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Analyzing Electromagnetic Wavelengths and Their Interactions

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“O, Sunshine! The most precious gold to be found on earth.”

— Roman Payne

Introduction

For millennia humanity has revered the stars and local celestial bodies. The light emitted by the Sun combined with its interactions with our atmosphere have provided us with a small oasis in the dark vacuum of space. This massive collection of hydrogen, helium, and other elements provides us with breathtaking moments here on Earth, from stunning sunrises to mesmerizing rainbows. However, these phenomena only represent a small fraction of the electromagnetic spectrum and their associated atmospheric interactions. It has only been within the last century that humanity has been able to detect, generate, and harness all forms of electromagnetic (EM) energy. Our knowledge of the EM spectrum has also enhanced our understanding of the Sun by using various wavelength to examine specific energy signatures. The Sun thus serves as a great model for understanding wave properties (i.e., wavelength and frequency) and wave interactions. The unit I envision will first have students analyze atmospheric phenomena including the color changes that occur during a sunrise, as well as the physics of a rainbow. We will then proceed with deconstructing common household technologies that utilize EM spectra. As a class we will analyze the relevant components (i.e., light, receiver, transmitter, screen) of cellphone technology that utilize EM waves. The goal of this unit is for students to deeply understand EM wave properties so that they can further investigate how various technologies utilize these fundamental principles of waves.

Demographics

I serve as the 11th-grade academy Physics science teacher at Woodrow Wilson High School. The school is in Ward 3 in Washington, DC and consists of approximately 2,000 students. The diverse student body presents challenges for instructional delivery because of persistent achievement gaps within the school. Students have historically tested below grade level in mathematics with only a third of students meeting academic expectations for English Language Arts (ELA) and Mathematics.[1] The socioeconomic issues associated with urban schools are still present (i.e., in-seat attendance, assignment completion rate, etc.). The student body is often segregated due to the number of advanced placements classes offered coupled with minimal opportunities for remediation throughout the year. The two feeder-schools for Woodrow Wilson High School are Deal Middle School and Hardy Middle School which represent two different socioeconomic populations in DC.

The physics department is iteratively refining its curriculum to reflect more project-based study and analysis of phenomena to cultivate critical-thinking in a collaborative forum. Last year, SY20-21, presented novel challenges for students to access authentic learning due to distance learning, caused by the COVID-19 pandemic. After six years of teaching in the District of Columbia Public School (DCPS), I have learned that students respond best to a positive, dynamic classrooms, with collaborative hands-on activities and enthusiastic teaching. The development of this unit is intended to be implemented for in-person instruction in the hopes of cultivating vigorous inquiry opportunities that center around the electromagnetic spectrum anchored by solar and atmospheric phenomena. The more the student understands the content's relevance, the more likely they are to gain a greater depth of knowledge and retain it. In addition, this unit will provide individualized learning opportunities for students to select a technology of interest (e.g., TV, cellphone, X-ray, microwave) to study in the context of EM wave utilization.

Objectives

This two-to-three-week unit attempts to enhance students' content mastery (HS-PS3-2 & HS-PS3-3) and analytical skills by examining the properties associated with various wavelengths within the electromagnetic spectrum.[2] In addition, students will investigate the relationships associated with energetic states of EM waves and their interactions with matter. Students will acquire mastery in electromagnetic wave properties, types of wave interactions as well as a fundamental understanding in the function(s) of various technological components (i.e., TV and cellphone). Students will develop individualized proposals and presentations of their selected technology. In addition, students will suggest how the device could possibly be modified to overcome a preexisting constraint or be used for an alternative application. Prior to the technology analysis we will discuss the Sun's history and energy profile with regards to atmospheric phenomenon to contextualize and anchor students in the content of the unit. This unit is meant to be a project that elicits individual exploration as well as one that cultivates a depth of thinking that goes beyond the standards of NGSS. It is my hope that students will gain a deeper understanding of electromagnetic radiation and its implications with technological development and utilization in everyday life; and of course, to gain a deeper appreciation of the Sun through this process.

Unit Content

The History of the Sun and Our Solar System

Our middle-aged star in the cosmos is estimated to be only 4.6 billion years old.[3,4] This bright incandescent light is powered by the conversion of hydrogen to helium through nuclear fusion, in regions where conditions reach a temperature of at least 15 million Kelvin, hot enough to fuse protons in the nucleus of atoms.[5,6] The total energy emitted by the Sun is estimated to be 10^{34} Joules every year.[7] Our medium yellow dwarf is thought to of formed from a nebula of dust and gas with some heavy metals which formed in previous generations of stars. The sheer magnitude of the Sun and its impact on the celestial bodies which accompany it cannot be understated. It provides the anchoring gravitational force(s) that govern the orbits of the revolving planets due to its massive size. In fact, the Sun represents 99.5% of all matter in our solar system which is equivalent to 330,000 Earths.[8]

The Sun's birth directly coincides with the formations of the surrounding planets in our solar system. As the Sun coalesced from a cloud of gas, the central parts became the raging furnace we see today, the disk around formed the planets. The heat from the Sun caused the lighter materials to be swept away from the inner part of the disk leaving rocks and metals close to its center.[9] This explains why our four terrestrial planets (i.e., Mercury, Venus, Earth and Mars) are located closest to the Sun and the four gas giants (i.e., Neptune, Uranus, Saturn, and Jupiter) are substantially farther away. The galactic turbulence of the past has given rise to our very existence which we revel in today.

