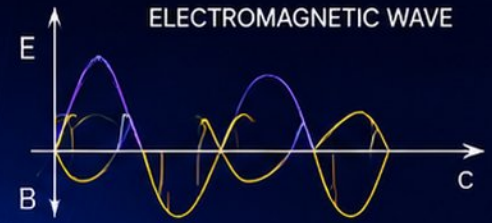


Light and Color: An Introduction to Optics



- Explore the nature of light as an electromagnetic wave



- Understand how light interacts: reflection, absorption, transmission



- Learn how wavelength determines the colors we perceive



- Discover applications in cameras, eyes, rainbows, and screens



- Course structure, learning objectives, and real-world connections



CAMERAS



EYES



RAINBOWS



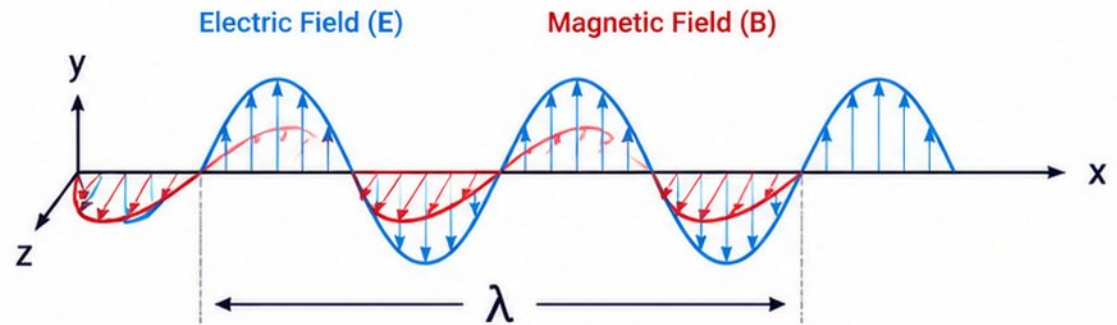
SCREENS

What Is Light?

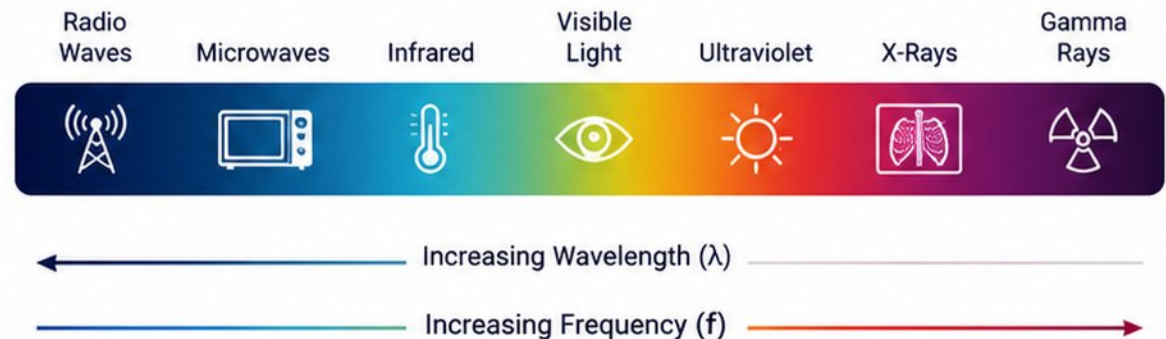
The Electromagnetic Wave



- **Light is an electromagnetic wave:** oscillating electric and magnetic fields moving through space
- The electromagnetic spectrum spans from radio waves to gamma rays, ordered by wavelength and frequency
- **Wavelength, frequency, and speed of light** are linked: $c = \lambda f$
- Light also behaves as discrete energy packets called photons



The Electromagnetic Spectrum

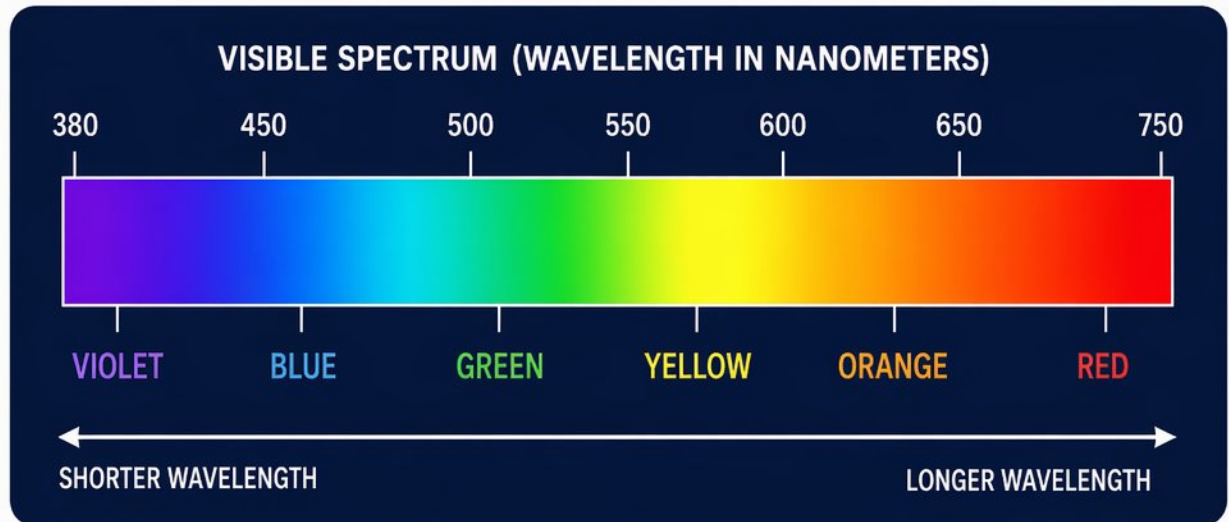
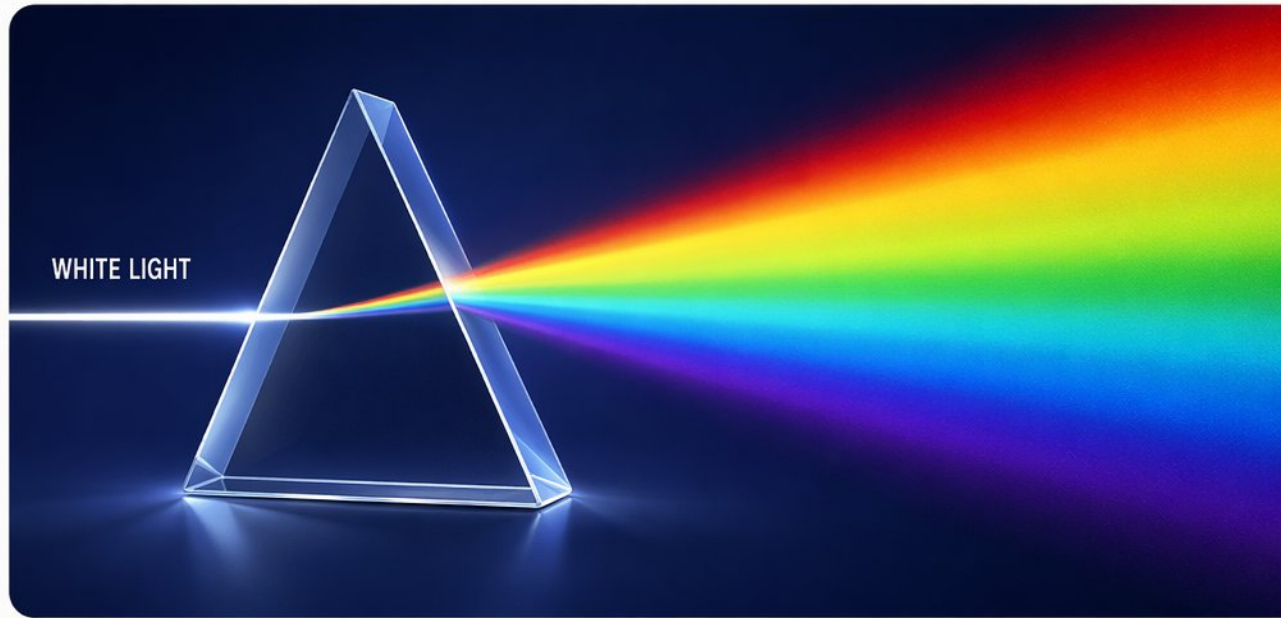


