TIME FOR A SWING

KAVITA KRISHNA

Pendulums have an important place in the history of science and technology. They are also excellent devices for exploring science because they illustrate several fundamental concepts in mechanics, and are simple to make and manipulate. What opportunities do they provide in the science classroom?

A playground swing or a tyre suspended from a tree by a rope are familiar examples of a pendulum. In a classroom, pendulums can be used to illustrate several fundamental concepts in middle- and high-school physics, like periodic motion, simple harmonic motion, velocity and acceleration, gravity, the laws of motion, and conservation of energy (see **Box 1**).

A **simple pendulum** is an idealized pendulum in which we assume that a mass (the pendulum bob) is suspended from a rigid, massless string, and is free to swing back and forth (see **Fig. 1**). We also assume that there is no friction or air resistance. When the bob is displaced by a small angle from its equilibrium position, it moves back and forth in a regular and repetitive manner — an example of simple harmonic motion.

Box 1. Topics in NCERT's science curriculum that are linked to pendulums:

1. **Grade VI:** Motion and measurement of distances
2. **Grade VII:** Motion and Time
3. **Grade IX:** Motion, Force and laws of motion, Gravitation, Work and energy

The velocity of the pendulum bob changes as it oscillates about its equilibrium position. The velocity is maximum at the lowest point, and is zero when it is at its highest point. Thus, as the bob moves upwards, the kinetic energy decreases and the potential energy increases. The total amount of energy remains constant (see **Box 2**).

Pendulums in the classroom

Pendulums are ideal devices for classroom investigations — they are simple, inexpensive, and easy to manipulate. Initial discussions in the classroom can uncover students' preconceptions about pendulum motion, and can help them design an investigation to test their beliefs (see **Box 3**).[1] For example, students may believe that a heavier pendulum moves slower than a lighter one. Or that a

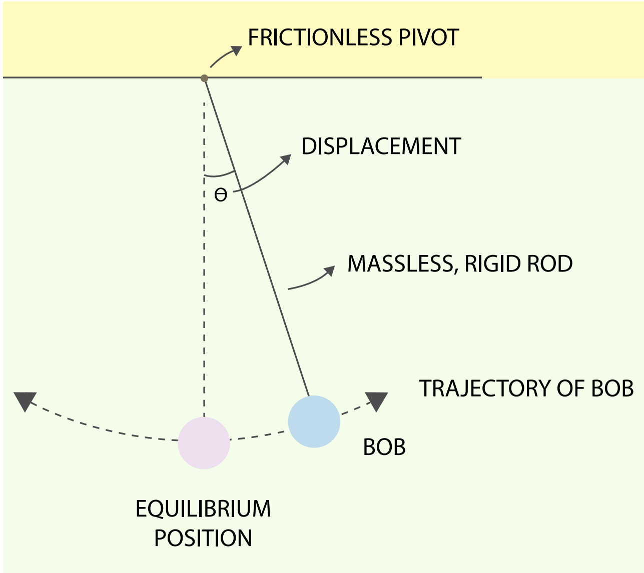

Fig. 1. Diagram of a simple pendulum.

Box 2. You can find more about the physics of pendulums here:

1. Henderson, T. The Physics Classroom Tutorial. Retrieved December 26, 2019, from https://www.physicsclassroom.com/class/waves/Lesson-0/Pendulum-Motion
2. University of Colorado Boulder. (2019) Pendulum lab. Retrieved December 26, 2019, from http://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html

pendulum takes longer to complete an oscillation if its displacement is greater. The **Activity Sheets (I-VI)** accompanying this article can help students investigate these ideas, and discover factors that affect the time period of a pendulum.

Pendulums beyond the classroom

Pendulums have always existed — a child on a swing or a lamp hanging from the ceiling are common examples. But the idealized pendulum that we study in a science class is a more recent concept.

