Activity description

In this activity students carry out an experiment to collect data about a trolley rolling down a slope. They use this to simulate the motion of a train by fitting a quadratic curve to their data, using a graphic calculator or spreadsheet.

The main emphasis of the activity is the modelling cycle.

In the extension students may use kinematics or dynamics to determine the velocity of the trolley.

Suitability

Level 3 (Advanced)

Time

2 hours

Resources

Student information sheet, worksheet
Optional slideshow

Equipment

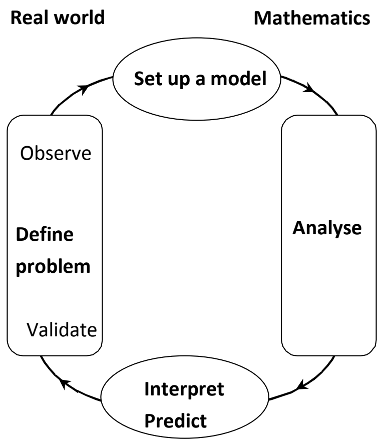
Trolley, track or other suitable surface, stopwatch, tape measure,
graphic calculator or spreadsheet

Key mathematical language

Model, variable, constant, gradient, velocity, resistance, average, function, predict, analyse, validate

Notes on the activity

Carry out a risk assessment and take suitable precautions before starting this experiment. Do not rely on what is said here.



This activity can be used after the 'Falling Ball' activity to give learners more practice in modelling real situations.

You could start by asking students what they think will happen if a train with faulty brakes rolls down a slope. The slideshow can be used to aid class discussion and outline some parts of the activity.

Before students begin the activity, introduce the modelling cycle (shown here) or remind students about it if they have met it before.

You may also want to discuss some of the following practical advice with students before they carry out the experiment.

Practical advice

It may be useful to have the trolley running down a track secured to a table. One end of the table could be raised using wooden blocks.

The trolley must move reasonably slowly so that measurements are easy to make. It is important to choose an angle of slope that gives a total time of more than 2 seconds for the trolley to roll down the full length of the slope.

Distances should always be measured to the front of the trolley.

To achieve consistency at release, students should practise a few times and count down to release.

In the analysis section of the worksheet, students are asked to use either a graphic calculator or a spreadsheet to find a function to model their data. Students will need to be able to recognise the shape of a quadratic function, so it may be necessary to revise graph shapes before they try this part of the activity.

Alternatively, students can try to estimate the coefficient of t^2 by trial and improvement or substituting coordinates of points into $x = kt^2$ to find a value for k.

During the activity

Students will need to work in groups to complete the experiment and collect suitable data.

The data is analysed and used to make predictions, which are then tested.

If the equipment cannot be left in place between the two experiments, students should ensure that they have taken sufficient measurements and recorded enough details so that they can replicate their experiment.

In particular, students should ensure that they use the same equipment and the angle of slope of the track must be the same for both experiments.

Points for discussion

What will affect the motion of the trolley?

What assumptions must be made when setting up the model?

Does the mass of the trolley affect its motion?

How realistic is the model? Is it appropriate to model the motion of a train in this way?

What does the quadratic function imply about the motion of the trolley or train?

Extensions

The introduction to the activity contains a specific question about how fast the train was travelling when it hit the barrier.

However the main activity involves finding a relationship between distance and time. Although the speed at a given point cannot be obtained directly from the data the students collect in their experiment, it can be obtained from their model. This is suggested as an extension activity and can be attempted in a several ways.

An alternative extension activity is for students to think about how they could adapt the experiment and collect data from which they could calculate the speed of the trolley directly.

Answers

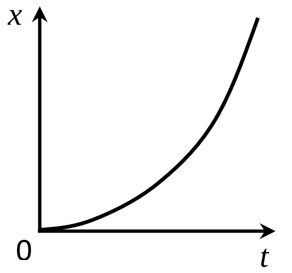
In theory, the acceleration of the trolley is given by $g \sin \theta$, where $g = 9.8 \text{ ms}^{-2}$ is the acceleration due to gravity, and θ is the angle of the slope. Students are not expected to know this, but you may find it useful when checking their work.

Using $a = 9.8 \sin \theta$ to model the acceleration leads to the functions

$v = 9.8 \sin \theta\, t$ for the velocity of the trolley and

$x = 4.9 \sin \theta\, t^2$ for the distance travelled by the trolley in t seconds.

This quadratic function has the shape shown in the sketch for all small values of θ.



In practice air resistance and friction will cause the acceleration, velocity and distance travelled in a given time to be slightly less than the theoretical predictions.

Acknowledgement

This activity is adapted from one suggested Nuffield Advanced Mathematics *Mechanics 1*, Longman, 1994. ISBN 0-582-09979-X