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Paper Airplane Building Machine: Paper Airplane Launcher

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MET SENIOR PROJECT

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Abstract

The project was motivated by an ASME 2016 design challenge. The challenge was to design and manufacture a device that would turn a single sheet of paper into a paper airplane and launch it. The project is divided into three portions. The three portions are the frame and paper loading, folding mechanism, and launching. The circumference equation is used, to determine what the proper speed of the paper loading motor is. Notably, a slow rpm motor is needed for the loading mechanism to prevent the paper from being damaged. To avoid any deflection in the frame, the total weight of the machine had to be considered. The shear and moment diagram is used to calculate the reaction forces, and to calculate the proper thickness of the material being used. Four motors are used for the paper loading and folding processes, in which each motor has fifteen RPM. Additionally, two linear actuators are used in the paper folding process. Moreover, the launching process requires two motors, each has fifteen thousand RPM. All of the motors that have been mentioned require a twelve-volt battery. Both the launcher motors and the actuators are connected to a single battery. For the other motors, each two motors are connected to one battery. Each battery is connected to on-off switch. As a result, the machine is able to fold a standard sheet of paper into an airplane shape and launch it within 2 minutes. The launcher is able to shoot the paper airplane 10 meters.

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1. Introduction

1a. Motivation:

This project was motivated by American Society of Mechanical Engineers to manufacture and design an engineering system in order to win the competition.

1b. "ASME" Function Statement:

The function of paper airplane building machine is to design a projectile from a standard sheet of paper and launch it.

1c. "ASME" Requirements:

The design requirement for paper airplane building machine may include:

- The system must be powered by a battery or multiple batteries
- The system must meet the ASME Design Competition rule
- The system must design to manufacture projectile from single sheets of 20-lb, A4 paper
- The system must be designed to load the paper manually one sheet at a time
- The ceiling in the competition space might be 8 ft or higher depending on the location of the competition
- The height of the assembled system must be less than 30 inches
- The system must be unloaded from the box, assemble, and feed in three sheets of paper in the five-minute competition period

1d. Subproject Function Statement: Projectile Launcher:

The statement function of the project is to design a device to launch paper airplanes to a maximum distance.

1e. Subproject Design Requirements: Projectile Launcher:

The design requirement for the launcher device may include:

- The device must launch the paper airplanes at least 20 meters
- The device must launch the object in less than 10 seconds
- The cost of the device must not exceed $200
- The tolerance of the device should not exceed the width 12" of the system frame
- The launcher must be able to adjust the angle to 10°

- The length of the launcher should be 7” or less

1f. Engineering Merit:

The engineering merit of this device is to structure and design a launcher for paper airplane that is similar to one that launches paper airplanes by using Legos and gears. The properties of air and aerodynamics equations will be used to launch the paper airplane as far as possible.

1g. “ASME” Success Criteria:

The success criteria of the project is that each team’s score will be calculated from the total distance traveled by the three projectiles and the volume of the box in which the system is initially packaged. The scoring will be based on the following equation:

$$S = \frac{distance_1 + distance_2 + distance_3}{Volume}$$

1h. Subproject Success Criteria: Launcher

The success criteria of the launcher is to create a device that can launch three different shapes of paper airplanes to a maximum distance to win the ASME competition.

1i. Scope of Effort:

The scope of effort of this project is to create a mechanism for launching projectiles compatible with frame integration and limitation.

1j. Benchmark:

In order to create the launcher device there is a similar device to launch paper airplanes by using Legos and gears. A motor attached with spring and gears can be used to launch the paper airplanes to improve the performance of the device.

1k. Success of the Project:

The success of this project is the final performance of the whole system at ASME competition when the machine creates the three designs of paper airplanes and launches it to the desired distance to win the competition.

2. Design and Analysis

2a: Approach: Proposed Solution for Launcher:

For the launcher design there are two phases, throw phase and ascent phase: throw phase is to get the paper airplane gliding as high as possible. In order to achieve this, launching the paper airplane as fast as possible, straight up will be required. The force of gravity and the force of drag will slow it down as it ascends. Thus, the throwing phase to maximum height will ensure the transition to gliding flight and the throw should be within 10° of vertical. Ascent phase is meant to control the angle of attack to be near to zero, which will result in zero lift to allow the paper airplane to fly vertically. To determine the launch energy required, kinetic energy equation will be used (.5*mass*v^2), potential energy =(mgh), and drag force = (.5*ρ*v^2*C_D*A).

2b: Description of Projectile Launcher:

The projectile launcher is a device that can launch paper airplanes at angles between 0-10 degrees and over distance up to 20 m.

2c: Benchmark:

The benchmark for this launcher will have a similar designed to the picture below. However, one motor will be used to drive one wheel while the other wheel will be a driven wheel attached with a spring to reduce the friction.

Figure 1-1 shows a similar Designed

2d: Performance Predictions

The velocity is calculated to be 28.28 m/s for the selected design of paper airplane. However, the required speed is depending on manner of folding the paper. The expected force required to launch the paper airplane is approximated to be 11.57 N. After that the torque was calculated using equation $\tau = r * F_{Launch}$. R is the radius of the tire. The torque is 0.58 N.m. Also the acceleration is calculated to be 3.54 m/s^2.

Moreover, the power was found using p= F_D * V. The power needed is 2.49 W. Finally, the lift coefficient of the paper airplane is 0.00131.

2e: Description of Analyses

To have a better performance a good paper airplane design is the key. After choosing the best design, the wing area of the paper airplane can be calculated to find Lift Coefficient using the following equation, $C_L = \frac{2*L}{\rho * V^2 * A}$. The wing area can be divided into two section, rectangle and triangle and added up together to find the whole wing area. The important flight parameters are the flight speed and the lift to drag ratio. Then, the drag coefficient can be calculated using

$C_D = \frac{F_D}{\frac{1}{2} \times \rho \times V^2 \times L \times D}$. (See Appendix A for more information about the calculations).

2f: Scope of Testing and Evaluation

Testing will be hold on campus since there are enough space to launch the paper airplanes in a hallway or any large indoor area in order to eliminate wind effects. Also, wind tunnel will be used to test the aerodynamic properties of the paper airplane such as drag and lift forces in order to derive the lift coefficients, drag coefficients, the aerodynamic efficiency, and the gliding ability. The evaluation sheet is attached in Appendix G.

2g: Analysis

Paper airplane with wing area that calculated to be 0.07 m^2 needs to be launched with a speed of 28.28 m/s at least to achieve the desired distance. Angle of launch is important to make the paper airplane fly as far as possible. The drag force is also calculated to be 0.0883 N. Glider is important key to make the paper airplane glide as far as possible.

2h: Device Shape:

The shape of the device will have two tires and a spring. The two tires will be running using one motor while tire B will be turning based on tire A. The material of the tires is made of rubber to grip the paper and launch it with less friction.

2i: Device Assembly, Attachments

Assembly of the paper airplane building machine will be from the ground essentially. First the frame will be designed to have a base for the launcher to be attached. Also, a spring will be added then a pushing rod. At this point, the machine will be completely assembled.

2j: Risk Analysis:

To ensure the success of the project, financial risk is important for the group not to exceed the limit, which is $200. Most of the parts are found in the energy 411 lab but some are not. Another possible failure risk is that paper airplanes are not like a full size airplanes so there might be some differences between the real aerodynamic calculations, which might affects how paper airplane fly.

3. Methods and Construction

3a. Description

The device will be manufactured in the Central Washington University machine shop or the wood shop. Some of parts are going to be used in this project such as electric motors and Lego gears to transfer the drive gear from a motor to suit our purposes in the best way possible. The main purpose of the gears is to transfer the torque from the electric motor to a larger speed. The driver gear will be attached to an electric motor and follower gear will be attached with a plastic tire to launch the paper airplane. The base is going to be made of aluminum for strength. During winter quarter 2016, the materials were delivered and we made a prototype of the launcher using the Lego gears and motors. Unfortunately, the Lego gears were not fixed or meshed together properly and the Lego motors were too slow to launch the paper airplane to the required distance. Thus, we had to come up with new design. In this report, the new design and the old design are showing in the following contents.

Figure 3-1 shows how the gears will be in meshed but the driver gear will be bigger and follower gear will be smaller

In Figure 3-2, shows a breakdown of assemblies and subassemblies of launcher device.

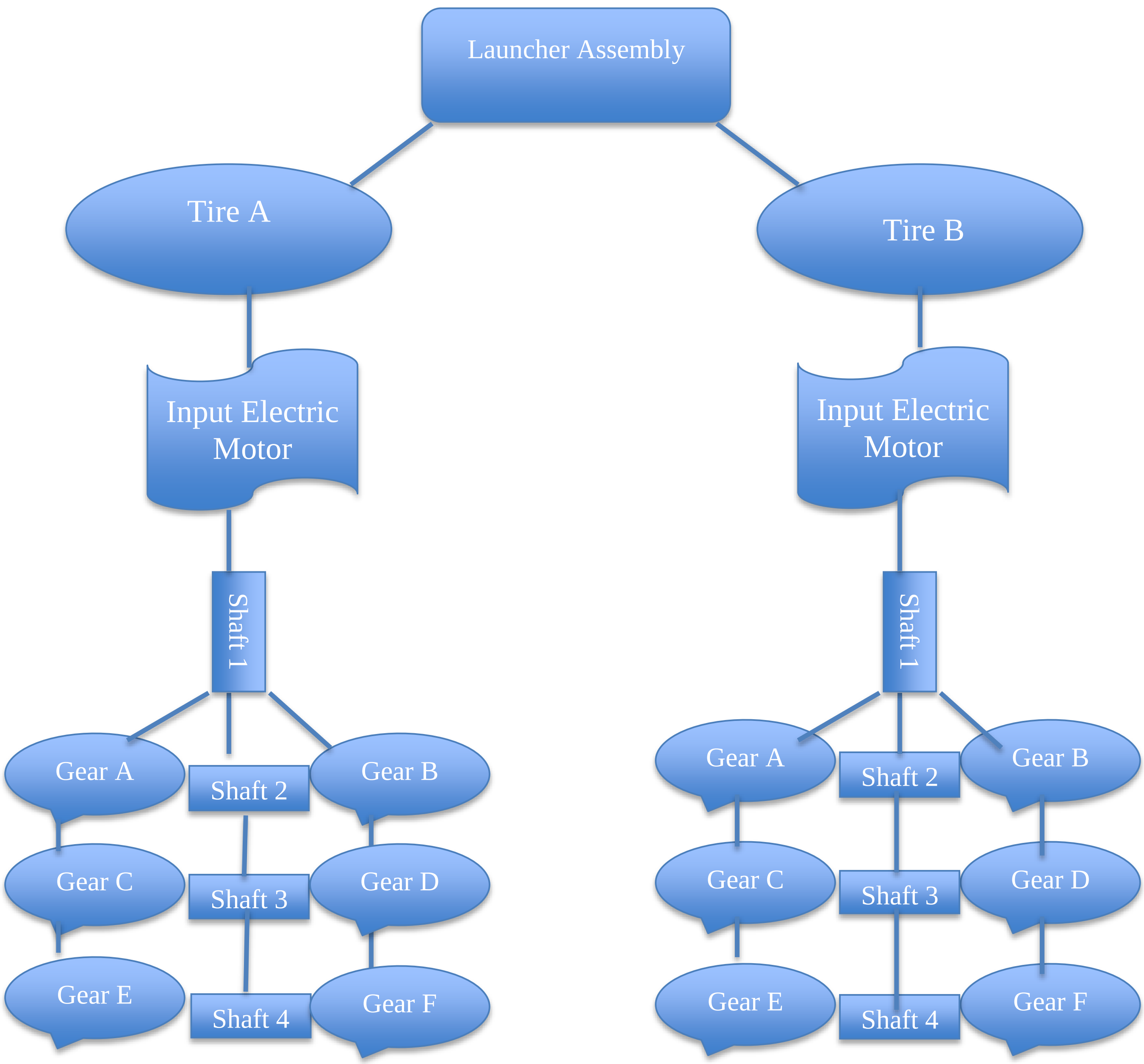

Figure 3-2 (Drawing Tree) for the Old Design

3b. Drawing Tree: New Design

In Figure 3-2, shows a breakdown of assemblies and subassemblies of launcher device.

