YEAR 9 PHYSICS, AQA GCSE, UNIT 2, PART 1

ENERGY STORES AND TRANSFERS

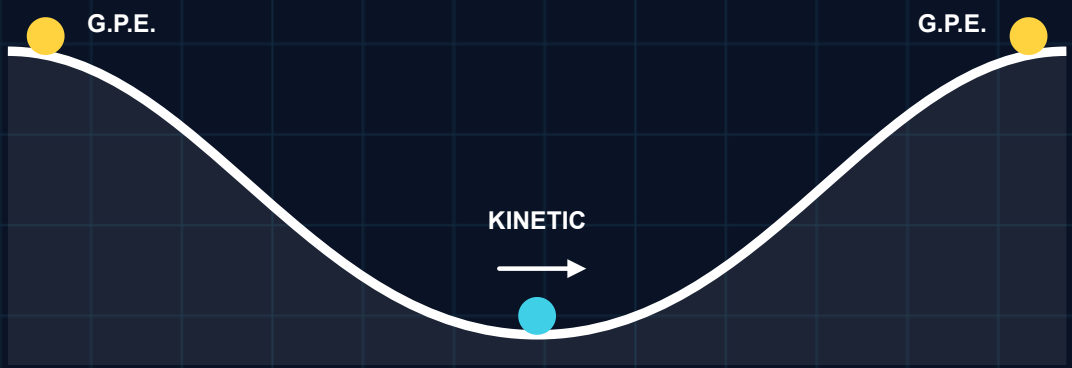
PART 1 OF 3

LESSONS 1–3: ENERGY STORES AND SYSTEMS, THE KINETIC STORE, THE GRAVITATIONAL POTENTIAL STORE

3 LESSONS

1 PRACTICAL

3 NEW EQUATIONS



NAME _____

CLASS _____

TEACHER _____

TARGET GRADE _____

START HERE

HOW THIS BOOKLET WORKS

Energy is never made and never destroyed: it only moves from one store to another. This booklet shows you how to follow it, and how to calculate it. Keep the booklet: it is your classwork book *and* your revision guide.

DO NOW
Quick questions from earlier lessons. Remembering again is what makes it stick.

LEARN IT
The explanation, diagrams and worked examples. Read this again when you revise.

TRY IT
Practice that builds up: first with support, then on your own.

PRACTICAL
Record your measurements and work out results from them.

EXAM CORNER
AQA-style questions with a tip on how the marks are given.

REVISE IT
Summary, cover-and-answer questions and an "I can" check to colour in.

! **Two kinds of question to know.** When a sentence has a gap, the choices are printed straight after it, like this: Energy is measured in _____ **(joules / newtons / watts)**. When you see a box of choices, **draw a ring around** the correct one, as AQA exam papers ask. The unit of energy is | **the watt** | **the joule** | **the newton** | .

THE ROUTE THROUGH THIS PART

#	LESSON	WEEK
01	**Energy stores and systems** The energy stores, four ways to transfer energy, systems	1
02	**The kinetic store** $E_k = \frac{1}{2} m v^2$; grams to kilograms; double the speed, four times the energy	1
03	**The gravitational potential store** What g means, $E_p = m g h$, height gained, finding h or m	2

This booklet is Part 1 of 3: Lessons 1–3. The **equation toolkit** on the last page has every equation you have met so far, with formula triangles to help you rearrange.

Lesson

01 ENERGY STORES AND SYSTEMS

AQA Physics 4.1.1.1; Combined Science 6.1.1.1

BIG QUESTION **A skateboarder rolls down one side of a ramp and up the other, but never quite gets back to the starting height. Where did the energy go?**

BY THE END YOU CAN

- name the energy stores and give an example of each
- name the four ways energy is transferred
- explain what a system is
- describe the energy transfers when something changes

energy store **transfer** **system** **closed system** **joule (J)**

YOU WILL NEED

This booklet, a pencil and a ruler.

REMEMBER

WHAT DO YOU ALREADY THINK?

No wrong answers: this is your starting point.

1

Name something that has energy. How can you tell?

2

Energy is measured in _____ **(joules / newtons / metres)**.

3

Rub your hands together. They get _____ **(warmer / colder)**. Why?

