

A Teacher's Guide to Hidden Misconceptions in Motion in Electromagnetic Fields

Why marks can hide shaky understanding, and what a class-level misconception heatmap shows about the force on a moving charge, charged-particle motion in magnetic and crossed fields, and the forces on and between current-carrying wires

For physics teachers and department leads

A guide to misconceptions in motion in electromagnetic fields that can sit behind good marks on routine problems, from the idea that a magnetic field pushes a charge at rest, through a magnetic force that changes a particle's speed and an orbit period tied to speed, to an electric account of the pull between two current-carrying wires. Includes example diagnostic output and details on how to run a free classroom pilot using the Motion in Electromagnetic Fields diagnostic.

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Why Marks Can Hide Shaky Understanding

A student scores 75% on a magnetism test. They can put numbers into $F = qvB$ and $F = BIL$, find the radius of a charged particle's circle from $r = mv/(|q|B)$, and get familiar problem types right. Their mark says they understand motion in electromagnetic fields.

A question that tests the idea behind a formula can give a different picture. Questions of this kind include what magnetic force acts on an ion held at rest in a strong field, whether the field speeds a particle up as it bends the particle's path, whether a proton moving twice as fast takes less time to go once round its circle, and why two neutral wires carrying currents pull on each other.

A student can get these wrong from a model that still gives right answers on routine problems. The student does not know the model is wrong, and a percentage score does not show it.

In this topic the wrong models are specific, and each one has a recognisable shape. A magnetic field is taken to push any charge in it, moving or not. Magnetic poles are treated as positive and negative charges. The magnetic force is taken to point along the motion, or to speed a particle up or slow it down. The period of an orbit is tied to the particle's speed. The two fields in a velocity selector are said to cancel. The force on a wire is treated as a separate law from the force on a moving charge, and the pull between two current-carrying wires is pictured as electric.

A test made of familiar problem types checks fluent use of formulas. It does not check whether the ideas behind the formulas fit together. A class can look secure on paper while carrying these models into later topics, such as electromagnetic induction, or into exam questions set in an unfamiliar context.

The **Motion in Electromagnetic Fields** diagnostic is built to show these models. It has 22 multiple-choice questions in 11 misconception bands, two questions to each band. The bands fall into five families: the force on a single charge, motion in a uniform magnetic field, crossed electric and magnetic fields, the force on a current-carrying wire, and the force between parallel wires. One band is the place to start: a stationary charge feels no magnetic force from B alone. The diagnostic is written for IB DP Physics D.3 and covers five of its six understandings. It does not test motion in a uniform electric field, or how to find the direction of the magnetic field around a straight wire carrying a current. When that field direction is needed, it is supplied. The eleven bands, in the order the remediation materials use, are:

Band	The idea it checks	Questions
RST-1 (start here)	A stationary charge feels no magnetic force from B alone	Q1, Q8
EQV-1	Electric and magnetic interactions are not interchangeable	Q3, Q10
DIR-1	Moving-charge force depends on direction, sign and angle	Q5, Q12
MWS-1	Magnetic force changes direction, not speed	Q2, Q9
ORB-1	Orbit timing follows q , m and B , not speed or radius	Q4, Q11
ORB-2	The bend of the path and the sign of the charge set which way it goes round	Q7, Q14
SEL-1	Crossed fields select one speed by force balance	Q6, Q13
LAW-1	The wire-force law comes from forces on moving carriers	Q15, Q19
SEG-1	The force on a loop depends on which parts are in the field	Q16, Q20
COL-1	Many slow carriers can produce a measurable wire force	Q17, Q21
PWI-1	Neutral parallel wires carrying currents interact magnetically	Q18, Q22

Five Magnetic-Force Misconceptions Worth Tracking

These are five of the eleven misconceptions the diagnostic tracks, one from each of the five families: the force on a single charge, motion in a magnetic field, crossed fields, the force on a current-carrying wire, and the force between parallel wires. Each can produce correct answers on routine problems and so stay hidden. The tag on each trap is the misconception band that tracks it, and the trap number matches its exhibit in the Mistake Museum.

Trap 1: The Field Pushes a Resting Charge RST-1

An ion is held at rest in a strong, uniform magnetic field. The tempting answer gives it a force, along B or across B , or one set by which pole the field comes from. The magnetic force is $F = q(v \times B)$, and with $v = 0$ it is zero however strong B is. Set the same ion moving at right angles to B and the force becomes $|q|vB$. The rest of the topic builds on this velocity condition: the direction rule, the circular orbit, the selector balance and the force on a wire all depend on it. Read this band first; its result does not decide whether any other band is flagged.

