GCSE

Edexcel GCSE in Additional Science
Rollercoasters and Relativity

(Context approach)

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Support material

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Authorised by Roger Beard
Prepared by John Crew

Contents

Topic 10: RollerCoasters and Relativity

Introduction

1 This booklet contains a context-driven scheme of work and some suggested activities for the Edexcel GCSE in Additional Science Topic 10: Rollercoasters and Relativity.

2 Two schemes of work are available for each topic and art publication in separate booklets. One contains a scheme of work that is concept-driven ie scientific ideas are presented before their applications are explored. The other contains a scheme of work that is context-driven ie applications of science are presented before the scientific principles used in these applications are explored.

3 Booklets for each GCSE in Additional Science topic are provided free of charge to centres offering the Edexcel GCSE suite of Science qualifications via the secure area of the Edexcel website (www.edexcel.org.uk).

4 Although Edexcel owns the copyright for the booklets, they are provided in Word format so that Edexcel centres may customise the schemes of work if required.

5 Each lesson is designed to last for 50 minutes although the total teaching time is not stated in the specification; teachers may adjust the schemes of work to accommodate the time available in their centres.

6 Centres are responsible for the overall risk assessment of experimental work undertaken by students.

7 Attention is drawn to the need for safe practice when students carry out laboratory experiments or observe demonstrations. Particular attention is drawn to the possible hazards associated with electrical equipment, the handling of micro-organisms and ionising radiation. Strict aseptic conditions should be used when undertaking practical work. Reference must be made to COSHH regulations and any specific local education authority restrictions.

Relevant advice can be obtained from the following publications:

- *CLEAPSS Laboratory Handbook* (available from CLEAPSS School Science Service, website www.cleapss.org.uk)
- C*ontrol of Substances Hazardous to Health Regulations* (HSE, 2005) ISBN 0717629813
- *Hazcards* (2004 update available from CLEAPSS School Science Service)
- *Topics in Safety, Third Edition* (ASE, January 2001) ISBN 0863573169.

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 1: Rollercoasters — what makes them move?							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.3	9I Energy and electricity.	Electric motors are used to make rollercoasters move.	**Starter:** Ask the students the question: '*If you could design a rollercoaster, what would it look like?*' Give them approximately 10 minutes to draw and label their own rollercoaster designs. Use A3 paper and then display the designs around the room. (These can be used in later lessons, for other aspects of rollercoasters.) This activity can be carried out using some of the websites listed. Discuss with students what happens first on a rollercoaster — they go up. **Main:** Discuss that the rollercoaster is pulled up the first hill (lift hill) by electric motors that operate a chain or belt on the tracks. Introduce the equation: electrical energy = voltage x current x time that shows the electrical energy requirements of the electric motor. Give students some sample rollercoaster calculations using this equation. **Plenary:** Ask students what the electrical energy from the electric motor is used for (converted into kinetic energy of the belt/chain that pulls the rollercoaster up the lift hill). Discuss that a greater voltage, current or time will increase the electrical energy delivered by the motor. And also that to get a high electrical energy from the motor you need to put in a high voltage, current or time.	A3 paper, marker pens (or felt-tip pens). 'Build a roller coaster' — Discovery Channel (http://dsc.discovery.com/convergence/coasters/interactive.html). 'Design a roller coaster' (www.learner.org/exhibits/parkphysics/coaster).	Apply the equation to situations that use electric motors: electrical energy = voltage x current x time (E = V x I x t).	C: 2.1 N: 2.1 2.2 2.3	General safety issues involved when using computers.

Lesson 1: Rollercoasters — what makes them move? (*continued*)
Homework: Draw your own rollercoaster design in detail and label it fully (including areas such as the lift hill, the start point, naming or numbering the hills, drops, turns and loops). This will be used in the next few lessons. Roller Coaster Tycoon computer game or the suggested websites will help with ideas for students.

Scheme of work for Topic 10: Rollercoasters and Relativity

<table>
<tr><th colspan="8">Lesson 2: How much work does a rollercoaster do?</th></tr>
<tr><th>Spec. code</th><th>Links and concept building from KS3</th><th>Learning objectives</th><th>Teaching activities</th><th>Resources</th><th>Learning outcomes</th><th>Key skills</th><th>Safety issues</th></tr>
<tr><td>P2 10.4
P2 10.6</td><td>9I Energy and electricity.</td><td>The energy transferred from the electric motor is used to lift the rollercoaster. This is called the work done.</td><td>Starter: Discuss with students how high they have designed the lift-hill in their rollercoaster, and ask them the question: ‘What affects how high your rollercoaster can be pulled up the lift-hill?’
Discuss with students that the height the rollercoaster can be pulled up the lift-hill depends on the energy of the electric motor pulling it.
Main: Explain that the energy transferred from the electric motor is called the work done. Introduce the equation:
work done = force x distance moved in the direction of the force (W = F x s).
Show students how to calculate the amount of work done, by the electric motor on their lift-hill, using the information about their own rollercoaster design (from lesson 1). Add this information to their poster.
Carry out experiment 10.2 investigating work done with students, investigating what effect the height/angle of the track (lift-hill) has on the work done to move a trolley (rollercoaster) to the top of it.
Plenary: Look at the class results from Experiment 10.2 and ask students what effect the height/angle of the track had on the work done to move the trolley to the top of it. Recap the work done equation, and why students obtained the results that they did.</td><td>Experiment 10.2: Investigating work done.</td><td>Explain that work done is equal to energy transferred.
Use the equation:
work done = force x distance moved in the direction of the force.
(W = F x s).</td><td>C: 2.1
N: 2.1 2.2 2.3
WO: 2.2</td><td>Take care when using the wooden tracks in the experiment (further notes on the Experiment 10.2 sheet).</td></tr>
<tr><td colspan="8">Homework: Explain how the height of the lift hill of your rollercoaster is affected by the electric motor, in terms of voltage, current and time.</td></tr>
</table>

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 3: How much power is needed on a rollercoaster?							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.5	9I Energy and electricity.	The power of the electric motor depends on the work done and the time taken.	**Starter:** Ask students the question: '*What makes the rollercoaster go up the lift-hill?*' Recap from Lesson 1 about the electric motor. Ask students to describe what happens to the rollercoaster as it is being pulled up the lift-hill. Discuss this with students and try to get them to think about how long it takes for this to happen (that it takes time). **Main:** Introduce the idea of the power of the electric motor to the students. Give them the equation: power = work done/time taken (P = W/t). Do Demonstration 10.3 factors affecting power, using a wooden track and trolley, to show how the time taken, distance moved and force needed all affect the power. Explain to students how to calculate the power and work done for a variety of different rollercoasters, on Activity sheet 10.3: Calculating power. Students should then calculate the power of the electric motor needed to move their own rollercoaster up the lift hill. Add this information to their posters. **Plenary:** Discuss the answers with students. Explain how the answer to each question is calculated. Examine the power values calculated by students for their own rollercoasters, and discuss the variety (or similarity) between these.	Demonstration sheet 10.3: Factors affecting power. Activity sheet 10.3: Calculating power.	Use the equations: power = work done/time taken (P = W/t).	C: 2.1 N: 2.1 2.2 2.3	If the students are helping with the demonstration take care not to use a wooden track that is too heavy for them to hold.
Homework: Explain why it is important to know how much power is needed by the electric motor. Explain also what factors might increase the amount of power needed to your rollercoaster design (eg weight of passengers, number of passengers).							

