Planetary Orbits – Teacher Notes

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Introduction:

This investigation looks at how planets orbit around the sun in a seemingly consistent way. However, what would happen if any one feature of the solar system was to change? This simple and inexpensive activity asks students to make a model of a planetary orbit and play a game in order to create a “balanced” spin. This creates a hands-on experience that engages students in a process of discovery and self-directed learning.

While students are given instructions on how to construct their model, the rest of the investigation is designed to be at a guided to open ‘inquiry’ level. Students develop their scientific skills by posing their own scientific question, choosing how to record their own results and perform their own analysis on the data. Students must identify how the relationships they find are reflective of gravity and a planet’s orbit.

This investigation covers information that is given in the junior sciences, such as understanding gravity and the development of models of the solar system. Students that are studying how energy transforms and transfers in a system will benefit from analysing their model in that context. Year 10 students will benefit from identifying how Newton’s Laws of Motion apply to the model.

Question:

Students are asked to first construct the model and have a play with it. Refer to Figure 1 to see how the model will work. Students are then asked to come up with a scientific question that looks at certain relationships within their model. These relationships will then be used in the Problem-Solving section, where students learn how this relationship reflects a property of gravity.

Examples of questions are: What happens to the spin speed when more washers are added? **OR** How fast is the rubber moving when it is closer to the pipe versus how fast it moves when farther away from the pipe? **OR** What happens to the speed of the spin with a larger or smaller rubber?

Students may work in groups and decide on the question that their group will target. For further guidance, teachers may request that students identify their independent, dependent and controlled variables before writing out their Aim and Hypothesis.

Below is an example of what students can write:

> **Question:** What happens to the spin speed when more washers are added?
>
> **Independent Variable:** Amount of washers **OR** Weight of washers
>
> **Dependent Variable:** Time taken for 5 revolutions

Controlled Variables: Radius of the revolution (mark the string at the desired length with a bit of tape, and then ensure the tape sits just above the pipe during the spin)

Aim: To find how the weight of the washers affects the spin rate required to keep the washers in position and with a consistent revolution radius of 10cm.

Hypothesis: We predict that the heavier the weight, the faster the spin rate.

Plan:

Students are provided with a materials list and instructions on how to construct their model. Spinning the model so that the washers stay in place can be a little tricky, and students will have to use their co-ordination skills. This will present a fun challenge for students, but can also be dangerous if safety precautions are not followed. Therefore, please ensure the following:

- All tied objects are double knotted. The rubber should have a hole through the middle of it in order to securely tie it down. Students should be told that no spinning is allowed until this is checked.
- A clear, open space is provided to students
- Students wear eye-protective gear at all times
- Students wear closed-toe shoes made with a thick material.

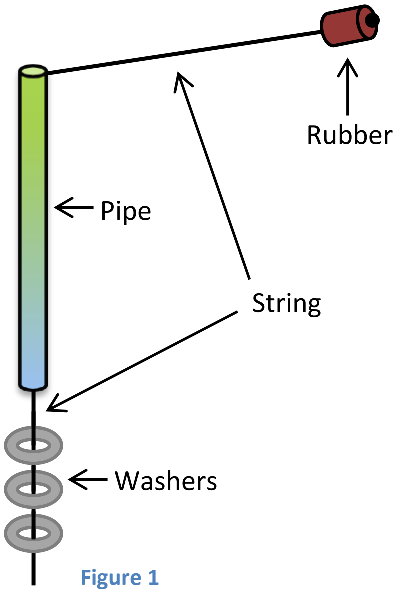
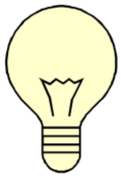


Figure 1

Once students have played around with their model and completed the Question Section, they will now perform their first test and be asked to record results in the way that they choose. Teachers may explain to students that their results table should represent the independent and dependent variables chosen. This will start students thinking about what method they need to follow in order to fill their results table.



To make this investigation more guided, teachers may ask students to write down their Method before commencing. These can be shared amongst lab groups and students may offer each other feedback.

Teachers can discuss with students how many tests are required in order to see a relationship. Usually two tests are insufficient to see a pattern; therefore students will have to perform three or more tests.

