

MARBLE RAMP: HEIGHT VS AVERAGE SPEED

STEM INVESTIGATION

Print-and-go STEM lab where students test how ramp height affects a marble's average speed.

Marble Ramp: Height vs Average Speed — STEM Investigation

Purpose
Use an engaging marble-on-ramp challenge to teach experimental design, variables and controls, averaging and unit analysis, graphing, and evidence-based explanations for motion and energy.

Learning Objectives

- Plan and carry out a controlled investigation with clear independent, dependent, and controlled variables.
- Collect sufficient data (replicates) and compute average time and average speed with correct units.
- Graph Average Speed (m/s) vs Height (cm) to analyze trends and identify the best condition.
- Explain results using gravitational potential energy, kinetic energy, slope/angle, and friction.

Safety

- Secure stacks of books/blocks supporting the ramp; avoid unstable towers.
- Keep the rolling path clear; prevent marbles from falling to the floor to avoid slips/trips.
- No pushing the marble—only release; keep hands/fingers away from the ramp end.

Materials

- Smooth ramp/track (foam channel, meter-stick groove, or cardboard track) — 1 per group
- Identical marble — 1 per group (keep size/mass the same across all tests)
- Books/blocks to set different heights
- Ruler (cm) for height; meter stick or tape for ramp length along the path
- Stopwatch or timer app
- Tape and sticky notes to mark start and finish lines
- Optional: angle finder/protractor; video or photo-gate timing if available

Background Science for the Teacher

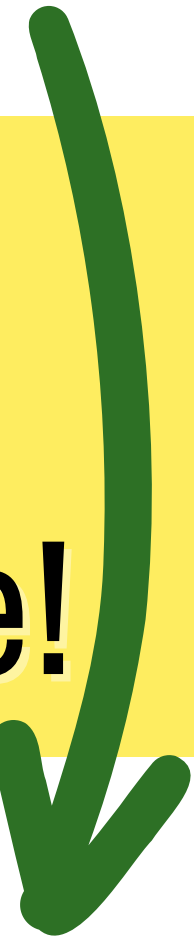
A marble released from a higher ramp has more gravitational potential energy ($GPE = mgh$). As it rolls, GPE transforms into translational and rotational kinetic energy ($\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$). Steeper ramps typically produce larger acceleration components along the track and lower run times, so average speed (d/t) increases. Friction and rolling resistance (including rotational inertia and surface roughness) limit the increase and introduce variability. Measuring the path length d along the ramp and timing from release to finish enables a consistent calculation of average speed in m/s.

Variables That Matter

- Height (cm) at the start (IV) — controls available GPE and effective slope/angle.
- Time (s) to roll from start to finish (DV) — used to compute Average Speed (m/s).
- Ramp length along the path (constant) — measure once and keep the same for all conditions.
- Ramp surface and alignment (constant) — surface friction and track straightness affect results.
- Marble type/size/mass (constant) — changes alter rolling resistance and rotational inertia.
- Release method and start point (constant) — no push; same start line every trial.
- Finish line definition and timing method (constant) — stop timing when the front reaches the line.



SCROLL
to take a look inside!



HOW THIS LAB WILL HELP YOU



- Print-and-go setup
- Fair-test scaffolds
- Data & math supports
- Low-cost & common materials

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Experimental Design
Test five heights: 5, 10, 15, 20, and 25 cm. For each height, perform 5 timed runs using the same release technique (no push). Measure the ramp path length d (in meters) one time and keep it constant. Record times, compute the average time for each height, then compute average speed $v = d / t$ (units m/s).

Type	Describe for This Experiment
Independent Variable	Ramp height (cm) at the start
Dependent Variable	Time (s) used to compute Average Speed (m/s) = d/t
Controlled Variables	Marble type/size; ramp length and surface; start line and finish line; release method (no push); timing method; environment

Summary Table

Height (cm)	Ramp Length (m)	Average Time (s)	Average Speed (m/s)
5			
10			
15			
20			
25			

Graphing
Create a bar or line graph with Average Speed (m/s) on the y-axis and Height (cm) on the x-axis.

