ACTIVITY 08 | SECONDARY | 70–100 MINUTES

Ready, aim, fire!

Explosive engineering

KS3
Design and Technology, Maths, Science

Third or Fourth level
Sciences, Technologies

Ready, aim, fire!
Explosive engineering

In this activity students will test the accuracy of Leonardo's diagram of projectile motion by building a catapult and taking accurate measurements of the flight of a ball through the air.

They will be able to compare the path of their ball to Leonardo's drawing and can use this to evaluate how successful his machines would have been.

IN THIS ACTIVITY PUPILS WILL:

DESCRIBE balanced and unbalanced forces.

DESCRIBE how the energy of a ball changes throughout flight.

BUILD and evaluate a design and discuss the effect of changing a variable.

UNDERSTAND that adapting a design to overcome a problem is part of the design process.

Focus image: *Mortars bombarding a fortress, c.1503–4, (RCIN 912275)*

WATCH A SHORT FILM

See *this interview* with Martin Clayton where he talks about Leonardo's amazing talent for coming up with ideas and recording his thoughts in his notebooks.

Inspiration

Leonardo lived through times of war in Europe. Many of his sketchbooks show designs for machines that could be useful to the military and be used in war. His interest in military engineering started early on in his life with designs for bridges, escape tunnels, catapults and crossbows.

Later, in 1502, he was appointed engineer to the commander of the pope's armies, this allowed him to suggest ways to improve defences as well as attack enemy fortifications. Military designs would have been at the cutting edge of technology at the time, so undoubtedly would have interested Leonardo.

In some of his drawings, Leonardo shows in detail how a machine would be made or used. In other drawings, he shows tactics of war, putting forward ideas about how battles and sieges could be approached.

This is the case in the diagrammatical drawing *Mortars bombarding a fortress, c.1503–4 (RCIN 912275)*, which shows how cannon and mortars could be used to breach a high wall, following the invention and introduction of gunpowder.

QUESTIONS TO ASK

Listen to Martin Clayton, Head of Prints and Drawings at Royal Collection Trust, talk about Leonardo's amazing talent for coming up with ideas and recording his thoughts in his notebooks.

In the films titled *Leonardo is often described as a polymath. What is a polymath?* and *There are many drawings of Leonardo's inventions. Did he make any of them?* he reminds us that many of his projects remained unfinished.

Think about and then discuss the questions below:

Why did Leonardo do these drawings if he didn't intend to make them?

What do they tell us about Leonardo's amazing brain?

How can we learn more about Leonardo's designs?

How can we turn Leonardo's designs into reality?

STEP 01

Discuss

Discuss the drawing *Mortars bombarding a fortress (RCIN 912275)* with the students. It is important that they understand there are four mortars on the outside of the fortress wall, firing stones into the fortress.

The lines coming from the mortars show the path of the flight of the stones.

Students use a copy of drawing *Mortars bombarding a fortress (RCIN 912275)* to label the parts of the flight where the kinetic, gravitational potential energy is at a maximum and minimum, and where energy is being transferred mechanically and thermally. You could use the labels from 'Get labelling' activity sheet.

You could also discuss thermal energy and how the kinetic energy that the mortar has at the end of its trajectory is transferred to the kinetic energy of whatever it hits.

You could question how and where energy is dissipated to the surroundings and what impact this has on the projectile.

This will give students an opportunity to explore the drawing in detail and revise their understanding of what is happening to the energy of an object in flight.

Following this, students can use the three drawings from *A scene in an arsenal, c.1485–90 (RCIN 912647)* and the top diagram in drawing *Designs for gun-barrels and mortars, c.1485 (RCIN 912652)* along with *Mortars bombarding a fortress* to discuss how Leonardo, engineers of his time and engineers today use ideas about forces in their designs.

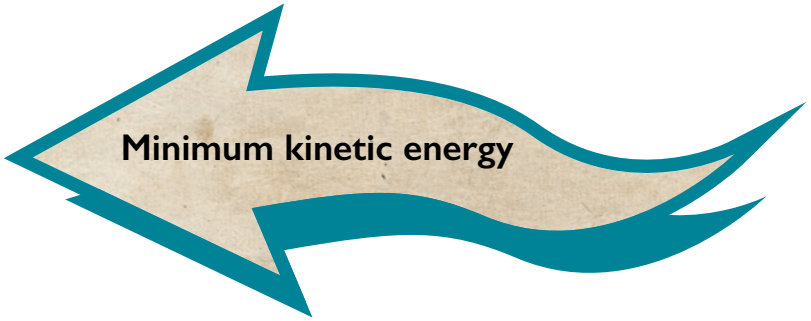
TRAJECTORY
The flightpath of an object flying through the air.

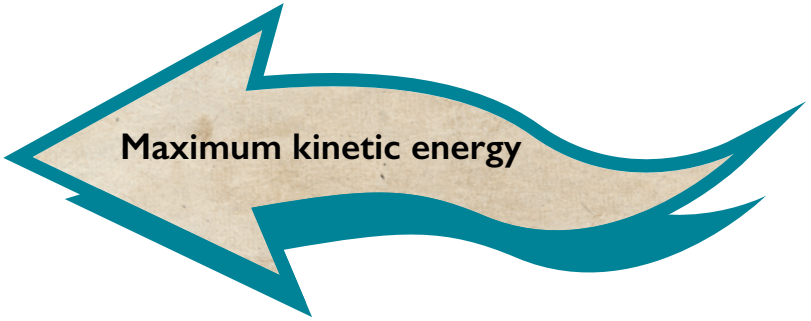
PROJECTILE
The object (in this case a stone) flying through the air.

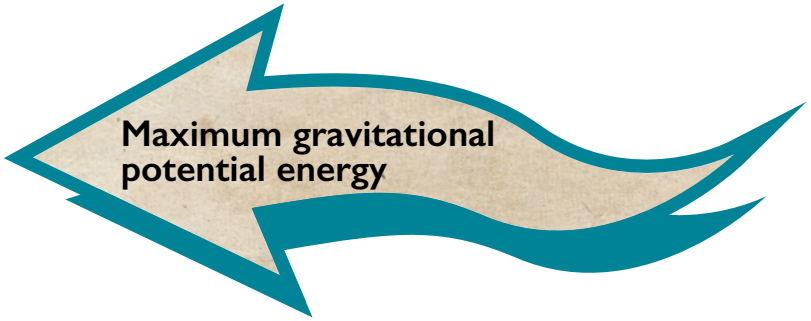
RANGE
How far a projectile travels horizontally.

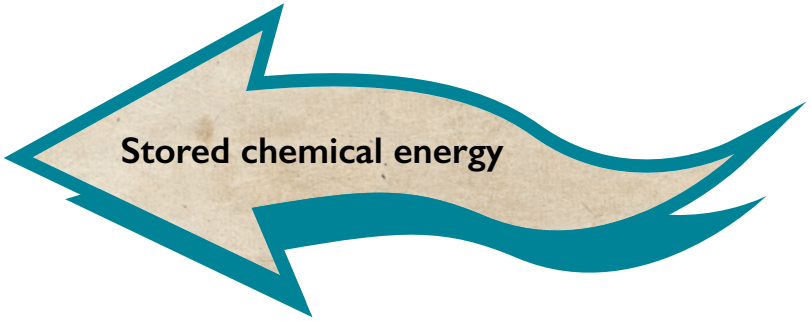
PARABOLA
A curve, like an arch that shows the shape of a projectile's path.

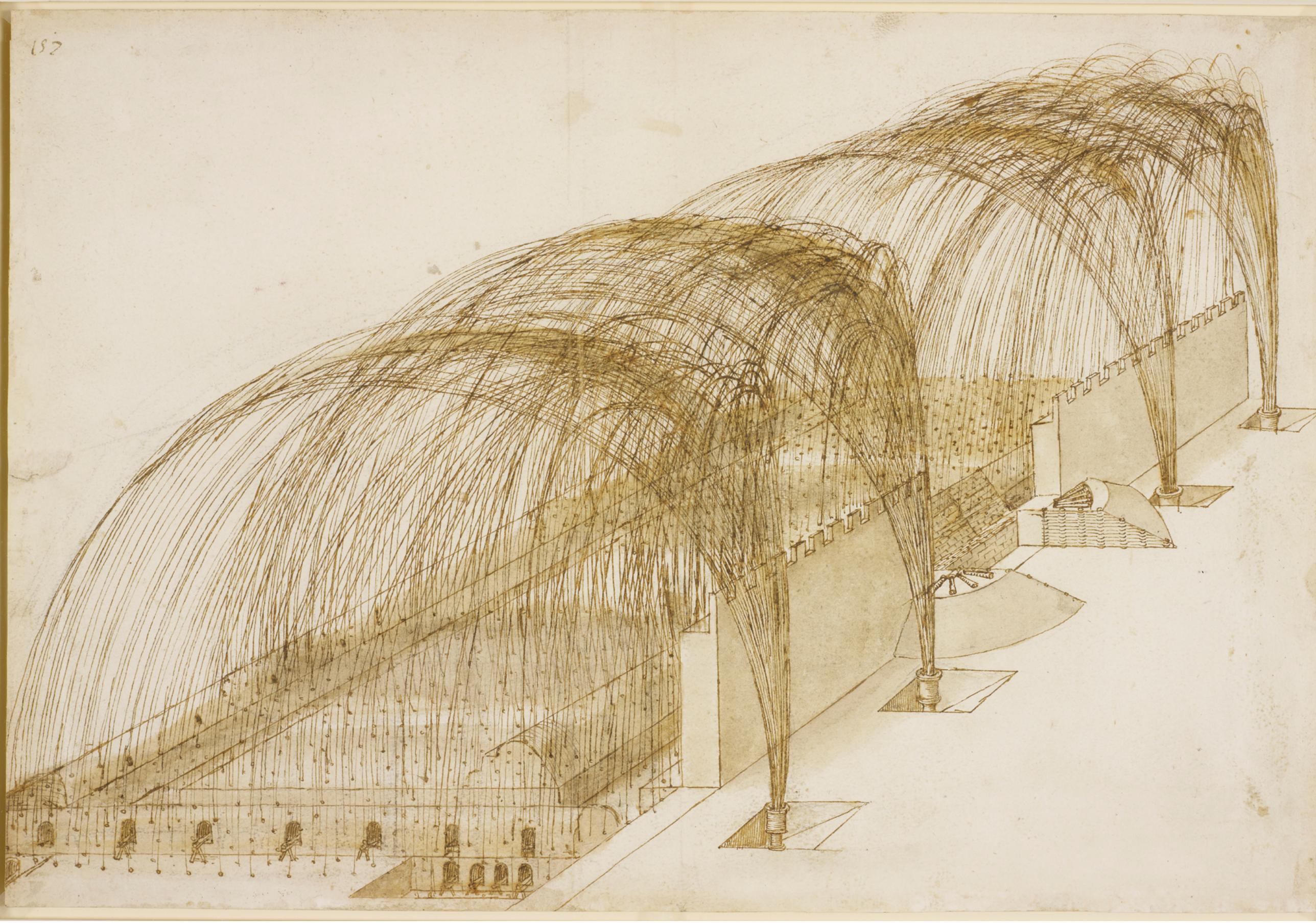
Get labelling











*Mortars bombarding a fortress, c.*1503–4 (RCIN 912275)

STEP 02

Experiment

Students can now make a firing machine and take some measurements of the trajectory of motion when a small object is fired from it. Students could build their own firing machine possibly based on Leonardo's drawing *Designs of gun-barrels and mortars*, or from their own design or a toy that fires a ball.

Small fluffy pompoms move well through the air and should be low-risk!

Students can then complete an investigation collecting data from firing their device.

Discuss with the students which independent variables they could change in order to change the height and the range of their projectile. These variables could include:

- The angle of release
- The force with which the projectile is hit
- The mass or shape of the projectile

Ideally, guide students towards investigating the angle of release and keep the other variable constant so that they are the control variables before feeding back to the class.

The projectile launcher can be used to fire the projectile at different angles into the air (independent variable) using the 'Angle of projectile' activity sheet, which we hope they enjoy!

After each throw, the height and range can be measured by a group of students taking careful measurements with tape measures and metre sticks during the trajectory or, more accurately, by digital photography.

Students could record the flight using a camera, tablet or phone, with vertical and horizontal metre sticks in the frame. By playing this back in slow motion measurements can be taken.

This data can be recorded in the table on the 'Recording Flight' activity sheet.

STEP 03

Check your diagram

Before analysing, students can plot this data on graph paper using different colour lines for each angle of release. Students will need to plot points for the starting point (the origin), the height and the range and then draw a curve to show the path.

DIFFERENTIATING THE TASK

Students could progress to investigating the different independent variables and observing the effect on the range and height. This could be done using similar equipment used to record the height and range.

The final diagram should look similar to Leonardo's drawing. Ask students what differences they can see.

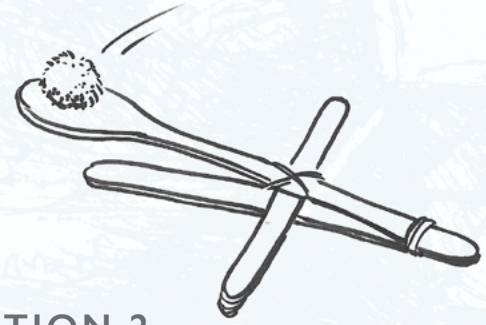
They may need to take some measurements from the picture, which show that the trajectory Leonardo drew was semi-circular.

