Digital Image Processing
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Module 10 Lecture Number 50
Color Image Processing: Color Fundamentals

Hello, welcome to the video lecture series on Digital Image Processing. In our last lecture we have talked about image restoration image registration problem.

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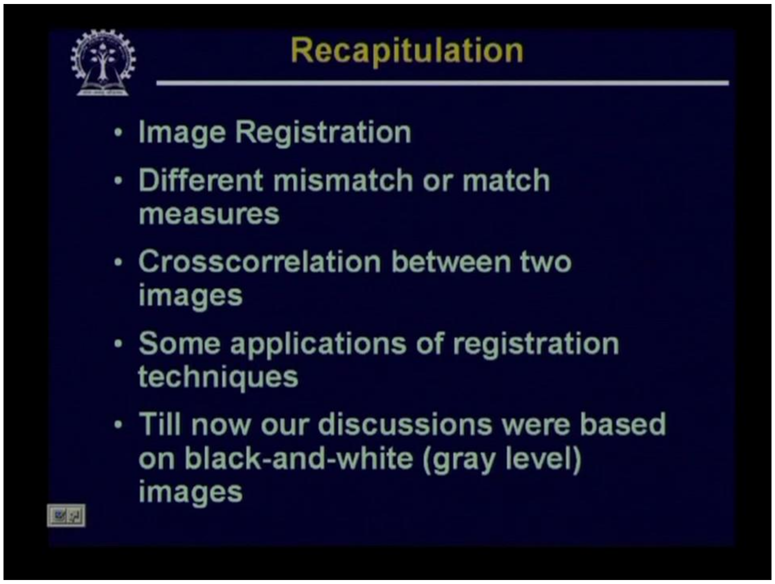

So we have talked about different image mismatch or match measures. We have talked about the cross correlation between 2 images. And we have also seen some application of registration technique. Now, including this image registration technique whatever we have done till now in our digital image processing course you have seen that all our discussion where mainly based on black and white images. That is we have not considered any color image during our discussion. Now studying from today at coming few lectures we will talk about the color image processing.

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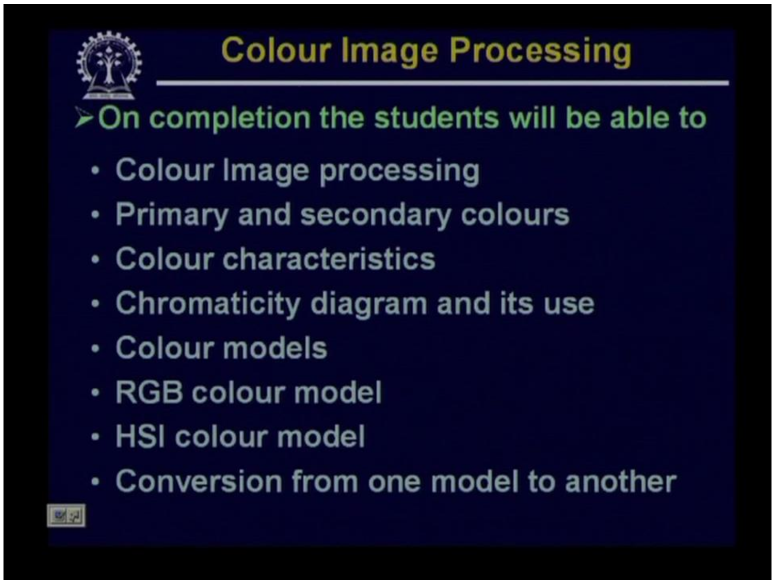

So today what we are going to do is we are going to introduce the concept of color image processing, we are going to see that what are primary and secondary colors, we are going to talk about color characteristics, then we will see chromaticity diagram and how the chromaticity diagram can be used to specify a color. We will see 2 colors models, 1 of them is RGB color model or red, green and blue color model and other 1 is HIS color model. And we will also see that how we can convert from one color model to another color model.

Now first let us talk about why we want color image processing, when we get information from black and white images itself. The reason is color is a very very powerful descriptor and using the color information we can extract the object of interest from an image very easily, which is not so easy in some cases using using black and white or simple grey level image. And the second motivation we why we go for color image processing is that or we talk about color images is that, human eyes can distinguish between 1000 of color and color shades whereas when we talk about on the black and white image or grey scale image we can distinguish only about 2 dozens of intensity distribution or different grey shades.

So that is the reason the color image processing is a very very important topic, firstly because we can distinguish between more number of colors and secondly we can identify some object seen at color image very easily which otherwise may be difficult from a simple intensity image or a gray level image. Now, coming to color image processing there are two major areas. One of the areas we call as full color image processing.