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and explain how each could affect your results.
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i would make for higher-quality data next time?



Teacher Guide: setup, safety, pacing, and background science.



Student Packet: clear, step-by-step setup and timing instructions with blank data tables.

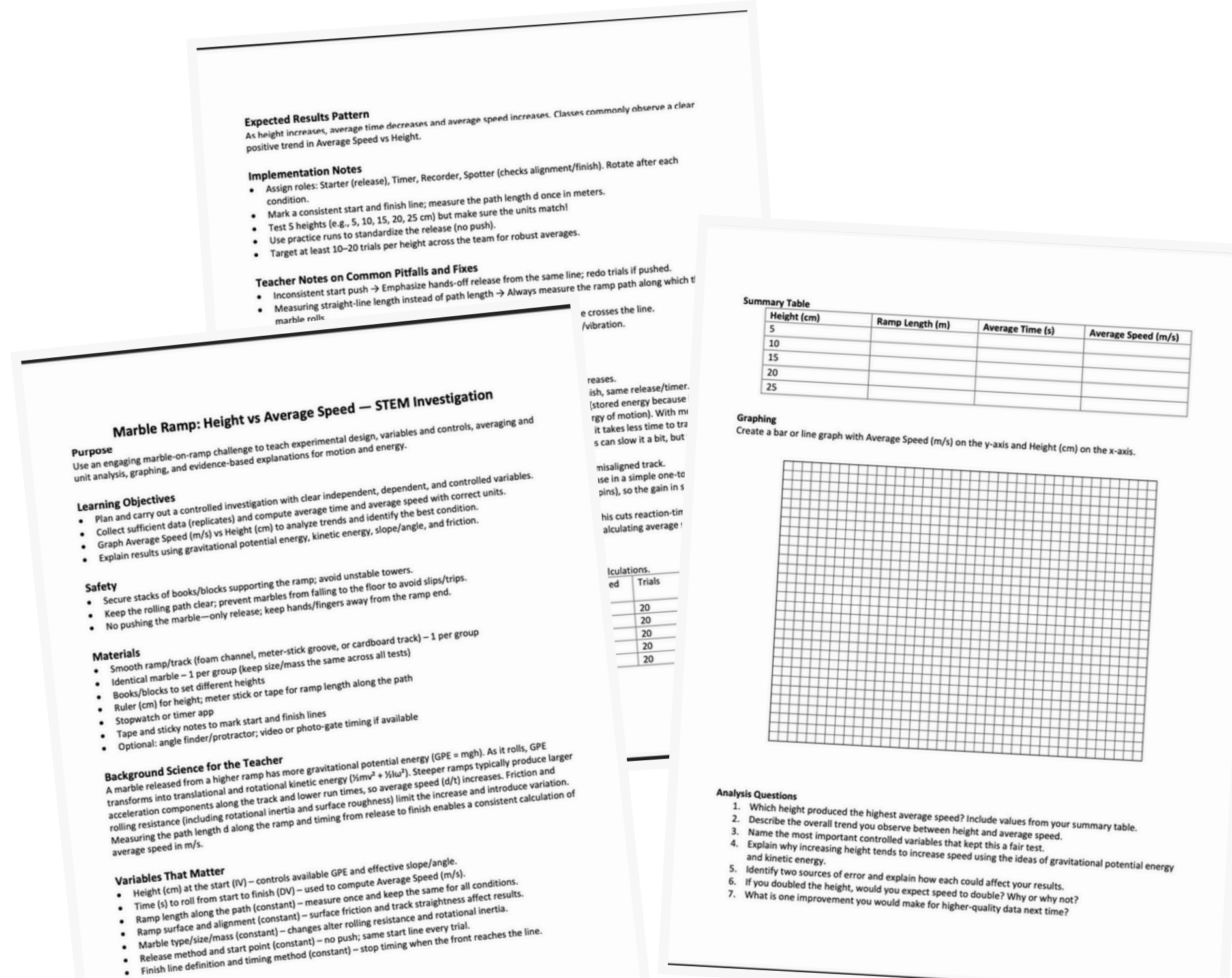


Graphing pages templates and calculation aids.



