Atomic and Molecular Physics
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Lecture – 03
Experimental observations and theoretical development in discovery of constituents of an atom (Contd.)

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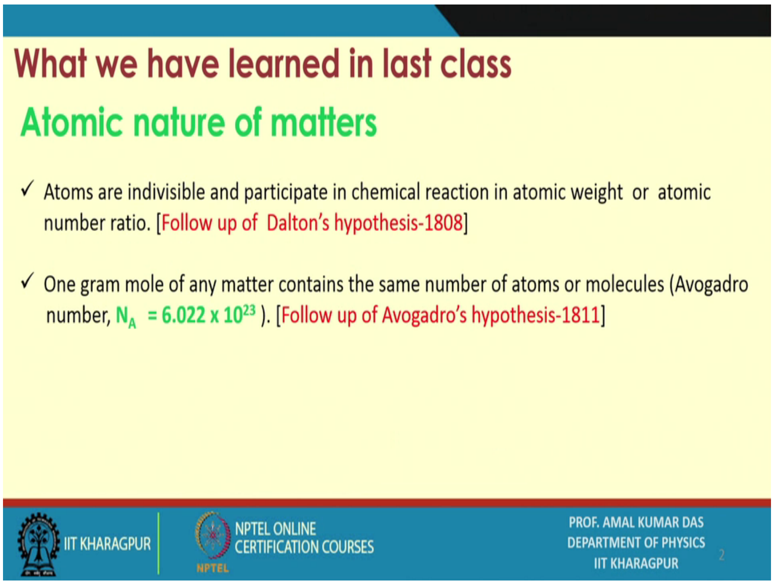

So, what we have learned in last class that basically atomic nature of a matters. So, atoms are individual and participate in chemical reaction in atomic weight or atomic number ratio, that this basically follow up of Daltons hypothesis then we have learned that one gram mole of any matter contains the same number of atoms or molecules, that is basically that number is Avogadro numbers 6.022 into 10 to the power 23.

So, that is the follow up of Avogadro's hypothesis. So, it is clear now that this matter is made of atom and atom, we can count atom we can get weight of atom. So, this type of situation are present.

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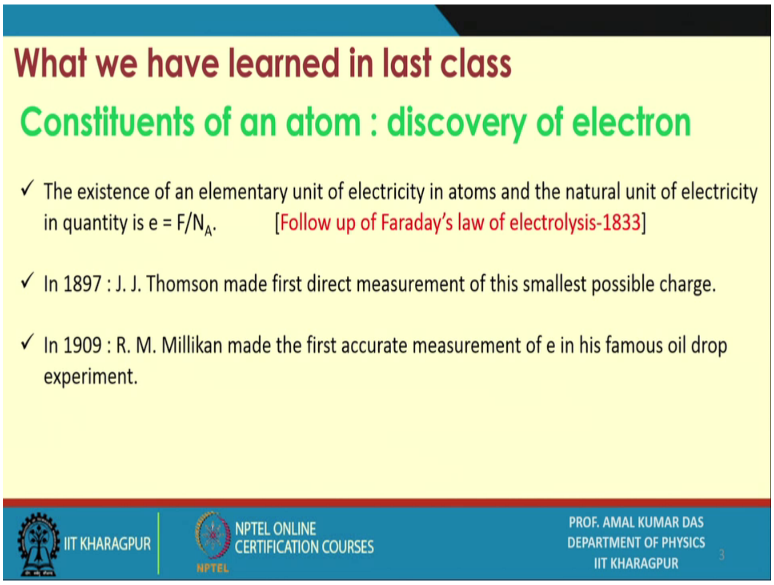

Now, also we have learned that second things we want to wanted to know that, what is the constituents of an atom. So, in that direction, you are working. So, this one constituent is electron, how the electron was discovered.

So, that we have seen this the existence of an elementary unit of electricity in the atoms and the natural unit of electricity in quantity is e equal to F by Avogadro number, F is faraday constant. So, this has come up following the Faradays law of electrolysis and then in 1897 J.J Thomson made first direct measurement of the smallest possible charge and in 1909 this Millikan made the first accurate measurement of e electronic charge in his famous oil drop experiment ok.

