FEEL THE FORCE

A science investigation pack for teachers of 9-11 year olds

CENTRE for INDUSTRY EDUCATION COLLABORATION

Supported by the Gatsby Charitable Foundation

Contents

Introduction

AGE RANGE

The activities in this book provide an opportunity for children to think about the properties of air and in particular, the frictional forces it exerts. The material is aimed at Year 4 pupils, and can be readily modified for use with Year 5-6 children, particularly by varying the types of measurement carried out.

CONTEXT

The ideas are put into a real-life context, that of a transport company looking for ways to reduce the fuel consumption of it's lorries. See Appendix 1 for more background information. Photographs that can be used with the class can be found on Activity sheet 2.

This approach makes the work more relevant and enjoyable for the children. While an industrial visit is not necessary to complete the work, if a local industry is available to support the work in these activities, it will certainly strengthen the children's understanding and enjoyment of the science work undertaken.

ACTIVITIES

The activities take approximately 3 hours, and the activities can be taught in 2 sessions, to suit the timetable, teacher and children. They should be completed in the order given, to follow the sequence of identification of a problem to investigation and finally a solution to the problem. Appendices 2-3 provide lesson plans, as well as a sample assessment grid for one investigation.

ACTIVITY SUMMARY

Title	Description	Timing
1. Feel the force	The children are introduced to the concept of air resistance as a force by running in playground with sheets of paper.	35 mins
2. Measuring the force 1	Children compare toy vehicles with different sized front areas to discover that vehicles with a larger front have greater air resistance.	50 mins
3. Measuring the force 2	Children investigate the impact of adding various shapes of card to the lorry front (known as fairings) to find out whether there is any impact on the air resistance.	60 mins
4. Report back to company	Graphs, patterns and data can be reported back to the company with final recommendations.	45 mins

The Activity sheets should help the children record their findings. At Key Stage 2 children are expected to *'...talk about their work and its significance, and communicate ideas using a wide range of scientific language, conventional diagrams, charts and graphs'*. The Activity sheets provide formats to help the children record their ideas, measurements and findings. It is hoped that the formats will increase the children's enjoyment of science by appreciating the variety of ways in which they can record their work, whilst supporting differentiated teaching in the classroom.

Resource requirements

All lists refer to resources required for a group of 4 children, unless otherwise stated.

ACTIVITY 1

- Activity sheets 1 and 2
- 1 sheet of A4 and/or A3 card (per child or pair)
- A roll of wallpaper and sellotape (optional)
- A few cycling helmets (for whole class discussion/display)
- Pictures of lorries with and without cab 'streamlined' fairings.
- Pictures of streamlined objects e.g. aircraft, racing cars (optional)

ACTIVITY 2 AND 3

- Activity sheet 1
- Activity sheet 3, copied onto A5 card
- Activity sheet 4, copied onto A4 card
- Toy vehicle (see below)
- Hair dryer (preferably with a 'cold' setting)
- 1 metre and 30 cm rulers 1
- 2-3 thick, large elastic bands[1]
- Newton force meter

Safety note

Emphasise to the children that they are not to actually put the tablet shapes in their mouths.

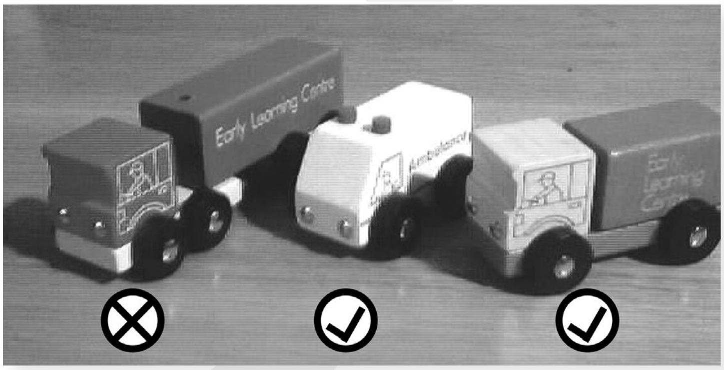
ACTIVITY 4

- Computer and associated software (word processing and graphing).

1 This provides an alternative to launching vehicles down a slope, which can introduce the classic error that a heavier object will fall faster than a lighter one. It also allows force measurement. See the activity notes for further details.

TOY VEHICLE

Avoid futuristic vehicles (e.g. Batmobile) or articulated lorries, which will not run in a straight line. Early Learning Centre vehicles are ideal (try the Reception class or nursery). It may be that construction kits for making simple vehicles are in school, and these could also be put to use. Vehicles must be free and straight running, and large enough to tape A5 pieces of card to the front.