Trap 4: The Field Changes the Speed MWS-1

A positive particle bends round a circular arc in a uniform magnetic field. Because the force keeps acting, the tempting answer has the field doing work on the particle, so that it speeds up or slows down. The magnetic force on a moving charge is perpendicular to its velocity at every instant, so it does no work, and with no other force acting the speed stays the same. In a uniform field, when the particle enters at an angle to B , the velocity component along B is also unchanged, and the path is a helix of constant pitch traced at constant speed. Hearing “accelerates” as “speeds up” makes this error easy to keep.

Trap 7: Any Speed Goes Straight Through SEL-1

In a velocity selector, for a particle moving through in the set direction, the electric and magnetic forces point in opposite directions. The tempting account says the two fields balance, so E must equal B and any particle passes straight through. The balance is between forces. For a particle moving at right angles to both fields, the electric force $|q|E$ is the same at every speed, while the magnetic force $|q|vB$ grows with speed, so they cancel only at $v = E/B$. A slower particle feels the smaller magnetic force and deflects towards the electric force. E and B have different units, so $E = B$ cannot be the condition. Reversing the charge reverses both forces, and the selected speed stays E/B .

Trap 10: Slow Drift, No Force COL-1

The electrons in a metal wire drift very slowly. The tempting conclusion is that the magnetic force on them is too small to matter, so any force on the wire must come from the field pulling on the metal itself. The average force on each carrier is small. The wire holds an enormous number of carriers, all pushed the same way on average, and for a wire at right angles to B their forces together give $F = BIL$, which for 2.0 A in a 0.50 T field over 1.0 m is 1.0 N, easily measured. The carriers cannot leave the wire. As they are pushed sideways, a little charge builds up on one side of the wire, and the electric field of that charge pushes the positive ions of the metal sideways, so the force on the carriers becomes a force on the wire as a whole.

Trap 11: The Wires Pull Electrically PWI-1

Two long, parallel, neutral wires carry currents in the same direction and attract. The tempting explanation is electric: the wires become oppositely charged, or the electrons in one wire attract those in the other. Each wire is electrically neutral overall, so, ignoring the small surface charges that drive the current, there is no net electrostatic force between them. The current in each wire makes a magnetic field, and that field exerts a magnetic force on the moving carriers in the other wire. Same-direction currents attract and opposite-direction currents repel, and reversing one current reverses the force. The diagnostic tests the mechanism; each question states whether the wires attract or repel.

Example Heatmap Using Simulated Data

Illustrative data for 25 simulated students

Simulated data shown in a simplified form of the class heatmap. Not drawn from a classroom or pilot cohort. The colours here are grouped into five steps. The class heatmap uses a continuous colour scale and gives a short name for each band beside its code.

Mean: 12.2/22 (55%) Median: 12/22 Range: 1 to 22

This heatmap shows the **Motion in Electromagnetic Fields** diagnostic (22 questions across 11 misconception bands, two questions to each band). Columns group students by total score.

Q#	Concept Tested	Overall	A (18–22)	B (14–17)	C (9–13)	D (0–8)	Band
Q1	Ion at rest in B	60%	100%	75%	44%	25%	RST-1
Q2	Speed after a quarter-turn	76%	100%	75%	78%	50%	MWS-1
Q3	Charged rod and magnet	56%	75%	75%	56%	0%	EQV-1
Q4	Period at doubled speed	48%	100%	63%	22%	25%	ORB-1
Q5	Force direction, B into page	80%	100%	88%	100%	0%	DIR-1
Q6	Slower particle in selector	48%	75%	63%	44%	0%	SEL-1
Q7	Electron path curvature	52%	100%	63%	33%	25%	ORB-2
Q8	Force at rest and moving	56%	100%	63%	56%	0%	RST-1
Q9	Helix: parallel component	60%	100%	75%	56%	0%	MWS-1
Q10	Magnet in uniform E and B	44%	75%	63%	33%	0%	EQV-1
Q11	$ q /m$ from the radius	44%	75%	63%	22%	25%	ORB-1
Q12	Force at 0°, 30°, 90°	60%	75%	75%	67%	0%	DIR-1
Q13	Straight path: $E = vB$	72%	100%	88%	67%	25%	SEL-1
Q14	Charge sign from the path	48%	100%	50%	33%	25%	ORB-2
Q15	$F = BIL$ from carriers	68%	100%	75%	67%	25%	LAW-1
Q16	Loop: sides in the field	60%	100%	63%	44%	50%	SEG-1
Q17	Force reaches the lattice	52%	75%	63%	44%	25%	COL-1
Q18	Same-direction currents	40%	75%	38%	44%	0%	PWI-1
Q19	Electron carriers, wire force	44%	100%	63%	22%	0%	LAW-1
Q20	Loop net force	48%	100%	50%	44%	0%	SEG-1
Q21	Slow drift, 1 N force	56%	75%	88%	33%	25%	COL-1
Q22	Opposite-direction currents	48%	100%	75%	22%	0%	PWI-1

