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**Original Article**

# Light and the laws of reflection and refraction as they impact on photography

# Fotoğrafçılıkta ışık ve yansıma ve kırılma kurallarının etkileri

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## ABSTRACT

It has been postulated severally by various authors that the basis of good photography is light and that there cannot be good photography without light. Primarily, light can be gotten from diverse sources like the natural lights of the sun and moon, artificial lights such as electricity and battery generated lights and indeed from open fire. Light goes with refraction and reflection and as has been put forward that light travels in straight lines, light has also been seen as energy in transit itself. Mixed together in suitable proportion, wavelengths between 4,000λ and 7000λ create a sensation of white light while narrower bands are recognized as violet, blue, green, yellow, red in order of increasing wavelengths. Photography is an aspect of the visual arts that falls within the scope of graphics and so photography as an art genre and as pure science has a lot in common with reflection as reflection and refraction has relationship with light. For any photographer to turn out good images he has to be conversant with the principles of light and so it is against this backdrop that this paper examines light and the laws of refraction and reflection as it affects photography.

## ÖZ

Çeşitli yazarlar tarafından iyi fotoğrafın temelinin ışık olduğu ve ışık olmadan iyi fotoğrafın olamayacağı ileri sürülmüştür. Öncelikle ışık, güneş ve ay ışığı gibi doğal kaynaklardan, elektrik ve pille üretilen ışıklar gibi yapay kaynaklardan ve açık ateş gibi çeşitli kaynaklardan elde edilebilir. Işık kırılma ve yansıma ile birlikte yolculuk eder ve ışığın düz çizgiler halinde yol aldığı ileri sürüldüğü gibi, aynı zamanda geçiş halindeki enerji olarak da gözlenmiştir. Uygun oranlarda karıştırıldığında, 4000λ ila 7000λ arasındaki dalga boyları beyaz ışık hissi yaratırken, daha dar bantlar, artan dalga boylarına göre mor, mavi, yeşil, sarı, kırmızı olarak farkedilir. Fotoğrafçılık, görsel sanatlardan grafik sanatı kapsamına girer ve bu nedenle bir sanat dalı ve saf bir bilim olarak fotoğrafçılığın, yansıma ile pek çok ortak yanı vardır; yansıma ve kırılmanın da ışıkla ilişkisi mevcuttur. Herhangi bir fotoğrafçının iyi görüntüler ortaya çıkarması için ışık ilkelerine aşina olması gerekir. Bu nedenle bu makale, fotoğrafçılığı etkilediği için ışığı ve kırılma ve yansıma kurallarını bu zeminde incelemektedir.

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## INTRODUCTION

Just how valid is this photographic theory? Langford, (1999) posit that learning photography is rather like learning how to write; first we have to shape the letters to form words then learn to spell and organize our grammar but a person who does only these steps is not yet a writer until he has ideas to express through words. In the same vein, similar theory to the photographer is a means to a visual end and this is only valid in so far as it offers him better control, improved self-confidence in achieving what he wishes to say through pictures. Theory then exists to support practice; this means that even the most imaginative photographer needs to know his tools and his craft therefore, the creative photographer handicapped by technical incompetence must be unfair to himself because all commercial fields of photography demand reliability. Photography or "light drawing' is an amalgam of techniques and visual observation therefore a knowledge of the nuances of the theory of light and the laws of reflection and refraction will go a long way in broadening the extant knowledge of the professional photographer. In the process of photography, we are faced with into using a variety of optical and chemical phenomena from the moment we first use a camera and process our results. Yet, if theoretical knowledge is not to be systematically acquired, it would be sensible to commence coverage with optics and image forming and work through to printing and finishing, so it is therefore helpful to know broadly what is going on in day-to-day procedure.

Some of those light rays, according to Hedgecoe (1996) reflected from or emitted by parts of the subject enter our camera lens and here, they are bent or 'refracted' to re-form as a detailed image of the subject. The image is formed upside-down at a set space from the lens relative to subject distance and the bending power (focal length) of the lens in use. This image can be checked on a floor glass display, moving the lens position until correct distance for clear or sharp focus is achieved and later a light-sensitive material will replace the screen to record the image chemically.

The above illustration gives a vivid description of the process of using the camera to snap an image and the follow-up. Having given the above description, it is pertinent to know that all these are possible with the presence of light and so what is light?

