Department of Physics

Worksheet for Lab 4: Impulse Momentum

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Section: A12

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Propagation of Uncertainty

Show your work for the propagation of uncertainty for each value. Paste your working and commented code here.

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In [101]: import numpy as nump #Import Python higher level mathematical library

T1ip = -0.3586 #The LoggerPro Calculated Impulse of Trial 1
T1ipus = (-0.015, -0.217, -0.461, -0.663, -0.902, -1.171, -1.300, -1.410, -1.471, -1.508, -1.508, -1.453, -1.386, -1.2
51, -1.080, -0.859, -0.645, -0.480, -0.223) #The data points collected from the Force v. Time graph over the interval
of impact for Trial 1
T1ipu = nump.std(T1ipus) #Calculation of uncertainty of the Impulse of Trial 1

T2ip = -0.5533 #The LoggerPro Calculated Impulse of Trial 2
T2ipus = (0.022, 0.046, -0.046, -0.101, -.480, -0.872, -1.202, -1.478, -1.772, -2.010, -2.206, -2.292, -2.347, -2.316,
-2.224, -2.047, -1.833, -1.545, -1.288, -0.927, -0.572, -0.242)#The data points collected from the Force v. Time graph
over the interval of impact for Trial 2
T2ipu = nump.std(T2ipus) #Calculation of uncertainty of the Impulse of Trial 2

T3ip = -0.4264 #The LoggerPro Calculated Impulse of Trial 1
T3ipus = (-0.049, -0.850, -1.273, -1.872, -2.411, -5.293, -1.964, -2.864, -1.683, -1.407, -0.997, -0.593, -0.214)#The
data points collected from the Force v. Time graph over the interval of impact for Trial 3
T3ipu = nump.std(T3ipus) #Calculation of uncertainty of the Impulse of Trial 2

V1i = 0.4249 # Initial Velocity of Trial 1
V1iu = 0.1296 # Uncertainty of the Initial Velocity of Trial 1
V1f = -0.2878 # Final Velocity of Trial 1
V1fu = 0.1282 # Uncertainty of the Final Velocity of Trial 1

V2i = 0.6118 # Initial Velocity of Trial 2
V2iu = 0.02124 # Uncertainty of the Initial Velocity of Trial 2
V2f = -0.4688 # Final Velocity of Trial 2
V2fu = 0.01958 # Uncertainty of the Final Velocity of Trial 2

V3i = 0.9322 # Initial Velocity of Trial 3
V3iu = 0.005857 # Uncertainty of the Initial Velocity of Trial 3
V3f = -0.5700 # Final Velocity of Trial 3
V3fu = 0.01551 # Uncertainty of the Final Velocity of Trial 3

m = (498.8/1000) # Conversion of the mass of the cart used in all three trials from grams to kilograms
mu = 0.1 # The Uncertainty of the Measurment of Mass

P1 = (V1f * m) - (V1i * m) # Calculation of the Change in Momentum of Trial 1
P1u1 = nump.sqrt((((V1fu)/(V1f))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vf *m of Trial 1
P1u2 = nump.sqrt((((V1iu)/(V1i))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vi *m of Trial 1
P1uc = nump.hypot(P1u1, P1u2) # Calculation of Uncertainty of the Change in Momentum of Trial 1

P2 = (V2f * m) - (V2i * m) # Calculation of the Change in Momentum of Trial 2
P2u1 = nump.sqrt((((V2fu)/(V2f))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vf *m of Trial 2
P2u2 = nump.sqrt((((V2iu)/(V2i))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vi *m of Trial 2
P2uc = nump.hypot(P2u1, P2u2) # Calculation of Uncertainty of the Change in Momentum of Trial 2

P3 = (V3f * m) - (V3i * m) # Calculation of the Change in Momentum of Trial 3
P3u1 = nump.sqrt((((V3fu)/(V3f))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vf *m of Trial 3
P3u2 = nump.sqrt((((V3iu)/(V3i))**2)+((((mu)/(m))**2))) # Calculation of Uncertainty of Vi *m of Trial 3
P3uc = nump.hypot(P3u1, P3u2) # Calculation of Uncertainty of the Change in Momentum of Trial 3

print('---------------------------Trial 1------------------------------------') # Visual Devider of Data
print('mass', m, 'kg', '+/-', mu, 'kg') # Prints the mass the cart used in the trial in kilograms as well as the uncer
tainty
print('Impulse', round(T1ip, 2), 'N/s', '+/-', round(T1ipu, 1), 'N/s') # Prints the Impulse of the trial in Newtons pe
r Second as well as the Uncertainty
print('Change in Momentum', round(P1, 2), 'N/s', round(P1uc, 1), 'N/s') # Prints the Change in Momentum of the trial i
n Newtons per Second as well as the Uncertainty
print('---------------------------Trial 2------------------------------------')
print('mass', m, 'kg', '+/-', mu, 'kg') # Prints the mass the cart used in the trial in kilograms as well as the uncer
tainty
print('Impulse', round(T2ip, 2), 'N/s', '+/-', round(T2ipu, 1), 'N/s') # Prints the Impulse of the trial in Newtons pe
r Second as well as the Uncertainty
print('Change in Momentum', round(P2, 2), 'N/s', round(P2uc, 1), 'N/s') # Prints the Change in Momentum of the trial i
n Newtons per Second as well as the Uncertainty
print('---------------------------Trial 3------------------------------------')
print('mass', m, 'kg', '+/-', mu, 'kg') # Prints the mass the cart used in the trial in kilograms as well as the uncer
tainty
print('Impulse', round(T3ip, 2), 'N/s', '+/-', round(T3ipu, 1), 'N/s') # Prints the Impulse of the trial in Newtons pe
r Second as well as the Uncertainty
print('Change in Momentum', round(P3, 2), 'N/s', round(P3uc, 1), 'N/s') # Prints the Change in Momentum of the trial i
n Newtons per Second as well as the Uncertainty

