GEORGIA INSTITUTE OF TECHNOLOGY
George W. Woodruff School of Mechanical Engineering
ME 2110 - Creative Decisions and Design
Summer 2017

STUDIO I
DISSECTION WORKSHEET

PearlyWhites, co. plans to design a new environmentally sustainable toothbrush offering in the $5-$20 cost range to meet customer requests for more sustainable products. Your team is tasked with characterizing and analyzing the designs of two competitors' products using the materials provided:

- Oral-B CrossAction Power toothbrush with replaceable battery
- Oral-B CrossAction Power toothbrush with reusable battery
- Crest SpinBrush PRO-CLEAN toothbrushes (one assembled, one dissected)
- Screwdriver

The task is to inspect and sketch the listed toothbrushes, identify key design features, or elements, in the design, determine the operation of the mechanisms, weigh the primary materials for a back-of-the-envelope impact assessment, and, finally, reassemble the toothbrushes back to working condition.

In this lab you will:

1. **Operate** the two toothbrushes
2. **Sketch** what you expect to see inside the Oral-B *CrossAction Power* electric toothbrush with replaceable battery
3. **Dissect** the Oral-B *CrossAction Power* electric toothbrush with replaceable battery
4. **Inspect** two *SpinBrush PRO-CLEAN* electric toothbrushes with replaceable batteries (one will be pre-dissected)
5. **Weigh** the primary materials of the Oral-B *CrossAction Power* electric toothbrush
6. **Reassemble** the Oral-B *CrossAction Power* electric toothbrush with replaceable battery
7. **Estimate** the global warming potential and water footprint of the toothbrush.
8. **Write** an Executive Summary for the PearlyWhites, Co. based upon your notes and observations

Only the Oral-B *CrossAction Power* electric toothbrush with replaceable battery will be fully dissected in the lab.

You will have 30 minutes to write an abstract summarizing your observations and recommendations. Therefore, it is critical that all pertinent information is collected in lab notes to facilitate writing.

Keep track of how parts fit together and relate to each other as the brushes are disassembled. This will allow proper reassembly of the device. Take photos after each step to help track the assembly steps. Utilize the tape to label parts or tape them down in the assembly order so as not to lose them.

Care must be taken during disassembly as the device needs to be reassembled and properly operate for completion of the studio – students from other sections will also need to dissect the device.

Procedure and Worksheets for Mechanical Dissection

Dissection Guide: Consider the following during dissection:
• Keep a good record of what is being done.
• Keep track of all the parts and periodically update the bill of materials during dissection.
• Be as specific as possible with function and material when taking notes.
• Be certain that the functionality of all internal parts are understood.

Dissection Steps:
These refer to the **Oral-B toothbrush** with replaceable battery, unless otherwise noted. READ ALL THE INSTRUCTIONS AND THE TOOTHBRUSH INSERTS BEFORE STARTING THE DISSECTION.

1. Operate the device.

Observe the sequence of operations that make it work. What indicates how to operate the device? How clear are the indications, if any?

Observe how the brush works. Note the brush head motion(s).

List the sequence of operations that a user would engage in. Think about how and where it might be stored in the home. (there may more or fewer steps than allotted below)

a.

b.

c.

d.

e.

f.

g.

h.

i.

j.

2. Predict how the toothbrush works on the inside. ***Sketch your prediction on a separate piece of paper.***

3. Take off the brush head carefully. Do not disassemble the brush head.

How was the brush head aligned and removed? Was it easy to remove? Why or why not?

Is the brush head meant to be replaceable? Is this obvious without consulting the directions?

4. Operate the device without the brush head attached.

What is observed?

5. Remove the bottom of the device by unscrewing it.

6. Remove the battery.

Observe how the device indicates which way to put in the battery.

7. Remove the battery/motor subassembly. Do not disassemble the subassembly.

How was the subassembly removed?

Why are the snap fits located where they are?

8. Put the battery back in the battery/motor subassembly.

9. Operate the subassembly.

Discuss observations about its operation. What physical phenomena are utilized to achieve device functionality?

10. Remove the rocker switch.

What happens? Why? How is this use of the physical properties of the material interesting?

11. Remove the battery.

12. Bend the motor out a bit to get a good look at it. Do not disassemble the subassembly.

What markings are on the motor?

Notice the lack of wires – why? What replaces them? Why?

13. Remove the metal rod. Do NOT remove the white plastic collar from the rod.
How was the metal rod removed from the housing?

What functions do the rod and the attached parts serve?

*14. Now compare the drive mechanism of the Oral-B toothbrush to that of a **Crest SpinBrush PRO-CLEAN toothbrush**.*

Do NOT disassemble either the dissected or non-dissected Crest toothbrushes. Only remove any covers or brushes to observe their workings.

