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LIGHT-EYE INTERACTION PHYSICS REVIEW

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ABSTRACT

As a result of advanced digital technology, we have become increasingly reliant on a global connectivity device such as laptops, tablets, and mobile phones. So, the interaction of human eyes with the industrial light of such devices becomes full of dangers caused by the short distance and the long duration of the view. With specific details, this study discusses and supports the physics of light-eye interaction. The physical treatment of light-eye interaction shows that the transmitted parts of the eye do not have a considerable amount of reflection, diffraction, scattering, or absorption of light rays, so they allow light to pass through them freely with some refraction. It has been established that about 98% of the incident light rays can pass through the eyes to reach the retina. The optical transmittance spectrum of the human eye has been shown to have a Gaussian shape with a center wavelength between 200 and 1400 nm. The duration of view, distance of vision, and shielding by a glassy substance have all been demonstrated to be effective procedures for protecting ourselves from the harmful effects of the screen light of handheld and tabletop digital devices. Moreover, it is reinforced that the prolonged viewing time on mobile devices is one of the most serious factors that leads to health problems in the eyes.

Contribution/ Originality: In this study, the information on light-eye interaction physics is examined and improved. It has been demonstrated that approximately 98% of incident light can reach the retina. It is also demonstrated that the optical transmittance spectrum of human eyes has a Gaussian shape centered around the visible spectrum.

1. INTRODUCTION

Light comes after air and water in terms of abundance in nature, and it has an important role in the growth and continuation of life. The optical spectrum, which is visible to the human eye, is a narrow part of the electromagnetic spectrum in the wavelength range from 400 to 760 nm [1-3]. As an electromagnetic radiation, light exhibits characteristics of both waves and particles (photons) and propagates in a vacuum at the speed of light (c). The frequency (f), wavelength (λ), and speed of propagation are elementary parameters of an electromagnetic radiation, and they are related to each other by the relations ($c = f\lambda\,,\ E = hf$), where (E) is the energy of photons and (h) Planck constant [1]. Light propagation through a medium is affected by phenomena like refraction, reflection, diffraction, attenuation, and interference [4]. In general, when light is incident upon a surface between two media, it will be partially reflected and partially transmitted as a refracted ray. The amount of bending (refraction) depends on the indices of refraction of the two media and is described quantitatively by Snell's Law. Diffraction manifests itself in the apparent bending of waves around small obstacles and the spreading out of waves past small openings. The wave properties of light lead to interference, but certain conditions of coherence must be met for these interference effects to be readily visible. Light may also be attenuated by absorption or scattering when it passes through an optical system. The human eye is equipped with a variety of optical components including the cornea, iris, pupil, aqueous and vitreous humors, a variable-focus lens, and the retina. Together, these elements collect light from objects to form an inverted image of the objects that fall into the field of view for each eye on the surface of the retina [5]. Human three-dimension color vision is a very complex process that is not completely understood, despite hundreds of years of intense study and modeling. As a result of advanced digital technology, our eyes have become increasingly reliant on devices such as laptops, tablets, and mobile phones for global connectivity. So the interaction of human eyes with industrial light becomes full of dangers caused by the short distance and the longtime of view. The study of influencing factors of light–eyes interaction has a great importance to take it advantage from one side and to avoid it disadvantage and risks from other side. There are many studies in the literature that deal with these issues [6-13]. Refraction and absorption are the primary causes of light ray interactions with biomaterials [9, 14, 15]. The energy of the photons that incident on the biomaterial has a photo-harmful property. The photo-dangerousness on a cell increases significantly as the frequency of irradiation increases. Blue and ultraviolet light, in particular, have been shown to distort the cell's genes [6, 7, 14-16]. Infrared light is safe, as long as the biomaterial thermal threshold is not passed [7-16].

To enhance the eye-light interaction physics, it is required to carefully review the past papers on this subject, and that is the aim of this study. The physical properties of the eye's transmitted parts (the cornea, anterior cavity, lens, and vitreous gel) are investigated here to demonstrate how they allow light rays to pass through the eye without experiencing significant attenuation. Matlab curve fitting tools are used to show that the optical transmittance spectrum of eyes has a Gaussian shape centered around the visible spectrum. Moreover, it has been demonstrated that we can rely on unrelated aspects like time of view, distance of vision, and glassy shielding in order to protect ourselves from the negative consequences of watching light.

2. LIGHT-EYE INTERACTION PHYSICS

There are two main reasons why understanding the eye's transmission characteristics to electromagnetic radiation is very important. First, the knowledge is necessary to evaluate the potential impact of strong radiation sources on the various eye parts. Second, these data are necessary if one wants to understand the physiological processes excited by any region of the spectrum. This is because, in such experiments, the spectrophotometric properties of the radiation can only be measured at the cornea, whereas excitation takes place after the light has reached the retina.

2.1. Properties of the Light

Either a wave or a stream of photons characterize electromagnetic radiation's behavior. The first behavior is sufficient for studying energy transport, whereas the second performance is appropriate for examining the interaction of light with matter and making it simpler to comprehend the toxicity of wavelengths. The following is a representation of the expression that links photon energy (E) to wave properties ($wavelength\ \lambda, frequency\ f, speed\ v$):

$$E = hf = h\,v/\lambda \qquad (1)$$

Equation 1 presents that, the energy of the radiation increases with frequency and decreases with wavelength. This fact explains why infrared IR light has less energy than ultraviolet UV light. Despite making up a very small portion of the overall electromagnetic spectrum, solar radiation has the greatest impact on our environment. It consists of three sets of wavelengths as shown in Figure 1: IR (760-10,000 nm), visible light (400-760 nm), and UV radiation (100-400 nm). Ordinarily, only visible light is detected by the human eye [1].

