Physics of Optics and Time

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Abstract*— A brief proposition on the nature of light waves and how it affects the measurement of observers. Imagine a stationary observer who is at a distance D, away from a stationary source of light that emits a light signal at a constant period t, and let's assume that both parties are provided with a clock. If the source of light emits a light signal that travels away to the observer for a period of time t, both parties will agree that there is no change in the wavelength of the light wave emitted. More also, both parties will agree that their respective clocks records same time t, for the period of the light signal. Now consider a similar instance where the source of light travels some meters during the same time t, as the period of the emitted light wave, the wavelength of the light wave recorded by a device attached to the source of the light will be different from the wavelength recorded by the stationary observer. Also, the clock attached to the moving source of light will disagree with the clock of the stationary observer over the period t, of motion of emitted light wave. The conclusion from the above instance is that: 1. There is No change in the measurement of the clocks of both parties when there is No change in the property of the light wave emitted.2. There is a change in the measurement of the clocks of both parties when there is a change in the property of the light wave emitted. It is clear that the motion of the light source creates a change in the physical property of the light wave. As I proceed in this article, I will show that the simple act of creating a change in the physical properties (wavelength) of the waves, automatically creates a difference in the measurements of observers of different frames. This change in the physical property of the light waves can make physical measurements of different frames to appear relative in nature depending on the magnitude of the disturbance produced in the waves of light.

***Index Terms*—Optics, Law of Reflection, Refraction, Superposition, Diffraction, Dispersion, Polarization**

I. INTRODUCTION

In this proposition on light waves and time, I wish to explain how the light waves surrounding a moving object affect the physical information about the motion of the object as measured by observers of different frames. According to Doppler's effect, during the motion of an object, the light waves reflected/emitted from the moving object either gets closer or further apart from each other and this results in changes, for example, the Blue or Red shift of a fast moving source of light. On the other hand, this change imposed on the physical properties of the surrounding light waves due to the motion of an object results in a phenomenon which I will summarize below. "In a given system of an observable experiment, A change in the physical properties (E.g. Wavelength, Period etc.) of the motion of the light waves emitted/reflected by an object due to motion, Results in change in the physical properties (E.g. Time, Distance etc.) of the motion of the object as measured by observers of different frames. "Simply, change in the physical properties of the motion of the surrounding light waves, Results in the Relativistic Effects we observe in our measurements. Every light source which emits light waves, has a series of light waves spreading out from its vicinity and likewise a body in an illuminated region of space, has a series of light waves spreading out from its vicinity. Light waves act as a medium by which some information about an object, either at rest or in motion, propagate from one region of space to another. Observation of most events is possible because of the ability of light waves to transmit information about an event to an observer located at a distance in space. Imagine an isolated region of space with just one light source that emits uniform light waves strong enough to illuminate all regions of that space. Let's have a stationary observer located somewhere on a plane surface in that region, and an object (car) of velocity V, located at a distance D, away from the stationary observer. Any observer located within this region of space who wishes to observe the motion of the car will depend on the light waves (either visible or non-visible electromagnetic waves) emitted/reflected by the moving object for information about the motion of the object. To the stationary observer who is at a distance of D, behind the car, let us analyze his observation and measurement of the time of motion of the car through a distance d. Let us take that the speed of light in this thought experiment is C. Light waves propagates information about an event from one region of space to another and it takes some time for light to propagate information about an event. During the measurement of the time of motion of the car by the stationary observer, the surrounding light waves also takes some little time to propagate information about the motion of the car to the stationary observer. This propagation of information by light waves matters most at the point when the car is just about to start its motion and at the point when the car immediately comes to rest.

II. MATHEMATICAL DERIVATION

Let us assume that the car has a clock attached to it which will record the time of its motion through the distance d and let us use the time, t, as the time measured by the clock attached to the car, for the motion of the car through the distance d. Let us assume that the stationary observer is also provided with a clock that will enable him to time the motion of the car through the distance d, and let the time he measures for the motion of the car through the distance d, be T. At the start of motion of the car, when the stationary observer starts his clock, the stationary observer DELAYS in starting his timing on the motion of the car by a time delay of amount equal to D/C, which is the time for light signal to travel from the car to the stationary observer and inform him of the departure of the car, which means that the stationary observer starts his timing at the time t - D/C. Also, at the end of motion of the car,

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through the distance of d, the stationary observer will require another light signal to travel from the final point of motion of the car to the point of the stationary observer to inform him about the coming to rest of the car. The time for this last light signal to get to the observer is d/C + D/C. This means that the stationary observer EXCEEDED in his measurement by the amount of time d/C + D/C. The total time resulting from the light propagation effect is D/C + d/C + D/C. Therefore the total time T, of motion of the car as recorded by the clock of the stationary observer is $T = t - D/C + d/C + D/C$. The propagation time of information by light can be removed in the above equation of time as below, $-D/C + (+D/C) = 0$.

Simplifying the equation gives:

$T=t+d/C$

$d/C= T - t$

The factor d/C is not a light propagation time but a change in the physical property (Period/time) of the surrounding light waves. The above equation simply says that: "Change in the physical property of the motion of the surrounding light waves equals (=) Change in the measurements of observers of different frames, that's the Relativistic Effects we observe in our physical measurements"

Since $d = vt$, where v is the velocity of the car. $T = t + vt/C$

Therefore; $T = t (1+v/C)$

To prove further that the factor d/C is a change in the physical property of light waves, precisely, a change in the period of the light waves, let's consider the below analysis using the Doppler's Effect.

