Computational Science 1

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Seminar Exercises

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Exercise 1 (13.10.2016): **2D motion with drag**

from ***An Introduction to Computer Simulation Methods***,
Chapter 3, Problem 3.10 and 3.11

a) Use `Projectile` and `ProjectileApp` to compute the two-dimensional trajectory of a ball moving in air without air friction. Plot y as a function of x. The ball is thrown from ground level at an angle θ above the horizontal with an initial velocity $v_0 = 15\text{m/s}$. Vary θ and show that the maximum range R_{max} occurs at $\theta_{\text{max}} = 45°$. What is the corresponding value of R_{max}? Compare your numerical result to the analytical result $R_{\text{max}} = v_0^2/g$.

b) Suppose that a ball is thrown from a height h with the same initial speed as in part (a). Do you expect θ_{max} to be larger or smaller than 45°? What is θ_{max} for $h = 2\text{m}$.

c) Consider the effects of air resistance on the range and optimum angle of a steel ball. For a ball of mass 7kg and cross-sectional area 0.01m^2, the parameter $C_2 \approx 0.1$. What are the units of C_2? It is convenient to exaggerate the effects of air resistance so that you can more easily determine the qualitative nature of the effects. Hence, compute the optimum angle for $h = 2\text{m}$, $v_0 = 30\text{m/s}$, and $C_2/m = 0.1$, and compare your answer to the value found in part (b). Is R more or less sensitive to changes in θ from θ_{max} than in part (b)? Determine the optimum launch angle and the corresponding range for the more realistic value of $C_2 = 0.1$.

d) Consider the motion of two identical objects that both start from a height h. One object is dropped vertically from rest and the other is thrown with a horizontal velocity v_0. Which object reaches the ground first? Give reasons for your answer assuming that air resistance can be neglected.

e) Assume that air resistance cannot be neglected and that the drag force is proportional to v^2. Give reasons for your anticipated answer for this case. Then perform numerical simulations using, for example, $C_2/m = 0.1$, $h = 10\text{m}$, and $v_0 = 30\text{m/s}$. Are your qualitative results consistent with your anticipated answer? If they are not, the source of the discrepancy might be an error in your program. Or the discrepancy might be due to your failure to anticipate the effects of the coupling between the vertical and horizontal motion.

f) Suppose that the drag force is proportional to v rather than to v^2. Is your anticipated answer similar to that in part (e)? Do a numerical simulation to test your intuition.