Photons

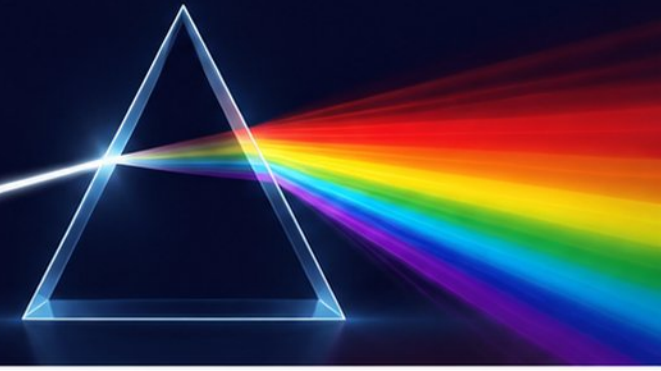


The Visible Spectrum: The Colors We Can See

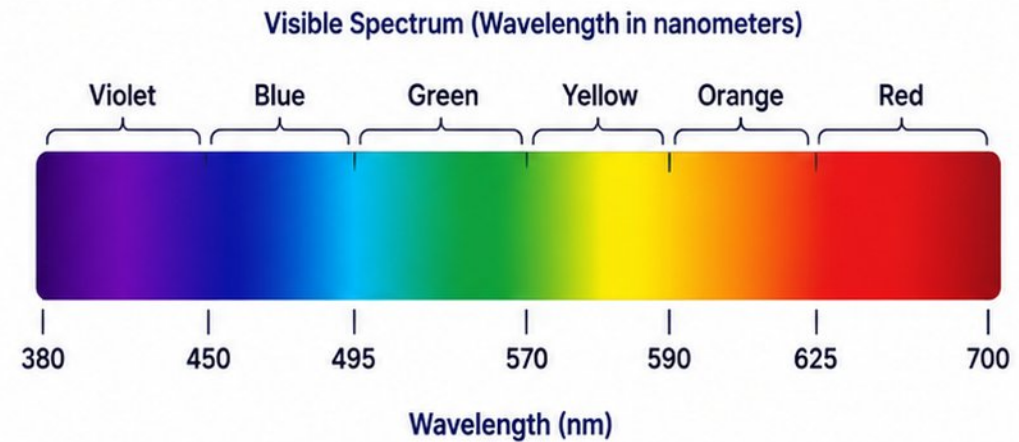
- The visible spectrum is the narrow band human eyes detect: roughly 380–750 nm
- Spectral colors, shortest to longest wavelength: violet, blue, green, yellow, orange, red
- Boundaries between colors are continuous, not sharply defined; they vary slightly per person
- Visible light matches the Sun's peak output and our photoreceptors' sensitivity



Wavelength: The Key to Color



- Each spectral color corresponds to a specific wavelength range
- Violet: ~380–450 nm, Blue: 450–495 nm, Green: 495–570 nm
- Yellow: 570–590 nm, Orange: 590–625 nm, Red: 625–700 nm
- Monochromatic light: single wavelength; polychromatic: mixture of wavelengths
- Objects appear colored through wavelength-selective interactions with matter



Monochromatic vs. Polychromatic Light

Monochromatic
(Single Wavelength)



Single wavelength
(e.g., 450 nm)

Polychromatic
(Mixture of Wavelengths)



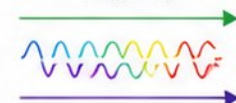
Many wavelengths combined
(white light)

Wavelength-Selective Interactions with Matter

White Light
(Many Wavelengths)



