E – MANUAL

CHAIN EXPERIMENT IN PRESCHOOL

LJUDSKA UNIVERZA JESENICE

1. INTRODUCTION

1.1. Project Title

Title of the project is **Chain experiment in preschool.**

1.2. Description for the need of the programme

Strategy of Europe 2020 agenda emphasizing smart, sustainable and inclusive growth calls for skills development and consequently achieving the objectives of economic growth. First one of challenges, addressed by this project, is badly formed technical skills – for about one fifth of ungraduate students of EU. Basic skills are vital for learning, achieveing basic competences and personal development.

Currently mismatch of skills and competences is compromising Europe's innovation capacity. A supply of highly qualified and well-educated workers is in growth, need for graduate engineers is getting bigger. Future demographic trends, technological development, digitalisation, increasing pressure on the environment and other goal trends require constant acquisitions of skills and competences in day to day life. It is important for life long learning to cover population at large as much as possible in which quality and accesibility are vital, especially towards most disadvantaged groups. Efficient and high-quality educational system which goal is to prepare individual for effective work, participation in society and thus achieving over all quality life – that is also basic condition of competitive economy and social well-being. Undergraduate students are getiing more and more mobile and they stay mobile also after graduation.

Exchange and transfer of knowledge is processed through engaging key elements: science, educational system and economy. High level od education amongst youth is growing rapidly which is actually desired according to economy needs for high educated and trained workforce. Although, there are numerous imbalances between supply and demand of available workforce. That si because of discrepancies between knowledge and skills of workforce and the needs of employers. The later impedes an increase of production, raises questions of usage of skills. There is also a significant risk of brain drain. Closing knowledge and skills gap is also one of the factors of reducing social excluding of individuals.

Technological progress brings rapid changes in economies by numerous variations and adaptations of production processes anf business models and therefore creating new products and services. Some traditional jobs are disappearing while new jobs, demanding skills and knowledge, are emerging.

Developing basic technical, mathematical and scientific skills among preschool children are ground cornerstone on which children are building knowledge grounded on understading and previous experiences. Through well run exploration of their thoughts child is able to compare them with new, different experiences, is able to reflect on natural phenomenon, on objects and substances. Preschool exploration is also based on familiarising intuitive concepts, child's naive ideas and interpretations and are integral part of natural enviroment. As long as we wish to develop basic preschool children technical skills and encouraging them to decide for innovations, we have to give them a possibility to experimenting and doing it in independent manner. Experimenting allows children to upgrade their knowledge and to aquire new skills. In that manner children are more interested for natural sciences, not just for further undergraduate education, but also later in their lives for the interest in Science, Engineering and Technology (SET) careers among them.

Second of the challenges is rapid ageing of population. Generation gap is also a deep cultural gap among different generations. Intergenerational learning is one of the most important ways to close that gap and is leading to solidarity and trust.

Intergenerational cooperation emerged as the initiative due to bigger differences between generations, which were leading to increasingly evident and mutual ignorance between younger and older generations. Big diffrences in knowledge and values can cause bigger generation gap and at the same time prevent free circuit of knowledge which would enriched all of them.

Apart from solidarity and harmony, intergenerational cooperation means active and equivalent work with a view to achieve same goals. Generations in coopeartion through various tasks and projects create strong and valuable social ties and networks, which benefit all participants. That is why it is important for us to create enviroments where all generations are equal partners. *

Future development of Slovenia will greatly depend on abillity to respond and adapt to global trends and challenges. Trends indicate significant changes in demographic trends, on pressures on ecosystems, competitions for global resources and global economic imbalances. In that light, cooperation and connection on global, european and national level and international cooperation are even more important.

Slovenia gradually advances in field of quality of life and economical development, some pressures on enviroment are also reduced. Despite that, Slovenia economically, socially and enviromentally still lags behind most developed countries, but also within Slovenia those lags are different from region to region. Further developing possibilities are limited by low productivity, by failure to adapt to demographic changes, by exessive enviromental pressure and by inefficient governmental task to promote development. For development potential, Slovenia fully embedded in international business and social and political enviroment, is extremly crucial.

EU demographic changes in next decades will be extremly important, because according to current trends, EU population will age even more due to low birth rates and increasing longevity. Even though migration has important role on population dynamics of European countries, it won't significantly change current trend of population ageing in the EU region. Due to low birth rates, number of students, active workers who support other population, will decrease and number of older population will increase. That older population will be in need for extra infrastructure, will need more health care services and adapted housing facilities. Potentially, structural changes could have more impact on government efficiency and could cause increasing tax collection to build up adequate pensions and health care services.

Slovenia is facing demographic changes that will have a major impact on the future development of society and quality of life. They are reflected in an increase number of people over the age of 65, low birth rates and a decrease in the population in the age group of 20-64, which is the current definition of the working active age population. According to population projections, the aging process will accelerate in the future, and the share of the population over the age of 65 will increase from around 19% in 2017 to around 30% by 2060. Demographic change thus leads to a relatively rapid decline in the capacity of the active population, which, due to the lack of adequate labor, can also significantly reduce the ability to accelerate economic progress, which is a condition for further improving the living standards of the population.

1.3. Target group of the program

a.) Preschool children

Children in pre-school period are learning and developing basic technical and scientific skills and therefore develop interests for technical trades further in their lives. Children up to 6 years of age are in so called pre-operational stage of development. In that particular time, they are starting to develop abillity to plan actions in advance and are capable of predict progress in concrete actions. In that stage child's cognitive development, specifically memory development, is increased. Because of that, aquisition of basic techical, mathematical and scientifical skills plays a very important role. Preschool children are getting important and positive intergenerational communicational skills. Intergenerational cooperation between retired mentors and preschool children is important factor of learning in which preschool children gain experiences and are able to learn from adults and are experiencing mutual positive feelings. Children with their playfulness, directness and open mindfulness also help to improve lives of adults participating in project.

b.) Senior mentors,

who will gain knowledge in the field of preschool education and child pedagogy, which will empower them for mentoring preschool children. They will have opportunity to seize new knowledges and practical skills and at the same time they will be able to exchange good practice and inovations in steps of Chain experiment. Connecting and collaborating between generations increases intergenerational coexistence and mutual understanding. The exchange and transfer of experience and knowledge, mutual assistance, socializing, learning and expanding the social network also help to increase the social inclusion of the elderly and reduce their loneliness. Senior mentors, with appropriate training for a quality life in retirement, spontaneously decide to volunteer and engage in one of the activities that develops, upgrades their interests, hobbies.

c.) Preschool teachers,

who will acquire the skills to produce the article. They will acquire both theoretical and practical knowledge about intergenerational cooperation, which will enable them to introduce various intergenerational activities in kindergarten. They will acquire skills and competencies for cooperation with adult education organizations and pensioners' associations, and gain knowledge on how to encourage the introduction of voluntary work in kindergarten activities. Discovering new, innovative methods to motivate older mentors to actively engage in preschool activities will help strengthen intergenerational collaboration. The kindergarten as an institution has an important role to play in developing friendly relations between the generations. By the way, completely new forms of coexistence of generations and relationships are being formed with the help of professionals who, with a sense of upbringing, ensure the interaction of children with senior citizens.

d.) Adult educators

will also gain the knowledge and practical skills to produce a Chain Experiment chain. They will develop competencies for working with preschool children, parents and grandparents, and strengthen intergenerational cooperation, which is important for existing and further work with these two target groups. By engaging in the activities of the Chain Experiment, adult educators gain important experience in working with preschool institutions and non-governmental organizations. Connecting with pensioners' associations significantly expands the network of volunteers. Life experience and knowledge are one of the foundations with which we enrich the function of the organization of adult education and reach various target groups. Adult educators will be able to disseminate examples of good practice among other adult educators, which will increase the number and quality of intergenerational activities in adult education organizations and the number of volunteer mentors.

1.4. Program objectives

- to develop mathematical, scientific and manual skills at preschool children, to acquaint them with physiological phenomena and to inspire them for technical professions through the acquired knowledge.
- encourage older mentors, educators and adult educators to increase interest in technical professions at pre-school children.
- developing communication skills and a positive attitude towards the elderly and encouraging learning from each other, thus strengthening intergenerational cooperation.
- encourage the development of volunteering among the elderly and prevent slipping into social exclusion.
- to raise awareness of the importance of sustainable development, as we encourage the re-use of various materials.
- expand the Chain experiment in preschool, as an example of good practice of intergenerational activities that connect the field of adult education and preschool education.

1.5. Scope of activity

The program comprises 60 hours.

It is recommended that program hours be scheduled within one school year. The workshop should take place once a week, for a maximum of 1.5 hours.

For easier planning, you can divide the hours according to the individual set of chain manufacture (eg. 15 hours / chain), which ofcourse you redistribute when needed.

2. SPECIAL PART

2.1. Chain experiment providers and their specific knowledge

- **Senior chain experiment mentors** who have expertise in physics, mathematics, engineering, and science and have expertise in pedagogy. Other seniors who have well-developed manual skills and are passionate about working with children can participate act as mentors.
- **Preschool teacher** who have knowledge of planning, organizing and carrying out educational work, working with parents, grandparents. They need basic knowledge of preschool pedagogy and child development. They must also have knowledge in the field of motivation of preschool children.
- **Adult educators** who have expertise in the field of knowledge of target groups (eg characteristics of the target group of the elderly), in the field of intergenerational cooperation, with which they connect educators and the target group of the elderly. Adult educators should also be equipped with the skills to monitor and identify educational needs and adjust the educational offer.

2.2. Content

2.2.1 What is a Chain Experiment?

Chain experiment is a set of devices that are driven one after the other, so that the previous device triggers the operation of the next, according to the principle of breaking dominoes. The connecting link between the devices of the chain experiment is a standardized metal ball, 2 cm in diameter. The ball, which travels between adjacent elements, rolls off to the adjacent device after the end of the operation of one device and starts its "experiment". CHAIN EXPERIMENT is named because the devices are chained together.

Chain experiment can be implementated in different environments: in the classroom, on playgrounds, at school camps, even at public events. With a touch of imagination, we can use any terrain to set up a chain experiment in nature.

2.2.2. Implementation a Chain Experiment in preschool?

We recommend that you include children from second age group, 5 years old, who are about to enter the school in the activity of the chain experiment. Fine motor skills, the ability to perceive and development of intellectual abilities are developed to the extent so it's easier for them to participate in given tasks, than younger preschool children.

First of all, we present the operation of the chain experiment to children. The most successful we will be if we show them physical phenomena through play with gadgets that we use in everyday life and that children know. This will make it easier for them to remember the cause-and-effect relationship, and it will be easier for the children to work together later when we make the device. The chain link connection can be shown in different ways. We can play the game in a circle by asking the question. When the first child answers the question, the touch communicates to the next child that he can is tje next to answer. The game of dominoes is also extremely popular. The children place dominoes at a short distance and in different direction. By pushing the first one, they break the set chain of dominoes. The game development should be accompanied by mentor explanation (which must be understandable to the child), which describes the physical phenomena. Slowly, the game involves manual skills such as driving nails, screwing screws, handling other various tools.