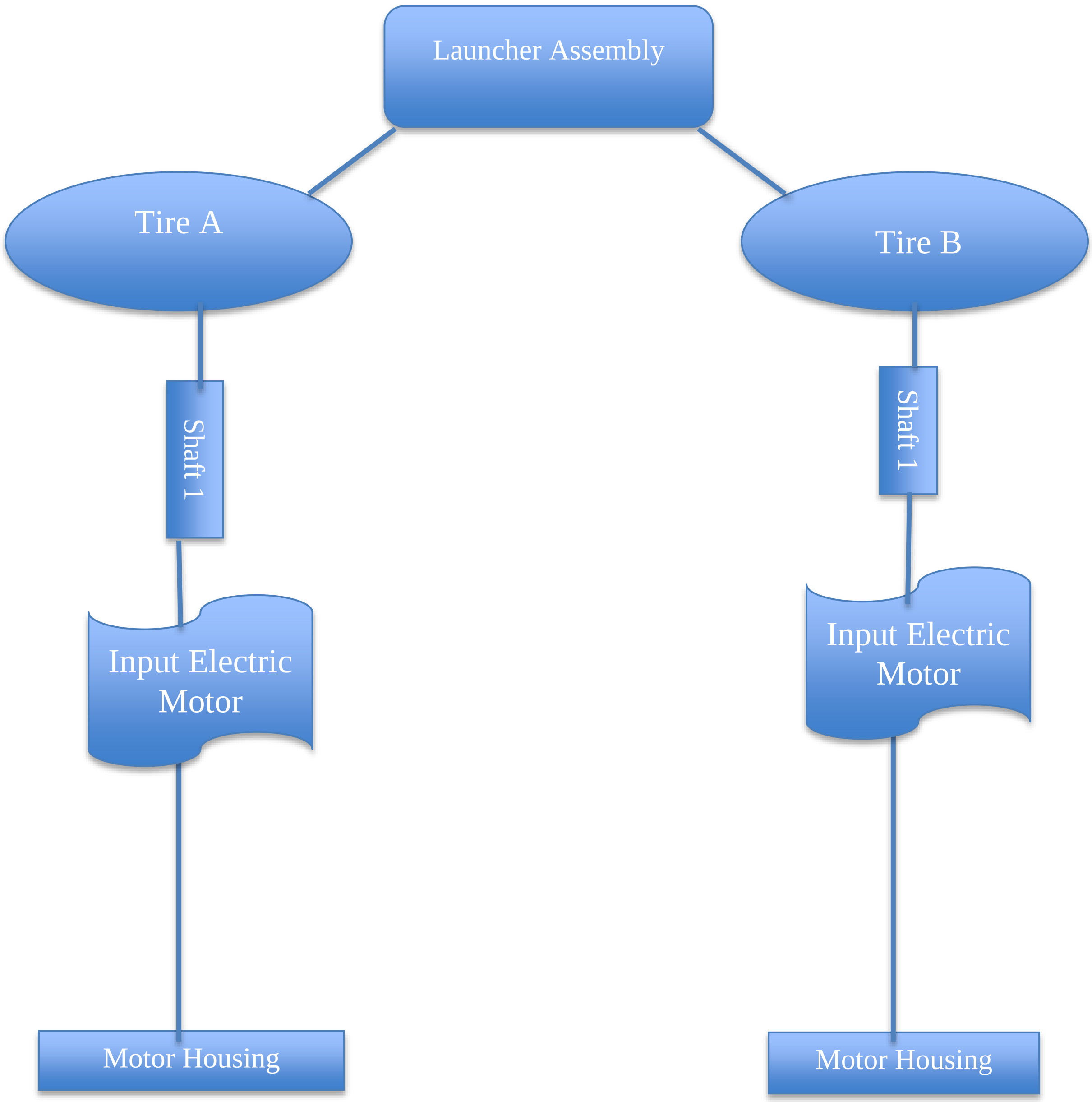

Figure 3-2 (Drawing Tree) for the New Design

3c. Parts list and labels: New Design

Table 3-1 shows the parts list of the launcher

ITEM NO.	PART NUMBER	Material	QTY.
1	Electric Motor	Combination	2
2	Rubber Tire	Rubber	2
3	Wheel	Plastic	2
4	Shafts	Aluminum 6061	2
5	Frame Launcher	Aluminum 6061	1
6	Motor Housing	Aluminum 6061	2

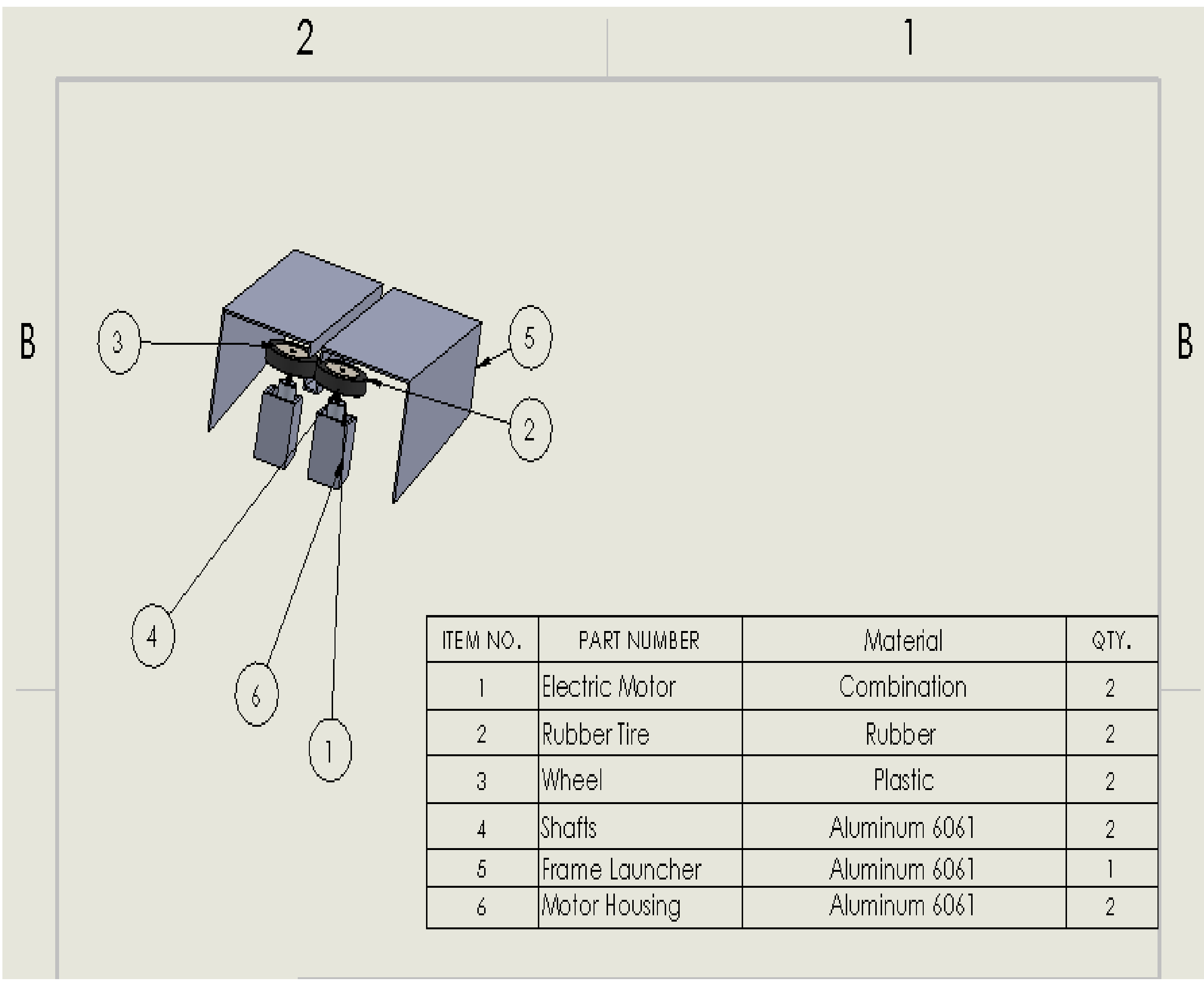

Figure 3-3 (Parts List and Labels) New Design

Parts list and labels: Old Design

Table 3-1 shows the parts list and the labels of launcher

ITEM NO.	DESCRIPTION	MATERIAL	QTY.
1	Base Holder	1060 ALLOY	2
2	Shaft Coupler Connector	1060 ALLOY	4
3	Motor		2
4	Shafts	ABS	4
5	Gear 44 Teeth	ABS	4
6	Gear 12 Teeth	ABS	6
7	Gear 24 teeth	ABS	2
8	Tire	BUTYL	2

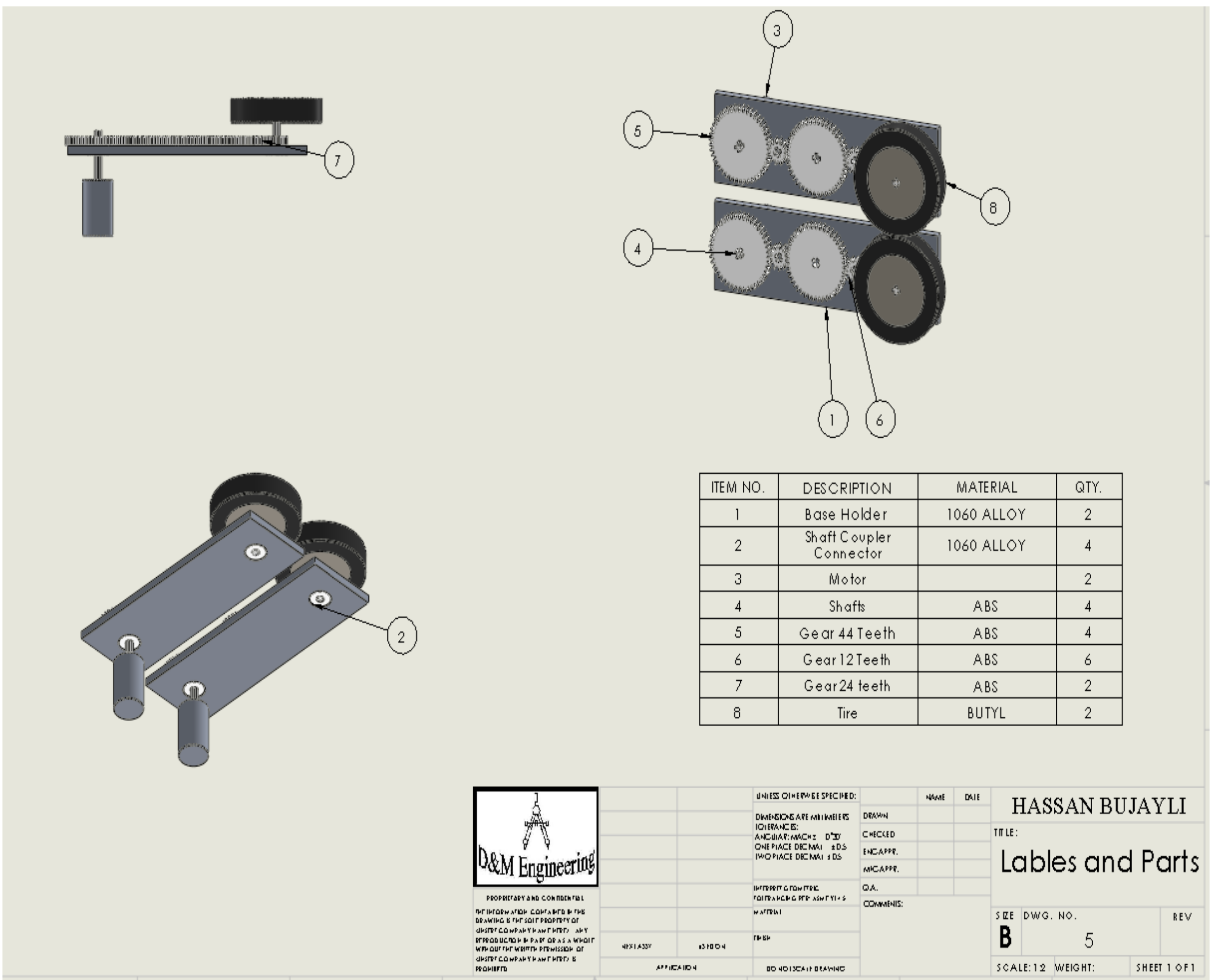

Figure 3-3 (Parts List and Labels) Old Design

3d. Discussion of assembly, sub-assemblies, parts, drawings:

Most of the parts listed above were available from energy system lab 411. Some gears with a specific number of teeth will be order online from Amazon. The two motors with a rotational speed of 170 rpm will be order from Lego store. Finally, the base might be designed in the machine shop. (See Appendix B for more Details). Due to the low speed of the rpm when using Lego motors and gears, as a group we decided to use electric motor connecting with a battery to power the motor. This alternative solution costs more money but it will work better. For the new design, the group started in the machine shop to cut and braze the holder board for the launcher into the frame. Then the T section were brazed into the frame, the housing motors were cut into the desirable dimensions and brazed the hosing motors into the frame. Also, two brush motors were tested and they both seem so fast and easier to work with. Some issues were encounters to insert both motors and the housing into the frame due to the frame dimension. Then, the alignments of both tires on the holder board were adjusted and the problem is solved.

