

# Acceleration Due to Gravity

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## 1 Introduction

It is well known that if the effects of air resistance are ignored, any object dropped in the vicinity of Earth's surface will move with constant acceleration  $\vec{g}$ . The direction of  $\vec{g}$  is down, towards Earth's center and its magnitude is approximately  $9.8 \text{ m/s}^2$ . The motion of freely falling objects is one dimensional motion with constant acceleration. In general, an object moving with an initial velocity  $v_0$  and a constant acceleration  $a$ , obeys the following kinematic equation [1]:

$$\Delta s = v_0 t + \frac{1}{2} a t^2 \quad (1)$$

where  $\Delta s$  is the displacement of the object in time  $t$ . For an object initially at rest falling in a gravitational field, equation (1) reduces to:

$$h = \frac{1}{2} g t^2 \quad (2)$$

where  $h$  is the vertical displacement or height. Our experiment is based on equation (2). Namely, if we have means of measuring height and time of the free fall for any object, then the acceleration due to gravity can be easily determined using equation (2).

## 2 Experimental Methods

Our equipment consists of small metal ball, which is our free falling object. This ball is held in a clamp which is released by a thumbscrew. Initially the ball is held in the clamp and completes an electrical circuit which is connected to an electronic timer. When the thumbscrew is released, the clamp springs open, releasing the ball and opening the circuit, causing the timer to start. A metal pad is placed directly under the ball and when the ball strikes this pad, the timer stops and the elapsed time is read. The clamp which initially holds the ball can be adjusted to varying heights above the metal pad on the floor. For this experiment we positioned the clamp at 7 different heights and released the ball 5 times for each height, recording the elapsed times. The height of free fall was measured with a meter stick from the bottom of the clamped ball to the metal pad with an accuracy of 0.5mm.

During the course of the experiment, we noticed several problems with the equipment that could result in systematic errors. First of all, the release contact was not very reliable, causing the timer to begin slightly before ball entered free fall. This would result in longer elapsed times and therefore, smaller values for  $g$ . Secondly, the contact plate on the detection pad was not parallel to the floor. The consequence of this is a random deviation of the elapsed time, depending on how high above the floor the ball made contact with the plate. We were able to minimize the effect of the timer starting early by placing a stiffer spring in the clamp and throwing out elapsed times which deviated by more than 0.2s from the average. This does not completely eliminate the problem but does throw out the trials which clearly had problems during release. The second effect was minimized by carefully sighting vertically from the clamp to the plate and making sure that the location of the plate was consistent from trial to trial. A consistent release was obtained by holding the clamp steady with both hands while releasing the thumbscrew. This minimized the horizontal velocity of the ball and resulted in a more consistent position of the ball on the metal pad.