It is recommended that the activities of the Chain Experiment are carried out with a small number of children (up to 10) so that all children can actively participate, express their personality and thinking. It is recommended that 3-4 adults should attend the workshop (1 mentor per 3 children), who advise children and guide them to solutions when they face the obstacle in the in the manufacture process. Smaller working groups of children within one workshop should be composed in a way that children in the group can exchange- according to interests, type of activities in friendly relations. Exchange in a group can be made only by preschool teacher, which knows the children. Experiences show that children should change activities every 20 minutes so that concentration can be maintained. Chain Experiment workshop should include several different work corners and individual work phases intertwined with play.

It is important that we stimulate the child's curiosity and desire to explore, so we keep the children busy with concrete work and make plans according to children's suggestions (the mentor encourages their critical thinking).

The materials from which the individual elements are made should be simple and inexpensive. It is desirable to use waste material from households, shops, crafts as possible. We make sure that the elements from which the device is built are strong enough for multiple use, easily repairable or replaceable, but above all interesting enough and not too difficult to build, so we can build it together with children.

When the chain is done, don't forget to celebrate. We organize a special event at which we launch the manufactured chain, and we also invite other children, parents, grandparents, educators to the event.

Many times, those who do not participate in the Chain Experiment workshops get excited about it the minute they see the chain and have the opportunity run it.

3. INSTRUCTIONS FOR MANUFACTURE OF DIFFERENT CHAIN LINKS

3.1. Instructions for Olympic games chain 2020

Space

The space should allow working in groups. Each group needs two tables (can be school benches), 1 m to 1.5 m long and 0.5 m to 1 m wide, and 5 chairs. In addition to the tables for groups, we need four more tables where we will place common tools and common material. To prevent damage to the tables, the table surface should be protected with waste cardboard from the boxes. Some old newspapers (about 1 kg) should be prepared, which we will use during painting and in preventing the spread of dust in the surroundings.

Common tools and material

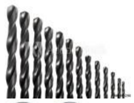
Common tools and materials should be available on the tables for all groups. When the group needs it, they take it and return it after use. Each group will build its own chain. It is desirable for the group to be creative and to look for and embed their own solutions in the production.

The need material and tools:

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)

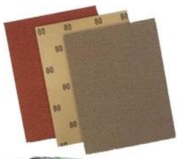
Nail puller pliers

Combined pliers

4 screwdrivers (flathead and Phillips)

Flat files (for wood and metal)

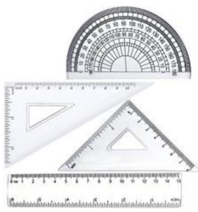
Abrasive paper for wood (rough and fine)



Hot air dryer

Tape meter (2 m)

Triangle



Clamp

Angular ruler

Pencil

Power strip

Stanley knife

Coloring brushes
Thin: 1 mm, 3 mm, 5 mm
Fat: 1 cm, 3 cm, 5 cm

Material for one contraption
Box (board 100 cm x 50 cm, thickness of 2 cm, 2 battens 50 cm in length and two battens 100 cm, width 4 cm,4 columns height 50 cm and cross section 4 cm x 4 cm)
A slab (0,75 m^2) of Styrofoam, about 3 cm thick
Plastic grooves of inner diameter about 2.5 cm or more. The total length is about 1.5 m
Wooden slats of square or rectangular cross-section of different dimensions (most useful 30 mm x 25 mm or 40 mm x 25 mm). Two slats should be 1,1 m long.
Wooden board with a thickness of 1 cm and a size of about 50 cm x 50 cm
Wooden carpentry waste
Wood screws of different sizes (from 1 cm to 5 cm)
Nails of different sizes (from 1 cm to 5 cm)
Wood glue
Colors (black, white, red, yellow, blue)
A rope of about 1 mm thickness and a length of about 2 m
Waste plastic bottles, stoppers and yoghurt cups
Metal wire with a diameter of about 2 mm and a length of 0.2 m
Plastic or metal balls with a diameter from 1 cm to 3 cm

Additional material
Curved pipe with a diameter of about 2.5 cm and a total length of about 20 cm - a drain pipe can also be used.
Plastic round tube about 2.5 cm in diameter and 30 cm long
Old cloths for cleaning
Wodden cube for support at brushing

Basic plan

Each section is designed in such a way that all planned events are combined together in a wooden box of dimensions: 100 cm x 50 cm x 50 cm. With this design, the device will quickly be ready for use and operation. The basic box will include working elements that should represent individual selected sports of Olympic Games 2020: marathon, basketball, rowing, field hockey, water polo, football, relay race, jump with a stick. If desired, the team will also be able to choose their own sports and will adapt to their choices. The dimensions of the base box are also optional and can be changed by the team.

If there are any changes to be made to the plan agree on it and draw a sketch of your chain. The sketch should describe as precisely as possible the events in the chain and the necessary elements.

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. By making the device, children under the supervision of the elderly will learn to use basic tools: hammer, pliers, screwdrivers, saw, file, sandpaper. By designing individual parts of the device, they will train their manual skills and learn about the different properties of the material and the natural laws of movement.

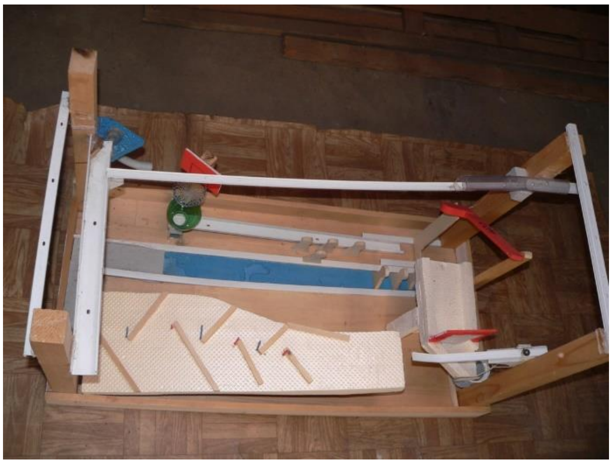
Instructions for creating a basic box

The base board (100 cm x 50 cm) can be bought in a shop or cut from a larger piece. The thickness of the board should be at least 2 cm and wooden, which will not twist and bend later. It can also be chipboard. The dimensions of the box are recommended, but not mandatory, and each group can adapt it appropriately.

Attach all four corners from the bottom with a vertical column screw. When placing pillars, we have to be careful that they are spaced from the edges as much as the thickness of the slats, which will connect the columns with each other. Prior to fixing the columns, it is helpful to lubricate the contact surfaces with adhesive glue. Plates connecting the columns should be placed on the base board, so that the base surface of the box remains 100 cm x 50 cm. The thickness of the strips should be at least 1 cm and the width should be at least 3 cm. The plates are glued to the base surface and screwed from the bottom with screws. With screws, we also screw the slats upright to the pillars to ensure the strength of the pillars. If desired, the intermediate surfaces can be lubricated with glue prior to fixing the strips on the column. The base box is finished. Allow the adhesive glue to dry. The shape of the box is similar to an upside-down table.

Note: in order for the screw heads not be seen from the base and cause scratches on the substrate, we expand the hole with the wider drill before fitting it to the drilled hole. We can do this manually.

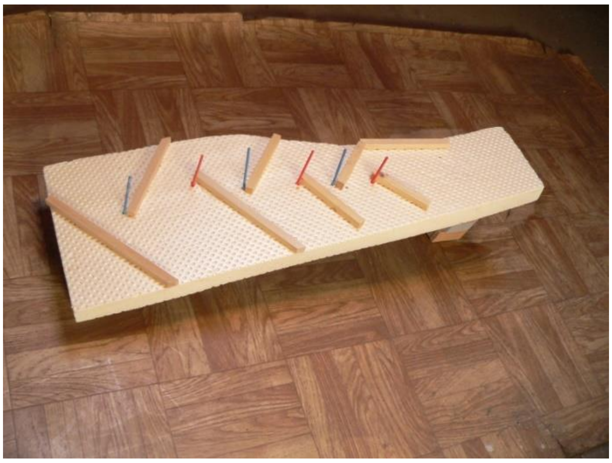
Instructions for building the basic section of the Olympic games 2020

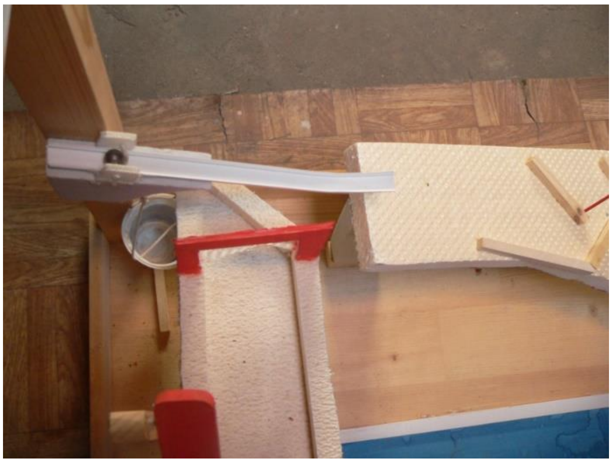


An excellent sketch makes it easier to work on the section and prevent subsequent falling apart of the already made construction. At the same time, it allows us to divide the work and the individual can produce a certain element or part of the section.

We begin to build a section with an element that occupies the most space. In our case, this is a football playground and water polo pool. It is made of Styrofoam. Cut off a plate of 60 cm x 25 cm. On the basis of testing the speed of the ball, we select the slope and paste the appropriate mountings below the plate, which ensure the stability of the slope and constant inclination.

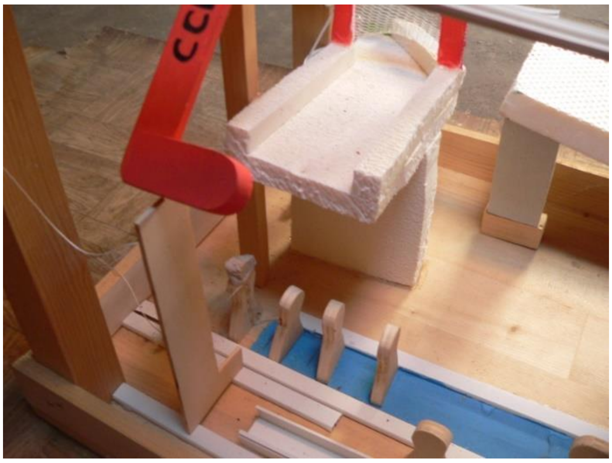
We will put players of football and water polo in the end when we test the performance of the device.



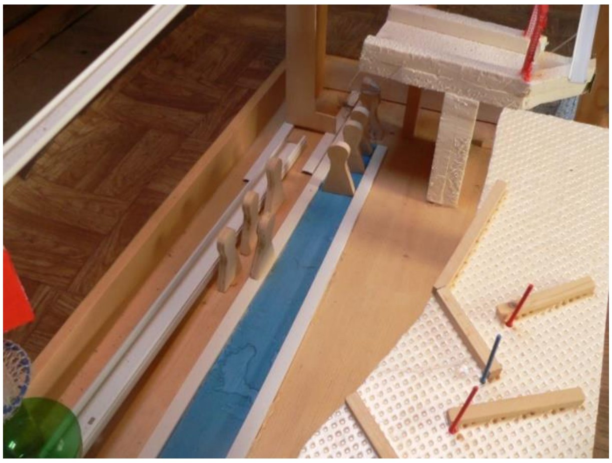


We make a hockey court from wood, but we can also make it from a styrofoam. The size of the playground is 27 cm x 12 cm, you can also change the dimensions. The court is slightly inclined towards the goal to make it easier for the ball to roll into water polo pool. On the opposite side of the goal, we make a hole in the playground, where we place a ball (it represents a hockey pack). A hockey stick strikes the ball into the goal. The stick is pivotally attached to the column above the ball. The hockey playground is raised above the base surface of the box, so that metal ball will fall on the water polo pool.

We have to move the hockey stick from a balanced position and support it with a wooden sling. In our case, the height of the slat is 22,5 cm. When the ball falls through the basket, it rises to the wooden sling on the slope and pushes it under the hockey stick, so the stick swings and hits the ball in the goal.

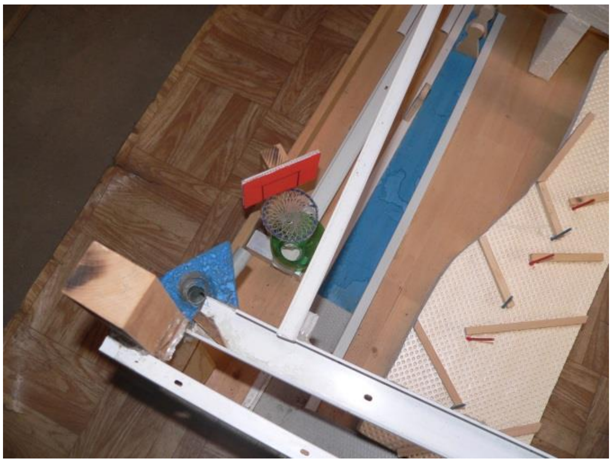
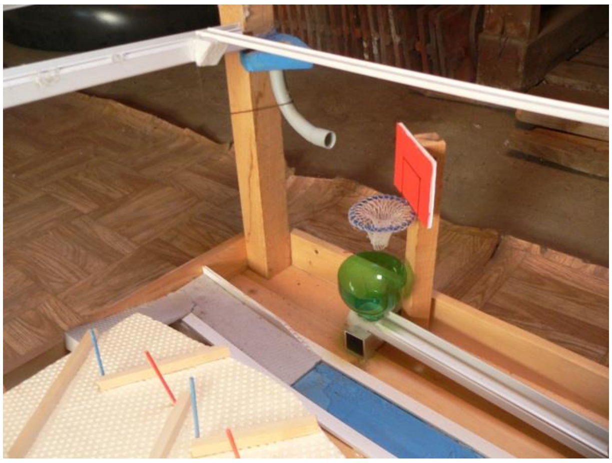


The slope (representing the rowing track) is made from a plastic groove, which is 4 cm wide, 2,5 cm deep and in our case 85 cm in lenght. At the beginning of the slope, under the basket, we can attach a cut-off funnel of a plastic bottle to ensure that the ball from the basket drops safely into the groove.



Above the funnel we make a basket, which is attached to the wooden pillar. The basket height is not important, we decided 6 cm above the slope. The rim of the basket can be metal or plastic. Waste material may be used. We desided for the upper part of the bottle. Its diameter is 6,5 cm, so it is more likely that the ball will drop into the basket.

The lower exit of the basket (bottle neck) must have a diameter greater than 2.2 cm. Shooting to the basket will represent a curved plastic tube. With the curvature of the tube and its position, the ball is always approaching the basket. We find the correct position by trying a few times. We attach the curved tube to the upright corner pillar with the upper part of the bottle. With a tension cord (option), which is tilted approximately at the turn of the tube, we can change the inclination of the tube and thus the direction of the flight of the ball to the basket if it is necessary.

Through plastic groove (they represent the marathon run track), we lead the received ball at the entrance of the device to the opening of the curved plastic tube carrier to the basket. The ball comes into the contraption at a height of 44 cm. The plastic tube is 1.1 m long and is removed during transport, so that the dimensions of the device are smaller. The cross-section of the tube is 4 cm x 2.5 cm, but it can also be 3 cm x 2.5 cm.

We need to finish the race of the ball after football. Since we do not know where the ball will come down from the football field, we place a long domino (21 cm in our country) across the width of the court. Behind them, we place parallel two domains (7 cm high), followed by one domino (height 11 cm) and the other (height 15 cm) and the third (height 20 cm). These domains represent a relay race. This is followed by a jump in height with a stick, which we present with a narrow stick of height of 50 cm.

The stick is slightly hinged on the ball that sits in the well at the beginning of the outlet groove. The last dominoes (20 cm high) are opposed to the stick and the rod pushes the ball through the groove to the next device at a height of 45 cm. The outlet groove is glued to the slat, which can be removed during transport in order to reduce the dimensions of the device.

3.2. Instructions for “happy marbles” chain

The needed tools

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)

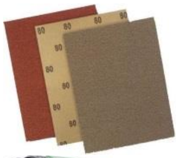
nail puller pliers

combined pliers

4 screwdrivers (flathead and Phillips)

Flat files (for wood and metal)

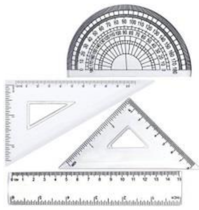
Abrasive paper for wood (rough and fine)



Hot air dryer

Tape meter (2 m)

triangle



clamp

angular ruler

pencil

power strip

Stanley knife

Coloring brushes
Thin: 1 mm, 3 mm, 5 mm
Fat: 1 cm, 3 cm, 5 cm

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Erasmus+

The needed material and tools

Material for one contraption
1 piece - board 80 cm x 50 cm, thickness of 2 cm (the base for Mysterious paths)
1 piece - board 50 cm x 50 cm, thickness of 2 cm (the base for Marjanca)
1 piece - board 50 cm x 25 cm, thickness of 2 cm (the base for Žerjav)
Note: Depending on the purchase, the dimensions may be slightly different from those which they are written.
4 piece – pillar long 30 cm and cross section 5 cm x 5 cm (for Marjanca legs)
1 piece – pillar long 60 cm and cross section 5 cm x 5 cm (for Žerjav)
Note: Depending on the purchase, the dimensions may be slightly different from those which they are written.
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
Wooden slats cross section 2 cm x 0,5 cm - total length 6 m
Wooden slats cross section 2 cm x 1 cm - total length 12 m
Wooden slats cross section 4 cm x 2 cm - total length 6 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).
Nails of different sizes (from 1 cm to 5 cm).
For one Marjanca we need about 250 nails in length of 4cm or 4.5 cm
Different waste plastic containers (ice cream, food, cottage cheese, cream, yogurt, ...)
Wooden balls with an opening, diameter 2.5 cm

Different plastic stoppers
Waste no colour plastic bottles - wide throat (diameter 4 cm)
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
Plastic stick that can twist. Cases of larger hooks, diameter of 50 cm or more (can also be used)
Plastic balls with a diameter round 2,5 cm
Elastic for closing glasses.
Plasticine
Ice cream sticks
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.).
Door hinges for connecting Marjanca and Mysterious paths (we need 2 pcs)

For coloring - Colors (black, white, red, yellow, blue). It is recommended that the colors 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 and waste rags.

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

Mysterious paths

Marjanca

Crane

3.2.1. Mysterious paths



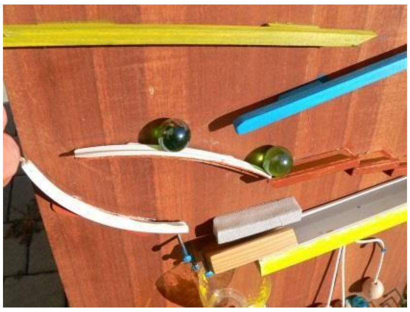

In the construction of the basic device, we used a board made of chipboards measuring 43 cm x 87 cm (we used the bottom of the wardrobe we got from the waste). The whole construction is built at an angle of 65 degrees. Parts of element are designed in such a way that the change in angle does not significantly change the operation of the element. The element also works if we change the angle on 15 degrees (higher or lower slope). 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. 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.

3.2.2. 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 used to prevent marbles to escape from the board. On the board we hammer the nails (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 hammering 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 is 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´t 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, it can be painted with lively colors.

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.

3.2.3. Žerjav (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.

The final look of our basic device is in the picture below.

3.3. Instructions for Chain on the wall and on the floor

Tools we need:

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

combined pliers

4 screwdrivers (flathead and Phillips)

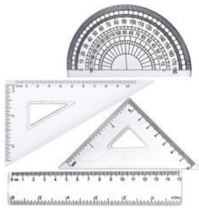
Flat files (for wood and metal)

Abrasive paper for wood (rough and fine)

Hot air dryer

Tape meter (2 m)

Triangle



Clamp

Angle ruler

Pencil

Power strip

Stanley knife

Coloring brushes
Thin: 1 mm, 3 mm, 5 mm
Fat: 1 cm, 3 cm, 5 cm

The elements for the chain experiment are simple and cheap. With some resourcefulness also waste material (from households, commerce or crafts) can be used. Chain wall experiment is very suitable activity implementation in school camps, it can be used for various activities in the classroom and in play areas, and also at public events. With family we can do it on picnics. With a touch of imagination, we can use every terrain to set up a chain experiment in nature. It is well suited for demonstration and promotional purposes of a Chain experiment in public.

The proposed implementation of the chain experiment is divided into two separate units:

a.) a chain experiment on the wall
b.) a chain experiment on the floor

In practice, the two units can always be combined with each other. From an elementary element we can set up an arbitrarily long Chain experiment.

3.3.1. Chain experiment on the wall

The needed material and tools which has to be prepared for each section

Material

Cardboard tubes about 5 to 8 cm in diameter (can be of different diameters) and any length - total length all of them at least 60 m. The pipes should be cut lengthwise into grooves in half.

Plastic pipes of square or rectangular cross-section of different dimensions (most useful: width 30 mm x height 20 mm or 40 mm x 25 mm).

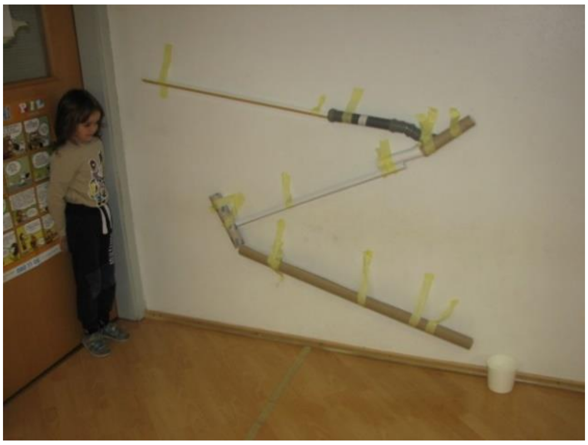
That can also be a waste material in electrical or electronic installations. The total length should be at least 30 m.

