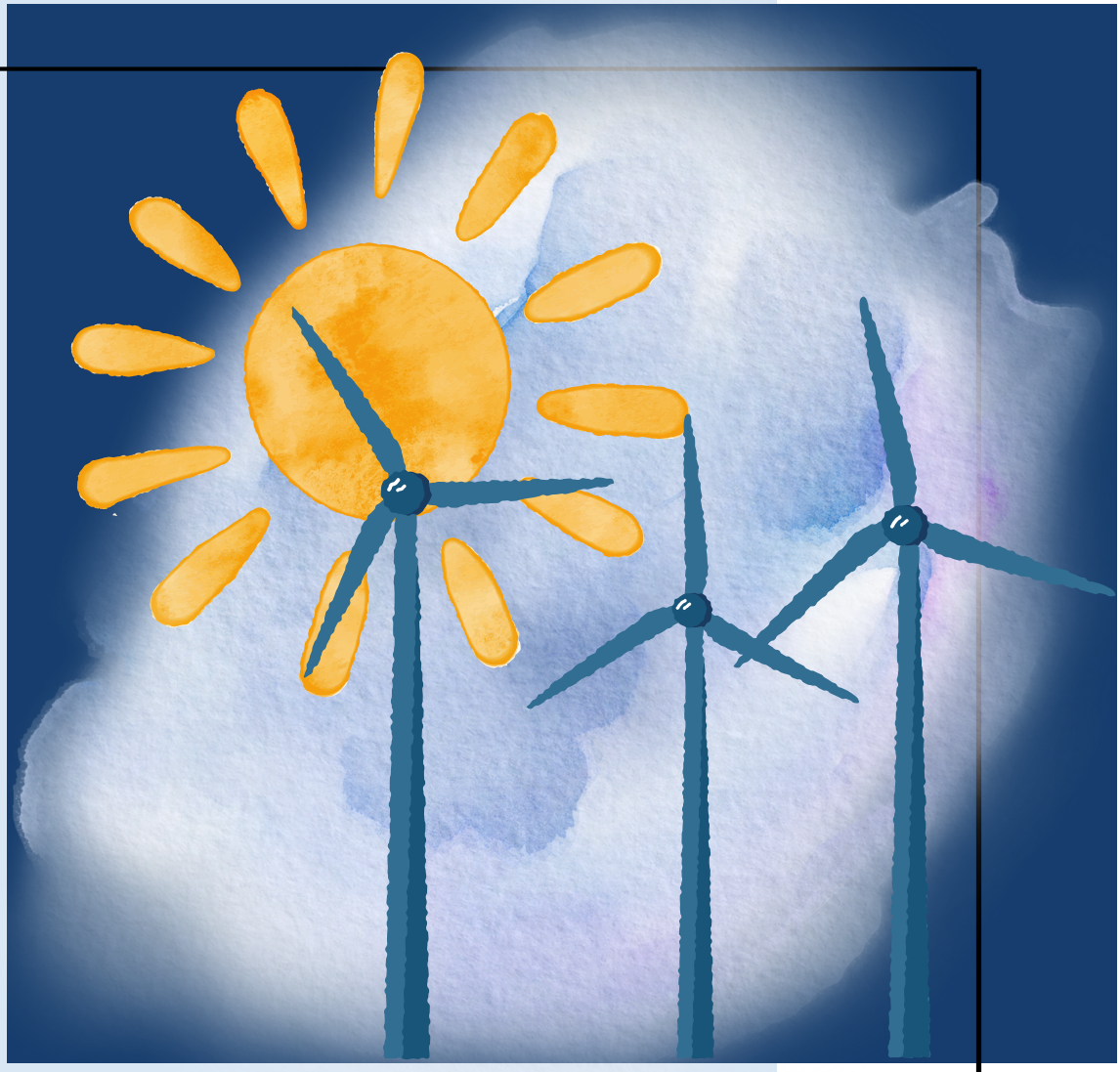


Unit Preparation Booklet

P4.2 Energy Conservation

Teacher name:

Science
Mastery

Ark Curriculum+

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Steps to Success

		What?	Why?	Who?	Page #
Preparing to teach	**1**	☐ Print this booklet or save a copy in a personal folder	To allow for engagement during planning and co-planning	*All teachers*	
	2	☐ Engage with the unit preparation checklist	To prepare for delivering the sequence of lessons	*All teachers*	4
	3	☐ Read the scope and sequence for the unit	To review the scope and sequence of the unit	*All teachers*	5
	4	☐ Complete the pre-unit quiz reflections task after administering to class	To plan how to remedy prior knowledge gaps	*New to teaching the unit only*	11
	6	☐ Complete the Mastery Quiz and exam-style questions activity	To learn/revisit the key assessment objectives of the unit	*New to teaching the unit only*	12-21
	7	☐ Complete the misconception activities	To develop a strong understanding of the most common misconceptions for the unit and how to address them	*New to teaching the unit only*	22-24
Delivering the unit	**8**	☐ Use the lesson by lesson objectives to monitor progression through the unit	To maintain a record of completion and to recognise what needs to be reviewed after each lesson	*Novice teachers only*	25-37
Utilise other features of the booklet	**9**	☐ Complete the advanced subject knowledge activity	To develop an understanding of where the unit can lead	*Non A-level specialists*	39
	10	☐ Engage in the keywords	To identify the correct definitions for keywords throughout the unit	*Novice teachers only*	41

Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

Scope and Sequence

Scope

This unit starts with a prior knowledge review of energy stores and transfers, particularly energy transfers in heating before looking at the different energy stores and their associated equations. Finally, it covers power and efficiency, then renewable and non-renewable energy resources.

Sequence

It begins with a prior knowledge of the different energy stores and pathways as well as linking back to specific heat capacity and the energy transfers that take place during heating. Physics only students will then look at the required practical to investigate the effectiveness of different insulators, building on their knowledge of energy transfer by heating.

