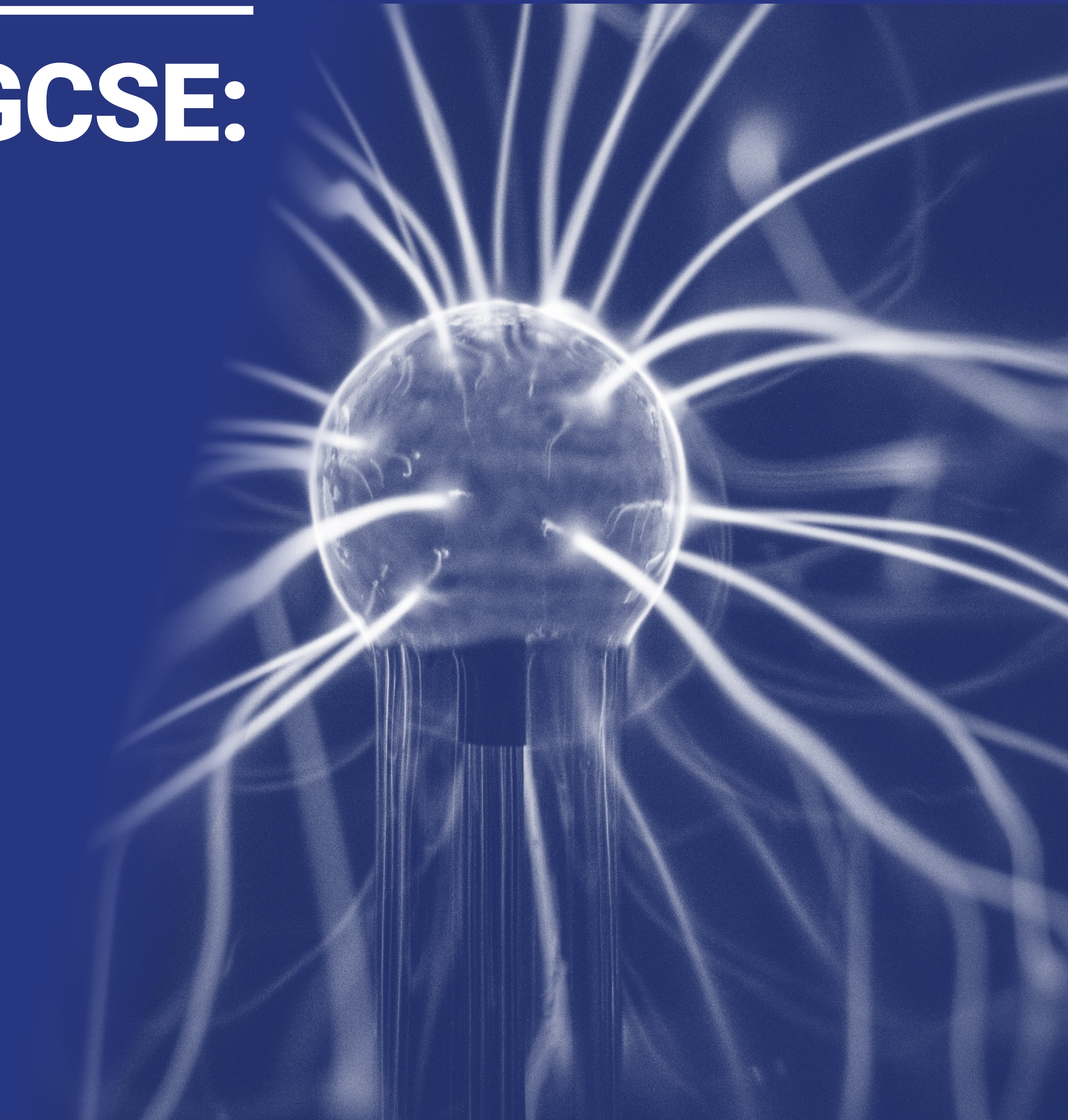
BEST STEPS GCSE:

Student Transitions to Enable Progress in Science

Physics

- *Specific heat capacity*
- *Analysing motion graphs*
- *Forces and reactions*
- *Wave diagrams*
- *Potential difference*
- *Calculating resistance*
- *Electromagnetic field*
- *Energy transfers*



By Neil Wade

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

BEST
Best Evidence Science Teaching

Welcome to BEST STEPS...

How to use the BEST STEPS GCSE resource:

BEST STEPS (Student Transitions to Enable Progress in Science) GCSE consists of a set of teaching progressions for biology, chemistry and physics. These use diagnostic questions from the Best Evidence Science Teaching (BEST) Project and GCSE examination questions to check student understanding of some key scientific concepts.

BEST STEPS GCSE facilitates an individualised approach by using formative assessment to identify the educational needs of students. This enables support to be provided to some students to address gaps in their understanding. Extension material may be offered to those students identified as having secure understanding, to ensure that they are not held back. Appropriate extension material could involve the application of understanding of a key concept to an unfamiliar context.

All GCSE subject content in this resource has been taken from the Department for Education subject guidelines (upon which all specifications in England are based), meaning that this resource is suitable for all GCSE specifications. The topics selected are studied by all students regardless of tier and are required for both combined science and triple science specifications. However, the science concepts developed are universal, so the resource can also be used to support students studying for equivalent qualifications in other countries.

Introducing the Best Evidence Science Teaching (BEST) resources:

Best Evidence Science Teaching (BEST) is a collection of free research evidence-informed resources for effective teaching of difficult ideas, embedded formative assessment and adaptive lesson planning. It is initially focused on science at ages 11-14, although new materials are now being written to extend BEST to support students aged 11-16.

Research evidence-informed progression toolkits for key concepts in science are available free to download from the BEST website.

Each progression toolkit includes:

- appropriately-sequenced learning steps;
- diagnostic questions that provide evidence of learning and of common misunderstandings; and
- response activities that promote purposeful practical work, metacognition and conceptual progression.

If you are unfamiliar with the BEST resources, a short introduction may be downloaded from the BEST website. You may also find it helpful to watch an introductory webinar on the project - “Introduction to Best Evidence Science Teaching (BEST)” - can be found in the “Secondary (11-19) science education “ section here on the ASE website.

Welcome to BEST STEPS...

How to use the BEST STEPS GCSE resource:

The eight topics may be used in any order so use the topics in the order that works best for your students. The resource provides a sequence of three questions for each topic, which together develop conceptual understanding of a key concept. Give your students the introductory question to start with. If students are successful, give them the next question. If students have not grasped the introductory level idea, provide additional material or teaching that will develop their understanding, before continuing to the next question in the progression. Use the final GCSE question to check that your students can apply their conceptual understanding at GCSE level.

How to navigate the Best Evidence Science Teaching (BEST) resources

For your convenience, the BEST diagnostic questions used in these progressions are hyperlinked from each topic page - just click on the question image.

The BEST resources are categorised into “big ideas”, with the “big ideas” in physics being:

- *Matter (PMA)*
- *Forces and motion (PFM)*
- *Sound, light and waves (PSL)*
- *Electricity and magnetism (PEM)*

Use the three letter codes to help you navigate the full set of resources on the BEST website. Here you will find response activities for each diagnostic question used in BEST STEPS GCSE, 11-14 subject maps and much more.

Using the GCSE questions

Clicking on the image of each GCSE question will bring up a word version of the question, guidance on how this can help to identify gaps in your students’ understanding and the official mark scheme.

Acknowledgements

All BEST resources are free to download thanks to the support of the Salters’ Institute and a partnership with STEM Learning. ASE is grateful to OCR for permission to use its questions in this resource.

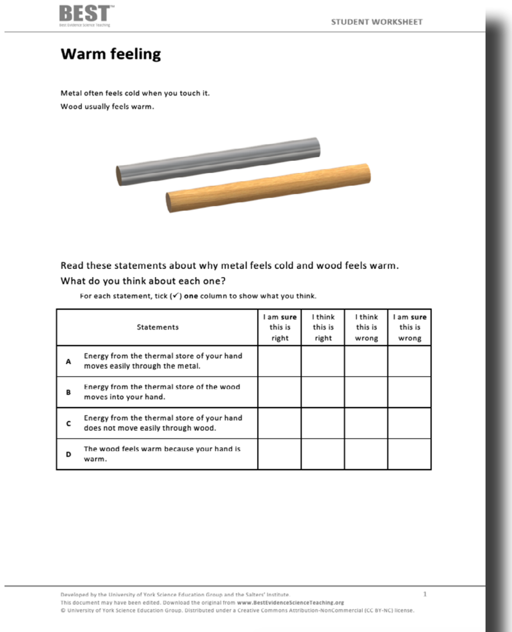
Specific heat capacity

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept PMA1.3: Thermal conduction

Heating makes the particles in a material move more quickly. Heating raises the temperature quickly throughout a good thermal conductor, and very slowly through a good thermal insulator.



BEST
STUDENT WORKSHEET

Warm feeling

Metal often feels cold when you touch it.
Wood usually feels warm.

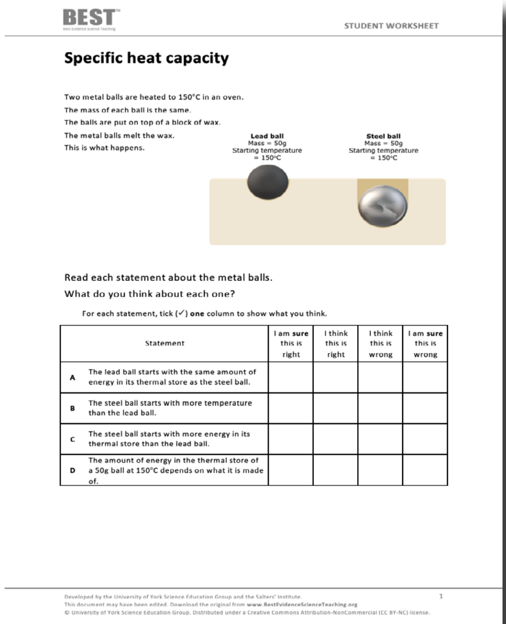
Read these statements about why metal feels cold and wood feels warm.
What do you think about each one?
For each statement, tick (✓) **one** column to show what you think.

	Statements	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
A	Energy from the thermal store of your hand moves easily through the metal.				
B	Energy from the thermal store of the wood moves into your hand.				
C	Energy from the thermal store of your hand does not move easily through wood.				
D	The wood feels warm because your hand is warm.				

Consolidating...

BEST Key concept PMA1.4: Thermal store of energy

Each different material will have more energy in its thermal store if either its temperature or mass is increased.



BEST
STUDENT WORKSHEET

Specific heat capacity

Two metal balls are heated to 150°C in an oven.
The mass of each ball is the same.
The balls are put on top of a block of wax.
The metal balls melt the wax.
This is what happens.

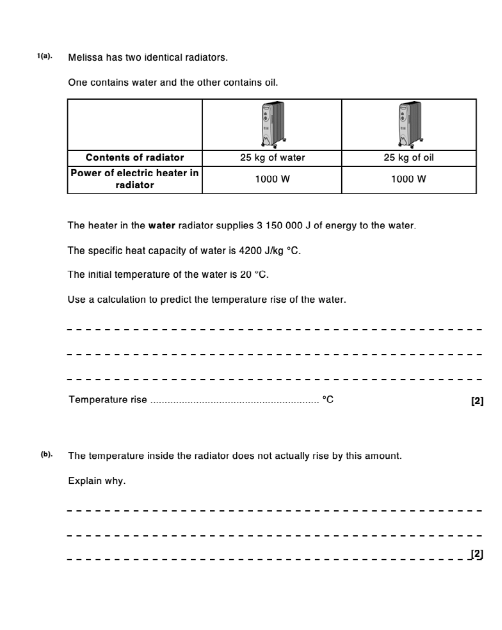
Read each statement about the metal balls.
What do you think about each one?
For each statement, tick (✓) **one** column to show what you think.

	Statement	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
A	The lead ball starts with the same amount of energy in its thermal store as the steel ball.				
B	The steel ball starts with more temperature than the lead ball.				
C	The steel ball starts with more energy in its thermal store than the lead ball.				
D	The amount of energy in the thermal store of a 50g ball at 150°C depends on what it is made of.				

Securing...

GCSE Subject content: Specific Heat Capacity

The energy required to heat the material will depend on mass and specific heat capacity. Using the equation E = mcΔT allows calculation of the energy needed to increase the temperature of a material.



1(a). Melissa has two identical radiators.

One contains water and the other contains oil.

Contents of radiator	25 kg of water	25 kg of oil
Power of electric heater in radiator	1000 W	1000 W

The heater in the **water** radiator supplies 3 150 000 J of energy to the water.

The specific heat capacity of water is 4200 J/kg °C.

The initial temperature of the water is 20 °C.

Use a calculation to predict the temperature rise of the water.

Temperature rise .... °C [2]

(b). The temperature inside the radiator does not actually rise by this amount.

