The Two Slit Experiment

Light *and* ***matter*** *are both* ***single*** *entities, and the apparent* ***duality*** *arises in the* ***limitations*** *of our* ***language****.*

Heisenberg

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Introduction

Aim:

The double-slit experiment in order to learn about the concept of wave - particle duality, the cornerstone principle of quantum mechanics.

Objective:

To understand the nature of elementary particles by carrying out the famous double slit ***experiment*** with **sands**, **light** and **electrons**.

Overview

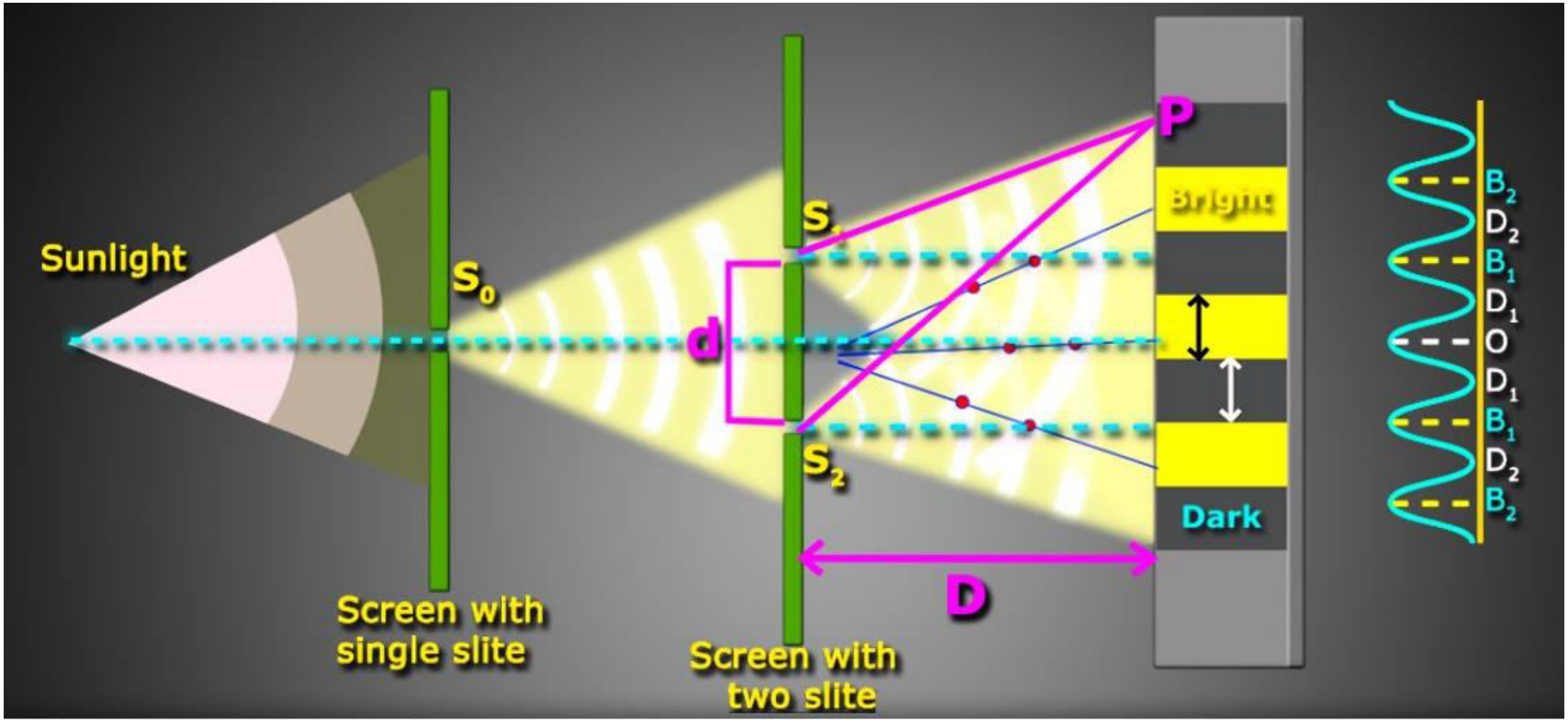
Thomas Young (1800):

