A Teacher's Guide to Hidden Energy Misconceptions

Why energy — the most quantitatively reliable topic in mechanics — hides some of the deepest conceptual confusions in upper-secondary physics

For physics teachers and department leads

A field guide to persistent misconceptions in energy — from what energy actually is, through conservation conditions, work-energy theorem subtleties, potential-energy diagram reading, to heat versus temperature — that survive conventional teaching and hide behind correct numerical answers. Includes an example diagnostic heatmap and details on how to run a free classroom pilot using the FundaFirst Energy diagnostic.

FundaFirst HS · A ConceptArc Education initiative

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Why Marks Can Hide Shaky Understanding

A student scores 80% on an energy test. They can apply conservation of energy to a roller-coaster problem, calculate spring potential energy, set up the work-energy theorem on an inclined plane. Their mark says they understand energy.

But ask them a different kind of question — one that probes what energy actually *is*, rather than how to compute it — and the picture changes. Ask them whether energy is a substance the spring contains and transfers to the block, or a bookkeeping quantity assigned to the system. Ask them where the gravitational potential energy “belongs” — to the ball, to the Earth, or to neither alone. Ask them how an astronaut pushing off a stationary floor gains kinetic energy when the floor does no work at the contact point. Ask them where the thermal energy comes from when a block slides at constant velocity across a rough table, and the kinetic energy is not changing.

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 the energy domain. Arons showed that the language of “converting work into heat” embeds a substance-like view of energy that the conservation framework is meant to replace. Chabay and Sherwood developed the systems-and-interactions framing precisely because the standard textbook treatment treats potential energy as if it belonged to a single object. Knight identified the cluster of errors around the work-energy theorem that emerge when the centre-of-mass displacement is conflated with the displacement of the contact point at which a force acts. Moore traced the heat-as-noun confusion through five decades of textbook prose. Across the literature, the finding is consistent: students can pass energy tests while holding the same misconceptions they entered with.

Energy is the topic where this gap matters most, because energy is also the topic where calculation reliably produces the right answer. The substance view of energy — energy as stuff that flows, gets stored, gets used up — will not produce a wrong number on most exam problems. It will produce a wrong intuition about every system in which energy is conserved through a transformation rather than transferred through a flow. That intuition resurfaces in thermodynamics, in electromagnetism, in modern physics, and persists into university courses.

The diagnostic layer most physics departments are missing is not a harder energy 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 **FundaFirst Energy Diagnostic** targets the conceptual surface of energy at the upper-secondary level: what energy is, when conservation holds, transfer versus transformation, potential energy as a property of interactions, the work-energy theorem and its subtle failure modes, spring and elastic potential energy, qualitative transformations, potential-energy diagram reading, heat versus temperature, and the friction paradox that closes the loop back to Newton's laws. The diagnostic surfaces eleven misconception bands across twenty-four items.

Five Energy Misconceptions Worth Tracking

Trap 1: The Substance Trap E1

Ask students what "energy" means for a stretched spring connected to a block. Many will say it is something the spring *contains* and will *transfer* to the block when released. This treats energy as a physical substance that can be stored, moved, and used up. The correct framing is that energy is a bookkeeping quantity assigned to the spring-block system in a given state, allowing comparison between states. The substance view is hard to dislodge because it works for most calculations — but it produces incoherent reasoning the moment energy is transformed rather than transferred, and it is the root of nearly every other misconception on this list.

Ref: Arons, 1997; Knight, 2002 (Five Easy Lessons §9.1, §9.3)

Trap 2: The Single-Object PE Trap E5

A ball is held at height h above the ground. Where does the gravitational potential energy "belong"? Most students say *to the ball*. Some say *to the Earth*. Both are wrong. Gravitational PE belongs to the ball-Earth interaction, not to either object alone. If only the ball is taken as the system, there is no gravitational PE inside the system — gravity becomes an external force doing work on the system. This pair-PE framing matters because it determines what counts as internal versus external, what is conserved versus transferred, and how cleanly conservation laws apply. Students who hold the single-object view systematically misidentify system boundaries in conservation problems.

Ref: Chabay & Sherwood, Matter & Interactions §6.7

Trap 3: The Astronaut Floor-Jump Trap E6

An astronaut in a space station pushes off the floor and gains kinetic energy. Ask students where the kinetic energy comes from. Most will answer that the floor does positive work on the astronaut, computing it as $F{\cdot}d_{CM}$. But the floor's force acts at the contact point at the astronaut's feet, and the contact point does not slide or displace during the push-off. The floor does *zero* real work on the astronaut. The kinetic energy comes from internal chemical energy in the astronaut's muscles, transformed into kinetic energy. The product $F{\cdot}d_{CM}$ is a useful quantity (it equals ΔK by Newton's second law applied to the centre of mass) but it is not the work done by the floor — it is what Sherwood and Bernard called *pseudowork*. This distinction is invisible at the calculation level and decisive at the conceptual level.

Ref: Sherwood & Bernard, 1984; Arons, 1997 (§5.6, §5.7); Chabay & Sherwood §7.2, §7.8; Moore, Six Ideas Unit C

Trap 4: The Heat-as-Noun Trap E10

Students — and most textbooks — routinely speak of "heat" as if it were a substance that flows, gets stored in objects, and can be possessed. Phrases like "the heat in the water," "friction converts work into heat," or "the kettle stores heat" all treat heat as a noun — a thing — rather than as a process: heat is energy in transit between systems due to a temperature difference. The substance once heat is inside an object is thermal energy or internal energy, not heat. This is not pedantry. The heat-as-noun framing prevents clean reasoning about the first law of thermodynamics, about phase changes, and about the relationship between heat and temperature. It is also the linguistic backbone of the substance view of energy that Trap 1 names directly.

Ref: Arons, 1997 (§5.5); Knight §17.4; Moore, Six Ideas Unit T

Trap 5: The Friction Paradox X1 CROSS-BAND

A block is pulled at constant velocity across a rough horizontal surface. Because the velocity is constant, the block's kinetic energy does not change: $\Delta K = 0$. Yet both the block and the table heat up. Where does the increased thermal energy come from? Many students say from the block's kinetic energy — but $\Delta K = 0$; there is no kinetic energy to lose. The correct answer is that external work enters at the rope-block contact point (where the rope *does* displace), and that input is dissipated at the sliding interface into thermal energy of the block-table system. Friction has no potential-energy function because the work associated with sliding friction is path-dependent. This item closes the loop: it ties energy back to Newton's laws, to the work-energy theorem, and to the limits of mechanical-energy conservation.

Ref: Chabay & Sherwood §7.10; Sherwood & Bernard, 1984; Arons, 1997 (§5.6, §5.7)

Beyond these five. The traps above were chosen for breadth — one each from the substance-vs-bookkeeping layer (Trap 1), the systems-and-interactions layer (Trap 2), the work-energy theorem layer (Trap 3), the language-discipline layer (Trap 4), and the cross-band closing item (Trap 5). The full diagnostic surfaces **eleven misconception bands** across twenty-four items: *substance vs bookkeeping* (E1), *conservation conditions* (E2), *transfer vs transformation* (E3), *state vs process* (E4), *PE belongs to interactions* (E5), the *work-KE theorem* (E6), *Hooke's law and spring PE* (E7), *qualitative transformations* (E8), *PE diagram reading* (E9), *heat vs temperature* (E10), and the *friction paradox* (X1, cross-band closing item). The next page shows how these surface in a sample classroom dataset.

Example Heatmap Using Simulated Data

ILLUSTRATIVE DATA (N = 25)

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

Mean: 12.5/24 (52%) Median: 13/24 Range: 2–20

This heatmap shows results from the **Energy** diagnostic (24 questions across 11 misconception bands, E1 through E10 plus a cross-band closing item X1).

Q#	Concept Tested	Overall	A (20–24)	B (15–19)	C (10–14)	D (0–9)	Band
Q01	Substance vs bookkeeping	60%	75%	88%	56%	0%	**E1**
Q02	Path-independence (frictionless)	60%	100%	75%	44%	25%	**E2**
Q04	Sliding-to-rest (Knight)	60%	100%	62%	56%	25%	**E2**
Q03	Transfer vs transformation	44%	100%	50%	22%	25%	**E3**
Q05	Scalar *E* vs vector *p*	52%	75%	62%	44%	25%	**E4**
Q06	Ball–Earth PE-as-pair	72%	75%	75%	89%	25%	**E5**
Q07	Single-object-no-PE	56%	50%	88%	44%	25%	**E5**
Q13	PE-reference + negative-PE	44%	100%	62%	22%	0%	**E5**
Q08	Ramp normal force (no-work)	64%	100%	75%	56%	25%	**E6**
Q11	W-K theorem *F*-*x* graph	44%	75%	50%	44%	0%	**E6**
Q14	Astronaut floor-jump	52%	100%	62%	44%	0%	**E6**
Q15	Wall-on-spring (no Δ*x*)	52%	75%	62%	44%	25%	**E6**
Q09	Spring-constant meaning	60%	75%	75%	67%	0%	**E7**
Q10	Length vs displacement (spring)	68%	100%	75%	56%	50%	**E7**
Q12	Drop-block-on-spring	32%	50%	62%	11%	0%	**E7**
Q16	Transformation chain	60%	100%	62%	56%	25%	**E8**
Q17	Internal vs thermal	48%	75%	75%	33%	0%	**E8**
Q18	Stable vs unstable equilibrium	64%	100%	62%	56%	50%	**E9**
Q19	Graph-shift invariance	44%	75%	50%	44%	0%	**E9**
Q20	Turning points / forbidden	52%	100%	38%	56%	25%	**E9**
Q21	Forbidden trajectory (3-hill)	32%	50%	25%	44%	0%	**E9**
Q22	Heat-as-noun recognition	36%	75%	50%	22%	0%	**E10**
Q23	Phase change at constant *T*	60%	100%	75%	44%	25%	**E10**
Q24	Friction paradox	36%	75%	38%	33%	0%	**X1**

