Virtual Reality
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Lecture - 7-4
Light and Optics (diopters)

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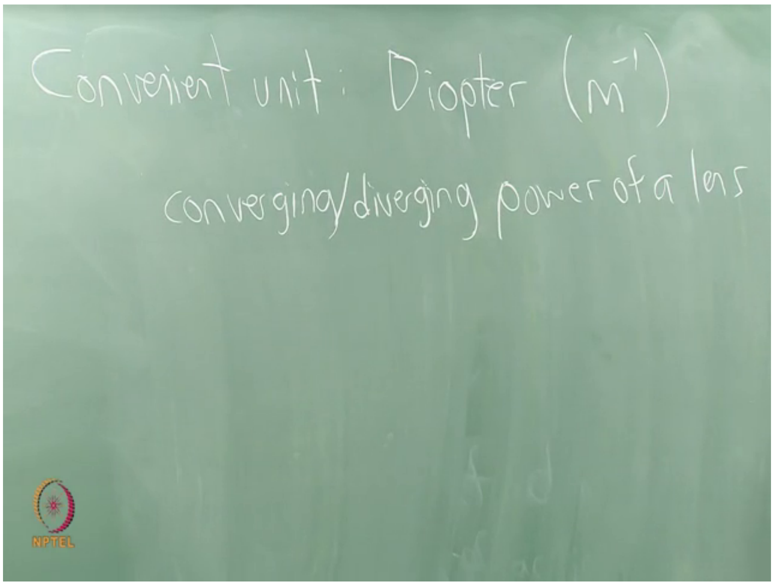

So, this is a convenient unit is called the diopter, it is units are 1 over m. So, 1 over meters is the unit of diopters, and what it tells you is the converging, it can also express diverging power of a lens. So, how hard does this lens work to bend rays and in which direction.

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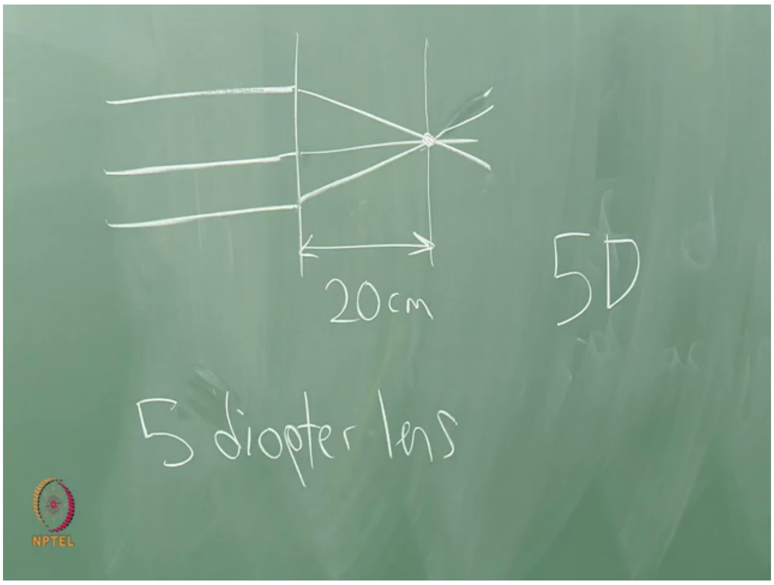

So, if I have parallel rays coming in, and I have let us say a really thin lens here that is. So, thin that I am not going to draw it and then these rays converge, to some point here that is supposed to meet, let us suppose this distance this is a simple example let me write 20 centimeters. So, the focal length is 20 centimeters the diopter is just going to be the inverse of that. So, it is just 1 over f. So, in this simple example we would have a 5 diopter lens which we write as 5 capital D.

So, this is a 5 diopter lens 5 diopter lens.

