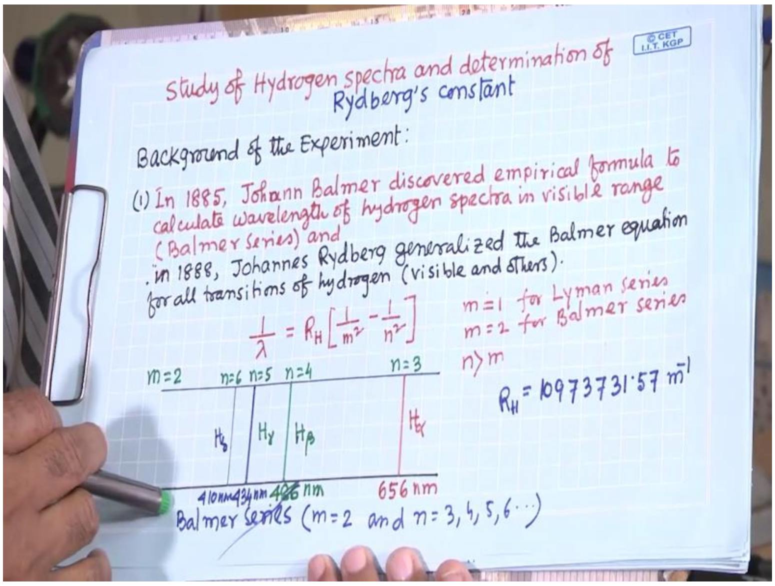
Experimental Physics - II
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture – 60
Experiment on Rydberg constant

(Refer Slide Time: 00:37)



today I will demonstrate hydrogen spectra and determination of Rydberg constant. you know that the first this hydrogen spectra were observed by.

Student: Helium.

Observed by the Balmer Johann Balmer in 1988 and that spectra were fitted; that spectral was fitted with the empirical formula given by Balmer. that empirical formula was is like this 1 by lambda equal to some constant 1 by m square minus 1 by n square. Where m equal to 1 for Lyman series m equal to 2 for Balmer series m equal to 3 for ah I think Paschen series.

n equal to 4 m equal to 4 for bracket. there are different series but this m equal to 2 for that the whatever series we observe that is that was in visible range. in spectrometer it was easy to see because of the visible range because the wavelength of this spectral lines was in the visible range.

that was observed first and the wavelength of the spectral lines; wavelength of the spectral lines was measured. And from this empirical formula if formula is like this. exactly that wavelength was reproduced from this formula, in that case one has to consider a constant. Later on, in 1988 Johannes Rydberg generalize the Balmer equation for all transition of hydrogen atoms.

So that means, Lyman series then Paschen series, Brackett series, Pfund series. he generalized and for that the same constant whatever Balmer got the constants same constant was valid. that is why this constant now it is called Rydberg constant today we will find out we will determine this Rydberg constant. this this is the of Balmer series for hydrogen source ah.

this for hydrogen atom we know this it's the principle quantum number n that is n equal to 1 n equal to 2 n equal to 3. different energy levels are there. the transition between n equal to 2 and the higher n; n equal to 3 n equal to 4 n equal to 5. that transition gives different spectral lines in visible range that is what we tell the Balmer series. And the name was given of these spectral lines like H alpha then H beta, H gamma, H delta.

it has also different colors it's a red color, this green, then blue color, light blue color and their wavelength also its this. if you measure; if you measure this wavelength, if you measure this wavelength and then if you consider the transition in case of Balmer series. m equal to 2 to 2 and then you vary n where n is greater than m. n equal to 3, 4, 5, 6.

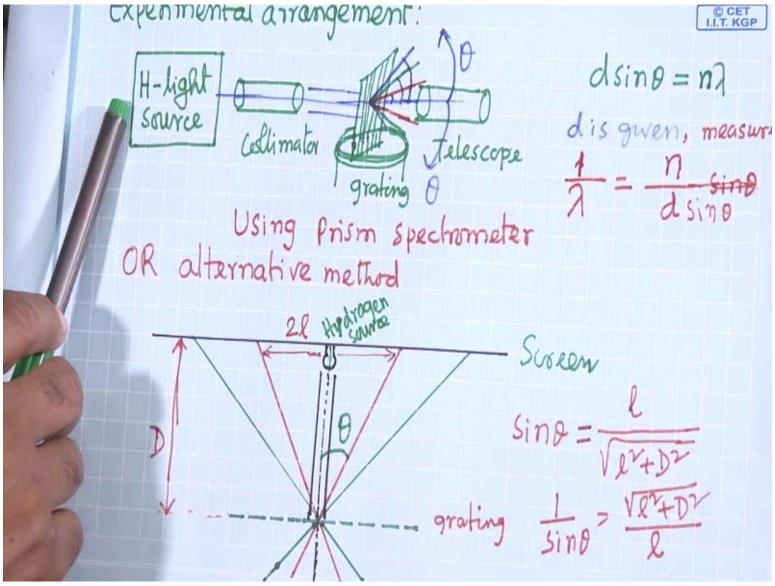
for different spectral lines for different wavelength you can putting the different value of n you can calculate this R H Rydberg constant. And this Rydberg constant should come same for all spectral lines and then one can take the average of this this Rydberg constant and that value is generally is should come like this.