Examples of the sort of vehicle which could be used.
The articulated lorry is not recommended.

1. Feel the force

35 mins

The children are introduced to the concept of air resistance as a force by running in playground with sheets of paper.

OBJECTIVES

- Appreciate that air can exert a force.
- Appreciate that a force can both assist or resist movement.
- Appreciate that the surface area of an object can create more, or less, air resistance.

RESOURCES

(Per group of 4 children)

- Activity sheet 1
- 1 sheet of A4 and/or A3 card (per child or pair)
- A roll of wallpaper and cellotape (optional)
- A few cycling helmets (for whole class discussion/display)
- Pictures of lorries with and without cab 'streamlined' fairings
- Pictures of streamlined objects e.g. aircraft, racing cars (optional)

INTRODUCING THE ACTIVITY (10 minutes)

Read the letter from the transport firm (Activity sheet 1) to introduce the problem. A new company is setting up its transport division, and is going to buy a fleet of lorries. The manager has noticed that many lorries have attachments fastened to the top of the cab, although many do not. He wants to know why there are attachments to the cabs, which he thinks have something to do with wind resistance. If he buys some he would like to know what effect they could have, and which sort might be the best. Can the children produce some information and data to help him make his decisions.

Brainstorm some ideas of types of force (pull, push and twist) and decide which ones might apply to this problem. Use cycling helmets and photographs of streamlined vehicles to ask why they have their particular shapes. If the answers given suggest that it is 'to make them go faster' ask how the shape will make them go faster? Establish that the wind (air) can give a *push force*, which can either oppose movement, or help it. Can they suggest some experiments to help them feel this force?

MAIN ACTIVITY (15 minutes)

Stress that **they** need to feel the force, so they will need to hold something that the wind (air) can resist. Give each child, or pair, a sheet of A4 and/or A3 card to hold at arm's length in front of them, as they run around the playground or school hall. (Larger sheets can be tried, by taping A3 card together, or cutting pieces of wallpaper.) On a windy day, children can experience running into the wind with their card.

After noting or discussing what they can feel, they try the same activity, but this time with the card held at an angle in front of them. Finally, they repeat the experiments with the card held above their head at arms length.

PLENARY (10 minutes)

Back in the classroom, the children discuss their findings. To focus on the main effects, the following questions can be posed:

- *What did they feel when they ran with the card held out in front of them?*
  Something pushing against the card.
- *What did they feel when they ran with the card held above their head? Did the force feel different?*
  The pushing force may have felt greater, because their arms were above their head, and it exerted greater leverage.
- *When the card was tilted at an angle, did they find any difference in the feel of the force? Did it feel less, more or the same?*
  The force probably felt less.
- *Did the force have any effect on the speed at which they ran?*
  They may have found it harder to run at the same speed as before.
- *How do their findings relate to the firm's problem?*
  The lorries must experience the same pushing force against their movement, and would also need to work harder to run at the same speed.

Phillips Haulage

Main Street
Seaford

Dear Research Group,

We have recently set up our new lorry haulage business, and we are about to buy our new fleet of lorries. The manufacturers have sent us their brochures, which show many of the lorries with big sloping shapes, which they call fairings, fastened to the top of the cab.

Some of these are just large metal sheets sloping back to the trailer, but some makers have sides to these sheets of metal too.

We think that the fairings are supposed to help the lorries move more easily on windy days and help improve the fuel consumption, but we are not sure if they really have any effect. We would like some information about the effect of these shapes before we buy any. If they do have a useful effect, we want to buy the best shape.

We understand that you are investigating the effect of wind on different shapes, and would be grateful if you could tell us if adding things to the tops of cabs of lorries makes any difference. We would also like to know if some shapes are better than others. Can you send us any results you have which will help us decide which brand to buy?

Yours faithfully,

J. Phillips

J. Phillips

Director

2. Measuring the force 1

50 mins

Children compare toy vehicles with different sized front areas to discover that vehicles with a larger front have greater air resistance.

OBJECTIVES

- Identify the effects of air resistance, water resistance and friction, that act between moving surface.
- To show that air resistance slows moving objects down.
- To show that air resistance depends on the area of the object.
- Planning different types of scientific enquiries to answer questions.

RESOURCES

(Per group of 4 children)

- Activity sheets 2 and 5
- Activity sheet 3, copied onto A5 card
- Activity sheet 4, copied onto A4 card
- Toy vehicle (Corgi or Early Learning Centre variety, see page 3)
- Hair dryer (preferably with a 'cold' setting)
- 1 metre and 30 cm rulers
- 2-3 thick, large elastic bands
- Newton force meter

INTRODUCING THE ACTIVITY (10 minutes)

In the first activity, the children should have discovered that there is a force exerted by the air on the card as the children run around, which seems to be greater if the card is bigger. Activity sheet 2 can be used here to reinforce the idea of changing vehicle shapes. See Appendix 1 for further information. However, there is no measurement of that force, and thus no objective evidence which can be presented to the transport manager. Therefore, the following can be discussed with the class:

- *How can the children measure the effect of different surface areas on the distance a vehicle will travel?*
- *Using the models we have, what experiments can be set up to compare a car and lorry?*
- *Should each group use just one model car?*
  Yes. The car should always run smoothly in exactly the same way. Different cars will not necessarily do this.
- *How can we make the front surface different?*
  Card can be stuck to the front of the model to represent the front of a lorry, with nothing fastened to it to represent a car.

- *How can we give the car the same push to make it run? The test would not be fair if different pushes were used?*
  Use a 'standard force' launcher. This can be explained and demonstrated if necessary.
- *What should we measure? What would be easy to measure?* The distance travelled from the launch point is easy to measure. The more force pushing against the car, the less distance it will travel.

Safety note

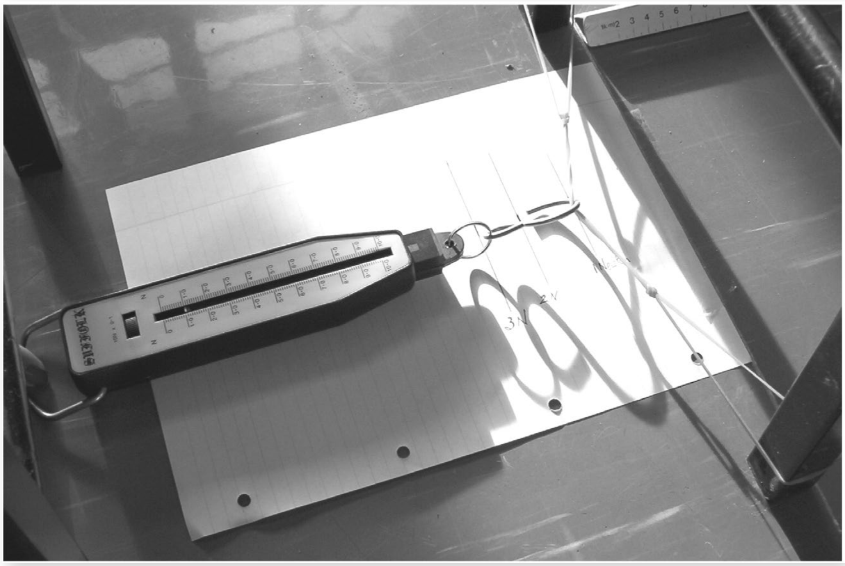
Electrical equipment brought into school must be safety-checked before use.

MAIN ACTIVITY (30 minutes)

First, each group makes their elastic band launcher, as outlined below. Activity sheet 5 provides an opportunity for children to record their predictions, and the results of their tests. The launcher is then used to test the vehicles first without a card front (representing a car) and then with Activity sheet 3 attached (representing a lorry).

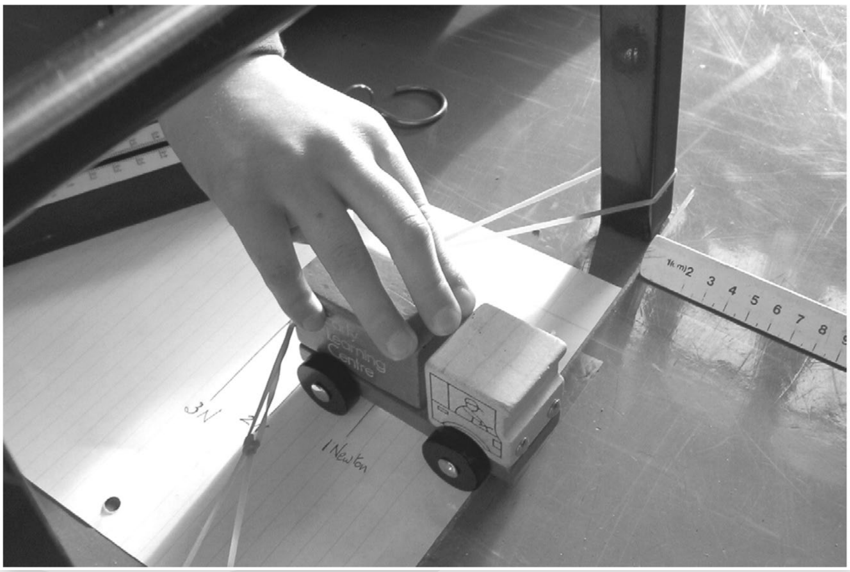
Elastic band launcher

Join 2-3 large elastic bands and stretch them between the legs of a stool or chair. Mark a line from leg to leg of the chair, and place a sheet of paper at right angles to this line. With a force-meter, pull back the elastic until a force of 1 Newton is registered, and mark the position of the elastic on the paper.



