Quantum physics

- Phenomena occurring on atomic and subatomic scales cannot be explained outside the framework of quantum physics

- There are many phenomena revealing quantum behavior on a macroscopic scale, e.g. quantum physics enables one to understand the very existence of a solid body and parameters associated with it (density, elasticity, etc.)

- However, as of today, there is no satisfactory theory unifying quantum physics and relativistic mechanics

- In this course we will discuss non-relativistic quantum mechanics

Kindergarten stuff

- Is light a wave or a flux of particles?
- Newton vs. Young

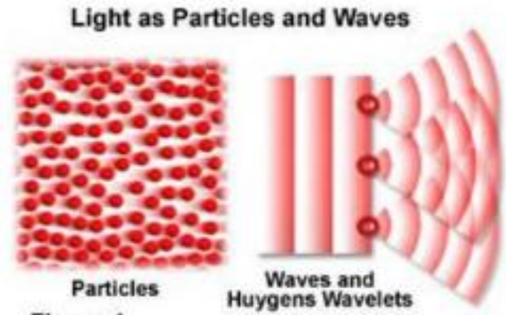
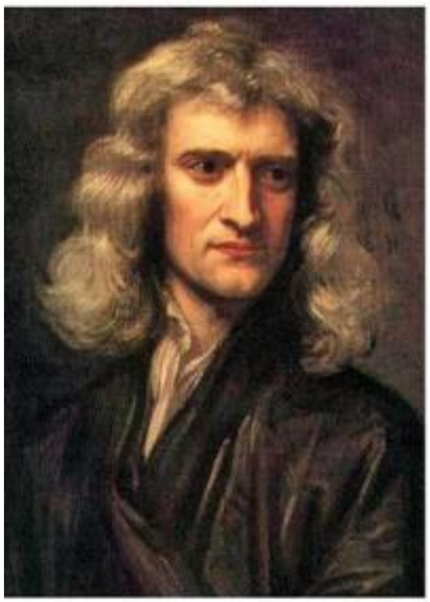


Figure 1

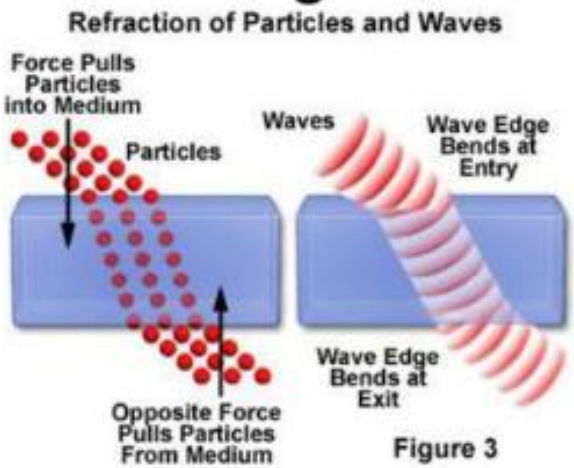


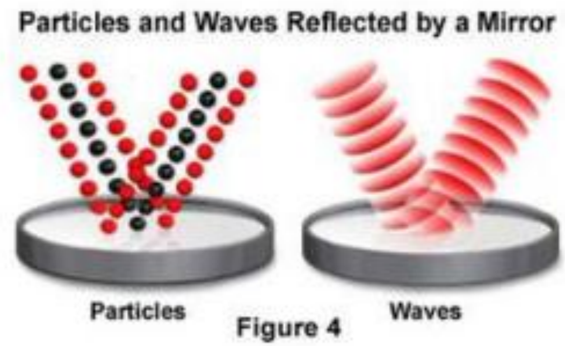
Isaac Newton
(1642 – 1727)

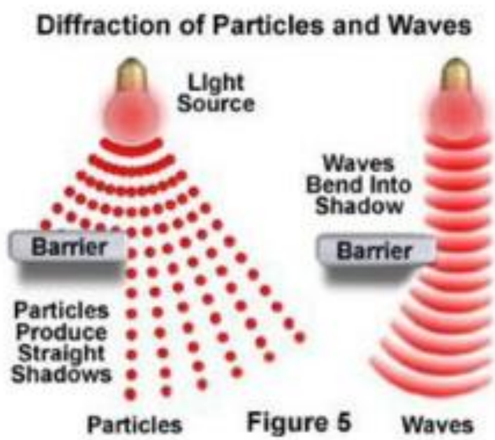
Thomas Young
(1773 – 1829)

