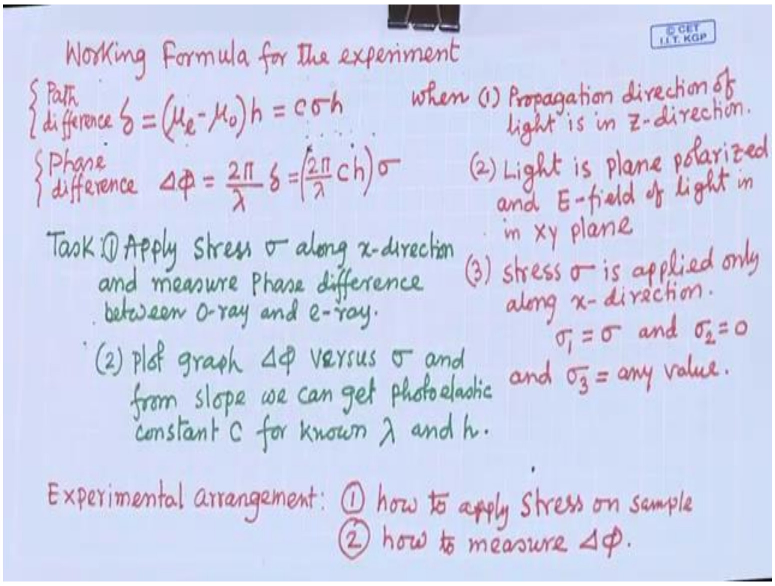
Experimental Physics - III
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture – 50
Photoelastic Property of Materials (continued)

Let me continue the Photoelastic constant of a crystal. In last class, I was showing you that this simplified relation we got that we can use as a working formula for the experiment.

(Refer Slide Time: 00:50)



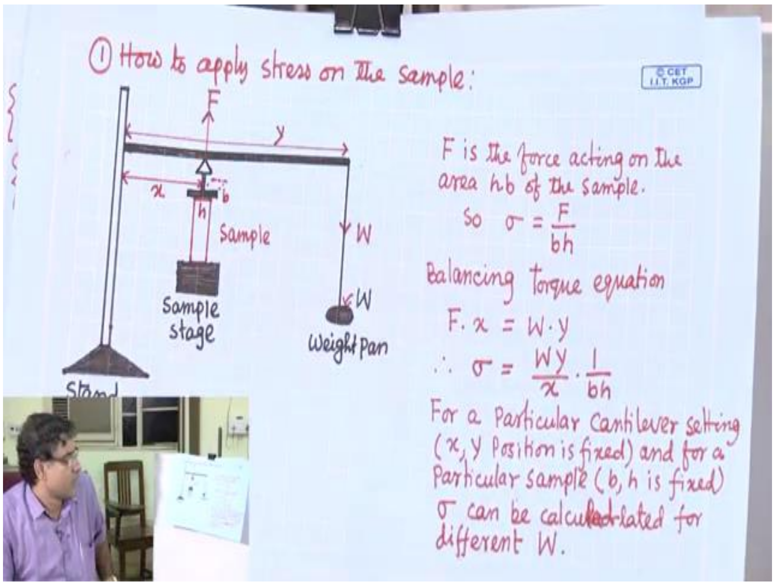
That path difference delta equal to mu e minus mu 0 into h equal to c sigma h. that is what in last class we have we have seen under certain condition. That condition we have to fulfil during the experiment. Corresponding phase difference we write we can write del phi equal to 2 pi by lambda and this in this delta so; that means, cs are 2 pi by lambda c h into sigma ok.

Here this relation is showing. this stress, this stress this phase difference is proportional to the stress, phase difference is proportional to the stress our task for this experiment, our task is; apply stress sigma along x direction and measure phase difference between o ray and e ray for different stress, we have to measure phase difference between o ray and e ray ok.

Then we will plot graph between this this del phi versus sigma and from slope, we can get photoelastic constant c for known, for known lambda means wavelength and the h; means, thickness of the crystal The thickness of the crystal means this along the z direction the light is propagating. What is the path of the light inside the crystal that is the experimental arrangement and these I have written this this formula is valid when propagation direction of light in z direction. When light is plane polarized and electric field of light is in xy plane. It will be is not in.