4. Testing Method

4a. Introduction:

Testing will be hold on campus where is a large area to fly the paper airplanes in a hallway or any large indoor area because the weather condition can affect the indoor flight. Also, wind tunnel will be used to test the aerodynamic properties of the paper airplane such as drag and lift forces in order to derive the lift coefficients, drag coefficients, the aerodynamic efficiency, and the gliding ability. Also, the distance and speed of the paper airplane will be tested.

4b. Method/Approach:

To achieve the best flight, an airplane that has balance of lift, thrust, gravity, and drag will fly longer. Thus, the testing will be on the finish paper airplane model. The aerodynamic properties are needed to test the drag force of the final design model.
To test the distance of each flight for each paper airplane, a tape measure will be used to measure how far the paper plane flow from a starting line. From there, the time for each flight will be test using stopwatch. With that being said, using this equation to test the speed of each flight V= D/T, D being distance, and T being time.

4c. Test Procedure:

1. Using the barometer and thermometer in the lab to determine the density of the air flowing inside the wind tunnel.
2. Using the wing tunnel calibration VI calibrate the wind tunnel test section by graphing velocity vs. motor frequency.
3. A Pressure wing is inserted vertically in the wind tunnel.

4. Operate the tunnel at airspeed of 20, 30, and 50 m/s and take pressure measurements on the wing at angles of attack of 0˚, 3˚, 7˚, 10˚, and15˚.

4d. Deliverables

The deliverable will be finding the normal force coefficient for all angles of attack and flow speed. Also, the based on the results of the wind tunnel, drag coefficient, lift coefficient can be compared to the calculations.

5. Budget/Schedule/Project Management

5a. Proposed Budget, Labor cost and Project Management:

The estimated cost of this project is $124.82. This can be seen in the budget in **Appendix C**. So far some of the Lego gears and motors were provided by prof. Roger Beardsley from energy lab 411. However, some gears are not available with the Lego set that was provided. Thus, the project needs extra gears and a specific motor with a specific number of rpm will be order online from a Lego group called Lego Education and were priced out to be $90.80. The majority of the shaft and tires are also provided with the Lego set that given be Prof. Roger Beardsley. The base holder will be cut in the machine shop and material lab in Hogue at Central Washington University. The estimated labor cost will be provided by Hassan Bujayli. No other labor will be required to complete this project. The total approximate number of hours in order to compete this project is about 125 hours. For the new design, two electric motors cost about $91.89. Aluminum rod shaft cost about $12.30. Tires were provided by a friend using RC Tire.

5b. Proposed schedule:

The schedule of this project is to help organizing the time by the MET 495 Senior Project Instructors, with a required due date and it is found in **Appendix D,** to be viewed for further details. This schedule will ensure an adequate time for designing, developing, and testing the overall project assembly, which is due at by the last week of the third quarter.

5c. Task:

Three sections of tasks break down the schedule: Proposal, Construction, and Testing. Moreover, each section includes sub-task and due date. For this project, the complete proposal is due on December 9, 2015. The construction project report is due at the end of March 2016 and final testing report and final draft of the proposal is due at the end of May 2016.

5d. Milestones:

The following milestones are the details for the tasks and sub-tasks.

- Proposal
  - ✓ Outline
  - ✓ Introduction
  - ✓ Methods
  - ✓ Analysis
  - ✓ Discussion
  - ✓ Parts
  - ✓ Budget
  - ✓ Schedule
  - ✓ Drawings
    - ❖ Estimated Total Hours: 36
      - Actual time: 58 Hours

- Construction
  - ✓ Parts Ordering
  - ✓ Parts Assembly
  - ✓ Frame Assembly
    - ❖ Estimated Total Hours: 69:30
      - Actual Time: 99:10 Hours
- Testing
  - ✓ Wind Tunnel Testing
  - ✓ Speed Testing
  - ✓ Distance Testing
    - ❖ Estimated Total Hours: 29
      - Actual Time: 39:30 Hours

6. Discussion

6a. Design Evolution:

This project is has gone through multiple designs due the launching distance that the paper airplane can fly to. The first design has one spinning motor and two plastic tires. The first design did not meet the requirements such as the distance and the speed. Thus, redesign another launcher was needed to meet the requirements. This leads to another design, which includes two spinning motors, two rubber tires, and Lego gears to increase the speed of the launcher. Recalculating the velocity of the airplane and angular velocity of the motors, the second design was decided to be more accurate and the one to move forward with.

6b. Risk Analysis:

There are two risks of analysis in this project. Time is a large risk factor in this project because changing an old project to a new project and starting from a scratch is a hard way to experience. Having three inexperienced engineers starting to think of project that is more competitive led to waste of time. The second risk is the cost associated with this project. The whole idea of this project is build a machine that can fold a paper airplane and launch with reducing the cost as much as possible.

6c. Successful:

This project will be successful if the group wins the 2016 challenge competition provided by ASME. The challenge is to "build a compact engineering system in order to manufacture a Projectile from a standard sheet of paper and test it by propelling it a maximum distance". If the group did not win the competition, the amount of work, research, and calculations in this project will lead to a huge increased in the future engineering knowledge and design.

6d. Next phase:

The next phase to the project is to order all the material associated with building the whole system. The faster all material arrived to build the frame and folding design, the faster the whole system will be assembled together and ready to be tested.

7. Conclusion

To conclude, paper airplane launcher will be successful because it has been pictured, analyzed, and designed to meet the function requirements as described in the beginning of the proposal. The design for this project consist two motors, two rubber tires, and two sets of gears in order to increase the speed of the motors from 170 to 4570 rpm.

The importance of the analysis in this project will contribute to have a successful device that can launch the paper airplane to the desired distance. Once all these parts are available, the construction will begin to assemble the device in the frame. As a team, we hope to win the competition and get the 1^{st} place in order to be awarded.

8. ACKNOWLEDGEMENTS

Thank you to Central Washington University for providing the workspace (Machine shop, wood shop, tools software, resources and references). This project was supported by Dr. Craig Johnson, Professor Charles Pringle, Professor Roger Beardsley, Ted Bramble. Thank you all so much for all the mentoring, advices, and providing some materials from the labs. Also, thank you to ASME (American Society of Mechanical Engineers) for coming up with project. A big thank you to the team partners (Abdullah Al Dakhail and Abdullah Alshahrani) for all the helps and supports to make this project to be real.

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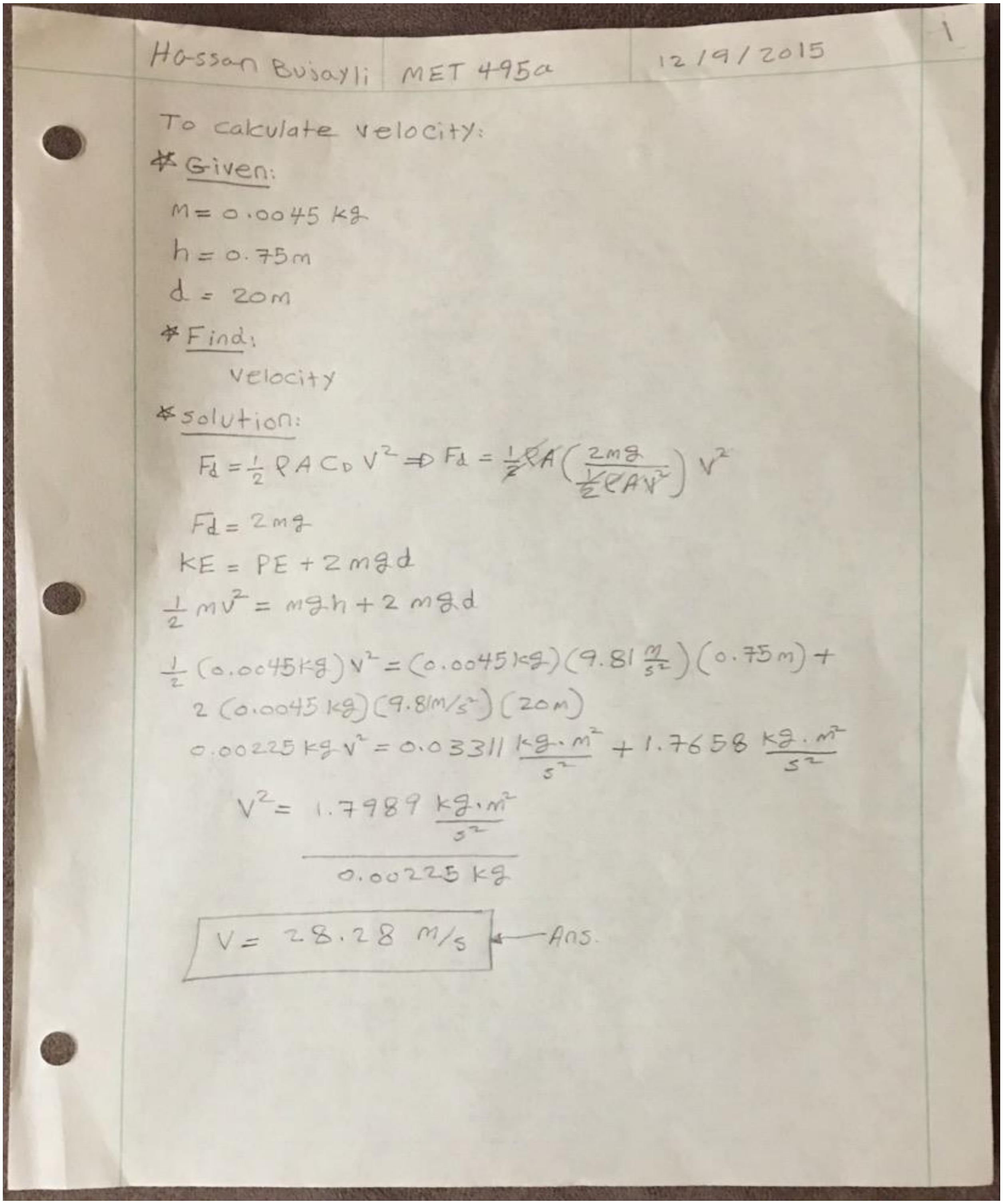
Appendix A – Analyses



Hassan Busayli | MET 495a | 12/9/2015 | 1

To calculate velocity:

* Given:

$m = 0.0045\ kg$

$h = 0.75\,m$

$d = 20\,m$

* Find:

velocity

* solution:

$F_d = \frac{1}{2}\rho A C_D V^2 \Rightarrow F_d = \frac{1}{2}\rho A\left(\frac{2mg}{\frac{1}{2}\rho A V^2}\right) V^2$

$F_d = 2mg$

$KE = PE + 2mgd$

$\frac{1}{2} m v^2 = mgh + 2mgd$

$\frac{1}{2}(0.0045\,kg)V^2 = (0.0045\,kg)(9.81\,\frac{m}{s^2})(0.75\,m) +$
$2(0.0045\,kg)(9.81\,m/s^2)(20\,m)$

$0.00225\,kg\,V^2 = 0.03311\,\frac{kg \cdot m^2}{s^2} + 1.7658\,\frac{kg \cdot m^2}{s^2}$

$V^2 = \frac{1.7989\,\frac{kg \cdot m^2}{s^2}}{0.00225\,kg}$

$V = 28.28\ m/s$ ← Ans.

