Kuwait University Physics Department
Physics 105

Determination of Acceleration due to Gravity

Introduction

In this experiment the acceleration due to gravity ($\boldsymbol{g}$) is determined using two different methods. In free fall method the kinematics of motion with constant acceleration is used, whereas in the second method the simple harmonic motion phenomenon of a simple pendulum is utilized to determine the value of ($\boldsymbol{g}$). You should be able to verify at the end of this experiment that both methods show that the value of ($\boldsymbol{g}$) is constant and equal within experimental error. Furthermore in the free fall method you would investigate whether the mass of the falling body would affect the value of ($\boldsymbol{g}$).

Objectives

- To understand the concept of acceleration in general and that due to gravity in specific.
- To study the free fall motion and find the acceleration due to gravity from free fall experiment.
- To find the acceleration due to gravity from the periodic motion of a simple pendulum.

Equipment to be Used:

- Experimental setup for free fall (Figure 1)

- Experimental setup for simple pendulum: $1\,m$ stand, massless thread, a spherical mass or bob (Figure 2)
- Measuring devices: metric Ruler, Free Fall Timer, Electronic Stopwatch.

Theory

Part A. Determination of (g) using Free Fall

A freely falling body is an object that is moving under the influence of gravity only. This object has a downward acceleration, denoted by ($\boldsymbol{g}$), toward the center of earth. In order to calculate the value of the gravitational acceleration, you will use the free fall experimental setup illustrated in Figure 1. The steel ball is fixed to the releasing mechanism of the free fall apparatus. Allowing the ball to fall a fixed distance h toward the Receptor Plate, the free fall timer will compute the time elapsed for the ball to fall that distance.

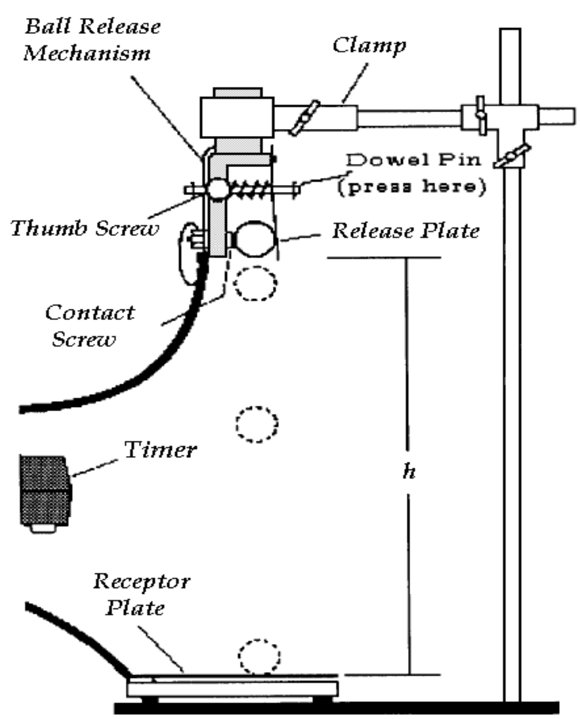

Figure 1 Free Falling Apparatus

The position of the steel ball, starting from rest at time $t = 0$ and undergoing constant downward acceleration along the y-direction, can be understood using the following equation

$$y(t) - y_o = -\frac{1}{2}\, g\, t^2, \tag{1}$$

where y_o is the initial position and $\boldsymbol{g}$ is the acceleration due to gravity. If h is the falling distance the body has traveled from its starting point during time t, then above equation can be written as

$$h = \frac{1}{2}\, g\, t^2. \tag{2}$$

Therefore, to calculate the value of $\boldsymbol{g}$, you should study the relation between the falling distance h and t^2. Some further analysis will be carried out to check whether acceleration due to gravity is constant or not.

Part B. Determination of ($\boldsymbol{g}$) using Simple Pendulum

The simple pendulum consists of a small bob (in theory a particle) of mass m suspended by a light inextensible thread of length l from some point about which it is allowed to swing back and forth. See Figure 2. The forces on the bob are the tension in the thread T and the weight mg of the bob acting vertically downwards (as shown in Figure 2). Resolving mg radially and tangentially at point **A** we see that the tangential component is the unbalanced restoring force acting towards the equilibrium position **O**.