And stress sigma is applied only along x direction. sigma 1 equal to sigma and sigma 2 equal to 0 and sigma 3 can be any value in principle because this formula is independent of sigma 3 what is the stress along the direction of propagation of light that that does not the effect now, our experimental arrangement we need, how to apply stress on the sample and how to measure, how to measure phase difference del phi. That arrangement we need.

(Refer Slide Time: 04:08)



How to apply stress on the sample; let me discuss first. Here this is our sample this sample we have put on a stage. Now on top side here you can see here this is a cantilever. one end of the cantilever is fixed here and on the other end; we are applying weight, we are applying weight you are applying weight on the cantilever at this end this is the it is the this weight or equivalent force mg force, it is working downwards

Now, here you can see, here the arrangement we have done in such a way at this point at this point here. If something is in contract with the cantilever there will be there will be force acting on this on this on this point and their corresponding reaction force will be there. That will be in opposite direction here whatever the force given on the sample through this point it is the one sharp pointer we have used and that that force acting on this point and bottom there is a flat kind of pins.

(Refer Slide Time: 05:59)

This is the sample, this is the sample and actually, we are putting like this, this is the sharp edge, this is the sharp edge. On that, this cantilever is there on that this cantilever is there at this point this end is fixed. Anything there is contract at this point. There will be force acting on this on this contract towards downwards. Reaction force will be in opposite direction.

This F is the reaction force. There will be torque balancing torque equation that is the cantilever principle, that the cantilever principle. If this is the force F upwards and the distance is x F x will be equal to F x will be equal to. This force is W this force is W and the distance from here it is y ok then that will be equal to w into y.

Force into displacement distance from the axis that is torque. Here it is, we tell this equation is a balancing torque equation balancing torque equation. From here, you know this. This force is, F is the force acting on the area bh of the sample of the sample. bh what is the area of this one? What is the area of this one that is bh ok; h is the thickness and b is this one width kind of pins width kind of pins ok.

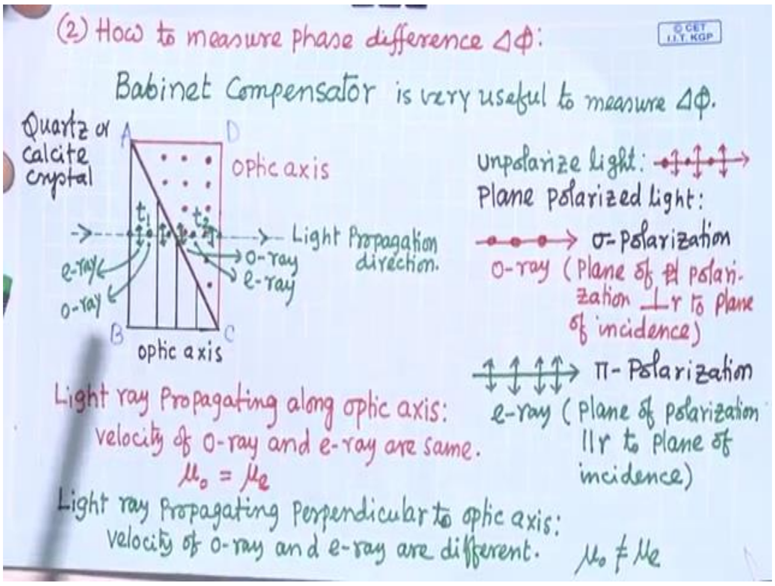
Actually a crystal we have we have this is the crystal this is the crystal that is this crystal actually we have put here fixed here this force is acting and the is this is if light will pass through it. This then this will by h, this will be h this will be z direction. other two direction one is y, say y another is x another is x. this y and this z, y z in this case y is this say I have written b here, I have written b here and z is h. this area this the force acting on it, this force acting on it. That will be bh; that will be bh

This sigma is equal to force by unit area. bh now, from here this force you can write. sigma I can write equal to F is F is W y by x into 1 by b h into 1 b h. for a particular cantilever setting x y position is fixed and for a particular sample b h is fixed, then sigma can be calculated for different W ok.

