A Design Methodology for Buoyant Prescription Sunglasses

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Abstract

As a means to develop fashionable, buoyant prescription sunglasses, this project focused on identifying a system of lens and frame materials that yield sunglasses that float in water. There was an emphasis on developing a product that could be integrated into the current sunglass market. The term fashionable is used to define a sleek frame style that does not require attaching additional floatation. This methodology relies on the relationships between the strength of the user’s prescription and the volume of the desired sunglass frame style. This relationship was verified through buoyancy testing. This testing included varying the lens material in a given sunglass frame and successfully predicting the frame’s buoyancy. An object was deemed buoyant, if it remained at the liquid’s surface indefinitely. As a result, an appropriate system of materials was selected for the product. An acceptable material system includes a dense lens material and a frame material that is less dense than water. The system is also defined by the volumetric ratio of lens and frame. This methodology was summarized into a customer friendly guide. A model was developed that allows the customer to enter their prescription, and the available sunglass frame styles are displayed. For most prescriptions, the user is able to choose from all available frame styles. However, users with stronger prescriptions may be limited to frame styles with large volumes.

Keywords: materials engineering, floating sunglasses, sunglasses, buoyancy, prescription lenses, optometry, 3D-printer, rapid prototyping
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1. Problem Statement

As a means to develop fashionable buoyant prescription sunglasses, this project will focus on identifying a system of lens and frame materials that result in a pair of sunglasses that float in water. This methodology will be used to create a product that can be integrated into the current sunglass market. The product relies on implications of Archimedes’ Principle, specifically the relationship between the strength of the user’s personal prescription and the volume of the desired sunglass frame style. This relationship will be verified through buoyancy testing. The buoyancy of the sunglasses is evident when the sunglasses do not sink to the bottom of the water tank but instead float. This testing includes varying the lens material in a given sunglass frame and confirming the frames’ buoyancy. The end deliverable is a mathematical model that allows the consumer to enter their prescription, and the available buoyant sunglass styles are displayed.

2. Purpose

The results of this project can be used further to develop a buoyant sunglass prototype and introduce it into the sunglass market. The methodology developed uses the user's prescription to select an appropriate buoyant material system and frame style.
3. Introduction

3.1 Buoyant Sunglass Market

Currently, the buoyant sunglass market is highly competitive. Many companies have developed buoyant sunglasses. The sunglass company Oakley even holds a broad patent for buoyant sunglasses [1]. However, there are many claims on the Internet that Oakley’s floating sunglasses do not float [2]. Most of the buoyant sunglass competitors have large, sporty frames that require additional floatation straps (Table I). This frame style with floatation strap may be undesirable to some customers. Furthermore, some sunglass manufacturers do not support prescription sunglass, such as the WAVIATORS. Conversely, some competitors do accept prescription (Rx) lenses, such as Barz Optics. However, even if they accept prescription lenses, the buoyant frames are not guaranteed to float with every prescription. Additionally, no competitors allow an optometrist to fit the user’s prescription lenses in the sunglass frame.

Normally, an optometrist would fit their patient’s prescription lens in the desired frame. Instead, these competitors require the user to ask their optometrist for their lens prescription prior to ordering the buoyant sunglasses. Each time the user’s prescription changes slightly, they must endure this hassle to fit their new prescription lenses in their buoyant sunglass frames. Allowing the optometrist to fit the prescription lenses in the buoyant frames simplifies this process.
### Table I - The Price, Prescription Lens Acceptability, & Floatation Description of Buoyant Sunglass Competitors

<table>
<thead>
<tr>
<th>Buoyant Sunglass Competitors</th>
<th>Floatation Strap</th>
<th>R\textsubscript{x} Lenses</th>
<th>Price (+ shipping)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waviators\textsuperscript{3}</strong></td>
<td>No strap</td>
<td>No R\textsubscript{x}</td>
<td>$40</td>
</tr>
<tr>
<td><strong>Yamaha Linex\textsuperscript{4}</strong></td>
<td>Strap</td>
<td>No R\textsubscript{x}</td>
<td>Inquiry-based</td>
</tr>
<tr>
<td><strong>Barz Optics\textsuperscript{5}</strong></td>
<td>No strap</td>
<td>R\textsubscript{x}</td>
<td>$270</td>
</tr>
</tbody>
</table>

