Project 1(a):

For the model used in introductory physics courses, a projectile thrown vertically at some initial velocity v_i has position $y(t) = y_i + v_i t - \frac{1}{2}gt^2$, where $g = 9.8$ m/s^2. Write a Python program that creates two lists, one containing time data (50 data points over 5 seconds) and the other containing the corresponding vertical position data for this projectile. The program should ask the user for the initial height y_i and initial velocity v_i, and should print a nicely-formatted table of the list values after it has calculated them.

Project 1(b):

Write a Python Program to plot y(t) from t=0 until the ball hits the ground.

Project 2:

In nuclear physics, the semi-empirical mass formula is a formula for calculating the approximate nuclear binding energy B of an atomic nucleus with atomic number Z and mass number A:

$$B = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(A-2Z)^2}{A} + \frac{a_5}{A^{1/2}},$$

where, in units of millions of electron volts, the constants are $a_1 = 15.67$, $a_2 = 17.23$, $a_3 = 0.75$, $a_4 = 93.2$, and

$$a_5 = \begin{cases} 0 & \text{if } A \text{ is odd,} \\ 12.0 & \text{if } A \text{ and } Z \text{ are both even,} \\ -12.0 & \text{if } A \text{ is even and } Z \text{ is odd.} \end{cases}$$

a) Write a program that takes as its input the values of A and Z, and prints out the binding energy for the corresponding atom. Use your program to find the binding energy of an atom with $A = 58$ and $Z = 28$. (Hint: The correct answer is around 490 MeV.)

b) Modify your program to print out not the total binding energy B, but the binding energy per nucleon, which is B/A.

c) Now modify your program so that it takes as input just a single value of the atomic number Z and then goes through all values of A from $A = Z$ to $A = 3Z$, to find the one that has the largest binding energy per nucleon. This is the most stable nucleus with the given atomic number. Have your program print out the value of A for this most stable nucleus and the value of the binding energy per nucleon.

d) Modify your program again so that, instead of taking Z as input, it runs through all values of Z from 1 to 100 and prints out the most stable value of A for each one. At what value of Z does the maximum binding energy per nucleon occur? (The true answer, in real life, is $Z = 28$, which is nickel. You should find that the semi-empirical mass formula gets the answer roughly right, but not exactly.)

Project 3:

A mass m is suspended from a spring of spring constant k. The mass is displaced from equilibrium by an initial distance y_o, then released. Write a Python program to plot $y(t)$ for some reasonable set of parameters.

For the previous problem, plot a *phase-space* plot. The horizontal axis should be position, and the vertical axis velocity.

Repeat the previous two problems, but add damping to the spring-mass system. In other words, the equation of motion for the system is

$$\ddot{y} = -\frac{k}{m}y - \beta\dot{y} \ .$$

Assume that $\beta < 2\sqrt{k/m}$.