Actually here the sigma is a for another parameter are fixed. It will be proportional to the W we will change it then sigma will change. Using a cantilever technique we apply we apply force on it. There is an advantage of this one. This you can increase the force with this ratio y by x. With this ratio, if I if I put this w at directly at this point. Whatever force will get here. In this using this cantilever technique, we can we can if increase the effective force effective force at this point with this ratio y by x ok.

This way we will apply the stress of the sample and we can just if you know, if you know the W; how much weight you are putting 1 kg, 2 kg, 3 kg, then you can calculate the sigma stress Knowing the other parameter of course, that is are known from the setup then how to measure phase difference.

(Refer Slide Time: 11:34)



This is very important how to measure the how to measure the phase difference del phi. This is the second task; how to measure the phase difference between o ray and e ray, when it is traveling through the sample under stress. Then for measuring these phase difference, we will use Babinet Compensator. Babinet Compensator is very useful to measure this kind of small phase change.

What is we have to know we have to understand the working principle of the Babinet Compensator? Babinet Compensator here you can see these a rectangular kind of shape Now these are diagonal this these are two half. This is one half; black one and this is another half red one this is made of quartz crystal or calcite crystal. One is called positive crystal, another is called negative crystal. for one case refractive index or e ray is greater than refractive index of o ray and for other case it just reverse one can use any one either quartz crystal or calcite crystal.

That crystal is double refraction crystal birefringent crystal it has optics axis. You can define, you can cut the crystal in such a way you can define the optics axis. For these half optics axis is this. Optics axis direction this is the optics axis is nothing is nothing but, direction it is not a line

direction of the optics axis is this for this half and for other half both are made of either quartz or calcite, but the these two pieces have taken in such a way their optics axis one is this, then another is this perpendicular to this paper dotted line doted dot I have used. Optics axis is this direction.

Now you have to know some principle hopefully you know. Light ray propagating along optics axis velocity of o ray and velocity of e ray are same. That means; mu o equal to mu e, refractive index it. along the optics axis refractive index are same for o ray and e ray light propagating perpendicular to optics axis ok, then velocity of o ray and e ray will be different; that means, mu o is not equal to mu e ok.

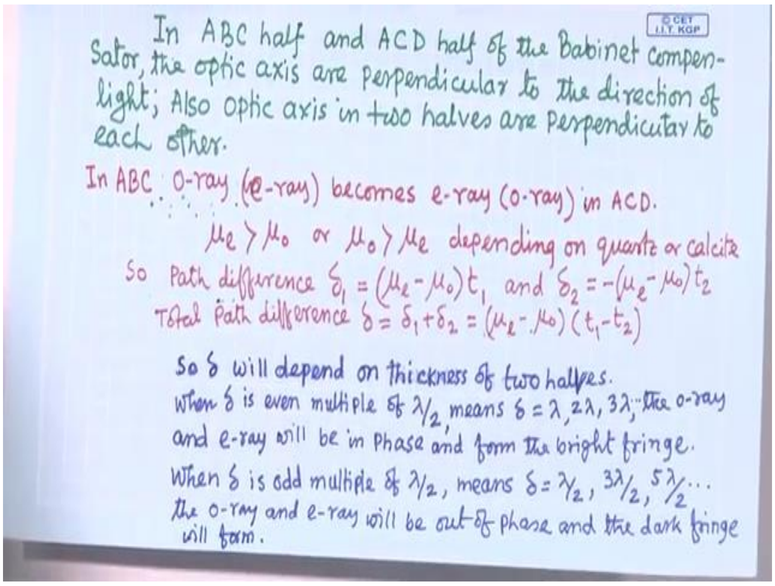
now unpolarised light as I mentioned you that it has all sorts of direction of the electric component and that we can we can always resolved into two component mutually perpendicular generally unpolarised light we can we express this way plane polarized light when this means one component only one component is there direction of the electric component is fixed and another could be this one. This this electric filed direction is this ok.

This we tell if this is the direction of the propagation, if this is the direction of the propagation and this, we can tell this o ray or sigma polarization and other one, we can tell e ray or pi polarization. Definition is plane of polarization is perpendicular to the plane of incidence. When plane of polarization; plane of polarization ok; that means, plane of polarization means direction of the light and the electric component On the plane, the plane contain the direction of the light and the and the direction of the electric component.

This plane contain this this two then, that is call plane of polarization and plane of incidence. When light is falling on a sample. normal to the sample and direction of the light and then reflection or refraction of the light all are on a plane ok; that is call plane of incidence when plane of polarization is perpendicular to plane of incidence, then it is called sigma polarization or it is also called o ray. In addition, when plane of polarization is parallel to the plane of incidence then it is called pi polarization or e ray ok.

This is the general concept about the about the polarization of the light as well as the property of the quartz crystal or calcite crystal or double refracts refraction crystal.

(Refer Slide Time: 18:15)



Then here what I have written. here I have shown you that this is the A, B, C, D, this this half is ABC and this other half ADC or ACD direction of the propagation is along this direction, propagation is this direction now, electric component; obviously, it will be on the on the on the plane perpendicular to the direction of the propagation then electric component here you can think that when it will fall on this crystal. Usually for plane polarized light if, it is an arbitrary direction. It can be resolved into two component if it is z direction it will electric component will be on xy plane.

ex and ey this this you can resolved into two component. So, electric component both electric component it is perpendicular to the direction of the propagation. one will be one will be along this direction, other will be along this direction plane of incidence is this, plane of incidence is this, plane of papers is plane of incidence now, when an electric component is this direction that is this plane of polarization will is parallel to the plane of incidence. Then it is e ray. This this is representing e ray and this dot whatever I have used. This is perpendicular to the plane of incidence. Then this is o ray ok.

Now you see here, you see here when light is plane polarized light is entering into this half ABC half. Light is light direction is perpendicular to the perpendicular to the optics axis ok, perpendicular to the optics axis. What will happen? What will happen? We will get e ray and o ray, e ray and o ray. Velocity of e ray and velocity of o ray will be different, will be different. As I mentioned here light propagating perpendicular to the optics axis velocity of e ray and velocity of o ray will be different.

Here it is already it is. Incident light when it is entering into this crystal. It is resolved into two component; one is e ray and another is o ray, both are traveling perpendicular to the optics axis. They are moving, they are going in same direction, but their velocity will be different because their refractive index are different. There will be, there will be retardation, there will be path difference between this o ray and e ray. There will be phase difference between e ray and o ray

When it is entering to the next half. Then also, this light is propagating perpendicular to the optics axis optics axis is this. Now you see; whatever e ray here in this half. This was the direction. Now, that ray here it is now perpendicular you see it is on the. Optics axis direction is this one optics axis direction is this one.

Now, this one is perpendicular to the optics axis this electric component is perpendicular optics axis where as in this half it was parallel to the optics axis that means; when it was parallel to the optics axis that was e ray when it is perpendicular that is o ray. Now, this this e ray when it is entering here. Now this component electric component is becoming perpendicular to the optics axis it will behave like an o ray. In addition, that o ray in this case. Now, in this case it was perpendicular to the optics axis, now when it is entering to the other half. It will be parallel to the optics axis. Then it will be e ray

In other half of ray become e ray and e ray, become o ray. now, you see refractive index will be just in this case refractive index will be for o ray whatever; here for o ray whatever the for say e ray whatever the refractive index mu e. now, for that same ray here refractive index will be mu o ok; here whatever the path difference introduced between e ray and o ray. In other half, that path difference will be introduced, but in other direction other way; path difference will reduce. Here whatever path difference if increase between these two.

Other half it will be reduce. If thickness, path difference equal to mu 0 minus mu e or mu e minus mu 0 into thickness t. if this thickness is t 1 and this thickness is t 2. A path difference will be that is what I am showing the next here. Here whatever I have discussed that I have written here. in ABC half and ACD half of the Babinet Compensator; the optics axis are perpendicular to the direction of light also optics axis in two halves are perpendicular to each other in ABC, in ABC o ray becomes e ray and e ray becomes o ray in ACD.

mu e is greater than say, mu e is greater than mu 0 or mu 0 is greater than mu e depending on the either it is quartz crystal or it is calcite crystal, but does not matter. Path difference in first half delta 1 will be mu e minus mu 0 into t 1. In addition, for the second half is ACD, delta two equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2.

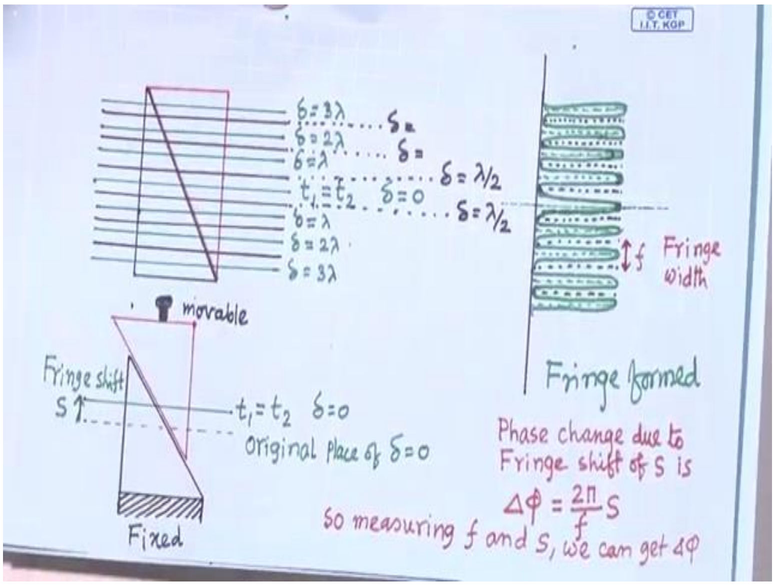
total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference. delta 2 as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok this path difference. delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

This path difference delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t one minus t 2 ok so this path difference. delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok; so this path difference.

delta two equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

This path difference delta two equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

(Refer Slide Time: 29:35)



this path difference; delta two equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

This path difference delta two equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok; so this path difference delta 2 equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2

This path difference delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference. delta two equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

this path difference; delta 2 equal to, as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference; delta 2 equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t

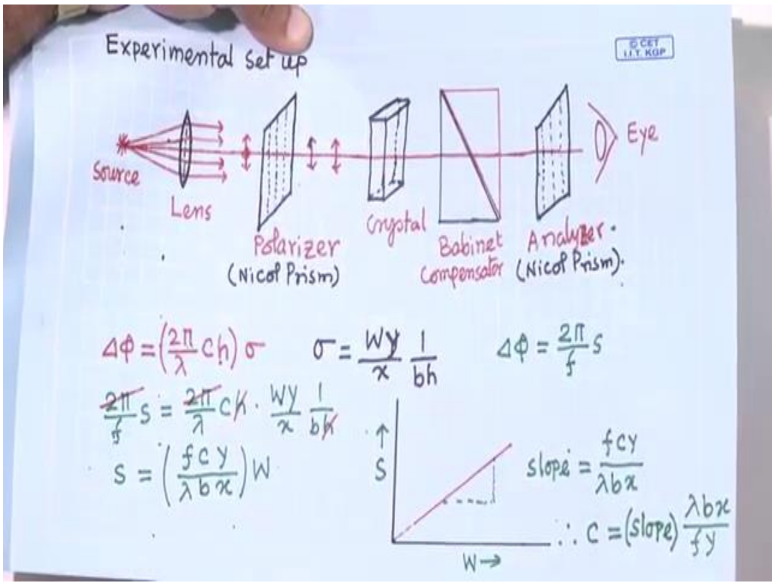
2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

So this path difference; delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference; delta 2 equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this 2 half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

this path difference; delta 2 equal to, as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference; delta 2 equal to, as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

This path difference; delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t two. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

(Refer Slide Time: 36:44)



this path difference; delta 2 equal to, as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. Total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok.

so this path difference; delta 2 equal to, as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference.

delta 2 equal to as I told this it will be just opposite effect minus mu e minus mu 0 into t 2. total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 ok so this path difference; delta 2 equal to as I told this it will be just opposite effect.

minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o t 1 minus t 2 so path difference; delta 2 equal to as I told this it will be just opposite effect. minus mu e minus mu 0 into t 2 total path difference by this two half that will be delta equal to delta 1 plus delta 2 equal to mu e minus mu o.