**Article Title:** An Online Mechanics Experiment

**Authors:**
1. Martin Connors, Centre for Science, Athabasca University, 1 University Drive, Athabasca AB, Canada T9S 3A3
2. Christy Bredeson, Department of Physics, University of Alberta, Edmonton AB, Canada T6G 2J1

**Physics and Astronomy Classification Indices:**
- 01.50p; Laboratory Experiments and Apparatus
- 06.30Gv; Velocity, Acceleration and Rotation Measurement

**Biographical Information**

Martin Connors is an associate professor and holds a Canada Research Chair at Athabasca University. Since 1996 he has worked there on techniques in distance education in physics and astronomy, which have had a period of rapid growth. He has an interest in instrumentation that can be used by home study students. He may be reached at martinc@athabascau.ca.

Christy Bredeson (née Tkachuk) expects to soon receive her bachelor's degree from the Physics Department of the University of Alberta. In 2002-3 she was an intern for the Centre for Science of Athabasca University, working on research and distance education projects in Physics and Chemistry.

**Abstract:**

Physics distance education has grown rapidly in recent years. The theory part of a physics course taught in this way has much common ground with other courses. However, lab instruction is an important part of introductory physics and presents special challenges for distance education. We have developed a prototype introductory mechanics lab which allows many of the instructional features of "on-campus" labs to be presented to students over the internet. These include the ability to control and operate a piece of equipment and to get precision data with included errors, which can be analyzed to give a meaningful result. The lab links theory to practice and allows students to see the principles of mechanics in action.

## An Online Mechanics Experiment

Distance education in general has grown rapidly in recent years, and physics at Athabasca University has grown even more rapidly. The theory part of our physics courses is based on a popular textbook supplemented by printed materials and is similar to many of our other courses. However, lab instruction is an important part of introductory physics and presents special challenges for distance education. We have developed a prototype introductory mechanics lab which allows many of the instructional features of "on-campus" labs to be presented to students over the internet. The students control, operate, and observe a custom-built piece of equipment to pick up and drop a steel ball. Each run gives raw data for the time to fall, valid at the microsecond level. These data, with included errors, are analyzed to show the validity of the model for the motion of a falling object, and to give a meaningful result for the value of the acceleration due to gravity.

### Distance education physics

Distance education involves presentation of curriculum to students who need not be in the same location as the educators. In the past it has often been thought of as 'correspondence school' while now many think of it as internet-mediated learning. In fact, there can be many forms of distance education, but it is becoming increasingly important on the world education scene[1]. At Athabasca University, which has only distance education courses, most based on print packages mailed to students, physics enrollments have outpaced overall growth in the past decade by rising by a factor of about eight. The physics courses have recently been described in great detail[2], but are based on the popular Giancoli non-calculus textbook[3] supplemented by print materials and recently with a supporting CD-ROM. We attribute much of the dramatic growth of our physics courses to the introduction of lab kits allowing the students to meet the laboratory requirement with work done at 'home'. We may not have been the first to use such kits[4] in distance education. The kits allow physics, despite its lab requirement, to be a true distance education course, with all work done at a location of the student's choice (we note that exams must be completed under formal supervision). We would have to consider this to be an achievement consistent with our university's mandate to "remove barriers" in education, but it has not been without cost. With the dramatic rise in student numbers, ever-increasing numbers of lab kits are needed. Even though we have had a successful distribution mechanism through our library, and the kits are re-used, they must be in proportion to student numbers. The kits are based on graphing calculators[5] and associated sensing units[6] and are relatively expensive, it has been difficult to keep up with the increasing number of kits required, both from a logistical and a funding point of view. In addition, there is work associated with refurbishing the kits, and this also grows proportional to student numbers. Unlike in campus-based labs, students may start at any time, and may be doing any of the numerous required experiments at any time of the year. Thus lab equipment must always be available to them. These issues were the motivation behind developing an online experiment. We describe here an exploration of use of the internet and 'telepresence' in addressing these problems and prototyping the next generation of distance education physics labs.