Complete answer key with example data tables.

What you get inside

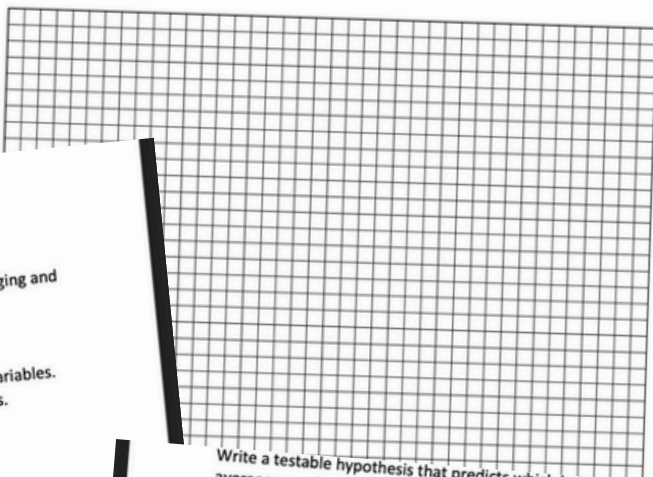


Skills Your Students Will Learn/Improve

- ✓ Identifying Variables
- ✓ Planning Controlled Experiments
- ✓ Precise Measurement
- ✓ Calculating Average Speed
- ✓ Graphing Data
- ✓ Claim–Evidence–Reasoning

25

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Background Science for the Teacher
A marble released from a higher ramp has more gravitational potential energy ($GPE = mgh$). As it rolls, GPE transforms into translational and rotational kinetic energy ($\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$). Steeper ramps typically produce acceleration components along the track and lower run times, so average speed (d/t) increases. Friction and rolling resistance (including rotational inertia and surface roughness) limit the increase and introduce variability.

Write a testable hypothesis that predicts which height (using the same length ramp) will produce the greatest average speed and why.

Variables	
Type	Describe for This Experiment
Independent Variable	Ramp height (cm) at the start
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5	1	
5	2	
5	3	
5	4	
5	5	
10	1	
10	2	
10	3	
10	4	
10	5	
15	1	
15	2	
15	3	
15	4	
15	5	
20	1	
20	2	
20	3	
20	4	
20	5	
25	1	

Your Lab

Marble Ramp: Height vs Average Speed — STEM Investigation

Driving Question

How does the ramp height affect the marble's average speed?

Hypothesis

Write a testable hypothesis that predicts which height (using the same length ramp) will produce the greatest average speed and why.

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10	5	
15	1	
15	2	
15	3	
15	4	
15	5	
20	1	
20	2	
20	3	
20	4	
20	5	
25	1	
25	2	
25	3	
25	4	
25	5	

All steps are clearly outlined and easy to follow

Students collect data in organized charts

Graphing

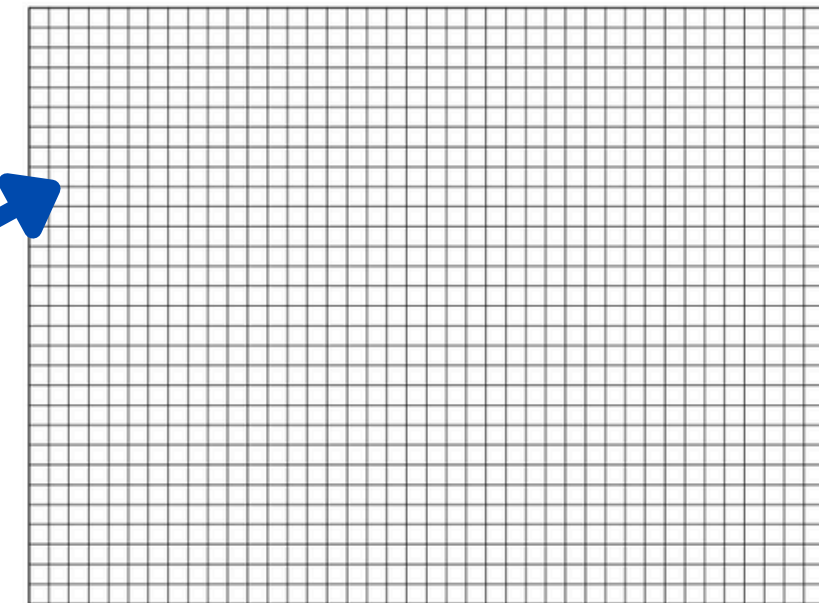
Students analyze their data and draw conclusions

