

# Large-Scale Introductory Mechanics Laboratory Instruction with LabVIEW at Purdue University

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# Large-Scale Introductory Mechanics Laboratory Instruction

- Setting and goals
- History of the effort, realizations
- Present operation
- Sampling of experiments
- Prelab exercises using Computerized Homework In Physics (CHIP, a.k.a. UIUC Tycho)
- Future work

# Setting

- Purdue University: Indiana state university with 38,000 students.
- Physics 152: the calculus-based mechanics course taken primarily by freshman engineers.
- Physics 152 grades assigned in 2001-2002: 500 in fall, 1,300 in spring, 55 in summer.
- 1,100 ft<sup>2</sup> room available for a computer lab (too small, but take what you can get).

# Problems in 1989

- Poor experimental results, leading to doubts about physics.
- Previous major lab upgrade was in the late 1950s. Money was not available for a conventional upgrade.
- Overwhelming number of students. ~2,000/year in PHYS 152.
- Non-uniform teaching and grading.
- Dubious reputation of PHYS 152; lingering rumors.

## What happened:

- 1989 Introductory Course Committee recommended “The Physics 152 lab must be updated so as to take advantage of the microcomputer revolution in teaching. Computers can easily be used for data acquisition, calculation, graphing, report preparation, and teaching via built-in tutorials.”
- Department Head sends a prioritized list of undergraduate microcomputer requests to the Dean. #1 is to get a couple of computers to begin. #5 is to do what we began in #1. Result: We get priority #5 only.

# Goals

- Provide students with straightforward, modern measuring instruments. These instruments must be 10X more precise and accurate than what was in the lab previously.
- Reduce the time spent in processing data so that students will think more about the physics in the experiment.
- Effort must be sustainable.

Physics 152 lab, January 2003  
15 stations in 1,100 ft<sup>2</sup>; 3rd generation of computers



# The Beginning

- Sudden start in Spring 1990. Computers (Mac Iicx) and software (LabVIEW 1.7) chosen within a few days. Sign-off on lab layout in a couple of weeks.
- Original manpower: ES, part-time postdoc (Chuck Wilson), 4 undergrads (Rich Fox, Jim Cavera, Bob Wistrand, John Schmitz), electronic tech Ian Rickey. Joined early on by Dan MacIsaac and Kathleen Falconer.
- (Silent) faculty mandate: real data, no simulations.
- Original intent: use counter/timer channels of multifunction DAQ board; ended up using digital I/O.
- November 1990: torsion pendulum experiment for 2 lab sections. Scrapped software 1 hour before class and went with simple tool backup.
- January 1991: beginning of a 4 experiment operation for 1,500 students; old laboratory kept intact in case of failure.



## Present Operation

- To handle 1,400 students/semester, students do an experiment every other week: one week to do a group lab report. We have one week to grade the report. 15 weeks  $\rightarrow$  7 experiments, plus a record check at the end.
- Students must complete prelab exercises on CHIP (Computerized Homework In Physics) before class begins: credit  $\rightarrow$  zero when class starts.
- Each class is handled by a GTA plus an undergrad grader.
- 110-minute sessions from 7:30 AM to 5:20 PM Tuesday through Friday. Lab open hours on Mondays and Monday – Thursday evenings.

