) apparatus together with a new prototype pulsed-current supply to excite the solenoid. The use of brief (<10 ms) pulses allows the solenoid to be exposed to currents of peak value near 50 A, about 10-fold larger than any steady current that could safely be used. Faraday rotations of >45 degrees are readily obtained; this allows the design and description of Faraday isolators. Students using this sort of apparatus will learn how electrical energy can be capacitively stored and then (safely) discharged in brief high-current pulses. They will learn techniques of data acquisition for brief single events, including the art of triggered acquisition. They will learn two independent techniques for quantifying pulsed large magnetic fields, and they will learn the modeling required to interpret experiments in the transmission of polarized light to infer instantaneous Faraday rotation.

Primary Contact: R. Seth Smith, Francis Marion University <rsmith@fmarion.edu>
Co-authors: David A. Van Baak, TeachSpin Inc.

W08: Unlock the Power of Data Analysis with Tailor - A Hands-On Workshop

Tailor is a user-friendly and versatile tool for data analysis and curve fitting that can improve the way you teach. With its intuitive design, students can quickly and easily enter and process data, shifting the focus from data processing to data interpretation. While Python is great, it is a bit cumbersome and can take precious time away from thinking about your data. Tailor provides a clean interface for data entry, calculation of quantities and uncertainties, and visualization of different models to find the best fit. With the ability to experiment with different parameters, students can gain a deeper understanding of the underlying physics behind their data.

Join us in this hands-on workshop to discover the power of Tailor. We will explore its features and discuss its potential applications in your teaching to enhance your educational practice. Tailor is open source and freely available for download at https://github.com/davidfokkema/tailor. Installers are available for both Windows and MacOS platforms, making it accessible to a wide range of users. This workshop offers an opportunity to learn about a new and intuitive tool for data analysis that can greatly benefit your students. Tailor is currently in use at several universities in the Netherlands.

Primary Contact: David Fokkema, Vrije Universiteit Amsterdam <d.b.r.a.fokkema@vu.nl>

W09: Flexible, low-cost phase-sensitive detection with a Teensy microcontroller

Phase-sensitive detection is widely used in experimental physics to recover a signal at a known reference frequency, particularly when there is a noise background. In this workshop, we describe how to use an inexpensive (<$30) Teensy microcontroller, which can be programmed like an Arduino, along with an open-source software package to perform phase-sensitive detection in the context of an undergraduate laboratory. Our platform provides a simple, accessible means to teach students about phase-sensitive

detection. In addition, for some experiments, our system could be a viable alternative to a commercial lock-in amplifier. Participants in this workshop will be shown how to replicate our system at their own institution.

Primary Contact: Jerome Fung, Ithaca College <jfung@ithaca.edu>

W10: An Affordable Starter Lab for Intermediate Optics

An affordable starter lab in intermediate optics is the measurement and simulation of transmitted irradiance distributions that result when multiple point sources of light illuminate a large aperture. The simulation of these distributions and corresponding development of computational skills is supported by the Shadows (Ray Optics) computational exercise set available from the Partnership for Integration of Computation into Undergraduate Physics (PICUP). This lab activity allows low-cost customization through the choice of aperture or relative positions of light sources, aperture, and screen, and can be extended in ways that make use of tools for 3D printing and/or laser cutting, or printed circuit design. Image analysis tools can also be used to extract irradiance distributions to compare to simulations. Participants will be guided through a sequence of tasks that help students develop multiple skills.

Primary Contact: Ernest Behringer, Eastern Michigan University <ebehringe@emich.edu>

W11: Open Source Microscopy in the Advanced Lab: Einstein, Boltzmann, Fluorescence, and More

This workshop demonstrates the use of an open-source microscope to measure Boltzmann's constant as well as to image fluorescent objects (biological cells and fluorescent microspheres). The core experiment, measuring Boltzmann's constant, follows Einstein's 1905 paper on Brownian motion and the molecular theory of heat. This experiment has been described in AJP by several authors: 200 nm fluorescent spheres are imaged as they diffuse in water and Boltzmann's constant is determined from the diffusion constant via the Einstein relation.

The point of this workshop, though, is the open source microscope: the microscope itself, the electronics board controlling the illumination and focus, and the software controlling the imaging and data analysis are all open source, meaning that each is potentially modifiable (and, ultimately, buildable) by students. Thus, students learn how to image microscopic particles, track diffusion at the single particle level, determine the diffusion coefficient from the mean-square displacement, and interpret the results in light of basic fluid mechanics. But they also can modify the microscope for their own experiments – whether they are interested in high-speed imaging of self-propelled microorganisms or measuring the diffusion constant of different sized particles simultaneously (using multi-color imaging). Through this, students can learn imaging optics as well as electronics control and image analysis.

Primary Contact: Douglas Martin, Lawrence University <douglas.s.martin@lawrence.edu>

W12: FPGA-Based Positron Emission Tomography

Positron Emission Tomography is an imaging method allowing for great precision by making correlation measurements to localize a positron source within a sample. It involves recording coincidences of 511 keV gamma rays as a function of a sample's lateral and rotational coordinates within a pair of scintillation detectors. With this data, numerical reconstruction algorithms are utilized to re-create a two-dimensional map of the distribution of positron emitting sources within the sample. Our setup allows for students to engage with the experiment on many different levels, from using a GUI to automate data collection remotely, to editing Verilog code, to building the apparatus as senior thesis project.

The apparatus is relatively straightforward, requiring a linear stage for translation and a stepper motion to rotate samples. A pair of standard NaI scintillation detectors are used for gamma detection. Lastly, a Red Pitaya FPGA/Linux device is used for the user interface, for signal processing, and for automation.

Participants will be introduced to how to choose setup parameters, gather data, and reconstruct position information using Jupyter Notebook based interfaces. A full BoM and all related code and software will be available.

Primary Contact: Kevin Van De Bogart, University of Chicago <Kevinv@uchicago.edu>

W14: Building Surface-Mount electronics

This workshop will give participants a guided opportunity to build a circuit board using modern surface-mount components. It will cover a variety of techniques including hand-soldering, hot-air reflow, solder paste and stencils, and reflow ovens. It is intended to serve as a quick start to get attendees over the initial challenges of producing SMT boards for labs.

Primary Contact: Eric Ayars, California State University Chico <eayars@csuchico.edu>

W15: Online Advanced Labs in Physics

At Arizona State University we have developed a fully online BS degree in Physics. A key component of the curriculum is a set of Advanced Lab courses, which include a suite of Nobel-Prize-winning experiments such as Interferometry, Zeeman effect, Cavendish Balance, Quantum Entanglement, etc. I will review the structure of these online Advanced Lab courses, and show examples of the custom-built simulator, overview videos, student worksheets, lab notebook and formal reports.
Participant requirement note: Participants will need a Windows computer to run Excel VBA macros.

Primary Contact: Peter Bennett, Arizona State University <peter.bennett@asu.edu>

W16: Demonstration of a simple setup for cosmic muon lifetime measurements and presentation of a setup for magnetic moment measurement of cosmic muons

The presence of cosmic muons has allowed the design of instructional laboratory experiments that demonstrate experimental methods of elementary particle physics. However, most of the setups have used expensive and demanding 'professional' particle physics detectors and electronics for signal processing and storage, which requires special expertise and also comes with correspondingly high costs.

In this workshop a simple setup for the measurement of the lifetime of cosmic muons based on a single scintillation detector with data processing and acquisition electronics composed of inexpensive and commercially available electronic components will be presented. Measurements and data analysis will be demonstrated. The innovative feature of the setup is registration of time stamps of the events detected in the scintillation detector from which the muon lifetime can be determined in the off-line analysis.
A possibility for the employment of this data processing and acquisition electronics in more advanced systems for measurements of the magnetic moment of cosmic muons will be presented.

