A Teacher's Guide to Hidden Motion Misconceptions

Why marks can hide shaky understanding — and what a class-level diagnostic heatmap reveals

For physics teachers and department leads

A field guide to five persistent motion misconceptions that survive conventional teaching and hide behind good test scores. Includes an example diagnostic heatmap and details on how to run a free classroom pilot.

FundaFirst HS • A ConceptArc Education initiative

admin@fundafirsths.com • fundafirsths.com

Selected FundaFirst content has been licensed by Cengage for worldwide distribution (print + eBook).

Why Marks Can Hide Shaky Understanding

A student scores 75% on a kinematics test. They can plug numbers into equations, match graph shapes to descriptions, and produce correct answers on familiar problem types. Their mark says they understand motion.

But ask them a different question — one that tests the concept behind the formula rather than the formula itself — and the picture changes. Ask them what “20 metres per second” actually means as a physical process. Ask them to find the average speed on a round trip where the two legs take different amounts of time. Ask them whether a vertical line on a position–time graph represents real motion.

What emerges is not a knowledge gap. It is something more persistent: a stable but incorrect mental model that produces right answers on routine problems and wrong answers on conceptual ones. The student does not know they hold it. The teacher cannot see it in a percentage score. And unless it is specifically surfaced, it survives instruction, revision, and even strong exam results.

Physics education researchers have documented this pattern extensively. Arons' detailed studies of introductory physics showed that students who could manipulate equations often could not explain the operational meaning of the quantities in those equations. Trowbridge and McDermott demonstrated that position–velocity confusion persisted even after targeted instruction. Beichner's work on graph interpretation showed that students could reproduce graph shapes without understanding what the graphs represented physically. Across decades of research, the finding is consistent: students can pass tests while holding the same misconceptions they entered with.

The pattern is consistent: conventional assessment rewards procedural fluency but is largely blind to conceptual coherence. A class can look competent on paper while carrying systematic misconceptions that will resurface under unfamiliar conditions — in later topics, in university courses, or on exam questions that probe understanding rather than recall.

The diagnostic layer most physics departments are missing is not a harder test. It is a different kind of test — one designed to surface the specific misconception a student holds, not just whether their answer is right or wrong.

Five Motion Misconceptions Worth Tracking

These are five persistent and instructionally important conceptual errors in kinematics, documented across decades of published research. Each one survives conventional teaching and produces correct answers often enough to stay hidden.

Trap 1: The Hill Illusion (graph-as-picture error)

Students look at a position–time graph where the curve is high but flat and conclude the object is moving fast. They are reading the graph as a picture of the path — higher means faster — instead of recognising that a flat section (zero slope) means the object is at rest. This confusion between position and velocity on graphs is one of the most robustly replicated findings in physics education research.

Ref: Beichner, 1994; McDermott, Rosenquist & van Zee, 1987

Trap 2: The Out-and-Back Zero (distance–displacement conflation)

Ask students for the distance travelled on a trip that goes 5 km east and then returns 5 km west. Many will answer zero — confusing distance (a scalar, always positive, equal to 10 km) with displacement (a vector, equal to zero). The same confusion runs in reverse: asked for average velocity on a round trip, students often give the average speed.

Trap 3: The Arithmetic Mean Trap (averaging error on unequal intervals)

A student drives from A to B at 40 km/h and returns at 60 km/h. Asked for the average speed, most students answer 50 km/h — the arithmetic mean of the two speeds. The correct answer is 48 km/h, because average speed is total distance divided by total time, and the slower leg takes longer. This error is remarkably stubborn.

Trap 4: The "Per" Misunderstanding (rate-as-event error)

Many students treat "20 metres per second" as a single event — the object moves 20 metres at one instant — rather than as a continuous rate describing what happens every second. They do not parse "per" as a ratio. This quietly distorts how they reason about speed, velocity, and later, acceleration.

Ref: Arons, 1990

Trap 5: The Chord–Tangent Confusion (interval-for-instant substitution)

Students are taught that instantaneous velocity is the slope of the tangent to a position–time graph. But when asked to find velocity at a specific instant, many draw a chord between two points on the curve — finding average velocity over an interval instead. The distinction between "velocity at a moment" and "velocity over a stretch" is the conceptual core of calculus-based reasoning in kinematics.

Example Heatmap from Exploratory Pilot Dataset

Exploratory pilot dataset (mixed self-selected cohort, n = 30)

Shown here to illustrate output format and the kinds of misconception patterns a diagnostic can reveal. This is not a classroom cohort.

