Southern New Hampshire University

PHY-150 Lab 4-2: Newton's Second Law
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1 Newton's Second Law Data Table 1

Suspended Mass (g)	**Weight Susp- -ended Mass**	**Time in seconds**	**Distance in inches**	**Acceleration** $(2\bar{d}/\bar{t}^2)$
3 Washers	7292.1303 N	Trial 1: 1.400 Trial 2: 1.866 Trial 3: 1.933 $\bar{t} = 1.733$	Trial 1: 18.967 Trial 2: 19.761 Trial 3: 22.819 $\bar{d} = 20.516$	13.662
4 Washers	9722.8404 N	Trial 1: 1.233 Trial 2: 1.167 Trial 3: 1.100 $\bar{t} = 1.444$	Trial 1: 23.475 Trial 2: 18.897 Trial 3: 16.989 $\bar{d} = 19.787$	18.979
5 Washers	12153.5505 N	Trial 1: 0.900 Trial 2: 0.634 Trial 3: 0.900 $\bar{t} = 0.811$	Trial 1: 18.573 Trial 2: 12.843 Trial 3: 18.234 $\bar{d} = 16.568$	50.380
6 Washers	14584.2606 N	Trial 1: 0.667 Trial 2: 0.900 Trial 3: 0.666 $\bar{t} = 0.744$	Trial 1: 16.295 Trial 2: 18.847 Trial 3: 18.178 $\bar{d} = 17.773$	64.216
7 Washers	17014.9707 N	Trial 1: 1.100 Trial 2: 1.100 Trial 3: 0.900 $\bar{t} = 1.033$	Trial 1: 22.861 Trial 2: 22.614 Trial 3: 22.342 $\bar{d} = 22.606$	42.370

With results, please note that...

- Weight suspended mass is: $m \times 385.827\ in/s^2$
- When computing the m, it is $m = 6.3k \cdot g$, where k is the number of small washers being suspended.
- In the last table, I added 3 extra inches to each final distance because the initialiation point started at the nose of the circular extension as opposed the start at the end of the cart. This was an anomaly in measurement and I attempted to correct for it.

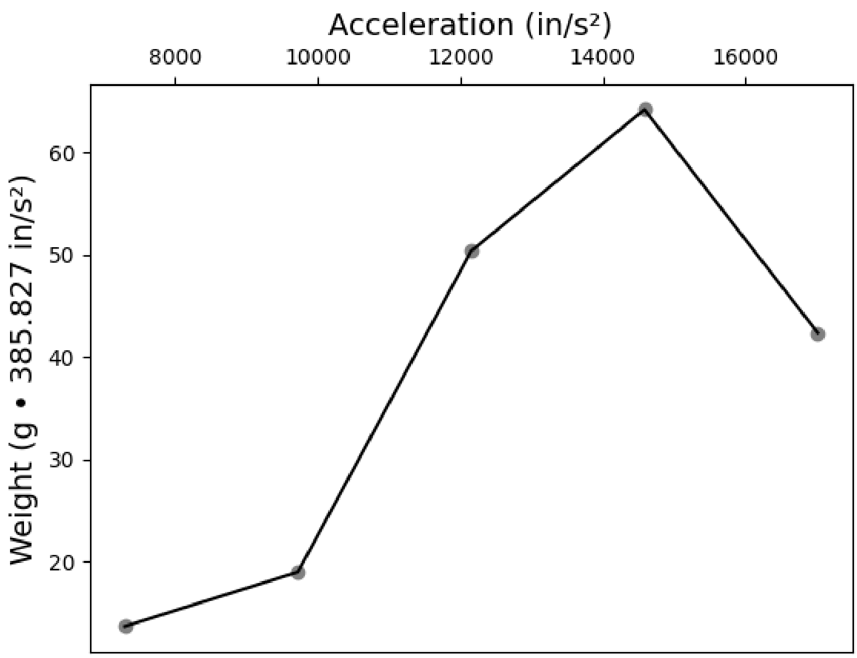

Figure 1: **Suspended weight versus acceleration.**

Note that this section part of Activity 1 (the *only* activity).

2 Questions for Newton's Second Law

2.1 Question 1: Doubling the force

Question: According to Newton's Second Law, if the force applied to an object is doubled, what happens to the acceleration?

