The Duckietown Operation Manual

Contents

This book describes the Duckietown appearance specifications and assembly instructions.

Specifications are a set of rules for which a functional system has been verified. This means that if these rules are followed while building a Duckietown, Duckiebots will work as expected.

Any Duckietown not adhering to the rules described here cannot be considered a Duckietown, and may cause the Duckiebots operating within them to fail in (possibly spectacularly) unexpected ways.

Small perturbations to the appearance specifications might affect negatively the performance of Duckiebots, although most algorithms are robust to variations.

Introduction

Functionally, Duckietown cities are an integral part of the robotic ecosystem we call Duckietown.

Duckietown cities are designed to communicate information to the Duckiebots, so these can operate effectively.

Duckietown cities are *modular*, i.e., they are composed of fundamental building blocks that can be combined to create nearly arbitrary city landscapes.

Duckietown cities are built in layers. Each layer sends information of increasing complexity to the robots operating in it. The layers are, namely, the: *floor*, *signals*, and *smart infrastructure* layers. “Non-functional” elements compliment the construction of every Duckietown.

Layer - Tilemap

The `tilemap` layer is the one defining the road network, i.e., the nodes and edges of the road system where Duckiebots will drive in.

Duckietown roads are obtained by applying colored lane markings to a black background.

Duckietown cities are a concatenation of fundamental building blocks. We often refer to these block as *tiles*, because of the medium we assemble them upon: foam “puzzle” tiles.

Each tile has rigorously defined geometry and color pattern and represents one road element: `straight`, `curve`, `3-way` intersection, `4-way` intersection and `empty` tile. These road elements are positioned in specific orders to create compliant Duckietowns. The road elements are shown in Table 1.

> **Note**
>
> Road markings convey important information to the Duckiebots:
>
> - delimiting the lanes (white and yellow markings), and
> - identifying stop signs (red markings).

> **Note**
>
> The left turn and right turn tiles are symmetric: one is the 90 degree rotation of the other.

Each tile is square and measures `61 cm x 61 cm` (`2 ft x 2 ft`) from the outer edges of the interlocking dents. The thickness of the tiles is not as important as the surface roughness, as long as the tiles are thick enough not to buckle. Tiles are used to guarantee a good grip between the Duckiebots and the road, to minimize slipping of the wheels.

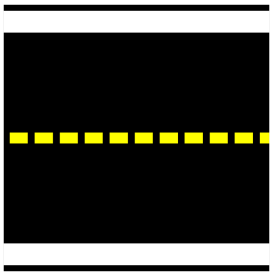


Fig. 1 The straight tile

Fig. 2 The left curve tile

Fig. 3 The right curve tile

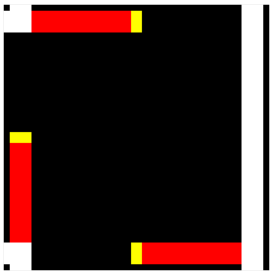


Fig. 4 The 3-way intersection tile

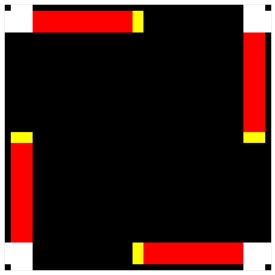


Fig. 5 The 4-way intersection tile

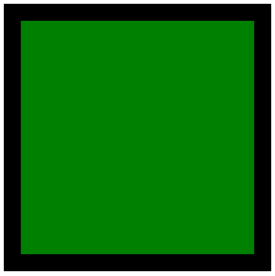


Fig. 6 The empty tile

Table 1 The principal tile types in Duckietown

> **Note**
>
> - Empty tiles are not actually green, but have a black backround as all other tiles. We represent them as green here (recalling grass) to clearly distinguish them from road tiles.
> - The empty tiles can be of covered with, e.g., felt of any color. We discourage using the same colors as the road markings (red, white and yellow) or any material with reflective surface to minimize disturbances to the Duckiebots.

For tiles to become road elements, we need to apply road markings. Road markings can be obtained through the application of tapes of different colors and sizes.

Tapes

There are 3 colors of tapes used in Duckietown: **white**, **yellow**, and **red**. All tapes used should have a matte surface.

The `white` tape

> **Proposition**
>
> A Duckiebot on a road never collides with Duckiebots or other Duckietown elements if it never crosses or touches a white tape strip.

Here are some facts about the white tapes:

- White tapes must be solid (not dashed);
- The width of the white tape is roughly **4.8 cm** (1.88 inches);
- The white tape is always placed on the right hand side of a lane. We assume that the Duckiebots drive on the right hand side of the road.
- For curved roads, the white lane marker is formed by five pieces of white tape, while the inner corner is formed by three pieces, placed according to the specifications in the image below, where the edge pieces are matched to adjacent straight or curved tiles (Fig. 7).

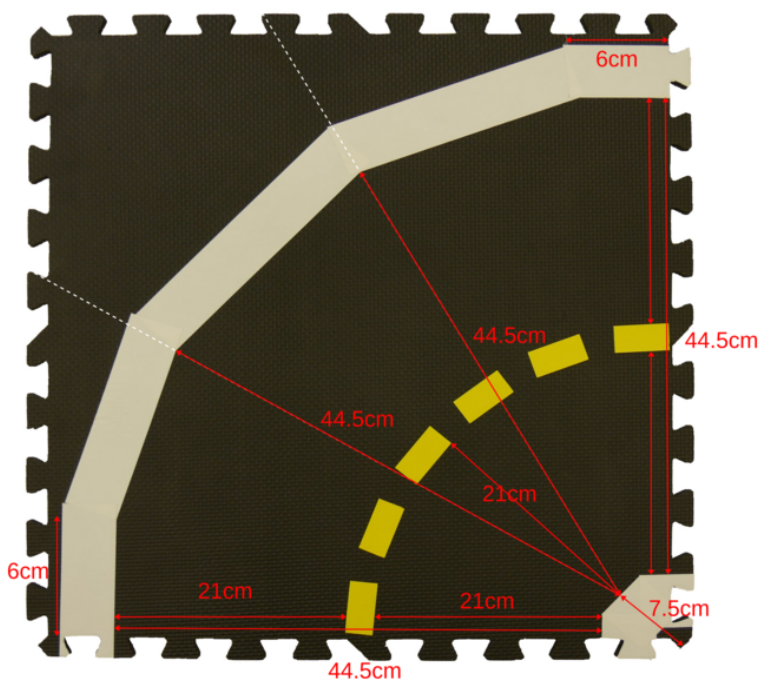


Fig. 7 The specification for a curved road tile

The `yellow` tape

Here are some facts about the yellow tapes:

- Yellow tape must be dashed (not solid);
- Each piece should be **5 cm** long and placed with a **2.5 cm** gap between each piece;
- The width of the yellow tape is roughly 2.4cm (0.94 inches);
- The yellow tape is always placed on the left hand side of a lane, i.e., in the center of the road. We assume that the Duckiebots drive on the right hand side of the road.

Yellow tapes on curves: see curved road image (Fig. 7) in white tape section. Pieces at tile edges should be in center of lane, piece at the middle of the curve should be approximately 21 cm from middle of inner center white piece of tape, with approximated circular arc in between.

The `red` tape

Red tapes MAY **only** appear on **intersection** tiles.

The width of the red tape must be the same as the white roll (roughly 4.8cm or 1.88 inches) and should cross the entire lane perpendicular to the road.

The placement of red tape should always be **under** yellow and white tape, as shown, e.g., in Fig. 9 or Fig. 10.

A Duckiebot navigates Duckietown by a sequence of:

- Navigating one or more straight tiles until a red tape appears,
- Waiting for the coordination signal,
- Executing an intersection traversal,
- Re-localizing in a straight tile.

> **Proposition**
>
> If the Duckiebot stops before or ON the red strip, no collisions are possible.

Topological Constraints During Map Construction

Here are some topological rule constraints that must be met:

1. An intersection can NOT be adjacent to a curved road tile or another intersection tile.
2. Any two adjacent non-empty tiles must have a feasible path from one to the other **of length two**: if they are adjacent, they must be connected.

Here are some examples of **conforming** topologies:

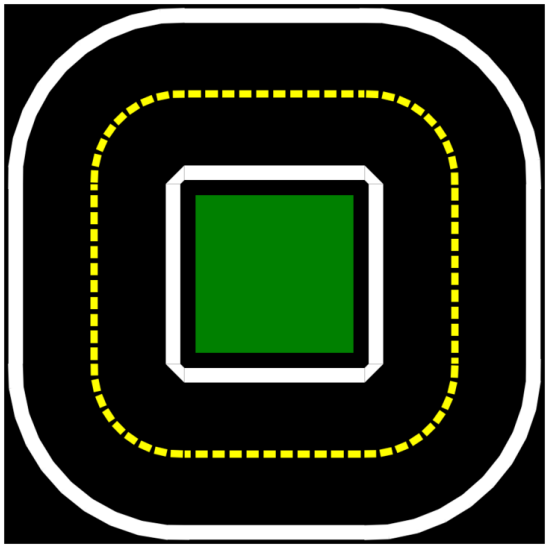


Fig. 8 A 3-by-3 city loop

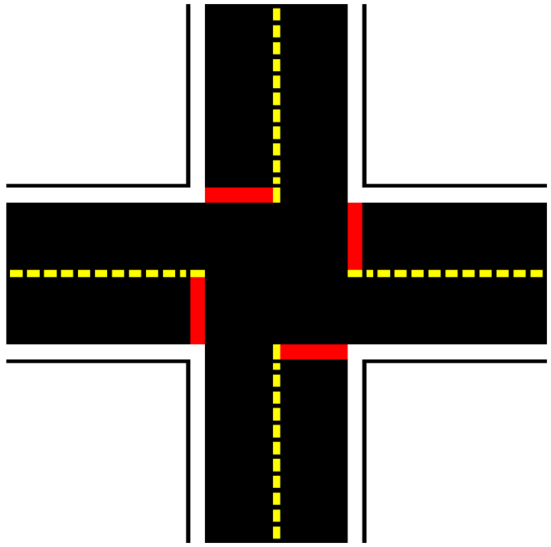


Fig. 9 Four way intersection usage

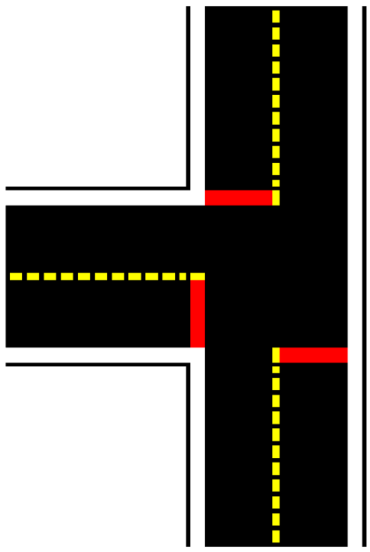


Fig. 10 Three way intersection usage

Some examples of **non-conforming** topologies are shown in the figure below.

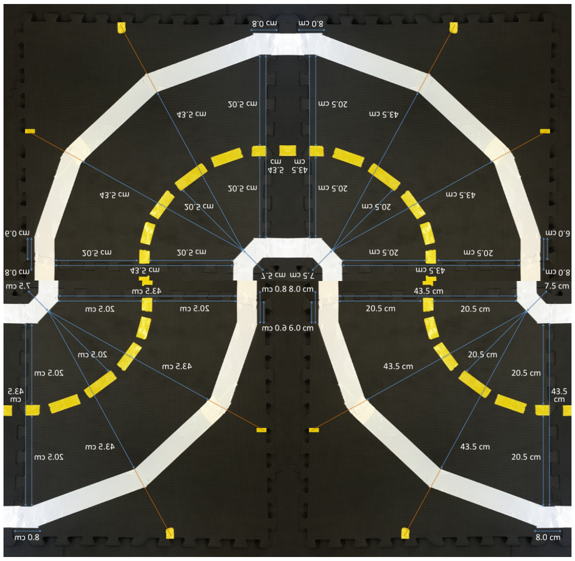


Fig. 11 Topology violates rule 2 since the bottom two curved tiles are adjacent but not connected

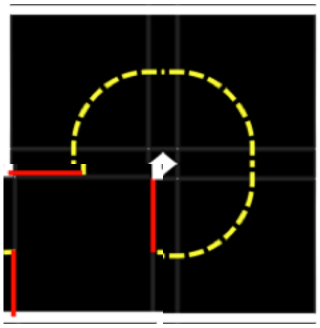


Fig. 12 Topology violates rule 1 since curved tiles are adjacent to intersection tiles

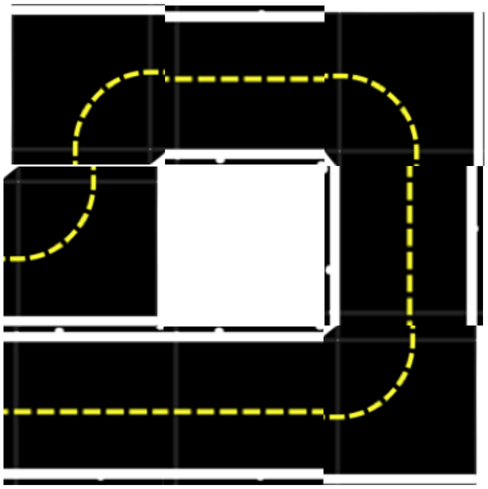


Fig. 13 Topology violates rule 2 since left-most tiles are adjacent but not connected

Layer - Traffic Signs

The signals layer is made of traffic signs.

Traffic signs sit on the road layer, outside the lanes, and can serve multiple purposes.

> **See also**
>
> The full set of currently existing signs is available here.

Functional purposes

Some examples of uses of traffic signs that have a function (these functions are encoded in some Duckietown legacy behaviors):

> **Note**
>
> Traffic signs:
>
> - identify the type of intersection (3- or 4-way);
> - identify the position of the Duckiebot at the intersection;
> - inform the Duckiebot of the coordination mechanism for this specific intersection (centralized or decentralized).

Non-functional purposes

Traffic signs can be used for other purposes (these functions are not encoded in any Duckietown out-of-the-box behavior):

> **Note**
>
> Traffic signs can moreover be used for:
>
> - naming roads (and making the department head proud);
> - identifying pedestrian traffic areas;
> - identifying parking lots.

Traffic signage in Duckietown is obtained through the union of traffic signs and `AprilTag` visual markers, as shown in Fig. 14.

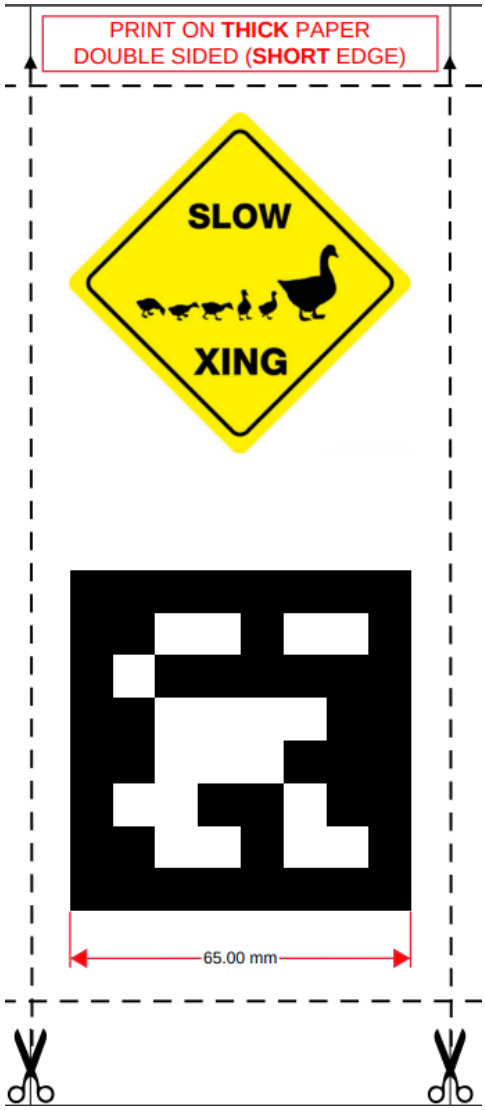


Fig. 14 A traffic sign in Duckietown (do not print this one out!)

We call the symbol above *traffic sign*, while the code below is an AprilTag.

> **Note**
>
> To print and assemble the signs refer to Assembly - Traffic Signs.

Specifications

For traffic signage to be compliant:

- The center of the traffic signs is 13 cm height from the floor layer;
- The AprilTag is 6.5 cm sq.;
- There is a white border of roughly 0.8 cm around them;
- The signage stands perpendicular to the ground, and the angle of the sign with the road is 90°.
- The signal is flat (no deformation / folding) and without wrinkles. This can be obtained, e.g., by printing the signs on thick paper.

Types

The allowable traffic signs are as in Table 2.

Fig. 15 stop

Fig. 16 yield

Fig. 17 no-right-turn

Fig. 18 no-left-turn

Fig. 19 do-not-enter

Fig. 20 one-way-right

Fig. 21 one-way-left

Fig. 22 4-way-intersect

Fig. 23 right-T-intersect

Fig. 24 left-T-intersect

Fig. 25 t-intersection

Fig. 26 pedestrian

Fig. 27 t-light-ahead

Fig. 28 duck-crossing

Fig. 29 parking

Table 2 Duckietown Traffic Signs

Placement

Signs may appear on the opposite side and at the corner of the adjacent tile from which they are viewed. In the absence of any signs, it is assumed that all network flows are allowed so a sign MUST be placed and visible whenever this is not the case.

Signs must only be placed on empty tiles, or next to one of the other tile types if on the border of a map. As mentioned, it is important to not overlap the base of the sign stand with any road marking.

The sign placements for four different cases are shown in Table 3. At intersections, from each stop line 2 signs should be clearly visible:

1. the intersection type (traffic light or stop sign)
2. the intersection topology (3-way with correct orientation, or 4-way).

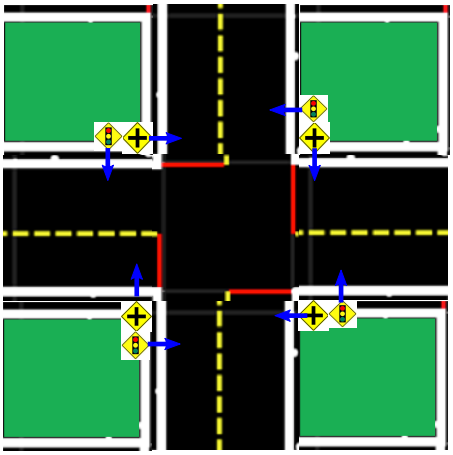


Fig. 30 4-way intersection

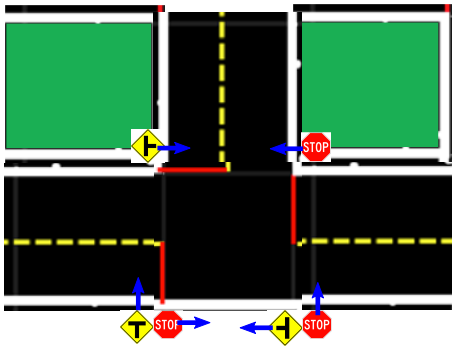


Fig. 31 3-way intersection

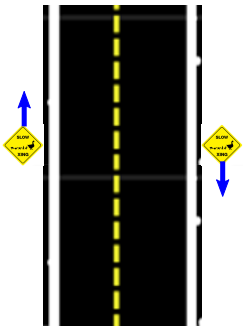


Fig. 32 straight road

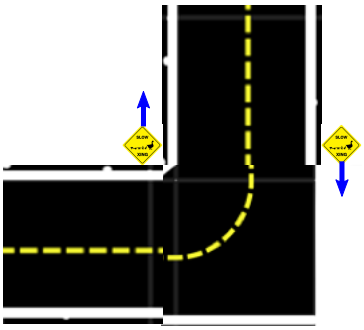


Fig. 33 curved road

Table 3 Placement of Traffic Signs

On straight and curved roads, additional signs can be added as desired. Their placement is indicated in Fig. 32 and Fig. 33. The signs should be placed at the border between two tiles and should face towards oncoming traffic as indicated.

In these figures the arrow is the direction of the sign.

Traffic signs - Street Name Signs

> **Attention**
>
> The traffic sign type described here is experimental. Use at your own risk!

Street names are non functional (i.e., they are not hardcoded in any Duckiebot behavior), but can add a pleasing outreach element to the city.

> **Tip**
>
> Especially if you are an Assistant Professor, you should consider dedicating the main avenue of your Duckietown to your Department Head.

Specifications

- Font: Arial.
- Alphabet = English upper case. Different writing systems may need different algorithms.

- Color: white as foreground and green as background.
- Border: no additional borders.
- Width: Currently 4.5 in for id 500-511. (**6.1 in +1.1 in "ST" or 5.5 in + 1.7 in "AVE"**)
- Text direction: Horizontal for alphabetical languages.

Placement

Street name signs should be placed outside of the allowable driving region. The street names should be visible from both sides of the road.

If you chose to adopt signs, every segment of road must have at least one road name sign.

Every turn tile should have a road name sign.

The placement of the road name signs is as indicated in Table 4).

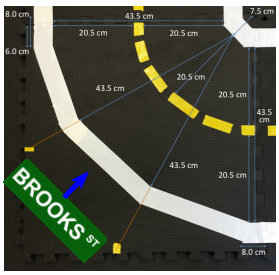


Fig. 35 Straight

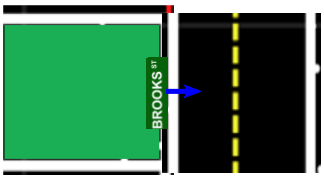


Fig. 34 Turn

Table 4 Placement of Road Name Signs

Street name signs should never be perpendicular to the road - they are too big and obtrusive.

Layer - Infrastructure

The infrastructure layer is made of:

- traffic lights, and
- watchtowers (legacy instructions, work in progress new instructions).

Infrastructure elements sit on the tilemap (floor) layer, outside the lanes, and interact with the Duckiebots in town.

Traffic lights and watchtowers are proper robots: they have computation, sensing, memory and actuation capabilities. As such, they can be programmed to exhibit behaviors, including communication with other agents.

The most fundamental behavior of a traffic light is to signal (stop and go) to the Duckiebots at intersections.

The most fundamental behavior of watchtowers is to localize Duckiebots and communicate their position to other agents.

A network of watchtowers is the first step to building a Duckietown Autolab (legacy operation manual, work in progress manual).

> **Tip**
>
> If this is your first read-through you may ignore Watchtowers. If you are planning on upgrading your Duckietown to an Autolab at any point in time, remember that traffic lights can be used as part of the Watchtowers network.

Infrastructure - Traffic Lights

Duckietown traffic lights are more than just blinking lights: they are static robots. We sometimes refer to traffic lights as “Duckiebots without wheels” because they originally had similar capabilities to the `DB18` Duckiebot models, less that to move.

Traffic lights are urban robots that can sense (e.g., the arrival of a Duckiebot) through a camera, run computation on the onboard Raspberry Pi, and communicate with other agents though the LEDs, and WiFi network.

> **Tip**
>
> (For advanced Duckietowners only) Traffic lights are particular cases of Duckietown Watchtowers, i.e., Watchtowers with LEDs. Watchtowers are the building blocks of Duckietown Autolabs.

Assembly

The assembly instructions for traffic lights can be found here:

- Traffic light assembly instructions,
- Legacy traffic light assembly instructions,

Placement

Traffic lights are typically placed over the diagonal direction of intersection tiles. Any intersection is allowed to have a traffic light.

> **Note**
>
> The lights must be at a height of 20 cm above the center of the intersection tile.

The computational stack of the traffic light is mounted in the appropriate housing, and placed outside the allowable driving region. The cabling is designed to be housed in the appropriate structure as detailed in the assembly instructions. The traffic light pillar stands are positioned so that the embedded traffic signs match their appearance specifications.

Fig. 36 A Duckietown-compliant traffic light.

Decorations

Non-functional objects like decorative buildings, sit on the floor layer of empty tiles. They are non-functional when used exclusively for decorative purposes.

The citizens of Duckietown love their cities colorful and fun, and encourage all efforts at adding non-functional components to the empty space.

A great starting point for a more visually pleasing Duckietown are colored felts to simulate grass or bodies of water. Any other contraption that would please the population is welcome, too.

> **Caution**
>
> 1. Make sure the placement of your decorations does not interfere with the tilemap and signals layers.
> 2. Choose colors that Duckiebots do not give meaning to. E.g., avoid red, yellow and white.
> 3. Choose materials that do not reflect light, and you will save many hours debugging algorithms.

Moreover, although Duckiebot drivers all have their driving licenses and know to focus on the road, the *background*, i.e., whatever is in the room the Duckietown was assembled, matters too.

