Physics Newsletter

March 2021

Satellite photo of Birmingham's Spaghetti Junction

Hi everyone! This is the last edition of the physics newsletter written by the year 13s, before we leave in May. We've had a blast writing these articles and hope you enjoyed reading them just as much! Thank you to everyone who contributed, and we look forward to handing over to the year 12s :)

If you would like to contribute to the next edition please email your article to:
15guptav699@kechg.org.uk , 15chowdhury914@kechg.org.uk , 15abir780@kechg.org.uk

This edition includes articles on:

- Radiocarbon dating
- Satellites

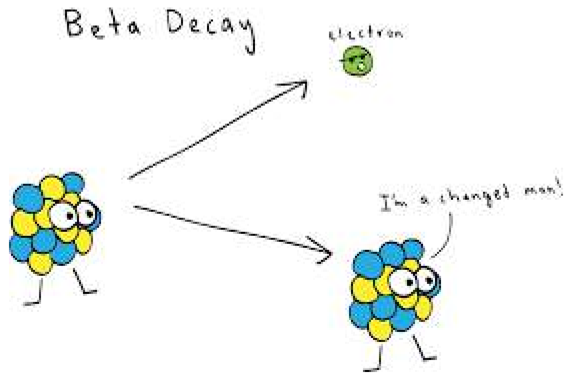
We would also like to thank everyone who took part in the Science Week activities, we hope you enjoyed them! This edition features the winning entry for the article competition - Telescopes by Sanskriti Singh in 8Z. We will be in touch with the winners in the other competitions shortly.

Radiocarbon Dating

What is radiocarbon dating and how does it work?

To answer this question we must first tackle the question: ‘what is radiocarbon?’. Radiocarbon is a radioactive isotope of carbon. Isotopes are atoms of the same element (meaning they have the same number of protons) but have different numbers of neutrons in their nuclei. The most abundant isotope of carbon is carbon-12, which gets its name from having a mass number of twelve (6 protons + 6 neutrons).

However, the isotope used in carbon dating is carbon-14 (6 protons + 8 neutrons), as this isotope is radioactive. Radioactivity is a property of nuclei that have too many neutrons, and carbon-14 decays by beta emission to fix its neutron to proton ratio. One of the neutrons in its nucleus turns into a proton, reducing the n:p ratio from 8:6 to 7:7, and the carbon atom turns into a nitrogen.



So how is this useful to archaeologists? The concept of carbon dating comes from one simple fact - all living things absorb carbon, from the atmosphere as CO_2, from their diet etc. A certain proportion of the carbon they absorb is carbon-14, and while the organism is still alive, this proportion is fairly consistent. However, once the organism dies, it will cease to absorb carbon and as time passes, the carbon-14 it contains in its body will decay, whilst the other stable isotopes of carbon remain constant.

$$N = N_0 \, e^{-\lambda t}$$

To date a specimen, archaeologists compare the proportions of carbon-14 and carbon-12 currently in the organism to proportions that the specimen would contain had it died today. Carbon-14 has a half-life of 5730 years, meaning that in this amount of time, half the C-14 atoms in a given sample will decay. Using this fact, and the equation for radioactive decay, they can calculate an estimate of the time that has passed since the organism stopped imbibing carbon and hence obtain its age.

Varying carbon levels in the atmosphere

The main issue with this method of dating is that it assumes the carbon levels in the atmosphere have been constant throughout the history of the Earth, which unfortunately is not true. Events like volcanic eruptions alter the amount of carbon dioxide in the atmosphere for several years, and

changes in the Earth's magnetic field can cause varying amounts of radiation to enter the atmosphere, altering the proportion of carbon-14 in the atmosphere. Even the oceans have an impact on carbon levels - oceans absorb carbon dioxide, therefore in the southern hemisphere, where there is more ocean, there will be a lower amount of carbon in the air.

