so welcome all of you for the second lecture on ah matter waves the so called de broglie waves and after this what we shall do is to look at the various models for atom will first of all make precise what we mean by an atom because that word itself has undergone a change in its meaning and then we will discuss some crucial experiment which supports what is called as the planetary model of the atom but before getting on to the atomic model we have to first conclude our discussion on matter waves by looking at one very important aspect of matter waves because as you people know no study of any wave phenomenon is complete unless we establish a relation between frequency wavelength and velocity

so you have frequency you have wavelength you have velocity and this of course is well known by elementary arguments that v is given by new lambda however it is not as simple as it seems to be because these are not ordinary frequencies and ordinary wavelengths that we have for the usual waves but the frequencies and the wavelengths are inferred from two other physical quantities remember in waves the energy carried by the wave is always proportional to the square of the amplitude

so we say a person is speaking louder a person is speaking softer or an instrument is being hit very hard what we are worried about is not the frequency or the wavelength but the amplitude how high the amplitude is

so for example if you have a percussion like tabla or vidangam or whatever drums

so harder you heat larger will be the amplitude of vibrations and that is what is going to contribute to the energy however when we come to the description of light as a photon or matter as a wave deep broly wave we are doing something which is counter to whatever we have discussed in the case of classical waves whether it is classical electromagnetic radiation or sound waves for that matter what we are doing is to associate frequency with energy

so we are saying e equal to h nu that is the statement that we are making and we are associating a wavelength with momentum

so we are writing lambda equal to h by p now these relations are quite harmless when we consider light that is something that i want to tell you and i already discussed that in my previous lecture because what is going to happen is that we have a fundamental relation u equal to p c for an electromagnetic wave let us say we have monochromatic plane wave then it is easy to show that u equal to pc a better way of representing it is u equal to pi c

so let us discard this expression where u is the energy density and pi is my momentum density where do i get these expressions i get these expressions from classical electromagnetic wave picture of maxwell that is something that you have to do but if i combine this with the planck idea

so what is it that is going to happen

so my u as i told you in my last lecture is nothing but n into h into nu i am assuming that the radiation has only one frequency and this n is my number density and what is my pi my pi is the same number density into the momentum carried by each of the photon that is the most important thing h nu is the energy carried by the individual photon and p is again the energy carried by the individual photon and what are we writing we are saying this quantity is nothing but u by c n h nu by c that is what we are writing

so now if i am going to compare this with the standard definition of the wavelength there is absolutely no conflict at all ok if you want you can even write this as n into p is h by lambda that is what you are going to get

so if you combine these two relations you will get the well known relation my c equal to nu lambda

so when it comes to the concept of a photon it is in complete consonance it is in complete agreement with the natural notion of a wave where the speed is propor product of the frequency and the wavelength

so it is some kind of a self consistent picture it is a self consistent picture in

so far as this equation is concerned but it is really not self consistent from the viewpoint of fundamental physics because we are without any care or without any botheration we are mixing up concepts of waves concepts of particles in order to get these relations but still even within that limited notion of consistency we are able to see that there is no conflict but when it comes to massive particles that was for radiation when it comes to massive particles situation change massive particles means deep broly waves

so before i do that i would like to direct your attention to this slide the davis and german experiment

so this is the great experiment which they performed in nineteen twenty seven and what are we finding we find that there are beautiful peaks which correspond to constructive interference that is what we are finding here

so what we are saying is that davis and jeremiah experiment establishes consistency is n lambda equal to 2 d sin theta i already argued how this equations comes about in the previous lecture provided that is the most important thing the results agree with this provided we assign lambda to be equal to h by p remember what they had was an electron gun with shot of electrons it could be something like a thermoelectric emitter or some such thing you pass current or you heat it and it produces the it ionizes the electron then it was accelerated through a certain voltage it kept on gaining momentum now the particles with this known momentum this known momentum are impinging on my nickel crystal but the scattering results can be understood if i associate a lambda with this p through this relation in other words p is what is known and lambda is what is associated this in fact is the great contribution or the grade intuition of deep broly when he proposed this hypothesis now we are going to encounter a rather peculiar situation because you have the momentum you have the energy coming from the particle and then you have the new and you have the wave number uh the wavelength which is going to correspond into the wave picture

