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

AC04

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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.

LAB

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GSAP
Global Sustainable Aid Project

Origins of the project

'Me sukuu wɔ daabi buukuu, daabi bobɔ, daabi anyinam, daabi kita tiefi ho, daabi samina na ketewa nsu.'

Typical School Headmistress lamentation

Lab in a Box & GSAP Portal

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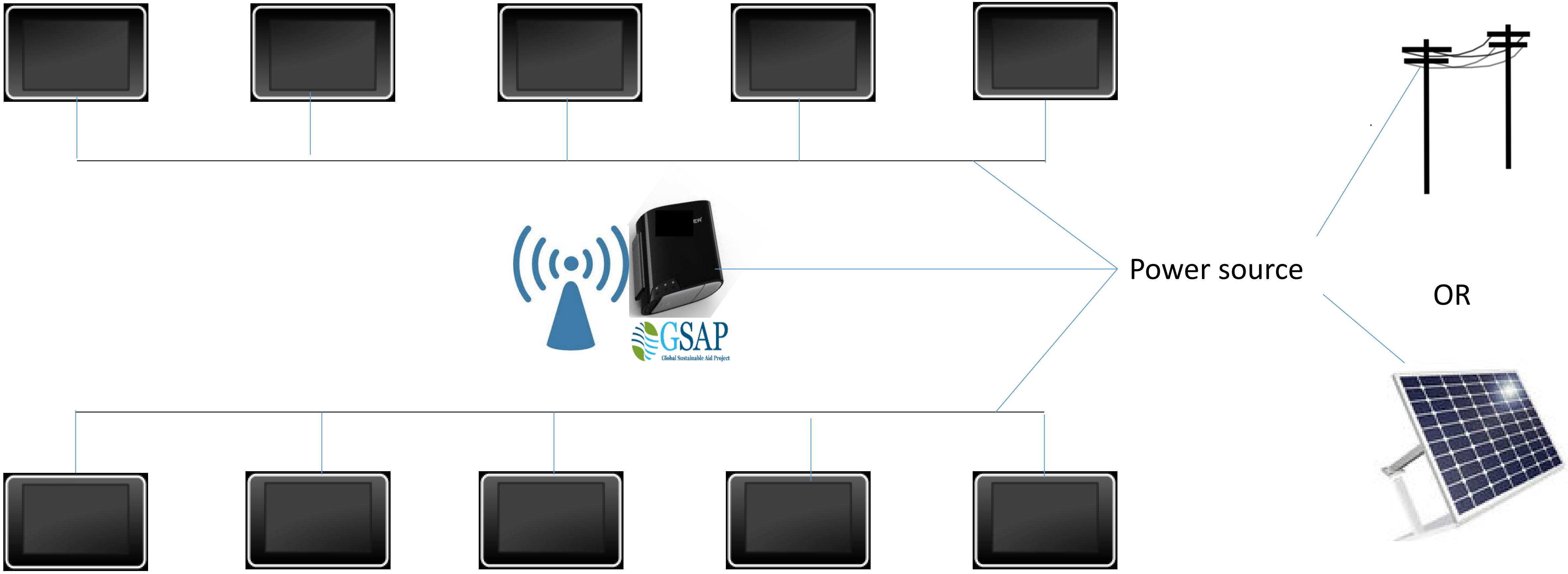
Lab in a Box



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GSAP
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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

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Extending the *Lab in a Box* as a Science Lab

The Tablet as the core of a science lab

Tablet

Apps

Instruments

Simulations

Analytical Tools

References

+

Supplementary Instruments & Components

Multimeter

Microscope

LiPo Battery

Components

Supplies

=

A Science *Lab in a Box*

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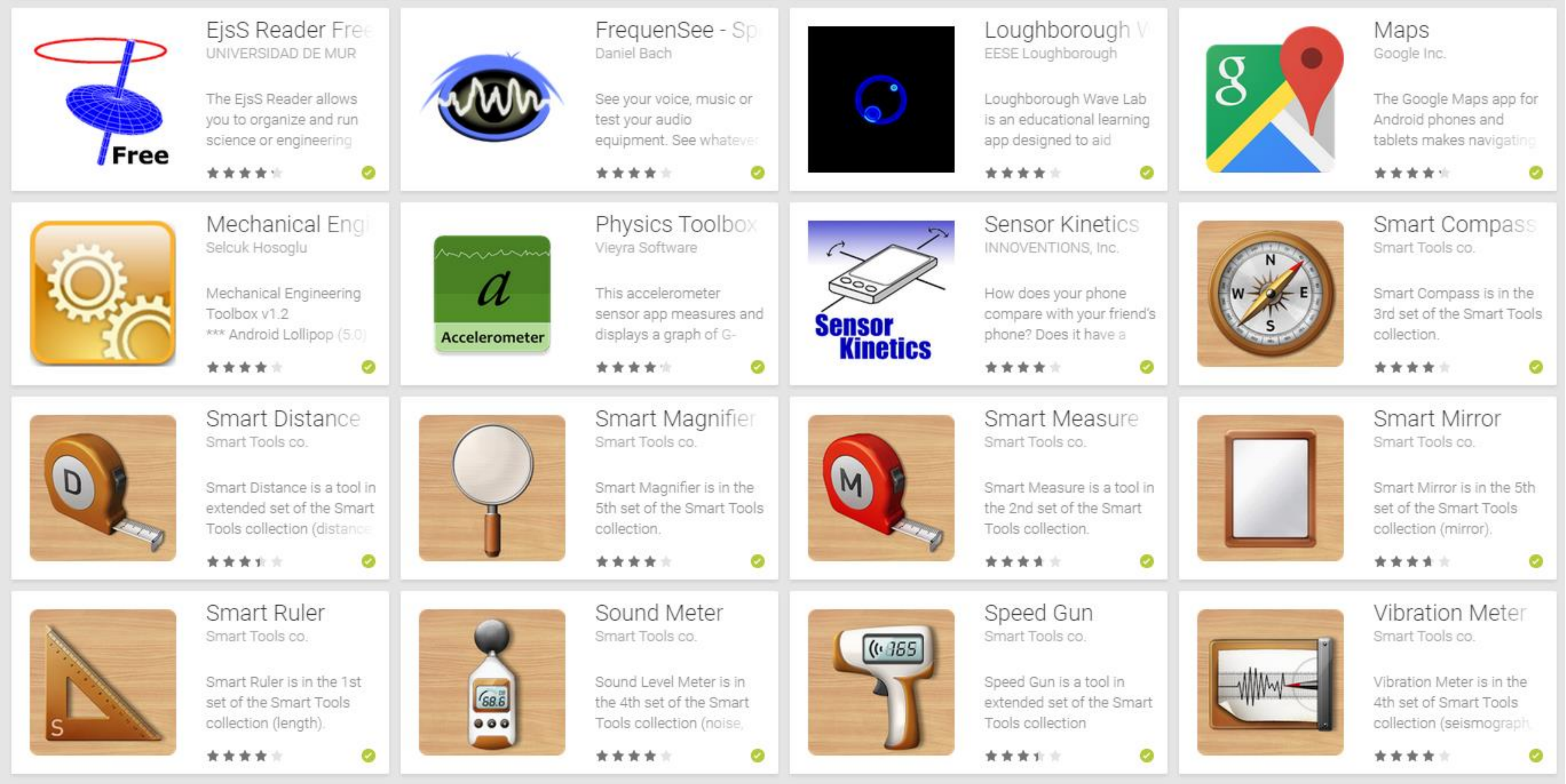
Science Lab in a Box – Apps