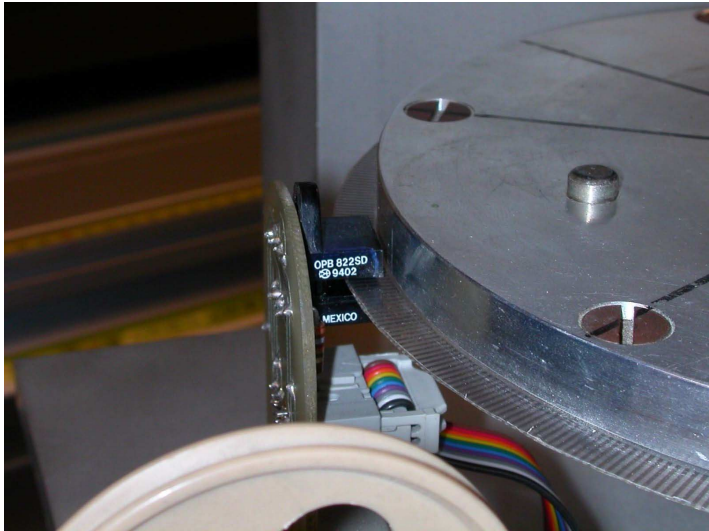
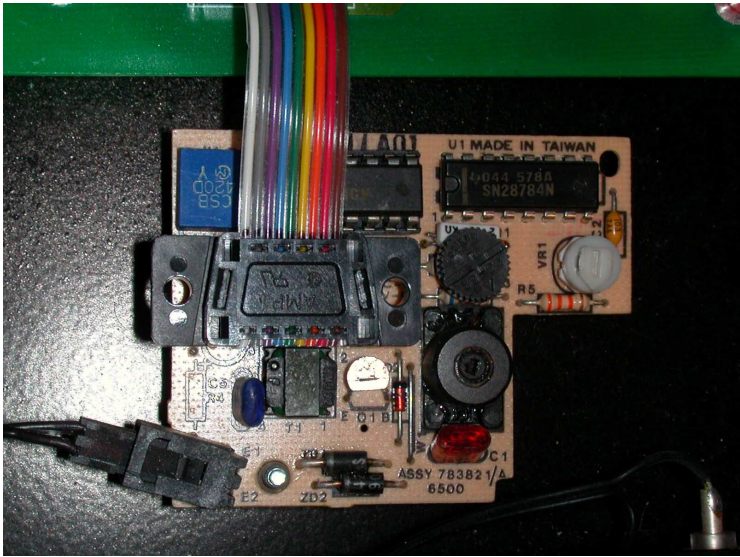
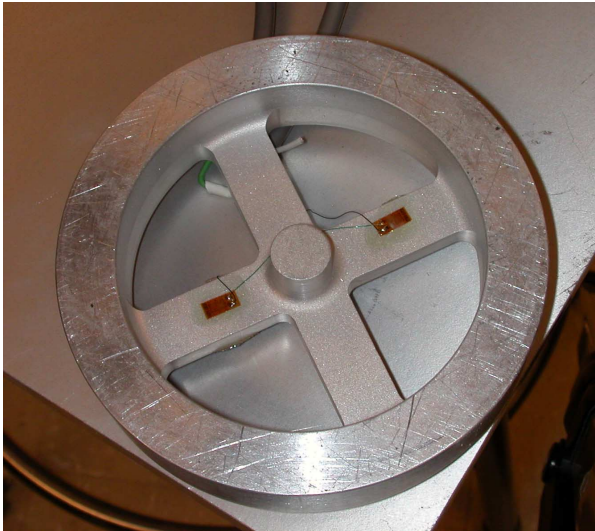
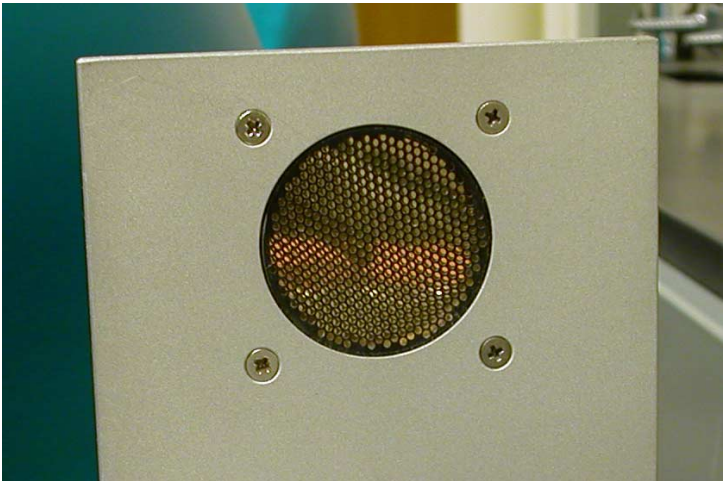
# Present Operation (continued)

- Optional, but highly recommended, evening Measurement Analysis (MA) talk by Ed Shibata, John Yeazell, or Head GTA for uniformity. MA covers uncertainties, their propagation (worst case treatment), quick lesson on spreadsheets and software graphing. MA exercises on CHIP plus handed-in graph is not optional.
- GTAs are given PowerPoint presentations for all experiments. These can be used as templates for 10 minute introductions for each lab session.

