1 Introduction

1.1 Research Question/ Problem Statement

The objective of this lab is to analyze the effect of gravity during free fall of a slat. The slat is dropped between an optical transmitter and receiver. This is done to determine the position of the slat in terms of time in order to calculate the gravitational acceleration.

1.2 Background/ Theory

Free fall refers to a situation when an object is only acted on by gravitational force. In this experiment, air resistance is negligible.

A rectilinear uniform motion can be used to describe free fall, relating the position in terms time. Uniform motion paths can be described using the following equation:

$$x(t) = x_0 + v_x(t - t_0) \tag{1}$$

Where v_x is defined as:

$$v_x = \frac{x_2 - x_1}{t_2 - t_1} \tag{2}$$

However, it is important to note that in free fall, the speed is not constant, therefore the equation for speed becomes:

$$v_x = \frac{dx}{dt} \tag{3}$$

The instantaneous acceleration is defined by:

$$a_x = \frac{dv_x}{dt} \tag{4}$$

Considering air resistance as negligible, using equation 3 the following equation is found:

$$\begin{aligned} dx &= v_x \cdot dt \\ dx &= (v_0 + a_x t) \cdot dt \end{aligned} \tag{5}$$

By integrating, we get:

$$x(t) = v_0 t + \frac{a_x t^2}{2} \tag{6}$$

The gravitational acceleration varies based on where on the planet it is measured. For example, it is smaller at the equator than the poles.

When the position of the object is measured, the difference in time must be as small as possible to get the most accurate results for the instantaneous acceleration. Therefore, multiple points of measurement need to be used.

In this experiment, the point in time is registered when the object has fallen a certain distance, 50 mm. Thus, we can calculate the instantaneous acceleration and velocity. Notably, when calculating the instantaneous speed, the difference in time, Δt, should approach 0.

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \tag{7}$$

To increase precision when measuring speed, the velocity also needs to be calculated for intermediate points in time. Having two successive measurement points, the speed is considered accurate when taken exactly at the half way point between the two measurements.

$$t_{i+\frac{1}{2}} = \frac{t_{i+1} + t_i}{2} \tag{8}$$

Therefore we calculate:

$$v_{i+\frac{1}{2}} \approx \frac{\Delta x}{t_{i+1} - t_i} \tag{9}$$

2 Method & Materials

2.1 Experimental Set-up

Figure 1 shows the set-up for the experiment. The sensor gate, the alternating stripes and the wire are shown. All the data collected by the software is captured using PASCO's Capstone program.

ADD PICTURE

2.2 Measuring instruments

In this experiment, the PASCO smart gate, model PS-3225, was used to measure the difference in time, having a resolution of 2 ms (refr to the gate manual). PASCO's Capstone software was used to collect the data, and a slate with 7 black strips 50 mm apart was used as the free fall object.

2.3 Method

A slat with alternating stripes is dropped through the light sensor. The resulting measurements are then used to create a table displaying time and position.

This procedure is repeated twelve times, ensuring the data falls in the expected range. All runs with erroneous data points are remeasured, to improve accuracy.

Due to the small mass and surface area of the slat, all external forces can be ignored, and the resulting acceleration can be considered the gravitational acceleration.