All students will then move onto the different stores of energy and their associated equations. Kinetic energy is one of the easiest stores for students to understand, so it is covered first. At this point in Y10 students have already had many opportunities for practice of algebraic equations, including indices, in maths, so should be prepared to meet the equation to calculate kinetic energy at this point. From kinetic energy, students will move on to looking at elastic potential energy, as this is also something that students can access more easily than gravitational potential energy. Students will revisit their understanding of elasticity and Hooke's Law and apply the two equations. Students will then move on to gravitational potential energy, consolidating their understanding of the difference between mass and weight, before having the opportunity to practice calculations and understanding scenarios that illustrate conservation of energy using multi-step equations.

Students will then move on to power, reviewing how to calculate it from P3.4, as well as application of the new energy equations. They will then revisit efficiency in terms of both energy and power, as well as being introduced to methods to increase efficiency.

Finally the unit reviews the advantages and disadvantages of renewable and non-renewable energy from P3.4, to which they can now apply their new understanding of the energy calculations and efficiency and the different energy transfers taking place.

A full set of knowledge objectives for this unit can be found as **Appendix 3.**

1	**2**	**3**	**4**
Prior Knowledge Review	Taking it Further: RPA Investigating Insulation	Taking it Further: RPA Investigating Insulation Analysis	Kinetic Energy
5	**6**	**7**	**8**
Elastic Potential Energy	Gravitational Potential Energy	Conservation of Energy	Power
9	**10**	**11**	**12**
Efficiency	Non-renewable Energy Resources	Renewable Energy Resources	Feedback Lesson

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

TASK: Below is the pre-unit quiz available for your pupils. Complete yourself and set for your pupils ahead of starting the unit. There is space to record the key outcomes from marking the quiz for your class. **See Appendix 1 for the mark scheme.**

1. Which of these statements is **true**? [1]
   Tick (✓) **one** box.
   - (a) Energy can be destroyed when it is wasted ☐
   - (b) Energy can be created by burning fuel ☐
   - (c) Energy can be transferred between different stores ☐

2. Which of these is **not** a store of energy? [1]
   Tick (✓) **one** box.
   - (a) Kinetic ☐
   - (b) Gravitational ☐
   - (c) Electrical ☐

3. In which state of matter do particles have the most energy? [1]
   Tick (✓) **one** box.
   - (a) Solid ☐
   - (b) Liquid ☐
   - (c) Gas ☐

4. Which method of thermal transfer does not require particles? [1]
   Tick (✓) **one** box.
   - (a) Conduction ☐
   - (b) Convection ☐
   - (c) Radiation ☐

5. Which correctly explains why metals are good thermal conductors? [1]
   Tick (✓) **one** box.
   - (a) They are solids ☐
   - (b) They contain free electrons ☐
   - (c) They are able to flow ☐

6. What happens when there is a temperature difference between objects? [1]
Tick (✓) **one** box.

(a) Energy transfers from a hotter to a cooler object ☐

(b) Coldness transfers from a cooler object to a hotter object ☐

(c) Heat transfers from a hotter object to a cooler object ☐

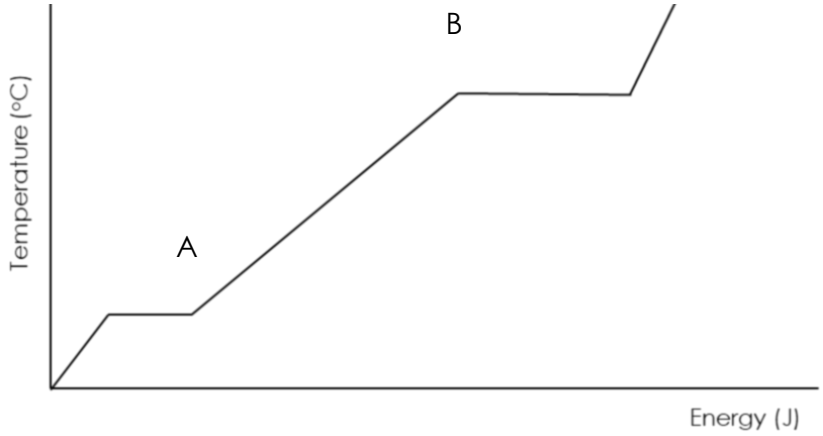
7. Choose the correct definition of internal energy. [1]
Tick (✓) **one** box.

(a) The total kinetic energy of all the particles in a system ☐

(b) The total kinetic and potential energy of all the particles in a system ☐

(c) The total energy transferred when a substance changes state ☐

8. A student has plotted a heating curve of water.



Choose the statement that is correct for line AB.
Tick (✓) **one** box.

(a) Kinetic energy and potential energy are increasing ☐

(b) Kinetic energy and internal energy are increasing ☐

(c) Potential energy and internal energy are increasing ☐

9. Choose the correct definition of specific heat capacity. [1]

Tick (✓) **one** box.

(a) The amount of energy needed to increase the temperature of 1 kg of a material by 1 °C. ☐

(b) The amount of energy needed to change 1 kg of a material from the initial temperature to the final temperature ☐

(c) The amount of energy needed to change the state of 1 kg of a material. ☐

10. 334,000 J of energy is required to convert 1 kg of ice to water. What quantity does this represent? [1]

Tick (✓) **one** box.

(a) Specific heat capacity ☐

(b) Specific latent heat of vaporisation ☐

(c) Specific latent heat of fusion ☐

Total = ___ /10

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

P4.2 Mastery Quiz: Energy Conservation

Section A

1. Choose which of the following is an energy store. [1]

   Tick (✓) **one** box.

   A. heating ☐

   B. current in a circuit ☐

   C. kinetic ☐

2. Using water waves is … [1]

   Tick (✓) **one** box.

   A. an unreliable energy source. ☐

   B. a constant energy source. ☐

   C. a type of non-renewable energy source. ☐

3. Choose which is an example of a fossil fuel. [1]

   Tick (✓) **one** box.

   A. Nuclear ☐

   B. Pollution ☐

   C. Gas ☐

4. A lawnmower has a total power input of 800 W.

The useful power output of the lawnmower is 368 W.

Calculate the efficiency of the lawnmower. [1]

Tick (✓) **one** box.

A. 46 % ☐

B. 46 W ☐

C. 217 % ☐

D. 217 W ☐

5. Below shows the equation for calculating the kinetic energy of a moving object.

$$\text{kinetic energy} = 0.5 \times \text{mass} \times (\text{speed})^2$$

A ball had a mass of 1 kg and was travelling at 3 m/s.