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Graphing

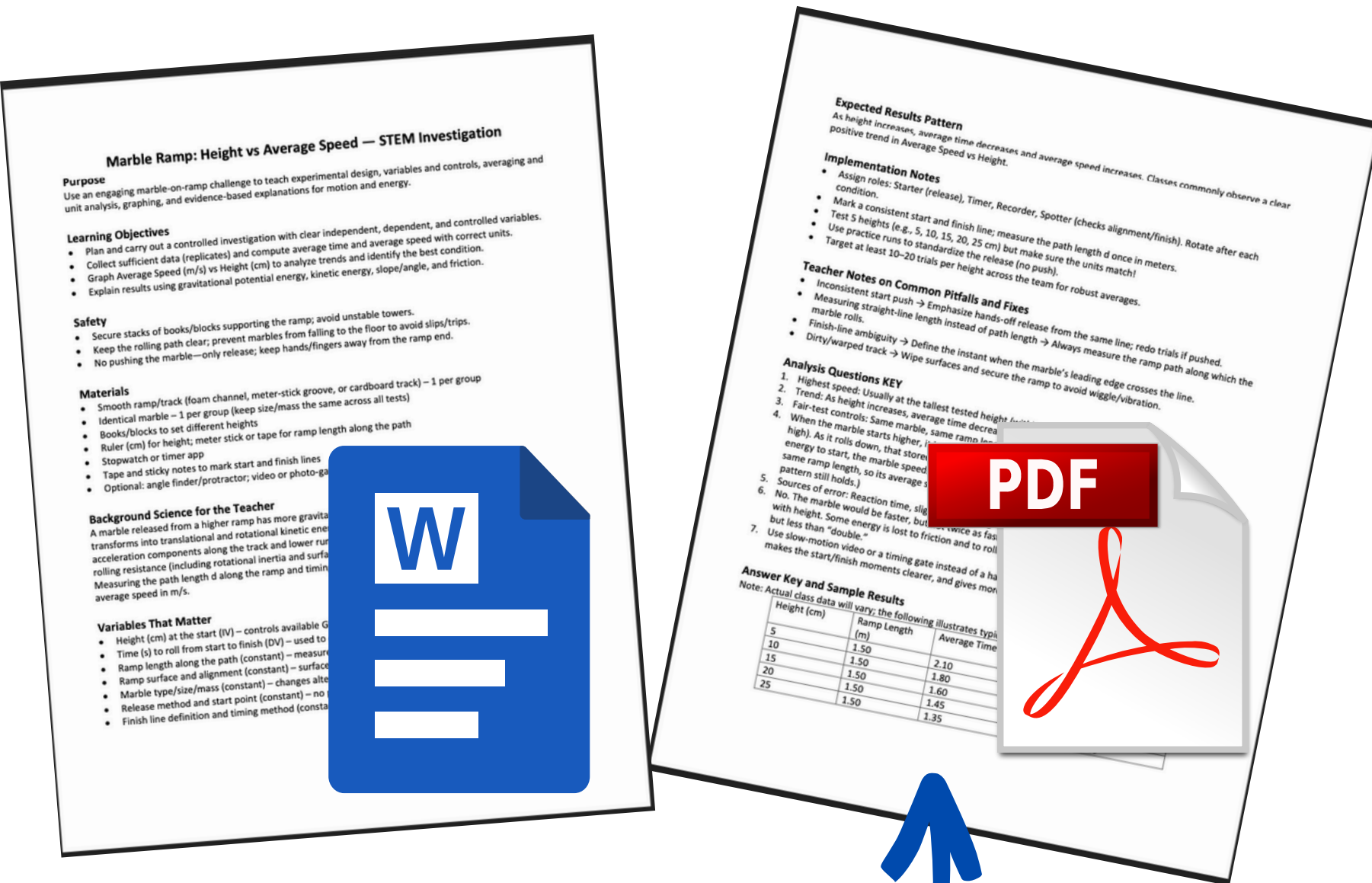
Create a bar or line graph with Average Speed (m/s) on the y-axis and Height (cm) on the x-axis.