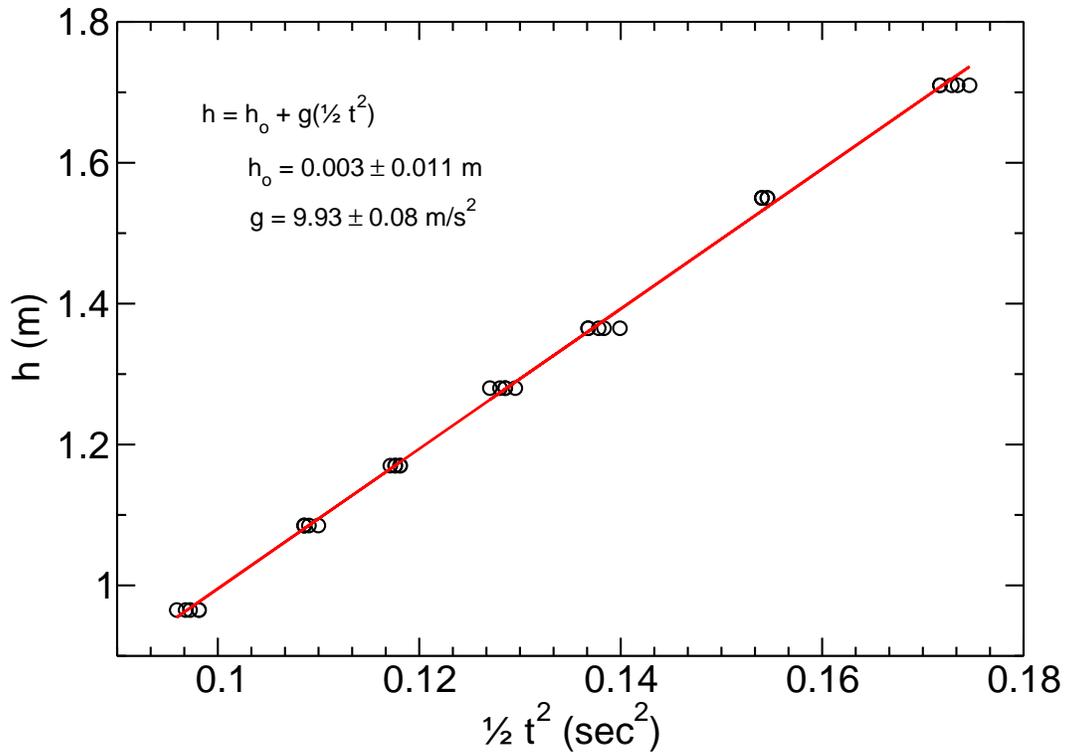


Figure 1: Free fall height  $h$  vs.  $\frac{1}{2}t^2$ . The slope of the graph is acceleration due to gravity.

### 3 Results and Discussion

Inspection of equation (2) shows that the free fall distance,  $h$ , depends linearly on the  $\frac{1}{2}t^2$ . The slope of this line is acceleration due to gravity. In Figure 1 we plot all the data in this way along with the best linear fit to the data. The slope is determined to be  $g = 9.93 \pm 0.08 \text{m/s}^2$  while the intercept is  $h_0 = 0.003 \pm 0.011 \text{m}$ . The value of the intercept is an indicator of the presence of systematic errors in our measurement of the free fall distance since we expect it to be exactly zero. The calculated error in the intercept is greater than the value itself, indicating that  $h_0 = 0$  is consistent with our data and that there are no significant errors in our measurement of  $h$ . The accepted value of  $g$ ,  $9.8 \text{m/s}^2$  is just outside the error bars of the value calculated from the fit to our data. Given that the point of contact of the ball with the metal pad which is used to stop the timer is somewhat above the floor, our slightly higher value for  $g$  is not surprising.

### 4 Conclusion

The acceleration due to gravity was measured by timing a freely falling metal ball. The value obtained from least squares fitting of the data yields  $g = 9.93 \pm 0.08 \text{m/s}^2$  which is slightly higher than the accepted value. Given the potential for systematic error in the apparatus, this result is quite satisfactory and can be accounted for by the oddly shaped metal pad used to stop the elapsed time measurement.

### References

- [1] D. Halliday, R. Resnick and J. Walker, *Fundamentals of Physics, Sixth Ed*, (John Wiley and Sons 2001).

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problems

no position release when timer starts

$h(\text{cm})$	$\Delta t(\text{sec})$
136.5	0.529
	0.525
	0.523
	0.521
	0.526

128	0.506
	0.507
	0.509
	0.507
	0.509

171	0.588
	0.586
	0.589
	0.586
	0.591

much more difficult to hit target consistently

155	0.556
	0.555
	0.557
	0.556
	0.555

96.5	0.442
	0.443
	<del>0.442</del> ?
	0.440
	0.438
	0.441

$h(\text{cm})$	$\Delta t(\text{sec})$
108.5	0.467
	0.469
	0.466
	0.466
	0.466
117	0.485
	0.486
	0.486
	0.484
	0.485