

dear students of class 12 my name is v ravi shankar i am a physics teacher in iit delhi and what i am going to do in the next seven or eight lectures we do not know how many is to discuss the topics on the

so called modern physics in your standard physics course

so essentially they will be chapters 11 to 13 and what we are going to cover are photoelectric effect the deep broly waves bohr model of the atom and nuclear physics this course is qualitatively different from whatever you have studied in your 11th and 12th standard you covered a whole lot of courses for example you studied mechanics both statics and dynamics then you studied electricity and magnetism thermodynamics optics properties of matter in all these topics you were trained to solve a large number of problems and some of them are quite intricate this course is not exactly like that because the mathematics that we are going to use is quite elementary in fact much more elementary than what you would use in let us say electromagnetism or mechanics or gravitation for that matter rotational motion especially but on the other hand the concepts that we discuss are very very deep they are radical

so radical that at the beginning of the 20th century last century when great physicist like hertz einstein millican name goes on and on lorenz bohr heisenberg when these people encountered they were completely startled

so it doesn't mean that the subject is only conceptually difficult and mathematically easy it is just that this particular course introduces to you the conceptual basis in a very simple way but of course after that when you join for your graduation or post graduation in physics you will start learning the mathematical aspects the quantitative aspects which actually is extraordinarily sophisticated the other thing about these topics that we are going to study is that there are some fundamental issues on which great physicists even ponder about for example wave particle reality what exactly does it mean what exactly is the meaning of the uncertainty principle what does one need what does one mean by measurement these are the questions that we do not normally ponder about when we study classical mechanics you will study you are taught particle properties you were taught wave properties you did not have to worry but here you do have to worry because the same physical system can show or exhibit both particle nature and wave like nature depending on the condition

so there are lot of implications not only for physics but also for metaphysics actually of course we are not going to get into that but the point that i am going to make here or i am trying to make here is that please don't take this lightly in a certain sense you can relax because there will not be too much of mathematics but in another sense you have to be completely alert because what we are going to discuss is really one of the most astounding achievements of humanity we can very safely say that and proudly say that

so with this brief introduction it is actually good to announce our motto what is the motto that we want to announce we want to keep it simple but we do not want to make it trivial and this was very beautifully expressed by another then the great einstein and you see that here in the next slide

so it is good to announce whatever motto is at this particular point and what i am trying to say is that we are trying to try to make things easy but not trivial and this was very beautifully put by none other than the great einstein which you will see in the next slide and if you look at the slide he said simplify as much as possible but never oversimplify oversimplification gives rise to a feeling that you have understood something or sometimes even everything when actually it is not the case and we shall try to follow this dictum

so as i told you this slide displays for you what are all the topics that i am going to cover

so let me repeat

so that it sorts of gets fixed in your mind the first topic that we are going to cover is photoelectric effect and i am going to spend a lot of time discussing this effect because not only do we have to write down the famous einstein formula for the stopping potential or the ionization potential we also have to describe the great experiments of hertz and mulikan very very carefully and also lennard i am going to spend a lot of time on that and you should remember that einstein got his nobel prize not for either his special theory of relativity or general theory of relativity but for photoelectric effect

so when you read photoelectric effect in your cbsca textbook or any other textbook you may there is nothing much to do why is it that he was given a nobel prize the answer to that came from einstein himself he said that creating special theory of relativity was a child's play comparing to obtaining an explanation a proper description of the experimental results on photoelectric effect because when it comes to relativity he had the wisdom of 300 years of electromagnetic theory and

so forth whereas when it came to photoelectric effect he was charting his own course

so that is something that we have to remember and therefore i am going to discuss the experiments very very carefully and in great detail

so when i speak of photoelectric effect i am discussing the particle nature of light light is an electromagnetic wave you people have solved many many problems conversely it was observed by d broly when he became aware of bohr's work on quantization that we can also ascribe a wave like nature to the particles

so in the first case what was behaving like a wave classically started behaving like a particle in some context in the second case what was behaving like a particle in your cathode ray tube or whatever when it goes to the atomic scale it starts behaving like a wave it starts showing wave like property and of course a brilliant experimental verification came from the works of division and germa and we are going to discuss that

