STUDY GUIDE

for

Physical Optics
and
Geometrical Optics

(UNIT 1-9)

LEVEL: B.Sc

C.CODE: 2429 **CREDIT: HALF**

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Vision Sciences programme
- Diploma In Vision Sciences
  for ophthalmic technicians
- B.Sc Vision Sciences
- B.Sc Honours in Vision Sciences

Department of Home & Health Sciences
ALLAMA IQBAL OPEN UNIVERSITY, ISLAMABAD

Edition 1st

Year of Publication 2004

Price Rs.30/-

Number of Copies 500

Printer..S.T. Printers, Rawalpindi

Publisher ....Allama Iqbal Open University,
Islamabad.

LIST OF CONTENT

Welcome From Course - Coordination

Dear students, this study guide follows the pattern and style of the previous study guides that you have already benefited from. It is divided into nine study units, focusing on individual topics regarding physical and geometrical optics. You will find some study units to be in detail while others will guide you about the reading material that could be very helpful in learning the relevant concepts. It is because wherever, a need is felt to explain a concept owing to its complexities; the authors have tried to help the student through their writing.

As always, each unit at the end gives you the list of reading material ranging from what you must know as prescribed reading to what is nice to know as suggested reading. This time too, your learning process is augmented by the self-assessment exercises at the end of each unit.

We hope, the study guide will help you promptly in understanding the physical and geometrical optics and the related concepts.

Structure of the course

The course "Physical and Geometrical optics" has been structured to make it as easy as possible for you to do the required work. Like a half credit course this course consists of nine units. One unit is study work of two weeks, thus the total study period will be of 18 weeks.

We have organized this course to enable you to acquire the skills of self-learning. For each unit, an introduction is given to help you to develop an objective analysis of the major and sub-themes, discussed in the prescribed reading material. Beside this, objectives of each unit are very specifically laid down to facilitate in developing a clear logical approach. We have also given you Self-Assessment Exercise, which are present at end of each unit. Questions in the Self Assessment Exercise are not only meant to facilitate you in understanding the required readings but to provide you an opportunity to assess yourself. Since the course work of one unit includes studying the prescribed reading material and carrying out the self-assessment questions, activities assignments and practicals, you are required to spend two weeks on each unit.

For this course "Fortnightly Tutorials" are arranged in the university's Selected Regional Study Centers. They provide you the facility of meeting with one another for discussion and mutual help & for group and individual discussion with fellows and tutors.

a) **How to use Reading Material:**

As this is a distance education course, we have organized the required course work in the following manner to help you in evolving a self-learning process in the absence of formal class room teaching.

1) A detailed course introduction
2) Introduction to each unit.
3) The major theme of the unit is listed along with readings. A list of suggested & prescribed reading in given at the end of each unit.
4) Self Assessment Exercise given in the reference text are not only meant to facilitate you in understanding but will also suggest a direction in which we expect you to think and analyze.

b) How to attend tutorials:

Tentative Tutorial & Practical schedule is provided to you in your study packs.& 70% attendance in the tutorials is compulsory in order to appear in the exam. Before attending the tutorial, you are required to prepare yourself by reading the topics to be taught in the next tutorial carefully and mark the points which you cant understand yourself in order to discuss them with your tutor and your colleagues.

INTRODUCTION TO THE COURSE

This course addresses Physical and Geometrical optics. Basically Optics is a branch of Physical Science that deals with the properties of light and vision. Optics are further divided into many branches for simplicity. Two branches concerning the eye care workers are the "Physical optics" that deals with the nature of light regarding its wave properties and the "Geometrical optics" which describe the transmission of light as waves and also the behaviour of different type of lenses towards light and the production of images.

It is of utmost importance for a refractionist to understand these. Therefore, the course is an effort to fulfill this demand.

OBJECTIVES:

After going through this course you should be able to:

1. Describe the nature and properties of light.
2. Define reflection of light and its related concepts.
3. Explain refraction of light and its associated phenomena.
4. Have the knowledge about the types, magnification, curvature and power of the lenses.
5. Have knowledge of the properties of toric surfaces and prisms.
6. Apply all this knowledge to their clinical practice.

UNIT 1: NATURE OF LIGHT

INTRODUCTION

As we all know, to be able to see, we need to have light. In other words light is the medium of vision. It would, therefore, be helpful if we know about the nature and properties of light.

OBJECTIVES

After studying this unit you should be able to explain:

1. What is wave- motion.
2. The basic terminology in relation to certain parameters of waves.
3. The wave nature of light.
4. The particle nature of light and the concept of photon.
5. The duality in the behaviour of light.

INDICATIVE CONTENT AND SUMMARY OF THE MAIN TOPICS

1.1 Nature of light

As we know light is a form of energy which can be detected by the eyes. Scientists have for centuries, debated the nature of light and have proposed two theories in this regard; the wave motion and the particle theory. We will study them one by one and as we will come to know, some of the properties of light can only be explained by wave motion whereas others only by particle theory. Light is, therefore, nowadays, regarded as having the nature of wave motion when it travels and particle nature when it interacts with matter such as, during the process of its absorption and production. We will elaborate these concepts further in the subsequent sections.

1.2 Wave Motion

Although we can see light, we cannot see its wave motion. But, fortunately, we can see the wave motion in certain other situations and the characteristics of such wave motion are directly applicable to light.

We have all seen waves in water when we throw a stone in it (fig 1). We can also produce waves in a rope when one end of it is tied to a fixed point and we shake the other end up and down rapidly.