Setting up the force scale

Repeat with forces of 2, 3 and 4 Newtons. When a vehicle is placed in front of the elastic and drawn back to the marked points, the force being used to push the vehicle is known.



A vehicle about to be launched with a force of 2 Newtons

Encourage the children to repeat their test 2-3 times, to obtain a pattern of results. Depending on their ability, the average can be calculated either by choosing the middle result (median) or by calculating the mean (adding the three results and dividing by 3).

PLENARY (10 minutes)

The results[1] obtained will have shown that the vehicle with no added 'lorry front' (the car) travels further than the one with a lorry front. Ask the children:

- *Why does the car go further than the lorry?*

The children should appreciate that the larger frontal area of the lorry is creating greater resistance to the air, similar to that which they felt when they ran around the playground holding large sheets of card.

However, the children may raise other potential 'reasons' for the difference. These might include:

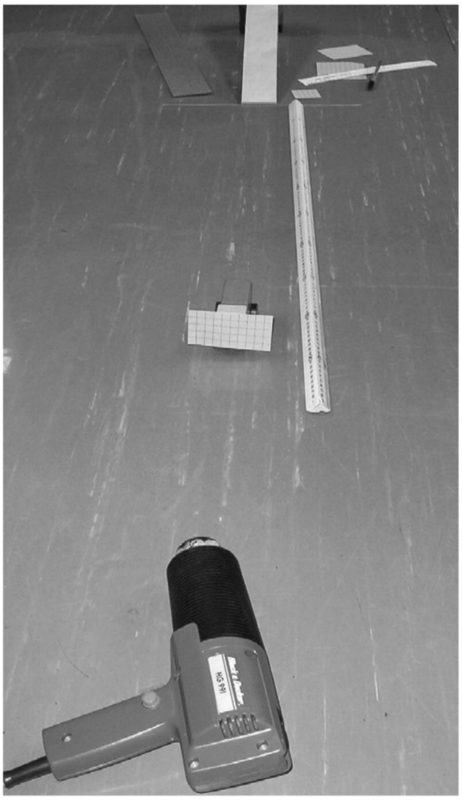
- Cars are quicker than lorries
- Cars/lorries have bigger engines
- Cars have less friction on their wheels.

It is therefore worth emphasising the controlled 'fair' nature of the tests, and that only the front of the vehicle was altered by the addition of a card 'lorry front'[2]; the same starting force and vehicle were used.

1 A sample set of results, using an Early Learning Centre vehicle and a launch force of 2 Newtons, sends the 'car' approximately 1.5 metres.

2 If a child raises the point that we have changed the weight of the vehicle as well, by adding card, then they can find out the weight of the card, and add an equivalent weight made from Blu-tack to the top of their 'car.'

The launcher is used to investigate the effect of air resistance on moving vehicles. Stick varying sizes and shapes of card to the front of the vehicle, and use a hair dryer to simulate a head wind. In this way, the effect of the front area on the distance travelled by the vehicle can be measured. The photograph below illustrates the type of set- up envisaged.



A hair dryer being used to set up wind resistance

The hair dryer could be laid on the floor, but it may be more convenient for it to be held by a child. As long as it is always held at the same position, probably around 2 metres from the launcher, the results will be 'fair' and consistent.

Using this method of measuring the distance travelled by the vehicle removes the need to make calculations of speed (distance divided by time) which could distract from the main objective of the work, particularly at Year 4. However, if groups of children, perhaps in Year 6, are capable of being extended by doing these calculations, then they should be encouraged to do so.

