The Olfaction Satisfaction Device has several main components (Figure 1). These include a base, exterior, user interface, electrical components, fragrance chambers, stepper motor and chassis, fan, and vacuum system. The base provides stability for the device and accessibility for the user. The exterior will protect the various components of the device from damage as well as prevent user injury by covering potentially dangerous components. The user interface will consist of an on/off switch and two switches. The on/off switch will be a master key switch so that it is only accessible to supervisors as oppose to the intended user. The two switches, on the other hand, will be tailored to the individuals and have the option to be interchangeable. The electrical components will include a circuit and a power supply to provide power and control for the switches, stepper motor, fan, and vacuum fans. A total of six fragrance chambers arranged in a circular fashion will hold the six possible scented oils. The fragrance chambers will be connected to the chassis frame that utilizes the stepper motor to rotate the chambers.
Activation of the first switch will activate the stepper motor, causing the fragrance chambers to rotate in order to choose a desired scent. A small fan will mounted in the center of the chassis, which upon activation of the second switch will activate the fan, causing diffused scent to travel from the fragrance chamber into the outside atmosphere. Finally, a vacuum system will be continuously on as it clears the air so another scent can be chosen.

**Base**

The Olfaction Satisfaction Device will be attached to a rectangular base resting on the floor to provide stability and protection. This rectangular base will be constructed from sanded pine plywood sheets (See Figure 1). Plywood was chosen on basis of its strength, stiffness, easy handling, and cost-effectiveness.

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1 Home Depot: Millstead. ¾ in x 4 ft x 8 ft BC Sanded Pine Plywood – 31.95
Using 2 ½ inch drywall screws and wood glue, a simple square frame will be assembled from the 2 x 0.375 ft and 1.875 x 0.375 plywood pieces (See Figure 2).

The remaining plywood pieces will be attached using the screws and glue to the top of bottom of the square frame creating a box. Carpet will be used to cover the entire box for safety purposes. Although sanded, the plywood has rough edges with the potential to cut, scratch, or splinter an individual. The ascetic appeal of the device will also be improved by covering the plywood box with carpet (See Figure 4).
The amount of carpet needed to cover the box was determined from the surface area of the box:

\[ 2 \text{ ft} \times 2 \text{ ft} = 4 \text{ ft}^2 \]
\[ 2 \text{ ft} \times 0.375 \text{ ft} = 0.75 \text{ ft}^2 \]
\[ 1.875 \text{ ft} \times 0.375 \text{ ft} = 0.703125 \text{ ft}^2 \]
\[ 2(4 \text{ ft}^2) + 2(0.75 \text{ ft}^2) + 2(0.703125 \text{ ft}^2) = 10.90625 \approx 11 \text{ ft}^2 \]

From this arithmetic, 11 sq ft plus an extra square foot to account for box edges will be needed to adequately cover the box. Industrial staples will be used to attach the carpet to the box. Additionally, tightly-woven, short carpet will be used to minimize thread loosening and removal and to create a more finished appearance.

**Exterior**

Figure 5: Dimension and Compartments
As mentioned, the outer casing (See Figure 1) will protect the various components of the device and the user from injury. Resting on top of the base, the bottom portion will house the various electrical components. As seen in Figure 5, the switch inputs and on/off switch will be located in this portion. The upper, cylinder shaped portion will house the fragrance chambers and fan system. This compartment consists of a frame to separate the chambers and the fan motor from each other. The frame provides a secure placement for the fragrance chambers and firmly fixed the fan motor in the cylindrical hollow area in the center of the chassis. Additionally, an opening covered with mesh will be located in the front region of this portion. This opening will serve as an exit for the diffused scent. The outer casing of the device (and fragrance chambers) will be composed of polyvinyl chloride or PVC.

**Table 1: PVC Properties**

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>Elastic Modulus</th>
<th>Tensile Strength</th>
<th>Yield Strength</th>
<th>Elongation at Break</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.30 – 1.58</td>
<td>350 – 600 ksi</td>
<td>5.9 – 7.5 ksi</td>
<td>5.9 – 6.5 ksi</td>
<td>40 – 80%</td>
</tr>
</tbody>
</table>

PVC was chosen due to its toughness, strength, durability, impact strength, excellent electrical insulation properties, good corrosion resistance, ease of processing, and affordability. In order to prevent damage to the device due to rough handling or mistreatment, it is essential that the outer casing have adequate strength and toughness. To prevent damage from accidents, the casing and chambers must also have sufficient impact strength. Since the device will be used frequently, durability is also important. Because one of the main concerns is user safety, it was crucial that the casing be electrical insulated to prevent harm from the electrical components inside the device. Additionally, resistance to corrosion will result in a greater longevity and efficiency for the chambers that will hold either fragrance cartridges or scented oil. Finally, fabrication ease and affordable minimize labor and cost.

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2 Industrial Plastic Supply, Inc. .250” x 24” x 48” sheet is $34.64
Fragrance Chambers

As mentioned previously, the fragrance chambers will be made of PVC (See Figure 7). The dimension of the chambers would be similar to a pie shaped forming a 60° angle for each step. These chambers will rotate via the step motor and chassis. Two holes are located on opposite sides of these chambers to provide passage of the flow from the fan to the outside atmosphere in order to diffuse a fragrance. The fragrance will be in the form of sponges or absorbent pads made damp with scented oils. Examples of scented oil include lavender, vanilla, banana, and tropical breeze. Since the chambers are removable, the user will be able to decide which set of scents that would be most enjoyable and remove and add new scents at will.

Step Motor and Chassis

Now that the exterior design has been discussed, discussion as to the interior of the device is now warranted. Design of the electrical circuitry and the placement of the different motors and fans must also be considered. The figure below shows the internal arrangement of the device’s components.
There are many different kinds of motors available in the market but it is highly recommended to use a stepper motor in our device. Stepper motors are highly reliable, simple and cost effective that precisely provide a step-wise rotating movement to a designated angle. Every step or rotation is driven by digital pulses from input switch. In the following diagram, it illustrates a block diagram on operating a stepper motor.

There are many properties to explore in order to choose a desired stepper motor such as resolution, torque, dimension, and compatible driver board. Resolution is a term used in describing the degrees or radians, a stepper motor takes each step. For our device the resolution must be $60^\circ$ or $\frac{\pi}{6}$ radians that is derived by dividing $360^\circ$ (full circle) by six (six scented fragrances in the top compartment) gives us how far each chamber must be separated. Choosing an optimal torque value is very important to power and rotate the object. The torque provided in this step motor is efficient in providing the force required to rotate the chambers. A motor with small torque properties won’t be able to power and rotate the rotating disc containing the chambers. There are many variables to consider such as the weight of the object required to rotate and the amount of voltage inputted in the motor. Typically, the dimension of stepper motors ranges from 1 – 2 inches, which is small and compact to fit in the device. The specifications of the stepper motor in the device are as follows:
Table 2: Stepper Motor specifications

<table>
<thead>
<tr>
<th>Voltage (VDC)</th>
<th>rpm</th>
<th>Torque</th>
<th>Dimensions (inches)</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 V</td>
<td>8</td>
<td>40 in.-lbs.</td>
<td>1.43&quot; x 0.91&quot; x 4.17&quot;</td>
<td>$42.03</td>
</tr>
</tbody>
</table>

In Figures 7 and 8 the stepper motor is placed near the side of the chassis due to rotating the chambers. In order to send power to the fan motor at the center of the chassis a stepper motor is connected to the bottom gear that is connected to the top compartment. A chain or belt is used to rotate the top compartment from the gear of the stepper motor to the gear in the chassis. The two gears will contain teeth for better gripping of the chain/belt to rotate the chassis.
Figure 9: Fragrance Fan

Note that in Figure 9 the fan is designed to form an air tight seal with the inlets of the fragrance chambers.