## Mechanics online through telepresence

The possibility of placing experiments online for use by students has been discussed recently with experiments more advanced than the traditional first year level[7,8]. If properly connected to a remote instrument, "a computer on the Internet can … collect data … as though the computer and instrument were directly connected[7]." For distance education this could offer many advantages. The first is that it could give remote students access to experiments without the need to send lab materials to them. This would be a solution to the cost issues of buying new lab kits as enrollment grows. Students would not face the difficulty of assembling the materials of their lab kit or dealing with malfunctions of their equipment. In many ways the lab experience available over the internet would be similar to that in a traditional laboratory setting where the experiments are initially set up and tested by a technician. Since the student could control the variables and have control over their own experiment, which would actually take place and return values with real errors, the lab experience would be very 'real'. To further increase the degree of involvement and control, we felt that 'telepresence' should be implemented through use of a webcam. For introductory students, we felt that it was important to be able to see (visually) responses to various operations involved in running the experiment, in addition to reading values returned by the instruments.

Since all of our formal courses are at the introductory level, we designed our first online lab to be in introductory mechanics. The measurement of the time taken for a steel ball to drop a determined distance indicates the acceleration due to gravity if properly analyzed[9]. Several such measurements make a curve demonstrating that the underlying theory is correct. The prototype experiment thus consists of a "balldrop" wherein the students pick up a steel ball, move it to a height which they specify, and release it. They have complete control over how many times to do this and a set of 100 different heights from which to drop the ball. The time taken to drop is measured by a microcontroller[10]. The pickup, release, and drop are viewed on a webcam, and it must be verified that the ball landed correctly. Data in the form of height-time are copied by the students and entered into Graphical Analysis[6] for graphing and reduction.

## Description of the Apparatus

A common device for performing translation is the simple dot-matrix printer. These must move the print head in response to characters sent to them through a parallel port. If the print head is removed and replaced by a solenoid, a steel object may be picked up and moved if the solenoid is energized and characters sent to the printer. Since these obsolete printers are available as discards, we obtained a wide-tractor model and modified it to stand vertically and pick up and release a steel ball. The control was through a PIC 18F252 microcontroller, a very versatile device for which the free programming environment "MPLab" is available[10]. Although this device has a "parallel" port, interface chips had to be used to drive the printer. The PIC controller had to be programmed to recognize characters representing numbers, read on its serial port, and to return timing values over that port. It handled the pickup and drop of the ball by controlling current to the solenoid on the print head using a transistor, and once the ball was dropped, used a timing loop to obtain the time to drop to a photogate to the nearest microsecond[11]. An important element of the design was use of a Siteplayer[12], which is a solid-state web interface, programmed with modified HTML on its own webpage. Through the web page which the Siteplayer serves to the web, students may enter the desired height and cause the experiment to take place. They may also reset the printer and the communications link if necessary. We chose a relatively expensive solid state webcam with its own IP address in order to implement a completely solid state solution.

In contrast to the other online experiments we know of[7,8,9], ours uses entirely solid state apparatus (plus the electromechanical modified printer) to implement the experiment, and a solid state webcam. We did not use PCs, partly since we had a large amount of experience with solid state devices, and wished to expand our knowledge of how to interface them to the internet for use in other research. We also felt that there was a reliability factor involved, with the solid state devices being more reliable and less vulnerable to outside interference. In retrospect, there could have been advantages to using more off-the-shelf hardware[9], and others may wish to do so. We suggest that linux computers may be suitable for web control experiments.

## Online Access

The experiment in its test phase is accessed at phys1.acad.athabascau.ca. We will implement access control as it is integrated into the main project for remote labs and it will then be accessed through www.remotelab.ca. Figure 1 shows the main page of our experiment. The student would use this page to obtain a table of values for “height” and resulting time to fall, watching on the webcam view the actions taking place in response to pressing buttons to operate the equipment. The “height” must be transformed to a drop distance in cm using a formula supplied to students. Students must record the results themselves, either by noting them down or by cutting and pasting into the “Graphical Analysis” program. In this way the remote experiment resembles one done in place in an undergraduate lab.

## Experimental Results

Figure 3 presents the graph pane of a Graphical Analysis session to analyze the tiem to drop as a function of the height of fall (calculated from a supplied calibration formula from the values entered on the web page). Although other methods could be used to analyze the data, Graphical Analysis is compelling since it immediately shows the student two important things. First, the theory appears sound since the data points fall near the expected curve. Second, the only variable in the theory is $g$ and this is solved for through the best fit to the theoretical curve. This value comes within 1% of the expected value of 9.81 $m/s^2$. This demonstrates that the online experiment produces useful and acceptable results. Obtaining the data (21 points) took about ten minutes.

