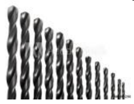
# Happy Marbles ( Chain experiment)

Happy Marbles will be manufactured at LTT2 in Villa San Sebastiano Nuova, Italy, from 1. to 5. April 2019.

**The needed tools for every contraption:**

| ***Tools*** | |
|---|---|
| Drill machine |  |
| Various drill bits (for wood and metal) – 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm |  |
| Foxtail saw – small saw teeth |  |
| Metal hand saw and metal saw blade |   |
| Strong scissors |  |
| Patex thermo gun + glue cartridges |  |
| Hammer  (200 g) |  |
| nail puller pliers |  |

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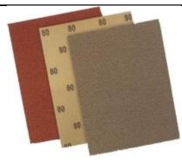
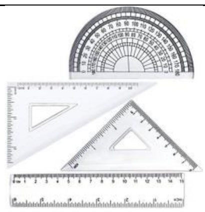
| combined pliers |  |
| 4 screwdrivers (flathead and Phillips) |  |
| Flat files (for wood and metal) |  |
| Abrasive paper for wood (rough and fine) |  |
| Hot air dryer |  |
| Tape meter (2 m) |  |
| triangle |  |
| clamp |  |
| angular ruler |  |
| pencil |  |

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|---|---|
| power strip |  |
| Stanley knife |  |
| Coloring brushes<br>Thin: 1 mm, 3 mm, 5 mm<br>Fat: 1 cm, 3 cm, 5 cm |  |

**<u>The number of necessary needed tools for the entire LTT2 workshop Happy Marbles has to be carefuly calculated (6 teams/ per 4-6 persons ) . Organizer must arrange that the work will run smoothly.</u>**

**Execution of section Happy Marbles.**

The paticipants will plan and build the contraptions in 6 groups. All groups will build a section on the same topic which will be based on the same basic plan that is presented below. It is important that during the execution of the article in the pilot group we emphasize the characteristics of each country (geographical, historical, artistic characteristics, habits ...).

The freedom of choice should develop the creative imagination of children and encourage them to try to realize their ideas by adding to the section the characteristic features of the countries in the project.

**Instructions for building the basic device of the Happy Marbles.**

The device consists of three separate parts, which can be combined into one device:

Mysterious paths

Marjanca

Crane

Mysterious paths:



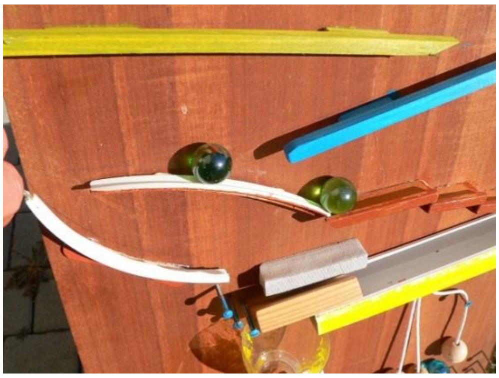

In the construction of the basic device we used a board made of chipboards measuring: 43 cm x 87 cm (we used the bottom of the wardrobe we got at the waste). The whole construction was built at an angle of 65 degrees. Parts of element are designed in such a way that the change in angle does not significantly change the operation of the element. The element also works if we change the angle on 15 degrees (higher or lower slope).The experiments determine the slope in which the operation of the device is optimal. On the lower part of the panel we installed door hinges so that children (constructors) can test the changes in the operation of the device with a changed slope (from 10 degrees to 90 degrees).

In designing the chain, we planned that the ball (marble) path would be unpredictable and would change according to the speed of the ball. The ball speed changes from collisions to obstacles, with slopes and rolling on a different basis. Confirmation that the path of the ball is really unpredictable, we provide by successive rolling of marbles along the same starting path (another yellow slope). For this purpose at the beginning of the path ( the first red slope) we prepared several balls (marbles) in the collector. Each ball through the wooden lever trigs~~s~~ the rolling of the next ball that is stored in the upper collector. Although all the balls start at the same place, their path through the device is different.


The ball starts to roll along the yellow slope to the red feeder. The feeder is made out of the cork. The purpose of the feeder is to deliver a single marble from one to the other slope and at the same time preventing the rolling of several marbles in the group. We removed the slats of slopes from the base plate so that the marbles roll over the edge of the slats in the gutter.