Lesson 4: Going up!							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.1	9I Energy and electricity.	Identify the factors which affect potential energy.	**Starter:** Ask students the question: '*What makes the rollercoaster ride last longer?*' Discuss with the students that the gravitational potential energy of the rollercoaster at the top of the lift-hill is the maximum energy for the rest of the ride. A good animation to show how the gravitational potential and kinetic energy change throughout the ride can be found at http://science.howstuffworks.com/roller-coaster2.htm. **Main:** Explain potential energy to the students and introduce the equation: potential energy transferred = mass x acceleration of free-fall x change in height (PE = m x g x h). Carry out a sample calculation with students. Students complete computer-based activity 10.4 investigating the effects of changing height, gravity and mass, on the performance of a rollercoaster (on www.funderstanding.com/k12/coaster). **Plenary:** Discuss with the students the effects the height of hill 1, the mass of the car and gravity, and therefore changing gravitational potential energy, had on the rollercoaster ride. Students to calculate the gravitational potential energy of their own rollercoaster lift-hill, and add this information to their poster.	Internet access. http://science.howstuffworks.com/roller-coaster2.htm Activity 10.4: Investigating effects of changing potential energy. Funderstanding Roller Coaster (www.funderstanding.com/k12/coaster).	Use the relationship: potential energy transferred = mass x acceleration of free-fall x change in height (PE = m x g x h).	C: 2.1 N: 2.1 2.2 2.3	General safety issues involved when using computers.
Homework: Explain what happened in the computer experiment when the height, mass and gravity were at their maximum values. Analyse all of the results and explain which had the biggest effect on the outcome of the rollercoaster ride — changing height, mass or gravity.							

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 5: Down we go!							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.2	9I Energy and electricity.	Identify factors which affect kinetic energy.	**Starter:** Ask students the question: '*Which parts of a rollercoaster ride make you feel sick?*' Discuss with students that going down the first hill is usually the biggest drop and you fall fastest so are more likely to feel sick on this part. Show the animation from the Lesson 4 starter roller and discuss the kinetic energy for the first hill. **Main:** Explain that when the rollercoaster travels down the first hill the gravitational potential energy is transferred to kinetic energy. Introduce the equation: kinetic energy = ½ x mass x $(\text{velocity})^2$ (KE = ½ mv^2). Carry out an example calculation with the students. Students should carry out Experiment 10.5: Changing mass and kinetic energy, to investigate how changing the mass of the trolley affects the kinetic energy. Students should complete the results sheet for Experiment 10.5, calculating the velocity and then the kinetic energy. **Plenary:** Discuss with students what they found from their experiment into how mass affects the kinetic energy. Students should identify and explain any anomalous results from their experiment.	Internet access. http://science.howstuffworks.com/roller-coaster2.htm Experiment sheet 10.5: Changing mass and kinetic energy.	Use the relationship: kinetic energy = ½ x mass x $(\text{velocity})^2$ (KE = ½ mv^2)	C: 2.1 N: 2.1 2.2 2.3 WO: 2.2	Take care when using the wooden tracks in the experiment (further notes on the Experiment sheet 10.5).
Homework: Explain why a large drop in height on a rollercoaster makes some people feel sick. Explain any issues that affect the height of the first hill (eg safety issues).							

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 6: How do rollercoasters keep on going?							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.7	9I Energy and electricity.	Energy can be converted from one form to another, but it cannot be created or destroyed.	**Starter:** Ask students the question: '*What keeps the rollercoaster going throughout the ride?*' Discuss with students that the gravitational potential energy is transferred to kinetic energy, and back and forth as the ride progresses. Show students the animations on the websites (listed in the resource column). **Main:** Explain to the students that the gravitational potential energy at the top of the first hill is transferred to kinetic energy at the bottom, and so on throughout the ride. Carry out Demonstration 10.6: Energy conservation to show this. Discuss with students what happened during the demonstration, and calculate the gravitational potential energy and kinetic energy at the top and bottom of each hill. Explain to students that the energy is finally transferred to heat energy and becomes less useful. This limits the length of the rollercoaster, as does the electric motor that pulls it up the lift-hill. **Plenary:** Recap on the principle of conservation of energy. Ask students to explain whether their rollercoaster design obeys this law, and whether it will work or not.	Visual Learning — Potential and Kinetic Energy Experiment (www.visionlearning.com/library/module_viewer.php?mid=46). Mechanics Virtual Labs — scroll down to energy and work (www.hazelwood.k12.mo.us/~grichert/sciweb/mechanic.htm). Demonstration sheet 10.6: Energy conservation.	Apply the principle of conservation of energy to examples involving gravitational potential energy, kinetic energy and other forms of energy.	C: 2.1 N: 2.1	Take care when using the toy car and track for the demonstration.
Homework: Write a description of the energy transfers in your own rollercoaster design. Explain whether your rollercoaster will work or not.							

Lesson 7: Faster and faster!							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.8	9K Speeding up.	Describe how speed, acceleration, force and energy are involved in a rollercoaster ride.	**Starter:** Ask students to write a description of what happens in their rollercoaster, throughout the ride. A few students should then present their descriptions to the class. Identify any similarities between the descriptions (such as references to speed and acceleration). **Main:** Explain to students that during the ride the rollercoaster accelerates due to forces that act upon it, and this affects its speed. Recap from Lesson 6 that the energy of the rollercoaster also changes. Students should complete Activity sheet 10.7: Rollercoaster ride, answering all the questions. This could be presented as a worksheet on an OHT. **Plenary:** Discuss with students the answers to the questions on Activity sheet 10.7. Explain how question 2b) is very subjective, and discuss how rollercoaster designers may answer this.	Activity sheet 10.7: Rollercoaster ride.	Describe how a rollercoaster or other ride works, using concepts such as speed, acceleration, force and energy.	C: 2.1 N: 2.1	
Homework: Research different types and designs of rollercoasters to find out what makes a ‘good’ rollercoaster. Find out how rollercoaster designers decide what will makes the best ride. Use websites such as How Science Works (http://science.howstuffworks.com/roller-coaster.htm) and Google (www.google.co.uk) as a starting point.							

