Chapter 12
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AN AUTOMATED SIDE-BY-SIDE REFRIGERATOR DOOR OPENER

Designers: Katie Allen and Christopher Howard
Client Coordinator: Cheryl Linn
United Cerebral Palsy of Greater Houston
Supervising Professor: W.A. Hyman
Biomedical Engineering Program
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INTRODUCTION

An automated side-by-side refrigerator door opener was made for the adult program at the United Cerebral Palsy Center of Greater Houston. A single linear actuator simultaneously opens both doors (Figure 12.1). A flat arm, attached to the linear actuator, holds two swivel arms that are each fixed to a single door. The entire system is operated by a switch that opens the doors when pushed up and closes the doors when pushed down. The switch was designed to accommodate most adult patients.

SUMMARY OF IMPACT

It is difficult for individuals in wheelchairs to open refrigerators. In the current project, a switch is positioned so that the wheelchair is not in the path of the opening door. The doors swing open wide enough to allow a wheelchair to pass. In the future, the switch may be changed to a mat or portable pushbutton.

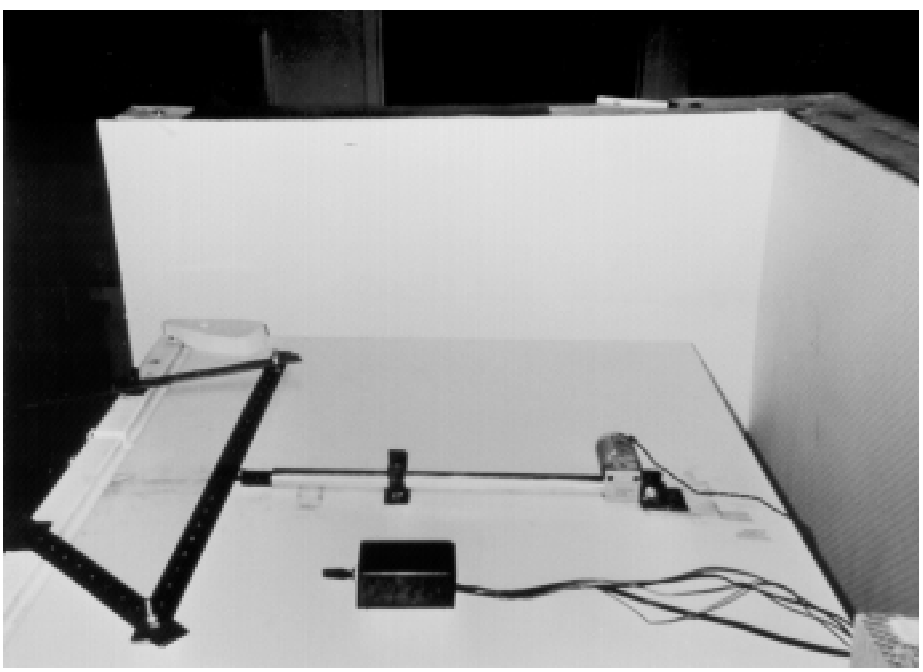

Figure 12.1. Automated Refrigerator Door Opener.

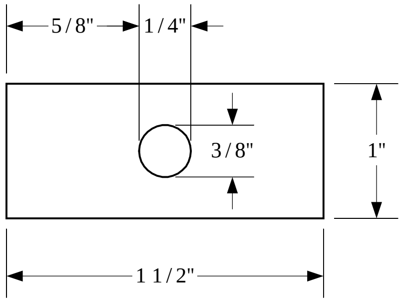

Figure 12.2. Peg and Plate Mounting.

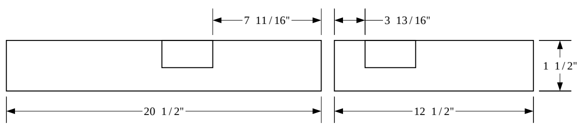

Figure 12.3. Plate Positioning on Refrigerator Door.

TECHNICAL DESCRIPTION

The door opener consists of four parts: 1) the arms, 2) the bar, 3) the linear actuator, and 4) the switch. Glued to each refrigerator door is a 2” x 1” steel plate mounted with a ¼” threaded steel peg (Figure 12.2). The doors are 12.5” and 20.5”. Peg 2 is positioned 3 13/16” from the inside edge of the door and peg 1 is positioned 7 11/16” from the inside edge of the door (Figure 12.3). Both are flush with the front of the door. Steel epoxy glue is used throughout.

Two 1” wide steel arms with pre-drilled 1/4“ diameter holes connect the linear actuator to the doors and force the doors open when the actuator moves outward. The arms vary in length due to the different door widths. Arm 1 is 9” and is attached to the longer door with peg 1. Arm 2 is 7” and is attached to the shorter door with peg 2. The pegs and arms are placed to allow for maximal door opening.

The bar is cut from the same 1” steel as the two arm pieces. It is 15” in length and attaches to the actuator with a ¼” screw that is 7/8” long located in the middle of the bar. Arm 1 is positioned 1” from the outside edge of the bar and arm 2 is positioned 2” from the opposite edge. Both arms are held in place by a loosely tightened ¼” nut and bolt. This allows the arms to have unrestricted movement during the opening and closing of the doors.

The linear actuator is a model Motion 85615/85616 Ball Drive Actuator, manufactured by Motion Systems Corporation (Figure 12.4). It has a dynamic operating load of 100 pounds and a static operating load of 600 pounds. The stroke length of the actuator is 12“ and a 12 VIC Permanent Magnet Brush DC Motor powers it. An AC adapter from Radio Shack provides conventional power to the actuator.

The actuator is positioned by a ¼” screw into a 2” x 3.75” steel plate mounted with screw holders. The screw holders are two 1” square steel plates, ¼” thick, welded upright onto the bottom plate (Figure 12.5). Each screw holder has a ¼” hole drilled through the middle of the 1” plate. The plate with screw holders is positioned on the refrigerator 4” from the back and 17” from the right side.

To prevent the actuator rod and casing from moving back and forth, a steel guide is placed 11.5” from the front of the refrigerator (not including the doors) and 17” from the right side. The guide is composed of a bottom plate made of ¼” steel measuring 2” x 1” and two upright restraining guides made of 1/8” steel measuring 0.5” x 2”. The restraining guides are welded to the bottom plate 1 3/16” apart. The guide is glued onto the top of the refrigerator, approximately in the middle of the rod casing.

