CaFD

Curriculum **a**nd **F**aculty **D**evelopment Newsletter for Two-Year College Physics Teachers

Real-World, Constructivist Carts for Microcomputer Based Laboratories

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As I embarked on the MBL approach to physics education I chose to use the latest in cost effective computers (LCs), the clearest in courseware (Tools for Scientific Thinking), and the commonest of other materials that were possible.

The audience was a college physics class that is dominated by associate degree technology students. I wanted them to be very comfortable with the other technologies in the course. I considered it essential that they

MBL: Ideas That Work

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Through the columns of this paper, I wish to share some of my experiences of the TST MBL curriculum we introduced last year at T-VI Community College in Albuquerque, New Mexico. We have two campuses nearly ten miles apart and we have been sharing computers (Mac IIsi) and software between them. The labs are scheduled at one campus for the earlier part of the week and at the other for the later part of the week for the convenience of transporting equipment we share. Both my colleague Boye Odom and I had the opportunity to attend the MBL workshops and had the chance to share our thoughts with physics teachers from other two-year colleges. This interaction has been extremely worthwhile.

Meaningful-Meaningless Calculations

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In the last newsletter I talked about the consequences of student's common use of means-ends analysis as their primary problem-solving strategy. I also talked about several ideas for modifying problems to get around students' tendencies to learn algorithms that they apply mechanically, i.e., the "plug and chug" syndrome. This time I would like to present some examples of another task aimed at getting students to process information about physical quantities in a different way. As the title of the column indicates these are called Meaningful-Meaningless Calculations tasks.

A Perspective On Science Teaching—

from Lillian McDermott's talk at the CE/OCS Workshop at Green River CC (Oct 93)

"Science is a way to teach how something gets to be known, what is not known, to what extent things are known (for nothing is known absolutely), how to handle doubt and uncertainty, what the rules of evidence are, how to think about things so that judgments can be made, how to distinguish truth from fraud, and from show." Richard Feynman as quoted in *Genius* by James Gleick

Inside—

As we all know when students have to solve a numerical problem they will usually take whatever numerical values they can find that seem reasonable to them to use in an equation. And what seems reasonable to them is frequently different from what is reasonable from the point of view of the physics. Students often have significant difficulty making some of the important distinctions that we as physicist consider critical. From their knowledge base these distinctions are non-existent, or in some cases "picky", but if they do not make these distinctions they do not have the appropriate conceptual understanding. Kinematics is an area where there are several good examples of this difficulty.

As Arons (1990) has pointed out the distinctions between position and distance traveled and between an instant, a clock reading, and a time interval are problematic for most students. One of the problems this lack of distinction creates for students is that they will use position values and clock readings when they are supposed to calculate average speed. Assigning standard numerical problems does little to remediate this difficulty since those problems normally only have the appropriate values for the required calculation as the given information, so when the students use means-ends analysis to solve the task they simply plug the given values into the equation for average speed. How do we get students to pay attention to the distinction?

One way to deal with the difficulty is to design tasks where using means-ends analysis will force the students to focus on the distinction. This is what the Meaningful-Meaningless Calculations tasks attempt to do. In these tasks the students are required to determine whether a specified calculation is meaningful or meaningless. This is entirely different from plugging numerical values into an equation and turning the crank. Let's look at an example and then examine what students are required to do to solve the task. Consider the following problem:

> *Given below is a position map for an object which is moving in a straight line. The positions of this object are shown for a number of items. Given below the position map are several calculations, which of these calculations are meaningful and which are meaningless? (Meaningful calculations are ones which give values that actually tell us something about the situation).*

$$\frac{35\ m}{2\ s} \qquad \frac{45\ m}{3\ s} \qquad \frac{80\ m}{3\ s} \qquad \frac{25\ m}{1\ s}$$
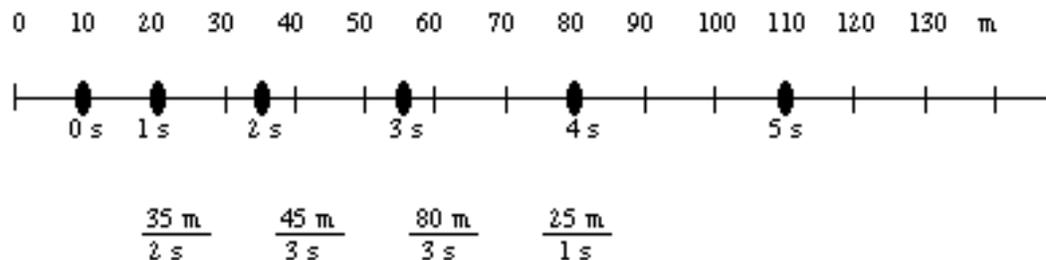
All of the calculations in this example have exactly the same form, they differ only in the values that are used in the calculations, which means that the usual plug and chug reasoning students employ is no help here. Rather in this task the students have to decide whether the values actually used in the calculations are appropriate to use. This in turn requires that the students un-

'the students are required to determine whether a specified calculation is meaningful or meaningless'

derstand that dividing a position by a time interval is meaningless and that dividing either position, or a distance moved, by an instant (clock reading) is meaningless. With this understanding in place the student must analyze the calculations above to determine if either positions or clock readings are used in any calculation.

Now that we have seen the basic idea for these tasks let's consider another example in a different topic. Students have difficulty with the idea that heat and work are process dependent quantities, while internal energy is a state variable. So we could set up a problem where a certain number of moles of a monatomic ideal gas at a particular temperature, pressure and volume undergoes an isobaric expansion to a new volume. Then we present the students with a calculation of $5/2nRT_f$ as the heat in the final state and a calculation of $3/2nR\ T$ as the change in internal energy and ask if either is meaningful.

2

In these first two examples what is meaningful and meaningless is straight-forward, but this is not always true. What is meaningful is context dependent in some situations. For example, suppose students are given the diagram and question below:

Will the following calculation give the electric field at point (3m, 4m) for this situation?

$$E = kq_1/r_1 + kq_2/r_{12} + kq_3/r_{13}$$

If the students are to determine the electric field at the location of charge one due to charge two, kq_2/r_{12} is meaningful, but if they are asked to calculate the electric field at the point (3m, 4m) then such a calculation is meaningless because the distance used is inappropriate. What I am calling meaningful-meaningless could also be called appropriate-inappropriate depending on the situation. If the student simply plugs and chugs then they may well not realize the error of using the distance r_{12}.

On these tasks students should be required to explain their reasoning for their decisions about each calculation, whether they decide it is meaningful or meaningless. Requiring reasoning is useful because students often have incorrect reasons for making the choice, correct or incorrect, they do, and getting those reasons identified often provides important ideas for how to help the students change their concepts.

The question of whether a calculation is meaningful or meaningless is different from the question of whether a specific numerical answer is reasonable. The decision of whether an answer is reasonable centers around the numerical value itself and/or around the units of the val-

'whether an answer is reasonable centers around the numerical value itself and/or around the units of the value. Neither of these considerations is tied to the students understanding of the concepts being applied'

ue. Neither of these considerations is tied to the students understanding of the concepts being applied. Determining whether something is meaningful is integrally tied to understanding the concepts.

