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The ‘quantum’ nature of reflection

When we go down to the atomic scale there is nothing like a ‘smooth surface’, says S.Ananthanarayanan.

At the very minute scale, the surface of anything consists of individual atoms. Some important details are whether the substance is a metal and whether it forms crystals.

Metallic surfaces reflect

Reflection of light involves the interaction of photons, or the particles of light, with what they find at the surface they strike. One of the features of this interaction is that photons interact most readily with electrons. As we know, atoms consist of a positive nucleus, surrounded by electrons. In metals, which have properties like being good conduction of electricity, their solid state consists of a substantial supply of ‘free’ or loosely bound electrons at the surface. Photons thus interact intensely and polished metallic surfaces are generally good reflectors.

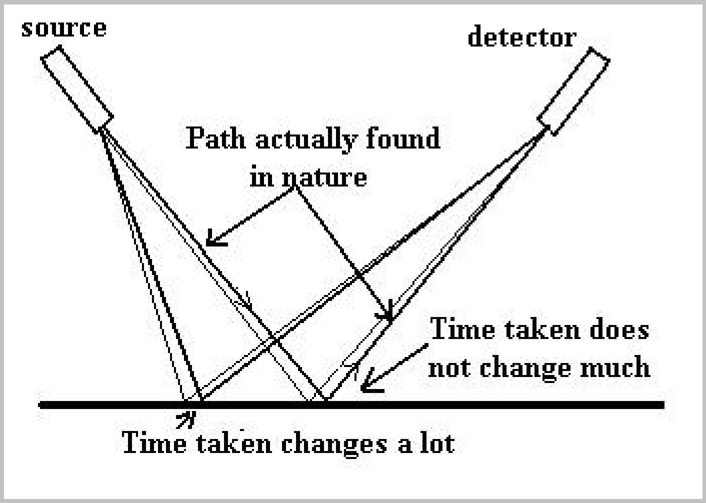
Another property of metals is that they form crystals. Polishing the surface amounts to causing the crystals on the surface to ‘shear’ along the direction of the ‘polishing’. Polishing then leads to large patches of crystalline surfaces and ‘uniformity’ in the surface presented to photons.

The mechanics of reflection

When the photon is reflected off an electron, what really happens is that the electron absorbs the photon and then emits it after a short gap of time. Given a pool of electrons along a metallic surface, it can be worked out that the probability of the emitted electrons being in the direction according to the laws of reflection is overwhelmingly higher than for any other direction. There is also some probability of reflected photons being in other directions, but these cancel out and what remains is as if the reflection occurs geometrically at a flat surface.

At the final level, the nature of reflection is not explained by ordinary physics, but has to invoke the methods of ‘quantum mechanics’ or the physics of the very small dimensions. At very small dimensions, the distinction disappears between particles and waves and the position of a particle is really just the place where the probability of it being found is highest. These probabilities have a wave nature and they can add and cancel, like the waves that roll in at the beach can add to the waves rolling back or can be neutralized by them.

Along the path of reflection in the geometrical sense, a slight variation in the path does not affect the phase of the waves too much. The waves are hence able to survive, the mean path coming out strongest. But along paths that are quite different, slight variations result in major changes in the timing of the waves. Hence, adjacent paths cancel out and we see no reflection.



In gases and liquids

In solids, the atoms are in fixed positions and in the case of most metals, the effect is reflection. But in liquids and gases, the orientation of the atoms is ‘random’ and reflection does not occur. Ordinary glass is really a very viscous liquid, rather than a solid. The main consequence is that the atoms are not in any fixed orientation. This is the reason for glass being transparent.