Unit 8 - UNIFORM CIRCULAR MOTION lab

Date: Sun, 29 Nov 1998
From: Steven Robinson <robinson@MATRA.COM.AU>
Subject: Circular Motion Prac

... I found the prac outstanding, but must give credit to Rich McNamara, who showed it to me.
Steven Robinson, The Aussie Modeler

CIRCULAR MOTION USING A PENDULUM - notes by Steven Robinson

This is an introduction to circular motion. The equipment consists of a longish (> 1m) simple pendulum, with a force measurer in the string near the top pivot (do not rigidly fix the force measurer, or friction will cause large errors when using large angles of swing. Either a good spring balance, or an electronic force measurer can be used (I used a Vernier Force Probe).

To stop it rotating, a bi-filar suspension can be used above the force measurer. (I found that letting the probe rotate on a round bar wrapped in insulating tape (through the hole in the middle) gave the best results. You need something smooth but with a little friction. The main thing is to eliminate little jerks, which cause jiggles in the force/time graph. Experiment.)

Use sufficient mass to give a reasonable reading on the force measurer (150 to 350 g).

The aim of the experiment is to relate net force in uniform circular motion to the speed of the mass, but do not start by telling the students this.

Start by demonstrating the set-up to the class, using a large swing. Tell them we want to be able to fully explain the motion of the mass at the lowest point in the swing. (The lowest point is chosen because it is the only point where the tangential acceleration is zero, so the model of uniform circular motion applies instantaneously. Do not bring in this complication - although it will come up in subsequent teaching, and should be dealt with then).

By Socratic questioning elicit the following:

--To explain the motion of the mass we must look at forces, and more specifically net force.
--Why can we be confident that the net force is not zero as it swings through the lowest point?(don't worry about its direction here)
--What forces are acting on the mass as it swings through the lowest point?
--Can we measure these? How?
--Can we work out the net force as it swings through the lowest point?

Show a large swing again.

--What variables might affect the net force as it swings through the lowest point?
(elicit at least length, mass, speed; write them on the board)
--How many can we vary at once and still analyse?
--Which one should we vary here? (At this point the discussion could go many ways.

The point to bring out is how can we keep the speed constant if we vary the length. In the students' minds, the same argument probably applies to mass, although a good student might be able to show that this is not true by conservation of energy. In this unlikely event, you will have to lay down the law and say you want to keep mass constant. Otherwise it is likely that you can steer them to suggest that the only variable that it is easy to use is speed.) (Which is where you want to be!)

Now write on the board "Aim - to investigate how the net force on a pendulum's mass at the lowest point in its circular arc of swing varies as the speed varies, and to illustrate this relationship graphically, algebraically and verbally." (or similar).

Now use Socratic questioning to elicit:

--Which is the independent variable and which is the dependent variable?

--How can we measure the speed at the lowest point? (Many wild suggestions might ensue. You might have to prompt to get the easy one - from conservation of energy - measure the height loss and hence calculate the speed at the bottom. I would advise against using a sonic ranger, having tried it)

--Do we know the net force for a speed of zero?

--What sort of range of speeds should we use? (max)

--How do we get the maximum range? (use wide variety of angles of swing, up to nearly 90o.)

--How many readings should we take?

--Should we repeat readings?

Then ask if there are any questions.

Point out to students:

1. If they have taken data carefully, they should be able to find a relationship between the variables that will be proportional or linear, but that it might not be net F versus speed.
2. They should record the value of the mass on the string and the length of the string (from pivot to centre of mass, not from the force measurer to the top of the mass), and the gradient and intercept data for their graph. These are not needed now, but will be useful later as a check on the theory of circular motion that they will be developing. (At a later stage when they have derived the formula Net F = mv^2/r , have them check the gradient of their graph against the value of m/r - agreement is good - and also have them reconcile units Nm^2/s^2 as against kg/m)
3. Use a spreadsheet or a program like Vernier's "Graphical Analysis" to manipulate data - they have to convert string tension readings to net force readings (subtract weight force), and release height readings to height loss readings (subtract lowest height) to speed readings (speed = square root(2*g*height loss)) - use of the computer can greatly speed this up.