STONY BROOK
STATE UNIVERSITY OF NEW YORK

PHY251 Modern Physics, 2nd midterm exam
Monday, 17 April Lecturer: Urs Achim Wiedemann

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You can gain a total of 24 pts. Good luck!

1. (**8 pts**) Apply your knowledge of one-dimensional quantum mechanics to the flux of particles of mass m and energy $E > 0$, incident from the left on a potential step of the form

$$\begin{aligned} V(x) &= 0\,, \qquad \text{for} \quad x < 0\,, \\ V(x) &= -V\,, \qquad \text{for} \quad x > 0\,. \end{aligned}$$

   (a) Write down the Schrödinger equation for this problem.

   (b) Find the solutions of the Schrödinger equation for $x > 0$ and $x < 0$. Then write down the continuity conditions.

   (c) Calculate the probability with which the particles will be reflected (reflection coefficient). What would happen classically?

2. (**4 pts**) A particle of mass m moving along the x-axis with a velocity component $+u$ collides head-on and sticks to a particle of mass $m/3$ moving along the x axis with the velocity component $-u$. Write down energy and momentum conservation for this system. Calculate the mass M of the resulting particle?

3. (**4 pts**) The pion has an average lifetime of $t_0 = 26$ ns when at rest. For it to travel $\Delta x = 10.0$ m on average, how fast must it move? Give first the formula in terms of velocity v, distance Δx and lifetime t_0, then put in numbers.

4. (**4 pts**) The z-component of the angular momentum operator takes the form

$$\hat{L}_z = -i\hbar \left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x} \right) . \tag{1}$$

   (a) Calculate the commutator $\left[\hat{L}_z, \hat{y}\right]$ between the position operator $\hat{y}$ in the y-direction and $\hat{L}_z$.

   (b) Answer without calculation the question: For the wave functions Ψ_{n,l,m_l} characterizing the bound states of the electron in the hydrogen atom, what is $\hat{L}_z\,\Psi_{n,l,m_l}$?

5. (**4 pts**) PHY251-Trivial pursuit: answer in one line without calculation

   (a) How do the energy levels E_n depend on the principal quantum number n for a) hydrogen atom, b) infinitely deep square well, c) harmonic oscillator?

   (b) For a hydrogen atom with orbital quantum number $l = 2$, what are the allowed magnetic quantum numbers?

   (c) space-quantization: Consider the total angular momentum L of the hydrogen atom, and its z-component L_z. What are the possible orientations of the total angular momentum with respect to an arbitrary z-direction?

   (d) State Bohr's correspondence principle in one sentence (not more!).