

Free-Fall Acceleration

Objective

To determine the acceleration due to gravity (g) by measuring the time taken for a steel ball to fall from various heights using an electronic free fall apparatus.

Apparatus

- Free Fall Apparatus
- Millisecond Counter
- Steel ball (16 mm diameter)
- Stand rod with scale
- Release mechanism with electromagnet and contact plate
- Connecting leads

Introduction

The position y of a particle moving along a straight line with a constant acceleration a is given by the following equation.

$$y - y_0 = \frac{1}{2} a t^2 + v_0 t \quad (1)$$

Where t is time, y_0 and v_0 are the position and speed at $t = 0$, respectively. In this experiment, you will find the free-fall acceleration by measuring the displacement of an object as a function of time.

A freely falling object is an object moving under the influence of gravitational force alone. It has a constant acceleration called free-fall acceleration. This acceleration is directed downward and its magnitude is denoted by g . The accepted value of g is 9.80 m/s^2 .

If there is another constant force, such as tension force, acting on the object in addition to the gravitational force then the acceleration of the object will be different from the free-fall acceleration.

The displacement of a freely falling body is given by:

$$y = (1/2) g t^2 \quad (2)$$

if $y_0 = 0$ and $v_0 = 0$ (the position and speed at $t = 0$)

where y is the vertical distance fallen, t is the time of fall, and g is the acceleration due to gravity.

You will determine the acceleration of a freely falling object.

By plotting y versus t^2 , the slope of the straight line gives $(1/2) g$, allowing us to determine the value of g .

Experimental Setup

The steel ball is held by an electromagnet at adjustable heights (20 – 960 mm). When the release lever is pressed, the ball is released and the counter starts timing. When the ball strikes the contact plate, the timer stops. The time of fall for each height is displayed digitally with a resolution of 1 ms.

The following figure (1) shows the Free Fall Apparatus with the millisecond counter. The ball is held by an electromagnet and released by the lever, while the counter measures the time from release until the ball strikes the contact plate.