so for the same entity let me call it as an entity electron in this particular case when i look upon it as a particle i am associating a momentum and i am associating an energy which is given by newton because these are essentially non relativistic particles their velocities are very small compared to the speed of light but when i am looking at it from the viewpoint of

so called quantum picture the world quantum theory i am associating a frequency nu and a wavelength with them now you see there are two notions of velocity what are the two notions of velocity that i have one notion is i will write p equal to m v and i will write e equal to half mv square let us say or i can write it as p squared by 2m

so i can put a vector sign here also

so there is one velocity which is coming because of the standard dynamics notions which you people studied in your revenge standard

so this is one particular picture the other picture is that what is given by v equal to new lambda that is what we have what we have found in my previous pages was that as far as light is concerned whether you look at the speed of light from the cons viewpoint of a photon or the speed of light from the view point of a wave they are going to agree

so v it always turned out to be c irrespective of whether you looked at it as a collection of photons or that where you looked it as a looked upon it as i collect a wave but the what we do not know is whether the same thing holds

so what i am trying to tell you is that we have two notions the velocity of a particle and the other one is velocity of a wave and the question is do they agree with each other i do not want to provide an answer to this question in this lecture rather what i would like you to show is that this is a rather unpleasant thing to encounter at this particular point but there is a very definite answer and i would leave it to you people to actually figure out how it comes about as i was mentioning in my last lecture what is required is actually the notion of a group velocity which we have not studied

so far but when we are teaching or when we are studying a subject like matter waves or photons matter it is good for us to be alive to these issues otherwise everything would be appearing to be simpler than what it is that is the most important thing

so now therefore let me analyze what is going to happen you have two concepts e equal to h nu which is equal to p squared by 2m it turns out that when people write down the relation between the frequency and the wavelength etcetera etcetera it is customary not to employ this frequency or the wavelength but it is customary to employ a different frequency which you people are all familiar with and that is angular frequency in a similar manner what people would like to employ when they are looking at the counterpart of the wavelength is not wavelength

so my new is replaced by omega purely for i mean it is a matter of convention my lambda goes to k and this is what is called as a wave number my lambda goes to k and that is what is called as a wave number

so how do i write my energy i write my energy to be h nu and what is the relation between omega and nu omega equal to 2 pi nu therefore this quantity is h into omega by 2 pi that is what we have and there is a very very special notation for this h by 2 pi and this is identically equal to h bar omega

so most of the time actually in physics later when you study more and more of quantum physics or even electromagnetic theory when we speak of frequency most of the time we speak of the angular frequency omega rather than the usual frequency there is no great difference between them except for a factor of 2 pi

so let me record it my omega is nothing but 2 pi nu that is what it is in a similar manner we wrote the relation p equal to h by lambda

so what i am going to now do is to replace h by h bar

so remember h bar is h by 2 pi therefore i am going to write it as

so h bar is h by 2 pi therefore h is 2 pi h bar by lambda that is what i have

so you people should know that h bar is a more commonly used quantity rather than the original prime constant itself and if i write it as h bar into 2 pi by lambda this is identically denoted as h bar k

so k has the dimension of inverse wavelength it is called the wave number

so the standard notation is that you describe the wave properties in terms of the frequency the angular frequency omega and the wave number k

so what would be the relation between omega and k visa vc when we wrote it in terms of nu and lambda we wrote v equal to new lambda the same relation becomes omega equal to c k

so this is the standard way we represent the relation between the angular frequency of the photon the wave number of the photon and the speed of light and this relation is what is called as a dispersion relation

so what is this telling us this is telling us that as you keep on changing your wave number that is as you keep on changing the momentum of the photon my omega also keeps changing that is the energy also keeps on changing such that the speed is always the same irrespective of what your frequencies are irrespective of what your wavelength is all frequencies travel with the same speed equal to c in free space that is the statement that we are making and essentially einstein

made use of it to propound this principle of relativity by saying that it is not only the same in one inertial frame but every other inertial frame all possible inertial frames

so this is a dispersion relation at this point actually we can take a detour and say ask what would happen if i were to get into a medium if i were to get into a medium then the speed would change because in a medium k would change to k prime omega will remain the same therefore my c would be different

so this becomes a c of k prime and that is the reason why when there is a refraction of white plate in a medium let us say in glass or water or whatever different frequencies travel with different velocities they get bent at different angles and on the right side you see the different colors that you are going to see that is a famous case of dispersion and this explains why you make use of the word dispersion relation at this point of course you should know it is not very important for us to use omega and k i just introduced it to you because it is some kind of a convention although in your 12th standard you may not use it

so now what we do is to return to matter waves let us return to the matter waves

so basically these are the questions that we have raised

so let us reiterate we are asking that given the fact that momentum fixes the wavelength what fixes the energy and then what is the relation between frequency wavelength and speed

so when we speak of the speed we have two different varieties of speed different kinds of speed one is the speed of the wave and another is the speed of the particle this question is very very important and it occupied deep rawley himself quite a lot because he gave a model called the pilot wave because we have to explain how a particle can have a wave like behavior it is easy to explain how your wave can behave like a particle because we can say wave is an extended object therefore lot of particles join together and behave as if they are aware but a particle is a highly localized object it is a point particle for all practical purposes what do you mean by associating a wave it is a very very important question that we have to ask ourselves and that is the reason why i have listed these three questions and although they are not technically a part of your syllabus it is very important for us to ponder over this

so what do we have i have lambda equal to h by p and i have nu is equal to e by h because h nu is equal to e now what i am going to do is to first consider non-relativistic case

so in the non relativistic case we all know the relation between energy and momentum my energy is simply given by p square by two m energy is simply given by p squared by two m

so i can play a game what i can do is i can multiply lambda into nu that would be the speed with which the wave would move

so this is the matter wave this is the matter frequency i am assigning this m

so i am going to write lambda m num and this would be the velocity of the deep broccoli wave de broglie wave and what is this quantity this quantity is nothing but h will cancel e by p this quantity is nothing but e by p

so what are we saying we are saying that the speed with which a deep rawley wave moves from the fundamental notions of wave phenomena is simply given by e by p and this is going to be bothersome to us

so let me repeat v matter wave is equal to lambda same thing let me call it as m w m w into nu m w which we found to be e by p and what is e e is given by half m v square p is given by m v of course it has the correct dimension of velocity but if we turn calculate this what are we going to get we are going to get v by 2 that is what we are going to get and what is this v this v is of the particle

so what we are saying is that if we imagine that the particle is moving with a velocity v then there is a certain wave associated with it that is what deep roll is saying it is not entirely a figment of imagination because the great experiment of davison and germa has shown that there is some meaning to that because although they are particles when they hit the one one one phase of nickel crystal and when they got reflected you had to use ray optics you have to find out the path difference you have to find the phase difference and you found there is a constructive interference which only waves can exhibit which particles cannot exhibit that is why davidson and germa were rather astonished and now we are saying when the particle is moving this poor wave cannot keep track of it cannot keep cannot run with the same speed

so this is the particle speed and my wave speed is given by v by 2 it is lagging behind

so if you naively use your known notions of velocity frequency etcetera etcetera you land into trouble although it worked out in the case of light you see that it is not going to work out in the case of matter waves

so that is one thing to worry about now of course there is a great distinction between what you do in the case of light and what you do in the case of let us say non relativistic particles we know that light is essentially quote unquote relativistic in the sense that nobody can enter the rest frame of light because it moves with the same speed with respect to all inertial frames you people have certainly heard of that in your popular lectures in relativity

