**Physics 105, 2009 Spring Project Guidelines**

Use a numerical method to solve a problem that has no analytical solution.

You are expected to give a lecture-style presentation and a formal write-up of your project. Presentations will take place the last week of class, **MWF May 11, 13, 15**, and write-ups are due the last day of class, **Friday May 15, 3pm**[1].

These are **individual projects** and all the work must be your own.[2] No two people may work on the same problem.

**Topics**

See next page

**What to include**

This is a formal write-up and presentation and should, therefore, be complete in its description and anaylsis of the problem. It should include:

- A statement of the problem. This means describing the system and what you are solving for using both text and diagrams.
- An analysis of the problem. This means deriving the equation(s) you plan to solve numerically. This is typically a differential equation (or two) that represents the equation of motion. Derivations require text to discuss assumptions and to explain the logic behind important steps. Additional diagrams may also be useful.
- An explanation of the numerical method. Describe your method and how you implemented it. That is, explain how you found $r(t), \theta(t), x(y)$, or whatever other function may be applicable.
- The results of your numerical analysis. Provide relevant graphs and **discuss** the results.
- An appendix that includes the code/spreadsheet and tabulated numerical results (print up to 5 pages, tiny font). In addition to including this in the write-up, **email me the code/ and numerical results.**

**Evaluation**

In order of decreasing importance, your project will be evaluated on:

- Analysis and understanding
  Is the problem statement clear? Is the analysis of the system correct? Is the numerical method correct and explained sufficiently? In addition to a table of numbers, are *relevant* plots provided to describe the solution? How well is the solution described and explained?
- Complexity and sophistication
  Is the problem particularly difficult or simple? Does the analysis have breadth and depth? In addition to straightforward position-time curves, are trajectories, phase diagrams, or other appropriate graphs included? Were different initial conditions or parameters considered to determine whether there are distinctly different behaviors/solutions?
- Presentation
  Are the write-up and lecture organized, well-prepared and well-presented?

[1] extensions will be given if asked for in advance

[2] Looking for solutions online is not allowed. You may ask me for guidance, but asking anyone else is also a violation of the honor code.

## Project topics

1. The double pendulum (Prob 7.7)
2. Pendulum around a disk (Prob 7.18)
3. Spherical pendulum or soap in a spherical bowl (Prob. 7.31)
4. Pendulum with support moving in a circle (Ex 7.5)
5. Bead on a wire bent into a parabola (Ex 7.7)
6. Trajectory of a spherical object subject to a drag force, such that

$$\begin{aligned} m\ddot{x} &= -c|v|\dot{x} \\ m\ddot{z} &= -c|v|\dot{z} - mg \end{aligned}$$

   where $c$ is the drag coefficient, approximated by $0.15D^2$ for spheres with diameter $D$ in air. Try this for a baseball, for example.

7. Pendulum on an accelerating train (Ex 7.6), but *without* using the small angle approximation. Try, for example, using the next term in the expansion, $\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!}$
8. A damped non-linear oscillator. That is

$$\ddot{\theta} - \gamma\dot{\theta} + \omega_0^2 \sin\theta = 0$$

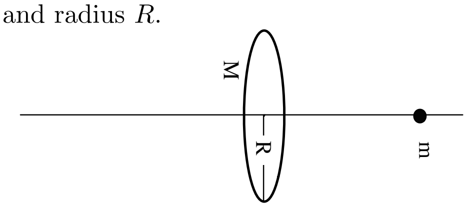
   where the small angle approximation is not valid. Try, for example, using the next term in the expansion, $\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!}$

9. A van der Pol oscillator where the damping term depends on speed and position. That is,

$$\ddot{x} - \gamma(A^2 - x^2)\dot{x} + \omega_0^2 x = 0$$

   This turns out to be a self-limiting oscillation.... no matter how you start it, it *becomes* a *simple* harmonic oscillator. This also turns out to be analytically solveable. The problem here is to start it at some arbitary initial condition and watch the system evolve towards the limiting condition.

10. Particle of mass $m$ subject to a force $F(r)$ that *isn't* gravitation or a Hooke's law spring. For example, try one of the following
    - $F(r) = cr^{-4}$
    - $F(r) = cr^{-3/2}$
    - $F(r) = ce^{ar}$
11. Consider a particle of mass $m$ constrained to move along the central axis of a ring of mass $M$ and radius $R$.




   Derive the following for the gravitational force: $\vec{F} = -\frac{gMmz}{[r^2+z^2]^{3/2}}\hat{x}$. Determine the equation of motion for $m$.