Table of Contents

Table of Figures

Table of Tables

1. Problem Formulation

1.1. Introduction:

Laurel Tree Charter School, located in Arcata, California, recruited Humboldt State University's Engineering 215 students to design an electric, commercial food blender that is powered by human energy to use in the school's cafeteria.

1.2. Objective

The objective of this project is to design a human powered blender for Kindergarten through 12th grade students.

Figure 1-1 Black box Diagram

This Black Box Diagram helps to identify and understand the problem and a possible solution.

2. Problem Analysis and Literature Review

2.1. Introduction to Problem Analysis

Section two overviews the initial problem analysis of the human powered blender project that will be completed under the provisions of the client, Laurel Tree Charter School. The problem analysis identifies criteria discussed with the client in order to clarify and focus on the needs that must be satisfied by the project. The problem analysis will review the specifications, considerations, criteria and constraints that will help define the problem.

2.1.1. Specifications

Specifications from the client are the minimum guidelines that must be met in order to complete the project successfully. The major specifications for this project are:

- Available Space- If the project is housed outside; there is more space for the project. If it must be stored inside, sizing it so it can fit through doors is important. In order for us to use the project inside, it must be small enough to fit into a storage closet/shed, confining the project to three and a half feet for one dimension.
- Evident Educational Value- Students must be able to witness their physical action is generating power for the device.
- User Guide- The device must include a user guide/repair manual illustrating how the device works, and how to repair any anticipated broken parts.

2.1.2. Considerations

Considerations are client-specific qualities that may influence future design decisions. These considerations are:

- Vandalism- Objects and structures located in front of the school grounds have reportedly been subject to frequent vandalism.
- Mobility- The machine should be, if necessary, easily transported between the storage room where it will be held, and the area in which it will be used.
- Usability- Children of all age groups form five-17 will be using this machine.
- Replaceable Parts- The interface between the blender container (carafe) and the different available blade attachments should be easily replaceable.
- Versatility- The device must be able to homogenize anything that at normal blender could.

2.1.3. Criteria

Criteria help to determine appropriate solutions to the problem by examining what is important. Criteria will also help to determine what is more or less necessary to research in the literature review.

Table 2-1 This table shows the criteria and the relevant constraints that go along with it.

Criteria:	Constraints:
Safety	-All moving parts should be housed so as to not come into contact with the user in any possible way. -Material should be sturdy, so it's not broken during use, and not flammable.
Usability	-Any time the blender is used there will be at least ten students present, and will be used for at least thirty minutes at a time. -Two students may use it simultaneously.
Production Volume	-The blender will also be used at school events, involving up to 50 people and a much longer duration for the use of the blender. -The blender should produce at least one, delicious blended beverage between the works of at least two people, within at least ten minutes.
Durability	-This device should be able to withstand multiple uses per week by different age groups.
Level of Educational Value	-Students should know more about mechanical, kinetic, or electrical energy and human power production than they did before use.
Cost	-The blender must cost less than $400.00 to build. -The breakable parts must cost less than one hundred dollars per year to replace. -The working blender must cost no money to function.
Repair and Maintenance	-The device should be easily repaired by identifying the problem in the user guide and following instructions to repair.

2.1.4. Usage

The blender will be used by students of all ages and even some adults. It may be used for up to thirty minutes to an hour at a time, for an unknown number of days per week. It must be able to make smoothies in a reasonable amount of time.

2.1.5. Production Volume

There will be only one blender produced for Laurel Tree Charter School. It must be able to supply smoothies for all participants and observers that are using the device. It will be a minimum of ten people to supply at once, which means more than one smoothie may have to be made.

2.2. Human Powered Energy systems:

2.2.1. Energy

There are many different forms of energy: kinetic, heat, chemical electrical, photon (light energy), and nuclear energy. (Jansen) The First Law of Thermodynamics states: energy can never be created or destroyed, which must be considered when dealing with energy and efficiency. One way to increase the efficiency of a system is to reduce the number of energy conversions to go through (Jansen). Eight practical conversions of energy are as follows:

- Photon to chemical energy (photosynthesis) (Jansen)
- Chemical to heat (combustion) (Jansen)
- Heat to kinetic (combustion engine, which is typically an expansion of chemical to heat) (Jansen)
- Kinetic to electric (electrical generator)/electric to Kinetic (electrical motor) (Jansen)
- Heat to Electrical (Thermo coupling) (Jansen)
- Chemical to Electrical (fuel cells and batteries) (Jansen)
- Nuclear to Heat (nuclear reactions) (Jansen)
- Photon to Electrical (photovoltaic) (Jansen)
- A model for a typical human powered system is as follows:

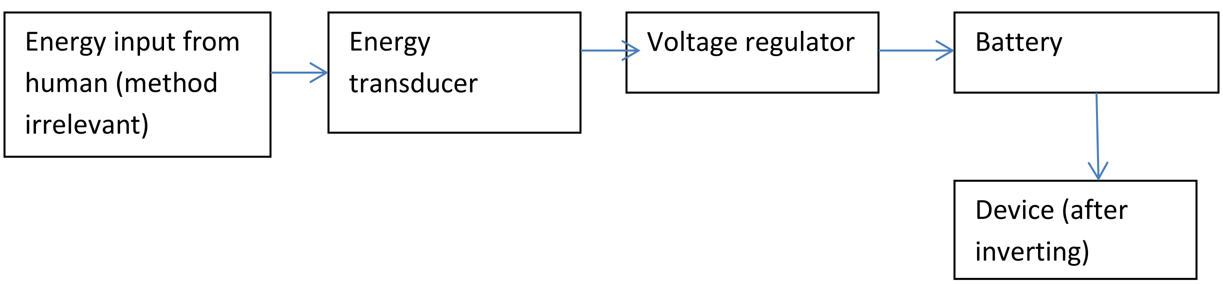

Figure 2-1 Flowchart demonstrating energy flow in small scale electrical systems (Image by Adam Clark)

This schematic incorporates the following conversions: Kinetic to electric (input to energy transducer), electric to chemical (battery charging), and chemical to electric (battery to inverter). Since the standard formula for efficiency is $\eta_{system} = \eta_1 x\ \eta_2 \ldots$(efficiency of each part multiplied together). From this it is inferred that the overall efficiency of the system could be increased by reducing the number of energy conversions. Leaving out the battery could increase the efficiency of the system, but would rid the possibility of future energy storage (Jansen).

2.3. Electrical Components

- Fuse: A fuse protects excessive current from flowing. (Windrock)
- Diode: Used to allow a current to flow in one direction, while blocking the other direction. They are commonly used to regulate voltage, because they are triggered by voltage thresholds. (Windrock)

- Energy Storage system: contain batteries to hold charge and discharge electrical energy as needed. (Windrock)
- Charge Control/Voltage Regulator: Prevent batteries from overcharging or receiving too much voltage to prevent damage to the battery. (Windrock)
- Rectifier: Converts alternating current (AC) to direct current (DC). (Windrock)
- Relays: Relays are switches that are operated electrically, typically to start and stop a system from running. (Windrock)
- Inverters: Convert DC to AC, which can travel further without losing power, and is more commonly used with household appliances. (Windrock)
- Generator: Converts mechanical power into electrical power. (Windrock)

2.3.1. Batteries:

Batteries store energy from a chemical medium. A standard car battery, for example, is filled with interleaved plates of lead and lead dioxide which are soaked in sulfuric acid diluted with water to be used of as an electrolyte. (Allen, Battery Maintenance). Batteries will charge by combining some sulfuric acid with lead, reducing its concentration and coating the plates with layers of lead sulfate, which is a rather spongy material. The reverse process yields over 90 percent of the stored energy back. As a battery is used (charged or discharged), the electrolyte diffuses from one plate to the other; at high rates of use, the acid begins to develop a gradient. (Allen, Battery Maintenance)

2.3.1.1. Charging

Voltage is a good indication of the charge of the battery. A battery at full charge will produce 12.6 volts, and when discharged it will produce as little as 11.2 volts. (Allen, How to Charge your Battery). A typical battery charger (for car batteries) is a transformer connected to a diode to regulate a constant charge. Overcharging a battery will damage it and prevent it from working correctly. Charging a 12 volt battery requires less than 14.4 volts to prevent an overcharge. It should be noted that fully discharging a modern "Maintenance-free" battery will prevent it from ever being able to take a full charge again. This is due to the fact that they lack filler caps and have higher levels of electrolytes covering the plates. (Allen, How to Charge your battery)

2.3.1.2. Safety:

Whenever working with a car battery, it is important to disconnect the negative terminal first. This is important, because if one were to touch the positive portion while the negative is still connected, one could get shocked. (Allen, Battery Maintenance)

2.4. Alternating Current versus Direct Current

The difference between Alternating Current (AC) and Direct Current (DC) is the flow of electrons. In direct current, electrons can only flow one direction, and in AC, they flow both directions. Batteries store power in DC, and thus to run an AC appliance, it must be inverted to

AC before it is utilized. AC energy cannot be stored. AC typically has more power, 12v DC can be inverted to 120v AC. (Jansen)

2.5. Human Power

2.5.1. Children versus Adults

NASA has recorded that the long term power output of an average male adult who is exercising at a comfortable pace is seventy-five watts (Dean, T). For people who are physically fit, they can produce one hundred watts for a long period of time and more than three hundred watts for a short period of time. Children, on the other hand, don't excel as well as adults in activities that involve endurance (Siegel J., Gilders R., Staron R., Hagerman F.). Therefore, their energy output is lower than that of an adult. Children's muscle mass is also lower than that of an adult (Siegel J., Gilders R., Staron R., Hagerman F.).

2.5.2. Methods of Human Output

Humans can generate quite a bit of energy throughout their daily routines, including walking, biking, and playing on a see saw. To be able to harvest energy humans generate, the energy people harvest has to come from somewhere. The food humans take in use energy from the sun to grow. From there, chemical energy is produced by eating the food they take in. The chemical energy is then stored in the muscles of the human. The movement, which may be any daily activities such as walking, causes the muscles to use the chemical energy and turn it into kinetic energy. That kinetic energy is turned into the electrical energy by a generator. The electrical energy is turned into chemical energy that is stored in a battery and is converted into electrical energy to power appliances or even a classroom ("See Saw to Light Classroom" *Science in the News*.).

2.5.3. Exerting Power and Force

Power is the rate at which energy is transferred or work is done.(Bernstein, T. (2011) "Human Power Output on a Bicycle) The rate of energy that people exert depends on the amount of exercise they engage in (Bernstein, T. (2011) "Human Power Output on a Bicycle). For someone who bikes, the energy output may vary depending on the speed and cadence(Bernstein, T. (2011) "Human Power Output on a Bicycle). Cadence is a fancy term for the rhythm a cyclist's legs have to keep the pedals moving. A faster rhythm and lower speed has similar energy output as having a slower rhythm and a higher speed(Bernstein, T. (2011) "Human Power Output on a Bicycle). Bicyclists who use a faster rhythm and lower speed usually aim towards exerting two hundred watts, while bicyclists who use a slower rhythm and higher speed usually aim towards exerting one hundred watts (Bernstein, T. (2011) "Human Power Output on a Bicycle). The more aerobic exercise someone does, the more energy that person uses ("Nutritional: Balanced Energy Output").

There have been many studies that have tried to answer people's speculation of how much more energy humans can generate if they use arm and leg power simultaneously. Three studies are mentioned in the book The Human-Powered Home, each with a different percentage of how much more energy people can produce. The first study the book mentions finds that using a hand crank and pedaling at the same time for a small amount of time will produce eighteen percent more power than pedaling alone. The second study the book mentions recorded that using a hand crank and pedaling at the same time would produce thirty percent more power than pedaling alone. The book mentions a third study that was done where researchers came to a conclusion that people can have output fifteen percent more power if they use a hand crank and pedal for approximately five minutes (Dean, T). More power can be generated in a small period of time if using the pedaling method. By cranking a hand crank away from oneself, thirty percent more energy can be generated than if cranking it towards oneself (Dean, T). Table 2-1 shows the output, in watts, of various activities such as pedaling and rowing. The table also includes the amount of time a person does the activity listed if the output varies with time. From the table, you can see that the activity with the most output is rowing within the time frame of one minute and the activity with the second greatest output is pedaling within the time frame one minute.

Table 2.2 Human Power Output Potential for Various Activities

Activity	Duration at Measurement	Potential Output (Watts)[15, 16, 17, 18, 19, 20, 21]
Respiration (passively harvested)	Unlimited	.1–1
Pushing a button	Unlimited	.3–.6
Heel strike and shoe flexure (passively harvested)	Unlimited	2–20
Squeezing a lever	> 1 hour	4–12
Pulling a 1-meter long cord	Unlimited (repeated pulls)	10–25
Hand-cranking (one-armed)	1 minute	110–140
Hand-cranking (one-armed)	30 minutes	40–45
Hand-cranking (one-armed)	> 1 hour	10–30
Pedaling	1 minute	400–500
Pedaling	10 minutes	300–400
Pedaling	1 hour	225–300
Pedaling	Unlimited	75
Rowing	1 minute	600–750
Rowing	5 minutes	350–380

Figure 2-2 Chart of various activities and the output (in Watts) that is produced (Davis 2008)

2.6. Blender Successes and Failures

2.6.1. Pedal Powered Blender

The most common method for a human powered blender is the Pedal Powered Blender. “This blender can be used for anything you would use a normal blender for. Simply add the ingredients and bike,” (Bike 2012). For this blender, you will need a few materials, tools, and a bike. You have the option of a trainer bike or a regular bike. A trainer bike is not mobile while a regular bike is. The blender is assembled by first removing the useless power draining materials from the blender, then by making wooden supports and a base to attach to the bicycle, next you install the blender and a friction wheel to the back tire of the bike and you are ready to use it. The way you use it is by adding your ingredients and pedaling the bike. As the back wheel spins, it rotates the friction wheel spinning the blades. Once you believe your product is finished, you may stop pedaling. The Pedal Powered Blender, like every other product, has its advantages and disadvantages. (Bike 2012)

Figure 2-3 Pedal Powered Blender.

2.6.1.1. Advantages

One advantage of the Pedal Powered Blender is how easy it is. Putting together the blender as well as using it is a very easy task. Another advantage is the convenience. You can have a nice work out with a reward when you are done. Depending if you are using a regular bike of a trainer bike, your blender can also be mobile. The biggest advantage is how fun it is to use.

2.6.1.2. Disadvantages

The pedal powered blender however has numerous disadvantages. For instance if you do not purchase a trainer bike, which is expensive, you will need to be mobile all the time to blend your product. If you do not already own a bike it could be expensive to purchase one. Something that

Indestructible also mentioned is "For really hard things such as ice, it is best to start moving before adding the ice, otherwise the blender just jams," (Bike 2012). This can be a big problem with the blender being on the back end of the bike. Overall the Pedal Powered Blender has stronger disadvantages than advantages.

2.6.2. Rowing Machine by Team Tandemonium

Another method of a human powered blender is Engineering 215 Introduction to Design rowing machine by Team Tandemonium. For building this rowing machine, you will need wood, hardware materials, a bicycle and bicycle supplies. Basic instructions for building the rowing machine are to construct a base, create a pulley compartment, create a wheel mount, build a blender mount, construct a blender drive interface, and build your rolling seat. The way the rolling machine blender works is by a person sitting on the rolling seat and moving back and forth. The motion of the person pulls a retractable band that spins the wheel which then spins a skateboard wheel that is attached to the blender and ultimately causes the blades to rotate. (Wong 2011).

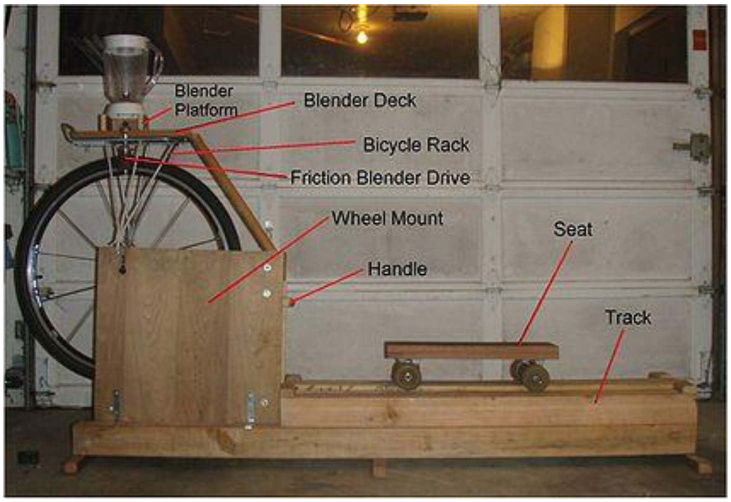

Figure 2-4 Engineering 215 Introduction to Design rowing machine by Team Tandemonium.

2.6.2.1. Advantages

Some advantages of using a rowing machine blender are how well the blender works. Team Tandemonium mentions that "multiple different items were tested in the blender and it was found that everything from fresh or frozen fruit to ice could be thoroughly pulverized into a homogeneous mixture," (Wong 2011). Other advantages would be how simple it is to use, how sturdy the machine is, and how stable the blender is held into place.

2.6.2.2. Disadvantages

Although based on the Appropedia page *Locally Delicious rowing machine blender for schools* there seems to be some critical disadvantages using this method as a human powered blender such as:

"Over time the skateboard wheel wears into an optimum phase with increase surface area contact, then wears further and does not hook up with the tire as well," (Wong 2011).

"The springs in the pulley system were quickly affected by the climate in Humboldt County and quickly showed signs of oxidation. The spring may lose some elasticity and become stiff," (Wong 2011).

"The bicycle wheel will require some maintenance as well, specifically the tire pressure. A somewhat low tire pressure increases the friction between the tire and the skateboard wheel," (Wong 2011).

Based on these maintenance results the disadvantages outweigh the advantages.

2.6.3. Hand-Cranked Blender

There is also a Hand-Cranked Blender named the Vortex created by GSI Outdoors. This blender has a detachable handle and "The long handle can be attached to ether one of two square-ended pins in the base for low power or high power blending," (Dean 2008). The pitcher is also made of a sturdy plastic and a weighted base. The way the Hand-Cranked Blender works is by placing your ingredients into the blender and simply cranking the handle. (Dean 2008).

Figure 2-5Hand-Cranked Blender named the Vortex created by GSI Outdoors.

2.6.3.1. Advantages
Some advantages of the Hand-Cranked Blender are how convenient it is. This blender is small and portable. “The Vortex blender comes with a C-clamp for mounting to a counter or a shelf,” (Dean 2008). The blender is also extremely easy to use. All you need to do is turn the crank.

2.6.3.2. Disadvantages
As convenient and easy as this blender is to use it has some major disadvantages. This blender was created more for campers. This product is small and portable, but it is flimsy. Even though this product seems easy to use *The Human-Powered Home* found out that “Users of the blender, including myself, have found that it blends liquids with moderate effort at low of high spends. Crushing ice or blending thicker substances, like waffle batter, can demand high significant effort and is best begun with the handle attached to the low power connector,” (Dean 2008). Another thing is this blender is said to be a bit noisier. Overall the disadvantages are concerning and overcome the advantages.

2.7. Blender Functionality

2.7.1. Function

A blender is a laboratory and kitchen appliance that is used to emulsify, puree, or mix food or other substances. (Bellis, Mary. 2010)

2.7.2. Power Usage
When predicting an appliance’s power usage, it is important to consider that a blender will require an initial burst of power upon startup that’s higher than the amount of power used to maintain the blender’s operating speed. A common household kitchen blender will use between 300-400 watts of power while operating.

2.7.3. Electricity
Electricity can be generated by electromagnetic force (EMF). Magnets create a magnetic field just like coils of wire do, and when the two magnetic fields interact with each other, electric energy is the result, whether it be static, direct, or alternating current. (Nave, R. 2012)

2.7.4. Electromagnetic Induction
Magnets have a north and south end. North attracts south and south attracts north. They are usually made of metals like iron, neodymium, aluminum, nickel, and cobalt. Wires that conduct electric charge also generate magnetic fields. Electromagnetic induction is the discovery that by moving a wire through a magnetic field, electric current is produced. The interaction between these two magnetic fields will create a force on the charge of the wire (Faraday’s Law). Work is performed on these charges and their potential energy is increased. Electromagnetic force (EMF, measured in Volts) equals the magnetic induction times the length of wire times the velocity of the wire. (http://library.thinkquest.org/13526/c3c.htm)

2.7.5. Voltage

Also known as Grippage (abbreviated V), voltage is electrical energy potential per unit charge. (1 volt = 1 joule/coulomb = energy/charge). Voltage is a measurement of pressure. A battery takes in energy at a low voltage, performs work on it, and releases it at a higher voltage. (E.g. a 12V battery performs twelve Joules of work per unit charge that passes through it. Ordinary house wiring is standardized at 120 Volts (line voltage). (Nave, R.)

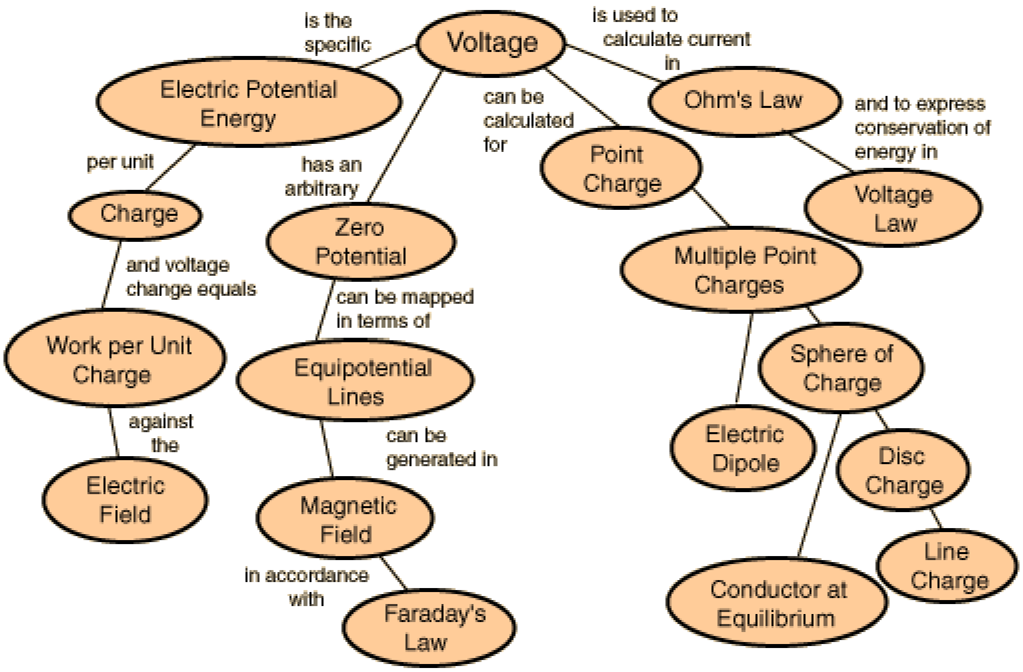

Figure 2-6 (R. Nave, http://hyperphysics.phy-astr.gsu.edu/hbase/electric/volcon.html#c1)

2.7.6. Ampere

Ampere (A) is a measurement of electrical energy flow, also called current. A 120 V household circuit is rated at 15 amps. Trying to pull to much amperage from a circuit can cause the wiring to heat up and cause a fire. More amperage requires a larger wire, similar to a bigger pipe being required to carry more flowing water. (Fey, 2006.)

2.7.7. Wattage

Many Loads are rated in Watts (W) or, (1 joule/second). Electrical wattage is the measurement of Voltage X Amperage. In this way, a household circuit is approximately 1800 watts. (Fey, 2006)

2.7.8. School Playground Equipment Requirements

"(Health and Safety Code section 115725-115735) begins:

All new playgrounds open to the public built by a public agency or any other entity shall conform to the playground-related standards set forth by the American Society for Testing and Materials and the playground-related guidelines set forth by the United States Consumer Product Safety Commission.

Replacement of equipment or modification of components inside existing playgrounds shall conform to the playground-related standards set forth by the American Society for Testing and Materials and the playground-related guidelines set forth by the United States Consumer Product Safety Commission. (leginfo.ca.gov)

3. Alternative Solutions

3.1. Introduction

Section 3 consists of alternative solution. For this, brainstorming sessions were held in order to create and develop these alternative solutions. During brainstorming sessions a total of seven alternative solutions for designing our human powered blender were created. Each of these designs satisfies the criteria and objective given by Laurel Tree Charter School.

3.2. Brainstorming

Team Pink Elephants came together for a total of two brainstorming sessions. One brainstorming session involved scratch paper and one involved a white board in an empty classroom. The purpose of the brainstorms was to approach creative ideas as a group and build off of them. During the brainstorm sessions the literature review was found to be very helpful. We also set guidelines allowing wild ideas and banning criticism. With this seven alternative solutions were produced.

3.3. Alternative Solutions

Listed below are descriptions of the seven alternative solutions created during the two brainstorming sessions. Each alternative solution includes a rough sketch as an aid to understanding the design. The alternative solutions are the Friction Drive Blender, the Rowing Machine Blender, the Recumbent Tandem Bicycle Blender (mechanical), the Recumbent Tandem Bicycle Blender (electrical), the Sustain-A-Swing, the Mechanical Blender-Hand Crank Method, and the See-Saw Playground Generator. From these seven alternatives, one will be chosen based on how well it suits the criteria and objective given by Laurel Tree Charter School.

3.3.1. Friction Drive Blender

The Friction Drive Blender is a stationary bike that when pedaled uses friction drive to power the blender. Items needed to create this blender are a blender, some wood, a bicycle rack, a stationary bicycle, a small stick or pole that can be lodged into the blender, and skate boarding wheels. This alternative would be assembled is by first removing the draining materials from the blender, leaving only the rotating-blades. Use the wood to create a base to attach to the bike rack where the blender will be put in place. Next, install the friction wheel to the blender. This part is created by sliding the skateboard wheels onto the end of the stick then mounting them and lodging the stick into the blender where the blade rotating pieces are. Once the pedaling starts, the tire will rub on the friction wheel, attached to the rotating-blades, and begin to spin the blade.

