# Science and Pseudoscience

# Weird Science: Wave Particle Duality

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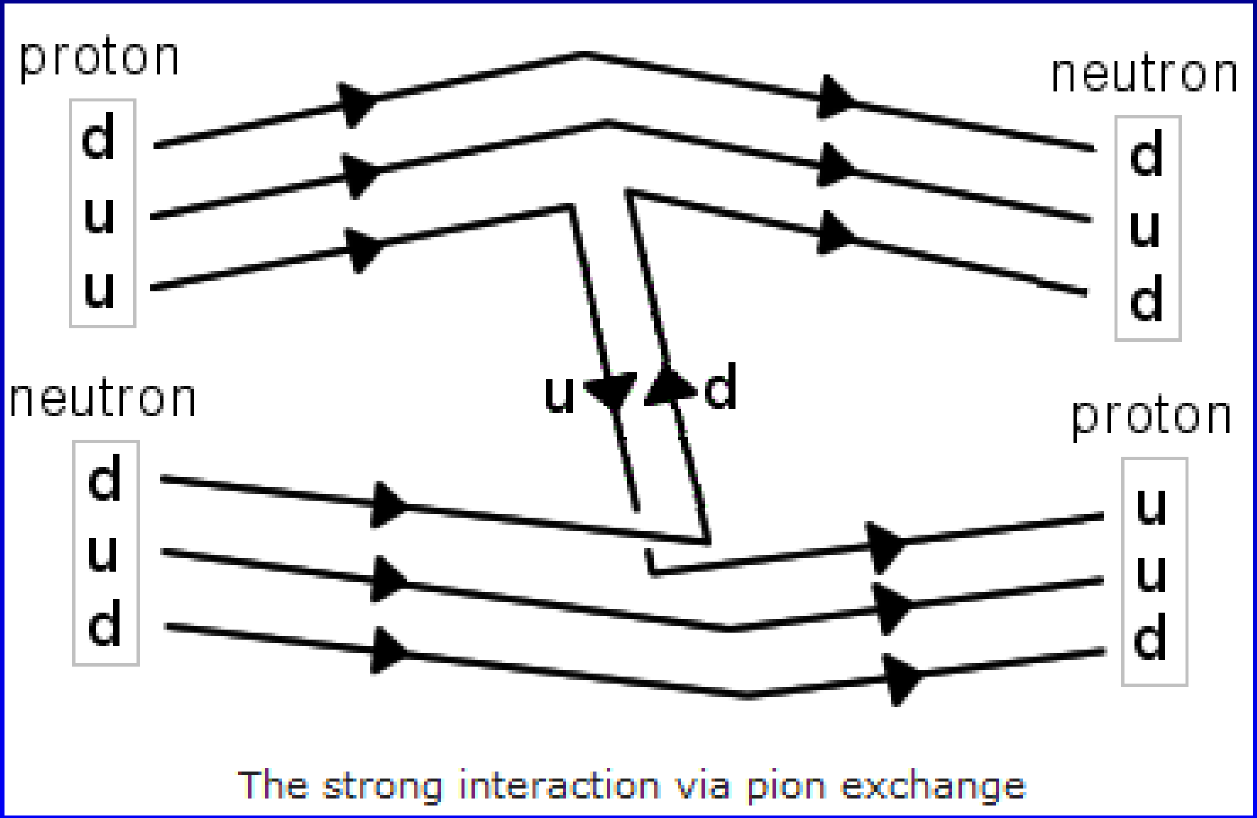
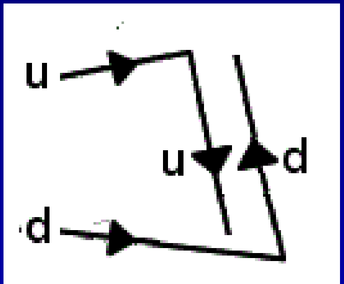
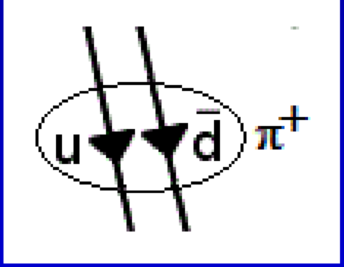
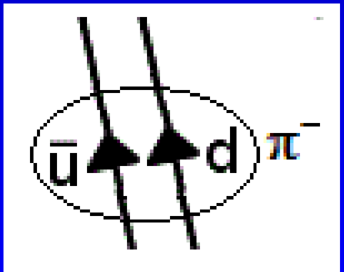
# How Things Interact

