Numerical Integration and Differentiation

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1. Write a C program to evaluate the derivative of sin(x) at $x = \frac{\pi}{4}$ for different values of h. Plot the results and comment on the importance of h and differentiation scheme
   (a) Forward Difference Scheme
   (b) Backward Difference Scheme
   (c) Central Difference scheme
2. Write a C program to calculate the area of a circle with $r = 1\ m$ without using the value of π
   (a) Using Monte Carlo technique
   (b) Develop an adaptive integration scheme such that any further increase in the number of sectors(or triangles) leads to less than 1% change in the area calculated
   $$\frac{A_{old} - A_{new}}{A_{new}} \times 100 \leq 1 \tag{1}$$
3. Given the equilibrium electrostatic potential profile in the diode calculate
   (a) Electric Field $\mathcal{E} = -\frac{dV}{dx}$
   (b) Charge density$\rho(x) = \epsilon_{Si}\frac{d\mathcal{E}}{dx}$
4. The electron mobility depends on the electric field along the transport. This dependence is given by
   $$\mu = \mu_0/(1 + \frac{\mathcal{E}}{\mathcal{E}_{\mathcal{C}}})$$
   where μ_0 is the low field mobility ($= 1400\ cm^2/V - s$) and $\mathcal{E}_{\mathcal{C}}$ is the critical electric field ($= 1\ MV/m$) Considering the 1D diode and the electrostatic potential profile in the diode, calculate position dependent mobility.
5. Calculate the electron, $n(x)$, and hole $p(x)$ concentration in silicon nanowire based FET. In this case, the $n(x)$ and $p(x)$ are given by
   $$n(x) = \int_{\varepsilon_i}^{\infty} g_{1D}(E)f(E)dE \tag{2}$$
   $$p(x) = \int_{-\infty}^{\varepsilon_j} g_{1D}(E)(1 - f(E))dE \tag{3}$$
   $$g_{1D}(E) = \frac{\sqrt{2m_{DOS}}}{\pi\hbar}\frac{1}{\sqrt{E - \varepsilon_i}} \tag{4}$$
   Assume $E_F = 0$, $\varepsilon_i = 0.1\ eV$ and $\varepsilon_j = -0.1\ eV$
6. The wavefunction ($\zeta(x)$) as calculated from the standard solvers is provided in the form of the data. Check if it has been normalized ? If not, then normalize it such that the normalized wavefunction, $\zeta_N(x)$, satisfies the following condition
   $$|\zeta_N(x)|^2 = 1$$