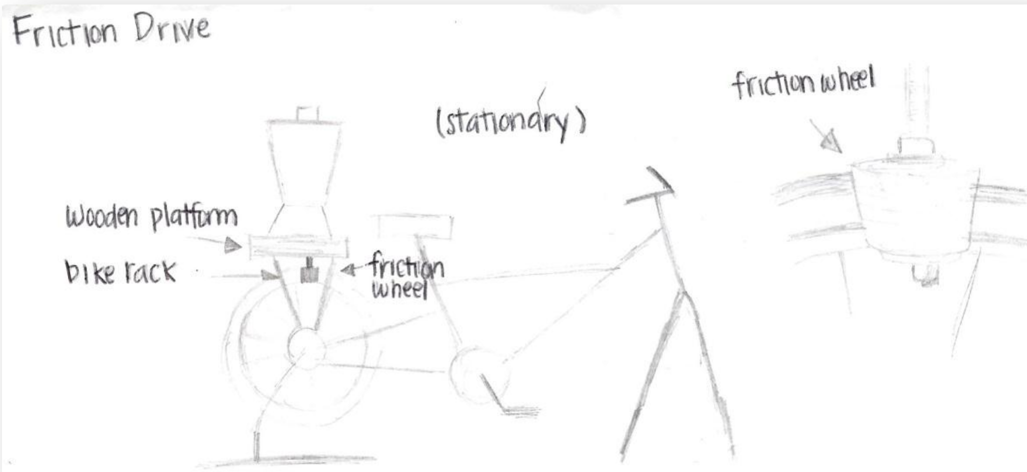

Figure 3-1 Labeled drawing of friction drive blender (photo by Michelle Aldrete)

3.3.2. Rowing Machine Blender

The Rowing Machine Blender is a friction and chain driven machine. Items need to create this blender are wood, hardware materials, a stick like item that can be lodged into the blender, skate boarding wheels and bicycle supplies such as wheels and chains. Basic instructions for building the rowing machine are, construct a base for the entire machine, create a pulley compartment that is durable, and make sturdy a wheel mount where the bicycle wheel will be place along with the bike chains, create a blender mount, construct the friction drive, and build your rolling seat. The rolling machine blender works by pulling a retractable band while moving back and forth on the pulley cart, which spins the bicycle wheel, which then spins a skateboard wheel that is attached to the blender causing the blades to rotate.

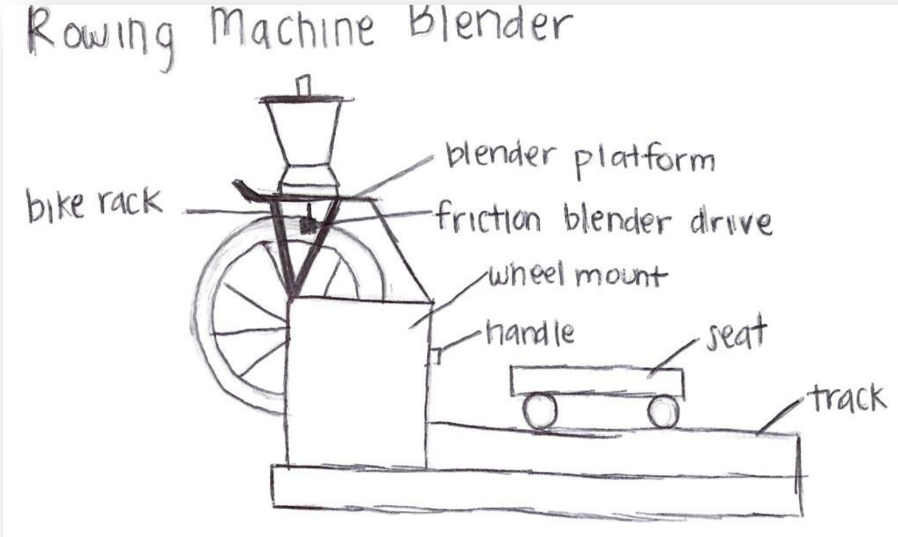

Figure 3-2 Labeled drawing of a Rowing Machine Blender (Photo (Wong 2011)).

3.3.3. Recumbent Tandem Bicycle Blender (mechanical)

A recumbent tandem would be preferred to a typical tandem bicycle, so multiple people of different sizes could use it simultaneously. The design is similar, except the bicycle has seats next to each other rather than one in front and one in back. Both people will be able to pedal and add power without the need to pedal at the same rate. There is just one wheel in the back, and the front mounted down. Connected to the chain shaft right next to the wheel is a gear which will spin and interact with another gear facing the upward direction to create the correct direction of spin, so the blender can sit up straight.

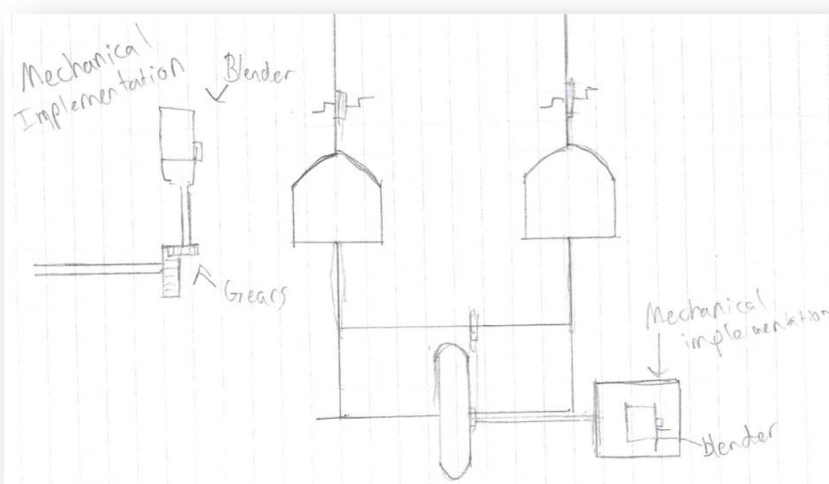

Figure 3-3 Labeled Drawing of a mechanical recumbent tandem bicycle blender (photo by Adam Clark).

3.3.4. Recumbent Tandem Bicycle Blender (electrical)

The design of the electrical version of the recumbent tandem bicycle blender is very similar in the setup. The difference lies in the chain shaft near the wheel. Instead of a gear connected to the chain, there is a generator hooked up. The generator turns mechanical energy into electrical energy, which is then stored in a car battery. The car battery is also hooked up to an inverter to change the direct current into alternating current, where the blender (and other A.C. appliances) can be plugged in.

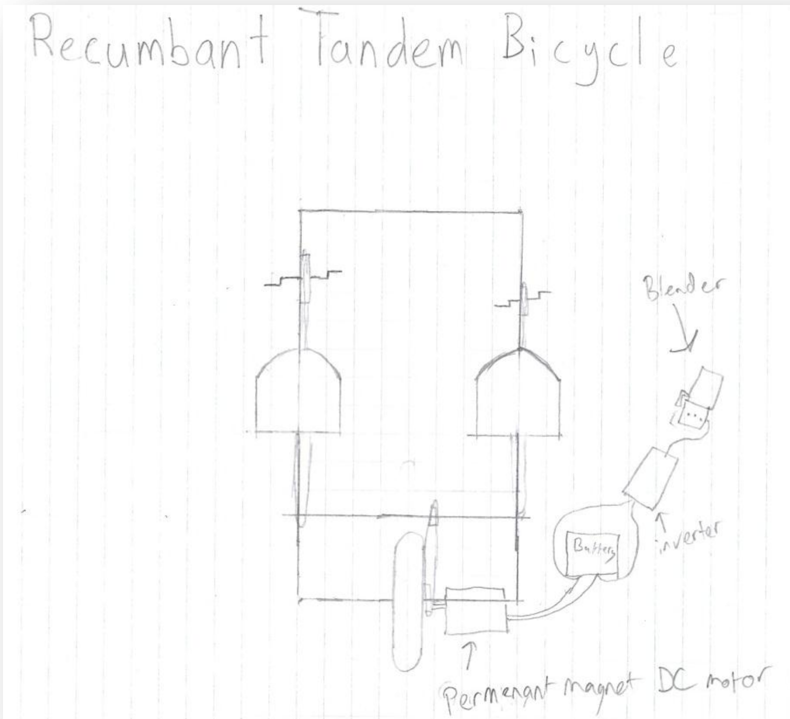

Figure 3-4 Labeled drawing of an electrical recumbent tandem bicycle blender. (Photo by Adam Clark).

3.3.5. Sustain-A-Swing

The sustain-a-swing consists of a rectifier, motor, mounting plates, tube clamp, metal tubing, and a swing set. From figure 3.3.5-1, you can see the illustration of the tube clamp and metal tubing that would be placed on part of the swing. From figure 3.3.5-2, you can see the illustration of where the rectifier would be placed, along with the mounting plates and motor. The motor is attached to the frame of the swing set and the arm from figure 3.3.5-1 is attached to the chain part of the swing. As a person swings, the arm spins the motor, generating energy to power the blender. If the person were to stop swinging, the blender would stop.