Explain why.

[2]

Analysing motion graphs

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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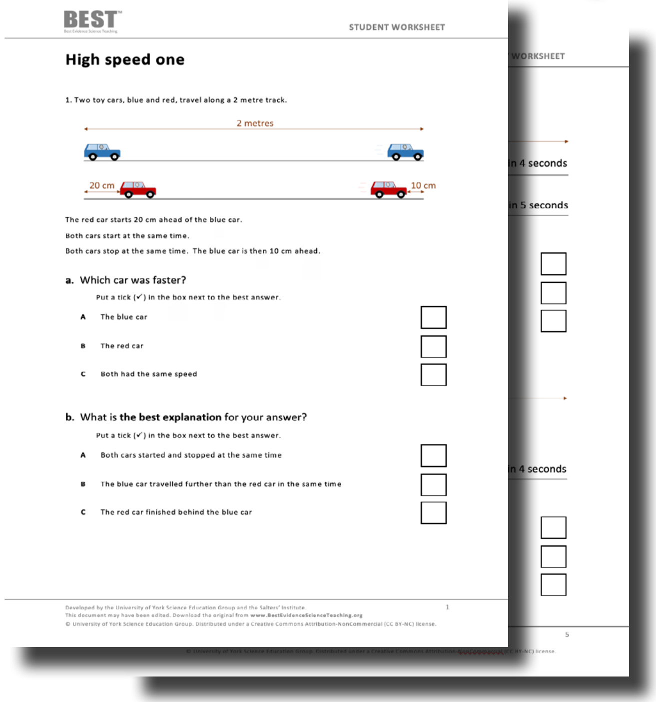
Introducing...

BEST Key concept PFM2.1: Describing speed

Speed is a measure of how fast an object travels: how far it goes in a given time.


BEST STUDENT WORKSHEET

High speed one

1. Two toy cars, blue and red, travel along a 2 metre track.

The red car starts 20 cm ahead of the blue car.
Both cars start at the same time.
Both cars stop at the same time. The blue car is then 10 cm ahead.

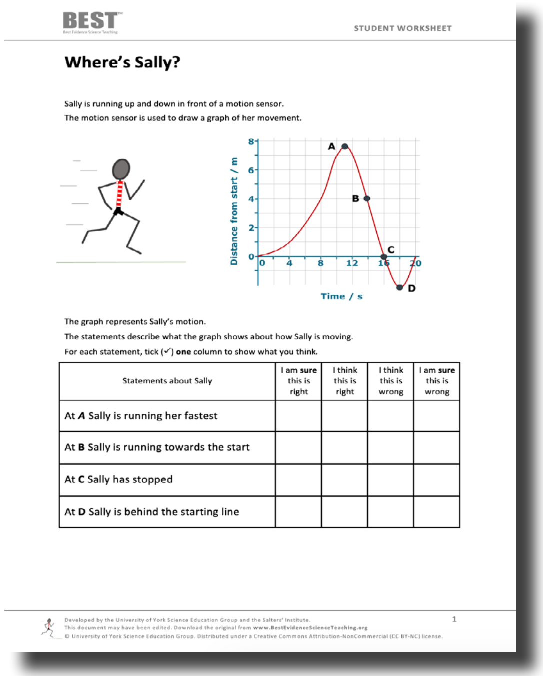
a. Which car was faster?
Put a tick (✓) in the box next to the best answer.
A The blue car
B The red car
C Both had the same speed

b. What is **the best explanation** for your answer?
Put a tick (✓) in the box next to the best answer.
A Both cars started and stopped at the same time
B The blue car travelled further than the red car in the same time
C The red car finished behind the blue car

Consolidating...

BEST Key concept PFM2.2: Motion graphs

Information about the motion of an object can be summarised on a distance-time graph.


BEST STUDENT WORKSHEET

Where's Sally?

Sally is running up and down in front of a motion sensor.
The motion sensor is used to draw a graph of her movement.

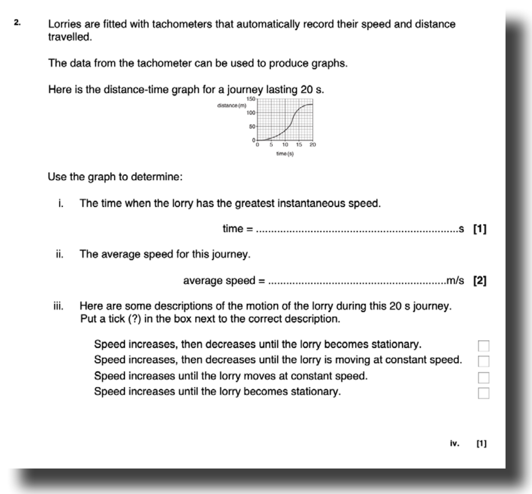
The graph represents Sally's motion.
The statements describe what the graph shows about how Sally is moving.
For each statement, tick (✓) **one** column to show what you think.

Statements about Sally	I am sure this is right	I think this is right	I think this is wrong	I am sure this is wrong
At *A* Sally is running her fastest				
At B Sally is running towards the start				
At C Sally has stopped				
At D Sally is behind the starting line				

Securing...

GCSE Subject content: Analysing motion graphs

Distance-time graphs and velocity-time graphs represent a motion in different ways and can be used to quantify displacement, velocity and acceleration.


2. Lorries are fitted with tachometers that automatically record their speed and distance travelled.

The data from the tachometer can be used to produce graphs.

Here is the distance-time graph for a journey lasting 20 s.

Use the graph to determine:

i. The time when the lorry has the greatest instantaneous speed.
time = ...s [1]

ii. The average speed for this journey.
average speed = ...m/s [2]

iii. Here are some descriptions of the motion of the lorry during this 20 s journey.
Put a tick (?) in the box next to the correct description.

Speed increases, then decreases until the lorry becomes stationary.
Speed increases, then decreases until the lorry is moving at constant speed.
Speed increases until the lorry moves at constant speed.
Speed increases until the lorry becomes stationary.

iv. [1]

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Forces and reactions

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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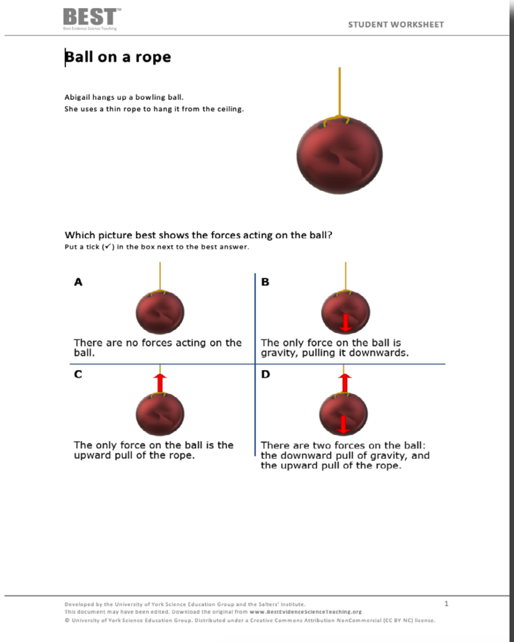
Introducing...

