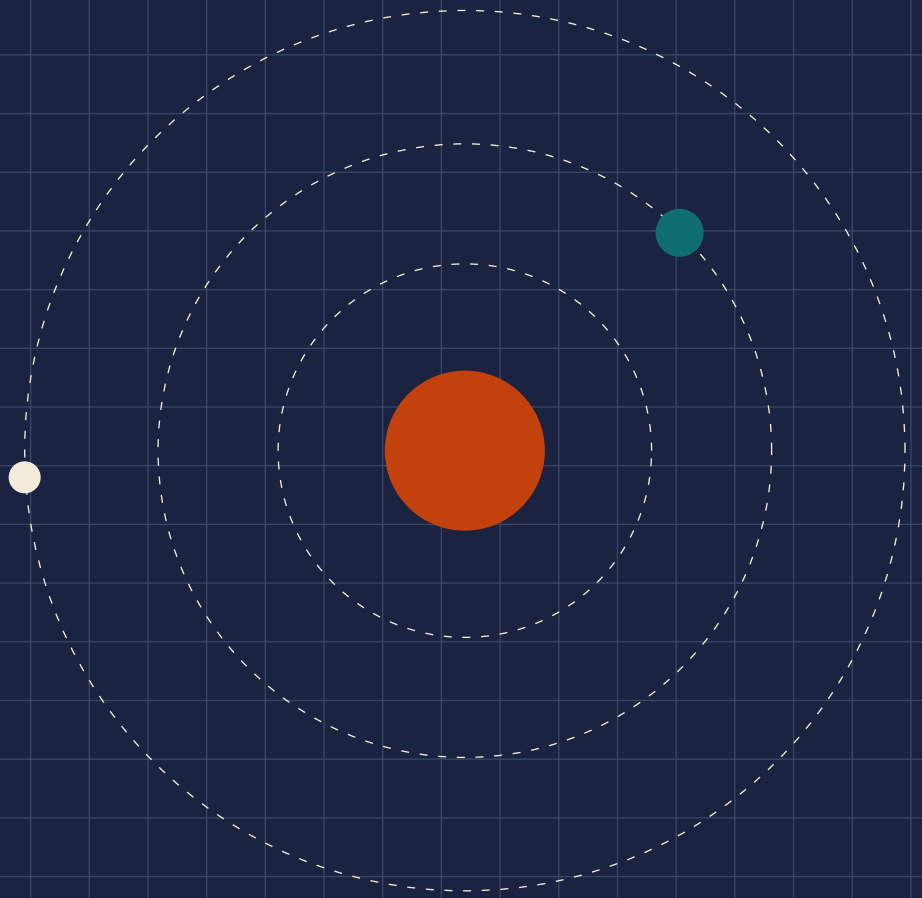
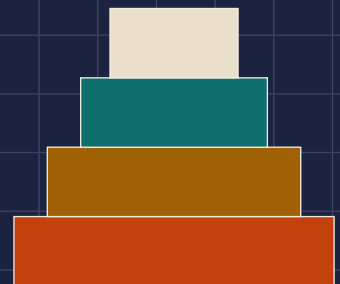


SAHILVERSE FIELD GUIDE · COMPANION TO GRAVITY ROOM



Physics for **Curious Creators**

Ten experiments, three challenges, and an honest model.



How to use this guide

This guide accompanies **Gravity Room**, a browser playground where you can drag, stack and throw objects, change gravity, friction and bounciness, and switch gravity off entirely. It is written for people who learn by touching things: designers, writers, teachers, students, game makers and anyone who stopped taking physics before it got interesting.

You do not need maths beyond multiplication. Where a formula appears, it is there to make a prediction you can check in the room — never as a test.

Three ways in

- **Play first.** Open the room, break things, then come back here to name what you saw.
- **Experiment in order.** Chapters 3–4 build concepts; Chapter 5 gives ten experiments that each isolate one idea.
- **Teach with it.** The challenge cards on pages 13–14 are designed to be printed, cut and handed out.

