Flexible Software for Computer-Based Problem Solving Labs

Brita L. Nellermoe[1]

Jennifer L. Docktor[2]

[1]Department of Curriculum and Instruction

[2]Department of Physics

Physics Education Research Group

Bill Gilbert[2], Sean Albiston[2], Brian Andersson[2], Ken Heller[2], Natalie Martimbeau[2]

Theodore Hodapp, Hamline University

UNIVERSITY OF MINNESOTA

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Outline

- Problem solving laboratories and Minnesota's Classrooms
- Motivation
- Why LabVIEW?
- Programs
  - Video Recorder and Video Tool
  - Hall Probe
  - Faraday Probe
- Adaptability
- Conclusions

Problem-Solving Labs

- Laboratory is a required part of introductory physics courses at UMn.
- 2-hours once a week
- 15 students per lab class, 1 TA coach
  - UMn has 70+ TAs and 2000 intro physics students per semester
- Cooperative groups of 3 students
- Practice problem solving:
  - Predict-explore-measure-evaluate
- Some lab problems are quantitative, some are qualitative (exploratory)
- The **focus** of the labs is to facilitate discussion and coaching.

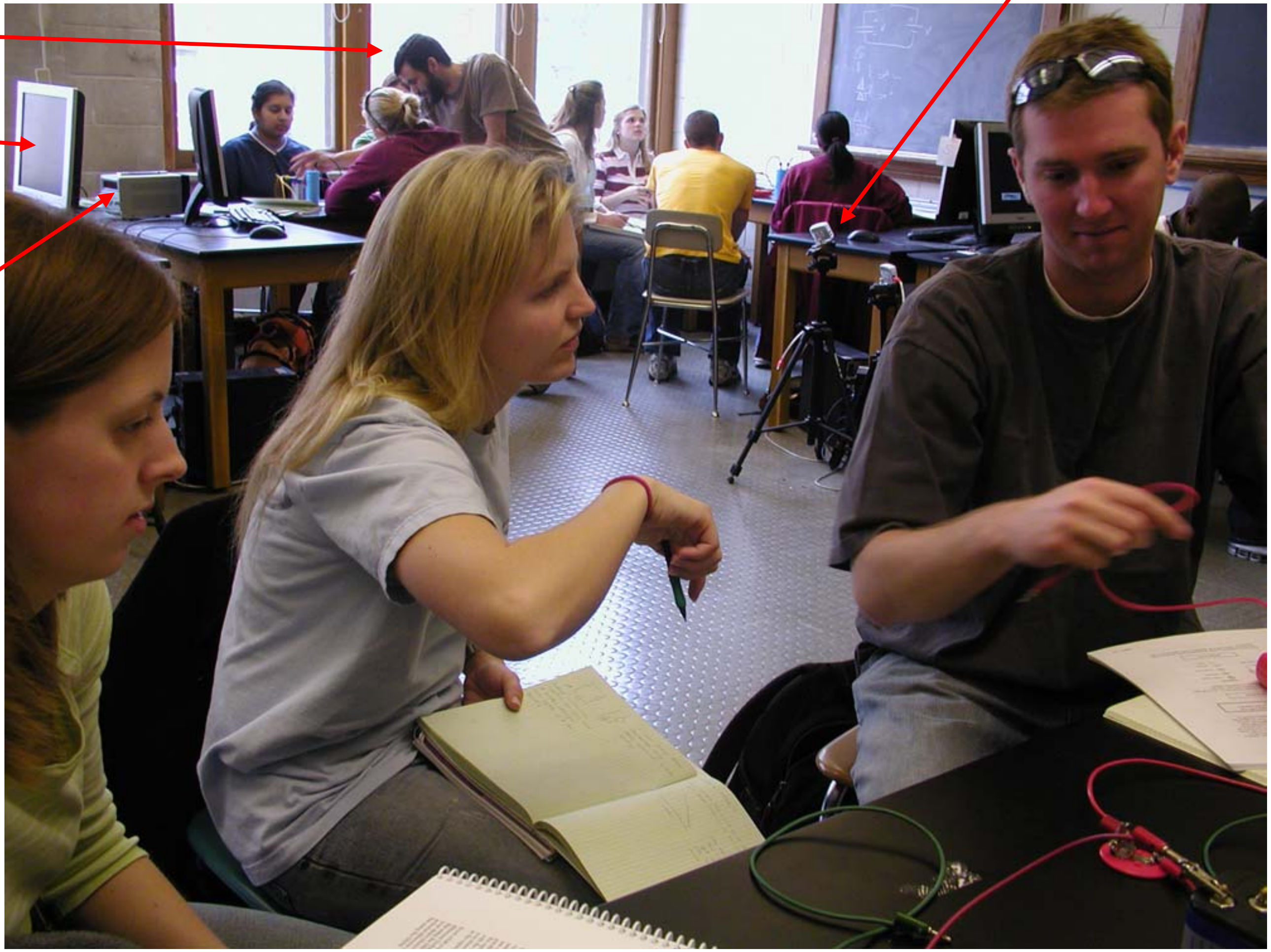
Minnesota's Teaching Laboratories

Camera

TA

19in Computer Screen

Lab Equipment



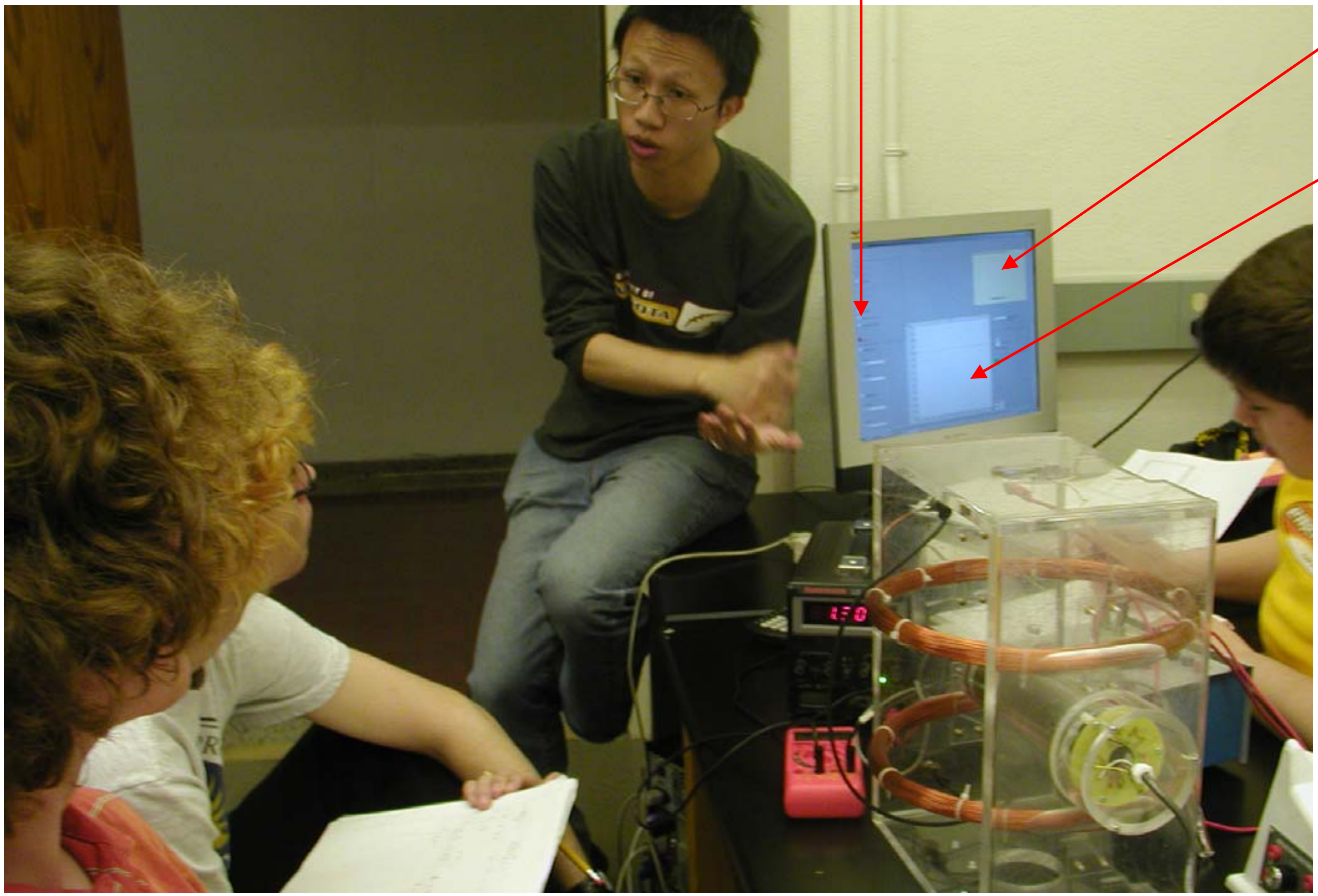
Coaching by a Teaching Assistant

Program controls

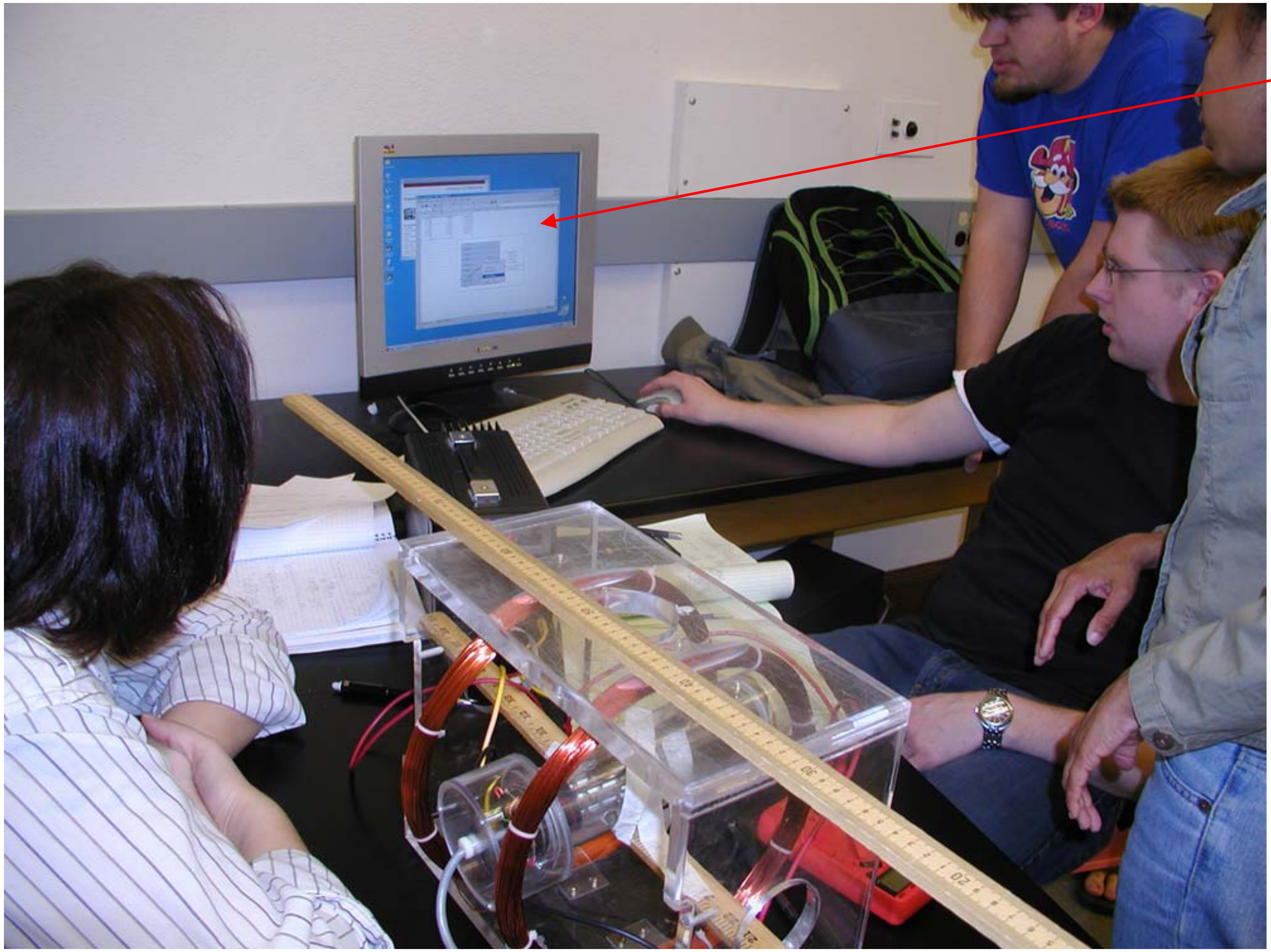
Program Instructions

Data Graph

Program: Hall PROBE



Exporting Data to EXCEL



Excel Spreadsheet

Also exportable To:
E-mail
Text file

PROBLEM #3
MEASURING THE MAGNETIC FIELDS OF PERMANENT MAGNETS

Context

Your team is designing a probe to investigate space near Jupiter. One device uses strong permanent magnets to track the motion of charged particles through Jupiter's magnetic field. You worry that their magnetic fields could damage computers on the probe. To estimate how close a magnet can be to a computer without causing damage, you have been asked to determine the magnitude of the field near the magnet.