The Sun's Energy and Emissions

EMR and the Anatomy of the Sun

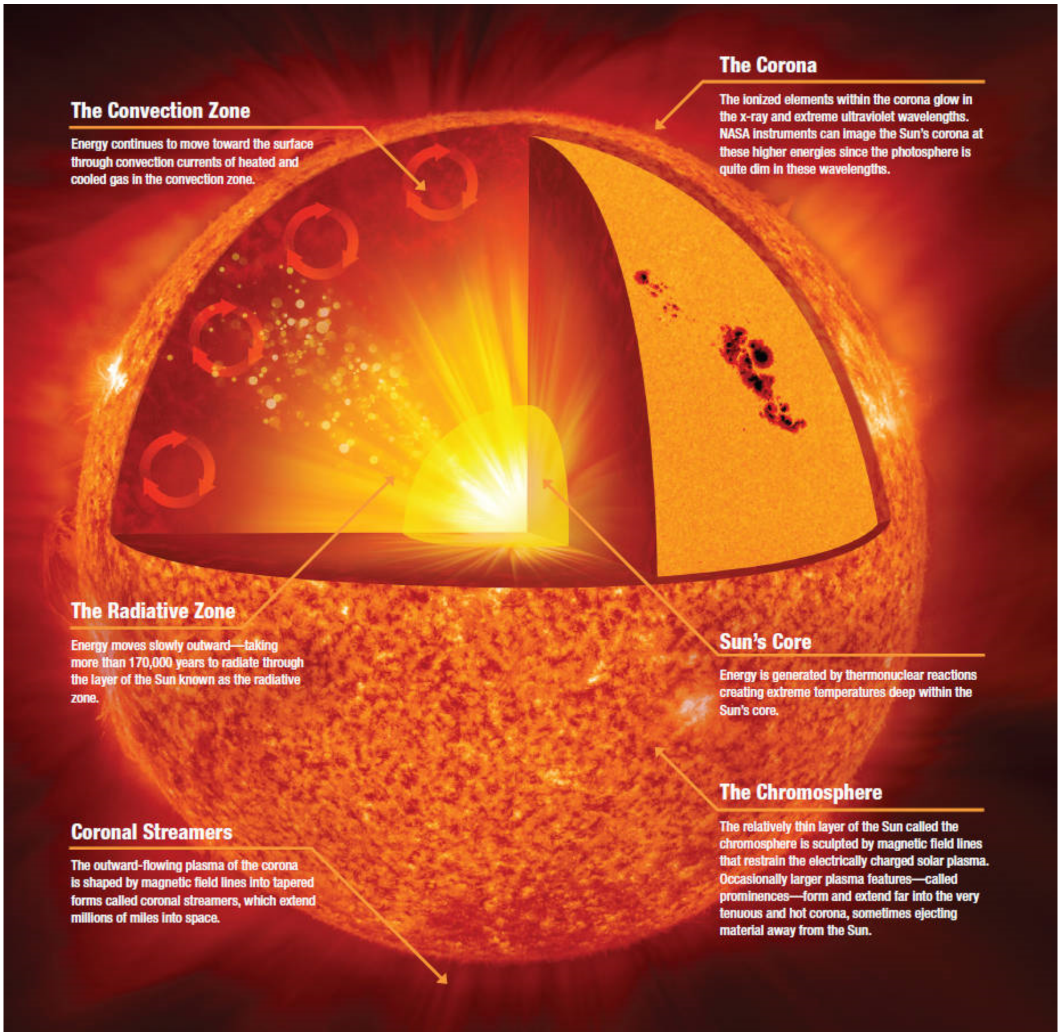

Figure 1. The main five main features of the Sun are shown above from a NASA publication titled “Mysteries of the Sun”.

