

THINKING ON YOUR FEET FOOTBALL AND PHYSICS

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SESSION 1 HOW CAN YOU THROW OR KICK A BALL FURTHER?

Footballers often need to make the ball go as far as possible, e.g. from a goal kick or a throw-in. Do you think the angle at which they kick or throw the ball makes a difference?

Imagine this situation: your friend says “See how high that goalie kicked the ball – couldn’t he make it go a lot further if he kicked it out much lower?”

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Finding the optimum angle

Think about what the optimum angle might be, then test your idea to see if you are right.

You can use the blow tube to launch the balls at different angle. You will need to work out how to measure the angles and the distance that the ball travels. You’ll also need to think about what variables to control.

USEFUL RESOURCES

- blow pipe
- blow balls
- metre ruler
- semicircular protractor
- string
- cardboard
- pencil and paper
- access to disinfectant solution
- if available, a mobile phone or camera with video function.

THINGS TO FIND OUT

Find out what angle gave the longest range for the ball. Is this what you predicted?

What happens when you use a steeper angle? What happens when you use a shallower angle?

How easy it is to make accurate measurements with this equipment?

How could you minimise the uncertainties?

CAUTION

If you are sharing blow tubes, make sure they are disinfected between each use.

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EXPLAINING THE OPTIMUM ANGLE

Here are some factors that affect how far the ball travels along the pitch:

Initial velocity How fast the ball is travelling after it has been thrown or kicked.

Angle The optimum angle lies between directly upwards (the ball doesn't move down the pitch) and a very shallow angle (it quickly hits the ground).

Horizontal velocity The speed that the ball is travelling in the horizontal direction

Time of flight The longer the ball is in the air the further its range.

Drag (or air resistance) This force acts in the opposite direction to the motion of the ball and slows it down.

THINGS TO FIND OUT

How does the angle affect the horizontal velocity?

How does the angle affect the time of flight?

How could you calculate the range from the horizontal velocity and the time of flight?

What is the theoretical optimum angle?

What effects do you think the following have on the optimum angle?

- the air - how might the angle be different on the Moon?
- the weight of the ball - would the angle be different with a very light and a very heavy ball?
- the wind - would the angle be different with a headwind and with a backwind?

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SESSION 2 TAKING BETTER PENALTIES

Knowing which penalty shots are most likely to score can give a team an important advantage. What kinds of penalty shots do you think goalkeepers find most difficult to save? What kinds of shots are penalty takers most likely to miss?

Imagine this situation: your friend says "Another missed penalty! Over the bar! They should kick the ball along the ground – there'd be a better chance of scoring!"

Analysing video evidence

You will watch some video clips of penalty kicks and record the outcomes.

Data analysis challenge

The following diagram shows typical outcomes from a larger number of penalty kicks.

THINGS TO FIND OUT

What information do you think would be useful to collect about penalty kicks?

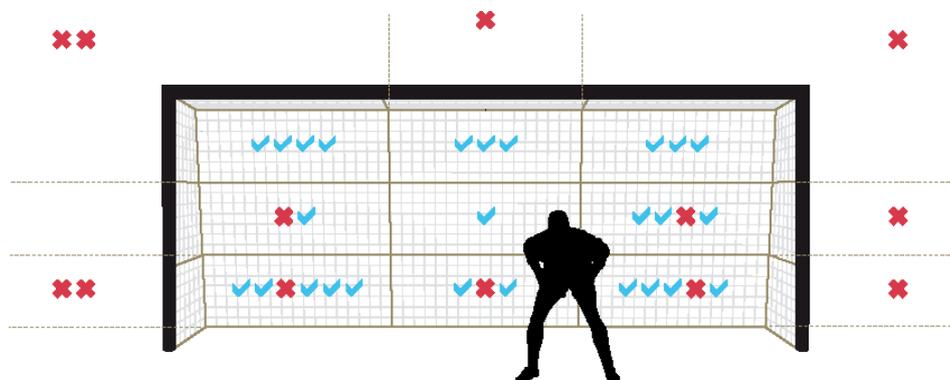
Use the table on page 3 to record the outcomes of the penalties in the video clips.

Can you see a pattern emerging or would you need to collect more data to decide?