#### 3.2 Stakeholders

Ultimately, this project yields a product that a customer would want to purchase. The customer makes the choice to purchase one sunglass over another style. The vendor or optometrist choose which styles they will sell in their store (or online store). The optometrist not only sells the frames but also fits the user’s prescription lenses in the frames. The designed product should be attractive to sunglass vendors, potential customers, and their optometrists.
3.3 User’s Needs

Potential customers must be attracted to the product and therefore the product must meet the customers’ requirements. User personas were created to symbolize a variety of potential customers (Appendix). The style of the sunglass initially attracts the customer to a particular sunglass. Where as, the price may deter the customer from purchasing that sunglass, if it is higher than what the customer is willing to pay. Also, some customers prefer to trust their optometrist to fit their prescription lenses in their sunglass frames. Ultimately, the customer makes the final choice to purchase a product and should be considered throughout the entire design process.

3.4 Design Constraints

3.4.1 Manufacturing

The competitive buoyant sunglass market restricts the development of future products. The final buoyant sunglass prototype developed must be different than all other buoyant sunglass competitors. For example, Oakley’s patent covers “injection-molded frames” each formed by a combination of “plastic and blowing agent” [1]. This broad patent restricts the manufacturing process of future buoyant sunglass competition. Thus, an alternative manufacturing process is desired.
3.4.2 Economic

To be competitive, the price of a new product must be attractive to consumers. Currently, buoyant sunglasses sell around $40 to upwards of $300 (Table I). The prescription sunglass frames are on the higher end of this spectrum. In order to exchange prescription lenses, prescription sunglass frames requires higher quality materials.

4. Background

4.1 Buoyancy Definition

The buoyant force acts on any object in a fluid, like water or air. This buoyant force is responsible for floating objects, such as balloons or boats. An object that does not sink in a fluid is considered a floating object. A floating object has positive or neutral buoyancy (Figure 1). Negative buoyancy describes a sunken object that sits at the bottom of the container.

Buoyancy arises from the fact that fluid pressure increases with depth and due to Pascal’s Principle, that pressure is exerted in all directions (Figure 2). The “water sphere” on the left in Figure 2 and the solid object on the right experience the same pressure environment. Therefore, Archimedes’ Principle follows; the
buoyant force on the solid object is equal to the weight of the displaced water [7]. Therefore, a sunglass will float if the weight of the sunglasses is equal to or less than the weight of the liquid it displaces.

### 4.2 Preliminary Buoyancy Model

Beginning with Archimedes’ Principle, the weight of a floating sunglass \( w_{\text{sunglass}} \) must equal the weight of the liquid \( w_{\text{fluid}} \) it displaces (Equation 1). The weight of an object is defined as its’ mass times gravity. The mass of the sunglasses can be broken up into the density \( \rho \) times the volume of the sunglasses. The sunglasses and the liquid it displaces experience the same gravitational field. For simplicity, the effect of gravity is assumed constant over the entire sunglass volume [8]. This simplification means the gravitational effect is independent of height. Due to Archimedes’ Principle, the displaced liquid also experiences this same constant gravitational value. Therefore, the weight of the sunglasses and liquid both contain the same constant gravitational term and this term cancels (Equation 2).

\[
\begin{align*}
  w_{\text{sunglass}} &= w_{\text{fluid}} \\
  (\rho \star V)_{\text{sunglass}} &= (\rho \star V)_{\text{fluid}}
\end{align*}
\]
Again for simplicity, the volume of the sunglass is defined as the summation of the two components, lenses and frame (Equation 3). Therefore, the sunglass density is equal to the frame and lens density times their respective volume fraction (Equation 4).