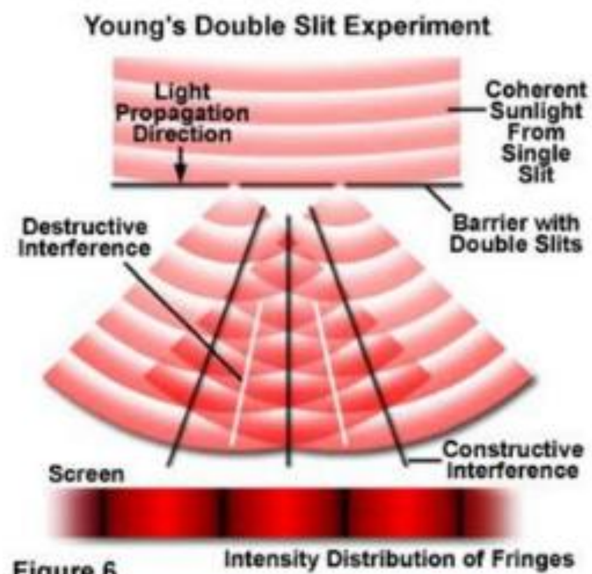
Kindergarten stuff

- Is light a wave or a flux of particles?



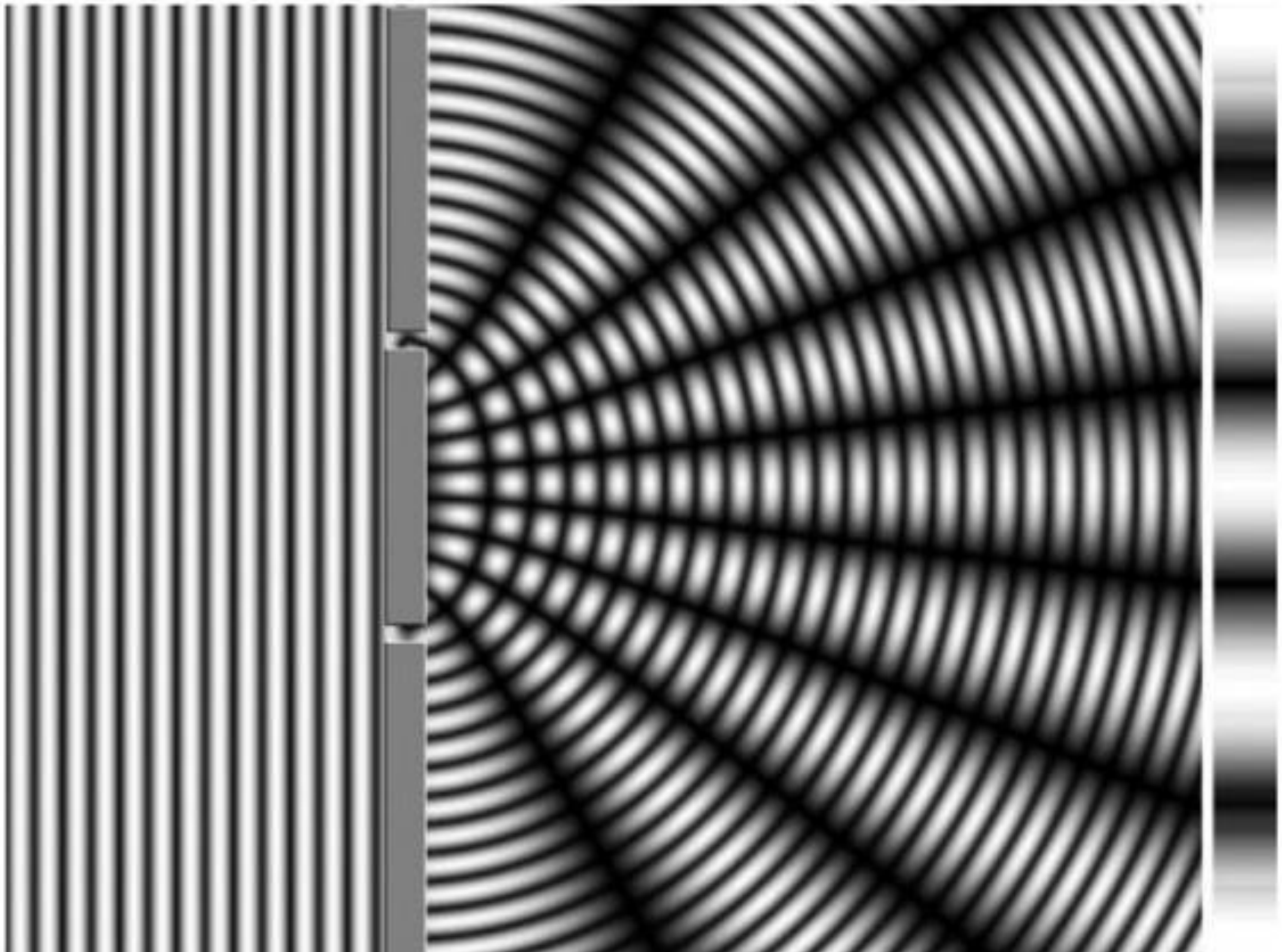




