N O T E

# Collecting Kinematics Data Over Long Time Intervals

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Various sensors used in computer data acquisition make it possible for students to collect data from more realistic and "interesting" experiments than the typical instructional laboratory experiments. Students can easily make measurements in situations that are somewhat complex and involve a variety of variables. But such data collection is for the most part limited to a laboratory setting because generally it is necessary that the interface be connected to the computer during the experiment.

We faced this constraint when we created a series of activities in which our students studied the kinematics of a moving bicycle.[1] In particular we wanted to address the common student difficulty of not distinguishing well between velocity and acceleration. To do this, we would combine the kinesthetic experience of acceleration on a bicycle with analysis of data. Such data have been collected for short time periods by using digital video analysis[2-4] and implementing any of several data-collection programs,[5,6] but our students needed to collect data over an extended period of time and outside of the lab.

Some manufacturers have addressed this "real-life" problem in a limited way by providing portable instruments that have some internal memory and operate on batteries.[7] Students can set up these systems for data collection, disconnect them from the computer, and move to another location. But collecting data "in the field" is always limited by the amount of memory in the interface.

## The System

We knew that electronic bicycle speedometers (sometimes called bicycle computers) do collect the data we were interested in, but bicycle computers do not have any readily available mechanism to read out the data they are receiving. So we created a new system—combining an electronic bicycle speedometer for data collection, an audiotape for data storage, and a computer for analysis.

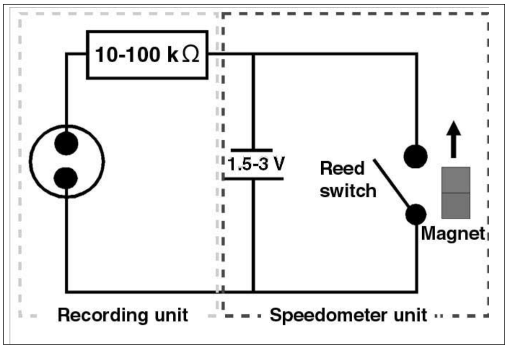


**Fig. 1. Circuit used to collect and record data from bicycle speedometer output to audiotape.**

The sensor of the speedometer includes a magnet and a reed switch. The magnet is attached to a spoke while the reed switch is fixed on the frame. The speedometer supplies approximately 1.5 V to the switch. When the magnet passes the switch, the switch closes and the voltage drops momentarily to zero. Thus, the bicycle speedometer can "count" the number of revolutions of the bicycle wheel by counting the number of drops in the voltage. From this information, the speedometer calculates the distance traveled and the speed of the bicycle.

After a little experimentation, we discovered that the reed switch is closed for an extremely short time. To be sure that we obtained data for each revolution of the bicycle's wheel, we needed to set the computer sampling rate at about 200 Hz. With this sample rate, however, the memory of both commercial devices we tried filled within a few minutes.

There were two ways by which we could increase the time available for data collection. We could design and build a circuit that converted the analog voltage information into time between pulses, which meant that we would need to store only one data point (the time) for each revolution. This information could then be put into a digital port on one of the portable data-collection devices. Or we could record the analog data in some other format so that it could be transferred to a computer later. We selected this alternative because it minimized the number of new devices or components needed. In the end, we connected the output from the sensor to the input of a small portable audio recorder. Only an attenuating resistor was added to the circuit (see Fig. 1). Now each closing of the reed switch sensor is recorded as a click on the audiotape. With this system, limitations on data collection time are overcome. Students can easily record up to two hours of data on a standard audio cassette.

