Chain experiment »Downhill sledding«

LTT4, Koprivnica, Croatia

Prepared by Stane Arh

The basic idea

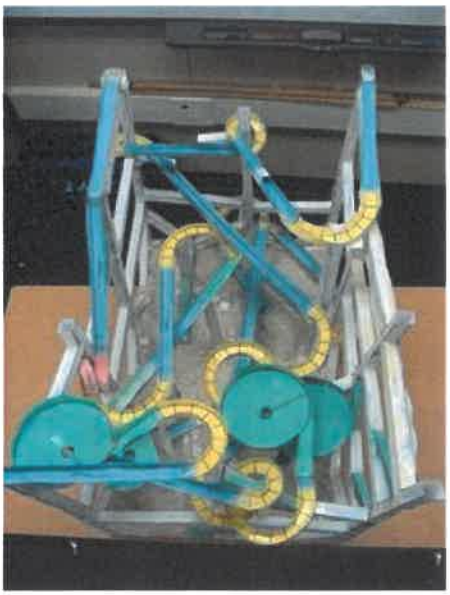
Paper is a widely used material for designing and manufacturing various products. We use it a lot in everyday life for various purposes, so it is easily accessible. The quality and type of paper is different, and only by trying different papers will we find the type that will be suitable for our particular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

Waste paper, paper packaging, paper folders, old calendars, promotional brochures, ... can be usefully 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.

In kindergartens, we often use paper for various creative activities, and children already have some experience in design and cutting. By building a chain link, this knowledge is further enhanced by the creation of a device that, with the help of a mentor, the children themselves design, make, and ultimately use as a toy. In doing so, they develop their creative imagination, their manual skills and learn to apply the laws of nature in practice.

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

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



Basic plan

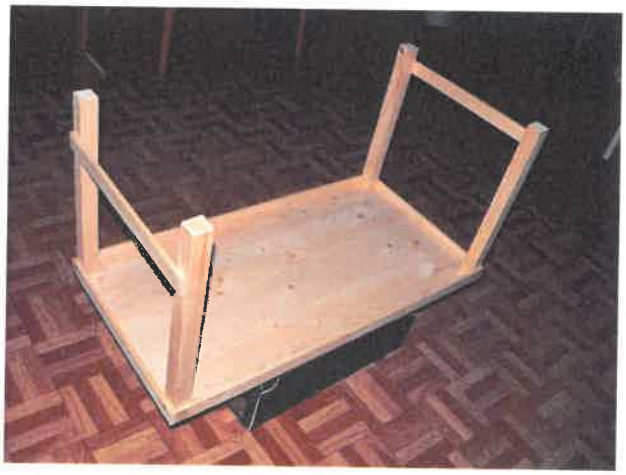
We designed the device so team members will connect all planned events together in a wooden box measuring 100 cm x 50 cm x 50 cm. With this design, the device will always be ready to use and operate quickly. In addition, the wooden box prevents movement damage, ensures the strength and durability of 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 article 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.

When we work with children, it is even desirable to adapt the design plan to each group of children individually according to the knowledge and skills of the children, according to their interest, wishes, ideas. The design should take into account the cultural, national and ethnological characteristics of the country. When we design a device, the mentor must take into account his knowledge and knowledge of the volunteer mentors, consider the tools he can use, and the options available to him in the collection and acquisition of the core material. With the freedom of choice, they should develop the creative imagination of children and encourage them to try to put their ideas into action.

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 / m2. Cardboard and very hard paper are not considered here because they are 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 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.

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.

In practice, we use three sides (cross-section is an equilateral triangle) and four sides (cross-section is a square) of columns. In my experience, the 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.

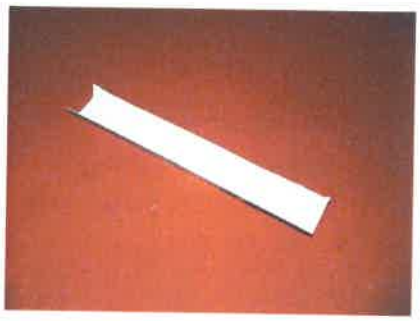


The width of one strip can be arbitrary. Mine had a width of 2 cm. I use a width of 3 cm to route the track through columns and cross links. From the edge of the paper, I draw five parallel strips of 2 cm wide. For drawing, I use a used ballpoint pen (kuli) so it doesn't draw lines. With it, I press 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.

