In this assignment, you will be developing a computer program to numerically solve some of the systems we have looked at in class. You may use any language of your choice (if you're not sure, try python). You will also be using using Linux, a free open-source operating system. Familiarity with linux is a *very* useful skill to have (as is programming and data analysis).

1. Warmup
   (a) Send an email to me (isaac.tamblyn@uoit.ca) with a username of your choice (for example, I typically use itamblyn). I will create an account for you on a remote machine where you can perform your work.
   (b) Use this user name to login to simulator.science.uoit.ca. From the terminal, type:
   ssh -Y myuserid@simulator.science.uoit.ca
   The initial password will be your student number.
   (c) Change your password on the system using the command: passwd
   (d) Explore. Here are some things to do: create a file, delete it, create a directory, delete it, make a file with some data in it and plot it with gnuplot. You will not be graded on these activities but you will need to be comfortable enough so that you can complete the remainder of the assignment.
   (e) Compile something: for C++, use g++, for C, use gcc, fortran (which I don't recommend, use gfortran), for python, just add #!/usr/bin/env python to the first line of your file (don't forget chmod u+x ./filename.py)
   (f) If there is some package missing that you need, let me know.

2. Consider a particle of mass m which is released from and initial height, h_0, in a gravitational field (assume $F = -mg$) in the absence of air friction. Assume it has some initial velocity, v_0.
   (a) Write down the equation of motion for this system.
   (b) Solve the equation of motion *analytically* (i.e. integrate it as we have done before).
   (c) On simulator.science.uoit.ca, make a directory called assignment8
   (d) If we iterate time in small chunks (Δt), it is possible to obtain a numerical solution for $x(t)$ by assuming acceleration is constant over this small interval. Given a value for $v(t)$, we can estimate $v(t+\Delta t) = v(t)+a(t)\Delta t$. Use this approach to numerically solve the problem of a ball (mass = 1.0 kg) released from a height, h_0=10.0 m, with an initial velocity $v_0 = 0.0$ m/s (use a value of $\Delta t = 0.001$ s). Leave a copy of your source code and executable (with python they are the same file) in your assignment directory. Call it q2
   (e) Compare your result from (**??**) with the analytic solution obtained in (**??**): i.e. produce a plot of $h(t)$ using gnuplot for both.
   (f) Try $v_0 =$ 30.0 m/s. Produce a plot, and again compare your numerical result with the curve produced from the analytic solution.

(g) Increase the timestep to $\Delta t = 1.0$ s and repeat part (**??**). Does this make sense?

(h) Produce a plot of the total energy vs time. Do this for $\Delta t = 0.001$ s and $\Delta t = 0.1$ s. Does this make sense?

3. We will now include linear (i.e. with respect to velocity) air friction. Copy your source code file to a new file called q3.

   (a) Write down the equation of motion in the presence of air friction with a linear dependance on the velocity.

   (b) What are the correct units for α (i.e. the coefficient of friction)?

   (c) Solve the equation of motion assuming an initial position h_0 and initial velocity v_0.

   (d) Modify q3 to include air friction.

   (e) Produce a plot of $h(t)$ assuming $h_0 = 10.0$ m, $v_0 = 30.0$ m/s, and $\alpha = 10.0$ for both the analytic and numerical solution. Does this plot make sense? What do you observe?

   (f) Reduce the drag coefficient by a factor of 100 ($\alpha = 0.1$). Rerun your simulation. Compare this result to the friction free case (produce a plot). Do you get the same answer? Does your result make sense?

4. We will now include nonlinear air friction. Copy your source code file to a new file called q4.

   (a) Write down the equation of motion assuming a non-linear (2^{nd} order) dependance on air friction (call the coefficient α').

   (b) What are the units for α'?

   (c) Modify q4 to include air friction which depends on the *square* of the velocity.

   (d) We did not attempt to solve this system in class, so now we must rely on your numerical solution. Assume $\alpha' = 10$. Compare $h(t)$ ($h_0 = 10.0$ m, $v_0 = 30.0$ m/s) obtained here with what you saw for the linear case where $\alpha = 10$.

   (e) Plot the total energy as a function for the friction free, linear friction, and 2^{nd} order friction on the same graph. Explain the differences.

   (f) Generate a phase-space plot for these three cases.