COMPILATION: Unit 8 - more Uniform Circular Motion Labs. Part 2

Part 2: paradigm labs that DON'T involve a string and a tube.

Date: Tue, 23 Apr 2002
From: Matt Greenwolfe <matt_greenwolfe@CARYACADEMY.ORG>

We did some work with the Uniform Circular Motion lab last fall at our first year workshop at Appalachian State University in Boone, North Carolina. Our workshop leader, Art Woodruff, brought in some ideas that we combined with a rotating platform available from the physics apparatus at the college. Trish Allen, myself and Art worked on it with some help and advice from Patty Blanton (our other workshop leader) and all of the other participants.

There were two main innovations.

First, we attached a force sensor and a LabPro to the center of the rotating platform. Some string was used to attach a mass to the force sensor. The remote data-taking function of the LabPro meant that it could record data during the motion without need for external wires hanging off of the apparatus, getting tangled, etc.

Second, we attached a ring stand to the center of the rotating platform (any vertical rod would do) and used a right angle clamp to extend a horizontal rod from the center out. A string was then attached to the horizontal rod and extended vertically down to the mass. This supported the weight of the mass so that the string attaching the mass to the force sensor could be completely horizontal. Since the mass and rod hung in the air and the platform rotated on bearings, friction (from a supporting surface or from string rubbing against the glass tubes in the old version of the lab) was minimized.

It took some practice to spin the whole thing by hand at a roughly constant velocity and to time it accurately with a stop watch, but we eventually got a nice quadratic fit for Force vs. Velocity

(Force = constant*velocity^2).

By repeating the force vs. velocity experiment with different masses or different radii, we also obtained some preliminary results for constant vs. mass (linear) and constant vs. radius (inverse). [The "constant" here turns out to be the mass, so it is not a constant at all!] While spinning, our mass swung out a little bit, but Trish came up with a method of accounting for this during the data analysis. The error could be eliminated by attaching the horizontal string at the center of mass.

All in all, we were much more successful at obtaining accurate quantitative results and drawing a clear conclusion than with previous versions of the experiment.

A better way to do it would be to use a motor with a vertical shaft to spin the apparatus. A rheostat or other speed control could control the speed, making it easy to obtain a constant velocity. Results would be more accurate, and it would be much easier to perform experiments on Force vs. Mass with constant velocity and radius, or Force vs. Radius with constant velocity and mass. It is difficult to maintain a constant velocity among different trials when spinning the apparatus by hand. We have not had time to actually build this contraption, but would like to find money and time to try it out. Borrowing my first name and a piece of Art's last name, we nicknamed it the MattWood machine!

I hope you are able to follow the description here, but if anyone has questions or would like to try to build one, let us know. John Matsik took some digital pictures of the whole thing, which we may be able to post on a website somewhere for people to see.

[He did! Read his note of April 25, below, for the URL. - Jane J]

Date: Tue, 23 Apr 2002
From: Paul Wendel <pwendel@KENT.EDU>

My students use Vernier accelerometers and old record players to study circular motion. Typical independent variables are period and radius. (These old record players have four frequency settings--78 rev/min, 45 rev/min, 33.3 rev/min, and 16.7 rev/min, so they can test four periods. Of course, they express T in seconds. When the A-V department at my school discovered that I was interested in the record players, they gave me eight of them.) The students find that centripetal acceleration

$a_c = K\ r\ /\ T^2.$

With some hints and coaxing, they can guess that K = 4 pi^2. Then it is easy to derive expressions for centripetal acceleration in terms of frequency, velocity, and angular velocity. Finally, since
F = ma, we have an expression for centripetal force.

The results are reliable.

Date: Tue, 23 Apr 2002
From: Brenda Royce <brroyce@ATTBI.COM>

I have also had trouble getting the UCM lab to be reliable (stopper on a string version), and realized the trouble lies with the fact that the string is not the actual radius, and especially at slower angular speeds the angle of the string with the horizontal becomes more than negligible. [Correction by Charles Rhodes, Jan. 2003: True, the string length and radius are not equal, but this fact does not affect the result. Both the tension force and the string length have horizontal components computed using the sine of the angle. So in the horizontal plane both the radius and the force contain the sine, and when substituted into the mathematical model for circular motion, the sine cancels out.]