Calculate the kinetic energy of the ball. [1]

Tick (✓) **one** box.

A. 1.5 J ☐

B. 2.25 J ☐

C. 4.5 J ☐

6. Spring 1 has a spring constant of 50 N/m.
Spring 2 has a spring constant of 40 N/m.

Choose which spring will require the **most** force to extend it by 1 cm. [1]

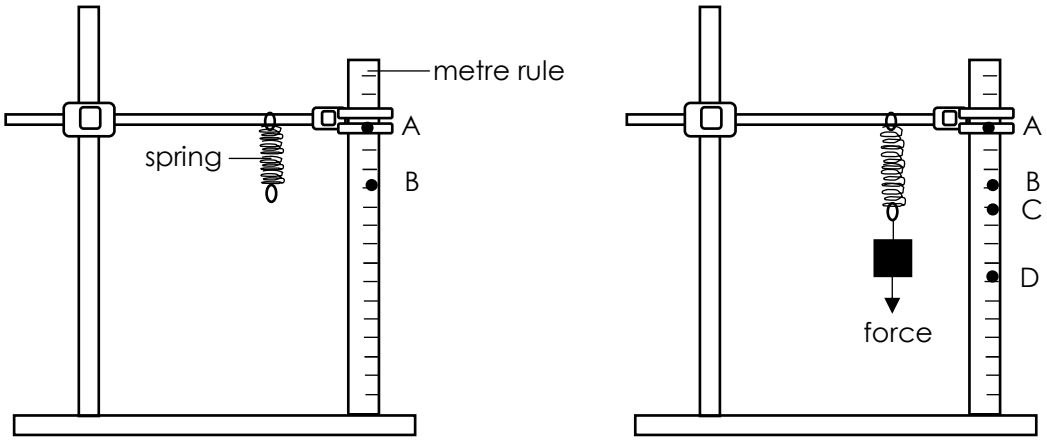
Tick (✓) **one** box.

A. Spring 1 ☐

B. Spring 2 ☐

C. Not enough information because the amount of energy is unknown ☐

7. A student sets up apparatus to measure the extension of a spring, as shown in the diagram below.



Choose the letters where extension of the spring is measured. [1]

Tick (✓) **one** box.

A. A to B ☐

B. B to D ☐

C. B to C ☐

8. In all system changes, energy is dissipated which means that… [1]

Tick (✓) **one** box.

A. it is transferred usefully. ☐

B. it is wasted. ☐

C. it is stored. ☐

9. Choose the action that would increase the efficiency of a machine by reducing friction. [1]

Tick (✓) **one** box.

A. Adding an insulator ☐

B. Adding a lubricant ☐

C. Adding heat ☐

10. Choose the correct equation. [1]

Tick (✓) **one** box.

A. Power = $\frac{\text{time}}{\text{work done}}$ ☐

B. Power = work done x time ☐

C. Power = $\frac{\text{work done}}{\text{time}}$ ☐

11. It is beneficial to use renewable energy resources, rather than non-renewable sources, because… [1]

Tick (✓) **one** box.

A. they contribute to global warming. ☐

B. they can be replenished. ☐

C. they are always reliable during peak demand. ☐

12. Choose the definition for power. [1]

Tick (✓) **one** box.

A. The rate at which energy is transferred ☐

B. The force needed to move an object ☐

C. The amount of energy that is in a store ☐

13. Choose which of the following is storing elastic potential energy. [1]

Tick (✓) **one** box.

A. The curved plastic of a cup ☐

B. A squashed ball ☐

C. A bent metal pole ☐

14. Below shows the equation to calculate amount of energy stored in a system as its temperature changes:

change in thermal energy = mass × specific heat capacity × temperature change

$$\Delta E = m\ c\ \Delta\theta$$

A kettle heats up 0.5 kg of water from 15 ºC to 100 ºC.
The specific heat capacity of water is 4200 J/kg ºC.

Calculate the change in thermal energy. [1]

Tick (✓) **one** box.

A. 178500 J ☐

B. 210000 J ☐

C. 99 J ☐

Physics Only

15. A student investigated how the temperature of a test tube of water changes over time when different materials are used to insulate the test tube. The materials they used were:
    - aluminium foil
    - newspaper
    - bubblewrap

(a) Choose the independent variable for this investigation. [1]

Tick (✓) **one** box.

A. Aluminium, newspaper, bubblewrap ☐

B. The type of material ☐

C. The temperature of water ☐

(b) Choose the most likely conclusion the student would draw from this experiment. [1]

Tick (✓) **one** box.

A. Aluminium foil is the best insulator ☐

B. The test tube wrapped in bubblewrap would show the greatest change in temperature ☐

C. The test tube wrapped in bubblewrap would show the smallest change in temperature ☐

Section B

1. State the law of conservation of energy. [1]

_____

_____

2. State **two** uses of energy resources. [2]

_____

_____

3. Describe the energy transfers that take place when a person starts to run faster. [3]

_____

_____

_____

_____

4. A child jumped up so that their mass was raised by 750 cm.

The child's mass was 25 kg.

Gravitational field strength is 10 N/kg.

Calculate the gain in gravitational potential energy. [4]

_____

_____

_____

_____

5. A power company is investing in a new power station.

   Evaluate whether they should invest in a hydroelectric power station or a nuclear power station. [6]

Higher Tier Only

6. Oil is added to a car engine to lubricate the moving parts.

   Explain how adding oil increases the efficiency of a car engine. [4]

Physics Only

7. Describe a simple method a student could use to determine which of the following methods is the most effective insulator. [6]

- aluminium foil
- newspaper
- bubblewrap

Mastery quiz reflections

Which aspects of this unit are likely to be the most challenging to teach?	
What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*
How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using Exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors and misconceptions

How would you tackle the following common mistakes, errors and misconceptions by pupils?

TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
Only moving objects have energy.	Moving objects have a store of kinetic energy, but there are other stores of energy. Any object that is above absolute zero (so all objects) have a store of thermal energy.	
All objects that have changed shape have a store of elastic potential energy.	Objects that have been deformed elastically (can return to their original shape) have a store of elastic potential energy. If an object has been inelastically deformed, such as metal hammered into a sheet, does not have a store of elastic potential energy.	
Weight is measured in kg.	Mass is measured in kg. Weight is measured in N.	
Power and energy are the same.	Energy is the capacity to do work. Power is the rate at which energy is transferred.	
Energy is not conserved in a transfer because some energy 'disappears'.	Energy is conserved in a closed system. Some energy may be wasted/dissipated to the surroundings (usually as thermal energy) so it cannot be measured/calculated, but it is still there.	
All renewable resources are unreliable.	This is a common disadvantage of some renewable resources (such as wind or solar) but not all. Hydroelectricity is very reliable.	
Nuclear energy is renewable because it is not a fossil fuel.	Nuclear energy is non-renewable because it cannot be replenished at the same rate that it is used.	
All non-renewable resources are 'bad'.	While renewable resources are preferable, it can be difficult for some countries to change because of the cost of existing infrastructure.	

Planning for the misconceptions

Misconception: Energy is 'lost' when it is wasted.
Whenever there is an energy transfer (unless in an ideal, frictionless system), energy is wasted. This means it is not transferred to the useful store.
Supporting pupil understanding Using Sankey diagrams with concrete examples, such as appliances (so students can feel their temperature increasing or hear the noise), where the useful and wasted stores are identified in each scenario. This can help students to understand that although the energy has not been transferred usefully, it has not disappeared.
Taking it further
Examples of energy transfers from non-renewable energy resources can be challenging for students to consider. Where an appliance is connected to mains electricity, energy is being transferred electrically from the National Grid, which is transferring energy from a chemical store (if the power station in use is a fossil fuel station). This can be difficult for students to phrase, as many textbooks and examples use the old language of 'the electric store' of energy.

Misconception: When an energy transfer occurs, all the energy is converted from one store to one new store.
Many exam questions are often phrased theoretically, such as 'if object X has a height of 2 m at the top of a ramp and a mass of 5 kg, calculate the maximum speed it could reach'. This often leads to students thinking that all the GPE is converted only to kinetic energy.
Supporting pupil understanding It is important to make it explicit for students that this is a maximum/ideal value and would not occur in real life. The I/We/You cycle for the lesson on conservation of energy includes a question after each scenario about why the maximum would not be achieved during the energy transfer. It can also be useful to show students this using the PhET skateboarder simulation with and without friction so they can see the difference, then linking this back into efficiency and how adding a lubricant would affect the efficiency.

Misconception: All renewable resources are good and all non-renewable resources are bad.
This is a simplification of the advantages and disadvantages of different resources. Non-renewable resources are environmentally worse but can often be cheaper or more reliable.
Supporting pupil understanding Giving students different scenarios can help to identify advantages and disadvantages of different energy resources. For example, solar panels would be useful in a country near the equator, but this may be a huge investment for a country that has other budget priorities.
Taking it further
Making links with current climate policy can be very interesting for students. Many students now are aware of the climate emergency and struggle to understand why renewables are not used exclusively now that scientists know the impact of burning fossil fuels in particular. Having a discussion with students about why some countries may not agree to cutting emissions targets can be very useful.

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that TBAT = to be able to

NOTE: All TKT statements can be found in Appendix 5 of this document

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior Knowledge Review

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT state the different stores of energy and the pathways by which energy can be transferred	State the stores of energy State the pathways by which energy can be transferred Identify the store of energy or pathway in a given scenario
TBAT define internal energy and describe the effect of heating on internal energy	Define internal energy Describe the effect of heating on internal energy Interpret a heating/cooling curve
TBAT calculate specific heat capacity and specific latent heat	Use the specific heat capacity equation Use the specific latent heat equation Define specific heat capacity Define specific latent heat
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2 and 3: Taking it Further RPA Investigating Insulation

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT measure temperature	State the unit of temperature State the resolution of a thermometer Measure temperature accurately
TBAT compare the effectiveness of different materials as insulators	Define an insulator Define thermal conductivity Identify materials that have high and low thermal conductivity Compare the effectiveness of materials as insulators from given data Explain what the temperature change shows about the thermal conductivity of a material
TBAT explain why different materials are suited for their use	Explain why and how insulators are used in homes Describe and explain the effect insulators have on the rate of cooling Explain why a material is used as an insulator
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 4: Kinetic Energy

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT use the equation $E_k = ½mv^2$	State the equation to calculate kinetic energy Identify the units and symbols for each quantity Calculate kinetic energy, mass or speed Explain the difference between speed and velocity
TBAT compare the kinetic energy stores of objects with the same mass and different speeds or same speeds and different masses	Compare the kinetic energy stores of two objects with the same mass and different speeds Compare the kinetic energy stores of two objects with the same speed and different masses
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 5: Elastic Potential Energy

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT identify objects that have a store of elastic potential energy	Identify whether an object has a store of elastic potential energy or not Explain the difference between elastic and inelastic deformation Explain the difference between extension and compression
TBAT Apply the equation $E_e = ½ke^2$	Identify the units and symbols for each quantity in the equation Calculate elastic potential energy, spring constant or extension Describe how to measure the extension or compression of a spring/object Calculate extension/compression from given values or diagrams
TBAT Describe the energy transfers that take place when a spring is stretched	Identify the energy stores that are filled and emptied as an object is stretched Describe the relationship between the work done in stretching a spring and the elastic potential energy stored in a stretched spring
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 6: Gravitational Potential Energy

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT explain the difference between mass and weight	State the equation to calculate weight Explain the difference between mass and weight State the units for mass and weight Compare mass and weight on the Earth and the Moon
TBAT recall and apply the equation E_p = mgh	Identify the units and symbols for each quantity in the equation State the value of gravitational field strength on Earth Calculate gravitational potential energy, mass, or height
TBAT compare the gravitational potential energy stores of different objects	State the gravitational potential energy store of an object on the ground Compare the gravitational potential energy stores of objects at different heights
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 7: Conservation of Energy

