Using a spreadsheet workbook to enhance student learning

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Many books exist to instruct teachers in the pedagocical use of spreadsheets. However, few books are aimed at helping the introductory student learn to use spreadsheets. One of these few [1] provides a structure that can help lead students to develop their own spreadsheets from their initial stage of spreadsheet knowledge. The spreadsheet exercises are embedded in the context of physics problems, and the students must supply the rationale for the use of spreadsheets supplied with the book on CD, while working through example problems. The emphasis is on the gradual building of student expertise first to extend then to create the spreadsheets needed to deal with the physics themselves. Example problems are chosen from the constellation expected of students using canonical texts. We present examples of our approach.

1. G. Aubrecht, T. K. Bolland, and M. Ziegler, *Doing physics with spreadsheets: a workbook* (Upper Saddle River, New Jersey: Prentice-Hall, 2000).

Our book is

Doing Physics with Spreadsheets: A Workbook with Disk

Gordon J. Aubrecht, T. Kenneth Bolland, and Michael Ziegler, The Ohio State University

Published by Prentice Hall
Format: Paper Bound with Disk; 304 pp, Published: 05/12/2000
ISBN: 0-13-021474-4

The basic idea: Students will not use any ancillary materials unless they have a reason to and unless they can learn usefully using them.

We begin by finding out where students are in Ch. 2, bringing them up to a basic functioning level through a series of questions.

2.6 Doing Subtraction

Do you know how to subtract in a spreadsheet?

Answer: ___________

If your answer is yes, go on to the next section. If your answer is no, read on.

Suppose you wish to calculate the difference of the numbers that appear in the row cells G1, and H1, and to display that sum in the cell I1.

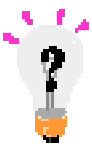
Enter the following into the cells:

	G	H	I
1	14	5	= G1 - H1

Once you have typed the recipe formula into I1, hit the **enter** key, and you will see this:

	G	H	I
1	14	5	9

1. Did this work? Explain what you obtained.



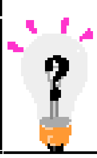
If you wish to calculate the difference of the numbers that appear in the column cells C1, and C2, and to display that sum in the cell C3, write into the cells:

	C
1	24
2	10
3	= C1 - C2

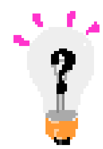
Once you have typed the recipe formula into C3, hit the **enter** key, and you will see this:

	C
1	24
2	10
3	14

2. Did this work? Explain what you obtained.



We give an example of our methods for involving students investigating transcendental equations in an application with circular motion.

We ask them to think through such a problem in small steps. In boxes we insert  to cue them to think about the topic.

The sections are designed to be assigned and torn out of the workbook.

Chapter 12 Rotational motion: solving a transcendental equation

Some problems in physics cannot be solved exactly. For such a situation, we may be able to use approximation techniques to arrive at an answer.

12.1 Motion of a Ball on the End of a Rope

Suppose you have a tetherball, which consists of a ball attached to a rope that is attached to the top of a pole. You give the ball a shove, setting it into motion with a speed V so that the ball travels in a circle about the pole. The rope will form an angle θ with the pole. Can you predict this angle θ for a given speed V? What general relation do you expect between θ and V?

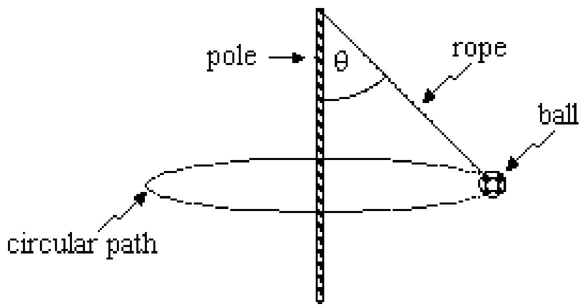
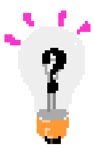
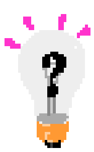


Figure 12.1 A tetherball travels in a circular path around a pole.

1. How would the size of the angle θ when the speed is small compare to its size when the speed is large?



2. What is your reasoning for the answer you gave?



You may have a general idea of how the angle and the speed are related, but the exact relationship between angle and speed is not simple to derive. We want to determine exactly why the ball moves in a circle.

To arrive at the answer, we need to break the problem into pieces. The first thing to realize is that there is something special about the ball's motion: the ball moves in a circle in a plane. The second thing to realize is that the ball moves in a circle because it is forced to.

3. Is motion in a circle natural? What does Newton's First Law say about this?

4. What do you know about the direction of the acceleration of the ball?

5. What do you know about the direction of the net force acting on the ball?

6. Explain qualitatively as best you can how it might be that the ball is forced to move in a circle. As part of your answer, indicate what forces act on the ball.