Throughout our history every generation has woken up to the ball of gas suspended along the horizon emitting light and welcoming a new day. Observations of solar phenomena have allowed us to determine how light is emitted through the numerous layers amongst the turbulent sea of hydrogen and helium. Since the Sun consists of vast quantities of only a handful of elements the Sun’s anatomy is primarily governed by its mass and size, and the subsequent density and temperature differentials that exist internally.[10] All light energy in our solar system is produced from the Sun’s core where temperatures reach 15 million Kelvin.[11] These extreme conditions of high pressure, density, and heat force four hydrogen nuclei to fuse together, through a chain of reactions that begin with two protons fusing together, creating a single helium nucleus. The overall net mass of the helium nucleus is less than the initial combined masses of the hydrogen nuclei which subsequently cause a significant amount of energy to be emitted. This phenomenon was explained by Einstein when he postulated that energy is equivalent to the mass times the speed of light squared ($E=mc^2$).[12] This release of energy is in the form of highly energetic photons, which are bundles of electromagnetic energy, that travel through the Sun, pass-through the vacuum of space and eventually enter our atmosphere to provide bath us in the warm light needed for life. However, before the photons can reach Earth, they must pass through 300,000 km of highly dense plasma in the radiative zone.[13] In fact, the plasma is so dense light only travels a few centimeters at a time before being scattered, absorb, or re-emitted by atoms along their journey.[14] Once photons pass through the radiative zone, they enter the convection zone which serves as a buffer circulating hot gas towards the surface, as seen in Figure 1. As the gas expands it subsequently cools and sinks back down closer to the radiative zone to then be heated again. As the photons travel through the Sun their overall energy state lowers due to the chaotic nature of being scattered, absorbed, and reemitted along their journey.[15] Scientists estimate that a single photon may take as much as 100,000 to 1,000,000 years to reach the surface of the Sun also known as the photosphere.[16] However, once the photons reach the Sun's surface it takes approximately 8 minutes to travel 150,000,000 km.[17] The observable light we see from our Sun is the result of the countless energy transformations that start in the Sun's core and eventually the Earth's atmosphere. The light which we see today is a direct result of past proton-proton chains and a collection of photons slowly escaping the dense plasma within the inner layers of the Sun.

Properties Electromagnetic Waves

Our continued existence as a species remains dependent on the reliable energy emitted by the Sun. This energy arrives as electromagnetic radiation (EMR) which consists of an electric field and a magnetic field that are fixed perpendicularly to each other. These transverse waves travel through the vacuum of space at the speed of light (i.e., 300,000,000 m/s) through particles called photons.[18] EMR are generated from the change of an electric or magnetic field as such these wave types interact with other charged particles, exerting a force upon them. This phenomenon can be seen in the polar regions of Earth with highly charged particles form the Sun interact with Earth's magnetosphere to create dazzling auras. The energy state of a single photon determines the strength of the accompanying electromagnetic fields however the speed of a photon remains the same in the vacuum of space.[19] The properties of an EM wave are described by its wavelength and frequency. A wavelength is defined as the distance between corresponding points of two consecutive waves like two throughs or two crests (see Figure 2). Whereas frequency is simply the number of waves that pass a fixed point per unit of time. The function of a wave is to carry energy. An EM wave carries energy from one point to another and its energy depends on its frequency, the higher the frequency that higher the energy.[20]

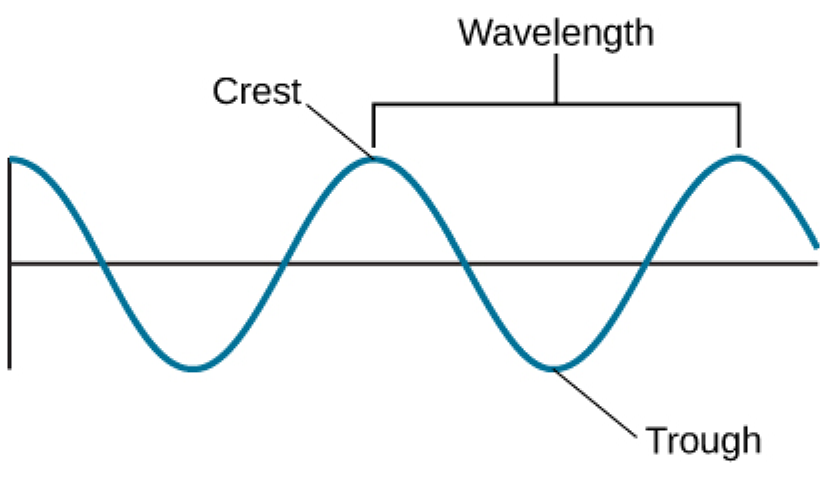

Figure 2. This diagram from the OpenStax Astronomy taken from chapter 5.1, illustrates a wavelength, in this case the distance between crest to crest, in a transverse wave.

The EM spectrum categorizes EM waves based on their wavelengths and frequencies which subsequently determine how they interact with matter of varying densities and charge. The classification schema falls on a logarithmic scale to denote the seven EM waves; these include radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays (See Figure 3).[21] EMR can have varying effects on life depending on its frequency. EMR with frequencies less than the visible spectrum are classified as non-ionizing as they lack sufficient energy to break molecular bonds to cause cellular damage.[22]