**What is Light?**

In physics, Hecht (2002) claim that light are electromagnetic rays that can be experienced by the human eye. Electromagnetic emission occurs over an exceptionally wide variety of wavelengths, from gamma waves with wavelengths of less than about ($1x10^{-11}$) meters to radio waves calibrated in meters. Supporting Hetch's claim, Smith (2003) advanced that within that wide band the wavelengths noticeable to humans occupy a very thin band, of about 700 nanometers (nm; billions of a meter) for red light to about 400nm for violet light. The spectral area near the noticeable band is mostly called light and also, infrared in one end and ultraviolet at another end. The swiftness of light in space is a basic bodily constant whereas the presently acknowledged rate of which is precisely 299,792,458 meters per second (299,792,458m/2). Different persons distinguish light in different contexts; the physics specialist is concerned with the material constituents of light while the graphic artist, albeit the photographer shows interest in the artistic and beauty positive reception of the visual, knowing that with the sense of vision, light is the chief means for appreciating the world and communicating about and within it. Light from the sun keeps the earth warm, propels universal weather condition and starts the life-sustaining process of photosynthesis. On bigger scale, light's interaction with matter has helped shaped the structure of the universe. Ultimately, light provides the pane on the earth, from astrophysical to minute scales; roughly all of the report concerning the remainder of the world gets to the earth in the shape of electromagnetic emission; and so by interpreting that emission, Fischer and Tadic (2000) postulates that astronomers are able to sight the initial era of the world, evaluate the general development of the earth and also decide the chemical constituent of stars and interstellar standard, just as the development of the telescope radically broadened examination of the earth so also the innovation of the microscope exposed the intricate world of cells and the view of Mann (2000) the breakdown of the frequencies of light sent off and taken in by atoms was a major force for the progress of quantum mechanics. Molecular and atomic spectroscopes kept on being the primary tools for questioning the configuration of matter, giving ultrasensitive examinations of molecular and atomic types and adding to studies of basic photochemical reactions. Light emits spatial and earthly reports; this quality establishes the foundation of the study of optics and optical interactions related to technology. Technological practices based on the control of light consist of lasers, holography and fiber-optic telecommunication systems and in most day-to-day situation, the constituents of light could be gotten from the hypothesis of conventional electromagnetism, in such instance; light is referred to as combined electric and magnetic fields going through gap as a moving wave. Nevertheless, this wave hypothesis that was developed in the middle of the $19^{th}$ century in the words of Born and Wolf (1999) seems inadequate to explain the constituents of light at low rate so a level quantum conception would be needed to clarify the personality of light and elucidate on the connections of light in the midst of atoms and the molecules. In its most mundane form, light is explained as comprising separate packs of energy known as protons; however, neither the traditional wave concept nor the conventional particle idea properly explains light because it has a twin nature that is exposed only in the sphere of quantum mechanics. The strange wave-particle dual nature is general to all the major components of nature for instance; electrons are known to have both particle-like and wave-like aspects. According to Langford (1999), at the start of the 20th century, a more all-inclusive conjecture of light known as *quantum electrodynamics* (QED) surfaced and this was accepted by physicists as most complete. QED combine the hypothesis of quantum mechanics, standard electromagnetism, and the unique conjecture of relativity. Suffice it here to stress that this supposition of light was fundamental to the materialization of Albert Einstein's theory of exceptional relativity in the year 1905.

**Theories of Light Through Historical Antecedents**

While there is vivid proof that plain optical gadgets like plane and curved and convex lenses were in use by some early civilizations, it was speculated that primordial Greek philosophers were normally recognized with the earliest official insinuations about the character of light. The theoretical obstacle of differentiating the human insight of visual property from the material nature of light in some way hindered the growth of light theories. Consideration of the machine vision overshadowed these early studies and researches. Whereas Pythagoras (c.500$_{BCE}$) projected that 'seeing' or 'vision' is occasioned by rays originating from the eye and falling on objects, and whereas Empedocles (c.450$_{BCE}$) seem to have advanced a type of vision where light got emitted by equally the object and the eye, Epicurus (c.300$_{BCE}$) was of the opinion that light is sent off by other bodies apart from the eyes and that sight is formed when light bounces off objects and goes into the eyes. The above postulations were advanced by Desmarais (1998) and also claimed that Euclid (c. 300$_{BCE}$) postulated law of reflection and elucidated on the spread of rays of light in straight lines. Ptolemy (c.100 $_{BCE}$) on his own part embarked on one of the earliest quantitative explorations of light refraction as it travels from one transparent body to the other, juxtaposing pairs of angles of incident and spread for a combination of some media but with the fall of the Greco-Roman empire, Ray (1997) averred that scientific development moved to the Islamic region. Sturken and Cartwright (2001), in support of the claim by Ray (1997) stressed that in particular, al-Ma'mun, the seventh 'Abbasid king of Baghdad, established the house of knowledge (Bayt al-Hikma) in the year 830CE to explain, learn and develop Hellenistic theories of philosophy and science. Amongst the early scholars were al-Khwarizmi and al-Kindi. Known as the "Arab's philosopher," al-Kindi spread the concept of straightening propagating rays of light and explained the system of vision. By 1000AD, the Pythagoras representation of light was dumped and the ray model, consisting of the basic theoretical frameworks of what is now referred to as geometrical optics, emerged. Ibn al-Haythan rightly ascribed vision to the inactive response of light rays reflected from other objects other than active release of rays from the eyes. Sturken and Cartwright (2001) continued that he also worked on the mathematical character of the reflection of light from parabolic and spherical mirrors and drew detailed pictures of the optical composition of the eye. The work of Ibn al-Haythan in13th century, served as inspiration and authority on the natural philosopher, Roger Bacon who studied the propagation of light through simple lenses and is credited as one of the earliest to have described the use of lenses to correct poor or bad vision.

With the dawn of 17th century, Ray (1997) claimed that significant renaissance happened in Europe in the sense that compound microscopes were first constructed in the Netherlands between 1590 and 1608, probably by Hans and Zacharias Jansen and some sources credited a certain Dutchman by name Hans Lippershey as inventing the telescope in 1608. Galileo, the Italian astronomer, improved upon the design of the telescope and utilized it in his discoveries of the Jupiter moons and the Saturn rings in the year 1610.

Refraction is the movement of light from one body into another so in this situation, from air to glass lens. Johannes Kepler, the German astronomer offered an estimated mathematical study of the focus characteristics of the lens in 1611. In 1621 an experimental progress was done by Willebrord Snell, the Dutch astronomer, by propounding the mathematical relation involving the angles of incident and diffusion for rays of light refracting through a boundary between two bodies (Snell's Law). In the year 1657, Pierre de Fermat the French mathematician, advanced an interesting variant of the Snell's law predicated on his principle of least time, which postulated that light travels through the course of minimum time in moving from one end to another. The works of Francesco Grimaldi the Jesuit mathematician shows what is now referred to as diffraction effect, where light passing through an obstruction is observed to penetrate into geometrical shadow. In the year 1676, Ole Romer, the Danish astronomer utilized his measurements of the differences in apparent orbital times of the Jupiter moons over the period of one year to infer an estimated rate of the velocity of light. The implication of Romer's effort was the recognition that the velocity of light was not endless.

Decisive material types of the character of light were advanced corresponding with a lot of experiential finds of the period of 17th century. Two opposing types of light, as a group of vigorous particles and a continuing wave were advanced. In 1637, the philosopher Rene Descartes saw light as a pressure wave moving through a persistent flexible medium. Robert Hooke, the English physicist considered diffraction property and interference and summed up that light was a fast pulsation of any material in which it operates. This assertion of Hooke, though very confusing led to another by a Dutch mathematician and astronomer Christian Huygens who propounded the first comprehensive wave hypothesis of light within the framework of where he was able to originate the laws of reflection and refraction. As can be seen, all or most of these precursors of the theory of light were philosophers, astronomers, physicist or mathematician and all of them had something in common and that is the quest for knowledge and discovery. Sir Isaac Newton was probably the most outstanding proponent of a particle deduction of light. Longair (2000) avers that Newton's painstaking quests into the property of light in the 1660s culminated into his innovation that white light comprises an admixture of colours eventually resulting in optics in 1704 that light comprises a flow of particles therefore to resolve his particle copy with the established rule of refraction; this can be exemplified from his prism experiment; one sunny day, Isaac Newton shaded his room and did a perforation in his windowpane to let in some light into his room, he placed a glass prism at the front of the sunbeam allowing the refracted rays beam on a screen and the amazing product was a multi-coloured array of colour light akin to those of the rainbow as shown in Figure 1 that shows the Newton's prism experiment.

The above experiment later became popularly known as the prism experiment; whose spectrum ranges from Red to Violet and has in between them orange, yellow, green, blue and indigo but before red are invisible colours known as infra-red and after violet are also invisible colours known as ultra-violet.

Miller and Friedman (2012) posited that Newton speculated that transparent objects such as glass exert attractive forces on the particles with the consequence that the velocity of light in a transparent medium is always greater than that in a vacuum; he also submitted that bits of diverse light colours have somewhat different masses, resulting in various speeds in see-through media hence the dissimilarity of refraction angles. Newton's particle model endured into the early 19$^{th}$ century and at this time, proof for the wavy character of light became widely known. The position of Miller and Friedman was buttressed by Zissis (2013) that speculative and investigational works in the middle of the 19$^{th}$ century without a doubt recognized light as electromagnetic wave and the subject seem resolved in the year 1900 with the coming of quantum mechanics.

With this analysis, it is seen that although these various personalities of the light theory did not practice photography during their time, there are enough evidence that photography was embedded in their researches as could be exemplified in the invention of the microscope and telescope which are both photographic tools and apparatus.

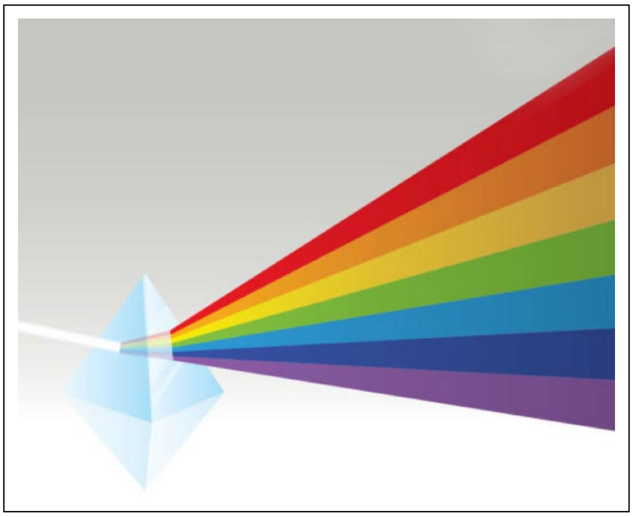

**Figure 1**. Newton's Prism Experiment.

Source: istockphoto.com

**Reflection of Light**

In a plain language, reflection, according to Goodman (2013) is the property of a propagated wave being thrown back from a surface such as mirror or any other reflective or smooth surface. In physics and science, reflection goes beyond what we see with our ordinary eye; it goes to the extent of the investigation of what transpires during this process. Goodman stressed that light may be '*specularly*' reflected when it strikes a smooth surface such as glass, water, polished chromium plating and such like; each ray reaching the surface is reflected in one direction determined by its angle of incidence. If an unreal line is drawn at right angles to the plane where a light ray is received, the angle between this 'normal' line and the ray is the angle of incidence. The ray leaving the surface, having been specularly reflected, forms angle of reflection with the normal equal to the angle of incidence. Figure 2 shows the diagrammatic reflection of light.

Reflection of light has three powerful laws and this explanation brings this essay to the first law of reflection which states that:

*The angle between the incident ray and the normal is equal to the angle between the reflected ray and the normal*

The second law is a derivation of the first and it states thus:

*The incident ray, the normal and the reflected ray all lay on the same plane*

The third law states:

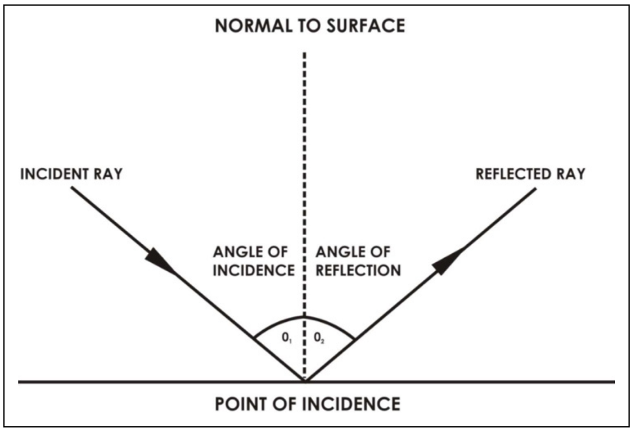


**Figure 2**. Diagrammatic reflection of light.

*The incident ray and refracted ray are on different sides of the normal*

In the wake of the 1600s, Meyer-Arendt (2015) submitted that a set of empirical rules describing the behaviour of light as it traverses transparent materials and reflects off smooth surfaces was adequate to support practical advances in optics. Known widely today as geometrical optics, the rules constitute an entirely useful, though very approximate, model of light; often, their primary applications are the analysis of optical systems like cameras, microscopes and telescopes.

**Explanation of the Laws of Reflection**

**Explanation of Law 1**

The angle between the incident ray and the normal is equal to the angle between the reflected ray and the normal.

This means that θi equals θr where θi = angle of incidence and θr = angle of reflection

As the angle of incidence (θi) increases, the angle of reflection (θr) also increases and they are always equal to each other. Figures 3, 4 and 5 explains the reflection of light law number one.

**Explanation of Law 2**

The incident ray, the normal and the reflected ray all lay on the same plane.

Θi = θr

Changing the direction of the incident ray changes the angle of the plane.

θi = θr

Again the incident ray, the normal line and the reflected ray all lie in the same plane. Figures 6 and 7 illustrates the reflection of light law number two.

**Explanation of Law 3**

The incident ray and the reflected ray are on different sides of the normal.