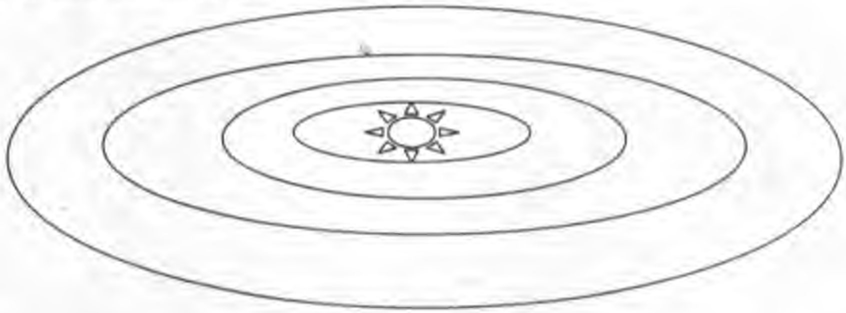


Fig .1

Now, if we put a paper boat in water, we will see its up and down movement when the wave arrives at it. The same thing happens to a ribbon tied to the rope. The extent of this upward and downward displacement is known as the amplitude of the wave and is measured from the resting position or the position of equilibrium to either the maximum upward displacement (the crest of the wave) or the maximum downward displacement (trough of the wave). Sometimes, the crests and troughs are also referred to as maxima and minima respectively .The distance between two consecutive crests or two consecutive troughs is known as the wavelength and is represented by λ.(Fig. 2)

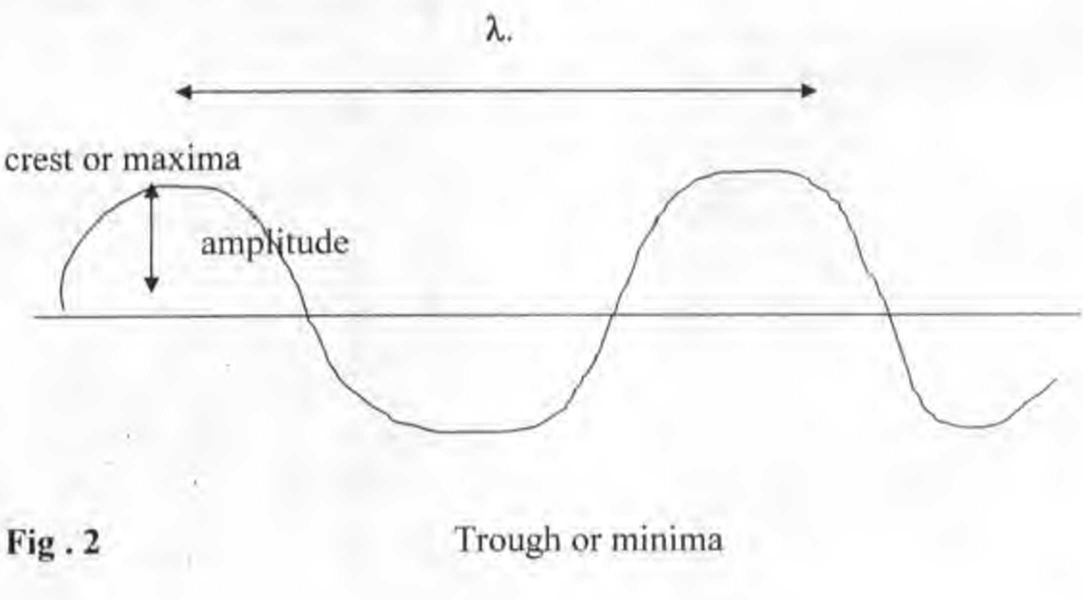


Fig . 2

If we count the number of wavelengths passing through a given point in one second, this will be the frequency, represented by ***f.***

Let us suppose that we have counted a hundred wavelengths crossing a given point in one second **(f = 100/ sec)**, and each wavelength is 2 feet **(λ =2 ft)**. It means that the wave will travel 200 feet in one second. In other words the velocity of the wave will be 200 ft/sec. So, when we multiply wavelength (λ) by frequency (f) , we get the velocity. In case of light, this velocity is presented by ***c*** and is given by the following equation:

$$c = f\lambda$$

By experimenting with the waves in the water, scientists had known for centuries the phenomena of reflection, refraction, diffraction, and interference of waves. For example, if a metal plate is placed in a water tank, then waves hitting it obliquely change their course in such a way that the angle of incidence is equal to the angle of reflection.

Water waves travel faster in deep and slower in shallow water and can be shown to show refraction or change of direction of propagation upon entering from deep to shallow or shallow to deep water unless the waves are incident normally(i.e; perpendicularly) at the boundary between the shallow and deep water.

The other properties of waves such as diffraction and interference can also be studied in water waves (explained in the relevant sections).

Based on such properties of light as reflection and refraction, the Dutch scientist Chiristian Huygens suggested in 1680 that light consists of waves. This idea was not acceptable to most scientists as they were, at that time, not able to demonstrate such wave properties as diffraction and interference in light. However, in 1801, Thomas Young demonstrated the interference of light based on diffraction and hence the wave theory of light was well established during the 19^{th} century.

1.3 Particle theory of light

Newton, who was a contemporary of Huygens, did not believe in the wave theory of light due to the lack of proof for diffraction and interference of light.. He proposed that light consisted of tiny particles traveling with great speed. He called these particles as "corpuscles". Many other scientists also believed in this theory till the beginning of 19th century when Thomas Young demonstrated the interference of light.