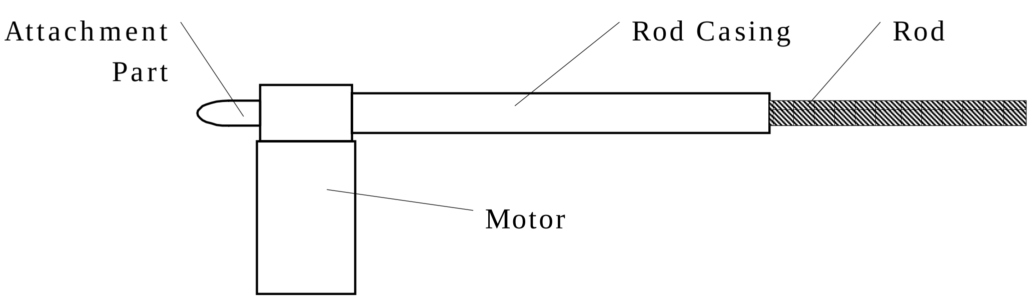

Figure 12.4. Linear Actuator.

The switch has three basic positions: up, down, and middle. The up position moves the actuator outwards, the down position moves the actuator to its original position, and the middle position turns the actuator off. To increase the size of the switch, a Styrofoam box was placed over the original device. This allows the switch to be moved by either a hand or fist, lessening the amount of coordination and dexterity required. The box is 4.25” long, 8” wide, and 2” high, a sufficient size for the user population. The switch is attached to the side of the refrigerator by a magnet, allowing it to be moved when not in use. The doors can be operated conventionally at all times.

A sketch of the unit is shown in Figure 12.6.

Expenses were as follows:

Linear actuator	Donated by Motion Systems
AC adapter	$22
Steel	$80
Misc. supplies	$50
Fabrication	$50

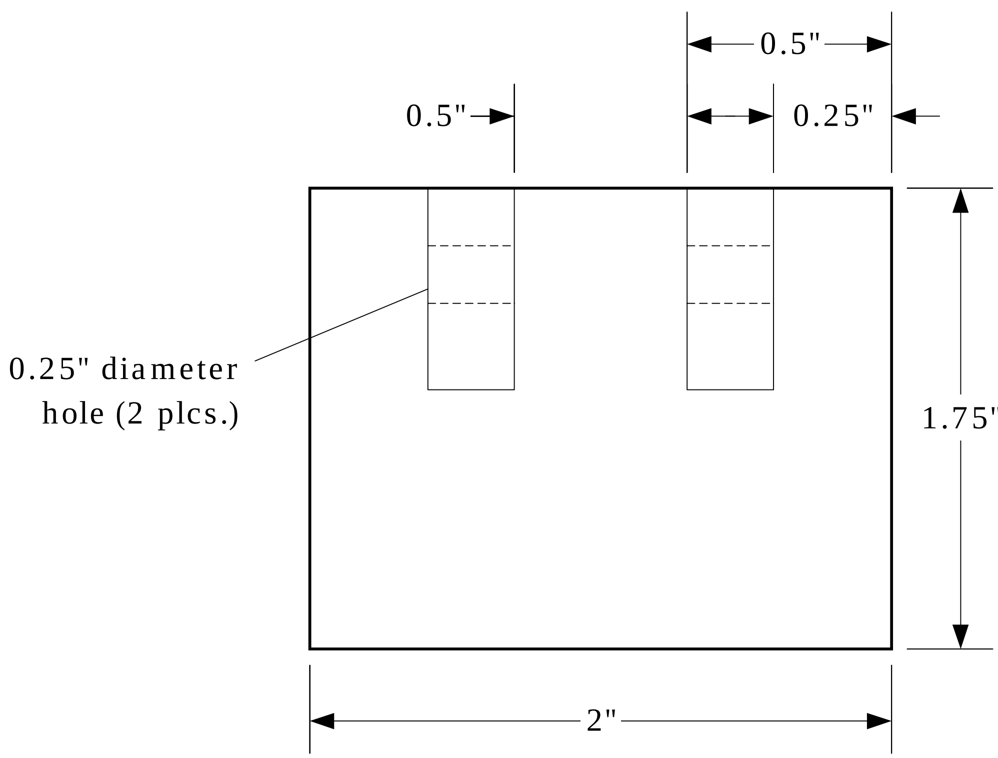

Figure 12.5. Attachment Plate.

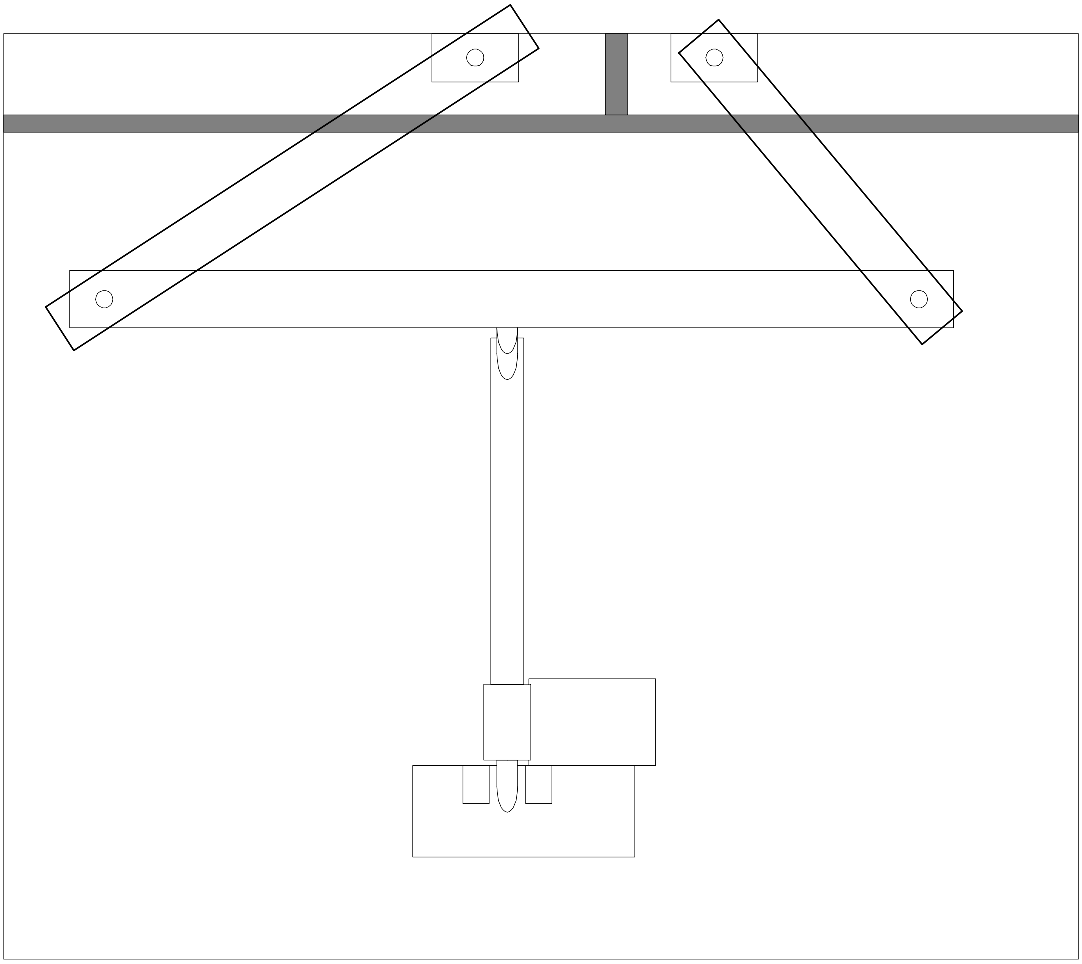

Figure 12.6. Schematic Drawing of the Refrigerator Door Adaptation.

