Ahmedabad University

School of Arts and Sciences

PHY 315 Atomic & Nuclear Physics

Mid Term Examination 2022 (Winter Semester)

Total Marks = 30 Time - 3 hours

Enrolment Number:.....

Date :07-03-2022

No.of printed pages: 02

General Instructions

Total No.of questions : 11

Non-scientific calculator is permitted to use in the examination.

Submit question paper along with answer sheet after completing the examination.

Useful Information

Planks Constant $h = 6.626 \times 10^{-34}\text{Js} = 4.1357 \times 10^{-15}\text{eV s}$

Bohr Radius $a_0 = 5.29 \times 10^{-11}\text{m}$

Bohr Magneton $\mu_B = 5.8 \times 10^{-5}\text{eVT}^{-1}$

Vacuum permittivity $\epsilon_0 = 8.854 \times 10^{-12}$ Fm^{-1}or $\text{CV}^{-1}\text{m}^{-1}$

$\psi_{1s} = \frac{1}{\sqrt{\pi} a_0^{3/2}}\ e^{\frac{-r}{a_0}}$

$\psi_{2s} = \frac{1}{4\sqrt{2\pi} a_0^{3/2}}\ \left[2 - \frac{r}{a_0}\right]\ e^{\frac{-r}{2a_0}}$

$\psi_{3s} = \frac{1}{81\sqrt{3\pi}} \left(\frac{1}{a_0}\right)^{3/2}\ \left[27 - \frac{18r}{a_0} + \frac{2r^2}{a_0^2}\right]\ e^{\frac{-r}{3a_0}}$

$E^1_{so} = \frac{E_n^2}{mc^2}\left[\frac{n[j(j+1) - l(l+1) - 3/4]}{l(l+1/2)(l+1)}\right]$

$E^1_r = -\frac{E_n^2}{2mc^2}\left[\frac{4n}{l+1/2} - 3\right]$

$g_J = 1 + \frac{j(j+1) - l(l+1) + s(s+1)}{2j(j+1)}$

Section A

1. Draw a plot of function $|r|=|(3\cos^2\theta - 1)\cos\phi|$ for $\phi = 0$ and $\phi = \pi$ in a polar coordinate system. [**2 marks**]

2. Find the commutator relations
   (a)$[L_z, z]$,
   (b)$[L^2, L_x]$. (To Get full marks, show all the steps) [**2 marks**]

3. Consider a p-orbital electron placed inside the magnetic field B=0.5 Tesla, which is applied along the z-axis. What is the maximum and minimum angle that the orbital angular momentum L can make with the applied magnetic field ? [**2 marks**]

4. Does the internal magnetic field of hydrogen atom exert a torque on the orbital angular momentum **L** of the electron ? Yes or No (justify your answer) [**2 marks**]

5. Calculate the induced electric dipole moment of ground state of hydrogen atom in the presence of external electric field $E_{ext} = 1.0 \times 10^6$ V/m.[**2 marks**]

Section B

6. Plot the radial function and radial probability density for 3s state of the hydrogen atom. Also mention number of radial nodes present in 3s state. [**3 marks**]

7. Calculate the expectation value of x for an electron in 1s state of the hydrogen atom i.e. $< x >$. [**3 marks**]

8. For a degenerate system like hydrogen atom, calculate the first order energy correction using perturbation theory for Normal Zeeman Effect (ignore spin). [**3 marks**]

9. Consider a hydrogen atom in state $^2P_{3/2}$ placed in the uniform magnetic field 2 Tesla. Calculate the energy difference between $m_j = 3/2$ and $m_j = -1/2$ state due to the Zeeman splitting. [**3 marks**]

10. For a hydrogen atom, derive first order energy correction expression of fine structure $E^1_{fs}(j)$ using the first order energy correction due to relativistic kinetic energy E^1_r and spin orbit coupling E^1_{so}. [**3 marks**]

11. Consider an atom with ground state $^2S_{1/2}$ and an excited state $^2P_{3/2}$. Nuclear spin of the atom is I=7/2.
    (a) Find the hyperfine energy levels F in the ground and excited states.
    (b) Draw an energy level diagram and indicate all the allowed electric dipole transitions between the hyperfine levels of ground and excited states. [**5 marks**]