so these two are two complementary aspects of the same what we call as the quantum mechanical systems and in the classical limit one of them exhibits only wave like nature and another exhibits only particle like nature but in the quantum limit well it depends on the situation that is something that we are going to spend quite some time about next comes the nature of the atom this of course is an extraordinarily important topic for us to study because ever since the early dawn of intellect in humanity people always wondered about what the ultimate constituents of matter can be and of course there were many many theories for example in our own country there is this school called the vaishashika school right they argued that everything is ultimately made up of atoms their propounder was a philosopher called kanada in a similar manner there was a corresponding school in the greek civilization where democrat has said that everything is ultimately made up of atoms of course there were counter theories where people believed that matter is actually continuous we do not really need the atomic nature and this discussion went on and on and on for example when you study electromagnetic theory or let us say problems in moment of inertia or problems involving rotational motion rigid bodies you assume that the density is a continuous function of space time coordinates okay if it is rigid it is a function of only space

so you treat them as continuous functions you treat the charge density as a continuous function whereas if you want to understand thermodynamics you would have to employ the molecular hypothesis

so you know sometimes it is convenient to treat it as a continuum sometimes you actually need the molecular hypothesis to understand equilibrium phenomena

so this is a fundamental problem to be actually decided by experiments and their interpretation and when it comes to atoms the primary unit of chemistry let us say the most important information the most important insight came from rutherford scattering and who gave the planetary model of the atom we are then going to argue that planetary model of the atom gives rise to whole lot of problems what are the problems that it is going to give rise to well there is a problem of stability there is a problem of why my electron will not fall off into the proton

so on and

so forth and in order to understand that bohr proposed actually his famous bohr model where he was able to quantize angular momentum quantize energy levels and he was able to describe atomic systems

so that is something that bohr did this is something that we will be studying at a great detail

so what i want to do at this particular juncture is to take a few minutes and recall to your memory whatever you have studied and point out what are the differences that we are going to see when we study the

so called atomic phenomena the microscopic phenomena visavi whatever you have studied in your macroscopic phenomena be it electrodynamics or be it the classical mechanics

so let us start with a few preliminaries and it does not harm us to get an overview by the way i am not going to start the lectures today i am only going to give you this kind of a broad overview and an introduction the real course will start from the next lecture when i will start discussing the great experiments on photoelectric effect okay

so let us start with the newtonian mechanics because you must have heard of the word quantum mechanics and we want to see what the differences are i am not in a position to tell you what all the differences are i am going to mention some of them and even what i mention falls into the realm of the

so called world quantum theory they get much more sophisticated and refined later

so please don't think that whatever i have told you is the gospel truth there is an element of truth but there is also some amount of ambiguity in it that is fine because all of learning is learning unlearning and relearning that is the process that we go up

so what we are saying is that in newtonian mechanics suppose you give me a particle let us say of mass m and it has an initial velocity v_{naught} and an initial position r_{naught} and you give me a force this force can depend on where the particle is located and the time

so you can imagine for example an electric field produced between two capacitor plates which are getting charged or discharged then to a large extent my electric field between the plates is uniform but it is a function of time actually if you take the edge of x into account it will also be a function of the position let us do that

so what does newton tell us newton tells us that if you give me the initial position and if you give me the initial momentum $m v_{\text{naught}}$ and if you give me the force then rest of it is a matter of detail what does detail mean i can tell you the position and momentum at all later times all observables that we construct are actually functions of position and momentum or maybe their derivatives if you really want to look at something like a torque or whatever therefore newtonian world is what we call as deterministic everything is determined

so what do you do if you consider the simplest example of one dimensional case i will write $m \frac{d^2 x}{dt^2}$ is equal to let us say $f(x, t)$

then i integrate you people have integrated in fact if my force is independent of time that job becomes even easier i will write $m \frac{dv}{dt}$ this is the general method is equal to $f(x)$ and what do i do on the right hand side i will write it as $m \frac{dv}{dx} \frac{dx}{dt}$ is equal to f

so therefore that means i can write my this equation and i can start integrating this equation

so how am i going to integrate this equation

so i can write $m v dv$ is equal to $f dx$ that is how i am going to write i can integrate this remember my f is a function of x

so let a let us say i integrate it from v naught to v

so i will put a prime here and i will put an x naught to x prime x and i put an x prime here the right hand side is an integral which you can evaluate you have been taught in the calculus

so for notation sake i will call x comma x naught that is a standard method of calculus and this is going to give me $m v^2$ by 2 minus v naught squared by 2 is equal to i of x comma x naught now the next step is even simpler i will transfer this to the right hand side and then i will get an expression for $v dv$ by dx and i will integrate the right hand side with respect to time actually i can show you that step that is the procedure that we are going to employ