Green Light
reflected



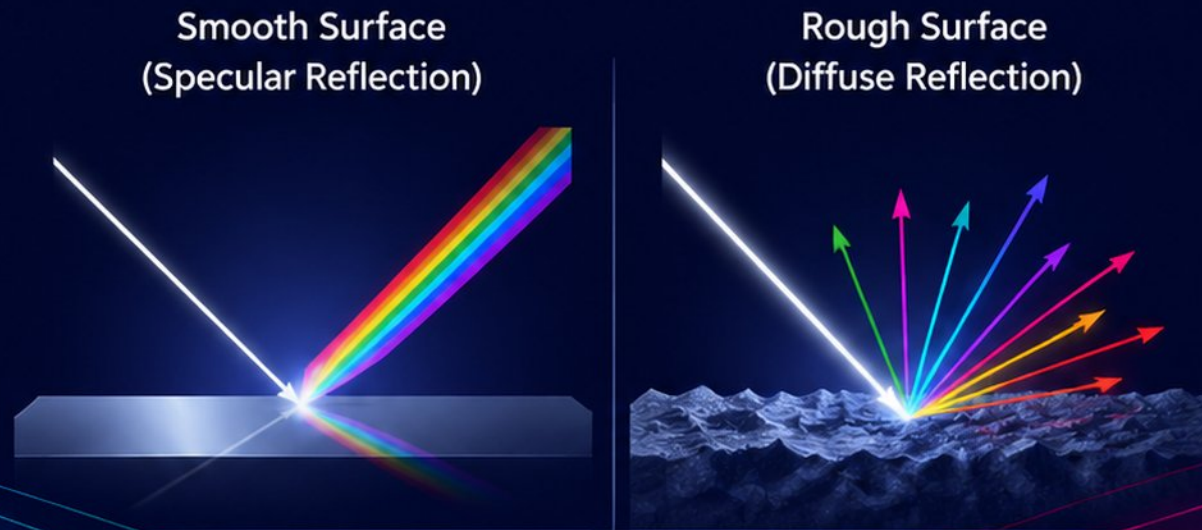
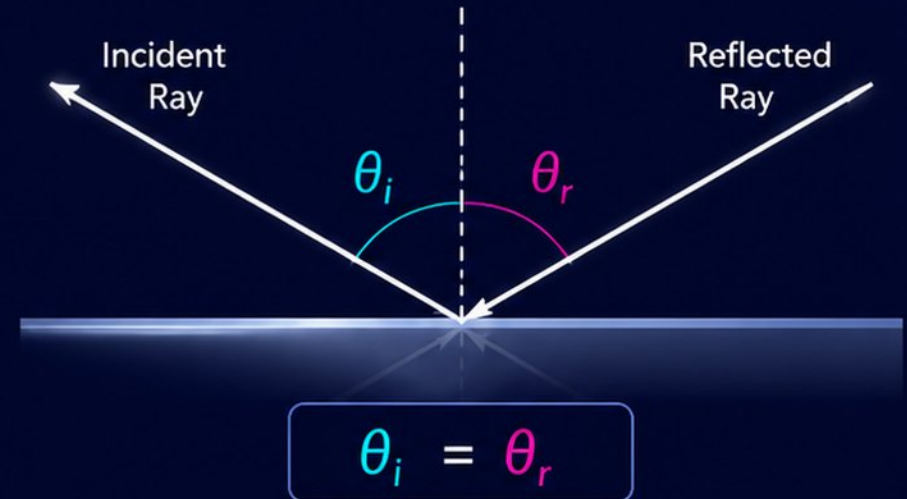
Other wavelengths
absorbed



We see
green

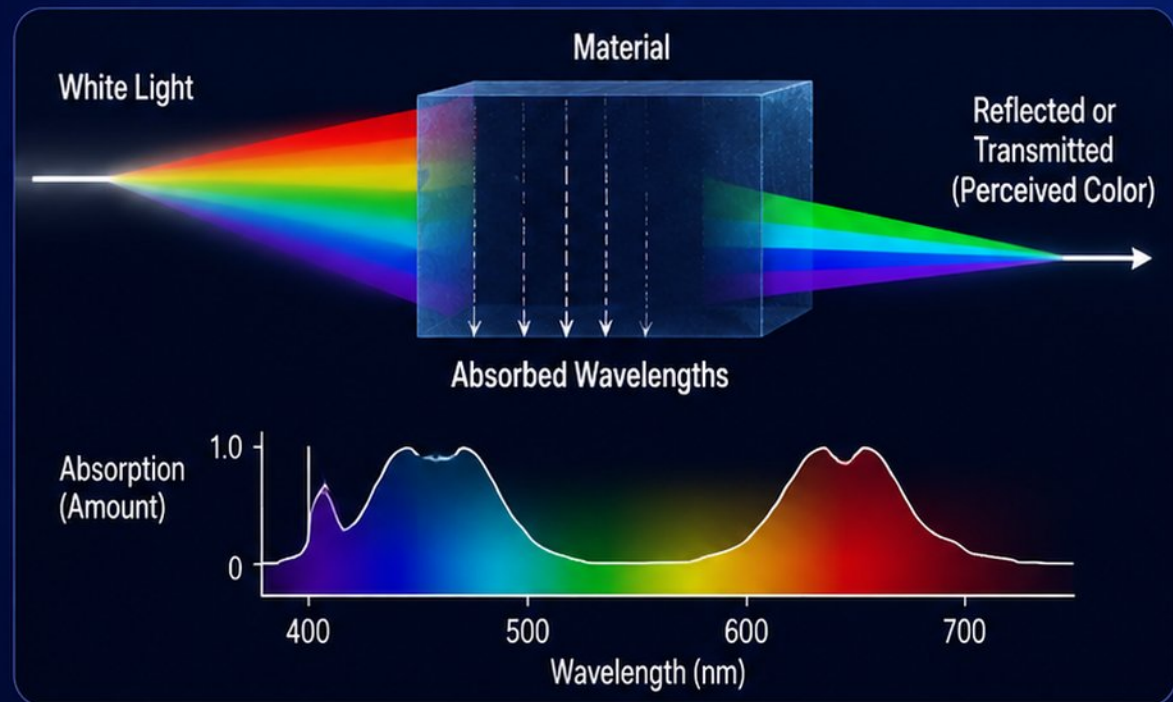
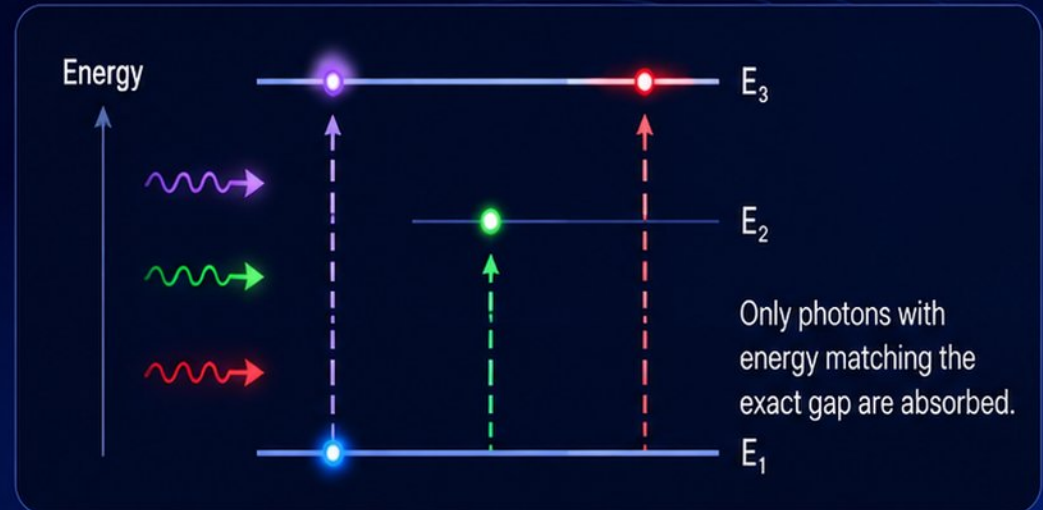
Reflection: How Light Bounces