- Instruments
- Simulations
- Analytical Tools
- Reference Works



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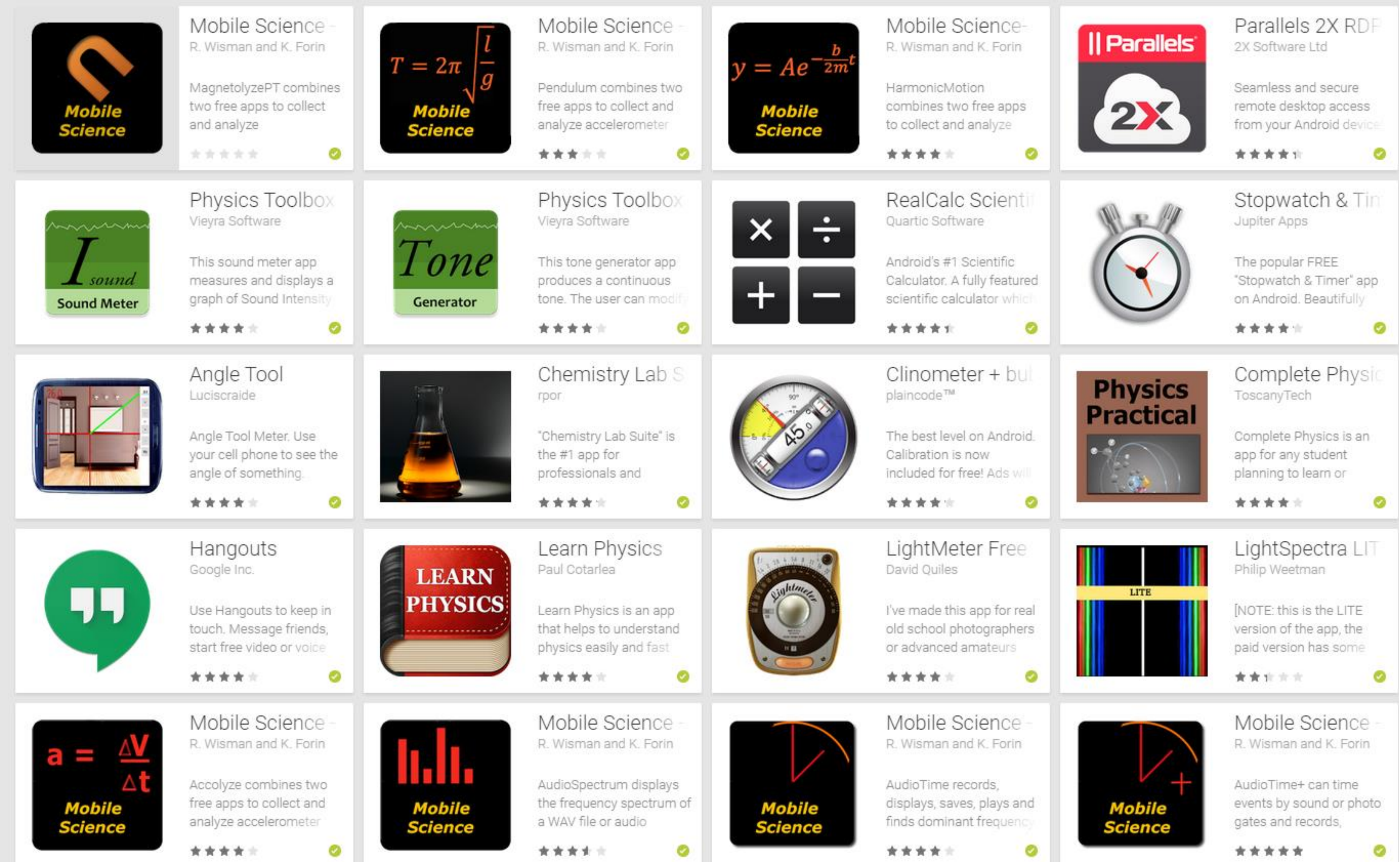
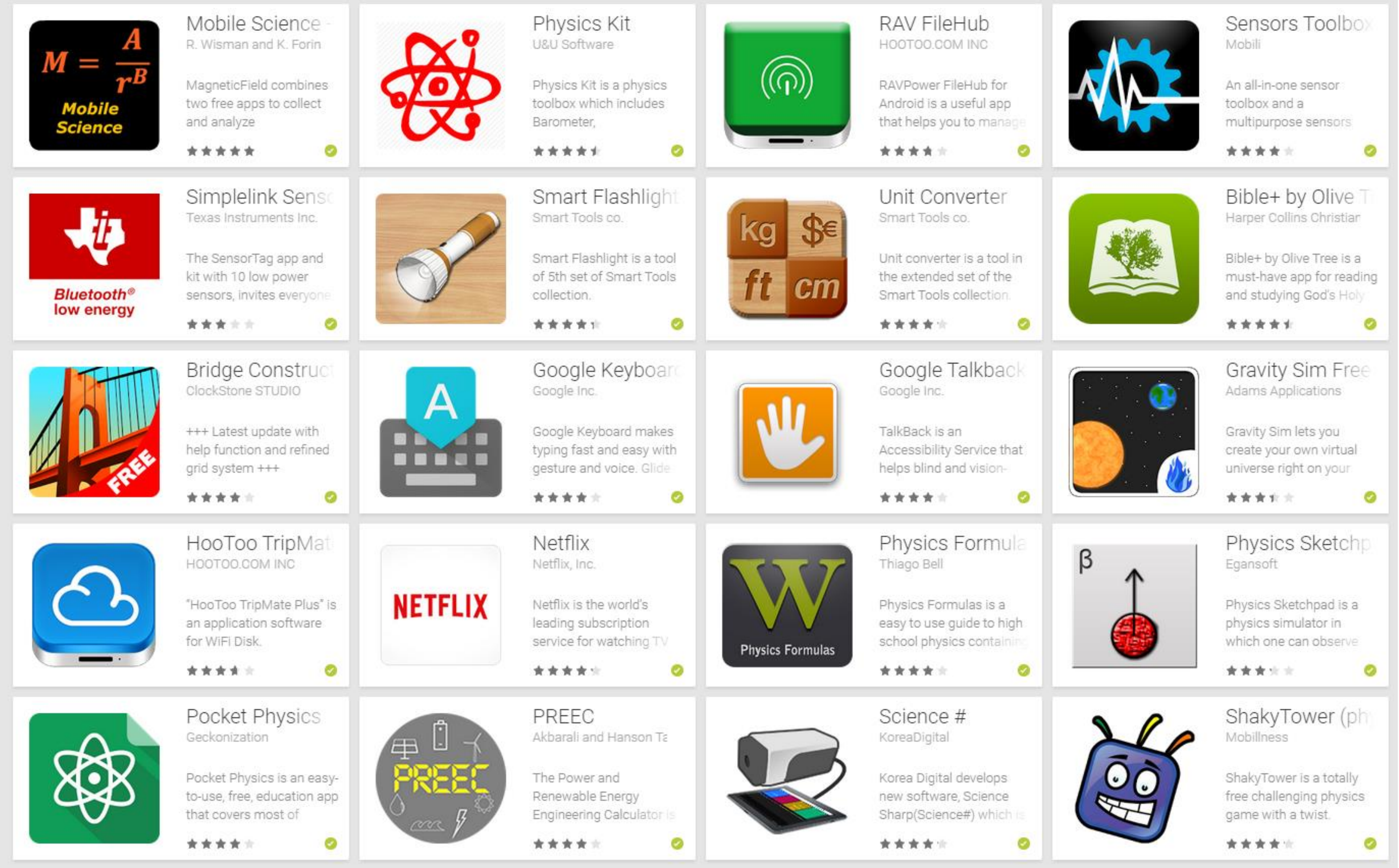
Apps