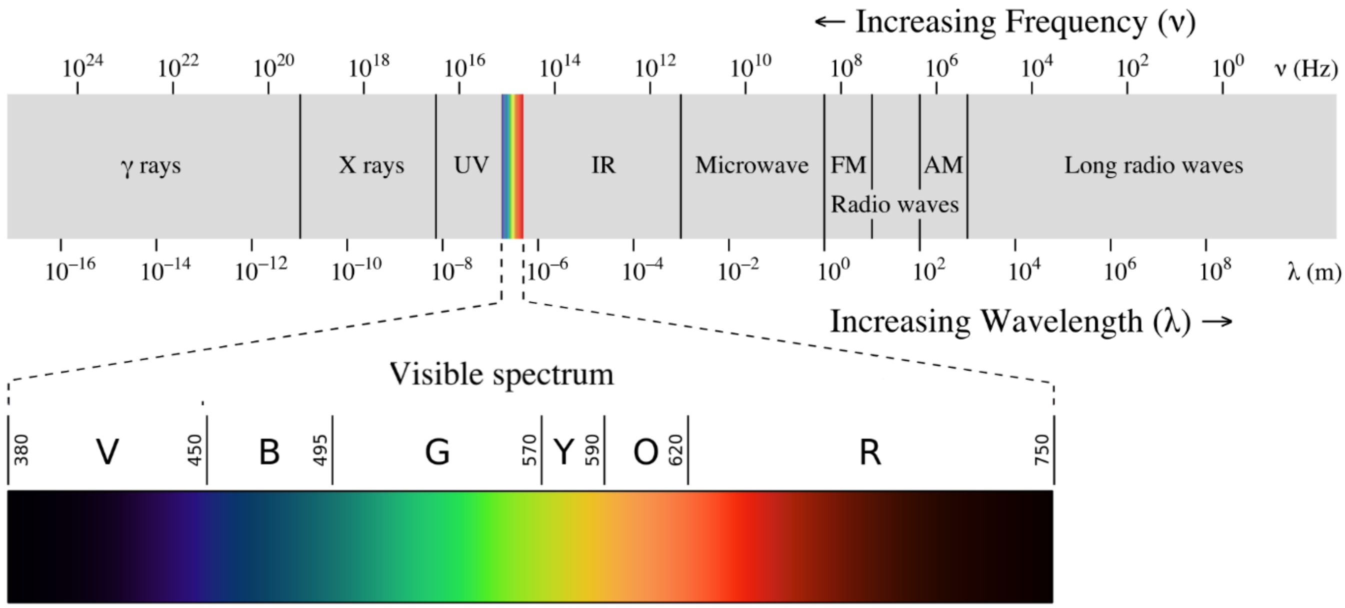

Figure 3. This illustration taken from Phillip Gringer, depicts the eight classifications of electromagnetic radiation along the spectrum along with the ranges in frequency and wavelength. The lower panel is a zoom of the part of the EM spectrum that is visible to the human eye.

EM Waves and Interactions with Visible Light Spectra

Most of the Sun's light that reaches Earth is within the frequencies of infrared, visible, and ultraviolet.[23] Through the interactions with Earth's atmosphere EM waves are either reflected, scattered, absorbed, or refracted depending on several factors – composition (e.g., the ozone layer absorbs a lot of the UV radiation, water vapor absorbs infrared), density of matter, charge of particles, reflectivity of material, energy state of photons, and angle of incidence.[24] These interactions are responsible for our everyday reality; from brushing your teeth in front of the mirror, to getting a sunburn on a hot summer day, to listening to music on the radio.

