Virtual Reality
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Lecture – 7-2
Light and Optics (refraction)

So, now let us take these rays or wave fronts or particles and have them interact with another material alright. So, they start off by propagating either in a vacuum or through air, which we might consider to be almost like a vacuum, and then let us think about what happens when we when the waves interact with some kind of medium, they hit a medium that is different.

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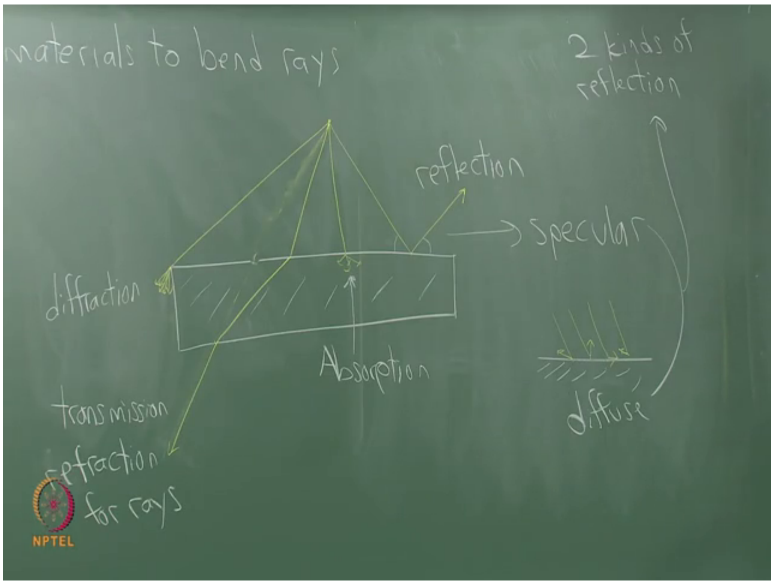

So, what is going to happen essentially is that we use materials to bend rays or alter the wave fronts if you like because they are; obviously, very closely intertwined. So, I take some kind of material let us see we just draw rectangular block of material. So, if some kind of material and then we start up here and we send our light rays on their way and let us talk about the different things that can happen.

So, I am going to mention four different cases, one of them is that light comes around here to the corner, and then starts to bend around the corner what is that called its one diffraction, right. So, here is another case and this one will be the most important for optical systems, the light comes along, then it is course is bent in some way say maybe I will draw like this and then back out. So, hopefully that looked like it was bending maybe I did not put it enough bend into it, it should not look like it is going straight through make it a little more let me do the whole thing over again I am going to go here put some obvious bend into it, and come out like that. So, we have some kind of bending going on this is the case of transmission of the light through the material through the medium.

So, this is transmission and the bending of the rays is called refraction, refraction of the rays. Another thing that can happen the light could come into the material and just kind of and let us say the light comes in the material and never comes out again. So, just absorption so, the light is lost forever probably the material would heat up then right heat is usually the ultimate place where energy gets a kind of lost or the final form for it let us say. So, this part is called absorption, it is something important to keep in mind the more the more materials the thicker they are the more materials you put into your optical system, the more you will be just losing some light right, what case remains what else can happen to the light reflects away, right.

So, if this surface happened to be a shiny mirror then we get reflection. So, comes down like this angle of incidence should be equal to the angle of reflection alright. So, this angle and this angle are should be the same and off the ray goes. So, this is reflection. So, let us talk about a couple of these in a little bit of detail mainly I am going to be interested in refraction today.

But for reflection I should say a little bit about it I have drawn one kind of reflection there, this kind of reflection where these two angles are the same is called a specular, there is another kind of reflection just kind of redraw the material here, where let us say rays come in, but they may go in what seems to be various random directions alright. So, they bounce in all different sorts of ways, and this is called a diffuse, alright. So, these are two kinds of reflection, and these become extremely important in computer graphics for rendering. So, when you want to model surfaces do they look shiny like a mirror you have the specular case, does it look like let us say the carpet on the floor here then this would be more of a diffuse case right you cannot look down on the carpet and see your face on it alright. So it is diffusing the light all over the place, it does not look completely dark. So, light is clearly bouncing from it.

But its diffuse; and now what is the most important law for refraction between two materials Snell's law alright. So, Snell's law is the basic expression.

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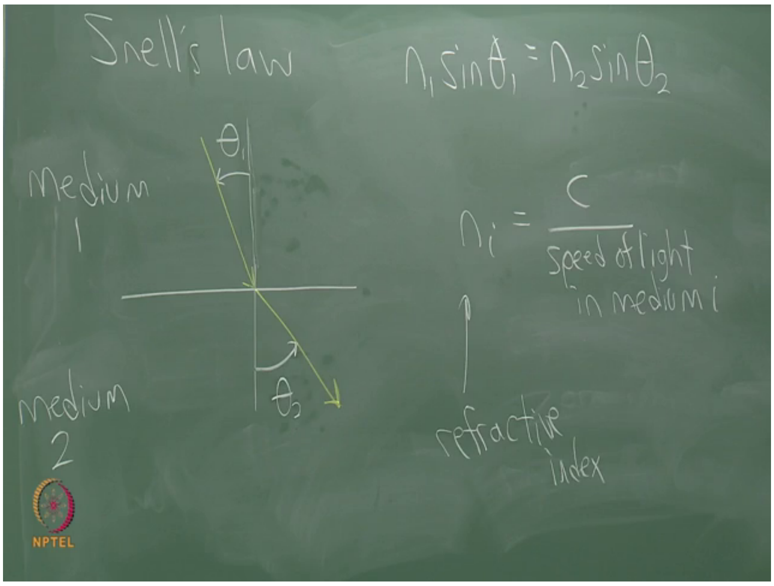

I have Snell's law which is n 1 sin theta 1 equals n 2 sin theta 2 I guess is meaningless until I make a picture. So, I have two different materials I have an upper material and a lower material, and which one is air and which one is say a piece of glass, one could be water one could be air all sorts of possibilities right. You have noticed that a swimming pool can act like a lens sometimes right and you get very interesting effects from that. So, any two materials coming together, and now we draw a perpendicular line. So, these are two materials let us say material 1, material 2 draw a perpendicular line, and now we have the light rate coming into the boundary and then the light ray leaving.

Now I mark my angles here, say it a 1 say it a 2 these are both meant to be a positive angle. So, whichever way you and I guess I have not fulfilled the formula here in terms of putting in all of the components and defining them. So, the ends I will put n sub i is equal to c the speed of light in a vacuum, over the speed of light in the medium. So, I will put in medium i since I have numbered my materials or media. So, sorry I have change the words a bit material or medium be a little more consistent medium one medium 2. So, n sub i is called the refractive index, and note that by the time you are done here what really matters at this interface is not the absolute value of the refractive index, but what matters is the difference between the two refractive indices correct let me just give some kind of simple qualitative examples, that correspond to the algebra here if you were to put these things in practice.

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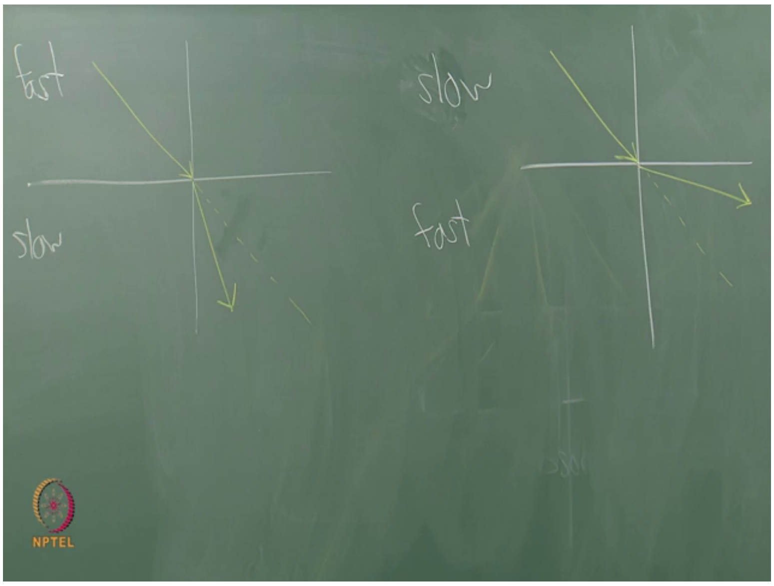

So, if I have a fast material and a slow material and the light ray is coming down going to make it look like it is about 45 degrees, what should happen to it? The waves are going to be propagating more slowly in the slow material. So, that causes it to bend upward or downward is that right down or up.

Student: Sir down (Refer Time: 10:14).

Let us see I am may have to actually go and do the calculations, that seems interesting that is material low material wave fronts yeah sorry thank you it is down yeah good I have a mistake here, but I see. So, alright; so, it goes downward. So, we draw a straight line through here and downward we go yep. I sometimes like to think of a kind of army marching along right and then it slows down the waves get closer together, but if you actually look at the normals, right which is the wave fronts then it propagates downward that is right. So, it is an interesting when I sort of think about imagine like a marching band coming along, but then they get slowed down they get compacted together, but yes the direction of the ray then ends up as perpendicular to the wave front ends up pointing more downward. If we go the other direction, I am slow too fast again at 45 degrees. So, in this case should be the opposite I hope right what do you think. So, I draw the rays here and should come off like this, couple more qualitative things and then we will start talking about lenses.

