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Lab Without a Lab: Prospects for an ioLab Kit to Provide Hands-on Introductory Physics Laboratory Learning Experiences Outside the Traditional Setting

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Introduction

Commercial and open-source multi-sensor instruments have become common in the marketplace. Basic tablets or smartphones can be inexpensive but often lack features such as adequate sample rates for basic motion experiments. Commercial products from Pasco and Vernier are available 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. In this project, we explore the feasibility of developing a "kit" including an ioLab along with a minimal set of additional components capable of replicating a majority of the existing General Physics laboratory exercises in our two semester sequence in the Department of Engineering-Physics-Systems at Providence College. The other vital part of this ioLab project is incorporating some means for students to electronically generate and submit a lab report remotely. Currently the Epicollect platform is being explored.

Motivation:

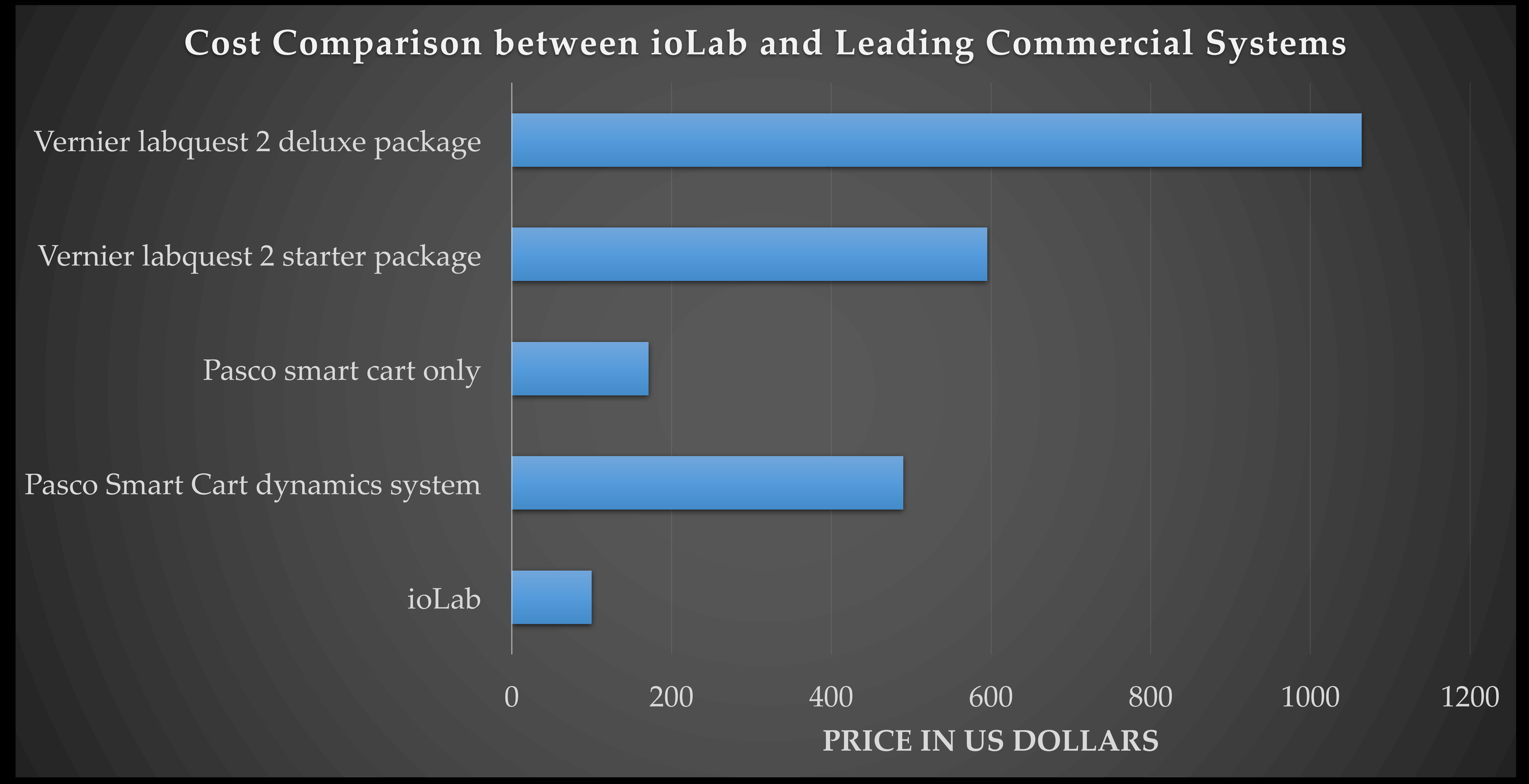
- Building renovations will lead to inadequate lab space and difficult access to stored equipment. This ioLab project offers the opportunity to run the labs out of any academic classroom, or even for students to complete their labs remotely if they take their "kit" home with them.
- Developed kits will eventually be tested in distance learning settings, offering the opportunity for hands-on laboratory experiences to be incorporated.
- The low cost of the ioLab, compared to some commercial competitors, offers the possibility for resource constrained environments or possibly in developing regions of the world.

