Virtual Reality
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Lecture - 7-3
Light and Optics (simple lenses)

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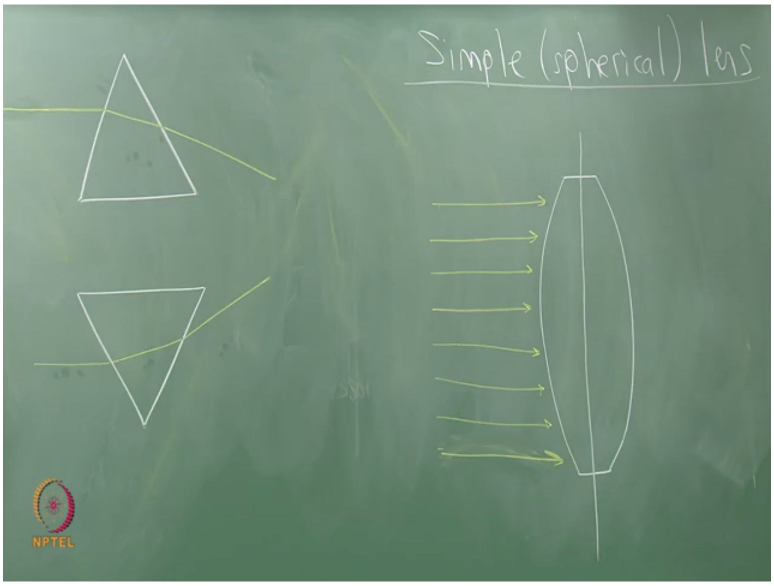

So, I can make a simple prism, I could have a ray of light coming in here try to make a look like as if it were the parallel case parallel rays case, if the row coming in horizontally, then I get some bending here and I get some more bending coming out again each one of these bends here is based on Snell's law which I just covered, I am not doing the exact algebra for this example on this drawing a kind of abstract picture and so, this is you know just a simple triangular shape; you can imagine that it just extends the same way in what we have been calling the z directions.

So, it is cylindrical in the z direction, if you like and has a triangular cross section. So, some kind of prism and I could make the upside down version of that may look something like this right. So, that is the behaviour of a single ray going through a prism where there is medium 1, then you go into medium 2, let us say and then you come back to medium 1. So, this is essentially the idea principle that is going to be applied in a continuous fashion across an entire lens.

So, if I make a simple spherical lens I get something like the following soon I am going to stop drawing pictures and switch to slides because it gets complicated to trace all visualize of light, but this will be one of the last pictures let us say that I try drawing myself. So, so these should be look like circular arcs and there is really another dimension to where these are spherical now.

So, these are spherical caps just like the way lenses look that you are familiar with whereas, this was supposed to be just the same outwards. So, there is no curvature I have my let us say I have a central axis for this kind of axis of symmetry and I have rays of light coming in and I am going assume this thing that I told you was fictitious which is there are parallel rays coming in and they are only fictitious if you live in a world with no mirrors or lenses. So, I guess we could have produced it through some other means, but if it came from a point light source then this is impossible, but a reasonable approximation.

So, we have these parallel rays coming in and when you think about the behaviour of these it is like when it comes in and when it comes out it is like having a slice of a prism right. So, that is a kind of thing to think about the slice of a prism and if these rays are coming in at a different angle then I guess it will be a different slice of a prism right. So, so it represents all of that somehow it is this prism bending effect, but manifesting itself in very localized ways depending on exactly what the curvature is here, right, this is not a curved surface.

So, you can predict what is going to happen all the way up and down its going to look the same, but because this is curved the bending is going to depend on where you are add along the curve of here.

So, as it goes through the lens we end up with let me draw another axis here which just should be the center of the lens I am not very good at straight lines today.

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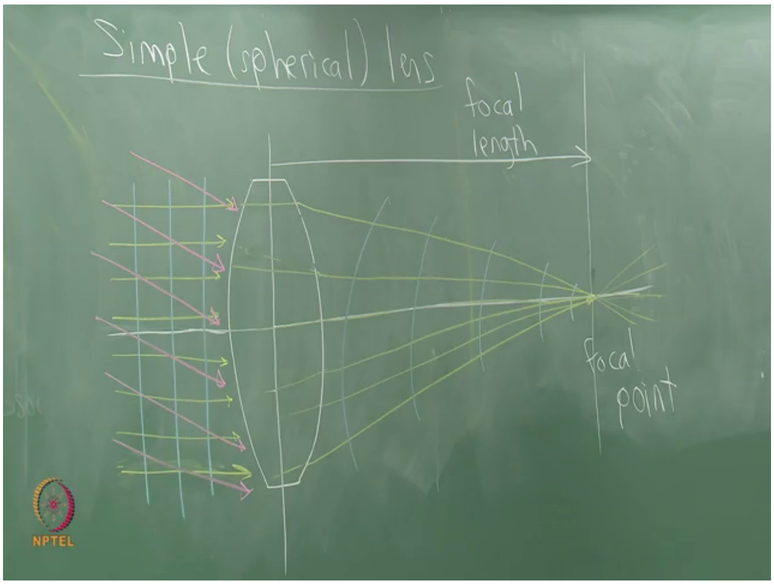