# Lessons

- Small mistake X 1,500 = large mistake.
- Keep the software basic and simple.
- Software changes must be quick and easy to make.
- 2% of the students cost > 90% of the problems.
- Computerized labs require more manpower.

# Transducers

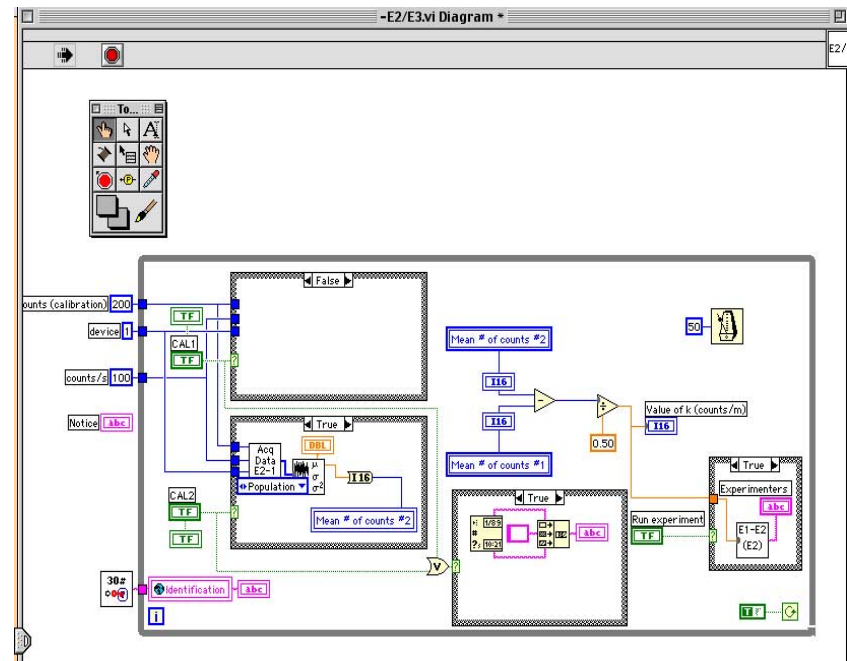
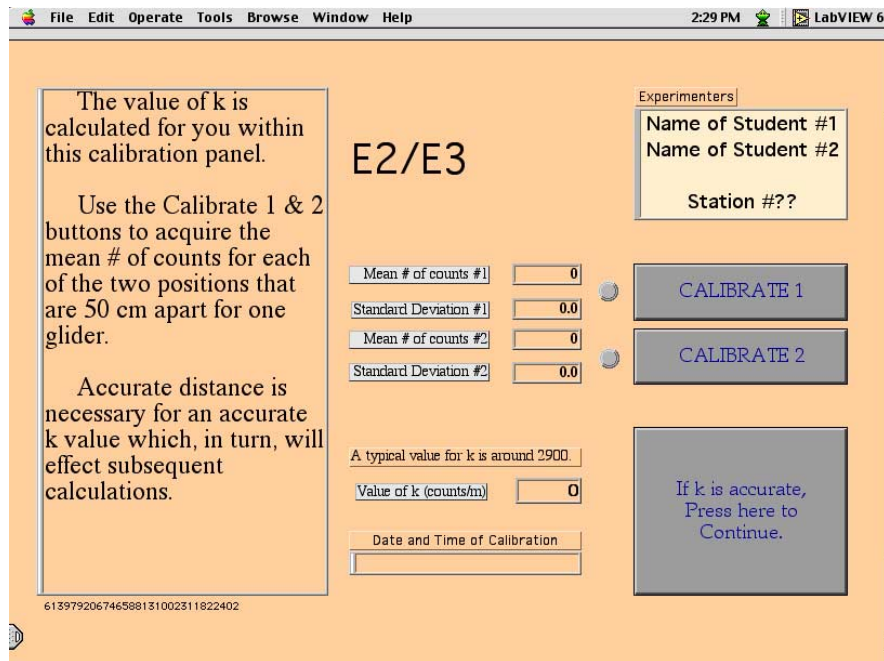


# LabVIEW programming

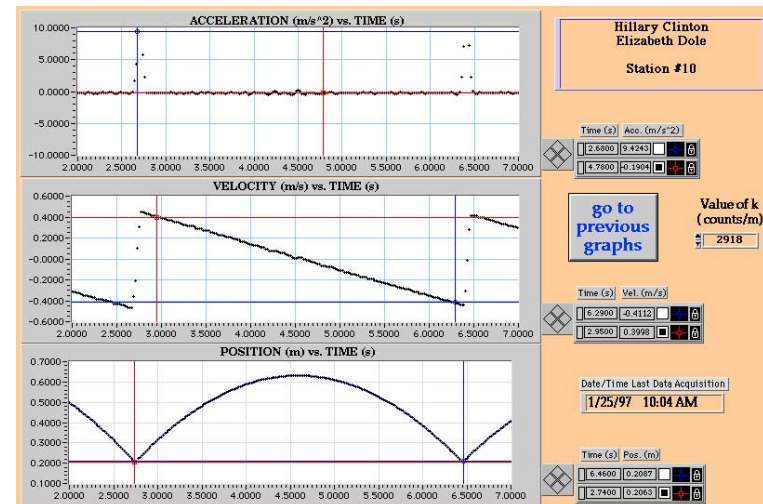
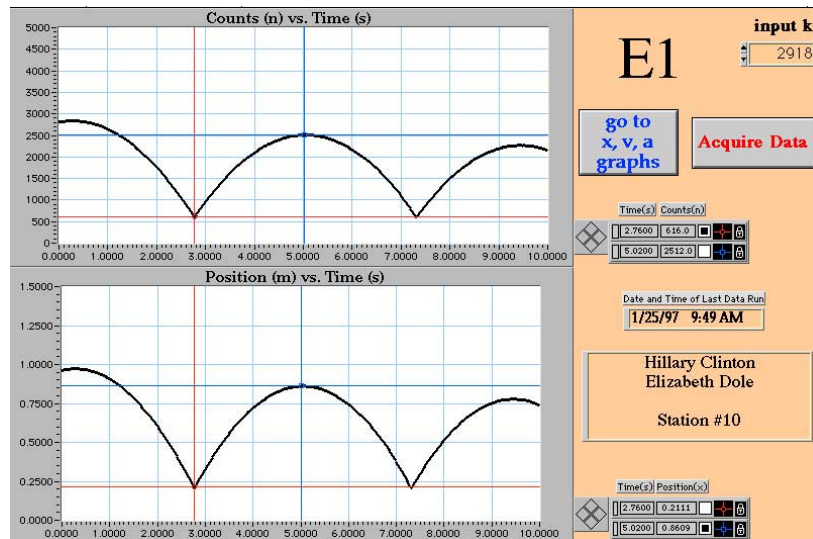
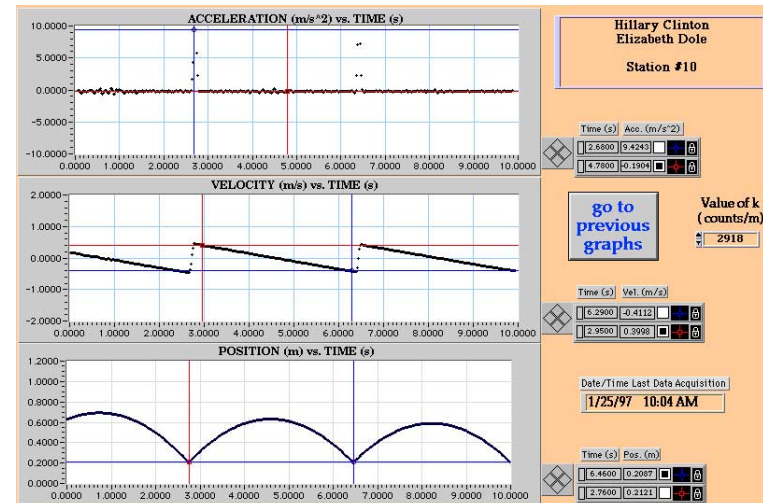
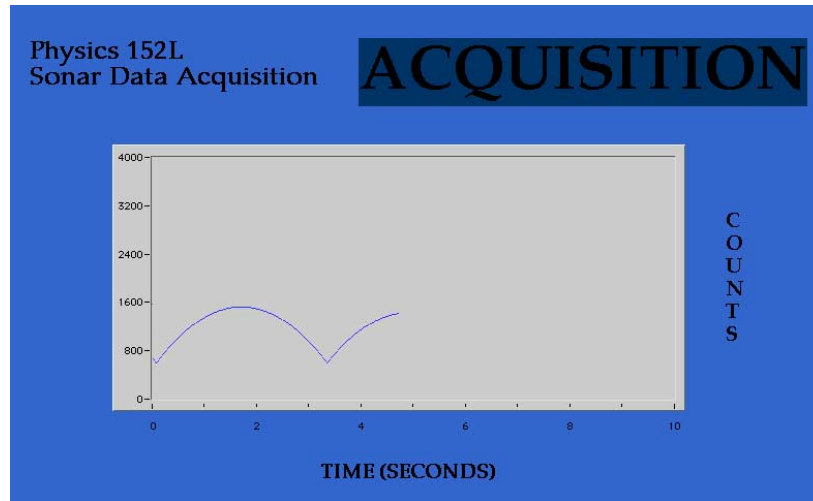
- Large initial discount made LabVIEW affordable. Now Purdue has a site license.
- Rapid programming using a Graphical User Interface. (Some inexperienced undergrads have actually been some of our best programmers: they have no preconceptions.)
- Relatively easy creation of interfaces for the student.
- Many useful features: rescaling of graphs, cursor readout, data readout, least-squares fitting.

# LabVIEW

A graphical programming environment that is relatively quick and easy.



# Typical displays for a glider on an inclined airtrack

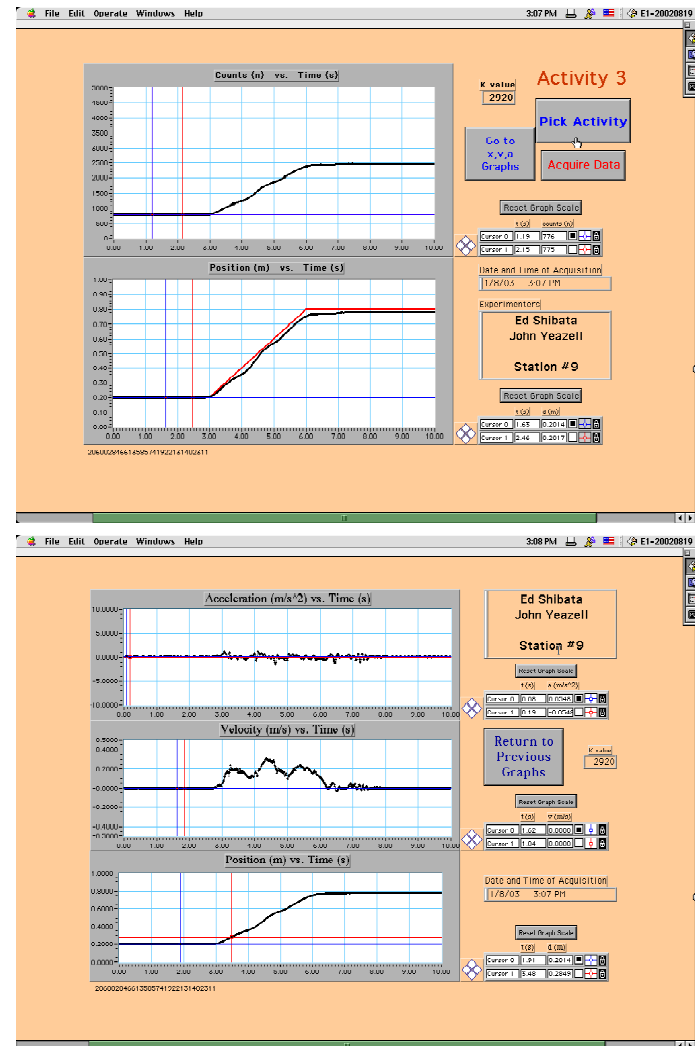
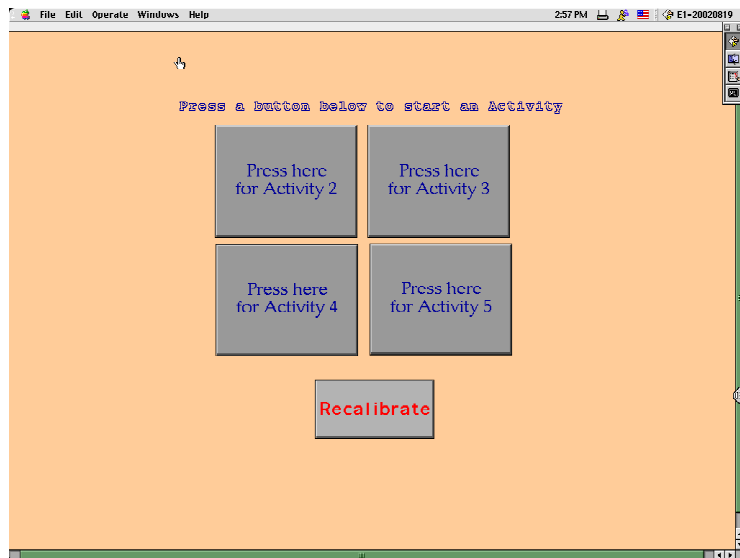


