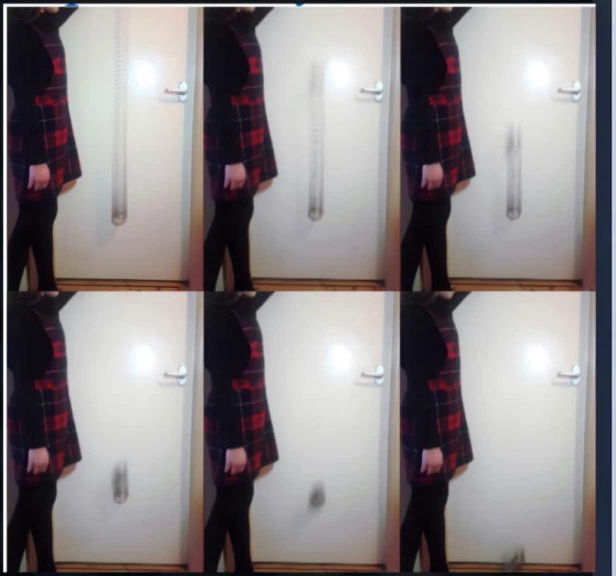
Physics Journal 2024

Issue 03.

A Falling Slinky

By Guneet 12W

Slinkies used to be my absolute favourite toy as a child. I used to spend ages walking it down the stairs or throwing it around the place. The way it moved was a mystery to me, and one of these such mysteries was what would happen when I dropped it.
Here is a picture of a falling slinky, as well as the link to the video that inspired this article:
https://www.youtube.com/watch?v=JsytnJ_pSf8



You'll notice that holding a slinky at one end, suspended by gravity, and then dropping it leads to the top of the slinky accelerating downwards, while the bottom of it seems to hover in the air. The bottom of the slinky does not begin to fall until the top section of the slinky collapses into and collides with the bottom.

What is a slinky?

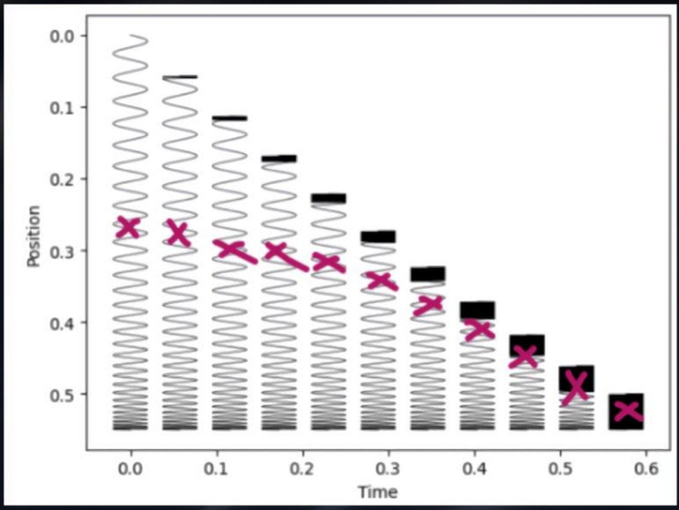
A slinky is essentially just a helical tension spring. Coils that have been wrapped tightly together that require tension (a pulling force), to separate these coils.

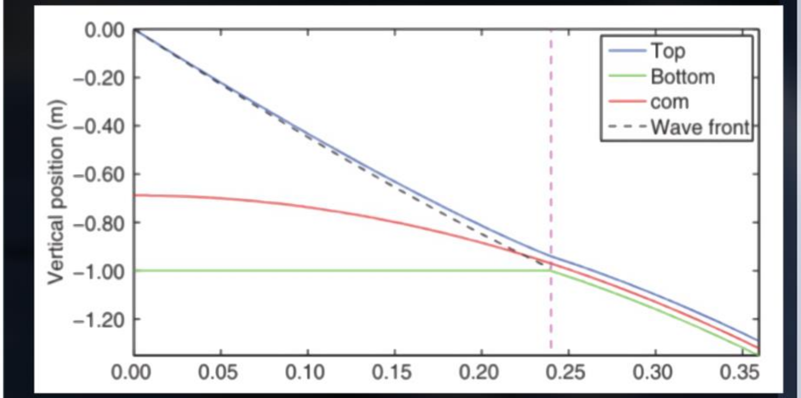
A Falling Object

The reason why the result of a 'levitating' slinky is such a surprise to us, is because it is different to what we observe in our day-to-day lives. The weight of an object is the force that makes things fall, and this is provided by gravity. We can use the equation W=mg (Weight = Mass*Gravitational Field Strength) to describe this. This force causes the object to accelerate or speed up after it is dropped.
We use the equation Fnet=ma (Resultant Force = Mass*Acceleration) to describe this motion, assuming the mass of the object is constant. The net force acting upon our object is the weight of the object which is equal to mg. Equating these two, we get mg=ma, and we can therefore conclude that g=a.
So, for objects that fall under the sole influence of gravity, we can conclude that any object will fall at the same rate, with acceleration of g (approximately 9.8ms^-2). However, objects also experience air resistance, which is dependent on the cross-sectional area of the object, as well as the relative speed compared to the fluid it travels through. This is why we don't expect marbles to fall to the ground at the same rate as which a feather does.
All this to say that dropping an object usually causes it to fall towards the ground.

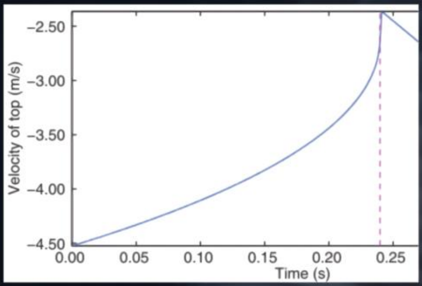
So, do Slinkys break the laws of physics?

Sadly, this is not the case. The force that pulls an object downward can be thought of as acting upon the centre of gravity of the object. This is a point where we can imagine the total weight of the body to be concentrated at. And in this case, this is equivalent to the centre of mass – the average location of all the mass of an object.





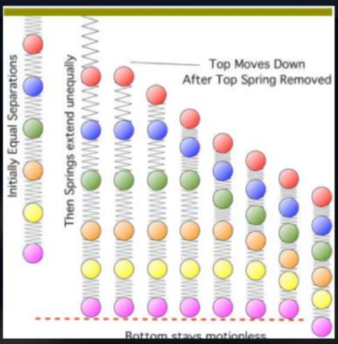
The above image to the left is a rudimentary estimation of where I estimated the centre of mass of the spring to be, assuming it was uniform. Although it is inaccurate, looking at it, you can see that the centre of mass of the spring is accelerating downwards. On the graph on the right, looking at the red line, we see a similar motion. Ignoring air resistance, it can be said that the centre of mass of our slinky accelerates downwards at 9.8 m/s2. Although the bottom of our slinky remains stationary, we can actually see that the top section of the slinky accelerates at a faster rate than g. Overall, this means our centre of mass accelerates at g.

