

AQA GCSE Combined Science: Trilogy — Physics

Topic 18

Energy

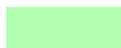
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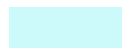
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define System

- an object or group of objects.

Define Energy store

- a way energy is held in a system (kinetic, thermal, chemical and so on).

Define Power

- the rate at which energy is transferred, or the rate at which work is done.

Define Dissipation

- energy stored in less useful ways, usually the thermal store of the surroundings; often called "wasted" energy.

Define Thermal conductivity

- the higher the thermal conductivity of a material, the higher the rate of energy transfer by conduction across it.

Define Renewable energy resource

- one that is being (or can be) replenished as it is used.

Define Closed system

- a system in which there is no net change to the total energy.

Define Energy transfer

- energy moving between stores: mechanically, electrically, by heating or by radiation.

Define Conservation of energy

- energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.

Define Specific heat capacity

- the amount of energy required to raise the temperature of one kilogram of a substance by one degree Celsius.

Define Efficiency

- the proportion of the total input energy transfer (or power input) transferred usefully.

Define Reliable energy resource

- one that can supply energy whenever it is needed.

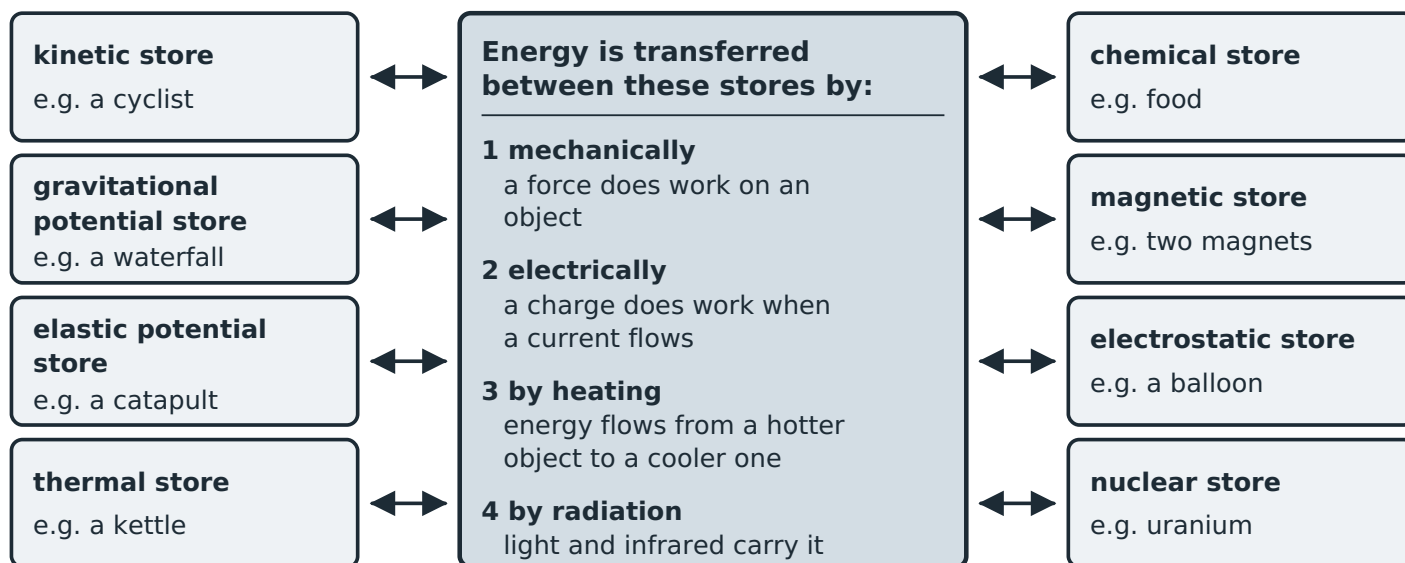
18.1 Energy changes in a system, and the ways energy is stored before and after such changes

18.1.1 Energy stores and systems

A **system** is an object or group of objects. There are changes in the way energy is stored when a system changes. The eight **energy stores**:

Energy store	Everyday example
Kinetic	A moving car
Gravitational potential	A book on a high shelf
Elastic potential	A stretched catapult
Thermal	A mug of hot tea
Chemical	Food, fuels, a battery
Magnetic	Two magnets held apart
Electrostatic	Two charged spheres held apart
Nuclear	Uranium fuel rods

Energy stores and transfers



Conservation of energy

Energy can be transferred usefully, stored or dissipated — it can never be created or destroyed. In a closed system there is no net change to the total energy: the total before a change is equal to the total after it. Dissipated energy is not lost — it is stored in less useful ways.

