Cart on an Inclined Plane Lab

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ABSTRACT

The point of this lab was to determine the motion of a cart down an inclined plane. To collect the data necessary for the experiment, we constructed a ramp from a piece of wood on a low stack of books and rolled a cart down it. The data was collected by way of a ticker timer recording the position in time of the cart at 60 times a second (60 Hz). The cart traversed the ramp (30 cm) in about 1.2 seconds, with a final velocity of about 3.6 cm/0.1s . The cart had a positive acceleration and increasing velocity, likely due to gravity.

OBJECTIVE

The goal of this lab will be to determine the motion of a cart down an inclined plane, and using the data gathered to determine if the cart moves with constant/changing velocity/acceleration. Will the cart move with a constant or changing velocity? Will the cart have an acceleration? If the cart does accelerate is it constant or changing? If there is an acceleration, how can we determine its value? Does the d = vt accurately predict the distance traveled? Does the area under a velocity vs. time graph accurately predict the distance traveled?

HYPOTHESIS

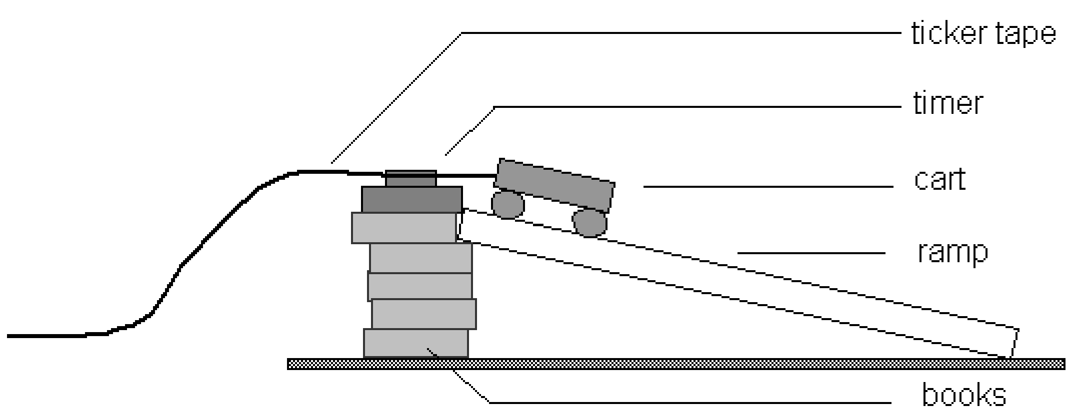
The cart will start off slowly, gathering speed and momentum from gravity as it heads down the ramp. It will have a positive acceleration and an increasing velocity.

PROCEDURE

The materials needed are as follows: several books, a cart, a wooden ramp, some tape, several meters of ticker tape, and a ticker timer. The procedure is as follows:

1. Place the wooden ramp on a stack comprised of several books to create a gradual incline.
2. Attach one end of the ticker tape to the back end of the cart with the tape.
3. Feed the other end of the ticker tape through the ticker timer, positioning both so that when the cart pulls the ticker tape, it passes through the timer.
4. Start the ticker timer.
5. Give the cart a gentle shove, enough to get it going but not enough to overly contribute to its original momentum.
6. Mark off every six dots created by the ticker timer.
7. Measure the distance between the dots.

