4. Superballs

1) During the collision with the floor, the bottom-most ball will retain its speed and change the direction of the velocity; its upwards speed $v_0 = v$. Let the k-th ball move up with a velocity v_k; we'll consider the collision between this and $(k+1)$-st ball, which moves down with the velocity v. In the frame of reference of the centre of mass, $u = \frac{v_k - fv}{1+f}$; hence, after the collision the upwards velocity equals to

$$v_{k+1} = v + 2\frac{v_k - fv}{1+f} = \frac{2}{1+f}v_k + \frac{1-f}{1+f}v.$$

With $v_0 = v$, we can conclude that

$$v_1 = \frac{3-f}{1+f}v = \left(\frac{4}{1+f} - 1\right)v.$$

2) One can see that if we apply the recurrent formula repetitively, the result at the n-th step will be

$$v_n = \left(2\left(\frac{2}{1+f}\right)^n - 1\right)v.$$

3) Now we need to relate the speeds to the jumping heights via $v^2 = 2gh_0$ and $v_n^2 = 2gh_n$; hence,

$$h_n/h_0 = \sqrt{v_n/v_0} = \sqrt{2\left(\frac{2}{1+f}\right)^n - 1}.$$

For $f = 0.5$ and $n = 10$ we obtain that the final height will be *ca* 1200 larger than the initial one.