ELECTRIC TOOTHBRUSH REDESIGN

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September 24, 2012

Team 4

Abstract

The goal of our project was to redesign the Oral B Advanced Power 400 electric toothbrush in order to make it more appealing to the average customer. The toothbrush is fairly basic as far as electric toothbrushes go. It is powered by two AA batteries, is of medium weight, and costs about $10.00. After several tests and surveys, we determined that our toothbrush should be more sustainable, should catch the customer's eye, and must be cheaper than its competitors. In order to make our toothbrush cheaper, we need to minimize the various components of the toothbrush. We realize that the makers of the Oral B Advanced Power 400 also had the goal of making the toothbrush cheap, but we are willing to make less of a profit in order to make a cheaper toothbrush as low cost seemed to be the most essential customer need. The other major customer need was availability. Customers are not willing to travel for specific toothbrushes and are most likely to buy the cheapest toothbrush that catches their eye. Because of this, the focus of our redesign is not necessarily to completely change the way in which the toothbrush functions, but to make the toothbrush look more appealing to the customer. In order to do this, we conducted several design activities including two labs, external research, bench marking, concept generation, and more. Our main objective was to create a more sustainable electric toothbrush that appeals to the average consumer and is low cost. Through our design activities, we decided to convert our toothbrush to a rechargeable toothbrush, versus one that uses disposable batteries, we altered the type of plastic used to make the body (polyethylene terephthalate- a plastic commonly used in water bottles), and we reduced the size of the replaceable heads. In addition, we decided on a semi-flexible neck. The final design is a more sustainable electric toothbrush whose innovative design should attract the attention of the consumer.

1.0 Introduction

As time has passed, the electric toothbrush has become more and more prevalent in the market. More and more people are ditching their manual toothbrushes for the promise of a better clean with an electric toothbrush. Better designs for such a toothbrush are constantly arising, bringing down the cost and making the electric toothbrush available to the masses. The Oral B Advanced Power 400 is obviously well designed and rather popular in the current market. Because of this, we realize that there is not much we can do to such a toothbrush as far as the way in which it functions besides converting it to a rechargeable toothbrush, versus its current use of disposable batteries. Therefore, our focus is to make the toothbrush more appealing to the eye and to minimize its cost. The reason we want it make it rechargeable is the increasing emphasis on the environment and being environmentally conscious. People have become more aware of the environmental hazards associated with disposable batteries, especially when disposed of improperly. We don't want our customers to have to question the "environmental-friendliness" of our toothbrush, and therefore made the decision to make it rechargeable. This change will, inevitably, bring up the cost of our brush which forces us to find other ways to make it cheaper. One way in which we will do this is to change the way in which the brush head is replaced. In order to change the current brush head of this toothbrush, one must dispose of the entire 7 cm piece. We would like to change this so that only the bristle piece is changed. This would lower the cost of the replacement pieces for the brush as much less material needs to be used.

Throughout the rest of this report we will discuss:

- -Initial Problem
- -Customer Needs/Analysis of Customer Needs
  - -How customer needs affected our design choice
- -Our Research
  - -Online Research
  - -Benchmarking
- -The Formation of our Design
- -Our Product Design

1.1 Initial Problem Statement

"Your team is to develop new concepts for a sustainable electric toothbrush," was given to us as the main assignment. The amount of mobile devices recycled last year was about 11% which poses a huge problem for future generations as the resources used in creating these products is being wasted. Be innovating new designs and concepts to be used in an electric toothbrush, we are able to eliminate a portion of this waste based off our product taking longer to be considered "junk" and thrown away.

2.0 Customer Needs Assessment

Initially, we created a list of what we thought were the 12 most essential customer needs for an electric toothbrush. Our next step was for each of us, on our own, to rank these in order of importance accordin g to our own opinions. Next, we deleted the needs that proved to be least important and ranked the remaining needs again. Finally, using our compiled ranking results, we created a survey that would test our hypotheses. We surveyed 20 people. Our results showed that customers are more likely to buy a toothbrush that is readily available. Price is important, but customers are not willing to make an extra effort to obtain a cheaper toothbrush. Also, far more people prefer the use of a charging station to the use of disposable batteries as a power source for the toothbrush. In addition, most people are willing to put some effort into their toothbrush, but not a large amount. Appearance is also important, as half of the people were more inclined to buy a toothbrush in their favourite colour. Also, historically, a customer is more likely to purchase a toothbrush that catches his or her eye. From these results, we were able to decide how we were going to redesign our electric toothbrush.

2.1 Weighting of Customer Needs

To obtain what kind of toothbrush we are designing, we listed eleven potential costumers' needs as shown in the following table. Since we are not able to satisfy all the needs at once, we ranked them according to the importance in order to find our priority in the design. We picked the first six: availability, cost, experience of brushing, maintenance, light weight, efficiency in cleaning and appearance, to help us conduct the survey. Furthermore, we conduct a series of tables to help us in our design. The first table shows the ideas we have initially; the following two assist us to select the important needs; and the last ones rank them, also give the rate of them.

Table 1. Initial Customer Needs List Obtained from Team Focus Group and Individual Interviews/Surveys

Letter	Costumers' Needs
A	Sustainability
B	Efficiency in Cleaning
C	Light Weight
D	Cost
E	Experience While Brushing
F	Maintenance (battery & tip replacement)
G	Availability
H	Size
I	Strength (durability)
J	Appearance (color, shape, etc.)
K	Head size & shape

Table 2. Ranking of Initial Customer Needs List Obtained from Team Focus Group and Individual Interviews/Surveys

Letter	Customer Needs	Rank
G	Availability	1
D	Cost	2
E	Experience While Brushing	3
F	Maintenance (battery and tip replacement)	3
C	Light Weight	4
B	Efficiency in Cleaning	5
J	Appearance (colour, shape, etc.)	6
A	Sustainability	N/A
H	Body Size	N/A
I	Strength (durability)	N/A
K	Head Size/Shape	N/A

Table 3. Hierarchal Customer Needs List Obtained from Focus Group and Individual Interviews

1. Availability
    1.1 Easy to find in stores
2. Cost
    2.1 Cheaper than other brands of toothbrush
3. Experience While Brushing
    3.1 Softness of brush
        3.2 Easy to handle
4. Maintenance
        4.1 Battery life
        4.2 Replacement of tip
5. Light Weight
        5.1 Relatively light in weight
6. Efficiency in Cleaning
        6.1 Cleaning can be done in a short period of time
        6.2 Cleanness after brush
7. Appearance
        7.1 Color of the toothbrush
        7.2 Shape & size of the tip

After the six potential costumers' needs were picked, we needed to figure out the exact weight among them. We used an AHP Scale to find the most important component as shown in the chart below. The letters correspond to the costumers' needs as in the table above. In the chart we find out Availability and costs are the two major considerations of the costumers; followed by maintenance and experience, which have medium weighting; efficiency and appearance are the least important elements. This helped us to conduct the survey.

	G	D	E	F	C	B	J	Total	Weighting
G	N/A	5	7	7	7	7	5	38	0.321
D	0.2	N/A	7	7	7	7	5	33.2	0.280
E	0.143	0.143	N/A	1	5	5	5	16.29	0.137
F	0.143	0.143	1	N/A	7	7	3	18.29	0.154
C	0.143	0.143	0.2	0.143	N/A	5	3	8.63	0.073
B	0.143	0.143	0.2	0.143	0.2	N/A	1	1.83	0.015
J	0.2	0.2	0.2	0.333	0.333	1	N/A	2.27	0.019

Figure 1. AHP Pairwise Comparison Chart to Determine Weighting for Main Objective Categories

Table 4. Hierarchal Customer Needs List Obtained from Focus Group and Individual Interviews

Rank	**Customer Need**
1	Experience While Brushing
2	Cost
3	Efficiency of Cleaning
4	Appearance
5	Availability
6	Maintenance
7	Weight of Toothbrush

Table 5. Weighted Hierarchal Customer Needs List Obtained from Focus Group and Individual Interviews

1. Availability (0.321, 0.321)
1.1 Easy to find in stores (0.321, 0.321)
2. Cost (0.28,0.28)
2.1 Cheaper than other brands of toothbrush (0.28, 0.28)
3. Maintenance (0.154, 0.154)
3.1 Battery life (0.077, 0.5)
3.2 Replacement of tip (0.077, 0.5)
4. Experience While Brushing (0.137, 0.137)
4.1 Softness of brush (0.0685, 0.5)
4.2 Easy to handle (0.0685, 0.5)
5. Light Weight (0.073, 0.073)
5.1 Relatively light in weight (0.073, 0.073)
6. Appearance (0.019, 0.019)
6.1 Color of the toothbrush (0.0095, 0.5)
6.2 Shape & size of the tip (0.0095, 0.5)
7. Efficiency in Cleaning (0.015, 0.015)
7.1 Cleaning can be done in a short period of time (0.0075, 0.5)
7.2 Cleanness after brush (0.0075, 0.5)

3.0 Revised Problem Statement

Our team's task at hand was to design a sustainable electric toothbrush. After assessing our target market needs and establishing requisites for the manufacturing, we determined that our toothbrush must possess adequate engineering design to consistently and easily perform its job (cleaning one's teeth), have the aesthetic appeal to attract customers, and be practical (not being too heavy, powerful, or large for regular use). Mechanical and electrical engineering will be the most-used engineering disciplines in our process, based on the amount of design, dynamics, and components involved with the toothbrush. With these facets, we have decided to improve on the previous model through these alterations: the toothbrush will be rechargeable with a docking station, the replacement heads will now solely be of the bristle face instead of the whole head and crank, and we will also design a new grip pattern that is more pleasing to the eye and more ergonomic.

4.0 External Search

Our external Search includes a patent search, product archaeology, and benchmarking of five different products. This external search allowed us to re-evaluate the problem statement and served as our guide for our concept generation.