Primary Contact: Damir Bosnar, University of Zagreb <bosnar@phy.hr>

W17: Cosmic Ray Muon Telescopes

The cosmic ray muons that pass through us every minute of every day provide a playground for the investigation of elementary particle physics. In our advanced lab, we build plastic scintillator-based muon

telescopes that allow us to measure the rate of muons as a function of their direction of travel. These directions are constrained by using coincidence signals from two cylindrical plastic scintillators placed at either end of the telescope. Each scintillator is a little thicker than it would need to be for the rate experiment so that a muon lifetime measurement is also conceivable. Attached to the telescopes are silicon photomultipliers (SiPMs). Aside from the printed circuit boards that house the SiPMs, students complete some of the electronics design themselves and implement them on solderless breadboards. The 3D printed assembly containing each scintillator and SiPM has recently been improved. Students have the freedom to alter this design if they choose. The construction of the telescopes give students extensive experience in detector technology, electronics and signal processing, and the experiments expose students to an interesting topic in high energy physics and the statistics of counting experiments. An associated activity challenges students to create a computational model that replicates the muon rates they observe. At a cost of roughly $250 for each telescope, these activities are within the budget of even some very small colleges.

Primary Contact: Brett Fadem, Muhlenberg College <brettfadem@muhlenberg.edu>

W18: Index-Matching Computer Tomography

Computer aided Tomography (CAT or CT) systems are a fundamental medical physics imaging tool. CT systems are typically based on X-rays, making student access to them costly due to safety concerns and initial start up costs. The fundamental physics behind CT systems is attenuation of X-rays by absorption. In this workshop a visible light CT system will be used to recreate the physics behind X-ray based systems. Colored Pyrex glass immersed in a fluid of identical index of refraction removes refraction losses and absorption can be accentuated using different colors of pyrex. Attendees to the workshop will collect data, produce sonograms and apply a simple algorithm to reconstruct images.

Primary Contact: Mark Paetkau, Thompson Rivers University <mpaetkau@tru.ca>

W19: Fluid physics laboratory experiments

Fluid mechanics is a topic not generally covered in undergraduate physics courses. We present experiments designed for a senior lab that explore fluid mechanics and are simple to implement. For some students, this is the only time in their undergraduate studies that they would be exposed to these topics. The main component of the set up is a magnetic stirrer. These are commonly used in several types of laboratories to mix different materials. It consists of a magnet rotating with an adjustable frequency around a fixed vertical axis below a flat horizontal surface. The rotation of the magnet brings a magnetic stirrer bar into rotation on the bottom of a container that contains a fluid seeded with micron sized particles placed on the flat surface. The rotation creates a toroidal vortex. As the funnel shaped vortex develops the liquid level rises at the edge of the container. This set-up is combined with Particle Image velocimetry (PIV) for the analysis. This is a whole-field technique providing instantaneous velocity vector measurements in a medium undergoing motion. Data analysis techniques like cross-correlation and pattern recognition allow to track the motion of the medium and determine velocity fields.

Primary Contact: Varghese Mathai, University of Massachusetts, Amherst <vmathai@umass.edu>

W20: Miniature Tesla Coil Teaching Lab

Participants will learn how to make a miniature Tesla coil, how the miniature Tesla coil functions, and use it to test the V~1/r scaling of the electric potential. The miniature Tesla coil is powered by a 9 V battery and utilizes a TIP31C resistor as the switch. Each coil costs about $10 and can be created from scratch by an undergraduate in under three hours. Demonstrating the functioning of the Tesla coil requires only a compact fluorescent lightbulb while measuring the electric potential requires an oscilloscope. After the lab activity students should be able to describe the functioning of a transistor, how the transistor combines with

the law of induction to create an oscillating electric potential, and how this electric potential decreases in strength with distance from the Tesla coil. This lab activity is intended for an upper level electronics course, but can be used at the introductory level by invoking the hydraulic analogy for circuits.

Primary Contact: Nathan Tompkins, Wabash College <tompkinn@wabash.edu>

W22: Acoustic resonance lab for Fourier and modeling skills

We have developed an acoustic resonance lab with a goal that students gain experience with Fourier transform spectral methods and assessment and revision of models. In this workshop, participants will use a digital oscilloscope to record audio signals from hollow cylinders struck with a mallet. The fast Fourier transform tool (FFT) of the 'scope provides the frequency spectrum in which the fundamental resonance mode and higher harmonics are observed. Used in a lab class, students measure fundamental frequencies for tubes of different lengths and compare first to a simple standing wave model. Finding disagreement with data for short tubes, they can revise the model to include end effects. Other topics explored may include broadening due to observation time, dependence of spectrum on point of impact, Q factor, driven oscillator response, distortion from signal clipping, FFT frequency limits, and aliasing. We will also show use of a FPGA signal analyzer (Moku:Go) as an alternate equipment option.