EXPLAIN

STORES AND TRANSFERS

Energy is never made and never used up. It is **stored**, and it is **transferred** (moved) from one store to another. Energy is measured in **joules (J)**.

THE FIVE MAIN ENERGY STORES

STORE	ENERGY IS STORED BECAUSE…	EXAMPLE
Kinetic	the object is moving	a rolling football
Gravitational potential	the object is raised up	a book on a high shelf
Elastic potential	the object is stretched or squashed	a stretched spring, a drawn bow
Thermal	the object is hot	a cup of tea
Chemical	of the substances it is made of	food, fuel, a battery

You may also meet the **magnetic** store (two magnets held apart), the **electrostatic** store (a charged balloon) and the **nuclear** store (uranium fuel), but GCSE questions rarely use them.

FOUR WAYS TO TRANSFER ENERGY

TRANSFERRED…	WHAT HAPPENS	EXAMPLE
mechanically	a force moves something	pushing a trolley
electrically	a current flows	a battery lighting a lamp
by heating	a hotter object warms a colder one	a hob heating a pan
by waves	a wave carries it: light, infrared (both called radiation) or sound	the Sun warming your face; a loudspeaker

! **Stores hold energy. Transfers move it.** Light, sound and electricity are **not** stores: they are ways energy travels from one store to another.

SYSTEMS

A **system** is the object, or group of objects, that we choose to study. In a **closed system**, no energy gets in or out, so the **total** energy stays the same. The energy only moves between stores.

DESCRIBE ANY CHANGE IN THREE STEPS

1. Which store **empties**?
2. Which store **fills**?
3. **How** is the energy transferred: mechanically, electrically, by heating or by waves?

EXAMPLE: A CAR BRAKING

The kinetic store of the car empties. The thermal store of the brakes fills. Friction is a force, so the energy is transferred mechanically. **Write:** “Energy is transferred mechanically from the kinetic store of the car to the thermal store of the brakes.”

PRACTISE

TRY IT

1 Draw a line from each store to its example.

Kinetic	a stretched bow
Gravitational potential	a hot bath
Elastic potential	a rolling ball
Chemical	a battery
Thermal	a book on a high shelf

2 Draw a ring around the correct answer in each box.

Light is **an energy store** | **a way energy is transferred**

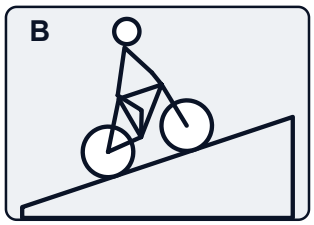
A battery stores energy in its **chemical store** | **kinetic store** | **thermal store**

At the top of its flight, a ball has most energy in its

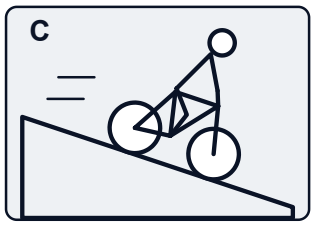
kinetic store | **gravitational potential store**

3 The pictures tell a story. For each picture, write the store that **empties** and the store that **fills**. Choose from the words under each gap.

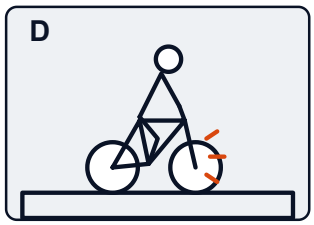
Eating breakfast



Cycling up the hill



Freewheeling down



Braking at the bottom

PICTURE	STORE THAT EMPTIES	STORE THAT FILLS
A Eating	chemical (in the food)	chemical (in the body)
B Cycling up	**chemical / kinetic**	**gravitational potential / elastic potential**
C Freewheeling down	**gravitational potential / chemical**	**kinetic / nuclear**
D Braking	**kinetic / thermal**	**thermal / chemical**

4 SUPPORTED Complete each sentence. The choices are after each gap.

A ball is thrown upwards. Energy is transferred from the _____ **(kinetic / chemical)** store to the _____ **(gravitational potential / thermal)** store.

A fireplace warms a person. Energy is transferred by infrared waves from the _____ **(chemical / kinetic)** store of the fuel to the _____ **(thermal / kinetic)** store of the person.

A child lands on a trampoline. Energy is transferred mechanically from the child's _____ **(kinetic / chemical)** store to the trampoline's _____ **(elastic potential / thermal)** store.

5 ON YOUR OWN A bungee jumper falls, and the cord stretches until the jumper stops at the bottom. Describe the energy transfers. Use the three steps.

6 Explain what is wrong with what Sam says.

Sam When the car stopped, its energy was used up.

AQA-STYLE

EXAM CORNER

Write in full sentences. Show every step of a calculation.

Get the marks: Name both stores and say which one empties and which one fills.

7 A student throws a ball straight up. Complete the sentence. **[2 marks]**

As the ball rises, energy is transferred from the _____ **(kinetic / chemical / thermal)** store of the ball to its _____ **(elastic potential / gravitational potential / nuclear)** store.

8 What is the unit of energy? Tick **one** box. **[1 mark]**

☐ joule ☐ newton ☐ watt ☐ kilogram

9 A child lands on a trampoline. Describe the energy transfer as the mat and springs stretch and the child slows down. **[2 marks]**

REVIEW LATER

REVISE IT

Use this box after the lesson and before tests.

SUMMARY

- Energy is measured in **joules (J)**. It is never made or destroyed.
- Main stores: kinetic, gravitational potential, elastic potential, thermal, chemical.
- Transfers: mechanically, electrically, by heating, by waves.
- In a closed system, the total energy stays the same.

COVER THE PAGE AND ANSWER

1 What is the unit of energy?

2 Name four energy stores.

3 Is light a store or a way of transferring energy?

4 What is a closed system?

I CAN…

- name the energy stores
- name the four ways energy is transferred
- explain what a system is
- describe energy transfers using “from … to …”

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Lesson

02 THE KINETIC STORE

AQA Physics 4.1.1.2; Combined Science 6.1.1.2

BIG QUESTION **A car travels twice as fast. Does it have twice as much energy in its kinetic store, or more?**

BY THE END YOU CAN

- say what the kinetic store depends on
- calculate kinetic energy with $E_k = \frac{1}{2} m v^2$
- convert grams to kilograms
- explain why doubling the speed gives four times the energy

kinetic store | mass (kg) | speed (m/s) | squared

YOU WILL NEED

Calculator. Practical: trolley, 1.00 m track, stopwatch, balance.

REMEMBER

DO NOW

From earlier lessons. No notes!

1

Which store does a moving object have energy in?

2

A car brakes. Which store fills?

3

Light is _____ **(a store / a way energy is transferred).**

EXPLAIN

ENERGY IN A MOVING OBJECT

Anything that moves has energy in its **kinetic store**. The more **mass** it has, and the faster it moves, the more energy it has.

$$E_k = \frac{1}{2} m v^2$$

kinetic energy = 0.5 × mass × (speed)²

E_k in joules (J), m in kilograms (kg), v in metres per second (m/s)

Only the speed is squared. In this unit you use the equation to calculate the energy.

! **Square the speed first:** $v^2 = v \times v$. Then multiply by the mass and by 0.5.

WORKED EXAMPLE

A 1200 kg car moves at 15 m/s. Calculate the energy in its kinetic store.

KNOW	m = 1200 kg, v = 15 m/s
EQUATION	$E_k = \frac{1}{2} m v^2$
SUBSTITUTE	$E_k = 0.5 \times 1200 \times 15^2$
ANSWER	$E_k = 135\,000$ J

YOUR TURN

A 60 kg runner moves at 5.0 m/s. Calculate the energy in their kinetic store.

KNOW	
EQUATION	
SUBSTITUTE	
ANSWER	

MASS IN GRAMS? CONVERT FIRST

The mass must be in kilograms. Divide grams by 1000: $450\ \text{g} = 0.450\ \text{kg}$. A 450 g football kicked at 20 m/s has $E_k = 0.5 \times 0.450 \times 20^2 = 90$ J.

DOUBLE THE SPEED, FOUR TIMES THE ENERGY

SPEED OF A 1200 KG CAR	v^2	E_k
15 m/s	225	135 000 J
30 m/s (2 × faster)	900	540 000 J (4 × more)
45 m/s (3 × faster)	2025	1 215 000 J (9 × more)

Twice the speed gives $2^2 = 4$ times the energy. Three times the speed gives $3^2 = 9$ times. This is why a crash at high speed does so much more damage, and why the brakes must transfer so much more energy to stop the car. Doubling the **mass** only doubles the energy, because the mass is not squared.