so it may occur to us that what we should be doing is not use the non relativistic expression but we should use the relativistic expression then perhaps everything will be fine and then i will take a limit

so this was newtonian now what i will do is i will use the relativistic expression and see what i will get

so we look at relativistic d broly waves matter waves let us look at that my fundamental relations are still intact e equal to h nu p equal to h by lambda that is what i have may be again i should write nu equal to e by h lambda equal to h by p therefore my nu as in the earlier case is given by e by p i am repeating this calculation because it is worthwhile to have this kind of redundancy

so that the idea gets completely fixed except that now for e and p i am not going to employ newtonian expression but i will employ relativistic expression

so what is my energy my energy is given by m naught c square over root of 1 minus v square by c square this is your relativistic energy in fact you are going to use it quite a lot when you study nuclear physics mass defect and all those phenomena

so you have that and my momentum is nothing but

so let me write here my momentum is m v over root of 1 minus v square by c square i will put an m naught because i have to remember it as a rest mass

so if i did that it is going to write it in this this one i made a mistake

so i should correct myself my lambda nu is given by e by p which is the velocity

so i have corrected myself here

so i am going to substitute for e by p e by p and what are we saying we are saying e equal to m naught c square over root of one minus v square by c square and p is equal to m naught v over root of one minus v square by c square of course i am not writing any vectorial sign at this particular point because i am assuming that all the particles are moving in the same direction we do not have to worry about that

so what is my e by p let us calculate that

so my v wave what is this quantity

so i am looking at this expression m naught cancels the gamma factor 1 over root 1 minus v square by c squared cancels i get an even more fantastic expression namely the speed with which the wave moves is given by c squared by v this v is the particle velocity if you look at the expression for this momentum this momentum goes to infinity when v goes to c which means no material particle no particle which has a rest mass can move with the speed equal to c let alone with a speed greater than c that is why we say speed of light is the maximum speed nobody can ever achieve that no material particle can achieve that

so that means my v is always less than c

so what do i be finding we are finding that v wave is always greater than c there is only one exception to this rule and that is when my propagating particle quote encode particle is not a classical particle but a photon itself then my photon is moving with the speed c i get c squared by c

so that is how you reconcile with the electromagnetic result therefore although davison and german experiment tells us haha there is something called a matter wave it is going to differ i get diffracted there is going to be an interference between two different layers and then you are going to see maxima whenever n lambda equal to 2 d sin theta that must be understood more carefully because in one case my matter way was not able to catch up with my particle and in another case my matter wave is running far ahead in fact it is running with super luminal speed which is impossible okay

so these are the two questions which you have to ponder about think deeply about to clue to the answer to this question is actually found in what is called as group velocity i will not discuss that but i would like you people to keep this in mind okay

so this concludes the study of the

so called matter waves you have all these standard problems now given the wavelength find the momentum given the energy find the frequency are given the momentum find the wavelength

so on and

so forth they are not of great interest although they would be of interest to calculate because that will give you a rough idea of what the deep broccoli wavelengths are things like that but all these studies the study of the concept of a photon or a matter wave raises an even more fundamental question

so remember what we are now doing is to look at particles which are incredibly small and which are difficult impossible to see with the naked eye

so for example when people first discovered the cathode rays or the anode rays

so on and

so forth they appear like rays and it was only very very careful measurements that revealed that they have a particle like nature that electrons are particles is that ok and now we have confounded the notions of wave and a particle is that ok

so basically what these studies do is to essentially raise a fundamental question what are the fundamental constituents of matter is matter continuous is matter discrete is the fundamental constituent wave is the fundamental constituent of particle because we have seen a particle can behave like a wave a wave can behave like a particle

so this takes us back to the great great question with the human beings posed thousands of years ago what are the fundamental constituents of matter and this is what leads us to the famous bohr model but then when we speak of the bohr model what we are actually doing is to jump over a few thousand years