so let us say for simplicity sake v naught is equal to 0 then what am i going to get i am going to get v^2 is equal to $\frac{2}{m} i$ into x comma x naught otherwise i will have to write the other term therefore my v is given by square root of $\frac{2}{m} i$ of x comma x naught and this is nothing but $\frac{dx}{dt}$

so we employ the same procedure and we write $\frac{dx}{dt}$ over root two by m into i is equal to dt integrate the left hand side integrate the right hand side you get a function of x you invert it then you can write x as a function of time in fact you can repeat this for your harmonic oscillator problem for instance and you will immediately find out what the solution is

so in other words newtonian mechanics is completely deterministic number one number two if i go back to the original slide and if you look at $m v$ naught and r naught there is no restriction on what your velocity can be and what your position can be there is absolutely no restriction that means you can specify your initial condition in any way you want with any degree of precision and then newtonian mechanics will take over and it will give you the position velocity acceleration angular momentum whatever you want at all later times and therefore what we have is a completely deterministic system and if you have good mathematical skills and if you have a powerful computer and you know how to write down your program then there is no problem at all what happens is that you should be able to solve everything that is how people were able to work out for example the planetary dynamics perturbation because of various planets

so on and

so forth now just to give you a flavor of how quantum mechanics is going to be different

so as i told you this is some kind of a general overall view let us take the example letter of gravitational force

so what do you have your f is given by $\frac{GMm}{r^2}$ that is what you have and let us say that your body is sitting in a circular orbit these are the problems due to solve they are going around the sun in a circular orbit a satellite going around the earth in a circular orbit moon is in a roughly circular orbit these are the problems geostationary orbits if you want to do that you will write $\frac{GMm}{r}$ that is what you are going to write of course this mass goes away and when you study your gravitational phenomena you will study the the importance of cancelling mass on both the sides in a great detail this r goes away and you get a beautiful expression v^2 is equal to

gm by r now you see there is a free parameter r here if you give me r then v squared get fixed and if the v squared gets fixed then of course its kinetic energy is fixed but the important point is that this r is a continuous parameter and you can change it at will

so what i would recommend to you people all of you students is to go back open up your youtube and look at how india was able to send its probe to mars the famous mangalyaan

so what did they do they first launched it into an orbit very close to the earth then there were these sling shots is that right there were these slingshots which kept on changing the orbit that means when you are changing the orbit this r is changing of course there are other things that change because there is also a question of angular momentum because in general the orbit is elliptical but they were able to change it continuously

so if i am to show it to you in a schematic manner you first put it in this orbit then give it a shot then it goes like this ok forget about this in this elliptical orbit then you get another shot like this then it enters an even larger orbit then you give it another shot somewhere here let us say then it escapes and it gets into the orbit of mars and it goes and here where you want to put your satellite this is my earth and this is satellite right depends entirely under your control

so this is like a caricature of mangalya

so look at that and that it in a very very controlled way because everything will be newtonian mechanics but when you study bohr atom bohr will say no no no you cannot simply write the equation $j = m v r$ square is equal to $m v$ squared by r because this r cannot be arbitrary is that ok this r cannot be arbitrary you should satisfy a very special condition

so what is that condition mean it says that for example if a particle can be in this orbit a particle can be in this orbit but a particle cannot be in any of these orbits inside or any of the orbits between these two and that is what is called as the quantization condition that is why it is called as quantum mechanics and all of you are familiar with the condition $m v r = n h$ that is what you are going to study right this is the orbital angular momentum this orbital angular momentum cannot take any value that you can give we should satisfy the condition that it is an integral multiple of h bar h bar is your famous planck's constant h by 2π h is usually called the planck's constant and h by 2π is your h bar and this planck constant actually came from the photoelectric effect and that is something that you are going to study in great detail depending on the experimental thing however in order to understand photoelectric effect there are some things that we have to recall and let me spend some time telling you what is it that you have to recall

so remember you studied electrostatics magnetism and of course you study electromagnetism i want to recall to your memory the salient features the most important features

so what is it that we learnt when it came to electricity and magnetism that is very very important

so all of you have solved for example the problem of rc circuit and you have studied how energy flows into the electric field between two capacitors