BEST Key concept PFM3.2: Hidden forces

A string can support objects of different weights and hold each one at rest by balancing the force of gravity on the ball.



BEST
STUDENT WORKSHEET

Ball on a rope

Abigail hangs up a bowling ball.
She uses a thin rope to hang it from the ceiling.

Which picture best shows the forces acting on the ball?
Put a tick (✓) in the box next to the best answer.

A There are no forces acting on the ball.

B The only force on the ball is gravity, pulling it downwards.

C The only force on the ball is the upward pull of the rope.

D There are two forces on the ball: the downward pull of gravity, and the upward pull of the rope.

Developed by the University of York Science Education Group and the Salters' Institute. 1
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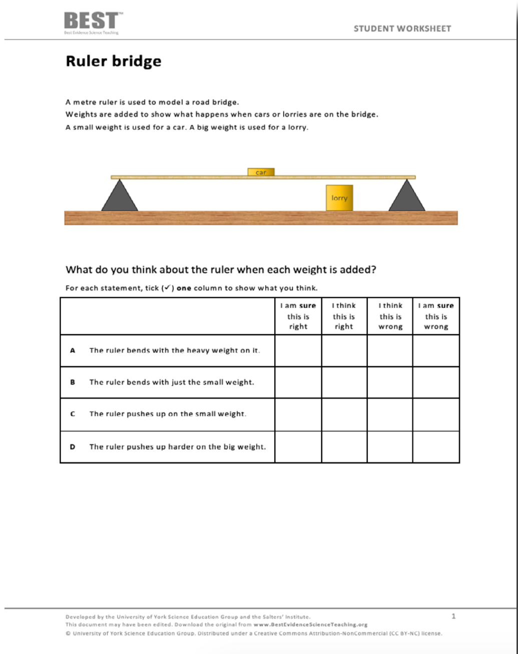
Consolidating...

BEST Key concept PFM3.2: Hidden forces

At a microscopic level a floor is springy. It pushes back on any object placed on it with an equal-sized force in the opposite direction to the object's weight.



BEST
STUDENT WORKSHEET

Ruler bridge

A metre ruler is used to model a road bridge.
Weights are added to show what happens when cars or lorries are on the bridge.
A small weight is used for a car. A big weight is used for a lorry.

What do you think about the ruler when each weight is added?
For each statement, tick (✓) **one** column to show what you think.

	I am **sure** this is right	I think this is right	I think this is wrong	I am **sure** this is wrong
A The ruler bends with the heavy weight on it.				
B The ruler bends with just the small weight.				
C The ruler pushes up on the small weight.				
D The ruler pushes up harder on the big weight.				

Developed by the University of York Science Education Group and the Salters' Institute. 1
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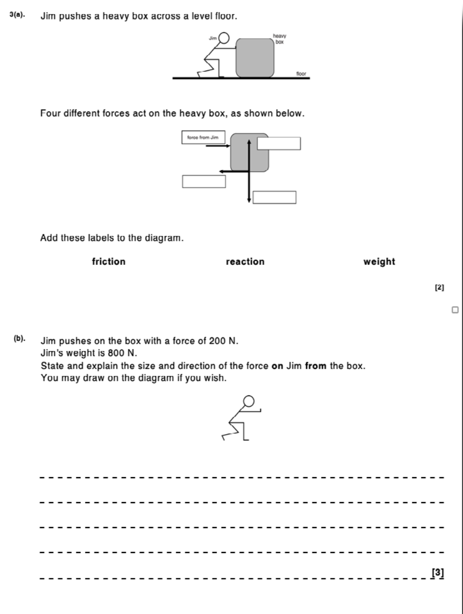
Securing...

GCSE Subject content: Forces and reactions

Interactions between pairs of objects produce a force on each object, which can be represented as vectors.



3(a). Jim pushes a heavy box across a level floor.

Four different forces act on the heavy box, as shown below.

Add these labels to the diagram.

friction **reaction** **weight**

[2]

(b). Jim pushes on the box with a force of 200 N.
Jim's weight is 800 N.
State and explain the size and direction of the force **on** Jim **from** the box.
You may draw on the diagram if you wish.

[3]

Wave diagrams

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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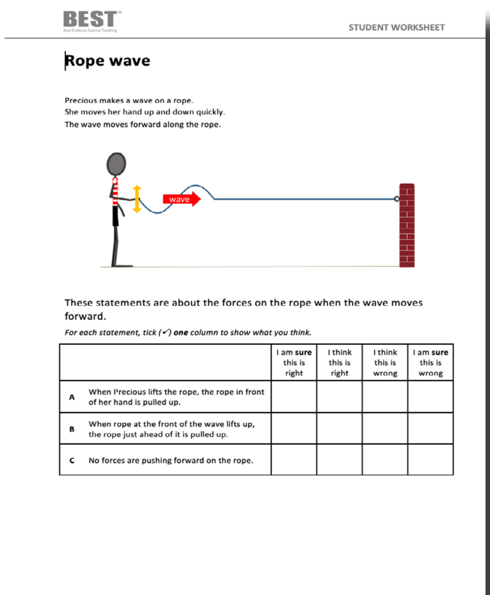
Introducing...

BEST Key concept PSL4.1: Waves on water and ropes

A transverse wave travelling across the surface of water (or along a rope) transfers energy, as particles of water (or rope) are successively made to vibrate at right angles to the direction in which the wave travels.



BEST
STUDENT WORKSHEET

Rope wave

Precious makes a wave on a rope.
She moves her hand up and down quickly.
The wave moves forward along the rope.

These statements are about the forces on the rope when the wave moves forward.