\[
V_{\text{sunglass}} = V_{\text{frame}} + V_{\text{lenses}} \quad (3)
\]

\[
\rho_{\text{sunglass}} = \frac{[(\rho_{\text{frame}}) * V_{\text{frame}}] + [(\rho_{\text{lenses}}) * V_{\text{lenses}}]}{V_{\text{sunglass}}} \quad (4)
\]

Breaking the sunglass term into its’ components, frame & lenses, results in the preceding equation (Equation 5).

\[
(\rho * V)_{\text{frame}} + (\rho * V)_{\text{lenses}} = (\rho * V)_{\text{fluid}} \quad (5)
\]

The sunglasses are assumed to be fully submerged under the liquids surface. For a partially submerged sunglass, the volume of the sunglass would be the submerged portion of the total sunglass volume. Therefore, the partially submerged volume is less than the total sunglass volume. The fully submerged volume is the maximum volume value possible and thus calculates the worst-case scenario. Therefore, the assumption of the sunglass’ volume is equal to the volume of the fluid it displaces is valid (Equation 6). Therefore, for a fully submerged sunglass, the buoyancy relation becomes equation 7.

\[
V_{\text{fluid}} = V_{\text{sunglass}} \quad (6)
\]

\[
(\rho * V)_{\text{frame}} + (\rho * V)_{\text{lenses}} = (\rho_{\text{fluid}})(V_{\text{sunglass}}) \quad (7)
\]
Breaking the sunglass term into its’ components, and combining like terms, the resulting equation becomes the requirement for a given material system and frame style to float (Equation 8). The left hand side of this relationship is the volumetric ratio of lenses to frame. The right hand side of this relationship is the ratio of densities. In theory, a material system and frame style will float if the relationship is followed (Equation 8).

\[
\frac{V_{\text{lenses}}}{V_{\text{frame}}} = \frac{(\rho_{\text{lenses}} - \rho_{\text{fluid}})}{(\rho_{\text{fluid}} - \rho_{\text{frame}})}
\]  

(8)

5. Experimental Procedure

5.1 Testing Overview

The goal is to verify the buoyancy relationship correctly predicts the buoyancy of a material system and frame style. The actual volume and density values of Waviators, a competitor’s buoyant sunglass, will be evaluated in the buoyancy relationship (Table I, Equation 8). To be consistent with the derived model, the actual values must equal or be less than the calculated values.

5.2 Waviators’ Volume

5.2.1 Waviators’ Lens Volume

The Waviators’ lens area was approximated using The Boxing System, a standardized system of lens dimension measurement [9]. The Waviators’ lens was traced onto a piece of paper. The outline of the lens was encased in a
rectangle. The area of the lens was determined by multiplying the length, A, by the width, B, of this rectangle (Figure 3a). The thickness of a non-prescription lens is a standard 1 mm (Figure 3b) [10]. Therefore, the volume of this lens is the standard 1 mm thickness multiplied by the previously determined area. A prescription lens would have a more complicated thickness profile.

![Diagram of lens area and thickness](image)

Figure 3: The volume of a lens is approximated using the area from The Boxing System (a) and a standard 1 mm lens thickness (b). Using The Box System, the length of the lens is marked A, and the width is marked B. A standard non-prescription lens profile has a 1 mm thickness (b).

5.2.2 Waviators’ Frame Volume

The frame volume of the Waviators was approximated using a CAD model (Figure 4). On an open-source website, Fredrick Josefsson uploaded a sunglass CAD file [11]. This model is an accurate approximation of the Waviators’ frame because it has similar dimensions and overall shape.
5.3 Waviators’ Density

5.3.1 Waviators’ Lens Density

An optometrist, Dr. Ron Rosa, determined the Waviators’ lenses were made of polycarbonate (PC). PC is a common optical lens material that any optometrist would be able to identify from tactical knowledge of the lens.

