Introduction

The Formula for Thrills suite of KS3/KS4 resources provides students with an opportunity to use mathematics in a real world environment through a variety of stimulating contexts based on a theme park. Each context presented aims to help students understand how real-life mathematical thinking is used by the engineers, designers, mechanics and planners whose job it is to entertain and thrill people, keep them safe and to look after their needs while enjoying the park.

Formula for Thrills supports the mathematics curriculum for pupils aged 12-16yrs and the science curriculum for pupils aged 14+. It has been developed in collaboration with theme park operator THORPE PARK Resort using realistic figures, statistics and situations as far as possible. Although there has been some modification to make the situations accessible to students, they are authentic and recognisable to people working in the industry.

The materials do not present problems in a purely mathematical way; instead students are required to use and develop their skills to identify situations in which the effective use of mathematics enables the development of solutions to problems. Students must consider and check their responses are realistic and practical as well as being technically correct.

The extension activities also link to the Totally in control Scheme of Work learning objectives. In these, students identify how sequences of commands can be used to run equipment, understand features of a system in terms of how its design responds to a detailed brief and also how a system can be modified to improve its performance.

About the resource

Formula for Thrills comprises two elements:

1. An interactive learning tool with a link to downloadable Teachers' Notes.
2. Supporting materials: An introduction, Formulae Tasksheets and a set of six Extension Activities.

The interactive learning tool

This is based on the design of a rollercoaster and track styles, and involves students finding out how it can be made to thrill and yet still finish at a safe speed by altering various factors. At Levels 1 and 2 this is done empirically; at Level 3 students need to calculate values from formulae.

Level 1
Students alter the height of the start and the end of the ride. The objective is to set the track up so that the train reaches the end at a safe low speed. This depends upon the difference in height between the start and the end; there is a range of combinations of heights (all of which have similar variations) which will satisfy this.

Students experiment with different values to find out what will work. To assist, there are speed cameras; these show the target speed and the actual speed, and will guide students in selecting values. Some of the tracks involve an intermediate increase in height, such as humps or a loop. As long as these aren't set up to be higher than the start point they, in fact, make no difference to the speed at the end.

Level 2
A further variable is introduced - that of horizontal distance. Students now need to 'trade off' one variable against another. If the length is increased, friction will cause more energy to be dissipated, which will need to be compensated for by increasing the difference in height between the start and the finish.

Level 3
The challenge increases as students are guided through making a series of calculations. The accompanying Formulae Tasksheets structure calculations for students, guiding them from selecting the height of each section of track to working out the speed of the train at various points. This enables students to predict the speeds and therefore decide if the design is a good one. An unsatisfactory design is one in which either the train stalls en route or reaches the end at a velocity (speed) of more than the limit indicated. Students may need to change the heights and recalculate the speeds in order to come up with a satisfactory design.

Supporting materials

The Formulae Tasksheets and six Extension Activities are based on different aspects of the planning and operation of a theme park. They all involve students in having to understand a context, assimilate information and develop a response. Some are relatively closed but others are open-ended and this is intentional. Part of being a mathematician is recognising what is known and can be responded to definitively and also what is not defined and can therefore only be answered in more general terms.

- Teachers' Notes
- Curriculum Links
- Formulae Tasksheets for use with Level 3 of the interactive learning tool
- Extension Activity 1 - Shape and structure: Design a ticket booth
- Extension Activity 2 - Structures and strength: Design a rigid shape
- Extension Activity 3 - Planning a business: Aiming for profit
- Extension Activity 4 - Running a business: Organising the staff
- Extension Activity 5 - Plans and maps: Setting out amenities
- Extension Activity 6 - Running a theme park: Managing the rides

Extension Activity 1 - Shape and structure: Design a ticket booth

Consideration of what data is needed in order to choose the dimensions of a ticket booth and how that translates into a finished shape. Communicating what that shape looks like is an important part of the process.

Extension Activity 2 - Structures and strength: Design a rigid shape

Use of simple construction materials to test shapes such as triangles and squares for rigidity, analysis of the findings to draw general conclusions about rigidity and the use of cross-bracing to make light structures strong.

Extension Activity 3 - Planning a business: Aiming for profit

Consideration of the cost of a rollercoaster not within a theme park and charging per ride. This will allow for getting a feel for the profit margins and other issues which will also apply to some extent to rides inside a theme park, and estimating likely numbers of people using the rollercoaster.

Extension Activity 4 - Running a business: Organising the staff

Staff involved with providing other services in a theme park, such as refreshments. Staffing as a major area of expenditure against highly-variable demand: people becoming hungrier later in the day and the kind of refreshments opted for depending on age and weather.

Extension Activity 5 - Plans and maps: Setting out amenities

How mathematics is used in the design of the theme park and what mathematics can be done in context around the park.

Extension Activity 6 - Running a theme park: Managing the rides

Running a rollercoaster: thinking about a ride and how it is managed. How systems are designed and have to be made to work with people in real situations. The challenge is both to understand how the system works and to consider the implications for passengers and staff.

How to use

This suite of materials has been designed to be used in a variety of ways. Teachers may need to modify and customise materials to fit a range of situations, depending upon class size, attainment, prior experience, interest and curriculum model.

The Formula for Thrills interactive learning tool is designed to be used by students working individually or in pairs. The model is a simplified one and increases in challenge from Level 1 through to Level 3.

The extension activities are based on other theme park contexts and develop different skills. Each one is supported by teacher and student resources in the form of learning objectives and outcomes, and learning activities.

Further resources

Find out more about how Siemens technology provides a formula for thrills:

Totally in control Scheme of Work: students identify how sequences of commands can be used to run equipment, understand features of a system in terms of how the design of a system responds to a detailed brief and how a system can be modified to improve its performance.

GreenPower Challenge**:** an annual engineering challenge where teams of young people design and build electric racing cars before competing in a low octane, high speed race to the finish!

Solid Edge: Free design and engineering software for students. Industry-leading mechanical design software, Siemens Solid Edge Student Edition is available at no cost (**free**) to students of all ages for use outside the classroom in support of their studies or extra-curricular activities such as the Greenpower Challenge. To obtain the Solid Edge Student Edition register at www.siemens.com/plm/solid-edge-student.