One of the earliest known uses of a pendulum was in a 1st century seismometer device developed by Zhang Heng, a scientist from Han Dynasty, China.[3] The first scientific investigation of the motion of a pendulum was conducted by Galileo, in 1602, after he observed the chandeliers in a church swinging periodically. His investigations led to the use of the pendulum as a timekeeping device. Accurate time measurement was necessary to determine longitudes when navigating on open seas. This was important to European colonizers who were seeking to expand their trade beyond Europe. Thus, pendulum research in the 18th and 19th centuries focussed on the quest for more accurate timekeeping.[4] This, in turn, led to more accurate mapmaking, as well as the expansion of European commerce, colonization, and exploitation, with far reaching effects across the world.

The pendulum was also studied by Huygens, Newton, and Hooke — other prominent 17th century scientists (see **Fig. 2**). It has also played a significant role in establishing the value of gravitational acceleration 'g', its variation with latitude and, hence, in establishing the shape of the earth.[5]

The many ways in which the pendulum has featured in the history of science and technology, and in the making of the modern world are fascinating. Cross-curricular projects around these ideas can provide an opportunity for students to understand how science and technology evolve and how they are

Box 3: Classroom investigations

Students have many ideas about natural phenomena based on their daily experiences and superficial observations. The science classroom can provide students with opportunities to explore these ideas, and modify them based on their own investigations. These kinds of investigations have multiple benefits. Students gain experience in conducting a practical activity, and in developing their ideas based on evidence and reasoning. They develop science process skills like systematic observation, careful measurement, and conducting a 'fair' test — all of which are an essential part of learning the methods of science. These activities also increase engagement with, and understanding of science.

Process skills enable students to use the methods of science in exploring and understanding concepts.[2] They include both mental skills like predicting or evaluating, and physical skills like using tools and materials effectively. Investigations and accompanying discussions in the science classroom can help students develop process skills at an age-appropriate level. Some examples of process skills that can be developed in the accompanying pendulum activities include:

- **Devising an investigation:** identifying what variables are to be kept constant for a fair test, identifying what is to be measured, deciding the order of steps in the investigation.
- **Handling and manipulating equipment:** using tools and instruments effectively and carefully, assembling the parts as planned.
- **Measuring and calculating:** measuring variables like time and length accurately, thinking about different errors in measurement and how to minimise them, recording data systematically, calculating average results correctly.
- **Finding patterns and relationships:** identifying a relationship between variables, checking an inferred relationship against evidence.

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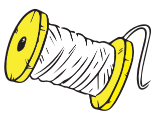
ACTIVITY SHEET 1: HOW TO MAKE A SIMPLE PENDULUM

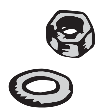
Aim:

In this activity you are going to make a simple pendulum, and observe how it moves.

You will need:



String
(about 1 m)

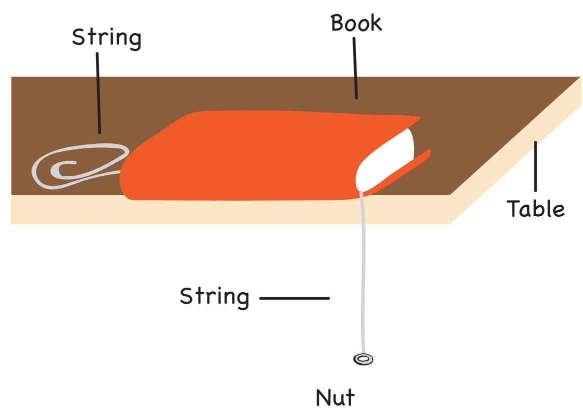


One weight
(metal washer or nut)

Heavy book

What to do:

1. Tie the weight to the end of a string.
2. Suspend the weight so it can swing freely. You can use a heavy book on a table, or tie the string to a hook. Make sure the weight can swing freely without any obstructions.
3. Make the weight swing by pulling it to one side, and releasing it. Make sure that the string is taut as you do this, and release the weight gently without applying any force.
4. Observe the movement of the weight. How does it move?



Discuss:

- Can you think of other objects which move periodically?

- Do you remember swinging on a swing? In what ways is it similar to a pendulum? In what ways is it different?

- How does the swing move during one oscillation — does it move at the same speed throughout? Where does it seem to move the fastest? Does it seem to stop anywhere?

