

Teacher key and teaching notes

Vertical Drop versus Distance | Separate answer guidance

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Goal and preparation

Observable goal: learners distinguish distance along a route from center-height drop, explain the conditional ideal finish-speed comparison, and identify why a real redesign needs checking. These materials provide reasoning practice; no tested duration, curriculum alignment or learning outcome is claimed.

Prerequisites: compare higher/lower positions, follow a labeled sketch, and understand that moving objects carry energy. Introduce the vocabulary below before supported questions, after the first prediction. No calculations are needed.

Vertical drop: the downward separation between the marble center at release and at the finish. Route length: distance along the track. Finish speed: how fast the marble center moves at the finish, rather than how long the whole trip takes. Ideal model: a deliberately simplified comparison with stated conditions.

A paper investigation, for class or home

Materials: the relevant student pages and pencil; a ruler is optional. No marble, construction, tools or internet are required. Print at actual size or use the editable text. Keep this key separate until learners have had a chance to reason.

Setup and steps: (1) Invite the first prediction without marking it right or wrong. (2) Compare the route lines and center-height guides. (3) Read the model conditions together. (4) Ask learners to revisit their prediction. (5) Use the changed-layout question to test the connection. The observation here is the drawn relationship; it is not a speed measurement.

Safety and limits: this is seated paper reasoning. Do not turn the sketches into instructions for tall runs, stairs, roads, riding devices or accessibility construction. No physical speed or catch test is assigned. A sketch cannot establish losses, elapsed time or a successful catch.

One learner: have the learner sketch and explain aloud; an adult can ask, "Which heights are you comparing?" Siblings or pairs: each first gives an independent prediction, then compares reasons. Accept pointing, oral explanation or a labeled sketch instead of writing.

Simpler route: cover the energy paragraph initially and identify start, finish, vertical drop and route line. Then read the model together. Deeper route: use HS03 and require competing explanations rather than a single guessed cause. If no printer or diagram is available, draw two starts equally far above two finishes; make one connecting downhill line longer. State that it is schematic.

Tempting reasoning to listen for

"Longer must be slower" confuses travel distance with height change and may also mix finish speed with trip duration. "Equal drop always guarantees equal speed" drops the model conditions. "All friction removes energy" misses ideal nonslip contact: do not rename the model friction-free; real losses are the excluded transfers. Ask for the missing condition before correcting the response.

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Middle school answers

MS01: accept any clearly reasoned initial prediction, including uncertainty. Do not score the prediction alone. A useful response identifies missing conditions rather than claiming measured results. Follow-up: "What stayed the same, and what might have changed?"

MS02: the route line represents distance traveled along the track. The arrow is vertical center-height separation. Accept tracing, pointing or words that clearly distinguish these. A diagonal distance is not the vertical drop. The sketches are schematic, so do not require measured lengths.

MS03: under the full ideal conditions, equal drops give equal finish speeds; extra length alone is not an ideal brake. Learners may retain a matching initial idea or revise it. The reason is equal gravitational energy for the same marble, with the same rolling relationship and no dissipative transfers or powered addition. Accept any two correct listed conditions as requested; remind the facilitator that the complete model needs all of them.

MS04: neither equal real finish speed nor a catch is guaranteed. A loose joint can change contact or transfers. Check the actual revised layout, release, joints, drop and catch arrangement. Accept a specific relevant check rather than "test it" alone. No outcome or measured quantity is supplied here.

MS05: the new finish marker remains at the old finish height; the release marker remains at the old release height. Their vertical separation stays the same. The longer sideways reach changes the route rather than the drop. Accept several descending route shapes, with equal center-height markers and a written/oral explanation. This establishes geometry, not guaranteed real speed or catch success.

Supporting a different answer

If someone says the real longer route might finish slower, ask whether they mean the ideal model or an actual track. That qualified possibility is compatible with MS03; an unconditional claim that extra distance always lowers finish speed is not. If a drawing has a changed endpoint height, have the learner compare markers before discussing speed.

