Restructuring the introductory physics lab with the addition of computer-based laboratories

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Abstract
Nowadays, data acquisition software and sensors are being widely used in introductory physics laboratories. This allows the student to spend more time exploring the data that is collected by the computer hence focusing more on the physical concept. Very often, a faculty is faced with the challenge of updating or introducing a microcomputer-based laboratory (MBL) at his or her institution. This article will provide a list of experiments and equipment needed to convert about half of the traditional labs on a 1-year introductory physics lab into MBLs.

Key words: Computer-based laboratories, introductory physics laboratories, physics lab renovation

INTRODUCTION
Often, a new physics faculty member is faced with the duty of renovating the introductory physics labs. This task is especially difficult when the faculty is on a solo position. We would like to share our experience in accomplishing this task. We will provide a list of experiments and equipment needed to convert about half of the traditional labs on a 1-year introductory physics lab into microcomputer-based laboratories (MBLs).

Our student body consists mostly of science majors that take the algebra-based course. But, the lab renovation described here could be used for the calculus-based group as well. We would suggest adjusting the lab manuals.

Nowadays, MBLs are usually the choice when thinking of a renovation. They have effectively demonstrated an advantage to the learning process over the years.[1-4]. Moreover, for our science students, the labs are important in reinforcing the concepts learned in class. MBLs can be set up to enhance this learning component.[5] It is very common to hear, during the lab sections, students commenting on their grasp of the concept learned in class due to the experiment being performed. MBLs seemed the appropriate choice.

We decided to adopt the PASCO system.[6] The next step was to look at their experiment library. A decision was made to update about half of all labs to MBLs. The other half was kept as traditional labs. The overall 1-year lab experience follows the guidelines provided by the American Association of Physics Teachers.[7]

LAB SETUP
Each MBL station consists of three students. It is suggested that the smaller the group size the better.[8] They are allowed to choose their own partners. The lab manual is provided 1 week before the experiment. It contains a brief theoretical description and the procedures to be followed on the day of the lab. On the lab day, the students should come prepared and ready to start without additional instructions. The instructor circles around the stations to guide and answer appropriate questions if needed.

On the lab day, the students are handed the lab report. It contains a data analysis part, some discovery questions, and ends with a summary and conclusion part. The report is completed by the student during the session. The group
works and completes most of the lab report together. The summary and conclusion part is written individually by each student. No conversation is allowed at this time. Therefore, the grade turns out more individualized for the lab.

EXPERIMENTS

About half of the experiments were computerized. We did not find an appropriate version for the other half to meet our overall goal. Therefore, we kept a few traditional labs.

The list of experiments is chosen based on the lecture material. One of the concerns was to always be able to cover the theory before the lab was performed by the student. This restricted the available choice of topics.

One-Year Introductory Microcomputer-Based Laboratory Experiment List

Understanding motion, free fall, projectile motion, Atwood’s machine, Boyle’s law, electrical equivalent of heat, heat transfer, electrostatic charge, Ohm’s law, RC circuit, and magnetic induction.

Lab manuals are provided by PASCO. We customized our own to accommodate our students and teaching style.

A suggestion for the beginner is to try all the experiments before hand until you get really familiar with the sensors and software and how they work. This advice should be followed by any instructor hired to teach a lab section. It can be frustrating if measurements cannot be taken. Most of the time, it is a lack of understanding of the use of the apparatus, assuming it is not defective of course.

EQUIPMENT

We will list here the total equipment needed per station to implement the 1-year lab described above. It is expected that the laboratory will have a printer that can be shared among all groups. The computerized experiments used PASCO hardware and software. The model numbers are provided in parentheses.

Each station consists of a laptop and the Science Workshop 750 Interface (CI-7650) with the Datastudio software (CI-6870G). Figure 1 illustrates a typical lab station.

Sensors to be used with the interface for data measurement: Motion Sensor (CI-6742A), Photogate and Pulley System (ME-6838), Accessory Photogate (ME-9204B), Time-of-flight Accessory (ME-6810), Pressure sensor (CI-6532A), Temperature Sensor (CI6605A), Power amplifier (CI-6552A), Charge sensor (CI-6555), Voltage sensor (CI-6503), Photogate Head (ME-9498A). Figure 2 displays a few sensors.

The Datastudio software collects and analyzes the data. It has an easy-to-use interface, allowing the students to explore the data. For instance, the left screenshot in Figure 3 displays a graph of voltage versus time. The data are collected using a voltage sensor when a magnet is dropped through a coil. The students can select a region on the graph and the software calculates the area under
the curve. The screenshot on the right in Figure 3 displays the curve-fitting feature of Datastudio.

The data can be displayed in a table as well. Figure 4 shows a table from the Boyle’s law experiment. The pressure column will be filled as the measurements are taken using the pressure sensor.

The additional equipment needed from PASCO to perform the experiments are: Picket fence (ME-9377A), projectile mini launcher (ME-6825A), photogate mounting bracket (ME-6821A), extension cable (PI-8117), thermodynamics kit (CI-6514A), charge producers (CI-6555), Faraday ice pail (ES-9057B), AC/DC electronics lab (EM-8656), and bar magnet (EM-8620).

General lab supplies needed include a pair of scissors and goggles, one digital balance – Ohaus (SP-601), one meterstick, one thermometer, tongs (handling hot bottles), gloves (handle hot containers), braided physics string (SE-8050), 500 mL glass container (90°C water), banana plug cord red and black (5 on set) (SE-9750) or (SE-975), Masses and Hanger set (ME-8979), Universal table clamp (ME-9376B), calorimetry cups (TD-8825A), and hot plates (SE-8830).

The total cost per station is approximately 3000 dollars.

**CONCLUSION**

Renovating an introductory physics lab requires a lot of investigation and consultation. Oftentimes, this task is hard to accomplish for a solo faculty in a small institution. We provided here a list of the experiments and equipment needed to upgrade about half the experiments to MBLs on a 1-year introductory physics lab.

We would like to add that although we used PASCO, there are other comparable systems in the market. The intention of this paper is to help others with their own lab renovation. In order to better fulfill this purpose, the part numbers were provided.

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