A Teacher's Guide to Hidden Projectile & Circular Misconceptions

Why marks can hide shaky understanding — and what a class-level misconception readout reveals across projectile and circular motion

For physics teachers and department leads

A field guide to persistent misconceptions in two-dimensional motion — from component independence and the acceleration of a projectile in free flight, through circular acceleration at constant speed, to the extra "centripetal force" arrow, the phantom outward force, and the banked curve — that survive conventional teaching and hide behind good test scores. Includes example diagnostic output and details on how to run a free classroom pilot using the Projectile & Circular diagnostic.

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Why Marks Can Hide Shaky Understanding

A student scores 80% on a mechanics test. They can resolve a launch velocity into components, find a time of flight, and substitute correctly into the circular-motion relations. Their mark says they understand motion in two dimensions.

But ask them a different kind of question — one that tests the concept behind the formula rather than the formula itself — and the picture changes. Ask them whether a ball dropped from rest and a ball launched horizontally from the same height land at the same time. Ask them for the acceleration of a projectile at the very top of its arc, where the vertical velocity is momentarily zero. Ask them why an object moving in a circle at constant speed is accelerating at all. Ask them to draw every force on a puck whirled on a string — and watch a fourth arrow appear, labelled “centripetal force”, beside the tension that is already doing the job.

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 in two-dimensional motion. Arons’ treatment of introductory mechanics showed that component independence is not one self-evident fact but two separate claims, established by two different experiments — and that students who are never shown the distinction quietly let horizontal motion change the vertical fall. He also reports a deflection question that over 40% of physics PhD candidates missed: “a small mass means negligible gravity” survives a remarkable amount of instruction. Knight’s motion-diagram work showed that students consistently locate acceleration along the velocity vector rather than along the change in velocity — the same error that produces both a tilted acceleration in projectile flight and “no acceleration at constant speed” on a circle. Moore’s two-dimensional units develop circular acceleration through the change-in-velocity construction — the kinematic reason behind “the acceleration points to the centre” that students so often memorise without. And Chabay and Sherwood’s treatment of curving motion reframes the classic car-turning scene in the ground frame: nothing throws the passenger outward; the door comes across and pushes the passenger in. Across the literature, 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. The **Projectile & Circular** diagnostic targets motion in two dimensions at the upper-secondary level — from component independence and the acceleration of a projectile in free flight to circular acceleration, the role of the net inward force, the vertical circle, the no-centrifugal discipline, and the banked curve. Thirty questions across eleven misconception bands, in a single sitting, with a cross-cutting lens that tracks the “acceleration points where you’re going” error across both families — and genuine discrimination left for near-ceiling cohorts, where strong procedural marks most reliably hide the conceptual gaps.

Five Projectile & Circular Misconceptions Worth Tracking

Five persistent conceptual errors in two-dimensional motion, documented across decades of published research — each surviving conventional teaching and producing correct answers often enough to stay hidden. The first two live in projectile motion; the last three in circular motion — five of the eleven bands the full thirty-question diagnostic surfaces.

Trap 1: The Sideways Ball Stays Up Longer Projectile

Release one ball from rest and launch a second horizontally from the same table height at the same instant. Many students answer that the launched ball stays up longer, or that a faster launch changes the fall time. They are letting horizontal motion change the vertical fall. It cannot: the fall is governed by gravity alone, and the two balls land together. Independence is also more than one fact — it is *two* separate claims, established by two different experiments: horizontal motion does not change the fall, and the fall does not change the horizontal motion. Students shown only the demonstration, never the distinction, hold the word “independent” without the idea.

Ref: Arons §4.4; Moore, Six Ideas Ch. N9; Chabay & Sherwood §2.4

Trap 2: At the Top It Stops, So Gravity Pauses Projectile

A stone thrown at an angle reaches the top of its arc. Ask for its acceleration at that instant and many students answer zero — the stone has “stopped rising”, so nothing is happening. Others keep a forward “force of the throw” alive in mid-flight, or tilt the acceleration along the motion. Once the stone leaves the hand the only force on it is gravity: the acceleration is g, straight down, at every instant — including the apex, where the speed is still nonzero. The apex error and the phantom throwing force are separate failures, and a diagnostic needs to tell them apart: one is a turning-point error; the other is impetus thinking that resurfaces in the Newton’s-laws unit.

