"Feynman" Diagram

$$\underset{\sim}{U}_I(t,t_0) = 1 - \frac{i}{\hbar}\int_{t_0}^{t} \underset{\sim}{H}'_I(t')\,dt' + \left(-\frac{i}{\hbar}\right)^2 \int_{t_0}^{t}\int_{t_0}^{t'} \underset{\sim}{H}'_I(t')\,\underset{\sim}{H}'_I(t'')\,dt'\,dt'' + \ldots$$

$\Rightarrow$ back to Schrödinger Picture

$$|\psi_I(t)\rangle = \underset{\sim}{U}_I(t,t_0)\,|\psi_I(t_0)\rangle$$

$$\underset{\sim}{U}_s^{+0}(t,t_0)\,|\psi_s(t)\rangle = \underset{\sim}{U}_I(t,t_0)\,\underbrace{\underset{\sim}{U}_s^{0+}(t_0,t_0)}_{1}\,|\psi_s(t_0)\rangle$$

$$\downarrow$$

$$\underset{\sim}{U}_s^{+0}(t,t_0)\,\underset{\sim}{U}_s(t,t_0)\,|\psi_s(t_0)\rangle = \underset{\sim}{U}_I(t,t_0)\,|\psi_s(t_0)\rangle$$

$$\boxed{\underset{\sim}{U}_s(t,t_0) = \underset{\sim}{U}_s^{0}(t,t_0)\,\underset{\sim}{U}_I(t,t_0)}$$

$$\underset{\sim}{H}'_I(t') = \underset{\sim}{U}_s^{0+}(t',t_0)\,\underset{\sim}{H}'_s(t')\,\underset{\sim}{U}_s^{0}(t',t_0)$$

so,

$$\underset{\sim}{U}_s^{0}(t,t_0)\,\underset{\sim}{U}_I(t,t_0) = \underset{\sim}{U}_s(t,t_0) = \underset{\sim}{U}_s^{0}(t,t_0)$$

$$-\frac{i}{\hbar}\int_{t_0}^{t} \underbrace{\underset{\sim}{U}_s^{0}(t,t_0)\,\underset{\sim}{U}_s^{0+}(t',t_0)}_{\text{study}}\,\underset{\sim}{H}'_s(t')\,\underset{\sim}{U}_s^{0}(t',t_0)$$

+ higher order

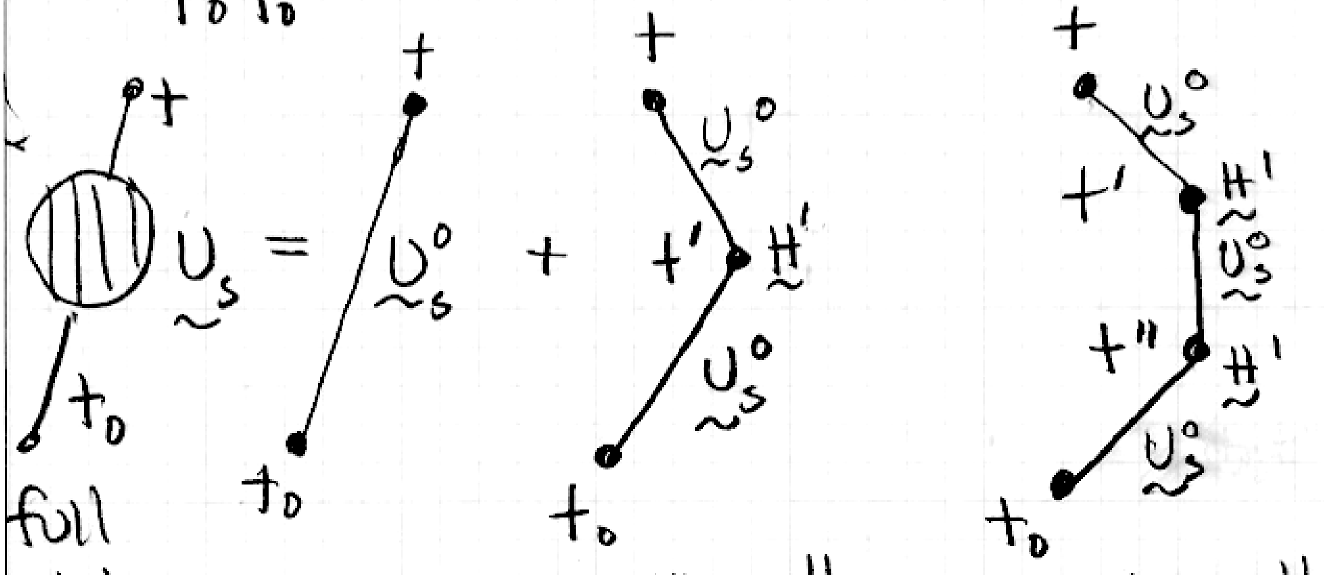
$$\underset{\sim}{U}_s^0(t,t_0)\underset{\sim}{U}_s^{0\dagger}(t',t_0) = \underset{\sim}{U}_s^0(t,t_0)\underset{\sim}{U}_s^0(t_0,t')$$
$$= \underset{\sim}{U}_s^0(t,t').$$

