Problem 1

For each of the following states of a particle in a cubic three-dimensional box, at what points is the probability distribution function a maximum?
(a) $n_X = 1$, $n_Y = 1$, $n_Z = 1$.
(b) $n_X = 2$, $n_Y = 2$, $n_Z = 1$.

Problem 2

For a particle in a cubic three-dimensional box, what is the degeneracy (number of different quantum states with the same energy) of the following energy levels?
(a) $\frac{3\pi^2\hbar^2}{2mL^2}$.
(b) $\frac{9\pi^2\hbar^2}{2mL^2}$.

Problem 3

(a) How many different 5$g$ states does hydrogen have?
(b) Which of the 5$g$ states has the largest angle between $\vec{L}$ and the $z$-axis, and what is that angle?
(c) Which of the 5$g$ states has the smallest angle between $\vec{L}$ and the $z$-axis, and what is that angle?

Problem 4

The 1$s$ wavefunction for hydrogen is $\psi_{1s}(r) = \frac{1}{\sqrt{\pi a^3}} e^{-r/a}$. The probability of finding the electron in the 1$s$ state between the radii $r_1$ and $r_2$ is determined by $P(r_1 \le r \le r_2) = \int_{r_1}^{r_2} |\psi_{1s}(r)|^2 4\pi r^2 \, dr$
(a) What is the probability that an electron in the 1$s$ state of a hydrogen atom will be found at a distance less than $a/2$ from the nucleus?
(b) Calculate the probability that the electron will be found at distances between $a/2$ and $a$ from the nucleus.

Problem 5

A hydrogen atom is in a $d$ state. In the absence of an external magnetic field the states with different $m_l$ values have (approximately) the same energy. Consider the interaction of the magnetic field with the atom's orbital magnetic dipole moment.
(a) Calculate the splitting (in electron volts) of the $m_l$ levels when the atom is put in a 0.400 T magnetic field that is in the $+z$ direction.
(b) Which $m_l$ level will have the lowest energy?
(c) Draw an energy-level diagram that shows the $d$ levels **with** and **without** the external magnetic field.

Problem 6

Calculate the energy difference between the $m_s = \frac{1}{2}$ ("spin up") and $m_s = -\frac{1}{2}$ ("spin down") levels of a hydrogen atom in the 1$s$ state when it is placed in a 1.45 T magnetic field in the $-z$ direction.

Problem 7

(a) Write out the ground-state electron configuration ($1s^2$, $2s^2$, …) for the carbon atom.
(b) What element of next-larger $Z$ has chemical properties similar to those of carbon?
(c) Give the ground-state electron configuration for the element in part (b).

Problem 8

Estimate the energy of the highest *l* state for
(a) the *L* shell of $Be^+$,
(b) the *N* shell of $Ca^+$.

Problem 9

The energies for an electron in the *K*, *L*, and *M* shells of the tungsten atom are −69.5 keV, −12.0 keV, and −2.20 keV respectively. Calculate the wavelengths of the $K_\alpha$ and $K_\beta$ x rays of tungsten.

Problem 10

Rydberg atoms are atoms whose outermost electron is in an excited state with a very large principal quantum number. Rydberg atoms have been produced in the laboratory and detected in interstellar space.
(a) Explain why all neutral Rydberg atoms with the *same principal quantum number n* have essentially the same ionization energy, independent of the total number of electrons in the atom.
(b) What is the ionization energy for a Rydberg atom with a principal quantum number of n = 350?
(c) What is the radius in the Bohr model of the Rydberg electron's orbit when n = 350?
(d) What is the ionization energy for a Rydberg atom with a principal quantum number of n = 650.
(e) What is the radius in the Bohr model of the Rydberg electron's orbit when n = 650?

Problem 11

If the angular momentum value of $L_z$ is known, we cannot know either $L_x$ or $L_y$ precisely, but we can know the value of the quantity $\sqrt{L_x^2 + L_y^2}$.
(a) Write an expression for this quantity in terms of *l*, $m_l$, and $\hbar$.
(b) What is the meaning of $\sqrt{L_x^2 + L_y^2}$?
(c) For a state of nonzero orbital angular momentum, find the maximum and minimum values of $\sqrt{L_x^2 + L_y^2}$.