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT state the law of conservation of energy	State the law of conservation of energy If the total energy store of a system is X before an energy transfer, state the total energy store after
TBAT describe energy transfers taking place in different scenarios	State the stores of energy State the pathways by which energy can be transferred Identify the energy store that is filled when a kettle is boiled Identify the energy store that is filled when a ball is thrown in the air
TBAT Use calculations to show how energy is conserved	State the equation to calculate gravitational potential energy State the equation to calculate kinetic energy Calculate the maximum speed a rollercoaster of mass A can reach at the bottom of a slope if it starts at B m high. Calculate the maximum height a projectile of mass A can reach if it is shot straight upwards from a spring with spring constant B and extension C
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 8: Power

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT define power	Define power State the units of power Explain what 1 W is equal to
TBAT calculate power	State the equation that links power, energy and time Define work done Calculate power using energy transferred or work done and time
TBAT compare the power in different energy transfers	Explain what it means for an appliance to have a power rating of 750 W Compare the time it will take for two appliances with different power ratings to transfer the same amount of energy
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 9: Efficiency

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT identify useful and wasted energy in energy transfers	State the law of conservation of energy Explain what it means for energy to be dissipated Identify useful energy stores for different appliances/scenarios Identify wasted energy stores in different appliances/scenarios
TBAT calculate efficiency of energy transfers and power	Define efficiency Calculate efficiency given useful and wasted energy values Calculate useful energy store values given efficiency and total energy input
TBAT describe methods to increase efficiency of energy transfers	Describe how to increase efficiency in a mechanical system Describe how to increase efficiency of heating in a home by reducing thermal transfer
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 10: Non-renewable Energy Resources

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT identify renewable and non-renewable resources	State examples of renewable resources State examples of non-renewable resources Define a renewable resource Define a non-renewable resource Identify whether nuclear energy is renewable or non-renewable Give examples of activities that humans require energy for
TBAT describe the environmental impacts of using fossil fuels	State some pollutants produced by burning fossil fuels Describe the environmental consequence associated with carbon dioxide emissions Describe the environmental consequence associated with sulfur dioxide emissions
TBAT describe the advantages and disadvantages of non-renewable resources	Describe the advantages of using fossil fuels Describe the disadvantages of using fossil fuels Describe the advantages of using nuclear energy Describe the disadvantages of using nuclear energy Explain why some countries still use non-renewable resources
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 11: Renewable Energy Resources

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT identify different renewable energy resources	State examples of renewable resources Briefly outline how each energy source is used
TBAT describe the advantages and disadvantages of different renewable energy resources	Describe the advantages of solar/wind/tidal/geothermal/hydroelectric energy Describe the disadvantages of solar/wind/tidal/geothermal/hydroelectric energy
TBAT explain why non-renewable resources are still being used	Interpret data from graphs and/or tables Evaluate the use of renewables and non-renewables in different circumstances Explain why governments still use non-renewable resources
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 12: Feedback lesson

Intended outcome	Example questions
Edit based upon your class's performance in the Mastery Quiz	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

Key learning from this unit is the different energy stores and pathways by which energy is transferred. Later in Year 10, students will look more at nuclear energy in more detail when they cover radioactivity. This is then built upon in much greater detail at A-Level, where students look at different particles and their relative stabilities. Also at A-Level, students will look more deeply at waves as a pathway by which energy is transferred.

Students will also build on their knowledge of forces and energy at A-Level, with topics including the equations of motion, projectile motion, work done and power, as well as conservation of energy.

A-Level Physics also includes a deeper study of the properties of materials, reviewing elastic potential energy, and introducing elastic strain energy and tensile strain and stress.

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS5?
What content from this unit is fundamental to student understanding at KS5?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Conservation	When something stays the same. *The Law of **Conservation** of energy states that the total energy in a closed system remains constant.*
Degrees Celsius	The unit used for temperature. *The melting point of water is 0 **degrees Celsius** (°C).*
Dissipated	When something (such as energy) spreads out in different directions. *When an appliance is switched on, energy is **dissipated** to the surroundings by heating.*
Efficiency	A measure of the proportion of energy that is transferred usefully. *An appliance with a higher **efficiency** transfers more useful energy and less energy is wasted.*
Elastic potential energy	The store of energy in objects that have been stretched or compressed. *When an elastic band is pulled tight, it has a store of **elastic potential energy.***
Energy	The ability to do work. *There are different stores of **energy**, such as potential energy and kinetic energy.*
Extension	The difference between the original and new length. *The **extension** of a spring is how much it has been stretched by.*
Friction	The resistive contact force when two surfaces rub together. *When an object is moved, work has to be done to overcome **friction**.*
Gravitational field strength	A measure of how strong the force of gravity is. *The **gravitational field strength** on Earth is 10 N/kg.*
Gravitational potential energy	The store of energy an object has because of its position in a gravitational field. *Any object that is lifted above the ground has **gravitational potential energy.***

Insulation	Any material that reduces thermal transfer. ***Insulation*** *is added to homes to reduce thermal transfer to the surroundings.*
Internal energy	The total kinetic energy and potential energy of all the particles in a system. *When a substance is heated, its* ***internal energy*** *increases.*
Kinetic energy	A store of energy that any object or particle has when moving. *Particles in a gas have the greatest store of* ***kinetic energy****.*
Mass	The amount of matter in an object. ***Mass*** *is measured in kilograms (kg).*
Non-renewable	A resource that cannot be replenished as it is used. *Fossil fuels are* ***non-renewable*** *resources.*
Potential energy	A store of energy related to the position of objects or particles. *Particles in a gas have the greatest store of* ***potential energy****.*
Power	The rate at which energy is transferred or work is done. *An appliance with a higher* ***power*** *transfers more energy per second.*
Radiation	Thermal transfer as a wave, by infrared radiation. ***Radiation*** *is the method of thermal transfer that does not require particles.*
Renewable	A resource that can be replenished as it is used. *Wind is a* ***renewable*** *resource.*
Specific Heat Capacity	The energy required to heat 1 kg of a material by 1 °C. *The greater the* ***specific heat capacity*** *of a material, the more energy it will require to increase its temperature.*
Specific Latent Heat	The energy required to change the state of 1 kg of a material (with no change in temperature). *Each different material has a different* ***specific latent heat****.*
Specific Latent Heat of Fusion	The energy required to change the state of 1 kg of a material from a solid to a liquid. ***Specific latent heat of fusion*** *is used when calculating how much energy is required to turn 1 kg of ice into water.*