A thin and flexible twisting rope about 1 mm in diameter. Overall length 25 m. It can be a rope used for interior window blinds.

Various waste plastic containers (ice cream, food, curd, cream, yogurt, containors, ...)
Different plastic stoppers
Waste transparent plastic bottles wide throat (diameter 4 cm)
Waste transparent plastic bottles (diameter 2,5 cm)
Plastic (or metal or wooden) balls with a diameter round 2,5 cm

Elastics for closing jars (they can be different sizes)
Plasticine
Boxes for collecting balls (you can use ice cream boxes).
Wooden carpentry waste
Metal wire diameter about 1 mm
Adhesive tape (used by wall painters), which does not damage the wall and after use is detached from the wall without damage and without leaving a trace on the base. The width of the strap should be 3 cm.

Waste cardboard and newspapers to protect furniture and floors and waste cloths.




Nn Oo Pp Rr Ss Šš Tt Uu Vv

Chain experiment on a wall is builded up on a vertical plane: wall, screen, cardboard or particle board, school board, fence, retaining wall, ... We can also use an oblique plane- slope uphill, a concrete or asphalt slope, grass slope, snow slope, ... even the stairs are fine. The choice depends on the options the environment allows and the elements available. The basic elements are cardboard tubes and gutter, which are diferent in length and cross-section size. For cardboard tubes, we can use tubes that we get as scrap (waste) material in print shops (wrapped with printing paper), shops (wrapped with textiles, plastic sheets, or floor coverings, or shopping plastic bags, etc.), in factories (wrapped with plastic foil), ... We can make gutter ourselves from round pipes by cutting it in half lengthwise (with a saw, circular saw or angle grinder). In addition to round ones, we can use square pipes and grooves. They are usually obtained as scrap from electricians and electronics (used to distribute cables around the premises), but can be purchased at a technical store. The cardboard can also be replaced with plastic. In addition to tubes and gutters, we also use plastic bottles, plastic yoghurt pots, various waste packaging pots, boxes containing food, tubes from paper towels, ... There are many household packaging waste items that can be used for a chain wall experiment.

For a chain experiment on the wall, find a vertical surface where pipes and grooves can be glued to the wall. The surface should not be dusty and too rough, because then the adhesive tape does not grip. The vertical surface can also be made of wooden board or cardboard, which is fixed vertically to the wall. We can also use freestanding screens. Chairs and tables can also be used for gutter supports. We glue with adhesive tape (used by wall painters in wall bleaching), which does not damage the wall and after use is detached from the wall without damage and without leaving a trace on the base. The strength of the adhesive tape is usually short and after a few hours the laden adhesive just peels off. Therefore, the Chain experiment on the wall is not permanent and is torn down at the end of the workshop.

Use plastic, metal or wooden balls (heavier balls get the speed more quickly), which should have a diameter of about 2.5 cm (so they can go through the throath of the bottles). In nature, tennis balls can be used because small balls often get lost in the grass. In the beginning, we use only one ball which can go through the whole experiment. Children use prefer more rolling balls, so it can be predicted that in some places the starting ball will trigger the balls that are set at individual places in the experiment itself. At the end of the experiment, place a catching box so that we do not chase the balls around the room.

We start building a chain experiment at the very top. We include each new element in the chain already builted when we are satisfied with the ball running through the added element. We try to find the right pitch and the right link to the previous element. The new element shall be firmly adhered to the base with adhesive tape or fastened with elastic or metal wire or with rope. We create the ball path on an ongoing basis and use the basic elements that we have prepared in advance. It is useful to make a preliminary sketch of the route, especially in teamwork. By drawing a sketch, we stimulate the initial motivation in children and get them used to teamwork.

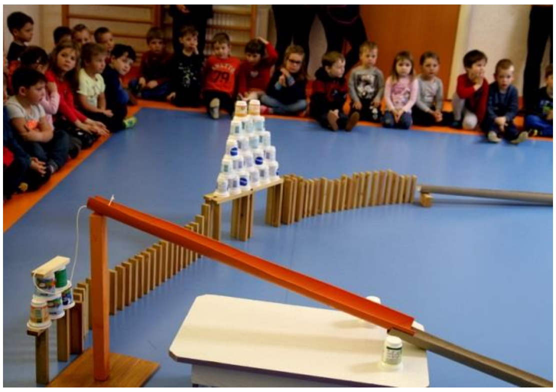
3.3.2. Chain experiment on the floor

Material

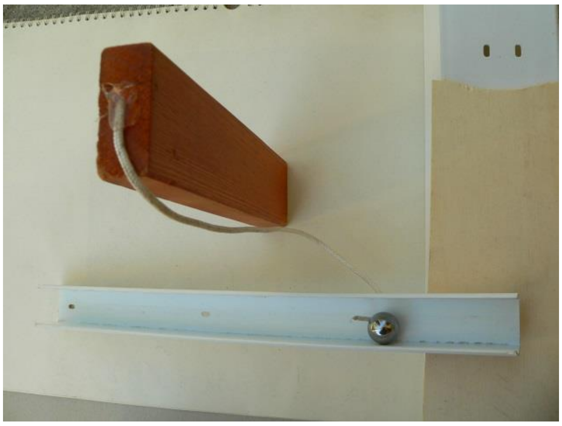
Board 30 cm x 30 cm, thickness of 1 cm (cardboard gutter holder)
Footnote: the dimensions may deviate slightly from the proposed dimensions.
Pillar (60 cm length) and cross section 5 cm x 5 cm (cardboard gutter holder)
Footnote: the dimensions may deviate slightly from the proposed dimensions
Wooden slats cross section 4 cm x 1.5 cm - overall length 6 x 25 m.
Footnote: the dimensions may deviate slightly from the proposed dimensions
Plastic cups (yogurt, cream, …)

A thin flexible rope about 1 mm in diameter. It can be a rope used for interior window blinds.

Wooden carpentry waste
Wood screws of different sizes (from 1 cm to 6 cm)
Nails of different sizes (from 1 cm to 5 cm).
Waste cardboard and newspaper to protect furniture and floors and waste cloths



For the chain experiment on the ground we use large wooden dominoes, empty yogurt pots, cardboard grooves and a spiral slope made of paper (plastic) plates and a flexible rope. Chairs or wooden supports can be used to set the ramps. Setting up a chain experiment on the ground is left to the creative imagination of the team. It is useful to draw a basic sketch before layout. Dominoes can be erected upright, floor buildings can be built from them, yogurt pots and other elements can be laid on them. To trigger a raised ball, for example in a sloping tube, use a rope attached to a domino. When the domino falls, it pulls a rope behind it and a trapped ball is released. We can also push forward dominoes via a cord attached to a domino or ball.

We make dominoes ourselves from wooden lath, 4 cm x 1.5 cm in cross section (the cross section may vary with the purchase option). The length of the lath does not matter. From the (lath) moldings we cut dominoes of different lengths: 5 cm (5 pc), 10 cm (20 pc), 20 cm (50 pc), 30 cm (20 pc) and 40 cm (5 pc). Practically the most useful dominoes are 20 cm in length. From the team is expected to make in total 100 dominoes, or more. We grind the dominoes to make them smooth. Later, after the workshops, they can be painted or just impregnated with oil, so that they can also be washed with water if necessary.

The production of dominoes should take 4 hours and the installation of chain experiment on the ground around 2 hours. A final trigger time of 0.5 hours is expected.

3.3.3. Spiral slope made of paper plates

Spiral slope

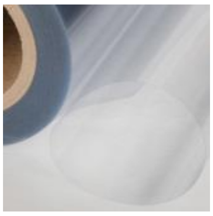
Consumables

The needed material and tools for each section:

Material

Board 30 cm x 30 cm, thickness of 1 cm (spiral base)
Footnote: the dimensions may deviate slightly from the proposed dimensions
Pillar (85 cm length) and cross section 5 cm x 5 cm
Footnote: the dimensions may deviate slightly from the proposed dimensions
Cardboard tubes, about 8 cm in diameter and 80 cm in length
3 metal balls with a diameter of 2.0 cm

Transparent plastic film (can be a hard film used for flower bouquets), measuring 70 cm x 70 cm. If it cannot be obtained, then 2 rolls of transparent wrapping fill

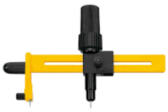


60 high-edged paper plates (also plastic ones are possible), about 22 in diameter. Inner side of the plates should't have any humps whitch could brake the ball from rolling.

Adhesive tape, 5 cm wide

School circle drawing pen

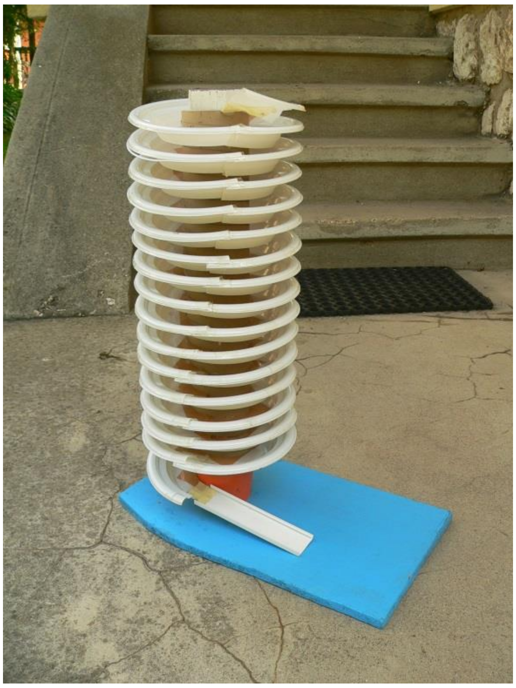
Rotary circle compass cutter



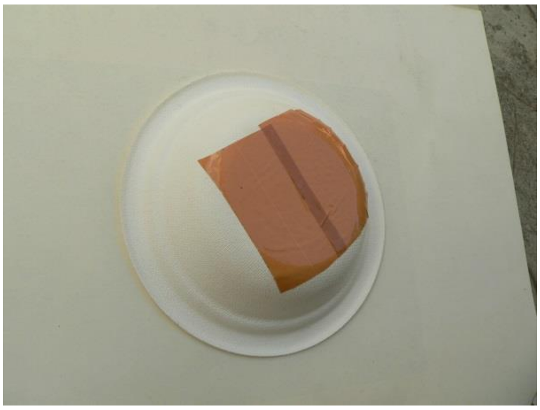
Transparent adhesive tape, 2 cm wide

For coloring - Colors (black, white, red, yellow, blue). Each color 1 kg. It is recommended that the colors are thinner with water and are durable when dried. They must not be harmful to children.
Waste cardboard and newspaper to protect furniture and floors. Waste cloths.