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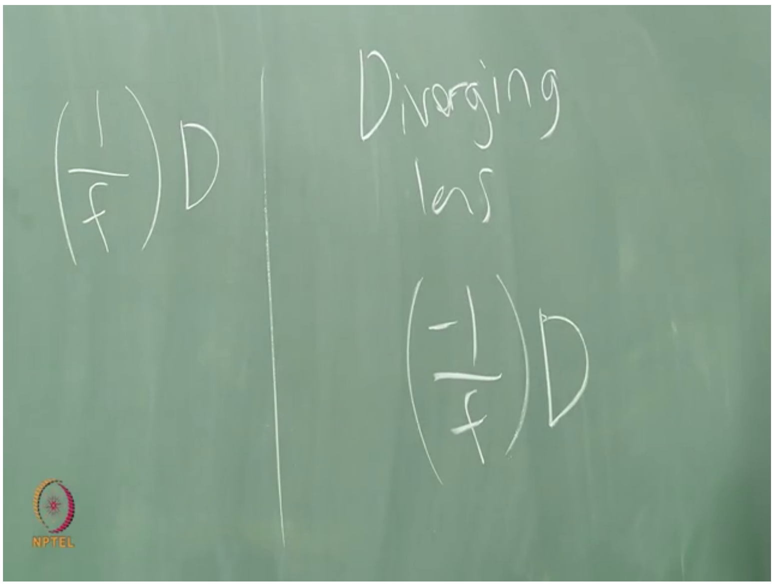

So, in general we write 1 over focal length D diopter. So, you can think of it as if I were to perform this operation over, and over again I took parallel rays converge into a point and then start with parallel rays again and conversion to a point, this tells me how many times in a row I could keep converging parallel rays inside of a meter right one way to look at it I do not know that is helpful or not I find it helpful.

So, it gives me you know the higher this number is the more times I could converge parallel rays in a small amount of space inside of one meter, let us say right and if this is less than one what is that mean if it is between 0 and one let us say between 0 and one not including 0 what would that mean, it is going to take a more than a meter to converge those rays. So, they may eventually converge, but it will take a while and if it is equal to 0 what does it mean. So, the lens should look like a flat piece of glass, such as keeps the rays all the parallel rays all go through and continue on their merry way without being affected, right if we have the case of a diverging lens.

So, for a diverging lens, we get negative 1 over f diopters. So, you can just write a negative number. And so, that will correspond to the amount of divergence and if you remember this picture here.

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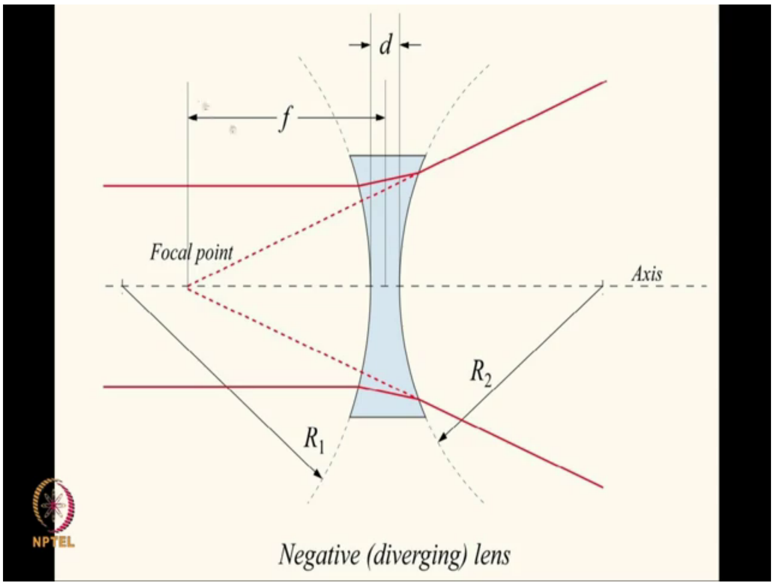

So, I guess in this case the focal point would be written as this f here is written, as a positive number and then you make it negative therefore, die after we could have instead made this assigned number and said f is negative for diverging lens is just a convention.

And so, as you see the stronger the divergent power of this lens, the closer the focal point will be to the center of the lens correct to the central axis of the lens here. So, and so, that makes good sense right. So, if you had a diverging lens of negative 100 diopters where would this focal point d.

Student: (Refer Time: 04:22).