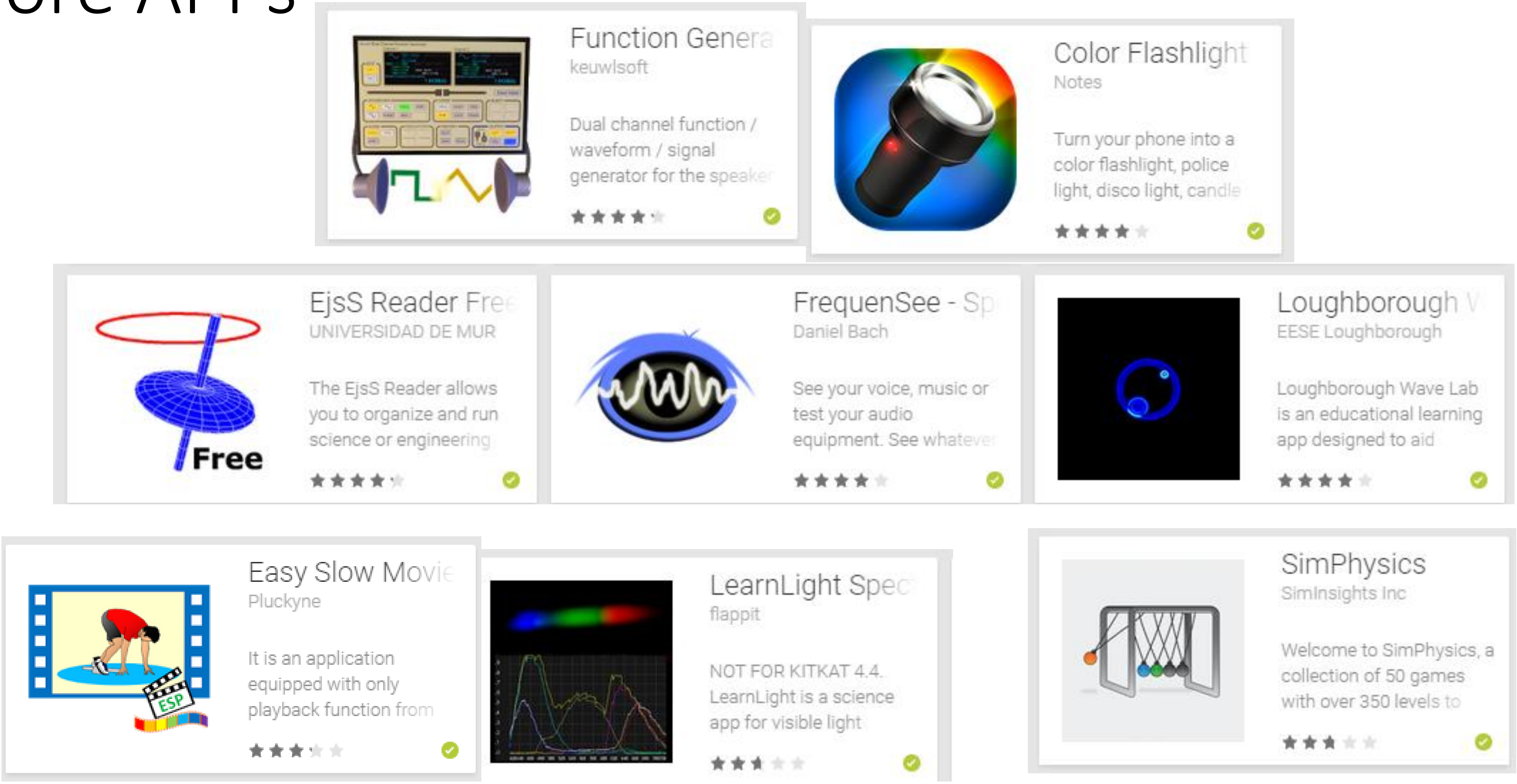
Mobile Science
R. Wisman and K. Forin
MagnetolyzePT combines two free apps to collect and analyze
Mobile Science
R. Wisman and K. Forin
Pendulum combines two free apps to collect and analyze accelerometer
Mobile Science
R. Wisman and K. Forin
HarmonicMotion combines two free apps to collect and analyze
Parallels 2X RDP
2X Software Ltd
Seamless and secure remote desktop access from your Android device
Physics Toolbox
Vieyra Software
This sound meter app measures and displays a graph of Sound Intensity
Physics Toolbox
Vieyra Software
This tone generator app produces a continuous tone. The user can modify
RealCalc Scientific
Quartic Software
Android's #1 Scientific Calculator. A fully featured scientific calculator which
Stopwatch & Timer
Jupiter Apps
The popular FREE "Stopwatch & Timer" app on Android. Beautifully
Angle Tool
Luciscraide
Angle Tool Meter. Use your cell phone to see the angle of something.
Chemistry Lab S
rpor
"Chemistry Lab Suite" is the #1 app for professionals and
Clinometer + bu
plaincode™
The best level on Android. Calibration is now included for free! Ads will
Complete Physic
ToscanyTech
Complete Physics is an app for any student planning to learn or
Hangouts
Google Inc.
Use Hangouts to keep in touch. Message friends, start free video or voice
Learn Physics
Paul Cotarlea
Learn Physics is an app that helps to understand physics easily and fast
LightMeter Free
David Quiles
I've made this app for real old school photographers or advanced amateurs
LightSpectra LIT
Philip Weetman
[NOTE: this is the LITE version of the app, the paid version has some
Mobile Science
R. Wisman and K. Forin
Accolyze combines two free apps to collect and analyze accelerometer
Mobile Science
R. Wisman and K. Forin
AudioSpectrum displays the frequency spectrum of a WAV file or audio
Mobile Science
R. Wisman and K. Forin
AudioTime records, displays, saves, plays and finds dominant frequency
Mobile Science
R. Wisman and K. Forin
AudioTime+ can time events by sound or photo gates and records,

Apps



Mobile Science
R. Wisman and K. Forin
MagneticField combines two free apps to collect and analyze
Physics Kit
U&U Software
Physics Kit is a physics toolbox which includes Barometer,
RAV FileHub
HOOTOO.COM INC
RAVPower FileHub for Android is a useful app that helps you to manage
Sensors Toolbox
Mobili
An all-in-one sensor toolbox and a multipurpose sensors
Simplelink Sens
Texas Instruments Inc.
The SensorTag app and kit with 10 low power sensors, invites everyone
Bluetooth® low energy
Smart Flashlight
Smart Tools co.
Smart Flashlight is a tool of 5th set of Smart Tools collection.
Unit Converter
Smart Tools co.
Unit converter is a tool in the extended set of the Smart Tools collection.
kg $€ ft cm
Bible+ by Olive T
Harper Collins Christian
Bible+ by Olive Tree is a must-have app for reading and studying God's Holy
Bridge Construct
ClockStone STUDIO
+++ Latest update with help function and refined grid system +++
FREE
Google Keyboard
Google Inc.
Google Keyboard makes typing fast and easy with gesture and voice. Glide
Google Talkback
Google Inc.
TalkBack is an Accessibility Service that helps blind and vision-
Gravity Sim Free
Adams Applications
Gravity Sim lets you create your own virtual universe right on your
HooToo TripMat
HOOTOO.COM INC
"HooToo TripMate Plus" is an application software for WiFi Disk.
Netflix
Netflix, Inc.
Netflix is the world's leading subscription service for watching TV
NETFLIX
Physics Formula
Thiago Bell
Physics Formulas is a easy to use guide to high school physics containing
Physics Formulas
Physics Sketchp
Egansoft
Physics Sketchpad is a physics simulator in which one can observe
Pocket Physics
Geckonization
Pocket Physics is an easy-to-use, free, education app that covers most of
PREEC
Akbarali and Hanson Te
The Power and Renewable Energy Engineering Calculator is
Science #
KoreaDigital
Korea Digital develops new software, Science Sharp(Science#) which is
ShakyTower (ph
Mobillness
ShakyTower is a totally free challenging physics game with a twist.

