Physics 237, Midterm Exam #2

Thursday March 25, 2010

12.30 pm – 1.45 pm

Do not turn the pages of the exam until you are instructed to do so.

Exam rules: You may use *only* a writing instrument while taking this test. You may *not* consult any calculators, computers, books, or each other.

1. Problems 1 and 2 must be answered in booklet # 1.

2. Problems 3 and 4 must be answered in booklet # 2.

3. The answers need to be well motivated and expressed in terms of the variables used in the problem. You will receive partial credit where appropriate, but only when we can read your solution. Answers that are not motivated will not receive any credit, even if correct.

At the end of the exam, you need to hand in your exam, your "cheat sheet", and the two blue exam booklets. All items must be clearly labeled with your name, your student ID number, and the day/time of your workshop.

Name: _____

ID number: _____

Workshop Day/Time: _____

Problem 1 (30 points) **ANSWER IN BOOKLET 1**

A particle of mass *m* and energy $E = 2V_0$ is approaching $x = 0$ from the left. The potential seen by the particle can be described by the following function:

$$V(x) = \begin{cases} 0, & x < 0 \\ V_0, & x \geq 0 \end{cases} .$$

a) What is the wave function in the region $x < 0$? You can set the amplitude of the incident wave to 1.

b) What is the wave function in the region $x \geq 0$?

c) Calculate the transmission coefficient.

Your answers need to be well motivated. A correct answer without any motivation will not receive any credit.

Problem 2 (30 points) **ANSWER IN BOOKLET 1**

Consider a particle of mass m, located in a region where the potential V is given by

$$V(x) = \frac{1}{2} m\omega^2 x^2$$

a) Show that $\psi(x) = Ae^{-\alpha x^2}$ can be an eigenfunction describing this system.

b) What is the value of α?

c) What is the value of A?

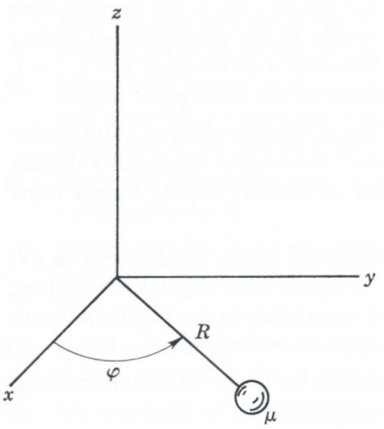
d) What is the energy E for this eigenfunction?

e) What is the expectation value of x?

f) What is the expectation value of x^2?

Your answers need to be well motivated. A correct answer without any motivation will not receive any credit.

Problem 3 (35 points) **ANSWER IN BOOKLET 2**



A particle of mass μ is fixed at one end of a rigid rod of negligible mass and length R, as shown in the Figure. The other end of the rod rotates in the x-y plane about a bearing located at the origin, whose axis is in the z direction. The Schrödinger equation for this system is

$$-\frac{\hbar^2}{2I}\frac{\partial^2\Psi(\varphi,t)}{\partial\varphi^2} = i\hbar\frac{\partial\Psi(\varphi,t)}{\partial t}$$

where $I = \mu R^2$ is the moment of inertia of the mass with respect to the z axis and $\Psi(\varphi,t)$ is the wavefunction.

a) Assuming that the wavefunction can be written as

$$\Psi(\varphi,t) = \Phi(\varphi)T(t)$$

show that the angle-dependent part of the wavefunction must satisfy the following time-independent Schrödinger equation:

$$-\frac{\hbar^2}{2I}\frac{d^2\Phi(\varphi)}{d\varphi^2} = E\Phi(\varphi)$$

where E is the total energy.

b) Show that

$$\Phi(\varphi) = e^{im\varphi}$$

is a solution of the time-independent Schrödinger equation.

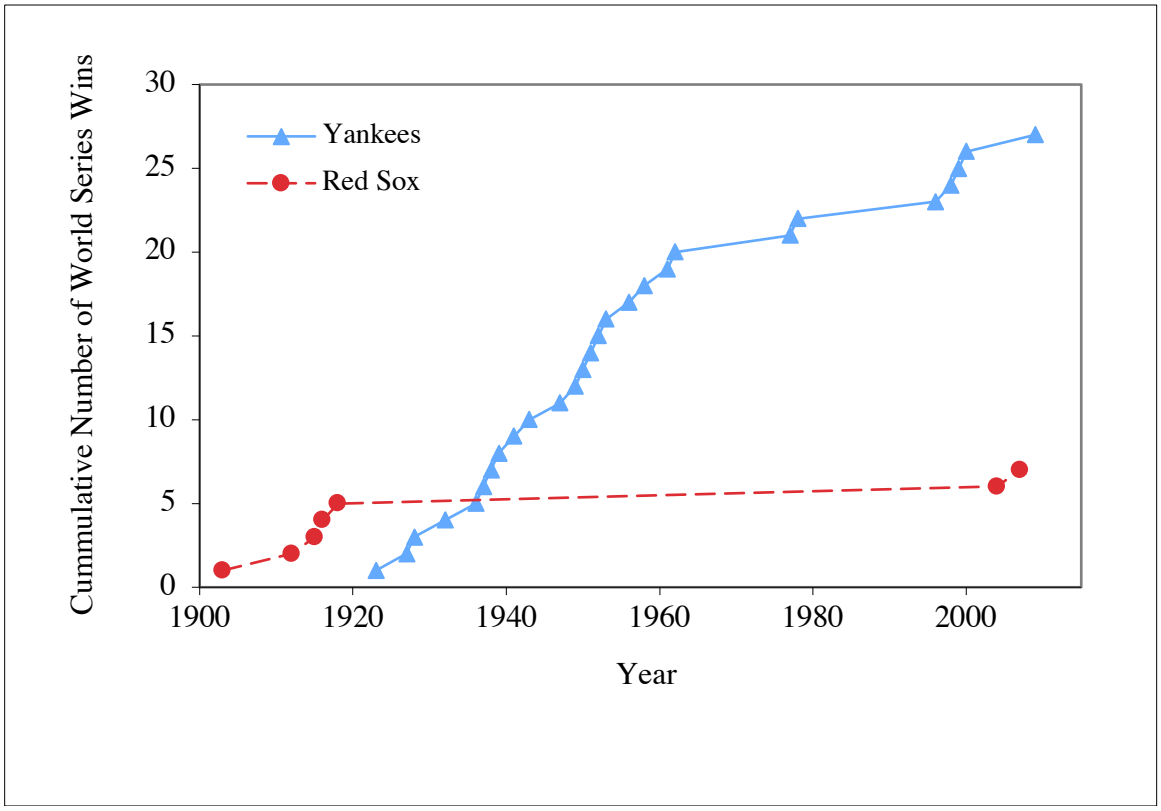
c) Since the system should not change when the azimuthal angle changes by 2π, what constraint does this impose on the possible values of m?

d) Find the selection rule for transitions between the energy states of this rigid rotor, assuming that the mass carries a charge $-e$.

Your answers need to be well motivated. A correct answer without any motivation will not receive any credit.

Problem 4 (5 points) **ANSWER IN BOOKLET 2**

The following graph shows the cumulative World Series wins of the Yankees and the Red Sox, as function of year. After careful examination of these scientific data, which is the better team?



1. The Yankees.
2. The Red Sox.
3. The Buffalo Bills.
4. I do not know.