Classical Field Theory
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Lecture - 27

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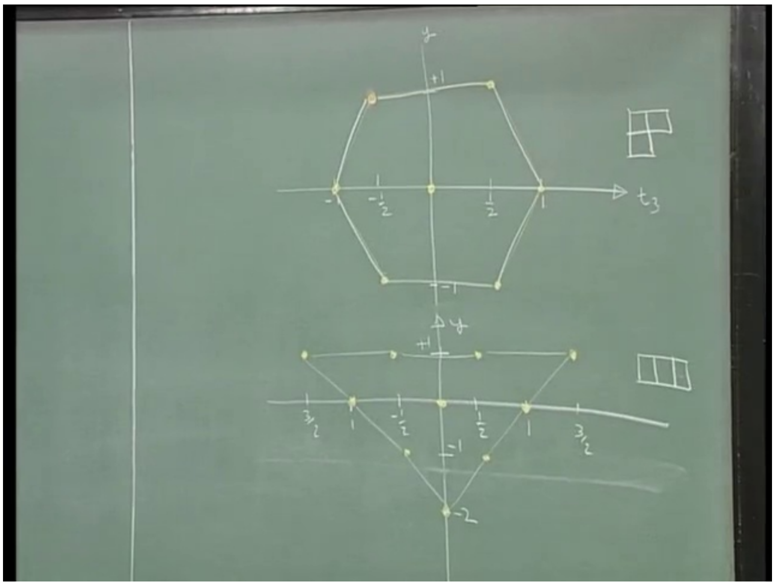

Most of it was abstract, but one thing we say was that all representations of s u n can be understood in terms of you know objects like this. Whereas, diagrams we also wrote out some formula for the dimension of these representations. Of course, I did not prove that this is a reducible or whatever, so but I mean you have to take it as a theorem that these are irreducible representations, that is part of a math course or whatever. And so the thing is that but there is something which you can do explicitly; since we s u 2 is too simple too trivial actually, so s u 3 is the first non trivial.

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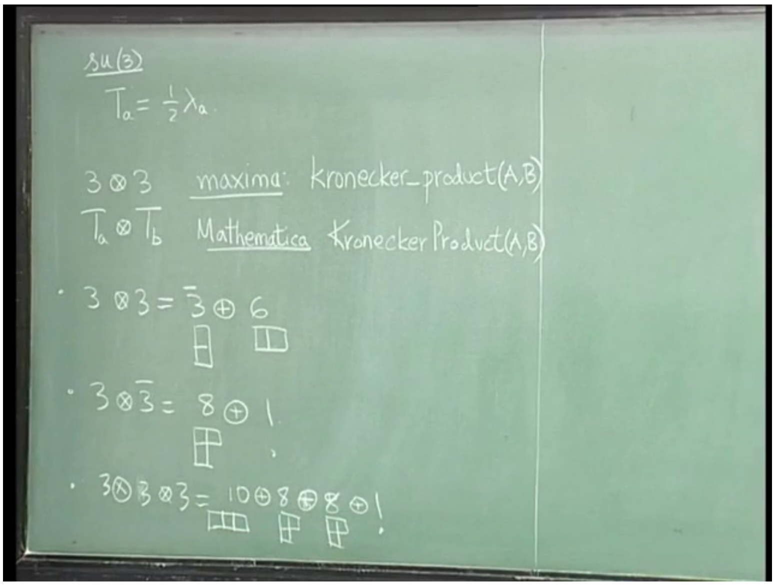

And so we saw that we could choose for s u3 .We the lie algebra s u 3 which was the t s to be half of the Gellman matrices. So, so now the thing is obviously, we can go ahead and do the tenser product. So, if you said analog of 3 tenser 3 can be realized by just taking the tenser product of these matrices Ta T tenser. So, so this will be a 9 by 9 matrix because these are all 3 by 3 matrices, it is a little bit of a pain to do it by hand.

So, what you can do is to use you know programs like maxima or mathematica and actually implement this by hand and, do the symmentrization, anti-symmetrization by hand and convince yourself that you actually you can make it into a block diagonal and this T composition actually works, it is actually fun to see. So, I will give you the commands in i just use the internet to check what are the commands for these things, the direct product of matrices is also called the kronecker product.

So, that is why? So, so it you go to maxima and if you give any two matrices it will give you its kronecker product or the direct product of the matrices. That is I am suggesting so, one like something like maxima is that is freely available, but if you have access to mathematica the same thing is called kronecker product. So, I am not suggesting that you go ahead and do these things by hand, it is it is not fun because if you see a runs over eight the thing.

So, this 8 into 864, such guys and then you and each will become a 9 by 9 matrix, but if you if you do it by or the symbolic program languages, which is available freely available these days you can actually play with these things and explicitly if you see for yourself how it works. I am never d1 this, so i i just I just it was a thought which occurred to me. So, at least the least you could do is we what was the things we should 3 tenser 3 is equal to what was this equal to, 3 bar plus 6 right and what was 3 bar was this and this was this. We also worked our 3 tenser 3 bar and, that was the easiest 8 tenser 1, so 8 was this and this is just a dot. And, so these two are easy to do little bit of a plain to do is the next one which I will write that is like that is if you have the 3 tenser 3 tenser 3 which was can someone remind me what that was.

So, that is 10 plus 8 plus 8 plus 1, so these were just these this was just a dot and, this is. So, what we are going to do today is to use all these things in explicit application as, in an in an explicit application like it. But, before that two lectures ago we did something totally obstruct, we said you know what are the labels that you would associate through to to a representation. And that was determined by looking at the generators and asking what is a maximum commuting set.

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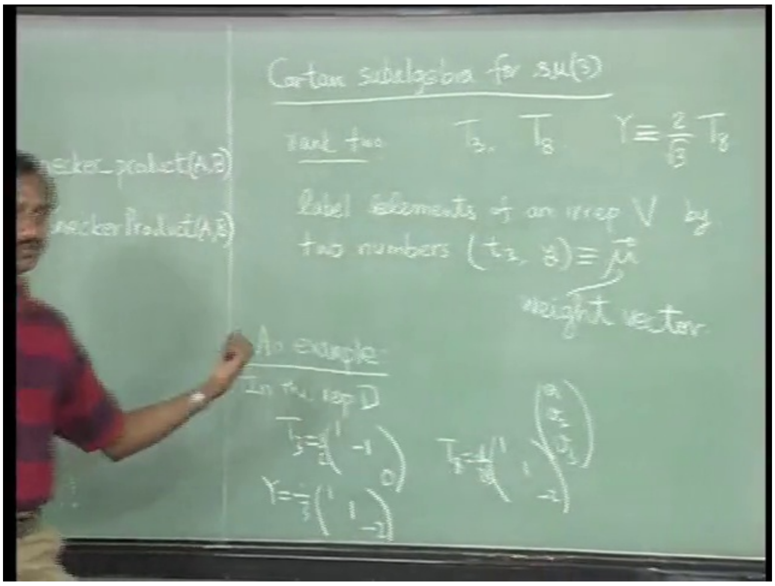

So, the carton sub algebra for s u 3, consisted of three two generators it is rank two. So, its rank two, which is just the number of and we are going to work with the convection T 3 and T 8. And to connect up with our particle physics application, which we were going to look at I will just define why which is is 2 by root 3 of T 8, so this is so the so so we will…

So, in other words label label vectors I mean elements of an irrep v by two numbers T 3 and y, I will I will combine this combination and I will call it mu since there are it is. So, any element will be given two such numbers and because it rank two. So, just to make a comment in a general case, if it is rank n there there will be, so as many elements in the carton sub there will be n such elements so the vector will be n dimension.

