Experimental Physics - III
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Lecture – 57
Determination of Velocity of Light in Free Space (Contd.)

I will demonstrate this first how to measure the permeability mu 0. mu 0 2 power mu 0 or epsilon 0 as I told only these 2 capacitor 2 parallel current carrying conductors or 2 parallel metal plates here you can see so we have 2 current carrying conductors parallel conductors. One is this is the, this top one this the conductor

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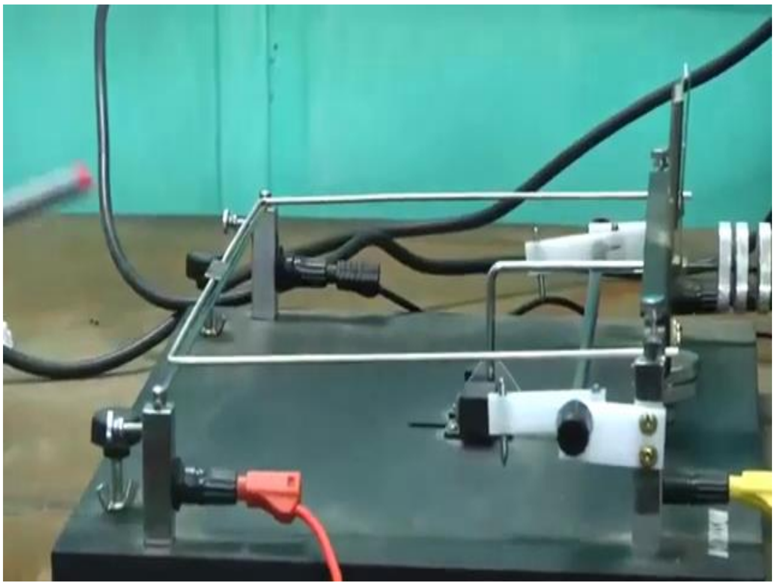

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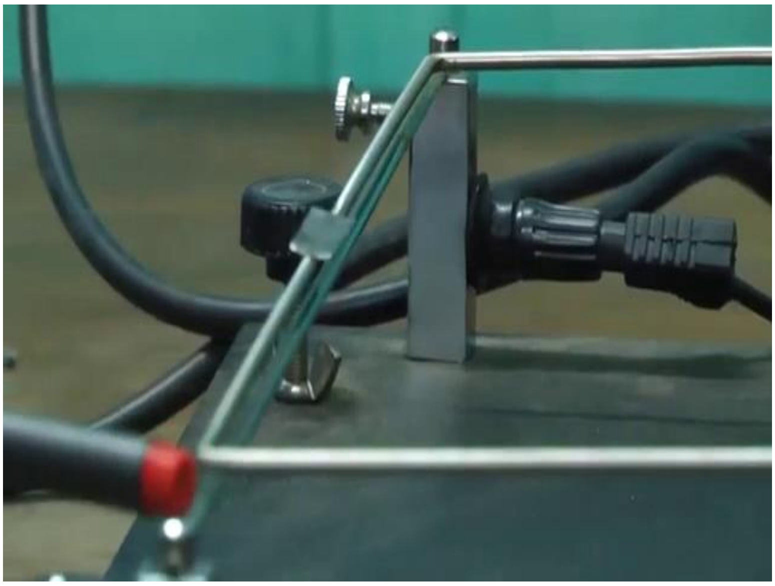

And, another conductor is below this is fixed below you can see this the another conductor, this is fixed and with respect to this top one see it is on this lever so it can change the position ok, it can change the position. Now just for a particular separation, for a particular separation for this particular separation I want to measure this separation d 0 as I told because I will do experiment at this for this length of this wire capital L.

And for the separation of this 2 conductor, d or d 0 keeping this 2 fixed constant we will apply different current and measure corresponding force. Now, experiment so experimentally I have to find out d or d 0 and the force

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We are using to get that one we are using laser, you see this is a laser now this laser light is falling on the mirror, here you can see this one mirror this laser light fallen on it. this mirror, so this mirror is fixed on this on the lever with respect to; with respect to that lever so these are rotating these are rotating ok, these are rotating.