All of this has effects on the accuracy of radiocarbon dating, however last year, new conversion tables were released which take into account these variations by calibrating them according to other comparison points. Stalagmites and lake sediments are two such comparison points, which both accumulate over time and act as a sort of archaeological clock with divisions of hundreds of years.

Tree rings have also been used for calibration in the past, where dates acquired from carbon dating are compared from those obtained by counting tree rings, which increase by one annually. How well these dates line up is considered in the estimation of age.

What's the point?

Carbon dating can give archaeologists a plethora of fascinating information. For example, in Romania, a jawbone belonging to the Homo sapiens species (that's us!) was recovered and its age was determined through carbon dating. Genetic analysis was also carried out on the bone, which revealed that the person who owned the jawbone had neanderthal ancestry going back 4-6 generations. From the carbon-dated age, therefore, it can be determined roughly around what time neanderthals were living in the area.

Mandible of Oase 1, found Romania

Could it stop working?

There are concerns among archaeologists that the incredibly high carbon emissions occurring right now could have a negative impact on the accuracy of carbon dating, which relies heavily on the proportions of different carbon isotopes in the atmosphere. Due to carbon-12 being the majority component of carbon emissions, these ratios are under threat. To find out more about how scientists plan to overcome this issue, watch the video below:
https://www.youtube.com/watch?v=rGtFP73uZIY

-Sai Potturu, 13.2

Satellites

Satellites are defined as any small mass which orbits a larger mass. In order to make an object move in a circular path, a resultant force called the centripetal force must act on the object. In the case of satellites, this is the gravitational attraction between the satellite and Earth and it always acts towards the centre of the orbit. If this force did not exist, the satellite would just continue on a straight path.

If you want to take a look at which satellites are currently in space, here's a link: Satellite Map

Types of Orbit:

Low Earth Orbit

The closer a satellite is to Earth, the faster it must move in order to remain in orbit as the gravitational force acting on the object becomes stronger. This means that satellites in low Earth orbits (~200 to 2000km) are travelling extremely quickly and so cover large areas of the Earth in very short times- a full orbit tends to take around an hour and a half. Although this is much closer to Earth than other orbits, given that the typical aeroplane flies at an altitude of 10km, it is still a very significant distance away. LEOs are the closest a satellite can be to Earth. At lower altitudes, satellites suffer from enhanced orbital decay, meaning they rapidly descend into the atmosphere, often burning up as they do so due to friction. Orbital decay is primarily caused by air resistance as a result of collisions with gas molecules.

One famous satellite in LEO is the International Space Station. This uses a LEO as the relative closeness to the Earth means that it is more easily accessible to astronauts. It orbits at an altitude of 408km and has an orbital period of 1.5 hours.

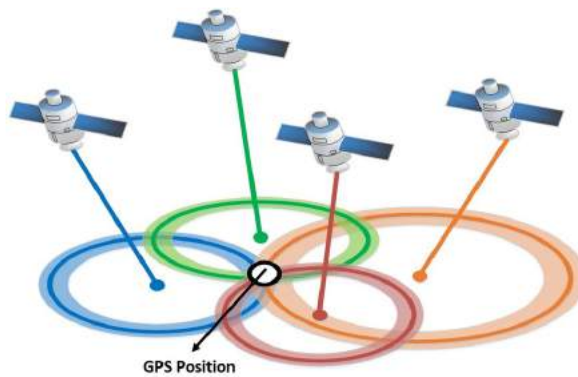
Satellite images are typically taken with satellites in LEO. The proximity to Earth that these satellites have allows higher resolution images to be taken. While detailed, high-quality satellite images of Earth are readily available today, the challenge involved in capturing such images cannot be underestimated. The first satellite image was only taken just over 60 years ago and is far from the images we are used to today. It was captured by NASA's Explorer 6 in 1959.

