Physics advanced laboratory designed for engaged learning experiences

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Motivations for this talk

• We wanted to evaluate our advanced laboratory experiments and review them based on:
  • Their alignment with different recommendations (Department, AAPT, etc…)
  • Employers or supervisors expectations
  • The level of engagement to motivate students
• Share and generate discussions about new experiments and potential topics that would be missing from our curriculum.
Difficulties to create a complete advanced lab curriculum

- Physics includes many subfields.
- Jobs with a physics degree are diverse.
- Students skills are developed at different levels.
- Labs are only a small fraction of a full degree.
- A new undergraduate astrophysics stream is offered this fall.
Carleton University  
Physics Department

Learning outcomes  
for  
physics programs and courses

What Things Should Every Physics Major Know?

Over the weekend, cosmologist and author Sean Carroll tweeted about what physics majors should know, namely that "the Standard Model is an SU(3)×SU(2)×U(1) gauge theory, and know informally what that means." My immediate reaction to this was pretty much in line with Brian Skinner's, namely that this is an awfully specific and advanced bit of material to be a key component of undergraduate physics education. (I'm assuming an undergrad context here, because you wouldn't usually talk about a "major" at the high school or graduate school levels.)
Lab courses offered (3rd and 4th years)

**PHYS 3007**  
*Third Year Physics Laboratory: Selected Experiments and Seminars*  
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.

**PHYS 3606 and PHYS 3608**  
*Modern Physics II (Modern Applied Physics)*  

**PHYS 4007 and PHYS 4008**  
*Fourth Year Physics Laboratory: Selected Experiments and Seminars*  
Students complete a small number of experiments selected from modern optics, holography, atomic physics, nuclear spectroscopy, radiation, etc. An exercise on literature searches and student seminars on experimental and numerical methods are included.
## All the experiments offered in 3rd and 4th year labs

<table>
<thead>
<tr>
<th>Atomic/Nuclear/Particle</th>
<th>Optics</th>
<th>E&amp;M</th>
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<tbody>
<tr>
<td>Alpha/Beta/Gamma Spectroscopy</td>
<td>Laser Doppler Velocimetry</td>
<td>Hall Effect</td>
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<td>X-Ray Fluorescence</td>
<td>Mach-Zehnder Interferometer</td>
<td>Haynes-Shockley Experiment</td>
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<td>X-Ray Diffraction</td>
<td>Holography</td>
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<td>Electron and Proton spin Resonance</td>
<td>Sonoluminescence</td>
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<td><em>Muon Life Time</em></td>
<td>Zeeman Effect</td>
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<td>Earth field NMR</td>
<td>Optical Pumping</td>
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<td>Pulsed NMR</td>
<td>Saturated Absorption Spectroscopy</td>
<td>Vacuum Techniques</td>
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<tr>
<td></td>
<td>Optical Tweezers</td>
<td>Others</td>
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*New experiments or modified recently for a more engaging experience, oriented for modern skill building.*
Laser Doppler Velocimetry, LDV

Typical water flow: 8 gal/h = 0.23 l/s
V ~ 3 m/s
Tube diameter = 15.9 mm
Laser: HeNe 474 THz

Beating at 7500 Hz
\( \frac{7500\text{Hz} \times c}{474\text{THz}} = v \sin(\theta) = 0.00474 \text{ m/s} \)
\( v = 1000 \times 0.0047 \text{ m/s} \)
DAQ: SoundCard -> FFT
Software: Sigview ($)

Measure water velocity profile across the radius. Seeds are 1um spheres.

Suggestions:
- PIV
- Hot wire anemometry

(Laser Doppler Anemometry, LDA)
http://www2.cscamm.umd.edu/programs/trb10/presentations/LDV.pdf
Advanced lab topics word cloud
Does not include first and second year labs

Electromagnetism
Nuclear Physics
Thermodynamics
Particle Physics

Math and Data Analysis

Detectors and Electronics

Programming
Astrophysics

Optics

Atomic Physics

Solid State Physics
Recommendations/Conclusions

• No need for a major reconstruction of our curriculum.
• New astrophysics experiments will be developed over the next 5 years.
• Experiments can be enhanced to make them more engaging and develop more skills with small changes. For example:
  • Letting students design their experiment, calibrate instruments, connecting cables, aligning optical elements.
  • Asking student to program a simulation or an analysis package of the experiment.
  • Removing the theory from the lab manual and instead giving a list of recommended articles.
  • …
• To develop extracurricular skills, we are working on a model to help students wanting to develop extracurricular skills (programming, electronics, job searching, etc…)
Open Discussion (if time permits)

• Have you done a similar review at your University?
• Have we missed something important?
• Any new experiments you want to share with us?
• How specialized/versatile should undergrad students be?