A take-home physics experiment kit for on-campus and off-campus students

by Joanna Turner and Alfio Parisi

A take-home experiment kit has been developed to reinforce the concepts in a first year physics course that both on and off campus students from a variety of educational backgrounds can successfully use. The kit is inexpensive and is composed of easy to obtain items. The experiments conducted with the kit are directed experiments that require background reading, setting up the experiment, measurement of the different variables and analysis of the given concept. The concepts covered by the experiment kit help to reinforce theoretical learning of everyday physics by the students in their home environment, without the use of a laboratory. At the same time, the process of conducting the experiments introduces basic laboratory-style work practices and reporting skills. All experiments are designed to enable students to develop research, measurement and reporting skills and for some experiments, apply theoretical reasoning.

Introduction

More and more students in a tertiary environment choose to enrol in courses that are available online or by distance education. Students choose these options to give themselves a flexible environment in which to learn, as well as to work and care for family. Laboratory work that is an essential component of some Physics courses can be difficult to include in an online or distance education course. As a consequence, students may be required to attend a compulsory residential school, where the laboratory work may be covered in a short time frame, an arrangement that often causes 'information overload'. Students must also pay for travel and accommodation and may have to take time off from work and family.

A study performed by Ruby (2006) investigated the differences between learning, using an in-class experiment approach and an at-home 'hands-on' experiment approach. Ruby found greater improvements between knowledge tests for at-home experiments than for in-class experiments. Students identified that time constraints and peer pressure were removed from at-home experiments, allowing the students to work at their own pace. Conversely, Ruby found that there was no significant difference between mean values for report scores, indicating there was no difference between student results due to learning environment. While Ruby points out this may have been due to experiment design, it suggests that experiments carried out at home can improve the comfort of the student in how they learn through practical work. Smith (2006) suggests that most students learnt more effectively working as a part of a group. However, Smith (2006) also points out that scores achieved were similar to students who worked alone. This result indicates that students working alone on experiments can learn just as effectively as students working in a group.

McAlexander (2003) produced a 'Physics to Go' kit, that consists of equipment that fits into a bread box. This kit encompasses eighteen simple experiments, some of which are observational experiments only. Murdoch University provides experiment kits for students, but requires local assessment, while Edith Cowan University supplies a kit consisting of thirty-one short experiments (Carrick Institute, 2005). The Massachusetts Institute of Technology (MIT) provide a take-home experiment kit in the course 'Vibrations and Waves' but require its return at the end of the teaching course (MIT 2007). Physics laboratory work through distance education at the University of Southern Queensland has proved successful. Students set up their own weather station at home and access data over the Internet for the first-year course 'Remote Sensing and Meteorology' (Carrick Institute, 2005).The third year course 'Advanced Topics in Physics' uses online access to detectors set up at the University, which the students use to complete a variety of practical activities (Parisi, 2005).

The aims of this paper are to describe a take home experiment kit that has been developed to reinforce the concepts in a first year Physics course studied by students that come from a variety of educational backgrounds. The kit was designed to be self contained with readily available equipment at a low cost for purchase by students and is not required to be returned to the University. The experiments in the kit are directed experiments that require background reading, setting up of the experiment, measurement of the different variables and analysis of the data and the given concepts. The take home experiment kit prevents excessive costs to the student, allows more flexibility in their study schedule and overcomes the challenges faced by online and distance education students, discussed above. Local students also benefit from this kit as they can carry out the experiments in their own time rather than at a fixed time-tabled class.

Experiments

Students taking the Physics Concepts course come from a variety of disciplines, with mandatory participation by students from Climatology and Physics majors and the rest from the general sciences, education, engineering, nursing and biomedical science disciplines.

The design of the experiment kit was based on the desire of the authors' to enable students to carry out a series of experiments that would require research, measurement and reporting skills, rather than just carrying out observational experiments. From this basis, the following was incorporated into each experiment:

- The experiments had to reinforce concepts provided in the lectures
- Each experiment required the student to research the topic in question from the course text
- Each experiment required some form of data measurement
- Calculations were required from the data measurement, including construction and analysis of graphs
- All the above information would be used to produce a written report as assessment.