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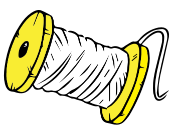
ACTIVITY SHEET II: HOW TO MEASURE THE TIME PERIOD OF A PENDULUM

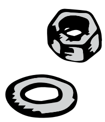
Aim:

In this activity you are going to measure how long a pendulum takes to complete one oscillation. One complete back and forth movement is called an oscillation. The time taken for one complete oscillation is called the **time period of the pendulum**.

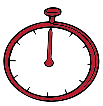
You will need:



String (about 1 m)



One weight (metal washer or nut)



Stopwatch (or phone with timer)

What to do:

1. Make the weight swing as you did in Activity Sheet I.
2. Use a stopwatch to measure how long it takes to make 10 complete oscillations.
3. Make sure you count an oscillation when the pendulum bob (or weight) is at the same point each time. (Tip: It is convenient to count a completed oscillation when the pendulum bob returns to the point where you released it from.)
4. Record your observations in the table.

Trial	Time for 10 oscillations	Time for 1 oscillation
1.		
2.		
3.		
Average time period		

5. Calculate the time period for one oscillation by dividing the time you measured by 10.
6. You can repeat this a few times and then calculate the average time period for one oscillation. (Tip: To calculate the average, add up the time for one oscillation for each trial and divide by the number of trials).

Discuss:

(a) Measuring time period:

- Was the time period of one oscillation the same in each trial? Why do you think there are differences?

PTO

- Do you think you measured the time for 10 oscillations accurately? What could you do to measure the time more accurately?

- Is it better to measure 100 oscillations or 10 oscillations to find the time period? Why?

(b) Making the pendulum move faster:

- Do you think you can reduce the time period of the pendulum (make the pendulum move faster)? How?

- Do you think the position from which you let it go (its initial displacement) makes a difference to the time period of the pendulum? Why do you think so?

- Do you think the length of the string makes a difference to the time period of the pendulum? Why do you think so?

- Do you think the weight of the pendulum makes a difference to the time period of the pendulum? Why do you think so?

- Can you think of other factors which could change the time period of the pendulum?

- How would you test your ideas?

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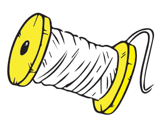
ACTIVITY SHEET III: DOES THE TIME PERIOD OF A PENDULUM DEPEND ON THE INITIAL DISPLACEMENT?

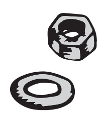
Aim:

In this activity, you will test whether the initial displacement of the pendulum makes a difference to its time period. For a fair test, make sure that you change only the initial displacement, while keeping the pendulum exactly the same in all other ways.

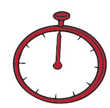
You will need:



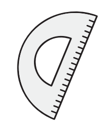
String (about 1 m)



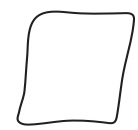
One weight (metal washer or nut)



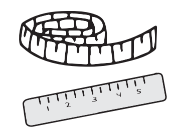
Stopwatch (or phone with timer)