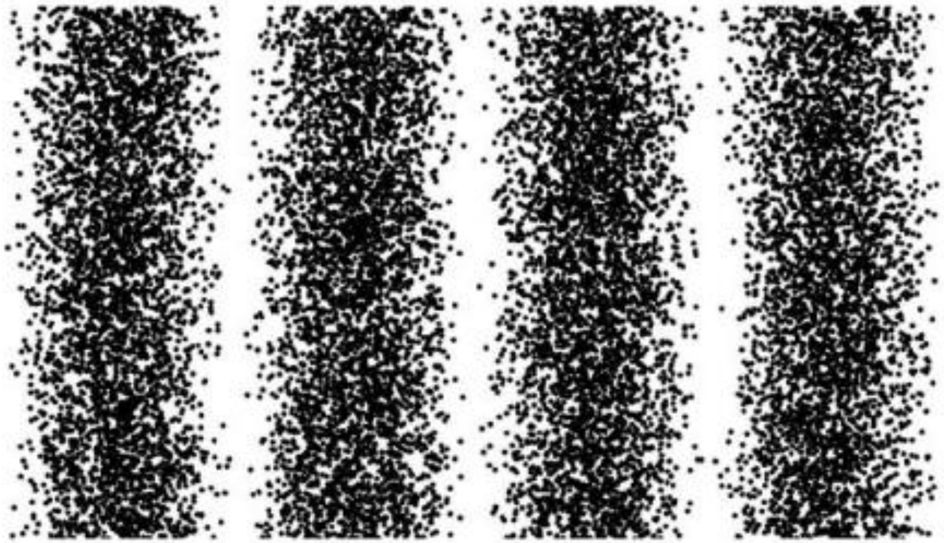


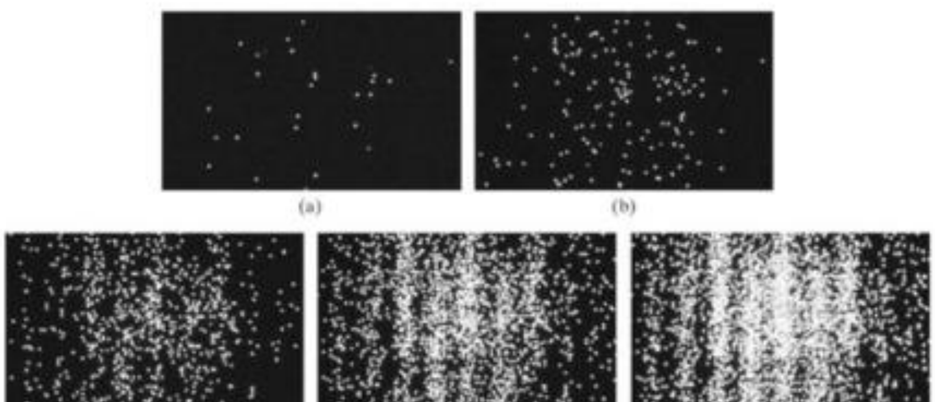
Kindergarten stuff

- Is light a wave or a flux of particles?

