

YEAR 9 PHYSICS, AQA GCSE, UNIT 2, PART 3

ENERGY STORES AND TRANSFERS

PART 3 OF 3

LESSONS 7–9: POWER, WASTED ENERGY, EFFICIENCY

3

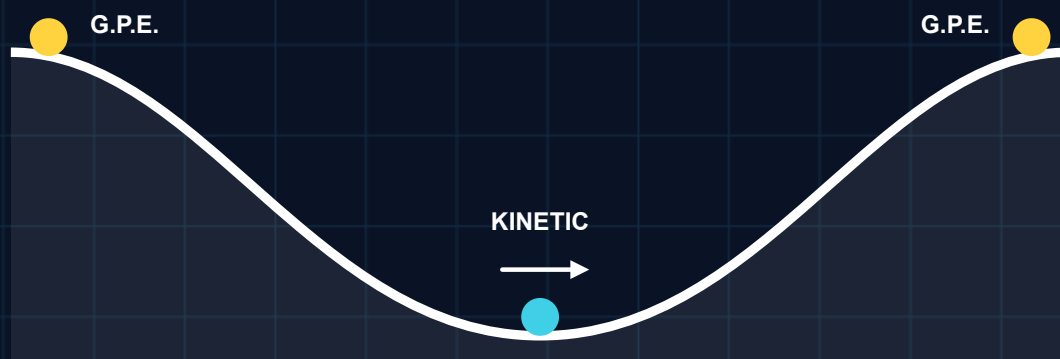
LESSONS

3

PRACTICALS

2

NEW EQUATIONS



NAME

TEACHER

CLASS

TARGET GRADE

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
07	Power Power as a rate, watts, $P = \frac{E}{t}$, how powerful are you?	4
08	Wasted energy Dissipation, lubrication, thermal conductivity, insulation, design an Eco House	4
09	Efficiency Efficiency from energy or power, decimals and percentages, Sankey diagrams	5

This booklet is Part 3 of 3: Lessons 7–9. The **equation toolkit** on the last page has every equation in the unit, with formula triangles to help you rearrange.

BIG QUESTION Two students carry the same bag up the same stairs. One runs and one walks. Who transferred more energy? Who was more powerful?

BY THE END YOU CAN

- say what power means
- state that 1 watt is 1 joule per second
- calculate power with $P = \frac{E}{t}$, and find E or t
- convert kW to W, kJ to J and minutes to seconds

power

watt (W)

kilowatt (kW)

rate

YOU WILL NEED

Practical: stopwatch, tape measure or metre rule, a flight of stairs.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

A 50 kg student climbs 3.0 m of stairs. Calculate the energy transferred to their G.P.E. store.

2

Convert 2.0 minutes to seconds.

3

State the principle of conservation of energy.



EXPLAIN

HOW FAST IS ENERGY TRANSFERRED?

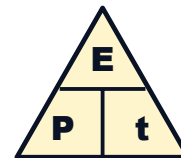
Power is how fast energy is transferred: the energy transferred **each second**. Two motors can lift the same load through the same height, so they transfer the same energy. The motor that does it faster is more powerful.

$$P = \frac{E}{t}$$

power = energy transferred ÷ time

P in watts (W), E in joules (J), t in seconds (s)

Rearranged: $E = Pt$ and $t = \frac{E}{P}$



1 watt (W) = 1 joule per second. 1 kilowatt (kW) = 1000 W. A 60 W lamp transfers 60 J every second.

	ENERGY TRANSFERRED	TIME	POWER
Motor A	29.4 J	2.0 s	$29.4 \div 2.0 = 14.7 \text{ W}$
Motor B	29.4 J	6.0 s	$29.4 \div 6.0 = 4.9 \text{ W}$

WORKED EXAMPLE

A motor transfers 600 J in 4.0 s. Calculate its power.