---------------------------Trial 1------------------------------------
mass 0.4988 kg +/- 0.1 kg
Impulse -0.36 N/s +/- 0.5 N/s
Change in Momentum -0.36 N/s 0.6 N/s
---------------------------Trial 2------------------------------------
mass 0.4988 kg +/- 0.1 kg
Impulse -0.55 N/s +/- 0.8 N/s
Change in Momentum -0.54 N/s 0.3 N/s
---------------------------Trial 3------------------------------------
mass 0.4988 kg +/- 0.1 kg
Impulse -0.43 N/s +/- 1.3 N/s
Change in Momentum -0.75 N/s 0.3 N/s
```

Figure 1: Python code to calculate the change in momentum of all the trials of the lab as well as the uncertainty of all values.

Based on the data that you took today, write and answer the questions in the following sections. Remember that even though you will have the same data as your partner, the writing in these sections should be done individually.

Experimental Method

Answer here: First, zero the Vernier Force sensor and insure that it is in the 10N setting position, this allows for more accurate data. Then using three different speeds, collect the data of the cart moving towards and then rebounding off of the force sensor. Then using logger pro analyze the graphs created. Within the Force graph select the region at which the cart applied force and using the integral function measure the area of the subsequent region. Then on your velocity graphs using the statistics function find the point before and after impact of the cart. Using this data you can then calculate the uncertainty of your data. Next using a beam scale measure the mass of your cart with uncertainty.