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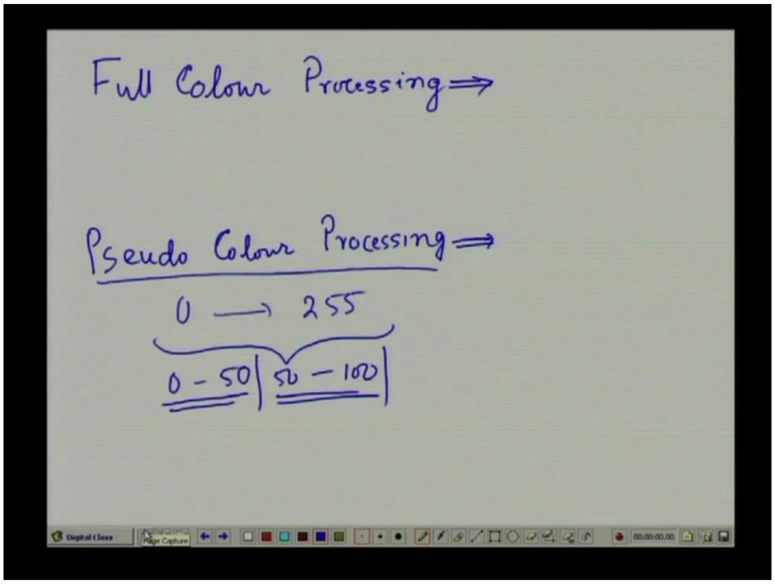

We say full color processing, and other area is pseudo color processing. Now, what is main point this full color processing or pseudo color processing. When we talk about full color processing, the images which are acquired by by full color TV camera or a by full color scanner then you find that almost all the colors that you can perceive they are present in the images. So that is what is meant by a full color image and when you try to such a full try to process such a full color image what will try to process we will taking to consideration all those colors which are present in the image.

Whereas when we talk about this pseudo color processing, the pseudo color processing is a problem where we try to assign certain colors to a range of gray levels. When we take an intensity image or simply a black and white image, which has intensity levels from say 0 to 255, what I can do is we can sub divide, we can divide this entire intensity range. Into a sub number of sub ranges. Say for example I can divide 0 to say 50, this intensity level will be in one range. May be 50 to 100 intensity levels will be in another range. And to this range I can assign one particular color whereas in this range 50 to 100 I can assign another particular color.

And the pseudo color image processing is mostly useful for human interpretation. So as we said that we can hardly distinguish around 2 dozens of intensity of gray shades whereas if we go for so in such cases it may not be possible for us to distinguish between two colors gray regions which are very near to each other, that intensity values are very near to each other. So in such cases if you go for pseudo color pseudo coloring technique that is we assign different colors to different ranges of intensity values then from the same intensity image of black and white image we can extract the information much more easily. And this is mainly useful as I said for human interpretation purpose.

Now, what is the problem which in the color image processing? The interpretation of color as the color is interpreted by the human beings, this problem is a psycho physic physiological problem. And we have not yet been fully understand what is the mechanism by which we really interpret eye color? So though the mechanism is not fully understood, but the physical nature of color we can represent formerly we can express it formally. And a formal expression is really supported by some experimental results.

Now the concept of color is not very new. You know from your school level physics, from school level optics that way back in 1666 it was Newton who discovered the color spectrum. So what he did is, his experimental set up was something like this.

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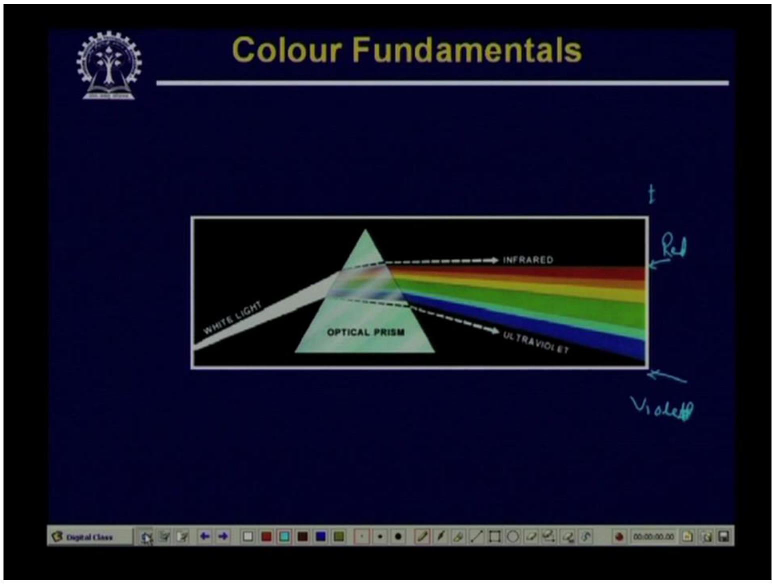

You have an optical prism and you pass white light through this optical prism, and as the white light passes through the optical prism, on the other side when this white light comes out of it the light does not remain white anymore. However it is broken into a number of color components which is known as spectrum. So as has been shown in this particular diagram you find that at one end of the spectrum. What we have is the violet at one end we have the violet and at the other end we have the red color. So the color components that vary from violet to red at this was really discovered by Newton way back in 1666.