DIAGRAM

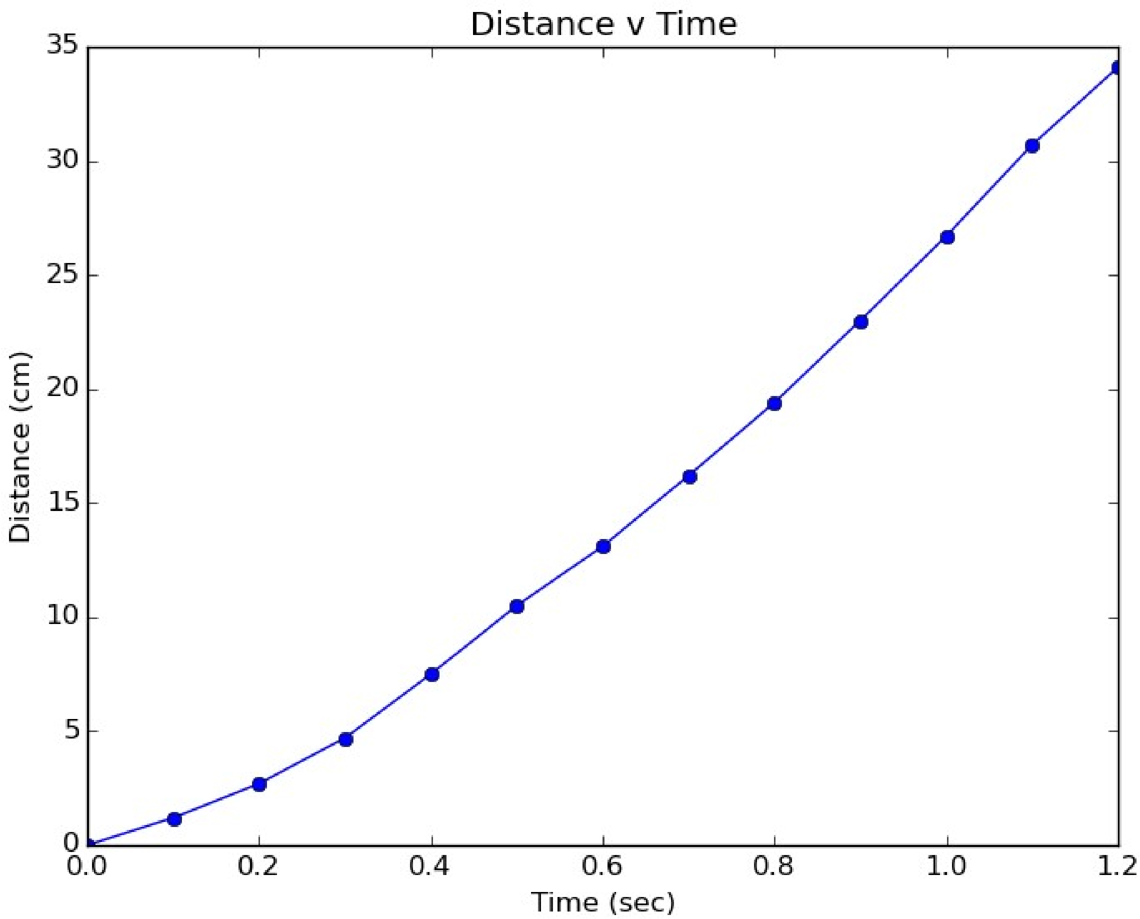


DATA AND OBSERVATIONS

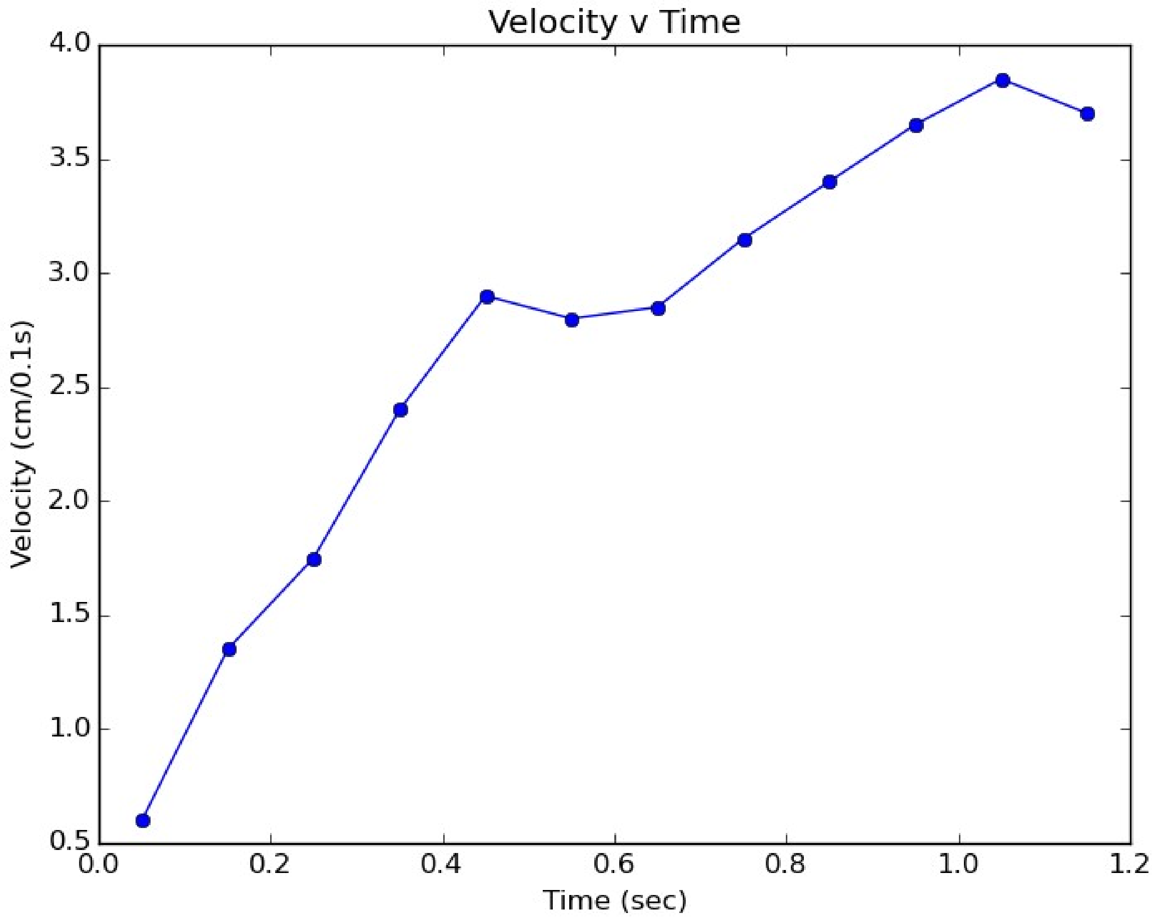
Distance Traveled vs. Time

Time (sec)	Length (cm)
0.0	0.0
0.1	1.2
0.2	1.5
0.3	2.0
0.4	2.8
0.5	3.0
0.6	2.6
0.7	3.1
0.8	3.2
0.9	3.6
1.0	3.7
1.1	4.0

TOTAL DISTANCE v TIME (net distance, increasing from dot to dot, assuming positive motion)



VELOCITY v. TIME (instantaneous velocity at each point versus time)



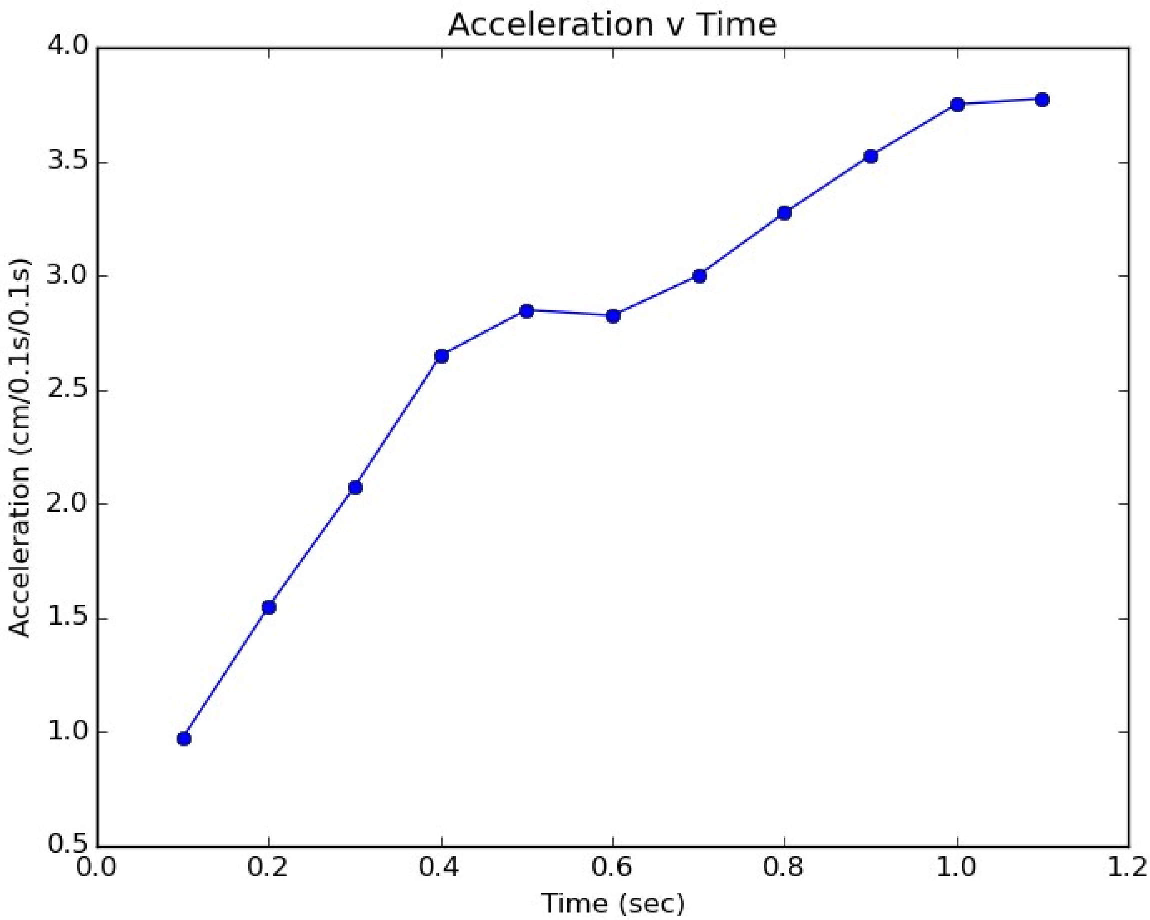
DATA ANALYSIS

The table has 13 data points, from 0 to float(13/10) in increments of 1, labeled with the corresponding distance value. As we measured every six ticker timer dots, we measured the distance from point to point, and not from the beginning.

The first graph is a net distance versus time plot. It adds up the distance as the graph progresses, which shows the total distance covered by the cart, not just from point to point, but over the whole time traveled. This shows us plenty of useful information, allowing us to infer velocity and acceleration just by looking at the graph.

The second graph shows velocity versus time. The data points were calculated by taking the averages of the distances (non net) and time values between each two points. The result is a clear positive trend, with a slight variation at t = .5 seconds. If we had used larger increments of time, the graph would have undoubtedly had a less jagged persona, but a trend is clear—in the first second, the cart accelerates down the ramp, until it reaches its maximum speed of about 3.8 $m.s^{-1}$.

The distance graph appears to have a linear shape at first, but closer examination reveals it to be more parabolic in structure. This is precisely the shape expected from a graph of a cart going down a ramp. The ticker timer dots show this by getting farther and farther apart for each interval, which shows definite acceleration.



Aside from the anomaly at t = 0.5 seconds, the acceleration is fairly linear. The anomaly is likely caused by an imperfection in the board, such as a dip or a small pothole. At a dip, the cart's speed would increase significantly and then slow down. The “natural” topography of the ramp is the most likely explanation for such an abnormality.

Using the formula d = $v_f t$, we can calculate what the distance should be and compare it to out actual value.

D = v*t
d = (3.6cm.(0.1)s^{-1})(11.5s)
d = 41.4cm

Percent Difference:
%dif= |approx value – exact value|/exact value
%dif = |41.4 – 30|/30
%dif = 37%

This is an incorrect approximation of the distance the cart traveled, which yields the 37% difference. This is because, while the cart reached its maximum velocity fairly quickly, it had already traversed the entire ramp, leaving it no time to “use” that velocity to its advantage.

The total area under the velocity versus time graph is 29.55cm. The actual traveled distance (as measured) is 29.99 centimeters, which yields a percent difference of 1%, with no significant difference (see Appendix A for calculation, `integrate` function).

The more accurate method for calculating the distance of the cart is plainly the integral method. This takes into account the subtle—or sometimes drastic—changes in the velocity, whereas the distance formula cannot. The result is less accuracy for the formula and pinpoint precision for the graph calculation.

The hypothesis in this case was supported by the data. Based off of the graphs, the cart had both a positive acceleration and a positive velocity.

CONCLUSION

The cart (which moved with a swiftly changing velocity/acceleration) traveled about 30 cm down a wooden ramp. The distance v time graph had a parabolic shape, while the velocity and acceleration vs. time graphs had a general linear trend. The hypothesis was completely supported. This has interesting contexts, especially for topics like alternative methods for space travel—a good algorithm (see Appendix A) for calculating and comparing velocities and accelerations could come in handy when, for example, comparing the potentials of solar sails versus chemical propulsion.

ERROR ANALYSIS

There were many limitations to this lab. I do not trust the data we collected for several reasons. First of all, the ticker timers were old and no doubt were not vibrating at the proper frequencies. Secondly, after measuring about 40 tiny dots on a slim piece of paper, one's eyes begin to get blurry and their hands shaky. Finally, I measured and recorded a good three quarters of the ticker tape, which means that it would NOT hold up in a court of law, thanks to my famously terrible estimation skills and horrifyingly hideous handwriting.

APPENDIX A

This section contains all the code that I used to complete the calculations and graphs.

Creating the Distance V. Time table

```
#!/usr/bin/python

import matplotlib.pyplot as plt
import os

try:
	os.system("rm -f table.png")
except:
	pass

# accessing data file
data = 'data.txt'
target = open(data, 'r+w')
lines = target.readlines()
# preparing arrays for data
x_values = []
y_values = []
labels = []
values = []
# putting data into arrays
for line in lines:
	print line
	if line[0]=="#":
		labels.append(line)
		pass
	else:
		if line[0]=='=':
			y_value_begins = lines.index(line) + 1
			break
		else:
			num = line.rstrip()
			print num
			x_values.append(float(num))
for i in range(y_value_begins,len(lines)-1):
	print line
	if lines[i][0]=='=':
		break
	else:
		num = lines[i].rstrip()
		print num
		y_values.append(float(num))

print x_values
print '\n'
```

```
print y_values
#setting up the graphs/table
print len(x_values), len(y_values)
final_x_values = []
final_y_values = []
for i in range(len(x_values)-1):
      values.append([x_values[i],y_values[i]])
colLabels=('Time (sec)', 'Length (cm)')
hcell, wcell = 0.3, 4.
hpad, wpad = 0, 0
nrows, ncols = len(values)+1, len(colLabels)
fig=plt.figure(figsize=(ncols*wcell+wpad, nrows*hcell+hpad))
ax = fig.add_subplot(111)
ax.xaxis.set_visible(False)
ax.yaxis.set_visible(False)
the_table = ax.table(cellText=values,
          colLabels=colLabels,
                 loc='center')
plt.title("Distance Traveled vs. Time")
plt.savefig("table.png")
```

Creating the Velocity and Acceleration v. Time graphs

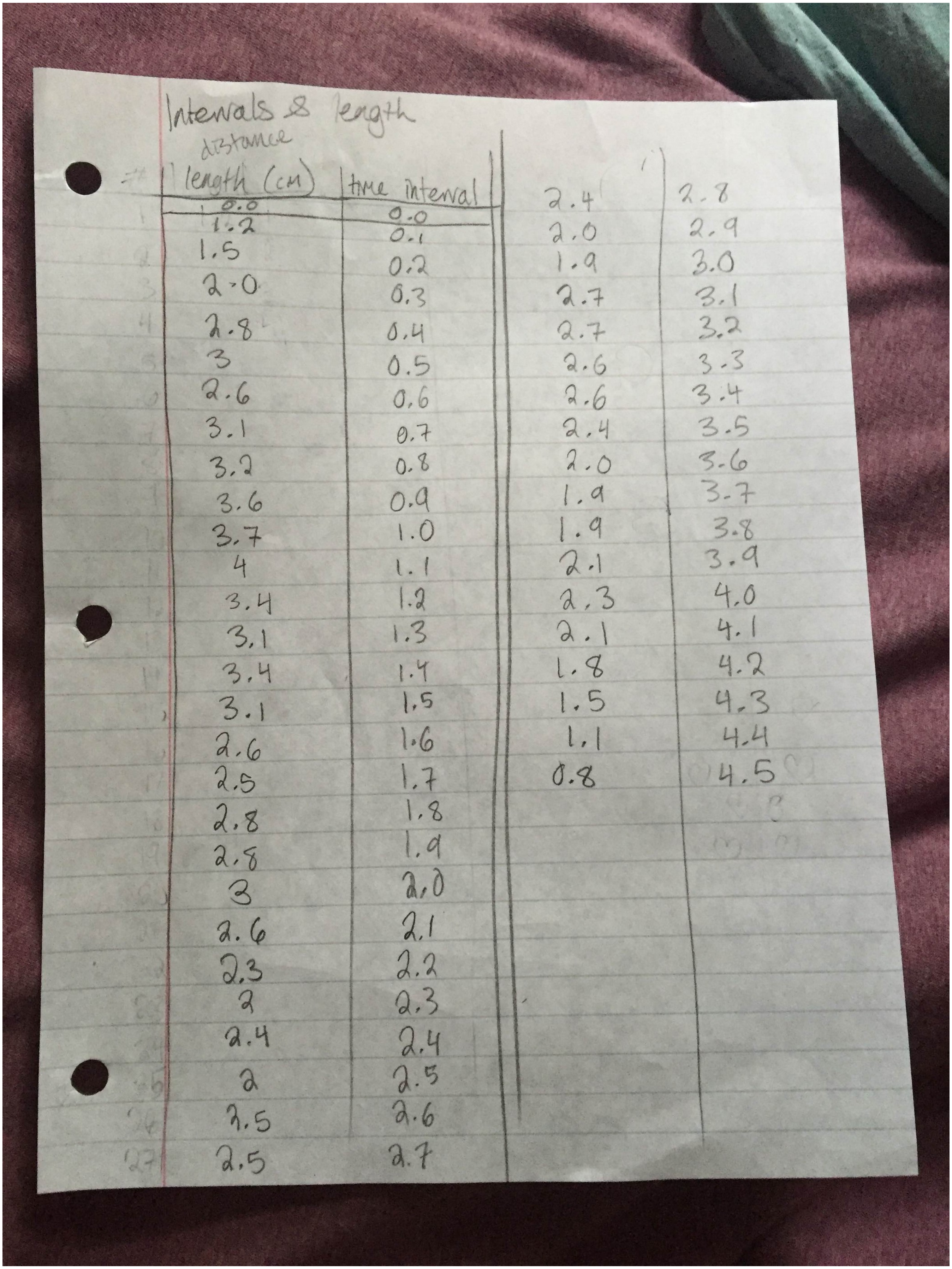
```
import matplotlib.pyplot as plt
import os

try:
      os.system("rm -f dvt_graph.png")
except:
      pass

def integrate(y_vals, h):
