Edexcel GCSE Physics

Your notes

Conservation of Energy

Contents

Gravitational Potential Energy

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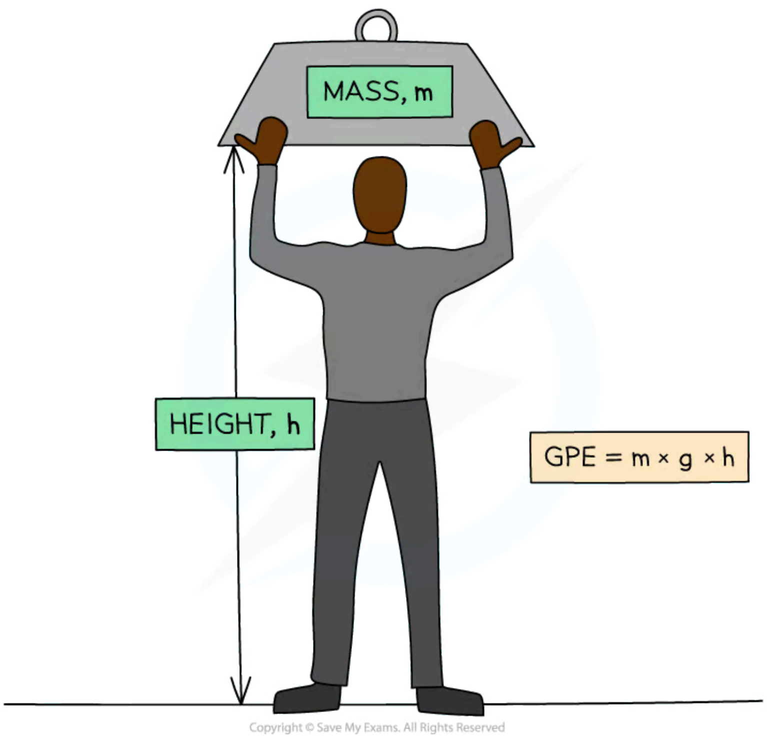
Gravitational Potential Energy

- Energy in the **gravitational store** of an object is defined as:

  The energy an object has due to its height in a gravitational field

- This means:
  - If an object is **lifted** up, energy is **transferred to** its gravitational potential store
  - If an object **falls**, energy will be **transferred away from** its gravitational potential store



- The change in the gravitational potential energy, ΔGPE of an object can be calculated using the equation:

$$\Delta GPE = m \times g \times \Delta h$$

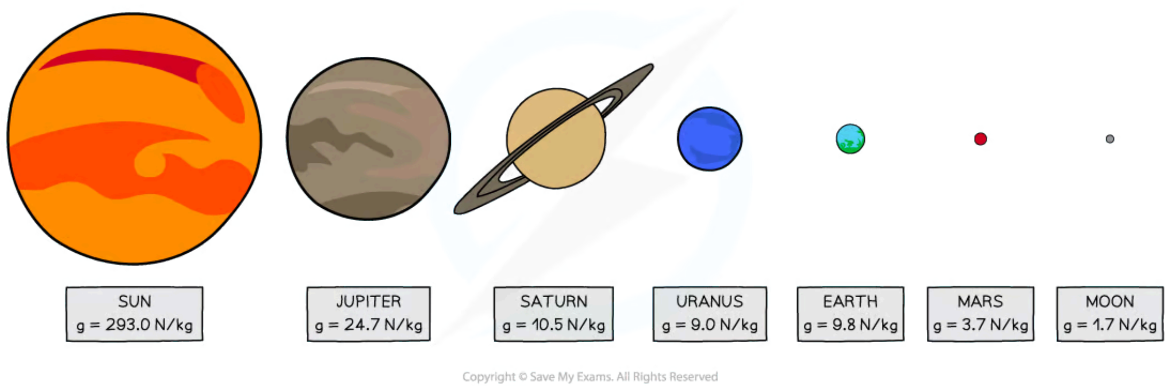
- Where:
  - ΔGPE = change in gravitational potential energy, in joules (J)

- m = mass, in kilograms (kg)
- g = gravitational field strength in newtons per kilogram (N/kg)
- Δh = change in vertical height in metres (m)

- In Physics, Δ is the capital Greek letter 'delta' which stands for 'change in'

Gravitational Field Strength

- The gravitational field strength (g) on the **Earth** is approximately 10 N/kg
- The gravitational field strength on the surface of the **Moon** is **less** than on the Earth
  - This means it would be **easier** to lift a mass on the Moon than on the Earth
- The gravitational field strength on the surface of the gas giants (eg. Jupiter and Saturn) is **more** than on the Earth
  - This means it would be **harder** to lift a mass on the gas giants than on the Earth



Some values for g on the different objects in the Solar System

Worked Example

A man of mass 70 kg climbs a flight of stairs that is 3 m higher than the floor.

Gravitational field strength is approximately 10 N/kg.

Calculate the increase in energy in his gravitational potential store.