KNOW $E = 600 \text{ J}$, $t = 4.0 \text{ s}$

EQUATION $P = \frac{E}{t}$

SUBSTITUTE $P = \frac{600}{4.0}$

ANSWER **$P = 150 \text{ W}$**

YOUR TURN

A lamp transfers 900 J in 15 s. Calculate its power.

KNOW

EQUATION

SUBSTITUTE

ANSWER

WORKED EXAMPLE

A 2.0 kW kettle is switched on for 2.0 minutes. Calculate the energy transferred.

CONVERT $P = 2000 \text{ W}$, $t = 120 \text{ s}$

REARRANGE $E = Pt$

SUBSTITUTE $E = 2000 \times 120$

ANSWER **$E = 240\,000 \text{ J}$**

YOUR TURN

A 1500 W motor must transfer 45 000 J. How long does it take?

KNOW

REARRANGE

SUBSTITUTE

ANSWER



PRACTISE
TRY IT

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

Power is measured in

joules	watts	newtons
--------	-------	---------

A more powerful motor transfers energy

faster	slower
--------	--------

1 W is the same as

1 J per second	1 J per minute	1 N per metre
----------------	----------------	---------------

- 2 **SUPPORTED** A 40 W fan runs for 5.0 minutes. Calculate the energy transferred. *Convert the time first!*

CONVERT	
EQUATION	
SUBSTITUTE	
ANSWER	unit:

- 3 Complete the table. Show your working underneath.

Appliance	Energy / J	Time / s	Power / W
Fan	1200	30	
Kettle		60	2000
Lamp	5000		100

<div></div>

- 4 **CHALLENGE** A 3.0 kW heater transfers 540 kJ. How many minutes was it on for?

<div></div>



INVESTIGATE

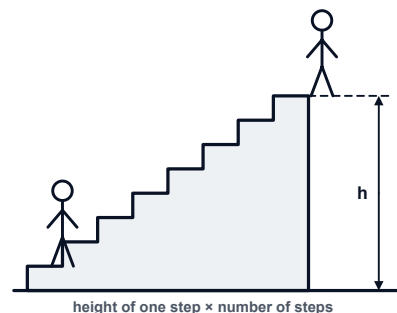
PRACTICAL: HOW POWERFUL ARE YOU?

Everyone uses a mass of 50 kg, so nobody is weighed.

STAY SAFE

- Walk briskly. Do not run. Hold the handrail.
- One person on the stairs at a time.
- Use dry, clear stairs.

- 1 Measure the height of one step. Count the steps. Height h = step height $\times$ number of steps.
- 2 Your partner times you walking briskly up the stairs.
- 3 Calculate the energy transferred: $E = mgh$, with $m = 50$ kg.
- 4 Calculate your power: $P = \frac{E}{t}$.



Height of one step / m	
Number of steps	
Height h / m	
Mass / kg	50
Time / s	

- 5 Calculate the energy transferred to your G.P.E. store.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

- 6 Calculate your power.

EQUATION	
SUBSTITUTE	
ANSWER	unit:

- 7 Is your real power output **higher** **lower** than your answer? Explain.



Get the marks: Two steps: find the energy first, then the power.

8

A lift motor raises a 600 kg lift through 15 m in 20 s. Gravitational field strength = 9.8 N/kg.

[2 marks]

(a) Calculate the energy transferred to the lift's gravitational potential store.

EQUATION

SUBSTITUTE

ANSWER

unit:

9

(b) Calculate the useful power output of the motor.

[2 marks]

EQUATION

SUBSTITUTE

ANSWER

unit:

10

Motor A lifts a load in 5 s. Motor B lifts the same load through the same height in 10 s. Complete the sentence.

[2 marks]

Motor A transfers _____ (more / less / the same) energy as motor B, and has _____ (a greater / a smaller / the same) power.



SUMMARY

- Power is the rate of energy transfer: the energy transferred each second.
- $P = \frac{E}{t}$; $E = Pt$; $t = \frac{E}{P}$.
- 1 W = 1 J/s; 1 kW = 1000 W.
- Time in seconds: minutes $\times$ 60.