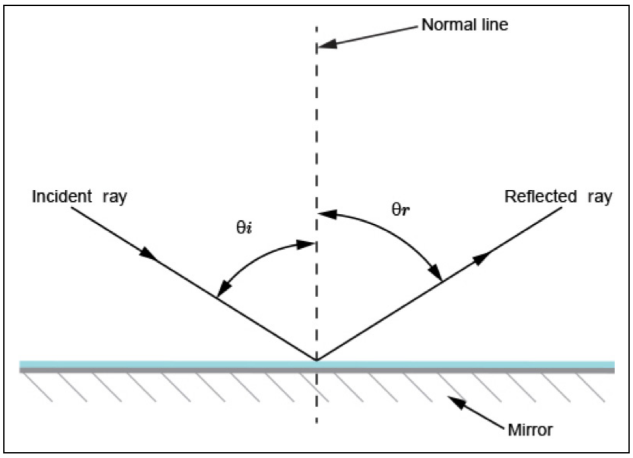


**Figure 3**. Diagrammatic representation of reflection of light law number one.

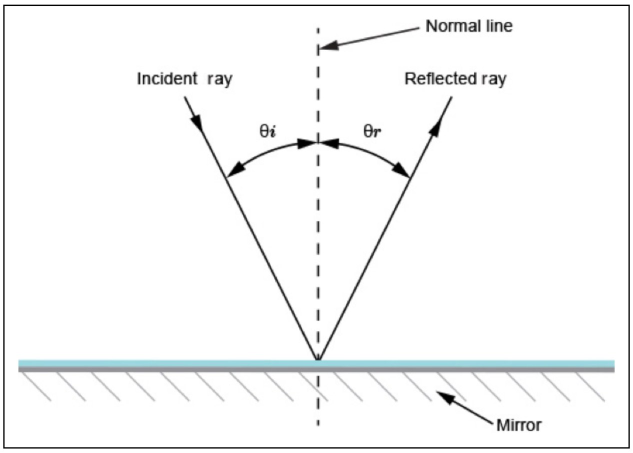


**Figure 4**. Diagrammatic representation of reflection of light law number one.

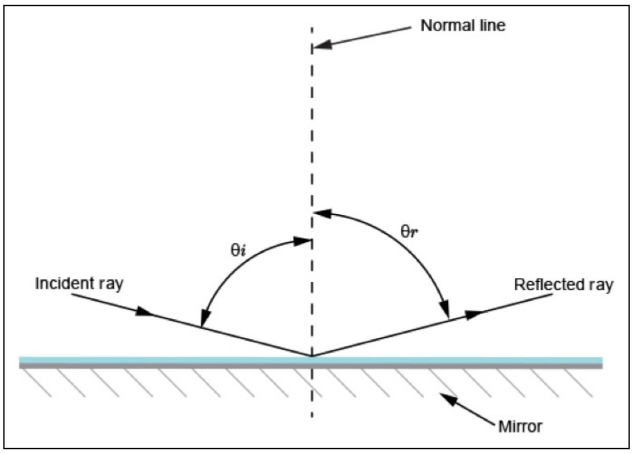


**Figure 5**. Diagrammatic representation of reflection of light law number one.

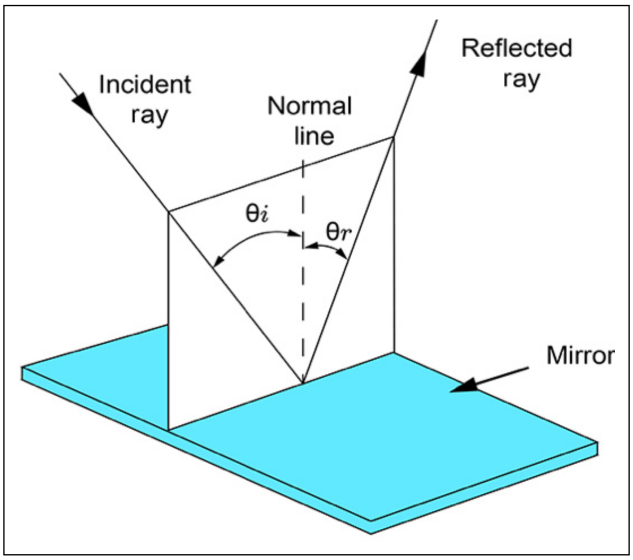


**Figure 6**. Diagrammatic representation of reflection of light law number two.

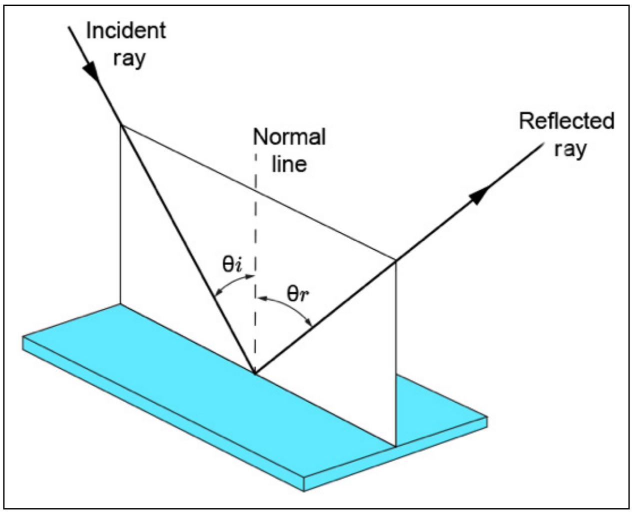


**Figure 7**. Diagrammatic representation of reflection of light law number two.

Figure 8 diagram is wrong. The incident ray and the reflected ray cannot be on the same side of the normal. On the other hand, Figure 9 is correct which is explains reflection law number 3.

The incident ray and reflected ray must be on opposite sides of the normal, therefore the above diagram is correct.

**Rays of Light**

The fundamental constituent in geometrical optics according to Goodman (2013) is light rays, a hypothetical contraption that shows the course of the transmission of light at any position in time and space. The starting point of this perception traces back to early postulations concerning the character of light whereas by 17th century, the Pythagorean concept of image rays has long been jettisoned but the notion that light moves in straight line culminated naturally in the growth of the ray perception. As light moves from one intermediate to the other, reflects from surfaces, spreads or comes into focus, the bunch of rays follows the beam's growth in an easy geometric fashion. Geometrical optics comprises a set of rules that suggests the paths travelled by light rays and in any consistent standard, the rays moves in straight lines; the light given off by a tiny restricted source is represented by a combination rays pointing radically outside from a spot; a collection of similar emission is used to symbolize light moving with consistent strength through space like the laser and light from star.

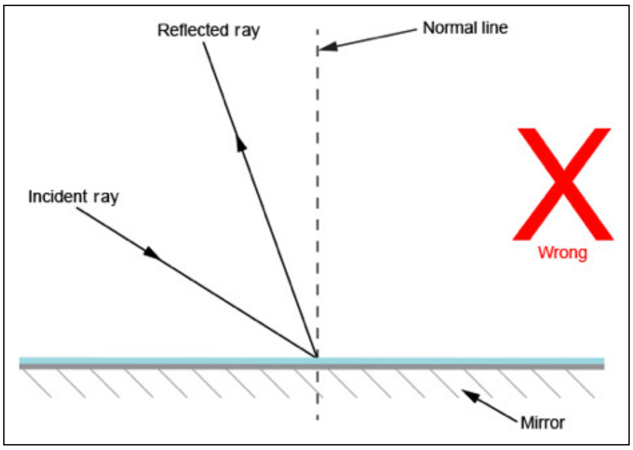


**Figure 8**. Diagrammatic representation of reflection of light law number three which is incorrect.

**Reflection and Refraction**

As has been said in the early stages of this essay that rays changes direction when they reflect off a surface or move from one transparent platform to another or travel through a medium whose composition is continuously changing, the law of reflection suggests that on reflection from a smooth surface, all angles of reflection is at all times alike those of incidence and by convention and as a result, Rouchi (2000) posits that all angles pertaining to geometrical optics is calibrated with relevance to the normal, that is to say, for a line that is perpendicular to the plane. These reflected rays are always in the surface suggested by the incidence ray and normal. The law governing reflection is applied to appreciate the images created by curved and plane mirrors and quite unlike mirrors, nearly all normal planes are coarse on the degree of light wavelength and as a result, corresponding incident rays are usually reflected in various directions or diffusely reflected. Diffuse reflection is accountable for the capacity to of people to perceive nearly all illuminated materials from any position and so rays get to the eyes following bouncing off every surface. Figure 10 (right) show