Results

Answer here: Upon analyzing collecting the data from all three trials we were able to calculate the change in momentum as well as the uncertainty of the impulse data. In trial one the LoggerPro software output -0.36 ± 0.5 N/s as the Impulse and we were able to calculate the change in momentum of trial 1 as -0.36 ± 0.6 N/s. In trial two the Impulse was calculated to be -0.55 ± 0.8 and the change in momentum was calculated to be -0.54 ± 0.3 N/s. In the third and final trial the impulse was calculated to be -0.43 ± 1.3 N/s and the change in momentum was calculated to be -0.75 ± 0.3 N/s. We also calculated the mass of the cart to be 4.98 x 10^-1 ± 0.1 kg.

Trial Number	Type of Motion	Impulse	Change in Momentum
1	Slow Speed	-0.36 ± 0.5 N/s	-0.36 ± 0.6 N/s
2	Medium Speed	-0.55 ± 0.8 N/s	-0.54 ± 0.3 N/s
3	Fast Speed	-0.43 ± 1.3 N/s	-0.75 ± 0.3 N/s

Figure 2: Table comprising the collected impulse and calculated change in momentum data from the three trials of the momentum lab.

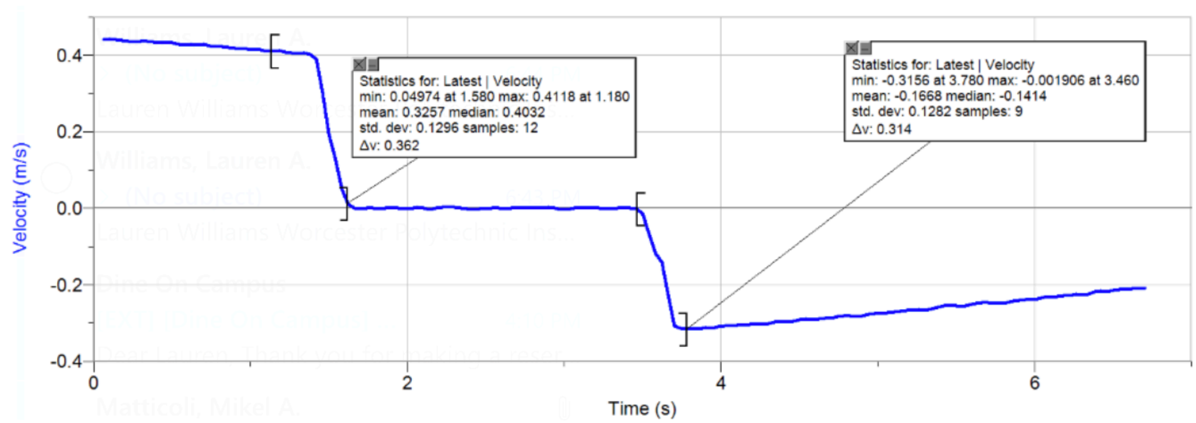

Figure 3: Velocity v. Time graph of trial one (slow speed) with the instances before and after the carts impact with the force sensor highlighted.

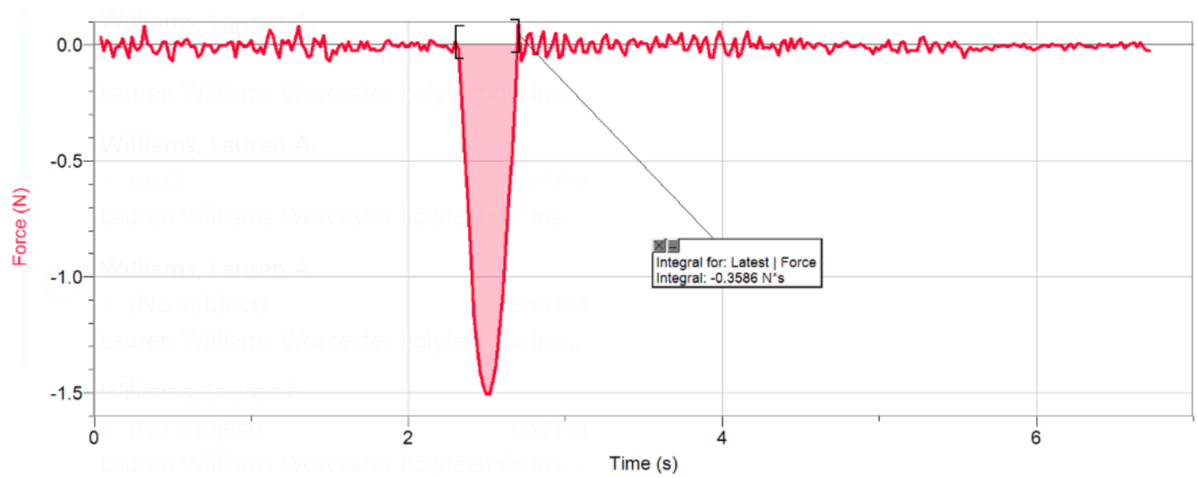

Figure 4: Force v. Time graph of trial one (slow speed) with the instances of impact with the force sensor highlighted and calculated to show impact.

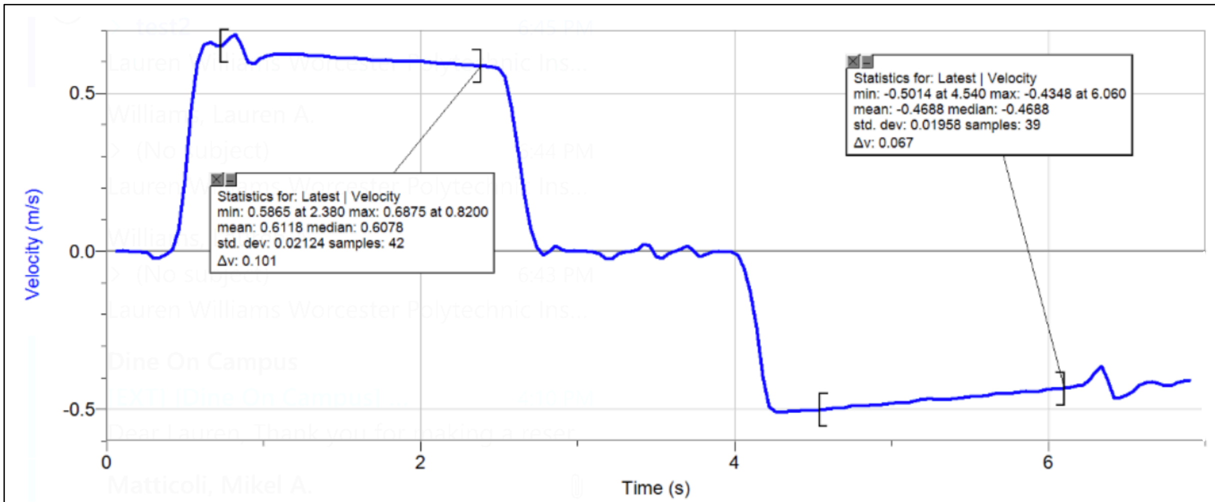

Figure 5: Velocity v. Time graph of trial two (medium speed) with the instances before and after the carts impact with the force sensor highlighted.