COVER THE PAGE AND ANSWER

1 What is power?

2 What is 1 watt?

3 A lamp transfers 600 J in 10 s. What is its power?

4 Write the equation to find energy from power and time.

I CAN...

define power as the rate of energy transfer

calculate $P = \frac{E}{t}$ and find E or t 

convert kW, kJ and minutes



measure my own power



WASTED ENERGY

AQA Physics 4.1.2.1; Combined Science 6.1.2.1

BIG QUESTION A hot chocolate always goes cold. Where does the energy go, and how can you slow it down?

BY THE END YOU CAN

- explain what “dissipated” means and where the energy ends up
- explain how lubrication reduces unwanted energy transfers
- explain how thermal conductivity and wall thickness affect how fast a house cools
- suggest and explain ways to insulate a home

dissipated

friction

lubrication

conduction

thermal conductivity

thermal insulator

SEEING HEAT

A thermal camera shows warm things as bright colours. Point one at a house in winter and the windows, the roof and the gaps round the door glow: that is where energy is escaping into the cold air outside.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

A fan transfers 600 J in 20 s.
Calculate its power.

2

Dissipated energy usually
ends up in the _____ (thermal /
chemical / nuclear) store of
the surroundings.

3

A pendulum swings lower
each time. Why?



EXPLAIN

REDUCING UNWANTED ENERGY TRANSFERS

In every real energy transfer, some energy goes to stores where it is not useful, usually the **thermal store of the surroundings**. This energy is **dissipated** (spread out). People often call it “wasted” energy. It is not destroyed, but we cannot use it again.

UNWANTED TRANSFER	HOW TO REDUCE IT	WHY IT WORKS
Friction between moving parts	Lubricate with oil or grease	The surfaces slide past each other more easily, so less energy goes to the thermal store
Air resistance on a vehicle	A streamlined shape	The air pushes back less, so less energy goes to the thermal store of the air
Conduction through walls and roofs	Thermal insulation	Materials with a low thermal conductivity slow the transfer

■ CONDUCTION AND THERMAL CONDUCTIVITY

Energy is transferred through a solid by **conduction**, from the hotter side to the colder side. A material with a **higher thermal conductivity** transfers energy **faster**. Metals have a high thermal conductivity. Air, wool and plastic foam have a low thermal conductivity, so they are good **thermal insulators**. Many insulators work because they trap air.



A house cools **more slowly** if its walls are **thicker** and have a **lower thermal conductivity**.

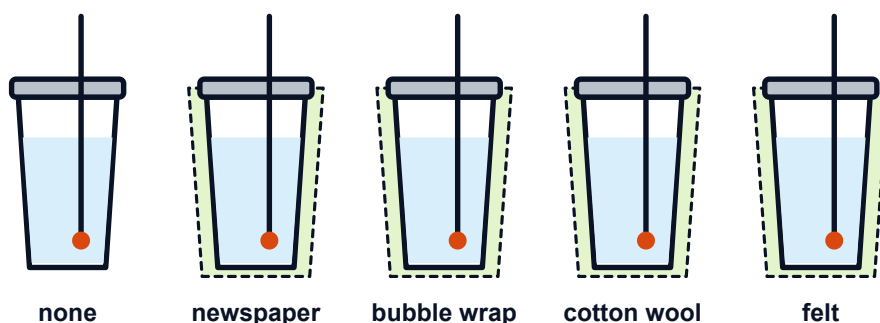


INVESTIGATE

PRACTICAL: COOLING CUPS

TRIPLE ONLY

Your teacher pours the hot water.



Question: which material is the best thermal insulator?