this a 10973731 decimal point 57 meter inverse. sometimes we express in centimeter Rydberg also. this is the background of this experiment one has to get hydrogen spectra and from that spectra using the spectrometer; one can measure the; one can measure the measure the wavelength of the spectral lines.

When we will measure the wavelength of the spectral lines and this part for visible range whatever you are seeing that is sure this is the Balmer series and m will be 2. Then you take n equal to 3, 4, 5 and then see this matching with the wavelength 1 by lambda actually 1 by lambda that wavelength you are measuring.

using that wavelength and this m is to and for n equal to 3, then this part is constant for this spectral lines. this divided by this will give you R H. Similarly, for next spectral line n equal to 4; n equal to 4 ok, then again you can find out R H. here I have showed this 4 spectral lines; 4 R H value you can get and more or less they should be same. But experimentally when we will measure there may be some difference. that is how we take average of those values and finally, we get the answer.

(Refer Slide Time: 08:34)

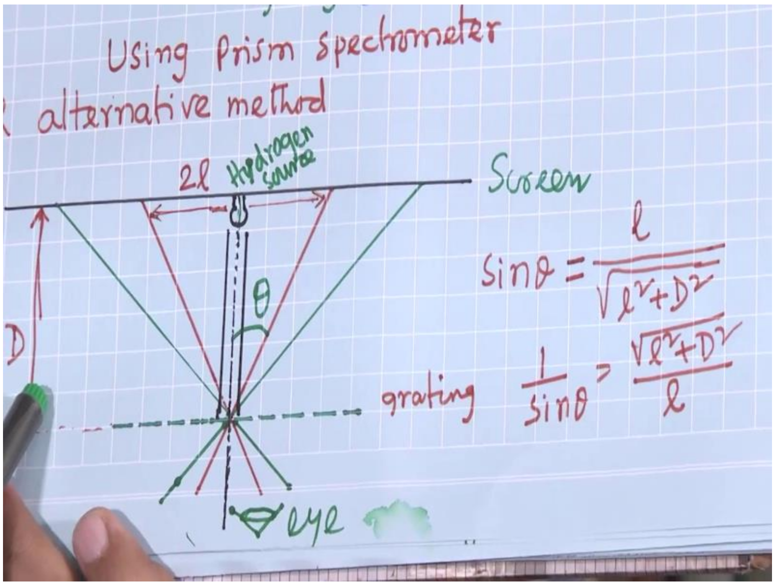


what is the experimental arrangement for this experiment? Experimental arrangement for this experiments it’s a, so to measure the wavelength to measure the wavelength of a light prism spectrometer is very popular. in spectrometer in prism spectrometer we put grating on the prism table and then there is a collimators in front of collimator there is a there should be source of hydrogen light.

for other if you want to measure the wavelength of sodium sodium source or helium, if you want to measure the wavelength of helium light. one can put helium light this kind of measurement we have done I have demonstrated in demonstrated earlier how to measure the wavelength using the grating. using that process you can measure the wavelength This is the telescope and then you can rotate the telescope to measure the angle. that angle if you can measure, then you can calculate the wavelength that is the d sin theta equal to n lambda, this is the formula for the for the grating d is the grating element and that value is given, now if you can measure the theta using the spectrometer. then from here I can write 1 by lambda equal to n by d sin theta n is the in this case it's the order first order second order third order.

if you take 1 only 1 order in 1 order different colors in case of hydrogen or helium you will get 3 4 5 spectral lines. And if you can measure the angle of that those spectral lines ok, that is spectral lines you will see because of the diffraction and using this formula you can find out the 1 by lambda.