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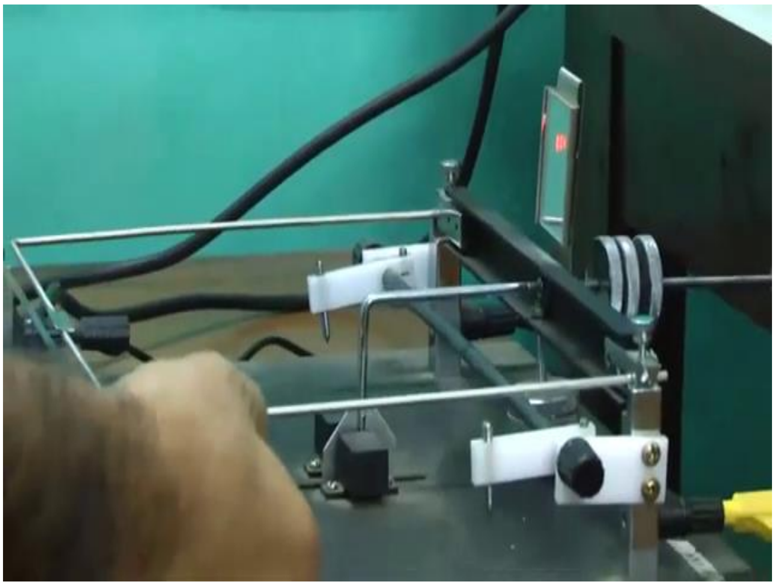

Now, with respect to this mirror what is the distance of this of the screen, reflected light fall on the screen here so it this on the wall and we have used the millimeter graph

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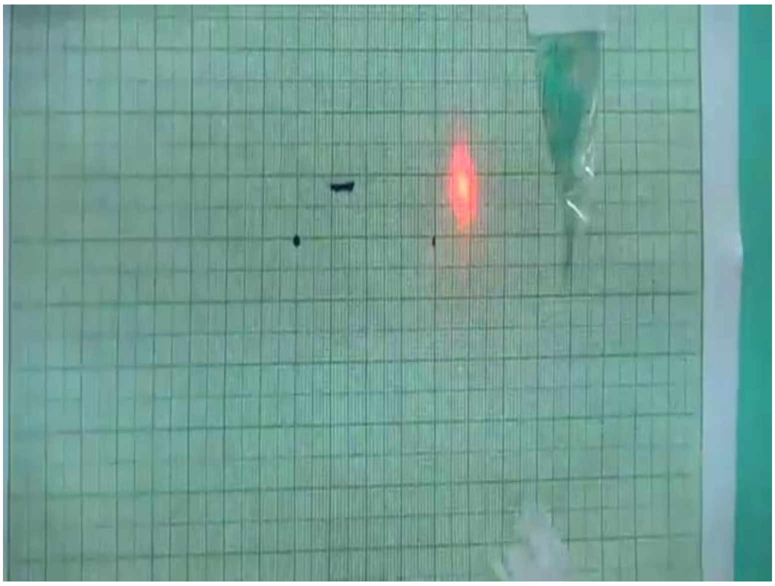

these seems this separation of these 2 conductor the just oscillating top one so it is the is the this reflected light also is just oscillating we have to fixed it first ok, we have to fixed it first let it be just I will touch it and make it just constant separation. Its oscillating I have to damp it, I am trying to damp it, but it is almost its static.

I will mark this position so I have not used current or the mass. this the original position I will mark it here let me mark it here ok, so I have mark it. Now, what I will do? I will put mass of say 100 milligram so 100 milligram mass I will put on it. This the 100 milligram you cannot see probably this, but it is 100 milligram.

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Student: (Refer Time: 04:58).

Is the 100 milligram here it is written whether you can see on not. Yes, I think you can see, this the 100 milligram.

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It is the 100 milligram 100 mg.

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this mass I will put on the top conductor so there is a pan on this you can see there is a pan on this ok, I will put on the. I have to put this mass on this pan I have put, I have put.

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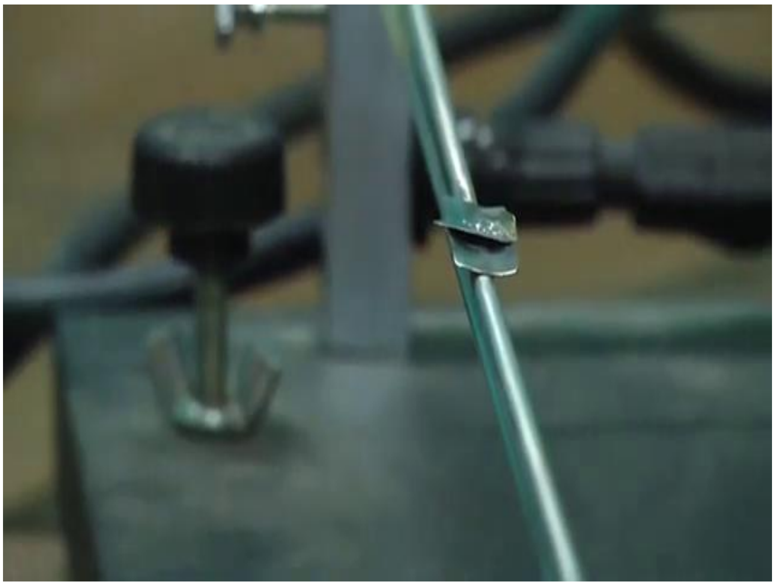

Student: Sir.