so when you work out the energy you write a beautiful equation $\epsilon_0 E^2$ is the energy density of the due to the electric field

so electric field is there that is the most important role of a capacitor in modern day appliances it puts charge and it stores energy and you can use that energy any time you want and where does that get the energy from of course it gets the energy from the battery or the cell to which you have connected

so let us not forget that it is not coming from nowhere

so you have your resistance you have your capacitor and then you have your charging thing and then you put a switch the minute you connect your switch the current flows the positive charges accumulate and now the energy gets stored in between them

so electric field can store energy in a similar manner when you look at induction for example there is a corresponding magnetic energy which can be again harnessed and that you write as i hope i am writing the correct expression v^2 is the magnetic energy density you people have studied this

so therefore energy can be stored either as magnetic energy or as electrical energy and it can be used but then we have another law the great law faraday's law of induction and what it is teach us he taught us that time dependent electric field implies non vanishing magnetic field

so how do i write that

so the change in the magnetic flux or the induced emf is nothing but $\int \text{curl } \mathbf{E} \cdot d\mathbf{l}$ which is the electric flux ok time dependent electric field can actually produce a magnetic field that is what we are going to write and this is the magnetic flux okay and again you are familiar with that problem because if you start producing a time dependent field then immediately you make use of this equation and find out how much energy is stored in the magnetic field but even more importantly what faraday taught us was that since a time dependent electric field can produce a magnetic field and in a similar manner maxwell taught us a time dependent magnetic field can produce an electric field what happens my electric field energy can go to magnetic field energy which i will denote it as em and vice versa and the great insight that came from this because of maxwell was electromagnetic waves electromagnetic waves where the electric field acts as a source for the magnetic field and the magnetic field acts as a source for the electric field that is what maxwell said and when you work out you find that these electromagnetic waves travel with a speed of $1/\sqrt{\epsilon_0 \mu_0}$

so all of you know what the values of ϵ_0 μ_0 are μ_0 is $4\pi \times 10^{-7}$ newton meter or whatever seamlessly ϵ_0 but the most important thing is when you substitute these values you will get this great magic number 3×10^8 meters per second that is what you are going to get independent measurements of the speed of light by lot of people including grommer who actually determined by looking at the eclipses of jupiter shows that light also travels with the same speed

so since it is extremely unlikely that there can be two important quantities with the dimension of light namely the speed of light itself and $1/\sqrt{\epsilon_0 \mu_0}$ maxwell made the great conjecture that what we call light is nothing but one part of the electromagnetic wave spectrum that is what he said and indeed that was very very brilliantly verified by hertz and in our own country by the great man jc bose who was able to produce microwaves when he was working in presidency college and he was able to see all of them all the in fact he was able to see diffraction phenomena in interference in the microwave region for the first time and today his portrait addons the famous hall of fame you know the great hall of fame of electrical engineers

so we can be very legitimately proud of that that is what we have now i am telling you all these things because i want to lay the foundations for the importance of the photoelectric effect and you people in your class 12 again when you are preparing for your exam or when you are studying in your class you know how to write down the expression for the electric field and the magnetic field

so let us do that

so the most important concept for you is that of a plane wave is that right

so what do i do i say a particle has a frequency ω this is of course the angular frequency and has a wave vector k we know what it is right

so $2\pi / \text{mod } k$ is the wavelength that is what i have and k divided by $\text{mod } k$ is the direction of propagation right and ω is $2\pi\nu$ where ν is your frequency

so what do we have $\omega = ck$ or if you feel like $\lambda = c / \nu$ where c is 3×10^8 meters per second that is what you have studied

so once i establish this i can write down my electric field and what is the expression for my electric field well let me write it down for a plane polarization

so i will write $E = E_0 \cos(\omega t - kx)$ and let me assume that the propagation direction is along the z axis

so i will write $E = E_0 \cos(\omega t - kx)$ set this is something i want you to pay a great attention to and all of you know how to immediately write down the expression for the magnetic field we are obviously employing the SI units my magnetic field will be $B = B_0 \cos(\omega t - kx)$ that is what you are going to get

so what are we going to do now what we are going to do now is to ask if this electromagnetic wave is propagating which is nothing but light at a certain frequency ω and a certain wave number k $2\pi / \lambda$ is of course my λ where is the energy after all we are all the time speaking of solar energy nowadays because it is clean energy in fact this cleanest form of energy was first employed by nature when photosynthesis was started by the plants and we all live because of that because of photosynthesis not only is energy harnessed but we also get a lot of oxygen

