Special Theory of Relativity
Prof. Shiva Prasad
Department of physics
Indian Institute of Technology, Bombay

Lecture - 2
Michelson- Morley Experiment

Hello, in our last lecture we had discussed some of the issues of classical mechanics. We started with a concept of a frame of reference, and we discussed what we mean by inertial frame, we said that when we talk of Newton's laws of motion, Newton's laws of motion are equally valid in all inertial fields. Therefore, one does not have to be a specific to a given frame while describing our motion, so long the frame is inertial. Unfortunately, when we came to electromagnetic theory our conclusions were somewhat different. We realized that electromagnetic theory it appeared as if all the frames of reference or all the inertial frames of reference they are not equivalent. There are some frames in which the velocity could be given by c is equal to 1 upon under root of 7 naught 1 more this is what we discussed.

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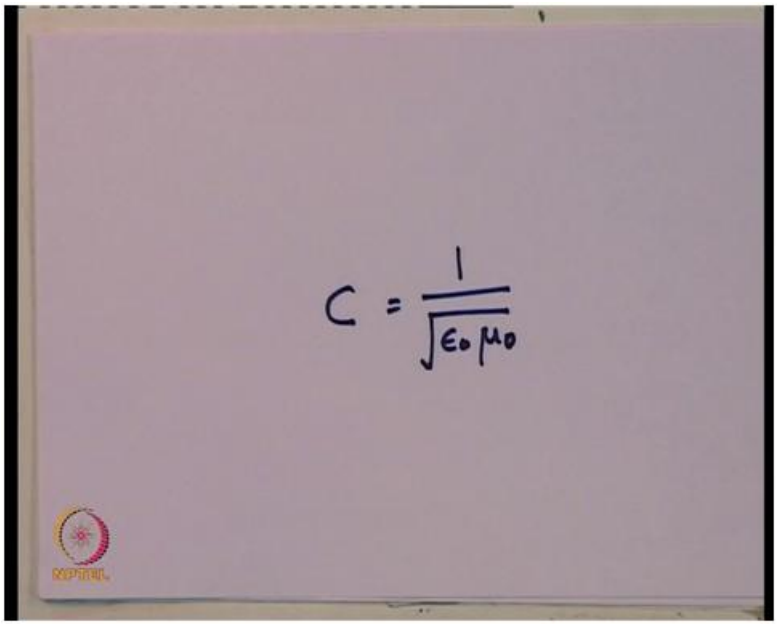

Because of 7 naught plus mu naught appeared to be fundamental constants, therefore we thought it is coming only one frame of reference, in which this is speed can be given by

this particular expression, otherwise the fundamental constants themselves will become frame independent which we did not like as an idea.

So, we thought that probably there is one preferred frame of reference, in which the expression of light is given by this standard formula involving the fundamental constants c is equal to 1 upon under root epsilon naught of mu naught. We are not very happy with the situation, because it appeared that in mechanics all the inertial frames used to be equivalent, but electromagnetic theory they are not is it so, that different branches of physics re replay different type of game probably we do not expect.

We expect that the nature would be uniform, different parts of physics should tell us the same thing. So, if in mechanics all the inertial frames turn out to be equivalent, we expected that the same thing should have happened, but we had lots of problems with electromagnetic theory.

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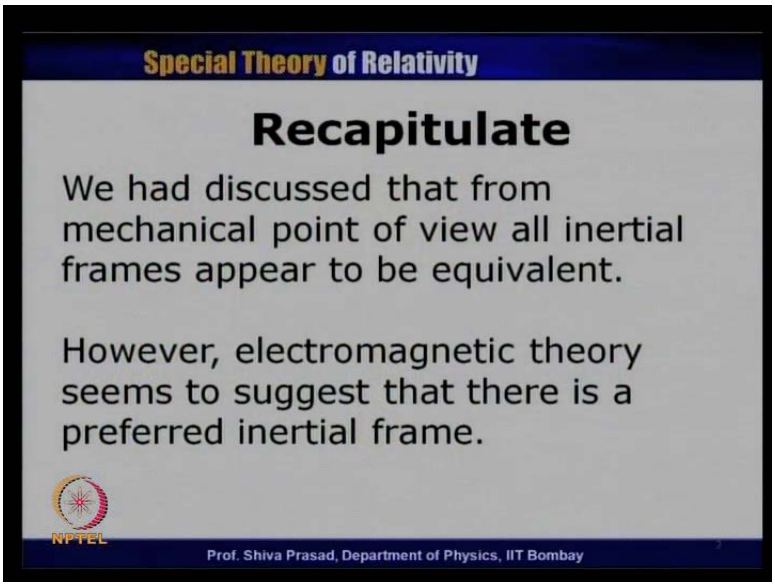

So, this is what I am trying to recapitulate, we had discussed that from mechanical point of view all inertial frames appear to be equivalent, however electromagnetic theory seems to suggest that there is a preferred inertial frame of reference in which the speed of light is given by the fundamental constants.

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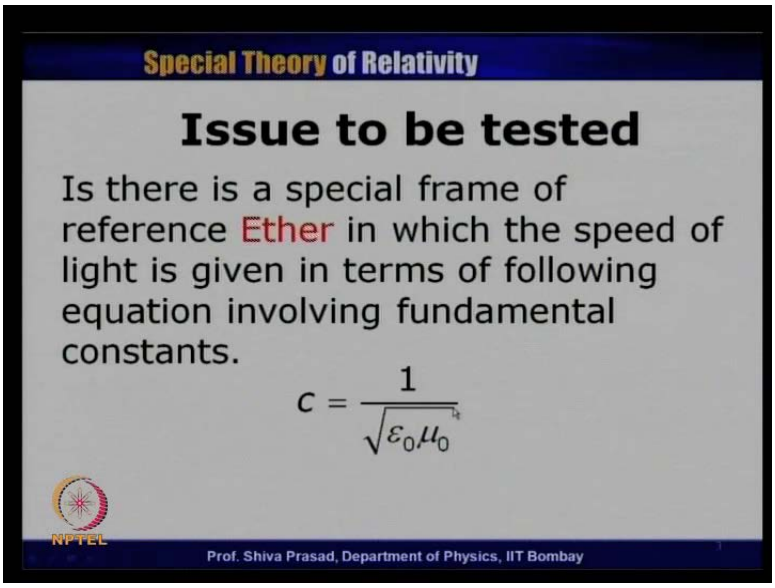

We said that we must go back to experiment to find out whatever we are saying is true. So, the issue which has to be tested is that is there any special frame of reference in fact this inertial, this special frame of reference, we decided to call by Ether or decided at that time to call it by Ether, and we thought that so only in this particular frame of reference that the expression of velocity of light is given by the c is equal to 1 upon under root epsilon of mu.

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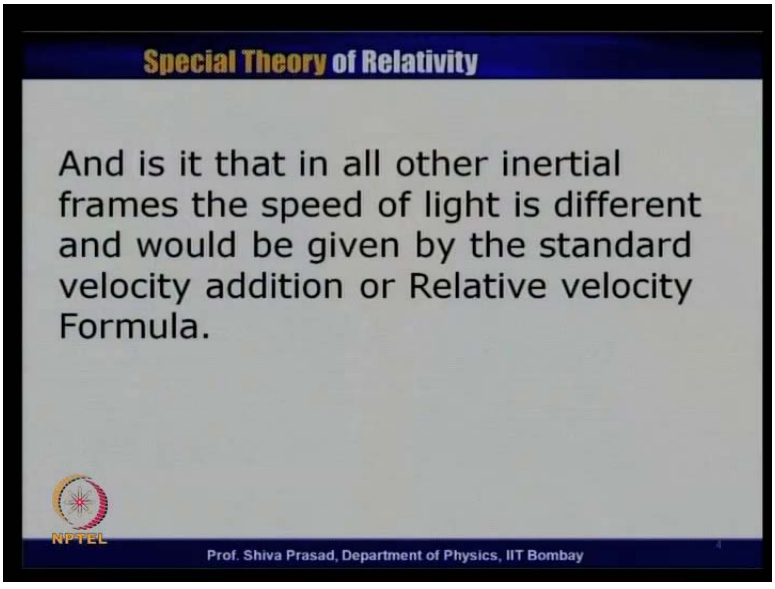

So, all we have to do is to test now find out an experimental mean by which we could test whether this particular hypothesis is correct. It means that if you go to any other frame, which is different from Ether frame, then the speed of light should be different, and normally should be given by this standard, velocity addition formula which is very well known in classical mechanists. So, official what I am trying to say, is that if I change my frame of reference from Ether even though, the frame of reference is inertial the speed of light would be different and this will follow the standard additional velocity, additional formula which is well known in the classical bionics.

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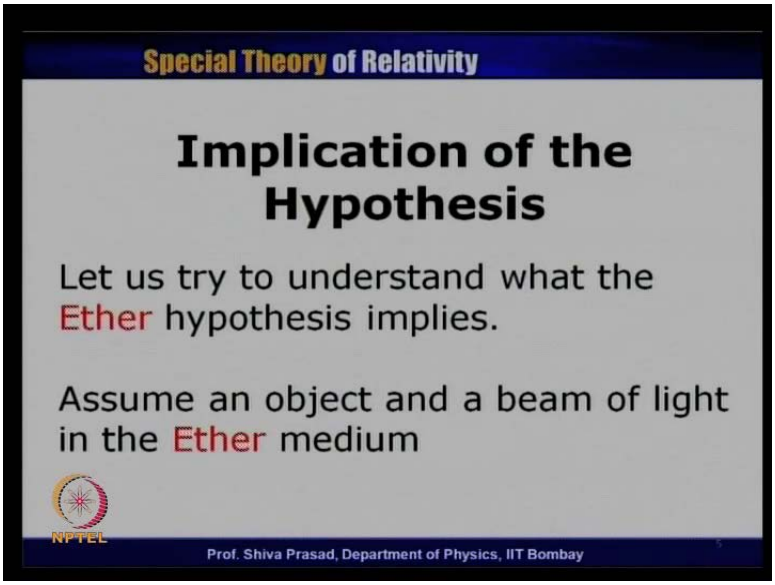

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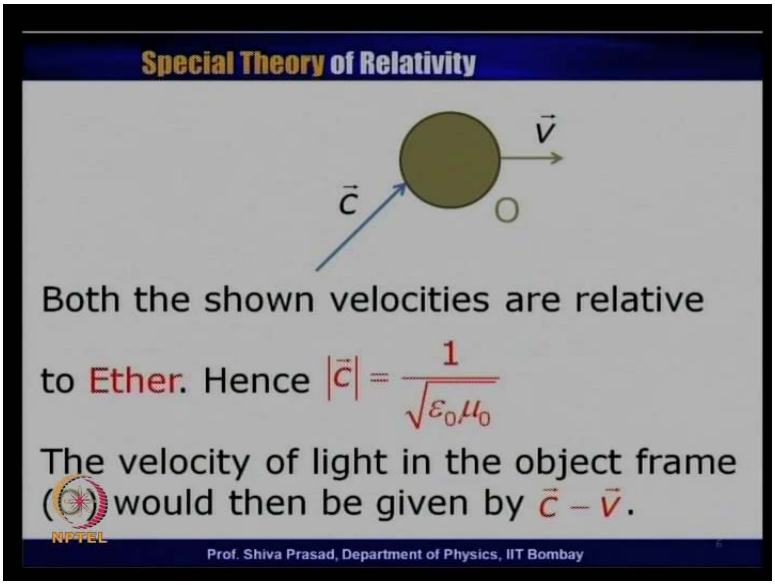

What is the implications of the hypothesis? Let us try to understand, what the Ether hypothesis implies let us, take a very simple example and assume that we have an object and a beam of light in Ether medium. Let just try to understand, whatever we are trying to say as far as, this hypotheses of Ether is concerned see in this particular figure I have shown: one particular object which is here, and let us imagine that I am talking of my Ether medium everything is given in this particular Ether medium, this object I am calling as an object O, this v is this speed as measured by person in the Ether medium, this c is of course, is the speed of light also given in the Ether medium and because I am talking in terms of Ether medium therefore, the magnitude of this velocity must be equal to one upon under root epsilon of naught remember, I repeat that this particular picture is assumed to be in Ether medium.