## Strong  Nuclear Force – Gluons



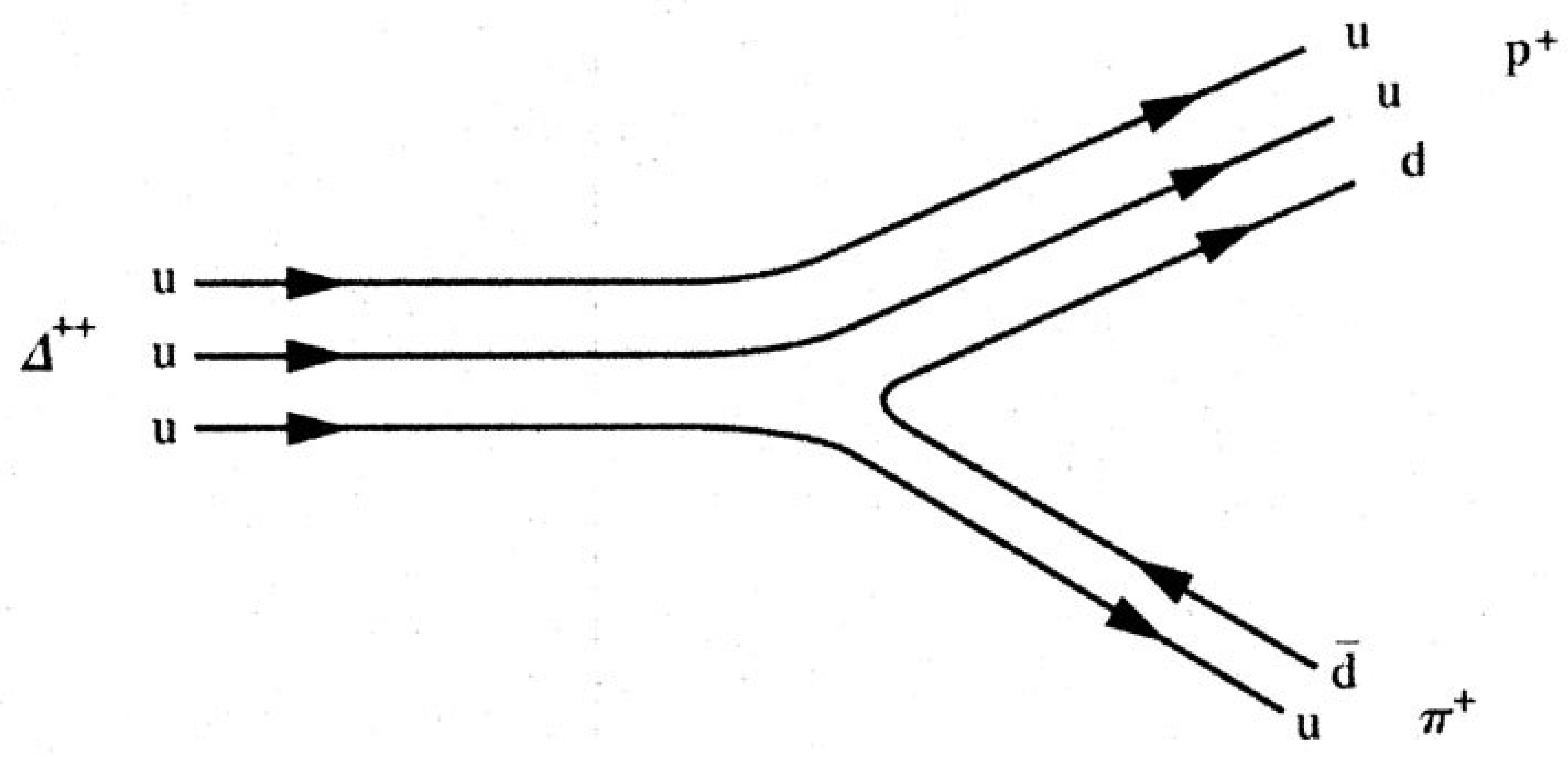



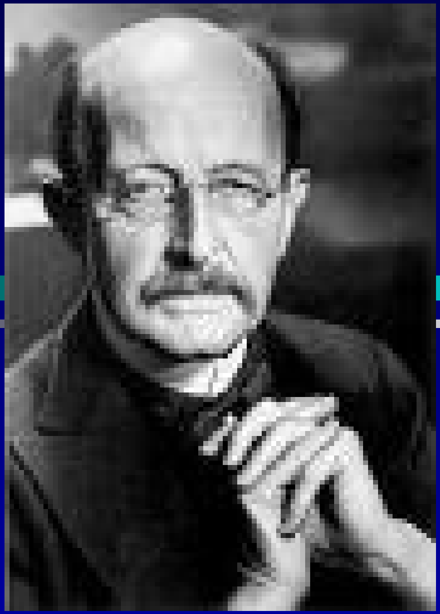



# How Things Interact

## Delta++ Decay

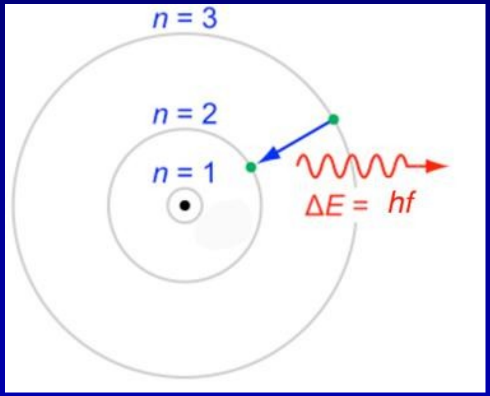