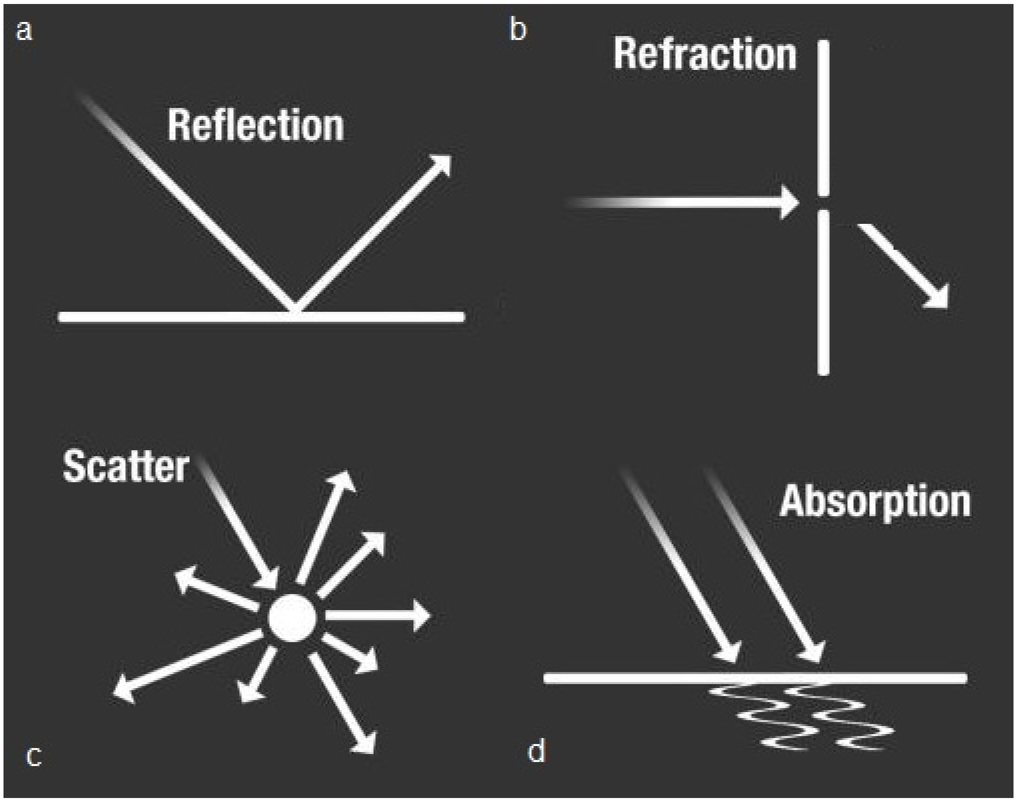

Figure 4. These diagrams illustrate the four primary wave interactions that occur when electromagnetic radiation interacts with matter. Images were taken and modified from NASA's "Wave Behaviors" supplemental material.

Reflection

Reflections can occur in two forms, both regular and diffuse, under specific conditions between the angle of incidence of light spectra and the properties of the mirror or material.[25] A reflecting surface often forms between the boundary of two different mediums (i.e., a gas interfacing with a liquid, or in the case of household mirrors, a solid interfacing with gas). A classic example is when you view your self-image on a placid lake, which appears to be reversed along the vertical axis.[26] The sharpness of the image is a function of the angle of the Sun as well as the smoothness of the water. This occurs because the visible EM spectra of light (380 – 750 nm) are all being bounced back at a similar angle as they encounter the interface between air and water.[27] Regular reflection can also take place along curved surfaces which cause images to become magnified or demagnified which is the foundational principle of how telescopes work.[28] Diffuse reflection occurs on rough surface which cause the incident rays of light to bounce a different angle resulting in an obscure image. It should be noted that not all light is reflected perfectly on a lake, some of the electromagnetic energy is absorbed by the water itself and some is refracted depending on the refraction index of the material which explains why the image often appear dimmer and not as sharp.[29]

Refraction

Refraction is the change in direction of EMR as it passes through one medium to another.[30] How much the EMR bends is determined by a material's refractive index which often is a function of temperature and density. Several atmospheric phenomena (i.e., rainbows and mirages) can be explained by the refraction of visible spectra interacting with gas molecules or suspended water droplets. Rainbows form when visible light bends while interfacing with droplets of water in the sky. As rays of light cross the boundary between air and water they refract. Since white light is a composite of all visible spectra, each color varying in wavelength and frequency refract at slightly different angles resulting in the colors of the rainbow. The colors of a rainbow are determined by the wavelength of light and the numbers of times it is reflected inside a water droplet. In ideal conditions a primary and secondary rainbow can been seen after a thunder shower. When viewing a primary rainbow, the red appears at the top of the rainbow's arch with violet at the bottom.[31] A secondary rainbow results when visible light is re-reflect causing colors to faintly appear in the inverse order. The incoming rays of light travel to the edges of the water droplet and are reflected within the droplet until they cause yet another instance of refraction.[32] The degree to which light bends is a function of the refractive index of the media and subsequently how much the medium is slowing down light.[33] A droplet of saltwater has a slightly high refractive index of 1.33 to 1.5 which form rainbows with smaller a smaller radius compared to freshwater droplets.[34] To determine the refractive index of a given material a ratio between the angles of incidence and refraction are compared following Snell's law or the law of refraction.[35] Snell's law states that the ratio of the sine of the angles of incidence and transmission is equal to the ratio of the refractive index of the materials at the interface.

Scattering

Scattering with regards to EMR occur when interacting with a nonuniform surface or medium causing the trajectory of the incoming wave to deviate from a predicted path.[36] Our own perceptions of color are largely governed by scattering as well as spectral absorption. Some of the most mesmerizing phenomenon occur during sunrise and sunset where clouds will take on a red hue especially if smoke particles from forest fires are suspended in the air due to specific type of scattering known as Raleigh Scattering. This type of scattering occurs when visible EMR collide with particles smaller than its wavelength.[37] According to the Raleigh model the particle must be at least 1/10 the diameter of the wavelength interacting with it.[38] Let us examine a typical sunny day, as the Sun's visible light passes through Earth's atmosphere some of the photons are scattered when they interact with molecules such as oxygen (diameter of 300 picometers) and nitrogen (diameter of 252 picometers) of gas.[39] As shown in Figure 2, visible light ranges from 380 nm to 750 nm and is comprised of red, orange, yellow, blue, green, and violet spectra. The diameter of a typical particle of dust can get as large a 10 nm which is substantially larger than the molecules of gas.[40] As longer wavelengths of light (i.e., red and orange) pass through the earth's atmosphere they have less of a chance being scatter amongst the gas a molecule compared to the shorter wavelengths of light (i.e., blue and violet). This is precisely why the sky appears blue rather than red on a typical sunny day, more of the blue wavelength is being scattered compared to the red wavelengths. However, during sunsets, the visible light passing through our atmosphere is at a shallow angle causing the visible light to travel through more of Earth's atmosphere. Since the blue light is easily scattered away, the red wavelengths become more visible during this time of day.

