

hello ah welcome to this lecture module on optics ah i am mr chenoy from the department of physics at iit delhi in the following lectures we will discuss about optics optics which is which deals with the science and technology involving light propagation the level of discussion will be at an introductory level compatible with the higher secondary school and we will try to emphasize more on the basic concepts and i will also try to work out some examples try to show some demonstrations in the course of the lectures ah

so optics in this first lecture we will give a general introduction i will try to cover the scope of the course and give you a general idea which should motivate about the importance of optics the limitations of various approaches in optics and the various applications optics deals with the science and technology involving the propagation of light the range of phenomena or effects and practical applications are very wide from most common applications like spectacles for correction of vision many of us wear spectacles including large number of students for vision correction and to modern high speed optical fiber communication for transmission of multi gigabits of information and data optics plays an important role from natural phenomena such as formation of rainbows which i will discuss in one of the classes in the one of the subsequent lectures from natural phenomena such as formation of rainbows to the most recent discovery of gravitation base the detection of gravitation wheels which involves optics and optics plays a very important role there are three different approaches in the study of optics usually there are three different approaches which are followed and they are the ray optics approach wave optics approach and quantum optics approach sometimes people talk of intermediate other approaches like beam optics and electromagnetic optics and

so on but broadly there are three approaches namely ray optics approach wave optics approach and quantum optics approach to study optics optical phenomena effects and applications why is it necessary to follow different approaches we will try to answer this as we discuss further let me start first with ray optics in ray optics in ray optics propagation of light is represented by rays

so what is ray a ray is a light path along which the optical energy flows the direction of energy flow is indicated by the arrow sign typically we show for example this is an array a ray path the arrow indicates the direction of flow of energy optics deals with light a form of light is a form of energy and the arrow indicates the direction of flow of energy in a homogeneous medium that is a medium of uniform refractive index normally when we say homogeneous medium it means that the properties of the medium are the same everywhere at every spatial point every location in the medium the properties of the medium are the same and then we say that its a homogeneous medium

so in this case a medium of uniform refractive index then ray paths are straight line ray paths are straight lines as shown here

so obviously if i underlined this that ray paths are straight lines the question arises does this mean that there are curved ray paths the answer is yes we will discuss this in more detail ah as we go in subsequent lectures if the medium for example if the medium

so let me draw a medium here

so this is a medium if the refractive index at different points in this medium are different for example we may have a graded index media a graded index medium graded index medium media for example in this medium the refractive index may be maximum here in the center and goes on decreasing on both the sides that is if i plot here the refractive index variation

so along this line if i plot  $n$  and lets say this is the  $x$  direction and i am plotting  $n$  of  $x$  then refractive index is graded lets say it is continuously dropping like this in fact this is a one of the practical cases which we will

try to discuss at a later point of time but if the refractive index varies in a particular direction it is called a graded index medium its not a uniform index medium its a graded index medium in such cases ray paths can be curved for example a particular ray path may be like this a ray may travel in this fashion may not be a straight line it may be a curved path in a graded index medium the more discussions are not really in the purview of this course but we must know that ray paths are straight lines only in a uniform medium that is a medium with uniform refractive index now the propagation of a beam of light in ray optics the propagation of a beam of light can be represented by propagation of a bunch of rays a beam of light can be treated as a bunch of rays for example if if you take light from a battery torch a battery torch a battery torch like this we know that the light which is coming out from a battery torch

so i do not know whether you can see this or not but if i show this battery torch here the beam of light which is coming from a battery torch

so let us say this is

so light beam is coming then the output beam can be represented in terms of a bunch of rays the beam is of course diverging the output beam can be represented in terms of a bunch of rays rays travelling in different directions because the beam is diverging as it travels

so its like this

so the torch is here and if i switch on the beam travels in the forward direction but it is spreading as it travels similarly if we take for example a laser if i take a laser we know that laser beam are highly collimated highly directional still it can be represented by rays parallel rays there is a finite divergence even in the laser beam but in general they are highly cultivated and therefore the divergence is very small the spreading is very small