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 8: Loop-the-loop!							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.9 P2 10.10 P2 10.11	9J Gravity and space.	For an object to move in a circular path a force must act on it.	**Starter:** Ask the students the question '*Why don't the rollercoaster cars fall off the track when they loop-the-loop?*' (or '*Why don't the passengers fall out?*'). Discuss the various answers the students give (eg the cars are fixed on, the passengers have safety bars), and that the main reason is that there is a force holding the cars and passengers in place. **Main:** Carry out demonstration 10.8: Circular motion, to show how a bucket of water can be swung in a circle no water falling out. Also show a toy car travelling along a loop-the-loop. Ask students to predict what will happen to the water in the bucket, and to the toy car on the loop-the-loop. Discuss the results and explain what happened. Explain to students how circular motion works and draw diagrams to show the forces acting in the bucket and toy car demonstrations, and in a rollercoaster. **Plenary:** Recap on how rollercoaster loop-the-loops work, asking students to explain this. Students should add further notes to their rollercoaster posters, for loop-the-loop.	A good website to use for extended research is Park and Side Science (www.jfk.herts.sch.uk/class/science/science/rollerc/phll.htm). Demonstration sheet 10.8: Circular motion.	Explain that an object moving in a circle at constant speed must be accelerating due to its directional change. Explain that there must be a resultant force acting on an object which is moving in a circle in order to bring about this acceleration. Apply the fact that a force is directed to the centre of the circle eg by drawing diagrams.	C: 2.1 N: 2.1	Be careful not to splash students with water. Take care when using the toy car and the track, as the car may be liable to fly off the track.
Homework: Students should complete all additional notes on their rollercoaster posters. These can then be used to aid revision for this topic.							

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 9: Reluctant scientists and thought experiments							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.12 P2 10.13	9M Investigating scientific questions. 9J Gravity and space.	New scientific theories are not always derived through experimental methods.	**Starter:** Ask students the question: '*How did Einstein come up with the most famous idea in physics — the theory of relativity?*' Discuss this with students and use the Nobel Prize website to help research an answer. **Main:** Introduce the idea of thought experiments, and discuss why these may be the only experiments that scientists can do (eg not physically possible to carry out experiments, experiments are too expensive to carry out). Use the websites listed to find out more information. Students should try to come up with their own questions to be answered by thought experiments. These could be written on A3 sheets of paper and displayed around the classroom. (Example includes: What would happen if two black holes collided, and why would they collide? Could you make a jelly strong enough to hold up a person standing on it?) Explain to the students the limitations of thought experiments, such as the lack of experimental data to back up theories. Discuss how Einstein's theory of relativity was not accepted at first due to this, and the fact that it overturned long-established explanations. **Plenary:** Recap on the use and importance of thought experiments, and why scientists are reluctant to change their mind. Choose some of the thought experiment questions, from individual students, and discuss them with the class.	Thought experiments (http://plato.stanford.edu/entries/thought-experiment). The Nobel Prize website — Relativity (http://nobelprize.org/physics/educational/relativity/index.html). A3 sheets of paper and marker pens.	Recognise that some theories, such as Einstein's theory of relativity, require creative imagination such as thought experiments, and do not emerge from experimental data automatically. Discuss the fact that some scientists are often reluctant to accept new theories, such as Einstein's relativity, when they overturn long-established explanations.	C: 2.1 ICT: 2.1	
Homework: Find out about famous thought experiments in physics (eg Schrödinger's cat and the twin paradox).							

Scheme of work for Topic 10: Rollercoasters and Relativity

Lesson 10: Time travel							
Spec. code	**Links and concept building from KS3**	**Learning objectives**	**Teaching activities**	**Resources**	**Learning outcomes**	**Key skills**	**Safety issues**
P2 10.14	9J Gravity and space.	Einstein's theory of relativity is believed because it has been successfully tested.	**Starter:** Ask students which thought experiments they found for their homework, from Lesson 9. Discuss these. Show the students the twin paradox animation: (www.swishzone.com/index.php?area=resources&tab=movies&do=page&action=detailed&link_id=2582) and then discuss what students think is happening. **Main:** Ask the students to research relativity in Activity 10.10 and to find out why it is now an accepted theory. Students should include information on the twin paradox, and on the atomic clocks and cosmic rays experiments. Students should produce a poster to show their research findings. **Plenary:** Discuss relativity and explain how it is now widely accepted as its predictions have been successfully tested in different situations, such as atomic clocks and cosmic rays. Review students' posters.	Nobel Prize website Relativity — (http://nobelprize.org/physics/educational/relativity/index.html). For an explanation of the twin paradox – (http://www.geocities.com/newmodel2k/Twins.htm). Atomic clock experiment – (http://hyperphysics.phy-astr.gsu.edu/HBASE/relativ/airtim.html). Activity sheet 10.10: Relativity research.	Explain that Einstein's theory of relativity is believed because it led to predictions which were tested successfully in different situations, such as atomic clocks and cosmic rays.	C 2: 1a C: 2.2 ICT: 2.1	General safety issues involved when using computers.
Homework: Students should complete their relativity posters.							

Experiment 10.2: Investigating work done

What you will learn from this experiment

The effect the height/angle of the track has on the work done to move a trolley to the top of the track.

What you will know when you finish this experiment

1 That work done is related to the height of the track.

2 That work done = force x distance travelled in the direction of the force.

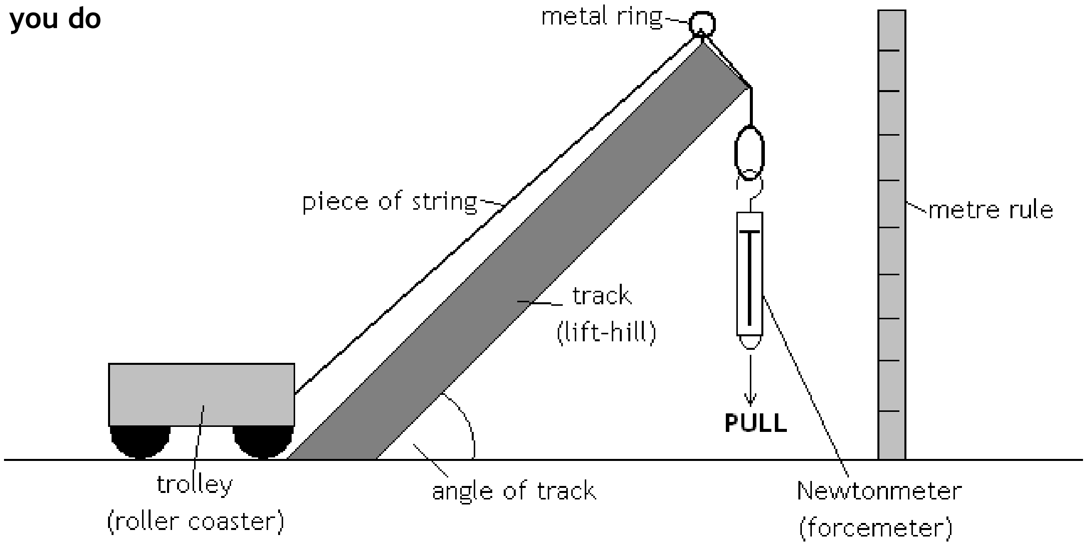
How you may be assessed

1 Your ability to carry out the experiment safely and accurately.

2 What you find out from your experiment.

3 Your analysis of the results of your experiment.

What you do



1 You will need to work in pairs for this experiment.

2 Put on your safety glasses.

3 Collect the equipment.

4 Measure the weight of the trolley using the Newtonmeter.

5 Tie a length of string to the end of the trolley.

6 Make a loop on the other end of the string.

7 Hang the string along the track and over the end of it.

8 Attach the Newtonmeter to the loop.

9 Use a protractor to measure the angle of the track (one person will have to hold this up for the duration of the measurement).