Primary Contact: Timothy Roach, College of the Holy Cross <troach@holycross.du>

W23: How to implement laboratory projects in microscopy

Laboratories are a great place for projects. Projects give students the opportunity to model outcomes, design experiments, analyze data, construct new knowledge, and communicate their results--all key activities recommended by the American Association of Physics Teachers (AAPT) in their "Recommendations for the Undergraduate Physics Laboratory Curriculum". Yet, projects are difficult to implement since time, resources, and instructor knowledge may be limited. Here, we describe how to implement laboratory projects in microscopy in introductory courses (electromagnetism or optics) or more advanced courses (optics, advanced laboratory, or biophysics) with standard 3-hour laboratory periods. To start, we describe the building of a brightfield, compound microscope depicted in many introductory physics textbooks. Building this microscope and measuring its magnification is a standard laboratory activity, but is often tricky for students and instructors. We then describe how to use this as a foundation to build a higher resolution microscope, a fluorescence microscope, or a total internal reflection fluorescence (TIRF) microscope. Other possible microscopes are darkfield, reflection, differential interference contrast (DIC), phase contrast, and confocal microscopes. Students would need one laboratory period to build the compound microscope and perhaps two additional laboratory periods to transform their microscope into one of the others listed, creating a perfect 3-week project. The different microscopes give students the thrill of building something new, but the limitation of building a microscope keeps the required parts, time-to-build, and instructor knowledge to a minimum.

Primary Contact: Ashley Carter, Amherst College <acarter@amherst.edu>

W24: Investigating Electronic Structure with a Single-axis Tunneling Microscope

We have developed a simplified alternative to the scanning tunneling microscope (STM) that restricts tip motion to one dimension: the z-axis tunneling microscope (ZTM). Here, the z-axis lies along the tip-sample separation. Students are able to observe the exponential dependence on tunneling current with tip-sample gap and observe qualitative differences in the electronic density of states between metals, semimetals, and semiconductors. The current pre-amp, stepper motor control, piezo actuator, and bias voltage are integrated into a single PC board. All signals are either analog <10 V or TTL, allowing either manual or programmatic

control. The ZTM is simpler and less costly to build than an STM, expanding access to a subset of STM experiments to more learners.

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Co-authors: Randy Lindgren, Wesley Kozan, Tikran Kocharian, and Karl Brakora, Grand Valley State University

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W25: Room temperature Superconductors! Experiment with superconductors and magnetic levitation.

New superconductivity and Magnetic Levitation experiments from quantunlevitation.com.
Experiments include:

- Superconductivity (persistent currents)
- Meissner effect (diamagnetic repulsion)
- Frictionless motion (maglev)
- Critical temperature (T_c) complete measurement (all included)
- Flux pinning – magnetic trapping
- Magnetic forces
- Maglev train setup

Primary Contact: Boaz Almog, Quantum Experience ltd. <boazal@quantumlevitation.com>
Co-authors: Ido Babay and Eran Tzinamon

W26: Quantum Control

Quantum Control is an experiment in the preparation, control, and read-out of quantum states of a spin-1/2 system. The apparatus is self-contained and commercially-available, and represents an exercise in proton nuclear magnetic resonance (NMR) that has been expressly tailored for teaching the quantum mechanics of a spin-1/2 system, including the non-perturbative treatment of interventions in this system.

This experiment is thus tightly tied not only to NMR in particular, but to the 'second quantum revolution' in general. It highlights the importance of quantum superpositions in the spin-1/2 system; how they are created, how they evolve freely and under external intervention, and how they can be detected. While Quantum Control is not a quantum computer, it can fairly be called a working 1-bit quantum register.

Primary Contact: David Van Baak, TeachSpin, Inc. <dvanbaak@teachspin.com>

W27: Some Extensions To The Quantum Analogs Experiment

Quantum Analogs is a "classic" first experiment in many Modern Physics labs - a series of acoustic experiments that model quantum phenomena. The experiment is based on an analogy drawn between the mathematics of the Schrodinger wave equation and the wave equations that describe ordinary sound waves in air. We will quickly review the basic experiments, such as development of a bandgap in a 1-D sonic lattice and spherical harmonics as the angular solution to acoustic standing waves in a spherical cavity (a sonic model for the H atom). We will then move to some interesting extensions of the system, such as defect states in 1-D lattices and using the spherical cavity to examine not just the angular components of the wave function, but also examine the radial solution and its predicted eigenfrequencies.

Primary Contact: David Lee, TeachSpin, Inc. <dslee@teachspin.com>

W28: Quantum Optics Kit

We present our new quantum optics kit where a non-linear crystal generates pairs of photons. In the kit, a variety of experiments can be performed: demonstrate that an attenuated laser is not a single-photon source, measure the 2nd order auto-correlation of the pairs to verify that they constitute a non-classical light source, observe single photon behavior at a polarizer, set up a single photon interferometer and perform the quantum eraser experiment. The setup stays away from black boxes and all elements can be individually adjusted. This allows for a realistic lab experience and future extensions. In the workshop, we explain the setup, demonstrate the measurements and exemplify the comprehensive alignment procedure which allows students to reliably find and return to a good alignment.

Primary Contact: Michael King, Thorlabs, Inc. <mdking@thorlabs.com>
Co-authors: Keerthanan Ulaganathan

W29: Fourier Optics Kit

In an imaging system, such as a microscope, image formation can be understood as the interference of light diffracted by the sample and collected by the objective lens. The Fourier transform of the object is found in the back focal plane of the lens, otherwise known as the Fourier plane. The image of the object, which is formed by a second lens, can be altered in a variety of ways by manipulating the pattern in the Fourier plane. In this kit, an etched, chrome-on-glass target with fourteen different patterns serves as the object. In the workshop, we alter the patterns in the Fourier plane to help a Smiley escape from prison, alter the direction of a diffraction grating, open the door of a house and more. Fourier optics allows students to enhance their understanding of Fourier transforms in general and image formation in particular.

Primary Contact: Michael King, Thorlabs, Inc. <mdking@thorlabs.com>
Co-authors: Jens Küchenmeister

W30: Quantum Cryptography

Our Quantum Cryptography Demonstration Kit contains components to model a data transmission setup using the BB84 encryption protocol. This encryption method allows a sender and receiver to generate an encryption key that only they know and eavesdroppers to be detected. In this analogy experiment, the polarization of transmitted light carries bits of information which are manipulated using half-wave plates and polarizing beamsplitters.

Even though this is a classical experiment because of the use of laser pulses instead of single photons, students are able to experience every step of the BB84 protocol. In particular, they learn about the preparation of a state and how they generate a tap-proof key. The experiment culminates in the placement of Eve between Alice and Bob to demonstrate how her presence inevitably leaves a trace that reveals her presence.

Primary Contact: Michael King, Thorlabs, Inc. <mdking@thorlabs.com>
Co-authors: Jens Küchenmeister

W31: Gamma-Gamma Coincidence and Half Life Determination

Demonstration of gamma-gamma coincidence and half life determination experiments from Spectrum Techniques.

Primary Contact: Richard Love and Roger Stevens, Spectrum Techniques
<stevensr@spectrumtechniques.com>

W32: Single Photon Counting Module demo

Using single photon counting modules in scientific applications from Pacer USA.