Analysis Questions

1. Which height produced the highest average speed? Include values from your summary table.
2. Describe the overall trend you observe between height and average speed.
3. Name the most important controlled variables that kept this a fair test.
4. Explain why increasing height tends to increase speed using the ideas of gravitational potential energy and kinetic energy.
5. Identify two sources of error and explain how each could affect your results.
6. If you doubled the height, would you expect speed to double? Why or why not?
7. What is one improvement you would make for higher-quality data next time?

At School or at Home



Word and PDF
versions of the lab



Fully digital and editable - can be
done in class or through distance
education/homeschool



Ways to Use this Resource



Introduce the Scientific Method



Reinforce key ideas like forces, motion, and energy



Teach data analysis and graphing



Formative or Summative Assessment

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Variables That Matter

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- Release method and start point (constant) — no push; same start line every trial.
- Finish line definition and timing method (constant) — stop timing when the front reaches the line.

Expected Results Pattern
As height increases, average time decreases and average speed increases. Classes commonly observe a clear positive trend in Average Speed vs Height.

Implementation Notes

- Assign roles: Starter (release), Timer, Recorder, Spotter (checks alignment/finish). Rotate after each condition.
- Mark a consistent start and finish line; measure the path length d once in meters.
- Test 5 heights (e.g., 5, 10, 15, 20, 25 cm) but make sure the units match!
- Use practice runs to standardize the release (no push).
- Target at least 10–20 trials per height across the team for robust averages.

Teacher Notes on Common Pitfalls and Fixes

- Inconsistent start push → Emphasize hands-off release from the same line; redo trials if pushed.
- Measuring straight-line length instead of path length → Always measure the ramp path along which the marble rolls.
- Finish-line ambiguity → Define the instant when the marble's leading edge crosses the line.
- Dirty/warped track → Wipe surfaces and secure the ramp to avoid wiggle/vibration.

Analysis Questions KEY

- Highest speed: Usually at the tallest tested height (within a safe range).
- Trend: As height increases, average time decreases and average speed increases.
- Fair-test controls: Same marble, same ramp length/surface, same start/finish, same release/timer.
- When the marble starts higher, it has more gravitational potential energy (stored energy because it's up high). As it rolls down, that stored energy changes into kinetic energy (energy of motion). With more stored energy to start, the marble speeds up more on the way down. That means it takes less time to travel the same ramp length, so its average speed is higher. (Friction and small bumps can slow it a bit, but the overall pattern still holds.)
- Sources of error: Reaction time, slight pushes, height measurement error, misaligned track.
- No. The marble would be faster, but not twice as fast. Speed doesn't increase in a simple one-to-one way with height. Some energy is lost to friction and to rolling (the marble also spins), so the gain in speed is real but less than "double."
- Use slow-motion video or a timing gate instead of a handheld stopwatch. This cuts reaction-time error, makes the start/finish moments clearer, and gives more reliable times for calculating average speed.

Answer Key and Sample Results
Note: Actual class data will vary; the following illustrates typical patterns and calculations.