Figure 1. Wavelengths schematic of UV, visible light, and IR radiation [1].

2.2. Optical Properties of the Eye

The eye's components and operations are intricate. Each eye continuously modifies the quantity of light it admits, focuses on both near-and far-away objects, and generates continuous images that are immediately communicated to the brain. The cornea, a transparent, curved layer located in front of the iris and pupil, is the pathway via which light enters the eye. The cornea helps focus light on the retina in the back of the eye, in addition to acting as a protective covering for the front of the eye. Light goes through the pupil (the black dot in the middle of the eye) after traversing the cornea. Due to the orderly arrangement of collagen fibrils in the cornea, it is highly transparent with transmission above 95% in the spectral range of 400-900 nm. The iris, a round, colorful region of the eye that surrounds the pupil, regulates how much light enters the eye. When it is dark outside, the iris dilates or widens the pupil, whereas when it is bright outside, it contracts or closes the pupil. The amount of light reaching the retina is regulated by the pupil size, which can vary between 1.5 mm and 8 mm. The lens, which is located behind the iris, focuses light onto the retina by altering its shape. Through the action of tiny muscles called the ciliary muscles, the lens thins to concentrate on distant objects and thickens to focus on nearby objects. The crystalline lens of the eye is composed of specialized crystalline proteins. The lens is about 4 mm in thickness and 10 mm in diameter and is enclosed in a tough, thin (5-15 mm), transparent collagenous capsule. In the relaxed eye, the lens has a power of about 20 D, while in the fully accommodated state, it can temporarily increase to 33 D. The anterior chamber of the eye, which is located between the cornea and the lens capsule, is filled with a clear liquid. The vitreous humor is a transparent jelly-like substance that fills the large cavity posterior to the lens and anterior to the retina. Photoreceptors, or light-sensing cells, are found in the retina along with the blood arteries that feed them. A small region of the retina known as the macula, which includes millions of densely populated photoreceptors, is the most sensitive component of the eye (the type called cones). The macula's high cone density gives the visual image detail, similar to how a high-resolution digital camera has more megapixels. A nerve fiber connects each photoreceptor. The optic nerve is made up of the nerve fibers that come from the photoreceptors [17].

The ratio between the wavelength of light and the size of the eye parts determined the kind of interaction with light. Visible light is referred to a wavelength in the range (0.4-0.76) um. A human eye is roughly (2.3) cm in diameter and is almost a spherical ball filled with some fluid, and the eyes pupil diameter ranging from (2-7) mm. So, most interaction factors of light have been established as absorption and refraction [14, 16].

2.3. Refraction Through Eyes

The refractive index (n) of a medium decides the speed of light waves in that medium [18, 19].

$$v = \frac{c}{n} \qquad (2)$$

Where (v and c) are the speed of light in the substance and vacuum respectively. As light passes through two mediums with different refractive indexes, it refracts. Since light travels at the fastest in vacuum and at the slowest in all other materials, the index of refraction of materials is always greater than one [19]. Figure (2a) shows the transmitted parts of eye and Figure (2b) depicts a light beam entering water from the air at an angle (θ_i) and being refracted at an angle (θ_r). Where (n_1) and (n_2) are the refractive indices of the two mediums (1) and (2) respectively. The two angles are measured with respect to the normal axis. Snell's law relates these angles to the indices of mediums by Equation 3 [18, 19].

$$\frac{\sin \theta_i}{\sin \theta_r} = \frac{n_2}{n_1} \quad (3)$$

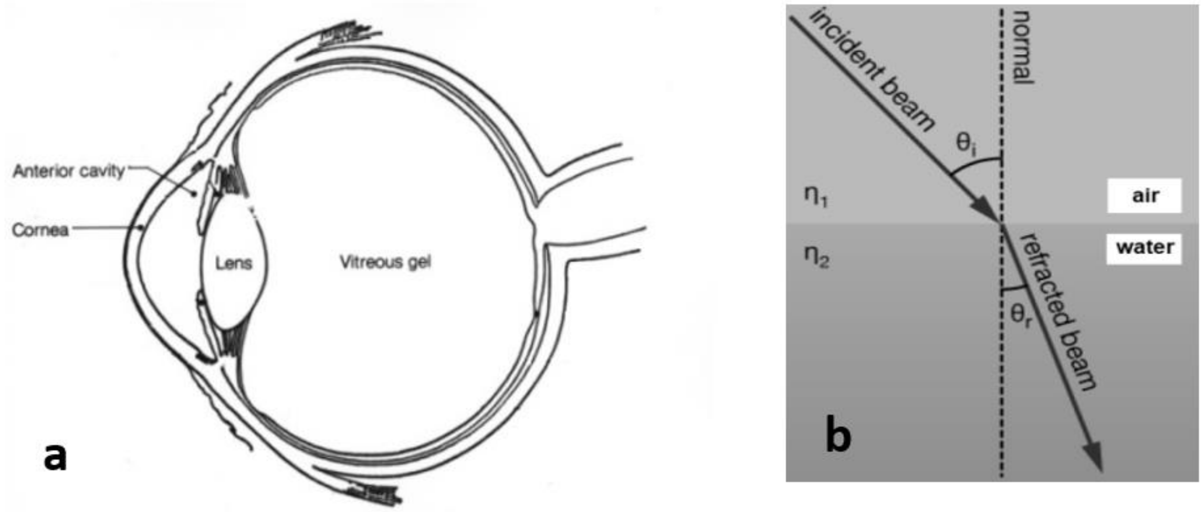

Figure 2. a) The transmitted parts of eye, b) Refraction between two mediums.

