4.1 · AQA GCSE Physics

Energy

activity booklet

Energy stores and transfers · work · power · efficiency · national and global resources

- 4.1.1.1 Energy stores and systems
- 4.1.1.2 Changes in energy — kinetic, elastic and gravitational
- 4.1.1.3 Energy changes in systems — specific heat capacity
- 4.1.2 Conservation and dissipation of energy
- 4.1.1.4 – 4.1.1.5 Work done and power
- 4.1.3 National and global energy resources
- Mixed practice

Name: _____

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How to use this booklet

- Work through in order — each section builds on the one before.
- Read the worked example, then do the Your turn question underneath it.
- Answer every Support and Core question. Try the Stretch ones too.
- Write on the dotted lines, and show your working in full.
- Check your work in the separate Answer Booklet, then fix anything wrong in a different colour.

Look out for these boxes:

Equation box
A key equation, with its units.

Worked example
A calculation done step by step. Then try the **Your turn** underneath.

Top tip
An examiner's tip or a common mistake to avoid.

In real life
Where the physics shows up in the world around you.

Challenge
Harder, beyond-GCSE problems to stretch you.

Question labels

Support — scaffolded questions — start here if you are stuck

Core — the standard you need for the exam

Stretch — harder questions to push you further

Higher Tier only — Foundation students can skip these

Separate Physics only — not needed for Combined Science: Trilogy

Remember: in every calculation use **FIFA** — Formula, Insert, Fine tune, Answer.

Retrieval starter · Five minutes, closed book, from earlier topics

1. Name the unit of energy.

2. State the equation linking speed, distance and time.

3. Give two energy stores.

4. What is a renewable resource?

5. Convert 2.5 kJ into joules.

Knowledge organiser · Everything in 4.1 on one page

Energy stores
- kinetic — a moving object
- gravitational — an object raised up
- elastic — a stretched or squashed object
- thermal — a hot object
- chemical — fuel, food, a battery
- nuclear, magnetic, electrostatic

Ways energy is transferred
- mechanically — by a force doing work
- electrically — by a current
- by heating
- by radiation — light and sound

Conservation
- energy cannot be created or destroyed
- it can be transferred, stored or dissipated
- a closed system has zero net change in total energy
- dissipated energy spreads out and is no longer useful

Reducing waste
- lubrication reduces friction
- streamlining reduces air resistance
- insulation and thicker walls reduce thermal transfer
- a lower thermal conductivity means slower cooling

Energy resources
- non-renewable: coal, oil, gas, nuclear
- renewable: solar, wind, hydro, tidal, wave, geothermal, bio-fuel
- uses: electricity, transport, heating
- renewable is not the same as reliable

Exam command words
- Calculate — show your working, give a unit
- Explain — give a reason, not just a description
- Describe — say what happens, in order
- Evaluate — both sides, then a conclusion

Equation bank · Every equation you need in this topic

Use it for	Equation	Units
Kinetic energy	$E_k = \frac{1}{2} m v^2$	J, kg, m/s
Elastic potential energy	$E_e = \frac{1}{2} k e^2$	J, N/m, m
Gravitational potential energy	$E_p = m g h$	J, kg, N/kg, m
Change in thermal energy	$\Delta E = m c \Delta\theta$	J, kg, J/kg °C, °C
Work done	$W = F s$	J, N, m
Power	$P = E \div t$ or $P = W \div t$	W, J, s
Efficiency	efficiency = useful output ÷ total input	no unit, or × 100 for %

Every calculation: use FIFA · Use FIFA — it is how the marks are awarded

F	**Formula**	Write the equation you need.
I	**Insert**	Put the numbers in, with units converted.
F	**Fine tune**	Rearrange, or work through the arithmetic.
A	**Answer**	State the answer with its unit.

Examiners give marks for the equation and the substitution even when the final number is wrong. Always write all four lines.

1 Energy stores and systems

4.1.1.1

Key words · Use these words in your answers — they earn the marks

Key word	What it means
System	An object, or a group of objects, that we are thinking about.
Energy store	Where energy is held: kinetic, thermal, chemical, gravitational, elastic and so on.
Transfer	Energy moving between stores — mechanically, electrically, by heating or by radiation.
Dissipated	Energy spread out to the surroundings so it is no longer useful.

Match up · Energy stores in action

Draw a line from each situation to the store that is full. Write the letter in the middle column.

