"Uniformly" Accelerated Motion

Introduction: Some experiments yield clear-cut, unequivocal data; some experiments do not. However, with enough data, some results can be deemed as trustworthy. In this lab we will take lots of data from primitive equipment and analyze it in the spreadsheet.

Theory: The theory behind uniformly accelerated motion is simple. Let a falling weight drag a tape through an apparatus which marks it at regular time intervals, t. Given this set of coordinates, the distance between each pair can be calculated. If the time for each interval is known, the quotient of $\triangle x/t$ yields the average velocity over the interval. (This also happens to be the velocity halfway between the coordinates, called the midmark velocity.) When one subtracts consecutive average (or midmark) velocities, and divides the differences by the same time interval, one arrives at a set of accelerations. If the driving force is constant, like gravity, the accelerations would be constant, or uniform. The graph of a = a(t) would be a horizontal line. Using integration, the graph of v = v(t) would be a sloping line. What would the graph of x = x(t) look like?

These are ideal situations. In reality, our apparatus has all sorts of random variations, frictions, and uncertainties. The raw graph of a = a(t) would not be a horizontal line, the graph of v = v(t) would not be a sloping line, etc. However, using statistical analysis, we can negate to some extent the vagaries of the equipment.

Task:

- To statistically analyze data from data tapes to determine the acceleration of a falling body, producing six graphs and four values for acceleration
- To analyze the apparatus for flaws, errors, and uncertainties (as always)

Equipment:

- Tape timers (clackers)

- Digital timers

- 100 gram mass

- meter stick

- computer and spreadsheet

- timing tape

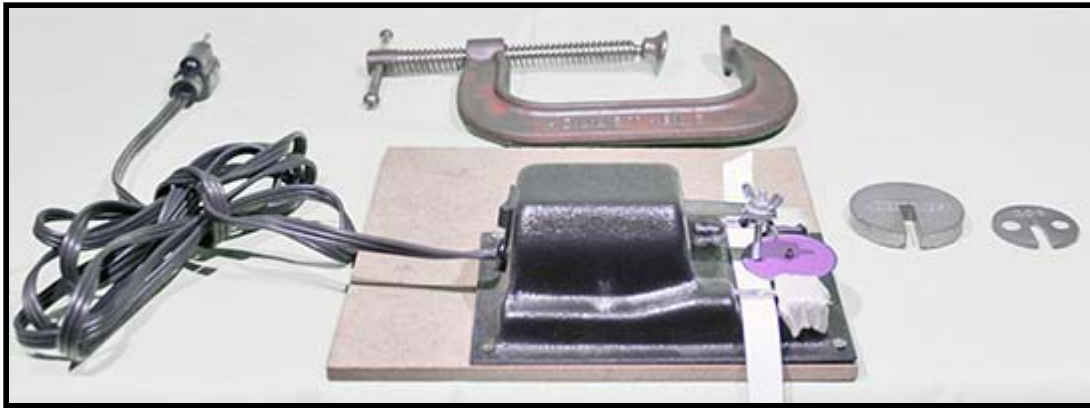## Procedure:

1. Set up the apparatus as shown below:

Figure 1

2. Drag the tape (by hand) through the apparatus and time how long it takes using the timer.
    a. Be sure to drag the tape at a constant speed.
    b. Count the number of dots.
    c. The number of dots and the pulling time is all you need from this action.
    d. Divide the time by the number of dots to calculate Δt.
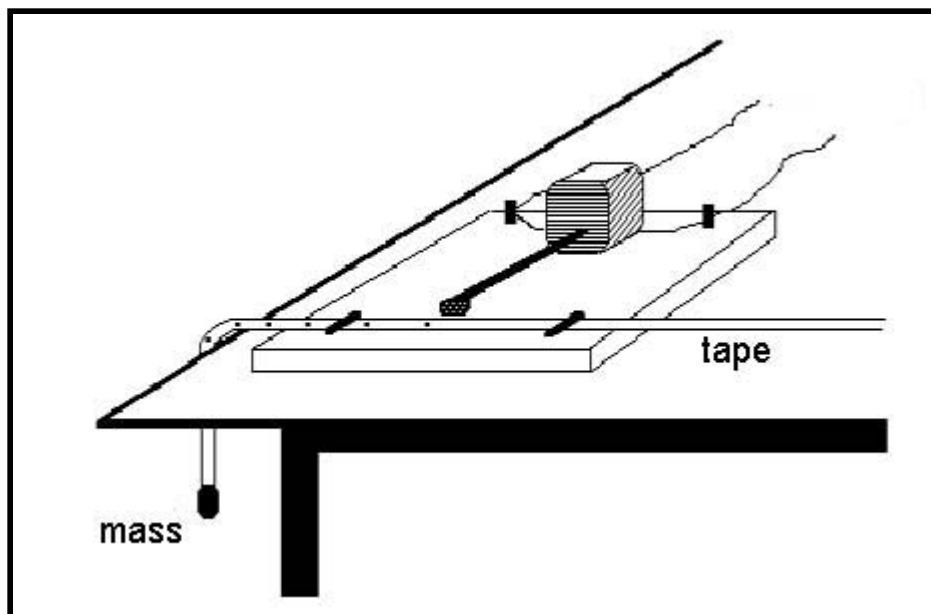3. Set up the apparatus as shown below:

Figure 2

4. Using the 100g mass, allow it to drag the tape through the tape timer. Be sure there is enough tape to reach the floor. You do not need the stop watch for this part.
5. Lay the tape on a meter stick and record the **POSITION** of **(not the distance between)** each mark.

Spreadsheet:

6. Title your file and label columns with units!
7. Make a single cell for time/dot from the first procedure (pulling the tape by hand), then refer to this cell when you need Δt. These values will be used for graphing.

8. Make a column for the elapse time. Start with t = 0 and add Δt to get the second cell.
9. Make a column for the raw data, the **position** of each mark in cm. Start with x=0.
10. The Next column should have the position in meter.
11. Next to this column, calculate the difference between positions.
    a. e.g. G3:(F3-F2), G4:(F4-F3). Cell G2 will be blank.
12. Next to this column, calculate the quotient of ΔX/Δt.
    a. ΔX is the difference between positions.
    b. Δt is the time interval derived from the 2) procedure.
        i. You should have this number calculated somewhere in your sheet.
    c. these are average or midmark velocities
13. Next to this column, calculate the difference between average velocities (ΔV).
14. Next to this column, calculate ΔV/t. These are your accelerations.
15. Compute the average acceleration by calculating the average of the values in the column. This is your first value for acceleration.

Graphs for 100g Mass:

Be sure to title, label and grid your graphs!

1. **Acceleration vs. time:**
    a. Type of graph: X-Y
    b. X: elapsed time
    c. Y (first series): computed accelerations
    d. Trendline: which (line, power, polynomial, exponential) will you choose? Show the equation and the intercept on your chart.
        i. For Series 1 select the series by right-clicking on a datum. Under Chart Tools / Layout choose the Error Bars pull down menu.Choose Error Bars with Standard Deviation.
        ii. Right click on any x error bar to delete them all.
        iii. Y error bars are a good way of showing data variation around a specified value.
    e. Your second value for acceleration lies here.
2. **Velocity vs. time:**
    a. Type of graph: X-Y
    b. X: elapsed time
    c. Y: computed velocities
    d. Trendline: which will you choose? Show the equation and intercept on your chart.
    e. Your third value for acceleration lies here.
3. **Position vs. time:**
    a. Type of graph: X-Y
    b. X: elapsed time
    c. Y: position (raw data)
    d. Trendline: which will you choose? Show the equation and the intercept on your chart.
    e. Your fourth value for acceleration lies here.
4. You need to create another three graphs using the maximum values to calculate the uncertainties.

Questions:

1. On the v(t) graph, what does the y intercept represent?
2. What do the quadratic coefficients b and c represent?