We had like one centimeter away I think from the left side of the lens right assuming this thing has 0 thickness, and does not get in the way of the lens itself right.

So, there is one very nice property about using diopters, and this is why optometrists prefer to it to use it, those of you who have prescription glasses may have heard a lot of discussion about diopters and such in correcting your vision.

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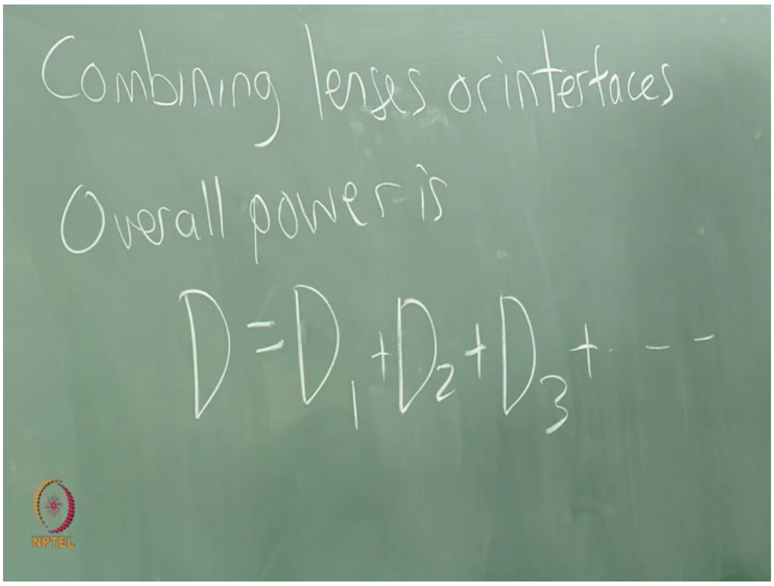

And what is nice is that in combining lenses, or interfaces also interfaces between media, the overall power is D equals D 1 plus, D 2 plus, D 3 plus dot, dot. So, you just take the diopter of your lenses that are all together sequentially in a system and just add them up. So, that makes the algebra very simple. So, an optometrist does not have to pull out a calculator do some very complicated calculations and algebra and all these kinds of things right by, calculating 1 over and then adding and then pulling it 1 over again. So, using diopter just makes it very easy to reason about the power of a sequence of lenses that are arranged in space, and it will work even if they are combining converging and diverging lenses.

So, I think that is very nice right. So, so. So, once you have done this 1 over f conversion or minus 1 over f conversion in the diverging case, then you just add up these D values and it ends up being very nice. Questions about that let me talk a little bit about the structure of the human eye, and I will tell you what the diopter of the human eye is anybody know the diopter of the human eye, anybody want to guess.

Students: (Refer Time: 06:22) forty.

Forty.

Student: forty body.

Forty good right. So, be the a diameter of the eyeball is around 20 millimeters so; that means, the focal length should be around that roughly, and if the focal length is around that, then maybe some ballpark estimate would be 1 over the focal length which would be about 50, right then interesting, because you have parallel light rays coming in let us say, and you have to focus them on the retina. So, let us look at this picture.

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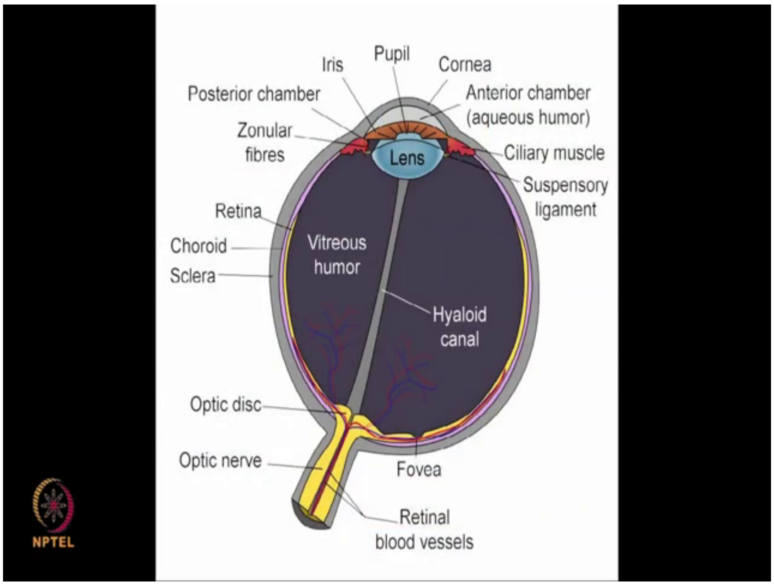

