Week 6 & 7 - Coasting vs Power braking

Situation:

During the week 6, group N conducted one of the advanced research, coasting and power braking. Coasting refers to switching off the motors so that the AEV could gradually slow down the speed until it stops completely. Power braking reverses the direction of the motors, so an opposing force is applied on AEV to help it stop. The goal of this research is to reduce energy consumption and braking distance.

Result & Analysis

The tests were performed for each braking method until the results became consistent. The testing codes are attached in Appendix G (*code 1,2*). The data are collected and calculated from Power vs Distance and Power vs Time plots (*figures 4-11*) using AEV data analysis tool. According to the data, the average braking distance for coasting and power braking were 133.235 in and 123.338 in and the standard deviation were 3.16 in and 2.71 in respectively. Coasting traveled an extra 10 inches on average. The average energy consumed for coasting and power braking were 26.934 J and 39.125 J respectively. Coasting consumed about 33% less energy than power braking. Also, based on the t-test, expected percentages of trials that fall within a 3-inch margin of the average for both coasting and power braking were 89.89% and 93.12% respectively. Based on this, the group concluded that power braking increases braking accuracy even though it will consume more energy. *Refer to Appendix F & G for details.*

The group also determined if weight affect coasting or not. Two different weights of 263 grams and 290 grams were chosen to do the comparison. Because the testing code remained the same, the energy consumed almost kept the same even though the weights were different. The average coasting distances for 263 grams and 290 grams AEV were 133.235 in and 127.573 in respectively. It is clear the heavier weight reduces the braking distance for coasting. Also, the expected percentages of trials that fall within a 3-inch margin of the average for both 263 grams AEV and 290 grams AEV were 89.89% and 74.17% respectively. The group concluded that increasing weight decreases the coasting distance accuracy. *Refer to Appendix F & G for details.*

The group also concluded the errors made during the research. First, the battery was not changed for power braking tests due to the time limitation. This might affect the efficiency of increasing AEV's speed. In the future test, the group will avoid it happening again. Second, Small power impulsion happened during braking process of coasting test 1-2. The energy consumed caused by this small power impulsion was almost 0. Even though the real reason has not been clarified yet, the team believes that this is due to the sensor's error. *Refer to Appendix F & G for details.*

Takeaways:

- Coasting Consumes about 33% *less energy* than Power Braking
- Power Braking *increases* braking accuracy
- Increasing weight was found to decrease the coasting distance accuracy.

Week 7 & 8– Solidworks Simulation

Situation:

The overall goal of Solidworks Simulation was to reduce assembly times when designing AEV models, address weight problems, and conduct a digital motion study for the group's AEV designs. To fulfill these goals, the team conducted mass study and motion study in Solidworks Simulations. Pravesh and Jingming were assigned to do these studies and combine their data.

Results & Analysis of Mass Study and Motion Study

The original AEV design weighed 1.21 pounds, had a volume of 10.32 cubic inches, and had a surface area of 226.81 square inches. The new design's mass properties after conducting the mass study are given in *Appendix C*. The AEV lost 0.89 pounds after the mass study. The volume and surface area also decreased. Volume went down by 2.6 cubic inches and the surface area decreased by 28.61 square inches. Since the materials available on Solidworks are not exact materials present in the AEV, the weight difference is about 9% when comparing Solidworks design's mass to actual AEV's mass.

After the mass study, the team conducted motion study in Solidworks. This study was much more challenging since the user interface for motion study is not well optimized. Also, many hours of practice are required to be proficient with this study. The animation conducted by Solidworks allocates an enormous amount of computer's graphics memory which was hard to run in many of the computers the group performed the study on. However, the video produced was smooth after it was uploaded so the latency was only temporary. *The findings of the motion study are provided in Appendix B.*

Since the motion study's data does not account for friction or air resistance, the data is not helpful. The animation of the design is a more effective representation of the AEV than the data produced by it. *Refer to Appendix B for the AEV assembly.* One of the key takeaways for AEV assembly was to use the placement of the Arduino as a constraint for AEV designs to produce the least amount of interferences and reduce the combinations of designs. Without using Arduino's placement as a constraint, there were 313 interferences and 212 combinations of designs. However, once the Arduino was placed, the interferences went down to 20, which were part of the Arduino. The number of design combinations also decreased to 6 from the previous 212. *Refer to Appendix A for the AEV design's exploded view.*

Takeaways:

- The group learned mass study was the most useful simulation
- Exceptional Solidworks skills required for motion study
- Assembling AEV using Solidworks provides hundreds of design combinations

Week 9 – Optimizing Coasting vs. Power Braking and Performance Tests

Situation

Accuracy for Combined Coasting and Power Braking (A for C+PB) will be completed in week 9. The CDR will begin the draft stage in week 9 and continue through week 10.

Accuracy for Combined Coasting and Power Braking (A for C+PB) & CDR

(A for C+PB) will allow for the most accurate braking mechanism to be identified for performance test 1. This identified braking mechanism's code will then be manipulated for the performance test track.

The team will use the flat track, same starting position, and use the same acceleration code as the "Power vs. Coasting" tests. A code will be created that will stop the AEV 5 inches short of the average coasting distance found from the Power vs. Coasting test (using same AEV design as the first aR&D). The 5 inches was chosen so coasting to a brake will not be an uncontrolled factor (89% of coasting distances are expected to be between 3 inches of the average coasting distance, so the likelihood of a coasted stop is negligible). The code will trigger power braking based on absolute position. Power braking will run until next absolute position is met. The exact power output of the motors for the power braking will be determined before testing by trial and error. When the correct code is identified, the test will be repeated 5 times (to match trial numbers of the power vs coasting tests). The average, standard deviation, and percent within 3-inch margin will be found and compared to Power braking and Coasting.

CDR Draft

Due to the approaching deadline of the CDR, teammates not directly involved in testing for (A for C+PB) will begin drafting the CDR. Since the CDR is similar but lengthier than a progress report and only two members are needed to complete testing, the group will be more productive by spreading the tasks with CDR and other Coasting and Power Braking research. Completing the CDR early will help the team focus on upcoming performance tests.