Now the thing is how do we perceive color or how do we say that an object is of a particular color. We have seen earlier that we perceive an object we see an object because light falls an object or the object is illuminated certain source of light. The light gets deflected from the object it reaches our eye then only we can see the object. Similarly we can perceive the color depending upon the nature of the light which is deflected by the object surface.

So because we have to perceive this nature of the light, so we have to see what is the spectrum of light which is or the spectrum of the energy which is really in the visible range, Because is only in the visible range that we are able to perceive any color.

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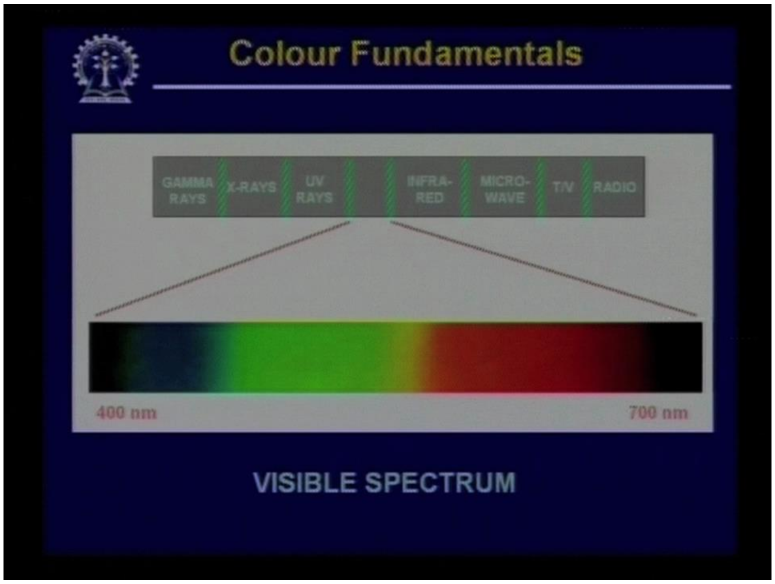

So if you consider the electromagnetic spectrum say as shown here. The electromagnetic, the complete electromagnetic spectrum ranges from gamma rays to radio frequency waves. And you find that this visible spectrum, the visible light spectrum it occupies only a very narrow range of frequencies in this entire electromagnetic spectrum. And here you find that the wavelength of the visible spectrum that roughly varies from say 400 nanometer to 700 nanometers. So at one end it is there on 400 nanometer wavelength and at the other end it is around 700 nanometer in wavelength.

So whenever a light falls on an object and if the object reflects lights of all wavelength in this visible spectrum in a balance manner, that is all the wavelength reflected in the appropriate proportion in that case that object will be appearing as an white object. And depending upon a wavelength, T dominant wavelength within this visible spectrum the object will appear to be a colored object and the object color will depend upon what is the wavelength of light? That is pre dominantly reflected by that particular object surface.

Now coming to the attributes of light if we have an achromatic light, that means a light which doesn't not contain any color component. The only attribute which describes that particular is the intensity of the light. Whereas if it is a achromatic light in that case as we have just seen the wavelength of the achromatic light within the visible range can vary from roughly 400 nanometer to700 nanometer. Now there are basically there quantities which describe the quality of light.

