Flexible Software for Computer-Based Problem Solving Labs

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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

- TA
- 19in Computer Screen
- Lab Equipment
- Camera
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 FIELD OF PERMANENT MAGNETS

PROBLEM #3
MEASURING THE MAGNETIC FIELDS
OF PERMANENT MAGNETS

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

Plan

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?

Write down a measurement plan.
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.

Graph data

Based on your exploration, 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

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.
Instructions:
The thin curve is the "Mystery Function." The thick curve is the "Fit Function." Adjust the "Function type" and 
constants (A, B, C) 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, so 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.
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.
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 video 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.
Video TOOL

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

- Use with Vernier Magnetic Field Sensor
- Predict, measure, and analyze magnetic fields
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.
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](http://groups.physics.umn.edu/physed)
  - Computerized Problem Solving Labs
  - Download our laboratory software
- lab@physics.umn.edu