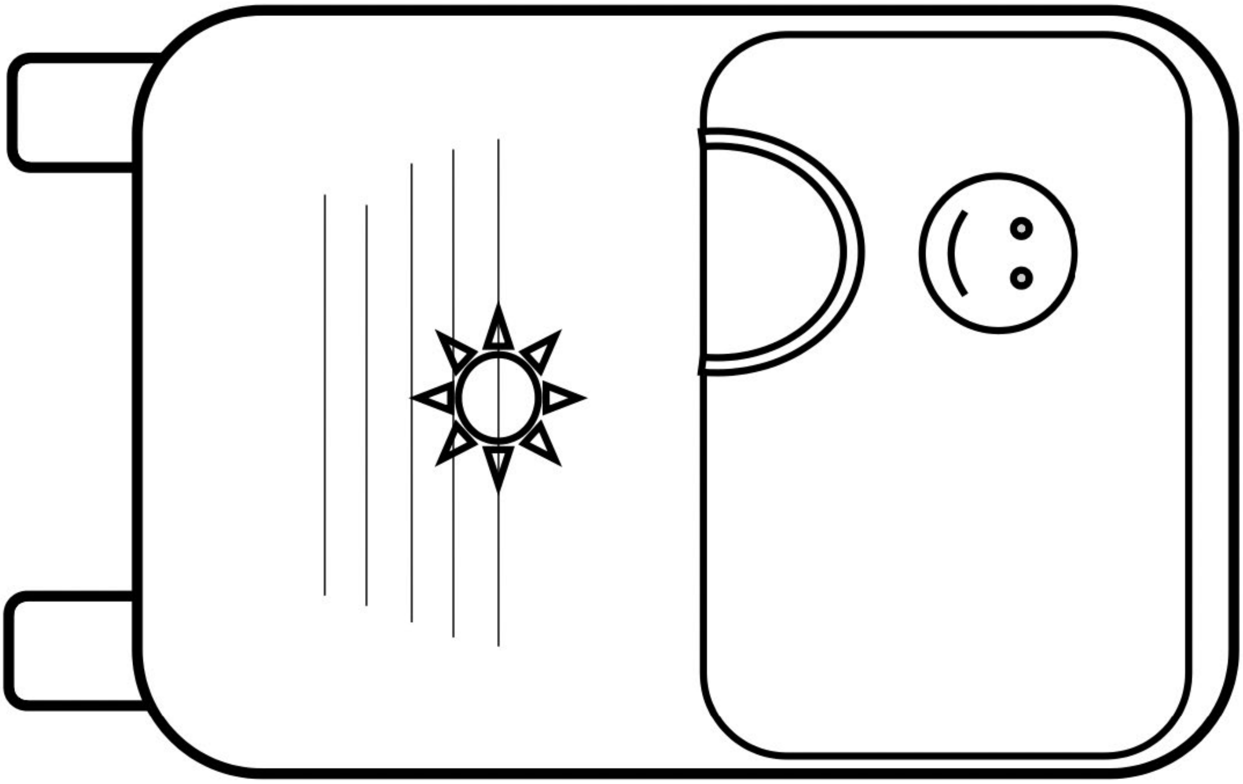
There are also opportunities in the work for links to technology. Years 5-6 pupils may already make simple vehicles using strip wood joined with triangles of card, to which wheels are attached. These would make excellent examples for testing purposes, if varying sizes and shapes of card are fastened to them. All such links are valuable, for they reinforce the ways in which science and technology are interlinked in industry, where an idea from science is put to use to make some part of everyday life better.

