Lesson 7 - Altimeters

Background

Roller coasters are fun because of their up and down path. The elevation of the roller coaster at any point in time can be measured with an altimeter. The simultaneous measurement of position (horizontal and vertical coordinates) and time can be used to estimate velocity. These types of measurements can be done with electronic data acquisition systems that include an altitude sensor, data logging (memory), and the capacity to download the data to a computer or other display device so that it can be used.

Concepts

1. Elevation
2. Experimental data acquisition
3. X-Z coordinate systems
4. Application of kinematic equations to estimate velocity from position-time graphs

Student Learning Objectives	NYS Standards
Students can use the altimeter data acquisition equipment to collect and download elevation data	
Students can utilize data to plot X and Z position coordinates as a function of time	
Students can calculate X and Z velocity vectors from data or graphs	
Define expected trends in the different frictional coefficients for different types of surfaces	

Key Terms

Elevation	Altimeter
Data acquisition	Coordinate systems

Lesson Plan

The class period is dedicated primarily to the use of altimeter data acquisition equipment and use of data.

1. Watch video of rollercoaster to define altitude/elevation

2. Draw (or have students draw) general trends in elevation vs. time
3. Discuss how kinematic equations can be used to estimate velocity (Z-component) based on these graphs.($v_z = \Delta Z/\Delta t$)
4. Explain that we will use special altimeters to create similar types of plots for a walking path around the school (up and down stairs, outside and up hill etc). The data analysis is easier if each segment of the path is straight and at an approximately constant slope.
5. Review how XCEL altimeter and vest are used and what data is required.
6. Go on walking tour
7. Down load data and complete data sheet (note – the distances between path markers can be measured by students during class or in advance by the teacher)
8. Assess that all students correctly plotting and interpreting data

Supplies

- Xplorer GLX data recorder with built-in altimeter and timer
- Xplorer Vest (http://www.pasco.com/middle/physical/amusement_park.html)
- Altimeter Fact Sheet
- Activity sheets

Roller Coaster Curriculum

Altimeter Fact Sheet Document

The curriculum requires the students use an Xplorer GLX Data Logger with an Altimeter sensor attachment. This material is taught Day 7 in the 8^{th} grade class after the main physics concepts have been introduced and after the use of motion sensors. In the high school curriculum, this activity falls on Day 6 after a more in depth introduction to the physics and math necessary for the remaining curriculum. The use of an altimeter concretes the understanding of altitude and advantages of change in altitude for roller coaster design. It also introduces data acquisition, measurement error, and data analysis.

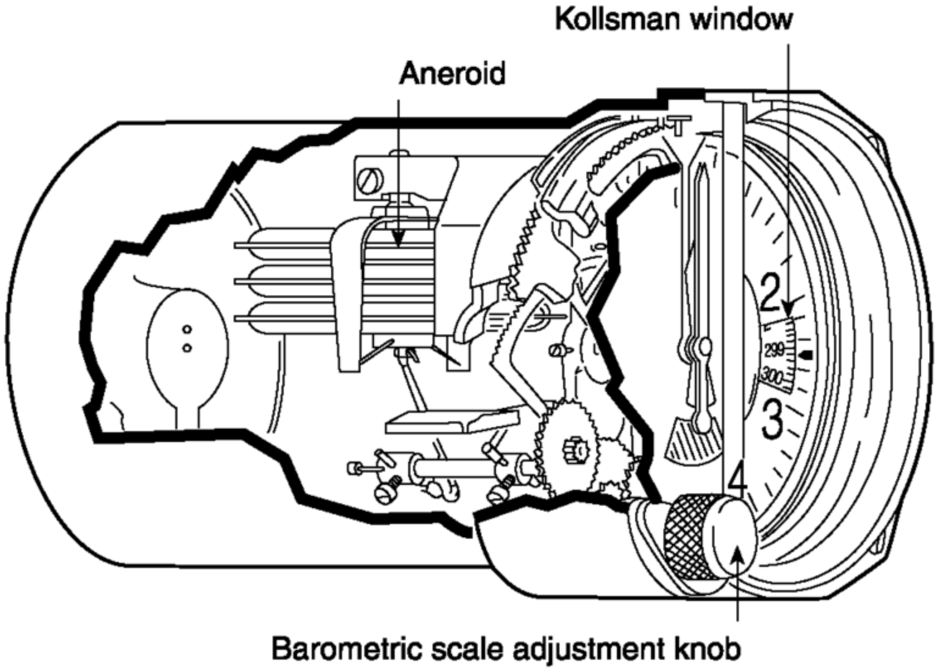


Figure1: Basic barometric altimeter.

The basic physics of an altimeter was explored. Figure1 shows a typical barometric altimeter. A barometric altimeter, such as the ones found in aircraft indicators, are air breathing (aneroid) barometers that measure the air pressure from a static pitot tube outside of the aircraft. Air pressure decreases with an increase of altitude about one millibar (0.03 inches of mercury) per 27 feet (8.23 m) near sea level. The altimeter is calibrated to show the pressure directly as an altitude, in accordance with a mathematical model defined by the International Standard Atmosphere (ISA). The reference pressure can be adjusted by a setting knob. The reference pressure, in inches of mercury, is displayed in the Kollsman Window, visible at the right side of the aircraft altimeter shown here. This is necessary, since sea level air pressure varies with temperature and pressure. After I understood the basic concepts of how an altimeter worked prior to the assignment so I focused on learning the details of this model in particular, seen in Figure2.

Figure 2: GLX Data Logger, Altimeter Attachment, Xplorer vest that holds Data Logger while the students walk the route that they are mapping.

The GLX Data Logger captures, analyzes, annotates, stores, and prints data quickly and without being connected to a computer. It can be connected to computer with the Data Studio software installed and the data can be manipulated further. The altimeter sensor is one of more than 60 sensors that the machine is compatible with including Acclerometer, Barometer, Conductivity, EKG, Flow Rate, Force, GPS Positioning, Heart Rate, Humidity, Pressure, Temperature, Voltage/Current, Water Quality, and Weather. The altimeter sensor shown above plugs into a port on the data logger and requires the use of a vest to keep the data logger at a constant reference altitude at the student's chest level. The sensor is a 3-Axis acceleration altimeter which measures changes in acceleration in three dimensions, calculates a resultant acceleration from the three dimensions of acceleration, and records changes in altitude. This allows for acceleration and altitude to be displayed on the same DataStudio plot, leading students to a better understanding of the introductory physics concepts and eventually, the design of roller coasters.

The specifications of the acceleration measurements are ±10g with 0.01 g resolution and can also be measured in m/s^2. The altitude measurements are accurate within 30 cm anywhere below 7 km above sea level. The data logger has a default sampling rate of 20 Hz which allows approximately 9 minutes of data to be stored in the equipment. The five measurements (acceleration in x, y and z axes, resultant acceleration and altitude) are taken simultaneously.

Sources of further information:

- http://www.pasco.com/glx/owners.html
- http://en.wikipedia.org/wiki/Altimeter

Activity - The Ups and Downs of Altimeters

Purpose:

The purpose of this activity is to learn how to collect data with an altimeter. You will have an opportunity to predict what the data will look like before analyzing it. This will help you read graphs of actual data.

Equipment:

- Xplorer GLX data recorder with built-in altimeter and timer
- Xplorer Vest (http://www.pasco.com/middle/physical/amusement_park.html)
- Paper and Pencil

Procedure:

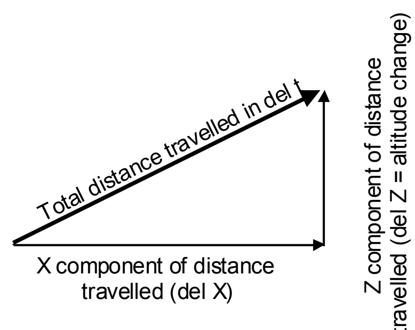
1. Break into teams of three-four students
2. Read and complete the following instructions.

Collect Data:

3. Carry the Xplorer GLX data recorder in vest or at waist level
4. Press Start on the data recorder
5. Follow the walking path designed by your teacher. Do not run!
6. At each marker, record the time (in seconds) on the timer
7. After you return to the station, the teacher will collect your equipment and help you download your altimeter data

Analyze Data:

8. After you return to the station, sketch a graph of what you think the altimeter data will look like as a function of time. (see next page)
9. Use data acquisition system to create an Altitude vs. time graph. Enter altitude data at each path marker in the data table below.
10. Estimate the X and Z coordinates of each path marker. Z coordinates are obtained directly from the altimeter data. X coordinates can be determined using trigonometry and the total distance data.



11. Use the data collected to make Excel graphs of the altitude (Z position) and X position as a function of time.
12. In Excel, calculate and plot v_x and v_z as a function of time. Note: this assumes your velocity was constant between each path marker.

$$v_x = \frac{\Delta X}{\Delta t} \qquad v_z = \frac{\Delta Z}{\Delta t}$$

PATH MARKER #	**Description** (e.g., up stairs)	**TIME (s)**	**Distance from previous point (m)**	**Altitude** (Z coordinate) **(m)**	**Horizontal distance** (X component) **(m)**
0	**Start**				
1					
2					
3					
4					
5					
6					
7					

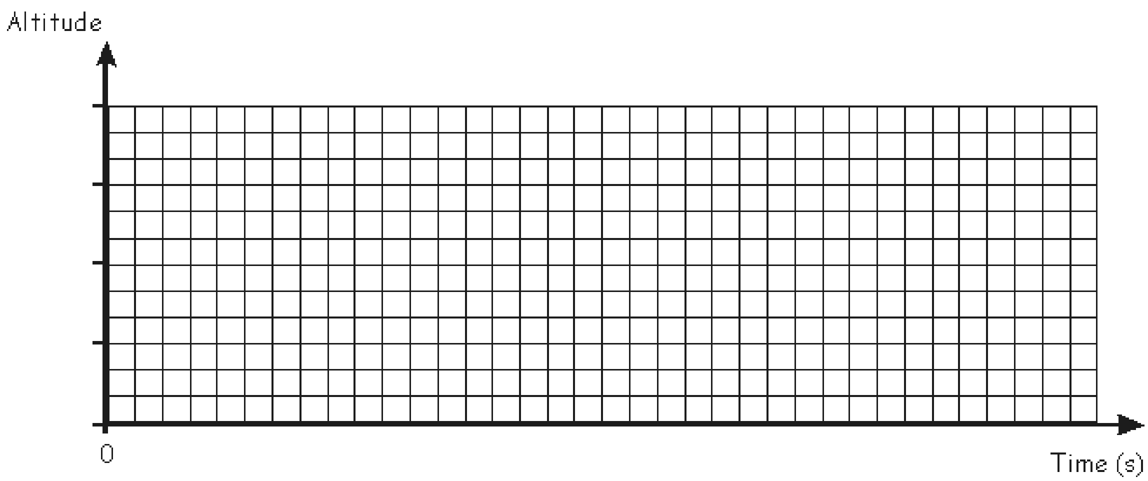


Figure 1: Hand drawn sketch of altitude as a function of time

Discussion Questions: (After you download and plot your altimeter data).

1. How well does your predicted graph (above) match with the real data?

2. What are some reasons for the differences?

3. How do your vertical and horizontal velocities compare? Does this make sense given the walking path you took?

4. Sketch the Z vs. t component of what you think might be a fun roller coaster ride. Estimate the maximum vertical velocity obtained on your ride from the steepest slope. Do some internet searching to determine the velocities that are achievable on a real roller coaster? Does your sketch of a roller coaster seem to be realistic?