No isolated magnetic monopoles have ever been discovered (a difference between magnetism and electricity) but you wonder how accurately one could *mathematically model* the field of a bar magnet as the vector sum of fields produced by monopoles located near each end of the magnet. With this model, you calculate how the magnetic field would vary with distance along each symmetry axis of a bar magnet. You assume that a magnetic monopole would produce a magnetic field similar to the electric field produced by a point charge. To test your model, you decide to measure the magnetic field near a bar magnet with a Hall probe.

EQUIPMENT

You will have a bar magnet, a meter stick, a Hall probe (see Appendix D), and a computer data acquisition system (see Appendix E). You will also have a Taconite plate and a compass.

PREDICTION

Restate the problem. What are you trying to calculate? What assumptions are you making?

Before Class

Warm-up Questions

Review your notes from Lab I problem 2, "Electric Field from a Dipole"

1. Draw a bar magnet as a magnetic dipole consisting of two magnetic monopoles of equal strength but opposite sign, separated by some distance. Label each monopole with its strength and sign, using the symbol "g" to represent the strength of the monopole. Label the distance. Choose a convenient coordinate system.
2. Select a point along one of the coordinate axes, outside the magnet, at which you will calculate the magnetic field. Determine the position of that point with respect to your

3….
4….
5….
6….

Exploration

Using either a Taconite plate or a compass check that the magnetic field of the bar magnet appears to be a dipole.

Start the Hall probe program and go through the Hall probe calibration procedure outlined in *Appendix E*. Be sure the switch on your amplification box agrees with the value on the computer.

Take one of the bar magnets and use the probe to check out the variation of the magnetic field. Based on your previous determination of the magnetic field map, be sure to orient the Hall probe correctly. Where is the field the strongest? The weakest? How far away from the bar magnet can you still measure the field with the probe?

Plan

Write down a measurement plan.

Measurement

Decisions

Based on your exploration, choose a scale for your graph of magnetic field strength against position that will include all of the points you will measure.