10 The first angle of the track should be 10°. Measure the height of the track at this angle.

11 Pull the trolley up the track, using the Newtonmeter, recording the force needed to pull the trolley.

12 Repeat this again for the following angles of the track: 20°, 30°, 40°, 50°.

13 Record all the results in the table on the next page.

Experiment 10.2: Investigating work done

Weight of trolley: ____________N			
Angle of track (degrees)	**Height of track (cm)**	**Force used to move trolley (N)**	**Work done (J)**
10			
20			
30			
40			
50			

14 Calculate the work done needed to move the trolley up the slope using the formula:

work done = force x distance moved **in the direction of the force**

(you will need to use the force used to move the trolley in your calculations, not the weight of the trolley).

15 Explain how the angle of the track affects the work done to move the trolley up the track.

Suggestions for further work/homework

1 Draw a graph of your results.

2 Identify any anomalous results from your graph, and explain them.

3 Explain why the wooden track had to have a metal ring on the end for the string to go through.

Experiment 10.2: Investigating work done

Note for teachers and technicians

Aim

To find out what effect the height/angle of the track has on the work done to move a trolley to the top of the track.

Previous skills, knowledge and understanding required

9I Energy and electricity.

Skills, knowledge and understanding

This experiment will enable students to gain the following skills and/or knowledge and understanding:

1 that work done is related to the height of the track

2 that work done = force x distance travelled in the direction of the force.

Equipment and chemicals required

For each pair:

1 a large wooden track, with a metal ring on the end

2 a wooden trolley

3 a Newtonmeter (forcemeter)

4 a metre rule

5 a protractor

6 a long length of string

7 safety glasses

8 students may need access to a calculator.

Health and safety issues

Safety glasses must be worn by all students. Take care when handling the wooden track, as students will have to hold this. Use wooden tracks that are not too heavy, or students could work in threes with two students holding the track. It may be possible to rest the wooden tracks on another object, but care should be taken that this object is stable (ie not a pile of textbooks).

Experiment 10.2: Investigating work done

Delivery strategies

- Introduce the experiment as a way to find out how the angle of the track affects the work done needed to move the trolley up the track.
- Students should work in pairs or threes to allow them to hold the track while the experiment is carried out.
- Students should swap who holds the track and who does the experiment, to make sure everyone gets a turn at undertaking all tasks.
- Students of low ability should be given help, check by asking how they are getting on, or by providing a help sheet (adapted version of the experiment sheet), or by teaming them with higher-ability students.
- The experiment can be ended by asking students to pack away when finished, and to draw conclusions from their result.
- Students can be asked about their results and also which angle of the track required the most work done by the trolley.

Assessment strategies

Students could be assessed on:

- their ability to carry out the experiment safely and accurately
- what they find out from their experiment
- their analysis of the results of their experiment.

Links

Links with Key Stage 3 (KS3).

This experiment builds on the skills, knowledge and understanding from Key Stage 3 (KS3):

- 9I Energy and electricity.

Links with other GCSE in Science topics.

This experiment is related to:

- P3 6.6
- P3 6.7.

Activity 10.3: Calculating power

1 Calculate the work done for the following:

a the rollercoaster is pulled up a 100m high lift-hill with a force of 50 N

b the rollercoaster is pulled up a 200m high lift-hill with a force of 75 N

c the rollercoaster is pulled up a 150m high lift-hill with a force of 120 N.

2 Calculate the power of the electric motor that is used to pull the rollercoaster up the lift-hill, for the following examples:

a the work done by the electric motor is 4000 J and it is running for 80 seconds

b the work done by the electric motor is 6000 J and it is running for 100 seconds

c the work done by the electric motor is 12000 J and it is running for 150 seconds.

3 Calculate the power of the electric motors used in the rollercoasters in Question 1, when used for the following amounts of time:

a 50 seconds

b 75 seconds

c 120 seconds.

4 Calculate the power of the following rollercoaster electric motors:

a electrical energy transferred from the motor is 12250 J, it is used for 125 seconds

b electrical energy transferred from the motor is 18400 J, it is used for 160 seconds

c electrical energy transferred from the motor is 22500 J, it is used for 180 seconds.

Activity 10.3: Calculating power

Answers

1 Work done = force x distance moved in the direction of the force

a 100 x 50 = 5000 J

b 200 x 75 = 15000 J

c 150 x 120 = 18000 J

2 Power = work done/time taken

a 4000 ÷ 80 = 50 W

b 6000 ÷ 100 = 60 W

c 12000 ÷ 150 = 80 W

3 Power = work done/time taken

a 5000 ÷ 50 = 100 W

b 15000 ÷ 75 = 200 W

c 1800 ÷ 120 = 150 W

4 Energy transferred from the electrical motor is equal to the work done, therefore power = electrical energy transferred ÷ time

a 122500 ÷ 125 = 98 W

b 18400 ÷ 160 = 115 W

c 22500 ÷ 180 = 125 W

Demonstration 10.3: Factors affecting power

What you will learn from this demonstration

In this demonstration you will find out about some of the factors affecting the power needed to move the trolley.

What you will know after you have seen this demonstration

The power is affected by time taken, force moved and distance moved.

What you do

You will watch the demonstration by your teacher.

You need to think about what factors affect the power needed to move the trolley. Think about the following equations to help you with this:

power = work done/time taken ($P = W/t$)

work done = force x distance moved in the direction of the force ($W = F \times s$)

Write any ideas in the notes section below.

Notes

Demonstration 10.3: Factors affecting power

Notes for teachers and technicians

Aim

In this demonstration students will find out about some of the factors affecting the power needed to move the trolley. This is an extension to Experiment 10.2 (from Lesson 2).

Skills, knowledge and understanding

This demonstration will enable students to gain the following knowledge:

1 the power is affected by time taken, force moved and distance moved.