1.4 Wave-particle duality of light

Interestingly, when it seemed that the particle theory of light was completely replaced by the wave theory, it was observed that when light interacted with matter such as during the process of its absorption or production, the amount of light absorbed or produced is in multiples of a certain quantity; in other words it comes in packets or quanta.

Einstein presented the idea of light energy consisting of packets of electromagnetic energy: like a bullet fired from a machine gun rather than the water flowing from a running tap. This was an extension of the idea put forward by Max Planck to explain the emission and absorption of energy from a black surface. According to Planck, the energy emitted or absorbed by the atoms in a black surface is in the form of indivisible packets which he called **quanta.**

Einstein extended Planck's idea to light. He put forward the idea that the energy in a light beam is quantized, i.e; comes in packets, or quanta, and only a whole number of quanta can exist. The quanta of light, or electromagnetic radiation in general, are known as photons. The energy of each photon is proportional to the frequency of the radiation (f) and is given by the equation :

$$E = hf$$

Where, h = the Planck's constant (6.63×10^{-34} Js).

As this concept of quanta can only be explained by particle theory, light is currently considered to have a dual nature i.e; it behaves like waves when it travels but, like particles when it interacts with matter. In other words we can explain such properties of light as reflection, refraction , diffraction and interference by the wave theory; whereas, energy transfer involved in its production and absorption by the particle theory.

RECOMMENDED READING LIST

PRESCRIBED READING

1. Notes in the study guide.

2. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 35-39.

3. Duke Elder's. General optics. Practice of refraction, 10th edition, p 11-12.

SUGGESTED READING

1. Optics, refraction and Contact lenses: American Academy of Ophthalmology.

2. David Miller, Paulo Schor. Physical optics. In Duane's Clinical Ophthalmology (Chapter 31): Lippincott Williams and Wilkins.

SELF-EVALUATION QUESTIONS

Mark as True or False

1. Regarding wave motion:

a. Water waves travel faster in deep than in shallow water.
b. Newton was a supporter of wave theory of light.
c. The amplitude of a wave is measured from the crest to the trough.
d. Water waves do not have the property of refraction.
e. If the velocity of a wave is kept constant, the longer its wavelength, the higher will be its frequency.

2. Regarding light:

a. A photon of light with a longer wavelength has lesser energy than a photon of light with a shorter wavelength.
b. The properties of light like diffraction and interference can be explained by the particle theory of light.
c. If a beam of light has 15 photons, then by blocking half of the beam we will have 7.5 photons.
d. The amount of energy in a photon depends upon the frequency of light.
e. The velocity of photon is the same as the velocity of light.

UNIT NO 2: PROPERTIES OF LIGHT AND RELATED PHENOMENA

INTRODUCTION

Light exhibits certain properties such as interference, coherence and polarization.

OBJECTIVES

After studying this unit you should be able to:

1. Describe how light waves interfere with each other when they are superimposed
2. Describe the types of interference
3. Identify the concept of coherence
4. Explain Polarization and its usefulness.

INDICATIVE CONTENT AND SUMMARY OF THE MAIN TOPICS

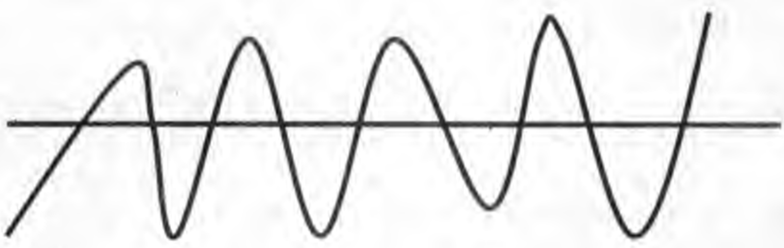
2.1 Interference

When two waves travel in the same direction , then if the crest and troughs of one wave coincide with the crest and troughs of the other wave, they will summate with each other and the resultant wave will have a greater amplitude. This is known as constructive interference.(fig 1)

If the crests of one wave coincide with the troughs of the other wave, they will cancel out each other. This is known as destructive interference (fig 2)

In other words, waves traveling in the same direction will have constructive interference when they are in phase and destructive interference when they are out of phase.

Wave No1.



Wave No 2.

Wave No 3.