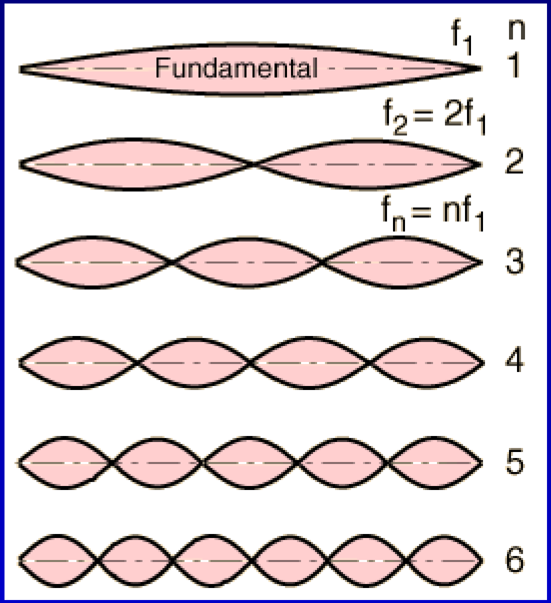
# The Quantum

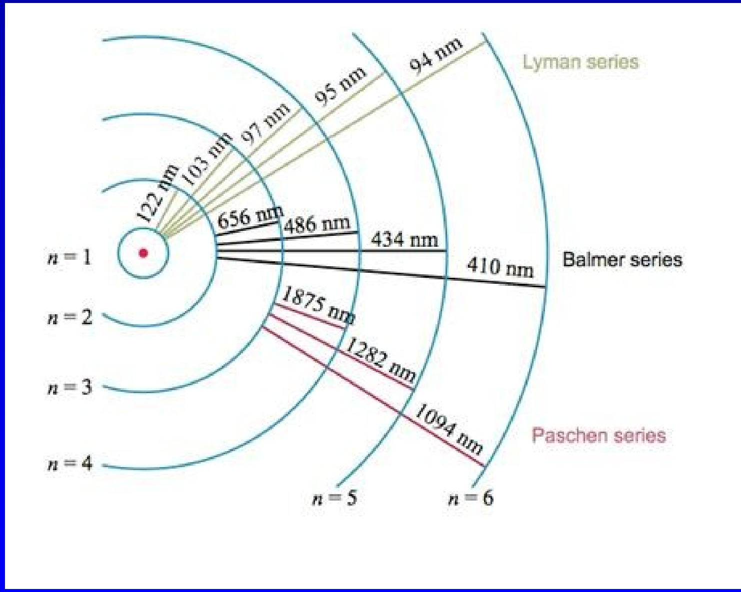


**In 1900, Max Planck discovered that light, thought to be purely wave-like, was actually composed of discrete energy packets, called “quanta”.**