Do you agree with your friend? In this activity you will be looking at the results of penalty kicks to help you explain your ideas to your friend.

Typical results showing the numbers of penalty shots aimed at different areas of the goal and the outcomes. Note that the view of the goal shown is as it would appear to the penalty taker.

- ✓ Goal scored
- ✗ No goal (saved or missed)



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THINGS TO THINK ABOUT

Which areas of the goal do penalty takers seem to aim at most often?

Which areas of the goal seem to be hardest for a goalkeeper to save?

Which areas of the goal seem to be most likely for a penalty taker to miss?

What do you think would be the place to aim for when you take a penalty?
How would you explain your reasons to someone?

How could you summarise the data in a way that would help to support your explanation?

Use the table on page 3 to produce a summary of the data.

Goalkeepers and reaction times

Goalkeepers do not have much time to react to a penalty, and they need to decide which way to dive before they see the direction of the ball.

THINGS TO FIND OUT

How long does it take the ball to cross the line in a penalty kick?

Useful information: a fast kick is about 70 mph (or about 30 m/s) and the distance from the penalty spot to the line is 12 yards (about 11 metres).

What is your own reaction time?

Useful information: You can do the 'drop test' where a partner drops a ruler between your fingers and you see what distance it falls before you to catch it. You can then work out reaction time from $t = \sqrt{(2d/g)}$. Alternatively, you could use a reaction timer app or a website.

How does the time of travel of the ball compare with your reaction time?

The 'drop test' measures the reaction time for your hand. Do you think your reaction time for using your legs to jump (like a goalkeeper) would be the same or different?

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RECORDING SHEET

Analysing video evidence

For each video clip you watch, decide which area of the goal the penalty taking aimed at. Then enter a tick (goal scored) or a cross (saved or missed) into the correct area.

Data analysis challenge

Use this diagram to summarise the data showing the outcomes of a larger number of penalties.

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SESSION 3 HOW CAN YOU ACCELERATE FASTER

In a football match, players will spend a lot of time running. Sometimes they move slowly and sometimes quickly, they will speed up and slow down, and will change direction. How would you explain the difference between speed and acceleration? penalty takers most likely to miss?

Imagine this situation: your friend says “These footballers run too slowly – Usain Bolt would make a great footballer because he’d get to the ball really quickly.”

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Exploring how things move

You will be using marbles on slopes to explore how things move. There are two things to try out:

- measuring how the velocity of the marble changes
- designing a demonstration to illustrate the difference between top speed and acceleration.

USEFUL RESOURCES

- lengths of cardboard (at least 1 metre long)
- sticky labels or tape
- 2 marbles
- metre rule
- stopwatch (or app on mobile phone)
- calculator
- paper and pencils
- if available, a mobile phone or camera with video function.

Measuring velocity

You can calculate an average velocity using the formula:

$$\text{average velocity} = \text{distance travelled} / \text{time taken}$$

THINGS TO FIND OUT

Put markings at 0 cm, 50 cm and 100 cm on a sloping length of cardboard.

Use a stopwatch to find out how long it takes for a marble to travel the first 50 cm, and then the second 50 cm.

Are these times the same or different? Why?

What is the average velocity of the marble for the first 50 cm and for the second 50 cm?

How could you estimate the velocity of the marble at 100 cm?

Repeat with a different slope for the cardboard. How do the times compare to the first run? Why?

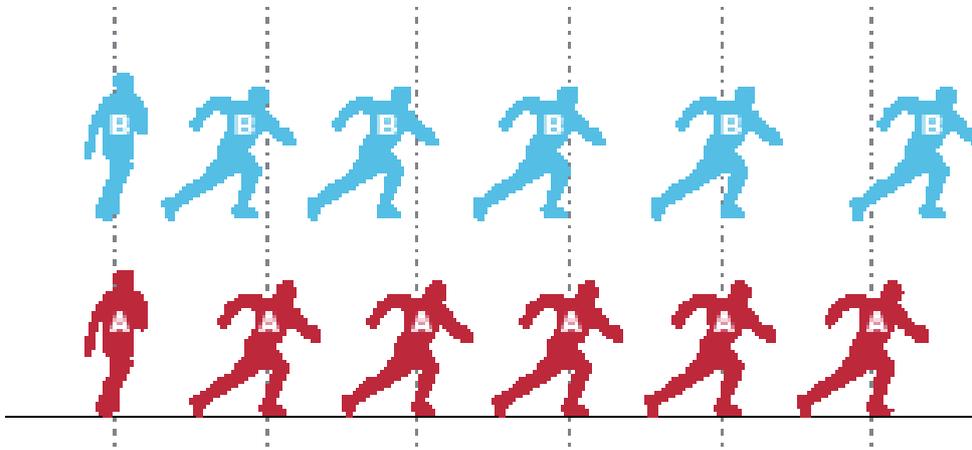
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Top speed and acceleration