- Angle of incidence equals angle of reflection
- Smooth surfaces create mirror-like specular reflections
- Rough surfaces scatter light in all directions
- Wavelength relative to roughness determines reflection type



Absorption: Where Light Goes

- - Absorbed light transfers energy to matter, often as heat
- - Electrons only absorb photons matching an energy-level gap exactly
- - Each material has a unique absorption spectrum, like a fingerprint
- - The wavelengths not absorbed are reflected or transmitted, creating color



Electrons and Energy Levels: The Quantum Picture



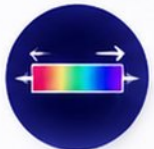
- Electrons occupy fixed, quantized energy levels—no in-between states exist



- A photon is absorbed only if its energy exactly matches the gap between levels



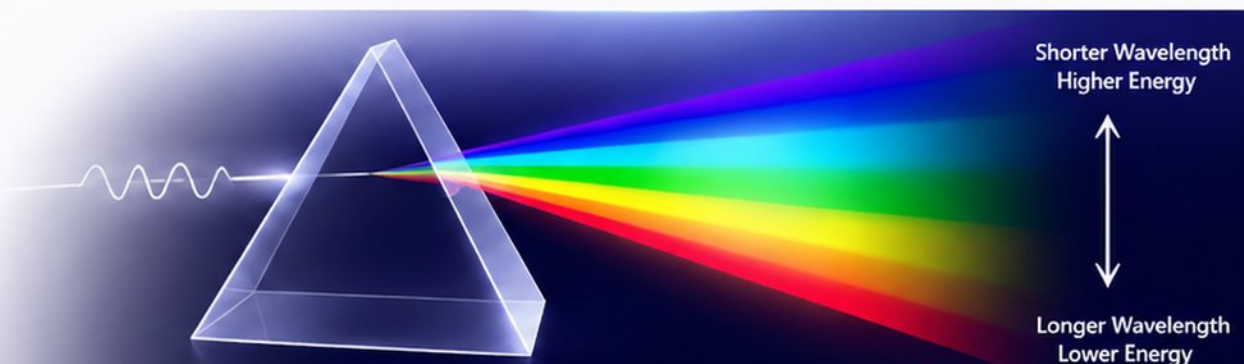
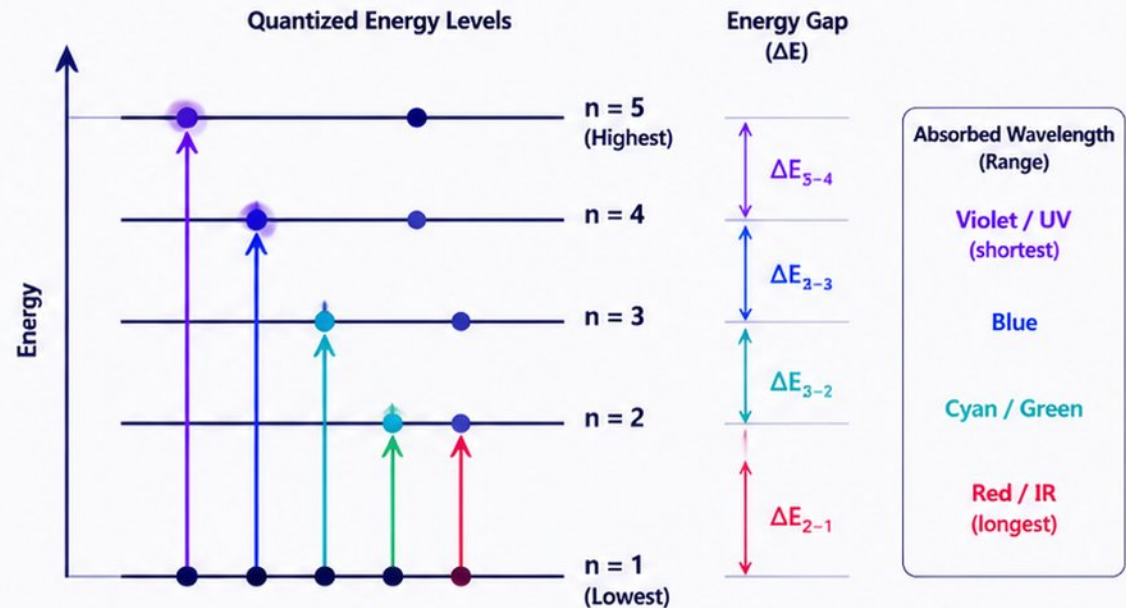
- Photon energy links to frequency: $E = hf$; shorter wavelength means higher energy



- Larger energy gaps absorb shorter wavelengths (UV/violet); smaller gaps absorb longer wavelengths (red/IR)



- Each material's unique energy gaps create its distinct absorption spectrum and color



Transmission and Refraction: When Light Passes Through



- **Transmission:** light passes through materials that don't absorb visible wavelengths



