Advanced Quantum Mechanics II

PEN425

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Week 1

Introduction

State

Stern – Gerlach Experiment

Dirac Notation

Ket and Bra Spaces

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Books

I. J.J. Sakurai, Modern Quantum Mechanics (2nd Ed.)
II. E. Merzbacher, QM (3rd Ed.)

NRQM

III. J. Bjorken, S. Drell, RQM (v.1)
IV. J.J. Sakurai, Advanced QM
V. W. Greiner, D.A. Bromley, RQM

RQM

NRQM

- Hydrogen Atom – Fine Structure (Addition of Angular Momenta)
- Quantum Mechanical Pictures – Time Evolution Problem
  - Schrödinger Picture
  - Heisenberg Picture
  - Dirac Picture
- Time Dependent Problems

- Time Dependent Perturbation Theory.
  - Constant Potentials
  - Harmonic Potentials
- Atoms in Classical Radiation Field
- Gauge Problems
- Spontaneous and Simulated emmissions

RQM

- Lorentz Transformations
- First attempt on Relativistic QM. Klein Gordon Eqns.
- Dirac Eqn.
- Non-Relativistic Limits
  - Free, in pure magnetic field (g=2)
  - Coulomb field (Fine Structures of Hydrogen)
- Classical Limits

State

- Classical Physics: $\{x_i, p_i\}$
- $\boldsymbol{F} = m\boldsymbol{a} = m\frac{d\boldsymbol{v}}{dt} = \frac{d}{dt}(m\boldsymbol{v}) = m\frac{d^2\boldsymbol{x}}{dt^2}$
- One can 'predict' $\boldsymbol{x}(t), \boldsymbol{p}(t)$
- Need '2 initial conditions' for ∀i

$x_i(0)$, $p_i(0)$ → $x_i(t)$, $p_i(t)$

- 'Causality'
- 'Deterministic'
- 'Physics' is Phenomenological Science

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Measurement
(Experiment & Observations)

- Quantization of Charge: $Q = ne$

Measurement in 'microworld' is order dependent.

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We need 'order dependent' mathematical entities to describe 'dynamical variables'

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Operators/Matrices

Stern-Gerlach Experiment (1921-22)

- 1900: Planck
- 1905: Einstein
- 1926:
  - Schrödinger
  - Heisenberg
  - Dirac
  - Born

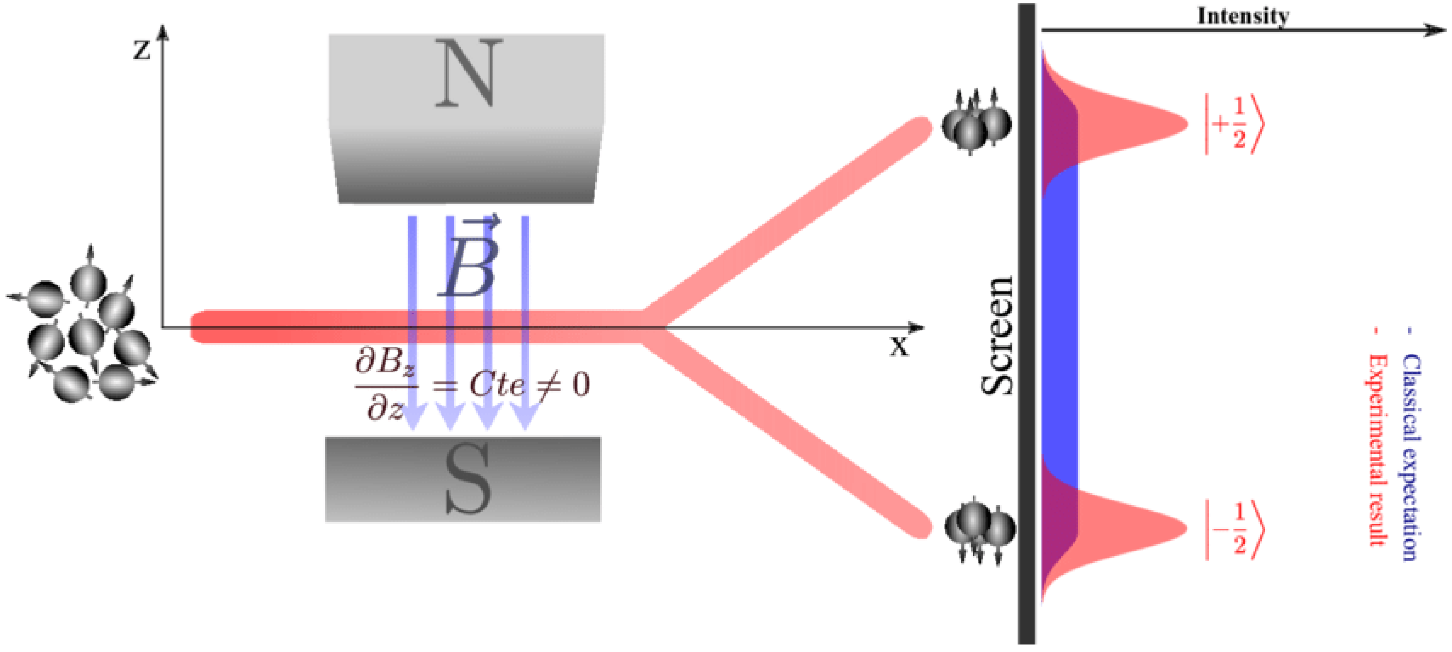

Figure: https://www.researchgate.net/figure/Sketch-of-Stern-Gerlach-experiment-A-beam-of-silver-atoms-is-sent-through-an_fig2_334586888

Classical

State: $\{x_i, p_i\}$

Dynamical Variables (c-numbers)

Quantum

Vectors in a Linear Complex Vector Space*

Hermitian (Linear) Operators

*Dimensions of Vector Space : Number of Linearly independent Basis Vectors

- Orthogonal
- Normalized
- Complete

Orthonormal

*Number of possible results of an experiment

- Hilbert Space: Infinite Dim.
- Complex Vector Space = {<u>State Vectors</u> ; <u>Observables</u>}

$|\alpha\rangle$ $\qquad\qquad$ A

Exp: Spin $\frac{1}{2}$

$$S_z|\pm\rangle_z = \pm\frac{\hbar}{2}|\pm\rangle_z$$
$$S_x|\pm\rangle_x = \pm\frac{\hbar}{2}|\pm\rangle_x$$

$$A(|\alpha\rangle)=A|\alpha\rangle \neq (const)|\alpha\rangle$$

If $A|\alpha\rangle = (const)|\alpha\rangle$
$|\alpha\rangle: eigenstate(ket)\ of\ A$
$\{\alpha_i; i = 1, \dots, n\}$
$c_i \in C$

$$A|\alpha_i\rangle=\alpha_i|\alpha_i\rangle$$

$eigenvalues$ $\qquad$ $eigenkets$

Arbitrary State

$$|\alpha\rangle = \sum_{i=1}^{n} c_i\,|\alpha_i\rangle$$

Ket Space	Dual Correspondance	Bra Space
$\|\alpha\rangle$	$\longleftrightarrow$	$\langle\alpha\|$
$\{\|\alpha_i\rangle\}$	$\longleftrightarrow$	$\{\langle\alpha_i\|\}$
$\|\alpha\rangle + \|\beta\rangle$	$\longleftrightarrow$	$\langle\alpha\| + \langle\beta\|$
$\mathrm{c}\|\alpha\rangle$	$\longleftrightarrow$	$\mathrm{c}^*\langle\alpha\|$
$c_1\|\alpha\rangle + c_2\|\beta\rangle$	$\longleftrightarrow$	$c_1{}^*\langle\alpha\| + c_2{}^*\langle\beta\|$