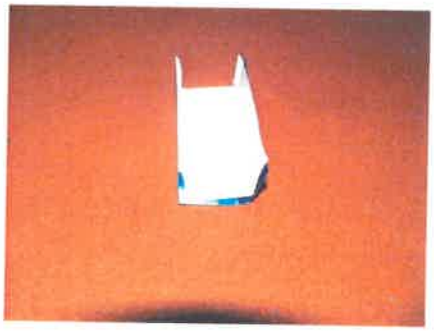
Straight track

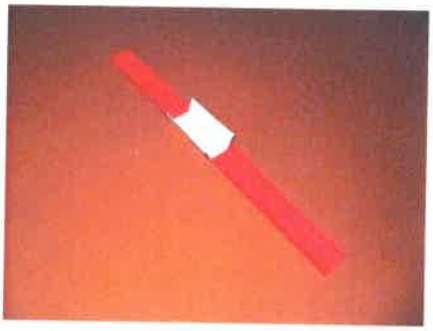


From the edge of the paper draw longitudinal parallel strips of width: 1.5 cm - 3 cm - 1.5 cm. Cut off at the end of the last strip to get a rectangle with three lines drawn. Fold the paper 90 degrees along the dotted lines to give a groove 3 cm wide and 1.5 cm high. With this we have a straight track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

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.

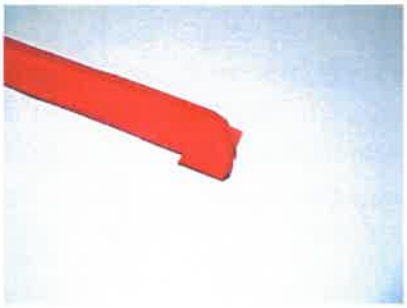




The double-wall link is more practical to use because it can also be moved up or down the track and is flexible. In shape, it is identical to a single-wall connecting member, except that we have two walls

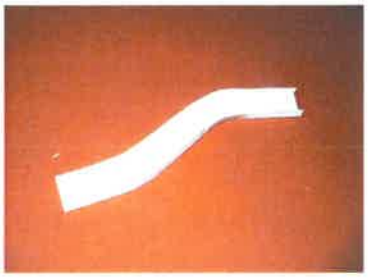
instead of one. This is achieved by folding the paper and then drawing parallel lines from the edge of the bend: 1.7 cm - 3 cm - 1.7 cm. At the end of the last line, cut and fold the paper to make a groove. Only glue it to the top of the walls.

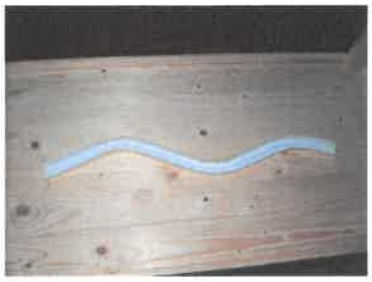
Straight track with rectangular exit



Let's make a straight track. 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.

S - shaped track





Let's make a straight 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.

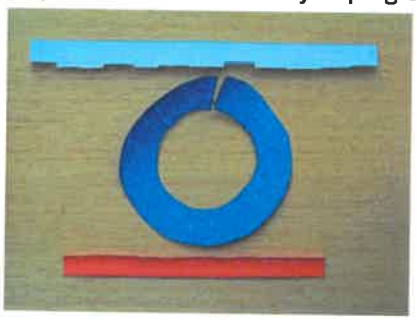
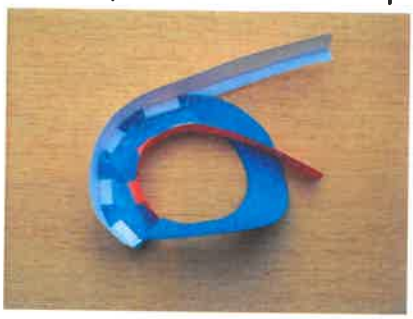
With a notch on the opposite side of the wall, as in the previous case, we will achieve a bend opposite to the original one. We can work left and right turns and adjust the size of the bend.

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.



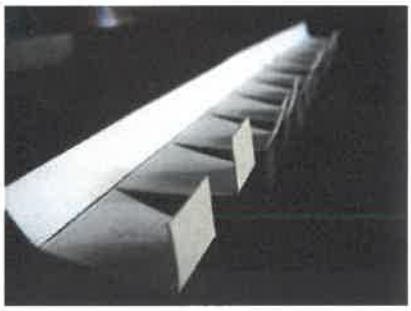
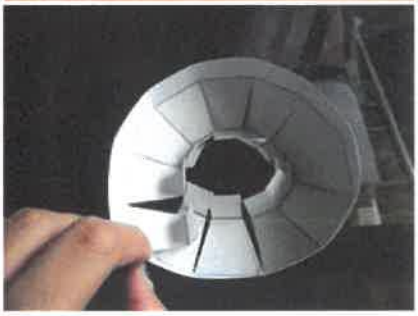

Draw three coils of width: 1.5 cm (wall), 3 cm (track) and 1.5 cm (wall). We choose the radius of the base circle according to whether we want a large spiral or a smaller one. Cut an incision on the inner and outer rings radially 1.5 cm long at approximately every 3 cm (at 2 cm if the radius of the ring 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.)

