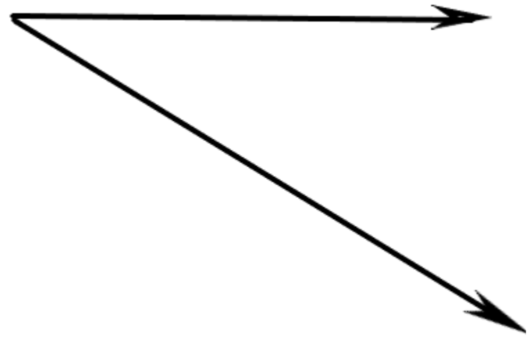
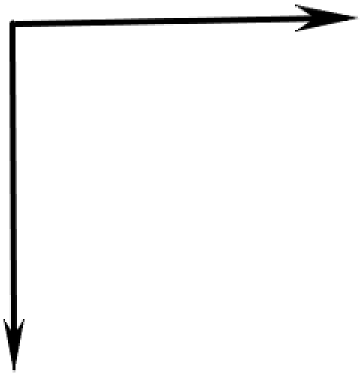
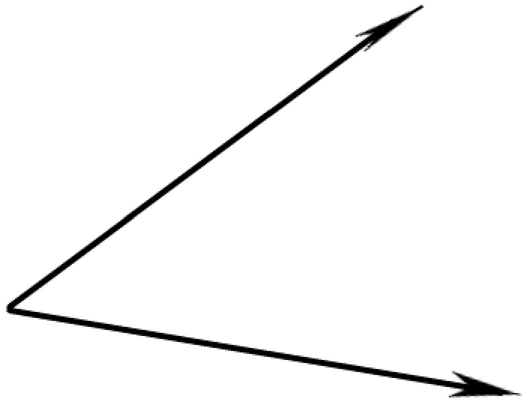
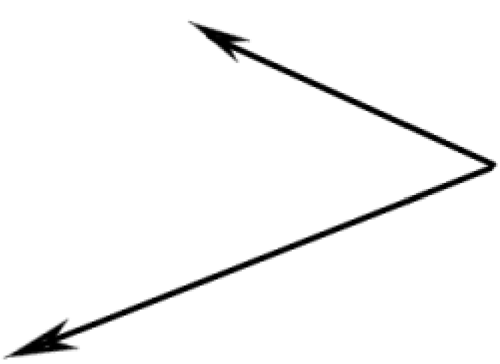
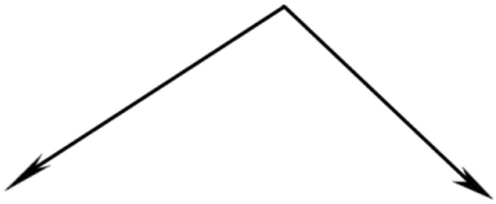
Combining forces – Find the resultant force