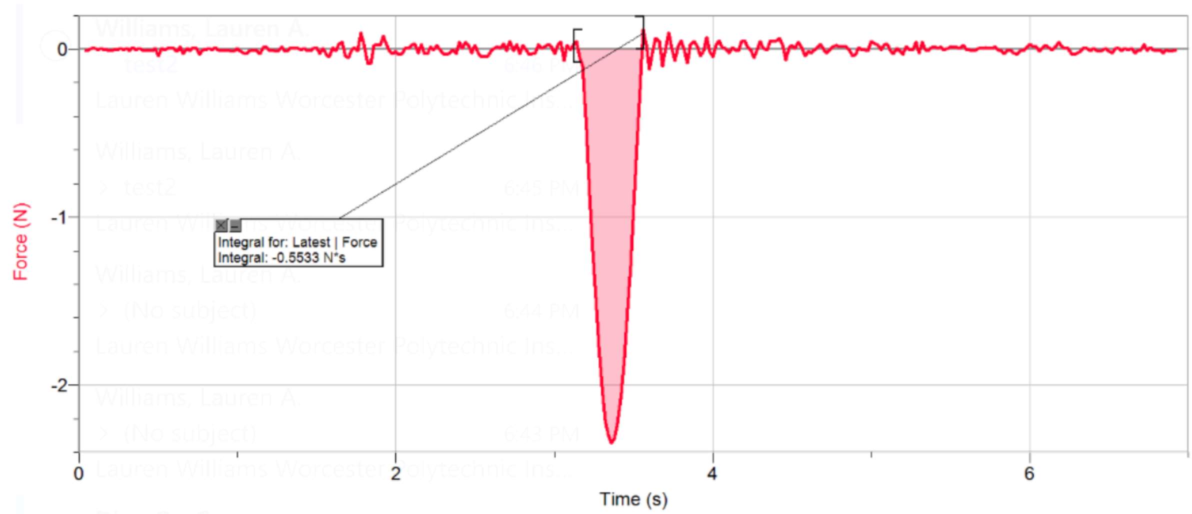

Figure 6: Force v. Time graph of trial two (medium speed) with the instances of impact with the force sensor highlighted and calculated to show impact.

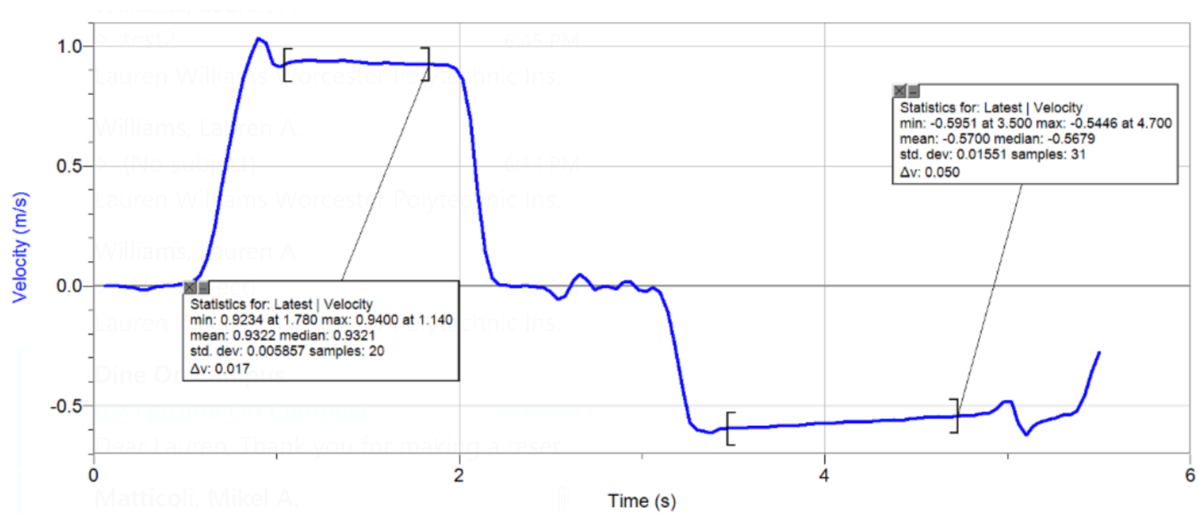

Figure 7: Velocity v. Time graph of trial three (fast speed) with the instances before and after the carts impact with the force sensor highlighted.

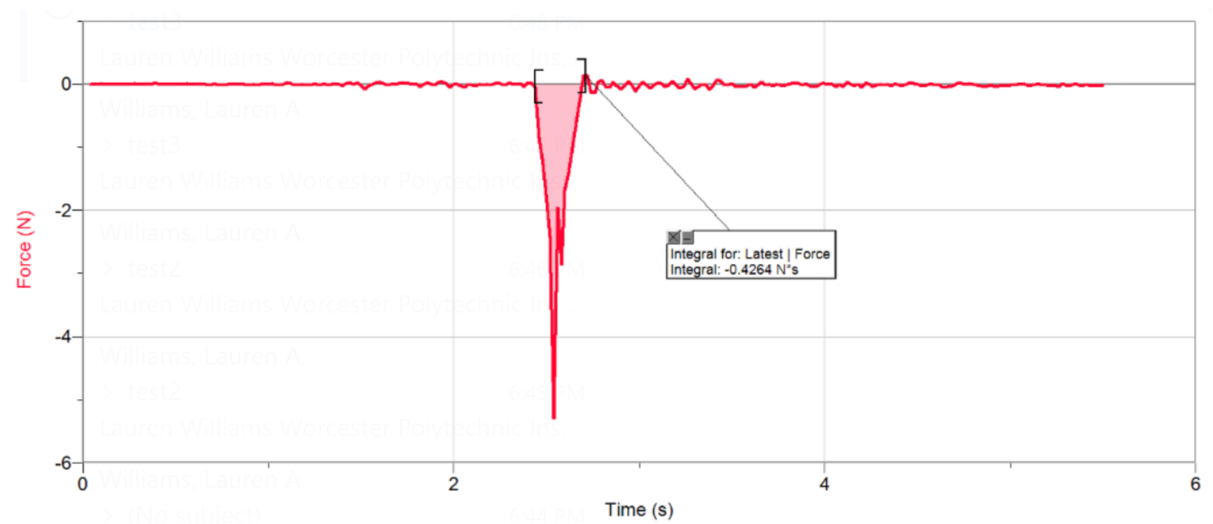

Figure 8: Force v. Time graph of trial three (fast speed) with the instances of impact with the force sensor highlighted and calculated to show impact.

Conclusion

Answer here:

- Based upon the collected data from all three of the trials it can be said that the change in momentum is not always equal to the impulse. In trials one and two the impulse, -0.36 ± 0.5 N/s and -0.55 ± 0.8 N/s, respectively, match that of the change in momentum, -0.36 ± 0.6 N/s and -0.54 ± 0.3 N/s. And in trial three, the fastest trial, the impulse and change in momentum data do not match, Impulse: -0.43 ± 1.3 N/s Change in momentum: -0.75 ± 0.3 N/s.
- My conclusion does not hold true to my data. However, in applying Newton's Second Law, it should hold true that the change in momentum is equal to the impulse. As for the changing speeds of the trials, as the trials speed up the change in momentum and impulse should increase similarly.
- To collect more accurate data from this experiment, one might decide on a consistent starting point of the cart on the track and a less sensitive force sensor. This will allow for more precise readings and data analysis that align with the impulse-momentum change theorem.