Kind of hoping this one would be looking to the side like our eyes normally do, but this is an eyeball looking straight up. So, so the lights coming in from the top the rays of light pass into the cornea, then there is this liquid area here, you may feel sometimes like your eyes are dried out especially if you are dehydrated. So, the aqua assumer co corresponds to a liquid area where the liquid is very frequently refreshed, for cleaning purposes let us say, and in through your pupil the light goes you have a lens which is called the lens, this lens is controllable so, you have muscles that can squeeze this lens or contract the lens, and that will change it is diopter, and then that will change the diopter of the entire system, if you are older this happens roughly in peoples late forties on average, then the ability to change the shape of this lens will start to deteriorate, which is why older people have reading glasses. And so, so you have automatic high-powered reading glasses built into your eyes if you are young and eventually you will lose that. So, sorry that is that is the way it works.

So, the light comes in, and then it eventually hits the retina it has to travel through this other liquid here called the vitreous humour, nothing funny about it, but it is it is humor as the kind of liquid I think environment, and it hits the retina notice how the retina is curved all the way around like this. So, that is different from projection screens or camera imaging systems that we tend to make, because things in engineering I said it is before engineering we tend to like rectangles flat surfaces and things like that, I know people are getting wild with curved screens now, and you know in the industry.

And so, they are they are trying to break out of the mold, but I am just notice that the images that are projected onto our retina, are actually being projected onto a curved screen, but it is the entire optical system is designed for that, and the part of greatest concentration where we can receive the most information and the highest density is at the fovea, because of that we end up rotating our eyes very frequently, there is some other reasons why we rotate our eyes and I am going to get into these kinds of details, but I just wanted to point out that while I am talking about focal lengths and focal planes, and I will be talking about images forming, keep in mind that your eye is an optical system, now let me say a couple of things about it is optical power, and then I will talk a bit about image formation probably after the break.

So, if we look at this top part again, we have light coming in through the cornea, travels through this aqueous humor, goes through this hole which is the pupil then traverses the lens then traverses the vitreous humor. So, it looks like there are 5 different materials that are relevant here, let me try to draw a picture of that (Refer Time: 09:53).

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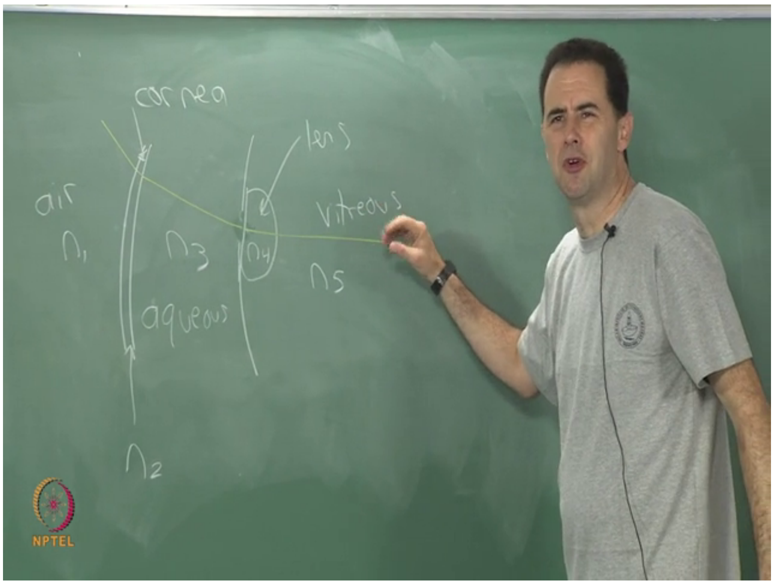

So, we have we have the cornea we have out here air, assuming you are swimming underwater while we were talking about this, which will of course, affect your vision then we have the aqueous, then we have there is the pupil where the light comes in, and then there is a lens on the back side here. So, this is the lens. So, the rays of light that are coming in, I do not pretty sure I can not draw the bending correctly here, comes in like that let us say right, and eventually has to go back and hit I guess I have drawn an enormous eyeball here. So, it has to hit the retina back here somewhere, right.