THORPE PARK Resort is celebrating the start of the academic year by launching a new set of tools to help teachers and inspire students. Alongside their existing KS4 Science resources and KS4 and KS5 Business Resource Pack, they will be producing some fantastic learning trails in Business and Physics. These simple visual guides are being designed to complement their thrilling rides and offer key curriculum elements to look out for while navigating the Resort.

Maths KS3

Through the mathematics content, students should be taught to:

Develop fluency

- select and use appropriate calculation strategies to solve increasingly complex problems
- substitute values in expressions, rearrange and simplify expressions, and solve equations.

Reason mathematically

- extend and formalise their knowledge of ratio and proportion in working with measures and geometry
- make and test conjectures about patterns and relationships; look for proofs or counter-examples
- begin to reason deductively in geometry, number and algebra, including using geometrical constructions
- interpret when the structure of a numerical problem requires additive, multiplicative or proportional reasoning.

Solve problems

- develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems
- develop their use of formal mathematical knowledge to interpret and solve problems, including in financial mathematics
- begin to model situations mathematically and express the results using a range of formal mathematical representations
- select appropriate concepts, methods and techniques to apply to unfamiliar and non-routine problems.

Maths KS4

Through the mathematics content, students should be taught to:

Develop fluency

- consolidate and extend their numerical, algebraic, geometric and graphical understanding
- apply appropriate reasoning strategies and degrees of accuracy to increasingly complex problems
- increasingly evaluate situations based on the underlying mathematical properties rather than on surface features
- increasingly understand the world of finance and apply arithmetical and graphical methods in this and other contexts.

Reason mathematically

- select and use other forms of reasoning as appropriate: algebraic, geometric, statistical, probabilistic and logical, and know when to express their arguments informally or formally, including working directly from definitions.

Solve problems

- use mathematical knowledge to solve problems within and outside mathematics, including financial mathematics and mechanics; particularly problems that are unfamiliar in presentation and context, and that embed mathematical ideas which have not yet been formally taught
- develop mathematical knowledge, in part through problem solving and evaluating the outcomes.

Science KS4

Students should be taught about:

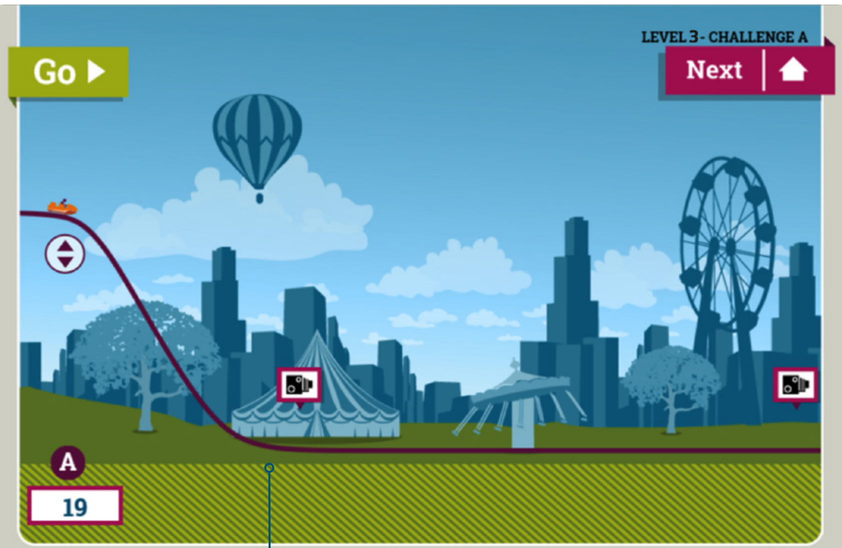
- energy changes in a system, calculating the stored energies and energy changes involved
- conservation of energy in a closed system, dissipation.

Important concepts:

- The rollercoaster starts from a high point and rolls from the start of the track to the end. It's only supply of energy is due to it being high up at the start. From this we can work out its speed at various points.
- Gravitational potential energy (GPE) is related to the height above ground. The higher up, the more GPE. At ground level, the object has no GPE.
- GPE is calculated from mgh:
  - **m** stands for the mass of the train and is 5000kg
  - **g** stands for gravitational attraction and is $10 m/s^2$
  - **h** stands for vertical height above ground level, is measured in metres and will be different at various points along the track
- Kinetic energy (KE) is related to speed. The faster an object moves, the more KE. Stationary objects have no KE.
- KE is calculated from $\frac{1}{2} mv^2$, in which:
  - **m** stands for the mass of the train and is 5000kg
  - **v** stands for velocity, is measured in metres per second (m/s) and is what you will be working out most of the time.
- At any point the total mechanical energy is the sum total of GPE and KE.
- As the train progresses, some of the energy is dissipated through friction and sound, so less is retained as mechanical energy. The percentage retained becomes less at each stage and you are told how much.
- It is useful to calculate the amount of GPE and KE at the top and bottom of each slope. For this we can use the two formulae:

$$GPE = mgh \qquad KE = \frac{1}{2} mv^2$$

Although we can calculate the speed at intermediate points, these don't actually make any difference to the speed at the end. The only thing that affects that is how much height has been lost from the start. The greater the overall drop, the faster the train will go at the end. However, the intermediate points can be no higher than the starting point (in fact, they can't even be close to it due to the energy losses).



a. At the top of the slope:

Total energy = GPE + KE

Calculate GPE using the selected height.

GPE =_______ J

KE = _______ J (What will the KE of a stationary object be?)

Therefore total mechanical energy = _______ J

b. At the bottom of the slope:

Total energy = 82% of that at the top (18% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (What will the GPE of an object at ground level be?)