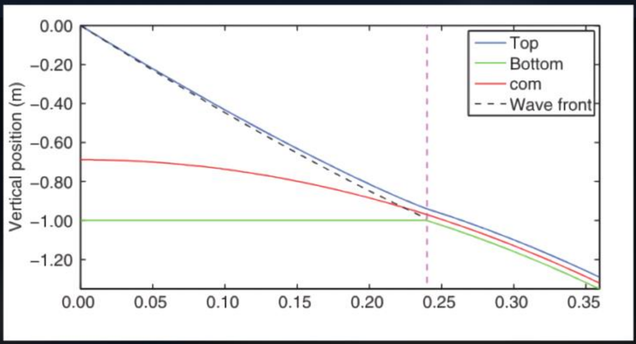


Why does this happen?

Our slinky initially is not moving or accelerating. This means that no resultant force is acting upon it. The bottom end of the slinky is being pulled downwards by gravity while tension is pulling it up. As for the top, gravity is pulling downwards on the top and all the segments below, while whatever that is holding the slinky provides the opposing force for this.

If you take any point in the slinky the tension pulling it up is equal to the weight below. Now, when we release the slinky, we remove the upwards force provided by our fingers. However, there is still the weight acting downwards as well as the tension between the red and the blue point. This causes the top to accelerate faster than it ordinarily would. Meanwhile, the bottom end still does not move, as the forces on it are still balanced – it has not yet received information about any change in the tension upwards in the form of compressions. It does not ’know’ that the top has been dropped.





The speed at which this change in tension propagates through the spring in the form of a longitudinal wave does not exceed the speed at which the top of the spring falls. So, the wavefront reaches the bottom of the spring approximately when the top does, and only then does the slinky begin to fall.

Visualising the slinky as n particles of equal mass with massless springs between them helps. We can imagine then imagine a linear decrease in tension crossing each particle. This takes around 0.3s.

Is this limited to Slinkys?

Actually, for all objects this is the same. Only something like a steel rod is much denser than a slinky, and so the propagation of this wave front takes much less time and looks instantaneous to our eyes. Everything can be considered to be a spring, except some are springier than others. Longitudinal waves depend on the compression and rarefaction of particles so in a vacuum, sound cannot travel through.

A thought experiment:

Let us pretend I had a really long metal rod, and poked something really far away with it. We would probably say that the object would move. If this object is long enough, then we have successfully transferred information faster than the speed of light, the universes' speed limit.

Why does this not work?

Pushing one side of the rod will not cause an instantaneous change in position at the other side. Each atom will push on the other, and this information will be transferred through a wave to the other side. The rate of transfer cannot exceed the speed of sound in that material, which will not exceed the speed of light.

Visualising the rod as a spring sitting on a table is helpful to see this.

Furthermore, signals between atoms can only be transferred at the speed of light, so there is no way we can overcome it, unless our rod was perfectly rigid.

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COLOUR of Clouds

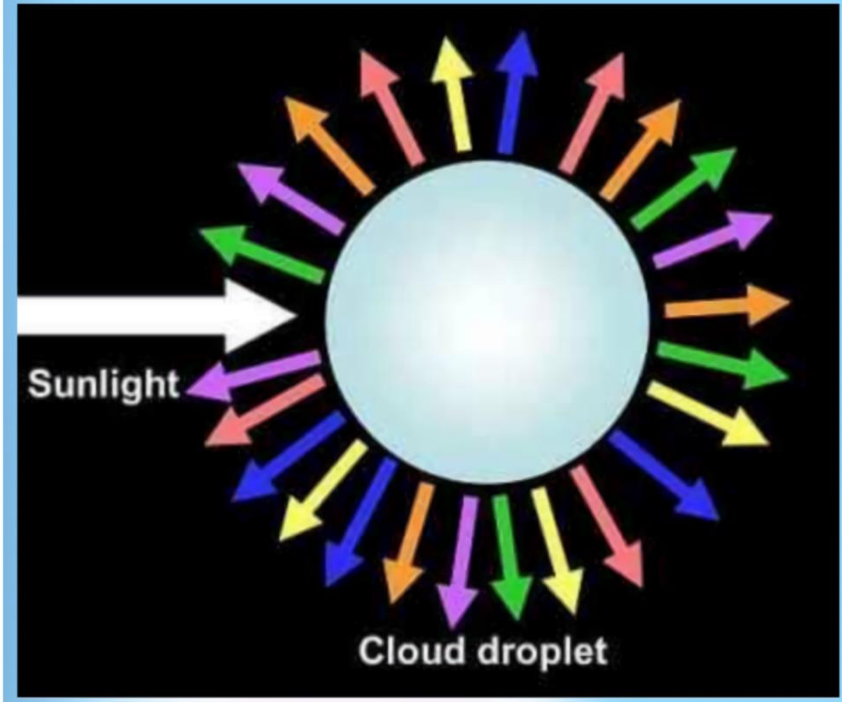
By Trevor 12W

What are clouds?

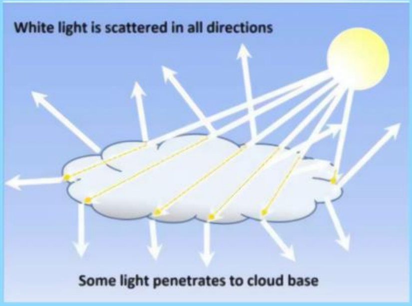
Clouds are visible accumulations of water droplets or ice crystals in the atmosphere.

Why are clouds (usually) white?

Light rays are waves that can differ in length, known as wavelength. Only some of these wavelengths can be detected by our eyes. They are collectively known as the visible light spectrum, which contains light with wavelengths between approximately 0.4μm and 0.7μm. We perceive something as white if it gives out or reflects light rays of all wavelengths in the visible light spectrum.



The sun emits light rays that come in all wavelengths in the visible light spectrum (white light). When these beams of white light come into 'contact' with the clouds, the much larger water droplets (≈10μm) in the clouds cause the beams of white light to undergo 'Mie scattering' - all the visible wavelengths are scattered roughly equally. The result is that 'white light' is reflected off the clouds, so clouds appear white in colour.



Why does rain only fall from grey clouds?

Clouds are grey for two reasons:

One, clouds are thick. As we established, water droplets scatter light, and most of these beams reflect upwards, meaning not much light reaches the cloud base.

Two, larger water droplets. Large water droplets tend to scatter less light and instead absorb more light. Since larger water droplets are heavier, they are more likely to fall and cause rain.

