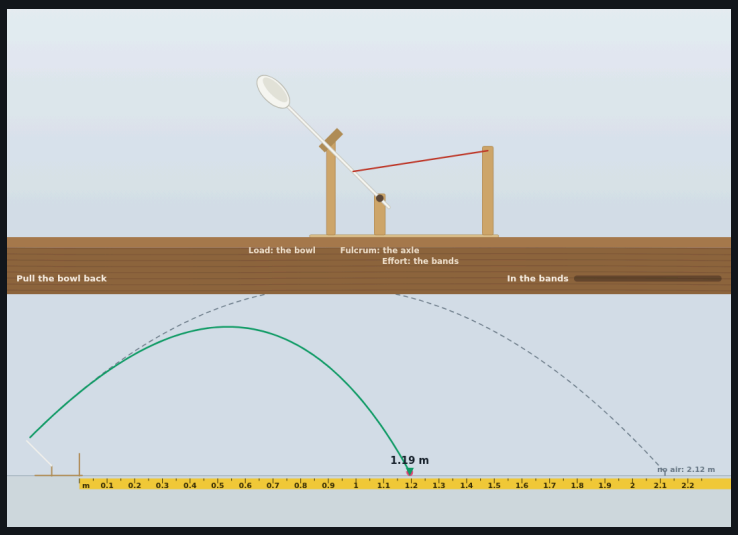
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Catapult Lab: Is 45 Degrees the Best?

Grades 6-8 · 45 minutes

Physical science · Engineering



Slides, rubric and answer key **Print and go** **No student accounts**

Chromebook friendly

What's included

- A one-page overview: objectives, essential question, vocabulary, standards and assessment
- A 45-minute lesson sequence: warm-up, direct instruction, guided practice, independent practice, closure
- Slides for the board: a PowerPoint file that also opens in Google Slides
- A student worksheet with a QR code and an angle table
- A 3-question exit ticket, two to a page, with an answer key
- A rubric: 3 criteria, 4 levels, scored out of 12
- Differentiation for English learners, students with IEPs or 504 plans, and students who need more support or more challenge
- Cross-curricular extensions, and notes for teaching it in grades 4 and 5 and in high school physics
- Standards: NGSS

Catapult Lab: Is 45 Degrees the Best?

Grades 6-8 · 45 minutes · Physical science, Engineering

Students throw a pom-pom from a spoon catapult with its cross-bar at every stop from 15 to 65 degrees and find the farthest. It is not 45: with one band the best is 25 degrees, 1.63 m, against 1.19 m at 45. A stop closer to upright gives the bands a longer pull, so the throw leaves faster. The app's sweep draws the chart and says why, and the stacked catapult adds a second answer: it cannot throw lower than 66 degrees at all.

At a glance

ESSENTIAL QUESTION

Is 45 degrees always the best angle to throw at?

OBJECTIVES

Students will be able to:

- change one thing, the stop, and record how far each throw goes
- find the best launch angle for a catapult from data
- explain why the best angle is not 45 degrees for this catapult
- say when 45 degrees would be best

VOCABULARY

Launch angle, Range, Launch speed, Variable, Optimal

STANDARDS

MS-ETS1-4

TIME AND MATERIALS

45 minutes, grades 6-8.

- One computer or Chromebook per student
- A projector
- The worksheet and exit ticket, one copy each per student
- The rubric, one copy per student if you grade the work

PREP

Make copies of the worksheet and exit ticket. Before class, open mytekdev.com/try/catapultlab?lesson=is-45-degrees-best&ref=tpt-catapultlab-2 once on a student computer: it opens on the spoon catapult with its stop at 45 degrees. Run it yourself, about ten minutes: move Pull back all the way and press Let go (1.19 m); set the stop to 30 (1.59 m); then press Find the best angle and read the chart.

ASSESSMENT

- Formative: the questions under What to look for, asked while students work, and the exit ticket (answer key included).
- Summative: the worksheet, scored with the rubric.

TECHNOLOGY AND PRIVACY

Runs in any browser, Chromebooks included, with nothing to install. Students need no account and no email: the link works signed out, and nothing they do is stored on our server unless they choose to save.

Lesson sequence

MINUTES	STAGE	WHAT YOU DO	WHAT STUDENTS DO
0 to 5	**Warm-up** Hook	Show the title, essential question and Today I can slides (about 1 minute). Then the warm-up: what angle throws farthest? Write every answer on the board.	Answer the warm-up on the worksheet.
5 to 12	**Direct instruction (I do)** Model it	Project the app with the starter open. Point at the cross-bar: the spoon stops there and the pom-pom leaves at that angle. Move Pull back all the way and press Let go: 1.19 m. Show the stat slide. > **It's working when:** Every throw is pulled all the way back to the same place, 80 degrees behind upright. A stop closer to upright lets the band pull the spoon farther before it stops, so the pom-pom leaves faster: 6.0 m/s at 25 degrees against 4.6 m/s at 45.	Watch, and fill in the vocabulary on the worksheet.
12 to 22	**Guided practice (We do)** Two stops and the chart	Students open the link or scan the QR code. A short guide walks them through 45 degrees, 30 degrees and the chart. Ask which went farther, and what the chart says the best is. > **Watch for:** Students who move the stop and do not pull all the way back. Every row of the table needs the same pull: the slider all the way right.	Fill in the 45 and 30 rows, and the best from the chart.
22 to 38	**Independent practice (You do)** Every stop	Students throw at every stop from 15 to 65 by 5 and fill in the table, then switch to Stacked sticks and press Find the best angle again. Walk the room with the What to look for questions. > **If they ask:** "Was the pom-pom leaving at the same speed at every stop? How do you know, and why does it matter?" Speed and angle	Fill in the angle table, then answer the questions.
38 to 45	**Closure** Showcase and exit ticket	Show the Showcase slide. Two students say when 45 degrees is best and why it was not here, then go back to the warm-up answers. Hand out the exit ticket.	Answer the exit ticket.

Before you teach: a ten-minute walkthrough

Open mytekdev.com/try/catapultlab?lesson=is-45-degrees-best&ref=tpt-catapultlab-2. A short guide opens over the app. The spoon catapult is on the table: a plastic spoon on an axle, a red band to a front post, and a cross-bar that stops the spoon. Where the cross-bar stops it, on the right, sets the launch angle.

1. **The first throw.** Move Pull back all the way: the strip says "Pulled back 78 mm". Press Let go. The spoon swings up, stops at the bar, and the pom-pom lands at 1.19 m.

2. **Every stop.** Pulled all the way back each time: 15 degrees 1.55 m, 20 1.61, 25 1.63, 30 1.59, 35 1.50, 40 1.36, 45 1.19, 50 1.00, 55 0.77, 60 0.54, 65 0.30.
3. **The chart.** Press Find the best angle: best 25 degrees, 1.63 m. The no-air line peaks there too. The sentences say why 45 is not the best, and that the launch speed went from 2.8 to 6.6 m/s across the stops.
4. **The stacked catapult.** Under Catapult, tap Stacked sticks and press Find the best angle: best 66 degrees with nine sticks, 1.48 m. It cannot throw any lower.

> The moment that lands is the chart: the no-air line peaks at the same 25 degrees. The air is not what moved the best angle here; the speed is.

Background for the teacher

The rule that 45 degrees throws farthest is true only when three things hold: no air, a throw that starts and lands at the same height, and the same launch speed at every angle. A catapult breaks the third. Every throw here is pulled back to the same place, so a stop closer to upright gives the band a longer stroke and the pom-pom leaves faster: 6.6 m/s at 15 degrees, 4.6 at 45, 2.8 at 65. Faster at a low angle beats slower at 45.

The stacked catapult is a different case: its arm rests at an angle set by the stack, and it throws back over the banded end steeply. With nine sticks it throws at 66 degrees, and that is as low as it goes, so its best is simply its lowest. Students who were told 45 in an earlier lesson are not wrong about the rule, only about when it applies. Catapult Lab works out each throw from the build: how stiff the stick and the bands are, how heavy the cup and the projectile are, and the air. Two of its numbers are estimates still to be measured (how hard the bands hold the end down, and that they give back 75% of what was stored), so a real catapult can land well short of the drawing or past it. The app never claims more: every speed and energy is shown as "about".

What to look for

Ask these while students work. A student who has understood the lesson can answer them without help:

- Which stop threw farthest, and how far?
- Did the pom-pom leave at the same speed at every stop? How do you know?
- Why does a stop closer to upright throw faster?
- When would 45 degrees be the best?
- Why is the stacked catapult's best 66 degrees?

> The fourth question is the real test: a student who names the same speed at every angle has understood why the rule failed here.

Cross-curricular extensions

- Math: graph distance against stop from the table. Where is the top, and is the curve the same on both sides of it?

- Math: in high school, use v squared sin 2 theta over g with the speeds from the app, and compare with the no-air line.
- Building: a real spoon catapult with a movable stop: test three stops five times each. Eye protection for everyone the whole time, building too. Light, soft things only: pom-poms, marshmallows, ping pong balls. Aim at a target on the floor, never at a person. A stick can snap and splinter, so press slowly.
- History: a counterweight trebuchet's sling sets its release angle. Read how builders tuned it.

Vocabulary

Launch angle	How steeply something leaves, measured up from level.
Range	How far a projectile lands from where it was thrown.
Launch speed	How fast it is moving when it leaves the cup.
Variable	Anything that can change in a test. A fair test changes one at a time.
Optimal	The best one, by the test you chose.

Differentiation

ENGLISH LEARNERS

- Keep the vocabulary slide up, and point at the screen as you say each word: the arc, the tape and the colored bars carry the meaning.
- Pair each learner with a partner; the chart is a picture of the whole table.
- Accept the table as numbers, and the reason as one sentence copied from under the chart.