Now, imagine a car that emits light of wavelength ƛ, when it is at rest but when it is in motion, it emits light pulse of wavelength ʎ. Let's take that the car is to travel away at a speed of v on a straight line from a stationary observer located at a distance of D behind the car and this car emits a pulse of light at a period of t when in motion. If at the beginning of the motion when the car is just about to move, it emits a pulse of light and after a time, t, it emits another pulse of light and comes to rest immediately, then it will be clear that the car travels a distance, d, during the t period of emission of the pulse of light.

Mathematically, the period t, of emission of the light pulse is the same as the time (t) of motion of the car through the distance, d. The distance, d, travelled by the car during the period of emission of the light pulse is: $d = vt$

Also, the change in the wavelength of the light waves brought about by the motion of the car is expressed as:

ƛ - ʎ = d = vt

From above equation ƛ - ʎ = d = Vt

d = ƛ - ʎ

Substituting d in equation $d/C = T – t$ gives:

$T - t = d/c$

T - t = ƛ - ʎ /C

Therefore: ƛ - ʎ /C = T - t = d/C

The above equation shows that " Change in the period of the light waves results in Change in the time of motion of the car as measured by an observer riding in the car and a stationary observer standing at the distance D"

In any given system, change in the physical information about the motion of light waves due to motion of an object, results in change in the physical measurement of the information about the motion of that object as measured by observers of different frames. That is to say; changes in the physical properties of light waves results to the Relativistic Effects we observe in our physical measurements. The above equation agrees with the conclusion that says: "There is a change in the measurement of the clocks of both parties when there is a change in the property of the light wave emitted."

III. The Corresponding Distance Equation

The corresponding distance can be derived through a more detailed form but let me use this short cut.

$T = t + d/C$

Since $t = d/v$ then $T = do /v$

Therefore: $do /v = d/v + d/C$

$do = d (1+v/C)$

T and do is the respective time and distance travelled by the car, as measured by the stationary observer. t and d is the respective time and distance travelled by the car as measured by the car or a clock attached to the car.

d/C is the change in the physical property of the light wave, which is also a change in the period of the light waves that were emitted when the car is at rest and when it is in motion.. It is very clear from the above derivation of time and distance that light travels through the same distance in all frames and time also runs the same in all frames. But what happens is that, when a disturbance is created in the waves of light due to the motion of an object, this disturbance does not just die out of existence. It goes on to affect the observation and measurements of all observers who depend on the light waves for their observation and measurement. This change in the physical property of the light waves can make physical measurements of different frames to appear relative depending on the magnitude of the disturbance produced in the waves of light. The laws of physics are very absolute in the sense that in reality, light travels the same distance relative to every frame but the laws of physics could be relative in the sense that in measurement, observers of different frames might measure different values for the distance travelled by the light waves as a result of the behavior of light waves which I explained above. Also, the measurements of some frames are better/more valid than the measurement of other frames, depending on the resultant change in the physical property of the light waves from both the system of the observer and the event being observed. It seems from the derived mathematical equations that the measurements recorded by a person attached to the frame of the event are always more accurate, and this must be because of the fact that the person attached to the frame of event does not depend on the surrounding light waves for its measurement. It does follow that (The motion of the Car results in changes in the physical properties of the waves (Doppler's Effect); The changes in the physical properties of the light waves results in changes/Relativistic Effects in the measurements of observers of different frames). In the earlier versions of this proposition, this, I was referring to as "Nwobu's Effect" (T - t = ƛ - ʎ /C = d/C).

IV. Classical Optics

Classical optics is divided into two main branches: geometrical optics and physical optics. In geometrical, or ray optics, light is considered to travel in straight lines, and in physical, or wave optics, light is considered to be an electromagnetic wave.

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Geometrical optics can be viewed as an approximation of physical optics which can be applied when the wavelength of the light used is much smaller than the size of the optical elements or system being modelled.

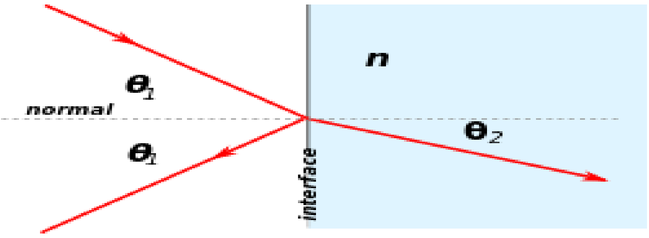

Fig:1 Geometry of reflection and refraction of light rays

A. Geometrical Optics

Geometrical optics: or ray optics, describes the propagation of light in terms of "rays" which travel in straight lines, and whose paths are governed by the laws of reflection and refraction at interfaces between different media. These laws were discovered empirically as far back as 984 AD and have been used in the design of optical components and instruments from then until the present day. They can be summarized as follows: When a ray of light hits the boundary between two transparent materials, it is divided into a reflected and a refracted ray. The law of reflection says that the reflected ray lies in the plane of incidence, and the angle of reflection equals the angle of incidence. The law of refraction says that the refracted ray lies in the plane of incidence, and the sine of the angle of refraction divided by the sine of the angle of incidence is a constant.

$$\frac{\sin\theta_1}{\sin\theta_2} = n$$

V. Reflection

Reflection is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated.

Reflections can be divided into two types: specular reflection and diffuse reflection. Specular reflection describes the gloss of surfaces such as mirrors, which reflect light in a simple, predictable way. This allows for production of reflected images that can be associated with an actual (real) or extrapolated (virtual) location in space. Diffuse reflection describes opaque, non-limpid materials, such as paper or rock. The reflections from these surfaces can only be described statistically, with the exact distribution of the reflected light depending on the microscopic structure of the material. Many diffuse reflectors are described or can be approximated by Lambert's cosine law, which describes surfaces that have equal luminance when viewed from any angle. Glossy surfaces can give both specular and diffuse reflection.

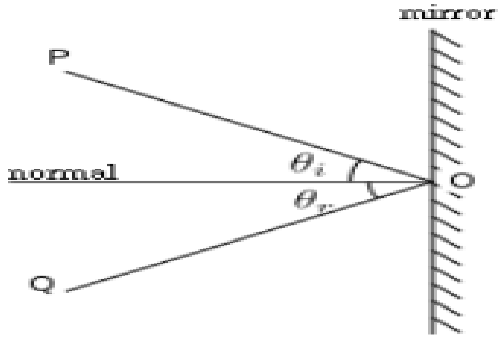

Fig:2 Diagram of Specular Reflection

In specular reflection, the direction of the reflected ray is determined by the angle the incident ray makes with the surface normal, a line perpendicular to the surface at the point where the ray hits. The incident and reflected rays and the normal lie in a single plane, and the angle between the reflected ray and the surface normal is the same as that between the incident ray and the normal. This is known as the Law of Reflection.

For flat mirrors, the law of reflection implies that images of objects are upright and the same distance behind the mirror as the objects are in front of the mirror. The image size is the same as the object size. The law also implies that mirror images are parity inverted, which we perceive as a left-right inversion. Images formed from reflection in two (or any even number of) mirrors are not parity inverted. Corner reflectors retro reflect light, producing reflected rays that travel back in the direction from which the incident rays came.

Mirrors with curved surfaces can be modelled by ray-tracing and using the law of reflection at each point on the surface. For mirrors with parabolic surfaces, parallel rays incident on the mirror produce reflected rays that converge at a common focus. Other curved surfaces may also focus light, but with aberrations due to the diverging shape causing the focus to be smeared out in space. In particular, spherical mirrors exhibit spherical aberration. Curved mirrors can form images with magnification greater than or less than one, and the magnification can be negative, indicating that the image is inverted. An upright image formed by reflection in a mirror is always virtual, while an inverted image is real and can be projected onto a screen.

VI. Refraction

Refraction occurs when light travels through an area of space that has a changing index of refraction; this principle allows for lenses and the focusing of light. The simplest case of refraction occurs when there is an interface between a uniform medium with index of refraction and another medium with index of refraction. In such situations, Snell's Law describes the resulting deflection of the light ray:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where θ_1 and θ_2 are the angles between the normal (to the interface) and the incident and refracted waves, respectively. This phenomenon is also associated with a changing speed of light as seen from the definition of index of refraction

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provided above which implies:

$$v_1 \sin\theta_2 = v_2 \sin\theta_1$$

where v_1 and v_2 are the wave velocities through the respective media.

Snell's law (also known as the Snell–Descartes law and the law of refraction) is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media, such as water, glass, or air.

In optics, the law is used in ray tracing to compute the angles of incidence or refraction, and in experimental optics to find the refractive index of a material.

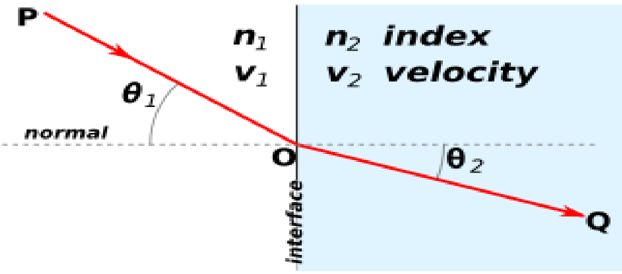

Fig:3 Illustration of Snell's Law

Various consequences of Snell's Law include the fact that for light rays travelling from a material with a high index of refraction to a material with a low index of refraction, it is possible for the interaction with the interface to result in zero transmission. This phenomenon is called total internal reflection and allows for fibre optics technology. As light signals travel down a fibre optic cable, it undergoes total internal reflection allowing for essentially no light lost over the length of the cable. It is also possible to produce polarised light rays using a combination of reflection and refraction: When a refracted ray and the reflected ray form a right angle, the reflected ray has the property of "plane polarization". The angle of incidence required for such a scenario is known as Brewster's angle.

Snell's Law can be used to predict the deflection of light rays as they pass through "linear media" as long as the indexes of refraction and the geometry of the media are known. For example, the propagation of light through a prism results in the light ray being deflected depending on the shape and orientation of the prism. Additionally, since different frequencies of light have slightly different indexes of refraction in most materials, refraction can be used to produce dispersion spectra that appear as rainbows. The discovery of this phenomenon when passing light through a prism is famously attributed to Isaac Newton.

Some media have an index of refraction which varies gradually with position and, thus, light rays curve through the medium rather than travel in straight lines. This effect is what is responsible for mirages seen on hot days where the changing index of refraction of the air causes the light rays to bend creating the appearance of specular reflections in the distance (as if on the surface of a pool of water). Material that has a varying index of refraction is called a gradient-index (GRIN) material and has many useful properties used in modern optical scanning technologies including photocopiers and scanners. The phenomenon is studied in the field of gradient-index optics.