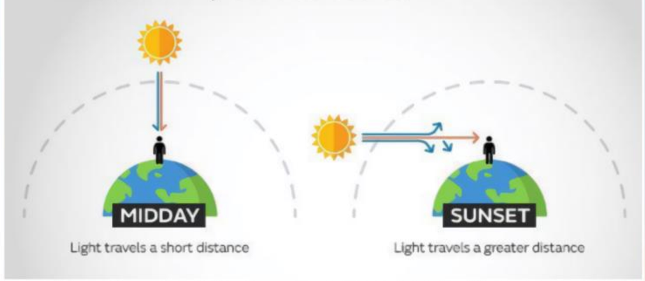
Clouds that are tall and have large water droplets are the ones that tend to rain. At the same time, they are the ones that have grey cloud bases as explained. Moreover, since the tops of the clouds always receive sufficient sunlight, they are always white. This explains why when you look out of an airplane, there are only white clouds.

Why do clouds appear red/orange during sunrise/sunset?

Normally in the day, the sky is blue as blue and violet light rays, with shorter wavelengths, are scattered more than red or orange light rays, with longer wavelengths. This is known as 'Rayleigh scattering', which takes place here instead of the aforementioned 'Mie scattering' because the air molecules and particulates in the atmosphere are similar in size to the wavelengths of visible light.

In case you are wondering why we don't see the sky as violet even though they have a shorter wavelength than blue light. This is because our eyes are less sensitive to violet light compared to blue.

During sunrise and sunset, sunlight has to go through a thicker layer of the atmosphere. This means that the blue and violet light rays are further scattered, leaving mostly red and orange light rays, so we observe a red or orange sky. This is the same with clouds: only red and orange light rays 'hit' the clouds, so only red and orange light rays are reflected from the clouds instead of the usual white light, giving the clouds a red/orange shade.



Sunlight travelling through the atmosphere (image from the Meteorological Office)

What about clouds at night?

Clouds at night have fewer light rays to scatter, so they are darker. Most of the light rays are from the white light of the moon, so they still appear white, and sometimes grey if there is little light.

However, the bottom of the clouds may have other light sources from streetlamps or shining buildings, etc. This makes the bottom of the clouds appear yellowish orange in urban areas and places with light pollution. This is more obvious with lower or denser clouds.

I have seen rainbow-coloured clouds before?

If you actually do, that is quite lucky! These are known as iridescent clouds. They are formed when tiny water droplets or ice crystals of similar sizes in clouds diffract sunlight. These water droplets and ice crystals all scatter light in different ways, causing iridescence. Iridescent clouds are usually high up, close to the sun, and thin. They are more commonly seen in cloud edges and semi-transparent clouds.

What about those pearlescent clouds?

I believe you are referring to nacreous clouds. They are clouds in the polar regions, usually at a height between 68,500 and 100,000 feet (the stratosphere). They often reflect vivid colours through the same effect of iridescence we just discussed above.

Iridescent clouds (photo from SKYbrary)

Closing

Clouds are a huge topic in geography, so this article is just the tip of the iceberg. I don't study Geography (or Physics), you can email me (18leet@newsteadwood.co.uk), or the editors of the Physics Journal if there is any wrong information.

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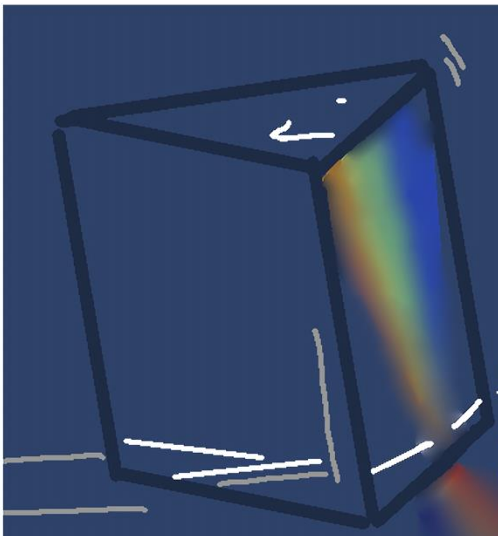


Physics and the Particle-Wave Theory of Light

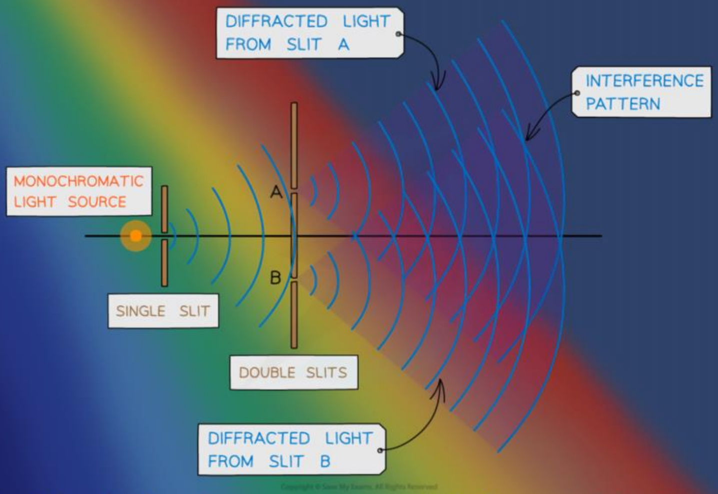
By Grace 12N and Estelle 12G

What did Newton think?

Ancient Greek philosophers like Pythagoras and Democritus debated the nature of light, laying the groundwork for future scientific exploration. However, it was not until the 17th century that Isaac Newton, through his prism experiments, claimed that light consists of small particles. Conversely, Christiaan Huygens proposed a wave theory, suggesting that light propagates as waves through a medium he called the ether.

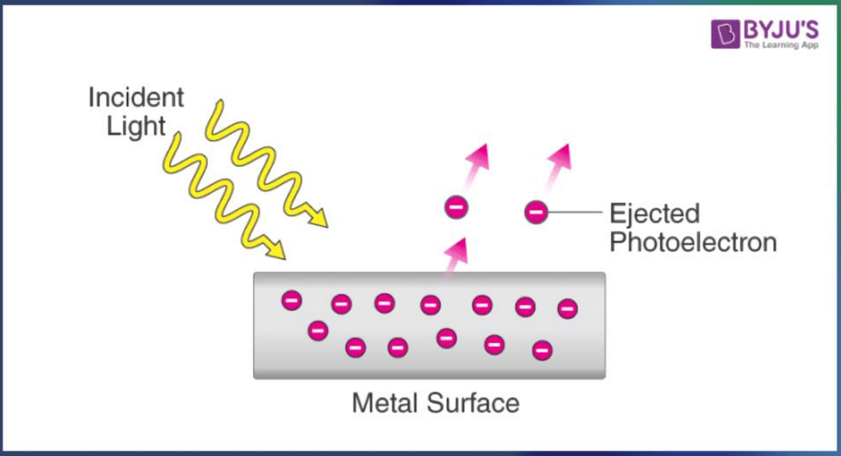
How is light waves proved?