Previous skills, knowledge and understanding required

1 Electric motors are used to make rollercoasters move.

2 Work done is equal to energy transferred.

Equipment and chemicals required

1 A large wooden track, with a metal ring on the end.

2 A wooden trolley.

3 A Newtonmeter (forcemeter).

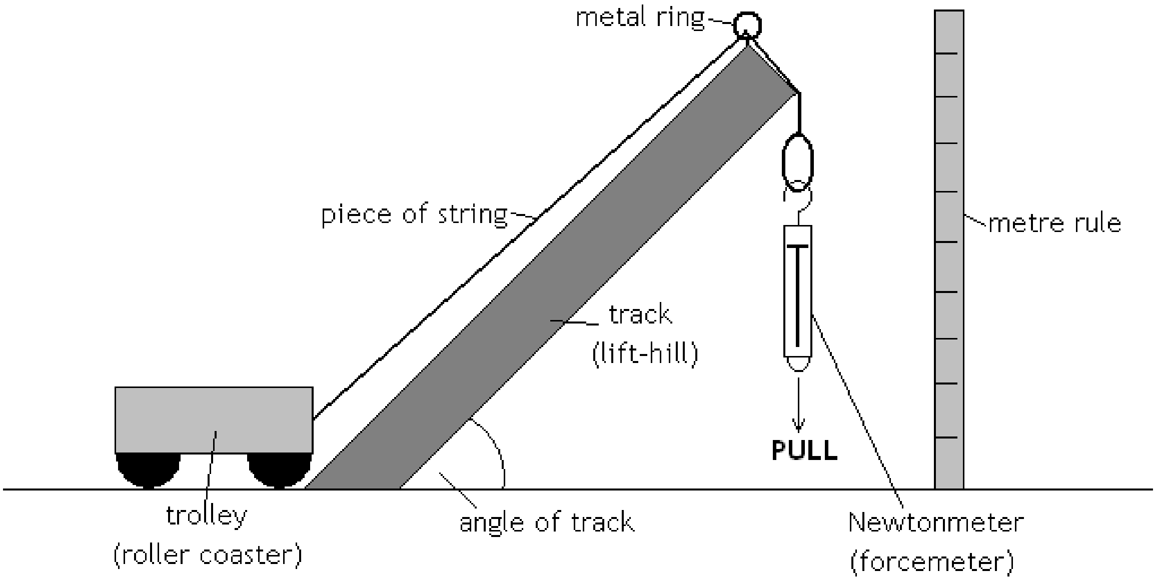
4 A metre rule.

5 A protractor.

6 A long length of string.

7 A stop clock.

8 A large lump of modelling clay.



Health and safety issues

Students should sit at a safe distance away from the demonstration. If students are holding the track take care not to use a heavy wooden track.

Demonstration 10.3: Factors affecting power

Delivery strategies

- Set up the experiment as shown in the diagram.
- Ask students to think about the two equations (for work done and power) and to predict what will affect the power needed to pull the trolley up the ramp.
- It may be useful to have students helping with certain tasks, such as measuring time, pulling the trolley up the track (and therefore measuring force), measuring height of the track, and recording the results.
- Choose the height of the track (by varying the angle of the slope), measure the force needed, height of track, and time taken to move the trolley up the track.
- Repeat this for a different track height, but trying to keep the time taken to pull the trolley up the same.
- Repeat this but this time keep the track at the same height and vary the time taken to pull the trolley up it.
- Repeat this again but keep the time and the height of the track the same and vary the mass of the trolley (and therefore the force) by adding the lump of modelling clay to the trolley.
- Complete the results table as a class activity.

Key factor varied	Angle of slope (degrees)	Height of track (m)	Force needed to move trolley (N)	Work done (Joules)	Time taken (seconds)	Power (Watts)
Height of track						
Height of track						
Time taken						
Time taken						
Force needed						
Force needed						

Links

Links with other GCSE in Science topics.

This demonstration is related to:

- P3 6.6
- P3 6.7.

Activity 10.4: Investigating effects of changing potential energy

What you will learn from this activity

In this activity you will find out which factors affect the potential energy of the rollercoaster, going up the first hill. You will also find out how this affects the rest of the rollercoaster ride.

What you will know when you finish this activity

1 That mass, height of the first hill and gravity affect the potential energy (PE).

2 The potential energy of the rollercoaster at the top of the first hill affects the rest of the rollercoaster ride.

How you may be assessed

1 Your explanation of the effect of changing mass, height of the first hill and gravity, on the potential energy.

2 Your explanation of the effect of changing mass, height of the first hill and gravity on the rest of the rollercoaster ride.

What you do

1 Find the rollercoaster simulation at Funderstanding rollercoaster (www.funderstanding.com/k12/coaster).

2 Use the table provided to record the effects of changing PE on the computer simulation.

3 Set the height of hill 1, mass and gravity to low (minimum setting).

4 Start the simulation and record whether the rollercoaster completed the course or not.

5 If the course was completed record the maximum speed that the rollercoaster reached, and the time taken to complete the course.

6 Repeat this again for all the settings listed in the table provided on the next page.

7 Rank the amount of potential energy in each experiment, from 1 = lowest to 9 = highest.

Suggestions for further work/homework

1 Explain which settings made the rollercoaster work well and complete the course, and explain why this happened.

2 Explain which settings stopped the rollercoaster completing the course, and explain why this happened.

3 Analyse all of the results and explain which had the biggest effect on the outcome of the rollercoaster ride — changing height, mass or gravity.

4 Explain what happened in the computer simulation when the height, mass and gravity were changed.

5 Extension: Which settings for mass, height of hill 1 and gravity produce the most thrilling ride? Explain fully.

Activity 10.4: Investigating effects of changing potential energy

Height of hill 1	Mass of rollercoaster	Gravity	PE (1 to 9)	Did it work?	Time taken to complete course	Maximum speed recorded
Low (minimum)	Low	Low				
Low	Low	Medium (mid-way)				
Low	Low	High (maximum)				
Low	Medium	Low				
Low	Medium	Medium				
Low	Medium	High				
Low	High	Low				
Low	High	Medium				
Low	High	High				
Medium	Low	Low				
Medium	Low	Medium				
Medium	Low	High				
Medium	Medium	Low				
Medium	Medium	Medium				
Medium	Medium	High				
Medium	High	Low				
Medium	High	Medium				
Medium	High	High				
High	Low	Low				
High	Low	Medium				
High	Low	High				
High	Medium	Low				
High	Medium	Medium				
High	Medium	High				
High	High	Low				
High	High	Medium				
High	High	High				

Activity 10.4: Investigating effects of changing potential energy

Notes for teachers and technicians

Aim

In this activity students will find out which factors affect the potential energy of the rollercoaster, going up the first hill. They will also find out how this affects the rest of the rollercoaster ride.

Skills, knowledge and understanding

This activity will enable students to gain the following skills, and/or knowledge and understanding:

1 that mass, height of the first hill and gravity affect the potential energy

2 the potential energy of the rollercoaster at the top of the first hill effects the rest of the ride.

Previous skills, knowledge and understanding required

An understanding that energy is required to make things move.

Materials required

Access to the internet.

Health and safety issues

If using the internet ensure student are not able to access unsuitable websites.

Delivery strategies

- This activity is part of the lesson, so other work will already have been covered.
- Provide an introduction to explain what to do with hill 2 (the loop, friction etc) as there are too many variables which students may change.
- Explain to students that they are to do this activity on their own, and to form their own ideas.
- Students of low ability could be given more help, or paired up with more helpful higher ability students.
- The plenary part of the lesson asks students what they have found out, and to summarise the information.

Assessment strategies

- The student's explanation of the effect of changing mass, height of the first hill and gravity, on the potential energy.
- The student's explanation of the effect of changing mass, height of the first hill and gravity on the rest of the rollercoaster ride.

Links

This activity builds on the following skills, knowledge and understanding from Key Stage 3 (KS3):

- 9I Energy and electricity.

Activity 10.4: Investigating effects of changing potential energy

Resources

- Funderstanding Roller Coaster (www.funderstanding.com/k12/coaster) website.

Experiment 10.5: Changing mass and kinetic energy

What you will learn from this experiment

What effect the mass of the trolley has on its kinetic energy when it travels down the track.