Just, I am trying to damp it because it is free to oscillate Still it is a slightly oscillating now you see after applying mass so this it is it was this horizontal now after applying mass so it is now this way. This light spot reflected light spot has come here

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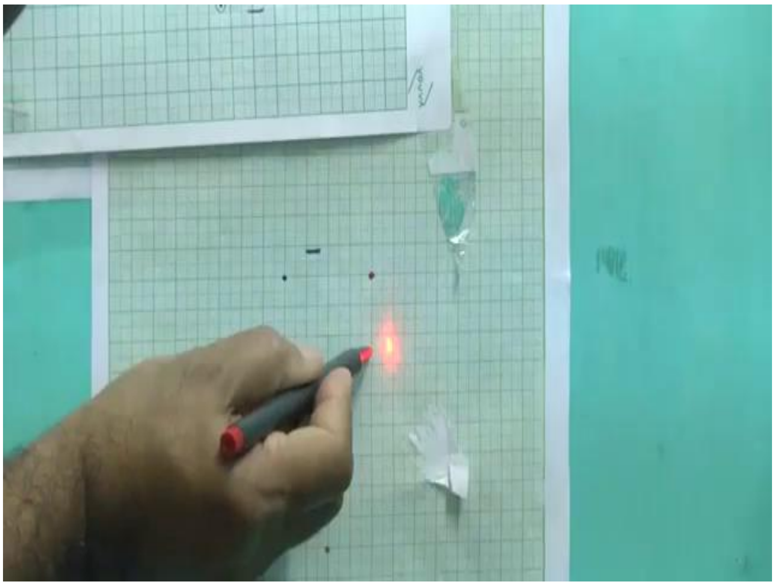

Now here I will mark it in the middle I will mark it is a here. what is the reading here you can see this 10 millimeter 10 20 25 millimeters.

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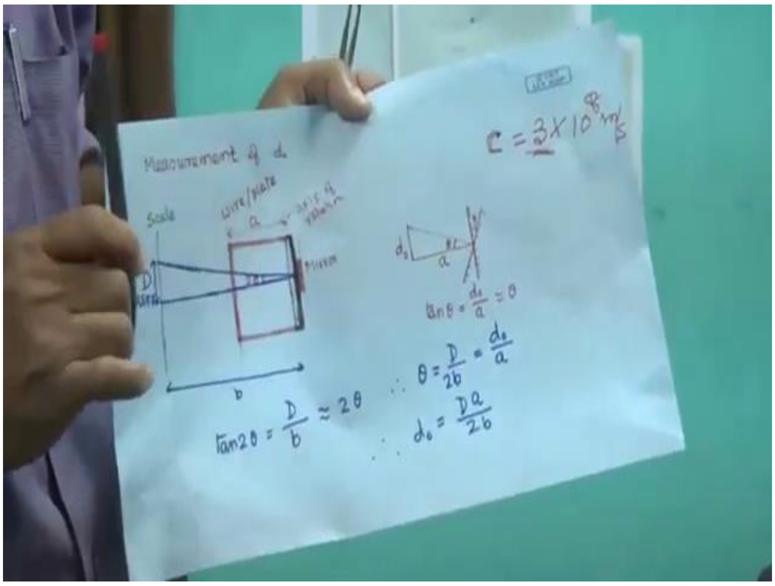

capital D, in this formula whatever I have written this capital D capital D is, is this 25 millimeter that you have to note down, also you have to measure this small b. distance from this mirror to this you have to tape and you have to measure. this is the tape I can use tape ok, I can use tape and I can measure, I will not measure, but you can use tape and you can measure. Capital B sorry, small b and capital D.

If you know this. this tan 2 theta equal to this is 2 theta so theta value you will get from here Now this one so this all is from mirror to the wire this are called distance of this, distance of this wire from the lever from the mirror with respect to that is it is rotating So; that means, this small a and this d 0 here at this position ok, from the mirror to distance of this conductors. This is a and this will be the d 0.

