# Activity 7. Catapults

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, their use to do work and how energy can be transferred from one form to another to enable work to happen. 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
- Glue/sticky tape
- Projectiles (weighted pom poms, marshmallows, etc)

**Teacher Notes**

**What is happening:**

What can students say about what is happening based on their results. For example, how does the number of icy pole sticks in the stack, 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. In this case, potential energy is energy stored in the lever and rubber bands where the energy has potential to do work or effect change; and kinetic energy is movement of the projectile once launched. There is also varying amounts of potential gravitational energy in the projectile as it flies through the air.

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

**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.

Vary the fulcrum point of the lever stick. Note how shifting the fulcrum point changes the angle of the lever stick. To be consistent among the catapults, you might 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 transformed to kinetic energy – or movement. This transfer of energy is what effects the change, enables work to be done. There is also a transfer of potential gravitational energy to kinetic energy as the projectile flies through the air. This also affects the work that can be done.

**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 band(s) 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?

want to make 5mm marks along the lever stick so each student is comparing the effect of the same fulcrum point. Alternatively, use a protractor to measure the angle of the lever stick. What effect does this 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.

-----------------------------------------------------

Warning: the catapult will fling things with some force. Avoid using projectiles that can cause damage or harm such as marbles. Stick with the marshmallows, pom poms or similar. Peanuts maybe?

-----------------------------------------------------

**Task**

Experiment with the design of your catapult. Make a change in the design to improve how far it can fling your chosen projectile.

Answer questions in Table 1 and 2. Use Figures 1 and 2 to help you.

**Variations**

Go bigger: Replace the icy pole sticks with 30cm wooden or plastic rulers. Does plastic or wood work better?

**Results**

Create a table to record distance of your launched projectile according to the different fulcrum points (or angle of your lever).

Compare this to your modified catapult.

What changes did you make to your modified catapult and what was their effect on the distance and height the projectile flew?

How did this modification affect the amount of potential elastic energy and therefore kinetic energy of the projectile?

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).

**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.

The answers to the questions in Table 2 and in table following (Table 3)

What effect did shifting the fulcrum point have?

If you did this with other groups in your class, what design of catapult flung a projectile the farthest distance and can you explain why?

Can you graph your results? For example, distance travelled by projectile against the position of fulcrum point (noted by measurement mark on the lever stick), or angle of the 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. See also Alternative game ideas in the extended thinking section.

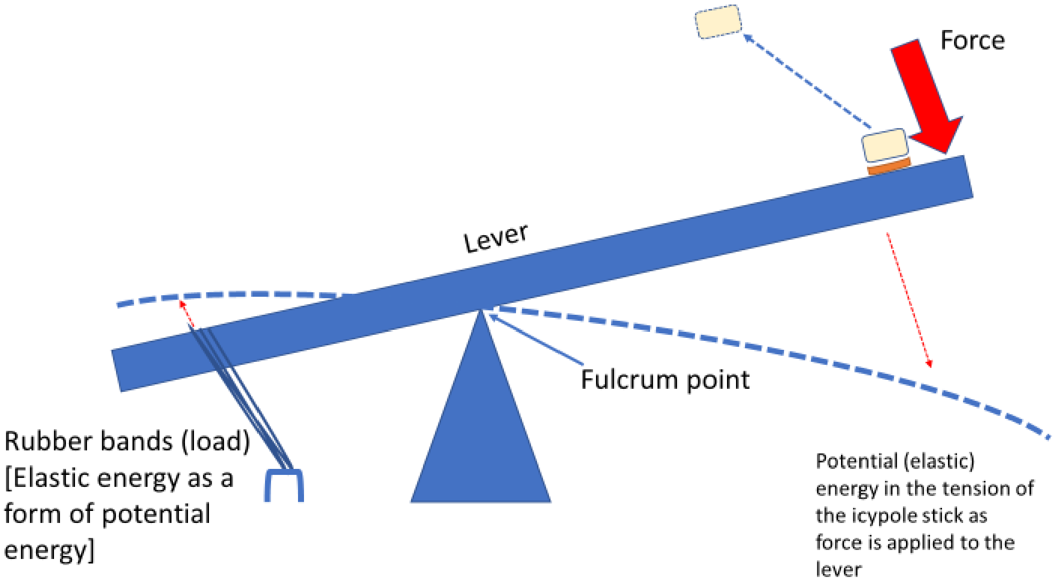

*Figure 1. Lever showing the load, fulcrum point and force. The load in this instance is the rubber bands holding down one end of the lever. We will assume the lever has some elasticity and therefore potential energy alongside the potential energy in the rubber bands. Applying force to the lever on the 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.*

**Example Table.**

| Lever angle (degrees) | Projectile distance (cm) |
|---|---|
| 30 | |
| 35 | |
| 40 | |
| 45, etc | |

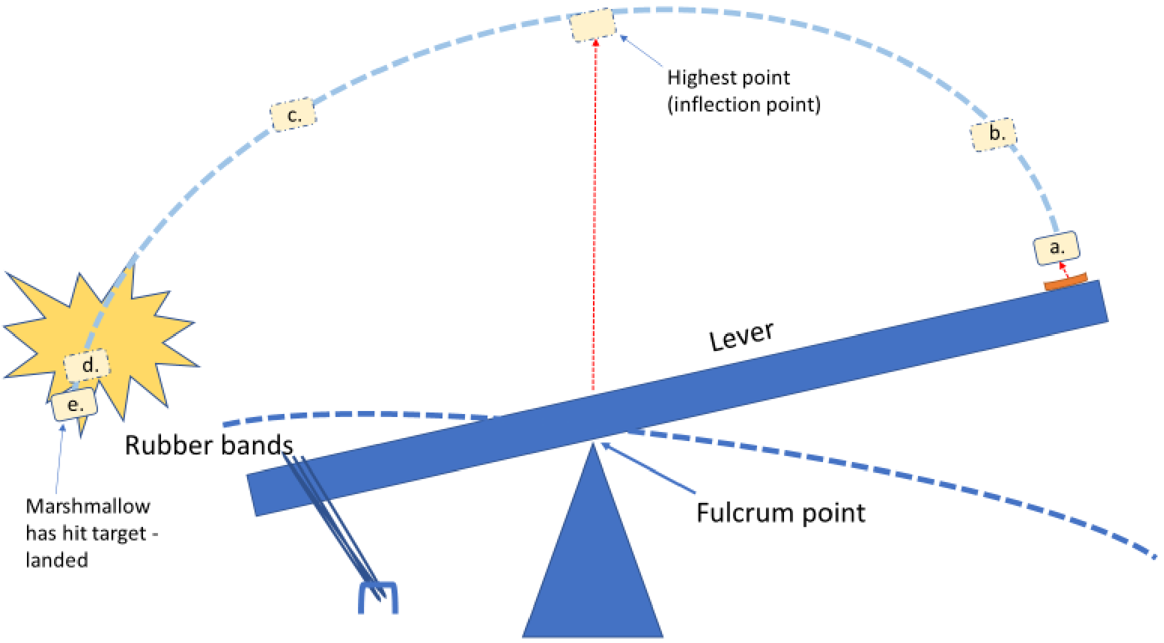

*Figure 2. Catapult following launch of projectile and the projectile path. Note the amount of potential gravitational energy and kinetic energy changes as the projectile heads upward to the inflection point then downwards to the impact site*

*Table 2. Questions linked to the kinetic and potential energy in the catapult and projectile*

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. Use the provided figures to help explain your answer?
4. What if you replaced the marshmallow with a lead ball of similar dimensions (size) to the marshmallow? What effect will this have on the potential elastic energy in the lever and rubber bands.
5. What can you say about the potential gravitational energy and kinetic energy of the lead ball compared to the marshmallow? Which projectile will do the greatest damage to the target following launch and why? (We will assume the catapult is capable of launching the lead ball – ie generating acceleration greater than 0.)

*Table 3. Answers to the questions in Table 2.*

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 that will be stored until the rubber band and stick is released transferring the energy into the marshmallow in the form of 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 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. Use the provided figures to help explain your answer?**
   As the marshmallow leaves the catapult, the energy will be completely kinetic energy at time = 0, but as time continues, up until the highest point of the trajectory (inflection point), the kinetic energy will decrease and the potential gravitational energy will increase.

   Beyond the inflection point there is now a decrease in potential gravitational energy and an increase in kinetic energy as the marshmallow continues to fall from positions c to d. At position e., all of the potential gravitational 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 and lever - well, nearly all. Some of the energy is lost to heat from friction as the marchmallow flies through the air. Once at rest, the marshmallow has only potential gravitational energy.

4. **What if you replaced the marshmallow with a lead ball of similar dimensions (size) to the marshmallow? What effect will this have on the potential elastic energy in the lever and rubber bands.**
   Due to the heavier nature of the lead ball, we can see that the rubber band would stretch out more and hence store more elastic potential energy at rest – until we apply an external force to the lever.

   The mass of the lead ball is greater than the marshmallow so depending on the mass of the lead ball, the question is whether there will sufficient potential energy in the rubber bands and lever to accelerate the lead ball beyond 0. That is, mass affects velocity and kinetic/potential energy. The potential gravitational energy stored in the rubber band and lever may be insufficient to launch the lead ball far, if at all.

5. **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 to the target following launch and why? (We will assume the catapult is capable of launching the lead ball – ie generating acceleration greater than 0.)**

| | |
|---|---|
| | 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 cause more damage than the marshmallow. |