similar "composition" influences second & higher order:

$$\underset{\sim}{U}_s(t,t_0) = \underset{\sim}{U}_s^0(t,t_0) - \frac{i}{\hbar}\int_{t_0}^{t}\underset{\sim}{U}_s^0(t,t')\underset{\sim}{H}_s'(t')\underset{\sim}{U}_s^0(t',t_0)\,dt'$$

read right to left

$$+\left(\frac{-i}{\hbar}\right)\int_{t_0}^{t}\int_{t_0}^{t'}\underset{\sim}{U}_s^0(t,t')\underset{\sim}{H}_s'(t')\underset{\sim}{U}_s^0(t',t'')\underset{\sim}{H}_s'(t'')\underset{\sim}{U}_s(t'',t_0)$$



full solution

sum over all possible t'

sum over all possible t', t'' keeping $t' > t''$

Material Since Midterm (approximately).

A. Spin 14.1, 14.2

14.3 1) Commutation Relations

2) "2-component" formalism

3) Spin operators – representation of a 3-vector in the 2-component formalism, meaning of $\hat{n}\cdot\underset{\sim}{\vec{S}}$ (14.3.27).

4) Pauli Matrices + Pauli Gymnastics

5) Rotation Operators

14.4 6) Spin Dynamics – torque, energy

7) precession

8) $\gamma = \frac{gq}{2mc}$, $\vec{\omega}_0 = -\gamma\vec{B}$, $\underset{\sim}{\vec{\mu}} = \gamma\underset{\sim}{\vec{S}}$,

$\underset{\sim}{H} = -\underset{\sim}{\vec{\mu}}\cdot\vec{B} = -\gamma\underset{\sim}{\vec{S}}\cdot\vec{B} = -\frac{1}{2}\hbar\,\vec{\omega}_0\cdot\underset{\sim}{\vec{\sigma}}$

$g = 2$

9) Paramagnetic Resonance

14.5 10) Stern Gerlach Experiments

a) General Functioning

b) Abstract Implementation of Postulate III (notes: 51–54)

c) multiple Stern Gerlachs.

B. Addition of Angular Momenta

15.1 1) Concept of product ket

2) That $\underset{\sim}{\vec{J}}_1 \cdot \underset{\sim}{\vec{J}}_2$ not diagonal in product basis, so $(\underset{\sim}{\vec{J}}_1 + \underset{\sim}{\vec{J}}_2)^2 = \underset{\sim}{\vec{J}}^2 = \underset{\sim}{\vec{J}}_1^2 + \underset{\sim}{\vec{J}}_2^2 + 2\underset{\sim}{\vec{J}}_1 \cdot \vec{J}_2$ not diagonal; $\underset{\sim}{\vec{J}}_1^2, \underset{\sim}{\vec{J}}_2^2$ are diagonal

15.2 3) How $j_1 - j_2 \leq J \leq |j_1 + j_2|$ preserves the # of states.

4) How to start from $|jm, j_1 j_2\rangle = |(j_1+j_2)(j_1+j_2), j_1 j_2\rangle$ and lower to get Clebsch-Gordan Coefficients.

5) How to skip to $|(j_1+j_2-1)(j_1+j_2-1), j_1 j_2\rangle$ by orthogonality.