Answer:

Your notes

Step 1: List the known quantities

- Mass of the man, $m = 70$ kg
- Gravitational field strength, $g = 10$ N/kg
- Change in height, $\Delta h = 3$ m

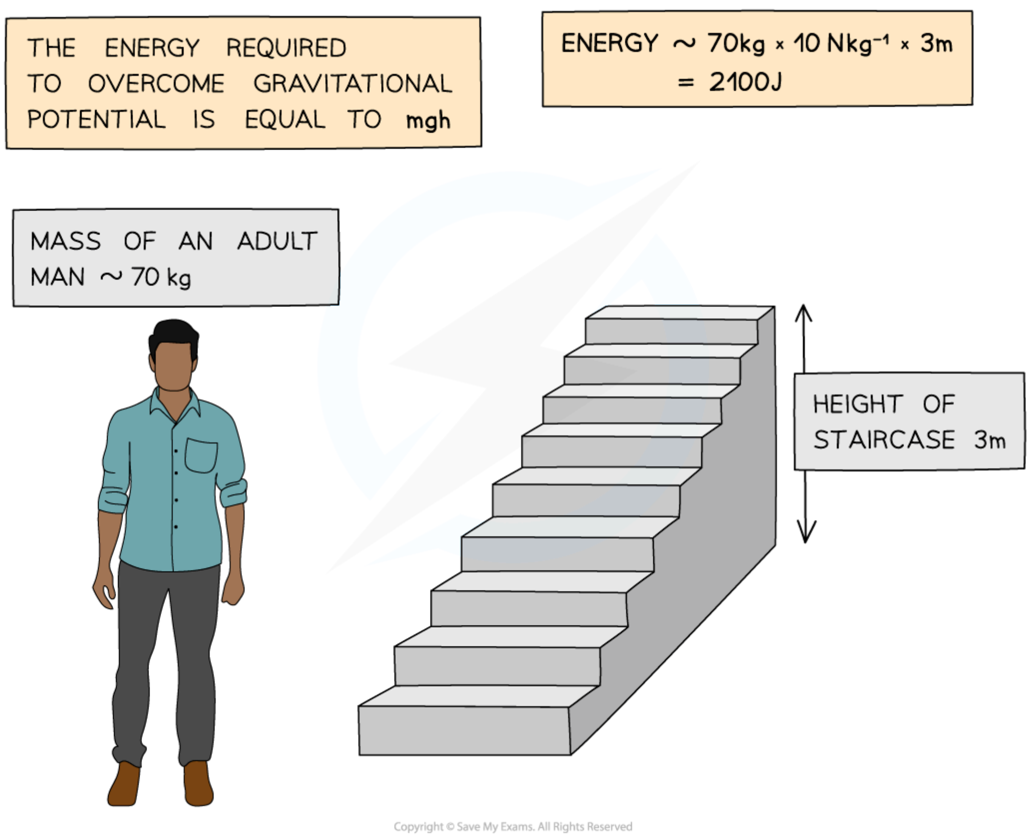
Step 2: Write down the equation for gravitational potential energy

$$\Delta GPE = m \times g \times \Delta h$$

Step 3: Calculate the gravitational potential energy

$$\Delta GPE = 70 \times 10 \times 3$$

$$\Delta GPE = 2100 \text{ J}$$



Examiner Tips and Tricks

When doing calculations involving gravitational field strength, *g*, always use the value of 10 N/kg unless you are told otherwise in your exam question. You will be expected to remember the value of *g* for your exam!

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Kinetic Energy

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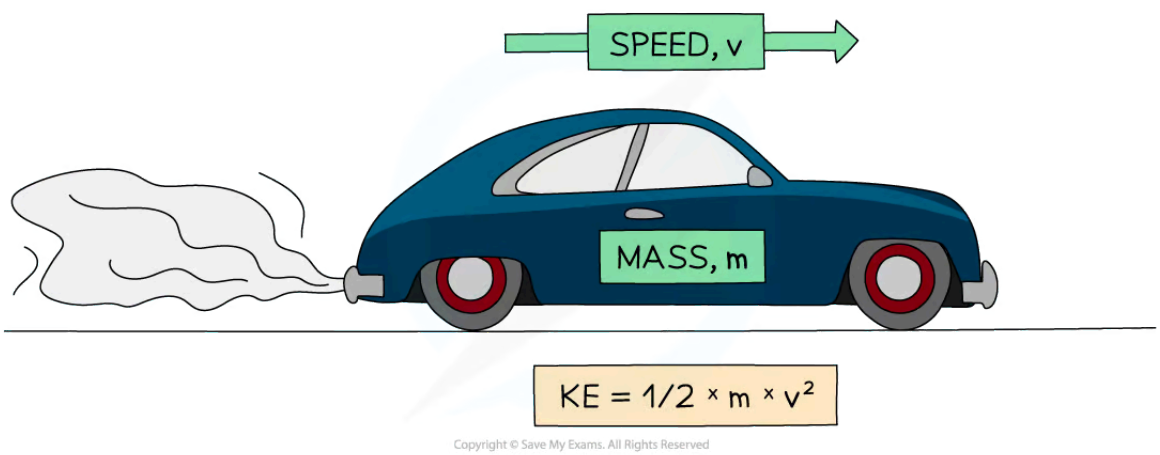
Kinetic Energy

- Energy in an object's kinetic store is defined as:

  The amount of energy an object has as a result of its mass and speed

- This means that any object in **motion** has energy in its kinetic energy store



- Kinetic energy can be calculated using the equation:

$$KE = \frac{1}{2} \times m \times v^2$$

- Where:
  - KE = kinetic energy in joules (J)
  - *m* = mass of the object in kilograms (kg)
  - *v* = speed of the object in metres per second (m/s)

Worked Example

Calculate the kinetic energy stored in a vehicle of mass 1200 kg moving at a speed of 27 m/s.

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Answer:

Step 1: List the known quantities

- Mass of the vehicle, m = 1200 kg
- Speed of the vehicle, v = 27 m/s

Step 2: Write down the equation for kinetic energy

$$KE = \frac{1}{2} \times m \times v^2$$

Step 3: Calculate the kinetic energy

$$KE = \frac{1}{2} \times 1200 \times (27)^2$$

$$KE = 437\,400 \text{ J}$$

Step 4: Round the final answer to 2 significant figures

$$KE = 440\,000 \text{ J}$$

Examiner Tips and Tricks

When performing calculations using the kinetic energy equation, always double-check that you have squared the speed. Forgetting to do this is the most common mistake that students make.

