

## Tareas 7 Tópicos de la Física Moderna

20 de Octubre 2020

1. For a hydrogen atom in the ground state, what is the probability of finding the electron *exactly* at the Bohr radius?
2. For the ground state of hydrogen, calculate the probability of finding the electron at a distance less than the Bohr radius.
3. The electron energy appears in the radial equation but not in the angular equation. What physical fact does this explain?
4. (a) What are the possible values of  $L$  and  $L_Z$  for the  $3p$  state? (b) For the  $3d$  state?
5. A hydrogen atom is in an excited state,  $n = 5$ . (a) What are the possible values of the quantum numbers  $l$  and  $m_l$ ? (b) What are the possible values of the orbital angular momentum  $L$ ?
6. (a) Show that the function
$$\Psi = C r e^{-r/2\delta} \cos \theta$$
is a solution of the hydrogen atom, where  $\delta = \hbar/mke^2$ . (b) Determine the energy of the state. (c) What is the value of the angular momentum?
7. In the Stern-Gerlach experiment, non-relativistic silver atoms with a kinetic energy of  $E_k$  are sent through a nonuniform magnetic field that has a gradient ( $dB/dz$ ) in the direction perpendicular to the initial trajectory of the silver atoms. (a) If the atoms pass a distance  $L$  through the magnetic field, show that the beam is split by an amount

$$x = \frac{\mu_B L^2}{4E_k} \frac{dB}{dz}$$

where  $\mu_B$  is the Bohr magneton. (b) If the silver atoms come from an oven at a temperature of 1000 K, and they travel a distance of 0.05 m through the magnetic field, calculate the magnetic field gradient needed to make a splitting of 0.001 m. (Hint: The average kinetic energy of a particle escaping from an oven at temperature  $T$  is  $2kT$ .)

8. What are the possible values for the total angular momentum  $J$  for an electron in a  $d$  state?
9. Can the orbital and intrinsic angular momentum vector ever be exactly aligned? Why or why not?
10. Consider the transition  $3d \rightarrow 2p$  in hydrogen. Calculate the possible energies of the emitted photons, taking into account the spin-orbital interactions. How many photon lines are there?
11. Calculate the energy levels of the  $2p$  states of hydrogen in an external magnetic field of 5 T.
12. Why did Willis Lamb perform his experiment in a magnetic field when his objective was to determine the “zero field” separation of the  $2s_{1/2}$  and  $2p_{1/2}$  states?
13. Read: *QED is not endangered by the proton's size*, by A. De Rújula. Physics Letters B 693 (2010) 555, arXiv:1008.3861 [hep-ph].