Swings and Pendulums – Teacher Notes

By Louise Lopes

Introduction:

An exploration into pendulums offer students a great basis in concepts found within the Forces unit. This investigation looks at the mechanics of a pendulum and asks some foundational questions about how they work. This investigation has been designed to be flexible and open enough to cater for students in grades 7-10.

For Year 7 students, the pendulum offers a unique case of how objects on the surface of the earth are affected by gravity due to its bidirectional motion. Year 8-9 students will find that pendulums are an interesting changing system due to the continuous transformations of potential and kinetic energy. Year 10 students will benefit from the clear example of Energy Conservation due to the pendulum's slow dissipation of movement as multiple forms of friction cause a reduction in useable energy and efficiency losses occur.

This investigation is mostly prescribed as the Aim section is provided, however a full recipe has not been included. Students will have to organise the step-by-step process of their experimental tests. Additionally, parts of the worksheet can be modified to make this investigation more open-inquiry; for example, the results table could be removed, as well as any suggestions and hints.

Question:

Observation: Students are asked to observe children playing on swings. If time allows and there is play equipment available, then students may demonstrate this to the class by swinging without the rider doing any self-pushing. If this is not possible, a video may be shown to the students. There are widely available videos on the internet showing various pendulum wave toys in motion. Here is a link to a 2min video which demonstrates this:

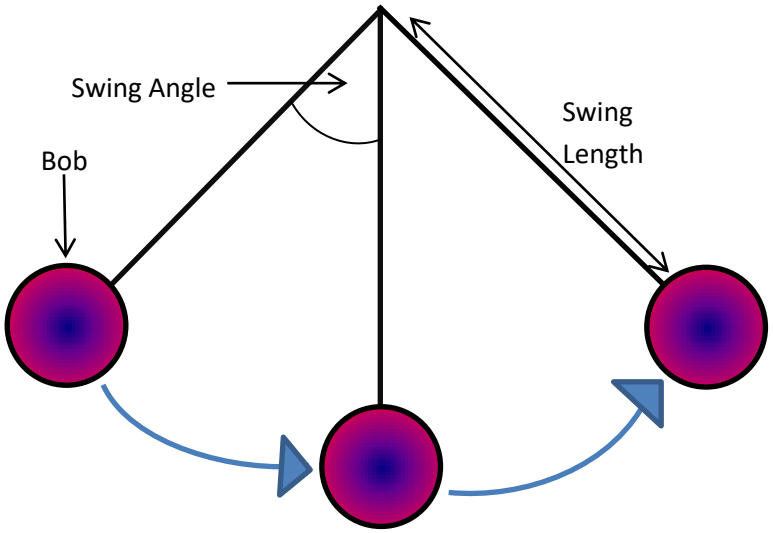
https://www.youtube.com/watch?v=yVkdfJ9PkRQ

Students are to devise a scientific question with the aim of finding whether the bob weight, swing release angle or the swing length is the biggest factor in determining the swing rate.
For example: *Is swing rate mostly affected by the bob weight/mass at the end of the swing, the height that the swing is released from (release angle) or the length of the chain/string?*

At this time, students are asked to write a hypothesis. Share and discuss what students predict will occur. Can students incorporate their understanding of how gravity affects objects on the earth to make their predictions more thought-out? This section will be revisited in the Problem-Solving phase of the Investigation.

Plan:
A materials list is provided to students.

If this is the first time that students are experimenting with pendulums, it may be beneficial to instruct them to copy the diagram shown on the right. Correct labelling will give students the foundation needed to conduct their experiment and describe their observations. This diagram can be used later as a base to form an energy flow diagram of the movement of a pendulum.



Moreover, depending on the available lab equipment, a class demonstration may be necessary for students to understand how to setup the equipment. Safety instructions can be given at this time.

This investigation does not provide all the steps required to perform the experiment. Students will have to devise how to conduct their own fair-test. For each test, students will have to choose what their **independent** and **controlled variables** are. Discuss with students what these are. Since the *Scientific Question* is focused on how the swing rate is being affected, it is appropriate to set this as the **dependent variable**.

Students are provided with the suggestion to calculate swing rate by timing 10 swings with a stop-watch, however they may wish to measure swing rate in another way. It may be beneficial to have a discussion comparing various methods of calculating swing rate. Which methods will provide the most accurate measurement? Can students understand that the reason for measuring the time for 10 swings (as opposed to just 1 swing) is that it minimises the effect of human error in the form of delayed reaction times when handling the stop-watch? This margin of error will be proportionally lower when more swings are timed. Moreover, why is measuring 10 swings better than 100 swings? In each test there will be slightly unequal effects of friction acting upon the system. Increasing the number of swings will make these inequities compound, causing more inaccuracies over time.