You ever have a bad straight line day you know also. So, so what is going to happen is in this lens is that we effect of refraction is going to cause these rays to bend inward to start to converge and if we make a simple spherical lens they will converge to a point somewhere.

Let me just invent the location of that here they will converge to some point and this point is called the focal point whenever you hear the term focal point remember that that corresponds to what the lens would do for parallel rays and I guess I have to start to draw what happens to these rays as they come through its going be very difficult for me, but let me do my best here, right. I am going draw all of them.

Of course, at the central part of the axis it just goes straight through without any bending right something like that guess I have to match these pictures a bit here oh I am not really sure I am probably not following the same rays, but get the idea of course, these come from somewhere inside the lens. So, do not think I have my arrows to the left matching exactly the ones to the to the right, but I think you understand the idea I will start providing some machine drawn pictures more correctly drawn pictures in just a bit.

So, that is the focal point that they all converge to and this distance here is called the focal length. So, that is how we think of a simple lens in this case as a kind of engineered device that takes parallel rays and makes them all converge to a point somewhere they do not stop at that point they keep going right. So, it could also continue onward they meet at that point, but there is nothing to stop them from continuing onward unless once you put something here what might you put here like a screen perhaps I do not know. So, if you put something here then the light will be focused on whatever you put here remember that there is an interpretation in terms of waves draw the waves in blue here. So, we had parallel waves coming in and now after they get through here they are getting curved in some way, right. So, that is another way to look at it is when the rays are being forced to converge through the lens you are introducing curvature now to the wave fronts.

So, if you were going to play everything in reverse this starts to look like a point light source and the waves are propagating out like this now is it not that interesting. So, you get this strange effect, all right. One more (Refer Time: 07:22) afraid to draw the picture let me see if I can just superimpose it on this; let us suppose I have rays coming in at an angle, but they are still parallel rays. So, let me let me draw rays coming in at some angle I realized is getting pretty cluttered now.

So, I just want to point out that just because they are parallel rays it does not mean that they come in perpendicularly, right, the rays are parallel, but they could be coming in at an angle because it could have I could imagine that there is this light source that is off at infinity, but it could be up really high right. So, if I am sitting out here in the open air theatre watching a big watching a movie on the big screen I could be and imagine that screen is gigantic and its really far away maybe it is 10 kilometers away and its enormous and it is a clear day and I can watch the movie like that there is still going to be the top part the rays are going come in they are almost parallel, but they are going be coming in at an angle, right.

So, in this case for an ideal spherical lens they will still converge, but they will converge somewhere else along this line. So, there may be these rays coming in to correspond to some distant feature or object the wave front has spread out. So, much that the curvature has as the curvature has turned out the radius turned out to be essentially infinity. So, that is when we have these parallel wave fronts coming in we have straight lines which is we have parallel lines which is represented by the pink here.

So, that everything comes in and we end up with the focal point being I am just going to draw in some arbitrary place down here somewhere the important thing to know you know is that they converge and they converge to another place along what is called the focal plane, right you know I think when I was talking about curvature going up and down; let us see curvature 0 means what straight line, but the radius of curvature would be infinite there, right.