4.1 Lab 1 & Lab 2 Reports

Lab 1 (see Appendix A)

The main purpose of this two part lab was to gather as much information about the toothbrush before it was taken apart so that conclusions could be drawn about its strengths and weaknesses. In the first part of the lab, the toothbrush was inspected at all exterior angles for individual parts and their corresponding material and functions. This gave insight on how the toothbrush itself and how it is put together. The second part of this lab was to seek out features of this toothbrush. These features make this toothbrush different from the rest. This stage was very important because it sets a benchmark of sorts when redesigning so that the good features can be maintained while the bad features can be re-designed.

First we took the toothbrush out of its package, which was fairly easy using a pair of scissors. The toothbrush was mainly made of plastic. We separated it into six different parts and most of them can be removed easily. Throughout some research, we found the general information of the toothbrush including price, features and patents. These gave us the general ideas of how we can improve the toothbrush in our design. We could cut down the price by using less material. Additionally, some of the technologies could also be used in our design.

Lab 2 (see Appendix B)

Similarly to lab 1, lab 2 created a benchmark of sorts to base re-designing decisions off of. However, this benchmark was not for the exterior design, it was for the internal power assembly. The first part of this lab was to measure the noise of the toothbrush at alternating distances from a decibel meter. The second part of this lab was to measure the power of the toothbrush in voltage and convert that to watts. This was done by using a voltmeter to measure the voltage in the batteries and then substituting a power supply at that voltage to measure that amps and watts. The third part of this lab was to dissect the toothbrush itself while pictures were taken at each step.

There were a few main findings in lab 2. The dissection was helpful because it explained how the energy from the batteries is transferred to the actual brush head. We also found that people brush for an average of 4 minutes per day. Another finding was that the average noise level for our original toothbrush was 73.8 dB. We also found that average current of our toothbrush. From this, we were able to calculate that there were 6.96 total hours of brushing available in our current batteries and it would take 105 days of brushing before needing replacement batteries.

4.2 Patent Search

We conducted our patent search through the United States Patent and Trademark Office's website at www.uspto.gov/.

Table 4. Art-Function Matrix for Electric Toothbrush

Function	Art					
	Rotatable head	Circular head with blue and white bristles	DC motor and crank shaft	Metal battery conductors	Bottom of handle, with rubber O-ring	Teal rubber grip with wavy pattern
Multi-motion	US 7,225,494 B2					
Oral-B specific brush head shape		US D536,876 S				
Motor gear system			6,000,083			
Powering of toothbrush head				US5524312		
Keeps battery in compartment and allows circuit to be complete					D527185S	
Grip						D636604

(US Patent Office)

The patents we decided to use in our final concept include only that of the DC Motor and crank shaft which will continue to be used to spin our brush head.

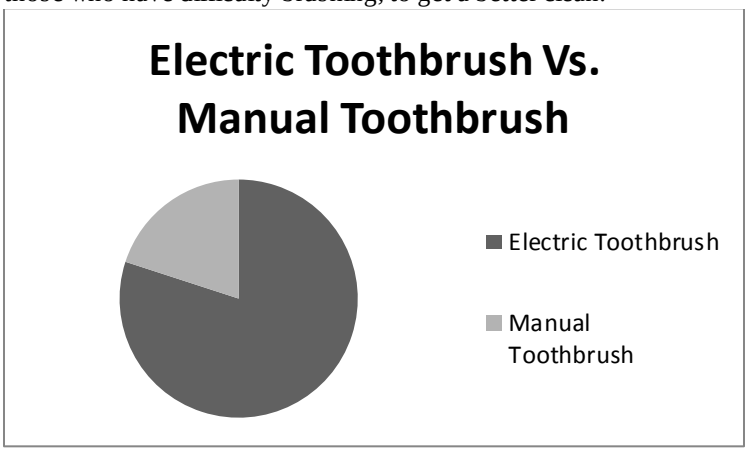
4.3 Product Archaeology

The electric toothbrush was first seen in 1954 and the first study that exhibited that electric toothbrushes clean more efficiently than manual toothbrushes came out in 1956 (Wikipedia). Although the original purpose for the electric toothbrush was for use by people with limited motor skills, the electric toothbrush has made its way into the average everyday household. Is this due to a promise of a better clean with less effort (the perfect product for an ever-increasingly lazy society)? It is quite possible. Regardless, the electric toothbrush has managed to evolve dramatically from its 1954 model, into the toothbrush that we see today, and plan to redesign.

In the early 1960s, the first rechargeable electric toothbrush hit the market. Although this model had countless flaws (its massive size, its lack of battery life, and more), it served as a marker in history for the electric toothbrush. By the 1990s, several new electric toothbrushes arouse, and thus, the market for the electric toothbrush was born (Wikipedia).

There are two types of electric toothbrush: rotation-oscillation and vibration. The rotation-oscillation has proven to require less effort as one simply needs to move the brush through the mouth in order to achieve the full effect, whereas vibrating electric toothbrushes require the same motion as used when using a manual toothbrush (Wikipedia). Due to this, we have decided on the rotation-oscillation. Another reason for this decision is the proven fact that rotation-oscillation toothbrushes work marginally better than manual toothbrushes. The truth of the matter is, more important than the choice of electric over

manual, is the way in which the individual brushes. Electric toothbrushes make it easier, especially for those who have difficulty brushing, to get a better clean.

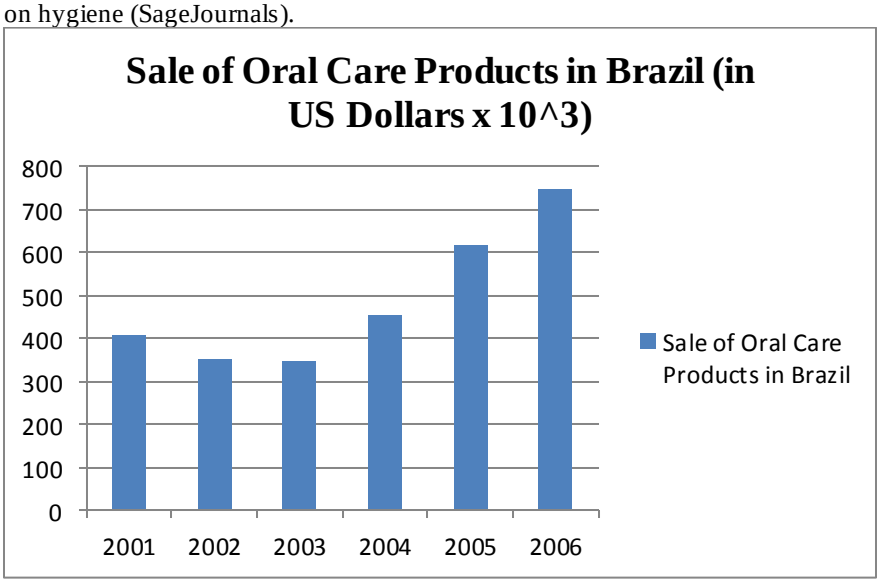


80% of people brush better with an electric toothbrush versus a manual toothbrush.

Most current day electric toothbrushes are run on replaceable battery, which may or may not be rechargeable. In addition, most current day rechargeable brushes use "contactless inductive charging." "Inductive charging" uses electromagnetic induction, which is the production of an electric current, through a magnetic field, across a conductor. Power is transferred from the handle of the toothbrush to the charging station via a coil in each (Wikipedia).

New technology for electric toothbrushes includes timer and/or an LCD screen. In addition, the latest version of the electric toothbrush is the "Ultrasonic," which cleans teeth using ultrasonic waves. Unfortunately, these brushes are far more costly than the rotation-oscillation brushes (Wikipedia). We do not plan on including these features in our redesign as they would bring up the cost of the toothbrush, and one of our main objectives is low cost.

The electric toothbrush is used around the world but is really limited to the middle and upper classes due to its increased cost versus a manual toothbrush. For example, the electric toothbrush is far more common in the United States than in Africa. In developing nations, the electric toothbrush is very rare. Demographically, the electric toothbrush is used most often by older men. Also, smokers are more likely to use an electric toothbrush than those who had never smoked (WhatJapanThinks). The electric toothbrush has become increasingly available to the general public, over time. Its market has grown with an increase in sales of oral hygiene products, not only because of this, but because of the increased emphasis on hygiene (SageJournals).



These results reflect a very similar trend in the United States

There are many degrees of electric toothbrush, some far more environmentally friendly than others. For instance, the use of disposable batteries has a far harsher impact on the environment than rechargeable batteries, especially because most consumers dispose of batteries improperly, allowing them to enter and spoil landfills. In addition, those that include a replaceable head are more environmentally friendly than those do not as those that do only require disposing of a small piece. In our toothbrush, we seek to minimize this piece by making only the bristles replaceable, instead of the entire neck and head. Environmental friendliness can be taken to a whole new level with the use of naturally occurring cellulose instead of plastic in the toothbrush, making the toothbrush recyclable (About.comEnvironmentalIssues).

Relevant Design Characteristics	**Reason**
Power Source	The main concept for making our toothbrush more sustainable is to make it rechargeable instead of it relying on disposable batteries.
Appearance	We want our toothbrush to catch the eye of the customer. The appearance of the toothbrush will set it apart from its competition based on what the customer sees at the store.
Material	Our focus is to make our toothbrush more sustainable. One way that we are going to do this is through the material, being more environmentally friendly with the use of a biodegradable cellulose material instead of plastic.
Maintenance Requirements	Based on customer needs analysis and our product research, maintenance of the toothbrush is very important. We want out toothbrush to be both cheap and easy to maintain with replaceable parts of minimal size.

4.4. Benchmarking

In order to learn more about the strengths and weaknesses and, in turn, know what to redesign, we must compare our original toothbrush to other toothbrushes on the market based on various features. We used a scale to rate each toothbrush in relation to each other (5-best, 3-average, 1-worst).