Conduct:
Students are instructed to perform their experiments in groups. Students are provided with a table which has space to enter the swing rates for 9 different combinations of mass, pendulum length and release angle. An additional table could be made to record qualitative observations.

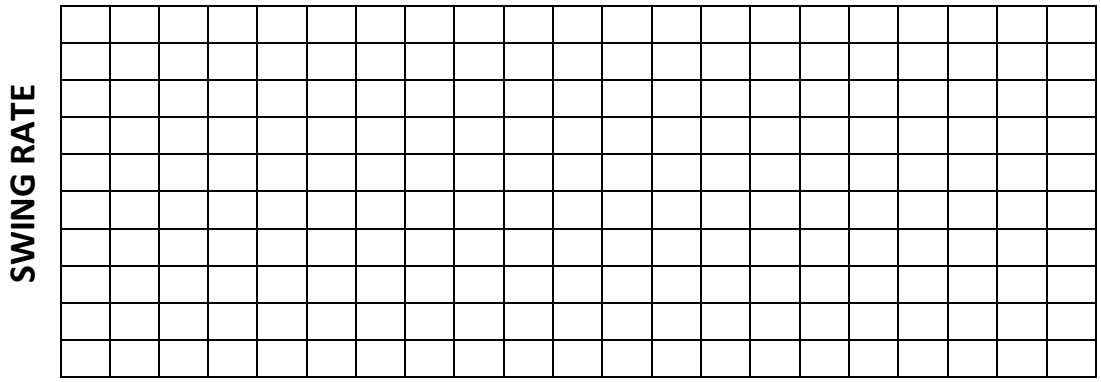
Teachers may motivate students to make as many additional observations as possible. Guidance can be offered with the following suggestions: Are there any non-obvious energy transformations taking place which are affecting the movement of the pendulum?

The first place to look for energy being drained from the system is through the friction of the string/chain rubbing against its attachment. Examine the mechanism which allows the string/chain to move freely. Are there any obvious signs which reveal inefficiency in the system, such as rubbing or sound generation (creaking)? Students can use their pinched fingers as the pivot point and take note if they can feel any heat being generated.

Another common place for energy to be drained from the system is through air resistance. Think of the whooshing sound that occurs when an object on a string is twirled in the air (this is likely too dangerous to perform in the classroom). Eventually all these forms of friction will make the pendulum swing lower and lower, until it stops completely.

Analysis:

Students are asked to represent the data collected in a graphical form in order to better identify any patterns. Students may plot their results in a graph with the below axis. All test data can be put into the same graph if students use a different colour for each independent variable, as well as a key. A line can be drawn between same coloured points in order to find any relationships:



From doing this line graph, students should see that the change in bob weight and release angle produced a horizontal line, while the change in pendulum length created a diagonal line. From this, students can deduce that the pendulum length is the biggest factor in swing rate.

Problem-Solving:

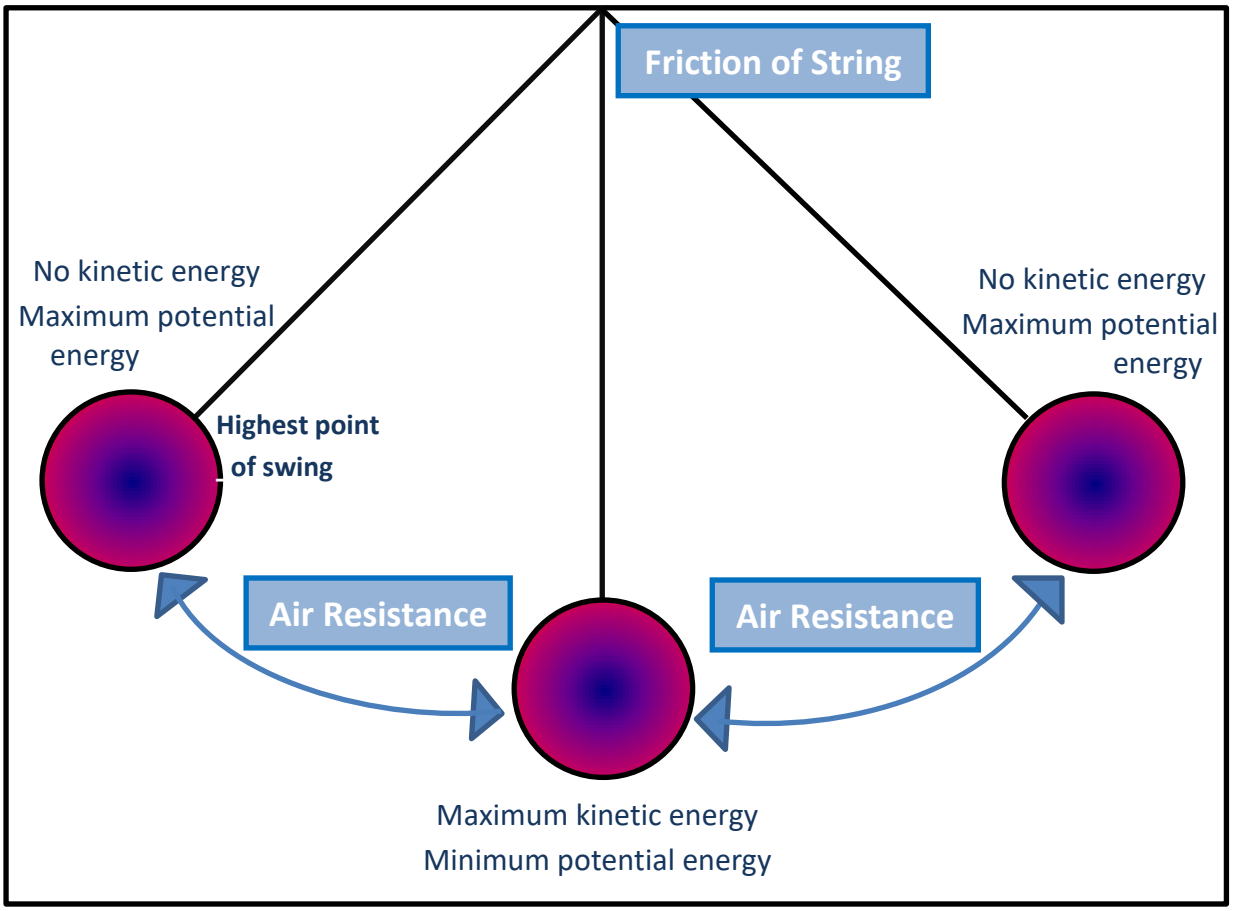
Conduct a class discussion with students with the below focus questions. Students should share if their hypothesis was correct, and what results were expected and unexpected. Students should also share their rationale as to whether their experiment was a fair-test.

- **What did you find agreeing with the science you know?**
- **What new things did you learn?**
- **What did you find surprising?**
- **How would you improve your investigation?**
- **What else could you investigate?**

Motivate students to **explain the movement of a pendulum using their theoretical knowledge**. Can Year 7 students explain the movement of a pendulum by identifying the role of gravity and all the balanced and unbalanced forces at play? Can Year 8-10 students explain the movement of a pendulum as a system of energy? Below is an example explanation with a flow diagram:

A moving pendulum is a system of energy which experiences continuous transformations between kinetic and potential energy. When the bob reaches the highest point of its swing, it stops moving just before it changes direction. As there is no movement, there is no kinetic energy. At this point the bob also has the greatest gravitational potential energy. As the bob swings downward, it speeds up as the potential energy is being transformed into kinetic energy. The bob's kinetic energy

is greatest at the bottom, propelling itself upwards again to another highpoint, repeating the process again in the opposite direction.



From understanding the theory presented above, can students now attempt to **explain why swing rate is most affected by pendulum length, and not the bob's mass or release angle?**

A longer pendulum length means that the bob has a longer path to travel. This takes more time.

The movement of the bob is powered by gravity. As the bob is released it experiences an accelerated fall towards the earth. The gravitational acceleration which acts upon the bob is not dependent on its mass.

When the release angle is higher, the bob is falling for longer. This speeds up its movement due to acceleration from gravity. So even if the bob has a longer distance to travel, due to the bigger release angle, the increase in speed compensates for this.

<u>Conclusion:</u>

In this section students will be able to answer their initial question, making a short statement about what their overall findings were.

Were students successful in answering their question? How many groups were able to show that their hypothesis was correct?

Extension activity: Students can explore how grandfather clocks keep time. Why can pendulums be used as a timekeeping element?