Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 47
Daylighting

So, we will we will start with day lighting.

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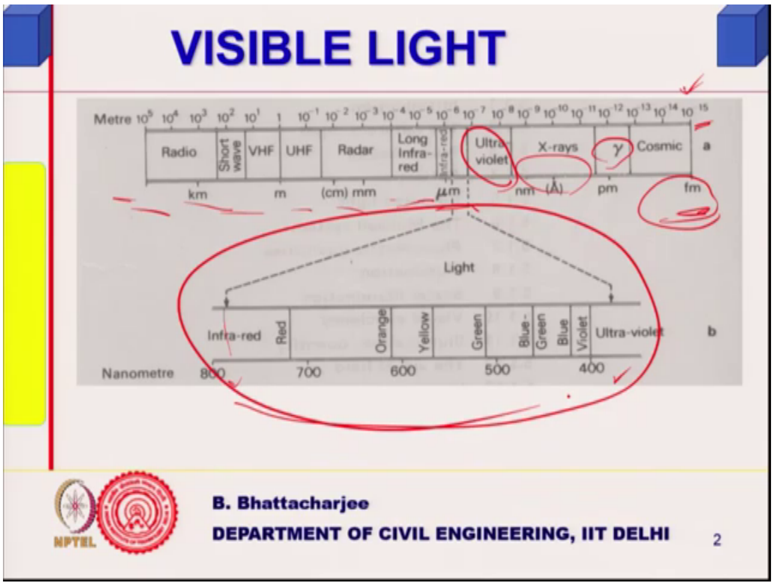

Now, lighting basically illumination design and if you look at it this we might have talked about somewhat earlier the totally electromagnetic spectrum, you look at it little bit of introduction to light that is what we will talk about in the beginning illumination related units because they are different units and first we will talk about that then we go to day lighting design and things like that.

So, if you see electromagnetic spectrum the wavelengths are given here; obviously, frequency will be smallest here, wavelength is maximum you know minimum here 10 to the power minus 15 and this side is 10 to the power 5 shows in terms of meter. So, wavelength so this is cosmic radiation is the, you know smallest wavelength highest because they come from far off so high energy stuff.

Then your gamma rays, X rays, ultraviolet and there is a small band of visible light right going from something like about 370 or so nanometre to around 760 nanometre or 7 nano close to 800 nanometres that is the visible light. Then you have got infrared radiation which we talked about earlier, the heat radiations heat radiations right then of course, rather ultra high frequency very high frequency shortwave radio waves etcetera etcetera.

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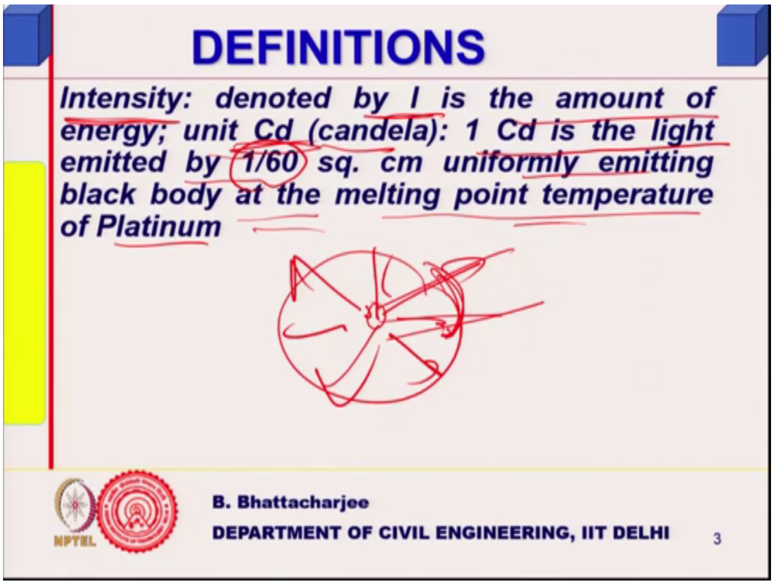

So, this is a small band which is visible light, which is visible light and sun's rays contains this insufficient quantity and therefore, you know we can make use of sun's radiation for lighting or for visual, visual um comfort or visual performance etcetera. Now, they need different units, why? Because the quantity of energy is very small, quantity of energy is very small we cannot use watts, watt is too large a quantity for illumination. So, illumination you know related to illumination units are different.