Independent variable	
Dependent variable	
Control variables (two)	



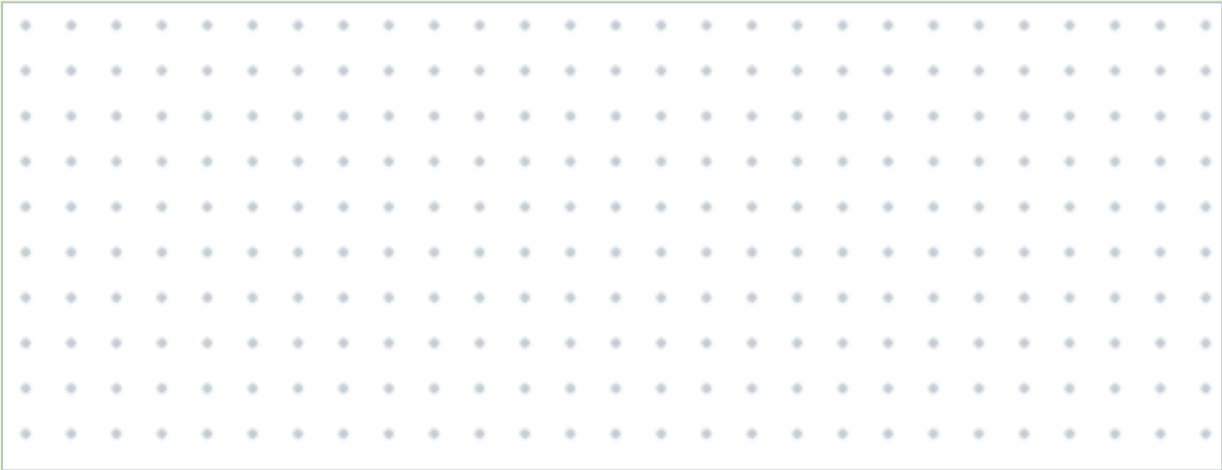
STAY SAFE

- The water is about 60 °C: hot enough to scald. Do not move the cups.
- Stand the cups in a tray. Report any spill straight away.

5 Record your results.

Material	Start / °C	After 10 min / °C	Drop / °C
none			
newspaper			
bubble wrap			
cotton wool			
felt			

6 The material is a categoric variable, so draw a line graph bar chart of the temperature drop. Draw it here.



7 Complete the conclusion.

The best insulator is the material whose cup had the _____ (biggest / smallest) temperature drop.

In my results, the best insulator was _____ (none / newspaper / bubble wrap / cotton wool / felt).

Good insulators trap air, which has a _____ (high / low) thermal conductivity.



PRACTISE
TRY IT

- 1 Draw a line from each unwanted energy transfer to the best way to reduce it.

Friction in a bike chain

a draught excluder

Air resistance on a lorry

oil on the chain

Conduction through a loft

a streamlined shape

Draughts under a door

thick loft insulation

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

Copper has a high thermal conductivity, so copper is a good

thermal insulator

thermal conductor

Making a wall twice as thick makes the house cool

faster

more slowly

- 3 Explain what insulation really does.

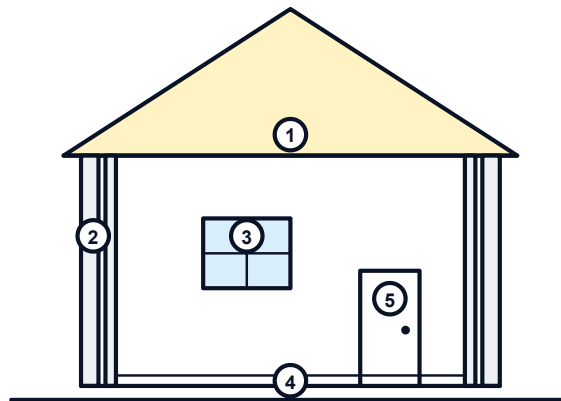
Lily

Insulation keeps the cold out.

4

DESIGN

Design an Eco House. For each numbered place on the house, name a feature that reduces energy transfer out of the house, and explain why it works. Where they fit, use the words *thermal conductivity* or *thickness*. For gaps, explain how the feature stops warm air escaping.



PLACE	FEATURE	WHY IT WORKS
1 Roof		
2 Walls		
3 Window		
4 Floor		
5 Door		



Get the marks: Say what the lubricant does to friction, and then what that does to the energy.