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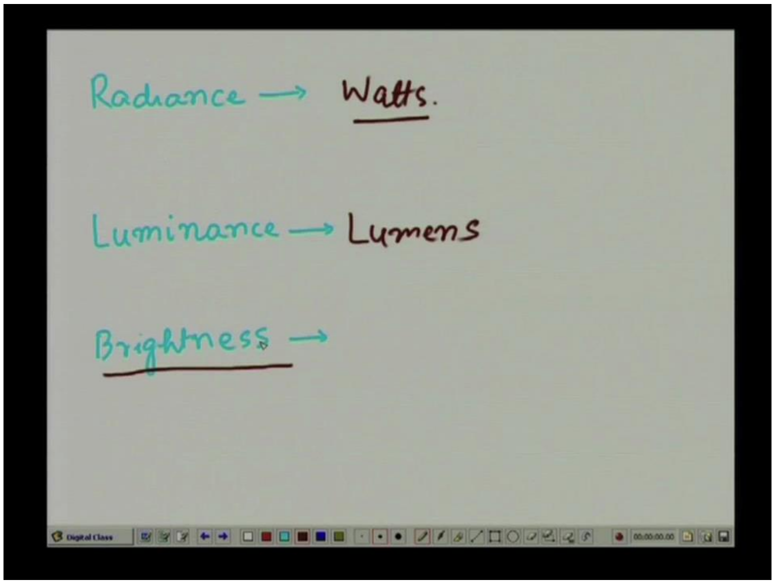

So what are those quantities? One of the quantity is what is called radiance. The second quantity is called is called luminance. And the third quantity is called Brightness. So we have these three quantities Radiance, Luminance and Brightness which basically describe what is the quality of light. Now what is these radiance? Radiance is the total amount of energy, which comes out of a light source. And as this is the total amount of energy. So this radiance is to be measured in the form of in units of watts. Whereas Luminance it is the amount of energy that is perceived by an observer. So you find the different Radiance and luminous.

Radiance is the total amount of energy which comes out of a light source, whereas Luminance is the amount of energy which is perceived by an observer. So as the Radiance is measured in units of watts. It is Luminance which is measured in units of what is called Lumen. Whereas the third quantity that is Brightness it is actually subjective measure, and it is practically not possible to measure the amount of Brightness. So though we can measure the Radiance, luminance, Radiance and luminance but practically we cannot measure what is Brightness.

Now again coming to our color images or color lights . Most of you must be aware that which we consider colors, or when we talk about a colors, we normally talk about three primary colors. And we say that the three primary colors are red, green and blue.

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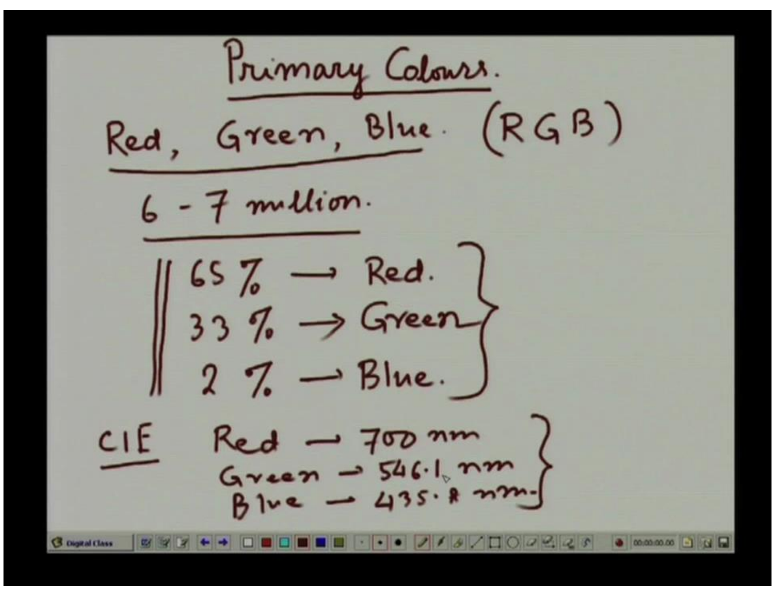

So we consider the primary colors of light, colored light. So which is considered the primary colors to be red, green and blue. So you consider these three colors to be the primary colors. And normally we represent it as R, G and B. Now you find that from the spectrum which was discovered by Newton there were actually 7 different colors. But out of those 7 colors we have chosen only these three different colors red, green and blue to be the primary colors. And we assume that by mixing these primary colors in different proportions we can generate all other colors.

Now why do we choose these three colors to be the primary colors? The reason is something like this that actually there are some cone cells in our eyes which are responsible for color sensation. So there are around 6 to 7million cone cells, around 6 to 7 million cone cells which are really responsible for color sensation. Now out of this 6 to 7million cone cells around 65 % of the cone cells they are sensitive to red light 33 % of the cone cells are sensitive to this senses green light and roughly 2% of the cone cells they sense blue light.

So because of the presence of this three different cone cells in our eyes which sense red, green and blue these three color components. So we considered red, green and blue to be our primary colors and assume that by mixing these primary colors in appropriate proportion we are able to generate all other different colors. Now as per this CIE standard specified three different wavelengths for three different colors. So CIE specified red to have an wavelength of 700 nanometer. Green to have an wavelength of 546.1 nanometer, and blue to be an wavelength of 435.8 nanometer.