Conservation of Energy

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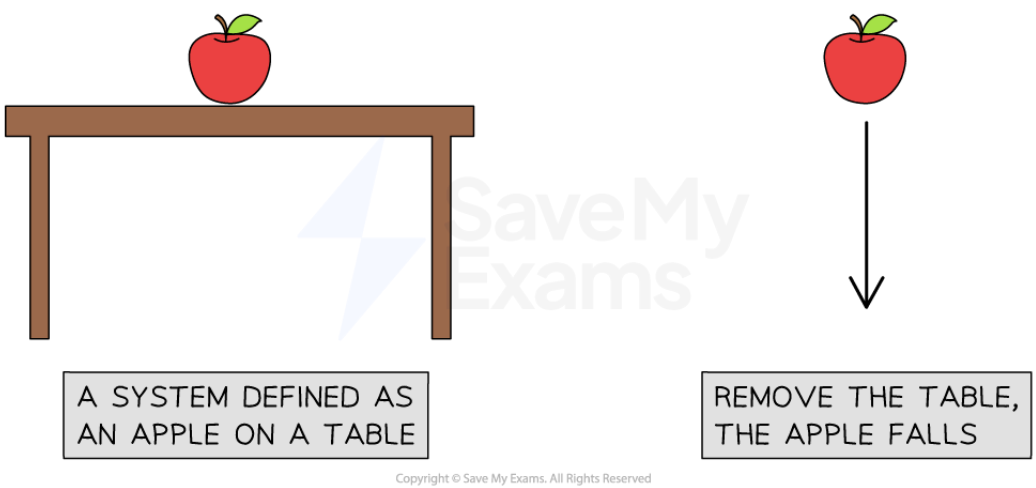
Closed Systems

- In physics, a system is defined as:

  An object or group of objects

- Defining a system in physics is a way of narrowing the parameters to focus only on what is relevant to the situation being observed
- When a system is in equilibrium, nothing changes and so nothing happens
- When there is a change in a system, energy is transferred
- An apple sitting on a table can be defined as a system
- If nothing changes, the apple will just sit there
- If the table is removed, the apple will fall
- As the apple falls, energy is transferred



A change in a system causes a transfer of energy from the apple's gravitational potential store to its kinetic store

- Energy is measured in units of **joules (J)**

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- A **closed system** is defined as:

  A system where there is no net change to the total energy in that system

- As a result, the total amount of energy within that system must remain **constant**
  - This is due to the **conservation of energy**

Conservation of Energy

- The principle of conservation of energy states that:

  Energy cannot be created or destroyed, it can only be transferred from one store to another

- This means the total amount of energy in a **closed system** remains **constant**
- The **total energy** transferred **in**to a system must be **equal** to the **total energy** transferred **out** of the system
- Therefore, energy is never 'lost' but it can be transferred to the surroundings
  - Energy can be **dissipated** (spread out) to the surroundings by heating and radiation
  - Dissipated energy transfers are often **not useful**, and can then be described as **wasted** energy

Energy Stores

- Energy is stored in objects in different **energy stores**

Energy Stores Table

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Energy store	Description
Kinetic	Moving objects have energy in their kinetic store
Gravitational	Objects gain energy in their gravitational potential store when they are lifted above ground
Elastic	Objects have energy in their elastic potential store if they are stretched
Electrostatic	Objects with charge (like electrons and protons) interacting with one another have energy in their electrostatic store
Magnetic	Magnetic interacting with each other have energy in their magnetic store
Chemical	Objects with energy in their chemical store can release energy in chemical reactions
Nuclear	Atomic nuclei release energy from their nuclear store during nuclear reactions
Thermal	All objects have energy in their thermal store, the hotter the object, the more energy it has in this store

Energy Transfer Pathways

- Energy is **transferred** between stores via **transfer pathways**
- Examples of these are:
  - Mechanically

- Electrically
- By heating
- By radiation
- These are described in the table below:

Energy Transfer Pathway Table

Transfer Pathway	Description
Mechanical working	When a force acts on an object e.g. pulling, pushing, stretching, squashing
Electrical working	A charge (current) moving through a potential difference e.g. charge flowing around a circuit
Heating by particles	Energy is transferred from a hotter object to a colder one
Heating by radiation	Energy transferred by electromagnetic waves e.g. light