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

- Q1, Q8: Band RST-1, the place to start.** The two questions sit at 60% and 56%, a combined 58% (29 of 50 responses), below the 60% line, so the class is flagged on this band. In score group D they fall to 25% and 0%. Read this band first: the direction, orbit, selector and wire bands all use the velocity condition in $F = q(v \times B)$.
- Q18, Q22: Band PWI-1; Q4, Q11: Band ORB-1.** PWI-1 is the lowest band at 44%, and Q18 is the lowest question at 40%. Every wrong option on Q18 gives an electric account of the attraction, and score group B is at 38% on it, so the electric picture is not confined to weaker students. ORB-1 (orbit period and charge-to-mass ratio) sits at 46%, with score group C at 22% on both questions.
- Q6, Q13: what the 60% line does.** SEL-1 combines Q6 at 48% with Q13 at 72%, which gives exactly 60% (30 of 50). That is not below the line, so the band is not flagged for the class. MWS-1 (68%) and DIR-1 (70%) are clear. A band is always read from its two questions together.

Red cells mark the lowest shares of correct answers. Each cell is the share of students in that column who answered the question correctly. A band's percentage combines the answers to all its questions, so it does not count the students who hold the misconception. Read each band against the weaker score groups as well as the overall column. A student is flagged on a band only when both its questions are wrong, with at least one answer that matches a known misconception; the cohort summary names the students to watch and the questions they missed. 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 Motion in Electromagnetic Fields diagnostic produces a self-contained set of materials:

Class-level misconception heatmap

Performance by question and by score group (A to D; the cohort summary calls these Band A to Band D), with each question tagged to its misconception band. Colour-coding shows the questions with the lowest share of correct answers. Scored against the 22-question total.

Two-page cohort summary

The flagged bands and what they mean, the areas safe to skip, and the priority order for remediation, with a short teaching move for the first priorities. Named follow-up for individual students is for use within the school only. Designed for a head of department or course leader to act on without re-deriving anything from the heatmap.

Per-band priority

Inside the cohort summary: the weakest bands, what they mean for your class, and the order in which to work on them. Read the start-here band, RST-1, first; its result does not decide whether any other band is flagged.

Remediation toolkit

A full set covering all eleven bands, with the cohort summary naming the sections to set first: a Mistake Museum of 11 named traps, a Words That Hurt guide of 11 teacher phrasings with what to say instead, a Remediation Worksheet of 12 items in 11 assignable sections, and a Teacher Key with a classroom move for each section. Trap 1, Entry 1 and the first worksheet section all deal with the same band, and so on through all eleven. You do not need to build any of these materials yourself.

How to read the flags

A band is flagged for a student when both questions in that area are wrong, with at least one answer that matches a known misconception. One wrong answer on its own never flags a band.

Not every wrong answer is a misconception. Some options are general wrong answers. Two of those in the same area show the area is not secure, but they do not name a misconception.

A band is flagged for the class when fewer than 60% of the responses to its two questions are correct. A question's percentage is the share of students who answered it correctly. A band's percentage combines the answers to all its questions.

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 Key. Apart from replying "completed" when the class has finished, 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, its work on magnetic forces and charged-particle motion and you want to find out what your students now understand, the diagnostic is designed for that point in the course; 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 and no software installs are needed. Each student enters a name or a student ID; schools may use anonymised IDs.

Step 3. Students complete the diagnostic.

Share the link with your class. The Motion in Electromagnetic Fields diagnostic takes about 30 minutes (22 multiple-choice questions, four options each) and can be completed in class or as a short take-home task. No calculator is required. When the class has finished, reply "completed" to our email.

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 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 Motion in Electromagnetic Fields diagnostic covers five of the six understandings in IB DP Physics D.3 (motion of charged particles in electromagnetic fields). It also covers AP Physics 2 and AP Physics C: Electricity and Magnetism (magnetic forces on moving charges and on current-carrying wires), A Level Physics (the force on a current-carrying conductor, the force on a moving charge, and the circular paths of charged particles), and, in part, IGCSE Physics (the force on a current-carrying conductor and on a beam of charged particles). **One diagnostic: 22 questions across 11 bands, two questions to each band.** It does not test motion in a uniform electric field, or how to find the direction of the magnetic field around a straight wire carrying a current. When that field direction is needed, it is supplied.

Also available: the Static Electricity, Electric Fields, Electric Potential, Current Electricity, Motion Foundations, Motion Change, Newton's Laws (six modules), Projectile and Circular Motion, Energy, Momentum, and Oscillations and Waves diagnostics. Together they cover kinematics, forces, momentum, energy, waves, electricity and magnetism.

Request a classroom pilot

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