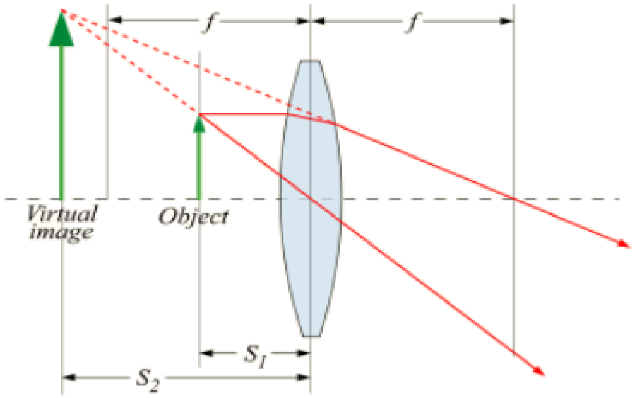

Fig:4 A ray tracing diagram for a converging lens.

A device which produces converging or diverging light rays due to refraction is known as a lens. Thin lenses produce focal points on either side that can be modelled using the lensmaker's equation. In general, two types of lenses exist: convex lenses, which cause parallel light rays to converge, and concave lenses, which cause parallel light rays to diverge. The detailed prediction of how images are produced by these lenses can be made using ray-tracing similar to curved mirrors. Similarly to curved mirrors, thin lenses follow a simple equation that determines the location of the images given a particular focal length (f) and object distance (S_1):

$$\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}$$

where S_2 is the distance associated with the image and is considered by convention to be negative if on the same side of the lens as the object and positive if on the opposite side of the lens. The focal length f is considered negative for concave lenses. Incoming parallel rays are focused by a convex lens into an inverted real image one focal length from the lens, on the far side of the lens. Rays from an object at finite distance are focused further from the lens than the focal distance; the closer the object is to the lens, the further the image is from the lens. With concave lenses, incoming parallel rays diverge after going through the lens, in such a way that they seem to have originated at an upright virtual image one focal length from the lens, on the same side of the lens that the parallel rays are approaching on. Rays from an object at finite distance are associated with a virtual image that is closer to the lens than the focal length, and on the same side of the lens as the object. The closer the object is to the lens, the closer the virtual image is to the lens.

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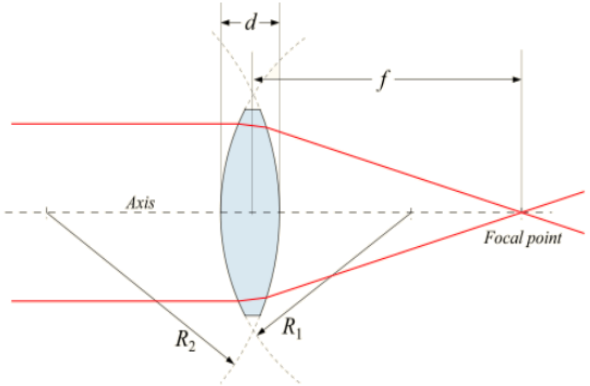


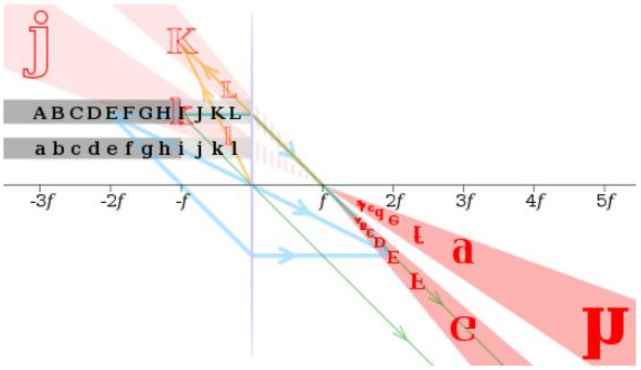
Fig: 5 Positive Converging Lens

Likewise, the magnification of a lens is given by

$$M = -\frac{S_2}{S_1} = \frac{f}{f - S_1}$$

where the negative sign is given, by convention, to indicate an upright object for positive values and an inverted object for negative values. Similar to mirrors, upright images produced by single lenses are virtual while inverted images are real.

Lenses suffer from aberrations that distort images and focal points. These are due to both to geometrical imperfections and due to the changing index of refraction for different wavelengths of light (chromatic aberration).



Images of black letters in a thin convex lens of focal length f are shown in red. Selected rays are shown for letters E, I and K in blue, green and orange, respectively. Note that E (at 2f) has an equal-size, real and inverted image; I (at f) has its image at infinity; and K (at f/2) has a double-size, virtual and upright image

VII. Physical Optics

In physical optics, light is considered to propagate as a wave. This model predicts phenomena such as interference and diffraction, which are not explained by geometric optics. The speed of light waves in air is approximately 3.0×108 m/s (exactly 299,792,458 m/s in vacuum). The wavelength of visible light waves varies between 400 and 700 nm, but the term "light" is also often applied to infrared (0.7–300 μm) and ultraviolet radiation (10–400 nm).

The wave model can be used to make predictions about how an optical system will behave without requiring an explanation of what is "waving" in what medium. Until the middle of the 19th century, most physicists believed in an "ethereal" medium in which the light disturbance propagated. The existence of electromagnetic waves was predicted in 1865 by Maxwell's equations. These waves propagate at the speed of light and have varying electric and magnetic fields which are orthogonal to one another, and also to the direction of propagation of the waves. Light waves are now generally treated as electromagnetic waves except when quantum mechanical effects have to be considered.