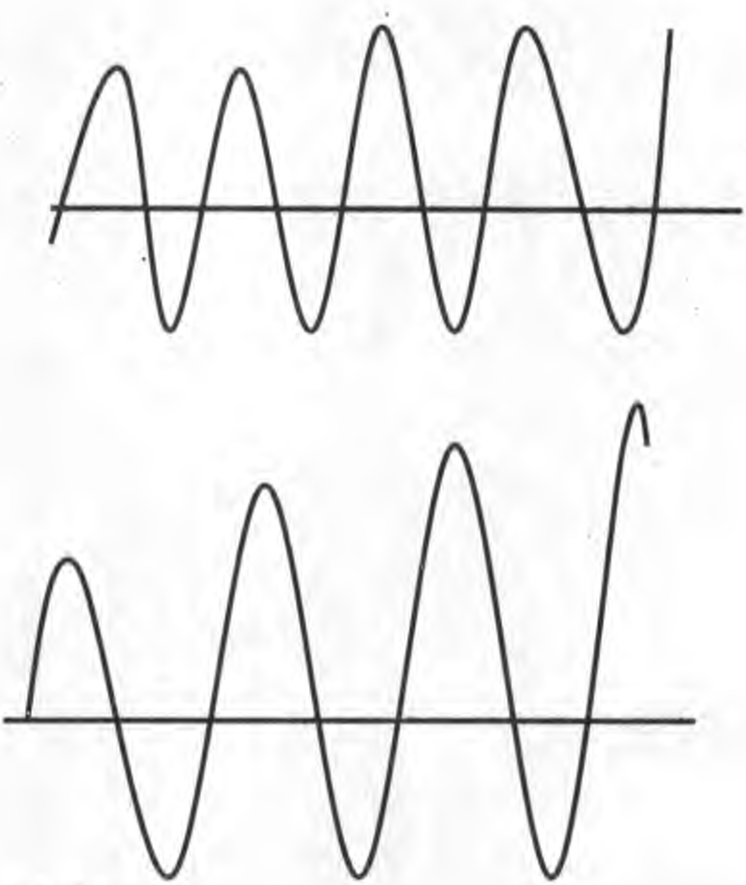


Fig 1. Constructive interference

2.2 Coherence

To be able to interfere with each other the waves should not only travel in the same direction but also should also have the same frequency and wave length. If we interfere two waves traveling in the same direction but having different wave lengths then at one point the crests may coincide with the trough of the other wave but after some distance the crest may coincide with the trough of the other wave. Therefore no consistent pattern of interference will develop.

Light waves are said to be coherent if they travel in the same direction and have got the same frequency and wavelength. They may be in or out of phase and therefore produce constructive or destructive interference. In other words coherence represents the ability to interfere with each other. (whether constructively or destructively)

Please note the mistake in some books that wrongly say that light is coherent when it is in phase and incoherent when it is out of phase.

2.3 Polarization

Any light wave has an electromagnetic field vibrating at right angles to the direction of propagation of the wave.

We can imagine a light wave coming out of this page and its field vibrating in a vertical direction, keeping an angle of 90 degrees to the direction of propagation of the wave. (fig.3)

We can also imagine another wave coming out of this page with its field vibrating horizontally and keeping an angle of 90 degrees to the direction of propagation of the wave. (fig 4)

Yet another wave can be imagined coming out of this page with its field vibrating in an oblique direction keeping 90 degrees angle to the direction of propagation of the wave. (fig 5)

Now imagine a whole beam of light consisting of innumerable waves, coming out of this page. As the field of the waves, comprising the bundle will vibrate in different directions, while still remaining at 90 degrees to the direction of propagation, we will have a picture represented in fig 6.

Fig. 3

Fig. 4

Fig. 5

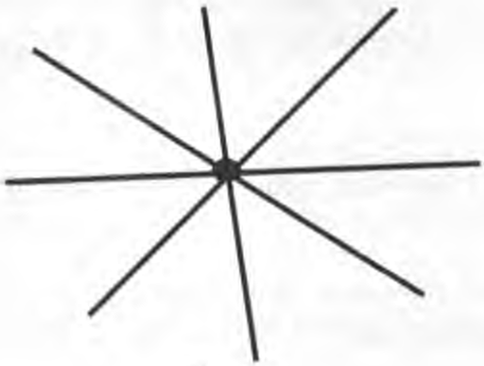


Fig. 6

Now suppose that we pass this beam through a filter which blocks all the other waves but allows only the waves whose fields are vibrating in a vertical direction (fig.7)

Fig 7

This is called polarization of light and the beam in fig 7 is vertically polarized beam. We can also produce a horizontally polarized beam or any other beam with a different direction of polarization. Obviously the beam in fig 6 will be known as non-polarized beam. We can use the process of polarization to reduce the glare and reflection while using various optical instruments as well as in making glasses.

RECOMMENDED READING LIST

PRESCRIBED READING

1. Notes in the study guide.

SUGGESTED READING

1. FRY, G.A. Ophthalmic optics. Philadelphia:Chilton.
2. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT QUESTIONS

Q. 1. Mark as True or False:

a. Interference is always constructive
b. Any light wave has an electromagnetic field
c. Light is coherent when it is in phase
d. Polarization of light is never helpful in ophthalmology

Q. 2. Describe the interference of light waves.

UNIT NO 3: DIFFRACTION, SCATTERING, REFLECTION, TRANSMISSION ABSORPTION AND ILLUMINATION

INTRODUCTION

When light waves travel and encounter certain surfaces or apertures they exhibit certain characteristics. This unit talks about these.

OBJECTIVES

After studying this unit you should be able to:

1. Describe how diffraction is produced and what is the effect of wavelength and the size of aperture on it.
2. Explain the scattering of light and its effect on vision.
3. Identify the factors determining the magnitude of reflection.
4. Determine the relationship between transmission and absorption.
5. Elaborate Illumination (illuminance) and its difference from luminance andcertain commonly recommended levels of luminance.

INDICATIVE CONTENT AND SUMMARY OF THE MAIN TOPICS

3.1 Diffraction

Light originating from a point source will travel in all directions in the form of certain wave fronts. After traveling for some distance these wave front will become less and less curved and will ultimately appear to be straight or plane wave front. (fig 8)

