Inexpensive DAQ Based Physics Labs

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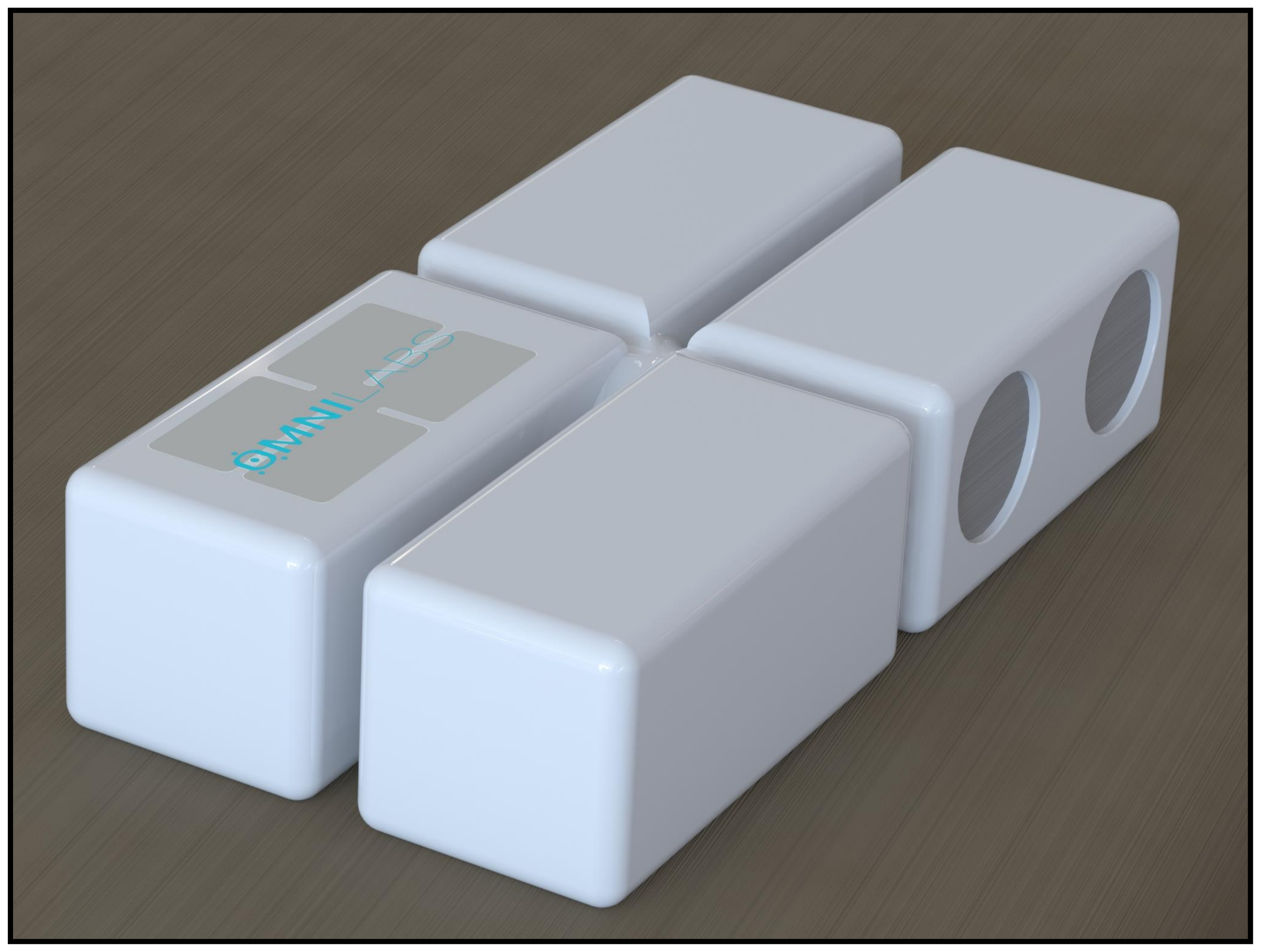
Abstract