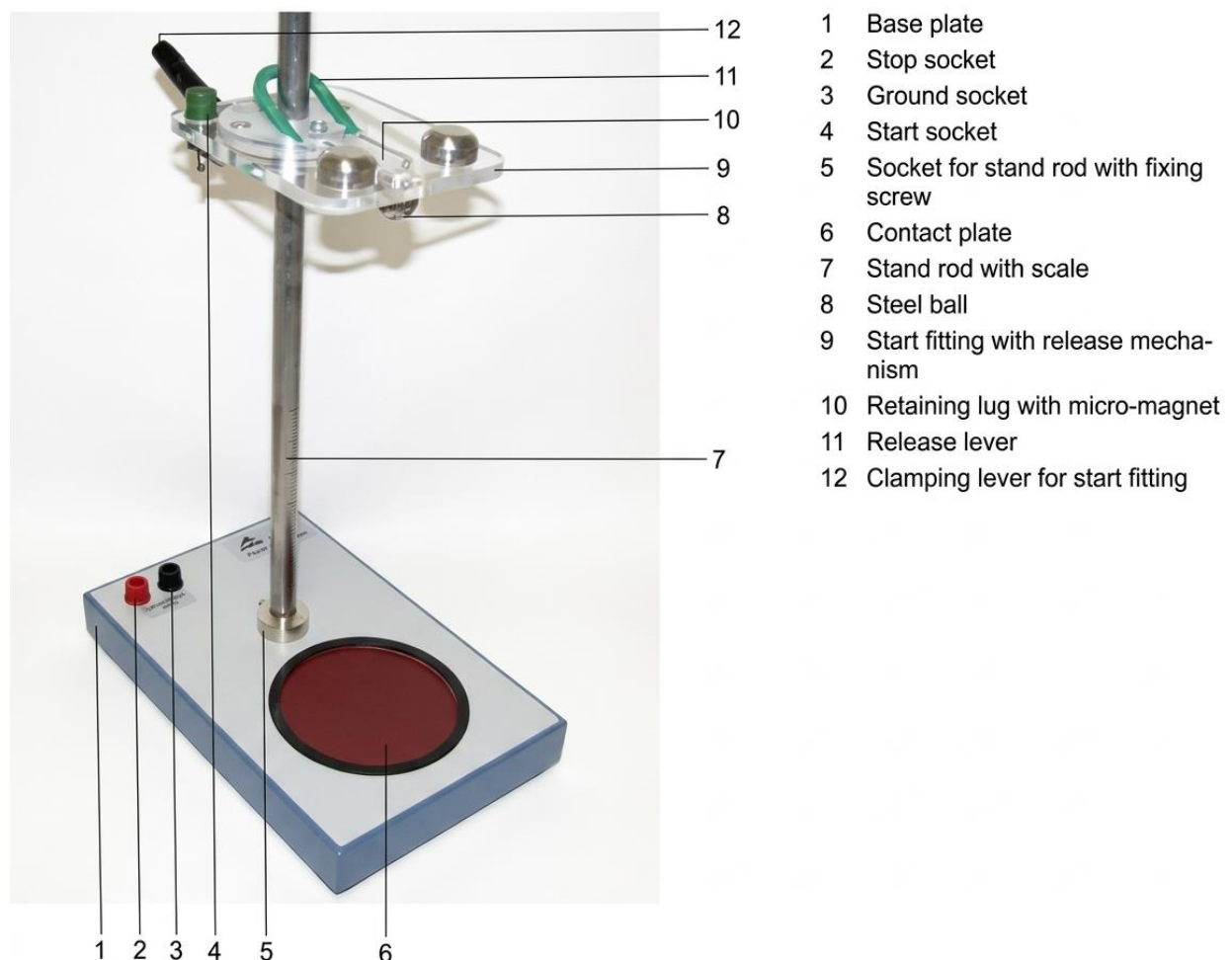


Figure 1: Apparatus with Illustration

Procedure

1. Connect the free fall apparatus to the millisecond counter (Start socket to release, stop socket to contact plate).
2. Adjust the height of fall (start fitting) to a known value using the scale.
3. Place the ball in the retaining lug and release it by pressing the release lever.
4. Record the fall time shown on the millisecond counter.
5. Repeat the measurement at least 5 different heights (e.g., 0.20 m, 0.40 m, 0.60 m, 0.80 m, 0.90 m). **Your instructor may assign a different set of heights for each group.**
6. For each height, repeat 3 times and take the average fall time.
7. When you take the readings, look at the reading straight on to avoid any parallax error (see Figure 2).

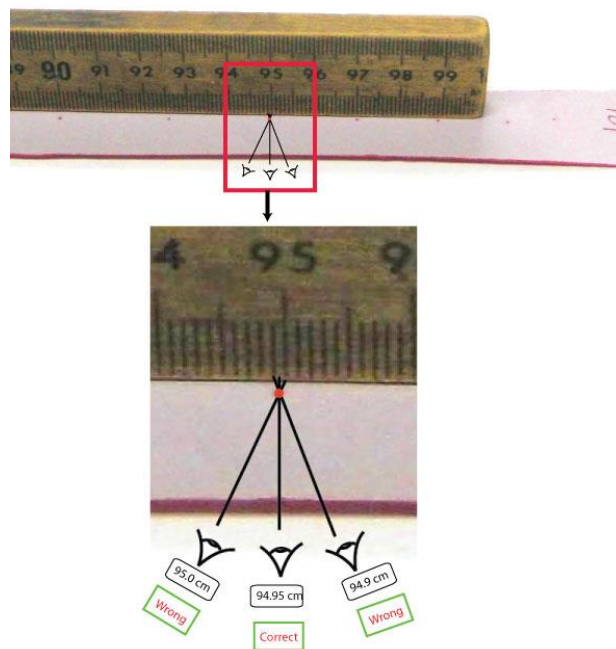


Figure 2: Parallax error explained

Data Collection

Height y (m)	Time t (s)	t^2 (s ²)

Analysis

In order to get the acceleration g , you need to plot the data so that you get a straight line. You can do this by redefining your variables. The redefined variables should make the original equation looks like that of a straight line.

$$Y = m X + b$$

Here, Y is the variable plotted on the vertical axis and X is the variable plotted on the horizontal axis. The constant m is the slope and the constant b is the y-intercept (recall Lab 1-Graphing).

1. Plot y vs. t^2 (**manually on graph paper not by using Excel**).
2. The slope of the line = $(1/2) g$.
3. Calculate g ?

Discussion Questions

4. From the y-intercept, find v_0 .
5. To get a good estimate of the accepted value for the acceleration due gravity in Dhahran,

you may use the formula (discussed in Chapter 13 of your Physics textbook)

$$a_g = \frac{GM_e}{r^2}$$

Where,

G is the gravitational constant = $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$

M_e is the mass of Earth = $5.98 \times 10^{24} \text{ kg}$

r is the distance from your location to the center of Earth $\approx 6370 \text{ km} = (6.37 \times 10^6 \text{ m})$

6. Calculate the percent difference between your measured value and the accepted value using:

$$\text{Percent difference} = \left| \frac{\text{Measured value} - \text{Accepted value}}{\text{Accepted value}} \right| \times 100$$

7. How well does your measured value agree with the accepted value?
8. Calculate the final speed of the object just before it hits the ground if you release the ball from Hight 0.9m?
9. Describe the speed of the object during its motion (is it constant, increasing or decreasing?).
10. Describe the acceleration of the object during its motion (is it constant, increasing or decreasing?).
11. Describe the distance travelled by the object during every second of its motion (is it the same, increasing or decreasing?).
12. List few sources of error in your experiment.
13. Write a conclusion.