## Lesson answers

2. No answer required.
3. a–h) For example:

| Length of spinner rotor (cm) | Time to reach the floor (s) | | | Average time (s) |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | |
| 8 cm | 1.59 | 1.64 | 1.60 | 1.61 |
| 4 cm | 1.05 | 0.94 | 0.915 | 0.97 |
| 2 cm | 0.68 | 0.78 | 0.62 | 0.69 |

i) The smallest size rotor should reach the floor the fastest. This has less surface area for the air to act upon, hence produces less air resistance.

j) The largest size rotor should reach the floor the slowest. This has more surface area for the air to act upon hence produces greater air resistance.

k) The larger the rotor, the longer it takes to reach the floor.

l) Make the rotor larger; make the paper spinner lighter; make the paper spinner 'wing' surface area larger.

4. a)

| Type of vehicle | Amount of air resistance acting when it moves (high/medium/low) |
|---|---|
| garbage truck | High |
| utility | Medium |
| racing car | Low |
| passenger plane | Medium |
| fighter jet flying | Low |
| fighter jet when taxiing | Low |

b) The garbage truck would experience more air resistance because it is larger, has a rough surface and lots of bumps to catch the air.

c) The passenger plane would experience more air resistance because it is larger and not as smooth/streamlined as the jet. The more aerodynamic an object is, the less drag it will experience.

d) Objects that smoothly move through air or water are described as aerodynamic because they produce very small forces of drag (resistance to the movement).

Lesson 3

Topic: Friction

# Analysing friction

**Lesson concepts**

- Change to an object's motion is caused by unbalanced forces acting on the object
- Earth's gravity pulls objects towards the centre of the Earth
- Questions and problems that can be investigated scientifically can be identifiedand predictions can be made based on scientific knowledge
- Investigation types including experiments, can be collaboratively and individuallyplanned and conducted, ensuring safety guidelines are followed
- Variables can be measured and controlled in fair tests and equipment can beselected to collect data with appropriate accuracy
- Representations can be constructed and used to represent and analyse relationships
- Data from investigations can be summarised and scientific understandings can be used to identify relationships and draw conclusions
- The method used to investigate a question or solve a problem can be reflected on, improvements to the method can be identified and the quality of the data collected can be evaluated
- Ideas, findings and solutions can be communicated using scientific language and representations.

## Learning alerts

Be aware of students thinking that friction always hinders motion, so reducing friction is always desired.

## Suggested next steps for learning

Remind students that without friction a range of movements would not be able to occur; for example, walking requires friction between the floor and foot.

## Prior knowledge notes

Students will consolidate free-body diagrams, friction and ways to reduce it from earlier lessons.

## Lesson notes

In this lesson students will further their understanding of friction and the factors that influence it. They will also develop their understanding of fair tests. A number of scenarios are provided in which students consider the variables, including the independent, dependent and controlled variables. Definitions of these variables are provided in the lesson.

## Practical information

Please ensure that for this lesson, if possible, the student will be able to try two different pairs of shoes or other footwear. One pair should have tread like a sports shoe, and the other relatively little tread, for instance some slippers, sandals, dress shoes.

## Prior knowledge answers

1.

| | | |
|---|---|---|
| a. friction | b | A force applied by a body that is in contact with the object it is acting on |
| b. contact force | g | A force that acts on an object to move it towards its point of application |
| c. non-contact force | d | When all the forces acting on an object are balanced the object will either remain at rest or continue to move at a constant speed and in the same direction of motion |
| d. balanced force | f | A force that acts on an object to move it away |
| e. unbalanced forces | a | A force that opposes motion |
| f. push | h | A force of attraction between two objects due to their mass |
| g. pull | e | When opposing forces acting on an object are unbalanced, the object will change its shape or state of motion. The object may speed up, slow down or change direction. |
| h. gravity | c | A force applied to an object by a body that is not in direct contact with it |

## Lesson answers

2. No answer required.
3. No answer required.
   a–b) **Sheet 3 — Analysing friction** (see answers on page 13).
4. a) **Sheet 3 — Analysing friction** (see answers on page 13).
5. No answer required.

## Sheet 1 Answers

# Exploring friction

### Aim

To measure and compare the frictional force between different textured surfaces when they are in contact with each other.

### Prediction

Predict which surfaces will produce the most friction.

Carpet

Predict which surfaces will produce the least friction.

Laminate

Predict the effect of increasing friction on the motion of an object.

Increasing friction will make it more difficult to begin the object moving and it might slow down the motion of the object.

### Risk assessment (How will you do the experiment safely?)

Personal safety (Tick which ones apply)

- ✓ Safety glasses
- ✓ Hair tied back
- ✓ Gloves
- ✓ Closed shoes
- ✓ Lab coat

| What are the risks? | How will you manage them? |
|---|---|
| Stretching elastic band | Pull gently and evenly, so the elastic band isn't overstretched. |

### Materials and equipment

- Large thin elastic band
- Ruler
- Shoe — preferably an old sneaker or jogger
- Different surfaces (carpet, concrete, tiles, sandpaper, paper, plastic, vinyl, laminate, corrugated card)

## Fair testing

1. Identify the variables in this investigation and classify them in the appropriate column below:

| Independent variable (What will you change?) | Dependent variable (What will you measure?) | Controlled variables (What will you keep the same?) |
|---|---|---|
| The surface on which the shoe is dragged | The force in newtons | Use the same elastic band and the same shoe The length of the surface The distance over which the shoe is dragged The speed at which the shoe is dragged Keeping the pull on the shoe even over the whole distance |

2. Explain how the selected equipment will be used to ensure fairness.

   Using the same equipment for each trial (balance and shoe) will ensure that different shoe soles won't impact the results. Making sure that the surfaces are all the same length helps to keep the distance over which the shoe is dragged the same, so that it is only the type of surface that will have an effect.

## Method

1. Attach the elastic band to the shoe.
2. Pull the shoe, using the elastic band, over one of the surfaces until it begins moving steadily.
3. Measure the length of the elastic band as the shoe moves across the surface.
4. Repeat steps 3 and 4 twice more using the same surface and shoe. Calculate the average length of the elastic band for the surface.
5. Repeat steps 3 to 5 using at least four different surfaces.
6. Record how long the elastic band stretched from its resting state. (Note: If it didn't stretch, record this as 0 cm.)

## Results table

| | Stretch length of elastic band (cm) | | | |
|---|---|---|---|---|
| Surface | Trial 1 | Trial 2 | Trial 3 | Average |
| e.g. carpet | | Data will vary depending on shoe selection | | |
| | | | | |

**Note:** For the purposes of this investigation the length of stretch represents the friction force, i.e. the longer the stretch the greater the friction.

## Discussion

1. How do your results compare with your predictions?

   For example: My results confirm my prediction that the carpet produced more friction than the laminate.

2. What actions did you take during this investigation to ensure fair testing and the accuracy of the data?

   I used the same shoe and the same elastic band and kept the length of each of my surfaces the same. I ensured that I dragged the shoe over the same distance each time, using an even pull and speed. I conducted multiple trials and averaged my results for each surface, to ensure that my data was reliable overall.

3. Looking at your results table, how reliable and accurate do you think your data is? Are there inconsistencies? Explain what makes you think so.

   For example: I think my data is reliable and accurate because the force measurements are fairly close together and there is a noticeable difference between the results for the carpet and the results for the laminate.

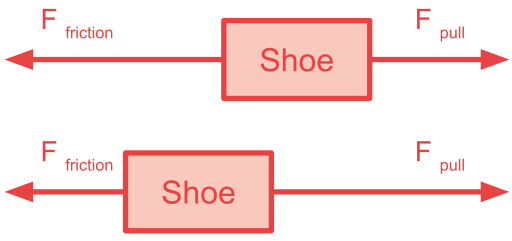
4. What aspects of the way in which you conducted this investigation might have reduced the accuracy of the data you collected?

   It was difficult to determine when to take the measurements of the force. Keeping the shoe moving evenly and at the same speed for each trial of each surface was difficult too. These things could have affected the accuracy of the data collected.

5. If you were to conduct this investigation again, what changes could you make to improve the accuracy of the data collected?

   I would use a tubular spring balance so I could collect measurements of force.

6. Draw force and/or free-body diagrams to show the forces acting on the shoe as it begins to move and then while it is moving at a steady rate. Indicate whether the forces are unbalanced or balanced. (Remember to use arrows to show the magnitude and direction of the forces acting on the shoe.)

| Shoe (pulled to start moving) | Shoe (moving at steady rate) |
|---|---|
|  Forces are unbalanced |  Forces are balanced |

7. In which direction does the frictional force act on the shoe?

   Frictional force acts in the opposite direction to the movement of the shoe.

8. Do the types of surfaces that are in contact with each other influence the magnitude of the frictional force? What explanation can you provide for this?

   The types of surfaces in contact do influence the magnitude of the frictional force. The rougher the surface, the greater the frictional force because, when rough surfaces are in contact, the grooves and ridges in the uneven surfaces interlock, making movement harder.

9. Describe situations where friction is useful and/or a hindrance to motion.

Friction is useful, for example:

- It would be difficult to walk without friction — as you step forward, you push your foot backward. Friction holds your shoe to the ground. You slip on wet or icy surfaces which have lower friction. When we hammer a nail into wood or into a wall, it is friction that holds the nail in place.
- Cars and bikes have rough tread on the tyres to increase friction and reduce slipping on the roads — the tyres would just spin without friction; without friction of the brakes and tyres you wouldn't be able to stop.
- We could not light a match without friction.
- Writing with a pencil requires friction — you would not be able to hold the pencil, it would slip out of your hand. The graphite tip would not make a mark on the paper without friction.
- When laying concrete, the surface may be 'raked' to increase the roughness and reduce slipping when it's wet; surface coatings for driveways or outdoor areas may have a textured finish to decrease chances of slipping.

The main disadvantage of friction is the conversion of moving energy (kinetic energy) into heat and sound energy during the rubbing of surfaces — like when we rub our hands together. Friction between moving parts means greater energy input is required to keep the parts moving, such as more fuel to keep the car engine running. (Note: The relationship between force and energy is addressed in detail in Year 10 and is not part of the Year 7 content.) Machine parts wear down from constant rubbing. Regular input of fuel and replacement of worn parts can be expensive.

10. Describe ways that science and technology have contributed to the development of products that work with or against friction for specific purposes?

For example:

- Running/walking/sports shoes have various thicknesses of tread on the soles, to increase grip. Some shoes have bumps or spikes to increase grip. Improved technology and sport science results in constant improvements to the design of sport shoes to increase/decrease grip and the ability to move faster.
- The blades of ice skates have been designed to be inward curving, so that there are two edges and a flat. Either edge applies force to the ice, increasing friction, so the skate grips the ice. The flat part of the blade slides across the ice instead of gripping into it, so there is very little friction. The varying structure of the blade enables the skater to either take advantage of friction to increase/decrease speed and to turn; or to reduce friction in order to coast across the ice.
- Making a surface smoother — development of fabrics and swimming suits to reduce friction between bodies and the water, like the smooth skin of sharks.
- Make an object streamlined — newer cars, trains and planes have a more rounded, bullet shape allowing them to move with less effort, increasing speed and reducing fuel consumption.
- Development of lubricants, such as water, oil, grease, between moving parts will separate the parts with a slippery layer, allowing them to slide more freely, and reducing rubbing, noise and wearing.
- Reducing the contact between surfaces and the forces acting on the surfaces — spherical objects move more easily than flat ones because very little of the rounded object is in contact with the other surface. The use of ball bearings between the hub and axle of wheels reduces friction and wearing.

**Conclusion**

When different textured surfaces are in contact with one another, different amounts of frictional force slow down motion. The rougher the surfaces, the greater the friction between them because, as the surfaces rub, the grooves and ridges in the uneven surfaces interlock making movement harder.

## Sheet 3 Answers

# Analysing friction

This is a sample investigation. Answers should be consistent with students' own findings.

| 1. Background | | |
|---|---|---|
| What scientific ideas could help solve the problem 'Which shoes would be best for playing indoor basketball?' | **Ideas about force and motion**<br>• forces operate in pairs<br>• frictional force opposes motion, working in opposition to pushing force<br>• increased friction between shoes and floor will provide more grip | **Ideas about planning an investigation**<br>• fair testing — identify variables and ensure all except independent are kept the same<br>• use appropriate equipment<br>• measure accurately and record data — conduct multiple trials to reduce impact of errors |
| Decide on two types of shoe you could test. Draw the soles of the two shoes and describe how they are different. | **Shoe 1**<br>Shoe selection should indicate a choice of clearly different sole profiles.<br>Court shoe — sole is ridged with grooves to produce a tread; made from rubber to provide greater traction | **Shoe 2**<br>Ballet pumps — sole is flat and thin with little or no tread; the sole feels slippery |
| **2. Aim** | | |
| What problem do you want to solve? | Which type of shoe sole will grip the floor best? | |
| **3. Prediction** | | |
| Predict a solution to the problem. | The court shoe will grip the floor best because the rubber sole and the tread rubbing on the floor will increase frictional forces between the shoe and the floor. | |

| 4. Risk assessment | Personal safety | |
|---|---|---|
| How will you do the experiment safely? | ✓ Safety glasses<br>☐ Gloves<br>☐ Lab coat | ✓ Hair tied back<br>✓ Closed shoes |
| | **What are the risks?** | **How will you manage them?** |
| | Stretching an elastic band | Do not over-extend the elastic band |

| 5. Fair testing | | | |
|---|---|---|---|
| How will you make sure that this is a fair test? | **Independent variable**<br>What will I change? | **Dependent variable**<br>What will I measure? | **Controlled variables**<br>What will I keep the same? |
| | Surface texture of shoe sole | Friction force (N) | Shoe size<br>Amount of shoe sole in contact with floor<br>Floor surface<br>Elastic band<br>Distance shoe was pulled across floor<br>Speed at which shoe was pulled across floor |

| 6. Materials | |
|---|---|
| What materials will you need to conduct your investigation? | Two shoes with different sole profiles (e.g. footy boot, hiking boot, ballet pumps, slipper/thong, aerobics shoe, running shoe, gumboot, aqua shoe, leather loafer, school shoe, clogs, court shoe)<br>Tape measure<br>Large bull-dog clip<br>Elastic band<br>Polished/smooth wooden surface (indoor court) OR<br>Coated concrete surface (outdoor court) |

| 7. Method | |
|---|---|
| What are the steps in the experiment? (Remember this should be written in third person and numbered) | Look for:<br>• numbered steps, written in third person<br>• description of fair testing methods:<br>» shoes with same size soles<br>» work area measured out and shoes dragged over same distance; at least three trials conducted for each shoe<br>» force reading taken at same point for each shoe |

Ask an adult to check your method, if possible. Once your method has been checked, conduct your method and record your observations and results.

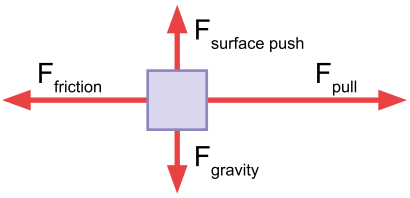
| 8. Results | Frictional force between floor and shoe surface | | | | |
|---|---|---|---|---|---|
| Use a table to record your results. | Stretch length of elastic band (cm) | | | | |
| | Shoe sole | Trial 1 | Trial 2 | Trial 3 | Average |
| | | | | | |
| | | | | | |
| | | | | | |

Data will vary depending on shoe selection

## 9. Analysis of results

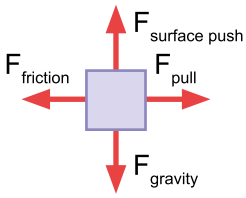
Draw force and/or free-body diagrams to represent, analyse and compare the impact of friction on the motion of the two shoes when they first begin to move and then when they are moving steadily. Your diagrams should show the direction and magnitude of forces acting on the shoes, and indicate if the forces are balanced or unbalanced.

**Shoe 1 as the pulling begins**



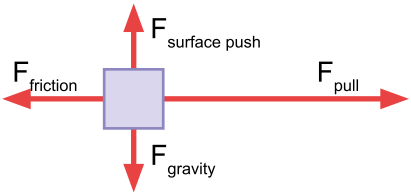

Unbalanced

**Shoe 1 as it is moving steadily**



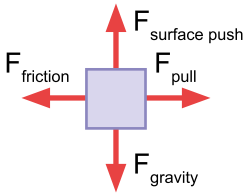

Balanced

**Shoe 2 as the pulling begins**




Unbalanced

**Shoe 2 as it is moving steadily**




Balanced

| How does frictional force relate to the design of the sole of the shoe? | There was greater friction between the rubber tread sole of the court shoe and the floor than between the flat, smooth sole of the ballet pump and the floor. The increased tread and rubber sole also meant that a larger pulling force was needed to get the court shoe to move at the start of the trial. |
|---|---|

| 10. Discussion | |
|---|---|
| **a. Data**<br>Write your answers in sentence form. | Which of the shoes you tested would be best for playing basketball? Explain your reasoning.<br>The court shoe would be best for playing basketball. There was greater friction between the court shoe and the floor, because the tread and rubber sole provide greater gripping contact between the two surfaces. Greater friction to oppose motion means that the wearer can run, turn and make sudden movements with less chance of sliding or skidding.<br>Was your data consistent with your prediction? Explain.<br>The prediction that the court shoe would provide more grip than the ballet pump was confirmed by the data. The measurements of frictional force between the court shoe and the floor were higher than those for the ballet pump.<br>Explain in terms of forces, how water on the floor would affect the performance of your shoes.<br>Water on the floor would lubricate the surfaces and reduce the overall contact between the shoe sole and the floor, therefore reducing the frictional force between the two surfaces. This may result in the shoe slipping and sliding over the floor surface<br>Using scientific understanding of friction, justify how the design of different sport shoe soles improves performance in the activity to which they are suited.<br>In court sports or gym sports where sudden changes in movement are required and the ground surface is flat and even, the frictional forces between the shoe and ground surface need to be increased. This is done through the use of rubber soles and varying tread thickness and pattern, depending on the sport. For track and field sports that require speed and agility, shoes need to dig into the grass or track, so they have spikes located at different places on the sole, depending on the sport. The spikes provide traction and greater friction, particularly when the wearer needs to rapidly speed up or jump.<br>Using scientific understanding of friction, suggest why the soles of sports shoes become worn down and shoes need to be replaced.<br>Friction is a contact force. The constant rubbing between the ground surface and the shoe sole increases the frictional force between the two surfaces, especially if the sport involves changes of speed and direction. The rubbing between surfaces generates heat and also causes the tread to wear down. |

| | |
|---|---|
| **b. Evaluating your experimental design** | How did your experimental method and equipment selection contribute to:<br>a) the accuracy of your data<br>b) the fairness of your experiment?<br>Students' responses should indicate how their choice of method and equipment enabled them to collect accurate data that clearly demonstrated a relationship between the type of sole and the measured frictional force. For example:<br>• Conducting multiple trials and calculating average reduces impact of measurement errors.<br>• Ensuring that both shoes have same size sole means that the area in contact with the floor surface is the same for both — this is important because friction is a contact force.<br>• Using a measure tape to mark out the experiment area, pulling the shoes over the same distance and measuring the force at the same point in the movement of the shoes removes the influence of these variables on the outcome of the experiment.<br>What aspects of your method did not work well?<br>Explain how this may have affected your data.<br>Students' responses should indicate aspects of their own method that would impact on the quality of their data and their ability to directly relate the type of shoe sole to the amount of frictional force. For example:<br>• The two shoes chosen didn't have the same area in contact with the floor. Because friction is a contact force, the shoe with more contact could feasibly have more frictional force working on it, regardless of sole properties.<br>• It was difficult to pull the shoes with exactly the same amount of force, so if one was pulled harder than the other, this would affect the force measurements taken during the experiment.<br>• Using an elastic band means measurements can not be collected. |
| **c. How could you improve your experiment?** | How could you change your method to improve the accuracy of the data?<br>Student responses should adequately address the issues identified above, so that the impact of these issues on the quality of the data, would be reduced if the experiment were conducted again. |
| **11. Conclusion** | |
| A sentence or two summarising the experiment results.<br>(Must relate to the aim.) | The best shoe to use for basketball, which requires the wearer to change speed and direction rapidly, would be the court shoe rather than the ballet pump. The court shoe has a thicker, rubber sole with increased tread that maximises the frictional force between the shoe and the ground surface, making them grip better. |