So, I will continue discussion on the how this measurement was done by J.J Thomson and his Millikan so, that I would like to discuss in this class.

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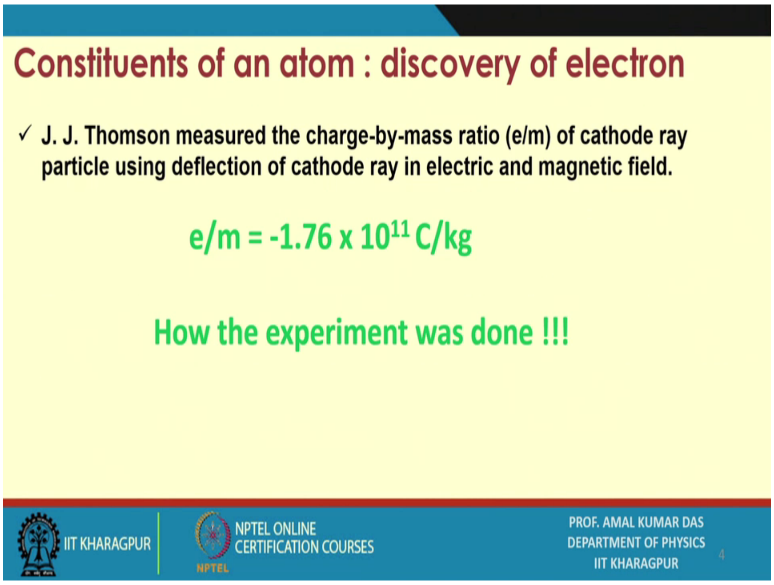

So, J.J Thomson measured the charge by mass ratio of cathode ray particle using deflection of cathode ray in electric and magnetic field. And he found the specific charge that is e by m equal to minus 1.76 into 10 to the power 11 coulomb per kg.

So, how the experiment was done that that is what I was I started to discussion in last class. So, I will continue that discussion.

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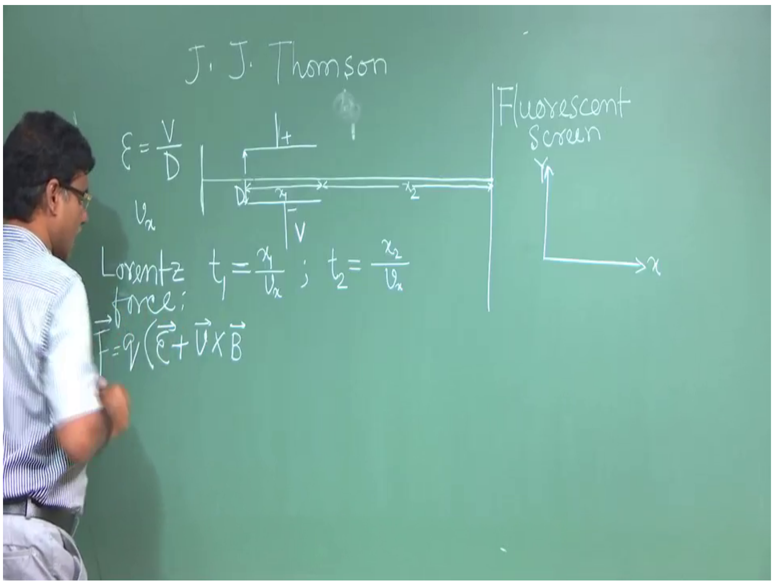

So, J.J Thomson. So, he used cathode ray. So, from discharge tube cathode ray is generated, now that cathode ray now from cathode, cathode ray is coming and falling on a screen fluorescent screen. So, cathode ray is a is consists of is its some particle, having charge charged particle and it has some velocity and if we put a screen here fluorescent screen. So, you can see where it is sitting. So, you can locate the position of bombardment.