That a you can measure just using the tape, but d 0 that we have to, we want to find out. if we know this capital D small a and small b then you can calculate this d 0 from this value I am measuring this so this d 0 whatever getting so throughout the experiment we will keep this same ok, we will keep this same or one has to. I think better to keep it same. Now what I will do?

It is because of this mass it has come here now, now this 2 now this 2 conductor now if I so now it has so one has come down now I want to I will bring it back to this original position. How I will know it has come back to the original position? When this laser spot will come here initial position so; that means, now it is this way I have to make it, so there should be repulsion between these two.

to get repulsion I have to apply current in opposite direction in the current carry conductor, if they are current are in same direction then they will attract each other, when current in opposite direction then they will repel each other. here I want to take them in original position so there should be repulsion. How much current I have to apply to bring it back so that current will produce force and that force will be equal to mg. that we have to do now.

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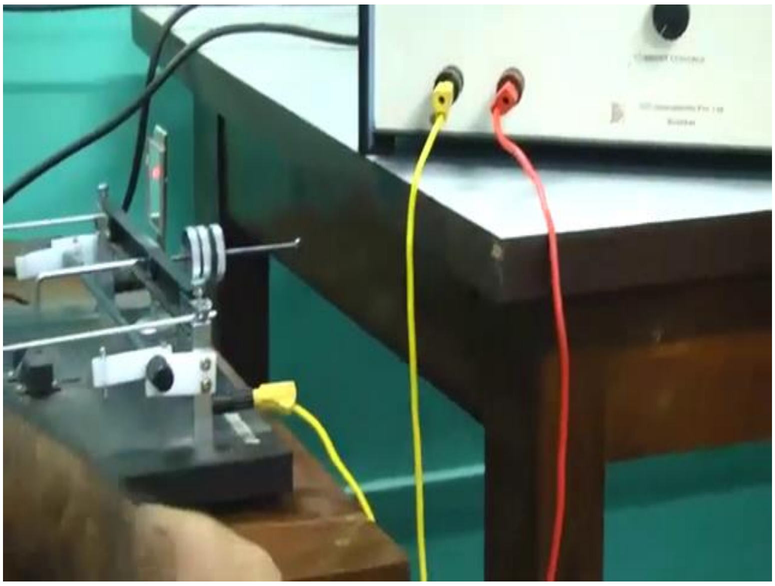

Here you can see this current this from the source current is coming yellow color light coming here and you see this it is connected with a way it is connected with this.

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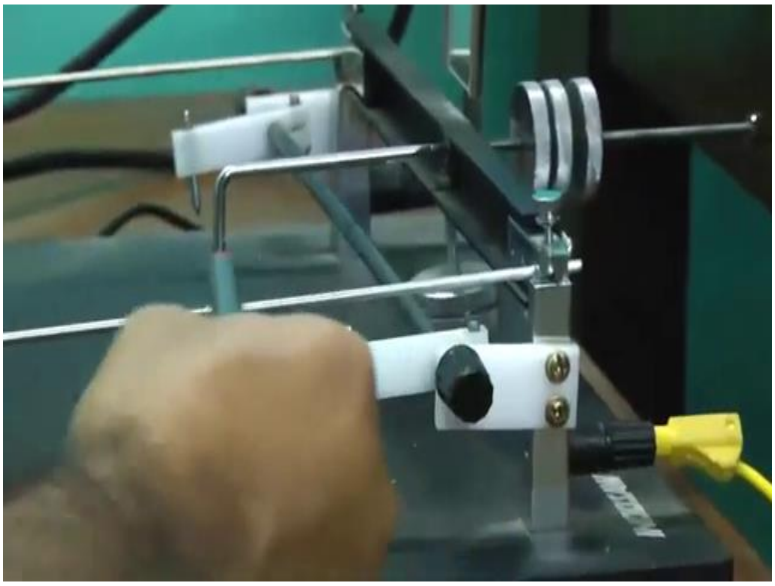

current is coming now this is conductor top conductor current is flowing this way and going back here and then coming through this black wire and here and then the conductor below current is going this direction and going back to that source current on top one current will go in this direction and bottom one current will go the other detection so there will be repulsion.

Now I will apply current and, I will take it back to the original position.

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Here I will switch on this magnet, this not magnet this power supply it is a high current power supply because current generally for this mass we have to apply around 10 ampere current. now, I will apply current as long as this laser spot will go back to this original positions and how much current I have to apply. Now I will apply the current here you can see I am applying current.