Therefore KE = _______ J

As KE = ½ mv^2, we can calculate v. v= _______m/s

c. At the end of the ride:

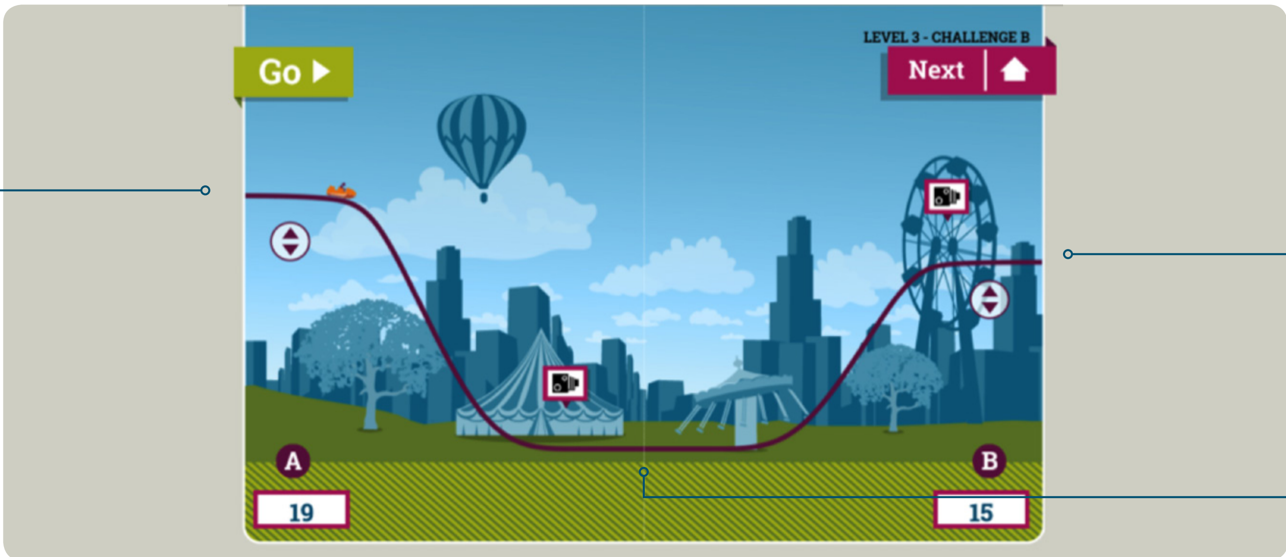
Total energy = 58% of that at the top (42% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (What will the GPE of an object at ground level be?)

KE = Total energy – GPE = _______ J

We can now calculate v. v= _______ m/s



a. At the top of the slope:

Total energy = GPE + KE

Calculate GPE using the selected height.

GPE =________ J

KE = ________ J (What will the KE of a stationary object be?)

Therefore total mechanical energy = ________ J

b. At the bottom of the slope:

Total energy = 89% of that at the top (11% lost through heat and sound) = ________ J

Total energy = GPE + KE

GPE = ________ J (What will the GPE of an object at ground level be?)

Therefore KE = ________ J

We can now calculate v. v= ________ m/s

c. At the top of the final slope:

Total energy = 70% of that at the top (30% lost through heat and sound) = ________ J

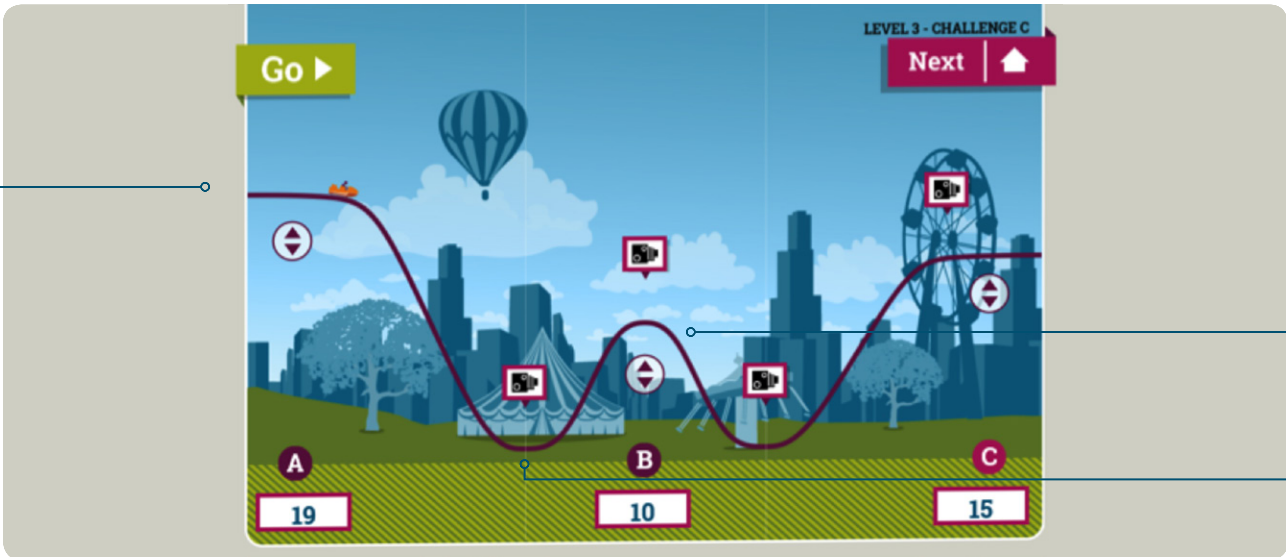
Total energy = GPE + KE

Calculate GPE using the selected height.

GPE = ________ J

KE = Total energy – GPE = ________ J

As KE = ½ mv^2, we can calculate v. v= ________ m/s



a. At the top of the slope:

Total energy = GPE + KE

Calculate GPE using the selected height.

GPE = _______ J

KE = _______ J (What will the KE of a stationary object be?)

Therefore total mechanical energy = _______ J

b. At the bottom of the first slope:

Total energy = 89% of that at the top (11% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (What will the GPE of an object at ground level be?)