So, initially it was hitting at this point at this point. Now what J.J Thomson did he applied electric field. So, how to apply electric field? You know this we use these 2 metal plate and then apply voltage between these 2 metal plate. So, put 2 metal plate say here to put 2 metal plate say here and apply voltage. So, it is plus terminal that is the minus terminal and this length of this plate you say x 1 and width of this plate this separation of this plate is say D capital D.

And then the screen distance from this end of this capacitor plate is say x 2. So, now, if we apply voltage V. So, electric field is defined an electric field E equal to V by D right.

Now, this initial velocity of this cathode ray is along x axis, say this is the x axis and if we take this is the y axis. So, initial velocity is along the x axis is we say v or we can write v x right. So, it will take time. So, this ray will take time to pass these distance x on distance, if that time is t 1 equal to x 1 distance divided by velocity v x and to traverse these distance x 2 distance it will if it takes time t 2. So, t 2 will be x 2 by vx right.

So, this is before applying electric field. So, this cathode ray will take time t 1 and t 2 to pass from here to here x 1 plus x 2 distance. Now if we apply electric field it will apply force on the charged particle because cathode ray consists of charged particle that is known. So, it will apply force on the charged particle what is that force. So, force you know this force is basically Lorentz force, I can write here or I can write here Lorentz force. So, you know that charge q force equal to charge q, then electric field plus V cross B magnetic field ok.

So, this is the Lorentz force due to electric field and magnetic field. So, now, due to electric field due to electric field there is no magnetic field at present. So, this force is basically F.

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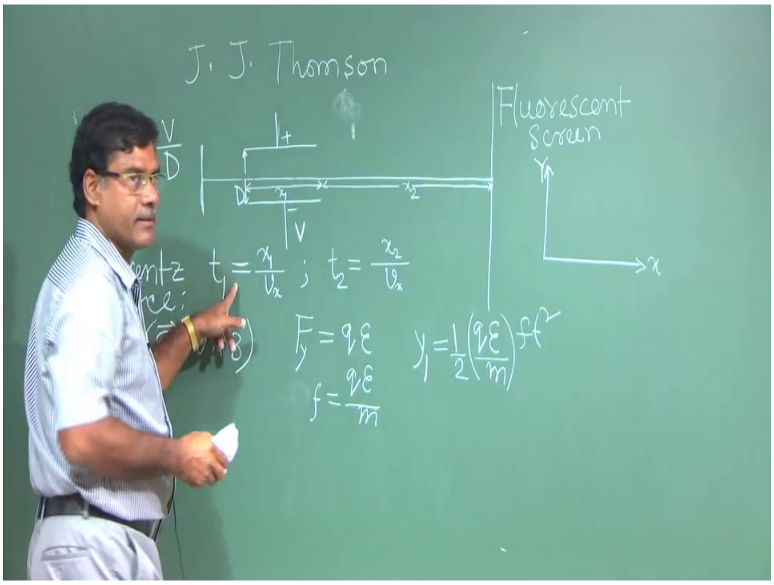

That force will act in which direction charge particle and this force direction is along the electric field direction. So, along the y direction, F y along the y direction force that will be charge q; and the electric field q E right F y. Now due to this force acting along the y direction, now this charged particle moving along the x axis with velocity vx, now what will be the velocity or what will be the distance traverse along the y direction, so that you know this value right. So, that will be say y 1 between this when it is in electric field. So, y 1 is ut plus half ft square you know this initial velocity, but this initial velocity is here along the y axis is 0.

So, ut that part is 0. So, value we write ut plus half f t square right. So, along the y axis this velocity 0, initial velocity 0. So, that is half ft square y 1. So, half f what will be F? F will be this is the force, force is you know mass into acceleration.

So, f will be equal to u this is by m right. So, I can write q E by m that is the and t square.

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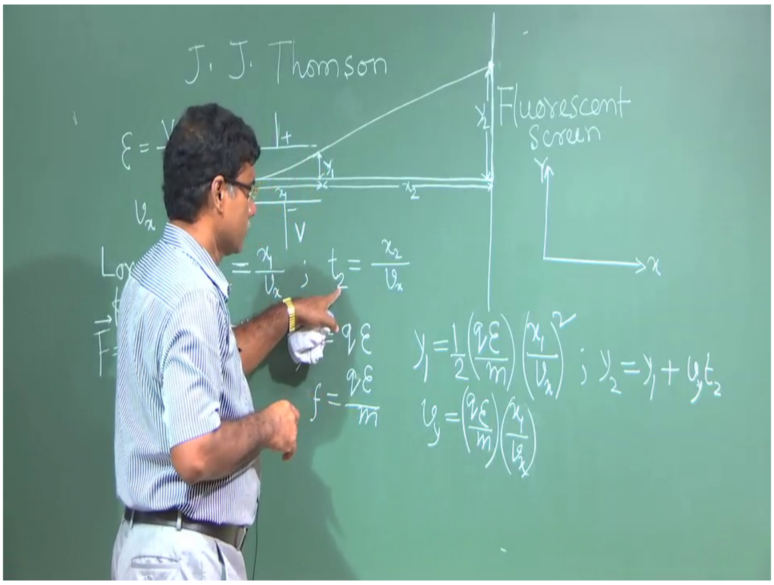

So, that is t 1 basically t 1. So, t square t 1 square, t 1 is x 1, x 1 by v x whole square. So, a starting from here, this velocity was along the x axis now when it is entered in this electric field. So, another force will act along the y axis along the y direction.

So, then it will move towards the y direction as well as x direction. So, as a resultant when it will reach here, it is nearly I think I have to take slightly. So, it will reach here then it will go out from the electric field after that there is no electric field. So, at this position this is basically y 1.

So, after that electric field is 0, but it has the velocity along this direction, what will be that velocity along this direction say v y. V y will be after time t 1. So, v y will be after time t 1. So, that I can write u plus initially u that is u plus ft initial velocity plus acceleration in to time. So, time is here t 1. So, that initial velocity along the y direction was 0.

So, this will be f t 1 f is q E by m, this is the f and t 1, t 1 is x 1 by v x right. So, that will be the velocity along the y direction at this point, now there is no electric field. So, there will not be any force on the charged particle. So, there will not be any acceleration. So, that will be the consists we move with that constant velocity and so, it will reach sorry no it is it will be straight line its more or less straight line fixed in the screen ok.

So, it will hit here on the screen. So, these distance if we take its y 2 on the screen. So, what will be the y 2? So, this is the y 1 and y 2 will be y 1 because it reach here after that it is moving. So, how long it is moving? This it is taking time t 2 right. So, basically it will move with velocity v y for time t 2, all right.

So, I know v y I know t 2. So, now, I can put here y 1. So, that is there.

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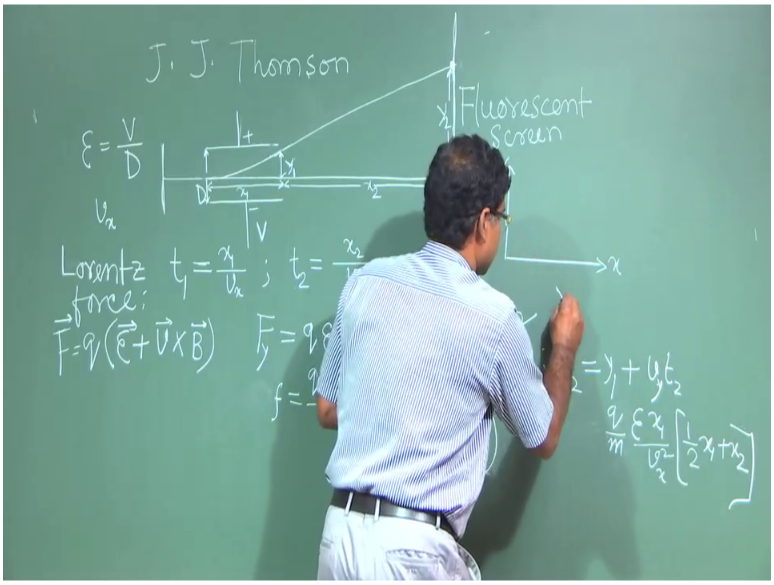

So, let me keep fit here y 1 plus what is v y? V y is this. So, this part is common x 1 vx also common and additionally I have to multiply with t 2. So, with that I have to multiply with t 2. So, what difference we are seeing. So, here x 1 by v x square and here x 1 v x and x 2, v x right and half is there additional. So, you can write here. So, I can take common q by m E and x 1 by v x square right then here half into x 1 by x 1.