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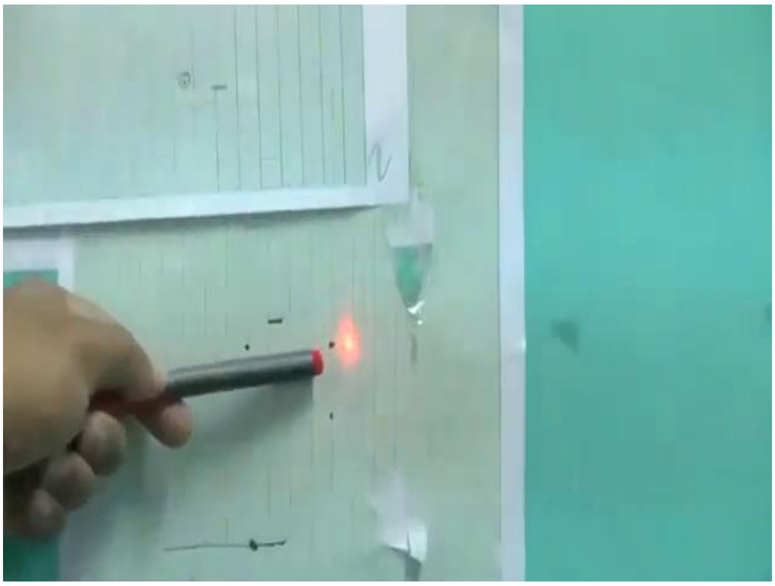

8 ampere and you can see it is going up you, see it is going up, it is going up it is going up I have to go slightly higher so still it is. I am increasing, I have put 10 so it is almost, but slightly more I have to put, I have to put. I put around 11.1 so it is now it is original position, it is oscillating one has to see it will oscillate, but one has to see that it is oscillating with respect to this point I will note down this current 11.3 so this one set up data you got.

Now again you so I will switch off because long time I should not put current long time I should not should not put current so I put this mass. now, again I will put. Now hope this force, you should note down that this we are considering the force between 2 conductors when the separation between them is d 0. this applying the mass it came down so this force is mg now I am applying current to bring it back at this.

This force is what is the force, electromagnetic force here. that force is, is for the separation of the conductor at, that separation is d 0 or d this way for different mass, for different mass it will go down And then how much force you have to apply to bring it back to bring it back their original position. When you are bringing it back to this original position; that means that force that is equal to mg and that force you are considering for the same separation between the 2 capacitor 2 parallel conductors.

The formula we are using for length L and this d 0 or d as in the final formula we have to use for the final formula we have to use.

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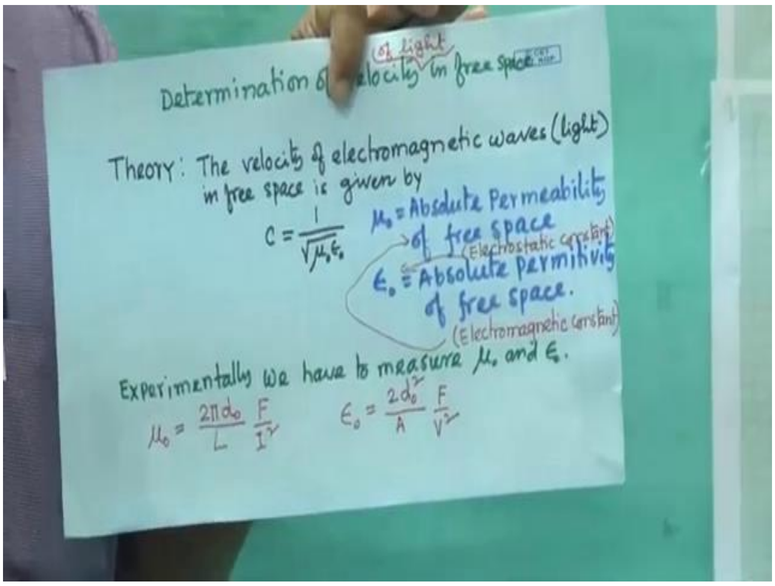

mu 0 equal to 2 pi d 0 by L F by I square. whatever the mass I am applying that will give me different force and it will give me different I ok, but we are doing this whole exercise for same d 0 and for same L that is why always we are bringing back to this original position this spot should come to the original position and at that position the separation of these 2 conductors are d 0 and length of course, it is always same

This is the measurement of mu 0. similar we have another set up the similar only now these 2 conductors, 2 conductors will now will use this 2 capacitor 2 plates ok, instead of applying current we will apply the voltage, and this measurement procedure here this d 0 as well as this force using the mass

This procedures are same that set up is the part of this same setup is the, but 2 parts one is, how one is how to measure the mu 0 another is how to measure the epsilon 0 and then from this two one can calculate the velocity of light. I will show the other one I will show you, now how to measure the epsilon, epsilon 0. I have shown the how to measure the mu 0 and as I mention that is in same way similarly we can also find out epsilon 0.

