

Fundamentals of Color and Appearance

Module 10

Color vs. Appearance

Color Science Educational Series



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Color vs. Appearance



The human eye perceives color based on how light interacts with a materials surface. Surface characteristics such as smoothness, texture, and gloss play a major role in this interaction. They determine how light is directionally and diffusely reflected, which affects both the intensity and quality of the colors we perceive.



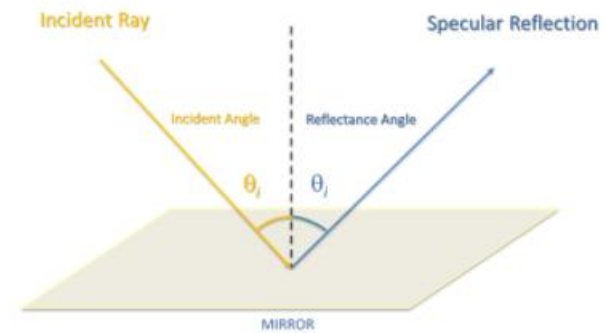


The Law of Reflection states that the angle of light incidence is always equal to the angle of light reflectance.

This principle governs specular reflection, where light reflects off a surface in a predictable direction.

Law of Reflection

$$\theta_i = \theta_r$$



The angle of incident light is always equal to the angle of reflected light





This law applies to optically smooth, mirror-like surfaces, where the surface irregularities are small compared to the wavelength of incident light.



Specular Reflection



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Optically smooth surfaces reflect light uniformly at the specular angle, preserving the geometry of the light rays. This results in specular reflection, forming a clear image, like this mirror.



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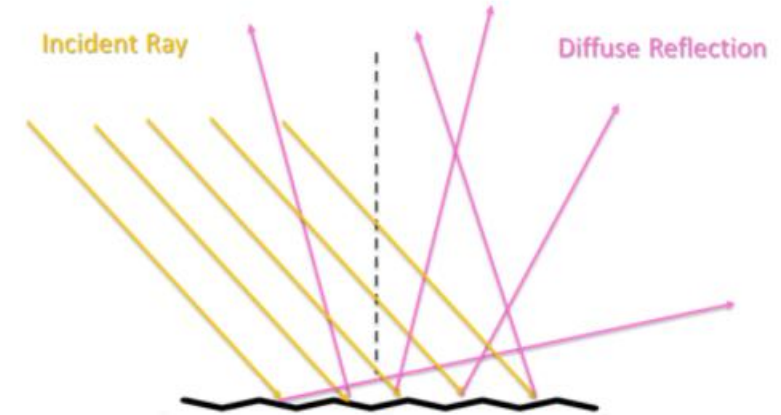


And a calm, smooth lake on a sunny day, which reflects a crisp image of the surrounding landscape.





Diffuse reflection on the other hand occurs when the surface of an object is rough or textured. In this case, incident light is scattered in many directions, rather than being reflected uniformly. As a result, diffusely reflected light does not form an image.



Diffuse reflection occurs when the surface of an object is rough or textured





This type of reflection is far more common in everyday materials, such as unpolished wood...



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Paper and paper stock...



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Or matte painted surfaces.





For most opaque materials, the incident light is reflected. Color is perceived in the diffuse reflection, while gloss is observed in the specular reflection, the brightest intensity of light at a single angle.



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However, despite its brightness, specular reflection accounts for less than 4% of the total reflected light. Most of the reflected light is diffuse reflection, which carries the color information our eyes perceive.





In this image, the reflection of the clouds on the water's surface is a result of specular reflection. The calm, mirror-like water acts as an optically smooth surface, forming a clear image of the clouds above.





We are seeing the specular reflection of the clouds, and the water appears darker compared to the choppy, more textured waters in the distance, where reflection is more diffuse and scattered.



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In practical terms, samples with identical color can appear different if their surface textures vary, as this example shows. This plastic plaque is molded with a uniform color, as seen from the back side. The front side is molded with different textures and gloss characteristics, from completely smooth and glossy, to course and fine surface textures.

Visually, the glossy surfaces appear darker and more saturated, due to higher specular reflection and reduced light scattering.

The matte or textured surfaces appear lighter and less saturated, because diffuse reflection scatters light in multiple directions, reducing color intensity.



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As we learned in Module 8, **Instrument Geometry**, understanding the impact of surface characteristics on visual color perception and instrumental color measurement is critical in determining the appropriate method for measuring your samples.

