Quantum Mechanics I

PHY 3103

Dr Mohammad Abdur Rashid

Course site

tiny.cc/phy3103

tiny.cc/qm20

References

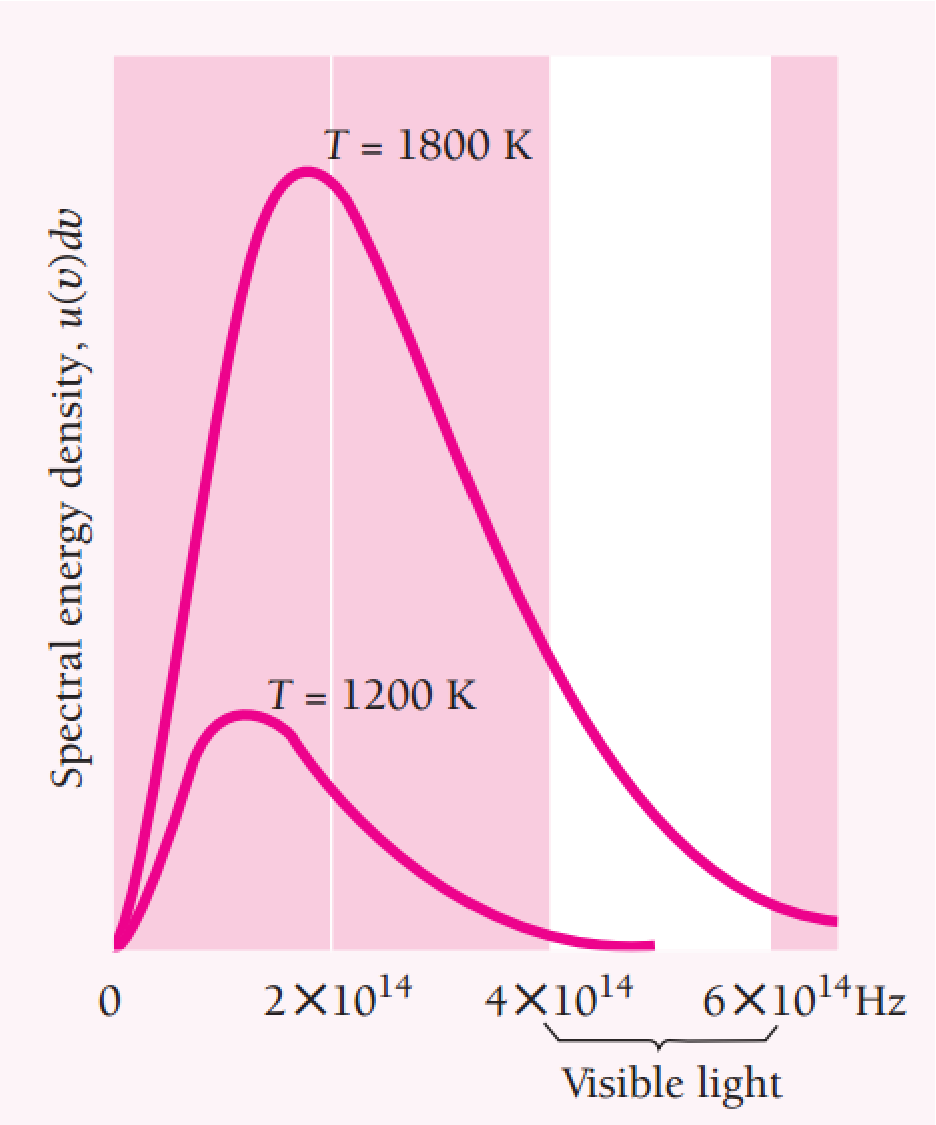
Quantum Mechanics (6th Ed.) – B.H. Bransden & C.J. Joachain

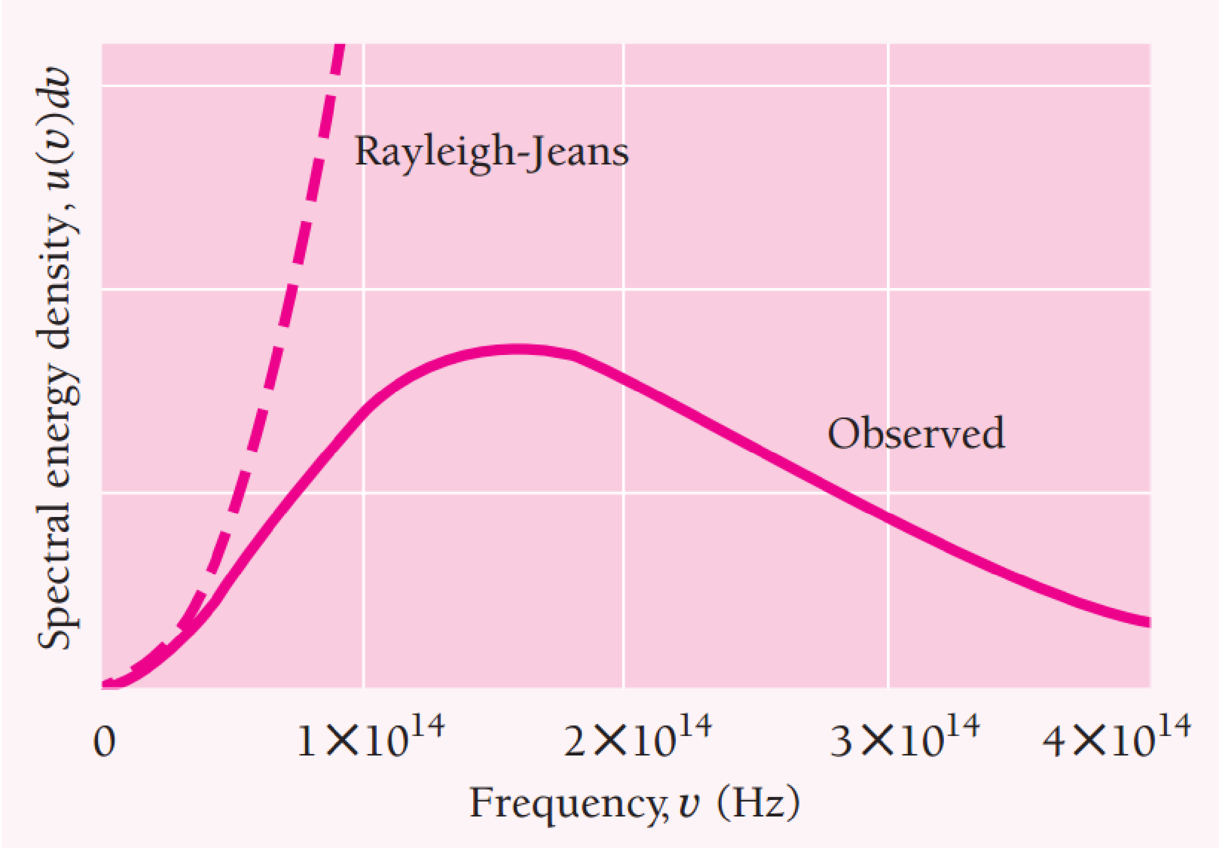
Quantum Mechanics (2nd Ed.) – Nouredine Zettili

Introduction To Quantum Mechanics (2nd Ed.) – David J. Griffiths

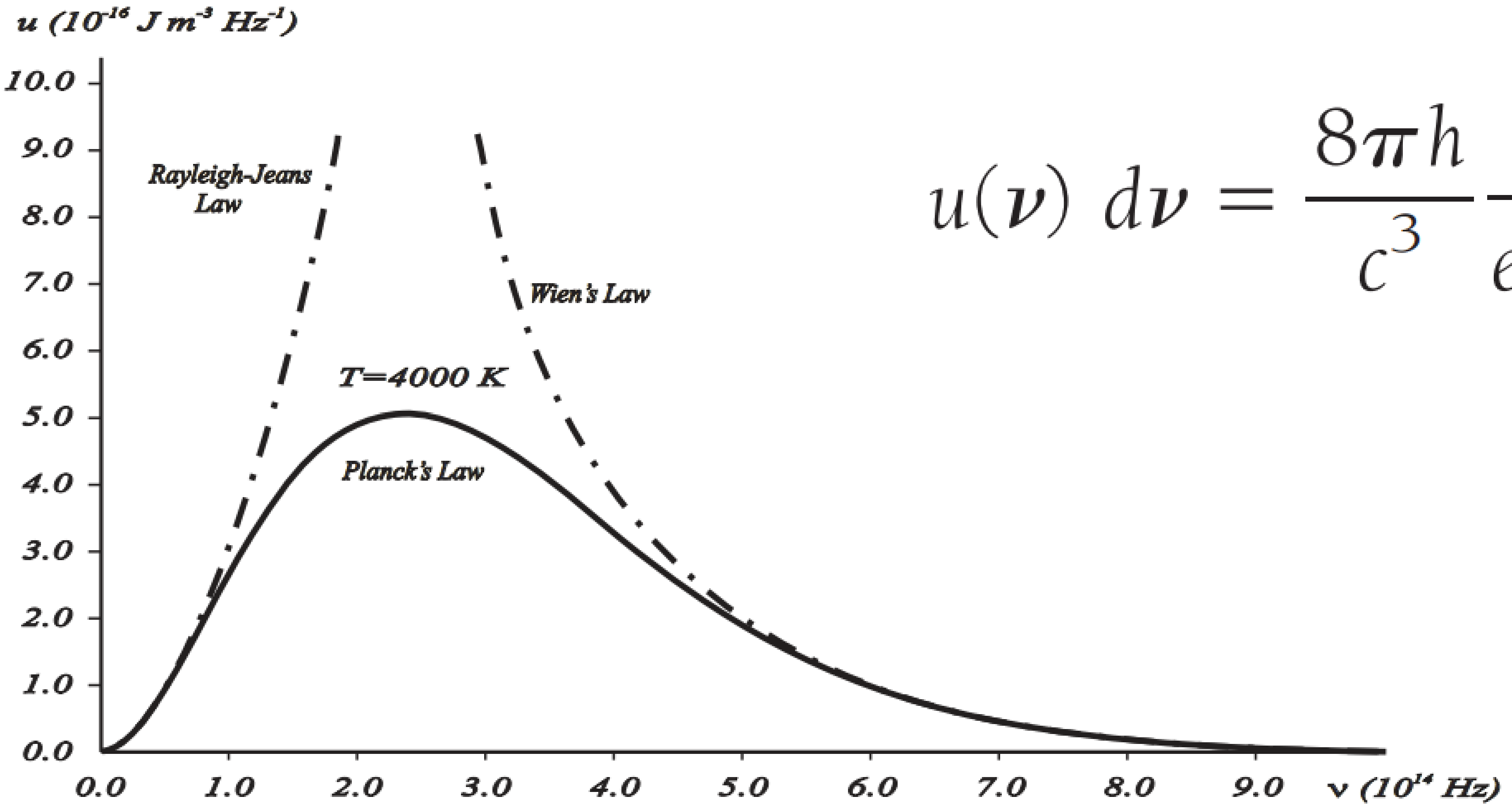
What is light?