- An example of an energy transfer is a hot coffee heating cold hands

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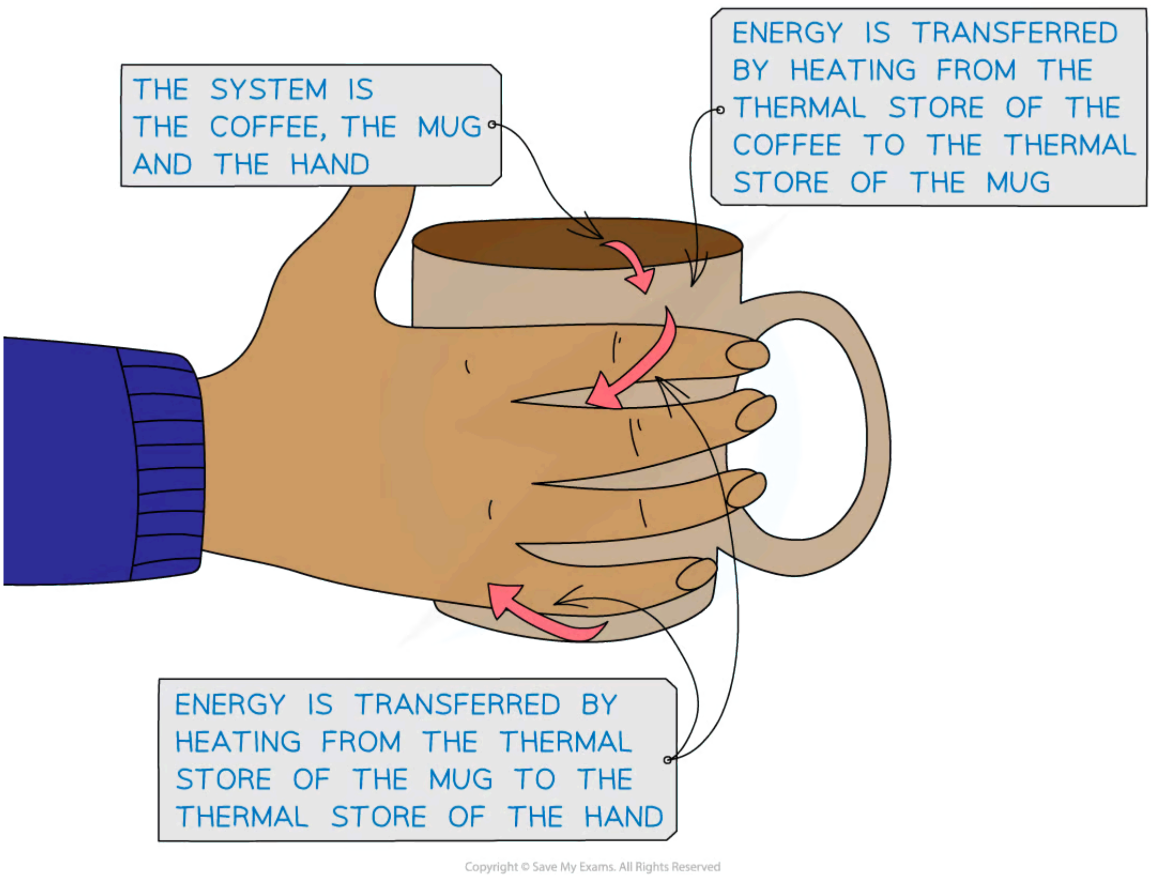

Energy is transferred by heating from the hot coffee to the mug to the cold hands

Representing Energy Transfers

Energy Flow Diagrams

- Energy stores and transfers can be represented using a flow diagram
  - This shows both the stores and the transfers taking place within a system

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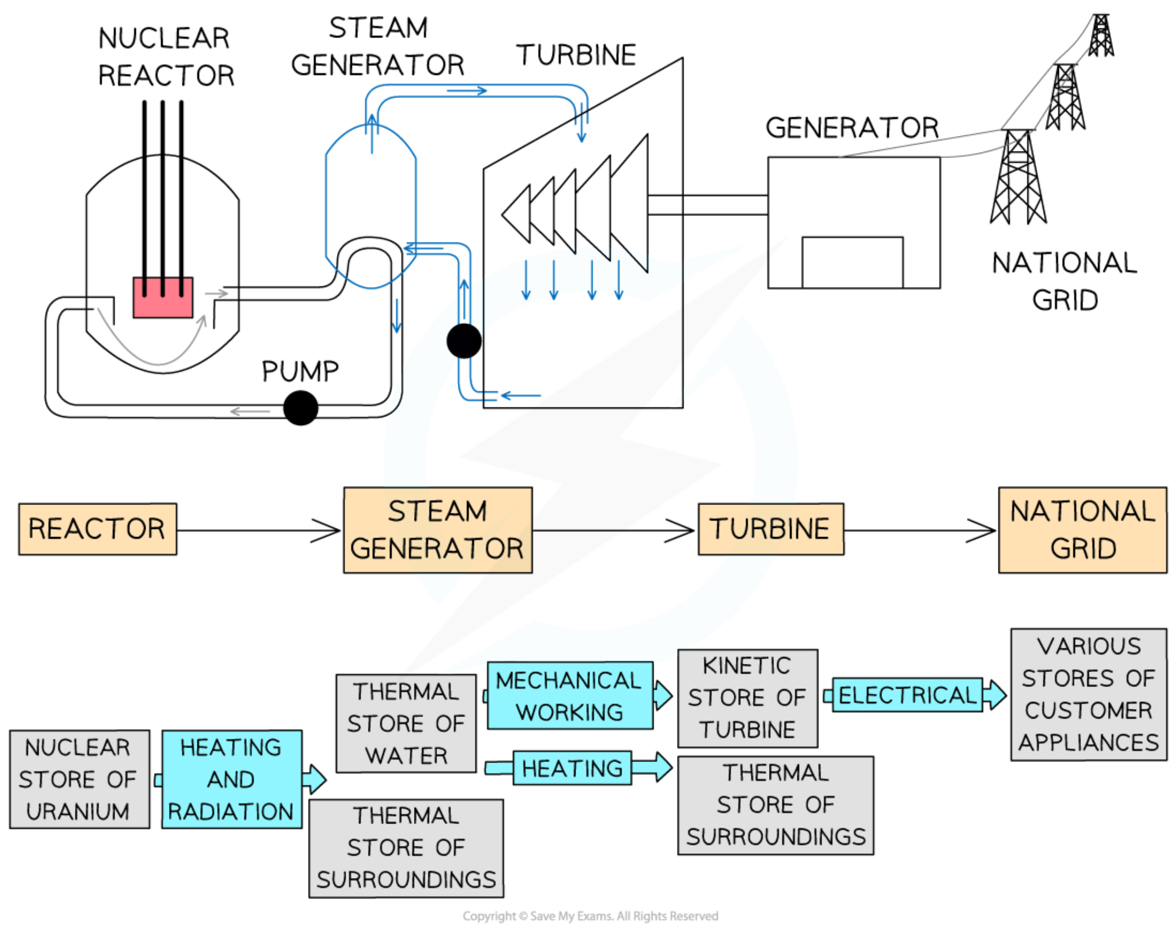

Energy flow diagram showing energy stores and transfers in a nuclear power plant.

