TECHNOLOGY – FORCES AND EFFECTS

SUMMARY CARD

Forces and effects are the basis of all technical applications. In the course of the development of technology, we have learned to use, avoid, or intensify these fundamental forces as circumstances require. When tobogganing, children soon realise that smooth, hard surfaces are more slippery than rough, soft ones – and that friction must be reduced to a minimum. When the children build and construct things, there's no getting away from the principles of equilibrium and gravity: If the structure is tilted, it will be unstable and fall over. Knowledge of these forces is a good basis for further engagement with technical topics. It helps us to understand technical devices and to develop our own new technical inventions.

The present set of cards offers ideas for exploring spring force, friction force, lever force, gravity, centrifugal force, and inertial force with the children. There is a separate card for each force. Each card offers several ideas to enable the children to get to know, and to systematically explore, the force in question and to discover how and where it plays a role in their everyday lives.

These cards have been supplemented with the new "methods cards". Taking the catapult as an example, the methods cards present four tried-and-tested methods from the didactics of technology. With the help of these methods, different technology-specific patterns of thought and action can be strengthened in children. You can find further suggestions and exciting background information on the subject of "Technology – Forces and Effects" in the accompanying brochure and at www.haus-der-kleinen-forscher.de.

Note on working with different age groups:
You will sometimes find this symbol on the cards. The "ladder" indicates that the inquiry activity in question,or the entire card, presupposes that children have already had certain basic experiences and/or have developed certain skills (e.g., in the area of perception, cognition, or motor development). As a rule, these experiences and/or skills are not acquired until children are of primary school age (i.e., between the ages of six and ten). Ideas and inquiry activities that do not bear this symbol are suitable for children of all ages.

A BRIEF OVERVIEW OF THE INDIVIDUAL CARDS:

EXPLORATION CARD
SPRING FORCE – STRETCHED, TWISTED, TWIRLED

The children investigate metal springs and their effects in everyday objects. They observe that springs always return to their original shape, thereby bringing buttons, levers, and other parts of devices back to their initial position. Moreover, they discover that rubber bands also behave like springs and can even be used to produce motion.

EXPLORATION CARD
FRICTION – RESISTANCE PERMITTED

The children explore materials with smooth, slippery, rough, "bumpy," and scratchy surfaces. They experience at first hand what things slide and what things don't, and they consider situations in which it is expedient to reduce or to increase friction.

EXPLORATION CARD
LEVER FORCE – LONG AND SHORT

The children experience the lever effect with a seesaw. They discover how a seesaw loaded with different weights can be balanced. They investigate how heavy objects can be lifted more easily with long levers and can be hurled high and far with short ones. Moreover, they discover which everyday tools make use of the lever effect.

EXPLORATION CARD
GRAVITY – EVERYTHING IS IN BALANCE

The children discover their own body balance and the way objects are balanced. By making a mobile, they discover that weights and the point of support can be varied in order to achieve equilibrium.

08/2015

EXPLORATION CARD
CENTRIFUGAL FORCE – NOW THINGS GO ROUND AND ROUND

The children experience centrifugal force at first hand and investigate how things can be catapulted away or held in a circular path. They discover how they can influence the effect of the centrifugal force, and what solutions exist to defy or make use of it.

EXPLORATION CARD
INERTIAL FORCE – EVERYTHING STAYS THE SAME

The children experience the inertia of their own bodies and the fact that weight has a considerable influence on inertia. Using a model, they analyse what happens to an unsecured object in a vehicle that crashes into a barrier. They discover that objects in motion remain in motion and that objects at rest remain at rest as long as no external force is acting on them.

ADDITIONAL CARD
BUILDING INSTRUCTIONS – SIMPLE CATAPULT

With step-by-step instructions, the children are shown how to build a simple catapult from everyday materials. A list of materials, and images of other models, inspire further ideas.

METHODS CARD
ANALYSIS

Using this card, the children investigate the parts and functions of different catapults. When doing so, they also compare the differences between the various catapults.

METHODS CARD
TECHNICAL INQUIRY ACTIVITY

With the help of a technical inquiry activity, the children optimise part of a catapult. They investigate which objects are especially suitable for use as spacers so that their missiles fly as far as possible

METHODS CARD
PRODUCTION

This task entails planning the entire production process: The children define sub-steps, arrange them into a process, and give thought to organising material and tools. At the end, they control the quality of the manufactured products and the entire production process.

METHODS CARD
INVENTION

As part of a game, the children develop their own catapults. They clarify the requirements that the catapults must fulfil, and they test their models. Then they play the game.

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Exploring force: Spring force

STRETCHED, TWISTED, TWIRLED

Where do we encounter it in everyday life?

Technical springs make our lives easier: When we press a door handle down, it comes back up again automatically. When we sit down on a sofa and make ourselves comfortable, it gives a little, and when we stand up again, it returns to its former shape. A garden shears that contains a coil spring opens again automatically; clothes pegs close automatically. When something snaps back, there is a spring in it!

What it's all about

The children investigate metal springs and their effect in everyday objects. They observe that springs always return to their original shape, thereby bringing buttons, levers and other parts of devices back to their initial position. The children discover that rubber bands also behave like springs, and that they can even be used to produce motion.

What you need

- Trampoline
- Spring-upholstered furniture (e.g., spring
- mattress, sofa, office chair, etc.
- Different small objects that contain springs (e.g., hair clips, ballpoint pens, clothes pegs, bicycle bells, pliers with return springs, hole punches,staplers, etc.)
- Rubber bands
- Forks, drinking straws, string, clothes pegs, PET bottles, adhesive tape, scissors
- Folded pieces of paper for use as projectiles
- Plastic or paper cups
- Paper clips or thin wire
- Wooden skewers
- Plastic screw cap from a PET bottle

08/2015

CUSHIONED (WARM-UP)

Ask the children whether they have ever jumped up and down on a trampoline or on the bed. Why is that so much fun? Have the children jump up and down on a trampoline, and jointly investigate the difference between that and jumping up and down on the floor. With the children, take a look under the upholstery of the trampoline.

Can you see the many springs to which the trampoline mat is attached? What happens to the springs when one of the children jumps up and down? Ask the children whether they know any other play equipment, for example in the playground, that contains springs. And what about the furniture at home: Are there also metal springs like that in sofas, mattresses, and chairs?

Look at this: *You can compress or stretch springs. When you let them go, they spring back to their original shape..*

SO MANY SPRINGS!

