PHYS:5905 Homework #6b

Please submit your solutions as a single PDF file with answers to the questions asked.
Please complete required problems before lecture on Thursday, February 28, 2019.

I am providing example Fortran90 code for these exercises, but you are welcome to do these exercises in any other language of your choice (C, Python, Matlab, etc.). You will, of course, need to use either C or Fortran when we cover MPI parallelization on the Argon cluster, so this is a good opportunity to familiarize ourselves with one of these two languages.

1. (Required) **Fortran 90 Code for Euler Timestepping**

   (a) I have produced an example Fortran90 code that computes the single particle motion in constant magnetic and constant perpendicular electric field using Euler timestepping (this is same $\mathbf{E} \times \mathbf{B}$ drift problem from HW#2a and HW#2b).

   (b) The code is packaged in a tar archive, `hw6_190221.tar`, available on the course webpage at `https://homepage.physics.uiowa.edu/~ghowes/teach/phys5905/lec5905.html`

   (c) Log onto Argon (follow steps in HW#6a)

   (d) Create a new directory for HW#6 using
   `mkdir hw6`
   and move into that directory
   `cd hw6`

   (e) Download the tar archive into the `hw6` directory using `curl` with the command

```
curl -o hw6_190221.tar https://homepage.physics.uiowa.edu/~ghowes/teach/phys5905/codes/hw6_190221.tar
```

   (f) Unpack the tar archive using
   `tar -xvf hw6_190221.tar`

   (g) The following files and directories will appear inside the `hw6` directory:

      i. `include` directory which is a place to keep object and module files that are generated during compilation

      ii. `Makefile` is a makefile for compiling all parts of the code and creating a tar archive of the code

      iii. `run_hw6.sh` is a batch submission script for submitting jobs to Argon

      iv. `src` is a directory that contains the following Fortran90 source code files:

         A. `hw6.f90` is the main source file

         B. `hw6_params.f90` is a module that contains parameters for running the code

         C. `hw6_funcs.f90` is a module containing functions for the single particle motion code.

   (h) To compile the code, simply issue the command `make`

   (i) NOTE (this is not necessary since the Makefile organizes compilation, but if you want to do it by hand, these are the commands):
   The general command to use the Intel fortran compiler (for serial codes) on Argon are:

      i. `ifort -c hw6_params.f90`
      which will compile the `hw6_params.f90` module, producing an object file `hw6_params.o` and a module file `hw6_params.mod`, but will not attempt to link files (since the `-c` option was invoked)

      ii. Once all of the necessary subordinate (module) files are compiled, then the main program can be compiled using the command
      `ifort -o hw6.e hw6_params.o hw6_funcs.o hw6.f90`
      which will compile `hw6.f90` and link it using the object files `hw6_params.o hw6_funcs.o`, producing the executable program `hw6.e`

   (j) To run the code, we will submit a batch job to the queue `all.q`. The `all.q` queue is the appropriate queue to use for serial codes. To submit the job, use the command
   `qsub run_hw6.sh`

(k) When you submit the job, if it submits without errors, it will give you the job id number ###### #

(l) You can check the status of the job either by using the job number
`qstat -j #######`
or by checking using your *HawkID*
`qstat -u` *HawkID*

(m) Once the jop has run, it will generate the log file `hw6.log` that was specified in the batch submission script, `run_hw6.sh`, and the output data file `hw6.dat`.

(n) The format output for the `hw6.dat` is a array with 10 columns in the order
$(t,\ x,\ y,\ z,\ v_x,\ v_y,\ v_z,\ x_t,\ y_t,\ z_t)$
and as many rows as there where timesteps. (Here the subscript "t" signifies the analytical solution.) You can use `gnuplot` (see instructions in HW#6a) to plot the trajectory in the (x, y) plane for the numerical and analytical solution.

2. (Required) **Fortran 90 Code for Leapfrog Timestepping**

(a) Modify the example Fortran90 code (or code in another language, if you prefer) to include the leapfrog timestepping scheme (see HW#2b for details).

(b) Model the $\mathbf{E} \times \mathbf{B}$ drift with initial conditions $\mathbf{x}_0/r_L = (0, 1, 0)$ and $\mathbf{v}_0/v_\perp = (1, 0, 0)$ and constant fields $\mathbf{B} = B_0\hat{\mathbf{z}}$ with $B_0 = 1$ and $\mathbf{E} = E_0\hat{\mathbf{y}}$ with $E_0 = 0.1 v_\perp B_0$. Run the simulation to a time $\Omega T_{end} = 20\pi$ with $N = 1000$ timesteps.

(c) (Return) Plot the Trajectory of the particle in the (x, y) plane.

(d) (Return) Plot the error in the position (relative to the analytical solution) at $\Omega t = 20\pi$ from the analytical solution as a function of the number of timesteps taken N for 1,000 $\leq N \leq$ 1,000,000.