

Why does a magnet attract some metals but not others?

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A magnet can lift an iron object while showing no obvious attraction to a similar-looking piece of copper. Both are metals and both conduct electricity. Electrical conductivity alone therefore does not determine whether a stationary object will stick to a magnet. The question concerns the magnetic response of the material and how strongly that response couples to the nonuniform field around the magnet.

“No obvious attraction” is not the same as “no magnetic response”. Weak responses can require sensitive measurements, and some responses tend to move a sample away from stronger field. A hand-held test divides materials by what is easily visible, not by a complete physical classification.

1. Microscopic moments do not automatically make a magnet

Electrons contribute magnetic moments through their quantum properties and motion. Whether those contributions cancel, remain only weakly correlated or develop collective order depends on the electronic structure and interactions in the material. The elementary classification distinguishes diamagnetism, paramagnetism and ferromagnetism [1].

In a paramagnetic response, an applied field produces a small net alignment of moments that thermal agitation tends to disrupt. Diamagnetic response opposes the applied field. These categories concern the net response in a stated regime; a real material can have several contributions at once. It would be wrong to infer that every atom supplies the same permanent moment or that all paramagnets align by one fixed fraction.

Ferromagnetic order is different from many independent moments merely following an external field. Interactions can favour parallel ordering over regions of the material. Explaining why a given substance orders requires quantum electronic structure, not a picture of classical electrons spinning like little mechanical planets. The observable consequences include a strong and often nonlinear response to a field.

2. A piece of iron can contain domains without being a strong permanent magnet

A ferromagnetic specimen can divide into domains with differently oriented magnetization. Their arrangement reduces competing energy costs, including the magnetic field outside the sample and the cost of domain boundaries. The magnetization within domains can be substantial while the specimen's net external effect is much smaller [1,2].

An applied field can favour growth of some domains and change the orientations of magnetization. The material then develops a net response aligned with the applied field. How readily boundaries move depends on microstructure and defects. This provides a physical route from a largely unmagnetized object to one that is strongly attracted.

The outcome after removing the field is not universal. Some materials retain substantial magnetization; others are designed to change magnetization readily and retain little under the relevant conditions. Ferromagnetism does not guarantee that every specimen becomes an equally strong permanent magnet after any exposure. Shape and history matter as well as composition.

3. Attraction requires a spatial variation

An ideal magnetic dipole in a uniform field experiences a torque unless appropriately aligned, but no net translational force from that uniform field. To pull a small object towards the magnet, the field must vary across the region it occupies. This is why field strength and field gradient answer different questions.

For a small, weakly magnetic sample with approximately linear isotropic susceptibility χ , negligible demagnetizing corrections and a prescribed field B in the surrounding vacuum, a useful approximation is $F = \chi V \nabla(B^2)/(2\mu_0)$. Here V is sample volume and μ_0 is vacuum permeability. A positive χ favours stronger field; a negative χ favours weaker field. The formula is an illustrative linear-response limit, not a model for a strongly magnetized iron object at saturation.

The factor of one half matters for an induced moment. As the applied field grows from zero, the induced magnetization also grows; the energy must account for that changing response. Treating the final induced moment as a fixed permanent moment throughout the process would give the wrong energy expression. No numerical force prediction follows without the material response and spatial field map.

4. Why conductivity is not the deciding test

Copper is a good electrical conductor, but ordinary copper does not acquire the strong ferromagnetic response of iron. Its weak net magnetic behaviour is a different property from its ability to conduct current. A stationary magnet test therefore cannot identify conductivity, and a continuity meter cannot identify ferromagnetic order.

Relative motion introduces another phenomenon. A changing magnetic flux through a conductor can induce currents, and their fields can oppose the change that produced them. Magnetic braking by a moving conductor is consequently not proof that the conductor is ferromagnetic. It is an induction effect whose size depends on geometry, motion and electrical resistance.

The distinction also prevents a common misreading of demonstrations: a magnet moving slowly near a conducting object may encounter a resistive force even if the same object does not stick to the stationary magnet. The two observations probe different processes. This article's title concerns the strong attraction familiar from a stationary hand-held test.

5. Temperature and material history can change the answer

Thermal agitation can destroy long-range ferromagnetic order above a material-dependent transition temperature. Below that temperature, the measured response still depends on domains, microstructure and the applied field. A material name without phase and conditions is not enough to predict an exact magnetization curve.

Alloys make this especially apparent. Altering composition or processing can change crystal structure and magnetic behaviour. The everyday category metal includes many electronic structures, so no rule that all metals are strongly attracted can survive even basic comparison. Nor does lack of strong attraction tell us that the material contains no iron in any form.

A rigorous identification would measure magnetization as the field is varied, preferably with controlled temperature and sample geometry. A hysteresis loop reveals history dependence: the same applied field can accompany different magnetization states depending on the path taken to reach it. A single attraction test does not supply that curve.

6. What is established, and what remains specimen-specific?

The established framework connects microscopic moments, collective ordering and the force produced by a nonuniform field. Experiments can distinguish weak reversible responses from strong, nonlinear and history-dependent ones. The exact strength of a particular attraction remains a quantitative problem involving the specimen and the magnet together.

The decisive material question is how magnetization develops and changes under the applied field. The decisive geometrical question is how the field varies in space. Separating those questions explains why two equally metallic objects can behave very differently.

A magnet strongly attracts some metals because their electronic interactions and domain structure allow a large induced or existing magnetization that couples to the field gradient. Other metals respond much more weakly or with the opposite sign. The everyday test is useful, but its apparent yes-or-no result sits on top of a richer and measurable range of material behaviour.

Related reading: IDE-009, on fields; IDE-021, on quantum fields.

References

[1] OpenStax. University Physics Volume 2, §12.7, Magnetism in Matter.

<https://openstax.org/books/university-physics-volume-2/pages/12-7-magnetism-in-matter>

[2] OpenStax. College Physics 2e, §22.2, Ferromagnets and Electromagnets.

<https://openstax.org/books/college-physics-2e/pages/22-2-ferromagnets-and-electromagnets>