B.Sc.(Hons.) Physics
32221501
Teacher: Mamta

S.G.T.B. Khalsa College
Quantum MEchanics (2022-23)
Lab Assignment # 1
Correspondence Principle

Due Date and Time : 24.07.2022, 11:59PM
Max. Marks : 20

The objective of this assignment is to understand the Correspondence Principle given by Bohr.

1. (10 marks) Theory
   (a) What is Bohr' Model for atom. Discuss Bohr' Postulates
   (b) Obtain the expression for the radius r_n of nth orbit in Bohr's model and hence the value of energy in the nth energy level
$$E_n = -\frac{me^4}{32\pi^2\epsilon_0^2\hbar^2}\frac{1}{n^2} = \frac{-13.6\,\text{eV}}{n^2}; \quad n = 1, 2, 3, \ldots . \tag{1}$$
   Draw a rough energy level diagram showing first five levels. For what values of n do you expect the classical behaviour i.e. the value of n for which the size of Bohr's atom becomes a lab-sized object, say ~ 1mm.
   (c) State Bohr's correspondence principle
   (d) Show that the frequency of revolution of an electron revolving around the nucleus in the n^{th} Bohr orbit of a hydrogen atom, f_{cn}, is given by
$$f_{cln} = \frac{me^4}{32\pi^3\epsilon_0^2\hbar^3}\frac{1}{n^3} \tag{2}$$
   A classical electron moving in nth Bohr orbit of radius r_n would radiate at this frequency.
   (e) Use equation (1) to determine the frequency $f_{n\to n-1}$ of radiation emitted by an atom when the electron makes a transition from orbit n to the orbit $n-1$
$$f_{qn} = f_{n\to n-1} = \left(\frac{me^4}{64\pi^3\epsilon_0^2\hbar^3}\right)\frac{2n-1}{n^2(n-1)^2} \tag{3}$$
   Show that this frequency is equal to the frequency f_{cln} given by equation (2) in the limit of large n. Thus, $f_{cln} \approx f_{qn}$ for n as large as required to have Bohr's atom of the size of 1mm.
   We can hence state that in the limit of large n, where classical and quantum physics overlap, the classical and quantum expressions for radiation frequencies are identical. This is an example of Bohr's correspondence principle.

2. (10 marks) Programming
   (a) Write a Python code to tabulate the values of n, f_{cln}, f_{qn} and the relative difference $\Delta f/f_{qn}$ (in %), with $\Delta f = |f_{n\to n-1} - f_n|$ for values of $n = 10^p$ with $p = 0, 0.5, 1, 1.5, \ldots$ till the difference becomes less than 10^{-5}.
   (b) Extend your code to plot the % relative difference as a function of $\ln(n)$.

3. (5 marks) Discussion
   Interpret and discuss your results in terms of the correspondence principle..