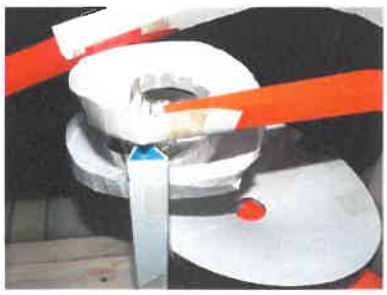
The spiral can also be made according to the procedure used in the manufacture of track S. The straight track is cut only on one side (wall and bottom) and the adjacent sections are glued together with adhesive tape.



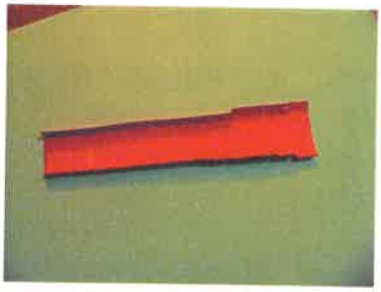
Depending on whether we slit on the left or right, we get a left or right turn. The individual turns are glued to each other and can be made any long spiral.

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.

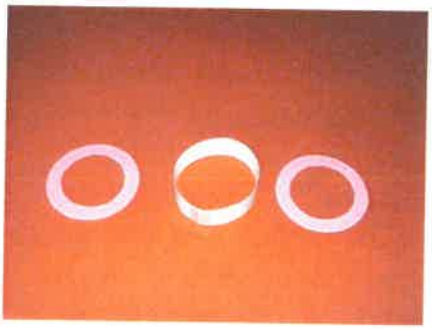



Jumping and luping

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.



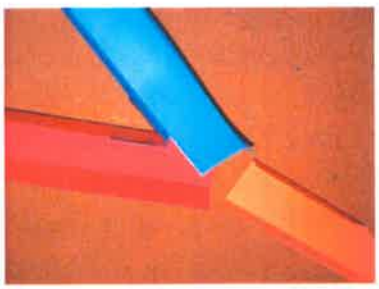
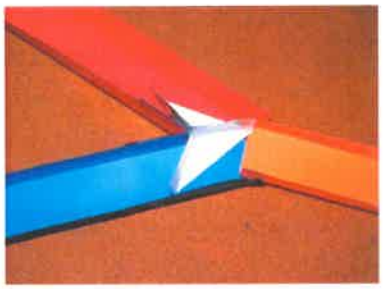
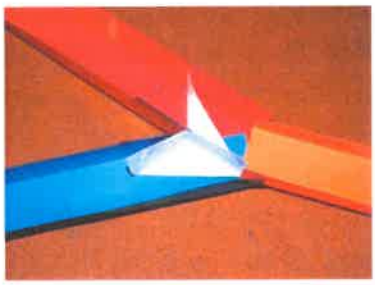
By cutting the walls through the entire length of the straight track, overlapping and gluing the adjacent parts, we can do the luping. For luping, the turn must be neatly wrapped and large enough to not stop the ball when changing direction. Making luping is demanding task and we have to do a lot of 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.

Crossroads and router

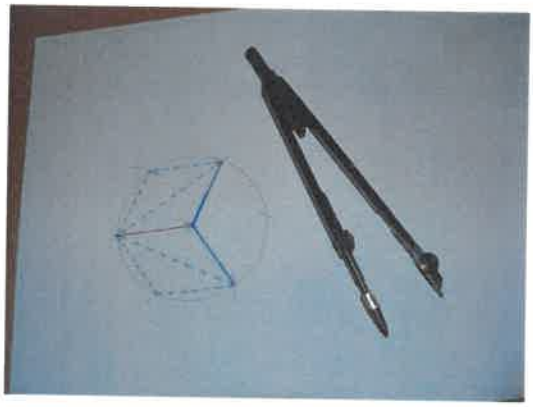
The crossroads is made of two straight traks. Let's put them side by side. Along the inner walls at the end of both traks, cut an edge between the bottom and the wall with a notch about 4 cm long. We get two strips that still stick to the walls. They are folded so that each strip fits into the wall of 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.

