Projects for COS2000, Semester II, 2019/20

Project A2: Bungee Jump, Free Fall, and Space Dive (February 17, 2020)

A Bungee Superman

Watch this video cliped form the 1978 movie version of *Superman*. Lois Lane falls from the heliport atop the Daily Planet building. Superman catches her and saves the day.

https://physics.info/falling/Helicopter_Accident.mp4

1 Do some preliminary estimates based on the video:

(a) How long was Lois Lane in apparent free fall? Call this time T_1.

(b) How far would she have fallen in this time? Denote this fallen distance as D. [$\frac{1}{2}gT_1^2$]

(c) What speed would she have when Superman caught her? Denote this speed (velocity) as V. [gT_1]

(d) How long did it take Superman to stop Lois Lane? Denote this time as T_2.

2 The bungee jump analogy:

(a) Lois Lane drops from a platform and free falls for a time of T_1 you estimated above. Take the estimated distance D she travels during this time to be the bungee cord length (L).

(b) The bungee cord is the Superman: it stretches and stops Lois Lane in the estimated time T_2.

(c) Run the bungee jumping code, adjusting the bungee cord elastic constant k to fit the rescue attempt.

- Assume Lois Lane to have a mass of 45 kg.
- Ignore air resistance.

Comment on the likelihood of surviving a recue attempt like this one.

[*In pulling out of a dive, for example, a trained pilot may be subjected to an acceleration as high as 9 g. If an acceleration of 4-6 g is sustained for more than a few seconds, the resulting symptoms range from visual impairment to total blackout.*]

There is no "correct" answer here.

B Space Dive Free Fall

On 24 October 2014, Google senior vice-president Alan Eustace fell from an altitude of 42000 meters to Earth from a helium-filled baloon, plummeting in a free-fall for 4 minutes 27 seconds before deploying his parachute.

Before he activated his parachute, Alan is subject to only the earth's grativational pull (Mg), and the air resistance ($c\,v^2$), where M is Alan's mass, g m/sec^2 is the earth's gravitional acceleration, v is the Alan's velocity moving, and c is the air resistance coefficient. Both g and c vary with the altitude h (in meters) above sea level.

(i) The gravitational acceleration varies according to the following formula:

$$g(h) = g_0 \times \left(\frac{R_e}{R_e + h}\right)^2 ,$$

where $R_e = 6371\,\text{km}$ (or $6,371,000\,\text{m}$) is the Earth's mean radius, and $g_0 = g(h = 0) = 9.8\,\text{m/sec}^2$ is the gravitational acceleration on the surface of the earth.

(ii) the coefficient c is approximated to vary with the altitude as

$$c(h) = 0.5 \times \exp(-h/6450)\,.$$

Simulate the free fall with these additional information.

- Set up a coordinate system with the origin at earth's surface, **upwards** is positive.
- The velocity and the gravitational acceleration are negative in this coordinate system. The air resistance force, however, is positive.
- Set the initial height x_0 to be $42,000\,\text{m}$.
- The fully suited up Alan weighs $180\,\text{kg}$.
- Include the altitude variations of g and c.

Solve the free fall equation (i.e. without the bungee cord) using the Python module `odeint`.

(a) Plot the position, the velocty, and acceleration (in units of g_0) of the fall.

(b) Does the speed exceed the speed of sound in air (343 m/sec) at any time of the fall? Roughly at what time and at what height?

(c) Based on your velocity and acceleration plots, describe qualitatively the fall experience. (Hint: Floating in space = zero g = no net acceleration.)

(d) One of the record that Alan was trying to establish was to stay in free fall for 5 minutes. He didn't. In your simulation computation, could he have made it? [The minimum altitude to deploy a parachute to land safely is about $220\,\text{m}$.]

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