Quality DAQ (Data Acquisition) based physics labs can be designed using microcontrollers and very low cost sensors with little other lab equipment. A prototype device with a few sensors and documentation for a number of DAQ based labs which is showcased. The device uses a simple software interface to acquire the data via Bluetooth, display real time graphs on a computer, and store the data in .txt and .xls formats. A device which includes a large number of sensors, combined with software interface and detailed documentation could provide a high quality lab experience in cases where it wasn't possible before. Examples of this are high schools which have a computer lab but no physics lab curriculum or equipment. Another example is students taking online physics classes. An entire semester lab course could be achieved using a single device with a manufacturing cost of under $20/device.

The Device

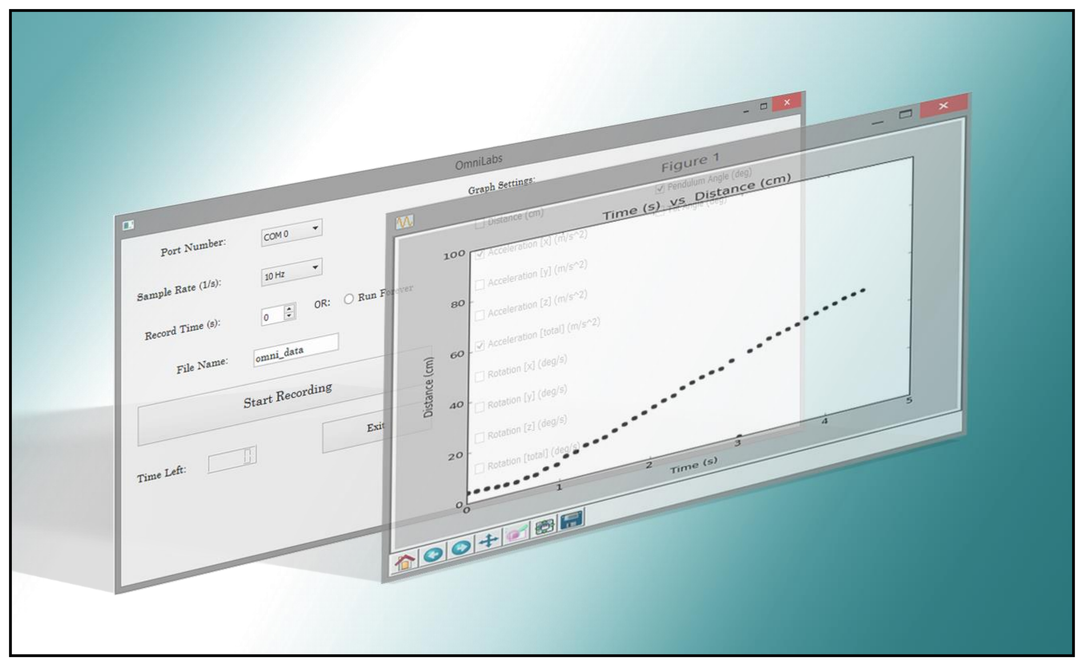


Sensors:
•3-Axis Accelerometer
•3-Axis Gyroscope
•Ultrasonic Distance

Communication:
The device uses Bluetooth to send data from all the sensors to your computer. The software interface allows to you set the sample rate on the device.

Why the 4 segment shape?
The 4 segment shape with a sphere in the center is actually a key design element making our experiments possible. It is designed so that a string can be wrapped around the sphere allowing us to spin it along 2 different moment of inertia axes. The overall rectangular shape is important so the device can slide on surfaces.