so you see my energy is stored both in the electric field and the magnetic field and i can write down my expression $\epsilon_0 E^2 + \mu_0 B^2$ i suppose there is some ϵ_0 here and there is a μ_0 here $\epsilon_0 \mu_0 = 1/c^2$ or whatever is that ok this is my energy density this is where the energy stored is and what is the important point that we have to notice here the important point that we have to notice here is that my wave is oscillating

so when you speak of an oscillation you give me the amplitude you give me the frequency and you give me the propagation direction and what this expression is telling me is that the energy carried by the wave is completely independent of what the frequency it is a function entirely of the amplitude that is what it is saying in other words my ω or k they do not contribute they do not contribute to energy that is the most important thing that is also true of the oscillators therefore in fact this can be looked upon as a collection of oscillators in other words my ω only tells me how many times it is oscillating but the real energy is actually in the amplitude how many times you go from you know $-x$ to $+x$ or whatever that is the information that is being given to you

so it depends only on E and B and this is something which is well known because as you keep on increasing the intensity of light for example you have 50 watt bulb 100 watt bulb 500 watt bulb then you are getting more and more energy if you want to heat you speak of rating of 1.

3 kilowatt or whatever whatever is that ok that is what happens

so this is a very well established fact and everything seems to be fine however what physicists observed was that this is all right if you are going to study electromagnetic theory only in isolation but this gets into trouble when you look at what when you are going to look at electromagnetic theory

so let me rate it fully electromagnetic theory plus thermodynamics i cannot study anything any fundamental theory in isolation it has to be studied together

with thermodynamics because all real systems are at some finite temperature and all systems are interacting with their environment that is an extraordinarily important thing how did you produce light you stuck a match and you go right at the little candle or you are going to hit something for example you may write a is a set 5 root on 5 or you may have embers burning coals or whatever all of them their laws are governed by thermodynamics and there are very very important principles in thermodynamics for example the first law tells you that the total energy should be conserved which is also there but equally important which you study in your kinetic theory of gases is that at any temperature at any temperature each mode this is very very important what is the mode degree of freedom carries an energy three by two $k_b T$ k_b is your famous boltzmann constant right it carries that unit of energy in other words thermodynamics asserts and there is extraordinarily good experimental verification in fact we may keep on changing our laws of physics but thermodynamics is going to be robust is that okay that this equipartition is a very very robust and a well established result there is a very good experimental evidence and this depends on the number of degrees of freedom that is a very important thing and at any given temperature only at T equal to zero can your energy be equal to zero the minute to switch on the temperature there will be oscillations you will start interacting with whatever is there and it will also acquire an energy and each mode will get that you students are thoroughly familiar with this because you have studied mono atomic gas diatomic gas and you know how to take for example the number of degrees of freedom into account for example if you have a diatomic gas should you worry only about the vibrational states or should you worry about the rotational state

so on and

so forth for example for a monoatomic gas

so i should make a correction here i am very sorry about that let me come back here at any temperature each mode gets not three by two degrees but half $k_b T$

so not three by two but half $k_b T$ units of energy that is what it is

so if i come back to mono atomic gas gases are sitting in three dimensions

so that will be three into half $k_b T$ that is the energy carried by each molecule that is the basis of the kinetic theory of gases and if you have n molecules you will multiply it by the n and this will be the total energy of the system and starting with this you people know how to obtain you know the famous gas class like $pV = nRT$

so on and

so forth by applying pressure either expand gas expands or rather the gas compressor

so on and

so forth that is what we have

so you may say

so what what does that have to do with my electromagnetic waves

so what we shall do and this is the great experiment that we are going to look at imagine that you are going to confine your radiation in a pipe it is closed here and this is a term temperature this cavity this is cavity is a temperature and there is electromagnetic wave

so it gets reflected at this point

so the wave is getting confined you know that my k cannot be continuous

so it will be something like $2n\pi$

so k will be quantized query will take discrete values

so k will be essentially k_n will be proportional to n by l where l is the length of the cavity how do you get this length of the cavity

so you create a standing wave and you get that now you see my k_n has become

discrete in fact if you want a wave there is a minimum k_1 which is given by $1/\lambda$ it gets multiplied by 2π or whatever you do not have to worry about that so then you will have k_1, k_2, k_3 etcetera etcetera and all these are discrete modes these are the degrees of freedom