Absorption

Absorption occurs in two types either by a charged free particle absorbing the EMR to a higher energy state or when the energy from the EMR is so great it causes electrons to be set free from an atom, also known as ionization.[41] When EMR bombards matter it provides additional kinetic energy which manifests as heat. Why do some objects appear to have different colors? The colors of our clothes, cars, and shoes are a function of light being reflected and absorbed at different wavelengths of visible light. A blue shirt will appear blue as all colors with exception to the blue wavelength of light is being absorbed. Objects that absorb light often transform the energy into heat.[42] If you have ever walked on a black sanding beach or a white sandy beach, there is a considerable difference in the experience. The elements that form black sandy beaches are such that they absorb all visible wavelengths generating an abundance of thermal emissions while the white sandy beaches reflect most of the visible light. Absorption can lead to deleterious effects on life through ionization. When sufficient EMR is applied to an atom an electron can become liberated from all its orbitals resulting in a positive ion.[43] This process creates a charge differential between neighboring atoms and molecules that is hostile to DNA often leading to mutations or cancer.[44] The extreme range of ultra-violet light can have this affect which is why sunburns occur during the peak of the day on sandy beaches. The EMR absorbed by your skin results in thermal emission causing your skin to burn by applying sunscreen you prevent the absorption of UV light and negate absorption at this frequency.

EM Theorical Discoveries

The modern technological era owes its prominence to the discovery of electromagnetism and electricity. The earliest documentation of electricity dates to 600 BCE from an ancient Greek philosopher and mathematician who described the phenomenon associated with rubbing animal fur on a variety of materials including amber.[45] It took a thousand years for mankind to have a rudimentary understanding the relationship between electricity and magnetism. During the late 1700's and early 1800's considerable progress was made with respect to magnetic fields and voltaic electricity.[46] In 1821 French physicist Andre Ampere discovered that electrical current produced an electrical force giving rise to his theory in electrodynamics.[47] Initially physicist and scientists believed that electricity and magnetism were two phenomena independent from each other. In 1831 Michael Faraday investigated the effect electric fields had on magnets which established the concept of electromagnetic fields.[48] James Maxwell further expanded upon the idea of electromagnetic fields by applying mathematics in 1873 which forms the basis for modern electromagnetic theory.[49] These iterative and refinement of scientific principles spurred a booming technological revolution which began with the Industrial Revolution in the 18th century and continue to this day.

EM Spectra and Cell Phones

The prolific access to cellular devices has completely revolutionized communication. In an instant we can check in with family and friends across the globe. This has had a profound affect in the economy of developing countries and transformed popular culture. Students' usage is typically confined to social media or texting. Further examination of the electrical engineering and the utilization of electromagnetic spectra may elicit greater appreciation for the technical marvel at their fingertips. This investigation will serve as a platform for critical thinking in the application of EMR interactions and the properties of EM waves.

Telecommunication

A cell phone is a two-way communication device that receives and sends radio signals at various frequencies.[50] This can come in the form of directly speaking to a friend during a phone call or sending a message via a text. When you speak into a cell phone a microphone turns your voice into a set of electric signals. A microchip in the phone modulates radio waves to carry the electric signal over vast distances through a network of towers owned by your service provider.[51] To prevent multiple carriers from broadcasting at the same frequency the Federal Communication Commission auctions off bandwidth every year to the highest bidder.[52] These licensed frequencies are what the radio waves are transmitted along via the antenna in your phone. A person receives the electric signal from to these networks of towers which is subsequently modulated yet again to produce a sound wave. The speaker in your phone contains an electromagnet and permanent magnet that vibrates a diaphragm made of flexible material to create sound waves. [53] The frequency of the vibrations determines the overall pitch generated from the speaker. Cellphones transmit radio waves in all directions, in fact while on the phone with your friend over half of the emitted energy from your cellular device is absorbed by your head or body.[54] However, since the EMR used in the transmission process is within the non-ionization portion of the EM spectrum few if any health sided effects result.

Touch Screen

Most of the electrical energy generated by the battery is used to provide ambient light to view content on screen. The display screen of a typical smartphone is made of three components, a liquid crystal display, a tiny grid of electromagnetically generating wires, and protective glass.[55] The liquid crystal display uses an electric current and a backlight to adjust the color of each pixel on your screen. When a fingertip or stylus applies pressure on the screen several thin resistive layers send a localized electrical signal thus detecting the position and magnitude of pressure being exerted.[56] There have been similar models that utilize infrared frequencies to yield a similar result.