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High school answers

HS01: extra distance alone does not establish a lower ideal finish speed. Accept an initial uncertainty or qualified real-track prediction if assumptions are explicit. Information needed can include center-height drop, whether the same marble was used, the release, skidding, contact, losses and powered forces.

HS02: equal drop near Earth supplies equal gravitational energy for the same marble. With rest release, nonslip rolling, maintained contact on a stationary track, negligible dissipative transfers and no powered addition, the same body has the same link between translational and rotational motion energy, giving equal ideal finish speed. Accept accurate qualitative reasoning without jargon. Changing the body, adding a push, changing drop or introducing dissipative transfers makes this particular inference unsupported; it does not prove an opposite result.

HS03: the report does not isolate length. A changed drop, altered release or additional joint/surface losses are competing explanations. Accept two, with relevant missing information such as whether center heights were preserved or joints/release were comparable. An actual apparatus may fail the ideal assumptions. The invented report does not measure a cause or refute a model used under its own stated conditions.

HS04: preserving center-height drop while reaching farther sideways preserves the ideal gravitational contribution. Keep the same marble, rest release, nonslip maintained contact, stationary track, negligible losses and no powered addition. The ideal inference concerns finish speed; actual transfers, contact and the catch need checking. Accept different practical layouts and wording if these distinctions remain. Do not demand a particular route profile or a claim about total travel time.

HS05: the same body/shape and mass-distribution condition changed. Rolling motion includes both forward motion and spin. A different body can have a different relation between those parts, so equal gravitational contribution alone does not justify borrowing the original same-marble finish-speed conclusion. Accept "not established"; no numerical ranking or cylinder formula applied to a sphere is warranted.

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Model reference for the facilitator

For this ideal comparison near Earth: use the same marble (same shape and mass distribution), release from rest without a push, maintain rolling without skidding and contact with a stationary track, neglect track losses and air resistance, and add no powered push. The start-to-finish vertical drop supplies the same gravitational energy when it is equal. A rolling marble moves forward and spins. Keeping the same marble keeps the relationship between those motion energies fixed. With these conditions, equal drops give equal finish speeds. Route length alone does not determine that finish speed. Real tracks can change losses and contact; their results need checking.

In ideal rolling on a stationary track, the contact point can be instantaneously at rest and static friction need not dissipate mechanical energy. This does not say real rolling has no losses. MIT Example 21.4 concerns a cylinder; the worksheet uses only the supported qualitative same-body relationship, not its numerical coefficient for a marble.

Discussion after the answers

Prediction: "What did you assume in your first answer?" Explanation: "Which part of the comparison concerns height, and which part concerns traveling?" Application: "What can a paper redesign establish before an actual test?" For an unexpected response, ask the learner to identify the model and its missing information before deciding whether the reasoning fits.

Unresolved here: the speed, travel time, losses and catch success of any homemade track. No apparatus data are supplied. The story offers an authored practical application, not a laboratory dataset.

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Keep exploring, if you want

Everything needed for these questions is on the worksheet. Online reading is optional.

Source micro-lesson: Vertical Drop versus Distance

<https://thisworldexplained.com/okay-but/vertical-drop-versus-distance/>

Story application: One More Take - Quinn changes the layout and checks it

<https://thisworldexplained.com/okay-but/one-more-take/#quinn-layout-application>

Sources for the explanation

MIT: Potential Energy and Conservation of Energy - section 14.2

https://ocw.mit.edu/courses/8-01sc-classical-mechanics-fall-2016/mit8_01scs22_chapter14.pdf

MIT: Rigid Body Dynamics - Example 21.4 (rolling cylinder model)

https://ocw.mit.edu/courses/8-01sc-classical-mechanics-fall-2016/mit8_01scs22_chapter21.pdf

OpenStax: Rolling Motion - energy and rolling conditions

<https://openstax.org/books/university-physics-volume-1/pages/11-1-rolling-motion>

NIST/SEMATECH: Experimental design - controlled and uncontrolled factors

<https://www.itl.nist.gov/div898/handbook/pri/section1/pri11.htm>