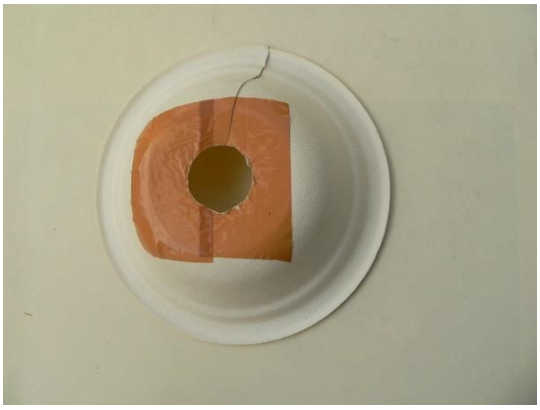
We will use a spiral slope made of paper or plastic plates in a chain experiment on the ground. In practice, it is a great freestanding toy that will catch your child's attention.



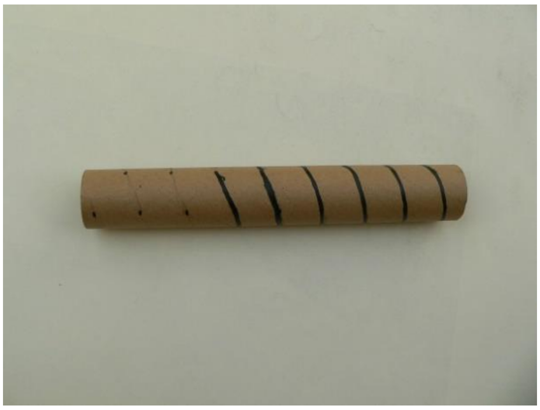

For spiral slopes made of paper or plastic plates, we need a cardboard tube about 8 cm in diameter and about 80 cm in length (different dimensions can be chosen). We need 30 paper or plastic plates with a high side edge that will prevent the ball from jumping out of the plate (if we are working with double plates we need 60 plates). The diameter of the plate should be at least 20 cm. Paper plates are recomended because they are firmer and more resistant to damage. Plastic plates are fragile and break quickly when we make a spiral slope (cutting the center opening in plate). Strength of plates is increased by combining two or three plates together (if we combine plates, we need to increase the »step« of the spirals). We reduce the possibility of breaking the plates by cutting of the center opening if the center of the plate is glued with adhesive tape.

In the middle of the plates we cut the opening that is the size of the outer diameter of the cardboard tube. The opening is first drawn with a compass on one plate. Before that, the center of the plate is determined by trying if the compass is stabbed in the center, then the second leg of the compass must slide all the way around the outer edge of the plate. We can define the center of plate also by constructing it, but this is a job for mathematicians. If the center deviates a few millimeters from the true center, the spiral slope will be asymmetrical but still function. Once the circle is drawn, we affix a wide adhesive tape to the other side of the plate (bottom) so that the plate does not break when cutting the opening. When we cut off the opening at the first plate, we use it to draw a circle at all other plates. We use that plate as a base. We put the base plate on another plate and draw a circle on it. Since we have determined the center only approximately, it is useful to immediately identify and mark the same spot on each circle on the plates where we will radially cut the plate. This ensures a finer finish to the spiral slope.



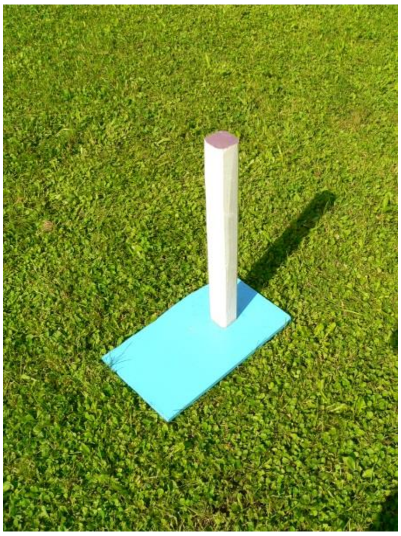
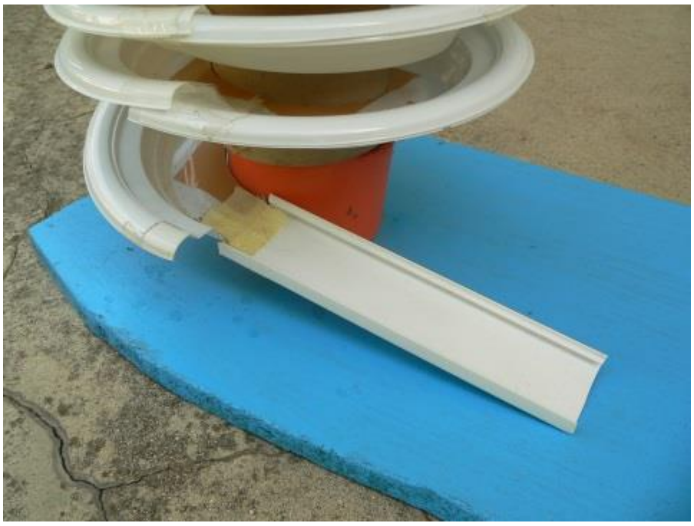
Glue all the plates (with the circle drawn on the underside) with a wide adhesive tape and cut them radially through the marked spot. Then cut out the center circle. You can use scissors or a stanley knife.

On the cardboard tube we draw a spiral with a pencil. On the shape of the spiral we will glue the plates. The spiral step should be 2.8 cm or 3.2 cm (at least 3 mm larger than the diameter of the ball). We use points to draw a spiral.

Draw points along the cardboard tube in four rows. They are spaced apart by a quarter of a pipe. We draw from the top of each row the multiple of a number of 2.8 cm (step): 2.8 cm; 5.6 cm; 8.4 cm; .... At the first raw we start at the very top. On the radially opposite side of the first raw, we start drawing points at 1.4 cm below the top and continue again with a multiple of the step, that is 2.8 cm. Similarly, we make points on a quarter part of a cardboard tube, only to start at one end 0.7 cm below the top and on the other end at 2.1 cm below the top. Drawn points we connect in a spiral line.


We glue cuted plates along a spiral line on a cardboard tube with thermal adhesive. Attach it by making a slope with a walk (step) of 2.8 cm (the back edge is 2.8 cm lower than the front). Glue on the bottom of the plate, so that the adhesive does not interfere with the rolling of the ball. We need to start at the top of the spiral and continue towards the bottom. At the bottom, leave 5 cm of cardboard tube bare (do not glue plates) so that we can direct the ball forward when it rolls out of the spiral slope. If we forget and paste the plates to the very bottom, we help with a ring cut from a cardboard tube that has the same cross-section as the carrier tube and place it on the bottom itself under the spiral. When we finish and put the spiral slope in the correct position, the recessed part of the plate should look towards the top and the bottom towards the lower end of the tube. The two adjacent plates overlap at the edge of the spiral about 1 cm wide (the rear end of the previous plate is above the first end of the next plate so that the ball cannot roll into the edges when rolling). Bond the overlapping with plastic adhesive or just with adhesive tape (I recommend transparent adhesive tape) to increase the strength of the coil. If the ball jumps out of the spiral slope over the edge of the plate because of the speed, the problem is solved by surrounding the outer part of plates with a transparent foil (it may be thicker, and a transparent foil for wrapping food is also useful). An iron ball 2 cm in diameter is used for rolling down a slope. We can also use other balls, but with a diameter smaller than the distance between adjacent plates (step).

The construction needs a strong and stable support. We make it from a board about 1 cm thick and from a round wooden cylinder or square molding that fits tightly with the inside of a cardboard cylinder. The length of carrier should be 5 cm longer than the cardboard roller, in our case it is 85 cm. To the board, measuring about 30 cm x 30 cm, we will screw in a roller or square lath that will carry a spiral slope. At the exit of the spiral slope, the ball is directed with a rectangular groove forward into the ball collector or into a continuation of the chain experiment. The gutter is glued with adhesive tape to allow it to change direction.

3.4. Instructions for Downhill sledding

Basic tools

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

Combined pliers

Screwdrivers (flathead and Phillips)

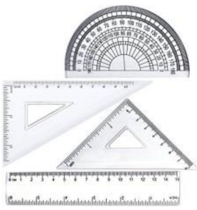
Flat files (for wood and metal)

Abrasive paper for wood (rough and fine)

Hot air dryer

Tape meter (2 m)

Triangle and ruler



Clamp

Angle ruler

Long ruler or lath 40 or 50 cm long (can be wooden or plastic lath without scale). It is useful if its width is 3 cm as wide as the track.

Pencil

Power strip

Stanley knife

School circle drawing pen

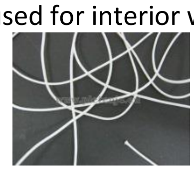
Rotary circle compass cutter

Coloring brushes
Thin: 1 mm, 3 mm, 5 mm
Fat: 1 cm, 3 cm, 5 cm

Consumables

The needed material and tools:

Material
Basic box
Board 100 cm x 50 cm, thickness about 2 cm
4 bars 50 cm long and 24 bars 100 cm long. The width of the slats should be between 4 and 6 cm and the thickness between 1 and 1.5 cm.
4 columns 50 cm high, 4 cm x 4 cm (or 5 cm x 5 cm) in section
Hard paper (seleshamer) from which we will cut support columns and grooves. We will cut it into strips 10 cm wide and 8 cm wide and 6 cm wide. Each group will need about 12 m of total length of strips.
The paper should be compact but suitable for cutting and bending and firm enough for rolling marbles. I found that 200g / m2 (or more) of photocopier paper would already fit. The better is a sheleshammer (200 g/m^2 or 250g/m^2), it is advised to purchase 50 sheets in A4 in addition to 50 A3 sheets in different colors of paper.
3 m^2 styrodur plates 1 or 2 cm thick
Plastic pipes of square or rectangular cross section of different dimensions (most useful): width 30mm x height 20mm or 40mm x 25mm). It can also be a waste material in electrical or electronic installations. The total length should be around 20 m.
A thin and flexible twisting rope about 1 mm in diameter. Overall length 25 m. It can be a rope used for interior window blinds.



Different plastic waste containers (ice cream, food, curd, cream, yogurt, ...).
Different plastic stoppers.

Waste transparent bottles with a wide neck (4 cm diameter)
Waste transparent bottles with a narrow neck (diameter 2.5 cm)
4 pieces of metal balls with a diameter of 2.0 cm.
15 Plastic balls about 2.5 cm in diameter (can also be wooden)
Elastics for closing jars (they can be different sizes).

Plasticine
Box for collecting balls (you can use ice cream box).
Wooden carpentry waste - wood sawing wastes (joiner)
Metal wire diameter about 1 mm. Total length 30 m.
Nails of different sizes (1 cm to 5 cm). Each type of 30 pcs.
Wood screws of different sizes (1 cm to 6 cm)
2 pieces of transparent adhesive tape, 2 cm wide and at least 25 m long. The total length should be at least 300 m
Pins

Paper clips

For coloring - colours (black, white, red, yellow, blue). It is recommended that the colors are thinner with water and are durable when dried. They must not be harmful to children.
Waste cardboard and newspaper to protect furniture and floors and waste cloths.