Assembly - Road Tiles

What you will need	• Knowledge of the Duckietown Appearance Specifications

	• Materials: compliant tiles, white, yellow and red road markings (Duckietown project shop) • Tools: scissors (or a sharp cutter) and a ruler
What you will get	• You will have tiles that comply to the Duckietown operation standards • You can move on to Assembly of other components

Before we begin

> **Tip**
>
> To ensure that your streets will last long, make sure to follow these:
>
> - Clean the tiles with a cloth and some water and soap before attaching any tape.
> - Place the yellow tape on the tile and cut out pieces rather than pre-cutting them and attaching them to the tile as glue will be lost if you do not directly place them at the intended spot.

Straight roads

Each straight road segment has:

- Solid white markings on the outer sides of the lanes (right of direction of travel)
- Dashed yellow markings at the center
- Each lane is 21 cm wide (from end of white to beginning of yellow)

Assembly

Start by placing the yellow tape in the middle of the tile as shown in Fig. 37.

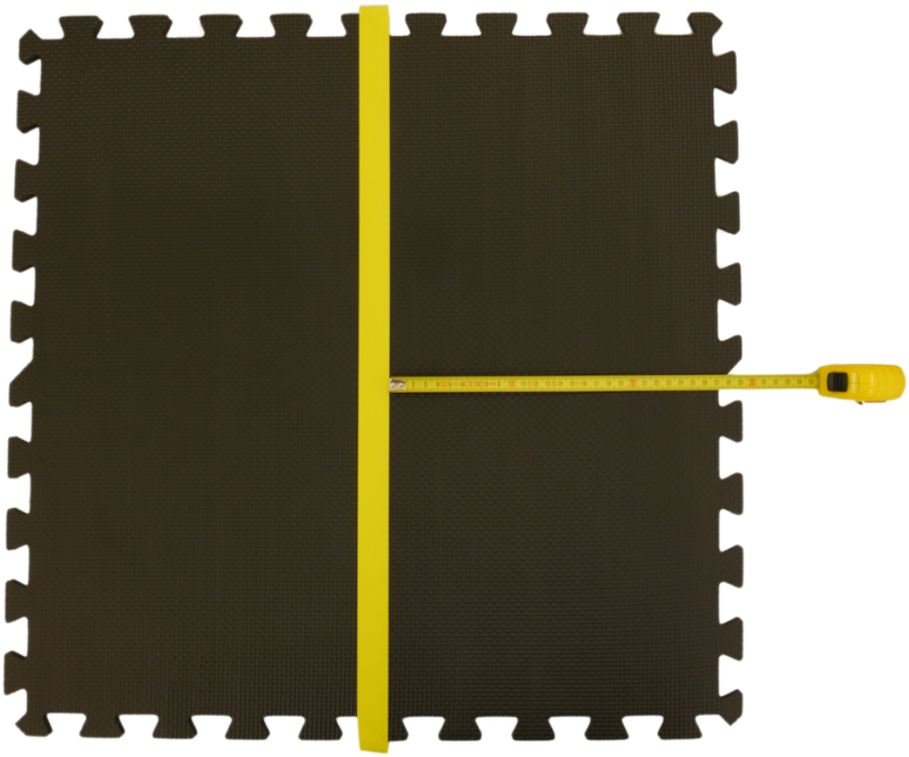


Fig. 37 Placement of the yellow middle lane in the center of the tile.

Make sure that the yellow tape is properly centered on the tile. The tile has a nominal width of 57cm without the interlocking teeth. This means from the end of the yellow tape to the end of the tile there should be a distance of 27.25cm as can be seen in Fig. 38.

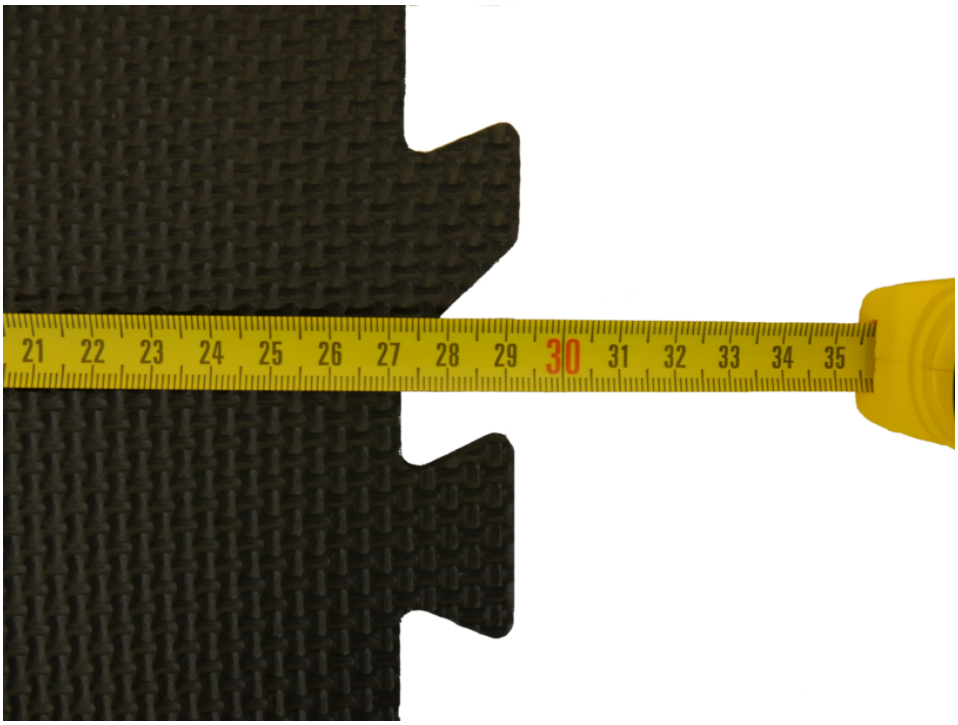


Fig. 38 Measurement from end of the yellow tape to the edge of the tile.

Once you have placed the yellow tape, cut out pieces of 2.5cm each, starting 5cm from the outer edge of the tile without the interlocking teeth (as shown in Fig. 39). Next, place the white lane markings at the outer part of the tile in a distance of 21cm to the end of the yellow tape. The Result can be seen in Fig. 39.

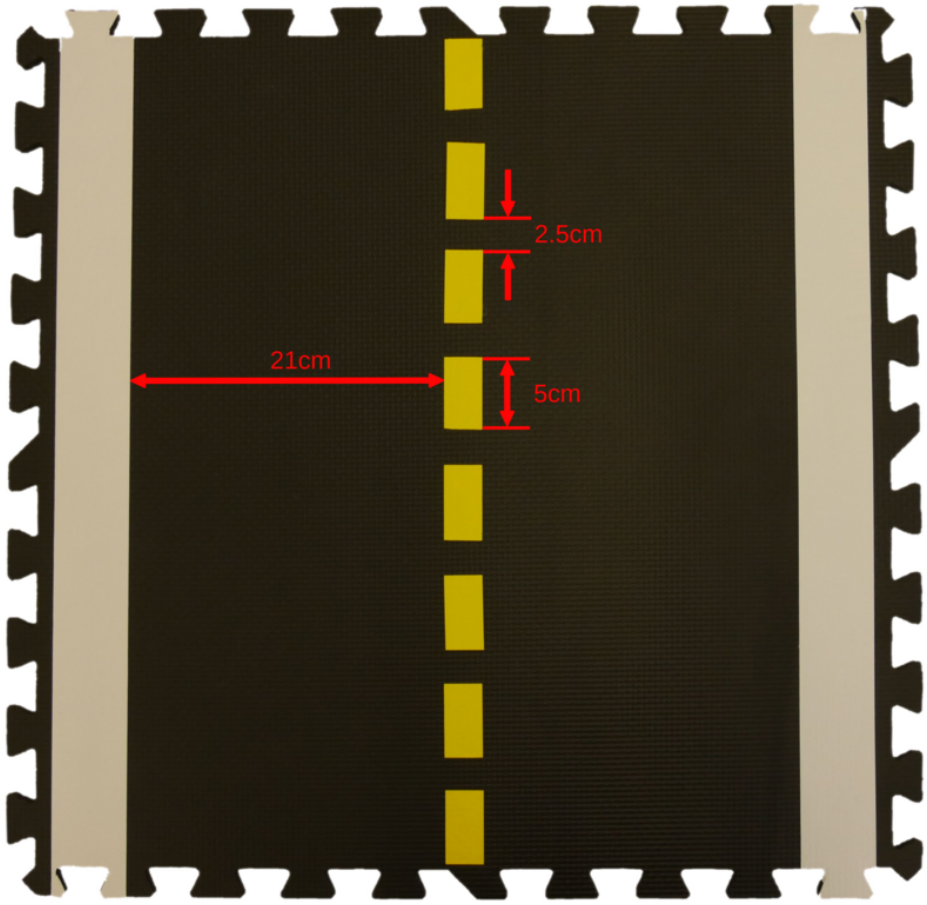


Fig. 39 Finished straight road segment with measurements.

Curved roads

Each curved road segment has:

- Solid white markings on the outer sides of the lanes (right of direction of travel)
- Dashed yellow markings at the center
- Each lane is 21 cm wide (from end of white to beginning of yellow)

Assembly

If you have a laser cutter available, you can use the provided file from here to laser cut the template shown below.

If you do not have access to a laser cutter, you have to create the middle line by hand. One way to do it is to take a string, place one end in the outer edge of the tile (excluding the interlocking teeth) and make small markings in the form of a quarter circle in a distance of 27.25cm. This represents the inner border of where you have to put the yellow tape. The length of the single tape pieces is 5cm as for the straight road segment. For more detailed measurements, refer to Fig. 7.

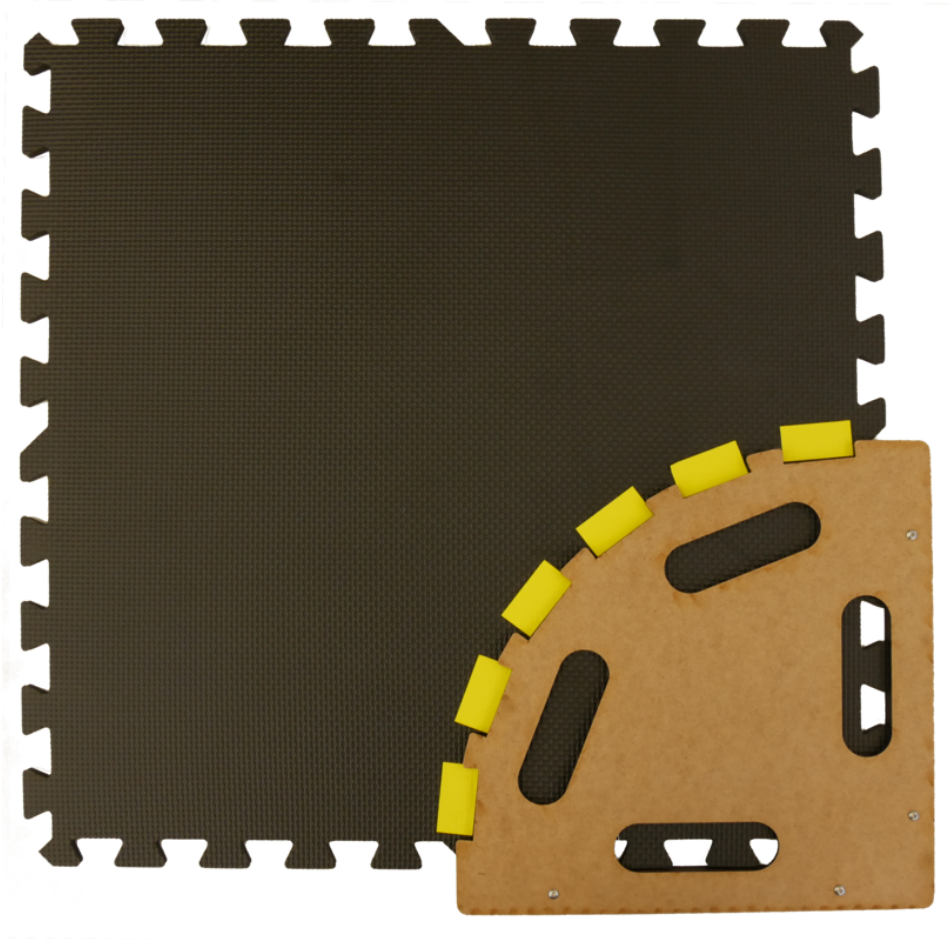


Fig. 40 Placement of the yellow tape.

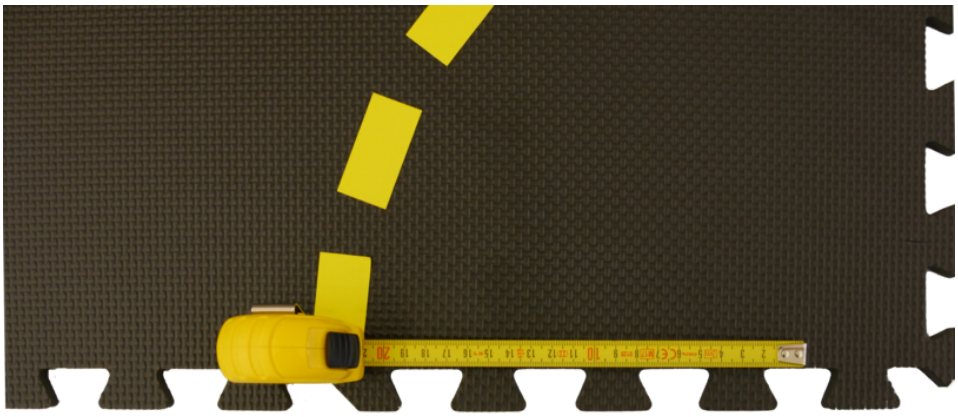


Fig. 41 Measurement of lane width.

Once you have the middle of the lane in place, you are ready to add the inner white line of the road. Make sure that the lane width is 21cm.

Fig. 42 Measurement of lane width and white tape placement.

To add the outer white line you can either use another template from above or you will have to measure again. You can use the same technique as for the yellow middle line: place one end of a rope in the edge of the tile and draw a quarter circle with a radius of 50.75cm which will represent the inner boundary of the white tape. Alternatively, you can mark the lane width of 21cm at different locations and place the white tape accordingly.

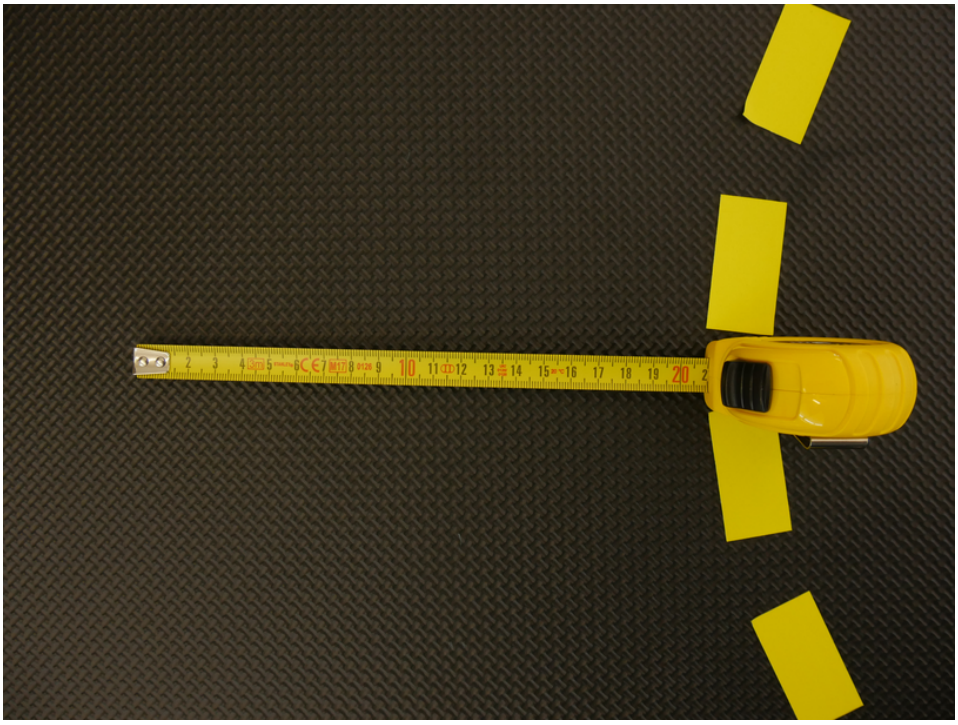


Fig. 43 Measurement of lane width.

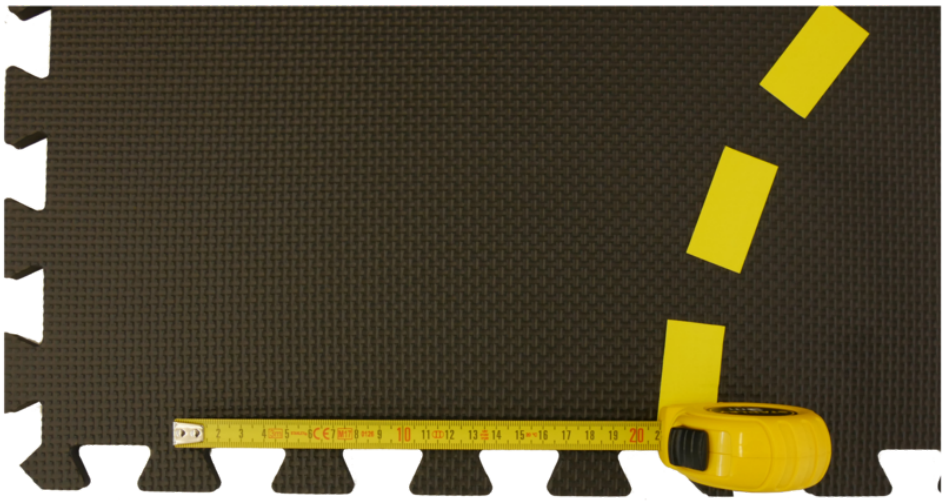


Fig. 44 Measurement of lane width.

Fig. 45 Measurement of lane width.

The finished curved lane segment looks as in Fig. 46

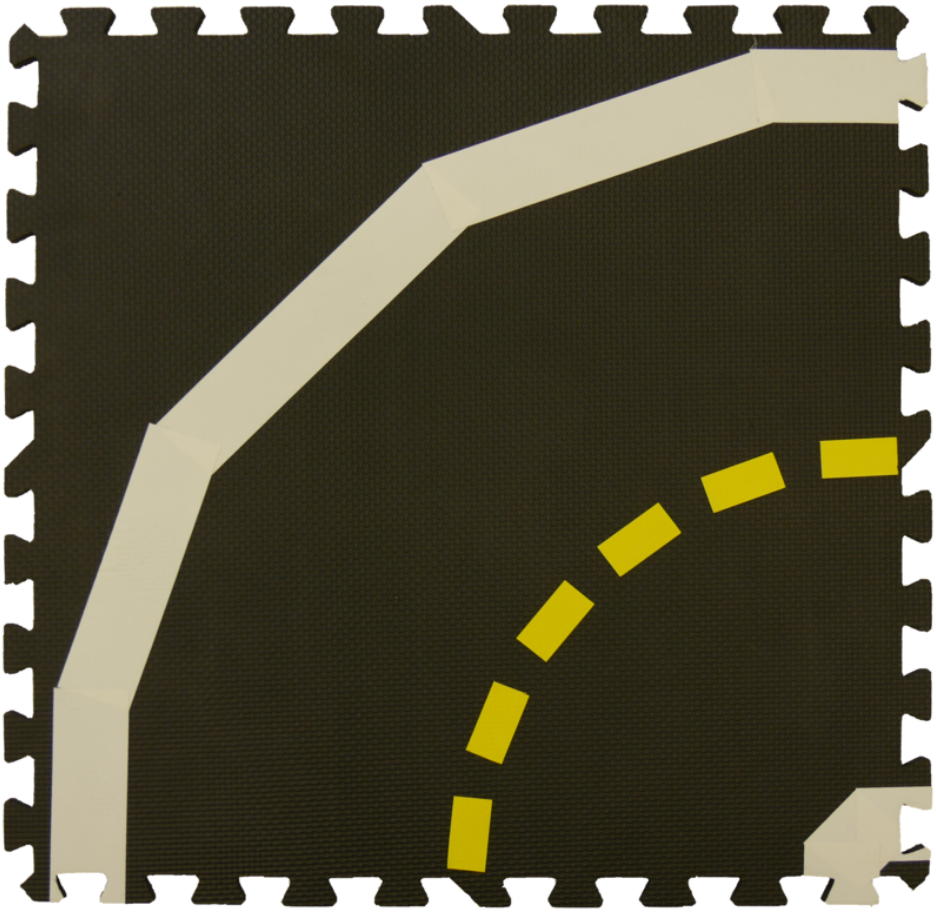


Fig. 46 Finished curved road segment.

Intersections

Each intersection road segment (3- or 4- way) has:

- Solid white markings on the outer sides of the lanes (right of direction of travel)
- Dashed yellow markings at the center
- Each lane is 21 cm wide (from end of white to beginning of yellow)
- Solid red markings as stop signs

Assembly of 4-way intersection

First, place four yellow tape strips as shown in the pictures below. Make sure that they are centered on the tile and that they reach in 6cm from the beginning of the tile without the interlocking teeth.

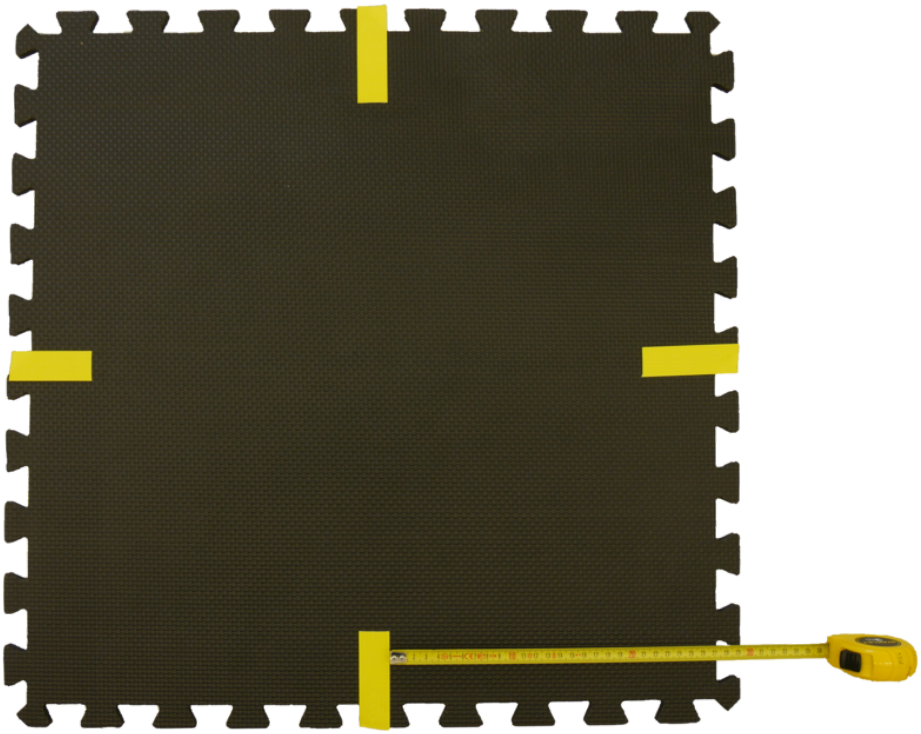


Fig. 47 Placement of the yellow tape.

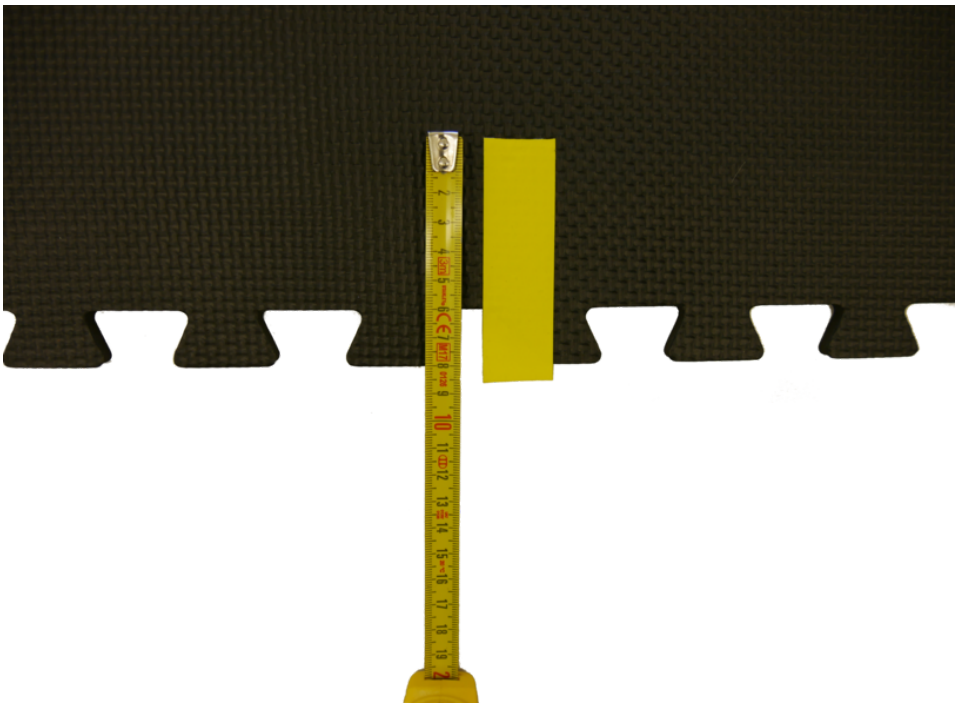


Fig. 48 Placement of the yellow tape.