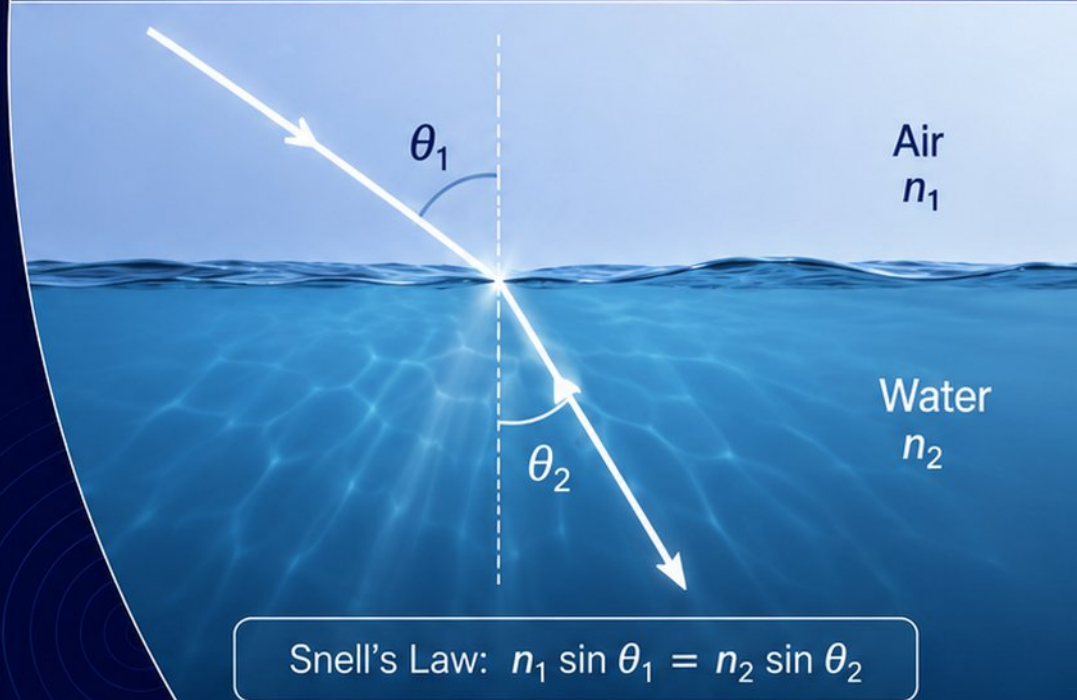
- **Refraction:** light bends when crossing boundaries between different optical densities

$$n = \frac{c}{v}$$

- **Refractive index** measures how much a material slows light down



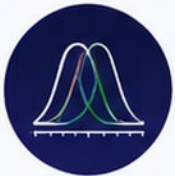
- **Glass and water** are transparent because they lack absorption bands in the visible range



The Human Eye: Our Color Detector



- Retina contains three cone types: S (blue), M (green), L (red)



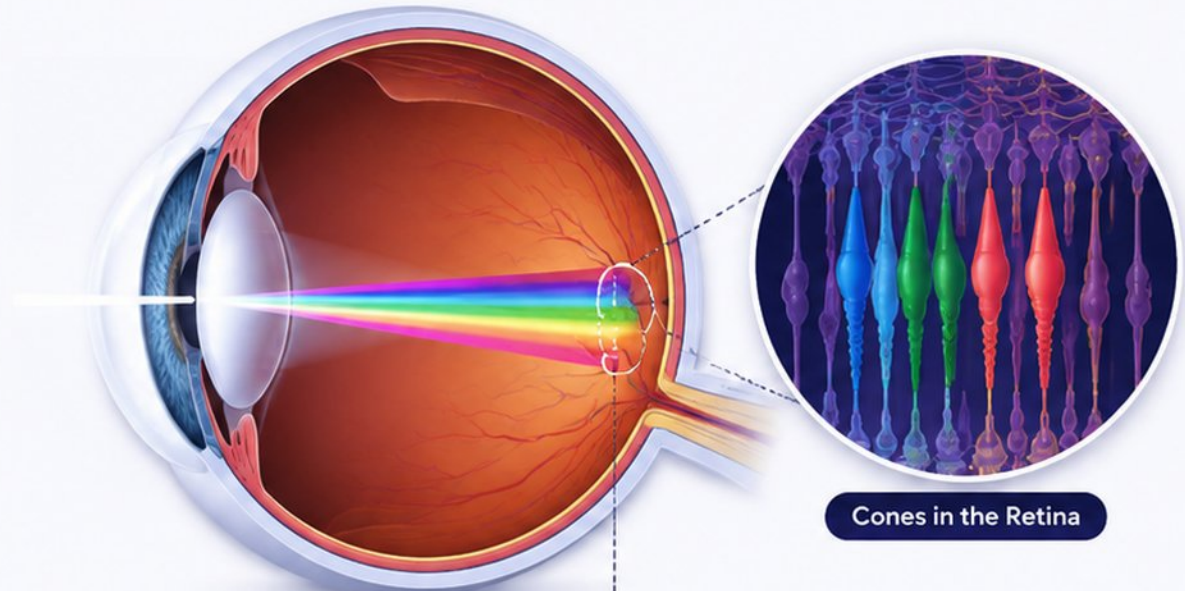
- Each cone type peaks in a different part of the visible spectrum



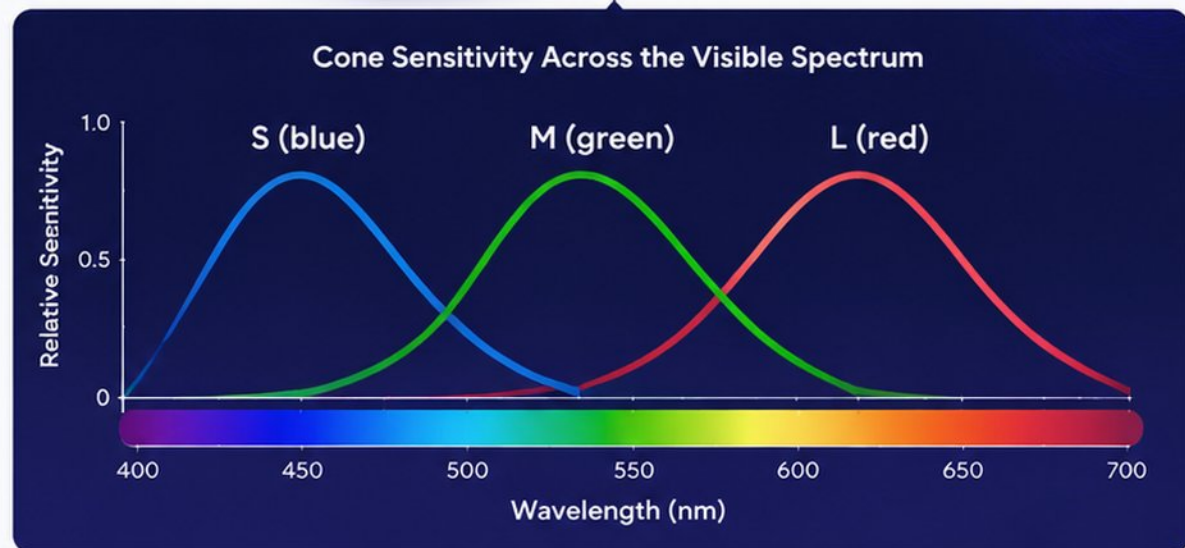
- Brain compares relative cone responses to interpret color



- Color is a brain-constructed perception, not a physical property



Cones in the Retina



How We See Color: The Physics-to-Perception Pipeline

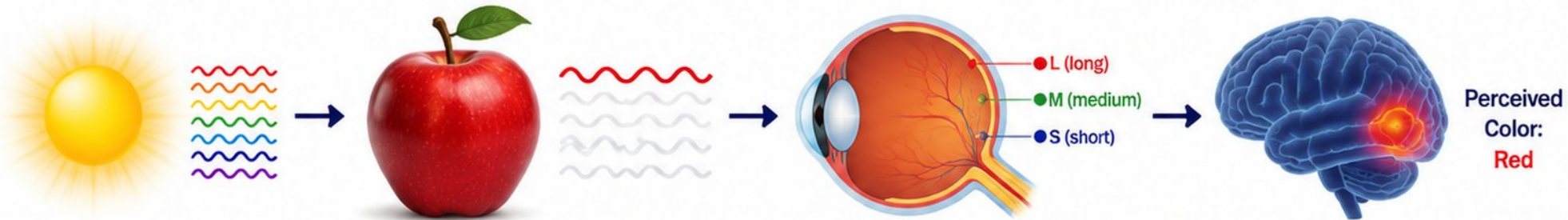


1. Light Source

2. Object Reflection/
Absorption

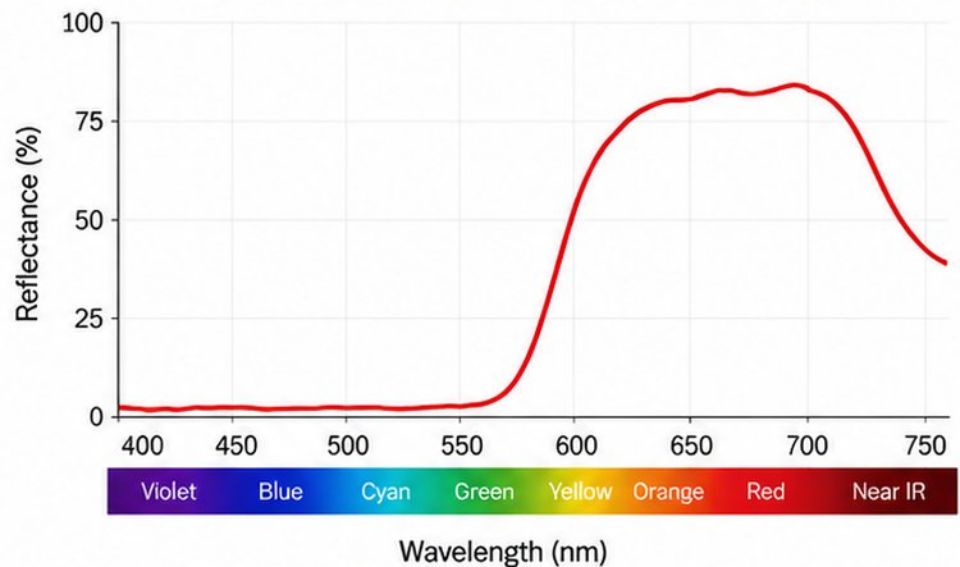
3. Eye Detection

4. Brain Interpretation



- Light source → object reflection/absorption → eye detection → brain interpretation
- A red apple reflects red wavelengths (~625–700 nm) and absorbs the rest
- Perceived color depends on both the object's reflectance and the light source spectrum
- Spectral reflectance curves plot an object's reflectance at each wavelength

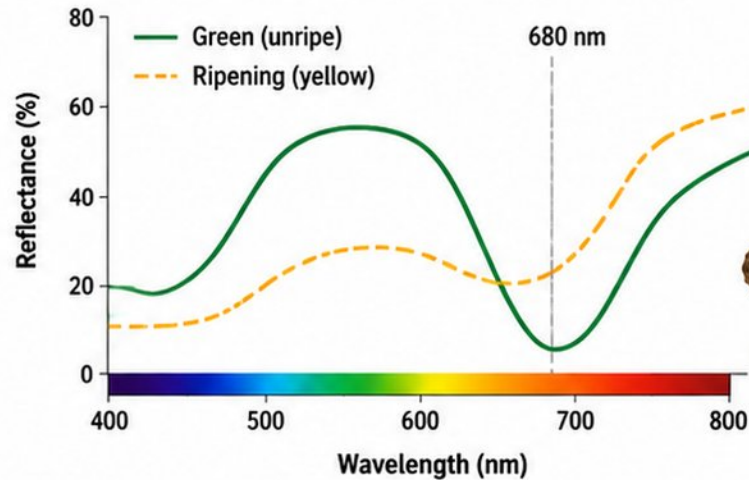
Example Spectral Reflectance Curve: Red Apple



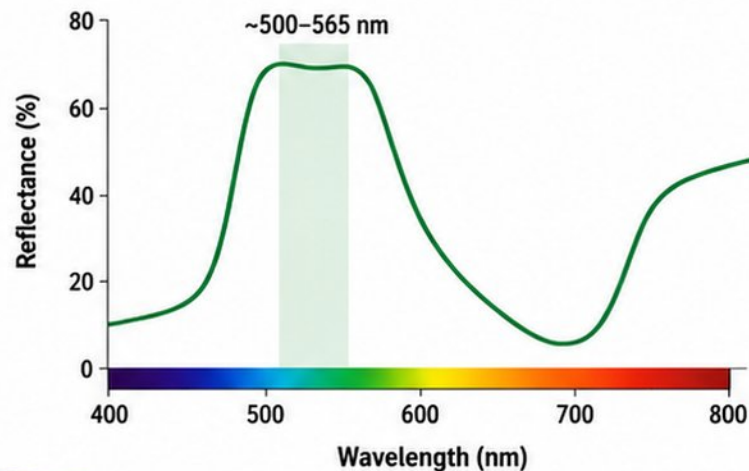
Real-World Reflectance: Banana and Leaf

- Green banana peel: chlorophyll absorption trough near 680 nm, reflectance peak around 550 nm (green)
- Ripening: chlorophyll breaks down; 680 nm trough disappears; carotenoids boost yellow-orange reflectance
- Green leaf: strong reflectance of green (~500–565 nm), absorbs red and blue for photosynthesis
- Spectral reflectance curves are material fingerprints revealing composition and condition