1. **Q12 — Band E7 (Hooke's law + spring PE).** Drop-block-on-spring procedural item: 32% overall, 11% in Band C, 0% in Band D. Even Band B is at 62%. Procedural fluency in spring problems does not imply ability to choose the right tool when both energy and kinematic methods are available.
2. **Q22 — Band E10 (Heat versus temperature).** Heat-as-noun recognition item: 36% overall, 22% in Band C, 0% in Band D. The linguistic discipline that distinguishes heat (a process) from thermal energy (a state) has not landed for most students — and the textbook prose they read mostly does not help.
3. **Q24 — Band X1 (Friction paradox, cross-band).** Constant-velocity-block-on-rough-surface item: 36% overall, 0% in Band D, 33% in Band C. The closing item ties energy back to Newton's laws. A class that misses Q24 broadly is also likely to misread work-energy theorem applications across the rest of the topic.

Red cells mark the highest-leverage targets. Compare the Overall column against Bands C and D to surface misconceptions that class averages may hide. The class heatmap is generated from the school's own student responses and delivered 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

Performance by question and by student performance band (A–D), with each item tagged to its misconception band. Colour-coding helps show where understanding breaks down across the class. Items are grouped by band so cluster patterns become visible at a glance.

One-page cohort summary

Which misconception bands hit hardest, what they mean, how your class distributes across performance bands A–D, and what the overall profile tells you about where your students are. Designed for a head of department or course leader to act on without needing to re-derive anything from the heatmap.

Band-level profiles

What each performance band means for your students — from “structurally sound” to “needs foundational rebuilding” — with specific guidance on what each group needs next. The four bands are deliberately coarse so the next instructional step is unambiguous for each group.

Targeted remediation toolkit

Not generic revision advice. A four-document set — an Energy Mistake Museum, a Words That Hurt language guide, a Remediation Worksheet, and a Teacher Answer Key — 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. Six PDFs total: heatmap, cohort summary, Mistake Museum, Words That Hurt, Worksheet, 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. Tell us which topic block matches your current unit. The Energy diagnostic suits classes finishing or revising work, energy, and conservation laws — typically late Y12 / Grade 11 or early Y13 / Grade 12 in IB and AP physics, or the equivalent stage in A-Level Physics.

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 Energy diagnostic takes about 25–30 minutes (24 questions, no calculator required, single sitting). Either in class or as a short take-home task — advise students not to discuss answers until all have submitted.

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 Energy diagnostic covers the conceptual surface of energy taught in IB DP Physics (A.3 Work, energy and power; B.1 Thermal energy transfers; HL extension B.4 Thermodynamics), AP Physics 1 (Unit 3 Work, Energy, and Power; Unit 6 Energy and Momentum of Rotating Systems) and AP Physics 2 (Unit 9 Thermodynamics), A-Level & AS Physics (Mechanics — Work, Energy, Power; Materials — Hooke's law and elastic strain energy), and GCSE / IGCSE Physics (Energy stores, transfers, and conservation). **Eleven misconception bands, twenty-four questions, single-sitting diagnostic.**

Two motion diagnostics (Motion Foundations, Motion Change) and a six-module Newton's Laws diagnostic are also available, covering kinematics and forces respectively. The Energy diagnostic builds on both: the work-energy theorem cluster (E6) draws on Newton's laws, and the friction-paradox closing item (X1) ties back to Newton-frame contact-point reasoning.

Request a classroom pilot

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