Energy is **transferred** between stores in four ways: **mechanically** (a force doing work), **electrically** (work done when a current flows), **by heating** and **by radiation** (such as light or sound).

Describe common changes as *store* → *store*:

- **Object projected upwards** — kinetic store empties, gravitational potential store fills.
- **Moving object hitting an obstacle** — kinetic store empties; thermal store of object, obstacle and surroundings fills (plus sound radiated).
- **Object accelerated by a constant force** — chemical store empties, kinetic store fills as the force does work.
- **Vehicle slowing down** — kinetic store empties; thermal store of the brakes and surroundings fills.
- **Bringing water to a boil in an electric kettle** — energy transferred electrically from the mains, then by heating; thermal store of the water fills.

Calculate the changes in energy when a system is changed by **heating**, by **work done by forces** and by **work done when a current flows**, and use those calculations to show on a common scale how the energy in a system is redistributed.

ANALOGY

Stores and transfers are like money in different bank accounts. Moving £50 from your current account to savings does not destroy the money — the total is unchanged, it is just stored elsewhere. Energy is never "used up"; it only moves between stores. Some always ends up in an account you cannot spend from: the thermal store of the surroundings.

18.1.2 Changes in energy

You must be able to calculate the energy associated with a moving object, a stretched spring and an object raised above ground level.

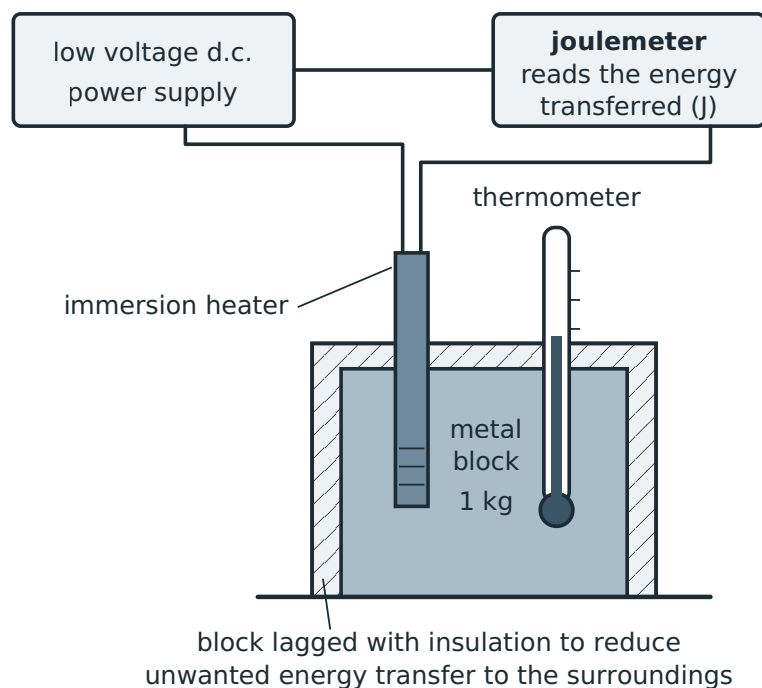
18.1.3 Energy changes in systems

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. A high value means it needs a lot of energy to warm up, and releases a lot as it cools.

ANALOGY

Specific heat capacity is like the width of a bucket. A wide bucket (water, 4200 J/kg °C) needs a lot poured in before the level rises 1 cm; a narrow bucket (copper, 385 J/kg °C) rises quickly. What you pour in is energy; the level is temperature.

