

Physics Lab 12: Pendulum Periods¹

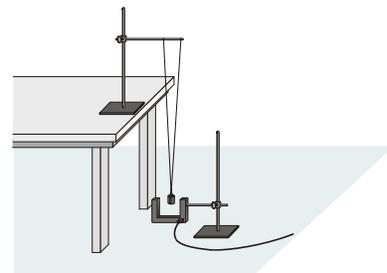
A swinging pendulum keeps a very regular beat. It is so regular, in fact, that for many years the pendulum was the heart of clocks used in astronomical measurements at the Greenwich Observatory. There are at least three things you could change about a pendulum that might affect its *period* (the time for one complete cycle):

- the length of the pendulum, measured from the center of the pendulum bob to the point of support
- the mass of the pendulum bob
- the amplitude or starting angle of the pendulum swing.

To investigate the pendulum, you need to do a *controlled experiment*; that is, you need to make measurements, changing only one variable at a time. Conducting controlled experiments is a basic principle of scientific investigation. By carrying out investigations similar to what you will do, Galileo revolutionized the practice of science (he had access to different technology!), arguably setting the stage for the way we make sense of the world today. In this experiment, you will use a photogate sensor capable of microsecond precision to measure the period of one complete swing of a pendulum. By conducting a series of controlled experiments with the pendulum, you can determine how each of these quantities affects the period.

Getting Started

- Gather and assemble the equipment as shown in the demonstration station at the front of the room. A similar set-up is shown in the figure. Depending on which stage of the investigation you are in, you might place the photogate assembly on a lab chair. Start by using the steel pendulum bob (ask if you're not sure).
- Plug the photogate sensor into the DIG/SONIC 1 port on the LabQuest. Launch LoggerPro. LoggerPro will probably not autodetect the sensor, so you will have to connect to it. Under Experiment: Set Up Sensors, choose LabQuest. Go to the DIG/SONIC 1 box as in previous labs, and choose the Photogate. Also make sure to choose the Pendulum mode under the Photogate settings.
- Do a test run by letting the pendulum swing back and forth several times. Practice your release technique. Hit Collect or press the space bar to collect data. Depending on your particular set-up, it will either collect data for a fixed number of events or until you hit Stop. You should note that the photogate only records a time for a full back and forth motion, and not every time an object passes through the sensor.
- Change the data collection mode so that it collects the time for 8 full periods: under Experiment: Data Collection, change the Mode from Time Based to Digital Events, and under Digital Events, change End Collection: to After 37 events.
- Right click on the graph, and select Graph Options. Under the Graph Options tab, select Point Symbols and unselect Connect Points, and click Done. Right click on the graph, and choose Column Options. Under the Options tab, choose Display every 1 points (using the drop down menu).
- Highlight a region of the data that corresponds to steady motion of the pendulum. Click on the Statistics button on the toolbar or choose Statistics under the Analyze menu. This will calculate the average (mean) value of the periods in your data run, along with some statistics. When you are doing your careful investigations, you will record the mean and the standard deviation (don't do it for this trial run, though). The mean is the average. The standard deviation is ideally close to zero, and represents the deviation of any individual measurement from the mean (average). If the standard deviation is close to zero, that means that the individual measurements were all close to the same value (in this case, the mean value). When you record data, you should write down all the digits that the program reports. That's too many digits, but we can round them later on in an analysis if we need to. Don't save this trial data run; clear the data run.



¹ modified from Experiment 14: Pendulum Periods, from Vernier *Physics with Computers*.

Part I: Changing Length

- a) In this investigation, you will explore the effects of changing the pendulum length for a pendulum with a steel bob released from a starting angle of 10° from vertical (straight down). If you're not sure which is the steel bob, make sure to ask. The **length of the pendulum** will be the **distance from the horizontal part of the string** (between the two support hooks for the hanging strings) and **the center of the steel bob**. It is important that you measure this distance as carefully as you can to the nearest millimeter. It is important that you always release from a starting angle of 10° .
- b) The approximate target distances are just that: approximate. It is more important that you carefully measure the length you are using. Remember that **length** is measured from the **horizontal part of the string** to the **middle of the bob**. Measure your **length to the nearest millimeter**. Remember that all releases need to be from a **starting angle of 10°** .
- c) An example data table is provided below. Create your own data table in your lab notebook; you may want to orient your table with columns instead of rows. Note that the starting length is approximately 0.20 m, that the lengths increase by approximately 0.20 m each time. Your longest length will depend on your particular set-up.

steel bob, fixed starting angle (amplitude) 10° , number of measured periods _____, changing length									
approximate length (m)	~0.200	~0.400	~0.600	~0.800	~1.000	~1.200	~1.400	~1.600	...
measured length (m)									
mean (average) period (s)									
standard deviation (s)									

Part II: Changing Mass

- a) In this investigation, you will explore the effects of changing the mass of a pendulum that is held at a fixed length (approximately 1.000 m) and released from the same starting angle (10°). You will use an aluminum bob, a steel bob, and a lead bob (you've already done a steel bob). Use the top loading balance to find the mass of your aluminum, steel, and lead bobs.
- b) You will need to take some care to make sure that the **lengths of all the pendula with the different bobs are the same**. This will be slightly challenging since you are switching the bobs. **Record the length** you actually use, measured to the **nearest millimeter**. As before, your **starting angle should be 10°** .
- c) An example data table is provided below. Create your own data table in your lab notebook..

fixed starting angle 10° , fixed length = _____, number of measured periods _____, changing mass			
bob type	aluminum	steel	lead
measured mass (g)			
mean (average) period (s)			
standard deviation (s)			

Part III: Changing Amplitude

- a) In this investigation, you will explore the effects of changing the amplitude, or the starting angle, for a steel bob pendulum with fixed length. Use a pendulum length of approximately 1.000 m (record the length to the nearest millimeter). You will need to take care with the bigger angles since deviations in your release for such large angles can result in wild swings. An example data table is provided below. Create your own data table in your lab notebook..

steel bob, fixed length = _____, number of measured periods _____, changing starting angle (amplitude)										
angle (degrees)	5	10	15	20	30	40	50	60		
mean (average) period (s)										
standard deviation (s)										

- b) Now, change your data collection settings back to Time Based and set the duration for 10 minutes. Start from 50° and collect data as the pendulum amplitude decreases due to friction and air resistance. Make sure to save this data in a usefully named LoggerPro file stored in a usefully named folder in your program workspace.