So, this has a name this is called a weight vector, so what I am going to do now is to take an example. So, the easiest one would be just asking the in the three representation in the representation box the vector space has three elements right, which will write as v 1, v 2, v 3 and.

So, the question is how does T 3 act can can you people remind me what T 3 is, T 3 was just 1 half of this right 1 minus 1 0 and what was t 8 1 1 minus 2 and 1 over 2 root 3. So, if I, it becomes 1 third sorry sorry it is 1 by 2 root 3 is it T 8. So, then y would be 1 third of this.

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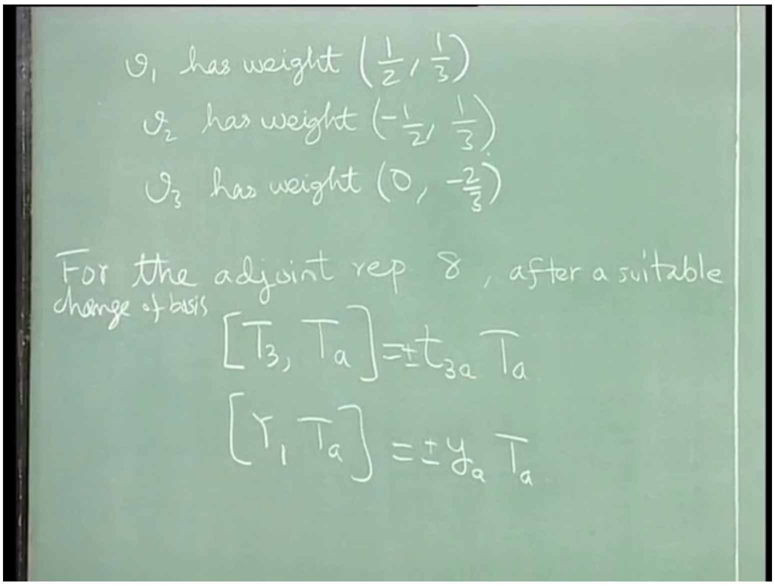

So, what this implies is the first element has so v 1 has weight half 1 3rd, v 2 has weight minus half 1 third and v 3 has weight 0 minus 2 3rd's. What, it does not matter it does not matter right i can even take any linear i just i need two linearly independent labels and the reason to you can one simple reason is that at least the square root of three goes away. But, I have the reason to choose why he is got to do with historical there has a historical reasons.

So, in mathematical literature you would not I do not think people would choose y they would 3 and 8 T 8 itself it is good enough. There is no I mean you do not lose anything right by how you specify things. So, so this is what you get now the question is what about what about these representations say this 3 bar is a kind of a easy 3 bar and 3 will you they have the same weights, there is no complex in this thing, so they have the same weights. Now, but we would like to ask what about the 6 for instance or for instance what about the 8.

So, infect 8 as we already saw that the adjoint representation is very natural it is actually related closely to the lie algebra and so, for the 8 there is a nice way of understanding it is just the you take. For the adjoint representation for the ad joint representation you have to just look at the Eigen T3 with any element. So, T 3 with say some element like t T 3 of t a will be some actually will be up to a sign, which I am not sure what is the I mean up to the sign this will give it. So, so the statement in the adjoint representation is equivalent to this commutation relation.

Already we saw some inkling of this in one of our assignments. So, so for the ad joint representation which is in the eight you can see that the these are just Eigen values of this, so you can. So, 1 way of doing that is to just now going back to to working out looking at the lie algebra of of of s u 3 and you can extract out these this two numbers, if you that find something is not in if if the way, it was written it was not in an Eigen state; then you have to take linear combinations and make it. So, for instance obviously, t t1 and T2 are not Eigen states of T3, but T1 plus or minus i t 3 T 2 would be Eigen values, so there is some, so you will need some change of basis.

So, let us put that after a suitable change of basis, because if you looked at T 3 T 2 you will get T 1 here that is not quit it is not an Eigen this thing so, but you can you can always find suitable linear change of basis such that the system. So, so now I am out here, I have written out.

So, what you can see is that, so one more thing you can see here is T3 with T3 is 0 and t y with T 3 is also 0. So, the Eigen value for the weight vector for the caton elements of the caton sub algebra in this case T 3 and y is 0 0 it. So, the point one more thing which you can see is that you can have elements in a representation, which have the same weight vector, but there is a notion of highest weight or a lowest weight vector, which is like our bottom and ceiling which we talked about those tend to be unique. I use the word height weight vector without I were defining what highest i meant. So, highest or lowest again that is a point of you right if you if you stand on your head I mean up becomes down, down become (( )). So, those kind of thing it is just at sometimes it just a convention. So, let us look at what happen in eight dimension representation, which is ad joint.

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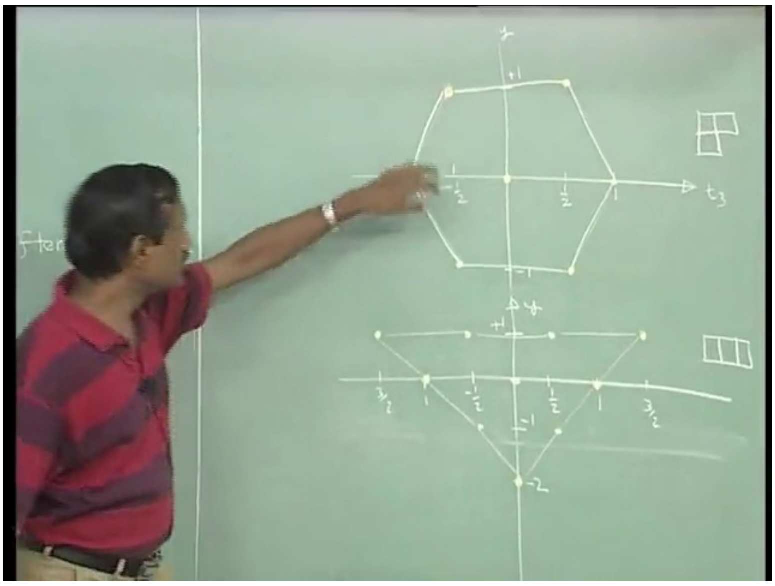

So, what you will find is I like to always locate in the following way, we know that T3 t 1 and t 2 from s u 2. So, algebra if you keep track of the T 3 Eigen values if you just this thing what you will see is that, if you know what just in s u 2, so you just need what spin multiplied it is, so I will look at this thing and I will do it that fashion. So, let us look here and see this, so what we see here is half and minus half. So, this is spin half you look at the s u 2 sub algebra given by T 3 T 1 and T 2.

So, this is spin half this is spin 1 minus 1 0 and plus 1 and this is again the spin half the why they different y Eigen value obtusely and these actually even the indicated by 1 dot, I actually should put two dots both are on top of each other. So, I am just drawing it because and there is also one guy which is spin 0, which is independent of this thing. So, you can see that if you just look at thus decomposition.