The Software



Features:
- Records the device data in .txt and .xls formats
- Adjustable sample rate
- Real time graphing while you record the data
- Measure all the physical quantities below simultaneously:
  - Distance
  - Acceleration in the x direction
  - Acceleration in the y direction
  - Acceleration in the z direction
  - Net acceleration
  - Rotation speed in the x direction
  - Rotation speed in the y direction
  - Rotation speed in the z direction
  - Net rotation speed
  - Tilt Angle
  - Pendulum Angle

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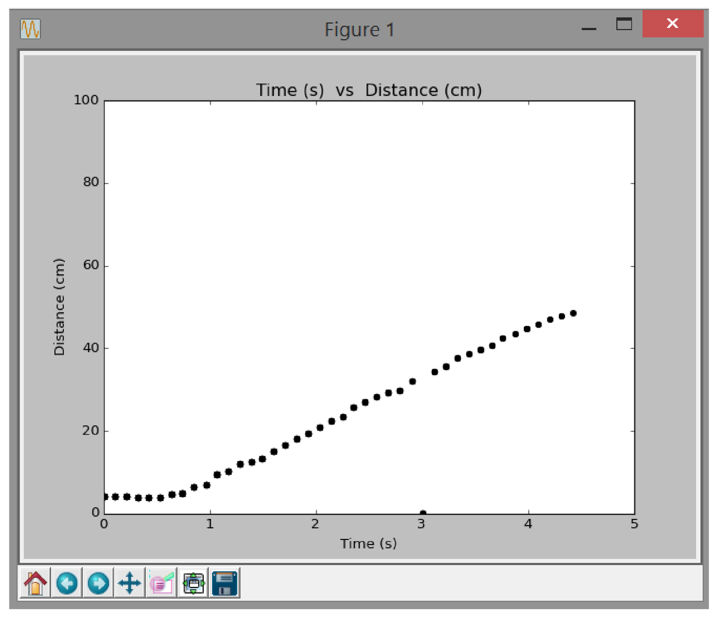
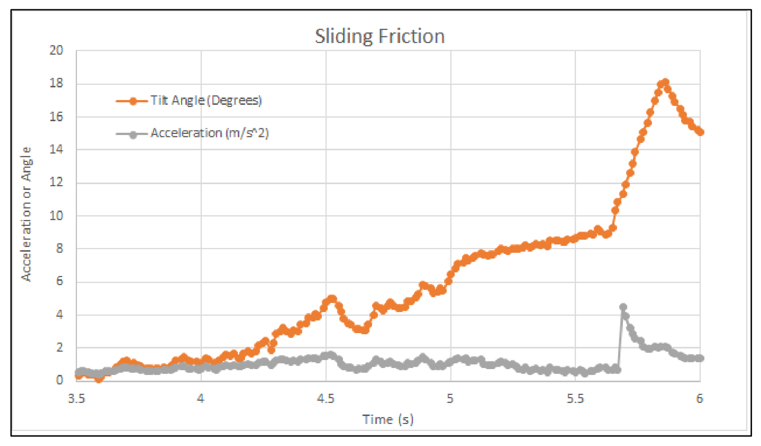
Experiments

Lab 1: Position and Velocity
__Objectives:__
- Learn how to acquire data using the device/software and make graphs in spreadsheet
- Develop a graphical understanding of position and velocity
- Learn how to calculate average velocity from discrete data
- Use a linear fit to determine average velocity

