Electron mass=9.1×10^{-31} kg

Planck's constant h=4.1357×10^{-15} eV · s

Boltzmann's constant k=1.38×10^{-23} J/K

1. A photon with energy E encounters an electron at rest, and then produces an electron-positron pair which moves off together. Calculate the energy of photon and the speed at which the group of particles moves. (10%)

2. In a region of space, a particle has the wave function given by $\psi(x)=A \cdot \exp(-x^2/2L^2)$ and energy $\hbar^2/2mL^2$, (a) find the potential energy as a function of x and sketch V versus x, (b) where is the classical turning point? (10%)

3. Seven identical noninteracting particles are placed in an infinite square well with L=1.0 nm. Compute the lowest total energy of the system if the particles are (a) electrons (b) pions. Pions have symmetric wave functions and mass of 264 m_e. (10%)

4. A hydrogen atom in the ground state is placed in a magnetic field of B_z=1T. (a) Compute the energy splitting of the spin states (b) When the atom relaxes from higher to lower energy state, what is the wavelength of the photon emitted? (10%)

5. A container at 300 K contains ^{4}He gas at a pressure of one atmosphere. At what low temperature will ^{4}He no longer obey the Boltzmann distribution? (one atmosphere =101 kPa) (10%)

6. State the major contributions of the following physicists to the advancement of the modern physics: (a) Max Planck, (b) Werner Heisenberg, and (c) Peter W. Higgs. (12%)

7. (a) Show that a free electron moving in vacuum cannot emit a photon. (6%)
   (b) How to make it possible for an unbounded electron to emit a photon? Suggest at least two methods. (5%)
   (c) Design an experiment to deduce the work function of a metal if you **don't know** the values of the Planck's constant h and the electronic charge e. (6%)

8. (a) Explain mathematically and physically why the wave nature of a moving body (the so called de Broglie wave) should be described by a wave packet (or wave group) instead of a single-frequency traveling wave? (6%)
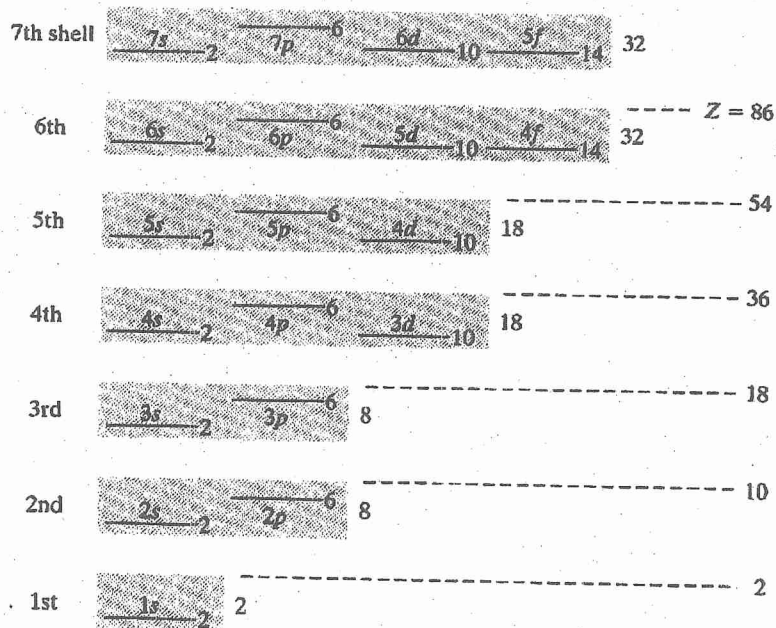
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(b) Find the smallest possible uncertainty in the angular position $\Delta\theta$ of an electron moving in a circle of a radius R with a linear momentum uncertainty of Δp. What would be the situation if the electron is moving in a Bohr orbit? (5%)

9. (a) Friedrich Hund developed a set of rules to determine the ground state of atoms that are governed by the LS coupling (the Hund's rules). Please state these rules and their corresponding physics behind. (5%)

(b) Show the ground state configuration of the atomic ion Nd^{3+} can be described by a "term symbol" as $^4I_{9/2}$ (the atomic number of Nd is 60). (5%)