ADVANCED LABORATORY COURSE

John Essick
Reed College

OUTLINE:

• What is the Advanced Laboratory?
• Funding and Hot Topics
• ALPhA
# VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th>Class</th>
<th>Intro Physics with Lab</th>
<th>Intro Physics With Lab</th>
<th>Intro Physics</th>
<th>Intro Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sophomore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior/Senior</td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
<td>Thermal Physics</td>
<td>Electrodynamics</td>
</tr>
</tbody>
</table>
## VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Intro Physics</th>
<th>Intro Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>with Lab</td>
<td>With Lab</td>
</tr>
<tr>
<td>Sophomore</td>
<td>Intro Physics</td>
<td>Intro Physics</td>
</tr>
<tr>
<td></td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td>Thermal Physics</td>
</tr>
<tr>
<td>Junior/Senior</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; Electronics Course</td>
<td></td>
</tr>
</tbody>
</table>
# VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th>Class</th>
<th>Intro Physics with Lab</th>
<th>Intro Physics With Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sophomore</td>
<td>Intro Physics</td>
<td>Intro Physics</td>
</tr>
<tr>
<td>Junior/Senior</td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td>Thermal Physics</td>
</tr>
<tr>
<td></td>
<td><strong>Specialty Course</strong></td>
<td><strong>Specialty Course</strong></td>
</tr>
<tr>
<td></td>
<td><em>with Lab</em> (e.g., Optics)</td>
<td><em>with Lab</em> (e.g., Optics)</td>
</tr>
</tbody>
</table>
# VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Intro Physics with Lab</th>
<th>Intro Physics With Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomore</td>
<td>Intro Physics</td>
<td>Intro Physics</td>
</tr>
<tr>
<td>Junior/Senior</td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td>Thermal Physics</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Independent Project Course</strong></td>
</tr>
</tbody>
</table>
# VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Intro Physics with Lab</th>
<th>Intro Physics With Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sophomore</td>
<td>Intro Physics</td>
<td>Intro Physics</td>
</tr>
<tr>
<td>Junior/Senior</td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td>Thermal Physics</td>
</tr>
</tbody>
</table>

Short Internship in Research Lab
# VARIOUS APPROACHES TO ADVANCED LAB

<table>
<thead>
<tr>
<th></th>
<th>Intro Physics with Lab</th>
<th>Intro Physics With Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freshman</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sophomore</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Junior/Senior</strong></td>
<td>Classical Mechanics</td>
<td>Quantum Mechanics</td>
</tr>
<tr>
<td></td>
<td>Electrodynamics</td>
<td>Thermal Physics</td>
</tr>
</tbody>
</table>

Lab Course with Guided and Independent Projects
GOAL: TEACH BASIC RESEARCH SKILLS

PHYSICAL UNDERSTANDING
- Apply Classroom Theory
- Background Literature Searches
- Consultation With Experts
- Adequate Level of Precision
- Range of an Approximation
- Suppression of Competing Effects

DATA-TAKING SKILLS
- Electronics
- Computer-Assisted Data Acquisition
- Optics
- Vacuum Technology
- Data Analysis Techniques
- Design of Sophisticated Instrumentation
- Patience
- Consistency Checking

RESPONSIBILITY TO THE COMMUNITY
- Outside Interest In Results
- Benefit Of Peer Review
- Honest, Timely, Concise Report of Results
REED JUNIOR-LEVEL ADVANCED LAB

**ELECTRONICS**
- Amplifier, Filter, Oscillator, Logic

**COMPUTER-BASED SKILLS**
- LabVIEW Programming
- Data Acquisition Board
- Instrument Control via Interface Bus
- Data Analysis

**PHYSICS**
- Guided and Independent Experiments

Novice Student

Autonomous Researcher

Senior Thesis
Summer Internship
Graduate School Career
SPRING-SEMESTER PHYSICS EXPERIMENTS

Guided Experiments:

- Optical Bandgap of Semiconductor (Monochromator)
- Doppler-Free Saturated Absorption Spectroscopy (Laser Diode)
- Temperature Dependence of Diode’s Saturation Current (Cryostat)
- Isotope Shift of Balmer Series in Hydrogen (Spectrometer)
- Mass of Cosmic Ray Muon (Fast-Timing Electronics)
- Fabrication of Fullerenes (Materials Fabrication)
- Proof of Existence of Photons (Single-Photon Detection)
SPRING-SEMESTER PHYSICS EXPERIMENTS

Independent Projects:

- High-Temperature Superconductor
- Chaotic Electrical Circuit
- Raman Spectroscopy
- Quantized Conductance in Nanowire
- Quantum-Dot Photoluminescence
- Period of Jupiter’s Moons
- Optical Tweezers
FUNDING ADVANCED LAB DEVELOPMENT

