Why Index Approaching?

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The organization of optical specification tables for ray tracing typically uses one or more lines of text to represent each optical surface. In a fully sequential trace, this list of surfaces defines the order in which rays visit each surface. There are no table entries for the spaces between optical surfaces. So, where to specify refractive media?

There are two possibilities: associate a surface with the refractive medium where light approaches the surface, or with the refractive medium in which light departs.

Here I explain why the "index approaching" choice is the correct choice.

An optical surface defines an electromagnetic boundary. To be a valid solution, the sum of all outgoing waves (reflected, refracted, diffracted...) must exactly add up to the single incoming wave. So this incoming wave is the foundation upon which the possible outputs are added.

What is this boundary condition? It is the electromagnetic potential along the surface. For an incoming wave at position $\vec{P} = (x, y, z)$ with propagation vector $\vec{Kin}$,

$$E = exp(i\vec{K_{in}} \cdot \vec{P} - i\omega t)$$

where $|K_{in}| = \omega / n_{in} c$ is its magnitude and n_{in} is the refractive index for the incoming wave. The boundary condition applies along this surface whose normal vector is $\vec{N}$. The only properties of this wave needed are its time dependence ωt and its spatial frequency along the surface, namely

$$K_{parallel} = (\vec{N} \times \vec{K_{in}}) \times \vec{N}$$

It is this $K_{parallel}$ field that is associated with the surface and which drives all the outgoing waves. It clearly depends on n_{in} alone. So "index approaching" is the right choice to associate with each surface.

Of course, for refraction and refractive diffraction, the outgoing waves will depend on n_{out} as well. For those cases, however, there will always be a following surface, whose associated refraction supplies the n_{out} for these outgoing waves.