(Refer Slide Time: 11:16)



Because here I have written 1 by lambda because in Rydberg constant theirs 1 by lambda equal to R H; as I showed 1 by lambda equal to R H 1 by m square minus 1 by n square. this n is different than the that n that is the order of the diffraction order, but here this n is principle quantum number. from that measurement from that measurement you can get the 1 by lambda using the grating you can get 1 by lambda.

for that you have to measure theta; you have to measure theta. that theta you can measure using the spectrometer. There is another alternative method for measuring this angle. here I think in laboratory I will demonstrate this one because many times I have used this spectrometer for different experiments. this is another new method how to measure the angle.

this method I will show you today in our laboratory. here you can see that you have a light source it's the hydrogen or helium or whatever from there's lights are coming and here this one is a grating; this one is a grating. light is coming falling on the grating. this you see this when light falls on the grating; see it generates secondary wavelets. And that secondary wavelets will interfere and give the diffraction pattern

in this case diffraction pattern, it can form in transmission side also it can form in the refraction side here whatever you are getting we are seeing the of the diffraction pattern in the reflection side; that means, the light is coming and falling on the grating. And the diffraction pattern we are seeing on the same side. If you see the other side then it's a its the we tell this the transmission, it's a other side in a same side then we tell the deflection.

here we will see when we will see the diffraction pattern through the grating, then that pattern will observe on the on the same side of the source. And we have put a scale; we have put a scale just behind the light source and there we have indicator we have indicators. we will see the image we will see the diffraction pattern there means we will see the spectral lines. And from the center; from the center at which distance you are getting at which distance you are getting the spectral lines of different colors.

that distance that indicator will match with the with the spectral lines image of the image of the source. spectral lines whatever we will get. that what will be the what will be the shape of that image? that is that will be the shape of the shape of the of the light source that is the its the image of light source.

we will see the image of the light source of different colors at different distance. that from the center what is the distance of the different spectral lines that we will find out So that means, this distance we will find out. Now, if you know these distance screen to scale distance screen sorry this grating to scale distance

if it is capital D and this here, I have written 2 l. we will not measure the distance from the center directly, what we will do. we will get symmetrically first orders of diffraction pattern on both sides secondary order also on both side. in this case only we will be able to see the first order; second order also one can see if you take this diffraction grating of higher number of lines.

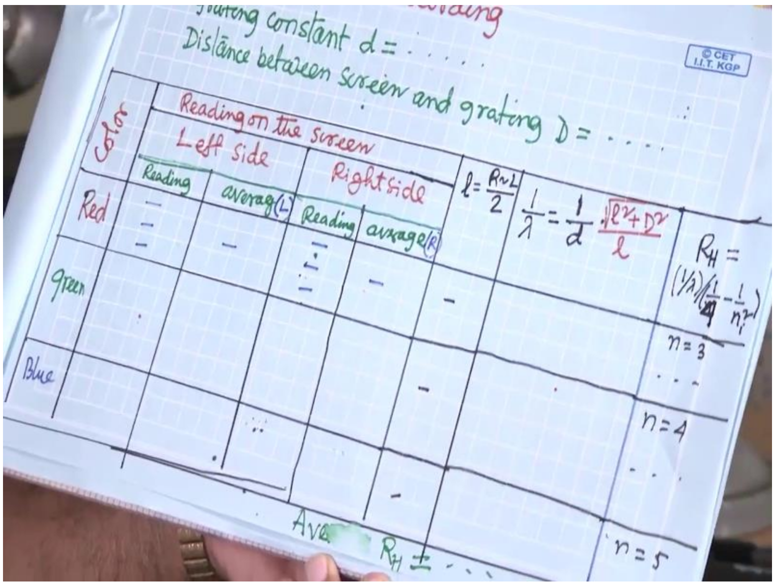
at present in laboratory if we will use a grating, which is having the 600 lines per millimeter, but we have seen that if you use the 1200 lines per millimeter then we can see also second order. But present in laboratory I will use the 600 lines of lines per millimeter. we will see the first order. on left hand side we will see the first order of first order of different colors. And side also we will see the first order of different color.

this here I have drawn this is the first order of red line red spectral lines. we will measure distance between these two and then half of will give you these distance. from the middle from the middle to the to the spectral lines. we will measures 2 l, then divide by two we will give me this l and this is D. now, sin theta will be sine theta will be this divided by this .

this is the perpendicular if this theta; if this is theta diffraction angle. then sine theta will be this l divided by square root of l square plus d square . if you can measure l and D these value, we keep fixed ok; l will vary depending on the position of the spectral line. we will take reading of this l small l then we will be able to calculate sine theta.

1 by sin theta is square root of l square plus D square by l. getting this data of l we can get 1 by sine theta, if you get 1 by sine theta d is supplied. n is in our case it will be 1. you can find out 1 by lambda. 1 by lambda for different cross we will find out. If you find out these then you can calculate the Rydberg constant from this formula ah. that is the experiment we will demonstrate.

(Refer Slide Time: 19:31)



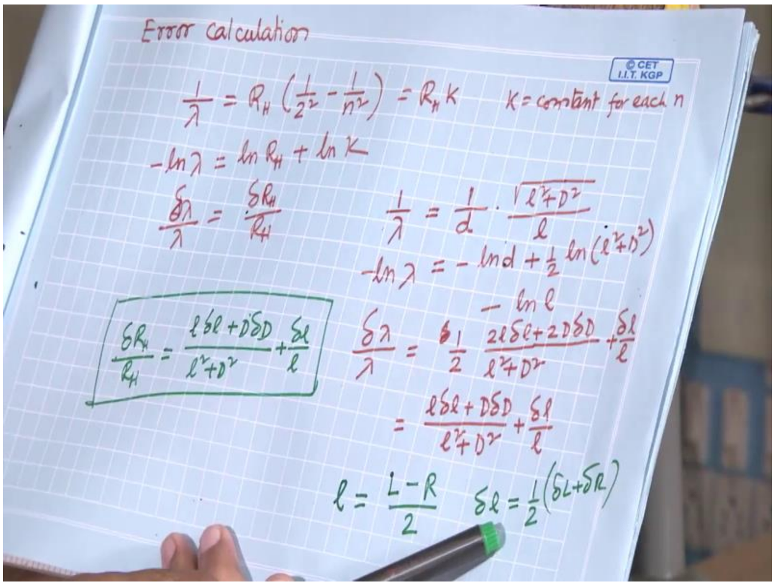
experiment of data we will record. this type of table we will use. grating element d; as I told this 600 lines per millimeter. what is the separation between the lines that you can calculate? that could be 1 by 600 in millimeters. that will be the d. that you should note it is since it is supplied. Distance between the screen and the grating that capital D whatever I showed in figure. that we should fix it we will not disturb it that you should note down.

then now you see the spectral lines and for different colors, you take reading you take reading of spectral lines. It's a left side and this side take reading generally we will take two three 4 readings. And then find out the average of that one for a particular spectral line that will be say this average is a from left side it is reading is capital L. And from side it is capital R.

small l it will be difference between these two reading left, and side reading divided by 2. we will note down this reading and then from there we will find out l. if you already I have told from this l you can calculate 1 by lambda. And when you know the 1 by lambda then you calculate R H Rydberg constant

1 by lambda divided by 1 by 4 minus 1 by n square. for n equal to 3 for a particular color say red color. you calculate Rydberg constant for n equal to 4 next colors calculate Rydberg constant. this way you calculate Rydberg constant three or 4 for 3, 4 spectral lines. And then take the average of those R H and find out final value of the Rydberg constant. that is the experiment we will do.

(Refer Slide Time: 22:14)



let me show the experiment, I think let me also tell you about the error calculation. our working formula is 1 by lambda equal to R H 1 by 2 square because m for Balmer series it is 2 minus 1 by n square this I can write R H into K constant some constant this is a constant for each n for each n it's a constant value. take the log on both sides minus l n lambda plus l n R H plus l n K. K; obviously, is constant we are not measuring anything. it will not contribute in the error.

now differentiate it del lambda by lambda equal to del R H by R H what is del lambda by lambda? 1 by lambda equal to 1 by d n by sine theta. 1 by sin theta is this one as I showed you square root of l square plus d square by l; because we have to express the parameter in terms of parameter which you have measured to calculate the error.

if you take log on both sides minus log lambda equal to minus log d; plus, half log this 1 l square plus d square minus log l . from here you can find out del lambda by lambda equal to you can see this d is supplied there is no error here. error from this part half is there. it's a log if you differentiate it.

1 by this 1 by this and then this one will give you 2 l del l plus 2 D del D ok, plus this part. Because in case of we are calculating maximum probable error all we have to take all individual error we have to add. that is why we are not taking minus sign we are taking plus sign del l by l from here from here this part this part this half is there.

it's coming l del l plus D del D divided by l square plus D square plus this part del l by l. Now l you remember when you are measuring l, we are taking difference of two reading capital L and capital R left side reading and side reading divided by 2.

from here it's a del l is del l is what about del here we will use that is half del capital L plus del capital R. this half is there this left side and side we are taking reading from the same scale. del capital L will be equal to del capital R. least count is same for that. 2 into that least count divided by 2 that is the del l is least count.

here what about del l that is the least count of the of the scale we are easily using for the for the measuring the position of the spectral lines. And that capital D also delta D here this also we have used meter scale. here also its a least count is 1 millimeter for del l there also we have used meter scale. this least count is 1 millimeter.

del lambda by lambda del lambda by lambda from where here you are getting that is that is nothing but the del R H by R H. error in R H; error in R H you can del R or del R equal to whatever this value you got multiplied with this Rydberg constant R h that will give the delta R H. error in the in the measurement in the calculation of the Rydberg constant that is the error calculation. next I will demonstrate the experiment in our laboratory.