Polar orbits are a type of LEO and are where orbiting satellites pass above both the North and South Pole during one orbit. One example of a polar orbit is the Sun-synchronous orbit (SSO), which orbits at 600 to 800km. As the name suggests, these satellites are synchronised so that they are always in the same position relative to the Sun and as a result always pass the same location at the same time during the day. This is hugely beneficial for scientists as it allows them to monitor areas by observing any changes over time but without the inconsistencies that would be caused by the satellite passing at different times of the day on each orbit. SSOs, such as Radarsat, have been used to gather data on issues such as deforestation and rising sea levels, as well as changes in land use.

Medium Earth Orbits

Medium Earth orbits occur at altitudes between 2000 and 36,000km and typically have an orbital period of 12 hours. The most famous example of satellites in MEO are those involved in GPS. Around 30 satellites are used to provide GPS. Any GPS receiver, such as your phone, needs to connect to at least 4 of these satellites before it can determine your location.

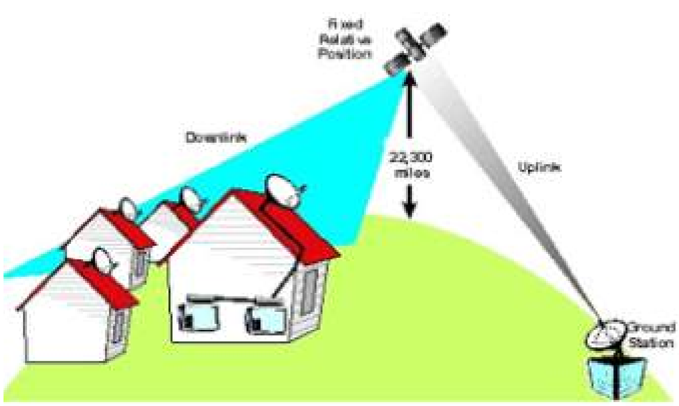
The satellites will send signals to receivers including information on the satellite that it came from and the time at which the signal was sent. These signals are radio waves and so travel at $3x10^8 ms^{-1}$ (although this speed does reduce when travelling through the atmosphere rather than space which is a vacuum). The receiver processes this information to calculate how long the signal took to arrive and so how far it is from the sending satellite. Combining this information from 4 satellites allows trilateration to be used to determine the position, by calculating the location of intersection.



High Earth Orbits

The most common high Earth orbits are geostationary satellites. These are satellites which have an orbital period of 24 hours (like the Earth) meaning that they always stay above the same point on Earth and so to a ground-based observer appear to be in a fixed position. Using the equation $r^3 = GMT^2 / 4\pi^2$ we can see that in order to have a time period of 24 hours, the radius of orbit of a geostationary satellite must be 42,000km. When accounting for the radius of the Earth being 6400km, the height above the Earth must be around 36,000km.

Communication satellites are often in geostationary orbit so that satellite dish antennas can be fixed in position and do not have to move to follow the satellite, as this would be hugely inconvenient and inefficient.



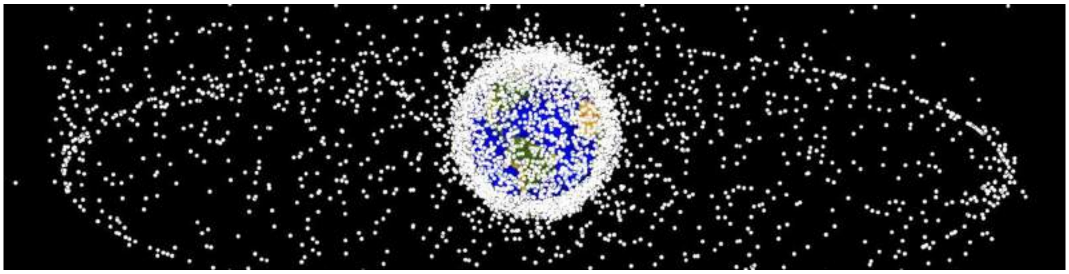
Communications satellites can be used to relay radio waves between locations on Earth. There are three main stages in this process:

- Data is transmitted to the satellite in the form of radio waves from a ground station. This is known as the uplink.

