1 Objective

Study the relationship between force, mass, and acceleration. Learn to use linear voltage probes. The probes we will be using return a voltage with a linear relationship to the measured quantity.

2 Equipment List

Item	Quantity
Arduino mini computer	1
Apple Computer	1
usb cable	1
Dual-Range Force Sensor	1
Low g Accelerometer	1
Wires	4 or 5
Low Friction Cart	1
string	1
small weights	5 or 6

3 Activities

3.1 Linear Voltage Vernier Probes

Some of the probes that we will use produce a voltage signal that depends linearly on the quantity being measured. Two of these probes are the Dual-Range Force Sensor and the Low g Accelerometer. In order to use them, we have to know how to read a voltage with the Arduino and how to convert that reading into the quantity being measured.

The Arduino can measure an analog voltage signal between 0V and 5V. It uses a 10 bit digitizer to translate the voltages into a number between 0 and 1023. Essentially, the Arduino will tell you which of 1024 bins the voltage level fits into. Bin 0 corresponds to 0 V, bin 1023 corresponds to 5V. Each bin in between will indicate voltages with a 0.0489V spread. Bin 2 we will correspond to 0.00489 V. It will represent voltages between 0.00489−0.00244V and 0.00489+0.00244V. Bin 3 will be correspond to 0.00976V and represent voltages between 0.00978−0.00244V and 0.00978+0.00244V. Notice that Bin 3 represents voltages more than half way above Bin 2 and less than half way below Bin 4. This is the same all the way up to 5 V.

You will use the command `analogRead(pin#)` to retrieve the voltage data from the Arduino. The Arduino does not give you the voltage that it senses, it gives you the bin number (0 - 1023). The relationship between bin number and voltage is a linear one with a slope of 0.00489 V/bin number and intercept of 0V. The sketch in the lab folder will read an analog input voltage. Make sure that you take this sketch apart so that you know what each line of code is doing. In your lab book make sure to explain this code.

3.2 Measuring Accelerations

The Low g Accelerometer can be used to measure accelerations in one dimension. There is an arrow on the top of the sensor that notes which direction is the negative direction. This sensor will provide a voltage that depends on the magnitude and direction of an acceleration between -5g and +5g. The Arduino can be used to measure the voltage output by the accelerometer. You will need to use one of the BTA adapters for this. There are 6 pins on the BTA. The list below shows what each of the pins does.

- SIG1 (pin 6, nearest the tab on the BTA socket) to Arduino pins A0 - A5. This is the 0 to 5 volt line used by almost all Vernier analog sensors.
- 5V (pin 5) to Arduino pin 5V
- ID (pin 4) *not used*
- Vres (pin 3) *not used*
- GND (pin 2) to Arduino pin GND
- SIG2 (pin 1, farthest from the tab) This is the -10 to +10 volt input line used by just a few Vernier analog sensors. *not used*

We will not need to use the ID, Vres, or SIG2 pins today. The SIG1 pin will give us the voltage associated with the acceleration.

The relationship between the acceleration and voltage is a linear relationship so you can find a slope and intercept that can be used in the Arduino to report the acceleration. The first thing that you need to do is to determine the slope and intercept for your sensor. The sensor will measure -9.8 m/s^2 (-g) when pointing straight down and +9.8 m/s^2 (+g) when pointing straight up. When it is laying horizontally and not moving, it should be measuring 0 m/s^2. This will give you three points on a straight line that can be used to determine the calibration equation. Record the output from the Arduino with the accelerometer in the three positions and use Excel to give the the slope and intercept for the line. If you do not get a straight line with these three points, something has gone very wrong. Once you have determined the calibration coefficients, *use them in your code to verify that the Arduino reports the correct acceleration.*

3.3 Measuring Forces

The Dual-Range Force probe returns a voltage that depends on the magnitude and direction of the force being applied to the probe. There are two ranges available, -10 N to +10 N and -50 N to +50 N. We will use the lower range today. You will need to calibrate this device as well. With your lab table, develop a procedure to calibrate this sensor. Have your procedure approved before you begin. This procedure should be explained in your lab report.

3.4 Measuring Force and Acceleration Simultaneously

With your cart on a level track, attach a force probe and an accelerometer to the cart. Hang a few weights over the end of the track pulling on the force probe. Measure the acceleration and the force on the cart after you release it and before the weights hit the floor.

What is the relationship between these two?

What are the uncertainties in your measurements of all quantities in this lab?

Does this relationship change as you add more weight (up to a maximum of 500 g)?

What are the uncertainties in your measurements of all quantities in this lab?

Explain your results.