6) Notation: $|jm, j_1 j_2\rangle$, $|j_1 m_1, j_2 m_2\rangle$

$$\langle j_1 m_1, j_2 m_2 | jm, j_1 j_2\rangle = \langle j_1 m_1, j_2 m_2 | jm\rangle$$

even $= \langle m_1 m_2 | jm\rangle$

7) That $m_1 + m_2 = m$

8) Modified Spectroscopic Notation

$\Rightarrow$ nothing from 15.3, 15.4, Chapter 16

C. Time-Independent Perturbation Theory

17.1 1) $\underset{\sim}{H} = \underset{\sim}{H}^0 + \underset{\sim}{H}'$, crude: $|\underset{\sim}{H}'| \ll |\underset{\sim}{H}^0|$

$|n\rangle = |n^0\rangle + |n^1\rangle + |n^2\rangle + \ldots$

$E_n = E_n^0 + E_n^1 + E_n^2 + \ldots$

$\longrightarrow$ Non-degenerate.

2) $\boxed{E_n^0 = \langle n^0 | \underset{\sim}{H}' | n^0 \rangle}$ 17.1.7

3) To first order

$$|n\rangle = |n^0\rangle e^{i\alpha} + \sum_m{}' \frac{|m^0\rangle\langle m^0|\underset{\sim}{H}'|n^0\rangle}{E_n^0 - E_m^0}$$

17.1.3

4) $$E_n^2 = \sum_m{}' \frac{|\langle n^0|\underset{\sim}{H}'|m^0\rangle|^2}{E_n^0 - E_m^0}$$

17.2 5) Examples from S.H.O, Hydrogen Atom, Square Well... maybe more.

6) Selection Rules:

a) $[\underset{\sim}{\Omega}, \underset{\sim}{H}'] = 0 \Rightarrow$ perturbation diagonal in eigenkets of $\underset{\sim}{\Omega}$.

b) Parity.. when $l' = l \pm 1, l \pm 3, \ldots$
and when $l' = l, l \pm 2, \ldots$

7) Dalgarno Lewis p. 462

17.3 8) Degenerate, First Order (Diagonalize in Degenerate Subspace)

a) Stark Effect.

D. Time Dependent Perturbation Theory.

1) $\underset{\sim}{H} = \underset{\sim}{H}^{0} + \underset{\sim}{H}'(t)$

static — small, time dependent

2) $d_f(t) = \delta_{fi} - \frac{i}{\hbar}\int_0^t \langle f^0|\underset{\sim}{H}'(t')|i^0\rangle e^{i\omega_{fi}t'}\,dt'$

first order

3) Sudden versus Adiabatic

τ – time scale variation of $\underset{\sim}{H}'(t)$

$\omega_{min} = \text{minimum}(\omega_{fi})$

$\omega_{min}\tau \gg 1$ Adiabatic → states "track"

$\omega_{min}\tau \ll 1$ Sudden → transitions

4) Fermi's Golden Rule

5) "Pictures" – Schrödinger
Heisenberg
Interaction (Dirac).

Material Prior to Midterm

A. Radial Equation

1) know Y_ℓ^m's (pp. 335 - 339)

12.6 2) Radial Equation

a) $R_{E\ell} = U_{E\ell}/r$

b) $U_{E\ell} \propto r^{\ell+1}$ at origin

pp. 346 → 352 not covered.

c) fall to the center

d) finite/∞ # of bound states!

$r^2 V(r) \to \infty$ as $r \to \infty$
∞ bound states

→ constant or 0
finite #

e) Power Law Potentials

→ length scale

→ energy scale

→ "reduced" equation

3) Numerical Integration Technique

B. Hydrogenic Atoms

13.1 1) Energy Eigenvalues

2) Angular Momentum, Degeneracy.

3) Radial Wave Functions

4) Powers of $\alpha = e^2/\hbar c$

$\frac{v}{c} \cong \alpha$ in Hydrogen Ground State.

$E_n = -\frac{1}{2}\mu c^2 \times \frac{\alpha^2}{n^2}$ et cetera.

5) Two body problem, $\mu = \frac{m_1 m_2}{m_1 + m_2}$

et cetera.

6) Other Bound States

a) quarkonium

b) deuterons