Dear Engineering World Health,

We are taking a biomedical engineering design course at UW-Madison and seek funding for our prototype. The EWH project that we chose is the aspirator (a locally produced item). In last semester's design course (Spring 2007), our group came up with a design and built a working prototype. Over the summer, we contacted Robert Malkin from EWH (who we had previous contact with) about our final design and prototype. He expressed interest and wanted us to develop a set of instructions for the current prototype to send to developing world hospitals. However, as a group, we felt aspects of the design and prototype could use significant improvements. Therefore, we decided to work on the aspirator for another semester. Our major goals are to improve the pump, the diaphragm, the one way valves, reduce the overall size, and develop a set of instructions for EWH.

Last semester, our prototype cost a total of $49.50, as shown by the Parts Table on pages 4 and 5. We are requesting funding of $130 from EWH. $49.50 would be for last semester's prototype, an estimated $50 to build a new aspirator, and the remaining $30.50 for extra expenses and testing (renting a manometer to test pressure).

Thank you for considering our proposal and we hope to make great progress on this project this semester.

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Current Design

The main components of the final design include a 12 V car battery, fan motor, diaphragm system, pair of one-way valves, fluid collection chamber, and tubing with an autoclavable tip **(Figure 5)**. The battery provides 12 V DC voltage to turn the fan motor. The radial motion of the fan is converted to linear motion by means of a string. This linear motion oscillates the diaphragm, creating a continuous cycle of air flow into and out of the diaphragm compartment. The air flow into the one way inlet valve creates a partial vacuum in the attached tubing system. A vacuum is therefore created in the collection chamber which is used to draw fluid in through the opening in the autoclavable suction tip.

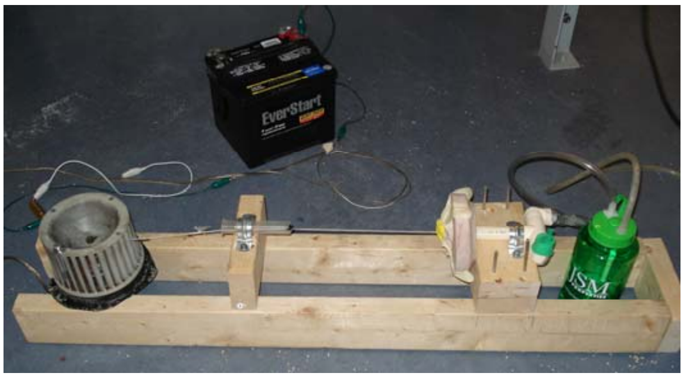

Figure 5: Overall

Due to inconsistent electricity in developing world hospitals, the power source for the design runs independent of AC power. The 12 V DC car battery provides enough energy to power the fan motor and allows the aspirator to be run for at least two hours without recharging. When the battery dies, it can be recharged using a car or with AC power when it is available. The car battery can easily be salvaged from an abandoned vehicle.

Standard wires complete a simple circuit consisting of the battery, a 2 ohm power resistor, and a fan motor connected in series **(Figure 6)**. The power resistor decreases the power reaching the motor and is necessary to slow the rotational velocity. The 2 ohm power resistor can be substituted with four 10 ohm light bulbs in parallel. These light bulbs give an equivalent power resistance of 2.5 ohms and are readily obtainable. Once the circuit is connected, the fan motor runs at a more manageable speed. Also, by being able to change the number of light bulbs used in the circuit, this feature allows the users to vary the amount of resistance and thus optimize the speed of the motor to vary the rate of aspiration.

Figure 6: Circuit

Figure 7: Fan Motor

The fan motor is salvaged from the heater blower of a car. Any other motor that provides a similar circular rotation would also work, as long as it is able to pull on the diaphragm with enough force. A bolt and washer is glued, tied, and/or taped through the outer rim of the fan that is attached to the gear of the motor **(Figure 7)**. Tied to the washer is an approximately 70 cm long string. The washer allows free rotation and prevents the string from coiling up and breaking.

The string is fed through a syringe casing that is mounted at the same height as where the string is tied to the washer. The syringe is approximately 1/3 of the way to the diaphragm system. The syringe refines the motion of the string, eliminating unnecessary perpendicular motion and increasing the linear pull on the diaphragm. The other end of the string is tied to a rubber balloon which is part of the diaphragm system.

A cylindrical lid (~8 cm radius) from a food container is fitted around the lone end of one inch diameter, T-shaped PVC pipe, acting as the base of the diaphragm. A thick rubber balloon is stretched over the lid to create the diaphragm and the string is tied to the tip. A layer of rubber glove is super-glued to the balloon and over the string for added support **(Figure 8)**. The center of the diaphragm (where the string is tied) should also be the same height as both the syringe and the washer-string connection to prevent friction and wear on the string.

The outlet one-way valve is the stem of a balloon glued half shut and stretched over one end of the PVC pipe. The inlet one-way valve is a check valve obtained from the bulb of a sphygmomanometer. This is located in the tubing adapter attached to the other PVC pipe opening. From this tubing adapter at the input check valve, a 1.3 cm diameter, noncollapsible tube (~70 cm) is connected which leads to the collection chamber **(Figure 8)**. The tubing must be stiff so the vacuum generated does not collapse the tubing and cut off air flow.

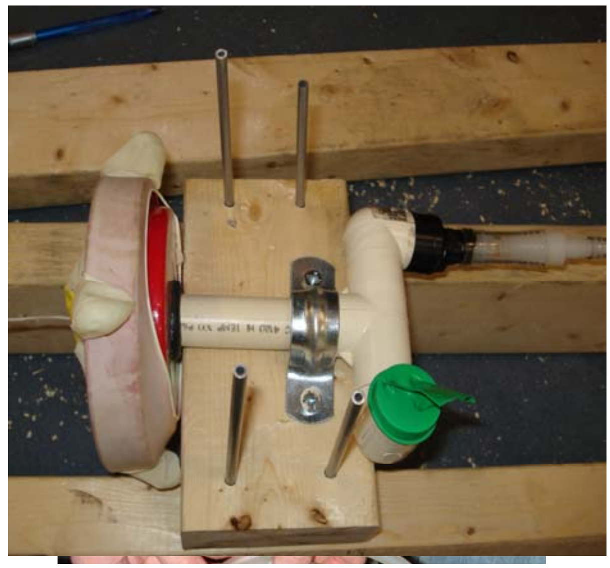

Figure 8: Diaphragm and Valves

Left: diaphragm; Right: green output valve, black inlet valve

The collection chamber shown in **Figure 9** is an air tight, hard plastic water bottle (e.g. Nalgene). Holes were drilled into the lid and fitted for tubing adapters. Attached to the air/fluid intake tube adapter is a pen shell or other long cylinder object, such as a straw, that will direct aspirated fluid to the bottom of the collection chamber and thus prevent liquid uptake into the diaphragm system.

Finally, a longer (~130 cm) 1.3 cm diameter, non-collapsible tube is attached to the collection chamber and connects to the autoclavable pipette suction tip **(Figure 9)**. The tip is cut so a wider opening can take in water at a faster rate (see testing). The pipette tip is a hard durable plastic that can withstand the high temperature and pressure of the autoclave machine.

Figure 9: Collection Chamber, Tubing, and Autoclavable Tip

The entire system is mounted on a frame of 2x4 boards to hold each of the individual components in its correct position in relation to the other parts. The placement of the motor and diaphragm should be such that it maximizes the amount of air flow created by system (determined through trial and error). The collection chamber is not permanently attached to the frame. This allows it to be removed, emptied, and cleaned. The battery is also not attached to allow easy removal for recharging. The entire system can be placed on a cart where it can be easily moved throughout the operation room. Ideally, the cart would be as low to the ground as possible. This would decrease the amount of obstruction and allow easy storage under tables, beds, etc. As an added benefit, this will maximize the flow rate of the aspirator by using gravity to create a siphon effect.

Future Design

We believe that our current device is an excellent starting point and proof of concept. Further work is need however, before the aspirator can be safely and effectively used on humans. Three major components of the design have been identified as major rooms for improvement. The diaphragm and check valve system is a source of pressure leakage and needs optimization. Furthermore, our current string mechanism is only pulling on the diaphragm. We propose to improve our system to both push and pull on the diaphragm to greatly increase the vacuum. We would use a thicker rubber diaphragm from a car tire tube to replace the thinner lab gloves. We propose to develop flapper or ball valves for greater efficiency. Finally, we hope to create an alternative means to power the device (i.e. hand or foot powered) Currently, our device can produce a liquid flow rate of 1.6 L/min, after further optimization we hope to raise this number to around 4 L/min. After testing and documenting performance, we will write complete instructions for making and using this aspirator.

Parts

Part	**Cost**	**3rd World Source**
1" PVC pipe	$1.09/foot x 2 feet = $2.18 *Source: Home Depot*	Plumbing equipment
Lab Gloves	$.28 x 4 = $1.12 Source: *medicalsupplyco.com*	Operating room
DC Fan Motor	$5.00 *Source: Moemart Salvage*	Salvaged automobile
12 V Battery	$20 *Source: Moemart Salvage*	Salvaged automobile
Pipette Tip	$.04 *Source: Fisher Catalog*	Hospital lab
Plastic Syringe	$.75 *Source: Ax-man Surplus*	Operating room
2x4 Lumber	$.80/foot x 6 feet = $4.80 *Source: Home Depot*	Natural environment Abandoned building
Nails/Screws	$.20 x 8 = $1.60 *Source: Home Depot.com*	Abandoned building Construction material
Water Bottle	$4.00 *Source: Walmart.com*	Household item
Tygon® Tubing	$1.09/foot x 6 feet = $6.54 *Source: medicalsupplyco.com*	Operating room Salvaged automobile

2 Ω Power Resistor	$1.09 x 2 bulbs = $2.18 *Source: Home Depot*	Two 60 watt light bulbs (wired in parallel)
Check Valve	$.99 Source: Ebay.com	Sphignomonometer: Operating room
Wire	$.15/foot x 2 feet = $0.30 *Source:Walmart.com*	Salvaged automobile Electronic devices
Total	**$49.50**	