So, I will get half x 1 and here I will get x 2 this x 2, I will get x 2 right. So, it is not visible. So, I think I can write.

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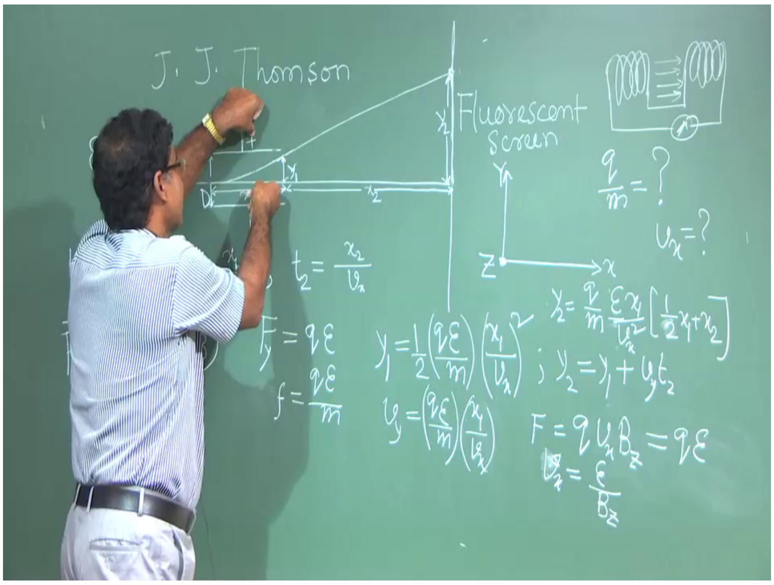

I can write here basically y 2 is equal to q by m, x 1 divide by vx square half x 1, x 1plus x 2. So, that is my expression.

So, here what I want to find out? I want to find out here. So, y 2 I can measure from geometry. So, this initially that is the before applying electric field it hit here, and after the applying electric field it hit here. So, this y 2 I can measure x 1, x 2 I can measure, I can measure E because applied voltage and this separation D is known. So, I can measure E ok.

So, only I have to know v x if I know v x, then I can find out q by m. So, for that I have to know v x. So, how to find out v x that is the question. So, now, to find out vx basically what J.J Thomson did he applied magnetic field? So, how to get magnetic field basically we will use Helmholtz coil.

So, you know Helmholtz coil this 2 coil and another coil is this. So, between a 2 coil its produce electric field or magnetic field. So, basically in coil if you app if you if you pass current through it. So, it generates magnetic field. So, 2 coils in same direction your putting current. So, basically if you pass current through this coil.

So, this you will get magnetic field between these 2 coil, and this field will be uniform if the separation of these 2 coil is equal to the radius of the coil. So, that is the condition for getting the homogeneous magnetic field. So, now, these 2 coils was put along the y direction. So, it was put like this. So, field direction is this. So, what is this direction? This is the z direction ok.

So, Helmholtz coil this 2 coil one is other side and another is this side. So, magnetic field will be in this direction. So, magnetic field thus it is applied here and. So, that due to that magnetic field what is this moving charge field force. So, what is that force that basically F equal to q v cross. So, V is now along the x direction. So, and B is along the z direction.

So, x cross z. So, its force will act along the y direction thus it is the same direction of the force due to the electric field. So, this q v x then magnetic field; magnetic field one can write B z along the z direction. So, this force will act along the y direction and electric field also act along the y direction. So, when these 2 force.

