Universität Leipzig, Fakultät für Physik und Geowissenschaften

# Test exam for Experimental Physics 4 (IPSP) (Summer Term 2013)

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Note: Please write your name and matriculation number on EACH sheet of paper.
Use a new sheet of paper for each exercise.
You have 120 min. to answer the following questions:

There will be no homework this week. Instead, if you need some more points to gain 50 % to participate in the exam, you can submit the answers to **3** exercises until Tuesday, 9 July 2013, 11:00 am at the usual place.

**Exercises:**

1. The quantity $\sqrt{\langle x^2\rangle - \langle x\rangle^2}$ is a measure of the average spread in the location of a particle. (a) Consider an electron trapped in a harmonic oscillator potential. Its lowest energy level is found to be $2.1 \cdot 10^{-4}$ eV. Calculate $\sqrt{\langle x^2\rangle - \langle x\rangle^2}$ for this electron.
(b) Now consider an electron trapped in an infinite square-well potential. If the width of the well is equal to $\sqrt{\langle x^2\rangle - \langle x\rangle^2}$, what would be the lowest energy level for this electron in eV? (Hint: You know from previous exercises that $\left\langle x^2 \right\rangle = \frac{\hbar}{2m\omega_0}$) (10 Points)

2. A particle is in the ground state of a one-dimensional box that has length $L$. (The box has one end at the origin and the other end on the positive $x$ axis.) Determine the probability of finding the particle in the interval of length $\Delta x = 0.002\,L$ and centered at $\frac{1}{4}x = L$. (Because $\Delta x$ is very small you need not do any integration.) (5 Points)

3. The energy required for the ionization of a certain atom is 5.12 aJ (atto: $10^{-18}$). The absorption of a photon of unknown wavelength ionizes the atom and ejects an electron with velocity 345 km/s. Calculate the wavelength of the incident radiation. (4 Points)

4. In an X-ray photoelectron experiment, a photon of wavelength 121 pm ejects an electron from the inner shell of an atom and it emerges with a speed of 56.9 Mm/s. Calculate the binding energy of the electron. (5 Points)

5. The deuteron, the nucleus of deuterium (heavy hydrogen), was first recognized from the spectrum of hydrogen. The deuteron has a mass that is approximately twice the mass of the proton. (a) Calculate the Rydberg constant for hydrogen and for deuterium using the definition of the reduced mass. (b) Using the result obtained in Part (a), determine the difference between the longest wavelength Balmer line of hydrogen protium and the longest wavelength Balmer line of deuterium. (9 Points)

6. The rubidium isotope $^{87}$Rb is a $\beta^-$ emitter that has a half-life of $4.9 \cdot 10^{10}$ y. It decays into $^{87}$Sr. This nuclear decay is used to determine the age of rocks and fossils. Rocks containing the fossils of early animals have a ratio of $^{87}$Sr to $^{87}$Rb of 0.0100. Assuming that there was no $^{87}$Sr present when the rocks were formed, calculate the age of these fossils. (7 Points)