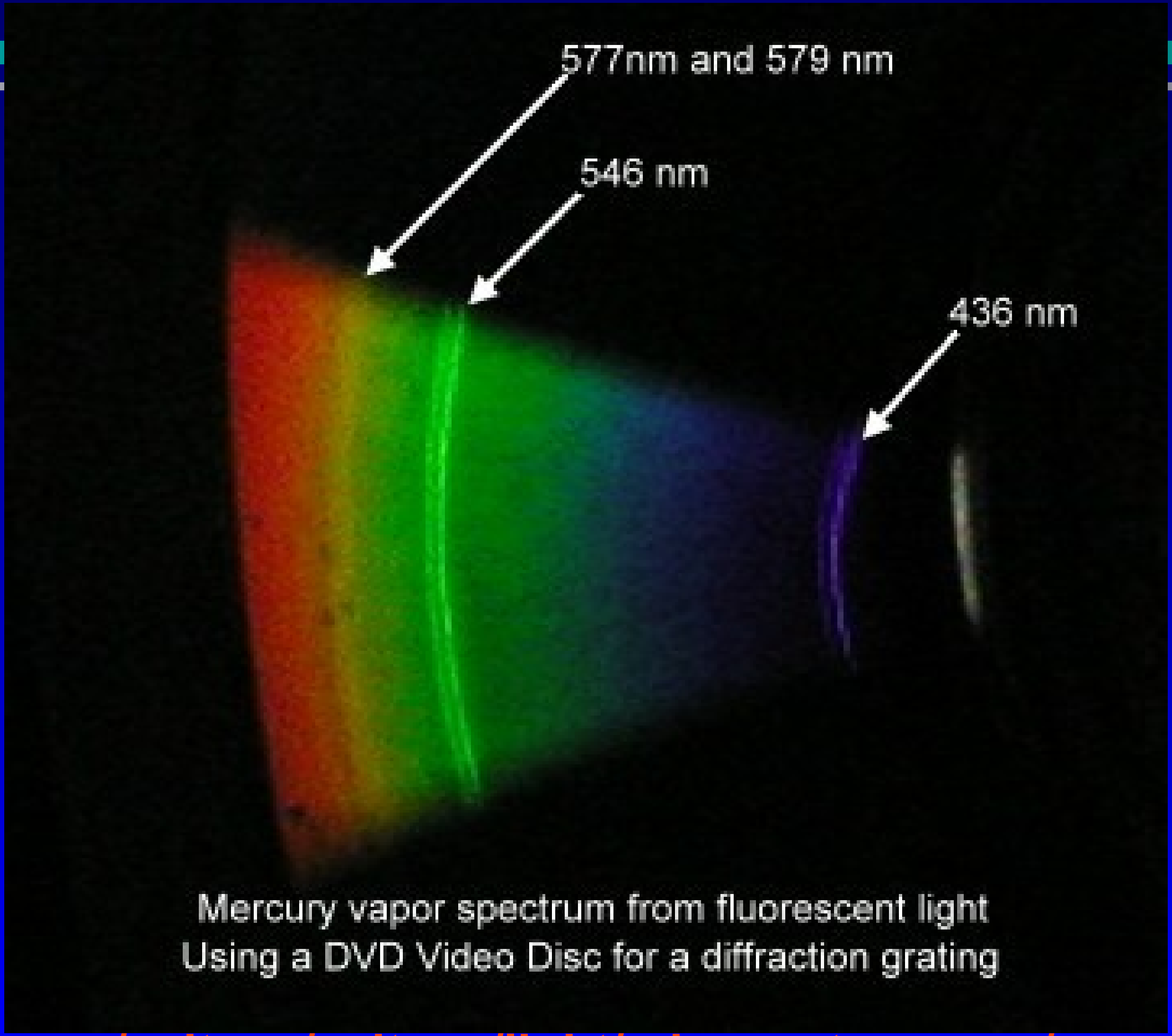
# Photons are Quantized



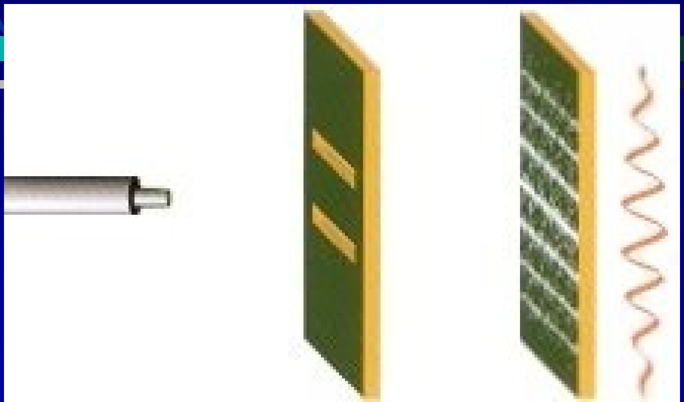



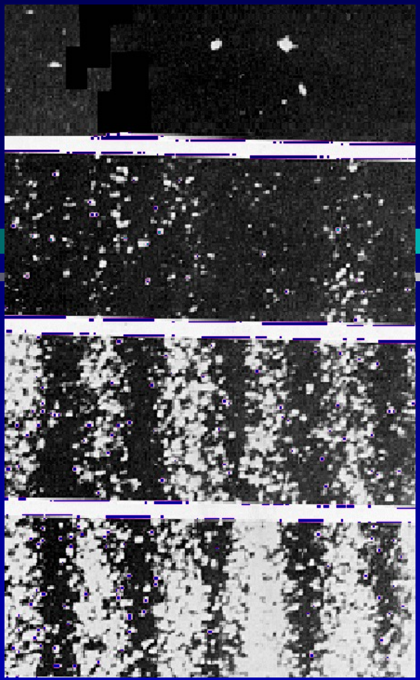

# Photons are Quantized

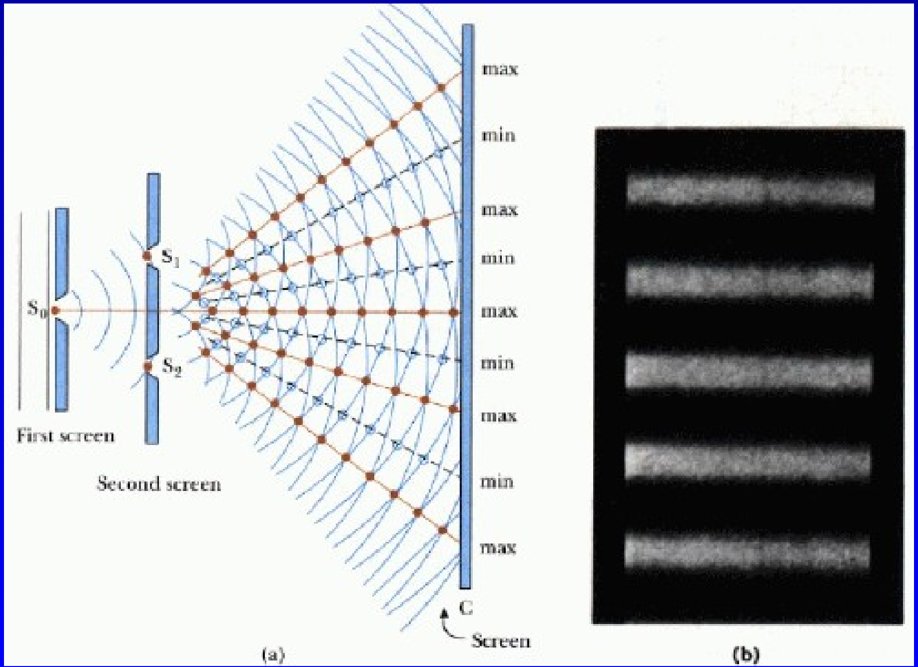


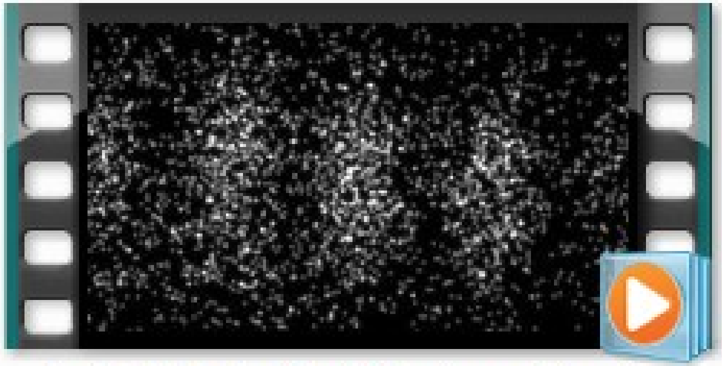

sci-toys.com/scitoys/scitoys/light/cd_spectroscope/spectroscope.html

# Wave/Particle Duality







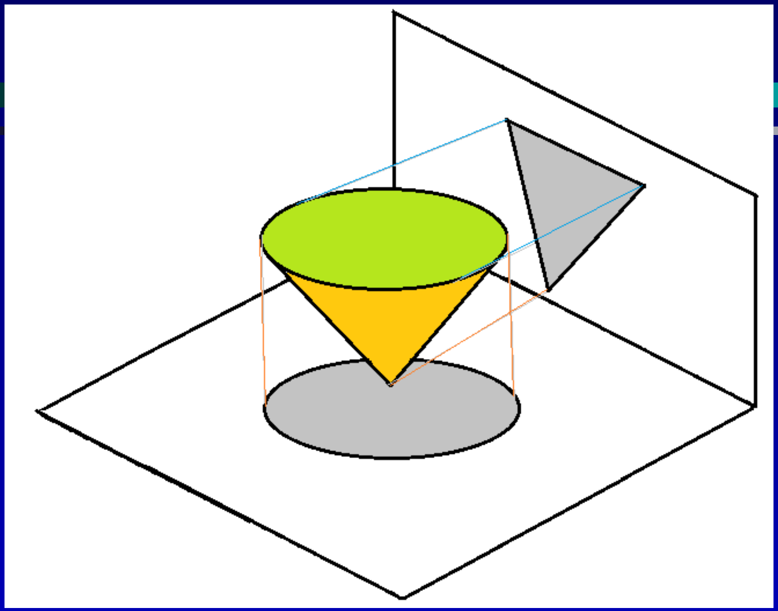
Controlled double-slit electron diffraction_ electron buildup pattern.mp4

# Which Slit is Used?

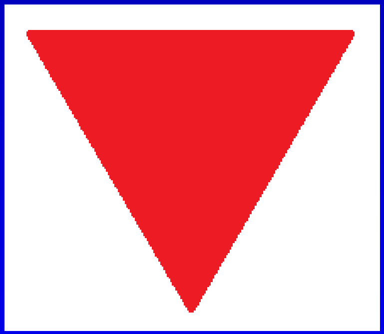
- Both of them!
- But, if we try to detect which slit an electron is passing through, we'll always find whole electrons or no electrons at all.

# Wave/Particle Duality

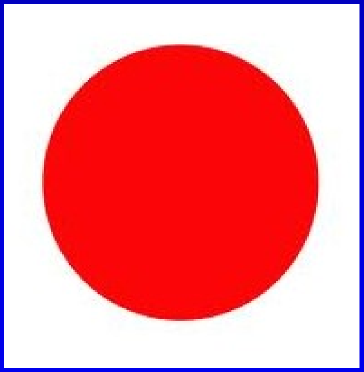
Consider a 3D Cone...



Looks like a Triangle



*And*, Looks like a Circle



Depending on how you "measure" it.

# The Act of Measurement

The position of the observer must be defined in order to determine the position of the rainbow. It is as if the act of observation is necessary to define the rainbow's position property, and hence its very existence:
no observer, no rainbow.

**Measuring which slit the electron passes through is called “collapsing” its wave function.**

# Superposition of States

**This roulette wheel has several discrete states that a ball can land in. In classical physics, given knowledge of initial conditions, we might be able to predict where the ball will land. *Not so* in Quantum Mechanics!**

# Superposition of States

Rather, we consider the system as a *superposition* of all possible states (positions); by analogy "The Ball is Racing Around the Track." Letting the ball land is like making a measurement.

# Heisenberg's Uncertainty Principle

To "see" an electron, we must shine some light upon it. There is *uncertainty* in the electron's position, related to the light wave's wavelength (and thus momentum).