Apparatus for the specific heat capacity practical



No joulemeter? Put an ammeter in series and a voltmeter across the heater, then $E = V \times I \times t$

Variables

Independent variable

the energy transferred to the block, read from the joulemeter (J)

Dependent variable

the temperature of the block (°C), read from the thermometer

Control variables

the mass and material of the block, the power of the heater, the insulation, the starting temperature and the room temperature

Equation used

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

ΔE = change in thermal energy, J

m = mass, kg

c = specific heat capacity, J/kg °C

$\Delta \theta$ = temperature change, °C

Rearranged: $c = \Delta E \div (m \times \Delta \theta)$

18.1.4 Power

Power is the rate at which energy is transferred, or the rate at which work is done. An energy transfer of 1 joule per second equals a power of 1 watt.

WATCH OUT

Power is not energy. Power is how *fast* energy is transferred, not how much. Two motors lifting the same load the same height transfer the same energy (joules), but the faster one has greater power (watts). Never write "the lamp uses 60 J of power".

18.2 Conservation and dissipation of energy

18.2.1 Energy transfers in a system

Energy can be transferred usefully, stored or dissipated, but **cannot be created or destroyed**.

- In a **closed system** there is no net change to the total energy — for example a sealed vacuum flask of hot water, or a pendulum plus the air around it.
- In all system changes some energy is **dissipated**, stored in less useful ways; this energy is often described as being "**wasted**". It usually ends up in the thermal store of the surroundings, spread too thinly to be used again.

Reducing unwanted energy transfers

- **Lubrication** — oil or grease between moving surfaces reduces friction, so less energy is dissipated to the thermal store of the surroundings.
- **Thermal insulation** — cavity wall insulation, loft insulation and double glazing reduce the rate of energy transfer out of a building.
- Streamlining and smoother surfaces also reduce friction and air resistance.

Thermal conductivity and the rate of cooling of a building

- The higher the **thermal conductivity** of a material, the higher the rate of energy transfer by conduction across the material. (You do not need to know the definition of thermal conductivity.)
- A building with walls of **low thermal conductivity**, or with **thicker** walls, cools **more slowly** — energy is conducted out at a lower rate.
- So the best walls are thick and made of low thermal conductivity material — exactly what cavity wall and loft insulation provide.

ANALOGY

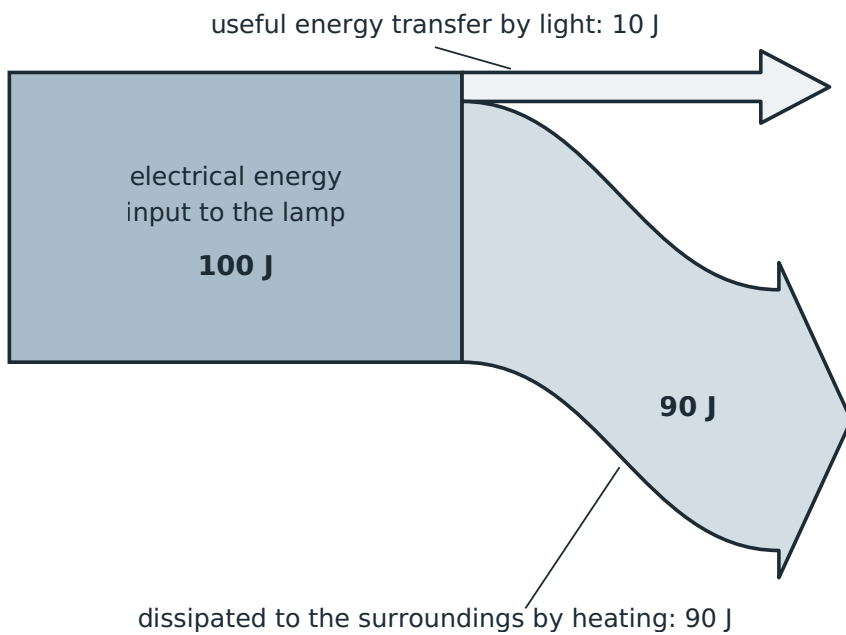
Dissipation is like dropping a bag of sugar. Not one grain is destroyed, but it is spread so thinly across the room that you will never scoop it back. Dissipated energy is still there, just too spread out to be useful.