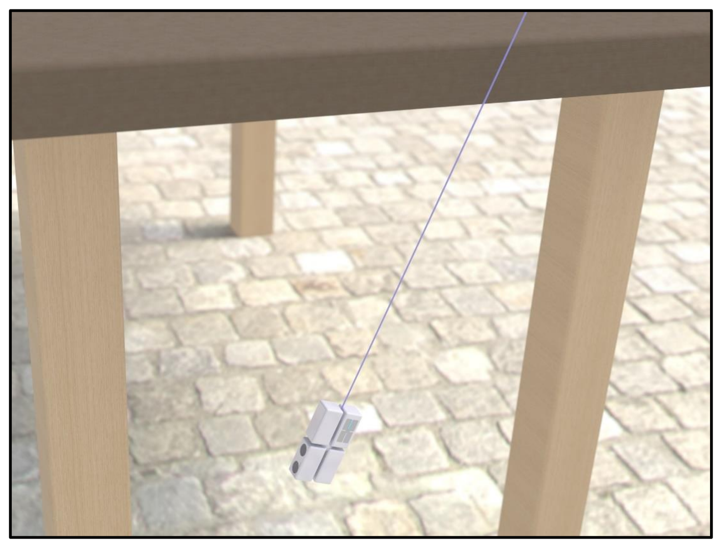


Lab 2: Acceleration Due to Gravity
__Objectives:__
- Learn how to graph velocity as a function of midpoint time
- Develop a graphical understanding of acceleration and its relation to position and velocity
- Determine acceleration from position versus time data
- Measure g

Lab 3: Force of Air Resistance
__Objectives:__
- Introduction to force and free body diagrams
- Introduction to linear and quadratic drag
- Determine when non-linear drag terms are negligible
- Determine linear drag of a falling coffee filter

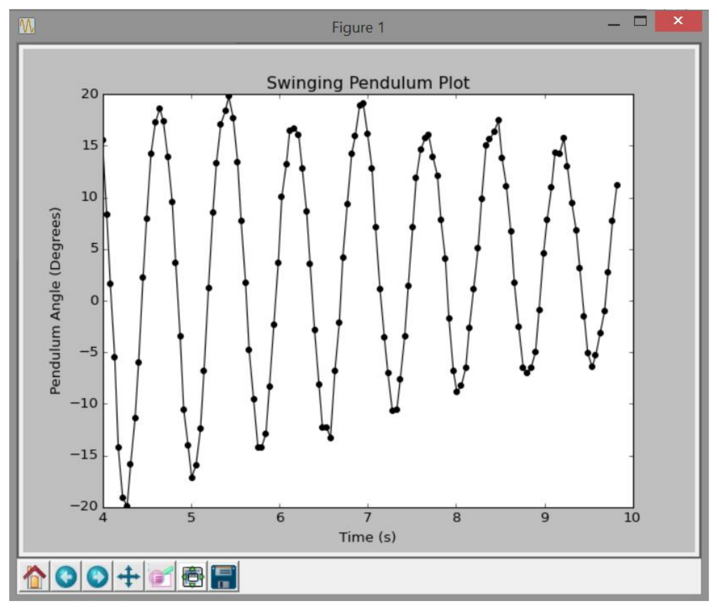


Lab 4: Static and Kinetic Friction
__Objectives:__
- Introduction to vectors
- Learn how to break a force vector into its components
- Derive a relationship between the coefficient of static friction and angle of incline for an object on an incline
- Measure static friction between two surfaces
- Measure acceleration along the axis of tilt
- Measure kinetic friction between two surfaces



Lab 5: Period of a Pendulum
__Objectives:__
- Learn how to measure period and frequency of a wave from angular position vs time graph
- Determine the proportionality constant between the period of a pendulum and $\sqrt{L/g}$

Lab 6: Modeling Angular Position of a Pendulum
__Objectives:__
- Model simple harmonic motion with trigonometry functions and the physical parameters of waves
- Use angular position vs time graph and model curve to:
  - Use least squares fitting
  - Determine wave amplitude
  - Determine phase shift
  - Determine angular frequency



Lab 7: Using Torque to Determine g
__Objectives:__
- Introduction to rotational motion
- Introduction to torque
- Determine rotation speed from gyroscope data
- Measure g using the torque and a free body diagram

Lab 8: Moment of Inertia
__Objectives:__
- Introduction to conservation of energy
- Introduction to moment of inertia
- Calculate angular velocity and angular acceleration from gyroscope data
- Determine the moment of inertia of the device around two different rotation axes
- Calculate torque