Infrared Spectroscopy for Pollution Monitoring

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Lecture-10
Interaction of electromagnetic radiation with matter – III

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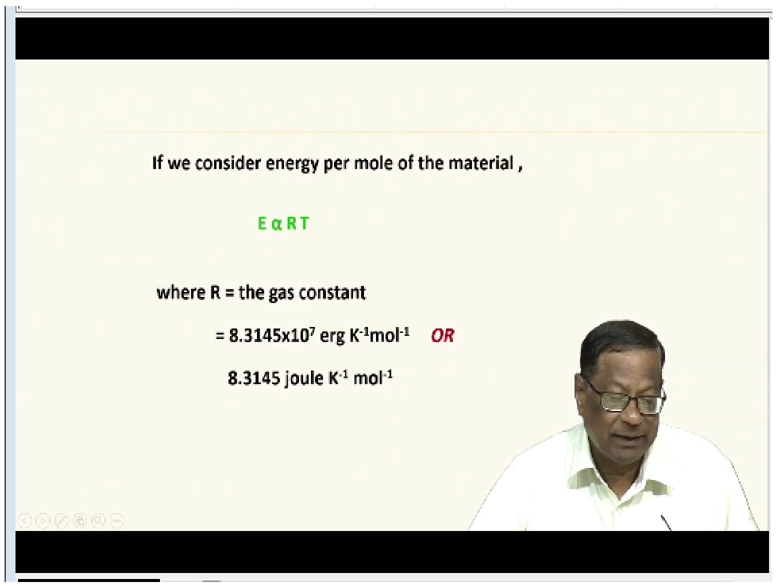

If you consider energy per mole of the material then I can write E is proportional to RT, R is the gas constant, T is the temperature absolute temperature. And gas constant value is 8.314*10 raise to 7 erg per degree per mole okay, this is a very standard equation and you should remember it even though it has not much relevance to our topic of discussion okay.

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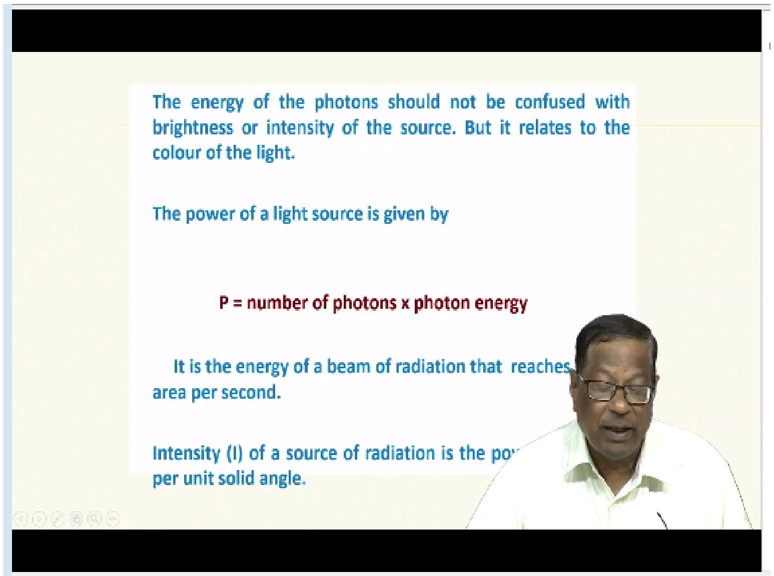

So, the energy of the photon we should understand for our understanding only the energy of the photon you should not be confused with the brightness or intensity of the source. The more energy more intense no nothing like that but it relates to the color of the light energy, energy corresponds to the color of the light as far as visible ranges concerned. What about ultra violet rays you may feel the ultra violet rays that also you will feel only the energy.

You do not see the ultra violet range energy electromagnetic radiation sometimes infrared, you can see the colors. But it looks like as it is name suggest it looks like only red, so other areas no you cannot see the colors, sometimes ultra violet substances which absorb ultra violet rays a radiation. They look a little bit yellow, so from yellow to red you can only you can see personally as a human being.

I do not know about the animals what colors that pursue or something but my understanding is most of the animals see they do not see visible colors that is my understanding. I may be wrong also because if many animals will see the whole world only as if they are seeing a black and white photo. They will look dark shade or light shade. But they cannot see red color, green color etc.

So, if you are looking at a red color in a Spanish bull fight or something like that, the idea how it looks to that is your holding something dark shade red. But we can as well use a black flag also it does not make any difference to the bull okay that is the difference that apart, it is only my way of understanding how we pursue the colors, so the intensity of the color is you can feel you can see it.

The power of a light source is given by P=number of photons*energy of the photons. So, it is the energy of a beam of radiation that reaches a given area per second. This I think you can imagine, take a torch light and see the focus it on a wall opposite to you. And you will see if you are very near you will see a squarish area illuminated by the light or round area depending upon the actual size of the actual shape of the torch.

But it is what you can see if you are further away the area that is illuminated will be bigger. So, that is understood is not it, so it is a energy of a beam of radiation that which is a given area per second. If the given area is very far the energy remains diffuse and you may not be able to see the illuminated area at all. If the energy is less definitely you will see the illuminated area. So the intensity of a source of radiation is the power emanating per unit solid angle okay.

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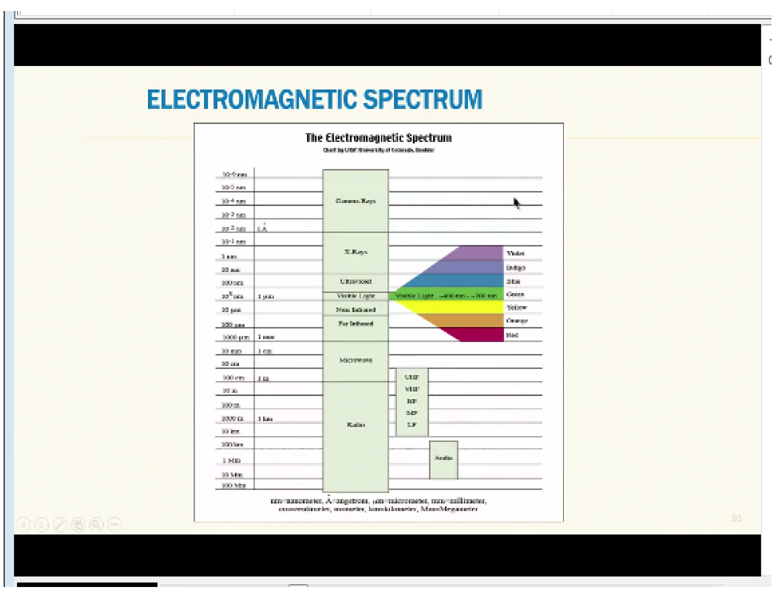

So, this is how we will define scientifically this as again the electromagnetic radiation which I have explain to you earlier. But this another way of representation it is a very beautiful way of representation this is from Clarke's table I have taken earlier.

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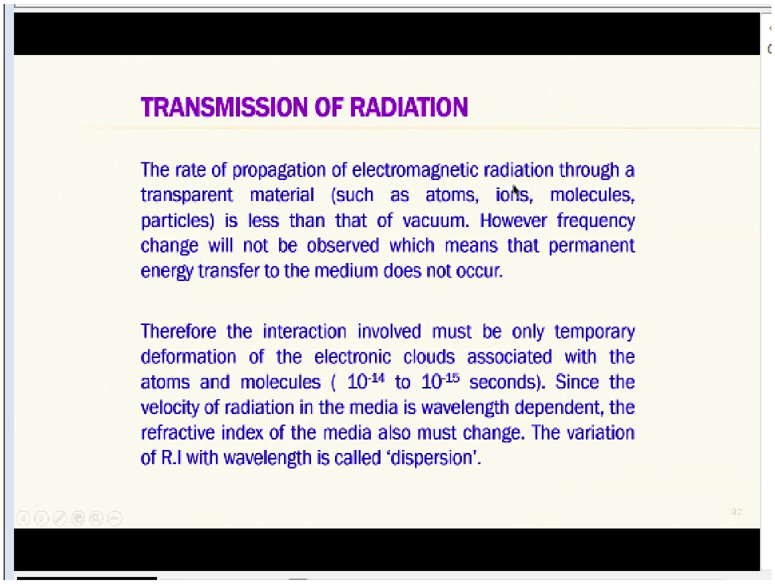

So, now we have understood so for the properties of the electromagnetic radiation correct. So, now what you will do for the next 1 or 2 hours is to understand. How the electromagnetic radiation will interact with the materials. Because any spectroscopic instrument will contain a radiation source it will have the radiation source has to pass through prisms and then through a vacuum through the sample.