Figure A1 (Analysis for velocity)

Hassan Bujayli | MET 495a | 12/19/2015 | 2

To calculate Drag coefficients.

* **Given:**

$V = 28.28\ m/s$

$A = 0.07\ m^2$

$\rho = @\ 20^\circ C = 1.204\ kg/m^3$ Table A-22 Properties of Air at 1 atm Pressure

$m = 4.5\ g$

* **Find:**

Drag coefficient, C_D

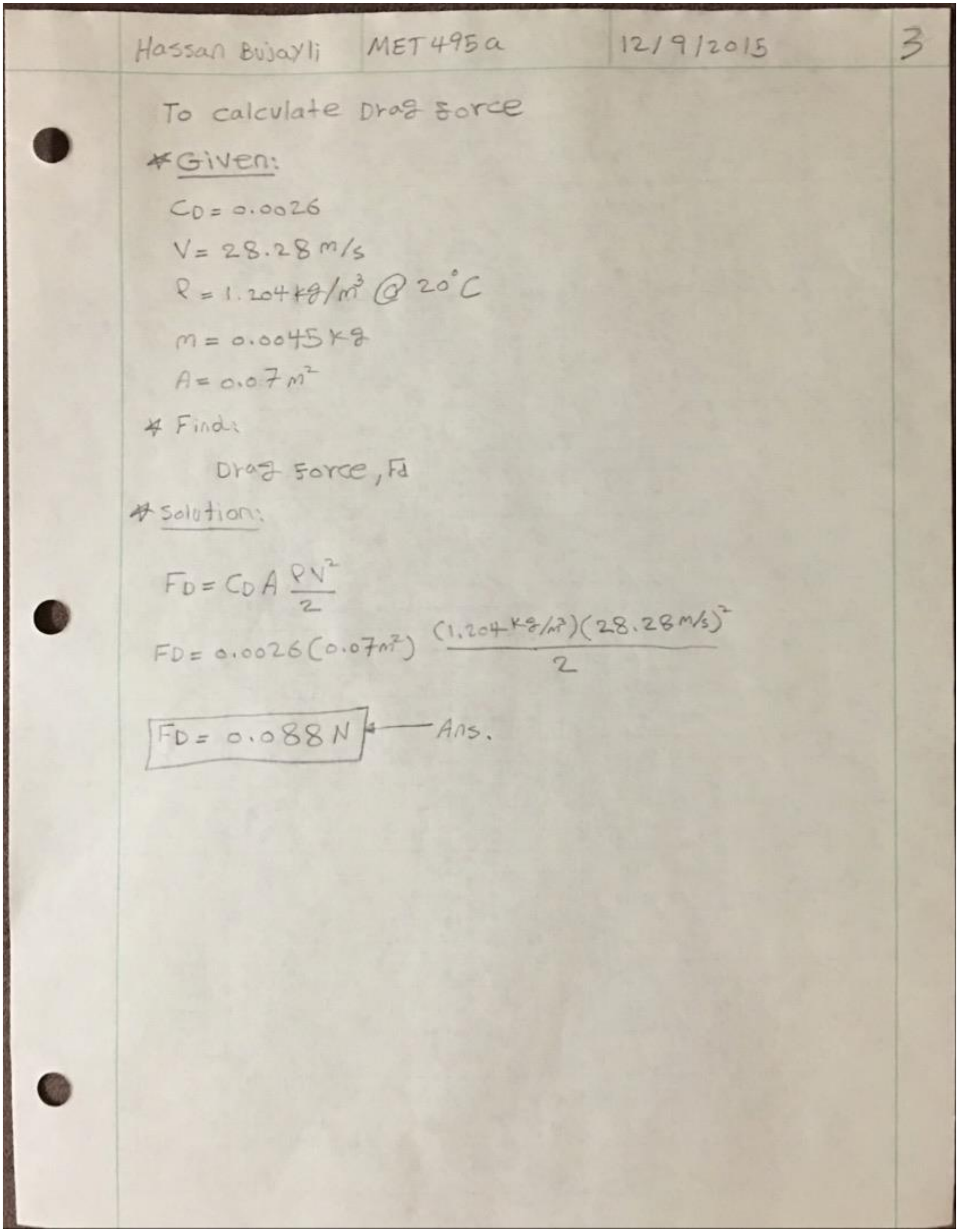
* **Solution:**

$$C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A} = \frac{2mg}{\frac{1}{2}\rho V^2 A}$$

$$C_D = \frac{2(0.0045\ kg)(9.81\ m/s^2)}{\frac{1}{2}(1.204\ \frac{kg}{m^3})(28.28\ \frac{m}{s})^2(0.07\ m^2)}$$

$C_D = 0.0026$ or 2.619×10^{-3} ← Ans.

Figure A2 (Analysis for Drag Coefficient)



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To calculate Drag force

*Given:

$C_D = 0.0026$

$V = 28.28\ m/s$

$\rho = 1.204\ kg/m^3$ @ $20°C$

$m = 0.0045\ kg$

$A = 0.07\ m^2$

* Find:

Drag Force, Fd

* Solution:

$$F_D = C_D A \frac{\rho V^2}{2}$$

$$F_D = 0.0026(0.07 m^2)\frac{(1.204 kg/m^3)(28.28 m/s)^2}{2}$$

$$\boxed{F_D = 0.088 N} \leftarrow \text{Ans.}$$

Figure A3 (Analysis for Drag Force)

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To calculate lift coefficient

*Given:

$F_L = W = mg = (0.0045\,kg)(9.81\,m/s^2) = 0.0441\,N$

$m = 0.0045\,kg$

$\rho = 1.204\,kg/m^3$ @ $20°C$

$V = 28.28\,m/s$

$A = 0.07\,m^2$

*Find:

Lift coefficient, CL

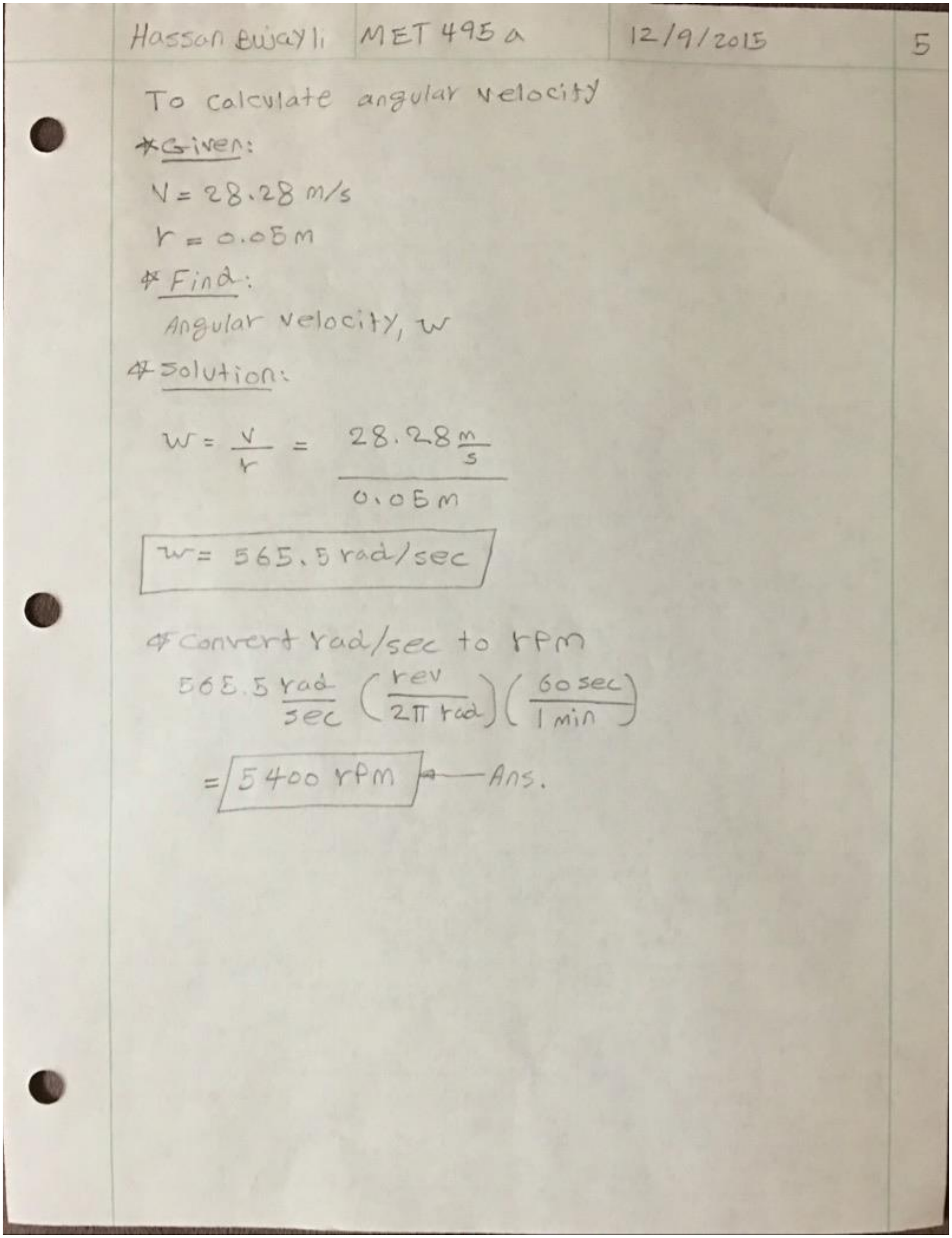
*Solution:

$$C_L = \frac{F_L}{\frac{1}{2}\rho V^2 A}$$

$$C_L = \frac{0.0441\,N}{\frac{1}{2}(1.204\,\frac{kg}{m^3})(28.28\,m/s)^2(0.07\,m^2)}$$

$C_L = 0.00131$ ← Ans.

Figure A4 (Analysis for Lift Coefficient)



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To calculate angular velocity

*Given:

$V = 28.28\ m/s$

$r = 0.05\ m$

*Find:

Angular velocity, w

*Solution:

$$w = \frac{v}{r} = \frac{28.28\ \frac{m}{s}}{0.05\ m}$$

$$w = 565.5\ rad/sec$$

*Convert rad/sec to rpm

$$565.5\ \frac{rad}{sec}\left(\frac{rev}{2\pi\ rad}\right)\left(\frac{60\ sec}{1\ min}\right)$$

$$= 5400\ rpm$$ ← Ans.

Figure A5 (Analysis for Angular Velocity)

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To calculate the Power,

* Given:

$F_D = 0.088\ N$

$V = 28.28\ m/s$

* Find:

The Power that needs to be supplied to provide enough thrust to overcome wing drag.