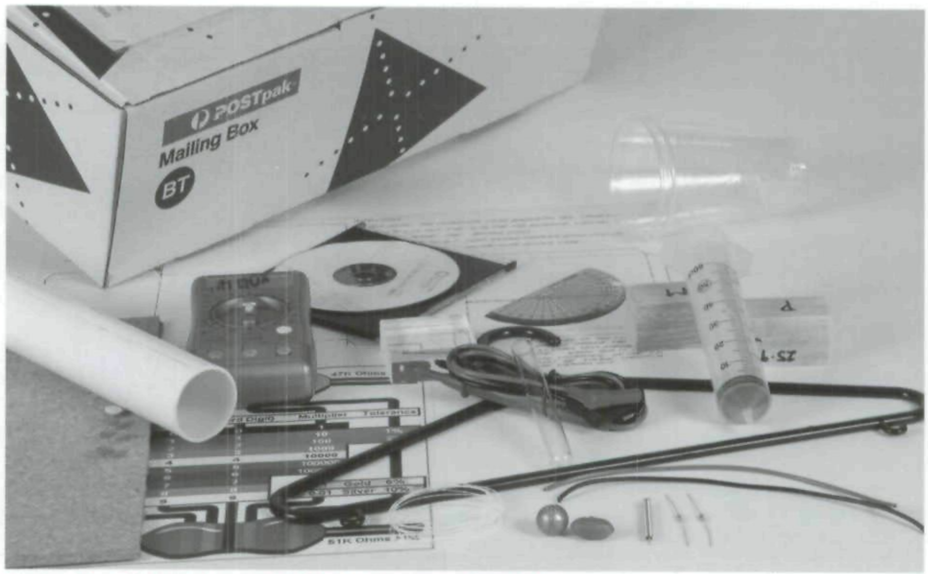

Figure 1. ***Material provided in the experiment kit.***

With these features in mind, the experiments were designed so that all equipment in the kit would be inexpensive and easy to obtain (Figure 1). Items that students were required to supply to carry out the experiments were items that could be found in the home.

The content of each experiment satisfies each of the five criteria. The six experiments that were developed are:

- the simple pendulum
- refraction and reflection
- electric circuits
- the spring constant
- fluids
- speed of sound.

At least the first four of these final experiments are classic designs where the action of the experiment is the main focus of the concept explored. These four experiments were adapted from commonly-known experiments, except for the CD spectroscope (Wakabayashi *et al*., 1998) included as a part of *refraction and reflection*. The *fluids* experiment is a multiple task experiment, comprising an adaptation of a laboratory experiment by Daniel (1998) and an experiment originally carried out in the laboratory at the University of Southern Queensland. The *speed of sound* experiment was developed by Da Silva *et al*., (2005) and provides a challenging measurement exercise for students.

To assist students with any foreseeable problems and to minimise confusion, instructions for report writing, marking schemes and some photos of the experiments (for example, Figures 2 and 3) were supplied with the experiment kit manual to provide a comprehensive guide.

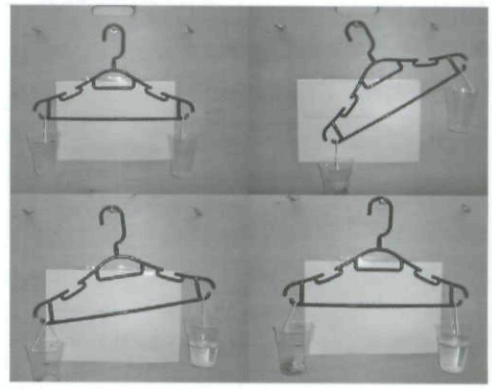

Figure 2. ***Example photograph in the experiment kit manual: calculating the density of a fluid in the experiment 'Fluids'***

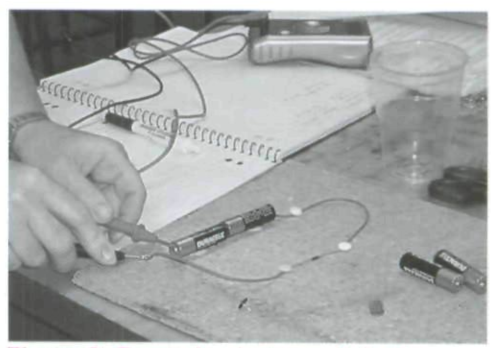

Figure 3. ***Example photograph in the experiment kit manual: Using the multimeter in 'Electric circuits'***

Results

Table 1 shows the aims of each experiment and the equipment used for each experiment in the kit. This table lists separately the equipment that is provided in the kit and the material that the students provide. A photograph of the material in the experiment kit, along with the packing box is shown in Figure 1.

The outcome of each experiment was designed so that students will gain a basic knowledge and understanding of the relevant physics concepts. For the

Table 1. *Contents of the take-home experiment kit.*

Experiment	Aims	Equipment supplied in kit	Equipment supplied by student
The simple pendulum: calculating the acceleration due to gravity	To observe the motion of a simple pendulum. To use the lengths and periods of a pendulum to calculate the value of the acceleration due to gravity. To observe that mass does not affect the period of a pendulum.	Length ofString/fishing line 2 × Sinker (different masses)	Tape measure or Ruler Stop watch Capped pen Heavy books Graph paper
Fluids	To observe Archimedes Principle –adapted from Daniel (1998) To calculate the density of a fluid. To estimate the density of an object floating in a fluid. To construct and understand the principles of operation of a Cartesian Diver.	Plastic coat hanger with hooks Two plastic cups Fishing line/ string Wooden blocks Syringe with graduated markings 10cm test tube	Coins Water Pen Ice cube 2L plastic milk bottle with top cut off Clear plastic bottle Ruler
Refraction and reflection	To measure the refractive index of a transparent substance using Snell's Law. To construct a CD spectroscope (Wakabayashi et al. 1998)	Perspex Protractor CD Template	Graph paper Torch Cardboard Scissors/Stanley knife Sticky tape Thin cardboard sheet or cardboard from a large cereal box
Electric circuits	To verify Ohm's Law for an ohmic resistor.	Cork board Lengths of wire Resistors Thumb tacks Multimeter Resistor colour code	4 × Batteries (either AA, C or D) Blu-Tack
Spring constant	To determine the spring constant of a spring using Hooke's Law.	Spring Plastic cup with string tied to top (as constructed in fluids experiment)	Small pliers (or similar). Coins Ruler Tack/map pin/nail Hammer Blu-Tack/ sticky tape Cardboard scissors
Speed of sound (da Silva et al. 2005)	To determine the speed of sound in air, using the concept of standing waves. To understand the concept of standing waves.	Length of PVC pipe Audio.wav files :	Bucket/ container Access to a computer Ruler/ tape measure Graph paper
Total cost of experiment kit per student		$44.80 AUD (including tax)	