What you will know when you finish this experiment

1 That kinetic energy is affected by mass.

2 That kinetic energy is affected by velocity.

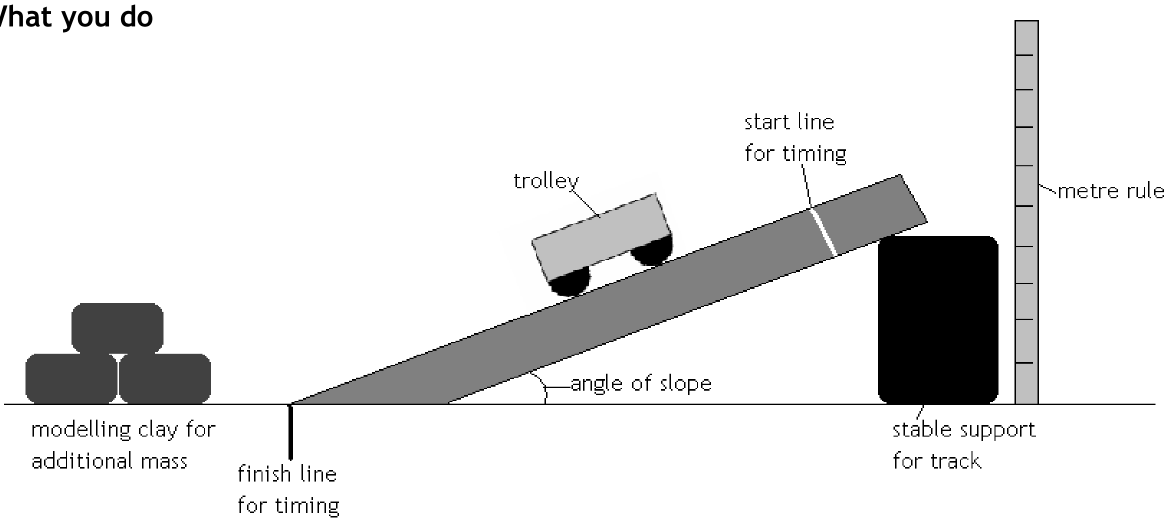
How you may be assessed

1 Your ability to carry out the experiment safely and accurately.

2 What you find out from your experiment.

3 Your analysis of the results of your experiment.

What you do



1 You will need to work in pairs for this experiment.

2 Collect the equipment.

3 Measure the mass of the trolley, using the scales, and record this in the table provided.

4 Set up the track with one end on the support and one on the desk, so that it doesn't slip.

5 Measure the angle and height of the track and record these in the table provided.

6 Hold the trolley at the start line and make sure you are ready to start the stopwatch.

7 Release the trolley and start the stopwatch.

8 Stop the stopwatch when the trolley gets to the end of the track.

9 Repeat this again adding 20 g of modelling clay to the trolley each time, until you have added at least 80 g.

10 Record all the results in the table provided.

11 Calculate the velocity of the trolley and velocity squared.

12 Calculate the kinetic energy of the trolley travelling down the track.

13 Explain how changing the mass of the trolley affects the kinetic energy.

Activity 10.5: Changing mass and kinetic energy

Suggestions for further work/homework

1 Draw a graph of your results.

2 Identify any anomalous results from your graph, and explain them.

Experiment 10.5: Changing mass and kinetic energy

Angle of slope (°): ______________ °   **Height of slope (m):** ______________ m

Distance travelled (m)	**Time taken (seconds)**	**Mass of trolley (kg)**	**Velocity (m/s)**	**Velocity ^{2}**	**Kinetic energy (J)**

Activity 10.5: Changing mass and kinetic energy

Note for teachers and technicians

Aim

What affect the mass of the trolley has on its kinetic energy when it travels down the track.

Previous skills, knowledge and understanding required

9I Energy and electricity.

Skills, knowledge and understanding

This experiment will enable students to gain the following skills, and/or knowledge and understanding:

1 that kinetic energy is affected by mass

2 that kinetic energy is affected by velocity.

Equipment and chemicals required

For each pair:

1 a large wooden track, with a line across one end school

2 something to support the track on (a plastic box/tray)

3 a wooden trolley

4 modelling clay (in 20g lumps)

5 scales

6 a metre rule

7 a protractor

8 students may need access to a calculator.

Health and safety issues

Take care when handling the wooden track, and use wooden tracks that are not too heavy. Rest the wooden tracks on a stable object such as a rigid plastic box or a school tray (ie not a pile of textbooks).

Experiment 10.5: Changing mass and kinetic energy

Delivery strategies

- Introduce the experiment as a way to find out how the mass of the trolley affects the kinetic energy of the trolley travelling down the track.
- Students should work in pairs as the experiment involves many simultaneous tasks.
- Students should swap tasks to make sure everyone gets a turn at undertaking all tasks.
- Students of low ability should be given help, check by asking how they are getting on, or by providing a help sheet (adapted version of the experiment sheet), or by teaming them with higher-ability students.
- The experiment can be ended by asking students to pack away when finished, and to draw conclusions from their result.
- The experiment should be carried out for at least five different masses, however students could investigate further if they are fast workers.
- Students can be asked about their results, and also which angle of the track required the most work done by the trolley.

Assessment strategies

Students could be assessed on:

- their ability to carry out the experiment safely and accurately
- what they find out from their experiment
- their analysis of the results their experiment.

Links

This experiment builds on the following skills, knowledge and understanding from Key Stage 3 (KS3):

- 9I Energy and electricity.

Demonstration 10.6: Energy conservation

What you will learn from this demonstration

In this demonstration you will find out about the principle of conservation of energy.

What you will know after you have seen this demonstration

Energy cannot be created or destroyed, but just transferred from one form to another.

What you do

You will watch the demonstration by your teacher.

You need to think about what is happening to the toy car at each stage of the demonstration, and also what energy forms are present.

Write any ideas in the notes section below.

Notes

Demonstration 10.6: Energy conservation

Notes for teachers and technicians

Aim

In this demonstration students will find out about the principle of conservation of energy.

Skills, knowledge and understanding

This demonstration will enable students to gain the following knowledge:

1 that energy cannot be created or destroyed, but just transferred from one form to another.

Previous skills, knowledge and understanding required

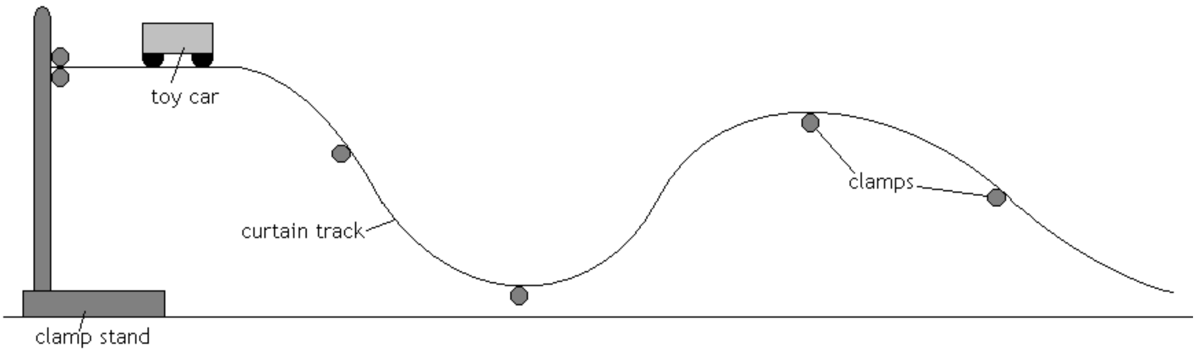
There are many different forms of energy (kinetic, gravitational potential, chemical potential, elastic potential, heat, light, sound, electrical and nuclear).

