Motion 3 - Tracking

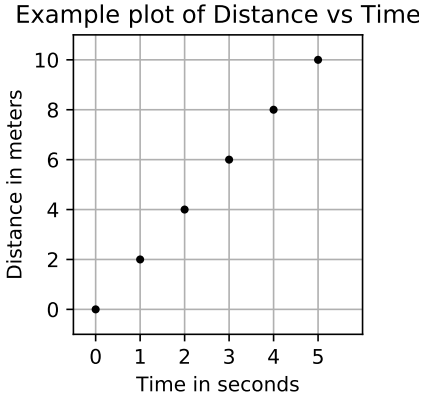
You have been throwing things since your first tantrum as a child. In fact, we are so good at throwing that it has been suggested as one of the main differences between humans and other primates, (https://www.nature.com/articles/nature12267).

It is only natural then that the first examination you do of motion is of throwing an object. Mythbuster's analyzed motion of objects by recording them with a camera and playing the video back frame-by-frame. You too will have that power!

Notes

Calculating Velocity and Acceleration

Velocity and acceleration are BOTH calculated from a table of time vs distance.



Time (s)	**Distance** (m)	**Velocity** (m/s)	**Acceleration** (m/s^2)
0	0	-	-
1	2		-
2	4		
3	6		
4	8		
5	10		

Velocity is the slope of distance and time. Think of how you calculate speed, I went 60 miles in 1 hour, so I went 60 miles per hour. The formula is:

$$\text{Velocity} = \frac{\text{Change in Distance}}{\text{Change in time}} = \frac{\text{(Current distance) - (Previous distance)}}{\text{(Current time) - (Previous time)}}$$

Acceleration is the slope of velocity and time.

$$\text{Accleration} = \frac{\text{Change in Velocity}}{\text{Change in time}} = \frac{\text{(Current velocity) - (Previous velocity)}}{\text{(Current time) - (Previous time)}}$$

Example

Time	**Distance**	**Velocity**	**Acceleration**
0s	0m	-	-
1s	2m	$\frac{2m-0m}{1s-0s} = \frac{2m}{1s} = 2\,\text{m/s}$	-
2s	4m	$\frac{4m-2m}{2s-1s} = \frac{2m}{1s} = 2\,\text{m/s}$	$\frac{2\,\text{m/s}-2\,\text{m/s}}{2s-1s} = \frac{0\,\text{m/s}}{1s} = 0\,\text{m/s}^2$

Instructions for notes - (you need to fill out the table)

This section is to help you fill out the velocity and acceleration portions of the table you copied into your notes.

The first question to answer is what does 'change in' mean. 'Change in' means that you look at where you are at and where you were, the difference is 'change in'. Example, if I start off against the wall (call it 0m), then take one step, I'm at 1m. My change in distance then is 1m (1m - 0m).

Change in time works the same, when I started against the wall time was 0s. When I was step away, it was 1s, hence the change in time was 1s.

Using the two equations we can finish filling out the table above.

What follows is a more detailed version of what is in the example table that you copied into your notes. To calculate velocity at 1s:

$$\text{Velocity at 1 second} = \frac{(\text{Position at 1 second}) - (\text{Position at 0 seconds})}{(\text{Time at 1 second}) - (\text{Time at 0 seconds})}$$

$$V(1) = \frac{P(1) - P(0)}{T(1) - T(0)} = \frac{2m - 0m}{1s - 0s} = \frac{2m}{1s} = 2\,\text{m/s}$$

$V(1)$ is called function notation. $V(1)$ means that V, velocity, at time 1 second.

To calculate velocity when time is 2 seconds:

$$\text{Velocity at 2 seconds} = \frac{(\text{Position at 2 seconds}) - (\text{Position at 1 second})}{(\text{Time at 2 seconds}) - (\text{Time at 1 second})}$$

$$V(2) = \frac{P(2) - P(1)}{T(2) - T(1)} = \frac{4m - 2m}{2s - 1s} = \frac{2m}{1s} = 2\,\text{m/s}$$

Now fill out the rest of the velocities.

Note, we cannot calculate the first velocity since we don't have a distance for -1 second.

What follows is a more detailed version of what is in the example table that you copied into your notes. To calculate acceleration at 2s:

$$\text{Acceleration} = \frac{(\text{Velocity at 2 seconds}) - (\text{Velocity at 1 second})}{(\text{Time at 2 seconds}) - (\text{Time at 1 second})}$$

$$= \frac{2\,\text{m/s} - 2\,\text{m/s}}{2s - 1s} = \frac{0\,\text{m/s}}{1s} = 0\,\text{m/s}^2$$

Now fill out the rest of the accelerations. Note, we cannot calculate the acceleration for the 0s and 1s because you need two consecutive velocities to calculate the change in velocity

Things to note:

- The velocity is the slope of the distance graph.
- The acceleration is zero if the velocity doesn't change.

Activity

You will record yourself throwing a ball in front of the marker board at the back of the room, then analyze the video using the 'Tracker' program that you will put on your computer.

Procedure

- Record a video of a person throwing a ball underhand in an arc.
  - Make sure the ball is visible in the whole video
  - Try to NOT move the camera
  - Have the meter stick in the background for calibration
- Get a flash drive with the 'Tracker' program on it.
- Open the 'Tracker' application from the 'Tracker' folder on the flashdrive.

  Import the video

Tracker program overview

- To launch the program double click the 'Tracker' application in the Tracker folder.
- To add the video you took, click 'Import' in the 'Video' menu at the top.
- Once the video is imported.
  - Move the black arrows on the playback bar to the beginning and end of the ball being thrown.
  - Click the cross hairs on the icon bar to set the origin at the starting location of the ball.
- Next we have to tell the program to track something.
  - Click the 'Create' button, and then click 'Point Mass'.
  - Now when you press 'shift + click' on your ball, it will save that point and advance to the next frame.
  - Continue to press 'shift + click' on the ball until you have went through all the frames.
- Now that you have all the points, you can look at the table and the plot.
  - To expand the table or plot, click the arrow in the top right hand corner of either.
  - Expand the table.
  - If you click on 'Table' in the top left, you can add columns. Add vx (the x-velocity), vy (the y-velocity), ax (the x-acceleration), and ay (the y-acceleration).
  - (Note that the program can automatically calculate the velocity and acceleration.)
  - Reduce the table by pressing the arrow in the top right.

- Expand the plot by pressing the arrow in the top right of the plot.
- Clicking on 'Plot' allows you to select the number of plots.
- Clicking on the y label of each plot allows you to select what each plot shows.
- Select three plots, and then have the top be 'x', the second be 'vx', and the third be 'ax'. That way you are looking at the distance, velocity, and acceleration for each.
- For the velocity and acceleration plots, make sure that you can see the zero. If you right click the y-scale there is an option to 'show vx=0'.

Prompts - put these in your notebook

1. Sketch the x vs y plot for your ball.
2. Sketch the x vs time plot for your ball.
3. Sketch the y vs time plot for your ball
4. Sketch the plots for vx, and ax vs time.
5. Sketch the plots for vy, and ay vs time.