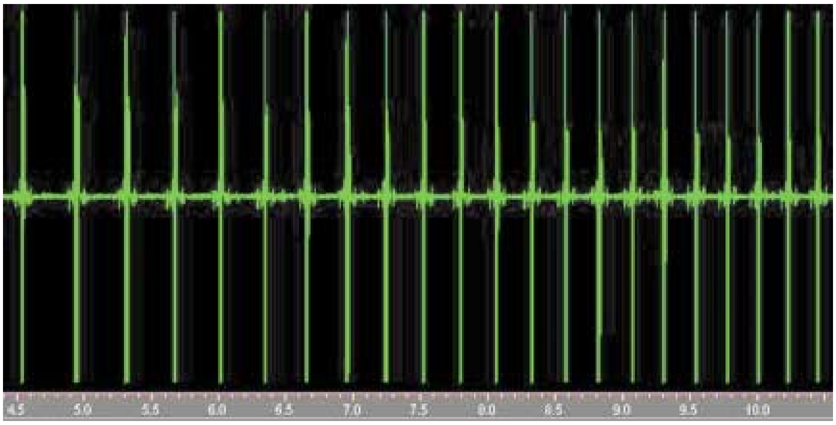


**Fig. 2. Intensity versus time for some sample data.**

## Digitizing the Data

The audio data are converted to digital form by using a standard soundboard, available in most computers. The student connects the audio recorder to the computer's soundboard and captures the data as a .WAV file. Using one of several available programs, the student displays the data as sound intensity versus time and simultaneously plays it through the computer speakers. These two methods of "displaying" the data can offer students special insight into velocity and acceleration. For example, they can see that equally spaced pulses indicate a constant velocity, while changes in the times between pulses indicate acceleration. With the audio playback, constant time between clicks indicates a constant velocity, whereas short times between clicks indicate a higher velocity than long times. Changing times between clicks indicates accelerations. This aural input provides a medium that is not normally available for the display of distance-versus-time data. Research into whether it helps students understand velocity and acceleration would be useful.

Figure 2 shows some sample data, although at this point not in a format that could be analyzed. Two steps are necessary to convert the data into a file that can be read by other common data-analysis programs. Several programs will convert a .WAV file into text information. For each of the sampling points in the .WAV file, the program writes a number to indicate the relative intensity of sound at the time. For this step in the conversion process, we use Cool Edit.[8]

This process creates a text file that is usually extremely large and contains much more information than we need. One of us (GB) has written a short program that reads through the text file and finds the times between the pulses.[9] The program looks for high values in the text file and determines the times between consecutive pulses. The program also cleans the data in two ways. First, a threshold is set so that low-level noise, which can be seen in Fig. 2, is not counted as pulses. Second, pulses that occur extremely close together are counted as a single pulse. Thus we remove spurious data that occur as a result of bouncing of the reed switch. By debouncing in software, we have avoided the need for creating additional electronic circuitry. The pro-