- Transponders on the satellite process the data and amplify the signals
- The signals are sent to many different ground based receivers (e.g. satellite dishes on homes). This is known as the downlink.

This is how satellite TV works- there is an uplink per channel and the many downlinks are received by each individual household satellite at once.

Space Junk



One of the biggest issues surrounding the use of satellites is space junk, which is defined as any piece of defunct machinery or debris left by humans in space. Relative to the number of satellites sent into orbit, very few are returned to Earth after they have completed their mission, meaning that they will simply remain in orbit until they begin to break down or orbital decay causes their return. Some satellites in HEO will remain in space for hundreds of years after use. As more satellites are sent into space, space junk is becoming a more prevalent issue, as it becomes increasingly likely that the junk will collide with other satellites. The most extreme scenario is described by Kessler syndrome- this states that once the amount of space debris in orbit exceeds a critical mass, during a collision, enough new space debris would be created to cause a chain reaction of collisions, meaning the Earth's orbit would become unusable.

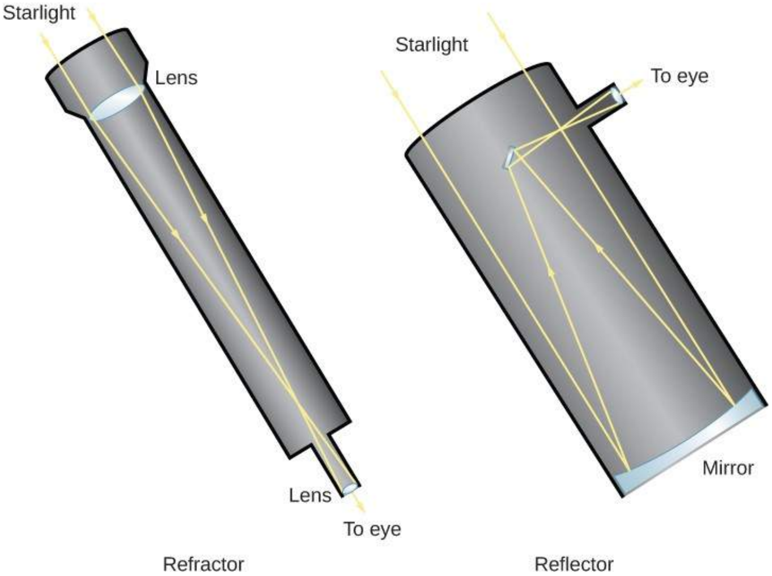
Mega constellations are vast new groups of satellites planned by companies such as SpaceX and Amazon to provide global Internet coverage. The scale of these projects is already becoming clear. The first operational Starlink satellite (operated by SpaceX) was launched in 2019, meaning that within just 2 years, over 1000 satellites have been launched into orbit as part of this one project. This means that the removal of space junk will have to take a much greater role in future space missions as the huge numbers of new satellites being launched means collisions are becoming more likely.

Although Kessler's syndrome is highly unlikely, new missions, such as ClearSpace-1 are planned for the next decade to begin removing space debris. Just last week a demonstration of a potential space debris removal mission- Astroscale- was launched. These missions primarily work by sending spacecraft to dock with debris and lower it so that it re-enters the Earth's atmosphere. This would cause the debris to burn up or break up, due to orbital decay.
-Natalie Smith 13.2

And now for the winner of the science week article writing competition for physics, Sanskriti Singh, in 8Z. Well done!!

Ingenious Inventions

The telescope has helped us in so many ways - it helped us see that black holes were real, they can allow us to look into the universe and actually be able to examine the things we see and even showed us that Earth was is not the centre of the universe (***gasp!***). They even allowed us to make the first measurement with high validity of the speed of light, and Edwin Hubble discovered that the universe was expanding using a telescope. You might think that the telescope is a very common invention to talk about, but it is extremely fascinating and has helped us discover, see and do many admirable feats (but you're not supposed to explain everything in the introduction, so read on!).



Refracting and Reflecting Telescopes

There are two types of telescopes - refracting telescopes and reflecting telescopes. Refracting telescopes use curved lenses as their optics whilst reflecting telescopes use curved mirrors. Reflecting telescopes are better to use than refracting telescopes as the lens has to be bigger for you to see further away objects, but glass is heavy. Furthermore, as the lens gets larger in size, so does the thickness (and glass is quite heavy). On the other hand, mirrors only have to increase their diameter, and not their thickness, to magnify objects more. Mirrors are also much lighter than glass.
But first, here's some more information about both types of telescope.

Refracting Telescopes

A refracting telescope uses curved lenses as its optics. In a refracting telescope, the larger lens at the end of the telescope gathers light from the object in the sky that the telescope is pointing at and bends it. The bent light travels through the body of the telescope and then the small lens closer to your eye magnifies and focuses the light, which you then see. (see image above.) Lenses are made of glass.

Reflecting Telescopes

A reflecting telescope uses curved mirrors as its optics. In a reflecting telescope, the large mirror at the end of the telescope gathers the light from the object in the sky that the telescope is pointing at and reflects the light to the smaller mirror, which then reflects the light into the eyepiece, which is what you then see. (see image above.)

Reflecting telescopes are better to use than refracting telescopes because glass is heavier than mirrors and in space telescopes, mirrors are better to send into space as they are lightweight. In addition to this, heavier objects are harder to position properly and more and more light is prevented from entering as the lens becomes thicker (mirrors don't need to increase their thickness). It is also much easier to make mirrors that are the perfect size than perfect-size lenses (one more mistake and the image you see won't be right or accurate).

There are a few more types of telescopes, but these two are probably the ones everyone is most familiar with.

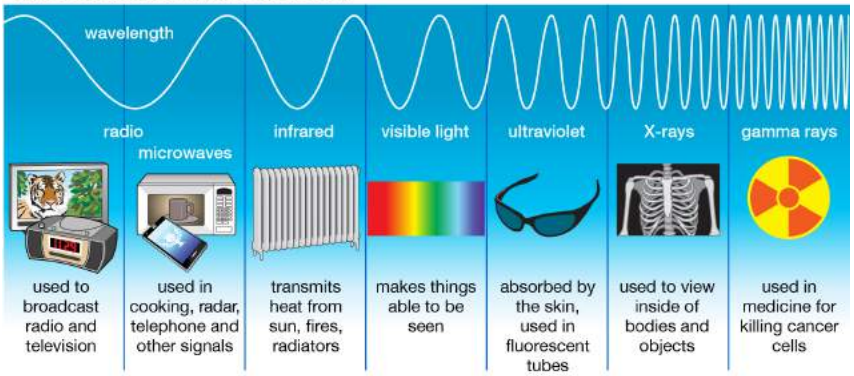
But you probably want to know who actually invented telescopes. So, here's just a bit of simple information about the creators of the terrific telescope. In 1608, a Dutch eyeglass maker called Hans Lippershey was the first person to make a telescope (though others have claimed to be to be the first human to make a telescope, but Lippershey was accepted to be the first person to make one), and his telescope was able to magnify things up to 3x larger. Then Galileo Galilei heard about Lippershey's invention and decided to make a telescope as well. By 1610, Galileo had made a telescope that could magnify objects up to 20x, with which he could see some of Jupiter's moons and the craters on our own moon! Galileo was the person who first used a telescope to explore space. After that, Johannes Kepler decided to improve refracting telescopes by using two convex lenses instead of one convex lens and one concave lens. Isaac Newton then decided that using mirrors would be better than using lenses for the optics of a telescope, and he built the first reflecting telescope in 1668. And the telescope has since been developed and used by many people to make amazing and astonishing discoveries about the universe!

FACT: Lyman Spitzer was the person who had the idea of using telescopes in space (not just to look at objects in space from Earth.

What are telescopes used for / what can they do?