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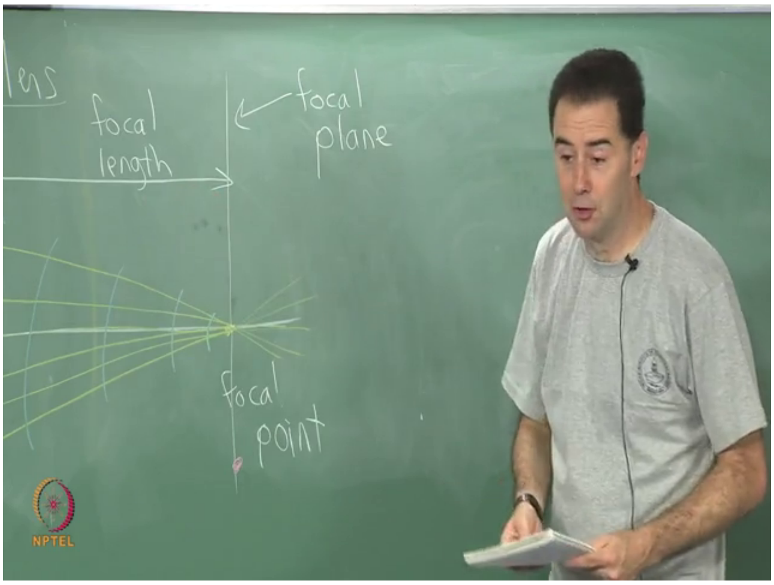

So, I got to be very careful I think it is part of the confusion in my speech, just a little bit ago I think that. So, I wanted to say that the curvature of the wave front is approaching 0, but the radius of curvature would be approaching infinity. So, make sure I have said the right things at different times or system there is those 2 are inverses of each other even though the names are very similar, all right.

So, there are simple formulas for determining the focal length of a simple spherical lens.

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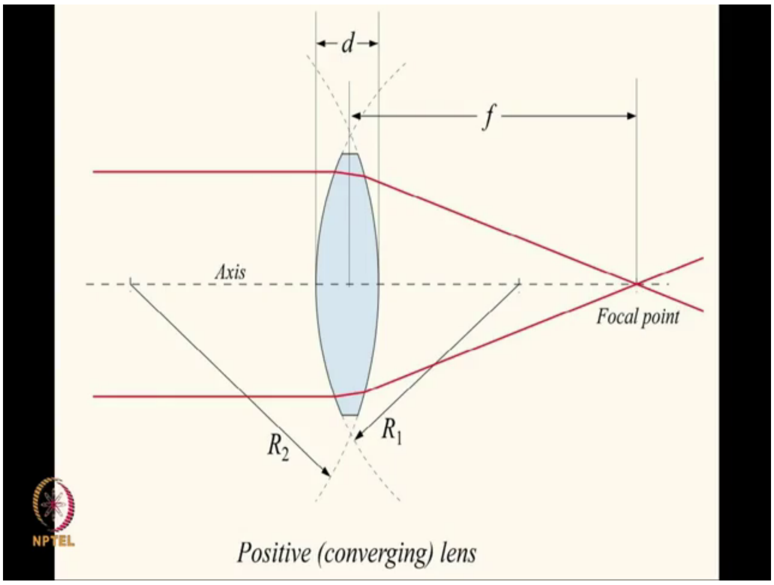

And so, I want to go into some pictures of that explain some optical properties and things will go back and forth between the board and some pictures. So, this should correspond pretty closely to the picture that I have drawn and oops do not do that notice that we have the focal length as I have drawn it there is also a thickness of the lens d here and note that we have 2 different radii.

R 1 and R 2 that correspond to the curvature of the; one of them corresponds to the place where the light first hits which it looks like R 2 in this case and then there is R 1 (Refer Time: 10:37) sorry, sorry, hold on; the R 1 corresponds to a circular disc and that is the place where the light first hits and then R 2 corresponds to the place where the light hits second, but note that the center of the circle is before the light hits for the second circle and its after for the first circle. So, to determine the focal point we have the following the lens maker's equation.

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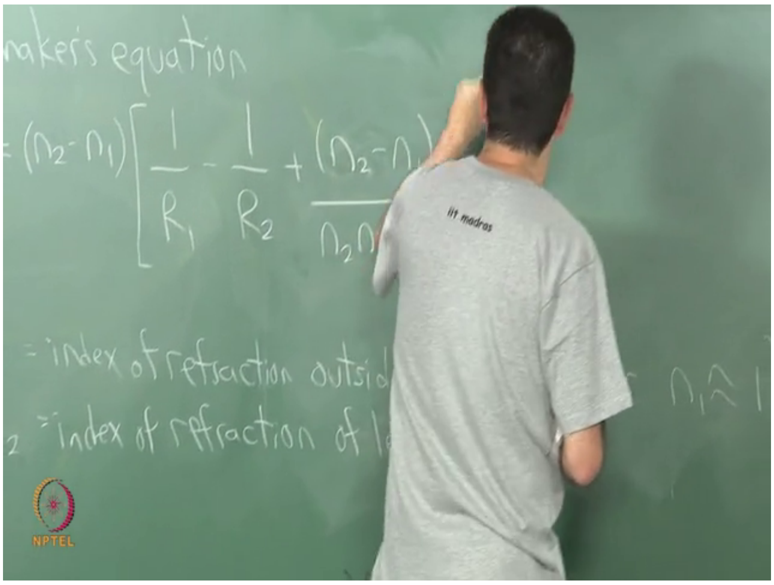