What is in here

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An honest label. Gravity Room is an *illustrative* simulation written for this project. It is useful for intuition and discussion. It has not been validated against laboratory measurements and should not be used for engineering, safety or academic grading. Chapter 6 lists its simplifications.

The predict-test-explain loop

Most of what makes a scientist is not knowledge; it is a habit. You say what you think will happen *before* you look, then you look, then you account for the difference. Without the first step, every result feels obvious in hindsight and you learn very little.

The loop

- **Predict.** Write one sentence and, if possible, a number. “The heavy ball lands first, about half a second earlier.”
- **Test.** Change one thing only. Use snapshots so every run starts identically.
- **Observe.** Describe what happened before explaining it. “Both landed in the same frame.”
- **Explain.** Name the idea that accounts for the gap between prediction and observation.
- **Adjust.** Make a new, sharper prediction. The loop is only finished when you get bored.

Separate the layers

It helps to label each statement you make as one of four kinds. This guide does the same.

Observation	What you saw. “The box stopped at 6.1 m.”
Model	A rule that predicts it. “Distance = $v^2 \div (2\mu g)$.”
Interpretation	What you think it means. “Mass doesn’t matter for sliding distance.”
Limitation	Where it might not hold. “Real friction varies with speed and surface.”

Worked example

Prediction: “If I double gravity, my tower falls.” **Test:** build a tower, save snapshot 1, raise gravity to 2 g. **Observation:** the tower stands, but pressing the stack makes it chatter more. **Explanation:** in this model boxes cannot tip, so stronger gravity only presses them together harder; it actually *increases* friction between them. **Limitation:** a real tower can topple, and that is the main way real towers fail. The model has taught you something true about friction and something false about towers — which is exactly why naming limitations matters.

Six ideas in plain language

Gravity

A steady pull that speeds things up downward. On Earth it adds about 9.8 metres per second of downward speed every second. In the room, the gravity slider multiplies that number: 0.17 g is roughly the Moon, 0 g is floating.

Why it matters: Every object falls with the same acceleration regardless of mass (when there is no air). A heavier object is pulled harder, but is also harder to speed up, and the two effects cancel exactly.

Mass and inertia

Mass measures how much an object resists changes in its motion. A heavy object is hard to start and hard to stop. In the room, mass is shown in kilograms on each object, and bigger drawings mean more mass.

Why it matters: Push two objects with the same impulse: the one with ten times the mass gets one-tenth the change in speed.

Force and impulse

A force is a push or pull. An impulse is a force applied for some time — a kick rather than a lean. Impulse changes momentum: $\Delta(\text{speed}) = \text{impulse} \div \text{mass}$. Tapping empty space in the room delivers an impulse to nearby objects.

Why it matters: Impulse is how the room handles collisions too: it calculates the instant kick that stops two objects passing through each other.

Friction

A sideways resistance where surfaces touch. The simplest model (Coulomb friction) says friction can push back up to μ times how hard the surfaces are pressed together. μ (“mu”) is the friction coefficient: about 0.05 for ice, 0.4 for wood on wood, around 1 for rubber on dry concrete.

Why it matters: Because friction grows with how hard you are pressed down, and pressing grows with mass, heavier objects feel more friction but also have more inertia. For sliding, those cancel too.

Restitution (bounciness)

The fraction of approach speed that survives a collision as separation speed. 0 means objects stick (clay); 1 would mean a perfectly elastic bounce that never loses energy.

Why it matters: Real materials sit between. In the room, very slow contacts are treated as non-bouncy so that stacks can rest instead of vibrating forever.

Momentum

Mass $\times$ velocity, an arrow pointing where the object moves. In a closed system with no outside forces, total momentum stays the same: what one object loses, others gain.

Why it matters: Gravity and walls are outside forces, so momentum only stays constant in zero-g away from walls. Watch the $|p|$ readout in the zero-g drift scene.

Momentum, energy and orbits

Energy is not the same as momentum

Kinetic energy is $\frac{1}{2} \times \text{mass} \times \text{speed}^2$. It is a single number with no direction.