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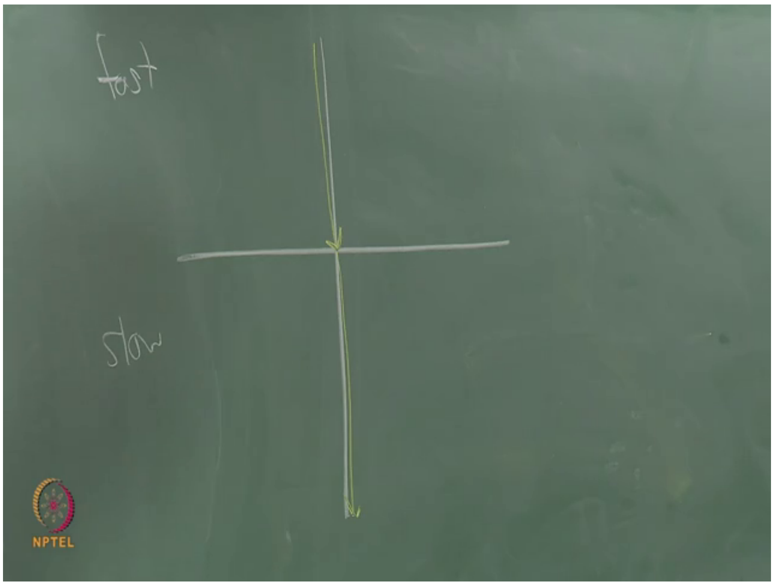

So, let us go back to the fast slow case, and if the ray of light is very close to perpendicular, then when it leaves it is going to remain very close to perpendicular right. So, the amount of bending is not very much for a close to perpendicular ray right that is close to the perpendicular to this boundary between the two media. So, that is just something to pay attention to. So, when a light when a ray of light goes straight in or the wave fronts come right in parallel to the surface to this boundary, then there is effectively no change due to the propagation speed difference. So, the different refractive indices; however, when you come in at a larger angle, when the ray comes in at a larger angle we see significant bending correct.

So, just something to pay attention to. So, so two things become important the difference in refractive indices, and the angle at which the ray comes into the boundary. So, those are two things to pay attention to, you could make that angle. So, extreme. So, that when you take Snell's law.

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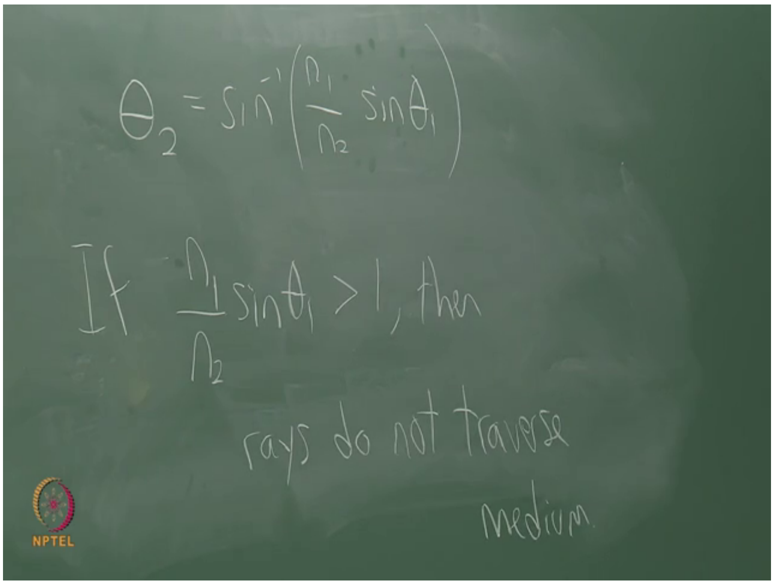

And you try to figure out what the outgoing angle is let us say I do sin inverse n 1 over n 2 sin theta 1 if it turns out that n 1 is greater than n 2 and its significantly greater and let us say this sin theta one ends up being significantly large is not it possible inside of here to get a value greater than 1 does that mean Snell's law is wrong the way I mean it has to cant violate the laws of trigonometry right so.

So, it turns out that eventually it tries to bend so, much that the light will not even enter the medium anymore. So, if it turns out. So, if n 1 over n 2 sin theta 1 is greater than 1 then rays do not traverse the medium. So, just one sort of extra warning there, so when you are close to perpendicular it looks very much like as if you had as if both media were the same as you start offsetting the direction that the rays are coming in you get more bending eventually there is some limit to where the rays will not reverse the medium and it does not have to be perfectly parallel just somewhere along the way based on this algebra. So, now, I want to start to talk about simple lenses any questions so far? Have you seen this somewhere probably maybe a while ago maybe preparing for some exams somewhere who knows.