The better you know a particle's *position*, the worse you know its *momentum*, and vice versa.

$$\Delta x \, \Delta p \cong h$$

# Feynmann Lectures on Physics Vol. III

SUMMARY

(1) The probability of an event in an ideal experiment is given by the square of the absolute value of a complex number $\phi$ which is called the probability amplitude:

$$
\begin{aligned}
P &= \text{probability,}\\
\phi &= \text{probability amplitude,}\\
P &= |\phi|^2
\end{aligned}
\tag{1.6}
$$

(2) When an event can occur in several alternative ways, the probability amplitude for the event is the sum of the probability amplitudes for each way considered separately. There is interference:

$$
\begin{aligned}
\phi &= \phi_1 + \phi_2,\\
P &= |\phi_1 + \phi_2|^2
\end{aligned}
\tag{1.7}
$$

(3) If an experiment is performed which is capable of determining whether one or another alternative is actually taken, the probability of the event is the sum of the probabilities for each alternative. The interference is lost:

$$P = P_1 + P_2. \tag{1.8}$$

One might still like to ask: "How does it work? What is the machinery behind the law?" No one has found any machinery behind the law. No one can "explain" any more than we have just "explained." No one will give you any deeper representation of the situation. We have no ideas about a more basic mechanism from which these results can be deduced.

# Feynmann Lectures on Physics Vol. III

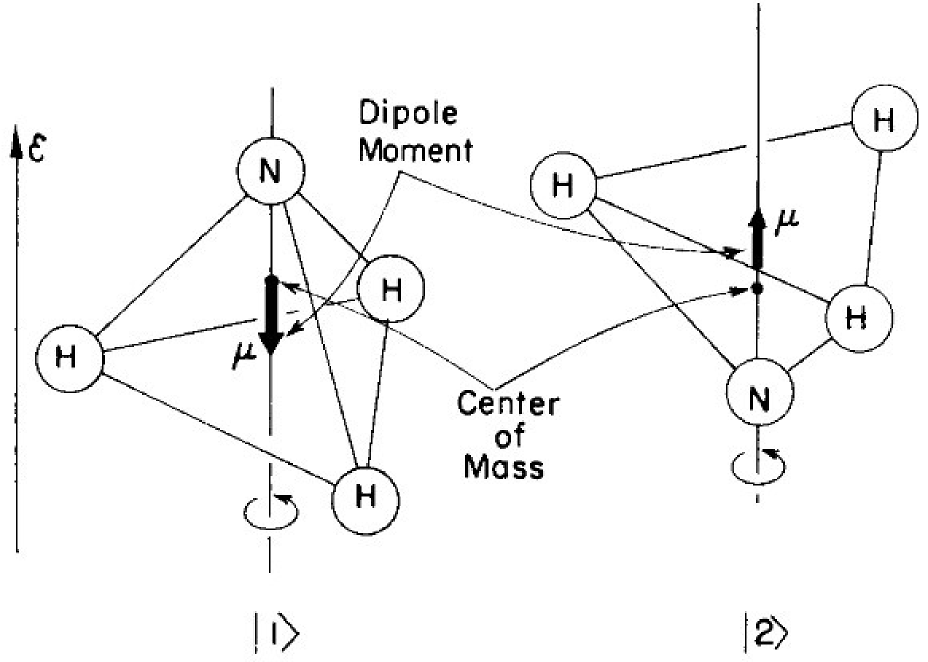



Fig. 9–1. A physical model of two base states for the ammonia molecule. These states have the electric dipole moments $\mu$.

# Feynmann Lectures on Physics Vol. III

Ordinarily the light shining on such a system is not exactly monochromatic. It is, therefore, interesting to solve one more problem—that is, to calculate the transition probability when the light has intensity $\mathcal{I}(\omega)$ per unit frequency interval, covering a broad range which includes $\omega_0$. Then, the probability of going from $|\,I\rangle$ to $|\,II\rangle$ will become an integral:

$$P(I \to II) = 2\pi \left[\frac{\mu^2}{4\pi\epsilon_0\hbar^2 c}\right] T^2 \int_0^\infty \mathcal{I}(\omega) \frac{\sin^2[(\omega - \omega_0)T/2]}{[(\omega - \omega_0)T/2]^2}\,d\omega. \tag{9.54}$$

In general, $\mathcal{I}(\omega)$ will vary much more slowly with $\omega$ than the sharp resonance term. The two functions might appear as shown in Fig. 9–8. In such cases, we can replace $\mathcal{I}(\omega)$ by its value $\mathcal{I}(\omega_0)$ at the center of the sharp resonance curve and take it outside of the integral. What remains is just the integral under the curve of Fig. 9–7, which is, as we have seen, just equal to $2\pi/T$. We get the result that

$$P(I \to II) = 4\pi^2 \left[\frac{\mu^2}{4\pi\epsilon_0\hbar^2 c}\right] \mathcal{I}(\omega_0) T. \tag{9.55}$$

This is an important result, because it is the *general theory of the absorption of light by any molecular or atomic system.* Although we began by considering a case in which state $|\,I\rangle$ had a higher energy than state $|\,II\rangle$, none of our arguments depended on that fact. Equation (9.55) still holds if the state $|\,I\rangle$ has a *lower* energy than the state $|\,II\rangle$; then $P(I \to II)$ represents the probability for a transition with the *absorption* of energy from the incident electromagnetic wave. The