PORTABLE PARALLEL BARS FOR CHILDREN WITH WALKING DIFFICULTIES

Designers: Gretchen Meyer and Emily Stephenson
Client Coordinator: United Cerebral Palsy Institute of Greater Houston
Supervising Professor: WAY. Hyman
Biomedical Engineering Program
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INTRODUCTION

Portable parallel bars for children with walking difficulties (Figure 12.7) were designed to be easily transported by a therapist for in-home patient care. They may also be installed permanently. The bars consist of two PVC pipe railings seated in galvanized steel pipe flanges. All parts are available in any large home center and the system can be easily and inexpensively constructed.

SUMMARY OF IMPACT

Due to the restructuring of the Cerebral Palsy Institute into smaller home health care satellites, existing parallel walking bars do not meet the needs of many clinicians because they are not easily transported and because they are expensive, heavy, and consist of many parts. This design is lightweight and compact. The bars are small enough to be stored the trunk of a car, and require a minimal amount of space when assembled.

Figure 12.7. Portable Parallel Bars.

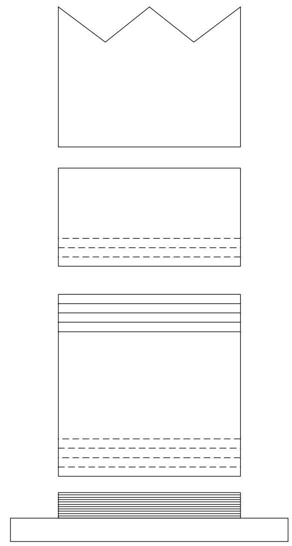

Figure 12.8. Base Construction.

TECHNICAL DESCRIPTION

The main design requirements of the portable parallel bars were that they be: 1) suitable for small children, 2) easily transportable (lightweight, involving few parts, quickly assembled), 3) sturdy, 4) and safe.

The railing supports are built with four 2" diameter galvanized steel pipe flanges attached to two 8" x 32" pieces of fabric covered plywood. The plywood bases are both covered with a 14" x 38" piece of fabric and padded with a 10" x 34" piece of cotton matting. The fabric and matting are attached with a staple gun. Two pipe flanges are placed on a plywood base 20" apart and attached by four 1/4" x 1" lag screws.

Connected to each pipe flange is a 4" piece of 2" diameter threaded galvanized steel pipe. The steel pipe is then attached to a 2" diameter PVC pipe female adapter (Figure 12.8). The adapter enables the PVC pipe legs to be firmly seated in the base.

Each vertical support is constructed from 2" diameter PVC pipe, 19" in length. A U-shaped cut, approximately 1.5" deep, is removed from each support using a jigsaw and a 1/4" diameter hole is drilled 0.75" from the top of the leg (Figure 12.9). The supports are permanently attached to the female adapter using PVC pipe adhesive or epoxy. The total base/leg component is two feet tall, a height appropriate for pediatric patients.

The two horizontal railings each consist of a 5' piece of 1 1/2" diameter PVC pipe with a 1 1/2" diameter PVC rounded cap. The caps protect the user from the unfinished ends of the railings. After assembly, a 1/4" diameter hole is drilled 6" from the end of each rail. The PVC pipe is painted after sanding and applying one coat of primer.

The parallel bars are assembled by placing the two bases 4' apart, measuring from the legs. The rails are placed in the legs and secured with a hex cap screw and wing nut, with the wing nut facing the outside.

The approximate cost of the parallel bars is $75.00.

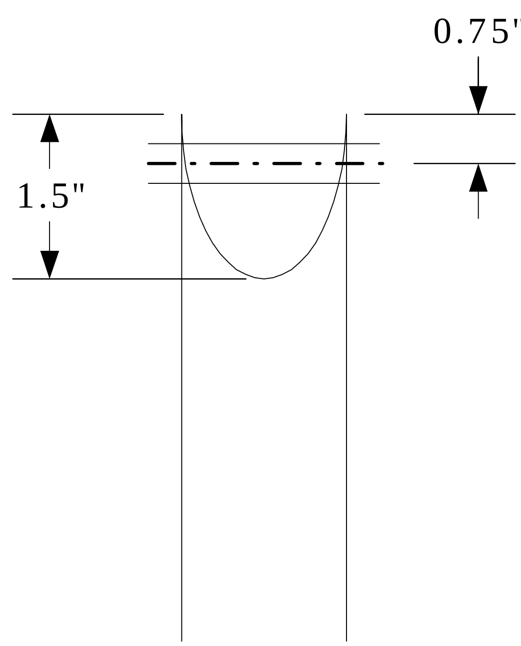

Figure 12.9. Pipe Cut-Out Detail.

PORTABLE PARALLEL BARS WITH A TEXTURED WALKWAY

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Client Coordinator: Gretta Cherry
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INTRODUCTION

A set of parallel bars with a textured walkway was built for children with cerebral palsy. The design consists of a platform with three different textures, a ramp, a step, and parallel bars (Figure 12.10). The base is rectangular and has two supports to provide stability. The platform is accessible by a ramp on one end and a step on the other. The ramp and step fold for easy storage. The parallel bars are removable and the unit transportable.

SUMMARY OF IMPACT

The textured walkway is designed to create different sensations as children walk, so that they may learn to alter their steps accordingly, while fostering improvements in balance and coordination.

TECHNICAL DESCRIPTION

The main design requirements of the textured walkway were that it: 1) have at least three different textures; 2) be portable; 3) have a ramp and a stair; and 4) have parallel bars for safety and balance.

The textured walkway has three main components: the platform, the ramp, and the step. The platform is created with 1/2" plywood measuring 45" x 22" supported by two 2" x 4" boards, which span the length of the plywood. The 2" x 4" supports are attached 2 3/4" from each edge by four 2" zinc corner braces (two on each side). Eight screws are countersunk along each support for torsional support. The supports raise the finished platform to a height of 4 ½". All edges are covered with white vinyl.

Layers of cardboard inserts beneath the different walking textures are added to level the surface of the textured walkway. 1/8" hobby plywood covers the cardboard to assure that the foundation is hard and flat. The three textures include a 16" x 22" piece of gray carpet attached to the base with 5/8" brads, a 14 ½" x 22" piece of blue foam attached with glue, and a 14 ½" x 22" piece of black and white tile attached with self-adhesive backing.