## Conclusions

We have only recently completed our online experiment and are now making it available for student use. After a lot of work[9], we have made it reliable and relatively easy to use. One particular problem was making the ball stop in a location where it could be picked up again[9] and we solved that problem by having it drop into a hole in a piece of wood, which seemed to be a 'dead' material. Further we aided capture of the ball by turning on a second solenoid after it passed the photogate. We feel that the degree of interaction and learning are comparable to that in similar labs set up for student use on campuses. Since the actual amount of time needed to gather data is small and since no materials need be sent to students to use at home, the apparatus should serve many students and at little cost. We would not necessarily suggest duplication of our prototype experiment. We feel that the basic concept is sound and encourage others to experiment in effective implementation of online labs, which likely can find wider application than only for distance education. We have noted a similar lab which appears to have been developed in parallel with ours yet has significant differences in solving the problem of internet mechanics[9]. Those authors noted that many trials were necessary to get it right, much as we found. In the end, they appeared to concur that the effort was interesting and worthwhile and represents a new direction in web instruction. We are willing to advise those embarking on similar adventures in internet physics.

## Acknowledgements

Jason Ponto played a large role in initial development of the balldrop and a related experiment. Some of this work was supported through a New Projects in Learning Technologies grant from the Office of Learning Technologies of Human Resources Development Canada, and was done with partners at the Northern Alberta Institute of Technology.

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11. A similar PIC-based application is described in detail by M. Connors, “Extend the Timing Capabilities of a PC,” EDN Magazine, *January 10 2002, pp. 72, 74, 76,* (2002), also available by online search at www.edn.com .
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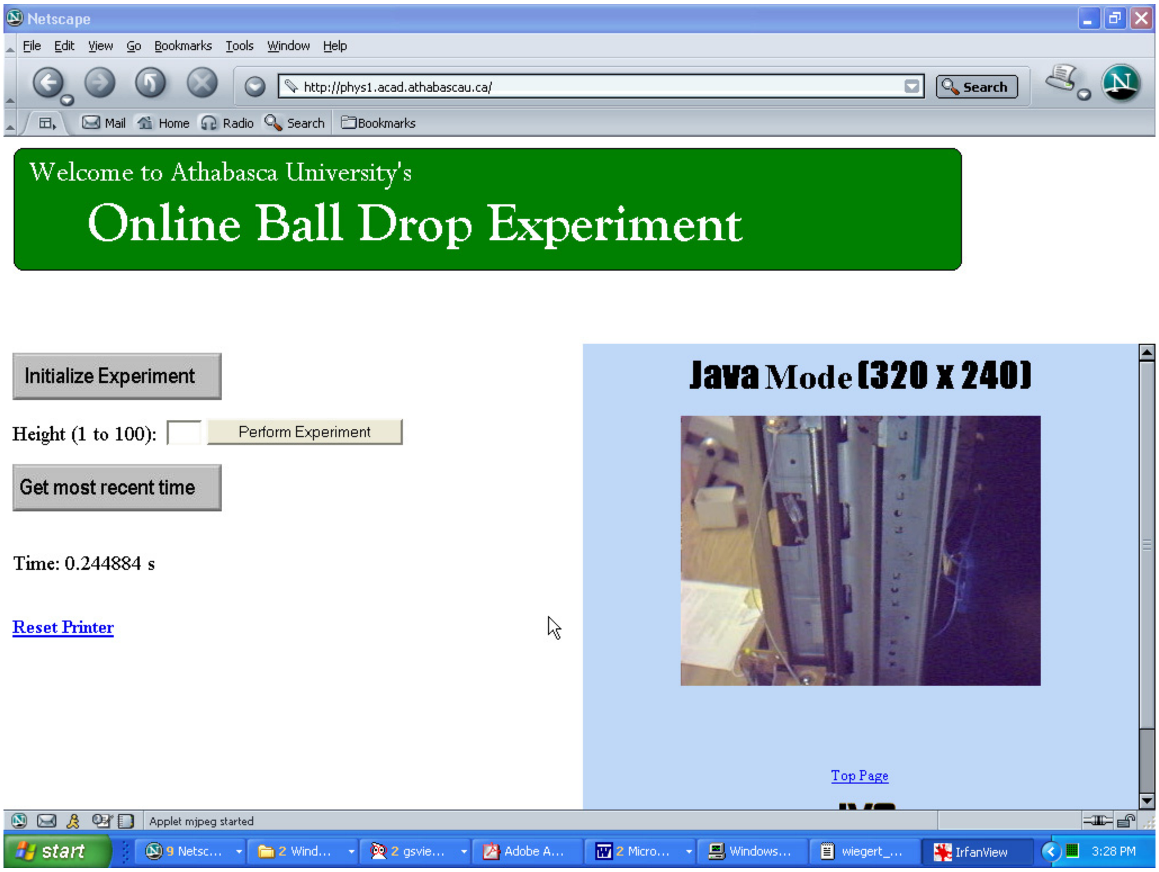
**Figure Captions**

