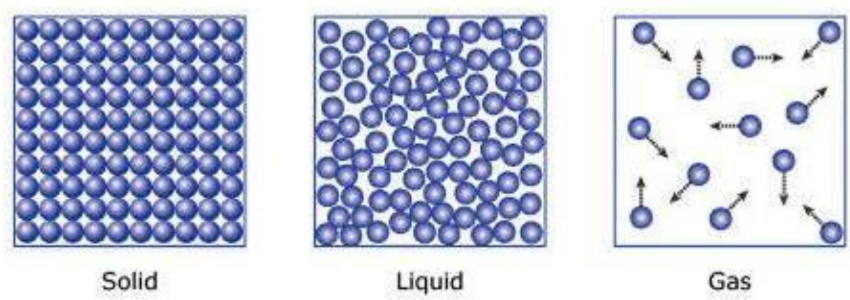
Unit 3.3 - Making use of Energy

Density

Density tells us how much mass of a certain material is contained within a certain volume.
The more material in a given volume, the greater the density.

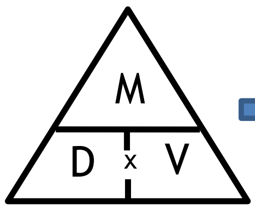
So, in general, solids have high density values because the atoms are more tightly packed whereas gases have very low values since the space between molecules is greater.



Here's the equation for calculating density :

$$\textbf{Density} = \frac{\textbf{Mass}}{\textbf{Volume}}$$

$$D = \frac{M}{V}$$



...and the other two forms of the equation are :

$$V = \frac{M}{D} \qquad M = D \times V$$

Higher tier only

Example

Calcuate the density of a glass block, length = 14cm, width = 4.5cm, height = 2cm, whose mass = 315g.

Volume of the block = l x w x h = *14 x 4.5 x 2* = ***126 cm³.***

So, density of block, D $= \frac{M}{V} = \frac{315}{126} = \mathbf{2.5\ g/cm^3}$

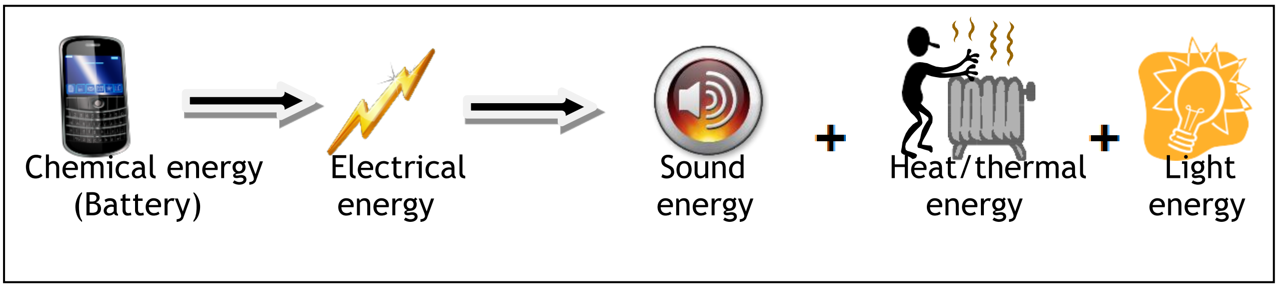
Water has a density of exactly 1 g/cm^3 (or 1000 kg/m^3).
Air has a density of about 0.0013 g/cm^3.

This is why a turbine driven by a certain volume of water is capable of generating more electricity than a turbine driven by the same volume of air.
1 m^3 of water weighs about 854 times the same amount of air.

Energy Transfer

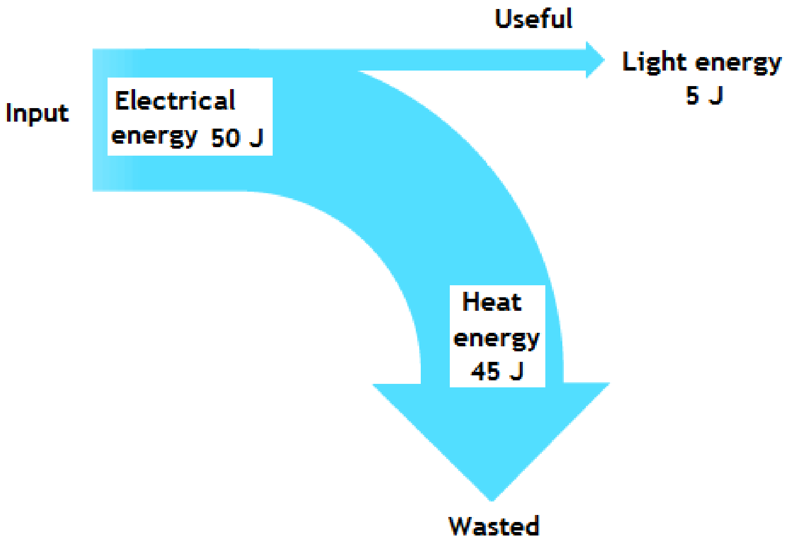
Type of energy	Example
Electrical	Into hairdryer.
Heat	Cooker.
Kinetic	Moving energy - car.
Sound energy	Speaker
Light energy	An object which emits light - LCD screen.
Chemical energy	Stored in food/battery.
Gravitational potential energy	Increases with height above ground - pump storage station.
Elastic potential energy	Stored in stretched elastic band/spring.

Example: energy transfer



Sankey Diagrams

Energy transfers can be shown using **Sankey** diagrams. They show the energy types which are involved and also the amount of energy involved. Below is a Sankey diagram for a filament bulb.



Key points

- Energy input = Energy output: 50 J (input) = 45J + 5 J (output)
- Useful energy is straight on.
- Wasted energy is curved downwards/upwards.
- Width of arrow tells us the amount of energy (to scale)
- Width of arrow is proportional to the amount of energy. They are drawn to scale e.g. 10J = 5mm

Efficiency

Energy efficiency: this is a measure of how much useful energy comes out of a device. It is measured in %.

$$\% \text{ Efficiency} = \frac{\text{USEFUL energy out (or power) tranfer}}{\text{TOTAL energy (or power) input}} \times 100$$

Example: using the data from the Sankey diagram.

$$\% \text{ Efficiency} = \frac{5}{50} \times 100 = 10\%$$

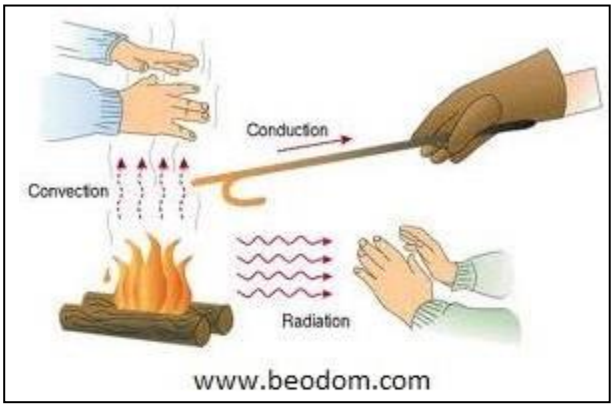
This is very poor and shows that the bulb is not very efficient. You cannot get more than 100%!!!

Coal power station 35% efficient, LED lights are 90% efficient and car engine 40% efficient.

The more efficient a power station is the ***less energy*** that is needed to be burnt so the ***less carbon dioxide*** emitted and also fossil fuels last longer.

Thermal energy (heat) transfer.

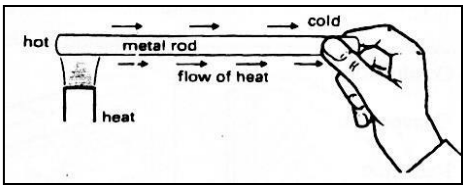
Thermal energy moves from **HOT** (High temperature) to **COLD** (lower temperature) (down a temperature gradient) e.g. a hot cup of tea gives out thermal energy to the surroundings. The greater the ***difference in temperature*** the more thermal energy transferred per second e.g. so the temperature of your mug of tea will drop at a greater rate when it is very hot.



3 types of thermal transfer: Thermal energy can be transferred via conduction, convection and radiation.

Conduction: In conduction the thermal energy flows through the object itself. It takes place in solids and liquids.

Conductors: materials which are good at conducting thermal energy e.g. metals like copper. **The hotter moleculetels (more energetic) collide with cooler particles, transferring some of their kinetic energy in the process. This process is repeated over and over until eventually all the molecules in the rod become hotter**.



The main reason metals are such good conductors of heat is because they have **free electrons.**

Insulators: materials which are poor at conducting e.g. air, plastic. Many materials which are insulators like wool trap air e.g. jumper.

Convection: Heat flows by convection in **liquids** and **gases** only. Convection cannot occur in solids because the particles are fixed.

This applies to liquids and gases:

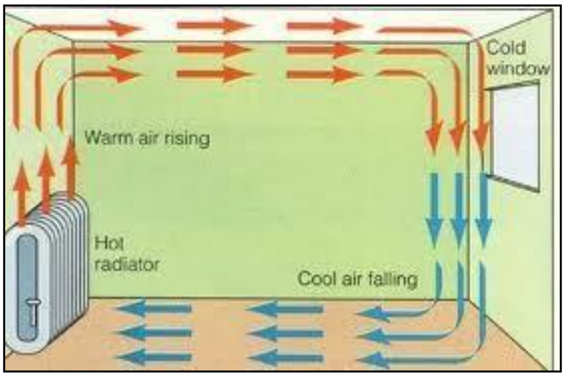
1. When gas/liquid heated.

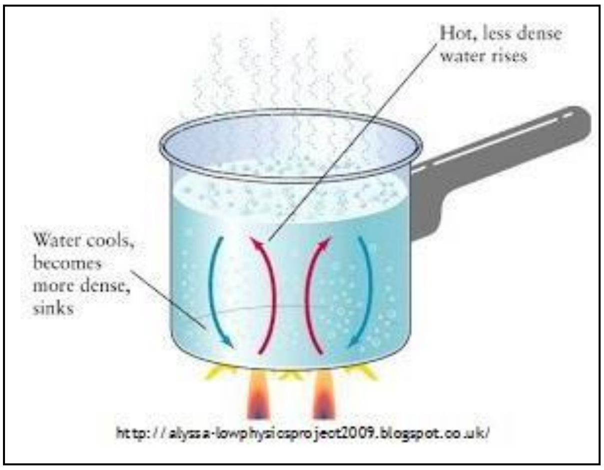
2. The particles speed up

3. Volume of gas/liquid increases. Gas/liquid expands.

4. Density decreases and so gas/liquid rises.

5. Colder, denser gas/liquid falls.





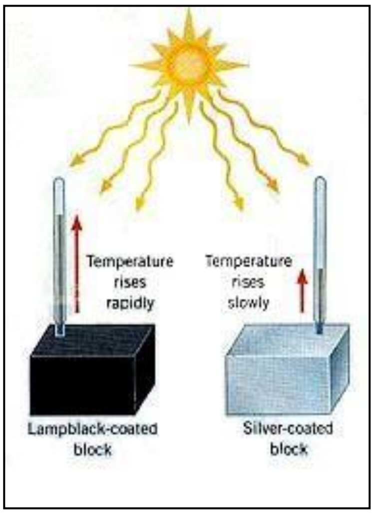
Some materials like foam **trap air,** which reduces the convection current since the hot is less able to rise and the cold air is less able to fall. This reduces heat loss/transfer through convection.

Thermal Radiation (infrared). Any hot object will emit thermal radiation in the form of infrared electromagnetic radiation.

The higher the temperature of an object the more thermal radiation it will emit. This is the only means of heat transfer through a vacuum (space). Objects can ***emit*** and ***absorb*** heat/thermal radiation

Shiny objects are good at reflecting thermal radiation e.g. aluminium foil around food, caravans painted white.

Matt black objects are very good at absorbing/emitting thermal radiation e.g. wood burning stove is painted black and black cars become hotter in the sun.



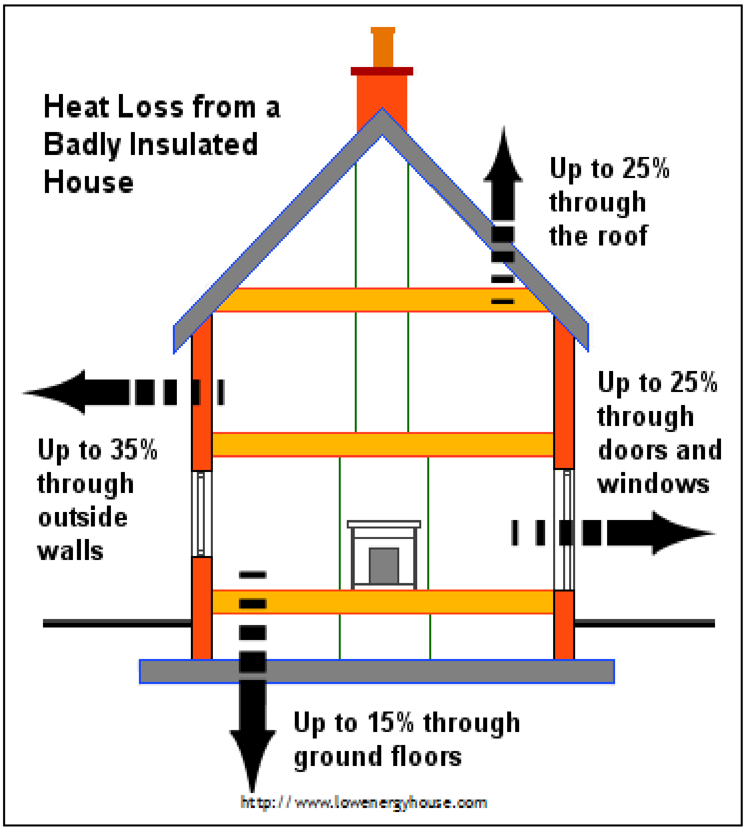
Matt Black	Shiny Black	Colours (dark --> Light)	White	Silver

Best Emitter/ Absorber → **Poorest Emitter/ Absorber**

Insulating the house

It is important to try and reduce the thermal energy loss from a house. This will reduce ***energy bills*** (saving money) and also reduce the ***carbon dioxide emissions*** as the result of heating your home. CO_2 is a greenhouse gas which increases global warming.

There are many types/systems of insulation that can be installed in the house to reduce **NOT stop** heat loss. Most of these insulating materials work because they ***trap air*** which is a poor conductor. If the air is trapped heat loss through convection is reduced because warm air cannot rise and cold air cannot fall.



Insulating systems

Insulation type/system	How it works.
Double glazing	Two sheets of glass separated by a gap filled with e.g. argon or a partial vacuum. It reduces heat loss through conduction and convection.
Draught proofing	Strips of draught proofing can be fitted around doors and window frames. Draught excluders can be placed at the bottom of doors. It reduces heat loss through convection.
Loft insulation	Rock wool (mineral wool) can be placed between the rafters in the loft. These materials are good at trapping air. Reduces the heat loss through conduction and convection.
Floor insulation	Fibreboard or mineral wool is placed to reduce heat loss via conduction and convection.
Cavity walls	Walls are built with an inner and outer wall. The gap/cavity can be filled with foam or insulation board which reduces conduction and convection.

Installing wind turbines and solar planes DO NOT reduce heat loss

Note: The higher the temperature of the inside of your house compared to the outside the more energy your house will lose per second because of a greater difference in temperature.

Comparing the costs

There are 2 main energy requirements in the home :

1. Electricity

2. Heat

You will be expected to compare the different energy sources in terms of their cost, their effect on the environment, **payback time**, etc.

"Payback time" is the time it takes to get the money back in energy savings for the money spent on a particular improvement. Here's the equation for calculating "payback time" :

$$\text{Payback time} = \frac{\text{installation cost}}{\text{Annual saving}}$$

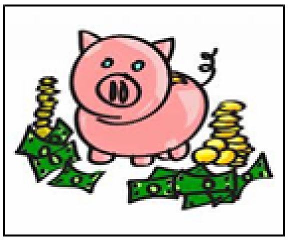
(in years)

Note : This equation is not given in the exam at all, so you'll have to memorise it !!

So, payback time can be calculated by dividing the cost of the system with the saving per year (how much your bill has been reduced).

Example: it costs £4000 to install double glazing in your house. Your energy bills are reduced by £175 per year. How long will it take before the cost of your investment is paid back.

$$\text{Payback time} = \frac{4000}{175} = \quad 22.9 \text{ years.}$$



You will not be expected to remember data about different energy sources, only use what is given in the exam question.

See the example on the next page.

Comparing the costs

Example from a past paper

1. A householder is considering using a **renewable** energy source to help him save money on electricity bills. He used some information from a local store to draw up the following table.

	Installation cost (£)	Saving per year (£)	Payback time (years)	Maximum power output (W)	Conditions needed
Wind turbine	1 200	600	2	5 400	Average wind speed 4 m/s, (maximum 12 m/s)
Roof top photovoltaic cells (PV) of area 4 m^2	14 000	....	7	1 800	South-facing roof

(a) What is meant by a renewable energy source ? [1]

(b) (i) Complete the table by calculating the saving per year for the roof top Photovoltaic cells (PV). [1]

(ii) Give reasons why the payback times for the wind turbine and roof top photovoltaic cells (PV) may be different from both those shown in the table.[3]

(iii) Calculate the area of roof top photovoltaic cells (PV) needed to produce the same maximum power as a wind turbine.[2]

(c) Explain how the introduction of roof top photovoltaic cells (PV) and wind turbines would benefit the environment. [2]

Answers

(a) Easily replaced / replenished / will not run out / sustainable

(b) (i) [£] 2000

(ii) Wind - variable wind speed (1) Solar - hours of sunshine / roof may not face South or intensity of Sun (1) Fuel costs could change (1)

(iii) 5400 ÷ 1800 = 3 (1 mark)

3 x 4 = 12 m^2 (1 mark)

(c) Reduces CO_2 (1) which reduces the greenhouse effect / global warming (1) or
Less SO_2 (1) which results in less acid rain (1) or
Use less fossil fuels (1) so less extraction needed / less CO_2 / less SO_2 (1)
("less pollution" not accepted as it's not specific enough).

Comparing the cost of different energy sources used in transport

Scenario: You and 2 friends are planning a trip to see your favourite group in concert in Paris! (One of the parents is driving you there and back!). Each of the 3 families have the same car, but each car uses a different fuel.

Distance from Llanrwst to Paris (one way) = 750km

Fuel type	Cost per litre (£ / l)	Fuel used to travel 100km (l / 100km)
Diesel	1.15	5.46
Petrol	1.13	6.31
Liquid Petroleum Gas (LPG)	0.65	7.41

Use the data below to calculate the fuel costs to drive from Llanrwst to Paris **and back,** for each fuel type.

Step 1 : Calculate the total distance travelled for the journey there **and back.**

Total distance = 750km x 2 = 1500 km

Step 2 : Use the 3rd column to calculate the total amount of fuel used by each type of car.

Diesel

Fuel used = 1500 ÷ 100 = 15

= 15 x 5.46

= 81.9 L

Petrol

Fuel used = 15 x 6.31

= 94.65 L

LPG

Fuel used = 15 x 7.41

= 111.15 L

Step 3 : Use the 2nd column to calculate the cost of those amounts of fuel.

Cost = amount of fuel x cost per litre

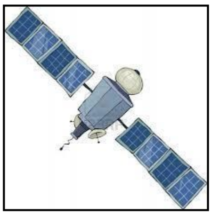
= 81.9 x 1.15 = £ 94.19

Fuel	Amount of fuel (l)	Cost (£)
Diesel	81.9	94.19
Petrol	94.8	107.12
LPG	111.2	72.24

Time delay.

Method 1, satellite: If the distance from the Earth's surface to each satellite is 3.6×10^7 m, the total distance the microwaves must travel to go from Wales to Italy is (up and down once) = $\mathbf{2 \times}\ 3.6 \times 10^7$ = $\mathbf{7.2 \times 10^7\ m}$

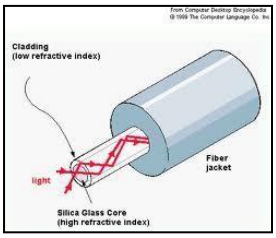
Microwaves are electromagnetic waves so travel at 3×10^8 m/s.



$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{7.2 \times 10^7}{3 \times 10^8} = \mathbf{0.24\ s}$$

Method 2, optical fibres: The distance from Wales to Italy is about 2000 km = 2×10^6 m.

Infrared waves travel at about **70%** of the speed of light in an optical fibre, so, $0.7 \times 3 \times 10^8 = \mathbf{2.1 \times 10^8\ m}$



$$\text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{2 \times 10^6}{2.1 \times 10^8} = \mathbf{0.0095\ s}$$

There is less time delay with optical fibres and they are not affected by the weather.