CDR will contain a detailed report of our advanced research and the completion of Coasting and Power Braking research will be a major part of it. Pravesh and Jingming will organize the data from Coasting vs. Power braking, the preliminary labs, and Solidworks simulation and they will continue to work on it during week 10. *Refer to Appendix E for future schedule.*

Goals:

-Determine correct braking code for (A for C+PB)
-Complete 5 tests of (A for C+PB), determine percent within 3-inch margin and determine the most accurate braking mechanism
-Beginning draft of the CDR should be completed and timeline determined

Week 10 – Optimizing Coasting vs. Power Braking and Performance Tests

Situation:

'Optimal "Speed/ Motor Power Percentage" to Optimize Braking Accuracy' (OS to OBA) will be tested immediately after "Accuracy for Combined Coasting and Power Braking". 'Optimal "Speed/ Motor Power Percentage" to Optimize Braking Accuracy' (OS to OBA) will be tested to determine the most accurate code for performance test 1. Since this test will be conducted on the performance test track, the determined, most accurate code will not need to be adjusted for the performance test (additional code will need to be added for the AEV to accelerate a second time through the gate). So, this test will double as Performance Test 1 pretesting. (OS to OBA) will be tested immediately after testing "Accuracy for Combined Coasting and Power Braking", because the best braking mechanism must be determined before determining the optimal speed to improve braking accuracy. Also, the approaching deadline for Performance Test 1, forces (OS to OBA) to be completed by Wednesday, March 21. *Refer to the schedule below or in Appendix E.*

From determined braking mechanism, optimal speed will be tested to maximize the accuracy of braking position on performance track (initially assuming the slower the speed, the more accurate). The initial, final, and braking distance will be held constant. The time for acceleration and the "goFor" time after accelerating to top speed will also be held constant. The independent variable is the percent power of the propeller motors (both motors will run the same code). The dependent variable is the power needed to stop at the desired location. Because braking power cannot be changed due to slight differences in acceleration between tests (of the same code), an estimated braking power will be determined (through pretesting trial and error). Since the braking power will be held constant (relative to the motors' top percent power), the independent variable becomes the accuracy of the braking mechanism (or the standard deviation from the average stopping distance, which should be equal to the standard deviation from the desired "final" distance. These tests will be conducted on the performance test track.

Refer to Appendix D for Team Meeting Notes in Week 9 and 10.

Future Schedule:

Task	Subtasks	Start Date	Due Date	Time Needed	Teammates	Materials
Coasting vs. Power Braking Accuracy	Perform standard deviation of data	3/9/2018	3/9/2018	1 hour	All	AEV, Battery, Rails
CDR Draft	Collect all data from previous labs	3/19/2018	3/23/2018	4 hours	Pravesh, Jingming	Computer, Data
Performance Tests	Write Arduino code for the scenario	3/19/2018	3/21/2018	1 hour	Joey, Feifan, Pravesh	AEV, Battery, Rails
Optimizing Coasting vs. Power Braking	Compare data: Coasting & Power Braking	3/19/2018	3/21/2018	3 hours	All	AEV, Battery, Rails

Goals:

-Determine correct power for each braking mechanism (relative to motor power output)
-Determine the best speed for most accuracy braking distance
-Continue and finish the CDR

Appendix A
AEV Exploded View

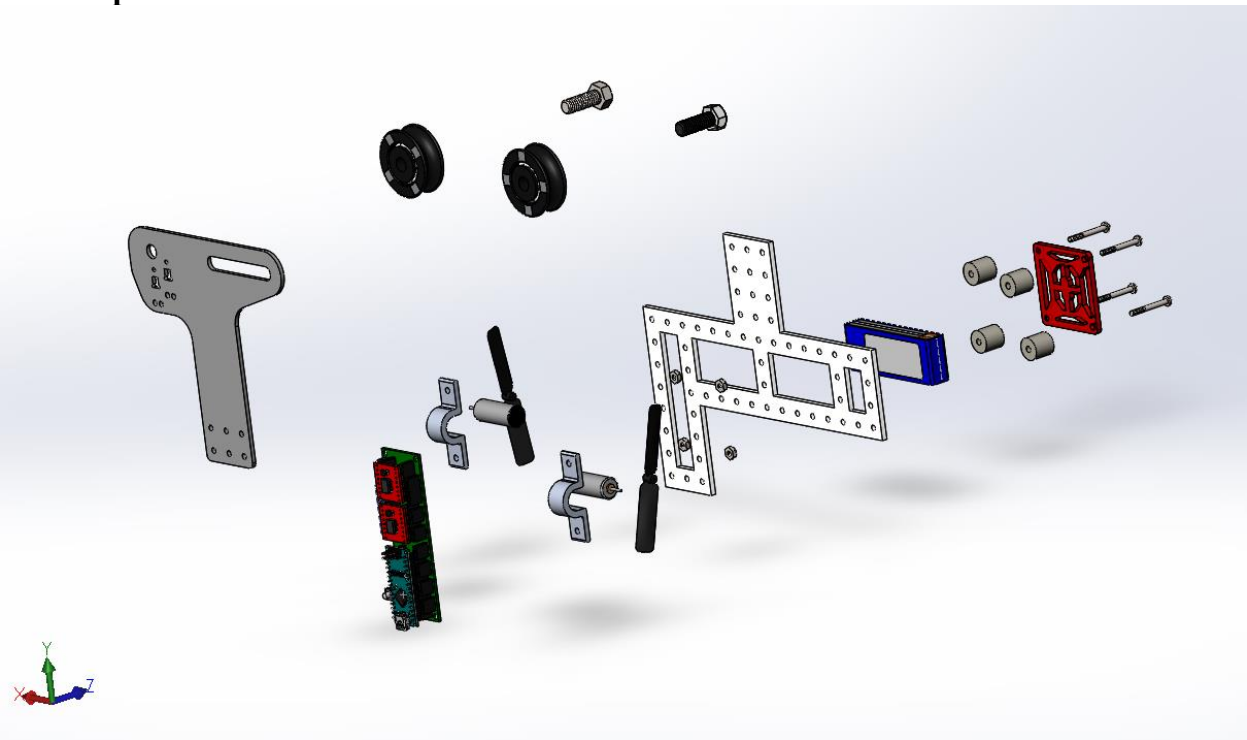

Figure 1. AEV exploded view after implementing the design combinations and conducting mass and motion studies.