Table of traditional 101 and 102 labs and ioLab compatibility

Physics I Labs	Probes and Loggers	Specialized equipment	ioLab kit equivalent
Match the Graph	✓		✓
Freefall	✓		✓
Vector Resolution of Forces		✓	✓
Centripetal Force		✓	✓
Work and Energy	✓		✓
Conservation of Energy	✓		✓
Conservation of Linear Momentum	✓		✓
Ballistic Pendulum		✓	
Torque		✓	✓
Simple Harmonic Motion		✓	✓

Physics II Labs	Probes and Loggers	Specialized equipment	ioLab kit equivalent
Coulombs Law		✓	
Electric Field Mapping		✓	
Resistors in Series and Parallel		✓	✓
Charging a Capacitor		✓	✓
Magnetic Fields	✓		✓
Faraday's Law	✓		✓
Voltmeter and Ammeter		✓	
Standing Waves		✓	
Double Slit Interference		✓	✓
Optics with Thin Lenses		✓	?

Cost Considerations



The ioLab includes a wide range of sensors relative to its cost. It's durability has also been remarkable in its year plus of testing. We are encouraged at the prospect of loaning kits to students for a semester or full year. If the rate of repair or replacement of kit components can be kept low, the economics of this "loaner kit" program improve. Determining this rate of repair or replacement will be a key component in determining the viability of this program.

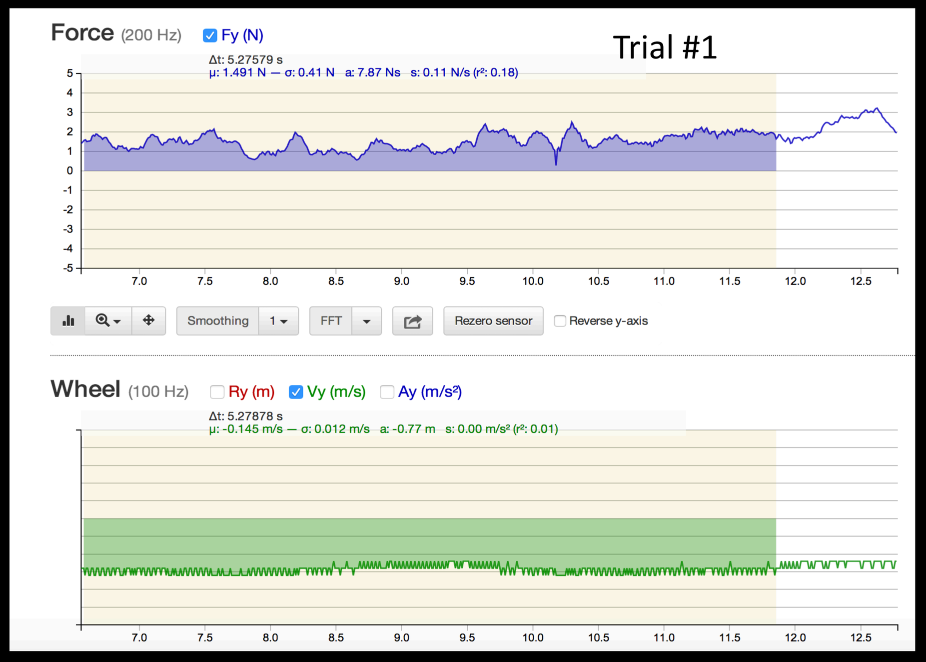
Examples: Torque and RC Circuit Lab Concepts