Camera

As the evolution of cellphone and smart devices has progressed so too have their camera features which is a marketing strategy for every generation of cellular device. The camera on a cellphone operates like traditional digital single-lens reflex cameras with some key differences. Since the lens on a smartphone are relatively small an image is capture using a series of convex and concave lenses that work to focus visible light towards a sensor thus creating a digital image.[57] Most cellphones sold today come with multiple cameras with lenses of varying focal lengths which allows users to capture wider angles-of-view or magnify the image depending on settings. Once the visible light interfaces with the system of lenses the EMR is refracted at varying angles which pass through a sensor. Most mobile devices utilize a Complementary Metal-Oxide semiconductor (CMOS) to digitize EMR as its extremely energy efficient.[58] This sensor is made up of millions of light-catching cavities called photosites.[59] The strength of the digital signal is dependent on exposure length and shutter speed. A gray scale composite image is formed from this process. The photosite will result as white with a large exposure of light and black with low exposure to EMR.[60] An additional filter is needed for the sensor to interpret color. Most commonly digital cameras use a Bayer filter which consists of an array of red, green, and blue filters which captures light only within those bandwidths.[61] Once the photosites relay the composite information of RGB a post processing calculates the color values for neighboring pixels resulting in a digital image.[62] This complex sequence of events occurs every time your students take a selfie. The rapid advancement of digital technology is thanks to the fundamental understanding of electromagnetism and the constant source of electromagnetic radiation from the Sun. I truly hope we can appreciate the marvels of science by simply reflecting on the marvels of taking a digital photo with our classes.

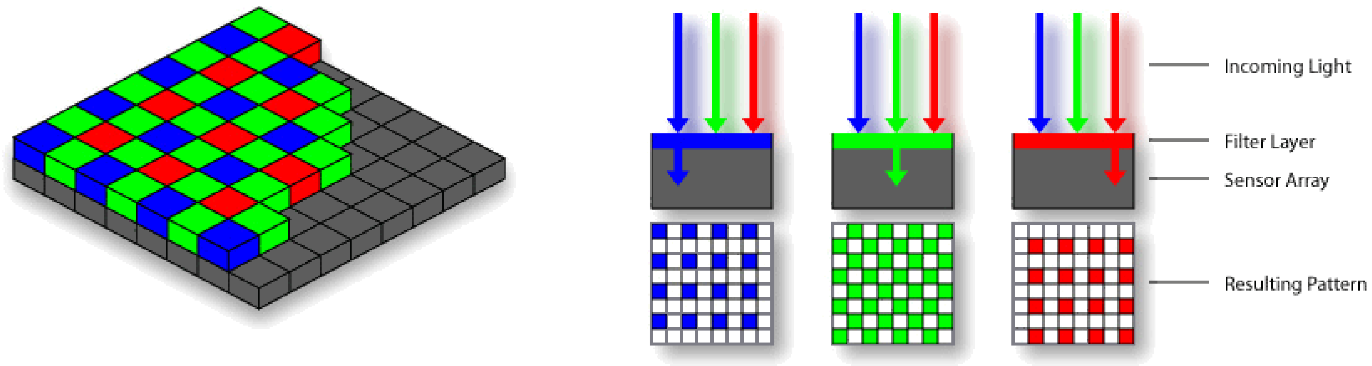

Figure 5. This illustration from commons media shows the Bayer filter array which allows color values to be associated with pixels when taking photos on a cellular device.

Teaching Strategies

Extended Constructed Response (ECR)

Extended constructed response questions provide an opportunity for students to demonstrate the extent of mastery within a given content area while building capacity for sustained critical thinking. Students will be provided an essential question (i.e., Why do darker materials feel warmer on a hot day?), every two weeks, that complements an observable phenomenon or data driven inquiry lab. The Next Generation Science Standards (NGSS) heavily emphasize students' ability to rationalize phenomena with supporting evidence. Last year, during distance learning students dramatically enhanced their capacity to articulate complex and nuanced ideas by either developing a written response or producing a video clip in FlipGrid. To encourage a growth mindset, multiple iterations are required prior to final submission. This process provides numerous opportunities for students to refine their content mastery and improve the mechanics of their responses. The process must be done with fidelity with opportunities for students to peer-review. By the end of the year students often see their own growth in writing or critical thinking about a specific content area and want to help each other. This process takes great patience, but the rewards are well worth the wait.

Synthesized Notes

From my experience at Woodrow Wilson High School, students associate notetaking with simply copying down information or formulas. Last year through distance learning a substantial amount of reference material was provided to students to help bridge the any gaps in content mastery, with limited success. This year the physics department will be utilizing a new model of note taking which emphasizes content synthesis and identify misconceptions. At the end of every lesson, students will be required to write for ten minutes about the activity, lab, or information that was introduced. Several prompts will be provided; however, the goal is for students to record their struggles, successes, and content connections made during class so that they can go back for review later. To support this growth mindset and cultivate a culture of information synthesis I will be meeting with each student during lunch or office hours twice a month to monitor the fidelity of the system. It is my hope that his new model may allow questions about content to arise as well as promote information retention for future lessons.

Station Rotation with Heterogenous Groups

Station rotation facilitates the engagements of students through several concurrent activities throughout the class period or week, depending on the model. This instructional strategy allows students multiple opportunities to refine conceptual understanding and mastery by participating in activities. Students will spend approximately 20-30 minutes working independently or in groups. Students will share findings, observations, and misconceptions that persist once every student has rotated through each station.

The unit will concentrate heavily on deconstructing energy transformations from a myriad of observable phenomenon. Thus, it is imperative that students take detailed notes and effectively communicate their thoughts to peers. Students will be expected to take notes, ask questions, organize information, and summarize key ideas. Student groups will be compiled from pre-assessment data, attendance, and behavioral from the first 2-3 weeks of the year. At the conclusion of every marking period the groups will be reassessed. The number of stations may vary based on the number of students and classroom dynamics. In my experience station rotations have shown to be an effective strategy for students to maximize their learning and to develop skills of independent problem solving.

Activities

Optics Labs – Wave Interactions

Students will explore and observe a series EMR interactions with different media illustrating refraction, absorption, scattering, and reflection. A heavy emphasis will be placed on the wavelength and frequency of incoming light and the subsequent angles of reflection or refraction that take place. In addition, students will measure and investigate focal length and magnifications of lens combinations and construct an optical instrument to carry a specific task (i.e., reading glasses, binoculars). All instruments will be prototypes and students will work collaboratively in groups to develop designs. At the end of the week students will present their findings from both inquiry labs and report on their design status. A variety of optical kits from Carolina Biological (i.e., Laser Prism Set) and School Specialty (i.e., Frey Scientific Deluxe Whiteboard Optics Kit) will be utilized for in person instruction. For students that remain remote, a Phet simulation (i.e., Bending Light) will be used to supplement their learning experience.

Build A Flashlight

Students will be tasked with building their own flashlight(s) out of household supplies (i.e., rubber bands, paper towel cardboard, copper wire, aluminum foil, masking tape). Prior to this activity students will have been introduced to open and closed circuits, with circuit design experience. A flashlight will be disassembled to examine the functional elements need to construct the device. Every student will sketch the electrical elements within the circuit design. As a whole group, we will identify the parts of the flashlight and briefly discuss strategies for their own designs. In groups of four, students will sketch their own designs and identify the materials needed for assembly. Students will work in groups much of the class to construct their flashlights. At the end of class, students will present their prototype flashlight as a whole group and will be asked questions about their design and choice of materials. This activity is designed to bridge content from the circuits design to energy. In addition, it will serve as a reference when students' prepare to their research writing.

Research Writing – Summative Project-Based Digital Exploration

The summative project will task students to examine and deconstruct a device, identifying the EMR utilized and its subsequent wave interactions that allow the device to perform its function. Prior to this, students will investigate the critical components involved with cell phones and have experience with optics fundamentals. Student may need to conduct research to determine the intricacies of their chosen electrical device. Students will identify and describe the types of energies present, the location of energy transformation as well as develop a proposal to alter or improve a design component. Students will be given a rubric with several checkpoints over a two-week period. Ultimately, students will present to the class about the functionality and operation of their device, the energy required for operation, and explain their proposals. This project will provide an opportunity for students to gain a deeper understanding and appreciation for every day digital devices (i.e., microwave, washer, phone, tv, computer).

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Teacher Resources

For supplemental information that will be utilized at varying degrees throughout the unit please review the following. A deactivated link is provided along with a summary of the resource. In addition, several referenced materials are recommended for review that further supplement the content in this unit.

Khan Academy

Khan Academy is a non-profit educational organization that provides free lectures in the form of YouTube videos. There are practice exercises along with a personalized dashboard if students register on the website. This resource is helpful for students that require supplemental learning or need to make up work due to absences. (https://www.khanacademy.org)

Physics classroom

Physics classroom is a free online resource for beginning students and teachers. There are several animations, problem sets, and tutorials that supplement classroom content. The website provides guidance to targeted misunderstandings and strengthens students’ critical thinking skills with multi-tiered word problems. Students who require additional support should be guided to this website. (http://www.physicsclassroom.com)

PHET simulations

PhET simulations offer free virtual labs from several topics in physics, chemistry, biology, and earth science. Each simulation comes with teacher instructions but can be modified depending on the scope of your investigations. There is browser (i.e., Chrome and Safari) and software compatibility constraints (i.e., HTML5, Java, and Flash) that should be checked prior to each virtual lab. If students are using district computers, ensure they have the necessary software your chose PhET simulation. Overall, this is a great resource to bridge the gap during hybrid instruction.

Appendix on Implementing District Standards

NGSS Standard Integration

The unit will incorporate standards from the Next Generation Science Standards (NGSS) in Unit III. The focus will be primarily on the nature of electromagnetic energy and their associated wave interactions with matter.

Disciplinary Core Ideas

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (HS-PS3-1)

Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) (HS-PS3-2)

When two objects interacting through a field relative position, the energy stored in the field is changed. (HS-PS3-5)

Crosscutting Concepts

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined, their inputs and outputs analyzed and described using models. (HS-PS3-4)

Science & Engineering Practices

Use mathematical representation of phenomena to describe explanations. (HS-PS2-2)

Notes

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