About 80% of the eye's refracting power is provided by the cornea, which is the eye system's strongest component. The cornea's refractive index is around 1.376. The majority of refraction occurs at the cornea-air contact because light travels from the cornea into the aqueous humor, a watery fluid with an approximate 1.336 index of refraction. The crystalline lens, which is around 9 mm in diameter and 4 mm thick, contributes about 20% of the eye's refracting power. Hecht compares it to an extremely small, translucent onion with 22,000 tiny layers. It's a gradient index lens because the index varies from roughly 1.406 in the middle to roughly 1.386 in the outer layers. To accommodate for near focus, it is malleable and alters shape. The cloud over or darkening of this lens is referred to as a "cataract". The liquid "aqueous humor," with a refractive index of roughly 1.336, fills the anterior chamber of the eye. It is situated just behind the cornea. The "vitreous humor," a gelatinous substance with an approximate refractive index of 1.337, fills the bigger chamber of the eye. The two fluids that make up the inside of the eye have refraction indices that are very similar to water, n = 1.333. Cataracts are the medical term for when the inner lens of the eye darkens or becomes opaque. Plastic lenses can be implanted in place of the lens during surgery. By doing this, the eye's eyesight may be dramatically improved. Because the implanted lens has a fixed focal length, it cannot accommodate like a normal lens. People who get cataracts after the age of 60 typically have little remaining accommodation since the inner lens has become less flexible with aging, so this is typically not a serious worry [20].

2.4. Refractive Defects of Vision

Refraction has been identified as one of the key mechanisms by which light interacts with the eye [14]. Hence, vision impairments resulting from errors in refraction through the lens of the eye are by far the most prevalent. Old age can occasionally cause the eye to gradually lose its strength and precision of vision. This makes it impossible for the human eye to correctly focus an object's picture on the retina. The person's vision blurs in these situations. As a result, he is uncomfortable and unable to see either far away or close-up items. These eye flaws are referred to as refractive faults. Myopia, or nearsightedness, hypermetropia, or farsightedness, astigmatism, and presbyopia are frequent defects [21].

2.4.1. Myopia or Short-Sightedness

Myopia, often known as near-sightedness, is an optical condition that makes it difficult for a person to see clearly and precisely items that are far away. The image of a distant object in a myopic eye is created in front of the retina rather than on the retina. The two potential reasons of this deficiency are severe eye lens curvature, or because of the eye lens's high converging power (short local length), and elongation of the eyeball. By wearing eyeglasses with a concave lens of the appropriate focal length or power, this problem can be remedied.

2.4.2. Hypermetropia or Long-Sightedness

Far-sightedness, also known as hypermetropia, is an eye condition that makes it possible to view far objects clearly but not up-close items. When this imperfection exists, a person's near-point deviates from the ideal point (25 cm). A hypermetropic eye forms the image of a nearby object behind the retina rather than directly on the retina. The high local length of the eye lens and its low converging power are the two potential reasons of this deficiency. as well as the eyeball's short length (compressed). Using eyewear with a convex lens of the proper focal length or power will be able to rectify this flaw.

2.4.3. Presbyopia or Old Sight

Old sight, also known as presbyopia, is an eye condition that makes it difficult for elderly people to see adjacent objects well. A presbyopic elderly person's near point gradually recedes until it is substantially greater than 25 cm. Because the ciliary muscles gradually weaken with age and the eye lens becomes less flexible, presbyopia develops. Presbyopia is a form of hypermetropia brought on by the aging eye's loss of accommodation capacity. Similar to hypermetropia, presbyopia problems are treated by wearing eyewear with convex lenses. A person may occasionally experience both myopia and hypermetropia. These folks frequently wear glasses with bifocal lenses, which have a concave lens in the upper part to correct their vision.

2.4.4. Astigmatism

Astigmatism is the eye's inability to clearly concentrate on objects in both horizontal and vertical lines. Cable Gauge Standard Wire Gauge with Horizontal and Vertical Lines that are Distorted The eye lens's changing curvature in both the horizontal and vertical directions is what causes this problem. The use of cylindrical lenses is used to rectify this flaw.

2.5. Reflection on Eyes

Light may reflect on the surface of the eye rather than passing through it as it passes from the air to the eye. From a microscopic point of view Reflection is influenced by the microstructure of the target surface [18, 19]. When a plane electromagnetic wave passes from medium1 of impedance $Z_1$to medium2 of impedance Z_2 then the fraction of reflected power of the wave is given by Matthew [22],

$$\frac{P_r}{P_i} = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2 = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2 \quad (4)$$

Where $(Z = \mu c \frac{1}{n})$, μ the magnetic permeability of the medium, (P_i) the incident power and (P_r) the reflected power. A small amount of light is reflected on the anterior surface of the cornea, which is the boundary with the highest change in index of refraction. The air- eye interface is seem to be like air-water interface so if we substitute the indices of air and water in Equation 4 we deduced that the fraction of reflected power from an eye is about (2%).

This reflected power is due to differing indices of refraction of cornea-air and cornea-lens [19]. This means that the reflection of light from eyes can be neglected and about (98%) of light power are transmitted into the eyes to the retina.