• **Attempt to resolve whether light is a particle or a wave**

•**Small size two close slits, produced distinct bands of color separated by dark regions**

•**Interference patterns.**

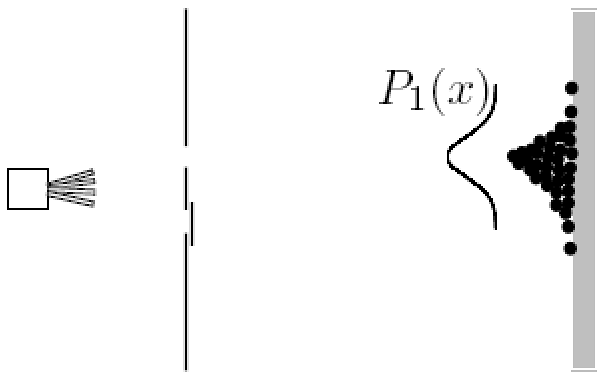
•Confirm, **light were acting like a wave**.



Classical Particle Case

Doing same experiment with grains of sand by shifting the slits in 90 degree. Each particle is either going through one slit or the other.

Bullets: Particle Case



Firing bullets at the screen when only <u>one</u> slit is <u>open</u>.

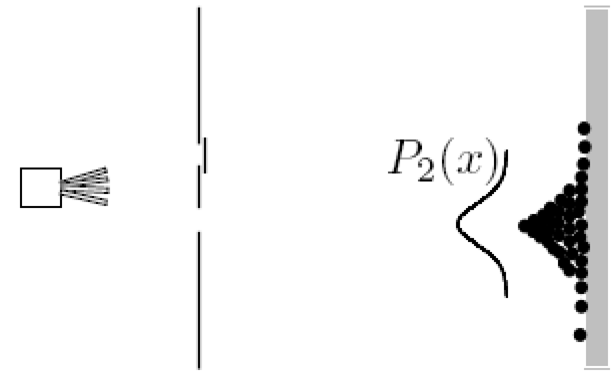
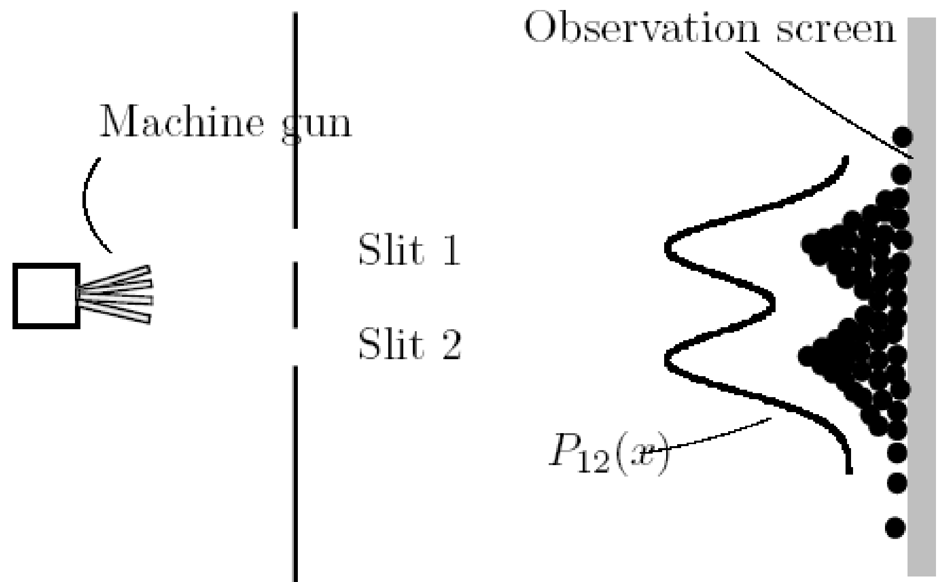