PRACTISE

TRY IT

1 Draw a ring around the correct answer in each box.

Doubling the mass makes the kinetic energy

stay the same	**2 times bigger**	**4 times bigger**

Doubling the speed makes the kinetic energy

stay the same	**2 times bigger**	**4 times bigger**

2 SUPPORTED A 2.0 kg ball rolls at 3.0 m/s. Calculate the energy in its kinetic store.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

3 SUPPORTED A 450 g football is kicked at 20 m/s. Calculate the energy in its kinetic store. *Convert the mass first!*

CONVERT	
EQUATION	
SUBSTITUTE	
ANSWER	unit:

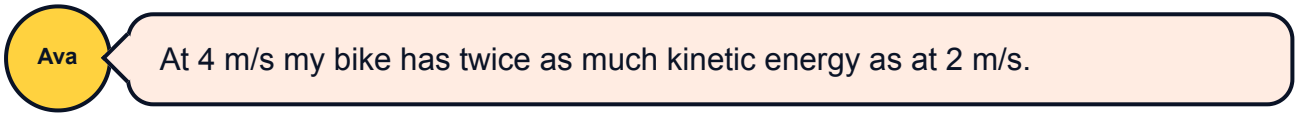
4 Complete the table. Show your working underneath.

Object	Mass	Speed	E_k / J
Lorry	**30 000 kg**	**2.0 m/s**	
Cyclist and bike	**80 kg**	**6.0 m/s**	
Tennis ball	**58 g**	**50 m/s**	
Bullet	**10 g**	**400 m/s**	

5 **ON YOUR OWN** A 0.16 kg cricket ball is bowled at 40 m/s. Calculate the energy in its kinetic store.

6 **CHALLENGE** A car speeds up from 10 m/s to 30 m/s. How many times bigger is the energy in its kinetic store? Explain without calculating the energy.

7 Explain what is wrong with what Ava says.



INVESTIGATE

MEASURE THE ENERGY OF A MOVING TROLLEY

Work in a group of three: one pushes, one times, one records.

1. Measure the trolley's mass on the balance in grams. Convert it to kilograms.
2. Mark a 1.00 m section of the track with tape.
3. Give the trolley a gentle push so it rolls through the section. Time how long it takes to cross the 1.00 m.
4. Repeat twice more with the same push, and find the mean time.
5. Calculate the speed, then the kinetic energy.

8. Record your results.

Mass / g	Mass / kg	Time 1 / s	Time 2 / s	Time 3 / s	Mean time / s

9. Calculate the speed: $\text{speed} = \dfrac{\text{distance}}{\text{time}}$.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

10. Calculate the energy in the trolley's kinetic store.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

11. Which measurement has the biggest effect on your answer? **the mass** | **the time**

Explain why.

AQA-STYLE

EXAM CORNER

Write in full sentences. Show every step of a calculation.

Get the marks: Write the equation, then substitute, then give the answer with its unit.

12 A cyclist and bike have a total mass of 70 kg and move at 8.0 m/s. Calculate the energy in their kinetic store. **[2 marks]**

EQUATION	
SUBSTITUTE	
ANSWER	unit:

13 Car A and car B have the same mass. Car B moves twice as fast as car A. Complete the sentence. **[2 marks]**

Car B has _____ **(2 / 4 / 8)** times as much energy in its kinetic store as car A, because in the equation the speed is | **halved** | **squared** | **doubled** | .

REVIEW LATER

REVISE IT

Use this box after the lesson and before tests.

SUMMARY

- $E_k = \frac{1}{2}\,m\,v^2$: mass in kg, speed in m/s, energy in J.
- Convert grams to kilograms: divide by 1000.
- Only the speed is squared: 2 × the speed gives 4 × the energy.
- 2 × the mass gives 2 × the energy.

