Energy Transfers and Efficiency
Energy Transfers and Efficiency

- How is energy transferred?
  - Conservation of energy
- How is energy wasted?
  - Reducing wasted thermal energy
- Energy efficiency
- Summary activities
Energy comes in many different forms. Doing something often involves changing energy from one form to another.

For example, cars are designed to move by transferring the chemical energy of fuel into kinetic energy.

This is a useful transfer of energy.
Energy can be stored

Transferred energy can be stored. Stored energy is also called potential energy.

A stretched spring has elastic potential energy.

A book on a shelf has gravitational potential energy.

This type of energy transfer is usually reversible.

When a stretched spring is released, the stored elastic potential energy is transferred into kinetic energy and the spring moves.
Energy can be dissipated

In an energy transfer, energy can also be **dissipated**, or spread out.

This tea dissipates **heat energy** to its surroundings.

The surroundings get a little hotter, and the tea gets a lot colder.

What other examples of energy being dissipated can you think of?
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Energy can be usefully transferred, stored or dissipated. However, energy *never* just disappears or appears.

In other words, the **total** amount of energy in a closed system (a system that is isolated from its surroundings) **always** stays the same.

\[
\text{total input energy} = \text{total output energy}
\]

This is called the **principle of conservation of energy**.

Energy is always conserved. It cannot be created or destroyed.

In **all** energy transfers, some energy is dissipated. Usually, this energy is considered **wasted**.
Think of a pendulum.

6. At the top of its swing, all KE has been converted back into GPE.
If all energy is **conserved**, why doesn’t the pendulum swing back and forth forever?

The pendulum stops because energy is being **dissipated** by air resistance.

When the pendulum swings, it pushes air molecules out of the way. Colliding with air molecules transfers energy.

Eventually, all of the kinetic energy of the pendulum is dissipated and it stops moving.

**Remember**: in all changing systems, energy is being dissipated.
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How is energy wasted?

This cordless drill transfers the chemical energy of the battery into kinetic, sound and heat energy.

The kinetic energy can be used to do useful work, but the sound and heat energy cannot.

Energy that does not do useful work is called wasted energy.

Appliances usually waste energy as sound and heat.

All electrical devices produce a small amount of heat energy when they are used, which is normally wasted.
If a device makes noise but is not designed to make noise, then energy is being wasted as **sound**.

Examples of devices that waste energy as sound include:
If a device gets warm but it is not designed to get warm, then energy is wasted as *heat*.

Examples of devices that waste energy as heat include:
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Which type of energy is wasted?
Reducing wasted energy

Energy dissipated as **thermal energy**, or **heat**, is often not useful. There are ways to **reduce** the amount of energy wasted.

For example, adding oil to the gear chain on a bike will reduce the amount of energy wasted.

Bike chains are used to transfer energy from the pedals to the wheels.

Some of that **kinetic energy** is dissipated as heat. Adding a lubricant reduces friction and means that **less** energy is wasted.
Conduction

One of the ways that thermal energy can be transferred is conduction.

Different materials conduct heat differently. **Thermal conductivity** is a measure of how good a material is at conducting heat.

The higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material.

For example, **metals** have good thermal conductivity. This makes metals a good choice of material for cooking equipment.
What are thermal insulators?

Materials that are very poor at conducting heat are called thermal insulators.

Examples of materials that are thermal insulators include plastics, wood, ceramics and air.

Air becomes a very effective insulator when it is trapped and stopped from moving.

This is how clothes keep people warm – air is trapped between the fibres and so acts as an insulator.

Other insulating materials, including polystyrene and loft insulation, utilise trapped air because it is so effective as an insulator.
Factors affecting thermal insulation
A poorly-insulated house dissipates heat energy quickly and so costs more to keep warm.

A **thermogram** can be used to show where heat energy is escaping.

The white, yellow and red areas show the **warmest** and therefore the **worst insulated** parts of the house.

The blue and green areas show the **coolest** and **best insulated** parts of the house.
Wasted energy from buildings

It is important not to waste energy. Reducing the amount of thermal energy lost from a building to the surroundings saves money and is more sustainable.

When considering how well **insulated** a building is and how quickly it will cool down, it is important to know:

- how **thick** the walls are

  Thicker walls will be better insulators, so the rate of heat transfer will be **slower**.

- the **material** that the walls are made from.

  Different materials have different thermal conductivities. For example, concrete is a better insulator than solid brick.
Reducing heat loss
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**What is energy efficiency?**

**Efficiency** is a measure of how good a device is at changing energy from one form to another.

All devices waste energy, so no device is perfectly efficient.

The **more efficient** a device is, the **less energy** is wasted.

An energy-efficient light bulb is more efficient than a filament bulb because it wastes less energy.

It converts a greater proportion of the energy that it is supplied with into light energy and not heat.
Why is energy efficiency important?

Appliances that are more efficient need less electricity to run.

New electrical appliances display information about how energy efficient they are.

This helps consumers to identify which appliance will use the least energy and cost the least to run.

Energy efficiency is not just about saving money – it is also about reducing pollution and conserving finite energy resources.
The energy efficiency of a device can be calculated using this formula:

\[
\text{energy efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}
\]

- Useful output energy is measured in joules (J).
- Total input energy is measured in joules (J).
- Energy efficiency does not have any units. It is a number between 0 and 1 which can be converted into a percentage by multiplying by 100.
Efficiency and power

The efficiency of a device can be calculated using power instead of energy. Power and energy are closely related. Power is the rate at which energy is transferred.

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

- Useful power is measured in watts \((W)\).
- Total power is measured in watts \((W)\).
- Efficiency calculations using power are carried out in exactly the same way as calculations using energy. Efficiency can be expressed as a decimal or a %. 
All the energy transfers (useful and wasted) that are associated with a device can be represented by a **Sankey diagram**.

A Sankey diagram uses arrows to represent all the output energies. The **thickness** of each arrow is proportional to the amount of energy output.

### Representing energy transfers

**filament light bulb**

- **100 J electrical energy (input)**
- **90 J heat energy (wasted)**
- **10 J light energy (output)**

**energy efficient light bulb**

- **20 J electrical energy (input)**
- **10 J light energy (output)**
- **10 J heat energy (wasted)**

How do these light bulbs compare?
We can draw accurate **Sankey diagrams** to represent the amount of energy input, the amount of useful energy output and the amount of energy wasted.

Graph paper makes this easy for us to do. The width of each line can be measured in **squares**. If we look at the energy efficient light bulb:

- **Input energy** = 20 J
  - = 10 squares
- **Useful output energy** = 10 J
  - = 5 squares
- **Wasted heat energy** = 10 J
  - = 5 squares
The bounce of a ball
Interpreting bouncing ball data

For each of the three independent variables, analyse the results by answering the following:

1. How did the change in variable affect the bounce height?

2. How efficient was the transfer of energy?

For example:

\[
\text{efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}
\]

\[
= \frac{40 \text{ cm}}{100 \text{ cm}} = 40\%
\]

Therefore, \textbf{60}\% of the energy has been wasted.
**Experimental conclusions**

Did increasing the drop height affect the efficiency?

**No.** Increasing the drop height *increases* the amount of energy input. It does increase the bounce height, but does not affect the efficiency of the energy transfer.

Which variables *did* affect the efficiency?

- changing the type of ball
- changing the bounce surface
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