Choose an axis of the bar magnet and take measurements of the magnetic field strength in a straight line along the axis of the magnet. Be sure that the field is always perpendicular to the probe. Make sure a point appears on the graph of magnetic field strength versus position every time you enter a data point. Use this graph to determine where you should take your next data point to map out the function in the most efficient manner.

Repeat for each axis of the magnet.

Analysis

Graph data

Compare the graph of your calculated magnetic field to that which you measured for each axis of symmetry of your bar magnet. Can you fit your prediction equation to your measurements by adjusting the constants?

Conclusion

Evaluate Results

Along which axis of the bar magnet does the magnetic field fall off faster? Did your measured graph agree with your predicted graph? If not, why? State your results in the most general terms supported by your analysis.

How does the shape of the graph of magnetic field strength versus distance compare to the shape of the graph of electric field strength versus distance, for an electric dipole along each axis? Is it reasonable to assume that the functional form of the magnetic field of a monopole is the same as that of an electric charge? Explain your reasoning.

Motivation

- Why computers?
  - Can lead to faster, more accurate data taking
  - Familiar technology for most students
  - Concern: should not detract from the physical phenomena being studied
- Why video?
  - 2-D motion, less abstract, familiar technology
- Why design our own software?
  - Facilitate discussion and coaching
  - Features force specific decisions:
    - Predict an equation before plotting data
    - Choosing a coordinate system; origin and rotation
    - Calibration
    - Manually plot and analyze data; Unlabeled axes
    - Cannot “go back” or “undo”

Why LabVIEW?

- Many departments already own and are familiar with LabVIEW.
- Graphical programming allows for easier adaptability by instructors.
- Industry standard and continued support.

