Outline

March 10, 2011

$$H = \underbrace{\frac{p^2}{2m} + e\Phi}_{H_0} + V(x)$$

1 Introduction

1.1 Description of the problem

Describe the general problem we investigate:

Two charged particles in a loosely bound system, each particle having arbitrary spin

Calculate corrections to g-factor for particles in such a system

Talk about experimental motivation, measurements in O and C molecules.

Discuss how the problem is nonrelativistic, the precision we need, and the types of approximations we can then make.

1.2 theoretical background

Briefly discuss various theoretical approachs: NRQED approach

Discuss prior work.

spin 1/2 approach

BMT equation

Khriplovich general spin formalism

Faustov ?

2 Background for Nonrelativsitic Quantum Electrodynamics

2.1 Effective theories

Some worked examples

2.2 Nonrelativistic Quantum Electrodynamics

General approach

Example with muonium

3 The case of spin one-half

General discussion of properties of the spin 1/2 case, in both relativistic and nonrelativistic cases.

Calculation with Foldy-Wouthyusen method, starting from equations of motions

Calculation with NRQED approach, calculations with diagrams.

4 The case of spin one

General discussion of properties of the spin 1 case, in both relativistic and nonrelativistic cases.

Contrast with spin 1/2.

Calculation with Foldy-Wouthyusen method, starting from equations of motions

Calculation with NRQED approach, calculations with diagrams.

4.1 Spin-1 through diagrams

The plan is to start from the exact spin-1 theory, and obtain the NRQED Lagrangian.

Start with relativistic Lagrangian.

Derive the electromagnetic vertices.

Discuss wave functions and find the connection between the relativistic and non-relativistic free theories.

Find one-photon terms by calculating scattering off an external field.

Find two-photon terms by calculating Compton scattering.

Write down NRQED Lagrangian.

4.2 Spin-1 through equations of motion

4.2.1 Equations of motion

Derive the Euler-Lagrange equations from the spin-1 relativistic lagrangian

Contrast the form of the wave functions here with in the previous approach.

Eliminate non-dynamic fields, and solve for the energy.

4.2.2 Non relativistic wave functions

Transform so that particle-antiparticle are uncoupled.

Find NR single-particle Hamiltonian.

Show that there are no corrections from a FW transformation that enter at our level of precision.

Finally find the nonrelativistic Hamiltonian.

5 The case of general spin

Describe the features of both the relativistic theory:

Definition of wave functions; spin degrees of freedom

Spin operators S and Σ

Describe nonrelativistic theory along the same lines.

Describe the connection between the two free theories.

5.1 NRQED Lagrangian for general spin

Our goal is to calculate the NRQED Lagrangian.

Discuss what constraints we have: symmetries, hermiticity, etc.

Given assumptions about the strengths of the EM field and the momentum of the particles, we need up to $\frac{1}{m^3}$ terms.

Write down all allowed terms in the Lagrangian up to that order.

Note that only up to two-photon interactions appear, and they can be fixed by gauge invariance from the one-photon interactions.

5.2 One-photon interaction in relativistic theory

Now take the relativistic theory, and consider what the one-photon interaction will look like.

Constrained by Lorentz transformation properties and current conservation.

Show how only two bilinear terms are then allowed.

Their coefficients will be just charge and g-factor, with corrections at a higher order than we need.

Write down this general interaction.

5.3 One-photon interaction in NRQED

Express the current in terms of the nonrelativistic wave functions.

Thus, fix the NRQED coefficients.

Write down this general-spin NRQED Lagrangian.

6 Corrections to g-factor in nonrecoil case

Write the general NRQED Lagrangian.

Write as a Schroedinger like nonrelativistic Hamiltonian.

Calculate corrections to the g-factor for S-orbitals.

Show that no higher order terms in perturbation theory enter.

7 Recoil case

From the NRQED Lagrangian, we can calculate the effective Breit potential.

7.1 NRQED calculation

Calculate that potential from the one-photon interaction diagrams in NRQED.

7.2 relativistic calculation

We can calculate the same process in the relativistic theory, to make sure it agrees.

7.3 CoM transformation

Transform coordinates to the center of mass system.

When an external magnetic field is present, we need an additional unitary transformation.

7.4 g-factor calculation

Calculate the corrections to the g factor, now taking into account recoil effects.

8 Conclusion