GUIDED PRACTICE

Class: 4110A - Quantum Spin Measurement Tutorial
Date assigned: Second week of class on Thursday
Date due: Third week of class on Tuesday
Time estimate to complete this assignment: 40-50 minutes

Overview/Introduction

"Spins first" upper-division Quantum Mechanics courses, taught using McIntyre's Quantum Mechanics as text. This is our first week's Tutorial, it can come after just one or two days of instruction!

Prerequisite knowledge for this tutorial:

1. This Tutorial can come very early – basic familiarity with Stern-Gerlach experiments.
2. Basic ideas of probability and statistics
    a. use probability and statistics to predict outcomes of quantum measurements.
    b. use mean and standard deviation to argue whether outcome agrees with theory.
3. introduction to basic bra and ket notation, including basic conventions (e.g |+> means an eigenstate of S_z, even though no subscript z is written.)
4. Basic introduction to the idea that the state of a quantum mechanical system, including all the information you can know about it, is represented mathematically by a normalized ket.

Note: Items 2 may require a review of your previous math/statistic courses; items 2 and 3 are already introduced in class and will be enforced with reading the text.

Learning Objectives

Basic objectives

Introduction to Stern Gerlach Spin computer simulations

- familiarize students with the online computer-based Spin ½ measurement apparatus (SGD)
- Students use the simulations to conduct spin measurement experiments
- determine the the result from a measurement
- calculate the probability of a measurement outcome given a quantum state
- determine the resulting quantum state after a measurement

Preparatory Activities and Resources:

Use the following simulation to prepare for the class:

1. Use the worksheet "A_SpinLab1_Measurement_Probability" prelab instruction attached* to familiarize yourself with the spin measurement simulations and the tutorial worksheet. (estimated time for 15-20 minuets)

2. Read the following pages from your textbook
    a. Chapter 1, sections 1.1 & 1.2 (estimate 15-20-minutes)
3. Take the online WEEK1- preflight on blackboard (estimated time 10 minutes)

Note: *Basic HTML5 version (works on pad/phones/in any browser):* ***https://tinyurl.com/spin3220****. More featured JAVA Version: (Only if you can run Java!)* ***http://tinyurl.com/jdo2ybd*** *Download the "Standalone Package" (middle of the page, 1st link in the APPLICATION section). On Macs, you need to ctrl-click the downloaded file and agree to let it run.*

Associated Homework Problems: are posted on Blackboard with links and attachments to the related documents.

Note: All related assignments and information will be posted on Blackboard with links and attachments to the related documents.

Flipped IN-CLASS Lesson Plan

Topic or concept:

1. Topic: "Spins first" upper-division Quantum Mechanics courses, taught using McIntyre's Quantum Mechanics as text. This is our first week's Tutorial, it can come after just one or two days of instruction!
2. Class size: Our tutorial sections capped at 24 students with a typical student, often with an instructor and a Learning Assistant with tables of 4, with paper or whiteboards for scratch work.
3. Timing: We give 90 minutes for this Tutorial. Most will get close to done (**not** including the "challenge" question on the last page)
4. NOTE: Java is problematic to run on many computers (esp. tablets/phones). The html5 version below is fine for everything *except part 4C (and the challenge question),* which ask students to "input the state" in the form of a complex spinor. You could just have the instructor run the Java sim. (Next tutorial this becomes a little more problematic) We tell students in advance to get it set up, and many of them were fine during Tutorial.

Basic objectives for preparatory work:

After completing this tutorial, students should be better able to…

1. determine the values that could result from a measurement of a given physical observable in quantum domain
2. calculate the probability of a measurement outcome given a quantum state
3. determine the resulting quantum state after a measurement

Advanced objectives for classwork & after class work:

1. determine whether two observables can be simultaneously determined
2. use technical language of QM correctly (here, *bra, ket, state*)
3. complete homework exercised to practice bra, ket, and statistical

	Time planned	Activity and rationale	Resources needed
Beginning of class period	5 min	Course reminders, announcements, passing out laptops Grouping students, collections of pre	Laptop cart from stock room
Introduction & review	10 min	Discussion of the preclass assignments - online preflight related to reading and pre-class guided practice - student responses and questions	Sumary of student responses to preflight and statistical data to MC questions from blackboard
Group work and peer instructions	50 min	Pass out the Tutorial worksheet to individuals each two students will get a laptop to share - Students conduct the computer-based experiments that are outlined - Discussed the results and interpretations with peers and the instructor using whiteboards - write out the results and their responses to the questions on the worksheet	Copies of tutorials worksheet and laptops
Whole class Discussion	20 min	- Whole class discussion of the results, data, - Group presentations of selected solutions - Summary and take-home messages	Small whiteboards for groups And blackboard and chalk
Reminders and deadlines	5 min	Description of the after-class assignment, homework exercises and deadlines, etc. Reminders for the pre-class assignments for next Tutorial	

Flipped AFTER CLASS Work Plan Template

Advanced learning objective	Activity and rationale	Instructions to students
1. determine whether two observables can be simultaneously determined 2. use technical language of QM correctly (here, *bra, ket, state*) 3. practice bra, ket, and statistical calculation for further comfort with Dirac notation	- Completing the remaining of worksheet for students who may not had enough time to finish the worksheet in class - Reflection and review of results of tutorial to enforce the concepts and also provide feedback on the course material to the instructor - Independent practice: Homework problems to practice and reinforce the key ideas	- complete the remaining of worksheet if you did not get to do so in class - scan and upload your worksheet on blackboard assignments - provide a brief reflection about this assignment by answering the post tutorial survey - complete homework exercised on blackboard to practice bra, ket, and statistical analysis of the experimental results - Read Ch1.1 Stern-Gerlach and Ch1.2 Probability again - Write any questions you may have for class and office hours

Note: See Blackboard for the related homework exercises for this Tutorial. All related assignments and survey will be posted on Blackboard with links and attachments to the related documents.