Blackbody spectra





Planck Radiation Formula



$$u(\nu)\, d\nu = \frac{8\pi h}{c^3} \frac{\nu^3\, d\nu}{e^{h\nu/kT} - 1}$$

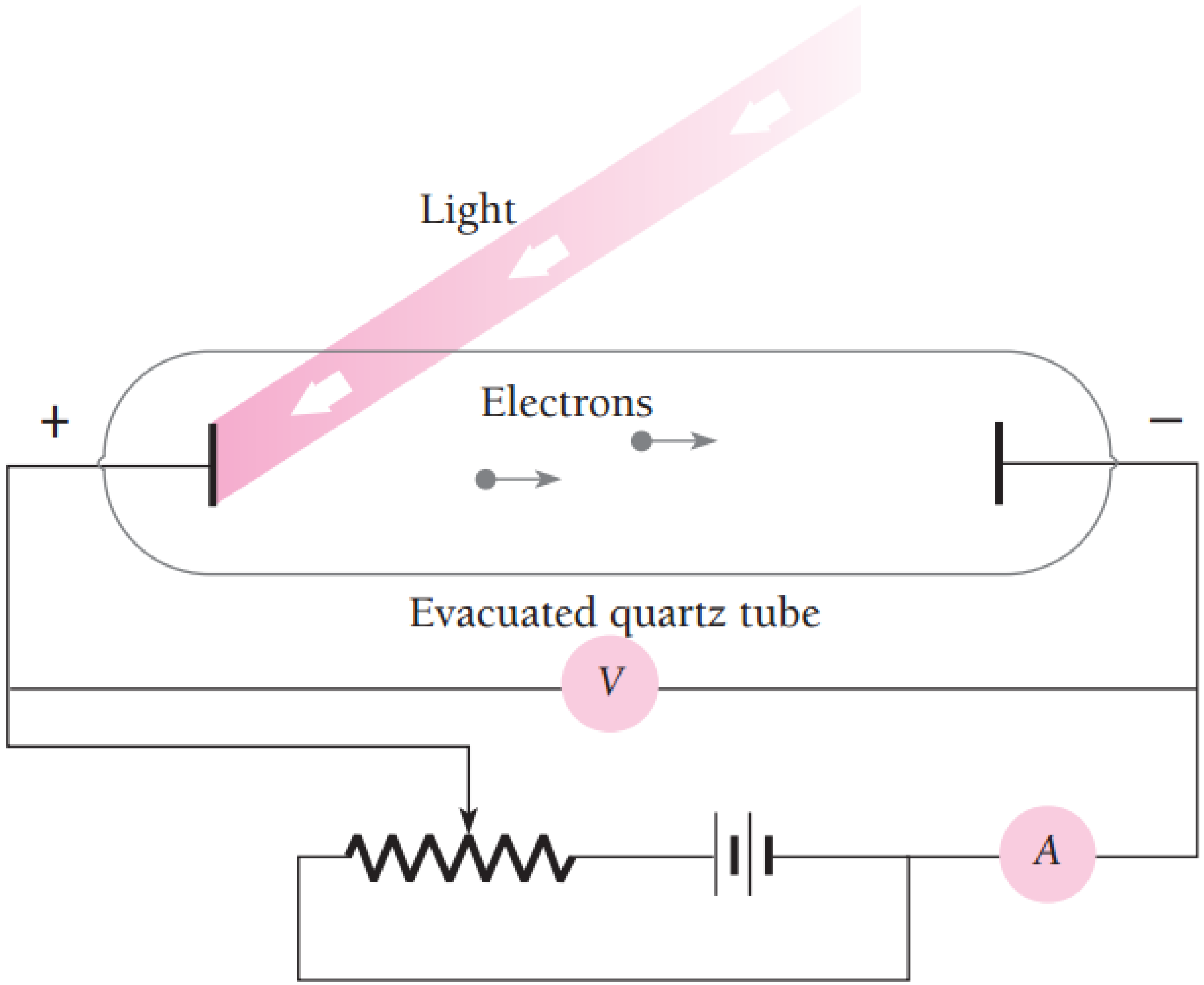
Planck Radiation Formula

$$u(\nu)\, d\nu = \frac{8\pi h}{c^3} \frac{\nu^3\, d\nu}{e^{h\nu/kT} - 1}$$

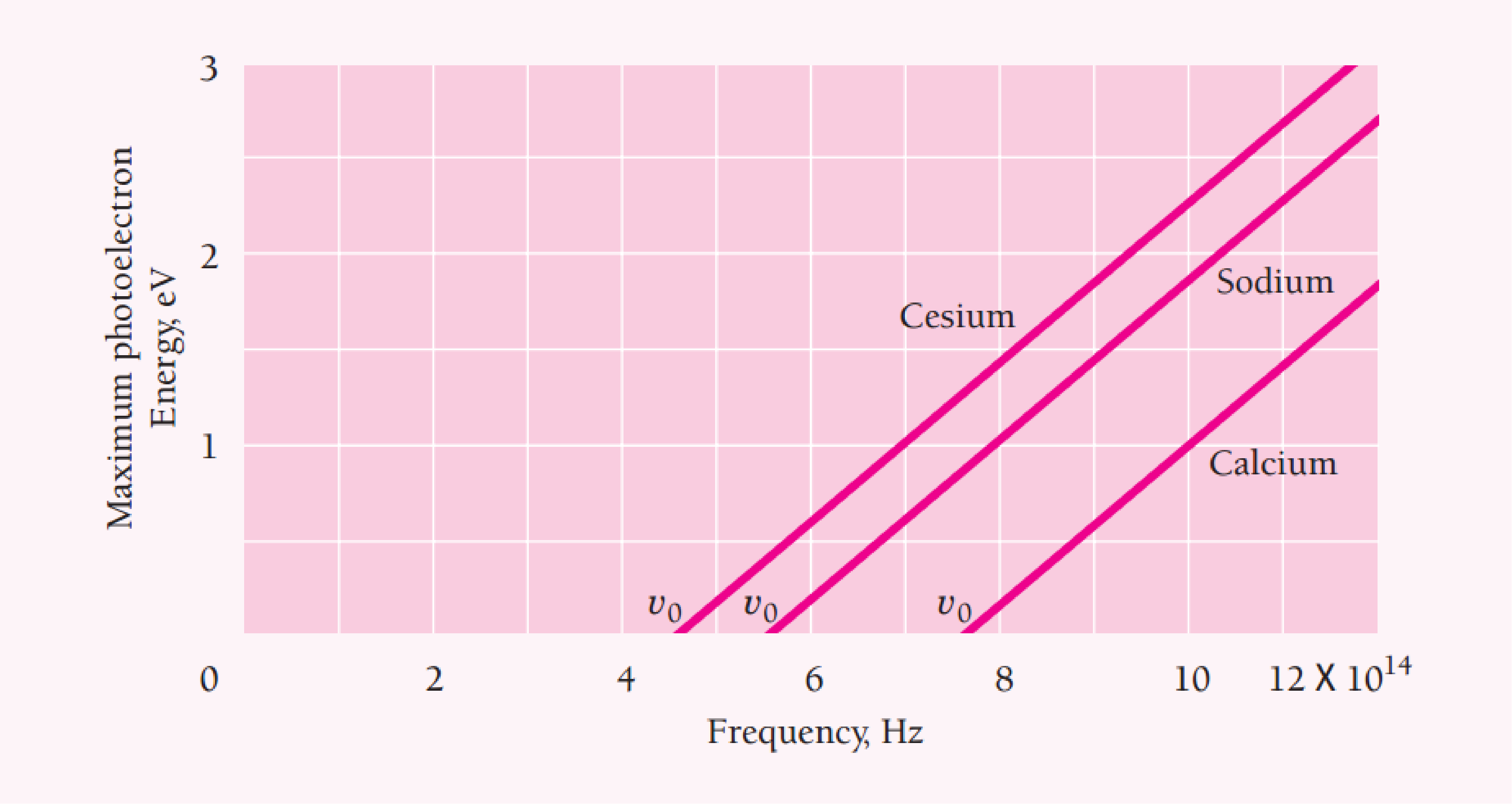
$$h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s}$$

