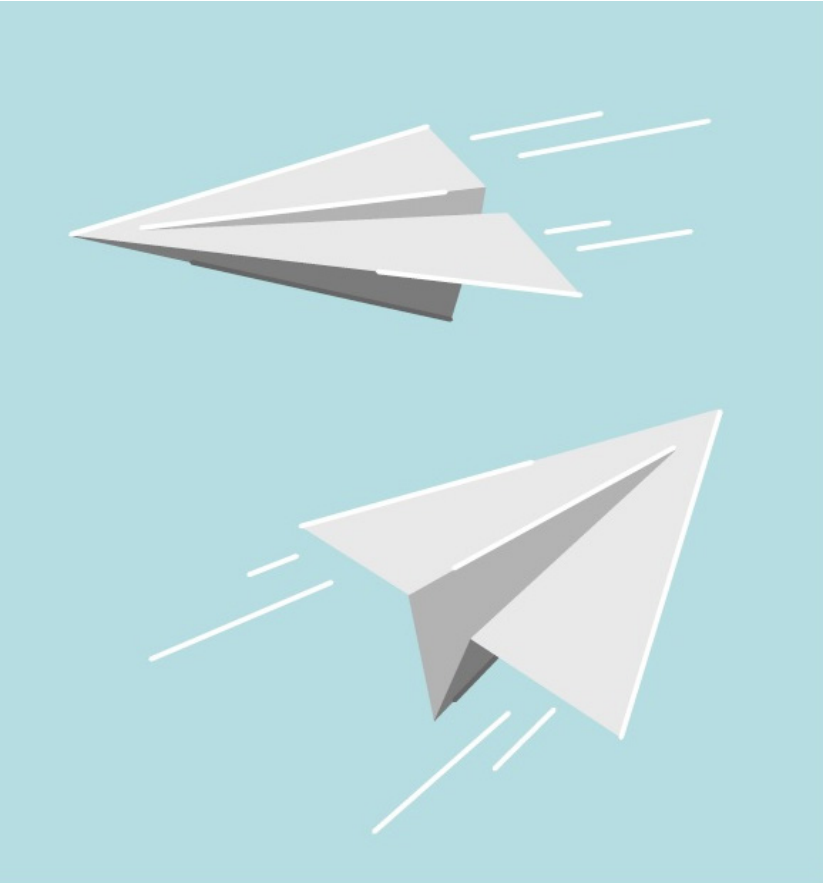
Teacher Resource



Forces
How do forces affect my speed?

Forces

Terrific Scientific Campaign

Investigation: Forces

Hello! Welcome to the Forces investigation from the Terrific Scientific campaign!

At Terrific Scientific, we think it is vital to develop science learning in primary schools across the UK. By taking part in this activity, you will be developing your class's scientific thinking and investigative skills.

At Key Stage 2 (Second Level), **children need to:**

- **Develop** investigative skills.
- **Understand** when it is important to control variables.
- **Predict, observe and record** results.
- **Draw conclusions** (which may generate new questions).
- **Understand** the need to repeat activities.
- **Record** what they see and not what they want to see.

We have incorporated these principles into this exciting activity. We've made it suitable for primary classrooms by using readily available equipment and suggesting opportunities for support and differentiation.

The BBC deems this activity safe if following some basic precautions. It is your responsibility as a School to carry out your own risk assessment and we recommend you consider the risks and mitigations we have described in this activity pack, as well as any risks which may be relevant to your specific class environment.

Related links:

Find out more about Terrific Scientific and our other investigations at bbc.co.uk/terrificscientific

As well as these key working scientifically principles, we have made sure there are links to the science curriculum for each nation, as well as cross curricular opportunities for further learning. We think these are just as important, as they help to explain the relevance of science and how it links to the world around us.

On our website you will find a supporting 'How to' film which shows teachers and teaching assistants how to set up and carry out the experiment. You will also find additional resources including a step-by-step lesson presentation, including an introductory film, which sets the investigation into context for your students.

We hope this inspires you and your students to get scientific and we look forward to seeing your results!

The Terrific Scientific Team.

Supported by: The Institution of Engineering and Technology and Institute of Physics.

Contents

What will the children learn

Watch the intro film:

Watch Elinor Barker and Jody Cundy investigate forces. bbc.co.uk/guides/zxvhrwx

These activities aim to encourage children to:

- **Plan** their own investigation by identifying variables - choose which variable to change, which to keep the same and which to measure.
- Look for patterns in their data and **identify** causal relationships.
- **Learn** about how the size and shape of objects affects their air resistance.
- **Evaluate** their investigation and results, commenting on whether they were able to control all of their variables, whether they answered the enquiry question and suggesting ideas for how to improve their methodology.

Assessment indicators

Notes:

Ask pupils to check out the sports scientist biographies on the Terrific Scientific website. bbc.co.uk/guides/zg8mv9q

Children will show evidence of learning by:

- **Planning investigations** - to produce valid results, selecting the most suitable variables to measure, change and keep the same.
- **Recording data accurately** - using repeat measures.
- **Using data to identify causal relationships** - explaining how air resistance is increased by increasing the surface area of an object or speed an object is moving.
- **Evaluating** - the effectiveness of the investigation, suggesting improvements to the way that variables were controlled.

Curriculum points (England, Scotland, Wales and Northern Ireland)

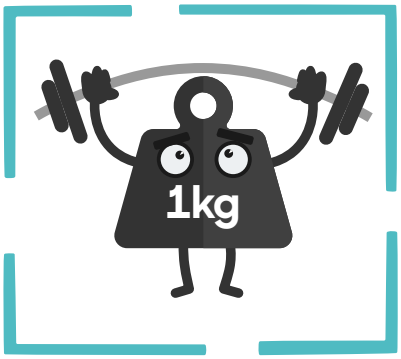
England

Working scientifically

- Planning different types of science enquiries to answer questions, including recognising and controlling variables where necessary. (p166)
- Taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings where appropriate. (p166)
- Reporting and presenting findings from enquiries, including conclusions, causal relationships and explanation of and degree of trust in results. (p166)

Forces

- Identify the effects of air resistance, water resistance and friction, that act between moving surfaces. (p171)



Scotland

Science experiences and outcomes

- Develop the skills of scientific enquiry and investigation using practical techniques. (p259)
- Apply safety measures and take necessary actions to control risks and hazards. (p259)
- Recognise the role of creativity and inventiveness in the development of the sciences. (p259)

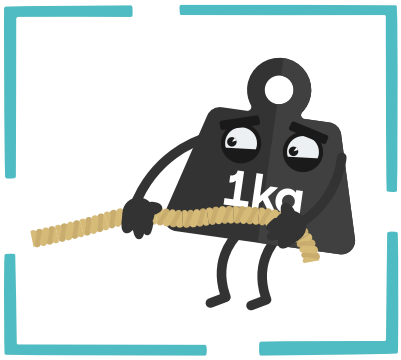
Forces

- Investigate how friction, including air resistance affects motion. Suggest ways to improve efficiency in moving objects. (SCN2-07a p265)

Wales

Skills - planning

- When carrying out a fair test, identify the key variables that need to be controlled and how to change the independent variable whilst keeping other key variables the same. (p13a 4)
- Decide upon the observations or measurements that need to be made. (p13a5)
- Identify any hazards and risks to themselves and others. (p13a7)

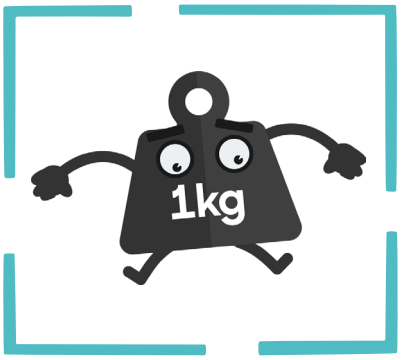


Skills – developing / reflecting

- Check observations and measurements by repeating them in order to collect reliable data and information. (p13a3)
- Use some prior knowledge to explain links between cause and effect when concluding. (p13b5)

How things work

- Investigate the science behind forces of different kinds e.g. air resistance. (p13b2)



Northern Ireland

Movement and energy

- Examine and collect real data. (p85)
- Design and carry out fair tests. (p85)
- Pupils should explore the causes and effect of energy, forces and movement. How forces can affect the movement and distance objects can travel. (p90)

Health and safety

- Watch overhead cables when exploring kites and parachutes etc. Avoid places in which cables could get caught up.
- To minimise trip hazards, encourage the children to invent outfits that are worn above the waist and consider the weight that the person will have to carry, so that they can move as freely as possible. Also encourage them to consider the wearer's field of vision so that they can run safely in their outfit.

Investigating Forces

Introduction

Have you ever wondered what it takes to win at the Olympics? Not only does it require athletes to undertake hours of dedicated training, but working alongside them is a highly talented team of scientists too. Physiotherapists, dieticians, and sports scientists all work with the athletes to ensure that they are in the best possible shape they can be. Sports engineers also help athletes to win by designing the best equipment for them to use; everything from their clothes, to their footwear and sports equipment is designed, tested and improved to help the athlete win those marginal gains, enabling them to get ahead of the field.

As a result of work done by sports scientists, some athletes now use air resistance to help them train. They wear parachutes attached by cords to a harness on their body. When the parachute is open it provides resistance, making the athlete work harder to overcome the drag caused by the parachute, therefore building their strength, speed and endurance.

Air resistance is a friction force between air and a moving object. As a moving object pushes the air forwards, the air pushes back on the object to slow it down. Faster objects experience more air resistance. Air resistance works in the opposite direction to the direction of movement. We put air resistance to good use when we want to slow objects down. For example we use parachutes to slow down all sorts of moving objects from Mars landers, to land speed record breaking cars.

In this series of activities, children are going to work as sports engineers. They are going to work scientifically by making their own decisions, planning their own scientific enquiry and then apply their learning about air resistance when they design and make an outfit for our Wacky Air Resistance Race. They will run two races, one as they normally would playing with friends, another wearing modified costumes to increase their air resistance. This will allow you to compare your results with schools all over the UK using the Terrific Scientific Map.

Preparing for the investigation

The activities below have been designed to prepare your students for the main part of the investigation.

Notes:

Be extra careful when designing suits so the pupils can move freely and safely.

Expected duration

This investigation is split into several parts. The main part of the investigation should take half a day to complete.

What is a sports engineer?

Optional introductory activity - 10 minutes

This activity could be used to introduce your children to the work of sports engineers. Ask them to read the biographies of Aimee and Andy.

- What problem did each person overcome?
- How did they use science in their work?
- What it is like to work as a sports engineer? Ask the children to make a list or mind map of all the skills and attributes they think a sports engineer might need.

The children should observe that all of our sports engineers are great problem solvers, who use creative thinking, maths, communication skills and scientific knowledge to come up with solutions. They test their ideas scientifically to improve their inventions.

Notes:

The sports biographies can be found here.

guides.files.bbci.co.uk/terrific-scientific/Aimee_Sports_Biog.pdf

guides.files.bbci.co.uk/terrific-scientific/Andy_Sports_Biog.pdf

Playing with air resistance

Introductory outdoor activity - 15 minutes

Ask:

Why do you think that happened?

What can you feel happening?

Can they feel the air resistance?

What has happened to their surface area?

Equipment needed

- Sheets of A4 paper.

1. To get the children thinking, drop a piece of A4 paper onto the floor. Challenge the children to investigate how they could make a second piece of paper fall faster. If needed, show the children how to do it. Scrunch one piece of paper into a ball. Leave the other one intact. Hold them at the same height and drop them together; the children will see the scrunched paper falls much faster. Ask the children to consider **why do they think that happened?** Encourage them to discuss their initial ideas in pairs, then to share with the class. **THINK, PAIR AND SHARE.**

2. Go outside into the playground. Give the children a large piece of cardboard and ask them to walk about with it held vertically above their heads. **When they walk with it do they feel much air resistance?** Next, get them to pick up the pace - jogging or running. As their speed increases, ask the children **what can you feel happening? Can they feel the air resistance? What has happened to their surface area?** They should begin to associate the increase in surface area with an increase of air resistance.

3. The children will feel the air pressing against the sheet of card. Challenge the children, **how could you reduce the air resistance whilst holding the card?** They could cut holes to let the air through or make the paper smaller or hold it side on. It is important that the children have time to play and to experiment with changing the amount of air resistance at work.

4. **Ask the children I wonder if you could you use air resistance to slow moving vehicles down, what do you think?** Get the children to **THINK, PAIR AND SHARE** their ideas and justifications with the class.

Plan a science investigation exploring air resistance

Introductory outdoor activity - 1 hour

Watch the film:

To find out more watch the Brain Freeze film. bbc.co.uk/programmes/p04ydqcp
After the film, ask the children.
Why are parachutes particularly useful for slowing moving vehicles down?
Why is a parachute a good braking device?
Where else do we use parachutes to slow things down?

Watch the intro film:

Watch Elinor Barker and Jody Cundy investigate forces. bbc.co.uk/programmes/p04y5jf4

Equipment needed

- Paper cupcake cases

Plan

The children will plan a pattern seeking investigation to explore air resistance, using paper cupcake cases as parachutes. Cupcake cases make good parachutes and are small enough to get a decent result dropping them from a standing height.

Pattern-seeking investigations require children to look for patterns and relationships between variables.

1. Encourage the children to throw a cupcake case into the air. **What do you notice? What is keeping the cupcake case in the air for so long?** Usually the cupcake case will right itself, landing on its base. Get the children to play with cupcake cases for a few minutes, encourage them to change them and see what happens.

2. On the planning sheet, ask the children **what variables could you change.** The children might try investigating: different size cupcake cases; slits cut into the cupcake case; height of drop; numbers of cases dropped together; the shapes of cases, for example crunched into a ball or flattened out. The children should record this onto the change section of the Student Worksheet.

3. Ask the children to consider **what they might measure when the cupcake case falls.** The most sensible variable to measure in these cupcake case enquiries is the time that it will take for the parachute to land. Record this onto the measure section of the Student Worksheet.

4. Ask the children to choose one of the variables to test to create their own enquiry question on the Student Worksheet.

5. The children need to consider how they will conduct their investigation. Which variables will you keep the same each time? The children should notice that the variables which they did not select for their enquiry question are the same ones that they need to control. In most of the enquiries the children will pursue they will also affect the weight of the cupcake cases. This is therefore a pattern seeking enquiry and not a fair test.

6. Encourage the children to make a reasoned prediction about what they think might happen.

7. Next ask them to plan a table for their results. Note that when children create a table in science, the left column refers to the variable you are changing. The right hand column refers to the variable you are measuring. Children need to decide if they are going to make repeated measurements: Repeat measurements are taken in order to check the reliability of a result. By taking more than one reading, we can check whether the initial reading was correct; we can gather more evidence and find an average result.

Discuss:

As a class discuss point 6. Have a conversation around what the children think will happen to the cupcake cases.

Ask:

Can you describe the pattern?

Was your prediction correct? Why? Why not?

Were there any unusual readings?

In what ways could they have improved what they did?

Do

As they work, encourage the children to be systematic and careful in their approach. Remind them about the need to be making careful observations and measurements. **Do a quick check with the children – which variable are you testing? How are you keeping the other variables the same? Is your timing accurate? Are all your results being recorded in the right place on your table?**

Review

Once all the data is collected, ask the children to analyse their data and evaluate their investigation.

- Is there a pattern between the two variables - what you have changed and what you measured? Can you describe the pattern? Can you think of a reason for it?
- Can you come up with a causal statement that reflects what you found?
- Can you use some scientific knowledge to support your causal statement?
- Was your prediction correct? Why? Why not?
- Were there any unusual readings? Get children to look for anomalies and inconsistencies in their data and to think back about how they worked. How could they have been more systematic and precise? In what ways could they have improved what they did?

Main Activity

To invent an outfit that uses air resistance to slow a racer down

Main investigation - Half a day

Equipment needed

For the main investigation

- Stopwatches or timers – with milliseconds.
- Large A2 pieces of cardboard.
- Student worksheet.
- Tape measures or meter rulers.
- Dressing up clothes or old shirts, t-shirts, fabric, card, sticky tape, safety pins, bin liners or plastic sheeting.

A race with a difference!

Utilising all they have learnt about air resistance, the children will invent an outfit for their partner to slow them down. This race allows the children a further opportunity to feel air resistance and to make observations about how it behaves. Their inventions will need to be pretty large to really slow their partner down. The winner will be the person whose outfit makes the most difference to their partners speed but beware this data is not all it seems and we wonder if your children can spot the other forces that may have been at play to influence the race.

Notes:

Remind the children that they need to keep their racer safe. They can do this by:

1. Taking care to ensure that their racer is fully able to move their head and has maximum visibility, so nothing over the eyes.

2. Design air resistance outfits for above the waist only, so that their racer is able to move freely.

Important:

Remember your race distance must be 50m!

1. Before you share this idea with the children, get them to record their fastest run over 50m. This is their baseline measurement.

