Build Instructions for LEGO: MINDSTORMS Course:
Wishmaster

Step 1: Setting Up

Safety:
Please observe all safety procedures recommended when using power tools.

Beginning Organization:
Please refer to the Bill of Materials for materials purchased/used to build this course. It would be prudent to read this entire document before beginning the building. There are Final Notes at the end as well as a few suggestions contained herein.

Tools used to build this course:
Power Drill
Jigsaw
Table Saw
Compound Miter Saw
Tape Measure
Pencil

Additional notes:
Be aware of the width of your saw blades before cutting. 1/8" tolerances can become a nightmare when you realize your saw blade is actually ¼" wide.

Step 2: Cutting Lumber

Mark all your lines and align your board properly otherwise you will have a crooked cut. Double-check your measurements.

Baseboard:
We used a table saw to cut our 15x32" sheet of plywood down to size. First: Measure 78" from one end of the sheet. Be sure to mark at multiple points so that you can draw a cut line that is straight.

Walls:
Be careful of your measurements: A 1"x12"x8' piece of whitewood is not 1"x12." The actual measurements are .75" x 11.25". We were sure to center our measurements, but that is because of 1/8" tolerances for the actual course. For simplicity sake: I will refer to the boards as 1"x12" and when they are split as 1"x6".

We will start with the 6" walls: Using the table saw, split one 1"x12"x8' board lengthwise down the center. Then, measure out the proper wall lengths needed on each of your now 1"x6"x8' boards. I suggest doing these cuts 1 at a time. Measure a length, then cut it, then measure the next length.

Lengths needed:
14.25" 19.50" 20.00" 23.50" 39.00" 43.75"
Take the 1”x12”x6’ board and measure out three segments for cutting:

22.75”  29.50”  4.00”

* As shown, we were forced to extend our 12” high wall out farther. If there was sufficient material, I would suggest extending the 29.50” board another 5”. However, this would also change the dimensions of the attaching boards.

Be sure not to use the second 1”x12”x8’ board. That entire board will be needed for the next step.

Finally: Turn the remaining 1”x12”x8’ board into:

Cut off 20.50” from one end and set that to the side.
Next, measure to the center of the remaining 75.50” board. It should be about: 5.63”
Then, from the center measure in 23” on either side. Leaving 29.5” of 12” high board in the center.
Cut along the lines using a circular and/or jigsaw to achieve the cuts shown.
The last boards you need to cut are the small sections and angled wall for the fish tank.
Please refer to the drawings and pictures for how to cut the boards.

Finally: Cutting the holes for the 2” blocks:
Refer to the drawings for exact dimensions on the holes and placement.

**Ramp Boards:**
The ramp is built with both the plywood and whitewood.

For the whitewood, cut a piece that is:
8.5"x11.5"
For the plywood, cut two pieces:
1. 12.5"x11.5"
2. 19"x11.5"

**ECU and Hopper:**

Hopper:
The hopper is built with both the plywood and whitewood.

Whitewood:
X2: 10.5" x 5 5/8"
X2: 9.75" x 5 5/8"
X2: 10.5" x 11.25"

Plywood:
X2 10.5" x 2.75"

ECU:
Plywood:
X2: 4.5" x 4.5"
X2: 5" x 11.5"
4.75" x 11.5"
5" x 5"

Extra pieces: There will be scrap left over after cutting these boards out. You will need to save it. We used small plywood board cuttings to mount our servos for the hopper. We also used remaining scrap whitewood to create supports for our ramp. There are also the pedestals that hold the 3 block game pieces.

Fish: Nemo is outlined in actual size in the drawings. Print out a copy of the drawing and cut out a piece of whitewood to the stencil. Using the whitewood, we rounded off the corners with a wood file and made the top and bottom flatter so it could be placed upright on the course.

Pedestals: Using scrap wood, we created extra supports for the blocks in the Wall-E section of the course. They are dimensioned in the drawings and we simply glued them on with wood glue.

Blocks: Dimensions in the drawings. We filed out the holes in the walls of the course so that any block could fit in any hole easily. The blocks themselves are not filed or modified in any way.

**Step 3: Putting it Together**
All fasteners are the 1 5/8" drywall screws that are in the Bill of Materials unless explicitly stated otherwise.

**Part 1: Putting on the walls**
We took our baseboard and flipped it over, then we drew lines on the back that *mirrored* how the walls were supposed to attach on the top side. Then we pre-drilled holes into the baseboard along those lines.

Next: Take two sawhorses (or the edges of two tables) and place the baseboard on top of them. Then, having one person hold the wall in the correct position, drill in from the bottom through the pre-drilled holes in the baseboard. Insert your drywall screws to secure.

For additional strength, we inserted a screw between many of the wall joints to strengthen the course overall and also added a scrap metal support near the fish tank supporting the walls in the middle of the course.

**Part 2: Building and attaching the ramp**

Your 8.5"x11.5" whitewood piece is the platform. The ramp is supposed to be 4.75" high. Therefore: you will need to cut supports for it that are 4" high as the whitewood is .75" thick. We cut our supports out of scrap whitewood, making them about an inch and a half wide so that we could drill through them without them splitting.

We cut 4 supports for the whitewood platform. A piece for each corner of the whitewood. Be sure to angle the supports with the correct orientation.

Note: Here is how we aligned the ramp: As the ramp begins at the start of the 11.25" high wall facing away from Nemo, we laid our boards out starting there to determine where the center went. Be sure to raise your boards to the proper height, as the angle will shorten the distance of actual placement.