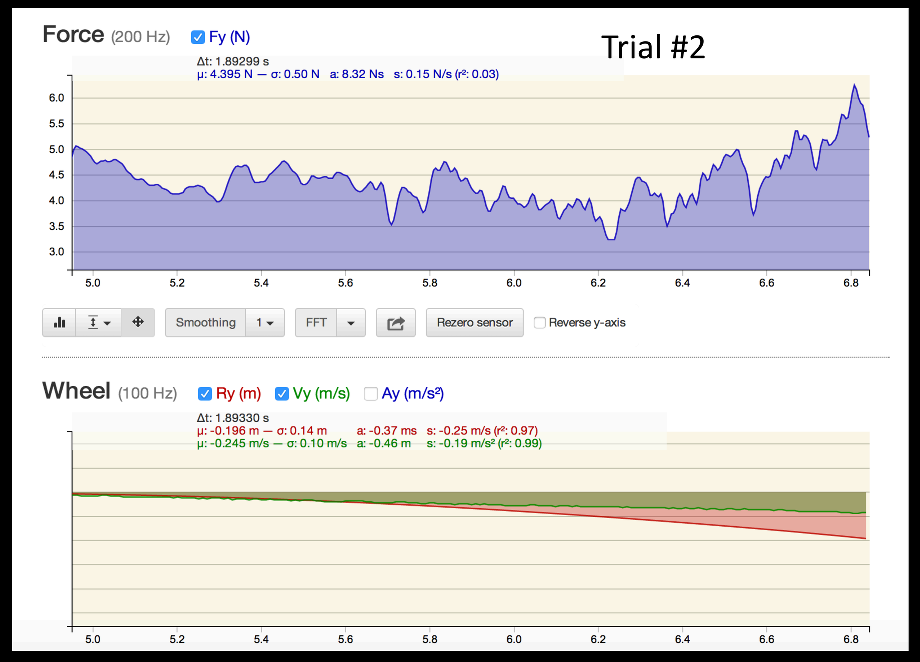
Torque lab concept: In two successive trials, a hinged door is rotated using the ioLab. The force sensor records the force applied at a measured distance from the hinges while the wheel records position and velocity.

Trial one: The door is rotated at constant speed, and the torque applied allows determination of the friction present in the hinges.

Trial two: The door is accelerated. Frictional torque is subtracted from net torque. Angular acceleration is determined using the wheel data. Door's moment of inertia is determined.

Follow-up: Door's moment of inertia is determined based on dimensional measurements, it's mass, and its axis of rotation about its edge. Compare values of door's moment of inertia.





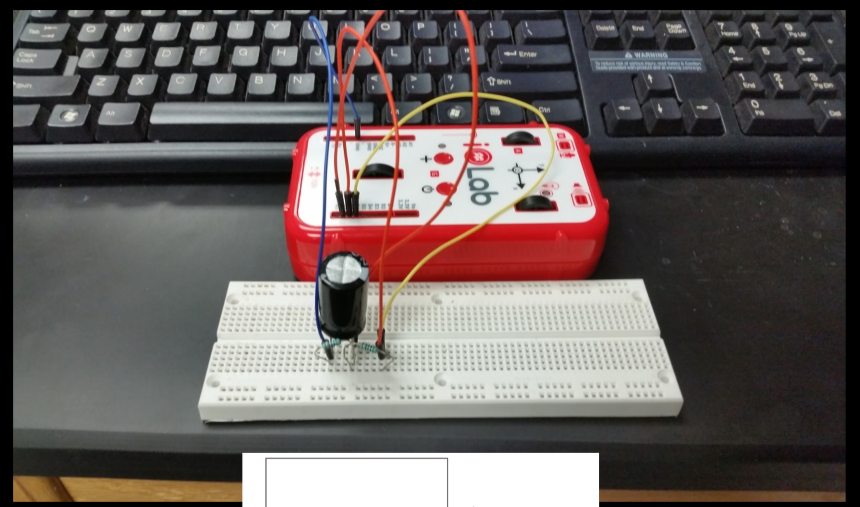
- Trial #1 summary:
- Maintain a constant wheel velocity while applying a force at R=0.75m from the rotation axis (door hinges).
- Average force (~1.49 N) x (R=0.75 m) gives the torque required to overcome the friction in the hinges (~1.12 N · m)