We now know that projectiles never follow a semi-circular path but that they are a parabolic shape.

Recording flight

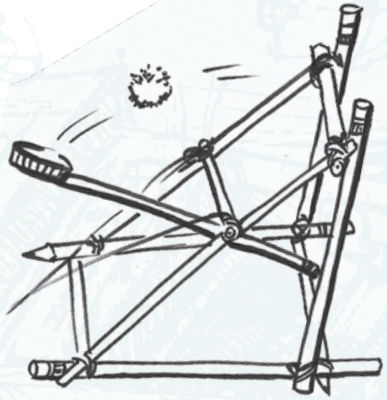
OPTION 1

For a quick, but less accurate investigation, it is possible to use a use your fingers to flick the pompom off a ruler. It is essential to try and get the same force hitting the projectile each time in order to keep the control variable constant.



OPTION 2

Students are given a design and the materials to make this. This could be a simple catapult from four lolly sticks and elastic bands. Other examples can be found online.

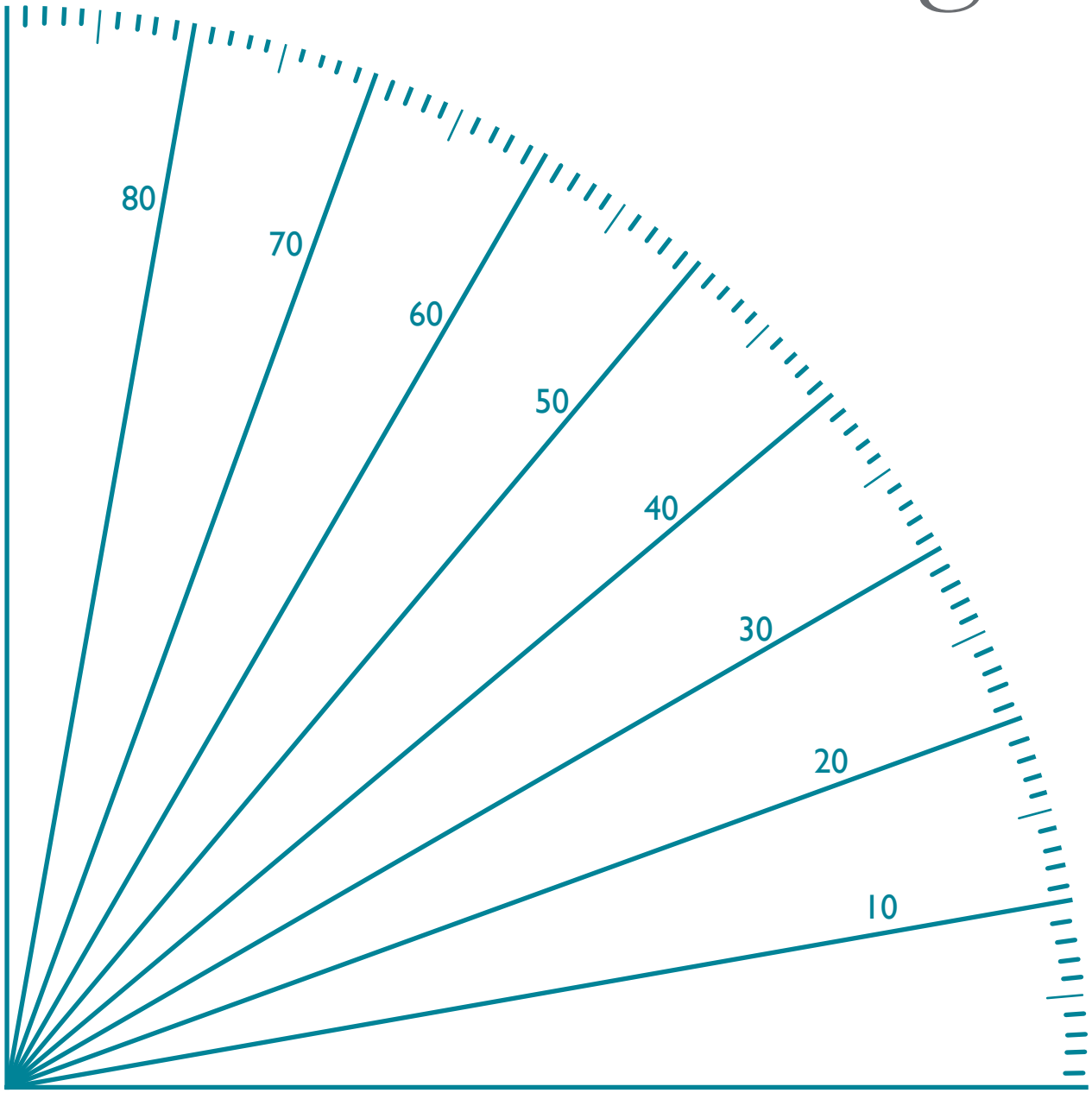


OPTION 3

Students have a tray of materials from which to design their own firing device. See the resource list. Students could be provided with the *Designs of gun-barrels and mortars drawing* for inspiration.

Angle of release (degrees)	Horizontal distance (metres)	Height (metres)
15		
30		
45		
60		
75		
90		

Angle of projectile

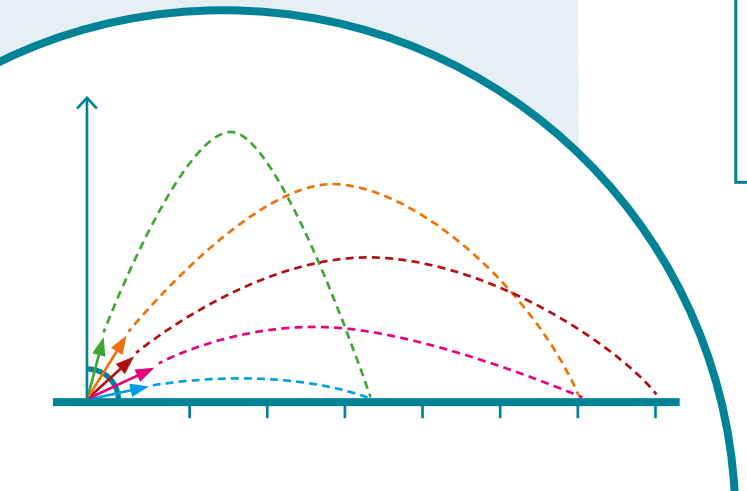


Trajectory diagram

Draw the final diagram on this page. It should look similar to the example shown below.

What differences can you see compared to Leonardo's drawing?

They may need to take some measurements from the drawing, which shows that the trajectory Leonardo drew was semi-circular. We now know that projectiles never follow a semi-circular path but that they are a parabolic shape.



Resources

EQUIPMENT

- Questions and copies of the Leonardo drawings
- Equipment for one of the three options for making a firing device:

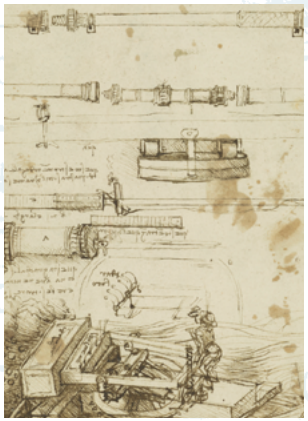
  OPTION 1 Ruler

  OPTION 2 Lolly sticks and elastic bands

  OPTION 3 Lolly sticks, elastic bands, stiff plastic from ice cream tubs, string, springs, paperclips, wooden spoons, craft sticks
- Metre sticks and tape measures
- Digital recording device, (eg, a phone, camera or tablet), data-logging equipment and sensors
- Printed 'Get labelling' resource
- Printed 'Angle of projectile' resource
- *Martin Clayton's videos 4 and 5*

RESOURCE IMAGES

A scene in an arsenal, c.1485–90 (RCIN 912647



Designs for gun-barrels and mortars, c.1485 (RCIN 912652

FANTASTIC FINISH

Students could produce a display showing how Leonardo's ideas about flight were far ahead of their time. We now use his theories of how objects move in toys for children, launchers used to throw balls for dogs, and even to launch spacecraft.

Despite designing machines for war, Leonardo has sometimes been described as a pacifist.

Lead an ethical discussion amongst students about why Leonardo, despite his principles, suggested strategies to siege fortresses.

- Is war ever justified?
- When can designing weapons be supported?
- How do you think Leonardo would have defended his decisions?

Look at the resource image *Mortars bombarding a fortress, c.1503–4 (RCIN 912275)*

ASK YOUR STUDENTS

What is happening in this drawing?

Why would armies 500 years ago have needed this drawing?

Is this drawing about an attack or defence of the fortress?

Why was this an innovation at the time?

How would Leonardo have known the flightpath of the projectile?

What is the scale of this diagram?
Hint: Can you see any people?

Can you work out how high the projectile is travelling?