Assignment-3 (12^{th} Feb)   deadline: 19^{th} Feb, 2019

Assignments must be submitted in the form of a report along with MATLAB codes (through moodle). For all the problems below, **provide graphs (from the simulation) in your report**(use "hold on" and "subplot" wherever necessary to generate the graphs)**.Plots/graphs must be properly labeled with proper units and right choice of axis.**

For each problem: describe the model (governing mathematical equations), approximations made and conclusions based on the simulation (final data/plot). Choose realistic initial conditions, take help from google.

You can do more investigations with your program/code in addition to what have been asked in the question for a particular problem (put these investigations under "additional investigation" section in your report below each problem.)

Use Matlab ODE solver for the following problems:

1. **Simple Harmonic Motion:**
   Computationally investigate the motion of a **pendulum** and a **spring-mass system** as discussed in the class (without any damping). Draw phase plots to explain your observations.

2. **Projectile Motion: Cannon Shell/ Missile Problem**

   (a) Investigate (computationally) the cannon-shell trajectories ignoring both air drag and the effect of air density. Compare your result with exact solutions.
   Acceleration due to gravity depends on altitude; include this effect in your computational model by making some rational assumption.

   (b) Investigate the trajectory of the canon shell including both air drag (proportional to square of velocity) and reduced air density at high altitudes. Perform your calculation for different firing angles; and determine the value of the angle that gives the maximum range.

$$F_{drag} = - B v^2$$

Density of atmosphere varies as follows:

$$\rho = \rho_0 \exp(-y/y_0)$$

y is the altitude; y_0 =1000 m.

Drag force with air resistance:

$$F^*_{\text{drag}} = \frac{\rho}{\rho_0} F_{\text{drag}}(y = 0)$$

Take initial speed=750 m/s;
B/m= 4E-5 m^{-1}.

(c) Generalize the program so that it can deal with situations where the target is at a different altitude (higher or lower) than the canon. Investigate for both the cases. How the minimum firing velocity to hit a target varies as the altitude of the target varies.

(d) **Optional:** Effect of wind on shell trajectory. Can you include this in your computational model and investigate the effects.

3. **Bicycle problem:**

(a) Rewrite the bicycle problem/code as discussed in the class. Investigate the effect of rider's power, mass and frontal area on the ultimate velocity.

Generally for a rider in the middle of a group the effective frontal area is about 30% less than the rider at the front. How much less energy does a rider in the group expend than one at the front (assuming both moving at 12.5 m/s).

(b) Run your code (case (a) discussed during class) with initial v=0; observe the output and give possible explanation. Explain why it is important to give a non-zero initial velocity.

(c) As discussed in the class, we have assumed that the bicyclist maintains a constant power. What about the assumption when the bicycle has a very small velocity? (instantaneous power=product of force and velocity).

(d) At low velocities it is more realistic to assume, that the rider is able to exert a constant force. That means for small "v" there is a constant force, which means eqn is dv/dt=F0/m

Modify your matlab code to include this term for small velocities, that means we have 2 regimes and 2 eqns one for small velocities and one for larger velocities. Make your code work automatically for both the regimes and crossover from small to large v occur when the power reaches P(=F_0v) . Take F_0=P/v where v=5m/s.

Change different parameters and report about important observations.