Calculations involving physical quantities have to have physical meaning, i.e. they have to identify some quantity that actually applies to the situation, but students often are only interested in getting an answer since that is the goal of the usual numerical problems. These tasks have a

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different goal than the usual numerical problems so the means used to solve them are also different. In order to determine whether a calculation is meaningful the students needs to know whether the values used in the calculation are the appropriate ones for that calculation. Under the right conditions that entails a clear and concise understanding of the concepts and the ability to recognize when they are being properly applied. Meaningful-Meaningless Calculations tasks can test for such understanding.

Meaningful-Meaningless Calculation tasks are one more tool for us to have available when we want to get students to process information about a concept of principle in a different way. I would welcome any examples you think up, and/or any objections or difficulties you might have with this type of task.
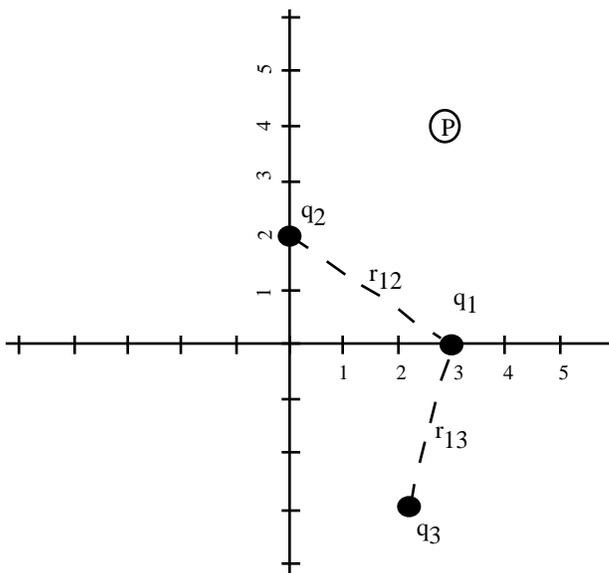
consider their time in physics to be an extension of their experiences when they entered the classroom and that what they did in the physics class would apply to their world. It should not be something that they would only see applied in the physics laboratory.

Another reason for keeping the other equipment simple was dictated by economics and classroom politics. The investment in computers, ULIs, and tranducers is substantial. I decided that it would be better politics to "go cheap and local" with the other materials. Hence, the boards were common pine and the carts were constructed from materials that are available from hardware stores and lumber yards.

The common pine boards provided a challenge for the students, which they enjoyed. Sanding, gluing loose knots, and filling the boards provided an opportunity for the students to gain "ownership" of part of their learning experience, and some points toward a grade. The students learned about the need for careful sanding and leveling of the wood, and found that bumps did

•Foam bumper
•2x4 pine block w/slots cut for the axles
•In-line skate wheels
•Threaded rod
•Airplane nuts
Screw eye
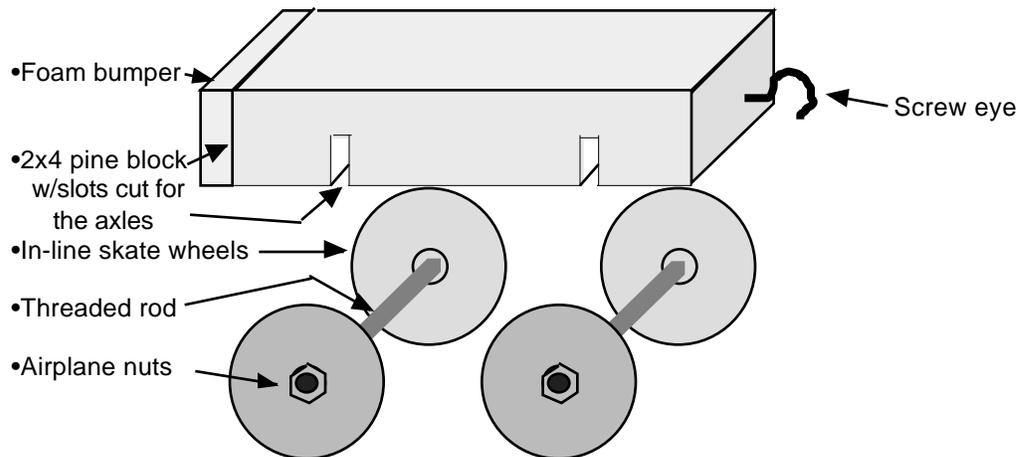
show up on the graphs in MacMotion. Too, they found out about warpage of common pine boards. (A retrospective alternative, locust wood, was subsequently proposed by members of the maintenance staff at Firelands College.)

The body of the cart was a block of 2x4. The most cost-effective wheels that I found were replacement wheels for in-line roller skates. I picked up four replacement wheels for in-line skates at Toys-R-Us a year ago for $ 9.98. The axles were threaded rods. The wheels were secured onto the threaded rods with "airplane nuts." The axles were glued into slots cut into the 2x4 pine blocks. A foam pad on one end provided a cushioned collision. A screw eye on the other end provided a place to pull on the cart. A drawing of the arrangement is shown above. We used a piece of foam covered with canvas that was taped onto the bottom for a friction brake. The amount of friction was adjusted by the tension of the tape.

With a first model, there is always the fun of "field modifications" as the students find problems with the apparatus. Often when the carts fell off of the pine boards, the axles would be bent. After a bit of practice, some of the students became very skilled at "wheel alignment with impulsive applications of a hammer. Also, the bearings of the in-line skate wheels must be oiled frequently to keep the bearing friction low.

Suggestions for improvements in the next model are (1) some way to add mass at the center of mass of the cart and (2) a way to insert the force gauge along the center of mass. Of course I could do it. But, it will be more beneficial if the students are given the opportunity to provide the design and construction. Perhaps it will be a competition with extra points for the work. Or perhaps we will hire a student assistant.

CONFESSIONS OF AN IBM (MAC)MOTION USER

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At Chaffey Community College in Southern California, the physics department has 6 model 55 IBM machines that have been in use with the Universal Laboratory Interface (ULI) and (Mac)Motion software for just over a year. Both the ULI and the Motion software are available from Vernier Software in Portland, Oregon. If you have IBM-compatible machines, its very easy to use Vernier's ULI with the (Mac)Motion software for IBM-compatible machines. The only special requirement is that the ULI must connect to the COM1 port on your computer. This means that you must use a mouse that does not require the COM1 port. The IBM brand machines with microchannel architecture (model 50 and higher, I think) eliminate this problem because they use a bus mouse. In addition to the ULI, I have a motion detector, force probe, and temperature probe with each machine.

The only problems I have encountered have been minor gliches in the IBM beta version Motion software. The IBM version of MacMotion has now been released for distribution and can be purchased from Vernier Software. I should probably add that Vernier's hardware is of excellent quality, their prices are very reasonable, and their technical support is unsurpassed.

I do all of the Tools for Scientific Thinking (TST) mechanics experiments. There are now IBM versions of the TST lab manuals (also available from Vernier Software). When I first did the TST experiments there was not a lab manual available with instructions specific for the MacMotion IBM interface. So I rewrote the experiments for the IBM interface. When rewriting, I also reworded several questions in each activity that I found to be so vague that I didn't know what the question was asking and I expected that my students wouldn't understand either. I also inserted at strategic steps in the experiments the following sentence: "When you think you have a good run, call the instructor to look at your run on the computer screen and initial here ___ before you go on to the next step". This allows me to check crucial steps to verify that the students will see what they are supposed to be able to see on that step.