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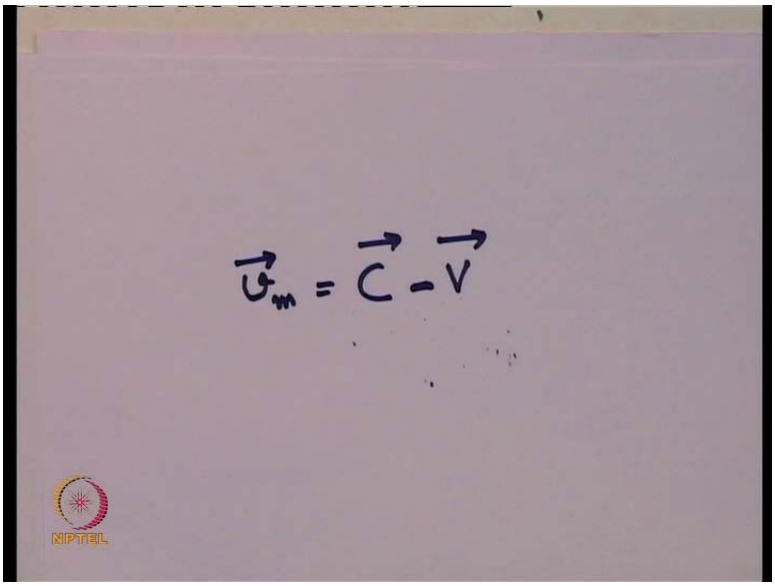

This velocity v is also in the Ether medium, this c is also in Ether medium, and because this is in Ether medium. Therefore, the magnitude of the velocity must be given by the fundamental constants. Now suppose there is an observer sitting on this particular object O, what is the speed? that it will measure for this particular light, as we have just observed that, this must be given by this standard velocity addition formula which means that if an object is, if the observer is sitting on this particular object O he or she would measure this speed of light, to be different and that would be given by c minus v, this is a standard velocity addition velocity formula; which I will write as v m the velocity as measured, velocity of light as measured in object frame O, this am I have written just to

imply that this is the velocity. I would measure by sitting on this particular object, if my hypotheses of Ether is correct.

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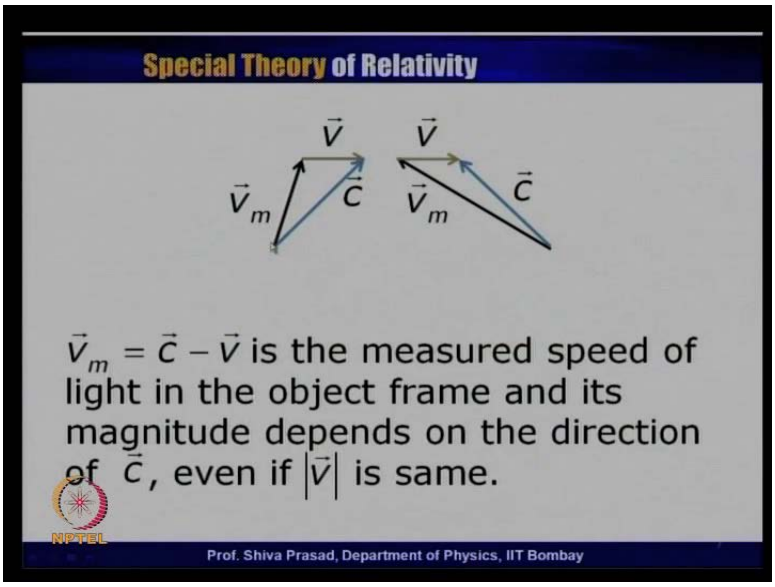

Now, I want to make a claim under this particular hypothesis, is that even if v is same of course, the magnitude of c is also same. If I change the direction of speed of light, then both the magnitude and direction of this speed measured in object frame, will turn out to be different. This is what I am trying to show by very simple vector additional formula; let us look at this particular figure see, this is the same v which I have drawn in the figure last transparency, and this is c which is the speed of light, this is also c which is the speed of light, this is also in Ether frame, this c is also Ether frame, all that has become different is that in this particular first figure, this c is been shown to be directed in this particular direction; while in this second figure c is been shown to be directed in this particular direction.

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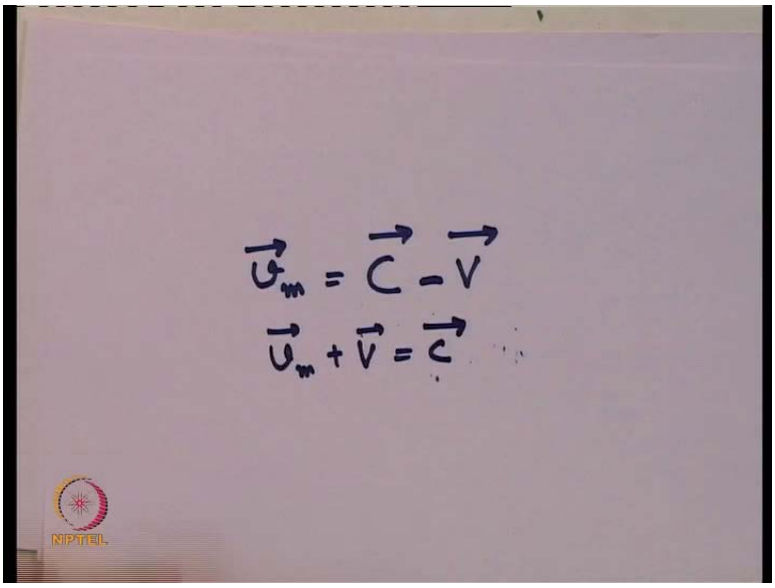

The magnitude of this particular c magnitude of this particular c is same, this v both magnitude and in direction are same. Again I mention that, this particular object is means is moving with a velocity v, as seen in the Ether frame and this c, that I am talking is also been measured in such frame; my question is what will be the velocity of this speed? as would be measured by an object by an observer sitting on co-frame or the object frame as we have just now said, this formula that we have to use is v m is equal to c minus v, which is this particular formula, which I have written it here also, this particular formula which will give us, what is the speed of light as measured in these two cases; In the first case as, you can see that this will be v every number, when I am saying v m is equal to c minus v; it means that v m plus v is equal to c, and if you look at this particular figure, standard velocity additional formula v m plus v is equal to c. If I walk in this particular direction, then walk in this particular direction my mid displacement is here.

This is the way, we remember normally remember our velocity addition formula therefore, I expect here v m plus v is equal to c similarly, here v m plus v is equal to c. So this v m is given by c minus v, as I can see that this v m is pointed out at this particular direction. This v m is pointed out in this particular direction and as also very clear, the magnitude of this v m is much smaller in comparison to the magnitude of this v m. So this is what I am trying to explain saying that, if the velocity of light is measured in different direction, I would find that not only the direction; which is of direction of measurement but, it is magnitude will also become different, so one conclusion, which I

want to draw that, if my Ether hypotheses is correct, then if I am in any other inertial frame, which is also in which I am taking the measurement. I will find that in that frame these magnitude of this speed of light, would be direction dependant depending upon, which direction I measure this speed of light, I will find magnitude to be different. This is what I am trying to say, even if I am talking of the same v, even if y object or inertial frame, is the same inertial frame.

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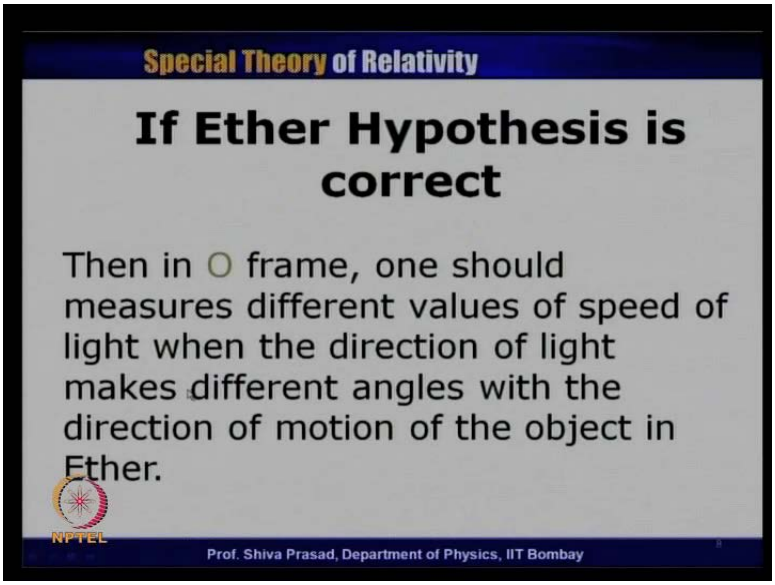

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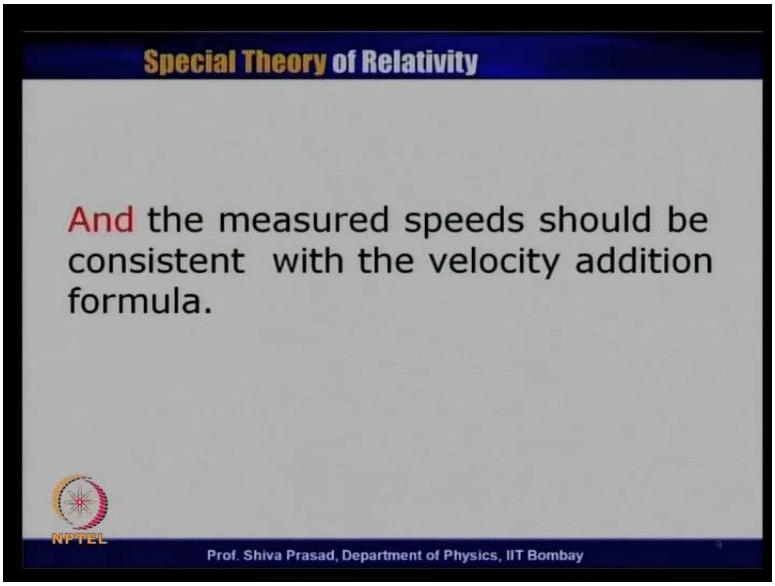

So, this is what I have reiterated in this particular transparency; that is Ether hypotheses is correct, then in O frame one should measure different values of speed of light, when the direction of light makes different angle, with the direction of motion of the object in Ether, and the measures speed should be consistent with the velocity addition formula, now let us imagine, that is object about which I was just now talking is actually earth and for simplicity let us, not go to the too much of complications as of now, assume that this v, this particular earth is moving with a constant velocity, in this Ether medium which I am calling as v.

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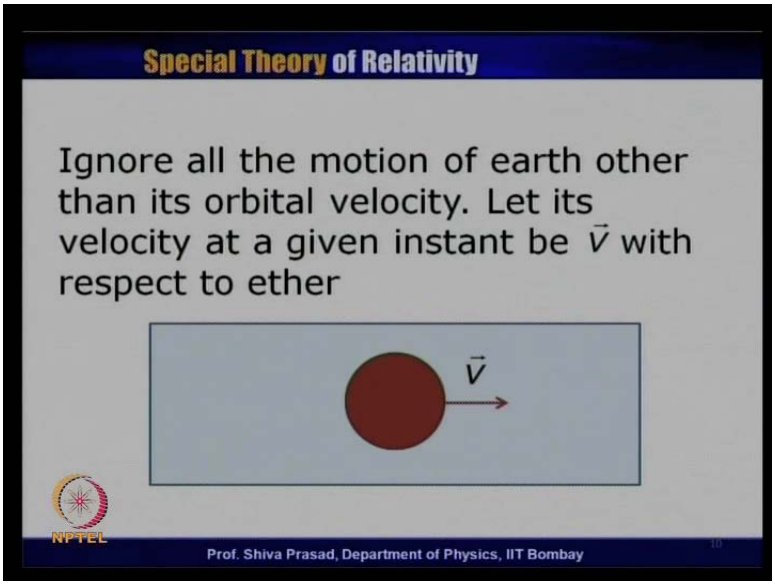

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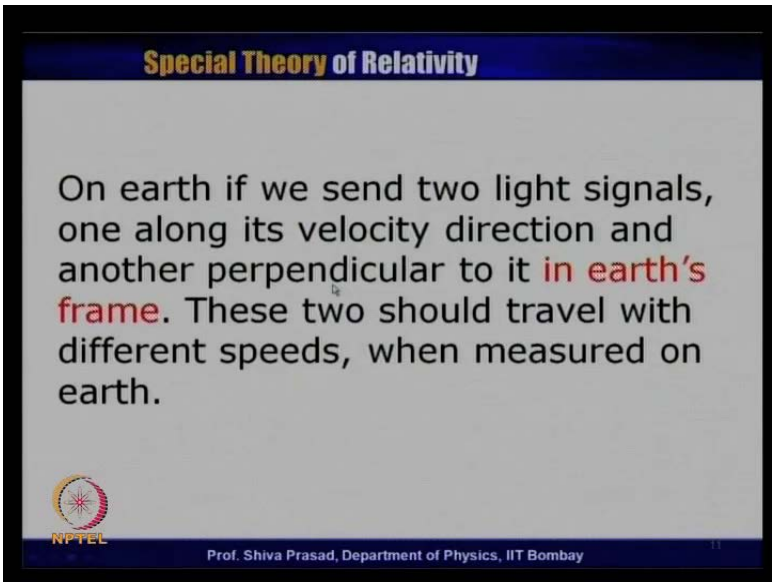

We know, that this is not strictly been correct, because the motion of earth around sun is fairly complicated, it also has a spin movement but, let us ignore all those things. Let us imagine, that earth is really in inertial frame, let us imagine that at this moment that it has only velocity in orbital velocity v, which I assume at moment to be constant, because then only I can assume that the earth is n inertial few. So let us imagine that this object is earth about, which I have just now talked, now this earth let us try to shine light into different directions, as we have just now said, I will find that the magnitude of this light meant to this speed of this light, which are travelling in two directions would be different, let us make some specific cases and try to understand, this particular thing you keep better, this is what I said on earth. If we send two light signals; one along the velocity direction and another perpendicular to it in earth's frame, then we should travel with different speeds when measured on earth.