# Data Acquisition and Display

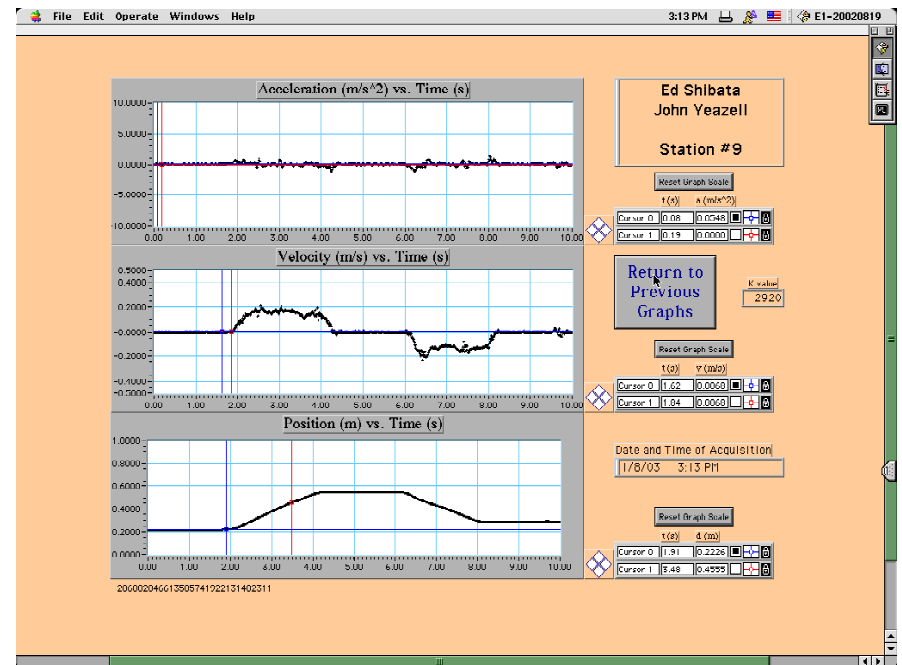
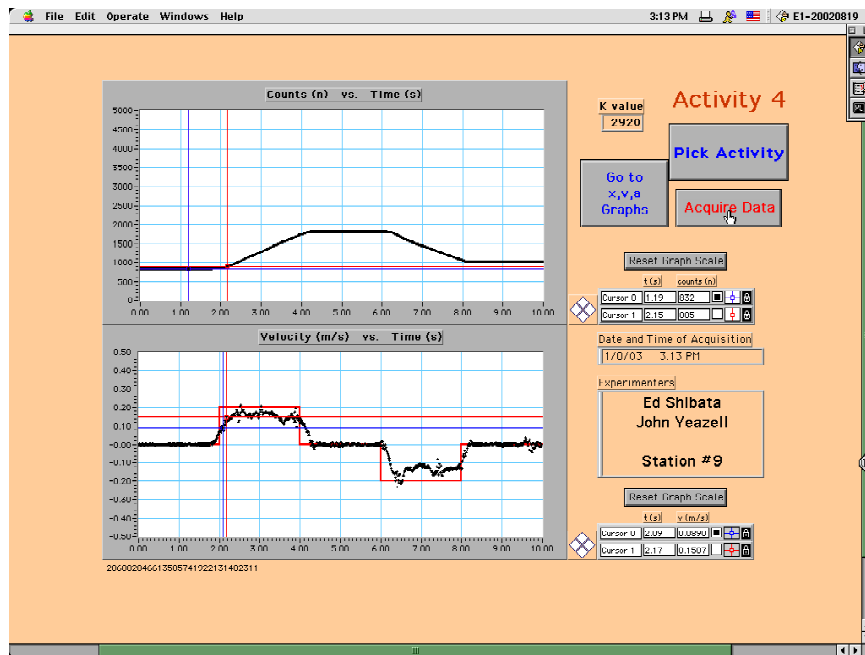
- Beginning: data were read into a buffer and then displayed using Macintosh IIcx's (16 MHz, 4 MB RAM).
- Later we were able to display “position” in real time at 50 Hz. With new computers we went to 100 Hz.
- Now we can display  $x(t)$ ,  $v(t)$ , and  $a(t)$  in real time at 100 Hz with our 3rd generation of computers (Macintosh blue G3's, 350 MHz, 512 MB RAM). Also, Rev-R-Dist, which restores original hard disk contents, can be run after each logoff.