Note the colour difference of the labels (stores) and the arrows (transfer pathways)

Sankey Diagrams

- **Sankey diagrams** can be used to represent energy transfers
  - Sankey diagrams are characterised by the splitting arrows that show the proportions of the energy transfers taking place
- The different parts of the arrow in a Sankey diagram represent the different energy transfers:
  - The left-hand side of the arrow (the flat end) represents the energy transferred **into** the system

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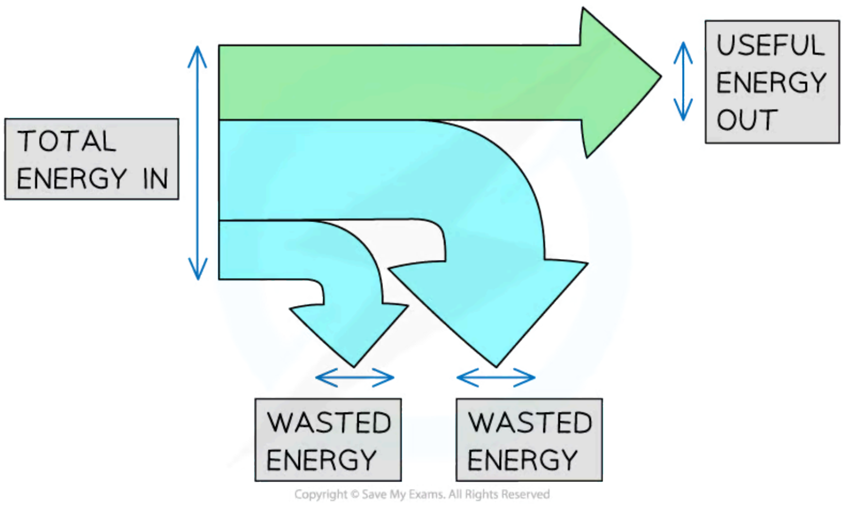
- The straight arrow pointing to the right represents the energy that ends up in the desired store; this is the **useful energy output**
- The arrows that bend away represent the **wasted energy**

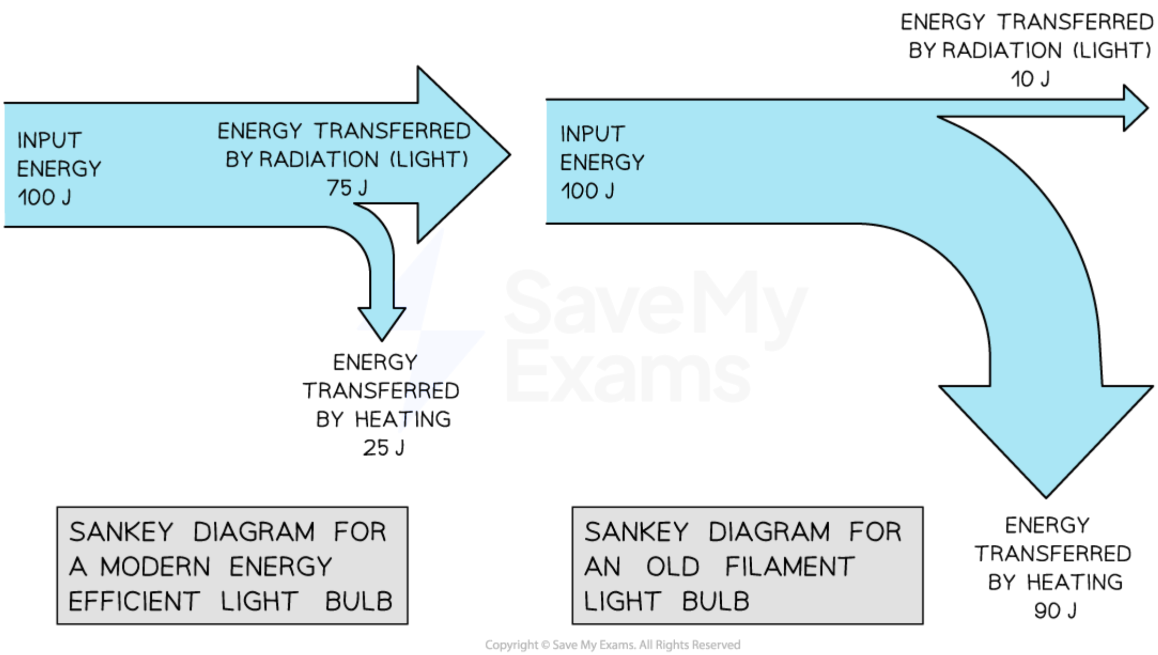


Total energy in, wasted energy and useful energy out shown on a Sankey diagram

- The width of each arrow is proportional to the amount of energy being transferred
- As a result of the conversation of energy:

Total energy in = Useful energy out + Wasted energy

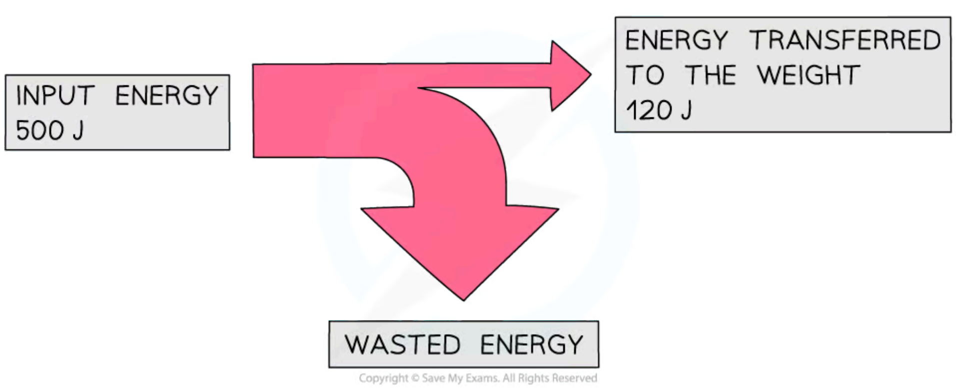
- A Sankey diagram for a modern efficient light bulb will look very different from that for an old filament light bulb
- A more efficient light bulb has **less** wasted energy
  - This is shown by the smaller arrow downwards representing the heat energy



Sankey diagram for modern vs. old filament light bulb

Worked Example

An electric motor is used to lift a weight. The diagram represents the energy transfers in the system.