Protractor



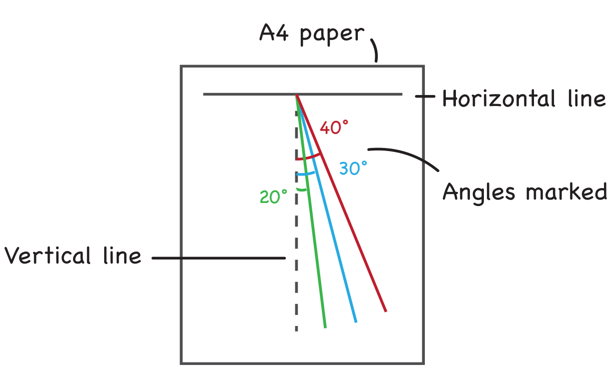
Paper

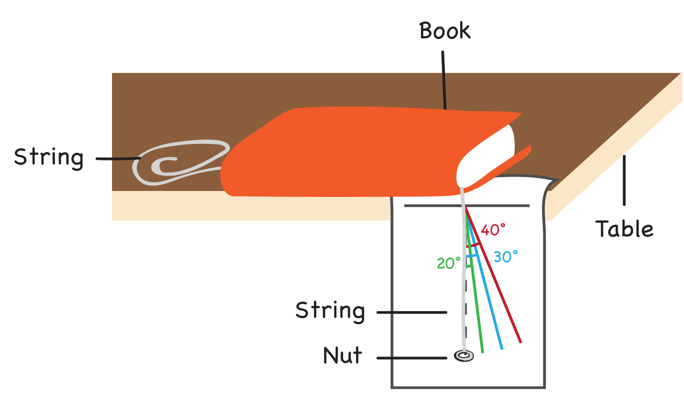


Metre scale or tape measure

What to do:

1. Measure the length of the pendulum — the distance from the point it is suspended till the point it is tied to the metal nut. Note this down.
2. Draw a vertical line on the paper and mark the angles at 20°, 30°, and 40°. You can use these markings to check where you are releasing the pendulum weight from.
3. Fix the paper behind the pendulum so that the string is in line with the vertical line when it is stationary (see image of set-up). The pendulum should hang free and not touch the paper.
4. Release the weight from the 20° position. Make sure the pendulum is moving parallel to the paper and not touching it.
5. Measure the time for 10 oscillations like you did in Activity Sheet II.
6. Conduct at least three trials, releasing the weight from the 20° position. Calculate the average time period.
7. Repeat these steps to find the average time period when you release the pendulum weight from the 30° position, and then the 40° position.





Record: your observations of time taken for 10 oscillations in each trial. Use this to calculate the time for one oscillation in each trial. Then calculate the average time period for each angle of release.

Angle of release	Trial	Time for 10 oscillations	Time for 1 oscillation	Avg. Time Period
20°	1.			
	2.			
	3.			
30°	1.			
	2.			
	3.			
40°	1.			
	2.			
	3.			

Discuss:

- What did you keep the same in this experiment? What did you change?

  What I kept the same:

  Length of the pendulum = ______________ cm

  Number of nuts used as the weight =

  What I changed:

- Did the time period of the pendulum change when you changed the position you released it from?

- If yes, did the time period of the pendulum increase or decrease when you increased its initial displacement?

- What can you conclude from this experiment? Does the time period of a pendulum depend on the initial displacement of the weight?

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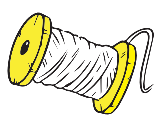
ACTIVITY SHEET IV: DOES THE TIME PERIOD OF OSCILLATION DEPEND ON THE LENGTH OF THE PENDULUM?

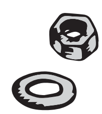
Aim:

In this activity you are going to test whether the length of the pendulum makes a difference to its time period. For a fair test make sure that you are changing only the length, while keeping the pendulum exactly the same in other ways.

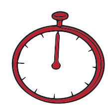
You will need:



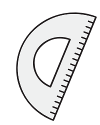
String (about 1 m)



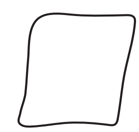
1 weight (metal washer or nut)



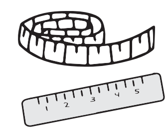
Stopwatch (or phone with timer)