Running and rolling on different grounding can be shown on the first twisted hill, which is made of hard, white plastic (cut out from the edge of the hood cover for the inner colors). If this slope is covered with a soft grounding (with a hook we attach a cardboard, a mild, rubber, foam, ...) the collision of the ball changes and the marble loses more or less speed. The ball can reach the top of the slope or not. When it does not reach the top of the slope, the ball scramble back to the stairs.



We deliberately leaned the first step to create a "pocket" for the marble. A marble which rolls on a sloap, clash into a stationary marble and stops, while the stationary marble rolls ahead (presentation of the physical law of the collision of two identical balls).

The slab of styrofoam (gray colour) under the plastic slope is leaning slightly backwards, so the marbles, which hit a soft base and lost almost the full amount of energy, can roll back to the bottom "bottle". Marble, who rolls at the stirodur at an appropriate angle, retains sufficient energy and only flies and lands in a plastic gutter (yellow color). If it has enough energy, it could rolle a little also into the slope. From the yellow groove the marble rolles into the bottle, where it circles ,if it had flown at an appropriate angle. The bottle must be firmly glued to prevent marble swinging of the bottle and not lose too much energy.

Under the neck of the bottle there is a scale, which diverts the marble once on one side and then on the other. The redirect is achieved by a triangular wooden tile that is at the center of the scales and below the center of the bottle neck. With the oblique sides, the triangular tile redirects the marble to the opposite side of the tilt of the scale. The axis of the balance is at the bottom in the middle of the plastic groove (in the center of gravity).

The three pendulums show the transfer of energy in collisions between solid bodies. The horizontal force of the marble in a collision with wooden balls is transferred through wooden balls to a marble that is mounted on screws. The marble ran into a white gutter.

The marble after a collision with a wooden ball falls between the pendulums on the plastic gutter due to gravity. During the rolling on white gutter, the marble moves a wooden lever that releases one ball from the balls store (red ramp). During rolling the gutter the ball from store release the next marble from the red slope by moving the wooden lever. The events are repeated until balls are in the warehouse.

The plastic groove is clamped only at one end to bend when the ball is rolling through. The bending increases as the marble move away from the clamp. At the end of the plastic groove, the marble falls through the hole. The flexibility of the plastic varies with temperature, so at low temperatures it can happen that the deflection is too small and the ball stops near the bottle's throat above the opening. In this case, the plastic groove must be additionally loaded with the mass at the end of the groove (at the stopper).

On the other end of the scale (the opposite side of the pendulum ) the rolling marble falls into the middle cut-off bottle and them into the hole the groove, which is clamped only at one end. Marbles that do not accidentally fall into a plastic bottle are caught in a gutter that leads to a red warehouse.

After falling down through the hole of the groove, the marbles roll over the circular path to the lower edge, where the path along Marjanca (name of the device) continues in the middle. The bottom part can also be concluded in other different ways. Some suggestions: marbles travel between the stoppers of bottles, marbles travel between short inclined tiles, etc.

When we finish with the construction of Mysterious paths and carefully test its operation, we paint it in lively colors. We need to involve children here to show their creativity. Be careful when you paint that you don't change with colour the essential characteristics of the path were the ball will roll.

**Marjanca**

We used a board made of chipboards measuring 45 cm x 45 cm for Marjanca (we used the door from the wardrobe we got at the waste). On the edge of the board we vertically screw two slats (1 cm in height and 1.5 cm in width), wich are preventing marbles  to escape from the board. On the board we nail (4 cm in length) according to the previously made sketch. We make sure that the distance between the adjacent nails is larger than the size of the marbles (2.7 cm). In our case, the diameter of the largest marbles was 2.5 cm. Marjanca can be used for all marbles with a diameter of less than 2.5 cm. When nailing nails, we must be careful not to make a "pocket" where the marbles can catch up. Such "pockets" are often created along vertical side slats, where the distance to the slats is less than 2.5 cm. "Pockets" are simply eliminated by stitching an extra nail or by extracting a superfluous nail.

At the bottom of the Marjanca, we made rectifiers, which direct the ball into the middle. In the middle, we left an opening of 5 cm wide. Through the opening, the marbles are falling into a plastic box. Box prevents the marbles from rolling uncontrollably over the room. The tilt of the rectifiers is 15 degrees to the bottom edge of the board.

On the upper edge we screwed a slat length of 20 cm and a width of 5 cm, which provides support and solid contact with the first part of the Mysterious Path. Alongside the skateboard, we have connected Mysterious paths and Marjanca with hinges which makes the connection firm and allow us to change the slope of Mysterious paths. We prevented uncontrolled removing of hinges with a wooden barrier.