Now place the red tape aligned to the yellow tape. Ensure that the red tape is horizontally aligned with the edge of the tile and 21cm long.

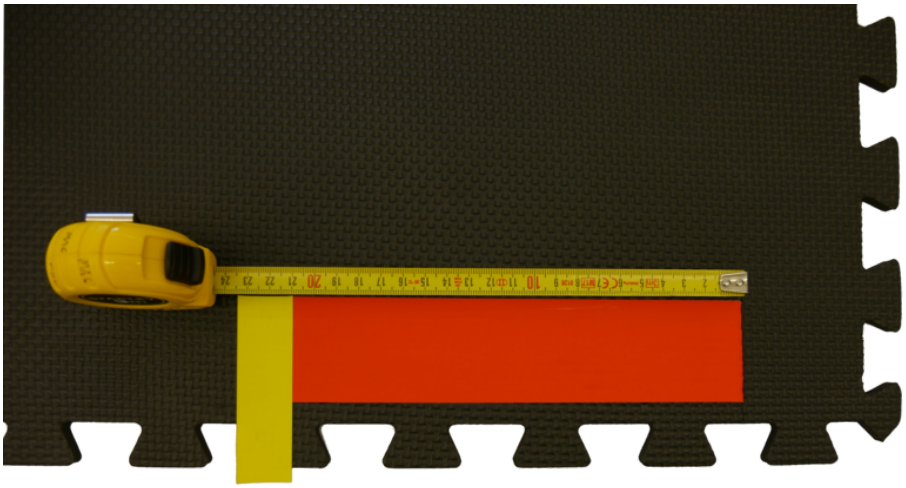


Fig. 49 Placement of the red tape.

Repeat this for the other edges of the intersection.

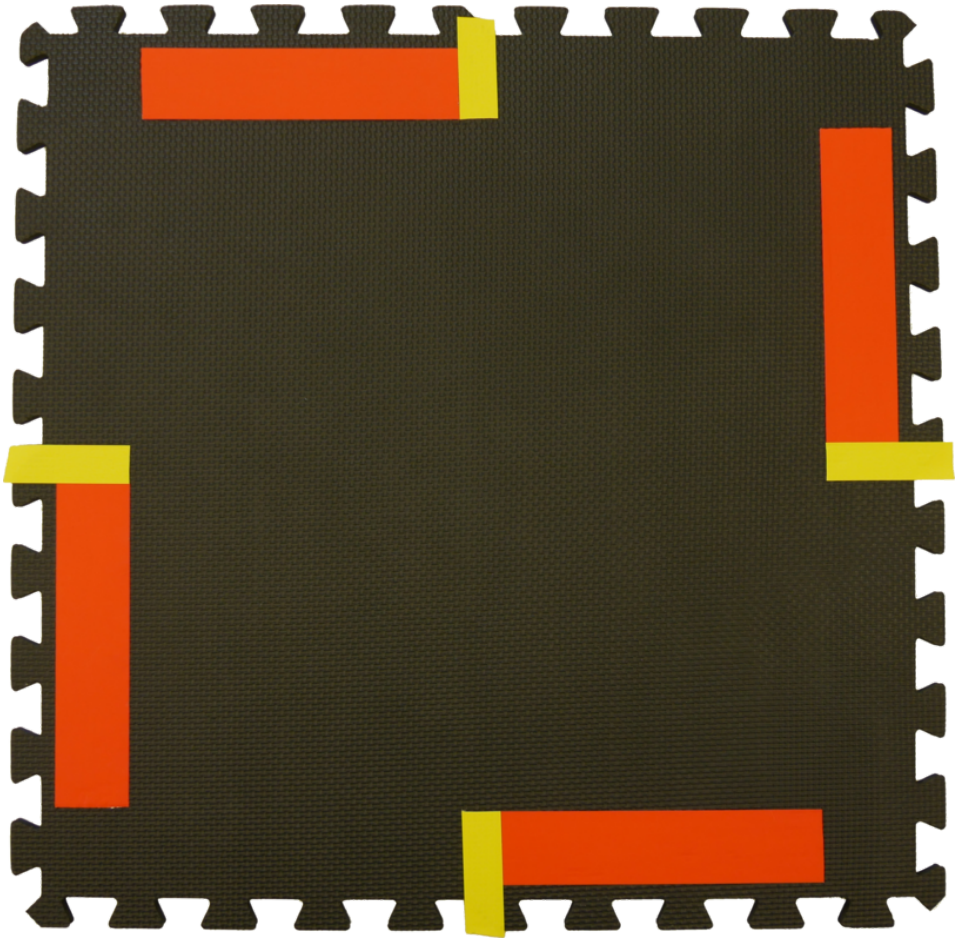


Fig. 50 Placement of the red tape for whole intersection.

Cut the yellow lane markings to a length of 5cm.

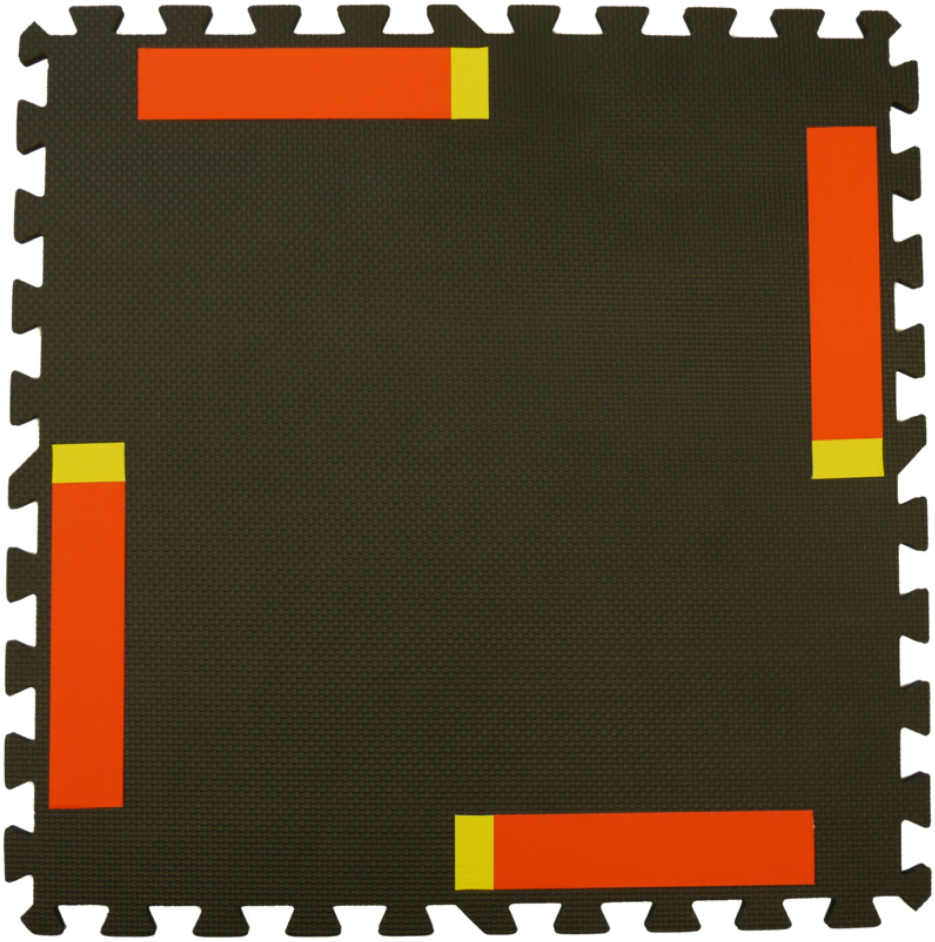


Fig. 51 Yellow tape cut to 5cm length.

Finally, add the white tape on the sides. Do this for all the corners of the intersection.

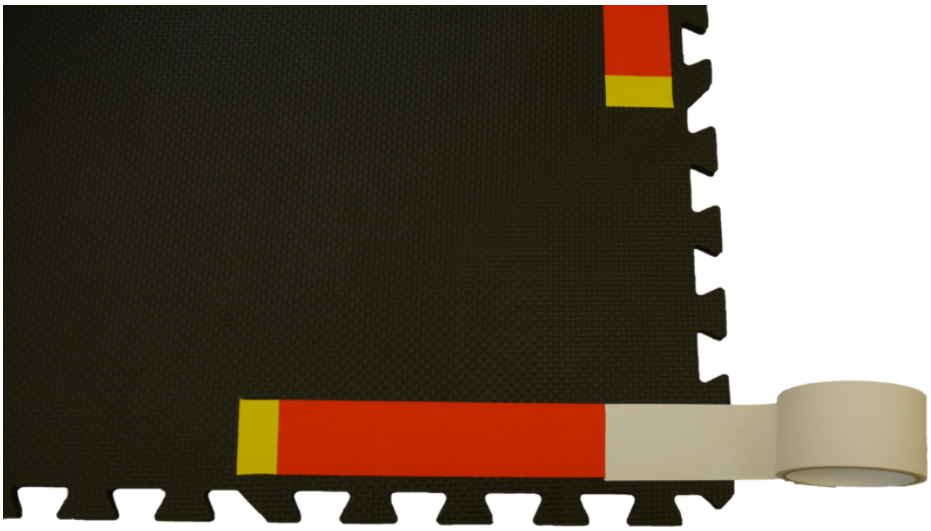


Fig. 52 Placement of the white tape.

The finished 4-way intersection lane segment looks as in Fig. 53

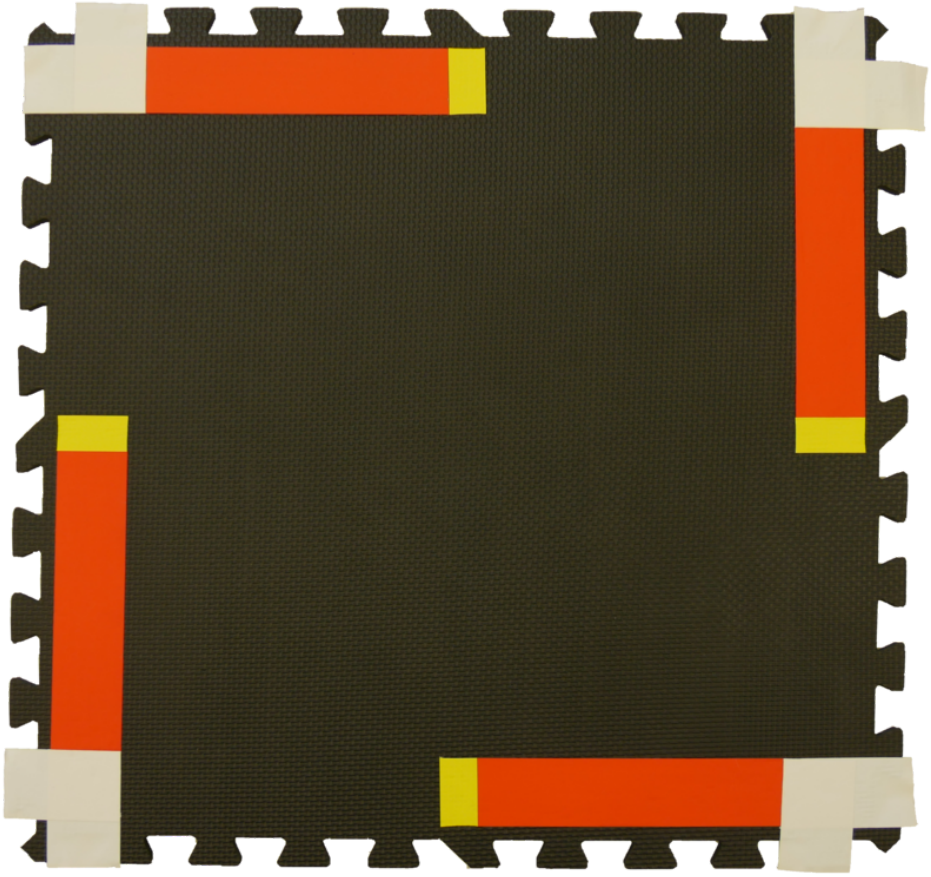


Fig. 53 Finished 4-way intersection road segment.

> **Tip**
>
> You don’t have to cut out the edges of the interlocking teeth from the white tape. Just use the overlapping tape to connect the road segment to the surrounding tiles nicely.

Assembly of 3-way intersection

3-way intersections are built the same way as 4-way intersections with the difference that on one edge white tape is placed instead of red and yellow. The resulting 3-way intersection can be seen in Fig. 54.

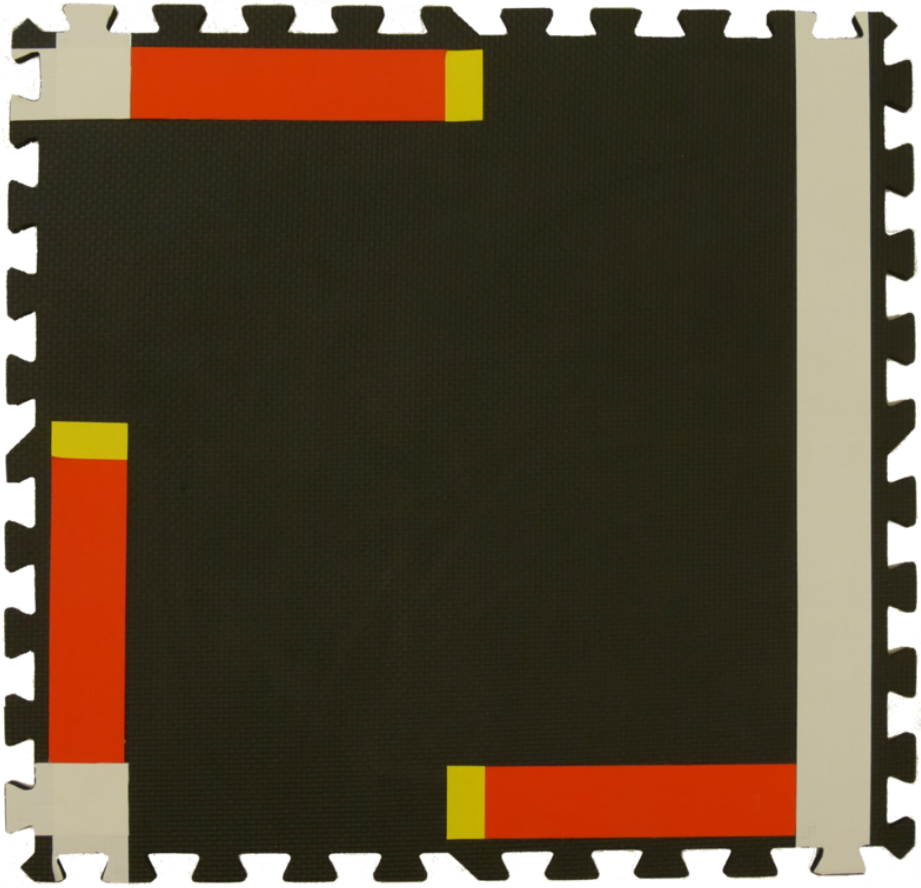


Fig. 54 Finished 3-way intersection road segment.

Troubleshooting

Troubleshooting	
SYMPTOM	My tape tends to detach from the tiles. The glue is no good.
RESOLUTION	Make sure you follow these steps: 1. clean the tiles with a water and alcohol solution to remove residual oils before placing the tapes, and dry them completely 2. apply the tape directly to the tiles and cut it on site, rather than using an intermediate medium 3. use a heat source, e.g., a hair dryer, to warm up the tape after the first application. The objective is to soften the glue. Once back to room temperature, the stickyness will be much improved.

Assembly - Traffic Signs

What you will need	The materials to build Duckietown signals (Duckietown project shop)
What you will get	A set of signs to be used for assembling your Duckietown.

Build a Map

Before beginning with sign assembly you should design a tilemap that adheres to the tilemap layer specifications.

The full set of currently existing signs is available here.

Making New Signage

If you find that what is available in the database in insufficient for your needs, then you will need to add to the existing database.

Clone the signs-and-tags repo:

```
git clone git@github.com:duckietown/signs-and-tags
```

The file `tag36h11.pdf` (`tag36h11.ps`) in the repo contains the tags already generated. Which tag you should use depends on what type of sign you are trying to add. The ranges of tags are specified in April tag ID ranges.

Purpose	Size	Family	ID Range
Traffic signs	6.5cm x 6.5cm	36h11	1-199
Traffic lights	6.5cm x 6.5cm	36h11	200-299
Localization	6.5cm x 6.5cm	36h11	300-399
Street Name Signs	6.5cm x 6.5cm	36h11	400-587

Table 5 April tag ID ranges

First, find the last sign of the type that you are trying to make in the `Signs_and_tags_V3.docx`. You will use the next available ID after this one.

Construct the new sign by first copying and pasting an existing sign of similar type, and then replacing/adding the new AprilTag. To add the new april tag, use a screen capture mathod to crop precisely around the tag at the top and sides and include the sign id at the bottom. Then paste the tag into your word file under your desired and resize it exactly `6.5cm` (`2.56in`).

If you make a new road name sign, you may need to change the font size of the name so that it appears on one line.

> **Attention**
>
> You must also add your new sign to the `apriltagsDB.yaml`.

Add a new block like the ones that already exists or modify the one with the appropriate tag id:

```
- tag_id: ![NEW_TAG_ID]
  tag_type: in {TrafficSign, Light, Localization, StreetName}
  street_name: either ![NEW_STREET_NAME] or blank
  vehicle_name: currently not used
  traffic_sign_type: either ![TRAFFIC_SIGN_TYPE] or blank
```

The value of `![NEW_STREET_NAME]` is up to you to decide (have fun with it!). The value of `![TRAFFIC_SIGN_TYPE]` should be one of the signs in Duckietown Traffic Signs.

When finished, regenerate the PDF version of the Word file, and commit everything to the repo (via a pull request of course).

> **Note**
>
> It is also possible of course to start you own completely different signs and tags database, but make sure that you specify in the `april_tags` code which database to load from.

Traffic Signs Assembly

Assemble the stands

A traffic sign stand consists of a laser cut structure as is show Traffic sign stand kit.

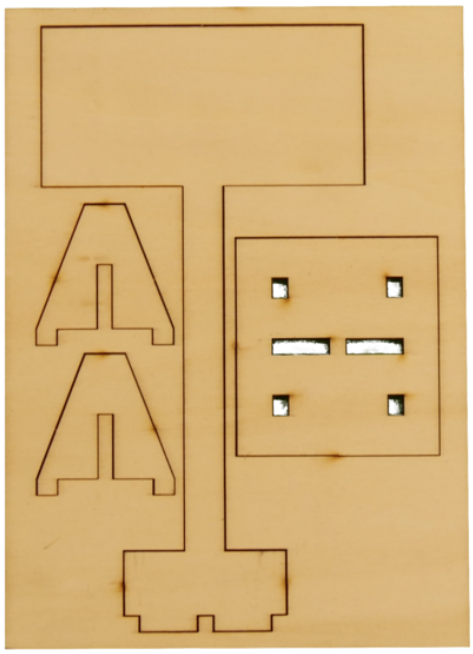


Fig. 55 Traffic sign stand kit

Detach the components from the wooden plate and plug them together as in Traffic sign stand assembled. Typically, the stands are very rigid, but if the structure seems a bit loose, use wooden glue to increase stability.

Fig. 56 Traffic sign stand assembled

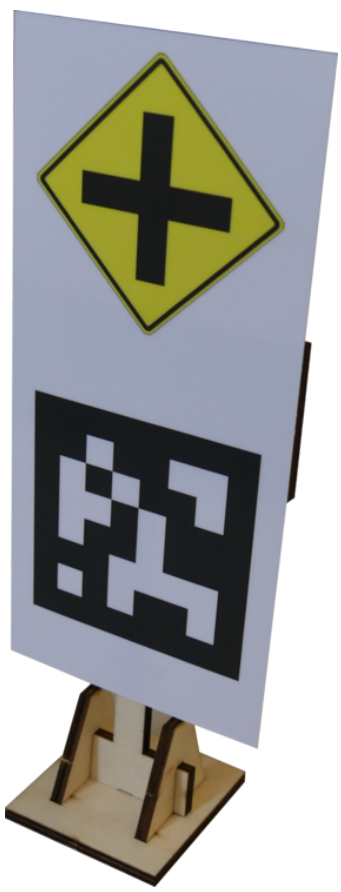


Fig. 57 Traffic sign stand assembled with mounted traffic sign

Placement

For placement of signs see [Placement](#).

Assembly - Traffic Light

What you will need	• Traffic light components (Duckietown project shop) • An appropriately configured SD-card. • Tools: (strong) wood glue or hot glue gun, tape, double-sided tape.
What you will get	• An assembled traffic light in configuration `DT21-TL` (latest) or previous legacy versions.

This section describes the physical assembly and installation of traffic lights.

Overview

Traffic lights are crucial elements of modern cities as city dwellers rely on them to have well-organized traffic. In Duckietown, traffic lights serve the same purpose.

Traffic lights can be used as centralized coordinators of traffic at three or four way intersections in Duckietown, or as elements of a Duckietown Autolab watchtower network.

> **Attention**
>
> For Duckiebots to know traffic lights are governing a certain intersection, appropriate signage must be placed at the intersection (traffic light traffic sign instead of stop sign).

- Hardware wise, traffic lights are essentially “Duckiebots without wheels”, and a beautiful, different chassis.
- They are composed of two supports connected by an overhanging tube.
- They are intended to be placed on the diagonal direction of an intersection.
- One of the supports is equipped with the computational stack and an overseeing camera.

Hardware Assembly

- For traffic lights of the **latest** configuration, please refer to this for the assembly instructions.
  - Assembly - Traffic Light DT21-TL
- For legacy build, the assembly instructions for configurations prior to `TL21` can be found in
  - Assembly - (Legacy) Traffic Light DT18-TL.

SD-card Image Preparation

Even at software level, traffic lights are essentially Duckiebots without wheels. In initializing the SD-card of your traffic light, follow the instructions here, with the extra step of using the option `--type traffic_light`.

Also, Wi-Fi configuration for traffic lights by default is not set. You can add it using the `--wifi` option as specified in the instructions.

An example flashing command for a Wi-Fi connected traffic light can be:

```
dts init_sd_card --hostname watchtower![XX] --country ![COUNTRY] --type
traffic_light --configuration TL21
```

> **Note**
>
> For Autolab users: since traffic lights will work as watchtowers adopt the convention:
>
> ```
> hostname : `watchtowerXX`
> ```
>
> where `XX` are, e.g., increasing numbers.

- However, if you just want to use it as a traffic light, use the traffic light setup:
  - hostname : `trafficlightXX`
- The default username and password are all the same:
  - Username: `duckie`
  - Password: `quackquack`

> **Warning**
>
> For Autolab users, do not change the username and password.

Launch Traffic Lights

By choosing the `robot_type` to be `traffic_light`, the blinking behaviour should happen as soon as you boot your device.

If you need to manually restart the behaviour inside the `duckiebot-interface` container, you can restart the traffic light behaviour by running, inside the container:

```
roslaunch duckiebot_interface all_drivers.launch veh:=![NAME]
robot_type:=traffic_light
```

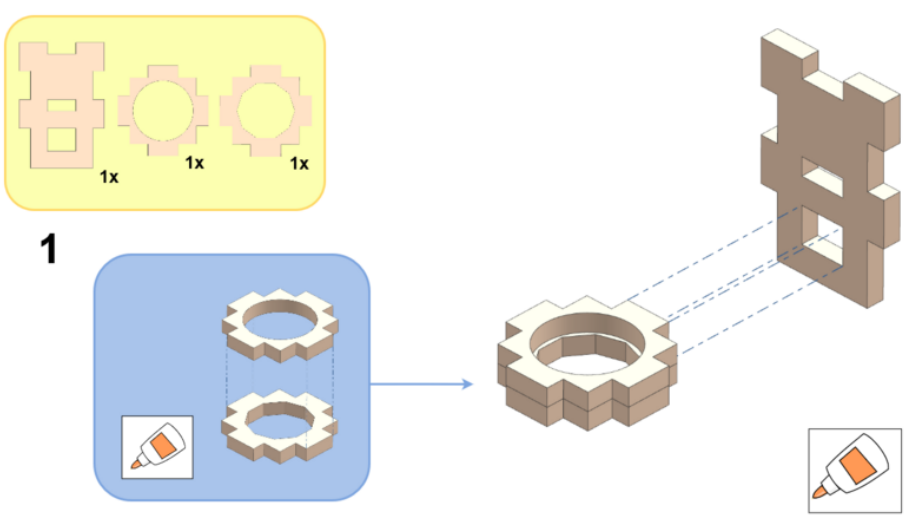
Assembly - Traffic Light `DT21-TL`

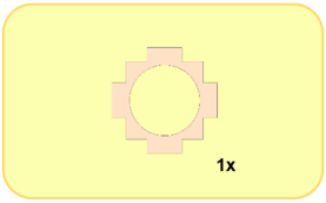
Part 1: Preliminaries and part overview

There is a small yellow box in the top left corner of each picture. This box is telling you which parts are needed to complete that assembly step.