When two clay balls collide and stick, momentum is conserved, but kinetic energy drops: some becomes (in reality) heat, sound and deformation. In the room the KE readout falls after every inelastic collision. Set bounciness near 0.95 in zero-g and the drop becomes small.

Worked example. A 1 kg ball at 4 m/s hits a resting 1 kg ball and they stick. Momentum before: $1 \times 4 = 4 \text{ kg}\cdot\text{m/s}$. After: 2 kg moving together, so speed = $4 \div 2 = 2 \text{ m/s}$. Energy before: $\frac{1}{2} \times 1 \times 16 = 8 \text{ J}$. After: $\frac{1}{2} \times 2 \times 4 = 4 \text{ J}$. Half the energy has “gone”, yet momentum is unchanged.

Why orbits happen

An orbit is falling while moving sideways fast enough to keep missing. Newton’s thought experiment imagines a cannon on a mountain: fire slowly and the ball lands nearby; faster, and it lands further away; fast enough, and the ground curves away beneath it as fast as it falls.

In the orbit challenge, a core pulls the probe with a force that weakens with the square of distance. Throw the probe straight at the core and it falls in. Throw it sideways at the right speed and it loops. For a circular orbit, the needed speed is about $\sqrt{GM \div r}$. In the room $GM = 30$ (in model units), so at 2.5 m from the core a circular orbit needs roughly $\sqrt{12} \approx 3.5 \text{ m/s}$ sideways.

What to notice

- The probe moves fastest when closest to the core and slowest when farthest — an echo of Kepler’s second law.
- Slightly too fast gives a stretched ellipse; much too fast and the probe escapes.
- The softening near the core (see Chapter 6) means very close passes are gentler than in real gravity.

Ten experiments

Each experiment changes one thing. Before running it, write your prediction in the margin. Times are approximate; your results may vary slightly with device frame rate.

EXPERIMENT

1 • The fair drop

Set up: Sandbox, gravity 1 g. Pause. Drag a 0.5 kg ball and a 6 kg ball to the same height. Save snapshot. Play.

Predict: Do they land together?

What usually happens: Same acceleration regardless of mass. If one seems faster, check that they started at exactly the same height.

EXPERIMENT

2 • Moon, Earth, Jupiter

Set up: Load snapshot from experiment 1. Repeat at 0.17 g, 1 g and 2.5 g. Count seconds to land with the time readout.

Predict: If gravity is 4× stronger, is the fall time 4× shorter?

What usually happens: Fall time scales with $1 \div \sqrt{g}$, so 4× gravity halves the time. Most people predict a quarter.

EXPERIMENT

3 • The ice rink

Set up: Sandbox. Friction 0. Throw a box along the floor.

Predict: When does it stop?

What usually happens: Without friction or drag it would slide forever; the room's small stability damping slowly bleeds speed. That is a model artefact, not physics.

EXPERIMENT

4 • Heavy vs light on the same floor

Set up: Challenge 3. Masses 1 kg and 10 kg, friction 0.3 for both. Launch.

Predict: Which stops first?

What usually happens: They stop at the same place. Sliding distance = $v^2 \div (2\mu g)$ — mass cancels.

EXPERIMENT

5 · Halve the grip

Set up: Challenge 3. Masses equal. Friction 0.3 and 0.15. Launch.

Predict: How much further does the slippery one go?

What usually happens: Twice as far. Distance is inversely proportional to μ .

EXPERIMENT

6 · Clay and superballs

Set up: Ball rain. Run at bounciness 0, then 0.9. Watch the KE readout.

Predict: How long until the pile settles?

What usually happens: Low restitution removes energy every impact; high restitution keeps it bouncing. Settling time grows sharply near 1.

EXPERIMENT

7 · Newton's cradle, sideways

Set up: Zero-g. Bounciness 0.95. Line up three equal balls touching; throw a fourth into the line.

Predict: What leaves the far end?

What usually happens: Momentum and energy pass through the line. Imperfect alignment in 2D makes it messier than the desk toy — note what differs.

EXPERIMENT

8 · Momentum bookkeeping

Set up: Zero-g drift. Watch $|p|$ for 30 s, then turn gravity back on.

Predict: Does $|p|$ stay flat?

What usually happens: In zero-g it stays nearly constant except at wall hits (walls are outside forces). With gravity on it changes continuously.

EXPERIMENT

9 · The tower under load

Set up: Challenge 1. Build a tower. Save. Raise gravity to 2.5 g. Then drop a 10 kg ball beside it.

Predict: What breaks it — gravity or the impact?

What usually happens: In this model gravity alone cannot topple the tower (no rotation); only sideways impulses can. Compare with a real block tower.

EXPERIMENT

10 · Find the orbit speed

Set up: Challenge 2. Using the forecast line, throw the probe from 2.5 m above the core at different sideways speeds.

Predict: Can you find the speed that makes a near-circle?

What usually happens: Theory says about 3.5 m/s. Your throws will scatter around that. Write down three attempts and how each orbit looked.

Challenge cards

Print this page and the next, cut along the borders, and hand out one card per person or group. Each card lists a reproducible start so different groups can compare results.

CHALLENGE 1

Balance a tower

Start: scene “Challenge 1”, gravity 1 g, friction 0.40, bounciness 0.30.

Goal: lift one block above the dashed line and hold the room still for 3 seconds.

Extensions: succeed at 2 g; succeed with bounciness 0.9; use only four blocks.

Discuss: why does this tower never tip over? What would change if it could?

CHALLENGE 2

Make an orbit

Start: scene “Challenge 2”, gravity 0 g (the core provides the pull).

Goal: throw the probe so it completes one full loop around the core without touching it or flying beyond 6 m.

Extensions: make the most circular orbit you can; make the most stretched ellipse that still returns.

Discuss: where in the loop is the probe fastest? Why?

CHALLENGE 3

Mass vs friction

Start: scene “Challenge 3”, gravity 1 g. Each launch gives both blocks 6 m/s.

Goal: predict each block’s stopping distance to within 0.5 m, then compare with the log.

Extensions: try at 0.5 g. Which variable doubled the distance? Which changed nothing?

Discuss: a heavier car takes longer to stop in real life. Why might that differ from this model?

Record sheet

One row per run. Change one thing at a time; note the snapshot slot you started from.

Run	What I changed	Prediction	Observation	Explanation

What the model gets wrong

Every model is a simplification chosen for a purpose. Gravity Room is built for clarity and smooth performance on phones. These are its known limits, and how to see each one for yourself.

No rotation

Boxes are axis-aligned: they never tilt, spin or topple. Real towers usually fail by tipping around an edge when the centre of mass passes beyond the base.

See it: Stack a narrow block on the very edge of a wide one. In reality it would fall; here it stays.

Two dimensions

All motion happens in a flat plane. The depth view only tilts the picture.

See it: Real Newton's cradles and orbits are three-dimensional; small misalignments push things out of plane.

Impulse contacts

Collisions resolve as instant velocity changes followed by a gentle positional correction. Contacts are handled pair by pair in a few repeated passes, not solved simultaneously.

See it: Tall stacks of heavy-on-light blocks can sink or jitter slightly.

One friction number

Static and kinetic friction use the same μ . Real surfaces usually need more force to start sliding than to keep sliding.

See it: Objects in the room never "stick then slip".

Fixed time steps

The room advances 1/60 s per tick, split into four substeps, using semi-implicit Euler integration. This is stable and cheap but not exact.

See it: Very fast small balls can occasionally tunnel through a thin object. Long orbits slowly drift.

Softened gravity well

The orbit core uses force = $GM \div (r^2 + s^2)$ with $s = 0.25$ m so nothing divides by zero.

See it: Close passes are gentler than true inverse-square gravity.

Stability damping

Every object loses 0.5% of its speed per frame so stacks settle and nothing vibrates forever.

See it: Frictionless sliding slowly stops; measured race distances come out a little shorter than theory.

Resting contacts

Impacts slower than 0.6 m/s do not bounce, regardless of the bounciness slider.

See it: Very gentle drops never bounce even at high restitution.