More APPs



Function Genera
keuwlsoft
Dual channel function / waveform / signal generator for the speake
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
Free
FrequenSee - Sp
Daniel Bach
See your voice, music or test your audio equipment. See whatever
Loughborough W
EESE 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
ESP
LearnLight Spec
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

Items	Cost
Multimeter	$ 5
LiPo Battery Pack	$ 38
60x Microscope	$ 5
Stapler	$ 3
Components: *Capacitors, Thermistors, USB to Alligator Cable, Alligator-terminated cables, Magnets*	$ 15
Supplies: *#2 Pencil, Straw, Staples, Tape, Glue, Scrap File Folders, Wire, Foil*	$ 5
Total	$ 71

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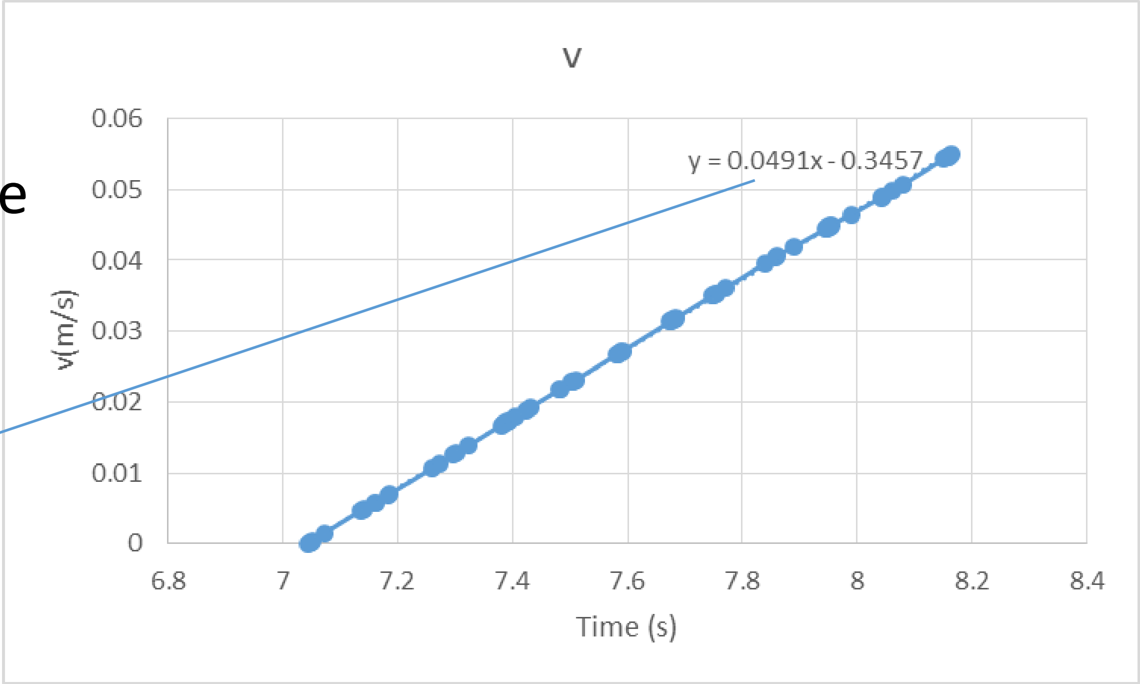
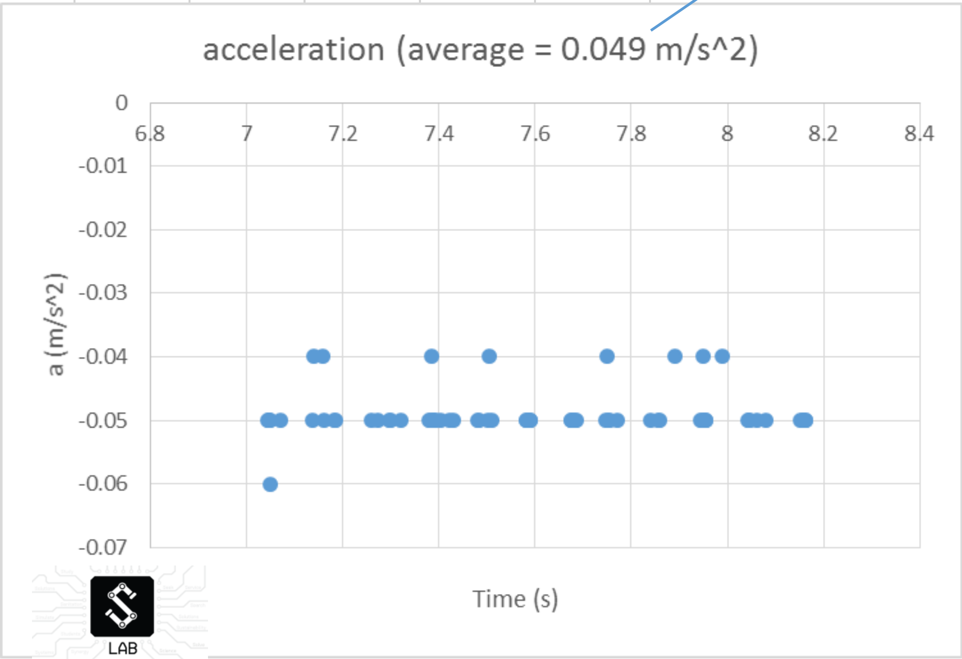
Time	a	-a	v	y
7.044	-0.05	0.05	0	0
7.046	-0.05	0.05	0.0001	1E-07
7.048	-0.05	0.05	0.0002	4E-07
7.049	-0.05	0.05	0.00025	6.25E-07
7.051	-0.06	0.06	0.00036	1.24E-06
7.072	-0.05	0.05	0.001515	2.09E-05
7.137	-0.05	0.05	0.004765	0.000225
7.14	-0.04	0.04	0.0049	0.00024
7.159	-0.04	0.04	0.00566	0.00034
7.162	-0.05	0.05	0.005795	0.000357
7.184	-0.05	0.05	0.006895	0.000497
7.185	-0.05	0.05	0.006945	0.000504
7.261	-0.05	0.05	0.010745	0.001176
7.274	-0.05	0.05	0.011395	0.00132
7.296	-0.05	0.05	0.012495	0.001582
7.301	-0.05	0.05	0.012745	0.001646
7.322	-0.05	0.05	0.013795	0.001924
7.38	-0.05	0.05	0.016695	0.002808
7.383	-0.05	0.05	0.016845	0.002859
7.386	-0.04	0.04	0.01698	0.002909