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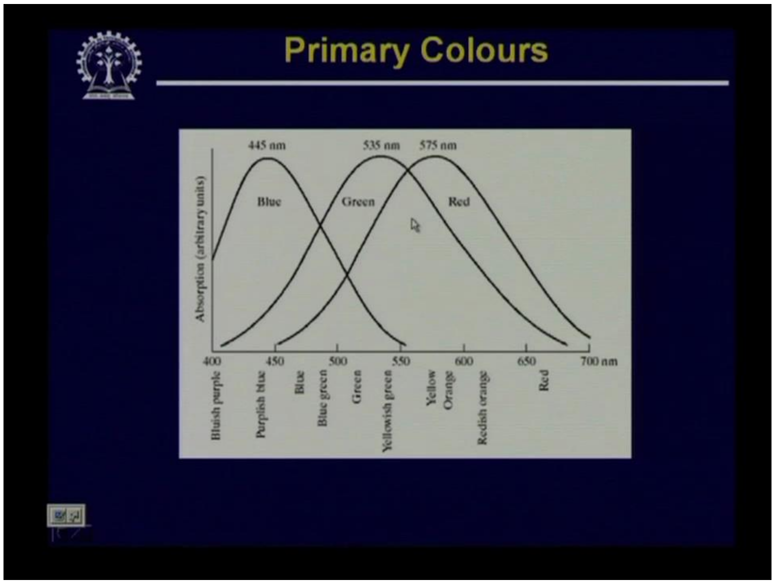

But the experimental result is slightly different from this. Let us see how the experimental result looks like. This one this diagram shows the sensitivity of those three different cones in our eyes that we have just said. So you find that the cones which are sensitive to blue light, to blue color . These cones actually receive wavelength ranging from around 400 nanometer to 550 nanometer whereas the cones which are sensitive to green lights they are sense sensitive to wavelengths ranging from slightly higher than 400 nanometer to an wavelength of something around say 650 nanometer.

Whereas the cones which area sensitive to red light, they are sensitive to wavelength starting from 450 nanometer to around 700 nanometer though the sensitive is maximum for this type of cones. Says blue cone is maximumally sensitive at an wavelength of 445 nanometer as is shown in this diagram.

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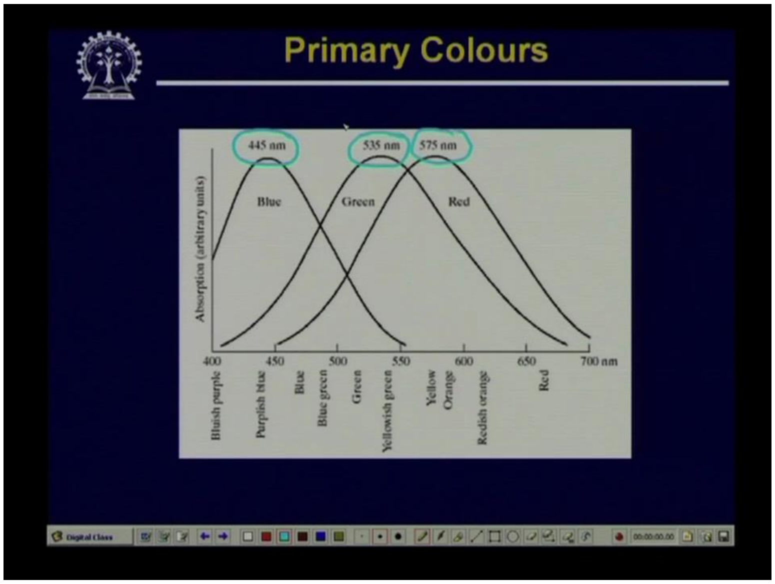

So as is shown in this diagram you find that the blue cells the blue cones. They are most sensitive to an wavelength of 445 nanometer. The green cones are most sensitive to an wavelength 535 nanometer. Whereas the red cone are most sensitive to an wavelength of 575 nanometer. So these experimental figures are slightly different from what was specified by CIE. And one point has to be kept in mind that though CIE standard specifies a red, green and blue to be of certain wavelength but no single wavelength can specify any particular color.

In fact from the visible spectrum, from the visible domain of the spectrum that we have just seen it is quite clear that when we considered two spectrum colors two adjacent spectrum colors there is no clear cut boundaries between those two adjacent spectrum colors. Rather one color slowly or smoothly gets merged into the other colors.