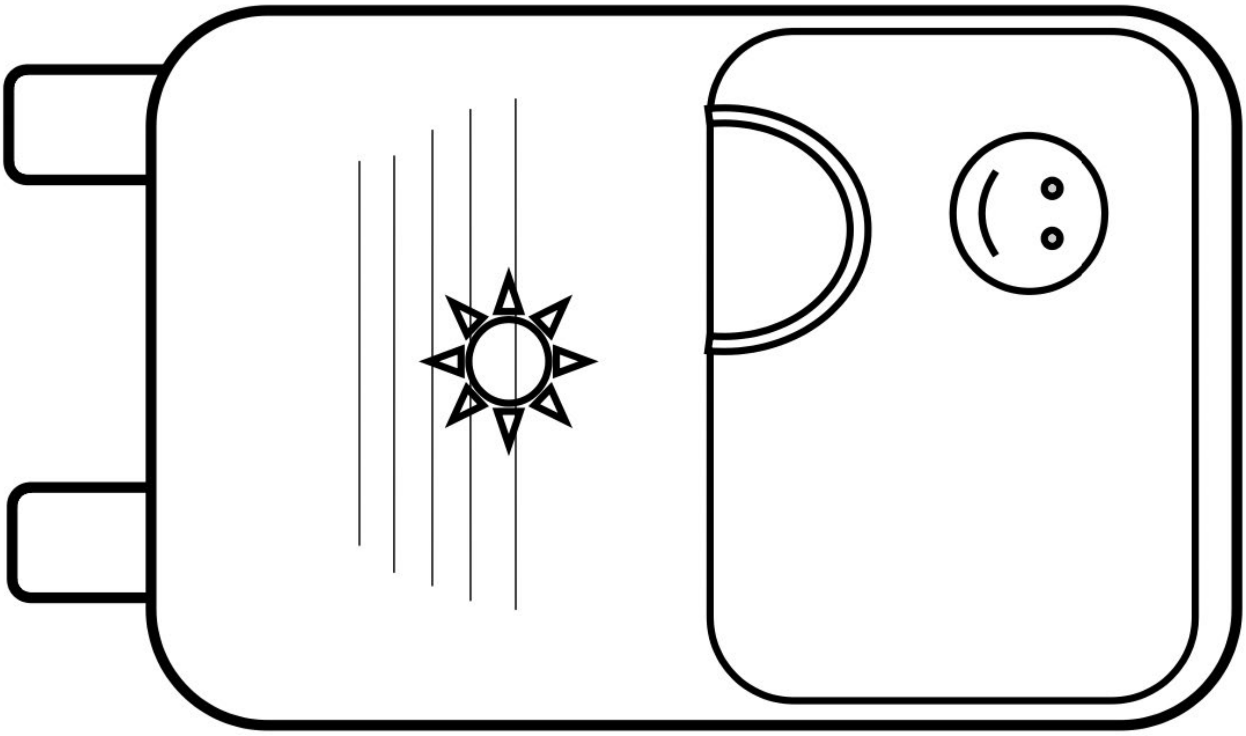
Activity Sheet 2

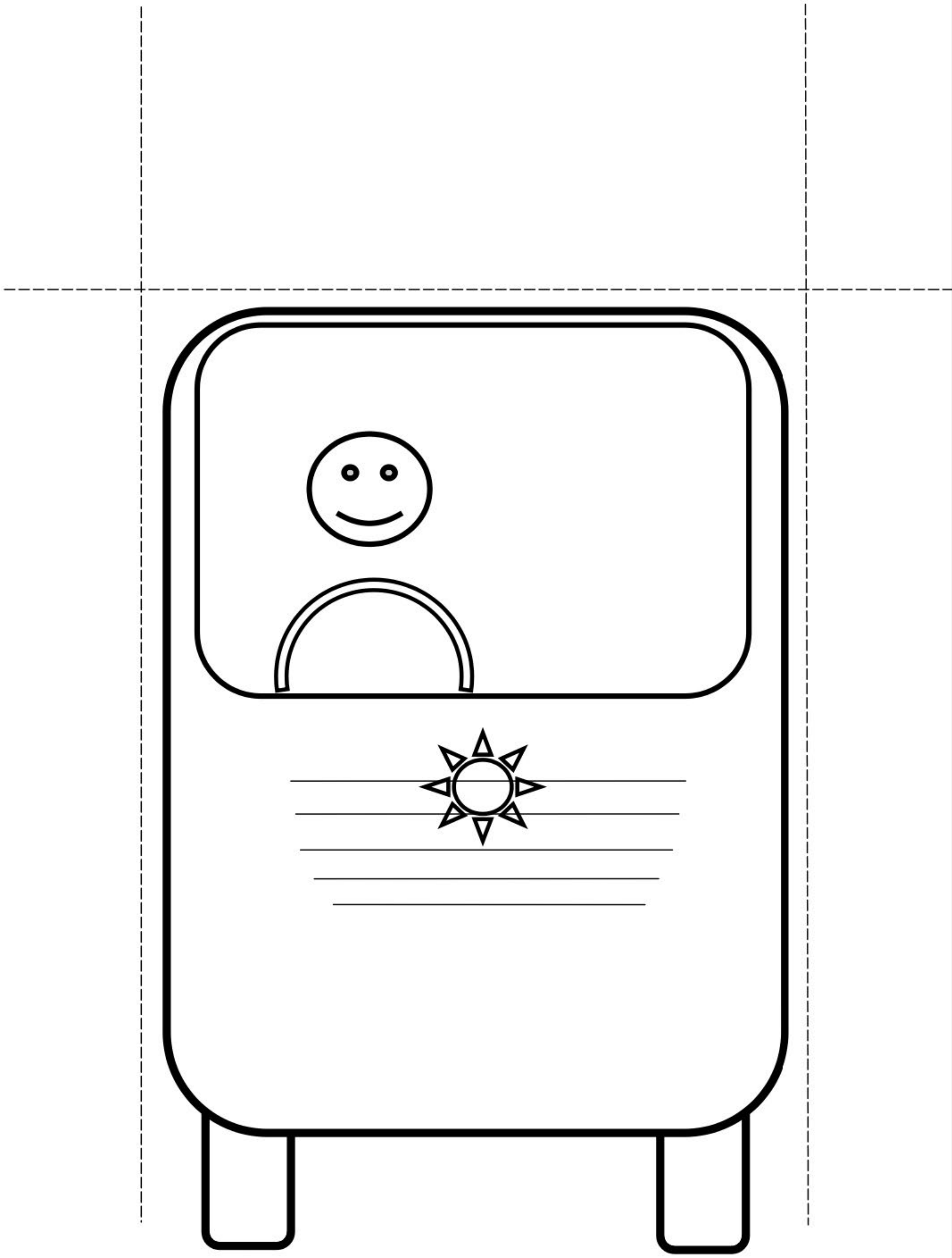
An A3 Pacific engine of 1928

NER A4 Pacific engine of 1935
(Note that the smoke is lifted clear of the cab due to its shape.)

A Japanese 'Bullet train' or 'Shinkansen'







Activity Sheet 5

Measuring the distance travelled by 'car' and 'lorry'

You are going to measure how far your car goes with nothing fastened to the front. Next, you will stick the flat A5 card from Activity sheet 3 to the front of your car to make it into a lorry and repeat the test.

What do you think will happen?____

____

____

____

Force used with elastic band launcher: __________________ Newtons.

No wind blowing

	Car	Lorry
Distance travelled 1		
Distance travelled 2		
Distance travelled 3		
Average distance		

Force used with elastic band launcher: __________________ Newtons.

Wind blowing

	Car	Lorry
Distance travelled 1		
Distance travelled 2		
Distance travelled 3		
Average distance		

3. Measuring the force 2

60 mins

Children investigate the impact of adding various shapes of card to the lorry front (known as fairings) to find out whether there is any impact on the air resistance.

OBJECTIVES

- Identify the effects of air resistance, water resistance and friction that act between moving surfaces.
- To show that smoothing the air flow reduces air resistance.
- Planning different types of scientific enquiries to answer questions.

RESOURCES

(Per group of 4 children)

- Activity sheet 6
- Toy vehicle, as used in the previous activity
- Hair dryer
- Metre rules and 30 cm rulers
- A4 card with lorry front from Activity sheet 4
- Thick elastic band 'standard force launchers'
- Newton force meter
- Sheet of A4 paper

INTRODUCING THE ACTIVITY (10 minutes)

Referring to the pictures of lorries with cab fairings, raise the question as to their use. From the previous experiments, the children have discovered that increasing the surface area of the front increases the air resistance. Can the children find out what effect different shapes attached to the front of their vehicle have on the air resistance, and thus the distance it travels? A challenge could be set to discover which group can produce the best design to give the greatest increase of distance travelled.