BANANA PEEL REFLECTANCE



GREEN LEAF REFLECTANCE

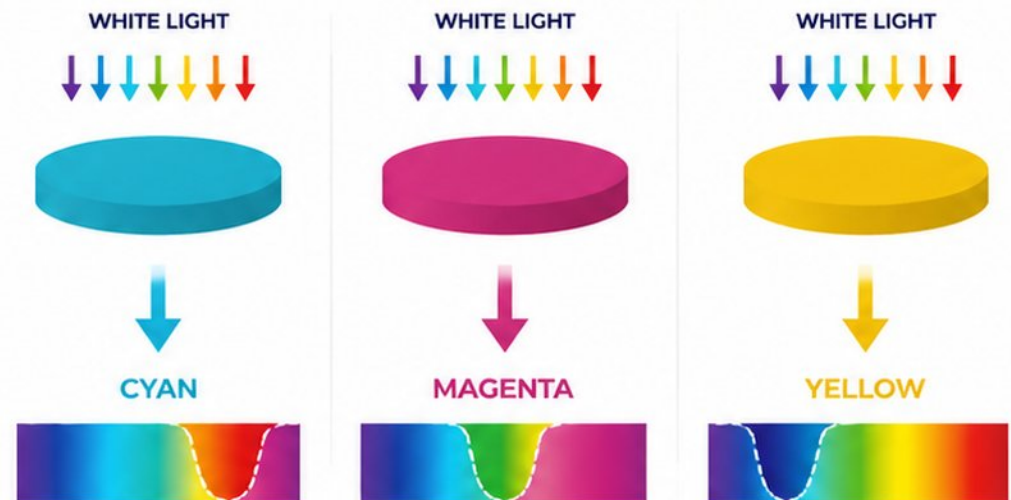


Subtractive Color Mixing: Pigments and Filters

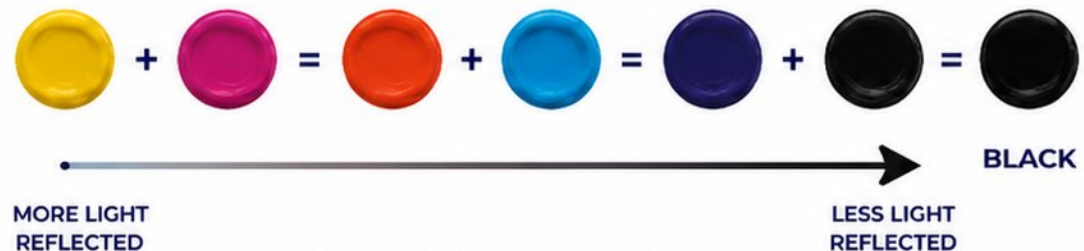


- Pigments absorb (subtract) wavelengths from white light leaving only the reflected color
- Cyan, magenta, and yellow are the primary subtractive colors each absorbing one-third of the spectrum
- Mixing paints adds more absorption, progressively subtracting light until reaching black
- Unlike additive mixing (RGB light sources) where combining colors produces white