Only those 2 conductors that is replaced by 2 capacitor plate, 2 metal plates.

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Here you can see it is in a box we had kept in box because if I (Refer Time: 18:16) and so here vibrate. this capacitor plate is will it will oscillate. You can see this 2 capacitor plate weak plate.

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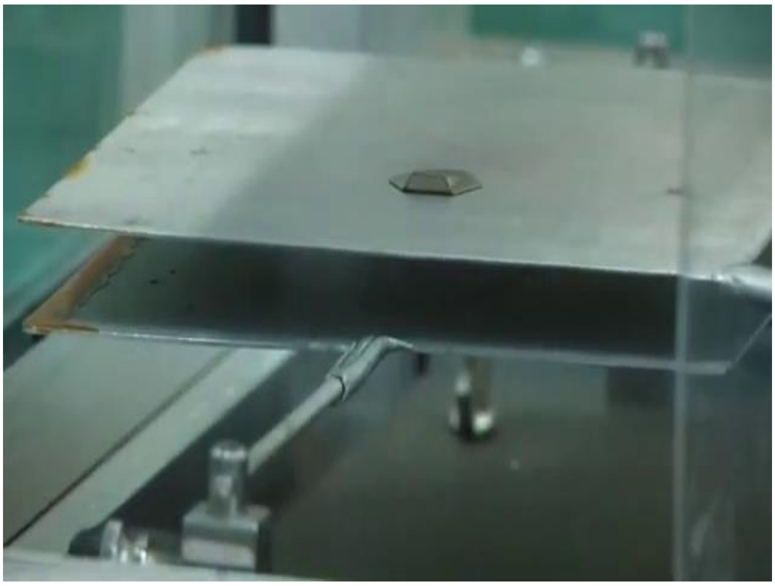

This is one top one it is the movable and the bottom a one bottom one that is the fixed this same as these 2 conductor parallel conductor now that is the replaced by 2 capacitor plate ok, bottom plate is fixed top plate is on the lever so it can oscillate.

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This lever here you can see this that is the lever axis and that is the mirror. This capacitor place from the middle we will take this distance small a now I have to measure force for different voltage in this case for different voltage. Now here one difference is that other case I was initially, I was what is the position of the laser spot that I marked.

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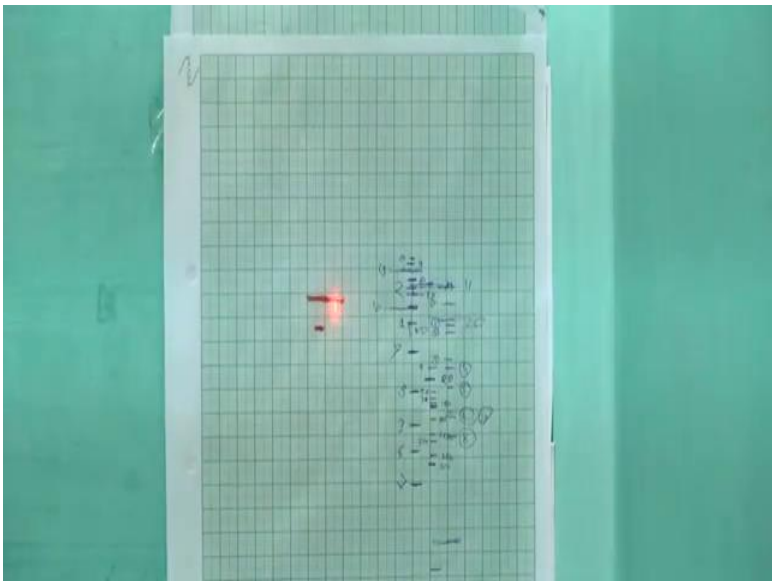

here also position of the laser spot marked, but this is the initial conduction without any force now I will apply force, means I will put weight on this top, top capacitor plate metal plate then it will this reflector all will displaced so that I have to mark. Then that will be capital D, capital D and this from mirror to it is from mirror to that distance of this wall that will be the small b.