so what i will now do is to start with the notion of an atom

so we have essentially made a transition to the next topic the bohr model but the bohr model will come a little bit late we have to do lot of preliminary work

for that
so look up on this as a second lecture in this series what we have is to worry about the structure of the atom
so let us have some preliminary discussions
so all the matter that we see around us are what we call as gross matter and we can actually break you can even break stone diamond is a very hard material but diamond will be polished and cut by other diamonds and of course whether it is wood or plastic or any other material you can break we know that mountains are formed mountains break mountains actually lose soil because of continuous erosion
so on and
so forth
so that means we know that all the objects that we see around us are actually made of finer particles there is no question about that
so you take a sugar crystal you take salt crystal or you take anything you can actually crush it into a powder you can take wood and you can crush it into your powder
so the big question that people have asked philosophers scientists they have asked is that what are the ultimate constituents now when i speak of ultimate constituents of matter there are two things that we have to worry about those ultimate constituents must be somehow become perceptible to me i must be able to feel them i cannot say that matter is made of an ultimate constituent which nobody can ever know anything about then that is a useless statement through there may be a very large number of links but eventually it may be related to it should be related to the way i am going to observe them that is one very important notion and another of course is that when i speak of an ultimate constituent of matter is it possible that i can keep on making finer and finer and there is no end to it at all
so it is like a mathematics question
so what do you do you give me two numbers i will always produce a number in between them a is a number b is a number a plus b by two you rise in between them now take that number and let us say you take b there is another number between them there is no end to this limit in fact the whole real nine is a continuous line
so other possibilities that matter is continuum
so whether matter is continuum or whether matter it is discrete is a different matter but if you take it from the viewpoint that eventually all kinds of matter if they have to be understood by me have to be related to me through observation in some manner we ask ourselves how do we observe you may build the most sophisticated instrument but ultimately you get to know it either through your eyes or through your nose or your ears or your sense of touch or your sense of taste
so when we look at the second one other schools the great elements these are called the mahabhutas in india right people argued that there must be an underlying quality which is responsible for my sense of touch sense of sight sense of hearing sense of smelling and all these five attributes and these entities were given names these are the great five elements which they call earth water fire air and ether ether does not particularly exist in greece they spoke of only four elements but in india they also introduced the concept of concept corresponding to ether not exactly either that is what was called as akasha
so what i essentially say is that when i see this piece of wood or when i see you or when i touch this there is a certain quality inherent in me corresponding to the touch there is a quantity quality inherent in that corresponding to touch

and that is the reason why there is a certain knowledge that is accruing this is not a humdrum idea it is not a useless idea because after all we say if i want to know that there is an electric field i need an electric charge after all the charge produces its own electric field if i want to know that there should be there is a gravitational field i need a mass because of after all the mass produces its own gravitational field

so that was the idea

so people postulated the existence of these great elements or the mahabhutas these are the great elements out of each everything has been constituted at this point you should not confuse words like earth water fire air or akasha to be the earth that we see the water that we touch or the fire that we feel no that is not what it means these were simply the names given basically you are saying earth has a preponderance of that quality water has a preponderance of this quality it is not doesn't mean that the element itself is earth that the element is water or fire or anything you simply pick up names from ordinary words and you are calling them that is something that you have to remember now the question is given these great elements they may be there they may not be there is there a continuum or no continuum the schools were divided but today for us the most attractive school is the school which propagated the atomic theory of matter because we believe that matter is discrete and it is not continuous however when these ideas were postulated thousands of years ago there was no evidence either way

so in india for example when we speak of the great elements they are found in the upanishads probably they were composed thousand bc or 1500 bc

so it is that ancient whereas the later philosophical school we have six schools of philosophy one of them is what is called as the veisheka school where they try to classify all matter known to us they postulated the existence of a fundamental unit of matter and that was called anu

so i should write that here the indian school of atomism the founder of the school was kanada

so we have to be careful if i write k n a d a it can give rise to a confusion

so we write in devanagari

so that there is no confusion about it at all and there is an interesting pun about his name because the word means a particle okay