MAIN ACTIVITY (40 minutes)

They already have data on the distance their lorry travelled with an A5 card front. Using the sheets of A4 card with the same A5 sized drawing of the 'lorry' on it, the sides and top can be folded or bent to various angles to form fairings. These can be attached to the front of the vehicle in the same way, and using the same standard force launcher to provide a force of 2 Newtons the children can discover the effects of these on the distance travelled against the 'wind'. Activity sheet 6 provides an opportunity to record predictions, measurements and conclusions.

This activity can be tailored by the teacher to suit the class or groups. Some groups may need teacher direction on folding the fairings while others could respond to the more open challenge of producing a range of designs. The results of the experiments can be compared with the previous activity's results to discover which shape gives the greatest increase of distance travelled. Again, results can be repeated in groups of three, and the central value taken as the 'average', or older groups allowed to use a calculator to generate an average value.

PLENARY (10 minutes)

The results should show that by folding the card back at the top and sides, the air resistance is reduced, allowing the vehicle to travel further, even though the front area is still large. To help the children understand what happens, they can be reminded of the effort needed to walk through water in the swimming pool. When standing and walking, the effort required is quite great, and if they look behind themselves the water can be seen swirling in behind them in a very confused way. If they then push off in the swimming position, without paddling or kicking, the water behind them does not show nearly as much swirling (or turbulence) and it is much easier to move through the water.