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Module 8

Instrument Geometry

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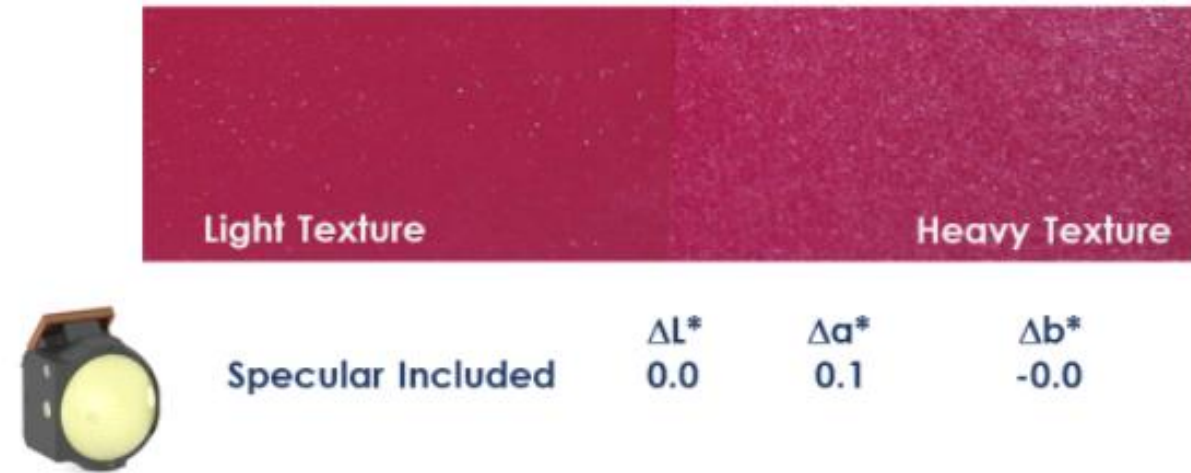


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Instruments that measure in specular included mode capture all reflected light from the sample, including the specular reflection. This means the measurement includes both the intrinsic color and the gloss or sheen created by surface reflection. In specular included mode, the light and heavy textured samples appear the same to the instrument.



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Instruments that measure in specular excluded mode intentionally remove the specular reflection from the measurement. This means the measurement captures only the diffusely reflected light. As a result, the measurements better represents the visual appearance of the sample, not just its color. The resulting measurement data reflects these visual differences.



Specular Included
Specular Excluded

ΔL^*	Δa^*	Δb^*
0.0	0.1	-0.0
1.8	-1.6	-0.9



Specular Excluded

ΔL^*	Δa^*	Δb^*
1.4	-1.5	-1.2

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The important takeaway is this. Always standardize on a single instrument geometry when creating product standards and perform all quality control measurements using that same instrument to maintain consistency and avoid incorrect conclusions.



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If it is important to evaluate how color changes with and without the influence of surface characteristics on your opaque product, then the optimal choice is a reflectance instrument with diffuse geometry, specifically one that offers both Specular Included and Specular Excluded measurement modes.

Having both modes in one instrument allows for a comprehensive understanding of color and appearance, supporting more informed decisions during product development and color formulation.

Specular Included Applications

Reflectance with Diffuse geometry that provides both Specular Included and Specular Excluded measurement capabilities is required to measure the effects of color change including and excluding the impact of surface characteristics.





Diffuse sphere geometry instruments, like the **HunterLab UltraScan VIS** provide the option to measure both specular included and specular excluded modes.





Directional reflectance measurements using $45/0^\circ$ or $0/45^\circ$ geometry are ideal for quality control of opaque materials.

These geometries are designed to simulate how the human eye perceives color for accurate evaluation of the visual color of a product as it will appear to consumers.

Specular Excluded Applications

Directional reflectance geometry is preferred for quality control of opaque objects to ensure that the final color of goods produced meet the manufacturers specifications as they will be viewed by consumers.



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Directional reflectance instruments like the HunterLab Agera (0/45° geometry) and ColorFlex L2 (45/0° geometry) measure exclusively in the specular excluded mode.



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Let's finish this module by discussing surface gloss and gloss measurement.





Gloss measurement is based on quantifying the specular component of reflected light at specific angles to determine gloss level, reported in gloss units.

To accurately evaluate gloss, direct illumination must be used. Diffuse illumination causes scattered reflection, which diminishes the specular component and leads to reduced gloss perception.