Item	Letter	Options
A stretched catapult		**A** Kinetic store
A moving tennis ball		**B** Thermal store
A book on a high shelf		**C** Chemical store
A cup of hot tea		**D** Elastic potential store
A charged battery		**E** Gravitational potential store

1 Name the main energy store that is filling when a ball rolls down a hill. Support

2 A kettle heats water. Describe the energy transfer, naming the store that empties and the store that fills. Core

3 Explain what is meant by a closed system. Core

4 A diver stands on a high board, jumps, and enters the water. Describe the energy transfers from standing on the board to coming to rest in the water. Stretch

2 Changes in energy — kinetic, elastic and gravitational

4.1.1.2

"Energy is never used up. It only ever moves — and spreads out."

Top tip from the examiner

Keep to FIFA even when the question looks easy — the equation and the substitution each earn a mark, so you can score 2 out of 3 with the wrong final number. The most common slip in this topic is forgetting to **square the speed** in $E_k = ½ m v^2$. Square first, then multiply. The second most common is leaving the answer in grams or centimetres — convert to kg and m before you substitute.

Worked example · Kinetic energy

A car of mass 1200 kg travels at 15 m/s. Calculate its kinetic energy.

F	Formula	$E_k = ½ m v^2$
I	Insert	$E_k = 0.5 \times 1200 \times 15^2$
F	Fine tune	Square the speed first: $15^2 = 225$, then $0.5 \times 1200 \times 225$
A	Answer	**135 000 J, or 135 kJ**

Your turn · Kinetic energy

A motorbike of mass 250 kg travels at 20 m/s. Calculate its kinetic energy.

F	Formula	Write the equation you need.
I	Insert	Put the numbers in.
F	Fine tune	Square the speed, then multiply.
A	Answer	

Worked example · Gravitational potential energy

A 3.0 kg bag is lifted 1.8 m onto a shelf. g = 9.8 N/kg. Calculate the gain in gravitational potential energy.

F	Formula	$E_p = m\ g\ h$
I	Insert	$E_p = 3.0 \times 9.8 \times 1.8$
F	Fine tune	$3.0 \times 9.8 = 29.4$, then $29.4 \times 1.8 = 52.92$
A	Answer	**53 J (2 significant figures)**

Your turn · Elastic potential energy

A spring of spring constant 40 N/m is extended by 0.25 m. Calculate the energy stored.

F	Formula	Write the equation you need.
I	Insert	Put the numbers in.
F	Fine tune	Square the extension, then multiply.
A	Answer	

In real life · Why speed matters more than mass

Kinetic energy depends on the square of the speed, so doubling your speed does not double the energy — it quadruples it. That is why a car at 60 mph needs roughly four times the braking distance of the same car at 30 mph, and why speed limits near schools make such a difference.

Spot the mistake · Kinetic energy calculation

A pupil has written:

A pupil calculates the kinetic energy of a 60 kg runner moving at 8 m/s:
E_k = ½ × 60 × 8 = 240 J

What has gone wrong, and what is the correct answer?

5 Write down the equation linking kinetic energy, mass and speed. Support

6 Calculate the kinetic energy of a 0.50 kg ball moving at 4.0 m/s. Support 2 marks

Working

7 A 70 kg cyclist climbs a hill 24 m high. g = 9.8 N/kg. Calculate the gain in gravitational potential energy. Core 3 marks

Working

8 A spring stores 0.80 J of energy when extended by 0.20 m. Calculate the spring constant. Core

9 A 0.20 kg ball is dropped from 1.8 m and rebounds to 1.2 m. g = 9.8 N/kg. Calculate the energy dissipated in the bounce. Stretch

10 Show that a 1500 kg car travelling at 30 m/s has about four times the kinetic energy of the same car at 15 m/s. Stretch

3 Energy changes in systems — specific heat capacity

4.1.1.3

The specific heat capacity of a substance is the amount of energy needed to raise the temperature of one kilogram of the substance by one degree Celsius.

Worked example · Specific heat capacity

How much energy is needed to raise the temperature of 2.0 kg of water by 30 °C? The specific heat capacity of water is 4200 J/kg °C.

F	Formula	$\Delta E = m\ c\ \Delta\theta$
I	Insert	$\Delta E = 2.0 \times 4200 \times 30$
F	Fine tune	$2.0 \times 4200 = 8400$, then $8400 \times 30 = 252\ 000$
A	Answer	**252 000 J, or 252 kJ**

Your turn · Rearranging for temperature change

A 0.50 kg aluminium block is given 9000 J of energy. The specific heat capacity of aluminium is 900 J/kg °C. Calculate the temperature rise.

F Formula — Write the equation you need.

I Insert — Put the numbers in.

F Fine tune — Rearrange: divide both sides by (0.50 × 900).

A Answer

In real life · Why the sea is slow to warm up

Water has one of the highest specific heat capacities of any everyday substance: 4200 J/kg °C. That is why coastal towns have milder winters than places inland, why a hot water bottle stays warm for hours, and why your body — about 60% water — can cope with a hot day without your temperature soaring.

Required practical 1

practical

Aim: Investigating the specific heat capacity of a material

Method

1 Measure the mass of a metal block using a balance, and record it in kilograms.
2 Place an immersion heater in the large hole and a thermometer in the small hole, adding a drop of oil for good thermal contact.
3 Wrap the block in insulation and record the starting temperature.
4 Switch on the heater and a stopwatch at the same time, and record the energy supplied using a joulemeter.
5 Record the temperature every minute for ten minutes, then plot temperature against energy supplied.

Why is the block insulated?

Why is oil put in the thermometer hole?

How do you find the specific heat capacity from the graph?

11 Write down the equation linking change in thermal energy, mass, specific heat capacity and temperature change. Support

12 Calculate the energy needed to heat 0.30 kg of water from 20 °C to 100 °C. c = 4200 J/kg °C. Core 3 marks

Working

13 A 2.0 kg copper block is heated with 15 400 J and rises by 20 °C. Calculate the specific heat capacity of copper. Core

14 Water has a much higher specific heat capacity than copper. Explain what this means for a hot water bottle and for a saucepan. Stretch

4 Conservation and dissipation of energy

4.1.2

Top tip from the examiner

When a question says ‘explain’, naming the store is not enough. Say which store empties, which store fills, and **how** the energy is transferred — mechanically, electrically, by heating or by radiation. Three ideas, three marks.

Fill the gaps · Wasted energy

dissipated **destroyed** **friction** **thermal** **insulation** **kinetic** **created**

Energy can be transferred usefully, stored or _____, but it cannot be created or _____. Whenever there are energy transfers, some energy is _____ to the surroundings, so it is no longer useful. In a mechanical system this is usually caused by _____ between moving parts, which fills the _____ store of the surroundings. Lubrication reduces this, and _____ reduces unwanted transfer through the walls of a house.

True or false? · Conservation of energy

Statement	True or false?	Correction (if false)
Energy can be created in a chemical reaction.		
Dissipated energy has disappeared.		
Lubricating a machine reduces wasted energy.		
A thicker wall always has a lower thermal conductivity.		
Efficiency can be greater than 1.		

Required practical 2

Separate Physics only | practical

Aim: Investigating how effective different materials are as thermal insulators

Method

1 Place a small beaker inside a larger beaker and fill the gap between them with one insulating material, such as cotton wool, bubble wrap or shredded newspaper.

2 Pour 80 cm^3 of hot water from a kettle into the small beaker and cover it with a lid made of the same material, with a hole for the thermometer.

3 Record the starting temperature, start a stopwatch, and record the temperature every three minutes for twenty minutes.

4 Repeat with each of the other materials, keeping the volume and the starting temperature of the water the same each time.

5 To investigate thickness, repeat with one material using different numbers of layers wrapped around the beaker.

Name the independent variable, the dependent variable and one control variable.

Why must the water start at the same temperature each time?

How would you use your results to decide which material is the best insulator?

Predict how adding more layers of the same material affects the rate of cooling, and explain why.

Worked example · Efficiency

A motor transfers 1200 J of energy. 900 J is transferred usefully. Calculate the efficiency as a percentage.

F	Formula	efficiency = useful energy output ÷ total energy input
I	Insert	efficiency = 900 ÷ 1200
F	Fine tune	900 ÷ 1200 = 0.75, then × 100 for a percentage
A	Answer	**75%**

Your turn · Efficiency

A lamp is supplied with 60 J each second and transfers 48 J each second to the thermal store of the surroundings. Calculate its efficiency.

F	Formula	Write the equation you need.
I	Insert	Put the numbers in — work out the useful output first.
F	Fine tune	Work it through, then convert to a percentage.
A	Answer	

15 State what happens to energy that is dissipated. Support

16 Give two ways of reducing unwanted energy transfers in a machine, and explain how each works. Core

17 A kettle transfers 180 kJ and 162 kJ usefully heats the water. Calculate the efficiency. Core

18 Explain how the thickness and thermal conductivity of walls affect the rate of cooling of a building. Core

19 An electric motor lifts a 25 kg load 3.0 m in 8.0 s using 1500 J of electrical energy. g = 9.8 N/kg. Calculate the useful work done, the efficiency and the power input. Stretch

5 Work done and power

4.1.1.4 – 4.1.1.5

Worked example · Work done

A force of 250 N pushes a crate 6.0 m along the floor. Calculate the work done.

