Lab Away From Lab: The IOLab’s Potential for Avoiding the Space and Equipment Constraints of the Traditional General Physics Lab

by Stephen Mecca, Seth Ashman, Nicole Boyd, Kerry McIntyr

Mon 07/18, 9:00AM - 9:10AM

Type: Contributed

Commercial and open-source multi-sensor instruments have become common in the marketplace. Some of these, for example the basic tablet or smartphone, can be inexpensive but may lack features such as adequate sample rates for basic motion experiments. Commercial products from PASCO and Vernier are being introduced with Bluetooth capability allowing a laptop, tablet or hybrid logger to acquire data wirelessly. These products and the open-source IOLab device offer the opportunity to accomplish particular lessons of the general physics laboratory without the need for a physical laboratory and without an expensive inventory of lab equipment. This paper presents the authors’ use of the IOLAB with a minimal set of additional components to replicate or slightly modify the existing General Physics laboratory exercises in our two semester sequence in the Department of Engineering-Physics-Systems at Providence College. The potential of this approach to laboratory instruction in traditional laboratory curricula, for distance learning or for resource constrained environments, such as rural schools in the developing world is discussed.
Origins of the project

‘Me sukuu wo daabī buukuu, daabī bōbī, daabī anyīnam, daabī kita tiefi ho, daabī samīna na ketewa nsu.’

Typical School Headmistress lamentation

Lab in a Box & GSAP Portal
Lab in a Box
GSAP Learning Resources Laboratory Portal

A Set of educational resources to enhance teaching and learning

Rachel Initiative

Primary & secondary Web Sites & Materials

Additional Related Materials
Extending the *Lab in a Box* as a Science Lab
The Tablet as the core of a science lab

**Apps**
- Instruments
- Simulations
- Analytical Tools
- References

**Supplementary Instruments & Components**
- Multimeter
- Microscope
- LiPo Battery
- Components
- Supplies

=A Science Lab in a Box
Science Lab in a Box – Apps

• Instruments
  - EjsS Reader Free
    - Universidad DE MUR
  - Mechanical Engineering Toolbox v1.2
    - Android Lollipop (3.1)
  - Smart Distance
    - Smart Tools co.
  - Smart Ruler
    - Smart Tools co.

• Simulations
  - FrequentSee - Sparse
    - Daniel Bach
  - Physics Toolbox
    - Viyra Software
  - Smart Magnifier
    - Smart Tools co.
  - Sound Meter
    - Smart Tools co.

• Analytical Tools
  - Loughborough WaveLab
    - EESE Loughborough
  - Sensor Kinetics
    - INNOVATIONS, Inc.
  - Smart Measure
    - Smart Tools co.
  - Speed Gun
    - Smart Tools co.

• Reference Works
  - Maps
    - Google Inc.
  - Smart Compass
    - Smart Tools co.
  - Smart Mirror
    - Smart Tools co.
  - Vibration Meter
    - Smart Tools co.
Apps
More APPs

Function Generator
- kewlsoft
- Dual channel function / waveform / signal generator for the speaker

Color Flashlight
- Notes
- Turn your phone into a color flashlight, police light, disco light, candle

EjsS Reader Free
- UNIVERSIDAD DE MUR
- The EjsS Reader allows you to organize and run science or engineering

FrequentSee - Sp
- Daniel Bach
- See your voice, music or test your audio equipment. See whatever

Loughborough V
- EEE Loughborough
- Loughborough Wave Lab is an educational learning app designed to aid

Easy Slow Movie
- Pluckyne
- It is an application equipped with only playback function from

LearnLight Spectrometer
- flappit
- NOT FOR KITKAT 4.4.
- LearnLight is a science app for visible light

SimPhysics
- Siminsights Inc
- Welcome to SimPhysics, a collection of 50 games with over 350 levels to
# Science Lab in a Box – The additional items

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimeter</td>
<td>$ 5</td>
</tr>
<tr>
<td>LiPo Battery Pack</td>
<td>$ 38</td>
</tr>
<tr>
<td>60x Microscope</td>
<td>$ 5</td>
</tr>
<tr>
<td>Stapler</td>
<td>$ 3</td>
</tr>
<tr>
<td><strong>Components:</strong> Capacitors, Thermistors, USB to Alligator Cable, Alligator-terminated cables, Magnets</td>
<td>$ 15</td>
</tr>
<tr>
<td><strong>Supplies:</strong> #2 Pencil, Straw, Staples, Tape, Glue, Scrap File Folders, Wire, Foil</td>
<td>$ 5</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$ 71</strong></td>
</tr>
<tr>
<td>Time (s)</td>
<td>$a$ (m/s$^2$)</td>
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<tr>
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<tr>
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<td>7.383</td>
<td>-0.05</td>
</tr>
<tr>
<td>7.386</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Homemade Cart
Rolling down an inclined table
Tablet accelerometer data along direction of motion