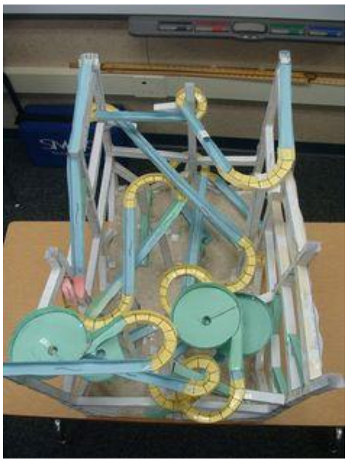
Paper is a widely used material for designing and manufacturing various products. We use it a lot in everyday life for various purposes, so it is easily accessible. The quality and type of paper is different, and only by trying different papers will we find the type that will be suitable for our particular use, in our case a chain experiment.

Waste paper, paper packaging, paper folders, old calendars, promotional brochures, ... can be used in the creative activity of a chain experiment. This gives the waste paper a new useful value. This is the goal that we wanted to achieve when constructing a device »Downhill sledding«. The device is constructed mainly of paper, only individual parts, mainly due to the strength and durability of the structure, are made of other materials.

Here are some examples of "Downhill sledding" from the web:

https://www.pinterest.com/pin/499336677405717986/






Basic plan

We designed the device so team members will connect all planned events together in a wooden box measuring 100 cm x 50 cm x 50 cm. With this design, the device will always be ready to use and operate quickly. In addition, the wooden box prevents movement damage, ensures the strength and durability of the paper structure that it would not have on its own.

The size of the base box is selected according to the size of the trunk of the passenger car so that the machine can be transported in the trunk of the car. In the base box, we connect different elements that will together represent the sledding track. Marbles rolling down the track will be a sled. In the given chain I have given only instructions for making individual elements that constructors bind to each other in their own way. The design of the device is not deliberately defined so that the constructors can unleash their creative imagination and make the device according to their abilities and their knowledge.

Instructions for making a basic box

The base board (100 cm x 50 cm) can be purchased in the shop or cut from a larger panel. A panel can be used (also from used furniture). The thickness of the board should be 1 cm or more and made of treated wood, which will not bend later. The dimensions of the base box are recommended but not mandatory and can be adjusted by each group to suit themselves.

Attach the base columns to all four corners of the baseboard from below with screws (5 to 7 cm long) upright posts. One screw in the middle of the pillar is sufficient. When we position the columns, care must be taken that they are spaced from the edges as far as the thickness of the slats that will connect the columns to each other. Before screwing the columns with screws, it is advisable to grease the contact surface with glue. Place the battens that connect the columns on the base board so that the base of the box remains 100 cm x 50 cm. The slats should be about 1 cm thick and at least 3 cm wide. Adhere the slats to the base and screw them in from the bottom. Screw the slats onto the pilars with the screws to keep the columns solid. If desired, intermediate glue surfaces can be applied to the pillar before the panels are wrapped. Base box is complete. Allow the adhesive to dry. The shape of the box is an inverted table.

Warning: to prevent the screw heads from projecting from the base and causing scratches on the base, the drilled hole should be widened initially with a wider drill bit to hide the screw head in the hole. This can be done manually.

Instructions for making individual items

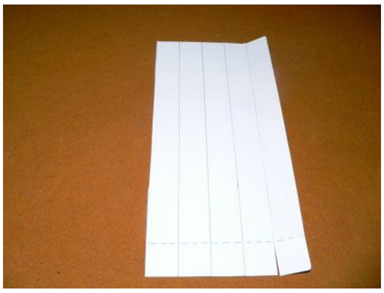
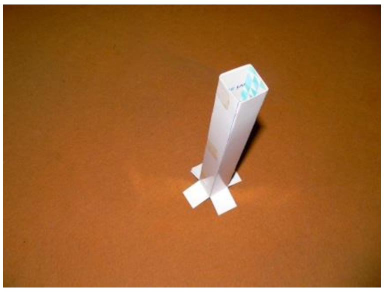
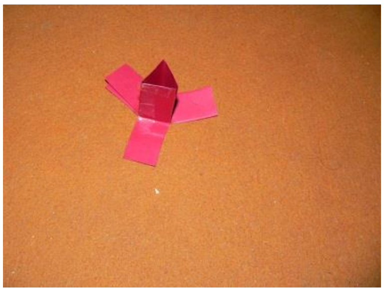
All basic elements are made of paper having a density greater than 200 g/m^2. Cardboard and very hard paper is not considered here because it is difficult to design. Most useful is the so-called "sheleshamer", which is solid, flexible and retains shape after design. It is not susceptible to changes in atmospheric humidity. It is available in different colors, which enhances the appearance of the chain device. We can also use waste paper, which is the residue of different folders, calendars, commercials, packaging for different products, ...

In our case, we design a track whitch is 3 cm wide and a side fence between 1 cm and 2 cm high. These dimensions are suitable for rolling marbles up to 2.5 cm in diameter. For faster track construction, we use a ruler 3 cm wide and at least 30 cm long. We can also make this ruler ourselves out of a wooden square or rectangular bar or strip, which has one side 3 cm wide. The recommended length is 50 cm. We can also use plastic tiles used in electrical installations.

3.4.1. Support columns

Paper support columns ensure the stability of the structure. They can also be made from hard paper or even cardboard. Waste packaging can be used (tetrapack made of milk or juices, plastic containers, ...). Round cardboard or plastic tubes are also suitable. In our instructions, we will limit ourselves to paper columns only.

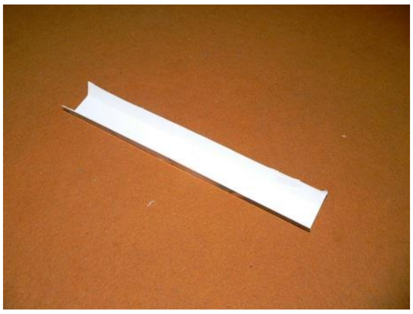
It is recommended to use three sides (cross-section is an equilateral triangle) and four sides (cross-section is a square) of columns. Four-sided pillars are firmer and also useful for cross-links and additional supports. We make the three sides and four sides of the pillars in the same way: we have four parallel strips on three sides and five on four sides.

The width of one strip can be arbitrary. The width of the tape is 2 cm. For example: use a width of 3 cm to route the track through columns and cross links. From the edge of the paper draw five parallel strips of 2 cm wide. For drawing use a used ballpoint pen so it doesn't draw lines. With it press firmly into the paper to make a groove and therefore the paper folds better (the paper does not crack). After drawing the lines, I fold the paper up to get a square profile pillar. The end faces overlap, giving the pillar a firm grip. I glue on the edge and cut the bottom of the pillar at the edges about 3 cm into the inside of the pillar. I bend the resulting strips outwards and glue them to the base with adhesive tape. If the pillar is too long, I shorten it appropriately at the top edge. If the pillar is too short, I extend it with the other pillar by gluing them together.

I make the transverse columns the same way as the supporting columns, except that I cut at the edges at both the bottom and top of the column. I attach the resulting strips on the posts to the structure with adhesive tape. In the same way, I also make the supporting columns, except to adjust the length of the individual cuts at the edges accordingly. I tape the strips to the structure and to the base.

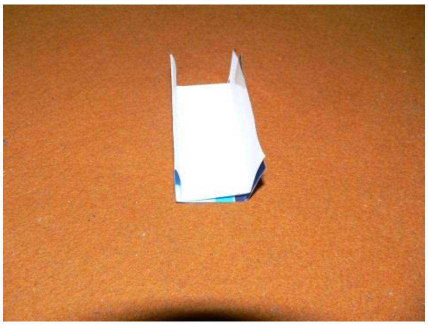
3.4.2. Straight track

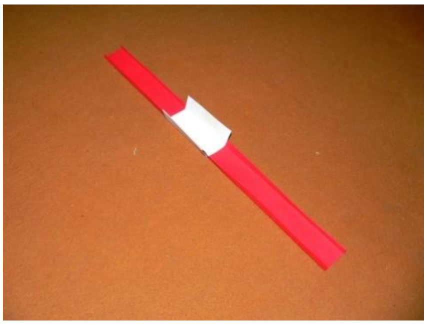


From the edge of the paper draw longitudinal parallel strips of width: 1.5 cm - 3 cm - 1.5 cm. Cut off at the end of the last strip to get a rectangle with three lines drawn. Fold the paper 90 degrees along the dotted lines to give a groove 3 cm wide and 1.5 cm high. With this we have a straight track made.

3.4.3. Connecting link

We connect the individual parts with the connecting link, especially the grooves. It has the same shape as a straight track, except that the walls are about 2 mm higher. The length of the connecting link should be 5 cm or more, depending on use. We paste the connecting link at the end e.g. straight lines so that only the upper part of the walls is glued and the gap is left sideways. Through the gap along the walls and at the bottom we can insert the next straight line and thus extend the length of the straight line.





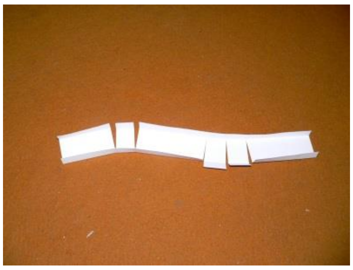
The double-wall link is more practical to use because it can also be moved up or down the track and is flexible. In shape, it is identical to a single-wall connecting member, except that we have two walls instead of one. This is achieved by folding the paper and then drawing parallel lines from the edge of the bend: 1.7 cm - 3 cm - 1.7 cm. At the end of the last line, cut and fold the paper to make a groove. Only glue it to the top of the walls.

3.4.4. Straight track with rectangular exit

At the end of the course, cut only one edge between the bottom and the wall, 4.5 cm long (bottom width + width of the groove wall). 1.5 cm from the beginning of the notch make a rectangular notch across the bottom of the groove. The resulting equilateral triangle is folded to the underside of the gutter (it can also be left unobstructed). Glue the two resulting ribbons to represent the wall of the gutter, which is wrapped at right angles. On the opposite side of the gutter, cut through the wall to the bottom at a distance of 4.5 cm (bottom width + width of the gutter wall) from the end of the gutter, making a rectangular exit for the ball.

3.4.5. S - shaped track

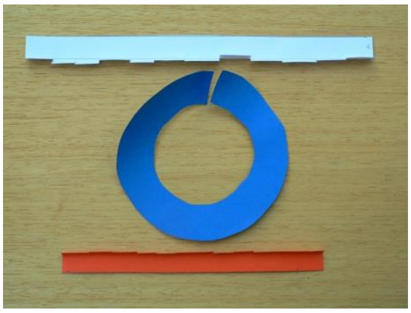
At the point where we want to have a turn, cut the line perpendicularly across one wall and across the bottom. At the cut-off point, cover both parts by about 10 degrees (at the upper edge of the wall, the cut-off parts overlap by about 2 to 3 mm) and glue them with adhesive tape on the outside of the bottom and on the wall. Care is taken that the marble will roll from the top to the bottom of the glued bottom (so that it does not slow down in the edge). If the bend seems too small, make another rectangular notch across the wall and bottom and repeat the procedure described above. The new notch should be about 3 cm away from the first. The more notches we make, the bigger is the bend.