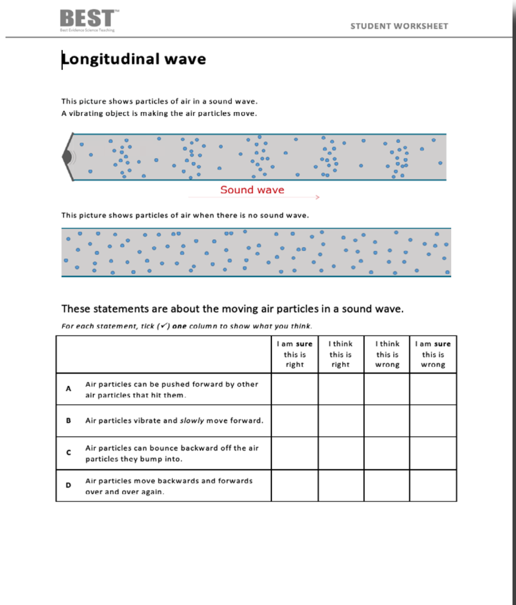
*For each statement, tick (✓) **one** column to show what you think.*

		I am **sure** this is right	I think this is right	I think this is wrong	I am **sure** this is wrong
A	When Precious lifts the rope, the rope in front of her hand is pulled up.				
B	When rope at the front of the wave lifts up, the rope just ahead of it is pulled up.				
C	No forces are pushing forward on the rope.				

Consolidating...

BEST Key concept PSL4.2: A wave model of sound

As a sound wave (longitudinal wave) travels, it transfers energy, as particles of the medium through which it travels are successively made to vibrate forwards and backwards along the direction in which the wave travels.



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Longitudinal wave

This picture shows particles of air in a sound wave.
A vibrating object is making the air particles move.

This picture shows particles of air when there is no sound wave.

These statements are about the moving air particles in a sound wave.

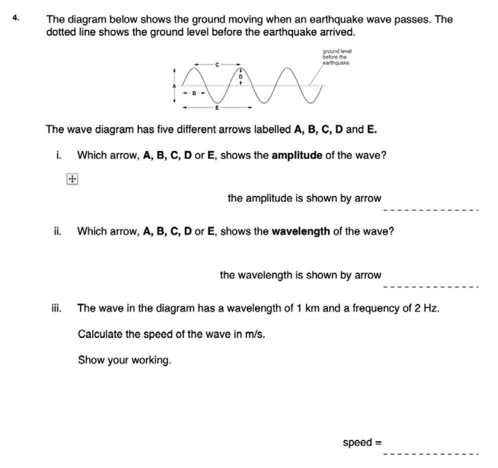
*For each statement, tick (✓) **one** column to show what you think.*

		I am **sure** this is right	I think this is right	I think this is wrong	I am **sure** this is wrong
A	Air particles can be pushed forward by other air particles that hit them.				
B	Air particles vibrate and *slowly* move forward.				
C	Air particles can bounce backward off the air particles they bump into.				
D	Air particles move backwards and forwards over and over again.				

Securing...

GCSE Subject content: Wave diagrams

Wave diagrams represent measurable features of both longitudinal and transverse waves.



4. The diagram below shows the ground moving when an earthquake wave passes. The dotted line shows the ground level before the earthquake arrived.

The wave diagram has five different arrows labelled **A, B, C, D** and **E.**

i. Which arrow, **A, B, C, D** or **E**, shows the **amplitude** of the wave?

the amplitude is shown by arrow ....

ii. Which arrow, **A, B, C, D** or **E**, shows the **wavelength** of the wave?

the wavelength is shown by arrow ....

iii. The wave in the diagram has a wavelength of 1 km and a frequency of 2 Hz.

Calculate the speed of the wave in m/s.

Show your working.

speed = ...

Potential difference

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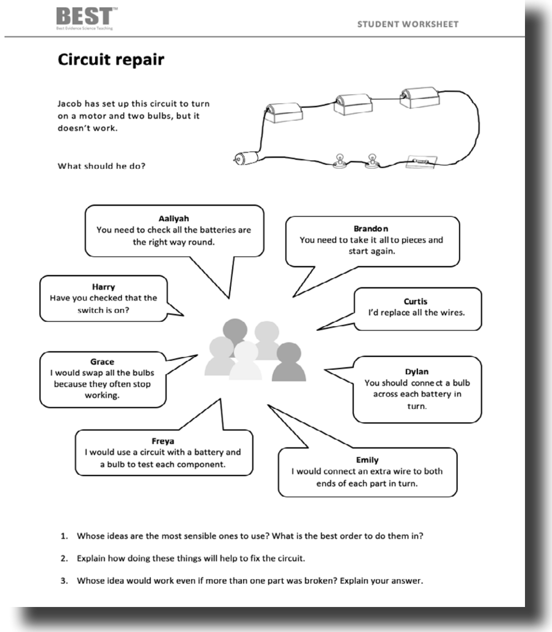
Introducing...

BEST Key concept PEM1.1: Making circuits

An electric circuit is a closed conducting loop containing a battery.



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STUDENT WORKSHEET

Circuit repair

Jacob has set up this circuit to turn on a motor and two bulbs, but it doesn't work.

What should he do?

Aaliyah
You need to check all the batteries are the right way round.

Brandon
You need to take it all to pieces and start again.

Harry
Have you checked that the switch is on?

Curtis
I'd replace all the wires.

Grace
I would swap all the bulbs because they often stop working.

Dylan
You should connect a bulb across each battery in turn.

Freya
I would use a circuit with a battery and a bulb to test each component.

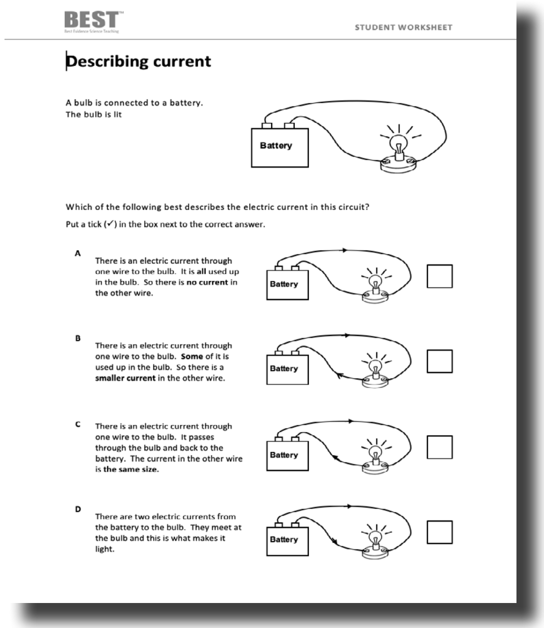
Emily
I would connect an extra wire to both ends of each part in turn.