    i=1
    total=y_vals[0]+y_vals[-1]
    for y in y_vals[1:-1]:
        if i%2 == 0:
            total+=2*y
        else:
            total+=4*y
        i+=1
    return total*(h/3.0)

data = 'data.txt'
target = open(data, 'r+w')
lines = target.readlines()
x_values = []
y_values = []
velx = []
vely = []
```

```
accely = []
accelx = []
labels = []
values = []
for line in lines:
      print line
      if line[0]=="#":
            labels.append(line)
            pass
      else:
            if line[0]=='=':
                  y_value_begins = lines.index(line) + 1
                  break
            else:
                  num = line.rstrip()
                  print num
                  x_values.append(float(num))
for i in range(y_value_begins,len(lines)-1):
      print line
      if lines[i][0]=='=':
            break
      else:
            num = lines[i].rstrip()
            print num
            y_values.append(float(num))
y_values2 = []
y_values2.append(y_values[0])
for i in range(1, len(y_values)):
      y_values2.append(y_values2[i-1]+y_values[i])
print len(x_values), len(y_values2)
for i in range(len(x_values)-1):
      velx.append((x_values[i]+x_values[i+1])/2)
for i in range(len(y_values)-1):
      vely.append((y_values[i]+y_values[i+1])/2)
for i in range(len(velx)-1):
      accelx.append((velx[i]+velx[i+1])/2)
for i in range(len(vely)-1):
      accely.append((vely[i]+vely[i+1])/2)
x = accelx
y = accely
area = integrate(vely,1)
print area
plt.plot(x,y)
plt.xlabel('Time (sec)')
plt.ylabel('Acceleration (cm/s/s)')
plt.title('Acceleration v Time')
# plt.show()
plt.savefig("accelvtime_graph.png")
```

Raw Data, text file format, in file “data.txt”

```
#TIME(SEC)#
#LENGTH(CM)#
=
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0
4.1
4.2
4.3
4.4
=
0.0
1.2
1.5
2.0
2.8
3
2.6
3.1
3.2
3.6
3.7
4
3.4
3.1
3.4
3.1
2.6
2.5
2.8
2.8
3
2.6
2.3
2
2.4
2
2.5
2.5
2.4
2.0
1.9
2.7
2.7
2.6
2.6
2.4
2.0
1.9
1.9
2.1
2.3
2.1
1.8
1.5
1.1
```

APPENDIX B



Intervals & length

distance length (cm)	time interval		
0.0	0.0	2.4	2.8
1.2	0.1	2.0	2.9
1.5	0.2	1.9	3.0
2.0	0.3	2.7	3.1
2.8	0.4	2.7	3.2
3	0.5	2.6	3.3
2.6	0.6	2.6	3.4
3.1	0.7	2.4	3.5
3.2	0.8	2.0	3.6
3.6	0.9	1.9	3.7
3.7	1.0	1.9	3.8
4	1.1	2.1	3.9
3.4	1.2	2.3	4.0
3.1	1.3	2.1	4.1
3.4	1.4	1.8	4.2
3.1	1.5	1.5	4.3
2.6	1.6	1.1	4.4
2.5	1.7	0.8	4.5
2.8	1.8		
2.8	1.9		
3	2.0		
2.6	2.1		
2.3	2.2		
2	2.3		
2.4	2.4		
2	2.5		
2.5	2.6		
2.5	2.7		