Instructor: Sohrab Maleki

Quantum Theory: Session 02

Introduction to Quantum Physics

Contents

a_1, δ_1

a_2, δ_2

$\downarrow$

$|X\rangle$

$|Y\rangle$

$e^{i\delta}$

$$|\pm 45^\circ\rangle = \frac{|X\rangle \pm |Y\rangle}{\sqrt{2}}$$

$$|\pm\rangle = \frac{|X\rangle \pm i|Y\rangle}{\sqrt{2}}$$

Introducing the Quantum Language

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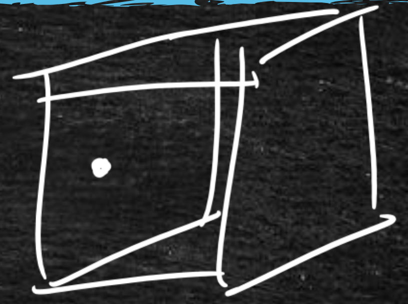
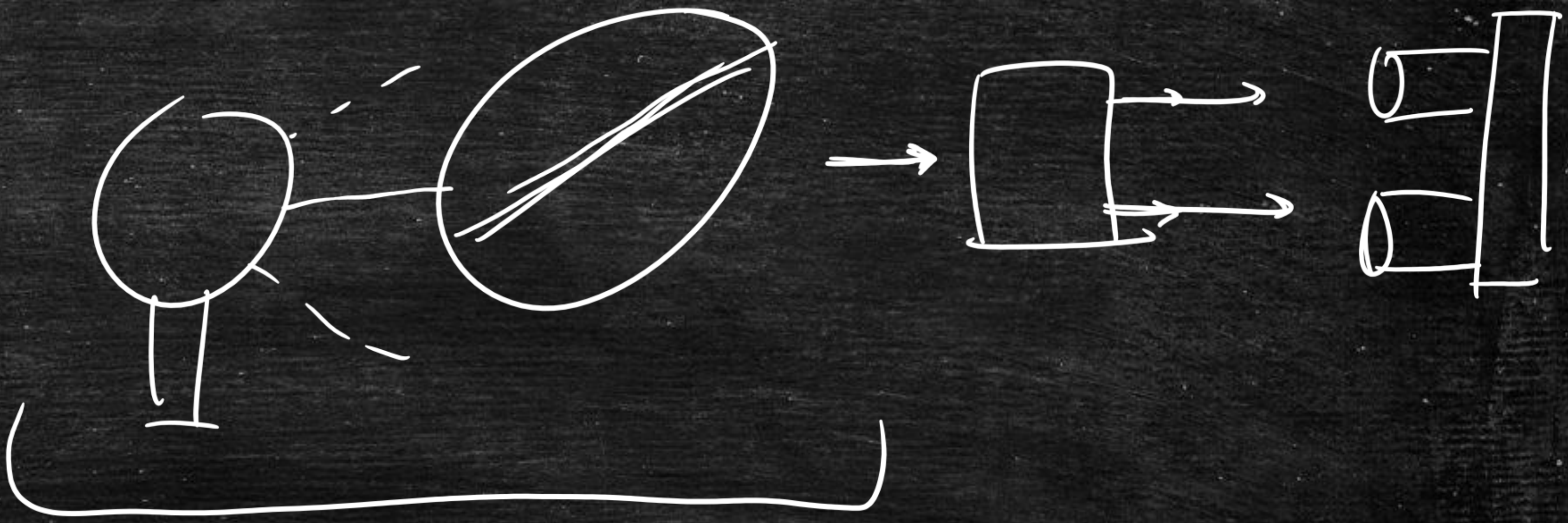
- What is the polarization of "that" photon?
- Same words with different meaning (such as those of SR)
- A geometric analogy





