

1. (20%) Describe below in brief.

- (a) spontaneous emission
- (b) Lyman series
- (c) half-life
- (d) anomalous Zeeman effect
- (e) Bardeen-Cooper-Schrieffer (BCS) theory
- (f) Bloch's theorem
- (g) Davisson-Germer experiment
- (h) spin-orbit coupling
- (i) Auger effect
- (j) Higgs

2. (20%)

- (a) By using the de Broglie relation, derive the Bohr condition $mvr = n\hbar$ for the angular momentum of an electron in a hydrogen atom.
- (b) Use this expression to show that the allowed electron energy states in hydrogen

$$E_n = -\frac{me^4}{8\epsilon_0^2 h^2 n^2}$$

atom can be written as

- (c) How is this expression modified for a triply ionized beryllium atom $Be(Z=4)$?
- (d) Calculate the ionization energy in eV of Be^{+3} (hint: ionization energy of hydrogen = 13.6 eV).

3. (20%) A particle of mass m is trapped in a square well of width L and infinitely deep. Its normalized wave function within the well for the n th state is

$$\psi_n = \left(\frac{2}{L}\right)^{1/2} \sin\left(\frac{n\pi x}{L}\right)$$

- (a) Show that its mean position is $L/2$. (8%)
- (b) Show that the variance is $\left(\frac{L^2}{12}\right)\left(1 - \frac{6}{n^2\pi^2}\right)$. (6%)
- (c) Show that these expectations are agreed with the classical values when $n \rightarrow \infty$. (6%)

4. (20%)

- (a) What values can the quantum number j have for a d electron in an atom whose total angular momentum is provided by this electron?
- (b) What are the magnitudes of the corresponding angular momenta of the electron?
- (c) What are the angles between the directions of \mathbf{L} and \mathbf{S} in each case?
- (d) What are the term symbols for this atom?

5. (10%) The spacing between scattering planes in nickel is 2.15×10^{-10} m. What is the scattering angle at which 80 eV electrons have a diffraction maximum?

6. (10%) Show that photoelectric effect can not take place with a free electron.