capital D by 2 b small b so that will be theta that will be theta and that theta will be equal to this here this separation d 0 separation between these 2 plate that is d 0 and distance from the lever axis this distance of the plate that will be a small a And capital A you need, capital A you need for. That is the area of the so this is the I think rectangular shape not square probably so anyway. Length and breadth one has to note down and one can find out the this so area A

This area you will get, now d 0 you will find out from that formula, from this formula. that is this d 0 equal to this now here one difficulties is that force I was measuring in other cases mu 0 so after putting weight this it came down. now separation of this 2 parallel 2 parallel wires was whatever. Now, I was applying current so there was a repulsion and it was coming back to the original position.

my force now is for this for original position so separation d 0 now for next another mass it will be it will come down and again I will apply force to bring it back to the same separation But in this case; in this case that we cannot do, because always the between this 2 plate when we apply the same apply the positive and negative voltage between these 2 plates. Because of this voltage difference ok, always they will attract each other so no way to make repulsion between these two.

That is why when we will do experiment applying different mass so it will so different mass. I will apply mass so it will come down now, this one is fixed, now what happens now I will, in this case I have to remove that mass and bring it back to the original position, to measure this force I will apply voltage to bring it to the position, where that position of the laser spot we got after applying mass

now for a particular mass so this now whatever voltage I applied that voltage is now this force corresponding force is not for d 0 original position, it is for these separation here when we will do a experiment for different mass so different mass that. It will come down at different position now, actually I will remove the mass and bring it back to this original position and from that original position after applying voltage I am getting to that, to that is position which one I got after applying the mass

Now that net force ultimate that force F we are using so that force is for this separation this if you so this d 0 is not constant in this case so that is why it is. All the allow if after just putting mass what is the position so that you have to note down that that you have to. In each case, you have to find out d 0 so d 0 will be different for different mass and corresponding force you have to find out this.

in this case I cannot I think we should not assume that separation will remain same so in this case we should not we will not be able to since D 0 are not remaining same, so we cannot plot the graph force verses V square. better you can do experiment for few masses and for each mass d 0 will be different that you have to measure ok, and for corresponding what is the force and the voltage so you can calculate epsilon 0. Now, epsilon 0 for different mass you will get now then we take the average of that epsilon 0

It is just not like this in this case the way we are doing the experiment so d 0 remain constant for all masses and corresponding current since the we are using the repulsive force there, but in this case, there is no scope of repulsive force, force is attractive. That is why we are measuring the, force just after removing the mass as I told that so d 0 I cannot we cannot keep same for all masses. That is why better not to plot this force verses V square.

Better, you calculate epsilon 0 for different mass and corresponding force and voltage and the d 0, d 0 will be different and calculate so few value of epsilon 0 you will get and then take average of it. now, this I have not put mass so this the original position I have marked it. This is the position I marked it

Now. this is the position I marked it ok, I marked it. Now here what I will do? I will put a, I will put a. I think this is again 100 milligram, 100 million weight I am putting just middle of this plate on top plate, but at the middle I am putting mass another mass on top it is there, but that is a dummy mass so.

With that mass, it that we have taken the original position now I have put mass you can see this just it is oscillating, now I can just try to make it there is no voltage, but so I can just try to make it I tried to.

Here we can see this for this mass it has come down so it is oscillating with respect to. I can hold here so I think it is with respect to this position

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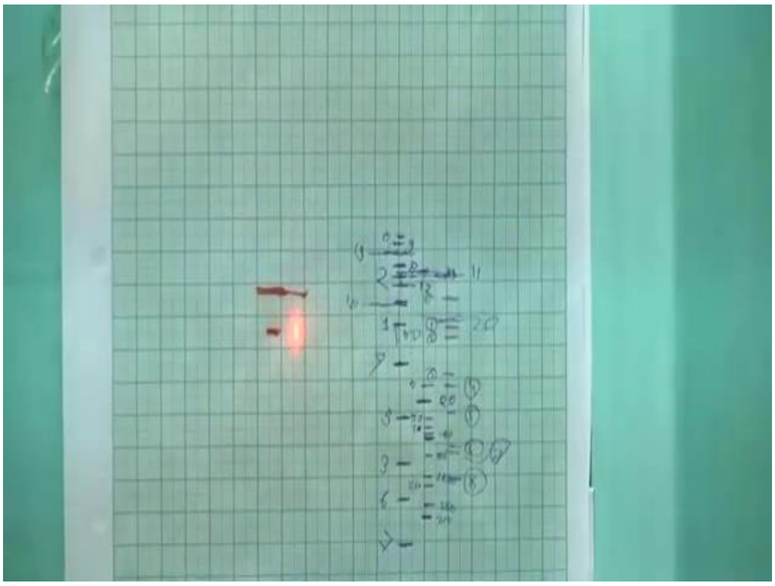

I can take this is the position so it is oscillating with respect to this so this position I can take as a shifting position. this reading I have to say it is in my this is the 5 and this is the say it is the 8 so 13 millimeters. Capital D now in this case for this much is 13 millimeters.

