COMPANION GUIDE · VOLUME 1 · GRAVITY GAMES

the Shoebox Lab *Kit Series*

Gravity Games

A Racing Science Adventure

ADULT FACILITATOR COMPANION

AUDIENCE	GRADES	TIME	ACTIVITIES
Facilitator + Learner	3–5	~3–4 hrs	3 + Challenge

Welcome to Gravity Games!

GRADES	AGES	TIME	ACTIVITIES
3-6	**8-11**	**about 3-4 hours**	**3 + Challenge**

This kit is a science lab in a box. The child will build cars, race them down ramps, and learn real science. They will learn

- What gravity is — and how it moves your car
- The difference between stored energy and motion energy
- How changing the car and the ramp change how far a car rolls
- How to collect data and use it to make real design choices

Everything you need is in the box. It is all the child's to keep. Keep the box — everything stores back inside!

YOUR JOB IS SIMPLE: ASK QUESTIONS. DON'T GIVE ANSWERS.

You do not need to be a science expert. The kit, the workbook, and the videos help the child learn.

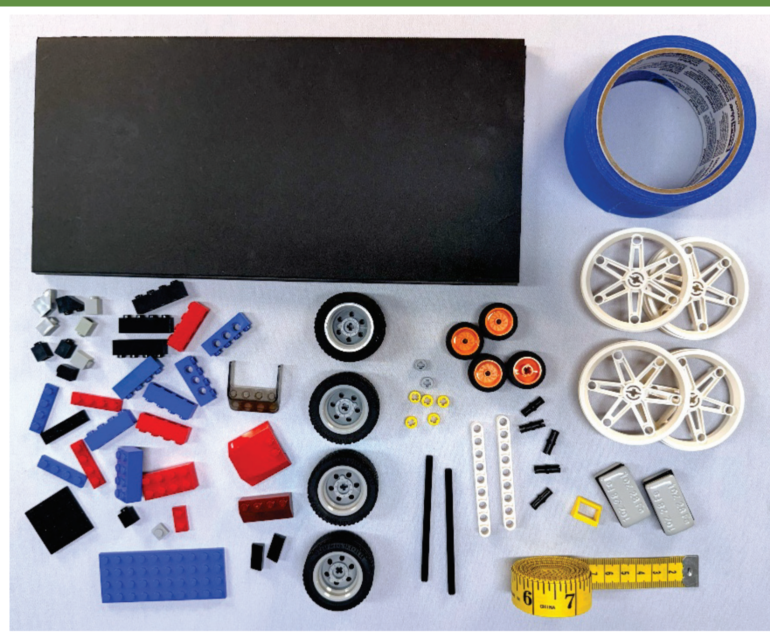
WHAT IS IN THE KIT?

Check the box: is everything there?

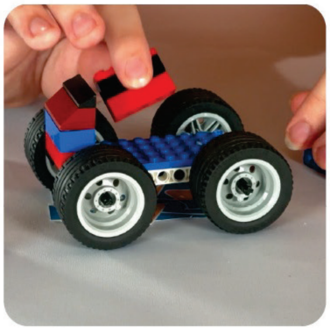
- Building bricks (including wheels, axles, body bricks)
- 2 weighted blocks
- 1 ramp board (foamboard)
- Measuring tape
- This workbook + a pencil

You will also need a few large, heavy books from home.

Note: Elements in the kit may be different colors



How It Works




1 BUILD	2 TEST	3 WRITE	4 TALK
The child builds.	**The child tests.**	**The child writes what happened.**	**You talk about it together.**

The workbook leads the child step by step. Children can do most steps alone. The best part? Doing it together. Who knows, you might learn something, too!

ONE TIP: DON'T CORRECT A GUESS BEFORE THE TEST!

Wrong guesses can be good science. – Let the tests show the answers.

WHAT TO SAY

"What do you notice?"

"What do you think will happen?"

"Show me how it works."

"What changed?"

"Why do you think that happened?"

"Great try — test it again!"

Children often learn to read English fast. If they want, let the child read the workbook out loud to you!

Watch the Videos

SCAN ME

GG • All Videos
shoeboxlab.org/gg

GG • Activity 1	GG • Activity 2	GG • History Spotlight	GG • Activity 3	GG • Science Spotlight	GG • Grand Challenge

No reading is needed. Every step is in a short video. Scan a code with a phone camera. Watch together before you build. Each activity has its own code — find it in the table.

What are the Activities

Activities at a Glance

	Activity	WORKBOOK	THIS GUIDE	VIDEO
1	**Build & Roll — Ramp Angle Test** *Does ramp height change distance?*	pp. 4–8	p. 11	gg1
2	**Load It Up — The Weight Test** *Does car weight change distance?*	pp. 9–11	p. 14	gg2
H	**History Spotlight — Ramps Long Ago** *Ramps in history and today*	pp. 12–13	p. 20	gg6
3	**Size It Up — Wheel Size Test** *Does wheel size change distance?*	pp. 14–16	p. 17	gg3
S	**Science Spotlight — Gravity & Energy** *The why behind the results*	pp. 17–18	p. 22	gg5
★	**Challenge — Build the Best Car** *Put it all together*	pp. 19–21	p. 24	gg4

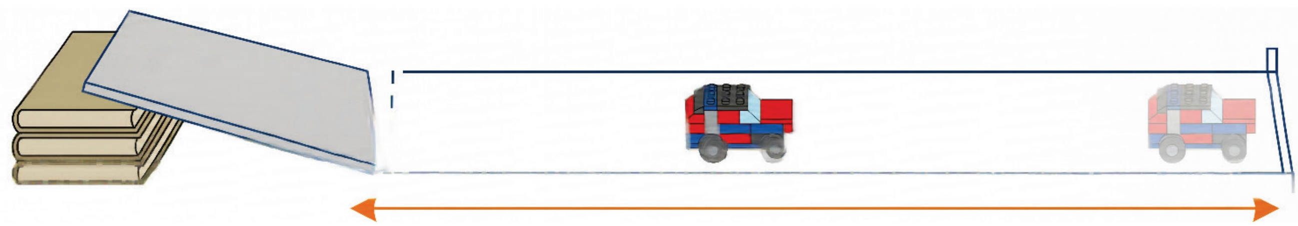
Three Safety Rules · You're Ready!

✓ THREE SAFETY RULES

1. Give the car room to roll.
2. Keep small bricks away from little children.
3. Test on a smooth, flat floor.

✓ BEFORE THE FIRST RUN

- Gather at least 5 books of similar thickness.
- Clear 6–8 feet of smooth, hard floor.



YOU'RE READY!

Open the workbook to page 4. Bolt the Bear meets you there. Have fun!

! IF SOMETHING GOES WRONG !

- The car rolls off the side → check that the wheels spin free. Set the ramp on a flat spot.
- The car barely moves → move to a hard floor. Carpet slows it down.
- The numbers are all different → start every run at the same line. Tape marks the spot.
- You can't break the kit. Try again — that's what scientists do!

Need help?

The child is stuck → p 33.

Something sounds wrong (mix-ups) → p 31.

Check an answer → the end of each activity.

A science word → p 40.

A Note to the Facilitator

❖ HOW THIS GUIDE REFERS TO YOU AND THE LEARNER

A note on language used in this guide: the adult leading the session is called the facilitator, or "you" when addressed directly. The child doing the kit is called the learner. These terms are used throughout regardless of your relationship — adult facilitator, grandparent, homeschool educator, older sibling, or any other trusted adult.

Welcome — and thank you for taking the time to do this with the learner in your life. You don't need a science background, a teaching degree, or any special equipment beyond what's in this box. What you do need is curiosity, a willingness to ask questions rather than give answers, and a bit of floor space.

This kit is designed so that the learner does the discovering. Your job as the facilitator is to set up the experiment, ask the right questions at the right moments, and get out of the way. This guide gives you those questions, explains the science behind what's happening, and tells you what to expect at each step — including when things don't go as planned.

A few things worth knowing before you begin:

- You do not need to read this guide front to back. It is a reference. Section 2 (Activity Guide) is the part you will use most — work through it alongside the student workbook.
- Unexpected results are not failures. When the learner's data doesn't match their prediction, that's science working correctly. This guide helps you turn those moments into the best teaching opportunities in the kit.
- The kit works equally well spread across several days or completed in a single long session. Session suggestions are in Section 1.

MEET BOLT THE BEAR

Bolt appears throughout the student workbook as a mascot and guide. When the learner reads a "Bolt Says" box, feel free to read it together — they're often the most important tips in that section.

How This Guide Is Organized

This guide has five sections. You don't need to read them in order — skim the table below, find what you need, and come back as questions come up.

Section	What It Contains	When to Use It
1 — Before You Begin *page 8*	Kit checklist and how to set up your space — read this before Session 1.	*Read before Session 1*
2 — Activity Guide *page 11*	Step-by-step facilitation for each activity: learning goals, prep tips, questions to ask, and what good results look like.	*Use alongside the student workbook*
3 — Supporting the Learner *page 29*	Opens the For Teachers & Group Leaders pages: the science primer, grade tips, common mix-ups, and troubleshooting.	*Reference when needed*
4 — Standards & Awards *page 36*	Full Next Generation Science Standards (NGSS) alignment, math connections, and Cub Scout Adventure connections.	*For homeschool documentation or program tracking*
5 — Quick Reference *page 40*	Word Watch answer guide for every vocabulary term, plus suggested outside resources.	*Use after finishing the kit*

SECTION 1

Before You Begin

This section gives you everything you need to run the kit well: what's in the box, how to set up your space, and a plain-language primer on the science. You don't have to read every word before Session 1 — skim what's useful and come back as questions come up.

1.1 Kit Contents

Confirm the following items are in the kit before your first session:

Kit Item	Notes
Building-brick base plate (×1)	The car's chassis — connects to axles and wheels
Wheel sets (×3 sets)	Original, small, and tall wheels for Activity 3
Body bricks (assorted)	For building up the car body
Weighted blocks (×2)	Set aside in their own bag — do not use until Activity 2
Ramp board (×1)	Foamboard; check for warping before use
This companion guide	You're reading it!
Student workbook	One per learner participating

You will also need to supply:

- 3–5 large heavy books (encyclopedias, textbooks, or large hardbacks work well)
- A measuring tape or ruler (metric preferred — centimeters give more precise readings)
- A pencil
- A flat running surface — see Section 1.2
- A strip of painter's tape (to mark a consistent release point on the ramp)

1.2 Setting Up Your Space

The ideal setup is a smooth hard floor (hardwood, tile, or laminate) with at least 6–8 feet of unobstructed running space in front of the ramp. A hallway works exceptionally well.

Place a strip of painter's tape across the floor at the base of the ramp as a fixed measurement start line. This ensures every distance is measured from the same point across all activities.

IF YOUR HOME HAS MOSTLY CARPET

Carpet significantly increases friction and will shorten the car's travel distance, reducing the visible differences between test conditions. The kit still works on most carpets, but a consistent smooth runway helps. Try any of the following — no new materials needed:

- Unroll a yoga mat smooth-side up
- Lay a tablecloth tightly over the carpet — tape the edges so it doesn't bunch
- Or a large piece of cardboard works well

(Note: the ramp board itself is in use as the ramp, so it can't double as the running surface.)

CONSISTENCY MATTERS MORE THAN PERFECTION

Whatever surface you use, keep it identical for every run across every activity. A carpet surface used consistently will still show clear differences between conditions — but a surface that changes mid-kit hides those differences.

RUNNING THE KIT WITH MULTIPLE LEARNERS

If more than one learner is participating, assign roles for each run: one learner releases the car (without pushing), another marks where it stops, and a third records the measurement. Rotate roles between runs to keep everyone engaged.

⚠ SAFETY NOTES

- Position the ramp so it does not face a stairway, a drop-off, or a pet's food or water area. At steep ramp angles, the car can travel with surprising speed.
- Small bricks are a choking hazard for children under three — keep younger siblings out of the workspace during build-out and between sessions.

Suggested Session Schedule

Now that your space is set up, here's a suggested pacing for getting through the kit:

Session	Activities	Estimated Time
Session 1	Activity 1 (Ramp Angle) + Activity 2 (Weight Test)	80–100 min
Session 2	Ramps Throughout History + Activity 3 (Wheel Size Test)	50–70 min
Session 3	Science Spotlight + Grand Challenge	60–80 min
Total		~3–4 hours

FOR HOMESCHOOL FACILITATORS

These three sessions map cleanly onto three lesson periods and can be spread across a week without losing continuity. The Science Spotlight in Session 3 works well as a short read-and-discuss lesson that directly prepares the learner for the Grand Challenge.

Before You Open the Kit: What Your Learner Already Knows

Before you open the kit with your learner, spend three to five minutes in conversation. Their answers will tell you where to pitch the activities, what vocabulary to reinforce, and which misconceptions to watch for. You don't need to correct anything yet — just listen and jot a quick note if something surprises you. You'll come back to these same ideas at the end of the kit.

- What do you already know about gravity? Where have you felt it?
- If we roll a car down a ramp, what do you think makes it go farther or shorter?
- Have you ever done an experiment where you changed one thing at a time to see what happened?
- What would you like to find out by the end of this kit?

SECTION 2

Activity Guide

This section walks through each activity. Every activity has the same rhythm: a short build, a test with data, and a reflection. You don't need to read it all before you start. Work through it with the student workbook, one activity at a time.

Each activity opens with learning goals, standards, and a “Before the Session” checklist. While you work, use the Questions to Ask sidebar for prompts. The Answer Guide at the end of each activity covers the workbook's Reflect questions. Read it yourself before the learner gets there.

ACTIVITY 1

Build & Roll: The Ramp Angle Test

LEARNING GOALS

For the learner to understand…

- How the height of a ramp changes how far the car travels
- How to record data consistently across three trials
- How starting height builds up stored energy — the intuition behind Potential Energy, which gets formal treatment in the Science Spotlight

STANDARDS AT A GLANCE

Primary: 3-PS2-1, 3-PS2-2

Also supports: K-PS2-1, K-PS2-2, K-2-ETS1-2, K-2-ETS1-3

Full alignment details are in Section 4.

TIME BUDGET FOR THIS ACTIVITY

Build ≈ 20 min · Investigate ≈ 30 min · Reflect ≈ 10 min

A short break between the build and the investigation helps — the build uses different muscles than the data-collection work that follows.

✓ BEFORE THE SESSION

1. Confirm you have at least 5 books of similar thickness for consistent height increments.
2. Place a strip of painter’s tape at the base of the ramp as a fixed start point for measuring.
3. If you have time, do a test run yourself before the learner starts — this gives you a realistic sense of distances and lets you spot any setup issues in advance.

How the activity runs

The learner starts by building the car using the included bricks *(workbook pp. 4–7)*. They then run three trials at each of four ramp heights — 1, 2, 3, and 5 books — recording distance for each in the data table *(workbook p. 8)*. The activity closes with reflection questions. Figure 1 shows what a single run looks like.

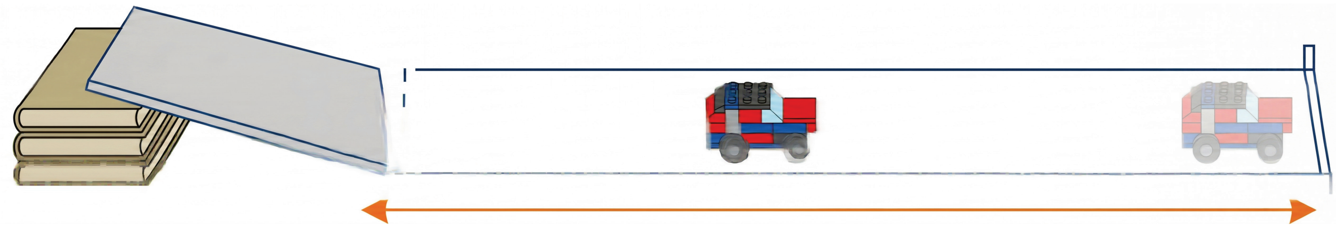


Figure 1. *One run of the ramp-angle test: the car leaves the ramp and coasts until friction stops it. The learner measures how far it travels from the bottom of the ramp.*

Your job during the test: keep the release point the same every run. Keep the learner measuring, not rushing to the next trial. And don't predict for them. The pattern lands best when the learner finds it in their own data.

WHY THREE TRIALS?

The workbook asks for three trials at each height — not one. The reason: any single run can be thrown off by a tiny variation (the car's release angle, a wheel-wobble). Taking and examining three measurements lets the learner see where the "real" answer sits. This is the same reasoning behind repeated trials in professional science — and it's one of the most portable habits the kit teaches.

✎ QUESTIONS TO ASK THE LEARNER

During the build: *Why do you think the wheels need to spin freely? What would happen if they were stuck?*

Before the first run: *Before we try it — what do you predict will happen when we add more books? Why?*

After each run: *Did that match your prediction? What surprised you?*

After all runs: *Look at your data (the distance values). Is there a pattern? Can you describe it?*

★ Challenge question: *Do you think a ramp that goes straight up — like a wall — would make the car go the farthest? Walk me through your thinking.*

○ WHAT GOOD RESULTS LOOK LIKE

Expected range. On a smooth, hard floor, expect distances of 20–30 cm with 1 book, rising to 80–120 cm with 5 books. These ranges vary significantly by floor surface. Small differences between trials are normal — that's exactly why the workbook calls for three trials per height.

