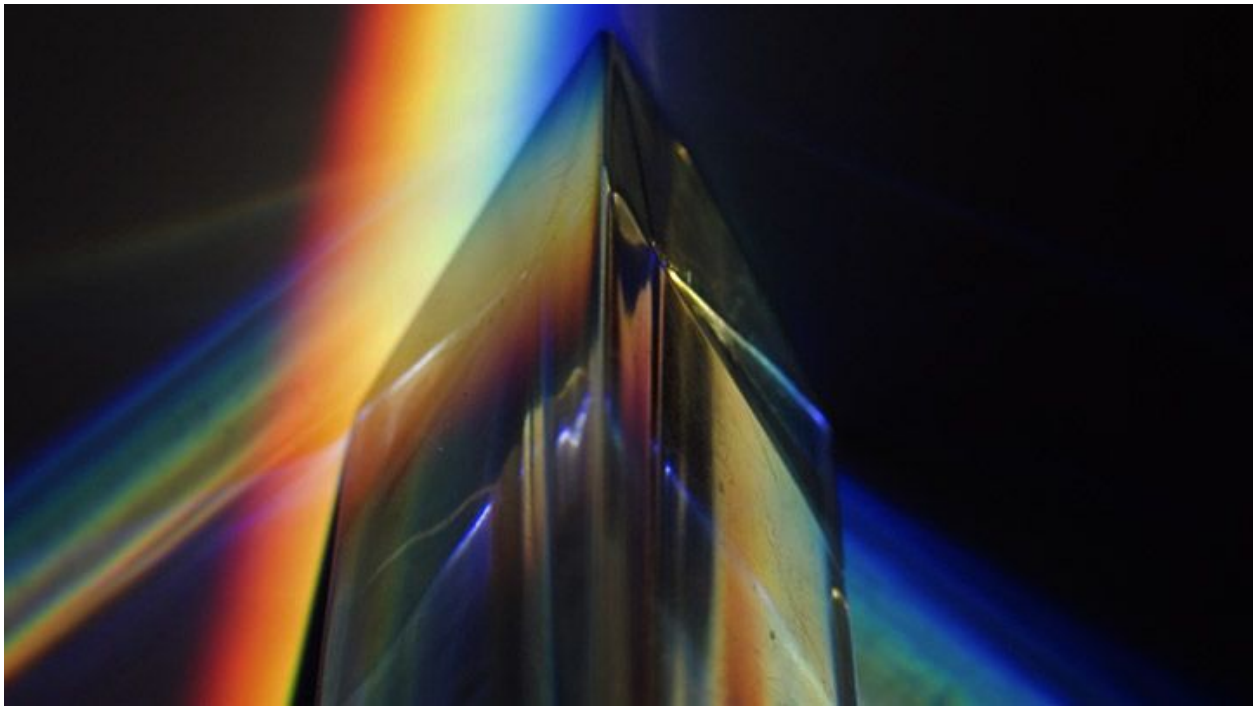
Physics Newsletter

January 2021



Hi everyone, here is the 8th edition of the physics newsletter! Hope you enjoy it!

If you would like to contribute to the next newsletter, please email the following addresses:

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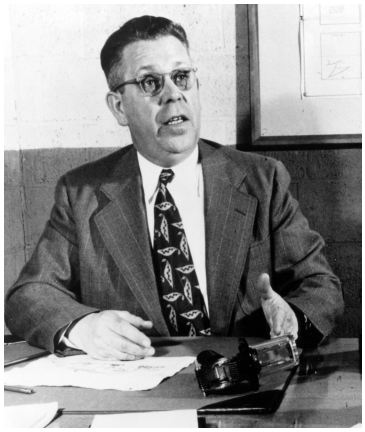
This edition includes articles on:

- Microwaves
- Microscopes and the Human Genome Project

Microwaves

Invented over 80 years ago, microwaves have become an essential part of each and every one of our kitchens, but did you know that they were created by accident?