Therefore KE = _______ J

We can now calculate v. v = _______ m/s

c. At the top of the intermediate rise:

Total energy = 82% of that at the top (18% lost through heat and sound) = _______ J

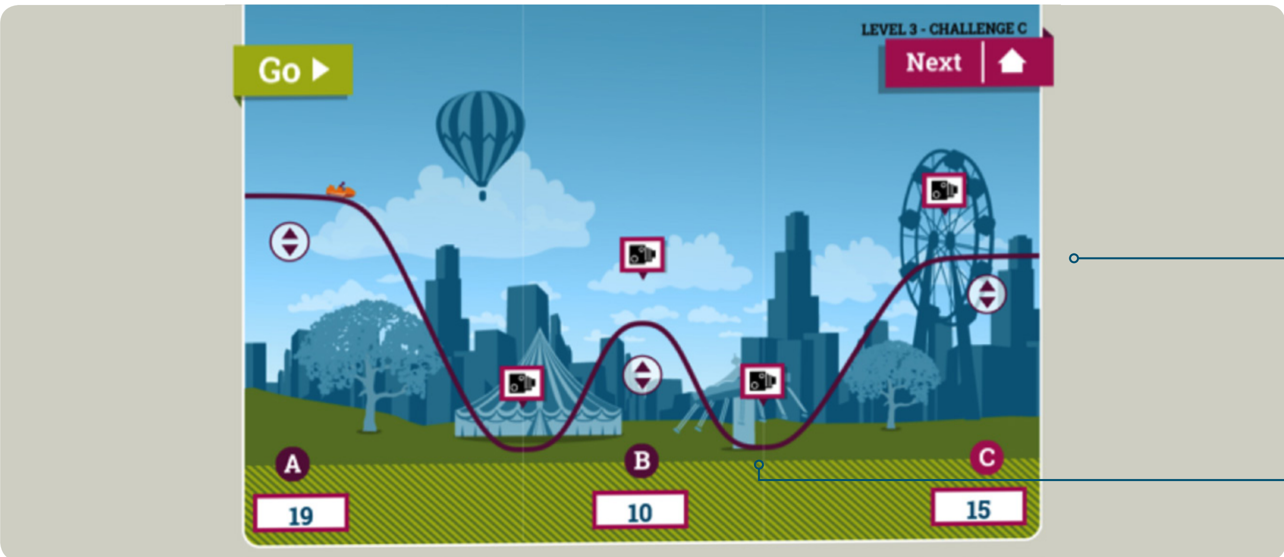
Total energy = GPE + KE

Calculate GPE using the selected height.

KE = Total energy – GPE = _______ J

We can now calculate v. v = _______ m/s

Continued



d. At the bottom of the second slope:

Total energy = 74% of that at the top (26% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (What will the GPE of an object at ground level be?)

Therefore KE = _______ J

We can now calculate v. v = _______ m/s

e. At the top of the final slope:

Total energy = 66% of that at the top (34% lost through heat and sound) = _______ J

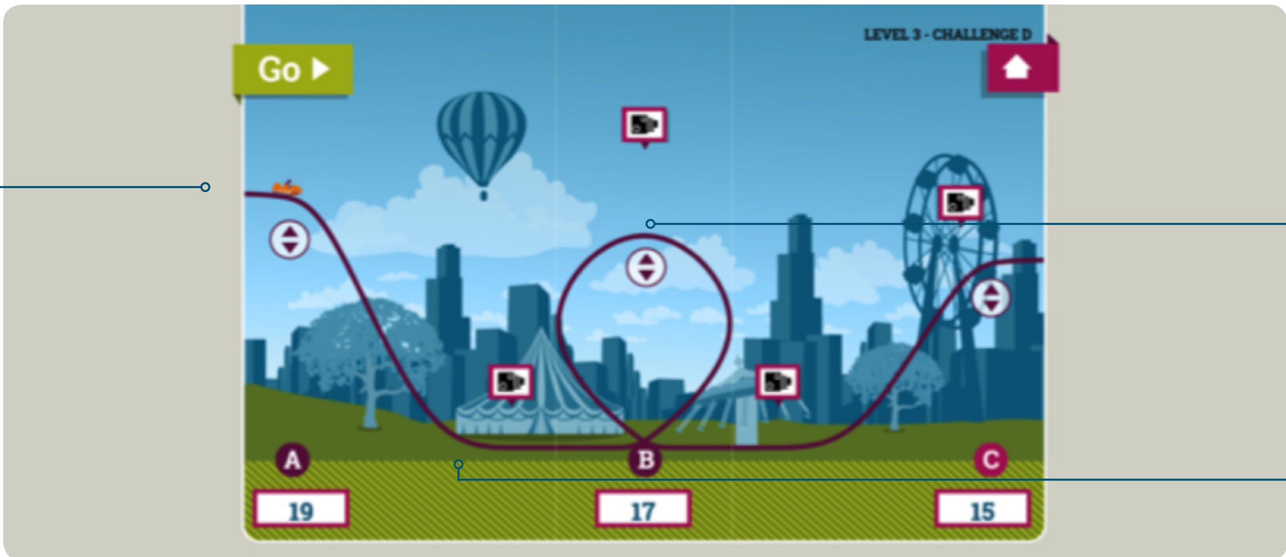
Total energy = GPE + KE

Calculate GPE using the selected height.

GPE = _______ J

KE = Total energy – GPE = _______ J

We can now calculate v. v = _______ m/s



a. At the top of the slope:

Total energy = GPE + KE

Calculate GPE using the selected height.

GPE =_______ J

KE = _______ J (What will the KE of a stationary object be?)

Therefore total mechanical energy = _______ J

b. At the bottom of the first slope:

Total energy = 89% of that at the top (11% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (What will the GPE of an object at ground level be?)

Therefore KE = _______ J

We can now calculate v. v = _______ m/s

c. At the top of the loop:

Total energy = 70% of that at the top (30% lost through heat and sound) = _______ J

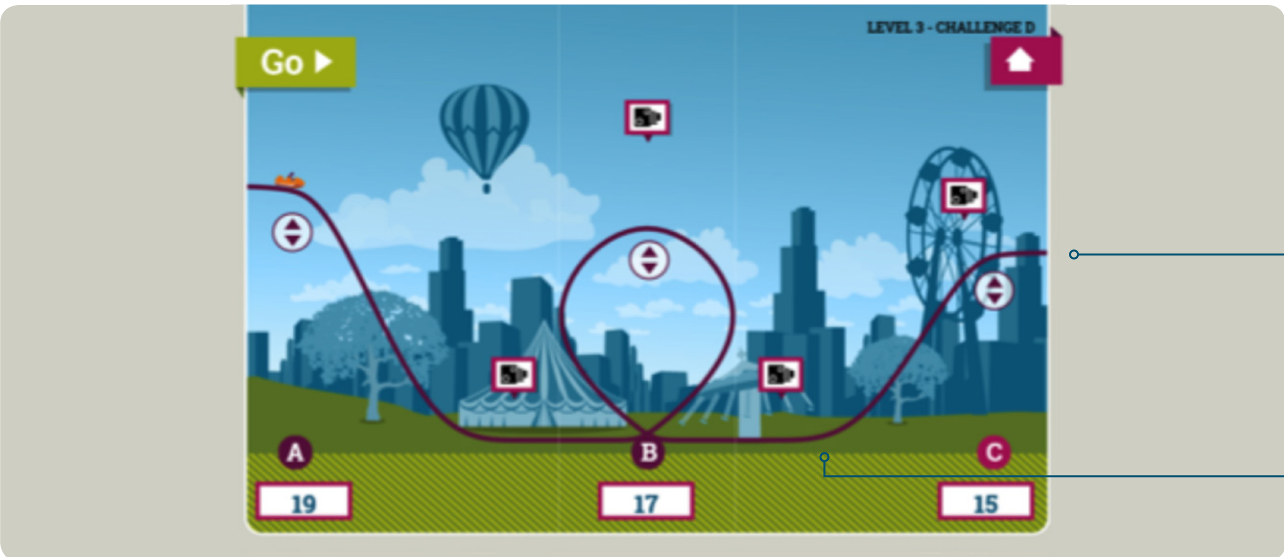
Total energy = GPE + KE

Calculate GPE using the selected height. GPE =_______ J

KE = Total energy – GPE = _______ J

We can now calculate v. v = _______ m/s

Continued



d. **At the bottom of the second slope:**

Total energy = 60% of that at the top (40% lost through heat and sound) = _______ J

Total energy = GPE + KE

GPE = _______ J (what will the GPE of an object at ground level be?)

Therefore KE = _______ J

We can now calculate v. v = _______ m/s

e. **At the top of the final slope:**

Total energy = 54% of that at the top (46% lost through heat and sound) = _______ J

Total energy = GPE + KE

Calculate GPE using the selected height.

GPE = _______ J

KE = Total energy – GPE = _______ J

We can now calculate v. v = _______ m/s

Design a ticket booth

Introduction

Theme parks expect a great many visitors who all turn up at the same time. They need plenty of ticket booths to get the people through as quickly as they can. The booths need to be small but functional. People have to work in them for hours at a time!

Objectives	Outcomes
• Apply knowledge of 3D shapes in context • Make and justify decisions about dimensions • Draw scale diagrams	• A 3D drawing of your design • A scale diagram, or diagrams, that show the dimensions • A description of why you chose that particular design • A justification for the dimensions you have chosen

Context

The context for this set of activities is the consideration of what data is needed in order to choose the dimensions of a ticket booth and how that translates into a finished shape. Communicating what that shape looks like is an important part of the process.

Learning activities

These will take you through the process from design ideas to making it work and further developments.

1. What 'classic' 3D shapes are there? List at least three and write down some advantages and disadvantages of each. You may want to discuss this with other students.

2. Now choose one of them. Does it need adapting to make it fit for purpose? Could you combine it with another shape? You may decide to do this later in the process when you decide on the dimensions.

There are many considerations when designing a ticket booth. The person inside needs to fit and customers paying for their tickets don't want to bend or stretch to pay.

3. The position of the window is a key decision to make. How high up from the ground should it be? How wide and how high the should the window be? Justify your decisions.

4. Consider the height of the person who will be inside. There are other measurements, like leg length and distance from the back of the buttock to the back of the lower leg while seated - this indicates how deep a seat needs to be. What is your design going to allow for? What are the minimum and maximum sizes of person you will work with?

5. Now choose the dimensions for your ticket booth and the position of the window. Draw a sketch to show them. Justify your choices. Draw scale drawings of the plan view, and left side and front elevations, labelled appropriately. Remember it needs a door.

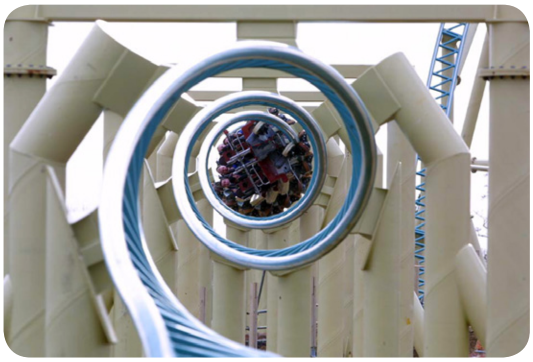
Investigations

There are now several investigations you can undertake to apply these ideas further. Remember that you have taken account of some of the issues in your design so far and used some mathematics to help with it. Now you will continue to use some mathematics in the investigation you choose to extend your work.

6. The outside surface of the booth will need to be painted to make it weatherproof. What area will that be? You may also wish to paint the inside to improve the environment for the person working there.
7. During the winter months the booth will need to be heated. The amount of heating, and therefore the cost of it, depends on the volume of the booth. Work out the volume of your booth.
8. In practice, many booths will be used for a large theme park. Show how eight of your booths should be arranged to use the area available efficiently. Show how the queues will be managed and the routes into the park. Draw a scale diagram of the area. Have you included disability access in your arrangement?

You'll have noticed there is a great deal of mathematics in the process. Can you think of any other aspects of designing a ticket booth that would use mathematics that are not in this task?

Design a rigid shape



Introduction

Many objects, such as bridges and aircraft, need to be rigid. It is important that they keep their shape, even when under load. Structures in a theme park are like this too. It might be possible to make them rigid by building them out of a strong material such as concrete but concrete is heavy. Part of the strength is then needed simply to support its own weight. Engineers often look for something that will be both light and rigid (as in Colossus at THORPE PARK Resort, pictured). They may design a framework.

Some shapes are inherently more rigid than others. They don't necessarily use any more material (in fact, in some cases they may use less) but the properties of the shape mean that it is more rigid. When it is loaded it will keep its shape. Of course, every structure has its limits.

Objectives	Outcomes
• Explore the rigidity of different shapes • Use evidence to develop explanations • Understand why structures are designed using certain shapes	• Various shapes being constructed and tested • Conclusions from the tests being discussed and recorded • Further investigations being conducted to embed ideas about rigid shapes

Context

The context for this set of activities is the use of simple construction materials to test shapes such as triangles and squares for rigidity, analysis of the findings to draw general conclusions about rigidity and the use of cross-bracing to make light structures strong.

Learning activities

In this activity you will be investigating the rigidity of various shapes. Start in 2D and then go to 3D. There are various ways to set up structures and explore them. One of these is to use dried spaghetti and marshmallows; another is to use drinking straws and short pieces of pipe cleaner. In both cases you can assemble shapes and then see how well a load can be added.

1. Start with a square. Assemble a square using the materials and hold it so that the shape is vertical and resting on the table top. Gently apply a load on the top surface by pushing down and see what the shape does (but don't grip the top edge – let it slide if it wants to). Sketch before and after views showing what happened to the shape. What happened at the corners?

2. Now try a triangle. Assemble an equilateral triangle, stand it vertically and apply a load. Sketch the effect and describe it. How does this compare with the square?

3. Now see if the rigidity of the triangle can be used to improve the strength of a square. You need to assemble a square and add another piece as a diagonal. This will involve some cutting but it's worthwhile getting the joints right. Now try loading this. How does this compare with the square with no cross-bracing?

Real structures are three dimensional. See if you can apply ideas about rigidity to them.

4. Then set up a cube using your building material. The size doesn't really matter but you should make sure that the sides are the same length as each other and that the corners are all right angles. You will find it easier if you don't make it too large (you'll find out why later). Before you test it, think about how rigid you expect it to be. Now try loading it, and see what happens.

5. Now try using a triangular-based structure. The easiest way of doing this is to make a triangle to use as a base and then add three more pieces, one coming up from each corner, to meet at the tip. (This shape is called a tetrahedron.) Think about how rigid you expect this to be and then try it out.

6. Then try using triangles to strengthen the cube. It would be useful to have a stronger cube as it's often a more convenient shape than a tetrahedron. Set up the cube but with cross struts across each face (this is why it's a good idea not to have a cube that is too large, as the diagonals are longer than the sides and if the pieces are jointed they may not be as strong). Think about how well this works and then try it out.

Investigations

There are now several investigations you can undertake to apply these ideas further. Remember that it's not simply a case of can you make a structure strong, but can you make it strong without having to use cross struts. By having a go at some or all of these investigations you'll improve your ability to explore mathematical ideas and understand how structures can be both light and rigid.

7. In part 5 you used a pyramid with a triangular base. You can also use a square as a base for a pyramid (just as the Egyptians did). Construct one of these and see how it compares with the tetrahedron from earlier.

8. If you make a cube, you can cross brace it by going from the front lower left corner to the back upper right corner, instead of cross bracing each of the sides. Try setting this up and see how it compares with the one you made in part 6.

9. Of course, there are shapes other than triangles and squares. Select another shape such as a hexagon and test this for rigidity.

You'll have seen how useful triangles are. See how these various structures use triangular shapes to add strength.

Aiming for profit

Introduction

Theme parks constantly need to regenerate the selection of rides and other attractions that are available to encourage visitors to keep returning. The cost of a new rollercoaster is immense and needs to pay for itself over a number of years. Theme parks do not charge for each ride - they have one entrance charge and then the rides are free. This makes it difficult to separate out the extra income comes from the new ride. The arrival of a big new ride such as a rollercoaster arouses lots of interest and so more visitors to the park (as with Stealth, THORPE PARK Resort, pictured). However, a new rollercoaster can cost up to £20 million.

Objectives	Outcomes
• Break down a complex task • Make sensible estimates for unknown quantities • Make and justify decisions about calculations • Work with complex formulae	• Calculations that show the likely profit or otherwise for different scenarios • Reasoning to produce estimates of likely passenger journeys • Calculations of the repayments for different interest rates and lengths of loan • Your thoughts on the project, evaluating whether or not it's a good idea financially

Context

In this task we are first going to consider a rollercoaster on its own. It is not within a theme park and so has a charge per ride. This will allow you to get a feel for the profit margins and other issues which will also apply to some extent to rides inside a theme park. You will have to make estimates for likely numbers of people using the rollercoaster.

Learning activities

These will take you through the calculations that inform pricing of tickets and help you decide whether to embark on the project in the first place.

First, some figures:

- The rollercoaster that is planned will cost £10 million
- The aim is to repay that money over 5 years
- The interest rate for the loan is 3% at compound interest

The calculation comes later, assume a repayment each year of £2,183,546.

- Running costs are £5,000 p.a. (per annum meaning per year)
- The maximum number of passenger journeys per day is 8,500
- The suggested ticket price is £2.50
- Assume the ride is open 360 days per year
- Assume 4 staff on an average salary of £15,000 to operate it

1. If the rollercoaster is full to capacity for every ride on each day, what is the profit for each year?

2. You cannot afford to lose money so you have, at least, to break even. Breaking even is when there is no profit, but no loss either. How many passenger journeys do you need each day on average in order to break even?

3. Ticket price is £3.00? What are the answers to questions 1 and 2? Comment on your answers.

Knowing how many passengers you can expect is a central part of your business plan and the hardest to know. If you are likely to be close to maximum capacity then you have few concerns. Clearly, if you are close to the point where you move from a profit to a loss then there is plenty to be concerned about. The next questions are about trying to estimate the likely passenger numbers.

4. a. The ride is open for 360 days each year. Which days do you think it would close?

   b. Some days the number of passenger journeys will be close to the maximum. Which days do you think they will be? How many days is that each year? What will be the total income from those days? Justify your decisions.

5. Some days there will be hardly any passenger journeys. When do you think they will be? How many of those are there?

6. Write down your conclusions about passenger journey numbers at different times of the year and the effect on the money that can be made. Make some recommendations about how to manage that. You can use a spreadsheet to work this out.

Investigations

The calculations so far have been based on a 3% rate of interest with the money being repaid over 5 years. The formula for working it out is:

$$X = P\,\frac{\frac{R}{100}\left(1+\frac{R}{100}\right)^{N}}{\left(1+\frac{R}{100}\right)^{N}-1}$$

X is the repayment each year

P is the original amount borrowed, called the Principal

R is the rate of interest

N is the number of years that it takes to repay

So far we have had P = £10,000,000, R = 3, N = 5

7. Substitute P = £10,000,000, R = 3, N = 5 into the formula and check that you can work it out to get £2,183,546. (It has been rounded to the nearest £).

8. What if the interest rate goes up to 4%? What are the repayments now? What effect does this have on your calculations about passenger journeys?

9. What if you need to reduce the payments to break even? This means borrowing over a longer period of time. What effect does this have on the yearly calculations? You could use a spreadsheet to work it out.

10. Finally - is it a good idea? Give your opinion and justify it from your work so far.

    There is a great deal of mathematics in developing the plan for the business. You can see the effect of the numbers changing but how will it work out in practice? If you borrow for longer you are more likely to make a profit, at least at the start, but if it is too long people will get bored with the ride and go elsewhere. One advantage of being part of a theme park is that the refreshment stalls near the ride will generate money too. This helps pay for the ride and so new rides can be brought into the park on a regular basis.

Organising the staff

Introduction

This activity is based on the challenges facing the manager of three refreshment outlets. It requires students to respond to constraints and patterns of demand. They need to suggest solutions and explain how these are reconciled to meet the challenge. In a number of cases there is not a single solution but compromises are needed. Some questions need calculations and logical analysis whereas others ask for a considered opinion.

People don't like having to queue for too long. Matching staffing to demand isn't easy but it has to be got right. Theme parks often have an arrangement whereby one admission ticket buys access to all the rides, but when a new ride is opened it often has its own set of refreshment sales points, (as in THORPE PARK Resort, pictured). These can generate and recover a significant amount of the money needed to cover the cost of developing and building the ride.

Objectives	Outcomes
• Use rates to solve problems • Select the appropriate mathematics to solve problems both within mathematics and outside mathematics • Use reasoning to solve a problem involving mathematics • Make decisions, informed both by the mathematics and by the context	• Responses which show clear reasoning and present logical responses • Responses which make use of data when available and which deal with both mathematical and non-mathematical situations

Context

As well as providing rides, there are many other staff in a theme park who are involved with providing other services, such as refreshments. This needs quite a few people, especially if the food is prepared at the time of sale, such as making up ice-cream cones. Staffing is a major area of expenditure, so park managers want to ensure efficient use of staff. However, demand is highly variable. People get hungrier later in the day and the kind of refreshments they opt for depend on age and weather. Hot dogs sell better on cooler days and ice-cream on hot days. The weather can change pretty quickly in the UK.

Learning activities

Imagine you are the manager of three refreshment stands near to a rollercoaster ride. These are a slush station, a juice bar and a sandwich bar.

On a typical day, the visitor demand is as follows. The figures show how many visitors per minute (on average) during that 15-minute period for the first half of the day. The park opens at 10am.

Period of day	Slush Station	Juice Bar	Yummy Sandwiches
10.00 -10.15	0	0	0
10.15 - 10.30	1	0	0
10.30 - 10.45	1	1	0
10.45 - 11.00	2	1	1
11.00 - 11.15	2	2	2
11.15 - 11.30	3	2	4
11.30 - 11.45	4	2	3
11.45 - 12.00	3	3	4
12.00 - 12.15	3	2	5
12.15 - 12.30	4	3	6
12.30 - 12.45	3	4	7
12.45 - 1.00	3	5	6
1.00 - 1.15	4	4	7
1.15 - 1.30	3	5	7
1.30 - 1.45	2	5	6
1.45 - 2.00	3	4	6

As the manager you need to make sure you've got enough staff to handle the demand. You need to allocate staff to the outlets so that they can cope.

1. Why is there no business in the first period?
2. How does demand vary during the four-hour period?
3. Staff on the slush station can serve, on average, one customer per minute. This includes taking the order, pouring the drinks, taking the money and giving change. It varies according to how many drinks are needed per order, but this is the average. There always have to be at least two staff on duty and every two hours each staff member is entitled to a 10-minute break. You can vary when staff start and finish their period of duty but the total period can't be less than two hours. How many staff will you need and when will you start and finish each of them?
4. The juice bar can serve people quicker as the juice is in bottles with screw top lids. A worker can serve, on average, a customer every 30 seconds. Again, there always needs to be at least two staff on duty at any one time, staff need breaks and the minimum shift length is two hours. Plan your staffing needs.
5. A senior manager has suggested that as these two outlets are close to each other, there isn't a need for at least two people to be on both at all times – at quiet times the second member of staff could be shared. Does this help to reduce the staffing requirements?
6. The sandwich bar sells a greater range of products; although the sandwiches and snacks are packaged, the hot drinks need preparing and speciality drinks such as cappuccinos and lattes take longer. A staff member can serve one customer, on average, every two minutes. The bar always has at least two staff on duty; their comfort breaks and minimum shift lengths are the same as the other outlets. Plan the staffing needs.
7. The senior manager wants your view on allowing customers to pay with contactless credit and debit cards. The banks charge 20p per transaction but it speeds up payments and means there are no problems with having the right money for change. The senior manager says you'll need to increase sales to cover the bank charges but you think this might be possible. Suggest a response.
8. In the afternoon the clouds gather and it gets cooler. The rides are still busy but you'll need to predict how the demand in each of the outlets might change. How might you need to re-allocate staff as the day goes on?
9. Staff are entitled to a longer break after a maximum of five hours if they work a full day. However the demand is greatest at lunchtime. How might you cope with this?
10. Staff need time to set up an outlet before the customers arrive. This varies according to which one it is - 15 minutes for the slush station and juice bar and 30 minutes for the sandwich bar. Can your staff rotas be modified to allow for this without causing problems?

Setting out amenities

Introduction

Theme parks fit a great deal into a small area but it doesn't always feel like that when you're walking around it. It can seem a long way between where you are and the next ride you aim to enjoy. A map of the park with the attractions on it and other important things like toilets and places to buy food and drink is essential. The map that visitors use as they go round is different from the map that the designers use when placing rides and other amenities. One of the most striking things about it is the three-dimensional look of it and the colours, a style that many town centre visitor maps use too.

You are going to draw a conventional map, to scale, of THORPE PARK Resort. You are going to use it to evaluate the placing of the amenities. You are going to see if you could do better!

Objectives	Outcomes
• Use a scale to draw a map • Interpret the scale drawing • Calculate with speed, distance and time • Identify mathematics around a theme park	• A map, to scale of the theme park, with key features labelled • Responses to questions involving interpreting the map • Calculations of time and distance • An evaluation of the amenities and updated plan for the amenities • A maths quiz about the park and the rides

Context

The context for this set of activities is how mathematics is used in the design of the theme park and what mathematics can be done in context around the park.

Learning activities

These will allow you to explore the park and find some of the mathematics behind what you see. The first task is to draw a map, to scale of the park.

A copy of the THORPE PARK Resort visitor map is available with this extension activity, download it and enlarge it as you need to see specific parts more clearly. There are also images from Google Earth that will allow you to measure true distances. The scale can be worked out from the fact that the Tidal Wave ride is 130 metres when you measure from one end of the loop to the opposite end.

Or use the internet and go to Google Earth which will allow you to measure distances 'on the ground'. Load and search for 'THORPE PARK Resort'. Along the top bar you will see a ruler. Click on it to select it. Click on the start of the distance you plan to measure then on the end and a dialogue box which allows you to choose your units.

1. Sketch the theme park and identify key distances you need to measure. Measure them and record the distances on your sketch.
2. Choose a scale that will allow the map to fit on your paper. A scale of 1:2500 or 1cm:25m will allow you to use A4 paper, portrait orientation, with the North direction up the page.
3. Draw an accurate scale drawing of the layout of the theme park.
4. Label important features on your map.

Now you have a map that is to scale you can use it to work out some information about distances and times and evaluate the layout of the park. Assume an average walking speed of 4 km/hour.

5. The average walking speed is 4 km/hour. Convert it to metres per minute. How long would it take to walk 100m? Is this reasonable?
6. Toilets are located at various places across the park.
   a. Assuming you are not actually on a ride, what is the furthest you can be from a toilet?
   b. How long will it take to get to the nearest one in that case?
   c. Is it true to say that you are always within five minutes of the nearest toilet?
7. Now consider food and drink outlets. Are you more likely to be within five minutes of a food and drink outlet than a toilet? Comment on your answer.
8. You are asked to reposition all of the toilets and food and drink outlets. Where would you put them?

Investigations

There are now several investigations you can undertake to look further at the features of THORPE PARK Resort.

9. What is the surface area of the water in the Tidal Wave ride? How deep do you think it is on average? What is the volume of water around the Tidal Wave ride?
10. Which ride goes the highest?
11. Write some questions about THORPE PARK Resort and the rides as a maths quiz for other students to do.


ENDLESS FUN
NEMESIS INFERNO
STEALTH
THE SWARM
COLOSSUS
SAW THE RIDE
THRILL RIDES
FAMILY FRIENDLY RIDES
NEW FOR 2015


Abbey Lake
Thorpe Park Resort
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Managing the rides

Introduction

This activity is based on the challenges facing the operations manager of a busy rollercoaster ride that has lots of people wanting to use it. The ride uses a multi-train system on a single track and has automatic safety systems. However, a shutdown is to be avoided if at all possible.

Objectives	Outcomes
• Use rates to solve problems • Select the appropriate mathematics to solve problems both within mathematics and outside mathematics • Use reasoning to solve a problem involving mathematics • Make decisions, informed both by the mathematics and by the context	• Responses which show clear reasoning and present logical responses • Responses which deal with both mathematical and non-mathematical situations

Context

Running a rollercoaster is a skilled business. The rides are designed to cope with demand that will vary from one time of year to another and also at different times in the same day. Although staff help passengers to get on board and start the ride going, there are then automatic control systems that control the trains.

This activity involves thinking about a ride and how it is managed. It shows how systems are designed and then have to be made to work with people in real situations. The challenge is both to understand how the system works and to consider the implications for passengers and staff.

Learning activities

In this rollercoaster ride, the train goes round a complete loop, starting and finishing in the same station. When the train comes in, the passengers leave from one side of the train and the next set of passengers embark on the other side. When they are seated, restraints are lowered and locked down to keep them safely in place. The system won't allow the train to leave until all the restraints are in place. The staff member in charge can then release the train, which goes on its journey.

When the ride gets busier, a second train is brought into use, and goes around the same track. The station can only hold one train at once, so one train empties and reloads while the other one is moving around the track. If there is a hold up in the station with reloading one of the trains, the following train is automatically brought to a halt outside the station, at the top of a gentle slope. Once the train in the station has gone, the brakes on the following, waiting train are released and it rolls into the station.

However, at really busy times, a third train is brought into use, again, on the same track. The staff now have to work hard to make sure that when a train comes in, it is immediately reloaded with passengers. In fact, they have 90 seconds between a train arriving and having to be ready to depart. If it takes longer than that the second train will be held outside the station. This is not a problem; however if the hold up persists, the third train is then (automatically) brought to a halt. This will be out on the main part of the track on a high-level section. Whereas the second train can be easily brought into the station, the third train can't be re-started from this point while loaded, so the passengers have to leave the train and be escorted down. This is to be avoided if at all possible as passengers sometimes have difficulty coping with descending vertical steps from a high level, even with staff assistance.

1. Why do you think the system is designed to use multiple trains on the same track?
2. Explain why stopping one train outside the station is not a problem, stopping a second train is.
3. What could go wrong with reloading a train in 90 seconds?
4. Why do you think the system is designed so that passengers board from one side of the train and leave from the other?
5. Designing a system like this is done so that maximum possible use is made of the ride and that as many passengers as possible can use it. Using the ideas in the text and your own views, explain whether you think that three-train operation is a good thing or not.
6. System shutdowns that involve de-training passengers from a high level are very rare. Should a fourth train be introduced?