Physics 11 Kinematics Activities - Introduction

Kinematics Activity #1: Investigation of Uniform Motion

Problems/Questions addressed in this lab:
- graphing uniform motion (non-accelerating)
- interpreting graphs of uniform motion

Materials:
- spark timer (f=10.0 Hz)
- approximately 1.5 meters of ticker tape (for the recording timer)
- constant velocity car
- masking tape
- 1 piece of mm rule graph paper

Lab Procedures:
1. Set up the recording timer on a flat surface, and attach the ticker tape to the constant velocity car.
2. Record the motion of the car for about 1 meter.
3. The space between each spark on the ticker tape represents a time of 1/10 second (f = 10Hz therefore T = 1/10 s)
4. Choose a segment of the ticker tape where the sparks/dots appear to be evenly spaced. Label the first dot as t_o = 0s. The next dot is t_1 = 1/10 s.
5. Measure the total displacement from t_o to each of the subsequent dots.
6. Create a data table like the one shown below to record the time and displacement values. Record values for 15 to 20 data points.

Time (s)	Displacement (cm) *[measured from the dot labeled t_o]*
0	0.000
1/10	?
2/10	
3/10	
	(continue for 15 to 20 data points)

7. Draw a Displacement (cm) vs Time (s) graph of the motion (displacement on the y axis, time on the x axis)

Questions:
1. Calculate the average velocity of the trip by dividing the total displacement by the total time taken (use the values on your data table, rather than the values on your graph).
2. On your graph use a ruler to draw the line of best fit.
3. Calculate the slope of your graph, and write the equation of the line (in the form y = mx + b). Be sure to include appropriate units.
4. What physical quantity does the slope of the graph represent?
5. What shape would the graph have if the motion were perfectly uniform?
6. What shape would the graph have if the motion were perfectly uniform, but faster?
7. What shape would the graph have if the motion were perfectly uniform, but slower?
8. Draw a ***sketch*** of graph that is moving at a uniform speed for the first half of its journey, and then speeds up to a faster uniform speed for the second half.

Kinematics Activity #2: Acceleration of a Freely Falling Object

Problems/Questions addressed in this lab:

- Determining the acceleration of an object in free fall
- Interpreting graphs of *position vs time*, *velocity vs time*, and *acceleration vs time* for an object accelerating at a constant rate.

Materials:

- spark timer (f=60.0 Hz)
- approximately 1.5 meters of ticker tape (for the recording timer)
- 100g or 200g mass
- 2 pieces of mm rule graph paper

Useful Equations:

* ***Percent error calculation:*** This equation is used when comparing a measured value to a widely accepted value

$$\% \text{ error} = \frac{(\text{measured value} - \text{accepted value})}{\text{accepted value}} \times 100\%$$

* ***Percent difference:*** This equation is used when comparing two measured values -

$$\% \text{ difference} = \left| \frac{x_1 - x_2}{(x_1 + x_2)/2} \right| \times 100\%$$

Lab Procedures:

1. Set up the recording timer and attach the ticker tape to the 200g mass.

2. Hold the timer against a wall as high as possible, and as still/stable as possible. Turn on the timer and drop the mass to record the motion of the falling mass.

3. Complete **2 data tables,** for **15 to 20 data points**, as described below. The two data tables represent the same data acquired from the recording timer i.e. the same number of dots over the same total time and displacement.
   a. Data table 1: **Position, d(m) vs. Time, t(s) of a 200g Mass in Free Fall**
   b. Data table 2: **Velocity, v(m/s) vs. Time, t(s) of a 200g Mass in Free Fall**.

<u>Data Table #1 – Position [d(m)] vs. Time [t(s)] of a 200g Mass in Free Fall</u>

Total time elapsed (s)	**Position (m)** *[measured from the first discernable dot]*
$t_o = 0$ s	0.000
$t_1 = 1/60$ s	?
$t_2 = 2/60$ s	?
$t_3 = 3/60$ s	?
	(continue for 15 to 20 data points)

Data Table #2 – Velocity vs Time of a 200g Mass in Free Fall

NOTE: Several mathematical steps are required in order to determine the velocity of the falling mass at specific moments in time during its fall (instantaneous velocity). The data you collect is position vs time. Through mathematical analysis of the position and time data you will determine the average velocity of the mass within each time interval. This is the same as the instantaneous velocity of the mass midway in time between the position data points collected.

First, measure the distance travelled in each 1/60 second time interval (i.e. not the total distance travelled, but just distance from one dot to the next). Plot this in the column titled "Δd".

Second, calculate the average velocity in each time interval $v_{ave} = \Delta d/\Delta t$ (for the time interval) *("Δd in interval" divided by 1/60 s*). For an object accelerating at a constant rate the average velocity in a time interval equals the instantaneous velocity (v_{inst}) of the object at the midpoint in time within the interval. When you plot the points on the Velocity vs Time graph, you must plot the instantaneous velocities midway in time between the data collection time (i.e. the average velocity of the mass between 4/60 s and 5/60 s equals the instantaneous velocity of the mass at 4.5/60 s. So, the x coordinate for that velocity is 4.5/60 s (not, 4/60 s, and not 5/60 s).

NOTE: *distance measurements must be represented in meters (m), and velocity in m/s.*

			(y axis of graph)	*(x axis of graph)*
Time interval (s)	**Δd (m)** *[distance between the end points of the interval]*	**Δt in interval (s)**	**v (m/s)** *[= v_{ave} = Δd/ Δt]*	**Time (s)**
0 to 1/60		1/60		0.5/60
1/60 to 2/60		1/60		1.5/60
2/60 to 3/60		1/60		2.5/60
3/60 to 4/60		1/60		3.5/60
4/60 to 5/60		1/60		4.5/60
(continue for 15 to 20 data points)				

4. Use the information on **Data Table #1** to plot the graph of *"Position vs. Time of a 200g Mass in Free Fall***"** ("position" on the y axis, and "time" on the x axis)

5. Use the information on **Data Table #2** to plot the graph of "*Velocity vs Time of a 200g Mass in Free Fall*". On the y axis (Velocity), use the values from the "v" column of the data table (the 4th column). On the x axis (time), use the values from the "time" column (the fifth column).

Questions:

1. Determining velocity through analysis of the position vs time graph:
   a. Calculate the average velocity of falling object dividing the total distance travelled (final position minus initial position) by total time.
   b. Calculate the instantaneous velocity of the object at the point when time = (total time)/2 (the half way point in time). To do this, draw the tangent to the curve at time = (total time)/2, and calculate the *slope of the tangent*.
   c. Calculate the % difference between the average velocity calculated in 1(a), and the instantaneous velocity calculated in 1(b).

2. Determining acceleration through analysis of the velocity vs time graph.
   a. Calculate the slope of the velocity vs time graph (with correct units).
   b. Write the equation of the graph (in the form y = mx +b)
   c. The slope of the velocity vs time graph represents the acceleration of the object. The accepted value for the acceleration of a freely falling object is 9.80 m/s^2 (the symbol for this number is “g”). Use your calculated slope, and the accepted value, to calculate the percent error.
   d. Sources of Error: Describe and explain the sources of error associated with this lab. Why would there be a discrepancy between your measured value and the accepted value? (explain)

3. Determining displacement through analysis of the velocity vs time graph.
   a. Calculate the total area under the velocity vs time graph (with correct units!).
   b. Calculate the percent difference between the area calculated in (a), and the total measured displacement of the mass (final position).

4. Sketch the shape of the acceleration vs time graph for a freely falling object.