As seen in all the components of the device, there will be three muffin fans. These fans are also known as equipment cooling fans that are compact and easy to install. Two fans would be use in the design of the vacuum system and the other fan is use to blow the scent out from the selected scent chamber. The specifications of the three fans would be as follows in Table 3:
Table 3: Fan Specifications

<table>
<thead>
<tr>
<th>Dimension (Length and Width)</th>
<th>2.36 sq. inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension (Depth)</td>
<td>1 inch</td>
</tr>
<tr>
<td>CFM</td>
<td>24</td>
</tr>
<tr>
<td>Voltage</td>
<td>12 V</td>
</tr>
<tr>
<td>Amps</td>
<td>0.21 A</td>
</tr>
</tbody>
</table>

Vacuum System

To provide an affordable device, we’ve designed a simple way to filter the air as the user continually diffuses scents. Instead of using a sophisticated and expensive filtered air cleaning system which can cost up to $300, our design would provide the device an optimal and inexpensive air purification system. The system will be placed around the device with two openings, both facing the user interface as seen in figure 1. Each opening will be provided with screens for safety. The circular tube surrounding the device contains two inexpensive filtered muffin fans. One fan will primarily draw in air from the environment and another will push cleansed air out of the system (figure 11). This system is activated and deactivated continuously whenever the user turns the device on or off. In order to reverse the blade movement of one fan to draw air into the system, this could be done by switching the leads. In order to optimally filter the scented air, there will be two filters attached to each fan. The position of the two fans will be
place parallel with the circuitry compartment that is attached to the power supply for activation.

**User Interface**

The two main components of the user interface are an on/off switch and two interchangeable switches. In order to prevent the user from shutting the device off or turning the device on, the on/off switch will be a SPST key switch\(^3\). This single pole switch will have three positions (on-off-on) with position two as the key removable position.

**Table 4: Key Switch Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Capacity</td>
<td>3A @ 125 VAC</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>1,500 VAC</td>
</tr>
<tr>
<td>Mechanical Life</td>
<td>3,000 cycles per min</td>
</tr>
<tr>
<td>Electrical Life</td>
<td>10,000 cycles per min</td>
</tr>
<tr>
<td>Operating Torque</td>
<td>0.026 Nm</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>25 - +70°C</td>
</tr>
<tr>
<td>Angle of Throw</td>
<td>45°</td>
</tr>
<tr>
<td>Maximum Panel Thickness</td>
<td>0.315 inch</td>
</tr>
</tbody>
</table>

The two switches are a squish switch\(^4\) and a large touch pad\(^5\) switch (See Pictures Below). Since the device requires two switches to operate, two squish switches and two large touch pad switches will be available.

\(^3\) Allied Electronics: NKK Switches of America. SK Series 12 mm Miniature Low-Security Keylock Switch - $11.96

\(^4\) TFH USA – $49.00

\(^5\) TFH USA - $69.00  (14” x 5.5” x 4”)
This way a user will be able to have both switches as squish switch or both as large touch pad or some other desired combination. Since both of these switches are 1/8 connectors, they can both plug into ¼ adapters. Because of this, only two ¼ adapters need to be included on the exterior of the device.

In addition to these aspects, an accessible battery compartment\(^6\) will also be available. This compartment will be located on the back side of the lower portion of the exterior. Four D batteries will be required. It will have a flap opening only accessible to supervisors. As part of the design, the fragrance chambers will also be easy to remove, clean, and replace with a new fragrance. The fragrance chambers will be accessed through a lid on the top of the device. Three surface mounting draw latches\(^7\) will be used to keep the lid in place during use. Made of plastic to increase corrosion resistance, these latches have an operating temperature from -25 to 125°C.

**Electrical Components**

This circuit is responsible for taking commands from the switches and processing them into a logical signal that will control the fan motor, the step motor, and the vacuum array according to our specifications. In this design, a digital approach to the

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\(^6\) Radioshack. Battery Holder – $1.89
\(^7\) McMaster-Carr – 10 for $5.80
circuitry was tried. Digital circuits provide the most easy to understand circuit designs which are derived from simple logic. For this reason, the control circuit is approached from a digital perspective.

In order to control the step motor for the rotating chassis, a control circuit is needed that can interpret the user’s inputs from the user interface into electrical impulses that will control the step motor and fans. The figure below shows the overview of the modular components that make up the control circuit for the step motor. This circuit also controls other elements in the device such as the fans as well.

![Control Circuit Diagram](image)

**User Interface**

The User Interface portion of the circuitry contains a simple digital circuit that allows user inputs to be processed according to simple directives before the signal is sent to the Indexer.

In order to interpret commands from the switches (i.e. control switches), a control circuit within the user interface circuitry is needed. The user has two switches with which to control the device. One switch controls the fan motors that are responsible for releasing the fragrance from the fragrance chambers. When the switch is connected a digital 1 (or ‘Hi’, ‘true’) is sent to the control circuit. When the switch is not activated, a digital 0 (or ‘Low’, ‘false’) is sent to the control circuit. For identification, this signal will be designated *Activate*. Therefore, Activate tells the circuit whether or not to turn on the fan.

Similarly, a user controlled switch will be responsible for telling the device to rotate the fragrance chambers (enabling the user to switch to different fragrances). The signal coming from this switch will be designated ‘Select’. When Select is asserted, the device will rotate the fragrance chambers. When select is not asserted, the device will stop rotating the fragrance chambers when the next chamber is in position with the fan.

Finally, signal ON/OFF will be designated as the signal telling the circuit whether or not the device is turned on or off. When the device is on, ON/OFF will be asserted (i.e. will send out a digital 1). When the device is off, the ON/OFF signal will send out a
digital 0. Only the personnel with the right key will be able to turn the *Olfaction Satisfaction* device on.

At this point, it is necessary to understand how the motors will activate based on the user's inputs. When the device is off (i.e. ON/OFF is not asserted) the device will not respond to the input from the user interface. When the device is on (i.e. ON/OFF is asserted), it will do nothing when no input is given from the user interface, will activate the fan if Activate is asserted and Select is not asserted, and will not activate the fan if Select is asserted.

This characteristic behavior of the circuit can be described in the truth table seen below. Note that Fan and Rotate are output signals that will be sent to the Indexer portion of the control circuit.

Table 5: User Interface I/O Table

<table>
<thead>
<tr>
<th>ON/OFF</th>
<th>Select</th>
<th>Activate</th>
<th>Fan</th>
<th>Rotate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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<td>0</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

From this table, one is able to derive the logical equations that will govern the outputs of Fan and Rotate. These Equations are:

\[
\text{Fan} = \text{ON/OFF} \times \text{Activate} \times \neg \text{Select}
\]

\[
\text{Rotate} = \text{ON/OFF} \times \text{Select}
\]

Such equations are easy to implement on the circuit board with the use of AND gates and NOT gates. This circuit is seen below:
Signals from the user interface are then sent to the Indexer portion of the control circuit (see Figure 9). As stated earlier, the step motor must rotate 60 degrees in order for the next chamber to be aligned with the fan. Using a step motor that is in full step mode (i.e. 1.8 degrees per step) one can calculate that 33 and 1/3 steps are needed for a full 60 degree rotation. Therefore, a counter is needed to count how many steps the motor has taken. When 33 steps have been taken, the device sends a signal to stop rotating because the chamber is in position (assuming the user has stopped activating the select switch on the user interface).

However, simply rounding to 33 steps will result in an error that will be manifested in the misalignment of the chambers after many rotations. Therefore, the 1/3 step must be accounted for. Every third chamber must be rotated an extra step in order to account for this error. This problem can be solved by adding another counter to the circuit that will count how many chambers have been rotated into position. When the counter reaches a count of 2 (the counter starts at 0), a signal will be sent out to allow the step motor to go one extra step.

Seen below is the circuit that will count the desired quantities and output the desired signals. 74_163 Binary Counters are used in this circuit. Note that they are connected to a clock signal. This clock signal will also drive the step motor. Hence counting the number of clock ticks is equivalent to counting the number of steps in the motor. The output CLICK33 is the signal that indicates whether or not the motor has gone 33 steps. When CLICK33 is asserted, the motor has gone 33 steps. When CLICK33 is not asserted, the motor has not gone 33 steps. The output 3RD represents the signal that tells the circuit whether or not the 3rd chamber has been reached. When 3RD is asserted the motor is rotating the 3rd chamber, and a signal is sent out to tell the motor to rotate one extra step. Otherwise 3RD is not asserted and the signal is sent out to continue stepping the usual 33 steps.
The next portion of the Indexer circuit is the D-latch which will process the signals from CLICK33 and 3RD. Note that this portion of the circuit will tell the motor to go an extra step when rotating every 3rd chamber into position. Note that the desired behavior of this portion of the circuit is to send out a signal for the step motor to keep stepping when neither 3RD nor CLICK33 is asserted or when 3RD is asserted but CLICK33 is not. Furthermore the circuit must tell the motor to stop stepping when CLICK33 is asserted and 3RD is not. Finally, when both CLICK33 and 3RD are asserted, the signal must remain the same (i.e. telling the motor to step) for one more step. The table below summarized this behavior:
Table 6: D-Latch I/O Behavior

<table>
<thead>
<tr>
<th>3RD</th>
<th>CLICK33</th>
<th>QN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>LAST QN</td>
</tr>
</tbody>
</table>

In order to get this behavior, the D-Latch must be wired as seen in the figure below. Note that the D-Latch will pass out the value of CLICK33 when the enable command C is asserted. The enable command C is controlled by the simple equation:

\[ C = !(3RD) + !(CLICK33) \]

This ensures that the circuit will send out a signal for the motor to continue one extra step when both CLICK33 and 3RD are asserted.

Figure 14: Indexer Circuit: D-Latch

Finally, the clock signal that will go to the driver can be disabled according to whether Rotate or QN are asserted. If either of these elements is asserted, then the clock signal will go through to the Driver (see Figure on page 8). If both are not asserted, then the clock signal is not sent to the driver and the motor will hold position. Note that the AND gate functions to either pass the clock signal or block it from getting to the Step Motor Driver.
The output from the OR gate in the above circuit is given the designation CLK_EN, which is the clock enable signal for the Indexer. This output serves another useful purpose, however. When asserted, CLK_EN will also send a signal to the fans of the Vacuum System (see page 18) to activate. Therefore, while the fragrance chambers are being rotated, fresh and unscented air will be pumped into the room so that when the next fragrance is selected, the previous fragrance has been filtered out of the immediate area.

**Driver**

The Driver is responsible for interpreting the electrical pulses that are sent to it and driving the step motor in response. Fortunately, step motor drivers are fairly inexpensive to buy as an IC Chip. Most suppliers will sell a Driver IC Chip for around 5 or 6 dollars. For our circuit, the Driver will interpret a single pulse and cause the step motor to rotate one step Clockwise. Note that this works perfectly with the design of the Indexer. The figure below shows the block diagram for a 3977 Microstepping Driver with Translator:
Conclusion

The Olfaction Satisfaction device will meet all of the client's demands. It will provide a complete olfactory stimulation experience for the user. The user interface will be simple and easy to use, so that frustration does not result when the user interacts with the device. Furthermore, a versatile interface consisting of interchangeable switches will ensure that the device can be used by any user regardless motor skill or disability.

Furthermore, the Olfaction Satisfaction device will be durable enough to withstand rough handling and mistreatment. A wide base provides adequate stability when in use but does not hinder mobility, making it a very functional and portable device. The smooth exterior also provides for the safety of the user, making it able to be used without risk of injury. This fact, combined with the easy to use interface, makes the device able to be used with little to no supervision required.

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8 3977 Microstepping DMOS Driver with Translator, Allegro Microsystems Inc.
Also, the removable scent chambers make it easy to clean and allows for the placing of new fragrances in the device. This allows it to stimulate with a wide variety of scents and odors, giving the Olfaction Satisfaction device the ability to offer a constantly changing and engaging sensory experience. Able to be renewed with new and different scents, the Olfaction Satisfaction device becomes a new sensory experience every time the scents are changed.

This fact makes it a very cost effective device, ensuring that users will get a new and different experience as new scents are loaded into the scent chambers. Nevertheless, an analysis of the cost of components and parts to build the device shows that it is able to compete price-wise with current devices on the market today that are designed with children in mind.

Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide a pure and simple stimulation of the individual’s senses. In this regard, Individuals with these severe cognitive and motor disabilities find themselves in an environment that lacks stimulation of their senses. In response to this situation, the device’s main purpose is to provide stimulation of the individual’s senses. The Olfaction Satisfaction device not only delivers quality sensory stimulation, but also goes further and improves on deficiencies seen in products with olfactory stimulation technology on the market today. Most importantly, however, is the fact that the Olfaction Satisfaction device will improve the quality of life the disabled adults who use it.