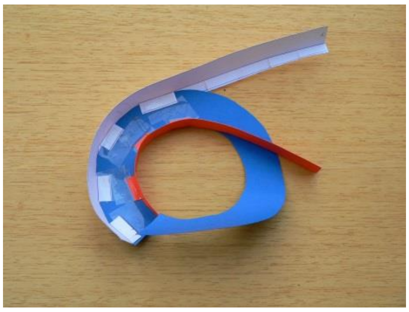
With a notch on the opposite side of the wall, as in the previous case, we will achieve a bend opposite to the original one. We can work left and right turns and adjust the size of the bend.

3.4.6. Spiral track

The spiral line can be made in many ways.

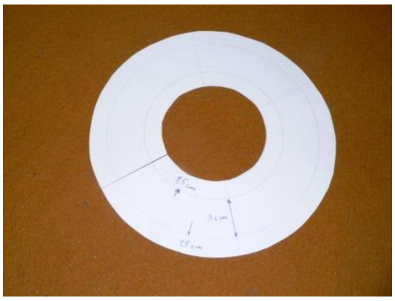
a.) The easiest way to make a spiral is to make rings (two circles with the same center) 3 cm wide and connect them one after the other into a spiral. We choose the radius of the base circle according to whether we want a large spiral or a smaller one. To prevent the ball from escaping from the spiral, we still need to make a wall that is 1.5 cm high (it can also be higher to prevent the ball from jumping out of the spiral due to too much speed).

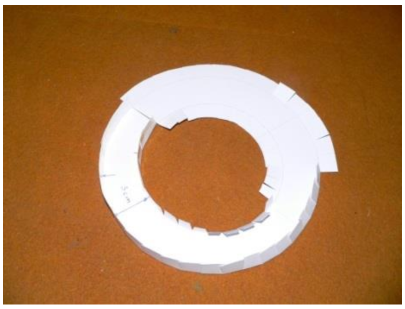


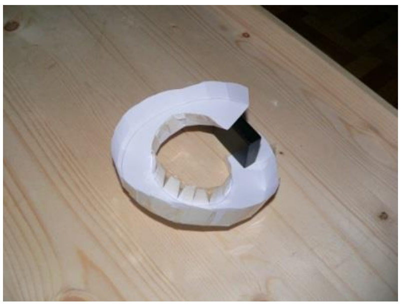


The wall is made of tape that is 2 cm wide. Divide it lengthwise into two parts, 1.5 cm is the height of the wall, and 0.5 cm is used to attach the fence to the spiral. On the lower, 0.5 cm wide strip, make a rectangular notch in the length of 0.5 cm every 3 cm (every 2 cm for a small ring, the diameter of the ring is less than 10 cm). The resulting consecutive rectangles (0.5 cm x 3 cm), which adhere to the wall with one side, are glued alternately to the top and then to the underside of the ring. Thus, the wall of the coil is more solid than if it were glued to the underside of the coil only. If the paper is sufficiently rigid and flexible, the wall can also be glued directly to the spiral without the need for extensions of 0.5 cm. The wall gets enough strength by twisting down the spiral.

b.) The spiral is made in pieces (circle) and finally glued together.



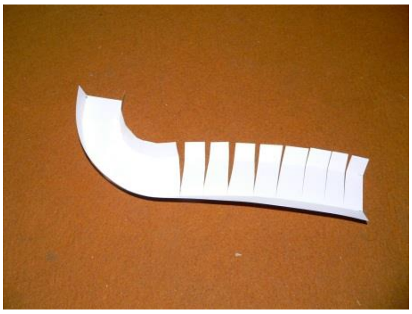


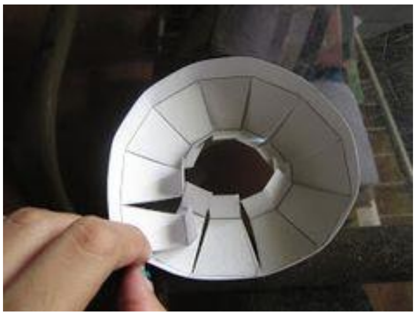


Draw three coils of width: 1.5 cm (wall), 3 cm (track) and 1.5 cm (wall). We choose the radius of the base circle according to whether we want a large spiral or a smaller one. Cut an incision on the inner and outer rings radially 1.5 cm long at approximately every 3 cm (at 2 cm if the radius of the ring is less than 5 cm). The resulting rectangles are folded up (wall) and glued to each other. When gluing, make sure that the marble rolls so that it does not lose speed at the edges. The individual elements of the spiral are glued together and one can get any long spiral.

If the radius of the spiral is small, then the stroke must be large enough to allow the marbles to roll down the spiral, which means that the slope of the track is large and the speed of the ball is high.

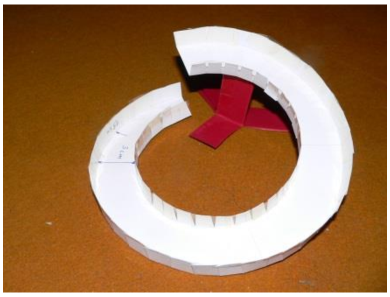
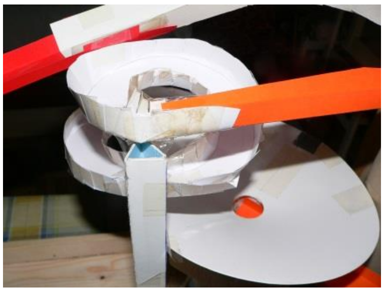
c.) The spiral can also be made according to the procedure used in the manufacture of track S. The straight track is cut only on one side (wall and bottom) and the adjacent sections are glued together with adhesive tape.



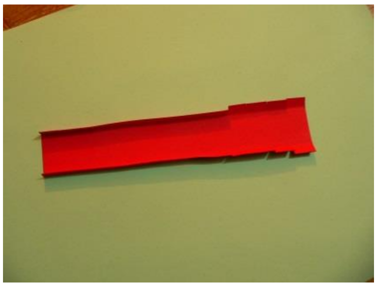
Depending on whether we slit on the left or right, we get a left or right turn. The individual turns are glued to each other and can be made any long spiral.

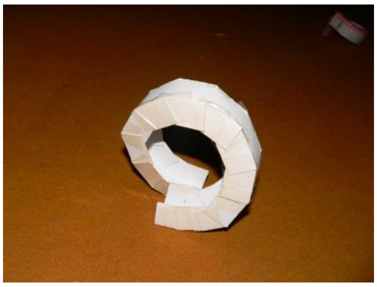
For a spiral with a small radius of less than 5 cm, the width of the track is reduced when bending, so this must be taken into account when making a basic straight track: the track width should be 3.5 cm instead of 3 cm. Since the overlapping of adjacent parts is larger with a smaller radius, we help to cut an equilateral triangle instead of a straight rectangular cut and then glue the adjacent parts. This results in less cover and easier shaping.

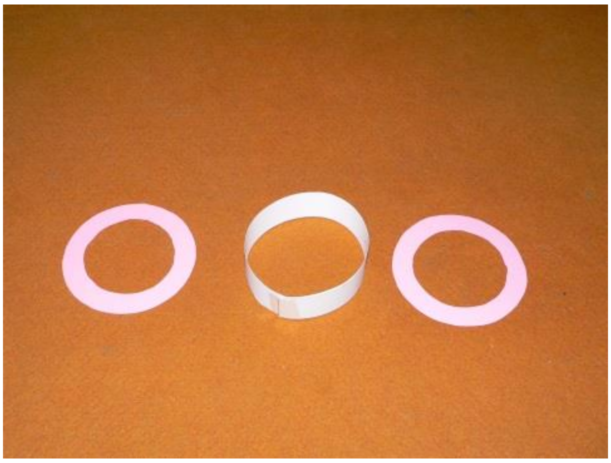
3.4.7. Jumping and luping

The jumper is obtained by cutting a few notches with the scissors perpendicularly and symmetrically on both sides of the walls on the back of the straight track. The notches should be approximately 3 cm apart. We don't cut the bottom track. At the cut-off point, cover the two adjacent parts with each other by about 10 degrees (at the upper edge of the wall, the cut-off parts overlap by about 3 mm) and tape them with adhesive tape. Watch out for the marble to roll so it doesn't hit the edges.





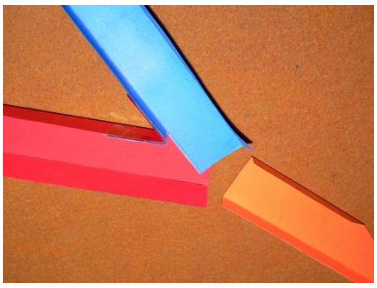
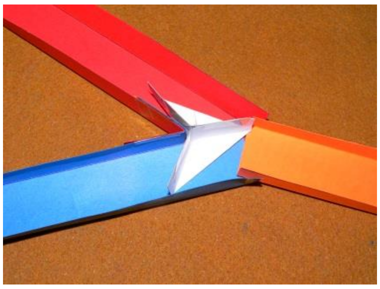
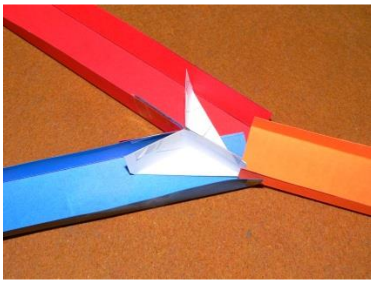
By cutting the walls through the entire length of the straight track, overlapping and gluing the adjacent parts, we can do the luping. For luping, the turn must be neatly wrapped and large enough to not stop the ball when changing direction. Making luping is demanding task and we have to do a lot of experiments. We need to secure the luping structure well so it does not move. The marble must come in luping at a high enough speed to roll around the circumference due to centrifugal force (it does not fall to the ground). In practice, the marble should be started from a height that is about twice the diameter of the luping.



Luping can be made easier by cutting a 3 cm wide strip of paper and twisting it into a cylinder and gluing the ends together. Glue the resulting cylinder with adhesive tape on both sides with rings that fit the cylinder. Luping walls represent both rings. The height of the walls (width of the ring) should be 1 cm. If we want a more solid construction, we can make a 0.5 cm wide ring on the outside of the basic ring. We cut it to 3 cm in length and glue the resulting parts to the outer circumference of the luping.

By cutting the walls of the straight track and bending the bottom up, a gap is made between adjacent parts. Paste the spaced parts together and get a bulge. Combine the bulge with the recess (the jumping pad we explained in the first paragraph) and make the marble rolling more varied. In doing so, we must be careful that the ball can overcome the resulting hill and not stop in the valley.

