Quantum Physics, Preparation for Tuesday, Apr. 2

Study the Remainder of Chapter 12

You have studied a few exact solutions of Schrodinger's equation far more than Moore is expecting you to have when reading Sections 12.4 to 12.7. They should be much easier and more intuitive as a result.

However, the numerical ideas in Section 12.4 are new and important — so important that Moore took the unusual step of writing out Eq. 12.12 twice.

Plan for Class

I have been in NM working on telescope gear for five days, and I apologize for the inattention, and in particular for the lateness of this document. I hope the problem set is fairly straightforward for you.

We have three things we can do for Tuesday's class. Not all will fit, I don't think. Please come prepared to prioritize:

(1) The two-dimensional rotationally-symmetric Schrodinger equation is a gateway to the three-dimensional rotationally symmetric one. We could study how it is solved.

(2) We could spend lots of time on 12.4 and 12.5, which is how numerical solutions of Schrödinger's equation are done

(3) We could spend time on 12.6 and 12.7, qualitative graphical solutions of Schrödinger's equation and the application of qualitative methods to tunneling

Also, come ready to decide, do you feel ready to leave the gruelingly mathematical work on Schrödinger equation behind and turn to nuclear physics on Friday?

PROBLEM SET 14 ON REVERSE

For Problem Set 14

The Idea of Local Wavelength

1. Understand and write out Ex. Q12X.1, p. 186 — personally, I think of the inverse of wavelength as a measure of curvature — large wavelength is low curvature — short wavelength is high curvature — in any case, it is a way of conceptualizing the second derivative of the wave function

The Numerical Approach to Schrödinger's Equation

2. Derivation Q12D.1, p. 198 — Moore is doing a more extensible version of a derivation we have done in class — by more extensible, I mean that it can be used to get better and better approximations to derivatives when you are studying a function that is defined on only discretely-spaced points

3. Understand and write out Ex. Q12X.3, p. 187 — this is a totally straightforward and fast but important exercise — it is in the guts of what SchroSolver is doing

Using SchroSolver (Requires Web Access) Basic

4. , Q12B.1, p. 197 — uses the web app at http://physics.pomona.edu/sixideas/SchroSolver/

Sketching and Comparing with SchroSolver (also Requires Web Access) Intermediate

5. Q12M.3, p. 197 a multi-part problem where you both sketch and use SchroSolver to examine the Hydrogen atom radial solutions.

Quantum Physics, Preparation for Friday, Apr. 5

Nuclear Physics from 1896-1911

You have pp. 19-40 of *The History and Science of the Manhattan Project* by Bruce Cameron Reed. This is the best short, scientific summary of nuclear physics I know of. It begins in 1896 with Becquerel's discovery that uranium fogs film. The pages I have chosen end in 1911 with the explanation of scattering of alpha particles off of gold foil by Rutherford.

Remember, these scientists don't know any quantum mechanics! The atomic and subatomic phenomena they are discovering are what is ultimately explained by quantum mechanics and quantum field theory. It isn't until the late 1920s that quantum mechanics is invented and understood. Quantum field theory isn't developed until after WW II.

Study Moore Q13.1, Q13.2 and Q13.6

We'll do Moore Chapter 13 in two bites. We will save Q13.3, Q13.4 and Q13.5 for Tuesday.

Q13.1, Q13.2 and Q13.6 go well with Reed, pp. 19-40.

Plan for Class / Presentations

I think **it would be fabulous if three groups of two people self-organized and coordinated with one another to do three substantial presentations.**

Anything in the 1896-1911 reading would be great to go deeper into. In other words, it is wide open for you to decide what is important, and I am curious what you will pick. The presentations could range from historical documents, personalities and experimental techniques to theoretical ideas.

You can even go beyond 1911 if you like. In fact, **it would be great if one of the groups recounted the discovery of the neutron which doesn't happen until 1932.** It is the discovery of the neutron that finally sets the world up for the unleashing of fission chain reactions and the atomic bomb.

PROBLEM SET 15 IS ON THE REVERSE

For Problem Set 15

Exponential Decay

Even though Moore has marked two of these problems as “basic” all three of them require you to understand the equations on p. 212 of Moore and on pp. 26-27 of Reed.

1. Q13B.11, p. 214

2. Q13B.12, p. 214

3. Q13D.5, p, 215

Nuclear Collisions

4. Q13M.2, p. 214, you can use that the radius of a gold nucleus is 7.0 fm. The radius of the alpha particle isn’t needed because Moore intends you to treat it as a negligibly-sized point particle. By “inside the gold nucleus” I think Moore just means “at the surface of the nucleus.”

5. Q13M.3, p. 214, you can use that the radius of a silver nucleus is about 4.7 fm, and otherwise this is the same as the problem above with slightly different charge and mass values. If you want to be fancy, make a table for Problems 4 and 5 and include uranium, which has a nuclear radius of 7.4 fm.