Specific Latent Heat of Vaporisation	The energy required to change the state of 1 kg of a material from a solid to a liquid. ***Specific latent heat of vaporisation*** *is used when calculating how much energy is required to turn 1 kg of water into steam.*
Spring constant	A measure of the stiffness of a spring, how much force is required to produce a given extension. *A* ***spring constant*** *of 30 N/m means that a force of 30 N needs to be applied to stretch a spring by 1 metre.*
System	A body, object or group of bodies. *When looking at the internal energy of a* ***system****, you must consider the kinetic and potential energy of all of the particles in it.*
Temperature	Related to the average kinetic energy of particles in a system. ***Temperature*** *is measured in °C.*
Thermal	Relating to heat. *The three methods of* ***thermal*** *transfer are conduction, convection and radiation.*
Thermal conductor	A material that allows heat to move through it quickly. *Metals are good* ***thermal conductors****.*
Thermal insulator	A material that does not allow heat to move through it quickly. *Non-metals such as wood and plastic are* ***thermal insulators****.*
Velocity	The speed of an object in a given direction. *When an object's* ***velocity*** *increases, it has more kinetic energy.*
Watt	The unit of power. *An appliance has a power rating of 250* ***Watts****, which means that it transfers 250 J of energy every second.*
Weight	The effect of gravity on an object's mass. *An object has a mass of 60 kg and a* ***weight*** *of 600 N.*
Work done	Energy transfer when a force moves an object through a distance. *When a crane lifts a box in the air,* ***work is done****.*

Appendices

Appendix 1: Mark scheme for pre-unit quiz

P4.2 Pre-Unit Quiz: Energy Conservation Mark Scheme

Qu	Answer	Marks	Supporting information for fix-it tasks
1	C	1	Answering A or B shows that pupils are not secure with the concept of conservation of energy. *Task: State the law of conservation of energy and describe what a Sankey diagram can be used for. It may be useful to use further examples of Sankey diagrams to show pupils the energy values in different stores before and after a transfer.*
2	C	1	Answering A or B shows that pupils have not understood the difference between a store of energy and a method/pathway of energy transfer. *Task: State the different stores of energy and describe the ways (pathways) by which energy can be transferred.*
3	C	1	Answering A or B shows that pupils are not secure in the properties of the different states of matter. *Task: Describe the movement of particles in the different states of matter and explain this movement in terms of forces of attraction.*
4	C	1	Answering A or B suggests a gap in knowledge about the methods of thermal transfer. *To fix it, reteach a summary of the different methods and get students to summarise each with a diagram.*
5	B	1	Answering A suggests a misconception that all solids are good thermal conductors. *To fix it, present students with different solid materials and explain the difference between metals and non-metals in terms of free electrons (a diagram of metallic bonding is not expected at this stage).* Answering C suggests a confusion around the free electrons in a metal being able to move through the metal and the metal itself being able to flow. *To fix it, ask students describe the movement of particles in a solid.*
6	A	1	Answering B suggests a misconception that cold is transferred, linked to the idea that cold air will get in if you leave windows/doors open.

			To fix it, reteach what happens when there is a temperature difference and explain that 'coldness' is just a lower energy state. Answering C suggests that students have understood the direction of thermal transfer but not understood that energy is transferred, rather than 'heat'. *To fix it, reteach what happens when there is a temperature difference.*
7	B	1	Answering A suggests a misconception that particles only have a store of energy when they are moving. *To fix it, reteach the definition of internal energy and how it changes throughout a heating curve.* Answering C suggests a misconception that internal energy only refers to changes of state. *To fix it, reteach the definition of internal energy and how it changes throughout a heating curve.*
8	B	1	Answering A suggests a misconception that potential energy also increases when temperature increases. *To fix it, give students a copy of this graph to annotate and explain what is happening to the particles at each stage.* Answering C suggests a gap in knowledge that the temperature is related to the kinetic energy of the particles. *To fix it, give students a copy of this graph to annotate and explain what is happening to the particles at each stage.*
9	A	1	Answering B suggests a confusion around the definition of specific heat capacity and the measurements that are taken when calculating it. *To fix it, review the definition and show how the definition fits into the equation, using the values for the specific heat capacity of water.* Answering C suggests a confusion between specific heat capacity and specific latent heat. *To fix it, reteach the definitions and ask students to describe when each could be calculated.*
10	C	1	Answering A suggests a confusion between specific heat capacity and specific latent heat. *To fix it, review the definitions of each and describe when each would be used in a calculation.* Answering B suggests a gap in knowledge around the difference between heat of fusion and vaporisation. *To fix it, give students examples of different changes of state and ask them to identify whether they represent fusion or vaporisation.*

Appendix 2: Mark scheme for mastery quiz

P4.2 Mastery Quiz: Energy Conservation
Mark Scheme
Section A

Qu	Answer	Marks	Supporting information for fix-it tasks
1	C	1	Answering A or B suggests a misconception that the ways energy can be transferred between stores (i.e. heating and when current flows) are types of stores. *To fix it, give students a jumbled list of energy stores and types of transfer (heating, work done by current, work done by force) and ask them to sort them into 'stores' or 'ways energy is transferred).*
2	B	1	Answering A suggests a misconception that water waves are unreliable. However, there are always waves so this makes wave energy reliable. *To fix it, ask students to compare the reliability of water waves and wind as energy sources.* Answering C suggests a misconception that water waves are non-renewable. *To fix it, ask students to write out the definition for 'renewable energy source' and they should then explain why water waves are a type of renewable energy source.*
3	C	1	Answering A suggests a misconception that nuclear energy is a fossil fuel. *To fix it, ask students to list three types of fossil fuels.* Answering B suggests a confusion of an example of a fossil fuel and an effect of fossil fuels. *To fix it, ask students to list three types of fossil fuels and two effects fossil fuels have on the environment.*
4	A	1	Answering B suggests the misconception that efficiency has the units of watts. *To fix it, reteach that efficiency can be a percentage or a decimal and if a device was completely efficient it would have an efficiency of 1 or 100 %. Ask students to state what watts (W) is the unit for.* Answering C or D shows the misconception that efficiency is calculated by total power input/useful power output. *To fix it, reteach the equation for calculating efficiency and model some worked examples. Then ask student to write out the equation and then they should do many practice questions. Stretch – include rearranging this equation.*
5	C	1	Answering A shows that the values have been incorrectly substituted into the equation. *To fix it, recap or introduce a technique for labelling/highlighting relevant values from the information in the question and then model how this is substituted into the equation.* Answering B shows the error of squaring 0.5 x m x v, rather than just squaring v. *To fix it, recap the equation and include that it is only speed that is squared. Then give students many practice questions.*

