

Teacher key and facilitation notes

Finish Speed versus Arrival Time | OBML-005 | Matches middle school MS01-MS06 and high school HS01-HS06, version 1.

Learning goal: learners can explain why equal endpoint speed does not establish equal journey time, identify the evidence needed and retain the stated model limits. Middle school emphasizes identifying quantities, labels and a supported revision. High school adds source comparison, model boundaries and a proposed evidence plan. These are intended routes, not measured age suitability or curriculum alignment.

Prerequisites: reading release/finish labels; distinguishing a location from an interval. All needed science is supplied locally. Introduced vocabulary: endpoint, elapsed time, ideal model; high school also uses translation, rotation and model boundary. Read the model note before facilitating its applications, but let the learner make the opening prediction first.

Finish speed describes how fast an object moves at the finish. Elapsed journey time describes the interval from release to arrival. For the ideal marble comparison, equal drops give equal finish speeds. That does not specify the motion throughout the routes or establish equal journey times. Real tracks require observation; a route drawing supplies no measured winner.

Ideal marble comparison: the same marble starts from rest with no push, rolls without skidding, loses no movement energy to its surroundings, and receives no powered boost. Compare the vertical drop of its center from release to finish.

Prepare and guide

Print or read the appropriate student sheet and keep this key separate. No equipment preparation or specialist formula is needed. Ask 'Which part of the journey does that evidence describe?' or 'What would the camera or timer need to observe?' before offering the solution. Accept reasoning in prose, labelled sketches or spoken explanations.

Simpler route: first invite the optional MS01 prediction, aloud or in writing, using only its clue before showing MS02, the model explanation or any answer-bearing scaffold. Then use MS02 and the text equivalent for support, and return to the prediction before MS03. Deeper route: use HS03 to compare demonstration and mathematical model, then HS05 to define evidence. With one learner, have them predict aloud, read, then explain their revision. Siblings or partners can take endpoint and whole-journey roles and switch; each states their own reasoning. A nonspecialist adult can use the guiding questions without supplying the answer.

Activity: proposed paper reasoning only. Materials: student sheet and pencil; setup: display the diagram or read its description. Steps: predict; trace each full route; point only to its finish; identify which observation belongs to which quantity; revise a claim. Record the learner's explanation, not an invented timed run. No-material version uses spoken descriptions. Limits: this reveals a reasoning distinction, not measured arrival order, real-track speed or learning effectiveness. No construction, small parts or hazardous physical imitation is requested.

Middle school: answer reasoning

MS01

Do not announce a tie from finish speeds alone. Equal speed at one endpoint leaves the earlier motion unknown. Need release-to-finish times, or directly observed arrival order after comparable starts. Accept 'cannot tell yet' plus the missing interval. If the learner initially predicted a tie, invite a reasoned revision rather than treating a plausible expectation as foolish.

MS02

'How fast at the finish?' is FINISH SPEED; 'How long from release to arrival?' is JOURNEY TIME. Accept endpoint-versus-whole-interval wording or a point/circle versus bracket drawing. 'Both are speed' needs a prompt about which question a timer answers.

MS03

Release is at the upper left and finish at the lower right of each panel. Bracket the full interval, circle only the finish marker. The drawing shows matching endpoint heights and different route profiles. It does not give measured time, speed or winning route. The printed ideal conditions support the equal-finish-speed comparison; the drawing alone is not experimental evidence. Accept labels outside the figure if clear.

MS04

Shorter distance does not by itself describe how the marble moves throughout both routes. Time both release-to-finish intervals using clearly defined start and finish events, or observe arrival order with comparable releases. Accept a plan to collect actual times without naming a winner. A claim 'the curve wins' merely reverses the shortcut; Harvard's particular comparison is not all curves.

MS05

Record release and arrival relative to the film cue, or the whole release-to-finish interval with a specified cue schedule. A finish-speed check describes endpoint motion, not whether the cue is met. Accept comparable timing evidence; do not require a numerical target or claim an actual successful design.

MS06

Example acceptable revision: 'I need journey times before announcing a tie, even if finish speeds match.' A retained initial 'unknown' prediction is equally valid when explained. Remaining question may be which route arrives first or how real losses affect its time. The tracing step is a conceptual observation, not a marble experiment.

High school: answer reasoning

HS01

Arrival order is not fixed by endpoint speed. Missing information is motion along the entire routes or measured elapsed times for comparable start/finish events. Accept a qualified claim that times could match or differ; do not require that the two generic drawn routes differ by a particular amount.

HS02

Same resting marble, matched center-height drop, nonslip rolling, no dissipative transfer and no powered boost give the same ideal finish speed. Conditions that may fail include release with a push, skidding, different marble, or energy transfers from real track contact/air/impacts. Accept two clearly named violations and explain that duration needs whole-path motion or observed timing. No universal loss from static friction should be inferred.

HS03

Both illustrate why endpoint or route length alone does not answer the whole-path time question. Harvard is an institutional demonstration description for a specific cycloidal-versus-straight ball race, not a timing dataset for the learner's tracks or proof every curve wins. Illinois is an ideal frictionless sliding-particle derivation, not a rolling-sphere speed formula or apparatus measurement. Accept these distinctions in different wording, including the shared lack of homemade-track measurements.

