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| **How does Santa’s sleigh fly?** |
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| **Stay safe** |  |  |
| Whether you are a scientist researching a new medicine or an engineer solving climate change, safety always comes first. An adult must always be around and supervising when doing this activity. You are responsible for: • ensuring that any equipment used for this activity is in good working condition• behaving sensibly and following any safety instructions so as not to hurt or injure yourself or others  Please note that in the absence of any negligence or other breach of duty by us, this activity is carried out at your own risk. It is important to take extra care at the stages marked with this symbol: ⚠ |
| **Age range:** 7 – 13 years**Approx time:** 2 hours |  | **Key words / Topics:** * Forces
* Drag, thrust
* Gravity, lift
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| **Equipment** ⚠ |  |  |
| * A4 plain paper
* Paperclips
* Cotton or thin string
 |  | * 2 x paper straws
* Hairdryer
* Sticky tape or glue
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| **Introduction** |  |  |
| There are four important forces which affect how Santa’s sleigh will fly. We’re going to explore these forces so that you can design your own sleigh to help Santa.**DRAG****THRUST****LIFT****GRAVITY****DRAG****THRUST****LIFT****GRAVITY** |
| **Exploring gravity and air resistance** |  |  |
| You’re going to make a helicopter. **Step 1**⚠Cut a rectangle measuring 20cm x 8cm from a piece of plain paper.**Step 2**Cut and fold (where shown on the diagram below).**Step 3**CUTCUTCUTFOLD INFOLD INFOLD AFOLD BThen fold **A** away from you and Fold **B** towards you, to make the rotors of the helicopter.**Step 4**Drop the helicopter to see how it spins then add a paperclip at the bottom to see if that makes a difference. |
| **Extension** |  |  |
| **Now you can really get to work as an engineer.** * Try folding the rotors the opposite way and see how that affects the direction of spin as it falls.
* Add another paperclip to the bottom to see if that affects the way it falls.
* Make other helicopters with longer or shorter rotors to see if that affects the way they fall.
* Use other types of paper such as tissue paper or heavier card to see if that changes the way they fall.
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| **Exploring thrust** |  |  |
| Make a paper aeroplane using any design you want. Throw it forwards and see how far it goes. ⚠ Make sure you have space around you. A paper aeroplane in the eye will hurt! **How can you make it go further?** Does throwing it harder help? Does changing the shape help? (You might want to explore this further through our activity Paper Aeroplane resource which you can find here [Paper aeroplane (theiet.org)](https://education.theiet.org/secondary/teaching-resources/paper-aeroplane/). |
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| **Exploring lift** |  |  |
| **Step 1**Make an aerofoil by folding over an A4 piece of plain paper, shorter side to shorter side. Move the top side slightly in from the bottom side and then tape or glue the edge.You will end up with a shape like this.**Step 2**Make two small holes and pass a straw through each one on each side of the aerofoil.**Step 3**Pass string through the straws and then fix either end to something so that the aerofoil can move up or down freely on the string. Fixing it to a door frame works well.**Step** **4** ⚠Use a hairdryer to blow air onto the front of the aerofoil. What happens? **Step 5**Try angling the hairdryer up or down to see if there is any change.**Step 6**Try bending the end of the aerofoil upwards to see if that changes how it moves |
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| **Exploring drag** |  |  |
| Try running holding a large piece of fabric behind you like a parachute. (A bed sheet works well for this but please ask before you take one off someone’s bed!) What effect does it have on your ability to run fast? Why? |
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| **Science** |  |  |
| By now you will have realised that some forces help Santa’s sleigh to fly but some don’t, so let’s go through them.**Gravity****Gravity** is a force exerted by everything which has **mass**. The larger the mass, the larger the force of gravity which is why the Earth has a greater force of gravity than the moon. Gravity pulls objects towards a mass, the closer you are to it, the greater the pull. Our helicopter falls because the Earth pulls it towards it. If it had no opposing force it would fall really quickly, but it does – **air resistance**.**Air resistance** **Air resistance** is the force which acts in opposition to gravity and is caused by motion of an object moving through the air. The air particles need to be pushed out of the way which is why it spins around. You can see this if you drop a single sheet of plain paper. It sways around as it falls as it pushes the air particles out of the way. If you then screw up the piece of paper and drop it, it falls quickly and in a straight line.