

A Teacher's Guide to Hidden Electric Potential Misconceptions

Why marks can hide shaky understanding — and what class-level misconception heatmaps reveal across potential, potential energy, the field-potential link, reference and sign, and the conductor at equilibrium

For physics teachers and department leads

A field guide to persistent misconceptions in electric potential — from the field read off the value of the potential, through potential confused with potential energy, to the lone potential value with no reference and the sign quietly dropped from the field-potential link — 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 Electric Potential diagnostic.

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Why Marks Can Hide Shaky Understanding

A student scores 75% on an electricity test. They can put numbers into $V = kq/r$, work out a potential difference, read an equipotential diagram, and produce correct answers on familiar problem types. Their mark says they understand electric potential.

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 what the electric field is at a point where the potential happens to be zero. Ask them whether “fifty volts” means anything until a reference is named. Ask them what the potential energy of a charge at a point actually belongs to. Ask them which way a negative charge moves when it is released in the field.

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. Knight's instructor-side work catalogues the families of error around potential: the field read off the value of the potential rather than its rate of change, potential confused with potential energy, the reference treated as fixed, and the sign dropped from the field-potential link. Chabay and Sherwood develop the potential from the energy of a system of charges and the field as its signed gradient, making path independence and the role of a chosen reference explicit. Moore builds the potential as energy per unit charge and recovers the field as its gradient, with the conditions that bound each result. 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. The **Electric Potential** diagnostic targets this layer: 22 questions across 12 misconception bands in four families – potential and potential energy, the field-potential link, reference and sign, and path, dielectrics, and conductors – with one keystone band (the value of the potential does not fix the field) and three cross-cutting lenses surfaced from the option patterns. It is designed for upper-secondary physics and introductory university electromagnetism.

Five Electric Potential Misconceptions Worth Tracking

These are five persistent and instructionally important conceptual errors in electric potential, documented across decades of published research. Each survives conventional teaching and produces correct answers often enough to stay hidden. The tag on each trap is the misconception band that tracks it; the fifth is a cross-cutting lens.

Trap 1: Zero Volts Means Zero Field FLD-1

At the midpoint between a positive charge and an equal negative charge the potential is zero, yet the field there is strong — the field comes from how fast the potential changes, not from its value. The converse traps too: inside a charged conductor the potential is large and constant while the field is exactly zero. Reading the field off the value of the potential, rather than off its rate of change, is the foundational electric-potential misconception — the discrimination the rest of the topic rests on.

Ref: Knight, 2002; Chabay & Sherwood; Moore, *Six Ideas That Shaped Physics*

Trap 2: Potential Is the Energy POT-1

A charge sits where the potential is V . Asked for its potential energy many answer V ; asked what the potential becomes if the charge is doubled, many double it too. But potential is energy per unit charge, fixed by the source charges; the energy of a charge placed there is qV . Doubling the charge doubles the energy it carries and leaves the potential, and the field, unchanged. Reading the potential as the energy collapses the distinction the topic is built on, and it propagates into capacitance and circuits.

Ref: Moore, *Six Ideas That Shaped Physics*; Chabay & Sherwood

Trap 3: Drop the Minus Sign FLD-4

The field is the slope of the potential — but with a minus sign: it points from high potential to low. Asked to read the field off a potential-against-position graph, many keep the slope's sign, so their field points uphill, toward increasing potential. The minus sign carries the physics: a positive charge is pushed from high potential to low, shedding potential energy as it goes. Dropping it inverts the field direction and the energy argument together, and it is among the most persistent errors once the algebra appears.

Ref: Chabay & Sherwood; Moore, *Six Ideas That Shaped Physics*

Trap 4: Fifty Volts Is Fifty Volts REF-1

A point is at a potential of fifty volts. Asked what that means physically, many treat it as an absolute fact about the point. But only potential differences are physical: the fifty volts is measured relative to a chosen zero, and moving the zero — to the other plate, to earth, to infinity — changes the number without changing any field, force, or motion. A potential can perfectly well be negative. Treating a lone value as absolute, with no reference named, surfaces wherever signs and earthing matter.

Ref: Knight, 2002; Moore, *Six Ideas That Shaped Physics*

Trap 5: The Sign Looks After Itself L3

Across several items the same habit surfaces: a sign dropped or flipped — the field sent uphill, a pair's negative potential energy made positive, or a charge sent the way the opposite sign would go. The diagnostic tracks this — a sign lost or inverted — as a cross-cutting lens, surfaced from the option patterns rather than scored as a standalone band: the discipline that, when it slips, undermines the field, the energy, and the motion at once. It is the most populated lens by design, flagged where it does the most damage.

Ref: Chabay & Sherwood; Knight, 2002

Example Heatmap Using Simulated Data

Illustrative data (n = 25)

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

Mean: 12.4/22 (56%) Median: 12/22 Range: 4–20

This heatmap shows the **Electric Potential** diagnostic (22 questions across 12 misconception bands in four families, plus three cross-cutting lenses surfaced from the option patterns). Columns group students by total score.