# Matching $x(t)$ : realtime display is essential



# Matching $v(t)$

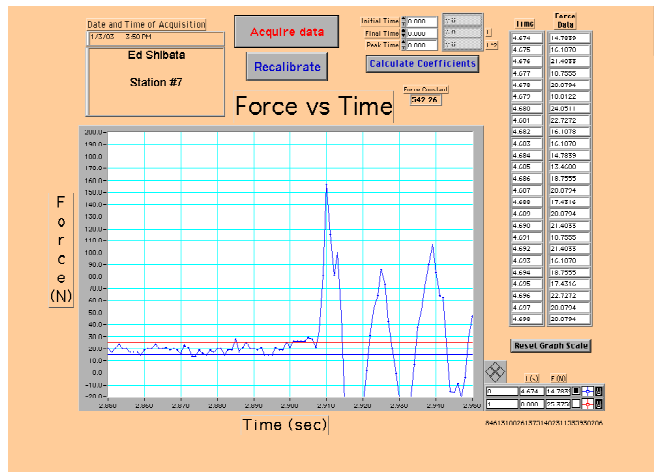


# Experiments with a Force Plate

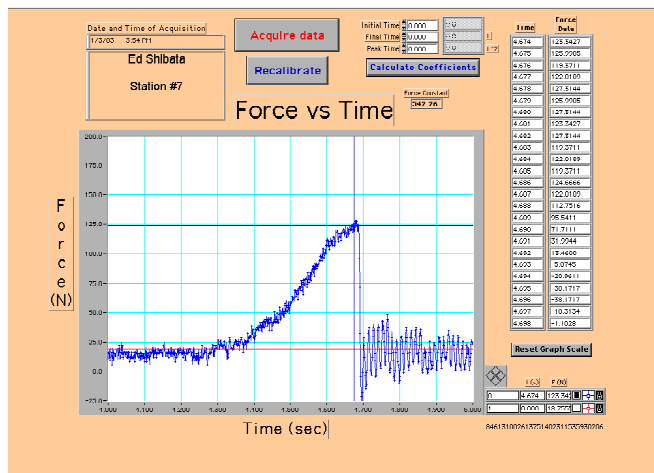


- Almost completely elastic collision using a golf ball. Discovery: today's Superballs are inferior to the originals and to golf balls.
- Completely inelastic collision using a golf ball into a bed of dry rice.
- Form a piece of paper as a cushion to minimize force.
- Karate chop a wooden \$0.013 tongue depressor.

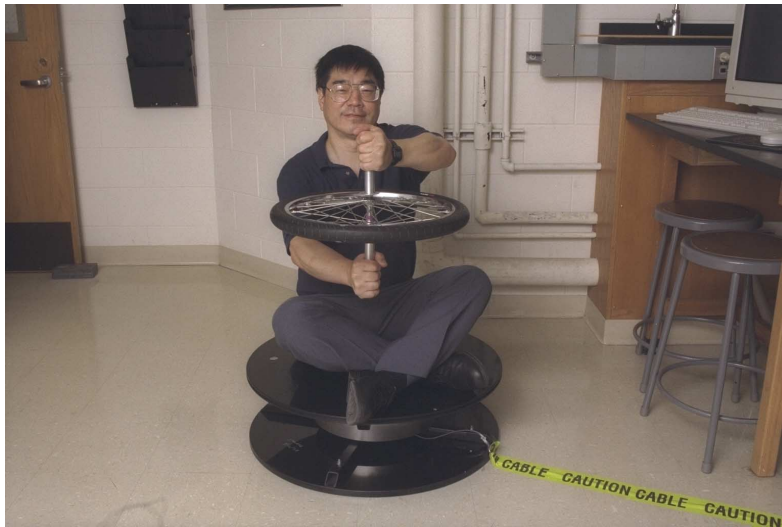
# Karate Chop Results



- Fast break:  $F_{\max} \sim 150 \text{ N}$
- Slow break:  $F_{\max} \sim 95 \text{ N}$
- Dry wood takes more force than damp wood (winter/summer effect).



# Rotational Dynamics



- Barbells in and out.
- Bicycle wheel with lead-loaded rim: most intriguing part for students.
- Inelastic angular collision (quantitative)

# CHIP: web-based system to present and grade homework

- Based on Tycho source code from University of Illinois.
- Variables in a numerical problem can be chosen randomly, using username characters as the seeds.
- Due dates and times can be set for various sections. Prelab exercises are worth 25% of the credit for an experiment. Credit  $\rightarrow$  0 after deadline.
- Some interactive exercises that guide a student's thoughts and reasoning: reduces student frustration.
- For lab: significant figure arithmetic.

# Future Work

- Generate more experiments that actively involve the students. Matching of  $x(t)$ ,  $v(t)$ ,  $a(t)$ , rotating platform, and force plate experiments have been successful.
- Write more interactive exercises for CHIP.
- Get away from the “ratchet effect” in the programming effort.
- Get a larger laboratory with a better projection arrangement; go to a Fairleigh Dickinson lab table arrangement.
- Reassess writing component and uncertainty calculations in lab reports.

## The next Purdue Physics 152 laboratory

- Old lab is 1,100 ft<sup>2</sup> with traditional lab tables.
- New lab will be 1,550 ft<sup>2</sup> with “Dickinson” lab tables.
- This will happen when Computer Science gets their new building.





## If I were to do it again ...

- Look at the commercial hardware (transducers and interface boxes) that are now available. (Our two large enrollment algebra-based courses are using PASCO equipment, and have never needed the expertise of our Electronics Shop.)
- Try to use software (e.g., LabVIEW) that can be altered.