$$\epsilon_n = nh\nu \qquad n = 0, 1, 2, \ldots$$

The photoelectric effect

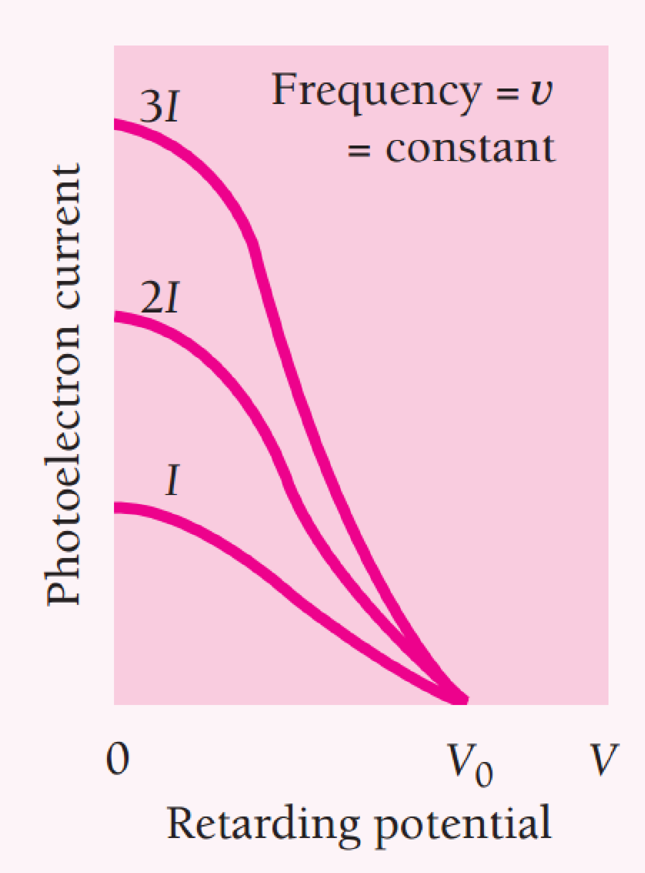


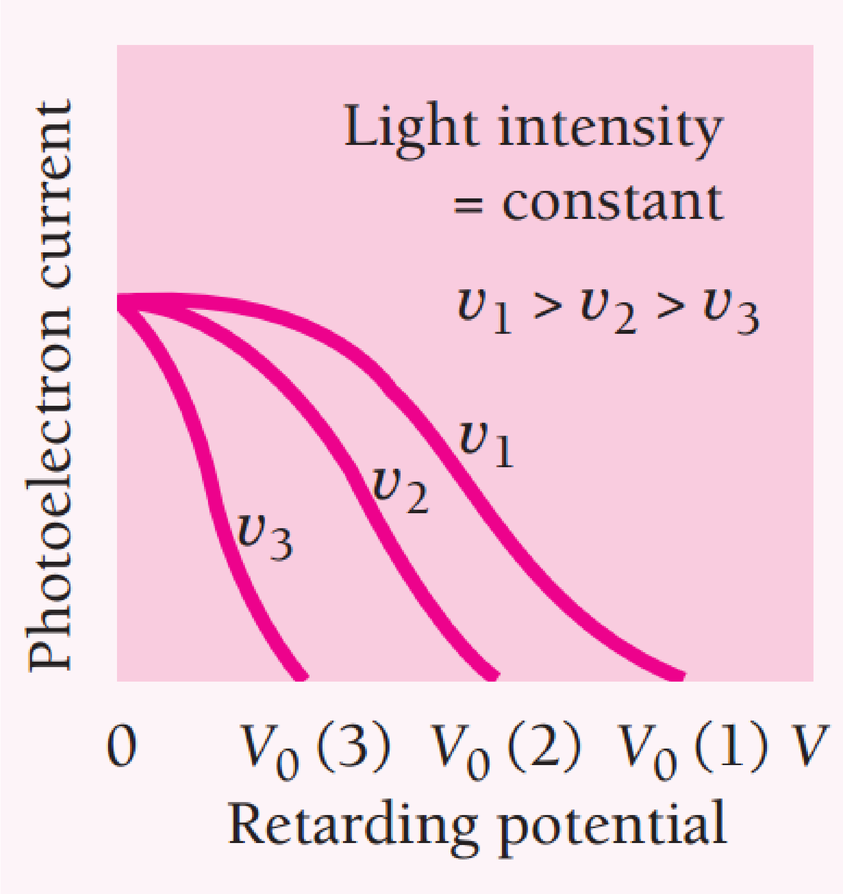
The photoelectric effect



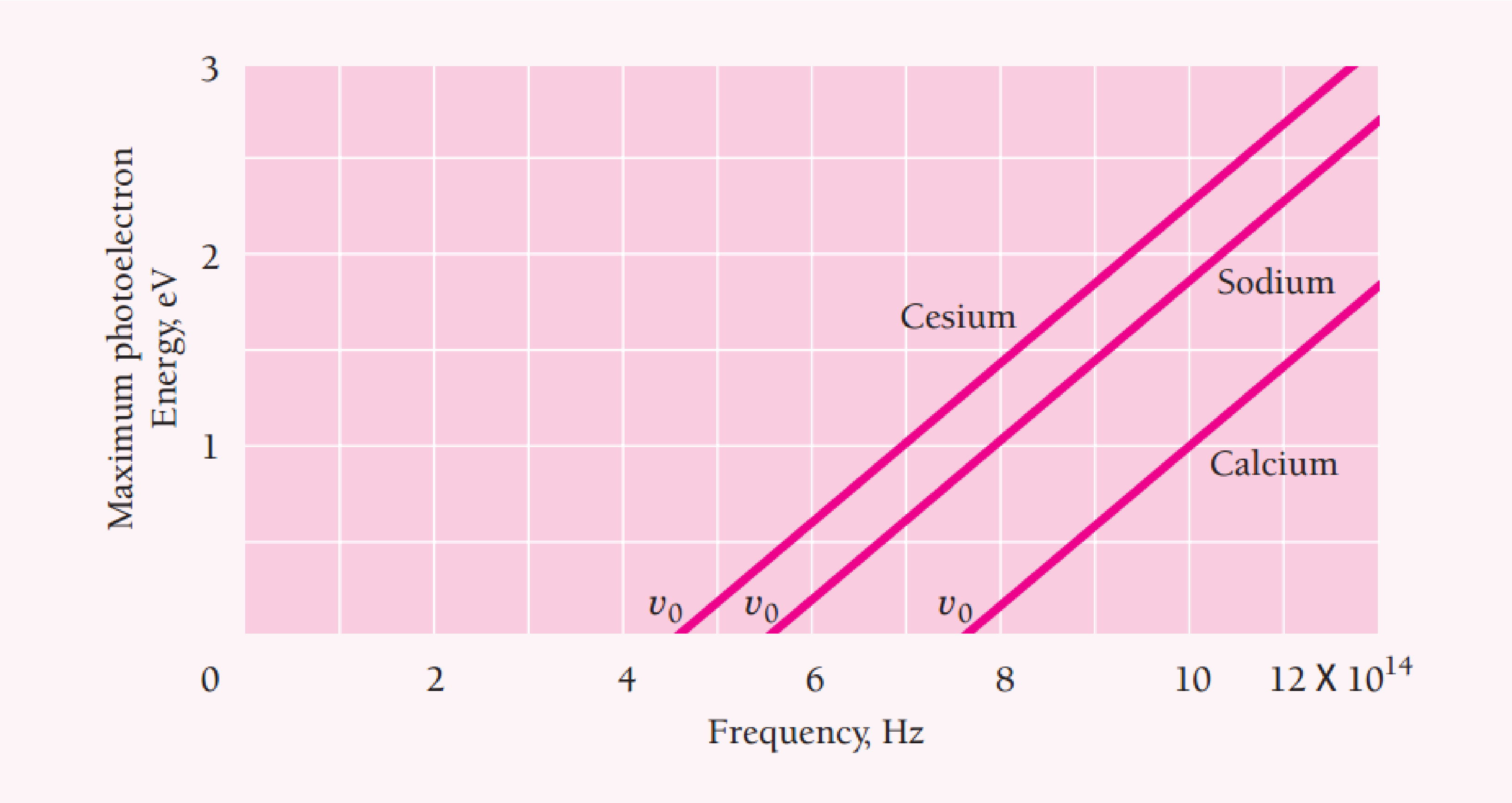
The photoelectric effect

Photoelectric effect $$h\nu = KE_{max} + \phi$$





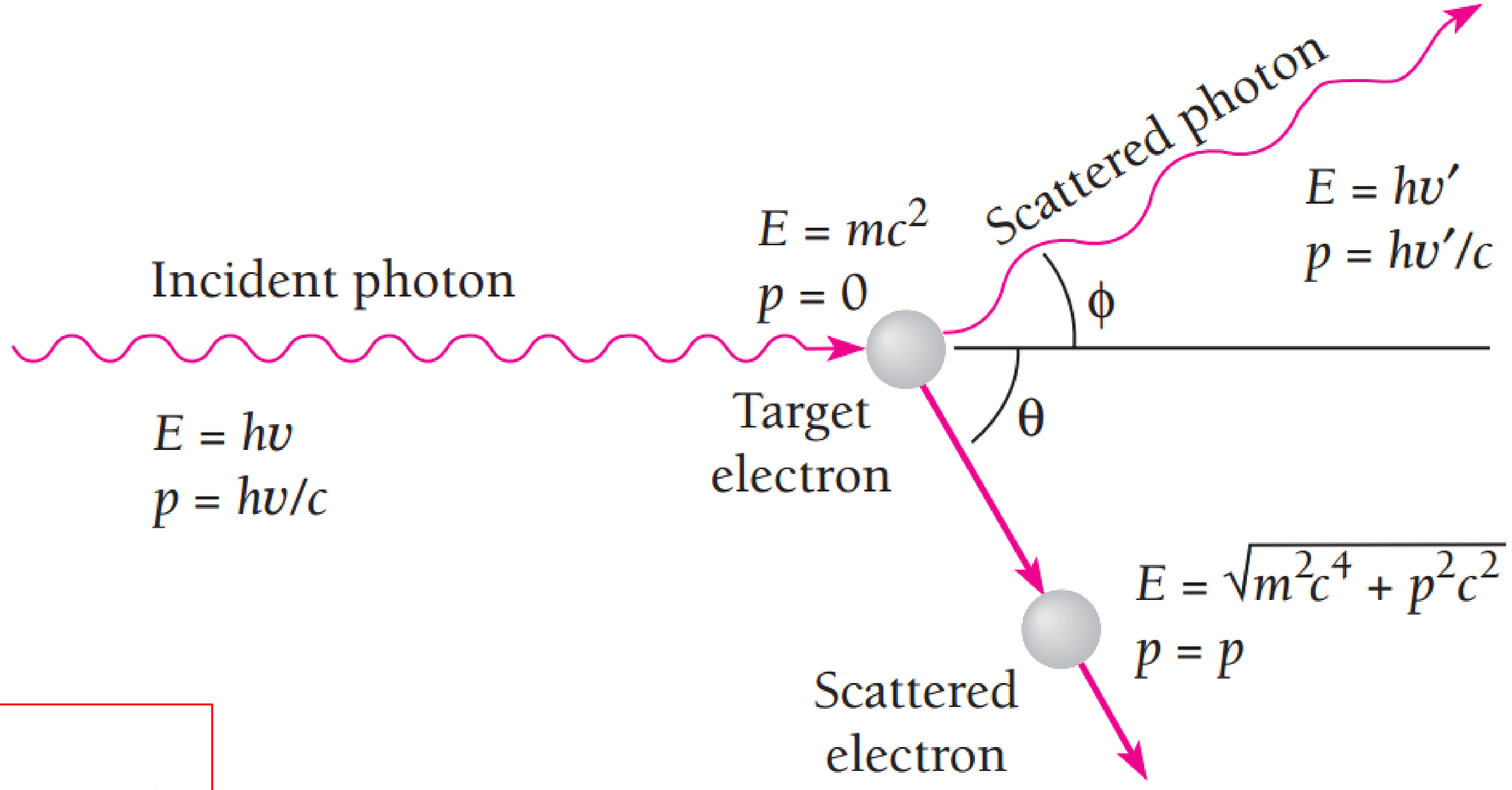
The photoelectric effect



Work function $\phi = h\nu_0$

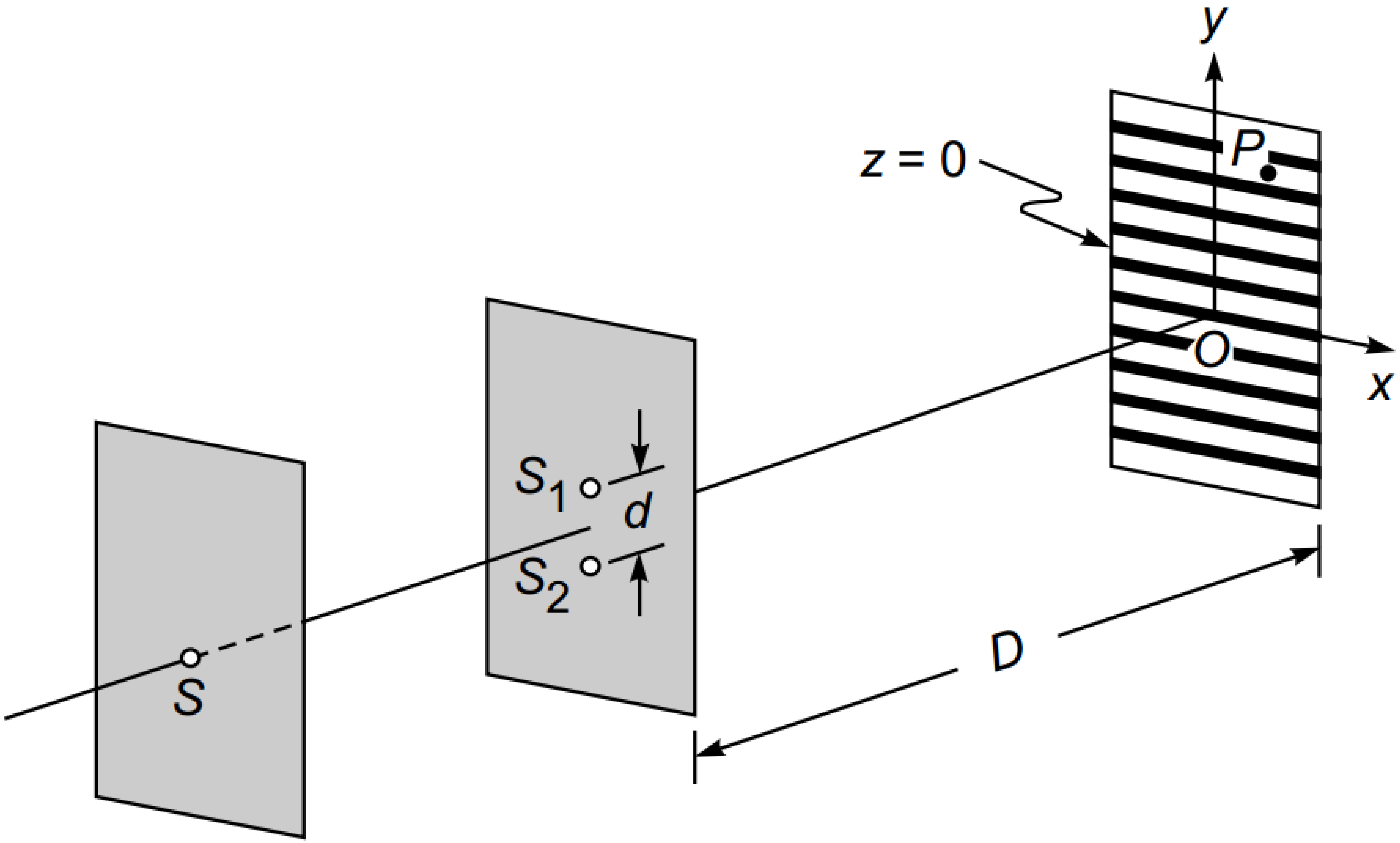
What is light?

The Compton effect



$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\phi)$$

Interference of light



WHAT IS LIGHT?

Both wave and particle

Can particle behave like wave?

De Broglie Waves

A moving body behaves in certain ways as though it has a wave nature

$$\lambda = \frac{h}{p}$$

De Broglie wavelength $$\lambda = \frac{h}{\gamma m v}$$

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

Example

Find the de Broglie wavelengths of (*a*) a 46-g golf ball with a velocity of 30 m/s, and (*b*) an electron with a velocity of 10^7 m/s.

Solution

(*a*) Since $\boldsymbol{v} \ll c$, we can let $\gamma = 1$. Hence

$$\lambda = \frac{h}{m\boldsymbol{v}} = \frac{6.63 \times 10^{-34}\ \text{J}\cdot\text{s}}{(0.046\ \text{kg})(30\ \text{m/s})} = 4.8 \times 10^{-34}\ \text{m}$$

The wavelength of the golf ball is so small compared with its dimensions that we would not expect to find any wave aspects in its behavior.

Example

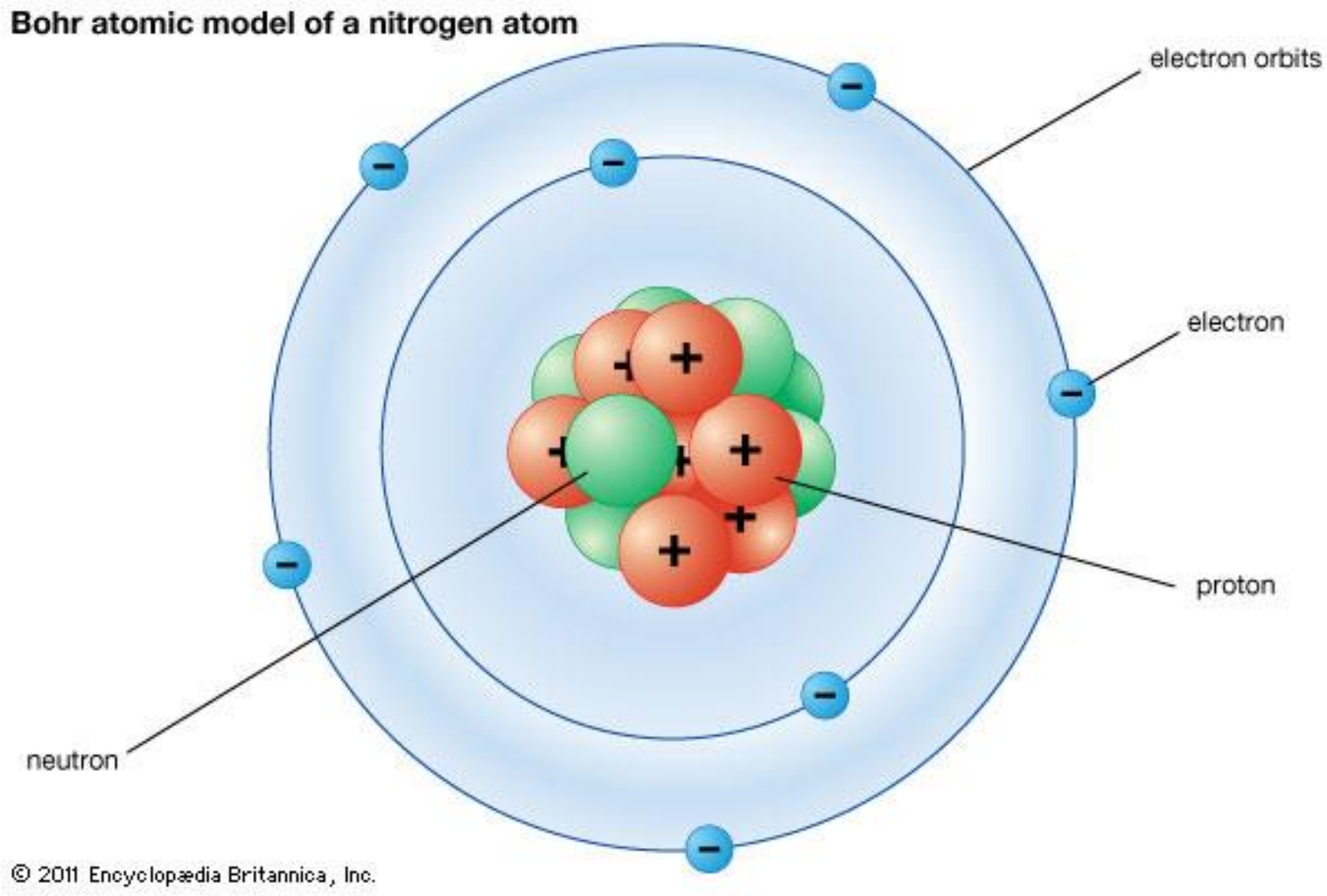
Find the de Broglie wavelengths of (*a*) a 46-g golf ball with a velocity of 30 m/s, and (*b*) an electron with a velocity of 10^7 m/s.

Solution

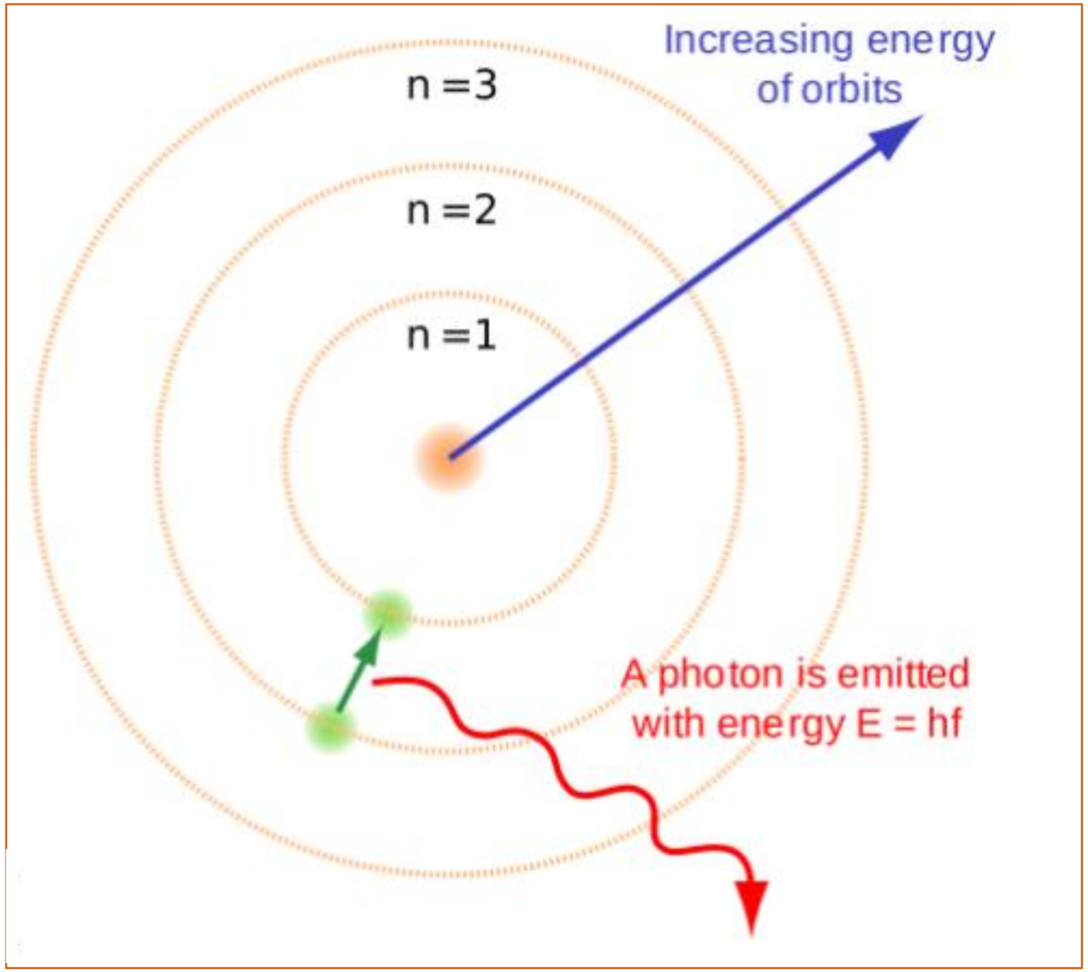
(*b*) Again $\boldsymbol{v} \ll c$, so with $m = 9.1 \times 10^{-31}$ kg, we have

$$\lambda = \frac{h}{m\boldsymbol{v}} = \frac{6.63 \times 10^{-34}\ \mathrm{J \cdot s}}{(9.1 \times 10^{-31}\ \mathrm{kg})(10^7\ \mathrm{m/s})} = 7.3 \times 10^{-11}\ \mathrm{m}$$

The dimensions of atoms are comparable with this figure—the radius of the hydrogen atom, for instance, is 5.3×10^{-11} m. It is therefore not surprising that the wave character of moving electrons is the key to understanding atomic structure and behavior.


Bohr atomic model of a nitrogen atom
electron orbits
electron
proton
neutron
© 2011 Encyclopædia Britannica, Inc.

Bohr Atom Model

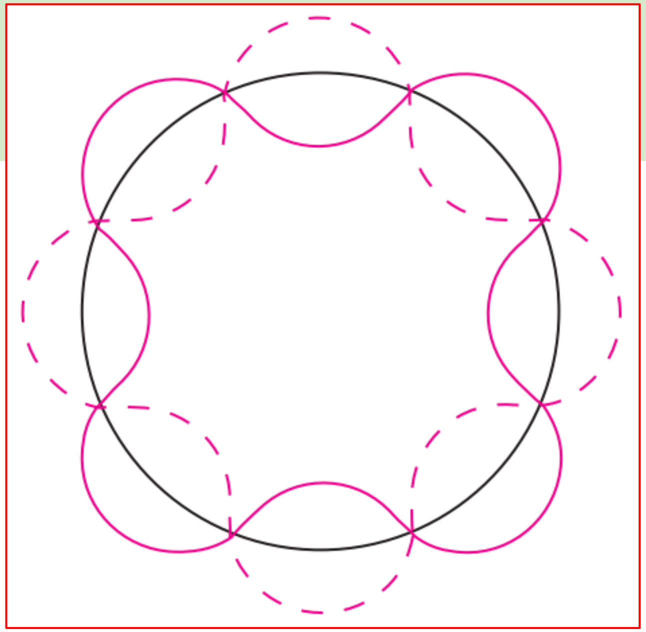


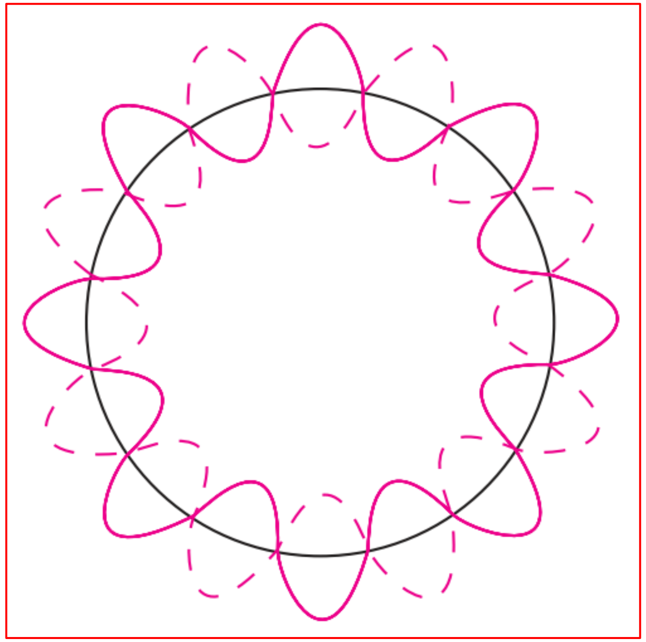
Condition for orbital stability

$$mvr = \frac{nh}{2\pi} \qquad n = 1, 2, 3, \ldots$$

Condition for stable orbit

An electron can circle a nucleus only if its orbit contains an integral number of de Broglie wavelengths.