8

Explain how oiling a bicycle chain reduces the energy wasted when you cycle. **[2 marks]**

9

Two houses have walls of the same thickness. The bricks of house A have a higher thermal conductivity than the bricks of house B. Which house cools faster? Explain. **[2 marks]**

**SUMMARY**

- Dissipated (“wasted”) energy usually goes to the thermal store of the surroundings.
- Lubrication reduces friction, so less energy is dissipated.
- Higher thermal conductivity = faster energy transfer by conduction.
- Thicker walls with lower thermal conductivity make a house cool more slowly.
- Many insulators trap air.

COVER THE PAGE AND ANSWER

1 Where does dissipated energy usually end up?
.....

2 How does lubrication reduce wasted energy?
.....

3 What does a high thermal conductivity mean?
.....

4 Give two ways to make a house cool more slowly.
.....

I CAN...

explain what dissipated means



explain how lubrication reduces wasted energy



explain the effect of thermal conductivity and wall thickness



design and justify ways to insulate a home



BIG QUESTION An old filament lamp and an LED give out the same light. Why does the LED cost much less to run?

BY THE END YOU CAN

- calculate efficiency as a decimal and as a percentage
- explain why efficiency can never be more than 100%
- find the useful output or the total input from the efficiency
- draw and read Sankey diagrams
- describe ways to increase efficiency

efficiency

useful output

wasted output

total input

Sankey diagram

LAMPS

A filament lamp transfers only about 1 joule in every 10 by light. The rest heats the room. An LED transfers several times more of its energy by light, so it needs much less energy for the same brightness.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

A 2000 W heater is on for 30 s. Calculate the energy transferred.

2

Where does most wasted energy end up?

3

Give one way to reduce friction in a machine.



EXPLAIN

HOW MUCH IS USEFUL?

Efficiency tells you what fraction of the energy put into a device is transferred usefully. The rest is wasted, usually dissipated to the thermal store of the surroundings.

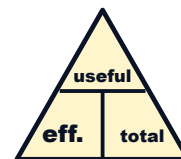
$$\text{efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$$

Energy in joules (J). Efficiency has no unit.

Answer as a decimal (for example 0.80), or multiply by 100 for a percentage (80%).

Rearranged: useful output = efficiency × total input, and

$$\text{total input} = \frac{\text{useful output}}{\text{efficiency}}$$



$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

The same idea, using power in watts (W).

Use whichever pair the question gives you: energies or powers.

! Efficiency is **never more than 1** (100%). If your answer is bigger than 1, you have divided the wrong way round. To use a percentage in a calculation, change it to a decimal first: 25% = 0.25.

WORKED EXAMPLE

A motor is supplied with 500 J and transfers 400 J to the kinetic store of its load. Calculate its efficiency.

KNOW useful = 400 J, total = 500 J

EQUATION $\text{efficiency} = \frac{\text{useful}}{\text{total}}$

SUBSTITUTE $\text{efficiency} = \frac{400}{500}$

ANSWER **0.80, or 80%**

YOUR TURN

A lamp is supplied with 60 J and transfers 12 J by light. Calculate its efficiency.

KNOW

EQUATION

SUBSTITUTE

ANSWER

WORKED EXAMPLE

A 60 W lamp has an efficiency of 25%.
Calculate its useful power output.

CONVERT efficiency = 25% = 0.25

REARRANGE $\text{useful} = \text{efficiency} \times \text{total}$

SUBSTITUTE $\text{useful} = 0.25 \times 60$

ANSWER **15 W**

YOUR TURN

A motor is 0.80 efficient. It transfers 400 J usefully. Calculate the total energy supplied.