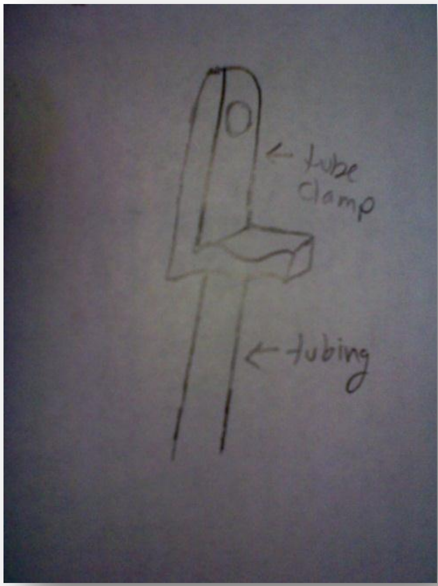

Figure 3-5 Sustain-a-Swing clamp and tubing. (Photo by Danielle Salamoni)

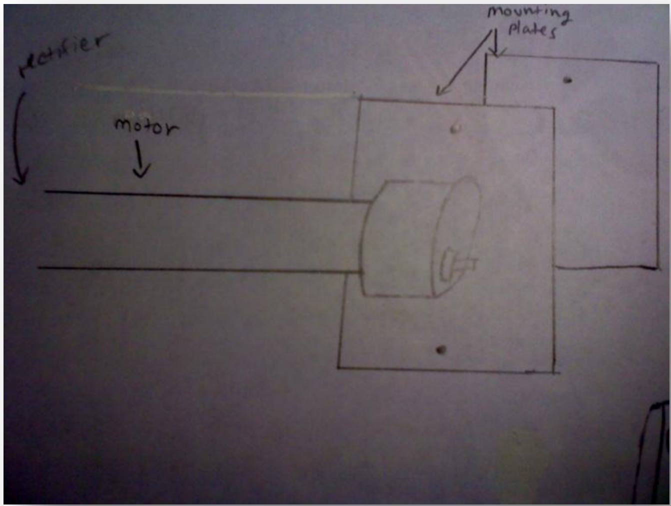

Figure 3-6 Sustain-a-Swing Rectifier, motor and mounting plates. (Photo by Danielle Salamoni)

3.3.6. Mechanical Blender- Hand Crank Method

The mechanical hand crank blender takes advantage of a system of gears that work together to turn the blades of the blender at an optimum speed. A base for the blender carafe will be constructed and fitted with a handle on the front to be cranked by the user. Inside, one small gear will be arranged to make contact with a larger gear rotated ninety degrees about the first gear. Finally, the flat gear will have a spindle attached to it with the opposite end having the blade fittings for the blender carafe. The advantage this design alternative has over any other is simplicity and a relatively low cost.

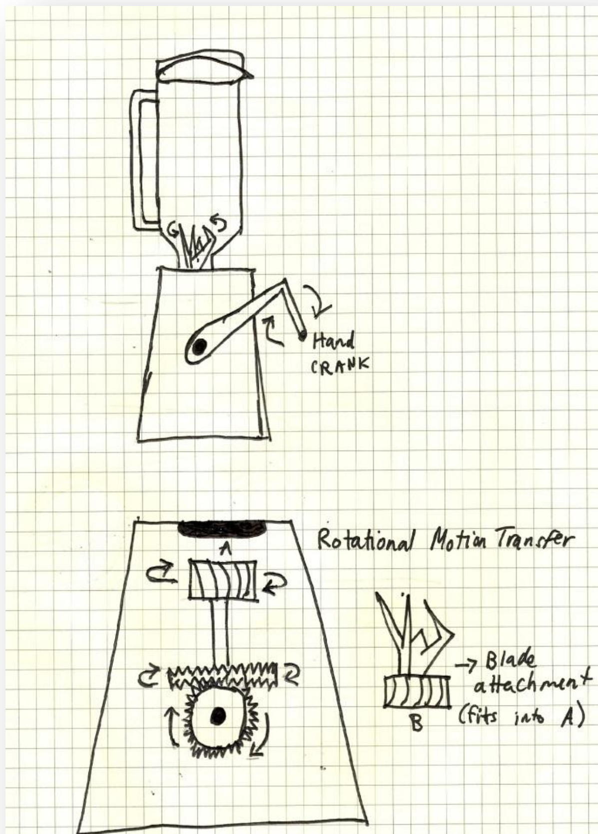

Figure 3-7 Labeled Drawing of a Hand Crank Blender. (Photo by Garett Sietz)

3.3.7. See-Saw Playground Generator

The electricity producing playground equipment is described by the figure below. This system involves a permanent magnet DC motor, a 12V lead-acid battery acting as a capacitor, an inverter, and several chain driven gears. A total of 4 gears will be used at the pivot point on the see-saw for maximum power output. When the rotational motion is transferred from either side of the downward swing, the two separate chain drives allow for the magnet to spin and generate electric current to the battery. The electrical energy stored in the battery will be supplied to an electric powered blender via the inverter. This design alternative has the advantages of being fun, inclusive of many students, and an age appropriate method for learning electric power generation for this client.

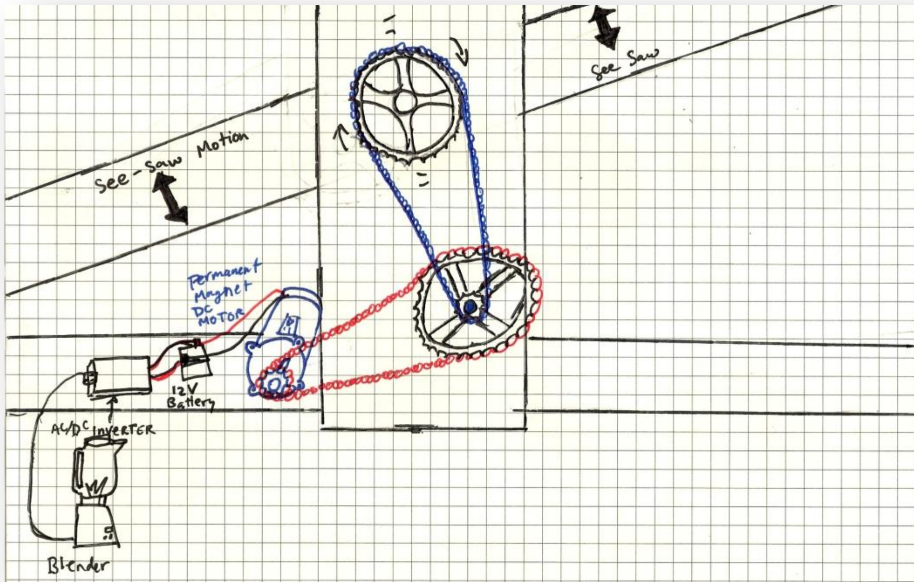

Figure 3-8 Labeled Drawing of a Seesaw Powered Blender. (Photo by Garett Sietz)

4. Decision

4.1. Introduction

Section 4 will be focused on the decision process by factoring in the criteria from Section 2 and the alternative solutions from Section 3. In this document, the criteria will be defined and with the help of the Delphi Matrix each alternative solution will be weighted based on these definitions. Depending on these weights, a final decision will be made.

4.2. Criteria

The criteria are as follows:

- Safety: The users and observers cannot be physically harmed while using the device.
- Usability: Easy accessible by five year olds to adults, and do not need to know how it works.
- Durability: For every 15 hours of use, only 30 minutes of maintenance are required; parts do not break easily or come apart; device shouldn't fall apart while using.
- Level of Educational Value: The user gains knowledge proportionate to their year in school, along with the inherent learning of how much physical work is required to power devices.
- Repair/Maintenance: Commercial/replacement parts can be easily obtained and simple repairs that can be followed by an instruction manual.
- Effectiveness: Must have appropriate consistency of drink and successfully make a smoothie within ten minutes.

- Cost: Project costs less than $400.

4.3. Solutions

The following list is the seven alternative solutions created during Section 3 based on our criteria.

- Friction Drive Blender
- Rowing Machine Blender
- Recumbent Tandem Bicycle Blender (mechanical)
- Recumbent Tandem Bicycle Blender (electrical)
- Sustain-A-Swing
- Mechanical Blender- Hand Crank Method
- See-Saw Playground Generator

4.4. Decision Process

The decision process consisted of team brainstorming, discussing of alternative solutions, creating specifications and deliberating with the client on the importance of each design qualification. Each design criterion was given a numerical value weighted on level of importance. The Delphi Matrix is the tool that offered the best alternative solution design properties.

4.4.1. Delphi Matrix

In order to choose the design or design aspects that will make up our final project the criteria from Table 4-1 were assigned a numerical value of importance on a scale of one to ten determined by the client for the project. Each alternative solution was then rated for how well ten, ultimately de it fit each criterion on a scale from one to fifty. Using the Delphi Matrix shown in Table 4-2, a score was assigned to each alternative solution by multiplying the criterion weight by the individual design score and totaled for each criterion and design. The highest score would influence our final decision as well as comparable scores that will have to be combined for one final solution.

Table 4-1 Criteria and Weights

Safety	10
Usability	9
Repair and Maintainability	9
Durability	8
Effectiveness	7
Level of Educational Value	4
Cost	3

Table 4-2 Delphi Matrix

Criterion	Weights	Friction Drive	Rowing	Recumbent	Rucumbent	Swing	Hand Crank	pump n power
Safety	10	40 / **400**	45 / **450**	40 / **400**	45 / **450**	25 / **250**	50 / **500**	35 / **350**
Usability	9	35 / **315**	45 / **405**	45 / **405**	50 / **450**	42 / **378**	20 / **180**	45 / **405**
Durability	8	35 / **280**	30 / **240**	38 / **304**	40 / **320**	30 / **240**	35 / **280**	43 / **344**
Level of Educational Value	4	35 / **140**	35 / **140**	50 / **200**	40 / **160**	35 / **140**	25 / **100**	40 / **160**
Cost	3	45 / **135**	35 / **105**	10 / **30**	30 / **90**	5 / **15**	50 / **150**	25 / **75**
Repair/mainenance	9	45 / **405**	20 / **180**	40 / **360**	45 / **405**	10 / **90**	40 / **360**	40 / **360**
Effectiveness	7	30 / **210**	30 / **210**	50 / **350**	45 / **315**	15 / **105**	20 / **140**	50 / **350**
	Totals:	**1885**	**1730**	**2049**	**2190**	**1218**	**1710**	**2044**

4.5. Final Decision

The electrical recumbent tandem bicycle solution was the highest scoring solution from the Delphi matrix. The bicycle is hooked up to the generator that changes the mechanical energy to electrical energy, which is then stored into the car battery. The design of this solution allows the energy being collected to be stored in a car battery. This solution also allows more than one person to generate energy.

5. Specifications

5.1 Introduction

Section 5 includes a detailed description of the final solution of the human powered blender as well as project cost in terms of dollars, man hours of work, and instructions for implementation and use of this model. The final solution is detailed with photos of the project and its individual components. The cost of the project is determined by dollar cost of materials and maintenance as well as total team hours spent on design and construction. Instructions are written to be understood by the Staff at Laurel Tree and will cover how the human powered blender should be used and how to repair it.

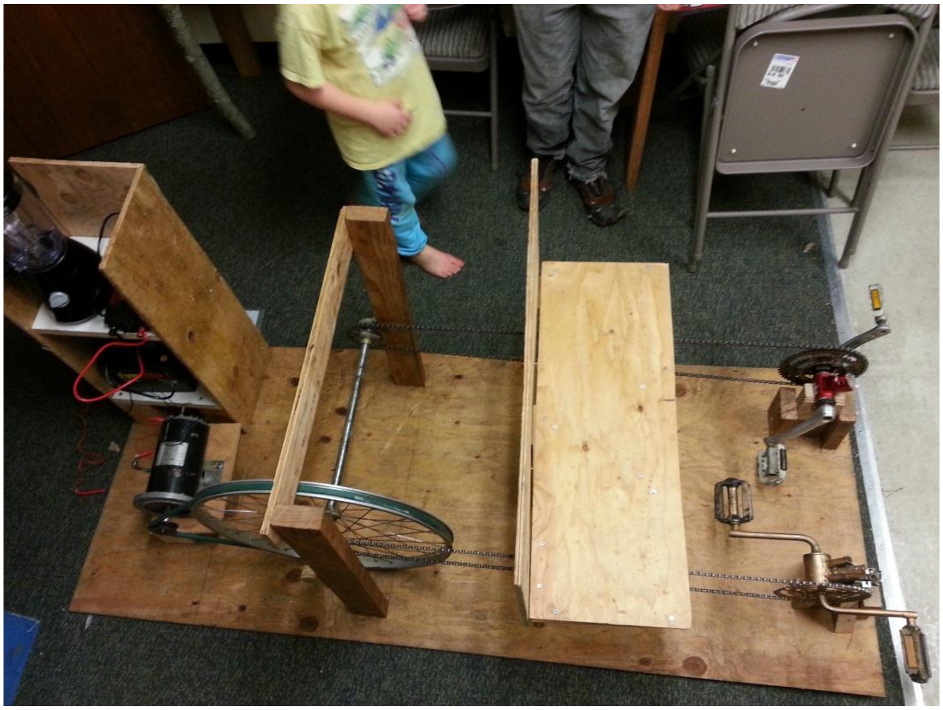

Figure 5-1 Overview picture of Human Powered Blender

5.2 Description of Solution

The blender is run off of stored energy in the 12 volt battery. The charging process comes from converting kinetic energy into electrical energy. The design implements a 36 volt permanent magnet DC motor, driven by a half inch thick v-belt. A 26-inch bicycle wheel drives the 2 inch pulley mounted to the end of the generator. The wheel is mounted on an axle with sprockets on each end. The gear ratio from front to back for both sides is two, giving an overall ratio of 26. A 45 amp blocking diode restricts electricity flow to the battery, and not from it. The battery is then wired through a fuse (to prevent dangerous shorts) to the 400 watt inverter. The inverter then provides AC power to the blender with a peak output capacity of 600 watts.

5.2.1 Wooden Base and Parts

The platform that every component is mounted to is a piece of plywood that is 3/4” thick by 32” wide by 78” long. Each crank is mounted to a 10” long two by four. The 32” by 12” plywood bench is supported with three 17” four by fours. The rear axle is mounted with two by fours that are equal in height to each crank that they are linked to. At the rear, there is a shelving unit that houses the battery, blender, inverter and monitoring equipment. The motor is mounted on its own shelve attached to the plywood.

5.2.2 The Pulley System

The shaft of the generator is turned by pedaling the cranks at the front of the systems, which turns a fixed axle with a mounted bicycle wheel. The 26" bicycle rim is connected by a drive belt to the 2" diameter on the shaft of the motor. The gear ratio between the diameters of each pulley is 13:1.

5.2.3 Electricity Production

The generator included is rated to produce just over 12V at 1056rpm which is the minimum speed required to charge the battery. The ratio of the bicycle wheel to the pulley on the shaft of the generator is 13:1, which means that one person pedaling alone would have to pedal 81 times a minute in order to charge the battery.

5.3 Costs

The costs for this design are included in this section. The costs are divided into implementation cost, design hours, and maintenance costs for the design chosen.

5.3.1 Implementation Cost

The table below shows the cost of the materials used to build the design.

Table 5-1 Monetary cost of Human Powered Blender.

Item	QTY	Team Cost	Retail
36V DC Motor	1	50	100
Bicycle Chains	4	Donated	39.88
12V Battery	1	35.47	35.47
Bicycle Wheel	1	Donated	35
81" Drive Belt	1	30	30
Steel Bearings (3/8 in)	2	23.59	23.59
Plywood (5ft by 5ft)	1	Donated	22.51
Plywood (8ft by 6ft)	1	22.51	22.51
Green Paint (1 quart)	1	11.5	11.5
Yellow Paint (1 quart)	1	11.5	11.5
Multimeter	1	9.97	9.97
Waterseal (12 Oz)	2	8.63	8.63
Blocking Diode	1	7.49	7.49
Jumper Cables	1	7.49	7.49
4 by 4 (6ft)	2	6.5	6.5
Project housing Box	2	6	6
Rim Tape (Roll)	1	5.39	5.39
2" Stainless Steel Screws	30	5.1	5.1
2 by 4 (8 ft)	1	5	5
2 by 4 (Various Lengths)	7	Donated	5
Battery/Alternator Testor	1	4.99	4.99
10 gauge Copper Wire (5 ft)	1	4.5	4.5
Corner Brace (1 1/2 in)	1	3.99	3.99
3" Stainless Steel Screws	20	3.8	3.8
Fuse 30 A	1	2.99	2.99
Steel Rod (1/2 in, 3ft)	1	2.97	2.97
Sandpaper (Package)	1	1.5	1.5
Total		**270.88**	**423.27**

5.3.2 Design Hours
The cost of the design is shown as a pie chart in figure 5-1 below. These hours are calculated by summing up the hours that the Pink Elephants put into the project. The total hours include the research involved, writing of documents, and building the design chosen.

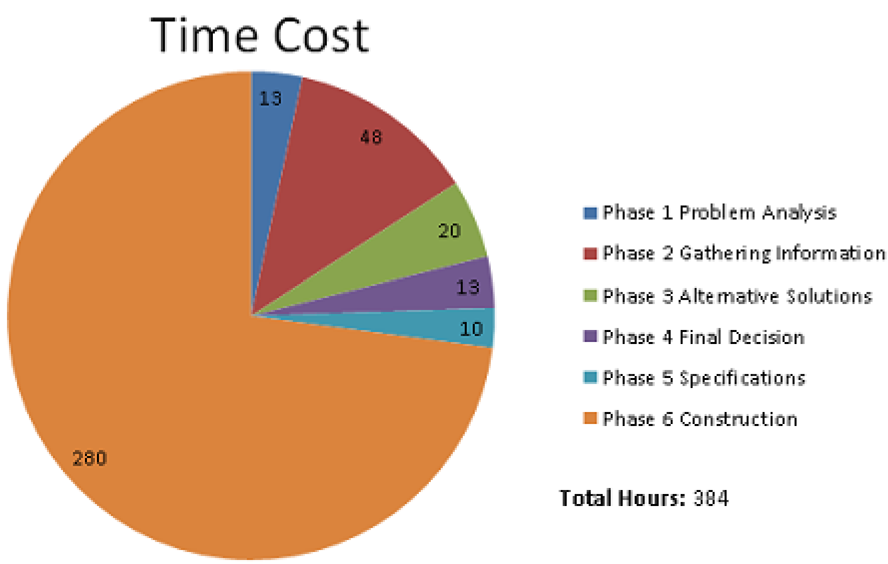

Figure 5-2 Time cost (in hours) for the overall project.