Institutional Sources:
- Departmental Budget Line-Item
- Development Office
- Alumni Donations
- Local Industry Donations

External Sources:
- Foundations (e.g., Keck)
- NSF (Broader Impact, Dissemination)
HOT TOPICS IN ADVANCED LAB DEVELOPMENT

Quantum Optics Experiments:
- Existence of Photon
- Single-Photon Interference
- Entanglement and Quantum Eraser
- Bell’s Inequality

Computer-Based Data Acquisition:
- LabVIEW
- MATLAB
- Arduino

Low-Cost Electronics:
- Field Programmable Gate Array (FPGA)
- Microelectromechanical Systems (MEMS)
- Wireless Communication
ADVANCED LABORATORY PHYSICS ASSOCIATION (ALPhA)

**Purpose:**
Promote Advanced Experimental Physics Instruction

**Organization:**
- Founded 2007
- 250 College and University Advanced Laboratory Developers
- Web Page – advlab.org
- $30 Membership Fee

**Programs:**
- Laboratory Immersions
- Conference on Laboratory Instruction Beyond the First Year (BFY)
- Discounted Equipment
LABORATORY IMMERSIONS PROGRAM

Purpose:
Advanced Lab Faculty and Staff Development

Format:
• Taught at Volunteer Mentor’s Institution
• Two- or Three-Day Training on One Advanced Lab Experiment
• Cost – $350 Registration (includes meals) plus Travel Expenses

Note:
Mentor Can Use For Dissemination Component of NSF Grant
<table>
<thead>
<tr>
<th>Date</th>
<th>Institution</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2-4</td>
<td>Harvey Mudd College (CA)</td>
<td>• Single Photon/Entangled Photon Experiments</td>
</tr>
<tr>
<td>June 2-4</td>
<td>Colgate University (NY)</td>
<td>• Experiments on Photon Quantum Mechanics</td>
</tr>
<tr>
<td>June 9-11</td>
<td>Univ. of Tennessee (TN)</td>
<td>• X-ray Diffraction and Compton Scattering</td>
</tr>
<tr>
<td>June 15-17</td>
<td>CSU - Chico (CA)</td>
<td>• Arduinos in the Advanced Lab</td>
</tr>
<tr>
<td>July 7-9</td>
<td>Princeton Plasma Physics Lab (NJ)</td>
<td>• Low Cost Plasma Physics: Paschen Curve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low Cost Plasma Physics: Spectroscopy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low Cost Plasma Physics: Electron Temperature</td>
</tr>
<tr>
<td>July 8-10</td>
<td>Bethel University (MN)</td>
<td>• FPGA Exercises in the Advanced Lab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ultrafast Optics - Frequency Comb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nano-Plasmonics and Surface-Enhanced Spectroscopy</td>
</tr>
<tr>
<td>July 8-10</td>
<td>Miami University (OH)</td>
<td>• Arduinos for the Advanced Lab</td>
</tr>
<tr>
<td>August 1-3</td>
<td>Univ. of Michigan (MI)</td>
<td>• Galactic Rotation and Evidence for Dark Matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Faraday rotation in optical media</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Measuring the Cosmic Microwave Background</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ℓν - ℓν Pair Production</td>
</tr>
<tr>
<td>August 5-7</td>
<td>Caltech (CA)</td>
<td>• Electrodynamic Ion Trapping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Precision Measurements Using Interferometry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Magneto-mechanical Harmonic Oscillator</td>
</tr>
</tbody>
</table>

Learn more at: www.advlab.org
BFY CONFERENCE

Purpose:
Community Building for Advanced Lab Developers

Format:
- 2.5-Day Conference Once Every Three Years
- Limited to 150 Participants
- 12 40-Minute Workshops on Different Advanced Lab Experiments
- Plenaries and Breakout Sessions on Advanced Lab Topics
- Poster Session
- $199 Registration Fee, Includes All Meals
The Second Conference on Laboratory Instruction Beyond the First Year of College
University of Maryland
July 22 - 24, 2015
WWW.ADVLAB.ORG
DISCOUNTED EQUIPMENT

Purpose:

Support Implementation of Laboratory Immersions Experiments

Quantum Optics Experiments = Most Popular Immersion:

- Single-Photon Detectors are Most Expensive Component
- ALPhA Sells Detectors for $1430 Each (About Half Retail Price)
- Total Experiment Cost is about $20k
DISCOUNTED EQUIPMENT

Jonathan F. Reichert Foundation ALPhA Immersions Support:

For Immersion Attendee,
up to 40% of Cost of Immersion Experiment Equipment
($7,500 Maximum)