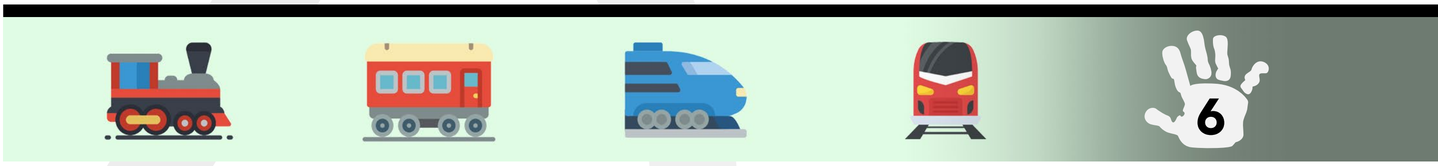
OPTIONAL ACTIVITY (10 minutes)

If a video clip can be found (perhaps from a local secondary school), the children can be shown 'wind tunnel tests'. In these tests, smoke is blown into the air passing round objects designed to be streamlined (or not). The smoke enables scientists to see the air movement, and how smoothly it is passing round an object.

Discussion points and questions can include:

- *What does the air do when it passes around a square or 'non-smooth' shape?*
  The air seems to swirl around the shape.
- *In what direction does the air seem to move behind a box-like shape?*
  The air moves in all directions, sometimes in the same direction as the main flow and sometimes in the opposite direction.
- *What happens to the air around a smooth shape?*
  The air parts easily to let the shape through and then comes back together behind the shape.

Activity Sheet 6



Does the fairing make a difference?

Cut and fold the top and sides of the lorry card from Activity sheet 4 to the best shape, leaving the flat lorry front. Stick it to the front of your car.

What do you think will happen?

Force used with elastic band launcher: ___________ Newtons.

	Lorry with fairing
Distance travelled 1	
Distance travelled 2	
Distance travelled 3	
Average distance	

Has the fairing made a difference to the distance travelled? Compare it to the results you got from your first lorry tests.

4. Reporting back to company

45 mins

Graphs, patterns and data can be reported back to the company with final recommendations.

OBJECTIVES

- Reporting and presenting findings from enquiries, including conclusions, causal relationships and explanations of and a degree of trust in results, in oral and written forms such as displays and other presentations.
- To summarise the findings, linking to Literacy and Numeracy across the curriculum.

RESOURCES

- Computer and associated software (word processing and chart/graphing)

INTRODUCING THE ACTIVITY (5 minutes)

Remind the children of the original request from the haulage firm. They wanted to know what affect the cab fairings had and if any particular shape was better than another. The children need to give the firm the evidence they have gathered, in a form which is easy to understand.

MAIN ACTIVITY (30 minutes)

They may want to write their findings down, which could be done long hand, or using a word processor. The measurements they made are important, and the data can be presented as tables or charts. Simple bar charts could be produced using 'First Graph' to show the different distances travelled under the various conditions investigated. Explanations of these charts and tables will also need to be written, showing how the experiments were set up, and what the data shows.

Children in Year 6 could use more sophisticated software like Microsoft Excel to produce their charts and tables.

Drawings and designs for the various fairings the groups produced need to be illustrated for the firm, and there is an opportunity for the children to use a digital camera to photograph their work and import these into their documents.

PLENARY (10 minutes)

The children's work can be displayed in school, or presented to parents or other classes.

Appendix 1

THE INDUSTRIAL CONTEXT

Air resistance on moving vehicles can raise the energy costs significantly, for extra energy is needed to overcome the resistance and merely maintain speed. Back in the 1930s the National Physical Laboratory conducted tests for the London North Eastern Railway (LNER) to discover how much power was needed to overcome the air resistance at various speeds for an ordinary flat fronted engine.

They then tested the new streamlined engines being produced, and discovered how much power (and thus fuel) was saved with a streamlined shape. Some sample results from the work are quoted below.

Horsepower needed to overcome head-on air resistance

Speed (mph)	Standard engine	Streamlined type	Horsepower saved
60	97	56	41
70	154	89	65
80	231	134	97
90	328	190	138
100	451	261	190
110	599	347	252
120	779	451	328

The speeds quoted in the table are relative speeds. The engine could, for instance, be travelling at 60 mph in still air, or doing 50 mph against a 10 mph head wind. It is no accident that since the introduction of those first streamlined engines in 1935, all subsequent high speed trains like the Intercity 125s, 225s, Eurostar and the Japanese 'Bullet Train' have had carefully designed fronts and backs to minimise air resistance, and are all remarkably similar in shape.

CIEC offers support for the teaching of science across the primary age range and beyond. This support includes CPD programmes, bespoke in-school CPD, interactive websites for teachers to use with their pupils, and a wide range of downloadable resources which encourage collaborative, practical problem solving. For more information, please visit our website:

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The unit was funded by the Gatsby Charitable Foundation.

First Published 2003

Revised 2021

ISBN 1 85342 584 2

EAN: 978185342905

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Editor – Joy Parvin

Design by Abdullah and Design Solutions.