Rollercoasters – Teacher Notes

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Introduction:

Learning about Forces can be a lot of fun when looking at rollercoasters. Not only are these engineering marvels absolutely thrilling, they are also an impressive display of balanced and unbalanced forces and energy transfers and transformations. This investigation is safe and inexpensive, and it covers content in the Year 7 to 10 Physical sciences. This investigation can be extended to include an excursion to the local amusement park or fair.

Students will be allowed to utilise their creativity in order to design their own rollercoaster track. Before they make their design, students will be required to compare the efficiency of three simple tracks. From this initial activity, students will gather data that they can then apply to their own unique track design. This will give students the impetus to understand the scientific theory underpinning this investigation, such as gravity, friction and conservation of energy, in order to make an optimal design.

This investigation has elements that are guided and open inquiry. Students are presented with an aim and instructions; however they must choose how they will record and analyse their data. Students will also decide how to apply the knowledge that is gained. This will allow students to practice their science inquiry skills while being engaged.

Question:

Activity One: An Aim has been provided to students, which is to measure the efficiency of three different tracks. However, the scope of this activity can be extended to include additional measurements. For example, students could be asked to measure the speed of the marble. Advanced students may measure the acceleration of the marble at different points on the track. As the purpose of this activity is to collect data in order to inform the students' designs later on, any additional questions that assist in this process could be included. Discuss with students what their predictions are by looking at the rollercoaster track diagrams in the Conduct section. Students can then be asked to write a Hypothesis.

Activity Two: An Aim has been provided to students, which is to design their own rollercoaster, however there is enough room in this for students to focus on a particular design feature that they prefer. Students may choose to make a track with the longest run-time possible while ensuring a safe ride by not including any falls with less than a 15^{o} incline. Other students may choose to incorporate as many twists, turns and loops that they can while also maximising runtime. If a class competition is chosen, then it is recommended that a more defined Aim is decided upon. For example, there could be a minimum standard for 3 changes in direction, with the longest running track being the winner.

Plan:

Activity One: Students are provided with a materials list and instructions. However, if teachers wish to extend the scope of this investigation, then additional materials could be included. For example, balls of different weights could be included to see if there is any impact on the efficiency of the track. The consideration here would be whether the increased force (F=ma) would be countered by the friction against the pipe surface. A video camera would also be a valuable tool when attempting to measure speed and/or acceleration of the marble.

Activity Two: In this activity students must plan out the construction of their track design. They will do this by making sketches of their desired shape. Their sketches should be informed by the data collected in Activity One. Discuss with students how their designs have been influenced by the results of the previous activity, such as avoiding sharp turns. Students may also come up with a strategy to test their ideas in order to improve on their design over time. For example, students may wish to include loops, but are unsure as to how big they can be without running the marble through them first.

Additional piping may be given to students in order to allow more elaborate designs. Of course, each group should be given an equal length of piping. Additional retort stands may be needed to hold the track in its desired shape, while pipe cleaners can be used to hold loops into place. Placing books or other items under the pipe to create small "hills" could also be considered.

Conduct:

Activity One: Students have been given instructions to follow. They will need to construct a table in order to record their results. Teachers can provide guidance by discussing with students what the dependent and independent variables are. This would be the height that the marble reached and the track number respectively. Students should also be advised to leave a column to include qualitative observations. Below is an example table that could be given to students to make the investigation more prescribed:

Track Design	Start Height (cm)	Reach Height (cm)	Observations
1	120		
2	120		
3	120		

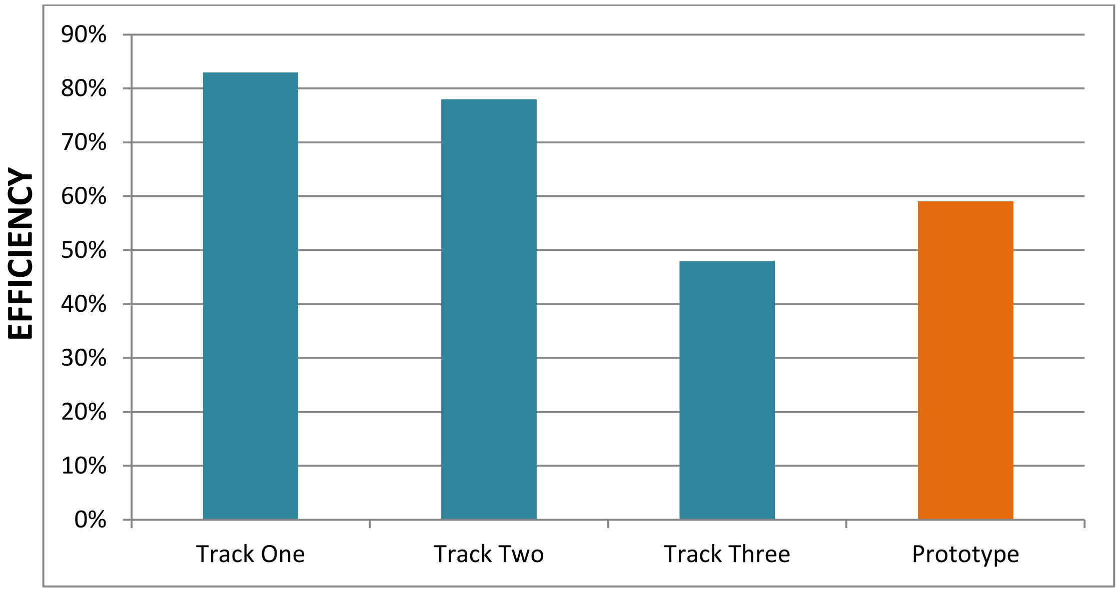
As this task is designed for students to gather data for their track design, encourage students to make as many additional observations as possible. Can students identify any energy transformations occurring that are leaking energy away from the system? These could be in the form of sound or heat energy from friction. Can students approximate where on the track the marble is speeding up and where it is slowing down? How smooth is the marble when rounding corners? Is there any bouncing occurring in the pipe? If this is happening, then quite a bit of energy could be lost, making the system have a low efficiency score.

Activity Two: Students are required to construct their track from their sketches. Students can be encouraged to test out their design and revise their sketch if desired. Advise students that this is an important part of developing ideas. As students are testing their design, ask them to make observations. Can they link what they learnt in Activity One to what is occurring in their own design? Are there any components of the previous tracks that they have added or left out?

Analyse:

Activity One: Students are required to calculate the efficiency for each of the three tracks. A formula has been provided to students. Each answer should be expressed as a percentage that is less than 100%. Discuss with students how these calculations can assist us when comparing the three tracks.

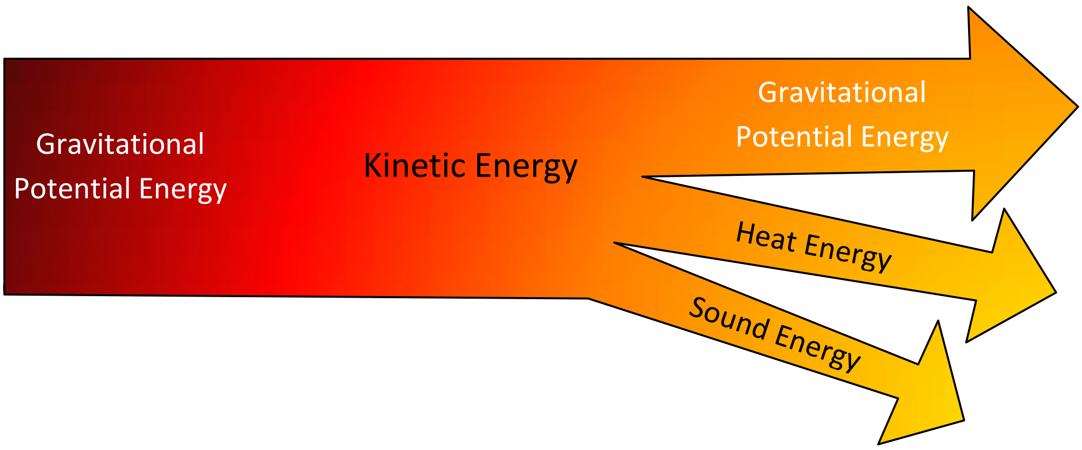
Activity Two: Students are asked to calculate the efficiency of their track design. They can then compare that number with the three other efficiency calculations made in Activity One. Students are asked to construct a graph so that their data can be expressed visually. An example graph is given below:



Problem-Solves:

Assess: Students are asked to discuss the strengths and weaknesses of each track design. Which track design was the most fun to watch? Which track was the shortest-running or inefficient? As gravitational potential energy is the determining factor of how much energy goes into the system, did students think of elevating the start of the track from the end?

Explain: Students are asked to identify any energy transfers and transformations. Students should be able to identify that the ball has gravitational potential energy when it is dropped. This energy is then transformed into kinetic energy which can be seen as the marble moves. Energy is lost through friction in the form of heat and sound energy. When the marble moves into an elevated position, getting ready for another drop, gravitational potential energy is rebuilt. This engages the cycle once again. Motivate students to draw a diagram of this, similar to the one provided below:

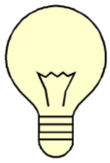


The reason that the cycle depicted in the above diagram does not continue indefinitely is because of the efficiency losses in the form of friction. Friction continuously leaks energy from the system in the form of heat and sound energy. This explains why the efficiency of each track is less than 100%.

Evaluate: Students are asked to evaluate the reliability of their experiment. Discuss with students their method for measuring and recording results and discuss any potential improvements. For example, students could have performed repeat tests in order to find an average result for each track. Another consideration is whether any force was applied to the marble as it was dropped into the pipe. If there was extra force applied, then additional energy was put into the system and the efficiency calculations will be inaccurate.

Conclusion:

Students are invited to write a short conclusion to this investigation. Ensure that students include whether their Aim was achieved and if any predictions that were made turned out to be correct.



Research: Students can research what g-forces are and which rollercoaster provides the highest g-forces.

Reference: