WJEC (Eduqas) Physics A-level

Topic 3.D: Energy And The Environment

Notes

Temperature Rises on Earth

Thermal Equilibrium

The Earth's **atmosphere** traps gases and stops it from going into space, and prevents **heat** from escaping the planet entirely.

Without an atmosphere, Earth would be too cold to live on. But the greenhouse gases in the atmosphere trap heat. This is how it works:

- The sun **radiates** short wavelength infra-red rays, which reach the atmosphere around the Earth.
- The **atmospheric layer** traps some of these rays and itself gets hotter. A percentage of these rays penetrates the gas layer and is absorbed by the planet itself.
- The soil and water surfaces **reflect or re-radiate** some of the heat back as long wavelength infra-red rays that cannot escape the Earth's atmosphere.

There are certain gases that contribute to the greenhouse effect:

- Water vapour
- Carbon dioxide
- Methane
- Ozone

In the last century, the **concentration** of carbon dioxide and methane in the atmosphere has significantly increased. The main reason for this is **human activity**. The concentration of greenhouse gases is influenced in several significant ways:

- **Industrial activity:** plants and factories produce a lot of smoke that contain CO2.
- **Transport**: trains, cars and ships also emit gases – CO2 included.
- **Cattle**: cows and other species of cattle produce a lot of methane while they are grazing. And they produce it in huge quantities, as farmers usually have big herds concentrated in one place.
- **Deforestation**: in order to have fields to plant crops and have wood to build

houses and other things, people have destroyed many acres of forests. Trees are the main natural tool that helps lower the carbon dioxide content: they take up carbon dioxide and produce oxygen instead during photosynthesis. This results in oxygen concentration falling and carbon dioxide concentration rising.

- **Farming**: farming some crops – rice, for instance, – also leads to methane release.

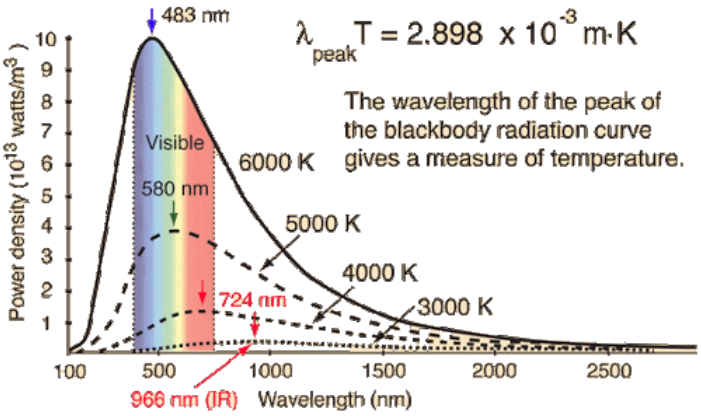
Solar Energy

Solar energy is transmitted to Earth in the form of **Electromagnetic Radiation** (Light waves) across a range of frequencies.

The electromagnetic radiation emitted by the sun covers a very large range of **wavelengths**, from radio waves through the infrared, visible and ultraviolet to X-rays and gamma rays. However, 99% of the energy of solar radiation is contained in the wavelength band comprising the near ultraviolet, visible and near infrared regions of the solar spectrum. About 40% of the solar radiation received at the earth's surface on clear days is visible radiation, while 51% is infrared radiation. As we can see, a lot of the wavelengths are 'converted' to infrared.

Wien's Law and Stefan-Boltzmann's Law

Wien's Law - States that the higher the temperature, the lower the wavelength λ_{max} for which the radiation curve reaches its maximum. The shift to shorter wavelengths corresponds to photons of **higher energies.** In other words, λ_{max} (**peak wavelength**) is inversely proportional to temperature.



Stefan-Boltzmann Law - This law states that the energy radiated from a **black body** is proportional to the fourth power of the **absolute temperature.**

$$\frac{P}{A} = \sigma T^4 \, j/m^2 s \quad \text{Stefan-Boltzmann Law}$$

$$\sigma = 5.6703x10^{-8} \, watt/m^2 K^4$$

Archimedes Principle and Sea Levels

We remember that density is mass per unit volume:

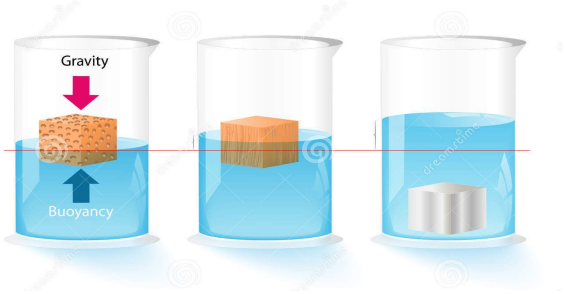
$$\rho = m/V$$

Archimedes' principle states that the upward **buoyant** force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the **weight** of the fluid that the body displaces:

$$F = \rho g V$$

Additionally, the volume of the immersed part of the body is equal to the **volume** of the fluid displaced by the body.

