Edexcel Physics IGCSE

Topic 4: Energy Resources and Energy Transfers

Summary Notes

(Content in **bold** is for physics only)

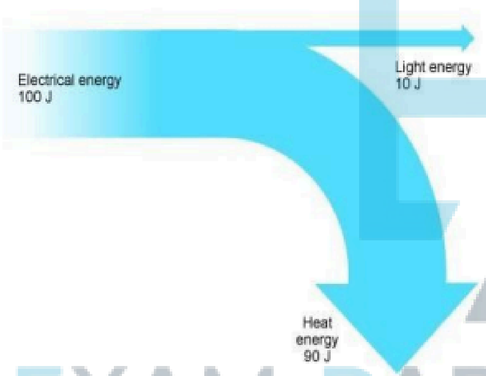
Energy transfers

Energy can be transferred between different stores including **chemical, kinetic, gravitational, elastic, thermal, magnetic, electrostatic** and **nuclear** as a result of an event or process.

Energy can be transferred in various ways including:

- **Mechanically** e.g. when gravity accelerates an object and gives it kinetic energy.
- **Electrically** e.g. when a current passes through a lamp and it emits light and heat.
- **By heating** e.g. when a fire is used to heat up an object.
- **By radiation** e.g. when vibrations cause waves to travel through the air as sound, or an object emits electromagnetic radiation.

Energy is always conserved. The total energy before is equal to the total energy after.



The **efficiency** is the **ratio** of the **useful energy output** to the **total energy supplied,** often expressed as a percentage.

$$efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100\%$$

Sankey diagrams can be used to represent the **transfer** of input energy into useful energy and wasted energy. For example, the diagram on the left shows the Sankey diagram for a lamp.

Conduction:

- Thermal energy in **solids** and **liquids** can be transferred by the vibration of particles - this is known as **conduction.**
- Non-metals are usually poor conductors known as **thermal insulators.**
  As a substance is heated up, the molecules **vibrate more** hitting and cause adjacent molecules to vibrate more too, **transferring heat energy** from hot parts to cooler parts.

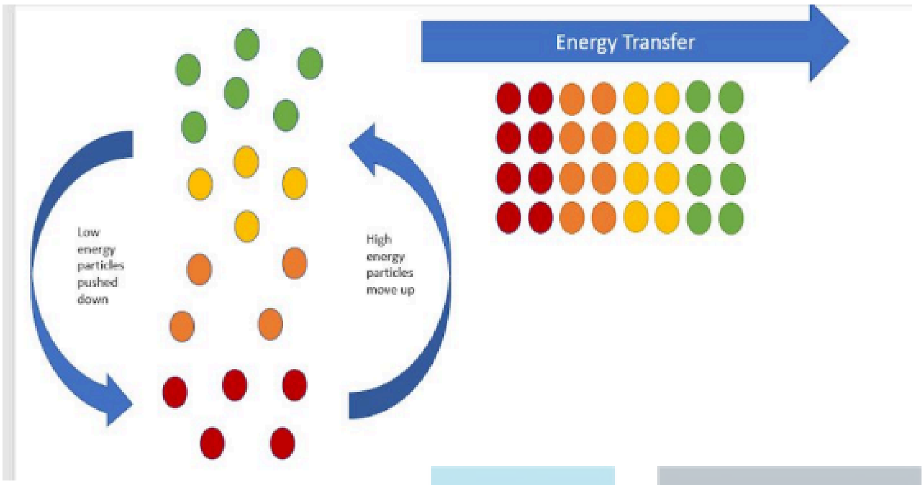
Because insulators transfer heat much more slowly, they are used to **reduce unwanted energy transfer** such as in homes.

- Metals are usually good conductors. The electrons can leave the atoms and move freely among positively charged ions. As the metal is heated, the ions and electrons **vibrate more.** The **free electrons collide with ions** throughout the metal and **transfer heat energy** from hot parts to cooler parts.

Convection:

- Thermal energy in **fluids** (liquids and gases) can be transferred by **convection.**
- Convection occurs when molecules in a fluid (which are not fixed together by forces between molecules like in a solid) move from an area of high to low thermal energy. Preventing the circulation of the fluid can help reduce unwanted energy transfer by convection.
- When part of a fluid is heated, it expands - the particles move further apart - and becomes **less dense.** It therefore **rises** up to less dense areas in the fluid. Denser, colder fluid falls down to take its place.
- Examples of convection include in **water boilers** and **hot air balloons.**

EXAM PAPERS PRACTICE



Radiation

- Thermal energy is also transferred by **infrared radiation** which does **not require a medium.** Infrared radiation is part of the **electromagnetic spectrum.**
- **Black** bodies with a **dull** texture are the **best absorbers and emitters** of radiation. **White** bodies with a **shiny** texture are the **best reflectors** of radiation. Shiny surfaces can be used to **reduce unwanted energy transfer** such as on the surface of a vacuum flask.
- The **higher the temperature** and the **greater the surface area** of a body the **more infrared radiation** emitted.