# Feynmann Lectures on Physics Vol. III

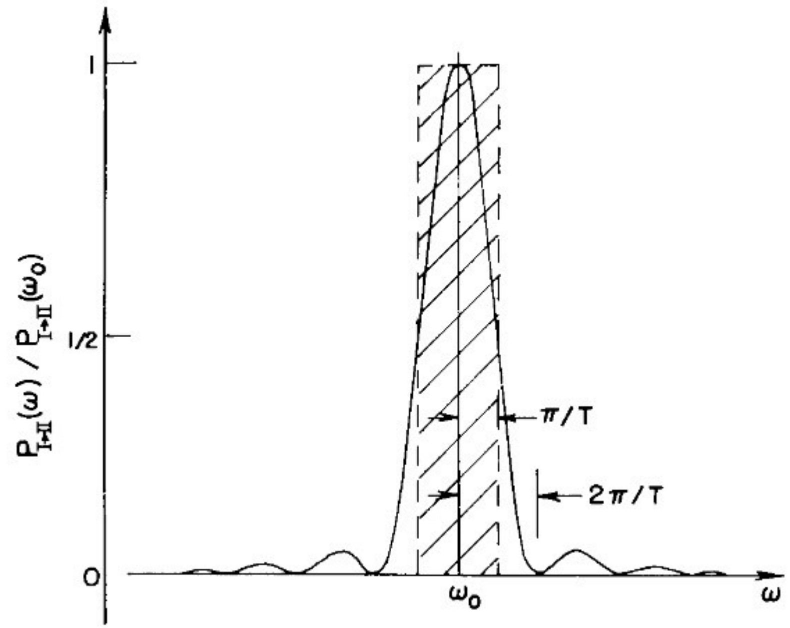



Fig. 9–7. Transition probability for the ammonia molecule as a function of frequency.

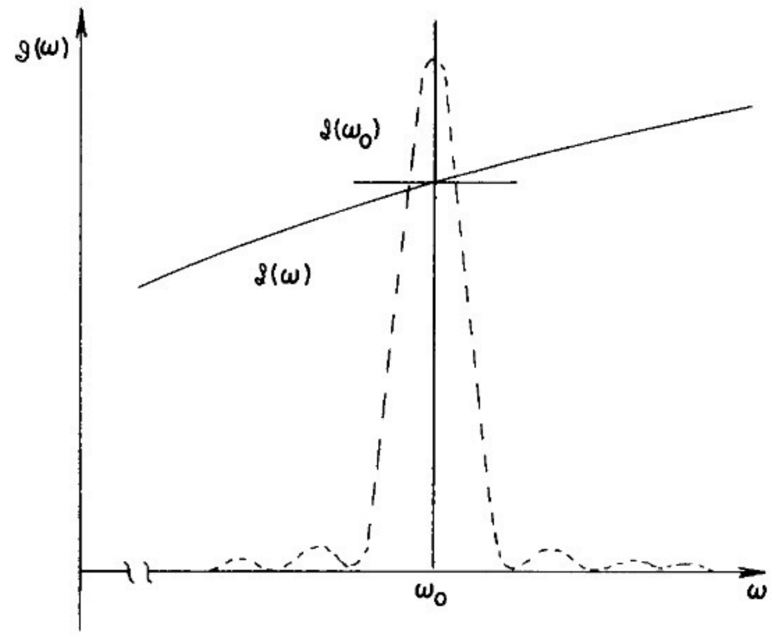
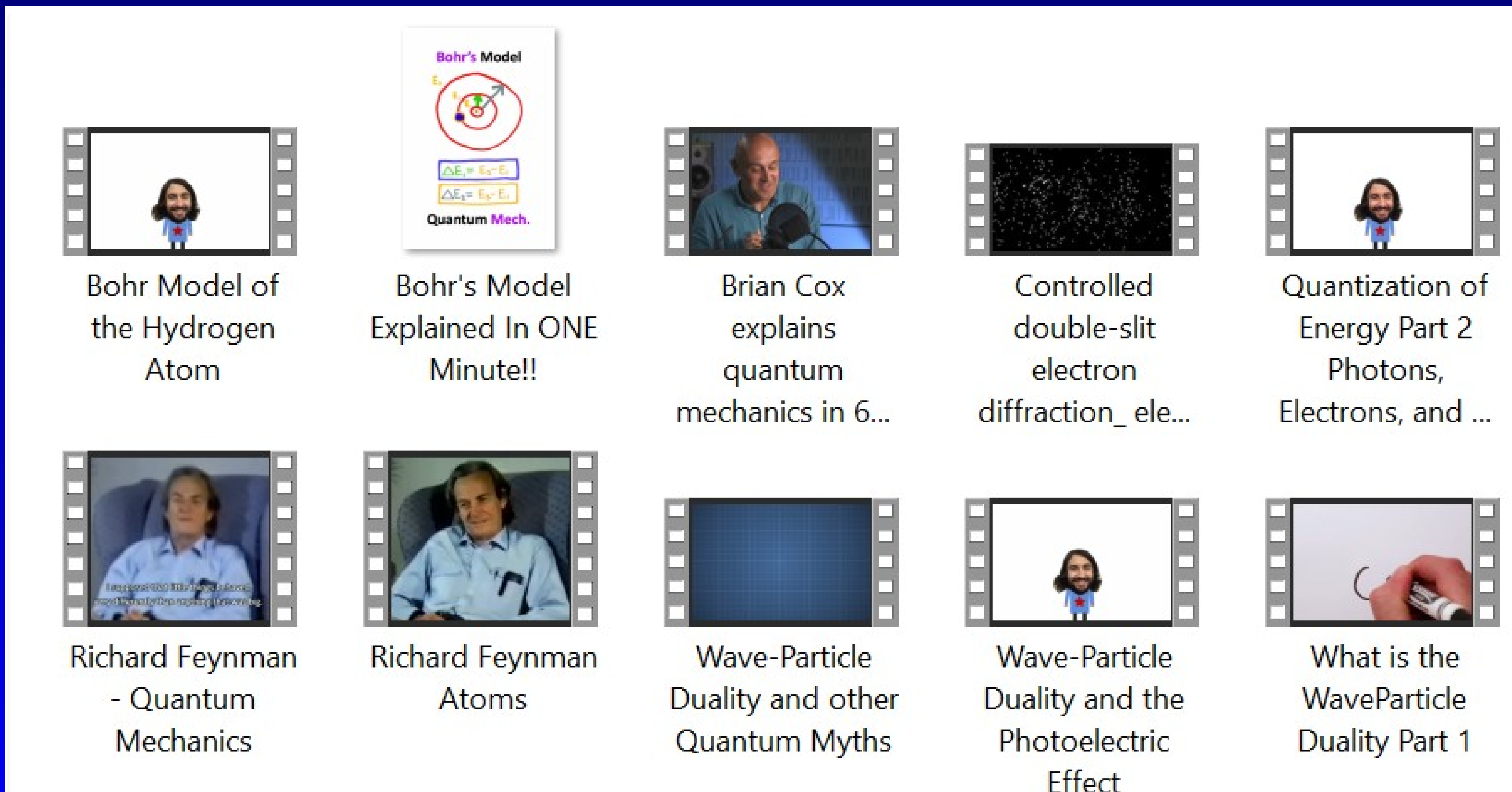