Oral B Cross Action:

Crest Spinbrush:

Colgate SpongeBob SquarePants Toothbrush:

Philips Sonicare Xtreme e3000:

Pursonic S300 Deluxe Plus:

Table 5. Benchmarking of Five Products

Feature	Oral-B Cross Action	Crest Spinbrush	Colgate SpongeBob SquarePants Toothbrush	Philips Sonicare Xtreme e3000	Pursonic S300 Deluxe Plus
Packaging	3-average	4-rugged, simple	5- colourful, kid oriented, appealing	3-average	4-professional, technologically advanced
Aesthetics	4- nice hand grip	3-average	2-large handle for kids?	3- too big of a handle	4-slim easy to hold
Ease to clean	4-double action	2-not powerful	1-horrible cleaning power	3-average	4-dentist approved
Convenience of on/off switch	5-right in middle	4-switch	4-in middle	3-average	2-can't be seen easily
Low Cost	1-expensive	4-fairly cheap	5-very cheap	3-average	2-fairly expensive
Long Battery Life	5-lithium ion	2-alkaline	2-alkaline	2-alkaline	5-lithium ion

4.5 Design Target

Through our external research, we have made several decisions concerning the redesign of our electric toothbrush. First, we targeted the way in which we will make our toothbrush more sustainable. We will do this by converting it to a rechargeable toothbrush, instead of one that requires disposable batteries . In addition, we will look more into the use of a cellulose-based material instead of plastic for the make of our toothbrush. As far as its replacement parts, we seek to minimize their size, i.e., the replacement head will be just that, a replacement of the head and bristles. It will not be a replacement of the entire head and neck. This will both lower their cost and be more environmentally friendly. In addition, our brush will be a rotation-oscillation brush versus a vibrating brush due to the fact that rotation-oscillation brushes require less effort for a good clean. Our goal is keep the cost of the brush as low as possible, which may mean reducing the grip size. But, we are also aware of the importance of appearance as we want our toothbrush to catch the eye of the customer. We would like to offer our toothbrush in a variety of colours in order to keep the customer coming back Some customers enjoy change and are more likely to buy the same model brush more than once if different colour options are available. This design target will guide us through our upcoming concept generation.

5.0 Concept Generation

5.1 Concept Generation

As a team, we developed design concepts for the energy mechanism of the brush head, power generation and power accessories, brush head design, and body design of the toothbrush. We started working in class, each generating concepts for two different categories. We worked for 20 minutes. After the allotted time was complete, we commented on each other's designs (which we liked, what we liked about it; which we didn't like, what we didn't like about it, etc.) and decided, together, which concepts would be best suited for our toothbrush redesign.

Energy Mechanism for Brush Head (function)

While generating concepts for the energy mechanism, we quickly realized that there were only a few options that would actually work. We wanted to simplify things in order to maintain a functional design. Our options came down to the type of dc motor, if there would be a gearbox, and, if so, what ratio would we use. These concepts were drawn up and we concluded through pugh charts that a directly driven energy mechanism would be the best.

Student Name Patrick Trumbolla

Team 4

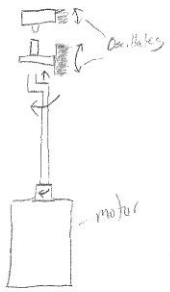
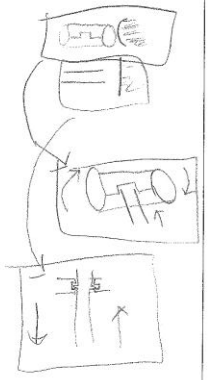
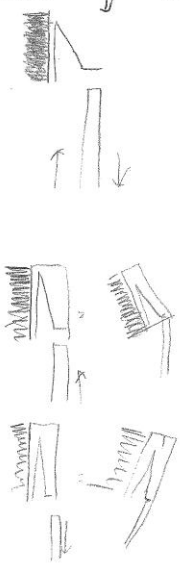
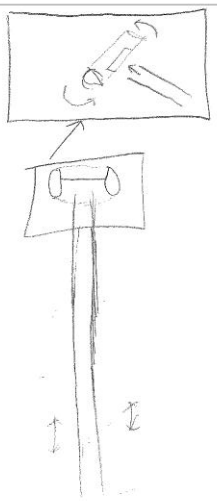
Energy mechanism for brush head (function)

Concept 1	Concept 2	Concept 3	Concept 4
 - How can we make this faster? - Is there lost efficiency because of the lateral change in energy?	 - Need to think of ways to make neck flexible - would this work as well as design works very well; I'm not sure that it needs to be changed. RFM	brushless dc motor with direct drive	brushless dc motor with gearbox

Student Name Patrick Trumbolla

Energy mechanism for brush head (function)

Concept 5	Concept 6	Concept 7	Concept 8

Concept 4	Concept 3	Concept 2	Concept 1	Student Name Justin Miller
Original Oral-B 		requires more effort than rotation brush - FFM 	 End: Solid concept, needs more detail added to see if it is a possibility	Energy mechanism for brush head (function)

our research focuses on rotation-oscillation brushes b/c they require less effort for better clean than vibration brushes - FFM — These two ARE rotation

Concept 8	Concept 7	Concept 6	Concept 5	Student Name Justin Miller
		Normal, DC motor which spins at the prong, potentially being connected to cams that would spin the crank shaft	Inside of Brush head	Energy mechanism for brush head (function)

Power Generation and Power Accessories (function)

The concepts for power generation were mostly developed through real-world examples and experiences. We already knew a multitude of ways we would be able to supply power to the toothbrush but we had to initially narrow our choices down to those who had an optimal balance of functionality and efficiency. That being said, our concepts mostly mirrored those that would already be seen in the common household. Batteries, AC power adapters, Docking stations, and solar power are by no means foreign to the common consumer and they have all been proven to do their intended job with little to no effort.

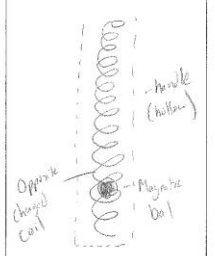
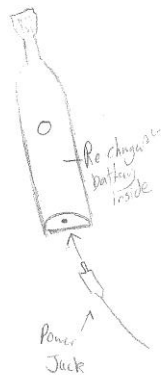
Student Name Patrick Trowbridge

Power generation and power accessories (function)

Concept 4	Concept 3	Concept 2	Concept 1
lithium polymer (rechargeable)	nickel cadmium battery (rechargeable) N.Cd	lithium ion (rechargeable)	current alkaline battery

Student Name Justin Miller

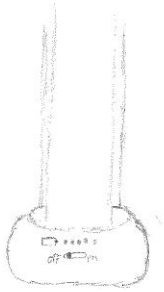
Power generation and power accessories (function)

Concept 4	Concept 3	Concept 2	Concept 1
Magnetic Flux  The point of an electric toothbrush is to save the energy to move your hands. Jiciness	Flat back 	3.6 Lithium ion batter Only need one	

2.6

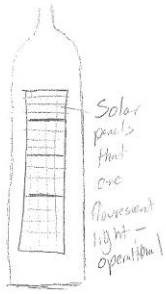
Student Name Patrick Trapp butta

Power generation and power accessories (function)

Concept 8	Concept 7	Concept 6	Concept 5
Charging station 	Nickel Hydrogen battery (not rechargeable)	Lead Acid (best choice)	Nickel metal hydride (Ni MH) (re-chargeable)