Work and power

Work is done when a **force** moves something through a **distance** (whenever energy changes forms). The work done is **equal** to the energy transferred.

$$work\ done = force \times distance \qquad W = Fd$$

The conservation of energy produces a link between gravitational potential energy, kinetic energy and work. For example, when a ball is dropped, gravity does work on it and its gravitational potential energy becomes kinetic energy as it accelerates downwards:

- $kinetic\ energy = \frac{1}{2} \times mass \times speed^2$

  $$E_k = \frac{1}{2}mv^2$$

- $gravitational\ potential\ energy = mass \times gravitational\ field\ strength \times height$

  $$E_p = mgh$$

Power is the **rate at which energy is transferred** or the **rate at which work is done.** For example, a lamp with a greater power will be brighter because it transfers more energy from electrical energy to light and heat energy in a given time.

$$power = \frac{work\ done}{time\ taken} \qquad P = \frac{W}{t}$$

Energy resources and electricity generation

- Renewable energy is energy which can be replenished as quickly as it is used. Examples include:
    - Wind
    - Water (hydroelectricity, waves, tides)
    - Geothermal
    - Solar (heating systems and cells)

  All have a potentially infinite energy supply, but they are usually more costly (e.g. the manufacture and implementation of solar panels is very expensive) and less reliable (e.g. the wind is intermittent and solar energy relies on good weather).

- Non-renewable energy is used more for large-scale energy supplies due to the large energy output but will eventually run out. Examples include:
    - Fossil fuels (coal, oil, gas)
        - Cheaper than most renewable sources but harmful for the environment because they release greenhouse gases which cause global warming.
    - Nuclear power
        - A small amount of radioactive material produces a lot of energy, but they produce highly toxic nuclear waste which needs to be safely stored underground for many years.

Energy transfers take place in the generation of electricity. For example:

- In burning fossil fuels: chemical energy in chemical bonds
- In nuclear reactors: nuclear energy in atomic nuclei
- In a solar cell, light energy from the sun
- In geothermal energy: heat energy from the Earth's core
- In wind energy: kinetic energy from the moving wind
- In HEP: kinetic energy of the moving waves or GPE of water stored high up

… is transferred into kinetic energy in a turning turbine, then into electrical energy.

Energy Efficiency and Sankey Diagrams

Energy efficiency measures how effectively energy is transferred to do useful work, and is given by the formula:

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Total energy input}} \times 100$$

Efficiency is a dimensionless quantity expressed as a percentage. An efficient system wastes less energy, with more energy transferred to useful forms.

Sankey diagrams are graphical representations of energy transfers within a system. The width of each arrow in a Sankey diagram is proportional to the amount of energy it represents. Energy flows from the input to various outputs, with separate arrows for useful and wasted energy. Wasted energy typically dissipates as heat.

The study of efficiency and Sankey diagrams helps visualize energy losses and improve system performance.

Non-renewable Energy Resources

Non-renewable energy resources are those that cannot be replenished in a human timescale. They include fossil fuels (coal, oil, and natural gas) and nuclear energy. The energy stored in these fuels is released during combustion or nuclear reactions, usually to generate electricity.

Advantages:

- High energy density, providing a lot of energy for small amounts of fuel.
- Reliable and consistent supply (at least in the short term).

Disadvantages:

- Finite availability – these resources will eventually run out.
- Significant environmental impacts, including air pollution and greenhouse gas emissions contributing to global warming.
- Extraction and use can cause land degradation, oil spills, and water contamination.

The SI unit of energy released is the joule (J), but often energy in fuels is measured in larger units like kilojoules (kJ) or megajoules (MJ).

Renewable Energy Resources

Renewable energy resources are naturally replenished and can be used repeatedly. They include solar, wind, hydroelectric, tidal, geothermal, and biomass energy sources. These resources harness natural processes for power generation, reducing dependency on fossil fuels.

Advantages:

- Sustainable, as they do not deplete over time.
- Minimal environmental impact compared to fossil fuels, with low carbon emissions.

Disadvantages:

- Some renewable sources, like solar and wind, are intermittent and depend on weather conditions.
- Higher initial costs for infrastructure and technology compared to non-renewable resources.

Renewable energy resources are essential in reducing carbon footprints and mitigating climate change. Power output is measured in watts (W), where 1 watt equals 1 joule per second.

Thermal Energy Transfer: Conduction, Convection, and Radiation

Thermal energy is transferred by three main mechanisms: conduction, convection, and radiation.

- **Conduction** is the transfer of heat through direct contact between particles in a solid. It occurs when vibrating particles transfer kinetic energy to neighboring particles. Metals are good conductors because they have free electrons that facilitate energy transfer.
- **Convection** occurs in fluids (liquids and gases) when warmer, less dense regions rise, and cooler, denser regions sink, forming convection currents. This process is crucial in atmospheric circulation and ocean currents.
- **Radiation** is the transfer of energy by electromagnetic waves, such as infrared radiation. Unlike conduction and convection, radiation does not require a medium and can occur in a vacuum (e.g., heat from the Sun reaching Earth).

Each transfer process is measured in joules (J), and understanding them is critical in designing systems to manage heat transfer effectively.

Energy Transfer by Heating and Insulation

Energy can be transferred by heating in various ways, such as through walls, windows, and roofs of buildings. Heat always flows from hotter areas to cooler areas, and insulation materials are used to slow down this energy transfer.

Common methods of reducing heat transfer include:

- **Fiberglass insulation** in walls and attics, which reduces conduction.
- **Double-glazed windows**, which trap air (a poor conductor) between two panes, minimizing heat loss.
- **Reflective surfaces**, which reduce heat transfer by radiation.

The effectiveness of insulation is measured by its thermal conductivity, denoted by λ, with lower values indicating better insulating properties. Insulating materials help maintain desired temperatures inside buildings, reducing energy consumption for heating and cooling.

The energy saved by insulation is typically calculated in joules (J), and good insulation reduces wasted energy and lowers energy bills.