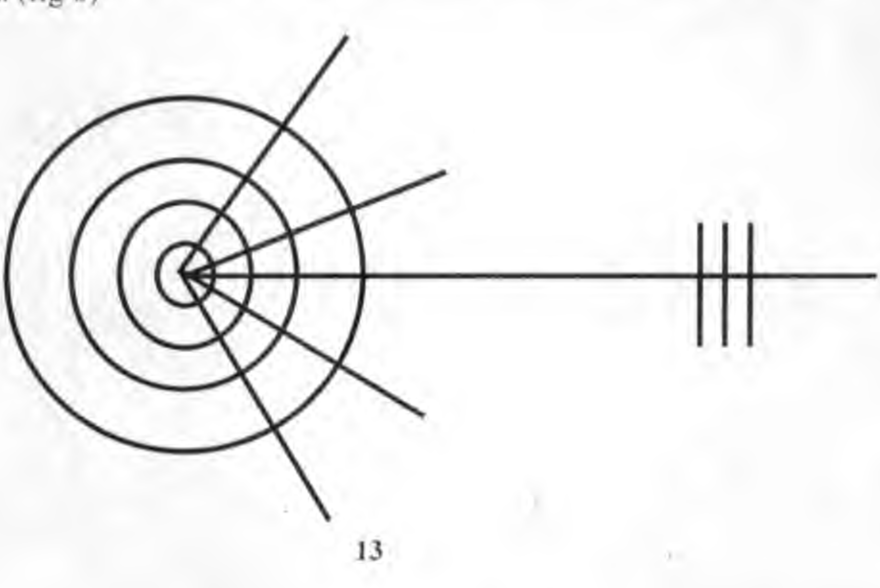


Fig. 8

Interestingly each point on these wave fronts is potentially capable of acting as a new point source, generating secondary wavelet, which spread out in all directions with circular wave fronts. This happens when the light encounters an obstruction such as the edge of an object or while passing through small apertures. This spreading out is known as diffraction.

In addition to generating secondary wave fronts, the aperture will also allow a portion of the original or primary wave front which will travel straight ahead. As these are in phase they will show constructive interference and will produce a central bright area. This is known as Airy disc. This is surrounded by alternating dark and light bands produced by destructive and constructive interference of the multiple secondary wavelets with their circular wave fronts as they interact with each other. (Fig 9)

Fig. 3.7 The diffraction of light.
Light brought to a focus does not come to a point, but gives rise to a blurred disc of light surrounded by several dark and light bands (the 'Airy disc'). (W. H. A. Fincham.)

Fig. 9

Certain features of diffraction should be remembered. The smaller the aperture the greater will be the diffraction. Diffraction is also greater for longer wavelengths so that red light is diffracted more than blue light.

3.2 Scattering

Scattering occurs when light encounters irregularities in its path, such as particles in a medium. Shorter wavelengths are scattered more and the sky appears blue because blue light from the sun is scattered more strongly than the other wavelengths.

Scattering of light in ocular tissues can result from a number of conditions much as corneal oedema, cataract or protein in the aqueous humor producing flare in the anterior chamber.

Scattering may interfere with vision in two ways. The scattered light which falls on the retina may reduce the contrast between the retinal image and the surrounding retina thereby obscuring the detail in the image. This is known as glare. The second effect is a reduction in the light available to form the image on the retina.

3.3 Reflection

The laws of reflection related to image formation will be discussed in the section on geometrical optics. Here we will mention the magnitude of reflection occurring at an interface between two media. This magnitude depends on the difference in index of refraction between the first and the second medium.

A glass with a refractive index of 1.5 in air will reflect about 4% of light (at normal incidence) from its anterior surface and will transmit 96% to its posterior surface. Further 4 % of this 96% (i.e. 3.84%) will be reflected at the posterior surface, so that a total of 7.84% is reflected and 92.16% is transmitted.

The air-cornea interface reflects about 2 % where as the cornea-aqueous interface reflects only about 0.02%.

Reflection from an interface also depends upon the angle of incidence (increases with angle of incidence) and reflectivity. Total reflection can occur when light is incident at an oblique angle from a medium of high index of refraction into a medium of lower index (total internal reflection) this will be further discussed in geometrical optics.

3.4 Transmission and absorption

Transmission and absorption are related to each other so that when light passes through a material, then the more this light is absorbed the less will be transmitted and vice versa.

Transmission is measured in terms of percent transmittance and absorption is usually measured as an optical density (OD). These are reciprocally related in a logarithmic manner, so that OD= log 1/T where T is the transmittance. OD of 1 means a transmittance of 10%, other values are:

OD	transmittance, T
2	.01 = 1%
3	.001 = 0.1 %

3.5 Illumination

The quantitative measurement of light is carried out in two different ways i.e. radiometry and photometry. These, along with the different units, will be explained in the relevant section. Over here a basic distinction must be made between illuminance and luminance as employed by and taught to as by illumination engineers.

Light incident on a surface is known as illuminance (incident and illuminance both start with I) light reflected or emitted by the surface (i.e; the light leaving the surface) is referred to as luminance (leaving and luminance both start with L).
We should be familiar with certain frequently recommended levels of illuminance (illumination) such as:

Office, kitchen	150 foot candles
Reading	70 foot candles
Wall	25 – 50 foot candles
Operating	2500 foot candles

RECOMMENDED READING LIST
PRESCRIBED READING

1. Notes in the study guide.

2. Duke Elder's. Physiological optics. Practice of refraction, 10^{th} edition, p 32.

SUGGESTED READING

1. FRY, G.A. Ophthalmic optics. Philadelphia:Chilton.

2. Tunnacliffe, A.H. and Hirst J.G.Optics, 2^{nd} edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT QUESTIONS

Q. 1. Mark as True or False:

a. The smaller the aperture, the greater will be the diffraction.
b. Scattering has no effect on vision.
c. Reflection from an interface depends on the angle of incidence.
d. Transmission and absorption of light are directly related.

Q. 2. Explain the phenomenon of illumination.

UNIT NO 4: THE SPECTRUM OF LIGHT AND LASERS

INTRODUCTION

Visible light is part of the larger electro magnetic spectrum. In this unit we will study this spectrum. We will also study certain fundamentals of laser light and will define certain units of measurement in the section on radiometry and photometry.

