WJEC (Wales) Physics GCSE

1.3: Making Use of Energy

Detailed Notes

(Content in **bold** is for higher tier **only**)

Energy & Temperature Change

Temperature differences can lead to the transfer of thermal energy by **conduction, convection or radiation**.

Conduction

Conduction is the primary mechanism of heat energy transfer in **solids**. It operates by the transfer of energy through the **vibration of atoms** that cannot move since atoms in a solid lattice are held in place by **chemical bonds**.

Although fixed within these bonds, atoms are free to vibrate, whereby the amplitude of vibration increases with temperature. As one end of a solid is heated, atoms nearest to the heat source gain energy causing them to vibrate with greater amplitude. This increase in vibrational amplitude stimulates an increase in the vibrational amplitude of adjacent atoms. As a result heat energy gets passed on from one atom to the next. This passing on of vibrations (conduction) means temperature is able to diffuse through the solid.

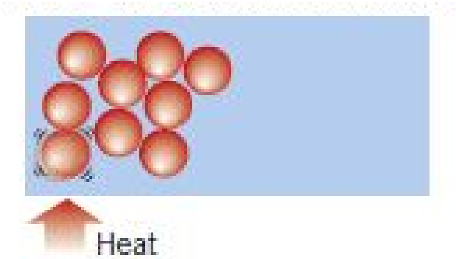


Diagram showing the transfer of heat via conduction (revisionscience.com).

<u>Conduction in metals</u>

Additional conduction processes may take place in metals because metals consist of positively charged particles (ions) and free (delocalised) electrons. When heated, electrons become excited and gain kinetic energy. Since they can move freely they can collide with adjacent metal ions which absorb the energy from the excited electron as vibrational (or heat) energy. Kinetic energy can also be transferred directly from electron to electron. Both of these mechanisms permit much faster heat diffusion than the transfer of bond vibrational energy alone. As a result metals are much more effective heat conductors than non-metals.

Poor conductors are referred to as insulators.

Convection

Convection is the primary mechanism of heat energy transfer in **liquids and gases (fluids)**. In fluids, particles are **free to move** around. Convection occurs when the particles with a lot of heat energy **move to take the place** of particles with less heat energy.

Fluid particles move faster when heated and expand to take up a greater volume. Therefore hot fluids are less dense than cold fluids making hot material rise with respect to the colder material. As a result hot fluid tends to move into cooler areas, further from the heat source. Cooler fluid then infills the space previously occupied by the rising hot fluid. Once far from the heat source the originally hot fluid cools down and becomes cool fluid once again, where the originally cool fluid heats up, as it is now proximal to the heat source. The formation of the convection cell described facilitates efficient heat transfer within the volume.

Convection can take place on many scales, from water within a beaker, to global weather systems.

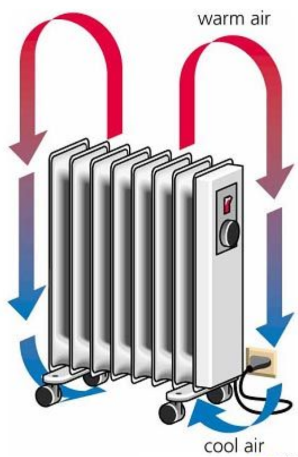


Diagram showing a convection current of air around a heater (revisionscience.com)

Radiation

Radiation is a form of energy transfer that **doesn't require particles** and instead uses **infrared electromagnetic (EM) radiation** to transfer energy. This type of EM wave can transfer energy in a vacuum as it doesn't require particles, explaining how energy from the sun can be felt here on Earth having been transferred through space.

Different surfaces are better at **radiating** heat or **absorbing** radiation than others. **Black, matt** surfaces make good emitters and absorbers of radiation whereas **light, shiny** surfaces make poor emitters and absorbers of radiation.

Density

Density is a measure of **mass per unit volume** and is measured in kg/cm^3 and sometimes g/cm^3:

$$\rho = \frac{m}{V}$$

To calculate the density of an object, its volume must be calculated. For regular objects this can be done by measuring its **dimensions** whereas for irregular objects volume can be measured from **displaced water** in a measuring cylinder.

This principle helps to explain the differences in states of matter. Particles in a **gas** spread out to occupy a **greater volume** meaning they tend to have a **lower density** than solid and liquids, which tend to occupy **smaller volumes** and therefore have **higher densities**.

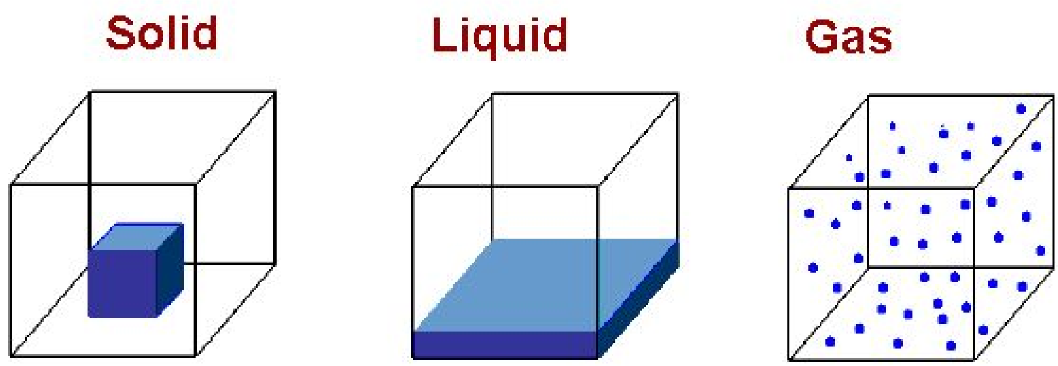


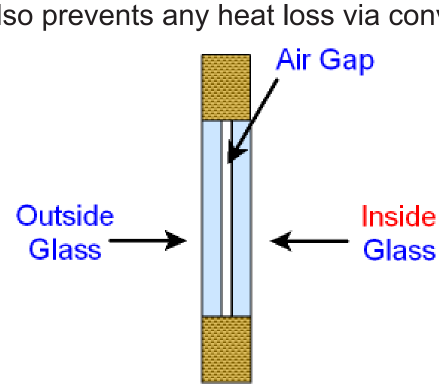
Diagram showing the varying volumes and densities of the three main states of matter (tes.com)

Reducing Energy Losses

Heat energy can be lost from buildings via the roof, windows, walls, floors and through any gaps around windows and doors, however, these losses can be reduced by considering the method of heat transfer involved. Reducing this heat loss is **good for the environment** as it means less energy is required to heat the house.

Double Glazing

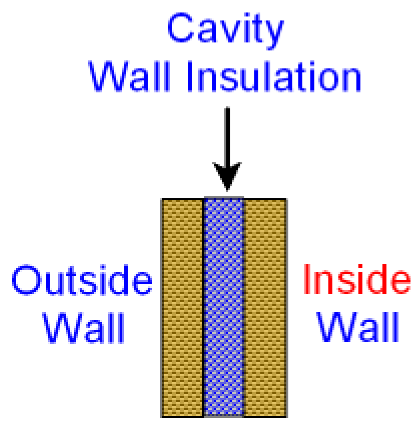
Heat loss via **conduction** through windows can be reduced by using double glazed windows. These windows contain a layer of **air or a vacuum** between two panels of glass. This **insulating layer** reduces conduction to almost zero. Air is a **poor conductor** and use of a vacuum also prevents any heat loss via convection too.



A double glazed window (gcsescience.com)

Cavity Wall Insulation

Heat loss via **conduction** through walls can be reduced by using cavity wall insulation. This is when an insulating material is placed in the gap between the outer bricks and the inside wall of a house. The insulating material is made up of lots of **little fibres**, meaning it contains **pockets of trapped air** which reduces conduction and **convection**. It can also reduce convection on the outside walls of the building.



A layer of cavity wall insulation between two walls (gcsescience.com)

A thin layer of **silver foil** can be added to the cavity wall insulation in order to reduce any additional heat loss via **radiation**. Instead, it is reflected back into the building.

Loft Insulation

Heat loss via **convection** and **conduction** through the roof can be reduced by installing loft insulation, which works in a similar manner to cavity wall insulation.

Retrofitting

Some simpler methods of reducing heat loss can be **retrofitted** (installed afterwards) to reduce heat loss. These include fitting carpets, curtains, draught excluders reflective foil in the walls.

Cost Effectiveness

Each method reduces the amount of energy by a different amount and has a different cost. All methods therefore have different **payback times**:

$$Payback\ time = \frac{Installation\ Cost}{Annual\ Saving}$$

The payback time is **shortest** when the energy saving method is **cheap to install** and **saves a lot of money** each year.