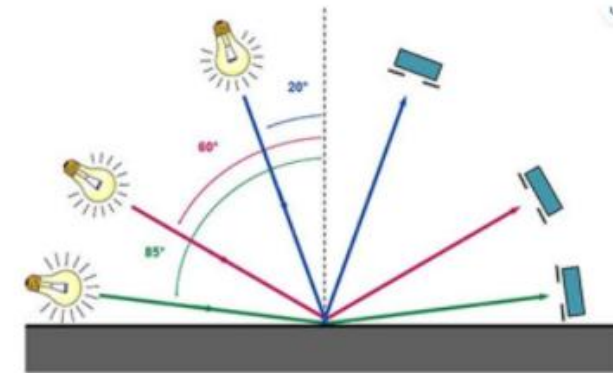
The principle of gloss measurement is based on the measurement of the specular component of reflected light.

The intensity of reflected light is measured in a specific angle range.

In order to evaluate gloss, it is necessary to use direct illumination.

Diffuse illumination causes diffuse reflection resulting in decreased gloss impressions

Gloss Measurement



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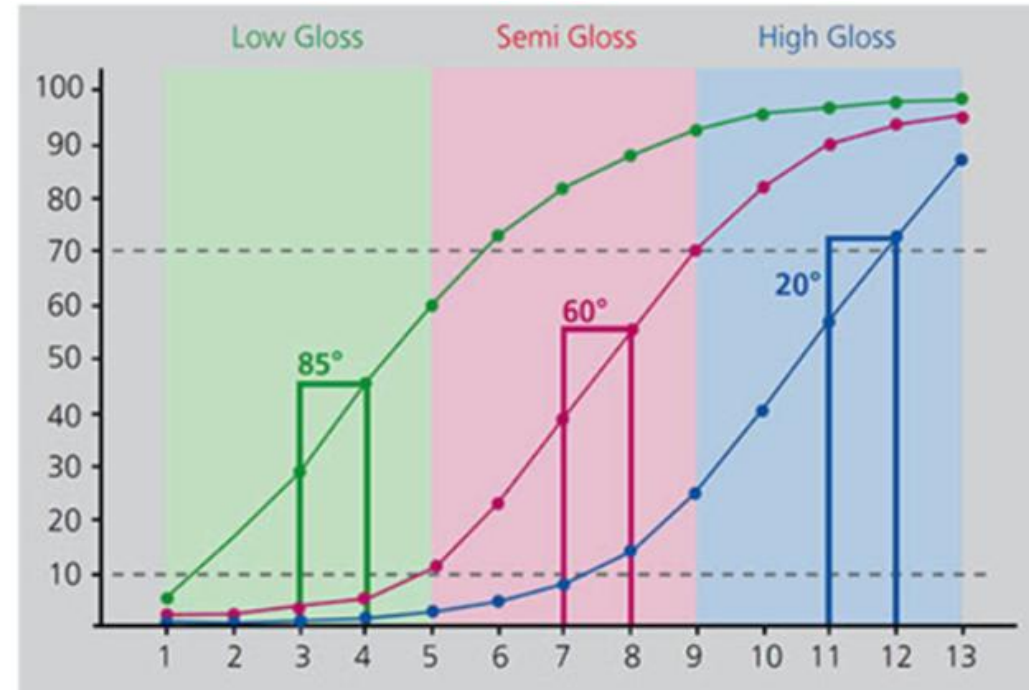


Gloss is commonly measured at three standard angles:

60-degree is the universal standard and is used for comparing most specimens. It also helps determine when 20-degree or 85-degree measurements may be more appropriate.

20-degree is used for high-gloss surfaces, specifically when the 60-degree gloss value is greater than 70 units. It provides enhanced resolution in the high-gloss range.

85-degree is used for low-gloss or matte surfaces, where the 60-degree gloss value is below 10 units. It offers better differentiation among low-gloss finishes.



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Thank you for joining us on this journey through color science.

Be sure to watch Module 11, **Fluorescence**, where we will explore how fluorescing whitening agents and optical brightening agents significantly impact color appearance, used to enhance the perceived whiteness and brightness of materials, and why they must be accounted for in color measurement.

And be sure to visit hunterlab.com to learn more about how our solutions can help you achieve color confidence, every time, or to schedule a consultation with one of our color experts.

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Module 11

Luminescence

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