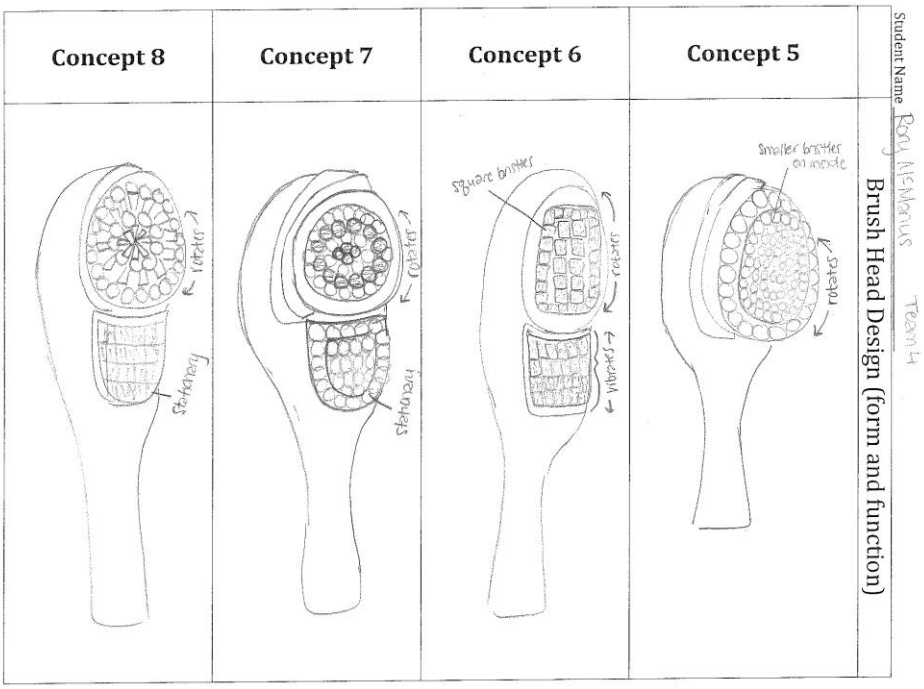
Student Name

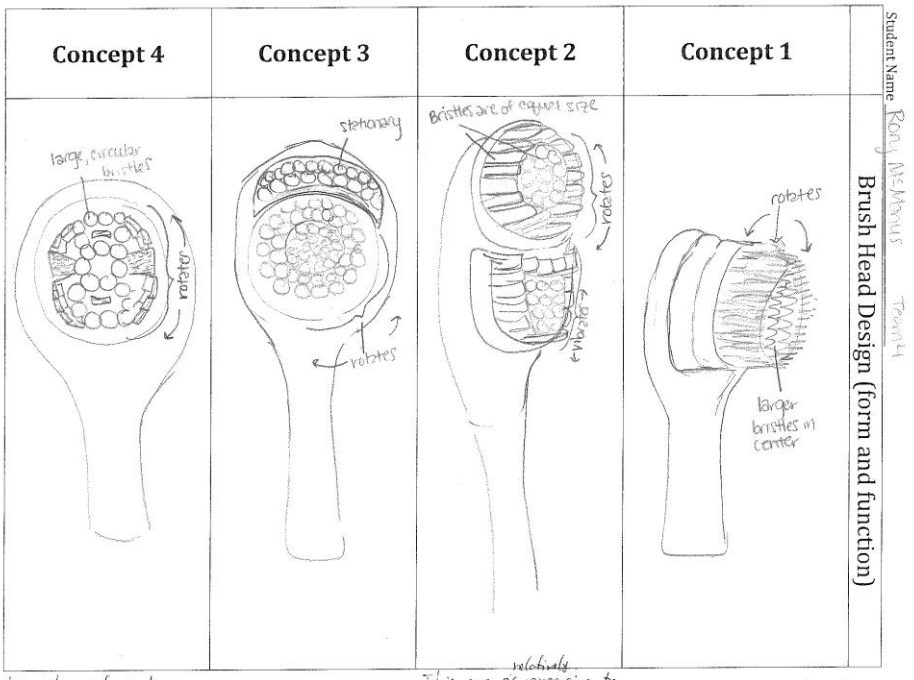
Power generation and power accessories (function)

Concept 8	Concept 7	Concept 6	Concept 5
			BACK OF TOOTHBRUSH 

Brush Head Design (form and function)

We experimented with the number of brush heads, the shape of the brush heads, the type of bristles, and the actions that the brush heads would perform. We created concepts involving rectangular bristles, circular bristles, vibrating bottom heads, stationary bottom heads, and more. We focused on appearance, cost, experience, and efficiency.



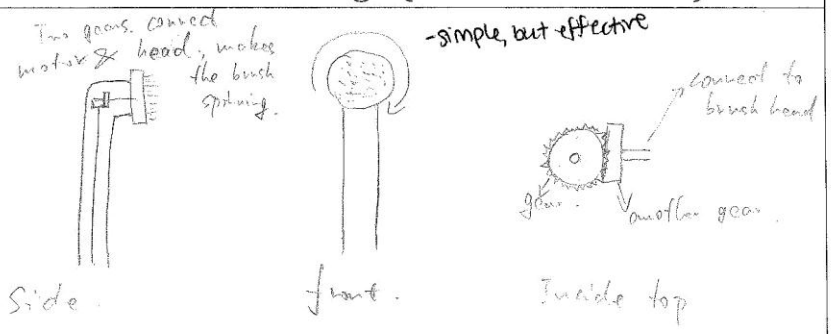
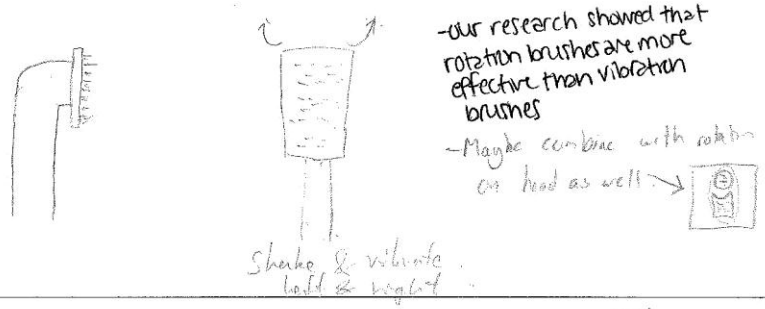
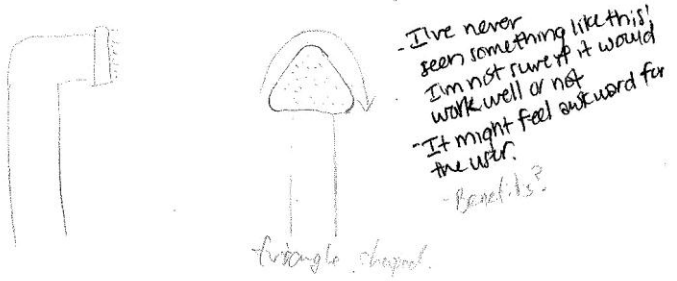
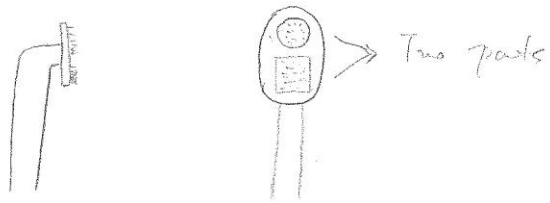


Vivid pictures!

This one is relatively expensive to build. ~~It~~ Will it be broken easily?

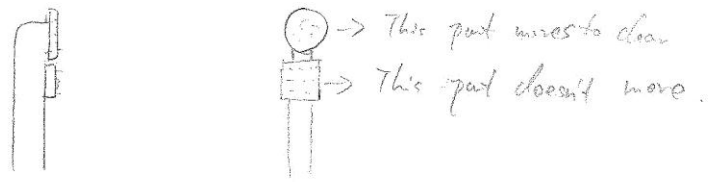
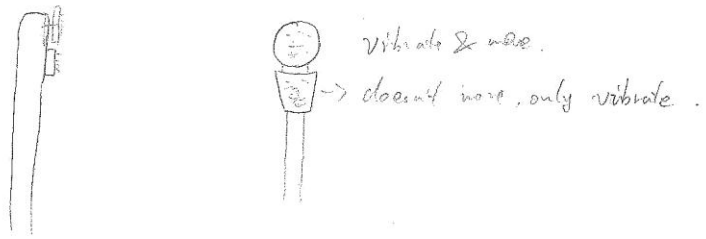
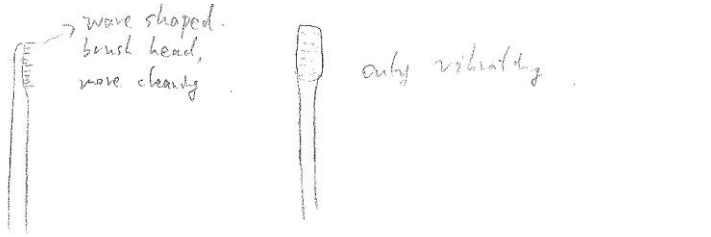
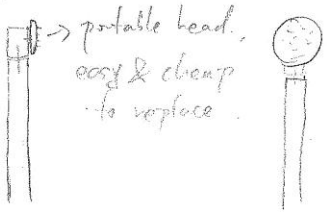
Jichen

