**Plan for a Talk on Quantum Mechanics**

**Introduction:**

Lay out what is to be explored and explained

First, examples of where quantum mechanics is required

Then Schrödinger equation, examples of use

Heisenberg uncertainty principle

Entanglement

**Double slit experiment:**

Classically, waves generate interference, particles generate two Gaussians

Mathematics involving phasors - interfering complex waves worked

Magnitude squared of resulting wave gives correct distribution

Electrons, even one at a time, generated interference - infers wavelike nature

Same occurs with photons – one at a time generates interference

Marking the photons destroys the interference – particle-like nature

Classically, it is known two orthogonally polarised waves do not interfere

Knowledge of the slit passed destroys interference

**Structure of Atom:**

Classical electromagnetism predicts unstable atom – electrons would spiral inwards

Discrete spectral lines show atoms absorb and emit only at certain frequencies/energies

Describe electrons as standing waves around the nucleus

Discrete energy levels – only certain energies are possible

The discrete jumps between these levels give rise to the spectral lines

Full Schrödinger equation gives atomic orbitals used in chemistry

**Schrödinger Equation:**

Obscure to derive but is now a postulate of quantum mechanics

Time-independent Schrödinger equation applies when the energy is certain

When particle is confined, discrete energy levels emerge as standing waves

Notice that definite-energy particles are spread out

**Heisenberg Uncertainty Principle:**

Show wave functions of definite momentum

Probability density at all positions is the same

Qualitative uncertainty principle

Show variances of position and momentum for a general wave function

Show product of standard deviations of x and p is always greater than ℏ/2

Neither position nor momentum can be known exactly

Explain why quantum effects don’t scale up to the macroscopic world

**Pauli Exclusion Principle:**

Show how many different states there are per energy level of an atom – 2, 8, 18, etc.

Explain that periodic table shows how those states are filled one by one

Periodic table shows that all electrons do not fall to the lowest energy level

This shows that no two electrons can be in the same state

Changes to one electron has small effects on other electrons

This is true for all fermions, but not true for bosons such as photons of light

This is why lasers can be constructed – many photons in the same state

**Entanglement:**

Explain that entanglement can occur in a system of multiple particles

Entangled particles can’t be described fully individually

The whole system must be taken into account

Entanglement leads to correlations between the particles’ properties

However, each individual entangled particle’s property is random

Show examples – spins of electrons in atomic orbitals and SPDC photons

Show quantum eraser – entangled photons created by SPDC – explain SPDC

The photons are entangled and therefore have opposite polarisations

They have horizontal and vertical polarisations or clockwise and counter-clockwise polarisations

Photon A goes to a detector that can measure its polarisation

Photon B goes to a double slit in front of a detector – the slits have polarising filters in front of them

Slit 1 has a clockwise circular polariser and slit 2 has a counter-clockwise circular polariser

Suppose photon A is not measured:

Photon B has either clockwise or counter-clockwise polarisation

Photon B can therefore pass through either slit

Photon B has therefore not been marked and an interference pattern emerges

Suppose photon A is measured to have clockwise or counter-clockwise polarisation:

Photon B has the opposite polarisation and can only pass through one of the slits

Photon B has therefore been marked and no interference pattern emerges

Suppose photon A is passed through a linear polariser before being measured:

Photon A is measured to have vertical or horizontal polarisation

Photon B has the opposite polarisation and can now pass through either slit

This is because a linear polarisation is a combination of clockwise and counter-clockwise polarisation

Photon B has therefore not been marked and an interference pattern emerges

The information about which slit photon B passed through has been ‘erased’

Explain that information from both detectors was required to show the effect

Explain why this can’t be used to send information faster than light