> **Note**
>
> At times you will see a small glue icon in the yellow box. That is to indicate some parts will no longer be separated, no matter if you are building a Watchtower (WT) or a Traffic Light (TL). While actual glue might not be necessary, we recommend a rigid connection.

Part 2: Ground Structure





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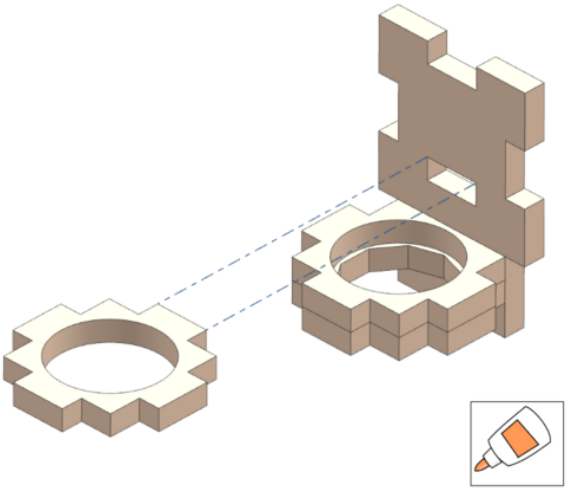

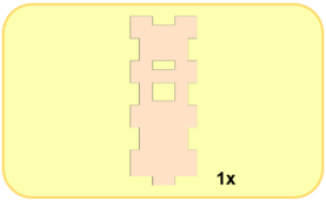

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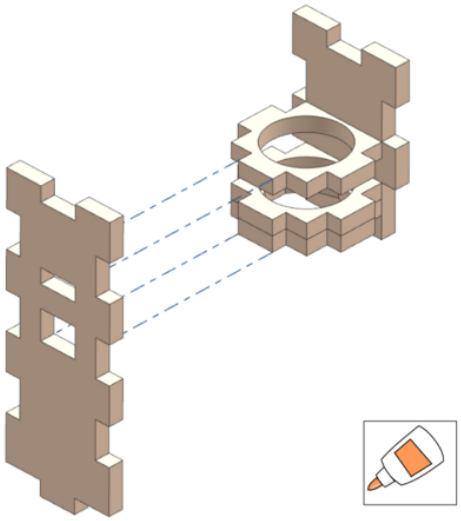

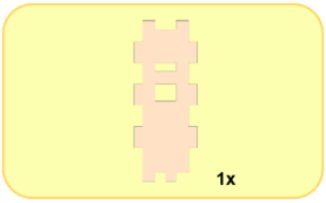

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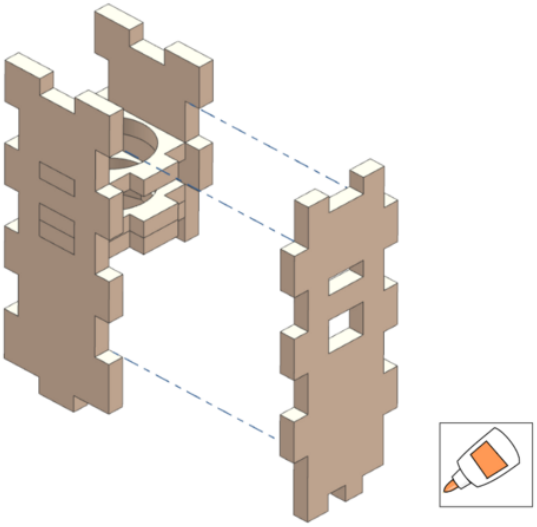

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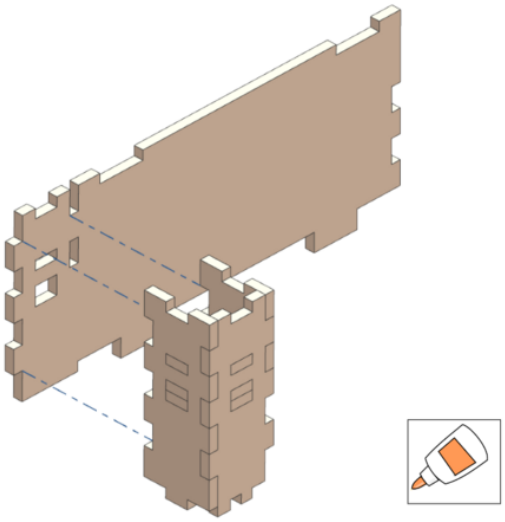

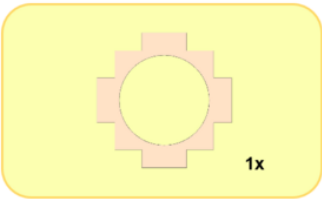

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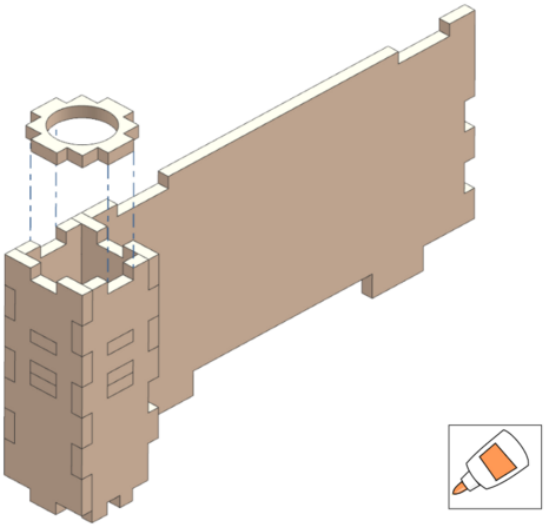

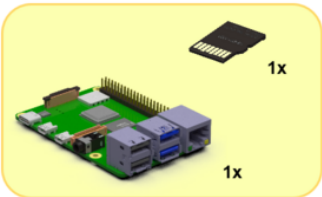

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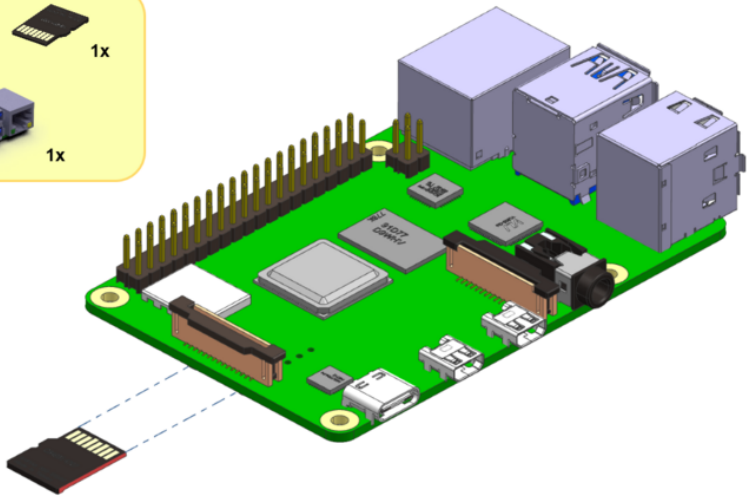

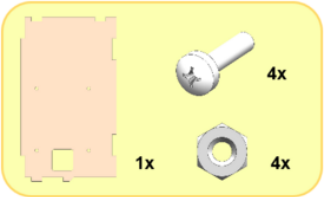

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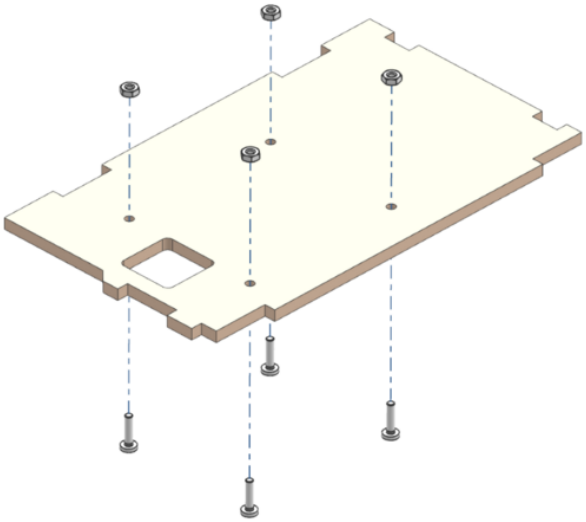

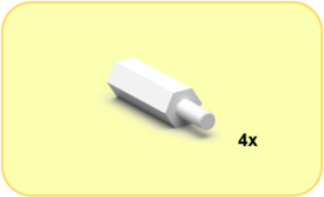

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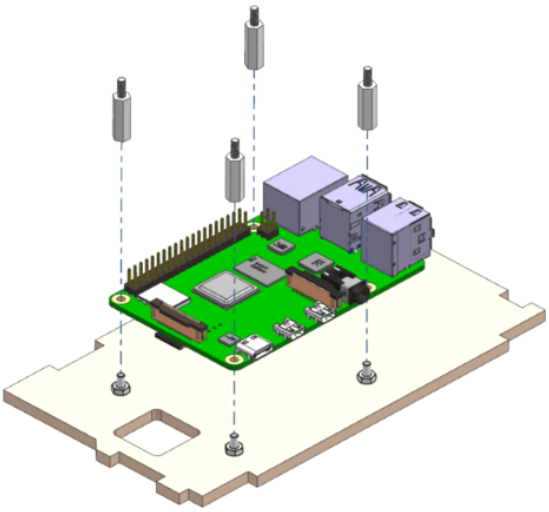

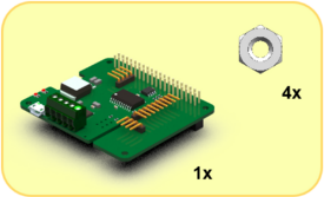

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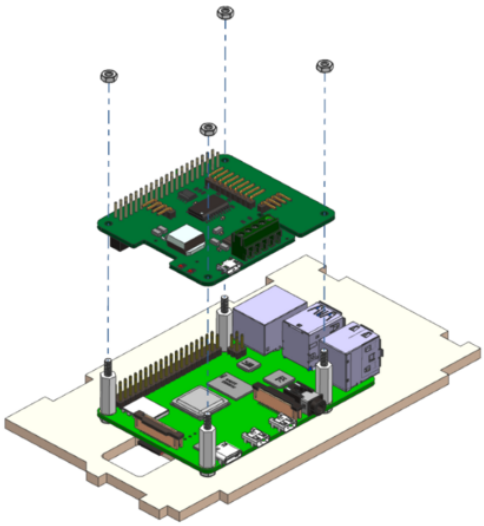

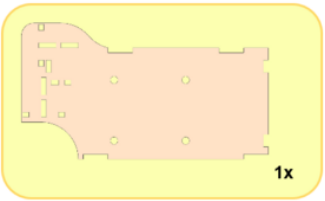

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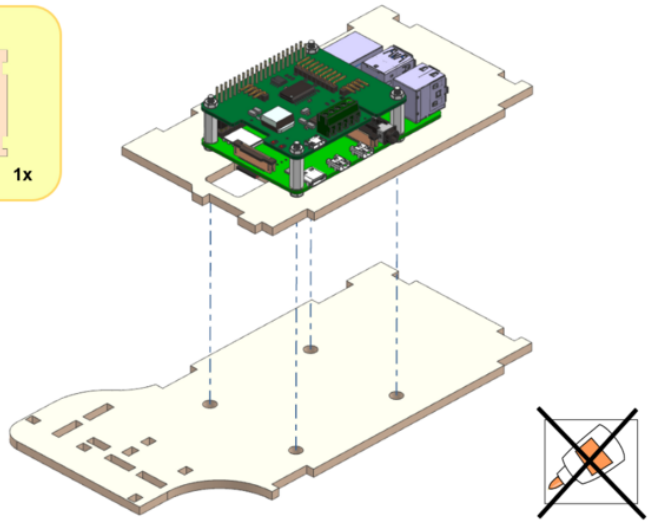

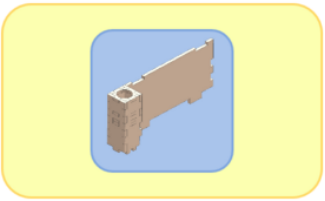

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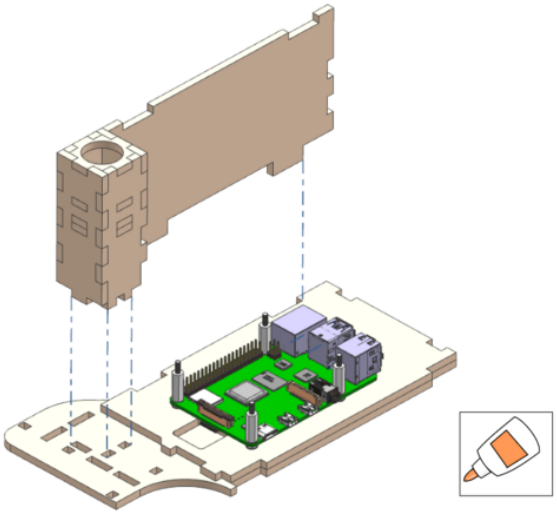

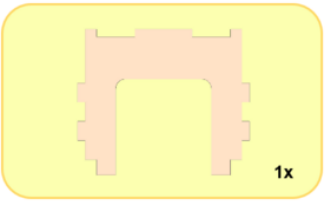

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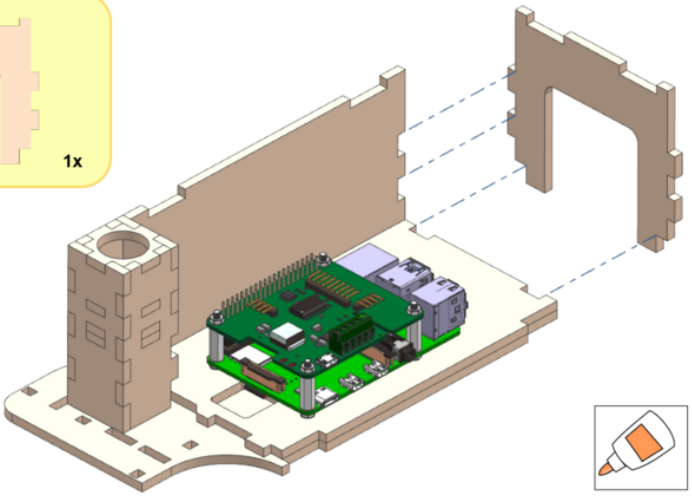

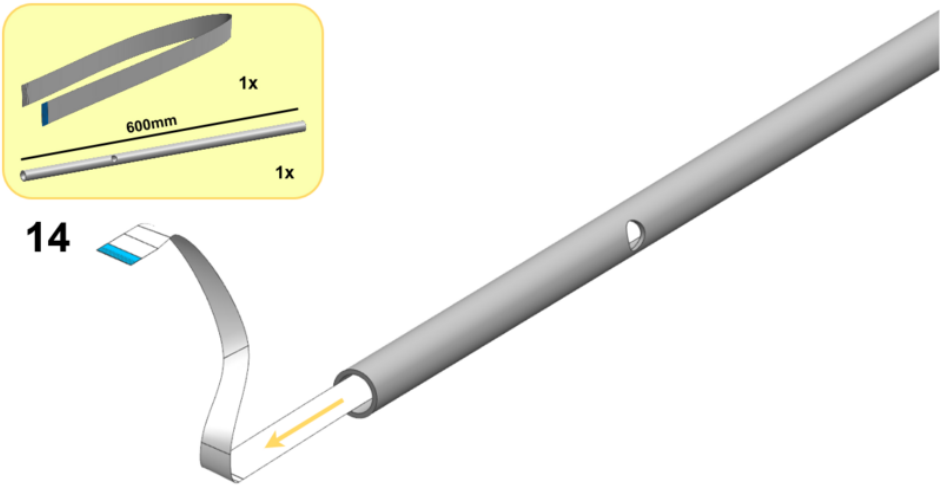

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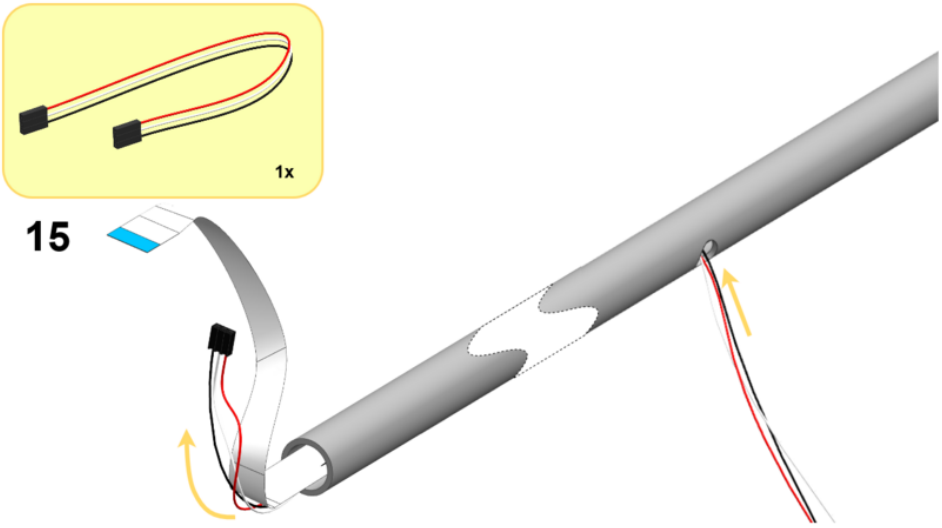

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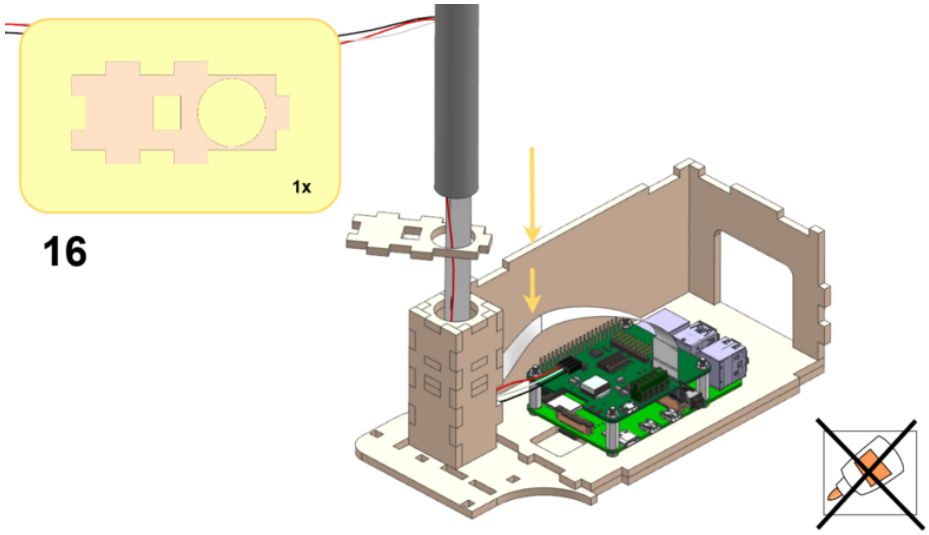

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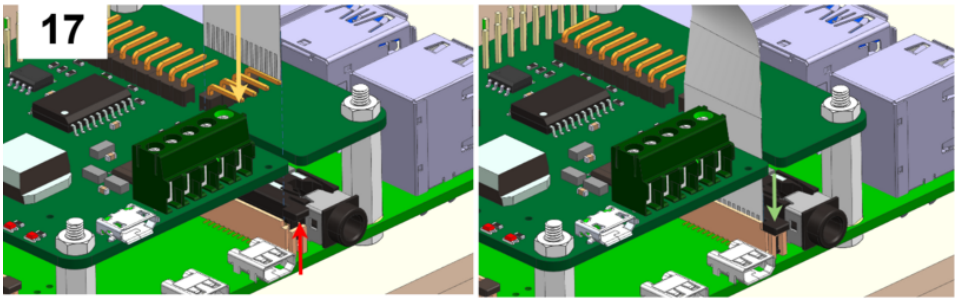
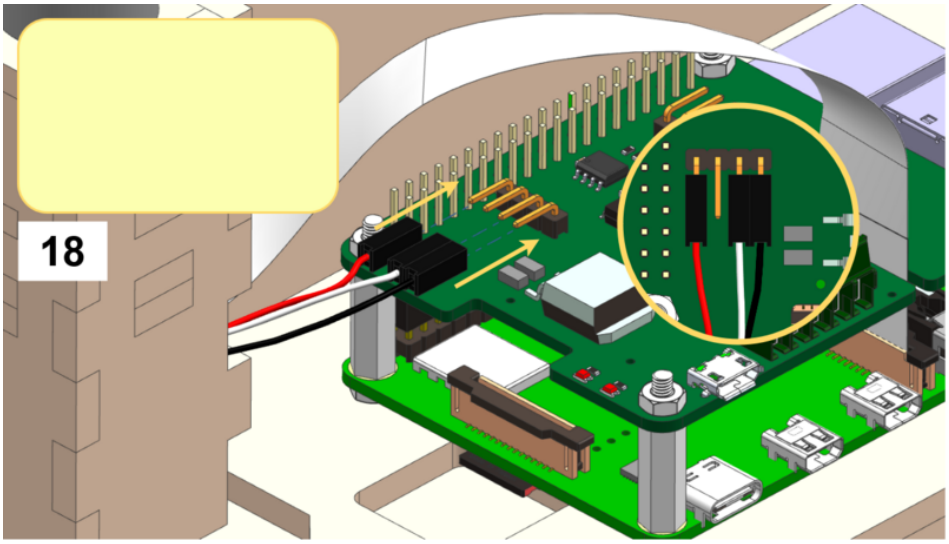
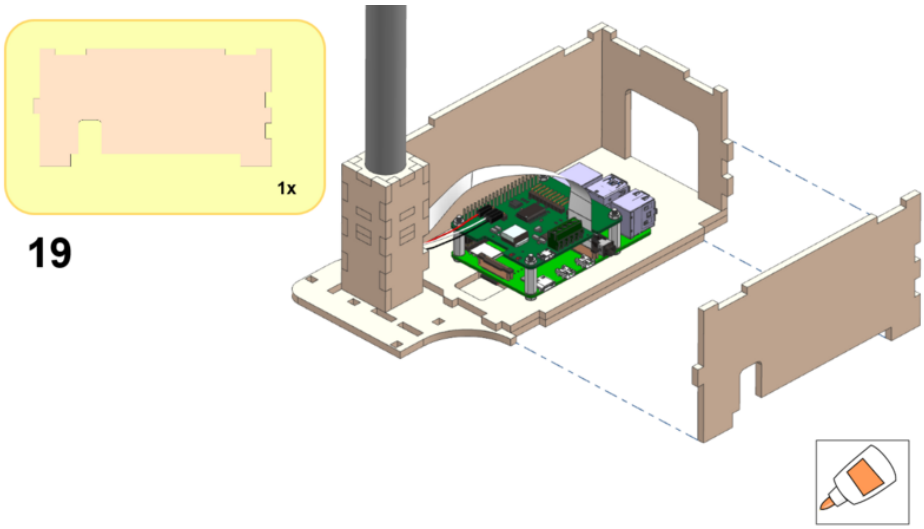
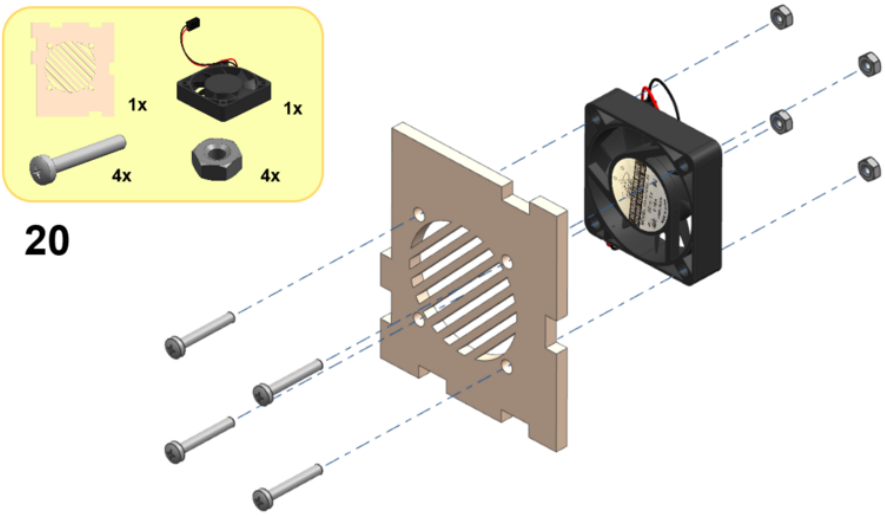




Note

Make sure to connect the LED cables exactly as indicated in the picture. Otherwise, the LEDs will break irreversibly.