And then through the machine up to that on to that detector etc. So, it has to interact with several types of materials, so what are the effects of the interaction of the material on the nature of the electromagnetic radiation. So, to study that let us look at the how the radiation is transmitted okay. So the rate of propagation of the electromagnetic radiation through a transparent material that is atoms, ions, molecules, particles anything liquids okay, gases also we can improve that is less than that of a vacuum what you are saying essentially is in the vacuum.

If the electromagnetic radiation passes across a given space at a particular speed. If it is vacuum at a particular speed but if that vacuum is filled with ions, gases, molecules or liquid or solid or glass or plastic or anything. If you have to make them pass through then the speed of the light would be the rate of propagation would be slightly different inside that space matrix then in the vacuum, so the frequency will not change.

But it is only the speed that will change and the frequency change will not be observed it means that permanent energy transfer to the medium does not occur. Why if part of the energy is absorbed by the material then the total energy of the wavelength electromagnetic radiation should change. So, if the total energy changes frequency should change, wavelength should change but we do not see such things in the normal practice by because whenever radiation passes through a given by a matrixes for example through a solution.

In the solution its speed will be different but outside the solution when it comes out of the solution again it has to it passes at its own speed that means the energy is not pass down to the material. Whenever electromagnetic radiation passes through a given matter or matrix therefore the interaction involved must be only temporary that is time reason is it not. So, what is that inform what is the temporarily interaction.

It is an interaction which is nothing but a little bit of deformation of the electron clouds temporarily again. And the movement they come out of the media again it the electromagnetic radiation regains its original energy or a glory or whatever it is okay. So, the electronic clouds associated with the molecule they get a little bit disturbed the electromagnetic radiation passes through a given ~~metries~~ matrix containing atoms, molecules, electrons etc. etc.

So, I think all of you would know atoms, molecules, electrons etc. they all contain the electrons. So, what is the time frame the electromagnetic radiation will interact with the matter I have written it here in the slide it varies from 10 raise to -14 to 10 raise to -15 seconds within that time there is an interaction between the electromagnetic radiation and the matrix material that is molecules, gases, ions etc. etc.

Since the velocity of the radiation in the media is wavelength dependent the refractive index of the media also must change. This is one of the consequences of the electromagnetic radiation that passes through a material which does not absorb, if it absorbs the consideration changes. But if it has to pass through and come out then only the refractive index of the media changes rather than the electromagnetic radiation.

So, the variation of refractive index with wavelength we call it as dispersion, this is an important concept with respect to the properties of the transmission of the radiation.

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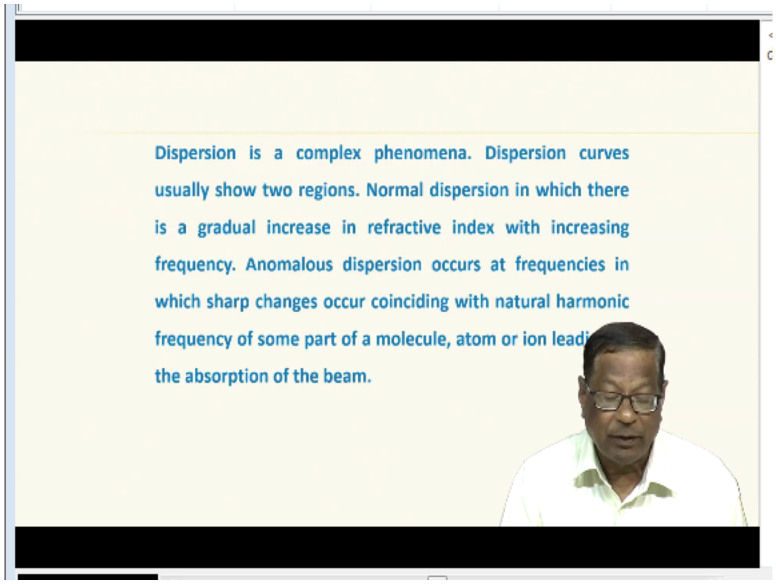

So, dispersion, what is a dispersion, so dispersion is basically complex phenomena. So, it is cannot be uniform for all types of matrix, so what happens the dispersion curves we obtain whenever we plot the energy of the electromagnetic radiation. When it is passing through a given matter, so given matter means you can assume a block of glass or a prism for most of the discussion that we are going to have here in this session okay.