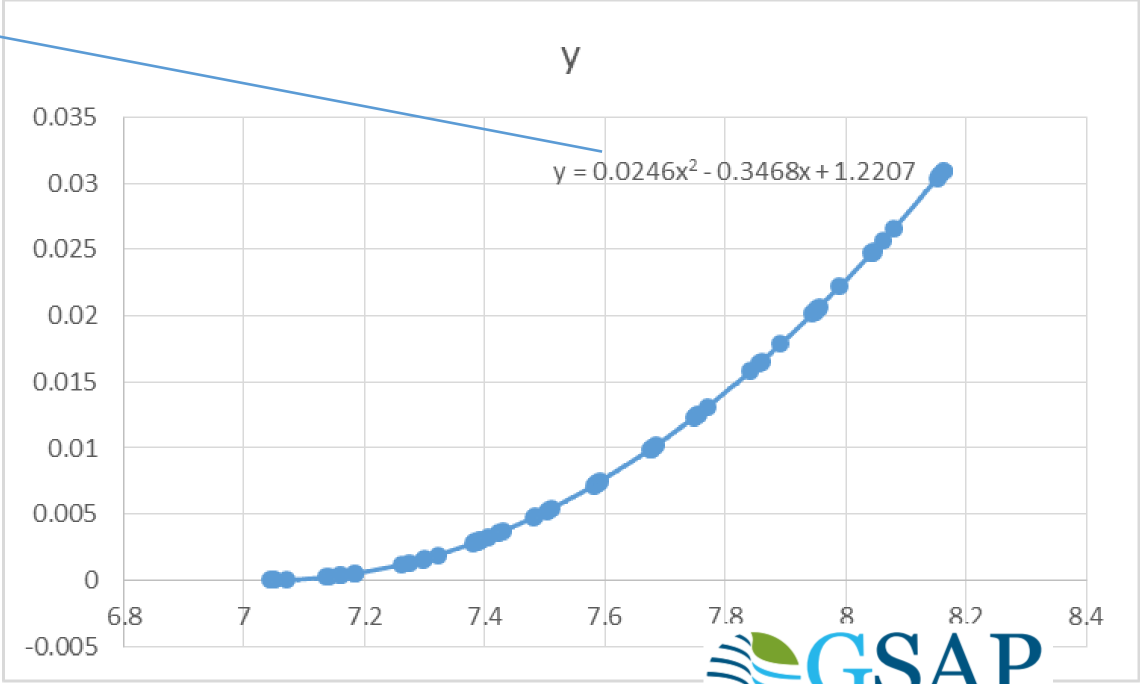
Homemade Cart
Rolling down an inclined table
Tablet accelerometer data along direction of motion

a

a/2







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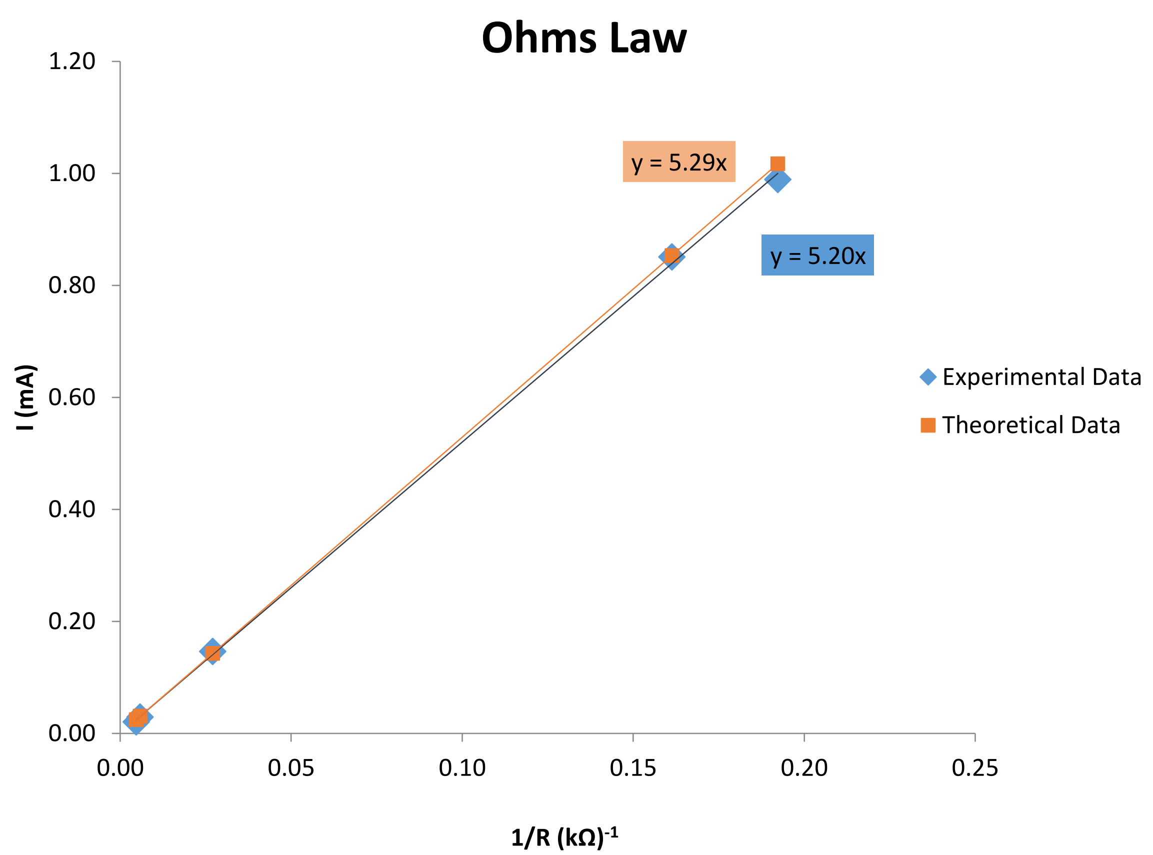

Ohms Law
y = 5.29x
y = 5.20x
1.20
1.00
0.80
0.60
0.40
0.20
0.00
I (mA)
0.00
0.05
0.10
0.15
0.20
0.25
1/R (kΩ)-1
Experimental Data
Theoretical Data

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

IOLAB

“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”

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IOLABs equivalents Physics I

Physics I Labs	**Probes & Loggers**	**IOLAB 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		✓