Appendix B

Additional data available on the website below under "Motion Study"

https://u.osu.edu/eng1182groupn/solidworks-simulation/

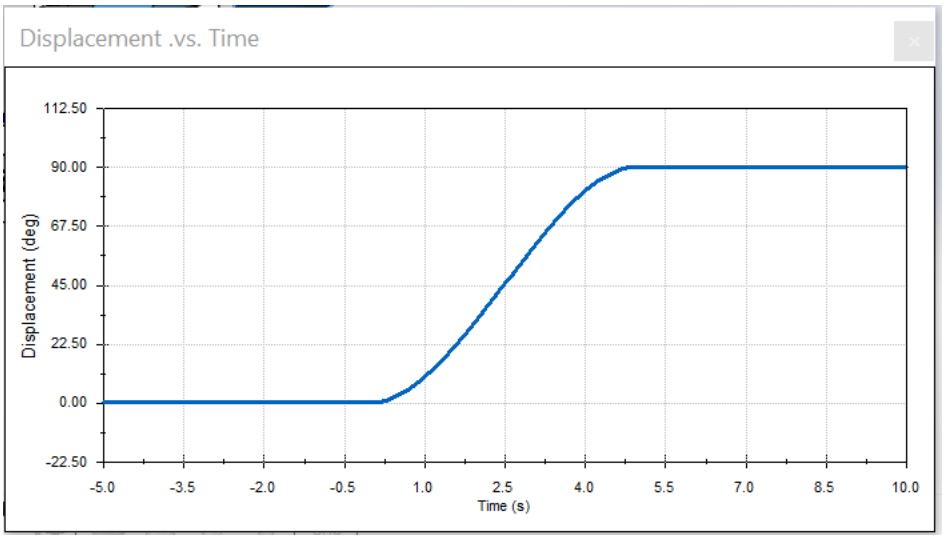

Figure 2. Motion study data for the displacement of the AEV as time increases.

Appendix C
Mass Study Data

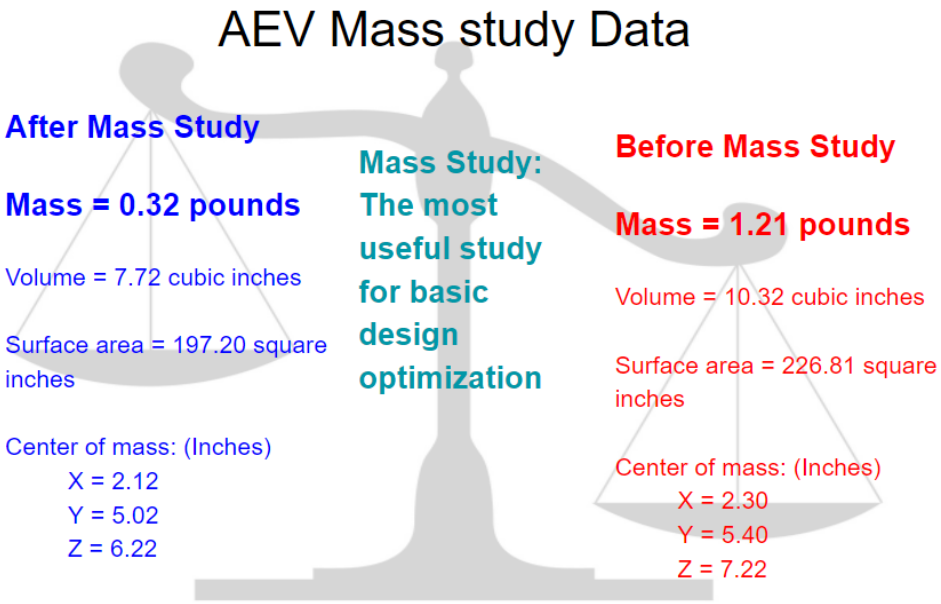

Figure 3. AEV mass study data containing mass, volume, surface area, and center of mass before mass study and after mass study.

Appendix D

Team Meeting Notes

Refer to the link below to check out the team meeting notes under “Meeting” tab.
https://u.osu.edu/eng1182groupn/meeting/

Week 5

February

Meetings #10,11

Date: February 8, 2018
Time: 5:30 PM – 9:30 PM (face to face)
Place: Hitchcock 324, 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Progress Report and AEV Design

Date: February 9, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Coasting vs. Power Braking

Objective:

During the week 5 meetings, the group’s goal is to finish the Progress report 1 and start Advanced Research and Design.

To do/Action items:

The group attended the 5:30 lab on Thursday to make up lab 2 and lab 4. They discussed details about the AEV design and tested their code during this time. After the make-up lab, the group met in Engineering lab 324 for 4 hours to discuss the progress report and each person’s responsibility.

The group researched Coasting vs. Power braking. The group tested two separate codes to determine whether Coasting or Power braking was more energy efficient. The group discussed how wedge-like wings could potentially harm the AEV stopper since it is like catching a knife. The team encountered several problems when uploading the code to the AEV. The AEV was not recognizing the reverse command. The coder, Feifan learned that a brake command did not have a time specified which caused the motor to be powerless and the reverse command was not working. Joey noticed the error and told Feifan to fix the error which ultimately fixed the problem. The team was confident that 50% power would not be too much, but the result showed that the AEV reversed too much.

Initial ideas:
Provide specific roles for each member for Coasting vs. Power Braking. (J.G., F.L. P.K., J.C.)
Each member received a part for Coasting vs. Power Braking.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Finish each assigned role before the submission deadline for upcoming deliverables. (FL, JG, JC, PK)

-Prepare for additional Advanced R&D topics. (FL, JG, JC, PK)

-Plan ahead for the upcoming presentations (PK, FL, JG, JC)

Upcoming tasks:
Prepare for another Advanced R&D topics. (J.G.)

Start the Progress Report 2 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 6

February

Meetings #12,13,14

Date: February 12, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Grant Proposal Roles

Date: February 15, 2018
Time: 5:30 PM – 9:30 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Committee Meeting 1 and Grant Proposal

Date: February 16, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Grant Proposal Presentation and Committee Meeting 1

Objective:
During the week 6 meetings, the group's goal is to finish the grant proposal presentation and the committee meeting 1.

To do/Action items:
In the tenth meeting, the group talked about various base designs for the grant proposal. Joey asked the team what we would decide on the number of blades on the propeller. The team also assigned each member a specific part of the grant proposal presentation.

In the eleventh meeting, the group met in the Engineering lab to discuss and finish the committee meeting 1. Pravesh wrote down the team meeting notes and organized the presentation for the grant presentation. Feifan modeled the base as the part being pitched. Pravesh discovered that the current design had a flaw because it lacked a place to attach a magnet. So, the group decided to modify the design to have an attachment at the back of the AEV to hold the magnet.

In the twelfth meeting, the group finalized the grant proposal an hour before the lab in HI 324. Joey presented the grant proposal. The group discussed each part in the committee meeting. Joey

and Jingming were responsible for the research and development aspect and Feifan was responsible for public relations. Pravesh submitted the HR portion of the committee meeting online.