HS04

Every-curve claim overgeneralizes a specific comparison; equal-endpoint-speed claim discards the earlier motion; interchangeable-model claim discards the rolling object's spin and conditions. Accept repairs that narrow scope and identify missing evidence. Calling Illinois 'wrong' is not a repair: its model answers a different specified problem.

HS05

A suitable proposed plan changes route shape while matching marble, center-height drop and rest-release method; names release and crossing the finish as start/end events; proposes recording all elapsed times and repeat-trial variation. It notes real differences in surface, joints, skidding or timing procedure may remain. Include how those differences limit attribution. Accept other clearly bounded factor choices and meaningful comparable conditions. This is a plan only, no physical activity or performance guarantee. One-factor control is useful here, not a definition of all experiments.

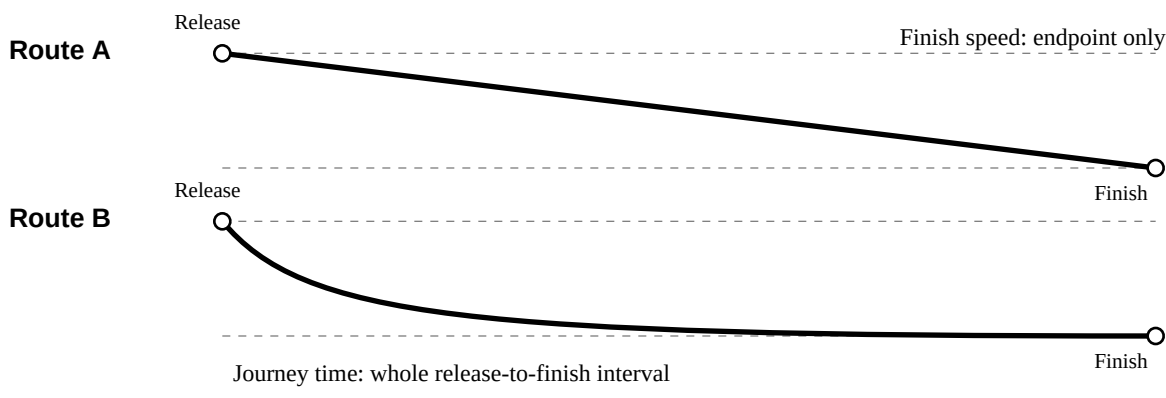
HS06

A bounded conclusion says the drawing suggests questions, supplies no winner, and needs actual repeated comparable timing observations. One successful cue is limited evidence about that arrangement, not every curve. Accept a conclusion that also identifies uncertainties or separates ideal prediction from real testing. Do not fabricate a measured result to complete the report.

Misconceptions and next questions

Tempting idea: 'Same finish speed means a tie' because the endpoint feels like the whole race. Response: ask what happened before that point and what a release-to-finish timer records. Tempting idea: 'Shorter always arrives sooner' because distance alone feels decisive. Response: ask what is known about motion throughout each route; use the specific Harvard example without announcing a generic winner. Tempting idea: 'Ideal means true for every real track.' Response: ask which printed assumptions actual equipment may fail to satisfy.

When a learner gives an unexpected answer, identify its quantity and assumption before correcting. A reasonable 'unknown' answer is productive when it specifies evidence needed. No supplied observations determine a winner for the worksheet's generic route sketch. Open questions include actual timing variation and how different real losses alter a result.



Two routes have matching release and finish heights. A straight route and a differently shaped downhill route connect them. A separate release-to-finish interval represents journey time; a marker only at the finish identifies endpoint speed. The drawing contains no measured time, speed or winning route. It is not to scale.

Optional source and story connections

Finish Speed versus Arrival Time provides the focused concept. One More Take ends with Quinn's timing question; it does not demonstrate a timed route comparison. Keep the optional origin link distinct from an application claim. All essential explanation is printed here, so links remain optional offline references.

Finish Speed versus Arrival Time - optional original micro-lesson |
<https://thisworldexplained.com/okay-but/finish-speed-versus-arrival-time/>

One More Take - Quinn ends with a timing question, rather than a timed route demonstration |
<https://thisworldexplained.com/okay-but/one-more-take/>

Harvard ball-race description - a particular cycloidal route beats a straight incline |
<https://sciencedemonstrations.fas.harvard.edu/presentations/brachistochrone>

Illinois teaching notes - whole-path time for a frictionless sliding particle, not a spinning marble |
<https://liberzon.csl.illinois.edu/teaching/cvoc/node24.html>

OpenStax Rolling Motion - ideal rolling energy and its conditions |
<https://openstax.org/books/university-physics-volume-1/pages/11-1-rolling-motion>

For the proposed comparison plan: NIST/SEMATECH, What is experimental design? - deliberate factors, response and uncontrolled influences | <https://www.itl.nist.gov/div898/handbook/pri/section1/pri11.htm>

For repeat-trial limits: NIST/SEMATECH, Variability - stable-looking measurements still vary |
<https://www.itl.nist.gov/div898/handbook/mpc/section1/mpc114.htm>

All worksheet scenarios and plans are authored proposals; no empirical dataset, tested duration, curriculum certification or demonstrated learning effect is asserted. Free to print for classroom and home use.