Calculate the amount of wasted energy.

Answer:

Step 1: State the conservation of energy

- Energy cannot be created or destroyed, it can only be transferred from one store to another
- This means that:

$$\text{Total energy in} = \text{Useful energy out} + \text{Wasted energy}$$

Step 2: Rearrange the equation for the wasted energy

$$\text{Wasted energy} = \text{Total energy in} - \text{Useful energy out}$$

Step 3: Substitute the values from the diagram

$$500 - 120 = \mathbf{380\ J}$$

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Examples of Energy Transfers

Examples of Energy Transfers

- Energy transfers occur all the time in various everyday circumstances
- Some common situations include when:
  - An object projected upwards or up a slope
  - A moving object hitting an obstacle
  - An object being accelerated by a constant force
  - A vehicle slowing down
  - Bringing water to a boil in an electric kettle

An Object Projected Upwards

- Before the ball is thrown upwards, the person holding the ball has **energy** in their **chemical store**
- When the ball is thrown, some of that **energy** is transferred to the **kinetic store** of the ball as it begins to **move** upwards
- As the **height** of the ball increases, **energy** from the **kinetic store** of the ball is transferred to its **gravitational potential store**

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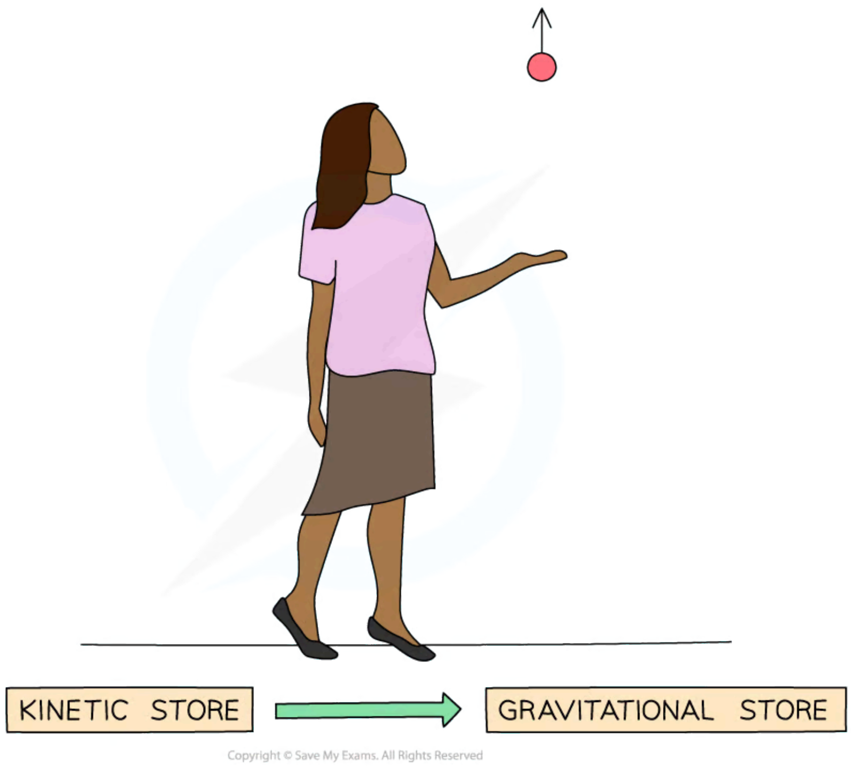

A Moving Object Hitting an Obstacle

- When an object, such as a car, is **moving**, **energy** in the chemical store of the **fuel** is transferred to the **kinetic store** of the car
- If the object hits an obstacle, such as a car hitting a wall, the **speed** of the car will **decrease** very quickly
  - Therefore, the energy in its **kinetic store** will **decrease**
- In this scenario, most of the energy from its **kinetic store** is transferred to the **thermal store** of the surroundings (**dissipated**)
- Energy is transferred **mechanically** to the thermal store of the wall (the **force** of the car on the wall)
- Energy is also transferred by **heating** to the thermal store of the air as the **sound waves** transfer energy away from the system (causing the air particles to vibrate)