Now if we take the effect of the incident angle in our consideration then the total internal reflection can only happen if ($n_1 > n_2$) [18, 19]. It's clear that this condition is not satisfied for air-eyes interface so, there is no total reflection can be obtained in air for any incident angle of light on the eyes. The total reflection condition is satisfied between lens-vitreous, but to obtain it the incident angle must be greater or equal to the critical incident angle (θ_c) which given by Equation 5 [18, 19].

$$\theta_c = sin^{-1}\left(\frac{n_1}{n_2}\right) \qquad (5)$$

For lens-vitreous we obtained ($\theta_c = 71°$), this angle is less than the central field of vision angle where most people covers an angle between ($50° - 60°$) [23]. Within this angle, both eyes observe an object simultaneously. Therefore, we have no total reflection in the human eyes. eyelid

2.6. Diffraction from Eyes

Diffraction occurs when a wave of wavelength (λ) hits an obstacle of size (d) or passes through a hole of diameter (d), as displayed in Figure 3, if the following condition is met [24].

$$d \leq \lambda \qquad (6)$$

The visible light wavelength ranging from (400-700) nm while the eyes pupil diameter ranging from (2-7) mm, so the condition of diffraction not satisfied and light waves passes through eyes without diffraction.

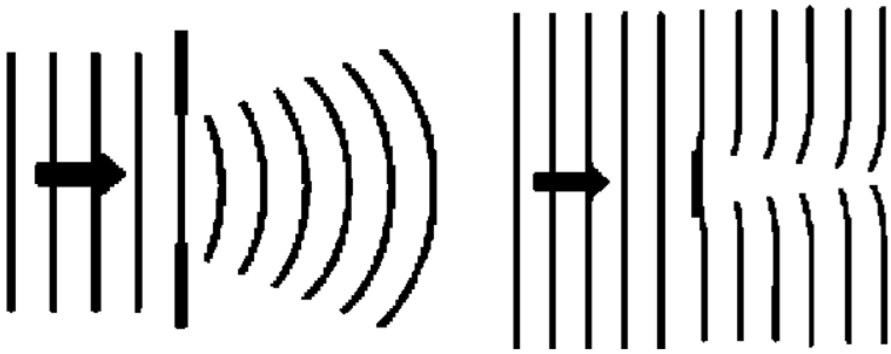

Figure 3. Diffraction of a plane wave through a hole and around an obstacle.

2.7. Attenuation in Eyes

Light can be attenuated (scattered or absorbed), and in all cases, the transmitted strength decreases exponentially with the thickness (x) of the substance through which it passes.

2.7.1. Scattering

When light strikes a small particle or molecule, it is dispersed and changes direction. Scattering produced from particles placed or moved randomly i.e. from rough surfaces, solutions and gases. Scattering distinguishes from reflection in that the scattering direction is uncertain, while the direction of reflection is known. Scattering will cause a light beam to be weakened [23, 24] as shown in Figure 4.

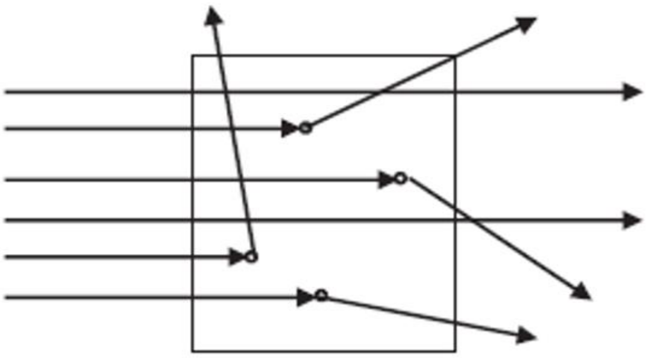

Figure 4. The transmitted light is weakened by scattering.

The equation of attenuation due to scattering is usually given by,

$$I = I_o e^{-\tau(\lambda)x} \quad (7)$$

Where, (I_o) the incident intensity, (I) the transmitted intensity, and $\tau(\lambda)$ is called the attenuation coefficient of material and it is a function of light wavelength. Rayleigh, Mie, and non-selective scattering are the three forms of scattering. The wavelength (λ) of the incident light and the size (d) of the particle encountered determine the type of scattering.

2.7.2. Rayleigh Scattering

It is a form of molecular scatter that occurs when the diameter of the molecules and particles is several orders of magnitude smaller than the wavelength of the incident light [24], i.e.

$$d \ll \lambda \quad (8)$$

The minimum size of transparent parts of eyes (2mm pupil) is much greater than the wavelengths of visible light (0.4-0.7) μm, so light waves don't satisfied the Rayleigh scattering condition.

2.7.3. Mie Scattering

This kind of scattering occurs when the medium comprises essentially spherical particles with diameters approximately equal to the wavelength of light [24], i.e.

$$d \approx \lambda \quad (9)$$

Light wavelength (μm) are also don't satisfy the Mie scattering condition with transparent parts of eye sizes (mm) [24].

2.7.4. Non-Selective Scattering

Non-selective scattering is a complete scatter (all wavelengths of light are scattered), that occurs when particles with diameters several times the wavelength of light being transmitted are present in the medium, which means [24].

$$d > (3 \sim 9)\lambda \quad (10)$$

The sizes of transparent parts of eyes are much greater than the wavelengths of light, so there in no scatter neither due to the size of these parts nor due to rough surfaces or particles placed or moved randomly in these parts. However, the amount of light scattered by normal human lens is less than 5%. Such scattering is expected from random fluctuations in the refractive index of lens during viewing process [5, 9, 10].

2.8. Absorption

Light absorption occurs because of electron transition from a ground state to an excited state in a molecule or atom. This transition will require a photon have the required energy. The light photon energy (E) is a function of frequency ($E = hf$), where is (h) Planck constant and (f) the frequency of light wave. The attenuation due to absorption is usually written by Thomas and Van [11].

$$I = I_o 10^{-\mu(\lambda)x} \quad (11)$$

Where $\mu(\lambda)$ is the absorption coefficient of the substance through which the light passes, which has no simple form and is typically calculated experimentally. The absorption coefficient of transmitted parts of eyes can be explained on the basis of pure water content. The optical transmittance (I/I_o) spectrums of eye are considered by many references [7, 10, 11].