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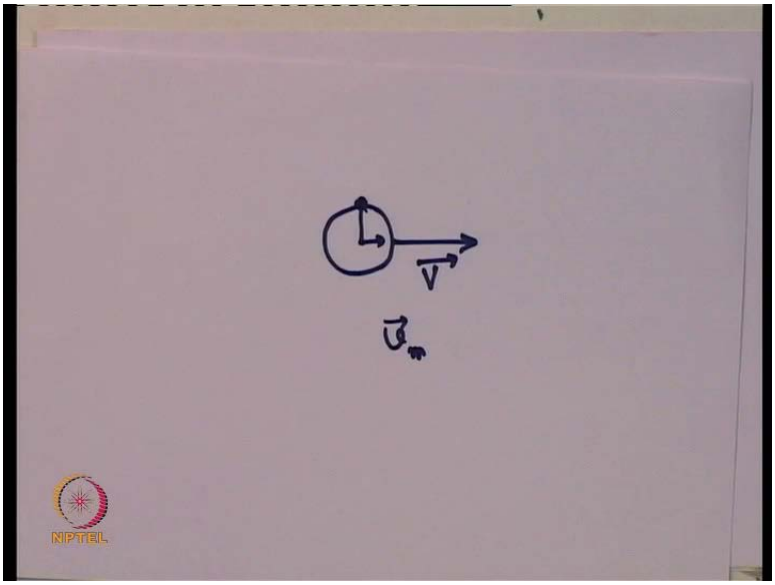

So, what I am trying to say is that, let us choose two directions; one along the direction of the motion of earth in the Ether medium, so this is my earth which is moving in this particular direction with velocity assumed to be constant. Then I sent one light signal along this particular direction, which is the direction of v. I sent another signal which is perpendicular to this direction. So one light signal goes like this, one goes like this; Remember these signals are being emitted, with respect to an observer sitting on earth. So this piece of these two will not be seen but, we what why have mentioned earlier would be v m and as, we have discussed earlier the magnitude of this v m would be

different, because they are making different angles related to the velocity v, which is the velocity of earth in the eternity.

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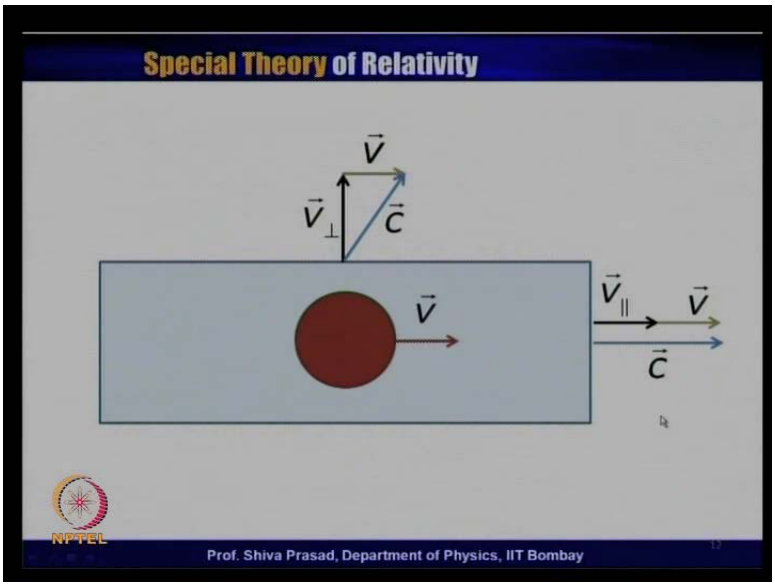

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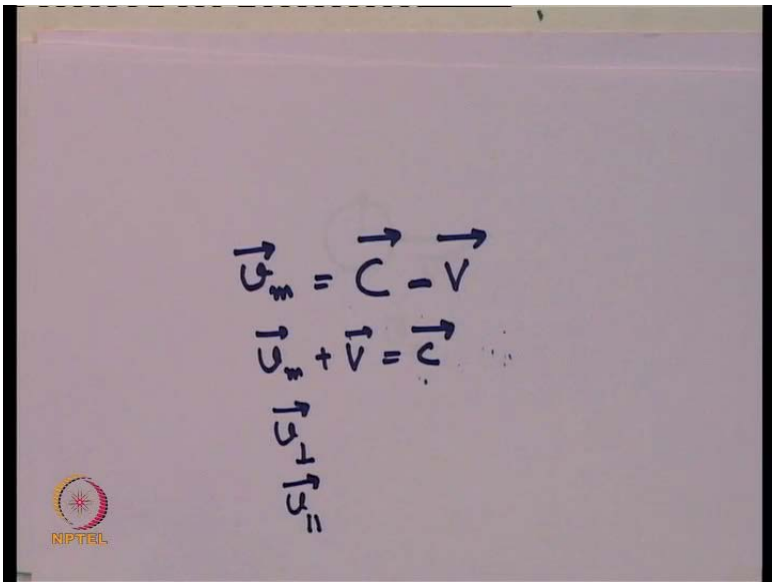

Let us, try to make a calculation and try to find out, what are what are the velocities in the perpendicular in the parallel and the perpendicular direction? and next figure shows, the same thing this is assumed to be earth, which is moving with the velocity v in this Ether medium, there is one light signal, which is being sent perpendicular to the direction v, which I am writing as v perpendicular. There is a light signal, which is being sent

parallel to v, which I am writing as v parallel. Remember the velocity of light c as per my both hypothesis is c only in Ether way, so let us suppose this is my c, remember what I am measuring is, this let us look at perpendicular direction; first what I am measuring is this particular thing but, this is a result of two velocities components; one is velocity of light c, which I in the Ether medium and one v, which is because of the fat, that this particular earth is moving with a velocity v in Ether medium.

Once, I go back to my old equation, which I had written earlier, which is v m plus v is equal to c therefore, this v m in this particular case would be, my v perpendicular so, I must get v perpendicular plus v is equal to c, so what I am measuring is, this component v perpendicular which is the outcome of a vector subtraction within c and v and let us come to the parallel of this. if I come to this parallel case situation is exactly similar except that, this v parallel and v both are in the same direction but, this v parallel must have been obtained, as a result of subtraction of c m v by the same formula v m is equal to c minus v, which I have just now written here now in this particular case my v m, now becomes v parallel and this v parallel must be given by c minus v or c plus v must be given by two parallels. If we lift here v parallel plus v must be equal to c, so this is the velocity component, that I am measuring, which I have shown in this particular figure, by this v parallel vector.

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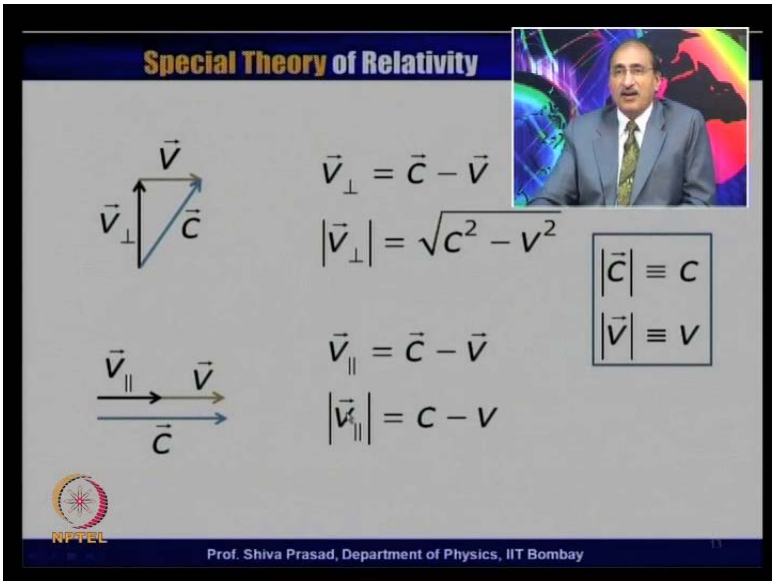

This v parallel plus this v vector must be to c, which of course, is given by the fundamental constants, one upon under root epsilon of mu, let us try to find out, what is v perpendicular? and what is v parallel? the one most vector is easy to find it out all. I have done is reproduce these two figures, from my previous transparencies or we realise, that v perpendicular must be equal to c minus v same expression, which I have written earlier. If I look v perpendicular, this is v c and if I look at the magnitude of this, we will realise that this makes an right angle triangle, this is the hypot loose, so c square of magnitude must be divided by v perpendicular square plus v square therefore, v perpendicular square must be equal to c square minus v square, this is the standard theorem therefore, this is what I have written is the magnitude of v perpendicular must be given by under root c square minus v square, where I have used the notation that when I do not write any vector sign on the top of it, I mean only the magnitude effect.

So, magnitude of c is being represented by just seeing without a vector sign similarly, the magnitude of v is being represented by v without a vector sign, so this is just the magnitude c is also, just the magnitude in magnitude of v perpendicular is given by under root c square minus v square by looking at this particular triangle, which is a right angle triangle. Now let us see that, let v parallel v parallel is too simpler, because v parallel and v both are in the action, so we realise that v parallel is equal to c minus v by same formula. We have discussed earlier, so v parallel means which would is just simple magnitude c minus, so this is what I have written that v parallel magnitude is c minus as we realise and as have been mentioning, that this v perpendicular and v parallel would be of course different in magnitude.

Now, let us try to do one more thing, we have just now seen, what would be the velocities of just what would be have evaluated, what would be the velocities, if a light signal is sent on earth perpendicular to the v direction, and parallel to the v direction, let us just reverse this direction. Let us say imagine, that light signal is perpendicular to v but, not in the original direction but, to the opposite direction similarly, for the v parallel we will assume, that is not really parallel but, anti parallel to the velocity that exchange, let us evaluate these velocities situation is exactly similar as before other than that I have revert reverted this particular vector, so v this v perpendicular, which was earlier pointing towards up is now.

