INTRODUCTION
A rehabilitation agency expressed a need for a wheelchair wheel washer (Figure 22.1) that could make the cleaning process less intensive for staff and allow the wheelchair user the opportunity to actively participate in the wheel cleaning process. The nature of this project also required that it meet specifications outlined in The Americans with Disabilities Act regarding safety of usage.

SUMMARY OF IMPACT
After outdoor fieldtrips, wheelchairs track mud and water into the facility, creating hazardous conditions, especially for clients having limited ambulatory abilities. Previously, the staff had to hand-clean every wheelchair entering the building. This was time-consuming and created significant amounts of soiled laundry. It also limited the independence of the user. The wheelchair wheel washer provided a monetary savings in the reduction of labor costs while promoting independence.

Figure 22.1. Wheelchair Wheel Washer.
TECHNICAL DESCRIPTION

A base unit (Figure 22.2) houses the cleaning mechanism, consisting of water sprayers, air jets, and brushes. As the wheels are rolled in reverse, the sprayers wet the wheels, while brushes scrub the debris away. Air jets dry the wheels when the sprayers shut off and cleaning is complete. All debris is collected in plastic reservoirs under the rollers and removed via a vacuum system consisting of an ordinary shop-vac. Absorbent utility carpeting was placed in the path of the exiting wheelchairs on the exit ramp of the base unit to absorb any moisture remaining on the wheels.

A control unit, constructed primarily of wood (Figure 22.3), supplies water to the base unit from a reservoir where a pump is used to provide clean water for spraying the wheels. The air jets and vacuum system are controlled by a shop-vac inside the control unit. The debris is evacuated from the plastic reservoirs and subsequently deposited inside the shop-vac. The exhaust air from the shop-vac is routed to the air jets and serves to dry the wheels. Dirty water from the shop-vac can be removed via a drain valve located on the external surface of the control unit. A section of hose routes the waste to a suitable drain.

The engineering principles utilized in the design of this project include circuit analysis, material analysis and static force analysis. Circuit analysis (Figure 22.4) is straightforward. Due to the fact that the device is metallic, uses water, and contains electrical devices in the control unit, electrical concerns involved eliminating the risk of electric shock to users. To accomplish this end, GFCI protection is incorporated in the power cord to shield the entire device from the power source.

Materials analysis focused on judicious selection of materials for strength and resistance to corrosion. The base unit is aluminum framework covered in aluminum diamond plate. Wheel rollers are made of stainless steel rods covered with PVC for strength and durability and are fitted with stainless steel bearings.

Static force analysis was performed utilizing Cosmos® (Figure 22.5) and an Instron® stress analyzer. The roller mechanism was shown to tolerate forces in excess of 600 pound/in² and the maximum displacement incurred by the frame under a load of 1000 pounds was determined to be 170 microns. The design can accommodate wheelchair base widths from 31 inches for large wheelchairs to 18.25 inches for smaller chairs. The ADA requirement for ramp inclines is one inch of rise for every 12 inches of ramp length. Ramps on the base unit are therefore made to be three feet long and three inches tall making its overall length approximately nine feet. Dimensions of the control unit are 43 inches by 30 inches by 30 inches. The base unit can be folded and the entire device transported in a small pickup truck.

The total cost was $998.
Figure 22.2. Base Unit.

Figure 22.3. Control Unit.
Figure 22.4. Diagram of Electrical Circuit.

Figure 22.5. Displacement Plot from COSMOSWorks®.
INTRODUCTION
Individuals with sensory integration dysfunction experience deficits in processing tactile signals. This results in improper and sometimes excess tactile sensory feedback. The application of deep pressure at the skin’s surface, which is then transferred into the muscle, has been shown to calm these patients. Ideally, by not being overloaded with sensory feedback, they are able to better process sensory information.