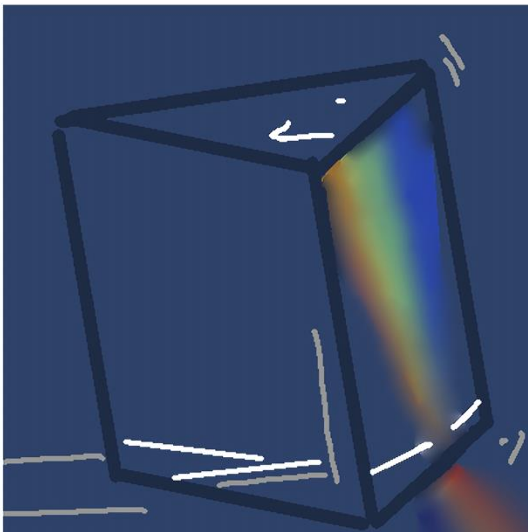
The wave theory gained substantial support in the 19th century, particularly with the work of Thomas Young . Young's double-slit experiment in 1801 demonstrated that light creates interference patterns indicative of wave behaviour. When light passes through two closely spaced slits, it produces a pattern of bright and dark fringes on a screen, a phenomenon explainable only if light behaves as a wave, with peaks and troughs that can reinforce or cancel each other.



Quantum theory: photoelectric effect

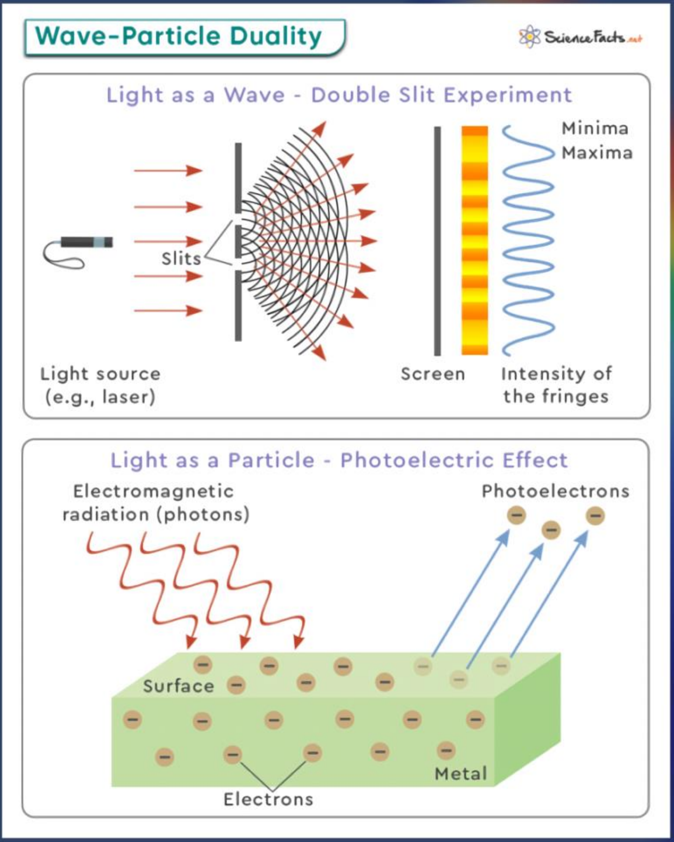
Despite the successes of the wave theory, certain phenomena eluded explanation until the early 20th century, when quantum mechanics emerged. The photoelectric effect, observed by Heinrich Hertz and later explained by Albert Einstein in 1905, revealed that light could also exhibit particle-like properties. Einstein proposed that light consists of photons, each carrying discrete energy packets. This particle-like behaviour was crucial for explaining why light of certain frequencies could eject electrons from metal surfaces, a process not explicable by wave theory alone.





Duality

The wave and particle theories culminated in the establishment of wave-particle duality. This principle posits that light exhibits both wave-like and particle-like properties, depending on the experimental context. Louis de Broglie extended this duality to matter, suggesting that particles such as electrons also possess wave properties which lead to studies carried out by Schrodinger.



Schrodinger’s Cat Theory (my favourite!!)

It is a theory which illustrates the nature of quantum mechanics, superposition and the role of the observer and A cat is placed in a sealed box with a radioactive atom, a Geiger counter, a vial of poison, and a hammer. If the Geiger counter detects radiation (indicating the atom has decayed), it triggers the hammer to break the vial of poison, killing the cat. If the atom does not decay, the cat remains alive. According to quantum mechanics, the cat is in a superposition of being both dead and alive simultaneously. The state of the cat (dead or alive) is not determined until the box is opened and an observation is made. This act of measurement collapses the superposition into one of the definite states. Different interpretations of quantum mechanics, like the Copenhagen interpretation and the many-worlds interpretation (dead in one universe and alive in another), offer various explanations for this phenomenon.

Conclusion

The particle-wave theory of light is a huge breakthrough in physics, connecting old and new ideas. It shows how science can grow through experiments, new ideas, and big changes in thinking. By accepting that light acts both like particles and waves, we understand the universe better, opening doors for new discoveries and technologies. This theory not only shows how science constantly evolves but also reveals the beauty and complexity of nature. Thank you for reading!!

Superposition:

A Cornerstone of Quantum Mechanics

By Grace 12N and Estelle 12G

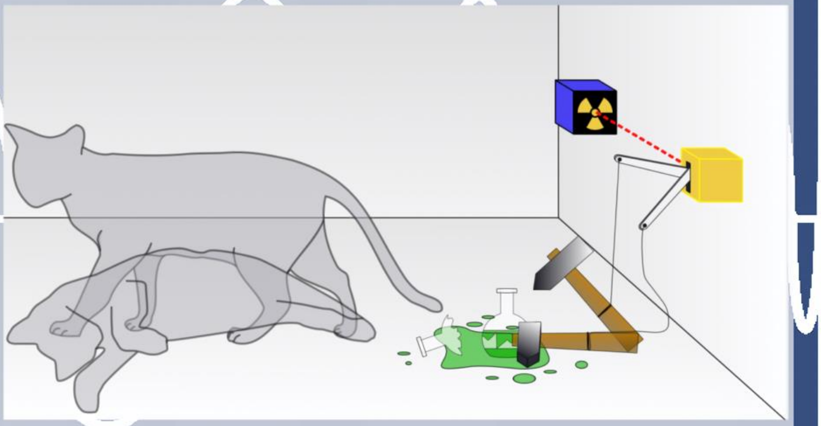
The Concept of Superposition

Superposition is a key idea in quantum mechanics, the study of how tiny particles like electrons and photons behave. It shows that particles can exist in multiple states at once, which is very different from how we see things in our everyday world.

In everyday life, objects are in one clear state at a time. For instance, a coin is either heads or tails, not both. However, in the quantum world, particles can be in multiple states simultaneously. This strange concept can be illustrated with Schrödinger's cat thought experiment. In this experiment, a cat in a sealed box can be considered both alive and dead until someone looks inside.