F	Formula	W = F s
I	Insert	W = 250 × 6.0
F	Fine tune	250 × 6.0 = 1500
A	Answer	**1500 J**

Worked example · Power

A crane lifts a load, doing 36 000 J of work in 24 s. Calculate the useful power output.

F	Formula	P = E ÷ t
I	Insert	P = 36 000 ÷ 24
F	Fine tune	36 000 ÷ 24 = 1500
A	Answer	**1500 W, or 1.5 kW**

Your turn · Power from work done

A student of weight 600 N climbs stairs of height 4.0 m in 5.0 s. Calculate her useful power output.

F Formula — Write the two equations you need.

I Insert — Put the numbers in.

F Fine tune — Work it through.

A Answer

20 State the unit of work done and the unit of power. — Support

21 Calculate the work done when a 40 N force moves an object 2.5 m. — Support

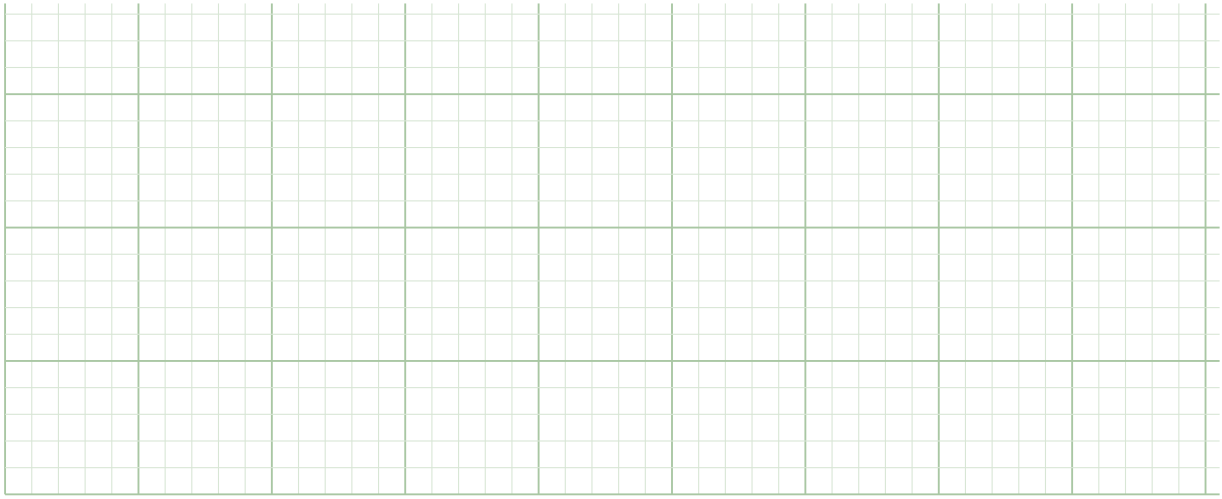
22 Explain what is meant by a power of 500 W. — Core

23 Two motors lift the same load through the same height. Motor A takes 10 s and motor B takes 25 s. Compare their power outputs. — Core

24 A 1200 kg car accelerates from rest to 24 m/s in 9.0 s. Calculate its average useful power output. — Stretch

Graph skills · Energy transferred against time

A heater transfers energy at a constant rate of 300 W. Plot energy transferred (y-axis, up to 3000 J) against time (x-axis, up to 10 s), then use the gradient to check the power.



6 National and global energy resources

4.1.3

In real life · The grid in numbers

In 2024 the UK generated roughly a third of its electricity from gas, around a third from wind and solar combined, and about 14% from nuclear. Twenty years earlier, coal alone supplied a third. Exam questions often ask you to read trends like this from a pie chart or a line graph — quote figures from the data you are given.

Key words · Use both 'renewable' and 'reliable' — they are not the same thing

Key word	What it means
Renewable	A resource that can be replenished as it is used, so it will not run out.
Non-renewable	A resource that is used faster than it can be replaced, such as fossil fuels.
Reliable	Available whenever it is needed, rather than depending on the weather or time of day.

Data · UK electricity generation by source, 2024 (approximate share)

Source	Share
Gas	33%
Wind	29%
Nuclear	14%
Imports	11%
Solar	5%
Biomass	5%
Hydroelectric	2%

Use this table to answer the next two questions. Exam questions on energy resources nearly always give you data — quote figures from it in your answer.

