SECTION C

Physics Experiments For Online Courses

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ABSTRACT

In 2007 a Faculty Technology Grant was awarded by the Office of the Provost, the Center for Teaching and Learning Excellence, and the Educational Technology Department of Embry—Riddle Aeronautical University (ERAU). The goal of the grant was to develop 8-10 experiments that could be used in an online physics class offered by the University. These experiments, designed to be performed totally online using the Internet, would introduce students to new instructional practices and involve them in an effective way in using the current technology. This paper is about the development of those experiments and how they have recently been incorporated into ERAU's Worldwide curriculum.

INTRODUCTION

In 2007 ERAU's Provost Office, the Center for Teaching and Learning Excellence, and the Educational Technology Department sponsored several Faculty Technology Grants. Among the goals of these grants, as stated in the announcement were the following:

1. to introduce new instructional practices,
2. to explore effective ways to use technology for teaching and learning,
3. to advance student achievement, and
4. to increase student retention.

This paper is a report on the activities of one of those grants that focused on an innovative approach to the teaching of physics. The main objective of the grant was to develop 8-10 experiments that could be performed online by students using the Internet in a physics class.

BACKGROUND

Among the courses in ERAU's curriculum is PHYS 102—*Exploration in Physics*. It is a physical science elective in the *General Education Core*. At one time it was a requirement for the A.A. and some B.S. degrees. At present it is an elective in the *General Education Core* for many of the academic programs. Recently it has been reinstated as a required course in two B. S. degrees, i.e., the Professional Aeronautics and also the Aviation Maintenance programs.

PHYS 102 is a survey course in which emphasis is placed on the basic concepts and principles, as well as the history of the development of physics. Topics are selected from mechanics, heat, light, sound, electricity, magnetism, electromagnetism, and modern physics. As part of the *General Education Core* it focuses on applying one's knowledge of mathematics to physics and the applied sciences so as to develop an understanding of how to identify and solve problems. One of the learning outcomes of this course is to provide students with opportunities to interpret the results of experiments and demonstrations of physical principles.

PURPOSE OF THE EXPERIMENTS

The experiments that were developed as a result of this grant were designed to meet the Learning Outcomes as delineated in the *General Education Program* [see Appendix A for *General Education Program* outcomes]. The experiments provide an opportunity for students to analyze and interpret data. Employers have identified these skills as being important ones they want their employees to possess. In particular, these new experiments address outcomes 1, 7, 8, and 14 in the list.

DEVELOPMENT

Available on the Internet are various simulated science experiments. Most of these are free downloads offered to teachers and students. However, Java and Shockwave programs also available online at no cost are required on one's computer.

When a student initially accesses these simulations he is often frustrated. Instructions as to how to proceed are frequently lacking. Though sliding tabs and windows are available to change variables, a neophyte is not sure what to do with these simulations and on what to focus so as to learn from running them.

The written experiments that were developed contain step-by-step instructions on initial settings and how to change and enter variables. After playing/pausing/playing the simulation students are directed to observe and record measurements found in the simulation. Tables were prepared for them to enter data and perform calculations from their measurements. Space to enter predictions made from these measurements were provided as needed. Some of the simulations provided graphs from which the students were directed to obtain their data. On occasion, some of the experiments required students to describe the nature of the graph, such as:

1. A horizontal line—and what the slope of this line represents,
2. An increasing straight line—and what the slope of this line represents,
3. A decreasing straight line—and what the slope of this line represents,
4. An increasing curved line—and why it is increasing,
5. A decreasing curved line—and why it was decreasing,
6. An increasing curved line which then decreases—and the interpretation of this graph.

Each experiment contained an Introduction which was written to provide a review of the physical principles and often contained the equation(s) describing these principles. These equations were in the same notation found in the course textbook [Ostdiek and Bord]. Following this introduction a list of Learning Outcomes was given which correlated with those found in the course syllabus. At the end of every report there were questions about the interpretation of the data and calculations, as well as review questions. All of this was designed to enhance student learning and assist students in a formative sense so as to develop a better understanding of physics principles and the laws of physics. An example of one experiment, *Freely Falling Bodies* is found in Appendix B. A list of these experiments, including sub-sections is found on the following page.