I now have freshmen (an 'honors' algebra level group), and just couldn't justify losing them in a bunch of inconclusive data with multiple linearizations, etc.

I had the students analyze the forces on a marble moving around the inside circumference of a plastic picnic plate with a pie-shaped piece cut out of it.

First they looked at the marble in several different positions in the plate and then after it leaves the plate (thanks to Don Yost for the idea - my students call these the PacMan plates) . They fairly readily concluded they must have one model of motion in the plate (Fnet>0 => c. accel.) and another after it leaves the plate (Fnet = 0 => c.vel.). Therefore, Fnet = ma must apply to the marble moving in a circle. We also discussed an object being swung around on a string and came to the same conclusion. However, now we needed to rethink how to calculate the acceleration, since a=Dv/Dt is for changing speed and the marble is changing direction.

To evaluate the acceleration, we looked at objects moving in a circular path for a certain amount of time and then decided if the amount of direction change increased or decreased as we first changed the speed, and then changed the radius. Drawing or imagining tangential velocity vectors at the beginning and end of the timed path helped them see the change in direction. They fairly easily reasoned that the rate of change in direction increased as speed increased, and decreased as radius increased. Initially they proposed that a is prop. to V/r. Unit analysis revealed that the V must be squared, and we had a = v^2/r. They trusted this treatment as well (maybe better) than the full lab experience.

They now knew they could still use the constant force model, but they had to decide if the acceleration was due to speed change or direction change and use the appropriate acceleration equation. I also saw better model-based thinking with this approach than before.

Date: Wed, 24 Apr 2002
From: Bill Jameson <WJameson@deforest.k12.wi.us>

Modelers. may I humbly suggest looking at the Dec. 99 issue (or it might have been Nov?) of Physics Teacher. I wrote the Apparatus article that month on a UCM lab that I and some other modelers developed the preceding summer as part of our workshop time.

The device described is based around the hub of a bicycle wheel. I found that dumpster-diving behind my neighborhood bike store during the summer (when they are doing the most repairs) was a great source for the hubs - just snag the whole wheel and cut the spokes to remove the hub. If you have particularly good relations with a bike repair shop, you may be able to get them to save the hubs for you.

This year my AP class got excellent results - they were able to resolve the mass (~10g) of the internal parts of a Vernier force probe against the external mass (~100g), and get final results within a couple % of theory.

If you are interested in more details about the construction, e-mail me directly. I may even have the article stored on my home computer and could send it to anyone interested.

Date: Wed, 24 Apr 2002

From: Patrick Daisley <patrick@DAISLEY.NET>

The recent discussion about the Central Force Lab prompted me to contribute to the list. I came up with an apparatus for this lab that while it's crazy looking works great. My students have enjoyed excellent results and they have enjoyed the lab.

So as not to overwhelm your email with this list I have put a web page together that shows photos of the apparatus, students working with it and sample graphs. If you have any questions or comments please send them to me. The web address is:

<http://www.daisley.net/cfp> (Everything in lower case.)

Date: Thu, 25 Apr 2002

From: Matt Greenwolfe <matt_greenwolfe@CARYACADEMY.ORG>

Subject: pictures of UCM apparatus

I mentioned the apparatus for uniform circular motion that we worked on at our modeling conference last fall. I've posted some of John Matsik's pictures on the web at

<https://web1.caryacademy.org/facultywebs/matt_green/UCM-lab.htm>

Our idea seems very similar to the apparatus put together by Patrick Daisley that he mentioned yesterday.

Date: Fri, 26 Apr 2002

From: stan hutto <fizwiz2@YAHOO.COM>

Last summer, Patrick shared the designs for his "contraption" (his own words) for the UCM lab. I had an old fan in storage so I built a version. It works very well and I plan to make more this summer for each lab group.

From a previous posting, it sounds as if PASCO will be marketing a somewhat similar apparatus, but I believe I will prefer using Patrick's design. I think the students really get something extra out of seeing a homemade device that works well. It shows the practical nature of physics and how anyone can do experimentation with a little ingenuity. And last, but not least, it is CHEAPER! In fact, Patrick, if you don't mind I would like to do a workshop at our state association meeting next fall about your UCM-contraption, giving you due credit, of course.
