Free fall and air resistance

Some people might think that a light thing like a feather is less affected by gravity than a heavy thing like a bowling ball. A feather does normally fall more slowly, but that has nothing to do with gravity. The reason is that air resistance affects the acceleration of the feather more than the ball. To show that the acceleration due to gravity is the same we need to drop them both in a vacuum. We can't take the air out of a room ourselves, but it can be done. *Watch the video that this frame was taken from.*

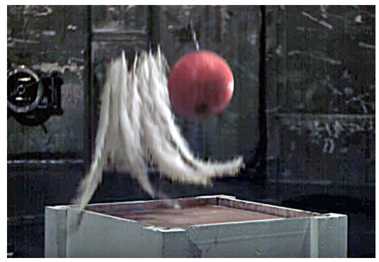

Fig 1

https://youtu.be/E43-CfukEgs

A demonstration of air resistance with polystyrene balls

Three polystyrene balls with diameters of 18, 12 and 8 cm are dropped in succession above a motion detector placed on the floor.

Fig 2 – polystyrene balls.

Data has been copied from Logger Pro files, averaged, and compiled in figure 2. The data rate of 20 points per second was low, but sufficient for a qualitative demonstration.

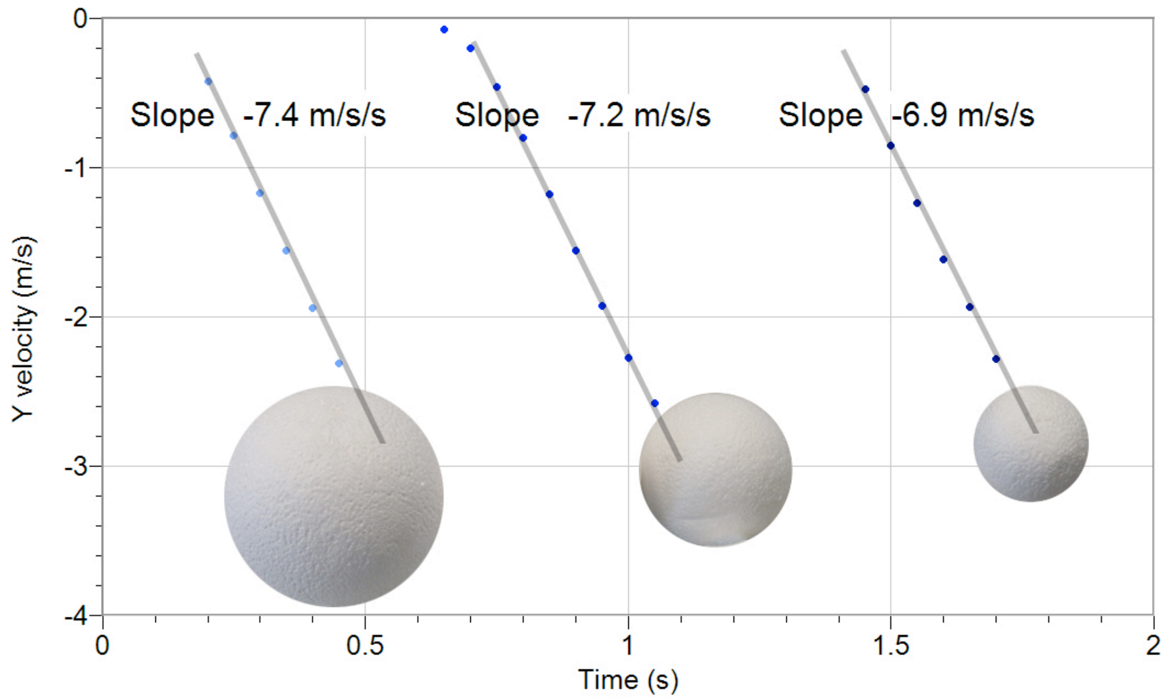

Fig 3 – velocity-time graphs with balls associated with the appropriate lines.

Straight lines have been fitted to the data points. Within errors the accelerations are constant. Less than -9.8 m/s^2 and depends on the diameter of the ball.

It can be shown that air resistance in turbulent flow is proportional to cross sectional area, and ball mass is proportional to volume. The acceleration of a larger ball is expected to be less affected by air resistance. That is confirmed by the data above.

Caution

It is assumed that the density of the three balls is uniform and the same. Air resistance in turbulent flow (as here) is proportional also to velocity squared. Larger balls reach slightly higher velocities over the same times and this adds to the uncertainties.

Note: graphs and figures

Graphs in books and papers have not been drawn by hand since the 1990's but some teachers argue that students still need to plot graphs by hand and learn to draw smooth curves "between" the data points. Young people are alarmed by what they see as a waste of time. There is, I believe, a compromise and a valid point often missed. Students begin by blindly printing raw graphs from Logger Pro and the like, without thought and without editing. They neglect the auto-scale function and report four significant figures in data from curve fits when two is more appropriate with an error to one significant figure.

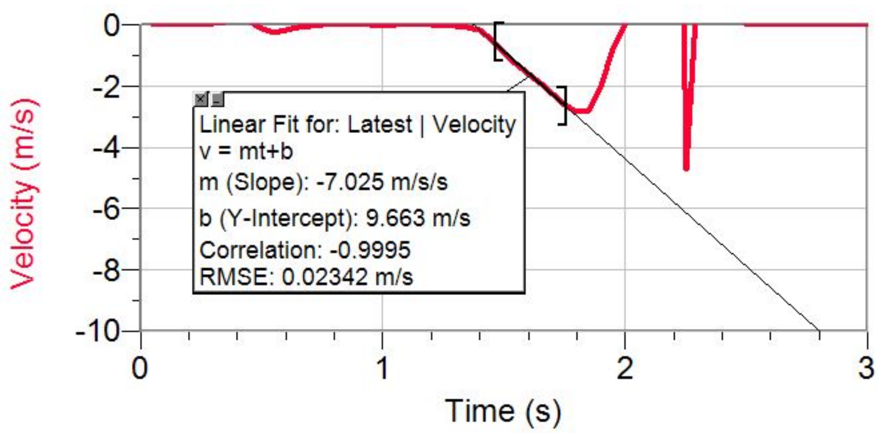

Fig 4 – a single data plot for the smallest of the three balls, showing constant negative acceleration. The data is not well presented for many reasons.

Figures in published work and lab reports are the responsibility of the author, not the clever people at Vernier.com.

Figure 3 was prepared by the writer in Logger Pro and edited *by hand* in a computer. Small data sets were copied and pasted from the original data files. Line fits have been done by hand to leave the data points clearly visible. Accelerations calculated from automatic line fits in Logger Pro are reported to two significant figures with an error of 0.1 m/s^2 (confirmed by repeated drops: with data to three significant figures). Photographs of the balls were added to scale, under the fitted lines, to provide the reader with information quickly and efficiently. The ball diameters are in the text.

Figure 3 is not the careful hand-drawn "work of art" in Indian ink that it might have been in the 19st Century. In the 21st Century, *by hand*, means thoughtful computer-assisted work that accurately and clearly reports data and analysis at a glance. Authors are responsible for their figures, as they have always been: only the skills and details have changed.