5.3.2 Waviators’ Frame Density by ASTM Standard

The Waviators' frame density was determined experimentally using ASTM D792-08 [12]. This standard requires the analytic scale to have 0.1 mg precision. This method involves comparing the weight of the sample in air to the weight in liquid. The sample is suspended by string in a liquid (Figure 5). The weight of the sample suspended by string, in that liquid is recorded, $b$ (Equation 9). Also, the weight of the partially submerged string in that liquid is recorded, $w$ (Equation 9).
For an accurate reading, the sample must be completely immersed under the surface of liquid. To ensure the frame sample would not float, acetone ($\rho = 0.791 \text{ g/cm}^3$) was used as the immersion liquid. Also, the sample must not touch any part of the immersion vessel. The specific gravity of the frame sample is found using equation 9. The frame density is determined by multiplying the experimental specific gravity (Equation 9) by the density of the immersion liquid (Equation 10).

\[
\text{sp gr } 23^\circ\text{C} = \frac{a}{a+w-b} \quad (9)
\]

\[
\text{density } 23^\circ\text{C} = \text{sp gr } 23^\circ\text{C} \times 791.00 \text{ kg/m}^3 \quad (10)
\]

*where:*

- \text{sp gr } 23^\circ\text{C} = \text{specific gravity of specimen}
- \text{density } 23^\circ\text{C} = \text{density of specimen (kg/m}^3\text{)}
- \text{a} = \text{apparent mass of specimen, without wire or sinker, in air}
- \text{b} = \text{apparent mass of specimen (and of sinker, if used) completely immersed and of the wire partially immersed in liquid}
- \text{w} = \text{apparent mass of totally immersed sinker (if used) and of partially immersed wire}
5.3.3 Waviators’ Frame Density by Immersion

Alternatively, the frame density was determined by immersing the Waviators frame in a variety of liquids. The density was determined to be greater than the liquid the frame sinks in. Conversely, the density is determined to be less than the liquid the frame floats in. Therefore, depending of the liquids used, the frame density is determined to be a range of densities between the liquid densities that float and sink the frame.

Most of the liquids used were high purity chemical solvents, such as Acetone and Methanol. These high quality solvents have known density values. However, the density of olive oil is dependent on the mixture bottled. Therefore, the density of olive oil was determined using a weight-per-gallon cup, in accordance with ASTM Standard D1475-60 [13]. The midget weight-per-gallon cup has a capacity of 8.32 grams of water at 25°C (Figure 6) [14]. The weight of the empty cup is recorded \( w_{\text{cup}} \) and used to calculate the weight of the contained liquid \( w_L \) (Equation 11). The sample liquid is poured into the cup. The cap is screwed on and the excess liquid oozes out. This implies the cup was properly filled. After the excess liquid is wiped off, the cup filled with sample liquid is weighed \( w_{\text{cup+L}} \). Therefore, the weight of the contained liquid \( w_L \) is equal to the total weight minus the weight of the cup (Equation 11). The weight-per-gallon (lbs/gal) of this liquid is equal to the weight of the contained liquid, \( w_L \) (Equation 11). In metric units, the density of this liquid is found by using a conversion factor, 1 lbs/gal = 119.8 kg/m\(^3\) (Equation 12).
\[ W_L = W_{\text{cup+L}} - W_{\text{cup}} \quad (11) \]
\[ \text{density } 23^\circ C = w_L \times 119.8 \, \text{kg/m}^3 \quad (12) \]

where:
- \( W_L \) = apparent mass of contained liquid (lbs/gal)
- \( W_{\text{cup+L}} \) = apparent mass of the weight-per-gallon cup and contained liquid (lbs)
- \( W_{\text{cup}} \) = apparent mass of weight-per-gallon cup (lbs)
- \( \text{density } 23^\circ C \) = density of specimen (kg/m\(^3\))

6. Results

6.1 Confirming the Buoyancy Model

The Waviators’ buoyant sunglasses are used to verify the derived buoyancy relationship (Equation 8). This buoyancy model is consistent if the model confirms that the Waviators float. For the Waviators’ frame style, the volumetric ratio between the frame and two lenses is 2.3, meaning the volume of the two lenses is a little more than twice the frame volume. The density of the PC lenses is 1.20 g/cm\(^3\). Using these experimental density and volume values, the calculated frame density \( \rho*_{\text{frame}} \) is .91 g/cm\(^3\) (Table II). This calculated frame
density is the maximum density that will float. Meaning in order to float, the actual frame density is equal to or less than the calculated \( (\rho_{\text{frame}}) \). Thus, how does this calculated value compare to the actual Waviators’ frame density?