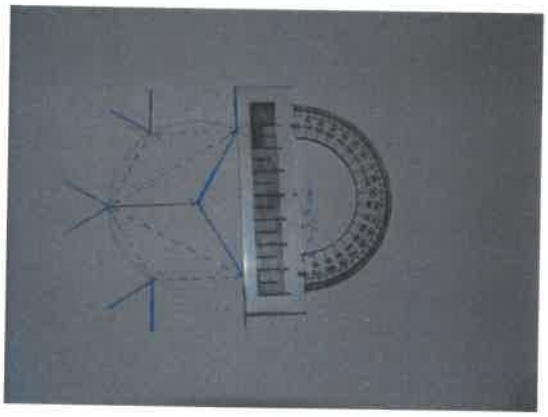
The router can be used to direct the marbles once in one lane, another in another lane.

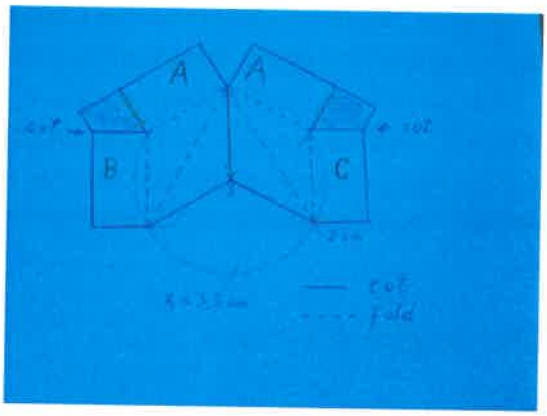
To make a router, we need a smooth, moldable paper. Draw a circle with a radius of 3.5 cm and divide it into 8 equal parts. We connect each other point on the circle with a dashed line, and we connect the center of the circle with two points with a solid line. We will bend the paper along the dashed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



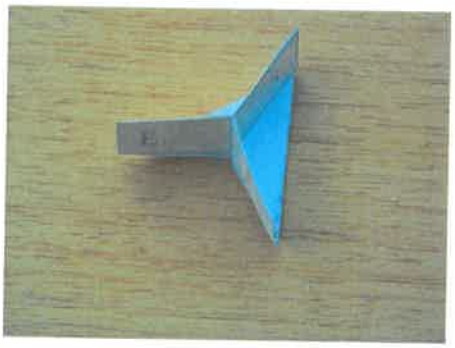
Draw the rectangles on the dashed lines connecting the adjacent points on the circle (also obtained as an extension of the side of an equilateral triangle, as shown by the geometric triangle side in the figure below). The rectangles are 2 cm long (slightly higher than the wall). Connect the ends of the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



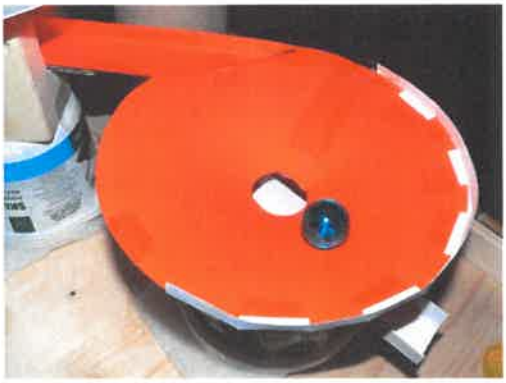


Cut out the image along the solid line. The dashed lines indicate only paper folding. Inside the image cut only along the line marked with a »cut« in the picture.

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.



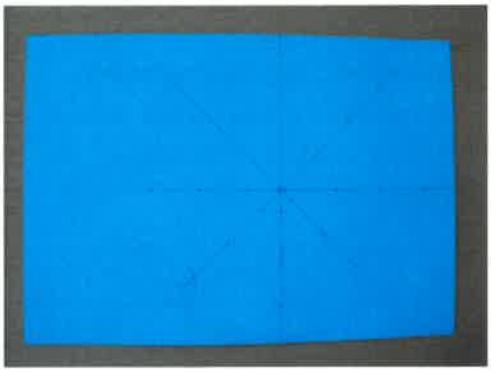
Recessed cone

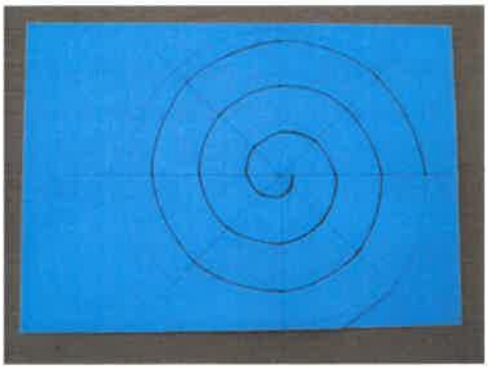


Draw and cut a circle out of hard paper (seleshamer). The circle can be arbitrary, but larger than 10 cm in diameter. The larger the circle, nicer and longer the ball rolls along the inner cone. Draw a 4cm diameter circle in the middle and cut it. This gives an opening through which the ball will roll out of the cone. Cut this ring radially and cover the resulting ends by about 30° to form a cone with a slope of about 30°. 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.

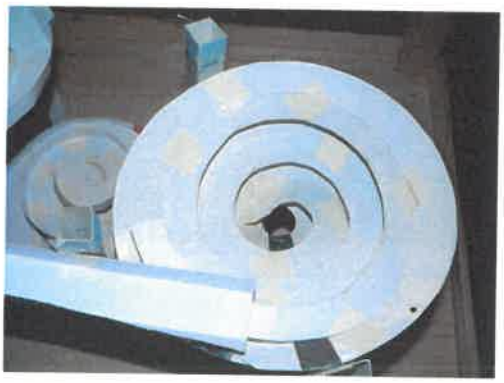
Arhimedes spiral on a cone

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.

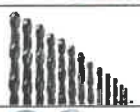
If the paper is sufficiently rigid and flexible, the wall can be glued directly to the spiral without extensions of 0.5 cm on the wall. The paper wall gets enough strength by twisting down the spiral.

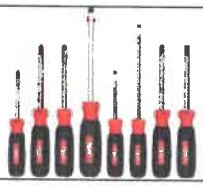
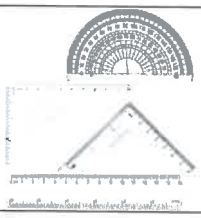
Slope

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.

THE TOOL WE NEED

Basic tools for 6 groups na LTT4:

Tools	
Drill machine (4 pieces)	
Various drill bits (for wood and metal) – 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm (4 pcs each)	
Foxtail saw – small saw teeth (2 pcs)	
Metal hand saw and metal saw blade (6 pcs)	 
Strong scissors (20 pcs)	

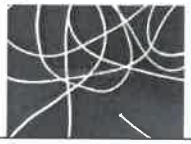
Patex thermo gun + glue cartridges (6 pcs)	
Hammer (200 g) (6 pcs)	
nail puller pliers (6 pcs)	
combined pliers (3 pcs)	
4 screwdrivers (flathead and Phillips) (3 pcs each)	
Flat files (for wood and metal) (2 pcs each))	
Abrasive paper for wood (rough and fine) (10 pcs each)	
Hot air dryer (1 pcs)	
Tape meter (2 m) (6 pcs)	
triangle and ruler (3 pcs each)	
clamp (12 pcs)	
angle ruler (6 pcs)	

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. (6 pcs)	
pencil (6 pcs)	
power strip (6 pcs)	
Stanley knife (6 pcs)	
school circle drawing pen (3 pcs)	
3 pieces OLFA rotary circle compass cutter (Stanley knife)	
Coloring brushes Thin: 1 mm, 3 mm, 5 mm Fat: 1 cm, 3 cm, 5 cm (3 pcs each)	

Consumables

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

Material for six contraption
Basic box - 6 pcs board 100 cm x 50 cm, thickness about 2 cm - 6 pcs 24 bars 50 cm long and 24 bars 100 cm long. The width of the slats is between 4 and 6 cm and the thickness is between 1 and 1.5 cm. 24 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 / m2 or 250 g / m2). I suggest purchasing 50 sheets for each group, a total of 300 A4-size sheets. In addition to 50 A3 sheets. I suggest buying 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, ...).
30 pcs - Different plastic stoppers.
30 pcs - Waste transparent bottles with a wide neck (4 cm diameter) 20 pcs - Waste transparent bottles with a narrow neck (diameter 2.5 cm)
24 pieces of metal balls with a diameter of 2.0 cm.
90 pcs plastic balls about 2.5 cm in diameter (can also be wooden)
100 pieces – eraser for closing jars (they can be different sizes). 
0,5 kg plasticine 
6 pieces boxes for collecting balls (you can use ice cream boxes).
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). Each type of 20 pcs.
12 pieces of transparent adhesive tape, 2 cm wide and at least 25 m long. The total length should be at least 300 m. 
200 pieces of pins


200 pieces paper clips 
For coloring - Colors (black, white, red, yellow, blue). Each color 1 kg. I recommend colors that 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.