Preperations & Tests

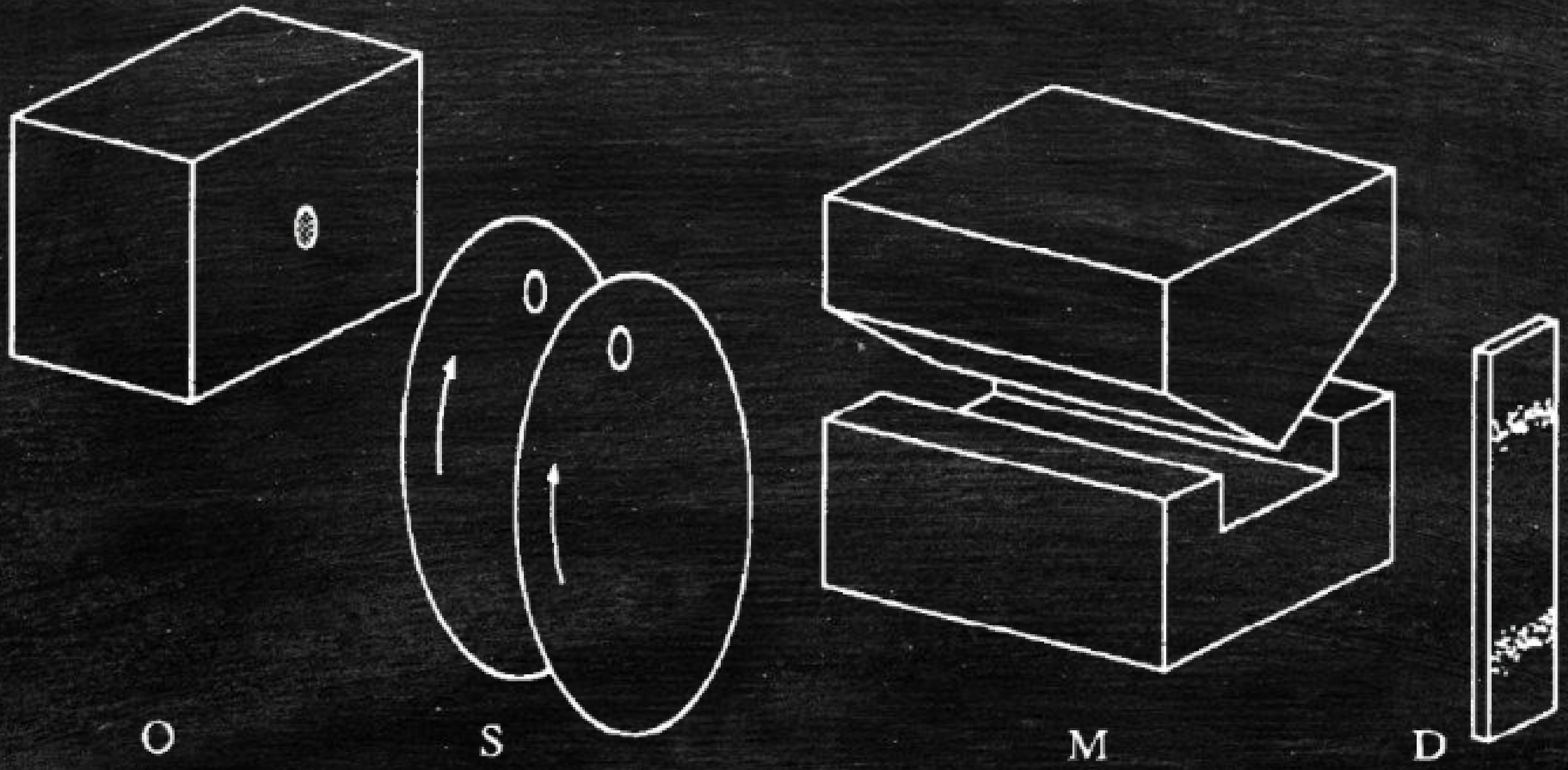
Preperations & Tests

- Primitive tasks ←
- Definition of Quantum Theory

What Is a Measurement?

What Is a Measurement?

- Stern-Gerlach experiment



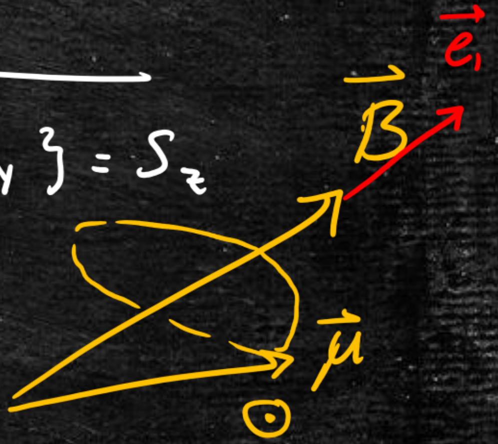
What Is a Measurement?