Prompts for creators

Physics is not only for engineers. Game designers tune gravity to make jumps feel good. Animators exaggerate squash and stretch. Writers use momentum as metaphor. These prompts invite you to use the room as a sketchbook.

Design prompts

- **Feel over fact.** Find the gravity and bounciness that make throwing a ball feel most satisfying. Is it Earth-like? Many platform games use stronger-than-real gravity for snappier jumps.
- **Weight you can see.** Without reading the labels, can a friend sort objects by mass just by throwing them? What visual cues would help?
- **Choreography.** Use snapshots to design a chain reaction: one throw that knocks three things in sequence. Save the start, share the link with settings.
- **Calm machine.** Make a zero-g scene that is pleasant to watch for a full minute. What makes motion soothing rather than chaotic?

Thinking prompts

- A metaphor test: people often say a project “has momentum”. Using the definitions in Chapter 2, what would the project’s mass be? Its friction? Where does the metaphor break?
- Is a habit more like inertia or like friction? Argue both sides in a paragraph each.
- Pick one limitation in Chapter 6. Describe a decision someone could get wrong if they trusted the model too much.
- Explain the mass-cancels-out result to a ten-year-old in three sentences, without the word “acceleration”.

For teachers and facilitators

A 45-minute session that works well: 10 minutes free play; 5 minutes for everyone to write one prediction about Experiment 4; 10 minutes of challenge cards in pairs; 10 minutes comparing race logs across groups; 10 minutes on Chapter 6, asking “where would this model mislead us?”. The final question tends to produce the best discussion.

Formulas and glossary

Idea	Formula	In the room
Fall under gravity	$\text{distance} = \frac{1}{2} g t^2$	$g = 9.8 \text{ m/s}^2 \times \text{slider}$
Impulse	$\Delta v = J \div m$	Tap pushes give J up to 4 N·s
Momentum	$p = m v$	p readout
Kinetic energy	$KE = \frac{1}{2} m v^2$	KE readout (joules)
Sliding friction	$F \leq \mu N$	Friction slider = μ
Stopping distance	$d = v^2 \div (2 \mu g)$	Theory column in race log
Restitution	$v_{\text{after}} = -e v_{\text{before}}$	Bounciness slider = e
Circular orbit	$v = \sqrt{GM \div r}$	GM = 30 model units

Acceleration — how quickly velocity changes, in m/s per second.

Coefficient of friction (μ) — a number describing how grippy two surfaces are together.

Elastic / inelastic — a collision that keeps / loses kinetic energy.

Integration — how a simulation steps time forward, updating velocity then position.

Inverse-square law — a force that drops to a quarter when distance doubles.

Model — a simplified set of rules that makes predictions; never the thing itself.

Substep — a smaller slice of time used inside one frame for stability.

Tunnelling — a fast object skipping through a thin one between steps.

References and further reading

These are real, widely available sources. They inform the explanations here; none of them reviewed or endorse this guide or the simulation.

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- OpenStax. *University Physics Volume 1* (2016). Rice University, free and openly licensed. Chapters 5–9 cover forces, friction, energy, momentum and collisions; Chapter 13 covers gravitation and orbits.
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- Catto, E. “Iterative Dynamics with Temporal Coherence”, Game Developers Conference (2005), and related Box2D talks. The family of sequential-impulse methods this simulation simplifies.
- Fiedler, G. “Fix Your Timestep!”, *Gaffer On Games* (2004). On fixed-step simulation loops, the approach used here.
- Millington, I. *Game Physics Engine Development*, 2nd ed. (2010). Morgan Kaufmann. A readable introduction to contacts, impulses and integration.
- PhET Interactive Simulations, University of Colorado Boulder. Research-based physics simulations (e.g., “Forces and Motion”, “Gravity and Orbits”) that are a good next step after this room.

Credits and honesty notes

Written and designed by Sahil Tayal for the Sahilverse, October 2026. Simulation code is original and dependency-free. The worked examples use the model's own parameters, and the “what usually happens” notes describe the model's behaviour as designed; they are not experimental measurements of the physical world.

Try it: gravityroom.sahiltayal.online · **More experiments:** sahiltayal.com