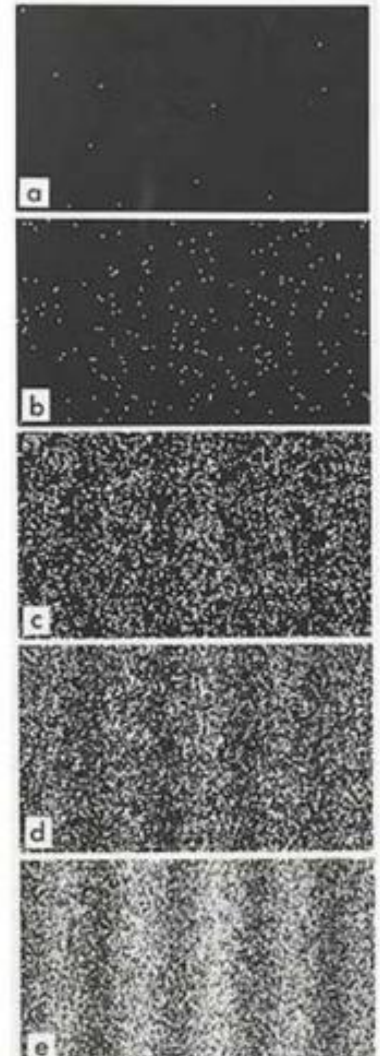


Wave-particle duality

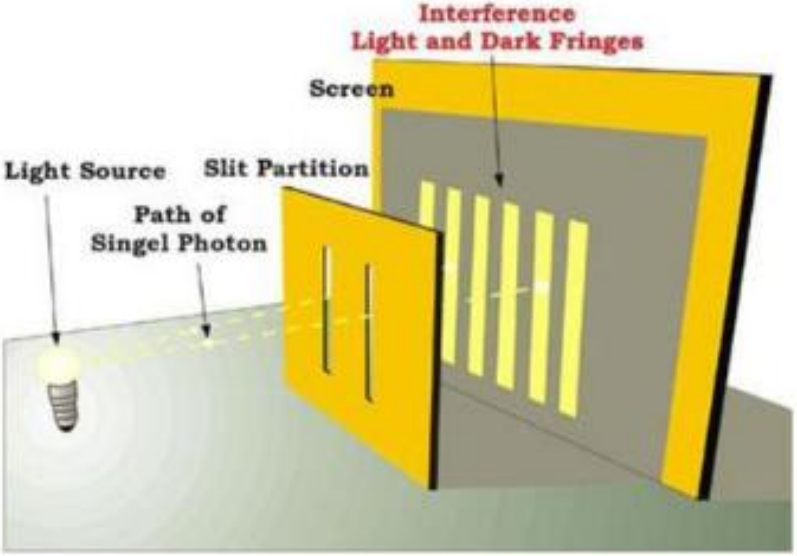


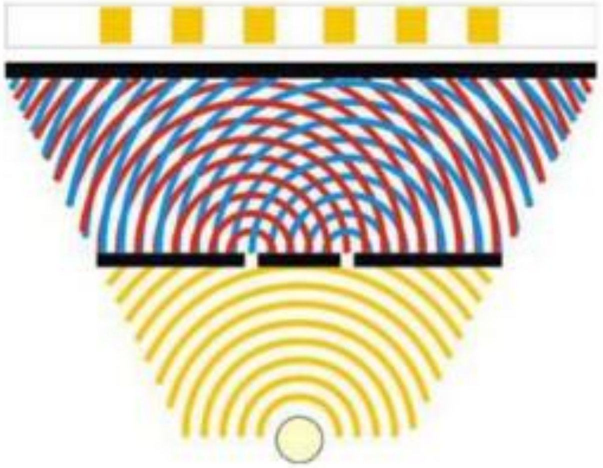


(a) (b) (c) (d) (e)



Wave-particle duality





The wave function

- In quantum mechanics the object is described by a **state** (not trajectory)

- The state is characterized by a complex **wave function** Ψ, which depends on particle's position and the time

- The wave function is interpreted as a **probability amplitude** of particle's presence

- The **probability density** (probability of finding the object at time *t* inside an elementary volume *dxdydz*):

$$\left|\Psi(x, y, z, t)\right|^2 dxdydz$$

The wave function

- Let us first consider 1D systems

- Then, the probability of finding a particle between *a* and *b*, at time *t*:

$$\int_a^b \left|\Psi(x,t)\right|^2 dx$$

- Since the particle should be somewhere:

$$\int_{-\infty}^{+\infty} \left|\Psi(x,t)\right|^2 dx = 1$$

- This is called normalization

- Wave functions normalized in this fashion describe physical quantum systems

Schrödinger equation

- **In 1926 Schrödinger proposed an equation for the wave function describing the manner in which matter waves change in space and time**

- **Schrödinger equation is a key element in quantum mechanics**

$$i\hbar\frac{\partial\Psi(\vec{r},t)}{\partial t}=-\frac{\hbar^2}{2m}\left(\frac{\partial^2\Psi(\vec{r},t)}{\partial x^2}+\frac{\partial^2\Psi(\vec{r},t)}{\partial y^2}+\frac{\partial^2\Psi(\vec{r},t)}{\partial z^2}\right)+V(\vec{r},t)\Psi(\vec{r},t)$$

- ***V*** **– potential energy ("potential")**

- **Superposition principle applies**

Erwin Rudolf Josef
Alexander Schrödinger
1892 – 1987

Schrödinger equation

- In 1926 Schrödinger proposed an equation for the wave function describing the manner in which matter waves change in space and time

- Schrödinger equation in 1D:

$$i\hbar\frac{\partial\Psi(x,t)}{\partial t}=-\frac{\hbar^2}{2m}\left(\frac{\partial^2\Psi(x,t)}{\partial x^2}\right)+V(x,t)\Psi(x,t)$$

- Let us accept it as a postulate

- Shortly we will discuss its meaning

Erwin Rudolf Josef
Alexander Schrödinge
1892 – 1987