The ramp is ½" painted plywood measuring 20" x 13 ½". The step consists of four pieces of wood, two 3" x 0.5" x 1.5" legs, one 13" x 0.5" x 2.5" step platform, and one 13"x 0.5" x 2.5" attachment board. The ramp and step are attached to opposite ends of the platform with four 3" x 3" hinges. Anti-slip traction tape is applied to both the ramp and step.

Four 1 1/4" holes are drilled 2" from each corner of the platform. Four 1" diameter PVC pipe connectors are inserted into the drilled holes. The four vertical supports are made from 1" diameter PVC pipe, 24" in length, and are inserted into the pipe connectors. The two handrails are 1" PVC pipe, 40" in length, and are connected to the vertical supports by two 1" PVC elbows, secured with PVC cement.

The estimated cost is $75.00.

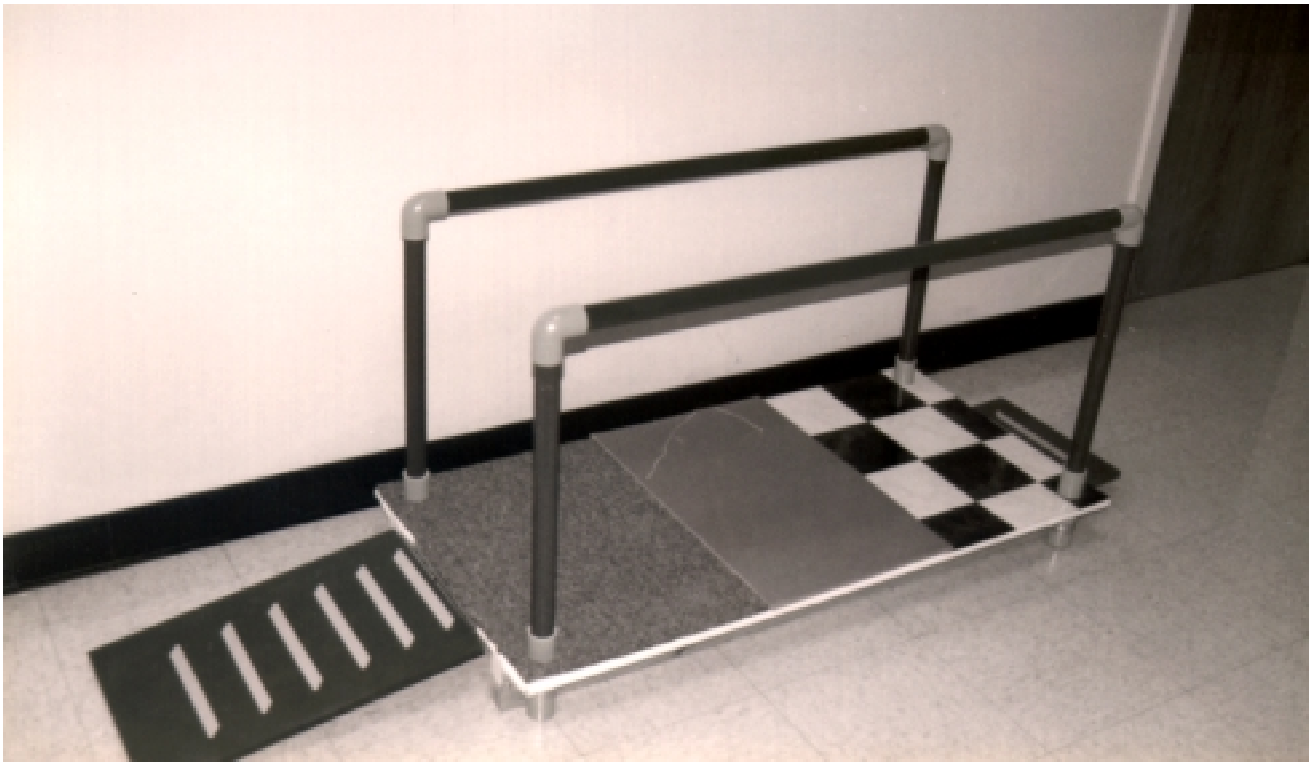

Figure 12.10. Parallel Bars with a Textured Walkway.

AN ADJUSTABLE TABLE FOR CHANGING OLDER CHILDREN

Designers: Elisabeth Neely and Bincy Paulose
Client Coordinator: Liz Crawford
Therapist, College Station Independent School District
Supervising Professor: W.A. Hyman
Biomedical Engineering Program
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INTRODUCTION

A variable height changing table has been designed for teachers at an elementary school (Figure 12.11). The device consists of two main parts: (1) a table and (2) a foot-operated hydraulic lift. The hydraulic mechanism was purchased from a catalogue. Its pedal and release knob/shaft are easily removed and stored inside the unit to clear the floor area when desired. The changing table measures 25.5" x 19.5" and can lift 440 pounds. The front rail is attached with two strap hinges so that the rail may be lowered to allow children to climb onto the table. There is a storage space between the hydraulic lift and table for diapers and related items.

SUMMARY OF IMPACT

The changing table was designed teachers who work with children who are four years of age and older. They requested a table that could be lowered to the ground to allow the children to climb onto the table with little assistance, thus preventing back problems experienced by the staff. Prior to having this device, the teachers were changing the children on the floor of the bathroom to avoid lifting them three feet to the conventional table.

TECHNICAL DESCRIPTION

The main design requirements of the table were that it: 1) fit into an allotted space (approximately 51" x 20" and 32" in height) 2) be lowered and raised with a foot pump; 3) have a table top covered in a material that was easy to clean; 4) have railings on two or more sides to ensure safety; 5) be able to accommodate children's varying size and weight, and 6) be safe to use.

Figure 12.11. Variable Height Changing Table.

The hydraulic lift is constructed of heavy gauge steel and massive welds for superior strength. The lift measures 25.5" x 19.5" and is elevated 0.5" per stroke of the foot pedal. It has a minimum height of 5" and a maximum height of 21". To raise the height of the changing table, a storage space with a height of 10" was added between the lift and table.

The base of the changing table is 1.25" plywood measuring 34"x 20.5". It is attached to the hydraulic lift with four carriage bolts (5/16" x 1.5"). The dimensions of the 1.25" plywood tabletop are 50" x 20.5". The base and the top of the table are connected to four 8"x 2"x 4" pieces of wood located 1/25" from each corner of the base at the back and flush with the corners in the front (Figure 12.12). Three sides of the storage space were enclosed with 1.25" plywood. The dimensions of the two sidepieces are 20.5" x 8". The back piece measures 33" x 7.75".