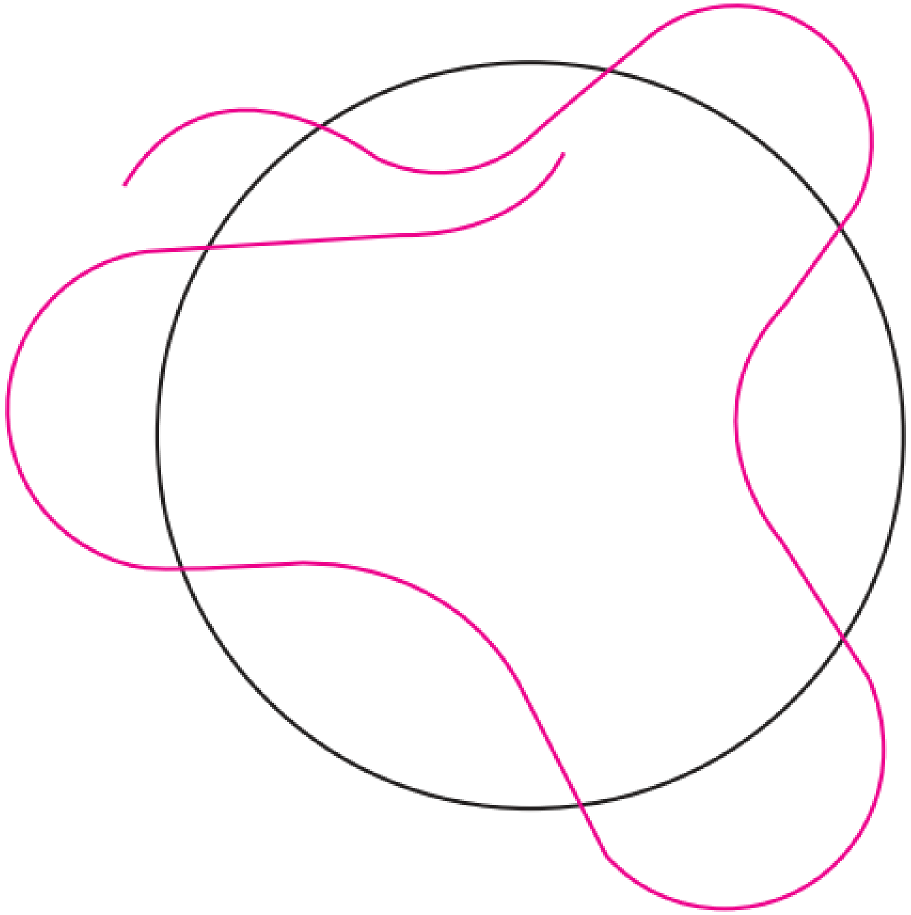




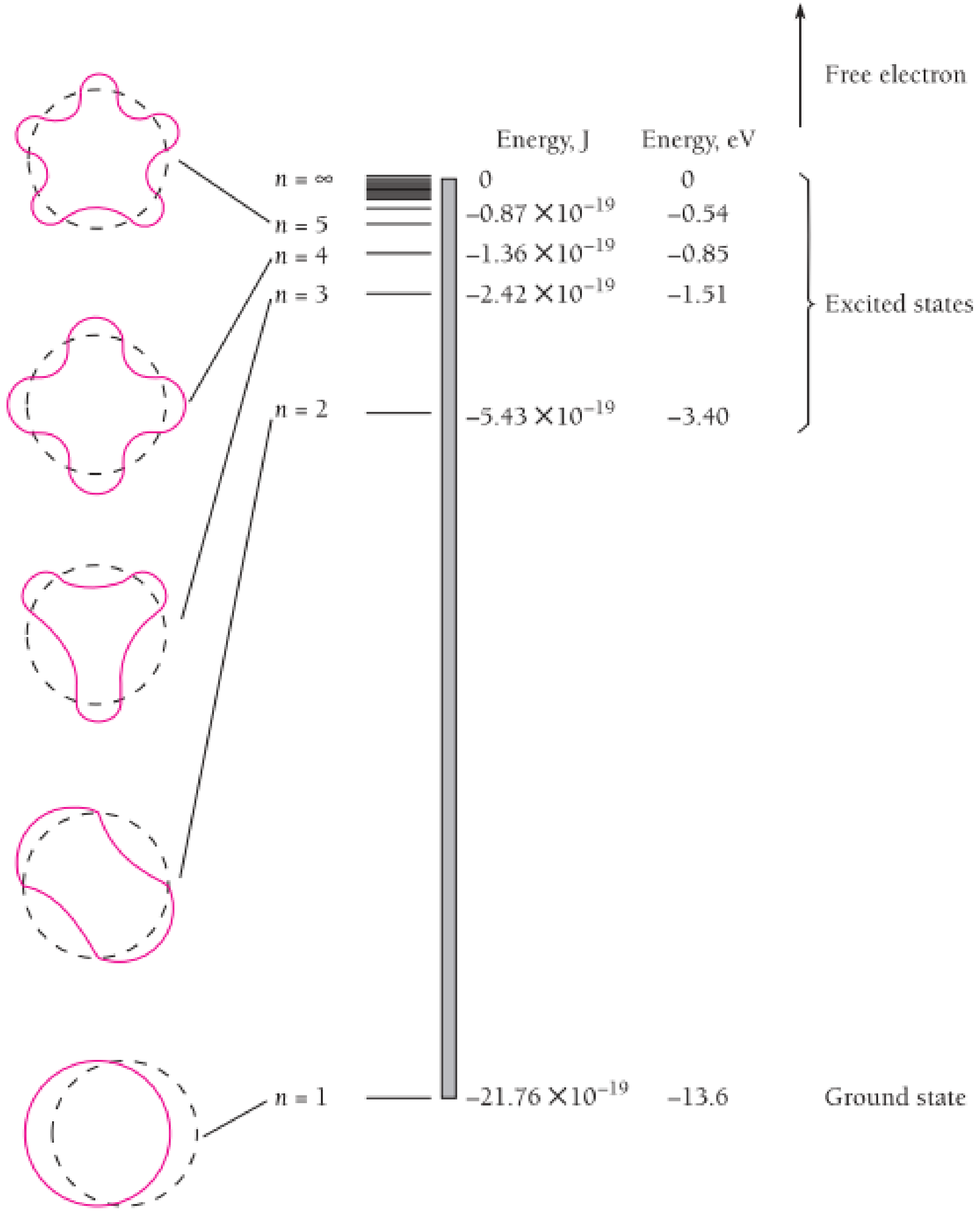
Condition for orbit stability

$$n\lambda = 2\pi r_n \qquad n = 1, 2, 3, \ldots$$

A fractional number of wavelengths cannot persist because destructive interference will occur