so we can represent it represent it by ray if i if we consider the sun for example we see this in various photographs or pictures that sun

so here is the sun then sun rays coming out in all directions

so sun rays are shown like this in the ray picture

so in the ray picture different sources

so this is a laser it's a torch light a battery torch light or a sun ray in fact i think i have a diagram which shows this very clearly

so bunch of rays from different sources a torch light a laser beam and a sunlight i have taken three typical sources and i will look at the representation the representation of a beam of light coming out when it is ray optics approach when we have wave optics approach and when we have quantum optics approach

so let us see further we can also trace rays through a medium for example tracing rays through a medium how can we trace rays through a medium a simple experiment which we had done many years before when i was a school student that we had an experiment where we had a glass block a glass block and we need to trace rays through this medium

so what is done is the experiment is quite simple

so you first draw a line around this glass block keep the glass block and draw its margins its periphery

so this is the periphery drawn by pencil then keep the glass block draw a line which represents an incoming ray keep two all pins pins here that is on a on a drawing board we clip two pins and then observe the image of these two pins from this side

so what would happen is that the ray if this were ray it enters from a rarer medium to a denser medium

so this is glass

so this is glass refractive index let us say 1.

5 and outside we have we will discuss this in more detail later but the ray will start bending towards the normal

so it will bend and it will come here of course we cannot see this

so the ray bends here at this interface it will bend again away from the normal away from the normal

so if you are observing from here that is if we observe this is the human eye

so this is the human eye

so if we are observing from this end here the block is kept here we are observing from here then we align ourselves such that the two all pins are along the same line and appear as one pin one post one post like this and in that direction we place the third pin here we take one more pin and place the fourth pin this ray is not there this ray is right now it is not there

so i place the fourth pin here

so that all four pins are aligned that is the two pin and the images of these two pin are aligned and look like one then connect these two points connect remove the pins and connect the points

so join a line

so this is array first we draw a ray draw a ray path a straight line place two pins here that is pin two two pins like this vertically and then keep the block observe from here and place a pin in a in a position such that it masks or it all the three pins that is the pin placed and its images look like one single pin place the fourth pin such that all four pins are aligned the two pins and the images of these two are aligned and then take out the pins and join this line here the point of intersect now we have the point of intersects let us say this is p and this is and join this with a straight line this is a glass block a uniform medium and what we have achieved is tracing gravity path through the medium now how do you know that this is correct this is correct because we also verify the snell's law the snell's law

so if we measure this angle here we measure the angle here we also measure the angle here and we measure the angle here

so this is the angle of incidence and

so this we will discuss in more detail at a later time this here is the angle of refraction r this is the angle of incidence and we verify the snell's law snell's law we will discuss this at a later time snell's law which says that  $\sin i \sin i$  by  $\sin r$  is equal to  $n_2$  by  $n_1$

so this is  $n_1$   $n_1$  and this is  $n_2$   $n_2$

so this is snell's law and what we do is we trace the rays measure the angle i here measure the angle r here and verify whether this relation is satisfied indeed we find that the relation gets satisfied within the limits of of course experimental error in fact snell's law is determined empirically using a similar phenomena is using a similar method of tracing rays through the medium however snell's law comes out analytically automatically in the case of wave optics

so in wave optics in wave optics snell's law comes out analytically is not an empirical or proposition snell's law comes out analytically analytically because in wave optics we treat light as an electromagnetic wave it has to it has to satisfy certain boundary conditions and when we apply the boundary conditions the snell's law comes out automatically and analytically in the case of

so that brings us to the next approach

so what i have briefly described is what is ray optics and we will discuss more about ray optics in the subsequent lectures

so that brings us to wave optics in wave optics in wave optics a beam of light comprises of large number of propagating waves a beam of light is represented is the same torch light now i have represented it by a large number of waves waves which are travelling emanating from the torch light

so this is the same beam earlier we represented these as rays now we are representing these as waves what type of waves are these these are electromagnetic waves electromagnetic waves

so those of you who have studied the chapter on electromagnetic waves you may be familiar with it but if you do not know i will briefly show what is an electromagnetic wave

so an electromagnetic wave

so here is an illustration of an electromagnetic wave a wave which is propagating in the z direction has electric and magnetic fields varying the electric field varies sinusoidally for example in the x direction electric field is varying oscillating sinusoidally

so what is shown is the arrow is the electric field electric field is a vector so with the time or with the position the electric field is oscillating sinusoidally and the magnetic field is perpendicular to it

so the electric field in this case in this diagram the electric field is in the x z plane it is oscillating in the x z plane whereas the magnetic field is oscillating in the y z plane that is in the horizontal plane here y z plane

so its perpendicular to each other at every point the electric field and magnetic field are perpendicular to each other this is this representation of electromagnetic field clearly tells you that it is a propagating wave with sinusoidal oscillations of the electric and magnetic field

so the electric field if you take the electric field for example it can be represented it is in the x direction

so i have written  $\hat{x}$  which is a unit vector in the x direction amplitude a of a certain amplitude a a maximum displacement maximum strength here of the electric field is a and  $\sin(\omega t - k z)$   $\omega$  is the angular frequency which can be written as  $2\pi f$   $f$  is the frequency into time minus  $k$   $k$  is the propagation constant which is given by  $2\pi/\lambda$  where  $\lambda$  is the wavelength of the oscillations

so  $2\pi/\lambda$  into  $z$

so if we take out  $k$  for example this  $2\pi/\lambda$  if we take out we will get here  $f$  into  $\lambda$  which is nothing but the velocity frequency into wavelength is velocity

so we can also write in the case of a light light propagating in the medium in free space this  $v$  is nothing but  $c$  the velocity of light

so  $\hat{x} a \sin(k v t - z)$  we can write this in different forms

so you can write the electromagnetic wave in different forms but the important point to see is it has an amplitude a certain velocity and a frequency wavelength frequency wavelength amplitude like typical of any wave

so light is an electromagnetic wave and in wave optics we deal with the electromagnetic waves

so if i were to represent if i were to represent the same three sources namely the torch light the laser and the sun how would i represent

so here it is

so i could represent it as here is the torch light light waves emanating from different sources earlier i represented it as straight lines coming out rays coming out now we represent it by waves a bunch of waves a bundle of waves which are coming out of the torch if you see more carefully i have drawn it in such a way that the laser light here the waves are coherent they are coherent waves coherent waves we will discuss about this when we when we come to wave optics we will discuss about coherent waves and incoherent waves in more detail but at the moment coherent waves here represent if the two waves which are shown here typically its not just two waves but i have shown two waves which are in phase everywhere or if there is a constant phase difference between the component

waves then we say that they are coherent waves in contrast what i have shown here are incoherent waves because there is no phase relationship between the two sinus between the component sinusoidal waves which are coming out of this this makes a lot of difference when we discuss interference in wave optics and i have illustrated here how would we represent the sun

so that is wave optics in quantum optics propagation of light

so this is the third approach this is the most advanced approach quantum optics is an advanced approach which is used or which is applicable which is practical in certain circumstances which i will discuss

so in quantum optics propagation of light is described in terms of propagation of large number of tiny particle like it is particle like its not particles

so tiny particle like packets of optical energy packets of optical energy called photons

so in quantum optics propagation of light is described in terms of propagation of large number of tiny particle like packets of optical energy called photons which travel with the speed of light the energy of a photon corresponds corresponding to light of a particular color or wavelength  $\lambda$  is given by  $e$  is equal to  $h c$  by  $\lambda$  which is equal to  $h \nu$   $\nu$  or  $f$   $\nu$  is the frequency or  $f$  is the frequency you can write  $h f$  or  $h \nu$   $h$  is called the planck's constant this is named after the scientist max planck  $h$  is the planck's constant

so  $e$  is equal to  $h \nu$  is the energy of a photon now before i proceed further if i i were to represent the same source torch laser and the sun in the quantum optics picture how would i represent is is just a schematic

so i would represent it as a bunch of photons emanating from different sources is the torch light

so bunch of photons the number are extremely large we will come to this the bunch of photons emanating from the torchlight laser again the bunch of photons but highly collimated almost aligned in a along a line and bunch of photons coming out of the sun the number really this is just a schematic illustration but the number of photons which are coming out are extremely large and really i cannot show it as discrete points because the number is

so large that it would look all pervasive everywhere it would look the whole whole region outside would look uniform with the photon energy or photon packets now what is the energy of a photon the energy of a photon corresponding to visible light let us get some idea what is the energy of this packet the photon

so energy of a photon is given by  $hc$  by  $\lambda$   $h$  is the planck's constant its value is 6.