Q#	Concept Tested	Overall	A (18–22)	B (14–17)	C (9–13)	D (0–8)	Band
Q01	Potential energy belongs to a system	68%	90%	76%	53%	42%	POT-2
Q02	Zero potential is not zero field	44%	66%	52%	29%	18%	FLD-1
Q03	A negative charge moves against the field	56%	78%	64%	41%	30%	SGN-1
Q04	Zero field is not zero potential	40%	62%	48%	25%	14%	FLD-1
Q05	Potential is energy per charge, not energy	64%	86%	72%	49%	38%	POT-1
Q06	The sign of a pair's potential energy	60%	82%	68%	45%	34%	POT-2
Q07	Potential difference is path-independent	64%	86%	72%	49%	38%	PTH-1
Q08	Constant potential, zero field	48%	70%	56%	33%	22%	FLD-1
Q09	The field runs down the potential	52%	74%	60%	37%	26%	FLD-3
Q10	A longer path, the same difference	60%	82%	68%	45%	34%	PTH-1
Q11	Field direction from the potential	56%	78%	64%	41%	30%	FLD-3
Q12	Constant, not zero, inside a conductor	56%	78%	64%	41%	30%	CON-1
Q13	The sign of the charge sets the energy	48%	70%	56%	33%	22%	SGN-1
Q14	The field is minus the slope	52%	74%	60%	37%	26%	FLD-4
Q15	Moving the zero changes the number, not the physics	60%	82%	68%	45%	34%	REF-1
Q16	Doubling the charge, not the potential	72%	94%	80%	57%	46%	POT-1
Q17	A dielectric with the charge fixed	52%	74%	60%	37%	26%	CFG-2
Q18	Field strength from the spacing	64%	86%	72%	49%	38%	FLD-2
Q19	A lone potential value needs a reference	56%	78%	64%	41%	30%	REF-1
Q20	Reading field strength off a map	60%	82%	68%	45%	34%	FLD-2
Q21	Minus the signed area for the difference	48%	70%	56%	33%	22%	FLD-4
Q22	Potential is a scalar	60%	82%	68%	45%	34%	POT-3

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

- Q2, Q4, Q8 – Band FLD-1, the field-versus-potential keystone.** Reading the field off the value of the potential sits among the lowest in the diagnostic, at 14% in Band D and 22–25% in Band C on the hardest items. Until what the field comes from is settled – the change in the potential, not its value – the bands that build on it cannot.
- Q5, Q16 – Band POT-1, potential versus potential energy; Q9, Q11 – field direction from the potential.** Potential collapsed into energy, and the field pointed up the potential rather than down it, fall through Bands C and D – this confusion is not confined to weaker students, and it carries into the energy and the sign.
- The sign lens (L3); the lower-confidence single-item bands.** Submissions that drop or flip a sign – in the field-potential link, the energy, or the motion – fire the cross-cutting sign lens, reported as a cohort percentage. The single-item bands (POT-3, CFG-2, CON-1) are read as directional, lower-confidence signals, never settled.

Red cells mark the highest-leverage targets. Read each band against the weaker performance bands rather than the cohort average; the single-item bands (POT-3, CFG-2, CON-1) are treated as lower-confidence, directional signals. The cross-cutting lenses and the folded threads are reported as annotations, never as band flags. For classroom pilots, FundaFirst HS generates a class heatmap from your students' responses 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. The Electric Potential diagnostic produces a self-contained set of materials:

Class-level misconception heatmap

Performance by question and by student performance band (A–D), with each item tagged to its misconception band. Colour-coding shows where understanding breaks down across the class, and the folded threads appear as annotations. Scored against the 22-question total.

Cohort summary

Each band's standing — from a serious class-level misconception to a lighter watch-pattern — with the cross-cutting lens readout, what the flagged bands mean, and the priority order for remediation. Designed for a head of department or course leader to act on without re-deriving anything from the heatmap.

Per-band priority

What each band means for your class — from a consolidated misconception that needs structured repair to a wide-but-shallow pattern worth a single targeted lesson — with the single-item bands (POT-3, CFG-2, CON-1) explicitly caveated as lower-confidence, directional signals.

Targeted remediation toolkit

Not generic revision advice. A set mapped to the specific bands your class triggered — a Mistake Museum of named traps, a Words That Hurt language guide, a Remediation Worksheet in assignable sections, and a Teacher Answer Key with a classroom move for each band. 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. Six PDFs: heatmap, cohort summary, Mistake Museum, Words That Hurt, the Remediation Worksheet, and the Teacher Answer 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. If your class is partway through — or just past — an electric-potential unit and you want to find out where understanding has actually settled, this is the right instrument; if you are earlier in the sequence, we will recommend the right starting point.

Step 2. We send the diagnostic link.

You receive a class-specific 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 anonymised student IDs instead.

Step 3. Students complete the diagnostic.

Share the link with your class. The Electric Potential diagnostic takes about 25 minutes (22 questions) and can be completed in class or as a short take-home task. No calculator is required.

Step 4. You receive the full analysis.

We generate your class heatmap, cohort summary, priority misconception bands, 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 Electric Potential diagnostic covers the electric-potential content taught in IB DP Physics (electric fields, potential difference, and electric potential energy), AP Physics 2 (electric potential and electric potential energy), AP Physics C: Electricity and Magnetism (electrostatics and electric potential), A-Level & AS Physics (electric potential, equipotentials, and potential energy), and IGCSE Physics (introductory electric fields and potential, where the topic is first introduced). **One diagnostic — 22 questions across 12 bands in four families** — plus three cross-cutting lenses and two folded threads tracked as heatmap annotations.

The Static Electricity diagnostic covers the electrostatics that precedes this topic; Motion (two diagnostics), Newton's Laws (six modules), Projectile & Circular Motion, Energy, Momentum, and Oscillations & Waves diagnostics are also available — together they cover the kinematics-forces-momentum-energy-waves-electromagnetism arc.

Request a classroom pilot

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