In this section, we will look at what telescopes can do (space telescopes *and* ones you look into from Earth). There's an immense amount of things telescopes can do and are used for, so this is just a tiny and condensed description of what they

Types of Electromagnetic Radiation



do (because it would just be tiring to write it *all* out). Telescopes allow us to see objects in space much closer, and they also detect radio, gamma, microwave, infrared, x-ray and ultraviolet! They can see and detect so many things that we can't. They can analyse radiation from objects in space - objects both close and far away.

What is the influence of telescopes today?

Firstly, telescopes have changed the world a lot as many people based the appearance of the universe on their religious beliefs, but when telescopes came into use, people could see that many things they thought about the universe were incorrect. They have helped us to not only see the universe's appearance but look at how old the universe is, the speed of light, lots about celestial bodies and so much more!

Now, telescopes are still being used to make all sorts of discoveries. We use telescopes to observe planets around other stars and other solar systems. We use telescopes to study galaxies, and to observe objects by the type of electromagnetic radiation they emit. Telescopes capture beautiful and extraordinary images of space which scientists can study and discover staggering things about the universe we are part of. Without telescopes, space travel would not have been possible. We may never have known that black holes existed, and we might have simply stuck to religious and spiritual beliefs about the universe rather than the facts, and if anyone ever did have any sort of theory about the universe, it would have been extremely difficult to prove. We wouldn't have discovered how old the universe is without telescopes. We would have missed out on so much.

In the future, telescopes will continue to observe the wonders of our universe. They will continue our search for life on other planets. We may even develop telescopes more which would allow them to do things that are entirely out of this world (get it?) and things we never thought about. Telescopes are wonderful inventions that have developed humankind and allowed us to see things we thought were impossible to see, impossible to even exist. Telescopes really are just great - there's no word in any language that could possibly describe them as well as they deserve!

JOKE:

Somebody whacked my head with a telescope today

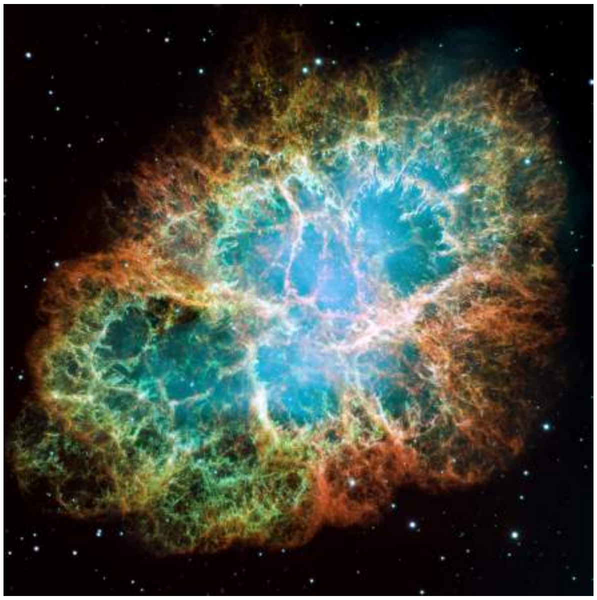
I was seeing stars

I hope you enjoyed looking at the breathtaking qualities of telescopes, and the sources I used are below. There's lots more you can look at though - all the dazzling aspects of telescopes are impossible to fit into one article!

- https://www.britannica.com/science/optical-telescope

- https://www.nasa.gov/centers/jpl/education/telescopes-20100405.html#:~:text=Telescopes%20have%20opened%20our%20eyes,and%20craters%20on%20the%20moon.&text=Telescopes%20have%20also%20helped%20us,laws%20of%20the%20physical%20world.
- https://spaceplace.nasa.gov/telescopes/en/
- https://www.astronomynotes.com/telescop/s3.htm
- https://museumsvictoria.com.au/scienceworks/visiting/melbourne-planetarium/fact-sheets/how-do-telescopes-work/
- https://www.bbc.co.uk/newsround/50819852
- https://www.ducksters.com/science/physics/telescopes.php

By Sanskriti Singh 8Z.



The Crab Nebula