COVER THE PAGE AND ANSWER

1 What two things does the kinetic store depend on?

2 Write the equation for kinetic energy.

3 Convert 250 g to kilograms.

4 The speed triples. What happens to the kinetic energy?

I CAN…

- calculate kinetic energy with $E_k = \frac{1}{2}\,m\,v^2$
- convert grams to kilograms
- explain why doubling the speed gives four times the energy

Lesson

03 THE GRAVITATIONAL POTENTIAL STORE

AQA Physics 4.1.1.2; Combined Science 6.1.1.2

BIG QUESTION **Carrying a bag up the stairs is hard work. Where does that energy go, and can you get it back?**

BY THE END YOU CAN

- explain what $g = 9.8$ N/kg means
- calculate energy with $E_p = m\,g\,h$
- use the height gained
- rearrange to find a height or a mass

gravitational potential store

gravitational field strength **newton (N)**

height gained

ELECTRIC MOUNTAIN

At Dinorwig in Wales, water is pumped up into a lake high on a mountain. When the country suddenly needs electricity, the water rushes down through turbines. The energy waits in the water's gravitational potential store until it is needed.

REMEMBER

DO NOW

From earlier lessons. No notes!

1

In $E_k = \frac{1}{2}\,m\,v^2$, what does v stand for? Give its unit.

2

Convert 600 g to kilograms.

3

A 2.0 kg ball moves at 4.0 m/s. Calculate its kinetic energy.

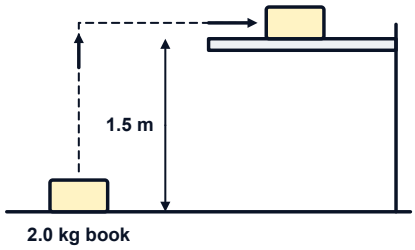
EXPLAIN

ENERGY FROM HEIGHT

Lift an object up and you transfer energy to its **gravitational potential store**. Let it fall and the energy is transferred to its kinetic store. The heavier the object and the higher you lift it, the more energy it stores.

WHAT g MEANS

! On Earth, gravity pulls every kilogram down with a force of **9.8 newtons**. We write this as $g = 9.8$ N/kg (newtons per kilogram). It is called the **gravitational field strength**. On the Moon, $g = 1.6$ N/kg, so the same lift stores less energy there.

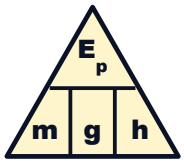


$$E_p = m\,g\,h$$

gravitational potential energy = mass × gravitational field strength × height

E_p in J, m in kg, g in N/kg, h in m

Rearranged: $h = \dfrac{E_p}{m\,g}$ and $m = \dfrac{E_p}{g\,h}$



WORKED EXAMPLE

A 2.0 kg book is lifted onto a shelf 1.5 m high. Calculate the energy transferred to its gravitational potential store.

KNOW	m = 2.0 kg, g = 9.8 N/kg, h = 1.5 m
EQUATION	$E_p = m\,g\,h$
SUBSTITUTE	$E_p = 2.0 \times 9.8 \times 1.5$
ANSWER	$E_p = 29.4$ J

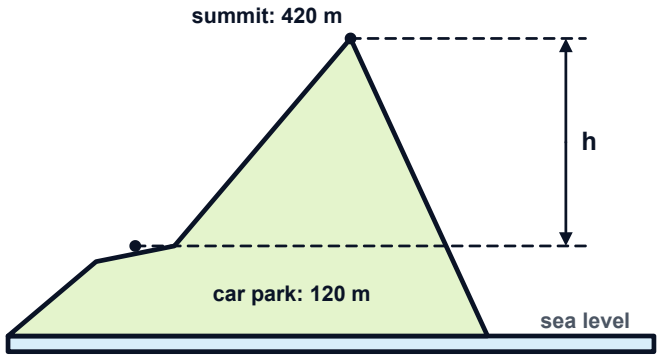
YOUR TURN

A 5.0 kg bag is lifted 2.0 m. Calculate the energy transferred to its gravitational potential store.

KNOW	
EQUATION	
SUBSTITUTE	
ANSWER	

USE THE HEIGHT GAINED

Only the **change** in height matters. A hiker climbs from a car park 120 m above sea level to a summit 420 m above sea level. The height gained is $h = 420 - 120 = 300$ m. A 55 kg hiker gains $E_p = 55 \times 9.8 \times 300 = 161\,700$ J.