EXPERIMENT	TITLE
1	Mathematical Review a. Scientific Notation b. Powers of Ten c. Significant Figures
2	Motion a. Constant Velocity b. Constant Acceleration (+)—Initial Velocity Zero c. Constant Acceleration (−)—Initial Velocity (+)
3	Freely Falling Bodies
4	Newton's Laws of Motion a. Newton's 2nd Law of Motion b. Newton's Cradle
5	Density and Pulley Systems a. Density b. Pulleys: 2, 4, 6
6	Temperature a. Absolute Zero b. Thermal Equilibrium
7	Ohm's Law
8	Electrical Circuits a. Series Combination b. Parallel Combination
9	Light a. Refraction b. Prisms
10	Modern Physics a. Bohr Theory—Hydrogen Atom b. Relativity—Time Dilation

FIELD TESTING and EVALUATION

During the 2007-08 academic year the experiments were field tested at three different onsite and two online Worldwide classes. As part of their report, the students were required to provide an evaluation and critique of each experiment [See Appendix C for Evaluation Form]. From their comments and suggestions the experiments were revised and made more user-friendly.

EXAMPLES of EXPERIMENTS and STUDENT COMMENTS

The experiment on *Density and Pulleys* is found on the following link: http://www.physicslessons.com/iphysics.htm

Below are a few comments made by the students on this experiment.

"I thought the experiment was neat, to see the correlations from the calculations to whether the object will sink or float"

"This has always been a difficult topic for me, but I made it through"

The experiments on *Motion—Constant Velocity and Constant Acceleration* is found at:

http://www.walter-fendt.de/ph14e

Comments on this experiment follow:

"I would share this with our instructor pilots. They are always trying to explain vectors when they teach aerodynamics. It would be good to show them this site as a tool"

"Honestly, I was not very impressed with this experiment. It used everything found in the chapter. I just did not like it!"

The experiment on *Relativity—Time Dilation* is found at: http://www.walter-fendt.de/ph14e

For this experiment the comments were as follows:

"Great experiment!"

"The whole theory of relativity is hard to grasp. Especially the whole time dilation thing."

"It was interesting as usual."

"I didn't know you could do that online"

CONCLUSIONS, RECOMMENDATIONS, and UPDATE

Most of the students felt that these experiments contributed to their understanding of the physical concepts. Many commented on how the visualizations found in the simulations enhanced what they read about in the text. Collecting data, making calculations, followed by predictions from their measurements gave them an appreciation of the techniques utilized in the scientific method. In general, they all felt that their math skills, especially the reading and interpretation of graphs had improved significantly.

A few recommendations are listed below:

1. Several of the experiments still need some editing and revision to make them more user-friendly.

2. Some are rather lengthy and should be subdivided into 12-14 experiments.

In the spring of 2008, a new template for PHYS 102 was developed under the direction of Dr. Thomas E. Sieland, Physical Science Discipline Chair. The experiments have been expanded to twelve and are embedded in the new template. During the development of the template further editing was undertaken. The method of submitting the report for the experiments has been improved so as to be interactive.

These revised experiments have now become part of the Wolrdwide curriculum found in the template for PHYS 102 launched in July 2008. They continue to be modified and polished as students and instructors use them and interact with each other. Their recommendations have been, and continue to be, incorporated into the new template as it continues to become an excellent method for teaching a basic physics course.

APPENDIX A

General Education Learning Outcomes

1. Apply knowledge of college level mathematics to defining and solving problems;
2. Apply statistical methods in the analysis and interpretation of data for the purpose of drawing valid conclusions relating to the solutions of problems;
3. Communicate ideas in written form in both technical and non-technical areas;
4. Communicate ideas in non-written form, such as through oral presentations or visual media;
5. Recognize the importance of professional, ethical and social responsibility;
6. Understand the natural world, to include the impact of the environment on aerospace operations and aerospace operations on the environment, as well as everyday life and professional experiences;
7. Use digitally-enabled technology to organize and manipulate data, perform calculations, aid in solving problems, and communicate solutions, ideas, and concepts;
8. Use scientific information in critical thinking and decision-making processes;
9. Function on multi-cultural and/or multi-disciplinary teams;
10. Apply economic principles to identify, formulate, and solve problems within professional and personal environments;
11. Identify and participate in professional and personal development activities through organizations and self-directed learning;
12. Understand contemporary issues in society;
13. Recognize the complexity and diversity of the human experience, including cultural, aesthetic, psychological, philosophical, and spiritual dimensions;

14. Conduct and report research in accordance with professional standards.

APPENDIX B
EXPERIMENT 3

FREELY FALLING BODIES

INTRODUCTION:

1. Look in a physics book or on the Internet for the definition of "freely falling bodies." http://theory.uwinnipeg.ca/physics/onedim/node8.html
2. Essentially, it means the effects of air resistance, wind, etc., are neglected—as if the object were falling in a vacuum.
3. Calculations: In physics texts, the equation below is given to find the distance (*d*) an object has fallen when dropped from rest

$$d = \frac{1}{2} g t^2 \qquad \text{(Equation 1)}$$

where g is the acceleration due to gravity here on Earth and t is the time of the fall. In the scientific system used in the text, $g = 9.8\ m/s^2$ or $32\ ft/s^2$ in the English system.