At the MBL follow up workshop in Joliet (September 24-26) I was a member of a group that discussed use of the ULI with IBM-compatible machines. The following are comments by IBM/ULI users about some problems encountered.
1. You may encounter inadequate memory sometimes when running under windows. Possible solutions:
     a. Get DOS 6.0 and use a boot configuration that loads only the programs that you use.
     b. Use DOS 6.0 memory manager.
     c. Load various programs using batch files instead of in the autoexec.bat.
2. Tom Embry has had printer problems under windows using a Panasonic 1124i printer (Motion won't print properly under windows but it will under DOS.)

The best contributor of information to our group was Dave Vernier (of Vernier Software) who mentioned the following:
1. He emphasized that whenever you encounter problems that you have determined are (Mac)Motion software related, to let Dave Vernier know the specific details of the problems. Give him the exact version number of the software, the type of hardware being used, and as much detail about the nature of the problem as possible.
2. The IBM version of Data Logger with the two-force probe capability is version dated 8/4/93 or later. Motion, Temp, and Sound programs latest versions are also 8/4/93 or later.
3. Rotational Dynamics, Electricity, and Event counter IBM versions don't exist now, but will sometime in the future.
4. Photogate and Smart Pulley Timer use with ULI under IBM probably won't be put out by Vernier Software. It is possible to use Microsoft Works to collect data (it has telecommunications built into it) from the ULI and then use Works to put the data into the Works spreadsheet. The ULI programmers manual must be used to get the necessary commands to talk to the ULI. Or, Dave Vernier is willing to write a simple IBM program to collect a stream of times that could then be put into a spreadsheet.

MBL Update

Curtis Hieggelke
Joliet Junior College
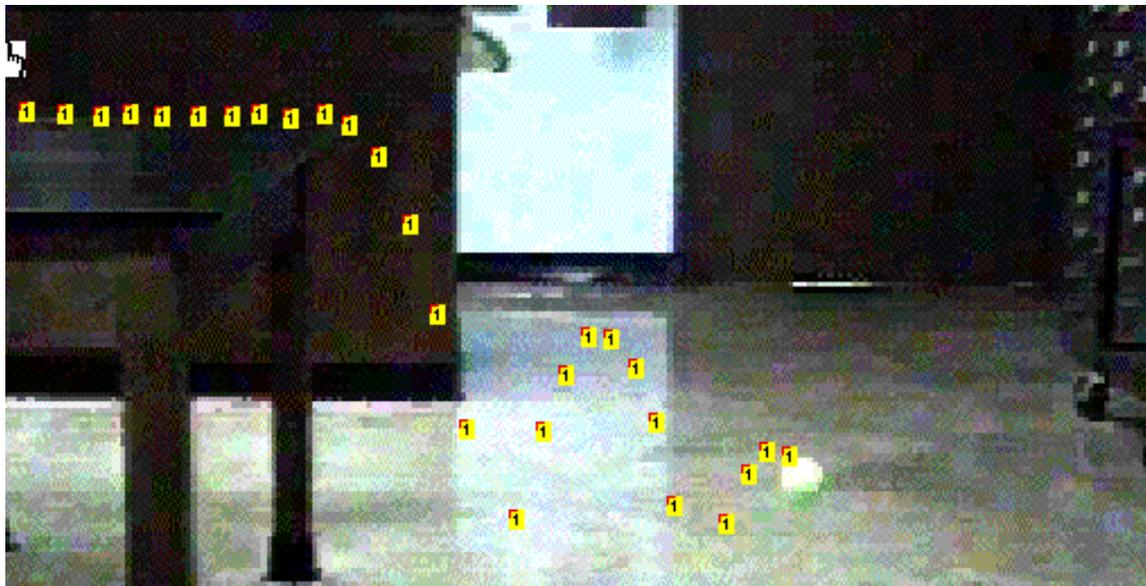**Joliet, IL 60436**

4.0 Software-Mac and IBM

One of the things we discovered at our follow-up workshop in Joliet was that a number of people did not realize that the 4.0 versions of the Mac and IBM software were available from Vernier Software. They were not aware that Vernier announces new versions in their newsletter since they charge so little for a site license. Thus Vernier has been shipping MacMotion 4.0, Data Logger 4.0, MacSound 4.0, and MacTemp 4.0 since last Spring. The new features are great and Vernier Software prices are excellent!

Vernier has a new ULI Timer program which replaces the old Event Timer program from Dickinson. It works nicely with PASCO's Smart Pulley and various photo-gate experiments. Work is underway by the Tufts-Dickinson group on a new Event Counter. We are using a beta version of it and it has some nice new features such as a live histogram as counts are recorded by the Geiger Counter.

Digital Movies

2D Video QT is a new piece of Mac HyperCard software currently being developed at Dickinson College under the direction of Priscilla Laws. Allowing the frame-by-frame analysis of Quick-Time movies, up to 12 data points can be logged with respect to either a fixed origin or moving origin. This data can then be saved and/or transferred to a spreadsheet program such as Excel. Some other features include calibration either in a vertical or horizontal direction, automatic center of mass calculations, and overlay display of previously logged data points and center of mass.

The picture below shows the overlay of points using 2D Video QT on a QuickTime movie made at Joliet Junior College of a tennis ball rolling off the edge of a lab table. The data can be ex-


ported to Excel and carefully analyzed. Ask your students to predict the v_x and v_y graphs for this problem and then let them determine the answer from real images of the motion. You can also run a simulation of this using the simulation software Interactive Physics. The Dickinson group is working on providing many top quality physics QuickTime Movies in areas such as free fall, one dimensional cart collisions, two dimensional collisions of pucks, rotational motion, etc. This type of analysis can be done on any Macintosh running system 7 with the QuickTime extension without the addition of special hardware. QuickTime has been demonstrated at most of the MBL workshops and at the MBL follow-up workshop participants had a chance to extensively use the latest version which has links to a series of Excel macros that the Dickinson group has developed. It is expected to be commercially available sometime in 1994.

If you want to make your own QuickTime movie you will need a digital card. You will have a choice of about 4 products. The highest cost is to buy a new Mac, one of the AV types which has built in hardware that will accomplish this task. The other way is to install a digital video capture card in one of the available slots. This is considerably cheaper costing from about $800 for a RasterOps Card to around $300 for SuperMac Video Spigot, or a Sigma Designs Movie Movie card. The participants used the SuperMac Video Spigot at the MBL follow-up workshop. We did not experience any problems and it was simple enough to use. After about 15 minutes of instruction and demonstration, everyone was making QuickTime movies. Note: the speed of the computer limits how many frames per second you can capture (it is about 15 on a Mac IIsi).