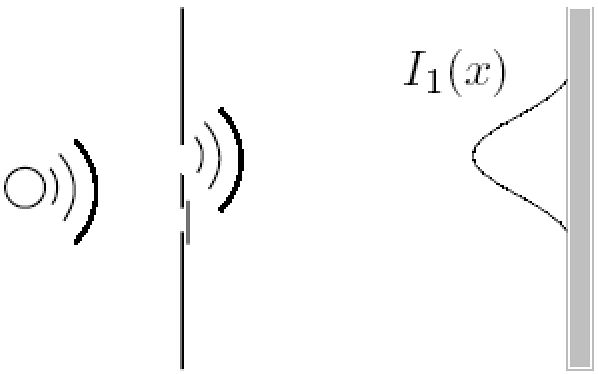
Fig: Curves P(x) give the <u>probability densities</u> of a bullet passing through slit and striking the screen at x.

Both slits are *OPEN*



$$P_{12}(x) = P_1(x) + P_2(x)$$

Light: EM Wave Case



Only one slit is open

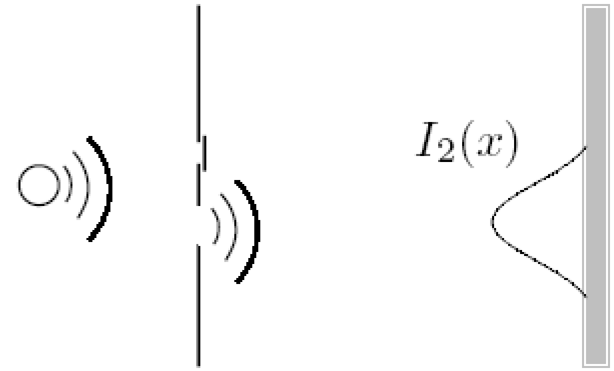
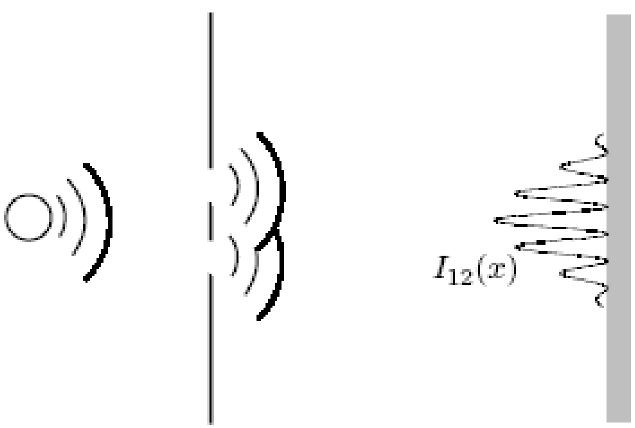


Fig: Curves I(x) give the intensities of the waves passing through slit and reaching the screen at x.

Usual two slit interference pattern



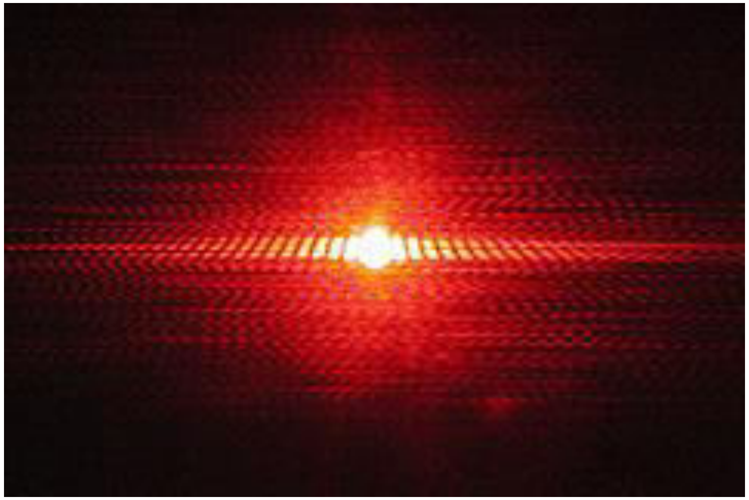
$$I_{12}(x) = I_1(x) + I_2(x) + 2\sqrt{I_1(x)I_2(x)}\cos\delta$$

- **Different from what we obtained for bullets**
- **There was no interference term**

LASER: Wave Case

Interference of light experiment:

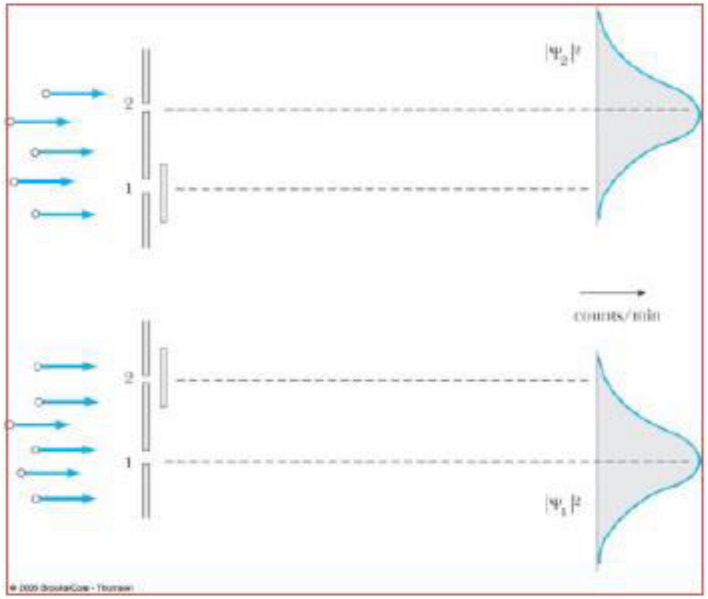
Using LASER, single and double slits.



Laser beam through a single slit

Laser beam through a double slit

Electron: Quantum Case



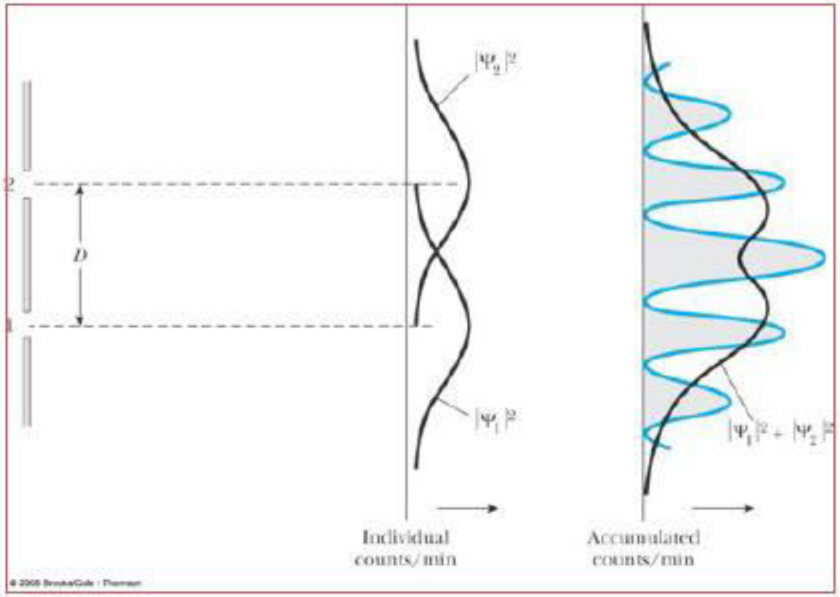
Only one slit is open

Wave function for electron passing through slit: ψ

The sum of the patterns with one slit closed at a time is not equal to the interference pattern with both slits open!

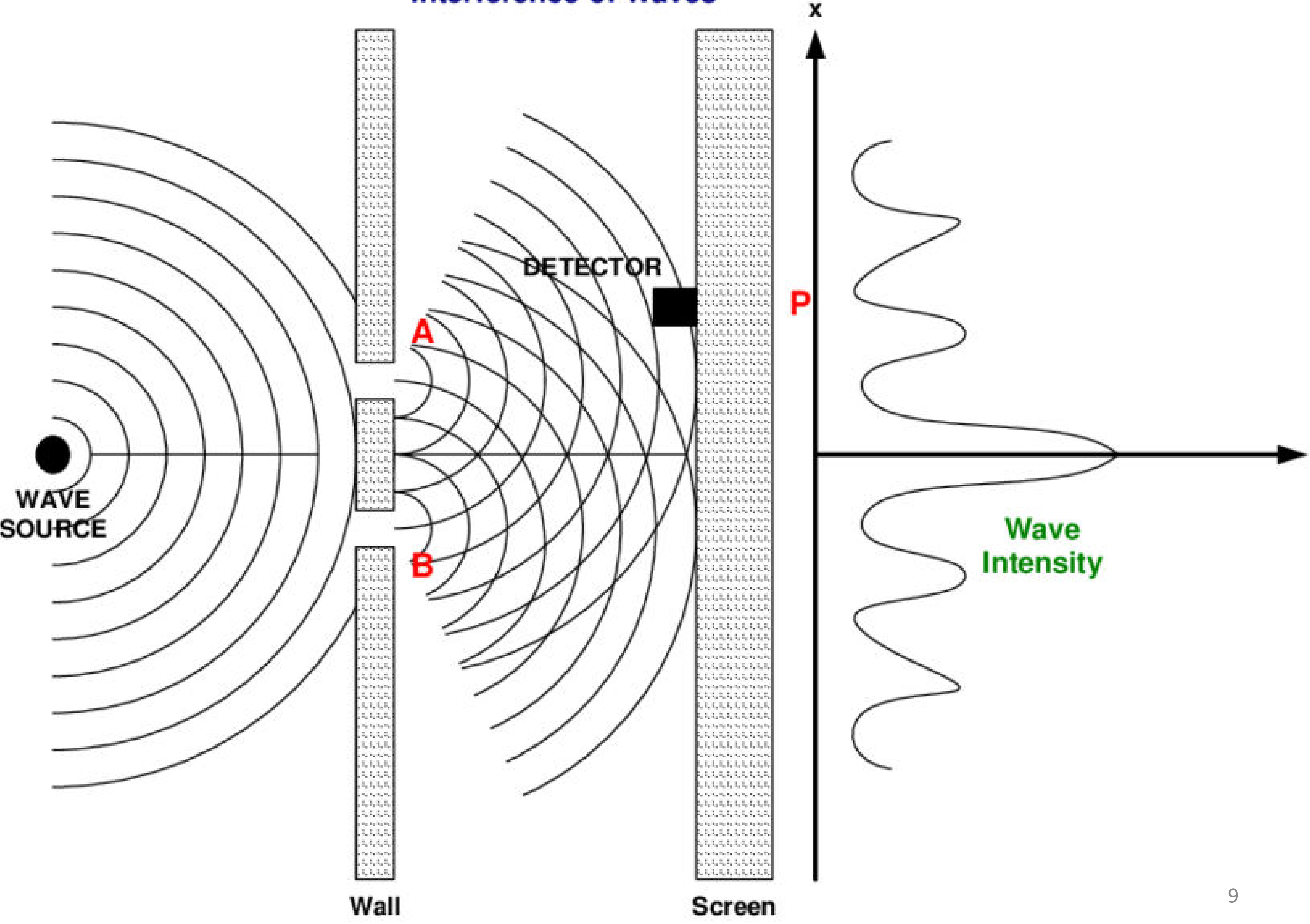
$$\left|\psi_1+\psi_2\right|^2 \neq \left|\psi_1\right|^2+\left|\psi_2\right|^2$$

Interference pattern cannot be the result of an electron going through one slit or the other, but being present at both slits!



Electron is passing through slit 1 or slit 2: Use a spy (Detector)

Interference of Waves



Summery

Case	Wave function	Counts at Screen
Detector ON: Electron is measured to pass through slit 1 or slit 2	Ψ_1 or Ψ_2	$\lvert\psi_1\rvert^2 + \lvert\psi_2\rvert^2$
Detector OFF: No measurements made on electron at slits	$\Psi_1 + \Psi_2$	$\lvert\psi_1 + \psi_2\rvert^2$

- **Double slit experiment shows wave-particle duality**
- **Matter waves can be in a superposition of waves at two positions!**
- **Measurements can disturb the state of a quantum object**

Reference: The Feynman Lectures in Physics, Vol. III