simple pendulum, the final outcome involves using the force of gravity on a pendulum consisting of a lead sinker on string to calculate the acceleration due to gravity, and introducing the student to the work of Galileo Galilei. For *refraction and reflection*, the outcome requires understanding Snell's Law, dispersion of light and light paths, including recording light paths. For *electric circuits*, the student will gain a basic knowledge of Ohm's law, voltages, currents, resistors and the use of a multimeter. The *spring constant* introduces Hooke's law and shows how stress, strain and elasticity affect a spring. In *fluids*, the student will gain a better understanding of buoyancy and Archimedes Principle, be able to calculate the density of fluids and the density of objects in fluids and use the concept of hydrostatic pressure with Pascal's Principle. The *speed of sound* in air experiment is the most challenging, using standing waves and resonance to measure the speed of sound. Most experiments require graphing skills, and all experiments require the setting up of the equipment, data measurement and analysis. Through extension questions, students are required to extend the analysis process by using the information they have learnt to answer a theoretical question.

The experiment kit was included as a part of the Physics Concepts course in semester one 2007, that is studied by both on-campus and off-campus students, to replace the laboratory based experiments. Before the final inclusion of the kit as course assessment, we asked a student to trial and evaluate the experiments and associated instructions in the instructions manual for potential problems. The student's response to the experiment kit was positive, allowing fine tuning of the instructions in the manual that accompanies the experiment kit.

Students of the 2007 class were also asked to complete a survey after handing in final reports for the experiment kits. Responses indicated that the majority of the students found the experiment kit as an interesting exercise, but wanted a reduction of the amount of time required to write the reports for the assessment. One student had difficulty completing the *speed of sound* experiment, due to the frequencies used affecting their health. This problem is overcome by the students taking regular breaks as instructed during the experiment. No other students reported this problem. Examination of the assessment reports submitted suggest students had a good grasp of what was expected of them.

Changes to next year's assessment will include reducing the total number of reports to be submitted to two, and the remaining experiments to have a results sheet submitted in place of a report. While this will have reduced the total time required for students to write up the assessment, it will not reduce the learning time for students, as the results sheet requires analysis of the experimental data and understanding of the relevant concepts in order to undertake this correctly. A second change is that students will submit each report and results sheet progressively throughout the semester rather than at the end of the semester, thereby allowing students to receive feedback early in the semester and reducing the marking workload for the examiner at the end of the semester.

Discussion and conclusions

A take-home experiment kit has been described that has been developed to reinforce the concepts in a first-year physics course studied by students that come from a variety of educational backgrounds. An initial maximum of AUD$80.00 was allocated to the cost of the kit. The final cost price of the experiment kit is AUD$44.80, including tax, which meets the aim of producing a low-cost kit. The experiment kit is sold through the university bookshop and the price includes the overheads of the bookshop. This price is less than half the cost of some textbooks.

Two pieces of equipment that students are required to supply themselves are the stopwatch for the *simple pendulum* and known masses for the *spring constant*. The authors found that if students did not have these items, replacements could be found. The Internet has software timing devices available for free use, while the known masses were replaced with coins. As mass sets can be expensive, the use of coins was a simple alternative, as the mass of a given coin is supplied on a national government website (Royal Australian Mint 2006). Students can then approach a bank and exchange notes for coins to carry out the experiment. Once the experiment is finished, the student can take the coins back to the bank. This means that students do not have to purchase a set of scales, nor do known masses have to be included in the kits.

The use of simple apparatus that is readily available for the experiment kits, reinforces the concept that physics is an integral part of our everyday lives. The experiments supply additional reinforcement of the concepts studied by the students in their home environment, without the use of a laboratory. Additionally, the experiments were open ended without having to fit into a scheduled class timetable of when they were to be performed and the amount of time to devote to them. This allows students the flexibility of working at their own pace and repeating experiments if required, or exploring other possible avenues, while at the same time using time management to ensure that the final deadline is met.

Acknowledgements

The authors thank Graham Holmes and Oliver Kinder for their assistance with the kits and the University of Southern Queensland for providing a Learning and Teaching grant.

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