Now, first we look at intensity, that is the fundamental unit actually. Now, what is intensity? Intensity that we have seen was for radiation it was watt per meter square, energy density power density similarly in case of sound also we have seen it was watt per meter square we talked in terms of watt per meter square right.

So, that is power density here we talk in terms of intensity we call it candela, in s I unit we call it candela right. So, we denote it generally by I, I is the intensity and is the amount of energy candela, that is can candela. So, one candela is the light emitted by 1 by 60 square centimetres uniformly emitting blackbody at the melting point temperature of platinum. So, everything else have been fixed, the temperature at which it is emitted is fixed right and size of the element is also fixed. So, amount of light energy emitted from 1 by 60 square centimetre uniformly emitting; that means, is almost like a point source emitting in all direction, blackbody at melting point temperature of platinum. It is close to at the frequency is fixed actually the wavelength is fixed is close to a yellow light or whatever it is whatever particular nanometre 550 nanometre perhaps.

So, that amount of light is called 1 candela, 1 candela 1 candela right and then 1 candela. So, therefore, this in intensity is associated with source, remember we when we talked of sound field we talked of intensity of the field for source we talked of power level right here the intensity per unit area emitted intensities the you know the energy emitted, total energy emitted from in all direction from a source that we are calling as one candela right.

So, how much it would be if I want to find out because it going in all direction, that is what by definition right uniformly emitting in all direction. So, I do a very small say point source going in all direction.

Now, the density I if I want to find out density then I must divide it by area or something of that similar kind, but here you do not divide by area because the area is too small right, area is too small. So, if we divide by area it becomes very it will become very large point source what is the idea.

So, what we do instead we divided by solid angle per unit solid angle. So, you know so or the light that is passing through unit solid angle right. So, we talk in terms of flux then, we talk in terms of flux and the amount of energy emitted through unit solid angle.

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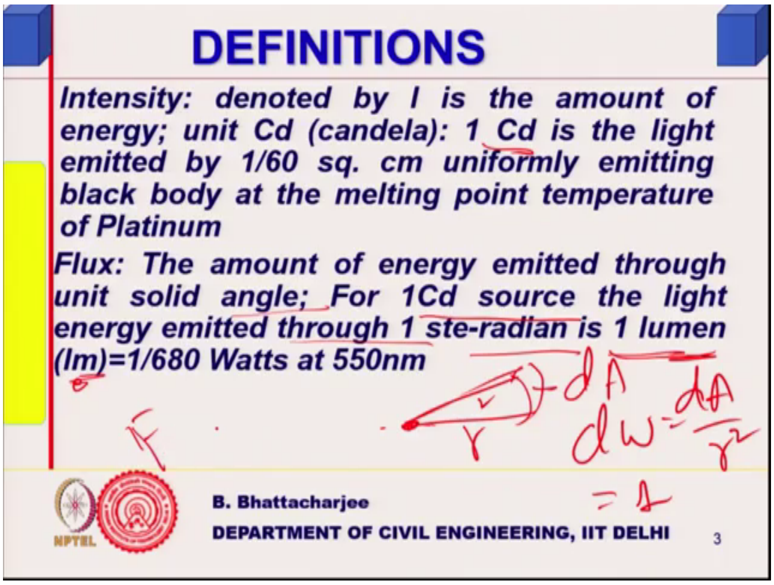

We talk in terms of energy emitted through you need solid angle, for 1 candela source the light energy emitted through one ste radian, you know you remember we talked of solid angle earlier. So, 4 pi ste radian is the solid angle subtended at a point you know in all direction of spherical front going on.

So, one candela source the amount of energy passing through unit solid angle we call it one lumen or flux, you know it is 1 lumen, it is 1 lumen denoted by l m this is denoted by candela. So, 1 lumen so 1 lumen is nothing, but if I have a 1 candela a source that light energy that passes through unit solid angle from such a source. Now, a point source actually subtends 4 pi ste radian therefore, a point source will emit 4 pi lumen, is this point all right the one candela I have a one candela a source I take you know this is a area anyway this is a area this is a area.

So, this is let is say d a divided by r square, remember we talked in terms of d omega will be equals to d A by r square when this equals to 1, 1 solid angle and if my source is 1 candela then the light that is passing through unit solid angle that I call as 1 lumen or unit of flux unit of flux right.