Invention by mistake



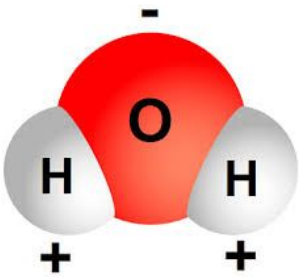
Percy Spencer, the man credited with the inception of this kitchen necessity, discovered the power of microwaves in a moment of serendipity as he worked to improve radar units for the American Navy during World War 2. His aim was to increase the strength of radar magnetrons, which were used to create the electromagnetic waves used as signals out at sea.

One day, in 1946, he was testing a magnetron when he reached into his pocket in search of his peanut cluster bar, only to discover it had melted completely. Intrigued by the occurrence, he decided to carry out further experimentation, and the following day he brought in an egg. The egg exploded when put under the magnetron tube, and he knew the cluster bar experience wasn't a coincidence. The last straw was when he brought in corn kernels and made popcorn to feed all his colleagues - a mere year later, the very first commercial microwave oven was released. Although it took two more decades for microwave ovens to really take off, it is undeniable that Spencer hit the jackpot with his discovery.

How They Work

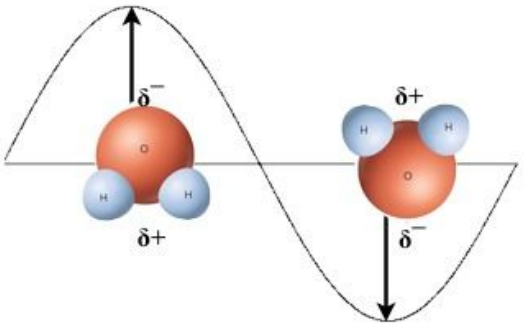
You may have heard the idea that a typical heat conduction oven heats food from the outside in, but microwaves heat food from the inside out. This isn't exactly true - they simply heat food that has more water in it the quickest, because microwaves heat food by exciting water molecules.

Microwaves are the second longest wavelength in the electromagnetic spectrum, a type of wave which is an oscillation of the electric and magnetic fields. Electromagnetic waves influence charged particles by exerting forces on them.



What relevance does this have to water- aren't water molecules uncharged? Overall, water molecules are neutral, but due to discrepancies in electron distribution around the molecule, the oxygen atoms are slightly negatively charged and the hydrogen atoms are slightly positively charged. Given the shape of water molecules, this results in one side of the molecules being negatively charged and the other positive - inducing what is called a dipole moment.

Consequently, when microwaves pass through food, they cause water molecules' 'poles' to align with the peaks and troughs of the wave in the electric field. The molecules oscillate up and down, generating friction, and therefore heat. Microwaves have a similar influence on fat and sugar molecules, but the effect is not quite as drastic. This explains why, if you were to heat up an apple pie, the filling (containing a higher water content) becomes much hotter than the pastry.



Are They Bad For You?

In terms of radiation damage to health - the answer is a decisive no. Radiation can damage cells if it is ionising, where the radiation knocks electrons off atoms it comes into contact with and turns the atom into an ion. This can cause damage to DNA and therefore to your cells.

Electromagnetic waves with low frequencies such as microwaves, however, are very weakly ionising, meaning they very rarely remove electrons from atoms. To increase safety, microwave ovens contain a thick metal casing which absorbs any microwaves that weren't already absorbed by the food.

If this still isn't convincing, then there is one thing everyone can do to minimise the radiation they absorb, which is to stay at least 30cm away from the door. The intensity of radiation decreases proportional to the square of the distance from its source. This means you will receive 900x less radiation if you are 30cm away from the microwave than if you are 1cm away from it.
-Sai Potturu 13.2

Probing Biological Matter

Microscopes

One key piece of equipment in the discovery of new biological concepts is the microscope, as this allows scientists to view and identify things which are much smaller than can be observed by the naked eye. The first type of microscope to be invented was the optical microscope. This uses visible light and a series of lenses to magnify the sample.