SUMMARY OF IMPACT
If the tactile system is not properly functioning, abnormal signals are sent to the brain, causing tactile defensiveness. The result is that a person is very sensitive to light touch, perceiving it as painful because the nerves in the periphery are sending abnormal signals to the brain about tactile contact. The Deep Pressure Machine (DPM) (Figure 22.6) allows patients to self-treat sensory integration dysfunction.

TECHNICAL DESCRIPTION
Mechanical/structural design and static force analysis were the key engineering principles employed in the design of this project. The framework of the DPM is constructed of two-inch by two-inch by eighth-inch A36 square tubular steel. Two steel rollers, 27 inches in length and 4.41 inches in diameter are positioned in a linear track constructed of one-inch by half-inch by eighth-inch channel steel. The device is fitted with locking casters to keep in place while in use. The rollers that apply the deep pressure are cushioned with foam padding and enclosed with vinyl roller coverings. Deep pressure is supplied with the innovative use of rubber Soloflex® bands stretched between two rollers. Simply adding or changing bands may adjust the amount of deep pressure.

Static force analysis was performed utilizing SolidWorks® (Figure 22.7) coupled with COSMOS WORKS® and focused primarily upon the strength of the rollers against a downward distributed force. Based on the COSMOS WORKS® analysis it was determined that the weak point of the design is located at four bolts holding a mounted bearing to the frame. The spring constant of the Soloflex® bands was determined using a CSD 500 dynamometer. The dynamometer was used to measure the force applied to the Soloflex® bands. By measuring the distance that the bands stretched the equivalent spring constant was calculated for the...
five and ten pound bands. Hence, the force applied to the body as a function of band stretch distance was determined.

The DPM was found useful for the self-treatment of patients (Figure 22.8) with tactile defensiveness due to SID. Clients and users reported the DPM provided enough pressure to give the desired calming sensation. The DPM may be cleaned with any type of standard vinyl cleaner. Locking casters allow for movement and safety during usage. When not in use, the dimensions (Figure 22.9) of the device allow for storage in a standard closet.

The total cost was $1,212.
INTRODUCTION
Clients at a rehabilitation agency requested a means by which their patients could vacuum and/or manually sweep floors from a wheelchair. Previous solutions to this problem involved using a corded vacuum in a stop-and-go fashion, or a robotic solution, such as the Roomba®. Users found the manual solution too tedious and the automated solution did nothing to contribute to their rehabilitation. Client supervisors sought a solution which would empower patients with mobility impairments to sweep or vacuum independently.

SUMMARY OF IMPACT
This design allowed users to clean floors (Figure 22.10) in a domestic or institutional setting. Although assistance in attaching the device to a wheelchair is usually required, users still derived feelings of independence and self-sufficiency from performing the simple task of vacuuming floors. The client supervisors hope to utilize this device to secure gainful employment for some of their patients.

TECHNICAL DESCRIPTION
Mechanical and structural design and analysis were the chief engineering principles used in the design of this project. However, electrical circuit design and analysis were also employed.

Initially, design features common to most wheelchairs and most cleaning implements were examined to determine a feasible way to merge the two. It was found that most wheelchairs incorporate tubular footrest supports and most cleaning implements have a (roughly) cylindrical shape. Hence, it was decided to use these common features as attachment points. The device (Figure 22.11.) is constructed of one-inch and three-quarter inch diameter aluminum tubing with an eighth-inch thick wall. A clamp/jaw system was designed and machined to connect the aluminum tubing to the footrest supports. Clamps were designed to fit the two diameters of tubing. This was done to allow telescopic adjustment between footrest supports in order to accommodate footrests from 13 inches to 20 inches apart. A V-shaped trough and strap system
was then utilized to hold a vacuum or push style broom/dust mop handle. To allow retraction from the floor when not in use, the trough was allowed to pivot on a horizontal bar and a bayonet catch was used to hold the cleaning implement in a position several inches off the floor.

Electrical concerns focused on an adequate power supply and appropriate mode switch. A rechargeable battery powers the cordless vacuum for at least four hours and was mounted to the rear of the wheelchair. This served to counterbalance attachments on the front of the wheelchair in order to avoid any undesired weight distribution problems. A three position double-pole, double-throw switch was mounted on the wheelchair armrest, allowing for carpeting (vacuum and roller brush motors on), flooring (vacuum motor only on) and off modes.

The device was found to be an effective means of attaching most cordless vacuums and push style brooms/mops to most wheelchairs.

The total cost was $660.
AUDITORY AND VISUAL TIMER

Designers: Andrea Horstman, Jaqueline Jones
Supervising Professor: Dr. Ping He
Department of Biomedical, Industrial and Human Factors Engineering
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INTRODUCTION
The purpose of this project is to help children tell time, understand the concept of time, and monitor passage of time during activities.

SUMMARY OF IMPACT
The timer’s use encourages children’s improved concept of time. This, in turn, may lead to greater autonomy and more efficient use of time by these students. The timer (Figure 22.12) also allows for more efficient usage of time available to educators in the supervision of these young learners. The timer may be used for timed activities, such as playtime, time outs and quiet time.

Figure 22.12. Auditory and Visual Timer.
TECHNICAL DESCRIPTION

Engineering principles employed in the design of this project include circuit analysis, mechanical/structural design, and computer programming.

Circuit analysis is involved in the light, sound and motion components of the project. An array of 15 multi-colored LEDs with resistors is located in equal intervals around the face of the timer. Initially all LEDs are on. When the timer is activated LEDs turn off sequentially at the rate of one every 20 seconds. An amplifier circuit with accompanying speaker is utilized to provide the sound requirements and an audible tone is initiated once after the passing of each one-minute interval. A DC step motor and driver circuit (Figure 22.13) is employed for motion and serves to rotate a colored disc through one color segment each minute. A toggle switch located at the top of the timer housing serves to activate/deactivate the mechanism. All electrical components are powered with a single nine-volt battery.

Mechanical and structural design is straightforward and involves construction of the timer face and housing as well as the mounting of electrical circuitry. The housing is constructed primarily of Plexiglas® and has dimensions of 7.5 inches by 7.5 inches by five inches.

PBasic® programming language is utilized to program a BASIC stamp. The stamp (Figure 22.14) is incorporated in the coordination and timing of lights, sound and motion.

The timer is found to exhibit a fair modicum of durability and has been well received by instructors as well as the intended users.

The total cost was $466.
RANGE OF MOTION ARC

Designers: Daniel Allred, Erin Hanlon, Hilary Gallagher
Supervising Professor: Dr. Chandler Phillips
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INTRODUCTION
This is a redesign of a typically available range of motion arc used by orthopedic therapists to exercise the shoulders and arms of patients. The physical therapist in an elementary school desired a device that would promote increased range of motion of the shoulder while holding the attention of her clients. The previous product, known as a shoulder arc, did not incorporate a positive feedback mechanism, hence redesign was deemed appropriate.

SUMMARY OF IMPACT
Utilization of the arc promotes greater range of motion of the shoulder and thereby increases motor skills and coordination leading to increased independence. The device is helpful for users who have experienced a degree of reversible motion loss or impairment. The inclusion of positive feedback promotes better pediatric user compliance (Figure 22.16).

TECHNICAL DESCRIPTION
The engineering principles employed in the design of this project include circuit and mechanical/structural design. The circuit (Figure 22.17) design is driven by a standard 555 timer and a 12-volt rechargeable Gel Cell battery. The peripherals such as the lighting display and music chip utilize a five-volt three terminal voltage regulator. A total of 33 high intensity, red LEDs make up the lighting display and are wired in parallel with 1.2 kΩ resistors to allow a current flow of 10 mA to each LED. Both the visual and auditory devices are timed out using the 555 timer. A magnetic ring is integrated into the design to trigger the positive feedback. Six reed switches are wired in parallel and positioned at either end of the arc to facilitate activation of the feedback mechanisms. Recharging of the Gel Cell battery is accomplished with a 12V adapter and current limiting circuit to allow the battery to trickle charge overnight.

The arc itself is constructed of three-quarter inch flexible plastic tubing. Additional lengths of tubing allow for increasing the total range of motion and permit for an arc height of between 15 and 41 inches. A toggle switch is used to set the starting position to either side of the arch base in order to accommodate ambidextrous movement for suppination to pronation or vice versa. A case, with inside dimensions of 34 inches by 18 inches by six inches, is fitted with two sheets of eighth-inch white acrylic plastic which houses the electrical components and provides a platform for the tubing arc. Five metal clamps affixed to the platform behind the arc allow for the storage of the additional lengths of arc tubing when not in use. The product is portable for transporting to different classrooms, has adjustable difficulty levels, provides positive feedback to the user with both visual and auditory rewards and is safe and durable.

The total cost was $663.
Figure 22.16. Child Using Range of Motion Arc.

Figure 22.17. Block Diagram of Circuit.
HEAD MOUNTED DISPLAY VISION SCREENER FOR PRESCHOOLERS

Designers: Joseph Cunningham, Adam Lenger, Cayti Zelnio
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INTRODUCTION
This project essentially automates the process of vision screening in preschoolers. In preschool vision screening, flashcards or posters are used to test for visual acuity, stereo acuity and colorblindness. Currently, screeners in a client program use a measuring tape to fix the appropriate distances between the child and the testing cards. The children are then asked to determine what shapes are being displayed. Often, the children will lean forward to view the images. As a result, the measured distance is not standardized. Based on these shortcomings, vision screening utilizing a head mounted display was deemed appropriate.

SUMMARY OF IMPACT
In addition to standardizing the distances required for vision screenings, the head mounted display (Figures 22.18-22.19.) also regulates effective lighting levels.

The system is compact and easy to carry.

Figure 22.18. Head Mounted Display (HMD).

Figure 22.19. HMD with Lenses.
TECHNICAL DESCRIPTION
The engineering principles utilized in the design of this project included optical analysis, static force analysis and computer programming in JAVA®. Optical calculations were the basis for a large portion of the work on this project. Lens powers were calculated to obtain the desired convergence and focal depth from the viewer’s aspect. Calculations were made to determine equivalent image sizes at varying distances. Focal planes were also taken into consideration during the placement of the lenses.

Another principle utilized for this project was the calculation of force balances on both the display mounted on the head, as well as, the display resting on a stand. It was important to see exactly what forces were being compensated for and how different parts of the body (i.e. head, neck, and back) would be affected when the display is worn on the user’s head. Some flexibility for the children was obtained by creating a stand (Figure 22.20) to support the display if a child chooses not to wear it (Figure 22.21) on their head. When used in conjunction with the stand, it was important to provide, for the safety of people and of the display itself, a support for the potential problem of the apparatus tipping over. The stand, which is likely to be used on the floor, can be adjusted from 18 to 48 inches fully accommodating a preschool child sitting in a chair or in the standing position.

A flow chart was made to sketch out the proper ordering of the testing cards. This involved outlining what to do and where to proceed when certain series of tests were passed or failed by the subject. In some cases, a failed testing series meant more tests needed to be conducted to guard against a false negative being obtained from the screening test. Once the outline was finalized, the JAVA program had to be written to accommodate the testing procedure. The program had to take into account image sizes and be tailored to the display.

The total cost was $995.
INTRODUCTION
This project involved redesigning a commercially available gripper for an eight year old child with arthrogryposis multiplex congenital, which causes the fusion of the patient’s joints, resulting in severe movement restrictions. The user is unable to lift a large amount of weight or bend elbows or wrists to assist in getting objects within reach. The gripper will be used in a physical education setting to facilitate the retrieval of objects, such as balls and beanbags, and to aid in the grasping of a plastic hockey stick.

SUMMARY OF IMPACT
The primary effect resulting in the use of this device is the improvements experienced in the self-sufficiency of the child in physical education class. In time, psychological and sociological improvements may be derived as a result of the child’s enhanced interactions with others. Continued use may show therapeutic improvements resulting from increased muscle mass and some decrease in muscle atrophy.

TECHNICAL DESCRIPTION
Primary engineering principles employed in the design of this project included mechanical, ergonomic and materials analysis. Mechanical analysis involved computation of the precise gear size and ratio needed for the interface of the gear key and finger assemblies (Figure 22.22.). It was also necessary to incorporate a dual locking mechanism at either end of the gripper to facilitate retrieval of objects to the child’s lap and provide for their subsequent release. This was accomplished with dual three-position bayonet catches (Figure 22.23) on both the handle and gripper ends of the device. Positions of the bayonet catches allowed for grasping, holding and release of small, medium and larger objects less than six inches in diameter.

Ergonomic analysis was employed in the design and size of the handle and several prototypes were tested on the user for comfort and ease of use. The handle was made of PVC tubing covered in moleskin at the location most likely gripped by the user’s hand.

Materials analysis involved research of suitable materials for their lightweight characteristics and durability. The product needed to withstand being hit lightly on the ground while the user gets the gripper fingers around the object to be retrieved. Delrin® was utilized for the construction of the finger assembly, lever handles and an inner rod connected to the gear key as it fulfilled the aforementioned materials requirements.

The final product weighed approximately one pound and is nearly three feet long. The gripper proved capable of grasping, holding and releasing three specified objects (Figures 22.24-22.26). The gripper was capable of grasping objects having average diameters ranging from two inches to six inches.

The total cost was $798.
Figure 22.22. Key and Finger Assembly.

Figure 22.23. Handle and Bayonet Catch.

Figure 22.24. Large Ball.

Figure 22.25. Small Ball.

Figure 22.26. Bean Bag.
VOICE ACTIVATED SENSORY SYSTEM

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INTRODUCTION
Instructors at a middle school desired a voice-activated system incorporating lights, sound and motion for the sensory stimulation of their students with cognitive and physical disabilities, ranging in age from 10 to 13 years.

SUMMARY OF IMPACT
The Voice Activated Sensory System (Figure 22.27) serves to empower users by giving them a sense of comfort and control. Providing these children with various types of sensory stimulation is known to have a calming effect and affords them a sense of independence and individuality. Enabling these educators to supply their students with sources of stimulation allows for more efficient use of their limited time.

Figure 22.27. Voice Activated Sensory System (VASS).
TECHNICAL DESCRIPTION

Three commercially available toys mounted at the top of the unit were employed to provide the sound and motion components of the design while back lighted pictures fulfilled the lighting specification. Circuit and structural design, as well as computer programming, were the primary engineering principles exploited in the conception of this project.

Circuit design (Figure 22.28) focused primarily on the control of the system and was centered about a voice-activated relay (VOX) powered with a 12-volt AC to DC converter. Reed relays and diodes were used to facilitate the control signal for activation of the toys. The power source for the toys was supplied with rechargeable batteries. Flashlight bulbs were utilized to deliver back lighting of the pictures on the front of the unit. A three-position rocker switch allowed for the selection of voice activated, manual and off modes.

Structural design skills were employed in the fabrication of the project’s housing and mounting the electrical components and toys in and upon the enclosure. Disposable, aluminum roasting pans were used as reflectors for back lighting of the pictures. The project enclosure was fabricated of quarter-inch thick plywood and clear Plexiglas®. Dimensions of the enclosure are 30 inches by 30 inches by five inches.

PBASIC® programming language was used in conjunction with the BASIC stamp in providing the signals to sequentially activate the three toys. The BASIC stamp’s power supply was provided by a nine-volt AC to DC power converter.

The total cost was $527.

Figure 22.28. Circuit Design for the Voice Activated Sensory System.