LEARNING OUTCOMES: (from Syllabus)

Topic 1/Week 1 Learning Outcomes Addressed

6. Understanding of basic experiments proving the concepts of mechanics.

Topic 2/Week 2 Learning Outcomes Addressed

4. Understanding of a gravitational interaction.

PART I—FREELY FALLING BODIES:

1. Click on the following link: http://www.physicslessons.com/iphysics.htm
   (a) Scroll down and select Experiment 6 Free Fall.
   (b) **Important**: the settings throughout this experiment should be: wind speed = 0 m/s and air density = $0\ kg/m^3$. Leave the mass and radius of the ball at the default settings of 0.05 kg and 0.10 m respectively.
   (c) **NOTE**: When you release the ball to make a run, the time to reach the bottom and hit the floor is kept in the center left of the screen. As the ball hits the floor the time to travel that distance will appear, but then very quickly resets to zero. You will have to watch your time of fall carefully.
2. Using the slide tab, set height to 5 m. Drop the ball. Watch the time carefully. Record this time in the second column of TABLE I.
   (a) Observe the 3-graphs—**blue** for distance fallen, **red** for average velocity, and **green** for acceleration. Describe these curves in TABLE II.
3. Repeat 2. above after setting the height to 10 m, then 30 m, ... 100 m as shown in TABLE I. As before, record the times in TABLE I and describe the curves in TABLE II.
   (a) Use equation (1) and the value of g to calculate the distance fallen in each case. Place your calculations in the right column of TABLE I. Be sure

to use the value of $g = 9.8$ m/s^2, since the distances in column 1 are in meters.

TABLE I

Distance Fallen (m)	**Time** (s)	**Calculated Distance** (m)
0	0	0
5		
10		
30		
50		
65		
85		
100		

TABLE II

Fallen (m)	**Describe**		
	Distance curve	**Velocity curve**	**Acceleration curve**
0			
5			
10			
30			
50			
65			
85			
100			

PART II—QUESTIONS:

1. The distance curve is an increasing curved line upwards. Why?
   ____
2. The velocity curve is an increasing straight line. What does this mean?
   ____
3. Calculate the slope of the red line (the velocity curve). Do you recognize what this is?
   ____
   ____
4. The acceleration curve is a horizontal straight line. What does this mean?
   ____

APPENDIX C

Sample Evaluation Form—Experiment 5 Density and Pulleys

DIRECTIONS: On a scale of 1—5, with 5 being the highest answer the following questions by putting one of the numbers in the right column.

PART I—DENSITY (WILL IT SINK OR FLOAT?)

1.	Were the Instructions for this experiment clearly written? 1 2 3 4 5	
	If your score was low, suggest how you would you improve the sentence/paragraph/wording in the instructions. ________________________. ________________________. ________________________.	
2.	Was this experiment worth doing or was it a waste of your time? [Worth doing = 4 or 5; waste of time = 1 or 2.] 1 2 3 4 5	
3.	Did you learn something from doing this experiment? Did it help to improve your understanding of the physical principles? [Learned something/improved understanding = 4 or 5.] 1 2 3 4 5	

PART II— PULLEYS

1.	Were the Instructions for this experiment clearly written? 1 2 3 4 5	
	If your score was low, suggest how you would you improve the sentence/paragraph/wording in the instructions. ________________________. ________________________.	

	____.	
2.	Was this experiment worth doing or was it a waste of your time? [Worth doing = 4 or 5; waste of time = 1 or 2.] 1 2 3 4 5	
3.	Did you learn something from doing this experiment? Did it help to improve your understanding of the physical principles? [Learned something/improved understanding = 4 or 5.] 1 2 3 4 5	

REFERENCES

1. Ostdiek, Vern J. & Bord, Donald, J., *Inquiry Into Physics*, 6th Edition, 2008.

2. The following links are found within the various experiments

   http://www.nyu.edu/pages/mathmol/textbook/scinot.html

   http://www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm

   http://en.wikipedia.org/wiki/Computer_multitasking

   http://www.physicslessons.com/iphysics.htm

   lhttp://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/index.htm

   http://www.walter-fendt.de/ph14e

   http://theory.uwinnipeg.ca/physics/onedim/node8.html

   http://www.colorado.edu/physics/2000/bec/temperature.html

   http://www.spectroscopynow.com/coi/cda/tools/HELApplet.html