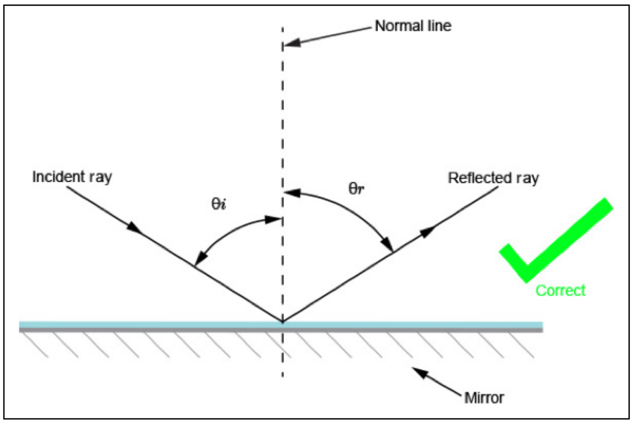


**Figure 9**. Correct diagrammatic representation of reflection of light law number three.

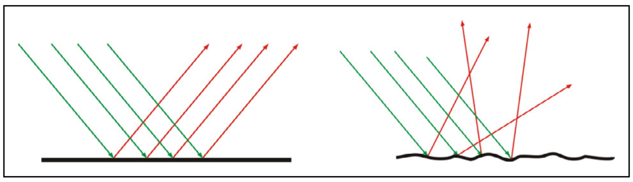

**Figure 10**. LEFT: Regular or Specular Reflection. RIGHT: Irregular of Diffused Reflection.

regular or specular reflection while (left) shows irregular or diffused reflection.

If light traveling in one transparent medium comes in contact with a second transparent medium for instance air and glass, a portion of the light is reflected while a portion is transmitted into the second medium and as the transmitted light gets into the following plane, the course of the travel or movement changes, that is known as refraction therefore the law of refraction which is also called the Snell's law explains the connection between the incident angle and the reflection angle calibrated in relation to the normal called the perpendicular line to the plane and so in mathematical connotation, the equation goes thus:

$n_1 \sin 0_1 = n_2 \sin 0_2$

Here, $n_1$ and $n_2$ are the refraction index of the first and second media respectively. The refraction index for any medium is a dimensionless constant equal to the ratio of the speed of light in a vacuum to its speed in that medium. This essay has dwelt extensively on reflection and the next part of the essay will be devoted to the nuances of refraction.

**The Nuances of Refraction**

The primary features of refraction are simply derived from Snell's law. In the opinion of O'shea (2021), the amount of deviation of light ray as it permeates a border between two media is dictated by the dissimilarity in the indices of refraction. When light passes into a denser surface, the ray is bent toward the normal. Conversely, light emerging obliquely from a thicker plain is bent out from the normal and in exceptional cases where such incident ray is at right angles to the border which is the same as the normal as could be seen in figure11 which explains the law of reflection; there will be no alteration in the course of light while it enters the second plain. Snell's law guides the imaging characteristics of lenses that is to say that light ray moving through the lens are refracted at both surfaces and different focusing results could be achieved. O'shea gave an example as light rays diverging from a light source could be repositioned by lens to meet at a point thereby resulting in a focused image. This is the case of the eye whereby the optics is centered around the focusing properties of the cornea and the lens; light rays from far objects passes through these two media and focused into a sharp image on the screen (retina), this is how the human visualizes; and so it is not unlikely for modern camera has up to six or more distinct lens essentials intended to create certain magnification and minimize loss of light via unwanted reflection and also minimize distortion of image occasioned by lens defects.

Smith (2000) reiterates that the law of refraction that is commonly referred to as Snell's law prevails over the action of light rays as they transit across a boundary linking two see-through dielectric medium. Considering a light ray incident on a plane interface between two transparent media labeled medium 1 and 2 as Figure 12 represents the law of refraction posits that the incident ray, the refracted ray and the normal all lie on the same plane, meaning:

$n_1 \sin 0_1 = n_2 \sin 0_2$ where $0_1$ is that angle extended amid the incident ray and the normal and $0_2$ being the angle extended amid the refracted ray and the normal whereas the quantities $n_1$ and $n_2$ are the refractive index of medium 1 and 2 in that order therefore the law of refraction suggests that a ray of light always deviate further to the normal in

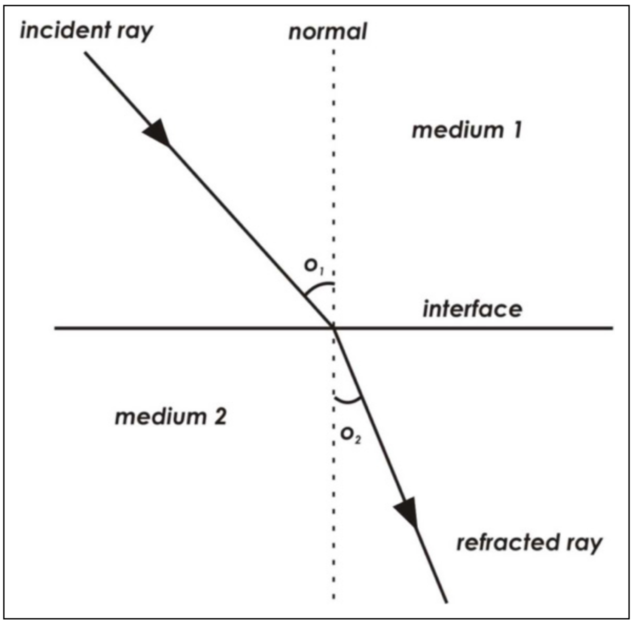


**Figure 11**. Diagram of the law of refraction.

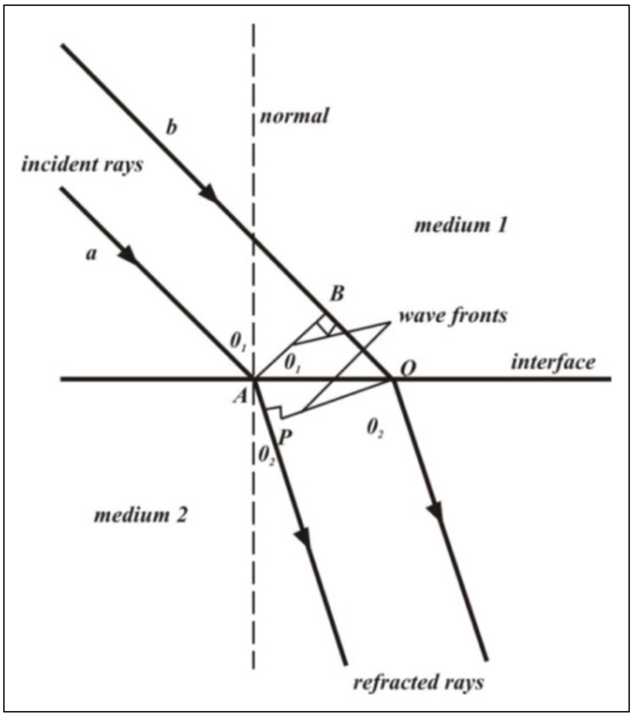


**Figure 12**. Derivation of Snell's law of refraction.

the more opaque optical medium which is the plain with the greater refractive index; so by simple explanation, the refractive index n of a dielectric plain of constant k is represented by the formula $n = \sqrt{k}$ and so the law of refraction follow absolutely from the reality that the velocity v at which light moves across a direct dielectric plain is inversely proportional to the refractive index of the plain $v = c/n$ where c is the velocity of light in space.

In consideration of two parallel light rays represented as a and b incident by an angle 01 in relation to the normal between two given media, 1 and 2, Fowles (2010) thinks that if the refractive index of the two media are $n_1$ and $n_2$ respectively, with $n_2 > n_2$; it is obvious from Figure 12 that rays must move from point B to point Q in medium 1, in the same time interval, Δt in which ray a moves between points A and P in medium 2; so the speed of light in medium 1 is $v_1=c/n_1$ whereas the speed of light in medium 2 is $v_2=c/n_2$. It then follows that the length BQ is given by v1 Δt, whereas the length AP is given by $v_2$ Δt by trigonometry. This can be rearranged to define the Snell's law. It should be noted that the lines AB and PQ represents wave fronts in media 1 and 2 and therefore cross rays a and b at right angles.

To conclude this segment of this essay, just as was discussed on the law of reflection, refraction has its law that propels its operation and these laws are two-fold unlike that of reflection which has three. The laws of refraction otherwise known as the Snell's law states thus:

Law 1:

*The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie on the same plane.*

Law 2:

*The ratio of sines of angles of incidence and refraction is a constant, for the light of a given pair of media.*

**Differences between Reflection and Refraction**

Some persons are tempted to ask if there are any differences between reflection and refraction; this confusion stem from the fact that the process is similar and the media involved is the same with the light rays as the foremost character; but in actual fact there are differences between the two concepts. While reflection is primarily the property of light that rebounds on contact with a smooth surface, when light passes through a surface, it undergoes some phenomenal changes in the appearance, whenever it usually passes through a medium, this phenomenon is referred to as refraction whereas the two different types of light that are involved are the incident ray and the reflected ray. In the process of refraction, the incident ray enters the medium and the refracted ray is the ray that goes out through the medium and so there is a particular angle at which the light enters the medium through which it needs to disperse and refract off and below is a deliberate attempt to draw a dichotomy between the two concepts. In consideration of this, Nassau (2001) has advanced these differences as enumerated below.

1. While reflection occurs in mirrors and smooth surfaces, refraction occurs in lenses.
2. Reflection can be defined as the bouncing back of light rays as it hits a surface on a plane while refraction can be defined as the process of shift of light rays when it travels through a medium thereby resulting in the bending of the rays.
3. In reflection the light entering the medium returns to the same direction whereas the light entering the medium during refraction travels from one medium to another.
4. Considering the light waves, they bounce from the plane and change direction during reflection while in refraction, the light waves passes through the surface while simultaneously changes from medium to medium.
5. There are two forms of reflection: Regular reflection (Specular) and diffused reflection while there is only one type of refraction.
6. In reflection, when the light ray strikes the boundary of a shiny surface, the speed of light does not vary whereas the speed of light during the process of refraction varies with the medium the ray undergoes bending.
7. In reflection, the medium in which light propagates remains unchanged while in refraction, the medium changes.
8. In reflection, the angle of reflection and the angle of incidence is the same whereas in refraction, the angle of refraction varies from the angle of incidence.

Having dwelt on the nitty-gritty of light, reflection and refraction, let us examine the concomitant effect and impact of the nuances of light, reflection and refraction on photography.

