PHYDSC404P

LAB: NUMERICAL TECHNIQUES AND VIRTUAL LAB

Contact Hours: 60

Full Marks = 100

Course objective: *In this course, the students will learn various aspects of computational techniques and train themselves with skills of writing codes for numerical scientific computation and simulations. Moreover, this course also will also develop the skills of the students in designing and analyzing electrical/electronic circuits through exposure of virtual lab which, will intern enable the students to achieve the knowledge of working with various electronic devices and circuits without physically visiting the laboratory.*

Two Experiments are to be performed – one from each part

Part-A: Numerical Techniques

Use C/C++/FORTRAN/ Scilab/ Python/Matlab/Mathematica/others to solve the following problems:

1. i. To add, multiply two matrices and find transpose of a given matrix.
   ii. To find inverse, eigen values and eigen vectors of a given matrix.
2. To solve algebraic equations by:
   i. Bisection method.
   ii. Newton-Raphson method.
   iii. Secant method.
3. To solve transcendental equations by suitable approximate numerical method.
4. To evaluate trigonometric functions $sin\theta$, $cos\theta$ and $\tan\theta$ using Newton Gregory Forward and Backward difference formula.
5. i. To find the value of R from a given current (I) with voltage (V) data using least square fitting, assuming that the Ohm's law is obeyed.
   ii. To measure spring constant using Hooke's law (neglecting negative sign) from a given displacement (x) with applied force (F) data using least square fitting.
6. i. Using Rodrigues' formula as a user-defined function, evaluate and plot the first six Legendre polynomials from $x = -1$ to $+1$.
   ii. Using Rodrigues' formula as a user-defined function, evaluate and plot the first six Hermite functions of the first kind from $x = -1$ to $+1$.
7. Solve differential equations
   i. $\frac{dy}{dx} = e^{-x}$ with $y = 0$ for $x = 0$ ii. $\frac{dy}{dx} + e^{-x}y = x^2$

iii. $\frac{d^2y}{dt^2}+e^{-t}\frac{dy}{dt}=-y$ iv. $\frac{d^2y}{dt^2}+2\frac{dy}{dt}=-y$

8. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2u(r)}{dr^2}=A(r)u(r),\ A(r)=\frac{2m}{\hbar^2}\left[V(r)-E\right],\quad \text{where } V(r)=-\frac{e^2}{r}$$

Where, ***m*** is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wave-functions. Remember that the ground state energy of the hydrogen atom is $-13.6\ eV$. Take $e=3.795\left(eVA^0\right)^{1/2}$, $\hbar c=1973(eVA^0)$ and $m=0.511\times10^6\ eV/c^2$.

9. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2u(r)}{dr^2}=A(r)u(r),\ A(r)=\frac{2m}{\hbar^2}\left[V(r)-E\right]$$

where ***m*** is the reduced mass of the system (which can be chosen to be the mass of an electron) for the screened coulomb potential $V(r)=-\frac{e^2}{r}e^{-r/a}$.

Also, find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take $e=3.795\left(eVA^0\right)^{1/2}$, $m=0.511\times10^6\ eV/c^2$ and $a=3A^0,\ 5A^0,\ 7A^0$. In these units $\hbar c=1973(eVA^0)$. The ground state energy is expected to be above $-12\ eV$ in all three cases.

Part-B: Virtual Lab.

Use Multi-sim/ LT Spice/ Tinkercad/ TINA/Proteus/ Dcalab/ 123D circuits/ Circuitlab/ Other softwares or websites to perform the following experiments:

1. To study the characteristics of a p-n diode and find its knee voltage.
2. To study the characteristics of a zener diode find the breakdown voltage.
3. To study the characteristics of a npn transistor in CE mode to find the various *h*-parameters.
4. To design and study OPAMP as adder and subtractor.
5. To design and study OPAMP as differentiator and integrator.
6. To design and study OPAMP as inverting and non-inverting amplifier.
7. To verify the truth tables of AND, OR, NOT, NOR and NAND gates.
8. To study the truth tables of NAND and NOR gates as a universal gate.
9. To study the truth table of various combinational logic circuits.
10. To simplify a given Boolean expression (SOP/POS) and realize the corresponding truth table.

11. To design and verify the De Morgan’s theorem.
12. To design and verify Half Adder and Full Adder.
13. To verify the truth table of RS, JK and D flip-flops using NAND and NOR gates.

Expected learning outcomes: *For demonstrating comprehensive knowledge and understanding, at the end of the above course, the students are expected to have thorough familiarity with computing softwares and developing skills of writing codes for various numerical computations. The Online Virtual Lab Experiments are expected to give an insight in simulation techniques and provide a basis for modelling of electronic circuits.*

References:

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iv. Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal, 3rd Edn., 2007, Cambridge University Press.
v. A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
vi. Elementary Numerical Analysis, K.E. Atkinson, 3 r d E d n . , 2 0 0 7 , Wiley India Edition.
vii. An Introduction to computational Physics, T.Pang, 2nd Edn. , 2006,Cambridge Univ. Press
viii. Scientific Computing in Python, A K Gupta, 2018, TECHNO WORLD.
ix. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press.
x. Scilab (A free software to Matlab): H.Ramchandran, A.S.Nair. 2011 S.Chand & Company.
xi. Virtual Labs at Amrita Vishwa Vidyapeetham, https://vlab.amrita.edu/?sub=1&brch=74
xii. https://de-iitr.vlabs.ac.in/List%20of%20experiments.html