KNOW

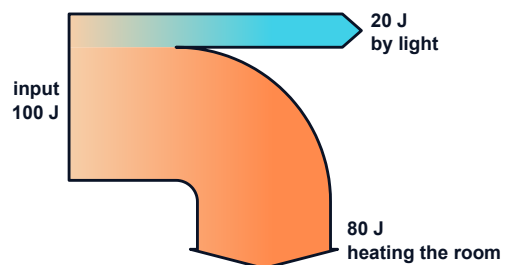
REARRANGE

SUBSTITUTE

ANSWER

SANKEY DIAGRAMS

- 1 The **width** of each arrow shows the amount of energy.
- 2 Useful energy goes **straight on**. Wasted energy **bends away**, usually downwards.
- 3 Input = useful + wasted. Here: 100 J = 20 J + 80 J.
- 4 Efficiency = $20 \div 100 = 0.20$ (20%).



INCREASING EFFICIENCY

Reduce the wasted energy: **lubricate** moving parts (less friction), **streamline** vehicles (less air resistance), **insulate** hot things (less energy transferred by heating), and choose devices that waste less, such as LEDs instead of filament lamps.



PRACTISE

TRY IT

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

An efficiency of 1.4 is

possible

impossible

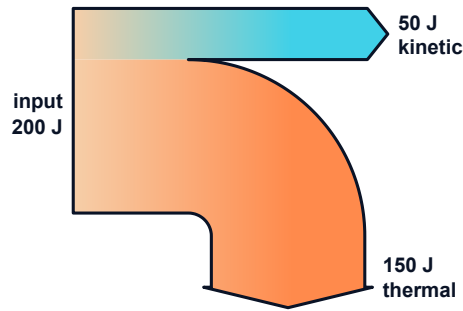
Efficiency has the unit

joules

watts

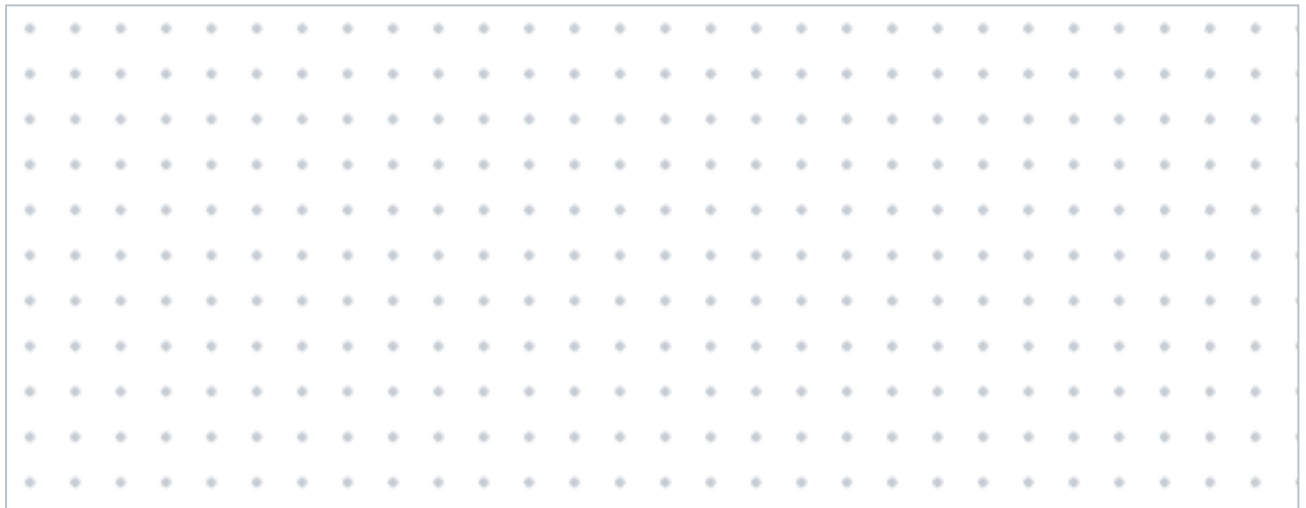
no unit

- 2 This is the Sankey diagram for an electric motor. Calculate its efficiency.



EQUATION	
SUBSTITUTE	
ANSWER	unit:

- 3 A kettle is supplied with 2000 J. It transfers 1800 J to the thermal store of the water, and 200 J heats the kettle and the room. Draw its Sankey diagram. Let 1 square = 100 J.