So, one over the focal length is equal to let us say n 2 minus n 1, I am writing in a little more general form that I have in my notes here, but it should be 1 over R 1 minus 1 over R 2 plus n minus 1 nope ha, this is the place where I am doing it a little more generally n 2 minus n 1 d divided by n 2 n 1 R 1 R 2 and then for see n 1 is the index of refraction; let us say outside of the lens make it very clear the ambient the air outside of the lens. So, outside the lens usually we mean air and usually n 1 is approximately equal to 1.

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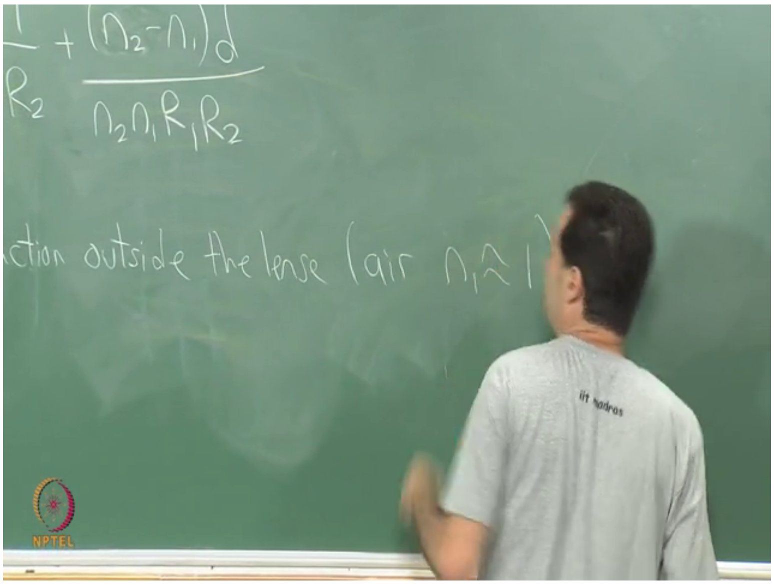

But you can put your lenses under water and it will do something different right behave in a different way.

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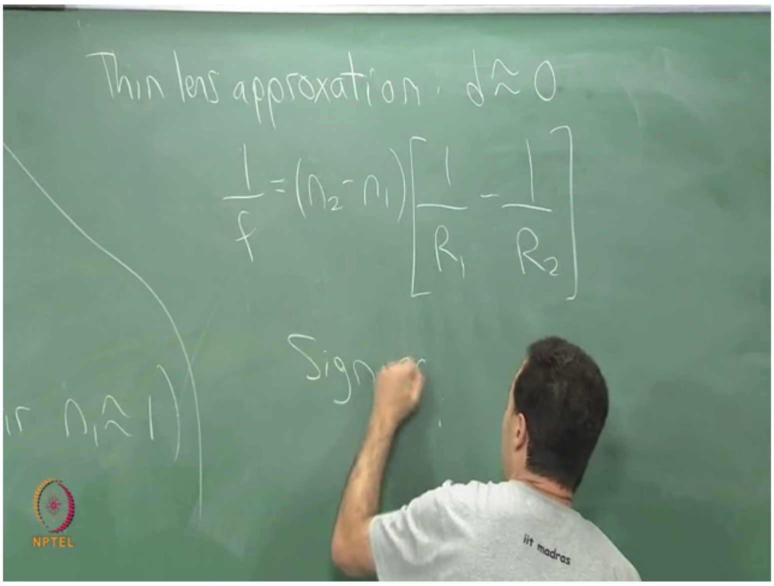

So, this is the index of refraction for the lens material there is a simple approximation that is often used to this and I will write that here it is called the thin lens approximation this is much more common now after this approximation where we get rid of this d parameter. So, here we say d is approximately equal to 0 in which case the lens maker's equation simplifies to 1 over f equals n 2 minus n 1.

So, it is the difference in refractive indices 1 over R 1 minus 1 over R 2 and there is a peculiar sign convention that is used for these r. So, normally when you are right R in this kind of geometric picture that we have on the on the display here in ordinary geometry the R is would always be positive; however, there is a convention here which is for a converging lens which we have just made we have a sign convention which is that R 1 is greater than 0 and R 2 is less than 0.

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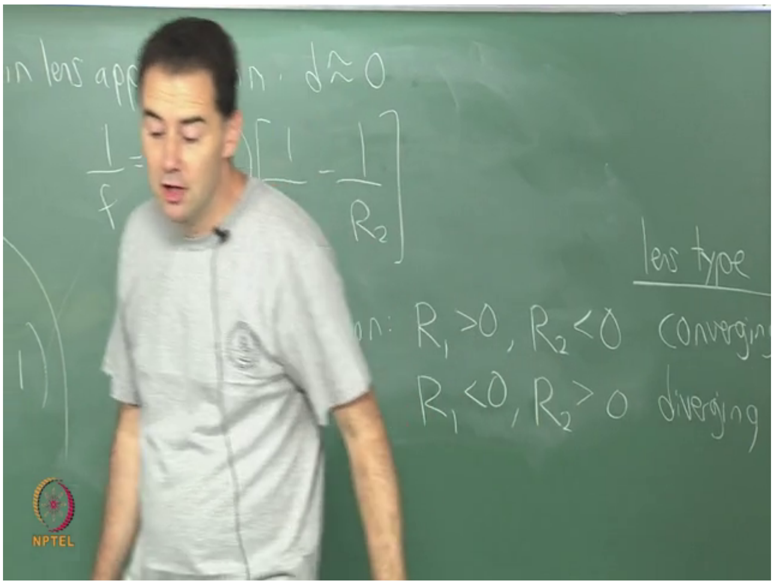

So, this is for a converging lens I upper lens type here that is only kind I have shown you. So, far for a converging lens one way to remember that is that the R 1 case is positive because you hit the surface that that circle corresponds to before you hit the center of the circle and the R 2 cases backwards is you hit the rays of light that are coming into the lens have hit the center of the circle before they actually hit the surface. So, in other words, R 1 corresponds to the case of a front side which is an entrance and R 2 corresponds to the case of an exit. So, so these are these are for the converging lenses, it ends up giving you these signs.

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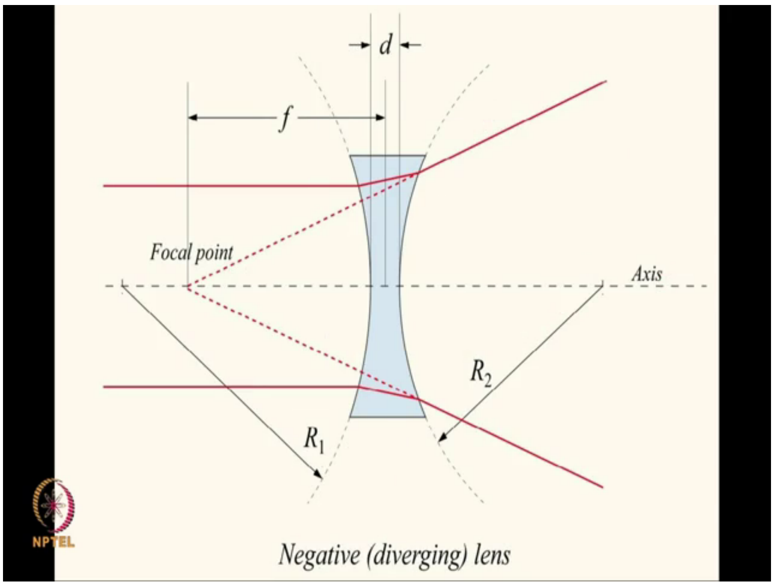

So, there is also diverging lenses if you seen optics before it should not be surprising. So, there is a diverging case where we can make rays of light instead of converging spread apart and I will just mention the sign convention in this case. So, R 1 in this case is less than 0 and R 2 is greater than 0 and so, you can directly apply the lens maker's equation in the original form and in the thin lens approximation to determine the focal point.

However notice that if its diverging it seems like it should not even make sense to talk about a focal point I have parallel rays coming in and then they diverge, but you can trace them backwards that is what these dash lines correspond to too to give a kind of let us say fictitious focal point right. So, because once these rays spray up spread apart they will still all point backwards if you reverse their direction to a common point. So, that is called the focal points of a diverging lens.

So, so the diverging lens does not cause focus to happen it is the opposite of that, but you can just reverse the direction we are on everything backwards and to the left of the lens you end up with the focal point right questions about that I want to let us see I want to now talk about a very useful representation called diopter which becomes very handy when combining lenses talking about optical power and then I will give an example of it in terms of the human eye human eye is going to be important because it is part of the virtual reality system.