

# M.A.P. MODULAR APPROACH TO PHYSICS LABORATORY

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## ABSTRACT

We present recent developments in the laboratory component of MAP - Modular Approach to Physics - Java enhanced modules to be used as aids in teaching the first three terms of university physics. The MAP project is very comprehensive and consists of a modular approach to physics that utilizes Java applets; Flash animations and html based tutorials. The overall instructional philosophy of MAP is constructivist and the project emphasizes active learner participation. In this talk we will provide a quick overview of the project and the results of recent pilot testing at several Canadian universities. Special emphasis in this presentation will be given to the use of the videolab aspect of MAP. This is a component that is integrated into MAP and permits students to capture and evaluate otherwise difficult to study phenomena on video.

## KEYWORDS

Collaborative Learning, Computer Aided Instruction, Conceptual Physics, Constructivism, html, Java, Pre-Conceptions, Laboratory.

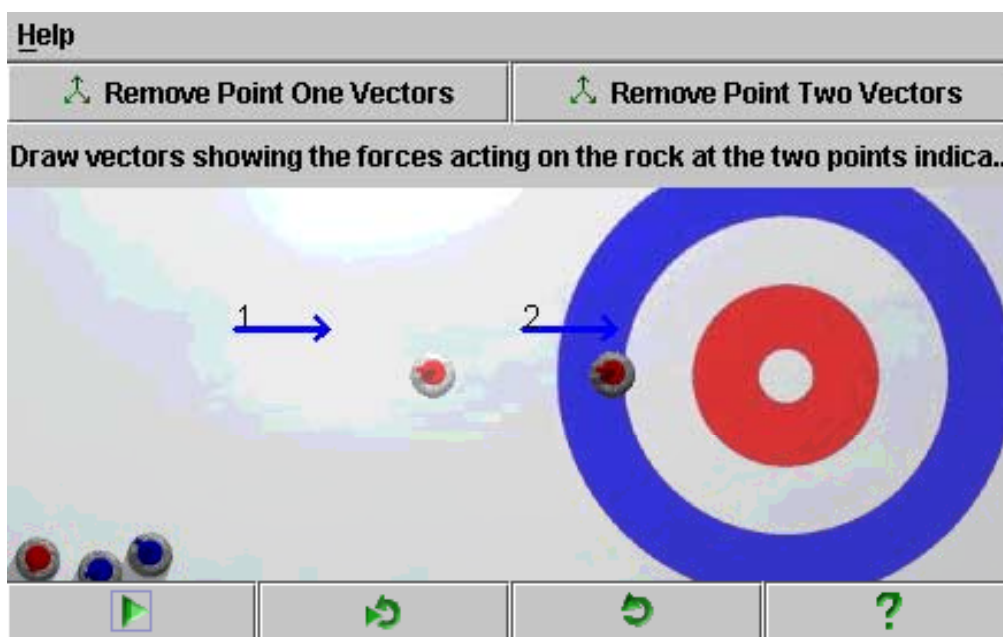
## INTRODUCTION

In this paper we describe the laboratory part of a project to develop multi-media, Java based physics modules (in the style of Wolfgang, 1997) designed to enhance, in a number of significant ways the teaching and learning of university physics. Unlike other applets the course materials are designed around concepts (Martin, 1999). Each major concept exists as a stand-alone entity and is explored through the development of appropriate models and, when possible, is supported with laboratory/tutorial activities. The flexibility of the materials enables us to utilize ancillary tools as spreadsheets or computer algebra systems where appropriate. The laboratory experiences are addressed through the use of QuickTime video and the Java Media Framework, JMF. We have developed a QuickTime/JMF interface that enables students to capture events on video and then analyze them using Java applets. It is our explicit intention to make teaching physics more interactive and more integrative than in the traditional lecture situations. A course organizer allows the instructor to easily set up the course and to choose modules.

The learning/instruction units in MAP are small, highly modular and are designed in as generic a fashion as possible to make them adaptable to a variety of course formats and instructor preferences. The more standard and basic materials are given preference over others to provide the kind of help that the majority of students need. The learning units are designed with no specific course or textbook in mind in order to make them more universally adaptable. Many of the items are intended to be suitable for in-class use by instructors as dynamic overheads. This helps to accomplish integration of the software into the course. The applets are available over the web or from a CD.