Initial ideas:
Provide specific roles for each member for Grant Proposal and Committee Meeting 1. (J.G., F.L. P.K., J.C.) Each member received a part of Committee Meeting 1.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Finish each assigned role before the submission deadline for Committee Meeting 1. (FL, JG, JC, PK)

-Prepare for Advanced R&D topics. (FL, JG, JC, PK)

-Rehearse the presentation for the Grant Proposal (PK, FL, JG, JC)

Upcoming tasks:
Prepare for Advanced R&D topics. (J.G.)

Start the Progress Report 1 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 7

February

Meetings #15,16

Date: February 21, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Jingming Chen(J.C.), Pravesh Khanal (P.K.)
Topic: Advanced R&D topics

Date: February 23, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Coasting vs. Power Braking and Solidworks Simulation

Objective:
During the week 6 meetings, the group's goal is to finish Coasting vs. Power braking research as well as start a new research for Wind tunnel. If the Wind tunnel is not working, Solidworks simulation is the next option.

To do/Action items:
In the 15th meeting, the group discussed how Solidworks assembly could be used to model AEV designs. This discussion led the group to talk about Solidworks Simulation. The group considered researching Solidworks simulation since it could provide a useful insight into designing the AEV and analyzing its properties.
In the 16th meeting, the group finished Coasting vs. Power Braking and discussed the results with the team. The wind tunnel lab was canceled, so Pravesh and Jingming decided to start Solidworks Simulation for the group's second research.

Initial ideas:
Research Solidworks simulations. (J.G., F.L. P.K., J.C.) Pravesh and Jingming received a part for Solidworks simulations.

Review the Advanced R&D topics for the lab. (J.G., P.K.)

Update the website for each part in Committee Meeting 1. (P.K., J.G., F.L., J.C.)

Decisions:
-Pravesh and Jingming will finish Solidworks simulations and upload the data for the upcoming presentation. (FL, JG, JC, PK)

-Prepare for Advanced R&D topics. (FL, JG, JC, PK)

-Rehearse the presentation for the oral presentation. (PK, FL, JG, JC)

Upcoming tasks:
Prepare for oral presentation. (J.G.)

Start the Progress Report 2 deliverables. (P.K.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 8

February

Meetings #17,18

Date: February 26, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Website Update 3 and Progress Report 1 Rewrite

Date: March 02, 2018
Time: 2:55 PM – 5:15 PM (face to face)
Place: Hitchcock 224
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Website Update 3

Objective:
During the week 8 meetings, the group's goal was to update the Website with the new Advanced Research & Design data as well as finish rewriting Progress Report 1.

To do/Action items:
In the 17th meeting, the team discussed the aspects of Progress Report 1 that needed improvement. Since the forward-looking portion of the Progress Report 1 was non-existent, the group asked TAs questions on what this portion is supposed to contain.
In the 18th meeting, the group met in HI computer lab 224 to discuss what the Website Update 3 was missing. Since the Website Update required updated team meeting notes, the group had to coordinate with other members to discuss whether the meeting notes were up to date.

Initial ideas:
Upload the Solidworks Simulations data on the website. (J.G., F.L. P.K.) Pravesh decided to upload the data in the website.

Upload the Coasting vs. Power Braking data into the website. (J.G., P.K.) Joey and Feifan will upload these materials.

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Decisions:
-Pravesh and Jingming will finish Solidworks simulations studies and upload the data on the Website. (JC, PK)

-Joey and Feifan will upload the data from Coasting vs Power Braking on the website. (FL, JG)

-Update the Team meeting notes. (PK)

Upcoming tasks:
Progress report 2 forward-looking portions. (J.G.)

Start the Progress Report 2 deliverables. (PK, JG, FL, JC)

Progress report 2 Solidworks Simulations potion. (PK, JC)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 9

March

Meetings #19,20

Date: March 07, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: AEV Base Printing and Progress Report 2

Date: March 08, 2018
Time: 4:45 PM – 5:20 PM (face to face)
Place: Hitchcock 324
Members Present: Feifan Lin(F.L.), Joey Gill(J.G.), Pravesh Khanal (P.K.)
Topic: Progress Report 2 and Website

Objective:
During the week 9 meetings, the group's goal was to update the Website, send AEV base to be printed out, and finish Progress Report 2.

To do/Action items:
In the 19th meeting, the group still needed to send the AEV base design to one of the TAs to be 3D printed. Right before submitting the design, the group had to alter the design of the AEV on the front part where the motor is located because the magnet placement interfered with the location of the motor.
In the 20th meeting, the group needed to meet and finalize progress report 2 as well as update the meeting notes on the website. Since this is the last meeting note that is being submitted on the Progress Report 2, the group had to double check the meeting notes for any errors.

Initial ideas:
Format everyone's part in Progress Report. (J.G., F.L. P.K., J.C.) Pravesh decided to format the Progress Report.

Implement the Coasting vs. Power Braking data into the report. (J.G., F.L.) Joey and Feifan have completed these materials.

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Decisions:
-Pravesh will format the Progress Report and number the Appendix accordingly (JC, PK)

-Joey and Feifan will write the Coasting vs Power Braking report. (FL, JG)

-Update the Team meeting notes. (PK)

-Joey will write the future portion of the Progress Report. (JG)

Upcoming tasks:
Progress report 2 submissions. (P.K.)

Prepare for the Performance Tests. (P.K., J.G., F.L., J.C.)

Write code for Performance Tests. (F.L.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Week 10

March

Meetings #21, 22, 23, 24

Future Schedule

Date: March 09, 2018
Time: 3:55 PM – 5:05 PM (face to face)
Place: Hitchcock 224
Members Expected: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: Accuracy for combined Coasting and Power Braking

Date: March 19, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Expected: Feifan Lin(F.L.), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (JC)
Topic: Optimize Speed for Optimal Power Braking / Performance Test 1

Date: March 21, 2018
Time: 4:10 PM – 5:05 PM (face to face)
Place: Hitchcock 324
Members Expected: Feifan Lin(F.L.), Joey Gill(J.G), Pravesh Khanal (P.K), Jingming Chen (JC)
Topic: CDR Draft / Optimize Speed for Optimal Power Braking

Date: March 23, 2018
Time: 3:55 PM – 5:05 PM (face to face)
Place: Hitchcock 224
Members Expected: Feifan Lin (F.L), Joey Gill(J.G), Pravesh Khanal(P.K), Jingming Chen (J.C)
Topic: CDR Draft and Performance Tests

Objective:
During the week 10 meetings, the group will complete Optimal Speed to Optimize Braking accuracy, performance Test 1, and CDR draft.

To do/Action items:
During the 21st meeting, the group plans to test the accuracy for combined Coasting vs. Power Braking.
In the 22nd meeting, the team will conduct experiments to Optimize Speed for Optimal Power Braking.
In the 23rd meeting, the group will discuss CDR draft and complete the Optimize Speed for Optimal Power Braking.
During the 24th meeting, the team will have completed the CDR draft and begin Performance Test 2.

Initial ideas:
Experiment and test Accuracy for combined Coasting and Power Braking. (J.G., F.L.) Joey and Feifan will complete this task.

Optimize Speed for Optimal Power Braking. (J.G., F.L., P.K.)

Update the website for the team meeting notes. (P.K.) Pravesh will update the team meeting notes.

Update the website with the new data from the labs.

Decisions:
-Experiment and test Accuracy for combined Coasting and Power Braking. (FL, JG)
-Optimize Speed for Optimal Power Braking. (FL, JG, PK)
-Update the Team meeting notes. (PK)
-CDR draft should be completed during the week after Spring break (JC, PK)

Upcoming tasks:
Performance Test 1.

CDR Draft. (P.K., J.G., F.L., J.C.)

Write code for Performance Tests. (F.L.)

Update team meeting notes. (P.K.)

Update the website. (F.L., P.K.)

Roles subject to change.

Appendix E
Future Schedule

Task	Subtasks	Start Date	Due Date	Time Needed	Teammates	Materials
Coasting vs. Power Braking Accuracy	Perform standard deviation of data	3/9/2018	3/9/2018	1 hour	All	AEV,Battery, Rails
CDR Draft	Collect all data from previous labs	3/19/2018	3/23/2018	4 hours	Pravesh, Jingming	Computer, Data
Performance Tests	Write Arduino code for the scenario	3/19/2018	3/21/2018	1 hour	Joey, Feifan, Pravesh	AEV,Battery, Rails
Optimizing Coasting vs. Power Braking	Compare data: Coasting & Power Braking	3/19/2018	3/21/2018	3 hours	All	AEV,Battery, Rails

Appendix F
Coasting vs Power Braking Data

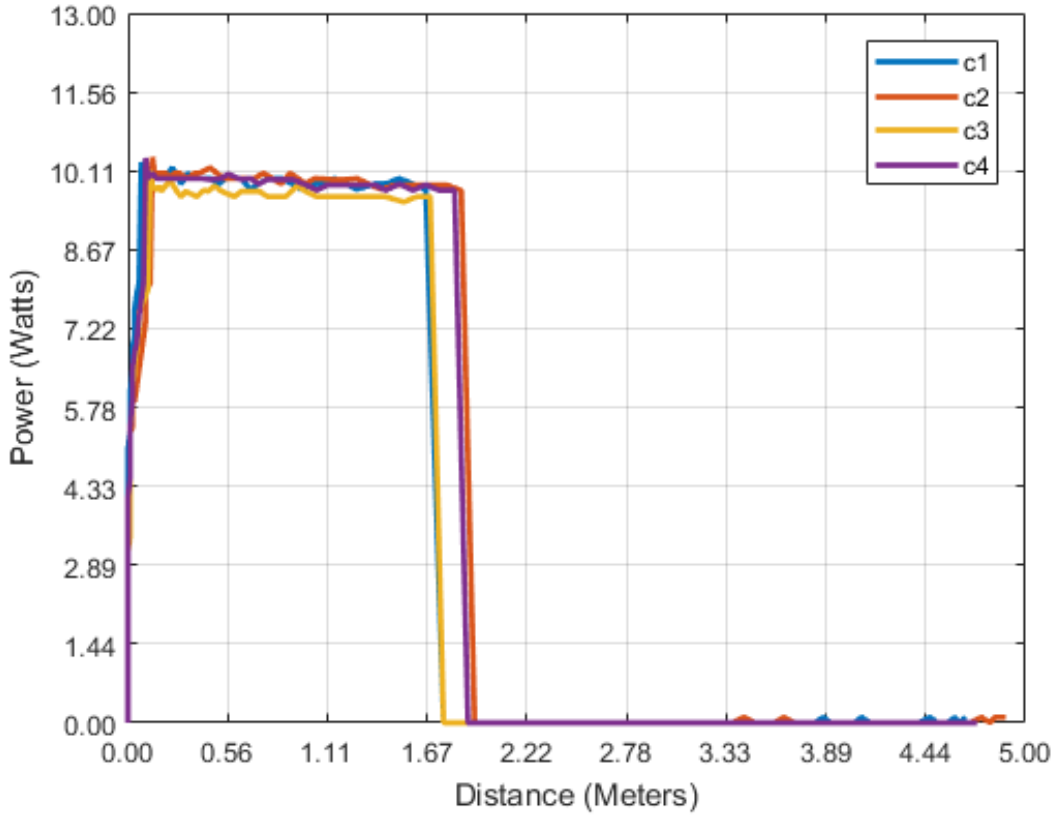

Figure 4. Power(Watts) vs Distance(Meters) Plot (Coasting Test 1-4)

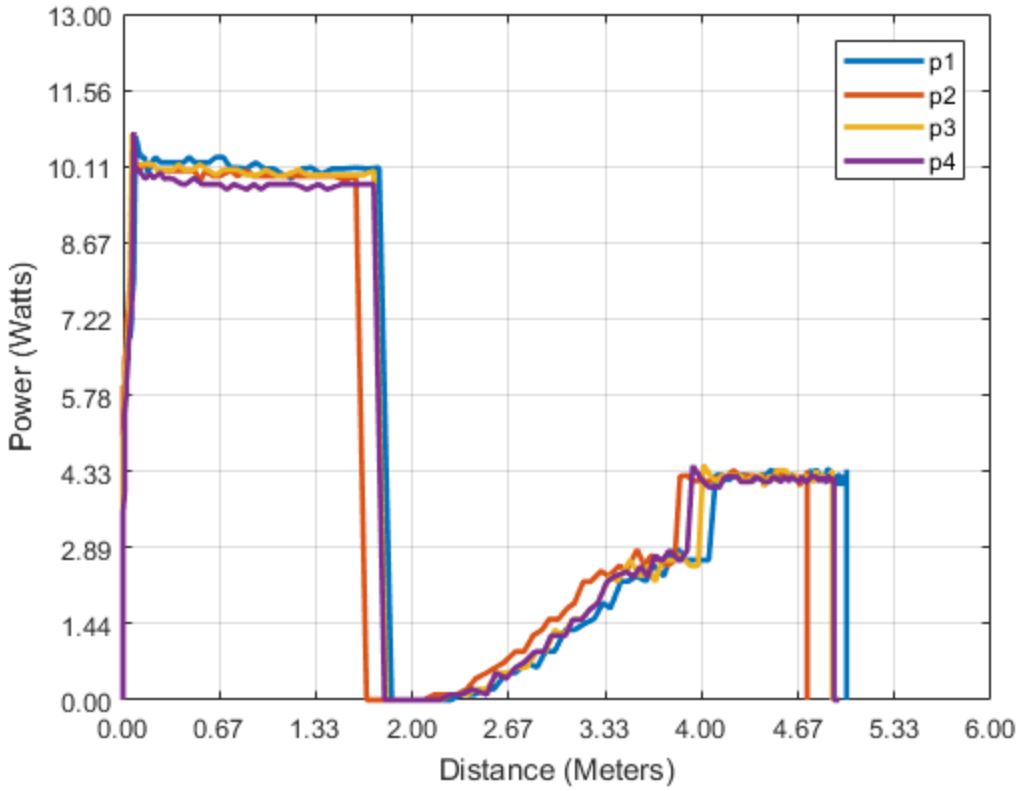

Figure 5. Power(Watts) vs Distance(Meters) Plot (Power Braking Test 1-4)

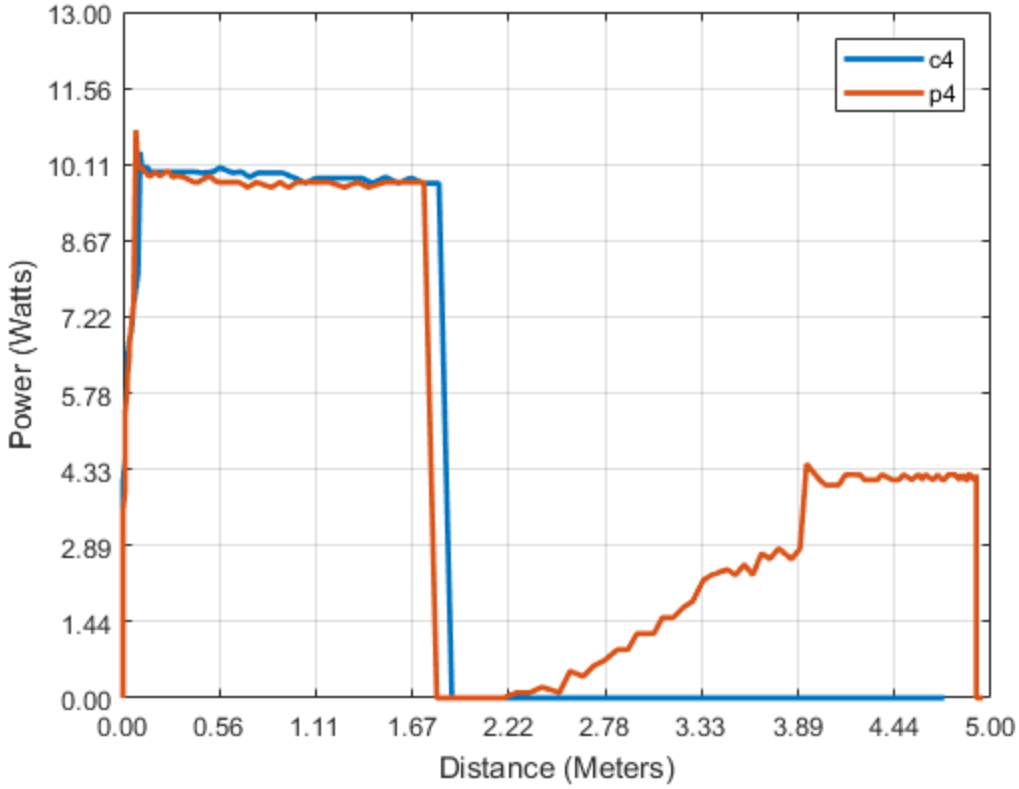

Figure 6. Power(Watts) vs Distance(Meters) Plot (Coasting Test 4 vs Power Braking Test 4)

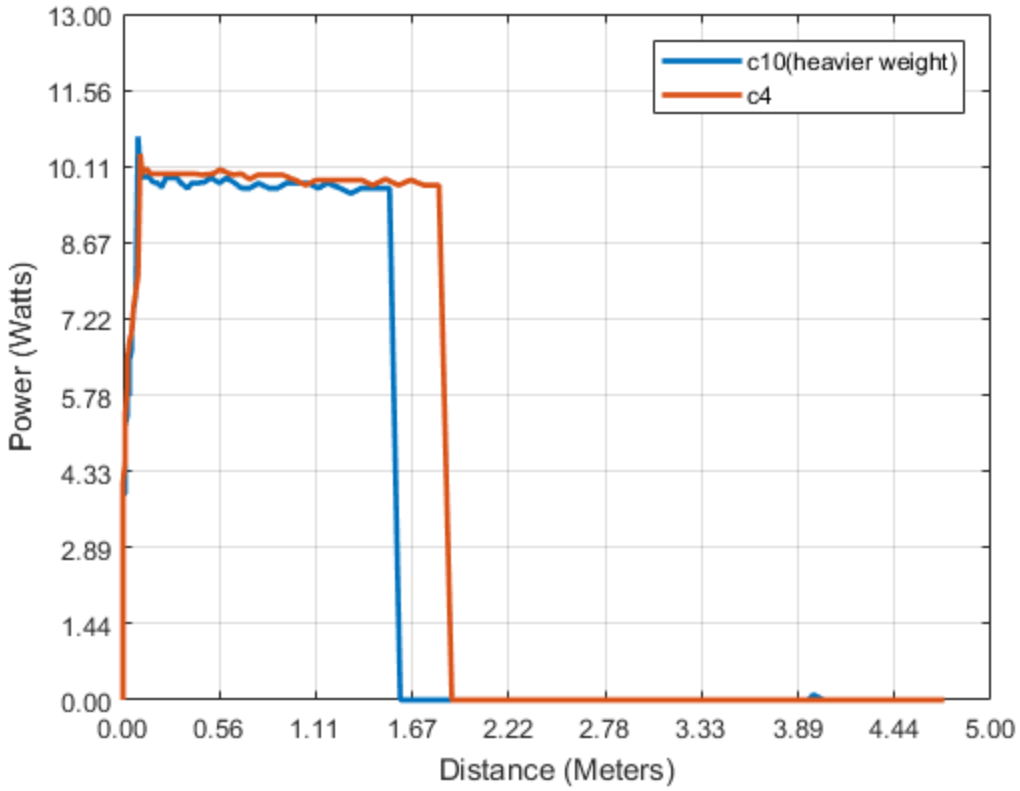

Figure 7. Power(Watts) vs Distance(Meters) Plot (Coasting 260 grams vs 293 grams)

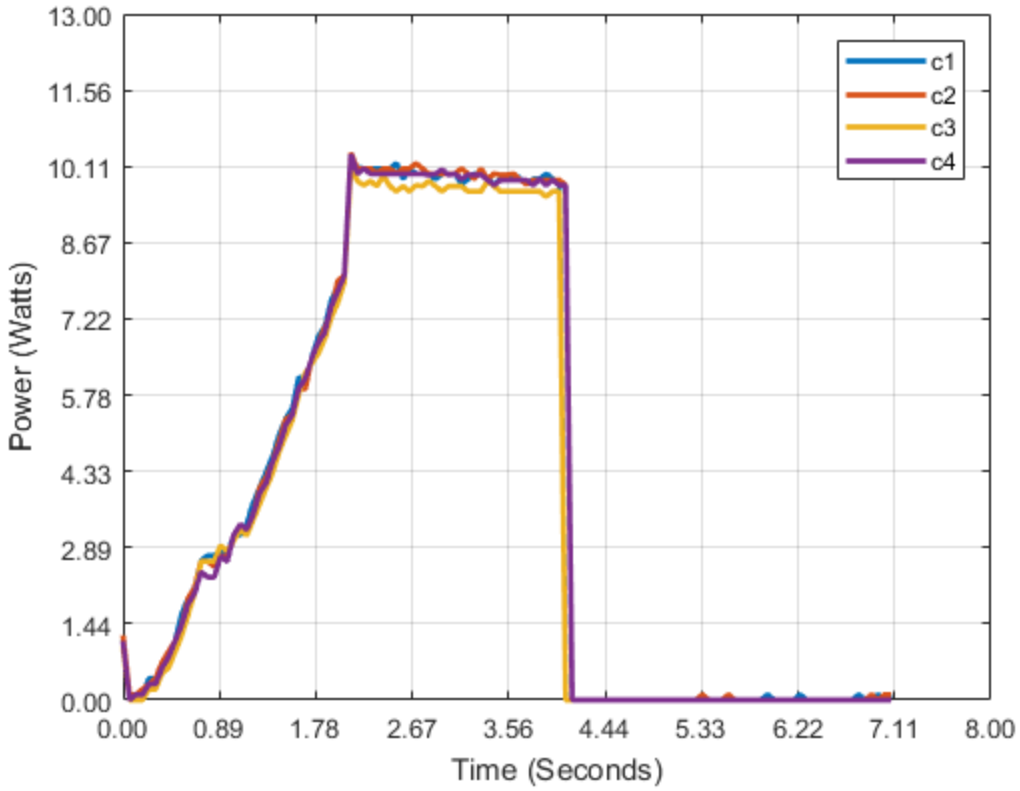

Figure 8. Power(Watts) vs Time(Seconds) Plot (Coasting Test 1-4)

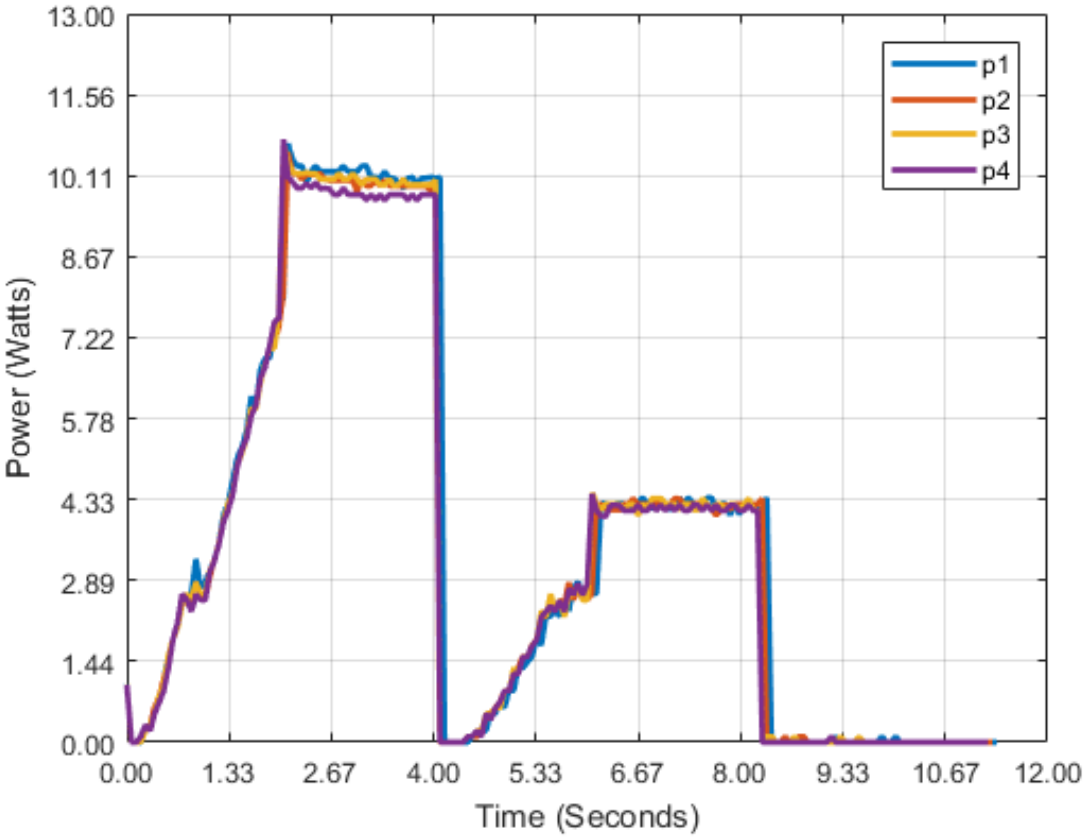

Figure 9. Power(Watts) vs Time(Seconds) Plot (Power Braking Test 1-4)