Talking about a player who 'runs fast' is a bit vague – it could mean that they have a high top speed or that they can accelerate very quickly.



Player A accelerates faster than player B so goes into the lead.
Player B however accelerates for longer and so catches up and overtakes player A.

THINGS TO FIND OUT

Use two marbles and two lengths of cardboard to design a demonstration to show the difference between top speed and acceleration. When the two marbles are released at the same time:

- the first marble accelerates faster at the start
- but then the second marble overtakes it.

Work out the positions of the marbles and the cardboard which gives the best demonstration.

Estimate the top speeds of each of the marbles at the end of the slope.

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SESSION 4 WHAT MAKES A GOOD PASS?

Footballers use different kinds of pass for different situations. They include short and long passes, and passes along the ground or in the air. Do you think that it is quicker to pass the ball along the ground or in the air?

Imagine this situation: your friend says “They always lose the ball when they are passing along the ground – if they passed quicker the other team couldn’t get the ball. Why don’t they pass in the air?”

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Two types of kick

Here are two ways you could kick a ball – the first travels along the ground and the second travels up into the air. To avoid the ball spinning you need to kick through the centre of mass of the ball.



A horizontal kick through the centre of mass will make the ball travel along the ground.

To make the ball travel in the air, the kick needs to be at an angle to the ground.

THINGS TO THINK ABOUT

What is meant by centre of mass?

What would happen if you did not kick the ball through the centre of mass?

To model the movement of footballs you will use beanbags. These are more convenient to use indoors. Also, their motion is simpler to study than footballs because they do not roll when moving along the ground or spin when travelling through the air.

Exploring two ways of passing

You are going to design a demonstration that compares two ways of passing the beanbags in order to answer this question: Is it quicker to pass the beanbags along the floor or through the air?

USEFUL RESOURCES

- beanbags
- metre rule
- stopwatch
- paper and pencils
- if available, a mobile phone or camera with video function.

CAUTION

To avoid back injury through bending, kneel down when sliding/throwing the bean bags.

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THINGS TO FIND OUT

Work out how you can model the two ways of passing a football starting and ending at floor level.

How easy it is to measure the time accurately for each pass? Is it better to do them simultaneously (at the same time)?

Which type of pass seems quicker?

Do different types of surface make any difference to your results?

Does passing the beanbag over longer distances make any difference?

Relating the beanbag model to football

THINGS TO THINK ABOUT

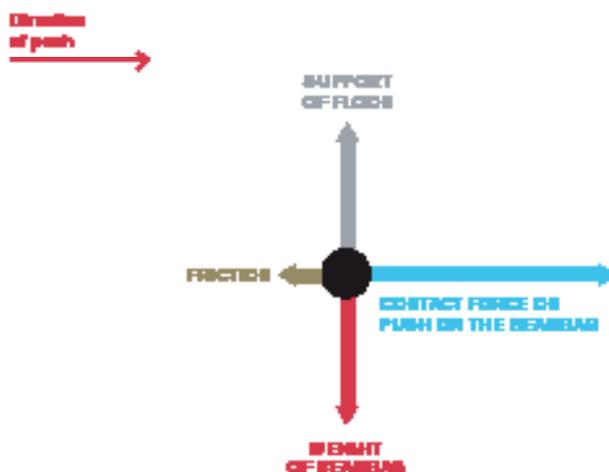
Can you explain why the beanbag takes longer one way than the other?

How does the beanbag demonstration relate to passing a football on a pitch?

