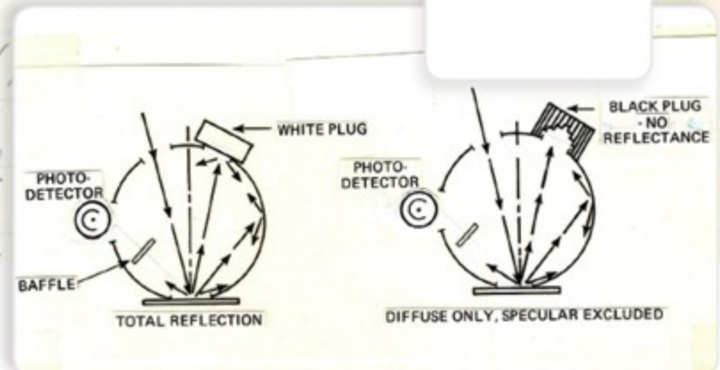
Applications Note

AN 1086



Understanding Reciprocal Instrument Geometries

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Abstract

The Helmholtz Reciprocal Relation defines this principal of inverse equivalency such that if you swap the positions of the light source and detector, everything else being equal, the measured values should be the same. That is, a 45°/0° instrument is equivalent to a 0°/45° instrument for reflectance measurements.
A diffuse/8° instrument is equivalent to an 8°/diffuse instrument for reflectance and transmittance measurements.

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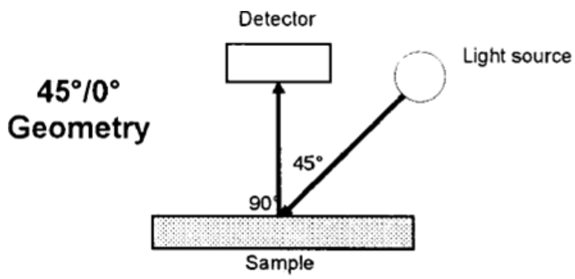
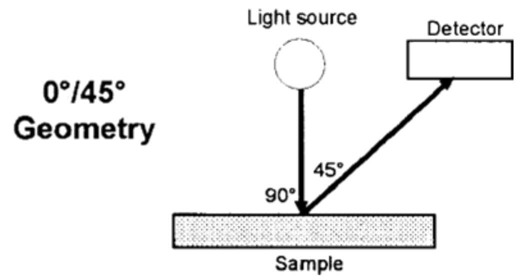
The geometry of a color measurement instrument is defined by the relative arrangement of the light source, sample plane, and detector positions. A line perpendicular to the sample plane is the reference for 0°. The geometry is described by first indicating the angle of illumination by the light source, and then the angle of viewing by the detector in a format such as 45°/0° or diffuse/8°. (See the *Applications Notes* titled "Instrument Geometries and Color Measurements.") However, when the geometry is the inverse (such as 45° *viewing* and 0° *illumination*, or 0°/45°, like HunterLab's LabScan XE), it is considered to be equivalent, as long as the illumination and viewing angles are exactly reversed.





A couple of caveats:

- The condition of "everything else being equal" rarely exists when we're talking about two different instrument types or brands. Usually some element in the optical path (area of view, sphere diameter, light collection angles, etc.) is different between instruments with inverse geometries.

  Although the Helmholtz Relation holds in most applications, in its most strict sense, reciprocity of inverse geometries yielding equivalent results assumes that the sample is a flat, uniform, non - fluorescent, opaque or transparent solid—in other words, a tile or a piece of glass—and the sample must have a regular scattering pattern. The relation seldom holds for samples that exhibit irregular scattering patterns, such as translucent samples (like plastic plaques) or samples that trap light (such as loose fibers or plastic pellets), or others with extreme non-uniform characteristics like curvature. Reciprocity exceptions also include gonioapparent samples (metallic, pearlescent, interference coatings, plastics, and cosmetics) where the reflectance and corresponding color values change with the angle of view.

Frequently Asked Question: I have never seen an 8°/diffuse instrument. All of the sphere instruments in the marketplace appear to be diffuse/8°. Why is this?

Answer: There have been sphere instruments in the past with 0°/diffuse and 8°/diffuse geometries, such as the HunterLab D25P. However, today most manufacturers build the diffuse/8° model only, as it is more robust when measuring real world samples, and is easiest to manufacture.

References

Clarke, F. J. J. and Parry, D. J., "Helmholtz Reciprocity: Its Validity and Application to Reflectometry," *Lighting Research and Technology*, Volume 17: 1985, pp. 1-11 is a key document that describes the application of Helmholtz Reciprocity to spectrophotometers.

CIE Publication 15:2004, *Colorimetry*, Section 5.2 provides a list of all the recommended instrument geometries for colorimetry, including inverse geometries.

ASTM E179, "Standard Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials," Section 8.2 calls the equivalency of reciprocal geometries the Helmholtz Reciprocal Relation.

ASTM E1164, "Standard Practice for Obtaining Data for Object-Color Evaluation," describes the inverse reflectance and transmittance geometries in Section 8.

ASTM E1767, "Standard Practice for Specifying the Geometry of Observations and Measurements to Characterize the Appearance of Materials," is a key document that defines instrument geometry precisely in terms of the azimuthal angle and includes inverse geometries.

ISO 5-2, *Photography -- Density measurements*, Part 2: "Geometric conditions for transmission density."

ISO 5-4, *Photography -- Density measurements*, Part 4: "Geometric conditions for reflection density."

These are key documents that provide a precise method of defining instrument geometry for reflectance and transmittance in terms of the azimuthal angle.

Berns, Roy S., *Billmeyer and Saltzman's Principles of Color Technology*, 3rd Edition, John Wiley & Sons: New York (2000:82-88) provides a good overview of reciprocal instrument geometries for colorimetry, and references inverse geometries.

About HunterLab

HunterLab is the technology leader in color measurement solutions, providing instruments, software, knowledge and service to a wide variety of industries.
With over 5 decades of experience in more than 65 countries, HunterLab applies our leading edge technology to your products helping you measure and communicate color simply and effectively.

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