

# ExpHPS: A very short introduction,

by Paolo Palmieri

I do research on the history and philosophy of early modern science. I am Assistant Professor in the department of *History and Philosophy of Science*, at the University of Pittsburgh. I focus on the intellectual traditions that shaped the values of modernity. I am fascinated by how knowledge is shaped by experiment. A few years ago, I worked in the private sector as an engineer. I used to develop mathematical models for complex systems. Then, my passion for Galileo led me to embark on a different career. Initially, I simply wanted to repeat Galileo's path-breaking experiments. I wanted to see what Galileo saw. Naïve. Subse-

quently, I realized that it is the questions we are interested today, as historians and philosophers, that might be illuminated not only by replicating the experiments- the pendulum, say- but, above all, by reconstructing the scenarios. I mean, by going behind the scenes. Thus, a year ago I started a project on Galileo's pendulums.

There is a lot of controversy about Galileo's experiments with pendulums (as indeed about a lot more). The pendulum, therefore, was an ideal case study to test the idea of scenarios, of the going behind the scenes. *Experimental History and Philosophy of Science* was

thus born. Of course I am not the first who has repeated Galileo's experiments, or other scientists' experiments! But I ask different questions than those asked by my predecessors. Recently, we were given by Pitt a new facility, a true lab, which we call the *HPSLAB*. We feel grateful and lucky!



The *HPSLAB* facility is located in the building of the Space Research Coordination Center (SRCC), at 206, SRCC, O'Hara St., Pittsburgh, PA 15260. Come and see us!

## Galileo's pendulums

Some scholars believe that Galileo was a consummate experimentalist. Other scholars do not believe that he actually did the experiments he reports doing. Some argue that the results cannot come out as he said.

I replicated Galileo's experiments with pendulums following a new approach.

My pendulum apparatus is as faithful as possible to that used by Galileo, although he says very little about it. In addition, it is equipped with modern

electronics and data acquisition systems which we use to build a computer model of the apparatus.

Simulating the computer model allows us to run tens of virtual experiments to explore all the uncertainties surrounding Galileo's

### Contents:

Galileo's pendulums- continued	2
Two buckets	2
Why do pendulums stop swinging?	3
Modeling and virtual experiments	3
Let's try again...	4
Our web presence <a href="http://www.exphps.org">www.exphps.org</a>	4
Our Mission	4

### Special points of interest:

- *Computer models of experiments*
- *Special apparatus to replicate experiments: load cells*
- *How is knowledge shaped by experiments?*

## Galileo's pendulums (continued)

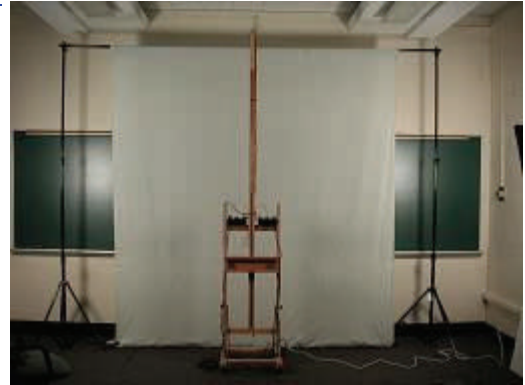
original experiments (length of the strings, weight of the bobs, air resistance, etc.).

By replicating the experiments with the computer model, I have come to the conclusion that Galileo confronted a continuum of possible outcomes. This suggests that the secret behind his “vague” reports lies precisely in the continuum of possible pendulum experiences.

I discovered fascinating patterns of behavior in pendulums that shed light on Galileo's texts. Why do pendulums stop swinging? Why did Galileo insist on using thin strings (*spaghetti*, says he)? How heavy were the lead bobs he used? Do experiments reveal the causes of phenomena?

Please read [Galileo's Experiments with Pendulums](#), for more details.

You will find documentation, pictures of replica apparatus, and videos of real and virtual experiments in the other e-books on our website ([www.exphps.org](http://www.exphps.org)).



I started in G28, our Pitt seminar room, in the summer of 2006. I built a wooden structure inspired by the apparatus illustrated by the *Accademici del Cimento*, experimenters who gathered in Florence after Galileo's death. Unfortunately, Galileo tells us little about his pendulums. You need to re-invent.

## Two buckets

Galileo “took a very sturdy rod pivoted like the beam of a balance, and he suspended at the ends of these balance-arms two equal weights. One of these consisted of two buckets, one of which hung at the said extremity of the beam and was filled with water. From the handles of this bucket hung two cords, to which was



attached another like bucket, but empty; this hung plumb beneath the bucket already described as filled with water. At the end of the other balance arm he hung a counterweight, which exactly balanced the weight of the whole assembly of buckets, water, and ropes. The bottom of the upper bucket had been

pierced by a hole the size of an egg or a little smaller, which hole could be opened and closed”.

The outcome of the experiment “was no less wonderful than it was unexpected. For the hole being suddenly opened, and the water beginning to run out, the balance tilted toward the side with the counterweight; but the water had

hardly begun to strike against the bottom of the lower bucket when the counterweight ceased to descend, and commenced to rise with very tranquil motion, restoring itself to equilibrium while water was still flowing; and upon reaching equilibrium it balanced and came to rest”.

*The outcome of the experiment  
“was no less wonderful than it  
was unexpected...”*

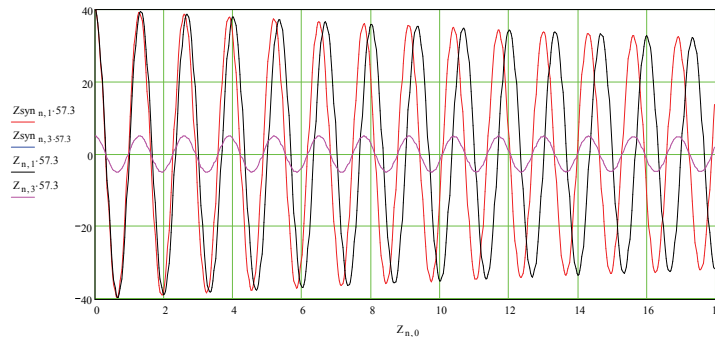
*Eric Hatleback reconstructed the two-bucket experiment. See his e-book forthcoming on our website.*

# Modeling

We design computer models of experiments. Why? Often the experiments performed by scientists are described in the literature only vaguely, especially in the early modern period. Therefore the accounts scientists provide are insufficient to answer questions about the evidence furnished by the experiments, and about the way scientists shape knowledge based on experiments. Modeling is the answer.

Modeling typically involves designing mathematical artefacts and operating the artefacts in a computer (simulation). This

allows us to explore some of the uncertainties surrounding the original experimental setting.



A diagram generated by simulating a mathematical model of pendulums.

A computer model is indeed very flexible. With the click of a button one can alter a parameter, and by doing so repeatedly one can quickly explore a large region of uncertainty. Thus we can gather precious information about classes of possible outcomes for a particular experiment.

But models are just that, models! How do we make sure that they capture the real situation? We calibrate the models by adjusting their parameters. We are satisfied when a few virtual experiments, based on the models, match the real outcomes with real apparatus.

## Why do pendulums stop swinging?

Why do pendulums stop swinging? Ask the question to Cesare Cremonini, the Aristotelian philosopher who was friends with Galileo in Padua. Cremonini did not want to look through the telescope, it seems. Yet he was a superb physicist, *more Aristotelico*. And he was a superstar in the firmament of philosophy, living in a great palace in Padua. So, Cremonini answers, the air pushes the body.

Are you sound of mind, Mr. Cremonini? Would you imagine the big lamp of the Padua cathedral (if there was one) swinging back and forth, or the massive bell of the campanile, regularly carried back and forth by the action of thin air?

If you have a hard time believing Cre-

*The air pushes the body... Are you sound of mind?*

monini, then you are on the right track about pendulums. Why do pendulums stop swinging, and quite rapidly?

It takes a new natural philosophy, or a new science, to answer this question. Galileo came up with one (two, to be more precise).

## VIRTUAL EXPERIMENTS

We perform virtual experiments by operating mathematical artefacts within a computer. We do this by means of powerful software which takes care of the technical implementation. The computer thus becomes a virtual lab for the history of science.

Simulation techniques have long been used by today's scientists in various fields of research.

The computational power of modern computers allows an unprecedented potential for running virtual experiments, thus expanding the reach of empirical investigation, especially when real experiments are difficult or impossible to perform.



Computers can help historians and philosophers of science

# Experimental History and Philosophy of Science

UNIVERSITY OF PITTSBURGH

Department of History and Philosophy of Science

1017 Cathedral of Learning  
Pittsburgh, PA 15260

Phone: 412-624-5881

Fax: 412-624-6825

E-mail: pap7@pitt.edu

[ExpHPS.org](http://ExpHPS.org)

**We are on the web:**

[www.exphps.org](http://www.exphps.org)

## OUR MISSION

*In the wake of other scholars who have adopted experimental approaches to the history and philosophy of science, we think that there is much to learn from re-enacting the experimental practices of scientists. Until not long ago the history and philosophy of science was dominated by hermeneutic work on the written records left by scientists (typically of a past period). While obviously fundamental, textual hermeneutics need not be exclusive, especially when experimentation is invoked in scientific texts of the past. It should be complemented with re-enacted practices. For, the meaning of texts invoking experiments may remain inaccessible from a perspective internal to the texts. But it can be restored on the basis of re-enacted practices.*

## LET'S TRY THE EXPERIMENT (AGAIN)

We build real apparatus to replicate real experiments. We do this:

- first because we believe that in order to investigate the historical dimension of science it is necessary to have first-hand knowledge of the experiments really performed by scientists;
- second, because by replicating experiments we can gather information to calibrate the mathematical models of those experiments. In order to do so we equip our apparatus with electronic data acquisition systems. By measuring the outcome of an experiment with high precision technology, we can fine-tune the parameters of the model until we find a satisfactory match between the virtual experiment and the real experiment.

The computational power of modern computers allows an unprecedented potential for running virtual experiments, thus expanding the reach of empirical investigation, especially when real experiments are difficult or impossible to perform.



*I have used high-precision load cells in order to read the tension in the strings of the pendulums. So, the time-history collected is the actual tension present in the string at any given moment during the motion of the pendulum. Load cells are wonderful engineering masterpieces which can output precise and reliable data. I then calibrated a mathematical model on the experimental data. With the model I tested cases beyond the reach of my apparatus.*