Ref: Arons §4.4; Moore, Six Ideas Ch. N9; Chabay & Sherwood §2.5

Trap 3: Steady Speed, So No Acceleration Circular

A car circles a roundabout at a steady 30 km/h. Ask for its acceleration and many students answer zero — the speedometer is not changing, so how can there be acceleration? But velocity is a vector, and on a circle its direction changes continuously: the acceleration is real and points to the centre. The deeper failure is the missing *reason*. Draw the velocity arrows at two nearby instants tip-to-tip and the change in velocity visibly points inward — that construction, not the word “centripetal”, is why the acceleration points to the centre. Students who have only memorised the word reach for “centre-seeking by definition” — and cannot handle the speeding-up case.

Ref: Moore, Six Ideas Ch. N7; Arons §4.7, §4.9; Chabay & Sherwood §5.7

Trap 4: The Fourth Arrow Circular

Ask the class to draw every force on a puck whirled on a string in a horizontal circle. Three arrows belong — tension, gravity, the normal force. In many diagrams a fourth appears — an extra inward arrow labelled “centripetal force”, beside the tension already supplying the turn. This is the keystone misconception of circular dynamics: treating “centripetal” as a separate force to be added, rather than as the *role* a real, named force — or a component of one — plays. It reappears as “the string *is* the centripetal force” (deleting the real tension), and as the belief that only a pull can do the job — when a fairground Rotor’s wall turns its riders with a push. Everything downstream — vertical circle, no-centrifugal, banked curve — is an application of getting this one right.

Ref: Arons §4.9; Moore, Six Ideas Ch. N7; Chabay & Sherwood §5.7, §5.10

Trap 5: Something Throws Me Outward Circular

A car takes a sharp left turn and the passenger is pressed against the right-hand door. Ask what pushed them outward and most students name a centrifugal force — some call inertia “an outward force”, others say the forces balance. In the ground frame nothing pushes the passenger outward: the passenger continues straight, by inertia, while the car turns left underneath — the door comes across and runs into the passenger, pushing them *inward*. The same confusion attaches an outward force to a whirled ball: the ball does pull outward on the string — the third-law partner of the string’s inward pull — but that force acts on the string, not on the ball.

Ref: Chabay & Sherwood §5.9; Arons §4.11

Example Cohort Readout Using Simulated Data

Illustrative data (n = 21)

Simulated dataset shown to illustrate the cohort readout and the kinds of misconception patterns the Projectile & Circular diagnostic can reveal. Informed by documented misconception patterns in physics education research. Not drawn from a classroom or pilot cohort.

Mean: 20.5/30 (68%)   Median: 21/30   Range: 12–28

Unlike a single percent-correct score, the Projectile & Circular readout reports each misconception band three ways. For each submission, a band is classified as **confirmed** (the misconception option chosen on two or more of the band’s questions), **provisional** (exactly one), or **clear** (none); unanswered questions make a band **incomplete**, never clear. The table shows the share of the class in each column, and each band carries a verdict, checked top-down: **MAJOR**, **WATCHLIST** (provisional-heavy with little confirmed — recheck next cycle), **MODERATE**, or **CLEAR**. The two 2-question bands are capped at provisional by design and marked accordingly. A per-question heatmap — every student against every question, grouped by band — accompanies this table in the delivered report.

Misconception band	Status	Confirmed	Provisional	Clear
P1 — Component independence	**CLEAR**	10% (2/21)	14% (3/21)	76% (16/21)
P2 — Projectile acceleration (g down)	**CLEAR**	14% (3/21)	24% (5/21)	62% (13/21)
P3 — Trajectory shape and graph-vs-path	**CLEAR**	5% (1/21)	19% (4/21)	76% (16/21)
P4 — Mass-independence vs drag (provisional-only)	**CLEAR**	—	19% (4/21)	81% (17/21)
C-K1 — Circular acceleration to the centre and why	**MAJOR**	43% (9/21)	24% (5/21)	33% (7/21)
C-K2 — Period / angular-to-linear (provisional-only)	**CLEAR**	—	24% (5/21)	76% (16/21)
C-D0 — Curving needs inward; release to tangent	**CLEAR**	10% (2/21)	19% (4/21)	71% (15/21)
C-D1 — Net inward force is a role	**MAJOR**	52% (11/21)	24% (5/21)	24% (5/21)
C-D2 — Vertical circle and passive force	**WATCHLIST**	14% (3/21)	43% (9/21)	43% (9/21)
C-D3 — No centrifugal force (inertial frame)	**CLEAR**	10% (2/21)	14% (3/21)	76% (16/21)
C-D4 — Banked curve	**MODERATE**	29% (6/21)	24% (5/21)	48% (10/21)

1. **C-D1 — Net inward force is a role.** The keystone circular-dynamics band shows the strongest signal in this cohort: 52% of submissions confirmed (11/21), with another 24% provisional. The extra “centripetal force” arrow beside the real tension is present across the class — and because the vertical-circle, no-centrifugal, and banked-curve work all build on this band, it is remediated first among the dynamics bands.
2. **C-K1 — Circular acceleration to the centre and why.** 43% confirmed (9/21), with 24% provisional. “Constant speed means no acceleration” and acceleration pointed along the motion both appear, and the change-in-velocity reason is not yet being given. This is the kinematic foundation under the keystone — in the delivered summary it is sequenced first.
3. **C-D4 and the watchlist.** The banked curve reads MODERATE (29% confirmed, 6/21) — inclined-plane axis habits and a mass-dependent banking angle — and is addressed after the two bands above, since it is an application of them. The vertical circle (C-D2) sits on the WATCHLIST: 43% provisional (9/21) but only 14% confirmed — rechecked next cycle rather than remediated now.

The strongest verdicts mark the highest-leverage targets. Read the Confirmed column against Provisional to separate settled misconceptions from one-off slips — the WATCHLIST verdict exists precisely for the provisional-heavy case. For classroom pilots, FundaFirst HS generates this readout and the accompanying per-question heatmap from your students’ responses and delivers both within 48 hours of class 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

Every student against every question, colour-coded by correctness and grouped by misconception band so cluster patterns become visible at a glance — the question order on the form already follows the band order, so the heatmap reads straight across the eleven bands.

Cohort summary

A 2–3 page summary: what to do next class (concrete, time-boxed fixes), the band distribution with counts and percentages, the key patterns in the cohort, the cross-cutting signal, and a sequenced three-step remediation plan. The first page is written to be forwarded to a head of department with zero context.

Band verdicts, not just scores

Each of the eleven bands is reported as the share of the class confirmed, provisional, and clear, and carries a MAJOR / WATCHLIST / MODERATE / CLEAR verdict — so the next instructional step is unambiguous. Two-question bands are capped at provisional by design and labelled accordingly, and unanswered questions are reported as incomplete, never as clear.

Targeted remediation toolkit

Not generic revision advice. A four-document set — a Mistake Museum, a Words That Hurt language guide, a sectioned Remediation Worksheet, and a Teacher Key — keyed to the bands your class actually flagged. Remediation materials use $g = 9.8\ m/s^2$; re-test in about two weeks with changed numbers, not an identical retest.

> *Everything is teacher-readable, designed for immediate classroom use, and delivered as part of the free pilot. Six PDFs in total: heatmap, cohort summary, Mistake Museum, Words That Hurt, Worksheet, Teacher Key. Nothing else is required from you between completion and delivery.*

How to Run a Pilot

Step 1. Request a pilot.

Visit fundafirsths.com or email admin@fundafirsths.com. The Projectile & Circular diagnostic suits classes finishing or revising projectile motion and circular motion — the two-dimensional block that sits across kinematics and forces.

Step 2. We send the diagnostic link.

You receive a class-specific diagnostic link and a short setup message you can paste directly to your students. No student accounts, no logins, no software installs needed. Student names are optional; schools may use anonymized student IDs instead.

Step 3. Students complete the diagnostic.

Share the link with your class. The diagnostic takes about 32–36 minutes (30 questions, single sitting). $g = 10\ m/s^2$ is stated on the form, and air resistance is ignored unless a question states otherwise.

Step 4. You receive the full analysis.

We generate your class heatmap, cohort summary, band verdicts, 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 Projectile & Circular diagnostic covers motion in two dimensions as taught in IB DP Physics (the projectile bands sit in A.1 Kinematics; the circular bands in A.2 Forces and momentum), AP Physics 1 and AP Physics C: Mechanics, and A-Level Physics, and works as extension material for GCSE / IGCSE Physics. Thirty questions across eleven misconception bands plus a cross-cutting lens, in a single sitting — with genuine discrimination left for near-ceiling cohorts.

Two motion diagnostics (Motion Foundations and Motion Change), a six-module Newton's Laws diagnostic, and a single-sitting Energy diagnostic are also available — same format, same 48-hour turnaround.

Request a classroom pilot

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Grounded in Physics Education Research: Arons, Knight, Moore, Chabay–Sherwood

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