### Slate of PHYS250 Experiments

<table>
<thead>
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<th>Experiment</th>
<th>Status</th>
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<tbody>
<tr>
<td>Mechanical Resonance</td>
<td>Procedural</td>
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<tr>
<td>Bending Beams and Strain Gauges</td>
<td>Procedural</td>
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<td><strong>Coupled Oscillations</strong></td>
<td>Design</td>
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<td>The e/m Ratio</td>
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<td><strong>Diffraction from a CD</strong></td>
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<td>Interference and Diffraction of Ultrasound</td>
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<td><strong>Young’s Modulus of Steel</strong></td>
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Three out of 11 are **Design Labs**. Eleven labs $\times$ 2 setups $\times$ 2 students = 44. The first week is tutorial labs and there are again 22 setups $\times$ 2 students $= 44$. 
Student Numbers

<table>
<thead>
<tr>
<th>Year</th>
<th>Enrollment</th>
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<tbody>
<tr>
<td>2019</td>
<td>50</td>
</tr>
<tr>
<td>2018</td>
<td>43</td>
</tr>
<tr>
<td>2017</td>
<td>39</td>
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<td>2016</td>
<td>33</td>
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<tr>
<td>2015</td>
<td>34</td>
</tr>
<tr>
<td>2014</td>
<td>28</td>
</tr>
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The ENPH second year labs splits into two sections when the enrollment > 28.
The STANDARD MODEL of Laboratory Instruction = 
Procedural Laboratory

Procedure

1. Turn on the oscilloscope and set it to display Channel 2 as a function of 
Channel 1 (XY Mode) by selecting: $Horizontal \rightarrow Main/Delayed \rightarrow XY$.

2. Connect the leads to the scope such that the H-field is displayed on the 
X-axis and the B-flux is displayed on the Y-axis. The horizontal and 
vertical sensitivity should be set to 200mV per division as a starting 
point.

\[
\ldots
\]

From the Ferromagnetic Hysteresis Outline
Procedural Workflow

For \( n = 1 \ldots N \) read and execute procedural item \# n

Think about the Physics

Test the results

o.k.

Write the report

Problem(s)

Ask for more time

0.0

2.X

time (hours)

“I never read an outline before I came to the lab”
What is wrong with Procedural Labs?

Science as it is taught should closely resemble science as it is practiced by professional scientists.

Whatever taxonomy of thinking you use, you should aim to have your students operate in the higher levels.

Laboratories should foster minimally restrictive free exploration rather than the prescriptive adherence for formal procedure.

The compact disk as a diffraction grating

James E. Kettler
Ohio University Belmont, St. Clairsville, Ohio 43950

Fig. 2. Diagram showing angles and distances used in calculating the wavelength of light or grating spacing of the CD.

\[ n\lambda = d(\cos \phi_n - \cos \phi_0) \]
Design Workflow

1. Read the outline and discover the task
2. Think about the Physics and make a plan
3. Execute your procedure
4. Test your results
5. Write your report

Time:
- 0.0 hours
- 3.0 hours

Problem(s):
- Refine

Status:
- o.k.
Our Responsibility as Laboratory Instructors

- To draw the students into the field by exposing them to interesting phenomena.
- To raise questions that students find personally meaningful.
- To support the students while they devise their own procedures and try things out.
A new Design Lab involving Coupled Systems

Coupled pendulums, are demonstrated by Professor Roger Bowley as part of little Easter series. He’s using creme eggs, of course. Sixty Symbols. YouTube
Connections to Quantum Physics

Coupling systems together produces symmetric and antisymmetric eigenstates with an energy/frequency splitting. e.g. covalent bonding and quantum wells:

\[ \sigma \text{ relation between two } 2 \text{ orbitals: } \text{He}_2 \]

\[ \text{Antibond } \sigma^* \]

\[ \text{Bond } \sigma \]

\[ \text{Energy versus barrier width } r. \]
Coupled Oscillators in the Literature.


PHYS250 Towards an Open Source Hardware Kit

Prototype 1 (Matt Frost)
- Magnetic coupling
- Hall probe

Prototype 2 (Will Kim)
- Mechanical coupling
- OPTEK sensor

Designed to be a high quality (Q > 1000) Open Source Hardware Kit (e.g. Adafruit). Jupyter Notebook interface with Raspberry Pi or Arduino via Python. Hot Topic at Third Conference on Laboratory Instruction Beyond the First Year in Baltimore - Targeting Student Design and Modeling Skills using Coupled Oscillators, Kim, Frosst, Cai and McLean. DESIGN EXPERIMENT
PHYS250 Open Source Hardware Kits e.g. AdaFruit