Operate the Crest electric toothbrush and observe its operation. Observe the operation of the subassemblies provided. Non-destructively take apart the complete Crest toothbrush. Untwist the Crest toothbrush head to remove and replace it.

A schematic of the drive train of the Crest toothbrush, reproduced here as Figure 1, is shown in US patent #6,932,216. For the purposes of this studio, the drive train includes components 200, 202, 208, 206, 210, 222, 220, 226, 224, 232, 250, 230, 234, 252, 253, 244, 240, 260, 246, 254, 262, 256, and 164.

What differences exist between the Crest Spinbrush PRO-CLEAN and the Oral-B Cross-Action Power electric toothbrushes?

How might these differences affect the brushing effectiveness?

How might these differences affect the maintenance and cleaning?

How might these differences affect storage of the device?

16. Put the toothbrushes back together so that they operate correctly. Note that the Oral-B toothbrush is more easily assembled with the battery removed.

What recommendations would you give to the PearlyWhites, Co.? (You might review the list of Design for Environment Guidelines on the last page of this document)

16. Table 1 shows possible materials used in the toothbrushes, estimates of their masses, and estimates of the water and global warming impacts incurred when producing one kilogram of that material. Table 2 shows basic data for electricity and water for toothbrushing.

Table 1: Estimates for Materials and Impacts (from CES EduPack)

	Steel	*Polypropylene*
Mass in a toothbrush	20 grams	30 grams
CO_2 emissions during processing of virgin material	3 kg_{CO2}/kg	2.7 kg_{CO2}/kg
CO_2 emissions during recycling of material	1 kg_{CO2}/kg	1 kg_{CO2}/kg
Water to mine and process virgin material	128 L/kg	33 L/kg

Table 2: Estimates of Global Warming Potential of Electricity and Water

	Electricity	*Treated Water*
CO_2 emissions during production	0.5 kg / kWh	0.002 kg/L

Make an assumption for how much water someone uses to brush (assuming an average faucet flow rate of 0.05 liters per second). Oral B states that their toothbrushes use about 2.8 kWh per year. In one year, what will the environmental impact from toothbrushing be? (Hint: with how many toothbrushes and how many times will someone brush their teeth?)

<u>Water to produce one toothbrush</u>

_____ x _____ + _____ x _____ = _____________ L of water
kg steel L/kg kg PP L/kg

CO_2 to produce one toothbrush

_____ x _____ + _____ x _____ = _____________ kg_{CO2}
kg steel kg_{CO2}/kg kg PP kg_{CO2}/kg

CO_2 for treating a year's worth of water used during toothbrushing

_______ x ______ x ______ x _______ = ____________ kg_{CO2}
kg_{CO2}/L L/sec sec/use uses/yr

CO_2 for powering a toothbrush for a year

_________ x ______ = ____________ kg_{CO2}
kg_{CO2}/kWh kWh

What aspects (water, electricity, materials) of the toothbrush use and design have the highest environmental impact? [note that these are just back of the envelope estimates] What do you think the impact of the batteries is?

MECHANICAL DISSECTION DELIVERABLES

Deliverables due at the end of this studio

1. Reassembled, working products
2. Tools
3. Cleaned up work area

Deliverables due at the beginning of next studio

4. Handwritten Executive Summary with Notes
5. Typed and Printed Executive Summary with Figures

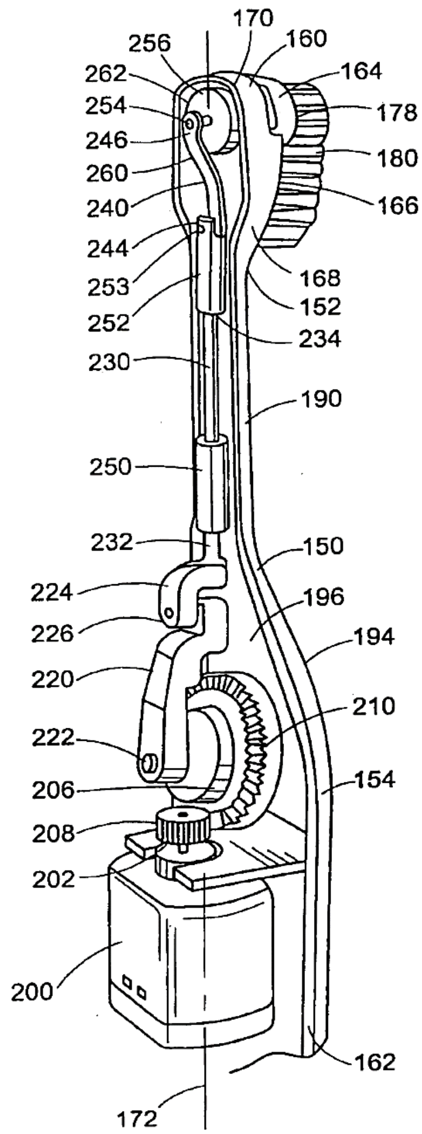

Figure 1: Crest Toothbrush from US patent #6,932,216

Table 3: Design for Environment Guidelines[1]