Mean: 12.9/25 (52%) **Median:** 12.5/25 **Range:** 1–25

Question	Overall	A (21–25)	B (16–20)	C (11–15)	D (0–10)	Domain
Q01 Event definition	37%	100%	33%	40%	10%	*Events, Position & Time*
Q02 Interval vs event	53%	100%	83%	50%	20%	
Q03 Origin shift (position)	43%	75%	50%	50%	20%	
Q04 Time-origin shift	43%	75%	50%	30%	40%	
Q05 Event notation (x, t)	50%	100%	33%	50%	40%	
Q06 Read x from graph	63%	75%	83%	80%	30%	*Graph Reading*
Q07 Read t from graph	70%	100%	83%	90%	30%	
Q08 Vertical line on x–t	33%	75%	50%	30%	10%	
Q09 Crossing x–t graphs	63%	100%	67%	70%	40%	
Q10 Horizontal line (at rest)	47%	100%	100%	10%	30%	
Q11 Distance vs displacement	33%	75%	67%	30%	0%	*Distance & Displacement*
Q12 Disp with direction	53%	100%	100%	50%	10%	
Q13 Avg speed (full lap)	73%	100%	100%	80%	40%	*Average Speed & Velocity*
Q14 Avg velocity calculation	37%	75%	50%	30%	20%	
Q15 Avg speed (round trip)	37%	75%	17%	50%	20%	
Q16 Avg velocity (two events)	43%	100%	67%	30%	20%	
Q17 Negative velocity meaning	53%	100%	67%	50%	30%	
Q18 Compare graph intervals	50%	100%	83%	50%	10%	
Q19 Instantaneous v concept	53%	75%	83%	50%	30%	*Instantaneous Velocity*
Q20 Turning point (v = 0)	60%	100%	83%	60%	30%	
Q21 Walking speed estimate	60%	100%	83%	50%	40%	*Estimation & Sense-Making*
Q22 Meaning of 20 m/s	57%	100%	100%	40%	30%	
Q23 Time to walk 1 km	60%	75%	100%	60%	30%	
Q24 Distance estimate (v×t)	53%	100%	83%	40%	30%	
Q25 Reasonableness check	67%	100%	100%	60%	40%	

% Correct: 0–20% 20–50% 50–70% 70–90% 90–100%

1. **Q11, Band D: 0% correct.** The distance–displacement distinction is not secured in Band D.
2. **Q15, Band B: 17% correct.** The out-and-back misconception is not confined to lower-scoring students — it persists into Band B.
3. **Q08, Band D: 10% correct.** Aggregate graph reading appears adequate (63–70%), but vertical-line interpretation is not secure.

Red cells mark the highest-leverage targets. Compare the Overall column against Band C/D to find misconceptions hiding behind class averages.

For classroom pilots, FundaFirst HS generates a class heatmap from your students' responses and delivers it within 48 hours of completion.

What Teachers Receive from a Classroom Pilot

Within 48 hours of your class completing the diagnostic, we deliver a complete misconception analysis to your inbox:

Class-level misconception heatmap. Performance by question and by student band (A–D), colour-coded to show more clearly where understanding breaks down across the class.

One-page cohort summary. Which misconception clusters hit hardest, what they mean, how your class distributes across performance bands, and what the overall profile tells you about where your students are.

Band-level profiles. What each performance band means for your students — from "ready to extend" to "needs foundational rebuilding" — with specific guidance on what each group needs next.

Targeted remediation toolkit. Not generic revision advice. A set of materials — including worksheets with solutions, targeted exercises, and conceptual correction resources — mapped to the specific misconceptions your class triggered. Diagnosis and remediation in one package, so you do not need to build anything yourself.

Everything is teacher-readable, designed for immediate classroom use, and delivered as part of the free pilot. The pilot is provided at no charge and without obligation.

How to Run a Pilot

Step 1. Request a pilot. Visit fundafirsths.com or email admin@fundafirsths.com.

Step 2. We send the diagnostic link. You receive a diagnostic link and a short setup message you can paste directly to your students. No student accounts, no logins, no software installs needed.

Step 3. Students complete the diagnostic. Share the link with your class. The diagnostic takes about 25 minutes and can be completed in class or as a short take-home task.

Step 4. You receive the full analysis. We generate your class heatmap, cohort summary, band profiles, and remediation toolkit, and email everything to you — typically within 48 hours of class completion.

There is no charge for the classroom pilot. No payment information is collected. No subscription is created. No ongoing commitment.

The diagnostic is relevant to core motion and kinematics content taught in IB Physics, AP Physics 1, A-Level/AS Mechanics, and GCSE/IGCSE Physics.

A six-module Newton's Laws diagnostic is also available.

Request a classroom pilot

admin@fundafirsths.com • fundafirsths.com

FundaFirst HS • A ConceptArc Education initiative

Selected FundaFirst content has been licensed by Cengage for worldwide distribution (print + eBook).