Lab Assignment 9

Wednesday, May 19, 2021

The first excited state of a one dimensional quantum harmonic oscillator is given by

$$\psi_1(x) = A_1 \left(\frac{1}{\pi}\right)^{1/4} \sqrt{2} x e^{-\frac{x^2}{2}} = A_1 \phi_1(x) \tag{1}$$

where, $\phi_1(x) = \left(\frac{1}{\pi}\right)^{1/4} \sqrt{2} x e^{-\frac{x^2}{2}}$ and $m = \omega = \hbar = 1$ (in appropriate units)

To obtain the normalization constant, we solve the following equation

$$\int_{-\infty}^{+\infty} |\psi_1(x)|^2 = \int_{-\infty}^{+\infty} \psi_1^*(x) \cdot \psi_1(x) = 1 \tag{2}$$

Question:

Write a program to calculate the normalization constant using numerical integration methods. Follow the guidelines below while writing your program.

1. Write a function that returns the value of $\phi_1(x)$ for a given x. Use this function to generate the values of $\phi_1(x)$ for $-3 \leq x \leq 3$ using step size, $h = 0.1,\ 0.2,$ and 0.5 and store them in an array.
2. Write a function each to perform the integration using
   - Trapezoidal rule
   - Simpson's 1/3 rule

   The functions should be of the form

   ```
   double integration_method( double ydata[ ], double step, double n );
   ```
3. Call these functions in `main()`, to obtain the area under the curve of $|\phi_1(x)|^2$. From this, you can estimate the value of A_1.
4. Solve the equation 2 (using pen and paper) to obtain the analytical value of A_1.
5. Calculate and tabulate the errors for the two methods, and various values of h. Comment about the accuracy of the results obtained from the two methods.

Note: Please send all the files attached to a folder and upload it. The uploaded folder (**folder-name format: Rollno.-name**) should contain the source code, and the observations in a seperate file. Please upload only the necessary files and refrain from uploading multiple files.