VIII. Modelling and Design of Optical Systems Using Physical Optics

Many simplified approximations are available for analysing and designing optical systems. Most of these use a single scalarquantity to represent the electric field of the light wave, rather than using a vector model with orthogonal electric and magnetic vectors. The Huygens–Fresnel equation is one such model. This was derived empirically by Fresnel in 1815, based on Huygen's hypothesis that each point on a wavefront generates a secondary spherical wavefront, which Fresnel combined with the principle of superposition of waves. The Kirchhoff diffraction equation, which is derived using Maxwell's equations, puts the Huygens-Fresnel equation on a firmer physical foundation. Examples of the application of Huygens–Fresnel principle can be found in the sections on diffraction and Fraunhofer diffraction.

More rigorous models, involving the modelling of both electric and magnetic fields of the light wave, are required when dealing with the detailed interaction of light with materials where the interaction depends on their electric and magnetic properties. For instance, the behaviour of a light wave interacting with a metal surface is quite different from what happens when it interacts with a dielectric material. A vector model must also be used to model polarised light.

Numerical modeling techniques such as the finite element method, the boundary element method and the transmission-line matrix method can be used to model the propagation of light in systems which cannot be solved analytically. Such models are computationally demanding and are normally only used to solve small-scale problems that require accuracy beyond that which can be achieved with analytical solutions.

All of the results from geometrical optics can be recovered using the techniques of Fourier optics which apply many of the same mathematical and analytical techniques used in acoustic engineering and signal processing.

Gaussian beam propagation is a simple paraxial physical optics model for the propagation of coherent radiation such as laser beams. This technique partially accounts for diffraction, allowing accurate calculations of the rate at which a laser beam expands with distance, and the minimum size to which the beam can be focused. Gaussian beam propagation thus bridges the gap between geometric and physical optics.

IX. Superposition and Interference

In the absence of nonlinear effects, the superposition principle can be used to predict the shape of interacting waveforms through the simple addition of the disturbances. This interaction of waves to produce a resulting pattern is generally termed "interference" and can result in a variety of

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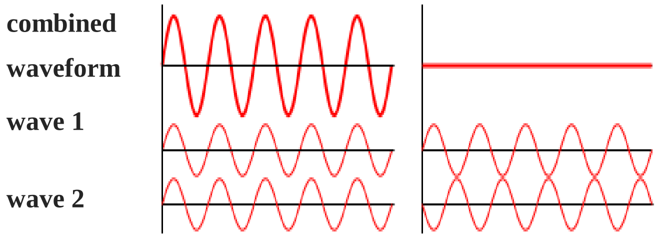
outcomes. If two waves of the same wavelength and frequency are in phase, both the wave crests and wave troughs align. This results in constructive interference and an increase in the amplitude of the wave, which for light is associated with a brightening of the waveform in that location. Alternatively, if the two waves of the same wavelength and frequency are out of phase, then the wave crests will align with wave troughs and vice versa. This results in destructive interference and a decrease in the amplitude of the wave, which for light is associated with a dimming of the waveform at that location. See below for an illustration of this effect.



Two waves in phase **Two waves 180° out of phase**

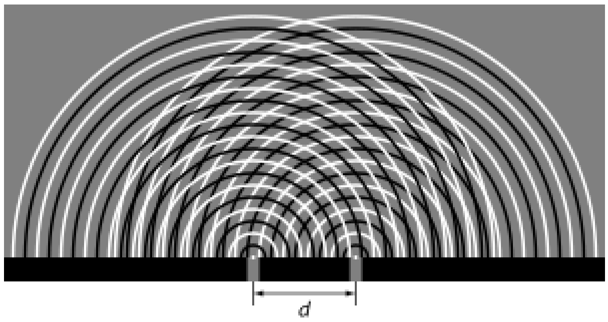
Fig:6 When oil or fuel is spilled, colourful patterns are formed by thin-film interference

Since the Huygens–Fresnel principle states that every point of a wavefront is associated with the production of a new disturbance, it is possible for a wavefront to interfere with itself constructively or destructively at different locations producing bright and dark fringes in regular and predictable patterns. Interferometry is the science of measuring these patterns, usually as a means of making precise determinations of distances or angular resolutions. The Michelson interferometer was a famous instrument which used interference effects to accurately measure the speed of light.

The appearance of thin films and coatings is directly affected by interference effects. Antireflective coatings use destructive interference to reduce the reflectivity of the surfaces they coat, and can be used to minimise glare and unwanted reflections. The simplest case is a single layer with thickness one-fourth the wavelength of incident light. The reflected wave from the top of the film and the reflected wave from the film/material interface are then exactly 180° out of phase, causing destructive interference. The waves are only exactly out of phase for one wavelength, which would typically be chosen to be near the centre of the visible spectrum, around 550 nm. More complex designs using multiple layers can achieve low reflectivity over a broad band, or extremely low reflectivity at a single wavelength.

Constructive interference in thin films can create strong reflection of light in a range of wavelengths, which can be narrow or broad depending on the design of the coating. These films are used to make dielectric mirrors, interference filters, heat reflectors, and filters for colour separation in colour television cameras. This interference effect is also what causes the colourful rainbow patterns seen in oil slicks.

X. Diffraction and Optical Resolution



Diffraction on two slits separated by distance d. The bright fringes occur along lines where black lines intersect with black lines and white lines intersect with white lines. These fringes are separated by angle θ and are numbered as order n.

Diffraction is the process by which light interference is most commonly observed. The effect was first described in 1665 by Francesco Maria Grimaldi, who also coined the term from the Latin diffringere, 'to break into pieces'. Later that century, Robert Hooke and Isaac Newton also described phenomena now known to be diffraction in Newton's rings while James Gregory recorded his observations of diffraction patterns from bird feathers.

The first physical optics model of diffraction that relied on the Huygens–Fresnel principle was developed in 1803 by Thomas Young in his interference experiments with the interference patterns of two closely spaced slits. Young showed that his results could only be explained if the two slits acted as two unique sources of waves rather than corpuscles. In 1815 and 1818, Augustin-Jean Fresnel firmly established the mathematics of how wave interference can account for diffraction.

The simplest physical models of diffraction use equations that describe the angular separation of light and dark fringes due to light of a particular wavelength (λ). In general, the equation takes the form

$$m\lambda = d\sin\theta$$

where d is the separation between two wavefront sources (in the case of Young's experiments, it was two slits), θ is the angular separation between the central fringe and the mth order fringe, where the central maximum is $m = 0$.

This equation is modified slightly to take into account a

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variety of situations such as diffraction through a single gap, diffraction through multiple slits, or diffraction through a diffraction grating that contains a large number of slits at equal spacing. More complicated models of diffraction require working with the mathematics of Fresnel or Fraunhofer diffraction. X-ray diffraction makes use of the fact that atoms in a crystal have regular spacing at distances that are on the order of oneangstrom. To see diffraction patterns, x-rays with similar wavelengths to that spacing are passed through the crystal. Since crystals are three-dimensional objects rather than two-dimensional gratings, the associated diffraction pattern varies in two directions according to Bragg reflection, with the associated bright spots occurring in unique patterns and being twice the spacing between atoms. Diffraction effects limit the ability for an optical detector to optically resolve separate light sources. In general, light that is passing through an aperture will experience diffraction and the best images that can be created (as described in diffraction-limited optics) appear as a central spot with surrounding bright rings, separated by dark nulls; this pattern is known as an Airy pattern, and the central bright lobe as an Airy disk. The size of such a disk is given by

$$\sin\theta = 1.22\frac{\lambda}{D}$$

where θ is the angular resolution, λ is the wavelength of the light, and D is the diameter of the lens aperture. If the angular separation of the two points is significantly less than the Airy disk angular radius, then the two points cannot be resolved in the image, but if their angular separation is much greater than this, distinct images of the two points are formed and they can therefore be resolved. Rayleigh defined the somewhat arbitrary "Rayleigh criterion" that two points whose angular separation is equal to the Airy disk radius (measured to first null, that is, to the first place where no light is seen) can be considered to be resolved. It can be seen that the greater the diameter of the lens or its aperture, the finer the resolution. Interferometry, with its ability to mimic extremely large baseline apertures, allows for the greatest angular resolution possible. For astronomical imaging, the atmosphere prevents optimal resolution from being achieved in the visible spectrum due to the atmospheric scattering and dispersion which cause stars to twinkle. Astronomers refer to this effect as the quality of astronomical seeing. Techniques known as adaptive optics have been used to eliminate the atmospheric disruption of images and achieve results that approach the diffraction limit.

XI. DISPERSION AND SCATTERING

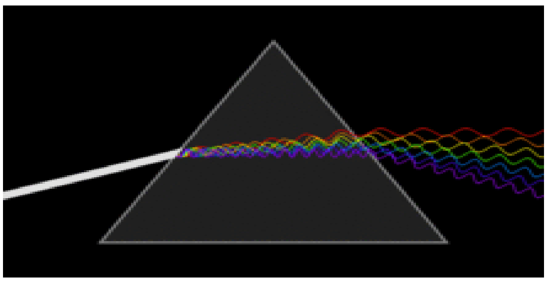
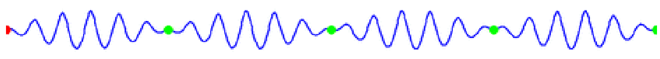


Fig:7 Conceptual animation of light dispersion through a prism. High frequency (blue) light is deflected the most, and low frequency (red) the least.

Refractive processes take place in the physical optics limit, where the wavelength of light is similar to other distances, as a kind of scattering. The simplest type of scattering is Thomson scattering which occurs when electromagnetic waves are deflected by single particles. In the limit of Thompson scattering, in which the wavelike nature of light is evident, light is dispersed independent of the frequency, in contrast to Compton scattering which is frequency-dependent and strictly aquantum mechanical process, involving the nature of light as particles. In a statistical sense, elastic scattering of light by numerous particles much smaller than the wavelength of the light is a process known as Rayleigh scattering while the similar process for scattering by particles that are similar or larger in wavelength is known as Mie scattering with the Tyndall effect being a commonly observed result. A small proportion of light scattering from atoms or molecules may undergo Raman scattering, wherein the frequency changes due to excitation of the atoms and molecules. Brillouin scattering occurs when the frequency of light changes due to local changes with time and movements of a dense material.

Dispersion occurs when different frequencies of light have different phase velocities, due either to material properties (material dispersion) or to the geometry of an optical waveguide (waveguide dispersion). The most familiar form of dispersion is a decrease in index of refraction with increasing wavelength, which is seen in most transparent materials. This is called "normal dispersion". It occurs in all dielectric materials, in wavelength ranges where the material does not absorb light. In wavelength ranges where a medium has significant absorption, the index of refraction can increase with wavelength. This is called "anomalous dispersion".

The separation of colours by a prism is an example of normal dispersion. At the surfaces of the prism, Snell's law predicts that light incident at an angle θ to the normal will be refracted at an angle arcsin(sin (θ) / n). Thus, blue light, with its higher refractive index, is bent more strongly than red light, resulting in the well-known rainbow pattern.



Dispersion: two sinusoids propagating at different speeds make a moving interference pattern. The red dot moves with the phase velocity, and the green dots propagate with the group velocity. In this case, the phase velocity is twice the group velocity. The red dot overtakes two green dots, when moving from the left to the right of the figure. In effect, the individual waves (which travel with the phase velocity) escape from the wave packet (which travels with the group velocity). Material dispersion is often characterised by the Abbe number, which gives a simple measure of dispersion based on the index of refraction at three specific wavelengths. Waveguide dispersion is dependent on the propagation constant. Both kinds of dispersion cause changes in the group characteristics of the wave, the features of the wave packet that change with the same frequency as the amplitude of the electromagnetic wave. "Group velocity dispersion" manifests as a spreading-out of the signal "envelope" of the radiation and can be quantified with a group dispersion delay parameter:

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$$D = \frac{1}{v_g^2}\frac{dv_g}{d\lambda}$$

where v_g is the group velocity. For a uniform medium, the group velocity is

$$v_g = c\left(n - \lambda\frac{dn}{d\lambda}\right)^{-1}$$

where n is the index of refraction and c is the speed of light in a vacuum. This gives a simpler form for the dispersion delay parameter:

$$D = -\frac{\lambda}{c}\,\frac{d^2 n}{d\lambda^2}.$$

If D is less than zero, the medium is said to have positive dispersion or normal dispersion. If D is greater than zero, the medium has negative dispersion. If a light pulse is propagated through a normally dispersive medium, the result is the higher frequency components slow down more than the lower frequency components. The pulse therefore becomes positively chirped, or up-chirped, increasing in frequency with time. This causes the spectrum coming out of a prism to appear with red light the least refracted and blue/violet light the most refracted. Conversely, if a pulse travels through an anomalously (negatively) dispersive medium, high frequency components travel faster than the lower ones, and the pulse becomes negatively chirped, or down-chirped, decreasing in frequency with time.

The result of group velocity dispersion, whether negative or positive, is ultimately temporal spreading of the pulse. This makes dispersion management extremely important in optical communications systems based on optical fibres, since if dispersion is too high, a group of pulses representing information will each spread in time and merge, making it impossible to extract the signal.

XII. POLARIZATION

Polarization is a general property of waves that describes the orientation of their oscillations. For transverse waves such as many electromagnetic waves, it describes the orientation of the oscillations in the plane perpendicular to the wave's direction of travel. The oscillations may be oriented in a single direction (linear polarization), or the oscillation direction may rotate as the wave travels (circular or elliptical polarization). Circularly polarised waves can rotate rightward or leftward in the direction of travel, and which of those two rotations is present in a wave is called the wave's chirality.

The typical way to consider polarization is to keep track of the orientation of the electric field vector as the electromagnetic wave propagates. The electric field vector of a plane wave may be arbitrarily divided into two perpendicular components labeled x and y (with z indicating the direction of travel). The shape traced out in the x-y plane by the electric field vector is a Lissajous figure that describes the polarization state. The following figures show some examples of the evolution of the electric field vector (blue), with time (the vertical axes), at a particular point in space, along with its x and y components (red/left and green/right), and the path traced by the vector in the plane (purple): The same evolution would occur when looking at the electric field at a particular time while evolving the point in space, along the direction opposite to propagation.

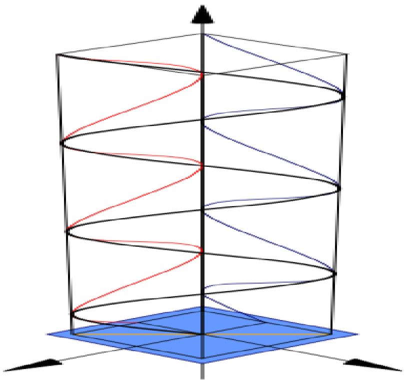

Fig:8 Linear Polarization Diagram

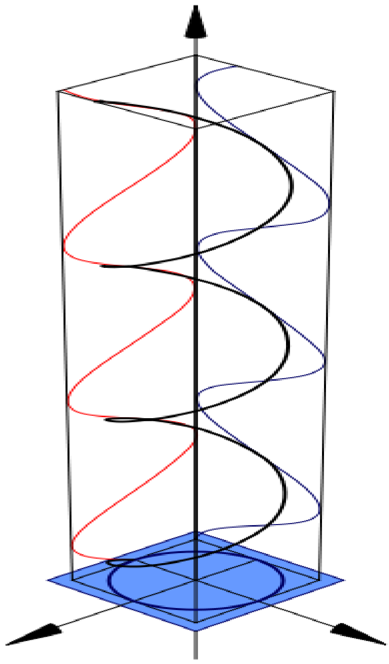

Fig:9 Circular Polarization Diagram

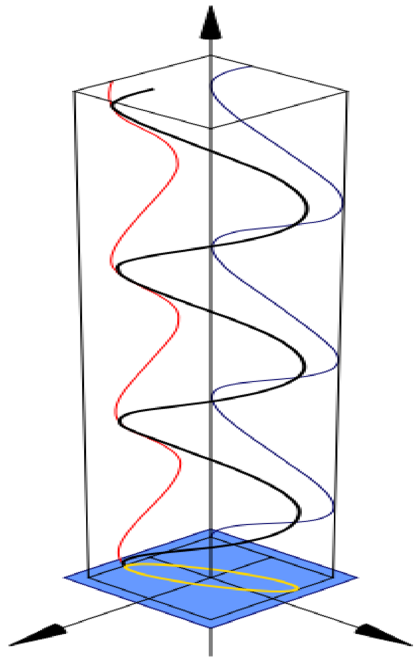

Fig: 10Elliptical Polarization Diagram

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XIII. ELLIPTICAL POLARIZATION

In the leftmost figure above, the x and y components of the light wave are in phase. In this case, the ratio of their strengths is constant, so the direction of the electric vector (the vector sum of these two components) is constant. Since the tip of the vector traces out a single line in the plane, this special case is called linear polarization. The direction of this line depends on the relative amplitudes of the two components.

In the figure, the two orthogonal components have the same amplitudes and are 90° out of phase. In this case, one component is zero when the other component is at maximum or minimum amplitude. There are two possible phase relationships that satisfy this requirement: the x component can be 90° ahead of the y component or it can be 90° behind the y component. In this special case, the electric vector traces out a circle in the plane, so this polarization is called circular polarization. The rotation direction in the circle depends on which of the two phase relationships exists and corresponds to right-hand circular polarization and left-hand circular polarization.

In all other cases, where the two components either do not have the same amplitudes and/or their phase difference is neither zero nor a multiple of 90°, the polarization is called elliptical polarization because the electric vector traces out an ellipse in the plane (the polarization ellipse). This is shown in the above figure on the right. Detailed mathematics of polarization is done using Jones calculus and is characterised by the Stokes parameters.

XIV. CHANGING POLARIZATION

Media that have different indexes of refraction for different polarization modes are called birefringent. Well known manifestations of this effect appear in optical wave plates/retarders (linear modes) and in Faraday rotation/optical rotation(circular modes). If the path length in the birefringent medium is sufficient, plane waves will exit the material with a significantly different propagation direction, due to refraction. For example, this is the case with macroscopic crystals ofcalcite, which present the viewer with two offset, orthogonally polarised images of whatever is viewed through them. It was this effect that provided the first discovery of polarization, by Erasmus Bartholinus in 1669. In addition, the phase shift, and thus the change in polarization state, is usually frequency dependent, which, in combination with dichroism, often gives rise to bright colours and rainbow-like effects. In mineralogy, such properties, known as pleochroism, are frequently exploited for the purpose of identifying minerals using polarization microscopes. Additionally, many plastics that are not normally birefringent will become so when subject to mechanical stress, a phenomenon which is the basis of photoelasticity. Non-birefringent methods, to rotate the linear polarization of light beams, include the use of prismatic polarization rotators which use total internal reflection in a prism set designed for efficient collinear transmission.

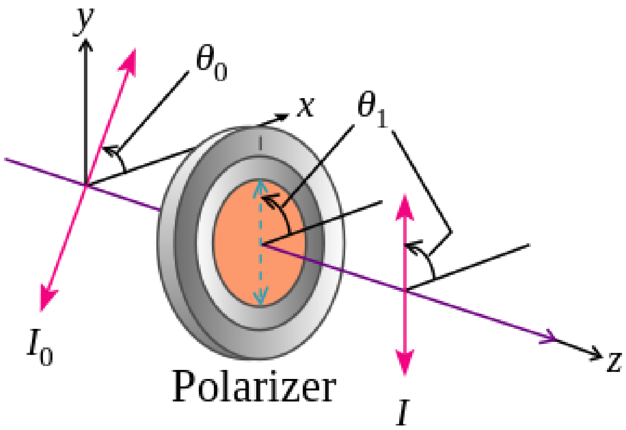

Fig:11 A polarizer changing the orientation of linearly polarised light. In this picture, θ1 – θ0 = θi.

Media that reduce the amplitude of certain polarization modes are called dichroic with devices that block nearly all of the radiation in one mode known as polarizing filters or simply "polarisers". Malus' law, which is named after Étienne-Louis Malus, says that when a perfect polariser is placed in a linear polarised beam of light, the intensity, I, of the light that passes through is given by

$$I = I_0 \cos^2 \theta_i \quad ,$$

where

I0 is the initial intensity,

and θi is the angle between the light's initial polarization direction and the axis of the polariser.

A beam of unpolarised light can be thought of as containing a uniform mixture of linear polarizations at all possible angles. Since the average value of $\cos^2 \theta$ is 1/2, the transmission coefficient becomes

$$\frac{I}{I_0} = \frac{1}{2}$$

XV. CONCLUSION

Below can be concluded from the above:

1. The velocity of any matter travelling through space is independent of any frame observing and measuring its motion.
2. Some matters can travel faster than the speed of light.
3. Some frames are better than others in the measurement of physical quantities.
4. Time runs the same in all frames even though our measuring devices may record otherwise.
5. Relative and absoluteness co-exist.
6. Between two or more inertial reference frames, an event which is present tense to one frame may not be present tense to other frames but may be past or future tense to other frames
7. Optical observation of our past time/world and its mathematical estimation is perfectly possible.
8. The future is not optically visible but is mathematically solvable.

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[7] Only primary and secondary rays are represented in the figure.
[8] Or, if the object is thin, it can exit from the opposite surface, giving diffuse transmitted light.
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