Current and Voltage Probes

At the MBL follow-up workshop, we also used prototypes of "smart" current and voltage probes in a series of new labs that will appear in the electricity version of RealTime Physics. They are "smart" since the software changes the graph label depending on whether a current or a voltage probe is plugged in. Everyone seemed impressed with their use. At this time, they are limited to around $\pm$ 6 volts and currents in the 500 mA range. However, to get them to operate over a larger range would result in a considerable delay in making them available. Rather than waiting, the group at the workshop voted overwhelmingly for the production of the limited prototypes. Dave Vernier, who was present at the workshop then promised that they would be available to workshop participants in January '94 for about $ 75. Because I have been using them in my lab since the workshop and have found them to be excellent for my purposes, I have ordered around 10 sets which I am eagerly awaiting. Whoops, almost forgot to mention that in order to use the
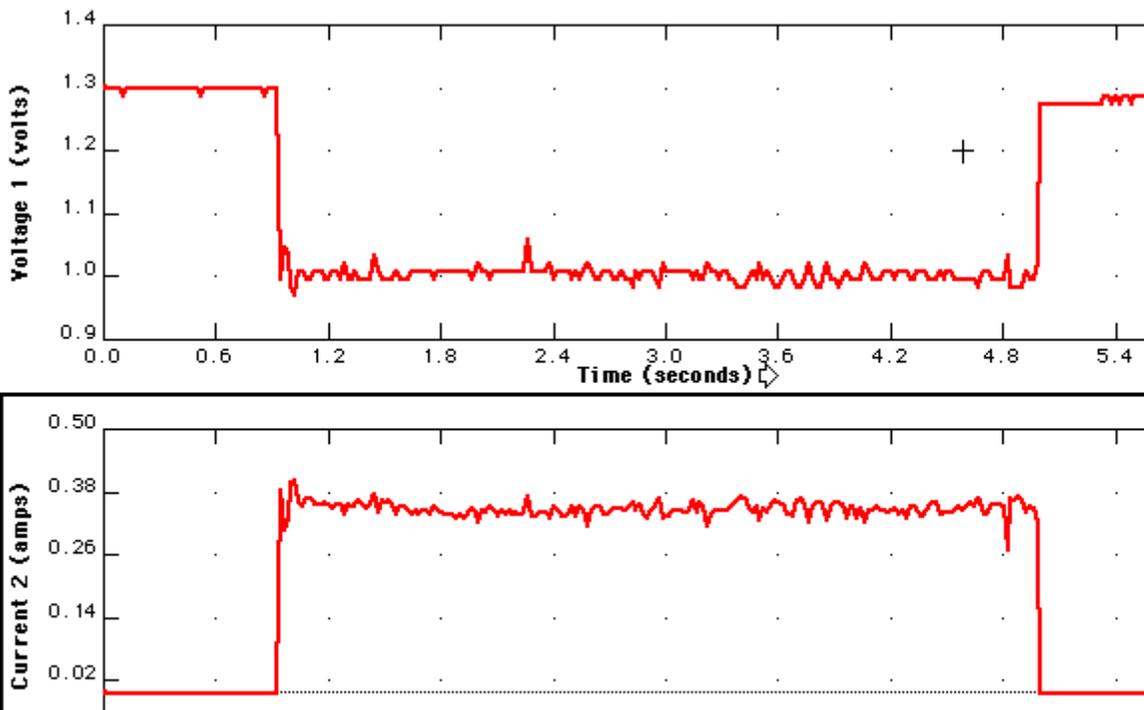
probes you will need some new software called Electricity 4.0. The figure above shows the voltage across a battery when a current is drawn and it really shows the effect of internal resistance. We were measuring the efficiency of a small electric motor lifting a small weight.

"Fast" ULI

There are a couple of major limitations of the ULI—only two data inputs and the relatively slow speed the data can be collected and stored into memory. PASCO is working on a new piece of hardware which will be the equivalent or better than the 6500 system they have for the DOS platform. It will offer much higher data collection rates as well as more inputs and output control like the 6500. I like to call it the "fast" ULI because it will be fast enough to let the Mac operate in a digital oscilloscope mode. It's software appears to be crafted well with considerable thought about the student/faculty user interface. I have been promised a beta unit when they are ready and they will be showing it at the national AAPT meetings. PASCO is planning to have these

Mac 65s ready to ship next summer. They will be priced at the levels of the current 6500 system and generally will be able to use any sensors that work on the 6500 or the MPLI system.

Rotational Motion Encoder

For rotational motion, I purchased 7 of the IBM PSL rotary encoders with the expectation that Vernier Software would build me the special connecting cable to hook them up to the ULI. I have one cable on loan from Vernier and the IBM encoder seems to work well. I have only had limited experience with it so far — mainly rotational kinematics and the Atwood machine. I have used University of Oregon/Tufts rotary encoders to demonstrate to my class the transmitted light intensity as a function of angle between two polarizers as shown and the single slit distribution of light intensity. The intensity of the center is saturated so that we could look at the sides. If you decrease the sensitivity, the center maximum looks like we see it in the text books. It took about 10 seconds to do each one — of course after 2 or 3 trials. In these cases, the encoder is used as an accurate position sensor. I think there is a great deal of potential in using this to develop a better understanding of the diffraction of light .
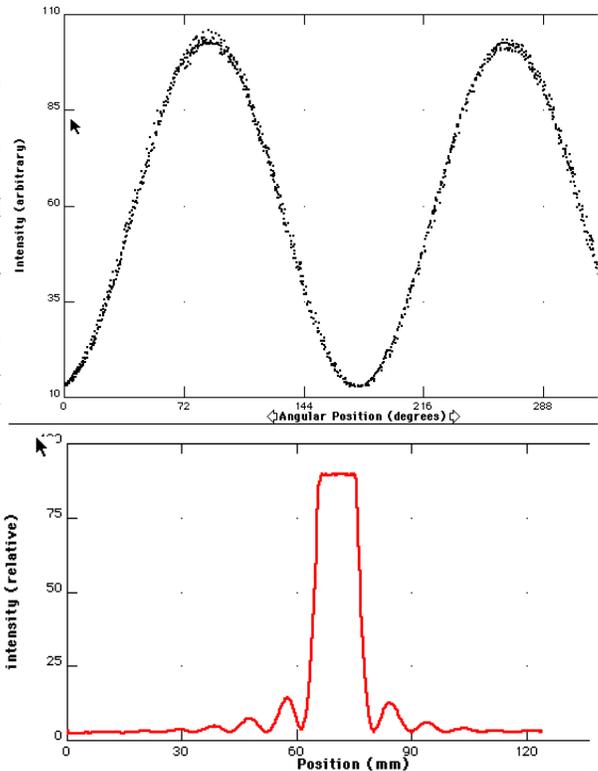
Computer Displays

One of the last purchases from my ILI grant was to get a quality computer overhead projection system. I decided to get an In Focus Panel Book 550 for about $ 5 k. It is a color, active-matrix system with over 1 Meg of colors. It offers not only outstanding computer projection but can also be used to produce a large screen projection image of a regular (NSTC) video signal since it is so fast. A final plus is that it is small (about the size of a powerbook) and lightweight.

RealTime Physics

RealTime Physics (RTP) is a new set of lab modules based on Tools for Scientific Thinking (TST) and Workshop Physics (WP). It is the result of a collaboration between the University of Oregon (David Sokoloff), Tufts University (Ronald Thornton), and Dickinson College (Priscilla Laws).

These modules are designed to give students a conceptual and quantitative understanding of physics. There will be a complete sequence of experiments which will allow changing the traditional 2-3 hour lab at colleges and universities into an active learning environment without changing the whole structure of the course. It features the use of the 4.0 versions of the software such as new columns and curve fitting. They will also have special homework questions.

The first set of modules called RealTime Physics - Mechanics (RTP-M) should be available in January from Vernier Software. A second set called RealTime Physics - Electricity (RTP-E) will be available later in 1994. RTP-M uses the fan carts designed by Robert Morse — see the October *Physics Teacher* for details on building them. RTP-E uses the new current/voltage probes and Lillian McDermott's approach of batteries and bulbs to attack misconceptions in basic circuits. Participants at the MBL follow-up workshop in Joliet had an opportunity to use these materials extensively. The final package will consist of a teacher's guide, a camera-ready and disk copy of the experiments, and a disk which contains special configuration files which accompany the labs. These configuration files when opened, will set up the graphs and software for each experiment which should make it easier for students to get started on a lab.