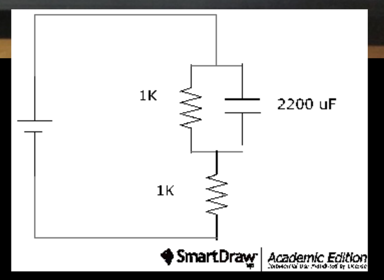
- Trial #2 summary:
- Apply constant force (our example F~4.39 N), so $\tau_{applied}$ = 4.39N * 0.75m. Observe the door's angular acceleration, α.
- Find net torque: $\tau_{net} = \tau_{applied} - \tau_{friction}$. Use the wheel velocity data and R = 0.75m to find the angular acceleration.
- From $\tau_{net} = I\,\alpha$, extract I, moment of inertia. Here I get I ~ 9.37 kg m^2
- Compare with dimensionally determined moment of inertia: $I = 1/3\, mR^2$ (~ 9.39 kg m^2)

RC time constant: IoLab has dc output of ~ 3 V, which can be used to charge a capacitor in an RC circuit. This output voltage can be turned on and off to switch between charging and discharging.

Upper plot shows applied voltage and lower plot shows capacitor voltage as a function of time.

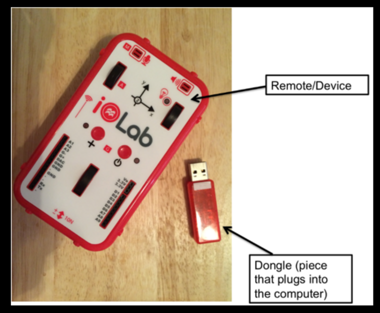
Small breadboard, capacitor and jumper wires are a few of the additional components included in the kit along with the ioLab.



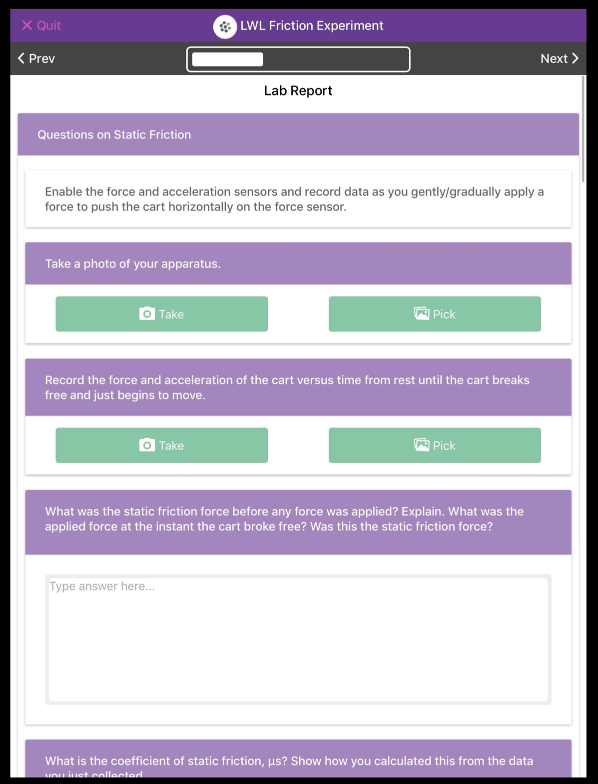


Data Collection and Lab Submission - Epicollect

The ioLab device connects via bluetooth to a laptop. The software for the ioLab is free to use and currently offers versions for Windows and Mac platforms. (http://www.iolab.science/running-application.html)



Distance learning and developing regions environments pose some challenges to an instructor that wishes to collect their students laboratory reports. The application Epicollect is currently being tested as a possible solution to this challenge. It allows submission of text, photo's, videos, and audio which provides flexibility in how students submit their lab reports and show the instructor their experimental setup (see image to right for sample). Epicollect can be run on a mobile device (iOS and Android) or tablet. Alternately through the use of an Android emulator, it could also be run on a laptop.



While Epicollect looks reasonably promising, we are exploring alternate options as well. Have you made use of, or simply heard about an alternate platform that might suit our needs, we'd love to hear about it. Please write any ideas you might have in the white space below and we will check them out to see if they are a better fit for this project! Thanks for any ideas you can offer!

Future Work

Complete the development of the General Physics I and II set of labs, including incorporation of lab report submission platform. Apply for grant funding to support purchase of kits and to run trial lab courses at Providence College. Eventually trials at some local participating high schools will be conducted. Collect data to assess learning gains as compared to traditional laboratory experiments and setting.