Creating Science – Forces and the Lever Catapult

Catapults are easy to make, they're just levers. But how can you make a catapult more accurate?

#CreatingScienceLevers** and **#CreatingScienceCatapults

Suggested Outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Physical Sciences 2: A push or a pull affects how an object moves or changes shape.
- Physical Sciences 4: Forces can be exerted by one object on another through direct contact or from a distance.
- Physical Sciences 7: Change to an object's motion is caused by unbalanced forces acting on the object AND Earth's gravity pulls objects towards the centre of the Earth.

Science inquiry skills

- Nature and development of science 3 & 4: Science involves making predictions and describing patterns and relationships.

Science as a human endeavour

- Science inquiry skills: With guidance, identify questions in familiar contexts that can be investigated scientifically and predict what might happen based on prior knowledge.

Cross curricular outcomes

- Design and Technologies Knowledge and Understanding 3 & 4: Investigate how forces and the properties of materials affect the behaviour of a product or system (ACTDEK011)

Design and Technologies Processes and Production Skills 5 & 6:

- Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions (ACTDEP024).
- Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques (ACTDEP025).
- Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions (ACTDEP026).
- Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions (ACTDEP027).
- Develop project plans that include consideration of resources when making designed solutions individually and collaboratively (ACTDEP028).

Science vocabulary words

Tier 1 (Everyday words)

- Catapult, force, motion, lever
- Force: A force is a push, pull or twist that can change the direction, speed or shape of an object.

Tier 2 (Dual meaning)

- Work: In science, work can be used in a very specific sense; to define how *far* an object moves by how much it *weighs*. It is measured in Newtons. We do not focus on this definition in this activity, but it is important to know.

Tier 3 (Specialised vocabulary)

- Inertia: A quality all objects possess all the time where A/ if moving they will keep moving until acted on by a force, and B/ If not moving they will not start moving until acted on by a force. Englishman Isaac Newton formalised this concept from ideas he grew from the Italian Galileo Galilei.
- Momentum: This is an objects' weight multiplied by its speed. So a heavy object moving slowly might have the same momentum as light object moving very quickly. An unmoving object technically has no momentum, but it does have inertia. Momentum is often confused with inertia[1].

Warning

- CATAPULTS ARE SEIGE ENGINES – they are designed to HURT and DAMAGE. Without careful management and discussion students WILL hurt themselves and others.
  - Always use appropriate ammunition. This can make the biggest difference.
  - Always discuss and practice safe launch behaviours. Most injuries happen when students are too close or holding on to the wrong part of the catapult.
  - Always allow safe launch distances, and be sure to clear the field properly before launch.
  - Do not underestimate any student's ability to overcharge their catapult, leaping on them to maximise launch potential. Catapults are powerful, but not indestructible, and students can get into serious trouble mistreating their devices.
  - Do not launch people or animals.
- While performing the catapult experiments, we recommend wearing eye protection and having some quality gloves such as garden gloves to help prevent friction burns.

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[1] For instance, in Star Trek, the massive spaceships can accelerate to beyond the speed of light almost instantly, which would normally squish everyone to atoms, but for their 'inertial compensator' – which is all well and good except it should be called a 'momentum compensator'. I hate it when sci-fi gets it wrong!

Preparation

For all groups

- Safety Glasses!
- A ruler.
- Ammunition – ping pong balls or high bouncing balls for more crazy fun.
- Cupcake holders and a way to fix them to the ruler.

For older groups

- Look online for catapult design schematics and materials. Use quality materials and not dubious, damaged, or decomposed materials.

Learning Intent (student friendly)

'We are learning to' (WALT) - safely use, play with, and understand levers.

Success criteria

'What I'm looking for' (WILF) – description and safe use of a simple catapult.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as 'find out how levers work' or 'make a more accurate catapult'.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

- A functioning, accurate catapult.
- A learning level appropriate report that describes the catapult parts.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is designed for this age group, however, children at this age can have difficulty with focus. Avoid tangents if you're attempting to make a key point.

Middle:

This age group should be able to describe the kind of lever their catapult is, and the various parts. They may enjoy the challenge of making a catapult which can fire more accurately.

Teen:

Teens should be encouraged to build their own siege engine, using the design and technology syllabus. They may be encouraged to mathematically describe the movement of the ammunition, or to develop more accurate catapults. Be aware of unwise ambition in this age group, as they are quite capable of building siege engines that can put ammunition through windows or skull bones if not carefully managed and counselled.

