

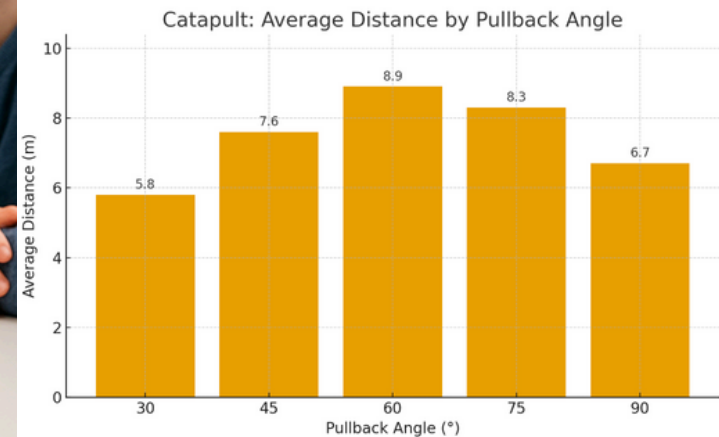
Catapult STEM Lab:

Pullback Angle vs Distance Investigation

Scientific Method • Variables • Data & Graphing

✓ Classroom-Ready

✓ Data tables + bar graph templates included



Catapult STEM Investigation: Pullback Angle

Purpose

Use a high-engagement craft-stick catapult to teach experimental design, variables and controls, proportional reasoning, data analysis, and communication of results.

Learning Objectives

- Plan and carry out a controlled investigation with clear independent, dependent, and controlled variables.
- Collect sufficient data (replicates) and compare results across pullback angles.
- Graph distance data to analyze trends and construct evidence-based claims.
- Explain the physical principles of elastic potential energy, energy transfer, and projectile motion.

Safety

- Use soft projectiles (pom-poms or marshmallows) only. No hard objects.
- Keep a clear launch lane. Never aim at people. Use eye protection if available.
- Check rubber bands for wear; replace if frayed. Keep fingers clear of the arm path.

Materials

- Craft-stick catapults (identical build across teams)
- Rubber bands (same size/type for all teams)
- Pom-poms (same size/mass), small cup or spoon launcher
- Protractor or angle card to measure pullback angle
- Tape line for launch; measuring tape or meter tape
- Data sheets (included), clipboards, pencils

Background Science for the Teacher

Elastic Potential Energy: Pulling back the launcher stores energy (within limits) generally stores more energy, which can increase range.

Projectile Motion & Drag: Greater speed increases range on launch; air resistance (drag) slows the projectile down, changing its path and decreasing range.

Consistency: Use the same catapult and projectile for all trials. Measure distance carefully for fair comparison.

Expected Results

- Distances vary by angle and drag.
- A mid-to-high pullback angle (60°–75°) generally produces the greatest distance.
- As technique improves, consistency increases.

Implementation

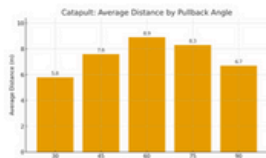
- Build catapults and launchers.
- Assign roles and practice.
- Measure distance and record data.

Answer Key and Sample Results

Note: Actual class data will vary. The sample below models typical trends and acceptable analysis quality.

Sample Summary Data

Pullback (°)	Average Distance (m)
30	5.8
45	7.6
60	8.9
75	8.3
90	6.7



Interpretation

- Greatest average distance at 60° (≈8.9 m) with a close second at 75° (≈8.3 m).
- 90° lost distance due to release angle and drag.

and accuracy.

60–75°).

use and using the same projectile

ectile mass, level surface, and

heavy). Hypothesis: A slightly to a point.

Catapult STEM Investigation: Pullback Angle

Driving Question

How does pullback angle affect projectile distance?

Hypothesis

Write a testable hypothesis predicting which pullback angle will maximize distance and why (energy stored in rubber bands vs accuracy/drag).

Variables

Type	Describe for This Experiment
Independent Variable	Pullback angle (degrees) OR equivalent rubber band stretch length (cm)
Dependent Variable	Horizontal distance from the launch line to first ground contact (meters)
Controlled Variables	Catapult design and build; rubber band type; projectile mass; launch surface; base stability; measurement method; number of launches per condition

Experimental Design

- Test five pullback angles: 30°, 45°, 60°, 75°, and 90°.
- For each angle, complete a practice block (3 launches, not recorded) to stabilize technique, then perform 10 measured launches with the same catapult and projectile type.
- Standardize technique: Keep the base fixed; measure pullback with a protractor or angle guide; release smoothly without pushing the arm.
- Measure distance from the launch line to the FIRST ground contact of the projectile (not where it rolls to). Record to the nearest 0.1 m.

Summary Table

Pullback (°)	Average Distance (m)
30	
45	
60	
75	
90	

Graphing

- Create a bar graph (or line graph) of Average Distance (m) on the y-axis vs Pullback Angle (°) on the x-axis.
- Start y-axis at 0; include a clear title and axis labels.

Analysis Questions

- Which pullback angle produced the greatest average distance? Include the mean distance and the angle value.
- Describe how consistent your launches were across trials. What helped keep the test fair?
- Which controlled variables were most critical to keep distances comparable?
- If time allowed, what follow-up experiment would you run next (projectile mass at the best pullback, different catapult builds)? State a testable hypothesis.

Rubric

Category	Exceeds (4)	Meets (3)	Approaches (2)	Beginning (1)
Experimental Design	Variables clearly named; procedure standardizes pullback, base, and release; practice round completed; enough launches for fair comparison.	Variables named; procedure mostly consistent; launches completed.	Variables partially named or unclear; inconsistent procedure; fewer launches than planned.	Variables missing; no consistent procedure; very few launches.
Data Quality	All launches recorded neatly; totals match; measured to first contact; summary complete.	Almost all launches recorded; minor slips corrected; summary mostly complete.	Several omissions or unclear entries; summary incomplete or mismatched.	Many missing or unreadable entries; summary not usable.
Graphing & Analysis	Correct graph with labeled axes and title; bars/points reflect each pullback; clear takeaway identifying best pullback with numbers.	Graph present with labels and title; takeaway stated.	Graph present but missing some labels or clarity; takeaway vague.	No graph or incorrect graph; no takeaway.
Claim–Evidence–Reasoning	Clear claim naming best pullback; evidence cites results from this lab; reasoning connects to elastic energy, projectile motion, and drag/accuracy.	Claim supported with basic evidence and some correct reasoning.	Claim present but weakly supported; reasoning unclear or generic.	Claim absent or unrelated to data; no reasoning.
Collaboration & Safety	Roles used effectively; launch lane kept clear; students on task and respectful.	Mostly cooperative; safe behavior with minor reminders.	Uneven participation; repeated reminders for safety or focus.	Off-task or unsafe behavior; roles unclear.

Data Collection Tables

Pullback (°)	Launch #	Distance (m)
30	1	
30	2	
30	3	
30	4	
30	5	
30	6	
30	7	
30	8	
30	9	
30	10	
Pullback (°)	Launch #	Distance (m)
45	1	
45	2	
45	3	
45	4	
45	5	
45	6	
45	7	
45	8	
45	9	
45	10	
Pullback (°)	Launch #	Distance (m)
60	1	
60	2	
60	3	
60	4	
60	5	
60	6	
60	7	
60	8	
60	9	
60	10	
Pullback (°)	Launch #	Distance (m)
75	1	
75	2	
75	3	
75	4	
75	5	
75	6	
75	7	
75	8	
75	9	
75	10	
Pullback (°)	Launch #	Distance (m)
90	1	
90	2	
90	3	
90	4	
90	5	
90	6	
90	7	
90	8	
90	9	
90	10	

What You Get

- **Teacher Guide:** setup, safety, pacing, and background science (elastic potential energy, projectile motion, drag/accuracy).
- **Student Packet:** clear, easy to follow instruction set and blank data tables.
- **Summary & Graphing Pages:** average-by-angle table and graph template (Average Distance vs Pullback Angle) with included graph paper.
- **Analysis & Model Answers:** four prompts with sample data and exemplar responses
- **Rubric & Extensions:** simplified rubric plus optional investigations