Once that is complete, place your supports along the edge of the outer course wall and secure them to the course. We drilled in from the side of the course, effectively securing 2 of the supports to the side of the course. You may do this for the inner side of the ramp supports, but we did not. Next, place the whitewood platform on top of the supports and secure it to them.
Part 3: Building, and attaching, the ECU and Hopper.

Hopper:

We used an approximately 9”x9” piece of cardboard covered in foil tape as the hopper door.

The walls are constructed out of whitewood:
X2: 10.5” x 5 5/8”
X2: 9.75” x 5 5/8”
and fastened together to create a 10.5” x 10.5” box.

Next is attaching the mounts to the box:

The plywood is used as a spacer to gain the desired width for the hopper mounts. Place the two plywood pieces in between the hopper and mounts which should be located on opposite sides of the hopper. Pre-drill the plywood and mount the supports 1.5” up the hopper sides so that you have a remaining 9.75” height on your 10.5” x 11.25” mounts.

Next, we mount the door to the servo.
We used a Futaba 3000 servo as our motor. Applying hot glue, we cut two cardboard squares large enough to cover the motor head and glued them onto the servo. Then, we grooved the 9”x9” cardboard door to fit over the servo and hot glued it on. Then covered the entire assembly in foil tape for aesthetics and stability.

Finally: Mount the door assembly to the hopper.

As you can see in the pictures, we used two pieces of scrap plywood fastened to the bottom of the hopper to serve as brackets for the servo. Then we took two small scrap wood screws that fit inside the servo’s screw mounts and attached it to the plywood.

As you can see, there is also a small groove cut in the door opposite the servo and a screw is inserted into the door. We used a 1/2 staple to secure the screw and provide additional support for the door. These small modifications are to add support to the door and allow it to open smoothly. Adjust your door accordingly before securing everything for a final time to ensure the door is able to work properly.

Note: The servo only rotates 90 degrees so make sure to place it properly so that the door may open downwards.

Finally, to mount the hopper to the course, we used pegs so that it would be easy to remove. Mount the hopper 9.5” from the start of the ramp.
ECU (Electronic Control Unit):

Revolving Door:

We took an empty spiral notebook and taped on an additional piece of cardboard to make the door 12" high using foil tape.

We then used the dowel rod as our support for the door to hinge on. Sliding the spiral binder onto the dowel, we used zip ties to secure the door to the servo motor and keep the notebook on.

We made our rod approximately 18" so not to interfere with the operation of the servo. We used six AA batteries for counterweights on the opposite end of the dowel rod, securing them with duct tape. This was enough weight to offset the door and allow it to balance quite well on top of the servo.

ECU box placement:
The box is 5"x5" square, made from remaining plywood. The box is 11.5" high.

The top 2" of the ECU box is actually a mount for the servo.

Using whitewood and small screws, we mounted the servo to the top of the ECU box. The top of the servo will supply an additional .5", allowing the 12" door to swing free.

Refer to the drawings for exact placement of the ECU box on the course.

Wiring:
After placing the electronic control unit (ECU) and fastening it to the course, you are ready to run the course wiring. We used 6' of CAT6 Ethernet cable as wiring for our course (However, the CAT5e in the BOM is sufficient). Drilling holes through our bottom supports and up through the bottom of the ECU, we effectively mounted the wires to the bottom of the course.

To start, strip the jacket off about 2' the CAT5e.
Once the wires are exposed, we recommend that you run the unstripped end of the cable under the course and up through the base (we drilled a ⅝" hole in the base up through the ECU to accommodate this) and up into the ECU. Although optional, we put a cable tie at the base of the ECU on the CAT6 cable and tightened it all the way so that the cable does not get pulled through the hole once it has been placed in the ECU.

The next major part of the wiring is to connect the DuPont connectors to the CAT6 (or CAT5e) wires. This is done using the RJ11 Telephone connectors which will be referred to as “Scotch Locks” for the remainder of this document. Take 3 of the DuPont connectors (we did red, white, and black for ease of remembering where each wire goes) and cut them in half. Then, connect the female end of the DuPont connectors to three of the 6 CAT6 wire using 3 Scotch Locks (one for each DuPont/CAT6 pair). To use a Scotch Lock, put both the CAT6 wire and the DuPont connector in as far as they can go into the Lock. Then, using pliers, push the button down as far as it will go. DO NOT STRIP THE WIRES BEFORE PLACING THEM IN THE LOCK.

Place the wires in as far as they will go.

It does not matter which wires you chose to use Scotch Locks on, you just need to remember which ones you used so that you know where the wires need to go on the ECU. (See Arduino Wiring Diagram) Next, place these Scotch Locked ends will go on the PIR sensor’s pins. The rest can be wired with CAT6 wires that are stripped at the end because the servos are all female-ended.

Next, follow the Arduino setup instructions, located in a separate file. Then use the wiring diagram to put the wires in their final place. We used a breadboard (in the BOM as optional) but you can twist the ground and the power wires together so that they fit into one pin on the Arduino.

**Final Notes:**

Our baseboard was cut too short. Instead of purchasing another piece of plywood, we carefully measured out and cut a second section of plywood to make up the difference. Using scrap whitewood and 2"x4", we spliced the extra length of plywood on and raised the entire course to keep it from being lopsided.
There are four boards, two down the edges, and two supporting the center.

Our infrared sensor was too sensitive when positioned in its original place on the course.

We cut a 1” square hole into the side of the course and recessed the placement of the sensor completely outside of the course using thumbtacks and wire anchors. We then covered the outside of the sensor and added an additional wall to prevent unwanted triggering.