STUDENTS WITH IEPS OR 504 PLANS

- Pair students for the independent part, one at the app and one filling in the table.
- Zoom the browser to 125%.
- Allow every other stop (15, 25, 35, 45, 55, 65), where the IEP allows a modified assignment.

STUDENTS WHO NEED MORE SUPPORT

- A sentence starter: "The best stop was ___ degrees, not 45, because ___."
- A check-in after the guide: every student has 45 and 30 in the table before moving on.
- Give five stops to try: 15, 25, 35, 45 and 55.

STUDENTS READY FOR MORE

- Set the level to High school and record the launch speed at each stop. Make a graph of speed against angle.
- Add a second band. Does the best stop move?
- Try the ping pong ball. Is its best stop the same as the pom-pom's?

Adapting for other grades

Younger students: In grades 4 and 5, set the app to Grades 4 and 5 (distances in centimeters, energy in words) and do the guide together on the projector. Pairs share a computer, one on the mouse and one recording. Skip the third rubric row; total 8, and 6 meets the objectives. Compare only the distances, in centimeters, and let the chart do the finding.

Older students: In high school physics, range with no air from floor level is v squared times sin 2 theta over g, which peaks at 45 degrees only when v is the same at every angle. Students record the launch speed at each stop, put it into that formula, and compare with the no-air line on the chart: the speed, not the air, moves this catapult's best angle.

Student worksheet

Name: _____ Date: _____

Open the app: scan the QR code, or go to mytekdev.com/try/catapultlab?lesson=is-45-degrees-best

Essential question: Is 45 degrees always the best angle to throw at?

Warm-up: To throw something as far as you can, what angle should it leave at? _____

1. **Vocabulary.** Launch angle, range, launch speed, variable, optimal: write each in your own words.

2. **The angle table.** For each stop from 15 to 65 degrees, by 5, pulled all the way back: how far _____ m. Best stop _____ degrees. Stacked catapult's best _____ degrees.

1. Which stop threw farthest? Was it 45 degrees? Why or why not?

2. When would 45 degrees be the best angle?

Catapult Lab: Is 45 Degrees the Best?

Exit ticket

Name: _____

1. On the spoon catapult, pulled back the same way each time, the best stop was (A) 45 degrees (B) about 25 degrees (C) 65 degrees

2. Why did a stop closer to upright throw faster? (A) The band pulled the spoon farther before it stopped (B) The air pushed it (C) The pom-pom was lighter

3. When is 45 degrees the best angle?

Catapult Lab: Is 45 Degrees the Best?

Exit ticket

Name: _____

1. On the spoon catapult, pulled back the same way each time, the best stop was (A) 45 degrees (B) about 25 degrees (C) 65 degrees

2. Why did a stop closer to upright throw faster? (A) The band pulled the spoon farther before it stopped (B) The air pushed it (C) The pom-pom was lighter

3. When is 45 degrees the best angle?

Answer key: exit ticket

QUESTION	ANSWER	WHY
1	B	With one band, 25 degrees threw 1.63 m and 45 threw 1.19 m.
2	A	Pulled back to the same place, a stop closer to upright gives the band a longer stroke, so the spoon is moving faster when it stops.
3	Same speed at every angle, no air, from the floor	All three are needed. "When there is no air" alone is half: the no-air line here still peaks at 25 degrees.

Rubric

Score each row from 1 to 4.

Name: _____

CRITERIA	4 EXCEEDS	3 MEETS	2 APPROACHING	1 BEGINNING
The angle table	Every stop from 15 to 65, each with the distance, and the stacked catapult's best.	At least six stops, each with the distance.	Some stops recorded.	No stops recorded.
Finding the best	Names the best stop from the data and gives its distance, and the stacked catapult's best.	Names the best stop from the data.	Names a stop with no data.	No answer.
Explaining it	Says 45 is best only with the same speed at every angle, no air and a throw from the floor, and that here a lower stop gives a longer pull and a faster throw.	Says the speed changes with the stop.	Says 45 is not best, with no reason.	No answer.

Total: ____ / 12. A score of 9 or more meets the objectives.

Standards

The lesson is built for MS-ETS1-4: students use the app as a model to generate data at every setting and find the design that does best. No NGSS performance expectation covers the two-dimensional arc itself, so the lesson does not claim one.

FRAMEWORK	CODE	GRADES	STANDARD	HOW THE LESSON MEETS IT
NGSS	**MS-ETS1-4**	6-8	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	Students generate distance data at eleven stops with the model, find the best, and test a second design.

Checked November 2026 against: NGSS MS-ETS1, Engineering Design.

Optional: save student work in a free class

The whole lesson runs at the link on the worksheet, with no accounts and no sign-up.

To keep students' work, and see it all in one place, make a free class. It takes about ten minutes, once, and covers every lesson in this series: mytekdev.com/tools/class-setup

Students in a class open mytekdev.com/tools/catapult-lab/lessons/is-45-degrees-best/start instead of the worksheet link. Each one gets their own copy of the starter, and the same link reopens it next time.

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