* Solution:

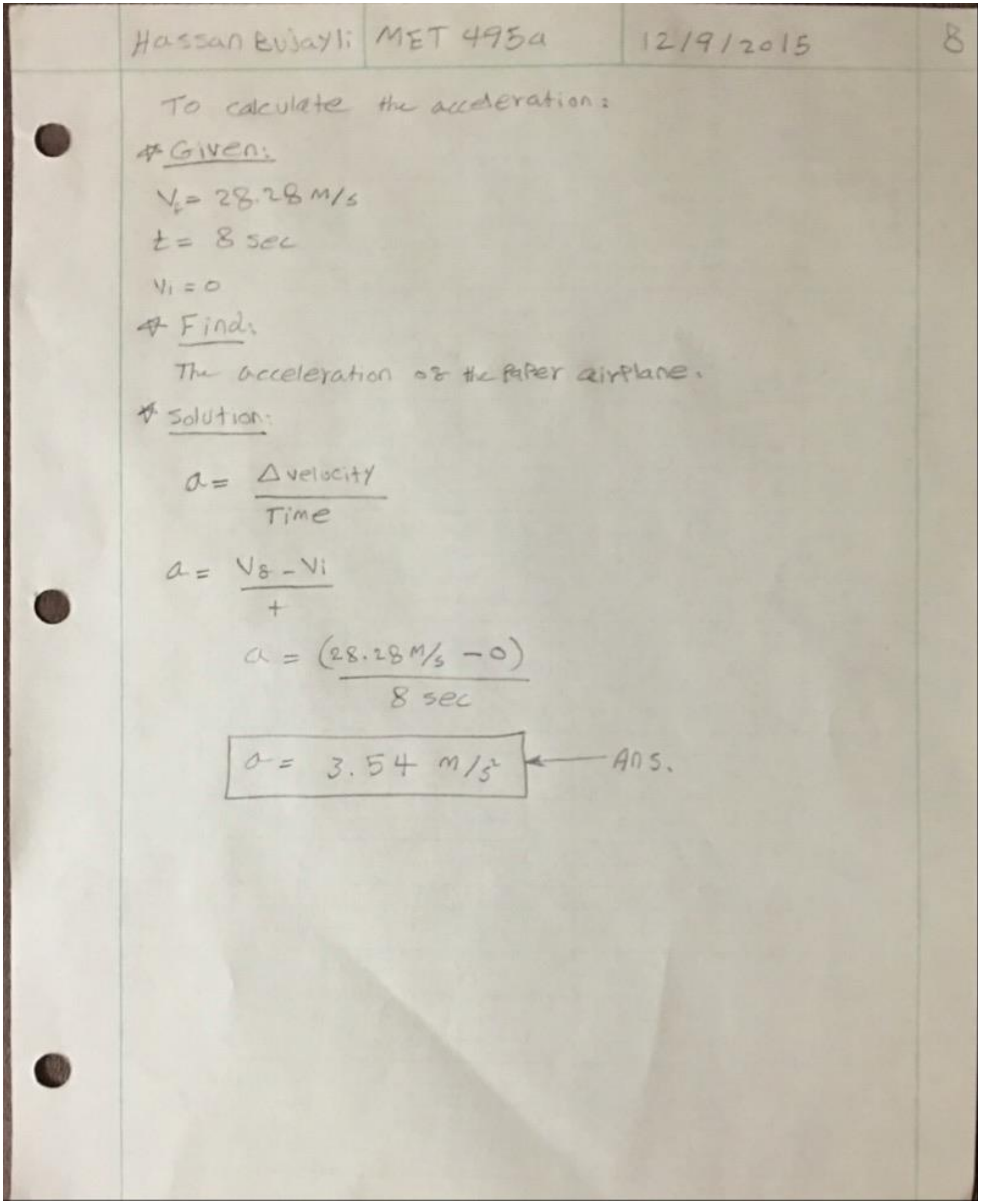
Power = Thrust x Velocity

Power = $F_D \times V$

Power $= 0.088\ N \times 28.28\ m/s \left(\frac{1\ W}{1\ N \cdot \frac{m}{s}}\right)$

P = 2.49 W ← Ans.

Figure A6 (Analysis for the Power)



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To calculate the acceleration:

* Given:

$V_f = 28.28$ m/s

$t = 8$ sec

$V_i = 0$

* Find:

The acceleration of the paper airplane.

* Solution:

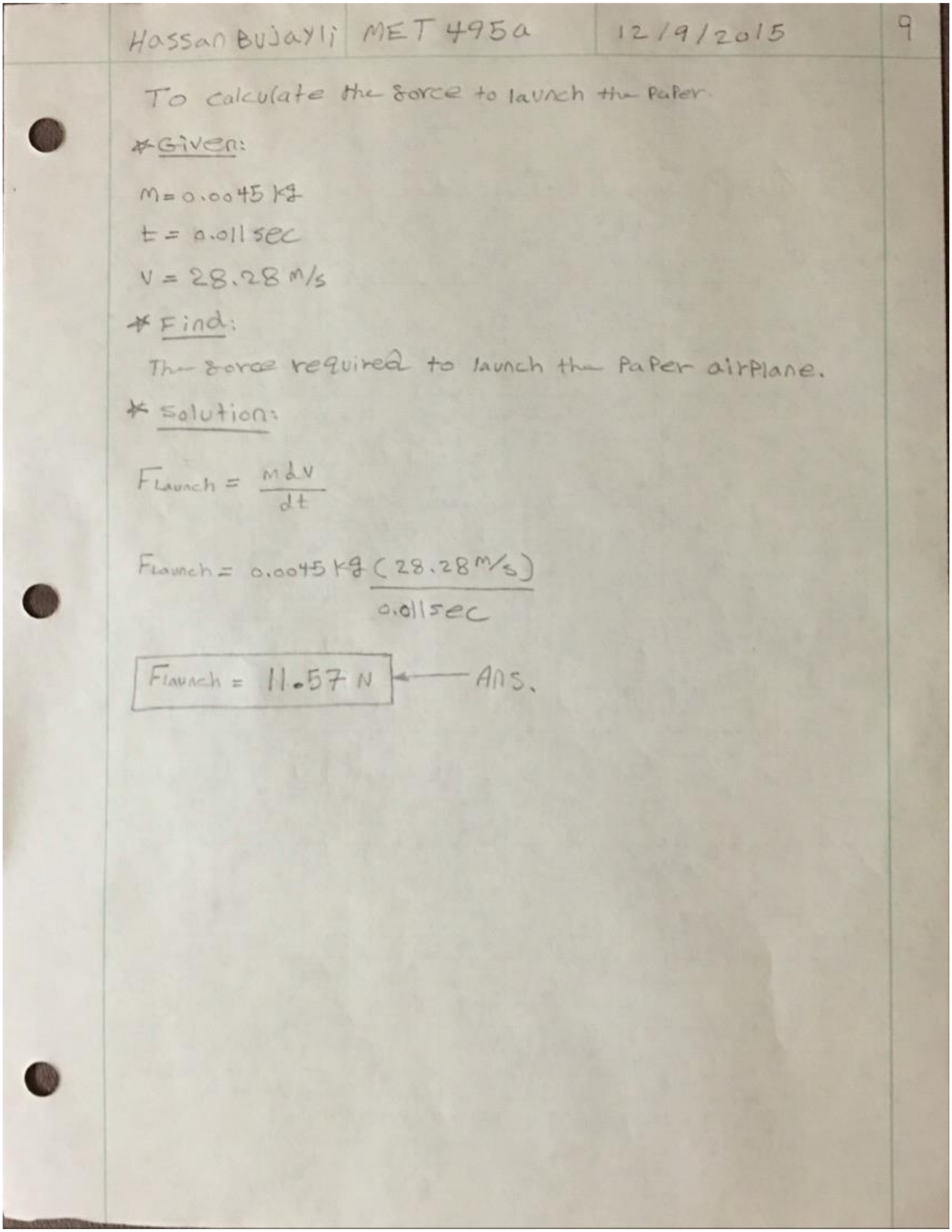
$$a = \frac{\Delta \text{velocity}}{\text{Time}}$$

$$a = \frac{V_f - V_i}{t}$$

$$a = \frac{(28.28\,\text{m/s} - 0)}{8\ \text{sec}}$$

$$\boxed{a = 3.54\ \text{m/s}^2} \leftarrow \text{Ans.}$$

Figure A7 (Analysis for the Acceleration)



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To calculate the force to launch the Paper.

*Given:

$m = 0.0045 \, kg$

$t = 0.011 \, sec$

$V = 28.28 \, m/s$

*Find:

The force required to launch the Paper airPlane.

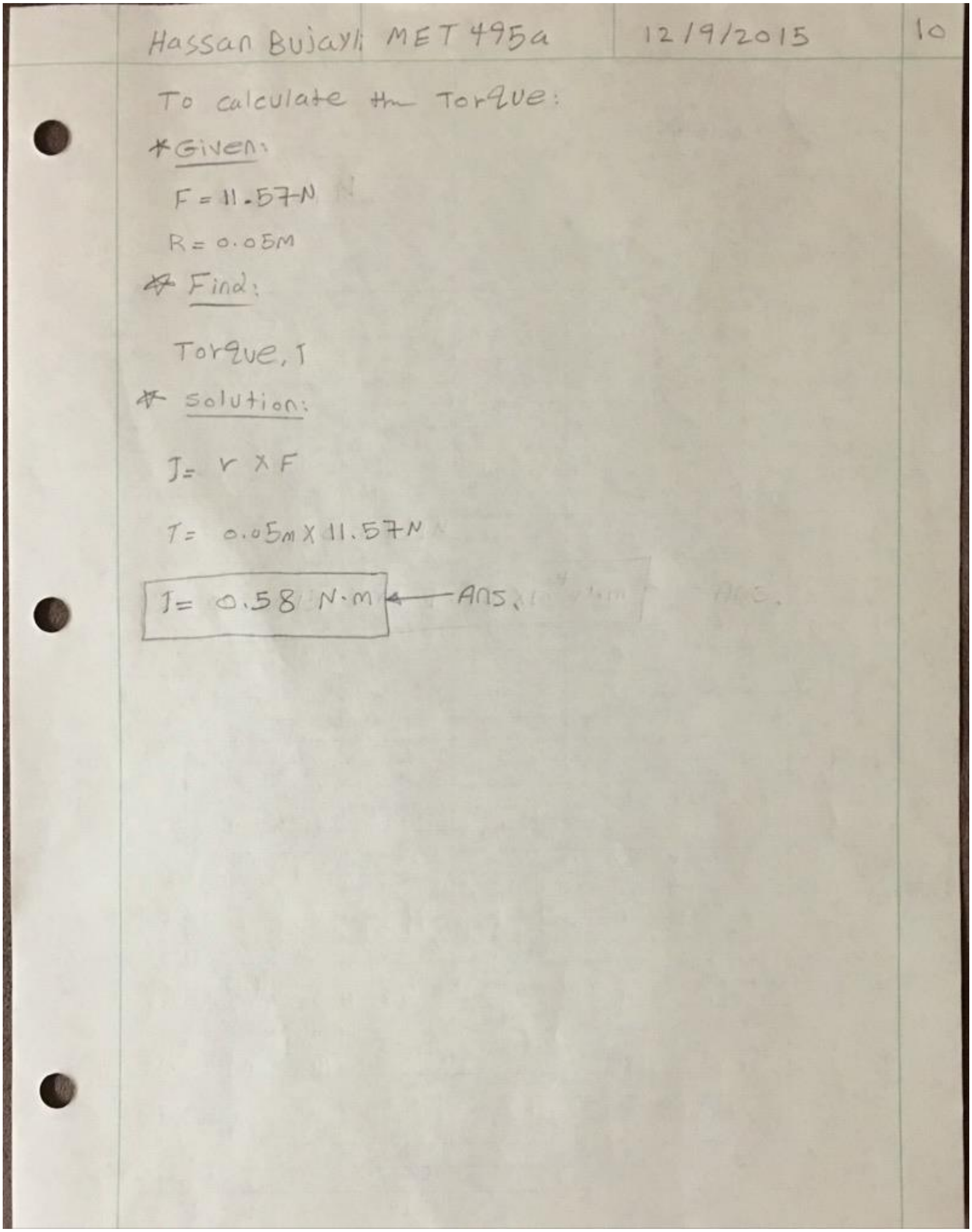
*Solution:

$$F_{Launch} = \frac{m \, dV}{dt}$$

$$F_{Launch} = 0.0045 \, kg \, \frac{(28.28 \, m/s)}{0.011 \, sec}$$

$$\boxed{F_{Launch} = 11.57 \, N} \leftarrow \text{Ans.}$$

Figure A8 (Analysis for the Force $_{Launch}$)



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To calculate the Torque:

*Given:

$F = 11.57N$

$R = 0.05M$

*Find:

Torque, T

*solution:

$T = r \times F$

$T = 0.05m \times 11.57N$

$T = 0.58\ N \cdot m$ ← Ans.