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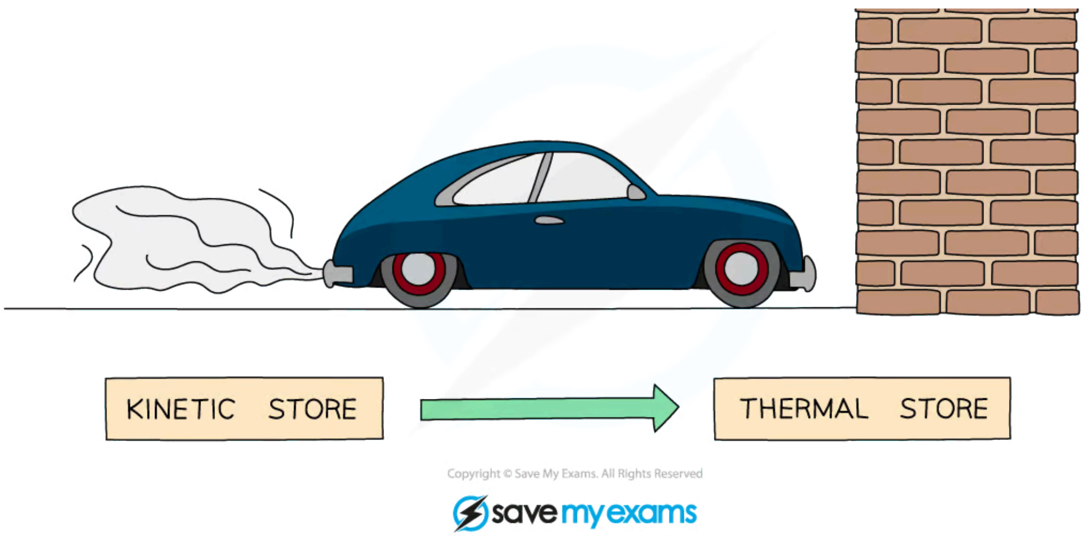
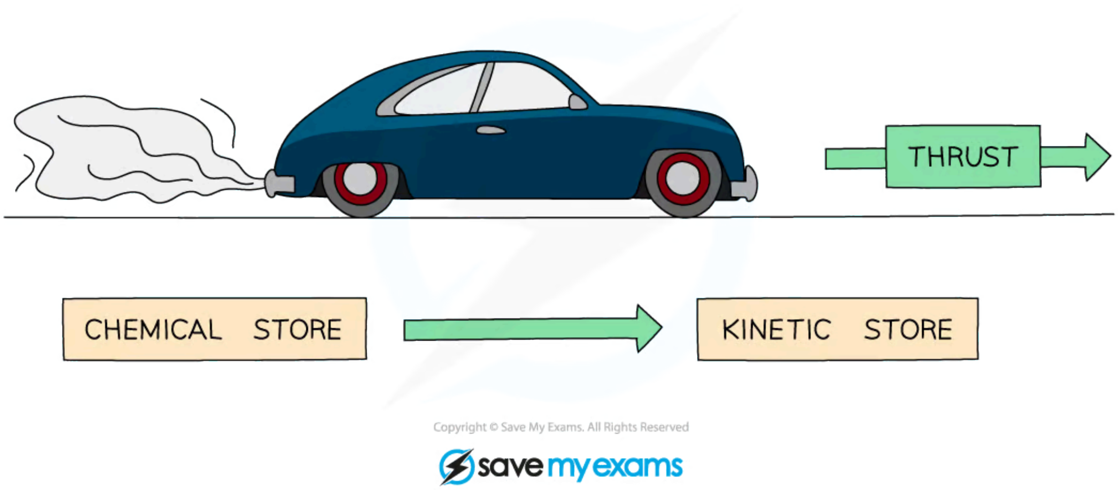


A Vehicle Being Accelerated by a Constant Force

- When an object, such as a vehicle is **stationary**, it has energy in the **chemical store** of the fuel
- When the vehicle speeds up or **accelerates**, the **energy** is transferred to the **kinetic store** of the car



A Vehicle Slowing Down

- When a vehicle is **moving**, it has energy in its **kinetic store**

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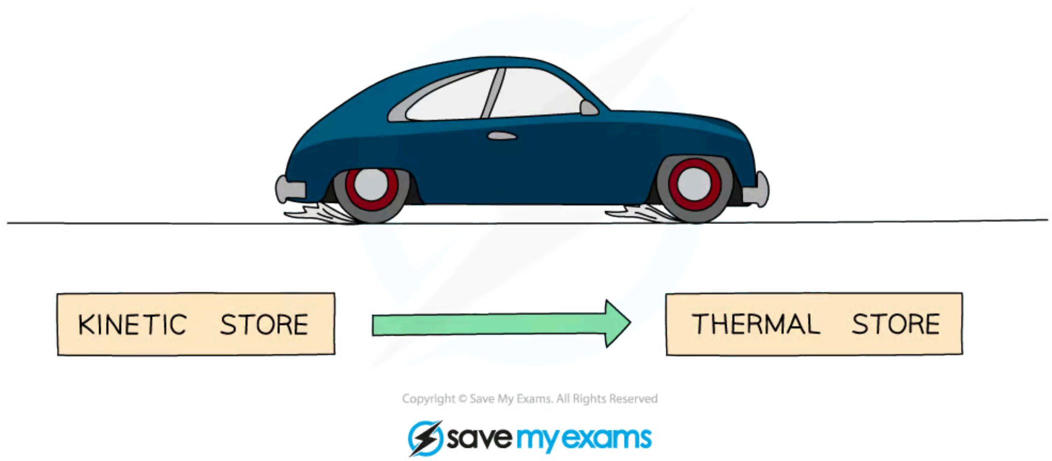
- As it slows down or **decelerates**, **energy** is transferred to the **thermal store** of the surroundings (**dissipated**)
- This energy is transferred **by heating** due to **friction** between the tyres and the ground, and due to **friction** between the brakes and the brake pads
- Energy is also transferred **by heating** as the **sound waves** transfer energy away from the system (making the air particles vibrate)



Boiling Water in an Electric Kettle

- When an electric kettle boils water, **energy** is transferred **electrically** from the mains supply to the **thermal store** of the heating element inside the kettle
- As the heating element gets hotter, **energy** is transferred **by heating** to the **thermal store** of the water