Protractor



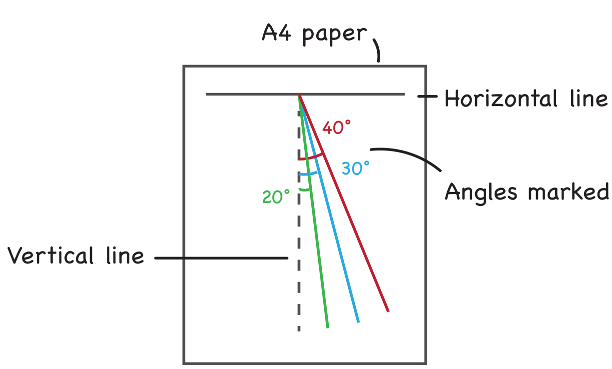
Paper

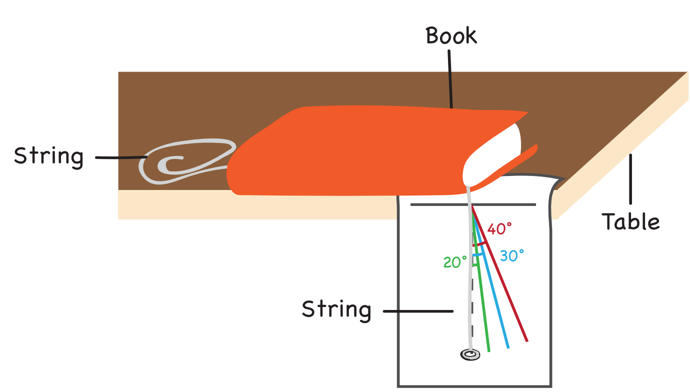


Metre scale or tape measure

What to do:

1. Measure the length of the pendulum. Note this down.
2. Decide where you will release the weight from. Note down this position (this is the angle marked on the paper you fixed behind the pendulum in Activity Sheet III). You need to release the weight from the same position in each trial.
3. Release the weight from this position and find the average time period like you did in Activity Sheets II and III.
4. Increase the length of the pendulum by 10 cm. Measure the length and note it down.
5. Find the time period for the pendulum again. Make sure you are releasing the weight from the same position you did in Step 2.
6. Increase the length of the pendulum by another 10 cm. Measure the length and note it down.
7. Find the time period for the pendulum again. Make sure you are releasing the weight from the same position you did in step 2.





Record: your observations from steps 1 to 7:

Length of string (cm)	Trial	Time for 10 oscillations	Time for 1 oscillation	Avg. Time Period
	1.			
	2.			
	3.			
	1.			
	2.			
	3.			
	1.			
	2.			
	3.			

Discuss:

- What did you keep the same in this experiment? What did you change?
  What I kept the same:
  Angle from where I released the pendulum = ______________
  Number of nuts used as the weight =
  What I changed:

- Did the time period of the pendulum change when you changed its length?

- If yes, did the time period of the pendulum increase or decrease when you increased its length?

- What can you conclude from this experiment? Does the time period of a pendulum depend on its length?

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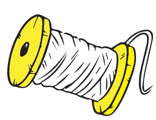
ACTIVITY SHEET V: DOES THE TIME PERIOD OF OSCILLATION DEPEND ON THE WEIGHT OF THE PENDULUM?

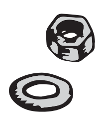
Aim:

In this activity you are going to test whether the weight of the pendulum bob makes a difference to its time period. For a fair test, make sure that you are changing only the weight, while keeping the pendulum exactly the same in other ways.

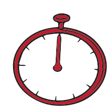
You will need:



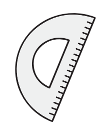
String (about 1 m)



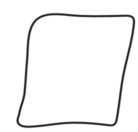
3 equal weights (metal washers or nuts)



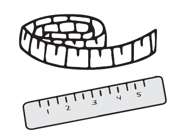
Stopwatch (or phone with timer)



Protractor



Paper



Metre scale or tape measure

What to do:

1. Make the pendulum by attaching one metal nut to the end of the string.
2. Measure the length of the pendulum. Note this down. You will be keeping this the same throughout this experiment
3. Decide where you will release the weight from. Note down this position (marked on the paper you fixed behind the pendulum as in Activity Sheets III and IV). You need to release the weight from the same position in each trial.
4. Release the weight from this position and measure the time period like you did in Activity Sheets II, III, and IV.
5. Increase the weight of the pendulum by adding another metal nut to the end. Make sure you adjust the length so that it remains exactly the same as before.
6. Measure the time period for the pendulum again. Make sure you release the weight from the same position as you did in Step 3.
7. Increase the weight of the pendulum by adding a third metal nut to the end. Make sure you adjust the length so that it remains exactly the same as before.
8. Measure the time period for the pendulum again. Make sure you release the weight from the same position as you did in Step 3.