3.4.8. Crossroads and router

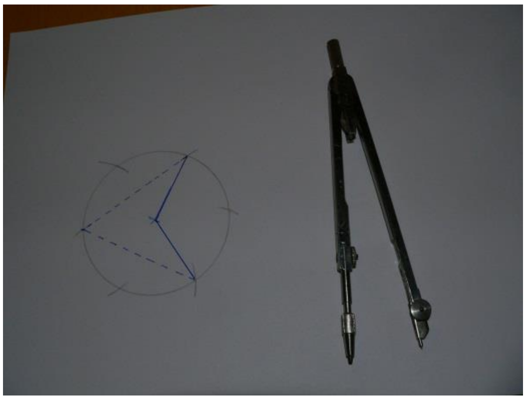
The crossroads is made of two straight traks. Let's put them side by side. Along the inner walls at the end of both traks, cut an edge between the bottom and the wall with a notch about 4 cm long. We get two strips that still stick to the walls. They are folded so that each strip fits into the wall of the another track (see first picture). They are glued to the walls so that the tracks can still change the angle of each other. Connect the other wall and the bottom of the two traks to the straight path in front of the crossroads and glue. The slope (fall) of the crossroads should be small. Also, keep the low speed of the marble rolling into the crossroads. Otherwise, the marble could skip over the wall. When the marble is rolled into the crossroads, it randomly selects one or the other line if the crossroads is correctly positioned. Marble hits the middle of the crossroads.

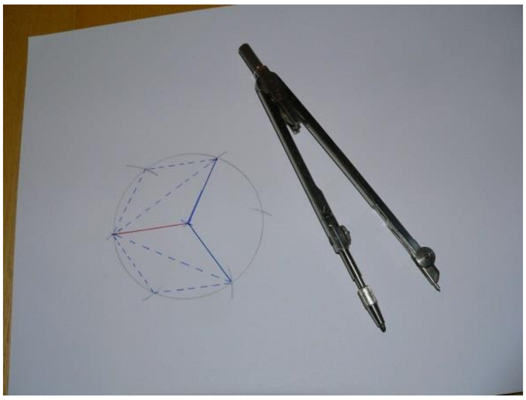
Turning the crossroads to the other direction, we get the two traks merge into one.

The router can be used to direct the marbles once in one lane, another in another lane.

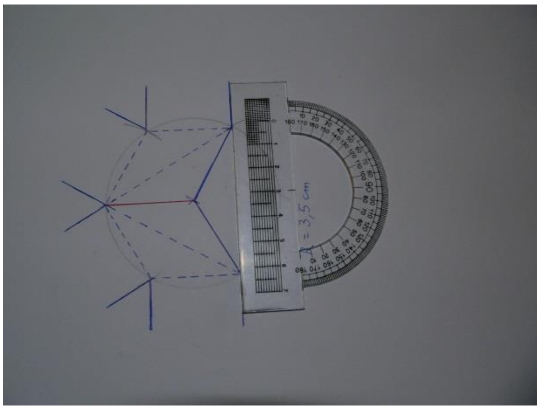
To make a router, we need a smooth, moldable paper. Draw a circle with a radius of 3.5 cm and divide it into 8 equal parts. We connect each other point on the circle with a dashed line, and we connect the center of the circle with two points with a solid line. We will bend the paper along the dashed line and cut the paper along the solid line (picture below).

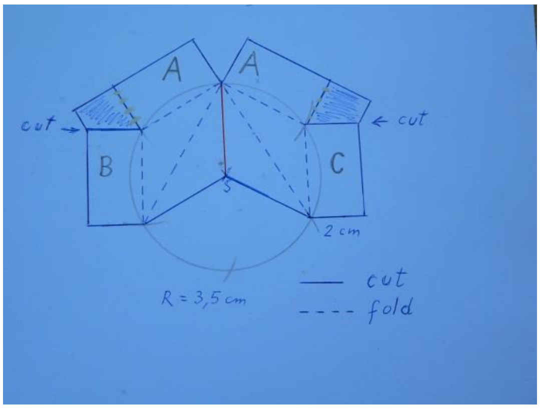
Connect the dotted line to the adjacent point on the circle, as shown in the figure below. We only indicated by the red line that the figure was symmetrical.





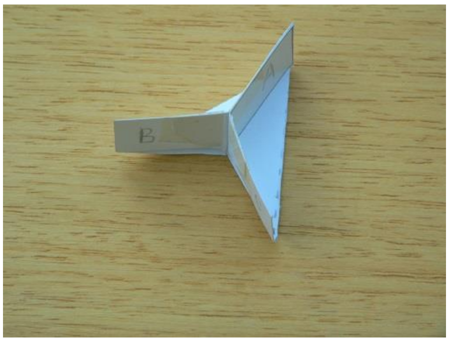
Draw the rectangles on the dashed lines connecting the adjacent points on the circle (also obtained as an extension of the side of an equilateral triangle, as shown by the geometric triangle side in the figure below). The rectangles are 2 cm long (slightly higher than the wall). Connect the ends of the rectangles with a solid line and finally draw as shown in the picture below.





Cut out the image along the solid line. The dashed lines indicate only paper folding. Inside the image cut only along the line marked with a »cut« in the picture.

The rectangles A, B, and C outside the circle are the walls of the router and fold them outwards. When we bend inwards along the dashed line connecting two non-adjacent points on the circle, the rectangles marked by the letter A are joined. The final look is in the picture below. To prevent the router from jumping off the track, attach it to the crossroads with the pin.

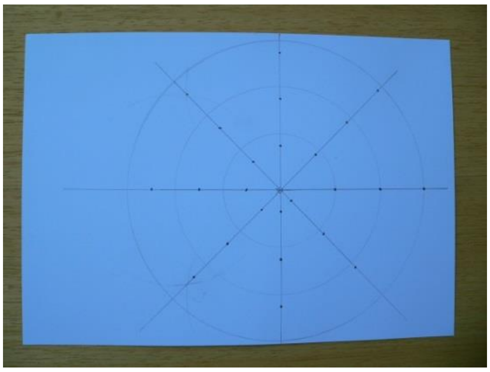
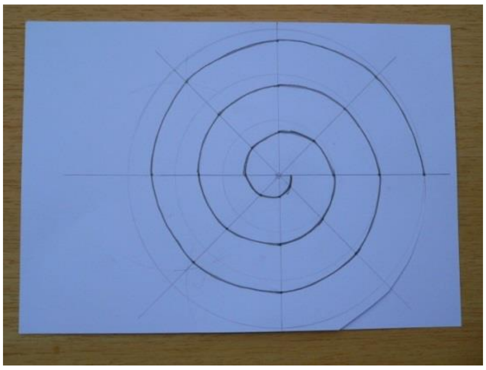
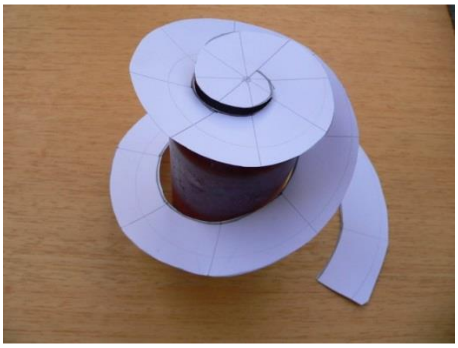


3.4.9. Recessed cone

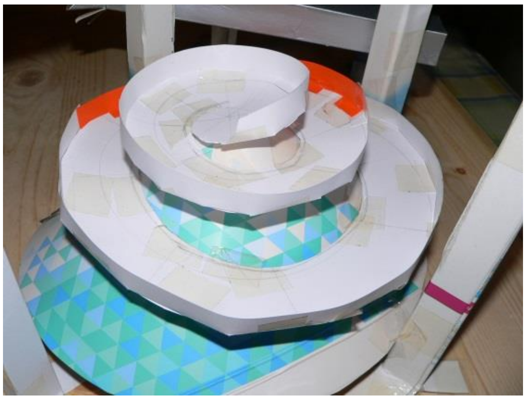

Draw and cut a circle out of hard paper (seleshamer). The circle can be arbitrary, but larger than 10 cm in diameter. The larger the circle, nicer and longer the ball rolls along the inner cone. Draw a 4cm diameter circle in the middle and cut it. This gives an opening through which the ball will roll out of the cone. Cut this ring radially and cover the resulting ends by about 30^{o} to form a cone with a slope of about 30^{o}. We seal the edges. If the slope is large, the murble quickly slides into the hole in the middle. If the slope is too small, the murble likes to jump over the edge and we need to make a barrier fence at the circumference. At low inclination, the ball rolls for a long time down the cone. Let the ball enter the cone tangentially to initially circulate around the outer circumference. Keep the ball speed low. The cone must be firmly attached so that the ball does not lose energy by swinging the cone.

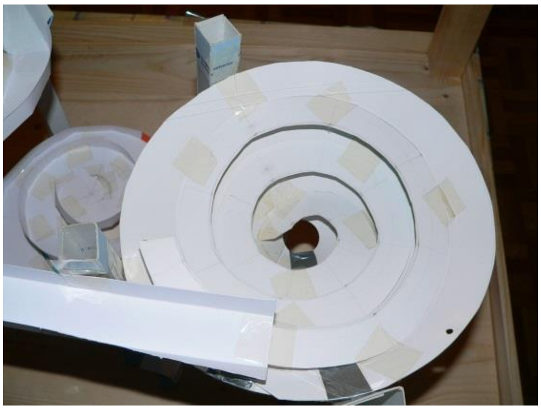
3.4.10. Arhimedes spiral on a cone

First, draw the Arhimedes spiral on solid paper (seleshamer). We determine the size of the spiral ourselves. It is useful that it is large.

Draw concentric circles with a radius difference of 3.2 cm. Divide the circles by diameters into 8 equal parts. Draw the spiral by points. We choose the basic radius where the points of the spiral are exactly at the intersection with the circle. At the adjacent radius, draw points of the spiral 0.4 cm (3.2 cm: 8 = 0.4 cm) below the intersection of the radius and the circle. Thus, we continue to draw points 0.4 cm lower with each subsequent eighth circle than with the previous radius. Connect the points obtained with the line representing the spiral. Cut a spiral along the line. Leave an uncut circle 2 cm in diameter in the middle.





The cut Archimedean spiral must be fixed to a solid support. The cone is best suited for this. We make it from a circle with a radius equal to or larger than the largest circle in the drawing of the spiral. Harder paper or cardboard can also be used. The shape of the cone is adapted to the shape of the spiral to fit the spiral and lateral surface of the cone well. Cut off the top of the cone to create a hole 3 cm in diameter. Glue the spiral to the lateral surface of the cone with adhesive tape.

We have two options: glue on the inside of the lateral surface or on the outside of the lateral surface cone.

If we glue the coil inside, the cone will stand facing and the ball enters the wider part of the cone and exits at the cut off top of the cone (hole). There is no need to work wall on the side of the spiral because the murble is rolling along the wall of the cone.

If glued on the outside of the cone, the murble will enter at the top of the sectioned cone and dissolve at the bottom of the expanded section of the cone. Murbles can be directed from the cone at the middle of the cone when it has some potential energy and can do some work with it. As centrifugal force pulls the ball from the track, we have to make a wall on the outside of the track.

If the paper is sufficiently rigid and flexible, the wall can be glued directly to the spiral without extensions of 0.5 cm on the wall. The paper wall gets enough strength by twisting down the spiral.

3.4.11. Slope

The slope can be made of stronger cardboard. We run a zigzag track on it, we can place various obstacles that divert the direction of rolling murbles. The construction is similar to the one we did on LTT2 in Italy, except that we have a smaller surface area.