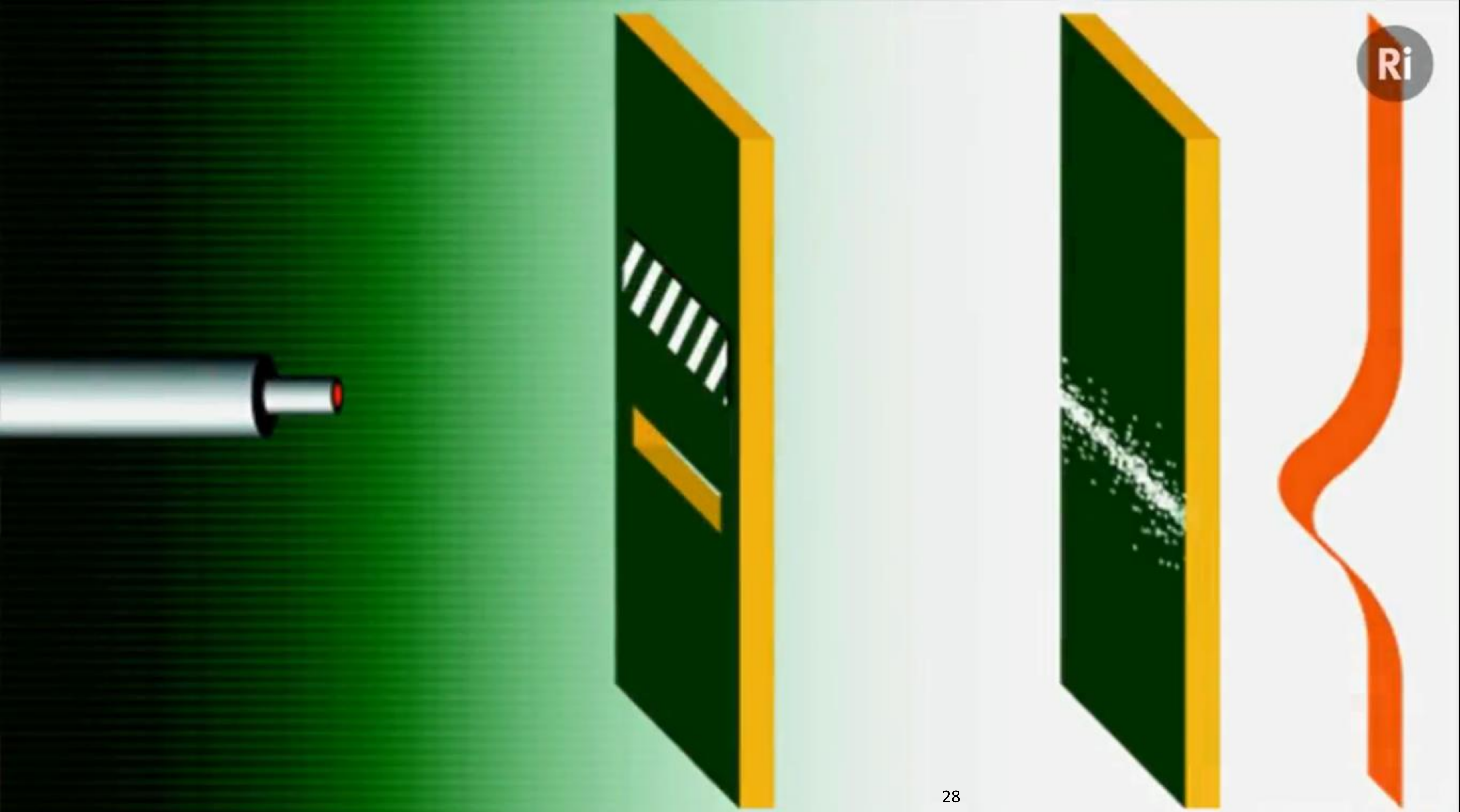


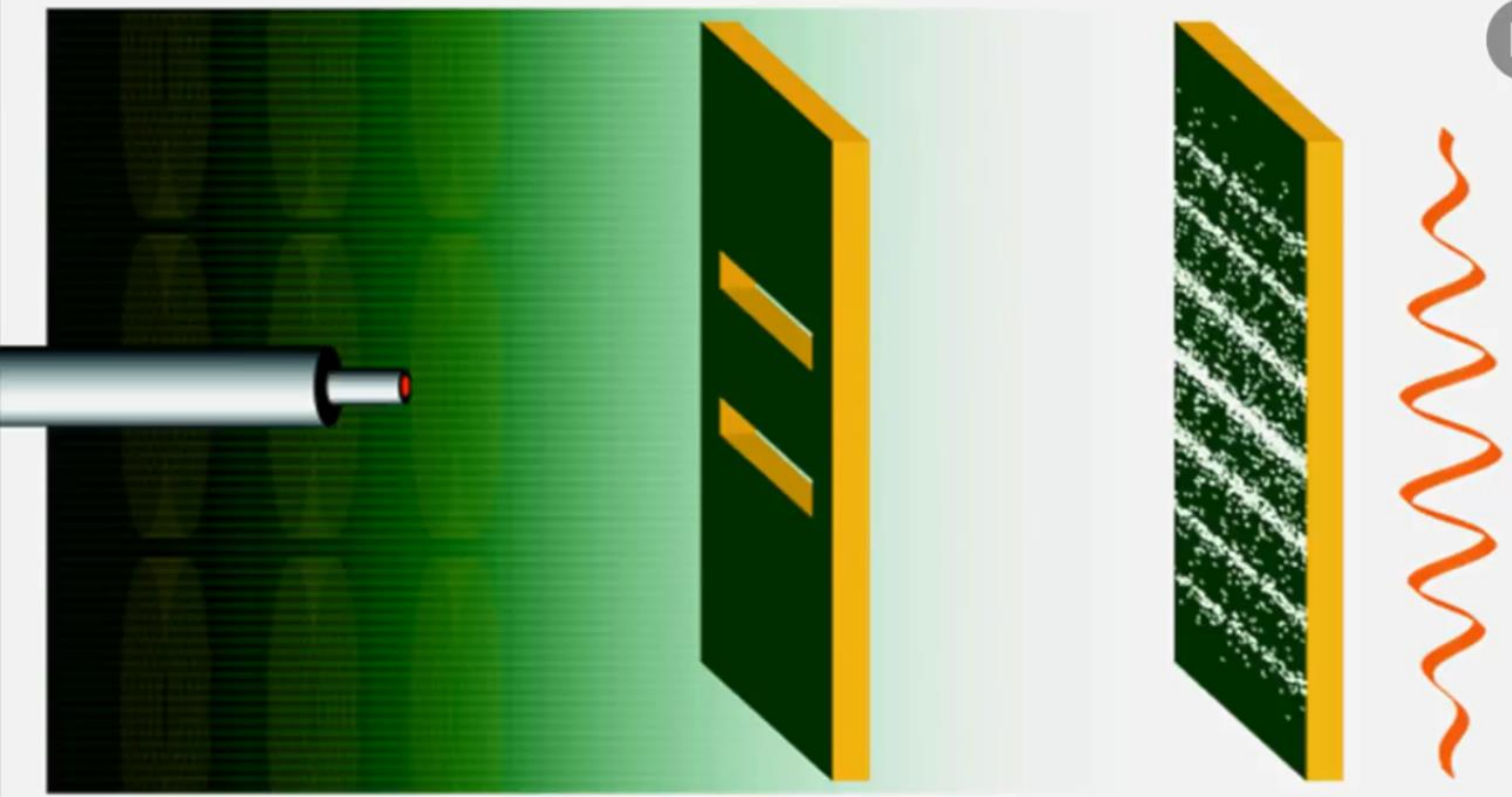
Energy levels of hydrogen atom

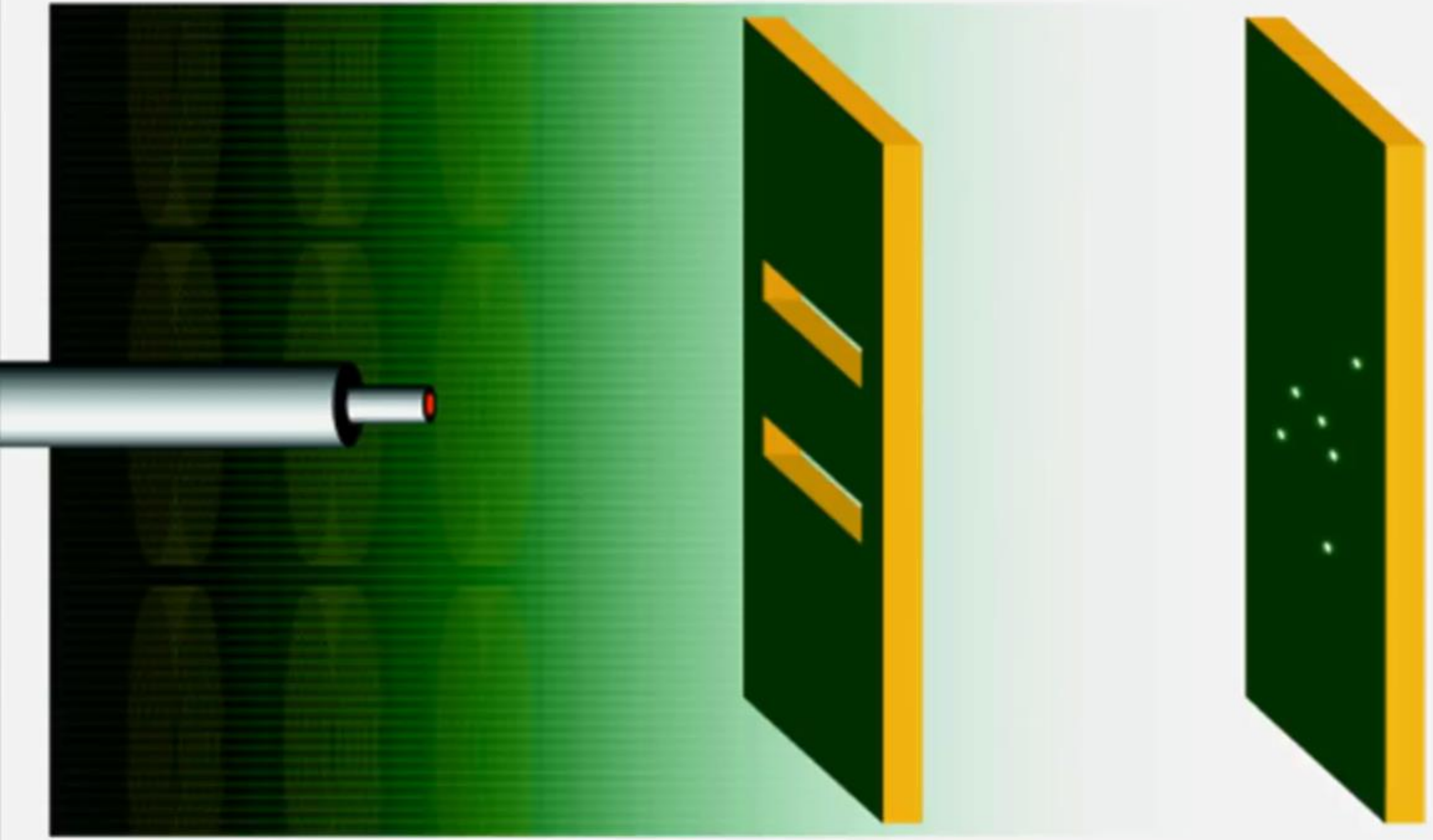


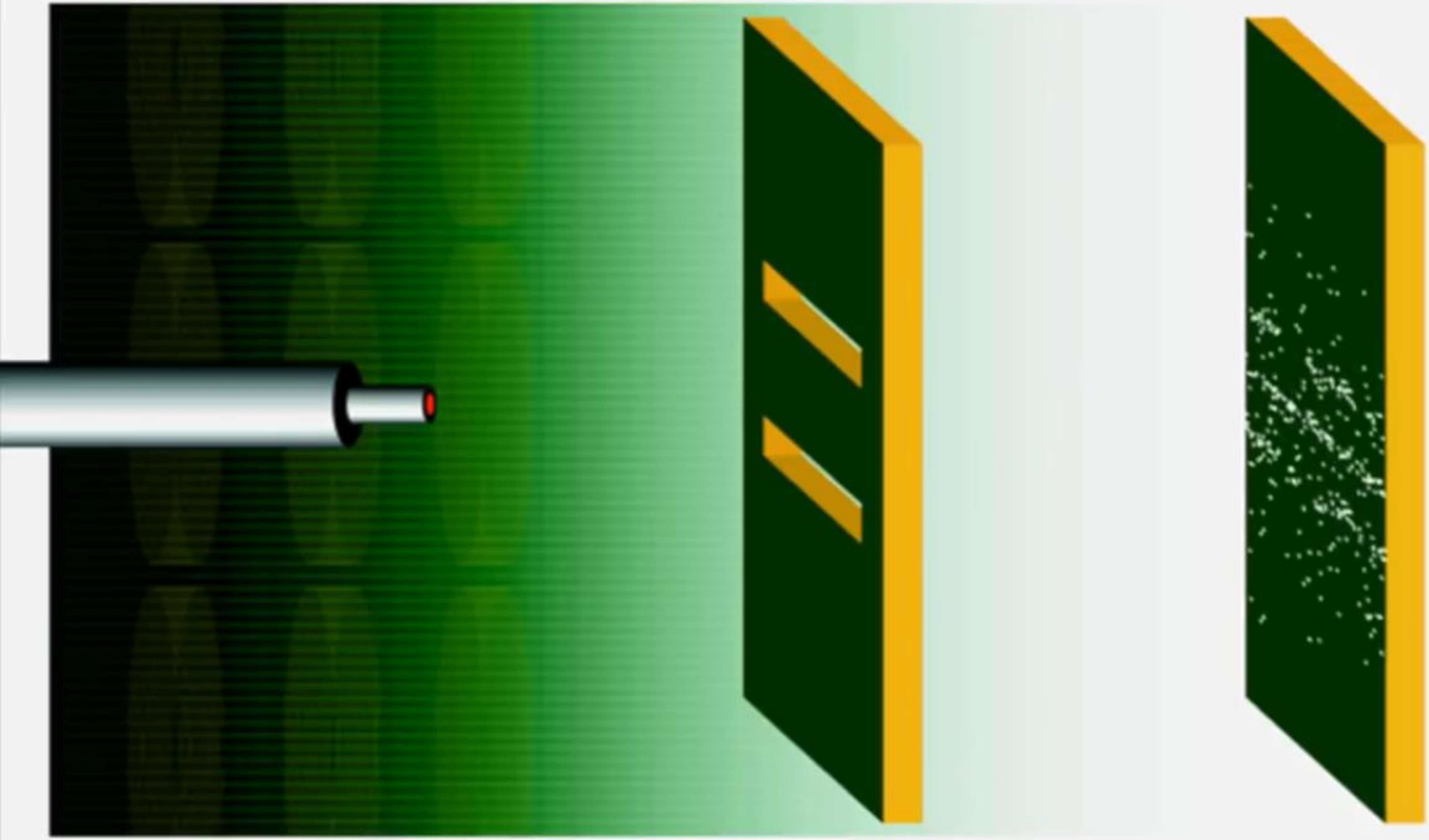