There are many different types of springs, and they can be found in many everyday objects. Have the children bring things from home that they think might contain springs, and have some ballpoint pens, bicycle bells, hair clips, pliers, clothes pegs, staplers, hole punches, and other objects with return springs ready.Give the children sufficient time to engage with and investigate these objects. Where can they press or squeeze something? What parts spring back with the spring? Can the children discover where the springs are located? For a closer investigation, give the children a ballpoint pen to take apart. Most ballpoint pens contain a spring. Can the children put the pen together again without the spring? Does it still work?

Look at this: *There are many types of springs. They look very different, and they can bring buttons, levers, handles, etc. back to their original position.*

RUBBER BAND CATAPULT I

Rubber bands behave like springs: You can stretch them, and when you let them go, they return to their original shape. Have the children make their own rubber band catapults by copying the models depicted on the left. Then, have them try out different rubber bands – thick, thin, long, and short ones – in their catapults. With which rubber band does a folded piece of paper fly farthest?

RUBBER BAND CATAPULT II

You can provide older children with a diverse selection of everyday materials that they can use to build their own catapults either by copying the models depicted on the left or by inventing their own devices. For example, what ideas do the children come up with themselves for the V-shaped holder or for securely attaching the rubber bands? Also have the children test which rubber band makes the projectile fly the farthest.

Look at this: *The spring force in a stretched rubber band is so great that it can catapult a small object through the air.*

ROTARY MOTOR

Similar to when you are sitting on a swing and you twist the rope or chain and then let it go, you can use the spring force of a rubber band to make things spin. With the children, build a model of a rubber-band-powered carousel:

1. Pierce a hole in the bottom of a paper or plastic cup and in a plastic screw cap.
2. Unbend a metal paper clip in such a way that it is bent in the middle at a 90 degree angle. Stick the paper clip through the hole in the cup and bend the end of the paper clip inside the cup to form a hook. Hang a rubber band over the hook.
3. Stick a wooden skewer through the sides of the cup, threading it through the suspended rubber band as you do so.
4. Stick the other end of the paper clip through the hole in the screw cap and also bend that end to form a hook.
5. The rubber band should not be stretched too tightly, nor should it be hanging too loosely.
6. Now the children can attach different objects to the outer hook of the paper clip, rotate the hook until the rubber band is twisted tightly, and then let it go. The carousel will turn!

Look at this: *The spring force of a twisted rubber band can produce rotary motion.*

To illustrate the construction method, we have cut a piece out of the cup.

INTERESTED ADULTS MIGHT LIKE TO KNOW

Springs come in very different shapes and sizes. However, they all have one thing in common – namely, that they undergo deformation when a force is applied to them, and they return to their original shape when that force is removed. Ballpoint pens, for example, contain coil springs; hair clips have leaf springs; and clothes pegs and safety pins have spiral springs. Most springs obey a principle of physics known as Hooke's law, according to which the application of double the force will stretch the spring twice as much. Springs are also frequently used as shock absorbers, for example in motor vehicles. The suspension makes the vehicle more stable and the driving experience more pleasant because it dampens the shocks caused by the bumps and dips in the terrain. Rubber bands are often used to produce motion in toys: The rubber band is wound up until it is tight; when it is released, it unwinds very rapidly and sets an axle in motion – for example, the axle of a toy car or a carousel.

Exploring force: Centrifugal force

NOW THINGS GO ROUND AND ROUND

Where do we encounter it in everyday life?

If you take a curve too sharply when cycling, you may fall off your bicycle. If you had been cycling a bit slower, you might have successfully negotiated the curve. In a car, too, we feel the force that pushes us sideways. Whenever something turns or makes a curve, we are pushed outwards. There is even a piece of play equipment in the playground that makes use of this effect, namely the turntable. And at the fairground, we voluntarily climb onto the merry-go-round and let ourselves be whirled around in a circle for a long time – it's a great feeling!

What it's all about

The children experience centrifugal force at first hand and investigate how things can be catapulted away or held in a circular path. They discover how they can influence the effect of centrifugal force, and what solutions exist to defy or make use of it.

What you need

- Fabric shopping bags
- Weights (e.g., oranges, apples, little sandbags)
- Ropes of different lengths (2 metres, 3 metres, etc.)
- Magnetic cuddly toys or cuddly toys with clamp fasteners
- Different plates, bowls, and beakers
- Play dough
- Marbles
- Salad spinner
- Salad
- Paper
- Finger paint/tempera paint
- Pipette

08/2015

RUCKSACK PIROUETTE (WARM-UP)

All the children go around in circles and pay attention to what happens to their bodies. Can they describe what it feels like to go around in circles like this? What do they do with their arms? Does their hair fly back? Now distribute fabric shopping bags containing weights such as oranges to the children. Have some of the children put the bags on their backs like a rucksack. To do so, they put their right arm through one handle and their left arm through the other one. Then have these children go around in circles again, and ask the other children to observe closely what happens to the bags. Do they turn with the children or do they take off? How do the bags move when the children stand still again? Do the bags also "stand still" straight away? Have each child do at least one rucksack pirouette.

Look at this:

When something goes around in a circle, it is pushed outwards.

CATAPULTED AWAY

Two children each hold one end of a rope and stand about two metres away from each other. Have them turn the rope as if it were a skipping rope. Do they succeed in turning the rope in big circles? Now have the children attach magnetic cuddly toys or cuddly toys with clamp fasteners to the rope and to try to throw them off by turning the rope. Which toy flies off first? How can the children manage to throw the toys off as fast as possible? Encourage the children to change the toys' journey. What happens if they use a short or a long rope? Or if they turn the rope quickly and then slowly, or in big circles and in small circles?

Look at this:

When you make something go around in circles quickly, it is pushed outwards. The longer the circular path is, the more the object is catapulted outwards.

MARBLE CAROUSEL

Give each child a paper dinner plate and a marble. Have the children try to make their marble go round and round on the plate. To do so, they place the plate on the table and rotate it back and forth. Those who are more proficient can lift the plate up and swivel it in such a way that the marble goes round and round on the plate. Give the children lots of time to try to find the speed at which the marble rolls around in a circle most smoothly. Now give the children some play dough that they can use to build a "wall" around the edge of the plate. In this way, the marble does not fly off so easily. How fast can the marble go around in a circle? How high must the play dough wall be? Try out different plates, bowls and beakers: deep, shallow, small, and big ones.

Look at this:

To prevent the marble from flying off the plate, it should not go around in circles too fast. A high wall can prevent it from flying away.

Primary school students can discover even more on the exploration card for children entitled "Now things go round and round".

SALAD SPINNER ART

The children take a look at a salad spinner and consider how it works. What happens when they turn the handle? Explain to them that the salad spinner is used to dry salad leaves. Wash the salad and jointly examine how many drops of water are hanging from, and dripping off, the leaves. Then have the children dry the leaves in the salad spinner. Each child is allowed to turn the handle once, then the salad leaves are removed. Are they now dry? Where have the drops of water gone?
After this, all the children make works of "salad spinner art". Each child is given a sheet of white paper and some finger paint. The paint is dripped onto the paper with a pipette. The children take turns putting their sheets of paint-drizzled paper into the salad spinner and turning the handle a few times. Then they take a look at their coloured pictures. The children can now try out different techniques. How do the colour trails change when they turn the handle very vigorously, when they drip the paint onto the middle of the page, or when they use a lot of paint or very little?

Look at this:

When the handle is turned, the water is pushed outwards. The colour trails reveal the route that the drops took when they flew out.

INTERESTED ADULTS MIGHT LIKE TO KNOW

The force that pushes us outwards, for example when we drive around a bend in a car, is called centrifugal force. We feel this force when two different motions take place simultaneously: that of our body, which actually wants to continue travelling in a straight line, and that of the car, which takes us with it into the bend. This combination means that we are pressed against the chassis of the car. If there was nothing to hold us – no chassis, no car seat, no seat belt– then we would fly out of the car when driving around a bend. The same applies to the marble rolling around the plate. If the edge of the plate is not high enough, the marble flies straight off. Centrifugal force is of relevance for many technical applications: A swing carousel spins around so quickly that the chairs fly up into the air and the passengers are pressed into them; in a washing machine, the wet washing moves around and around very quickly so that the drops of water fly away from it and out through the holes in the drum.

Exploring force: Gravity

EVERYTHING IS IN BALANCE

Where do we encounter it in everyday life?

Whether we are standing, walking, or balancing, if we don't want to fall over, we must distribute our weight equally on all sides – we must balance ourselves. The same applies when we build a tower with building bricks. The tower will fall over if we build it crooked, and the bricks will tumble to the ground.

What's it all about

The children discover their own body balance and the way objects are balanced. By making a mobile, they discover that weights and the point of support can be varied in order to achieve equilibrium.

What you need

- A picture of a tightrope artist
- Thick rope, a gymnastic bench, or a kerb
- Various small objects that you can balance on one finger or incorporate into a mobile (e.g., forks, scissors, pens and pencils, balloons, feathers, etc.)
- Broom handle or very long pole (e.g., telescopic handle)
- Cloth or bag containing a weight (e.g., a head of cabbage or several apples)
- Wooden skewers
- Pieces of string

08/2015

A TIGHTROPE ACT (WARM-UP)

Show the children a picture of a tightrope artist. Ask them what is special about tightrope walking and why it is an art. Then, have the children try a balancing act themselves . For this purpose, turn a gymnastic bench upside down or lay a thick rope on the ground. Have one child try to walk along the upturned bench or the rope. Together with the other children, observe the young tightrope artist very closely. What is he/she doing with his/her arms and legs? Is he/she walking upright or stooped? Is he/she looking upwards or downwards? Have all the children try this balancing act. Suggest to them that they first try walking the "tightrope" with their arms stretched out to the sides and then with their arms close to their bodies. Which way is better?

Look at this:

It is difficult to keep your balance on an upturned gymnastic bench or a rope. Balancing is easier if you stretch both arms out to the sides.

BALANCING THINGS

What things can you balance easily on one finger? Set off with the children in search of small objects such as forks, scissors, coloured pencils, feathers, etc. Jointly examine the diverse collection and suggest to the children that they try to balance the objects on one finger. Help the children a little if they do not succeed in balancing the objects at the first attempt, and give them lots of time to try everything out. At the end, have the children sort all the objects into two groups: those objects that can be balanced easily on one finger, and those that can not. Why is it that some objects are easier to balance than others? Also discuss where exactly you must place a spoon on your finger, for example, so that it does not fall off.

Look at this:

Each object has a centre of gravity where it can be balanced. This centre of gravity is not always located at the centre of the object.

Primary school children can explore further with the exploration card for children "Wackelklammer."

THE HEAD OF CABBAGE DOES THE ROUNDS

The fairy tale character “Hans in Luck” wrapped his luggage in a cloth and carried it on a stick over his shoulder. The children try this out: They wrap a weight, for example a head of cabbage, in a cloth and hang it to a broom handle, which they balance over their shoulder. Where must the children hold the handle so that it is comfortable to carry? Also give them the opportunity to try out what it feels like when the head of cabbage is very far away from their bodies or hanging directly at their backs. Which is more pleasant? Next, give the children a second, similar weight to hang on the other end of the handle. Suggest that they carry the handle across both shoulders. What do the children notice?

Look at this: *The closer to the body the weight hangs, the easier it is to carry. Two weights that balance each other out on both sides of the body are easier to carry than one weight on one side, although together the two weights are heavier than the one weight!*

MAKING A MOBILE

Suggest to the children that they make a mobile. First, give each child a wooden skewer, which they balance on one finger. The children mark the point on their skewer at which it can be easily balanced. They hang the skewer up with a piece of string that is attached to the skewer at the balancing point they have marked. Is the skewer hanging straight or does it have to be shifted a little? The children then attach a small object, for example a feather, to one end. How should the skewer be shifted in order to restore the balance. Once the skewer is hanging straight again, the children are given a second object to hang on it, for example a balloon or a little figure. Do they have to shift their skewer again to restore the balance? Suggest to the children that they put all the individual mobiles together to form one large, joint mobile.

Look at this: *In order for a mobile to hang straight, the weights must balance each other out. If the weights are different, the point of suspension of the wooden skewer can be shifted.*

INTERESTED ADULTS MIGHT LIKE TO KNOW

The force that plays a major role in balance is gravity. It pulls everything towards the Earth. The heavier something is, the greater is the force of gravity acting on it. To keep something in balance, you have to find its centre of gravity. Viewed from this point, the weight of the object is distributed evenly in all directions. In symmetrical bodies, the centre of gravity is located at the geometric centre of the body. In asymmetrical bodies, for example forks, the centre of gravity can often be found only by trial and error. Several objects that are joined together have a common centre of gravity. The balancing of weights is important in many technical applications, for example in elevators or building cranes: Cement blocks weighing several tons ensure that the elevator car moves at an even pace and that the crane with its long arm and heavy building materials does not topple over.

Exploring force: Lever force
LONG AND SHORT

Where do we encounter it in everyday life?

When someone cracks a nut with their bare hands, we are impressed because we know how difficult that is. It is much easier to crack nuts with a nutcracker: All you have to do is press the long levers together. And the farther down the levers you grip, the easier it is to crack the nut. We experience something similar at the playground: A small child can easily seesaw with a grown-up when the child sits far back on the seesaw and the grown-up sits nearer the middle.

What it's all about

The children get to know the lever effect with the help of a seesaw. They discover how they can keep a seesaw that is loaded with different weights in balance. They investigate how heavier objects can be lifted more easily with long levers and how they can be hurled high and far with short levers. Moreover, they discover which everyday tools make use of the lever effect.

What you need

- Seesaw
- Wooden ruler or narrow wooden strip
- Building bricks
- Rubber band
- Small objects to use as weights (e.g., metal nuts, coins, Lego bricks, pebbles)
- Heavy weight (4 kilos max.; e.g., toybox or several books)
- Plastic or paper cup
- Double-sided adhesive tape
- Light little balls (e.g., polystyrene, table tennis or tennis balls)
- Long board, approx. 1 to 2 metres in length
- Plastic bottle, a tin, or a stone
- Different tools and household objects

08/2015



LEVER ARMS OF EQUAL LENGTH (WARM-UP)

Almost every child has played on a seesaw before. Ask the children about their experiences of seesawing. Do they prefer to sit right at the back or more towards the middle? What is it like to seesaw with a grown-up? Where is the best place to sit in that case? And can you seesaw on your own?
Using a wooden ruler and a building brick, build a mini seesaw with the children. At first, the children should place the ruler on the brick in such a way that it is horizontal, in other words, in balance. You can attach the ruler to the brick with a rubber band so that it does not slip off. Have the children fetch several weights, for example metal nuts or pebbles, from a box and distribute them on the seesaw in such a way that it remains in balance. Give them enough time to shift the objects around and to try out lots of combinations. Have the children work in pairs and discuss their observations.

GREATER LEVERAGE

Conduct an inquiry activity with the children using the seesaw model made out of a wooden ruler and a building brick. Have the children agree on a heavy object, for example a toybox, that they want to place on one side of the seesaw. First, all the children jointly carry the heavy toybox to the seesaw and place it on one of the lever arms. Can they feel how heavy the box is? Now, they try to lift the box with the help of the other lever arm. Do they succeed? Suggest that they shift the building brick under the ruler. Does that make a difference? Is the toybox easier to lift when the building brick is closer to it? In a further inquiry activity, the children can investigate what properties the lever – that is, the ruler – must have. Is it also possible to lift the box with a very thin stick or a long stick, for example?

Look at this:

It is easier to lift heavy things by pressing on a long lever arm. You can alter the length of the lever arm by shifting the building brick.

SHORT LEVER ARM

Build a catapult with the children. You will need the following materials: a narrow board for use as a lever; an empty plastic bottle, as a supporting surface; a beaker, for use as a container for the missiles; and a few light missiles, for example table tennis balls. Have the children stick the beaker to the board with strong glue. The board should be placed on the supporting surface in such a way that the construction resembles a seesaw. Then, have the children try to catapult their balls as far or as high as possible by stepping or pressing on one side of the catapult. Jointly find out which construction is most suitable for sending the balls flying high or far, respectively. Encourage the children to systematically change the arrangement of their inquiry activity. For example, they could change the support point (fulcrum) of the board; instead of a bottle they could use a rolled-up towel or a thick book as a supporting surface; or they could trigger the catapult by first applying a lot of force and then applying only a little force. What other ways of changing the arrangement can the children think of?

Look at this:

By pressing on the short lever arm, you can send things flying quickly and far through the air.

Primary school children can explore further using the exploration card for children entitled "Gummy Bear Catapult".

LEVERS AT WORK

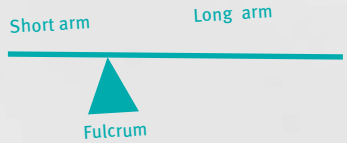
Search with the children for tools and kitchen utensils that can be used as levers to lift things. If necessary, supplement the collection with bottle openers, pliers, shovels, hole punches, staplers, nail clippers, and hammers. Jointly discuss with the children the things with which they are already familiar and what these things are used for. Have the children try the devices out. For example, they can make a hole in several sheets of paper with a hole punch, or they can staple the sheets of paper together with a stapler; they can open a bottle with a bottle opener; and they can remove nails from a board with a pliers or the claw end of a hammer, etc. Offer the children different versions of the devices, for example a hammer with a long handle and one with a short handle. Continue your journey of exploration throughout your institution. Where else can you find levers? A door handle or a tap, perhaps? Or on a pedal bin? And does it make a difference where you touch the lever: more towards the front or towards the back? What do the children discover when they try it out?

Look at this:

Levers can look very different, but they all make our work easier. The longer the lever is, the less force you need to apply.

INTERESTED ADULTS MIGHT LIKE TO KNOW

Levers are force converters. They can transmit force applied to one point to another point, and they can even amplify this force. When you push one side of a seesaw down, the other side goes up. Depending on where you push, it is easier or more difficult to lift the weight on the other side. A simple lever has two lever arms – which can be the same length or of different length – and a fulcrum.



By pushing the long lever arm down, you can lift heavy weights with little effort. More effort is required to push down the short lever arm, but the longer arm (e.g., catapult or oars) moves further. Bottle openers and wheelbarrows are also levers. However, they have only one lever arm, and the fulcrum is located at the end of that arm. Pliers and scissors are double levers that are connected by a hinge.

Exploring force: Friction

RESISTANCE PERMITTED

Where do we encounter it in everyday life?

If it weren't for friction, we could not run, jump, or grasp things. However, we usually realise this only when friction is too low, for example when we have hand cream on our hands and we are therefore unable to open a bottle, or when we are wearing woollen socks and we slip on a smooth floor. In such cases, grooved bottle caps, non-slip socks, and heavy-tread soles are helpful. They increase the friction and prevent you from slipping. However, when tobogganing, and in water slides and gearboxes, friction is a hindrance. Therefore, smooth surfaces and lubricators – for example water on the water slide – ensure that the friction is reduced.

What it's all about

The children explore materials with smooth, slippery, rough, "bumpy", and scratchy surfaces. They experience at first hand what is slippery and what is not, and they consider situations in which it is expedient to reduce or increase friction.

What you need

- Paper
- Sandpaper
- The children's shoes, non-slip socks, woollen socks, and hiking footwear or football boots with a deep tread
- Various materials with slippery and non-slippery surfaces (e.g., plastic bags, scarves, towels, cleaning cloths, etc.)
- Objects with a particularly rough surface (e.g., cheese graters, cleaning sponges, files, vegetable graters, pot scourers, sandpaper)
- Crayons, rubber erasers, and, if applicable, bicycle brakes and bicycle tyres

08/2015

SMOOTH AS GLASS OR ROUGH AND BUMPY (WARM-UP)

Ask the children to rub the palms of their hands together. What does it feel like? Do the children feel the palms of their hands and the way they are getting warm? Then give each child two sheets of paper and have them rub the two sheets together. What is the difference between rubbing your hands together and rubbing two sheets of paper together? After this, each child repeats the exercise using two pieces of sandpaper. What is difference this time? What do the surfaces of the paper and the sandpaper feel like when the children stroke them with their hands? Try out with the children how well or how badly other surfaces – for example, two towels or two transparent plastic folders – slide over each other.

Look at this:

Smooth surfaces slide over each other well. However, in the case of rough, "bumpy" surfaces, you feel resistance.

NON-SLIP TREADS

Ask the children whether they have ever slipped and fallen, for example at the swimming pool, on a smooth floor, or on an icy path. What solutions to this problem do they already know? Jointly examine the soles of the children's shoes. Have the children run their hands over them. What do they feel like? Then have them try out on a smooth floor which soles are good for sliding and which are not. Other interesting non-slip treads can be found on non-slip socks, football boots, or the tyres of three-wheelers, bicycles, and babies' prams. You can also examine grips and handles, for example on bicycle handlebars, doors, and kitchen utensils. Ask the children how they can grip things better when they have hand cream on their hands or their hands are slippery for some other reason.

Look at this:

Shoes with rough soles help us not to slip on or off things. Door handles, bicycle handlebars, or the handles of kitchen utensils often have rough or „bumpy" grips to make them easier to grasp.

AS IF LUBRICATED

Slipping and sliding is not always a bad thing; sometimes we want to have as little friction as possible. Accompany the children to the playground slide and have them investigate how sliding can be improved. They can slide down themselves and use different objects or materials – for example, their jackets, a cloth or a towel, a scarf or sand – as an intermediate layer. However, it is important to exercise caution because some things, such as plastic trays or laminated paper, make you slide very fast. You should also use things that do not slide well, for example a rubber mat. What do the children discover? What materials are good for sliding and what materials act as a brake? If the weather is bad, you can build a sloping surface indoors in the physical activity room. For example, you could place one end of a bench on a pile of books. The children can then test objects that do not slide spontaneously, for example shoes or rubber erasers. What solutions do the children come up with to make the shoes and erasers slide down the slope, nonetheless. And how can these objects be made to slide particularly fast?

Look at this:

To make things slide better, you can reduce the friction between two surfaces by using a lubricant or an intermediate layer.

RUBBED OFF

Friction is often one of the causes of wear and tear. Investigate with the children different devices that have a very rough surface and that wear things off or down by rubbing or scraping – for example, sandpaper, a cheesegrater , a nail file, a cleaning sponge, a pot scourer, etc. Have the children carefully run their hands over these objects and describe what they feel like. Also ask the children what these objects are used for. Lead pencils, coloured pencils, and crayons also get worn down when you use them. Have the children investigate exactly how they must draw in order to rub as much colour as possible off a wax crayon. You can rub lead pencil marks out with a rubber eraser. What do the children observe when they do this? Older children can also investigate the brakes and tyres of their bicycles. These things also get worn down when they are used. What do the brake pads of new bicycle brakes look like? And those of old bicycle brakes?

Look at this:

Things can be changed through friction: they get smoother, they are worn down, and the process of abrasion often produces lots of shavings.

INTERESTED ADULTS MIGHT LIKE TO KNOW

Movement without any friction exists only in theory. To enable machines to run as smoothly as possible and wheels to turn easily, friction is often reduced by using lubricants, such as oil, for example. On the other hand, high friction is desired in the case of shoes and wheel profiles. Grooves and depressions increase the grip of surfaces. This is the case, for example, with many handles on tools, kitchen appliances and bicycle handlebars. Rough surfaces are always helpful when you want to modify materials. For example, you can file your nails with a nail file, sand wood down with sandpaper, and grate cheese into little pieces with a cheese grater.

Exploring force: Inertial force

EVERYTHING STAYS THE SAME

Where do we encounter it in everyday life?

When the bus starts quickly, you are pressed into your seat. When it brakes at the next stop, your body initially continues to move in the direction of travel. That is also why it is important to wear a seat belt in the car because, when a vehicle brakes suddenly or crashes into a barrier, anything that is not secured simply continues to move straight ahead until it is abruptly stopped by something else, for example the windscreen.

What's it all about

The children experience the inertia of their own bodies and the fact that weight has a considerable influence on inertia. Using a model, they analyse what happens to an unsecured object in a vehicle that crashes into a barrier. They experience that objects in motion remain in motion and that objects at rest remain at rest as long as no external force acts on them.

What you need

- Cushions
- Heavy book
- Toy cars, skateboards
- Objects of different weight (e.g., nuts, toy figures, cuddly toys)
- Cloths, paper, plastic foil
- Paper cups or plastic cups
- Marbles
- Drinking glasses and buckets
- Water
- Coffee powder or colourful, powdered spices

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EVERYTHING STAYS WHERE IT IS (WARM-UP)

The children experience the inertia of their own bodies by trying to push each other along. To do so, one child sits on a cushion on the floor and another child tries to push him or her from behind. What's important here is that the child who is being pushed may not give any help. After a while, the children switch roles. Afterwards, jointly discuss whether all the children succeeded in pushing each other forward a little on the cushion. In whose case did this not succeed? Draw the children's attention to the fact that they differ in size and weight, and discuss who pushed whom. It is of course much more difficult for a small child to push a heavier child than vice versa. Sit down on a cushion yourself and have the children try to push you. How many children have to pitch in?

Look at this: *It is easy to set light things in motion; for heavy things you need more strength.*

FROM ZERO TO ONE HUNDRED

Have the children ever seen a magician pull a table cloth from under the dishes and cutlery on a table, and all the plates, cups, knives and forks simply remained standing on the table? Have the children try this out with a sheet of paper and a paper cup. The sheet of paper is placed on the table in such a way, that part of it protrudes over the edge. The children then place the paper cup on the sheet of paper and weigh it down, for example with a few marbles. Now, have one child pull the sheet of paper off the table. What happens to the cup? Does it move with the sheet of paper? The trick works really well when the sheet of paper is pulled downwards slightly. The children then explore what changes when they pull on the sheet of paper more quickly or more slowly, and when they place lighter or heavier objects on the sheet of paper. For example, they can change the number of marbles in the paper cup .

Look at this: *The faster the sheet of paper is pulled, and the heavier the paper cup is, the less the cup moves when the sheet of paper is pulled away.*

FASTEN YOUR SEAT BELTS

Talk to the children about why they must fasten their seat belts in the car. What do the children think happens when the brakes are applied fully and they do not have their seat belts on? Why is this so dangerous?
The children use little toy cars or skateboards to investigate what happens in such an emergency braking situation. Toy figures or nuts can be used as the passengers and the load. The vehicles are loaded and driven at high speed into a barrier, for example a thick book. What happens to the passengers and the load when the vehicle comes to an abrupt halt? The children can also investigate how the speed of the vehicle and the weight of the load influences the result of this inquiry activity.

Look at this: *Everything that is in motion stays in motion until it is actively stopped. The lighter and slower something is, the less force is needed to stop it; the heavier and faster something is, the more force is needed to bring it to a halt.*

Primary school children can explore further by using the exploration card for children entitled "Emergency Braking".

WATER CAROUSEL

To make hot chocolate, you have to stir cocoa into the milk. This gives rise to a rotating spiral of milk in the middle of the mug. For this inquiry activity, the children fill drinking glasses with water. They sprinkle a little coffee powder or colourful powdered spice onto the surface of the water so that the movement of the water can be seen better. The children then use a spoon to set the water in a fast rotating motion, and they observe how long it rotates when they stop stirring. Provide the children with vessels in other sizes and have them stir different amounts of water. Do they perhaps have any ideas about how they could stop the water rotating themselves?

Look at this: *The more water you use, and the faster you stir it, the longer it takes for it to come to rest again.*

INTERESTED ADULTS MIGHT LIKE TO KNOW

Inertia is a force that acts on all objects and bodies. It ensures that, unless acted on by an external force, a thing that is at rest stays at rest and a thing that is in motion stays in motion. The heavier a car, a person, or a thing is, the more "inert" it is. That means that heavy objects are difficult to set in motion while light objects can be moved with little force. If we have to push a car, for example because the engine has failed, a lot of force and several helpers are needed to get it moving. By contrast, a toy car can be set in motion by tipping it lightly with your finger. However, once the car is in motion, it is not so easy to bring it to a halt again. Moreover, speed increases inertia even more: The faster the car is moving, the harder it is to stop it.

Methodological approach: **Analysing technical devices**

HOW DOES A CATAPULT WORK?

ANALYSIS | **TECHNICAL EXPERIMENT**

PRODUCTION | **INVENTION**

The purpose of an analysis is to understand the structure or the workings of a technical object, such as a catapult, in order to be able to copy it, for example. In the course of carrying out an analytical task, the children learn to describe the functions of the object, to name concrete components, and to make and test assumptions. For a systematic analysis, questions should be formulated that can be answered by trying things out, taking things apart, and examining and observing things. Examples of possible questions about the catapult are:

- Which parts are fixed and which are mobile?
- What triggers the movement?
- What other types of catapults are there?

Accompany the children through the following steps:

1. Express assumptions
2. Try out and observe
3. Compare variants
4. Conclusion

1. EXPRESS ASSUMPTIONS

The children observe the catapults that have been prepared, and express their ideas about the way they are used and how they work.

Ask the children about their assumptions:

- *What exactly do you have to do?*
- *What will happen?*
- *What functions do the individual components have? Are they supposed to hold something, to stop something, or to make something spring back? What is their exact purpose?*

2. TRY OUT AND OBSERVE

The children try out the catapults and observe what happens. Ask them whether their observations correspond to their previous assumptions or whether perhaps something unexpected happened.

Have the children describe, for example:

What parts does the catapult consist of?
Which parts are mobile and which are fixed?

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Materials:

- *Different types of simple catapults (see instructions for building the catapults on the additional card "Building Instructions – Simple Catapult").*

You can find more information about the analysis in the accompanying brochure **"Technology – Using Forces and Achieving Effects"**.

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3. COMPARE VARIANTS

In the next step, the children investigate the catapults more closely and compare the different types. To this end, they can also take the catapults apart and put them back together again.

What answers do the children find to the following questions, for example:

- *What components do the catapults consist of?*
- *How are the components connected to each other?*
- *Do we find similar solutions in other devices?*
- *Could one component be left out?*
- *How, for example, do the levers of the different catapults differ?*
- *Which type of catapult do the children find the most practical/the nicest/the best?*

4. CONCLUSION

Jointly produce a summary with the children, for example in the form of a poster entitled "How does a catapult work?".

The poster could contain the following elements:

- *Components: The catapult consists of the following parts ...*
- *Use: This is the way you operate it./This is what happens.*
- *Effect: The components have the following functions ...*
- *Tips: Attention should be paid to ...*
- *Evaluation (examples):*
  What I like:
  "When you can hold and start the catapult with one hand." – "When there is a container for the balls."
  What I don't like:
  "I find the catapult with the ruler too shaky." – "I don't like the spoon as a lever because the ball always falls out."

Methodological approach: **Optimisation by means of a technical experiment**

HOW CAN THE CATAPULT SHOOT AS FAR AS POSSIBLE?

ANALYSIS

TECHNICAL EXPERIMENT

PRODUCTION

INVENTION

A technical experiment can help you to find a solution to a specific problem – for example, how a catapult can be made to shoot further. Technical experiments are not only a good way of strengthening technical creativity but also of refining questions and sharpening observations.

Accompany the children through the following steps:

1. First, the problem to be solved is defined.
2. Second, a concrete question is formulated, which the experiment is supposed to answer.
3. Then, the experiment is conducted.
4. The results of the experiment are evaluated. On the basis of this evaluation, a decision is made as to which solution should be chosen.
5. At the end, the chosen solution is implemented. In the present example, all the catapults are equipped with the spacer that proved to be the best solution.

1. DEFINE THE PROBLEM

The children's task is to improve the prepared catapults in such a way that they shoot as far as possible. So, the problem in this case is the flight distance.

Ask the children for their ideas:

What changes could you make to the catapults in order to be able to shoot as far as possible with them?

You will probably get a lot of suggestions because all the components of the catapult could influence the flight distance, for example the type of spacer, the length of the lever, or the elasticity of the rubber bands.

2. FORMULATE QUESTIONS

Suggest to the children that they should first concentrate on one component – the spacer. Formulate a concrete question about it, for example:

"With which spacer do the projectiles fly farthest?"

Agree with the children that they should not change any of the other parts – for example, the lever or the base – and that they should use the most similar types of projectiles possible so that the experiment focuses only on the influence of the spacer.

08/2015

Materials:

- *Simple catapults of the same type or of different types (see instructions for building the catapults on the additional card entitled "Building Instructions – Simple Catapult")*
- *Objects for use as spacers, e.g., pencils, pen caps, rubber erasers, corks, paper, etc.*

You can find more information about technical experiment in the accompanying brochure **"Technology – Using Forces and Achieving Effects"**.

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3. CONDUCT THE EXPERIMENT

The children investigate how the flight distance changes when they replace the spacer in their catapults with a different type.

The children can swap the original spacers in their catapults among themselves, or they can try out new ideas, for example little sponges, corks, or pens of different thicknesses. What other ideas do the children have about things that would be suitable for use as spacers?

4. EVALUATE AND DECIDE

Jointly evaluate with the children which solution achieved the best results in the experiment.

Discuss the following questions with them, for example:

- *Is there a clear winner among the spacers?*
- *Are several things equally suitable?*
- *Are some completely unsuitable?*

With older children, you can also proceed from the concrete objects, such as pencils and rubber erasers, to the more general properties that a suitable spacer should have.

Possible questions could be:

- *Is it the size of the spacer that counts?*
- *Should the spacer be hard or soft, round or angular?*

5. IMPLEMENT THE RESULTS

At the end, the children implement their results and install the "winning spacer" in all the catapults.

If the children would like to further improve their catapults, they can conduct additional experiments, for example on the length of the lever or the tension force of the rubber bands. It is likely that a lot of assumptions were collected at the beginning about all the things that may contribute to flight distance. Each of these assumptions may offer an opportunity for an experiment.

TECHNOLOGY – FORCES AND EFFECTS

Methodological approach: **Production**

HOW CAN YOU BUILD AS MANY IDENTICAL CATAPULTS AS POSSIBLE?

ANALYSIS

TECHNICAL EXPERIMENT

PRODUCTION

INVENTION

A production task entails manufacturing a product – perhaps in large numbers. This includes both the planning of the production process, the final control of the finished product, and the evaluation of the production process. Production tasks strengthen technical thought and action patterns. The children learn to arrange the production sub-steps into a process. They also discover the importance of final testing and evaluation procedures, for example, to enable them to decide whether they have completed the task correctly and with reasonable effort.

Accompany the children through the following steps:

1. Formulate the task: What is to be produced and what properties should it have?
2. Specify the task: What requirements should the product fulfil?
3. Planning: Production is planned, prepared, and organised.
4. Production: The children manufacture the object.
5. Evaluation: At the end, both the procedure and the manufactured catapults are reflected on and evaluated.

1. FORMULATE THE TASK

Give the children the task of manufacturing several catapults.

Before they begin the planning and production, the children should have understood the structure and workings of the catapult. To this end, have them try out and play with the model you have prepared

2. SPECIFY THE TASK

Specify the task more precisely – for example, how many products are to be manufactured in total, and what quality requirements should they fulfil.

Examples:

- *One catapult should be built for each child.*
- *All the catapults should comprise the same components.*
- *All the finished catapults should shoot the projectiles at least two metres.*
- *All the finished catapults should be able to shoot at least three times in a row without anything becoming loose/unstuck or having to be readjusted.*

08/2015

Materials:

- *A version of the simple catapults (for instructions for building the catapults, see the additional card entitled "Building Instructions – Simple Catapult")*
- *Materials for building several of the catapults featured in the aforementioned instructions*

You can find more information about manufacturing catapults in the accompanying brochure **"Technology – Using Forces and Achieving Effects"**.

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3. PLANNING

The children now plan the production in detail. Ask them what work steps are necessary and in what order these steps should be executed. Note down each work step on a separate sheet of paper, and have the children move the sheets of paper around until they have agreed on the order of execution.

Moreover, clarify the following questions with the children:

- *What materials and tools do we need and to which work step do they belong?*
- *How do you want to lay out the materials and tools so you have them at hand as quickly as possible for the individual work steps?*
- *Is an adequate supply of all the materials available or can they be acquired?*
- *Do you want small groups to each build a complete catapult or would you prefer to form an assembly line and divide the individual work steps up among yourselves?*

4. PRODUCTION

The children manufacture the catapults and proceed as planned. When bottlenecks or problems arise, they make a note of them for the final evaluation of the production process.

5. REFLECTION AND EVALUATION

In the reflection phase, jointly test with the children the finished catapults, and retrospectively evaluate the planning and production process. The main aim of this reflection is to give the children a wealth of experience for future production tasks.

Each catapult is tested to see if it meets the previously defined quality requirements – for example, shooting the projectiles two metres. Each catapult that passes all the tests is ceremonially "accepted," for example by awarding a small handwritten certificate containing the statement "Tested Quality Catapult".

Then, jointly evaluate the production process and the way it was planned.

What answers do the children have to the following questions, for example:

- *Was anything forgotten during planning, for example glue and scissors or other materials?*
- *Could all materials be acquired as intended or was it necessary to improvise and to change the plan?*
- *Was the arrangement of the work steps in the production process appropriate, or did it result in bottlenecks and waiting times? What would you do differently if you had to carry out the same task once again?*

TECHNOLOGY – FORCES AND EFFECTS

Methodological approach: **Invention**

DESIGN YOUR OWN CATAPULT

ANALYSIS

TECHNICAL EXPERIMENT

PRODUCTION

INVENTION

If a suitable solution to a concrete technical problem is not available, you have to design one. When doing so, existing technology can be used creatively, or new technology can be created. In the present example, technical creativity takes centre stage:
The children will be given the task of developing a game in which catapults are used to shoot little balls at a target.

Accompany the children through the following steps:

1. Needs must be precisely clarified: What object is to be developed and what properties should it have?
2. Proposed solutions are collected.
3. Models and prototypes are developed.
4. The models are tested to see whether they fulfil their purpose.
5. The solution that is chosen is documented, for example in the form of building instructions.

1. CLARIFY NEEDS

Give the children the task of developing a game of skill involving catapults. First, jointly agree on the rules of the game.

Examples of possible rules of the game are

- *Table tennis balls are used as flying objects.*
- *The playing field is a large circle in the middle of which there are several buckets and bowls in which the balls are to land.*
- *The vessels carry different numbers of points – for example, 100 points for the one in the very middle, 50 for the vessels next to it, and ten points for the outer vessels.*
- *The balls are shot from the periphery of the circle, for example from a standing or a sitting position.*

Now discuss with the children the requirements that the catapults must fulfil as a result of these rules. For example, the catapults will have to be big enough for table tennis balls and they must also achieve a certain flight distance and height, which depends on the size of the playing field and the shape of the buckets and bowls.

2. COLLECT IDEAS

Ideas for possible catapult designs are jointly collected.

For example, the children can examine and try out a finished catapult. You can find further ideas and suggestions for building catapults in specialised books, activities books, or on the Internet. Lay out appropriate books, pictures, and models so that the children can look at the different catapult variants again and again.

08/2015

Materials:

- *Materials for building catapults (many different everyday objects; for examples, see the additional card entitled "Building Instructions – Simple Catapult"*
- *Buckets and bowls, table tennis balls*
- *Possibly, suggestions and ideas for tried-and-tested catapult solutions, for example a model or books featuring images of catapults*

You can find more information about invention in the accompanying brochure **"Technology – Using Forces and Achieving Effects"**.

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3. BUILD MODELS

The children now build their models. You should allow plenty of time for this because the children have to try out a lot of things and to continually make modifications.

4. TEST AND EVALUATE

In the next step, the children present their catapult models and test whether they fulfil the necessary requirements for the game.

Request the children to report what components they used, how they arrived at the idea to build the catapult in this way, where the greatest difficulties lay, and how they overcame them.

Of course, the models are now tested and the game tried out.

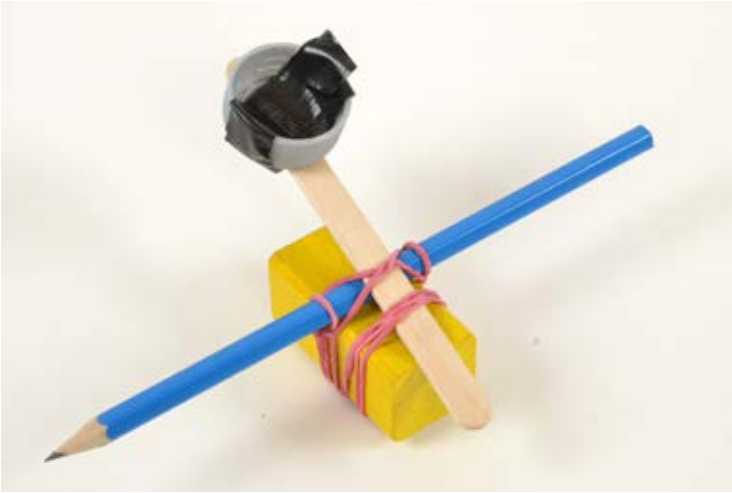
5. DOCUMENTATION

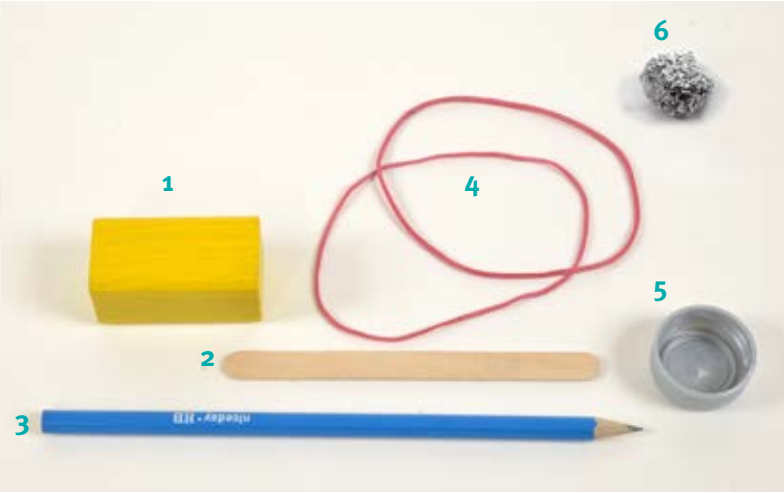
At the end, the result of the design and construction process is documented in the form of a large poster, for example.

The children can draw or photograph the catapults and their components. In the case of particularly tricky solutions, the children can use a red pen to apply markings and annotations or to number the individual design steps.

Additional card: **Building instructions**

SIMPLE CATAPULT





COMPONENTS

1. *Base (e.g., a building brick) which ensures that the catapult stands firmly on the table and can be picked up easily*
2. *Lever (e.g., a wooden spatula) that catapults the projectile into the air*
3. *Spacer (e.g., a pencil) which ensures that the lever does not lie horizontally on top of the base but rather at an angle against it*
4. *Rubber bands that connect the base and the lever elastically (i.e., in a spring-like fashion)*
5. *Container (e.g., a screw cap) for the projectile, so that it does not slip off the catapult lever at the start*
6. *Projectiles (e.g., balls of crumpled up aluminium foil)*

INSTRUCTIONS

1. The base and the lever are attached at one end with a rubber band, as close to the edge as possible. TIP: To prevent the rubber band from slipping forward when the catapult is fired, you can allow the lever to protrude about one centimetre over the base.

2. The spacer is inserted directly behind the point where the rubber band connects the base and the lever so that the lever slants upwards and no longer lies horizontally on the base.

3. The spacer is connected to the base and the lever with another rubber band so that it does not slip. When doing so, tie the rubber band crosswise. The exact tying technique is not important – the main thing is that it holds firm.

4. Attach the container for the projectile to the lower end of the lever (e.g., with strong adhesive tape). When doing so, leave about one centimetre of the lever free behind the container so that there is enough space to press the lever down with your finger.

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CATAPULT EXAMPLES

DIFFERENT VERSIONS OF THE SIMPLE CATAPULT

Materials:

- *Forks, building blocks, stiff rulers*
- *Pencils, wooden spatulas, clothes peg halves,teaspoons*
- *Pen caps, rolled up sheets of paper, rubber erasers*
- *Rubber bands*
- *Bottle tops, crown caps, adhesive tape, play dough*
- *Crumpled aluminium foil, pompons, polystyrene balls*

! *CAUTION: Do not use any hard objects, such as marbles, as projectiles as they could cause injury.*

EXAMPLES OF OTHER TYPES OF CATAPULTS