From the data of optical transmittance spectrums of eye shown in the reference [11], we tried to find a mathematical function that can be represent the optical transmittance spectrums of eyes. Using Matlab fitting tools it is obtained that the Gaussian function is a more proper function that can be represented the optical transmittance spectrums of normal eyes, as shown in Figure 5 and Figure 6.

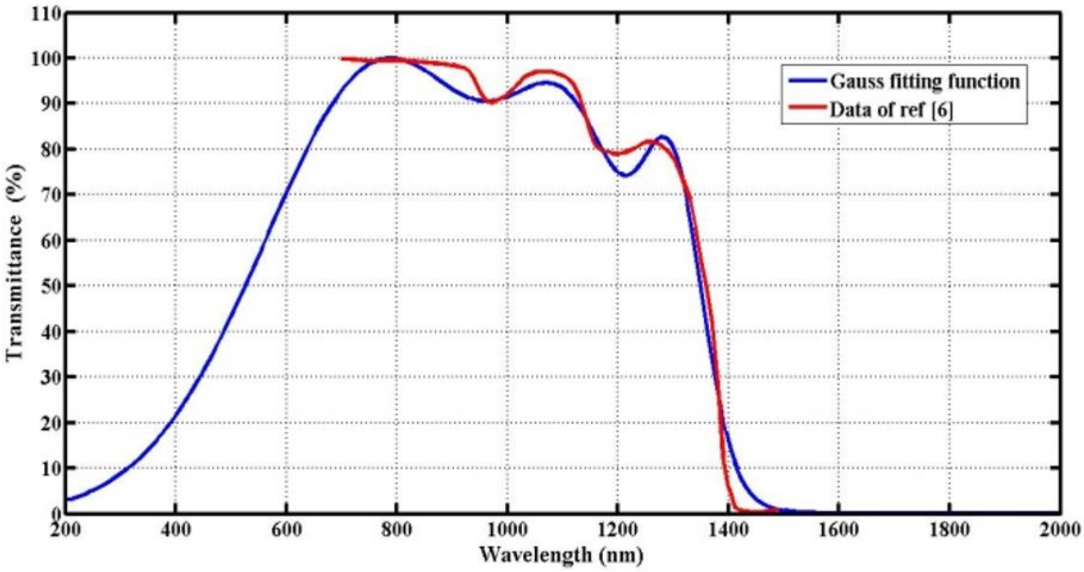

Figure 5. The optical transmittance spectrums of normal eye obtained from [11] and Matlab curve fitting tools.

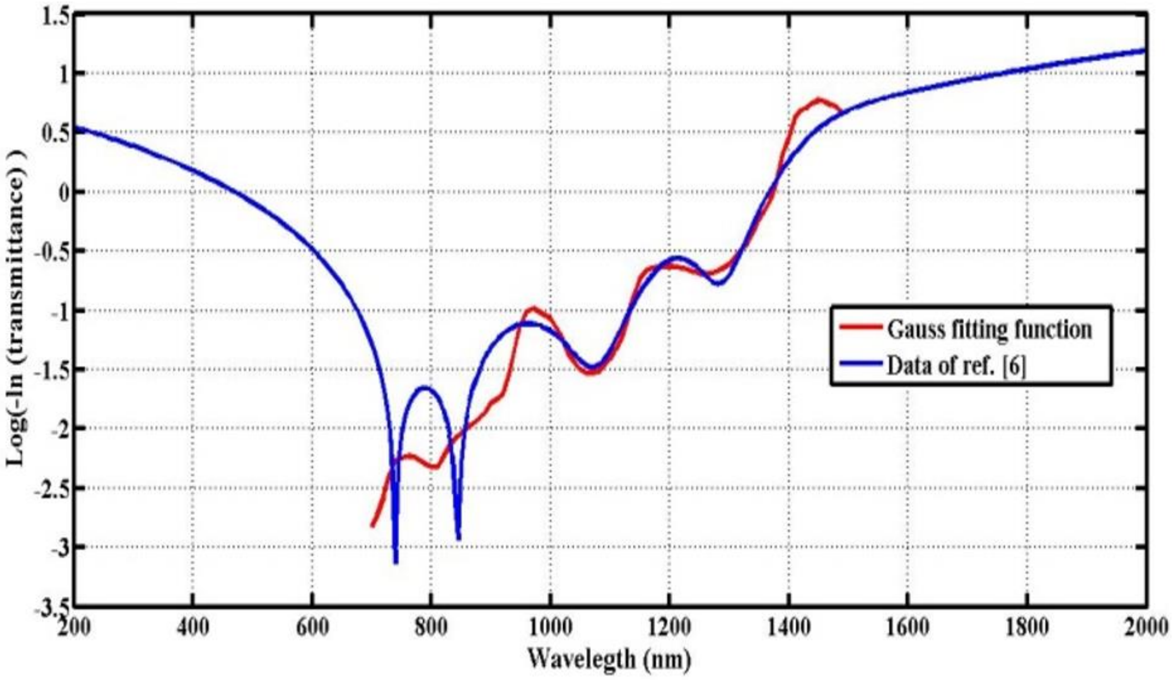

Figure 6. Test the correspondence in shape between log(-In) of transmittance data [11] and the corresponding gauss fitted function.

The Gauss function that obtained from Matlab fitting is given by Equation 12,

$$y = \sum_{i=1}^{3} a_i \, e^{-\left(\frac{x-b_i}{c_i}\right)^2} \qquad (12)$$

It is essentially a distribution function that can be used to describe many physical events [25]. Therefore, we deduced that the optical transmittance spectrum of normal eyes has a distribution nature around the visible spectrum. This is due the complicated structure of the transmitted parts of eyes [6], as well as to the complex dependence of absorption coefficient on the wavelength [7, 11].

2.8.1. Light Vision Absorption Effects

The lens has the ability to store incident photon energy by resonance absorption, just like any other material. Absorption happens as a binary event with a probability determined by the conformity between the incident photon energy and the energy gap that is open for the molecule to resonate if the photon energy matches to a specific absorption band in a molecule. Photon energy at UV and visible wavelengths is related to electron configurations in materials with a restricted absorption band. Broad, non-specific absorption bands in materials correspond to the vibration of molecules in the infrared (IR) spectrum.

Photochemical damage, a natural alteration of a specific chemical's reactivity, is caused by the absorption of UV or visible-wavelength photons. Proteins and other large, significant macromolecules frequently lose their spatial organization. According to the Arrhenius equation, the rate of protein denaturation is controlled by a temperature-dependent rate constant. Biological tissue damage brought on by a high rate of vibration damage is referred to as thermal damage. effects of low amounts of UV and infrared radiation on the crystalline lens that may appear after exposure to sunshine or other artificial sources that produce light with a similar intensity. The human cornea blocks light with shorter wavelengths than 290 nm. Almost all UV and IR light is absorbed by the lens, and this is age-dependent. The length of time between exposure to electromagnetic radiation and the lens' response reveals the biological effects of electromagnetic energy absorption. If the molecular absorption event has a significant impact on the lens, an immediate development of cataract follows exposure. If there is a little delay in the development of cataract, it often takes a biological expression of the main molecular absorption event during the delay (several days) for cataract to develop. If a cataract develops beyond 4 weeks, the damage doesn't manifest until enough molecular absorption events have been collected relative to biological healing. There are four different types of temperature effects on the anterior corneal surface: temperature changes brought on by blinking, heat transfer from the cornea to the environment, temperature changes brought on by tears spreading across the cornea, and temperature changes brought on by eyelid movement. The temperature of the cornea varies differently when the eyelid is closed and open. The cornea surface temperature is regulated during eyelid opening by convection, radiation, and tear evaporation. Typically, a thin lipid layer is present on the corneal epithelium's surface [18]. This layer has the purpose of preventing ocular surface tear evaporation.

The evaporation rate rises rapidly when this layer is lost. The corneal temperature drops as the rate of evaporation rises, but the pace of cooling is slower when the eyelids are opened than when they are closed. Eyelid closure time increases when the eye is exposed to high-speed wind, extremely hot or cold conditions, etc., whereas it reduces when the eyes are concentrated on an item for a prolonged period of time. The temperature of the ocular surface may alter even if eyelid closure time is much shorter than opening time [5]. Water makes up 65 percent of the lens. As an individual gets older, their lens' water content decreases [15]. Thermal conductivities will vary depending on the water content.

2.9. Emission

Emission is a process in which light photons transmit energy to biological molecules, causing their electrons to be promoted to higher levels of energy and leaving holes under them. The excess energy is returned as light as electrons return to these holes with less energy. Light enters the cornea and is projected onto the back of the eye, where it is converted into a nerve signal by specialized sensory cells (photoreceptors) of the retina via a combination of photochemical and electrochemical processes [6]. These signals are sent to the brain through the optic nerve for further processing, which is needed for perception. Therefore, there is no light emission from photoreceptors and all observed light are converted to nerve signals. Hence, the photoreceptor cell looks like a photocell in a solar-cells system that convert sun light to electric energy.

2.10. Viewing Light Safety Equations

The damage of electromagnetic radiation to the biological tissues can be of three types: photo thermal, photomechanical, and photochemical damage. The first injury results from the exaggerated temperature elevation at the cellular and molecular level, which causes denaturation of proteins, loss of tertiary molecular structure, and fluid infection of the membranes. It corresponds to the "burn" in the conventional language [7]. The second is related to mechanical damage (micro cavitation) resulting from the sudden compression and decompression of the tissues generated by the exposure to extremely high amounts of energy, in a small area, for picoseconds. The typical example is that of the Nd:Yag laser. In the third type of damage, the energy absorbed by the tissue results in the breaking of the chemical bonds of molecules and the release of free radicals that, once generated, attack other molecules in a chain reaction. This is the overall type of damage expected from UV radiation [7].

Light at wavelengths in the neighborhood of 400 nm (UV and blue light) consists of the highest-energy photons that can reach the retina; thus, there is concern about the effects of such high-energy light on the retina. Therefore, it is important to block or decrease UV and blue light from entering the eyes in order to protect the retina [26-29]. When electrons in molecular orbitals absorb electromagnetic energy in the blue light spectrum, photochemical processes or the internal conversion of light to heat may result. Because the absorption of UV and visible light can lead to energy transfer into vibrational states, internal conversion reactions have significant effects. Much of the energy that is absorbed from such light sources is converted to heat. Therefore, it is likely that using an optical device causes heat and dryness in the eye components. When light energy deposition due to thermal inactivation occurs faster than thermal diffusion, the target tissue warms up and suffers from photo thermal damage. As a result, there is now reason for concern regarding the possibly harmful effects of temperature increases on eye tissue during extended viewing. Generally speaking, thermal damage did not occur to the eye that was exposed to blue light with a power density of 200 mW/cm2 [2]. People should be aware that the amount of time spent being exposed to blue light while viewing screens shouldn't be longer than is absolutely necessary. The distance between the optical source and the eyes must be carefully considered as well. The current strategies used to safeguard the eyes from blue light-induced harm are based on limiting the amount of blue light that enters the eyes. Blue light is most successfully blocked by orange and/or bronze-colored filters. Compared to bronze filters, orange filters block more blue light [2]. Therefore, by making sure that blue light must pass through filters that include certain hues, such functional eyewear, it is feasible to significantly limit the impact of blue light on the eyes. Blue light emitted by optical devices can cause a variety of eye problems. Therefore, it is critical to actively eradicate those that are the most harmful to people, and individuals should strive to utilize extremely safe equipment based on scientific facts. As a result, it may be said that time, distance, and shielding are important tools for external safety and protection against light risks.

2.10.1. Time of Viewing

In radiation safety science, one basic way of controlling exposure to harmful radiation is limiting the time spent near a source of radiation. The radiation dose (D), the amount of radiation energy absorbed per unit mass of irradiated material at a specific location, such as a part of the human body (eyes), is directly proportional to the time (t) spent in the radiation area (viewing) [30].

$$D = t \times I \quad (13)$$

Where (I) is the intensity (irradiance). Many individuals experience eye discomfort and vision problems when viewing digital screens for extended periods. The level of discomfort appears to increase with the amount of digital screen use. To help alleviate digital eyestrain, one can follow the 20-20-20 rule, take a 20-second break to view something 20 feet away every 20 minutes.

2.10.2. Distance of Viewing

This distance of viewing has a strong effect on the light that reaches the retina according to the inverse square law, which explains the strength of light with respect to the distance of the source and states that: The intensity of the light to an observer from a source of strength (S) is inversely proportional to the square of the distance (r) from the observer to the source [31].

$$I = \frac{S}{4\pi r^2} \quad (14)$$

As per this law, the light loses it is brightness or luminosity sharply ($\frac{1}{r^2}$) as it moves away from the source. Consider the distance as 2, and when the distance is squared, it results in 4. The inverse of 4 would be 1/4. When we compare the results, we can see that the resulting power is one-quarter of the original power. Hence, if the distance between the eyes and the light source is doubled, they will experience one-fourth of the light from the source. As a result, the distance can be used as an external safety tool in the case of high-intensity light hazards. Equation 14 also shows that the strength of an artificial source can also be used to adjust the intensity of light directly.

2.10.3. Shielding of Viewing

Shielding is a barrier surrounding a region to exclude it from the influence of an energy field. to stop or reduce the level of radiation. Shielding simply means having something that will absorb radiation between the source of the radiation and the area to be protected. Filtration and brightness reduction by shielding are two principal methods to protect the retina from light damage. Radiation shielding is based on the principle of attenuation, which is the gradual loss in intensity of any energy through a medium, as shown in Paragraph 2.5 and Equation 11. The simplest way to shield the eyes is to wear proper glasses. The glasses should have a dark tint, and the light coming through the lenses should appear grey, brown, or yellowish brown. Polarization can also be used to decrease the amount of light coming through the glasses and help reduce brightness.

3. CONCLUSIONS

The physical treatment of light-eyes interaction shows that the transmitted parts of eyes do not have considerable reflection, diffraction, scattering, and absorption of light rays, and they allow light to pass through them freely with some refraction, where about 98% of the incident power of light can be reached to the retina. Matlab curve fitting tools are used to show that the optical transmittance spectrum of eyes has a Gaussian shape. This involves that the photoreceptor cells of the retina absorb all received light without any emission, so it seems like a photocell. To reduce eye harm while preserving the ability to use safely, it is crucial to rely on outside factors (light characteristics, distance from the light source, exposure period, and glassy shielding). More research on the physics of external safety aspects can be done to enhance the viewing settings that are safe for everyone.

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REFERENCES

[1] Y. N. Carlos and J. D. F. E. S. Sidney, "Ultraviolet radiation and the human eye. Retrieved from: http://dx.doi.org/10.5935/0004-2749.2021-0354," 2022.

[2] Y. Fumihiko and A. Yoshida, "Effects of blue-light irradiation during dental treatment," *Japanese Dental Science Review*, vol. 54, pp. 160-168, 2018.Available at: https://doi.org/10.1016/j.jdsr.2018.06.002.

[3] D. Dhankhar, R. Li, A. Nagpal, J. Chen, T. C. Cesario, and P. M. Rentzepis, "Extending human vision to IR and UV Light: Study using micro-particles and fluorescent molecules," *IEEE ACCESS*, vol. 8, pp. 73890 -73897, 2020.

[4] M. Alex and A. McDaniel, "Long-range propagation through inhomogeneous turbulent atmosphere: Analysis beyond phase screens," *Written Physics*, vol. 94, p. 034003, 2019.Available at: https://doi.org/10.1088/1402-4896/aaf32c.

[5] https://byjus.com/physics/structure-human-eye-functioning, 2022.

[6] I. V. Iliya, T. Mappes, P. Schaupp, C. Lappe, and S. Wahl, "Ultraviolet radiation oxidative stress affects eye health," *Journal of Biophotonics*, vol. 11, p. e201700377, 2018.Available at: https://doi.org/10.1002/jbio.201700377.

[7] P. Söderberg, N. Talebizadeh, Z. Yu, and K. Galichanin, "Does infrared or ultraviolet light damage the lens?," *Eye*, vol. 30, pp. 241-246, 2016.Available at: https://doi.org/10.1038/eye.2015.266.

[8] N. Teruo, "The cornea: Stasis and dynamics," *Nippon Ganka Gakkai Zasshi*, vol. 112, pp. 179-212, 2008.

[9] M. Michael, "Experiencing light's properties within your own eye," *The Physics Teacher*, vol. 49, pp. 19-21, 2011.Available at: https://doi.org/10.1119/1.3527748.

[10] S. H. David, "How light reaches the eye and its components," *International Journal of Toxicology*, vol. 21, pp. 501-509, 2002.Available at: https://doi.org/10.1080/10915810290169927.

[11] J. T. P. Thomas and D. B. Van, "Near infrared light absorption in the human eye media," *Vision Res*, vol. 37, pp. 249-253, 1997

[12] B. Claes, O. Nilsson, and L.-E. Paulsson, "Intraocular light scattering in vision, artistic painting, and photography," *Applied Optics*, vol. 33, pp. 4749-4753, 1994.Available at: https://doi.org/10.1364/ao.33.004749.

[13] B. A. Frederick and M. Paunovic, "Light scattering of normal human lens I. Application of random density and orientation fluctuation theory," *Biophysical Journal*, vol. 26, pp. 85-99, 1979.Available at: https://doi.org/10.1016/s0006-3495(79)85237-6.

[14] R. Edge, "The optics of the eye lens," *Physics Teacher*, vol. 27, pp. 392-93, 1989.Available at: https://doi.org/10.1038/sj.eye.6702607.

[15] N. Daniel, J. A. Marchal Corrales, A. Jorge de Mora, and L. Moroni, "Fundamentals of light-cell–polymer interactions in photo-cross-linking based bioprinting," *APL Bioengineering*, vol. 4, p. 041502, 2020.Available at: https://doi.org/10.1063/5.0022693.

[16] R. Matthes, "guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400nm (incoherent optical radiation)," *Health Physics Society*, vol. 87, pp. 171-186, 2004.

[17] D. Nieto, J. A. Marchal Corrales, A. Jorge de Mora, and L. Moroni, "Fundamentals of light-cell–polymer interactions in photo-cross-linking based bioprinting," *APL Bioengineering*, vol. 4, p. 041502, 2020.Available at: https://doi.org/10.1063/5.0022693.

[18] M. Rodrigues and P. S. Carvalho, "Laws of reflection and Snell's law revisited by video modeling," presented at the In 12th Education and Training in Optics and Photonics Conference, SPIE, 2014.

[19] Anton Paar Wiki, "Basics of refractometry, Retrieved from: https://wiki.anton-paar.com/be-en/basics-of-refractometry," 2021

[20] K. R. Heys, M. G. Friedrich, and R. J. Truscott, "Presbyopia and heat: changes associated with aging of the human lens suggest a functional role for the small heat shock protein, α-crystallin, in maintaining lens flexibility," *Aging Cell*, vol. 6, pp. 807-815, 2007.Available at: https://doi.org/10.1111/j.1474-9726.2007.00342.x.

[21] A. Pablo, "Optics of the eye and its impact in vision: A tutorial," *Advances in Optics and Photonics*, vol. 6, pp. 340-367, 2014.Available at: https://doi.org/10.1364/aop.6.000340.

[22] S. R. Matthew, "Transmission and impedance. Retrieved: https://scholar.harvard.edu/files/schwartz/files/lecture9-impedance.pdf," 2016.

[23] J. L. Odden, A. Mihailovic, M. V. Boland, D. S. Friedman, S. K. West, and P. Y. Ramulu, "Evaluation of central and peripheral visual field concordance in glaucoma," *Investigative Ophthalmology & Visual Science*, vol. 57, pp. 2797-2804, 2016.

[24] A. Authier and C. Malgrange, "Diffraction physics," *Acta Crystallographica Section A: Foundations of Crystallography*, vol. 54, pp. 806-819, 1998.

[25] M. I. Ribeiro, "Gaussian probability density functions: Properties and error characterization, Institute for systems and Robotics, 1049-001 Lisboa PORTUGAL, 2004. Retrieved: http://omni.isr.ist.utl.pt/~mir/pub/probability.pdf," 2004.

[26] https://en.wikipedia.org/wiki/Ultraviolet, 2022.

[27] S. Hattar, R. J. Lucas, N. Mrosovsky, S. Thompson, R. Douglas, M. W. Hankins, J. Lem, M. Biel, F. Hofmann, and R. G. Foster, "Melanopsin and rod–cone photoreceptive systems account for all major accessory visual functions in mice," *Nature*, vol. 424, pp. 75-81, 2003.

[28] J. Ambati, A. Anand, S. Fernandez, E. Sakurai, B. C. Lynn, W. A. Kuziel, B. J. Rollins, and B. K. Ambati, "An animal model of age-related macular degeneration in senescent Ccl-2-or Ccr-2-deficient mice," *Nature Medicine*, vol. 9, pp. 1390-1397, 2003.Available at: https://doi.org/10.1038/nm950.

[29] O. M. Ibrahim, T. Kojima, T. H. Wakamatsu, M. Dogru, Y. Matsumoto, Y. Ogawa, J. Ogawa, K. Negishi, J. Shimazaki, and Y. Sakamoto, "Corneal and retinal effects of ultraviolet-B exposure in a soft contact lens mouse model," *Investigative Ophthalmology & Visual Science*, vol. 53, pp. 2403-2413, 2012.Available at: https://doi.org/10.1167/iovs.11-6863.

[30] A. Wojciech, A. Luczkiewicz, and J. M. Sawicki, "Analysis of the radiation dose in UV-disinfection flow reactors," *Water*, vol. 12, p. 231, 2020.Available at: https://doi.org/10.3390/w12010231.

[31] V. Nikolaos and S. Oikonomidis, "Inverse square law for light and radiation: A unifying educational approach," *European Journal of Engineering and Technology Research*, vol. 2, pp. 23-27, 2017.Available at: https://doi.org/10.24018/ejers.2017.2.11.517.