Equipment and chemicals required

1 A long piece of flexible curtain track set up as shown in the diagram below.

2 A toy car that fits on the curtain track.

3 Clamp stands.



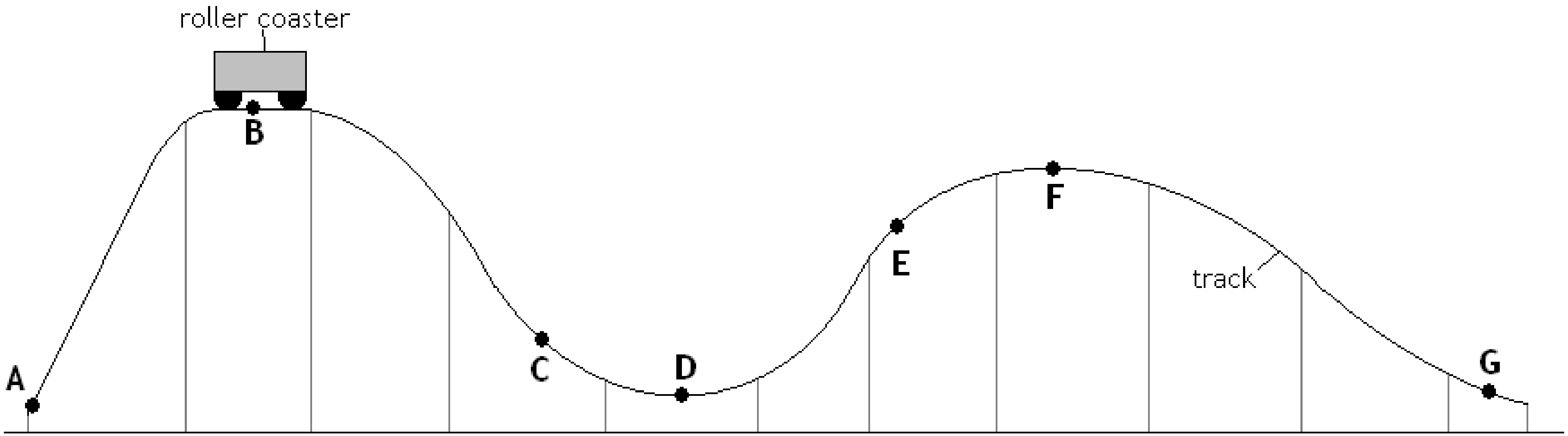
Health and safety issues

Students should sit at a safe distance away from the demonstration.

Delivery strategies

- Set up the experiment as shown in the diagram.
- Ask students to think about the gravitational potential energy and the kinetic energy as the toy car travels along the track.
- It may be useful to have students helping with certain tasks, such as measuring time, measuring height of the track, and recording the results.

Activity 10.7: Rollercoaster ride



1 Describe what is happening to the rollercoaster at points A to G, in terms of:

   a speed

   b acceleration

   c forces acting upon it

   d gravitational potential energy

   e kinetic energy

   f any other features you consider important.

2 Explain what needs to happen in order to make the ride:

   a longer

   b more exciting.

Demonstration 10.8: Circular motion

What you will learn from this demonstration

In this demonstration you will find out about circular motion, and how rollercoaster cars stay on the tracks when doing a loop-the-loop.

What you will know after you have seen this demonstration

1. An object moving in a circle at a constant speed must be accelerating as it is changing direction.
2. There must be a resultant (overall) force that is acting on an object, which is moving in a circle, in order for it to be accelerating.

What you do

You will watch the demonstration by your teacher.

You need to think about what is happening to the beaker of water and the toy car at each stage of the demonstration. Think about the speed, acceleration and forces involved in this demonstration.

Write any ideas/sketches in the notes section below. Can you add labelled forces eg those acting on the water and car?

Notes

Beaker of water demonstration:

Toy car and track demonstration:

Demonstration 10.8: Circular motion

Notes for teachers and technicians

Aim

In this demonstration students will find out about circular motion, and how rollercoaster cars stay on the tracks when doing a loop-the-loop.

Skills, knowledge and understanding

This demonstration will enable students to gain the following knowledge:

1 an object moving in a circle at a constant speed must be accelerating as it is changing direction

2 there must be a resultant (overall) force that is acting on an object, which is moving in a circle, in order for it to be accelerating.

Previous skills, knowledge and understanding required

1 That speed is equal to distance travelled multiplied by the time taken.

2 That velocity is speed acting in a particular direction.

3 That acceleration is the rate of change of velocity.

Equipment and chemicals required

1 500ml plastic beaker with water (with string securely tied) about half filled with water.

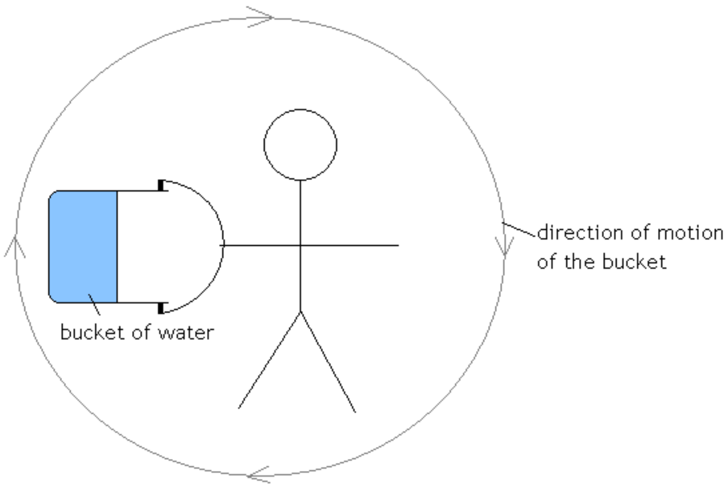
2 A long piece of flexible curtain track.

3 A toy car that fits on the curtain track.

4 Clamp stands.

5 Coat hanger and 1p coin.

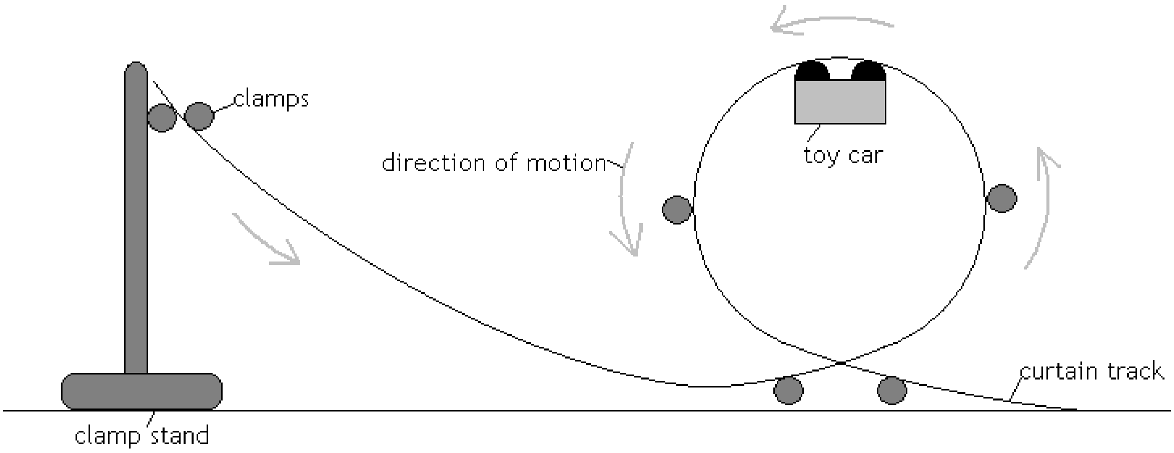
Demonstration 1: Bucket of water

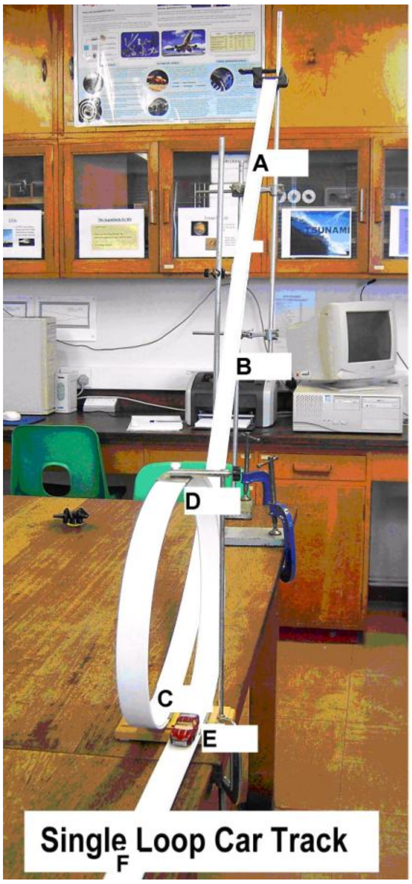


Demonstration 10.8: Circular motion

Demonstration 2: Toy car

(Not to scale — the point at which the clamp stand holds the track should have a height of at least 2.5 x the radius of the loop for this demonstration to work.)





Health and safety issues

Students should sit at a safe distance away from the demonstration, to make sure they are not splashed with water, and they are away from the toy car and track.

Delivery strategies

- Set up the experiments as shown in the diagrams.
- Ask students to think about the speed, acceleration and forces as the beaker is swung around, and the toy car travels along the track. Ask what are the forces acting on the water and car? Discuss.

Demonstration 10.8: Circular motion

Alternative demonstration

Pull open a wire coat hanger so that it forms a square. File the end of the hook flat and then bend the hook until it points towards the opposite corner of the square. Balance a 1p coin on the hook, put one finger in the corner of the square opposite the hook and then spin the coat hanger in a vertical circle — the coin stays in place! This is a very simple but excellent demonstration of centripetal force.

Theory and teaching notes

The force of the hook on the penny always acts towards the centre of rotation. This clearly shows the existence and direction of the centripetal force on a rotating object.

(www.resourcefulphysics.org)

Links

Links with other GCSE in Science topics.

This demonstration is related to P1b 11.16

Activity 10.10: Relativity research

What you will learn from this activity

In this activity you will find out about Einstein's theory of relativity, and why it is now an accepted theory. You will find out about the famous thought experiment, the 'Twin Paradox' and why this is useful in explaining relativity. You will also find out about the atomic clocks and cosmic ray experiments that support the theory of relativity.

What you will know when you finish this activity

1 That relativity is a widely accepted theory.

2 Relativity is accepted as its predictions were successfully tested in different situations.

How you may be assessed

1 Your explanation of relativity.

2 Your explanation of the experiments that support the theory of relativity.

What you do

1 Find out information on Einstein's theory of relativity, and why it is now an accepted theory.

2 Also find information on the twin paradox, and the atomic clocks and cosmic ray experiments that support the theory of relativity.

3 A good place to find this information is the internet, using websites such as:

   a Nobel Prize website, information on relativity — http://nobelprize.org/physics/educational/relativity/index.html

   b twin paradox — www.geocities.com/newmodel2k/Twins.htm

   c atomic clock experiment — http://hyperphysics.phy-astr.gsu.edu/HBASE/relativ/airtim.html

   d www.google.co.uk

4 Display your research in a poster.

Suggestions for further work/homework

Explain why it is difficult to test theories, such as the theory of relativity.

Activity 10.10: Relativity research

Notes for teachers and technicians

Aim

In this activity the students will find out about Einstein's theory of relativity and why it is now an accepted theory. They will find out about the famous thought experiment, the 'Twin Paradox' and why this is useful in explaining relativity. The students will also find out about the atomic clocks and cosmic ray experiments that support the theory of relativity.

Skills, knowledge and understanding

This activity will enable students to gain the following skills, and/or knowledge and understanding:

1 that relativity is a widely accepted theory

2 relativity is accepted as its predictions were successfully tested in different situations.

Previous skills, knowledge and understanding required

1 An ability to research websites to find the desired information, in a large volume of non-essential information.

2 The ability to present the desired information in an easy to understand manner.

Materials required

Access to the internet.

Health and safety issues

If using the internet ensure student are not able to access unsuitable websites.

Delivery strategies

- Explain to students that they are to do this activity on their own and to produce their own poster, with their own interpretations of the required information.
- Students of low abilities could be given more help, such as a help sheet.
- The plenary part of the lesson is asking students what they have found out and to summarise the information.

Assessment strategies

- The student's explanation of relativity.
- The student's explanation of the experiments that support the theory of relativity.

Links

This activity builds on the following skills, knowledge and understanding from Key Stage 3 (KS3):

- 9J Gravity and space.

Activity 10.10: Relativity research

Resources

- Nobel Prize website, information on relativity — http://nobelprize.org/physics/educational/relativity/index.html
- For an explanation of the twin paradox — www.geocities.com/newmodel2k/Twins.htm
- Atomic clock experiment — http://hyperphysics.phy-astr.gsu.edu/HBASE/relativ/airtim.html
- www.google.co.uk

Glossary for Topic 10: Rollercoasters and Relativity

What you will know when you finish this activity

By the end of this activity you will have created a comprehensive glossary to help you with your understanding of this topic.

What you do

Complete the glossary for each word or words.

You will be expected to be able to recall, explain, describe and use the words appropriately.

Key word	Definition
Acceleration	
Conservation of energy	
Current	
Electrical energy	
Energy transfer	
Force	
Gravitational potential energy	
Kinetic energy	
Mass	
Potential energy	
Power	
Resultant force	
Speed	
Velocity	
Work done	

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