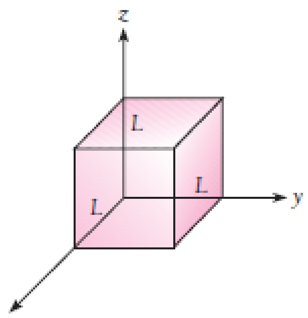
MSE228 Engineering Quantum Mechanics
Homework Assignment (Solve 10 questions)
Due date: Final Examination

1. Light of wavelength 400 nm is shone on a metal surface. The work function of the metal is 2.50 eV. (a) Find the extinction voltage, that is, the retarding voltage at which the photoelectron current disappears. (b) Find the speed of the fastest photoelectrons.
2. (a) Find the change in wavelength of 80-pm x-rays that are scattered 120° by a target. (b) Find the angle between the directions of the recoil electron and the incident photon. (c) Find the energy of the recoil electron.
3. To “observe” small objects, one measures the diffraction of particles whose de Broglie wavelength is approximately equal to the object’s size. Find the kinetic energy (in electron volts) required for electrons to resolve (a) a large organic molecule of size 10 nm, (b) atomic features of size 0.10 nm, and (c) a nucleus of size 10 fm. Repeat these calculations using alpha particles in place of electrons.
4. A proton has a kinetic energy of 1.0 MeV. If its momentum is measured with an uncertainty of 5.0%, what is the minimum uncertainty in its position?
5. Draw an energy-level diagram showing the lowest four levels of singly ionized helium. Show all possible transitions from the levels and label each transition with its wavelength.
6. In a *muonic* atom, the electron is replaced by a negatively charged particle called the muon. The muon mass is 207 times the electron mass. Ignoring the correction for finite nuclear mass, what is the shortest wavelength of the Lyman series in a muonic hydrogen atom? In what region of the electromagnetic spectrum does this belong?
7. The expectation value <x> of a particle trapped in a box L wide is L/2, which means that its average position is the middle of the box. Find the expectation value <x2>.
8. A particle is in a cubic box with infinitely hard walls whose edges are L long (see Figure. The wave functions of the particle are given by

$$\psi = A \sin \frac{n_x \pi x}{L} \sin \frac{n_y \pi y}{L} \sin \frac{n_z \pi z}{L} \qquad \begin{array}{l} n_x = 1, 2, 3, \ldots \\ n_y = 1, 2, 3, \ldots \\ n_z = 1, 2, 3, \ldots \end{array}$$



   a) Find the value of the normalization constant A.
   b) The particle in the box is in its ground state of $n_x=n_y=n_z=1$. Find the probability that the particle will be found in the volume defined by $0 \le x \le L/4$, $0 \le y \le L/4$, $0 \le z \le L/4$.
9. Calculate the most probable distance of the electron from the nucleus in the ground state of hydrogen, and compare this with the average distance.
10. Calculate the angular momentum for an electron in (a) the 4d state and (b) the 6f state of hydrogen.
11. (a) List the six possible sets of quantum numbers (n, l, m_l, m_s) of a 2p electron. (b) Suppose we have an atom such as carbon, which has two 2p electrons. Ignoring the Pauli principle, how many different possible combinations of quantum numbers of the two electrons are there? (c) How many of the possible combinations of part (b) are eliminated by applying the Pauli principle? (d) Suppose carbon is in an excited state with configuration $2p^1 3p^1$. Does the Pauli principle restrict the choice of quantum numbers for the electrons? How many different sets of quantum numbers are possible for the two electrons?

12. (a) What is the electronic configuration of Fe? (b) In its ground state, what is the maximum possible total m_s of its electrons? (c) When the electrons have their maximum possible total m_s, what is the maximum total m_l? (d) Suppose one of the d electrons is excited to the next highest level. What is the maximum possible total m_s, and when m_s has its maximum total what is the maximum total m_l?
13. (a) The ionization energy of potassium is 4.34 eV and the electron affinity of chlorine is 3.61 eV. The Madelung constant for the KCl structure is 1.748 and the distance between ions of opposite sign is 0.314 nm. On the basis of these data only, compute the cohesive energy of KCl. (b) The observed cohesive energy of KCl is 6.42 eV per ion pair. On the assumption that the difference between this figure and that obtained in (a) is due to the exclusion-principle repulsion, find the exponent *n* in the formula Br^{-n} for the potential energy arising from this source.