My answer: Newton's second law states that:

$$F = ma$$

where F is the net mechanical force,[a] m is the mass of the object being acted upon[b] and a is the acceleration function of the object.[c] In regards to its acceleration function, to study its behaviour, I need to solve for the a bit:

$$a = \frac{F}{m}$$

If one were to assume that the m is constant,[d] doubling the F would cause the a to double as a result, or

$$2a = \frac{2F}{m}$$

regardless of how F is parameterised.

[a]Typically in newtons; where $N = (\text{kg} \cdot m)/(s^2)$
[b]Typically in kilograms (kg)
[c]Typically in metres per second squared, or m/s^2
[d]Einstein's theory of relativity challenges this assumption in high speeds.

2.2 Question 2: Constant velocity

Question: You observe a vehicle traveling on a highway. The vehicle is maintaining a constant velocity. What can you determine about the forces on the vehicle?

My answer: I can infer that whatever forces are acting on the vehicle are causing the vehicle to be in uniform velocity motion, a situation where $a(t) = 0\ m/s^2 \because \sum F = 0\ N$ and $a(t) = F/m = 0N/m$ which always works out to 0.

2.3 Question 3: Measurement errors

Question: What are some error sources in the Second Law experiment?

My answer: While it is difficult to work out exactly what environmental things cause noise in the dataset, I have identified some possible interferences:

- In regards to data recording and processing, I have used a built in camera on a smartphone to record video of the experiments. I have also use a software tool to collect data on the displacement of the cart given time. It may be the case that the camera was setup incorrectly or that I was biased[a] when (manually) coding the displacement and time parameters.
- Towards the end of the experiment, I noticed that the book stopper moved from its original position (probably because of its impact with the cart). This may affect the total distance traveled which may introduce noise[b] to the data set.
- It may be the case that when I was measuring the distance from the start point to the book stopper that I misread the tape measure. This can introduce noise to the resulting data set.
- It may be the case that when I was weighing the paperclips and washers that the scale that I was using had some kind of implementation mistakes. This could add noise the results of working out acceleration from mechanical force and mass, or mechanical force from measured acceleration and mass.
- When initialising the position of the cart, I have measured the distance between the origin to be 22 inches, but I started "rolling" the cart with some kind of long nose that reaches the book stopper before 22 inches. This may bias the estimates.

See the Appendix for some more elaboration of my collection and analysis of the data.

[a] I use "bias" in the statististical sense which refers to the difference between the true parameter and the estimated parameter.

[b] As with "bias," I use "noise" in the statistical sense where I refer the "spread" of measurements.

2.4 Question 4: The kinematics equation

Question: In the Second Law experiment, the acceleration is calculated by measuring the time for the cart to move from the start point to the end point and applying the kinematics equation:

$$s = \frac{1}{2}at^2$$

Explain how this equation is used to find the acceleration.

My answer: The acceleration function can be discovered by multiplying the a by the (1/2) coefficient.[a]

[a] For a more rigourous derivation of acceleration, one would take the second derivative of $s(t)$ to discover its acceleration function:

$$a(t) = \frac{d^2 s(t)}{dt^2}$$

Note that this section part of Activity 1 (the *only* activity).

A Appendix: Data collection and analysis

My method to collect data was to use a built in camera on a smartphone to record video footage of the cart being pulled down by weights suspended on the paperclip. I would then transfer the footage onto my computer, slightly edit some of them to horizontally flip the video footage[1] and then chart the motion of the cart with the Tracker software (see Fig. 2).

With the Tracker tool, I will impose a Cartesian coordinate system based on my best "eyeballing" of the start of the cart as the origin and tilt it as best as I can to match the direction of the cart. I will then export this data from Tracker onto CSV.[2]

[1] This is to make easier to impose a Cartesian coordinate system from the perspective of the thing being studied.

[2] Comma-seperated values—or CSV— is a format for tabulating data and storing them in a text formatting with a comma delimiter for columns and a newline delimiter for rows.

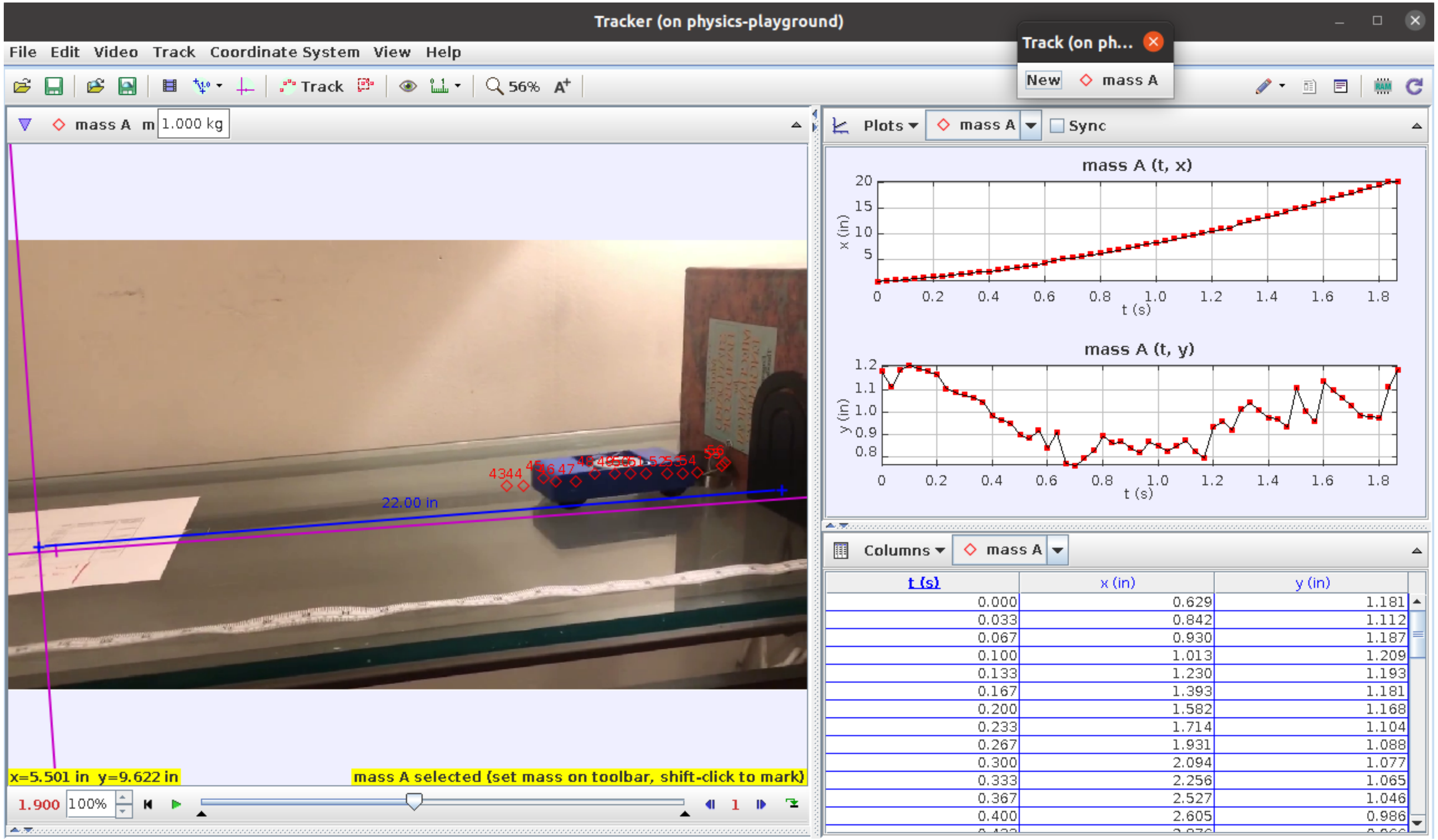

Figure 2: **An example of “tracking” the movement of the cart.**

In my attempts to mitigate measurement error, I will work out the difference in both the distance ($\Delta x = x_f - x_i$) and time ($\Delta t = t_f = t_i$). The differences are then encoded into Data Table 1 and derived figures are calculated from there. With regard to distance, I used inches instead of seconds (unfortunately), and to prevent overcomplication regarding calculations, I will use inches as both my base unit for length and for any derived units involving length.