**Table II- Buoyancy Model Correctly Predicts Waviators’ Buoyancy**

<table>
<thead>
<tr>
<th></th>
<th>Waviators + PC lenses</th>
<th>Waviators + CR-39 lenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Ratio</td>
<td>( \frac{V_{\text{frame}}}{V_{\text{lens}}} )</td>
<td>2.3</td>
</tr>
<tr>
<td>Lens Density</td>
<td>( \rho_{\text{lenses}} )</td>
<td>1.20 g/cm(^3)</td>
</tr>
<tr>
<td>Calculated Frame Density</td>
<td>( \rho^*_{\text{frame}} )</td>
<td>.91 g/cm(^3)</td>
</tr>
<tr>
<td>Experimental Frame Density</td>
<td>( \rho_{\text{frame}} )</td>
<td>(.870 g/cm(^3) - .792 g/cm(^3))</td>
</tr>
</tbody>
</table>

The frame density determined by the ASTM standard is .65 g/cm\(^3\), as tested in Section 5.3.3. The frame density determined by the ASTM standard does not align with the density range determined by immersing the frames in various liquids. If the frame was actually the density determined by the ASTM standard, then it should float in acetone (Table III). The ASTM standard’s procedure is highly specific and the result is highly skeptical. The frame density determined by immersing the frame in various liquids is more reliable because the calculation is apparent. If the frame floats, the frame is less dense than the liquid it floats in. If the frame sinks in a liquid, the frame’s density is greater than the density of the liquid it is immersed in. Therefore, the Waviators’ frame density is (.871-.792) g/cm\(^3\), highlighted by the red line in Table III. This actual Waviators’
frame density range is always less than the calculated frame density value \( (\rho_{\text{frame}}^*) \). And thus, the buoyancy model correctly predicted the buoyancy of the Waviators’ frame style and material system.

**Table III** - Waviators’ Frame Density Determined by Immersion in Various Liquids

<table>
<thead>
<tr>
<th>Liquid (25°C)</th>
<th>Density [g/cm³]</th>
<th>sink/FLOAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Olive Oil</td>
<td>.910</td>
<td></td>
</tr>
<tr>
<td>Toluene</td>
<td>.870</td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>.792</td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>.791</td>
<td></td>
</tr>
</tbody>
</table>

Continuing with the verification of the model, the same Waviators’ frame style was evaluated. However, the lens material is a denser Columbia Resin #39 (CR-39). Given this frame style and material system, the Waviators with CR-39 lenses sink. But does the model confirm this?

The volumetric ratio is the same as before, 2.3 but the lens density is now a denser 1.31 g/cm³. This requires the calculated framed density \( (\rho_{\text{frame}}^*) \) to now be .865 g/cm³ (Table II). This frame style and material style is observed to sink, as illustrated by the fact the actual frame density is greater than the calculated \( (\rho_{\text{frame}}^*) \). Thus, these observations and calculations align with the derived buoyancy model (Equation 8).
Ultimately, the derived buoyancy model (equation 8) correctly predicts the buoyancy of a given frame style and material system. Table II summarizes the model’s correct prediction of the Waviators’ buoyancy.

### 6.2 Initial Prototype

To continue with this methodology, the initial prototype was designed utilizing the derived buoyancy relation (Equation 8). The prototype’s frame was 3D-printed. The buoyancy of this frame style and material system was tested and compared to the predicted buoyancy. This methodology aligns with reality if the derived relation correctly predicts the prototype’s buoyancy.

The prototype uses the front frame piece from the previous borrowed CAD model [11]. However, the temple pieces are an original design. The overall frame style of the prototype is similar to the Waviators but not identical (Figure 7). Thus, this frame style has a different volumetric ratio of 2.4, meaning the volume of the two lenses is 2.4 times the frame volume. Given the prototype’s frame style and PC lenses, the calculated frame density ($\rho_{\text{frame}}$) is .92 g/cm$^3$ (Table IV). Thus, the frame style and material system will float, if the actual frame density is less than this calculated value.

![Figure 7](image)

*Figure 7: The frame style of the initial prototype. The dimensions are in millimeters.*
The prototype’s frame style was 3D-printed in acrylonitrile butadiene styrene (ABS) (Figure 8). This printed ABS materials is less dense than the bulk ABS material. Also, this printed ABS material floats in water but sinks in olive oil. Therefore, this printed ABS material’s density is narrowed to the range (1.0 - .91) g/cm³. This printed ABS material’s density is primarily greater than the calculated frame density. Thus, as predicted the prototype does not float.

![Figure 8](image_url)

*Figure 8: The prototype was 3D-printed in ABS. This frame style and material system does not float, as predicted by the derived relation (Equation 8).*

**Table IV- Buoyancy Model Correctly Predicts ABS Prototype’s Buoyancy**

<table>
<thead>
<tr>
<th></th>
<th>ABS Prototype + PC lenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Ratio</td>
<td>2.4</td>
</tr>
<tr>
<td>Lens Density</td>
<td>1.20 g/cm³</td>
</tr>
<tr>
<td><em>Calculated</em> Frame Density</td>
<td>.92 g/cm³</td>
</tr>
<tr>
<td><em>Experimental</em> Frame Density</td>
<td>1.0 g/cm³ 91 g/cm³</td>
</tr>
<tr>
<td>sink/FLOAT</td>
<td>Material system sunk</td>
</tr>
<tr>
<td></td>
<td>ρ_{frame} &gt; ρ^*_{frame}</td>
</tr>
</tbody>
</table>
6.3 Effect of the User’s Lens Prescription

The profile of a prescription lens is dependent on the user’s prescription. The lens profile is simply the thickness of the lens (Figure 3b). The frame style determines the lens area. Due to the derived buoyancy relation, the user’s prescription and desired frame style affect the frame volume that will float (Figure 9). The volume of the prescription lens is dependent on the user’s prescription and desired frame style. The derived relationship calculates the minimum frame volume ($V_{Rx\ frame}$) necessary to float the user’s prescription lens (Figure 9).

![Diagram](image)

Figure 9: The volume of a user's prescription lens is dependent on the desire frame style. The derived relationship calculates the minimum frame volume necessary to float the user’s prescription lenses.

Given the user’s lens prescription and desired frame style, those prescription sunglasses will float if volume of this desire frame style is greater to or equal to this calculated minimum frame volume ($V_{Rx\ frame}$). The graph in Figure 10 describes the frame volume of each frame style. The frame styles: S, M, L,
are based on qualitative values rather than quantities. Additionally, this graph represents relative values rather than numerical. This calculated minimum frame volume \( V_{Rx \ frame} \) represents the minimum frame material necessary to float the user’s prescription and is shown relative the volume of the L frame style (Figure 10a). Thus, the user’s prescription lens will float with the given frame style. In Figure 10b, the user’s prescription is too large to float with the desired frame style. Thus, some users may have to choose a larger frame style than desired.

![Graph showing frame volume comparison](image)

**Figure 10**: The graph describes the frame volume of each sunglass frame styles, S, M, L. This calculated minimum frame volume \( V_{Rx \ frame} \) is shown relative the volume of the L frame style. In (a), the user’s prescription lens will float with the given frame style. In (b), the user’s prescription is too large to float with the desired frame style.

### 7. Recommendations for Future Development

The methodology developed correctly predicts a sunglass’s buoyancy. Additionally, the 3D-printed prototype successfully accepted prescription lenses. The designed prototype will float if the frame density decreases or the frame
volume increases. Theoretically, a different frame style could improve the buoyancy of this material system.

Ultimately, this model relied on the volume of prescription lens. However, the investigation of the relationship between the user’s prescription and lens profile never developed. Ideally, the relationship between the user’s prescription and lens thickness can be quantified.

Nevertheless, the simplicity of the model was for preliminary use and should be developed further to account for a non-uniform gravitational field. The assumption of constant gravity does not model reality. This is evident by the unstable floating of the sunglasses [8]. To account for gravity, the buoyant force must be integrated over the sunglass’ volume.

8. Conclusions

Currently, the sunglass market does not have buoyant sunglasses that allow the user’s optometrist to insert the user’s prescription lenses in the frames. The simplistic buoyancy model was developed, based on Archimedes’ Principle and produced a threshold ratio of the volume of frame and lenses. This derived buoyancy model correctly verified a sunglass’s material system and frame style would float or sink in water. A known buoyant sunglass competitor, Waviators, was evaluated. The Waviators frame density was experimentally determined to be .655 g/cm³ by ASTM Standard D792-08. By immersing the Waviators frame in various liquids, the Waviators frame density was experimentally determined to be (.871-.792) g/cm³. Overall, the actual Waviators frame density is less than the
frame volume calculated by the model. This illustrates the model correctly predicted the Waviators will float. The ABS prototype by 3D printing was produced as proof of concept. Unfortunately, the density possible (with ABS 3D-printing) did not match that from the model and sank.
Acknowledgements

I am grateful that Ron Rosa, O.D. shared this idea with me. This project would not have been possible without guidance from the following people: Kathy Chen, Richard Savage, Dave Dean from LIVE Eyewear, Lee McFarland, Ross Gregoriev, Matthew Gagne, Michele Zoff, Fredrick Josefsson, and Jason Chang, O.D. from Envision Optometry.
References


Appendix
User Personas

Ronnie Wright
“Cool Dad”
40+ yr. old male
Entrepreneur/ self-employed

Hobbies:
1.) surfing everyday at home, on vacation in Mexico
2.) investing in properties
3.) teaching his kids to surf
4.) cruising with wifey on beach cruisers
5.) making money in order to retire early

Values
1.) strong family values
2.) whatever the wife wants
3.) do whatever he wants when he wants it

Likes
Locals only
Endless summer
Early retirement

Dislikes
Shoe-bees, non-locals
Getting old
Hard labor

Desires:
Keeping up with optical fashion trends, such that he is not embarrassed

Needs:
A good-looking way to avoid the misfortune of being unable to find the lost surfboard to paddle to shore
-able to find frames in water

Purchases
Surfboard & accessories
Food
Coffee
Electronic gadgets
Clothes
Toiletries
Concert, movie tickets

Location
Local surf shop
Local, non-chain, restaurants
Wife grocery shops
Coffee Bean, wife makes at home
Apple store, charity auctions
Wife purchases at local surf shop/Costco
Wife buys at target
Internet
**Appendix: User Personas (continued)**

Stacie Starr  
“Yacht Club Socialite”  
*20+ yr. old female*  
part-time bartender & trust fund baby  
her boyfriend/mother/father/sugar-daddy will satisfy all her desires

**Hobbies**
- Shopping
- Traveling
- Hanging out with friends
- Networking over drinks
- Clubbing
- Dance class

**Values**
- family
- friends
- God

<table>
<thead>
<tr>
<th>Likes</th>
<th>Dislikes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold &amp; diamond jewelry</td>
<td>Tacky costume jewelry</td>
</tr>
<tr>
<td>Real people</td>
<td>Fake people</td>
</tr>
<tr>
<td>Plastic surgery</td>
<td>Getting old</td>
</tr>
<tr>
<td>Early retirement</td>
<td>Hard labor</td>
</tr>
</tbody>
</table>

**Desires:**  
Sunglasses that compliment her outfit/face  
Sunglasses to stay in her possession longer than a drunken night swim

**Needs:**  
A way to recover lost sunglasses when at play  
-function as fashionable Rx sunglasses while afloat  
-a buoyant sunglass that does not sacrifice any style of normal frames