OBJECTIVES

After studying this unit you should be able to understand.

1. Define the basics of lasers and their properties.
2. Explain the light spectrum and its components.
3. Identify Certain units used in measurement of light and radiation.

INDICATIVE CONTENT AND SUMMARY OF THE MAIN TOPICS

4.1 Lasers (fundamentals)

Laser stands for light amplification by the stimulated emission of radiation.

As we know atoms contain electrons, which can exist at various energy levels. Normally most of the electrons exist in the lower energy levels. If we supply energy to these electrons in the form of photons, they will elevate to the higher energy levels. They are usually not stable at this higher level and spontaneously fall back to the lower level and during this process emit the photons of energy which they had absorbed. This is called spontaneous emission. Since different electrons will emit the photons at different times and in different direction, these will not be coherent and hence the energy produced during spontaneous emission remains weak.

Now consider the electrons which have already been elevated to higher energy levels if they are struck by photons whose wavelength is the same as the one which will be emitted by the electron, they will be knocked down to the lower level, but this time two photons will leave these electron – the one which is emitted by them and the one which strikes them. These two photons will be traveling in the same direction, will be of the same wavelength and will be in phase. As we can see this will be coherent and will be stronger than the spontaneous emission.

This is further strengthened by an arrangement in the laser tube in which two mirrors are placed at the ends of the tube and the distance between these mirrors is an exact multiple of the wavelength of the light produced. So that the light remains in phase when it is reflected and re- reflected and is made stronger and stronger. As we need this light to leave the system at some stage, one of the mirrors is made practically transparent, thereby allowing the light to come out of the system and be used as desired.

Laser light is monochromatic (i.e. of one wavelength) coherent in phase and collimated (parallel) and extremely strong as compared to ordinary light.
The following are lasers of ophthalmic interest.

Argon blue green laser
This emits a mixture of 488 nm wavelength (blue) and 514 nm (green) light. It is most commonly used for retinal photocoagulation in diabetic retinopathy and other vascular disorders and can also be used for laser trabeculosplasty in glaucoma.

The Nd – YAG Laser
The neodymium yttrium aluminum garnet (Nd- YAG) emits 106 nm infrared radiation and is used for posterior capsulotomy or peripheral iridotomy in glaucoma.

The diode laser
This emits a wavelength of 810 nm and can be used for retinal photocoagulation, cyclophotocoagulation (in glaucoma) and for neovascular membranes and tumours

The frequency doubled Nd - YAG laser
This emits a wavelength of 532 nm and has a similar action as argon laser for retinal photocoagulation.

The excimer Laser
This has a wavelength of 193 nm and is used for refractive and therapeutic corneal surgery.

4.2 Light spectrum
Visible light forms a very small part of electro magnetic spectrum and extends from 400nm to 780nm wavelength. The adjacent bands which are known as

ultraviolet and infrared radiation are also important as they have important pathological effects on the eye.

The ultraviolet waves are divided into:
UVC : 200 – 280 nm
UVB : 280 – 315 nm
UVA : 315 – 400 nm

The infrared radiation is divided into:
IRA : 780 – 1400 nm
IRB : 1400 – 3000nm
IRC : 3000 – 10000 nm

The cornea and sclera absorbs the UVB, UVC, IRB, IRC waves. The lens absorbs the UVA waves. The visible light and the IRA pass through the ocular media and fall on the retina. The visible light gives rise to sensation of vision whereas the infrared light may cause harmful effects.
The ultraviolet light may give rise to various degenerative processes much as pterygium, pinguecula, climatic dropt keratopathy, age related cataract and age related macular degeneration.

4.3 Radiometry and photometry

In radiometry, we measure the radiant energy in absolute terms from any part of the electromagnetic spectrum whereas in photometry we measure the energy from the visible part of the spectrum in term of the visual response it produces.

We basically make four types of the measurements in radiometry and photometry:-

1. When we measure the total amount of energy being emitted in all directions from the point source, then in radiometry we call it radiant flux and we measure it in Watts. In term of response of the eye (i.e. in photometry) we call it luminous flux and measure it in lumens. (Fig 10)

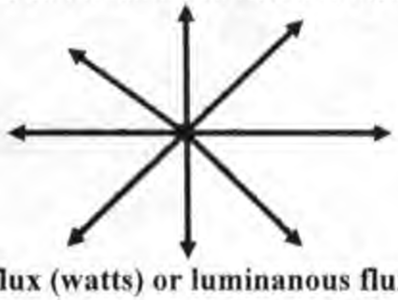


Fig 10: Radiant flux (watts) or luminanous flux (lumen)

2. If, instead of total energy, we measure the energy going in a particular direction, then we call it radiant intensity (in radiometry) or luminous intensity (in photometry). We measure this energy per unit of solid angle, which is known as Steradian. In radiometery we label it as watt per steradian and in photometery as lumen per steradian. One lumen per steradian is known as Candella. Fig (11)

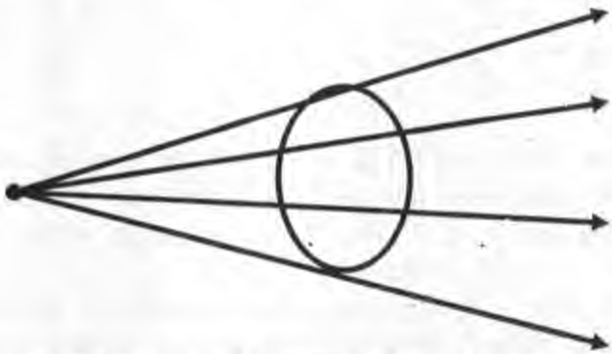


Fig. 11: Energy or light emitted per unit of solid angle.