If results look off. If the results don't show a clear upward trend, check that the car is being released from the same starting point each run and that the ramp hasn't shifted between heights.

→ GOING FURTHER

- Run the same four heights on a different surface (carpet vs. tile) — a natural introduction to friction without naming it formally.
- What if the ramp were longer but at the same height? Does length matter, or only height? This previews the inclined plane concept from the Ramps Throughout History section.

Activity 1 — Answer Guide

These notes describe the type of thinking to listen for in each Reflect question *(workbook p. 8)* — they are not scripted answers. ★ marks the challenge question.

Q1: How did the distance change as you added more books?

Key ideas: The car went farther as more books were added. A strong answer names the pattern — "every time I added a book, the car went farther" — not just one result.

If stuck: "Can you look at your data table and describe the pattern across all four heights?"

Q2: Which ramp height made the car go the farthest?

Key ideas: Should name the highest book count they used. A strong answer says why: the car started higher, so it stored more energy.

If stuck: "Why do you think the highest ramp made the biggest difference?"

★ Challenge: If you could add 10 books, would the car keep going farther?

Key ideas: The best answers see that at some point the car would tip, slide, or fall instead of rolling. Any reasoned answer works. Look for the learner wrestling with the question, not just saying "yes."

If stuck: "At what angle do you think the car would stop rolling smoothly? Sketch what you think would happen."

CARRYING FORWARD TO ACTIVITY 2

You just watched height change the car's final distance. Higher ramp, more potential energy, longer roll. In Activity 2 the ramp stays at one angle and the car's weight changes instead. Ask the learner to predict before the first run: "If height mattered, do you think weight will too? Why?" Their reasoning now — right or wrong — is exactly what you want to capture. Activity 2 will confirm, challenge, or complicate it.

ACTIVITY 2

Load It Up: The Weight Test

LEARNING GOALS	STANDARDS AT A GLANCE
For the learner to understand… ▪ How to isolate a single variable in a fair test ▪ How the mass (weight) of the car affects travel distance ▪ How mass and height each contribute to stored energy — setup for the Science Spotlight	**Primary:** 3-PS2-1, 4-PS3-1, 4-PS3-2 **Also supports:** K-PS2-1, 3-5-ETS1-3 Full alignment details are in Section 4.

TIME BUDGET FOR THIS ACTIVITY

Setup ≈ 5 min · Investigate ≈ 25 min · Reflect ≈ 10 min

Activity 2 reuses the car from Activity 1 — no rebuild needed. If you're running Activities 1 and 2 back-to-back in one session, a short water break between them helps the learner reset for a new question.

✓ BEFORE THE SESSION

1. Confirm the ramp will be set at exactly 2 books for every run — this is the single most common setup error in this activity.
2. Consider a brief conversation about fair testing before the activity begins: "What does it mean to make a fair experiment? What would make this test unfair?"
3. Make sure the weighted brick is pressed firmly onto the car before each run — a loose brick can shift mid-run and compromise the result.

How the activity runs

The learner reuses the car from Activity 1. They run three trials at one ramp height (2 books): first as is, then with one weight, then with both weighted bricks. Distances go in the data table (workbook p. 10).

Your job during the test: keep the ramp height the same. Hold the line on "one thing changes at a time." And don't predict with the learner. The point here isn't the answer. It's the habit of changing one thing and watching what happens.

Background for the facilitator — the concept of a fair test

This activity teaches one of the biggest ideas in science. To know whether one thing causes another, change only that one thing. Keep everything else the same. Scientists call this controlling variables. If the learner changes two things at once, such as ramp height and car weight, ask them to reset the ramp height first. Figure 2 shows the comparison they are making.

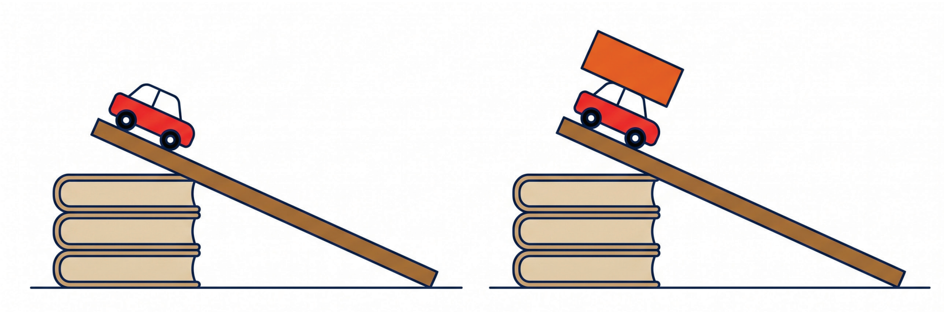


Figure 2. *A fair test in action: the ramp height stays the same in both setups, and the only thing that changes is the weight added to the car.*

✎ QUESTIONS TO ASK THE LEARNER

Before the first run: *What are we changing in this activity? What's staying the same?*

After the light-car run: *Write down your prediction for the heavy car before we test it.*

After comparing results: *What caused the difference? How do you know it was the brick and not something else?*

Connecting the two activities: *More height made the car go farther in Activity 1. More weight did something similar here. What do height and weight have in common?*

○ WHAT GOOD RESULTS LOOK LIKE

Expected pattern. The heavier car generally travels farther on smooth surfaces — but the difference can be more modest than the learner expects. That's a genuine result worth discussing.

If results look off. If results seem reversed or inconclusive, check wheel alignment (a slightly crooked wheel creates drag), verify the starting position, and check for floor irregularities. If results remain inconsistent after three careful trials, explore the causes together rather than dismissing the data — that's the interesting part of science.

→ GOING FURTHER

- If you have other small weights, try adding more — does adding mass always increase distance, or is there a point of diminishing returns?
- Shift the weighted brick to different positions on the car (front vs. back vs. center) — does placement of weight matter, or just total amount?

Activity 2 — Answer Guide

These notes describe the type of thinking to listen for in each Reflect question *(workbook p. 11)* — they are not scripted answers. ★ marks the challenge question.

Q1: Which car traveled farthest — lightest, medium, or heaviest?

Key ideas: The heavy car usually wins. A strong answer gives numbers from the table, not just "it went farther."

If stuck: "By how much did the heavy car go farther? Is that a big difference or a small one?"

Q2: Were you surprised by the result? What did you expect to happen?

Key ideas: Any honest answer works. The goal is for the learner to think about whether their guess matched the data.

If stuck: "If you were surprised, what caused the surprise? If you weren't, what gave you the right intuition?"

★ Challenge: If you added more weight to the car, what would happen?

Key ideas: A strong answer uses the Activity 2 data. It also sees there could be limits. Look for reasoning, not one right answer.

If stuck: "Could you test that? What would you need to do to make it a fair test?"

CARRYING FORWARD TO ACTIVITY 3

Height and weight both changed distance. Now the learner has tested two of the three big variables. Activity 3 looks at the car itself — specifically, wheel size. Before you begin, ask: "Wheels don't store energy the way height and weight do. So what do you think bigger wheels change?" Listen for ideas like friction, rolling, or how easily the car starts. All of these are worth exploring in the data, regardless of whether they turn out to matter.

ACTIVITY 3

Size It Up: The Wheel Size Test

A NOTE FOR THE FACILITATOR BEFORE YOU BEGIN

Heads-up: this activity is intentionally less dramatic. Activities 1 and 2 were designed to produce clear, satisfying results. Activity 3 is designed to produce subtler differences — and that's educationally intentional. In real engineering and science, not every variable has a large effect. Learning to interpret small or ambiguous results is a genuine scientific skill. Resist the urge to tell the learner what the data "should" show.

LEARNING GOALS

For the learner to understand…

- How to apply fair-testing principles independently, without reminders
- How to interpret subtle or ambiguous results — not every variable produces a dramatic difference, and that's a real scientific finding
- How to begin synthesizing findings across multiple activities

STANDARDS AT A GLANCE

Primary: 3-PS2-2, 3-5-ETS1-2, 3-5-ETS1-3

Also supports: 4-PS3-1

Full alignment details are in Section 4.

TIME BUDGET FOR THIS ACTIVITY

Setup ≈ 5 min · Investigate ≈ 30 min · Reflect ≈ 10 min

✓ BEFORE THE SESSION

1. Confirm the ramp is set at the same height used in Activity 2 (2 books) — the only variable is wheel type.
2. Lay out all three wheel sets so the learner can see them clearly before beginning.
3. Encourage the learner to make a written prediction before swapping wheels: "Which wheel type do you think will go the farthest, and why?"

How the activity runs

The learner runs three trials per wheel type: original, small, and tall. All at the same 2-book ramp height as Activity 2. Distances go in the data table (workbook p. 16). By the end they have data from all three activities, and can compare which change mattered most.

✎ QUESTIONS TO ASK THE LEARNER

Before starting: *You've already tested ramp angle and weight. What do you think wheel size will change? Make a prediction before you swap.*

After the original-wheels run: *How will you know if a different wheel makes a real difference?*

After small wheels: *Was the difference bigger or smaller than you expected? What might explain that?*

After tall wheels: *Look at all three rows. Which wheel type gave the best result? Why might that be?*

Looking across all activities: *Which change had the biggest effect? Can you back that up with numbers?*

○ WHAT GOOD RESULTS LOOK LIKE

Expected pattern. Wheel size effects are genuine but often modest. Taller wheels may cover more ground per rotation; smaller wheels may spin faster but cover less distance each rotation. Results can surprise even experienced facilitators.

If results look inconclusive. If the learner's data doesn't show a clear winner, use that: "Your data shows almost no difference here. Does that mean wheel size never matters — or just that it didn't matter much in your test? How could you find out?" This is the kind of thinking professional scientists do every day.

→ GOING FURTHER

- Try wheels of very different sizes if additional wheel types are available — does a larger size difference produce a clearer result?
- Try the same three wheel types on a different surface — does the surface interact with wheel size in an interesting way?

Activity 3 — Answer Guide

These notes describe the type of thinking to listen for in each Reflect question *(workbook p. 16)* — they are not scripted answers. ★ marks the challenge question.

Q1: Which wheel type made the car travel farthest?

Key ideas: Results will vary. A strong answer reports the data honestly and tries to say why. Tall wheels may cover more ground per turn. Small wheels spin faster but cover less each turn.

If stuck: "What does your data say? Is that what you expected?"

★ Challenge: What car design would travel the farthest distance overall?

Key ideas: A strong answer pulls all three data sets together. Ramp height and car weight gave the clearest gains. Wheel size mattered less. It should point to real numbers, not just guesses.

If stuck: "Which activity gave you the best evidence? Can you point to the numbers?"

CARRYING FORWARD

Three variables, three data tables, three conclusions. This is a good moment to flip back through the three activities with the learner and compare findings side by side. Which change made the biggest difference? Which one surprised you? The upcoming Ramps Throughout History reading shifts the frame from testing ramps to thinking about how humans have used them for thousands of years — and the Science Spotlight on Gravity & Energy will tie it all together before the Grand Challenge.

FACILITATED READING

Ramps Throughout History & Ramps Today

This section is a change of pace on purpose: a reading and talking break. It shows the learner that the simple tool on your kitchen floor shaped human history, and is still at work all around us. Figure 3 shows a few old examples.

Figure 3. *Ramps have done heavy lifting for thousands of years — from raising the stones of the Egyptian pyramids and Stonehenge to hauling ships overland.*

How to Approach It at Home

- have the learner read it silently. Then work through the questions together.
- Prefer read-aloud: take turns reading one panel each.
- this section links to social studies. The old examples — the pyramids, Stonehenge, the Diolkos — pair with ancient civilization units. The “Ramps Today” panel (Figure 4) pairs with modern engineering and accessibility.

QUESTIONS TO ASK THE LEARNER

1. The Egyptians had no cranes or steel cables. What other problems do you think they had to solve to build the pyramids?
2. Can you think of a ramp you used or saw used today?
3. What do an ancient Egyptian engineer and the person who designed the wheelchair ramp at our local library have in common?
4. You just tested different ramp angles in Activity 1. If YOU were the engineer moving stone blocks up the pyramid, would you pick a steep ramp or a gentle one? Why?

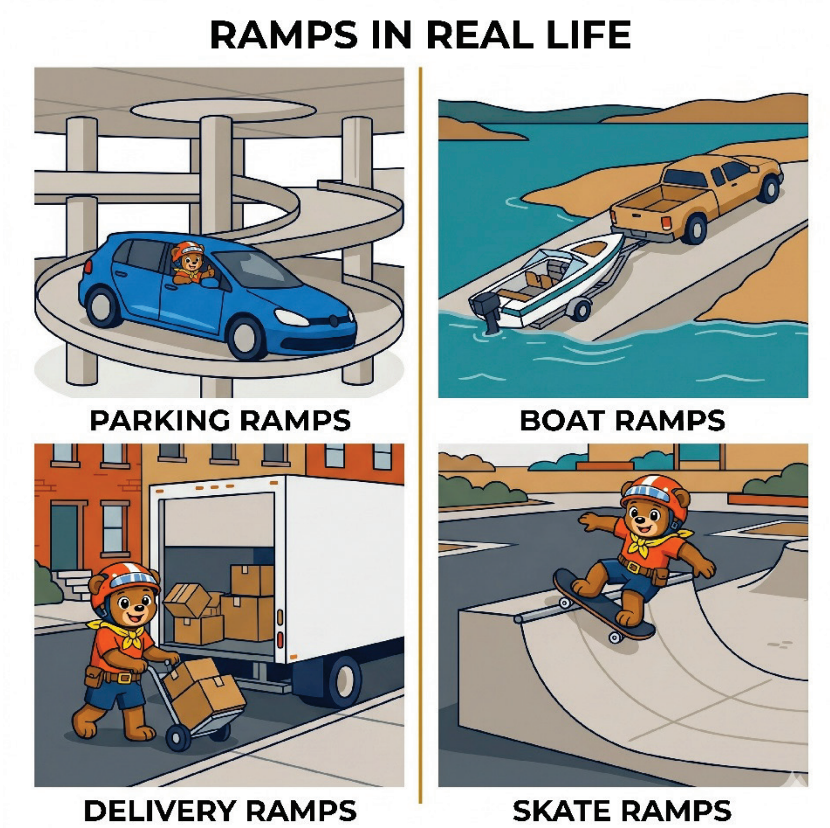


Figure 4. The same simple machine is all around us today. Look in parking garages, at boat launches, on delivery trucks, and at the skate park.

BRIDGE BACK TO THE EXPERIMENT

After the discussion, try this: "The Egyptians were doing exactly what you did in Activity 1 — figuring out the best ramp angle to move their load with the least effort."

SCIENCE SPOTLIGHT

Gravity & Energy

The Science Spotlight comes after all three activities on purpose. The learner has already seen gravity and stored energy at work. Now they get the words for it. Experience first, then the words — that order makes learning stick. Figure 5 traces the energy story from the top of the ramp to the floor.

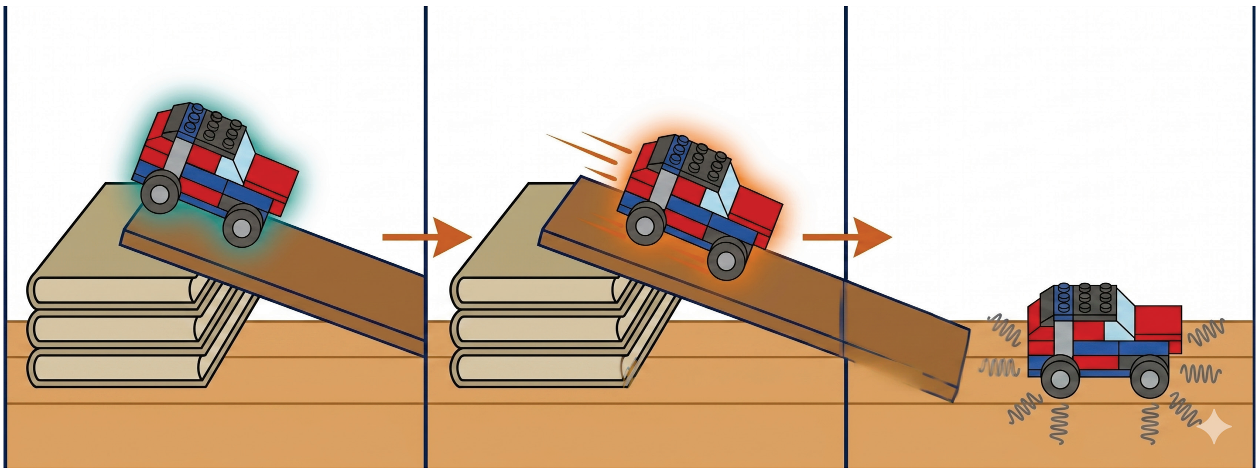


Figure 5. *Potential energy becomes motion: the car stores energy at the top of the ramp, speeds up as it rolls down, and spends that energy rolling across the floor.*

Connecting It to the World Outside the Kit

The same potential-to-kinetic story plays out everywhere. A few prompts to help the learner notice it in their own world:

- **Roller coasters.** The first hill is always the tallest. That is where the ride stores all its energy. Every hill after it must be shorter, because friction and air take some energy away.
- **A skier or sledder at the top of a hill.** Same setup as the ramp: height gives them stored energy, and the slope turns it into speed. A steeper hill feels faster for exactly the same reason a steeper ramp sent the car farther.
- **A toddler at the top of a playground slide.** A younger sibling, cousin, or neighbor is a great everyday example. The child climbs the ladder and stores energy. The slide turns it into a rush to the bottom. How slippery the slide is decides how much friction eats up.
- **A ball dropped off a kitchen counter.** Height gives it potential energy; gravity converts that to speed on the way down. Even a two-foot drop is the same physics as the ramp — just without the surface controlling the path.

A NOTE ON THE VOCABULARY

The three key terms — gravity, potential energy, kinetic energy — are introduced with everyday analogies. The learner does not need to recite formal definitions. The goal is that they can use these words naturally in conversation: "the car has more potential energy when the ramp is higher." If they can say something like that in their own words, they've understood it.

QUESTIONS TO ASK THE LEARNER

For the multiple-choice questions: *Don't just check the answer — ask "Why is B right?" and "Why is A wrong?" A correct answer without reasoning is less valuable than a thoughtful wrong answer.*

For question 3 (open-ended): *A strong answer connects potential energy to something concrete from real life or the experiment. If the learner writes the definition back verbatim, ask: "Can you give me an example of that from your own life?"*

If the learner is curious about the Newton apple story: *It's a great legend — but historians aren't sure it really happened the way it's usually told. What do you think matters more — the story, or the math Newton actually discovered?*

Background for the Facilitator — Key Ideas to Listen For

- **Gravity:** tie it to a downward pull and to what the learner felt, not just "a force."
- **Potential energy:** mention height or weight, and the idea of energy stored and waiting.
- **Kinetic energy:** tie it to movement, and to the switch from stored energy.

Science Spotlight — Answer Guide

The multiple-choice items check themselves in the workbook. The notes below cover what to listen for on the open question.

Q3: Q3: In your own words: what is potential energy? Give a real-life example!

Key ideas: The learner should say potential energy is stored energy. Then they give an example tied to height or weight. A ball on a hill. A stretched rubber band. A coaster at the top of a drop. Just repeating the workbook definition is a developing answer.

If stuck: "Can you think of an example that has nothing to do with cars or ramps?"

GRAND CHALLENGE

Design Your Best Car

The synthesis moment. The learner uses evidence from all three activities to plan, build, test, and improve a car of their own design. Then they write an engineer's report on what they found.

LEARNING GOALS	STANDARDS AT A GLANCE
For the learner to understand… ▪ The full engineering design cycle: plan with evidence → build → test → evaluate → reflect. ▪ How to make deliberate design decisions backed by data rather than intuition. ▪ How to articulate design reasoning in writing — a critical skill in both science and engineering.	**Primary:** 4-PS3-4, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3 **Also supports:** 3-PS2-1, 3-PS2-2, 4-PS3-1, 4-PS3-2 Full alignment details are in Section 4.

★ YOUR ROLE IN THE GRAND CHALLENGE

Your most important job in this section: step back. The Grand Challenge is the learner's synthesis moment. If they make a design choice that contradicts their own data, don't correct it — ask: "Show me where in your data table you found the evidence for that choice." Let the data do the correcting.

✎ QUESTIONS TO ASK THE LEARNER

During planning: *"You're choosing [X books / the weighted brick / that wheel size]. Which activity gave you the evidence for that choice?"*

During building: *"Is this the car you designed on paper? If you changed something mid-build, why?"*

After racing: *"Compare your best run to your very first run in Activity 1. What caused that change?"*

Final reflection: *"If you had to explain to a younger kid why your car goes so far now, what would you say?"*

What a Good Finish Looks Like

It helps to know what a successful finish looks like so you can reinforce it. Listen for these three signs:

- **Evidence-based design choices.** The learner points to results from Activity 1, 2, or 3 to explain a choice. A good finish sounds like this: "I made it heavier because Activity 2 showed that helped." The car does not have to break records.

- **At least one test-and-revise cycle.** The learner ran the car at least twice and changed something between runs based on what they saw. The distance doesn't need to improve — what matters is that the revision was intentional.
- **A reflection that mentions a trade-off.** The learner sees that one change helped in one way and hurt in another. Or that their guess didn't quite match the result. That is the mark of engineering thinking — not the "right" answer, but reasoning about it.

Marking the End Together

Finishing the kit deserves a few minutes of shared closure. Choose whichever of these feels natural:

- **Return to the opening questions.** Ask the same questions you asked before opening the kit (see "Before You Open the Kit" in Section 1). Note out loud how the learner's answers changed.
- **Invite a "show and explain."** Have the learner show their final car to a parent, sibling, or friend, and explain what they figured out. Teaching someone else is the strongest test of understanding.
- **Name something specific you were impressed by.** Skip a general "good job." Try: "I liked how you kept going after your first run didn't work." Or: "You noticed something I missed — the second-heaviest car went farther than the heaviest." Specific praise lands.
- **Ask what they want to explore next.** "After doing this, what do you wonder about now?" Their answer is a gift — it points straight to the next thing worth learning about.

Grand Challenge — Answer Guide

These notes cover what to listen for in each Reflect question (workbook p. 21).

Q1: How does your best run compare to your first run in Activity 1?

Key ideas: The learner should give real distances and describe the gain. A strong answer says which design changes caused it.

If stuck: "What did you change that made the biggest difference?"

Q2: Which design choices made the biggest difference?

Key ideas: Should tie straight to the data. Ramp height and car weight mattered most. A strong answer cites real trial numbers as evidence.

If stuck: "How do you know those choices mattered? What data tells you that?"

Q3: If you could run one more experiment, what would you test?

Key ideas: Any reasonable, testable question is a strong answer. Look for something specific. Not "I would test something different" but "I would test whether a longer ramp board changes the result." New questions are especially strong.

If stuck: "How would you set that experiment up to make it fair?"

For Teachers & Group Leaders

The pages after this one go deeper: the science behind the kit, common mix-ups, grade tips, and standards. Parents can stop here — or keep reading!

A Quick Science Primer for Facilitators

This section gives you just enough background to feel confident facilitating each activity. You don't need to read it all before you start — return to it as each topic comes up in the kit.

What is Gravity?

Gravity is an invisible force that pulls every object toward the center of the Earth, constantly and without stopping. It is why objects fall when you drop them, why a learner returns to the ground when they jump, and — most relevant here — why the car rolls down the ramp rather than staying put or rolling up.

A useful analogy: think of gravity as an invisible hand that is always gently pressing everything toward the floor. The ramp doesn't create any force — it redirects the force that gravity is already applying. Without gravity, a car placed at the top of the ramp would simply sit there.

ON THE NEWTON APPLE STORY

The story of Isaac Newton being struck by a falling apple and suddenly "discovering" gravity is one of science's most charming legends — and worth sharing because it makes a real historical figure feel accessible. However, historians note that the story was first written down by Newton's friend, William Stukeley, many decades after Newton's death, and that Newton himself never recorded it. The apple, if it existed at all, almost certainly didn't hit him on the head. More importantly, gravity was already understood in general terms before Newton — what Newton actually added to our understanding was the mathematics to describe and predict it precisely.

Feel free to tell the story — just add "...or so the legend goes!" at the end. The learner will remember it just as well, and they'll have learned something true about how scientific history gets retold.

What is Potential Energy?

Potential energy is stored energy — energy that is waiting to be released. When the learner lifts the car to the top of the ramp, they are loading it with stored energy in the same way that stretching a rubber band stores energy. The higher the car starts, the more energy is stored; the heavier the car, the more energy is stored. Both factors are tested in Activities 1 and 2.

When the car is released, that stored energy converts into motion energy — called kinetic energy. The car moves because potential energy is becoming kinetic energy. The more potential energy is stored, the faster and farther the car travels.

Putting it together: as the car rolls down the ramp, the potential energy stored at the top converts steadily into kinetic energy (motion) and a smaller amount of heat and sound from friction. By the time the car reaches the floor, almost all of its potential energy has become motion; friction with the floor and the wheels then slowly bleeds that motion away, which is why the car eventually stops. If the learner asks why the car doesn't roll forever, this is the answer: energy didn't disappear — it moved into the floor, the wheels, and the air.

HOMESCHOOL NOTE

The formal term "gravitational potential energy" and its associated formula are typically introduced in Grades 6–8. This kit builds the intuitive foundation for that concept. The learner doesn't need to know the formula — they need to experience the relationship. That's exactly what the experiments provide.

What is an Inclined Plane?

An inclined plane is a flat surface tilted at an angle — a ramp. It is one of the six classical simple machines identified by Renaissance scientists (the others being the lever, wheel and axle, pulley, wedge, and screw).

The key principle: moving something up a ramp requires less force than lifting it straight up, but you have to move it over a longer distance. The total work done is the same either way — the ramp spreads it out. This is why the Egyptians could move multi-ton stone blocks with human labor, and why every loading dock, wheelchair ramp, and ski slope in the world works the same way.

In this kit, the ramp is used in reverse — instead of making it easier to push things up, gravity uses the ramp to convert height into forward motion. Both directions use exactly the same principle.

What is Friction?

Friction is a force that resists motion whenever two surfaces rub against each other. When the car rolls down the ramp and across the floor, friction is constantly pushing back against it — slowing it down, and eventually bringing it to rest. Without friction, a car released at the top of a ramp would, in principle, keep rolling forever across a level floor.

Three everyday things make friction bigger or smaller:

- **Surface roughness.** Carpet has much more friction than hardwood or tile. This is why Section 1.2 suggests a smooth runway.

- **How firmly surfaces press together.** A heavier car produces more friction against the floor — but it also has more stored energy, which is why the heavier car in Activity 2 still travels farther overall. The relationship is a tug-of-war.
- **What the surfaces are made of.** Rubber wheels on a wood floor behave differently than plastic wheels on tile. This is partly why Activity 3's wheel-size results can be subtle — the wheel material matters too, not just the size.

Friction is not a villain. Without it, the car couldn't grip the ramp at all; it would just slide sideways. Every time the learner changes floor surfaces or wheel types, they are implicitly experimenting with friction — whether they name it or not.

SECTION 3

Supporting the Learner

This section gives you three kinds of support: how to adjust the kit to the learner's grade level, a map of the most common misconceptions that come up, and a troubleshooting table for when something physical goes wrong.

3.1 Adapting the Kit by Grade

3rd Grade

The workbook is slightly above the independent comfort level of many 3rd graders — but that stretch is productive. A few adjustments help:

- Prioritize observation and description over formal explanation. "The car went farther because the ramp was higher" is a complete, correct answer at this level — do not push for "potential energy" language.
- Focus on accurate data recording as the primary skill. Three neat, consistent entries in the data table is a genuine achievement.
- The hypothesis prompt in the Grand Challenge may work better as a spoken prediction written down together than an independent writing task.
- The open-ended question 3 in the Science Spotlight quiz may work better as a spoken conversation than a written answer.
- The ★ challenge questions are optional — skip them if they create frustration. They are enrichment, not requirements.
- Build in more time: sessions may run 20–30 minutes longer for 3rd graders. Keep sessions under 60 minutes if attention begins to wane.

4th Grade

The workbook is calibrated for this level and should feel appropriately challenging without being overwhelming.

- Encourage use of vocabulary terms in written reflections — not as labels but in explanatory sentences. "It went farther" is a starting point; "it went farther because it had more potential energy stored at the top" is the target.
- Push gently on the "why" in reflection questions.

- The hypothesis prompt in the Grand Challenge should be completed in writing before building begins.
- The ★ challenge questions are appropriate and worth attempting.

5th Grade

Push for quantitative reasoning throughout: “by how much did it go farther?” not just “it went farther.”

- Encourage the learner to describe the difference between their best and worst runs and explain what that difference means.
- Ask the learner to write their own prediction for Activity 3 before reading the workbook prompts.
- The ★ challenge questions should be treated as required, not optional.
- Consider asking the learner to write a short “lab report” after the Grand Challenge — one paragraph on what they tested, what they found, and what they would do next. This bridges into middle-school science-writing expectations.

☖ MATH EXTENSIONS (GRADE 5)

Math extensions for homeschool facilitators who wish to add a math layer:

- **Plot distance vs. number of books** on a coordinate grid — connects to CCSS.MATH.5.G.A.1 (coordinate-plane graphing).
- **Look for patterns in the data** and describe the rule — connects to CCSS.MATH.5.OA.B.3 (patterns and relationships).
- **Calculate the difference between trial results** — connects to CCSS.MATH.4.NBT.B.4 (multi-digit subtraction).

3.2 Common Misconceptions & How to Address Them

These are the most frequent misunderstandings that come up in this type of experiment. You don't need to raise them proactively — use this section when you hear them.

? "HEAVIER THINGS ALWAYS FALL FASTER"

Why they think it: Intuition, plus the visible difference between dropping a feather and a rock.

The real science: In a vacuum, all objects fall at the same rate regardless of weight — Galileo demonstrated this. In everyday life, air resistance and friction create visible differences. The heavier car in this kit goes farther not because it falls faster, but because it stored more potential energy at the top of the ramp.

How to address it: Affirm the intuition — "that makes sense from what we usually see" — then redirect to the data: "But what did your numbers actually show? Let's look together."

? "THE RAMP IS PUSHING THE CAR FORWARD"

Why they think it: The ramp is tangible and visible; it's natural to credit it with the car's movement.

The real science: The ramp redirects gravity — it doesn't create force. Without gravity, a car at the top of the ramp would simply sit there. The ramp is a guide, not an engine.

How to address it: "What would happen if we did this experiment on the International Space Station, where everything floats? Would the car roll?" Let the learner reason it through. *(A note for you, not the learner: gravity at the Station is about 90% as strong as on the ground — astronauts float because the station is in constant free fall around Earth. "Everything floats" is the level a learner needs.)*

? "MORE HEIGHT ALWAYS MEANS MORE DISTANCE — WITH NO LIMIT"

Why they think it: The pattern holds perfectly within the range of the experiment, so it feels like a universal rule.

The real science: At very steep angles the car begins to tip or slide rather than roll; friction and air resistance impose real limits; at 90° the car would simply fall straight down.

How to address it: The ★ challenge question in Activity 1 is designed to surface this. Take it seriously: "Sketch what you think would happen at a really extreme angle — what would the car actually do?"

? "MY EXPERIMENT FAILED BECAUSE MY PREDICTION WAS WRONG"

Why they think it: Learners are often conditioned to associate "wrong" with "failure."

The real science: A wrong prediction is not a failed experiment — it's new information that demands explanation.

How to address it: "Your prediction was wrong — that's actually the most exciting thing that can happen in science. Now we get to figure out why. That's a new question, and new questions are how discoveries happen."

? "I SHOULD GET THE EXACT SAME NUMBER EVERY TIME"

Why they think it: Learners expect precision from measurement; variability feels like error.

The real science: Variability between trials is normal and reflects the real-world complexity of physical systems — slight differences in release position, floor surface, and wheel alignment all contribute.

How to address it: "Scientists always see some variation between runs — that's exactly why we do three trials instead of one. Three runs gives us a much better picture than one run ever could."

3.3 When Things Go Sideways: Troubleshooting

Use this table as a quick reference when something physical goes wrong mid-activity.

Problem	Likely Cause	What to Do
Car veers off the side of the ramp	Wheels misaligned or ramp not level	Re-check wheel attachment; center ramp carefully on a flat surface.
Results are wildly inconsistent	Starting position varies between runs	Mark a consistent release line at the top of the ramp with tape.
Car barely moves even on steep ramps	High-friction surface (carpet)	Move to hard floor, or lay down a smooth makeshift track (see Section 1.2).
Weighted brick falls off mid-run	Brick not firmly pressed on	Press firmly before each run — also a useful design lesson about secure connections.
Large gap between Trial 1 and Trials 2–3	“Warm-up” effect or floor debris on first run	Do an unpublished practice run first; discard obvious outliers.
Car travels too far and hits a wall	Insufficient floor space	Reposition ramp toward center of room; see Section 1.2 for space solutions.
Learner wants to skip Grand Challenge planning	Eager to build immediately	Hold the line: “Engineers always plan before they build — 5 minutes of planning will make your car better.”
Learner loses interest mid-activity	Pacing issue	Allow one completely free “fun run” with no measurement; then return to the experiment.

3.4 When the Learner Gets Stuck

Every kit has a moment where the learner goes quiet, shrugs, or says “I don’t know.” That is not failure — it is exactly where real thinking happens. The facilitator’s job in those moments is to stay present without rescuing. These five prompts work across grade levels and activities. Use whichever feels natural.

- “Tell me what you’re noticing so far.” (Starts observation without demanding an answer.)
- “What would you try first if you could change one thing?” (Opens action without prescribing.)
- “Can you show me in the data where that happened?” (Anchors claims in evidence without telling them if they’re right.)
- “That’s a real question. What could we do to find out?” (Converts a confused moment into an experiment.)

- Silence and a patient nod. (The single most underused facilitation tool. Five to eight seconds of quiet is often what unlocks the answer.)

A note on resisting rescue: if you give the answer the moment the learner hesitates, you save them from the brief discomfort of not knowing — but you also take the learning with you. Research on productive struggle (sometimes called “productive failure”) consistently shows that the effortful, uncertain part of a task is what builds the durable understanding. Waiting is a gift.

3.5 Adapting for Different Learners

Section 3.1 offered adjustments by grade. Learners also vary within a grade. The adjustments below are drawn from Universal Design for Learning (UDL) — none of them change what is being learned; they only change how the learner can access it. Use any combination that helps.

- **For a learner who reads below grade level:** read workbook instructions aloud and have the learner talk through their thinking rather than write it. The workbook can be filled in together with you scribing.
- **For a learner whose first language is not English:** the physical nature of the activities lets understanding show through action. Pair English terms with gestures; accept responses in either language; use photos as a record alongside written answers.
- **For a learner with attention or focus differences:** split each activity into 10–15-minute chunks. The three-session structure (Session 1, 2, 3) can easily become six short sessions. A brief reset between chunks — water, stretch, a moment outside — is fine; it does not break the science.
- **For a learner with fine-motor challenges:** pre-assemble the car or help with the measuring tape. The scientific thinking is in the predictions, observations, and reasoning — not in the building.
- **For a learner who is well ahead:** encourage them to add a fourth variable of their own design (e.g., surface type, ramp length) and run it as a bonus experiment — their Grand Challenge report can include it.
- **For a learner who is quiet or shy:** drawing or pointing to a data row is a valid response. Let them write predictions down first; they can read them aloud afterward if they want.

3.6 Reading the Learner: When Behavior Is the Symptom

Section 3.3 troubleshoots the physical setup; this table does the same thing for the learner. If you see one of these behaviors, try the response on the right — and don't assume the behavior means the child isn't learning. It often means the opposite.

- **"I don't know" to every prediction.** Offer a forced choice: "Farther or shorter? Just pick one — the experiment will tell us if you were right." Predictions don't need to be correct; they just need to exist so the learner has something to compare against.
- **Racing through without measuring.** Slow it down with a hands-on prompt: "Show me exactly where the car stopped — put your finger on it. Now measure from the bottom of the ramp to your finger."
- **Frustration with variable results.** Normalize the messiness: "Real scientists always get a little spread in their data. That's why we take three trials. What's the pattern even with the spread?"
- **Constantly asking "am I right?"** Redirect to evidence: "What does your data show? That's your answer." This shifts the authority from you to the experiment.
- **One-word answers to Reflect questions.** Use their data to expand: "Point to the row where the distance changed the most. What do you see?" Concrete numbers are easier to reason about than abstract questions.
- **Jumping to conclusions after one trial.** Require the second and third trial before concluding: "Scientists check twice more before they're sure. Let's see if it holds up."

SECTION 4

Standards & Program Connections

This section maps the kit's activities to the national standards and program frameworks most relevant to its audience. Read the sections that apply to you — you don't need to work through all of them.

A NOTE ON ALIGNMENT

Standards *alignment* means the kit's activities touch the same concepts and practices the standards describe. Standards *achievement* is something a learner builds over many experiences, not a single kit. Treat the maps below as a signal of where this kit fits in a larger learning arc — not a checkoff list.

A NOTE FOR HOMESCHOOLERS

If you're homeschooling, use the following grade maps as guideposts. A strong reader in 2nd grade may work happily at the 3–5 level; a 5th grader who's new to physical-science vocabulary may benefit from spending time in the K–2 section first. You know your learner best — adjust the support you give (hints, read-alouds, extra trials) rather than the activity itself.

4.1 NGSS Alignment — Grades K–2

These standards apply if the kit is used with younger children, or as an informal framework for foundational concepts being developed.

Code	Standard Name	What the Learner Develops	How This Kit Addresses It
K-PS2-1	Push & Pull Forces	Investigate the effects of different strengths and directions of pushes and pulls on object motion.	Gravity acts as the "push" that propels the car down the ramp. Ramp angle changes the effective strength of that force.
K-PS2-2	Changing Motion & Speed	Analyze data to determine whether a design solution changes the speed or direction of an object.	Every activity involves observing how a design change (e.g., ramp height) changes the car's speed and distance.
K-2-ETS1-1	Defining Engineering Problems	Gather information about a situation to define a simple problem solvable through building.	The Grand Challenge opens with goal-setting before building begins — mirroring the "gather information first" sequence.
K-2-ETS1-2	Prototyping & Testing	Develop a sketch or physical model and test whether it functions as needed.	Each activity requires building a physical car (prototype), sketching it, and testing.
K-2-ETS1-3	Comparing Solutions	Analyze data from tests of two objects to compare strengths and weaknesses.	Every activity is structured as a direct comparison with data tables for evidence-based evaluation.

4.2 NGSS Alignment — Grades 3–5 (Primary)

These are the primary targets for this kit.

Code	Standard Name	What the Learner Develops	How This Kit Addresses It
3-PS2-1	Balanced & Unbalanced Forces	Investigate the effects of balanced and unbalanced forces on object motion.	Gravity creates an unbalanced force that drives the car forward. Learners vary the degree of imbalance across multiple trials.
3-PS2-2	Predicting Motion from Patterns	Use measurements of object motion to show that patterns can predict future motion.	By the Grand Challenge, learners have three sets of data to use in designing their optimal car.
4-PS3-1	Speed & Energy Relationship	Construct an explanation relating the speed of an object to its energy.	A car released from a higher ramp travels farther — arriving at the bottom moving faster. Data directly supports the speed-energy relationship.
4-PS3-2	Energy Transfer	Provide evidence that energy can be transferred from place to place.	Potential energy converts to kinetic energy on every run. The Science Spotlight names and explains this transfer explicitly.
4-PS3-4	Device that Converts Energy	Design, test, and refine a device that converts energy from one form to another.	The Grand Challenge directly implements this standard: learners use their understanding of energy conversion to engineer an optimized car.
3-5-ETS1-1	Constraints & Criteria	Define a design problem with specified criteria for success and constraints.	Each activity sets explicit constraints and an implicit success criterion. The Grand Challenge makes both explicit.
3-5-ETS1-2	Evaluating Design Solutions	Compare multiple possible solutions based on criteria and constraints.	Three activities generate comparative data. The Grand Challenge requires learners to draw on all three to select and justify a final design.
3-5-ETS1-3	Optimizing Through Iteration	Plan and carry out fair tests to identify aspects of a model that can be improved.	The kit's architecture is a direct model of iterative design: isolate variable → test → analyze → apply → synthesize in Grand Challenge.

4.3 Common Core State Standards (CCSS) Math Connections

The kit does not require formal math instruction, but it generates data that naturally connects to several mathematics standards. These are noted for homeschool facilitators who wish to extend the kit into math lessons.

Standard	Topic	Connection to This Kit
2.MD.A.1	Measuring with standard tools	Every distance measurement in every activity.
3.MD	Represent and interpret data	Data tables across all three activities.
4.NBT.B.4	Multi-digit subtraction	Calculating differences between trial results.
5.G.A.1	Coordinate-plane graphing	Plot distance vs. number of books after Activity 1.
5.OA.B.3	Patterns and relationships	Identifying the rule governing how distance changes with height.

A NOTE ON AVERAGES

Computing the mean (average) of trial results is a Grade 6 standard (CCSS.MATH.6.SP.B.5) and has been intentionally excluded from the student workbook. The workbook uses “Best Run” rather than average. If the learner asks about averaging, it’s fine to show the concept informally.

4.4 Cub Scout Program Connections

If the learner is a Cub Scout, this section is for you. If not, skip ahead to Section 5. Since the 2024 program update, Cub Scouting's science and engineering content lives in the rank Adventures themselves — and this kit fits several of them.

Adventure / Rank	How This Kit Connects
Race Time — Wolf and Bear (2nd–3rd grade), elective	“Identify how you could increase the speed of your chosen vehicle.” The ramp-height and wheel tests answer exactly that question, with data.
Race Time — Webelos (4th grade), elective	“Explore the properties of friction and how it impacts your vehicle.” The kit's friction Fun Fact and the rolling-distance tests are a ready-made investigation.
Engineer — Arrow of Light (5th grade), elective	Requirements 4–5: identify a project and build it using the engineering process. The car build and the Grand Challenge design cycle — plan, build, test, improve — fit as the project.
On Your Mark — Lion (kindergarten), elective	“Build a box derby and participate in a race.” The kit's ramp and cars scale down to a first race for a younger sibling.
What the kit does not cover	Pinewood Derby cars themselves, the race-day rules, and sharing with the den. The kit supplies the fair tests and the data behind a faster car.

The national STEM Nova awards were retired in June 2025; some councils now run their own local STEM Nova award, so ask your den leader. Adventure requirements change over time — confirm the current wording with your den leader or at scouting.org before recording anything.

4.5 Common Questions

A few questions come up again and again when learners — or other adults watching — get into this kit. Here's how we'd answer them.

Q: My learner keeps pushing the car instead of releasing it.

Acknowledge the play impulse, then give the push a job: "Can you push it the same way every single time?" Most learners discover within a few tries that a matched push is harder than a clean release — and they switch on their own. If they don't, pivot to a conversation about fair tests: on any one set of runs, you can push or you can release, but not both.

Q: My learner won't write anything down.

Start smaller. Have them mark where the car stopped with a sticker or with their finger, then ask, "Was the last one farther or shorter?" The data sheet is really a tool for noticing differences — writing it down comes later. Once the learner sees that the differences matter, the recording usually follows. You can also act as the scribe for the first activity so they can focus on the motion.

Q: The results are all over the place. Is the kit broken?

Almost certainly not. Ramp runs vary naturally because of small differences in release, friction, and wheel alignment. If trials in the same set differ by more than roughly 20–30%, check for a damaged wheel, a tilted ramp, or an inconsistent release — using the edge of a book as a gate fixes most release problems. Otherwise, the variation *is* the lesson. It's exactly why scientists do multiple trials and look at the middle value rather than any single run.

Q: How long should each activity take?

The workbook budgets 30–45 minutes per activity, but this varies a lot. Let the learner's questions set the pace. If they're still asking "what if," you haven't run out of activity — if they're watching the clock, you have. A long, curious Activity 1 followed by a shorter Activity 2 is a better session than three rushed ones.

Q: Do we need to do all three activities, in order?

In-order is strongly recommended: height, then angle, then mass. Each activity depends on the measurement habits and the "change one thing" mindset built in the one before. You can skip Activity 3 if time is tight, but don't skip Activity 1 — it sets up everything that follows. The Grand Challenge assumes all three activities have been run.

Q: My learner says, "I already know this."

Great — put them to work as the expert. Have them predict first, then explain the result to you in their own words. If their predictions are consistently right, promote them to the Going Further prompts and ask them to design a new trial. Knowing the answer and being able to *show why it's true* are different skills — this kit rewards the second one.

SECTION 5

Quick Reference Materials

This section collects the kit's ready-reference material: the Word Watch answer guide for all vocabulary terms and a list of outside resources for extending the learner's curiosity beyond the kit.

5.1 Word Watch Answer Guide

For each vocabulary term in the student workbook, this guide shows what key ideas to listen for in the learner's response, and a follow-up question to extend the conversation.

Term	Listen for · Go deeper
Observe *(workbook p. 9)*	**Listen for:** The learner connects observing to using their senses — eyes, ears, touch — not just "looking." Ideally gives an example from the experiment itself. **Go deeper:** *What did you observe on the run where you got your best result?*
Variable *(workbook p. 16)*	**Listen for:** The learner understands that only one thing changes per activity and can name what it is. Should not confuse variable with result. **Go deeper:** *If we changed both the weight and the ramp height in the same run, what would that do to our experiment?*
Force *(workbook p. 11)*	**Listen for:** The learner connects force to either a push or a pull on an object, and ideally mentions that gravity is the force in this experiment. **Go deeper:** *Is gravity a push or a pull? How do you know?*
Mass *(workbook p. 11)*	**Listen for:** The learner connects mass to "how much stuff" is in the car and understands that adding the weighted brick increases it. **Go deeper:** *If you had two cars that looked exactly the same size but one was plastic and one was steel, which would have more mass?*
Simple Machine *(workbook p. 12)*	**Listen for:** The learner can name at least one other simple machine beyond an inclined plane, or can explain why a ramp makes work easier. **Go deeper:** *Can you think of another simple machine you've seen or used?*

Term	Listen for · Go deeper
Inclined Plane *(workbook p. 13)*	**Listen for:** The learner connects inclined plane to ramp and can explain the trade-off — less force, but over a longer distance. **Go deeper:** *Why is a ramp easier to use than lifting something straight up?*
Friction *(workbook p. 22)*	**Listen for:** The learner understands friction as a slowing force between two surfaces, and can connect it to why different floor surfaces change the car's distance. **Go deeper:** *Where in our experiment does friction play a role?*
Gravity *(workbook p. 17)*	**Listen for:** The learner connects gravity to a downward direction and to their own experience. Should not just say "a force" without describing what it does. **Go deeper:** *If we could somehow turn off gravity, what would happen when we let the car go?*
Energy *(workbook p. 17)*	**Listen for:** The learner understands energy as the ability to cause change or movement, and can give an example from the experiment or daily life. **Go deeper:** *Where does the energy in the car come from before you let it go?*
Potential Energy *(workbook p. 18)*	**Listen for:** The learner mentions both height and weight as factors and uses language like "stored" or "waiting." A car on a higher ramp should be described as having more potential energy. **Go deeper:** *Which has more potential energy — your car at the top of the 5-book ramp, or at the bottom of the same ramp? Why?*
Kinetic Energy *(workbook pp. 17–18)*	**Listen for:** The learner connects kinetic energy clearly to movement and ideally links it to the conversion from potential energy. **Go deeper:** *When during the car's run does it have the most kinetic energy?*
Motion *(workbook p. 22)*	**Listen for:** The learner can describe motion in terms of position change — the car moves from the top of the ramp to a stopping point. **Go deeper:** *How would you describe the motion of the car in Activity 1 compared to Activity 2?*

Term	Listen for · Go deeper
Speed *(workbook p. 23)*	**Listen for:** The learner understands speed as distance covered in a certain time — a car from a higher ramp arrives at the bottom faster (greater speed). **Go deeper:** *In which run did your car have the greatest speed? How do you know?*
Distance *(workbook p. 14)*	**Listen for:** The learner can explain that distance is measured from the bottom of the ramp to where the car stops, and understands why a consistent start point matters. **Go deeper:** *Why is it important to always measure from the same starting point?*
Design *(workbook p. 16)*	**Listen for:** The learner understands that design involves making deliberate choices before building, not just building randomly. **Go deeper:** *What was the most important design decision you made for your Grand Challenge car?*
Prototype *(workbook p. 21)*	**Listen for:** The learner understands that a prototype is tested and improved — not a finished product. **Go deeper:** *How was your Grand Challenge car different from the car you built in Activity 1? What made it better?*
Hypothesis *(workbook p. 19)*	**Listen for:** The learner can make a prediction that references evidence from earlier in the kit, not just a guess. **Go deeper:** *How did you decide what hypothesis to write for the Grand Challenge? What data gave you the idea?*

5.2 Suggested Resources

External resources for extending the kit. None are required — include any that fit the learner's interests.

For the Learner

Resource	Notes
Rosie Revere, Engineer (Andrea Beaty)	A picture book about engineering persistence — great to read before or after the kit. Ages 4–8 but beloved at all levels.
National Geographic Kids: Machines	Accessible overview of simple machines with photographs. Available in most libraries.
PBS LearningMedia — Forces and Motion	Free interactive activities at pbslearningmedia.org — search "Forces and Motion grades 3–5."

For Facilitators Who Want to Go Deeper

Resource	Notes
Khan Academy: Forces and Newton's Laws	Free, beginner-friendly video lessons. Search "forces and Newton's laws" at khanacademy.org.
NGSS Standards Explorer	Full text of all standards with performance expectations at nextgenscience.org/search-standards.
CCSS Mathematics Standards	Full text at corestandards.org/Math — grade-specific standards under "Measurement and Data."

For Replacement LEGO Parts

Source	Notes
LEGO Pick-a-Brick	Official LEGO replacement-part store at lego.com/en-us/pick-and-build/pick-a-brick.
BrickLink	Third-party marketplace for new and used LEGO parts at bricklink.com — often less expensive for bulk replacement.

Gravity Games

A Racing Science Adventure

a ***Shoebox Lab*** kit

Contact us at *shoeboxlab@gmail.com*