Teachers may also ask students what their controlled variables are and what considerations they are taking to keep them consistent. Some good-practise suggestions are the use of markers, having multiple students take the measurements and performing repeat tests to find an average.

In order to incorporate technology and increase the accuracy of results, students can record the experiment on video. They may then play the video on slow-motion in order to more accurately time the revolutions and look for any spins that were off and should be disregarded.

Conduct:

Students can commence their experiment once their model is constructed and their results table has been drawn. Below are three examples of results tables that students may have drawn. If more guidance is required, a pre-constructed table can be provided to students:

No. of Washers	Time for 5 Revolutions (seconds)				Observations
	1st Trial	2nd Trial	3rd Trial	AVERAGE	
1					
2					
3					
4					

Radius of Revolution (cm)	Time for 5 Revolutions (seconds)				Observations
	1st Trial	2nd Trial	3rd Trial	AVERAGE	
5					
10					
15					
20					

Rubber Size	Time for 5 Revolutions (seconds)				Observations
	1st Trial	2nd Trial	3rd Trial	AVERAGE	
small					
medium					
large					

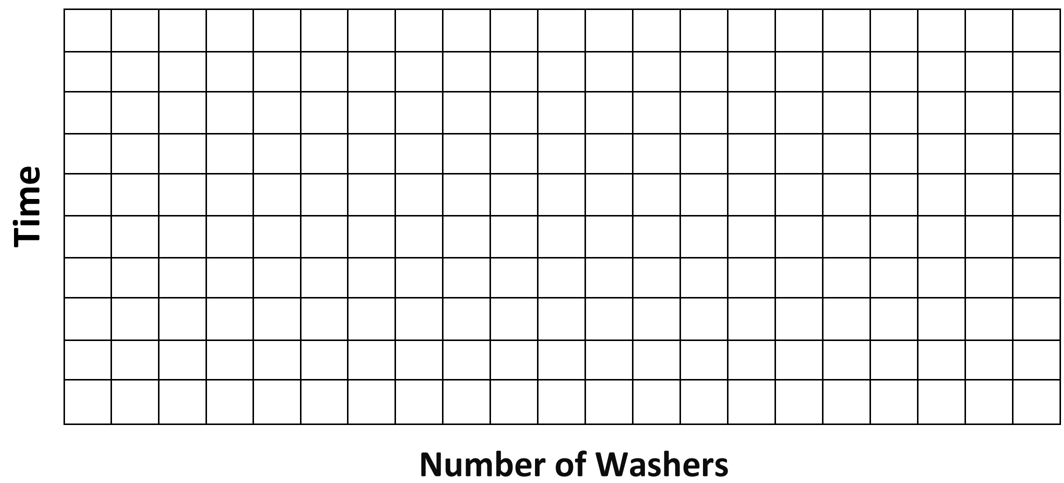
It is expected that there will be differences in the level of organisation and in the number of tests that each group has chosen to perform; therefore time to complete the experiment for each group may vary significantly. In this time teachers may motivate students to make as many additional observations as possible by asking them to record qualitative results. These will help students in the Problem-Solving section, as they try to explain the physics that is occurring.

Guidance can be offered with the following suggestions: Does the model generate any heat when being spun (touch parts of the model after a spin to find out)? Does the model make any sounds as it is being spun? Are there parts of the model that could be made more efficient (i.e. is the string catching on anything)?

If students are finding it difficult to time the spins, then why not create a mechanism that works similar to the spindle on the wheel of fortune? Cut a piece of butcher paper and hold it into place with clips so that the rubber swipes past it on every turn. Students will then be able to hear when a revolution has been completed.