The simplest optical microscope consists of two convex lenses- the eyepiece lens and the objective lens. The eyepiece lens usually provides 10x magnification, while the objective lens provides magnification in the range of 5x to 100x. Other, more complex optical microscopes can also be used, such as fluorescence microscopes and polarising microscopes.

Although the invention of the optical microscope was a significant development, its uses are limited. This is due to the resolution of the microscope, where the resolution limit is the smallest distance between two points at which the points can be seen as separate entities. The resolution of an optical microscope is related to wavelength as anything less than half a wavelength apart becomes impossible to see. Visible light consists of wavelengths between 400 and 700nm, giving it an average wavelength of 550nm. This means that optical microscopes have a resolution limit of around 250nm.

Electron microscopes:

In order to investigate smaller samples, electron microscopes are used.The key difference between optical and electron microscopes is that optical microscopes use photons of light, while electron microscopes use a beam of accelerated electrons. The reason for this is that electrons have a much smaller wavelength and so the resolution limit is around 0.2nm.

The electron beam is produced from a cathode through thermionic emission, where heating of a filament allows electrons to escape from its surface. Anodes are used to attract the electrons and concentrate them to produce a more powerful beam that can be focussed onto the specimen. This also allows the electrons to be accelerated. The reason for accelerating electrons is to reduce their wavelength. Due to wave-particle duality, when electrons are acting as waves their wavelength follows the equation $\lambda = h/mv$, meaning that by increasing the speed of the electrons, their wavelength is reduced and they can create more detailed images.

Due to using electrons, the inside of electron microscopes must be in a vacuum. If this were not the case, the electrons would be deflected by air molecules and so an image could not form. However, this means that no live specimens can be observed as water, which is heavily present in biological samples, instantly evaporates in a vacuum.

The other key difference between optical and electron microscopes is that the lenses used in electron microscopes are electromagnetic, consisting of a coil of wire and magnetic poles. As a current is passed through the coils, a magnetic field is generated which can be used to control the path of the electrons.

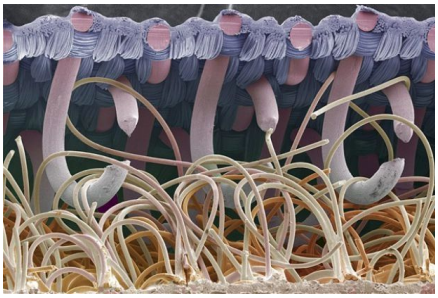
Types of electron microscope:

There are 2 key types of electron microscope: Transmission electron microscope (TEM) and scanning electron microscope (SEM). In TEM, the electron beam is passed through the sample. The number of electrons that are transmitted through the sample depends on its thickness and density. The lower the density and thickness, the higher the number of electrons that are transmitted. The transmitted electrons are concentrated by further lenses and will then hit a

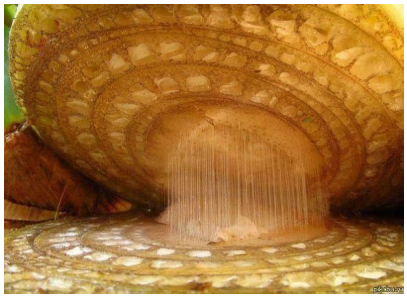
screen, which is often made of materials such as phosphors which emit visible photons and allow an image to form. Due to the electron beam needing to be able to pass through the sample, specimens must be extremely thin when used with TEM. This requires them to be sliced to between 50 and 100nm thick.

In SEM, the electron beam is scanned systematically across the surface of the specimen, as it is drawn back and forth by electromagnetic coils. The electrons from the beam hit the surface and cause the release of two types of electrons: backscattered electrons (electrons from the initial beam that are reflected) and secondary electrons (electrons from the atoms of the sample). The scattered electrons are registered by a detector which usually consists of a scintillator so that light is emitted and an image is displayed on the screen.