so even you fix the int even if you fix the intensity there is nothing in physics which will tell me whether i should look at k_1 whether i should look at k_2 or k_3 all these degrees of freedom are there and how many are there well i can draw a picture for you

so that is very much like a string that is what i have this is my fundamental mode the so-called first harmonic this corresponds to k_1 then i will write this there is one node then i will write this there is a second node

so on and

so forth there is no limit to the number of nodes that means k_n can take arbitrarily large values

so what are the what is the statement that we are making we are saying that if you confine electromagnetic wave for example within a certain region let us say by putting reflectors or whatever let us call it as a cavity this is also very much like a vibrating string if you feel like then it can take arbitrary large values means it has infinite degrees of freedom it has an infinite number of degrees of freedom an infinite number of degrees of freedom now what do i do i couple my electromagnetic theory with thermodynamics electromagnetic theory plus thermodynamics

so what does electromagnetic theory tell me it tells me my energy density is proportional to $\epsilon_0 E^2$ and this tells me it is proportional to number of modes degrees of freedom into $\frac{1}{2} kT$ and at for all finite temperature however small T may be

so long as it is not equal to 0 this is infinite and this is finite

so as students you people would have played a game where you know you suddenly get finite number is equal to infinite number and immediately your friend tells you or if your friend is committing a mistake you sell this your friend that you are doing something illegal you are looking at something like 0 by 0 which is not well defined and that is why you are getting that you have no business to do that because 0 by 0 is not defined in a similar manner here the problem that we are getting is not because of mathematical problems but there is a deep physical problem this tells me there must be a finite energy density this tells me there is an infinite energy density and people actually performed very very careful experiments and what is it that they found what they found was that actually the predictions depending on energy depending on the E^2 or the predictions depending on this $\frac{1}{2} kT$ was not going to work out the way we are looking at it what it required was quantization that is you do not associate energy with the amplitude but you associate energy with the frequency of course you also associated with the amplitude in a very sophisticated way and i will come to that later when i discuss einstein's explanation for the photoelectric effect but you see when i am speaking of photoelectric effect i am not thinking of a small correction it is not i mean these are all great achievements for example the discovery of the planet uranus is a great achievement but here we are looking at a deep contradiction in physics deep paradox deep problem in physics and this is a kind of thing which gets shown up which actually gets displayed when we look at a phenomenon like photoelectric effect or a compton scattering or black body radiation therefore what einstein's photoelectric effect did was to actually resolve this particular problem that is something that we have to know and the beauty of this is that once it was resolved this idea of planck constant you know planck gave that constant for in order to explain this einstein used it very intelligently to understand photoelectric effect and later

bohr put it into even greater use and a fantastic use by applying it to the atom and they actually resolved the problem of the

so called stability when i am using the word 30 result problem that of course is in a very very qualitative way you would have to study quantum mechanics at great depth and in great detail is it ok but still you should be able to actually understand at least qualitatively whatever is happening

so if i come back to my slide whatever i am showing you i am going to discuss after the photoelectric effect rutherford scattering planetary model of the atom and the bohr model is that ok where you have quantization of angular momentum quantization of energy and atomic transition and

so on and

so forth and after that we are going to look at the interior of the atom

so there is the beauty initially rutherford bombarded the gold foil with alpha particles and he showed that most of the atom is empty a similar experiment was done by hofstatter with electron beams and he showed that we can actually resolve the structure of the nucleus it is of the order of the size it sizes of the order of 10^{-15} meters that is what we are going to do and there we are going to study the properties of the atomic nucleus protons neutrons why are some nuclei stable some are why are some nuclei unstable we are going to study the famous alpha beta gamma t case fission and fusion after studying fusion i am going to give you an idea actually of how we can understand the fact that sun has been able to produce such an enormous energy for the for billions of years and you will continue to live for a few billion years we are going to discuss that and then of course there is an important part of nuclear fission and fusion reactors i am not going to spend too much time on that because there is not much to discuss except the matter of detail i may just hint at that and that should be essentially the course which is contained between chapters 11 and 13.