7. Note that every force must have such a source, or cause. For each of the forces you describe in the answer above, indicate its cause (for example, the cause of the weight is the ball's proximity to Earth; a non-contact force is exerted on the ball by Earth).

In order to make progress at understanding the ball's motion, we need to address exactly what forces act on the ball and how they make the ball go in a circle. First we need to agree that there is no force without a cause. The weight has a cause (the Earth). It is the only non-contact force acting on the ball. Any other force that may act on the ball can exist only because there is contact between the ball and the cause of that force. But only the rope is in contact, so only the rope can exert any force on the ball.

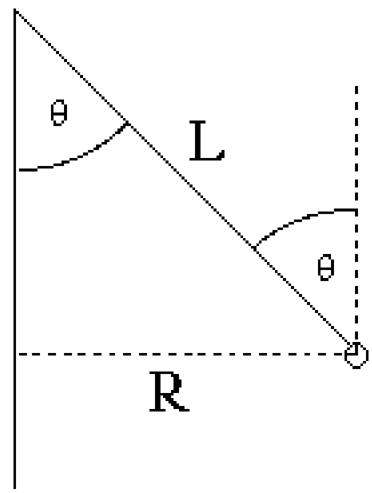
8. Suppose a classmate said to you: "There is a force pulling outward on the ball because it is being held away from the pole." How would you respond to your classmate's assertion? Is he correct? Why or why not?

If you agreed with your classmate that there is a centrifugal force (directed away from the center) caused by the ball's rotation, you are incorrect. If you disagreed, and said there is a centripetal force (directed toward the center) caused by the ball's rotation, you are also incorrect. There *is* a centripetal force, but it is not *caused* by the motion. It is *required* for the motion. The motion cannot produce a force. Any net force directed toward the center arises solely as the resultant of the physical forces that act on the ball. Rotation is an *effect*, not a *cause* of the net force acting on the ball.

12.2 Applying Newton's Laws to the Motion of a Ball on the End of a Rope

We wish to derive a relationship between the speed of the ball V and the angle θ. A picture of the rope, the pole, and the ball are provided below. Assume the ball travels at a speed V in a circle of radius R about the pole. The ball has mass M, and the rope's length is L.

1. Draw in the box on the left a free-body diagram of all the forces that act on the ball. Label each force. Also draw coordinate axes. Draw an arrow to indicate the direction of the ball's acceleration. Is it outward, inward, or in some other direction? Explain.

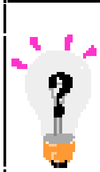


2. Write the sums of the vertical forces and radial (horizontal) forces separately below. They should be written in terms of the labels of the physical forces and trigonometric functions of θ.

Sum of vertical forces: ΣF_V = ______________________________

Sum of radial (horizontal) forces: ΣF_H = ___________________________

3. Write out the expression for the length of the radius R in terms of L and θ.



4. Is there anything we can say about what the sum of vertical forces is equal to? Why? What about the sum of the radial (horizontal) forces? Why?

5. Use your answers above to write out Newton's Second Law for the vertical forces in terms of the parameters M, θ, g, L, V, and R.

6. Use your answers above to write out Newton's Second Law for the radial (horizontal) forces in terms of the parameters M, θ, g, L, V, and R.

7. Combine your results from the questions above to obtain a relation between the speed V and the angle θ.

12.3 Solving for the Angle θ, exactly.

The equation you have derived in Question 12.2.7 for the relationship in the previous section should be equivalent to the transcendental equation:

$$\tan(\theta) \cdot \sin(\theta) = \frac{V^2}{gL} .$$

Can this equation be solved for the angle θ for a given speed V and length L? If not, we will have to resort to approximation techniques. Actually, we can solve for the angle θ if we first solve for $\cos(\theta)$ by using the identities

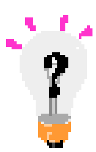
$$\tan(\theta) = \frac{\sin(\theta)}{\cos(\theta)}$$

and

$$\sin^2(\theta) = 1 - \cos^2(\theta).$$

1. Make the suggested substitutions and then solve for $\cos(\theta)$. You will need to solve a quadratic equation, which yields two solutions.

a) Show your work here.



b) Only one solution is physical. Indicate which one, and explain why.

We nurse the students along, but gradually we remove the legs of support and gradually the students do more and more of the work.

Early on, the spreadsheets are given (on the CD with the book).

Later, we encourage the students to change the given spreadsheets to another purpose.

Finally, we ask them to write the spreadsheets they need for themselves.

This parallels what we do in the questioning: We ask them to come up with more of the reasoning as the book progresses.

We include a table indicating how the book exercises may be used with all the popular algebra- and calculus-based texts.