How to tie the 3 nuts correctly

Record: your observations from steps 1 to 7:

No. of equal weights	Trial	Time for 10 oscillations	Time for 1 oscillation	Avg. Time Period
1	1.			
	2.			
	3.			
2	1.			
	2.			
	3.			
3	1.			
	2.			
	3.			

Discuss:

- What did you keep the same in this experiment? What did you change?
  What I kept the same:
  Angle from where I released the pendulum = ______________
  Length of the pendulum =
  What I changed:

- Did the time period of the pendulum change when you changed the weight of the bob?

- If yes, did the time period of the pendulum increase or decrease when you increase the weight of the bob?

- What can you conclude from this experiment? Does the time period of a pendulum depend on the weight of the bob?

i wonder... Rediscovering school science

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ACTIVITY SHEET VI: DISCUSS TOGETHER

Discuss together:

1. What can you conclude from Activities III, IV and V? What affects the time period of a pendulum?

2. Were your initial predictions about changing the time period of the pendulum correct?

3. What other factors do you think might affect the time period of a pendulum? How would you test them?

4. Why do we change only one thing about the pendulum in each experiment? What would happen if you changed more than one thing at a time in an experiment?

5. If you were to choose a swing to swing on, which one would you choose — the longer one or the shorter one? Why?

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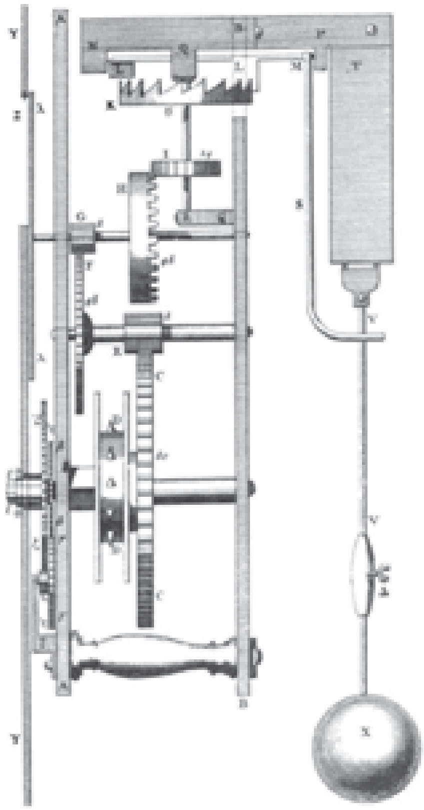

inextricably linked with the economic, social, and cultural issues of the time (see **Box 4**).

Box 4. Some cross-curricular project ideas related to pendulums:

- Researching and replicating Galileo's pendulum experiments.
- Researching the history of timekeeping devices.
- Researching European expansion – navigation, the longitude problem, and timekeeping.
- Where are pendulums used today?
- What is a Foucault's pendulum?
- Constructing a clock escapement.

Fig 2. Christiaan Huygens, inventor of the pendulum clock, built this clock around 1673. This drawing is from his treatise Horologium Oscillatorium.

Credits: Retrieved June 27, 2008 from Harold C. Kelly (2007) Clock Repairing as a Hobby: A How-To Guide for Beginners, Skyhorse Publishing, ISBN:160239153X, p.38, fig.13 on Google Books. URL: https://commons.wikimedia.org/wiki/File:Huygens_clock.png. License: CC-BY.

Key takeaways

- Pendulums can be used to illustrate many fundamental concepts in mechanics like motion, gravity, and energy.
- They are easy for students to make and use for investigations in the science classroom.
- Students can explore the significance of pendulums in the history of science and technology through cross-curricular projects.

Note: Source for the image used in the background of the article title: https://www.flickr.com/photos/eileendelhi/125635185/. Credits: Eileen Delhi, Flickr. License: CC-BY-NC.

References:

1. Duckworth, E. R. (2009). 'The having of wonderful ideas and other essays on teaching and learning'. New York: Teachers College, Columbia University.
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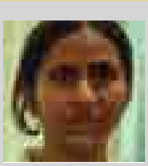

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