Graph and Data Checklist You should have six graphs with the appropriate title labels and a complete caption, answered all of the questions highlighted by the gray boxes and written a experimental methods, results, and conclusions section.

Worm extra credit should be included below if completed.

1. The data collecting by analyzing the motion of both of the worms in Tracker is quantitative where as the visual data of counting the number of body bends is based off of qualitative data. Thus it is easier to analyze and graph the data produced by the Tracker program. Although, the body bend data is useful it does not offer the same units of measurement as that of the tracker software.
2. Tracking the portion of the worms behind the pharynx proves to be a challenge in and of it self. Using the tracker software it can be difficult to determine where exactly it is at times and the repositioning of the video skews the data. The visual counting of the body bends is not affected in the same way by these camera

movements. So in tests like these worms it may be more affective to visually count the amount of body bends and calculate any needed data from there rather than using the Tracker data.

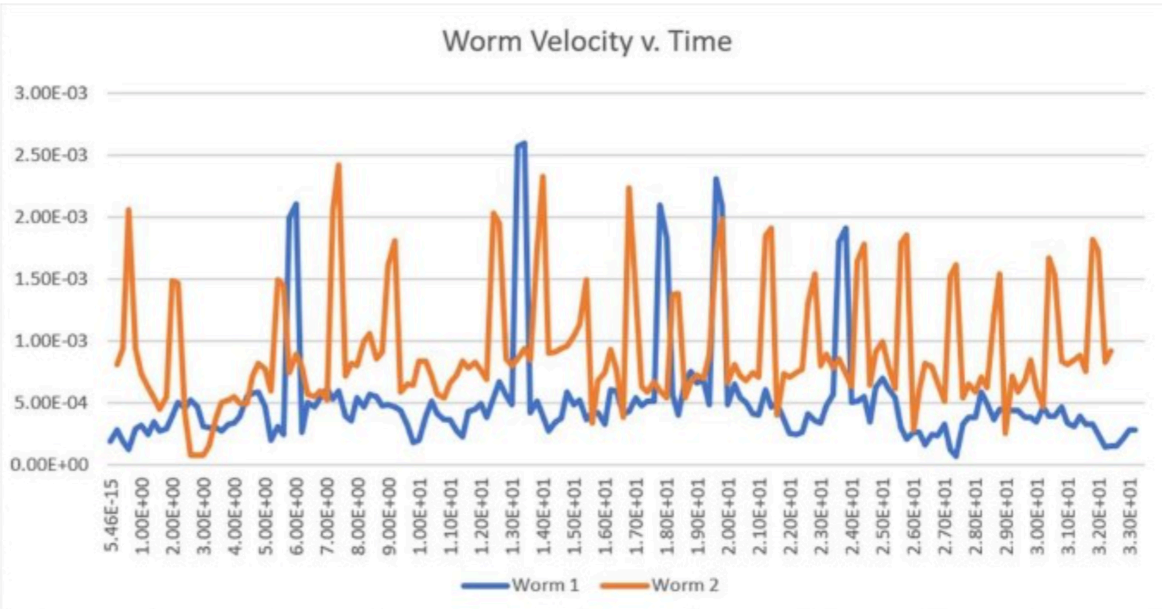

Figure 9:Velocity v. Time graph of both worms 1 & 2 over a 30 second interval.

Worm Number	Number of Body Bends
1	166
2	162

Figure 10: Table showing the number of body bends completed by both of the worms over a 30 second time interval.