Figure A9 (Analysis for the Torque)

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To calculate friction force

Given:

$m = 0.0045\ kg$

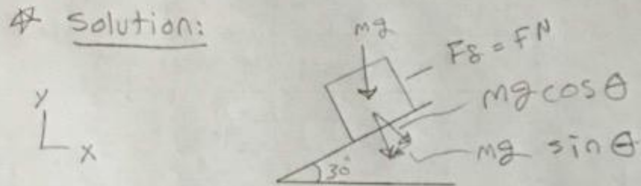
$\theta = 52^\circ$

$F_{launch} = 11.57\ N$

Find:

Determine the coefficient of static friction between the rubber and the paper airplane.

Solution:



$$mg \sin\theta = f\, mg \cos\theta$$

$$f = \frac{mg \sin\theta}{mg \cos\theta} = \tan\theta$$

$$f = \tan(52^\circ)$$

$$\boxed{f_s = 1.3}$$

Figure A10 (Analysis for the Coefficient of Static)

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To calculate the time.

* Given:

$V = 28.28 \, m/s$

$d = 0.297 \, m$

* Assume that the distance of the paper airplane when it starts gripping until it is launched.

* Find:

The time when it starts to grip until it is launched.

* Solution:

$$V = \frac{d}{t} \Rightarrow \text{solve for } t$$

$$t = \frac{d}{V} = \frac{0.297 \, m}{28.28 \, m/s}$$

$$\boxed{t = 0.01 \, sec} \leftarrow \text{Ans.}$$

Figure A11 (Analysis for the Gripping Time)

Appendix B – Drawings

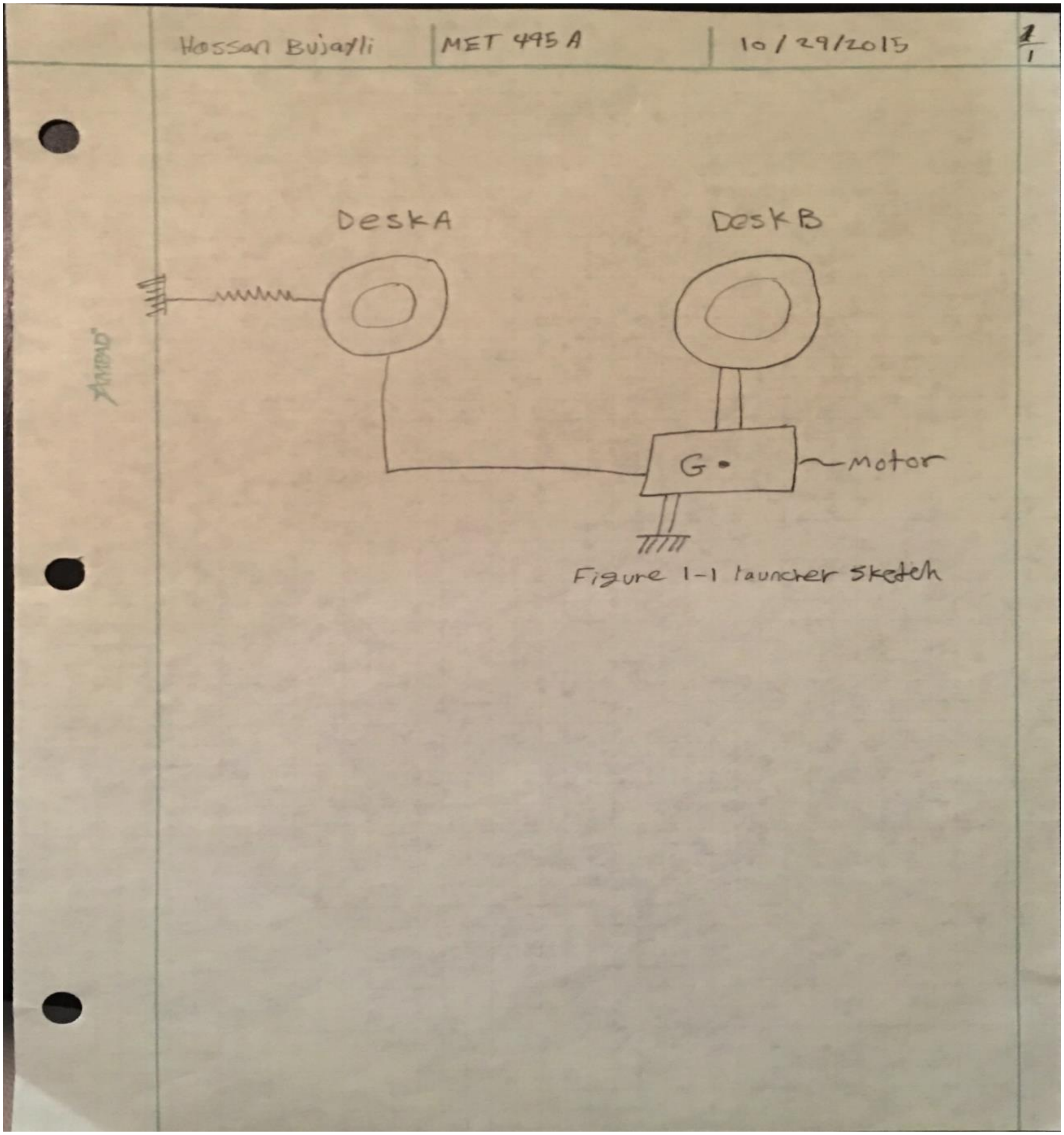


Figure B1:(Launcher Sketch)

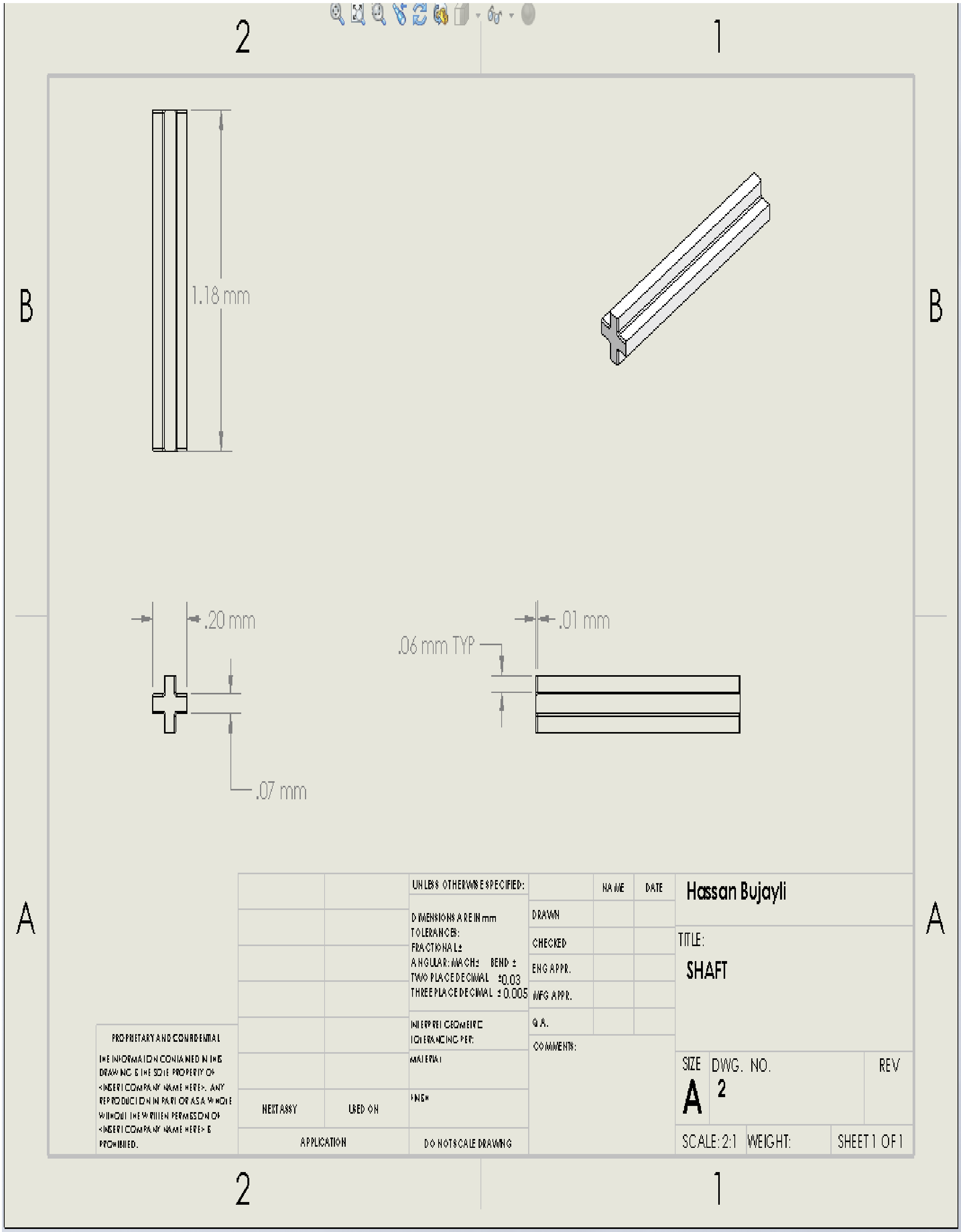
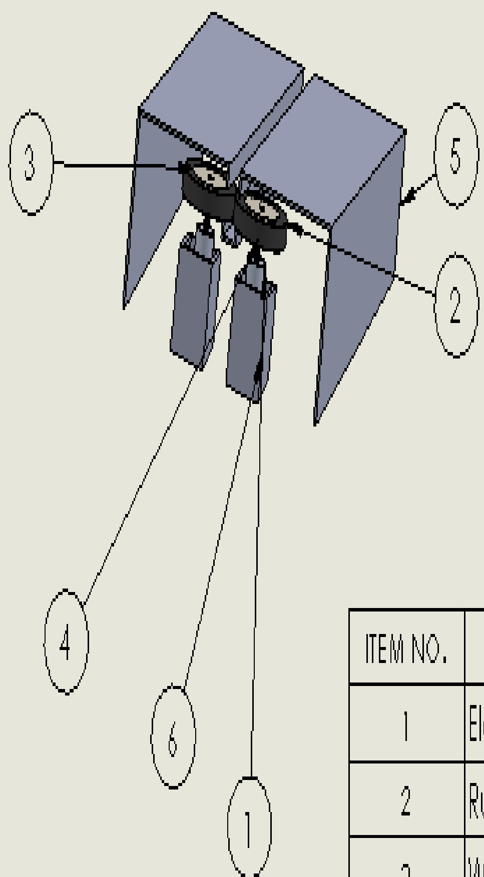


Figure B2 (Shaft)



ITEM NO.	PART NUMBER	Material	QTY.
1	Electric Motor	Combination	2
2	Rubber Tire	Rubber	2
3	Wheel	Plastic	2
4	Shafts	Aluminum 6061	2
5	Frame Launcher	Aluminum 6061	1
6	Motor Housing	Aluminum 6061	2

Figure B3: (Launcher Design and Part List with Labels)