So, there are 2 types of dispersions one is normal dispersion in which there is a gradual increase in the refractive index with increasing frequency okay. So, the refractive index gradually changes and you can predict what happens if I take 1 centimeter block or 2 centimeter blocks how much it will bend where it will come out of the system at what height or depth etc… So, that is normal dispersion okay anomalous dispersion occurs at frequencies with sharp changes suddenly it will change the direction in the matrix.

So, if you plot the energy changes verses the direction or the energy changes verses the thickness of the matter. Then it must coincide with the natural harmonic frequency of some part of a molecule existing at that point okay. So, it may be a molecule it may be an atom or it may be an ion, so leading to the absorption of the beam I hope you understood this slide.

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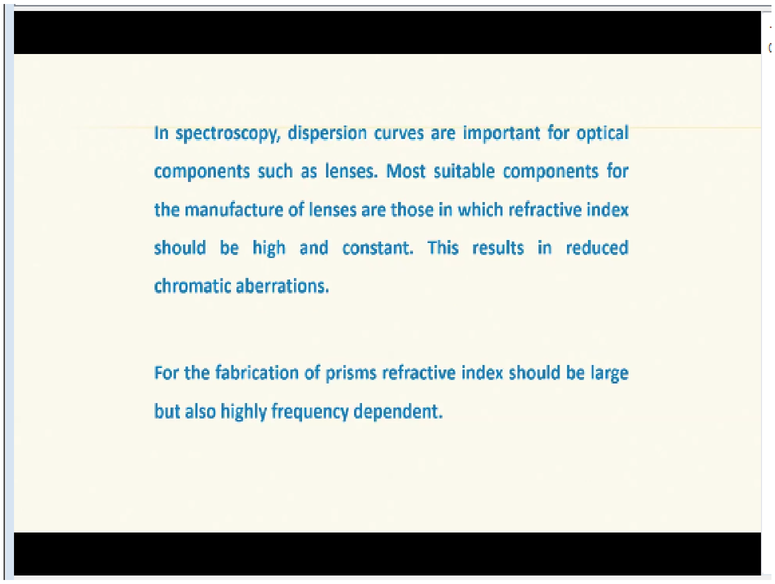

Now in spectroscopy dispersion curves are very important for us you know why because most of the optical components appear as lenses, mirrors etc. So, most suitable components for the manufacture of lenses are those in which refractive index should be high and it should be constant. So, this is the criteria that we normally infuse whenever I want to select a particular material because I need lenses, I need mirrors and several optical components in a spectrophotometer or in a spectrometer.

Whether it is spectrophotometer or infra red near infra red all are essentially the same. So, this results in which refractive index it must be high it must be constant. Why refractive index should be high because it will allow no distortion okay of the incident light. The incident light should not be distorted and it should be constant, it should not be it should not lose its properties the such are the energy frequency and this thing that is also important for us then what do you want from lenses and mirrors.

We want perfect transmission through the lens sometimes we want the lenses to give as a parallel beam of light that is high school physics or second year PU physics . If you look up the transmission of light through the lenses etc. mirrors you will come across those things. But at this point it suffices this to say that what to you want from a lens is a parallel beam of light, concentrated beam of light sometimes focused beam of light all those things we require.

And for such purposes the refractive index should be high and it should be constant another property. So, the results this results in reduced chromatic aberrations that means what is chromatic aberration, a chromatic aberration is the distortion of the incoming light are incoming electromagnetic radiation through a matrix that is chromatic aberration that are several types of chromatic aberration, sometimes if you take a look through a lens like this specs etc.

You look through one side you will see things blurred you know it is all very common experience sometimes they look blurred sometimes they look distorted you would have seen in your cars etc., the images appear bigger or very small. You know longer distances do not appear equal long they will appear too long or too near. You know most of the car mirrors shows such properties and sometimes they show bigger ~~pro~~ images.

So, the chromatic aberration is part and parcel of every matrix that is transmitted that is that allows radiation to pass through for transmission that is what we are discussing now, the transmission of electromagnetic radiation. So, for the fabrication of prisms and refractive index what we need is it should be large. But also highly frequency dependent this is important okay.