6	A	1	Answering B suggests a misconception that the lower the spring constant, the greater the force required to extend it. *To fix it, recap force = spring constant × extension, then use worked examples to show the relationship between force, spring constant and extension.* Answering C suggests a confusion between the equations: elastic potential energy = 0.5 × spring constant × extension^2 and force = spring constant × extension. *To fix it recap how the spring constant can be calculated practically and that you only need the force and the extension to calculate the spring constant.*
7	C	1	Answering A is the misconception that length = extension. Answering B is the confusion that the extension also includes the force that may have been applied. *To fix it, review the meaning of extension and practice how to determine it from data.*
8	B	1	Answering A or C suggests a gap in knowledge about the definition of dissipated energy. *To fix it, ask students to write a sentence that includes these key words: dissipated, energy, waste(d), transferred.*
9	B		Answering A shows that students have confused the methods of reducing unwanted energy transfers. Adding an insulator would reduce cooling, but not reduce friction. Answering C shows that students have assumed that heating an object automatically makes it work faster. *To fix it, review how a lubricant would affect efficiency of a machine.*
10	C	1	Answering A or B suggests a gap in knowledge when recalling the equation that links power and work done. *To fix it, reteach this equation, including the symbols and units. Then ask students to write down the equation without looking at their notes.*
11	B	1	Answering A suggests a misconception that renewable energy resources contribute to global warming. *To fix it, recap some examples of non-renewable vs. renewable energy resources to show that renewable resources do not create pollution or greenhouse gases that would contribute to global warming. Then ask students to compare renewable and non-renewable energy resources.* Answering C suggests a misconception that renewable energy resources are always reliable. *To fix it, ask students to explain why wind farms alone cannot always supply enough electricity to a city.*
12	A	1	Answering B suggests the common misconception that 'power' is only defined as a force needed to move an object – which is derived from the colloquial use of the word 'power'. Answering C suggests a gap in knowledge for the definition of power. *To fix it, recap the definition of power (the rate at which*

			energy is transferred or the rate at which work is done) then ask students to write their own definition, including the two equations.
13	B	1	Answering A or B suggests a misconception that just because an object is curved, that it has a store of elastic potential energy. *To fix it, recap that objects that have been squashed have a store of elastic potential energy then ask students to write out the definition using this as an example.*
14	A	1	Answering B shows that the student has not calculate change in temperature since only the highest temperature of 100 ºC has been used. *To fix it, recap that the 'triangle' symbol represents 'delta' which means a change in. Then ask students explain what Δt means.* Answering C shows that the student has confused the change in thermal energy and SHC, so the values in the equation have been substituted incorrectly. *To fix it, ask students to write the definition, symbol and units for SHC.*
15a (Physics only)	B	1	Answering A shows students have just listed the different materials rather than identifying the variable, which is a very common mistake. Answering C shows students are still confusing the independent and dependent variables. *To fix it, review the meaning of each type of variable and give students further practice identifying them from investigative questions.*
15b (Physics only)	C	1	Answering A shows students have confused conductors and insulators. Answering B shows students have misinterpreted the effect insulators have on the rate of cooling. *To fix it, review the meaning of insulators and give students model data to analyse.*

Section B

<table>
<tr><th>Qu</th><th>Model answer</th><th>Supporting information
Suggestions for fix-it tasks</th></tr>
<tr><td>1</td><td>The total energy store of a system remains constant

Or

Energy cannot be created or destroyed</td><td>1</td></tr>
<tr><td>1</td><td>Any two from:
• transport
• electricity generation for public services
• electricity generation for factories
• electricity generation for farms
• electricity generation for use in the home</td><td>2

A common error is to confuse the terms ‘use’ and ‘source’.</td></tr>
<tr><td>3</td><td><u>Chemical</u> energy store (of the person) is decreasing/being emptied

<u>Kinetic</u> energy store is increasing/being filled (as the person gets faster)

(Energy is also transferred by heating to the) <u>thermal</u> store of the surroundings and the person</td><td>1

1

1

A common area of confusion in this style of question about energy is the incorrect use of vocabulary (e.g. energy, transfer, store, source, etc).</td></tr>
<tr><td>4</td><td>GPE = mass x gravitational field strength x height

75 cm = 0.75 m

GPE = 25 x 10 x 0.75

GPE = 187.5 J</td><td>1 (equation)

1 (conversion)

1 (substitution/calculation)

1 (answer with units)</td></tr>
<tr><td>5</td><td>This question is level assessed.

<table><tr><td>Level 0</td><td>0 marks</td></tr><tr><td>Level 1</td><td>1-2 marks</td></tr><tr><td>Level 2</td><td>3-4 marks</td></tr><tr><td>Level 3</td><td>5-6 marks</td></tr></table></td><td>This question should be marked holistically. Typically, a level 0 answer will contain no (or possibly one) relevant point.

A level 1 answer may contain advantages or disadvantages of both resources or advantages and disadvantages of one resource.</td></tr>
</table>

<table>
<tr>
<td></td>
<td>Indicative content:

Hydroelectric
Advantages:
- Renewable
- No emissions/greenhouse gases
- Reliable, can be used to meet demand

Disadvantages:
- Expensive to build
- Can damage habitats

Nuclear
Advantages:
- Reliable, can be used to meet demand
- Releases large amounts of energy

Disadvantages:
- Non-renewable, cannot be replenished
- Accidents are very dangerous
- Expensive to store and dispose of radioactive material</td>
<td>A level 2 answer should contain advantages and disadvantages of both resources but may not be fully explained and may be missing a justified conclusion.