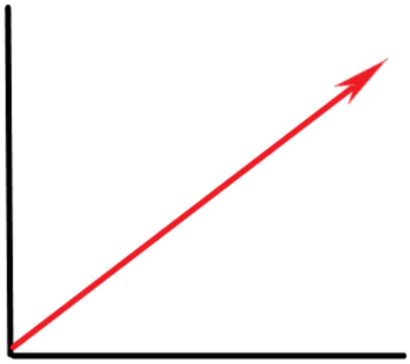


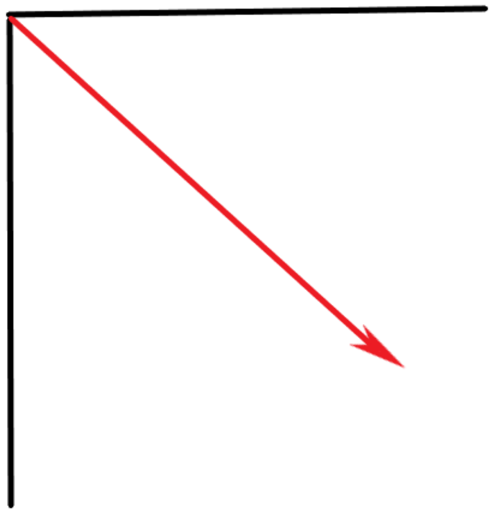


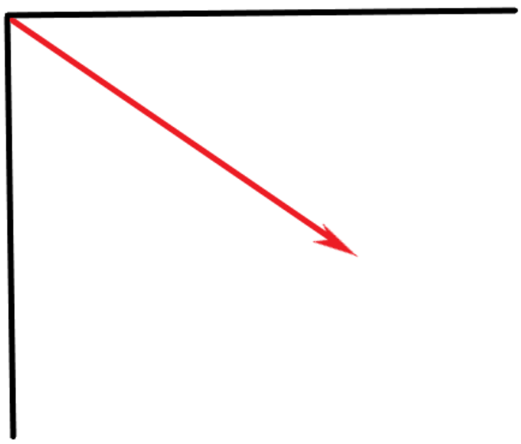


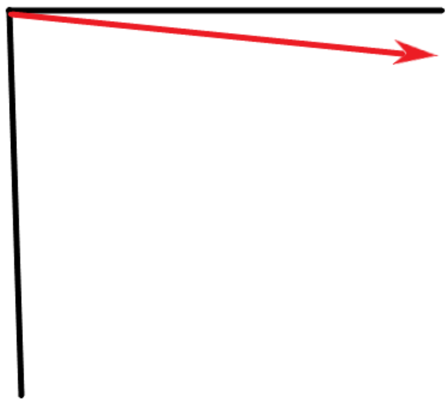


Decomposing of forces - Decompose the force into the vertical and horizontal directions









Free - Body Diagram

A free body diagram is like a special drawing in physics that helps us understand how forces act on an object. Instead of drawing the object itself, we represent it with a simple shape or an easy sketch. It could be as simple as a dot or a small picture of the object.

Now, imagine the object has different forces acting on it, like a push, a pull, gravity pulling it down, or maybe even forces pushing or pulling it in other directions. To understand how these forces work together, we draw arrows starting from the dot or shape. Each arrow represents a force, and it shows which direction the force is going and how strong it is compared to the others.

A helpful convention in drawing free body diagrams is to have these arrows start from the center of mass of the object and point away from that center. This way, we can have a clear idea of how the forces are acting on the whole object.

If the object is standing still or moving with a constant velocity, that means all the forces are balanced, and the resultant force is zero. This concept is called equilibrium.

We have learned that forces are vectors. It means not only the magnitude (how strong) of the force matters but also its direction. In our cases, we often work in a plane, which means we have to consider both vertical and horizontal directions when calculating the resultant force. But what if a force doesn't act in just the vertical or horizontal direction?

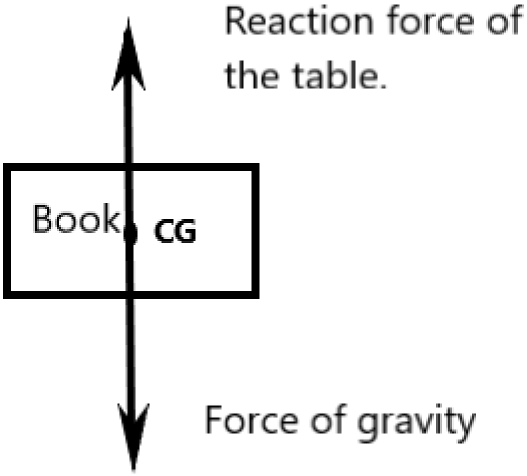
If a force is not directly vertical or horizontal, we need to break it down into its vertical and horizontal components. This was why we practiced combining and decomposing of forces. Once we know the vertical and horizontal components, we can add them up separately to find the resultant force in each direction.

Understanding free body diagrams and how to decompose forces will be useful for more complex problems in physics. We need it to analyze all sorts of situations, like how a car moves on a curved road or how objects fly through the air.

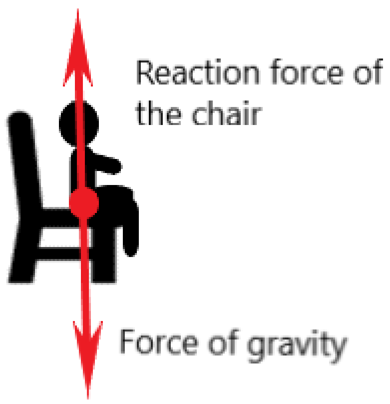
Following examples will help with understanding the concept.

<u>Example 1</u>: A book at rest on a table.

When an object is at rest, according to Newton’s laws, the forces are balanced. which means that the sum of all acting forces (considering both the magnitude and direction) is zero. In the case of the book on the table, there are two forces acting on it: the force of gravity pulling it downwards and the reaction force of the table pushing it upward in the opposite direction. (Note: CG – center of gravity - point of application of force)



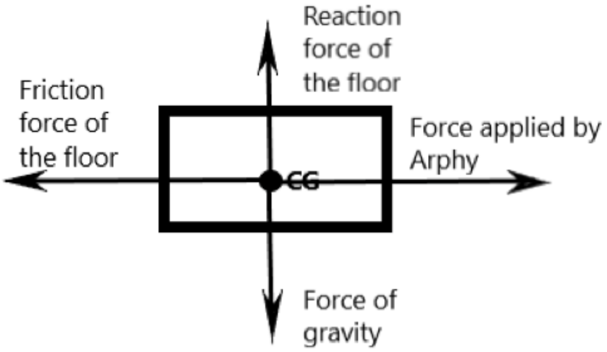
<u>Example 2</u>: Arphy sitting on a chair.



Similarly, there are two forces acting on Arphy while sitting on the chair. The force of gravity pulls Arphy downward, and the chair exerts an equal magnitude but opposite direction force to support Arphy. Both of these forces are balanced, allowing Arphy to sit safely on the chair. However,what would happen if we were to pull the chair?

<u>Example 3.</u> Pushing the crate

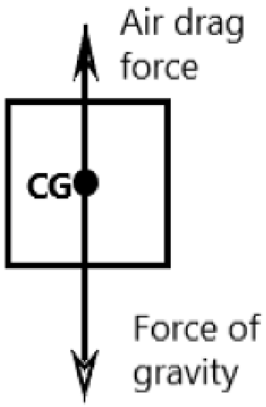
Now let us imagine Arphy pushing a crate to the right on the floor at a constant speed. When an object moves at a constant speed,it means the forces are in balance too, following Newton's laws.

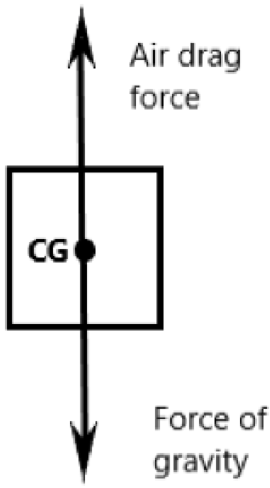


In this case, two forces are balanced in the horizontal plane: the force applied by Arphy to push the crate, and the friction force between the crate and the floor. In vertical plane the reaction force of the floor balances the force of gravity acting on the crate.

Example 4. Arphy is skydiving.

Arphy gets a parachute jump as a gift. When skydiving and falling downwards, the force pulling Arphy downward is stronger than upward force which makes Arphy speed up. Fortunately at a certain point the force of air drag balances out the force of gravity. The air drag force depends on how fast Arphy is falling, but we are not going into the details. Important is that at certain point Arphy reaches a constant speed, called limit speed.

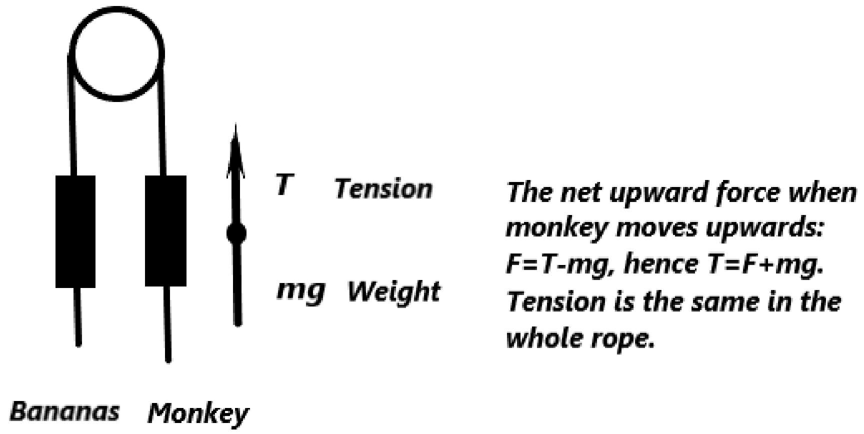




Example 5.

Here is a famous classic problem that will make you think. A rope is passed over a pulley suspended from a tree branch, and a stalk of bananas is tied to one end. A monkey hangs from the other end of the rope, and the mass of the bananas and the monkey are balanced. Now the monkey starts climbing up the rope. What will happen to the bananas? Will they stay in the same place, or will they move up away from the ground, or will they move down toward the ground?

Solution.



Look at the force diagram for the monkey. His weight mg acts downward, and the rope tension T acts upward. If the monkey is to start moving up from rest, he must accelerate upward, which means there must be a net upward force acting on him. The net upward force on the monkey is T - mg. But the tension is the same everywhere in a rope, so the tension at the end of the rope attached to the bananas is also T, greater than mg. Thus the bananas experience the same upward force as does the monkey, and so the bananas will move up with the same acceleration and velocity as the monkey. Both will move higher from the ground at the same rate. The net upward force on the system made up of the bananas plus the monkey is provided by the pulley.

Example 6.

You can find this example in different books, like Giancoli's "Physics: Principles with Applications" from 2005 or Ohanian's "Physics for Engineers and Scientists" from 2007.

Imagine you have four bricks, and you want to stack them at the edge of a table so that each brick sticks out as much as possible beyond the one below it. Here's how you do it:

the bricks must extend 1/2, 1/4, 1/6 and 1/8 of their length beyond the one below.

Before you start stacking them, it's a good idea to play around with these bricks. Since they're all the same size, it's easy to find their center of mass. That's the point where the brick would balance perfectly if you put your finger there.

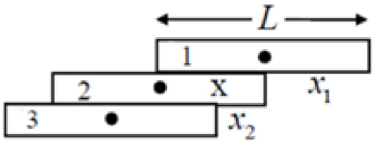
Now, let's start stacking the bricks:

Take two bricks , the maximum length one cube can overlap the edge of the cube lying on the table is half of its length.

$x_1 = l/2$

Now we have two cubes, which we want to put on the third one lying on the table.

We need to find out the center of mass of those two cubes and then lay them on the third cube lying on the table.

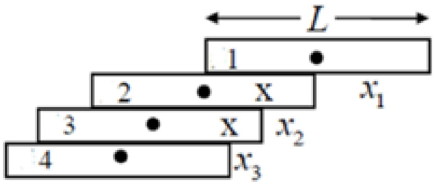


To find out the center of mass of 2 cubes is symmetrical task. The center of mass is between the two centers of mass. So $x_2 = l/4$

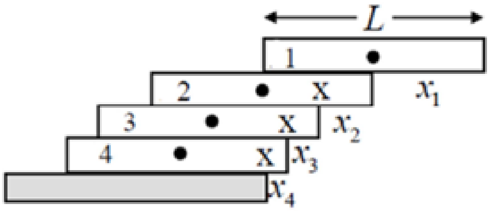
With three cubes that we want to put of the fourth one, we need to do the calculation

$$CM_3 = \frac{m(0) + 2m(l/2)}{3m} = \frac{l}{3}$$

Hence the distance $x_3 = l/2 - l/3 = l/6$



Now, we can see the pattern and for four bricks, the distance would be $x_4 = l/8$



If we summ up all overlapping distances we get $\frac{l}{2}+\frac{l}{4}+\frac{l}{6}+\frac{l}{8}=\frac{25l}{24}$

We can see that the top brick is completely beyond the edge of the table.

Experiment 7: Swinging candle

Task

Testing the principle of an unequal-armed lever.

Materials needed:

candle,

knitting needle,

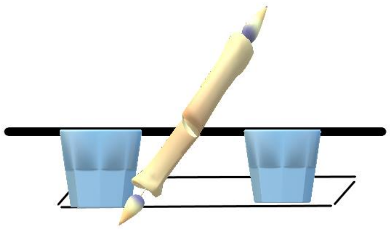
matches,

2 glasses (stands),

tray with water

Procedure:

- Adjust the candle so that it can burn at both ends. Make an unequal -armed lever with the candle and the knitting needle. To get the needle through the candle you must heat it.
- We then put the ends of the needle on the glasses



- Make the left arm shorter -r_1 and the right arm r_2 longer which means that it has higher weight.
- The moments of the forces acting on both ends of the lever are not equal, so the lever is tilted to the heavier right side.
- Light the candle. When burning, due to the inclination of the candle, more wax is heated on the longer right arm, which drips off faster than on the higher left arm. So, the longer arm shortens faster than the shorter arm.

- As each drop of wax changes the moment of force, which represents the turning effect of the force on the body, the "longer" right arm begins to rise and the "shorter" left arm begins to fall.
- When candle reaches an equilibrium state, the candle reacts sensitively to the change in the length and we have a swinging candle.

Conclusion

The moments of the forces:

$$r_1 < r_2$$

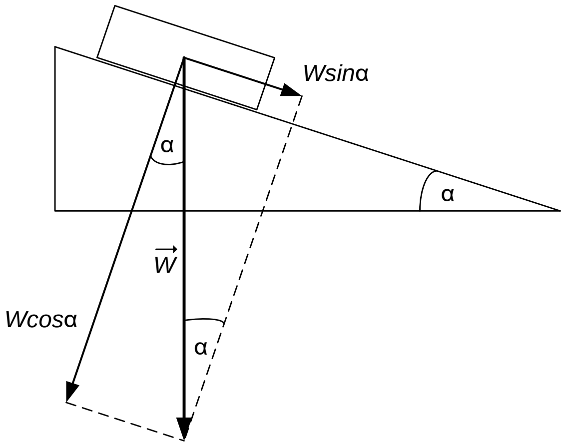
$$F_1 < F_2$$

$$F_1 r_1 < F_2 r_2$$

$$M_1 < M_2$$

Example 8

Measuring the coefficient of static friction. Using incline, we can measure the coefficient of static friction.



The component of gravitational force that causes the object to just start moving is equal to the resistive force to keep the object stationary. That is the static force of friction. Knowing the force required to overcome the friction and the force pushing the object onto the ramp, will allow you to determine the static coefficient of friction. When an object that weighs W is on a ramp, the force of gravity can be divided into components in perpendicular directions. Now when the angle α becomes steep enough, the object starts to move and $F = F_{fr}$. But we know that $F_{fr} = \mu F_N = \mu W \cos(\alpha)$ and $F = W \sin(\alpha)$, so we get $\mu W \cos(\alpha) = W \sin(\alpha)$ and from that $\mu = \tan(\alpha)$

Tasks from real life

Ice skating – myth and the truth.

Winter sports such like skiing, speed skating, figure skating, and curling rely on the slippery surfaces of ice and snow. We have experience that the ice surface is slippery but the physics behind is still not completely understood. In 1886 John Joly, an Irish physicist, offered the first scientific explanation for low friction on ice; when an object, i.e., an ice skate - touches the ice surface the local contact pressure is so high that the ice melts thereby creating a liquid water layer that lubricates the sliding. The current consensus is that although liquid water at the ice surface does reduce sliding friction on ice, this liquid water is not melted by pressure but by frictional heat produced during sliding.

Research has been done to understand friction on ice. Surface mobility of water molecules depending on temperature was studied. We will not delve deeply into the details, but here are the results.

Although the surface mobility continues to increase all the way up to 0 °C, this is not the ideal temperature for sliding on ice. The experiments show that the friction is in fact minimal at -7 °C. Speed skating rinks are maintained at the exact same temperature, -7 °C, as shown by the researchers. The researchers show that at temperatures between -7 °C and 0 °C, sliding is more difficult because the ice becomes softer, causing the sliding object to dig deeper into the ice.

The results are published in the *Journal of Physical Chemistry Letters*.

More information: Bart Weber et al, Molecular Insight into the Slipperiness of Ice, *The Journal of Physical Chemistry Letters* (2018), DOI: 10.1021/acs.jpclett.8b01188

Fashion without friction

Without friction there would be no fashion at all. Although the reserach shows that when it comes to yarn the transition from the fibres being free to slip, to a state in which the fibres are collectively locked together by friction depends on a combination of friction coefficient and turning angle per contact – where the turning angle is the number of twists in a fibre and a contact is a location where fibres are pinned together by friction.
https://physicsworld.com/a/physicists-explain-why-clothes-do-not-fall-apart/

Fabric strength:
Friction plays a significant role in holding our clothes together. Fabrics are made up of tiny fibers, like threads, that are woven or knit together. These fibers need friction to stay intertwined and create the fabric we wear. Without friction, these fibers would easily slip apart, causing our clothes to fall apart. So, we'd all be left with a pile of loose threads instead of our clothes

Staying dressed

Friction also helps us keep our clothes on. When we wear a T-shirt or pants, the friction between our skin and the fabric keeps our clothing in place. If there were no friction, our clothes would constantly slide down, making it pretty much impossible to stay dressed.

Fashion design

Fashion designers use friction to their advantage when creating different styles. They consider how fabrics will drape or hang on the body. Friction affects how a fabric moves and interacts with the body, which helps designers create unique and stylish clothing.

Footwear:

Think about your shoes. The soles of your shoes are designed with materials that provide grip, thanks to friction. Without this grip, you'd be slipping and sliding everywhere, making it tough to walk or run in style.

Accessories:

Even accessories like belts, zippers, and buttons rely on friction to work properly. Zippers wouldn't stay closed, buttons would easily pop off, and belts wouldn't keep your pants up if there was no friction.

Friction and the curves

Why are there some traffic signs on curved roads that tell you to slow down when it's raining or snowing?

Well, imagine your car is driving on a straight road. In that case, the tires have a natural resistance against the road called rolling resistance. When you want to make a turn, you turn the steering wheel, and that makes the wheels change direction. If your car still wanted to go straight, it would have to deal with higher friction between the tires and the road surface because the wheels can't rotate straight anymore. This would make the car want to go in the direction of the turned wheels, and it would have to fight against rolling resistance.

But here's the thing: if the road is slippery because of ice or snow,or the rain the friction between the tires and the road surface can become very low, even lower than rolling resistance. That means your car might not grip the road properly, and it could slide.

So, why do they put up those signs that say you should drive slower? Well, at lower speeds, we can assume that the amount of friction between your tires and the road remains pretty constant. But at higher speeds, it starts to decrease. So, when the road is slippery, you need to slow down to make sure your car has enough grip to stay safe. Those signs are a reminder to drive more carefully when the road conditions aren't ideal.

We need more friction

We want more friction when we're driving some vehicles, like trains, to make sure their wheels don't slip when they start moving.

Think about it like this: If you're trying to push a heavy box, it's easier to get it moving if there's enough friction between your hand and the box. If there's not enough friction, your hand might just slide on the box, and it won't go anywhere.

The same goes for trains and heavy cars. We want them to have good friction with the ground, especially when they're starting to move. This helps them get going without slipping.

But here's the tricky part: When we want to stop the car or train, too much friction can be a problem. It might make it harder to stop quickly because the wheels can grip the road or tracks too much. So, having the right amount of friction is important, depending on whether we're starting or stopping.

Why there are additives put into the gasoline?

Additives decrease the friction and the engine is quieter and more powerful, but the risk of corrosion increases.
Additives are like special ingredients we put into gasoline to make our cars work better. They do a few important things:

Less friction: Imagine if your car's engine parts rubbed against each other like sandpaper. That would cause a lot of wear and make the engine noisy. Additives help by making these parts smoother so they glide easily. This makes the engine quieter and more powerful, like a well-oiled machine.

Cleaning: Additives also work like a cleaning crew for your engine. They help get rid of gunk and dirt that can build up over time. This keeps the engine running smoothly.

But, there's a catch:

Corosion risk: While additives help in many ways, they can sometimes make the insides of the engine a bit more corrosive. Corrosion means that parts of the engine can slowly get damaged. So, it's like a trade-off – we get a smoother, more powerful engine, but we need to be careful about corrosion.

So, think of additives like a secret recipe for making your car run better, but we need to watch out for the side effects, like corrosion, to keep everything in good shape.

Playing the violine
Playing the violin is a bit like making music with a magic bow and string. Here's how it works:

When we pull the string on the violin and then let it go, the string starts to vibrate, and that's what makes the beautiful sounds we hear. But there's a trick to making the string vibrate.

To make the string move, we use a special bow. This bow has hair on it, and when we rub it against the string, it's like a secret code. The code is called "friction," and it's what makes the string making music.

Now, sometimes, the string doesn't want to vibrate as much as we'd like it to. That's when violin players use something called "colophony." Colophony is like a magical powder that they rub on the bow to increase the friction.

So, when you see a violinist playing, remember that they're using the power of friction and a little bit of magic to make those beautiful melodies.

We know that when we pull the string and then let it go, it vibrates and emits a tone. To deflect the string by using bow there must be friction between bow and string. The friction force then deflects and releases the string so that it vibrates, and a tone is created. If the friction is not big enough the player uses colophony.

Walking paper stick figure

Materials needed:

A4 office paper,
scissors,
markers,
inclined plane - for example, a bent bench,
hardcover notebook,
cardboard, etc.

Procedure:
Fold the paper: First, fold the paper like in the drawing below. You want to fold it so that one corner of the paper lines up with the opposite side. Then, cut off the part of the paper that's not folded.

Fold diagonally: Next, fold the square-shaped paper diagonally in both directions. This will give you some guideline creases.

Fold in half: Fold the paper along the line that connects the middle points of the opposite sides. So, it's like folding it in half one way and then the other.

Make the legs: Now, you're going to make the legs. Fold one corner to make a triangle shape, and bend the end to create the first leg of your paper figure. Do the same for the other three legs.

Decorate: Finally, have fun decorating your paper figure. Make it look like a cool walking person!

How to use it:

Place your paper figure on an inclined plane, like that bent bench or notebook. Watch what happens. If it doesn't start moving, try tilting the surface a little more. If it tips over without walking, try making the surface less slanted. You can also adjust the paper figure by spreading its feet apart slightly.

Observation:

Your paper figure should start moving down the inclined plane, and it will look like it's walking because its legs will move. How fast it goes depends on how slanted the surface is and how far apart the legs are.

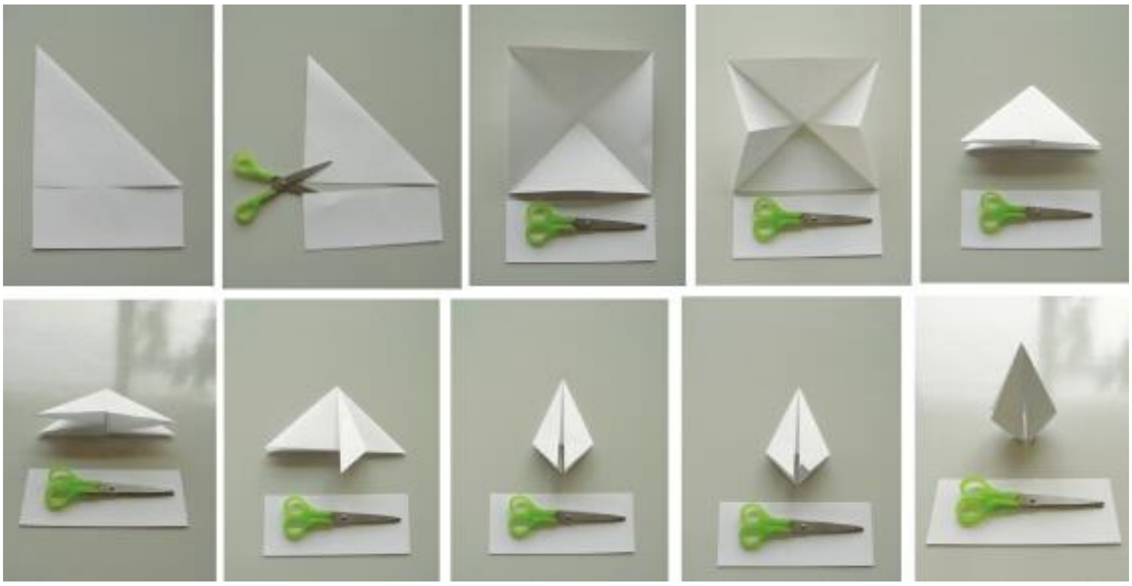
Note:

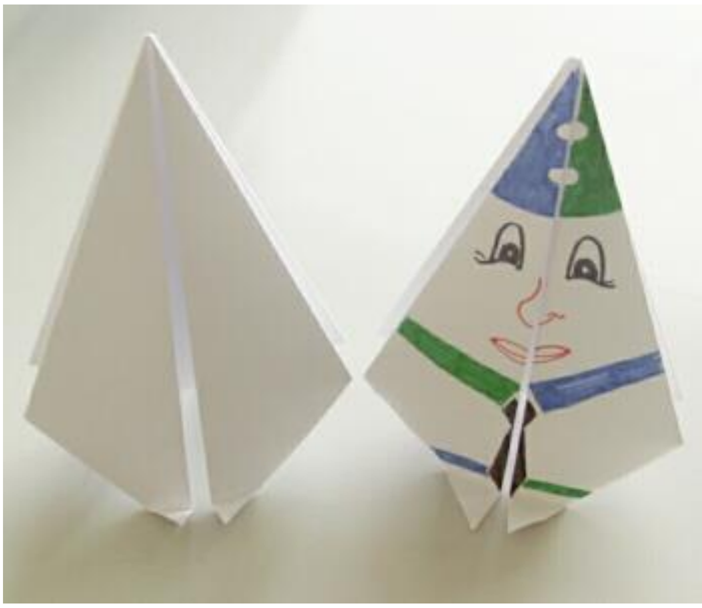
If it doesn't work at first, don't worry! You can try a few things:

Change the size of the feet or legs by cutting or folding differently.

Adjust the angle of the inclined plane.

Experiment with different surfaces, like rough or smooth ones, to see what works best.





Source :[FL -1-2005.doc (uniba.sk)]

Task for you

Let's learn about the ancient technique of making fire using a bow drill! This is a cool skill, especially if you're a scout. Here's what you need to know:

What is a bow drill:

A bow drill is like a DIY fire-making tool. It's pretty simple but super effective. It has three main parts:

- Spindle or drill shaft:

This is a long, thin rod. It's the part that does most of the work.

- Cord:

You need a strong cord or string. You wrap it around the spindle and pull it tight.

- Bow:

No, not the kind you shoot arrows with! It's a curved stick that you use to twist the spindle. You move the bow back and forth with one hand.

How it works:

- The idea is to create friction, which makes heat. Heat can start a fire. Here's how it all comes together:
- You put one end of the spindle on a piece of wood or material you want to make a hole in or use it as a fire starter.

- You loop the cord around the spindle.
- Hold the bow in one hand and move it back and forth. The cord spins the spindle really fast.
- As the spindle spins, it rubs against the material below, and that creates heat. A lot of heat!
- If you keep going, the heat can get so intense that it starts a fire in the material. And that's how you make fire with a bow drill!

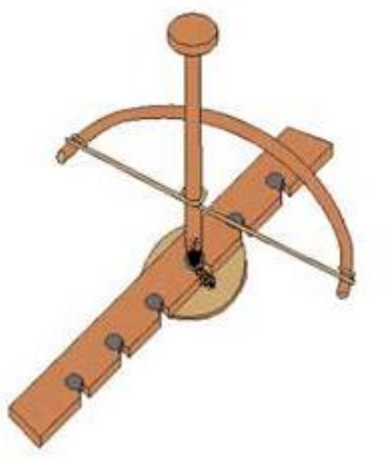


Figure from: https://survivalschool.com/product/bow-drill-set-completepre-test/

<u>Try it yourself:</u>

If you're up for a challenge, you can try making your own bow drill. You'll need to find the right materials like a sturdy stick for the bow, a long, straight stick for the spindle, and a cord that won't break easily. It's like building your very own fire-making machine!