Homemade Cart
Rolling down an inclined table
Tablet accelerometer data along direction of motion

acceleration (average = 0.049 m/s$^2$)

$\gamma = 0.0491x - 0.3457$

$\gamma = 0.0246x^2 - 0.3468x + 1.2207$

GSAP
Global Sustainable Aid Project
Ohms Law

Theoretical Data

Experimental Data

$y = 5.29x$

$y = 5.20x$
Lab in a Box

Teacher training - the critical piece

Student engagement and learning – the ultimate goal
That was 2015 ... presented paper at AAPT College Park in 2015

In addition to the Tablet sensors and APPS, we had played with:
TI’s Sensor TAG and a bit later (beat up on) the original IOLAB

Findings: Tablet sensors and APPS.. Worried about tossing a smart phone for a projectile experiment
TI’s Sensor TAG – inexpensive ($25) BUT limited sampling rate
IOLAB – overcomes the sampling rate issue AND offers so much more than the tablet alone or the Sensor Tag
“Could this replace our closet-full of sensors and loggers to effect a similar set of lessons learned for General Physics? And perhaps replace the physical space of the lab or serve as a distance learning lab”
# IOLABs equivalents Physics I

<table>
<thead>
<tr>
<th>Physics I Labs</th>
<th>Probes &amp; Loggers</th>
<th>IOLAB equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match the Graph</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Freefall</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vector Resolution of Forces</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Centripetal Force</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Work and Energy</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Conservation of Energy</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Conservation of Linear Momentum</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Ballistic Pendulum</td>
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<td></td>
</tr>
<tr>
<td>Torque</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Simple Harmonic Motion</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Sample 101 IOLAB Torque

- Use a hinged door, place IOLAB rolling in y-direction
- Maintain a constant $V_y$ while applying a force at $R=.75M$ from the axis
- Force ($\sim1.49 \, N$) x $R$ (0.75 m) gives the torque required to overcome the friction in the hinges ($\sim1.12 \, N-m$)
Now, increase and hold constant the force (~4.39 N) [torque=4.39*0.75] and observe the door speeding up.

Subtract friction torque from the applied torque to get net torque. Use the initial and final velocities and \( R = 0.75\text{m} \) to find the angular acceleration.

From \( \Gamma = I \alpha \), extract \( I \), moment of inertia. Get \( I \approx 9.37 \text{ kg m}^2 \)

Compare to \( I = \frac{1}{3} mR^2 \) (~ 9.39 kg m\(^2\))
Sample 101 IOLAB Torque – another alternative

- Use gyroscope and force sensors on a freely swinging door applying constant force and observing linear changing $\omega$ (rad/s).
- This gives a torque and a constant angular acceleration from which the moment of inertia can be calculated.
- Best to first observe the frictional torque from the hinges and subtract from the applied accelerating torque.
## IOLABs equivalents Physics II

<table>
<thead>
<tr>
<th>Physics II Labs</th>
<th>Probes &amp; Loggers</th>
<th>IOLAB equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coulombs Law</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-Field Mapping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistors in Series and Parallel</td>
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<td>✓</td>
</tr>
<tr>
<td>Charging a Capacitor</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Magnetic Fields</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Faraday’s Law</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Voltmeter and Ammeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing Waves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Slit Interference</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Optics with Thin Lenses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sample IOLAB RC Time Constant
Sensors (Remote 1)
- Accelerometer
- Analog 7 (100 Hz) [Selected]
- Analog 8 (100 Hz)
- Analog 9 (100 Hz)
- Barometer
- Battery
- Digital (100 Hz)
- Electrocardiogram (3)
- Electrocardiogram (8)
- Force
- Gyroscope
- High Gain (200 Hz)
- Light
- Magnetometer
- Microphone
- Thermometer
- Wheel

Output Config (Remote 1)
- DG output
  - Off
  - On

Analog 7 (100 Hz) Voltage (V)

Analog 8 (100 Hz) Voltage (V)
Export data to Excel for analysis
Budget considerations

IOLAB for sensing/logging versus commercial probes and loggers & meters

<table>
<thead>
<tr>
<th>Probe+Logger Comparison (similar required sensors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOLAB</td>
</tr>
<tr>
<td>Smart Cart Dynamics System</td>
</tr>
<tr>
<td>Pasco Smart Cart</td>
</tr>
<tr>
<td>Vernier Bluetooth</td>
</tr>
<tr>
<td>Vernier Wired</td>
</tr>
</tbody>
</table>

Tablet-based Lab in a Box Science Extensions ~ $22
(Multimeter & LiPo battery)

IOLAB may not yet be cost-effective in the Lab in a Box for developing world
But
IOLAB is very competitive against commercial logger-probe technology in traditional lab courses.
Future

• Planning to use IOLAB in 101 and 102 pilot sections

• Use same pre-post test for IOLAB and regular lab sections

• Will let you know the results at a future meeting
Acknowledgements