Student Name Jichen Shen Team 4

	Brush Head Design (form and function)
Concept 1	
Concept 2	
Concept 3	
Concept 4	

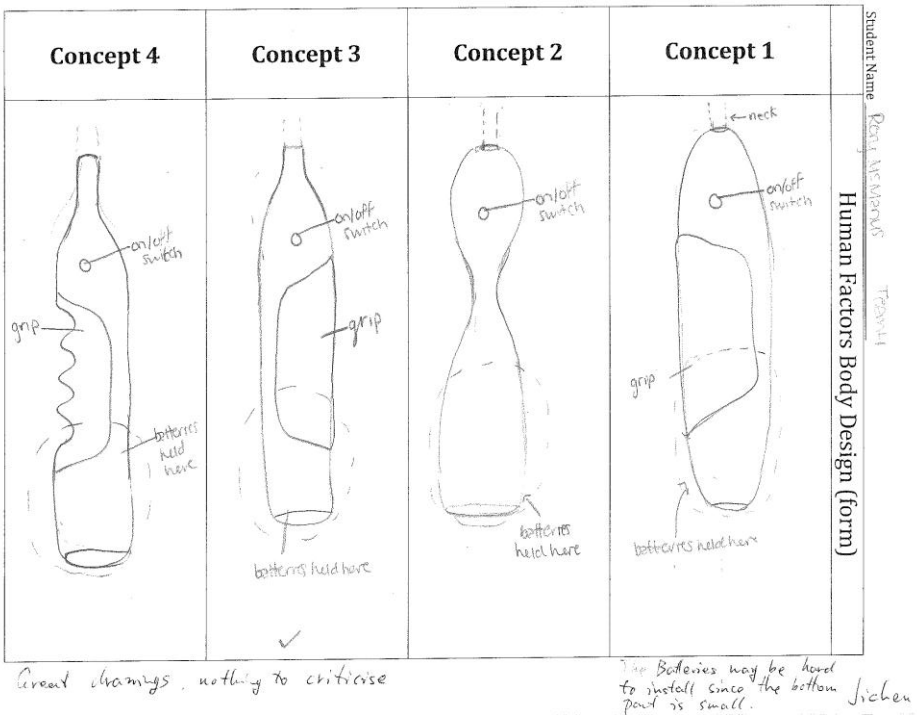
RFM

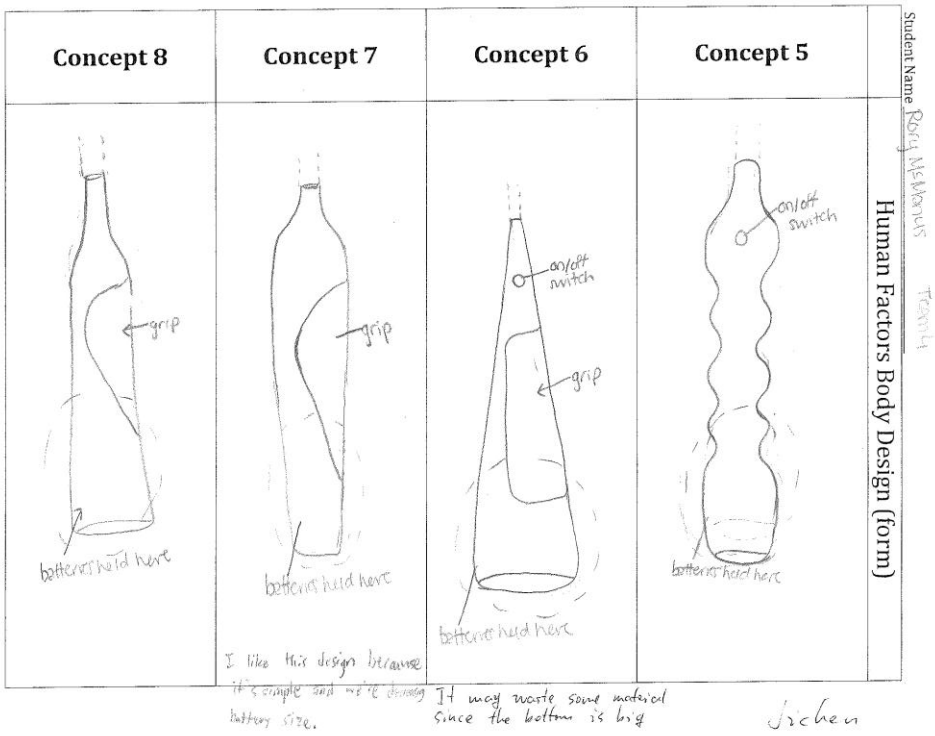
Student Name Yichen Shen Team 4.

	Brush Head Design (form and function)
Concept 5	
Concept 6	
Concept 7	
Concept 8	

Human Factors Body Design (form)

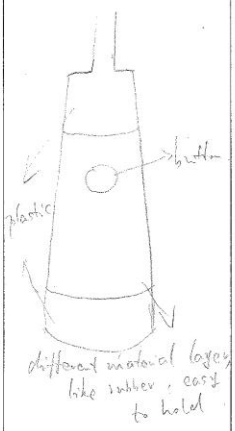
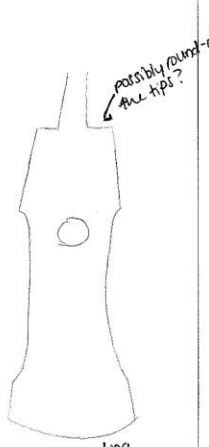
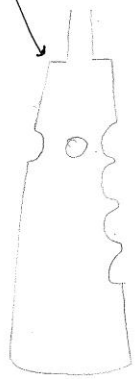
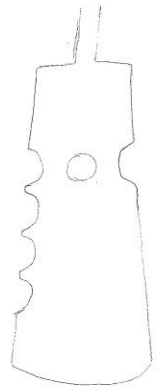
After examined the toothbrushes in the market, we generated these body designs. We wanted to included human factors in our design; however, it is cost effective to do so. Therefore we decided to keep it simple and chose the most basic design.





Student Name Jiahen Shen Team 4

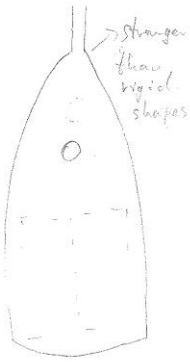
Human Factors Body Design (form)

Concept 4	Concept 3	Concept 2	Concept 1
	 -Are you including a grip? -I really like the shape of this one!	 Left-handed -it would be difficult to make the finger whole sites fit all consumers	 Right-handed would customers want to buy a dominant-hand specific toothbrush?

RFM

Student Name Jiahen Shen Team 4

Human Factors Body Design (form)

Concept 8	Concept 7	Concept 6	Concept 5
			 Cylindrical handle, more economical

6. Concept Selection

As a team, we created a pugh chart for each category in order to decide which concept would be best suited for our toothbrush. We compared our top three or four concepts based on the customer needs that applied to them. We compared each concept to each other concept and then ranked them according to their total scores.

Brush Head Design

	Efficiency	Appearance	Experience	Cost	Total	Rank
Weighting	0.015	0.019	0.015	0.137		
Concepts						
Iteration 1						
circular double head brush/stationary bottom head	1	-1	1	-1	-0.126	3
circular and rectangular double head brush/stationary bottom head	1	1	1	-1	-0.088	4
one and a half head cicular bristles	-1	-1	-1	1	0.088	1
one and a half head circular and rectangular bristles	0	0	0	0	0	2
Iteration 2						
circular double head brush/stationary bottom head	-1	-1	-1	1	0.088	1
circular and rectangular double head brush/stationary bottom head	0	0	0	0	0	2
one and a half head cicular bristles	-1	-1	-1	1	0.088	1
one and a half head circular and rectangular bristles	-1	-1	-1	1	0.088	1
Iteration 3						
circular double head brush/stationary bottom head	1	1	1	-1	-0.088	2
circular and rectangular double head brush/stationary bottom head	1	1	1	-1	-0.088	2
one and a half head cicular bristles	0	0	0	0	0	1
one and a half head circular and rectangular bristles	1	1	1	-1	-0.088	2
Iteration 4						
circular double head brush/stationary bottom head	1	1	1	-1	-0.088	3
circular and rectangular double head brush/stationary bottom head	1	1	1	-1	-0.088	3
one and a half head cicular bristles	-1	-1	-1	1	0.088	1
one and a half head circular and rectangular bristles	0	0	0	0	0	2

According to the Brush Head Design pugh chart, our best head design is concept 3 (the one and a half brush head with circular bristles). Ultimately it won out because it would be the lowest costing toothbrush. Cost was our most essential factor compared to efficiency, appearance, and experience.

Human Factors Body Design

	Strength	Size	Cost	Experience	Total	Rank
Weighting	0.2	0.2	0.3	0.3		
Iteration 1						
Concept 1					0	2
Concept 3	0	0	1	0	0.3	1
Concept 8	0	0	1	-1	0	2
Iteration 2						
Concept 1	0	0	-1	0	-0.3	2
Concept 3					0	1
Concept 8	0	0	0	-1	-0.3	2
Iteration 3						
Concept 1	0	0	-1	1	0	2
Concept 3	0	0	0	1	0.3	1
Concept 8					0	2

According to our Human Factors Body Design pugh chart, our best body design is concept 3. Concept 3 costs the least amount of money but gives a better strength. In addition it is easy to handle.

Energy Mechanism for Brush Head

	Cost	Weight	Power	Speed	Total	Rank
Weighting	**0.3**	**0.1**	**0.3**	**0.3**		
Iteration 1						
Direct Drive Brushed	0	0	0	0	0	**1**
Direct Drive Brushless	-1	1	-1	1	-0.2	3
1:2 Gearbox Brushed	0	0	1	-1	0	1
Iteration 2			0			
Direct Drive Brushed	1	0	1	-1	0.3	**1**
Direct Drive Brushless	0	0	0	0	0	3
1:2 Gearbox Brushed	1	-1	1	-1	0.2	2
Iteration 3						
Direct Drive Brushed	0	0	0	1	0.3	**1**
Direct Drive Brushless	-1	1	-1	1	-0.2	3
1:2 Gearbox Brushed	0	0	0	0	0	2

The Energy Mechanism for Brush Head pugh chart shows that using a direct drive brushed dc motor would be the best option for our design. This incorporates a low cost and a balance of speed and power.

Power Generation and Power Accessories

	Cost	Efficiency	Battery Life	Practicality	Total	Rank
	0.3	0.2	0.2	0.3		
Iteration 1						
Lithium Ion w/ Docking Station	0	0	0	0	0	1
2 AA Alkaline Battery	1	-1	-1	0	-0.1	2
Lithium Ion w/ Adapter	0	0	0	-1	-0.3	3
Iteration 2						
Lithium Ion w/ Docking Station	-1	1	1	0	0.1	1
2 AA Alkaline Battery	0	0	0	0	0	2
Lithium Ion w/ Adapter	-1	1	1	-1	-0.2	3
Iteration 3						
Lithium Ion w/ Docking Station	0	0	0	1	0.3	1
2 AA Alkaline Battery	1	-1	-1	1	0.2	2
Lithium Ion w/ Adapter	0	0	0	0	0	3

We chose to have the toothbrush be powered by a 3.6 V Lithium Ion battery that would also have a docking station for regular charging. This became our favorite and most logical choice because it combined the best mix user-friendliness and cost-efficiency. Because it can stand on the docking station while not in use, it became more popular than all the other lithium ion choices and the extended battery life and practicality made up for the small up-charge.