So, this is denoted usually by F flux is usually denoted by F and flux, how many flux will then come from 1 candela a source in total 4 pi lumen because through I am by definition I am saying whatever energy comes through unit solid angle that is 1 lumen since it is obtains 4 pi ste radians. So, it will be 4 pi lumen, 4 pi lumen.

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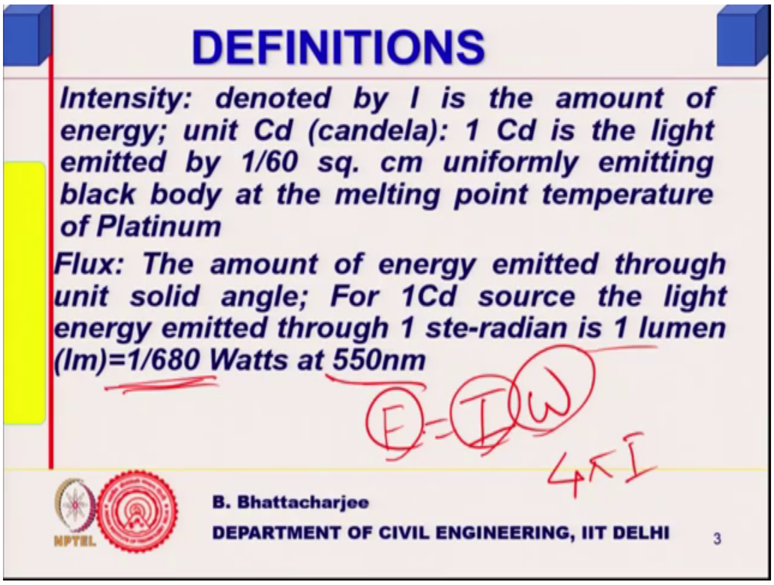

So, that is the definition of lumen or unit you know that unit and just compare this with watts 1 lumen is equals to 1 by 680 lumen you know sorry 680 watts 1 by 680 watts.

Now, this were earlier in F p s system. So, you find that you know coming why 680 why 1 by 60 centimetres square centimetre because they came from they actually came from a peer system foot candela etcetera, etcetera, but whatever it is. So, this is what is, so 1 lumen is equals to 1 by 680 watts at 550 nanometre, 550 nanometre wavelength of light wavelength of light right. So, that is how we define flux.

So, F is equals to actually I into omega, if I is the intensity for a point source 4 pi I will go in all direction, but through a omega solid angle it will be I into omega right. F flux, flux through omega solid angle for I intensity source is F equals to I omega because by definition I am saying F is that energy that is going through 1 solid angle, 1 solid angle alright one solid angle right.

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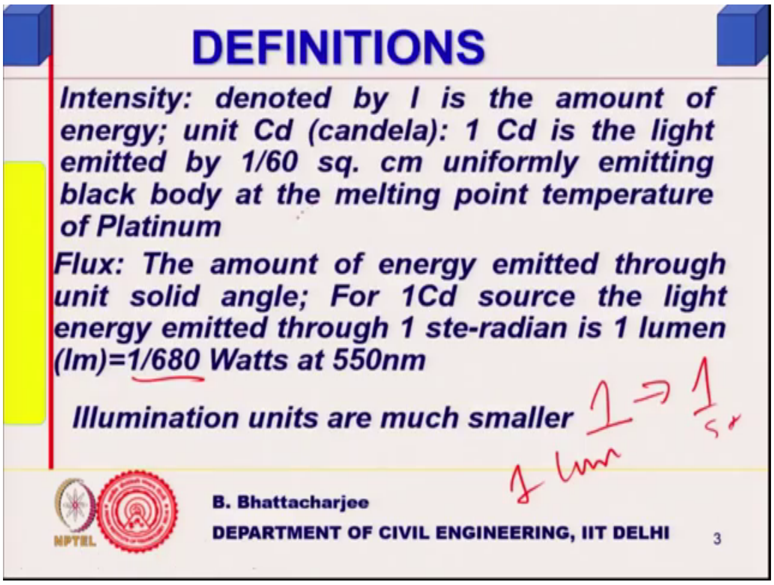

So, that is the whole idea illumination units are much smaller that you can see that is how you are using separate, separate units not using watts anymore. So, we are using you know flux n i. So, illumination is defined now, this is it this is this is for source I was for source, flux is also for source, but flux also links the receiver. In the sense that I have a source from the source light energy comes out, but to see something say for example, if it is a task you know working plane or your paper, where you are writing or reading from that is also acts as a source for the eye because light is reflecting from there and that is why you are.

So, the amount it will reflect is very important, how much it is receiving and how much it will reflect that is very important. So, finally, how much the how much the paper or your book or what we call task plane, working plane receives that is very important or emits that is very important.

So, illumination we define with respect to a receiver which acts like a source, see the source can be the light, but the light has to come on top of something and reflect for of me to see. So, the amount of light received on this one and then reflected back to my eye that is important. So, fluxes with respect to source, but flux is received on a working plane or task plane, on the task you know tasks for example, if you are doing watch repair on a table this fluxes received on this one and how much of it comes to my eye that would be governed by the reflectivity of that or lets for the time being take it out as 1 take that reflectivity as 1. So, the energy that is received on this surface or energy density there is important and that energy density is called illumination.

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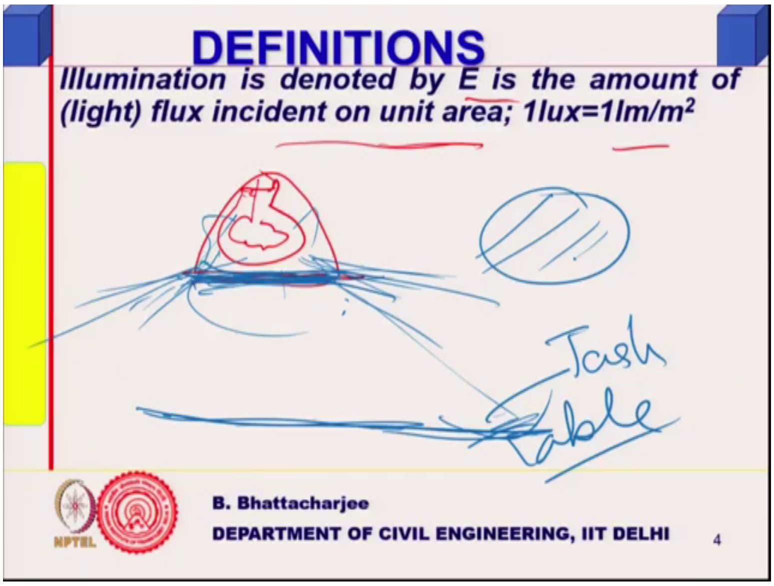

So, illumination is defined, it is given by E right and it is 1 lumen per meter square received on the receiving surface which will act like a source for the I, which will for example, is a blackboard or a board or the screen lumen will be received there, but lumen received per unit area is important because that would follow it will tell me how easily I am able to see or how easily I am not able to see.

That is related to you know why my ease of seeing will be dependent on this value of e. So, E is defined as is a illumination it is defined in terms of lumen per meter square. So, it is actually the link between the source and the receiving surface then finally, to the eye of course. So, is a flux per unit area incident you know black flux incident on 1 unit area. So, you can see that so this 1 we can link this up we of course, will link it up in a minute, but let us.

So, the characteristics of a source again is important, I took point source, but sources are not necessarily point here because if you have a lamp it is, it is you know its projected surface. If you consider a lamp it is projected surface area for example, if this is let us say a table lamp or something of this kind right here you have got the you know something like this the balloon. So, this portion, this portion through this actually light will be emitting right it might be emitting like this through this zone it might be emitting through this zone, more direct through this zone and something indirect through this zone, you know lamp table lamp or something like that a fitting lamp in the fitting.

Now, you see this dimensions would be of the order of 200 mm 250 mm and you might be reading at a distance of let us say half a meter or 1 meter or even less right. So, these size is comparable to this distance, this might be your touch plane or reading table, table. So, these distances are not very large compared to the dimension; that means, it will not be 6 time the dimension, you may not be able to treat them as point source all the time unlike my earlier cases.

So, I might be and how much you know I might be interested in the power of this source as well. So, we talk of brightness of the source, this projected area is what I see, projected area is the one which is responsible for passing the light because through this projected area finally, which will be elliptical in shape or may be circular in shape which will be a bright surface which will, which causes light to be received here.

Because, light from here direct light will come like this direct light from the lamp will come like this, but there will be a lot of reflected light coming and the last point you know reflected light coming from this side because some light will come and go like this. So, lot of reflected light will come from that lumena as we call it or the you know the shade lamp shade or whatever you call it fitting. So, it comes reflected light comes from there.

So, therefore, this will act as a it will appear as a bright surface to me the circular bright surface, circular bright surface. So, brightness is defined in terms of intensity per unit area and that is for a source for a task plane or by object which I want to see it is lumen per meter square, on which my seeing will be ability to see will depend right.

Ability to see I mean if you are walking on a corridor and it is absolutely dark then you cannot you might fall or something like that now that would depend upon illumination level their lumen per meter square, but it must be coming from a lamp or some portion of sky. So, it comes from the lamp, the lamp surface projected surface of the lamp fitting that will actually contribute and that capability of that one I judge in terms of its brightness. So, brightness is defined in terms of candela per meter square.

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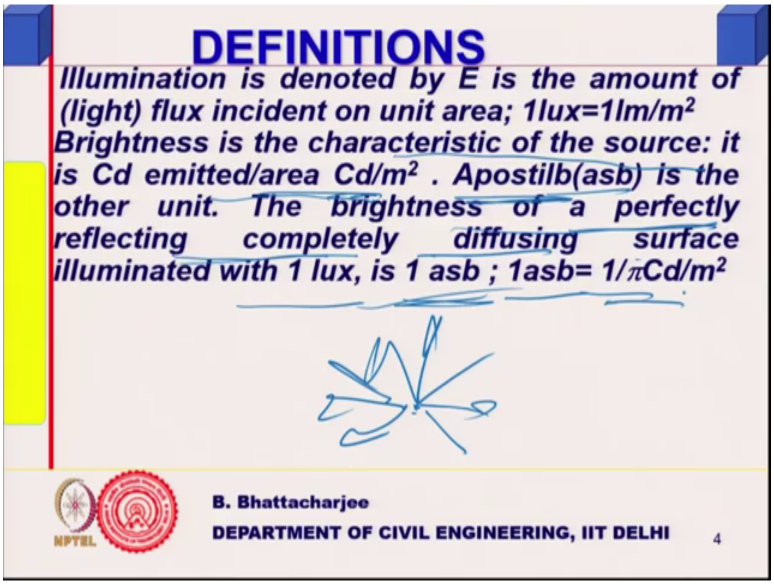

So, brightness is a characteristic of the source it is candela emitted per unit projected area actually. So, it is in terms of candela per meter square and there is another unit called apostil I will just come to that in a minute. So, candela per meter square is a brightness of the source. So, what will be the brightness of a source of a lamp let us say the table lamp that I was talking about, the candela that it emits divided by the projected area of the fitting, projected area of the fitting projector.

Now, for a you know diffused spherical lamp you know you have those globes you see in decorative places in the garden or something of that kind what will be the projected area pi r square, projected area pi r square. So, candela when I want to find out the brightness it will be the intensity of that source divided by pi r square r.

So, that is not that is the by brightness, but then that is the brightness of the source, but for my eye what is the source, it is the object itself for example, the blackboard, the paper therefore, I must have a way to talk about the brightness of such sources from where light comes to the eyes. So, another unit is used which is called Apostilb which is called you know apostilb, which is called apostilb.

Generally denoted by a s b, a s b and is the brightness of a perfectly reflecting. That means, if the reflectivity is one of a surface which is not a source, is not generating light it is receiving light and transmitting in to the eye or surrounding. So, such a surface is brightness if I want to express for example, the working task plane object or even surface of a building from daylight point of view, sun's light reaches to one of the building surface and then reflected back to into the room it can be reflected back into the room through the window.

So, next building it might, now then that surface it is receiving light from a source its itself infra is not creating light itself, but its acting like a source for the room. So, for such surfaces we talk in terms of another brightness unit called apostilb and it is defined as the brightness of a perfectly reflecting; that means, reflectivity is 1 whatever it receives gives out, but gives out in all direction completely diffusing.

What is diffusing we talked in conserve acoustic sound that is diffusing. So, it will be going in all direction, it will be going in all direction, normally the mirror they have specular reflection, ray incident ray and then reflected ray angle of incidence is equals to angle of reflection, but a roughs inner surface with lot of undulations something like a at not so polished tabletop it will tend to direct the light in all direction. So, that is diffuse reflection right.

So, it has to be perfectly diffusing and surface and if its illumination is 1 lux then its brightness we call as 1 apostilb. So, is linked to the, it is illumination level. So, we are talking in terms of surface which will be reflecting. So, that is 1 apostilb and actually the 1 apostilb is related to 1 candela per meter square, you know its related 1 by pi candela per meter 1 one apostilb will basically how. Let us see if I have something to tell you about that.

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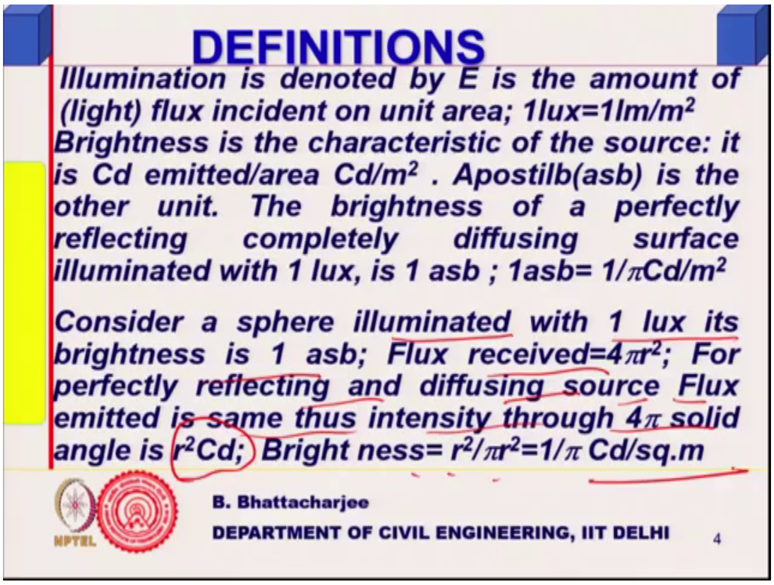

Supposing I have a small sphere ok, just draw a small sphere.

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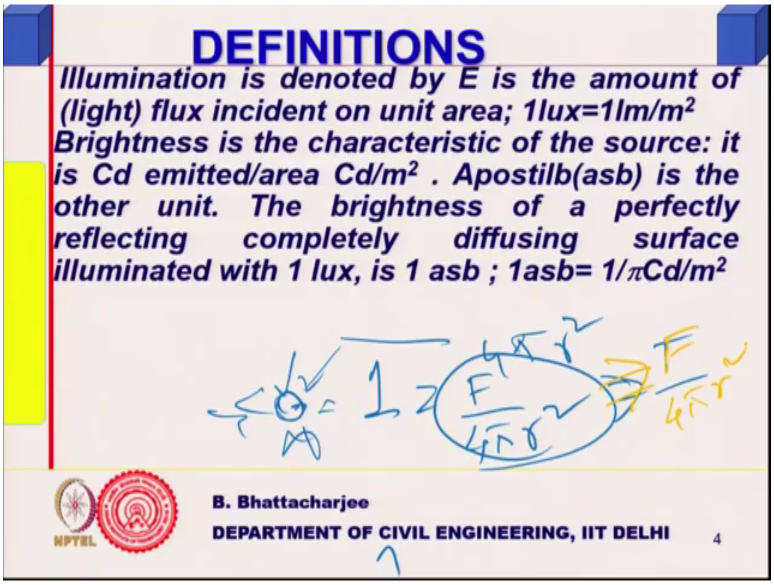

Illuminated by 1 lux small sphere light coming from all sides equally in a diffused field and this is illuminated with 1 lux, is illuminated 1 lux right. So, how much is the flux coming into it if its radius is r surface area is 4 pi r square right. So, how much is the flux, how did we define flux lumen, lumen per meter square is E which is 1 lux.

So, 1 1 is equals to F well flux coming divided by 4 pi r square, if r is a radius of that small point source sort of thing is very small point source illuminated with 1 lux. So, that is the flux coming in and if it is reflecting, if it is reflecting 100 percent then the flux going out will be same flux going out will be same, flux going out will be same.

So, F by 4 pi r square will be reflecting back you know reflected amount will be also reflected amount will be also, reflected amount will also be reflected amount also will be F you know by 4 pi r square right. So, it is suppose to reflect everything. So, again it would be 1 divided by 4 pi r square right.

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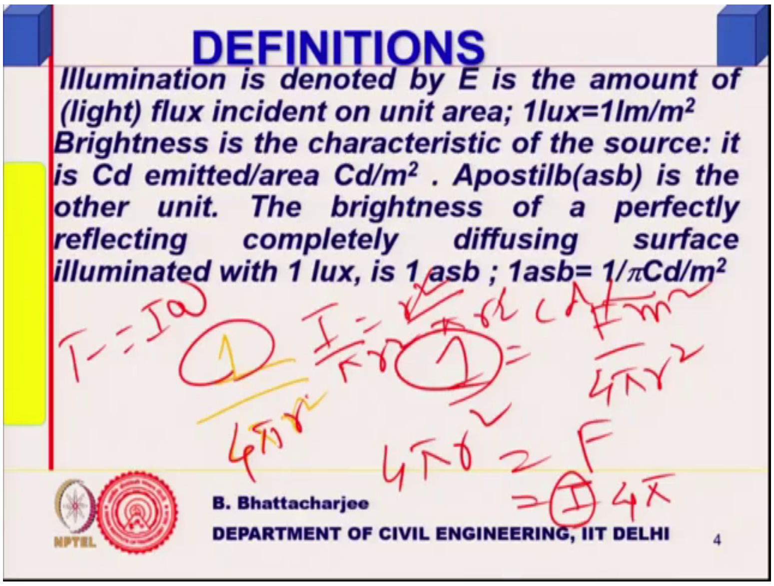

That is a that is the there's a flux I am talking of because illumination sorry one was equals to F divided by 4 pi r square. So, 4 pi r square is a flux, 4 pi r square is a flux right that must have been coming to this one. So, brightness we define in terms of candela per meter square, 1 apostilb means this is equals to 1, 1 apostilb means 4 pi pi r square flux must have come onto it right and we define intensity as. Intensity how do you define, intensity I defined as F is equals to F into 4 pi because it is coming from all sides its coming from all sides.

So, F was equals to I omega, if you recollect F was equal to I omega. So, the corresponding intensity is equals to I into 4 pi right. So, intensity is nothing, but I, I that is you know is equals to pi you know it is simply r square, I simply r square.

Now, through which area it is going out because I divided by the projected area is candela per meter square. So, candela per meter square will be this divided by pi r square. So, pi r square. So, 1 by pi, 1 by pi that is how it comes you know. So, 1 by pi candela per meter square 1 by pi candela. So, 1 apostilb is equals to 1 by pi candela per meter square you know it is, it is I, I just repeat this what I am saying is 1 lux is, a 1 lux is the illumination at the surface of this sphere, small sphere. So, if 1 lux is the illumination it must be reflective it must be you know 1 lux is a illumination it must be receive receiving 1 divided by 4 pi r square flux right and must be reflecting the same.

So, therefore, whatever it must be emitting 1 by 4 pi r square must have been getting the same. So, the flux is 1 by 4 pi r square and flux is equals to I into omega sorry, not flux flux is equals to 4 pi r square, flux is equals to 4 pi r square, flux divided by 4 pi r square is equals to 1. So, flux is equals to 4 pi r square and this was coming through I into 4 pi. So, intensity is nothing, but r square and intensity devices are projected surface area which is pi r square.

So, candela per meter square can the I candala divided by pi r square. So, this will be 1 by pi candela per meter square and this is written here, this is written exactly here consider a sphere illuminated with 1 lux is brightness is 1 apostilb flux received is 4 pi r square for perfectly reflecting and diffusing source for flux emitted is same that is intensity through pour 4 pi solid angle is r square candela. So, brightness is r square by 4 pi r spin over r square by pi r square 1 by pi is candela per square meter that is the derivation of this idea.

So, we use whenever we are talking of the object that I am viewing I talk in terms of brightness in apostilb quite often and if I have to convert it to candela per meter square then I use this relationship and if it is a source like light lamp or something like that I might still use the intensity. But generally it is a flux you know lumen output of a lamp is what we talked about for example, all these new lamps have come LED and those ones earlier CFL. So, their lumen output efficiency is much higher per watt ok.

So, I think we will stop here and then come back again.