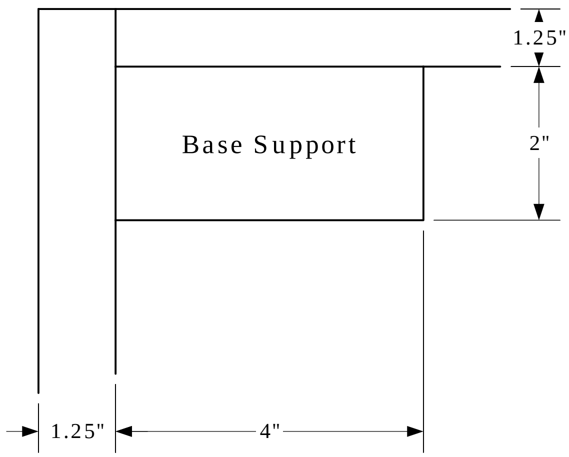

Figure 12.12. Back Base Support Dimensions.

The tabletop has 5” side railings on all sides, and is supported by 1.5” x 1.5” x 5” sections of wood located 0.5” from each corner (Figure 12.13). All railings are made from 0.5” plywood, the two side railings measuring 20.5” x 6.25” and the front and rear railings measuring 50” x 5”. The front railing is attached with two 4” strap hinges. Two hook and eye catches hold the railing in the upright position. The hinges are attached with four 0.75” screws and four hex nuts. The wood table components are attached with screws and nails.

The table is stained with golden oak wood stain and varnished with clear gloss. A pad for the tabletop is made from a piece of 0.5” foam, hot glued to a cardboard backing and wrapped in cloth and clear vinyl.

The estimated final cost for this project is $825.00, with the hydraulic lift priced at $720.00

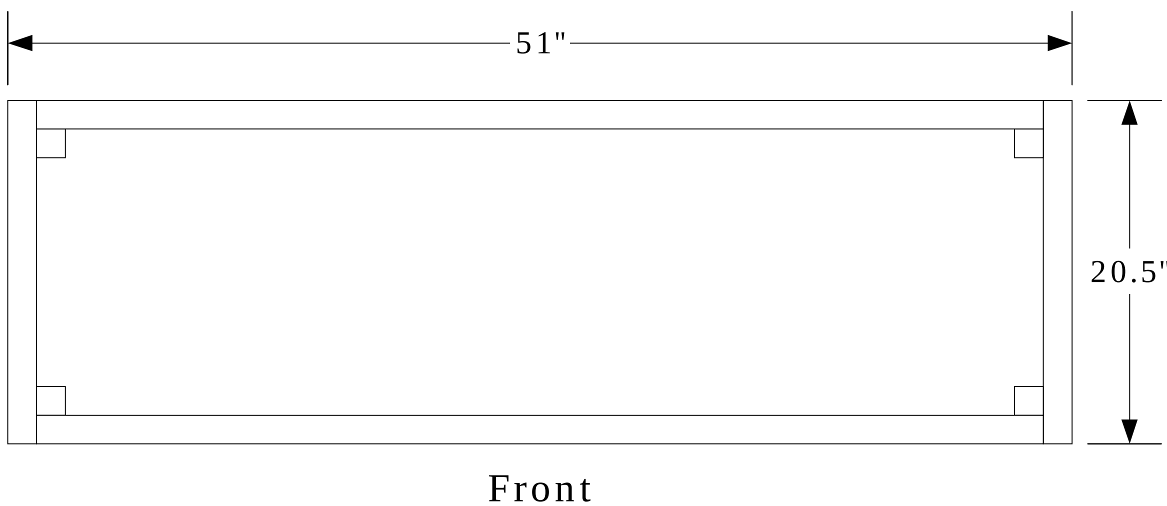

Figure 12.13. Tabletop Dimensions.

AN ELECTRONIC BLOCK TOY

Designer: John Holcomb
Client Coordinator: Teressa Edmonds
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Supervising Professor: W.A. Hyman
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INTRODUCTION

An electronic toy requiring the sequential placement of blocks was designed for children with cerebral palsy. The toy consists of an enclosed rectangular box and six wooden blocks of different shapes (Figure 12.14). The blocks fit into six corresponding holes on the top of the box, each block fitting only one hole. An electronic switch located at the bottom of each hole is triggered upon insertion of the correct block. An electronic circuit monitors the sequential placement of the blocks, which are labeled with large numbers that correspond to their correct placement order. When a block is placed into its corresponding hole in the correct order a large segmented LED display indicates the block number. A chime sounds when all six blocks are placed into the holes in the correct order. If any block is placed incorrectly a buzzer sounds and the toy is reset. The blocks are shaped and weighted to be easily handled by children. The toy is battery-operated, small, and portable.

SUMMARY OF IMPACT

Many children with cerebral palsy have difficulty with eye and hand coordination. The toys that are designed to improve these skills often lack a sufficient level of stimulation and cognitive challenge.

The development of eye and hand coordination greatly increases the interaction between the child and his or her surroundings. The sequential block game is unique in terms of the level and type of stimulation it provides. The child must consider not only placing each block in the appropriate hole but also the order of block placement. In addition, the successful completion of block placement is reinforced by both visual and audible stimuli.

TECHNICAL DESCRIPTION

The primary design considerations of the sequential block toy were that it: 1) include a minimum of four blocks; 2) have blocks approximately two inches wide; 3) be portable; and 4) provide a sufficient level of auditory and visual stimulation.

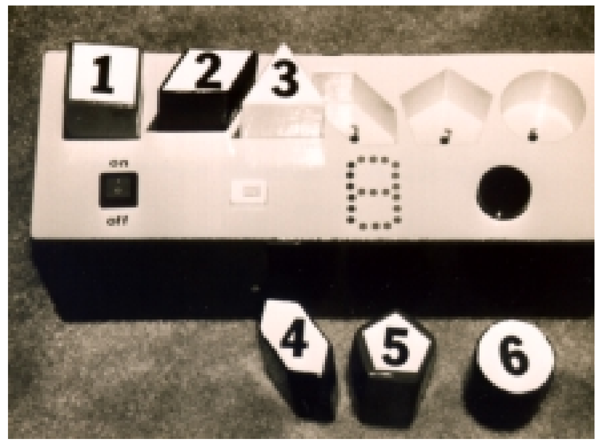

Figure 12.14. Electronic Block Toy.

The box is 6" in height with top dimensions of 14" x 6" (Figure 12.14). It is constructed of 1/4" plywood with an insert of dimensional 2" x 4" lumber into which the six holes are cut. The insert is attached to the inside top of the box to provide the walls for the six holes. The bottom of the holes is made of 1/4" plywood, approximately 13.5" x 3". The bottom of the box is made of two pieces of 1/4" plywood, 6" x 6" and 6" x 7.5". The smaller bottom piece is hinged to allow battery access. Each of the six blocks is made of a solid piece of dimensional lumber with an approximate width of 2" and height of 4.5".

The block shapes were symmetrically formed using a table and band saw. After the blocks were formed, the holes were cut in both the box top and insert with a jig saw to ensure a proper fit between the blocks and holes. The box was assembled with glue and 3/4" screws. Finally, the box and blocks were painted with acrylic paint in various bright colors.

The electrical component of the design required the use of several specialized components (Figure 12.15). Although sequential switches can be monitored using digital AND/OR gate chips, the most straightforward approach is to use a programmable logic chip such as the PAL22V10 used in this design. The PAL chip can be programmed with PALASM software and a digital chip programmer. Both can be found in a typical digital electrical engineering laboratory. The exact details of the programming are more extensive than can be provided here.

The PAL chip was programmed to recognize a sequence of six inputs from the switches at the bottom of each hole. The lever-type switches have an L-shaped extension. The extension fits through a small hole in the plywood of the block hole bottom. When triggered, each switch provides a 5-volt input to the PAL, which is recognized as a positive or correct input. Grounding the input pins of the PAL chip via a 1MΩ resistor provides the negative input. The PAL chip requires a clock signal to indicate when to monitor the inputs. This signal is provided by a 555-timer chip that is designed to provide a clock signal at approximately 1.5-second intervals. This interval allows the block to settle without causing multiple input triggers. The PAL sequence includes resting states for each block and an error state that is entered when a block is placed in the incorrect order. The chime indicating the correct placement of all the blocks is triggered by the output of the state for the sixth block. The incorrect buzzer is triggered by the error state. The correct block number is displayed by sending the output from each state to a second PAL chip that determines the proper LED segments to be lit. The outputs to the LED lights, the buzzer, and the chime cause a transistor to switch on, which provides the necessary voltage. The entire circuit requires four D batteries.

The components were obtained from Radio Shack and from the Rehabilitation Engineering Laboratory at Texas A&M University. The cost of the block toy was approximately $40.

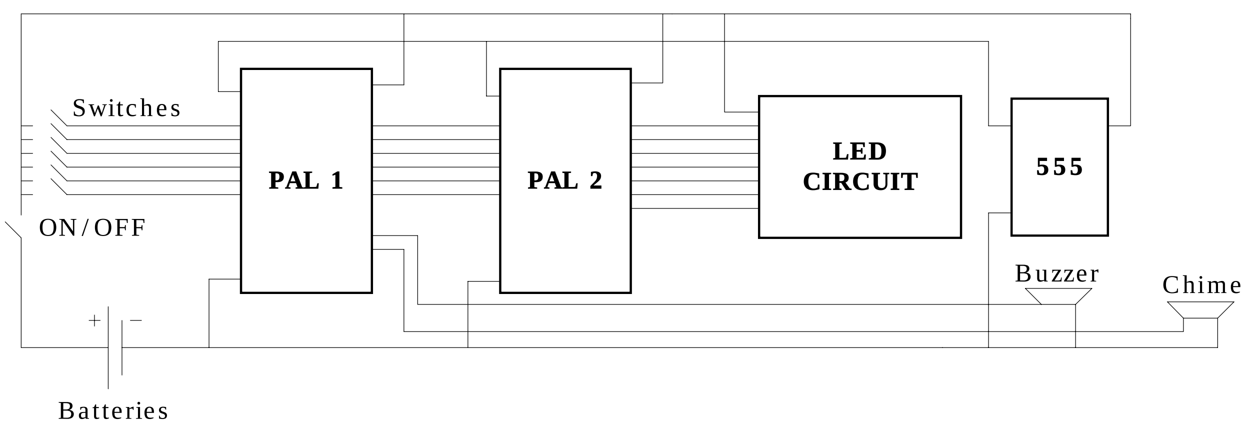

Figure 12.15. Generalized Circuit Diagram.

A REFRIGERATOR DOOR ADAPTATION FOR ADULTS IN WHEELCHAIRS

Designers: Elisabeth Neely and Bincy Paulose
Supervising Professor: W.A. Hyman
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INTRODUCTION

An adaptation for a standard refrigerator door was designed for adults in wheelchairs (Figure 12.16). The device is designed for a standard refrigerator with a side opening. It cannot be adapted to a side-by-side refrigerator unit. It consists of two basic parts: the arm and the hinge. The hinge is a triangular strap hinge, with one arm attached to the side of the refrigerator and the other to a metal arm that extends beyond the end of the hinge and is inserted into the door between the insulation and the refrigerator frame (Figure 12.17). Pressing the metal arm causes the refrigerator door to open. As the door closes, the arm is trapped, and the device is again ready for use. If the door opener is not needed, it can be removed and folded back on the outside of the refrigerator. The unit is easily installed and inexpensive to build.

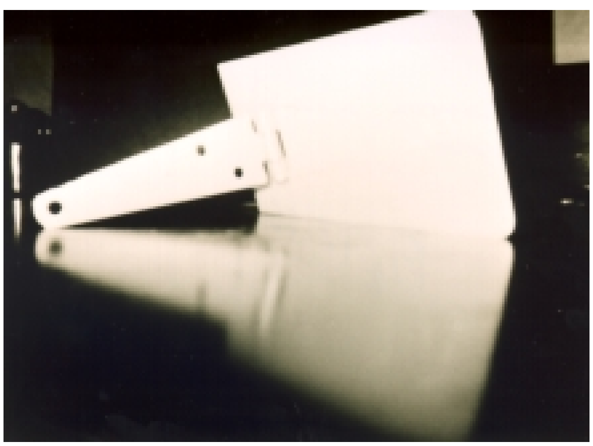


Figure 12.16. Refrigerator Door Adaptation.

SUMMARY OF IMPACT

Many people have difficulty opening a refrigerator door from a wheelchair because it is hard to produce enough force from a seated position. The design of this unit is based on the assumption that pushing is easier that pulling. A modification that could be easily attached to a standard refrigerator was needed.