1. Whose ideas are the most sensible ones to use? What is the best order to do them in?
2. Explain how doing these things will help to fix the circuit.
3. Whose idea would work even if more than one part was broken? Explain your answer.

Consolidating...

BEST Key concept PEM1.2: Electric current

Electric current is the flow of electric charge around a circuit that stops or starts flowing everywhere in the circuit at the same time. In a series circuit the current is the same in all places.



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STUDENT WORKSHEET

Describing current

A bulb is connected to a battery.
The bulb is lit

Battery

Which of the following best describes the electric current in this circuit?

Put a tick (✓) in the box next to the correct answer.

A There is an electric current through one wire to the bulb. It is **all** used up in the bulb. So there is **no current** in the other wire. (Battery) ☐

B There is an electric current through one wire to the bulb. **Some** of it is used up in the bulb. So there is a **smaller current** in the other wire. (Battery) ☐

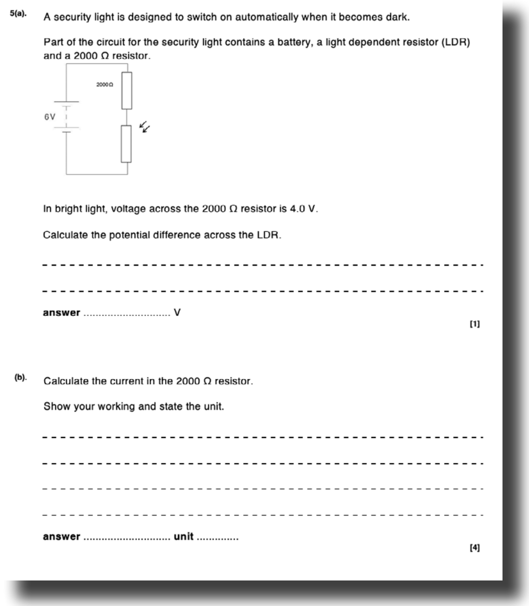
C There is an electric current through one wire to the bulb. It passes through the bulb and back to the battery. The current in the other wire is **the same size.** (Battery) ☐

D There are two electric currents from the battery to the bulb. They meet at the bulb and this is what makes it light. (Battery) ☐

Securing...

GCSE Subject content: Potential difference

Currents, potential differences and resistances in d.c. series circuits can be calculated and the design and use of such circuits for measurement and testing purposes explained. Conventions of positive and negative terminals, and the symbols, are important in understanding the action of any given circuit.



5(a). A security light is designed to switch on automatically when it becomes dark.

Part of the circuit for the security light contains a battery, a light dependent resistor (LDR) and a 2000 Ω resistor.

6V
2000 Ω

In bright light, voltage across the 2000 Ω resistor is 4.0 V.

Calculate the potential difference across the LDR.

- -

- -

answer V

[1]

(b). Calculate the current in the 2000 Ω resistor.

Show your working and state the unit.

- -

- -

- -

- -

answer .... **unit** ....

[4]

Calculating resistance

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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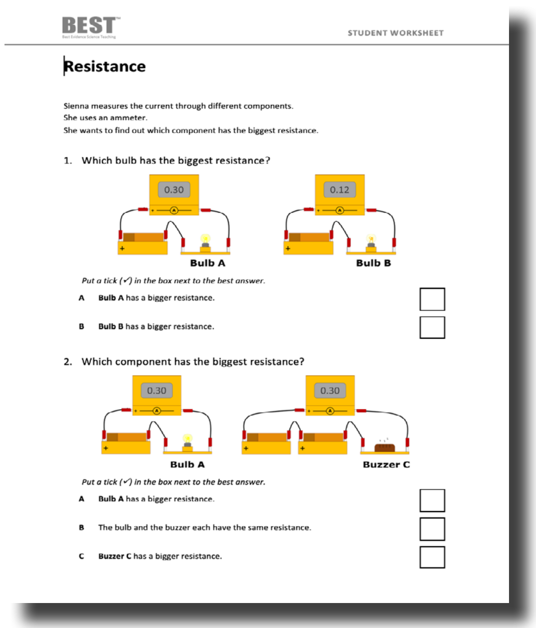
Introducing...

BEST Key concept PEM2.1:
Resistance

Resistance (in Ohms, Ω) is a measure of how hard it is for charge to flow.



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Resistance

Sienna measures the current through different components.
She uses an ammeter.
She wants to find out which component has the biggest resistance.

1. Which bulb has the biggest resistance?

Put a tick (✓) in the box next to the best answer.

A **Bulb A** has a bigger resistance.
B **Bulb B** has a bigger resistance.

2. Which component has the biggest resistance?

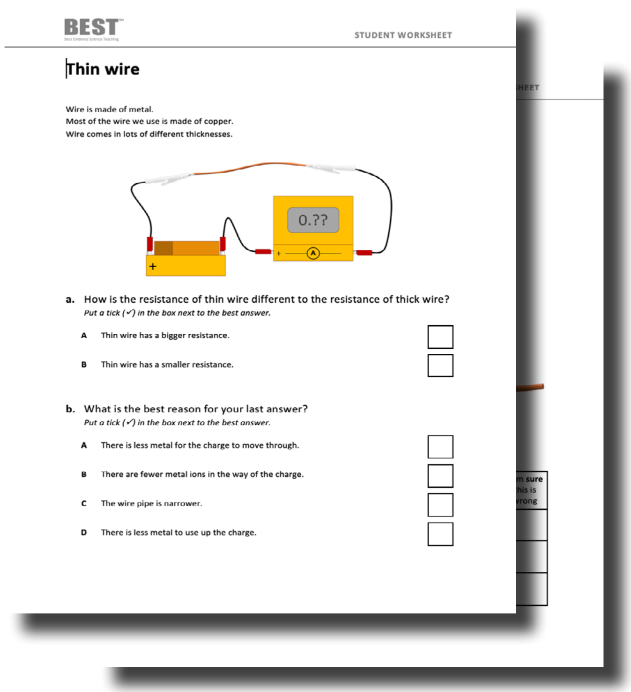
Put a tick (✓) in the box next to the best answer.

A **Bulb A** has a bigger resistance.
B The bulb and the buzzer each have the same resistance.
C **Buzzer C** has a bigger resistance.

Consolidating...

BEST Key concept PEM2.1:
Resistance

The resistance of a wire depends on its length and its cross-sectional area (its thickness).



BEST
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Thin wire

Wire is made of metal.
Most of the wire we use is made of copper.
Wire comes in lots of different thicknesses.

a. How is the resistance of thin wire different to the resistance of thick wire?
Put a tick (✓) in the box next to the best answer.