Fig. 9–8. The spectral intensity $\mathcal{J}(\omega)$ can be approximated by its value at $\omega_0$.

# Videos!


Bohr's Model
Quantum Mech.
Bohr Model of the Hydrogen Atom
Bohr's Model Explained In ONE Minute!!
Brian Cox explains quantum mechanics in 6...
Controlled double-slit electron diffraction_ ele...
Quantization of Energy Part 2 Photons, Electrons, and ...
Richard Feynman - Quantum Mechanics
Richard Feynman Atoms
Wave-Particle Duality and other Quantum Myths
Wave-Particle Duality and the Photoelectric Effect
What is the WaveParticle Duality Part 1

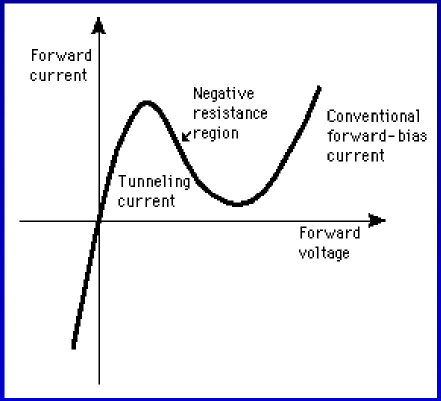
# Reality...

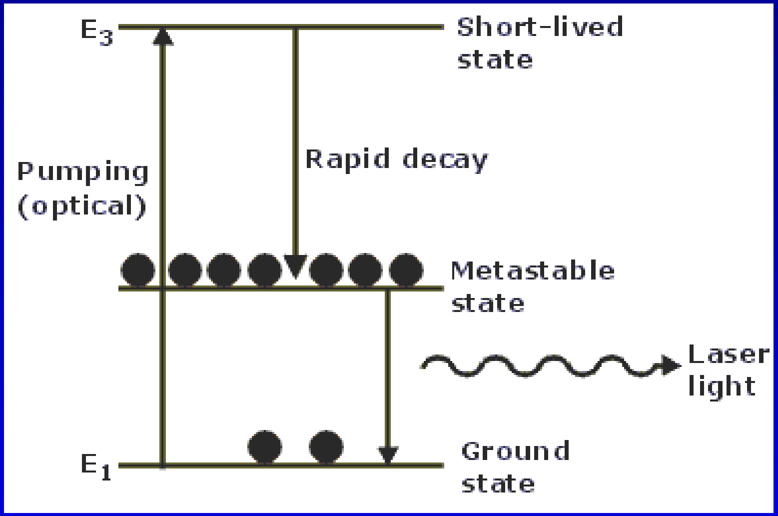
**“I like to think that the moon is there even when I am not looking at it.” - Albert Einstein**

# Quantum Mechanics in Real Life

**Integrated Circuits, computers; "Tunnel Diodes"**

**Lasers: metastable states**




**Coming Soon...**

**Cryptography, Quantum Computing**

# Questions??