**The Impact of Light on Photography**

Photography, according to Osaigbovo (2019) is a branch of the visual arts which falls within the domain of graphics, and even so, it is also in the pure sciences. One of the many things that distinguish a professional photographer from a person who merely takes photographs using a camera is that the professional photographer has the ability to look beyond the actual subject and see visual qualities that will produce cutting edge images. It is the photographer's ability to recognize the existence, or otherwise of certain vital ingredients that makes the difference between a snapshot and a good photograph. The qualities that make a good photograph are shape, form, texture, pattern, perspective and colour. They can exist in a scene or a subject that is, in itself, uninteresting and unimportant, but the presence of just one of those elements is often enough to create a striking image. Conversely, an interesting, or even beautiful scene or subject can be so lacking in these qualities that a photograph of it will not be aesthetically pleasing or satisfying. Added to the qualities of a good photographer and probably the greatest of these qualities is the ability to understand the principles of light and interpret it during the photography exercise.

Our world today is replete with objects we can only see with the help of light and so if there is no light available, nothing is deemed visible to us. Sturken and Cartwright (2001) posits that in the daytime, the light rays come from the sun and helps us see objects, that is to say, as light rays fall on objects, they reflect light which when received by our eyes, the objects becomes visible. Light is a major factor during photography exercise, and the wonderful thing about using reflections when taking photos is that they can completely alter the image from something fairly straightforward to something richer or abstract or otherwise more artistic. Using the principles of reflection in photography can result in some wonderful effects and stunning images. Refraction is useful to the photographer in the sense that the bending of light by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows, even the eyes of the photographer depends on this bending of light because without refraction, it might prove difficult to focus light onto the retina in order to get the proper angle to take shots. The camera itself presents a very vivid example of refraction because the refraction of light happens as it travels through the camera lens and creates a larger or smaller image depending on the focal length settings.

There is a term in photography known as reflection photography symmetry. In this, one of the most common composition techniques to create symmetrical images is reflectional symmetry, which refers to photos where one side of the composition is the mirror image of the other side.

This type of photography can be classified as belonging to the genre of creative photography as shown in Figure 13 which shows reflection symmetry photography.

In Figure 13, it could be seen that the vegetation on the right is reflecting as a result of the body of water on the left. In cases such as this, as the refractive index is increased, the focal point moves closer to the lens and vice versa, in a manner similar to altering the lens radius, changes in the refractive index influences the size and position of the image.

**Figure 13**. Reflection symmetry photography Source: www.shutterstock.com

The rainbow Figure 14 is a classical example of refraction process. Rainbow is the product of the refraction and reflection of light. Both refraction and reflection are happenings that involve an alteration in the direction of wave. A refracted wave may appear bent while a reflected wave might seem to bounce back from a surface or other wave front.

When it comes to photography, the type of lighting that we use is the most important element in the composition of any image. Light in photography refers to how the light source, natural or artificial and how the position of light source relates to the subject. The position and quality of light can affect any number of things in the final image from clarity to tone to emotion and many more and by paying attention to how light plays off the angles and curves of subjects and which parts of the subject are illuminated and which part are in the dark, the photographer becomes a better professional because he has started to learn how to harness light source and manipulate it in the most effective way in any composition.

Figure 15 depicts contrast photography of a bird and a man. The two photographs were taken in absolute darkness

**Figure 14**. Refraction photography (Rainbow) Source: www.shutterstock.com.

**Figure 15**. Contrast photography Source: www.photographylife.com.

that requires the photographer to make use of his camera flash or a spotlight whose source seem to emanate from the top left hand side of the bird and from the right side of the man; here, it takes the understanding of a professional photographer to exploit the trick involved in this type of project.

In Figure 16 which is high contrast photography, absolute highlight was involved in capturing the image and it is only the understanding of the laws of reflection and refraction that will enable a good photographer achieve this feat.

## SUMMARY AND CONCLUSION

A good understanding of the intricacies of light will make a photographer almost perfect in his projects. Even in reflection, there are two distinct types; if parallel rays of light are incident on a plane smooth reflecting surface then after reflection they remain parallel; this type of reflection is called regular or specular reflection whereas; if parallel rays of light are incident on the rough reflecting surfaces then they do not remain parallel after reflection, they are dispersed into different directions; this type of reflection is called diffused or irregular reflection. It is instructive to state here that the laws of reflection was propounded by Euclid, the ancient Greek mathematician at about 300 BCE while the law of refraction was propounded by Willebrord Snell, a Dutch mathematician and astronomer in the year 1621. The implication of this is that reflection and its law first gained recognition before refraction.

**Figure 16**. High Contrast photography Source: www.photographylife.com.

Light is the basis of good photography and so every professional photographer must, as a matter of necessity and importance take utmost cognizance of this fact before embarking on any project. All that have been said have been on still photography but it applies also to motion photography. Ultimately, reflection and refraction are information related to light; Reflection is when light goes back to the previous medium but changes direction while refraction is when the light is absorbed by the medium but the speed and direction are affected. Generally, in exploiting the various kinds of lights to be used in creative photography, we have the natural light, front or flat light, backlight, soft light, hard light, rim light, loop light, broad light, short light, butterfly lighting, split lighting and Rembrandt lighting. These types of light are used in different occasions.

Finally, artists in the area of photography have to constantly research and update their knowledge in this very interesting and lucrative area of study and vocation.

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