ARCHIMEDES PRINCIPLE



Archimedes principle is linked to rising **sea levels.** As ice caps melt into water, that water goes into the sea, displacing it and **increasing** the water level.

However, melting icebergs do not increase sea levels as the icebergs themselves have already displaced the water in the sea, so when it melts **no additional displacement** occurs, so the sea level is not affected.

Common Sources of Renewable and Non-Renewable Energy

Solar Power

- The **intensity** of light from the sun can be measured using the equation: **I = P/A**.
  A is the area over which the light shines (**A = 4 πr^2**). Notice that intensity is an **inverse square law** meaning it decreases at a rate of $1/r^2$(where r is the radius) as the radius increases.

- The main energy source of the Sun is the **proton-proton chain fusion reaction.** This is where four hydrogen nuclei (protons) are combined to form one helium nucleus. This reaction releases **gamma rays.**

- Photovoltaic cells convert light energy into electricity. To calculate how much light is converted into electrical energy is converted we use the following equations:

$$E_{Electrical} = E_{Light} \times (Cell\ Efficiency/100)$$

$$Cell\ Efficiency = (Useful\ energy\ out/Total\ Energy\ in) \times 100$$

- The UK is the third largest producer of electricity from solar panels in the EU. Italy and Germany are both ahead of the UK in the EU.

Wind Power

- Wind power is generated from wind turning the blades of a **turbine** which in turn spins a magnet inside of a coil, creating an **electrical current.**

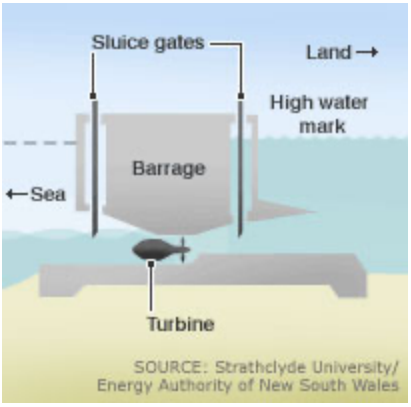
- Wind is a **fluid.** The average power available from a flowing fluid is: **P = 0.5 ρv^3**.

- Factors affecting the **efficiency** of a wind turbine are: wind speed, air density and blade radius. The faster the wind moves, the faster the turbine spins thus the more current is being produced. If the air is denser, more air particles are hitting the turbine blades, increasing the **pressure**, resulting in a higher power output. The larger the radius, the greater the area of blade there is for the wind to hit, thus a higher power output.

- Wind power contributes 20% of the UK's electrical output. It is the sixth largest producer of wind power in the world.

Tidal Barrages and Hydroelectric Power

- Tidal barrage systems are a tidal power generation method that work similar to hydroelectric power and have sluices that control the tidal flow to drive turbines and generate electricity.



- The barrage has a number of underwater tunnels cut into its width allowing the sea water to flow through them in a controlled way by using "**sluice gates**" on their entrance and exit points. Fixed within these tunnels are huge tidal turbine **generators** that spin as the sea water rushes past them, either to fill or empty the tidal reservoir thereby generating electricity.

- The water which flows into and out of these underwater tunnels carries enormous amounts of kinetic energy and the job of the tidal barrage is to extract as much of this energy as possible which it uses to produce electricity.

- The kinetic energy of the water is equal to the difference in gravitational potential energy of the water either side of the barrage: $\Delta E_p = E_k$.

- Power generated can be found using:

$$P = Fv$$

P = Power
F = Force (Water weight)
v = Velocity (Water velocity)

- Water is much **denser** than air so tidal energy is more powerful than wind energy.

- Tides are more **reliable** than wind therefore, tidal generators are steady and produce a reliable stream of electricity.

- The UK produces about 50% of all of Europe's power capacity.

Nuclear Fission and Fusion

- Nuclear Fission has a remarkable property- some nuclear reactors are designed to produce more fuel than they consume. This extraordinary technique is known as **'breeding'**.

- The nuclear fuel is **regenerated** by reactions which transform non-fissile nuclei in the fuel into fissile ones. These nuclei are called **fertile** for that reason. In reactors these fertile nuclei are uranium 238 and thorium 232, the most abundant natural **isotopes** of their respective elements. The first regeneration mode under way in uranium reactors in operation today is the transformation of non-fissile uranium 238 into fissile plutonium 239.

- Breeding is a technically difficult process. It requires fast **neutrons** and liquid **coolants** made of molten lead or sodium, necessary in order to optimize the number of neutrons captured by the fertile uranium.

- Uranium is found in nature consists largely of two isotopes, U-235 and U-238. The production of energy in nuclear reactors is from the 'fission' or splitting of the U-235 atoms, a process which releases energy in the form of heat. U-235 is the main **fissile** isotope of uranium.

- **Enrichment** requires uranium to be in a **gaseous** form, and the simplest way to achieve this is to convert it to a different chemical known as uranium hexafluoride. Uranium needs to be in a gaseous form for enrichment due to the varying chemical and physical properties the different isotopes (U-235 and U-238) have.

- Today, enrichment is achieved using a special centrifuge called a **gas centrifuge**. The separation process here relies on the mass difference of the molecules (see gaseous diffusion above). Here, uranium hexafluoride is fed into an evacuated cylinder containing a rotor. When these rotors are spun at a **high speed**, the heavier $^{238}UF_6$ collects near the walls of the cylinder while the slightly lighter $^{235}UF_6$ collects near the central axis. The enriched product is then drawn off.

- Fusion is the joining of two smaller nuclei to produce a larger one.

- Fusion releases a lot of energy in the process and is the future of renewable energy. The Sun fuses elements in its core.

- Fusion reactors are extremely **costly,** and at the moment require more power to run than they produce themselves.

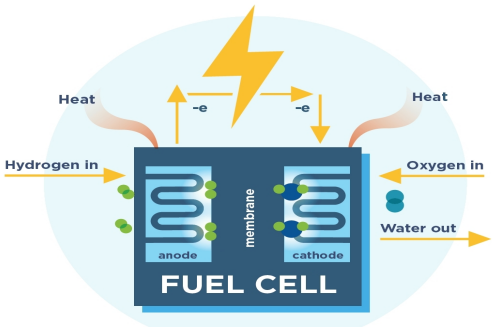
- For fusion to occur, **high temperatures and pressures** are required to superheat hydrogen into plasma form, which is difficult to achieve, and uses too much energy for fusion to be renewable at the moment.

- The **efficiency** of fusion has improved over the past 30 years.

- The fusion triple product is the product of n (Density of ions in the plasma), T (Temperature of ions) and τ_E (Energy confinement time) and gives us the **power produced.**

Fuel Cells

A fuel cell uses the **chemical energy** of hydrogen or another fuel to cleanly and efficiently produce electricity.



Fuel cells work like batteries, but they do not run down or need recharging. They produce electricity and heat as long as fuel is supplied.

A fuel cell consists of two **electrodes**—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. In a hydrogen fuel cell, a **catalyst** at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons **migrate** through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce **water and heat.**

Fuel cells have a number of advantages:

- No harmful emissions (Only emits water).

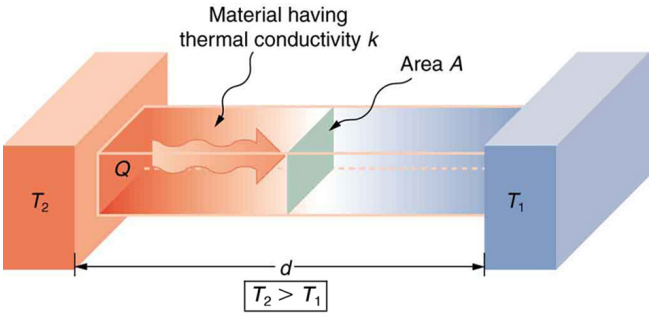
- Almost no noise pollution.

- Easy to store, there is not a large energy loss in storing hydrogen.

- Energy efficient.

Thermal Conduction

Thermal conduction is the transfer of internal energy by **microscopic collisions** of particles and movement of electrons within a body.



$$\frac{\Delta Q}{\Delta t} = -AK\frac{\Delta \theta}{\Delta x}$$

Q = Heat Energy

K = Conductivity

t = Time

θ = Temperature

A = Area of surface

x = Thickness of material

Insulating materials are bad conductors and so this reduces the **heat loss** by conduction. Heat loss for parallel surfaces can be calculated by:

$$\frac{\Delta Q}{\Delta t} = UA\,\Delta\theta$$

U = Constant of Proportionality.