so aadhaa means to eat i mean it seems that he kept on consuming small small particles of food or whatever

so obviously this must be some kind of a euphemism some name given to him because he propagated the atomic theory but technically the fundamental units were called anus and that is the name we have actually used today in order to describe an atom

so in today's chemistry book or physics book if you look at the hindi version an atom is called anu and a nucleus is called paramanu probably

so that is what we have actually it may sometimes it is also called nucleus is also called nabi we will not worry about that the technical word is and it was believed that there are many many kinds of atoms is that okay

so let us establish a correspondence with the idea of the greek school who called atom atom is a unit anu is a unit

so in greece it was democritus as we saw and the combination of these atoms is what gives rise to the visible matter

so there were this detailed questions about as to when it becomes visible

so one school said that you need a minimum of three atoms to join together in order to become visible to the naked eye obviously all these were speculations but they had a certain element of novelty a certain element of ingenuity in them because eventually people wanted to trace back all the ordinary activities

around us to something fundamental that is what we have of course all these had absolutely no evidence coming from either observation or experiment they were purely speculative

so if we go from let us say hundreds of years before christ and we come back to more recent middle ages the great proponents of atomic theory of course probably were in england dalton i suppose was a britisher the great proponent was isaac newton and dalton

so there is newton wrote a very famous book called principles of mathematical philosophy principia mathematica where he gave all the loss of mechanics and discussed gravitation but newton was not only great in mechanics dynamics but he also made fundamental contribution to optics after all he fabricated his own lens probably he made a first refracting reflecting telescope

so on and

so forth

so in his book on optics at the end newton actually posed 31 questions queries he raised the number of questions on the nature of matter because newton was not only doing physics but he was also in touch with lot of alchemists

so there was i think lavoisier in france and there were other people in england and the alchemists are the people who actually gave us the idea of an element and a molecule he was in touch with them

so he started speculating on the ultimate constituents of matter

so if you students get time actually you should try to read all the 31 questions that you have post they are amazing

so you ask questions like is it not possible that if a ray of light comes very close to matter it will start bending

so he had uncipa anticipated what einstein demonstrated 300 years later that is a gravitational bending of light

so in a similar manner he asked we know that in order to break a piece of wood for example you would require certain energy but to break the smaller piece of food it will require more and more energy as it becomes smaller and smaller the particles that bind them will become harder and harder and they ask is it not possible that you will reach an ultimate limit where you have the small spherical balls which are completely microscopic let us say which are infinitely hard and they were all created by the great god himself and they are complaining to me ordinary matter and they must be indestructible

so the whole idea of an atom is that it is indestructible nobody can ever destroy them nobody can ever modify them

so that was the great idea of newton as i told you i have already discussed the other schools but the real evidence for the existence of an atom actually did not come from physics in the sense you know we do mechanics or whatever it really came from people who do chemistry and thermodynamics chemists were great people i think priestly is the person who separated hydrogen for the first time the voicer was able to get oxygen for the first time people realized water was actually a composite of hydrogen and atom people were able to find out then of course dalton came and gave his theory of ideal gas etcetera etcetera then people found out that many many of the molecules that we see around could be actually understood in terms of the combination of more elementary quantities these are your famous elements and eventually mentally you came and gave us the periodic table of course there were a lot of missing things but people were able to make a distinction between an element and a molecule element is more primary than a molecule now the question is what is the fundamental unit of an element

so we have a rather nebulous vague idea of an atom yes but the great work of these chemists actually sharpened that idea