Requirements

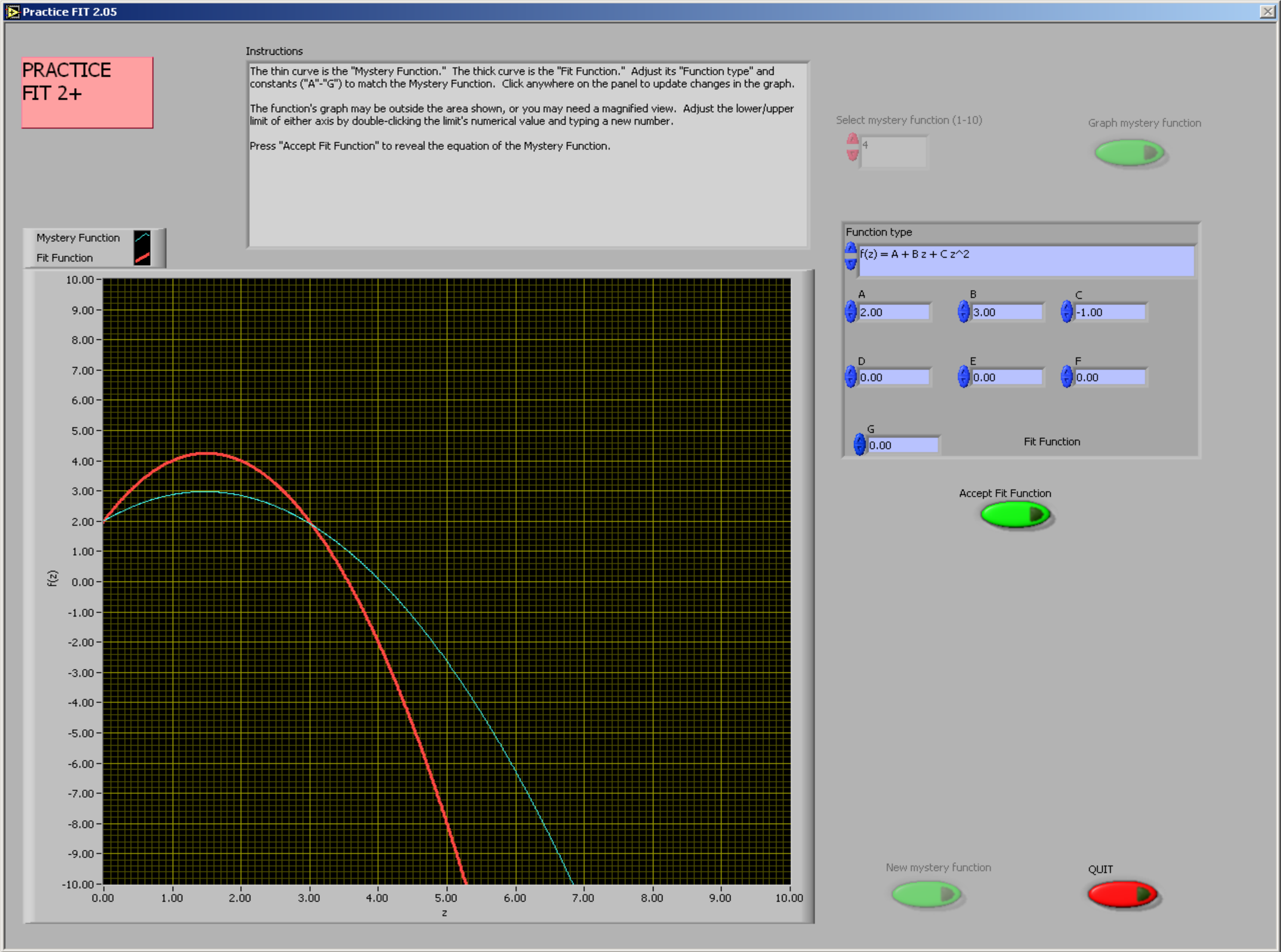
- LabVIEW base package version 7.2 or higher. (Most current version is 8.3)
- NI-IMAQ (Video Recorder and Video Tool)
- NI IEEE 1394 Firewire Driver (Video Recorder)
- Variety of platforms
  - Windows 2000/NT/XP
  - Mac
  - Linux
  - Solaris

Programs

- Practice FIT
- Video RECORDER
- Video TOOL
- Hall PROBE
- Faraday PROBE

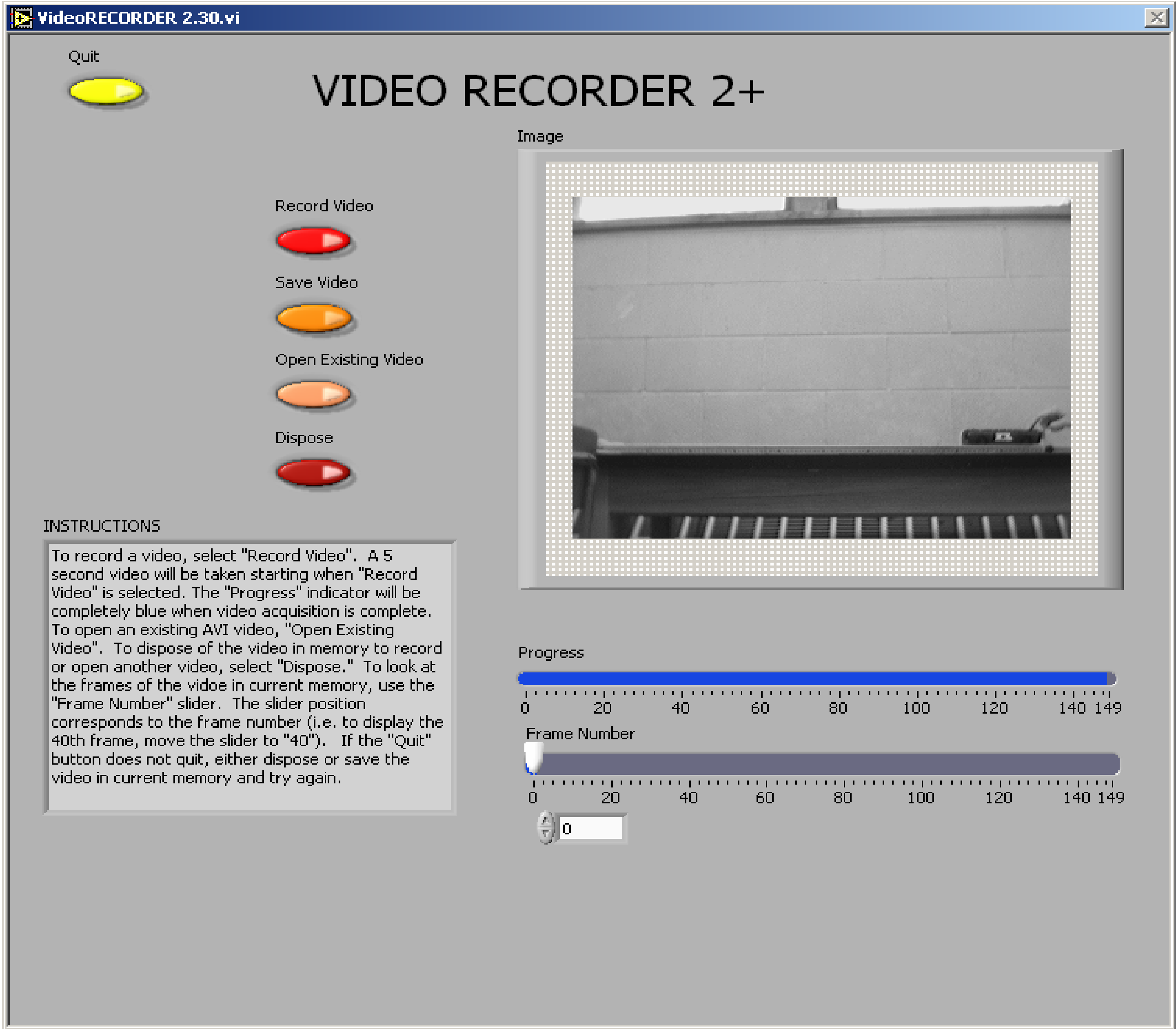
Practice FIT

- Allows students to practice their equation analysis techniques.
- First exercise done.


Practice FIT 2.05
PRACTICE FIT 2+
Instructions
The thin curve is the "Mystery Function." The thick curve is the "Fit Function." Adjust its "Function type" and constants ("A"-"G") to match the Mystery Function. Click anywhere on the panel to update changes in the graph.
The function's graph may be outside the area shown, or you may need a magnified view. Adjust the lower/upper limit of either axis by double-clicking the limit's numerical value and typing a new number.
Press "Accept Fit Function" to reveal the equation of the Mystery Function.
Select mystery function (1-10)
4
Graph mystery function
Mystery Function
Fit Function
Function type
f(z) = A + B z + C z^2
A 2.00
B 3.00
C -1.00
D 0.00
E 0.00
F 0.00
G 0.00
Fit Function
Accept Fit Function
New mystery function
QUIT
f(z)
z
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

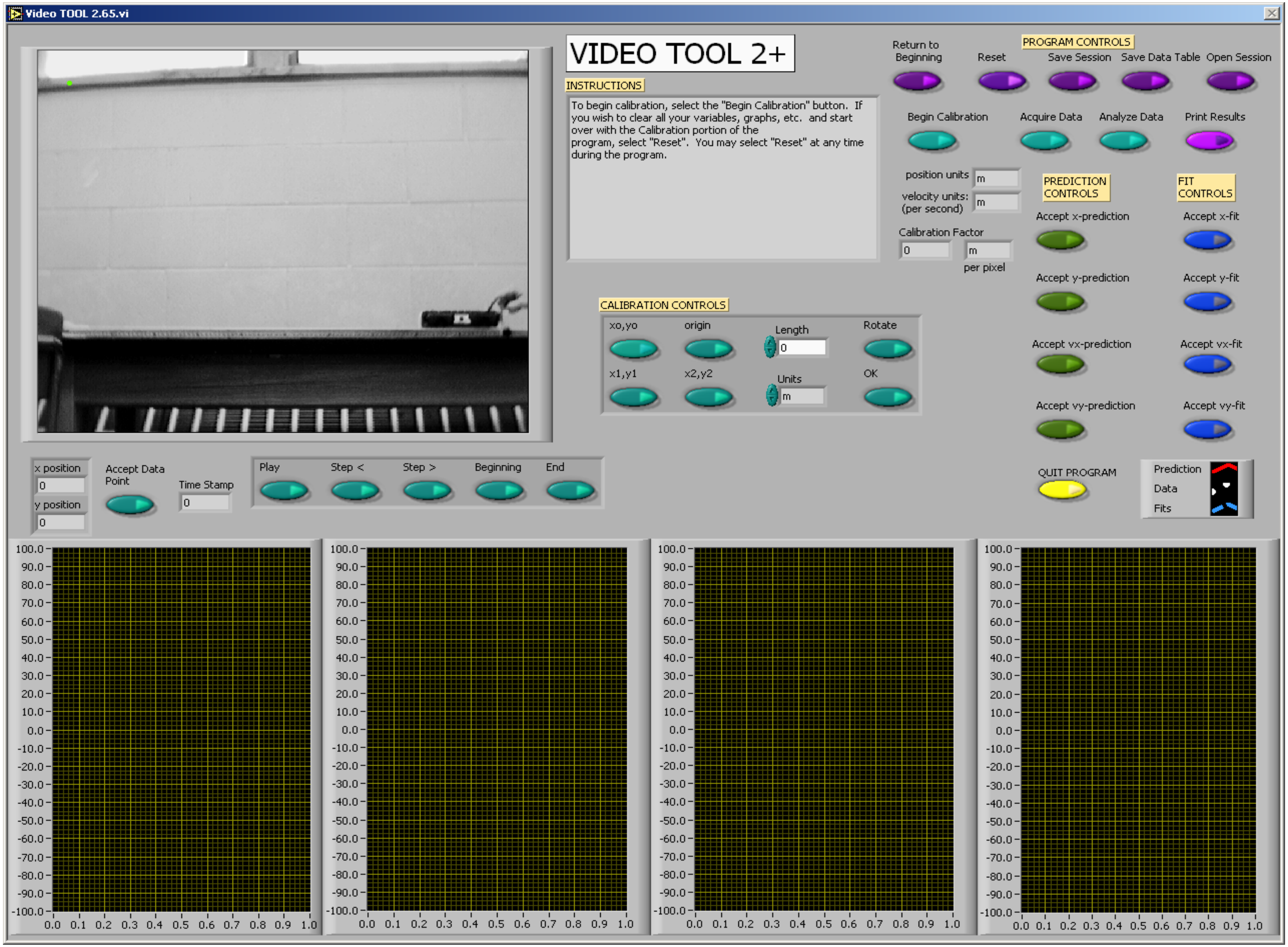
Video RECORDER

- Simple Format Video Display and Acquisition
- 30 frames/second, 5 seconds long
- AVI Format
- IEEE 1394
- Allows the user to step through frame by frame.


VideoRECORDER 2.30.vi
Quit
VIDEO RECORDER 2+
Image
Record Video
Save Video
Open Existing Video
Dispose
INSTRUCTIONS
To record a video, select "Record Video". A 5 second video will be taken starting when "Record Video" is selected. The "Progress" indicator will be completely blue when video acquisition is complete. To open an existing AVI video, "Open Existing Video". To dispose of the video in memory to record or open another video, select "Dispose." To look at the frames of the vidoe in current memory, use the "Frame Number" slider. The slider position corresponds to the frame number (i.e. to display the 40th frame, move the slider to "40"). If the "Quit" button does not quit, either dispose or save the video in current memory and try again.
Progress
0 20 40 60 80 100 120 140 149
Frame Number
0 20 40 60 80 100 120 140 149
0

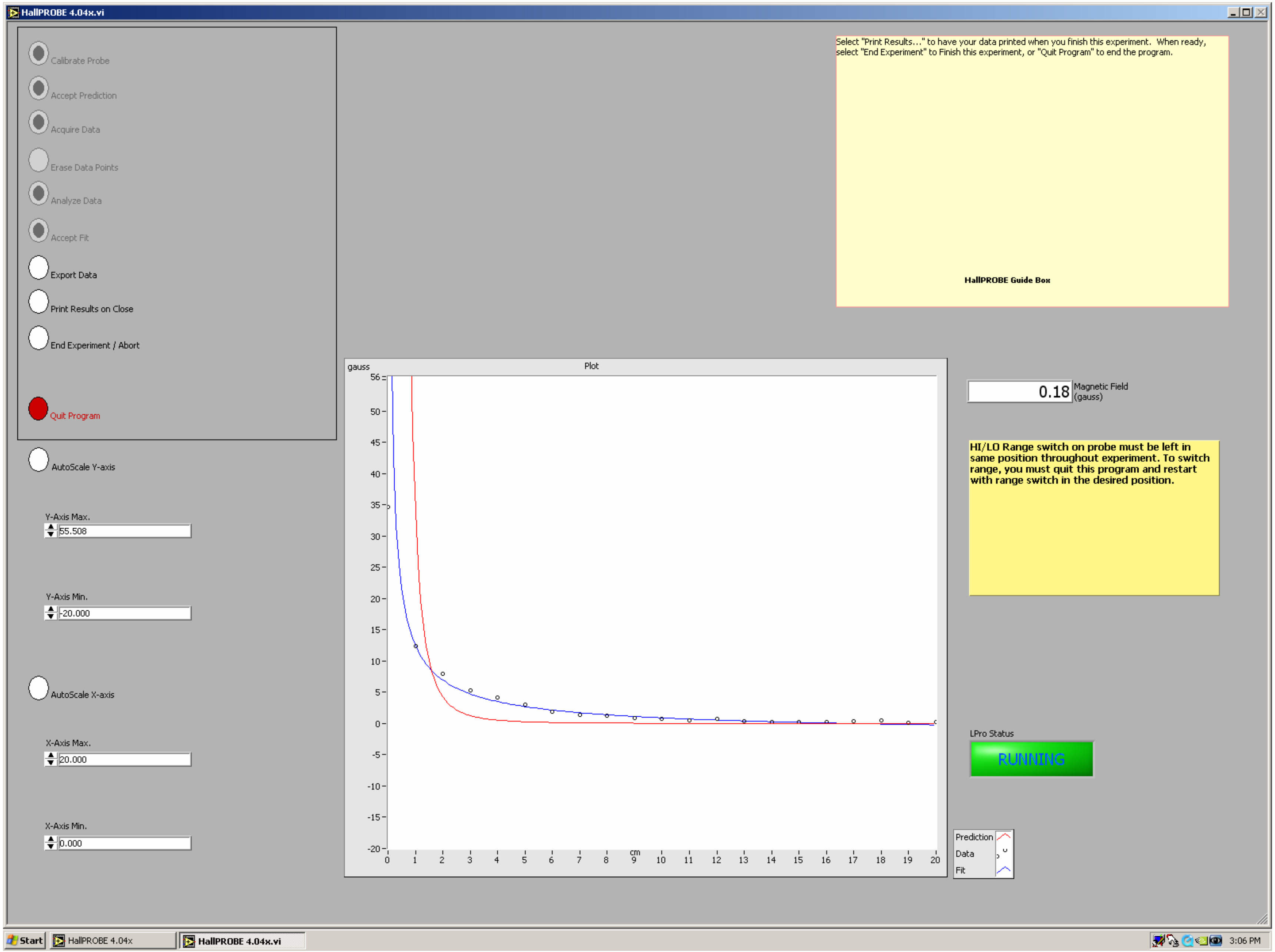
Video TOOL

- Load and view video
- Predict x and y position and x and y velocity
- Acquire data
- Analyze data


Video TOOL 2.65.vi
VIDEO TOOL 2+
INSTRUCTIONS
To begin calibration, select the "Begin Calibration" button. If you wish to clear all your variables, graphs, etc. and start over with the Calibration portion of the program, select "Reset". You may select "Reset" at any time during the program.
PROGRAM CONTROLS
Return to Beginning
Reset
Save Session
Save Data Table
Open Session
Begin Calibration
Acquire Data
Analyze Data
Print Results
position units
velocity units: (per second)
Calibration Factor
per pixel
PREDICTION CONTROLS
FIT CONTROLS
Accept x-prediction
Accept y-prediction
Accept vx-prediction
Accept vy-prediction
Accept x-fit
Accept y-fit
Accept vx-fit
Accept vy-fit
CALIBRATION CONTROLS
xo,yo
origin
Length
Rotate
x1,y1
x2,y2
Units
OK
x position
y position
Accept Data Point
Time Stamp
Play
Step <
Step >
Beginning
End
QUIT PROGRAM
Prediction
Data
Fits
100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0 -10.0 -20.0 -30.0 -40.0 -50.0 -60.0 -70.0 -80.0 -90.0 -100.0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

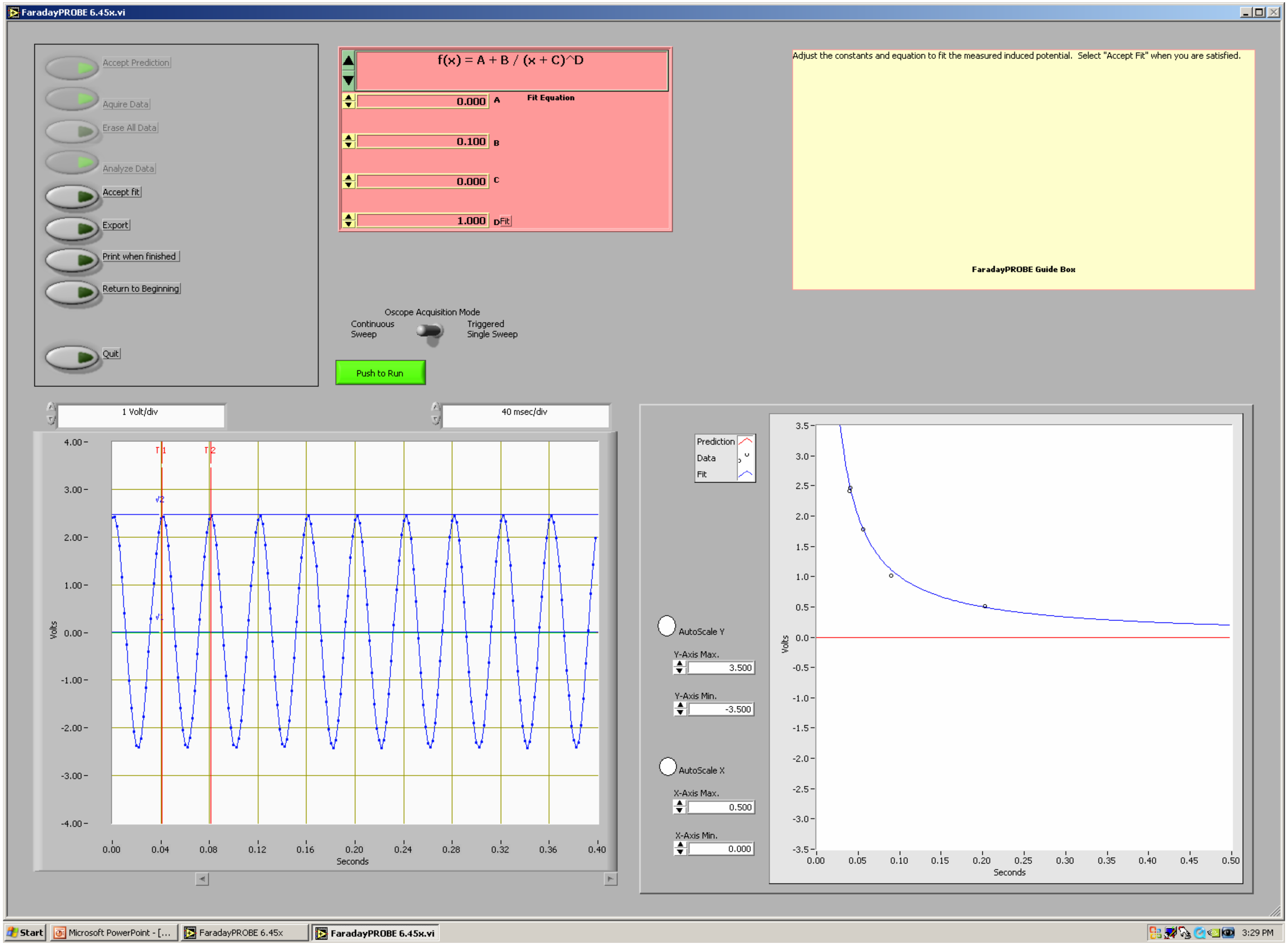
Hall PROBE

- Use with Vernier Magnetic Field Sensor
- Predict, measure, and analyze magnetic fields


HallPROBE 4.04x.vi
Calibrate Probe
Accept Prediction
Acquire Data
Erase Data Points
Analyze Data
Accept Fit
Export Data
Print Results on Close
End Experiment / Abort
Quit Program
AutoScale Y-axis
Y-Axis Max.
55.508
Y-Axis Min.
-20.000
AutoScale X-axis
X-Axis Max.
20.000
X-Axis Min.
0.000
Select "Print Results..." to have your data printed when you finish this experiment. When ready, select "End Experiment" to Finish this experiment, or "Quit Program" to end the program.
HallPROBE Guide Box
gauss
Plot
cm
0.18
Magnetic Field (gauss)
HI/LO Range switch on probe must be left in same position throughout experiment. To switch range, you must quit this program and restart with range switch in the desired position.
LPro Status
RUNNING
Prediction
Data
Fit
Start
HallPROBE 4.04x
HallPROBE 4.04x.vi
3:06 PM

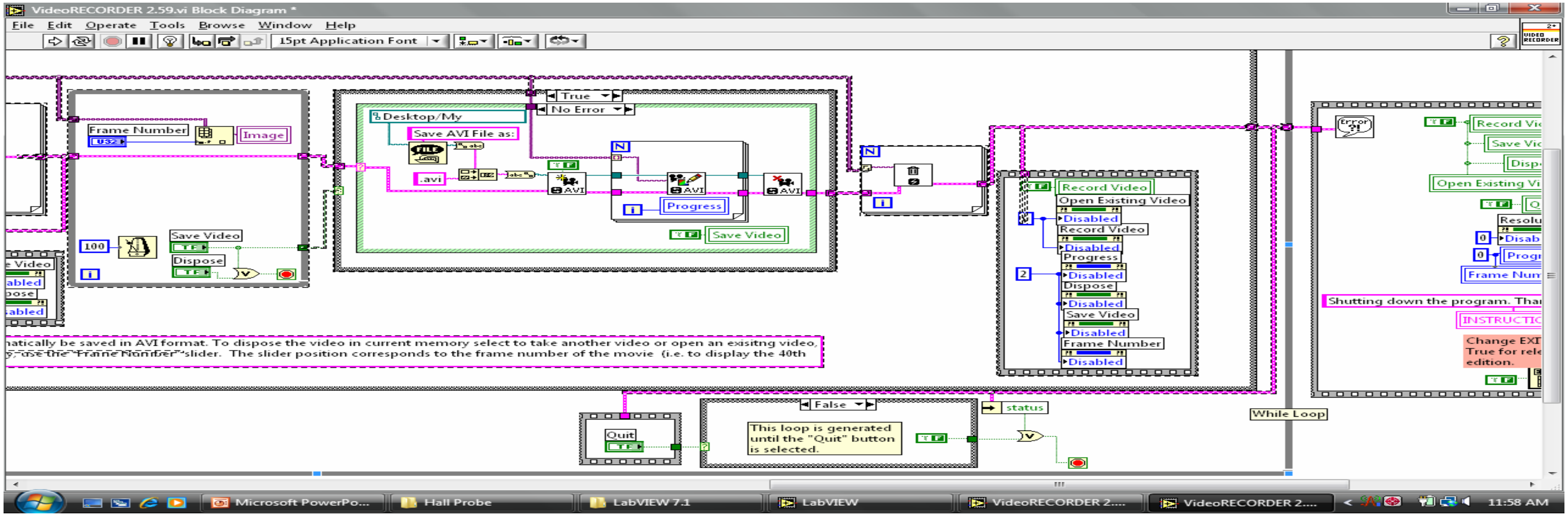
Faraday PROBE

- Mimics an oscilloscope
- Allows the measurement of the magnitude and period of an induced magnetic field.
- Use with the Vernier Magnetic Field Sensor and Differential Amplifier
- Prediction, data, and analysis.


FaradayPROBE 6.45x.vi
Accept Prediction
Aquire Data
Erase All Data
Analyze Data
Accept fit
Export
Print when finished
Return to Beginning
Quit
f(x) = A + B / (x + C)^D
Fit Equation
0.000 A
0.100 B
0.000 C
1.000 D
Fit
Adjust the constants and equation to fit the measured induced potential. Select "Accept Fit" when you are satisfied.
FaradayPROBE Guide Box
Oscope Acquisition Mode
Continuous Sweep
Triggered Single Sweep
Push to Run
1 Volt/div
40 msec/div
Volts
Seconds
Prediction
Data
Fit
AutoScale Y
Y-Axis Max. 3.500
Y-Axis Min. -3.500
AutoScale X
X-Axis Max. 0.500
X-Axis Min. 0.000
Start
Microsoft PowerPoint - [...
FaradayPROBE 6.45x
FaradayPROBE 6.45x.vi
3:29 PM

Adaptability

- Easily edited by the instructor after using the LabVIEW tutorial.
  - Approximately 1 hour for each change (based on no prior experience with LabVIEW).
- Any AVI file with 30 fps and no dropped frames.



Conclusions

- Developed software that runs on standard PCs and is based on a commercial product.
- Works for 1000’s of students and TAs every semester.
- Is easily modifiable to suit an instructor’s pedagogy.

To try this for yourself….

- http://groups.physics.umn.edu/physed
  - Computerized Problem Solving Labs
  - Download our laboratory software
- lab@physics.umn.edu