RTP-M employs the New Mechanics sequence strategy that features: one-dimensional kinematics and dynamics before studying two-dimensional motions; Newton's laws of motion in or-

der of difficulty (second, first, third); includes combining forces, friction, gravitational forces, and normal forces; and covers momentum conservation before energy conservation. It has been tested initially at the University of Oregon, Dickinson College, and Arizona State University and I am planning on using it for the spring semester at Joliet Junior College. Preliminary testing shows significant conceptual gains in mechanics and I am hoping for better results than I already have.

Newton's Third Law

I had a student challenge me in class one day to prove Newton's Third Law directly, since he could not believe it. Fortunately, I had a copy of the beta software that allowed the use of two force probes at the same time. I was able to take the class into the lab and clearly demonstrate Newton's Third Law. It is now available from Vernier Software as a special version of Data Logger 4.0. It is extremely convincing and works with both pushing and pulling on two force probes. An example of it is shown on the right.
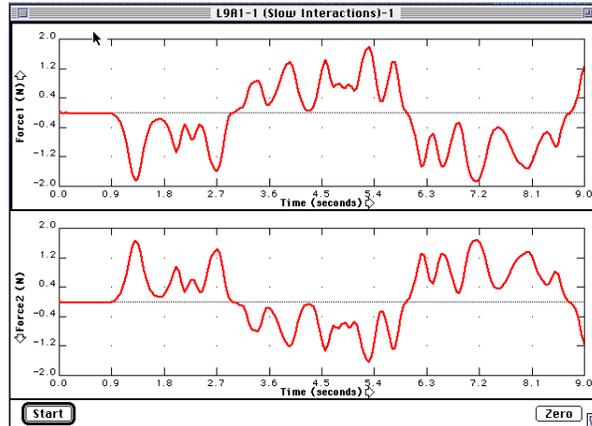
Only One ULI

If you only have access to one ULI set, there is a way to use it effectively in the classroom. You can use it as an Interactive Lecture Demonstration. Ron Thornton and David Sokoloff have provided us with a paper that describes the procedure and lists some good demonstrations with corresponding student worksheets. The basic idea is to first describe the demo and do it without MBL, next ask students to predict the MBL graphs and check these predictions with other students in class and modify them if necessary, these final predictions are then collected, next carry out the demonstration using MBL, and finally ask students to explain these results. Then go on to another one. If you want a copy, write us. Also note what Oshri Karmon is doing with only two ULIs.

Letter: ONGOING ILI

November 20, 1993

Hi Curt,

Thanks to your assistance the NSF already has another ILI application in the mail from me... (I will keep on pestering them until they break down...) In the meantime I managed to convince the Apple Computer Corporation to loan me one Mac and two data collection sets were loaned by the Vernier corporation. Since I have over 24 students in my class and only two computers, I divide the class into two sections: Section-A does a lab/workshop while Section-B is attending a lecture. (During the next class meeting I alternate the sections). Section-A students are grouped in fours and are assigned a collaborative problem solving and a computerized lab module. The computers are in the general study room across the hall from the classroom, and each group of students go there in turn. During that time I present a new topic to Section-B. I have to assign short "ALPS class exercises" (which the students work out in pairs) to allow me to I run across the hall to assist with computer problems...

The reaction of the students to the MBL, regardless of the operational difficulties, is very positive. Students even volunteered to do extra assignments on their own time. My most illuminating experience happened while discussing forces on a man walking at constant velocity (by Van Heuvelen's ALPS). One student decided to verify my explanations and discovered that a person cannot move at a constant velocity... (All those little accelerating and decelerating steps showed up clearly with the motion detector). Needless to say I was proven wrong, but after that incident my department agreed to invest in a motion detector...

Thanks for your ongoing help,
Oshri Karmon
Diablo Valley College
Pleasant Hill, CA

Some Uses of MacMotion 4.0/Motion Software in the Mechanics Laboratory

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Baytown, TX

Introduction

With the availability of MacMotion 4.0 (Motion for DOS users) software in the Spring of 1993 (Fall of 1993 for Motion)[1], a number of interesting and useful applications can be used in the first semester mechanics laboratory of introductory physics courses. Two applications studied using this software have been impulse-momentum and work-energy. Both of these broad topics can be investigated quite well with the MacMotion 4.0/Motion software with an ULI interface, motion detector and/or force probe, and assorted general laboratory equipment. This article concerns some studies of impulse and momentum using the new MacMotion 4.0 software. Results presented in this article are student results obtained by students in the conceptual-based, trigonometry-based, and calculus-based classes.

Macmotion/Motion Software

When MacMotion 4.0 software[2] was introduced in the Spring of 1993, it contained several new features that were extremely useful in the physics laboratory[3]. One very important feature introduced with the new software is the "new column..." feature[4]. This feature can be found within the "Data" menu or by displaying the "pop-up" menu on the y-axis of the graph. This feature will allow you to enter any function that depends on position, velocity, acceleration, or force. The "formula" line is used to type in the new function, e.g., momentum, kinetic energy, or potential energy. The "full name" line is used to type in the name of the new function and is what appears in the "pop-up" menus. The "short name" line is used in the pop-up menus if the "full name" is too long. Finally, the "units" can be used to display the units with the "full name". Once all information has been entered, click on either "Try it" or "OK". Your graph should now have the new "function" displayed. Once you have entered the new function, it can be used to create additional
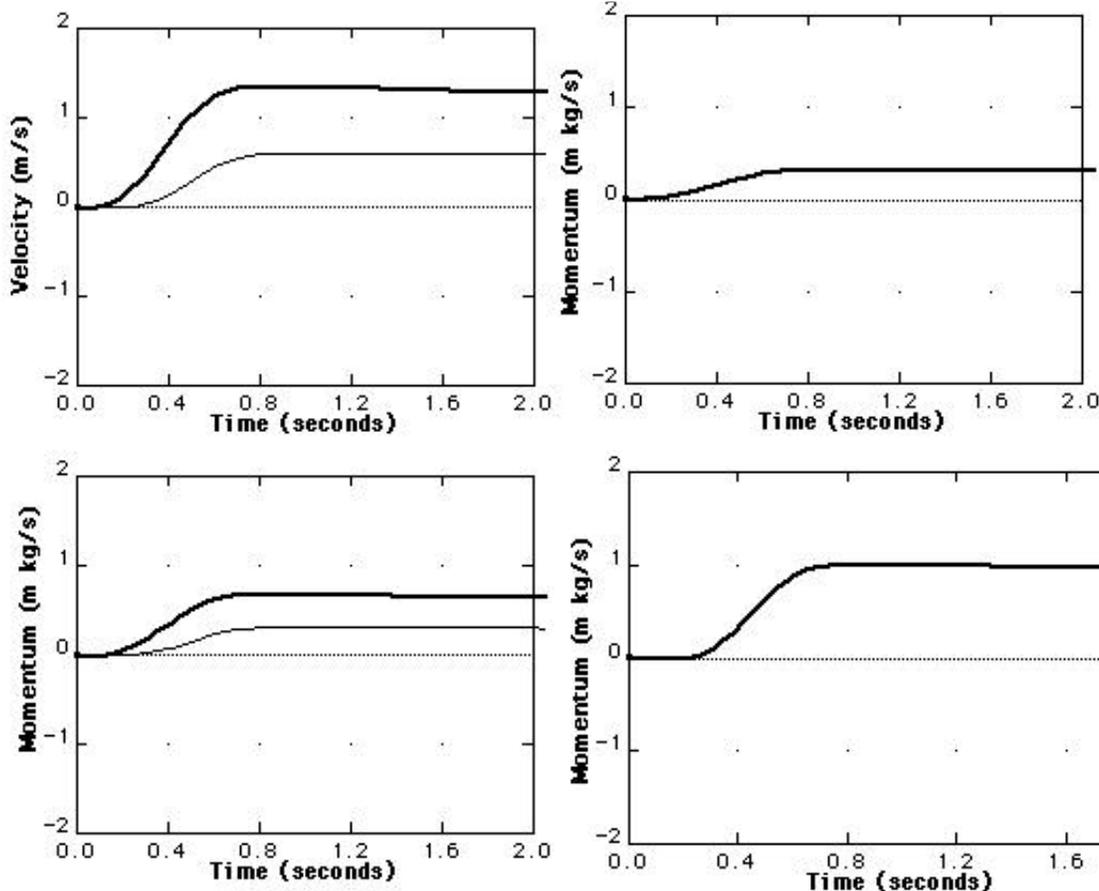

"functions", e.g., if you have separate momenta for cart 1 and cart 2, you can also have the sum of their momenta as a function.

A second useful feature found also in previous versions of the software is the ability to "integrate" functions (found under the "analyze" menu). For impulse studies, this will allow students to "integrate" the force function over time to find the impulse. Students could then compare their impulse result found by this method to the change in momentum found using the "new column..." feature.

Momentum Activities

One of the functions that can be programmed into "new column..." is momentum. The momentum is set up above for a dynamics cart to measure its momentum. One of the first set of activities that my students do is to "construct" the momentum concept. They do this, in part, by investigating the relationship between mass, velocity, and momentum. The next figure represents data taken by students using the velocity and momentum functions. The left two graphs represent two different data sets of a dynamics cart (mass .5057 kg) displaying both velocity and momentum. Students are able to deduce some relationship between velocity and momentum. Each graph has two sets of data, the lighter curves represent one set of data (at a smaller velocity/momentum) and the darker curves represent a second set of data (at a higher velocity/momentum). By holding the mass constant, students are able to "construct" part of the momen-

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tum concept. The right side represents two sets of data in which the top graph is the momentum of the dynamics cart at the smaller velocity. The bottom graph represents the momentum of three times the mass of the dynamics cart traveling at the same smaller velocity. These constant velocity data help students "construct" a more complete understanding of momentum.

Students next investigate the idea of a change in momentum. First, they perform a series of activities in which the momentum of an object goes to zero. The figure below depicts some results from a brief study of change in momentum. The object used is an air glider (mass of .1892 kg)
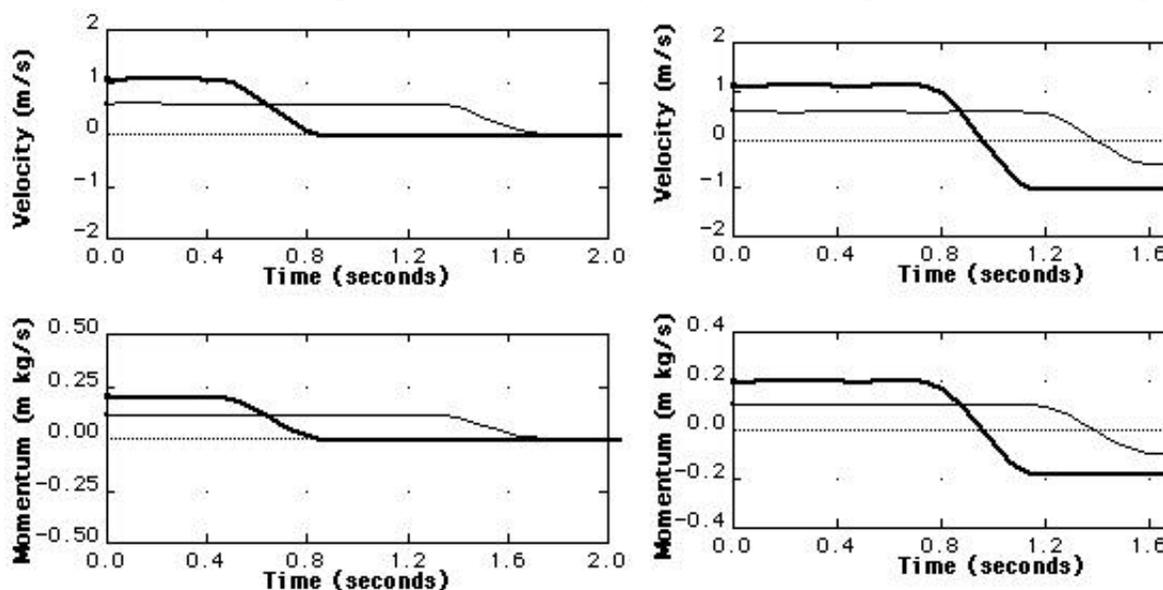
moving on an air track. The graphs on the left represent a change in momentum to zero. The light curves are for some initial velocity and momentum (**p** = - .108 mkg/s) and the dark curves are for approximately double the velocity and momentum (**p** = -.204 mkg/s). Then, students investigate the change in momentum for an object "reversing" its momentum. The graphs on the right

represent a change in momentum involving a "reversal" of direction. The lower curves have a **p** = -.204 mkg/s and the upper curves have a **p** = -.389 mkg/s. By comparing these results, students can "construct" the change in momentum to include change in direction. They may also begin to believe that a change in direction for the same initial momentum will be a larger change in momentum than going to zero momentum. (Note: air gliders were used in this last set of data because their is less loss of momentum during the "reversing of direction". One can do this change in momentum activity with "PSSC-type" carts as well as the dynamics cart. Air gliders have the least loss of momentum during the "rebounding" process, dynamics cart next best, and the PSSC carts the greatest loss of momentum.)

An additional activity that students sometimes perform is a simple toward and away from the motion detector measurement to develop a sense of direction for the momentum. These activities will hopefully allow students to obtain a better understanding of momentum through the use of a computer with the MacMotion 4.0 software. There are many other activities that could be used to obtain similar results.