The modular nature of the materials and the flexibility of the course organizer also enables us to adapt the MAP materials to a large variety of teaching venues from traditional lecture formats to more engaging collaborative, small group laboratory settings (Wilson, J. M., 1994). This will allow us to explore less traditional but arguably more beneficial pedagogical practices.

Figure 1 shows a typical applet illustrating the conceptual approach (Martin, 2000). The module is designed to be interactive to help students build on their conceptual framework. In this case, the students are asked to predict the forces on a curling stone at two locations. This illustrates a common confusion that force is needed in the direction of motion to keep the stone moving whereas, in fact the stone is slowing down and a force in the opposite direction is required. The motion of the curling stone based on the students' input is then displayed. Along with this motion the actual motion is shown with the help of a ghost rock. Students then refine their forces to eventually arrive at the correct result in which the ghost and actual are the same.

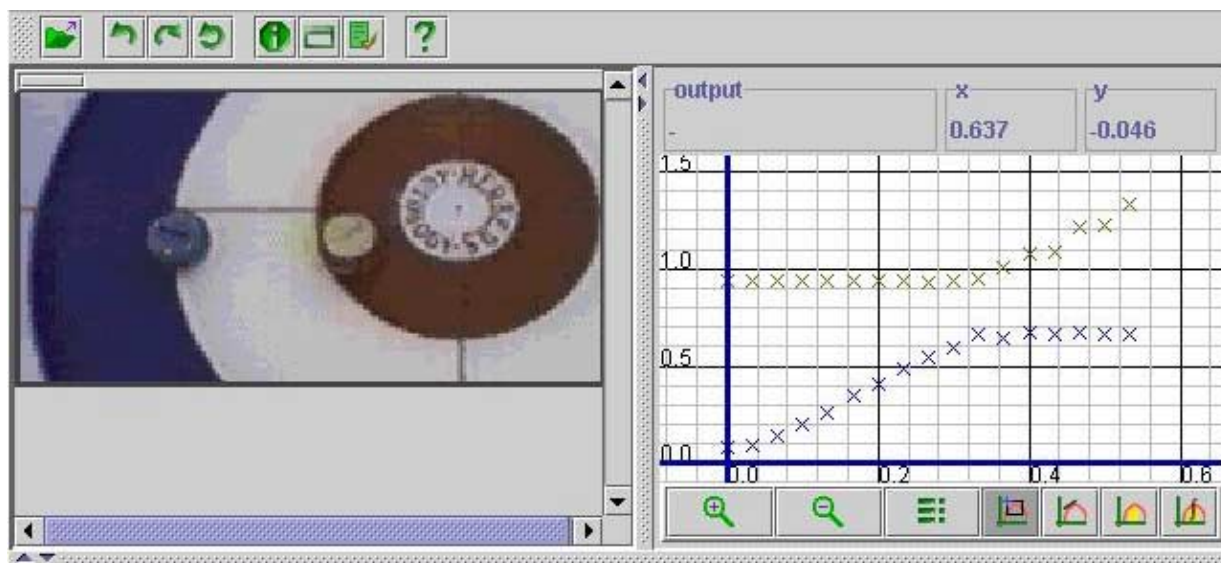


**Figure 1:** A sample screen from MAP illustrating an applet designed to address a well-known student preconception. A student is asked to draw the force on the rock at points 1 and 2. The ghost curling rock (center) shows the correct motion whereas the other curling rock (right) shows the motion as experienced by the forces drawn by the student.

## LABORATORY COMPONENT

Physics laboratories like our simulations involve an active learning experience: learning from doing and observing as opposed to listening to lectures and solving idealized mathematical problems. In laboratory situations students personally observe physical phenomena in action and obtain an understanding how physics theory came about, rather than accepting theory with blind faith. Students personally observe that physics works if you take into account idealized assumptions of the theory and the practical limitations of the experiment. Other important objectives of laboratories are listed in appendix I. Note that not all of the objectives of doing laboratories are met using videolab - for example number 10 cannot possibly be achieved without equipment: "to learn to operate and handle laboratory equipment". Most of the other objectives are addressed with videolab.