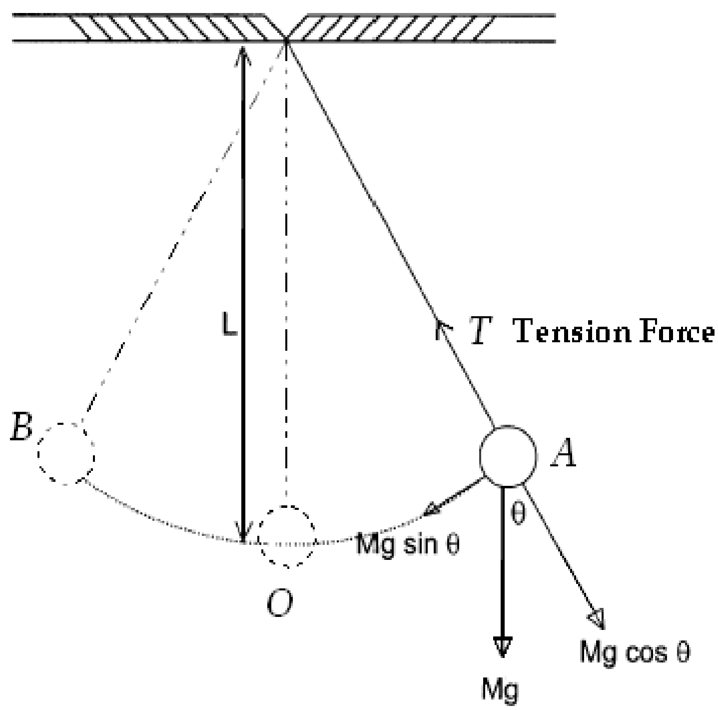

Figure 2. Simple Pendulum

If $\boldsymbol{a}$ represents the acceleration of the bob along the arc at point **A** due to the presence of force ($mgsin\,\theta$) then the equation of motion of the bob is represented by

$$-\,mg\,sin\,\theta = m\,a, \tag{3}$$

The negative sign indicates that the force is towards point **O** (restoring force) while the displacement $\boldsymbol{x}$ is measured along the arc from **O** in the opposite direction. When θ is small, then we can consider $sin\,\theta\ \simeq\ \theta$ in radians and $x\ =\ l\,\theta$. Hence

$$-\,mg\,\theta\ =\ -\,mg\,\frac{x}{l}\ =\ m\,a,$$

$$a\ =\ -\frac{g}{l}\,x\ =\ -\,\omega^2\,x. \tag{4}$$

Where $\omega^2\ =\ \frac{g}{l}$. The motion of the bob is thus a simple harmonic motion since the acceleration of the bob is directly proportional to its distance from the equilibrium point **O** and is always directed towards that point. Here ω is a constant representing the angular frequency of the motion in radian per second and so the period T is constant and given by

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{l}{g}}\,. \tag{5}$$

T is therefore independent of the amplitude of the oscillation and at a given place on the earth's surface where $\boldsymbol{g}$ is constant; it depends only on the length l of the pendulum.

Procedure

A. Free Fall

1) **Set up** the free fall timer as shown in Figure 1. Use the first steel ball.

2) Set the height h to 40 cm. **Press** the reset button on the timer, and then **loosen** the thumbscrew so that the ball drops and falls on the receptor plate. **Record** the time of fall t in Table 1. **Repeat** the measurement two times and calculate the average time of fall.

3) **Increase** the height h by about 15 cm and **repeat** the measurements made in the previous step until the height increases to approximately 115 cm.

4) **Calculate** the value of $\boldsymbol{g}$ for each height and **record** it in the appropriate column of your data table.

5) **Calculate** the average value $\bar{g}$ and the standard error $\sigma_{\bar{g}}$.

6) **Plot** the graph of height h versus t^2 and determine the acceleration due to gravity from the slope.

7) **Repeat** steps 1 through 6 for a different steel ball and record your data in Table 2.

Table 1. Free Fall of steel ball 1

h (m)	t_1 (s)	t_2 (s)	t_3 (s)	$\bar{t}$ (s)	$(\bar{t})^2$ (s^2)	$\boldsymbol{g}$ (m/s^2)

$\bar{g} \pm \sigma_{\bar{g}} =$ ....

Table 2. Free Fall of steel ball 2

h (m)	t_1 (s)	t_2 (s)	t_3 (s)	$\bar{t}$ (s)	$(\bar{t})^2$ (s^2)	$\boldsymbol{g}$ (m/s^2)

$\bar{g} \pm \sigma_{\bar{g}} =$ ....

B. Simple Pendulum

1) **Set up** the pendulum as in the Figure 2, and **adjust** the length l to about 50 cm. The length of the simple pendulum is the distance from the point of suspension to the center of the ball.

2) **Displace** the bob from its equilibrium position by a small angle and then release the bob to swing back and forth.

3) **Measure** the total time it takes to make 10 oscillations. **Record** your data in Table 3. (If the swing becomes elliptical you must **repeat** the swinging again to be in a vertical plane.)

4) **Calculate** the period T and the periods squared T^2 and **record** them in Table 3.

5) Increase the length of the pendulum by about 15 cm, and **repeat** the measurements made in the previous steps until the length increases to 125 cm.

6) **Calculate** the value of $\boldsymbol{g}$ for each length and **record** it in the appropriate column of your data table.

7) **Calculate** the average value $\bar{\boldsymbol{g}}$ and the standard error $\sigma_{\bar{g}}$.

8) **Plot** a graph of length l versus T^2 and **determine** the value of $\boldsymbol{g}$ from the slope.

Table 3. Simple Pendulum

l (m)	T_{10} (s)	T (s)	T^2 (s^2)	$\boldsymbol{g}$ (m/s^2)

$\bar{g} \pm \sigma_{\bar{g}} =$ ....