Quantum Theory (PHYS 450): Week 2

Spring 2008 v1.0

This week we launch into chapter 2, continuing the development of Dirac notation and building the connection to Heisenberg's matrix mechanics (if you don't know the history of how he came up with this let me know). Townsend introduces rotation operators - thingies that take a ket in one basis and gives components in another. Here we encounter the key idea of a *finite* rotation made from an exponentiated *infinitesimal* generator. (This may be seen as a link between algebras and groups.) The chapter closes with the matrix representation of operators and photon polarization.

Please keep me posted on how the problems are going, we could move 2.9 - 2.19 to next week.

Enjoy!

Reading:

Townsend Chapter 2

Problems:

Problems are due at the beginning of seminar. Please make a copy of your solutions before you arrive.

(1) How do we know that we are measuring the magnetic moment in the SG apparatus? Consider the usual conventions for the magnetic field, $\mathbf{B} = B\mathbf{k}$. Wouldn't the torque due to the magnetic field tend to align the magnetic moment with the magnetic field? If it does then this would change the z-component of the magnetic moment. Hint: Notice that $\mu \propto L$.

(2) Silver atoms are filtered through a sequence of SG experiments as shown. For each of the arrangements (a)-(d) find the expected number of atoms to arrive at Q. Assume that you start with N atoms at P.

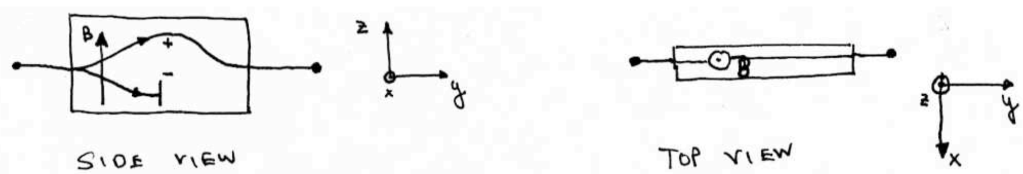
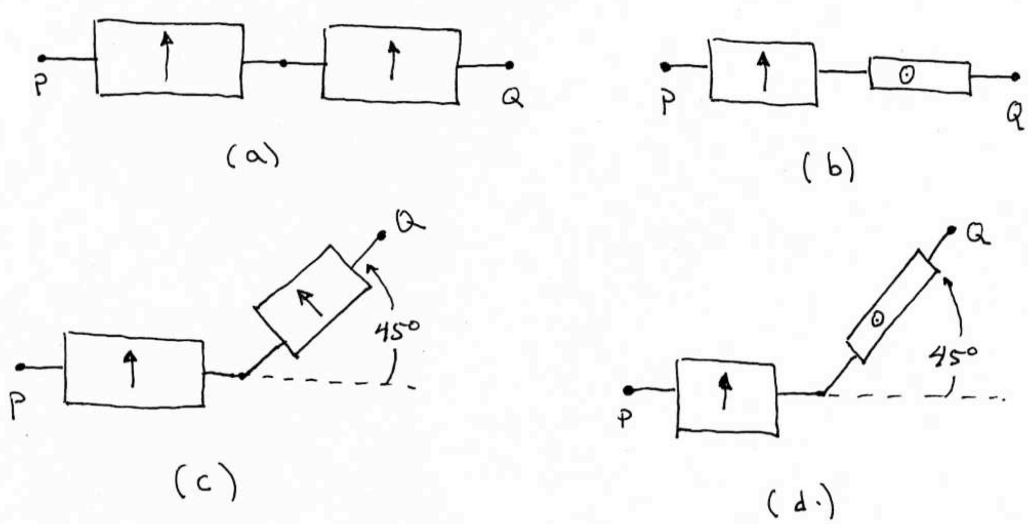


FIG. (1)



(3) 2.1
(4) 2.2
(5) 2.3
(6) 2.4
(7) 2.6
(8) 2.8
(9) 2.9
(10) 2.10
(11) 2.19

Seminar Presentations:

Please stop by or email me if you have any questions on your presentation. If you are planning on using the projection equipment, you'll need a laptop and some time before seminar to check that it is working.

- Seth: On operators in quantum mechanics
- Mike: Introduce our very first operator, $\hat{R}(\frac{\pi}{2}\mathbf{j})$. Explain the notation $\hat{R}(\cdot\ \cdot)$. Does this rotate the coordinate system, the state, some combination? Is it linear? (remind us what this means) Is this an "active" or "passive" transformation? Derive the adjoint operator. (pgs 28 - 30).
- Jordan: Tell us what a *unitary* operator is. Show that a non-unitary operator would destroy probability "conservation". Why is this a big deal for the interpretation of quantum mechanics? If you like, look up the black hole information paradox, tell us about it, and explain how (non-)unitary operators play a role.
- Dan C.: Tell us about the generator of infinitesimal rotations. Define a *self-adjoint* or *Hermitian* operator and show that J_z must be an example of one. Look up a GRE problem involving Hermitian operators and let us try to solve it. (pgs 30 - 32)
- Dan T.: Define *eigenstate* and *eigenvalue*. Following Townsend show that $\mid +z\rangle$ is an eigenstate of the operator J_z. Guide us through the "consistency argument" on pages 34-35 which give
$$\hat{J}_z \mid \pm z\rangle = \pm\frac{\hbar}{2} \mid \pm z\rangle$$
- Wex: What is unusual for spin-1/2 particles when the state is rotated by 360^o?
- Ruth: Remind us of the definition of *projection* operators and the *identity* (mention equation 2.57). How is the completeness relation related? Review the fundamental relations for projection operators. Show the SG realization of them. (pgs 36 - 38)
- Emily: Discuss the complicated way of writing 0, equation 2.56, and its physical implications. Lead us through the interpretation of the terms. The discussion is on page 40.
- Nguyen: Show us what an operator *matrix representation* is. Give the general form, an example with the projection operator, and $\hat{J}_z$. Present the solution of 2.3. (pgs 41 - 45)
- Walter: Explain how to change the representation using a matrix. Derive $\hat{J}_z$ in the y-basis. (pgs. 45 - 50). Present a solution 2.4, 2.5 or 2.6.