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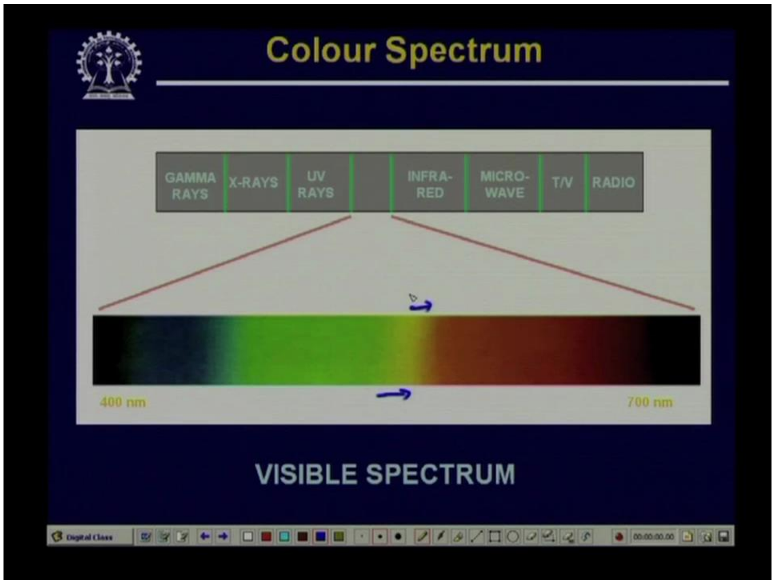

So as you can see from the same diagram that whenever we have a transition from say green to yellow. You find that we don't have any clear cut boundary between green and yellow. Similarly whenever there is transition from say yellow to red, the boundary is not clearly defined. But we have a smooth transition from one color to another color. So that clearly says that no single color may be called or no single wavelength may be called red, green and blue. But it is a band of wavelengths which give you color sensation, a band of wavelength that gives you green color sensation, a band of wavelength that give you red color sensation, at the same time a band of wavelength a band of wavelength that give you say blue color sensation.

So having specific wavelengths as standard does not mean that these fixed RGB components alone, components alone when mixed properly will generate all other colors. But rather we should have a flexibility that we should also allow the wavelengths object of these three different colors to change because as you have just seen that green actually specifies a band of wavelength, red actually specifies a band of wavelength, similarly blue also specifies a band of wavelengths.

So to generate all possible colors we should allow the wavelengths of these colors are red, green and blue also to change. Now, when I say that this are the different primary colors that is red, green and blue, mixing of the primary colors generate the secondary colors. So when I mixed say red and blue.

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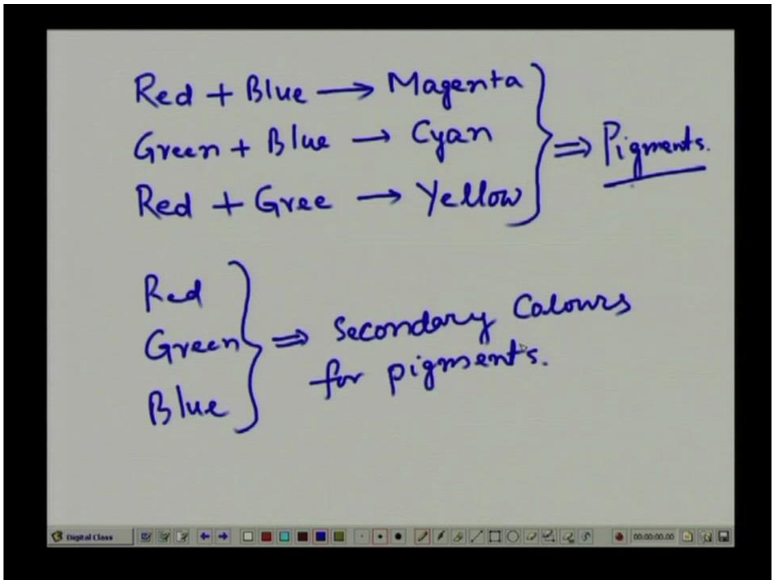

If we mixed red and blue, you find that both red and blue they area primary colors. Red and blue will generate a color called magenta which is a secondary color. Similarly if we mix green and blue this will generate a color which is called cyan. And if we mix yellow sorry red and green, if we mix red and green these two generate color yellow. So as we have said that the red, green and blue we consider these three colors as primary colors, by mixing the primary colors we generate the secondary colors.

So these three colors magenta, cyan and yellow they will be called secondary colors of lights. Now here another important concept is the pigments. As we have said that red, green and blue are the primary colors of light, and if we mix these colors we generate the secondary colors of lights which for example magenta, cyan and yellow. When it comes to the pigments the primary color of a pigment is defined as an wavelength which is absorbed by the pigment and it reflects the other two wavelengths.