Impulse Activities

A second set of activities can be constructed for impulse studies using the "integral" feature found under the "analyze" menu. If students take the force vs. time graph and integrate it, the integral will represent the impulse. For non-calculus based physics courses, students could take the
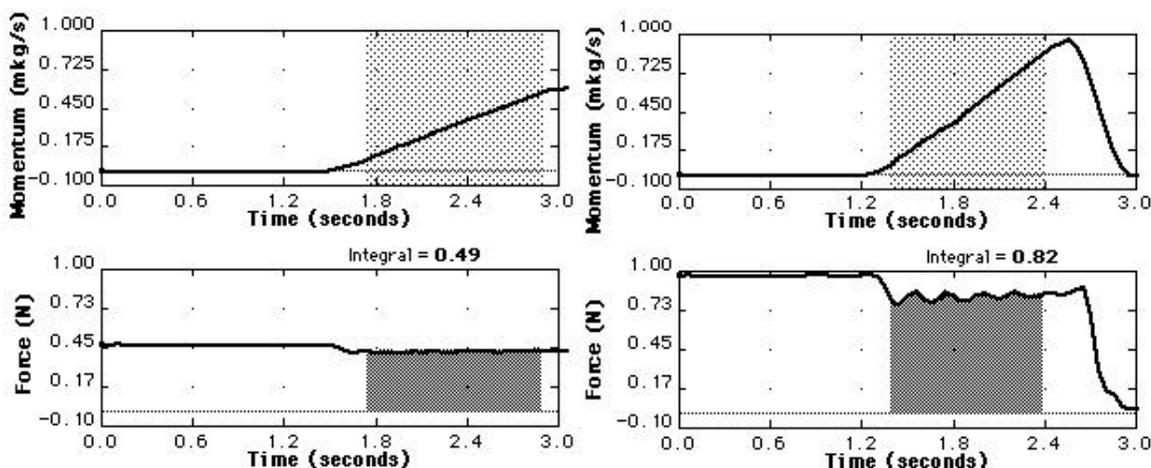
average force and multiply by the time interval to obtain the impulse. Students can then take this impulse value and compare it with the change in momentum of the cart. This figure represents some student data using the horizontal atwood machine of a dynamics cart (mass with force probe of .6219 kg) on a 2.2 m aluminum track using a very low inertia pulley. The graphs on the left represent data taken with a .0499 kg hanging mass. The impulse obtained by integral (see force graph) or by product of average force and time interval is .49 Ns. For the indicated interval (darkened region), the initial momentum was .093 mkg/s, final momentum was .565 mkg/s, giving a change in momentum of .472 mkg/s. The graphs on the right represent data taken with a .0999 kg hanging mass. The impulse obtained was .82 Ns, initial momentum was .082 mkg/s, final momentum was .876 mkg/s, giving a change in momentum of .794 mkg/s. (Notice that the force graph is oscillating a little as the system is moving. Students have found that this is due primarily to the hanging mass swinging and can be minimized with some effort on their part.) Both of these results are quite accurate and can be improved some with more diligence on the part of the student groups.

A second set of activities that my students do to help develop a better concept of impulse also involves the horizontal atwood machine. In this activity, the students push the cart toward the motion detector with the .04999 kg mass acting as an opposing force. This activity helps students understand direction change and the effect of impulse. The last figure represents a set of data taken by students that yielded an impulse of 1.00 Ns, initial momentum of -.484 mkg/s, final momentum of .497 mkg/s, and a change in momentum of .981 mkg/s.

Integral = **1.00**
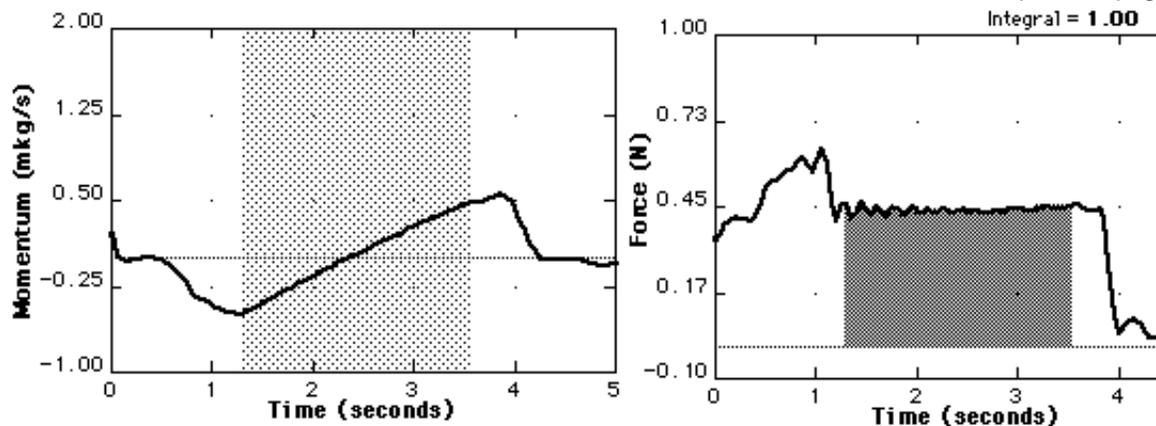
Additional activities can be done using the force probe, motion detector, and MacMotion 4.0 software to help investigate momentum and impulse ideas.

Conclusions

The use of the MacMotion 4.0 software has opened several new "topic areas" that can be investigated by students during the laboratory. One rich area of investigation concerns momentum and impulse. Students can "construct" the concept of momentum and impulse using this software in conjunction with appropriate sensors and apparatus. Students can also do accurate quantitative experiments in momentum and impulse. In an article to be published in a later newsletter, some results involving collisions studies will be presented.

References

[1] Available from Vernier Software Co.

[2] Developed at the Center of Science and Mathematics Teaching at Tufts University directed by Ron Thornton.

[3] See article by Curtis Hieggelke, "New Features in Mac MBL 4.0 Software", *CaFD* Newsletter, Spring 1993, pgs. 8-9.

[4] See manual "MacMotion: Exploring Force and Motion - Version 4", available from Vernier Software Co. and comes with the MacMotion software.

1993 Workshop Participant Colleges continued from next page

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San Jose City College	San Jose	CA
Santa Monica College	Santa Monica	CA
Santa Rosa Junior College	Santa Rosa	CA
Seminole Community College	Sanford	FL
Shelton State Community College	Tuscaloosa	AL
Shoals Community College	Muscle Shoals	AL
Sinclair Community College	Dayton	OH
Skyline College	San Bruno	CA
South Mountain Community College	Phoenix	AZ
Southwest Texas Junior College	Uvalde	TX
Southwestern College	Chula Vista	CA
St. Louis Community College-Florissant Valley	St. Louis	MO
St. Philip's College	San Antonio	TX
T-VI Community College	Albuquerque	NM
Tarrant County Junior College N.E.	Hurst	TX
Tri County Community College	Murphy	NC
W.R. Harper College	Palatine	IL
Walla Walla Community College	Walla Walla	WA
Wayne Community College	Goldsboro	NC
Whatcom Community College	Bellingham	WA
Wilbur Wright Community College	Chicago	IL

College	City	State
Antelope Valley College	Lancaster	CA
Bainbridge College	Bainbridge	GA
Baltimore City Community College	Baltimore	MD
Belleville Area College	Belleville	IL
Blue Mountain Community College	Pendleton	OR
Brookhaven College	Farmers Branch	TX
Broward Community College	Davie	FL
Cecil Community College	North East	MD
Central Alabama Community College	Alexander City	AL
Chaffey Community College	Alta Loma	CA
Colegio Regional De La Montana.UPR	Utuado	PR
College of DuPage	Glen Ellyn	IL
College of the Mainland	Texas City	TX
College of the Sequoias	Visalia	CA
Colombia Basin College	Pasco	WA
Del Mar College	Corpus Christi	TX
Diablo Valley College	Pleasant Hill	CA
Erie Community College-City Campus	Buffalo	NY
Everett Community College	Everett	WA
Fayetteville Technical Community College	Fayetteville	NC
Firelands College of B.G.S.U.	Huron	OH
Foothill College	Los Altos Hills	CA
Forsyth Technical Community College	Winston Salem	NC
Georgia Military College	Milledgeville	GA
Green River Community College	Auburn	WA
Henry Ford Community College	Dearborn	MI
Holyoke Community College	Holyoke	MA
Howard Community College	Columbia	MD
Indian River Community College	Ft. Pierce	FL
Isothermal Community College	Spindale	NC
Jamestown Community College	Jamestown	NY
Jamestown Community College	Olean	NY
John Wood Community College	Quincy	IL
Kent State University-Stark Campus	Canton	OH
Lane Community College	Eugene	OR
Lexington Community College	Lexington	KY
Los Angeles Harbor College	Wilmington	CA
Los Angeles Valley College	Van Nuys	CA
Manatee Community College	Bradenton	FL
Manchester Community College	Manchester	CT
Maple Woods Community College	Kansas City	MO
Massachusetts Bay Community College	Wellesley Hills	MA
Miami-Dade Community College	Miami	FL
MiraCosta College	Oceanside	CA
Mitchell Community College	Statesville	NC
Monroe Community College	Rochester	NY
Moraine Park Technical College	Fond du Lac	WI
Navajo Community College	Tsaile	AZ
New Mexico Military Institute	Roswell	NM
North Harris College	Houston	TX
Northeast State Technical Community College	Blountville	TN
Northwest College	Powell	WY
Pellissippi State Technical Community College	Knoxville	TN
Pensacola Junior College	Pensacola	FL
Pitt Community College	Greenville	NC
Rogers State College	Claremore	OK
Salt Lake Community College	Salt Lake City	UT

Having been associated with the Nuffield approach of teaching physics through investigations, I did not need to be convinced of the value of learning through doing ("Hear and forget; see and believe; do and understand"). Helping students understand the basic concepts of mechanics with Tools for Scientific Thinking over the past year has strengthened my belief further. I would like to share some of the positive outcomes of specific lab investigations with anyone who may be interested.

Constant Acceleration due to Gravity

Most teachers of physics, I have no doubt, have gone through the frustration of having to convey to the students the concept of acceleration due to gravity having a fixed value and direction. It seems difficult for some to understand that acceleration does not depend of the direction of travel in the case of objects sent vertically up or down a ramp. The MBL/TST investigations in the section on Introduction to Motion—Changing Motion brings home the idea spectacularly and effectively. The distance-time, velocity-time and acceleration-time graphs from a typical investigation involving a cart being pushed up a ramp, it coming to a momentary stop at the top of its run and then returning to the bottom of the ramp are shown below. The graphs show clearly that the acceleration is constant in magnitude and direction. This is evident from the acceleration graph as well as from the slope of the velocity graph. Some of the students are surprised by this
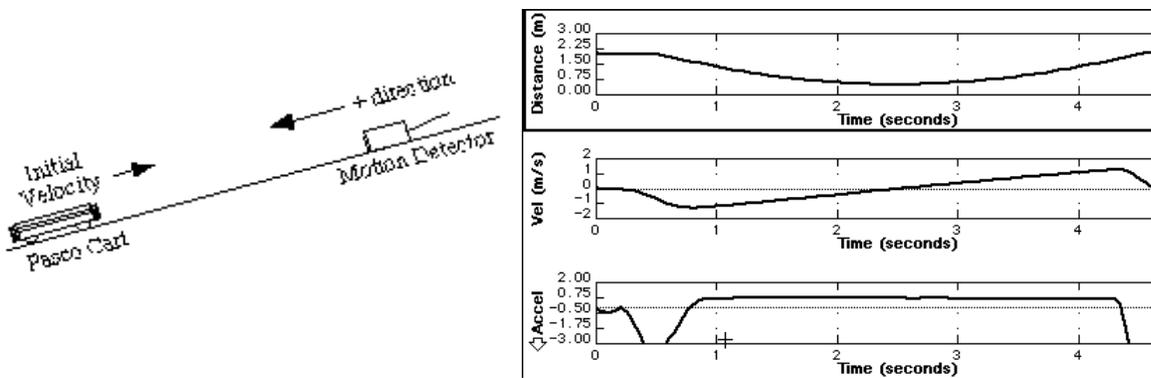
result in the beginning but take no time in grasping the idea. The homework questions that follow in the curriculum materials, reinforce the idea effectively.

SHM

Another spectacular result from the MBL experiments relates to the study of periodic motion of a mass hanging from the end of a vertical spring. The displacement, velocity, and acceleration plotted simultaneously bring home the phase relationships more clearly than a week's lectures and these graphs copied onto overhead transparencies can be used during lecture sessions also.

During the course of the periodic motion studies where we place the motion detector vertically below the oscillating mass, my colleague Boye Odom and I were concerned about the safety of the detector in the event of the mass accidentally being dislodged from the force probe hook. We tried getting the detector to see the oscillating mass after reflection at a polished metal sheet placed of the ground, 45 degrees to the horizontal and to the suspended mass. The detector placed away from the line of oscillations facing the metal sheet records the displacements after reflection and the danger of damage to the detector is avoided. Also, low cost strainers easily available in grocery stores and supermarkets, can be used as protective shields for the detectors.
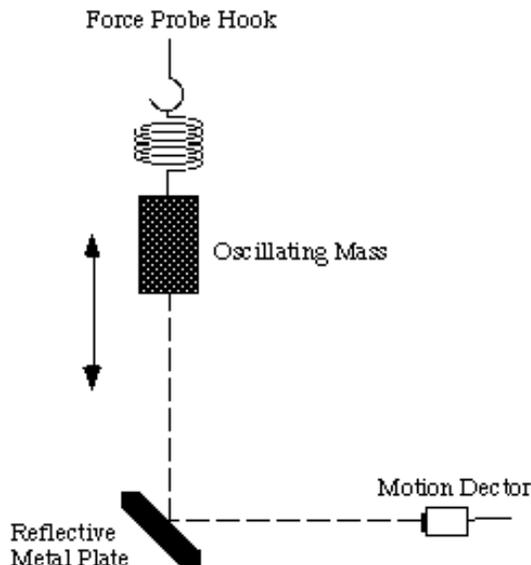
TYC Physics Workshop Project*

Directed by Curtis Hieggelke, Joliet Junior College (IL) and Tom O'Kuma, Lee College (TX)
*NSF Grant USE # 9150334, USE #9154271, DUE # 9255466

Three NSF, Joliet Junior College, and Lee College supported programs have provided twelve faculty and curriculum development workshops over the past several years for CC physics teachers around the country. There were two kinds of workshops: one on using microcomputer-based laboratories (MBL) and the other on conceptual exercises (CE) and overview case-studies (OCS). Professors Ron Thornton, Tufts University; Priscilla Laws, Dickinson College; David Maloney, Indiana University-Purdue University at Fort Wayne; and Alan Van Heuvelen, Ohio State University led these workshops. Both of these workshops presented details on teaching/learning strategies that are based on developments in physics education research.

The most recent efforts in 1993 provided for three introductory workshops (Lenoir CC-NC, San Jose CC-CA, Green River CC-WA) and two follow-up workshops (MBL at Joliet and CE/OCS at Lee College). They involved over 100 participants from approximately 80 two-year colleges located in different 25 states/territories (CA-16, NC-8, TX-7, FL-7, WA-6, NY-5). These colleges are listed in this newsletter.

Another grant is expected shortly and a tentative schedule has been set as follows

CE/OCS	April 7-9, 1994	Seminole CC	Sanford, FL
MBL	July 28-30, 1994	Pikes Peak CC	Colorado Springs, CO
MBL-DOS	Sept. 22-24, 1994	Chaffey CC	Alta Loma, CA
MBL-Follow-Up	Nov. 17-19, 1994	Lee College	Baytown, TX

For the short application form, write TYC '94 Physics Workshops, Natural Science Department, Joliet Junior College, Joliet, IL 60436 or call 815-729-9020 x 2603 or 800-728-1050.

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