5.3.3 Maintenance Cost
The design chosen has some maintenance. The maintenance for this design is to ensure the design is safe for the students K-12.

Task	Frequency	Task Time	Cost	Time
Belt Change	Approximately every 5 years	30 minutes	50	5 Years
Cleaning Blender	Before putting the blender away	15 minutes	0	Variable depending on usage
Changing Wood	As needed	Variable	Variable	Variable
Battery Replacement	As needed	15 minutes	30	3-5 Years

5.4 Instructions for Implementation and Use of Model
The human powered blender requires a low maintenance in order to be used after it has been stored. However, if the project has not been dismantled, setup is as easy as carrying it out to a level surface, plugging in the blender and turning on the inverter. Students may then pedal to charge the battery as necessary.

5.4.1 Electrical Components
Provided are a series of alligator clips, an inverter, a 12V battery, a 45amp blocking diode, a battery test kit, a blender, and a 36V permanent magnet DC motor mounted on a separate shelving unit. Should these parts need to be removed for maintenance or replacement, they must be put back in the correct order to

produce electricity again. The 12V battery is wired on the negative side directly to the motor and the inverter with two wires. On the positive side of the 12V battery, one wire should run to one end of the blocking diode and then to the generator, with a second wire running from the positive side of the battery to the inverter. The blender can be plugged into the inverter. Also included in the system is a battery test kit that can be used to check the status of the battery. A fuse prevents the system from shorting and starting fires and being dangerous. When the display shows the battery falling below sixty percent, charging should then be necessary.

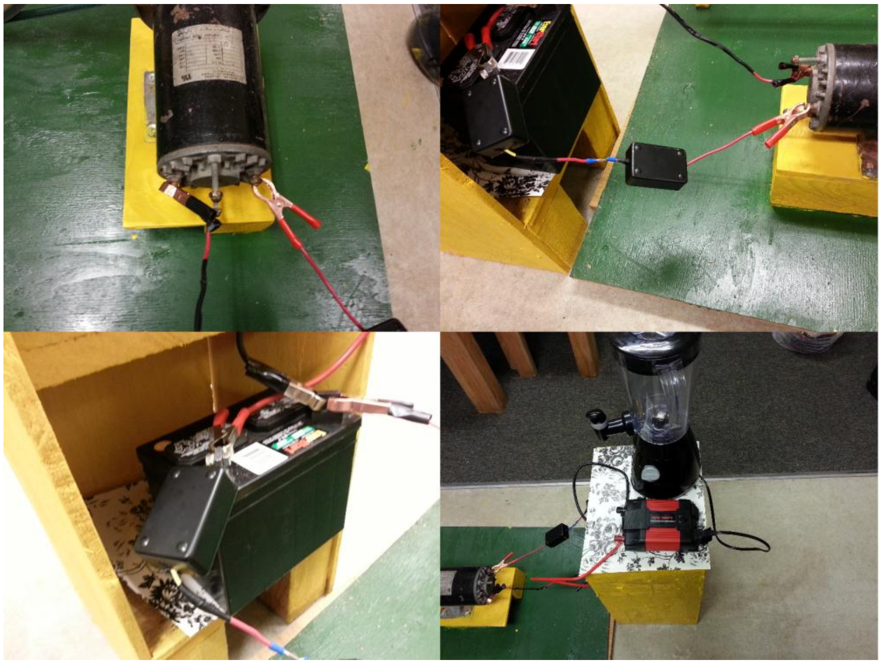

Figure 5-3 Red (positive) Electrical connections: Blocking diode, fuse, battery inverter; Negative (black): Battery, Inverter.

5.4.2 Chain System

There are two side by side pedal cranks on the project that are connected with two chains to the rear axle. If the chains happen to break and need to be replaced, fix a chain from one crank to the gear on the axle directly behind it, running under the bench and apply to both sides if necessary.

Figure 5-4 Chain and crank shaft system that rotates the wheel.

5.4.3 Pulley System

The pulley system in this model involves a belt that connects the fixed axle bicycle tire to a pulley mounted onto the shaft of the permanent magnet DC motor. The rim of the bicycle tire is taped on the inside with bicycle tape to prevent the spokes from damaging the belt and provide better friction. The project has a mounted motor, rear axle and the belt is fixed to the right position. When the belt needs to be replaced, a new one can be attached by dismounting the generator from the shelf. It is important that the generator be put back in the correct order for the determined belt size to be tight enough.

Figure 5-5 Pulley system driving the generator.

5.4.4 Wooden Frame

The lifespan of the project will be the same as the wood frame, if kept in good condition. Every piece of wood used in the project has been treated with water seal, making it water resistant but not waterproof. Stainless steel screws were used instead of other metals to prevent rust. The project was designed to be stored indoor. Keeping the project out of the weather is the best way to avoid the task of replacing these wooden parts.

5.5 Results

The results of building the design model concluded that the side-by-side tandem recumbent bicycle powered blender was an effective design. With moderate cadence of pedaling, 14 volts is easily achieved, and with two people adding the power, it is a light exercise for both. The multimeter used capped out at 10 amps on a short circuit with no resistors, thus if it produces 10 amps during regular use, it has a theoretical yield of 140 watts. The blender is 420 watts, thus for one minute of blending; only three minutes of pedaling are required. Since the battery used was nearly full, only six watts were effectively charging it, and as it drains, the maximum charge is more likely to be obtained.

Figure 5-6 Two Laurel Tree students using the Human Powered Blender.

References

"Blog." Energy Playground. N.p., n.d. Web. 25 Sept. 2012. <http://www.globalinheritance.org/energy-playground>.

"CA Codes (hsc:)." CA Codes (hsc:). N.p., n.d. Web. 25 Sept. 2012. <http://www.leginfo.ca.gov/cgibin/displaycode?section=hsc>

"Magnetic Induction." ThinkQuest. Oracle Foundation, n.d. Web. 24 Sept. 2012. <http://library.thinkquest.org/13526/c3c.htm>.

(July 1999) "Applications of Electromagnetic Induction" http://physics.bu.edu/~duffy/py106/Electricgenerators.html. Retrieved 2012-09-24

"Nutritional: Balanced Energy Output" <http://www.childrensheartinstitute.org/educate/nutritio/output.htm>

"See Saw to Light Classroom" *Science in the News*. <http://www.collinseducation.com/resources/ScienceinthenewsAug09GCSEKS3SeesawtolightclassroomGK.doc>

< http://hypertextbook.com/facts/2003/WeiLiangMok.shtml> (September 20, 2012)

Allen, Mike (2000) *Popular Mechanics, Issue 8, Vol. 177* "Battery Maintenance".

Allen, Mike (2003) *Popular Mechanics Vol. 180, Issue 7* "How to Charge your battery".

Bernstein, T. (2011) "Human Power Output on a Bycycle" <http://www.livestrong.com/article/500408-human-power-output-on-a-bicycle/>

Bike, I. _. "Bikes." *How to Create a Smoothie Making Human Powered Bike Blender for Less than $25*. Instructables, 31 May 2008. Web. 25 Sept. 2012. <http://www.instructables.com/id/How-to-create-a-human-powered-bike-blender-for-les/?ALLSTEPS>.

Dean, T. (2008). The Human Powered Home, New Society, Gabriola Island, BC, Canada.

Dean, T. (2008). The Human-powered Home : Choosing Muscles over Motors. Gabriola Island, BC: New Society Publishers.

Dean, Tamara. 2008. *The Human Powered Home: Choosing Muscles over Machines* New Society, BC, Canada.

Elert, G. (2003) "Power of a Human".

Fey, Carol. 2006. Plumbing & Mechanical, suppl. B.I.G. Book23. 10 (Dec 2005): 44,46.

Garimella, Niraj, Nirmal-Kumar C. Nair, (2010) *Energy and Buildings*. “Battery energy storage systems: Assessment for small-scale renewable energy integration”<http://www.sciencedirect.com/science/article/pii/S0378778810002185>

Jansen, Arjen (2011), *Human Power Empirically Explored.* (Ph.D Thesis) <http://www.io.tudelft.nl/fileadmin/Faculteit/IO/Over_de_Faculteit/Afdelingen/Design_Engineering/Sectie_Product_Engineering/Human_Power/doc/human_power_empirically_explored.pdf>

Lonny Grafman and Steven Pearl. Appropedia, 25 Oct. 2011. Web. 25 Sept. 2012. <http://www.appropedia.org/Locally_Delicious_rowing_machine_blender_for_schools>.