Morphological Chart

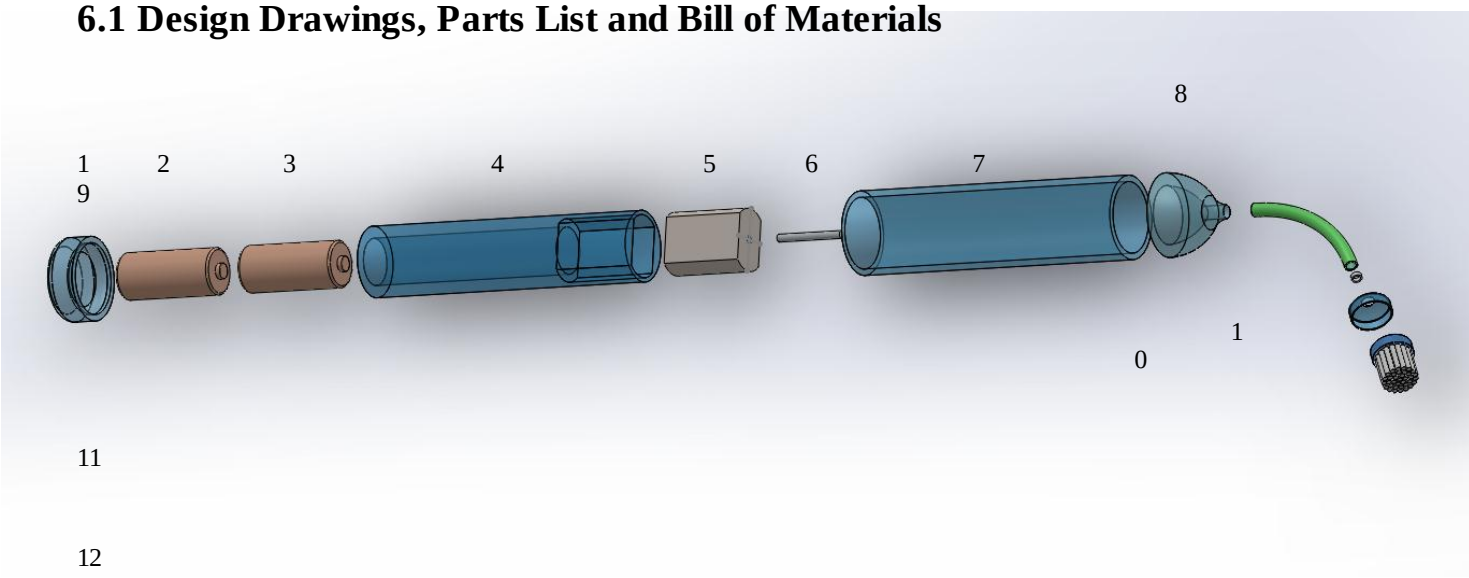
After completing the pugh charts, we generated a morphological chart showing which ideas we chose to use in our final design. The line across the chart indicates which concepts we chose to use.

Brush Head Design	**Body Design**	**Energy Mechanism for Brush Head**	**Power Generation and Power Accessories**
Circular, double brush head; Stationary bottom head	Concept 1	Direct Drive Brushed	Lithium Ion with Docking Station
Circular and rectangular double brush head with stationary bottom head	Concept 3	Direct Drive Brushless	2 AA Alkaline Battery
Circular one and a half head brush	Concept 8	Gearbox Brushed	Lithium Ion w/ Adapter
Circular and Rectangular one and a half head brush			

6.0 Final Design

Discuss details of the final design. This should be well illustrated with *multiple* 3-Dimensional models, as well as dimensioned part drawings for each component redesigned. These drawings completed in Solid Works should be placed in appendices.

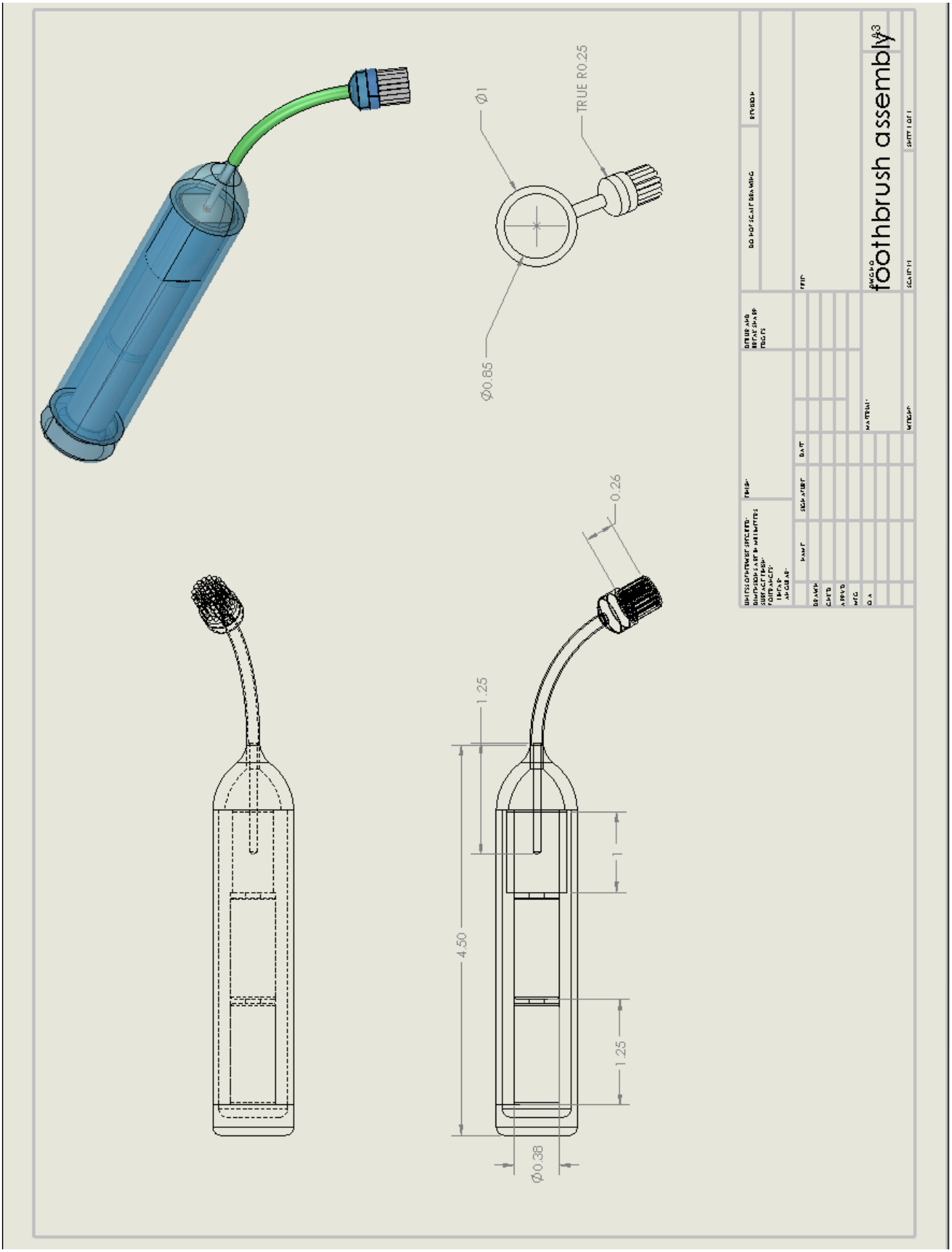
6.1 Design Drawings, Parts List and Bill of Materials

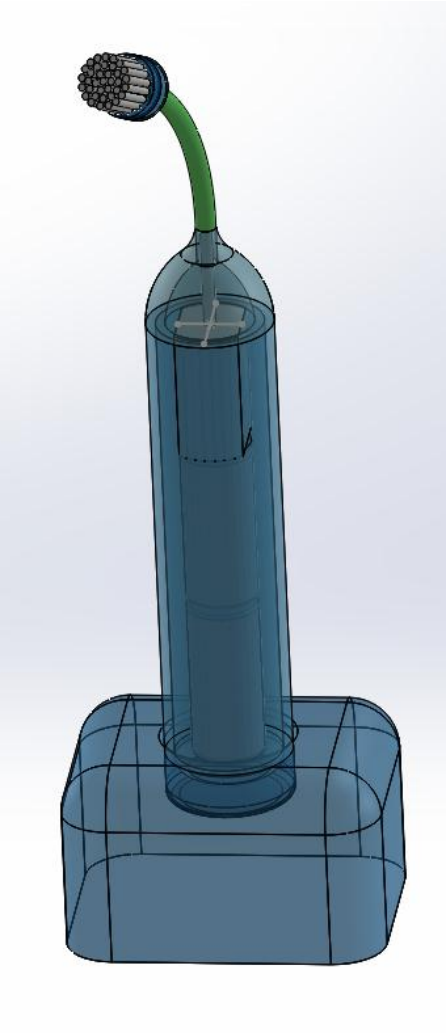


Bill of materials:

Numbers follow parts from left to right in the picture above:

1. Endcap
2. 3.6 volt lithium ion battery cell
3. 3.6 volt lithium ion battery cell
4. Internal housing unit
5. DC brushed motor body
6. Motor shaft
7. External shell
8. Topcap
9. Rubber neck
10. Microbearing
11. Bristle holder
12. Brush head


Ø1
TRUE R0.25
Ø0.85
0.26
1.25
4.50
1
1.25
Ø0.38
DO NOT SCALE DRAWING
SIZE
A3
DWG NO
foothbrush assembly
SCALE: 1:1
SHEET 1 OF 1



6.2 How does it work?

In the best way you can please explain how your design works giving as much detail as possible regarding technical information.

- Our design is simple, yet effective
- 2 3.6 volt lithium ion batteries in series deliver current to a brushed d/c motor.
- The spinning motor shaft is connected to a very tightly coiled spring (to allow for the neck of the toothbrush to bend and clean hard to reach areas)
- A micro-bearing in the neck is used to stabilize the spinning shaft regardless of its orientation.
- The interchangeable brush heads are fed into the end of the neck.
- The components are held in an internal housing unit and are then covered in an outer shell.
- All plastic used is eco-friendly and follows technology used in the Pilot B2B pen: from recycled water bottles.

7.0 Conclusions

Our final design was modeled around our customer needs as well as the goal of making it more sustainable. Due to these facts, our design meets our customer needs, for the most part, quite well. Unfortunately, the cost of our toothbrush is higher than we would like (based on customer needs) due to our conversion to a rechargeable toothbrush. But, this conversion was necessary in order to create a more sustainable toothbrush. This leads us to the idea that we should have asked our customers if they would be willing to pay more for a rechargeable toothbrush versus one that uses disposable batteries. If we were to survey again, we would ask this question. Overall, our toothbrush is easily maintained, fairly priced, good looking, efficient in it cleaning (with its one a half head brush design), and should provide a good experience for the consumer. Availability is not part of the design process, but is very important. As a whole, we are satisfied with our final design and feel we have accomplished the goal of making a more sustainable electric toothbrush the meets the needs of our customers.