Marjanca were placed on four legs, which ensure the stability and strength of the construction. Stability is easier to achieve with three legs, but due to the size of the Mysterious paths, the strength and stability of the structure is compromised. Legs must be strong. Two and two legs are exactly the same size and screwed to the same height that the structure dont swing.

The lower edge of the Marjanca is 12 cm high above the base (it can also be a higher, but it should not be smaller, because there are problems with the continuation of the device and catching balls). The upper edge of Marjanca is 22 cm high above the ground. With this, we created a Marjanca slope of 14 degrees. At an angle of 14 degrees, we must cut off the upper part of each leg, which we will screw them to Marjanca. The lower part of each leg will stand perpendicular to the base.

All dimensions are given here only for orientation and are flexible.

When you finish with the construction of Marjanca and you carefully test its function, you paint it with lively colors. Involve children here so they can show their creativity.

Marijanca allows us to develop the creativity of children and to enrich their technical experience. By stretching the elastic between the nails and by placing various obstacles between the nails, we change the path of the marbles through the marjanca.

Marjanca can be used as an independent play equipment and also as a social game. If we remove the rectifiers in the lower part and instead of them place the same large boxes or drawers into which balls are going to be cought, we can determine the probability that the ball will enter into a certain drawer (we always drop the marble from the same place). We can also play a game that each player will release a ball from the particular place and announce in which drawer the marble will be cought. We can also compete in the points collection. We assign a number of points to each drawer and then each player sums the points in ten attempts.

**Crane**

The marble should be given away to the next device on height of 45 cm from the base.
. From many different options, we decided to build a model of the Crane because it shows the characteristics of the lever. A lever can be presented to the children with a swing and by that show them the basic principles of changing the lenght of the lever.

The crane was fastened to the basic wooden panel 45 cm x 23 cm (the dimensions of the plate are not important, we must ensure the stability of the crane). We used for the base plate a waste shelf made from a chipboard and a wooden tram crosses 4 cm x 4 cm for the carrier.

The axis of rotation of the plastic tube on the carrier is 52 cm above the surface - when it is facing down, the exit from the tube is 45 cm above the ground. The height of the output can be partially changed with a screw which stops the movement of the pipe.

The length of the plastic tube is 32 cm and the axis of rotation of the tube is 19 cm from the exit of the pipe. The axis of rotation was moved back from the center of the tube for the diameter of the marble, which was not a good solution. It would be better to set the axis of rotation in the middle of the pipe, because this would reduce the counterweight opposite the exit of the pipe. We drilled the axis of rotation through the center of the tube, which presented marble cautch at the same time. We can make an independent closure at any length by moving the axis of rotation of the tube from the center to the lower or upper end of the pipe circumference (not through the tube).

At the end of the Marjanca we collect a lot of marbels in the jar of Žerjav, so there is no worry that the lever would't work. On one side of the lever, we hung a can full off marbles, and a plastic tube with an inner diameter of 2.9 cm (the diameter may be slightly different, but not smaller than the size of marbels) on the other side of the lever.

Both lever side arms (yellow batten) are equal to us in length (11 cm). In the experiment, it was subsequently shown that Žerjav would work better if the side arm of the container was shorter, e.g. by half, (6 cm), because then it would not be necessary to additionally weigh the lever on the side of the plastic tube. Making the Crane is a good challenge for creative imagination. When you finish with the construction of a Crane and carefully test its performance, you paint it in lively colors. You need to involve children here to show their creativity.

## Consumables

### The needed material and tools which has to be prepared for each section for six teams:

| **Material for six contraption** |
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| 6 piece - board 80 cm x 50 cm, thickness of 2 cm (the base for Mysterious paths)<br>6 piece - board 50 cm x 50 cm, thickness of 2 cm (the base for Marjanca)<br>6 piece - board 50 cm x 25 cm, thickness of 2 cm (the base for Žerjav)<br>Note: Depending on the purchase, the dimensions may be slightly different from those which they are written. |
| 6 x 4 piece – pillar long 30 cm and cross section 5 cm x 5 cm (for Marjanca legs)<br>6 x 1 piece – pillar long 60 cm and cross section 5 cm x 5 cm (for Žerjav ) |

