# DEPARTMENT OF PHYSICS

# GDC KULGAM

**Subject/Course:** **Physics**

**Topic:** **Wave Optics**

**Lesson Title:** **Electromagnetic nature of light**

**Semester:** **4th Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Dr. Hilal Ahmad Reshi**

**Lesson Description:**

Ever since the man could see, he has wanted to know as to what light is? Until the middle of the seventeenth century, light was generally believed to consist of a stream of some sort of particles or corpuscles emanating from light sources. Newton and many other scientists supported the corpuscular theory of light. Then the idea was proposed by Huygens and others that light might be following the wave phenomenon. Initially no one believed in the wave theory of Huygens, it got established only in 1801 when Thomas Young performed the very famous two-hole interference experiment. Because of this experiment scientists started believing in the wave theory of light, however they wondered about the nature of these waves and as to how it could propagate through vacuum. Around 1836, Faraday showed that a varying magnetic field induces an electromotive force and thus established the intimate connection between electricity and magnetism. Further, Faraday showed that the polarization of light was affected by a strong magnetic field, which was the first hint as to the electromagnetic nature of light. Then came Maxwell's equations which described the laws of electricity and magnetism. Maxwell unified the empirical laws of electricity and magnetism into a coherent theory of electromagnetism. Maxwell showed that wave like equations are solutions of these equations. He showed that the speed of electromagnetic wave equals the speed of light. This resulted in the prediction of electromagnetic waves. From this theory, Maxwell calculated the velocity of electromagnetic waves and found that this value was very close to the experimentally determined value of the speed of light. This led him to say that light was an electromagnetic wave. Thus Maxwell's theoretical prediction was later confirmed by Heinrich Hertz in 1887 using an oscillating circuit of small dimensions, succeeded in producing short-wavelength electromagnetic waves and showed that they possessed all the properties of light waves. They could be reflected, focused by a lens, polarized, and so on, just as could waves of light. Maxwell's electromagnetic theory of light and its experimental justification by Hertz constituted one of the triumphs of physical science. The waves were initially supposed to be supported by ether medium. Though electromagnetic theory fails to explain the processes of emission and absorption, however, the theory is capable of explaining the phenomena connected with the propagation of light.

**References:**


1. Optics by Ajoy Ghatak, 6th Edition
2. University Physics by F. W. Sears, M. W. Zemansky and H. D. Young, 6th Edition
3. Fundamentals of Optics by F. A. Jenkins and H. E. White, 4th Edition

**Subject/Course:** **Physics**

**Topic:** **Wave Optics**

**Lesson Title:** **Polarization of Wave**

**Semester:** **4th Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Dr. Hilal Ahmad Reshi**

**Lesson Description:**

One of the quantities need to describe the wave is its polarization. That is we must specify the direction in which the string is displaced, or in which the electric vector points. Therefore, the polarization is a property of certain electromagnetic radiations in which the direction and magnitude of the vibrating electric field are related in a specified way. Light waves are transverse i,e the vibrating electric vector associated with each wave is perpendicular to the direction of propagation. A beam of unpolarized light consists of waves moving in the same direction with their electric vectors pointed in random orientations about the axis of propagation. Light may be polarized by reflection or by passing it through filters, such as certain crystals, that transmit vibration in one plane but not in others. Interference and diffraction effects occur with all kinds of waves, including sound waves and surface waves on a liquid as well as electromagnetic waves. However they do not give any indication regarding the character of the waves. These effects are in general independent of whether the waves are longitudinal or transverse or whether the vibrations are linear or circular cannot be deduced from the above two phenomena as all kinds of waves under suitable conditions exhibit interference and diffraction.

The history of light polarization began with the Danish physicist, physician and mathematician, Erasmus Bartholinus who in 1669 discovered the phenomenon of double refraction of calc-spar (a variety of calcite), although he was not yet aware of the phenomenon of polarization. Christian Huygens a Dutch physicist and astronomer interpreted the double refraction by assuming that in the crystal there is in addition to a primary spherical wave, secondary ellipsoidal wave. It was in the course of this investigation that Huygens made the fundamental discovery of polarization in 1690. Isaac Newton an English physicist, astronomer and mathematician explained these phenomena by assuming that rays have ″sides″. Due to this transversality, rejected Newton the wave theory of light-proposed by Robert Hook an English physicist and chemist, and improved and extended later by Huygens, since at that time scientists were familiar only with longitudinal waves from the propagation of sound. Together with Arago, Augustin Jean Fresnel, a French physicist and engineer investigated the interference of polarized rays of light and found in 1816 that two rays polarized at right angles to each other never interfere. This fact could not be reconciled with the assumption of longitudinal waves of light, which had hitherto been taken for granted. Thomas Young an English physicist and physician, who had heard of this discovery from Aargo, found in 1817 the key to the solution when he assumed that the vibrations were transverse. He explained the absence of interference between light waves polarized in mutually perpendicular planes. Thus, the existence of polarization property is a direct consequence of light being a transverse wave. Light coming from common light sources is unpolarized. It can be transformed into different types of polarization using optical devices. The state of polarization cannot be perceived by an unaided human eye. An understanding of polarization is essential for understanding the propagation of electromagnetic waves guided through wave-guides and optical fibers. There are wide varieties of applications of polarization in engineering and industrial sector as well.

**Types of Polarization**:

The polarization of a light wave describes the shape and location of the tip of the electric field vector at a given point in space as a function of time. Depending upon the locus of the tip of electric vector component, light may exhibit three different state of polarization as;

1. Plane or linear polarization
2. Elliptical polarization and
3. Circular polarization

**Linear polarization**

Linear polarization or plane polarization of electromagnetic radiation is a confinement of the electric field vector or magnetic field vector to a given plane along the direction of propagation. From a technical perspective, linear polarization is defined as polarization of an electromagnetic wave in which the electric vector at a fixed point in space remains pointing in a fixed direction, although varying in magnitude. The orientation of a linearly polarized electromagnetic wave is defined by the direction of the electric field vector. If the electric field vector is alternately up and down as the wave travels, the radiation is said to be vertically polarized. However, if it is pointing either left or right, we call t horizontal polarization. The direction of electric field vector does not vary with time but its magnitude varies sinusoidally with time. Electric fields are not restricted to pointing exactly along vertical or horizontal axes but can be at any arbitrary angle to those axes. The light polarized at any arbitrary angle, may be regarded as a combination of horizontally and vertically polarized light, with appropriate amplitude, and which are oscillating in phase or 180 ° out of phase. However both the components should be coherent.

**Elliptical Polarization:**

This is the type of polarization of electromagnetic radiation such that the tip of the electric field vector describes an ellipse in any fixed plane intersecting, and normal to the direction of propagation. An elliptically polarized wave may be resolved into two linearly polarized waves in phase quadrature, with their polarization planes at right angles to each other. Since the electric field can rotate clockwise or counterclockwise as it propagates, elliptically polarized waves exhibit chirality. An elliptically polarized wave may be regarded as the resultant wave produced due to the superposition of two coherent waves of different amplitudes, oscillating mutually perpendicular planes and are out of phase. If waves of different amplitude are related in phase by 90°, then the resultant light is elliptically polarized. Elliptically polarized wave is the combination of horizontally polarized and vertically polarized waves that are of different amplitudes and out of phase by 90°.

**Circular Polarization:**

Technically speaking, circular polarization involves the plane of polarization rotating in a corkscrew pattern, making one complete revolution during each wavelength. In case of a circularly polarized wave, the tip of the electric field vector, at any given point in space, describes a circle as time progresses. At any instant of time, the electric field vector of the wave describes a helix along the direction of propagation. A circularly polarized wave can be in one of the two possible states, right circular polarization in which the electric field vector rotates in a right hand sense with respect to the direction of propagation, and left circular polarization in which the vector rotates in a left-hand sense. Circular polarization is a limiting case of the more general condition of elliptical polarization. The circularly polarized wave will radiate energy in the horizontal and vertical plane, as well as every plane in between. There are two directions of propagation that come with circular polarization: Right-Hand-Circular (RHC) which follows a clockwise pattern, and Left- Hand-Circular (LHC) which follows a counterclockwise pattern. As with linear polarization, both directions can be used simultaneously on the same frequency, allowing higher revenue generation through the doubling of capacity on the satellites. Circular polarization can be found on both C and Ku- frequency band.

**References:**


1. Optics by Ajoy Ghatak, 6$^{th}$ Edition
2. University Physics by F. W. Sears, M. W. Zemansky and H. D. Young, 6$^{th}$ Edition
3. Fundamentals of Optics by F. A. Jenkins and H. E. White, 4$^{th}$ Edition

**Subject/Course:** **Physics**

**Topic:**

**Lesson Title:** **Clouds**

**Semester:** **4th Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Bashir Ahmad Mir**

**Lesson Description:**

Clouds are aesthetically appealing and add excitement to the atmosphere. Without them there would be no rain or snow, thunder or lightening, rainbows or halos. How monotonous if one had only a clear blue sky to look at. A cloud is visible aggregate of tiny water droplets or ice crystals suspended in the air. Some are found only at high elevations, where as others nearly touch the ground. Clouds can be thick or thin big or little they exist in a seemingly endless variety of forms.

Cloud Identification:

1. High clouds: high clouds in the middle and low latitudes generally form above 6000 meter. Because the air at these elevations is quite cold and dry. High clouds are composed almost exclusively of ice crystals and/or also rather thin. High clouds usually appear white except near sunrise and sunset when the unscattered (red, orange, and yellow ) components of sunlight are reflected from the under sight of the clouds.
   a) The most common high clouds are cirrus (Ci) which is thin wispy clouds bloom by high winds into large streamers called mares, tails.
   b) Cirrocumulus (Cc): clouds seen less frequently than cirrus appear as small rounded white puffs that may occur individually or in long rows.
   c) Cirrostratus: the thin sheet like high clouds that often cover the entire sky are cirrostratus (Cs), which are so thin that the sun and the moon can be clearly seen through hem. The ice crystals in these clouds bend the light passing through them and will often produce a halo_ a ring of light that encircles the sun or moon. Thick cirrostratus clouds give the sky a glary

white appearance and frequently forms a head of an advanced storm; hence they can be used to predict rain or snow within 12-14 hours if they are followed by middle type clouds

2. Middle clouds: the middle clouds have basis between 2000-7000 meters in the middle latitudes. These clouds are composed of water droplets and -when the temperature becomes low enough- some ice crystals. There are different types of middle clouds, some of them are presented here as;

   a) Altocumulus (Ac): these clouds are middle clouds that are composed mostly of water droplets and rarely more one kilometer thick. They appear as grey, puffy masses, sometimes rolled out in parallel waves or bands. Usually one part of the cloud is darker than other which helps to separate it from the higher cirrocumulus.

   b) Altostratus (As): the altostratus is a grey or blue – grey cloud composed of ice crystals and water droplets. Altostratus clouds often cover the entire sky across an area that extends many hundreds of square kilometers. In the thinner section of the cloud, the sun (or moon) may be dimly visible as a round disk, as if the sun were shining through ground glass. This appearance is sometimes referred to as a “water, sun” .

3. Low Clouds: Low clouds with their basis lying below 2000 meter, or almost composed of water droplets; however in cold weather, they may contain ice particles and snow. Some of the kinds of low clouds are given here;

   a) Nimbostratus (Ns): it is a dark grey, wet- looking cloud layer associate with more or less continuously falling rain or snow. The intensity of this precipitation is usually light or moderate. The base of the nimbostratus cloudy normally impossible to identify clearly and its top May be over three kilometer higher.

   b) Stratocumulus: theses clouds are low lumpy clouds that appear in rows, in patches, or as rounded masses with below sky visible between the individual cloud elements. Often they appear near sunset as the spreading remains of a much larger cumulus cloud occasionally the sun will shine through the cloud breaks [producing bands of light (called crepuscular rays) that appear to reach down the ground. The color of the stratocumulus ranges from light to dark grey.

c) Stratus: this is a uniform grayish cloud that often covers the entire sky. It resembles a fog that does not reach the ground. Actually, when thick fog “lifts” the resulting clouds deck of low stratus. Normally no precipitation falls from the stratus, but sometimes it is accompanied by a light mist or drizzle. This cloud commonly occurs over pacific and Atlantic coastal waters in summer.

**References:**

**Subject/Course:** **Physics**

**Topic:** **Statistical Mechanics**

**Lesson Title:** **Black Body Radiation**

**Semester:** **3rd Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

The electromagnetic radiations trapped in a cavity and in thermal equilibrium with the walls of cavity are known as black body radiations. A perfect black body is one which absorbs radiations of all wavelengths incident on it. When such a body is heated and maintained at a constant temperature it then emits radiations of all wavelengths. We don't have a perfect black body in practice but have approximate models of black body viz. Fery's black body and Wien's black body.

Fery's black body consists of a double walled hollow copper sphere coated with lamp black on its inner surface and a narrow opening of pin hole size with a projection opposite to the hole. when radiations enter into this cavity after falling onto the projection, the radiations are dispersed in all directions and suffer multiple reflections and is therefore completely absorbed. When this body is kept at a constant temperature radiations come out of the hole. Thus the hole not the walls of cavity act as a black body radiator and absorber.

Properties of black body radiations:

- The nature of black body radiation is independent of the geometric shape of the body.
- Radiation inside a black body is isotropic i.e the nature, strength, intensity does not depend on which direction the radiation is coming from.

Black body radiations are independent of the nature of the substance of which the black body is made and depends only on temperature.

A perfect black body is one which is a perfect absorber and a perfect radiator. Therefore absorption coefficient of a perfect black body is 1. The krichhoff's law states the emissive power of a given wavelength at a particular temperature is the same for all black bodies and is equal to the emissive power of a perfectly black body.

$$e/a = E$$

where 'e' is the emissive power of a body, 'a' is the absorptive power of a body and 'E' is the emissive power of a black body.

Therefore for a body emissive power is proportional to its absorptive power i.e something that absorbs more will also tend to radiate more. Green piece of a glass is green because it absorbs red and all other colours and reflect the green colour, if this piece of glass is heated and is put in dark we will see red colour coming out of it because it absorbs red colour more hence emissive power of red colour is more. There are many laws that govern black body radiations but the most general law was given by Planck and is known as Planck's radiation law this law is in complete agreement with the experimental results obtained for black body radiations. Planck made some assumptions for deriving his law for black body radiations, known as plank's quantum postulates and are as follows:

- Black body is not filled only with radiations but also with linear harmonic oscillators also known as quantum resonators which can vibrate with all possible frequencies.
- These resonators cannot absorb or radiate energy continuously but energy can be emitted or absorbed in small packets of energy known as quanta. Planck assumed that energy of each such quanta is $h\nu$ where h is known as planck's constant and its value is 6.625×E-34 Js and $\nu$ is the frequency with which resonator vibrate. The exchange of energy between matter and radiations takes place only in small amounts called quantum.

For his work on black body radiations, Planck was awarded noble prize in 1918.The study of black body radiation also gave birth to new field of study known as quantum mechanics.

**Subject/Course:** **Physics**

**Topic:** **Quantum Mechanics**

**Lesson Title:** **Uncertainty Principle**

**Semester:** **$5^{th}$ Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

It is impossible to know both the exact position and exact momentum of an object at the same time.

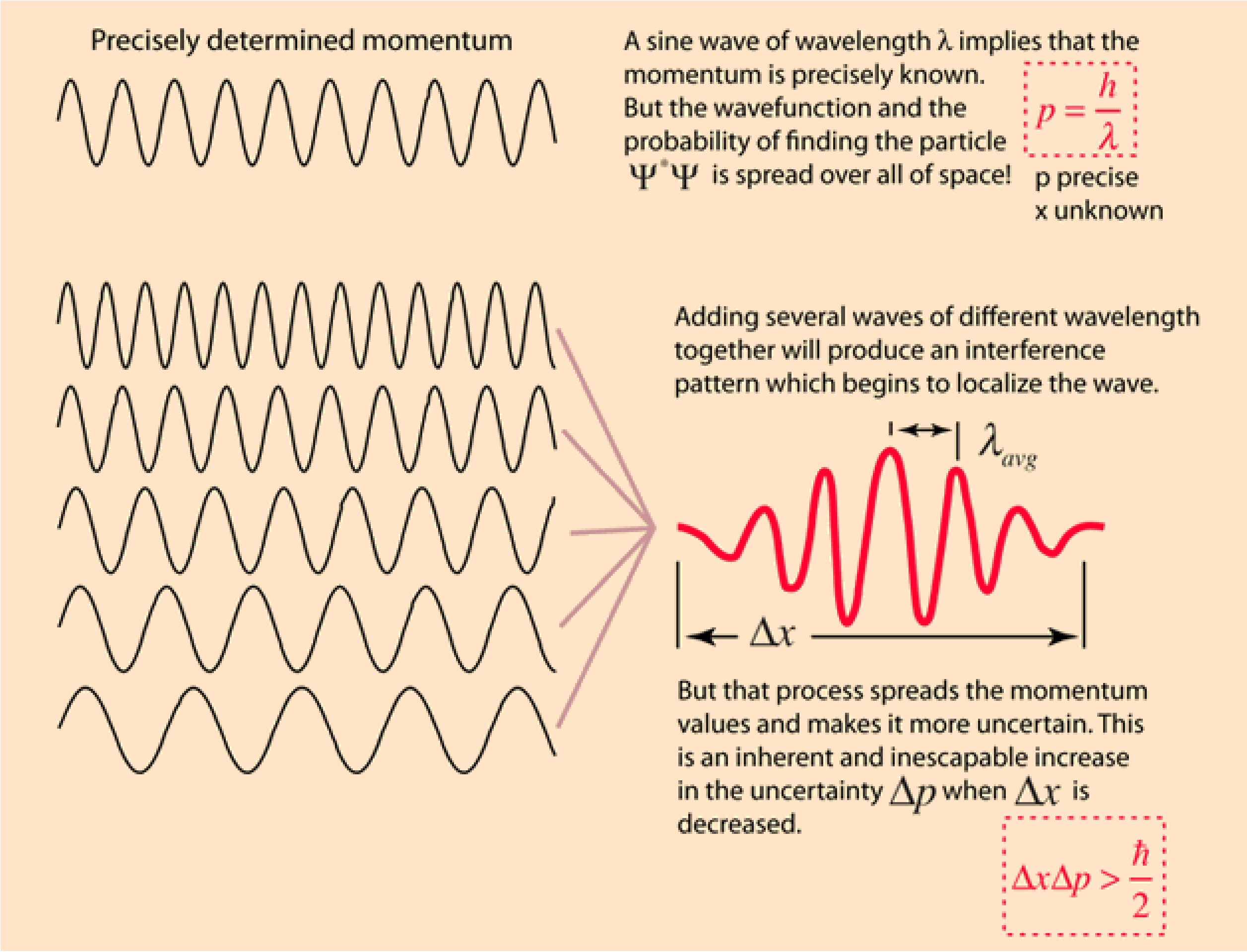
As per classical ideas, it is possible t determine all dynamic variables of a system to any desired degree of accuracy. This principle of determinism is the backbone of classical physics but the case is completely different in quantum mechanics. Heisenberg proposed that now two canonically conjugate quantities can be measured simultaneously with accurate accuracy. For the canonically conjugate variables x and $p_x$ , mathematically the principle is stated as

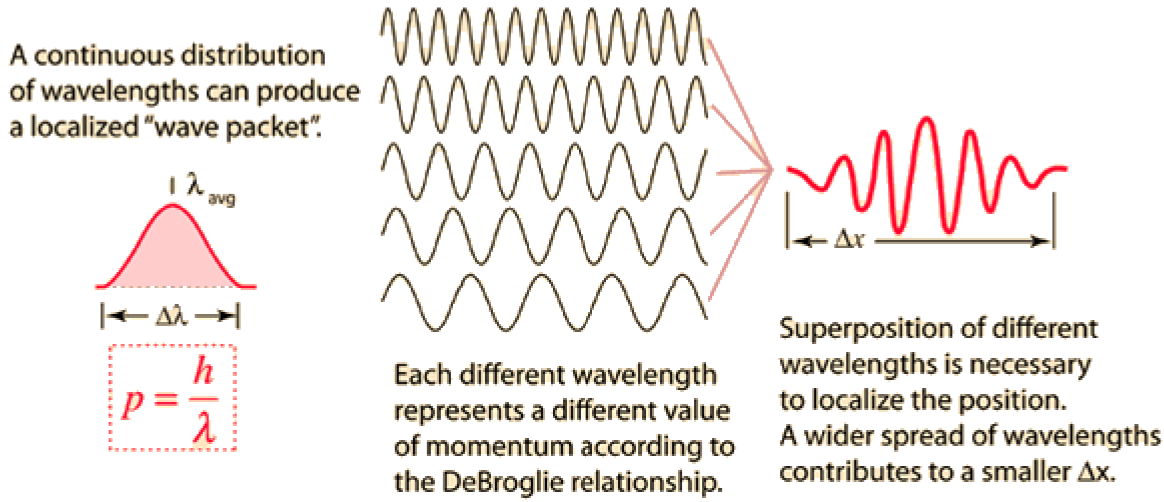
$$\Delta x \, \Delta p_x \geq \frac{\hbar}{2}$$

where $\Delta x$ is uncertainty in position of object and $\Delta p_x$ is uncertainty in its momentum.

This principle is known as uncertainty principle and was discovered by Werner Heisenberg in 1927 and is one of the most significant of physical laws. This principle asserts a fundamental limit to the precision with which certain pairs of physical properties of a particle, known as complementary variables(canonically conjugate variables) , such as position x and momentum $p_x$, can be known. This is not a statement about the inaccuracy of measurement instruments, nor a reflection on the quality of experimental methods; it arises from the wave properties inherent in the quantum mechanical description of nature. Even with perfect instruments and technique, the uncertainty is inherent in the nature of things. Since we cannot know exactly both where a particle is right now and what its momentum is , we cannot say anything definite about where it will be in the future or how fast it will be moving then. We cannot know the future for sure because we cannot know the present for sure.

Important steps on the way to understanding the uncertainty principle are wave-particle duality and the De Broglie hypothesis. As you proceed downward in size to atomic dimensions, it is no longer valid to consider a particle like a hard sphere, because the smaller the dimension, the more wave-like it becomes. It no longer makes sense to say that you have precisely determined both the position and momentum of such a particle. When you say that the electron acts as a wave, then the wave is the quantum mechanical wave function and it is therefore related to the probability of finding the electron at any point in space. A perfect sine wave for the electron wave spreads that probability throughout all of space, and the "position" of the electron is completely uncertain.




A continuous distribution
of wavelengths can produce
a localized "wave packet".
$\lambda_{avg}$
$\Delta\lambda$
$p = \frac{h}{\lambda}$
Each different wavelength
represents a different value
of momentum according to
the DeBroglie relationship.
$\Delta x$
Superposition of different
wavelengths is necessary
to localize the position.
A wider spread of wavelengths
contributes to a smaller $\Delta x$.

**Subject/Course:** **Physics**

**Topic:** **Electrodynamics**

**Lesson Title:** **Equation of Continuity**

**Semester:** **2nd Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

In Physics there are several universal Conservation Laws: the net energy, the net momentum, the net angular momentum, and the net electric charge of a closed system can never change regardless of what happens to that system. Bodies may collide or blow up, substances may freeze or boil, there may be all kinds of nuclear reactions, heck, a star may collapse into a black hole, but the net energy, momentum, angular momentum, and electric charge will always remain the same as they were when the system in question became closed (i.e., not interacting with the rest of the Universe). Moreover, for open systems there are local versions of these conservation laws. The electric charge and other conserved quantities do not instantaneously jump long distances, they have to flow at finite rate through all the intermediate locations.

A continuity equation in physics is an equation that describes the transport of some quantity. It is particularly simple and powerful when applied to a conserved quantity, but it can be generalized to apply to any extensive quantity. Since mass, energy, momentum, electric charge and other natural quantities are conserved under their respective appropriate conditions, a variety of physical phenomena may be described using continuity equations.

Continuity equations are a stronger, local form of conservation laws. For example, a weak version of the law of conservation of energy states that energy can neither be created nor destroyed—i.e., the total amount of energy in the universe is fixed. This statement does not rule out the possibility that a quantity of energy could disappear from one point while simultaneously appearing at another point. A stronger statement is that energy is locally conserved: energy can neither be created nor destroyed, nor can it "teleport" from one place to another—it can only move by a continuous flow. A continuity equation is the mathematical way to express this kind of statement. For example, the continuity equation for electric charge states that the amount of electric charge in any volume of space can only change by the amount of electric current flowing into or out of that volume through its boundaries. Continuity equations more generally can include "source" and "sink" terms, which allow them to describe quantities that are often but not always conserved, such as the density of a molecular species which can be created or destroyed by chemical reactions. In an everyday example, there is a continuity equation for the number of people alive; it has a "source term" to account for people being born, and a "sink term" to account for people dying.

Any continuity equation can be expressed in an "integral form" (in terms of a flux integral), which applies to any finite region, or in a "differential form" (in terms of the divergence operator) which applies at a point. By the divergence theorem, a general continuity equation can also be written in a "differential form":

$$\frac{\partial \rho}{\partial t} + \nabla \cdot J = \sigma$$

where $\nabla\cdot$ is divergence, $\rho$ is the amount of the quantity q per unit volume, J is the flux of q, t is time, $\sigma$ is the generation of q per unit volume per unit time. Terms that generate q (i.e. $\sigma > 0$) or remove q (i.e. $\sigma < 0$) are referred to as a "sources" and "sinks" respectively.

This general equation may be used to derive any continuity equation, ranging from as simple as the volume continuity equation to as complicated as the Navier–Stokes equations. This equation also generalizes the advection equation. Other equations in physics, such as Gauss's law of the electric field and Gauss's law for gravity, have a similar mathematical form to the continuity equation, but are not usually referred to by the term "continuity equation", because j in those cases does not represent the flow of a real physical quantity.

In the case that q is a conserved quantity that cannot be created or destroyed (such as energy), σ = 0 and the equations becomes:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot J = 0$$

In electromagnetic theory, the continuity equation is an empirical law expressing (local) charge conservation. Mathematically it is an automatic consequence of Maxwell's equations, although charge conservation is more fundamental than Maxwell's equations. It states that the divergence of the current density J (in amperes per square metre) is equal to the negative rate of change of the charge density ρ (in coulombs per cubic metre),

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot J$$

Current is the movement of charge. The continuity equation says that if charge is moving out of a differential volume (i.e. divergence of current density is positive) then the amount of charge within that volume is going to decrease, so the rate of change of charge density is negative. Therefore, the continuity equation amounts to a conservation of charge.

**Subject/Course:** **Physics**

**Topic:** **Theory of relativity**

**Lesson Title:** **Special Theory of Relativity**

**Semester:** **1st Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

This theory shows a connection between space and time, matter and energy, electricity and magnetism and has revolutionized the science since 19th century. This theory was proposed by Albert Einstein in 1905 in his paper "On the Electrodynamics of Moving Bodies" and thus changed our perception of the world forever. The theory was able to explain some pressing theoretical and experimental issues in the physics of the time involving light and electrodynamics, such as the failure of the 1880 Michelson–Morley experiment, which aimed to measure the motion of earth relative to a frame of reference in which the speed of light is same in all directions, the hypothetical medium called as luminiferous ether. The ether was then considered to be the medium of propagation of electromagnetic waves such as light.

A defining feature of special relativity is the replacement of the Galilean transformations of Newtonian mechanics with the Lorentz transformations. Time and space cannot be defined separately from each other. Rather space and time are interwoven into a single continuum known as spacetime. Events that occur at the same time for one observer could occur at different times for another.

Theory of relativity is based on two fundamental postulates:

- Principle of Relativity: The laws of nature are the same in all inertial reference frames
- The speed of light in a vacuum is the same in all inertial frames

Special relativity implies a wide range of consequences, which have been experimentally verified, including length contraction, time dilation, relativistic mass, mass–energy equivalence, a universal speed limit, and relativity of simultaneity. It has replaced the conventional notion of an absolute universal time with the notion of a time that is dependent on reference frame and spatial position. Rather than an invariant time interval between two events, there is an invariant space-time interval. Combined with other laws of physics, the two postulates of special relativity predict the equivalence of mass and energy, as expressed in the mass–energy equivalence formulae E=m$c^2$, where c is the speed of light in vacuum.

The predictions of special relativity are almost identical to those of Galilean relativity for most everyday phenomena, in which speeds are much lower than the speed of light, but it makes different, non-obvious predictions for objects moving at very high speeds. These predictions have been experimentally tested on numerous occasions since the theory's inception and were confirmed by those experiments. The major predictions of special relativity are:

- Time dilation:(An observer watching two identical clocks, one moving and one at rest, will measure the moving clock to tick more slowly)

  In the theory of relativity, time dilation is a difference of elapsed time between two events as measured by observers either moving relative to each other or differently situated from gravitational masses.

  The formula for determining time dilation in special relativity is:

$$\Delta t' = \gamma \, \Delta t = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where $\Delta t$ is the time interval between *two co-local events* (i.e. happening at the same place) for an observer in some inertial frame (e.g. ticks on his clock), this is known as the *proper time*, $\Delta t'$ is the time interval between those same events, as measured by another observer, inertially moving with velocity *v* with respect to the former observer, *v* is the relative velocity between the observer and the moving clock, *c* is the speed of light, and the Lorentz factor (conventionally denoted by the Greek letter gamma or γ) is

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \, .$$

Thus the duration of the clock cycle of a moving clock is found to be increased: it is measured to be "running slow".

Length contraction: (Along the direction of motion, a rod moving with respect to an observer will be measured to be shorter than an identical rod at rest). Length contraction takes place only in the direction of motion; lengths perpendicular to the direction of motion remain unaffected.

- Relativity of simultaneity: Observers who are in motion with respect to each other may disagree on whether two events occurred at the same time or one occurred before the other.

In physics, the relativity of simultaneity is the concept that distant simultaneity – whether two spatially separated events occur at the same time – is not absolute, but depends on the observer's reference frame.

Mass-Energy Equivalence:

- In physics, **mass–energy equivalence** is the concept that the mass of an object or system is a measure of its energy content. For instance, adding 25 kilowatt-hours (90 mega joules) of *any* form of energy to any object increases its mass by 1 microgram (and, accordingly its inertia and weight) even though no matter has been added.
- A physical system has a property called energy and a corresponding property called mass; the two properties are equivalent in that they are always both present in the same (i.e. constant) proportion to one another.

## APPLICATIONS

There is a common perception that relativistic physics is not needed for practical purposes or in everyday life. This is not true. Without relativistic effects, gold would look silvery, rather than yellow. Many technologies are critically dependent on relativistic physics:

- Cathode ray tubes,
- Particle accelerators,
- Global Positioning System (GPS) – These systems require very precise measures of time, so that the effects of relativity must be considered in calculations. These calculations actually require the more complete general relativity.

**Subject/Course:** **Physics**

**Topic:** **Wave Optics**

**Lesson Title:** **Michelson Interferometer**

**Semester:** **4th Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Dr. Hilal Ahmad Reshi**

**Lesson Description:**

There are, in general, a number of types of optical instruments that produce optical interference. These instruments are grouped under the generic name of interferometers. The Michelson interferometer causes interference by splitting a beam of light into two parts. Each part is made to travel a different path and brought back together where they interfere according to their path length difference.

The Michelson interferometer is a device that produces interference between two beams of light. A diagram of the apparatus is shown in Fig. 1. The basic operation of the interferometer is as follows. Light from a light source is split into two parts. One part of the light travels a different path length than the other. After traversing these different path lengths, the two parts of the light are brought together to interfere with each other. The interference pattern can be seen on a screen. Light from the source strikes the beam splitter (designated by S). The beam splitter allows 50% of the radiation to be transmitted to the translatable mirror M1. The other 50% of the radiation is reflected to the fixed mirror M2. The compensator plate C is introduced along this path to make each path have the same optical path length when M1 and M2 are the same distance from the beam splitter. After returning from M1, 50% of the light is reflected toward the frosted glass screen. Likewise, 50% of the light returning from M2 is transmitted to the glass screen. At the screen, the two beams are superposed and one can observe the interference between them.

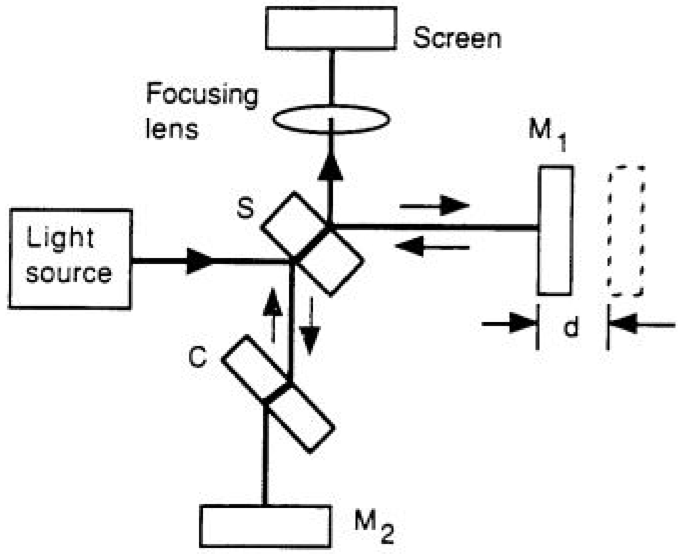



Figure 1: Schematic illustration of a Michelson interferometer.

The Michelson interferometer produces interference fringes by splitting a beam of monochromatic light so that one beam strikes a fixed mirror and the other a movable mirror. When the reflected beams are brought back together, an interference pattern appears.

The Michelson interferometer has also been used to provide evidence for the special theory of relativity, to detect and measure hyperfine structure in line spectra, to measure the tidal effect of the moon on the earth and to provide a substitute standard for the meter in terms of wavelengths of light. The Michelson interferometer is the best example of what is called an amplitude-splitting interferometer. It was invented in 1893 by Albert Michelson, to measure a standard meter in units of the wavelength of the red line of the cadmium spectrum. With an optical interferometer, one can measure distances directly in terms of wavelength of light used, by counting the interference fringes that move when one or the other of two mirrors are moved. In the Michelson interferometer, coherent beams are obtained by splitting a beam of light that originates from a single source with a partially reflecting mirror called a beam splitter. The resulting reflected and transmitted waves are then re-directed by ordinary mirrors to a screen where they superimpose to create fringes. This is known as interference by division of amplitude. This interferometer, used in 1817 in the famous Michelson- Morley experiment, demonstrated the non-existence of electromagnetic-wave-carrying ether, thus paving the way for the Special theory of Relativity.

**Applications**

1. The Michelson - Morley experiment is the best known application of Michelson Interferometer.

2. They are used for the detection of gravitational waves.

3. Michelson Interferometers are widely used in astronomical Interferometry.

**Subject/Course:** **Physics**

**Topic:** **Nuclear Physics**

**Lesson Title:** **Liquid Drop Model**

**Semester:** **5th Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

The liquid drop model, developed from the observation of similar properties between a nucleus and a drop of incompressible fluid, helps explain nuclear phenomena such as the energetic of nuclear fission and the binding energy of nuclear ground levels which cannot be illustrated by the shell model. In view of similarities such as the latent heat of vaporization of fluid which is comparable to the constant binding energy per nucleon, and the surface tension effects of nucleus as well as a liquid drop, the quantitative aspect of the model delivers a formula that approximates the mass and binding energy of nuclei.

More specifically, heat of vaporization represents the amount of energy required to convert molecules from liquid phase to gas phase. The latent heat of vaporization is proportional to the number of molecules in the liquid. The binding energy of nucleus displays a similar relationship where it is proportional to the number of nucleons. Using such analogy, the semi-empirical mass formula (also known as the Bethe-Weizaecker formula), was derived from the liquid drop model empirically as a function of mass number A and atomic number Z.

There are five factors that contribute to the binding energy of nuclei. The volume term, being directly proportional to the number of nucleons, illustrates the idea that each nucleon only interacts with its nearest neighbours and binds to the nucleus at a specific binding energy. The surface term suggests that fewer nucleon interactions are observed on surface compared to that of nucleus interior, which is analogous to the surface tension of liquid drop. The Coulomb term represents the electrostatic repulsion between protons in a nucleus. The asymmetry term accounts for the difference in the number of protons and neutrons in the nuclear matter. The pairing term corrects for the coupling effects of protons and neutrons.

According to this model, the atomic nucleus behaves like the molecules in a drop of liquid. But in this nuclear scale, the fluid is made of nucleons (protons and neutrons), which are held together by the strong nuclear force. The liquid drop model of the nucleus takes into account the fact that the nuclear forces on the nucleons on the surface are different from those on nucleons in the interior of the nucleus. The interior nucleons are completely surrounded by other attracting nucleons. Here is the analogy with the forces that form a drop of liquid. In the ground state the nucleus is spherical. If the sufficient kinetic or binding energy is added, this spherical nucleus may be distorted into a dumbbell shape and then may be splitted into two fragments. Since these fragments are a more stable configuration, the splitting of such heavy nuclei must be accompanied by energy release. This model does not explain all the properties of the atomic nucleus, but does explain the predicted nuclear binding energies.

The nuclear binding energy as a function of the mass number A and the number of protons Z based on the liquid drop model can be written as:

$$E_b(MeV) = a_V A - a_S A^{\frac{2}{3}} - a_C \frac{Z^2}{A^{\frac{1}{3}}} - a_A \frac{(A-2Z)^2}{A} \pm \delta(A,Z)$$

$$\delta(A,Z) = \begin{matrix} +\delta_0 \ for\ Z,N\ even \\ 0 \\ -\delta_0 \ for\ Z,N\ odd \end{matrix}$$

This formula is called the Weizsaecker Formula (or the semi-empirical mass formula). The physical meaning of this equation can be discussed term by term.

**Volume term – $a_V$.A.** The first two terms describe a spherical liquid drop of an incompressible fluid with a contribution from the volume scaling with A and from the surface, scaling with $A^{2/3}$. The first positive term **$a_V$.A** is known as the volume term and it is caused by the attracting strong forces between the nucleons. The strong force has a very limited range and a given nucleon may only interact with its direct neighbours. Therefore this term is proportional to A, instead of $A^2$. The coefficient **$a_V$** is usually about ~ 16 MeV.

**Surface term – $a_s$.$A^{2/3}$.** The surface term is also based on the strong force, it is, in fact, a correction to the volume term. The point is that particles at the surface of the nucleus are not completely surrounded by other particles. In the volume term, it is suggested that each nucleon interacts with a constant number of nucleons, independent of A. This assumption is very nearly true for nucleons deep within the nucleus, but causes an overestimation of the binding energy on the surface. By analogy with a liquid drop this effect is indicated as the surface tension effect. If the volume of the nucleus is proportional to A, then the geometrical radius should be proportional to $A^{1/3}$ and therefore the surface term must be proportional to the surface area i.e. proportional to $A^{2/3}$.

**Coulomb term – $a_C$.$Z^2$.$A^{-1/3}$.** This term describes the Coulomb repulsion between the uniformly distributed protons and is proportional to the number of proton pairs **$Z^2$/R**, whereby R is proportional to $A^{1/3}$. This effect lowers the binding energy because of the repulsion between charges of equal sign.

**Asymmetry term – $a_A$.$(A-2Z)^2$/A.** This term cannot be described as 'classically' as the first three. This effect is not based on any of the fundamental forces, this effect is based only on the Pauli exclusion principle (no two fermions can occupy exactly the same quantum state in an atom). The heavier nuclei contain more neutrons than protons. These extra neutrons are necessary for stability of the heavier nuclei. They provide (via the attractive forces between the neutrons and protons) some compensation for the repulsion between the protons. On the other hand, if there are significantly more neutrons than protons in a nucleus, some of the neutrons will be higher in energy level in the nucleus. This is the basis for a correction factor, the so-called symmetry term.

**Pairing term – δ(A,Z).** The last term is the pairing term δ(A,Z). This term captures the effect of spin-coupling. Nuclei with an even number of protons and an even number of neutrons are (due to Pauli exclusion principle) very stable thanks to the occurrence of 'paired spin'. On the other hand, nuclei with an odd number of protons and neutrons are mostly unstable.

One application of binding energy calculation is to determine the possibility of beta decay. In order for beta decay to occur, the binding energy of the final nucleus has to be higher than that of the original. Taking Selenium-82 (A=34) and Krypton-82 (A=36) as an example, the binding energy is approximately -277 MeV and 214 MeV respectively, calculated from the semi-empirical mass formula above. The decay of Selenium-82 into Krypton-82 is in fact double beta decay where two electrons are emitted in the process.

**Subject/Course:** **Physics**

**Topic:** **Electronics**

**Lesson Title:** **Extrinsic Semiconductor**

**Semester:** **$6^{th}$ Semester** **Time/Duration:** **40 minutes**

**Lecturer:** **Mr. Towseef Ahmad Bhat**

**Lesson Description:**

Semiconductors can be broadly classified into Intrinsic and Extrinsic Semiconductors. Intrinsic Semiconductors start conducting at temperatures above the room temperature, developing important electronic devices using these can pose a problem. This led to a need for improving the conductivity of intrinsic semiconductors. After some experiments, scientists observed an increase in the conductivity of a Semiconductor when a small amount of impurity was added to it. These materials are Extrinsic Semiconductors or impurity Semiconductors. Another term for these materials is 'Doped Semiconductor'. The impurities are dopants and the process – Doping. An important condition to doping is that the amount of impurity added should not change the lattice structure of the Semiconductor. To achieve this size of the dopant and Semiconductor atoms should be the same.

An extrinsic semiconductor is a semiconductor doped by a specific impurity which is able to deeply modify its electrical properties, making it suitable for electronic applications (diodes, transistors, etc.) or optoelectronic applications (light emitters and detectors).

**Types of Dopants in Extrinsic Semiconductors**

Crystals of Silicon and Germanium are doped using two types of dopants:

1. Pentavalent (valency 5); like Arsenic (As), Antimony (Sb), Phosphorous (P), etc.

2. Trivalent (valency 3); like Indium (In), Boron (B), Aluminium (Al), etc.

The reason behind using these dopants is to have similarly sized atoms as the pure semiconductor. Both Si and Ge belong to the fourth group in the periodic table. Hence, the choice of dopants is from the third and fifth group. This ensures that the size of atoms is not much different from the fourth group. Hence, the trivalent and pentavalent choices. These dopants give rise to two types of semiconductors:

1. n-type
2. p-type

**N-type Semiconductor**

An n-type semiconductor is created when pure semiconductors, like Si and Ge, are doped with pentavalent elements. When a pentavalent atom takes the place of a Si atom, four of its electrons bond with four neighbouring Si atoms. However, the fifth electron remains loosely bound to the parent atom. Hence, the ionization energy required to set this electron free is very small. Thereby, this electron can move in the lattice even at room temperature. To give you a better perspective, the ionization energy required for silicon at room temperature is around 1.1 eV. On the other hand, by adding a pentavalent impurity, this energy drops to around 0.05 eV.

It is important to remember that the number of electrons made available by the dopant atoms is independent of the ambient temperature and primarily depends on the doping level. Also, as the temperature rises, the Si atoms free some electrons and generate some holes. But, the number of these holes is very small. Hence, at any given point in time, the number of free electrons is much higher than the number of holes. Also, due to recombination, the number of holes reduces further.

In a nutshell, when a semiconductor is doped with a pentavalent atom, electrons are the majority charge carriers. On the other hand, the holes are the minority charge carriers. Therefore, such extrinsic semiconductors are called n-type semiconductors. In an n-type semiconductor, number of free electrons ($n_e$) $>>$ Number of holes ($n_h$)

**P-type Semiconductor**

A p-type semiconductor is created when trivalent elements are used to dope pure semiconductors, like Si and Ge. As can be seen in the image above, when a trivalent atom takes the place of a Si atom, three of its electrons bond with three neighbouring Si atoms. However, there is no electron to bond with the fourth Si atom. This leads to a hole or a vacancy between the trivalent and the fourth silicon atom. This hole initiates a jump of an electron from the outer orbit of the atom in the neighborhood to fill the vacancy. This creates a hole at the site from where the electron jumps. In simple words, a hole is now available for conduction.

It is important to remember that the number of holes made available by the dopant atoms is independent of the ambient temperature and primarily depends on the doping level. Also, as the temperature rises, the Si atoms free some electrons and generate some holes. But, the number of these electrons is very small. Hence, at any given point in time, the number of holes is much higher than the number of free electrons. Also, due to recombination, the number of free electrons reduces further.

In a nutshell, when a semiconductor is doped with a trivalent atom, holes are the majority charge carriers. On the other hand, the free electrons are the minority charge carriers. Therefore, such extrinsic semiconductors are called p-type semiconductors. In a p-type semiconductor,

Number of holes ($n_h$) $\gg$ Number of free electrons ($n_e$)

Important note: The crystal maintains overall charge neutrality. The charge of additional charge carries is equal and opposite to that of the ionized cores in the lattice.