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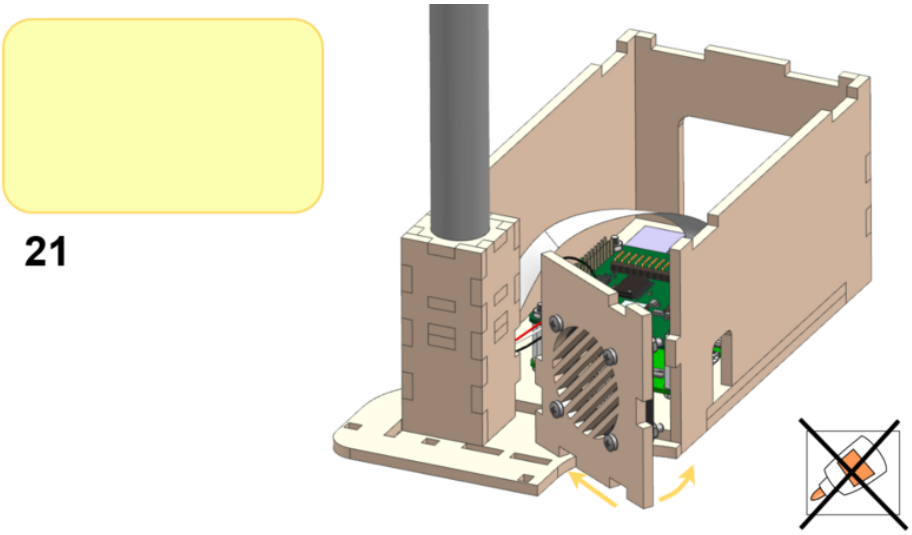

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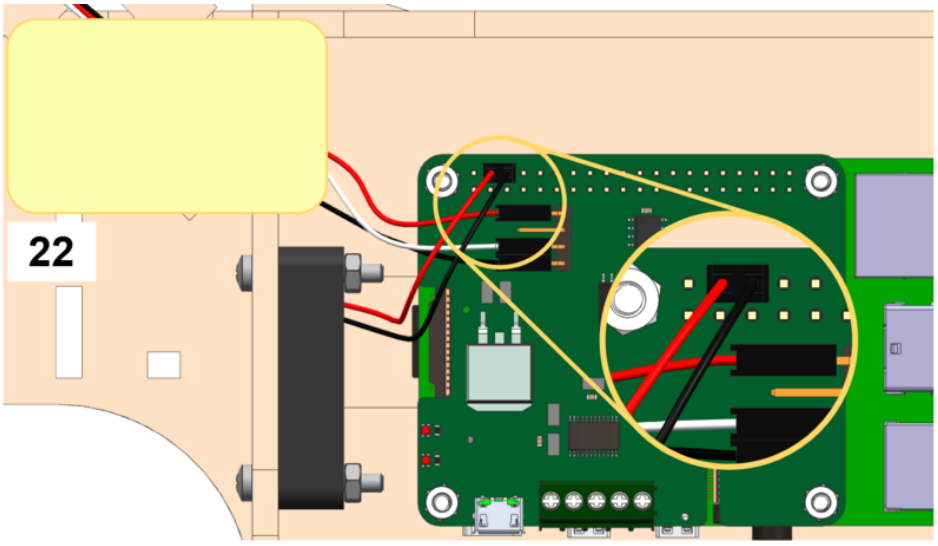

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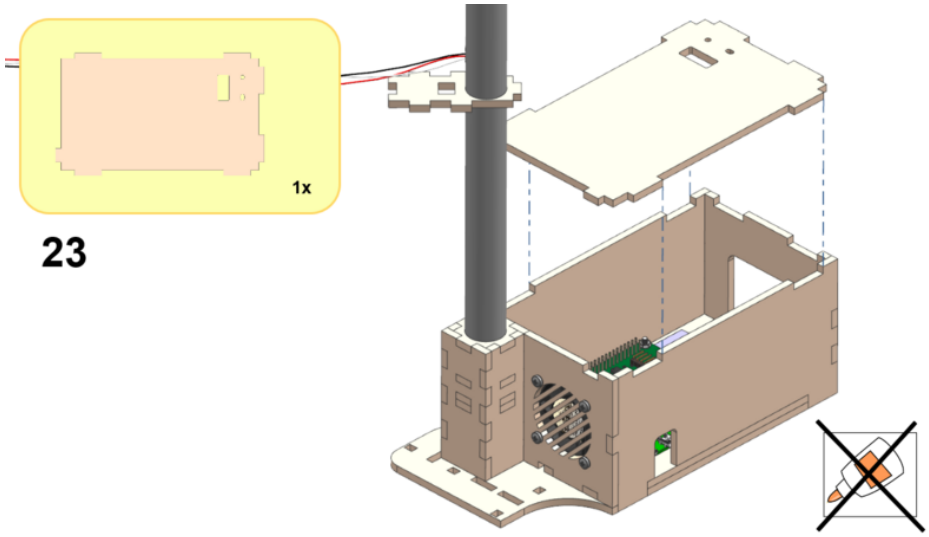
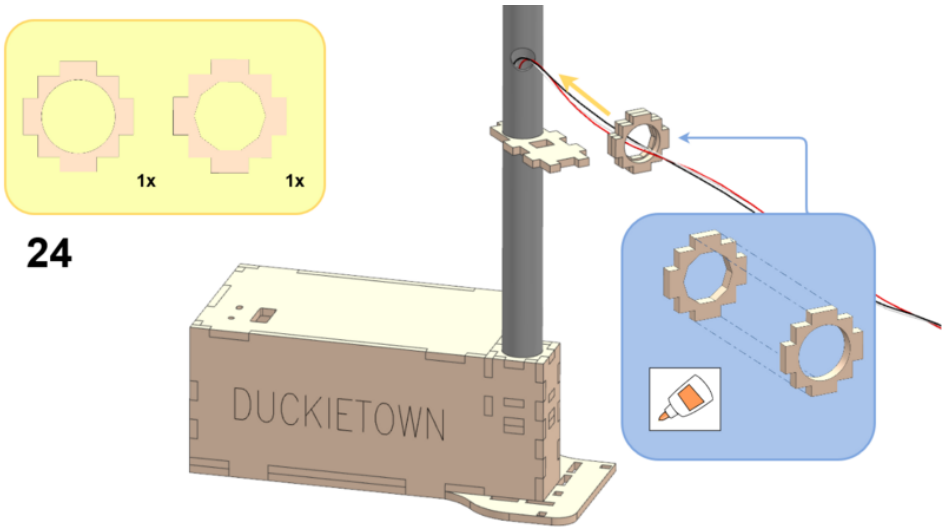
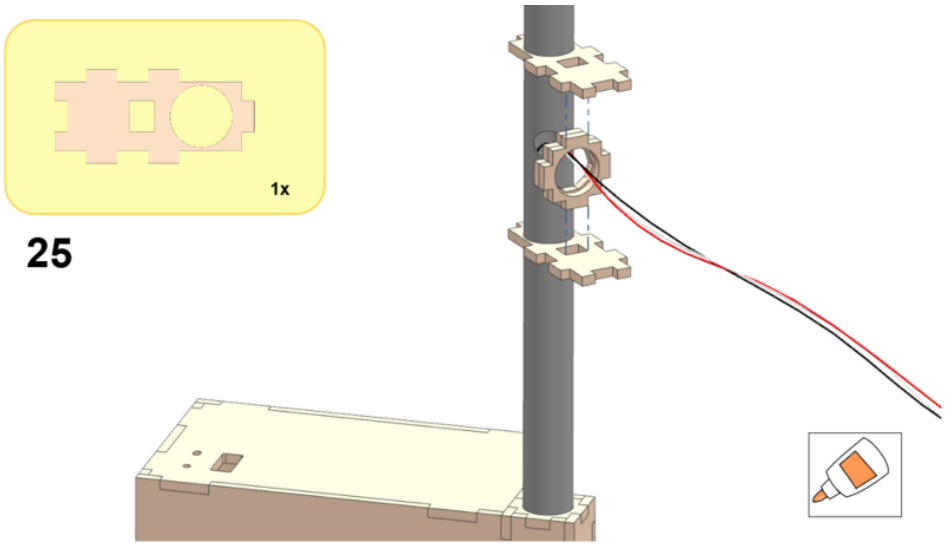
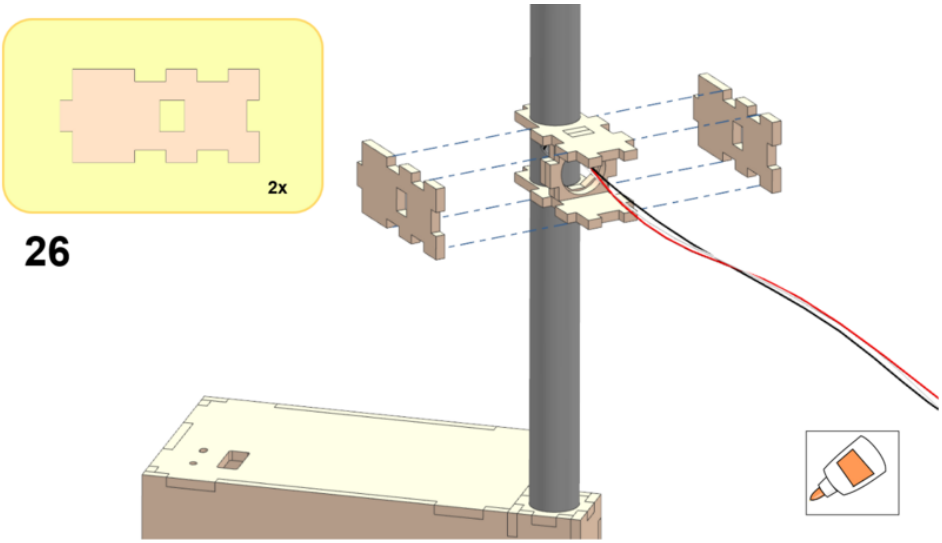
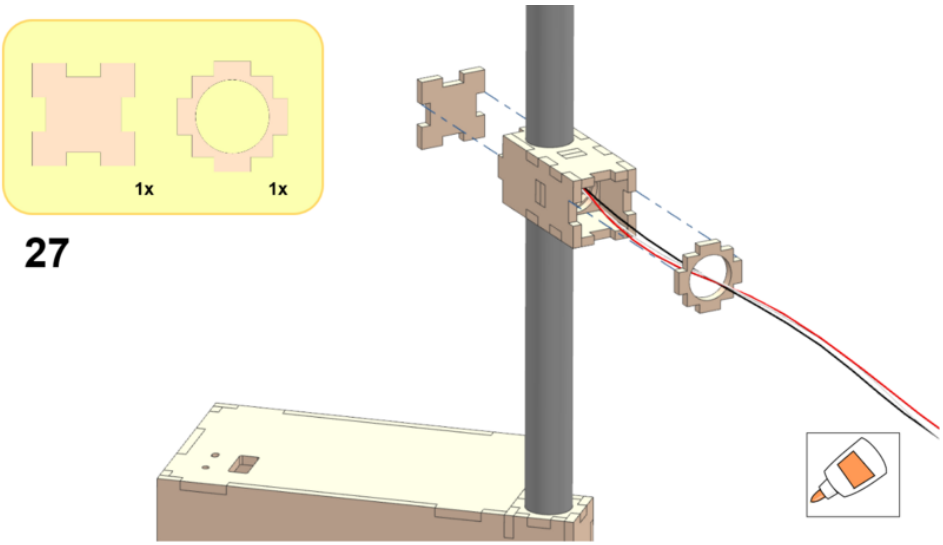


Part 3: TL Corner (Attached)

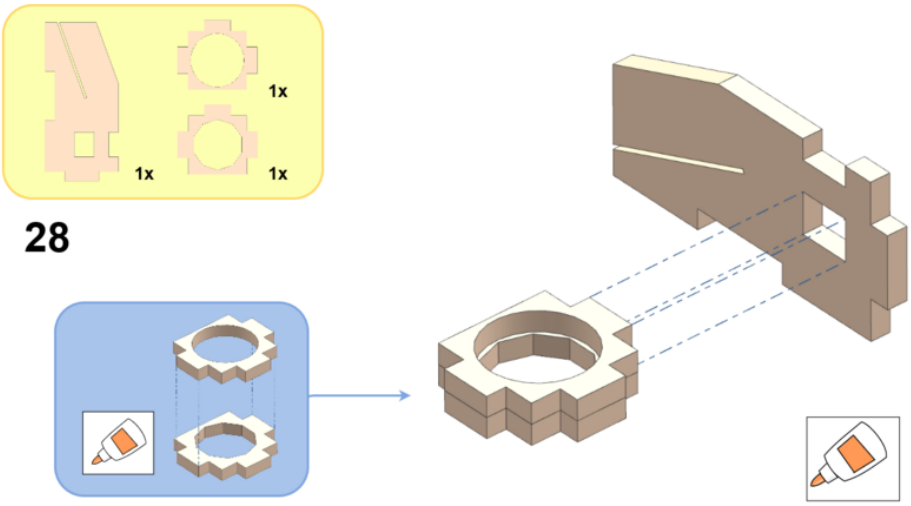


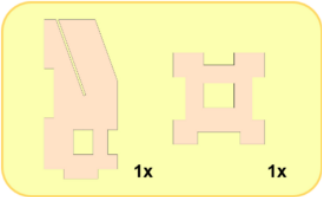






Part 4: Camera Housing





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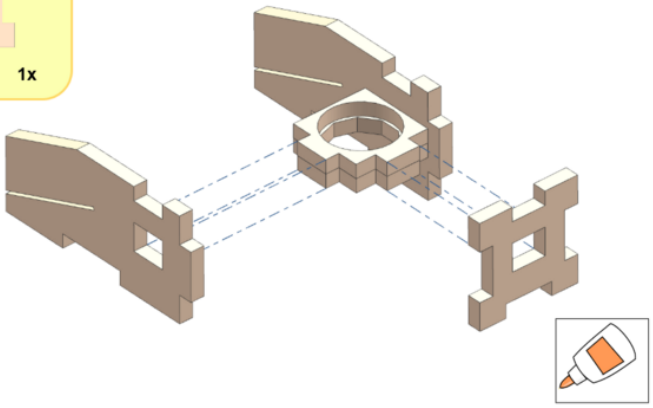

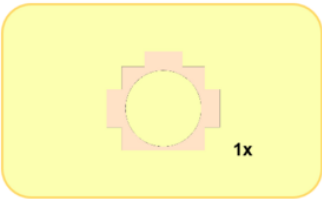

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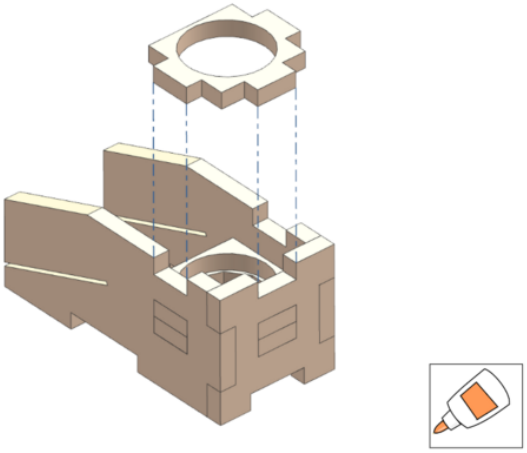

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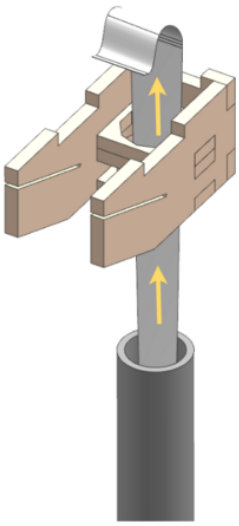
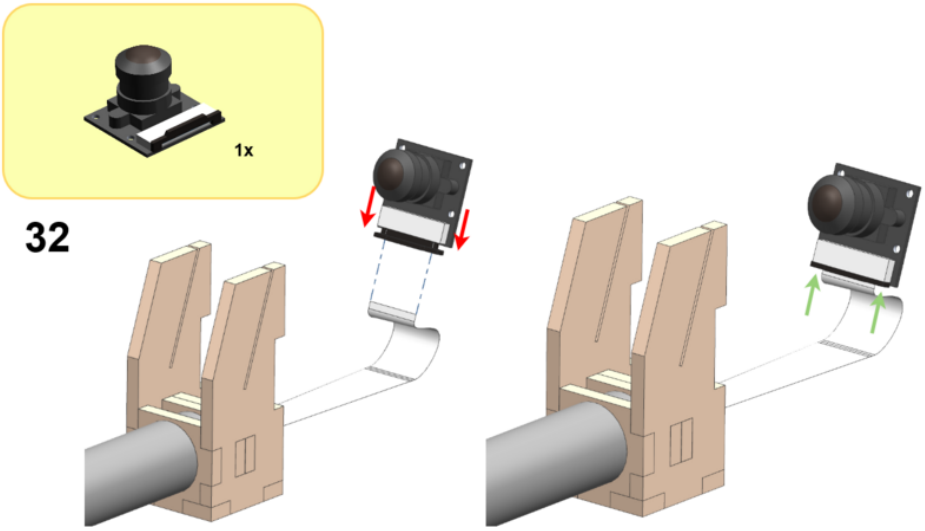
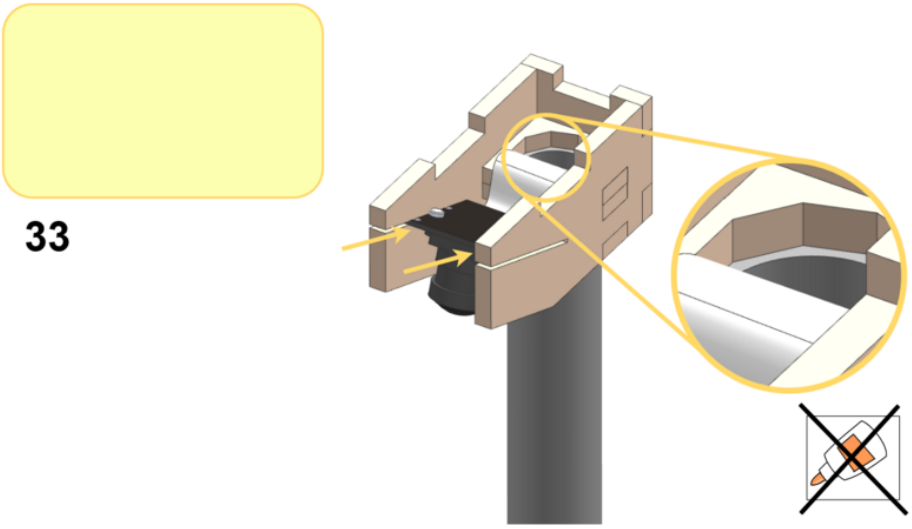
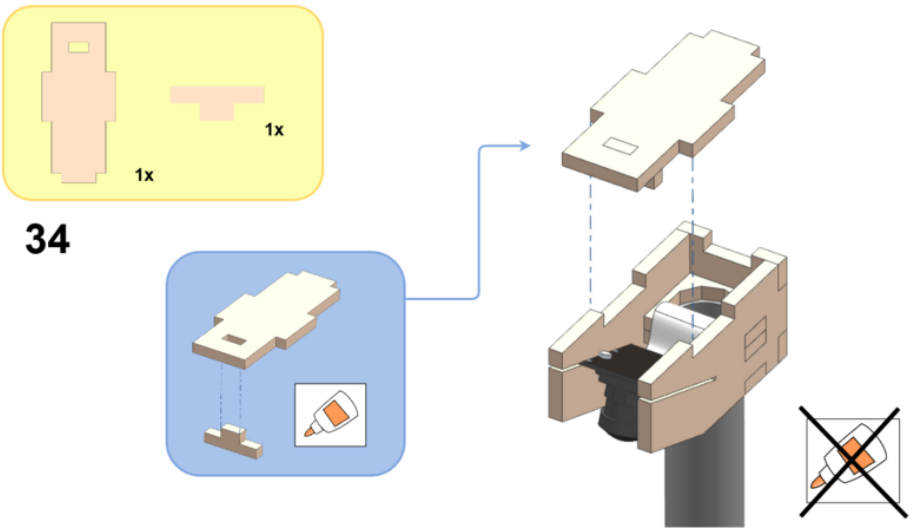
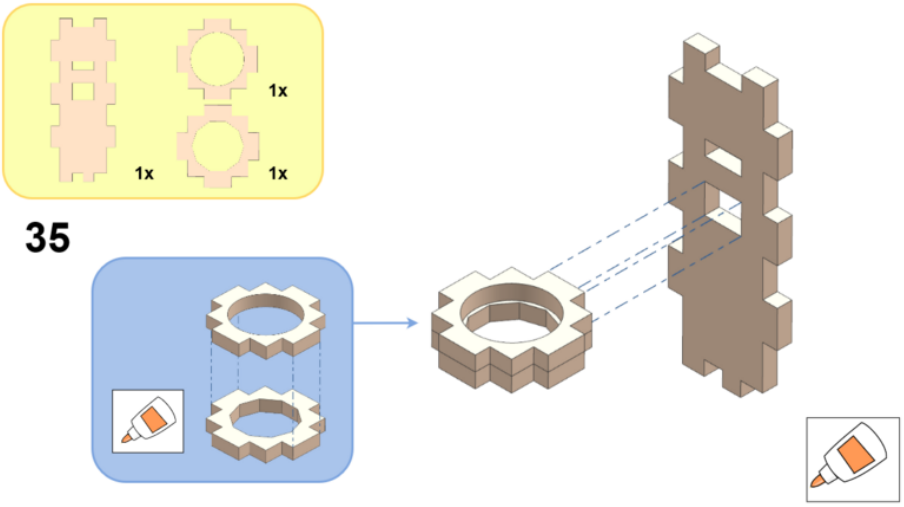








Part 5: TL Base



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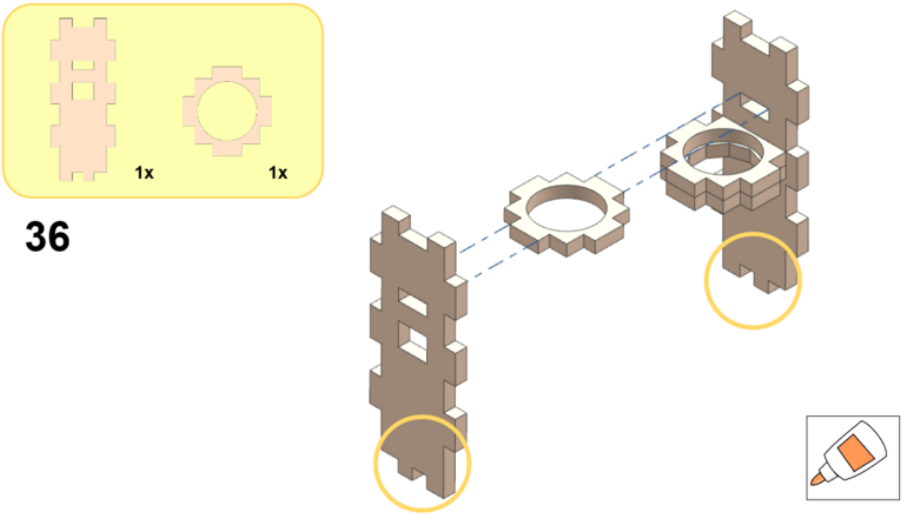

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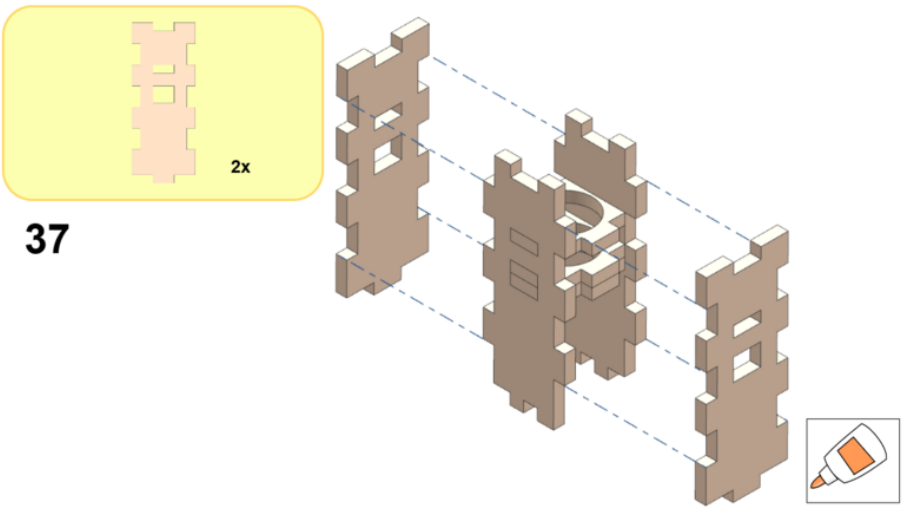