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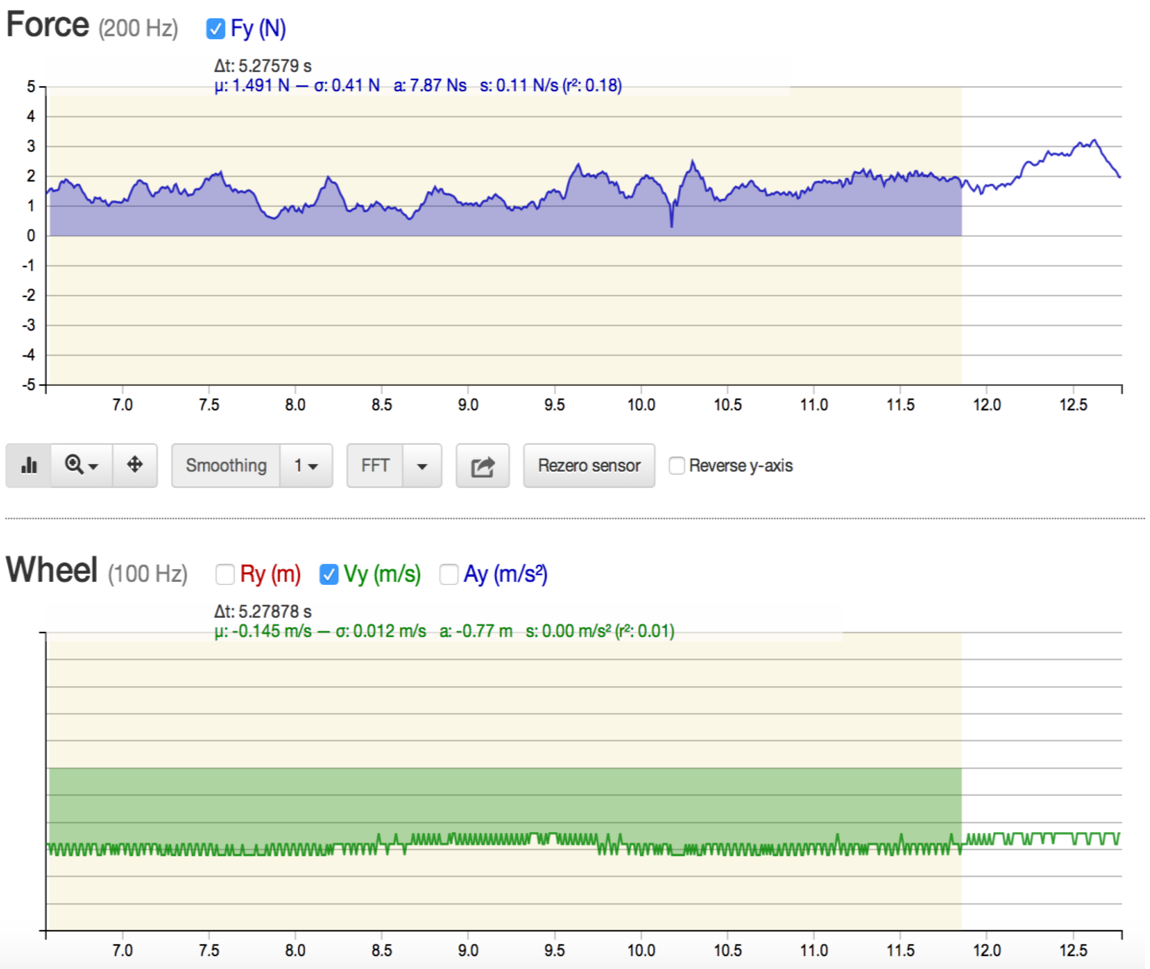
Sample 101 IOLAB Torque



- Use a hinged door, place IOLAB rolling in y-direction
- Maintain a constant Vy while applying a force at R=.75M from the axis
- Force (~1.49 N) x R (0.75 m) gives the torque required to overcome the friction in the hinges (~1.12 N-m)

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Sample 101 IOLAB Torque

- 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 = 0.75m to find the angular acceleration
- From $\Gamma = I\,\alpha$, extract I, moment of inertia. Get I ~ 9.37 kg m^2
- Compare to I= 1/3 mR^2 (~ 9.39 kg m^2)

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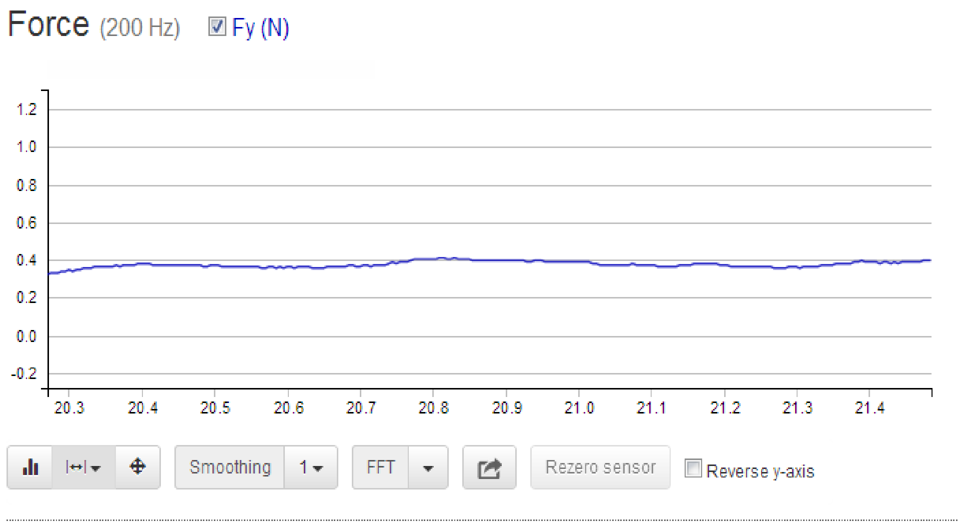
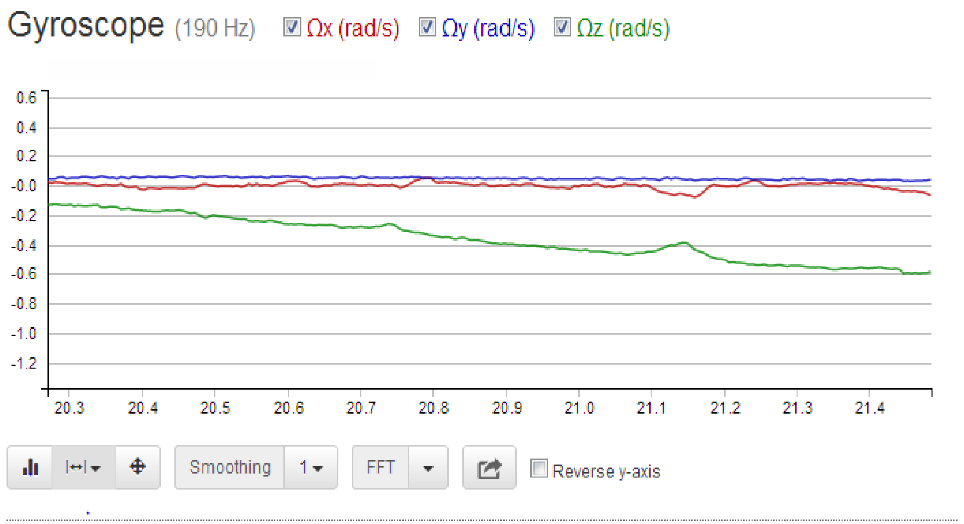
Sample 101 IOLAB Torque – another alternative





- Use gyroscope and force sensors on a freely swinging door applying constant force and observing linear changing Ω (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

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IOLABs equivalents Physics II

Physics II Labs	Probes & Loggers	IOLAB equivalent
Coulombs Law		
E-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		

