This is article from The Graphics Codex by Morgan McGuire. The full app contains 12 chapters of lecture notes for a physically based rendering course and 225 encylopedia-like reference articles. Buy the web or iOS edition for only $10 at http://graphicscodex.com.

$$F(c_\mathrm{r} \in [0,1], c_\mathrm{t} \in [0,1]) \in [0,1] = \frac{F_{\parallel}(c_\mathrm{r}, c_\mathrm{t}) + F_{\perp}(c_\mathrm{r}, c_\mathrm{t})}{2}$$

Discussion

The model for F depends on whether the medium on the transmissive side of the surface conducts electricity (which effectively determines whether it can transmit light at all). Note that the medium on the incident side of the surface *must* be a dielectric--otherwise the light would not have been propagating through it in the first place. For the different models, see the conductor model (F_c), dielectric model (F_d) and Schlick's approximation (F_s).

Specular (Optically Planar) Surfaces: All interfaces that are microscopically (i.e., “optically”) planar scatter light in the same way. They reflect some light a single specular (mirror) direction, transmit some along a refracted ray defined by Snell's Law, and absorb the remainder. Fresnel's equations describe the probabilities of a photon undergoing each of these mutually exclusive events, i.e., the coefficients scaling the intensity of the scattered light. These depend on the angle of incidence and the refractive indices of the materials on either side of the surface. In general, all materials are more transmissive near normal incidence and more reflective near glancing incidence. That is why a lake reflects the distant shore and sky when you look across it but you can see the bottom if you wade in and look straight down.

For such surfaces, the angle of incidence is equal to the angle of specular reflection (i.e., $\theta_{\mathrm{i}} = \theta_{\mathrm{mo}}$). The cosine of the angle of reflection is therefore $c_{\mathrm{r}} = |\hat{\omega}_{\mathrm{i}} \cdot \hat{n}|$. The cosine of the angle of transmission is $c_{\mathrm{t}} = |\hat{\omega}_{\mathrm{to}} \cdot \hat{n}|$, unless total internal reflection occurs.

Polarization: The magnitude of reflection from a planar surface also depends on and alters the polarization of the incident light. This effect is frequently ignored in computer graphics, so it is common to average the magnitude of the parallel $F_{\|}$ and perpendicular $F_{\perp}$ polarized coefficients (which physicists call S- and P- polarized). See [Wolff1990Polarization] [Tannenbaum1994Polarization] [Weidlich2007Birefringency] for some exceptions, notably for crystals.

Translucent, Specular Macroscopic Surfaces: The microscopic behavior directly matches the macroscopic behavior observed at the surface of a ``translucent'' object like a glass bottle. For other materials we must appreciate the impact of microgeometry and subsurface scattering.

Opaque Surfaces: surfaces are interfaces materials with very high extinction coefficients. They do transmit light in some theoretical sense, but the transmitted light is immediately absorbed by extinction within the medium and is not observable. For conductors this distance is truly negligible; for dielectrics the distance may be on the order of millimeters, producing the soft appearance of subsurface scattering but rendering objects of any larger thickness still opaque.

Glossy (Microfacet) Surfaces: Rough surfaces can be described as a collection of microscopic optically-planar facets. Each microfacet is a perfect specular reflector and transmitter, but they collectively disperse light. Reflection is perfectly specular for each facet, so if reflection occurs, it must be the case that the microfacet's normal was $\hat{\omega}_{\mathrm{h}} = S(\hat{\omega}_{\mathrm{i}} + \hat{\omega}_{\mathrm{o}})$. For microfacet surfaces we therefore ignore the macroscopic surface normal $\hat{n}$ and use the half vector. In this case, $c_{\mathrm{r}} = |\hat{\omega}_{\mathrm{i}} \cdot \hat{\omega}_{\mathrm{h}}| = |\hat{\omega}_{\mathrm{o}} \cdot \hat{\omega}_{\mathrm{h}}|$ and the refraction angle can be computed from Snell's Law and the microfacet normal. Likewise, if refraction occurs, then the observed outgoing direction and incoming direction uniquely determine the microfacet normal.

Symbols

Symbol	*Type*	*Description*	*Ref*
c_{r}	$[0,1]$	Cosine of the angle between the specularly reflected light ray and the microfacet normal.	[cr]
c_{t}	$[0,1]$	Cosine of the angle between the specularly refracted/transmitted light ray and the microfacet normal.	[ct]
η	$\mathbb{R}$	Refractive index.	[eta]
κ	$\mathbb{R}$	Extinction Coefficient.	[kappa]
$\hat{\omega}_{\mathrm{i}}$	$\mathbb{S}^2$	Unit incident light direction (opposite the direction of photon propagation, pointing back at where the light came from).	[sctvar]
$\hat{\omega}_{\mathrm{o}}$	$\mathbb{S}^2$	Unit exiting light direction (in the direction of photon propagation, pointing forward to where the light is	[sctvar]

		going).	
$\hat{\omega}_{\mathrm{h}}$	$\mathbb{S}^2$	Half vector, $S(\hat{\omega}_{\mathrm{i}} + \hat{\omega}_{\mathrm{o}})$.	[wh]
$\hat{n}$	$\mathbb{S}^2$	Unit normal to the surface point X.	[sctvar]

References

[Tannenbaum1994Polarization]

Polarization and Birefringency Considerations in Rendering
David C. Tannenbaum, Peter Tannenbaum, and Michael J. Wozny
in *SIGGRAPH '94: Proceedings of the 21st annual conference on Computer graphics and interactive techniques*, p. 221-222, ACM, New York, NY, USA, 1994.
http://doi.acm.org/10.1145/192161.192204

[Wolff1990Polarization]

Ray Tracing With Polarization Parameters
Lawrence B. Wolff and David J. Kurlander
IEEE Comput. Graph. Appl. 10:6, p. 44-55, IEEE Computer Society Press, Los Alamitos, CA, USA, 1990.
http://dx.doi.org/10.1109/38.62695