3. When we measure energy or light falling or incident on a surface, we call it irradiance in radiometry and illuminance in photometry. In radiometry, we measure it as watt per square meter. In photometry, we can measure it as lumens per square meter or lumens per square foot. 1 lumen / sq meter is known as a lux and one lumens / sq foot as a foot candle. (Fig: 12)

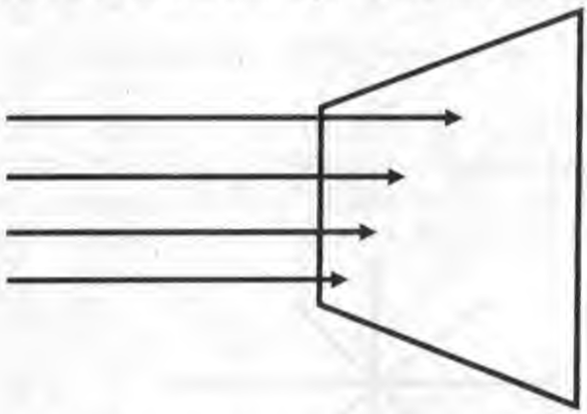


Fig. 12: Energy or light incident / unit area of a surface.

4. When energy or light is reflected or emitted from a surface then we call it radiance in radiometry and luminance in photometery. Here we measure

the amount per solid angle reflected or emitted by a unit area of the surface. In radiometery we measure it as watt / steradian / sq meter. In photometery we can measure it as lumens / steradian / sq meter or lumens / steradian / sq foot. As we have mentioned earlier lumens / steradian is also known as Candella. We can measure luminance as Candellas / sq meter or Candellas / sq foot. 1/∏ Candellas / sq miter is known as an apostilb and 1/∏ candilla / sq foot as a foot lambert. (Fig 13)

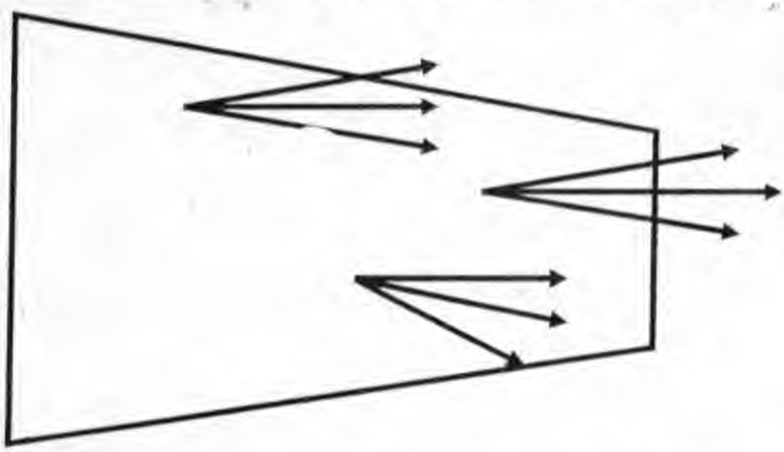


Fig. 13: Energy or light reflected or emitted per unit solid angle and per unit of surface area.

Please note that illuminance means the light incident on a surface (both illuminance and incident start with an I) and luminance means light leaving a surface, as by reflection on emission (both luminance and leaving start with L).

RECOMMENDED READING LIST

PRESCRIBED READING

1. Notes in the study guide.

2. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein.Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 35,36.

SUGGESTED READING

1. Bannett and Rabbetts. Astigmatism. Lasers in ophthalmology. Clinical visual optics. Third edition, p 312.

2. FRY, G.A. Ophthalmic optics. Philadelphia:Chilton.

3. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT EXERCISES

Q.1. Mark as True or False:

a. Argon Blue-Green Laser is most commonly used for retinal photocoagulation
b. The Nd-YAG Laser is used for posterior capsulotomy
c. The Excimer Laser is used for refractive and therapeutic corneal surgry
d. In radiometry we measure the absorbed energy from any part of the electromagnetic spectrum

Q.2. Define the following:

a. Steradian
b. Candella

UNIT 5: REFLECTION OF LIGHT

INTRODUCTION

Reflection is one of the important properties of light. Although it has been very briefly touched before, this unit focuses on it in detail.

OBJECTIVES

After studying this unit you should be able to:

1. Define what is reflection of light.
2. Explain the laws of reflection.
3. Elaborate how is light reflected from plane, spherical and parabolic mirrors.

INDICATIVE CONTENT

5.1 Reflection of light
5.2 Laws of reflection
5.3 Reflection from plane, spherical and parabolic mirrors

RECOMMENDED READING LIST
PRESCRIBED READING

1. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 41-43.

SUGGESTED READING

1. Bannett and Rabbetts. The eye's optical system. Clinical visual optics. Third edition, p 9.

2. FRY, G.A. Ophthalmic optics. Philadelphia: Chilton.

3. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT EXERCISES

Q 1. Mark as True or False:

-Regarding reflection of light:

a. It is the breaking up of the light into its spectral components
b. It is the rebounding of light
c. Mirrors illustrate this phenomena best
d. The angle of incidence sometimes is not equal to the angle of reflection

Q 2. Draw a diagram showing the reflection of light from a plane mirror.

UNIT 6: REFRACTION OF LIGHT

INTRODUCTION

Refraction of light or bending of light is a phenomena regarding light which is important to understand both for diagnostic as well as therapeutic aspects in ophthalmology. Therefore, this unit has been allocated to address its details.