Primary Contact: Kurt Gibbings, Pacer <kurt.gibbings@pacer-usa.com>

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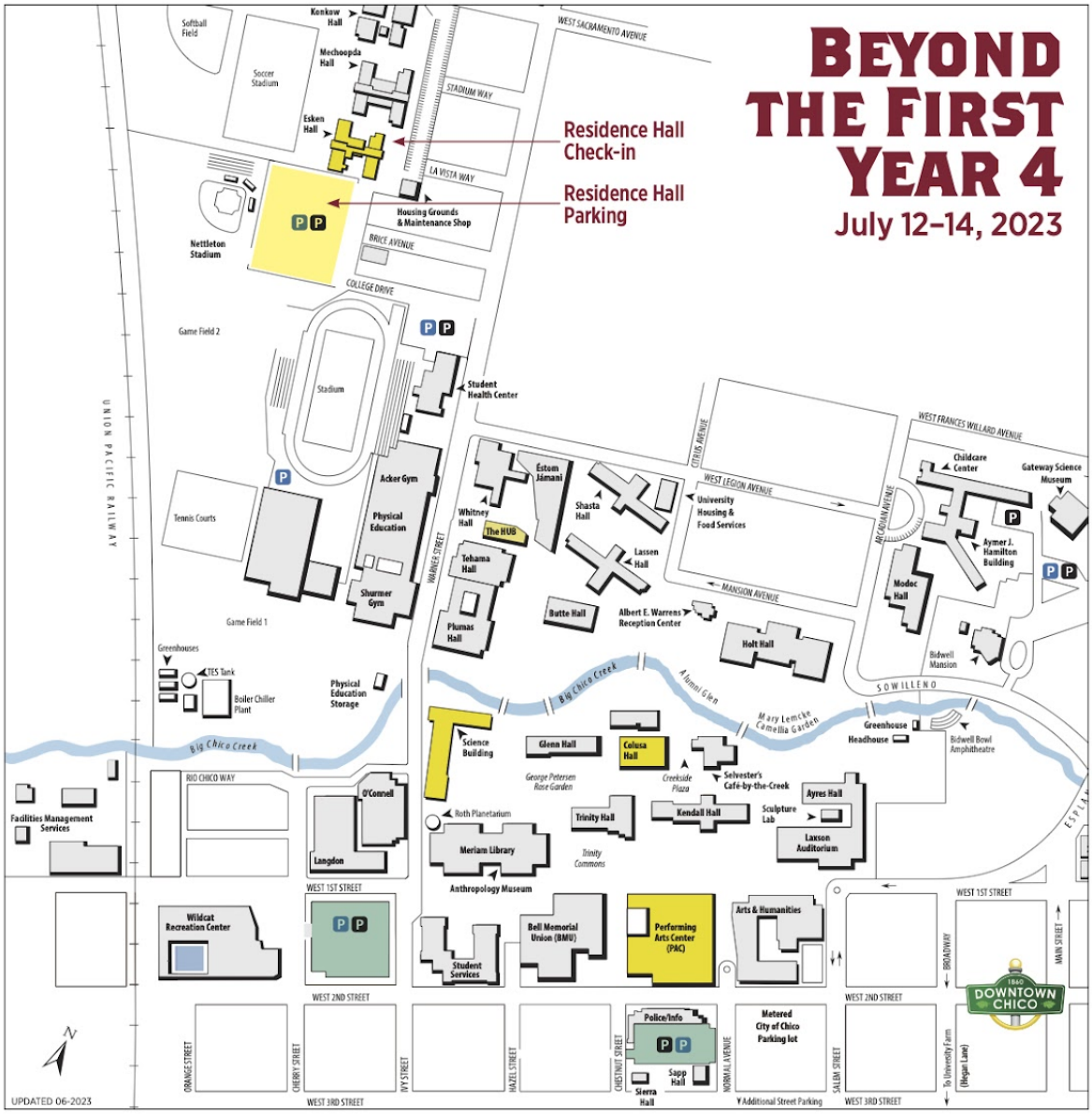
California State University Chico

Beyond the First Year 4

July 12–14, 2023



Reduced-Rate Campus Parking:

1. Visitor parking is available for guests in campus lots in any open General (G) or Faculty-Staff (FS) marked space.

2. Scan the QR code to the left after you've parked.

3. Enter the current date only then click the buy button. You will need to purchase a permit each day you park, Monday-Thursday. (Friday/Saturday/Sunday excepted.)

4. Enter your name, payment and vehicle. You MUST enter your license plate number. Enforcement is based upon license plate.

5. Click purchase to complete. Permits are digital (despite the instructions to print).

Residence Hall Parking:

If you are staying in the residence halls you will receive a weekly permit and you do not need to purchase a daily permit.

City Parking:

Free and metered street parking is available south of campus. Most metered spaces are 50 cents per hour.