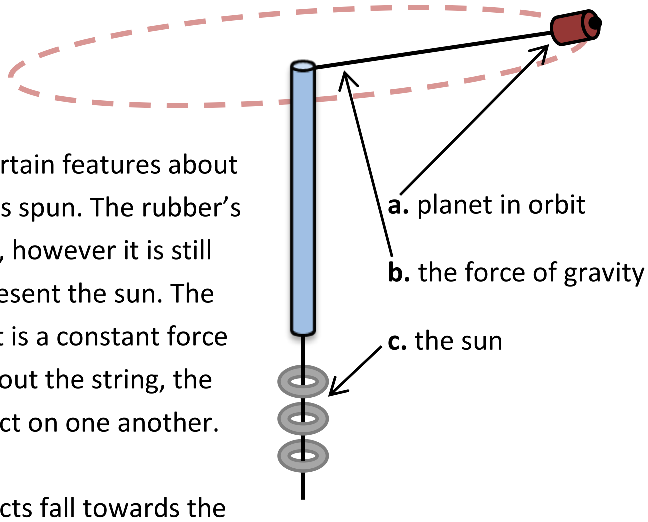
Analyse:

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, with the x-axis being whatever independent variable chosen, and the y-axis being the dependent variable.



Problem-Solving:

Students are asked to label a diagram of their model with three components involved in planetary orbit. This is the first step in students discovering how their model can teach them certain features about gravity. The planet in orbit is the rubber which is spun. The rubber's weight does affect the movement of the model, however it is still much less weight than the washers, which represent the sun. The force of gravity is represented by the string as it is a constant force of attraction. This force is called 'tension'. Without the string, the rubber and the washers wouldn't have any effect on one another.



Newton realised that the force that makes objects fall towards the Earth is also the same force that keeps the planets in orbit around the sun. The gravity acting on the washers, causing them to fall towards the Earth, is allowing the model to work. Therefore it can also be pointed out that the force of gravity causes the downwards force of the washers.

From analysing the results, students will be able to see that the closer the rubber is to the pipe, the faster is has to spin. They will see that the heavier the weight of the washers, the faster the spin needs to be to keep the rubber going around. They will also see that the heavier the rubber, the slower it can be spun. From these findings ask students what they can infer about the solar system?

Examples of questions are: Does Mercury orbit faster than Earth? (Mercury's orbit speed is 170,505km/h, while Earth's is 110,000km/h.) If the Sun became smaller, what would happen to the planets? (They would slowly orbit away from the Sun as the gravitational force of the Sun would decrease). What would happen if the Earth doubled in size and stayed in orbit at the same distance from the sun? (If the Earth maintained its present orbit, its velocity would slow down).

Advanced students can calculate the velocity of a planet by the equation: $v^2/R = g$ and the time period of an orbit is given by: $2\pi R / v$, where v is velocity of the planet, R is distance of planet from the Sun and 'g' is acceleration due to gravity ($9.8ms^{-2}$) of the sun at distance R from its centre.

Perform a class demonstration showing how massive objects in space bend space-time! Obtain spandex from the fabric store and attach it to a round frame. Then collect some weights and different sized marbles to show how satellites orbit a heavier object. You may observe this demonstration being done on the following link: https://www.youtube.com/watch?v=OKXVRu6JL54

Students may input the values of the model to see how closely it can predict specific orbits in the solar system.

Year 10 students will benefit from explaining how Newton's Three Laws of Motion apply to their model. Example explanations are below:

Newton's First Law: The constant manual spinning applied to the model (which counters the loss of energy from air resistance) is reflective of the constant motion of planets that move in a vacuum.

Newton's Second Law: Heavier objects accelerate less than lighter objects, when experiencing the same force. This is calculated by F=ma.

Newton's Third Law: Gravity is a constant force, and therefore always acting on objects. The Earth's materials, which form the ground are also exerting an equal and opposite force back. This allows us to be able to rest in a balanced state on the surface on the Earth.

At this stage students can evaluate whether their experimental design was satisfactory. Did they test the correct things in order to obtain an answer to their question? Did they conduct a fair-test? Did students ensure that the controlled variables remained consistent throughout, such as how low the washers hung as the model was being spun? Is having the same person do all the spinning a consideration? Were any markers used to keep tests consistent throughout? Discuss these issues with students as they assess the reliability of their results.

Conclusion:

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?

The calculation of the length of the solar year was refined to 365 days, 5 hours, 46 minutes and 24 seconds by Al- Battani in the tenth century. Students can research what model he used to calculate this, and present it to the class.