So, let us look at the refractive indices of these various materials. So, there is air out here, but I will call n1, I have n 2 for the cornea, I have n 3 in the aqueous, I have n 4 for the lens, and I have n 5 for the vitreous, which is a it is also kind of liquid or more like gelatinous let us say material. So, so what is interesting as well is that once the light hits the cornea, it never really sees air again right it goes through all this liquid gelatinous stuff and then ends up on your retina, which I find kind of interesting right. So, it is not like the optical systems that we build an engineering.

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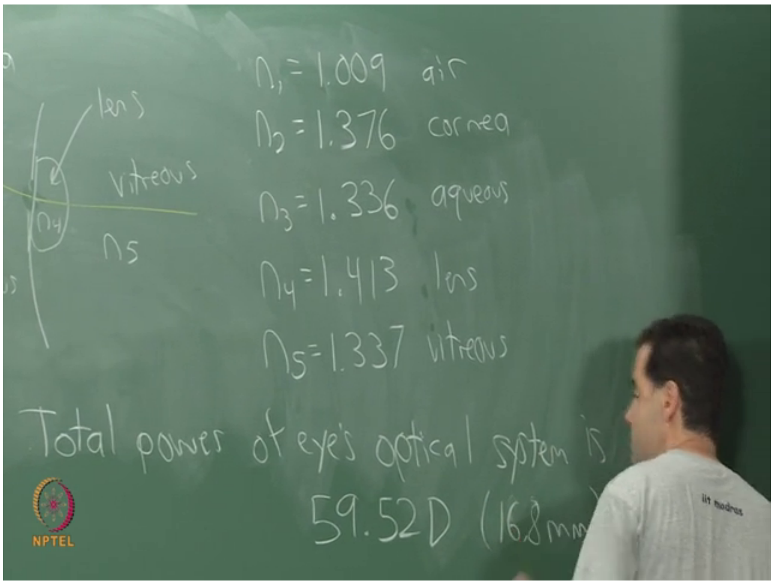

So, here there are the refractive indices, air is well about 1, when I look up these numbers it was 1.009, I am sure it depends on things like altitude and humidity and other things, but I am no expert on that, n 2 the cornea is 1.376, n3 the aqueous or oracular fluid is 1.336. So, not too different. So, there is not too much of a change going from the cornea to the aqueous, n 4 lens 1.4. So, a little more significant change there, and then vitreous is similar to the aqueous. So, n 5 is 1.337, who knows what the precision is here is essentially the same I think. So, air, cornea, aqueous, lens and vitreous, notice where the biggest transition occurs where is that.

Student: (Refer Time: 13:00).

So, air to cornea. So, actually the optical power, the convergence power that is greatest in your optical system is at the cornea. So, your cornea is doing more work to bend light, than any of the rest of these including the lens, which I find quite amazing. So, that is surprise that that surprises me and I remember emphasizing this over and over again to my students before, in in teaching this class and they still get it wrong on the test every time. So, be careful the cornea is the place where the greatest bending power happens the greatest amount of refraction happens in the eyes optical system.

So, if you combine all of these if you go through and do the math which I am not doing here, the total power of the eyes optical system is 59.52 diopters it corresponds to a focal length of 16.8 millimetres. So, that is quite a powerful lens, when you combine it all together that is quite a powerful lens right, it has to severely bend the rays if I just go and buy some lenses online somewhere, you know which I have a set of lenses here if you want to play during the break by the way, it is go buy some standard lenses chances are they are not so highly curved as to achieve nearly 60 diopters, right. So, the optical system that we have in our eyes is very, very powerful any questions.