Free Fall Acceleration

Purpose

The purpose of this investigation is to determine the acceleration due to gravity for an object near the surface of the Earth. In physics this value is known as "*g*" and it has many important uses.

Procedure

Set up a spark timer on its side clamped to a ring stand so that it extends over the edge of a lab table. Set the timer to 60 Hz operation, which means that it sparks 60 times every second (60 pairs of dots are made on the strip every second). Place a landing pad directly below the timer. Prepare a paper strip about 0.5 m long. Feed the paper through the timer in the direction indicated, making sure that the metallic treated side of the timer paper is facing the top of the timer. Attach the paper to a suitable mass. Make sure that the paper strip is not kinked and hold the strip at a point well above the timer so that it hangs straight down through the guide. First turn on the timer and then release the mass and strip. As soon as the mass hits the landing pad, turn off the timer. On the data table, record the mass of the object and the timer frequency.

Analyzing the Strip

There should be a "blur" of dots near the beginning of the strip (created as you held the object). Find a set of ten distinct pairs of dots near the beginning (but after the blur) that clearly illustrates the object's accelerating motion in freefall and label **A** through **J**. Measure the distance of each labeled pair from pair **A** and enter in the table column for position, **r**. Measure to the nearest 0.0001 m (0.01 cm). Complete the data table as shown in the example below. Position is the only measured value – all other values can be calculated. Note how the table cascades; it takes three measured position values to obtain one calculated value for acceleration.

Point	*t* (s)	**r** (m)	**d** (m)	**v** (m/s)	Δ**v** (m/s)	**a** (m/s^2)
A	0.0000	0.0000				
	0.0083		0.0123	0.738		
B	0.0167	0.0123			0.132	7.92
	0.0250		0.0145	0.870		
C	0.0333	0.0268			0.168	10.1
	0.0417		0.0173	1.038		
D	0.0500	0.0441			etc.	etc.

Time, *t*, is the total elapsed time from the initial point A. Calculate using 1/60^{ths} of a second.
Position, **r**, is distance from point A.
Displacement, **d**, is the change in position values shown in the previous column.
Velocity, **v**, is displacement divided by the corresponding *interval* of time (which is 1/60 s).
Change in velocity, Δ**v**, is difference in velocity values shown in the previous column.
Acceleration, **a**, is change in velocity divided by the corresponding *interval* of time (1/60 s).
Deviation, dev, is absolute deviation of each acceleration value.
Note: *t*, **r**, **v**, dev should be all be positive; Δ**v** and **a** may be positive or negative.

Interpretations

1. Make three separate graphs – position, velocity, and acceleration vs. time. Plot the values for each of these quantities shown in your table. The graphs should also include the analyses described below.
2. For both Position vs. Time and Velocity vs. Time you should include a line or curve of best fit and the corresponding best-fit equation. If you choose to do the calculations yourself then show work directly on the graph. If you choose to use a computer or calculator then include the correlation coefficient "*r*" and/or RMSE (root mean square error). Detailed instructions and examples can be found here: https://milliganphysics.com/physlab.html.
3. For the Acceleration vs. Time graph do not draw a best fit line or find an equation. Usually this graph is quite sporadic. Instead of finding a relation based on the data, draw a dashed line that shows what the results should look like theoretically for an object in freefall. Label this dashed line as "theoretical value". This is a useful technique for this graph since it is known what the result *should* be, based on the theory in question (and also because the pattern shown by the data is usually quite "noisy" or scattered).

Questions

1. Examine your equation for the position versus time graph and compare it to the displacement equation for constant acceleration. These two equations should be essentially the same. Use this fact to determine the value of the acceleration. Hint: equate the coefficients in the regression equation with the corresponding values in the displacement equation.
2. According to the results of your velocity versus time graph what is the acceleration rate indicated by your data? Hint: again consider the coefficients in the equation you found.
3. Calculate the relative (*i.e.* percent) error for the mean value of acceleration from the table.
4. Calculate the relative error for the acceleration found from the position graph.
5. Calculate the relative error for the acceleration found from the velocity graph.
6. Of the three graphs you made, which one most clearly shows that your test object had a constant rate of acceleration (which is what the theory of freefall predicts)? Explain specifically how this is evident.
7. Write a concise paragraph or two, free from errors in grammar and spelling, in which you discuss error in this experiment. Any complete discussion of error will address the errors that are apparent in your results and it will address the most probable causes of those apparent errors. In other words, you should describe how your results are less than perfect and attempt to reasonably explain why the results are less than perfect. Remember to consider both random and systematic error.

Your report (50 pts.) shall consist of the following material – neatly labeled and in this order:

- ❑ Completed data/calculations table (9)
- ❑ Position versus time graph with regression equation and best fit (9)
- ❑ Velocity versus time graph with equation and best fit (9)
- ❑ Acceleration versus time graph with theoretical curve or line (9)
- ❑ Answers to questions 1 – 7 (14)

Mass of object dropped:				Timer frequency setting:			
Point	*t* (s)	**r** (m)	**d** (m)	**v** (m/s)	Δ**v** (m/s)	**a** (m/s^2)	dev(m/s^2)
A							
B							
C							
D							
E							
F							
G							
H							
I							
J							
			Mean Value for Acceleration:				
			Average Absolute Deviation for Acceleration:				

Note: for all vector quantities in the table, a *positive* value indicates a *downward* direction.