So the primary colors of light should be the opposite of the primary color of a pigment. So as red, green and blue they are the primary colors object of light, whereas magenta, cyan and yellow they are the primary colors of a pigments. So when it comes to pigment we will consider this magenta, cyan and yellow, they are to be the primary colors. So these are the primary colors for pigments. And in the same manner this red, green and blue which are the primary colors of light these three will be the secondary colors for pigments.

And as we have seen that for the colors of light the primary colors of light if we mix red, green and blue in appropriate proportion we generate a white light. Similarly for the pigments if we mix the cyan, magenta and yellow in appropriate proportion we will generate the black color. So for pigments, appropriate mixing of the primary colors will generate black, whereas for light the appropriate mixing of primary colors will generate white.

Now, so far what we discussed that is the primary colors of light which are red, green and blue or the primary colors of pigments which are magenta, cyan and yellow, these are the concepts of the colors components we consider when we talk about the color reproduction or this are from the hardware point of view. That is for a camera or for a display device, for a scanner, for a printer we talk about this primary colors component.

But when we perceive a color as human being and when we look at a color we don't really think that how much of red components or how much blue components or how much of green component that particular colors has. But the way we try distinguish the color is based on the characteristics which are called Brightness, Hue and saturation.

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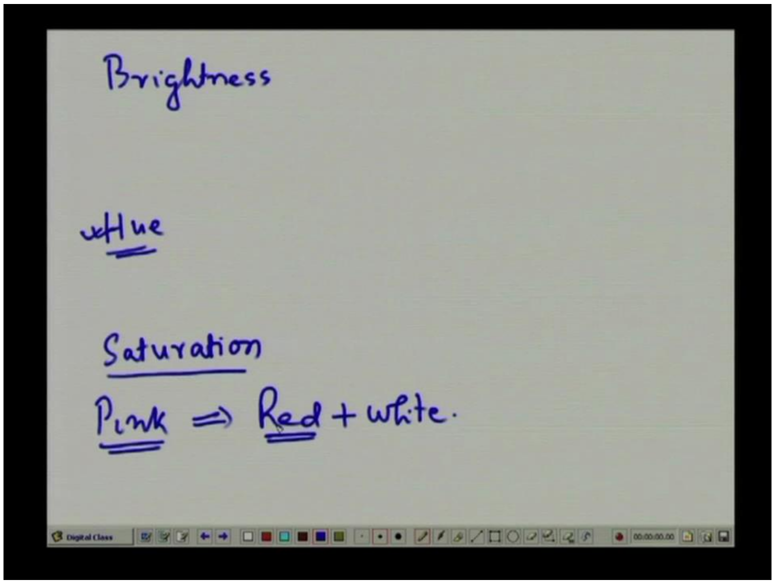

So for us for perception purpose the color components will be taken as or the characteristics are Brightness, Hue and saturation instead of the red, green and blue or cyan, magenta and yellow. Now, let us see that what does this three attributes mean. So what is Brightness is nothing but a chromatic notion of intensity. As we have seen that in case of black and white image we talk about the intensity. Similarly for a color image there is a chromatic notion intensity it is not really intensity which we call as bright or Brightness. Similarly Hue it represents the dominant wavelength in a mixture of colors.

So when you look at a secondary color which is a mixture of different primary colors there will be one wavelength which is dominant one, dominant wavelength. And the overall sensation of that particular color will be determined by the dominant wavelength. So this Hue this particular attribute it indicates that what is the dominant wavelength present in a mixture of color. Similarly the other term saturation, you find that whenever we talk a about particular colors red there may be various shades of it.

So this saturation indicates that what is the purity of that particular color or in other words what is the amount of light which has been mixed to a mixed to a particular color to make it a diluted one. So these are basically the three different attributes, which we normally use to distinguish one color from another color. Now coming to the spectrum colors because the spectrum colors are not diluted there is no white light, white components added to a spectrum color. So spectrum colors area fully saturated.

Whereas if we take any other color which is not a spectrum color, say for example if we consider a color say pink, pink is nothing but a mixing of white with red. So red plus white this makes a pink color. So red is a fully saturated color because it is a spectrum color and there is no white light mixed in it. But if we mix white light with red the color generated is pink, so pink color is not full saturated. But red is fully saturated.