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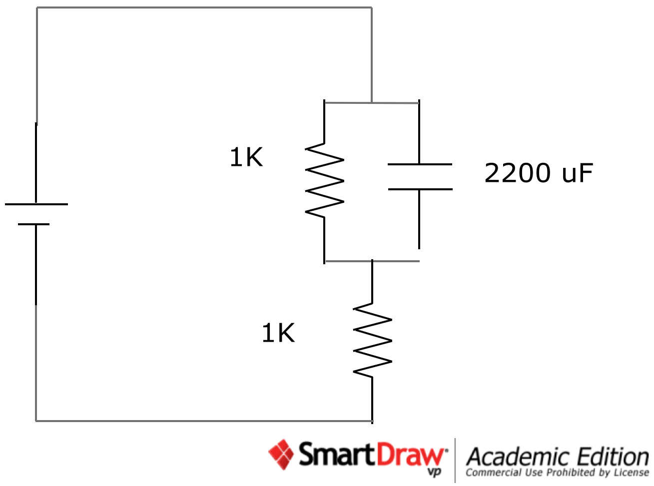
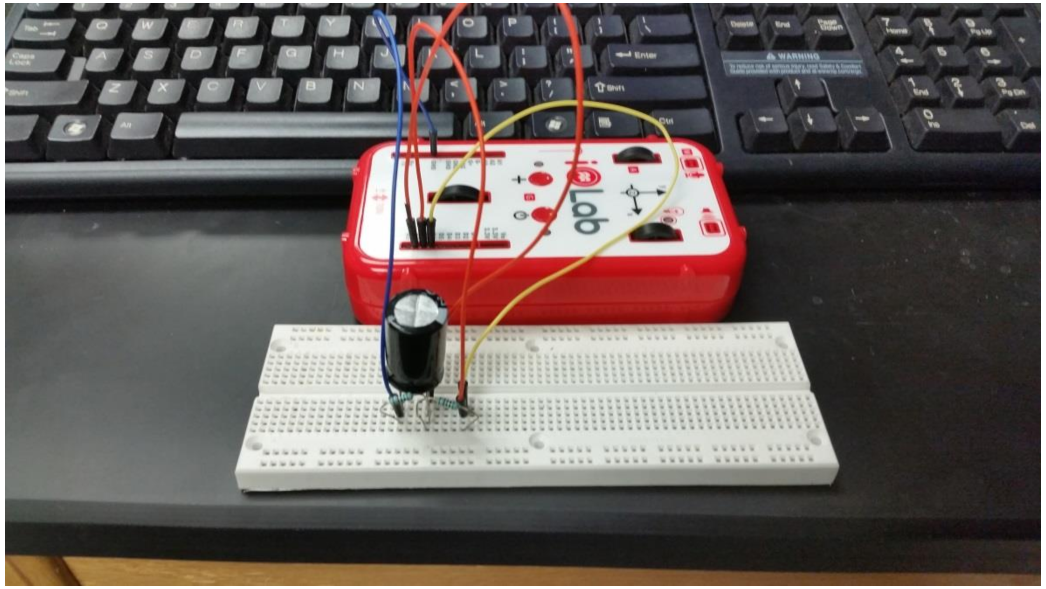
Sample IOLAB RC Time Constant





Sensors (Remote 1)

- Accelerometer
- Analog 7 (100 Hz)
- Analog 8 (100 Hz)
- Analog 9 (100 Hz)
- Barometer
- Battery
- Digital (100 Hz)
- Electrocardiogram (3)
- Electrocardiogram (9)
- Force
- Gyroscope
- High Gain (200 Hz)
- Light
- Magnetometer
- Microphone
- Thermometer
- Wheel

Output Config

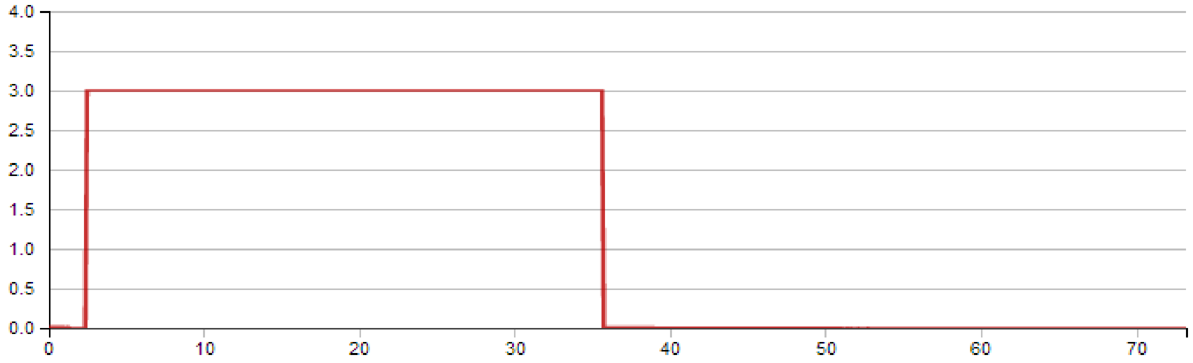
(Remote 1)

D6 output

Off On

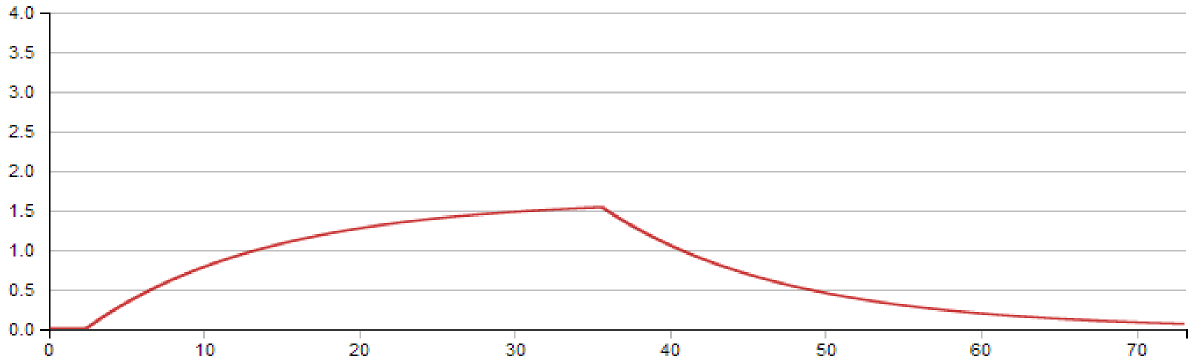
Expert Options +

Analog 7 (100 Hz) Voltage (V)



Smoothing 1 FFT

Analog 8 (100 Hz) Voltage (V)



Smoothing 1 FFT

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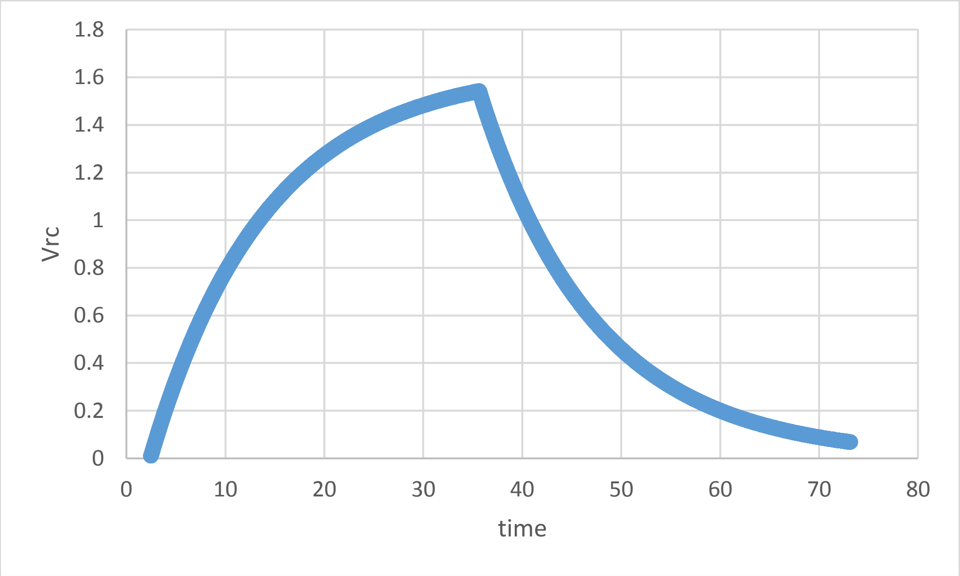
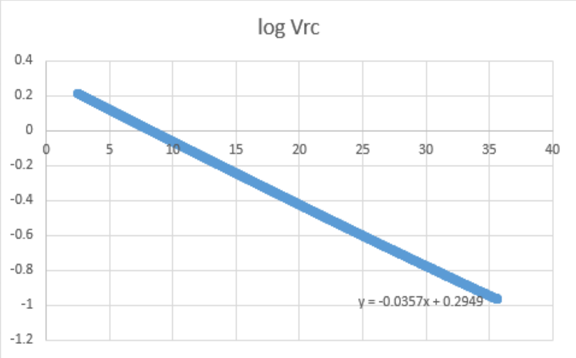
Export data to Excel for analysis