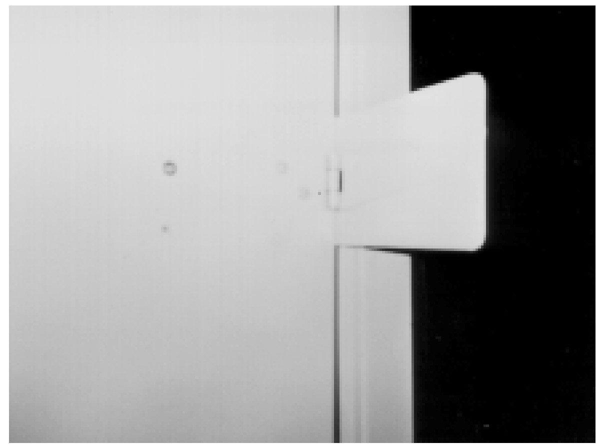
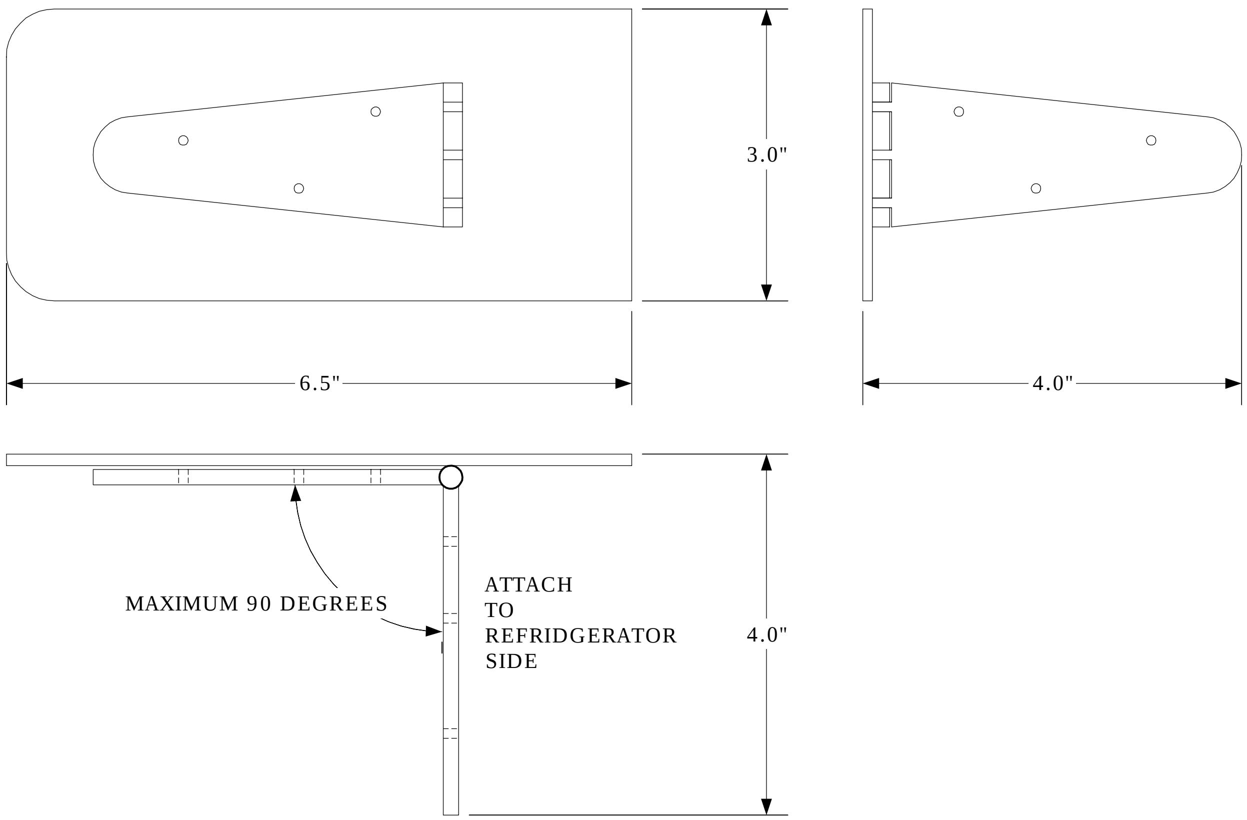


Figure 12.17. Installed Refrigerator Door Adaptation.

TECHNICAL DESCRIPTION

The main design requirements of this refrigerator adaptation were that it be inexpensive, simple, and easy for a person in a wheelchair to use. It is composed of a hinge and an arm. The hinge used is a 4" zinc strap hinge. One arm of the hinge is affixed with plastic steel epoxy to a 3" x 6.5" piece of 22 gauge weld steel (Figure 12.17). The edges of the steel are filed and rounded to prevent injury to the user. The device is attached to the side of the refrigerator with three 1.5" stainless steel screws.

The final cost of the device is approximately $10.



Figures 12.18. Mechanical Drawing of the Refrigerator Door Adaptation.

MODIFIED TRICYCLE AND WAGON FOR CHILDREN IN WHEELCHAIRS

Designers: Melissa Melton and Anna Whitehead
Client Coordinator: Lynn Anfinson
Special Education Coordinator, College Station Independent School District
Supervising Professor: W.A. Hyman
Department of Biomedical Engineering
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INTRODUCTION

Two existing pieces of playground equipment at a local elementary school, a rickshaw cart attached to a tricycle (Figure 12.19) and a wagon (Figure 12.20), were modified for use by students in wheelchairs. were improved. The rickshaw and wagon were fitted with a bicycle seat and highchair seat, respectively, so children with limited motor skills could safely use both toys. These additions provide extra support and security to passengers, with increased lumbar support and a safety belt restraint.

Figure 12.19. Modified Tricycle.

SUMMARY OF IMPACT

Three pre-school aged children at a local elementary were unable to participate in playground activities because they were confined to wheelchairs. The modified tricycle rickshaw and wagon were designed for safe play during use with the assistance of a classmate. A child rides in the attached seat of the tricycle or wagon as a classmate pedals or pulls.

Figure 12.20. Modified Wagon.

TECHNICAL DESCRIPTION

Tricycle Assembly

A child's bicycle seat was centered and balanced on a rickshaw cart attached to a tricycle. A 5/16" drill bit was used to drill two holes through the rickshaw cart, corresponding to the existing holes in the bicycle seat. Two 5/16" bolts with nuts and washers were used to attach the seat to the cart.

Wagon Assembly

The four screws holding the seat cushion to the frame were removed. Detaching the seat allows the frame to be easily accessible. Two ¼" holes were drilled through the chair frame, one in approximately the middle of each side bar.

Two 2" x 4" planks (pieces 1 and 2) with a length of 12" were placed perpendicularly onto a 1" x 2" plank (piece 3) with a length of 12.5". This construction allowed the chair to be placed in a slightly reclined fashion. Four 1/4" holes were drilled through the wooden frame, two on each side, approximately 2" from the each end (Figure 12.21). Corresponding holes were drilled into the wagon near the back. One

¼” hole was drilled through pieces 1 and 2, corresponding to the holes in the chair frame.

To attach the high chair seat to the wooden frame two bolts (1/4” x 2.5”) are positioned downward in the chair frame and hammered, so the bolt heads are flush with the frame. Four bolts (1/4” x 3”) are positioned downward in the wooden frame. The four original screws in the chair frame are tightened to reattach the cushion. The two bolts in the chair frame are placed in the corresponding holes in the wooden frame and secured with a ¼” nut. The four bolts in the wooden frame are placed in the corresponding holes in the wagon and secured with a ¼” nut, which allows all components to be maximally tightened.