Figure 1. Web page allowing access to the balldrop experiment. The “Initialize Experiment” and “Reset Printer” buttons should rarely be needed. The student enters a number in the “Height” box, and then clicks on “Perform Experiment”, and then can watch the experiment take place in the webcam window at lower right. Once the ball has dropped to its initial position (visible at bottom in the webcam image), the student clicks on the “Get most recent time” button and the time is displayed above the button.

Figure 2. The electronics side of the balldrop experiment. At left the electronics from the printer is visible. The small PC board at center holds a Siteplayer module (smaller green board near bottom), PIC and printer interface chip above that, printer port connector at right with cable leading to printer, and other parts. Jacks allow connection to the network (bottom left) and use with a serial port for testing (top right).

Figure 3. Graphical Analysis fit for time to drop in s (Y) as a function of height in m. The quadratic fit suggests the model of a square root dependence of time on height is a good one (although not perfect at smaller heights) and gives the only variable parameter, $g$ a best value of 9.89 m/s$^2$.



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Search
Mail Home Radio Search Bookmarks
Welcome to Athabasca University's
Online Ball Drop Experiment
Initialize Experiment
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Get most recent time
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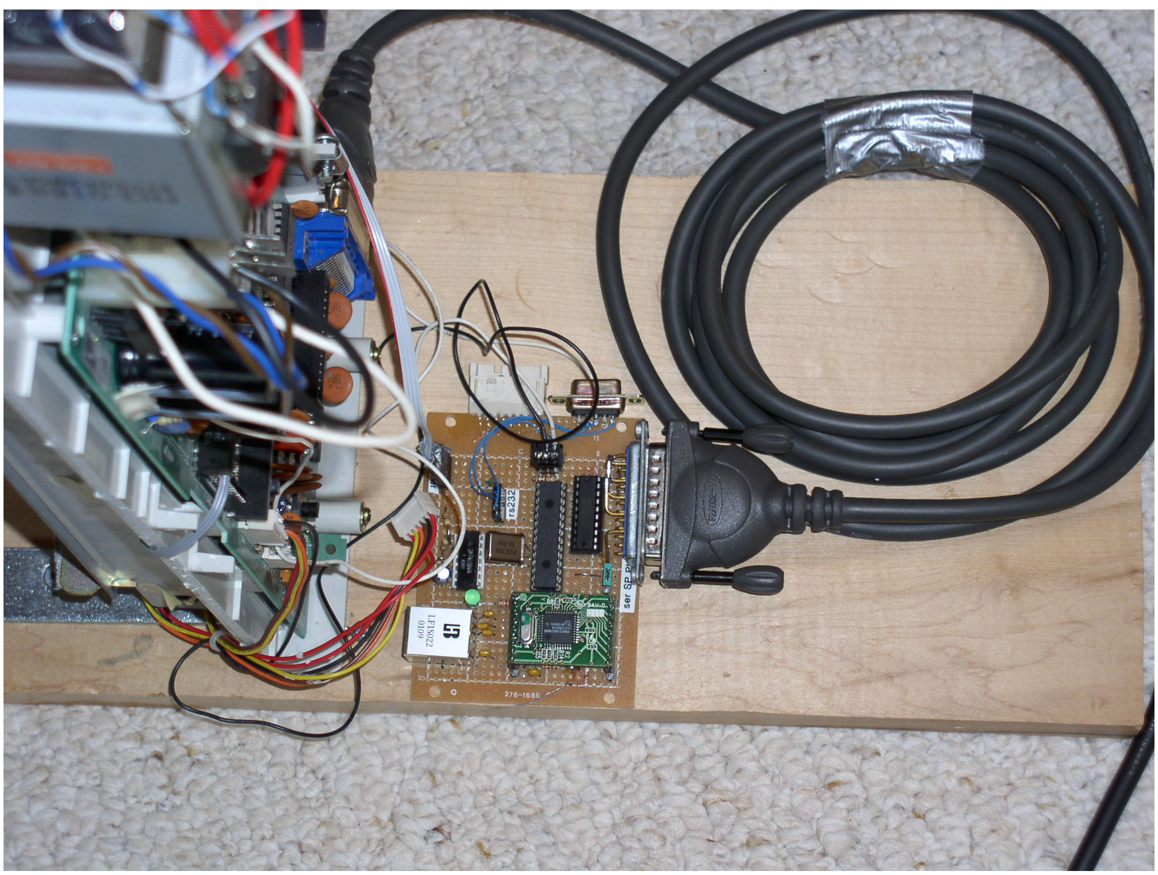

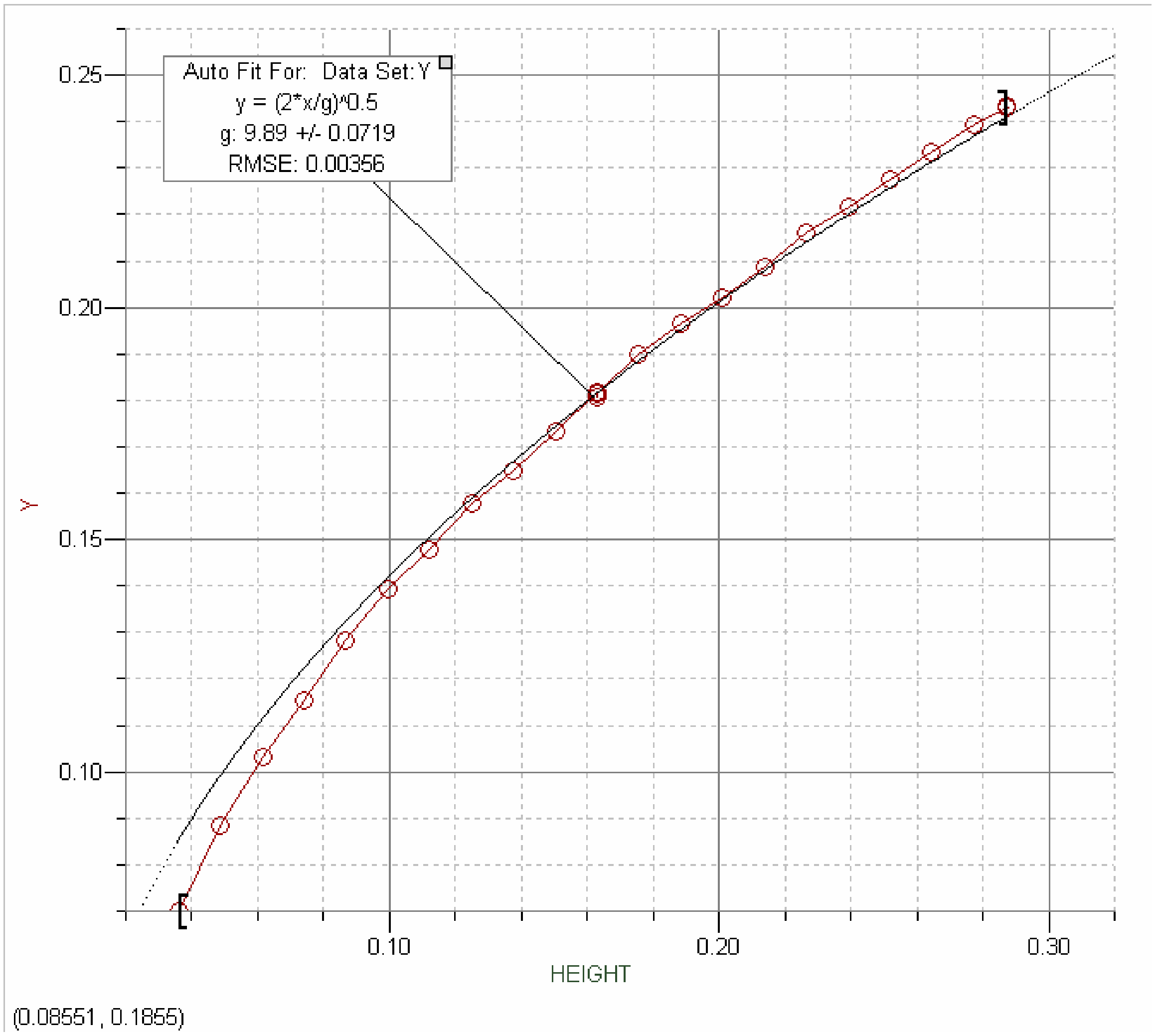

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RMSE: 0.00356
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0.20
0.15
0.10
Y
0.10
0.20
0.30
HEIGHT
(0.08551, 0.1855)