So, if I choose the direction of magnetic field in such a way that. So, if you change the direction this force reaction will change right in such a way that that whatever the force due to the electric field that will be balanced by the force due to the magnetic field. So, in that case these force will be balanced, when it will be balanced? There will not be there this net force on the net force on the charged particle will be 0, on the cathode particle cathode rays will be 0. So, then this qv x bz will be equal to the force qE that force q E right.

So, whatever the. So, in that case what will happen? The cathode ray it will not deviate in presence of electric and magnetic both field. So, it will move on deviation without deviation. So, that is the condition for the equal force due to the electric field and due to the magnetic field. So, from here one can get vx equal to q will go vx equal to E by Bz.

So, electric field and magnetic field is known. So, how much magnetic field we are. So, that one can measure. So, this is known. So, one can find out the vx. So, thus this vx is find. So, that is what we need to find out the q by m charge by mass, and that way, it is a very nice experiment and this Thomson found this value is q by m. So, whatever q in general we are writing. So, this basically electronic charge later on we found that this is the electric field get the name that is the that that cathode ray contains the negative charge and that negative charge one can find out this seeing the direction of this motion of the charge you know along the y direction.

So, if it is positive and this charged particle moving towards this positive plate so; that means, it is negative charge. So, that way one can find out the sign of the charge. So, that is q by m or e by m he found that was minus 1.76 into 10 to the power 11 coulomb per kg. So, this is nice experiment and J.J Thomson basically directly he measure the specific charge, but not exactly the charge of electron, but his experiment basically tells about the existence of the charged particle in atom. Yeah in atom or not that is probably; it is a difficult to say, but this cathode ray contains that is the those particles that particles is basically he called these particles electron and its charge and mass ratio is this that is the findings of this J.J Thompson.

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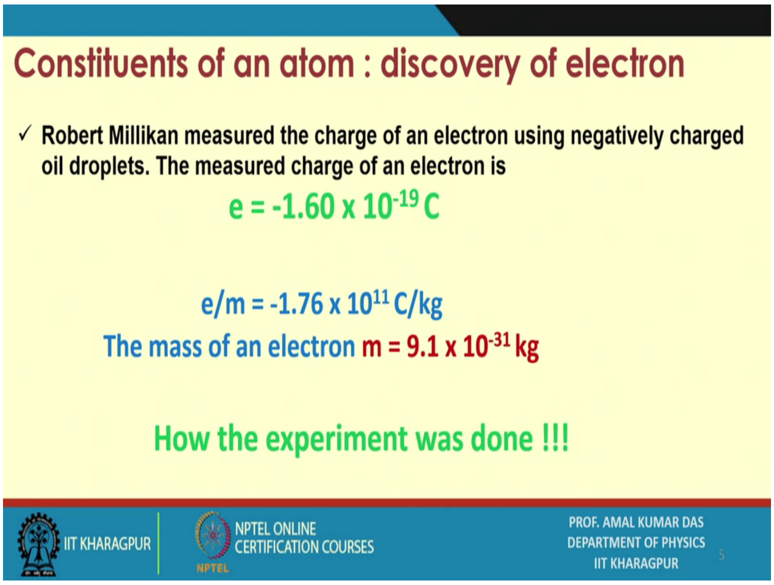

Now, next this exact accurate measurement of charge of electron, was done by Millikan in his famous experiment that is a Millikan oil drop experiment. So, he measured basically the charge of an electron using negatively charged oil drops, and he found that charge of electron e is minus 1.6 into 10 to the power minus 19 coulomb and this is. So, e by m that value was reported by the J.J Thomson and this mass of the electron one can find out from these 2 Millikan's measurement, that gives e is equal to 1.6 into 10 to the power minus 19, and specific charge from the Thomson's experiment. So, that is 1.76into 10 to the power 11 coulomb per kg.

So, then from these 2 relation one can find out the mass of an electron, and that is 9.1 into 10 to the power minus 31 kg. Now again this how what is that experiment Millikan's oil drop experiment, that is very famous experiment and that I will discuss I will continue this discussion in the next class. So, I will stop here.

Thank you.