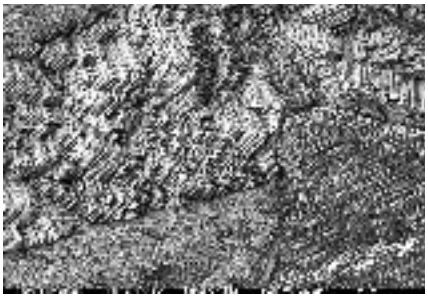
Everyday objects under microscopes:



Velcro



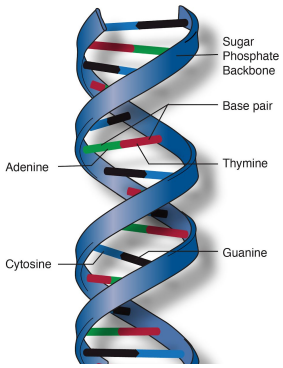
Banana

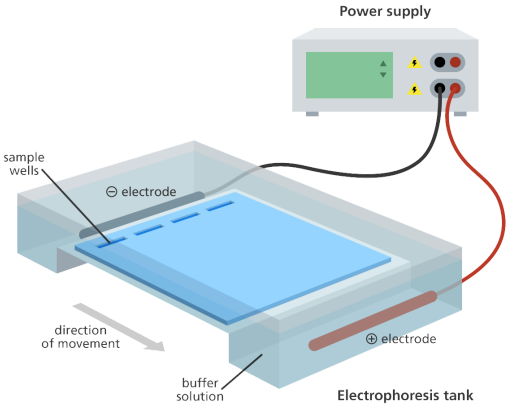


Penny

Human Genome Project

Physics has also played a part in the human genome project. This project began in 1990 and aimed to determine the sequence of all the base pairs in the human genome. The bases are part of the structure of DNA and there are 4 types- adenine, thymine, cytosine and guanine. Due to hydrogen bonding across the two strands, adenine will pair with thymine, while cytosine will pair with guanine. This means that identifying the bases on one of the strands allows the pair to be determined. After obtaining the raw DNA and separating this into many shorter fragments of varying lengths, gel electrophoresis is used in this process.

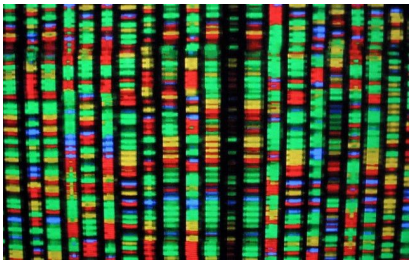


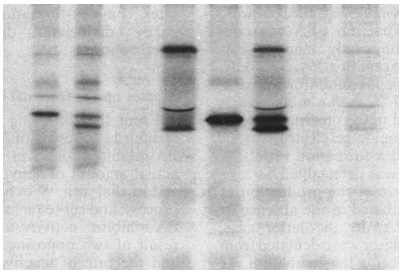


The DNA molecules have a negative charge due to the negative charge of the phosphate. This means that as an electric current flows through the gel as a result of positioning oppositely charged electrodes at each end, the DNA molecules are pulled through the gel. At the beginning of the experiment, the DNA is positioned in wells next to the cathode (negative electrode).

They are repelled from the cathode and will be attracted towards the anode (positive electrode), causing this movement. The resistance of the gel pores means that the larger strands travel more slowly, so in a given period of time the sample will have been sorted into size order.

Complementary fluorescent dyes or radioactive DNA probes are used to bind to certain bases to determine their final position. In the case of using fluorescence, this is done by shining UV light onto the sample, as this would cause the fluorescent dye to release visible photons, allowing the bases to be identified based on the colour observed. If radioactivity is used, a process called autoradiography is used for identifying the bases. This is where an X-ray film is placed over the gel and the radioactivity from the probes will cause areas of the film to become blackened. The sequence of each fragment can be determined in these ways. Computers then combine the results from each individual fragment to determine the complete sequence. Understanding the human genome in greater depth has major implications for the way in which diseases are identified and treated.





-Natalie Smith 13.2