Physics 214: Introduction to Quantum Mechanics  
Spring 2010  
Problem Set 4

Due: Wed 17 Feb 2010

Reminder: Exam 1 will be distributed on Friday 19 February. It is a closed book 2.5 hour take-home exam, but you may prepare one page of notes (front and back) to use during the exam. It will be due on Fri 26 February in class. That’s a little later than advertised on the syllabus, to give you extra time due to Hell Week. The exam will cover the material through Problem Set 4. In the textbook, this corresponds to Secs. 1.1 through 2.6, excluding Secs. 1.8 and 2.5.

Reading:

Fri 2/12: Townsend Sec. 2.6.

Mon 2/15: Townsend Secs. 2.8, class notes on momentum space wavefunctions.

Wed 2/17: Townsend Sec. 2.5.

Fri 2/19: Townsend Sec. 2.9.

Problems:


2. Bragg diffraction of neutrons by a crystal. Townsend Problem 2.14. In part (c), note that the kinetic energy of neutrons in a nuclear reactor is in the MeV (= 10^6 eV) range. Townsends asks why we wouldn’t want to do the experiment with the neutrons of that energy.

3. Phase and group velocity in shallow water waves. Townsend Problem 2.25. In part (b), here’s what is meant by dimensional analysis: Write

   \[ \nu = aT^\alpha \rho^\beta \lambda^\gamma, \]  
   \[ (1) \]
where $a$ is some unknown dimensionless number (which we do not expect to be too different from 1), and $\alpha$, $\beta$, $\gamma$ are exponents to be determined. Using the information that you are given, you can write the dimensions of $T$, $\rho$ and $\lambda$ in terms of powers of mass, length and time. You would like to choose the exponents so that so that the right hand side of Eq. (1) is a frequency. Show that only one choice of exponents gives an expression with the required dimensions of $(\text{time})^{-1}$.

4. **Upper limit on photon mass.** Townsend Problem 2.28. In part (b), to obtain a simple expression for $(c - v_g)/c$, you would like to first express $v_g$ as $c/\sqrt{1 + x}$ where $x$ is a small quantity that you will determine. For small $x$, this expression can be approximated using $(1 + x)^a \approx 1 + ax$.

5. **Wavefunction and probability.** Townsend Problem 2.18. You will need to estimate the area under various regions of the $|\psi(x)|^2$ versus $x$ graph to solve this problem.

6. **A “tent” wavefunction.** Townsend Problem 2.30. To implement the absolute value in the definition of $\psi(x)$, it is best to break up the integral into two parts: $x \leq 0$ and $x \geq 0$. Note that $\Delta x$ is defined by

$$\Delta x = \sqrt{\langle (x - \langle x \rangle)^2 \rangle} = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}.$$ 

7. **Feedback.** By Thursday of each week, please send me an email message to provide feedback on the class and on your reading. (My email address is mbschulz at brynmawr.edu). For example: Which parts were easier or harder to understand? Do you have any questions that you would like to clarify or areas where you would like more practice in recitation section? Was there something that you found particularly interesting or uninteresting? Was the problem set of reasonable length and difficulty. The textbook we are using is brand new, so we are on the cutting edge. If you have any thoughts on how to improve the textbook for future students using future editions, please let me know and I will pass that information on to the author, John Townsend. The purpose of the feedback is to help you to reflect on your learning process and to provide me with brief but valuable information that will help to make this class the best possible experience for everyone.