FINDING THE HEIGHT OR THE MASS

WORKED EXAMPLE

A 60 kg climber gains 17 640 J in their gravitational potential store. How high did they climb?

KNOW	$E_p = 17\,640$ J, m = 60 kg, g = 9.8 N/kg
REARRANGE	$h = \dfrac{E_p}{m\,g}$
SUBSTITUTE	$h = \dfrac{17\,640}{60 \times 9.8}$
ANSWER	**h = 30 m**

YOUR TURN

A crate is lifted 2.0 m and gains 392 J. Calculate its mass.

KNOW

REARRANGE

SUBSTITUTE

ANSWER

> **Get the marks:** Work out the bottom of the fraction first ($60 \times 9.8 = 588$), then divide. Or put brackets round it on your calculator.

PRACTISE

TRY IT

1 Draw a ring around the correct answer in each box.

On the Moon, lifting a box 1 m stores

more energy than on Earth	**less energy than on Earth**	**the same energy as on Earth**

Lifting a box twice as high makes the energy stored

half as big	**twice as big**	**four times as big**

2 SUPPORTED A 0.50 kg ball is lifted 3.0 m. Calculate the energy transferred to its gravitational potential store.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

3 **SUPPORTED** A 600 g book is lifted 1.2 m onto a shelf. Calculate the energy transferred. *Convert the mass first!*

CONVERT	
EQUATION	
SUBSTITUTE	
ANSWER	unit:

4 Complete the table. Use $g = 9.8$ N/kg. Show your working underneath.

Object	Mass / kg	Height gained / m	E_p / J
Child at the top of a slide	**30**	**2.5**	
Rock on a cliff	**4.0**		**196**
Crate on a lorry		**3.0**	**882**
Lift with passengers	**800**	**12**	

5 **CHALLENGE** A 50 kg student gains 4.9 kJ in their gravitational potential store climbing stairs. How high did they climb? *Convert kJ to J first.*

INVESTIGATE

ACTIVITY: LIFT IT

Work in pairs. Lift gently and keep the floor clear.

Choose three objects. Measure the mass of each and the height of the shelf or bench you lift it onto. Calculate the energy transferred to each gravitational potential store.

6 Record and calculate.

Object	Mass / kg	Height / m	E_p / J

7 How high would you need to lift your lightest object so that it stores the same energy as your heaviest object?

AQA-STYLE

EXAM CORNER

Write in full sentences. Show every step of a calculation.

Get the marks: g is always given in the question. AQA uses 9.8 N/kg.

8 A crane lifts a 250 kg load through a height of 12 m. Calculate the energy transferred to the load's gravitational potential store. Gravitational field strength = 9.8 N/kg **[2 marks]**

EQUATION	
SUBSTITUTE	
ANSWER	unit:

9 A 0.40 kg ball gains 7.84 J in its gravitational potential store when it is thrown upwards. Calculate how high it rises. Gravitational field strength = 9.8 N/kg **[3 marks]**

EQUATION	
REARRANGE	
SUBSTITUTE	
ANSWER	unit:

REVIEW LATER

REVISE IT

Use this box after the lesson and before tests.

SUMMARY

- $g = 9.8$ N/kg: gravity pulls each kilogram down with 9.8 N.
- $E_p = m\,g\,h$, with the height gained in metres.
- Rearranged: $h = \dfrac{E_p}{m\,g}$ and $m = \dfrac{E_p}{g\,h}$.
- Twice the height or twice the mass gives twice the energy.

COVER THE PAGE AND ANSWER

1 What does $g = 9.8$ N/kg mean?

2 Write the equation for gravitational potential energy.

3 A 5.0 kg bag is lifted 2.0 m. How much energy does it gain?

4 Rearrange $E_p = m\,g\,h$ to find h.

I CAN…

- explain what $g = 9.8$ N/kg means
- calculate $E_p = m\,g\,h$ using the height gained
- rearrange $E_p = m\,g\,h$ to find a height or a mass

REFERENCE

KEY WORDS

Learn the meaning and the spelling. In exams, precise words earn marks: say “transferred to the thermal store of the surroundings”, never “lost”.

Energy store L1: Where energy is held. The main stores are kinetic, gravitational potential, elastic potential, thermal and chemical

Joule (J) L1: The unit of energy

System L1: The object or group of objects that we choose to study

Closed system L1: A system that no energy enters or leaves; its total energy stays the same

Kinetic store L2: Energy an object has because it is moving

Gravitational potential store L3: Energy an object has because it is raised in a gravitational field

Gravitational field strength (g) L3: The force of gravity on each kilogram: 9.8 N/kg on Earth

FINISH

PROGRESS TRACKER

Colour one circle for each statement: **red** = not yet, **amber** = getting there, **green** = I can do this without help. Revisit your reds first.

I CAN…	R / A / G
01: Energy stores and systems	
name the energy stores	
name the four ways energy is transferred	
explain what a system is	
describe energy transfers using “from … to …”	
02: The kinetic store	
calculate kinetic energy with $E_k = \frac{1}{2} m v^2$	
convert grams to kilograms	
explain why doubling the speed gives four times the energy	
03: The gravitational potential store	
explain what $g = 9.8$ N/kg means	
calculate $E_p = m g h$ using the height gained	
rearrange $E_p = m g h$ to find a height or a mass	

CHECK YOURSELF

QUICK ANSWERS

Answers to the “Do now” and “Cover the page” questions, so you can check yourself when revising. Answers to the longer questions are in your teacher's answer edition.

LESSON 1: ENERGY STORES AND SYSTEMS

DO NOW

1. For example, a moving car (it is moving) or a hot drink (it is hot). Any sensible answer.
2. joules (J)
3. Warmer: rubbing (friction) transfers energy to the thermal store of your hands.

COVER THE PAGE

1. Joule (J).
2. Any four of: kinetic, gravitational potential, elastic potential, thermal, chemical.
3. A way of transferring energy (by waves).
4. A system that no energy enters or leaves, so its total energy stays the same.

LESSON 2: THE KINETIC STORE

DO NOW

1. The kinetic store.
2. The thermal store (of the brakes and the surroundings).
3. A way energy is transferred (by waves).

COVER THE PAGE

1. Mass and speed.
2. $E_k = \frac{1}{2}\,m\,v^2$
3. 0.250 kg
4. It becomes 9 times bigger.

LESSON 3: THE GRAVITATIONAL POTENTIAL STORE

DO NOW

1. Speed, in metres per second (m/s).
2. 0.600 kg
3. $E_k = 0.5 \times 2.0 \times 4.0^2$
   $E_k = 16$ J

COVER THE PAGE

1. Gravity pulls each kilogram down with a force of 9.8 N.
2. $E_p = m\,g\,h$
3. 98 J
4. $h = \dfrac{E_p}{m\,g}$

REFERENCE

EQUATION TOOLKIT

Every equation from Lessons 1–3. AQA prints all of them on the equation sheet in the exam, but you still need to know what each symbol means, its unit, and how to use it. Use $g = 9.8\ \text{N/kg}$.

1. Cover the quantity you want to find.
2. What is left side by side? **Multiply**.
3. One above the other? **Divide** the top by the bottom.

Example: to find h from $E_p = m\,g\,h$, cover h. E_p is above m and g, so $h = \dfrac{E_p}{m\,g}$. Kinetic energy has no triangle: in this unit you only use it to calculate the energy.

$E_k = \frac{1}{2}\,m\,v^2$

Lesson 2

kinetic energy = 0.5 × mass × (speed)²

J, kg, m/s

Use it to calculate the energy. Only the speed is squared.

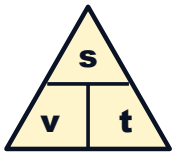
$s = v\,t$

Lesson 2

distance travelled = speed × time

m, m/s, s

$v = \dfrac{s}{t}$ and $t = \dfrac{s}{v}$



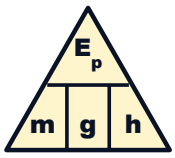
$E_p = m\,g\,h$

Lesson 3

gravitational potential energy = mass × gravitational field strength × height

J, kg, N/kg, m

$h = \dfrac{E_p}{m\,g}$ and $m = \dfrac{E_p}{g\,h}$



1

Write what you know. Convert first: g → kg, cm → m, kJ → J.

2

Write the equation in symbols.

3

Rearrange if you need to, then substitute the numbers.

4

Give the answer with a unit. Ask: is it sensible?