2. Then reveal to the children their challenge. Can you build an outfit that will catch the most air to slow your racer down? The children are going to work in pairs to create an outfit for their partner to slow them down.

3. Ask the children to list, sketch, or map their ideas about air resistance so far. Recap the main point of the investigations so far, which was that increase in surface area increases the amount of air resistance.

4. Next get them to consider ways in which they could increase their partner's surface area. For example, the children might try creating a really tall, wide hat; they might wear a cape or flappy coat; they could build a set of wings; they could tow a kite or a parachute – the sky's the limit! They may choose a combination of ideas.

5. Ask the children how you can prove which outfit has made the most difference. You may like to discuss a code of honour for the race. Everyone needs to promise that they will travel their fastest and not cheat! Remind the children that only once the maths has been done will they be able to work out the true winner. There may be some shocks in store!
   Time the children doing the same race with their outfit on. Then work out the difference.

   For example:

Average time	**1st Race**	**9.65 secs**
Average time	**2nd Race**	**10.27 secs**
Difference is	**0.62 secs**	

So the Wacky Air Resistance outfit made our runner 0.62 seconds slower.

6. It is really important to encourage the children to review their investigation and critique their results.

Ask the Children to do a PMI (Plus/Minus/Interesting) analysis using the PMI sheet (part of the Forces Student Resource Pack). Children evaluate their work using a PMI graphic organiser. Identifying what was good (positive), negative (minus) or Interesting about the activity.

a) What was positive about this investigation? What did you learn?

b) What was negative about this investigation? What did you struggle with? Did anything affect your results?

c) What was interesting about the race?

Ask the runners, how did you feel racing with your wacky outfit on? Could you feel the outfit catching the air? Were any other forces working on your outfit as you moved? The children will probably say that their designs meant that the racer was carrying more weight.

Ask the children, could you design a way to test air resistance without altering the weight variable? If you change the air resistance of something are you always changing the weight?

7. Finally remind the children that they were working as engineers. One of the challenges of sports engineering is about finding the best balance between forces such as air resistance and weight in order to create the best possible product.

Ask:

How did you feel racing with your wacky outfit on?

Were any other forces working on your outfit as you moved?

If you change the air resistance of something are you always changing the weight?

How well did your outfit balance adding weight to maximise air resistance?

You may like to ask the children to invent an enquiry to test the difference the weight made to their run?

Consider what other considerations engineers have to think about when they are working. Why is it important that engineers test their ideas out?

8. Use the Wacky Sports Day Pack to come up with more ideas for a Terrific Scientific Wacky Sports Day which can be found on our website.

Glossary

Air resistance	Air resistance is a friction force between air and a moving object. When objects move, the air pushes against them and makes it hard for them to go faster. Faster objects experience more air resistance. Air resistance works in the opposite direction to the direction of movement. We put air resistance to good use when we want to slow objects down. For example we use parachutes to slow down all sorts of moving objects from Mars landers, to Land speed cars.
Force	A push or pull, measured in newtons.
Friction	Friction is the force created when two surfaces move across each other. It is a force that can prevent an object from moving or slow it down. The amount of friction increases with the speed of movement between the objects.
Gravity	Gravity acts between all objects that have mass. Most noticeably, the gravitational attraction between the Earth and an object results in the object experiencing a force that pulls it down towards the Earth. All objects with mass have gravity acting between them.
Mass	The amount of matter that makes up an object. This is expressed in grams. People often confuse mass and weight. If you are weighing ingredients for a cake, you are measuring mass, not weight.
Newtons	A measure of the amount of force being exerted. The symbol for newtons is N.
Repeat measurement	Repeat measurements are taken in order to check the reliability of a result. By taking more than one reading we can check whether the initial reading was correct: we can gather more evidence and find an average result.
Upthrust	Some people confuse the term **upthrust** with the term **air resistance.** Upthrust can occur in air and water. For upthrust to occur in air the object must be less dense than the surrounding air. This is why helium balloons float in air.
Variable	A variable is any factor that can be controlled, changed, or measured in an investigation. In any investigation, you choose one variable to change (the independent variable) and one to measure (the dependent variable). All other variables are kept the same throughout the test.
Weight	An object's weight is a measure of how much gravity is pulling down on the object. If an object was on a different planet, it would have a different weight, according to the gravitational pull of that planet. Weight is measured in newtons.