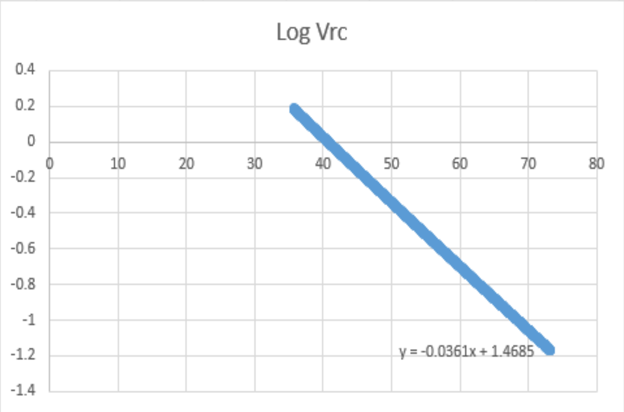


V	1.65				
time	Vrc	V-Vrc	log V-V$_{rc}$		
2.46	0.010256	1.639744	0.21477594	RC=	28.0112 from 1/slope
2.47	0.010256	1.639744	0.21477594		22 from RC
2.48	0.010256	1.639744	0.21477594		
2.49	0.010989	1.639011	0.21458187		
2.5	0.012454	1.637546	0.21419346		
2.51	0.015385	1.634615	0.21341559		
2.52	0.015385	1.634615	0.21341559		
2.53	0.01685	1.63315	0.21302613		
2.54	0.017582	1.632418	0.21283127		
2.55	0.01978	1.63022	0.21224616		
2.56	0.020513	1.629487	0.21205095		
2.57	0.021978	1.628022	0.21166027		
2.58	0.023443	1.626557	0.21126923		
2.59	0.024908	1.625092	0.21087785		
2.6	0.026374	1.623626	0.2104861		
2.61	0.027839	1.622161	0.21009401		
2.62	0.030769	1.619231	0.20930876		
2.63	0.030769	1.619231	0.20930876		
2.64	0.032234	1.617766	0.2089156		
2.65	0.0337	1.6163	0.20852208		
2.66	0.035165	1.614835	0.20812821		



20160210-112308_Ana8 | Charge | Discharge

	A	B	C	D	E	F	G
1	time	Vrc	Log Vrc				
2	35.68	1.53846	0.187086				
3	35.69	1.53773	0.18688		RC=	27.77778	from 1/slope
4	35.7	1.53626	0.186465			22	from RC
5	35.71	1.53333	0.185636				
6	35.72	1.53187	0.185222				
7	35.73	1.53187	0.185222				
8	35.74	1.5304	0.184805				
9	35.75	1.52894	0.18439				
10	35.76	1.52821	0.184183				
11	35.77	1.52674	0.183765				
12	35.78	1.52527	0.183347				
13	35.79	1.52381	0.182931				
14	35.8	1.52234	0.182512				
15	35.81	1.52088	0.182095				
16	35.82	1.52015	0.181886				
17	35.83	1.51868	0.181466				
18	35.84	1.51722	0.181049				
19	35.85	1.51575	0.180628				
20	35.86	1.51429	0.180209				
21	35.87	1.51355	0.179997				
22	35.88	1.51209	0.179578				



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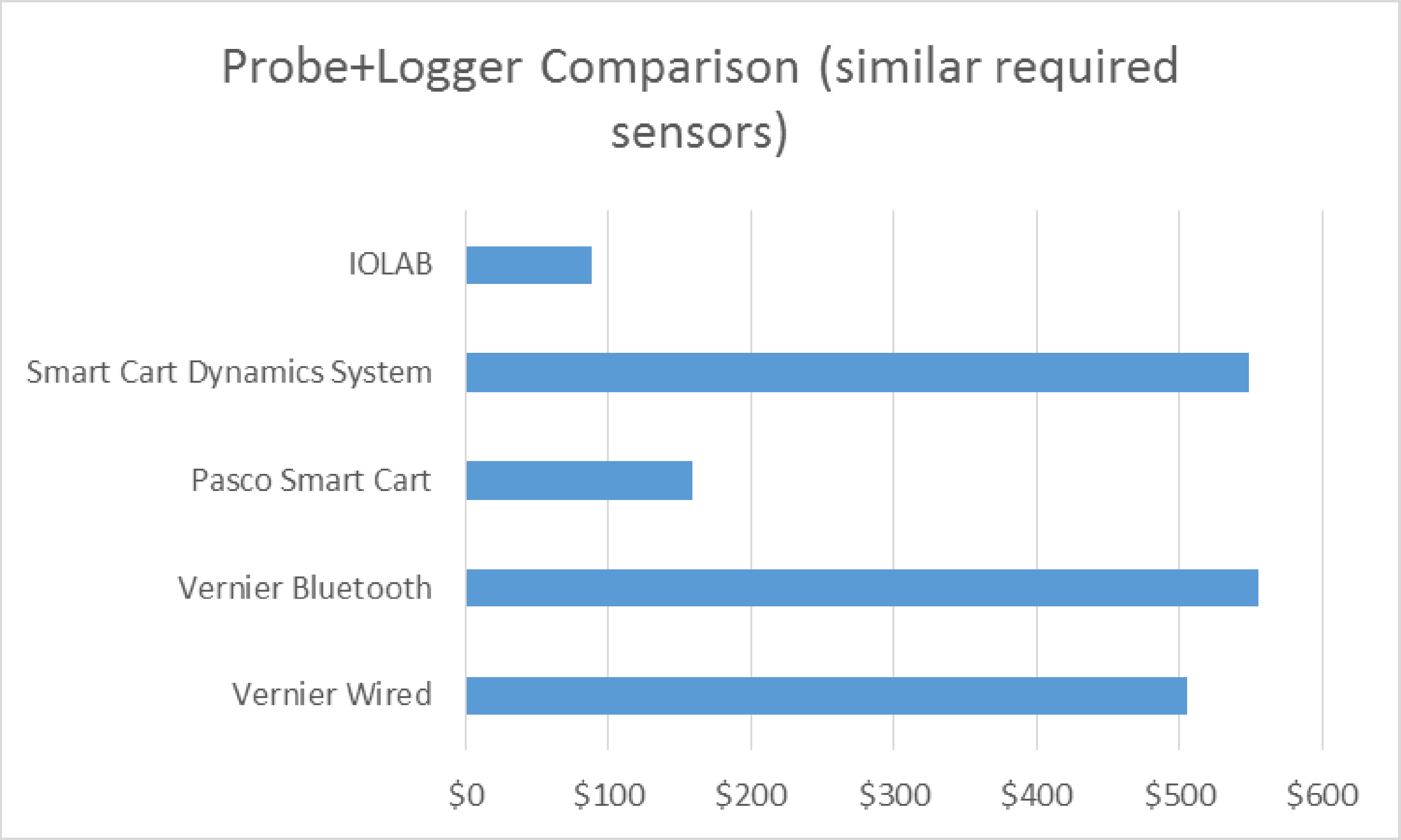
Budget considerations

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



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.

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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

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Acknowledgements

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PHYSICS EDUCATION
American Association of Physics Teachers
Enhancing the understanding and appreciation of physics through teaching

Bauder Fund