so we are not going to hurry up we are going to take our time and we are going to study them for those of you who feel that okay this is all there in some exotic nature somewhere deep subatomic physics why do i need quantum mechanics at all what is the role of you know planck's constant or black body radiation or photoelectric effect for everyday life you should understand that impact of quantum physics actually transcends everything is that ok it is used everywhere today and our later latter part of the 20th century and the beginning of 21st century would be nowhere without quantum physics

so let me remember in your future chapter on semiconductor devices that you are going to study is that okay all the phenomena are based actually on quantum mechanics classical mechanics cannot explain and you know all of modern technology is actually based on semiconductors and its various avatars that is what we have

so i have listed some of them to you in this slide your laptops and computers smartphones music recording systems home appliances or for that matter in medicine your you know mri magnetic resonance amazing pet cats capacity scans etc etc all of them are based on developments in quantum physics in other words today we live in a world where quantum physics not only deepens our understanding into the microscopic microscopic world or the microcosmic world you know of atoms nuclei and elementary particles it also helps us to produce better and better instruments to make our life easier is that okay

so that is something that we have to know within physics itself it covers various phenomena in particle physics in nuclear physics in atomic and molecular physics in condensed matter physics and there is something even called as quantum thermodynamics or quantum statistical mechanics it tells you how to

understand cosmology what the early universe was what will be the fate of the universe what was the beginning of the universe is that okay all these are intricately tied in fact completely tied to our understanding of quantum mechanics and the beginning of quantum mechanics is something that we owe to what planck and einstein did historically although planck introduced the concept of planck constant he did not believe in the existence of photon the real impetus you know the real belief in the concept of the photon was actually from einstein who believed that its really existing it is not a mathematical construction and many people thought that it was actually not being very sensible when he made that statement is that ok you will get a glimpse of that when i discuss my photoelectric effect later but that is how it is is that ok so that means all the developments that have taken place in the 20th century and taking in place in the 21st century woe a lot to plaque and einstein of course einstein also gave a special relativity and general relativity his three great papers were all published in 1905 that is why it is called annulus miraculous year of miracles as far as physics are concerned is that okay he wrote special relativity he wrote a paper on photoelectric effect and he wrote a paper on brownian motion which established the molecular hypothesis of boltzmann so they were fundamental papers and you are going to study them slowly as advance in your career in physics but then if at all we have to begin we have to start with photoelectric effect and that is what we are going to do

so as i told you it tells us about the physics of the interior of stars for example helmholtz made a calculation and said that lifetime of the sun is not more than 21 million years and it cannot live for more than another 5000 years whereas we know that sun has been there for at least 4.

6 billion years ok few million years ago there were actually dinosaurs and things like that and age of the earth was a big problem for example kelvin said that earth cannot be more than 100 million years old helmholtz said that sun cannot be more than 21 million sword how can earth be older than the sun that is first contradiction and more importantly we know that earth has been there for at least 4.

5 billion years old how do i know that i know that because of the evidence coming from the fossils and rocks and so on and

so forth all these issues get resolved about the you know physics of this planetary system physics of the earth once we understand quantum phenomena and radioactivity fusion and fission that is something that you should know therefore in other words our scale is enormous starting from let us say 10 to the power of minus 15 meters to probably 10 to the power of plus 15 or even more let me stop there there are 30 orders of magnitude there is no theory whose scope is as large as that as deep as that and that is something that we are going to study

so to summarize whatever i have told you we have studied laws of motion we have studied thermodynamics we have studied properties of matter we have studied waves and oscillations and we have actually studied that electrostatics and energy in electromagnetic field magnetostatics and energy stored in magnetic field i am summarizing whatever i worked out for you induction displacement current electromagnetic waves we are going to make use of them is that okay and once you brush all those things read faraday's law of induction see how energy is stored in capacitors how energy can be stored in inductors look at them there is a beautiful analogy you know between mass spring constant etcetera etcetera of an oscillator and capacitance and inductor and resistance of an electrical circuit resistance is like a frictional force damping force was that okay when you do that if you come back from the next lecture onwards lecture two we will

start our photoelectric effect with basic preliminaries

so at this point i am going to stop

so although it might appear to be some kind of a story actually it is more than a story it is more than history because i want you to go back open your 11th and 12th standard books read your chapters on gravitation electricity magnetism mechanics and thermodynamics and optics where you are assumed you know that light is array you did not even use the fact that it was a wave is that okay i mean assimilate all that remember that and you come then you will see how radical photoelectric effect how radical a theory that photoelectric effect gave rise to and that we will take up in the next lecture okay good bye you