Jim Al-Khalili

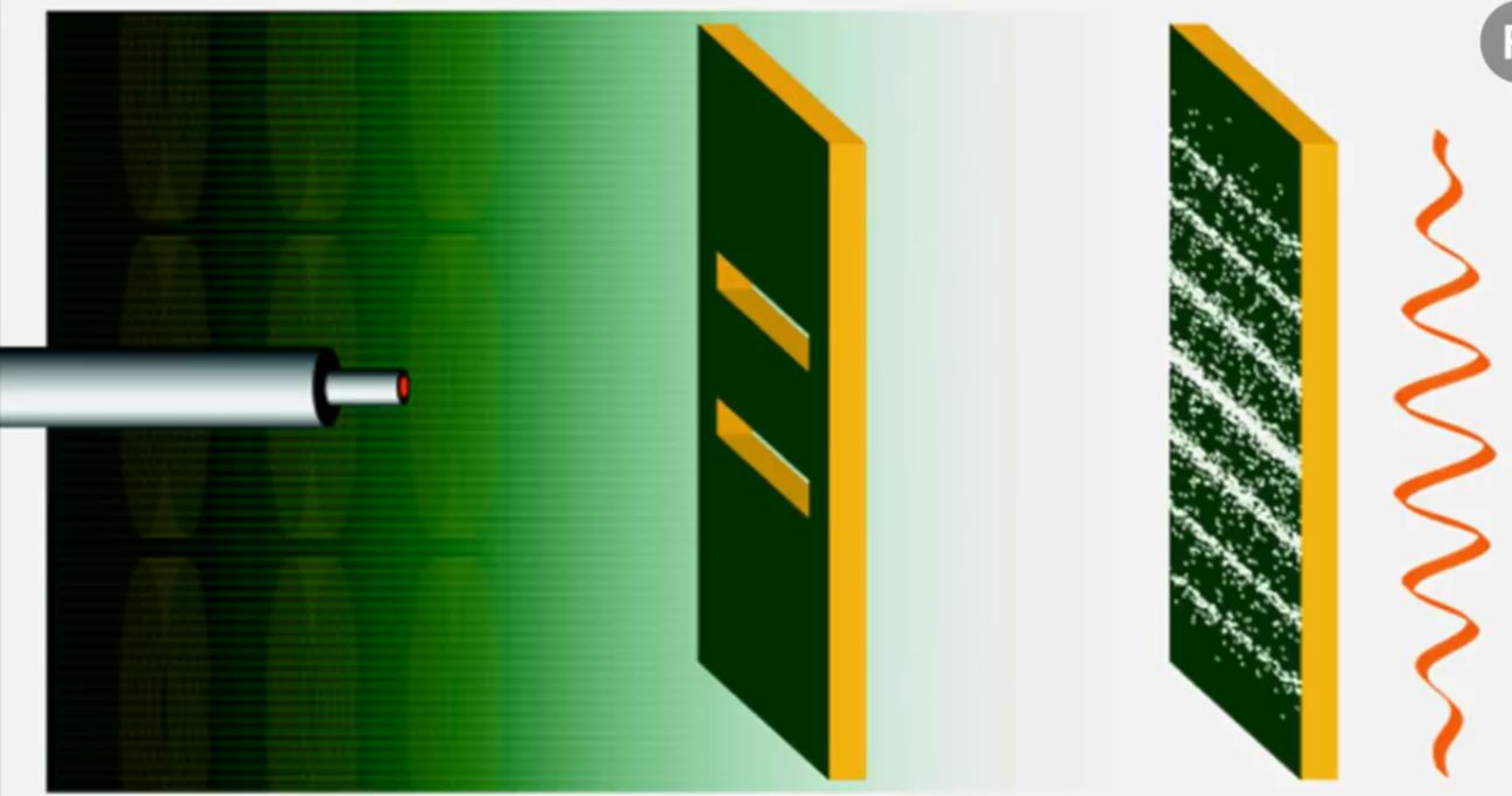
- Quantum Life: How Physics Can Revolutionise Biology
- Double Slit Experiment explained! by Jim Al-Khalili