Now, this is the power supply from this power supply we are applying the voltage between these 2 plates ok, between these 2 plates. Now, this sorry. Now what I have to do, because if I voltage, now apply voltage unlike this that current their. Apply voltage so this this point will come down more because the it is an attractive force so I cannot do this way experiment so I have to take out this mass now unlike this other one.

I will take out this mass and, I should take out this mass, but, but it is very sensitive. I should take out this mass I have taken out. You can see it is the oscillating with respect to this symmetrically. I can try to make it stand let us see, but it is oscillating more slightly, it is almost I will close it. It has come to the original position I have taken mass taken out mass.

Now, to displace it on here how much current voltage I have to apply. I switch on, I switch on this power supply you can see it is in volt and here there is a multiplied 1 or other one is multiplied 10. Whatever reading you will see so that reading is with multiplied 10, we have to multiply 10. Now, I am applying the voltage I am just changing the voltage slowly 3 I think this is the 3 into 10. 30 volt already I have given 30 volt, and then I am giving slowly.

It is started to come down yes it is started to no not much. I applied it is 90 volt, 90 it is 105 volt, because I have to multiply with 10 I have to take slightly not slightly here you can see that still it is coming down, but I need higher, higher one higher one still has not come. 200 volt I have applied, 200 volt, 250 almost

It is 200 so I have to give more and more slowly, I am going slowly because it sticks so charge will be accumulated. response may not be very fast. I am going so it is the 50 volt; it is the 500 volt 473. yes you can see it is the still we have to apply more voltage so slowly I am applying because it takes slight time to. Now it is the 600 volt. Now another reason why we kept in box because high voltage we have to apply you no way should touch it

That is why it is so we have kept in a glass box. it is a 680 volt now 720 40. its slightly it is a coming down its a coming down, but still we need more voltage to its the 825, it is a 900 it is the 1000 now, it is a 1000 volt it is it has as almost a come down. Now how much it is the 1100 you know it is the now, it is the 1100 it is the 1104. It is almost it is slightly more I have to put slightly more I have to put you can see.

1100. Yes, now it has come in the point. We have to note down this is 1184 volt ok, for that volt now. This force now at this position this force is the. What is the force? Force is equal to mg, mass is 100 milligram force we can find out. Now, for this position for what is that d? What is the d 0 or d ok? This capital D and this from this other factor so we will find F.

This capital D it will be different for different mass that is why that d 0 it will be different for different mass. And we cannot keep it keep the d 0 constant for all masses means all forces so we will not draw graph we will just find out the. We will just find out the find out we will take just few sets of data for different mass so and then we will calculate separately this epsilon 0 and we will take average of average value of them

I should switch up it ok, I will just decrease the voltage I am decreasing voltage so now voltage is 5 300 it is a 250 so it is a becoming 0. it is a 0 still not 0 40 30 so is its take time because it is it was high voltage. It is now 0 I will. it is still 10 volt 9 8 7 volt so 6 so it takes slight time to make a plate voltage 0. I will switch off, I will switch off this one ok, I will switch off this one. Now you see, now it has come back to the original portion. Now again I put another mass

For that, it will be displays 100 now I will put 200 milligram or 150 milligram so then this point it would be it will be more that we will mark it and same way we will repeat. few data on should take and calculate the epsilon 0. in that procedure are same in both cases in one case 2 capacitor 2 parallel conductors and other case 2 parallel plates capacitor plates Measurement of F and d 0 corresponding current and voltage

that is the task one has to do experiment and it is not very difficult, but here very interesting things that in class 12 we have you have read ok, this current carrying conductor 2 conductor so there will be attractive or repulsive force that 2 capacitor plate if apply voltage so they will attract each other.

that in this experiment that whatever in theory classes you have learn practically here you can see and not only see applying this concept one can measure, one can measure the velocity of light so that is the very interesting. I will stop here.

Thank you for your attention.