Physics 40: Laboratory Eight

Thursday, April 23, 2020

Today's Goals: Higher order derivatives;
Partial Differential Equations;
Diffusion Equation.

[0] Review: We have learned how to take derivatives and to do integrals on the computer. We also learned how to solve specific differential equation, Newton's second law:

$$m\frac{d^2x}{dt^2} = F(x, \frac{dx}{dt})$$

[1] Now we will learn how to solve partial differential equations(!!).
Our first application will be to the diffusion equation.
Arrays will be useful. Review Arrays.
Discussion of what a partial differential equation is.

[2] Preliminary: Discussion of how to write a code for a second derivative numerically.

[3] Discussion of diffusion equation.

[4] Discussion of code to solve diffusion equation.

[5] Review your code for differentiation! (Lab 3).

$$\frac{df}{dx} \equiv \lim_{dx \to 0} \frac{f(x+dx) - f(x)}{dx}$$

```
#include <stdio.h>
#include <math.h>
double myfunction();

int main(void)
{
     double x,dx,A,B,deriv;
     printf("Enter x and dx \n");
     scanf("%lf %lf",&x,&dx);
     A=myfunction(x);
     B=myfunction(x+dx);
     deriv=(B-A)/dx;
     printf(" df/dx=  %lf  \n",deriv);
     return 0;
}


double myfunction(double x)
{
     double fofx;
     fofx=x*x;
     return fofx;
}
```

[6] Type in this code for the second derivative of $f(x) = x^4$:

```
#include <stdio.h>
#include <math.h>
double myfunction();

int main(void)
{
     double x,dx,A,B,C,secondderiv;
     printf("Enter x and dx \n");
     scanf("%lf %lf",&x,&dx);
     A=myfunction(x);
     B=myfunction(x+dx);
     C=myfunction(x-dx);
     secondderiv=(B+C-2.*A)/(dx*dx);
     printf(" d^2f/dx^2=  %lf  \n",secondderiv);
     return 0;
}


double myfunction(double x)
{
     double fofx;
     fofx=pow(x,4);
     return fofx;
}
```

[PS4-6] What does the program in [6] give for $(x, dx) = (0.5, 0.1)$ and for $(x, dx) = (0.5, 0.01)$ and for $(x, dx) = (0.5, 0.001)$? Discuss.

[PS4-7] Modify the code to get the second derivative of the function $f(x) = e^x + 2/x$. What does the program give for $(x, dx) = (1.0, 0.1)$ and for $(x, dx) = (1.0, 0.01)$ and for $(x, dx) = (1.0, 0.001)$? Discuss.

[7] Type in this code for the diffusion equation. We will run it and discuss it carefully on Tuesday in Lab 9.

```
#include <stdio.h>
#include <math.h>
int main(void)
{
    FILE * fileout;
    int x,t,Nt;
    double rho[1000],newrho[1000],D;

    fileout=fopen("slughorn.txt","w");

    printf("\nEnter D*dt/dx^2   ");
    scanf("%lf",&D);
    printf("\nEnter number of time steps   ");
    scanf("%d",&Nt);

    for (x=0; x<1000; x=x+1)
    {
        rho[x]=0.0;
    }
    rho[500]=1.0;

    for (t=0; t<Nt; t=t+1)
    {
        for (x=1; x<999; x=x+1)
        {
            newrho[x]=rho[x]+D*(rho[x+1]+rho[x-1]-2.0*rho[x]);
        }
        for (x=1; x<999; x=x+1)
        {
            rho[x]=newrho[x];
        }
    }

    for (x=0; x<1000; x=x+1)
    {
        fprintf(fileout,"\n %6d %8.4lf",x,rho[x]);
    }

    fclose(fileout);
    printf("\n");
    return 0;
}
```