References (Times New Roman, 16, Bold)

"SciELO - Scientific Electronic Library Online." *SciELO - Scientific Electronic Library Online*. N.p., n.d. Web. 26 Sept. 2012. <http://www.scielo.br/scielo.php?pid=S1806-83242009000500004>.

"Sign In." *Sign In*. N.p., n.d. Web. 26 Sept. 2012. <http://intl-adr.sagepub.com/content/16/1/9.full>.

"ä¸–è«– What Japan Thinks." *Electric Toothbrush Usage in Japan*. N.p., n.d. Web. 26 Sept. 2012. <http://whatjapanthinks.com/2008/11/13/electric-toothbrush-usage-in-japan/>.

"Electric Toothbrush." *Wikipedia*. Wikimedia Foundation, 26 Sept. 2012. Web. 26 Sept. 2012. <http://en.\ wikipedia.org/wiki/Electric_toothbrush>.

"Can You Recycle Your Toothbrush?" *About.com Environmental Issues*. N.p., n.d. Web. 26 Sept. 2012. <http://environment.about.com/b/2005/12/20/can-you-recycle-your-toothbrush.htm>.

"United States Patent and Trademark Office." *United States Patent and Trademark Office*. N.p., n.d. Web. 12 Oct. 2012. <http://www.uspto.gov/>.

Appendix A

Lab 1

Product Dissection & Benchmarking Project: Lab I

Preparation:

1. Read about product dissection and benchmarking from the course text, *Engineering Design: A Practical Guide* Chapter 8.

Section: _7_____
Team: __4_____
Members: _Rory McManus_____
_Jichen Shen_____
_Justin Miller_____
_Patrick Trumbetta_____

Lab I Assignments:

1. Complete data sheet 1.
2. Make seven copies of your completed data sheet 1 (Do not include your name on the copies).
3. Prepare a comprehensive features comparison table for features that are in your list of features to be benchmarked.

Laboratory Tools:

1. Digital scale,
2. Camera.

Estimated time: 1 hour.

A. Visual Inspection:

Tasks:

1. Take digital pictures of the product, its parts and the packaging.
2. Record the following information for the product you are given for dissection on data sheet 1.
3. Recorded information should reflect everyone's opinion in the dissection team. Therefore, if there is a difference of opinion among members, opinions and members who provided them should be noted.

DATA SHEET 1

Getting Ready for Dissection: Part I

Manufacturer/Model Number: Oral B Advance Power 400; Model #: 4010

General Product Information:
How many detachable pieces the product has? __6____

Part number: Part name:
____1_____ _ Brush Head_____
____2_____ _ Bottom (Battery Cap)_____
____3_____ _ Battery (2 AA Batteries)_____ ____4_____ _ Head Cover_____
____5_____ __Body_____
____6_____ __rubber O-ring seal_____

Describe the pieces including their functions and their materials.

Part number: Material & Functional Description:
____1_____ Plastic; Bristles made from plastic; function: scrub teeth

____2_____ Plastic; function: keep batteries from falling out of the toothbrush

____3_____ Alkaline metals; function: give the toothbrush its power to function

____4_____ Plastic; function: keeps the brush clean when not in use

____5_____ Plastic; function: contains the batteries and serves as point from which all other pieces are attached; also serves as grip during toothbrush use

____6_____ rubber; prevents water from affecting the batteries

Is it easy to detach each part?

Part number: Detachment (Easy, difficult, use of force etc.):
___1_____ easily removable by hand
___2_____ easily removable by hand
___3_____ easily removable by hand
___4_____ easily removable by hand
___5_____ easily removable by hand
___6_____ difficult to remove; would require tools such as screw driver

Describe the packaging. Is it easily opened? Describe the opening procedure.

The packaging is a tight, clear plastic sealant. It is very difficult to remove without the assistance of scissors or a knife. With scissors, it needs only to be cut along the edge of the packaging.

DATA SHEET 1

Getting Ready for Dissection: Part I (cont.)

Product Features: Provide team's collective opinion related to features of the product using the following list as a starting point.

Packaging (including information insert)	Plastic sealant
Aesthetics (multi-color, etc.)	Mainly white, teal grip. Brush head is broken up into quarters with corresponding blue and white bristles
Cleaning	Rinse under running water while power is on.
On/off switch location	Middle of grip on the front of the toothbrush.
Battery location	Bottom of toothbrush.
Ease of switch use	Simple. Large button on front of grip that serves as both "on" and "off" switch
Handle (Ergonomics)	Wide enough to be comfortable but narrow enough to have a good grip.
Quality	Reviews indicate that our product cleans better than a manual toothbrush but better electric/battery-powered toothbrushes remain on the market
Safety	Sufficient. Rubber "O" ring on battery case prevents water from seeping into battery compartment
Versatility, attachments	No versatility. Brush head only has one function
Weight with batteries	.297 grams with brush head cover .292 without
Environmental friendliness	Not very environmentally friendly. Mostly made up of plastic and alkaline batteries aren't decomposable.
Other features	Brush head cover works to prolong the use of the brush head and prevent bacteria from reaching the bristles. "Advanced Bristle System": color on the bristles fade, indicating when brush head replacement is needed

Product Dissection & Benchmarking Project Handout I – Part II.

Laboratory Tools:

1. Computers which are connected to the internet,
2. Library resources.

Estimated time: 1 hour.

B. Market Realities for the Product:

Tasks:
1. Using on-line and library resources gather and record information on the market presence of the product.

DATA SHEET 1	
Getting Ready for Dissection: Part II	
Cost (Be prepared to record multiple values and sources)	$11.99; $11.10; $9.99 http://www.smilox.com/oral-b-advancepower-400-bright.cfm http://www.superdentalstore.com/Oral-B-Bright-AdvancePower-400-p-16139.html
How long has the product been in the market?	2003
Target population	**Very wide target audience; Young adults-Adults; Middle class**
Versions of the product (Previous versions of the product)	**400 is the first of its series. It is followed by several other versions such as the 400TX and the 450; there are many similar, simpler versions of Oral B toothbrushes that preceded or existed at the same time as the 400, but none of its series.**
What are improvements between versions of the product?	**More power; removable head; rubber grip**
How is it sold (TV infomercial, drugstores, etc.)	**Drugstores, Online, through local dentist**

Patented Features (Please include patent dates).	**US5524312-Powering of toothbrush head** Date: June 10, 1996 US5974615- Scrubbing teeth and removing any germs on the tooth surface Date: November 1, 1999 D527185S- Keeps batteries in toothbrush and allows the circuit to be complete Date: August 28, 2006 D636604- Handle (grip) Date: April 25, 2011

Appendix B

Lab B

Product Dissection & Benchmarking Project Handout II
Measurements and Dissection. Estimated time: 2 hours

Preparation before beginning the Lab:
Read *Noise Measurement* and *Electric Circuits* Handouts.

Section: 7_____
Team: 4_____
Members: Rory_____
Jichen_____
Justin_____
Patrick_____

Lab II Assignments:
Complete data sheet 2.

Laboratory Tools:
1. Camera
2. Sound intensity (Decibel) meter
3. Hack saw
4. Screw driver
5. Pliers
6. Multimeter
7. Connectors
8. Ziplock bags

I. Noise Measurement:

Tasks:
1. In a quite environment, place the Decibel meter's microphone close to the product running with no load. Record the decibel readings for various distances on data sheet 2.

II. Power Measurement:

Tasks:
1. Remove the battery (batteries) from the product place them on the workbench.
2. Using a multimeter, measure the voltage across the battery (or batteries placed in series). Record the voltage on data sheet 2.
3. Replace the battery (batteries) into their working positions, replace the battery cover, and turn the product on to ensure the batteries are placed correctly.
4. Measuring current under 'no load': Remove the battery cover and leave the batteries inside the product.
5. Connect a multimeter in series with the exposed ends of the batteries. The multimeter will thus complete the electric circuit.
6. Switch on the multimeter, set it to read current in milliamps (mA).

7. Turn on the product and record the current reading for the no load condition. Note that the reading will fluctuate a little. Record several readings and take the average. Turn the product off.
8. Measuring current under load. Repeat steps 5-7, except the toothbrush should be positioned with the bristles rubbing against the workbench (simulating brushing of teeth). The toothbrush should be pressed down with similar pressure as when brushing ones teeth. This will be the first 'under load' measurement.
9. Step 8 should be repeated with each group member taking a turn at simulating brushing. At the end of this step, there should be as many averaged 'under load' measurements as the number of team members.
10. Using the formula P=VI calculate the power required to run the product.
11. Assume that an average non-rechargeable battery has a capacity of 1000 mAh. Using the average power consumption 'under load' calculate how long (in hours) the tooth brush can run before the batteries die.
12. Estimate how long it takes (or you should take) to brush your teeth. Assuming you brush your teeth twice a day, calculate how many days use before you need to replace your batteries.

III. Dissection:

Tasks:

1. Disassemble, measure, and analyze function of each component. Record your findings in the Bill of Materials (BOM) table in data sheet 2 **(make sure you identify the team leader(s) for the dissection of each component). Make sure to note the start time and end time of the dissection for each component.**
2. Insert pictures or sketch components to the visuals table in data sheet 2. Indicate names of the components as you have given in the previous table. **Indicate who completed each drawing.**
3. Study and indicate (using a tree structure) how components, subassemblies, and final assembly relate to each other on data sheet 2.