Your notes

Trampoline

- Whilst jumping, the person has energy in their **kinetic** store
- When the person lands on the trampoline, most of that energy is transferred to the **elastic potential** store of the trampoline
- That energy is transferred usefully back to the **kinetic** store of the person as they bounce upwards
- Energy is transferred from the kinetic store of the person to the **gravitational potential** store of the person as they gain height
- Some of the energy is dissipated **by heating** to the **thermal** store of the surroundings (the person, the trampoline and the air)
- The useful energy transfers taking place are:

elastic potential energy → kinetic energy → gravitational potential energy

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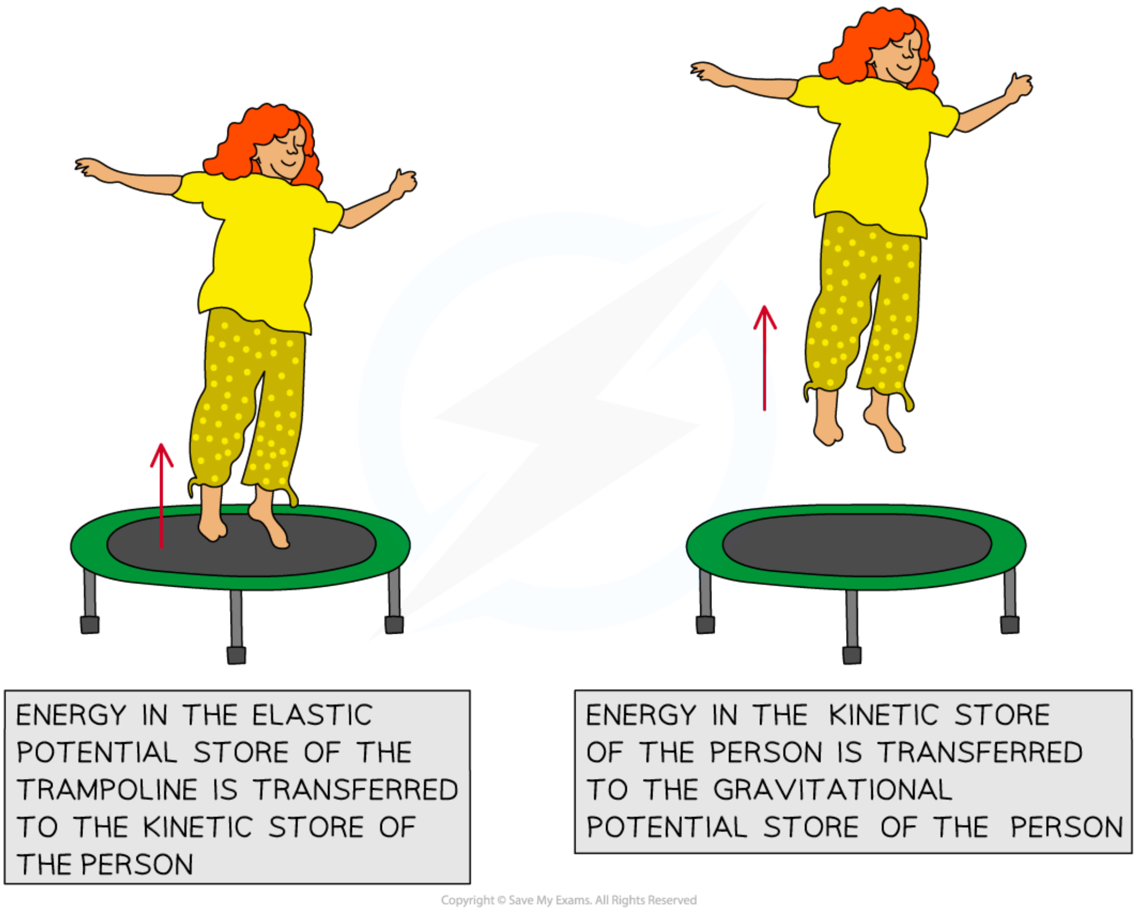

Energy transfers taking place when a person jumps on a trampoline

Worked Example

Describe the energy transfers in the following scenarios:

a) A battery powering a torch

b) A falling object

Answer:

Part (a)

Your notes

Step 1: Determine the store that energy is being transferred away from, within the parameters described by the defined system

- For a battery powering a torch
- The system is defined as the energy transfer from the battery to the torch, so this is the transfer to focus on
- Therefore, the energy began in the chemical store of the cells of the battery

Step 2: Determine the store that energy is transferred to, within the parameters described by the defined system

- When the circuit is closed, the bulb lights up
- Therefore, energy is transferred to the thermal store of the bulb
- Energy is then transferred from the bulb to the surroundings, but this is not described in the parameters of the system

Step 3: Determine the transfer pathway

- Energy is transferred by the flow of charge around the circuit
- Therefore, the transfer pathway is electrical

Energy is transferred **electrically** from the **chemical store** of the battery to the **thermal store** of the bulb

Part (b)

Step 1: Determine the store that energy is being transferred away from, within the parameters described by the defined system

- For a falling object
- In order to fall, the object must have been raised to a height
- Therefore, it began with energy in its gravitational potential store

Step 2: Determine the store that energy is transferred to, within the parameters described by the defined system

- As the object falls, it is moving
- Therefore, energy is being transferred to its kinetic store

Step 3: Determine the transfer pathway

- For an object to fall, a resultant force must be acting on it, and that force is weight, and it acts over a distance (the height of the fall)
- Therefore, the transfer pathway is mechanical

Energy is transferred from the **gravitational store** to the **kinetic store** of the object via a **mechanical** transfer pathway

Examiner Tips and Tricks

Don't worry too much about the parameters of the system. They are there to help you keep your answers concise so you don't end up wasting time in your exam.

If you follow any process back far enough, you would get many energy transfers taking place. For example, an electric kettle heating water. The relevant energy transfer is from the thermal store of the kettle to the thermal store of the water, with some energy dissipated to the surroundings. But you could take it all the way back to how the electricity was generated in the first place. This is beyond the scope of the question. Defining the system gives you a starting point and a stopping point for the energy transfers you need to consider.

Your notes