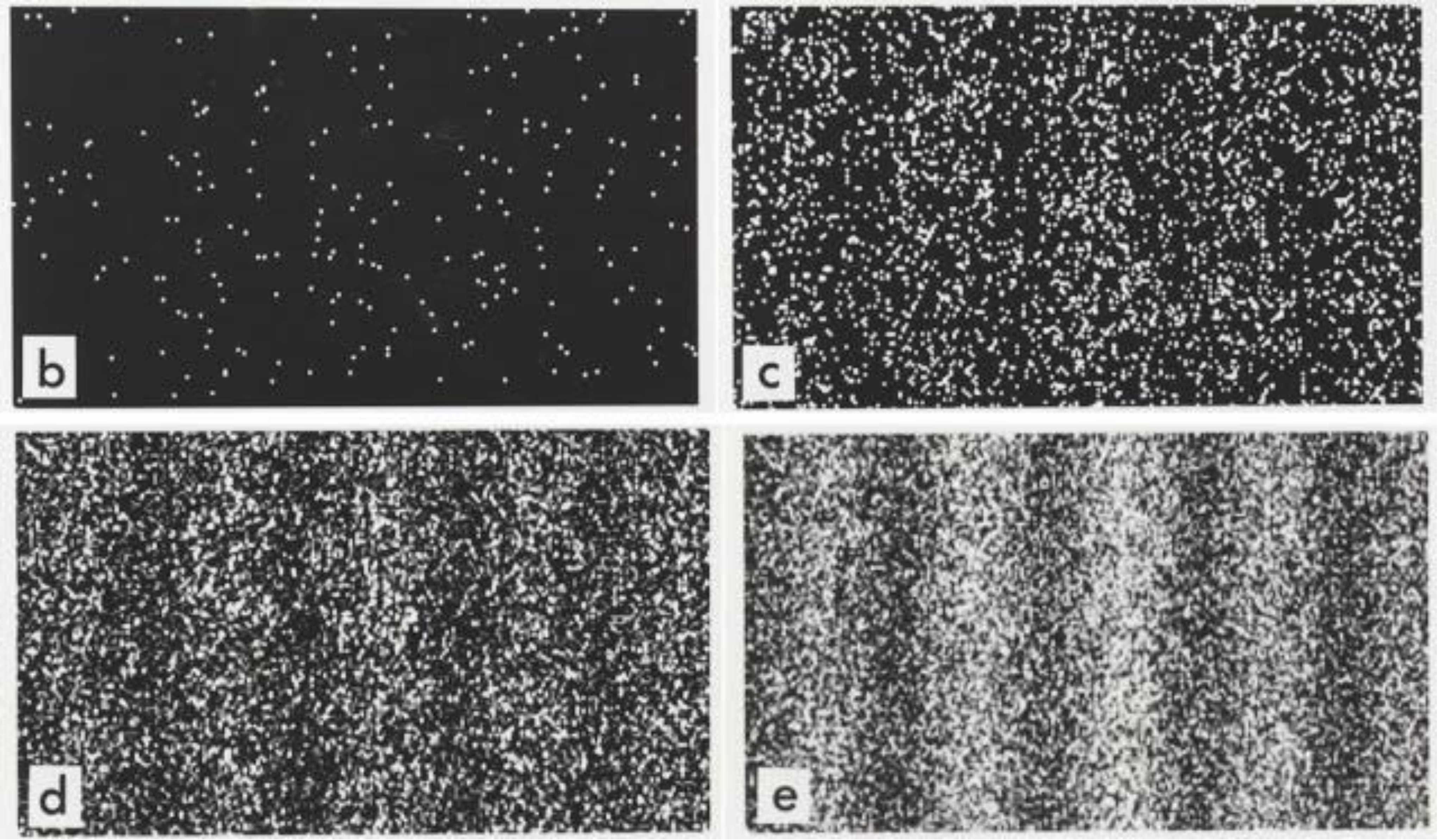


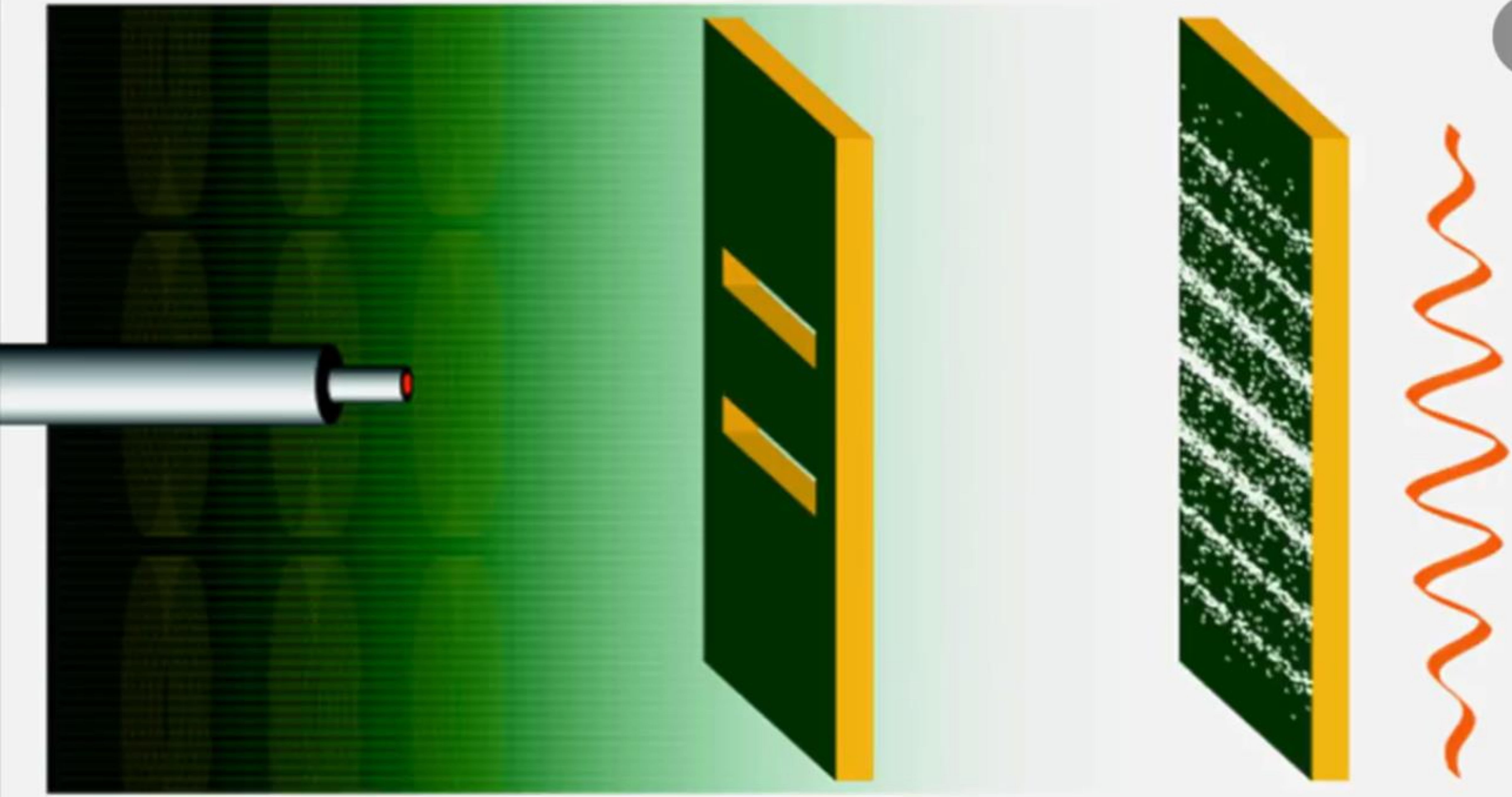


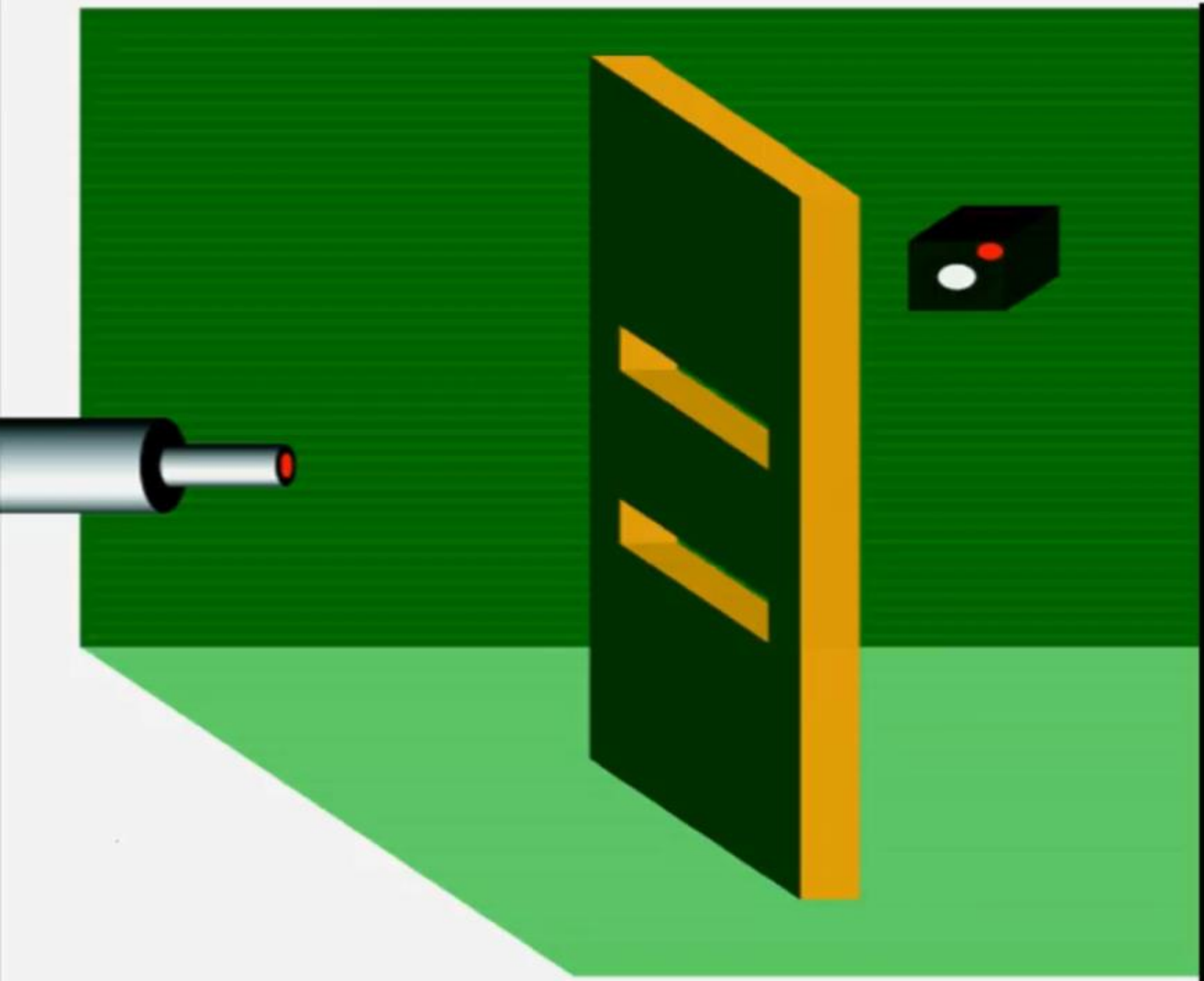


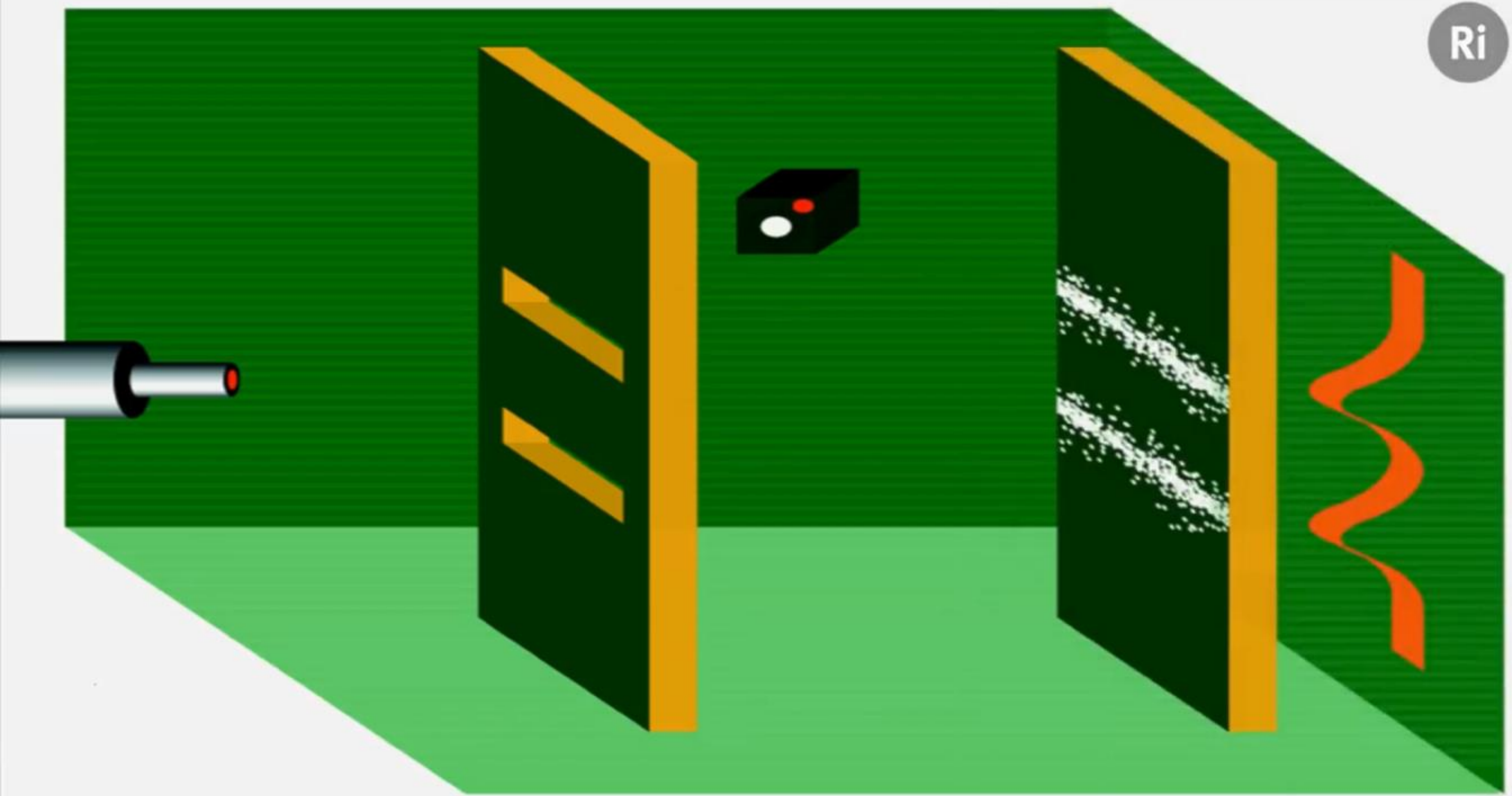


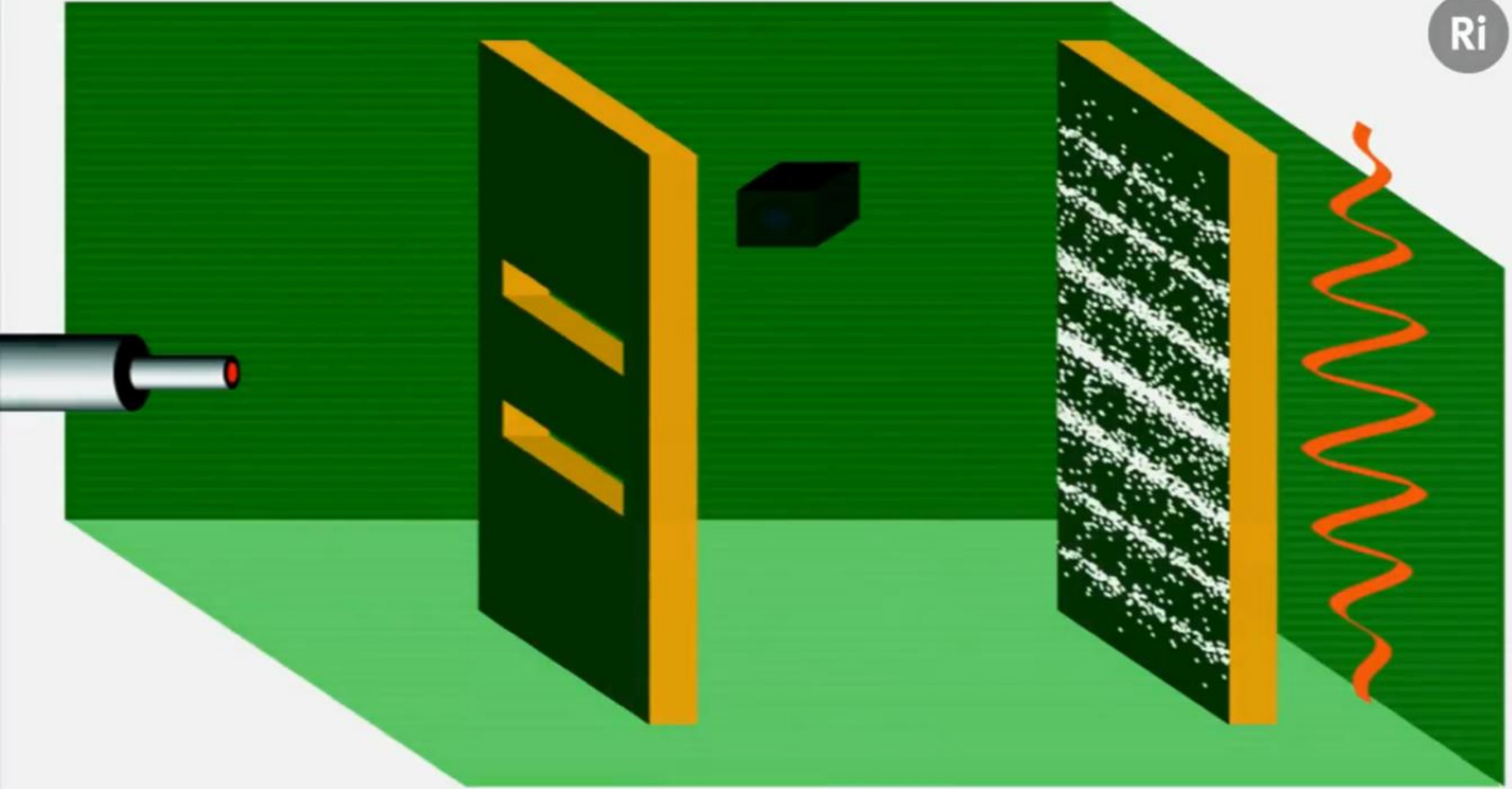



b
c
d
e









Are you shocked?

Those who are not shocked when they first come across quantum mechanics cannot possibly have understood it.

Niels Bohr