so now we say when we speak of an atom we are asking for a fundamental unit of

an element what is an element an element is that which is an elementary constituent of a chemical reaction in order to start understand any chemical reaction you have to start with elements and then you can go to molecules super molecules bigger molecules macromolecules
so and
so on and
so forth but elements themselves will not be understood in the language of chemical reactions they are the basic quantities that enter then of course there was thermodynamics people were studying thermodynamics people were studying gases you people have studied that and all of you have encountered a very very famous number called the avogadro number there are
so many molecules that was another philip that came from thermodynamics and moreover in the end of the 19th century there were these great experiments started with becquerel and then continued by mary and pierre curie there was the husband and queen couple where they found that there was something called radioactivity that was going on and it is because of which the the well known alpha rays beta rays gamma rays were observed but for whatever reason in your course you are going to study radioactivity not before atomic model but later but never mind when you do nuclear physics
so all these gave credence to the idea that there is a fundamental entity called an atom simply because of the elements that is the most important thing
so now we are able to give a rigorous definition of what we mean by an atom therefore when we speak of an atom in the 21st century or for that matter even in the 20th century these atoms should not be confused with the notion of an atom which either kanada or democritus had there is no point in comparing the two just as the notion of a graha in indian astronomy should not be confused with the modern notion of a planet these are technical words which are used in entirely different contexts
so we can read whatever is written in this slide we say atoms are fundamental units of chemical reaction if i give the definition no it is an operational definition there is a consequence we do not know whether they are ultimate constituents of matter whether they are not if there are ultimate constituents of matter you cannot break them if they are not then you can probably break them and moreover if they are ultimate constituents of matter if they are in some sense they must be
so small that you should not be able to see their size or otherwise i should be able to find out what the structure of these atoms is this is the most important thing and this is where models for the atoms come
so when i speak of the models of the atom you should understand that because of radioactivity because of the neutrality people had figured out an atom contains both positive and negative charges
so the negative charges are of course the electrons which were discovered by thomson and then the positive charges were known
so because after all in the periodic table you start saying you know there are these electrons although you do not know the shell model but these are the quantities that are contributing in fact i have not made a slide here there was a cubic model of an atom by the chemist where they used to place the electrons at different vertices of a cube if the if two vertices joined they called it a single bond if two lines joined they called it a double bond
so on and
so forth
so there were such models also we are not going to discuss them but we are going to look at two very very major contenders one is the plum pudding model which was proposed by thomson and another is the planetary model proposed by

rutherford the first figure that you see the you can see is democritus at 460 bc dalton in 1800 380 okay and if you speak of kanada probably he was somewhere in the first century ad or whatever we don't know what the time is i don't remember that they thought of atoms as impenetrable hard spheres
so that is what you have okay of course i am confusing the two words but it does not harm us because that cartoon is there the thomson model imagined that an atom is what a uniform distribution of positive charge
so that is your like you know some fruit
so that is the plum pudding model okay and inside those yellow lines that you see they are actually negative charged particles they are also distributed such that the whole system is stable and then of course it behaves as a single entity today we know there is a serious problem with this kind of a picture because when you people study electrodynamics in your next year when you go for engineering or pure sciences you will know you will see that it is impossible to have a stable equilibrium by static charges ok an atom would not be stable it will come apart even this latest disturbance would actually break away the atom at that point they did not worry too much or probably thompson imagine these electrons are all going round and round in an atom or whatever
so this was the picture the picture that is most appealing is actually that of rutherford because unlike thomson and democritus which was based on mere intuition or speculation rather for model actually came because as an experiment and that is what we are going to discuss next and reconciliation of rutherford model with classical mechanics because it was in conflict with the laws of classical mechanics gave rise to the bohr model
so that is what you have
so ignore the last two ones please stop at the rutherford model bohr model is also a correct description but the quantum cloud model is a completely misleading description we should be very careful about that although chemists know how to use it in a very nice fashion
so what we have to now do is to actually look at the experimental basis for modeling a what for modeling an atom and remember atom is a fundamental unit of an element and the element that rutherford chose in order to probe its structure was none other than gold it was a thin gold foil
so that is what we want to discuss
so this picture is taken from encyclopedia britannica i hope you people will be able to see this
so what did mr rutherford do this is a path breaking experiment in the world of physics and we should remember that bohr was actually rutherford's disciple he was sitting in the other first lab when he was making boar model and formulating bohr model
so what rutherford did was to realize that the so-called alpha particles everyone knew that it was carrying two units of charge electron charge with the positive side they would be emitted by radioactive material
so the radioactive material that he chose was actually bismuth
so probably i have the next light let me describe that and then let me come to the description of the apparatus
so he took this radioactive source 214 bismuth 83
so in modern language it has 83 electrons and the number of protons and neutrons is 214
so that means there are 83 protons and the rest are all neutrons that is something that we should remember that the number of neutrons is in large excess over the number of protons in fact it is more than twice that is what you have
so he took the source i do not remember what the half life is let us not worry about that and this produce alpha particles of energy 5.

