An Online Lab Section with IOLab and Remotely Operated Experiments

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Overview

The Course
PHYS 1100 is a one-semester algebra-based course with mechanics and E & M.

Our Pilot (Winter 2017)
Students took regular, on-campus class with either:

- on-campus lab sections (as usual), or
- online lab section (new)

Online Labs (9 total)

- 7 using IOLab
- 2 remotely operated
- content & sequence paralleled on-campus sections

Weekly Cycle

Pre-lab Assignment

- Available Sunday, due Wednesday
- Equips students with theory, orientation and analysis tools

Lab Experiment & Report

- Available upon pre-lab submission, due Sunday midnight*
- Students make prediction, perform experiment, write discussion incl. uncertainty

Learning Progression

Early Labs

- Student lab reports are heavily guided

Later Labs

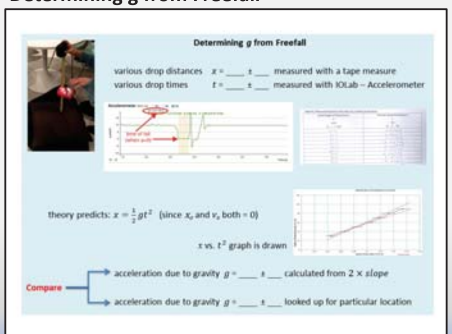
- progressively freer in format
- progression in student expectations

The Labs

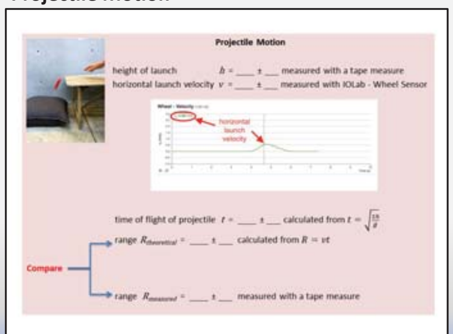
#	Topic	Experiment	mode	Pre-lab activity	Lab activity	Other Skills	Notes
1	Uniform Motion	Students explore motion in one dimension and its graphical representation.	IOLab	1. Explore x(t) graphs of objects in motion 2. Install the IOLab software on own device 3. Explore the basic functions/sensors of IOLab	Given sketches of x(t) graphs 1. reproduce graphs by moving IOLab accordingly.	Connecting physical motion to its graphical representation and vice versa.	This pre-lab is longer than most and is spread over 2 weeks.
2	Acceleration	Students explore how position and velocity change with time for various types of motion in 1D.	IOLab	1. Match a described motion with x(t) and v(t) graphs 2. Introduction to measurement uncertainties and their propagation	Students push the IOLab up a ramp to 1. produce x(t) and v(t) graphs 2. determine the acceleration and ramp angle	Comparing obtained graphs with prediction. Start work with uncertainties.	Students construct/improvise a ramp with household items.
3	Freefall	Students send IOLab in freefall. Graphical analysis yields g.	IOLab	1. Tutorial on data tables, graphing with error bars and interpreting linear graphs 2. Setting up the freefall experiment with IOLab	1. Drop IOLab onto a cushion from different heights 2. Measure time of freefall using accelerometer to plot a graph whose slope is predicted to be g/2	Constructing data tables Graphing with error bars Interpreting linear graphs	Students write discussion by filling in blanks as prompted.
4	Projectile Motion	Students launch IOLab over edge of table.	IOLab	1. Explore projectile motion from a horizontal platform using a simulation 2. Prepare and practice launching IOLab from table while taking data	1. Predict projectile range from table height and IOLab's speed at launch 2. Measure range from landing location	Uncertainty propagation Do measured result and prediction agree within uncertainty?	Students write discussion by filling in blanks as prompted.
5	Acceleration on an Incline	Students roll cart down inclined track using remote control.	remote	1. Simulation assisted tutorial to derive "a = g sin θ", with uncertainties 2. Tutorial on operation of remote equipment	1. Predict acceleration from height and length of track 2. Measure acceleration from slope of v(t) graph	Uncertainty propagation Do measured result and prediction agree within uncertainty?	Students write discussion from scratch, based on experience with prior labs.
6	Uniform Circular Motion	Students swing IOLab around in circle on a string while force sensor measures tension.	IOLab	1. Simulation assisted tutorial on uniform circular motion 2. Tutorial on using IOLab force sensor	1. Measure period and radius to calculate speed, centripetal acceleration and force. 2. Measure centripetal force using force sensor	Uncertainty propagation Do measured result and prediction agree within uncertainty?	Decreasing guidance given. Students have opportunity to discuss many potential sources of error.
7	Impulse and Momentum	Students bounce IOLab cart w/ spring bumper off a solid object.	IOLab	1. Students prepare and practice the collision while taking data	1. Change in velocity is compared to the area under F(t) graph	Interpreting v(t) and F(t) graphs for momentum and impulse	Students perform calculations and write discussion independently.
8	Conservation of Mechanical Energy	Students roll IOLab as a roller coaster.	IOLab	1. Roller coaster simulation, with friction 2. Students prepare a roller coaster-like track for IOLab	IOlab is sent down track and 1. calculate total energy from height and speed data	Performing relevant calculation and comparisons with minimal guidance	Energy is usually not conserved, as seen in pre-lab simulations.
10	Electron charge-to-mass ratio (e/m)	JJ Thomson's e/m experiment is performed by remote control.	remote	1. Orientation of equations used for analysis 2. Tutorial on operation of remote equipment	1. Measure accelerating voltage and Helmholtz coil current 2. Work out a value for e/m	Writing entire report from scratch, based on experience with prior labs.	Students given two weeks to complete this lab.

Sample IOLab Expts

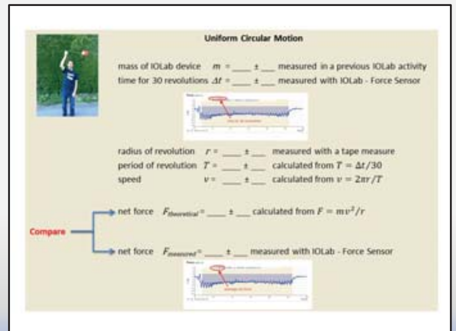
Determining g from Freefall



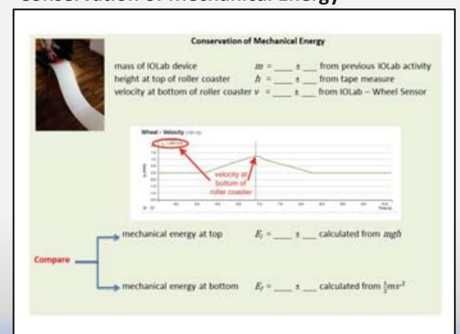
Projectile Motion



Uniform Circular Motion



Conservation of Mechanical Energy



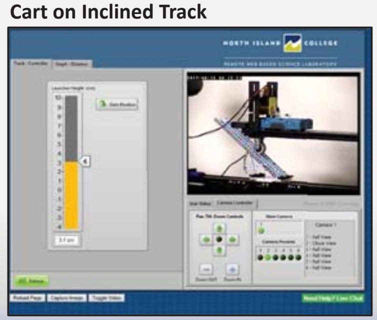
Remote Experiments

e/m - Electron Charge to Mass Ratio

Equipment located 150 km away at North Island College (Comox, Canada) are operated remotely by students through the internet.

RWSL/NANSLO facility includes lab equipment for Physics, Chemistry & Biology and are described further at
http://www.nic.bc.ca/rwsl and
http://www.wiche.edu/nanslo

Cart on Inclined Track



Future Plans

Encourage more interaction

- Peer-to-peer (e.g. online forum)
- Student-instructor (*adjust deadline to allow last minute help - no more Sunday midnight)

Measure student outcomes

Library to manage equipment return

Lab pilot continuing 2017/18

Class portion also moving online

- Sept 2017 – partially online
- Jan 2018 – fully online

Building own remote experiments

Thanks

Acknowledgements

We wish to thank the Creative Capital Fund of KPU for supporting the development of Remote and Online Physics labs, North Island College for making remote experiments available to our students and our KPU Physics Dept. colleagues for embracing and encouraging our pilot.

Resources & Contact

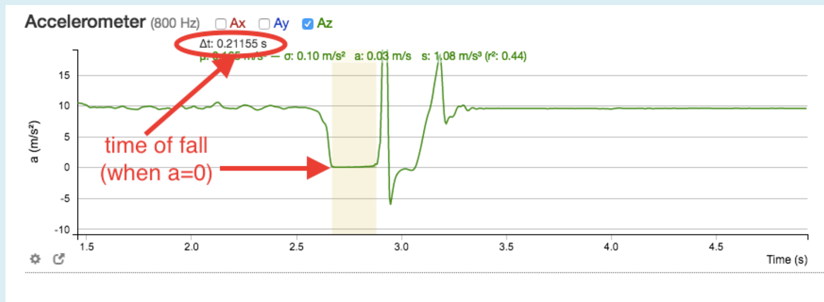
takashi.sato@kpu.ca 604-599-2656
jillian.lang@kpu.ca 604-599-2455
Handouts, lab manuals and more at
http://www.kpu.ca/physics/sato/AAPTCincinnati

Presented at AAPT Summer 2017 Meeting July 25, 2017, Cincinnati, USA.

Determining *g* from Freefall

various drop distances x = ____ ± ___ measured with a tape measure

various drop times t = ____ ± ___ measured with IOLab – Accelerometer



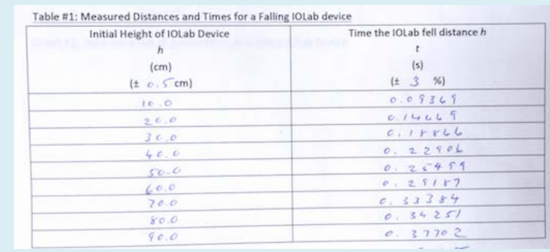
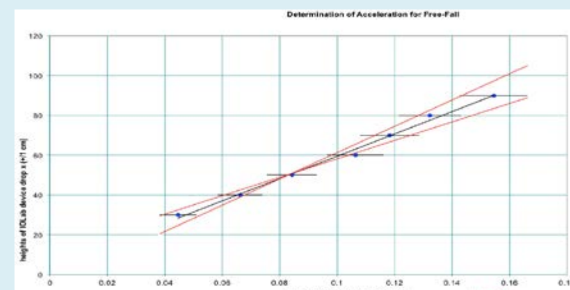


Table #1: Measured Distances and Times for a Falling IOLab device

Initial Height of IOLab Device h (cm) (± 0.5 cm)	Time the IOLab fell distance h t (s) (± 3 %)
10.0	0.09369
20.0	0.14669
30.0	0.17866
40.0	0.22906
50.0	0.25459
60.0	0.29187
70.0	0.33384
80.0	0.34251
90.0	0.37702

theory predicts: $x = \frac{1}{2}gt^2$ (since x_o and v_o both = 0)

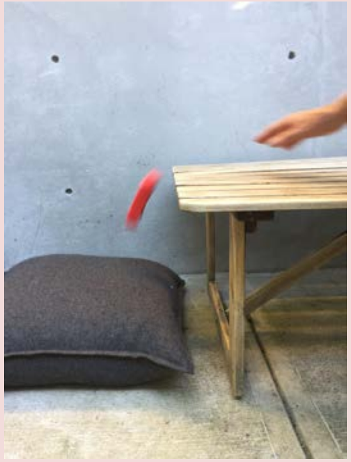
x vs. t^2 graph is drawn



Compare

acceleration due to gravity g = ____ ± ___ calculated from 2 × $slope$

acceleration due to gravity g = ____ ± ___ looked up for particular location



Projectile Motion

height of launch h = ____ ± ___ measured with a tape measure

horizontal launch velocity v = ____ ± ___ measured with IOLab - Wheel Sensor

time of flight of projectile t = ____ ± ___ calculated from $t = \sqrt{\frac{2h}{g}}$

range $R_{theoretical}$ = ____ ± ___ calculated from $R = vt$

Compare

range $R_{measured}$ = ____ ± ___ measured with a tape measure

Uniform Circular Motion

mass of IOLab device m = ____ ± ___ measured in a previous IOLab activity

time for 30 revolutions Δt = ____ ± ___ measured with IOLab - Force Sensor

radius of revolution r = ____ ± ___ measured with a tape measure

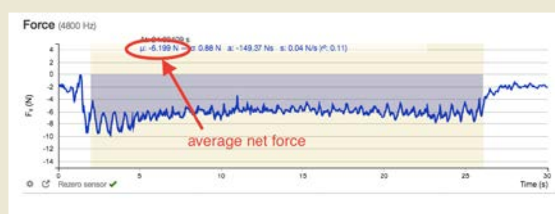
period of revolution T = ____ ± ___ calculated from $T = \Delta t/30$

speed v = ____ ± ___ calculated from $v = 2\pi r/T$

net force $F_{theoretical}$ = ____ ± ___ calculated from $F = mv^2/r$

Compare

net force $F_{measured}$ = ____ ± ___ measured with IOLab - Force Sensor

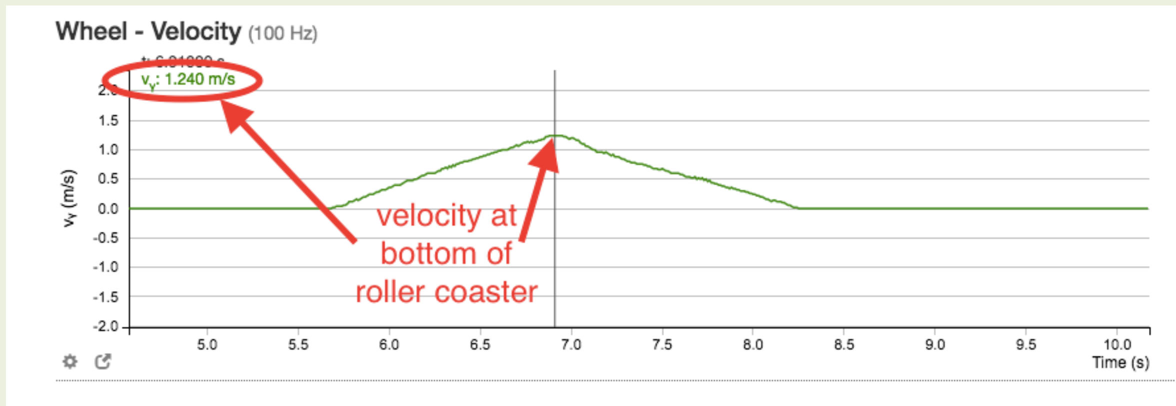


Conservation of Mechanical Energy

mass of IOLab device m = ____ ± ___ from previous IOLab activity

height at top of roller coaster h = ____ ± ___ from tape measure

velocity at bottom of roller coaster v = ____ ± ___ from IOLab – Wheel Sensor



mechanical energy at top E_i = ____ ± ___ calculated from mgh

Compare

mechanical energy at bottom E_f = ____ ± ___ calculated from $\frac{1}{2}mv^2$