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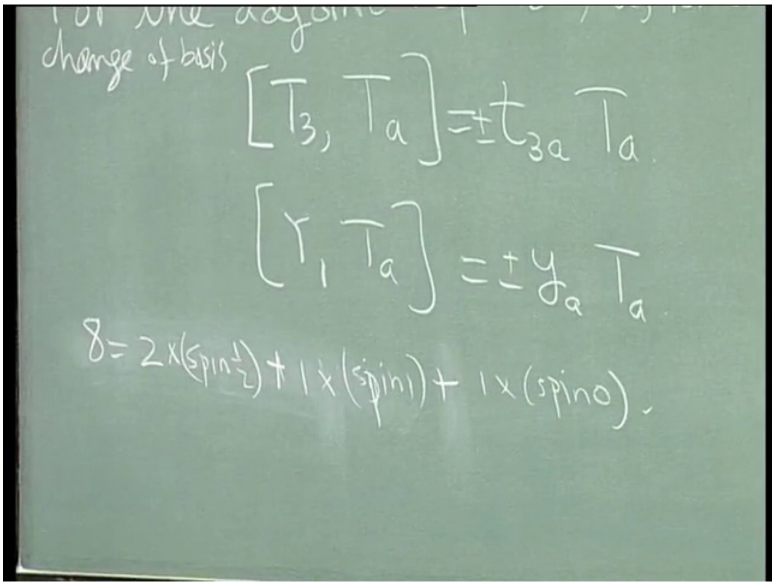

So, what we are see is the statement I am making can be understood in this for 8 of s u 3 decomposer into looking at this particular s u 2 sub algebra into two spin once. So, two copies of j equal T 3 equal to half, let just write it has two copies of spin half representation right plus 1 copy of spin 1, let me write spin. So, what we have is 8 breaks of it into 2 copies of spin of plus one copy of spin one time plus sorry 1 copy of spins 0 and there is also this 10, which is the symmetric guy and that is called a a decuplet.

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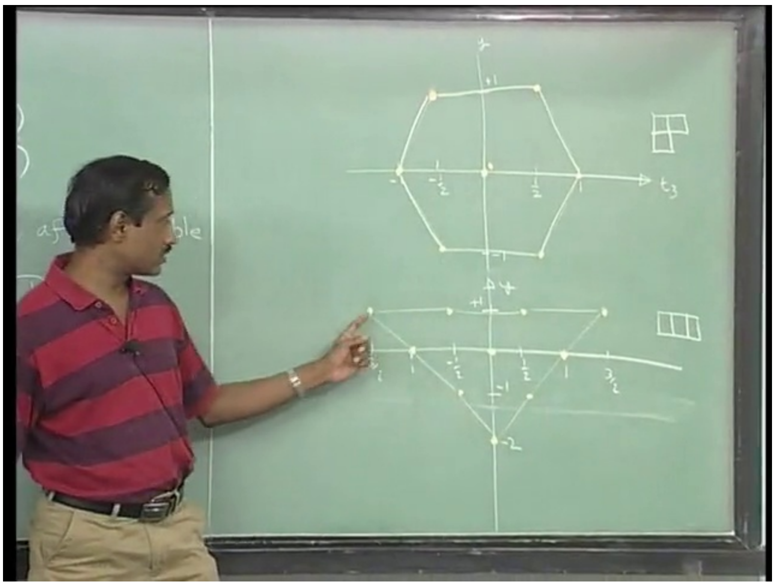

And you can how that kind of very nice it is 1 copy of spin 3 half spin 1 3 half 1 half and 0.

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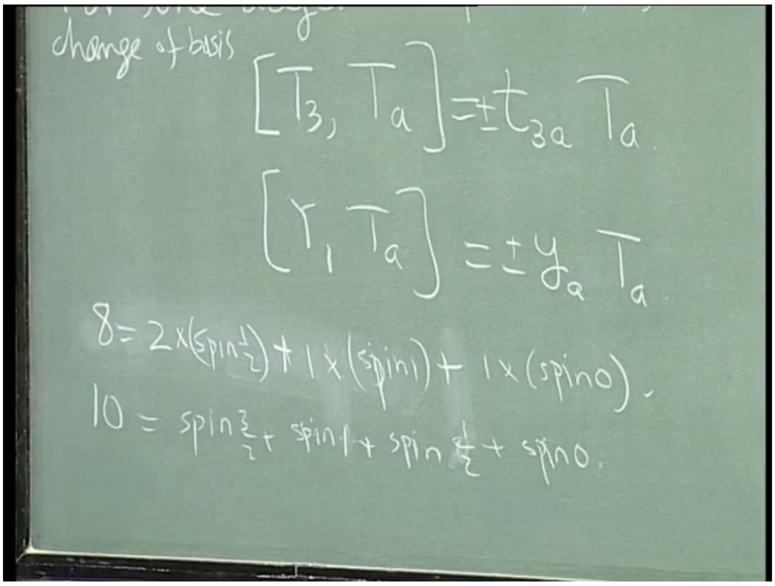

Similarly, 10 equal to (No audio from 16:38 to 17:00), so this picture tells you a lot more than that it also gives you the y Eigen value, but it is useful to located at 1 by 1. So, now, let us look at the y Eigen values.

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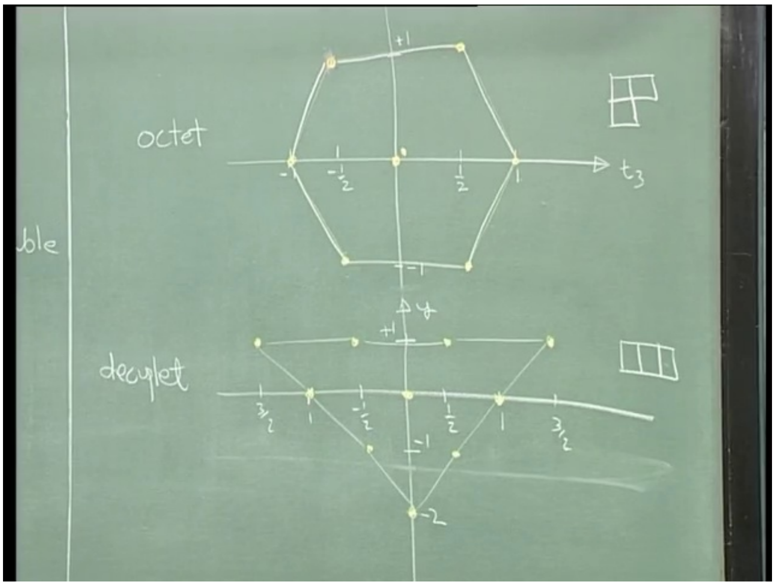

And we see that in the spin 8 there are four guys with y equal to 0. And so, with y equal to plus 1 and two with y equal to minus 1. And and the you can the reason I have to only go horizontally you you might think is can I have some weird thing like can I have one here somewhere else which can form, which can form a s u 2 multiply that is not quite true because y commutes with T 3, so you can simultaneously diagonal zed them. So, in other words if you take an, so if something is in a given representation of this thing it is all of them will have the same y Eigen values. So, that is why I am going, I am just look I do not even able to look very far, I just say I take these two have to be paired up because you are looking at the this.

If you go to higher higher representation there might be many ways of decomposing then you need to be you need to put in some work, but here there is no ambiguity out here. So, these pictures hopefully make sense from the abstract view point. This is obviously, called the octet and this is called the decuplet, so are there any questions. So, what I am going to do now is to put all these things together and use it in in what is called the quark model. So, I will spend about five minutes telling you about the quark model.