Mary Bellis (2010). "The History of the Blender". Inventors.about.com. Retrieved 2012-09-24

R Nave (2011) “Voltage Concepts”. hyperphysics.phyastr.gsu.edu/hbase/electric/volcon.html#c1 2012-09-24

Siegel J., Gilders R., Staron R., Hagerman F. (2002) “Human Muscle Power Output during Upper- and Lower-body Exercises”. < http://www.ncbi.nlm.nih.gov/pubmed/11991767>

Windrock International (2004) “Guide to Energy Options for Small-scale Rural ICT Projects” <http://www.winrock.org/clean_energy/files/Winrock_Energy_for_*Rural*_ICT_Guidebook.pdf>

Wong, Laura, Ross McCullough, Dakota Gillette, and Steven Pearl. "Locally Delicious Rowing Machine Blender for SchoolsÂ Â ." *Locally Delicious Rowing Machine Blender for Schools*. Ed.

6.

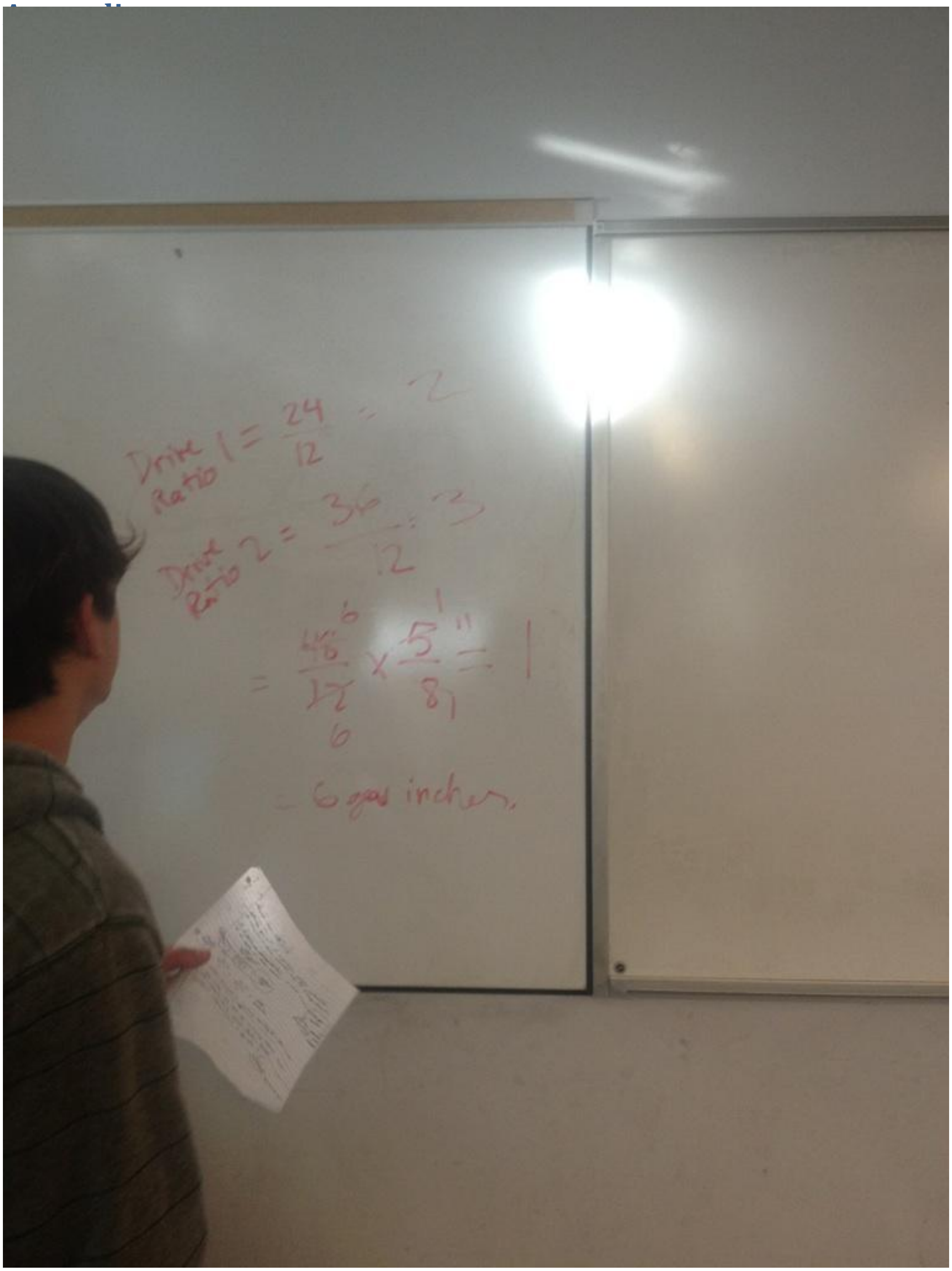

Figure 6-1 Picture of formal brainstorming determining gear ratios.

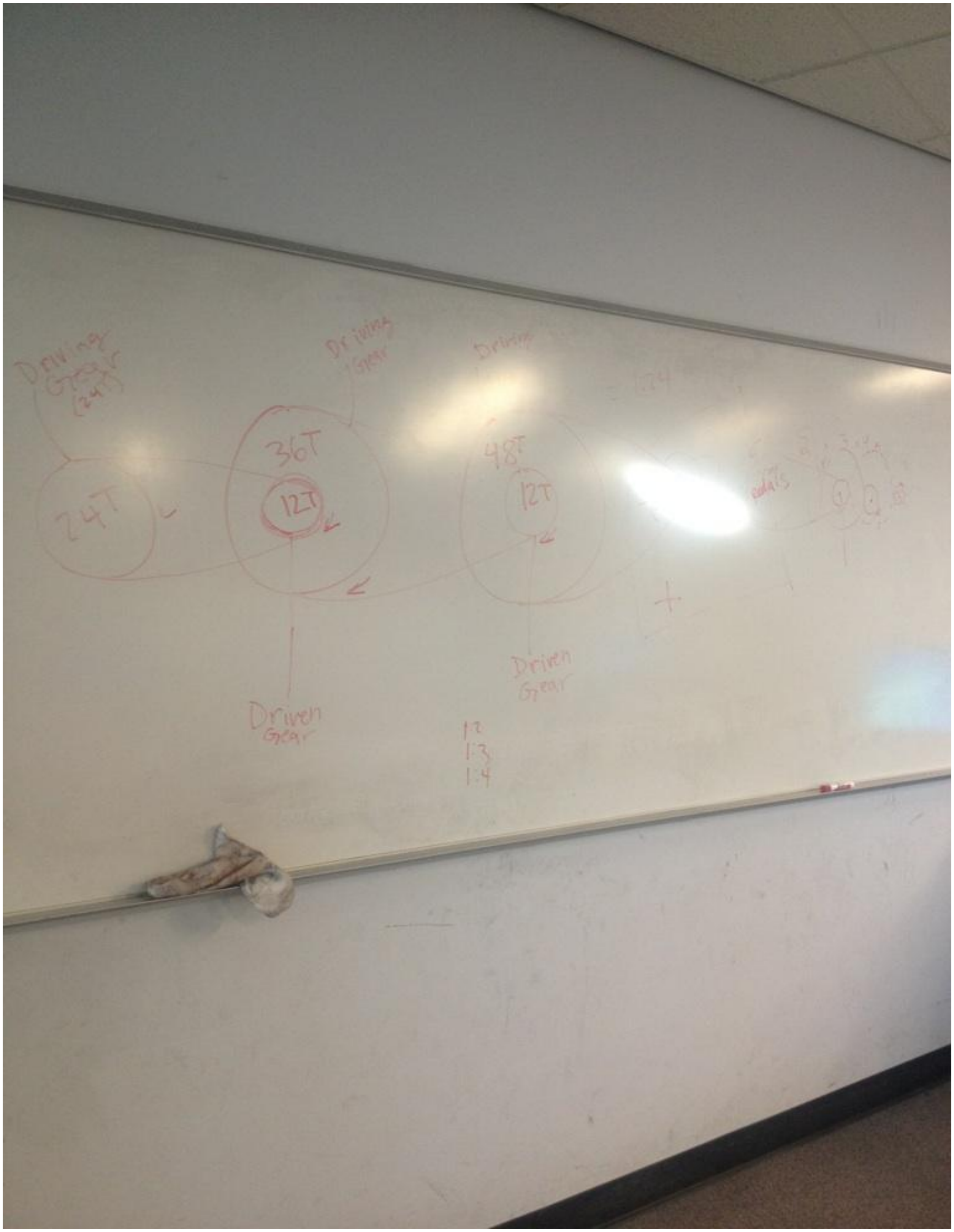

Figure 6-2 Picture of formal brainstorming session to accomplish the previously defined gear ratio.