What do you think is the most important factor to consider when deciding to pass the ball on the ground or in the air?

WHAT FORCES ARE ACTING?

This diagram shows the forces on the beanbag at the moment that it is pushed along the floor. The diagram for a football being kicked will look basically the same.



THINGS TO FIND OUT

Draw two similar diagrams to show the forces on the beanbag while it is sliding along the ground and when it has stopped. Choose the forces from the following list:

- weight
- support
- contact force
- friction
- drag (or air resistance).

Now draw a series of diagrams showing the forces on a beanbag as it is thrown in the air, while it is travelling through the air, and at the moment it lands on the ground.

Is there a forward force acting on the ball while it is travelling, either on the ground or in the air?

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SESSION 5 FORCEFUL TACKLING

Footballers need to be able to make effective tackles, but they also need to do this safely. You can get injured in a bad tackle. Do you think you are more likely to be injured if you are hit by the top of your opponent's boot or by the studs on the bottom? Or does it make no difference?

Imagine this situation: your friend says "I don't know why referees make such a fuss about showing the studs on a boot when tackling. It's going to hurt the same whatever part of the boot you get kicked by."

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.



A heavy ball is dropped down a cardboard tube onto a Lego brick resting on play dough.

By changing the orientation of the Lego brick, the damage caused by impacts over different surface areas can be explored.

Exploring damage from impact forces

You are going to design a demonstration to show the amount of damage caused by an impact force over surface areas of difference sizes. You can model this by dropping a heavy weight onto Lego bricks resting on Play-Doh.

USEFUL RESOURCES

- Lego blocks (rectangular)
- Lego block with flat top
- Play-Doh
- long cardboard tube
- heavy weight to drop down tube
- equipment tray
- matchsticks
- millimetre ruler
- paper and pencil
- if available, a mobile phone or camera.

CAUTION

Do this activity in an equipment tray to avoid the heavy weight rolling off the bench.



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THINGS TO FIND OUT

Work out how you are going to safely set up the demonstration.

How are you going to make sure that it is a fair test?

Decide what factors you can vary to get a good spread of results for the different positions of the Lego bricks.

Work out the best way of measuring the damage caused.

What are the problems in trying to measure the damage?

If you have a camera, it is useful to present the results as a set of images along with the measurements?

Why does an impact over a small area cause more damage?

The amount of damage done can be thought about as how long it takes to stop the impacting object.

THINGS TO THINK ABOUT

A mistimed tackle can potentially cause injury. What rule relates the surface area of contact with the amount of damage done?

How would you use your demonstration to explain the dangers of certain types of tackles?

How would you explain to a younger footballer that wearing shin pads is a good idea?

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SESSION 6 HOW CAN YOU CONTROL A BALL EFFECTIVELY?

Football often involves trying to control a moving ball. Sometimes you will want to stop the ball, and sometimes you will want to redirect it. Which parts of the body do you think are better at stopping the ball and which are better at redirecting it?

Imagine this situation: your friend says "That player never seems to head to ball – he's using his chest again to control it. I guess he's scared of hurting his head."

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Exploring how things bounce

You are going to design a demonstration to show that the way a ball bounces off different surfaces depends on two things:

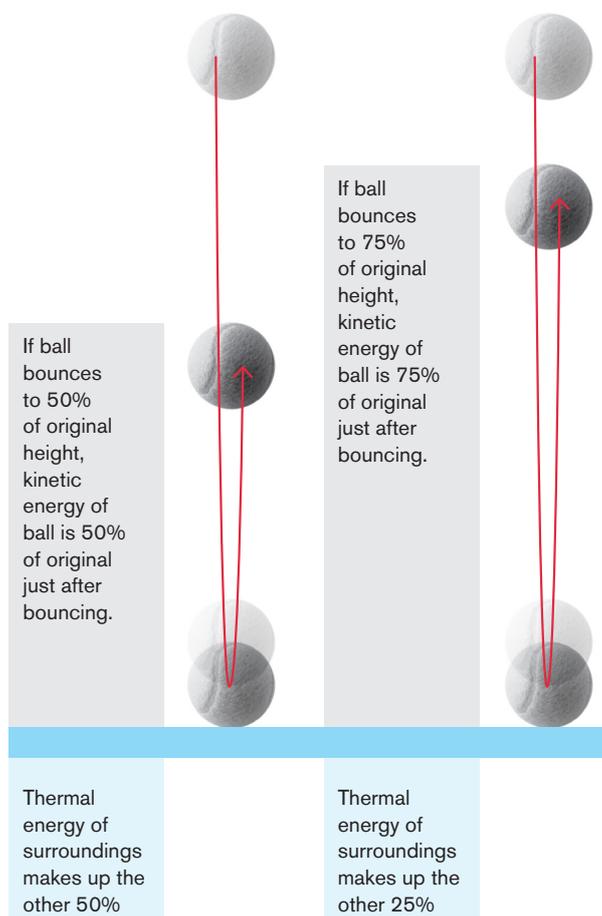
- the contact surface
- the rigidity of the structure (a rigid structure doesn't deform much when it is hit).

You can try different kinds of balls and try dropping from different heights. Measuring the height that the ball bounces gives an indication of how fast it rebounded.

When a ball bounces, some of the energy spreads out is transferred to the surroundings.

USEFUL RESOURCES

- tennis balls and table tennis balls
- metre rule
- calculator
- paper and pencils
- access to different floor coverings
- access to structures with different rigidities (e.g. a stable chair and a chair with a wad of paper under a leg to make it wobble)
- if available, a mobile phone or camera with video function.



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THINGS TO FIND OUT

Which kind of ball gave the best results for the demonstration?

What surface gives the best bounce?
What surface slows the ball down most?

What structure gives you the slowest rebound from a hard surface?

How easy it is to measure the bounce height accurately? How could you minimize the measurement uncertainties?

THINGS TO THINK ABOUT

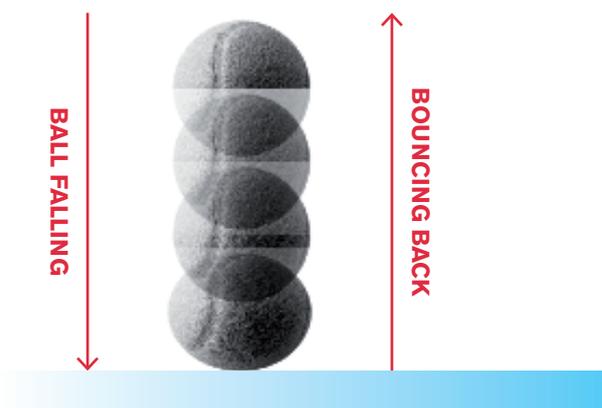
What direction is the force that causes the ball to decelerate?

What direction is the force that causes the ball to accelerate? good idea?

When a falling ball hits the ground it deforms before it bounces back again. This makes it first decelerate and then accelerate away from the ground.

What happens when a ball bounces?

When a falling ball hits the ground it deforms before it bounces back again. This makes it first decelerate and then accelerate away from the ground.



A falling ball deforms and decelerates as it makes contact with the ground, and then accelerates upwards.

THINGS TO THINK ABOUT

How big would the rebound be for the following?

- a tennis ball on concrete
- a table tennis ball in mud
- a ball of plasticine on concrete
- a football on a foam mat.

Why doesn't the ball bounce back to the height it was dropped from? What happens to the energy of the ball when it hits the surface?

How do these results relate to football? How well does a football bounce off different parts of the body - foot, thigh, chest and head?

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SESSION 7 USING YOUR BODY FOR BALANCE AND STABILITY

Footballers change their centre of mass to improve their balance and stability, whether they are stationary or moving. What effect do you think that lowering the centre of mass has on stability?

Imagine this situation: your friend says “The target man up front is big and strong – so why does he need to lower himself when he is receiving the ball in front of a defender?”