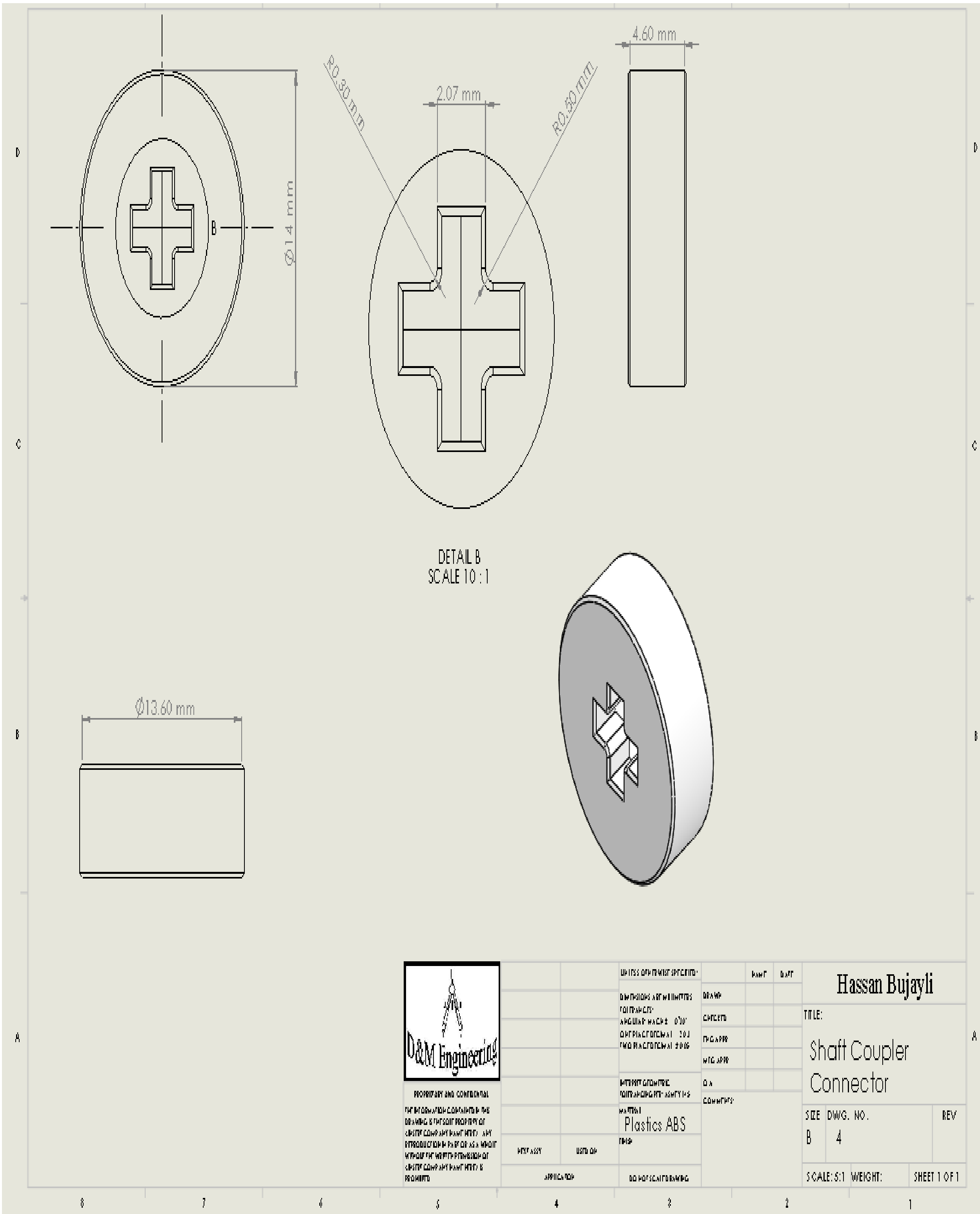
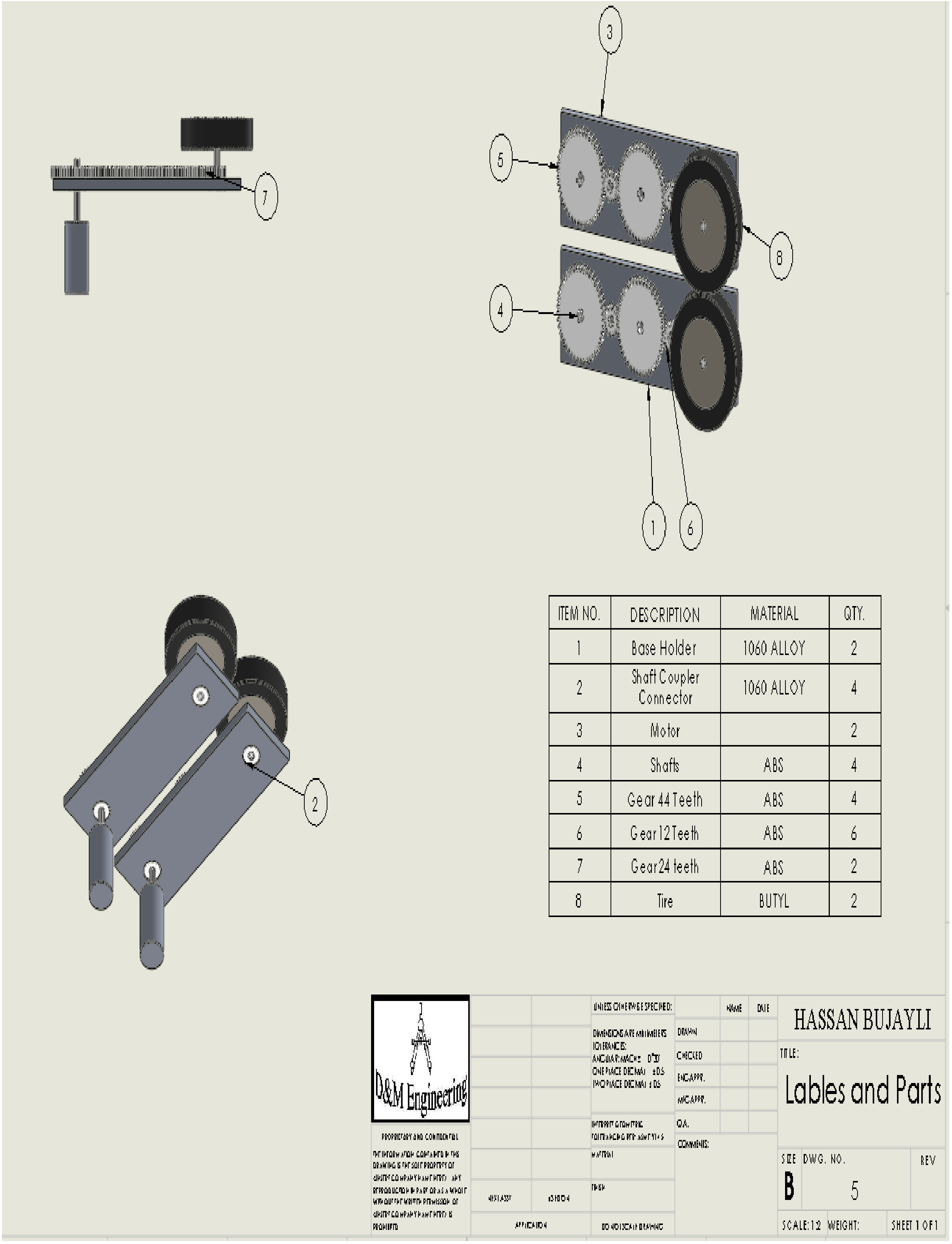


Figure B4 (Shaft Coupler Connector)



ITEM NO.	DESCRIPTION	MATERIAL	QTY.
1	Base Holder	1060 ALLOY	2
2	Shaft Coupler Connector	1060 ALLOY	4
3	Motor		2
4	Shafts	ABS	4
5	Gear 44 Teeth	ABS	4
6	Gear 12 Teeth	ABS	6
7	Gear 24 teeth	ABS	2
8	Tire	BUTYL	2

Figure B5 (Parts lists and labels)

Appendix C – Parts Lists and Budget

Parts Lists and Budget						
Part Ident	**Part Description**	**Source**	**Cost (Or Time)**	**Dispositio n**	**Quantity (or Hours)**	**Subtotal**
1	Electric Motor	Amazon	$39.99		2	$79.98
2	Gears	Lego Education	$10.17	Order 1/11/2016	6	$10.17
3	Shaft	Energy Lab 411	$12.30	Order 1/17/2016		$12.30
4	Tire	Friend (RC)	Free	Order 1/11/2016	2	$20.49
5	Shaft Coupler Connector	Machine Shop / Labor	5 hr		4	
6	Motor Housing	Machine Shop / Labor	4 hr		2	
	Total Est.				$122.94	

Figure C1 (Part Lists and Budget) Old Design

Appendix C – Parts Lists and Budget

Parts Lists and Budget						
Part Ident	Part Description	Source	Cost (Or Time)	Disposition	Quantity (or Hours)	Subtotal
1	Brush Motor	Amazon	$39.00		2	$78.00
2	Battery	Energy lab 411	Free	Order 1/11/2016	1	$0.00
3	Car Toys	Goodwill	$3.90	Order 1/11/2016	1	$3.90
4	Wood	ACE	$9.99	Order 1/15/2016	1	$9.99
					Total Est.	$91.89

Figure C2 (Part Lists and Budget) New Design

Appendix D – Schedule

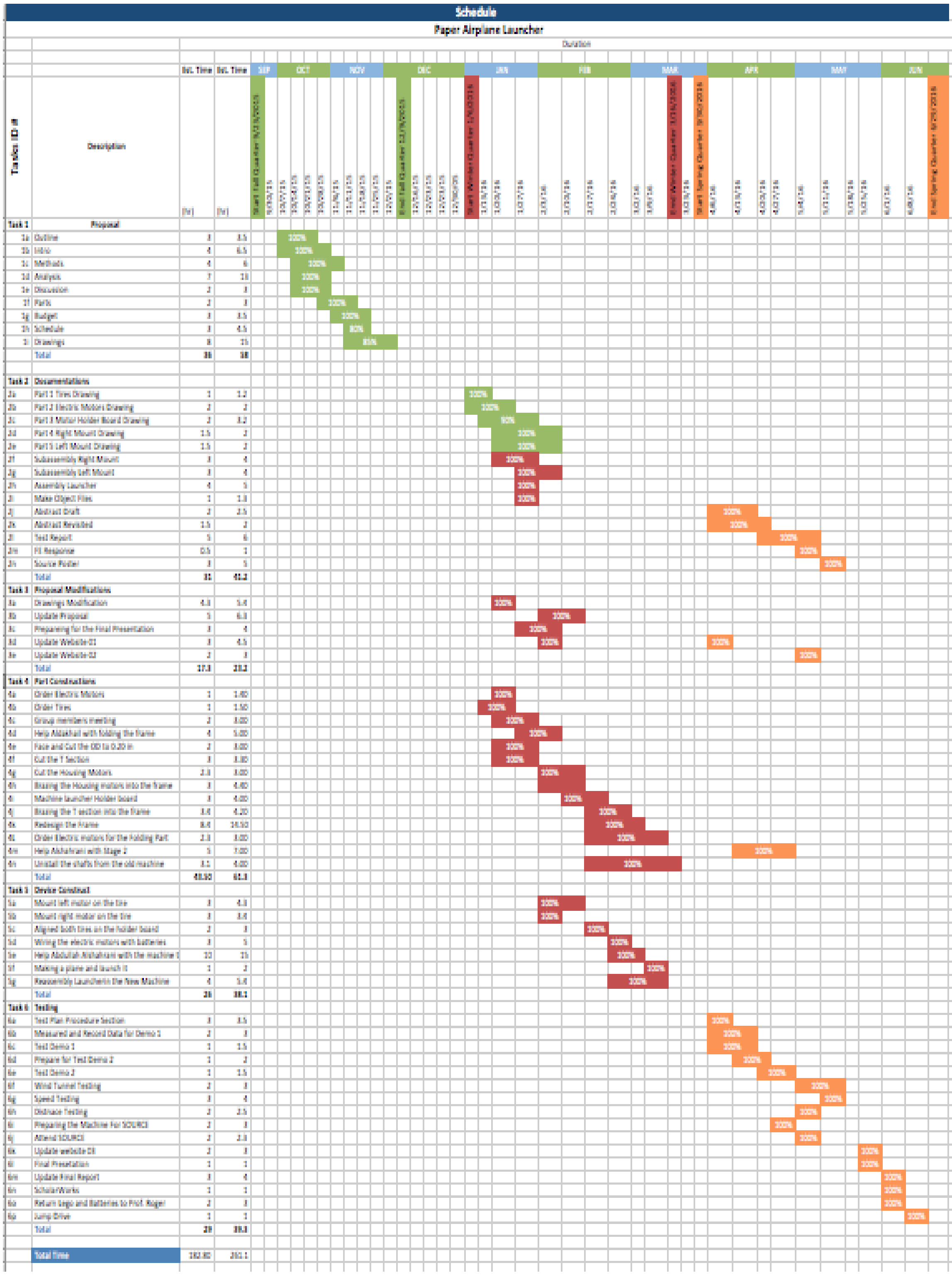


Figure D1: Gantt chart

Appendix E – Expertise and Resources

- Statics and Mechanics of Materials (By: Hibbler)
- Amazon for looking up and ordering some parts
- Matt Burvee for material acquisition and manufacturing advice
- Fundamentals of Thermal-Fluid Sciences (By: Cengel, Cimbala, and Turner)
- Finite Solutions, Inc. Solidcast Technical Workbook. 2014.