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| Note: Depending on the purchase, the dimensions may be slightly different from those which they are written. |
| 2 pieces - A slab ( 0,75 $m^2$) of Styrofoam, about 3 cm thick |
| Wooden slats cross section 1 cm x 1 cm - total length 12 m<br>Wooden slats cross section 2 cm x 0,5 cm - total length 6 m<br>Wooden slats cross section 2 cm x 1 cm - total length 12 m<br>Wooden slats cross section 4 cm x 2 cm - total length 12 m |
| Plastic tubes (hard plastic) of inner diameter about 2.5 cm or more. The total length is about 4 m. |
| Plastic or wooden pipes of square or rectangular cross-section of different dimensions (most useful 30 mm x 20 mm or 40 mm x 25 mm). For electrical installations can also be waste material. The total length should be 12 m. |
| Slim flexible rope, about 1 mm thick. Total length 25 m. It can be a rope for window blinds. |
| Wooden carpentry waste. |
| Wood screws of different sizes (from 1 cm to 6 cm). Each type of 60 pcs. |
| Nails of different sizes (from 1 cm to 5 cm). Each type of 60 pcs.<br>For one Marjanca we need about 250 nails in length of 4cm - total of 1500 nails in length of 4 cm or 4.5 cm for 6 teams. |
| Different waste plastic containers (ice cream, food, cottage cheese, cream, yogurt, ...) |
| 40 pieces of wooden balls with an opening, diameter 2.5 cm<br> |
| 200 pcs - different plastic stoppers |
| 40 pieces – Waste no colour plastic bottles - wide throat (diameter 4 cm)<br>15 pieces, Waste no colour plastic bottles - narrow throat (diameter 2,5 cm) |
| Metal wire with a diameter of about 2 mm, and a length of 6 m |
| 6 pieces of plastic sticks that can twist. Cases of larger hooks, diameter of 50 cm or more (can also be used) |
| 120 pcs of plastic balls with a diameter round 2,5 cm |
| 100 pcs - elastic for closing glasses. |
| 0,5 kg Plasticine |
| 100 pcs ice cream sticks |

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| It is useful to collect some other material that is discarded in the household, and we could use it in the manufacture of a device (plastic cutlery, retired toys, straws, etc.). |
| 12 pieces of door hinges (for connecting Marjanca and Mysterious paths we need 2 pcs)  |
| 24 pieces of door hinges, 3 cm long  |
| For coloring - Colors (black, white, red, yellow, blue). Each color of 1 kg. I recommend colors that dilute with water and are durable when they are dried. They should not be harmful to children. |
| Waste cardboard and newspaper for the protection of furniture and floors. Waste rags. |

***Day 1 – Monday***

Everyone in the team is assigned a post. The basic tools and the basic material for the contraption are distributed. The material and tools for the construction of the section will be chosen from the common collection by each team itself according to their needs.

The team will agree on possible changes to the plan and will need to draw a sketch of their section. The sketch should describe as accurately as possible the actions of the section and the necessary elements, as the members of the group will build the contraption.

When the sketch will be finished, we will set up the basic elements of the device under the guidance of a mentor.

***Day 2-*** Each group creates their section according to its plan. Two mentors help teams at work.

***Day 3 – Wednesday*** Each group creates their section according to its plan. Two mentors help teams at work.

***Day 4 – Thursday***

Teams complete all the elements of their device, connect them, and test the performance of the entire device. If necessary, the performance of the device is optimized and improved reliability.
At the end we paint the contraption.

***Day 5 – Friday***

Each team optimizes the reliability of the function of their section, because coloring can change the performance of each unit. We link all of the sections to the chain and we make a few experiments on the whole chain.

**The task for teams working for a kindergarten at home**

The LTT participants organize the creation of a section with the same theme (Happy Marbles) in the kindergarten where they are employed. The sections should be enriched with the characteristics of countries involved in the project.

By making the contraption, children under the supervision of adults will learn to use the basic tools: hammer, pliers, screwdrivers, saw blades, files, abrasive paper. By designing individual parts of the contraption, they will learn manual skills and learn about different material properties and natural laws of movement.

**An excellent sketch** makes it easier to work on the section and prevent subsequent falling apart of the already made construction. At the same time, it allows us to divide the work and the individual can produce a certain element or part of the section.

Once the device is completed, we test its operations and try to eliminate errors in operation and improve reliability. After all irregularities have been eliminated, and when we are satisfied with the operation of the device, it has to be only painted. Children like to have a bright and vibrant color. When we paint, be careful not to change the characteristics of the device by coloring. When the color is dried, we must check the operation of the device and, if necessary, correct the defects.
The final look of our basic device is in the picture below.