DATA SHEET 2

1. Noise Measurement:

Location:	**Noise level:**
Brush head 4 in away from decibel meter	69.6
Brush head 3 in away from the decibel meter	72.6
Brush head 2 in away from decibel meter	76.0
Brush head 1 in away from the decibel meter	77.0
DC motor 4 in away from decibel meter	69.6
DC motor 3 in away from the decibel meter	70.5
DC motor 2 in away from the decibel meter	72.5
DC motor 1 in away from the decibel meter	73.2

Approximate duration of brushing per day: 4 minutes

Average noise level during brushing: 73.8

2. Power Measurement:

Voltage supplied to the circuit:

	Battery Type	**Volts (V):**
Battery 1	AA Duracell	1.514
Battery 2	AA Duracell	1.5125

Total Voltage:

	Connection Type	**Volts (V):**
Battery 1 and Battery 2	in series	3.0265

Current Measurements	**Averaged Current Value**
No load condition	**.27 A**
Load condition(s)	
1. minimal pressure	.28 A
2. slight pressure	.30 A
3. medium pressure	.40 A
4. hard pressure	.49 A

Mean current 'under load' 0.37 A

	Voltage		Current		
Power (no load) =	3.0265 V	X	.27 A =	0.82	Units: watts

	Voltage		Current	
Power (under load) =	3.0265	X	0.37 =	1.13 (sig figs: 1.1)

Units: watts

3. Battery Life

1. Number of hours available per single battery 'under load' conditions: _6.96__ Hours

2. Estimate duration for each brushing _____.03_____ Hours

3. Number of days before battery replacement ___105_____ Days

Bill of Materials

Product Manufacturer/Model Number: Oral B Advanced Power 400 # D 4010

Date: 9/17/12

Disassembly method:

Subtract and Operate Procedure (SOP): Yes, No. **Force (Energy) Flow Diagram: Yes, No.**

Team leader name(s)	**Part#**	**Part Name**	**QTY**	**SOP** Effect	**Function**	Weight (lbs.)	**Material**	**Manuf. Process**	**Dimensions** (cm)	**Cost**	**Time to Complete Part Dissection**
Rory	**1**	Brush head	1		Brushes teeth	.012	plastic	Injection mold	7.3 (tall)	$0.30	10 seconds
Jichen	**2**	Battery cap	1		Keeps batteries contain-ned in body	.010	plastic	Injection mold	3.5x2.3	$0.15	3 seconds
Patrick	**3**	Battery	2		Power source of tooth-brush	.108	Alkali metal	purchased	5.0 (tall)	$0.50	3 seconds
Rory	**4**	Head cover	1		Keeps brush head clean when not in use	.006	plastic	Injection mold	6.3 x1.8	$0.20	3 seconds
Justin	**5**	Body	1		Holds parts together	.156	plastic	Injection mold	16.4x3.5	$0.15	5 minutes

Patrick	**6**	Rubber seal O-ring	1		Prevents water from contacting inside contents of toothbrush	NA	rubber	molding	D = 3.0	$0.03	10 seconds
Justin	**7**	Motor	1		Runs the brush	.074	metal	Purchased	4.6 (tall)	$2.00	7 minutes
Jichen	**8**	Crank shaft	1		Rotates brush head	NA	metal	CNC milling machine	7.7 (tall)	$0.20	5 minutes
Justin	**9**	Wires	2		Directs power through toothbrush	NA	metal	Wire forming	6.5 cm	$0.83	1.5 minute
Rory	**10**	Button	1		Allows brush to be turned on and off	NA	plastic	Injection mold	0.4x0.3	$0.15	2 minutes
Patrick	**11**	Battery holder	1		Assists in conduction of batteries	NA	metal	Press sheet aluminum	2.0x1.0	$0.25	1 minute
Rory	**12**	Spring	1		Allows for back and forth motion of head while brushing	NA	metal	Lathe	H = 0.7 D = 0.6	$0.02	1 minute
Justin	**13, 14, 15**	Other assorted pieces (rods and screws)	3		Keep bristles of tootbrush attached to the head	NA	metal	Lathe	NA	$0.05	2 seconds

Jichen	**16**	Grip	1		Makes it easier/ more comfort-able to hold toothbru-sh	NA	rubber	Injection mold	D = 5.7 D2 = 7.6	$0.31	3 minutes
Patrick	**17**	Bristles	1		Clean teeth	NA	Plastic/n ylon	Punchi-ng Machine	D = 1	$0.20	1 minute

Visuals: Component pictures, sketches and/or solid models

Toothbrush Assembled

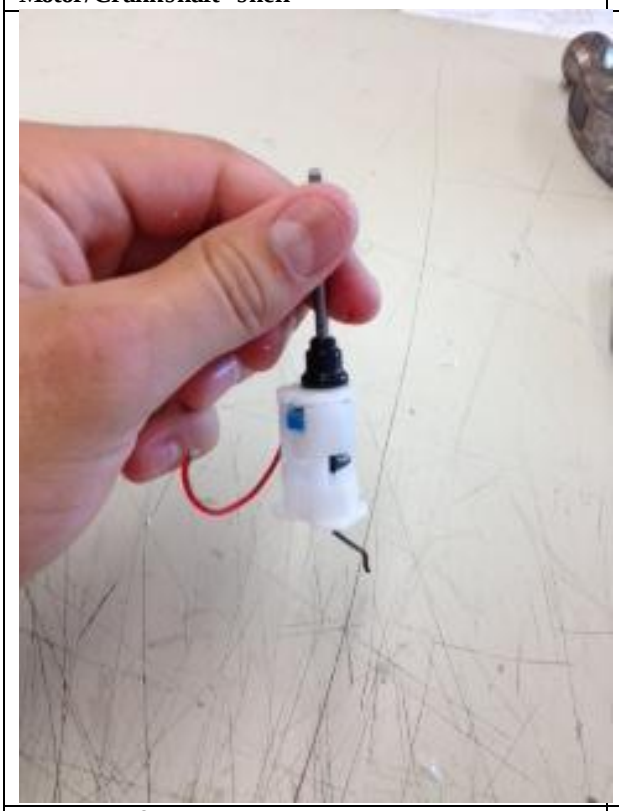
Toothbrush Parts

Toothbrush Parts (exploded view)

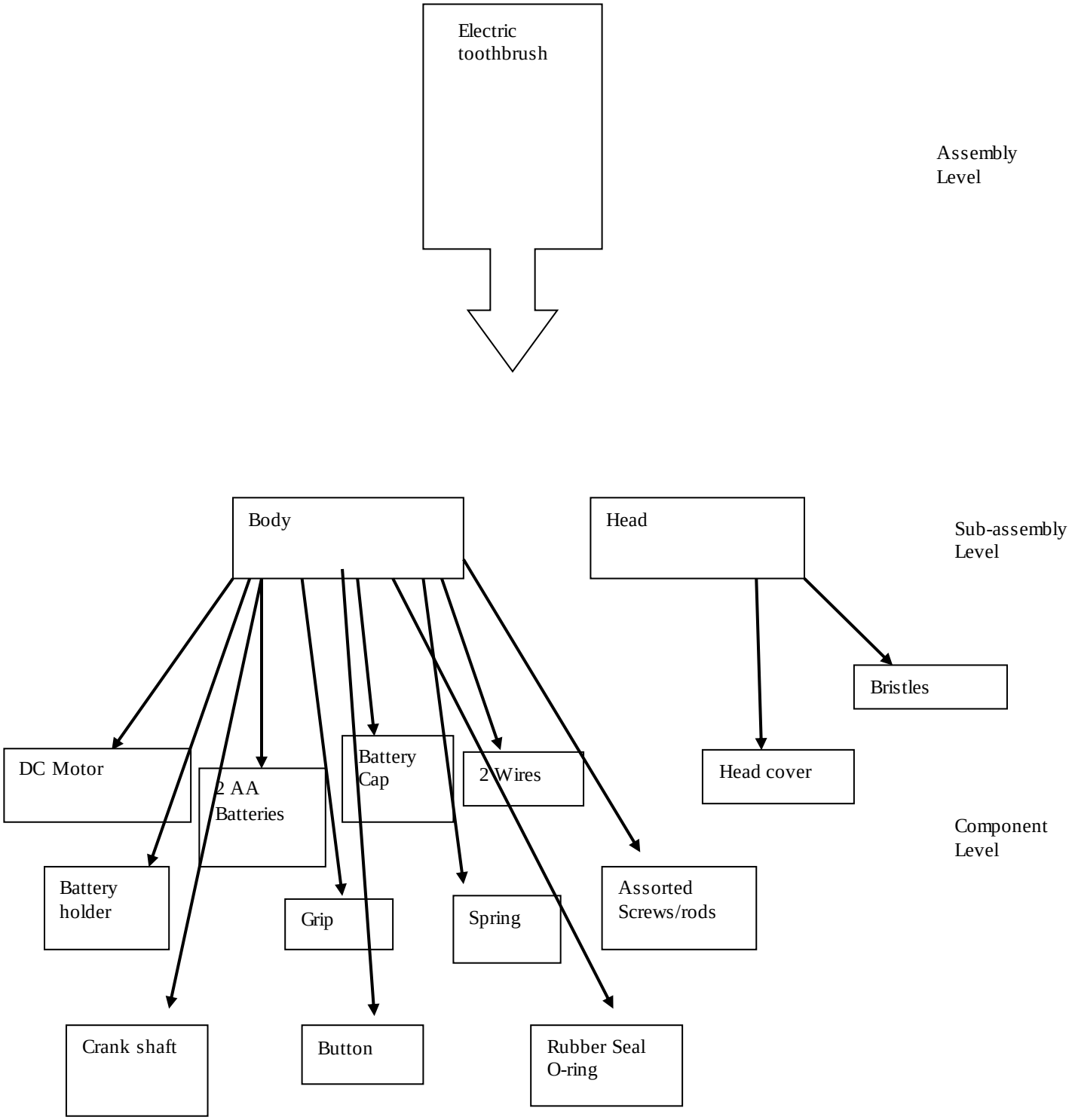
Inside of shaft (power button)

Motor/Crankshaft shell

Brush head exposed



Crank shaft

DC Motor

Component, subassembly, assembly hierarchy: