May 11, 2023

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To Whom it May Concern,

Within the attached report, you will find information about the design and prototyping of the QUE Aromatherapy Device to treat adults with post-traumatic stress disorder and anxiety. The idea for this device was originally created by Dr. Cindy Bimle, a pediatrician from West Monroe. She developed a patent and entrusted us to fabricate the outlined device.

The device is a wearable aromatherapeutic pendant that releases a calming scent in response to the wearer's anxiety symptoms in hopes of queuing memories and feelings of relaxation or peace. This device works by continuously monitoring heart rate because a rapid increase in heart rate is a common symptom of anxiety. If the heart rate exceeds a threshold, a valve on the pendant will open and a fan will blow on a wick saturated with essential oil. The scent from this oil will be propelled to the user's nose. After the fan has been on for a specified amount of time, the valve will close, and the device will continue monitoring heart rate.

We are so grateful to have had the opportunity to design and fabricate a prototype of this device which has the potential to be monumental in the future treatment of mental health. With more time and resources, this device can be miniaturized and marketed as a small, discreet medical device. This device will allow for future research on the effectiveness of aromatherapy on the treatment of mental health to be conducted.

Sincerely,

Gifford Courtney, Tyler Hight, Camryn Petrus, and Daniel Prado

Adult QUE Aromatherapy Device Technical Report

5/11/2023
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I. Abstract

Anxiety disorders are among the most common mental health disorders in the United States. More than 30 percent of the population experiences these disorders at least once in their lifetime. Inspired by this problem, Dr. Cindy Bimle, a pediatrician in West Monroe, Louisiana, developed the idea for a new form of treatment through a device called the QUE Aromatherapy Device. The patent she developed outlines a device that could treat anxiety disorders based on the connection between scent and memories and emotion. The device is wearable as a pin or a necklace and connects with a heart rate sensor to detect symptoms of anxiety. When the device detects an increase in heart rate, a linear actuator connected to a gate will activate and open the top of the device revealing a cotton wick saturated with an essential oil. A centrifugal fan underneath the wick will then turn on, propelling the calming aroma to the user's nose. After the fan turns on for a specified time interval, it will automatically turn off and the linear actuator will close the device. The device can also be controlled manually with a remote. This device was proven to successfully release a scent in response to increased heart rate. The biggest limitations to the prototype were size and sound. However, with more time and resources, the size and sound of the device could be significantly decreased. With a finished prototype, Dr. Bimle could move forward with testing aromatherapy as a new form of mental health treatment.

II. Executive Summary

Over 40 million adults in the United States alone suffer from what is known as an anxiety disorder [2]. An anxiety disorder is defined as a persistent feeling of fear or dread that interferes with daily life [3]. This condition can affect a person's relationship with loved ones, performance at work, and overall quality of life. One of the most common types of anxiety disorders is called Post Traumatic Stress Disorder, a psychiatric disorder that can cause a person to feel extreme anxiety because of a traumatic event or set of circumstances [4]. The current treatment options for a person with an anxiety disorder are a combination of medicine and therapy. While medications can be very effective for some people, many medications are accompanied by severe side effects such as nausea, lack of coordination, depression, emotional dysfunction, and addiction [5]. Cognitive Behavioral Therapy is a type of psychological treatment in which a therapist helps a patient work on negative thought patterns and behaviors. However, it is typically only helpful during daily, small, manageable tasks. Neither of these treatment options are very accessible because they can cost thousands of dollars per year [6].

More recently, aromatherapy has been used for the treatment of mental health. Preliminary studies show a correlation between decreased anxiety and essential oils [7]. Olfactory neurons pick up all the information associated with the smells in a person's environment and transfer the signals to the limbic system, a part of the brain strongly correlated to mood, memory, behavior, and emotion. Aromatherapy works on the idea that in a moment of anxiety, a scent could be used to remind a person to think about a happy place associated with the scent.

The sponsor of this project is a pediatrician named Dr. Cindy Bimle. She combined her passion about the problem of mental health and knowledge of the strong connection between scent and emotions to develop the idea patent for a wearable aromatherapeutic device. This device detects symptoms of anxiety and releases a calming aroma in response.

The sponsor is the first customer for this device. The patent she developed outlines specific requirements of design. The patient is the device user suffering from an anxiety disorder such as PTSD. The biggest needs for the patient are that it is user – friendly, discreet, and personalized to them. Lastly, psychiatrists and psychologists could use this device with patients and therefore it should be easily incorporated into a clinical setting.

This device was designed as a pendant that can either be worn on a necklace chain or as a shirt clip on. When the device is turned on, a linear actuator moves a valve exposing a cotton wick saturated with essential oil. A fan underneath the wick blows to propel the scent to the user's nose. This sequence of events is called an emission. An emission is controlled by monitoring heart rate and by a remote. If the heart rate increases, indicating a symptom of anxiety, the device will automatically emit a scent. A remote is used to release emissions on command, adjust the length of time of emissions, set emissions to be released on a timer, and turn the necklace on/off.

Through testing, this device can function based on heart rate, is mechanically durable for everyday wear and tear, and has a discreet scent. The limitations of this device are the size, weight, and sound. These problems can be solved with a custom printed circuit board, a Bluetooth remote, and custom manufactured component.

The next steps for this prototype are miniaturizing and beginning research on the effectiveness of this personalized aromatherapeutic device in treating anxiety. In the future, this device could be connected to a smartphone app for more personalization by the customer.

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A. Introduction

1. Background

Over 40 million adults in the United States alone suffer from what is known as an anxiety disorder [2]. An anxiety disorder is defined as a persistent feeling of fear or dread that interferes with daily life [3]. This condition can affect a person's relationship with loved ones, performance at work, and overall quality of life. One of the most common types of anxiety disorders is called Post Traumatic Stress Disorder, a psychiatric disorder that can cause a person to feel extreme anxiety because of a traumatic event or set of circumstances [4]. The current treatment options for a person with an anxiety disorder are a combination of medicine and therapy. While medications can be very effective for some people, many medications are accompanied by severe side effects such as nausea, lack of coordination, depression, emotional dysfunction, and addiction [5]. Cognitive Behavioral Therapy is a type of psychological treatment in which a therapist helps a patient work on negative thought patterns and behaviors. However, it is typically only helpful during daily, small, manageable tasks. Neither of these treatment options are very accessible because they can cost thousands of dollars per year [6]. There is a need for a treatment method that is both accessible and effective for all people.

More recently, aromatherapy has been used for the treatment of mental health. Preliminary studies show a correlation between decreased anxiety and essential oils [7]. Olfactory neurons pick up all the information associated with the smells in a person's environment and transfer the signals to the limbic system, a part of the brain strongly correlated to mood, memory, behavior, and emotion. Aromatherapy works on the idea that in a moment of anxiety, a scent could be used to remind a person to think about a happy place associated with the scent [8]. The concept for the product outlined in this report was developed by Dr. Cindy Bimle, MD based on her knowledge of the strong connection between scent and emotion and her passion about the problem of mental health in our country. With this device, Dr. Bimle's goal is to utilize the link between memory and smell, and in a moment of anxiety, a scent associated with a calming memory can be used to encourage the user to recall memories associated with peace and relaxation.

The **problem** addressed by this product is that **a personalized, wearable aromatherapy device that uses smell and memory to treat the symptoms of post-traumatic stress disorder (PTSD) and other anxiety disorders has not been fabricated.**

2. Project Objectives

Dr. Cindy Bimle, MD, is a Pediatrics Specialist in West Monroe, Louisiana. She has worked in the field of pediatrics for over 30 years. She developed the patent for the QUE Aromatherapy Device (**see Appendix A**). This patent outlines a device that is intended to release a scent that triggers the user to recall positive memories in hopes of reducing their symptoms of PTSD and anxiety. The device should be small enough to be wearable as either a necklace or pendant. It should be rechargeable and interactive with a remote. The product needs to have the ability to connect to a biological sensor that detects symptoms of an anxiety or PTSD episode. Overall, the objective of this project is to fabricate a personalized, discrete aromatherapeutic device that could be incorporated into clinical settings and be used as a daily treatment tool for anxiety disorders. Once a device is complete, more research on the effectiveness of aromatherapy as a form of mental health treatment could be conducted. A device like this could potentially fill the gaps in current treatment methods, such as medication and cognitive behavioral therapy. It would be accessible for all people, provide an opportunity for medication free treatment, and be effective at treating anxiety disorders.

B. Discovery

1. Market Analysis

The current treatments to relieve symptoms of anxiety disorders are medication, cognitive behavioral therapy, and aromatherapy bracelets, necklaces, or diffusers. While medications can be very effective for some people, many medications are accompanied by severe side effects such as nausea, lack of coordination, depression, emotional dysfunction, and addiction. There is also a risk of making the patient's experience with PTSD and anxiety worse [5]. Health plans typically cover medications that treat anxiety; however, the cost of insurance is high. On average, the cost of insurance per month is $500 for an individual and $1100 for a family [9]. Patients seeking a medication-free treatment use cognitive behavioral therapy to treat their symptoms. Healthy mind experts claimed, "Due to the structured nature of CBT, it may not be suitable for people with more complex mental health needs" [10]. This form of therapy is difficult to incorporate into daily life because the patient needs to plan the day out with small manageable tasks that will not overwhelm them [11]. Behavioral therapy is also not accessible, costing up to $200 a session with the number of sessions ranging from 5 to 20 [12]. More recently, aromatherapy necklaces, bracelets, and diffusers have started to be used as a form of treatment. The cost of aromatherapy is more affordable, but the diffusion is not controlled, and for the necklace and bracelets, the scent continuously permeates the air.

After analyzing the treatments that are currently on the market, a market landscape (**Figure 1**) was created to determine where there is an opportunity for a new type of treatment. Medication is costly, with a wide range of efficiency differing from patient to patient. Therapy is on the lower end of efficiency but can be a cheaper alternative to medication. The current aromatherapy options are on the middle to lower end of efficiency. There is an opportunity to introduce the QUE aromatherapy device to the market that will be affordable and has the potential to be highly effective.

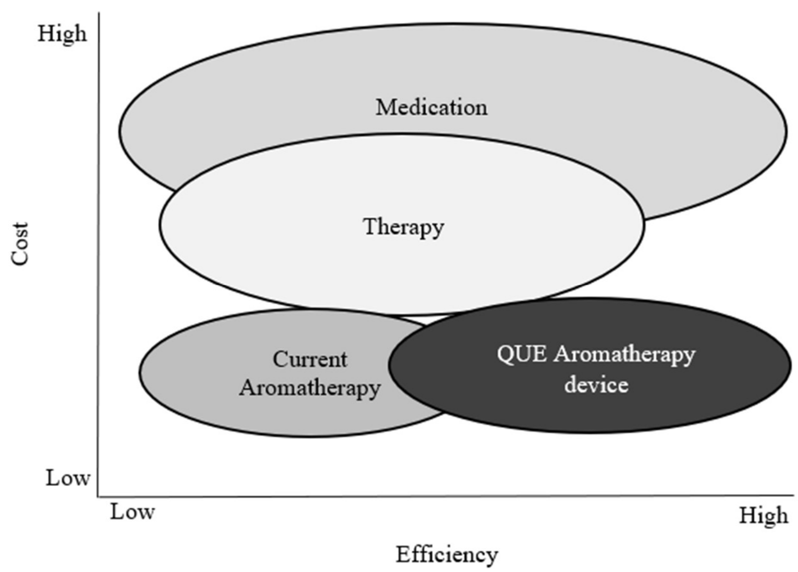

Figure 1: Anxiety Treatment Market Landscape

2. *Customer Needs*

The customers for this product include patients, providers, and the sponsor. Dr. Bimle is the sponsor for the project and created a patent outlining specific aspects of this product. The patients are the people who suffer from anxiety disorders, and they will be the end users of the device. The providers are therapists, psychiatrists, and physicians; they will be recommending and using the aromatherapy device with patients during sessions. The needs of these customers were identified through customer analysis, such as interviews and surveys.

Needs of the Sponsor

The sponsor required that the device include rechargeable batteries, a sensor to detect symptoms of anxiety, a mechanism to emit scent, and a replaceable scent. The mechanism to emit scent needs to work in response to the sensor detecting symptoms of anxiety. In addition to the device being automatically controlled by a sensor, the sponsor requires that the device be manually with a remote control. The patent for this device has already been created; therefore, the requirements outlined in the patent must be followed.

The sponsor is a physician who listened to the needs of patients when developing the requirements for an aromatherapy device. She provided a list of patient needs that will be discussed in *Needs of the Patient* below.

Needs of the Patient

As per the request of the sponsor, the patients need a device that does not bring unwanted attention to themselves and is discreet. To be discreet, the scent release needs to be quiet, and the scent should only be detectable by the user. Google Forms were created to ask potential patients their needs to create a device that is discrete. The needs for the device identified in these forms were small, lightweight, and stylish. One question in the form asked, "How often they would like to wear the device before recharging it?" The highest response was at least a full workday, so the device's battery life needs to last a full workday. The patients want the device to be user-friendly. For example, the sponsor requests the scent be replaceable; therefore, the users need to easily replace the scent. One of the biggest problems with using medication to treat mental health is the high cost. To encourage customers to use this device as an alternative, it needs to be affordable. Based on conversations with potential customers, the customer purchase cost should be less than $200. The sponsor needs the device to have a sensor. After mentioning this to the potential patients, they said it needs to be comfortable for them to wear the sensor.

Needs of the Provider

The provider or therapist, psychiatrists, and physicians need this device to be easily incorporated into a therapy session. Therapist Ashley Kasperski, LPC was asked about her thoughts on aromatherapy and any experience she has using this form of therapy. Ashley stated that when she was in training at a veteran non-profit organization, the therapists would spray an aroma in the direction of the veteran when suffering from an anxiety attack. After talking about her experience with cognitive therapy to treat an anxiety attack, she said she would be very interested in using aromatherapy because she believes the medical field is trying to move away from allopathic medical treatments to holistic medical treatment. Ashley requested a remote control that works with the device. She said the remote control needs to work in a clinical setting. For example, the remote and device need to connect wirelessly. This will help both the user and psychologist, or therapist use the device during cognitive behavioral therapy sessions. Ultimately, the provider wants to recommend a device to their patients that works well for them. This means that the providers' needs coincide with the patients' needs.

In summary, the sponsor, patients, and providers **need a mechanism to release a scent in response to symptoms of post-traumatic stress disorder (PTSD) and other anxiety disorders that can be used as an everyday aromatherapeutic tool.**

The stakeholders and their corresponding needs are outlined in **Table 1**.

Table 1: Stakeholder and Corresponding Needs

Stakeholder	Needs
Sponsor	• Rechargeable • One replaceable scent compartment • Sensor that triggers scent release • Wireless remote control
Patient	• Discreet (small and quiet) • Stylish and lightweight • User-friendly • All day wear • Affordable • Comfortable sensor
Provider	• Wireless remote control • Same as patient

3. Design Requirements and Technical Specifications

Physical Aspects

If the device is a necklace, the device will need a necklace chain that holds the pendant around the neck of the user. The material of the chain and pendant needs to be hypoallergenic, so it does not irritate the user's skin. The user would like to wear the device all day, so the chain and pendant need to be resistant to sweat, rain, and other oils that may be on skin. The chain should be adjustable in length to account for people of different sizes and preferences. Based on the typical necklace chain lengths, the length of the chain should be between 18 and 20 inches, and the weight of the chain should be less than 20 grams [13]. The user needs a lightweight necklace. After viewing several jewelry store websites, a lightweight necklace is less than 10g, the standard chain size is 1mm-2mm, and the standard pendant size is approximately 1 inch wide. For this device, the pendant will contain electrical and mechanical components that are typically not in jewelry, so it is likely the device will be slightly larger. A Google form was created to ask potential users their preference the pendant size and weight. The max weight was 50 grams, which is equivalent to one slice of bread, and a maximum pendant width of 3 inches.

Mechanical Requirements
The average American man 20 years old and up weighs 197.9 pounds [14], and the average American women aged 20 years and above weigh an average of 170.6 pounds [15]. To accommodate both men and women possibly stepping on the device, the maximum compressive force the device needs to withstand is 200 pounds. The average chest of drawers ranges from 40 to 60 inches. If the user places their device on the chest of drawers while they sleep or for storage, it may be knocked off or dropped off. To account for this, the maximum drop height the pendant must withstand is 5 feet. To prevent the attraction of unwanted attention to the user, the scent release needs to be quiet. To be considered quiet, the device needs to function at a sound intensity equivalent to 30dB when releasing the scent. According to the CDC, 30 decibels is equivalent to a whisper [16].

Anxiety Sensor
The sponsor requested a sensor to detect symptoms of anxiety. The mechanism to emit scent will be triggered by an increase in heart rate because the number one symptom of anxiety disorders is increased heart rate [17]. The sensor to monitor heart rate needs to be a photoplethysmography (PPG) sensor because it does not require adhesion to the skin and has low power usage. To be competitive with these devices, the photoplethysmography (PPG) sensor to monitor heart rate needs to have an absolute mean percent difference less than 10% compared to widely used devices on the market. To make the sensor comfortable, it will be located on the arm. To make the bracelet inclusive and comparable to marketed devices, the bracelet must adjust up to a wrist size of 200 mm and weigh less than 23 grams.

Scent Dispersion
The dispersion needs to be controlled and the device should be discreet. The sponsor set a technical specification for the length of time between an increase in heart rate and the user detecting the scent at 60 seconds. The customer needs the scent released by the user to be discreet. Lavender essential oil will be used for initial concentration testing because it is the most used oil for decreasing stress [18]. The odor threshold for lavender is approximately 3.2 ng/L [19]. This concentration is multiplied by a factor of safety of 2 to account for different people's scent sensitivities. Therefore, the concentration of lavender in the air at the nose of the user should be 6.4 ng/L within 60 seconds of scent release. However, if the scent coming from the device is strong enough for other people to notice, it may bring attention to the device, so the concentration of lavender in the air 2 ft away from the device should be less than 6.4 ng/L.

The scent needs to be refillable, so the device will have a storage chamber for a saturated cotton wick. To make replacing the saturated cotton wick easy for users, the storage chamber will be a drawer that slides in and out of the pendant. Competitors, such as The Essential Bracelet, claim that their device lasts for 7 days with just 3 drops of essential oils [20]. To keep this device competitive, it should last just as long or longer than similar devices.

Battery Life
One requirement, as outlined by the patent, is that the battery for the device needs to be rechargeable, and the potential patients' response to how often they would like to wear the device before recharging it was at least a full workday. According to the Bureau Labor Statistics, an average workday is 7.8 hours [21]. To meet these needs, the technical requirement for battery life needs to be 7.8 hours or greater.

Remote Control
As outlined by the sponsor in the patent, there must be a remote control that will allow the user to manually turn the device on and off and adjust emission features, such as frequency and duration. The therapist also needs a remote to incorporate into behavioral therapy sessions. After consulting with therapists, they would like the remote control to function within 20 feet of the device to account for the distance between the therapist and the patient. The sponsor would like the remote to control four functions: device on/off, duration of scent release, frequency of scent release, and manually release the scent. The remote needs to be a radio frequency remote rather than an infrared remote because radio frequency remotes can "work over much longer distances and pass through material that infrared cannot" [22]. The remote needs to work with 92% efficiency when 20 ft away from the receiver.

C. Product Development

1. Overall System
To start the design process, there were four initial questions to consider. The best scent release mechanism, sensor to detect anxiety, physical aspects of product, and remote control needed to be chosen. This section outlines the decisions and details of each of these design considerations.

Scent Release Mechanism
In the early stages of prototyping, there were four initial mechanisms to release the scent. The first was a necklace that contained a coil to heat the cotton wick and disperse the scent; however, heating essential oils risks damaging the compounds in the oil, and there may be health risks involved in inhaling the vapor of heated essential oils [23]. The second mechanism was a venturi to create a mist from the essential oil. An engineering analysis on this system was performed (*see **Appendix B***), and the results proved the pressure drop in the venturi was not obtainable with the pendant size requirement. The analysis showed that the velocity coming out of the system would be too high and risked spraying the user on the chin. The venturi also posed the risk of not being user-friendly because the system would need to be cleaned frequently. The final two mechanisms were basic diffusion and fan driven diffusion. A COMSOL model was created to compare the two mechanisms (*see **Appendix C***). The fan driven diffusion proved to be superior to the basic diffusion; the fan driven diffusion released the scent more directly than the basic diffusion. The COMSOL model results proved the fan driven diffusion shortened the time between the release of the scent and the moment the user could detect the scent. Without the convective force from the fan and a starting the odor threshold for Lavender was reached at approximately 200 seconds. With the convective force from the fan, the odor threshold was reached in approximately 25 seconds. Because the technical specification was 35, the fan met the design requirements. Based on this engineering analysis, the release mechanism chosen for the necklace was **fan driven diffusion.**

Pendant
Titanium was chosen as the material for the chain because it is lightweight, commonly used for jewelry and hypoallergenic. To ensure that the device is discreet and looks like commonly worn jewelry, the device was designed as a single pendant with the ability to be worn as either a clip on a shirt or jacket or on a chain as a device.

The designed pendant is 60 x 60 mm and 43.5 mm thick. The pendant was 3D printed in polylactic acid (PLA) filament. PLA is the most common material for 3D printing because it is the cheapest filament. Because it was cheap and accessible, the pendant was prototyped in PLA. However, because one of our major criteria for the pendant was for it to be durable and resistant to chemical corrosion, Acrylonitrile Butadiene Styrene (ABS) plastic was selected as the final material. ABS is durable, strong, and withstands adverse environmental conditions [24]. The components inside of the pendant include one of each of the following:

- Saturated Cotton Wick (enclosed in a drawer)
- 30x30 mm Centrifugal Fan
- Micro Analog Servo Loading Linear Actuator
- 3.7 V, 1600mAh battery
- 5V Charging Board
- Arduino Nano 33 BLE
- Radio Frequency Receiver

The battery charger is stabilized on a 24.5 x 20 mm plate that is held into place by attaching it to the screw hole that closes the whole pendant. The battery sits at the base of the pendant while the Arduino Nano sits in the left wall of the pendant held in place by a border wall. The centrifugal fan sits on corner stumps that are implemented into the case to reduce vibrational sounds. The linear actuator fits into a track case at the top of the pendant. The mechanics behind the linear actuator are discussed further in *mechanical engineering*. The wick drawer sits above the fan, and its mechanics are discussed further in *mechanical engineering*. The inside of the pendant and components are shown in **Figure 2**. The left image includes the Arduino Nano BLE, Battery, Linear Actuator, Gate, and Fan. The middle image shows the charging port sitting on top of the fan. The right image shows the remote receiver above the charging board.

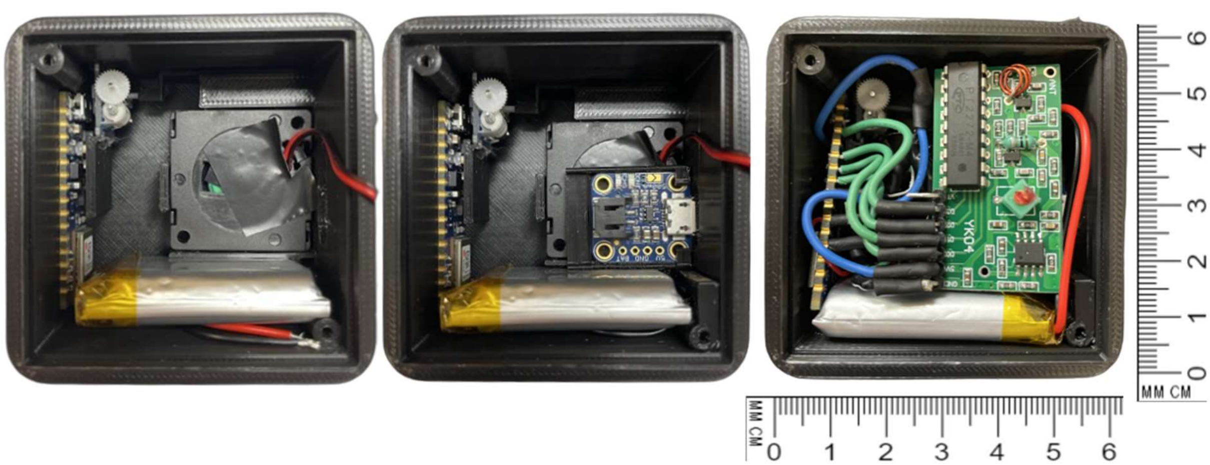

Figure 2: Inside of Pendant with Components

An expanded view of the pendant is shown in **Figure 3**.

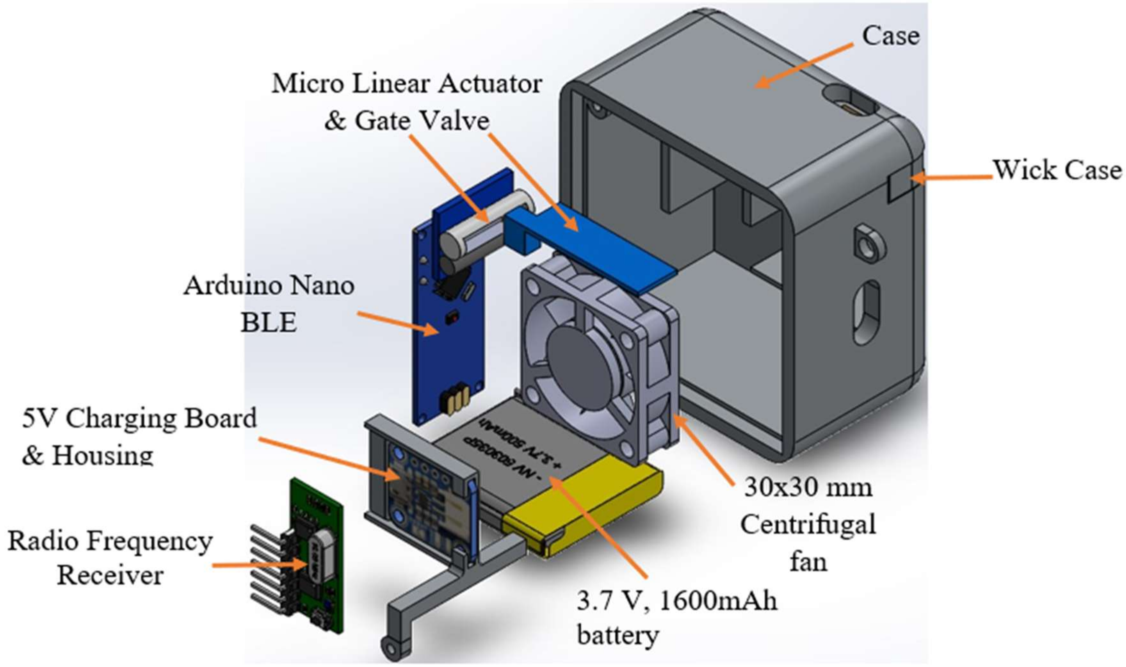

Figure 3: Expanded View of Pendant

The pendant has two external chain connections located on the right and left side of the pendant. On the front of the pendant, there are 25 two-millimeter diameter holes with 4 mm of spacing between each hole for the centrifugal fan to pull in air, and on the top of the pendant, there is a 6 x 3 mm hole to allow the centrifugal fan to push air towards the user's nose. On the left side, there is a 7 x 6.60 mm hole for a micro-USB charge to connect to the charging board and recharge the device. **Figure 4** shows the front and back faces of the pendant and the top and left sides. The inlet holes, outlet hole, charging hole, and chain connectors are also shown. The image on the left is the front face of the pendant. The image on the right shows the back of the pendant.

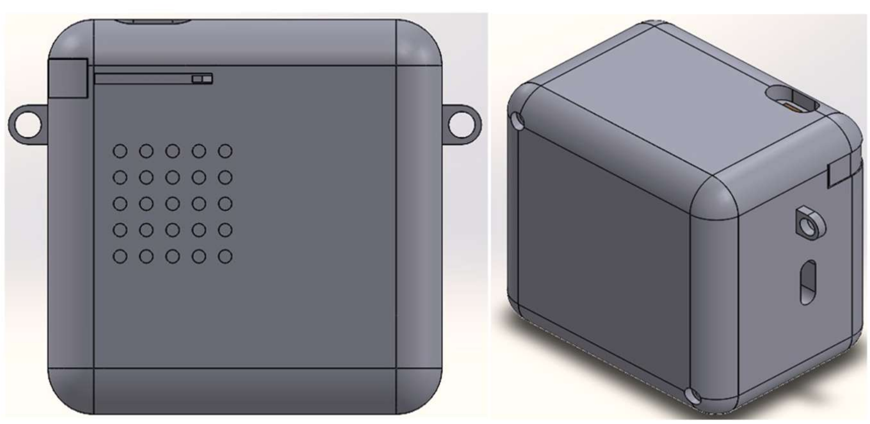

Figure 4: Outside Front and Back of Pendant

The back of the pendant is sealed with an O-ring to improve the pendant's ability to withstand sweat and rain, as shown in **Figure 5**.

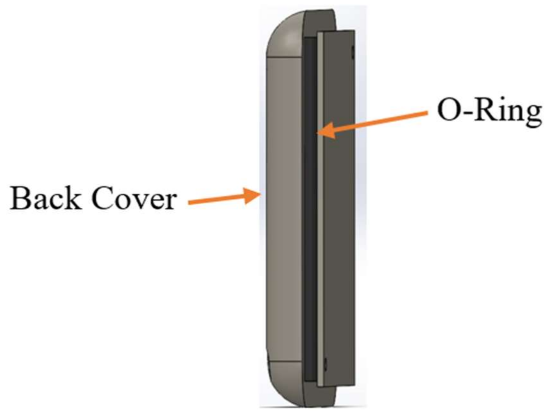

Figure 5: Back Cover of Pendant w/ O-ring

For versality, the pendant can be placed in a clip. The pendant slides in and locks into the clip. The clip can be attached to jackets, shirts, bags, or other locations via a hook. **Figure 6** shows the pendant locked into the clip. The clip is 68 x 51.5 mm, and its walls are 3.5 mm thick. The hook is 5 mm thick and extends 34 mm throughout the back of the clip to support the weight of the pendant. The image on the left shows the pendant in the clip from the front and the right image shows the pendant in the clip from the side – back view.

Figure 6: Front and Side View of Pendant in Clip

Anxiety Sensor

The mechanism to emit scent will be triggered by an increase in heart rate because the number one symptom of anxiety disorders is increased heart rate [14]. The team chose the Polar Verity Sense photoplethysmography (PPG) sensor to monitor heart rate because it does not require adhesion to the skin and has low power usage. PPG sensors emit light onto one side of a tissue volume and receive the transmitted light on the opposite side or the reflected light on the same side. The sensor is placed into an armband, and the armband can be placed anywhere along the user's arm. This sensor reads the heart rate in beats per minute and sends the data to the Arduino Nano BLE via Bluetooth. A heart rate threshold is encoded in the Arduino Nano, and when the threshold is exceeded, the linear actuator and centrifugal fan run. **Figure 7** shows the Polar

Verity Sense's PPG sensor placed inside the armband and the compatible USB charger for the PPG sensor.

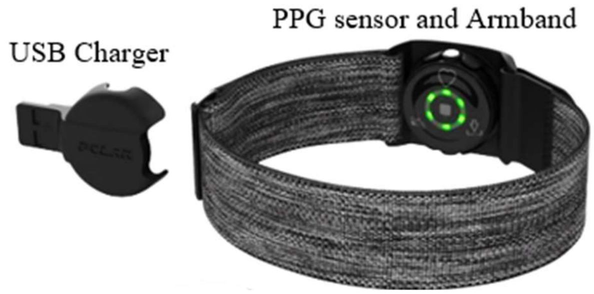

Figure 7: Polar Verity Sense PPG Sensor

Remote
A radio based remote was chosen for the design for its reliability and simplicity. A radio frequency receiver is compatible with the radio frequency transmitter located inside the remote. The remote has four buttons: A, B, C, and D. Button A triggers a manual emission. Button B changes the duration the fan is on during an emission, and Button C changes the amount of time between periodic emissions. Button D enables or disables the necklace's functionality. **Figure 8** shows the remote with four buttons and the transmitter's paired receiver.

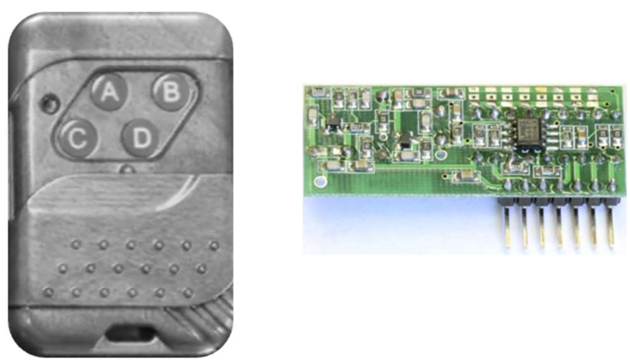

Figure 8: Remote and Paired Receiver

Overall, the main function of the device is to emit a scent in response to an increased heart rate. The device monitors heart rate until the heart rate increases above a threshold. When the threshold is crossed, the linear actuator turns on and opens the door over the wick. The fan then turns on for a specified amount of time to propel the scent toward the wearer's nose. After the fan turns off, the linear actuator closes the door, and the necklace returns to monitoring heart rate. The remote can be used in addition to allow for the user to have manual control over emissions.

2. Subsystems
This device has four subsystems: mechanical engineering, electrical engineering, computer science, and mass transfer. The mechanical engineering subsystem includes the forces and movements of the components on the inside and outside the pendant. The electrical engineering subsystem consists of the circuitry and power supply of the device. The computer science subsystem involves the code the device needs to perform its required functions. The mass

transfer subsystem is comprised of the diffusion, evaporation, and concentration of scented essential oil.

Mechanical Engineering
The mechanical engineering subsystem includes the forces and movements of the components on the inside and outside of the pendant. Inside the pendant is a micro analog servo linear actuator. The linear actuator has a 3D-printed 30 mm x 10 mm x 1 mm gate valve attached to its mounting plate. The linear actuator's mounting plate moves the gate valve in a horizontal direction (left to right). The gate valve is attached to the linear actuator's mounting plate via a 2.67 x 1.27 mm hole. The linear actuator's and gate valve's movement opens a hole on the top of the pendant to expose the wick, allowing for the aroma to diffuse towards the nose because of the fan's air flow. **Figure 9** shows the gate valve attached to the linear actuator.

Figure 9: Linear Actuator and Gate

The pendant case has a built-in linear actuator holder. The linear actuator slides into the holder and locks in place. **Figure 10** is a closeup of the linear actuator holder inside the pendant case. It is 30 mm long and 10 mm wide. The linear actuator holder is a built-in feature in the pendant.

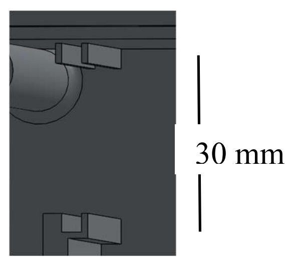

Figure 10: Linear Actuator Holder

The gate valve rides along the top of the wick drawer housing as a track. Instead of all the weight being applied on the far end of the gate valve, the track allows the weight to be dispersed evenly throughout the gate valve, preventing any excess stress on the mounting plate of the actuator. The track also helps to ensure that the gate does not fall off course causing any malfunctions when opening and closing to allow airflow.

Figure 11 shows a zoomed in view of the front face of the pendant with the wick drawer. There is a protruding tab that allows the user to slide the wick drawer open. There are tracks inside the pendant that allow the wick drawer to easily glide open and shut.

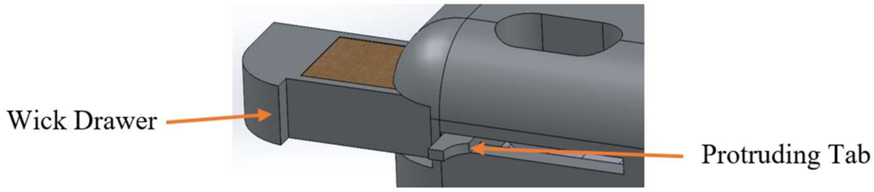

Figure 11: Zoomed in View of Wick Drawer

Electrical Engineering

The electrical engineering subsystem includes the circuitry and power source needed for the pendant to function. The internal components (see **Figure 2**) require power.

A 3.7 V, 1600 mAh battery is attached via a connector to the charging board. One end of a wire is soldered to the output pin of the charging board, and the other end of this same wire is connected to the 3.3V pin of the Arduino Nano. The centrifugal fan requires more milli-amperes than what the 3.3V pin on the Arduino Nano can supply, so the centrifugal fan receives its power from the V_{in} pin of the Arduino Nano. There is an NPN transistor wired to the V_{in} pin through the collector and a digital output pin wired to the base. The digital pin controls when the current is supplied to the centrifugal fan from V_{in}. The linear actuator is wired to a digital output pin and radio frequency receiver is wired to digital input pins and are powered by the 3.3V pin. The device needs 150mA to run continuously and 200mA to run if the components are releasing a scent. Therefore, with a 1600 mAh battery, the theoretical maximum battery life is 10.67 hours, and the minimum battery life is 8 hours. The detailed circuitry of these components and their connections are shown in **Figure 12.**

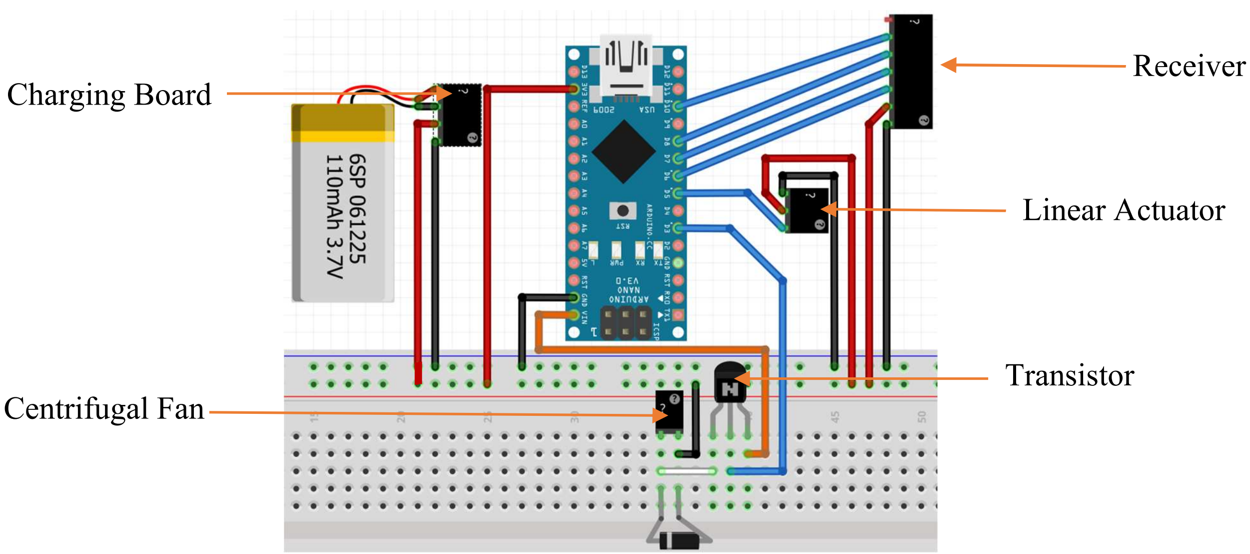

Figure 12: Device Circuit Diagram

Computer Science

The computer science subsystem involves the logic and processing behind handling the input and outputs (I/O) of the device and is coded in the Arduino programming language (a simplified form of C++). The detailed code can be referenced in **Appendix D**. The main coded functionalities of device include:

1. Collecting heart rate in beats per minute from the Polar Verity Sense heart rate sensor via Bluetooth
2. Releasing an emission in response to an increased heart rate
3. Releasing an emission in response to an input from the remote
4. Changing the duration of the fan on-time in response to an input from the remote
5. Changing the amount of time between periodic emissions in response to an input from the remote
6. Turning the necklace on/off in response to an input from the remote

All software settings can be set by an “administrator”. The administrator is an individual capable of changing values directly in the code. Two software settings can be set by a “user” via the remote. The user is an individual who does not intend to change values in the code.

Collecting the Heart Rate from Polar Verity Sense

To collect the heart rate from the Polar Verity Sense and activating the centrifugal fan and servo linear actuator, the Arduino Nano 33 BLE repeatedly tries to connect to Polar Verity Sense until a successful connection. Once the connection is successful, the Arduino Nano will collect the heart rate and request an emission if the obtained heart rate surpasses the admin-set heart rate threshold. The emission release function is also called if prompted by the remote or by a timer set by the user.

Emission Process

The following five steps are contained in the emission release function:

1. Check if the admin-set amount of time has passed since the previous emission to release a new emission.
2. Notify the user of a new emission request only if the admin-set amount of time has passed since the last notification (to prevent overpopulating the serial monitor).
3. Open the linear actuator.
4. Turn the fan on for a user-selected amount of time (with the remote).
5. Close the linear actuator.

Periodic Emissions

Periodic emissions are emissions that are released based on a repeating timer (for example, a user may choose to have an emission released every thirty minutes). To release periodic emissions, the program first checks if the amount of time has passed since the previous periodic emission surpasses a user-selected amount of time between periodic emissions. If enough time has passed, an emission is released.

Remote Button Program

There are four buttons on the remote: A, B, C, and D. For buttons A, B, and C, inputs are registered with an interrupt that changes the value of a Boolean variable that corresponds to whether that button was pressed or not. When the code executes a loop, the value of each of these variables is checked. If any of them are true, the corresponding code block is executed, and the variable is set back to false. This method of activating functions from remote input is necessary because any code that is encapsulated in an interrupt cannot obtain the current time or print to the serial monitor. Buttons B, C, and D also immediately execute other functionality in the interrupt.

Button A calls the emission release function. Buttons B changes how long the fan stays on during an emission. Button C changes the amount of time between periodic emissions. Button D turns the device on or off.

There are four possible settings for the duration that the fan is on and four possible settings for the length between periodic emissions. The four values for each setting are defined as four values in an array. The length of the arrays and the values in the arrays can be changed through directly editing the code while retaining all functionality so long as the values are positive real numbers. When either Button B or C are pressed, a pointer variable that is used to select a value in the corresponding setting array is increased by one until the pointer reaches the end of the array. If signaled to increase again after reaching the end of the array, the pointer value is set to zero and returns to the setting at the beginning of the array.

Button D turns the device on and off by enabling/disabling LED_PWR, PIN_ENABLE_SENSORS_3V3, and PIN_ENABLE_I2C_PULLUP. It does this through the toggleSleep() function, which is called through button D's interrupt, which enables the listed parameters if they are disabled or disables the parameters if they are enabled.

Mass Transfer

The mass transfer subsystem includes details on the diffusion of essential oil, scent detection, and essential oil concentration. Lavender oil was used for all analyses and testing because it is the most used essential oil for decreasing stress [7]. The essential oils will be placed into the device on a cotton wick with a length of 15 mm, width of 10 mm, and thickness of 2 mm. A volume of 0.3 mL of an essential oil and carrier oil mixture can fit on the wick. The recommended concentration to be placed on the wick is between 15% and 30% lavender oil, depending on the user's preference. This will ensure that the user can detect the scent while a person standing two feet away cannot. The cotton wicks will be bought pre saturated with an essential oil and come in a plastic wrap. The user will be able to unwrap the cotton wicks and place them in the pendant.

D. Testing & Validation

Sweat and Rain Resistance Test and Results

The patients need the pendant to be resistant to sweat and rain, so they can wear the device all day. The patient should not have to remove the pendant to work out or worry about rain seeping into the pendant. An ingression protection rating tests the level of protection an enclosure provides against intrusions. To prove the pendant is resistant to sweat and rain, it needs to have an IPX1 rating. An IPX1 test is defined as dripping water with vertically falling drops. The test includes a test duration of ten minutes and water equivalent to 1 mm of rainfall per minute. After ten minutes, the device is inspected for any signs of water penetration. The acceptance criterion is the vertically falling drops of liquid have no harmful effects on the device or enclosure [25].

The ingression protection rating equipment was not accessible, so a garden hose with an attached nozzle was used to simulate vertically falling drops. This hose and a measuring cup were used to set the flow rate of the water at 2 mm per minute. A dry paper towel was weighed with a precision scale; the weight of the paper towel before the test was 5.382 grams. The paper towel was placed into the pendant, and the pendant was sealed shut. The hose was positioned to spray vertical drops of water at a flow rate of 2 mm per minute. After ten minutes, the hose was turned off, and the paper towel was removed from the pendant and weight. The weight of the paper towel was 5.382 grams. The change in weight was zero grams, indicating no water entered the pendant. The pendant can withstand vertical rain drops.

Compression Test and Results

A theoretical tensile test was performed in SolidWorks to verify that the pendant can withstand the 200 – pound technical specification (*see* ***Appendix E***). A 200-pound compressive load was applied to the top and front face of an ABS material pedant. The yield strength of the ABS material in the SolidWorks simulation is 48 MPa or 7 ksi. The results from the SolidWorks simulation show that the pendant can withstand the 200-pound load on both faces with a relative maximum yield stress of around 6 ksi. Therefore, theoretically, the pendant will not break when a 200-pound load is applied to it.

To test that the SolidWorks model is accurate a tensile tester machine was used to conduct the test experimentally. The tensile tester determines the strength and deformation behavior of a material up to the point of fracture. A block of ABS that was cut into the 49 x 42 mm pendant using a CNC machine. The ABS block was placed in the tensile tester (*see* ***Appendix E***). The loading force at which the block endured complete failure was 2030 lb. For this test, the block's back side was open. There were also free-standing flaps, and the compressive load mounting tool for the tensile test was a circle. Therefore, the block can theoretically withstand more than 2030 lbs. Based on this result, when the pendant is made of ABS it will withstand greater than a 200-pound compressive load.

Drop Test and Results

The patients may want to place their device on a chest of drawers or shelves while they are not wearing the pendant or while the pendant is charging. To prove the device could withstand a fall from the user's dresser or approximately a five-foot fall, a drop test was performed. Two drop tests were performed: one on the front face and one on the top face. The drop test was performed with a SolidWorks simulation study (*see* ***Appendix F***). The top left corner of the front face of the pendant where the wick drawer is located did not withstand the fall. This location suffered more pressure than the ABS material can withstand (greater than 7 ksi). The future pendant can be coated in silicone to prevent this failure in the actual design. The bottom face did not exceed pressures greater than 5 ksi; therefore, on the bottom face, the pendant can withstand a 5-foot drop.

Sound Detection Test and Results

The patients need the pendant to be quiet and not attract unwanted attention to themselves. The pendant needs to function at a sound intensity less than 30 decibels. The centrifugal fan and linear actuator are the two components inside the pendant that make noise. A Cadrim decibel meter was used to measure the change in decibels when the two components were activated. The fan and linear actuator were tested separately to find their sound intensity individually. The test was performed in a soundproof room. The room's base sound (in Decibels) was measured, and the remote was used to turn on the fan ten times. The sound read by the decibel meter when the fan was on was measured. These two decibel readings were transformed into sound intensity levels and the difference in the sound intensity between the fan and the room was calculated. This procedure was repeated for the linear actuator. For all ten trials, the centrifugal fan had a sound intensity less than 30 decibels; however, the linear actuator had a sound intensity between 64-65 decibels. A sound intensity of 65 decibels is equivalent to the sound of a general conversation. A T-test with the hypothesis that the data set is less than the hypothesized mean was conducted on both data sets. The hypothesized mean was 30 dB with an alpha value of 0.05. There was not enough evidence to reject the hypothesis that the sound intensity of the linear actuator is greater than 30 db. However, there was enough evidence to reject the hypothesis and say that the sound intensity of the fan was less than 30 dB (*see **Appendix G***). Therefore, the sound of the fan is discreet while the sound of the linear actuator is not. However, this problem could be addressed by manufacturing or buying a quieter linear actuator.

Heart Rate Reliability Test and Results

To prove the Polar Verity Sense heart rate sensor reads heart rate with absolute mean percentage difference of less than 10% compared to a popular heart rate sensor, a heart rate reliability test was performed. The percentage difference was calculated with **Equation 1**, where heart rate 1 (HR_1) is an Apple watch and heart rate 2 (HR_2) is the Polar Verity Sense.

$$Percentage\ Difference\ (\%) = \frac{|HR_1 - HR_2|}{\frac{HR_1 + HR_2}{2}} * 100 \qquad \textbf{Eq. 1}$$

This test consisted of eight subjects: three white females, one white male, three Black males, and one Asian female. The subjects wore an Apple watch on their wrist and the Polar Verity Sense on their forearm or upper arm. For the Polar Verity Sense, the heart rate in beats per minute (BPM) was displayed on the Serial monitor in Arduino IDE. For the Apple watch, the heart rate in BPM was displayed on the screen of the Apple watch face. Two non-subjects read the heart rates from both devices; one non-subject read the Polar Verity Sense's heart rate and recorded it in an Excel workbook, and the second read the Apple watch's heart rate and recorded it in an Excel workbook (see **Appendix H**). The heart rates were recorded every ten seconds for three minutes. The heart rates from both devices were recorded in two different trials: the heart rate at rest and the heart rate after exercising. The percentage difference between the Polar Verity Sense and the Apple Watch for each ten second interval was calculated using **Equation 1**. The mean percentage differences of these percentages were calculated (see **Appendix H**), and the results for the heart rate at rest and after exercise were all less than 10%; therefore, the Polar Verity Sense is competitive with marketed devices.

An ANOVA test was performed to analyze the difference between the mean percentage difference between the eight participants (see **Appendix H**). The ANOVA was performed on a 95% confidence interval; therefore, the p-value needs to be less than 0.05 to be statistically significant. The hypothesis stated the mean percent difference between people is significantly different. For the mean percentage difference of the heart rates at rest, the p-value was 0.09. For the mean percentage difference of the heart rates after exercising, the p-value was 0.23. The p-values for both forms of heart rate collection were greater than 0.05; therefore, there is not statistically significant evidence to reject the hypothesis that the mean percent difference between the polar verity sense and apple watch for all subjects are not significantly different.

These results show that the polar verity sense heart rate sensor is comparable to other devices on the market. There was not enough evidence to show that race affects the mean percent difference between the devices. Another observation from the results of this test was that the largest percentage differences between the two devices occurred just after exercising. There seemed to be a slight delay between the apple watch and polar verity sense. This could be due to differing heart rate calculations in the device. This is not a concern based on the rest of the test results.

Essential Oil Longevity Test and Results
A published study on evaporation rates of essential oils was used for initial engineering analysis. This study looked at how long it took different essential oils to evaporate at different temperatures. The maximum and minimum evaporation times at different temperatures were recorded. **Figure 13** shows the data points taken from the study with power trendlines [26]. The equations on the top right of the plot were used to find the maximum evaporation rate. The maximum evaporation rate was determined to be approximately $2 \times 10^{-8}\,\frac{g}{s}$ (see **Appendix I** for a more detailed calculation).

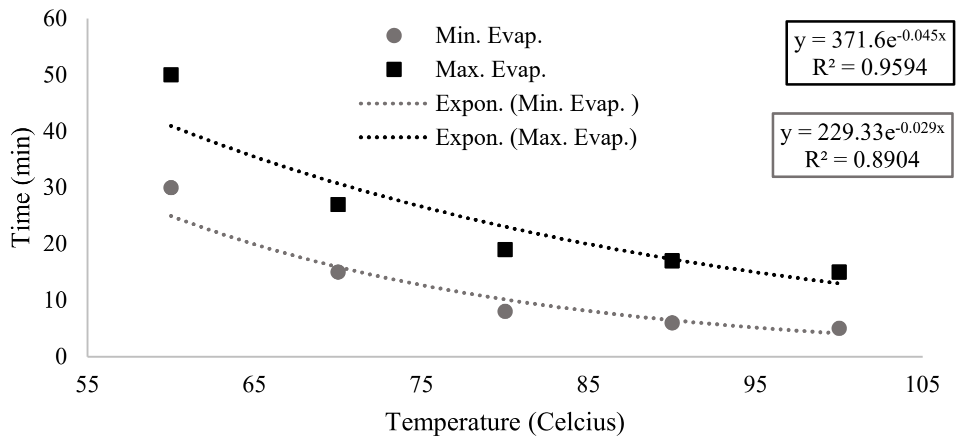

Figure 13: Time vs. Temperature Graph from Evaporation Study

To prove the essential oil would last for more than 7 days, an experimental longevity test was run with 5 concentrations of lavender and jojoba oil: 0% lavender, 16.7% lavender, 25% lavender, 50% lavender, and 100% lavender. Each mixture was placed on a separate cotton wick. A volume of 0.15mL of lavender oil was used on each wick. The wick's weight was recorded before and after the mixture was placed on it. Once a day for 14 days, the weight was recorded. The weight of the wick was subtracted from the data points to isolate the weight of the oil. The evaporation rate of just lavender oil was determined to be approximately $4.05 \times 10^{-8}\,\frac{mL}{s}$. This is comparable to the initial engineering analysis from the published evaporation study. **Figure 14** is a graph displaying normalized weight percentage (g/g) vs. time.

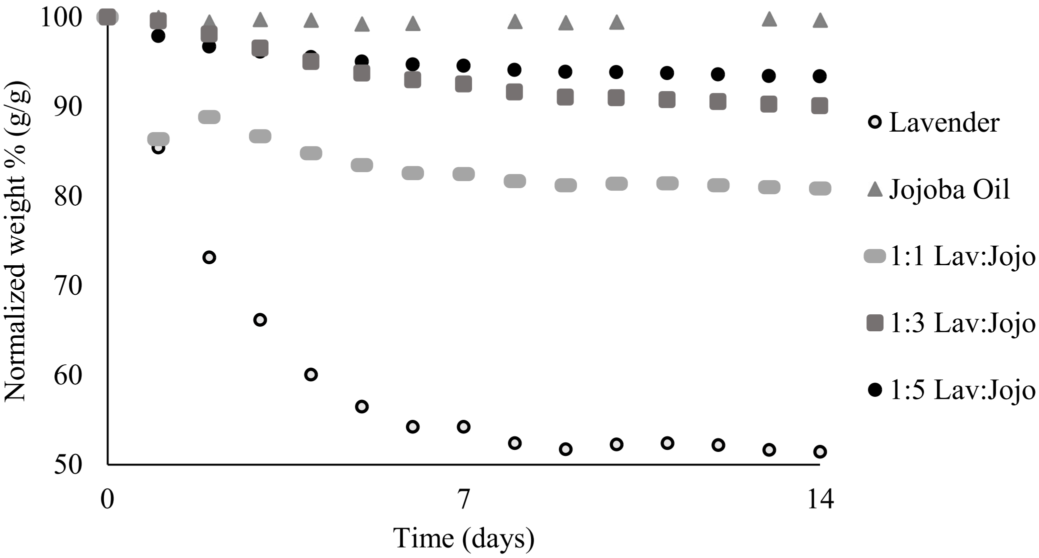

Figure 14: Graph of Normalized Weight vs. Time

The mixture with 100% lavender oil evaporated the quickest, to 50% of its initial weight. The mixture with 0% lavender oil did not have a significant change in mass over the time. This graph shows a rough correlation between increased volume of jojoba oil and decreased evaporation time. All the wicks with lavender had a detectable scent after the 14-day period except for the 100% lavender (*see **Appendix J***). This showed that to make the smell last longer, it should be mixed with a carrier oil, such as jojoba. This test also verified that these concentrations of oils will last 7 days, meeting the customer needs while staying competitive with other devices on the market. This test led the team to pick a concentration between 15% and 30% for the scent test.

Scent Detection Test and Results

Initial engineering analysis of scent detection was conducted in COMSOL modeling software. A 2D model was created to model the lavender essential oil dispersing in the air from a cotton wick. In this model, air flow was modeled at the wick and concentrations over time just above the wick and 2 ft away were observed. A parametric sweep was conducted to observe multiple starting vapor concentrations ranging from 1×10^{-5} to $5 \times 10^{-3}\ \frac{mol}{m^3}$. This model showed that the maximum starting vapor concentration should be around $1 \times 10^{-4}\ \frac{mol}{m^3}$. This theoretical value would ensure that the person sitting in front of the device could detect the scent while someone 2 feet away could not (*see* **Appendix C** *for more detailed calculations*). Raoult's law was used to determine the liquid concentration of lavender oil in Jojoba oil. To achieve this vapor concentration, the liquid mixture should be 0.06% lavender oil (*see* **Appendix K** for more detailed calculations). This mixture was created and in a preliminary test with the team, the scent was barely detectable. The concentration used for the scent detection test was 25% lavender oil and 75% Jojoba oil. This is significantly higher than what was determined from the COMSOL model. However, the COMSOL model did not consider factors such as air flow in the room, resistance from the cotton wick, and included many assumptions about properties of essential oils. This model also only considered the minimum threshold of scent detection. Variation in people's sense of smell could mean that the threshold is higher to elicit a response from the user.

The goal of this test is to verify that the scent can be detected by the user but not by a person 2 feet away from the device. Twelve people, unaware of the objectives of the project, participated in this study. These people were brought into a room. Four participants sat 2 feet from the device and 8 people sat directly in front of the device. There were LEDs in front of all participants and the linear actuator and fan created noise when turned on. The LEDs were controlled by a button and the device by a remote. The participants were asked to explain any changes they felt in their sensory environment for a five-minute period. During this time, the LEDs would flash, and the device would emit a scent 3 times. It was on for 15 seconds each emission. Sight and sound were included in the test to prevent bias. After the study, two participants explained that they have a deviated septum and therefore cannot smell, so they were excluded from the analyzed data. All participants noticed the LEDs and heard the sound from the device. None of the participants could smell the device when sitting two feet away. All the participants detected the scent in front of them except for one person. One person who was in front of the device was given a placebo wick with no lavender oil. This participant did not detect a scent. While this was a small trial, it showed that a good concentration for a customer to use with this device would be between 15% and 30%, depending on their preference. The participants sitting away from the device could not detect the scent meeting the customer's need of being discreet and not bringing unwanted attention to the user. A table of summarized results can be seen in ***Appendix L.***

Remote Distance Test and Results
For therapist and psychiatrist to integrate the device into behavioral therapy, the remote needed to function within 20 feet of the pendant. The goal for the efficiency of each button was 92% efficiency. Efficiency was defined as output per input. To test the remotes distance, buttons A, B, C, and D were pressed ten times each at 20 feet. The buttons being pressed were recorded as the input, and the required function of each button successfully performed was recorded as the output. For all four buttons, the required function was successfully performed each time the button was pressed. The confidence interval for this test was 95%. The margin of error was calculated to find the true confidence interval for each button. The efficiency chosen for calculation was 99% because 100% efficiency is impossible to obtain. For a sample size of ten, the standard error was 0.031, and the corresponding z-value for a confidence interval of 95% is 1.96 (*see **Appendix M** for detailed calculations*). The margin of error for this data set is 6.17%; therefore, the true portion of success for each button is between 92.83% and 99.99%.

E. Budget

Over the course of nine months, $495.06 was spent (*see **Appendix N** for detailed budget*). Major contributions to the money spent were the heart rate bracelet from Polar, three Arduino Nanos, and 3D printing. These contributed to over half the budget. One pendant cost approximately $100, which includes: the material of the pendant, centrifugal fan, linear actuator, battery, charging board, Arduino Nano, radio frequency receiver, and wiring and heat shrink. To make profit on the manufacturing of the pendant, the consumer would most likely pay around $200 for one pendant.

F. Federal Drug Association (FDA) Regulatory Considerations

Currently, essential oils are not regulated by the FDA. The FDA does not regulate heart rate monitors that simply monitor health and fitness [27]. The QUE Aromatherapy Device would not need FDA approval before it is marketed if it is marketed as a device that "promotes calmness and relaxation." If the device claims to decrease heart rate, then it is addressing a medical condition and will need FDA approval before it can be sold. However, in the future if the device claims to decrease heart rate, it will most likely be a De Novo Class II and use the apple watch as its predicate device.

G. Conclusion

The Adult QUE Aromatherapy Device is a novel method to help potentially treat patients who suffer from post-traumatic stress disorder and other anxiety disorders. The sponsor, patients, and providers **needed a mechanism to release a scent in response to symptoms of post-traumatic stress disorder (PTSD) and other anxiety disorders that can be used as an everyday aromatherapeutic tool.** The QUE Aromatherapy Device is designed to release a scent. The pendant has an Arduino Nano 33 BLE, a linear actuator attached to a 3D-printed gate, centrifugal fan, and a 3.7V power supply that functions to release a scent. The pendant has a compatible heart rate monitor, Arduino Nano, and power supply function to react to an elevated heart rate. The pendant can be used every day because it is discreet and user-friendly. The scent released is discreet and is not detectable two feet away from the user. The radio frequency remote makes the pendant user-friendly because it allows the user to have full control of the pendant without accessing the electrical components on the inside of the pendant. The user can control four functions: release an emission, increase or decrease fan duration, increase or decrease periodic emissions, and turn the pendant on and off. It can be worn every day because it is mechanically durable and has a long-lasting battery life. The pendant withstands over 200 pounds of compressive force. The pendant has an 8-hour minimum battery life, and it can be safely stored or recharged on a nightstand or chest of drawers. Because this prototype functions and meets the sponsor's, patients', and providers' needs, research on the device's effectiveness can begin. The research will evaluate if this device is truly an aromatherapeutic tool that treats PTSD and other anxiety disorders.

Future Modifications

The pendant is larger than the patients desired. Modifications can be made to the pendant to decrease its size. One modification is printing a small circuit board. There are two options for the circuit board: one with the radio frequency receiver and one without. The printed circuit board with the radio frequency receiver needs to be a Bluetooth circuit board with 6 digital output pins, a 3.3V pin, a voltage-in pin, and a ground pin. Four of the six digital output pins will be for the radio frequency receiver, one will be for the linear actuator, and the other will be for the NPN transistor. The printed circuit board without the radio frequency receiver needs to be a Bluetooth circuit board that can pair with more than one device. Theoretically, with this circuitry, the radio frequency receiver would be replaced by a phone app. This circuit board would need 2 digital output pins, a 3.3V pin, a voltage-in pin, and a ground pin. A phone app allows the user to have more access to the device.

In addition to the circuitry, the centrifugal fan, linear actuator, and battery can be manufactured in-house rather than bought. The desired dimensions for the pendant are 1 x 1 x 0.5 inches. The pendant is louder than the patients desired. With more resources, a quieter linear actuator can be bought or manufactured. The desired sound for the pendant is 30 decibels, which is equivalent to a whisper.

Currently, the Aromatherapy Device is only compatible with the Polar Verity Sense. Another modification is allowing the user to connect to other heart rate monitors, such as Apple Watches, Fitbit, etc.

H. Operation Manual

Diagram of System

Pendant

The Aromatherapy Device fabricated includes one pendant connected to a titanium chain. The pendant is 60 x 60 mm; it is 43.5 mm thick. There is a front and back face of the pendant and four sides: top, right, left, and bottom. The pendant is secured with 2 mm screws. **Figure 15** displays all the faces of the device.

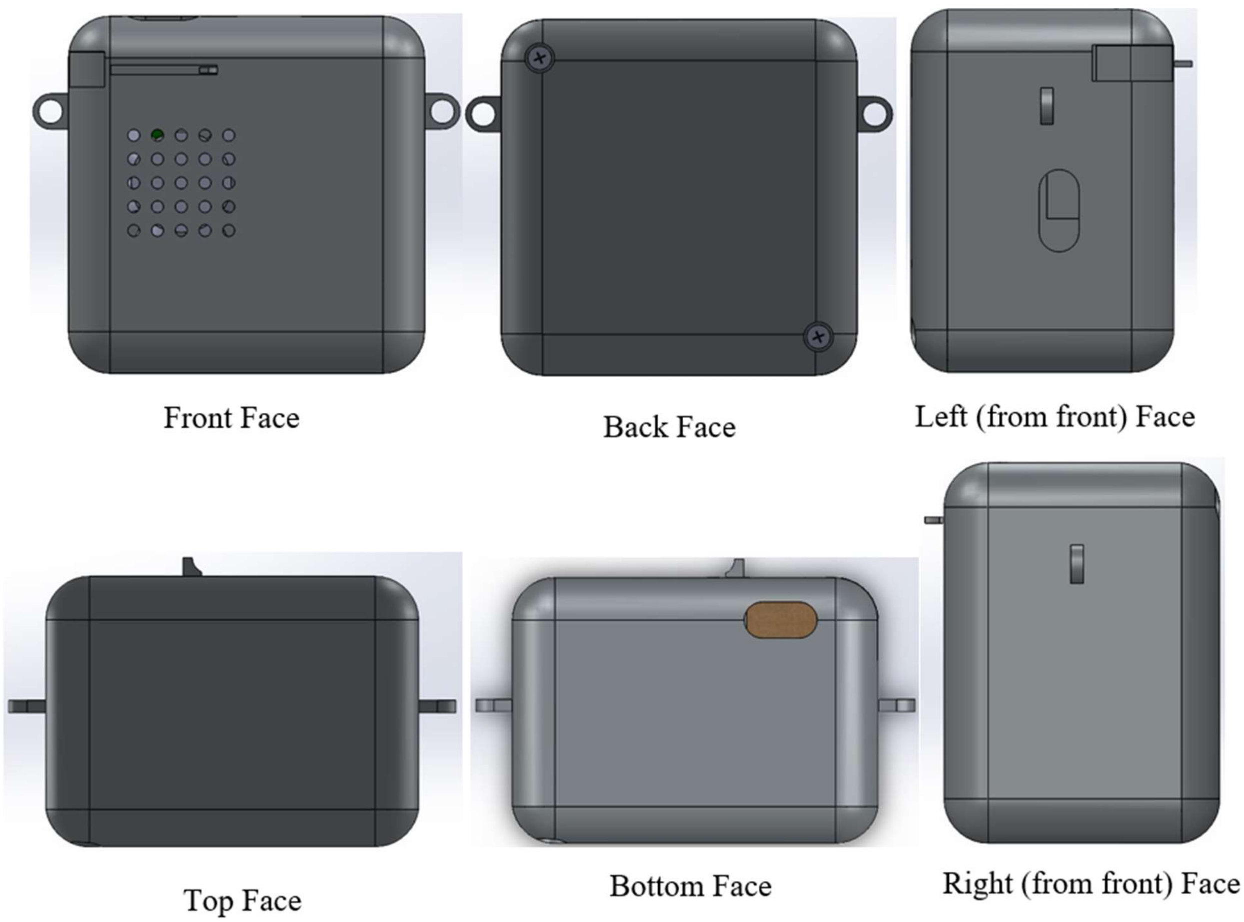

Figure 15: All Pendent Faces

The dimensions of the pendant are shown in **Figure 16** (see **Appendix O** for more dimensions and blueprints of the pendant). At the top of the blueprint is the top side of the pendant. The dimensions for the outlet hole and chain connections are outlined. On the bottom right is the front face of the pendant. The dimensions for the pendant, chain connections, inlet holes, and finger tab are outlined. In the middle is the inside of the pendant. The dimensions for the screw holes, the linear actuator holder, the corners for the fan, the battery holder, and Arduino Nano holder are outlined. On the right is the left side of the pendant. The dimensions for the micro-USB charging port and wick drawer are outlined.

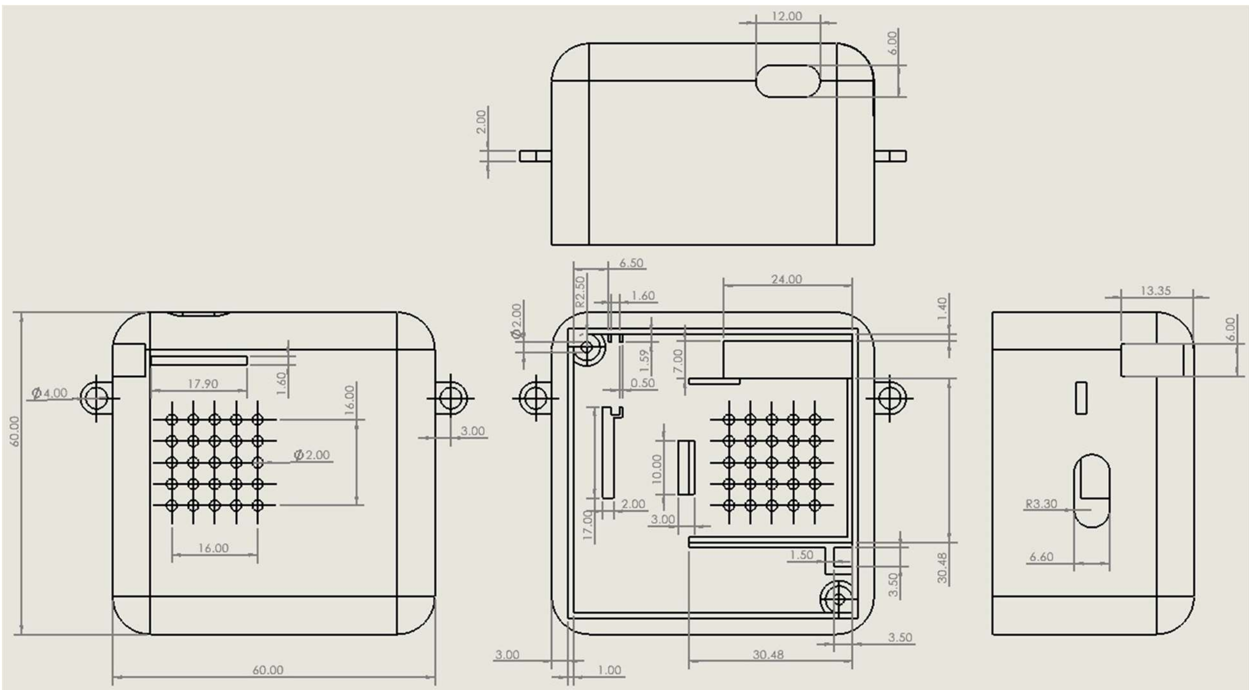

Figure 16: Dimensions of Pendant

The inside of the pendant includes one of the following:

- Saturated Cotton Wick (enclosed in a drawer)
- 30x30 mm Centrifugal Fan
- Micro Analog Servo Loading Linear Actuator
- 3.7 V, 1600mAh battery
- 5V Charging Board
- Arduino Nano 33 BLE
- Radio Frequency Receiver

Figure 17 shows the inside of the pendant with the parts assembled. In **Figure 18**, the parts are expanded and labeled.

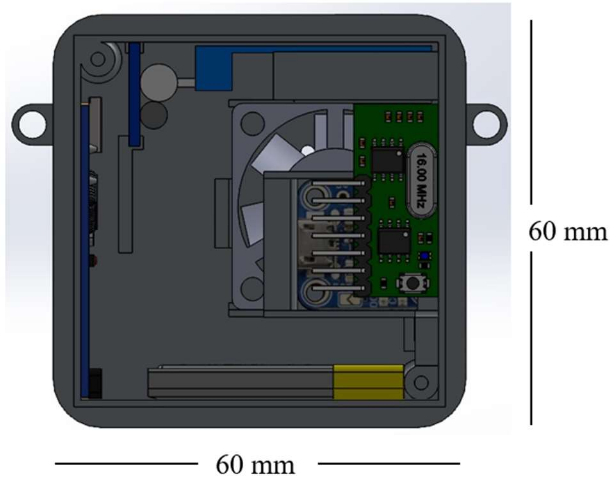

Figure 17: Inside Pendant

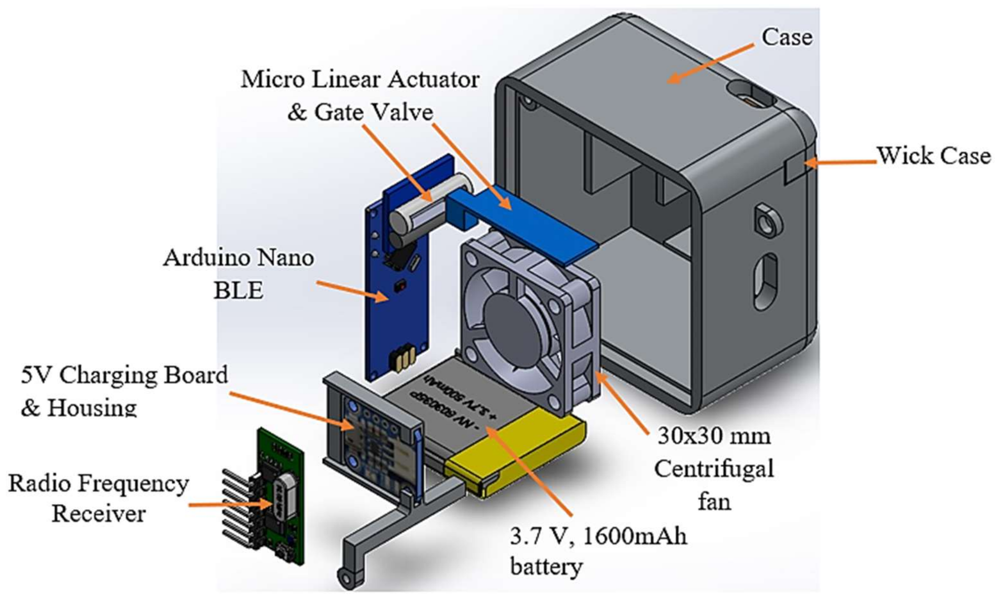

Figure 18: Labeled Parts Inside Pendant

Set Up

Pendant: Wick Replacement

The user will receive a wick that is 15 mm long,10 mm wide, and 2 mm thick. The wick is pre-saturated with an essential oil of the user's choice and packaged in standard wet wipe packaging that is made of several layers of various polymer that prevent moisture transfer. To place a new wick into the pendant, open the wick drawer using the that protrudes from the top left on the front of the pendant and place the wick into the drawer and close the drawer. After seven days, repeat the same procedure to replace the wick.

Pendant: Recharging
To charge the pendant, remove the rubber plug on the left side of the pendant and plug the micro-USB into the charging hole.

Heart Rate Sensor
The heart rate sensor compatible with the pendant is a Polar Verity Sense. The Polar Verity Sense can be purchased from Polar, and one purchase includes the photoplethysmography (PPG) sensor, the armband that holds the sensor, and a compatible USB charger.

Heart Rate Sensor: Pairing
To pair the heart rate bracelet, press Button D on the remote. The heart rate sensor and pendant will pair via Bluetooth.

Remote
The remote had four buttons with four unique functions. If the user would like to release a manual emission or an emission that is not based on their heart rate, press Button A. If the user needs more scent emitted or would like the scent to emit for longer, press Button B. If Button B is pressed, the duration the fan is on will increase. There are three options for fan duration: 10 seconds, 20 seconds, and 30 seconds. Button B can be pressed to cycle through these options. The default duration for the fan is 10 seconds. If the user would like the pendant to release in the scent in timed intervals, press Button C. Button C activates periodic emissions. There are three options for the interval between each release: 10 minutes, 20 minutes, and 30 minutes. When the user wants to turn the device on/off, press Button D. An illustration of the buttons and their function are shown in **Figure 18**.

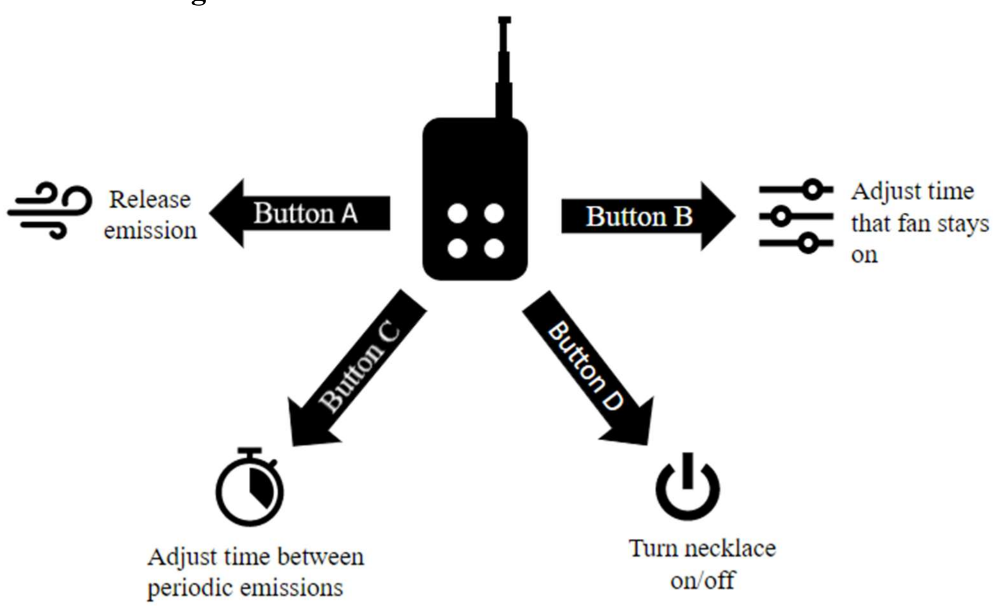

Figure 19: Illustration of Remote Buttons and Functions

Safety
Do not unscrew the pendant. Access to the electrical components risks damaging the wiring. If the device is warm, press Button D on the remote and make sure the necklace is off.

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Appendices

Appendix A: Patent

U.S. patent # of this product: 11,406,789 B2

Appendix B: COMSOL Model Simulating Venturi Design

Figure B1 shows the velocity in a venturi in mm/s. The venturi has a large diameter of 12 mm and a throat diameter of 2 mm. The inlet velocity is 0.007 $\frac{m^3}{s}$ and the exit pressure is 101325 Pa because it is exposed to atmospheric pressure. The 15 mm x 15 mm fan picked creates these parameters. Using these parameters, COMSOL was able to show the exit velocity of the air. Looking at **Figure B1**, it is seen that the exit velocity is around 2000 $\frac{mm}{s}$,or 2 $\frac{m}{s}$. This speed is fast and will cause the scent to shoot up into the user's face. The team wants the aroma to reach the users nose quickly, but comfortably and not spread on the face.

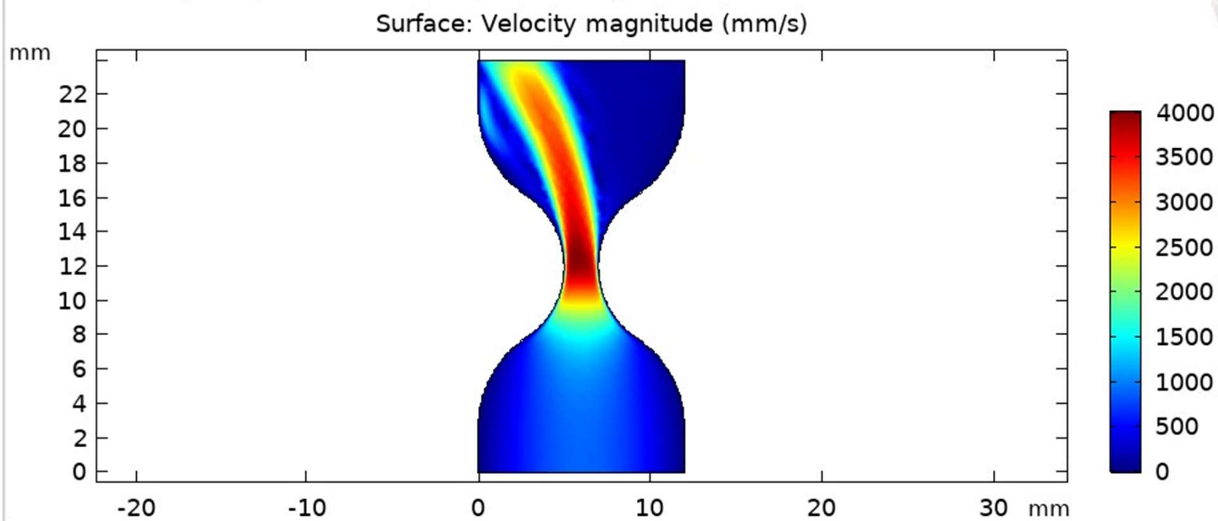

Figure B1: Velocity diagram of venturi system.

Figure B2 shows the pressure drop using the same parameters as above. The pressure drop is about 10 Pa, which is not sufficient to create a vacuum effect in the throat of the venturi. This means the essential oil would not be able to be pulled in and redirected towards the user's face.

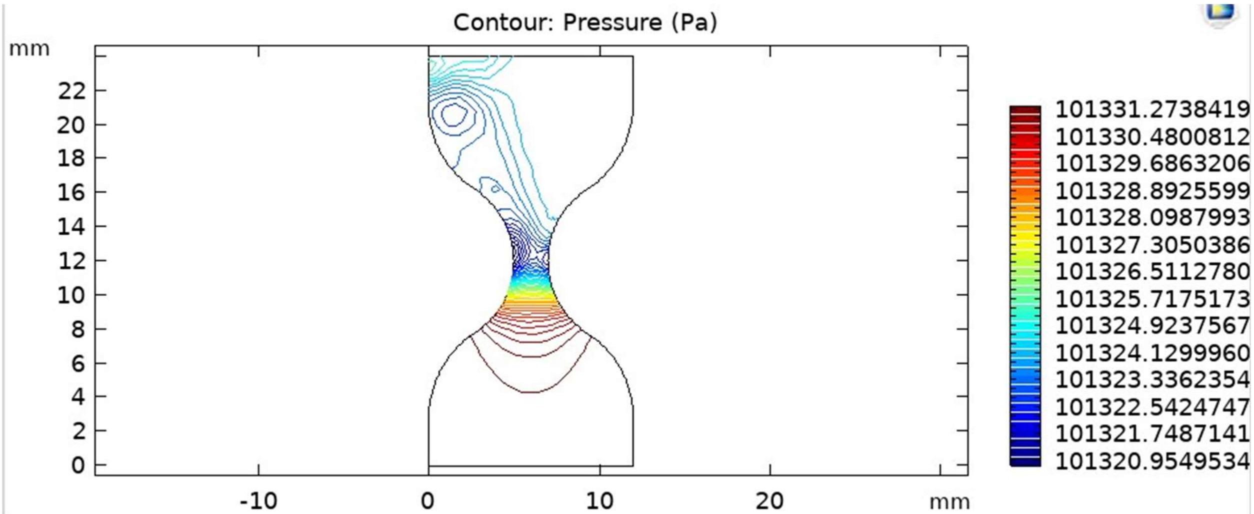

Figure B2: Pressure diagram of venturi system

Appendix C: COMSOL Diffusion Models

Geometry

Figure C1 shows the geometry for this model. A cotton wick is modeled as a line segment with a length of 15 mm, centered about 0. This line segment is highlighted in blue, and a concentration and velocity boundary were set on it. The large square has sides of 10 ft. These are large enough so that the concentration would not reflect off them. The boundary highlighted in blue in Figure 6 is where the concentration and velocity boundary were set on the "cotton wick". The red dots represent the two points where concentration was analyzed. These represent the "nose" of the user and the nose of a person 2 ft away. The material of the rectangle was set to air.

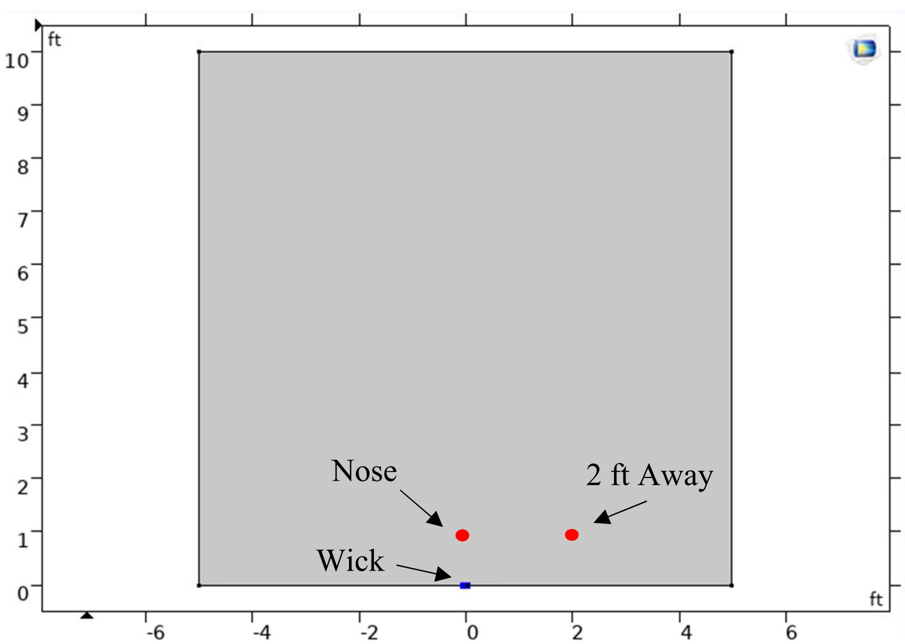

Figure C1: Geometry of second COMSOL Model

Physics

The physics of this model was the same as the previous. The only difference is the velocity of the fan was divided by a factor of safety of 10. This was to account for the fan blowing through the dense structure of a cotton wick.

Results

A parametric sweep was run on the transport for the following values of C_{max}: $1 \times 10^{-5}, 5 \times 10^{-5}, 1 \times 10^{-4}, 5 \times 10^{-4}, 1 \times 10^{-3}$, and 5×10^{-3}. **Figure C2** shows the concentration curve over 500 seconds (8.3 minutes) at the nose of the user. The scent needs to be detectable by the user and therefore the concentration at the nose needs to exceed $4 \times 10^{-8} \frac{mol}{m^3}$. More details on how this threshold was set can be seen in the basic diffusion section. All starting concentrations in this parametric sweep exceed the threshold.

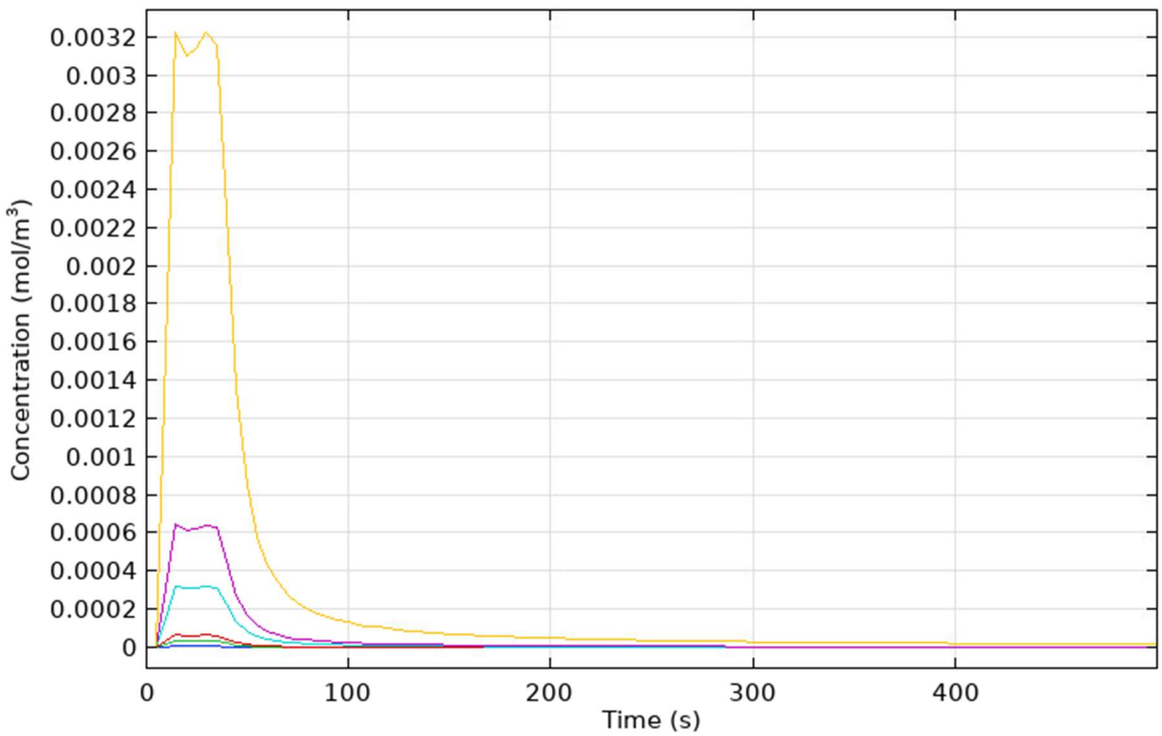

Figure C2: Concentration curve over time at the nose of the user.

Another need for the device is that a person 2ft away can NOT detect the scent. This will prevent other people from giving the user unwanted attention because they detected a scent. **Figure C3** shows the concentration curve over 500 seconds for different starting vapor concentrations 2ft away from the nose of the user. The concentration of $0.005\,\frac{mol}{m^3}$ was removed from the graph because it greatly exceeded the threshold, and it makes this graph easier to read. Concentrations less than or equal to $1 \times 10^{-4}\,\frac{mol}{m^3}$ do not surpass the threshold.

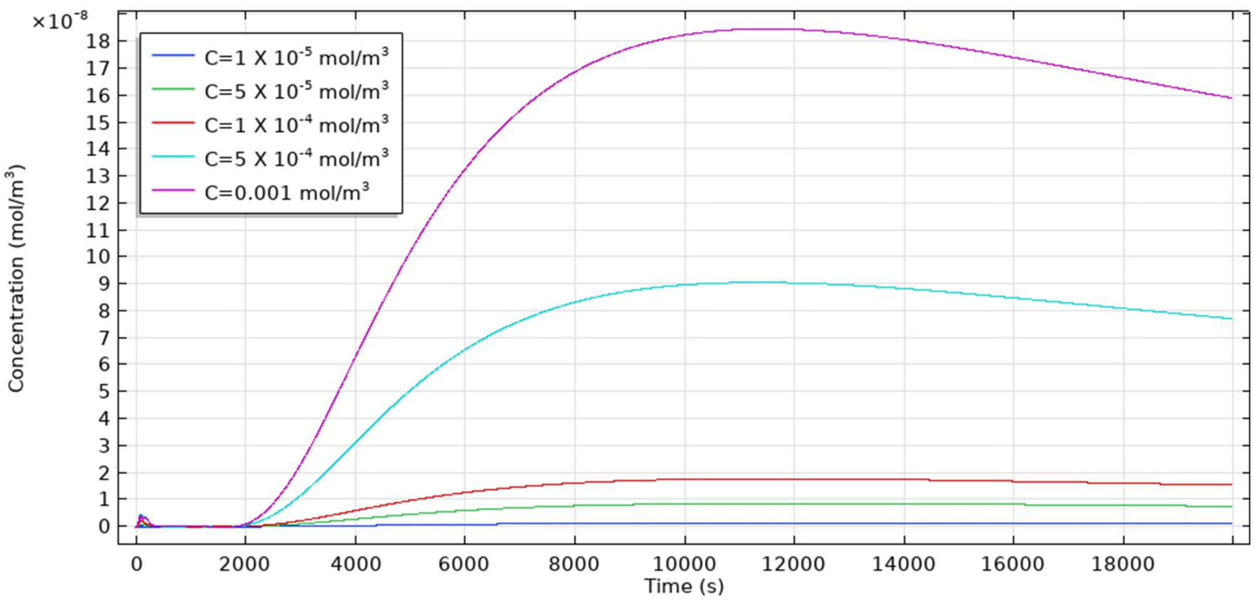

Figure C3: concentration curve over time 2 ft away from the nose of the user.

Figure C4 shows the concentration map of the system at $C_{max} = 1 \times 10^{-4} \frac{mol}{m^3}$ at time $t = 5, 25, 180,$ and $1500\ s$. These times were picked to show the starting concentration, the peak concentration, 3 minutes after release, and 25 minutes after release.

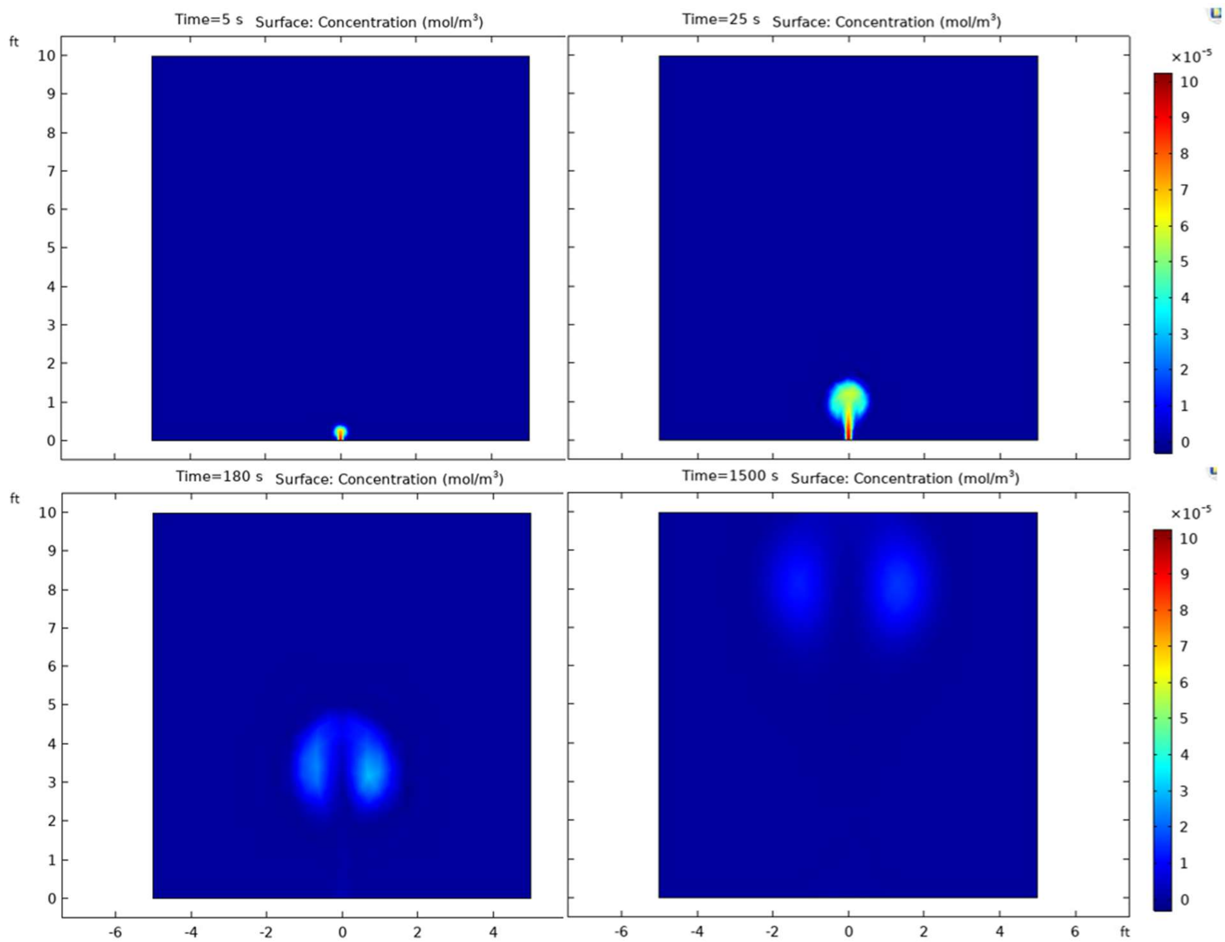

Figure C4: Concentration map with a starting concentration of $1 \times 10^{-4} \frac{mol}{m^3}$ at t = 5s (top left), 25 s (top right), 180 s (bottom left), and 1500 s (bottom right)

Figure C5 shows an animation of the diffusion with a starting concentration of $1 \times 10^{-4}\,\frac{mol}{m^3}$ over 500 seconds.

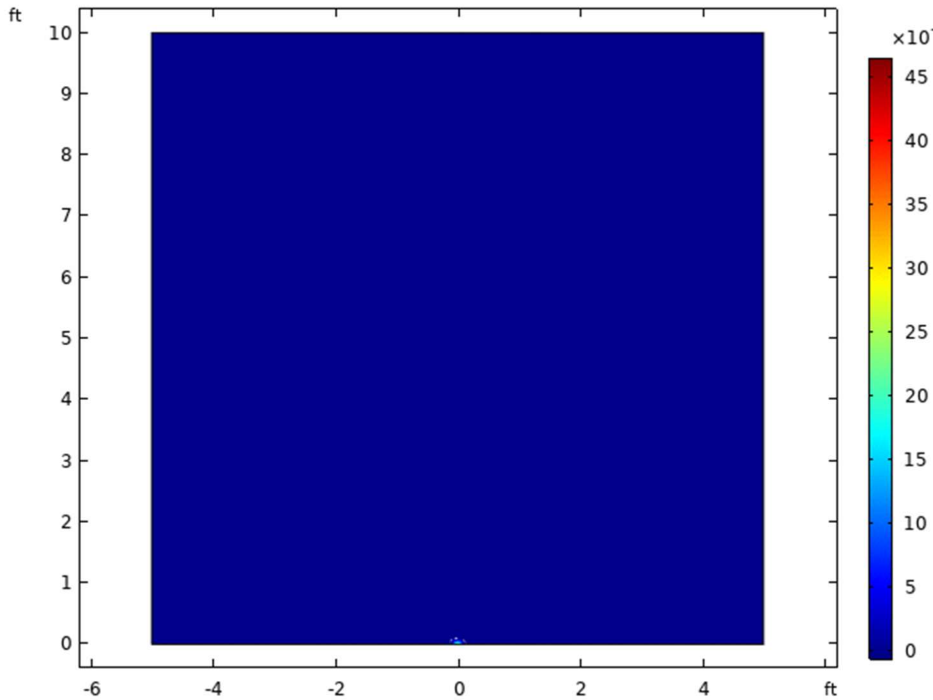

Figure C5: Animation of concentration map with starting concentration of $1 \times 10^{-4}\,\frac{mol}{m^3}$ over 500 s.

Conclusion

This is a second model that can be used to determine an approximate value for the starting vapor concentration. It is also an adjustable model to stimulate how long the fan should be turned out and further theoretical tests could be run on it. Some possible shortcomings of the model are that the diffusion coefficient is just an estimation, and the fan only turns on one time. The diffusion coefficient affects how quickly the substance disperses in the air. If the fan is turned on more than once, there could be buildup of the oil concentration in the air. This model also does not consider the barriers that the particles will face when diffusing, such as the neck and chin or other factors such as the movement of the user or the air in the room. Ultimately, the lowest starting concentration allowable in this model that will result in the correct concentration at the nose of the user and 2 ft away is $1 \times 10^{-4}\,\frac{mol}{m^3}$.

Appendix D: Code

File: QueAroma_3_7.ino

```
/**
File Name: QueAroma_3_7.ino

 Senior Design Group 2
 Tyler Hight, Gifford Courtney, Daniel Prado, Camryn Petrus
 Updated: 4/28/23
 For Que Aroma Therapy Necklace, a smart aromatherapy necklace
 Inputs: HR data or button presses on a remote
 Output: Releases an emission when HR > threshold or on remote command.
 An emission consists of turning on the linear actuator to open a door, turning on the
 fan to eject the scent, then closing the door with the linear actuator after the fan turns
 off.
*/

// Imports ////////////////////////////////////////////////
#include "Servo.h" // for controlling the servo motor
#include <ArduinoBLE.h>

// Settings ////////////////////////////////////////////////
// General //////////////////////////////
int HRThreshold = 9999999; // threshold for emission to be triggered from heartrate

int EmissionDelay = 10000; // delay time between emissions in ms

// Gate ///////////////////////////////
// see EmissionComponents.ino for more details about GateOpenSpeed and GateCloseSpeed
// speed that the motor spins at while opening the gate
// range: 1000 to 1499 where 1000 is the fastest
int GateOpenSpeed = 2000;
// range: 1501 to 2000 where 2000 is the fastest
int GateCloseSpeed = 1000; // speed that the  motor spins at while closing the gate
int GateOpenTime = 1000; // amount of time to open gate in ms
// amount of time to close gate in ms
int GateCloseTime = 1000;

// Fan ////////////////////////////////////
// amount of time to turn on fan in ms
int FanOnTime[4] = {3000, 5000, 7000, 9000};
// get the number of fan on time options
int numFanOnTimes = sizeof(FanOnTime)/sizeof(FanOnTime[0]);
```

```
volatile int FanTimeIndex = 0; // to be used as FanOnTime[FanTimeIndex] to select which fan
time to use

// Remote //////////////////////////////
// Labelling for the receiver_vals
char receiver_letters[4] = {'A', 'B', 'C', 'D'};
// records whether a button is currently being pressed or not so that an input
// only happens once instead of over and over again while the button is pressed
volatile bool button_press = false;
int RR_num_pins = 4; // number of input pins from the radio receiver
char button_pressed = '\0'; // stores the value of button input (initialized with null value)
int receiver_vals[4]; // For storing which button(s) are pressed. Index 0 is A, 1 is B, etc.

// Heart Rate /////////////////////
String hexString = ""; // heart rate as a string
int HR; // heart rate as an integer
long prevHrNotifTime = millis(); // for reducing the number of HR notifs
int HrNotifDelay = 3000; // three seconds between HR notifs

// Periodic Emissions ///////////////////
// Time options for periodic emissions (milliseconds)
long int periodicEmissionTimes[4] = {9999999, 5000, 10000, 15000};
// get the number of periodic emission time options
int numPeriodicEmissionTimes =
sizeof(periodicEmissionTimes)/sizeof(periodicEmissionTimes[0]);
volatile int periodicEmissionTimePointer = 0; // selects which periodic emission time to use
long int prevPeriodicEmissionTime = millis(); // holds the time of the previous periodic emission
long int currentTime; // for checking the current time (when updated)

// Emission Delays //////////////////////
/* A "cooldown" time for emissions can be set that prevents another emission
*  from being released until the cooldown time has been met since the previous emission.
*/
// stores the time of the most recent emission in milliseconds
// since the time that the Arduino started the program
unsigned long prevEmissionTime = 0;
// Stores the time of the most recent emission request in milliseconds
// since the time that the previous emission was released.
unsigned long emissionRequestTime = 0;

// Sleep mode ////////////////////////////
bool sleep = false; // whether or not to make the nano sleep
// records if the sleep condition changed for serial printing purposes
volatile bool sleepChange = false;
```

```
// Initialize other Variables and Objects /////////////////////////////////
Servo gate; // Servo motor object for the gate that covers the emission exit
// time variables for calculating the time of operations
long int t1;
long int t2;

// Enable/disable program functionality ////////////////////////////
bool RunEmissions = true;



// Pin Declarations ////////////////////////////////////////////////////
// Radio receiver
// 8 is A on the remote, 6 is B, etc.
int buttonApin = 8;
int buttonBpin = 6;
int buttonCpin = 10;
int buttonDpin = 7;
int receiver_pins[4] = {buttonApin, buttonBpin, buttonCpin, buttonDpin};


// Motor
int gate_pin = 5; // pin for positive polarity of the motor (opening direction)
int close_gate_pin = 4; // pin for positive polarity of the motor (closing direction)

// fan pin
int fanPin = 3;

// Heartrate



void setup() { // code that communicates once with the Arduino
  Serial.begin(115200); // Begin communicating at 9600 bits per second

  CloseGate(GateCloseTime); // close the gate

  // setup for things related to heartrate
  HRSetup();

  // Pin Initialization //////////////////////////////////
  // initialize radio receiver input pins
  for(int i = 0; i < RR_num_pins; i++){
    pinMode(receiver_pins[i], INPUT_PULLUP);
  }
```

```
  // initialize linear actuator
  gate.attach(gate_pin);
  // inialize fan pin digital output
  pinMode(fanPin, OUTPUT);

  // interrupt for the remote button A
  //attachInterrupt(digitalPinToInterrupt(8), changePeriodicEmissionFrequency, CHANGE);
  // interrupt for the remote button B
  attachInterrupt(digitalPinToInterrupt(6), changeFanOnTime, RISING);
  // interrupt for the remote button C
  attachInterrupt(digitalPinToInterrupt(10), changePeriodicEmissionFrequency, RISING);
  // interrupt for the remote button D
  attachInterrupt(digitalPinToInterrupt(7), toggleSleep, RISING);
}

int prev_index = 0;

void loop() {
  /**
    loop: Continuously monitors the HR data and button inputs,
    checks if an emission should occur, and if so, triggers the emission.
    It also updates the peak detection threshold and keeps track of the time between emissions.
    Emissions can only be released if a sufficient amount of time has passed between emissions.
    Optionally, emissions can also be set to release periodically (ex. release an
    emission every 30 minutes).
    @returns void
  */
  //PeriodicEmissionLoop(); // triggers periodic emissions
  // collect and calculate heartrate, adjust the peak detection threshold, and release
  // an emission if HR>Threshold
  HRLoop(true);
  // read the HIGH/LOW values from each of the radio receiver pins and store
  // which button was pressed in button_pressed and respond to input from the remote
  //RemoteLoop();
}
```

```
/**
File Name: EmissionComponents.ino
Updated: 4/28/23
Functions related to controlling the motor and fan to enable the release
of a scent emission.
*/
```

```
// Servo for gate //////////////////////////////////////////
// write(1500) completely stops the motor. write(1000)
// makes the motor spin at max speed in one direction (5V across leads) and
// write(2000) makes the motor spin at max speed in the opposite
// direction (-5V across leads). The closer the value is to 1500, the slower
// the motor spins.
void OpenGate(int OpenTime){
    Serial.println("Opening gate");
    // move the gate to open
    gate.writeMicroseconds(GateOpenSpeed);
    delay(OpenTime);
}

void CloseGate(int CloseTime){
    Serial.println("Closing gate");
    // move gate in opposite direction
    gate.writeMicroseconds(GateCloseSpeed);
    delay(CloseTime);
}


// Fan Functions ////////////////////////////////////////////
void ActuateFan(int OnTime){
  digitalWrite(fanPin, HIGH);
  Serial.println("Turned on fan");
  t1 = millis();
  while(millis() - t1 < OnTime){
    continue;
  }
  digitalWrite(fanPin, LOW);
  Serial.println("Turned off fan");
}


// Emission Function ////////////////////////////////////////
// amount of time between when emission request notifications will be printed to the Serial
monitor
int emissionReqNotifDelay = 5000; // milliseconds
long emissionNotifTime = 0; // hold the time of the most recent emission request notification
bool canPostNotif = true; // tells whether notification of an emission request can be printed or not
void ReleaseEmission(int GateOpeningTime, int GateClosingTime){
  /**
    ReleaseEmission: Checks whether a sufficient amount of time has passed since
    the previous emission and triggers a new emission sequence if sufficient time
```

```
   has passed. An emission sequence consists of opening the gate, turning on
   the fan, turning off the fan, then closing the gate.
   @returns void
  */
  if (RunEmissions == true){
   emissionRequestTime = millis();
   if (emissionRequestTime-emissionNotifTime>emissionReqNotifDelay){
     // only send a notification if a certain amount of time has passed
     // since the notification was last sent
     Serial.println("Emission requested");
     emissionNotifTime = millis();
     canPostNotif = true;
   }
   if (emissionRequestTime - prevEmissionTime > EmissionDelay){
    Serial.println("Releasing emission");
    OpenGate(GateOpeningTime);

    t1 = millis();
    ActuateFan(FanOnTime[FanTimeIndex]);
    t2 = millis();

    CloseGate(GateClosingTime);
    prevEmissionTime = millis();
   }
   else{
    if (canPostNotif == true){
     // only send a notification if a certain amount of time has passed
     // since the notification was last sent
     emissionNotifTime = millis();
     Serial.println("Emission denied due to insufficient delay time");
     Serial.print("Time since last emission: ");
     Serial.print((emissionRequestTime-prevEmissionTime)/1000);
     Serial.println(" seconds");
     canPostNotif = false; // dont print again until the "Emission requested" notif is printed
    }
   }
  }
}
```

```
/**
File Name: HeartRate.ino
4/28/23
```

```
Functions related to connecting to the Polar Verity Sense heart rate bracelet,
gathering values for calcuating heartrate, and calculations related to determining heartrate.
*/


// Heartrate Functions ////////////////////////////////////////
void HRSetup(){
  /**
    HRSetup: code that goes in the setup() function to set up the
    heartrate monitor code
    @returns void
  */
  Serial.println("Setting up HR...");

  // begin initialization
  if (!BLE.begin()) {
    Serial.println("starting Bluetooth® Low Energy module failed!");

    while (1);
  }

  Serial.println("Bluetooth® Low Energy Central - Peripheral Explorer");

  // start scanning for peripherals
  BLE.scan();
}

void HRLoop(bool emit){
  /**
    HRLoop: Calculates heartrate and triggers an emission if (HR > threshold)
    and (the time between emissions > the emission delay time). This function
    is placed inside the loop() function
    @param emit - true to enable HR triggered emissions, false to disable
    @returns void
  */
  // check if a peripheral has been discovered
  BLEDevice peripheral = BLE.available();

  if (peripheral)
  {
    // discovered a peripheral, print out address, local name, and advertised service
    Serial.print("Found ");
    Serial.print(peripheral.address());
    Serial.print(" '");
    Serial.print(peripheral.localName());
```

```
    Serial.print("' ");
    Serial.print(peripheral.advertisedServiceUuid());
    Serial.println();


    // see if peripheral is a LED
    if (peripheral.localName() == "Polar Sense C079112C") {
      // stop scanning
      BLE.stopScan();
        explorerPeripheral(peripheral);

      while (1) {
        // do nothing
      }
    }
  }
}


bool connectionStatus = false;
long connectionNotifTime = millis();
long currTime = millis();
int notifDelay = 2000; // delay between notifications
void explorerPeripheral(BLEDevice peripheral) {
  // connect to the peripheral
  Serial.println("Connecting ...");
  while (connectionStatus == false)
  {
    currTime = millis();
    if (peripheral.connect())
    {
      Serial.println("Connected");
      connectionStatus = true;
    }
    else
    {
      // if an adequate amount of time has passed since
      // the last notification, print another one
      if (true) //replace condition with "currTime-connectionNotifTime>notifDelay" to reduce
serial monitor pollution
      {
        Serial.println("Failed to connect!");
        connectionNotifTime = millis();
      }
    }
```

```
}


// discover peripheral attributes
Serial.println("Discovering attributes ...");
if (peripheral.discoverAttributes())
{
  Serial.println("Attributes discovered");
}
else
{
  Serial.println("Attribute discovery failed!");
  peripheral.disconnect();
  return;
}

// read and print device name of peripheral
Serial.println();
Serial.print("Device name: ");
Serial.println(peripheral.deviceName());
Serial.print("Appearance: 0x");
Serial.println(peripheral.appearance(), HEX);
Serial.println();
//If the service name is 180d, it will investigate only that service
if (BLEService service = peripheral.service("180d"))
{
  // print the UUID of the service
  Serial.print("Service ");
  Serial.println(service.uuid());
  //If this service has a characteristic called 2a37, investigate only that characteristic
  if (service.hasCharacteristic("2a37"))
  {
    Serial.println("Found Heart Rate Characteristic");
    Serial.println("Characteristic = 2a37");
    //Define characterisitc
    BLECharacteristic characteristic = service.characteristic("2a37");
    Serial.println();
    //Subscribe to notifications from this characteristic
  if (characteristic.canSubscribe())
  {
     Serial.print("Can Subscribe - ");
     Serial.println("Subscribed to Notifications");
        while (characteristic.canSubscribe())
        {
          PeriodicEmissionLoop();
```

```
            RemoteLoop();
            characteristic.subscribe();
            //Serial.print("HR = ");
            const uint8_t* hexData= characteristic.value();
            int dataSize = characteristic.valueLength();
            String hexString = "";
            for (int i =0; i <dataSize; i++)
            {
              if (*hexData< 0x10)
              {
                hexString += "0";
              }
              hexString += String(*hexData++, DEC);
            }
            //Serial.print(hexString);
            //Serial.println(" BPM");

            HR = hexString.toInt(); // get the HR as an int

          if (true) // replace with "emit"
          {
            // request an emission if HR > threshold and enabled in HRLoop(emit) call
            HREmission();
          }

          //String descriptorValue = String((const char*)descriptor.value(),
descriptor.valueLength());
          //printData(descriptor.value(), descriptor.valueLength());

          //delay(1000); //3 second delay between each reading
        }
      }
      else
      {
        Serial.println("Unable to Subscribe to Notifications");
      }
    }
  }
}


void HREmission(){
  /**
  * Converts the heart rate as a string (variable hexString) to an int
  * and requests an emission if the HR > threshold.
```

```
  */
  //Serial.println("Checking for HR release");
  currTime = millis();
  if (currTime-prevHrNotifTime > HrNotifDelay){
    prevHrNotifTime = millis();
    Serial.print("HR: "); Serial.println(HR);
  }
  if (HR > HRThreshold){
    ReleaseEmission(GateOpenTime, GateCloseTime);
    // reset HR so that a new measurement is made before another emission can be triggered
    HR = 0;
  }
}
```

```
/**
File Name: PeriodicEmissions.ino
Updated: 4/28/23
For triggering and keeping track of periodic emissions
*/

void PeriodicEmissionLoop(){
  currentTime = millis();
  if (currentTime-prevPeriodicEmissionTime >
periodicEmissionTimes[periodicEmissionTimePointer]){
    Serial.println("Requesting periodic emission");
    ReleaseEmission(GateOpenTime, GateCloseTime);
    prevPeriodicEmissionTime = millis();
  }
}
```

```
/**
File Name: Remote.ino
Updated: 4/28/23
Functions related to handling input from the radio receiver
and triggering an appropriate responses to remote input.
*/

// Remote Functions ////////////////////////////////////////
volatile bool triggerEmission = false; // request to trigger emission (changed by interrupt)
```

```
int prevPP = 0; // previous value of the periodic emission pointer
int prevFP = 0; // previous value of the fan on time pointer
void RemoteLoop(){
  /** function that goes in the main loop to implement remote functionality **/

  button_pressed = CheckRemoteInput(); // checks for button presses without interrupt
  RemoteResponse();

  /**Checks for variables changed by interrupts and executes respective code blocks
  before changing the variable back to false to wait for the button to be pressed again**/
  if (triggerEmission == true){
    Serial.println("Releasing remote-triggered emission");
    ReleaseEmission(GateOpenTime, GateCloseTime);
    triggerEmission = false;
  }
  else if (prevPP != periodicEmissionTimePointer){
    Serial.print("Delay between periodic emissions changed to: ");
    Serial.println(periodicEmissionTimes[periodicEmissionTimePointer]);
    prevPP = periodicEmissionTimePointer;
  }
  else if (prevFP != FanTimeIndex){
    Serial.print("Fan time changed to: ");
    Serial.println(FanOnTime[FanTimeIndex]);
    prevFP = FanTimeIndex;
  }
  else if (sleepChange == true){
    if (sleep == false){
      Serial.println("Turned necklace on");
      sleepChange = false;
    }
    else if (sleep == true && sleepChange == false){
      Serial.println("Entered sleep");
      sleepChange = false;
    }
  }
}

void RemoteResponse(){
  /**
    RemoteResponse:
    @returns void
  */

  // if button D is pressed (then released within 1 second),
  // display the analog values until D is pressed again
```

```
  if (button_pressed == 'D' && button_press == false){
    Serial.print("Remote button that was pressed: "); Serial.println(button_pressed);
    Serial.println("Turned necklace off");
    delay(1000); // give time for the user to let go of the button
    // change button_pressed to a value other than D so it is registered when pressed again
    button_pressed = '\0';
    while (button_pressed != 'D'){
      button_pressed = CheckRemoteInput(); // check for remote input
      HRLoop(false); // show heartrate
    }
    delay(1000); // give time for the user to let go of the button
  }
  // if button A is pressed, release an emission
  else if (button_pressed == 'A' && button_press == false){
    Serial.print("Remote button that was pressed: "); Serial.println(button_pressed);
    ReleaseEmission(GateOpenTime, GateCloseTime);
  }
  // if button B is pressed, change emission duration
  else if (button_pressed == 'B' && button_press == false){
    // only trigger on the initial press of the button and not while it's
    // being held down
    Serial.print("Remote button that was pressed: "); Serial.println(button_pressed);
    changeFanOnTime();
  }
  // change periodic emission frequency
  else if (button_pressed == 'C' && button_press == false){
    Serial.print("Remote button that was pressed: "); Serial.println(button_pressed);
    changePeriodicEmissionFrequency();
  }
  if (button_pressed == '\0' && button_press == true){
    // If the button is released, allow buttons B and C to trigger functionality again.
    // Checking (button_press == true) is necessary so this block does not
    // get called in every loop.
    Serial.println("The button has been released");
    button_press = false;
  }
  else if (button_pressed != '\0' && button_press == false){
    // If button_pressed is not \0, then a button is being held down.
    // Checking (button_press == false) is necessary so this block does not
// get called in every loop.
    button_press = true;
  }
}

void changeFanOnTime(){
```

```
  /**Changes the fan on time in response to remote input**/
    if (FanTimeIndex < numFanOnTimes-1){
        FanTimeIndex += 1;
      }
      else{
        FanTimeIndex = 0;
      }
}

void changePeriodicEmissionFrequency(){
  /**Change the amount of time between periodic emissions**/
  if (periodicEmissionTimePointer < numPeriodicEmissionTimes-1){
        periodicEmissionTimePointer += 1;
      }
      else{
        periodicEmissionTimePointer = 0;
      }
}

void RequestEmission(){
  triggerEmission = true;
}

char CheckRemoteInput(){
  /**Checks for input from the remote and return which button is pressed**/

  // check each reciever pin for input
  for(int i = 0; i < RR_num_pins; i++){
    receiver_vals[i] = digitalRead(receiver_pins[i]);
    if (receiver_vals[i] == HIGH){
      return receiver_letters[i];
    }
  }
  // return null if no button is being pressed
  return '\0';
}

void toggleSleep(){
  if (sleep == false){
    // put the nano to sleep if this function is called and the
    // nano is currently awake
    sleep = true;
    sleepChange = true; // becomes true when the sleep condition changed
    Sleep();
    }
```

```
  else if (sleep == true){
    // wake up the nano
    sleep = false;
    sleepChange = true; // becomes true when the sleep condition changed
    wakeUp();
  }
}
```

```
// File Name: Sleep.ino

void Sleep(){
  /**Minimize power consumption -- "turn off necklace"**/
  digitalWrite(LED_PWR, LOW);
  digitalWrite(PIN_ENABLE_SENSORS_3V3, LOW);
  digitalWrite(PIN_ENABLE_I2C_PULLUP, LOW);
}

void wakeUp(){
  /**Reactive parts of Arduino Nano to "turn necklace back on"**/
  digitalWrite(LED_PWR, HIGH);
  digitalWrite(PIN_ENABLE_SENSORS_3V3, HIGH);
  digitalWrite(PIN_ENABLE_I2C_PULLUP, HIGH);
}
```

Appendix E: Theoretical and Experimental Compression Tests

A theoretical compression test was performed in a SolidWorks CAD Simulation. **Figure E1** shows a 200-lbs compressive load on to the top face of our 49x42 mm pendant. The material used in SolidWorks was ABS. In SolidWorks, the ABS material has a yield strength of 48 MPa, which is equivalent to 6961.81 psi. Therefore, in the simulation, the ultimate failure of the pendant occurs at this pressure. In **Figure E1,** the scale on the right shows the top face does not reach this pressure; therefore, the case will withstand the 200-lbs of compressive force.

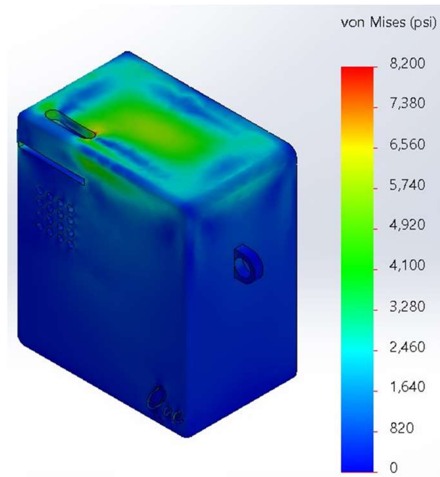

Figure E1: 200-lbs compressive load on top face of 49x42 mm pendant

The same procedure was performed for the 49x42 mm pendant on its front face. **Figure E2** shows the results gathered from the SolidWorks simulation. In **Figure E2,** the front face does not reach the 6,961.81 psi; therefore, the case will withstand the 200-lbs of compressive force on its front face.

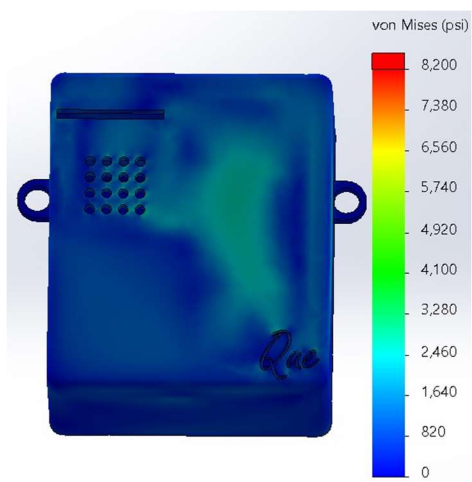

Figure E2: 200-lbs compressive load on front face of 49x42 mm pendant

To ensure the theoretical data was correct, an experimental compressive test was performed. An ABS block was cut out into a 49x42 mm hollow block. The cut-out ABS block was placed in a tensile tester machine and compressed until failure. **Figure E3** shows the results in a Load vs.

Deflection plot for the cut-out ABS case. The results in **Figure E3** shows that the ABS block can withstand 2030 pounds of compressive force, exceeding the 200-pound force required.

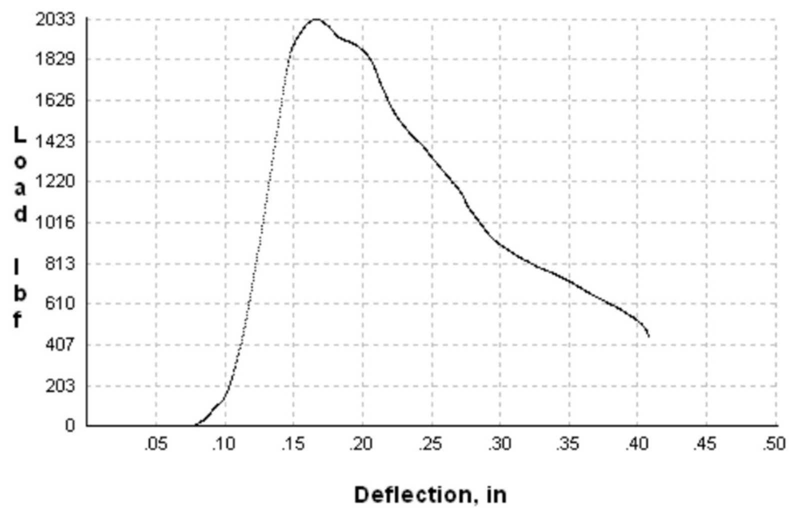

Figure E3: Load vs Deflection of compression test of case

Appendix F: SolidWorks Drop Test

A simulated 5-foot drop test was performed in SolidWorks. **Figure F1** shows the results of the 5-foot drop test with the pendant landing directly on its front face. The material used was ABS. The results show that the pendant will withstand the 5-foot drop; however, looking closely at the top left, the protruding finger tab will crack. This would occur if the pendant landed directly on its front face. Implementation of a silicon coat around the ABS material will help prevent this crack and allow the pendant to fully withstand the 5-foot drop test directly on its front face.

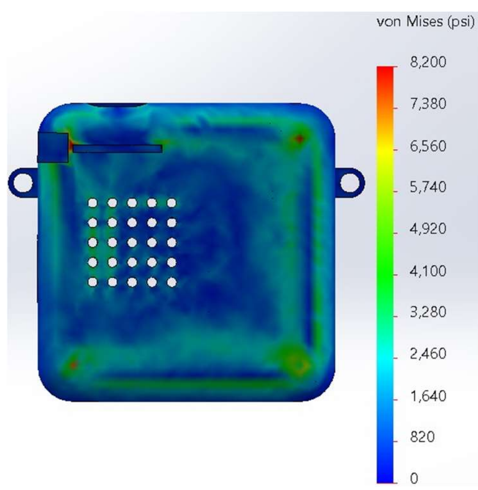

Figure F1: Results for simulated 5-foot drop test with pendant landing directly on its front face.

Similarly, a 5-foot drop test was performed again, with the pendant landing directly on its bottom face. **Figure F2** shows the results gathered from the CAD SolidWorks drop test simulation. The results show that the pendant will withstand a 5-foot drop and land directly on its bottom face. No cracks or breaks will appear.

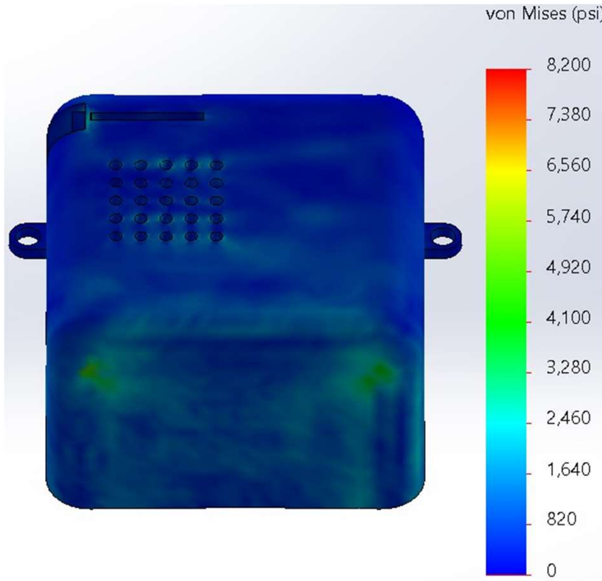

Figure F2: Results for simulated 5-foot drop test with pendant landing directly on its bottom face.

With a silicon coat around the pendant, the pendant will be able to absorb impact forces better and protect the inner components of the device.

Appendix G: Sound Intensity Results

Sound Intensity of Centrifugal Fan

Table G1: Sound (in Decibels) of the room before and after the fan turned on.

	Fan	
Trial	Sound Before (dB)	Sound After (dB)
1	35.5	36.1
2	35.5	36.5
3	35.8	36.2
4	35.5	36.2
5	35.6	36.4
6	35.4	36.3
7	35.5	36.4
8	35.4	36.3
9	35.6	36.3
10	35.4	36.4
AVG	35.52	36.31

Table G2: Difference in sound intensity before and after the fan turned on.

	Sound Intensity Before	Sound Intensity After	Difference	PASS/FAIL	Sound Intensity Level in Decibels
1	3.55E-09	4.07E-09	5.26E-10	PASS	27.20712
2	3.55E-09	4.47E-09	9.19E-10	PASS	29.63175
3	3.80E-09	4.17E-09	3.67E-10	PASS	25.64429
4	3.55E-09	4.17E-09	6.21E-10	PASS	27.92784
5	3.63E-09	4.37E-09	7.34E-10	PASS	28.6592
6	3.47E-09	4.27E-09	7.98E-10	PASS	29.02235
7	3.55E-09	4.37E-09	8.17E-10	PASS	29.12235
8	3.47E-09	4.27E-09	7.98E-10	PASS	29.02235
9	3.63E-09	4.27E-09	6.35E-10	PASS	28.02784
10	3.47E-09	4.37E-09	8.98E-10	PASS	29.53175

Sound Intensity of Linear Actuator

Table G3: Sound (in Decibels) of the room before and after the linear actuator turned on.

	Linear Actuator	
Trial	Sound Before (dB)	Sound After (dB)
1	35.6	64.2
2	35.5	64.4
3	35.3	65.1
4	35.6	64.7
5	35.5	64.8
6	35.4	65.2
7	35.5	65.1
8	35.7	64.4
9	35.4	64.5
10	35.5	64.9
AVG	35.5	64.73

Table G4: Difference in sound intensity before and after the linear actuator turned on.

	Sound Intensity Before	Sound Intensity After	Difference	PASS/FAIL	Sound Intensity in Decibel
1	3.63E-09	2.63E-06	2.63E-06	FAIL	64.194
2	3.55E-09	2.75E-06	2.75E-06	FAIL	64.394
3	3.39E-09	3.24E-06	3.23E-06	FAIL	65.095
4	3.63E-09	2.95E-06	2.95E-06	FAIL	64.695
5	3.55E-09	3.02E-06	3.02E-06	FAIL	64.795
6	3.47E-09	3.31E-06	3.31E-06	FAIL	65.195
7	3.55E-09	3.24E-06	3.23E-06	FAIL	65.095
8	3.72E-09	2.75E-06	2.75E-06	FAIL	64.394
9	3.47E-09	2.82E-06	2.81E-06	FAIL	64.495
10	3.55E-09	3.09E-06	3.09E-06	FAIL	64.895

T-Test

Table G4: Left Tailed T-Test

	Linear Actuator	Fan
	Change in Sound Intesnity to Decibels	Change in Sound Intensity to Decibels
	64.19	27.21
	64.39	29.63
	65.10	25.64
	64.69	27.93
	64.79	28.66
	65.20	29.02
	65.10	29.12
	64.39	29.02
	64.49	28.03
	64.90	29.53
Mean	64.72	28.38
Standard Deviation	0.35	1.23
Count	10.00	10.00
Standard Error of Mean	0.11	0.39
Degree of Freedom	9.00	9.00
Hypothesized Mean	30.00	30.00
T statistic	316.39	-4.18
P - Value	1.00	0.001191

Appendix H: Heart Rate Reliability Results

Mean Percent Difference

Table H1: Mean percentage difference between the heart rate displayed by the Polar Verity Sense and that of the Apple watch over a course of three minutes. The mean percentage difference is calculated for the heart rate at rest and after exercising.

		Mean Percent Difference	
		At Rest	After Exercising
Participant	1	1.37%	2.88%
	2	1.93%	4.11%
	3	2.03%	3.60%
	4	2.58%	2.46%
	5	2.51%	2.06%
	6	3.99%	2.62%
	7	2.45%	2.71%
	8	2.63%	1.97%

Anova

Table H2: The percentage difference between the heart rate collected by the Polar Verity Sense and the Apple Watch when the subject's heart rate is at rest.

Percent Differences for Heart Rate at Rest							
Person 1	**Person 2**	**Person 3**	**Person 4**	**Person 5**	**Person 6**	**Person 7**	**Person 8**
1.14%	4.32%	2.70%	2.47%	5.41%	7.30%	1.02%	9.38%
1.13%			5.92%	3.85%	2.99%	3.11%	4.80%
0.00%	0.00%	6.80%	1.08%	1.87%	1.46%	8.99%	3.33%
0.00%	4.88%	4.44%	2.27%	1.80%	0.00%	0.00%	1.65%
1.08%	1.55%	2.94%	3.59%	1.94%	8.57%	0.00%	6.15%
0.00%	0.00%	1.40%	0.00%	1.90%	5.63%	3.43%	0.00%
6.38%	1.53%	1.36%	3.47%	1.80%	10.81%	1.12%	1.57%
0.00%	1.38%	0.00%	1.17%	0.00%	1.36%	0.00%	0.00%
0.00%	1.57%	0.00%	2.41%	1.98%	2.63%	1.13%	
1.09%	0.00%	2.70%	3.64%	4.00%	8.81%	0.00%	1.50%
1.13%	1.42%	1.34%	8.19%	2.02%	0.00%	7.41%	3.28%
0.00%	1.38%	0.00%	2.38%	2.02%	1.16%	0.00%	1.63%
1.10%	1.42%	0.00%	1.17%	2.02%	1.26%	8.38%	1.65%
0.00%	1.46%	6.71%	3.55%	0.00%	6.62%	2.25%	4.80%
1.08%	6.80%	0.00%	3.68%	2.06%	2.74%	1.13%	1.50%
4.30%	0.00%	1.34%	1.20%	8.00%	1.36%	3.43%	1.50%
1.14%	4.20%	2.70%	2.38%	0.00%	4.03%	1.13%	4.65%
0.00%	1.44%	0.00%	1.17%	5.83%	4.08%	2.22%	0.00%
6.45%	1.46%		2.22%	4.08%	2.90%	1.17%	0.00%

Table H3: Anova Single Factor Test for Heart rate at Rest

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Person 1	19	26.04%	1.37%	0.04%		
Person 2	18	34.80%	1.93%	0.04%		
Person 3	17	34.45%	2.03%	0.05%		
Person 4	19	51.96%	2.73%	0.04%		
Person 5	19	50.58%	2.66%	0.04%		
Person 6	19	73.70%	3.88%	0.10%		
Person 7	19	45.91%	2.42%	0.08%		
Person 8	18	47.41%	2.63%	0.06%		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.007178	7	0.001025	1.806799	0.090453	2.075589
Within Groups	0.079455	140	0.000568			
Total	0.086633	147				

Table H4: The percentage difference between the heart rate collected by the Polar Verity Sense and the Apple Watch when the subject's heart rate is elevated.

Percent Difference for Elevated Heart Rate							
Person 1	**Person 2**	**Person 3**	**Person 4**	**Person 5**	**Person 6**	**Person 7**	**Person 8**
10.04%	4.88%	10.06%	8.00%	2.44%	8.98%	9.21%	11.21%
0.76%	6.84%	2.13%	0.95%	0.00%	0.84%	1.65%	0.98%
2.47%	0.96%	1.08%	4.08%	2.53%	1.94%	0.90%	0.00%
0.83%	0.00%	2.30%	1.14%	1.40%	10.20%	2.84%	4.76%
2.47%	0.00%	0.00%	0.00%	0.00%	0.00%	2.02%	1.21%
9.52%	1.10%	3.92%	3.28%	1.42%	0.00%	2.06%	3.03%
0.00%	16.15%	4.08%	0.00%	1.77%	1.34%	3.14%	3.33%
1.96%	1.42%	5.71%	3.14%	0.00%	0.00%	5.24%	0.00%
1.07%	7.41%	2.90%	1.05%	1.71%	8.11%	1.02%	0.00%
2.35%	6.56%	1.40%	0.00%	10.91%	0.00%	3.24%	3.23%
1.20%	1.77%	1.42%	0.99%	0.00%	1.34%	2.20%	0.00%
2.17%	10.53%	7.19%	3.24%	1.87%	2.56%	3.35%	1.65%
1.03%	1.68%	6.25%	4.44%	1.77%	1.34%	2.25%	0.00%
4.44%	6.90%	3.08%	3.47%	1.71%	1.42%	0.00%	1.74%
0.00%	1.77%	3.03%	2.30%	1.57%	1.48%	0.00%	1.68%
6.74%		0.00%	1.16%	4.51%	1.48%	2.20%	1.48%
1.12%	6.06%	2.99%	4.49%	0.00%	1.50%	2.22%	3.13%
5.35%	0.00%	6.25%	1.09%	1.40%	2.82%	4.12%	0.00%
1.18%	0.00%	3.23%	1.10%	0.00%	1.44%	1.08%	0.00%

Table H5: Anova Single Factor Test for an Elevated Heart Rate

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Person 1	19	54.71%	2.88%	0.09%		
Person 2	18	74.01%	4.11%	0.20%		
Person 3	19	67.01%	3.53%	0.07%		
Person 4	19	43.93%	2.31%	0.04%		
Person 5	19	35.01%	1.84%	0.06%		
Person 6	19	46.81%	2.46%	0.09%		
Person 7	19	48.75%	2.57%	0.04%		
Person 8	19	37.43%	1.97%	0.07%		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.007783	7	0.001112	1.349251	0.23155	2.074185
Within Groups	0.117844	143	0.000824			
Total	0.125628	150				

Appendix I: Scent Longevity Results

A study was found that analyzed how quickly different essential oils evaporated at different temperatures [15]. The study uses 2 mg of essential oil. **Figure I1** shows the data points relating to oven temperature to the time it took for the essential oil to evaporate graphed in excel. The black rectangles represent the maximum time it took for one of the oils to completely evaporate and the gray circles represent the minimum time it took for one of the oils to evaporate. Each of these data sets were fitted with an exponential trendline and an equation was obtained for the min and max sets. The trendlines fit the data well as the R^2 value is over 0.89.

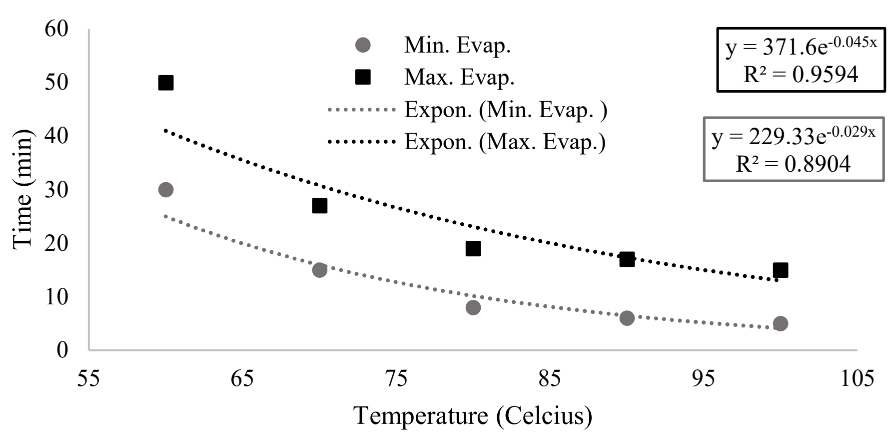

Figure 1: Temperature to Evaporation Time from study [14].

Equation I1 was used to determine the volume of essential oil used in ml where V is the volume of the oil, m is the mass of the oil, and p is the density. It is estimated that essential oils have a density approximately equal to $0.9\frac{g}{cm^3}$. From this calculation, it is determined that this experiment used approximately 0.0022 ml.

$$V = \frac{m}{\rho} = \frac{2 \times 10^{-3} g}{0.9\frac{g}{cm^3}} = 0.0022\ cm^3 = 0.0022\ ml \qquad \textbf{Equation I1}$$

This experiment was completed using higher temperatures than the device would be exposed to; therefore, the time it takes for 0.0022 ml to evaporate at $20°C$ is estimated using the trendline equations above. The minimum evaporation time equation was used first and the calculation is shown in **Equation 22** where t is time in minutes and T is the temperature in $°C$.

$$t = 229.33 * e^{-0.029T} \qquad \textbf{Equation I2}$$
$$t = 229.33 * e^{-0.029(20°C)} = 128\ min$$

The evaporation rate of the oil can be determined with **Equation I3** where V_e is the volume of oil evaporated and t is the amount of time it took for it to evaporate. The value for V_e is from **Equation I1** and the theoretically time for evaporation using the estimated equation for minimum evaporation times is from **Equation I2.**

$$\text{Evaporation Rate } (\mathrm{E_r}) = \frac{V_e}{t} = \frac{0.0022\ ml}{128\ min}\left(\frac{1\ min}{60\ \mathrm{s}}\right) = 2.86 \times 10^{-7}\frac{ml}{s} \qquad \textbf{Equation I3}$$

This value is how much volume of essential oil is evaporating per second. An equation can be set up to determine how long it will take for the given amount of oil to evaporate. In the equation below, V_s is equal to the starting volume of the oil in ml, t is time (in seconds), and E_r is the evaporation rate determined above. V_s is multiplied by 0.1 because we will consider the saturated wick to be empty when the final value is 10% of the initial volume.

$$V_s(0.1) = V_s - E_r t$$

Solving for t

$$t = \frac{0.9V_s}{E_r}$$

There are approximately 20 drops in 1 ml of essential oil. If 3 drops were placed on a wick, this would be equivalent to approximately 0.15 ml. If this is plugged into the equation above, the time of evaporation would be approximately 5.5 days.

$$t = \frac{0.9(0.15\ ml)}{2.86 \times 10^{-7}\frac{ml}{s}} = 472027.97\ s = 131.12\ hrs = 5.46\ days$$

Appendix J: Longevity Test Results

Table J1: Weight of Cotton Wicks and Essential Oil Over Time

	Weight of 0.15mL (3 drops) (g)	**Weight of 0.15mL (Carrier Oil) (g)**	**Weight of 1:1 (g)**	**Weight of 1:3 (g)**	**Weight of 1:5 (g)**
Both	0.8854	0.9014	0.9031	0.9075	0.9474
Weigh Boat (g)	0.5446	0.5642	0.5579	0.5555	0.5819
Cotton Wick (g)	0.3408	0.3372	0.3452	0.352	0.3655
Day					
0	0.1321	0.143	0.243	0.4276	0.8042
1	0.1128	0.1429	0.2099	0.4257	0.7872
2	0.0966	0.1422	0.2159	0.4194	0.7777
3	0.0874	0.1426	0.2107	0.4127	0.7729
4	0.0793	0.1425	0.2061	0.4063	0.768
5	0.0746	0.1419	0.2028	0.4007	0.7641
6	0.0716	0.142	0.2007	0.3975	0.7616
7	0.0716	0.1434	0.2004	0.3956	0.7603
8	0.0692	0.1423	0.1985	0.3917	0.7567
9	0.0683	0.1421	0.1974	0.3893	0.7548
10	0.069	0.1422	0.1978	0.389	0.7546
11	0.0692	0.1434	0.1979	0.388	0.7537
12	0.0689	0.1431	0.1974	0.3871	0.7526
13	0.0682	0.1427	0.1968	0.3859	0.7513
14	0.0679	0.1425	0.1965	0.3852	0.7509

Table J2: Normalized Weight Percentages of Essential Oil over Time

	% Weight of 0.15mL (3 drops) (g)	% Weight of 0.15mL (Carrier Oil) (g)	% Weight of 1:1 (g)	% Weight of 1:3 (g)	% Weight of 1:5 (g)
Day					
0	100.0	100.0	100.0	100.0	100.0
1	85.4	99.9	86.4	99.6	97.9
2	73.1	99.4	88.8	98.1	96.7
3	66.2	99.7	86.7	96.5	96.1
4	60.0	99.7	84.8	95.0	95.5
5	56.5	99.2	83.5	93.7	95.0
6	54.2	99.3	82.6	93.0	94.7
7	54.2	100.3	82.5	92.5	94.5
8	52.4	99.5	81.7	91.6	94.1
9	51.7	99.4	81.2	91.0	93.9
10	52.2	99.4	81.4	91.0	93.8
11	52.4	100.3	81.4	90.7	93.7
12	52.2	100.1	81.2	90.5	93.6
13	51.6	99.8	81.0	90.2	93.4
14	51.4	99.7	80.9	90.1	93.4

Appendix K: Raoult's Law Calculation

From the COMSOL simulation, the starting vapor concentration around the wick was determined to be $1 \times 10^{-4} \frac{mol}{m^3}$. This concentration ensures that the user can detect the scent within the 60 second technical requirement and a person 2 ft away would not detect it. Raoult's law will be used to determine the necessary liquid concentration. Equation 1 is Raoult's law where P_i^{sat} is the saturated pressure of component i, x_i is the molar fraction of component i in the liquid phase, y_i is the molar fraction of component i in the vapor phase, and P is atmospheric pressure in Pascals (Pa).

$$y_i P = x_i P_i^{sat}$$ **Equation K1**

The atmospheric pressure is 101325 Pa. To solve for x_i, y_i and P_i^{sat} need to be determined. The molar fraction of lavender essential oil (component i) is displayed in **Equation K2** where n_i is the number of moles of component i and n_a is the number of moles of air.

$$y_i = \frac{n_i}{n_i + n_a}$$ **Equation K2**

The number of moles of component i is equal to $1 \times 10^{-4} \frac{mol}{m^3}$. To find n_a, the number of moles of air in 1 m^3 of space needs to be determined. The density of air is 1.293 $\frac{kg}{m^3}$ and the molecular weight is 28.97 $\frac{g}{mol}$ [21,23]. The number of moles of air in 1 m^3 can be found using **Equation K3** where ρ is air density and MW is the molecular weight.

$$n_a = \frac{\rho}{MW} = \frac{1.293\left[\frac{kg}{m^3}\right]}{28.97\left[\frac{g}{mol}\right]} \times 1000\ \left[\frac{g}{kg}\right] = 44.63\frac{mol}{m^3}$$ **Equation K3**

Plugging in n_a and n_i into Equation 6 gives a molar fraction of lavender essential oil in the vapor phase of 2.24×10^{-6}.

The saturated pressure of lavender essential oil is not known. However, two main components of lavender oil is linalool and linalyl acetate [24]. The vapor pressure of linalool is $25°C$ is approximately 23 Pa. The vapor pressure of linalyl acetate at $25°C$ is approximately 13 Pa. To achieve approximate values for the vapor pressure of lavender oil, 18 Pa will be used. **Equation K4** solves for x_i.

$$x_i = \frac{y_i P}{P_i^{sat}} = \frac{(2.24 \times 10^{-6})(101325\ Pa)}{18\ Pa} = 0.0126$$ **Equation K4**

Jojoba oil will be used to dilute lavender oil. The density of this oil is $866\frac{kg}{m^3}$ and the molecular weight is $325.38\frac{g}{mol}$. It will be assumed 20 mL of jojoba oil will be used. This is equivalent to $2 \times 10^{-5}\ m^3$. **Equation K5** can be used to solve for the number of moles of jojoba oil where n_j is the number of moles, ρ_j is the density, V_j is the volume, and MW_j is the molecular weight.

$$n_j = \frac{\rho_j V_j}{MW_j} = \frac{\left(866\frac{kg}{m^3}\right)(2 \times 10^{-5}\ m^3)}{325.38\frac{g}{mol}}\left(\frac{1000\ g}{1\ kg}\right) = 0.0532\ mol$$ **Equation K5**

The moles of jojoba oil (n_j) and molar fraction of lavender oil (x_i) can be plugged into **Equation K6** to find the number of moles of lavender oil (x_i).

$$n_i = -\frac{x_i n_j}{x_i - 1} = -\frac{(0.0126)(0.0532)}{0.126 - 1} = 6.79 \times 10^{-4}\ mol$$ **Equation K6**

The molecular weight of lavender oil is 170.25 and the density is 885 $\frac{kg}{m^3}$. **Equation K7** can be used to find the volume of lavender oil.

$$V_i = \frac{n_i MW_i}{\rho_i} = \frac{(6.79 \times 10^{-4} mol)\left(170.25\frac{g}{mol}\right)}{885\frac{kg}{m^3}}\left(\frac{1\ kg}{1000\ g}\right)$$ **Equation K7**

$$= 1.31 \times 10^{-7} m^3 = .131\ mL$$

It is estimated that 1 drop of essential oil is equal to 0.05 ml [15]. **Equation K8** can be used to determine the number of drops that V_i is equivalent to.

$$Drops = (.131\ ml)\left(\frac{1\ drop}{0.05\ ml}\right) = 2.62\ drops \qquad \textbf{Equation K8}$$

A ratio can be created with Equation 8. Every drop of lavender essential oil should be diluted with approximately 7.5 ml of jojoba oil.

Appendix L: Scent Detection Results
Table L1: Scent Detection Result Summary

Participant	Gender	Location	Concentration	Scent Detection	Time (s)	# emissions until scent or end of experiment.
1	Female	0 ft	25%	Yes	20	1
2	Male	2 ft	25%	No	NA	3
3	Male	0 ft	25%	No	NA	3
4	Male	0 ft	25%	Yes	90	2
5	Male	0 ft	25%	Yes	70	2
6	Female	0 ft	25%	Yes	90	2
7	Female	2 ft	25%	No	NA	3
8	Female	0 ft	0%	No	NA	3
9	Male	2 ft	25%	No	NA	3
10	Female	0 ft	25%	Yes	106	2

Appendix M: Remote Reliability Results
The sample size, n, was ten, and the probability, p, was 99%. The 95% confidence interval was used, so the corresponding z-value is 1.96. The standard error (SE) was calculated using **Equation M1**.

$$\text{Standard error (SE)}= \sqrt{\frac{p(1-p)}{n}} \qquad \textbf{Equation M1}$$

The standard error was 0.031:

$$\text{Standard error (SE)}= \sqrt{\frac{0.99(1-0.99)}{10}} = 0.031 \qquad \textbf{Equation M1}$$

The margin of error for the confidence interval of the remote's reliability was calculated with **Equation M2**.

$$\text{Margin of error} = z(SE) \qquad \textbf{Equation M2}$$

The margin of error was ±0.017:

$$\text{Margin of error} = 1.96(0.013) = 0.0617 \qquad \textbf{Equation M2}$$

Therefore, the confidence interval for this remote is 0.99 ± 0.0617. The true proportion of success in population is between 92.83%-99.99%

Appendix N: Detailed Budget

Table N1: Prototyping Budget

Prototype Budget				
Item	**Supplier**	**Quantity**	**Unit Cost**	**Total Cost**
Cotton Diffuser Pads	Amazon	1	$9.39	$9.39
Smaller Centrifugal Fan	AliExpress	3	$12.00	$36.00
Wire Mesh	Amazon	1	$12.97	$12.97
Remote	LaTech	1	$20.00	$20.00
Necklace Chain	AliExpress	1	$12.00	$12.00
Pulse Sensor	Amazon	1	$25.00	$25.00
Centrifugal Fan	Amazon	1 (pack of 2)	$8.99	$8.99
3D Printing	LaTech	1	$100.00	$100.00
Rechargeable Battery with Charging Cable	Adafruit	2	$5.95	$11.90
Charging Connection for Batteries	Adafruit	1	$6.95	$6.95
Arduino Nano BT	Arduino	3	$26.30	$78.90
Polar Verity Sensor	Amazon	1	$89.00	$89.00
Lobster Jewerly Clasp	Amazon	1 (pack of 120)	$6.99	$6.99
MicroUBS Plug	Amazon	1 (pack of 20)	$6.49	$6.49
ABS block	McMaster-Carr	1	$15.00	$15.00
Heat Shrink	Lowes	2	$2.74	$5.48
600 mAh batteries	Amazon	2	$15.00	$30.00
Shipping			$20.00	$20.00
			Total	$495.06

Appendix O: Pendant Dimensions

The blueprint of the pendant dimensions are shown in **Figure O1**. At the top of the blueprint is the top side of the pendant. The dimensions for the outlet hole and chain connections are outlined. On the bottom right is the front face of the pendant. The dimensions for the pendant, chain connections, inlet holes, and finger tab are outlined. In the middle is the inside of the pendant. The dimensions for the screw holes, the linear actuator holder, the corners for the fan, the battery holder, and Arduino Nano holder are outlined. On the right is the left side of the pendant. The dimensions for the micro-USB charging port and wick drawer are outlined.

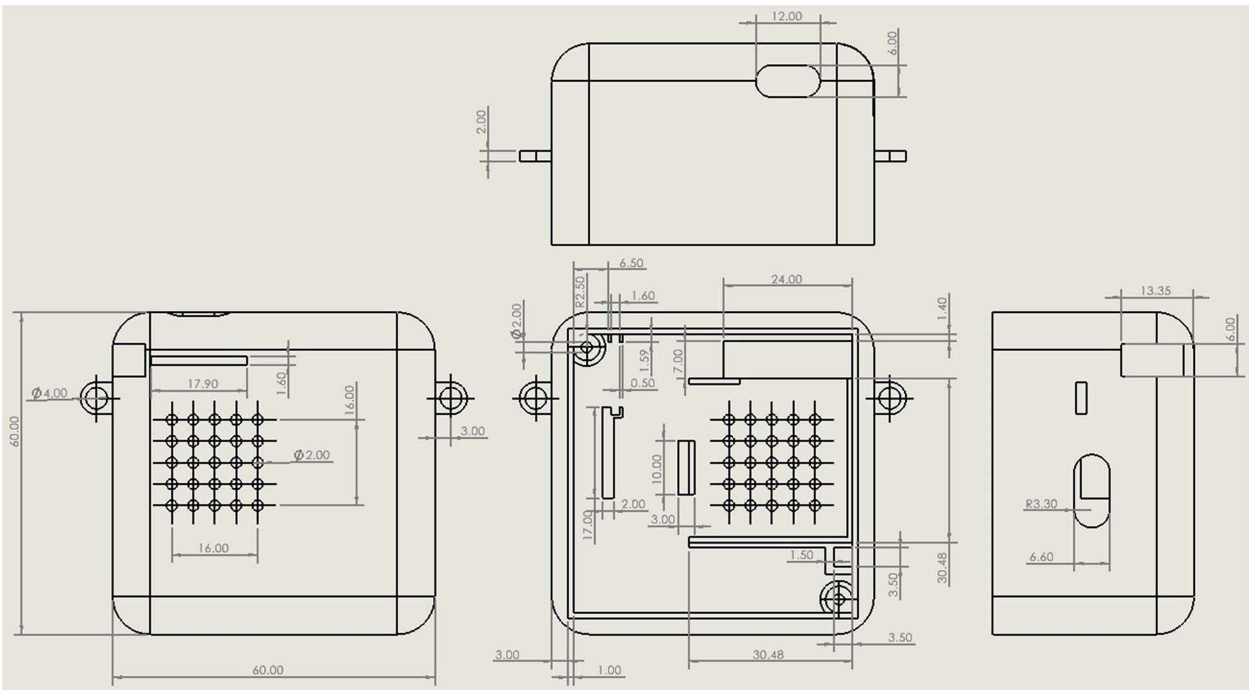

Figure O1: Pendant Dimensions

The dimensions for the back cover and the back side of the pendant are outlined in **Figure O2**. The screw hole dimensions are also outlined on the bottom right of the blueprint.

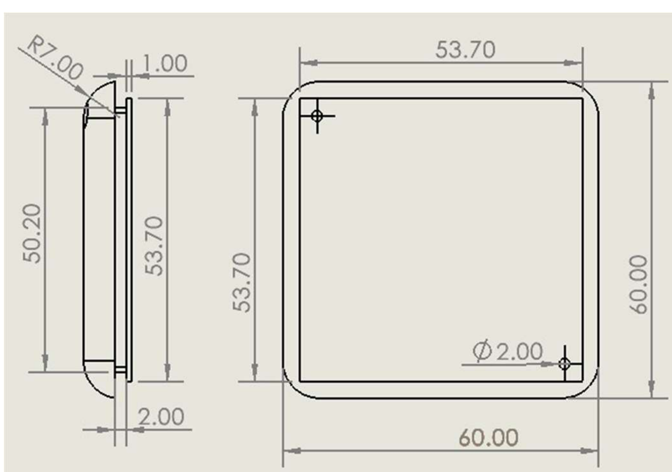

Figure O2: Blueprint for the back cover, back side of the pendant, and screw holes

In **Figure O3**, the dimensions for the charging board is shown. The charging board holder ensures the charging board is locked into place and does not slide around inside the pendant.

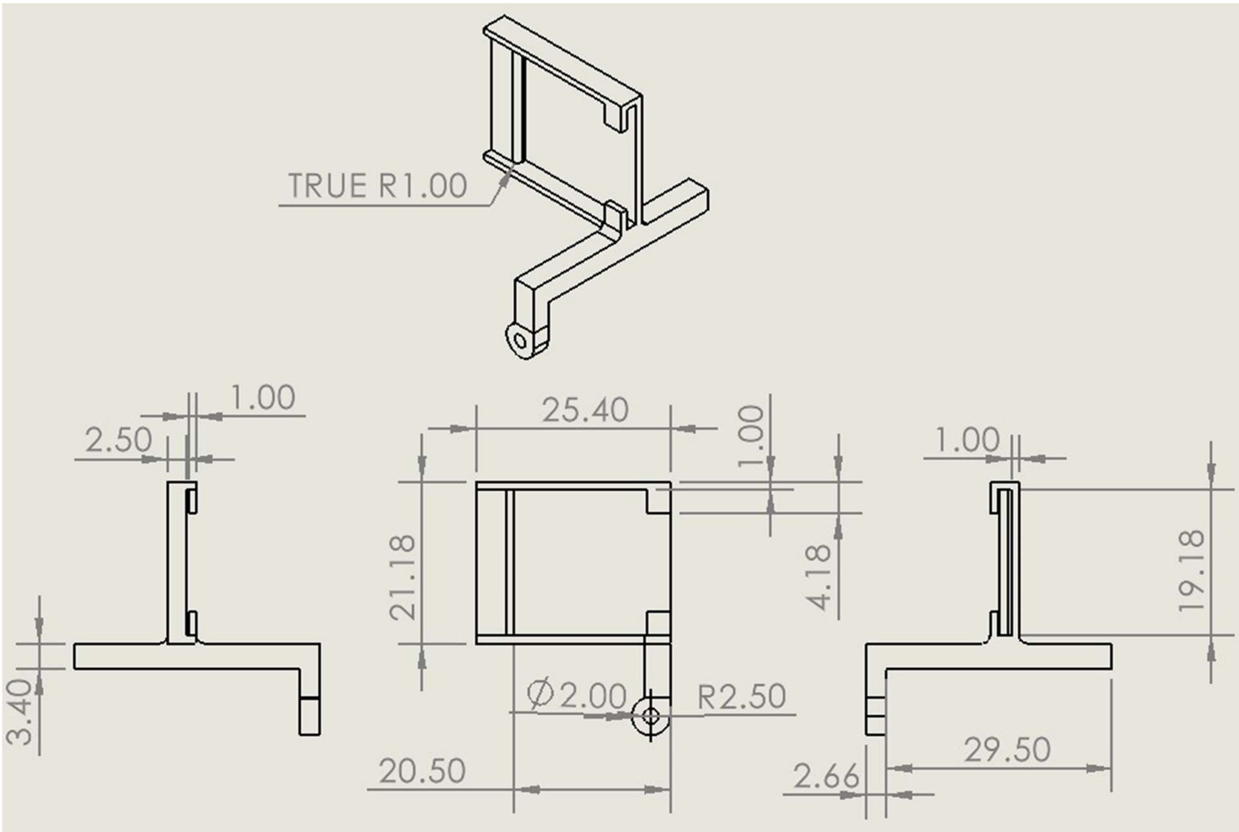

Figure O3: Charging Board Holder Dimensions

In **Figure O4**, the dimensions for the wick drawer are outlined,

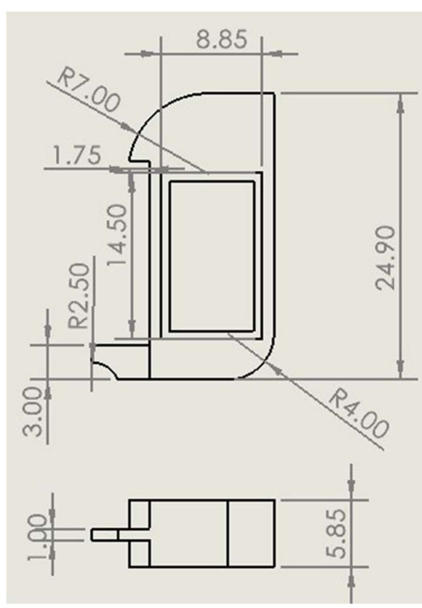

Figure O4: Wick Drawer Dimensions