Appendix F –Testing Data

Date: Taster Name:

Test Procedure:

- The approximate time to complete the speed test of each flight is 5-15 minutes.
- The test can take a place at the Hogue building exhibit area in front of the machine lab.
- The speed test required a group of two or three to operate the machine, and record data.
- **Equipment:**

  3 regular A4 papers**,** tap measure, stopwatch, notebook.

1. Make sure the launcher battery are fully charged.
2. Set the top frame on the four legs and secures them with the screws.
3. Once the loading and the folding process are done and the paper airplane is completely free to launch, turn on the switch on.
4. Start the stopwatch once the paper airplane starts to launch and then stop the stopwatch when the paper hit the ground.
5. Turn the launcher switch off when it is not in used.
5. Measure the flight distance where the paper airplane falls.
6. Record the time in second and the distance in meter.
7. Repeat the steps 3-6 three times and calculate the speed of each flight using V= D/T, D being distance, and T being time.

Safety: Don't stand of the launcher so the paper does not hit you. There is no other safety issue to concern about this test.

Discussion: Depending on the design of the paper airplane determines its ability for speed, distance, accuracy, and performance. The airplane models with the larger wing area flew greater distances. The longer based and larger wing designs flew fastest.

Paper Size: A4 Paper made by hand

	Trail #1	Trail # 2	Trail # 3
Distance (m)			
Time (s)			
Speed (m/s)			
Average Speed (m/s)			

Appendix G – Evaluation Sheet

Procedure Checklist for the launcher Device		
Done?	**Required Equipment:**	**Notes**
	Three or more A4 paper	
	Tap Measure	
	Stopwatch	
	Notebook	
Done?	**Procedure**	**Notes**
	Make sure the launcher battery is fully charged	
	Set the top frame on the four legs and secures them with the screws	
	Insert the paper in the loading	
	Machine is able to fold the paper into an airplane shape	
	The paper airplane is compeletly free to launch	
	Turn on the launcher switch on.	
	Start the stopwatch once the paper airplane starts to launch and then stop the stopwatch when the paper hit the ground.	
	Make sure to turn the launcher switch off when it is not in used	
	Measure the flight distance where the paper airplane falls	
	Record the time in second and the distance in meter	

Figure G1 (Evaluation Form)

Appendix H – Testing Report

Introduction:

The design requirement for the launcher device is to design a launcher that can launch paper airplanes to a distance of 20 meters and launch within 10 seconds or less. The tolerance of the device should not exceed the width 12" of the system frame. Also, the length of the launcher should be 7" or less. The parameters of interest of launcher device are speed, distance, acceleration, dimension and time. The predicted performance of the launcher device is to launch the paper airplane with speed up to 28.28 m/s. The angular velocity was calculated to be 5400 rpm in order to reach the distance of 20 meters. The power needed to supply the motors is 2.49 watts. The required acceleration is 3.54 m/s^2. Finally, the expected time to launch the paper airplane is 0.01 second. The data acquisition was collected physically. Measuring tap was used to measure the distance that the paper airplane reached to. To measure the time, stopwatch was used to record the time when the paper launched until it hit the ground. From there, the velocity and acceleration were calculated using the formula V= d/t, d being the distance, and t being the time and A=v/t, v being the velocity and t being the time. The schedule shows test demo 1 and 2. Test demo 1 is about the maximum distance of the paper airplane made by the machine. Test demo 2 is about the distance, acceleration, velocity, and time of the paper airplane that made by the machine vs. the hand. Gantt chart shows the date of each test in the report appendix E.

Method/Approach:

The resource needed to make the testing is three people at least to run the machine in order to fold a standard sheet of paper into an airplane shape and launch it. To achieve the best flight, an airplane that has balance of lift, thrust, gravity, and drag will fly longer. Thus, the testing will be on the finish paper airplane model. The aerodynamic properties are needed to test the drag force of the final design model. To test the distance of each flight for each paper airplane, a tape measure will be used to measure how far the paper plane flow from a starting line. From there, the time for each flight will be tested using stopwatch. With that being said, using this equation to test the speed of each flight V= D/T, D being distance, and T being time. The data that is need for the two tastings is the time and distance. After getting the needed data, acceleration and velocity can be calculating using the above formulas. The only operational limitation of the device is temperature and the location. The temperature should be around 60° to 80° F. Due to the properties of air, the flight of the paper airplane might be affected. The testing should be done in a closed area and no fans or air conditioners running. The precision and accuracy may vary depending on the design of the paper airplanes. An airplane might fly to a farther distance if the drag value and the weight are little as possible. A balance of drag, gravity, thrust, and lift will result in long flight. The data storage/ manipulation/ analysis are kept in Microsoft Excel and presented as table to show the maximum, minimum, and average of the distance, speed, time, and acceleration.

Test Procedure:

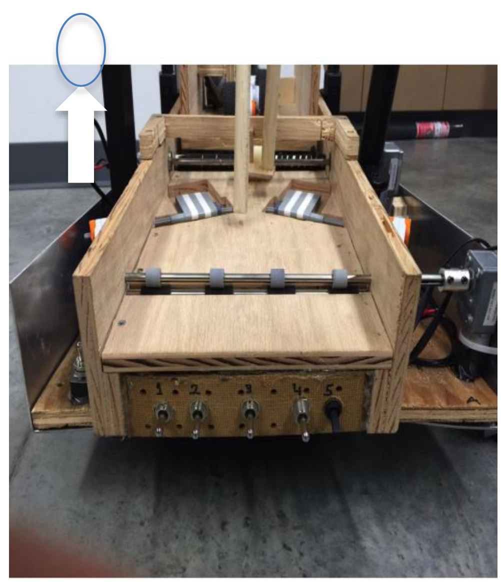
- The approximate time to complete the speed test of each flight is 5-15 minutes.
- The test can take a place at the Hogue building exhibit area in front of the machine lab.
- The speed test required a group of two or three to operate the machine, and record data.
- **Equipment:**

  A4 papers**,** tap measure, stopwatch and notebook.

  1. Make sure the launcher battery are fully charged.

  2. Set the top frame on the four legs and secures them with the screws.

  3. Insert the paper in the loading to fold the paper and when the folding process is done and the paper airplane is completely free to launch, turn on the launcher switch on.



  4. Start the stopwatch once the paper airplane starts to launch and then stop the stopwatch when the paper hit the ground.

  5. Turn the launcher switch off when it is not in used.

  5. Measure the flight distance where the paper airplane falls.

6. Record the time in second and the distance in meter.

7. Repeat the steps 3-6 three times and calculate the speed of each flight using V= D/T, D being distance, and T being time.

Safety: Don’t stand of the launcher so the paper does not hit you. There is no other safety issue to concern about this test.

Discussion: Depending on the design of the paper airplane determines its ability for speed, distance, accuracy, and performance. The airplane models with the larger wing area flew greater distances. The longer based and larger wing designs flew fastest.

Deliverables:

The parameter values are showing in the table 1-1 below

	Paper Airplane Made by the Machine			Paper Airplane Made by Hand		
Trail #	1	2	3	1	2	3
Distance (ft.)	18.5	28.5	22	14.5	19	12
Average Distance (ft.)	23			15.2		
Velocity (ft./s)	13.2	11.4	11	9.17	9.74	7.7
Average Velocity (ft./s)	11.9			8.9		
Time (s)	1.4	2.5	2	1.58	1.95	1.58
Average Time (s)	2.0			1.70		
Acceleration (ft./s^2)	9.4	4.56	5.5	5.8	5.0	4.9
Average Acceleration (ft./s^2)	6.50			5.2		

Table 1-1 shows the parameter values of testing 1 and 2

- The calculated value for the distance is 65 feet. The calculated value for the speed is 93 ft./s. The predicted time starting from gripping the paper until it is launched is 0.01 second. Finally, the calculated value for the acceleration is 11.6 ft./s^2.
- Success criteria values did not meet the calculated values. The calculated speed is 93 ft/s. However, the average speed is 11.9 ft/s. The calculated distance is 65 feet and the average value for the distance is 23 feet. Finally, the calculated value for the acceleration is 11.6 ft/s^2 and the average value for the acceleration is 6.50 ft/s^2.
- To conclude, the main reason for high differences between the calculated and the actual values might be due the changes of airplane design and the

aerodynamics. Also, the motors when they start, they are not in their full speed which 5400 rpm. The assumption is made based in their full speed. These two reasons might make a lot of changes with the testing values.

	Paper Airplane Made by the Machine			Paper Airplane Made by Hand		
Trail #	1	2	3	1	2	3
Distance (ft)	18.5	28.5	22	14.5	19	12
Average Distance (ft)	23			15.2		
Velocity (ft/s)	13.2	11.4	11	9.17	9.74	7.7
Average Velocity (ft/s)	11.9			8.9		
Time (s)	1.4	2.5	2	1.58	1.95	1.58
Average Time (s)	2.0			1.70		
Acceleration (ft/s^2)	9.4	4.56	5.5	5.8	5.0	4.9
Average Acceleration (ft/s^2)	6.50			5.2		

Table 1-2 shows the data and the result values.

Appendix I – Resume

HASSAN **BUJAYLI**

800 E Juniper Ave Apt # 3, Ellensburg , WA 98926 | C: (610) 999-7574 | bujaylihassan@gmail.com

Summary

Highly-motivated senior Mechanical Engineer with over 1 years experience dealing with automotive mechanics complete system diagnostics and full automotive troubleshooting and testing. Seeking to get an opportunity to work in a position as Mechanical Engineer in order to contribute the success of the employers and at the same time my individual growth.

Education

Associate of Applied Science: Motor vehicles and Technology **2007**
Jeddah Collage of Technology Jeddah, Makkah, Saudi Arabia

Bachelor of Science: Mechanical Engineering technology **2016**
Central Washington University Ellensburg, WA, United States
Member of International Club
[3.01] GPA
Coursework in Product Design, Material Engineering and Design Engineering
Coursework includes Fluid Mechanics

Highlights

- Proficient in SolidWorks
- Project management
- Mechanism design and analysis
- Written and verbal communication skills in English and Arabic
- Advanced in Microsoft Excel, Word, and PowerPoint
- Time management skills
- Proficient in AutoCAD

Experience

Automotive Technicians **01/2008 to 01/2009**
Mercedes Benz **Jeddah, Makkah**
Perform work as outlined on repair order with efficiency and accuracy, in accordance with dealership and factory standards.
Diagnose cause of any malfunction and perform repair.
Inspect and diagnose diesel, gas, electric automotive equipment, components and systems to determine necessary repairs.
Perform works on autos and trucks.

Figure I1 (Resume)