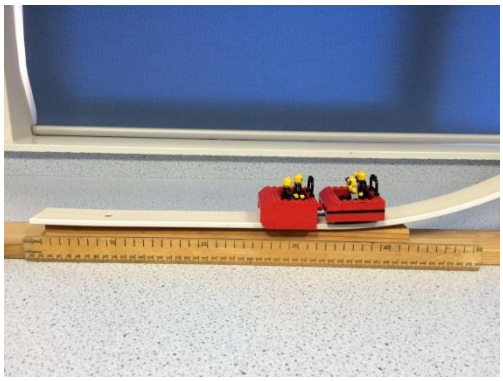
Rollercoaster energy transfers

Introduction



This learning scenario allows pupils to work as a team in order to design the fastest rollercoaster. It incorporates different areas of the GCSE physics curriculum and allows the use of ICT in several new and innovative ways.

Lesson Outlines

Lesson 1: The pupils are provided with a lesson which teaches them the theory of gravitational and kinetic energy. The pupils need to know how to calculate energy values for both of these types of energy using the formulas below:

$$\textbf{KE} = {}^{1}/_{2}\ \textbf{mv}^2 \text{ and } \textbf{GPE} = \textbf{mgh}$$

After examples are provided and the pupils have the opportunity to use these formulas in calculations provided on a worksheet the context of a rollercoaster is introduced. To make the context more real life the top 5 highest rollercoasters in the world are used for the calculations.

You have 5 minutes to work out the remaining velocities, using your values for GPE

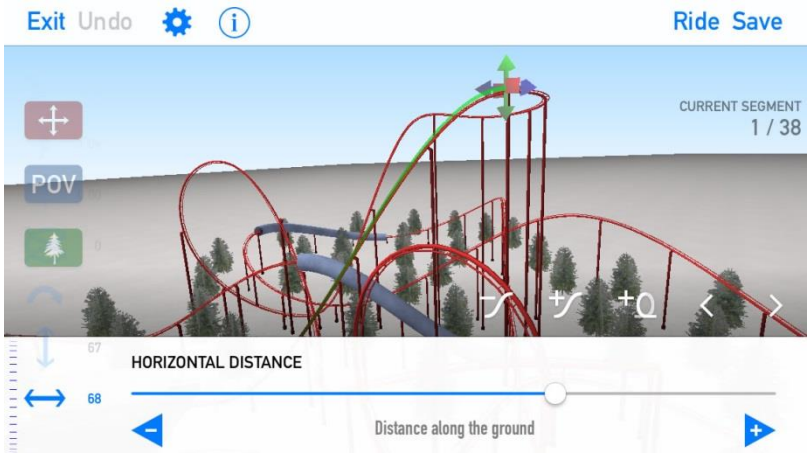
Kinetic energy = $\frac{1}{2}$ x mass x [velocity]^2

Roller Coaster	GPE (J)	Velocity (m/s)
Kingda Ka	4,170,000	52.7
Top Thrill Dragster	3,900,000	
Tower of Terror	3,450,000	
Steel Dragon	2,910,000	
Millennium Force	2,820,000	

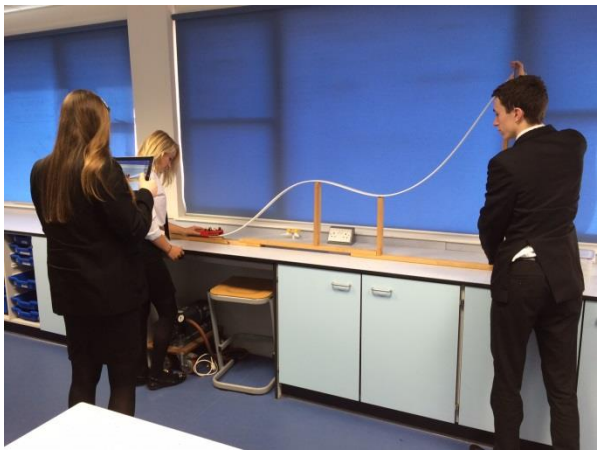
Extension: Write down the relationship between the height and the velocity of the roller coaster

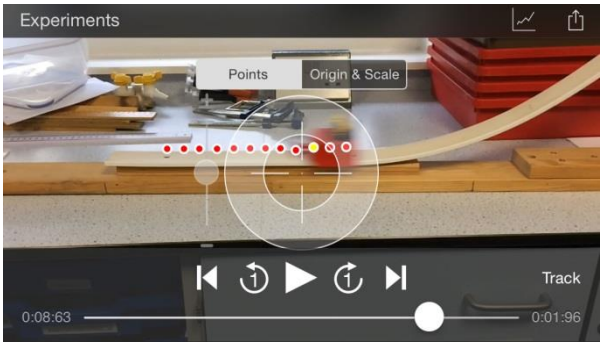
The pupils need to understand the link between the gravitational potential energy the rollercoaster car has at the top and the kinetic energy it is then converted to at the bottom. Again example calculations are provided to show the pupils how to rearrange the kinetic energy formula so that you can find the velocity of the rollercoaster at the bottom of the slope. (see left)

Lesson 2 : This lesson allows the pupils to consolidate the theory they learnt in the previous lesson through the use of ICT. Working in small groups the pupils will have 2 tasks to complete. The first task is to design a roller coaster that will reach a speed of 60 m/s using the app "Coaster Physics" on a tablet. In this app the pupils have to change the design of the track and then ride the track



while the app shows the velocity and energy changes through each part of the track. The pupils can use the theory they learnt in the previous lessons to calculate the theoretical height needed for their rollercoaster before designing it at that height and seeing the actual result.





While some students in the group use the app the other members of the group are going to measure the actual speed on a model rollercoaster. The model roaster can be built by the students themselves using toy race tracks and cars or they can be made in advance using simple hardware materials.

The pupils initially measure the start height of the rollercoaster on the model and then work through the calculations to find the theoretical speed of the rollercoaster at the bottom. Once they have done this they are going to use a speed measuring app (either "Video Physics" or "Speedclock") to find the actual speed of the rollercoaster. The app allows them to video the rollercoaster and then the app will calculate the speed of the moving object.

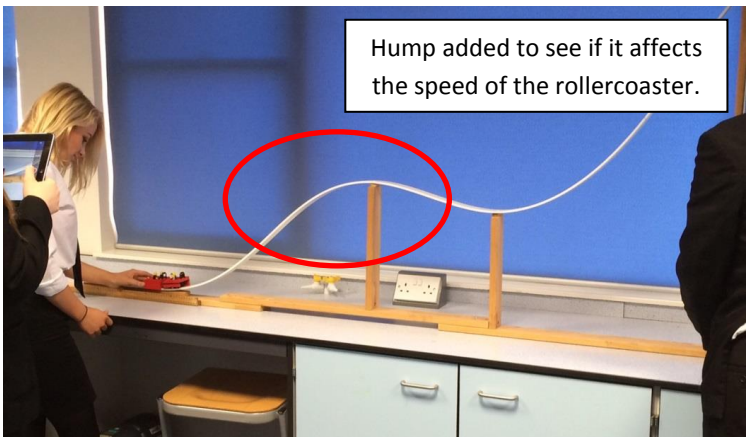
Prompt a discussion with the pupils to think about why there actual measured speed will be less than the theoretical speed they calculated. This allows them to think about friction and air resistance and how these forces effect the energy transfer involved.

Lesson 3 – Can be used as an extension for more able pupils

The final stage which can be developed from this scenario is to get the pupils to think about two further rollercoaster designs.

- A rollercoaster with a hump in the drop from the top to the bottom
- A rollercoaster with a different mass

The common misconception in both of these scenarios is that the extra hump or the extra mass will have an effect on the final velocity of the rollercoaster car. However, when the pupils work through the calculations they will see that they have no effect. Once they have done the calculations they can use the model made for the last lesson to test their theory by changing the mass of the rollercoaster and using the app to find the speed again. They can also calculate the values for KE and GPE at different points down the slope including the hump in the middle.



Wider Context

Classroom Use: This scenario has been used in my lessons during the last two years. I use it with both Year 11 GCSE classes and top set Year 9 classes. It proves very effective at engaging the pupils in their learning but also making them inquire about the physics presented to them in a hands on way. A number of my pupils commented on working through this scenario: *"I have really enjoyed the last 3 lessons as I feel I have been able solve a real life problem. Working in a team is great and we are quite competitive to beat the other teams"* (Kyle, Year 11). One of my year 9 students was particularly interested in the ICT involved *"Using the iPads in this new way was really exciting, it was great to use them for some real Physics rather than just internet research"* (Jake, Year 9).

Collaboration: This scenario provides a fantastic basis for working in collaboration with another school. There are two ways this can be set up, both of which make use of the ODS toolbox and the user guide it provides for inter-school collaboration.
Option 1: - Schools can pair up with another school. Both schools using the app "Coaster Physics" will then design rollercoasters in their teams. These designs can then be posted on an ODS blog where the teams in the other school have to calculate the energy changes involved and ultimately the final velocity. The teams from each school can then check the other schools' calculations.
Option 2:- Using an ODS blog a specific rollercoaster design requirement can be posted. That design requirement could include: max speed values, maximum build costs, location requirements, material availability, etc. Each school involved could then post their entries to this challenge which would have to include a summary of why their design would be the best including all the relevant energy calculations. A winning design could be chosen by the schools taking part.

Economics and Ethics: As part of the design process of the rollercoaster the economics can always be included. The teams can have a fixed budget of materials that they can use which means they would need to think carefully how they could maximise the height of their rollercoaster in order to achieve the maximum speed. If this was being run as a STEM project the economics could be taken further by asking students to estimate an annual income for their rollercoaster based on a ticket price from a similar theme park.

As an extended project and a further lesson a discussion could be initiated between pupils to decide if a theme park should be built. Different members of the class could be assigned different roles, e.g. Local resident, Environmentalist, Theme park owner, Local building company, Job Centre employee, etc.

Each member of the class then needs to think about how they would feel as that person if a theme park was to be built in their town; what would be the advantages and disadvantages. Once the class has had time to think then an open discussion can be started and the pupils can be encouraged to come to a mutual agreement while being considerate for all the opinions put forward.

Implementation in the Classroom

Rollercoaster energy transfers – Teacher Notes

Equipment

- App called “Coaster Physics”. This allows the pupils to design their own virtual rollercoasters
- App called “Video Physics” or “SpeedClock”. Both of these apps allow the pupils to measure the speed of the rollercoaster
- Toy race track to make model roller coasters or alternatively basic hardware materials to manufacture your own rollercoaster.

How to use the scenario

This scenario can be used to cover many different parts of the curriculum. Some of them are listed below:

Science :

- KS3 – Simple energy transfers if used as a demonstration without the calculations.
- KS3 – Speed, an engaging way of showing how to measure speed using the Video Physics app or Speedclock ap.
- KS4 Physics – Energy transfers, potential gravitational energy transferred to Kinetic Energy
- KS5 Physics - Equations of motion and circular motion as the students can calculate the theoretical speed the rollercoaster would take off going over the hump and then use Video Physics to see if they are correct.