Videolab further builds on proper student understanding of concepts by introducing real, albeit filmed, laboratory situations. Due to the limitations of computers we developed a videolab involving movies of actual experiments. Figure 2 shows an instance of videolab in which students measure the motion using a film from an actual game of curling (Austen, 2000). The data collected serves to reinforce concepts and further strengthen the correct conceptual interpretations. The movie shows the standard curling situation where a curling stone collides with another stone of the same mass. From the movie it is possible to find the coefficient of friction and the energy and momentum before and after the collision to check for conservation of momentum and energy.



**Figure 2:** The QuickTime movie and graph of colliding curling stones generated in videolab. The coefficient of friction is measured to be .015. The energy and momentum before and after the collision are also easily measured.

## SAMPLE IN-CLASS ACTIVITY

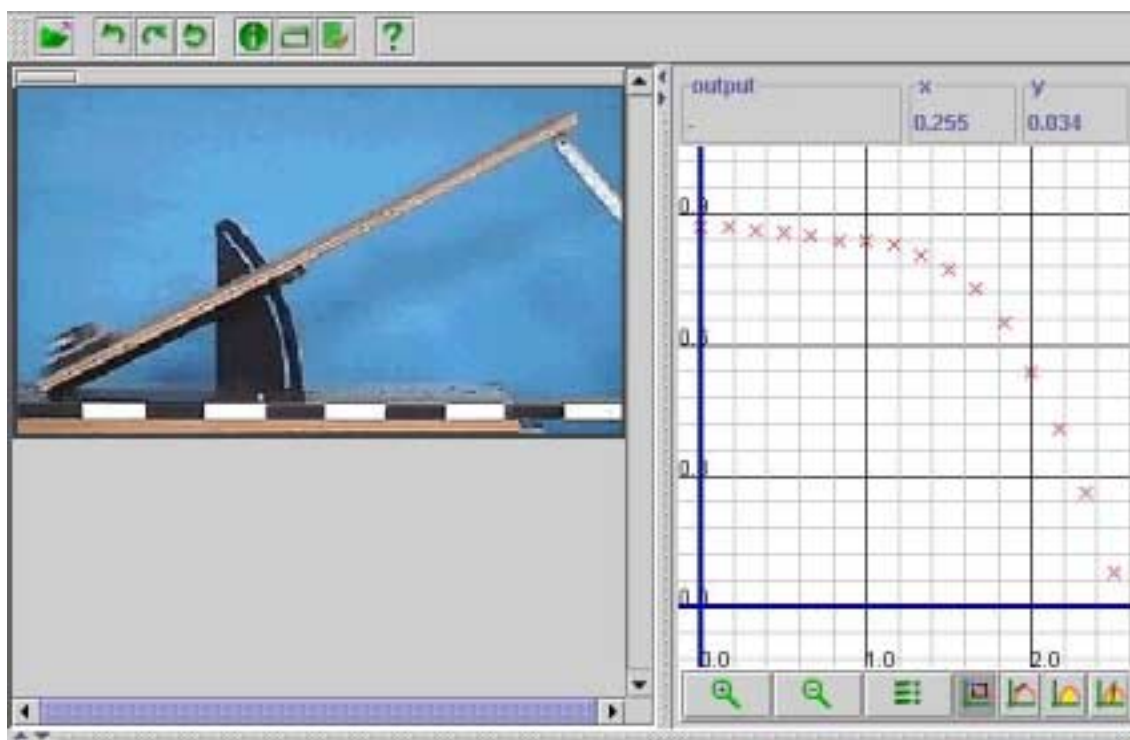
A second example illustrating the use of videolab, is the inclined plane. These are the steps students follow to log the data in this example - see Figure 3.