- 4 Complete the table. Show your working underneath.

Device	Total input	Useful output	Efficiency
TV	200 J	60 J	
Electric motor	1000 J		0.75
Solar panel		30 W	0.15



- 5 Complete the sentences. The choices are after each gap.
- Oiling the gears of a machine _____ (increases / decreases) its efficiency, because less energy is transferred by _____ (friction / light).
- An LED is _____ (more / less) efficient than a filament lamp, because _____ (more / less) energy is wasted heating the room.



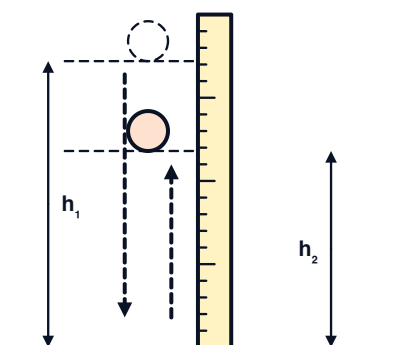
INVESTIGATE

PRACTICAL: HOW EFFICIENT IS A BOUNCE?

Filming the bounce against the ruler makes it much easier to read.

- 1 Measure the mass in kg. Drop the ball from 1.00 m.
- 2 Measure the height of the first bounce.
- 3 Repeat three times and find the mean bounce height.
- 4 Repeat with a different ball.

Measure both heights from the bottom of the ball. Use $E_p = mgh$ with $g = 9.8 \text{ N/kg}$ for each energy; then $\text{efficiency} = \frac{E_{p2}}{E_{p1}}$. Round only at the end.



- 6 Record your measurements.

Ball	Mass / kg	Drop / m	Bounce 1 / m	Bounce 2 / m	Bounce 3 / m	Mean / m
		1.00				
		1.00				

- 7 Calculate the two energies, then divide useful output by input.

Ball	Input E_{p1} / J	Useful E_{p2} / J	Efficiency

- 8 Where did the rest of the energy go?



Get the marks: Check: is your efficiency less than 1 (100%)?

- 9 A 1200 W hair dryer has a useful power output of 1080 W. Calculate its efficiency as a percentage. **[3 marks]**

EQUATION

SUBSTITUTE

ANSWER

unit:

- 10 Explain why an LED is more efficient than a filament lamp. **[2 marks]**

**SUMMARY**

- **efficiency** = $\frac{\text{useful output}}{\text{total input}}$, using energy or power.
- As a decimal (at most 1) or a percentage (at most 100%). No unit.
- $\text{useful} = \text{efficiency} \times \text{total}$; $\text{total} = \text{useful} \div \text{efficiency}$.
- Sankey diagrams: arrow width shows energy; wasted energy bends away.
- Higher: lubricate, streamline, insulate to increase efficiency.

COVER THE PAGE AND ANSWER

1 Write the equation for efficiency using energy.

2 A device transfers 30 J usefully from 120 J. What is its efficiency?

3 Why can efficiency never be more than 100%?

4 On a Sankey diagram, what does the width of an arrow show?

I CAN...

calculate efficiency as a decimal and a percentage



find the useful output or the total input



draw and read a Sankey diagram



describe ways to increase efficiency



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”.

Power [L7]: The rate of energy transfer: energy transferred per second

Watt (W) [L7]: The unit of power: $1\text{ W} = 1\text{ J/s}$

Lubrication [L8]: Oil or grease between moving parts, to reduce friction

Thermal conductivity [L8]: How fast a material transfers energy by conduction; higher means faster

Thermal insulator [L8]: A material with a low thermal conductivity

Efficiency [L9]: Useful output $\div$ total input; a decimal up to 1 or a percentage up to 100%

Sankey diagram [L9]: A diagram in which the width of each arrow shows the amount of energy