- Stern-Gerlach experiment

$$\nabla \cdot B = 0$$

$$H = \frac{p^2}{2m} - \vec{\mu} \cdot \vec{B}$$

$$\vec{\mu} = g\,\vec{S} \quad ; \quad \{S_x, S_y\} = S_z$$



$$\dot{\vec{\mu}} \perp \vec{\mu} \quad ; \quad \bar{\mu} = \mu_1 \vec{e}_1$$

$$\begin{cases} \dot{\vec{r}} = \{\vec{r}, H\} = \dfrac{\vec{p}}{m} \\ \dot{\vec{p}} = \{\vec{p}, H\} = \nabla(\vec{\mu} \cdot \vec{B}) \\ \dot{\vec{\mu}} = \{\vec{\mu}, H\} = g\,\vec{\mu} \times \vec{B} \end{cases}$$

$$\frac{d}{dt}(\vec{e}_1 \cdot \vec{p}) = \mu_1 B_1' \Rightarrow B_1' = (\vec{e}_1 \cdot \nabla)(\vec{B} \cdot \vec{e}_1)$$

$$\Delta P_1 = \mu_1 B_1' \Delta t = \mu_1 B_1' \frac{L}{v} \rightarrow \theta = \mu_1 B_1' \frac{L}{2E}$$

What Is a Measurement?

- Stern-Gerlach experiment

$$\theta = \mu B_1' \frac{L}{2E} \longrightarrow \mu \Rightarrow \pm \mu$$

$$\mu_1 = \vec{e}_1 \cdot \vec{\mu}$$

$$\mu_2 = \vec{e}_2 \cdot \vec{\mu}$$

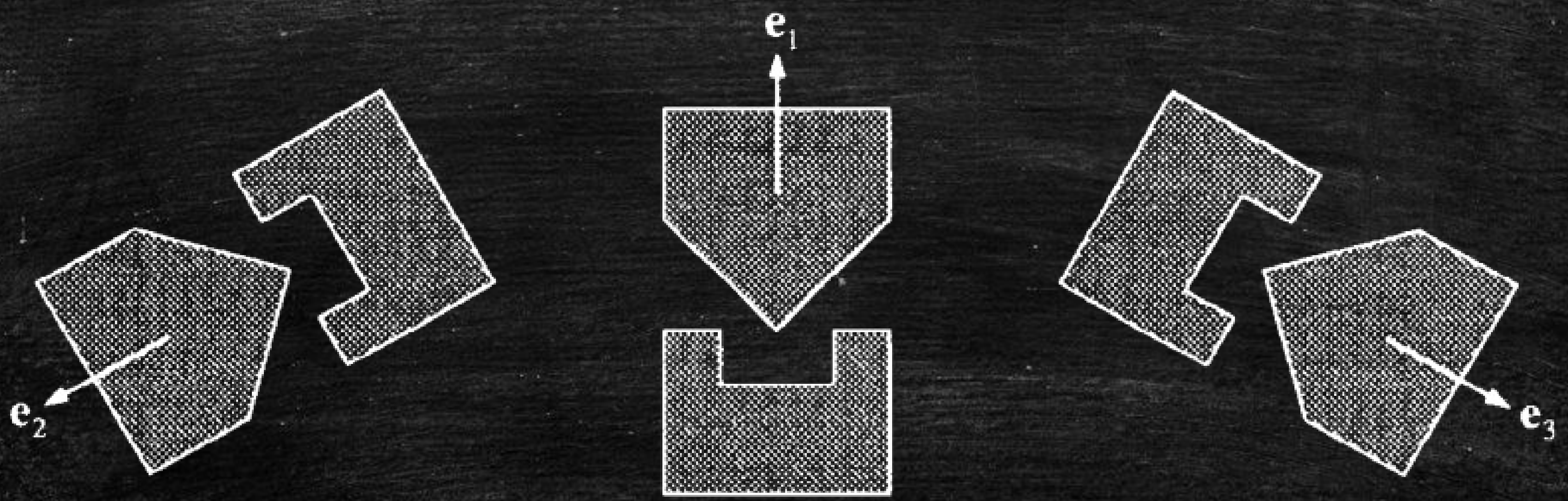
$$\mu_3 = \vec{e}_3 \cdot \mu$$

$$\underbrace{\mu_1 + \mu_2 + \mu_3}_{\mu(\pm 1 \pm 1 \pm 1)} = \vec{\mu} \cdot \big(\underbrace{\vec{e}_1 + \vec{e}_2 + \vec{e}_3}_{0}\big)$$

What Is a Measurement?

- Stern-Gerlach experiment

$$\vec{e}_1 + \vec{e}_2 + \vec{e}_3 = 0$$



What is a Quantum System?

What is a Quantum System?

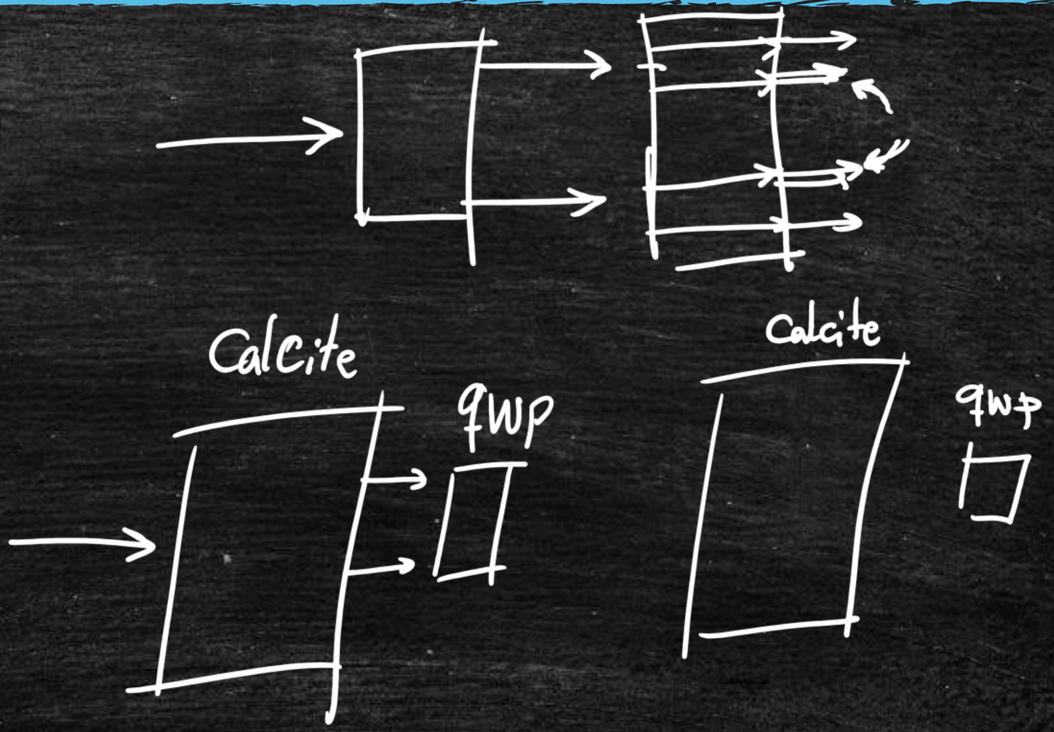
- Definition of Quantum System
- Definition of Quantum States
- "Probability"

$\{ P_i \}_i$

Repeatable Tests

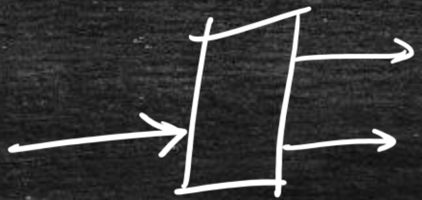
Repeatable Tests

- Definition of "Repeatable Tests"
- Examples: Photons – Silver Atoms.
- Are "nonrepeatable" tests "bad"?