1. Play the movie - open a html page containing the QuickTime movie
2. Open videolab - click on the videolab button

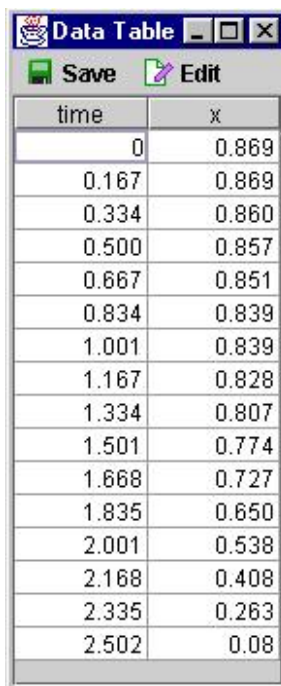
3. Scale the movie - drag the movie in videolab to a convenient size
4. Take the data - click on the object as it moves for a set number of frames
5. Scale the graph - select the portion of the graph that you want
6. Copy the data - click on generate data, copy
7. Paste data into a spreadsheet - open Excel and paste
8. Create a fit to the data - use polynomial fit in Excel
9. Save or print your work

Note that videolab automatically keeps track of the timing and position, adjusts the scales on the graph, and plots and displays the data. This takes much of the drudgery out of the experiment and allows students to focus on the concepts involved.

In the experiment, students capture video images of an object sliding down an incline. Students are asked to determine the coefficients of static and dynamic friction between the incline and the object. The (x, y) positions and time are logged with the help of videolab applet. The sample graph shows the x versus time from the data collected from the movie. The data is then shown in a separate pop up window - see figure 4. Data is copied to the clipboard and is available to paste into a spreadsheet application such as Excel. All the curve fitting features of Excel or other programs are available to the student for analysis. For the accelerated part of the motion, one finds a very good fit to a polynomial for the position versus time graph for both the x and y components. The coefficient of dynamic friction from the acceleration is found to be .34 and the coefficient of static friction, easily found from the critical incline angle of 27 degrees works out to be .50.



**Figure 3:** Graph of the motion of an object on an inclined plane as the incline is slowly raised. When the object starts to accelerate the incline is held at a constant angle. Shown is a graph of the x versus t motion. Students use the x, y and t data to determine the coefficient of static and dynamic friction.



time	x
0	0.869
0.167	0.869
0.334	0.860
0.500	0.857
0.667	0.851
0.834	0.839
1.001	0.839
1.167	0.828
1.334	0.807
1.501	0.774
1.668	0.727
1.835	0.650
2.001	0.538
2.168	0.408
2.335	0.263
2.502	0.08

**Figure 4:**

Position and time data generated by videolab. It is easy to save the data as a text file or to cut and paste the data into a spreadsheet for further analysis.

## EVALUATION

Evaluation of our modules is an ongoing process as the material is being created. Both students and instructors are given the material and asked for their reactions. This informal evaluation provides a good indication of what has been accomplished. A formal evaluation process for the videolabs remains to be designed. We are planning to solicit help from one or two graduate students who are interested in making a study of our system and its evaluation into a thesis project.

We have used videolab in combination with regular experiments in the summer and fall of 2000. Students worked in groups of two supervised by graduate students. In the summer course consisting of 48 students we replaced five videolabs out of the usual ten traditional laboratories with videolabs. A group of eight students was chosen and interviewed. Reactions were mixed. Two students preferred the videolab to traditional laboratories and two preferred the traditional format. The remaining four liked the combination of video and traditional laboratories. The students also filled out an evaluation, which again showed mixed preferences. Students mentioned they liked the ease of use and accuracy of videolab. Students who preferred traditional laboratories found them easier to visualize and liked the style of the write-ups. The traditional laboratories had more detailed write-ups since they were the result of many years of refinement whereas it was the first time for videolab write-up and much was left to the student to fill in. Further refinement will be needed for the write-up accompanying the videolabs.

## CONCLUSIONS

Our hope is that a laboratory experience in which real life situations are presented through video will help students to change their preconceptions (Brouwer, 1991) and/or misconceptions (McDermott, 1984). Although using video is more abstract than using real equipment it is as close as we can achieve on a computer. In our initial testing we found mixed reactions from our students in the laboratory. About half of the students preferred videolab to traditional laboratories. We are somewhat pleased that students still value real experience with equipment. We are also encouraged that the videolabs are at least as popular as traditional laboratories.

The advantages of the videolabs seem to lie in the precision of the measurements and the automatic data collection, graphing, and ease of analysis. The videolabs can be done by large numbers of students without the complications of equipment. They can be done at home or in a computer lab, and the software is free for the student. On the other hand videolab is not as versatile as traditional laboratories. For example, only position and time are readily measurable. Quantities such as temperature, electric charge, etc. are not directly measurable using videolab although indirect methods may still be possible. Another possible drawback is the initial time spent in overcoming the learning curve required to use the videolab software; although, we found that many students could carry out the exercises very quickly. It is difficult to produce professional looking video but this was not deemed a serious problem. On the

positive side students asked many questions related to the concepts underlying physics and this fits with our purpose of developing videolab.

#### APPENDIX I: OBJECTIVES FOR LABORATORIES

1. To obtain a feel for physical magnitudes - eg. kg, newtons, joules, etc.
2. To gain a sense of personal familiarity with abstract physical theories.
3. To obtain a grasp of physical "relations" as opposed to viewing equations as purely mathematical identities - eg. " $F = kx$ " implies "F is proportional to x" rather than "F equals k times x".
4. To recognize the connection between mathematical formulation and the behavior of physical quantities.
5. To identify the variables and constants in a problem situation; to learn the technique of controlling variables in analyzing relationships between quantities (parameters).
6. To be able to make reasonable predictions or formulate hypotheses regarding the probable outcome of an experiment.
7. To be able to identify the assumptions of the theory being investigated, and likewise, the assumptions of the experiment being performed.
8. To learn and use various techniques of graphical analysis to investigate the relationship between experimental variables; to interpret the significance of slope and intercept in linear graphs.
9. To learn to plan and work in an organized and systematic fashion; to recognize the best way of collecting, recording, representing data and analyzing results.
10. To learn to operate and handle laboratory equipment, some of which may be useful in later life.
11. To learn some standard measurement techniques - eg. measurement of velocity, wavelength, period, etc.; to appreciate the use of both direct and indirect methods of measurement.
12. To understand the concepts of experimental error, uncertainty, accuracy, discrepancy, random error, systematic error, reliability, percent error, etc.
13. To learn to estimate errors and perform error analysis of data and the effects of propagation of errors on experimental results; to learn statistical treatment of data (in senior experiments).
14. To encourage students to work independently and think for themselves; to learn to troubleshoot and recognize experimental blunders versus anomalous experimental behavior; to be able to make educated judgements regarding the validity of experimental data and results.
15. To learn safety precautions and procedures applicable to experiments; use this knowledge in the home, etc.
16. To promote critical thinking regarding the validity of theory and the validity of experimental results;
17. To learn to draw proper conclusions based on direct experimental evidence; to assess the range of validity of results and to show the correlation of experiment to theory.
18. To identify anomalous or unexpected behaviour and provide a scientifically logical explanation -- by considering the validity of assumptions, idealizations, experimental limitations, etc.
19. To be able to write a clear, informative, and logical scientific report.
20. To foster creativity and individual exploration; to identify further ideas for investigation.
21. To learn to carry out an experiment with minimal instruction, and ultimately (in senior experiments) to be able to design an experiment and employ scientific method.

22. To conduct library research necessary for obtaining the relevant background underlying an experiment (particularly emphasized in senior experiments).
23. To stimulate interest in physics through "hands on" learning and discovery.
24. To impress upon students that Physics is an experimental discipline and that the laws of physics can be verified; to foster a faith in science and an appreciation of facts.
25. To do some classical experiments (e, G, e/m, c, h ...) and to appreciate the ingenuity of the pioneer physicists in conducting these experiments without the aid of modern technology.
26. To illustrate the concepts presented in lectures, and alternately, to learn physics from the lab and anticipate lecture topics.
27. To change students negative attitudes and habits and inspire a positive regard for scientific experimentation.
28. To be able to suggest "real life" applications of the physics principles studied.
29. To discuss concepts with graduate students and peers in a small classroom setting; to interact with a physics instructor on a more personal basis than in a lecture theatre.
30. To learn to use computers in the collection and analysis of experimental data and presentation of reports.

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