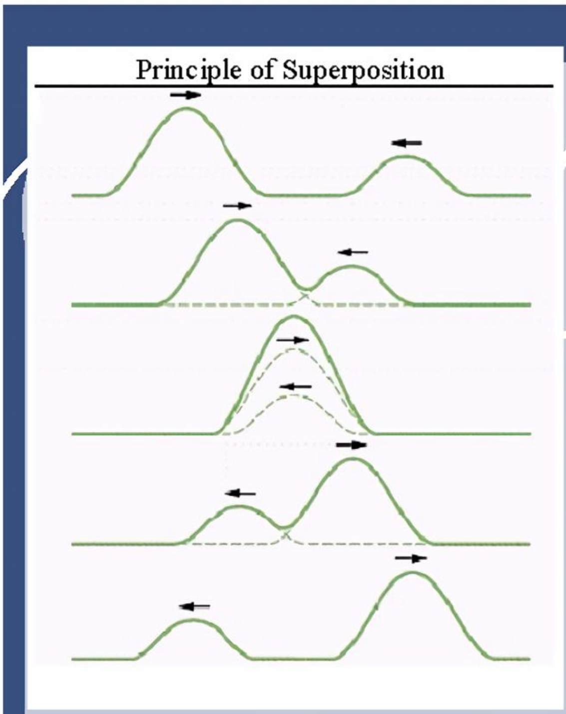
Implications of Superposition

Superposition has major implications for our understanding of reality. One important outcome is quantum interference.



When particles in a superposition state interact, their wave functions can add up or cancel out, creating patterns that classical physics can't explain. This is shown in the double-slit experiment, where particles like electrons create an interference pattern when not observed, suggesting they go through both slits at the same time.

Superposition also leads to quantum entanglement. When particles become entangled, the state of one particle is directly connected to the state of another, no matter how far apart they are. This means that information about one particle's state is instantly known by the other, challenging our traditional ideas of how information travels.



Applications in Modern Science and Technology

Superposition isn't just a weird idea; it has practical uses in modern technology. One exciting application is quantum computing. Regular computers use bits as the basic unit of information, which can be either 0 or 1. Quantum computers use qubits, which can be both 0 and 1 at the same time due to superposition. This allows quantum computers to process many possibilities at once, potentially solving certain problems much faster than classical computers.

The most common use of wave superposition is noise-cancelling headphones. Headphones can receive sound waves coming from the environment and produce waves in 'anti-phase' and of the same amplitude essentially 'cancelling out' the noise.

Superposition is also important in quantum sensing and measurement. Devices that use superposition can achieve extremely high levels of sensitivity and precision. For example, atomic clocks, which are crucial for GPS systems, use superposition states of atoms to keep very accurate time.

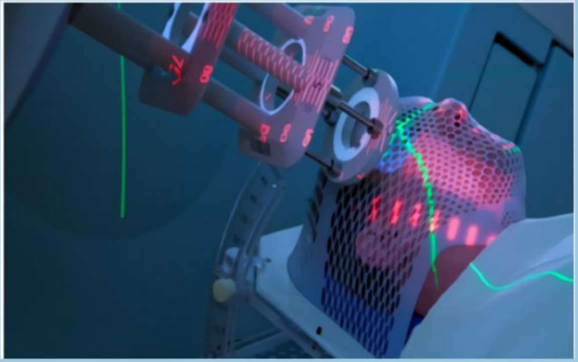
Conclusion

Superposition is a fundamental concept in quantum mechanics, showing that particles can be in multiple states at the same time. This challenges our everyday understanding of reality and has significant implications for science and technology. As we continue to explore and understand superposition, it promises to open new frontiers in areas like computing, communication, and measurement. The study of superposition not only deepens our understanding of the quantum world but also paves the way for innovations that could revolutionize various fields in the future.

The way Physics is used for medical equipment by opticians

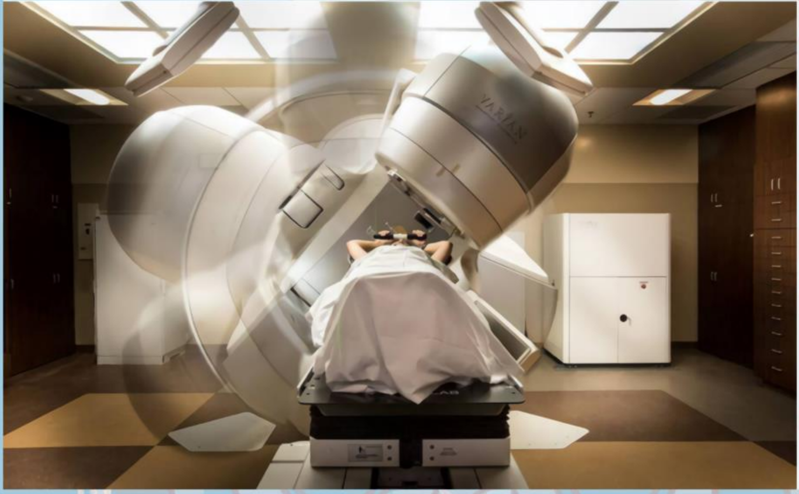
By Gobi 12P

Physics plays a crucial role in the development and functioning of various medical equipment. Here are some ways physics is used in medical equipment:



1. Imaging Techniques : Physics principles are the backbone of various medical imaging technologies like X-rays, CT scans, MRI, ultrasound, and PET scans. These techniques rely on different physical phenomena such as radiation absorption (X-rays), magnetic resonance (MRI), sound waves (ultrasound), and positron emission (PET) to create detailed images of the internal structures of the body.

2. Radiation Therapy: Physics is essential in radiation therapy for cancer treatment. It helps in the precise delivery of radiation doses to targeted areas while minimising damage to surrounding healthy tissues. Techniques like intensity-modulated radiation therapy (IMRT) and stereotactic radiosurgery (SRS) rely heavily on physics principles for accurate treatment planning and delivery.



3. Monitoring and Diagnosis : Physics is used in medical equipment for monitoring vital signs such as heart rate, blood pressure, oxygen saturation, and brain activity. Devices like electrocardiograms (ECG/EKG), blood pressure monitors, pulse oximeters, and electroencephalograms (EEG) operate based on principles derived from physics.

4. Surgical Instruments :Physics principles are applied in the design of surgical instruments such as lasers used in laser surgery, endoscopes for minimally invasive procedures, and robotic surgical systems. These instruments leverage optics, electromagnetism, and mechanics to enable precise and less invasive surgical interventions.

Medical Equipments:

- Phoropter: Used to measure refractive error and determine the appropriate prescription for glasses or contact lenses.
- Auto refractor/keratometer: Measures the curvature of the cornea and refractive error to assist in determining the prescription.
- Ophthalmoscope: Allows examination of the back of the eye, including the retina, optic disc, and blood vessels.
- Slit lamp: Provides a magnified view of the eye's anterior segment, including the cornea, iris, and lens, for detailed examination.
- Lensometer: Measures the power and orientation of lenses, ensuring accuracy in prescriptions and lens fittings.
- Visual field tester: Evaluates a person's peripheral vision to detect any abnormalities or vision loss.

- ←Pupilometer: Measures the distance between pupils, crucial for proper alignment and fitting of eyeglasses.
- Tonometer: Measures intraocular pressure to screen for glaucoma, a condition characterised by increased pressure within the eye.
- Retinal camera: Captures images of the retina for documentation, monitoring eye health, and detecting various eye conditions.
- Optical coherence tomography (OCT): Provides detailed cross-sectional images of the retina and other eye structures, aiding in diagnosis and management of eye diseases.

How does physics shape earthquake resistant architecture in Japan?

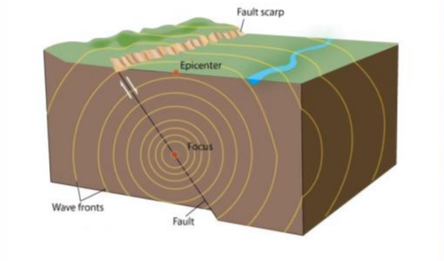
By Kelly 12N

What are earthquakes and how are they formed?

Earthquakes are the sudden violent shaking of the ground, this is caused by the movement of the Earth's tectonic plates. Due to the fact that the plates are constantly moving, they sometimes get stuck, this leads to pressure building up because the plates will continue to move. The pressure would get released and it would release lots of energy, causing the Earth's surface to shake rapidly.

Earthquakes originate from a point on Earth called the 'focus'. The rapid movement releases energy in the form of seismic waves, which spreads out from the focus. The seismic waves probate through the earth's layers and cause the ground to vibrate resulting in an earthquake.

Seismic waves radiate from the focus of an earthquake



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Why does Japan experience frequent earthquakes?

Japan is located along the pacific Ring of Fire, which is a major area in the basin of the Pacific Ocean where many earthquakes and volcanic eruptions occur. Japan sits at the convergence of four tectonic plates : the Pacific Plate, the Philippine Sea Plate, the Eurasian Plate and the North American Plate. The movement and interaction of these plates create significant geological stress, which leads to seismic waves being produced more frequently.

How does physics help in architecture to make the place safer?

Seismic isolation:

Base isolation : this technique involves placing building foundations on flexible bearings or pads, which will absorb and dissipate the seismic energy, reducing the impact greatly.

Rubber and steel are often used to reduce the amount of energy transferred to the structure, also minimising impact. This relies on the physics behind harmonic motion and energy dissipation

Damping systems:

Tuned Mass Dampers: these are large masses installed in buildings that would move in opposition to the building's sway. This reduces motion during an earthquake. This is based on the physics behind Newton's laws of motion and the principles of damping, which is when the damper absorbs and dissipates vibrational energy

Material science:

Flexible materials: engineers use advanced materials with high ductility. Some examples are certain steels and reinforced concrete. They can deform without breaking. The physics behind this is the understanding of stress-strain relationships. Selecting materials are crucial as some are better at absorbing seismic energy than others

The application of physics in architecture is paramount in earthquake-prone regions like Japan. Through the use of base isolation systems, tuned mass dampers, and flexible materials, architects and engineers can create buildings that not only withstand seismic forces but also protect lives and property. Physics greatly enhances our understanding of this world, and even though you might not notice it, it plays a huge role in our daily life.

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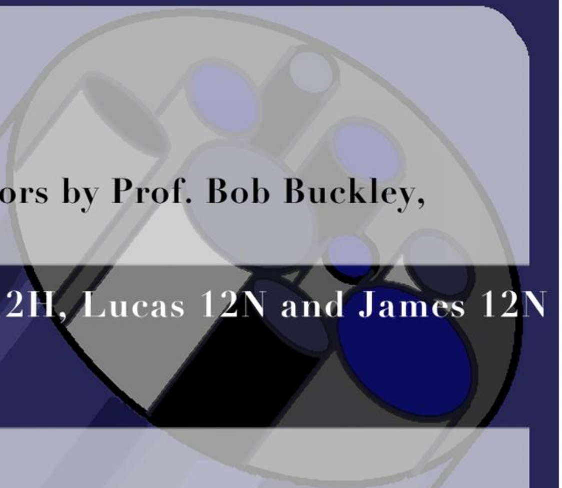
High Temperature Superconductors

An overview of modern developments on superconductors by Prof. Bob Buckley, Victoria, Wellington University NZ



By Helena 12H, Lucas 12N and James 12N

What Are Superconductors?

Superconductors are modern materials placed in specific environments that allow current to pass through them freely, without resistance of any kind. A new material, superconductors have potentially many applications such as efficient power transmission, quantum computers, and particle accelerators.

How Do Superconductors Work?

In a circuit using normal wires, electrons collide with the vibrating positive metal ions in the lattice arrangement of the conducting metal – this is what causes friction/ resistance in a circuit. The more the positive metal ion vibrates, the more collisions with electrons – and the higher the resistance. Superconductors work differently in the sense that electrons move with the patterns of vibrations of ions – reducing the number of collisions and decreasing the overall resistance. A perfect superconductor has no collisions/resistance.

The Problem with Existing Superconductors

Superconductors, in their modern state, require extremely cold temperatures to work – to prevent the positive metal ions from vibrating and causing collisions. Most commonly, superconducting materials are kept at ~1.9K (-271°C). This kind of temperature can be suitably sustained in an environment like CERN, which hosts the Large Hadron Collider (LHC) – using a cryogenic system containing 96 tonnes of liquid helium, the biggest of its kind. Alternatively, in other industrial contexts, it's not viable to do this.

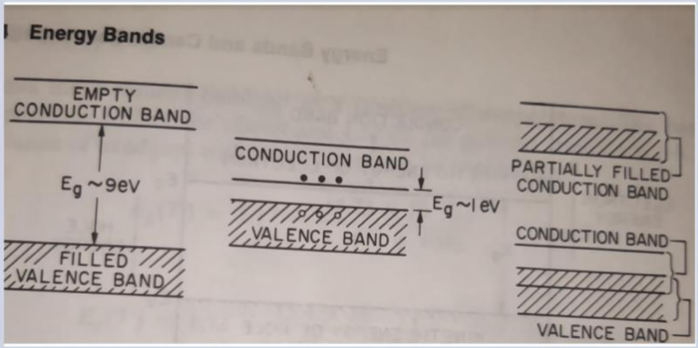
The Modern Solutions & Applications

Prof. Bob Buckley (NZ) at Wellington University has spent his life researching superconductors and has produced new concepts for superconducting materials with commercial viability. An example of one of these being, Copper-Oxide based superconductors. This superconductor works at a much higher temperature relative to other options making it more suitable for use in a commercial setting. These new high-temperature superconductors allow for the creation of new particle accelerators which will deepen our understanding of particle physics.