<table>
<thead>
<tr>
<th>Purchases</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunglasses</td>
<td>Sunglass Hut</td>
</tr>
<tr>
<td>Food</td>
<td>Trendy restaurants</td>
</tr>
<tr>
<td>Coffee</td>
<td>Starbucks</td>
</tr>
<tr>
<td>Electronic gadgets</td>
<td>Apple store</td>
</tr>
<tr>
<td>Clothes</td>
<td>Designers: D&amp;G, Chanel, Dior</td>
</tr>
<tr>
<td></td>
<td>Department stores</td>
</tr>
<tr>
<td>Toiletries</td>
<td>Department store, hair salon</td>
</tr>
<tr>
<td>Concert, movie tickets</td>
<td>Internet</td>
</tr>
<tr>
<td>Plane tickets</td>
<td>Friends private jet, internet</td>
</tr>
</tbody>
</table>
Appendix: User Personas (continued)

Ben Smith
“Radical Dude”
20+ yr. old male
Sponsored Action Sports Athlete
His wakeboarding sponsors are sick of spending $1000s on sunglass replacements

<table>
<thead>
<tr>
<th>Hobbies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Wake boarding</td>
<td>- Kicking it with the homies</td>
</tr>
<tr>
<td>- Girls</td>
<td>- Nightlife at the clubs</td>
</tr>
<tr>
<td>- Boating/tubing fun on lakes</td>
<td>- Making his sponsors happy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- no regrets</td>
<td></td>
</tr>
<tr>
<td>- a pretty smile</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Likes</th>
<th>Dislikes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>Rain</td>
</tr>
<tr>
<td>Endless wake</td>
<td>Choppy waters</td>
</tr>
<tr>
<td>Red Bull</td>
<td>Monster</td>
</tr>
<tr>
<td>Making money</td>
<td>Hard labor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Desires:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Free sunglasses</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Needs:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Something that works</td>
<td></td>
</tr>
<tr>
<td>- Reliable</td>
<td></td>
</tr>
<tr>
<td>- Similar style of sunglasses</td>
<td></td>
</tr>
<tr>
<td>- Impact resistant: safe-on impact</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Purchases</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunglasses</td>
<td>Sponsors</td>
</tr>
<tr>
<td>Food</td>
<td>Restaurant chains, fast food</td>
</tr>
<tr>
<td>Coffee</td>
<td>Red Bull</td>
</tr>
<tr>
<td>Electronic gadgets</td>
<td>Apple store</td>
</tr>
<tr>
<td>Clothes</td>
<td>Sponsors, internet</td>
</tr>
<tr>
<td>Toiletries</td>
<td>Rite Aid</td>
</tr>
</tbody>
</table>
Appendix: User Personas (continued)

Sally Wjoawski
“Sensible Sally”
30+ yrs. old mother
Psychiatrist
Doesn’t have time to waste trying out the best brand
Understands accidents happen

Hobbies
• Planning exotic family vacations
• Gardening
• Cooking

Values
• Family first
• Christ is our savior

<table>
<thead>
<tr>
<th>Likes</th>
<th>Dislikes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adventure</td>
<td>Lazy hippies</td>
</tr>
<tr>
<td>Family time</td>
<td>Unproductive moments</td>
</tr>
<tr>
<td>Reliable products</td>
<td>Poorly designed products</td>
</tr>
<tr>
<td>Sunscreen</td>
<td>Skin cancer</td>
</tr>
</tbody>
</table>

Needs:
• to locate lost sunglass in water
• her Rx sunglasses to float
• reliable frames
• safe

<table>
<thead>
<tr>
<th>Purchases</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunglasses</td>
<td>Sporting Equip. Store, REI</td>
</tr>
<tr>
<td>Food (Coffee)</td>
<td>Grocery Store, farm stand</td>
</tr>
<tr>
<td>Electronic gadgets</td>
<td>Costco</td>
</tr>
<tr>
<td>Clothes</td>
<td>Chico’s, REI</td>
</tr>
<tr>
<td>Toiletries</td>
<td>Costco, for entire family</td>
</tr>
</tbody>
</table>