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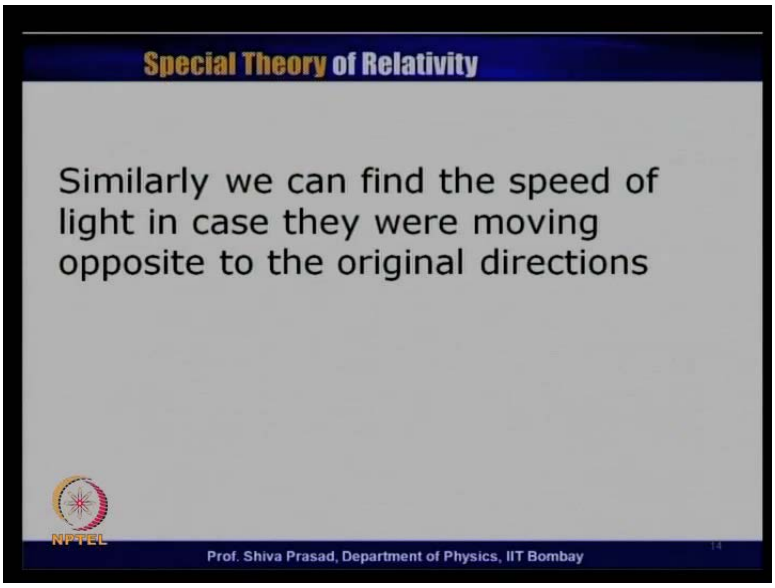

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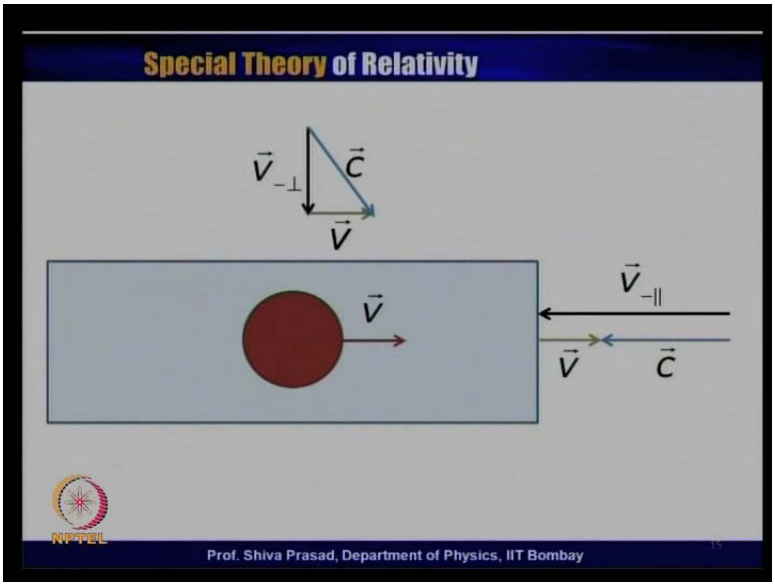

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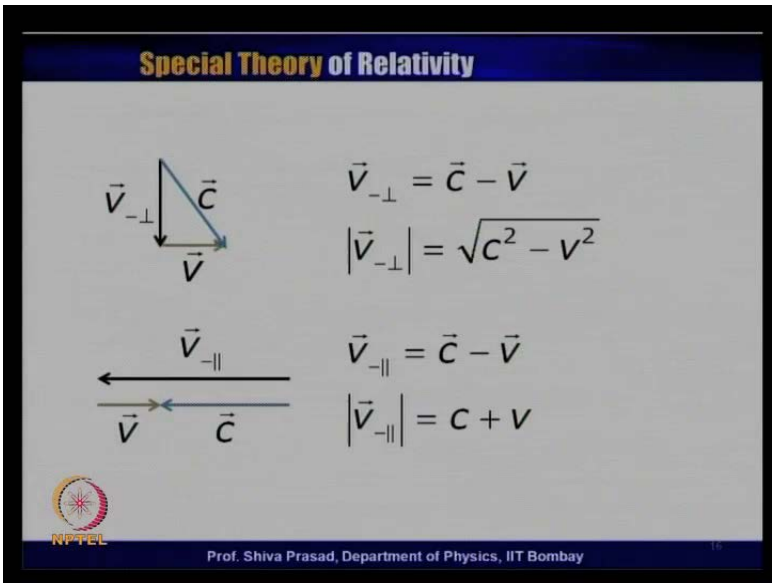

Pointing towards bottom, this v parallel which has pointing towards right hand side, is not pointing towards the left hand side, that is why I have written here v perpendicular is the negative sign. Here so this, is v minus perpendicular, this I have written is v minus back ground. Now my idea is to calculate, this v perpendicular minus and v parallel minus, I will use exactly the same terminology or the same method the one, which I have used to calculate v perpendicular and v parallel all that has happened with the directions of the vector, such is again like before these two figures have been copied from the earlier transparencies. Now you realise that in this case hardly anything has changed, because this c is still the hypothesis of this right angle triangle, this v min minus perpendicular is still v minus c changing, the sign has not changed. This magnitude it is still given by magnitude of c square, or the magnitude of this square is still given by the magnitude of c square minus magnitudes of v square by the standard theorem.

Therefore, we write this v minus perpendicular also, as under root c square minus v square, which has not changed from my previous value. However there has been lot of change in v minus perpend parallel, because as you can see from the figure, itself earlier minus v by by v parallel was very small but, no my v parallel has become very very large, because to this I must add v to get, my c. If I go this much then I must revert back to get this c and because this magnitude of c is same, and I have to actually subtract this v from the magnitude wise, then only I will be able to get this c therefore, it is very clear that using this particular equation, by v minus parallel. Now we will be c plus v, so what

we find out is that this particular velocity minus parallel direction has increased it has become c plus v, I repeat in v minus perpendicular and v plus perpendicular, there was no change as per the velocity direction is concerned, it means if I am sending a beam upwards like this and or in the reverse direction towards backwards it makes no difference it will still give you the same speed of light.

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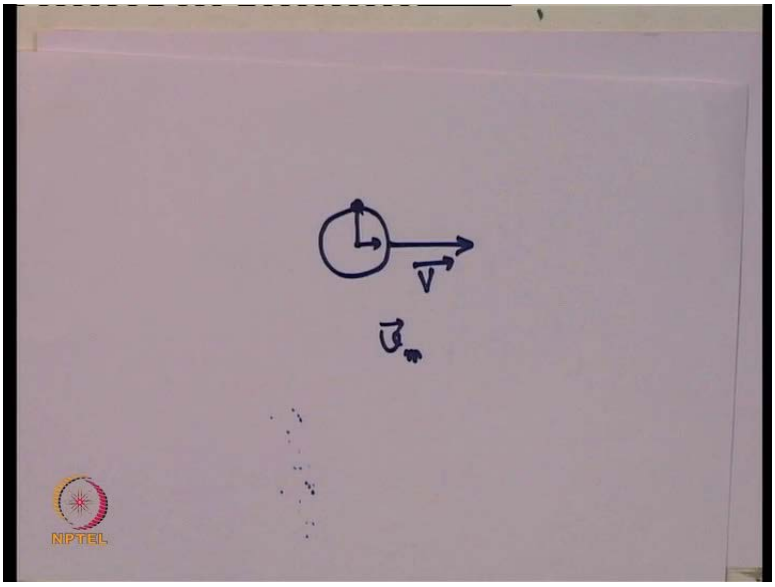

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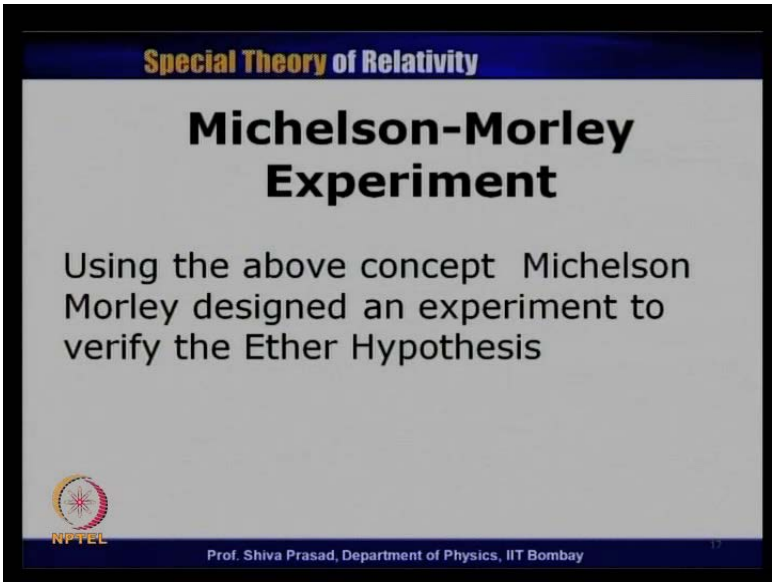

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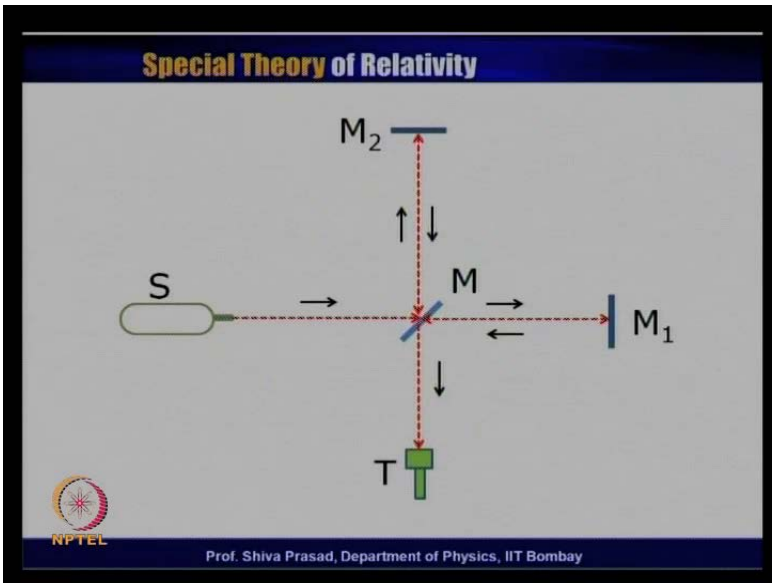

However, if the light travels in this particular direction, this will travel with that different speed, then when light is travelling in opposite directions, it makes a difference when light speed of light is being measured in the direction of this, now let us discuss this famous Michelson Morley experiment, Michelson Morley was one of the great experiments, which was defined to test the Ether hypothesis and this is a very very remarkable experiment, because as we we shall be seeing it gave a negative result, and this negative result itself was a pock making and changed the way e look at physics, today this is a very interesting experiment using essentially, the same ideas that, we have just now discussed. Let us look at the experimental set up in this transparency I am show in rough sketch of this particular Michelson Morley experiment by s I mean e have a source of light here.

Let us assume that, this is a locomotive source of light, you know how to create a locomotive source of light even at that time of Michelson? it was known how to create a mono locomotive source of light? we have a mono locomotive source of light as light is coming being emitted by this for the moment, let us assume that this particular direction is the same direction, as the direction v that I have been talking, which is the direction of velocity earth in Ether medium for simplicity. We can discuss the other cases later now. Here we have what I have written m is a half silvered mirror by half silvered mirror we mean, that it does not reflect all the light, it reflects some of the light approximately 50 percent of the light and 50 percent of the light allows to be transmitted.

And if I put this particular mirror at an angle of approximately 45 degrees from the direction of the velocity of light, then we will find that approximately half of it is light will travel in this direction, which was the original direction of the light while half of the light or half the intensity of the light will travel in a direction perpendicular to the ocean direction of light, because the angle of incidence has to be angle of reflection therefore, and I have taken this angle as 45 degrees or I have designed this particular angle as 45 degrees, therefore, this light beam would, now travel at an angle of 90 degrees from my original direction. So this beam is divided into two beams; one travelling upwards, one travelling towards right, and as I have said I have assumed that this right direction is actually the direction of v this direction therefore, is direction perpendicular to v.

Now, here we have two mirrors; one is m 1, another is m 2; these two mirrors are the normal mirrors, they are not half singled mirrors so, they will reflect most of the light which is being vigilant on them and let us assume, that these two mirrors are being put in such a way, that this light is normal to them this incident is normally to them. If the light is incident normally to them the light will be reflected back and therefore, this light will go up and will come back similarly, this particular light upwards, the right hand side also go and will get reflected from this particular mirror m 1 which is also a fully silvered mirror and this mirror will reflect, the light the light will go retrace it is path backwards and will keep upcoming backwards and again these two sources of light would meet, this half silvered light because this, mirror is this half silvered mirror, because this mirror is half silvered, again some of the lights of this particular beam will be reflected in this particular direction, and some may be transmitted let us ignore that particular beam, similar to the light which is coming back from this particular direction part of the lights will be transmitted parts will be reflected, let us ignore the reflected beam in this particular case let us, look only at this particular beam, which is now resulting as the super imposition of two beams; one which is reflected from m 1 and again reflected from n another one, which is reflected from m 2 and then refracted from n and now this particular beam is being observed by a telescope.

This is what is standard Michelson Morley experiment, you know about the Michelson there is Michelson is also devised an interferometer which is very very known as micro centerferometer using essentially some or similar concepts in that sense, the ideas are where we is of course, here we are testing something which is very different. Now let me

try to calculate, what will happen to these two beams of light; one which has gone upwards and got reflected from m 2 and the one which has gone to the right and got reflected from m 1. We realise that when the light as travelling upwards, if you travel the same speed, as we need for travelling backwards and of course, both these speeds will be different from speed of light in Ether as far as this particular light is concerned, because this is travelling along the direction of beam. We realise that this velocity is going to be different from, this particular velocity here is just travelling backwards, because this is in a direction opposite to v what I will do is to calculate the time, that this particular light will take this beam will take to travel from this distance to this distance and come back, and the light which travels from this, here this distance and come back and assume that these two lengths are same.

Just for easiness let us assume, that that two lengths are same, so the lengths are same only thing which is different are the speeds. So we calculate how much time the light would take one it is reflected from original beam to go upwards, and come back here and going this way and coming back here, because this these are the two things which are different, otherwise everything is same just we have come and joined this particular point, the two wheels are travelling together. Let us do that particular calculation and find out the time distance.

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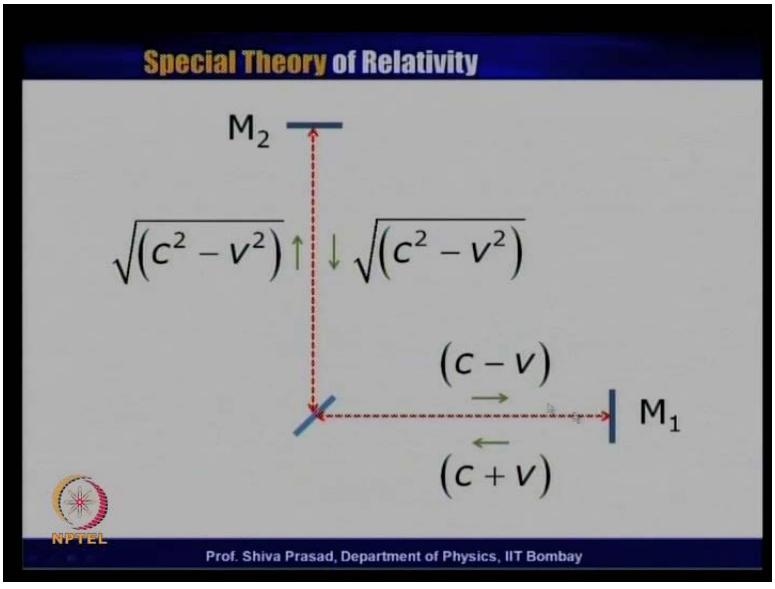

This picture shows what are the velocity directions? What are the velocity magnitudes? this is just now, what I have mentioned that, when it travels upwards it travels with a

speed of under root c square minus v square, when it travels backwards it travels exactly the same speed under root c square minus v square on the other hand, this particular beam when it travels in this particular direction, it travels with a single c minus v when it comes back it travels to the speed of c distance.

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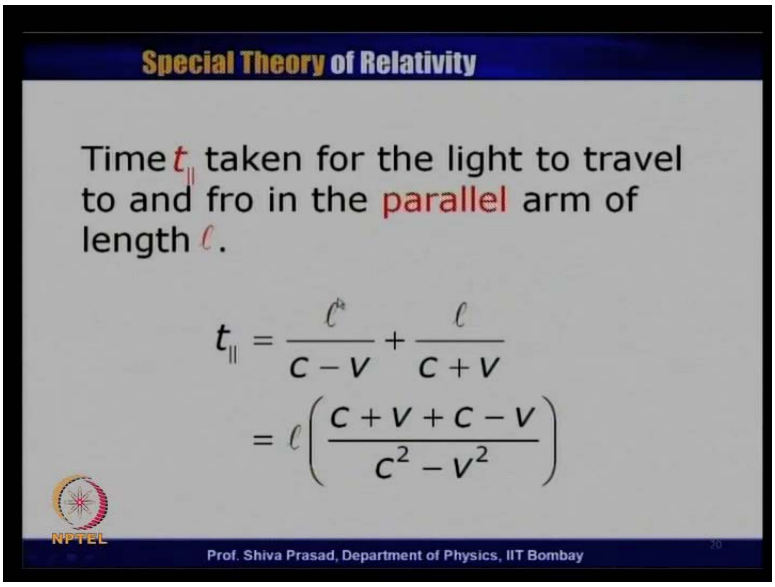

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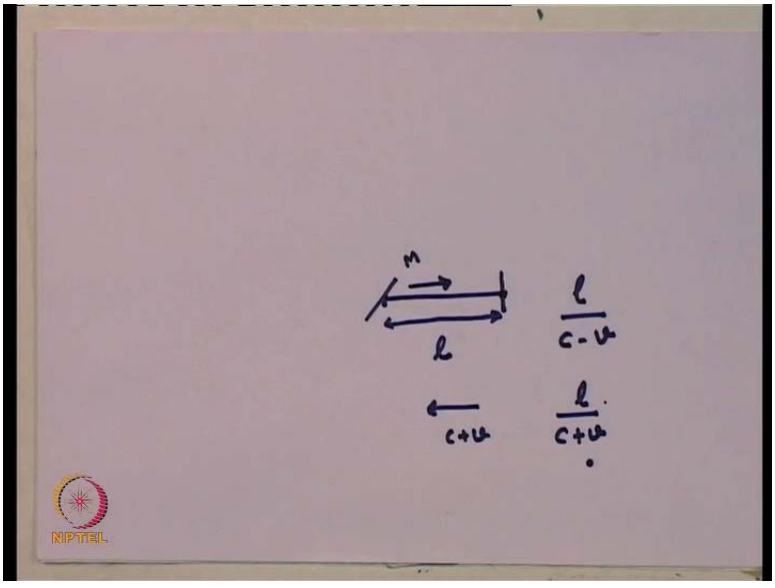

But, one of the standard expressions the time taken by a particular beam will be length l divided by this speed. Let us first calculate the time taken for the light travelling in the parallel hour, the ark which I have shown to be along the direction of v, which is the

relating speed between the earth and the Ether medium, as we have said the first beam is travelling to the right, it travels with the speed of c minus v, so the time that this would have taken, if we assume that the length is l then if you will take a time of l divided by c minus v, to go from this particular original mirror let me, write here this was my mirror m, this was my other mirror fully mirrored silvered mirror. I have first calculating the time, that it takes the light beam takes to travel this way this length I have assumed it to be l, this is pth as I have said for c minus v, so the time taken for this will be l divided by c minus v, then when the light beam travels this way this speed becomes different the length is same this speed is c plus v.

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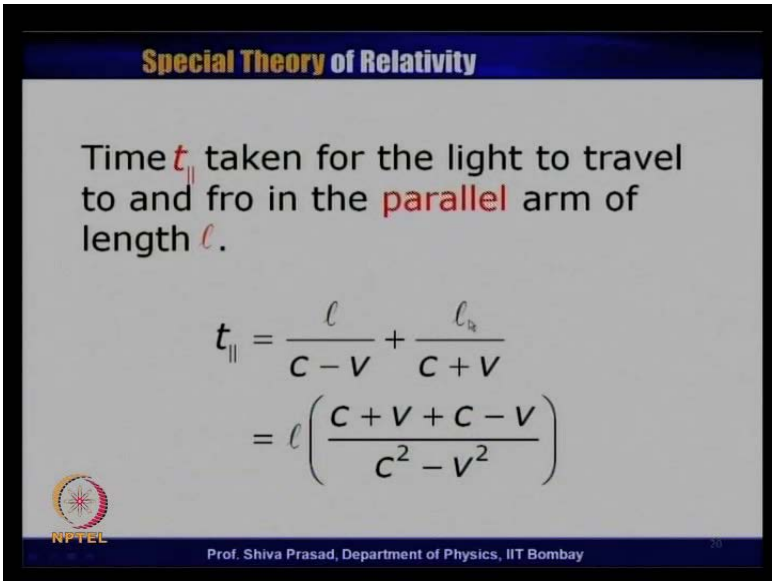

So, this time will be l divided by c plus v, so the time taken for the light would travel from this point to this point is l divided by c minus v, the time taken for the light you call from this point back of this point is l divided by c plus v, so the total time taken by the light, to go from this point to here and come back will be the addition of these two times, which is what I have mentioned here l divided by c minus v plus l divided by c plus v and let us, simplify little bit we just multiply both the sides by this side by c plus v numerator and denominator, this side of also c minus v both numerator and denominator, then our denominator becomes c square minus v square, the standard algebraic simplification they will be c plus v, here there is c minus v, here look of this side I have multiplied and divided by c minus 1 v this side I have multiplied and divided by c plus v numerators and denominator. So there is c plus v remaining here and there is a c minus v

remaining here, as we can see very easily this v and this v would cancel here numerator ought to be remaining is only 2 c divided by c square minus v square.

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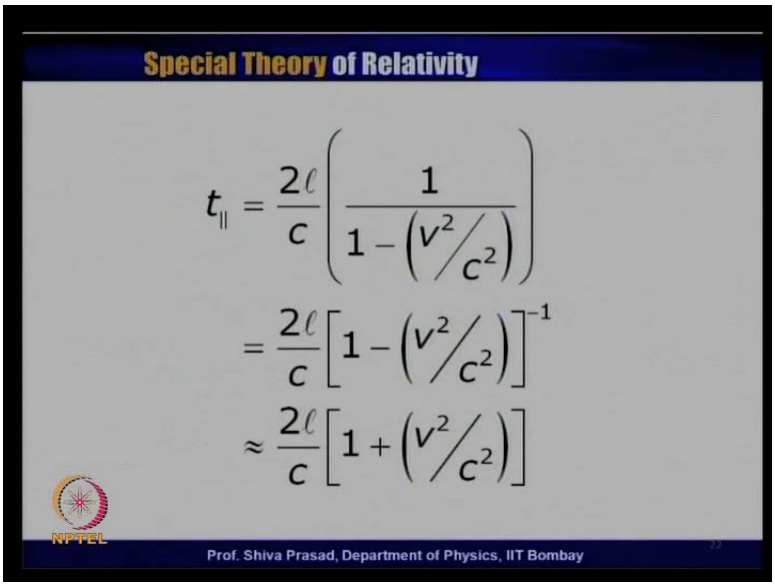

This multiplied by l will be the time taken for the light travel, along the parallel r this r i simplified, it further this si what I have mentioned l is equal to 2 c divided by c square minus v square I have taken c square common from this denominator, so this c square I have written out here this 2 c I have taken out here so numerator here becomes two l multiplied by c but, this 2 c has been taken out of this particular bracket, so what is remaining is only one here c square has been taken out of this particular bracket, so here what remains is one and this case divided by c square, so what is remaining inside this bracket is 1 divided by 1 minus v square by c square, because there is a c here and there is a c square, so I have cancelled one of the c and this expression given by 2 l divided by c multiplied by 1 divided by 1 minus v square by c square.

So, this is the time light would take to travel along the parallel direction in going from half silvered mirror to the silvered mirror, and coming back I simplify this equation a little further by assuming, that v is smaller than c much smaller than c, which is I think correct this speed. We whatever we are talking is much smaller than the speed of light, so under that particular approximately on this particular expression can be further simplified, and because I have to compare this particular result with something else so, that is why I am looking for this particular simplification. So, what I have done this

expression which I had written earlier 2 l divided by c 1 divided by 1 minus v square by c square. I have written this particular expression as 2 l divided by c, which is still remaining there and one minus v square by c square to the power of minus 1.

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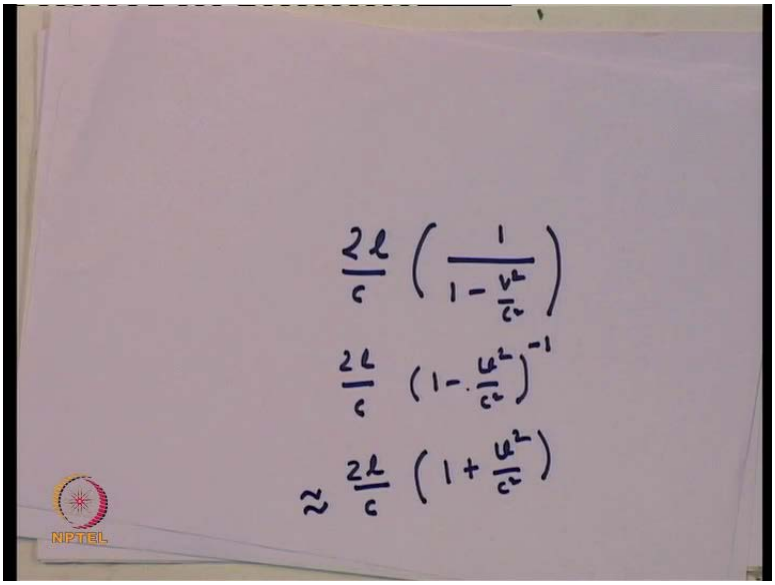

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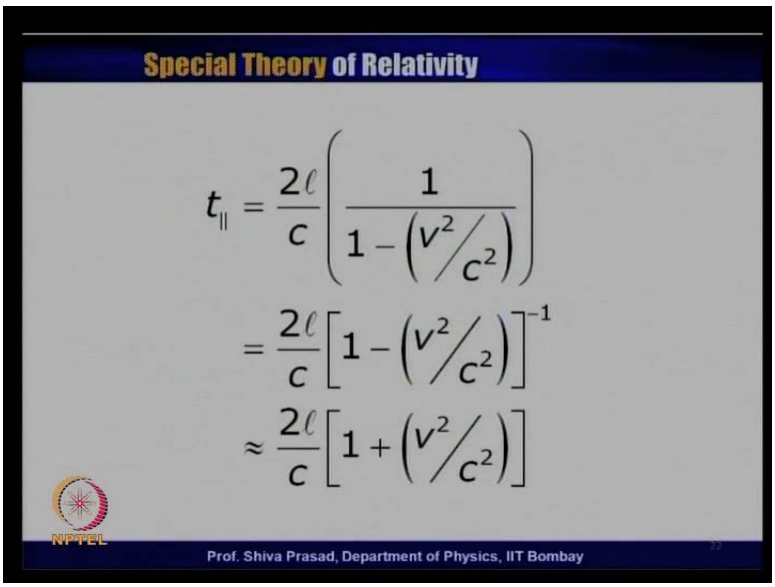

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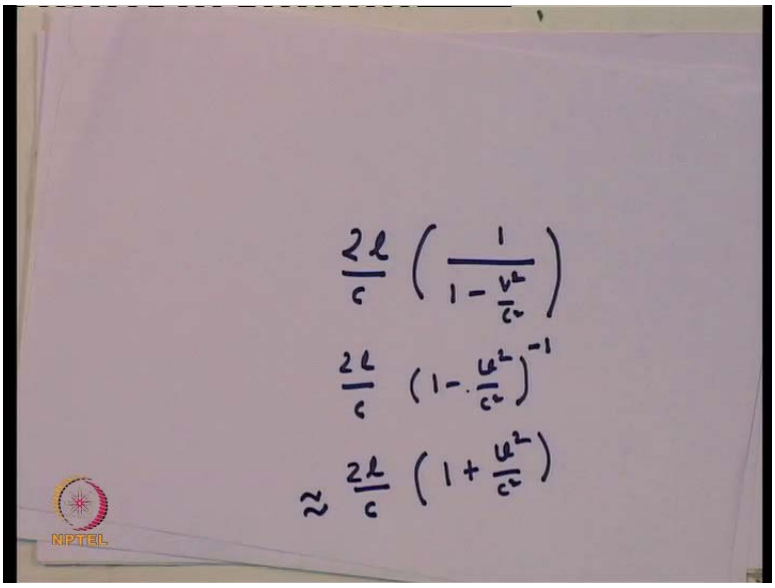

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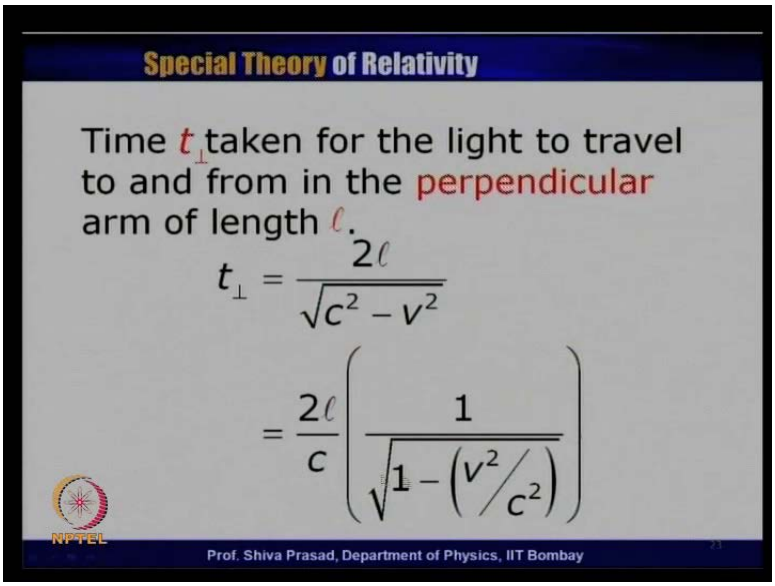

This is a very standard mathematical way of writing it, why I write this as 2 l divided by c 1 minus v square by c square to the power minus 1, the advantage of writing this, in this particular form is, that I can use a binomial expression and expand this into a series and because this series will contain higher orders of v square by c square, I can neglect higher orders and retain only the first term and by binomial expression this minus 1 they'll get multiplied by here therefore, what will be remaining is 2 l by c 1 plus v square by c square, so this is an approximation which we must realise, because this is only correct and the limit that v is not much smaller in comparison to c. This is what I have

written in this particular transparency; that this particular time turns out to be 2 l divided by c multiplied by 1 plus v square by c square. Now let us try to calculate the time in the perpendicular r, now we realised that this speed and the perpendicular r in both the directions; whether upwards or downwards is same, which is given under root c square minus v square therefore, time can also be obtained, in a very simple fashion which is just 2 l divided by under root c square minus v square, which is I have written the time in perpendicular direction.

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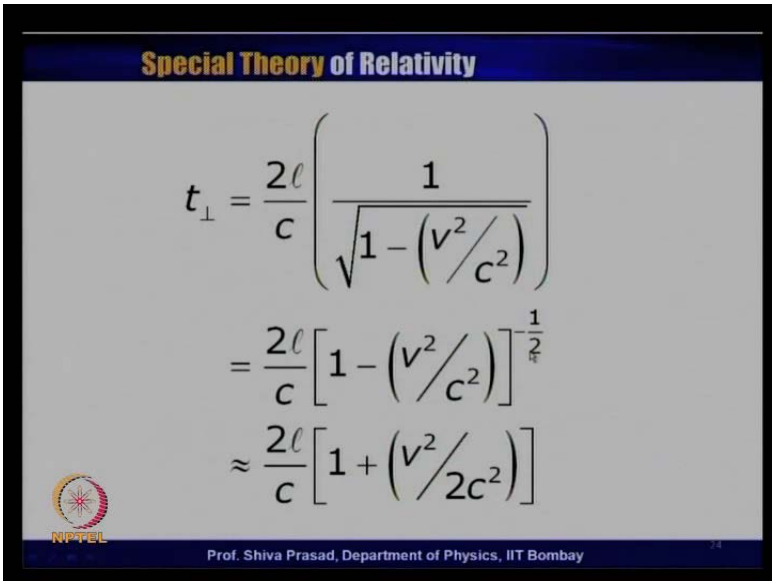

This two factor is, because the beam goes up and comes back and of course, with the same speed therefore, this is two l under root divided by under root c square minus v square, again I am trying to simplify, this same time by using the same approximation, that v is much smaller than c therefore, i have decided to write this under root in this particular form, I have taken 2 l by c out and written this particular thing in bracket as 1 divided by under root 1 minus v square by c square, which has taken this c square out of then, the root once I take c square out of the root. Then this will become under root c square which is just c. So what I am getting here is, just 2 l divided by c multiplied by c is very important. Ok remember here there is under root, that is what is the difference for the earlier expression, now we know that this particular under root can be written as to the power of minus 1 by 2. So this is what I have written here, this is 2 l divided by c multiplied by 1 minus v square by c square everything to the power of minus 1 by 2, because under root is nothing but, to the power of 1 by 2, because this is in the

denominator. So there is a negative sign and this becomes to the power minus 1 by 2. Now I will do the same trick, I expand this into binomial series therefore, this particular factor end of course, neglect higher order terms just retaining it, term involving v square then what is happening I must multiply this by minus 1 by 2 when I multiply by minus 1 by 2 this minus becomes plus and this 1 by 2 becomes, now v square by 2 c square which you remember in the earlier expression there was no 2 c.

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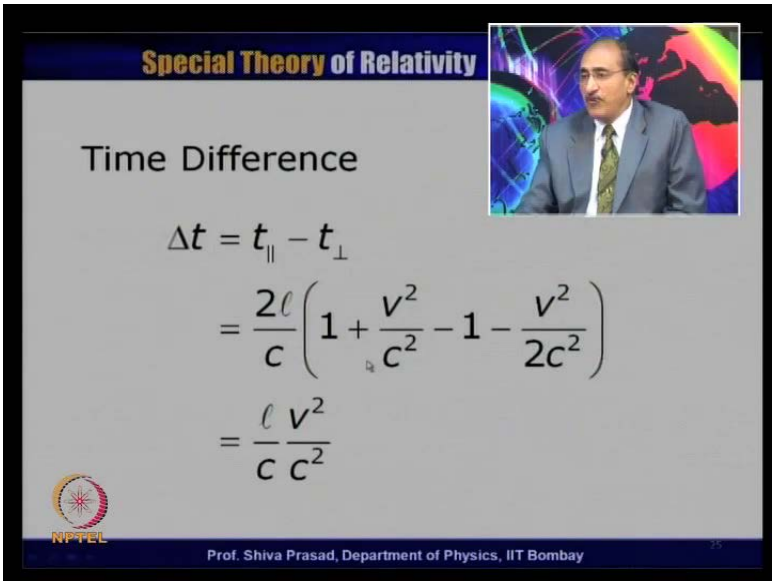

There was only v square by c square, here we are having v square by v c square. We find that time perpendicular time taken by the b perpendicular direction is different from the time taken in the parallel direction. this is what I was trying to do, let us calculate the time difference the time difference, which I have written here is e parallel minus t perpendicular of course, you will realise that time taken in a parallel direction is more than in perpendicular direction, because here we had only v square by c square while here we had v square by 2 c square (( )) because, I have divide by 2, this expression has become smaller. Now I am taking the difference of the 2. So I have just taken 2 l by c, which is a common factor out, and this t parallel we had 1 plus v square by c square, In this t perpendicular we had 1 v square minus 2 c v square by 2 c square, because there is a negative sign everything becomes negative, so this becomes minus 1 minus v square by 2 c square.

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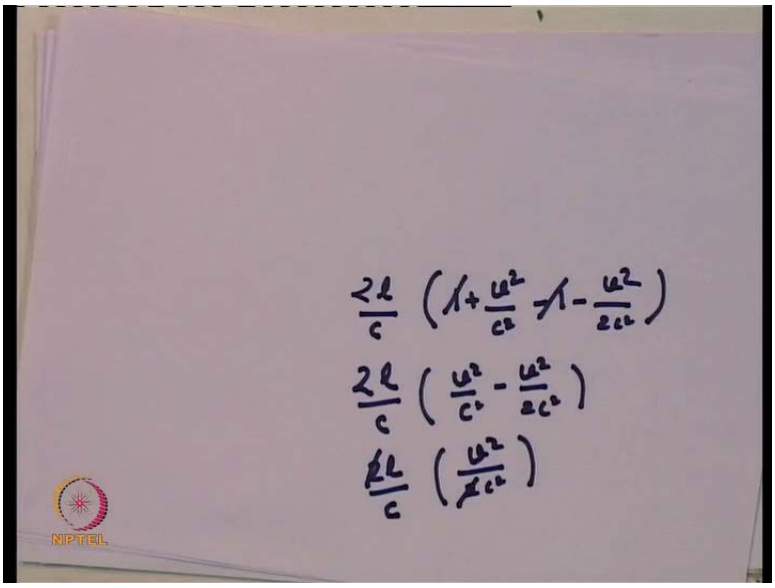

So, this sign 1 plus n minus 1 cancels out ,and you get 2 v square sorry, v square by 2 c square, because there is a v square by c square and minus v square by 2 square c square, so this will give me v square divided by 2 c square, this two factor would cancel with this 2 and this is what I will be getting just write it, and explain here 2 l by c minus 1 minus v square by 2 c square, this 1 cancels out so, what I have will be having is 2 l divided by c into v square by c square minus v square by 2 c square, this will give me 2 l divided by c into v square by 2 c square, this 2 will cancel with this 2 and this is, what I will get l divided by c multiplied by v square by c square. This is what I have written the time difference between these 2 l by 2 multiplied by v square by c square.

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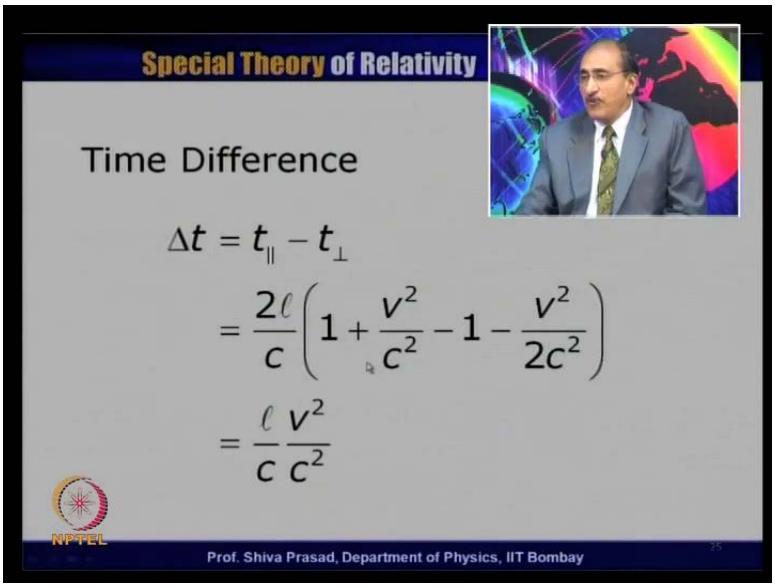

Now, let us come to nex actual experimentation, see in actual experimentation these angles that we are talking are not really especially the mirrors m 1 and m 2, they are never perfectly normal to the beam, they are made very very small marginal angle difference, so what happens the beam when it goes and comes back the different parts of the beam are slightly deflected more or less and therefore, you find there is a continuous path difference between, these two or this beam m 1 is reflected from m 1 and the beam which is reflected from m 2, because they take different time route travel therefore, when they come and super impose on each other and are being viewed by the mirror, you will find just because of these small angle you will find a fringes.

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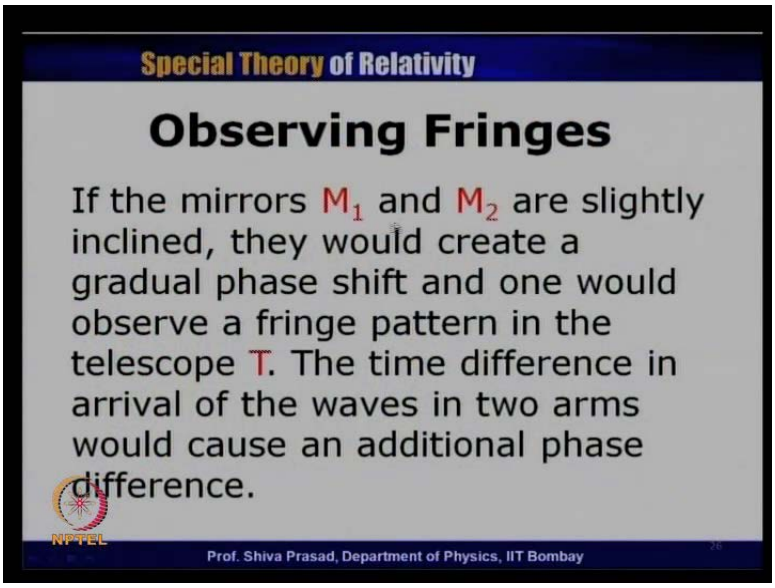

Of the fringes, you will be observed even, if there is no time difference obviously, the fringes now because of this particular time, difference there will be a shift in the fringes, because now the time difference will cause a small amount of shift in the ozone fringe pattern had there not been any time difference, so what you see is a bright fringe and a dark fringe which means a bright portion of light, where there is a light is bright and there is a darkness, this is what is called standard fringes, so these fringes would be seen but, because of this additional apathetic difference, the fringe pattern would shift, this is what I have written here, if the mirrors m 1 and m 2 are slightly inclined they would create a gradual phase shift, and one would observe a fringe pattern in the telescope t, the time difference in the arrival of the waves in two arms would cause an additional phase difference, so there is already some phase difference.

And the time difference will be on the tonsick but, basic problem is that if I want to really check by if my hypothesis is correct, then I must be able to check and show that, there is a really this much of time difference between these two beams, if I am able to check it, if I am able to verify it then I have proved my hypothesis, if I have not been able to do it, I have not been able to prove my hypothesis, so question is very simple but, there is a problem the problem is that, we have said whenever even if there was no change in the the time taken by the light, if the two beams would have taken the same light even if they even that there would have been a fringe, now because of this time difference there has been an additional shift but, how do I measure the shift, because it is

not possible for me, to create a situation when these two beams take the same time; because this beam this particular whole pattern has been devised with taking the motion of earth into consideration.

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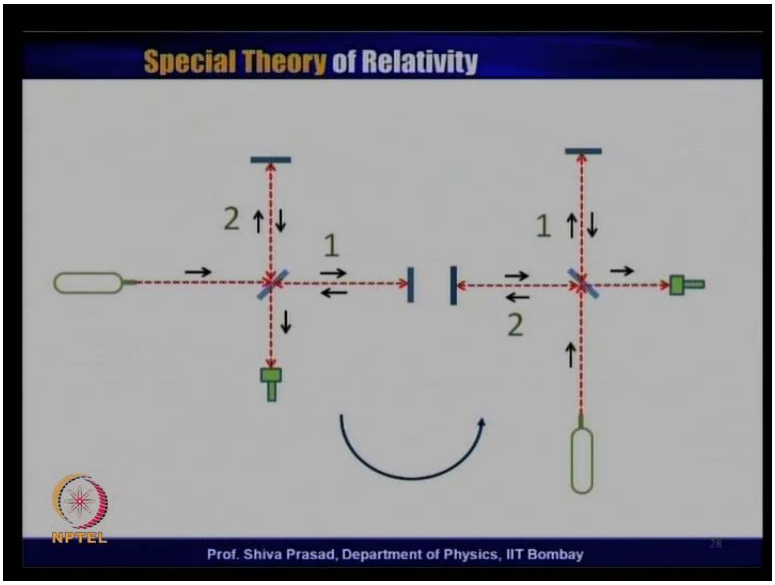

So, it is not really possible for me, to what I call a point is 0 of this particular fringe saying that, this was this is where my original fringe should have been and not, because of this it has shifted by this measure amount, because it is not possible for me to create a situation or it is not possible for me to find a situation when there is no time difference between the two beams so, time difference has been created, because of the motion of earth in the Ether medium. So how do I find 0, so how do I find there has been a real shift, so this particular problem was solved very nicely with a brilliant idea by Michelson Morley, what they said has been shown in this particular transpires, they said let us try to rotate, the whole apparatus what will happen if I wrote.

Let us assume that we are rotating over this particular axis normal to this particular picture, so this particular telescope has not come here, sorry this particular source has come here. This particular telescope has come here, this mirror has been rotated by 90 degree, this particular mirror, which is I was calling is m 1 or m 2 have now changed their position, there is one mirror here there is one mirror here now remember, this was my original r in, which I was my light was travelling now, this has gone here after rotation of 90 degree, so this r which was originally parallel with the velocity direction

has now become perpendicular to the light direction, this r which was perpendicular because it has not been rotated by 90 degrees, this particular mirror has come here.

So, this particular arm which was earlier perpendicular has, now become parallel so because of this particular rotation, an arm which has originally perpendicular has not become parallel and the arm, which has parallel has not become perpendicular. So whatever is happened the arm in, which the light was taking earlier a larger time, now after 90 degrees of rotation in that particular arm time taken, is will be smaller similarly, in an arm the light time taken was smaller, now will become larger now that is, what I am trying to say is correct, then by this rotation I would be able to see that fringe is now moving and if I am about to see it is motion, then I have verified my hypothesis this is what they did is trying to create a rotation in this particular Michelson Morley experiment, to see this particular fringe shift because they were not able to decide, they were not able to find out, how to check the finite equations?

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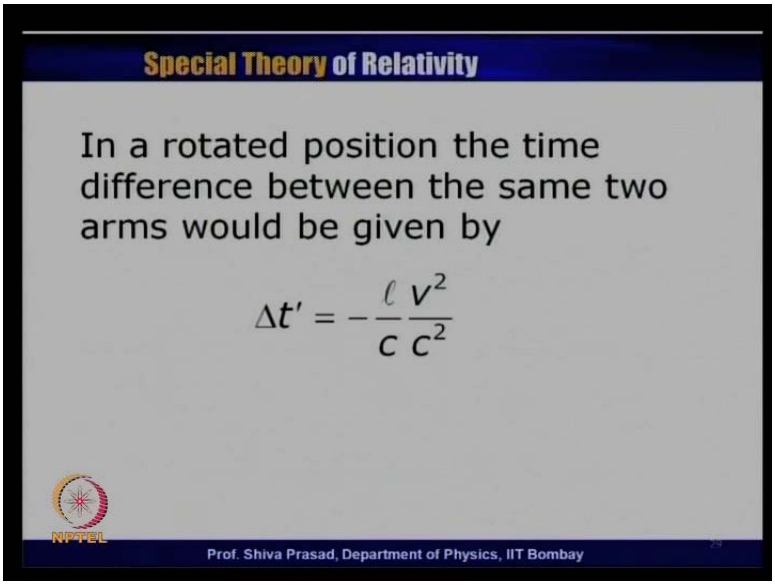

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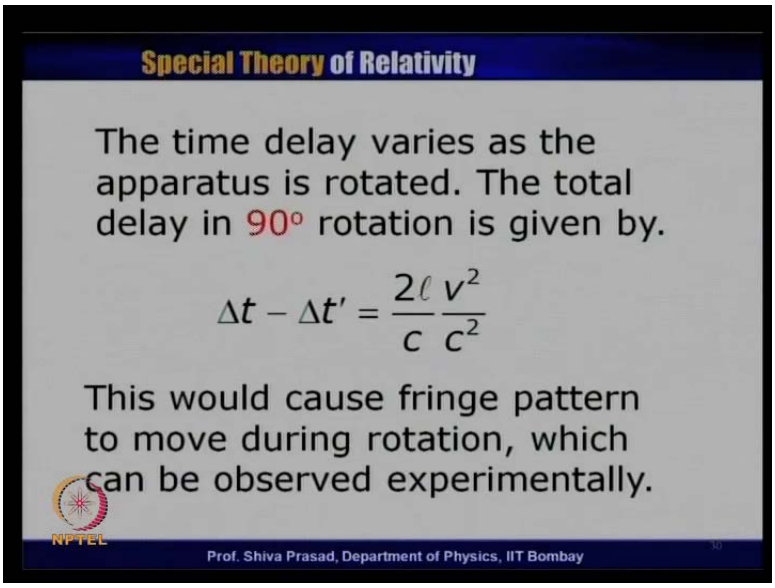

So, what is aid in a rotated position time difference on the same arm will be same but, now with a negative sign, because the arm initiative was positive, now it has become negative it is taking longer time, so the time difference magnitude wise will be same l by c multiplied by v square by c square but, this time difference will be negative and if I rotate by 90 degree, then the total rotation will be just the difference of these two, which because of negative sign as surely implies an addition therefore, the total phase difference the total I am sorry, total time taken would now be 2 l v square 2 l 2 l multiplied by v square and divided by c multiplied by c square, this will be the time difference between the two arms, this would cause as an emission is shift in the fringe pattern. So as I rotate if I keep on rotating, I will see my fringe is getting shifted and if I am able to form this shift in the fringe pattern, as surely I have proven my hypothesis.

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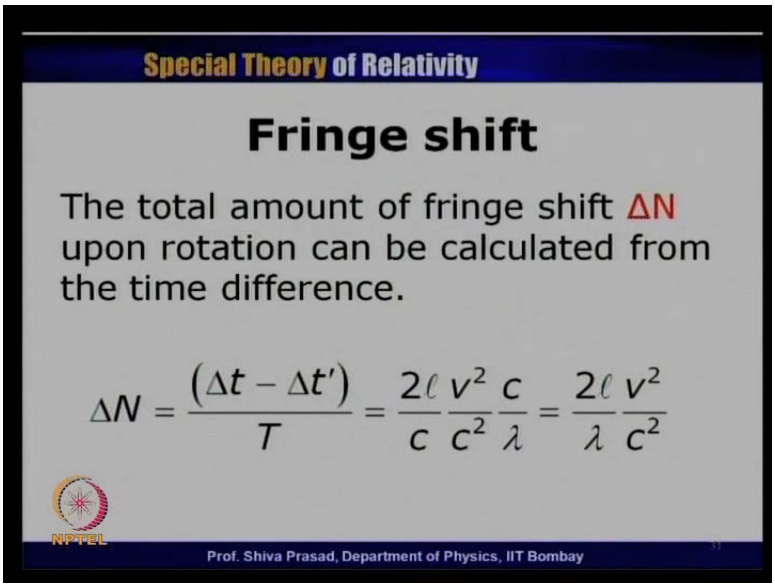

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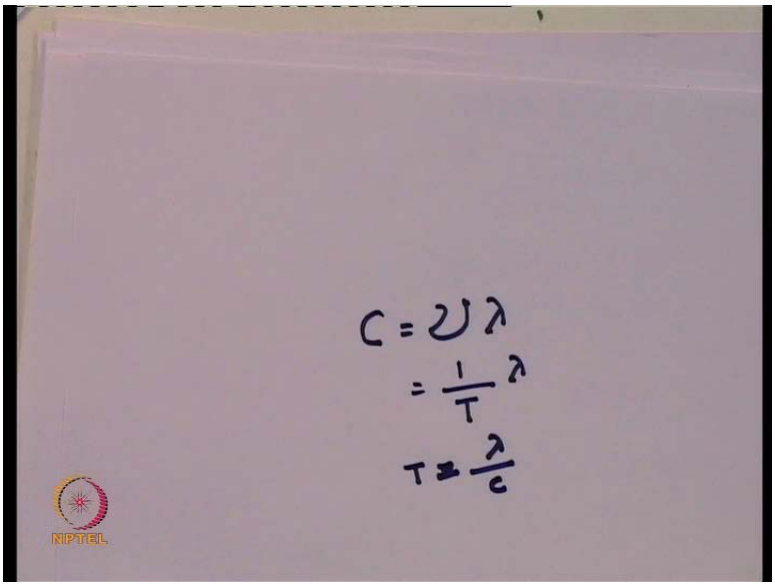

Now in order to find out, how much is the fringe shift I must divide this particular time difference in comparison to must divide, by the time period what I say per particular oscillation and this particular time period, is inverse of the frequency, so you are aware this frequency, this speed is given by frequency multiplied by lambda, which is the wavelength, this frequency I can write as 1 divided by t multiplied by lambda therefore, this t would be given by lambda by c, this is the time period of one of the oscillation in a harmonic oscillate, that is what we normally call, so this time difference must be compared with the time upon oscillation must be divided by this, so this is what I have

done delta p minus delta t must be divided by t and this t would be given by c lambda, if I calculate this particular thing, this is get as 2 l divided by lambda multiplied by v square by c square, so this will be the amount of the fringe shift that, we would be observing as a result of this particular (( )).

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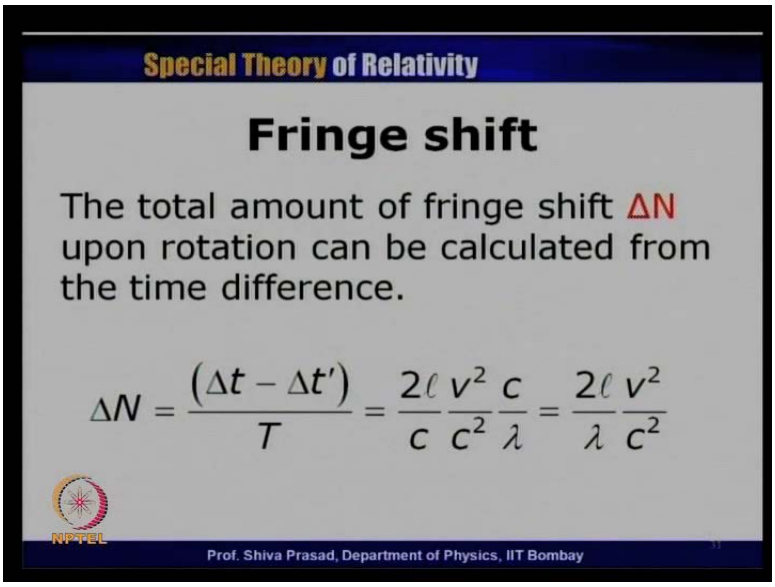

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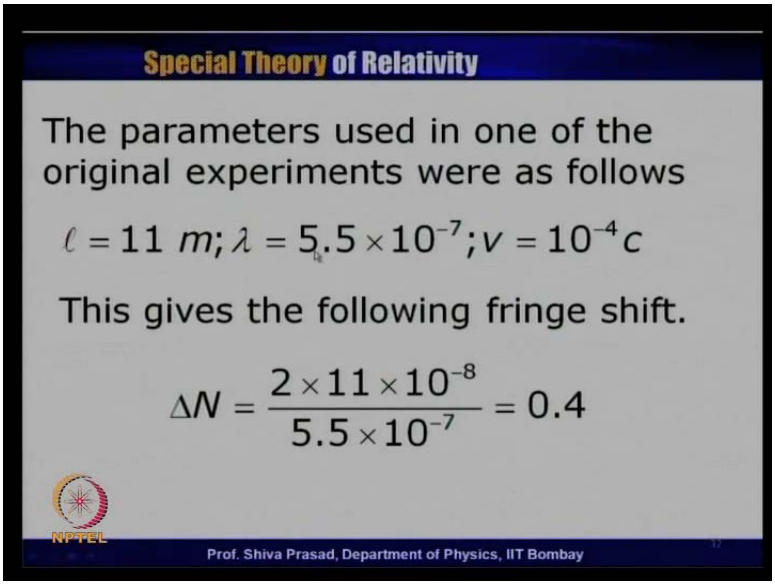

Of course, this particular experiment has been performed number of times but, in one of the original experiments these were the standard values which were taken this l length sagginess 11 metres not very large the lambda was taken approximately as 5.5 difference

of minus 7 and the speed of earth in Ether medium medium was taken as 10 to the power minus 4 c, so I give these numbers here I will find that the fringe shift turns out to be equal to 0.4, I have just substituted the numbers in the earlier expression, which I have written earlier to find that there will be approximately, the 1/2 of the fringe shift Michelson Morley had done an error analysis, and we will very show that, it is a different shift was really there was existing they will be able to observe this particular fringe shift.

However, we never observed in fact this particular experiment was repeated number of times in different seasons, because you are never sure, what is the direction of Ether? Whether earth is how eth how the earth is floating Ether different seasons different positions has never found to be true never found out a differential, as I mentioned that this experiment has been repeated by current years, noti would not say very recent years but, in this particular century this particular experiment has been reputed by better precisions, and everytime we found that, the result is negative. There was no fringe shift, that was observed appears there is something really wrong with the Ether hypothesis, this is what I mentioned that experiments are performed in various seasons but, never gave a positive results.

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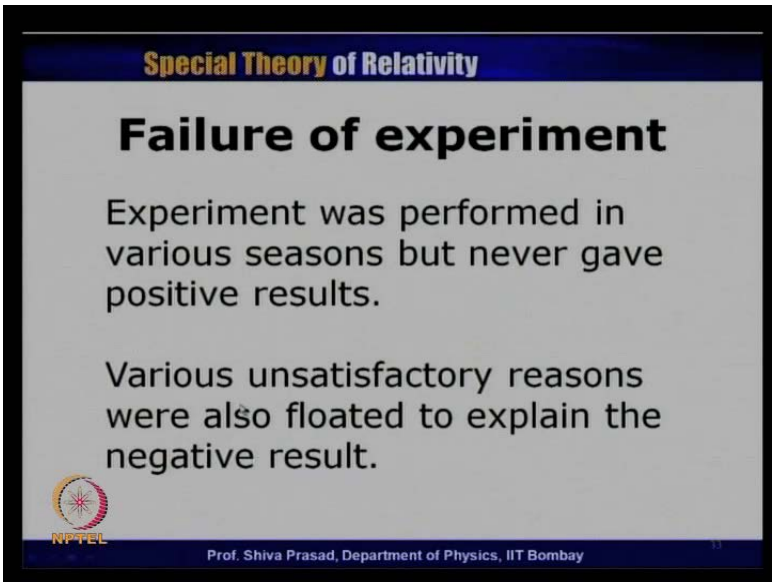

Then there are lot of attempts to explain, why we are getting negative results of Michelson Morley? and none of these explanations they are really found to be very

strong would never believe, that Michelson Morley experiment could be understood to the failure of Michelson Morley experiment could be understood by these explanations, I would like to mention that, other than Michelson Morley experiment, which is basically an experiment based on light there had been other attempts also one of the standard attempts to look, because if you remember in our last lecture, we had mentioned that the basic starting problem was v cross b, when we are talking about the Lorentz force and we said that, what is this v that we are talking at that time we said that probably this v that would mean is also, that speed of that particular object that particular charge in Ether medium ok.

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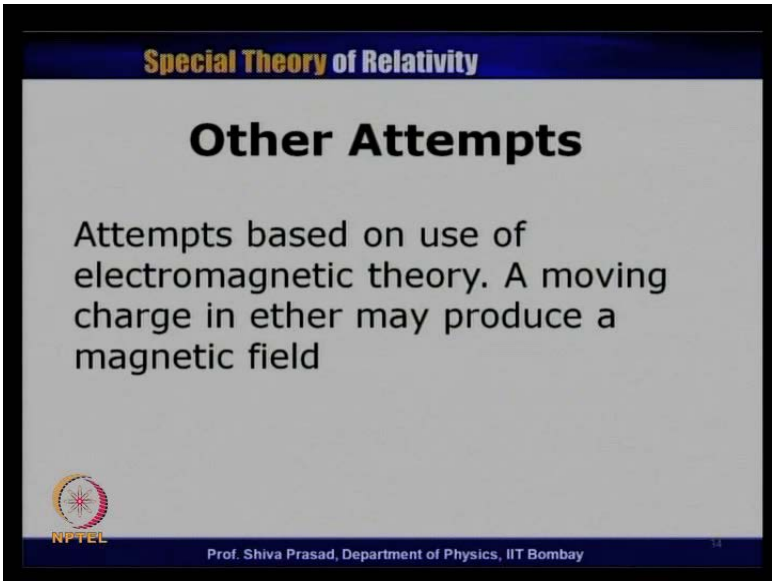

So, if earth is actually eth moving in Ether medium then, if I put a particular charge then it would have a v and therefore, in a given velocity it should experience a force of v cross v, so there were some attempts which were made in order to assume a force on a given charge, all these attempts relate to a fringing, that there is no Ether, there is nothing like Ether medium.

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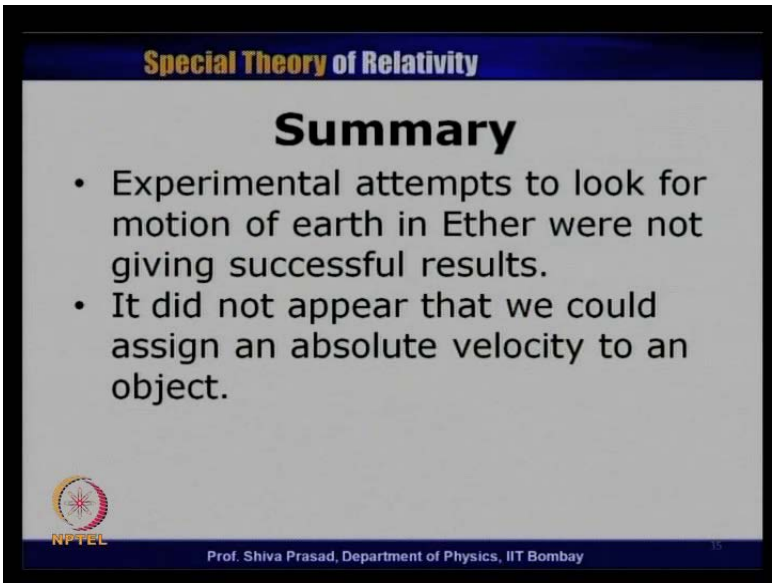

So, this is what is the summary of whatever we have discussed today. Experimental attempts to look for motion of earth in Ether, we are not giving successful results, it did not appear that we could assign an absolute velocity to an object.

Thank you. .