Unveiling the Physics: How Camera Sensors Capture the World

By Preston 12P

*There's a dictionary at the end to help with all the physics jargon in here

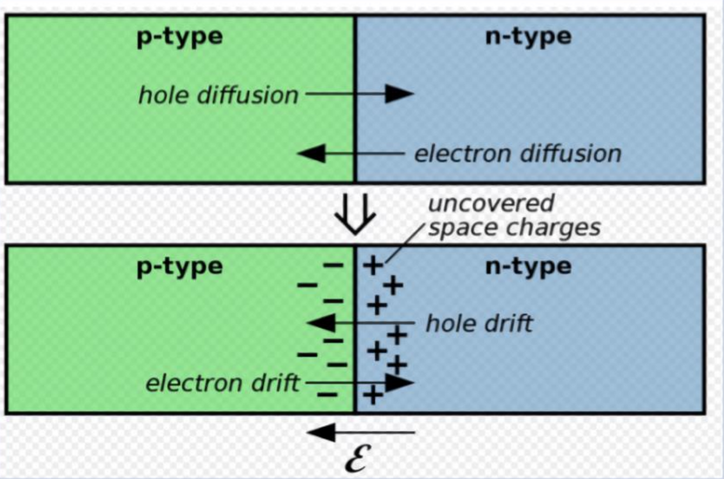


Cameras make up a crucial part of our modern lives, from ensuring our security, recording memories, monitoring populations, or allowing us to communicate across the globe. However, behind these nearly ubiquitous devices is an intricate and complex application of concepts from many different fields of physics. All modern digital camera sensors, such as those on your phones, actual cameras, CCTV systems, and basically anything made within the last 20 years, are made of semiconducting materials- defined as materials that have the conductivity(o) of around 10-°S cm' (Siemens per centimetre) to 103S cm' [1]; though this is extremely sensitive to temperature, magnetic fields, illumination, and the presence of impurities.

When atoms are distant they have the same energy levels(this is referred to as having one doubly degenerate level), however when they are brought close together (like if they bonded) these levels will split into multiple separate bands- for example if there is a there is a lattice structure of N atoms within its unit cell it will form N degenerate energy levels. However, these energy levels are extremely close together forming what is effectively a continuous band. Semiconductor materials, have such a lattice structure and can conduct electricity under some conditions, but for this to occur the electrons in the valence band of a covalent bond must jump to the conduction band - the energy required to make this jump is called the bandgap(Eg); with electrons in semiconductor being able to do so with little energy as the covalent bonds in semiconductors are weaker than that of others(so they have a low bandgap). When an electron jumps the bandgap it will end up in the conduction band, but also leave behind a gap in the valence band- this can be treated like a conventional particle would be, which can be thought of as a bubble moving through a liquid like syrup, with a charge opposite to the electron but of equal magnitude[1]. There is also an important distinction that needs to be made in the types of semiconductors that will be relevant later, some semiconductors will have a higher number of electrons, whilst others will have an electron scarcity (or be rich in holes). Those which have an electron scarcity are P-type semiconductors, whilst those with an electron abundance are called N-type semiconductors.

The nature of light and how it is modelled in semiconductor physics:

To understand the inner workings of camera sensors you must also (kind of) understand what it is meant to capture, light. Light is an extremely complicated concept(really), so in semiconductor physics the main ideas that encompass how light is treated is Maxwell's electromagnetic theory of light and the quantum electrodynamic (QED) model of light. In Maxwell's theory of light, light is a propagating wave of electric and magnetic fields oscillating together- given that James Clerk Maxwell found that electricity & magnetism, and optics are governed under the same law by Maxwell's equations [2]. So light can be treated as a wave and Maxwell's theory will show how it propagates through space, and its optical properties- such as how it refracts, diffracts, and reflects[3].Whilst in the quantum electrodynamic model light is considered to be made of a series of quanta(packet of energy) called photons, which are considered to be massless(as they do not interact with the Higgs boson and the Higgs field). Light consisting of packets of energy was first experimentally proven by Albert Einstein in 1905 in his paper on the photoelectric effect. In this model photons can interact with charged particles, such as electrons absorbing an electron-causing them to gain energy (which will be important for later).

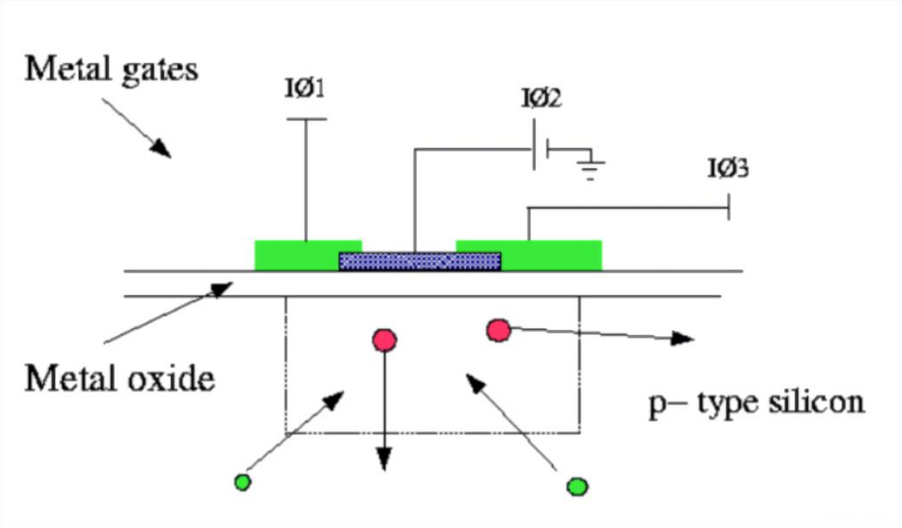


Types of camera sensors:

There are two main types of digital camera sensor technology that exist, CMOS (complimentary metal oxide semiconductor) and CCD (charge-coupled device) sensors. Both types may contain either a traditional photodiode or MSM devices, with photodiodes consisting of both n-type and p-type semiconductors placed next to each other. Since p-type will have an electron scarcity(so a lot of holes) and n-type will have an abundance of electrons when placed next to each other some electrons from the N side will migrate to the P side, and holes may migrate to the N side and combine with electrons. This leads to a positive on the N side of the P-N junction (where the N-type and P-type semiconductors meet) and negative on the P side- the P-N junction becoming a depletion region. Since there is a potential difference between the two sides it will inhibit the flow of both holes and electrons. When photons are incident on them then it will lead to the electrons on the P-N junction to gain energy and produce an electron-hole pair, due to their low bandgap, and they will travel in opposite directions leading to the flow of current.