Engage

⇨ Note the Learning Intention of this lesson for students.
⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Play with levers - there are so many, it's amazing:

- You might have some toy catapults around.
- A crowbar or the back of a hammer is a lever.
- Your forearms and knees are levers.
- A nut cracker or can opener are often levers.
- A shovel, wedged under a fridge and lifted up, is a lever.
- A wheel barrow or door.

Explore

⇨ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Demonstrate the parts of a catapult as a lever (see section in the Appendix: Catapults) and help students to generate a testable question, such as:

- How far can we make the ammunition go?
- Will light ammunition travel further than heavy ammunition?
- What will be the effect of streamers or an aerofoil shape on the ammunition?
- How do we make it go high, rather than along?

And the big question is:

- How accurate can we make the catapult?

And REMEMBER – it's not science until you write it down! This forces students to make a prediction, which means they need to have a theory to base their prediction on. Thus we help scaffold scientific thinking and behaviours.

TESTING IS WHAT MAKE SCIENCE, SCIENCY!

Explain

- How far can we make the ammunition go?
  - More tension in the catapult will place more force on the ammunition and thus make it travel further, though too much tension and the catapult will break.
- Will light ammunition travel further than heavy ammunition?
  - Heavy ammunition takes more force to get moving, however, another force is in play here – air resistance. It is pushing back against the ammunition almost any time you fire it. So the ammo needs to be just the right balance – light enough to launch, but heavy enough to push through the air.
- What will be the effect of streamers or an aerofoil shape on the ammunition?
  - Aerodynamic ammunition, pointed like a bullet or rocket, will travel further.
  - Foils or fins, such as rockets and arrows have, might help keep the ammo accurate but will also slow the ammo down. You'll have to find out what works best for you.
- How do we make it go high, rather than along?
  - This all depends on launch angle. The lower the angle, the more upwards the ammo will go.
  - But for every centimetre up, the catapult will have less energy to send the ammo along. On the other hand, if your ammo is launched directly parallel to the ground it will not fly for very long, since gravity is pulling it down and it'll hit the ground. So the launch angle needs to be carefully arranged to be high enough to fly for the maximum amount of time, but not too high as to waste any distance. It turns out that around 30° is about right.

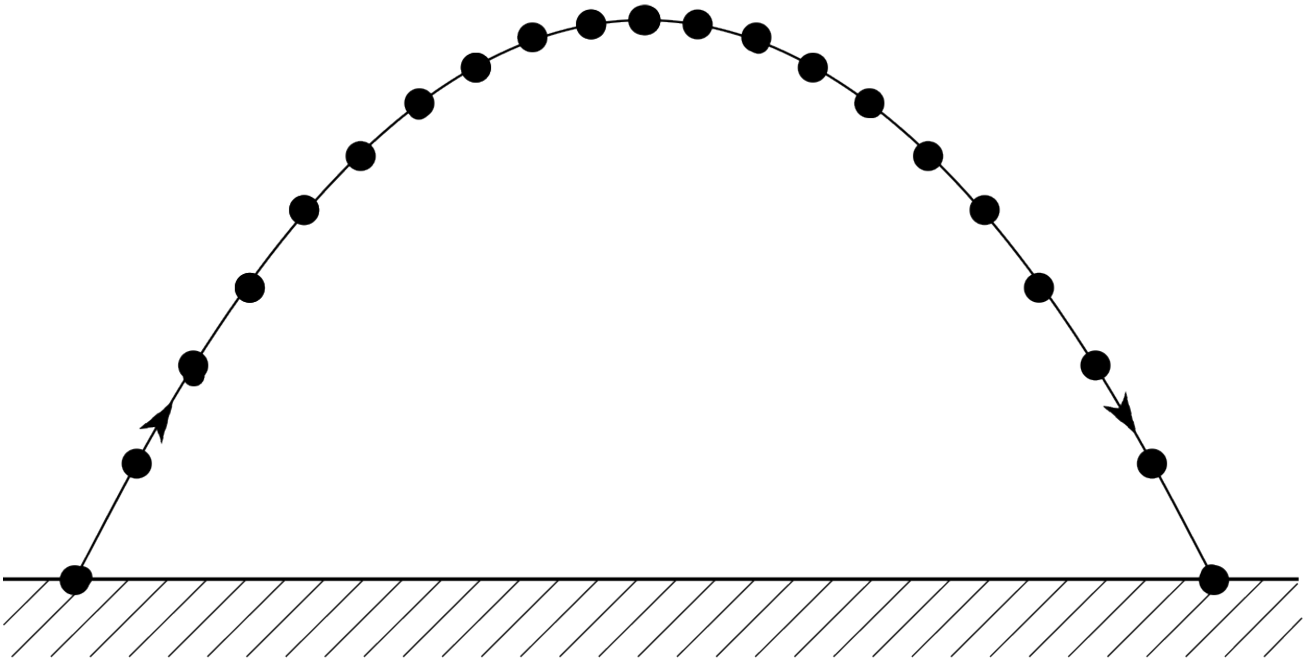
Elaborate

⇨ Ask students if they can design new ways to test this explanation - is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Parabolas

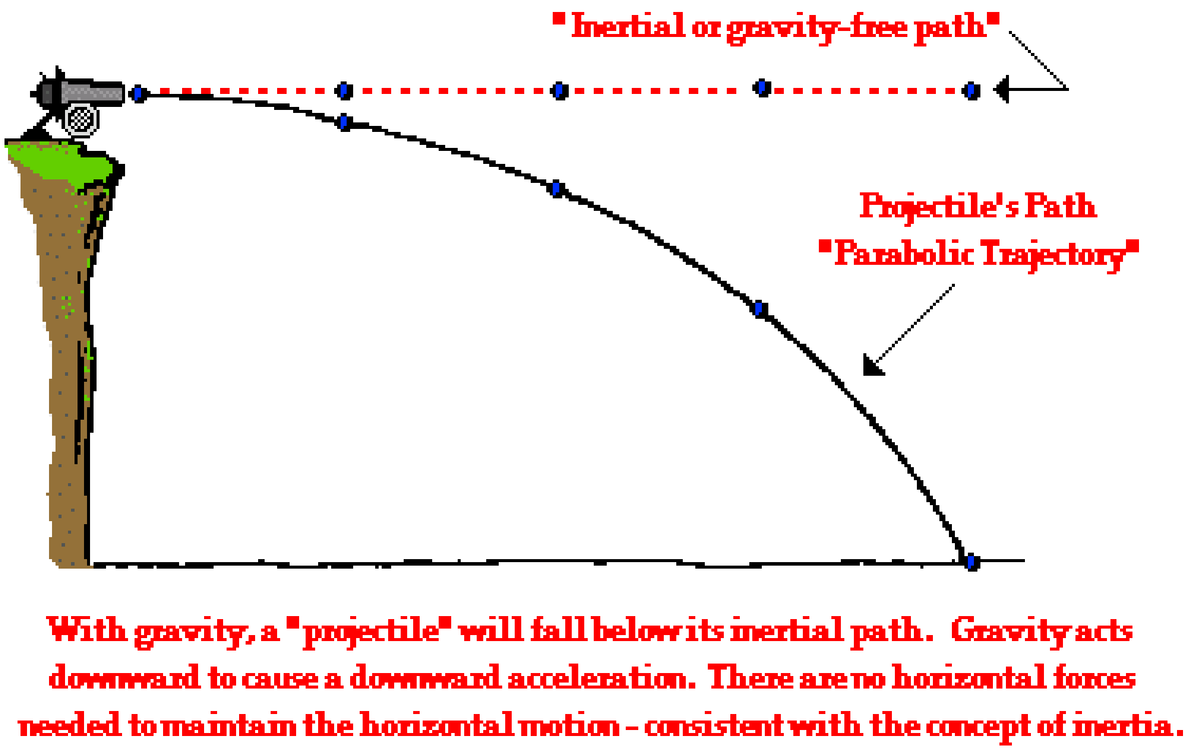
Due to gravity, the ammo does not fly in a straight line, but instead it moves in a special curve known as a parabola.

Have older students film the movement of the projectile from the side and plot its motion on a graph.



Taken 2018 from http://www.physics.brocku.ca/PPLATO/h-flap/phys2_2.html

Note how the ammo starts it's upwards motion very quickly at first, slowing down near the top, then as it falls it does so faster and faster. This website above has a great section on displacement and acceleration, etc.



Taken 8 Sep 18 from https://sites.google.com/site/foundations11projectilemotion/projectile-motion-with-quadratics-and-trigonometry Note how the ammo will fall faster and faster in the downwards direction (try looking at the vertical distances between the measurements above).

Recoil!

Remember – to every action, according to Isaac Newton "To every action, there is an equal and opposite reaction[2]".

Thus: *Forces are always in pairs!*

- The force that pushed the ball away,
- Is also the force that pushed the catapult in the opposite direction!

BE CAREFUL!

If your catapult is not secured to the ground properly, the force on the ball will also make the catapult fling <u>backwards</u>, tipping it over or potentially hitting you!

Bullets and arrows also experience this, as the gun or bow experiences a 'kick back' every time it is used. Have you ever noticed? Some large guns can knock you over with their enormous recoil.

Other ways to try and be accurate

- Bullets and arrows spin, dragging air along with them and using the spin to resist changes in the air. Can you develop spinning catapult ammo? Some of the energy for forward motion is always lost in an effort to make things spin.
- Use the same force every time to launch the catapult, such as a falling beam or the same number of elastic bands.
- Make sure the catapult is set up in exactly the same position every time. Maybe even trace out a shape and place the catapult in that shape every time.

Evaluate

⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- Did you achieve your learning goal?
- What did You learn?
- What worked to help you achieve it?
- What might you do better next time?
- (If needed) Where can you go for extra help or information?

[2] Isaac Newton's third law of motion

Assessment

Prior learning:

Focus on the outcomes – how can we create the BEST scientific knowledge?

Be sure to watch out for the following common alternative conceptions (Gilbert and Watts[3]):

- Forces are to do with living things [living and non-living things can apply forces.]
- Constant motion requires a constant force [due to inertia, something that is moving will keep moving forever unless a force acts on it, usually air resistance, friction, or gravity].
- Faster objects need more force again, [objects don't need force to keep moving, only to prevent stopping. Things that have nothing in their way to stop them, such as spaceships or planets, can be moving incredibly fast with no forces on them at all].

And as Galileo demonstrated;

- Heavy things fall faster [heavy and light objects fall at exactly the same rate, when air resistance is ignored].

Formative:

As students are learning, help them self-monitor their own learning and achievements.

- Be aware of all safety instructions.
- Are you taking accurate enough results so you can make conclusions?
- Do you think one test is enough to accurate results here?
- Are you keeping the test fair – are you sure you're only testing one thing at a time so that you can get the most accurate conclusions?
- WHY do you think you got the result you just got?

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Prepare a slide show on catapult manufacture, science and use.
- Demonstrate the ammunition and techniques that resulted in the most accurate catapult.

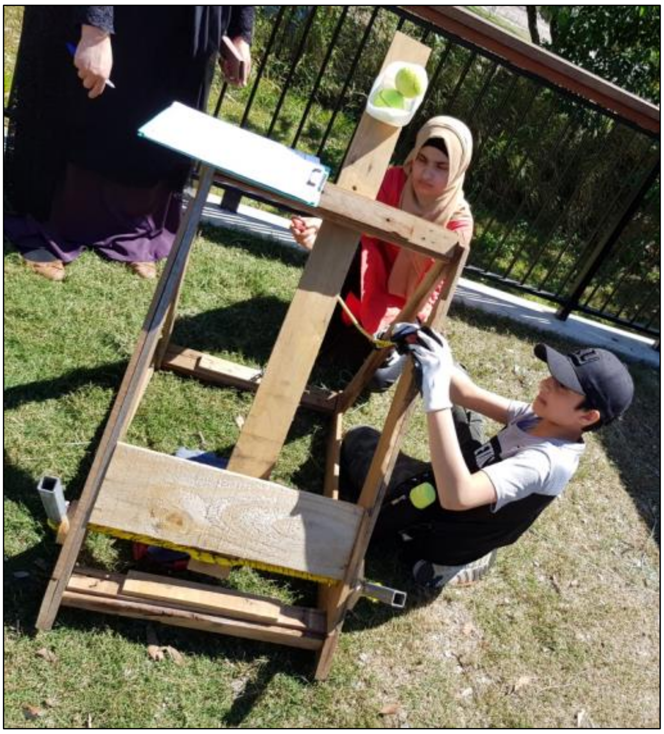
So what?

Catapults are dangerous fun, but can help us learn scientific ways of thinking.

It was **really hard** to make catapults accurate in ancient and medieval times.

[3] Gilbert, J. & Watts, M. 1985. Force and motion. In R. Driver, E. Guesne & Tiberghien (eds), *Children's Ideas in Science*. Milton Keynes, UK: Open University Press, pp. 85-104.

Creating science



Science understanding

As we explored catapults, we saw that:

- Physical Sciences 2: A push or a pull affects how an object moves or changes shape.
- Physical Sciences 4: Forces can be exerted by one object on another through direct contact or from a distance.
- Physical Sciences 7: Change to an object's motion is caused by unbalanced forces acting on the object AND Earth's gravity pulls objects towards the centre of the Earth.

Science inquiry skills

As we tried to improve our catapults, making them more accurate or powerful, we saw that:

- Nature and development of science 3 & 4: Science involves making predictions and describing patterns and relationships.

Science as a human endeavour

By asking questions about our catapults, and developing testable science questions about how they work, we saw:

- Science inquiry skills: With guidance, identify questions in familiar contexts that can be investigated scientifically and predict what might happen based on prior knowledge.

Cross curricular outcomes

As we developed our own catapults, we were learning about:

- Design and Technologies Knowledge and Understanding 3&4; Investigate how forces and the properties of materials affect the behaviour of a product or system (ACTDEK011).

And as we chose equipment, tools, and materials, as we built our catapult and shared ideas about how it worked and how to work it, we were using our:

- Design and Technologies Processes and Production Skills 5&6: etc.

Tips from the Masters to make it work:

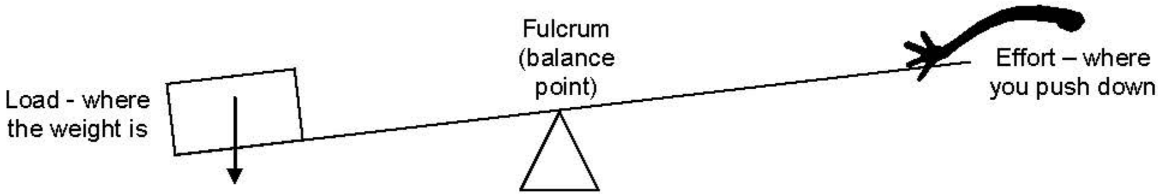
When using a larger catapult such as this torsion / tension hybrid catapult, be sure you;

- Wear gloves to prevent rope burn or wood splinters.
- Stand everyone well back.
- Put your catapult somewhere safe. Watch for recoil.
- Set up the lynch pin so that it is attached to the catapult body or it will go flying and might hit someone in the face.

Appendix: Catapults

The Lever Catapult

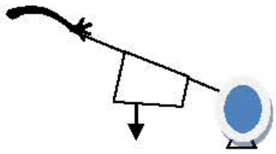
Now for something *dangerous!!*
Catapults can teach us a lot about levers, which are one of the most important tools we have in life and in science! Can you name the three parts of a lever?



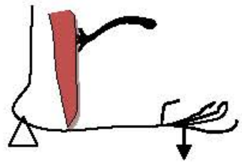
Can you memorise the three kinds of levers?

Type 1 – fulcrum in center
(e.g. seesaw)

Type 2 – Load in center
(e.g. wheelbarrow, arm)



Type 3 – effort in center
(e.g. your forearm)



Now, let's build the world's most simple catapult!

SAFETY FIRST: stand well back from the launch zone, and use safe, soft projectiles such as tissue paper and ping pong balls! Be very careful where you projectiles will land: is the area clear of people and other things that might break, such as glass windows?

You'll need a cup cake holder, some glue, a ping pong ball, a ruler, and some safety glasses.

Glue the cup cake holder onto the ruler.

Place the ruler on the table as illustrated, and load it with the ping pong ball

STAND WELL BACK and launch your catapult. Can you land exactly 1 meter away??

Knowing how to get a projectile to travel properly is one of the most important technological problems in history – especially sport and war. What things can you try to change to make your ping pong ball travel the **most accurately**? We call those 'things' in science "variables".

Launch angle?

Airfoils and streamers?

Projectile size?

HINT: The further the effort is from the fulcrum the less effort required to move the load, but it won't move as far. So does a long or short effort arm work best for this catapult?

All levers are *force / distance multipliers*: so either you move an object very far, but it takes extra effort, or you move an object a little way but it's hardly any effort at all!

Scientists:
Date and Time:

Catapults in action!

What do we want to find out? What's your Question?	We're trying to get the ammo to hit the target plate, but it keeps falling short. How can we make the ammo go further
What will you try to do to answer your questions? What is your hypothesis?	Make the arm of the catapult longer.
WHY do you think this will work?	That is, move the ruler so that the load arm is longer and the effort arm is shorter. If we hit it now, it will go further because the load arm will move further.
What happened in your test? What were your RESULTS?	It went TOO far.
What can you CONCLUDE? What will you try next?	We moved the arm too far and it overshot. We didn't measure how far the arm was in the first place, so we don't really know. Next time we'll measure it and be more accurate!

Experiment 1

What do we want to find out? What's your Question?	
What will you try to do to answer your questions? What is your hypothesis?	
WHY do you think this will work?	
What happened in your test? What were your RESULTS?	
What can you CONCLUDE? What will you try next?	

Scientists:

Date and Time:

Experiment:

What do we want to find out? What's your Question?	
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