**Unbalanced forces** **Unbalanced forces** make things start moving, speed up, slow down or stop but if we **balance** forces objects either stay where they are or they move at a steady speed. If we could balance the air resistance on Santa’s sleigh with the force of gravity on it then we could get it to stay still hovering in the air. We could get Santa and the reindeer to fly high above the Earth which would reduce the force of gravity but, unfortunately, that would also mean that there are fewer air particles in the atmosphere and therefore air resistance would also be reduced. We could try making Santa’s sleigh really light, with a large surface area. This would reduce gravity and increase air resistance, but it wouldn’t be able to hold Santa and definitely wouldn’t hold any of our Christmas presents. Even if we could balance gravity and air resistance it still wouldn’t fly forwards.So, we have a problem, the flight of Santa’s sleigh must be more than just balancing gravity and air resistance. We need to look at lift and thrust as well. If you look at an aeroplane they can be absolutely huge and carry lots of people and their luggage. Gravity and air resistance are definitely not balanced there. The reason they can fly is because of other forces.**Thrust** **Thrust** is the force which enables an object to move forward through the air. In Santa’s case, thrust is caused by the reindeer pulling the sleigh. Like all forces though, it has a force acting in opposition. We call this **drag**. This is caused by the movement of an object through the air. An object with larger surface area causes more drag but we can minimise this by making our shape **aerodynamic**. This allows the air particles to move smoothly past the object reducing drag. Movement of airMovement of airWhilst drag is something Santa wants to reduce, the effects caused by the movement of air particles can also be really useful to him. If he shapes part of his sleigh like an aerofoil then he can use **air pressure** to make his sleigh fly upwards or bring it back down, or just keep it flying in a straight line.When you pointed your hairdryer at the front of your aerofoil the flow of air goes over the top and the bottom of the aerofoil. The shape of the aerofoil, however, creates differences in air pressure. The air flows faster over the top of the aerofoil than it does over the bottom as the camber creates a vortex which slows flow down. Faster moving air creates less pressure than slower moving air so the higher pressure underneath the aerofoil causes it to lift. If we bend the end of the aerofoil upwards to create a camber on the top then we can make it move downwards when we flow air across it. This is how the flaps on an aeroplane wing work. We can also do the same thing by shaping and angling the rotors on a helicopter to make it move upwards or downwards.Remember, though, it is the movement of the aeroplane forwards through the air which generates this lift. Without something to thrust it forwards it would fall from the sky. So, all this means that Santa needs to do the following:1. keep the weight down in his sleigh to minimise the effects of gravity
2. have a sleigh which is shaped aerodynamically to reduce drag
3. have something shaped on his sleigh which will allow him to change air pressure, such as an aerofoil
4. keep the reindeer well fed and fit so they can keep his sleigh moving through the sky

We all know that all Santa needs to do is sprinkle his sleigh and his reindeer with magic dust and it will fly whatever shape it is. Phew, thank goodness! |
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| **Curriculum links**  |
| **England: National Curriculum**ScienceKS2 Year 5 Forces:* explain that unsupported objects fall towards the Earth because of the force of gravity acting between the Earth and the falling object
* identify the effects of air resistance, water resistance and friction, that act between moving surfaces.

**Scotland: Curriculum for Excellence**SciencesForces:SCN 2-08aTechnologiesTCH 3-01a |  | **Northern Ireland Curriculum**KS2 – The world around usMovement and energy:the causes and effect of energy, forces and movement.Technology & Design* Design – identifying problems; investigating, generating, developing, modelling and evaluating design proposals; giving consideration to form, function and safety

 (Objective 2) Developing pupils as Contributors to Society* Explore technical inventions and designs that have met a social need cost-effectively

**Wales: National Curriculum** ScienceKS2 – How things work:* forces of different kinds, e.g., gravity
* the ways in which forces can affect movement.
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