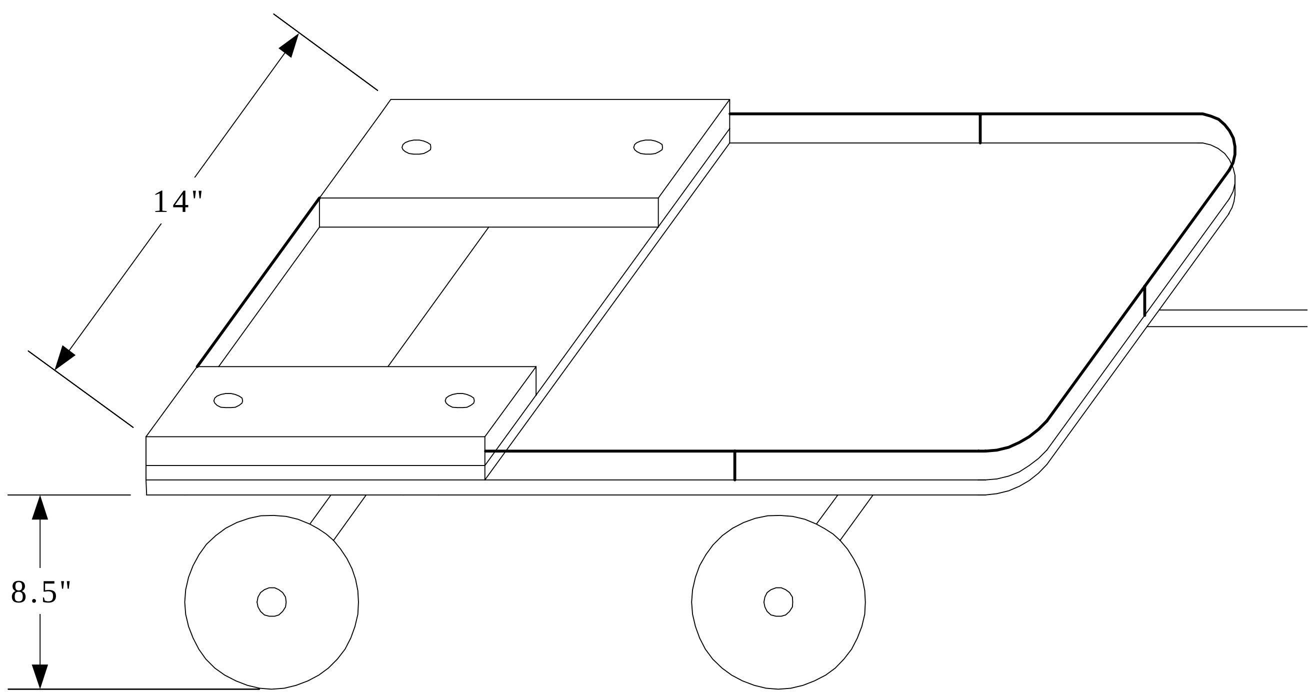

Figure 12.21. Wagon with Attachment Sites for Carrier Seat.

COLLAPSIBLE REHABILITATION STEPS

Designers: Price Bradshaw III and Robert Meltzer
Client Coordinator: United Cerebral Palsy of Houston
Supervising Professor: W.A. Hyman
Department of Biomedical Engineering
Texas A&M University
College Station, Texas 77843

INTRODUCTION

A set of collapsible steps was designed for children with cerebral palsy. It consists of a large box containing two sets of smaller nested boxes (Figures. 12.22). The outside box is mounted on casters for storage and transport. These five boxes create a set of five steps - three up and two down (Figure 12.23).

SUMMARY OF IMPACT

These steps are designed to assist children with motor problems learn to accommodate stairs. The steps can simulate regular stairs when the boxes are placed so that they begin at an elevation of 6" and increase 6" with each step. They can be used as an obstacle course when placed at varied distances apart, allowing the child to negotiate different riser heights and stride lengths.

TECHNICAL DESCRIPTION

The design requirements of the device were that it: 1) be lightweight, so that it could be easily transported; 2) be small enough to fit into the trunk of an average car; 3) have casters for easy transport; 4) be sturdy enough to hold adults; and 5) be safe.

The steps have three main components: a large box and two sets of smaller nested boxes. The boxes were constructed out of 3/4" plywood, each with four faces. The largest measures 24" x 16" x 18", the middle boxes 21.5" x 8" x 12", and the smallest 20" x 8" x 6". The largest box has four casters and a brass handle attached to opposing 16" x 18" rectangles. Strips of anti-slip traction tape were applied on the walking surface of all five boxes. All boxes were assembled with wood screws and can be combined into a single nested unit with four bolts and wing nuts. The boxes were coated with tung oil to preserve the wood and increase durability. Four casters were added to help improve transportability.

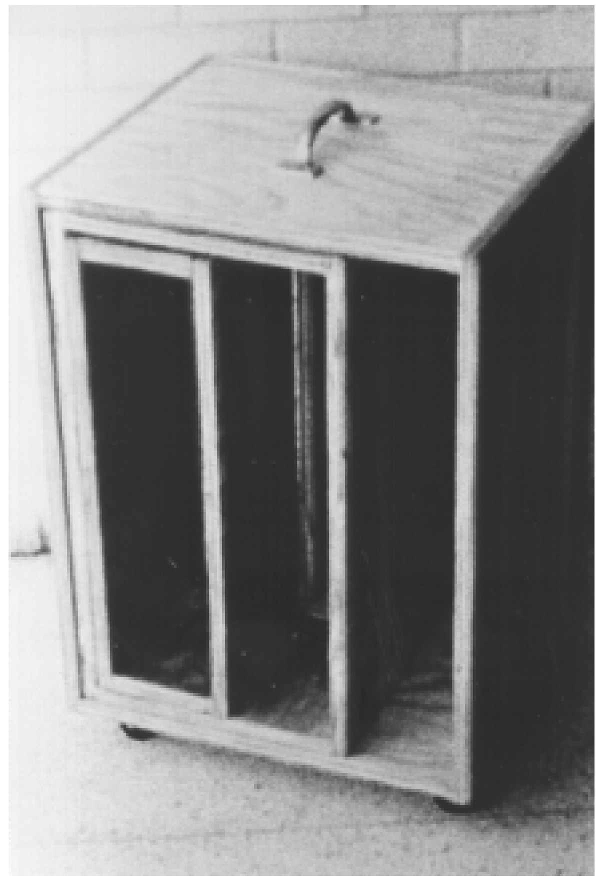

Figure 12.22. Nested Steps.

Although the collapsible unit is small enough to fit into the trunk of a car, it is too heavy to be easily carried because of the ¾” plywood used for rigidity and durability.

The total project cost was approximately $75.00.

Figure 12.23. Steps Expanded for Use.