Hello everyone. In this module we will discuss Max Born's interpretation of the wavefunction and the probability concept. This is model number 11. First I will just discuss introduction to the wavefunction and then discuss Max Born's Interpretation of the wavefunction, and I will also mention statistical interpretation and philosophy of quantum mechanics. So the learner will be able to understand the significance of the wave function and comprehend the Max Born's interpretation of the wavefunction and it's probabilistic interpretation.

The wave function is the wave associated with the particle. It is denoted by capital Psi, which is a function of position and time.

These functions are complex mathematical functions. The wavefunction being complex is not a weak point in quantum theory. Actually it is desirable as we should not attempt to give a physical existence to wave. So we should not ask questions as to what is waving or where is it waving in. Actually nobody has a fundamental understanding of what a wave function is, but using the wavefunctions we can predict all the properties of the particles and actually the wave function contains all the information which the uncertainty principle allows to know about the associated particles. So this concept of the wave function is the key in quantum mechanics. Once we know the wavefunction, we know all the properties of the particle that we wish to know.

Now the question is how do we obtain the wavefunction? We obtain the wavefunction by solving the Schrodinger equation. So this is a one-dimensional time independent Schrodinger equation. Which is minus h cross square by two m into partial d square Psi by partial dx square plus V Psi is equal to ih cross partial d Psi by partial dT. This is a second order partial differential equation. The wave function is nothing but the solution of this differential equation. This differential equation is not easy to solve, but we can also obtain the wave function by solving the time independent Schrodinger equation. If the potential is time independent and it's a constant, then we can convert this time dependent Schrodinger equation to time independent Schrodinger equation, which is given as over here. Which is minus h cross square by two m d square psi by dx square plus V psi is equal to E psi.

Where this small psi is a function of only position and is time independent, and this small psi is called the eigenfunction.

So there is a relation between the wave function and the eigenfunction. That is, the wave function is equal to the product of the eigenfunction which is function of position and phi which is a function of time. Which is equal to psi (x) into exp to the power minus -iEt by h cross. E is the total energy. We have just briefly introduce the Schrodinger equation. This will be

done in detail when we do Unit 4 of this course. So once we solve this time independent equation, we obtain the eigenfunction. So we plug in the eigenfunction over here to get the wave function and if once you get the wavefunction, we're done.
Next we discuss the Born's interpretation of the wave function.
There's a basic connection between the properties of the wave function and the behavior of particle which is expressed in terms of the probability density.
So there is a relation between the probability density and the wave function, which is P is equal to Psi* Psi. Psi* is the complex conjugate of the wave function.
So the probability density is defined as probability of finding a particle in a unit length. Now P into dx is the probability that the particle will be found in the range between x and x plus dx. So pdx is equal to Psi* Psi which is equal to mod Psi square dx. Again, this is the probability of finding a particle in the range between x and x plus dx. So as this is a probability, it does not have any units. The probability density on the other hand, has units meter inverse. Now, what is the justification of Born's postulate? The particle in motion and the wave associated with the particle should be connected in space. So the particle must be in some location where the wave function has an appreciable amplitude. Where the wave function has an appreciable amplitude the probability density also should have an appreciable amplitude, as you can see in this diagram here. The probability of finding the particle in this region should be large compared to at the ends and the wave function is a complex function, but Psi* Psi will be always real and positive. Now we'll discuss something about the statistical interpretation and philosophy of quantum mechanics.
So as we have seen before, Psi* Psi dx is the probability of finding a particle in the range between x and x plus dx. So if you want to find the particle, let's say between a and b, the probability of finding a particle between a and b is given by integral from a to b mod Psi square dx. This plot here is a plot of Psi square versus x. The probability density for different points in x.
So as you can see here, the probability for finding the particle at this point A is 0. The probability of finding the particle at point B is maximum, and so on. Now suppose you would like to measure the position of the particle and let's say after measuring you find the particle is at point C. So now the question is, where was the particle just before the measurement?
In this case there were three positions that physics took in the last century. One position is the realist position that the particle was at C all along. This view was taken by Albert Einstein. What he said was quantum mechanics although it is a correct theory, but it is incomplete. So some additional hidden variables or hidden information is required to completely describe the

state of the system. Next position is the orthodox position.
The particle wasn't really anywhere. This view was taken by Niels Bohr and
his followers and as Bohr was from Copenhagen this interpretation is called
Copenhagen interpretation of quantum mechanics. In this position, the
particle does not have a precise position prior to the
measurement, so it's the act of measurement that compels the particle to assume a
definite position. The third position is the agnostic position,
refused to answer. In this case, it does not actually matter whether the particle had a precise
position prior to the measurement or not. By only the act of measurement we can measure
whether the particle is there or not, so it actually does not matter where the particle was before
we make a measurement. In 1964, John Bell shocked the physics community and showed that
it makes an observable difference whether the particle had a precise position prior to
the measurement or not. So it does make a difference. Because of this the agnosticism was
eliminated as a viable option and it was left with
experiments to decide whether the realist position is the
correct interpretation or the orthodox position is the correct interpretation.
Now the experiments have decisively confirmed that the orthodox position or
interpretation is the correct one. The Bell theorem also showed
that any local hidden variable theory is incompatible with
quantum mechanics. So if we have a local hidden variable
theory, then quantum mechanics is not just incomplete, but it
is wrong. So we cannot have any local
hidden variable theory because quantum mechanics has never been proven wrong.
Of Course there are other formulations that are possible.
We can still have a nonlocal hidden variable theory, such as that
of David Bohm and also other formulations like the many world
interpretation, but they are somewhat more extreme than the quantum mechanics itself.
So we have three formulations, one is hidden variable theory.
which is not possible. Then we have nonlocal hidden variable
theory, and we also have theory which contains no hidden variables and no hidden
information, and that is standard quantum mechanics. So according to quantum
mechanics, our world is nonlocal, and the nonlocality
shows in the form of collapse of the wavefunction. If we make a second
measurement immediately after the first, the measurement must
return the same value. So if you measure the position
of the particle again it must show C, provided
you make the measurement immediately. If you wait for some
time, then the wave function might evolve according to time
dependent Schroedinger equation. What happens here is that the first measurement radically
alters the wave function so that the wavefunction is sharply peaked about C, as you can see
here. So this wave function which was
there before the measurement is altered and now it's sharply peaked about C.
So we say that the wave function collapses upon measurement to a

spike at the point C. So this is called the collapse of the wavefunction. So we have two physical processes going on over here. One process is the normal process where the wave function evolves in time according to Schrodinger's time dependent equation and we have the other process in which the wave function collapses suddenly and discontinuously. These are some important differences. Thank you.