Experiment 4: Free Fall and Air Resistance

Required Equipment:

- Free-fall apparatus
- Metallic tape (for free-fall apparatus)
- Masking tape
- 1 kg mass
- Meter stick
- Calipers

Theory:

An object moving freely under the influence of gravity alone, no friction, air resistance or otherwise, is called a **freely falling object**. The average velocity (v_{avg}) is defined as the displacement (Δs) divided by the time elapsed(Δt).

$$v_{avg} = \frac{\Delta s}{\Delta t} = \frac{s_f - s_i}{t_f - t_i}$$

The average acceleration $\left(a_{avg}\right)$ is defined as the change in velocity (Δv) divided by the time elapsed (Δt).

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

For convenience, let $t_i = 0$ and t_f be any arbitrary time t. With this notation, we can express the acceleration as:

$$a_{avg} = \frac{v_f - v_i}{t}$$

or, solving for v_f,

$$v_f = v_i + at$$

If an object is moving in a straight line, making equal changes in speed in equal intervals of time, the object is said to have a constant acceleration. In this motion the constant acceleration is called the **acceleration due to gravity, g**. The standard value of **g** is approximately 980 cm/sec near the surface of the Earth.

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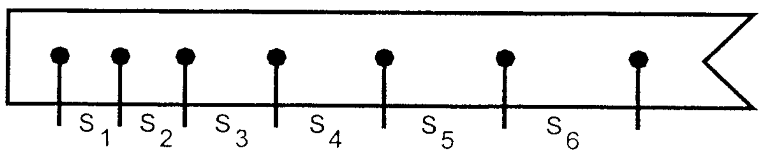
Procedure: In this experiment, an object is allowed to fall freely and its position at the end of successive equal intervals of time is recorded on a coated paper strip by means of electric sparks. Your tape will look something like:



1. Tear off ~ 2 m of the metallic tape.
2. Tape the 1 kg mass to one end of the metallic tape.
3. While one partner is standing on the table, feed the other end of the tape up through the free fall apparatus to them.
4. The partner on the table should hold the tape as vertical as possible. Make sure that the free-fall apparatus is set to $\frac{1}{60}$ of a second.

   Turn the free fall machine on and release the tape. Your tape should look like the figure above.
5. Choose 15 consecutive points. Ignore the first few points.
6. Measure the intervals s_1, s_2, s_3 .....etc....between successive spark dots using calipers.
7. Calculate the average velocity for each interval.

$$v_{avg} = \frac{\Delta s}{\Delta t} = \frac{\Delta s}{\frac{1}{60}\ sec} = \left(60 sec^{-1}\right) \Delta s$$

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Constant Acceleration Data

Spark Tape Point Number	Distance between adjacent points (cm)	Velocity (cm/sec) v = 60 x distance	Time in sec
s_1			1/60
s_2			2/60
s_3			3/60
s_4			4/60
s_5			5/60
s_6			6/60
s_7			7/60
s_8			8/60
s_9			9/60
s_{10}			10/60
s_{11}			11/60
s_{12}			12/60
s_{13}			13/60
s_{14}			14/60

8. Graph velocity versus total elapsed time using Excel (velocity on the y-axis). Your plot should be an xy scatter. To make it easier to print your chart, you should put it on a separate worksheet. Once you have the chart add a linear trendline. Make sure that you display the equation of the trendline on your chart. If you are not sure how to generate this in Excel, ask your instructor for assistance.

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9. Compare the acceleration you found from the slope of your graph to that of gravity, 980 cm/s^2. Determine the percentage error.

$$\% \text{ error} = \left| \frac{g_{actual} - g_{experimental}}{g_{actual}} \right| * 100\%$$

Additional Questions:

1. If the falling body had been given an initial downward push instead of being only released, would the resulting observed value of g be different? Explain.

2. Which of the following statements properly characterizes the motion of a heavy object thrown downward with high initial speed from a tall building? Neglect air resistance. Circle one.
    a. uniform speed,
    b. constant acceleration,
    c. uniformly increasing acceleration, or
    d. non-uniformly changing acceleration?

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3. How long does it take a rock to fall 30 meters if it is released from rest? Show calculations.

4. Does a ball dropped out of the window of a moving car take longer to reach the ground than one dropped from a car at rest? Use a diagram to explain.

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