Binding Energy

6. Q13M. 4, p. 214, part (a) only. Requires Eq. Q13.4, p. 203.

Quantum Physics, Preparation for Tuesday, Apr. 9

Finish Moore Q13

Finish your study of Q13

Presentations/Examples for Class

(1) Brian will present the relativistic kinematics that forced the hypothesis of the neutron.
(2) Two people (who did not present last time) pair up and present how Aston's mass spectrometer works and what it accomplished
(3) We will look ahead to Chapter 14 and do an exercise and a problem from that chapter in-class

For Problem Set 16

Nucleus Size

1. Q13B.4, p. 213. In the previous problem set, we used some nucleus radii. In this problem, you use the empirical formula for nucleus size to get some radii

2. Take your answers to the previous problem and calculate the nucleus volumes for carbon and uranium. Can you see a simple way to get these answers?

Binding Energy

3. Make a table consisting of the answers to Q13B.6, Q13B.7 and Q13B.8 on p. 213.

4. Add to the table you just made an additional column representing the binding energy per nucleon. This is just taking the binding energy you calculated in the previous problem and dividing by 23, 56, and 208, respectively.

Radioactivity Rates

5. Q3M.10, p. 214. Also, as easy units conversion problems, convert the sample radioactivity rate in this problem to Curies and Becquerels (two of the units Jay presented). Moore doesn't introduce either of these units until p. 237.

Quantum Physics, Preparation for Friday, Apr. 12

Study Moore Q14

I hope you can manage the entire chapter.

Problems to Work in Class

Let's do Q14R.2 and Q14R.3 in the next class. You don't need to prepare. We'll just set aside class time to puzzle through them. Perhaps you all will choose some other interesting problems from Q14.

For Problem Set 17

Reasoning about decays

In Sections Q14.2 and Q14.3, Moore makes quantum-mechanical energy-level-filling arguments that help us understand why some isotopes are stable, and what decays are preferred. I'll be frank and say that I don't remember how these arguments go! So I am looking forward to doing them too.

1. Q14B.2, p. 229, the decay of ${}^{12}_{5}$B.
2. Q14B.5, p. 229, the decay of ${}^{41}_{20}$Ca (see also the next problem on electron capture)

β^+ Decay vs. Electron Capture

If a nucleus emits a positron (and a neutrino), then at the same time, a proton must turn into a neutron, or charge would not be conserved. A different process called electron capture also turns a proton into a neutron.

3. Q14B.6, p. 229, electron capture
4. Q14B.7, p. 229, β^+ decay

α Decay

5. Q14M.3, p. 229, α decay of Uranium into Thorium

The Hypothesis of the Neutrino

6. Q14M.5, p. 230, part (b) only

Quantum Physics, Preparation for Tuesday, Apr. 16

Study Moore Q15

The final chapter, technological applications of nuclear physics.

Presentation

Miles (maybe someone wants to join him!?): How are atoms or electrons or ions counted so as to make 1 mole (abbreviated mol) *in practice;* and in particular, how is the gram which is now defined as 1/12 of the mass of an Avogadro's number (602,214,076,000,000,000,000,000) of Carbon-12 atoms counted, *in practice*

Special Topics

Let's plan (so I can start preparing) the special topics for the last two Fridays of the semester. See schedule below:

- Friday, Apr. 19 — Special Topic 1 (your choice, such as an atomic or nuclear physics phenomenon like MRI?)

Week 14 — Exam 4 — Final Topic

- Tuesday, Apr. 23 — Exam 4 Covering Problem Sets 14-18 (Moore Section Q12.5 to end of Chapter Q15)
- Friday, Apr. 26 — Special Topic 2 (your choice, such as an introduction to special relativity focusing on time dilation or an introdution to the Feynman path integral)

For Problem Set 18

I hope and think you will find these easy, so I assigned more than usual.

Energy Released in Fission

1. Q15B.5, p.249, answer in MeV, and as far as I can see there isn't an estimate in Section Q15.4 to compare to

Energy Released in Fusion

2. Q15B.7, p.249

CONTINUED ON REVERSE

For Problem Set 18 (CONT'D)

Temperature Required to Initiate Fusion of Deuterium

3. Q15B.8, p.249

Temperature Required to Initiate Fusion of Carbon-12

4. Q15B.9, p.249

The Age of the Sun

5. Q15M.5, p.249, in the early 1900s, before fusion, people thought the Sun might be burning coal or gasoline

6. Q15M.6, p. 250, what the Sun is actually doing instead of burning gasoline

Carbon Dating

7. Q15M.9, p.250

Some of the scrolls found near Qumran, between late 1946 and 1956: