Home Science Activity: Catapult

Make a simple catapult that can fire small items across rooms. Students can invent games to play and experiment with their catapults and test their understanding of potential and kinetic energy.

Learning Intentions
Students will use the scientific process to identify and understand potential and kinetic energy, how such energy is used to do work and how energy is transferred from one form to another. Students will learn how the use of energy, in this case potential and kinetic energy, has been used to develop technologies and affect the world they live in.

Materials

- Icy pole sticks
- Rubber bands
- Bottle cap (optional but it works much better with one)
- Strong glue or adhesive tape to attach bottle cap

Teacher Notes

What is happening:
What can students say about what is happening based on your results. For example, how does increasing the tension on the rubber band or the position of the fulcrum point affect the distance or height of the projectile.

There are two types of energy involved in a catapult: Potential and kinetic energy. Potential energy is stored energy and kinetic energy is movement.

The energy to do the work in a catapult – fling stuff across the room – is the potential energy stored in the tension in the lever stick and rubber bands that you create by bending the icy pole stick and stretching the rubber band.

A bow and arrow work on a similar principle. You can fling an arrow because of the stored tension you create in the bow when you pull back on the bowstring to bend the bow.

In our catapult, when you bend the lever stick and stretch the rubber bands and let it go you release all the stored energy in the lever stick and rubber band in one go. In other words, the potential energy in the rubber bands and lever stick is transferred to kinetic energy – or movement.

Teaching Notes: Running the activity

Method

1. Get a stack of 5 – 8 icy pole sticks, depending on how high you want your catapult to be. Secure both ends by wrapping rubber bands around them.
2. Slide another icy pole stick between the bottom two sticks in the stack. Slide it so that only a small part is sticking out of the stack, with most of it sticking out in the other direction.
3. Attach the bottlecap to the end of another icy pole stick – the lever. The bottle cap holds the projectile easier.
4. Place the lever icy pole stick on top of the stack. Use a rubber band to secure the end of the lever without the bottle cap to the stick coming from out the bottom of the stack. The point on the lever where it pivots up and down over the stack is called the fulcrum point.
5. Push the top and bottom icy pole sticks through the stack so they spread out. Note, this changes the fulcrum point and angle of the lever.
6. Put something small in the bottle cap, pull the lever down and let it go. Watch your item fly.

Warning: the catapult will fling things with some force. Avoid using projectiles that can cause damage or harm such as marbles. Try marshmallows, pom poms, peanuts.

The fulcrum point

The fulcrum point in our catapult sits between the force and the load. The load is applied by the rubber bands – how many you have, or how many loops you placed around the sticks. The force is what you apply to the end of the lever stick that holds the projectile.

The closer your fulcrum point is to the load the greater force can be applied to the load. Students should be able to notice that it is easier to apply greater tension to the lever stick and rubber bands the closer the fulcrum is to the load, which is the rubber bands holding the lever stick and bottom stick together.

On a normal lever, the load might be a weight you place at one end of the lever and the force will be what you apply to the other end in an attempt to lift that load. Think about a see-saw. The fulcrum point is in the middle. Imagine you place one student on the end of the see-saw. Where along the see-saw is easiest to push the see-saw down to raise the student in the air? It should be the point furthest along the see-saw from where the student is sitting. If you have access to a see-saw, get students to test the idea out.

Think about where else you think fulcrum points are used to help humans do work. Think about levers, for example how do you use a spoon to open the lid from a tin? The spoon is the lever, the fulcrum point is where the spoon rests on the lip of the tin. You apply a downward force on the end of the spoon to lift the lid off. What would make the job of removing the lid easier: a shorter or longer spoon?

In a see-saw the distance you will push down will be the same as the student sitting on the other end will go up because the fulcrum is in the middle of the see-saw. In the example of the spoon and lid, the distance you will push the spoon down will be far greater than the distance the other end of the spoon will need to rise to lift the lid because the fulcrum point is only a short distance from the load (lid).

Variations

Vary the fulcrum point of the catapult. Note how shifting the fulcrum point changes the angle of the lever stick. To be consistent among the catapults, you might want to make 1cm marks along the lever stick so each student is comparing the effect of the same fulcrum point. What effect does the angle have on the distance and height the projectile reaches? Ensure also that when comparing the catapults you have the same number of icy pole sticks in the stack.

Go bigger: Replace the icy pole sticks with 30cm wooden or plastic rulers. Does plastic or wood work better, and why or why not?

Increase the tension in the rubber bands that hold the lever and bottom stick by adding one or more extra loops around the stick. What effect does this have on the distance and height of the projectile? What effect does it have on the amount of force you need to apply to the lever? Consider modifications to your lever. See Figure 1. Below.

Apply what you have learned from the above to help you amend your catapult design to send a projectile further and higher.

Results

Create a table to record distance and height of your launched projectile. Get students to discuss their modifications and how that affected the performance of their catapult

Students might consider the following:
What effect did increasing the tension on the rubber band have?
What effect did shifting the fulcrum point have?
What modifications improved the performance of a catapult and why?

Student challenge Castle seige. Students could make up their own rules, but consider giving each student 10 identical projectiles per catapult to fire at the targets. The student or team with the most points after firing all their projectiles wins. What can the students tell you about what they learned about potential and kinetic energy, fulcrum points and levers from building the catapults. See Figure 1 and example results table below.	(Other modifications might include a stronger or longer lever.) **Have some fun. Challenge yourself** Build a castle, with targets in and around the castle. Each target can be worth different amount of points, depending on the perceived difficulty to hit the target with a catapult projectile. Design two types of catapult based on what you have learned above: One to fling a projectile over the castle wall; a second that will fling the projectile on a flatter trajectory to hit the castle wall or obstacles (eg soldiers, dragons, trolls) on the outside of the walls. Determine a scoring system for specific targets such as parts of the castle wall, trolls, soldiers, etc. Create teams and set a time limit to see which team can score the most points in your time limit.

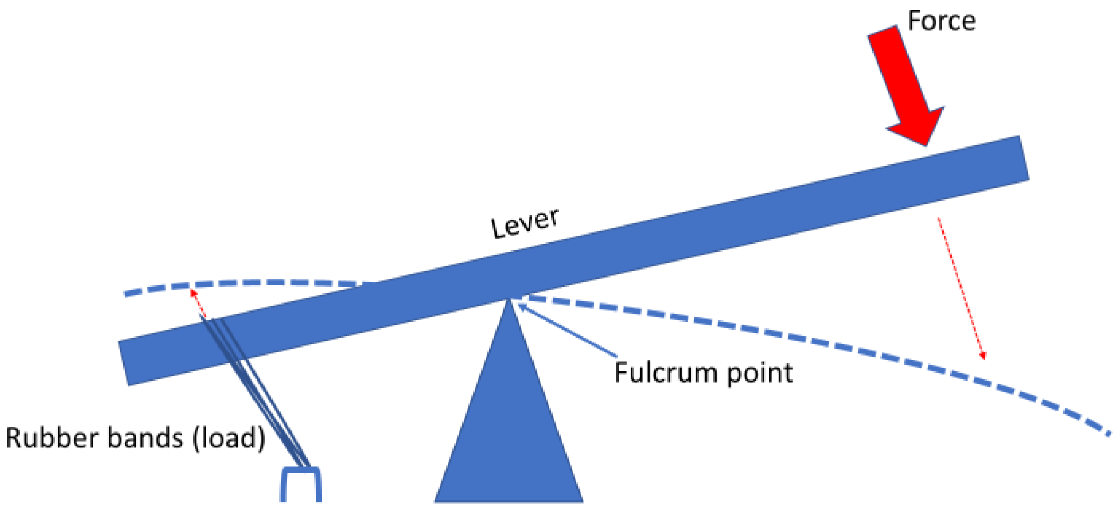

Figure 1. Lever showing the load, fulcrum point and force. The load in this instance is the rubber bands holding down one end of the lever. We will assume the lever has some elasticity and therefore potential energy alongside the potential energy in the rubber bands. Applying force to the lever on the other side of the Fulcrum point from the load will provide tension in the rubber bands and lever. Releasing the force on the lever will release that energy in the form of kinetic energy (movement) as the lever and rubber bands return to their natural shape. The projectile is not bound to the lever so it will continue to as a projectile to its target. Note the lever where the force is applied moves over a much greater distance than the load end. As the fulcrum point moves closer to the load the mechanical advantage of the lever increases or the force required to achieve an effect on the load is decreased. In other words, it is easier to lift the load when the fulcrum point is closer to the load.

Activity

Label where the potential energy is in the loaded catapult in Figure 2. below. Assume a force has been applied to the lever and there is a load on the rubber bands

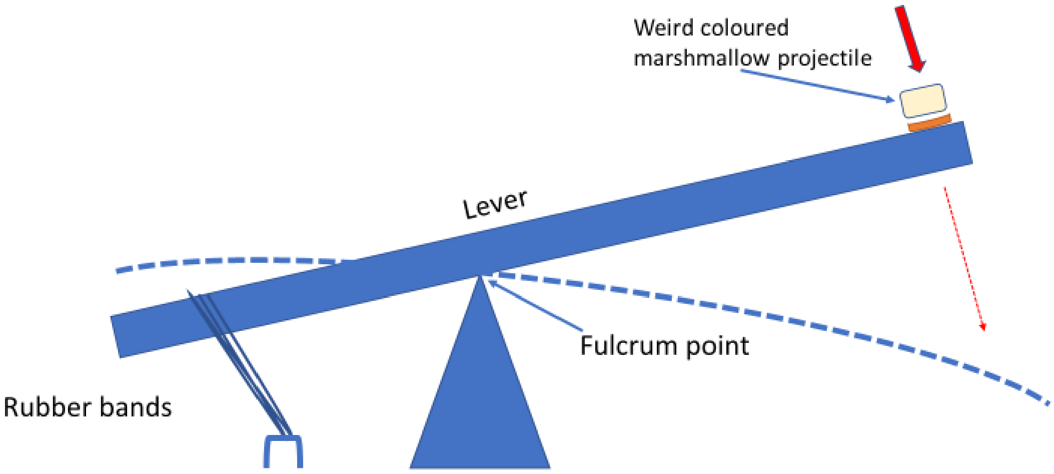

Figure 2. Catapult ready to be launched. A forced has been applied to the lever to depress the lever and apply a load to the rubber bands.

At each of the marshmallow point (a. – f.) in Figure 3. below, label where the kinetic energy and potential gravitational energy is once the lever is released

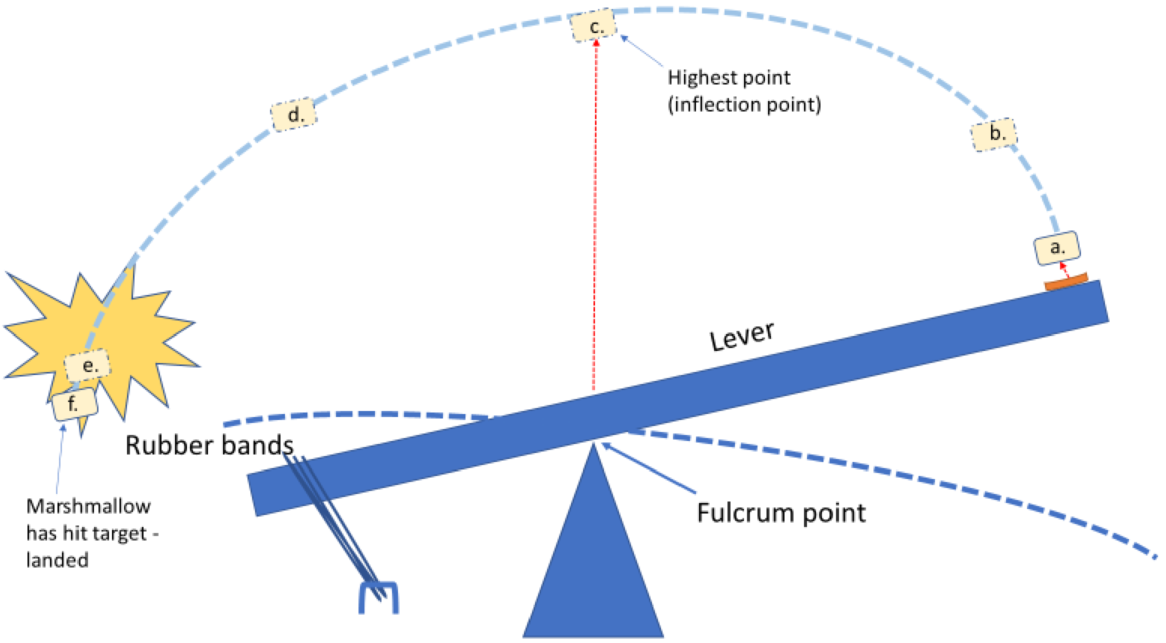

Figure 3. Launched catapult with marshmallow projectile at different stages of its flight path, from leaving the catapult to where it lands

Student questions to ponder as a class

What happened to the potential elastic energy in the rubber bands once the lever is released?

[Build discussion around the transformation of energy. That is, we can't create or destroy energy. It just gets transformed from one form into another. For example, humans have exploited this to generate electricity. We burn coal to generate heat that boils water to create steam that moves a turbine that makes electrons move in a circuit and generate electricity.]

More extended thinking

See Table 1 for questions to extend student thinking about the relationship between force, mass and acceleration and the differences between potential and kinetic energy.

Table 1. Questions that apply student understanding of the relationship between force, mass and acceleration, and the differences between potential and kinetic energy

1. When you depress the lever and bend the icy pole stick the rubber band stretches, what form of energy does the stick and rubber band have?
2. What form of energy does the projectile (marshmallow) have once it has left the catapult?
3. What else can you say about the different forms of energy/force acting on the marshmallow and the transfer of energy as the marshmallow flies toward its target using Figure 3. to help explain your answer?
4. What if you replaced the marshmallow with a lead ball of similar dimensions (size) to the marshmallow? What can you say about the gravitational potential energy and kinetic energy of the lead ball compared to the marshmallow? Which projectile will do the greatest damage and why?

See next page for answers

Table 2. For teachers: Answers to the questions from Table 1

1. When you depress the lever and bend the icy pole stick the rubber band stretches, what form of energy does the stick and rubber band have? Both have elastic potential energy; it will be stored energy up until the rubber band and stick is released where the energy is transferred to the marshmallow and transforming the energy from potential into kinetic energy.
2. What form of energy does the projectile (marshmallow) have once it has left the catapult? This is kinetic energy (motion) because all the built-up (potential) energy in the system is transferred into motion upon release.
3. What else can you say about the different forms of energy/force acting on the marshmallow and the transfer of energy as the marshmallow flies toward its target using Figure 3. to help explain your answer? As the marshmallow leaves the catapult, the energy will be completely kinetic energy at time = 0, but as time goes on the kinetic energy will decrease and the amount of gravitational potential energy will increase. Then at a particular point in time (at position c. – the inflection point) the kinetic energy would have all transferred into gravitational potential energy and hence kinetic energy will = 0. Beyond the inflection point (point c.) the gravitational potential energy is transferring its energy back into kinetic energy. This means there is a decrease in potential energy and an increase in kinetic energy as the marshmallow continues to fall from positions c to e. At position f., all of the gravitational potential energy would have converted completely into kinetic energy once more and hence the object (target) that is in its trajectory path would experience all of the energy that it had built up from the rubber band (though there will be small amounts of the energy that is lost to heat from friction as the marshmallow flies through the air). At position f. the marshmallow at rest, has only potential gravitational energy.
4. What if you replaced the marshmallow with a lead ball of similar dimensions (size) to the marshmallow? What can you say about the gravitational potential energy and kinetic energy of the lead ball compared to the marshmallow? Which projectile will do the greatest damage and why Because of the heavier nature of the lead ball (greater mass), we can see that the rubber band would stretch out more and hence storing more elastic potential energy at rest – until we apply an external force to the lever. The kinetic energy of the lead ball upon launch would decrease much quicker than the marshmallow due to its weight (mass). This means the transfer rate between gravitational potential energy and that of kinetic energy would be far higher, therefore it would decrease its height quickly and reach the target more quickly. But, the kinetic energy of the lead ball would be higher because of its greater mass, which means more energy would be transferred into the target and hence causing more damage than the marshmallow.