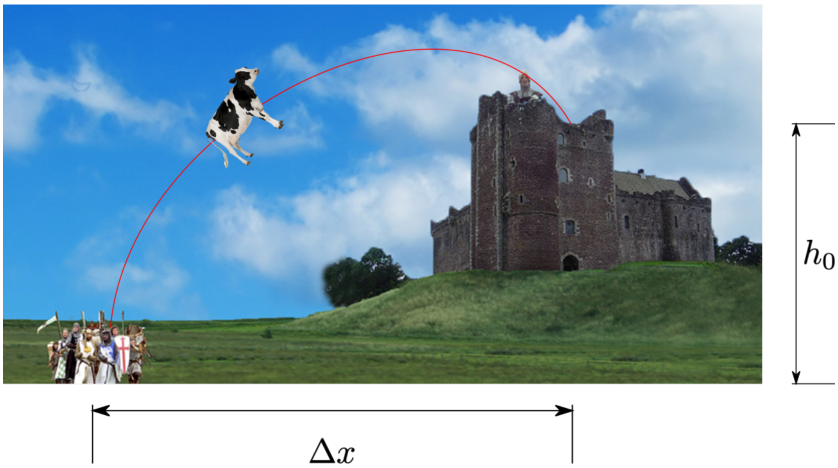
AE1205 Assignment 4: Monty Python's French Castle Scene

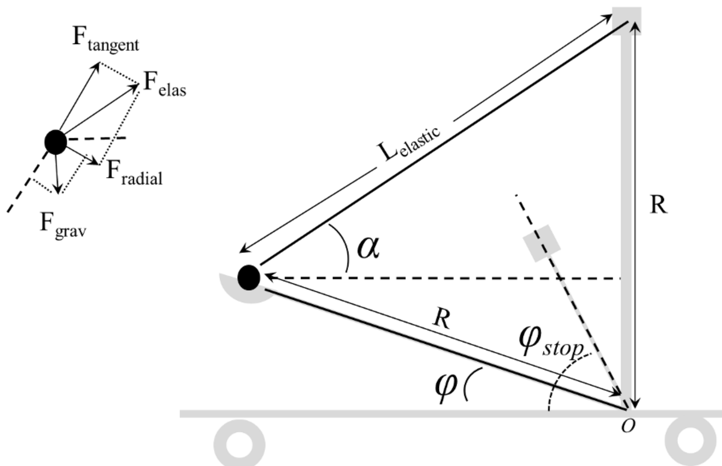
In this assignment we'll attempt to simulate a cow-catapult, from the famous French Castle Scene in the Monty Python film 'The Search for the Holy Grail'. If this doesn't ring a bell I recommend you first watch it here!

Fetchez la Vache!

After the conversation between king Arthur and the French soldiers has really gotten out of hand, the French try to scare away Arthur and his men by shooting livestock at them. You may know that trying to hit a far-off target with a catapult is already difficult with an inert projectile, imagine how difficult this will be when trying to launch a live cow!



In this assignment you will simulate a simple type of medieval catapult, and vary some of the different design parameters to see the effect on the trajectory of a complicated type of projectile, livestock!. As shown above, the catapult is located h_0 meters above, and Δx meters horizontally away from its target. Assume the catapult has an arm of length R. We then assume the elastic band to be tied with one end to the top of the catapult at a height R above the hinge. The other end of the elastic band is tied to the holder of the projectile. We assume the schematic lay-out as below.



The simulation will have two distinct phases each with their own calculations:

1. The launch, where the elastic band accelerates the projectile until the arm reaches the stop.
2. The ballistic trajectory.

The following assumptions can be made for the simulation:

- During the launch phase, drag, the weight of the projectile-holder (plus arm) and the friction can be ignored as the elastic force and the gravity force on the projectile have a much larger magnitude.
- For the elastic band a simple spring equation can be used: $F_{elas} = k_{elas}(L_{elas} - L_0)$, where L_0 is the length of the elastic band when the force is zero.
- Assuming that, like humans, animals are essentially just fancy bags of water, Use as projectile density 1000 kg/m3. Also assume that, out of fright, your projectile rolls up to a ball with radius r, making its effective area equal to $S = \pi r^2$. Aerodynamic drag is equal to $C_D = 0.7$, and air density $\rho_{air} = 1.225 kg/m^3$.
- During the ballistic trajectory apply air drag and gravity. Assume the projectile starts at $h = h_0$ and $\phi = \phi_{start} = 0°$.
- The launch stops suddenly when $\phi = \phi_{stop}$.
- The elastic force and the gravity force have to be decomposed into a tangent force (and a radial force but this does nothing) when you know ϕ. Only the total tangent force creates an acceleration. When divided by R, this is the acceleration of the angle ϕ in radians/s^2. Use this angular acceleration to change the angular speed of the catapult. Use the angular speed to calculate the position at the next time step.

Use as start parameters:

- Castle on the hill: $h_0 = 60$ m, $\Delta x = 300$ m.
- Catapult: arm $R = 10.0m$, $\phi_{stop} = 60$ degrees
- Elastic band: $L_0 = 0.5m$, $k_{elastic} = 9000.0N/m$
- Cow: $m = 550kg$, $V_{sphere} = 4/3\pi r^3$

Steps to take:

3. Make a sketch of your model, signs, origin, and derivation of relation of angles, forces, accelerations etc. for both phases (also show this when handing in).

Now we will make the simulation which will create three lists: the time, x-coordinate and y-coordinate relative to the origin at the hinge of the catapult. So the projectile starts at position (–R, h).

4. Calculate all required parameters. For the following steps, first add a plotting of the trajectory to the end of the program.
5. First simulate the launch phase: initialisation and while loop till phi=phistop, use a time step of 0.1 millisecond (0.0001 s) for this! Calculate the acceleration of phi by dividing the tangent force by the mass and the radius. Print the launch speed, this speed should be 50.174 m/s.
6. Then simulate the ballistic trajectory without drag first until h=0.
7. Add air drag.

8. Now change your program into a function, which returns three lists: t, x, h. The last element of x show the distance achieved, print this value (should be around 274 m).

9. Make main program which calls your function catapult. As input parameters, use: R, ϕ_{start}, ϕ_{stop} , L_0, k_{elas} , mass of projectile, Output is trajectory, time axis and distance.

10. Now make trajectory plots for the effect of a changing: k_{elas}. L_0 and ϕ_{stop}. How can you reach the 300 m? Using the arrays x,h,t, add a plot with the flight path angle and the speed against time in subplots. Give the parameters with which you can reach the 300 m as answer as well.

11. When handing in, also show your sketch with how your model works, how you defined the angles to help the TA understand your code and model.

****I shall taunt you a second time!****

Can't get enough of taunting? Use Pygame to make a real-time animation of airborne livestock, and Arthur and his men, and with a user deciding upon phistart interactively? You can find the relevant graphics on BrightSpace and Teams. You can even add different kinds of animal to play out the entire scene from the movie!