Maximal Tests

Maximal Tests



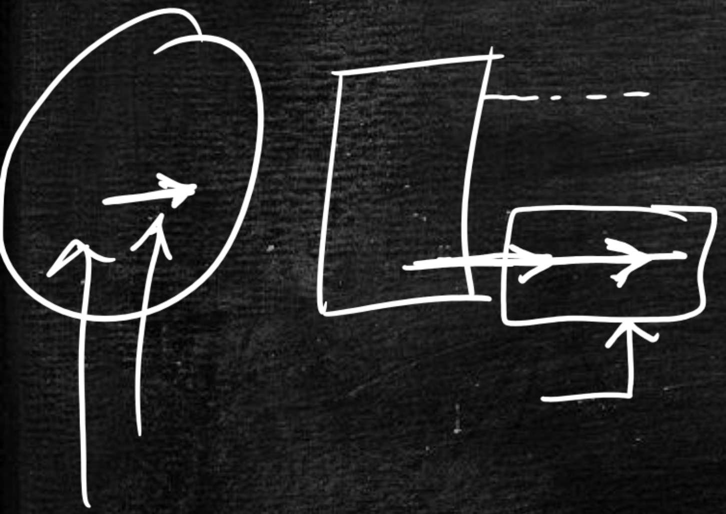
$N < \infty$

$N_{max} \rightarrow$ maximal

$S = 1 \rightarrow \begin{cases} -1 \\ 0 \\ +1 \end{cases}$

$2S + 1$

Maximal Tests

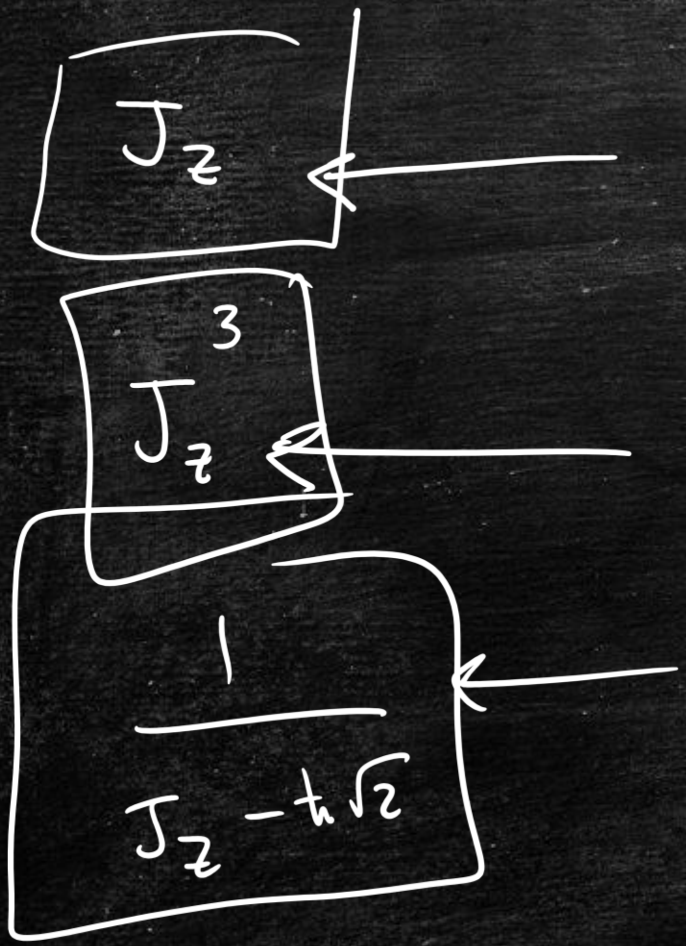


A. Statistical determinism.

If a quantum system is prepared in such a way that it certainly yields a predictable outcome in a specified maximal test, the various outcomes of **any** other test have definite **probabilities**. In particular, these probabilities do not depend on the details of the procedure used for preparing the quantum system, so that it yields a specific outcome in the given maximal test. A system prepared in such a way is said to be in a **pure** state.

Maximal Tests

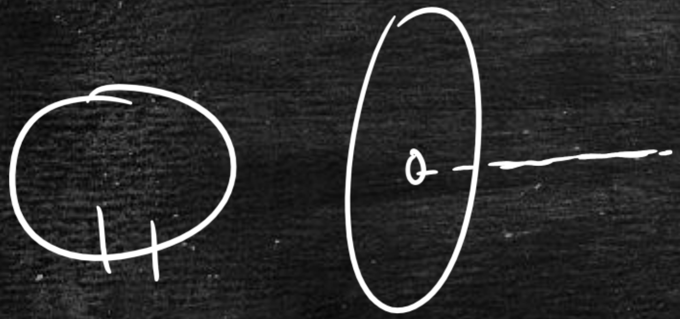
$$X = \sum x_i \, |i\rangle\langle i| \qquad |\langle i|\psi\rangle|^2$$



B. Equivalence of maximal tests.

Two maximal tests are equivalent if every preparation that yields a **definite** outcome for one of these tests also yields a **definite** outcome for the other test. In that case, any other preparation (namely one that does not yield a predictable outcome for these tests) will still yield the same **probabilities** for corresponding outcomes of both tests.

Maximal Tests



C. Random Mixtures

Quantum systems with N states can be prepared in such a way that every unbiased maximal test has the same probability, N^{-1}, for each one of its outcomes.

Consecutive Tests