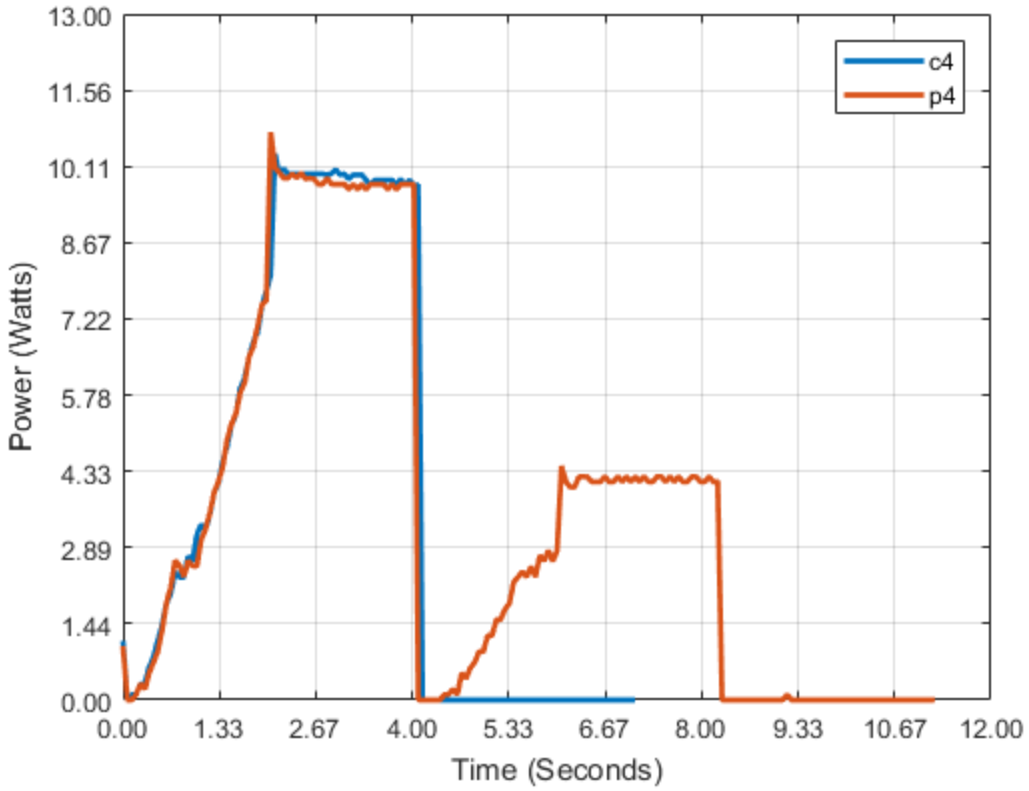

Figure 10. Power(Watts) vs Time(Seconds) Plot (Coasting Test 4 vs Power Braking Test 4)

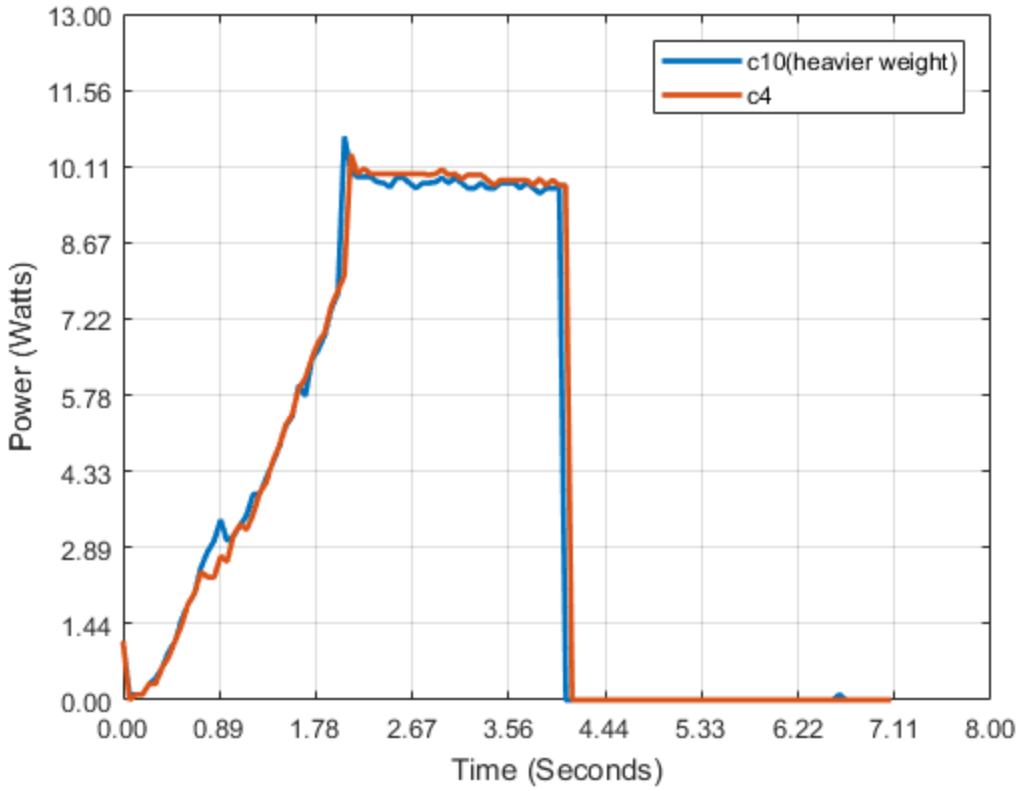

Figure 11. Power(Watts) vs Time(Seconds) Plot (Coasting 260 grams vs 293 grams)

Appendix G
Coasting vs Power Braking Codes

```
//accelerate all motors from 0 % power to 40% power in 2 seconds.
celerate(4,0,40,2);
//run at current speed for 2 seconds.
goFor(2);
//brake all motors.
brake(4);
```

Code 1. Coasting Test Arduino Code

Test Code for Power Braking:

```
//accelerate all motors from 0 % power to 40% power in 2 seconds.
celerate(4,0,40,2);
//run at current speed for 2 seconds.
goFor(2);
//brake all motors.
brake(4);
//reverses the polarity of all motors
reverse(4);
//accelerate all motors from 0 % power to 20% power in 2 seconds.
celerate(4,0,20,2);
//run at current speed for 2.2 seconds.
goFor(2.2);
```

Code 2. Coasting Test Arduino Code