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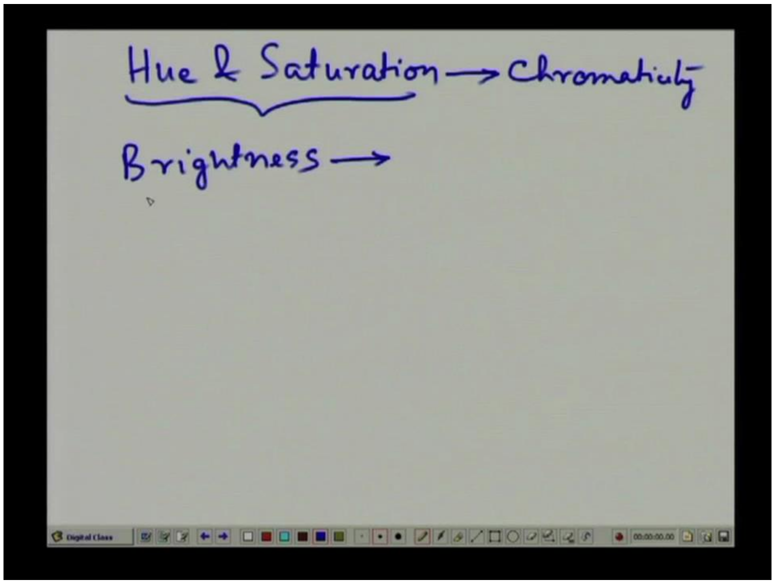

So we have these three concepts for color perceptions that is Hue and saturation and the other one is Brightness. And as we said that Brightness indicates a chromatic notion of the intensity whereas Hue and saturation they gives you the color sensation. So you say that Hue and saturation together they indicate what is the chromaticity of the light, whereas this Brightness gives you some sensation of intensity. So using this Hue saturation of intensity what we are trying to do is. We are separating the Brightness part and the chromaticity part.

So whenever we try to perceive a particular color we normally perceive it in the form of Hue saturation and Brightness whereas from the point of view of hardware, it is the red, green and blue or magenta, cyan and yellow which are more appropriate to describe the color. Now, the amount of light or the amount of red, green and blue lights which are required to from any particular color is called a tristimulus, we call it tristimulus.

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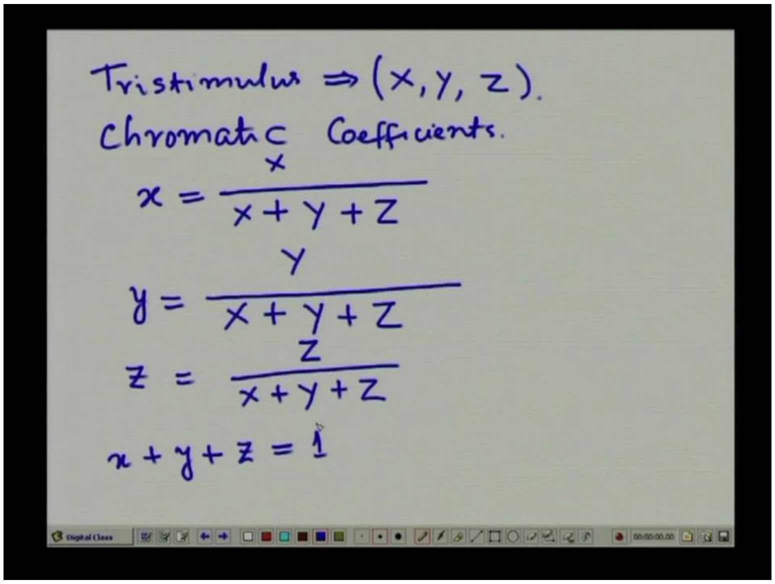

And obviously because this indicates what is the amount of red light, green light and blue light which are to be mixed to from any particular color. So this will have three components one x components, y component and z component. And a color is normally specified by what is called chromatic coefficients. So we call them as chromatic coefficients, and this chromatic coefficient are obtained as the coefficient for red is given by x, lower case x is equal to X by X + Y + Z. So this X is the amount of red light, Y is the amount of green light and Z is the amount of blue light which are to be mixed to form a particular color.

So the chromatic coefficient for red which is given by lower case x, which is computed like this. Similarly chromatic coefficient for green is computed as lower case y equal to Y by X+Y+Z, and similarly for blue it is Z by X+Y+Z. So this lower case x,y,z, these are called the chromatic coefficients of a particular color. So whenever we want to specify a color, we have to specify it by its chromatic coefficient. And from here you find that this sum object of the chromatic coefficient that is lower case x + lower case y + lower case z is equal to zero, is equal to one. So this is represented in normalize form.

So as any color can be specified by its chromatic coefficient, in the same manner there is another way in which a color cab be specified that is with the help of what is known as a CIE chromaticity diagram. So a color can be specified both by its chromatic coefficient as well as it can be specified with the help of chromaticity diagram. Thank you.