

# Atomic and molecular physics

first written exam retake

December 11, 2019

1. (25 pts) For 1s hydrogen-like orbital ( $\Psi_{100} = \sqrt{\frac{Z^3}{\pi}}e^{-Zr}$ ) calculate  $r_{max}$  where the radial probability function ( $4\pi r^2\Psi^2$ ) has a maximum and also calculate  $\langle r \rangle$  expectation value.
2. (30 pts) The electron configuration of oxygen atom is  $1s^2 2s^2 2p^4$ . For this configuration, determine all the possible atomic terms and order them by increasing energy.
3. (45 pts) We used  $H_D = G_0 m + \sum_{i=1}^3 G_i p_i + qV$  as the Dirac Hamiltonian for an electron in a spherically symmetric potential  $V(r)$ .  $G$ -s can be expressed by the following Kronecker products:  $G_0 = \sigma_3 \otimes I, G_i = \sigma_1 \otimes \sigma_i$ , where  $I$  is the  $2 \times 2$  unit matrix and  $\sigma$ -s are the Pauli-matrices. Prove that the  $[H_D, (r \times p)_z + \frac{\hbar}{2}\sigma_z]$  commutator is zero.