A Thin wire has a bigger resistance.
B Thin wire has a smaller resistance.

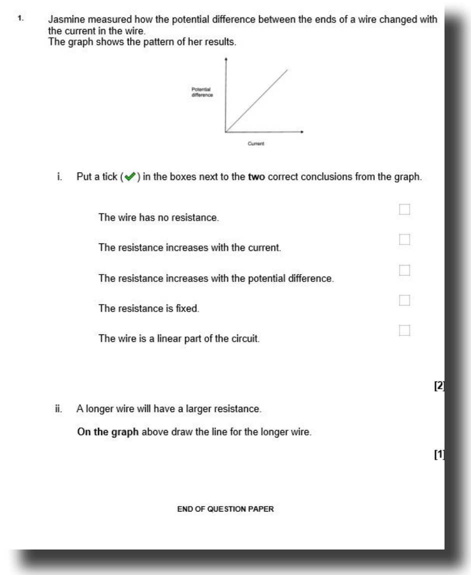
b. What is the best reason for your last answer?
Put a tick (✓) in the box next to the best answer.

A There is less metal for the charge to move through.
B There are fewer metal ions in the way of the charge.
C The wire pipe is narrower.
D There is less metal to use up the charge.

Securing...

GCSE Subject content:
Calculating resistance

Current (I) depends on both resistance (R) and potential difference (V) with the relationship between I, R and V being recalled and applied. For some resistors, the value of R remains constant but, in other specific components, resistance can change as the current changes. The design and use of circuits to explore such effects – including for lamps, diodes, thermistors and LDRs – can also be related to this relationship.



1. Jasmine measured how the potential difference between the ends of a wire changed with the current in the wire.
The graph shows the pattern of her results.

i. Put a tick (✓) in the boxes next to the **two** correct conclusions from the graph.

The wire has no resistance.
The resistance increases with the current.
The resistance increases with the potential difference.
The resistance is fixed.
The wire is a linear part of the circuit.

[2]

ii. A longer wire will have a larger resistance.
On the graph above draw the line for the longer wire.

[1]

END OF QUESTION PAPER

Electromagnetic field

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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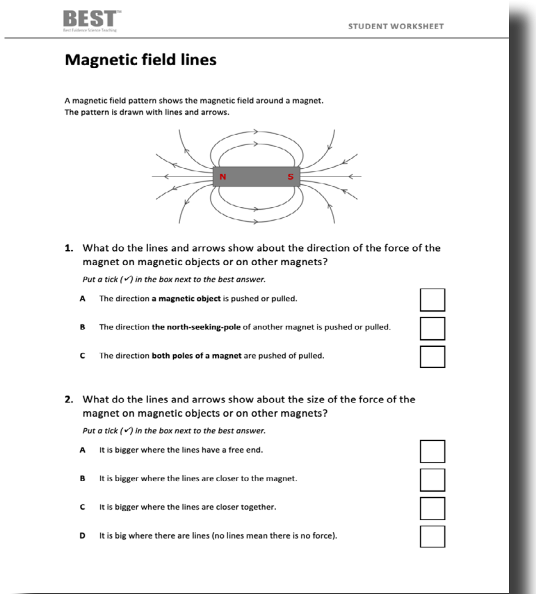
Introducing...

BEST Key concept PEM3.1: Magnetic fields

The magnetic field around a magnet can be represented by field lines, which indicate the size and direction of the force of the magnet on the north-seeking pole of another magnet.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Magnetic field lines

A magnetic field pattern shows the magnetic field around a magnet.
The pattern is drawn with lines and arrows.

1. What do the lines and arrows show about the direction of the force of the magnet on magnetic objects or on other magnets?

Put a tick (✓) in the box next to the best answer.

- **A** The direction **a magnetic object** is pushed or pulled. ☐
- **B** The direction **the north-seeking-pole** of another magnet is pushed or pulled. ☐
- **C** The direction **both poles of a magnet** are pushed of pulled. ☐

2. What do the lines and arrows show about the size of the force of the magnet on magnetic objects or on other magnets?

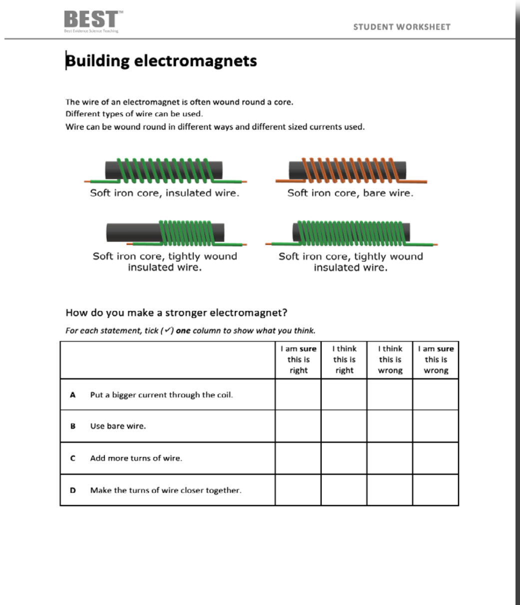
Put a tick (✓) in the box next to the best answer.

- **A** It is bigger where the lines have a free end. ☐
- **B** It is bigger where the lines are closer to the magnet. ☐
- **C** It is bigger where the lines are closer together. ☐
- **D** It is big where there are lines (no lines mean there is no force). ☐

Consolidating...

BEST Key concept PEM3.2: Electromagnets

Different factors can change the strength of a magnetic field around a coil of wire.


BEST
STUDENT WORKSHEET

Building electromagnets

The wire of an electromagnet is often wound round a core.
Different types of wire can be used.
Wire can be wound round in different ways and different sized currents used.

How do you make a stronger electromagnet?

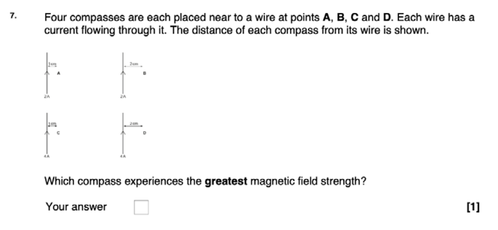
*For each statement, tick (✓) **one** column to show what you think.*

		I am **sure** this is right	I think this is right	I think this is wrong	I am **sure** this is wrong
A	Put a bigger current through the coil.				
B	Use bare wire.				
C	Add more turns of wire.				
D	Make the turns of wire closer together.				

Securing...

GCSE Subject content: Electromagnetic field

The direction of the magnetic field around a conducting wire can be shown using compasses. The strength of the field depends on the current and the distance from the conductor.


7. Four compasses are each placed near to a wire at points **A**, **B**, **C** and **D**. Each wire has a current flowing through it. The distance of each compass from its wire is shown.

Which compass experiences the **greatest** magnetic field strength?

Your answer ☐ **[1]**

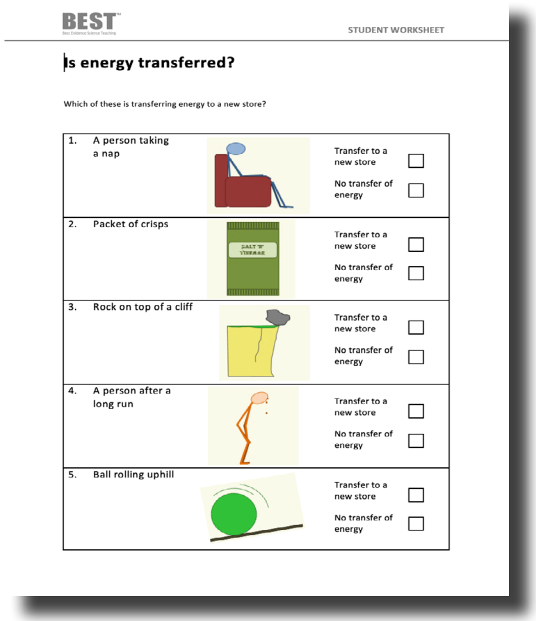
Energy transfers

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept PFM1.5:
Energy stores and transfers

An energy store of some kind is necessary for something to happen, and something happens when energy transfers between energy stores.



BEST STUDENT WORKSHEET

Is energy transferred?

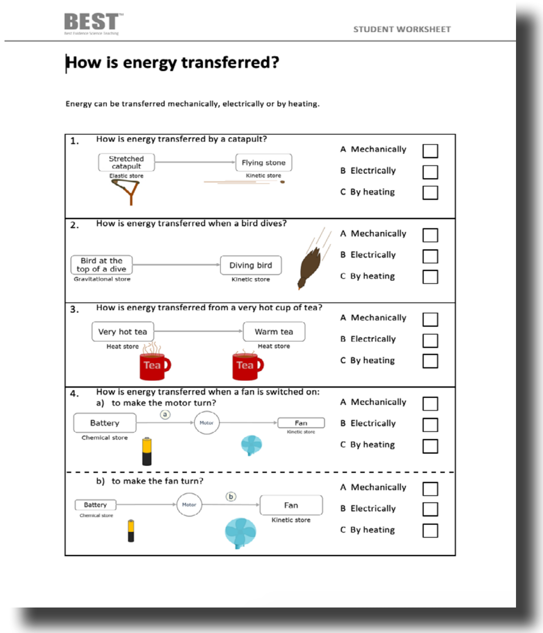
Which of these is transferring energy to a new store?

1. A person taking a nap		Transfer to a new store ☐ / No transfer of energy ☐
2. Packet of crisps		Transfer to a new store ☐ / No transfer of energy ☐
3. Rock on top of a cliff		Transfer to a new store ☐ / No transfer of energy ☐
4. A person after a long run		Transfer to a new store ☐ / No transfer of energy ☐
5. Ball rolling uphill		Transfer to a new store ☐ / No transfer of energy ☐

Consolidating...

BEST Key concept PFM1.5:
Energy stores and transfers

When a force makes things change, it mechanically transfers energy between different energy stores. Friction transfers energy mechanically into a heat store of energy.



BEST STUDENT WORKSHEET

How is energy transferred?

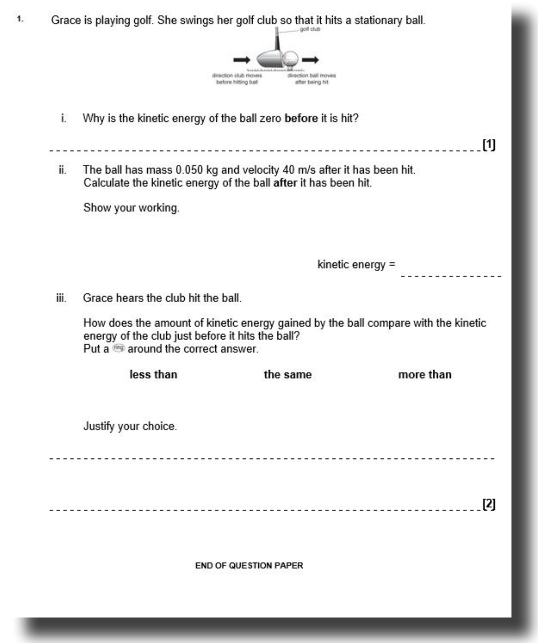
Energy can be transferred mechanically, electrically or by heating.

1. How is energy transferred by a catapult? (Stretched catapult, Elastic store → Flying stone, Kinetic store) A Mechanically ☐ B Electrically ☐ C By heating ☐
2. How is energy transferred when a bird dives? (Bird at the top of a dive, Gravitational store → Diving bird, Kinetic store) A Mechanically ☐ B Electrically ☐ C By heating ☐
3. How is energy transferred from a very hot cup of tea? (Very hot tea, Heat store → Warm tea, Heat store) A Mechanically ☐ B Electrically ☐ C By heating ☐
4. How is energy transferred when a fan is switched on:
   a) to make the motor turn? (Battery, Chemical store → Motor → Fan, Kinetic store) A Mechanically ☐ B Electrically ☐ C By heating ☐
   b) to make the fan turn? (Battery, Chemical store → Motor → Fan, Kinetic store) A Mechanically ☐ B Electrically ☐ C By heating ☐

Securing...

GCSE Subject content:
Energy transfers

Students should be able to describe all the changes involved in the way energy is stored when a system changes, for common situations.



1. Grace is playing golf. She swings her golf club so that it hits a stationary ball.

   i. Why is the kinetic energy of the ball zero **before** it is hit?
   .... [1]

   ii. The ball has mass 0.050 kg and velocity 40 m/s after it has been hit. Calculate the kinetic energy of the ball **after** it has been hit.
   Show your working.
   kinetic energy = ...

   iii. Grace hears the club hit the ball.
   How does the amount of kinetic energy gained by the ball compare with the kinetic energy of the club just before it hits the ball?
   Put a (ring) around the correct answer.
   less than **the same** **more than**
   Justify your choice.
   ....
   .... [2]

END OF QUESTION PAPER

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