Whilst MSM (metal-semiconductor-metal) devices only have P-type semiconductors, instead of P and N type, and Schottky metal with the P-type semiconductor. This will also form a depletion region, where electrons from the metal migrate to the P-type semiconductor (filling some holes).
However due to the large conductivity of metals(at around 103 S cm'' and above[1]) the ions formed on the Schottky metal side are just absorbed by the metal lattice- leading to the depletion region only forming on the side of the P-type semiconductor, but the generally mechanism of when a photon is incident is basically the same thing[4].
Though most camera sensors use N-P photodiode devices, as they have a lower dark current, so it makes sensors more sensitive and with lower noise.

In terms of sensors CCDs each pixel will contain three electrodes and a photodiode, a photodiode being a semiconductor device that effectively converts light into electrical energy [5]. The electrodes in them serve two purposes, one will be responsible for creating a potential well (a region in space where electrically charged particles will experience a lower potential energy than at the surrounding areas) and the others transferring charge out of the CCD’s pixel. When light is incident on a CCD electrons in the photodiode are excited, which will lead to the production of electron-hole pairs, with the charge generated being proportional to the intensity of incident light. Once this happens the charge that was generated by the photodiode will accumulate in potential wells, this will occur over the time of exposure- allowing each pixel to capture information on incident light.

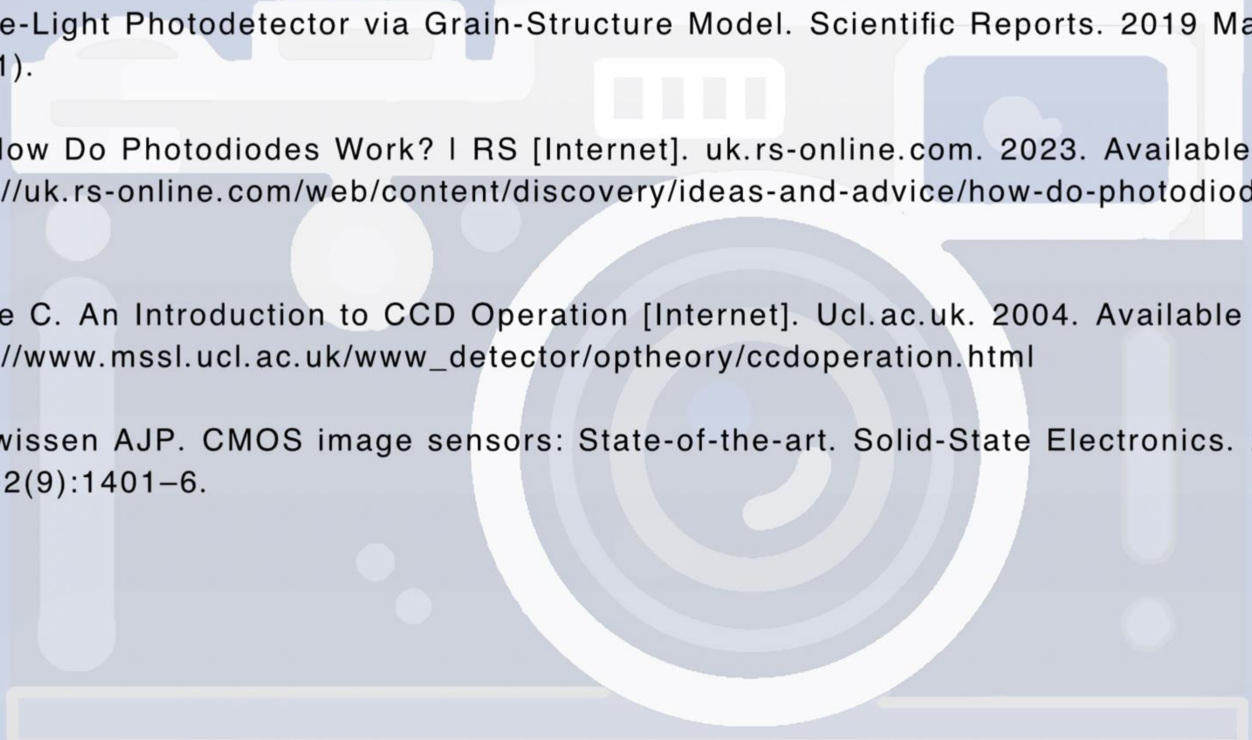


Using the electrodes the charge accumulated will then need to be ‘clocked out’, where charge will be moved along to reach the readout register, first travelling horizontally pixel to pixel then once the charges have reached the end of a row it will vertically transfer down to the next row. Finally charge in the readout register is sent to an output amplifier and converted to voltage (where it is digitised by an analogue to digital converter or ADC) [6].

On the other hand, CMOS sensors have it so that each pixel has its own readout circuit, instead of having the charges transferred horizontally and vertically, so each pixel can be readout independently- allowing parallel processing [7]. As with CCDs when light is incident photons will knock electrons from valence band to conduction band resulting in an electron-hole pair in a photodiode, however they are collected in a region called the depletion region (which is a region between p-n junctions that prevents electrons flow). Also unlike in a CCD each individual pixel of the CMOS will contain a charge-to-voltage converter- so its charge is converted to voltage within each pixel. Each pixel will also contain its own amplifier, that will allow the signals to be read directly out from the pixels. Due to its ability to parallel process CMOS sensors produce images far more quickly than CCD sensors, CMOS sensors are more heavily used and adopted in commercial applications such as digital camera, CCTV systems, to almost every single smartphone camera- even though due to another series of reasons CCDs produce a superior image with better low light performance.

Dictionary:
Siemens- Unit of conductance named after Werner Von Siemens
Doubly Degenerate Level- When two orbitals have the same symmetry and same level of energy
Electron Volt(eV)- Unit of measure of energy, used due to the large size of the unit joule on the quantum scale. It is the equivalent of the work done on or by an electron accelerated through one volt of potential difference
Bandgap- The amount of energy (measured in eV) required to jump from the valence band to conduction band
Higgs Boson- A type of boson that gives other particles the property of mass (bit of a simplification

Photoelectric effect- When photons are absorbed by electrons on a one-to-one basis providing them with energy to escape the surface of a material, to become photoelectrons.
N-type semiconductor- A semiconductor with an electron abundance
P-type semiconductor- A semiconductor with an electron scarcity
P-N junction- on a photodiode where the N-type and P-type semiconductors touch/meet
Depletion region- a region which prevent the flow of charge carriers, unless if the particles gain energy
Dark current- the extremely small current that will flow through photosensitive diodes even when photons are not present
Clocked out- when the number of electrons in a pixel are measured and the scene reconstructed
Potential well- the region surrounding the point with minimum potential energy
Schottky- a potential energy barrier formed at the boundary/ junction between metals and p-type semiconductors



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Thank you for reading :)

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