WATCH OUT

Energy is never "lost". Energy cannot be created or destroyed, so never write "energy is lost" or "used up". Write "**energy is dissipated to the surroundings**" or "transferred to the thermal store of the surroundings". Marks are dropped for this alone.

18.2.2 Efficiency

A Sankey diagram and efficiency



Efficiency

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

(or useful power output ÷ total power input)

$$\text{efficiency} = 10 \text{ J} \div 100 \text{ J} = 0.1$$

$$\text{efficiency} = 10\%$$

Only 10 J in every 100 J is transferred usefully by light.

The other 90 J is dissipated to the surroundings by heating, which warm up slightly.

ANALOGY

Efficiency is like the useful part of your wages: earn £800, spend £320 on things you actually wanted, and you are 40% efficient. The rest has not vanished, it has just gone where you get no benefit — wasted energy is dissipated, not destroyed.

HIGHER TIER

HT ONLY Ways to increase the efficiency of an intended energy transfer: lubricate moving parts to reduce friction, insulate to reduce energy transfer by heating, streamline to reduce air resistance, and use lower-resistance wires that dissipate less energy.

18.3 National and global energy resources

The main energy resources available for use on Earth include: **fossil fuels (coal, oil and gas), nuclear fuel, bio-fuel, wind, hydro-electricity, geothermal, the tides, the Sun and water waves.**

A **renewable** energy resource is one that is being (or can be) replenished as it is used. Fossil fuels and nuclear fuel are **non-renewable**.

The **uses** of energy resources are: **transport, electricity generation and heating.**

Resource	Renewable?	Reliable?	Environmental impact	Cost
Fossil fuels (coal, oil, gas)	No	Yes, on demand	CO ₂ (global warming), sulfur dioxide (acid rain); oil spills; mining damage	Low build, rising fuel cost
Nuclear fuel	No	Yes, steady output	No CO ₂ in use; radioactive waste stored for a very long time; small accident risk	Very high build and decommissioning
Bio-fuel	Yes	Fairly — can be stored	Roughly carbon neutral; land cleared for crops, habitat loss	Moderate
Wind	Yes	No — needs wind	No pollutants in use; visual and noise pollution; hazard to birds	High build, no fuel cost
Hydro- electricity	Yes	Yes — stored behind a dam	Valleys flooded, habitats destroyed, people displaced	Very high build, no fuel cost
Geothermal	Yes	Yes — continuous	Very low; only in volcanically active areas	High drilling, no fuel cost
Tides	Yes	Yes — predictable	Barrages damage estuary habitats	Very high build
The Sun (solar)	Yes	No — none at night	No pollutants in use; manufacture uses raw materials	High build, no fuel cost
Water waves	Yes	No — weather-dependent	Small; may affect coastal habitats	High, still developing

Reliability. Fossil fuels, nuclear, biofuel, geothermal, hydro-electricity and the tides supply energy whenever it is needed. Wind, solar and water waves depend on the weather or time of day, so are **less reliable** and need a backup supply. Transport relies almost entirely on fossil fuels and biofuels; heating uses gas, electricity, biofuel and solar.

Patterns and trends. UK use of renewables has risen sharply and coal use has fallen, because of concern about global warming, government targets and the falling cost of wind and solar. Global energy use is still rising, and fossil fuel supplies are finite.

Why the problem is not simply solved. Science can **identify** environmental issues arising from the use of energy resources, but does not always have the **power to deal with** them, because of **political, social, ethical and economic** considerations:

- **Political** — international agreements are hard to reach and enforce; countries disagree on who should cut emissions.
- **Social** — people object to wind farms and dams near their homes; jobs are lost when mines and power stations close.
- **Ethical** — is it fair to ask developing countries to give up cheap fossil fuels that richer countries have already burnt, or to leave nuclear waste to future generations?
- **Economic** — renewables have very high build costs, fossil fuels are cheaper in the short term, and energy prices affect every household.

NOTE

Descriptions of **how** energy resources are used to generate electricity are **not required** by the specification — only the comparison of resources, uses, reliability, environmental impact and cost.