6 into  $10$  power minus 34 joule second  $c$  is the velocity of light speed of light 3 into  $10$  power 8 meters per second  $\lambda$  if i consider for example say yellow light

so let me say  $\lambda$  is about 600 nanometers just to estimate what is the kind of energy that we have for a photon of yellow light

so you substitute here and what we get is  $e$  is equal to 3.

3

so 6 goes 1.

1 times multiplied by 3

so 3.

3 into  $10$  to the power of minus 19 joules that is an extremely small energy  $10$  to the power of minus 19 joules what does this mean this kind of energy what does it tell us it tells us if there are  $10$  power 19 photons where to be incident on a screen or a photo detector in one second it would correspond to a power of 3.

3 watts what is this

so i have energy  $e$  is equal to energy of one photon is 3.

3 into 10 power minus 19 joules if 10 power this is the energy if if there were 10 power 19 photons incident per second that is second inverse then we have this is equal to 3.

3 into joule second inverse joule second inverse is joule per second is what so this is nothing but watt so that's how i have written 3.

3 watt

so what is this this is the power energy per second is the power so the power is about 3.

3 watts when 10 to the power of 19 photons are incident per second on a photo detector let us say or on a screen then the power is approximately three to three point three watt this is the kind of power that we handle in practice in practice we have bulbs which are of 40 watt 60 watt a tube light which is of 40 watt an led lamp which is of 5 watt or 10 watt

so typically we handle light sources which are of the order of watts

so what does this mean if an led is of 5 watt it means it is giving of the or this is 3.

3 watt i have just calculated 3.

3 watt with 10 to the power of 19 photons incident per second

so an led of 5 watt or 3.

3 watt to be precise would give 10 to the power of 9 would emit 10 to the power of 19 photons per second the number of photons involved in the common power levels which we handle every day are extremely large or extremely large and therefore if we the numbers are

so large that it is it is beyond comprehension or beyond measurable limits this is the kind of numbers which you cannot measure but if the intensity were to be very low if the power were to be very low for example at extremely low powers let us say at extremely low powers 10 to the power of minus 15 watt or less the number of photons involved are in thousands and it is possible to count the number of photons incident on a photo detector at very low powers it is possible to count the number of photons incident on a detector and in fact these are there are commercial equipments commercial devices which are available which are called photon counters photon counters one can buy these photon counters

so these can count the number of photons incident per second when the power levels are extremely small if we push this a little forward if you reduce the power further then it is possible the power is

so small that the photons come almost one at a time the photons come out of the source one at a time

so these are called single photon sources they are not coming at a regular period they the output photons follow certain distributions and statistics and of course with applications single photon source this is the current advance in quantum optics with the applications this is beyond the scope of our course of lectures here

so we will stop this discussion about quantum optics here but the discussion with these three what do they bring out they bring out that quantum optics becomes extremely important and you can see the quantum nature of light that is you can count photons coming out of a source when the power levels involved are very small and the precision of measurement required is extremely small for example let me give you ah an idea that if we when do we use calculator for example e to multiply two and four two into four is eight we do not need a calculator but suppose i have to multiply 2.

387416 by another number say zero zero two four six two and i am expecting a answer with a precision of six decimals then i cannot do it i have to use a calculator when i need such level of precision i need a calculator to get up to

six decimals

so when the precision required is very high then i use a calculator or when the numbers involve

so it is up to fourth decimal sixth decimal that we have to measure or we have to calculate and then we need the help of a calculator otherwise we do not need a calculator if you have a simple quadratic equation where you can factorize the terms and get the roots directly you do not need a computer to calculate that but if the quadratic equation is complicated where you cannot get analytical solutions then you have to use a computer to solve it

so exactly like that practical effects phenomena and applications which can be dealt with ray optics or wave optics we do not need to go to quantum optics but there are applications as i mentioned for example the detection of gravitational waves i just mentioned detection of gravitation waves the variation in the optical power levels to be detected is extremely small and extremely precise and one has to go for quantum optical techniques to detect these gravitational waves

so the approach why do we need different approaches we use different approaches either when one of the approach is not applicable as i will show subsequently then we have to go for another approach which is more advanced which takes care of the limitations or when the precision required is

so high that one of the approaches or other approaches fail then we have to go for just as the example of a calculator need of a calculator or a need of a computer to take care or to or to calculate difficult calculations which are with high accuracy which we cannot do ah mental by our mental calculation or simple analytical solutions then we go for calculators exactly like that when the approach is necessary when the other approaches fail then we go to quantum optics approach and today quantum optics is extremely important with novel applications coming out all right with this i will proceed to recall some of the facts which already we know

so recall that light is an electromagnetic radiation very quickly we will recall most of these are familiar to you at your level and the visible light corresponds to a small spectrum a small portion of the spectrum of electromagnetic radiation

so what i have shown here is on the x axis the wavelength and different regions of the wavelength

so visible light is here between 400 nanometer for wavelengths corresponding to 400 nanometer to 750 nanometer is the visible region beyond below this we have the ultra violet region and of course if we go down further we go to the x ray region and gamma ray region with wavelengths which are of the order of angstroms the other hand if we go to the other other side here that is longer wavelength region we go to infrared and then millimeter waves microwaves and

so on

so electromagnetic radiation has a wide spectrum that is the range of wavelengths out of which visible light occupies a small band between 400 nanometer to 750 nanometer the first second we normally say that white light comprises of seven colors but there are no discrete seven colors

so it is actually a band of wavelengths with continuously varying shades from this end to that end continuously varying colors and shades from the violet end to the red end however

so just to identify a certain range of wavelengths we could call the wavelength from approximately 390 nanometer to 420 nanometers as violet region indigo region from 420 to 450 450 to 500 as the blue region 500 to 550 as the green region 550 to 600 as yellow 600 to 650 as orange and 650 to 750 as red i must emphasize that these are not hard boundaries these are just approximate boundaries to mark the commonly called seven colors which is denoted as vibgyor

violet indigo blue green yellow orange and red why do why is it important because if someone says i have given you blue light then i know that we are talking of wavelengths around 450 to 500 nanometers if it is yellow light we know that we are talking of approximately 550 to 600 nanometer region the very well known sodium lamp the sodium lines d one d two lines have a wavelength of about 583 nanometers

so that is the yellow line of sodium

so we know that it is the approximate range of wavelength corresponding to this that is why this range has been marked otherwise these are not hard and fast boundaries second the common light sources some of the common light sources the tungsten bulb the bulb which we have where a tungsten filament once these are broad spectrum broad wavelength range in fact this tungsten bulb gives you wavelengths from anywhere from 200 nanometer an incandescent bulb gives to 2000 nanometer to 2000 nanometer that is from uv to right up to infrared 2000 nanometer its a broadband spectrum the fluorescent tube again a broadband light source which looks white led bulbs the led bulbs used for domestic lighting they are again broadband sources which looks white and the leds which are used in instruments and various panels which may be red yellow blue different colored leds may have wavelengths as you can see the red wavelength is around 650 yellow is around this and blue is around 420 nanometer the laser the orange red laser the common laser which is the hini laser widely used hini laser which i am sure most of you have seen the common heany laser which is here

so here is the hini laser

so its the orange red color and that is 633 nanometer in fact its a precise wavelength 632.

8 nanometers is the wavelength of this laser the green laser which is also used widely in various applications ah pointers for example with the brighter outputs

so let me show the here

so this is at 532 nanometer its a laser at 532 nanometer

so the lasers are highly monochromatic sources of radiation and therefore

so 532 similarly you have blue lasers with the different range of colors about 430 to 450 nanometers

so these are some of the common light sources the second point is the speed of light in vacuum  $c_0$  is  $3 \times 10^8$  meters per second meter second inverse of course the precise value of  $c_0$  is about two point nine nine seven nine two four five eight into ten to the power of eight meter second inverse

so it is written up to

so many decimals not because some calculator gave this value today it is possible to measure precisely the velocity of light with this kind of precisions accurate to as many decimals it is possible to measure and that is why the precise value of  $c_0$  is given here in a material medium light travels at a slower speed which is given by  $c$  is equal to  $c_0$  by  $n$  where  $n$  is the refractive index of the medium therefore  $n$  is equal to  $c_0$  by  $c$  which is greater than one we know that  $n$  for example typically glass has refractive index of one point five water refractive index one point three three

so the refractive index is normally greater than one for practical media and therefore the velocity of light in a medium the speed of light in a medium is a slower is lower compared to the speed of light in vacuum

so speed of light in vacuum is the highest speed which is  $3 \times 10^8$  meters per second third the speed of light in any material medium depends on the wavelength

so some of these aspects we will discuss in detail in the subsequent lectures

so  $c$  is equal to  $c_0$  is identically equal to  $c_0$  of  $\lambda$  which means velocity of

light is a function of the wavelength this implies  $n$  is equal to  $c_0$  by  $c$  of  $\lambda$

so just now we had written  $n$  is equal to  $c_0$  by  $c$   
so here

so  $n$  is equal to  $c_0$  by  $c$  now i am saying in the medium  $c$  is a function of  $\lambda$  and therefore this implies that  $n$  is a function of  $\lambda$  that is refractive index is a function of  $\lambda$  the basic reason of this one has to go to the microscopic picture because then we can see that refractive index basically represents the response of the medium to the incoming electromagnetic radiation the response of the medium is a function of the wavelength and therefore the refractive index is a function of the wavelength

so this ah detail is not part of our level and therefore ah part of this course and therefore we i would not go into the into further details of this but we assume or we should note that  $n$  is a function of wavelength refractive index of an optical medium depends on the wavelength of light this leads to an important phenomena called dispersion this we will discuss in detail phenomena called dispersion where light of different wavelengths disperse in different directions so in this course therefore let me come to now specifically the coverage that we will have in this course module

so in this course we will discuss two approaches namely ray optics approach and wave optics approach in dealing with light

so in ray optics three important phenomena which is reflection of light we will discuss in detail reflection of light refraction of light and dispersion of light using the ray optics approach using the wave optics approach we will discuss again three important aspects namely interference of light diffraction of light and polarization of light i must mention here that reflection refraction and dispersion can be described using wave optics approach as well but the reverse is not true that is interference diffraction and polarization are concepts from wave optics these cannot be explained by ray optics

so wherever ray optics is applicable it is simple and we follow ray optics to discuss these three but these three phenomena or these three important aspects will be discussed using wave optics

so this also illustrates where with this we will also illustrate that where one approach is applicable over the other approach in some cases a particular approach is not applicable or one has to follow another approach to discuss the observed practical phenomena and to deal with the applications at this level of discussion we need a textbook as a backup and reference

so in this course module i will follow the textbook which is the physics a text book for class 12 by ncert new delhi

so ncert standing for national council of educational research and training

so we will follow this text book this has large number of worked out examples and large number of exercises and i would try to stick to the notation of this book there are as far as possible and we will try to follow this book and those of you who follow you can have this as a backup however i must say that there are large number of very good books extremely good books and i just want to list a few of them just at least a few of them some of the reference books

fundamentals of physics by halliday resnick and walker a very standard book this is by john wiley there are several additions similarly physics for scientists and engineers with modern physics by survey and basiner concepts of physics by h c verma a colleague and professor at iit kanpur a very widely used book this has two volumes volume one and two concepts of physics and for optics specifically for optics you could also follow this book by professor ajoy ghatak was a former professor at iit delhi i must again emphasize that there are large number of books very good books which are available but it is more important that one

should stick to one or two books and try to work out the examples and exercises given in these books rather than trying to follow large number of books before we ah proceed with our formal lectures on formal topics

so let me just discuss some about some optical components i would show some of the optical components for those who have not seen these components

so first a double convex lens

so let me i have just picked up some components which i have got i could lay hands quickly

so i just picked up some components

so let me show you these components

so first a biconvex lens

so here is a biconvex lens

so let me take out the biconvex layer i have one more biconvex lens

so two biconvex lenses

so let me show you this picot

so it is a biconvex lens which means if you see from the top it will look like a circle

so that is why front view or the top view is front view is like this but if i hold it like this

so so this is the top view if you are seeing from above

so you can see the bulge here and the bulge here

so that is why when we show like this what we are showing is the side view either from this side or from the top

so when we show a lens a bicon mix lens like this then we are looking at this from the top

so we can see the bulge here and the bulge here both the surfaces this surface here this is the surface upper surface and this is the lower surface

so both form parts of sphere they may be of the same radius of radius here the sphere of radius  $r_1$  and  $r_2$  with a center  $c_1$  and  $c_2$

so the radius may be same or they may be different but this is even a convex lens i hope you can see these surfaces here

so this is one surface and this is the second surface we can also see this clearly here that if i

so you see the magnified image of the grid

so you can see the magnified image of the grid through the lens or if i place on any one of these

so we can see that as i change the size of the the size of the letters look bigger if i another lens here

so i have another of different size there are different applications require lenses of different size and this is also a biconvex lens

so you can see the bulge on this side here and on the other side here

so this is also a biconvex lens this for those who have not seen there are a large number of different types of lenses

so we have a double convex lens we can have a double convex lens a plano convex lens

so different types of lenses are possible where both the surface are concave

so this is a double concave lens again each of these surface form part of the sphere of radius  $r_1$  and  $r_2$   $r_1$  may be equal to  $r_2$  there are others where one surface is plane and one surface is convex one surface is plane and one surface is convex or a combination of these lenses

so it is possible to have combination of these lenses

so why do we need such kind of different lenses we will see that depending on the application one may have to use one or more number of lenses and therefore you need ah different types of lenses for different applications i then come to

another optical component that is optical mirrors well this is what we will start from the next class optical mirrors and we can see that there are plane mirrors convex mirrors and concave mirrors

so the shaded region here tells that this is the opaque side the reflecting side is on the other side the back side here is coated with the reflection coating and therefore this is opaque but the front side is reflecting

so the shaded region marks the opaque side and the front side shows reflection and finally i will show prisms

so these are prisms

so let me show just one prism here

so this is a prism

so we could see it like this

so there is one surface here two surface these are the refracting surfaces and the third surface there are three refracting surfaces and the ends are ground surfaces which is called the base of the prism

so whenever we keep for example let me keep on this

so when we show a prism here and ray is passing through this what we are actually showing is a prism sitting like this a ray entering from this refracting surface and emanating from this refracting surface coming out from here

so we are showing a cross section of the actual figure there are of course different types of prisms retro reflecting prisms

so prisms which are reflecting

so you can see this is the ground surface and we have reflecting prisms here and we will discuss more about these as we proceed with the the course of lectures

so finally i would like to list some practical applications of these optical components looking mirrors the mirror the plane mirror that we see magnifying glass the lens that i had shown itself is a magnifying glass you can see this acts as a magnifying glass rear view mirrors in cars one uses convex mirrors spectacles all of us are familiar with spectacles which use both convex and concave mirrors camera cameras have large number of lenses the bigger ones the slrs and the bigger cameras but today of course almost every mobile has a camera a small lens there which gives us very good pictures and microscopes telescopes periscopes a number of instruments i would show microscope and telescope in one of the subsequent lectures and we will discuss about microscope and telescope in more detail we will also discuss the magnifying effects and magnifying power of a lens in subsequent lectures

so with this introduction i will stop here this first lecture on in the optics module and from the next class we will start with the first topic that is reflection of light thank you you