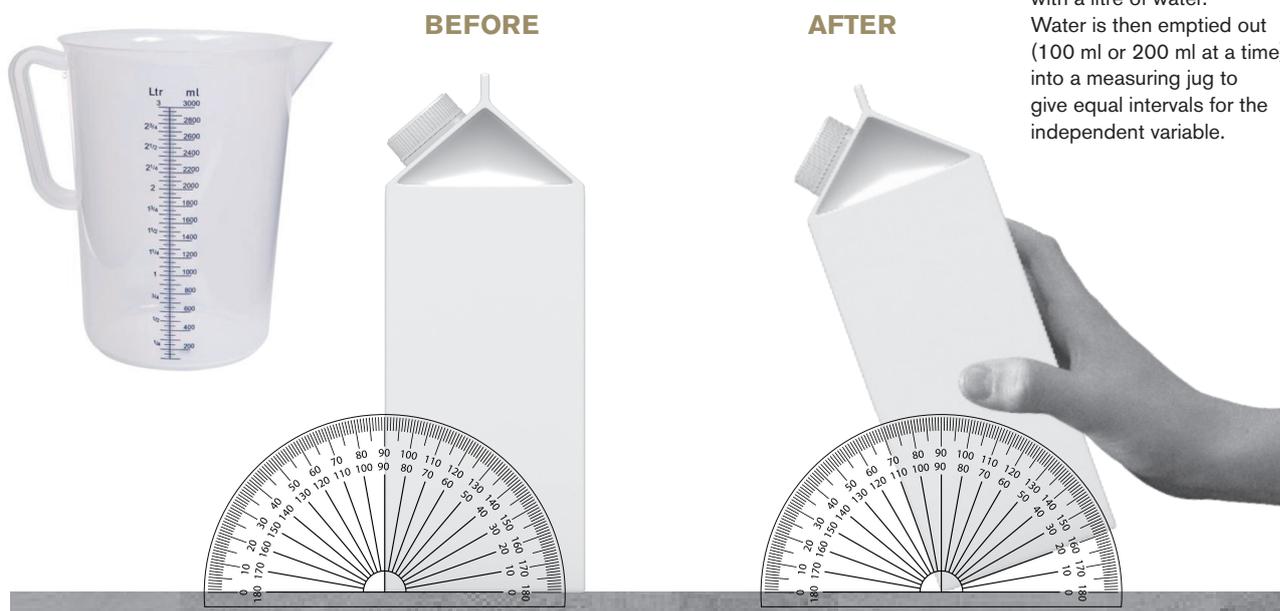
Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Exploring stability and balance

You are going to design a demonstration to show how the height of an object's centre of mass affects its stability. You can model this by filling an empty drinks carton with different amounts of water, and finding the tipping angle.

USEFUL RESOURCES

- empty 1 litre cardboard drinks carton
- measuring jug
- semicircular protractor
- paper and pencils
- if available, a mobile phone or camera with slow motion video function.



Initially, the carton is filled with a litre of water. Water is then emptied out (100 ml or 200 ml at a time) into a measuring jug to give equal intervals for the independent variable.

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THINGS TO FIND OUT

What is the best way of measuring the tipping angle as accurately as possible? (If you have slow motion video, is this useful for finding the angle?)

Which way is it easier to do the demonstration - by starting with an empty carton and filling from the measuring jug, or starting with a full carton and emptying into the jug?

What happens to the tipping angle when there is more water in the carton - does it increase, decrease, or is there another pattern?

What happens when it tips?

When you increase the amount of water in the carton, the water level goes up. The centre of mass of the water therefore goes up. However, to work out what happens to the centre of mass of the whole object you need to think about the mass of the carton as well.

USEFUL RESOURCES

- metre rule and large lump of Play-Doh or Plasticine

THINGS TO THINK ABOUT

Where is the centre of mass of the carton when it is empty?

What happens to the centre of mass if just a little amount of water is added?

Where do you think the centre of mass is when the carton is half full of water?

Where is the centre of mass of the carton when it is full of water?

How is the centre of mass related to the amount of water in the carton?

Can you think of a rule that relates the height of the centre of mass of the carton to the tipping angle?

How does this apply to football? What advice would you give to someone who wants to make their body as stable as possible?

Movement and balance

Tipping a drinks carton models one aspect of a footballer, but does not model how a footballer keeps in balance while running or moving. You can model this by trying to balance a metre rule on your finger.

THINGS TO FIND OUT

Put the lump of Play-Doh about 20 cm from one end of a metre rule. With your finger at the other end, try balancing the metre rule upright.

Now try balancing the metre rule with lump of Play-Doh at the bottom end.

Which way did you find easier to balance? Can you suggest a reason?

How does this apply to football? What advice would you give to someone who wants to maintain their balance?

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SESSION 8 HOW CAN YOU SPIN AND BEND THE BALL?

Footballers sometimes kick across the ball to control how it moves through the air and to make it bend. How do you think you would need to kick a ball to give it backspin?

Imagine this situation: your friend says “I can’t believe that he made that ball curve around the wall into the goal. You can’t kick a ball like that – surely it must have been the wind that helped it bend?”

Do you agree with your friend? In this activity you will be developing a practical demonstration to help you explain your ideas to your friend.

Exploring spinning and bending

You are going to use plastic cups to make a spinner that models different ways of spinning and bending a football.

USEFUL RESOURCES

- 2 polystyrene (white) or polythene (clear) cups
- sticky tape and scissors
- 2 elastic bands
- cling film
- paper and pencils
- if available, a mobile phone or camera with slow motion video function.

THINGS TO FIND OUT

Tape the cups together at the base to make the spinner and tie the elastic bands together.

Hold one end of the elastic on the spinner where the cups join and wind it around a few times until the other end of the elastic is at the bottom and pointing away from you.

Hold the spinner in one hand and stretch the elastic with the other then fire the spinner like a catapult to get backspin.

Which way does the spinner bend?

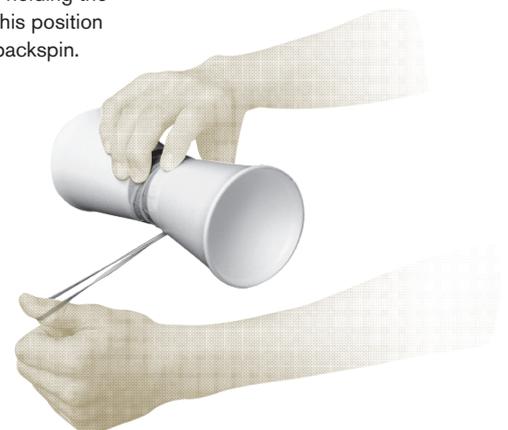


The first step is to tape two expanded polystyrene cups together to make the spinner.



Next, join two strong elastic bands together with a knot.

The spinner is now ready to launch – holding the spinner in this position will give it backspin.



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THINGS TO FIND OUT

Now launch the spinner upside-down to get topspin. Which way does the spinner bend?

For sidespin, you need to launch the spinner on its side, and at an upwards angle so it doesn't fall too quickly to the ground. (Putting cling film over the ends of the cups also increases the time in the air.) Which way does the spinner bend?

If you have a camera, try to capture the most dramatic video footage of each type of spin and the resulting motion.

THINGS TO THINK ABOUT

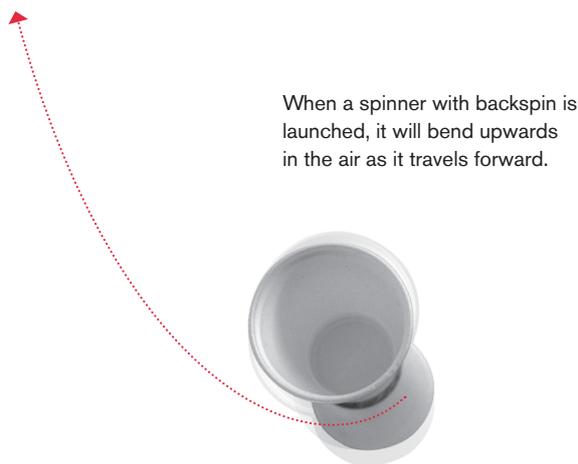
Can you think of a rule that relates where the force of friction is applied to the resulting direction of spin?

Can you think of a rule that relates the direction of spin to the way the spinner bends?

How does this apply to football? What advice would you give to someone who wants to bend a free kick around a wall of defenders into the goal?

What happens when the spinning cups change their path?

This diagram shows two of the types of spin backspin and topspin.



When a spinner with backspin is launched, it will bend upwards in the air as it travels forward.

In both cases, the force of friction from the elastic band will make the spinner go forwards. This force will also make the cups spin, but in opposite directions in each case. This will affect how the spinner moves through the air.