Galileo's Acceleration Experiment: Fertile Ground for Student Investigations

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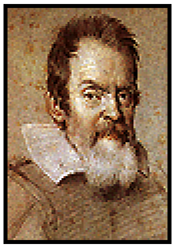


Although the story of Galileo, and the two cannonballs of different masses that he allegedly dropped from the top of the Leaning Tower of Pisa, is generally considered to be apocryphal, it seems that he did investigate the motion of falling bodies by slowing down the motion. To accomplish this, he says:

"A piece of wooden moulding or scantling, about 12 cubits long, half a cubit wide, and three finger-breadths thick, was taken; on its edge was cut a channel a little more than one finger in breadth; having made this groove very straight, smooth, and polished, and having lined it with parchment, also as smooth and polished as possible, we rolled along it a hard, smooth, and very round bronze ball."

His results: "...*in such experiments, repeated a full hundred times, we always found that* the **spaces traversed were to each other as the squares of the times***, and this was true for all inclinations of the plane, i.e., of the channel, along which we rolled the ball."*

Technology for measuring time: "*...we employed a large vessel of water placed in an elevated position; to the bottom of this vessel was soldered a pipe of small diameter giving a thin jet of water which we collected in a small glass during the time of each descent... this with such accuracy that although the operation was repeated many, many times, there was no appreciable discrepancy in the results."* **Source**: Galileo Galilei, Two New Sciences, page 178.

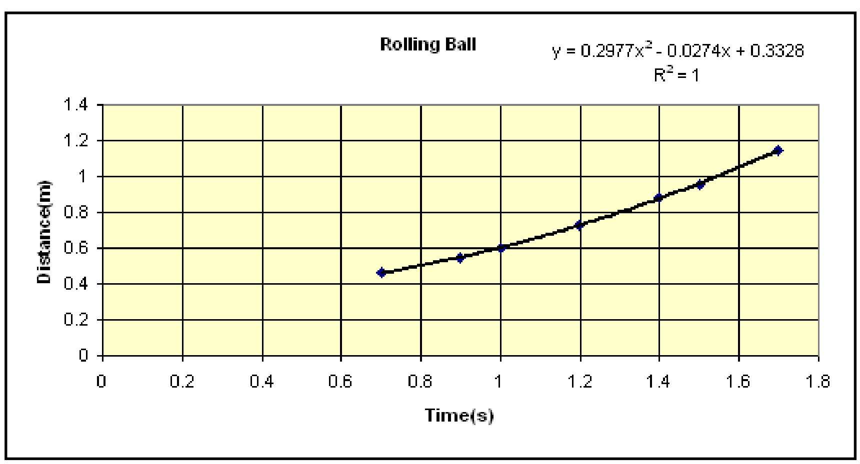
An obvious student project would be to repeat Galileo's experiment, as described, including the "water clock". We can also expand on Galileo's experiment using some modern technology.

Let's Give Galileo some Modern Technology

Although Galileo found a quadratic relationship, would a rolling ball produce such a relationship if it could be measured with more accuracy? After all, we know that a rolling ball is not like a falling ball. A rolling ball will convert some of its gravitational potential energy to rotational kinetic energy, as well as the usual translational kinetic energy. Let's give Galielo a CBR sonic sensor connected to a TI83Plus, or other modern technology for measuring position and time, and see what he comes up with.

Sample Results

Data was gathered using a CBR pointed at a bowling ball rolling down a plane inclined at about 5°. Students learn how to do quadratic regression in grade 10 math. They should have no problem in producing the graph, along with a quadratic regression line including a coefficient of determination, as shown.



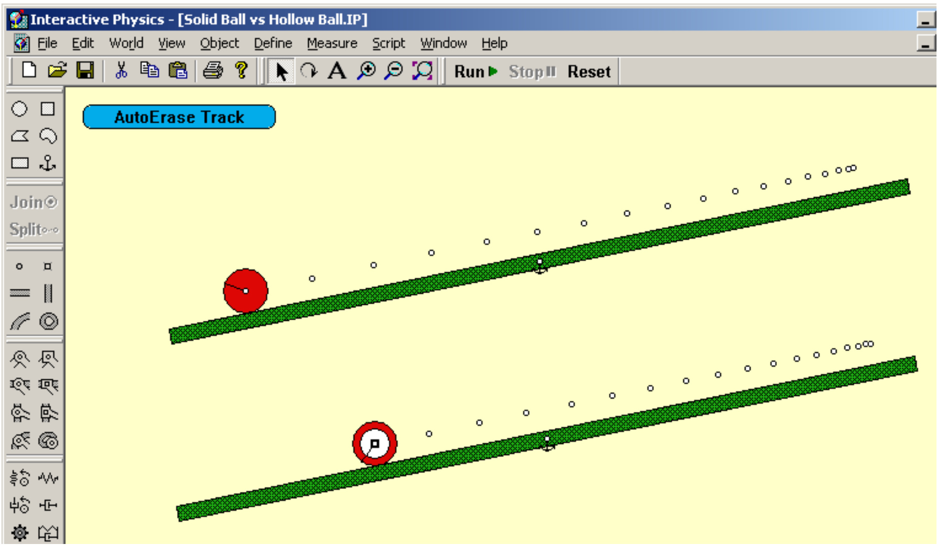
Notice that the relationship is indeed quadratic, with an excellent coefficient of determination. The usual methods of analysis yield an average accleration of 0.60 m/s^2 for the rolling ball. A little trigonometry lets us calculate the value of $g = 6.5\ m/s^2$, certainly less than the accepted value.

Further Experiments

Now the question arises: would a different ball result in different results, such as a smaller five-pin bowling ball or a pool ball? Does it matter whether the ball is solid or hollow? How about other rolling objects, such as rods or hoops? You can try a series of hoops cut from empty cans such that the mass is the same for each hoop, but the radius varies. Some rather interesting relationships arise from these experiments.

Simulations

Another student project involves programming simulations of Galileo's experiment using a software package such as Interactive Physics 2000. The screen shot below shows the acceleration of a solid ball and a hollow ball, both with the same mass, down an incline. The dots are 0.2 s apart. A student can export data from IP2000 to a spreadsheet or other analysis program, and determine accelerations. All of the experiments described above can be simulated using IP2000.



(if you would like this IP2000 simulation, send email to the address above)

An interesting variation on this experiment is to use cans of soup. Use one can of "solid" soup, like cream of mushroom, and one of "liquid" soup, like onion. Try short and long "races" between the two types. Then use technology to analyse the actual motion. Predict what other flavours of soup will do.

Summary

Galileo's experiment is fertile ground for a host of senior physics projects. It also lends itself well to group work. One member of the group can make the required apparatus, another can collect the data, another can analyse the data, and another can program simulations whose results can be compared to the experimental results.