5 million electron volts
so now we are speaking of really large energies and i want to spend quite some time playing around with that energy if not today but in the next class the target was a very very thin gold foil a foil is a very very thin sheet
so a good example of such a foil probably would be this sliver of silver which we see on our sweets it's a very very thin layer right you can actually not peel it at all it is stuck to the sweet it is a very thin layer
so how thin was it the thickness was as small as two point one into ten to the power of minus seven meter that is what it was then of course the detector was a zinc sulphide which was a scintillating object
so every time an alpha particle or a charged particle itself it scintillates
so you know where the scattered alpha particle has hit
so he had a microscope through which he would see that and he would record the number of alpha particles that are scattered by this gold foil
so all these numbers are taken from your ncrt book
so you can go there and look them up rutherford was fortunately a careful person because by that time people had understood how dangerous radiation from radioactive sources are
so initially actually when radioactivity was discovered people thought that because you know radioactive materials glow because they also emit light in the visible range people thought it would be very nice and initially these radioactive materials were mixed with paints and they were used for white washing hoses because it would give a nice glowing colour it was done particularly in germany and probably in france and one person who worked extensively on radioactivity and got a nobel prize marie curie actually got
so badly affected by radioactivity she developed cancer but by the time of rutherford people knew how to do experiments more carefully
so you see he has put a source and has put a thick leg shield
so that the observer is outside and lead is a very very good absorber of radioactivity
so that that means you are reasonably safe and that is what they do when you go for example for your x-ray and all that they put a shield is that ok that is what it is he made a thin hole and the beam of alpha particle goes you want an even better collimation
so he put another lead shield and made a small hole okay because the length absorb whatever falls outside will be there and there was the thin gold foil and it is shown in golden color in the picture that is what he did
so probably i can show it here in the cursor not that it matters and then what you have is a rotatable
so that is what is shown in the green lines rotatable zinc sulfide detectors
so you keep on moving from place to place and radioactivity is a continuous process ok in the sense that it will not stop but the beam itself is not continuous
so you have to be very patient to do this experiment because the emission of an alpha particle is a stochastic a probabilistic process you do not know when the next one will be emitted and that fellow has to be scattered
so you wait patiently till you accumulate enough number of scattered particles in all directions
so this experiment might have taken months or a year or whatever that is what you do and then you see whether you can infer anything about the structure of the gold atom this was the great experiment that rutherford did
so so much
so that apparently at some point somebody made a remark that rutherford was lucky to write the crest of a wave there was a big wave when he was on the top

of it and they became a famous man but actual reality is what rutherford himself told in response to that he said i made the wave this experiment he conceived and there were students geiger and marsden who did even more careful observations and he was able to build a beautiful picture out of the scattering and that is what is important for us to us

so what i will do is i will stop at this particular point in the next lecture i am going to discuss what the results of the rutherford experiment are and i am going to try to work out not completely rigorously but to the extent possible i will try to work out whether the plum pudding model will be able to explain it or a planetary model will be able to explain it i will argue in the favor of planetary model and then we will see the rutherford model is going to give rise to even more problems every time you solve a problem it is giving rise to more problems we saw that with the deep broly wave we are going to

so that see that and that is when the bohr model comes to the fore

so we will stop at this particular point we will meet tomorrow you