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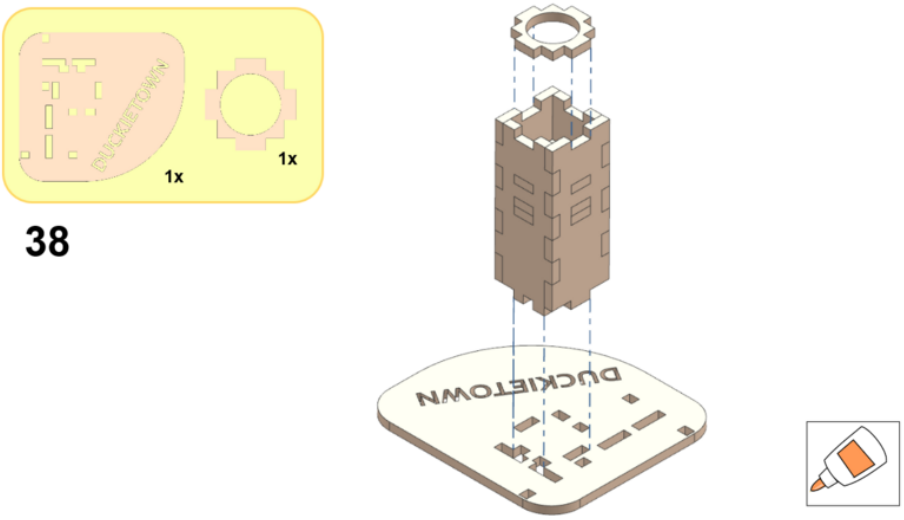
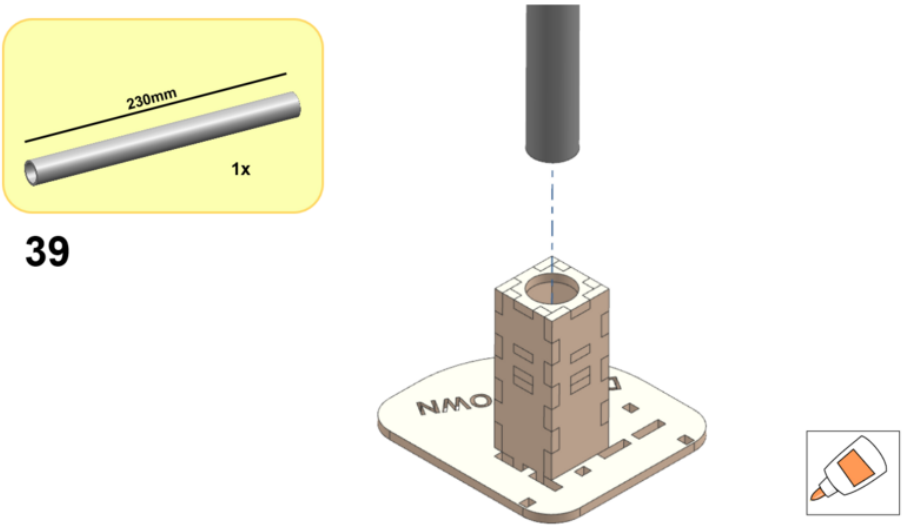
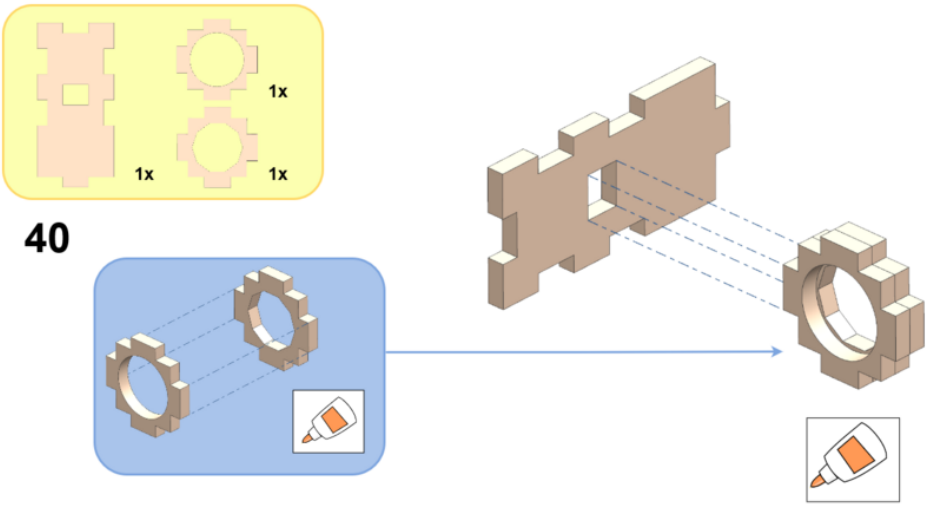
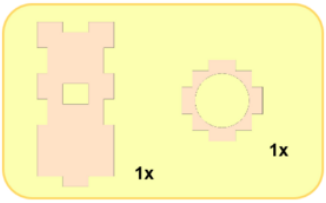




Part 6: TL Corner (Single)





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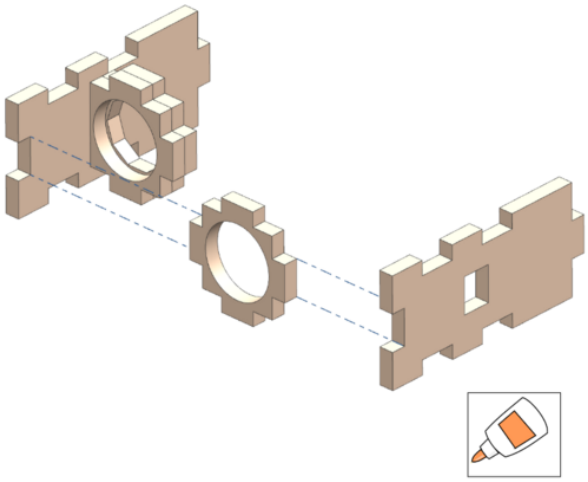

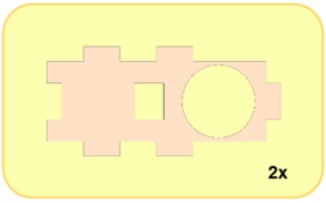

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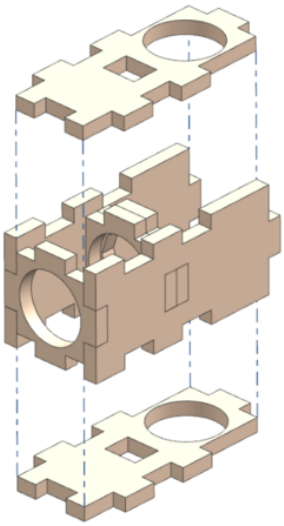

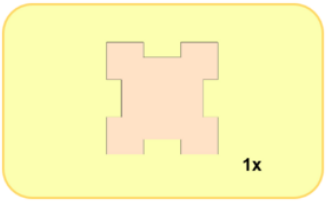

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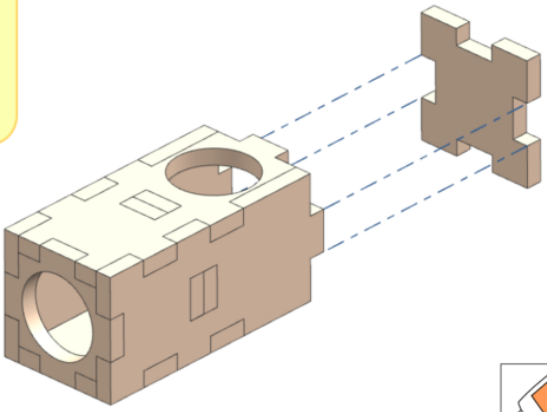
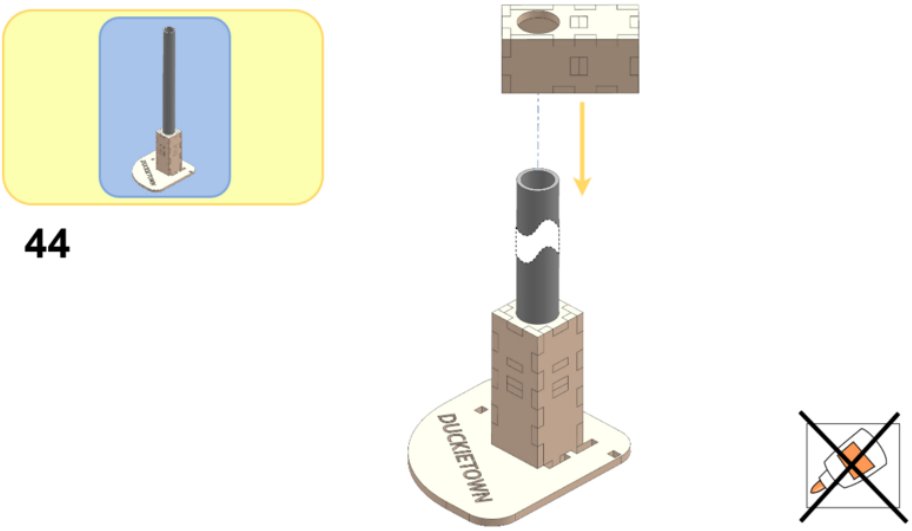
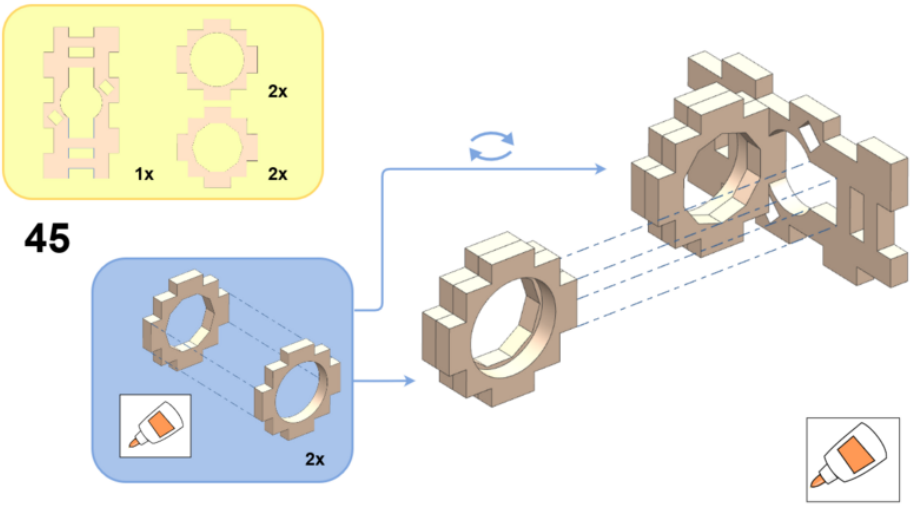
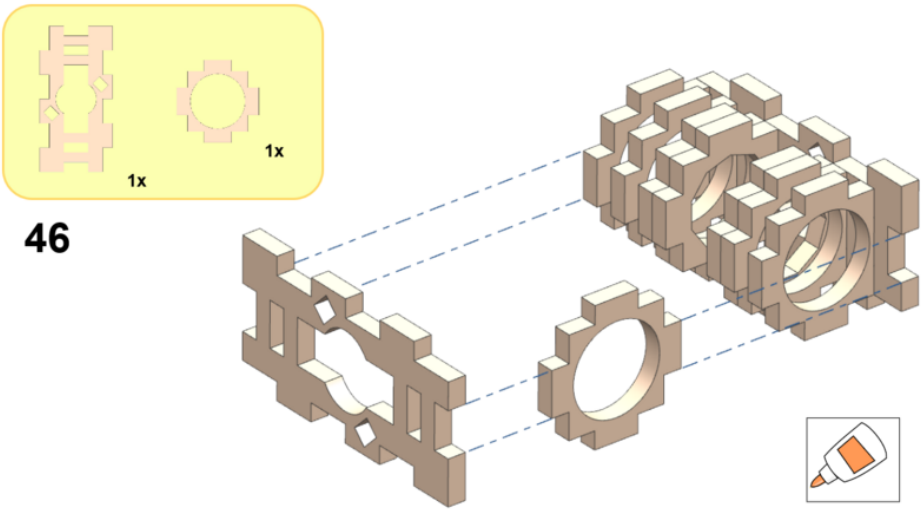
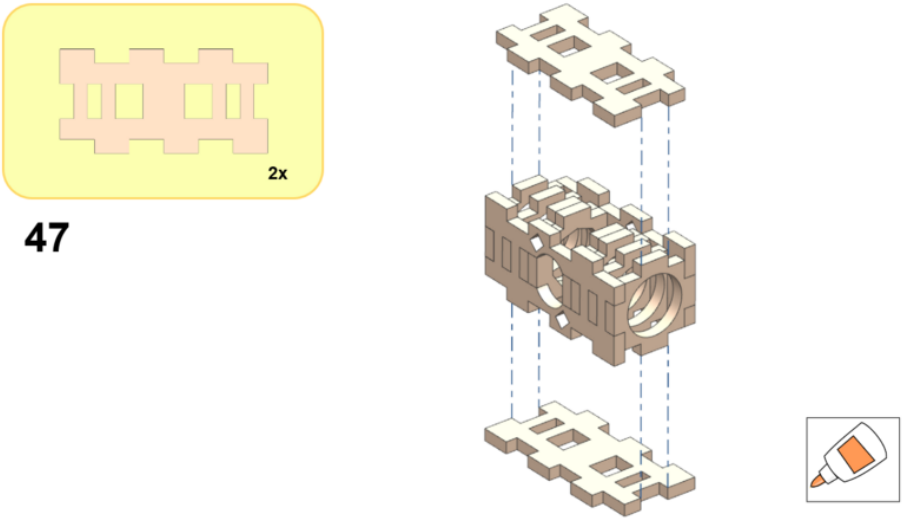


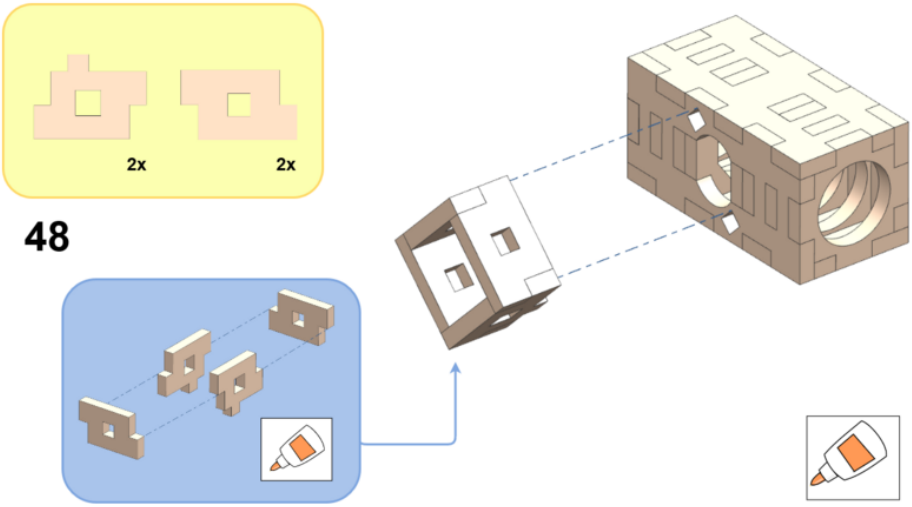


Part 7: LED Housing

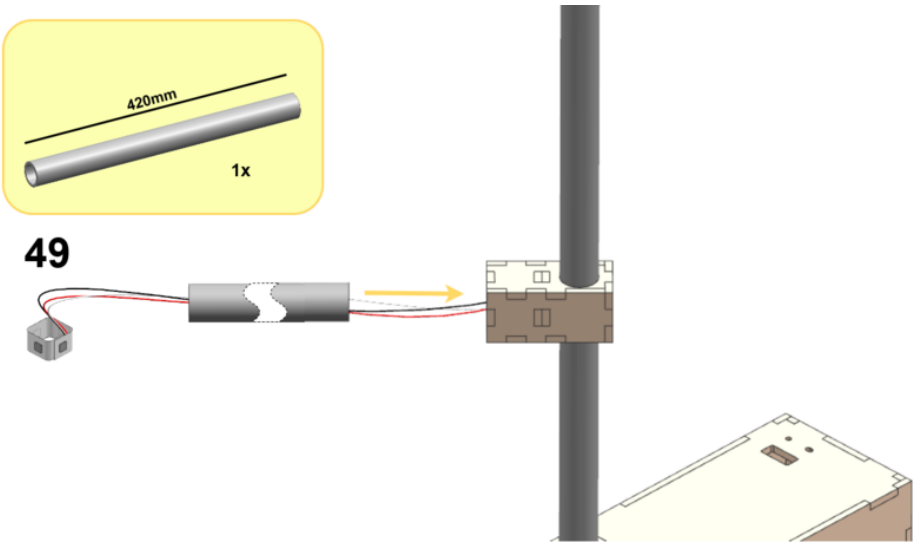


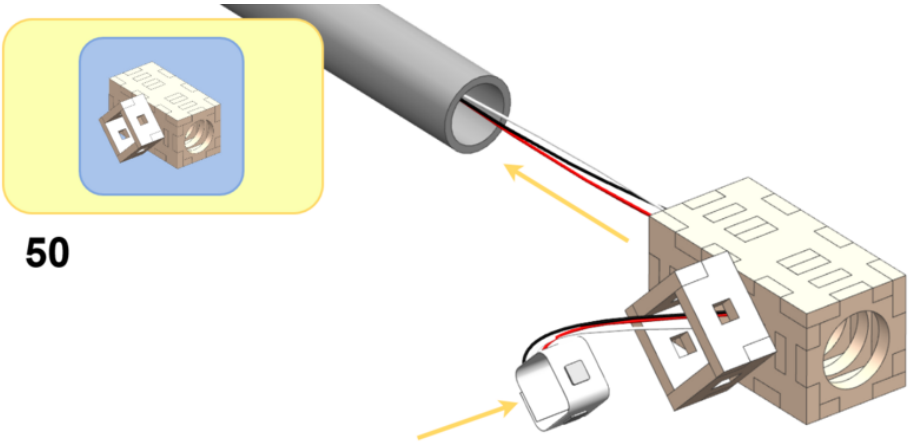






Part 8: Complete Assembly





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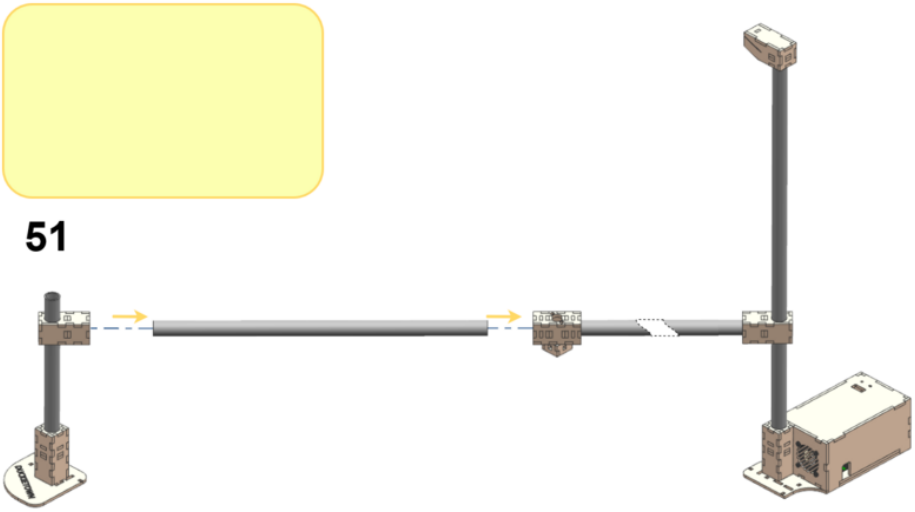

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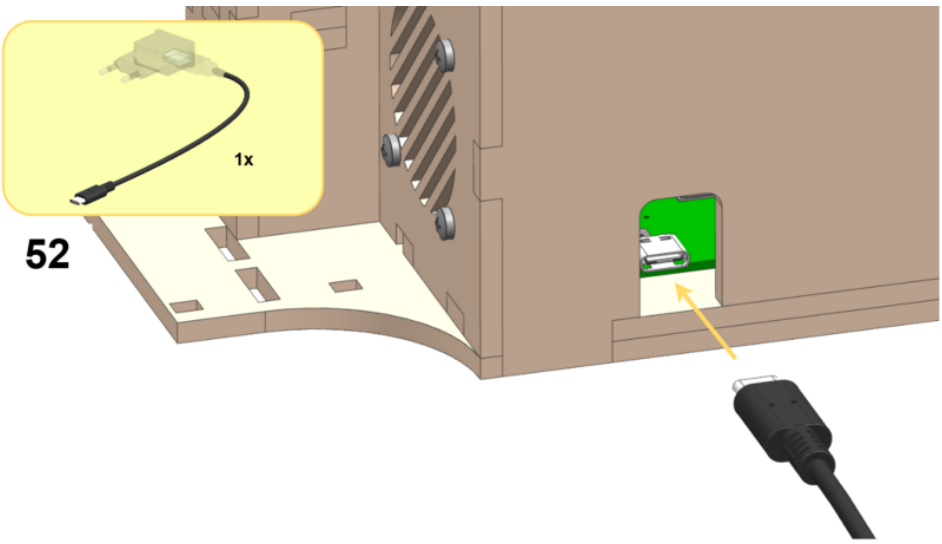
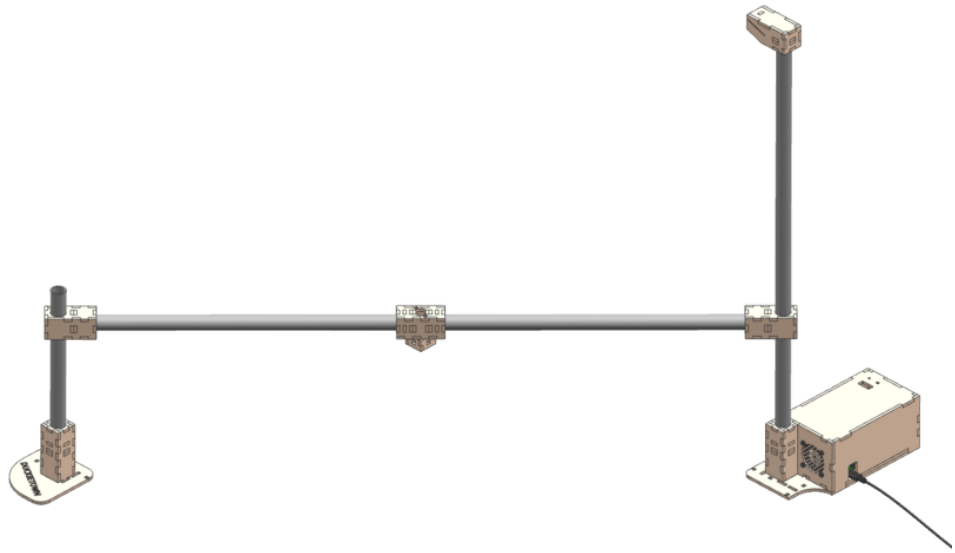


52



Congratulations, at this point you have completed the traffic light.

Assembly - (Legacy) Traffic Light `DT18-TL`

Assembly of the traffic light parts

This section shows how to assemble the components from the laser cut traffic light parts.

> **Warning**
>
> The small parts with the hole in the middle, i.e., the ones in the left of Fig. 58, are not all equal. Some have a round hole, others a polygonal hole. Double check you are using the right ones in the process (compare with the pics).

All parts should be glued together as showed in the pictures for enhanced structural stability.