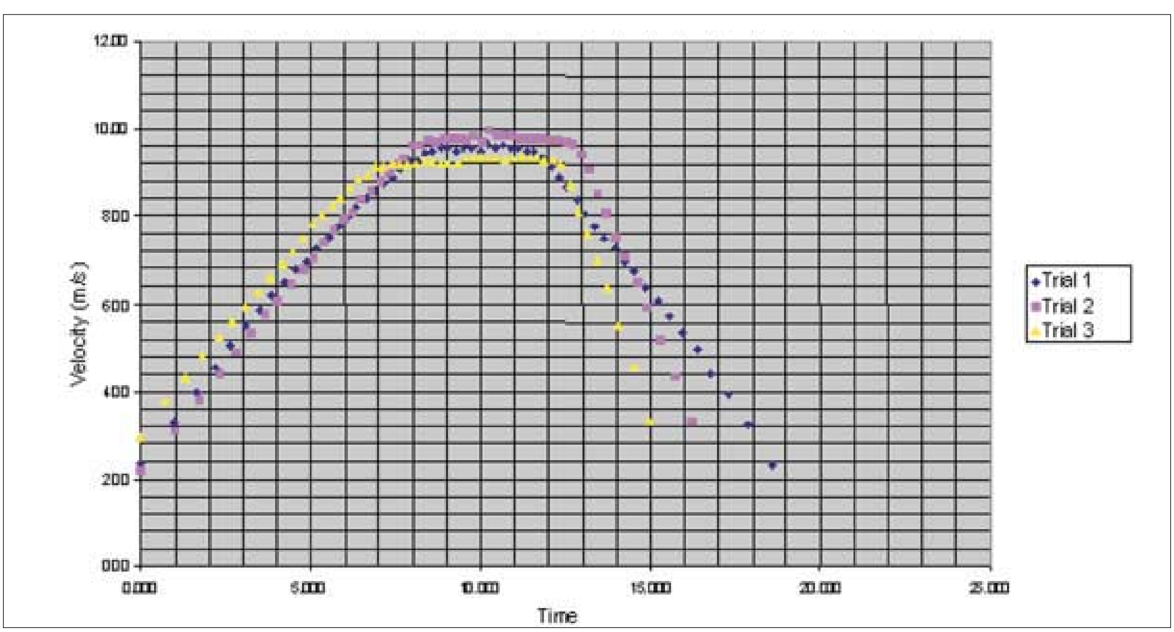


**Fig. 3. Typical velocity-time data collected by students.**

gram writes the time data to a comma-delimited text file that can be imported into a spreadsheet or into the analysis component of programs such as PASCO's Science Workshop.

## Analysis of Data

With the distance-time data, students can readily calculate the speed and acceleration for all times under investigation. Sample curves are shown in Fig. 3.

In addition to learning about the relationships among distance, time, speed, and acceleration, students can also investigate some of the forces on the bicycle and its rider. For instance, several different bicycles can be ridden at identical speeds and then allowed to coast to a stop. From the distance-time curve students can determine the acceleration. Similar analyses can be made for the same bicycle and rider in different configurations. By looking at the acceleration curve, students can calculate the force of friction being applied to the bicycle in this and other situations. They can complete further analysis for different types of bicycles and for varying road conditions. Likewise, they can look at the ways various conditions affect the increase or decrease in speed when they are attempting to go from zero to some maximum speed.

## Extensions

We would like to combine the kinematic bicycle data with some physiological data of the rider, such as recording pulse rates or heartbeats. However, to correlate these data with the kinematics data we would need a stereo tape recorder. Although small portable stereo recorders are now available, they are somewhat expensive. Another possibility would be to correlate video and audio data collection, perhaps by using a wireless microphone or a very long wire to collect pulses on the audio track of a videotape. Simultaneously, video of the bike's motion would be recorded. Students could then compare four representations—audio, video, numerical, and graphical—of the kinematic data.

## Comments

We believe that the system described here could be used in a variety of situations where students would be collecting data in the field. Most components are readily available in the instructional laboratory and any additional costs are minimal.

In one sense, collecting data on audiotape seems rather old fashioned. It was the method of choice before floppy disks became available for personal computers. But as demonstrated in our bicycle projects, there are often creative opportunities for physics teachers to combine the advantages of older devices with more recent technology to improve learning and increase motivation of students in the introductory course.

### Acknowledgments

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### References

1. For more information about the overall bicycle project, see http://www.science.uva.nl/research/amstel/bicycle/.
2. Robert Fuller and Dean Zollman, *Energy Transformations Featuring the Bicycle* (videodisc) (Great Plains Network, Lincoln, Neb., 1985).
3. D. Zollman and R.G. Fuller, "Teaching and learning physics with interactive video," *Phys. Today* **47**, 41-47 (1994).
4. L. Escalada, R. Grabhorn, and D. Zollman, "Applications of interactive digital video in a physics classroom," *J. Educ. Multimed. Hypermed.* **5**, 73-97 (1996).
5. Doyle Davis, "VidShell" (Berlin, N.H., 1998) http://192.233.237.47/vidshell/vidshell.html.
6. M. Leutzelschwab and P. Laws "Videopoint 2.0" (Lenox Softworks, Lenox, Mass., 1997).
7. For example, PASCO's Science Workshop or Texas Instruments' CBL.
8. David Johnston, "Cool Edit" (Syntrillium Software, Phoenix, Ariz., 1999) http://www.syntrillium.com.
9. For copies of the program written for data conversion and more information (in German) about the use of these techniques with secondary school students, see http://planet.ipn.uni-kiel.de/projekte1999/braune/.