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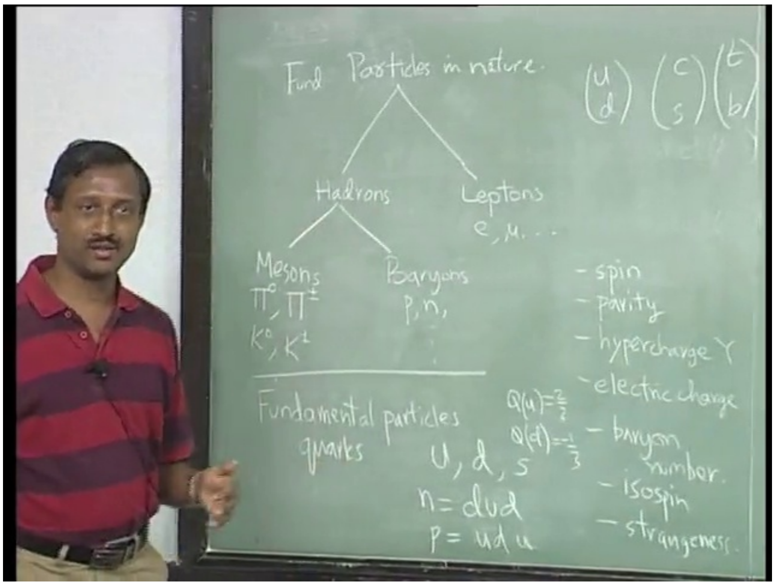

So, first thing is that particles in nature by that I mean fundamental particles. So, are broken up into two kinds of things will call things which we call Hadrons and things we will call Leptons. This so, first thing is that actually first thing first what you do is to disturbing between bosons and fermions. And all the bosons that we know of like proton w and g bosons they are all they they transmits they are carriers of some force the exchange of them gives you various forces in nature. So, we so, when I mean particles, I mean i mean things which are constructed from fermions.

So, so, the thing is that the Leptons do not feel what is called the strong force. This is what keeps the nucleus together. So, you cannot I mean you cannot have protons together because they have both positive charge and without any so, there must be something which cancels the electromagnetic repletion. And so, people conjunct there is this strong force, which which which is attractive and which cancels this thing, but then you may say why is it we do not see this thing and the the answer to that, is that it has very finite range.

So, up to some distance it has an action, but if you go far enough it becomes very weak. And beautiful model for that is to thing of the potential going as e power mu r 1 r, when mu is some mass. So, you can see something like this can be this this force will die off of very exponentially first, when I use mu here because in nature units mu is like a mass or one over mu is like a length scale. So, at length scale it is greater than one upon mu, you will find that the force will die down.

So, this is called the Yukawa potential. And you can show in from elementary calculations in quantum field theory that you will get this kind of potential if if a force a carrier has mass mu. And you are asking what is the what is the potential due to one exchange and this is what you get. So, this is wonderful model, but that is not relevant for a what is relevant to us is that there a strong forces, there are things which do not feel any strong forces. It is similar to un charge particles not experiencing an electromagnetic force.

So, there are particles which do not experience the strong force, they are called Leptons, examples are electrons, neutrons. But Hadrons they experience a strong force so obviously, examples would be proton neutrons etcetera. So, but they also fall into two categories, Mesons and something called Baryons, so this examples of these are protons and neutrons.

And here examples are what are called pi Mesons pi is 0 pi plus pi minus, this were I guess first observed in cosmic rays. And then there are many more I do not know k 0 k plus minus, even here there are many, many more. And what happened is that when experimentally started doing carrying out experiments they started observing what are called resonances.

So, if you have looked at any computation of differential cross sections in quantum mechanics or in in some particle physics course. What you will see is that, there will be if you there will be a peak as you change your energies you will find somewhere a peak coming. And usually even in a quantum mechanical problem you will see that these peaks are related to the existence of some bounce state or some new or production of some new particles or what. So, now, the thing is in fact, there is more stuff to it the width of the resonance is related to the life time of the particle.

So, particles need not, so these particles can be Meta stable they can decayed they can decay into other channels. So, they will exist only for a finite amount of time, whether if i have a free neutron does anybody know its life time 15 minutes. The question is why do not we decay, we are made up of protons and neutrons why do we decay. So, there why we do not have free neutrons in our body they are bound they are sitting inside the nucleus so that is why do not decay.

So, so the question is so, but the thing is what happened is that people started finding lots and lots of resonances and there was a if I you know every day you discover one if I give it a name, and you name after whomever your dog or your wife for your girl friend or whatever. So, you could give it all sorts of names and the question was you know it is total I mean it was more like a zoo of particles when you have this classification that was a historical set up. And Gellman and Niemenare came up with this idea or may be these these objects which we are which we see are not fundamental particles they actually consists of some some other constituents.

But the actually that was not the reason first group there he was used, Gellman came up with something called the eight fold way. I just this was takeoff on Buddhism or whatever. Gellman is a polyglot, he knows many languages, he knows allot and so, it is so, it is not surprising he knows lot about eight fold way and stuff like that. But he was he came up with this idea that we could organize the zoo of particles into octets maybe decuplets etcetera.

And so, somewhere he said know if you three as some role to play and then they found that by assigning and all particles which you saw you would assign quantum numbers to it. So, quantum number which were assign were obvious once, spin of a particle you can ask, you know that, you would know it is parity. Then you then they started assigning other things there was something called hypercharge which is y and, then of course electric charge of the particle then baryon number so, the idea was that he just distinguishes.

So, Mesons have baryon number 0, Baryons have baryon number plus 1, anti Baryons have baryon number minus 1. So, they so, this kind of quantum numbers people, I mean there were assign to all this particles and what what was remarkable was that Gellman and Niemenare able to show that by using s u three representation theory. They were able to relate some of these things and organize the stuff. And little bit down the road they, I mean Gellman and I forget who, proposed the quark model and few few others.

So, it let to constituents which we are called quarks so, so the thing is that these where not fundamental particles. The fundamental particles this supposed to be quarks. So, what where the kind of quarks so, the first thing you would like to know is what what are the quarks, which are in proton and electron etcetera. So, first thing they need a two quarks u and d, up and down you could call them and there was some more I mean iso spin.

So, there was there so, I am not writing a complete list so, you have u and d. And so, people put things together and so, the neutron was suppose to be made up of 1 u and 2 d is. And a proton suppose to be 2 u is and a d and they remember things is that I think of neutron is that the dud it has zero charge. So now, we can we have to now sit down and assign electric charges to u and d such that neutron and proton have they appropriate charges. So, already you can see that d should be half of u, and there will be a sign difference.

So, we fix that by coming here so you will see that you will require u to be charge q of u should be I thing two thirds and q of d should be minus 1 third. So, this was the electric charge of this guy. But the power of the quark model is now if you said that there is something else made up of these guy, the charges you have additive and may should work out no need to know details about this thing.

So, there lot of consistency checks etcetera and, but then it was discovered that this two quarks were not enough. And then they found that there was a third quark which you which you need it to introduce and that was done by introducing one more yet a other quantum number called strangeness. But today we know, I mean today we have observed up to six quarks and, they are of u d there is a reason of writing there are families or whatever charm and strange top and bottom or top and beauty or truth and beauty depending on whom you ask or which part of the world you are in.

So, these are, so you have six such things, but there is a sense in which u and d. So, if you ask in terms of what were there masses the lightest guys are u and d and as you keep increasing masses it goes s c b and t. And t is at t is like a in hundred it is around 100 and 50 GB or something like that and it so obviously, it is very massive it is more massive than the w boson and and it has many channels to decay.

So, you have so many things, but so obviously since these guys are massive. To so, if you are looking at low energy, energies which are much much lower than these the masses rest masses quote and quote of these particles you know as much as you can observe them. But then you need to only work with three three such quarks, that is u d and s. And if you push things you will get to see, today we have reached a point where there are be factories. Be factories are those which whose energies high enough to produce Mesons and Baryons, which I mean bottom quark copiously.

So, you can see that you take is taken quieter bit we taking of 40 years since all these things were found. So, for the rest of this lecture lecture will have soon since there are only three quarks. And we made a big deal about symmetry out here in the in this course, but actually the s u three which we are going to discuss is called s u three flavor it is only an approximate symmetry. If you do really a symmetry then first thing is you should see that u d and s should have the same masses.

They do not they do not even have the same some other quantum numbers are not even the same. So, it is a case of an approximate symmetry but, that itself was very useful book keeping device. And you can fit it into much more robust thing called the standard model that is not require this thing.

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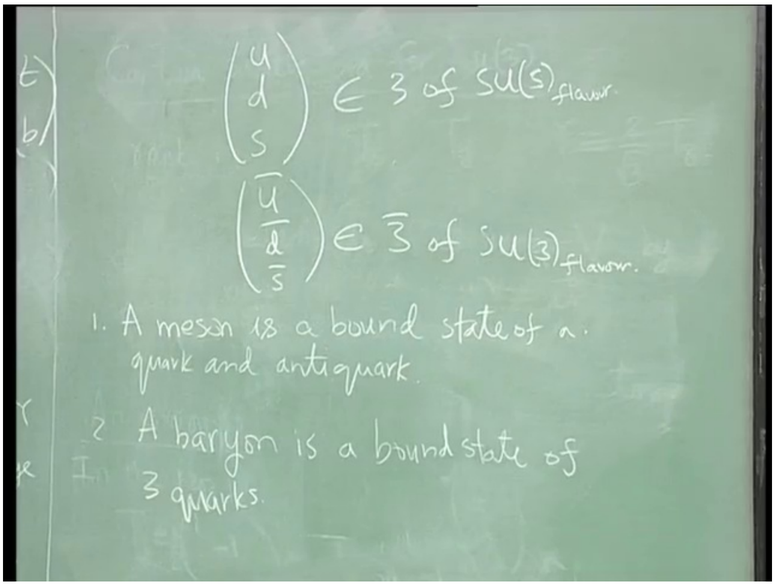

But the great idea was to think of u d and s as forming a three of some s u 3 flavor.. And the s u 2 which I was talking about corresponds to looking at the sub group which acts only in which u and d or a doublet. And this T3 actually this have fits into something nicely in the standard model to the Eigen values of T3 something called iso spin. They get related to that, but that is not so, so this was the idea of Gellman. Let us put these guys into this think.

And then the the anti particles will be in the complex conjugate representation, so we just write u bar d bar and s bar belong to 3 bar of s u 3 flavor. So now, the question is can we ask what what are the constituents of Mesons and Baryons. So, I will just these are only rules or whatever, 1.1 is a meson consists of a quark or I can say it is a bound state of a quark and anti quark 2.

And a baryon is a bound state of three quarks so, how many such bound states can we have it says take a three and it is 3 bar. So, we can get nine of them. But now we want to organize them in terms of s u three reducible representations, this is something which we already solved. So, we get 3 into 3 bar which was equal to 8 plus 1, so it tells you that the the Mesons that you would find consisting of u d and s should sit in a octet so, let me write out those things.

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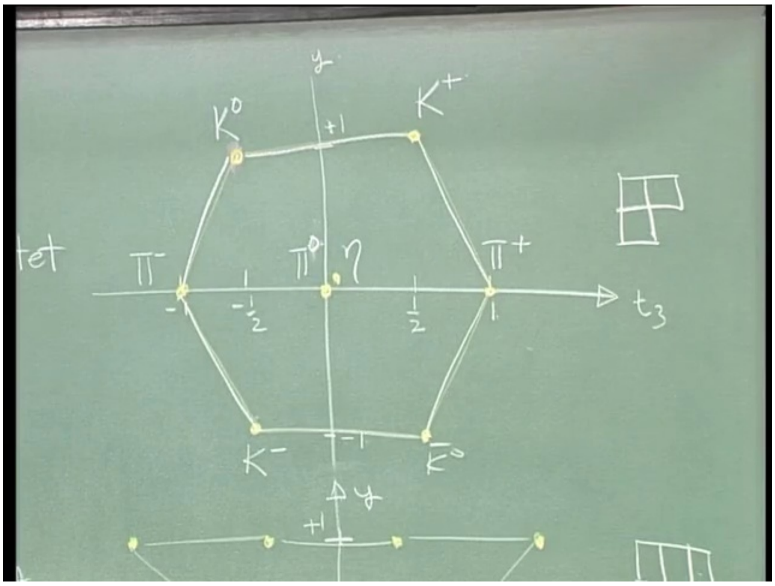

So, these are the names given to these guys and I think when Gellman made the prediction I thing eta would not observed or whatever so, it said you should observe it in this thing. And in fact, there is of mass even there was a formula for the masses so, what should do is of zero third r approximation we was soon that quark and anti quark are mass less. But they they have masses and you can you put those masses in and, if you So, you you can sort of do it there is a very beautiful compute.

I think, it goes back to where you can actually compute what the masses of this thing should be. So, that in terms of some unknown quantities which you can fit by one or two masses so, there are not too many free parameters. So, the parameters will be I guess the masses of the u d s quarks and also the strength of the bound binding this thing. So, with these three four numbers you could actually give eight masses so, that is a prediction.

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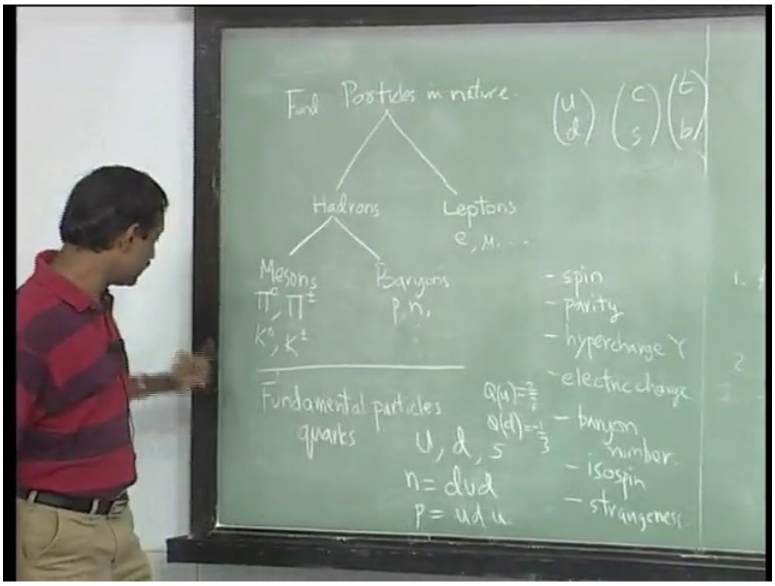

So one more thing is these are all these are these are spin half particles, they are fermions. So, if you look at this, if you look in terms of spin its half tensor half so, it could either be 1 or a 0 and So, and what I have drawn for you is the 0 a octet so, it is called the 0 minus a parity you can show is minus.

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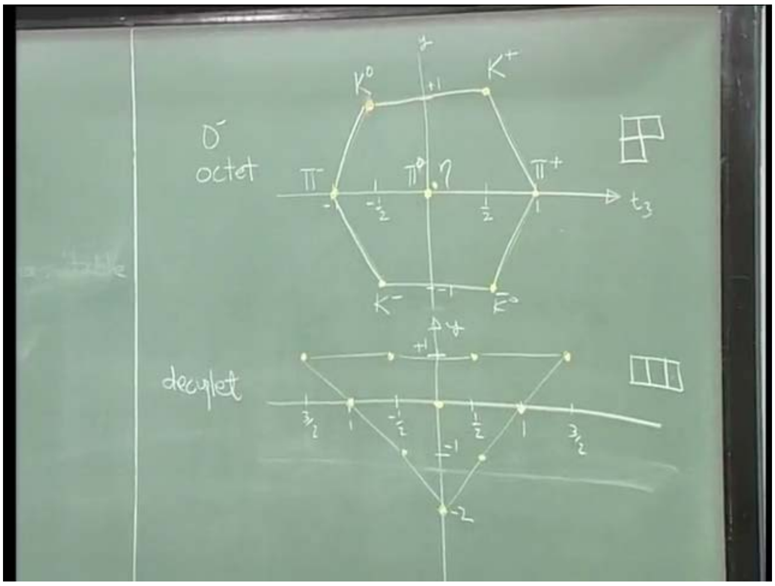

So, what I have drawn is this 0 minus octet of masons. And the numbers these are all predictions and in fact, there is a beautiful formula call the Gellman Ishijima.

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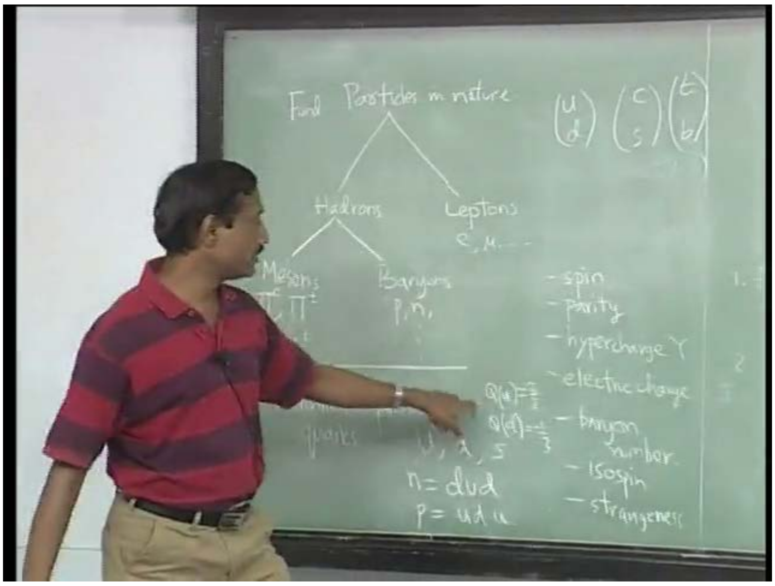

So, I told you there are a whole bunch of quantum numbers, u one hyper charge strangeness s. So, out here strangeness has once you understand in terms of quarks tells you how many, how many strange quarks are in it. For historical reasons it turns out that strange quark has strangeness minus 1 and a anti quark of that has strangeness plus 1 so, I will just write out for you.

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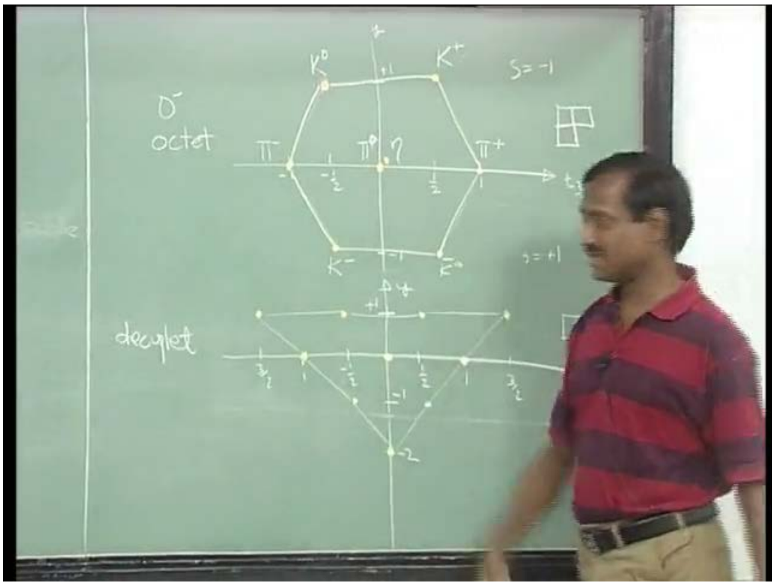

What the strangeness so, this contains this turns out to be s equal to minus 1 and this turns out to be s equal to plus 1 goes in the opposite direction, does not matter.

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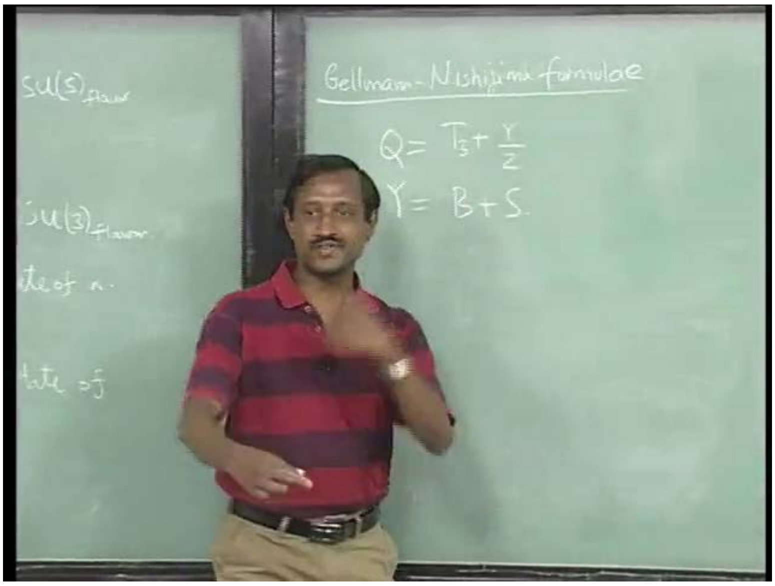

So or, formulae was so, these are like consistency checks, because the you can see. Now, people have observed masons they are giving a whole bunch of numbers, and the fact that you put these things in to s u three gives you all these rules which connect up different what look like different numbers. So, that is the check of this idea and it clearly pass the test so that is that is with respect to the the masons, but what about octet, the octet so, we have to look out there.

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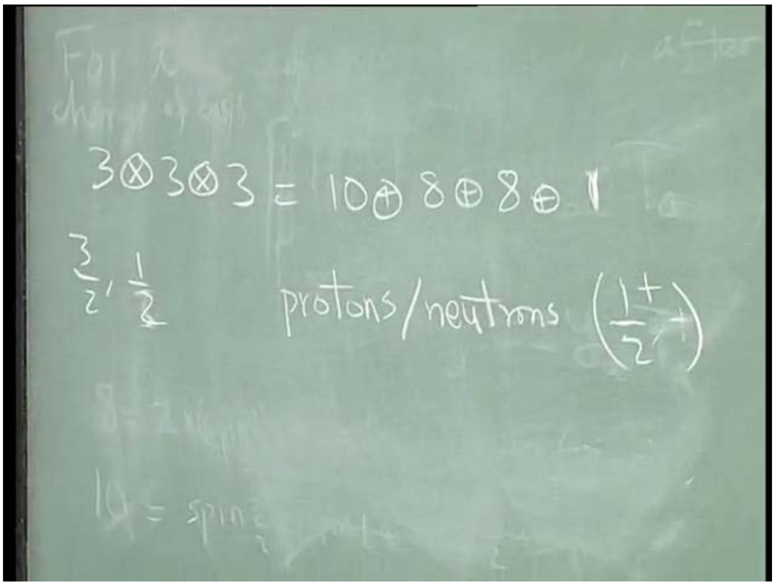

We have to look 3 tenser 3 tenser 3 and this we saw broke up in to 10 plus 8 plus 8 plus plus how much was this 1. So obviously there is an octet first thing is let us do the spin part its half tenser half tenser half. So, the maximum you can get is 3 half and then you can get half. So, Baryons will have either spin half or spin 3 half so, which turns out that proton neutron sit in an octet and it, and we know that protons and neutrons have spin half. So, protons neutrons half plus is what is written. Spin half plus particles it tells you that the full octet has this property not just one of them. And so, these are standard in this thing, but nice thing here is a decuplet at a couplet coming out here.

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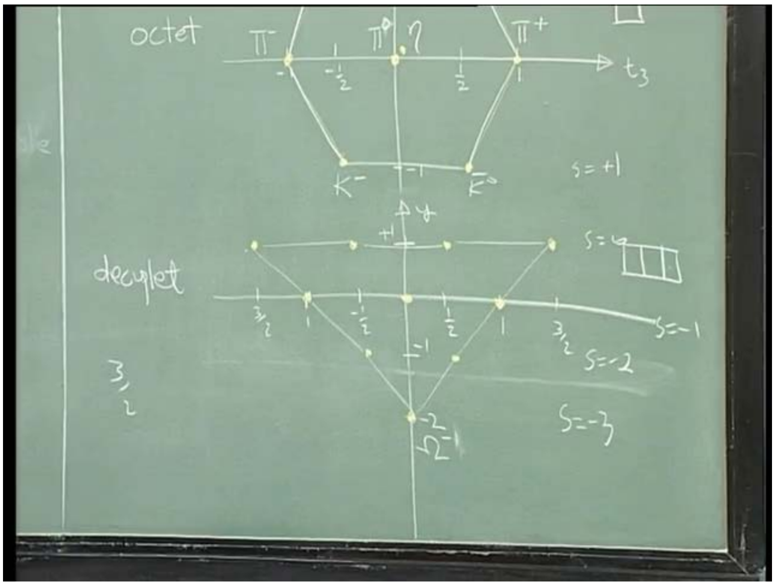

So, you look out the decuplet you find that there are these are whole new set of things and that the cuplet again is decuplet we will have I am just looking at the figure, which I have good. So, so the thing here is let us look at something like this is called omega minus I think. And so, in this thing if you come start here s is equal to here minus 3 s equal to minus 2 s equal to minus 1 s equal to 0.

So, these four guys are things which do not which are made up of only up and down. They do not contain any any strange quark. So, if you look at this particular guy, it has s equal to minus 3 how do you how do you get that, you would get it from three strange quarks. And let us say we are looking at the three halves guy, spin 3 half that means all the spins are also lined up. So, it looks as if you have an object which violates what called the Pauli Exclusion Principle all quantum numbers are the same s ss. So, you have to anti symmetries etcetera if everything is the same you will get zero existence of something like this, sort of was a puzzle. And the resolution was done in the following way resolution was that that their exists some other quantum number their exists another quantum number called color so, which we have not seen the out here.

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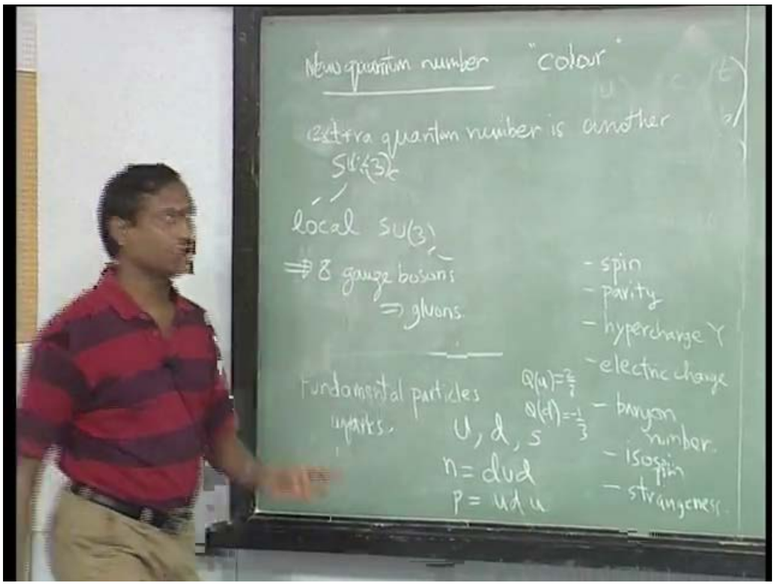

So, add a new quantum number now let me write it some were else, called color. So, in other words so, the minimum number you would require is at least 3. So, in other words it can take so, that can be so, the but it is better even that includes what happens there is that the extra quantum number is another s u 3. So, if you take fundamental of s u 3 if you say that the quarks are in the fundamental of s u three then, it will have another quantum number there will be three such numbers.

So, then, you can see that I can choose even though it likes the spins are lined up its maximum 3 half. I can construct that guy such that these things all line up, but the other quantum numbers i can anti symmetrize in that sector. So, an Pauli exclusion principle is not worth but the nice thing is that this s u three is a local s u 3. And people usually put a c out here and this local s u 3 implies that you will have how many gauge bosons implies you will have 8 new 8 we should not call it new new gauge bosons, called gluons. So, so now you can see that ,if look at the strong sector.

We see that first in terms of fermions there are new particles called quarks and the then, there also eight gauge bosons which are called gluons. And these are suppose to be carriers of the strong force in some sense (No audio from 43:45 to 43:53). So if, you combine all these the idea of the quark model plus the idea of having color. You find that you you need.

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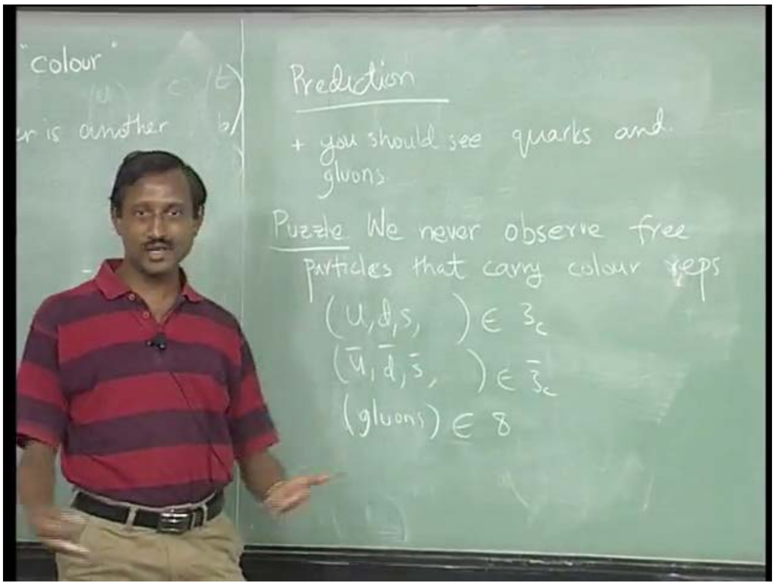

So, the prediction should see quarks at least 3 quarks quarks and gluons puzzle we said as actually no we never observe free particles that carry color quantum numbers. Actually color representation is the correct. I do not like I do not want to call it color I do not want to call color as a quantum number, because it is not something like charge which is additive it is a non able language group we know that thing. So, it is more like the representations, so it should be in some representation and so like, so we said for instance use u d s and all other quarks belong to 3 c.

So, the subscript here is to remind you that it is color 3 this combination also i mean by that i mean each one u belongs to 3 c, d belongs to 3 c, s belongs to 3 c so on so forth. It is different from saying put u d s as a multiplate and belongs to three flavor. And u bar of course u bar d bar s bar whatever also will belong to 3 bar c or whatever. And do once belongs to the 8 this in the ad joint. So, the whole point here is that we cannot see this thing so, what happen so the thing is what see or object like protons, neutrons, pions, etcetera; are masons which are which actually do not seem to carry any color.

Because we really we saw that this whole discussion we never needed to discuss anything called color. And you could ask can it be s u2 can it be s u three can it why not s u four why not s u 5 so on so forth. All these things are issues, but which cannot be decided in a room. But they lead to predictions of some other experiments and that will discussed in you high energy physics course. And so that, tells you that that you require s u three will do. But there is a theoretical issue why is color not observed.

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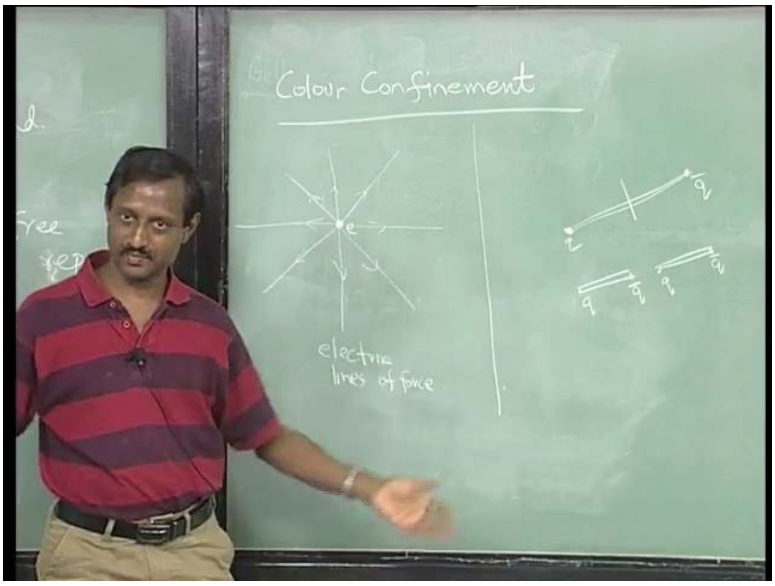

So, this can leads to something called the idea of color confinement. So, just to contrast things what we do is first look at, object which carriers electric charge. So, if you have something like this it has lines of force which sort of spread out in all directions. And if you did some integral flux computation, you will get some charge. So, this is for electric. So, let us put electron or something electric but if you if you consider color charge what happens is something quite interesting.

So, let us say let us put an electric electron here we put q for a quark here what you find is that it is a it is energetically favorable for all the flux lines to get sort of bunch step in to a tube. So, you end up with a flux tube, which could go an end at, a for instance it could end at a quark bar so, this would be the model of a mason. If you try to pull it, but do remember it as I mean the strong forces as finite range etcetera. So, what happens is that you should try to pull make separate them further I mean this is only a theoretical experiment if you try to pull them.

It is sort of favorable for this to snap here because this has some energy density, so the energy you can i think of it as a spring tension. So, t times length will be the energy as we increase the thing the energy keeps of that thing is increasing at some point its favorable for it to break to form quark anti quark pack, out of vacuum no quantum numbers are violated nothing. So, you can break this and you can end up with q q bar q q bar so, this is so, this idea that, that color flux has to be confined this is what happens.

So, in other words you will never I mean the idea here in pulling this apart was to you see can I create a creak war. So, I have what i have d1 here is sort of considered a mason which has a quark and anti quark. And try to pull them apart by smashing something or whatever does not matter. But the idea is can we separate them and this is what happens.

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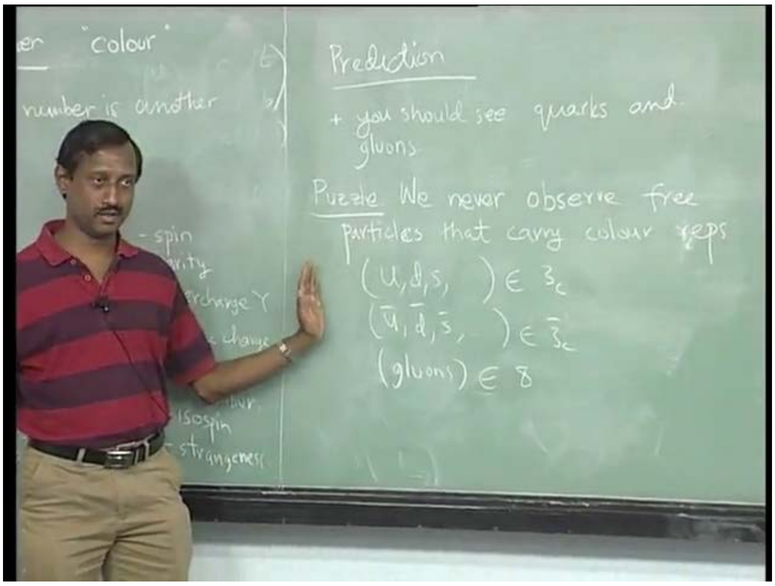

And this sort of this captures the problem in our solves this puzzle. This cannot happen. And theoretically in quantum field theory you can show, you can start with a theory which is Which has free quarks and free this thing and you see that what you see is that the it goes to strong coupling.

At so, if you come to lower and lower energy you find that the coupling constant which binds things where keeps becoming becoming stronger. So, at low energies which is what we are proceeding may not looking at things at high energies we would what we would see is only objects which, are color singlet’s and nothing else.

So, now you might ask what happens in the accelerators there we go ahead and smash things and pull them apart. And there you can actually do things do you will reach regions where you will actually produce quarks anti quarks for brief amount of thing again. What will happen if precise the these sort of things where I mean, at the as it they start and decaying loosing energy they will end up at the end being colorless objects. That is what you would see, but you end up seeing jets.

So, people have now experimenters are really clever they have reached a point, where they can tag objects and say hey this is a u this is d this is c this is s o, on and so, forth. They really very very clever. I mean they have signatures of how each of these thing decay. And it is sort of there is some theoretical back in to it but it is more like, there is certain art also in that thing not just science. And so, so people have reached a point where they can identify this a etcetera. So, this part of this thing is called the, what what is it called. It is called s u3 color or whatever so, I I will stop here.