

Optics Math

In this business, we do a lot of math. Whether we are buying, selling, designing or using optics, we are frequently scrambling for one equation or another, to convert one cryptic wedge specification into something measurable, or to go back and forth between the wave-front specifications and the results on the test plates. Most of the math we need is buried somewhere in one or more of our optics textbooks or in some spreadsheet we built once and can't find any more. Identifying the right equation is often elusive, even with the wonders of Wikipedia and Google. Optics math, it seems, doesn't pop to the top of the search engines very cleanly.

Thankfully, Ray Williamson of [Ray Williamson Consulting](#) has posted on the web a wonderful cheat sheet of [handy formulas](#) drawn from his Optics Shop Math course. I've pulled from it some of my favorites, but I recommend looking for yourself.

Ever since taking Geometrical Optics I have been able to remember the equation for converting sag to radius, assuming the radius is long. When R is a long radius, y is semi-diameter, and S is sag,

$$S = y^2 / 2R$$

But it's not always good enough, and there's a longer equation for the exact result that I can never remember:

$$S = \left(\frac{y^2}{R} \right) / \left[1 + \sqrt{1 - \frac{y^2}{R^2}} \right]$$

Thankfully, Ray has it on his list, where I can find it quickly. Some other nice resources are the blocking equations, for calculating appropriate batch sizes, the plate distortion equation for thermal and pressure differentials, and the formula for converting fringes of power in a test plate (N) to radius error:

$$\Delta R = 4N\lambda \frac{R^2}{\phi^2}$$

Then there are the equations I can remember, but I can't be sure I got all the n's and n-1's in the right place. For example, you can predict the double pass transmitted wave front error of a window from its internal Fizeau fringes using:

$$TWF = OPD_{Fizeau} (n - 1) / n$$

Better than all of these, though, is the table of conversions to/from wedge, edge thickness variation, decentration, and beam deviation. Not only does he have the relatively simple equations for windows and plano convex/concave optics, but table 2 has all the conversions for any general lens, convex or

concave on either side. This table alone is reason enough to bookmark Ray's website for future reference.

Some day Ray or someone will put all these equations into an iPhone application, like [Bruce Truax](#) has done with the lens equations and the Fresnel formulas in his [OpticsCalc](#) application. But until that happens, Handy Equations will remain my resource for optics math.