Tube holder with big ground plate

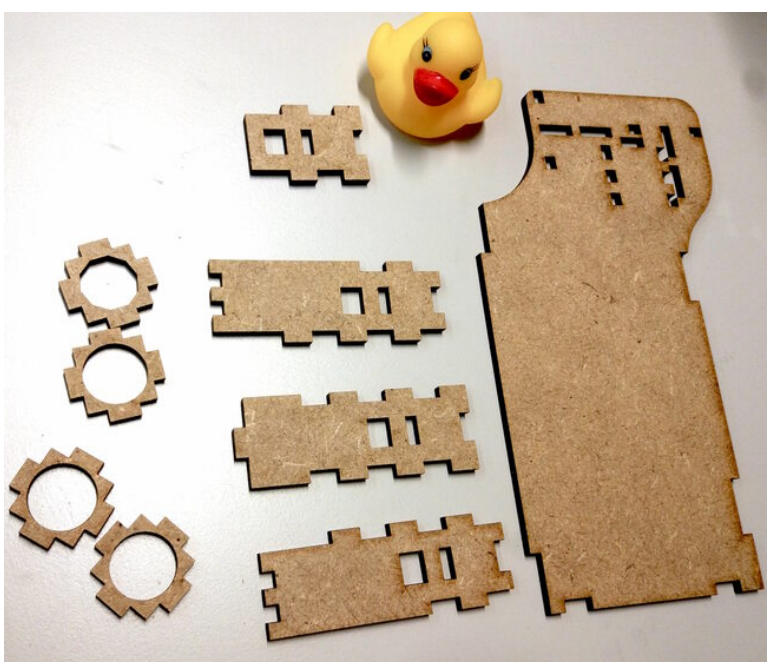


Fig. 58 Traffic light parts

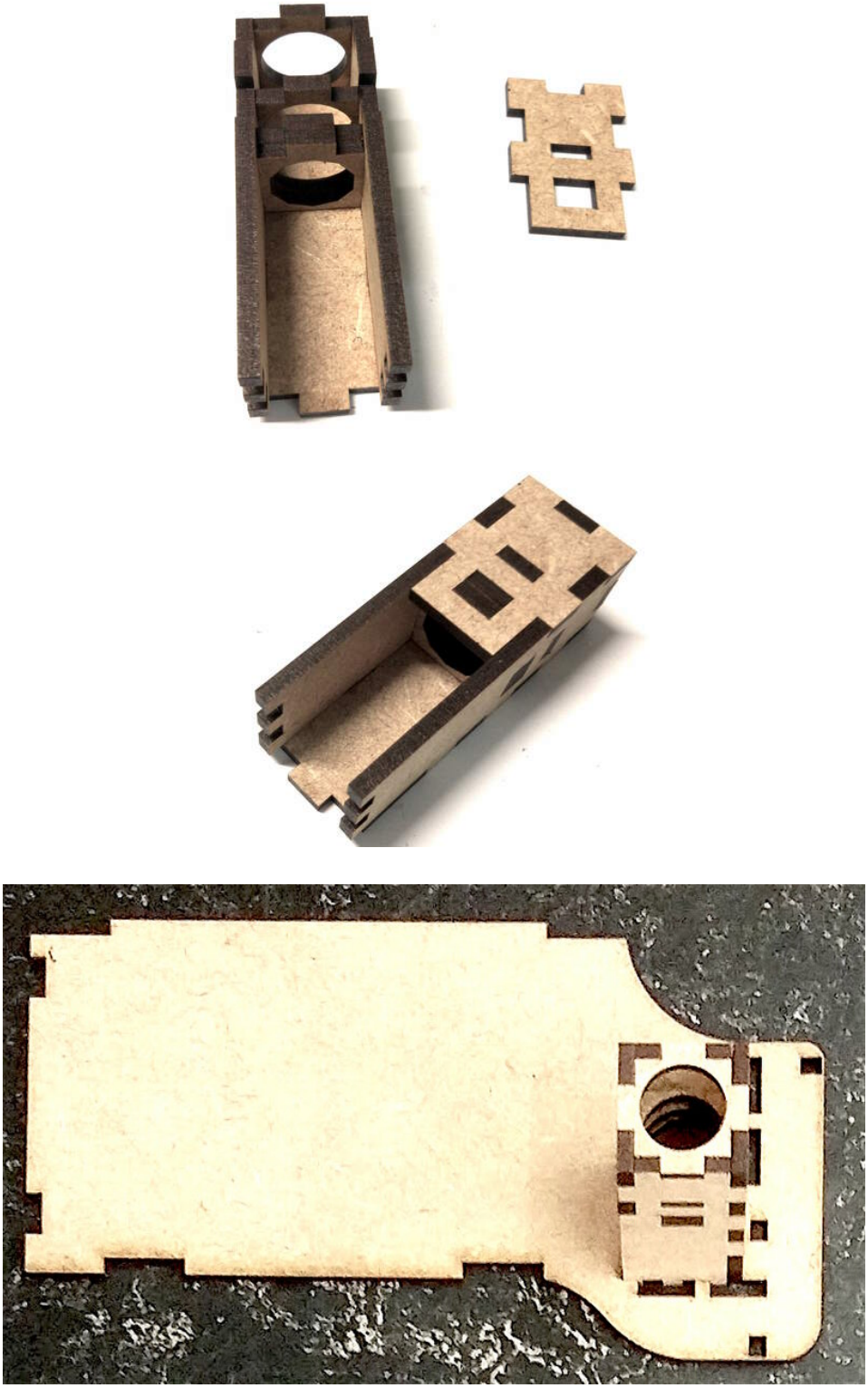
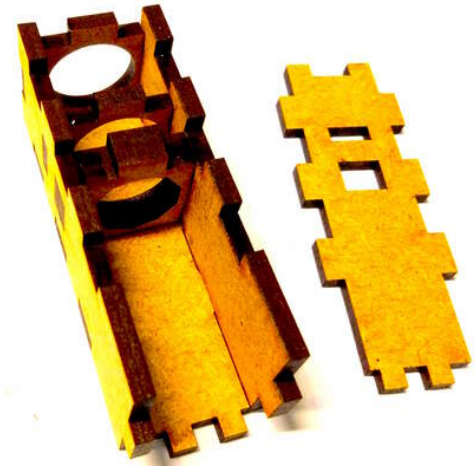


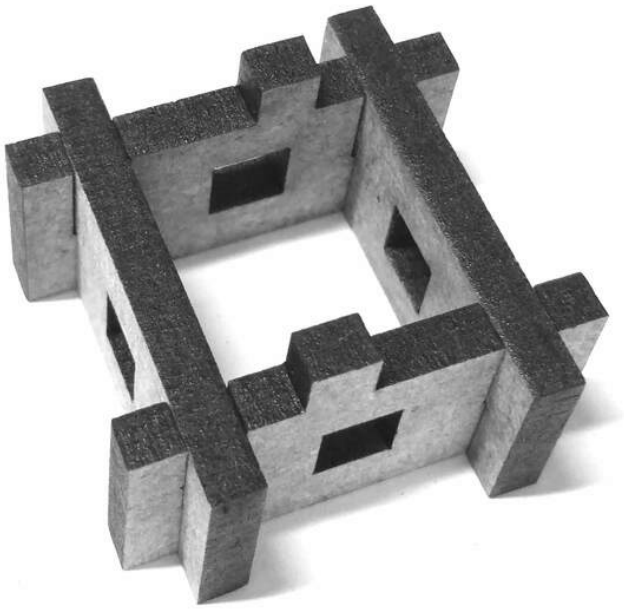
Fig. 59 :width: 80% :name: fig:G-8

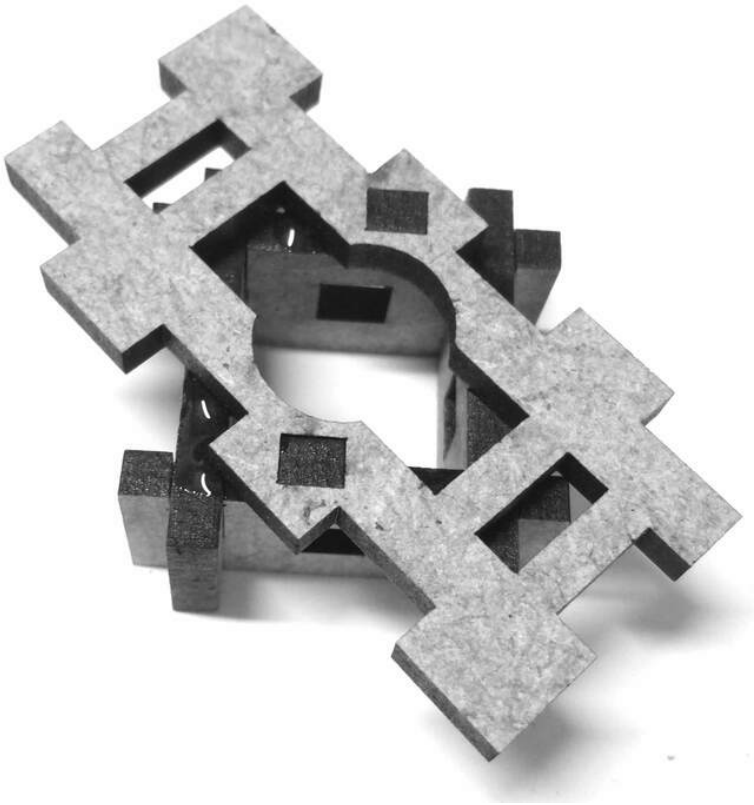
Tube holder with small ground plate

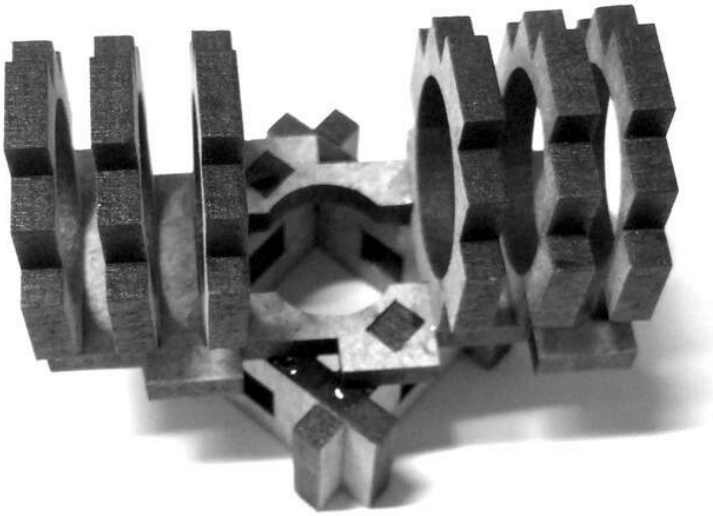
LUCKIETOWN

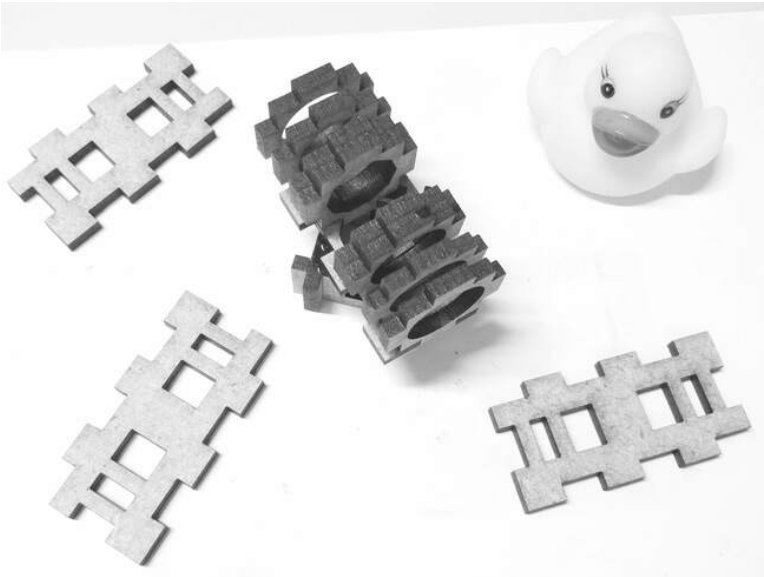


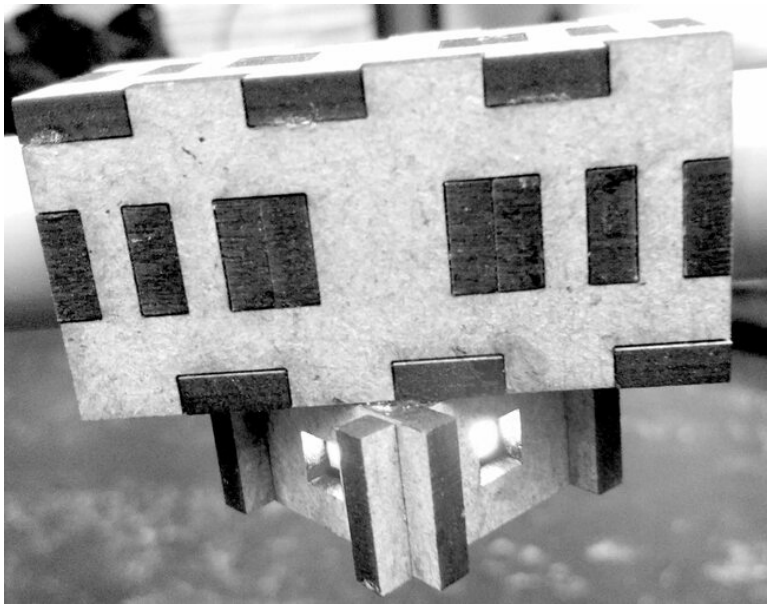
Traffic light LED housing





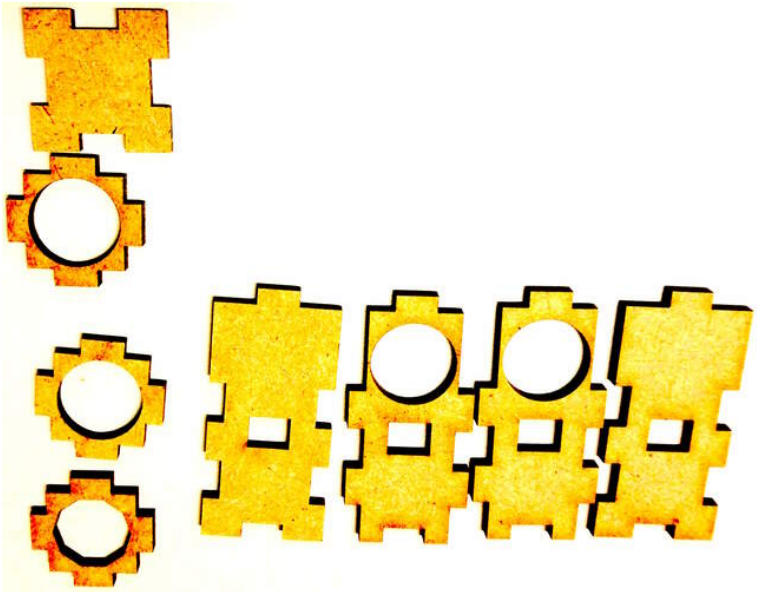


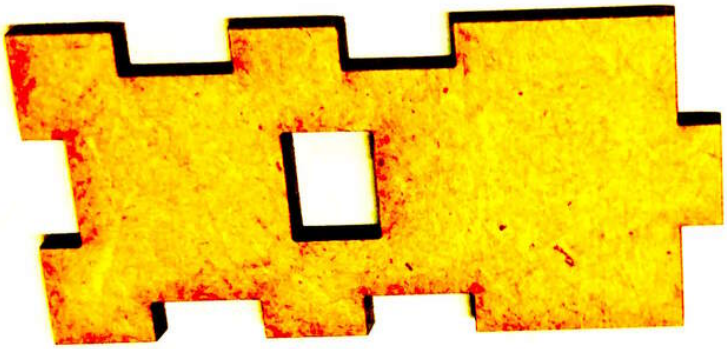


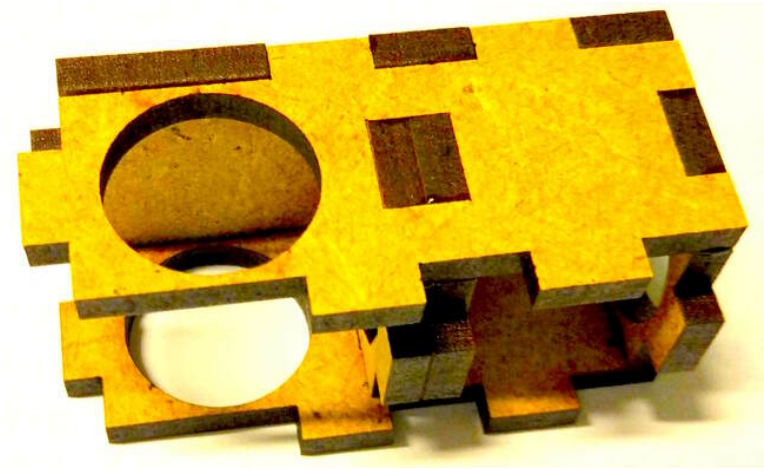


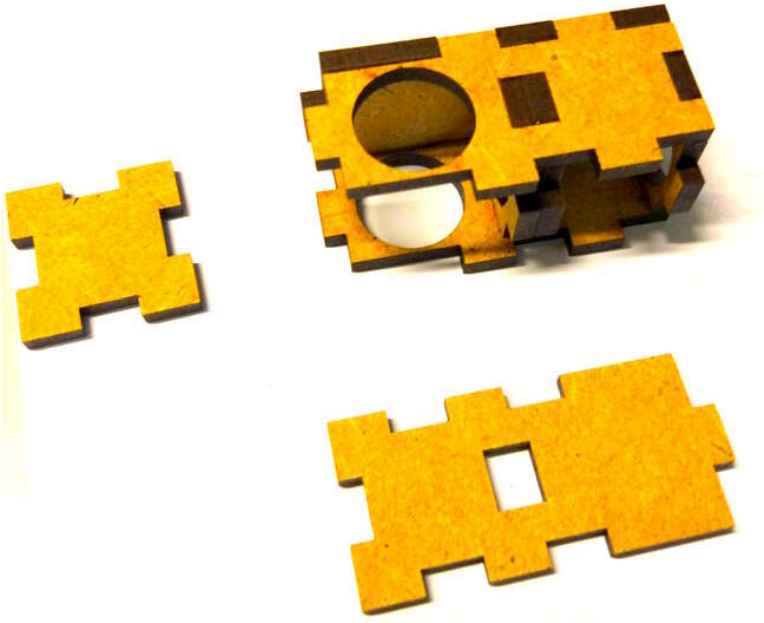
Ground module cover

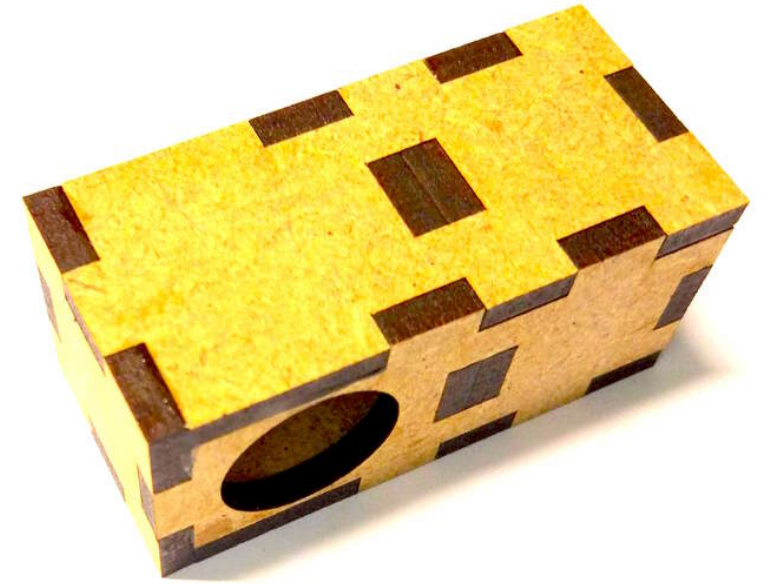
Joint module











Components of the traffic light

Now that you have assembled the traffic light chassis, you are ready to add the electronics.

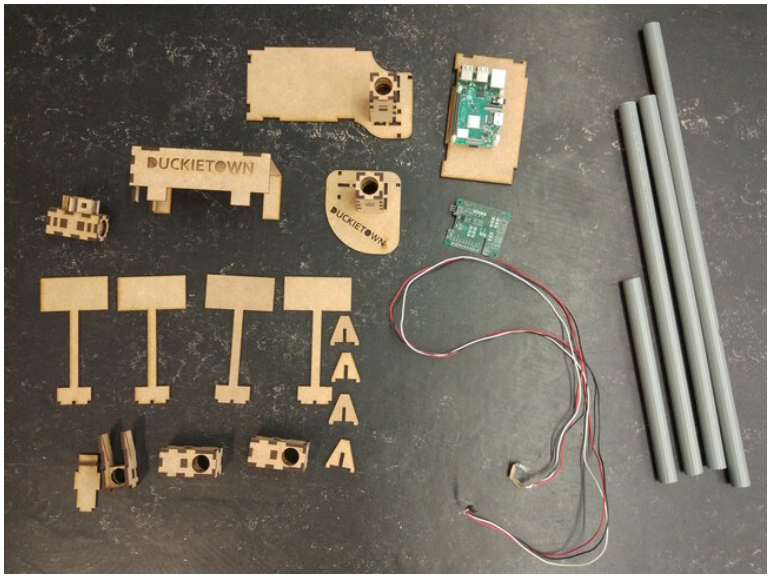


Fig. 60 Parts of a traffic light needed to complete these instructions.

These components are needed for one traffic light:

- Tube holder with big ground plate
- Tube holder with small ground plate (Duckietown)
- Cable with soldered LED strip
- Joint module (2x)
- Traffic light LED housing
- Raspberry Pi base plate
- Ground module cover (Duckietown)
- Camera mount
- Camera mount cover
- Short tube
- Medium tube (2x)
- Long tube with hole at the side
- Raspberry Pi
- Raspberry Pi shield
- M2.5x10 MF Nylon spacers (8x)
- M2.5x8 Nylon screws (4x)
- SD card with Duckietown software
- USB cable
- Ethernet cable

Additionally, the traffic light structure can host:

- Traffic sign stands (4x)
- Traffic sign stand supports (4x).

Assembling the Traffic Light

Put the LEDs into the housing

Bend the LED strip at an angle to reduce the chance that the exposed soldered wires short. The exposed part of the wires should **not** be in contact, **especially** when turning on the power.

> **Warning**
>
> The actual traffic light in your hands might vary slightly from the pictures above. In particular, the electrical cables could have different colors or be soldered in different positions. Take note of what each color cable is soldered to, as same will go go with same on the other end.