A. Maximize availability of resources: [3,20–23,32,38,41,42,46–50,52]

1. Specify renewable and abundant resources
2. Specify recyclable or recycled resources
3. Layer recycled and virgin material where virgin material is necessary
4. Employ common and remanufactured components across models
5. Specify compatible materials and fasteners for recycling
6. Minimize the variety of materials in the product and its subassemblies

B. Maximize healthy inputs and outputs: [3,15,20–23,41,42,46–50,52]

7. Contain pollutants and hazardous materials for reuse or processing
8. Specify environmentally benign materials
9. Create biodegradable outputs
10. Specify resources with low emissions
11. Include labels and instructions for safe handling of toxic materials
12. Concentrate pollutants and hazardous materials for easy removal and treatment
13. Recover emissions and outputs

C. Minimize use of resources in production and transportation phases: [17,20–23,32,38,42,47,49,52]

14. Replace the functions and appeals of packaging through the product's form
15. Employ folding, nesting or disassembly to ship and store products in a compact state
16. Apply structural techniques and materials that minimize the total volume of material
17. Specify lightweight materials and components
18. Structure the product to avoid rejects and minimize material waste in production
19. Minimize the number of components
20. Specify materials with low-intensity production and agriculture
21. Specify materials that do not require additional surface treatment of inks
22. Exploit intrinsic properties of materials
23. Specify clean production processes within the supply chain
24. Employ as few manufacturing steps as possible
25. Source from suppliers with low transportation impacts

D. Minimize consumption of resources during operation : [3,15,20–24,38,41,42,47,48,50,52–55]

26. Implement reusable supplies
27. Incorporate timed, noticeable incentives into operation
28. Minimize energy and material loss
29. Minimize the volume and weight of materials to which energy is transferred
30. Optimize the rate and duration of resource use to the task
31. Provide discrete quantities of resources
32. Provide automatic or manual tuning capabilities
33. Indicate the current state of processes
34. Create separate modules for tasks with different ideal solutions
35. Support complex decision-making by the user
36. Specify best-in-class efficiency components
37. Incorporate partial operation to disengage subsystems that are not in use
38. Minimize start up and power down time
39. Interconnect available flows of energy and materials
40. Maximize system efficiency for a range of real world conditions
41. Create shared or service systems that de-materialize
42. Harmonize the operation with users' daily activities within the product and its environment
43. Permit users to turn off systems in part or whole
44. Reveal how much resource is being consumed
45. Incorporate intuitive controls for resource-saving features
46. Incorporate features that prevent or discourage waste of materials by the user
47. Automatically reset the product to its most efficient setting
48. Employ transformation or multi-functionality

E. Maximize technical and aesthetic life of the product and components:[3,15,20–23,32,41,47,48,50,52,56]

49. Reutilize resource intensive components
50. Plan for ongoing efficiency improvements
51. Improve aesthetics and functionality to ensure the aesthetic life is equal to the technical life
52. Minimize required maintenance
53. Protect products from dirt, corrosion, and wear
54. Indicate through the product how parts are maintained
55. Minimize the number of service and inspection tools
56. Facilitate testing of components
57. Allow for repetitive dis- and re- assembly
58. Increase the value with age
59. Communicate durability and reliability through the form

F. Facilitate upgrading and reuse of components: [3,15,20–23,32,38,41,42,46–50,52,57]

60. Make wear detectable for repair and upgrade
61. Indicate through the product how it should be opened
62. Ensure that joints and fasteners are easily accessible
63. Facilitate upgrading and reuse of components that experience rapid change
64. Maintain stability and part placement during disassembly/assembly
65. Minimize the number of tools required for disassembly/assembly
66. Minimize destructive disassembly and its effects
67. Ensure reusable parts can be cleaned easily and without damage
68. Make incompatible materials easily separated
69. Make component interfaces simply and reversibly separable
70. Organize in hierarchical modules by aesthetic, repair, and end-of-life protocol
71. Implement reusable/swappable platforms, modules, and components
72. Specify adhesives, labels, surface coatings, pigments that are compatible with cleaning during and after the useful life
73. Employ one disassembly/assembly direction without reorientation
74. Minimize the number and length of operations for detachment
75. Mark materials in molds with types and reutilization protocol
76. Use a shallow or open structure for easy access to sub-assemblies

[1] Telenko, C., O'Rourke, J. M., Conner Seepersad, C., & Webber, M. E. (2016). A Compilation of Design for Environment Guidelines. *Journal of Mechanical Design*, *138*(3).