OBJECTIVES

After studying this unit you should be able to:

1. Define Refraction of light, its laws and related terminology.
2. Explain Refraction from spherical lenses and prisms.
3. Identify Basic principle of fibreoptics

INDICATIVE CONTENT

6.1 Refraction of light, laws of refraction, refractive index, refraction at plane and spherical surfaces

6.2 Vergence and surface power, reduced Vergence and reduced thickness

6.3 Coaxial system of spherical lenses

6.4 Critical angle, total internal reflection and prisms, fibreoptics.

RECOMMENDED READING LIST

PRESCRIBED READING

1. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 43-49.

2. Duke Elder's. General optics. Practice of refraction, 10th edition, p 11-28.

SUGGESTED READING

1. Bannett and Rabbetts. The eye's optical system. Clinical visual optics. Third edition, p 8,9.

2. FRY, G.A. Ophthalmic optics. Philadelphia: Chilton.

3. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT QUESTIONS

1. Define Refraction of Light.
2. What are the basic principle of Fiberoptics?
3. How would you explain refraction from spherical lenses and prisms?

UNIT 7: TH'E LENSES

INTRODUCTION

Lenses are widely used in clinical ophthalmology in diagnostics and therapeutic procedures. It is therefore mandatory for a refractionist to have working knowledge to different types of lenses. We have already discussed many of the concepts in this regard. However, owing to their importance in refraction, this unit is all about the lenses.

OBJECTIVES

After studying this unit you should be able to:

1. Identify the types of lenses.
2. Graphically analyze lens systems.
3. Explain the relationship between lens shape, vertex and effective lens power.

INDICATIVE CONTENT

7.1 Lenses-types nomenclature

7.2 Graphic analysis of lens system

7.3 Lens shape and vertex Vs effective lens power

RECOMMENDED READING LIST
PRESCRIBED READING

1. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 43-49.

2. Duke Elder's. General optics. Practice of refraction, 10th edition, p 11-28.

SUGGESTED READING

1. Bannett and Rabbetts. The eye's optical system. Clinical visual optics. Third edition, p 8,9.

2. FRY, G.A. Ophthalmic optics. Philadelphia: Chilton.

3. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London:Association of British Dispensing Opticians.

SELF-ASSESSMENT QUESTIONS

1. What are the different types of lenses?
2. How would you explain the relationship between lens shape, vertex and effective lens power.

UNIT 8: MAGNIFICATION AND POWER OF LENSES

INTRODUCTION

We have already touched power of lenses. Here we will talk about it in further detail. Magnification of the images is a very useful property of the lenses specially regarding the management of low vision. This unit will discuss it as well.

OBJECTIVES

After studying this unit you should be able to:

1 Understand what is power of lenses and the relationship between the curvature of lenses and their power.

2 Have working knowledge of magnification of lenses.

INDICATIVE CONTENT

8.1 Magnification of lenses
8.2 Curvature, unit of curvature and effect on power of refracting surface

RECOMMENDED READING LIST

PRESCRIBED READING

1. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 45-51.

2. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Visual aids for the partially sighted. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 718-723.

3. Duke Elder's. General optics. Practice of refraction, 10th edition, p 22-28.

4. Duke Elder's. Objective methods of refraction. Practice of refraction, 10th edition, p 161-163.

5. Duke Elder's. Visual aids. Practice of refraction, 10th edition, p 270-280.

SUGGESTED READING

1. Bannett and Rabbetts. Spherical ametropia. Clinical visual optics. Third edition, p 64-66.

2. Bannett and Rabbetts. The eye's optical system. Clinical visual optics. Third edition, p 17.

3. Bannett and Rabbetts. Magnifying devices. Clinical visual optics. Third edition, p 247-250.

SELF-ASSESSMENT QUESTIONS

1. Describe relationship between curvature of lens and its power.
2. Define magnification.

UNIT 9: CYLINDER, SPHERE, TORIC SURFACES AND PRISMS

INTRODUCTION

So far, we have considered different types of surfaces and their optical behaviours. The knowledge however is somewhat scattered. Now we will talk about these in a more systematic way.

OBJECTIVES

After studying this unit you should be able to:

1. Differentiate what are cylinder, sphere and toric surfaces and prisms.
2. Define the relevant terminology.
3. Explain their optical properties.
4. Describe the optical system of an eye as a camera system.

INDICATIVE CONTENT

9.1 Cylinder, sphere and toric surface
9.2 Back and front vertex powers
9.3 Prisms
9.4 Eye and the camera

RECOMMENDED READING LIST
PRESCRIBED READING

1. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Physiology of the eye. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 26,27.

2. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Optics. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 43-51.

3. Harold A. Stein, Bernard J. Slatt,Raymond M. Stein. Understanding ophthalmic equipment. The Ophthalmic Assistant, A Guide for Ophthalmic Medical Personnel. Seventh Edition. p 179-180.

4. Duke Elder's. General optics. Practice of refraction, 10th edition, p 14-28.
5. Duke Elder's. Objective methods of refraction. Practice of refraction, 10th edition, p 161-162.

SUGGESTED READING

1. Bannett and Rabbetts. The eye's optical system. Clinical visual optics. Third edition, p 7.

2. FRY, G.A. Ophthalmic optics. Philadelphia: Chilton.

3. Tunnacliffe, A.H. and Hirst J.G.Optics, 2nd edition. London: Association of British Dispensing Opticians

SELF-ASSESSMENT QUESTION

1. Define spherical cylindrical and toric surfaces and prisms.
2. How does optics of eye resembles with the camera? Describe.