Height (cm)	Ramp Length (m)	Average Time (s)	Average Speed (m/s)	Trials
5	1.50	2.10	0.71	20
10	1.50	1.80	0.83	20
15	1.50	1.60	0.94	20
20	1.50	1.45	1.03	20
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Download my Angle of Attack STEM Lab FREE
CLICK HERE

Paper Airplane Angle of Attack STEM Lab

Scientific Method • Variables • Data & Graphing

✓ Classroom-Ready

✓ Data tables + bar graph templates included



✓ Teacher guide with setup, safety, background science, pacing

✓ Step-by-step procedure for testing

✓ Analysis questions with model answers and Rubric



Paper Airplane: Angle of Attack STEM Investigation: Scientific Method Activity

Teachers Reference:

Angle of Attack Explained - <https://youtu.be/D1J1oUP-aKA?si=vsnb9a72PajoWnZs>



Purpose

Use a high-engagement paper-airplane challenge 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 angle conditions.
- Graph distance data to analyze trends and construct evidence-based claims.
- Explain the physical principles (lift, drag, stall) that affect flight distance.

only airplanes; no paper clips or sharp nose cones.
a clear launch lane; stand behind the throw line; throw parallel to the floor.
ing area clear; retrieve planes only after all throws in a round are complete.

- Use a standard 8.5x11 in. — identical for all planes
- Use a standard template (optional, one standard design for all teams)
- Use a protractor (or angle guides) to set release angle relative to horizontal
- Tape for a throw line and distance marks; measuring tape or meter tape
- Data sheets (included), clipboards, pencils

Background Science for the Teacher

Lift vs Angle of Attack (AoA): Lift generally increases with AoA up to a point. Beyond a critical AoA, airflow separates (stall), causing lift to drop and drag to rise, shortening distance.

Drag and Energy: Higher AoA increases frontal area and induced drag; too much drag slows the plane quickly. Moderate AoA balances adequate lift with manageable drag for a longer glide.

Consistency: A single plane design, constant throw force/height, and a clear angle-setting method are key to fair comparisons.

Expected Results Pattern

- Distances typically peak at a moderate AoA (around 10°–15° for a simple dart design).
- Very low AoA (0°–5°) may dive or fail to generate a strong glide; very high AoA (20°+) often stalls or climbs then falls rapidly.
- As throw technique becomes consistent, variation decreases and the distance curve vs angle becomes clearer.

Implementation Notes

- Use one standard airplane design per class for consistency (provide a template or model).
- Assign roles: Thrower, Angle Setter/Checker, Measurer, Recorder. Rotate roles between angles.
- Mark the throw line and measure angle at release using a protractor or an angle card taped to the forearm or launcher guide.

Answer Key and Sample Results

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

Sample Summary Data

Angle (°)	Average Distance (m)
0	7.8
5	10.6
10	12.9
15	12.1
20	8.9

Interpretation

- Greatest average distance at 10° (=12.9 m) with a close second at 15° (=12.1 m).
- Very low angle (0°) underperformed (dives/low lift). Very high angle (20°) lost distance (near-stall and higher drag).
- The trend supports a moderate-angle optimum due to balance of lift and drag.

Model Responses to Analysis Questions

- Best angle: 10° with an average of ~12.9 m (our class graph shows a peak around 10–15°).
- Consistency: Results were reasonably consistent after the practice round; using the same thrower and angle card reduced variation.
- Controls that mattered most: Plane design and paper type, release height and throw force, indoor/no-draft room, and measuring to first contact.
- Follow-up: Test nose mass with paper clips at the best angle. Hypothesis: Adding a small nose mass (1–2 clips) will increase distance by improving stability without greatly increasing drag.

STEM INVESTIGATION BUNDLE

Build a high-engagement, low-prep STEM program.

- This Bundle includes my best STEM investigations—each one built around true engineering design, fair testing, repeated trials, data tables, graphing, and CER writing.
- STEM develops crucial skills like critical thinking and creativity and prepares students for a changing world and future opportunities.



Tell me and I forget. Teach me and I remember. Involve me and I learn. - Benjamin Franklin



STEM Investigation Growing Bundle

Scientific Method • Variables • Data & Graphing

✓ Classroom-Ready

✓ A Variety of Science Topics Included



**Click to
learn more!**

As a special bonus, I want to send you a few resources that you can use in your classroom tomorrow. Completely free and geared towards what you teach!



Just  **and then choose what you teach!**

thanks
**for your interest
in this resource!**