Fig. 61 Bent LED strip cable

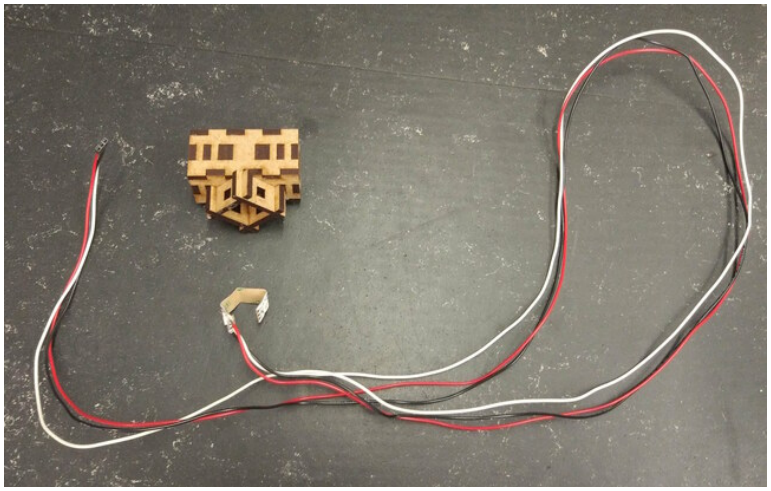
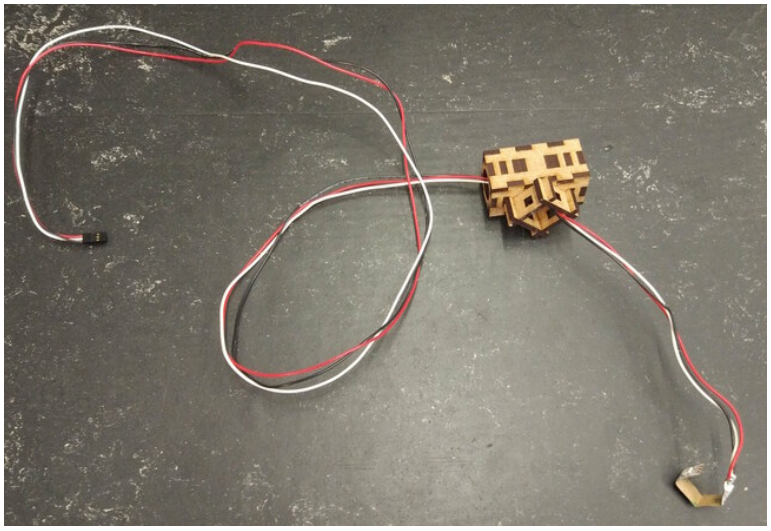
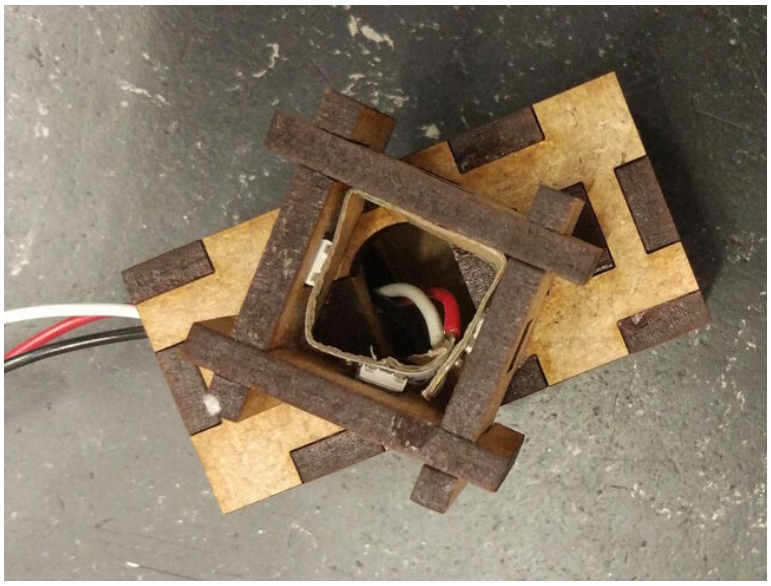
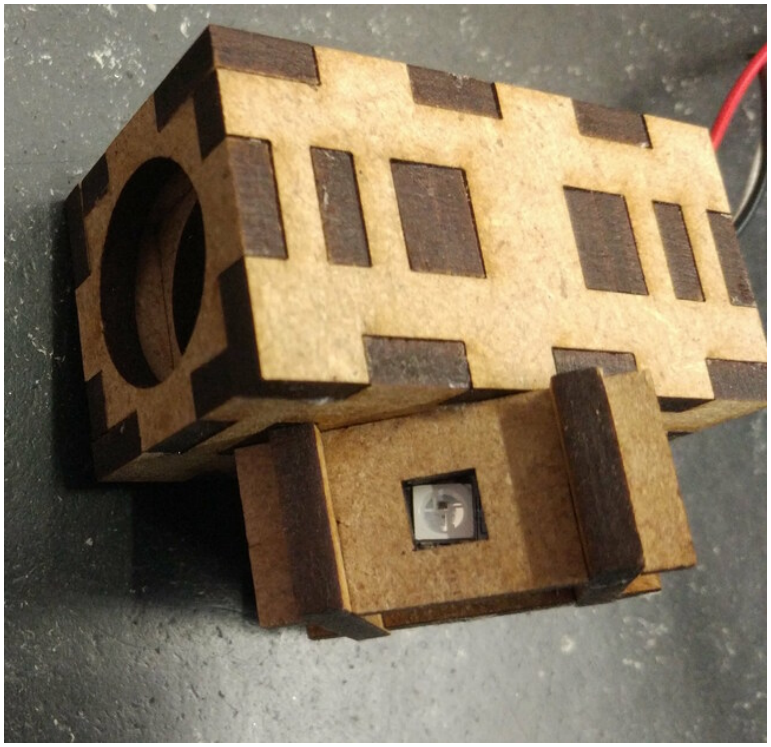


Fig. 62 Cable with soldered LED strip LED housing

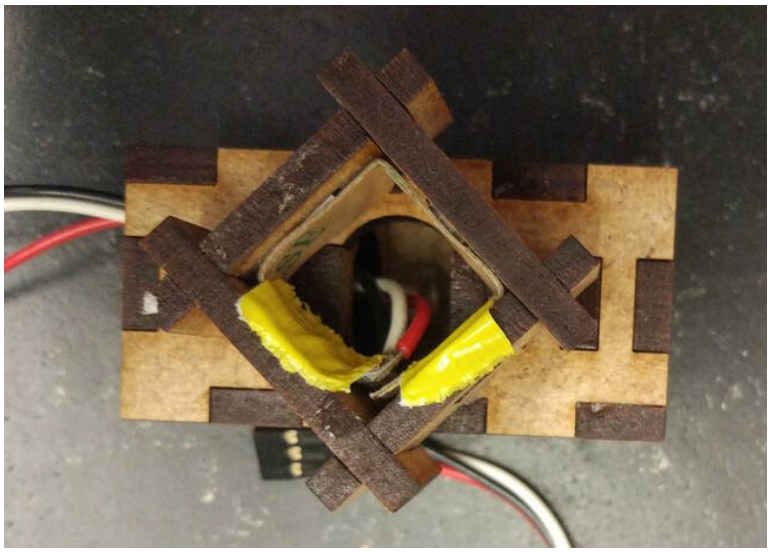


Carefully push the LEDs into the designated holes.





Fix the LEDs with some tape, don’t use glue.



Connect the tubes

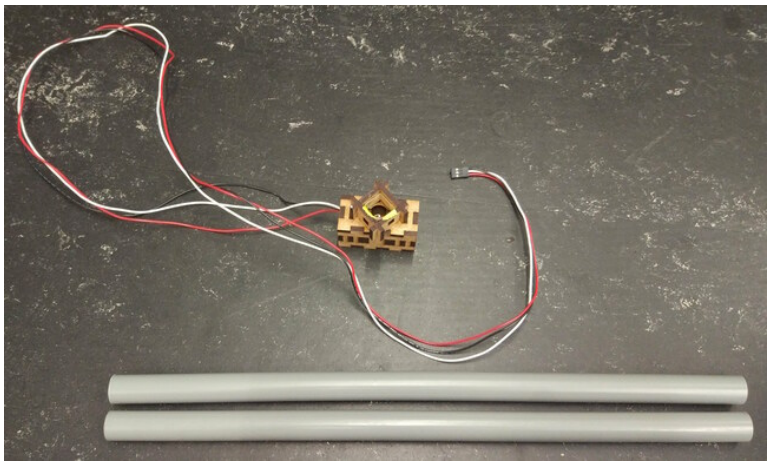
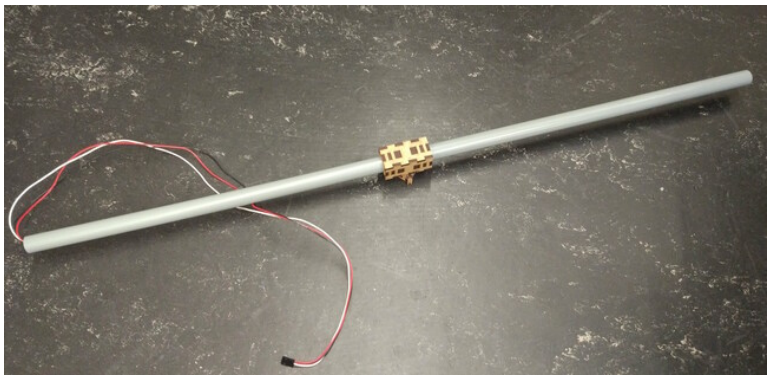
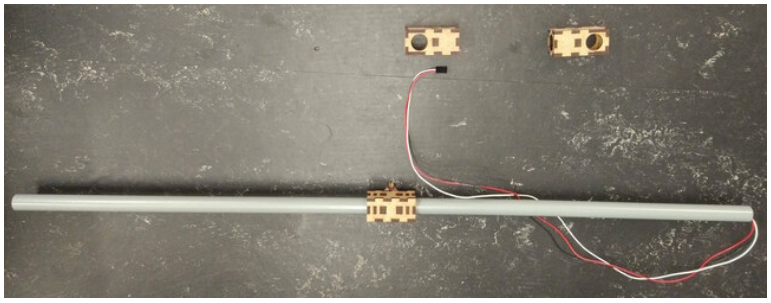


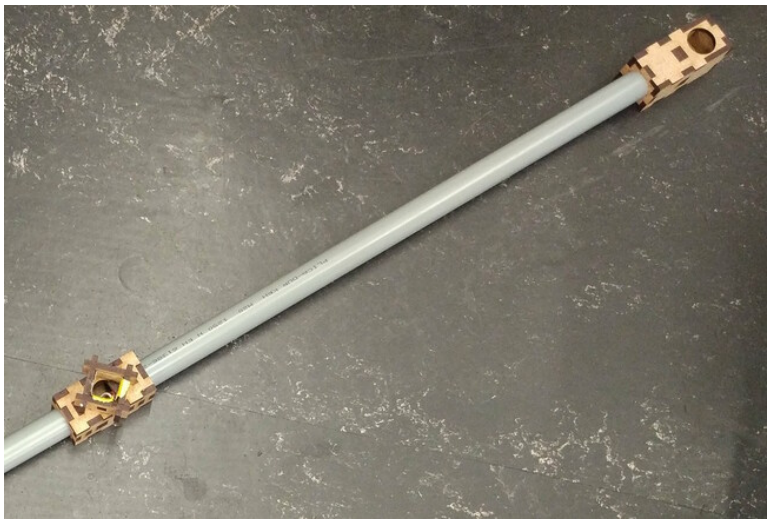
Fig. 63 Medium tubes and LED housing.

Stick the tubes into the sides of the LED housing and pull the cable through one side.



Add the joint modules on the side of the tube without the cable.





Mount the other joint module on the long tube, such that it aligns with the hole.

You can add additional tape under the joint modules to prevent them to slip down.

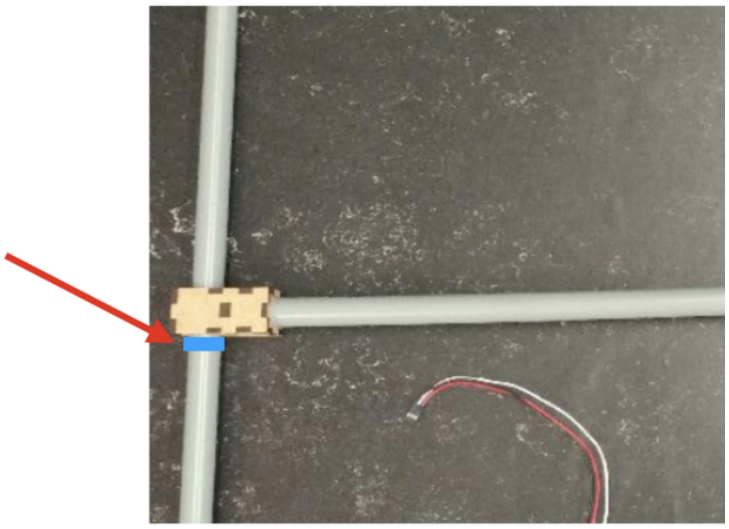
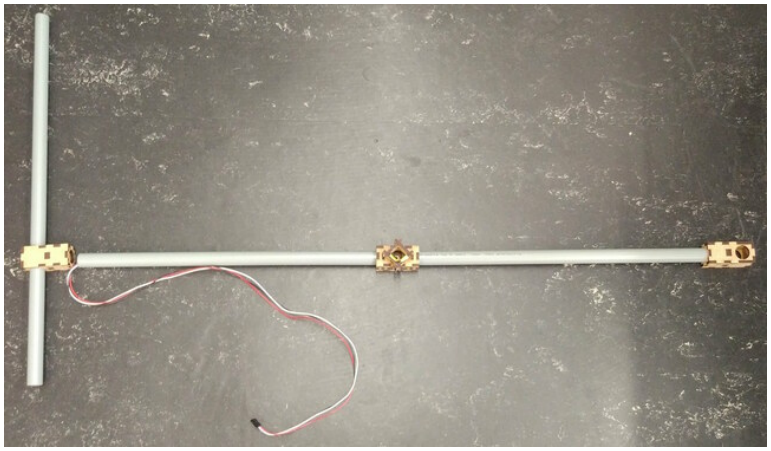
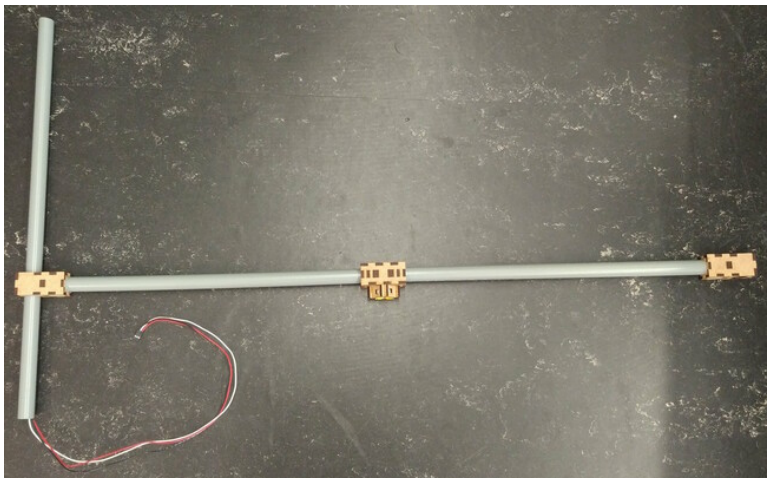


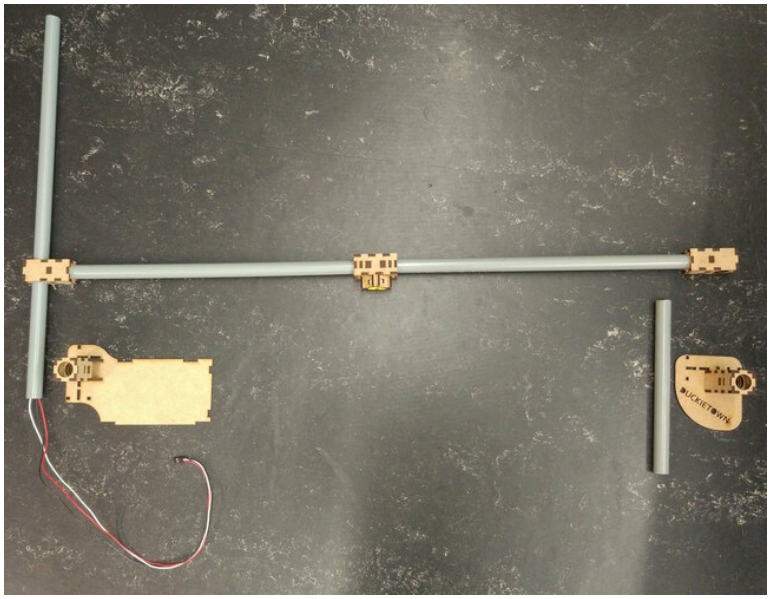
Fig. 64 Fully assembled traffic light.

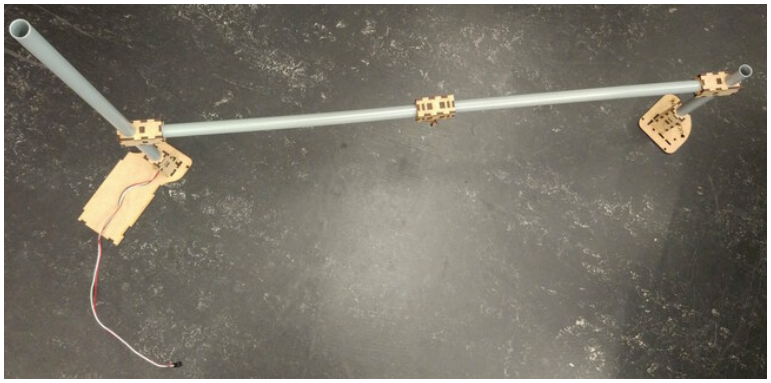
Pull the cable through longer tube and stick the tube into the joint module.





Put the tubes into the tube holders.





Connect the Raspberry Pi

Use the spacers and the screws to mount the Raspberry Pi on the Raspberry Pi ground plate as shown in Fig. 65.

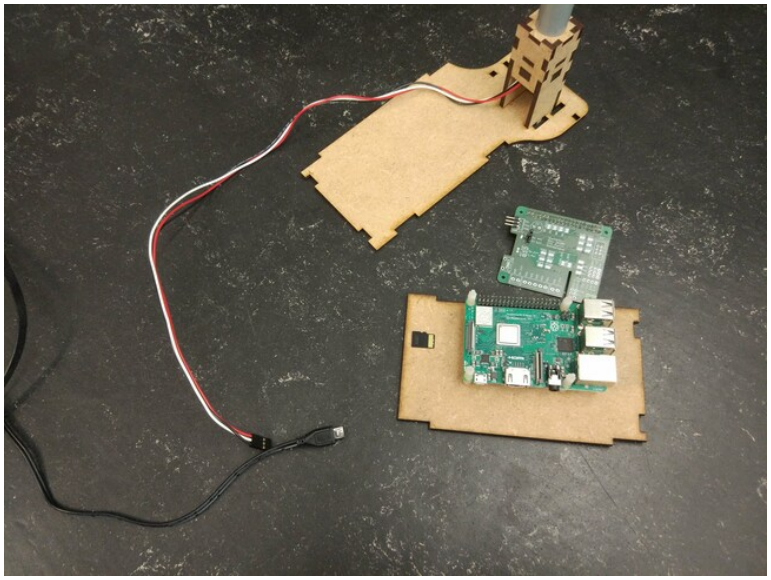
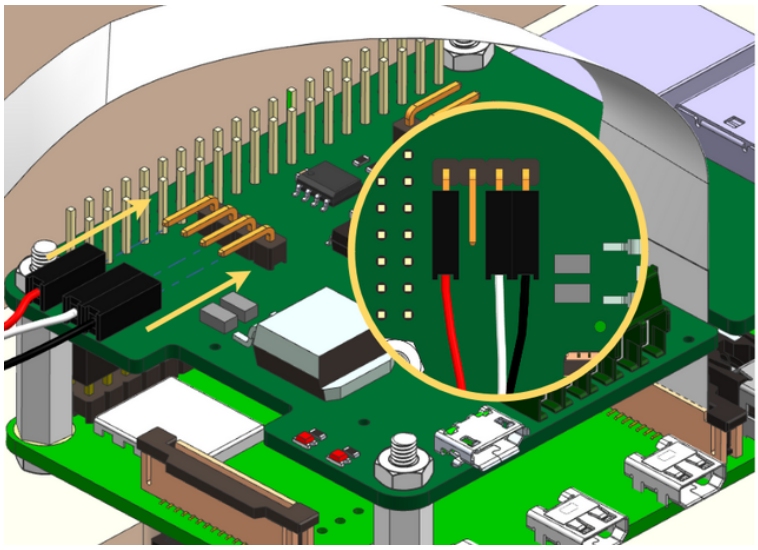


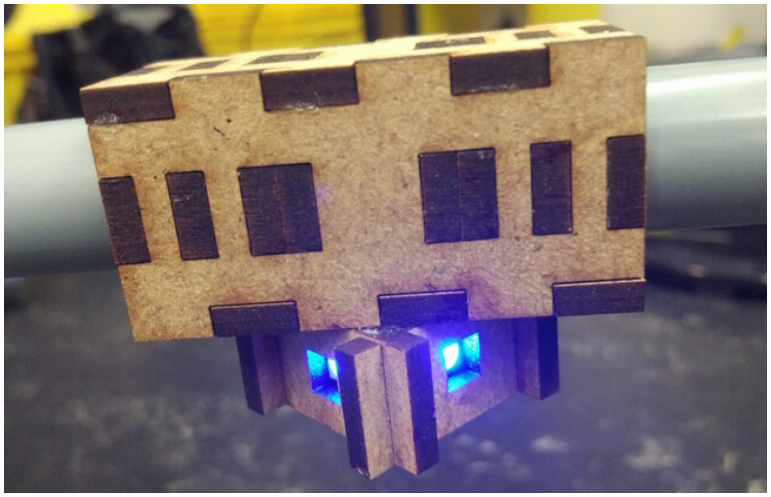
Fig. 65 Raspberry Pi mounted on ground plate

Plug the shield on top of the Raspberry Pi.
Insert the SD card.
Connect the LED cable to the shield.

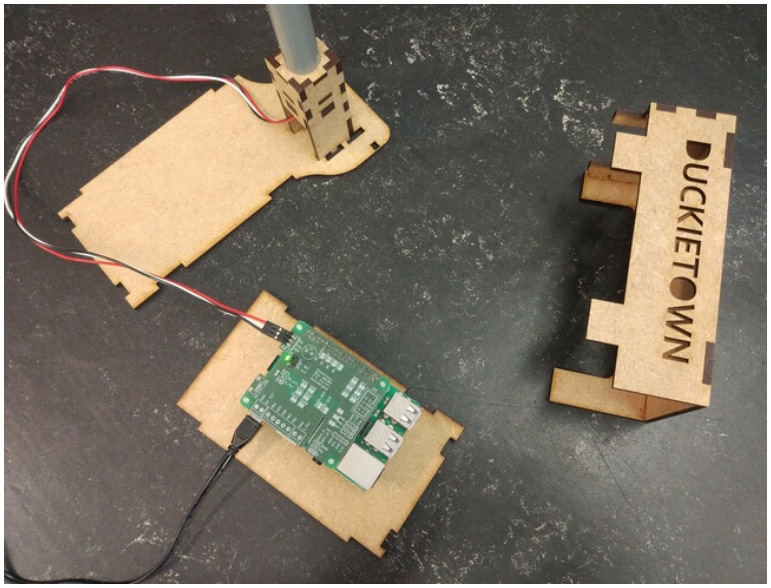


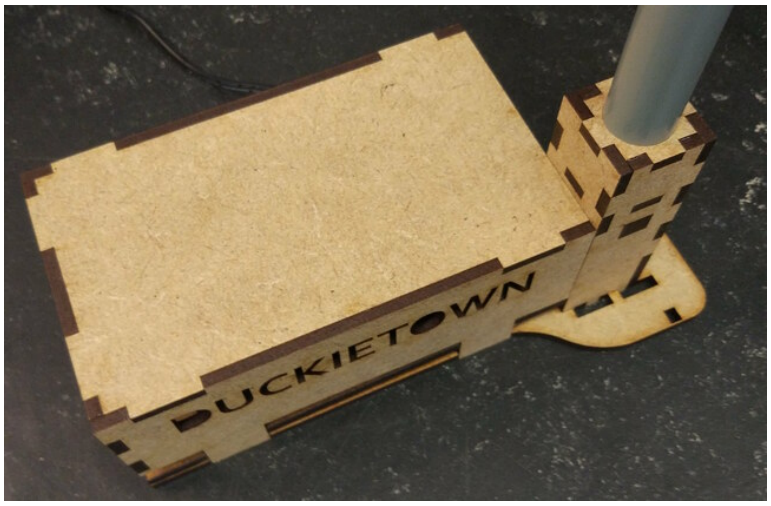
Connect the Ethernet cable.
Connect the USB cable.

If done correctly the LEDs should be on.

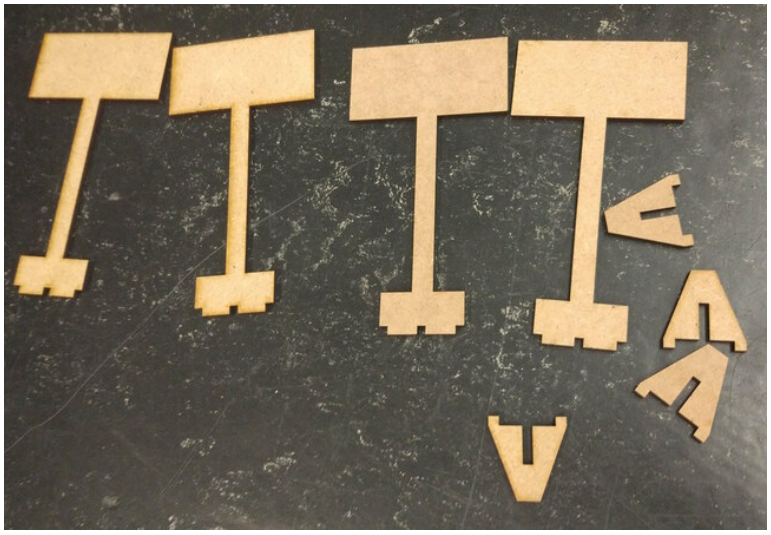


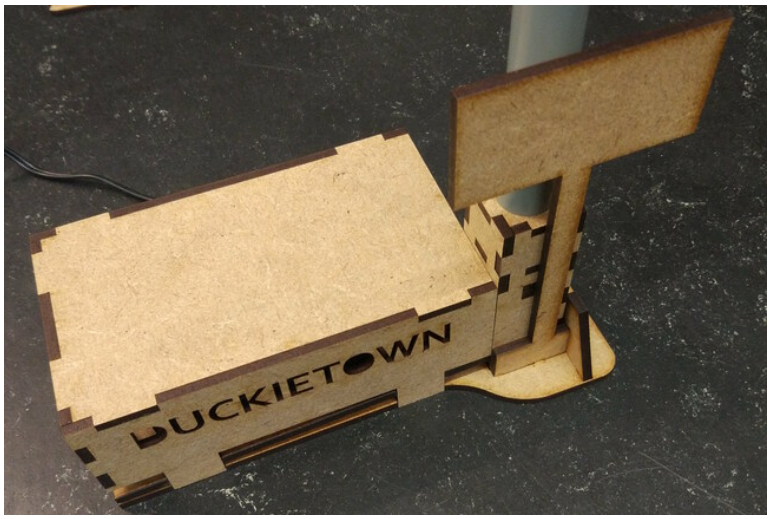
Close the ground module with the case.





Add traffic sign stands





Fully assembled traffic light

Fig. 66 Fully assembled traffic light.

Place the traffic light at an intersection such that the LEDs are exactly in the middle and are facing each incoming lane perpendicularly.

You can verify the position is correct by verifying that Duckiebots at the red stop lines can see only one light blinking, and no reflections of LEDs facing other directions.

You can finally use the provided double-sided tape pads to fix the traffic light to the tiles.