25 Name the three fossil fuels. Support

26 Use the table above. Calculate the percentage of UK electricity generated from renewable sources. Core

27 Use the table above. Suggest why the country still needs gas-fired power stations. Core

28 List four renewable energy resources. Support

29 Give two uses of energy resources other than generating electricity. Core

30 Explain why wind power is renewable but not reliable. Core

31 Describe the environmental impact of using fossil fuels. Core

32 Nuclear power produces no carbon dioxide during generation, yet many people oppose it. Evaluate the use of nuclear power. Stretch

True or false? · Energy resources

Statement	True or false?	Correction (if false)
Hydroelectricity is renewable and reliable.		
Solar panels generate at a steady rate all day.		
Bio-fuels are non-renewable.		
Tidal power is reliable because tides are predictable.		
Nuclear fuel is a renewable resource.		

Six-mark question · Extended response · 6 marks

A town council is deciding whether to build a wind farm or a gas-fired power station. Compare the two options, considering reliability, cost and environmental impact, and give a recommendation.

Sentence starters

- The main advantage of wind is…
- However, a problem with wind is…
- In contrast, a gas-fired station…
- Overall I would recommend… because…

Mixed practice

Questions from across the whole topic

33 Name the energy store that is filled when a spring is stretched. Support

34 State the unit of power and the unit of work done. Support

35 Calculate the work done when a 25 N force moves a box 4.0 m. Support 2 marks

Working

36 A 0.15 kg apple falls 2.5 m from a tree. g = 9.8 N/kg. Calculate the energy transferred from its gravitational store. Core 3 marks

Working

37 A 500 W motor runs for 2.0 minutes. Calculate the energy it transfers. Core 3 marks

Working

38 Explain why a bicycle slows down when the rider stops pedalling, in terms of energy stores. Core

39 A loft is insulated. Explain how this reduces the rate of cooling of the house. Core

40 A 60 kg skier starts from rest at the top of a 40 m slope. At the bottom she is travelling at 24 m/s. g = 9.8 N/kg. Calculate the energy dissipated by friction. Stretch 5 marks

Working

41 A power station is 38% efficient and supplies 950 MW usefully. Calculate the input power and the power wasted. Stretch 4 marks

Working

42 Compare the environmental impact of generating electricity from coal with generating it from solar panels. Stretch

Exam-style question · Answer all parts · 10 marks

A 1500 W electric heater is used to warm 0.80 kg of water in a kettle. The water starts at 18 °C. The specific heat capacity of water is 4200 J/kg °C.

(a) Calculate the energy needed to raise the water to 100 °C. **3 marks**

(b) Calculate the minimum time this would take. **3 marks**

(c) In practice the kettle takes longer than this. Explain why. **2 marks**

(d) The kettle is 85% efficient. Calculate the energy actually supplied. **2 marks**

Mark your work from the Answer Booklet. **Score: _____ / 10**

Quick check · Energy — can you spot the right answer? tick one box

1. Which store fills as a ball falls?

   ☐ **A** Elastic ☐ **B** Kinetic ☐ **C** Chemical ☐ **D** Nuclear

2. A machine takes in 500 J and usefully transfers 150 J. Its efficiency is:

   ☐ **A** 15% ☐ **B** 30% ☐ **C** 35% ☐ **D** 70%

3. Doubling the speed of a car multiplies its kinetic energy by:

   ☐ **A** 2 ☐ **B** 3 ☐ **C** 4 ☐ **D** 8

4. Which is a renewable but unreliable resource?

☐ **A** Gas ☐ **B** Nuclear ☐ **C** Wind ☐ **D** Coal

5 Power is measured in:

☐ **A** Joules ☐ **B** Newtons ☐ **C** Watts ☐ **D** Pascals

Challenge · Heating a swimming pool

beyond GCSE

A pool holds 250 000 kg of water at 14 °C. A heat pump supplies 90 kW. The specific heat capacity of water is 4200 J/kg °C. Estimate how many days of continuous running it would take to raise the pool to 28 °C, and state one assumption you have made.

Checklist: I can... · Tick a box each time you can do it

- ☐ Name the energy stores and describe transfers between them
- ☐ Use $E_k = \frac{1}{2} m v^2$, $E_p = m g h$ and $E_e = \frac{1}{2} k e^2$
- ☐ Use $\Delta E = m c \Delta\theta$ and rearrange it
- ☐ Describe required practicals 1 and 2 and explain the sources of error
- ☐ Explain conservation of energy and how energy is dissipated
- ☐ Calculate efficiency, and describe ways of reducing unwanted transfers
- ☐ Use $W = F s$ and $P = E \div t$
- ☐ Compare energy resources by reliability, cost and environmental impact
- ☐ Write a structured 6-mark answer comparing two energy resources