Online with Integers

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Integers are sometimes used in physics problems to simplify the mathematics so the arithmetic does not distract students from the physics concepts. This is particularly important in exams where students should not have to spend a lot of time using their calculators. Common uses of integers in physics problems include integer solutions to $a^2 + b^2 = c^2$ for right triangles,[1] and integer solutions to $1/z = 1/x + 1/y$. The latter equation is relevant for resistors in parallel, capacitors in series, and geometrical optics.[2] In this article we point out another way in which integers can enhance a physics course: integers in online problems. We first describe what we mean by integer online problems and how we set them up. Then we discuss the advantages and disadvantages of their use.

We define an integer problem as a problem where two or more variables are integers and the answer is an integer. A screenshot of a typical online integer problem is shown in Fig. 1. Using the given integer values of n_1 and n_2, the students need to determine the value of the integer n_3 and enter their choice in the box. For this particular problem, $n_3 = n_1 + n_2/4$. If the button "grade" is clicked, the response "correct" or "incorrect try again" is displayed in the box under n_3. If "try again" is clicked, new values for the integers n_1 and n_2 are displayed. The student can then solve for n_3 with the new n_1 and n_2. In our problems, we offer five different combinations of n_1 and n_2 that are picked randomly when "try again" is clicked. We use online integer problems in our class as a homework supplement. If the problem is answered correctly, the computer can record the student's score. Another option is to have the students print the screen and sign their name to receive homework points. At present we use the online problems as credit to make-up for any problems missed on our regularly assigned homework.

We use Java to create the integer-based problems, and they are run online via an applet. The integers n_1, n_2, and n_3 for the problem are stored in a five-by-three number-answer array. The Java applet imports the figure, sets up the box, and "tosses" the random number for the row of the number-answer array. We write the text of the problem in HTML since mathematical symbols are relatively easy to write in this format. When "grade" is clicked, the program checks if the integer entered for n_3 equals the integer answer, then displays "correct" or "incorrect try again" in the text box under n_3. All our problems are produced from a common template, and it takes only 15-20 minutes to produce the online applet. Our integer online problems can be found at Ref. 3.

There are several ways one can design integer problems. One can use integer values for the variables in the problem, e.g., n_i could equal 5 Ω or 5 m/s. In this case, the integer answer n_3 will have units and only for a particular unit will the answer be an integer. One can also express the answer in terms of an integer times an expression, as shown in Fig. 1. In this case, the integer can be unitless. Or one can ask for the ratio of a quantity for two different situations, as shown in Fig. 2. In this case too, the answer n_3 will be unitless. For the problem in Fig. 2, $n_3 = 2n_1n_2 / (n_1 + n_2)$.

Student reaction to the online integer problems has been very positive, with some of the advantages being the following:

- The problems can be solved without the use of a calculator, encouraging students to think first about the "physics." Ideally the students solve the problem with the variables and obtain an expression for n_3 in terms of n_1 and n_2. After checking n_3 for the different combinations of n_1 and n_2, the students know that they have the correct analytical solution.

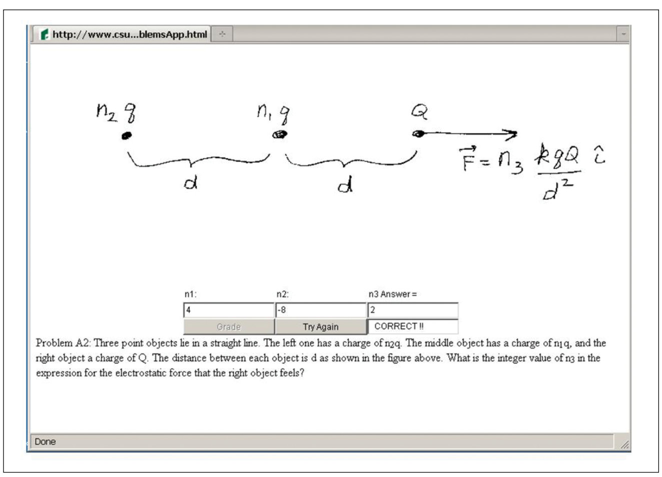

Fig. 1. The screenshot of a sample problem.

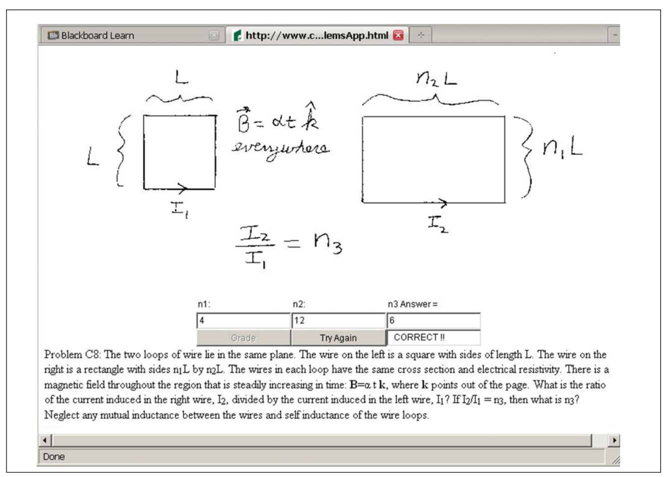

Fig. 2. The screenshot of a problem that asks for a unitless ratio of two quantities.

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- Having integer answers is useful in conceptual questions. The students can be led to consider how variables scale, and to apply dimensional analysis.
- The answers have a simple format. Students don't need to wonder if they have the correct number of significant figures or if the answer is in the right format, a common complaint with commercial online homework problems.
- It is relatively easy to write the online problem and check the answer using standard computer languages: Java or JavaScript.

Despite these benefits, one might object to the use of integers in physics problems. After all, many physical quantities are not integers, and using only integers in problems may be misleading for the student. Also, the advantage for the students not having to worry about significant figures has the flip side that integer online problems cannot teach students to consider the number of significant figures for their answers, an important consideration in laboratory work.

In any case, the role that integers play in physics can lead to interesting discussions. For example, one can pose the question: Are there any quantities in physics that are truly integers? The number of particles, atoms, or molecules in a sample is an integer. The charge on a particle is an integer multiple of the electric charge. In quantum mechanics many (maybe most) quantities are associated with integer quantum numbers. Laboratory counting experiments (i.e. the Geiger counter) yield integer quantities. Sometimes the slope of log-log plots will be integers or integer fractions. Although time is believed to be a continuous quantity, we define the second as a certain integer number of oscillations of a transition in Cesium.

Integers often make our lives easier. Now, online physics problems are as easy as n_1, n_2, n_3.

References

1. R. T. Lagemann, "Some diophantine equations," *Am. J. Phys.* **13**, 268 (Aug. 1945).
2. M. A. Heald, "Integer Solutions of $1/x + 1/y = 1/z$," *Phys. Teach.* **28**, 617 (Dec. 1990) and references therein.
3. Sample online problems are available at www.csupomona.edu/~pbsiegel

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