

Why can we see through glass but not metal?

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A window and a metal sheet both contain matter packed closely enough to resist a hand. Yet visible light can cross the window while a sufficiently thick metal sheet blocks the view. The difference cannot be explained by saying that glass is mostly empty space and metal is not. Both contain charged constituents that interact with electromagnetic fields. What differs is their response at the frequencies we are trying to see.

The question also needs a qualification. Not every glass is transparent at every wavelength, and a sufficiently thin metallic layer can transmit some light. Transparency belongs to a material, wavelength range, thickness and structure together. It is not an unconditional label attached to a chemical name.

1. Following the incident energy

When light meets a sample, some energy may be reflected, some transmitted and some absorbed [3]. For a passive sample in a steady optical measurement, with no significant wavelength conversion and with all outgoing directions counted, the fractions satisfy $R + T + A = 1$. Reflection and absorption can both reduce transmission, but they leave energy in different places.

An opaque mirror and an opaque black surface therefore need not behave similarly. The first returns much of the incident light; the second absorbs much of it. A measurement collecting only the direct transmitted beam can also mistake scattering out of that beam for absorption. To separate the mechanisms, reflected and diffusely scattered light must be considered as well.

These distinctions turn the title into an experimental question. Specify the wavelength and thickness, then ask which channels remove light from the forward beam. “It cannot get through” is a description of the outcome, not yet its physical explanation.

2. Transparent matter still responds

In a transparent region of an ordinary dielectric, the material's charges respond to the light field without dissipating a large fraction of its energy over the sample thickness. Their collective electromagnetic response changes propagation. Refraction is evidence of interaction, not evidence that the light has avoided the material altogether. The classical response treatment connects this change to the frequency-dependent motion of charges [1].

It is misleading to picture propagation through a window as a sequence of ordinary absorptions followed by random spontaneous re-emissions. That picture would lose the phase and directional relationships responsible for coherent transmission and refraction. The macroscopic optical field includes the incident field and the organized response of the material.

In a quantum description, the electronic structure constrains available absorption processes. Common clear glasses have a visible transmission window because strong electronic absorption is not spread uniformly across that range. Other absorption

processes become important elsewhere in the spectrum. The phrase transmission window is more accurate than “glass does not absorb light”.

3. Why a metal responds differently

Metals have mobile charge carriers that can respond strongly to an applied optical field [2]. In a simple free-carrier description, the dielectric response depends on frequency, carrier density and damping. Over appropriate frequency ranges, the response produces strong reflection and fields that diminish rapidly into the material. Real metals also have electronic transitions beyond this elementary carrier model.

One idealized expression, with damping omitted, is $\epsilon_r(\omega) = 1 - \omega_p^2/\omega^2$. Here ϵ_r is relative permittivity and ω_p is the model's plasma frequency. Below ω_p the expression is negative. In that lossless limit, the field inside a semi-infinite material can be evanescent even though absorption is zero. Blocking transmission therefore does not, by itself, prove that all incident energy is absorbed.

Adding damping permits dissipation. Including bound-electron response and electronic band transitions is necessary for a realistic optical spectrum. The simple expression identifies why electrical response matters; it should not be used as a universal numerical spectrum for every metal or as an explanation of every metallic colour.

4. Thickness makes an essential difference

If the field amplitude in an absorbing homogeneous medium decreases as $\exp(-z/\delta)$, intensity decreases as $\exp(-2z/\delta)$. The amplitude decay length δ is therefore twice the corresponding intensity decay length. Quoting a penetration depth without defining whether it describes field or intensity introduces a factor-of-two ambiguity.

A convenient intensity expression is $I(z) = I(0) \exp(-\alpha z)$, where α is an attenuation coefficient for the specified process and wavelength. Suppose, only as an illustration, that $\alpha = 10 \text{ m}^{-1}$ and the path is 0.01 m. The internal intensity factor is $\exp(-0.1)$, about 0.905. At 0.1 m it is $\exp(-1)$, about 0.368. These are hypothetical inputs, not measured values for a named glass.

Even that calculation omits interface reflections and possible interference between the front and back surfaces. Thin metallic coatings can be partly transmitting, and optical multilayers exploit interface effects deliberately. The familiar distinction between a window and a sheet of metal describes common macroscopic samples, not a theorem that one category always transmits and the other never does.

5. Why some glass looks cloudy or coloured

A material can have low absorption and still prevent a clear view if it scatters light strongly. Variations in refractive index, pores, inclusions or a rough surface can redirect rays into many directions. A frosted pane makes this distinction visible: light can enter the room without preserving a sharp image of what lies outside.

Colour introduces another possibility. If transmission varies across the visible spectrum, the emerging light can have a different spectral balance. Impurities and deliberate additives can alter absorption, while structural variations can affect scattering. One cannot infer the microscopic mechanism from a colour name alone.

A meaningful comparison therefore asks both how much energy emerges and how it is distributed over angle and wavelength. “Transparent”, “translucent” and “opaque” describe different practical outcomes, but the underlying measurements are continuous. A sample can be useful as a window in one spectral band and unsuitable in another.

6. What the explanation does and does not settle

Transmission and reflection spectra, measurements at several thicknesses and observations of diffuse scattering can constrain a material-response model. If a proposed absorption coefficient predicts the wrong thickness dependence, the model or its assumed sample description needs revision. A single successful fit can still leave ambiguity among different microscopic explanations.

The secure physical distinction is frequency-dependent electromagnetic response, combined with geometry and thickness. Predicting a particular specimen requires its optical constants, structure and surface conditions. The electronic response of actual materials is more detailed than either the elementary bound-charge model or the free-carrier limit, but their limits are instructive rather than contradictory.

We can see through suitable glass because it transmits a useful fraction of visible light while preserving enough directional information to form an image. Common thick metals instead strongly reflect and attenuate that light. Neither outcome follows from a simple count of empty spaces between atoms, and neither explains why a solid resists being penetrated by another solid. That is a different question.

Related reading: QTC-003, on solidity; IDE-020, on the particle concept.

References

- [1] Feynman, R. P.; Leighton, R. B.; Sands, M. The Feynman Lectures on Physics, Vol. I, Chapter 31, The Origin of the Refractive Index. https://www.feynmanlectures.caltech.edu/I_31.html
- [2] Feynman, R. P.; Leighton, R. B.; Sands, M. The Feynman Lectures on Physics, Vol. II, Chapter 32, Refractive Index of Dense Materials. https://www.feynmanlectures.caltech.edu/II_32.html
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