A level 3 answer would contain clear advantages and disadvantages of both resources and a well justified conclusion.</td>
</tr>
<tr>
<td>6</td>
<td>(Moving parts cause) friction

(so) energy is wasted as thermal energy/heating the engine/surroundings

Lubrication reduces friction

(increases efficiency because) a lower proportion of energy is wasted/dissipated</td>
<td>1

1

1

1</td>
</tr>
<tr>
<td>7</td>
<td>This question is level assessed.

<table><tr><td>Level 0</td><td>0 marks</td></tr><tr><td>Level 1</td><td>1-2 marks</td></tr><tr><td>Level 2</td><td>3-4 marks</td></tr><tr><td>Level 3</td><td>5-6 marks</td></tr></table>
Indicative content:
Key steps are in bold.</td>
<td>This question should be marked holistically. Typically, a level 0 answer will contain no (or possibly one) relevant point.

A level 1 answer will contain few relevant points but would not allow a valid conclusion to be drawn.

A level 2 answer would not allow a valid conclusion to be determined but may if small changes were made to the method. Level 2 answers may be missing some key</td>
</tr>
</table>

	• **Using equal volumes of water in test tubes** • **Wrapping each test tube in (a given number of layers of) material** • Add hot water to each test tube • **Record temperature of (water in) each test tube at the start** • Leave test tubes for given time period • **Record temperature of (water in) each test tube after given time period** • Calculate the temperature change for the test tube with each material • Test tube/material with smallest temperature change is the most effective insulator	steps. A level 3 answer would allow a valid conclusion to be determined and must mention all the key steps. To achieve the highest level 3 mark, the answer should contain additional details (steps not in bold).

Appendix 3: Core knowledge statements

Energy Stores

- The different energy stores are: kinetic, elastic potential, chemical potential, gravitational potential and thermal
- Energy can be transferred between stores through: heating, mechanically, by waves or by radiation
- A system is an object or group of objects.
- Energy changes can be calculated when energy is transferred by heating, work done by forces or work done when a current flows.
- The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:
- Change in thermal energy = mass × specific heat capacity × temperature change
- $\Delta E = mc\Delta\theta$, with change in thermal energy, ΔE, in Joules, J; mass, m, in kilograms, kg; specific heat capacity, c, in Joules per kilogram per degree Celsius, J/kg °C; temperature change, $\Delta\theta$, in degrees Celsius, °C
- The specific heat capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.
- The kinetic energy of a moving object can be calculated using the equation:
kinetic energy = 0.5 × mass × speed^2
- $E_k = \frac{1}{2}mv^2$, with kinetic energy, E_k, in Joules, J; mass, m, in kilograms, kg; speed, v, in metres per second, m/s
- The amount of elastic potential energy stored in a stretched spring can be calculated using the equation: elastic potential energy = 0.5 × spring constant × extension^2
- $E_e = \frac{1}{2}ke^2$
- with elastic potential energy, E_e, in Joules, J; spring constant, k, in Newtons per metre, N/m; extension, e, in metres, m
- The extension of a spring is the difference between its original length and its new stretched length
- The amount of gravitational potential energy gained by an object raised above ground level can be calculated using the equation:
- g.p.e. = mass × gravitational field strength × height
- $E_p = mgh$

- with gravitational potential energy, Ep, in Joules, J; mass, m, in kilograms, kg; gravitational field strength, g, in Newtons per kilogram, N/kg; height, h, in metres, m
- The gravitational field strength on Earth is 10 N/kg
- The total energy store of a system remains constant. This is the Law of Conservation of Energy.

Efficiency and Power

- Power is defined as the rate at which energy is transferred or the rate at which work is done.
- Power = energy transferred/time
- $P = \frac{E}{t}$
- Power = work done/time
- $P = \frac{W}{t}$
- Power, P, in Watts, W; Energy transferred, E, in Joules, J; time, t, in seconds, s; work done, W, in Joules, J
- An energy transfer of 1 joule per second is equal to a power of 1watt.
- An appliance with a higher power rating will transfer energy faster than an appliance with a lower power rating
- Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
- In all system changes, energy is dissipated, meaning that it is wasted rather than being stored in useful ways
- Efficiency is a measure of how much useful energy is transferred
- Efficiency can be calculated using the equation:
- efficiency = useful energy output/total energy input
- *The efficiency of different energy transfers can be increased in different ways.*
- Some unwanted energy transfers can be reduced by using lubrication or thermal insulation
- The rate of cooling of a building or object is affected by the thickness and thermal conductivity of its walls
- Efficiency may also be calculated using the equation:
- efficiency = useful power output/total power input
- Efficiency values can be decimals or percentages.

Energy Resources

- The main energy resources available for use on Earth include: fossil fuels (coal, oil and gas), nuclear fuel, bio-fuel, wind, hydroelectricity, geothermal, the tides, the Sun and water waves.
- The uses of energy resources include: transport (buses, trains etc), electricity generation for public services (machinery and buildings), factories and farms and for homes (heating, cooking and other appliances).
- The use of non-renewable resources contributes to global warming and other environmental impacts such as acid rain.
- Nuclear energy is a non-renewable resource.
- A renewable energy resource is one that is being (or can be) replenished as it is used.
- Some renewable energy resources may be unreliable in different conditions or at times of peak demand.
- There are different energy requirements at different times of year and times of day.
- More renewable resources are being invested in but there are political and economic reasons for countries to continue using fossil fuels.
- Developed countries are increasing their use of nuclear power stations.

Practical Skills

49. Safe use of appropriate apparatus to measure energy changes/ transfers and associated values such as work done

Disciplinary Knowledge

7. a. Describe and explain specified examples of the technological applications of science.
b. Describe and evaluate, with the help of data, methods that can be used to tackle problems caused by human impacts on the environment.
56. Construct and interpret bar charts, pie charts and histograms
66. Change the subject of an equation
84. a. Use percentages
b. calculate percentage increase and decrease.