Háskóli Íslands
Raunvísindadeild
Eðlisfræði

Vor 2020

Frumeinda- og ljósfræði

Dæmablað 4

Skilafrestur 6. Febrúar 2020 kl. 15:00

1. **Energy level scheme for helium** (10)

   Discuss (qualitatively) the energy level scheme for helium if (a) electrons were identical bosons, and (b) if electrons were distinguishable particles (but with the same mass and charge). Pretend these "electrons" still have spin 1/2, so the spin configurations are the singlet and the triplet.

2. **The $\langle(1/|\mathbf{r}_1 - \mathbf{r}_2|)\rangle$ term** (20)

   Calculate $\langle(1/|\mathbf{r}_1 - \mathbf{r}_2|)\rangle$ for the state ψ_0. Hint: Do the $\mathrm{d}^3\mathbf{r}^2$ integral first, using spherical coordinates, and setting the polar axis along $\mathbf{r}_1$, so that

   $$|\mathbf{r}_1 - \mathbf{r}_2| = \sqrt{r_1^2 + r_2^2 - 2r_1 r_2 \cos\theta_2}.$$

   The θ_2 integral is easy, but be careful to take the positive root. You'll have to break the r_2 integral into two pieces, one ranging from 0 to r_1, the other from r_1 to ∞.

   (b) Use your result in (a) to estimate the electron interaction energy in the ground state of helium. Express your answer in electron volts, and add it to E_0 to get a corrected estimate of the ground state energy. Compare the experimental value. (Of course, we're still working with an approximate wave function, so don't expect perfect agreement.)

3. **Angle between L and S** (10)

Consider the states in which $l = 4$ and $s = 1/2$. For the state with the largest possible j and largest possible m_j, calculate

(a) the angle between **L** and **S**

(b) the angle between μ_l and μ_s

(c) the angle between **J** and the $+z$ axis.