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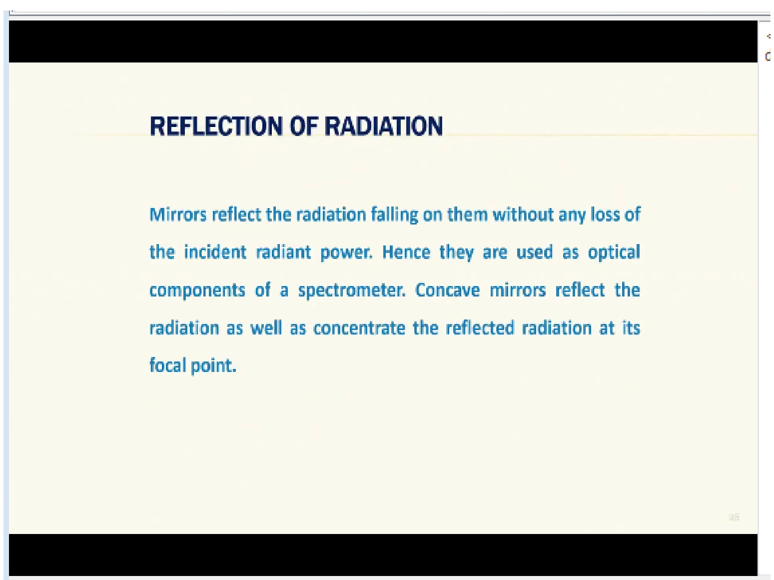

Now we will discuss a little bit about the reflection of radiation I think I have already refer to you talk to you about the reflection of the radiation is it not. So, we see our reflection in several mirrors etc, right from morning to evening mirrors, tooth brushing, face decoration getting ready and all those things. They are all plane mirrors, so plane mirrors are not supposed to show you different picture of yourself across the mirror otherwise the whole concept of mirroring is gone is not it.

So, it should show exactly as you are now sometimes we also want reflection without any loss of incident radiant power. We want the mirror image should be as bright as the brightness prevailing outside the mirrors okay. So, such mirrors they can be concave or plane, plane mirrors are usually what we normally use in our day today life sometimes we use a curved mirror something like this.

If you consider this it is convex, if you consider the mirror this side then it is concave mirror okay. So, it does not mean that a mirror is always convex or concave whichever way you use know one side is only mirroring the other side is only reflecting. So, concave mirror will have a non-reflecting material on the convex side and convex mirror will have a non-reflecting mirror on the convex side okay.

So, they are basically used as optical components in a spectrometer okay. So, concave mirrors normally reflect the radiation as well as they concentrate that is one of the advantages of mirrors. Because they do 2 jobs one is reflection and another is the concentration. So, in cars etc. there are concave mirrors because they want to show you long distances what is coming at the back may be 10 feet, 15 feet, 100 feet etc. whenever he is trying to negotiate a curve.

So, in cars etc. we need concave mirror and sometimes we also need convex mirrors to show convex mirrors means they show the reflection in greater detail. If you must have seen in several pictures the heroes and heroines they show bigger face and what not compared to the screen size. So, concave mirrors reflect the radiation as well as concentrate the reflected radiation at its focal point okay.

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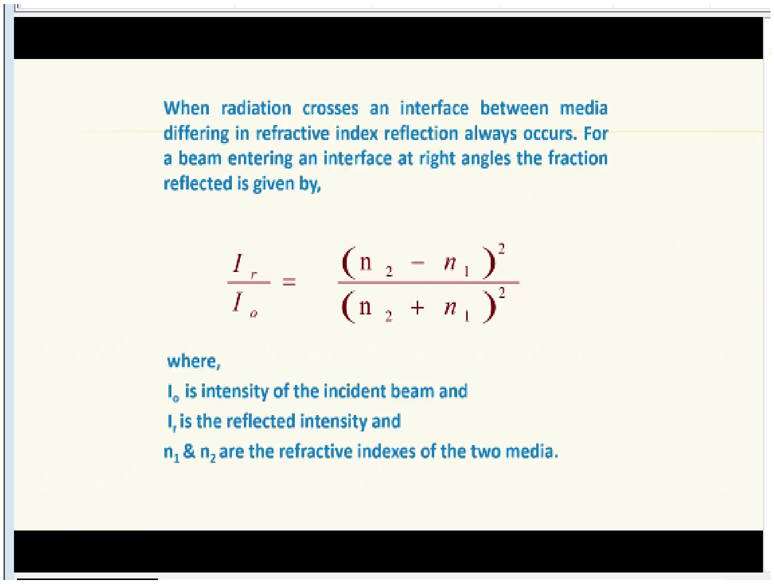

When radiation crosses an interface between media differing in refractive index reflective index reflection always occurs. This you should understand, so the radiation crosses an interface between 2 different media we can always imagine radiation passing through an air and then passing through a glass mirror or a glass block or a plastic block and then coming out. So, that is what we have talking about.

So when radiation crosses an interface between media differing in refractive index reflection always occurs. So, for a beam entering an interface at right angles the fraction reflected is given by this relationship that is intensity of the radiation reflected to that of the intensity of the incident radiation is given by n2-n1 whole square/n2+n1 whole square. So, here I0 is the intensity of the incident beam and Ir is the reflected intensity.

And n1 and n2 are the refractive indexes of the 2 media okay. So, these 2 this expression is assumes very important because whenever we want to use a material I have to know what is the refractive index of the material.

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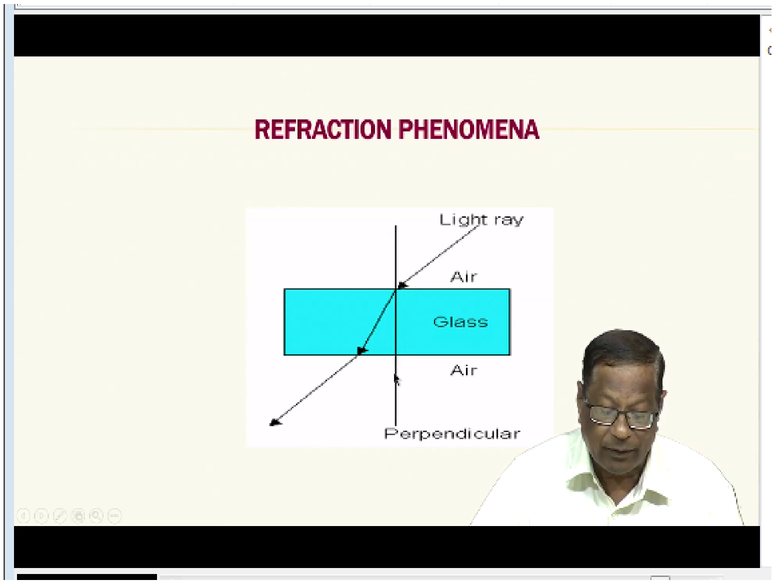

So, refractive phenomena I can always show like this that it is this is a block of glass and then radiation is coming like this. This is the perpendicular to the glass and then it comes here, changes direction and then again comes out of this thing that means if they changes were not there. If the glass was not there it would I have travelled like a straight line, even though we say that it is wave electromagnetic radiation travels in waves etc. in simpler terms for practical purposes.

We can you think of it as passing through a passing as a straight line as I have told you in the torch light. So, system even in the torch light system there is a glass there is media change from the bulb to the glass of the torch. And then to the air outside, so this is what happens most of the time and then we will see this refraction phenomena in general like this okay.

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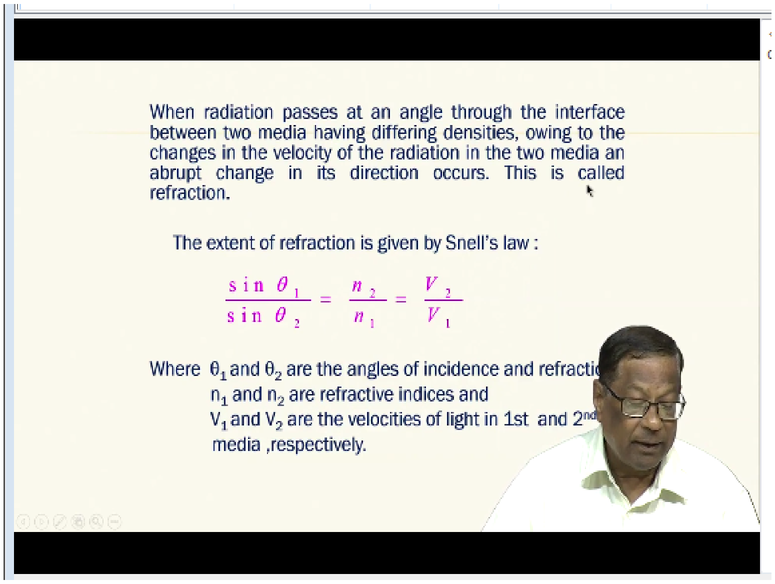

And I think you will look at the Snell's law and other things in our next class. So, thank you very much, we will continue our discussion on the transmission of electromagnetic radiation through other systems also we will consider the interactions, thank you very much.