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
07: Power	
define power as the rate of energy transfer	☐ ☐ ☐
calculate $P = \frac{E}{t}$ and find E or t	☐ ☐ ☐
convert kW, kJ and minutes	☐ ☐ ☐
measure my own power	☐ ☐ ☐
08: Wasted energy	
explain what dissipated means	☐ ☐ ☐
explain how lubrication reduces wasted energy	☐ ☐ ☐
explain the effect of thermal conductivity and wall thickness	☐ ☐ ☐
design and justify ways to insulate a home	☐ ☐ ☐
09: Efficiency	
calculate efficiency as a decimal and a percentage	☐ ☐ ☐
find the useful output or the total input	☐ ☐ ☐
draw and read a Sankey diagram	☐ ☐ ☐
describe ways to increase efficiency	☐ ☐ ☐

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 7: POWER

DO NOW

1. $E_p = 50 \times 9.8 \times 3.0$
 $E_p = 1470 \text{ J}$
2. 120 s
3. Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.

COVER THE PAGE

1. The rate of energy transfer (energy transferred per second).
2. 1 joule per second.
3. 60 W
4. $E = P t$

LESSON 8: WASTED ENERGY

DO NOW

1. $P = 600 \div 20 = 30 \text{ W}$
2. thermal
3. Some energy is dissipated by air resistance and friction.

COVER THE PAGE

1. In the thermal store of the surroundings.
2. It reduces friction, so less energy is transferred to the thermal store.
3. The material transfers energy by conduction quickly.
4. Thicker walls; materials with a lower thermal conductivity (insulation).

LESSON 9: EFFICIENCY

DO NOW

1. $E = P t = 2000 \times 30 = 60\,000 \text{ J}$
2. The thermal store of the surroundings.
3. Lubricate it with oil or grease.

COVER THE PAGE

1. $\text{efficiency} = \text{useful output energy transfer} \div \text{total input energy transfer}$
2. 0.25 (25%)
3. Energy cannot be created: the useful output can never be more than the input.
4. The amount of energy.

EQUATION TOOLKIT

Every equation in the unit. 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 $E_p = mgh$, cover h . E_p is above m and g , so $h = \frac{E_p}{mg}$. Kinetic and elastic potential energy have no triangle: in this unit you only use them 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.

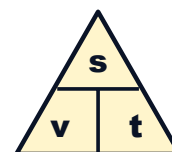
$$s = vt$$

Lesson 2

distance travelled = speed × time

m, m/s, s

$$v = \frac{s}{t} \text{ and } t = \frac{s}{v}$$



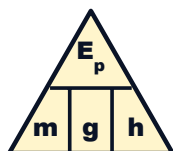
$$E_p = mgh$$

Lesson 3

gravitational potential energy = mass × gravitational field strength × height

J, kg, N/kg, m

$$h = \frac{E_p}{mg} \text{ and } m = \frac{E_p}{gh}$$



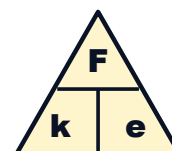
$$F = ke$$

Lesson 4

force = spring constant × extension

N, N/m, m

$$k = \frac{F}{e} \text{ and } e = \frac{F}{k}$$



$$E_e = \frac{1}{2} k e^2$$

Lesson 5

elastic potential energy = 0.5 × spring constant × (extension)²

J, N/m, m

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

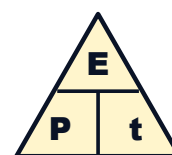
$$P = \frac{E}{t}$$

Lesson 7

power = energy transferred ÷ time

W, J, s

$$E = Pt \text{ and } t = \frac{E}{P}$$



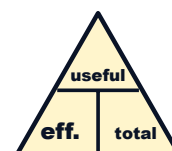
$$\text{eff.} = \frac{\text{useful output}}{\text{total input}}$$

Lesson 9

efficiency = useful output ÷ total input, using energy (J) or power (W)

no unit: a decimal up to 1, or × 100 for a percentage

$$\text{useful} = \text{eff.} \times \text{total}; \text{total} = \frac{\text{useful}}{\text{eff.}}$$



1

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

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?