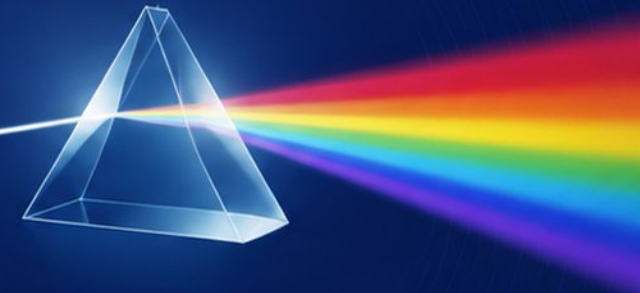
SUBTRACTIVE PRIMARY PIGMENTS



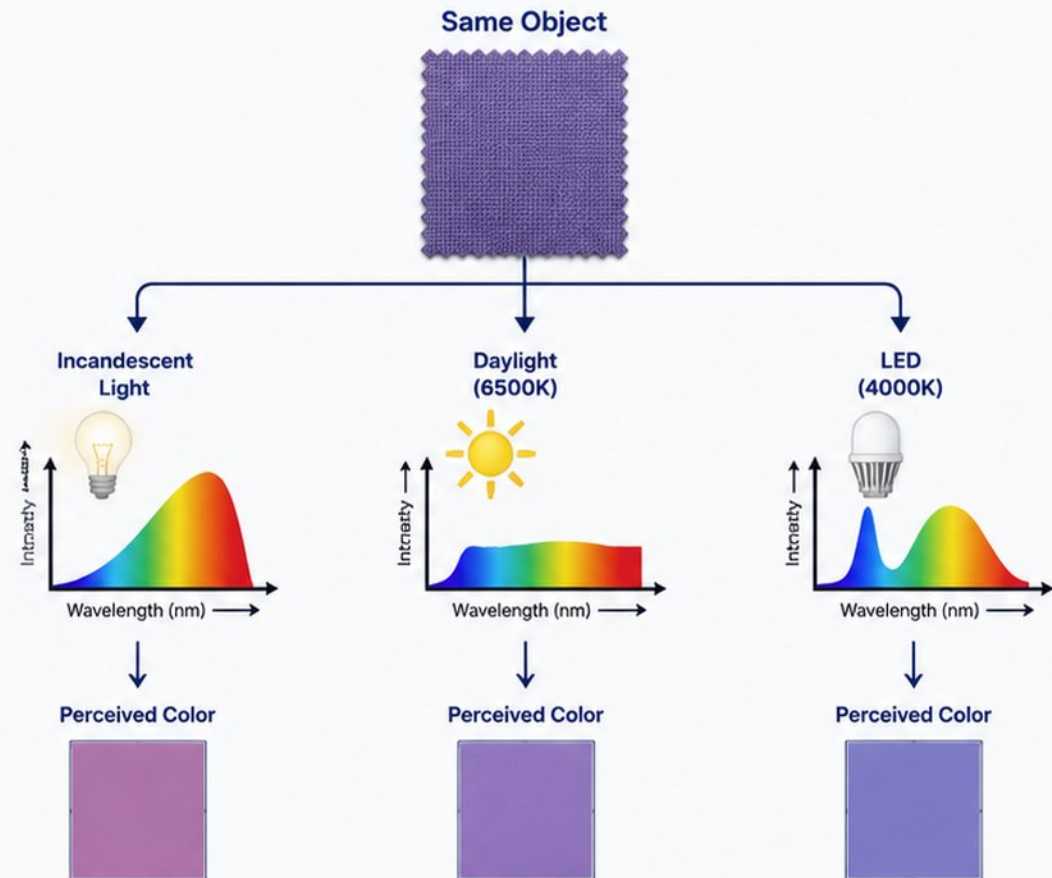
MIXING PIGMENTS ADDS ABSORPTION



The Same Object, Different Light: Metamerism



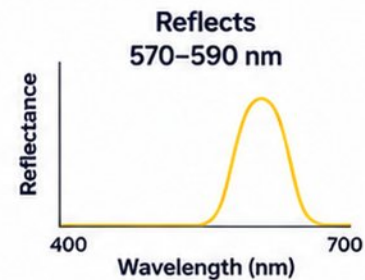
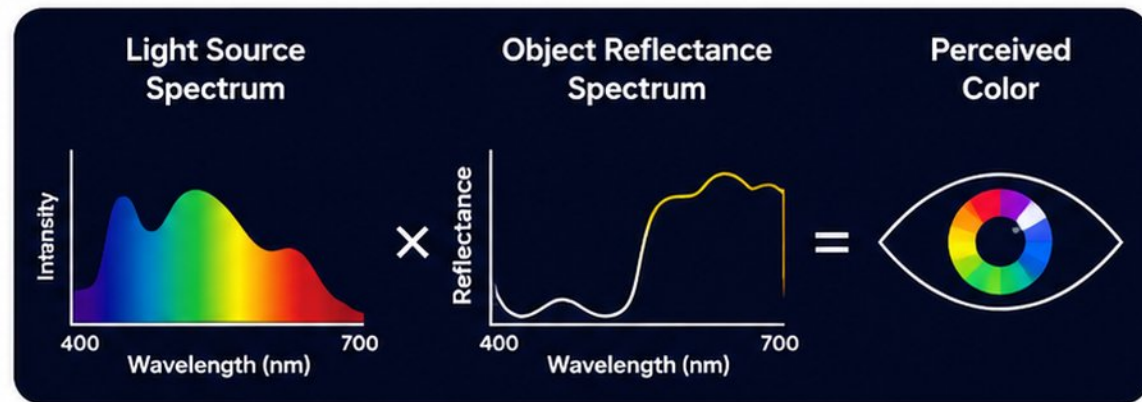
- Perceived color = light source spectrum $\times$ object reflectance
- Same object shifts under incandescent, daylight, or LED
- Metamerism: colors match under one light, mismatch under another
- Critical for design, photography, retail, and color matching



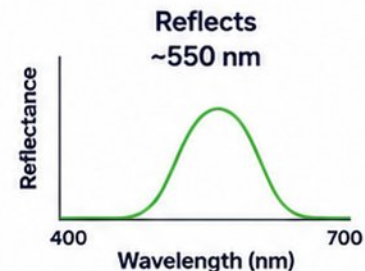
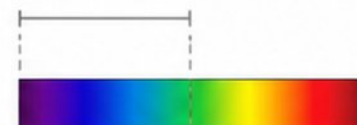
Colors can match under one light source, but appear different under another.

Putting It Together: Reflection, Absorption, and Color

- Perceived color = light source spectrum $\times$ object reflectance spectrum
- A banana looks yellow: it reflects 570–590 nm, absorbs shorter wavelengths
- A green leaf reflects ~ 550 nm; chlorophyll absorbs red (~ 680 nm) and blue
- The same object can appear different under different lighting conditions



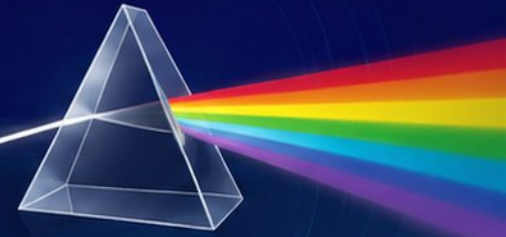
Absorbs shorter wavelengths



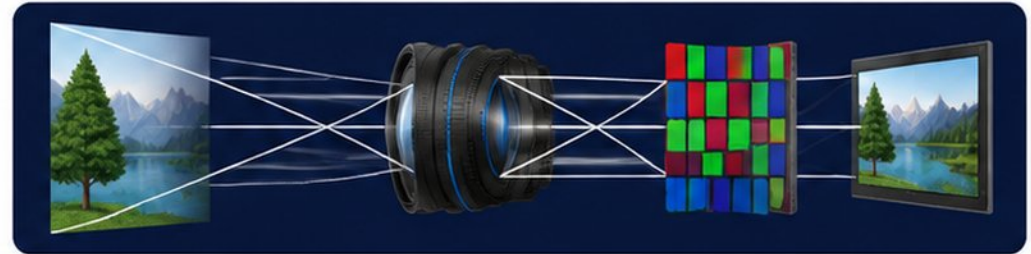
Absorbs red (~ 680 nm) and blue



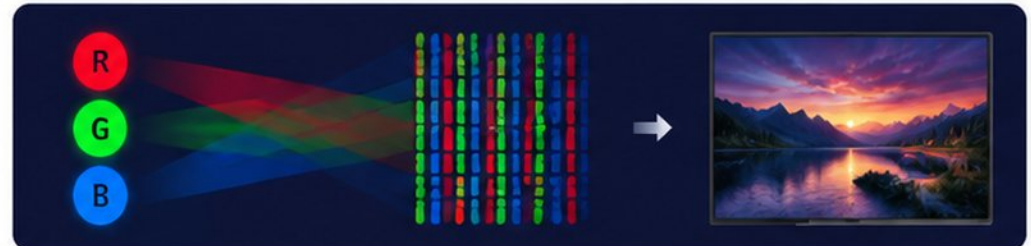
Applications: Optics in Everyday Life



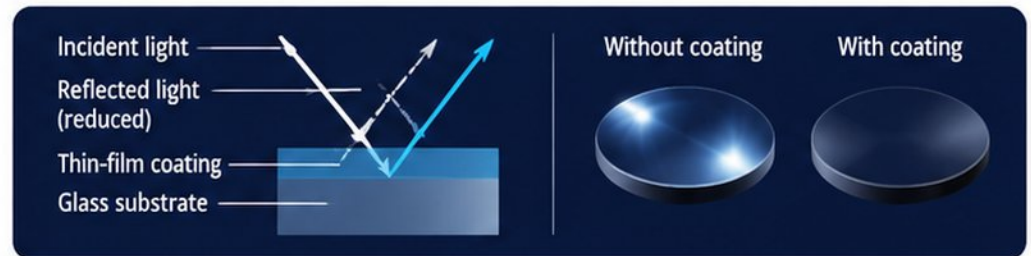
- Cameras use lenses, sensors, and color filters to capture images via refraction and wavelength selection



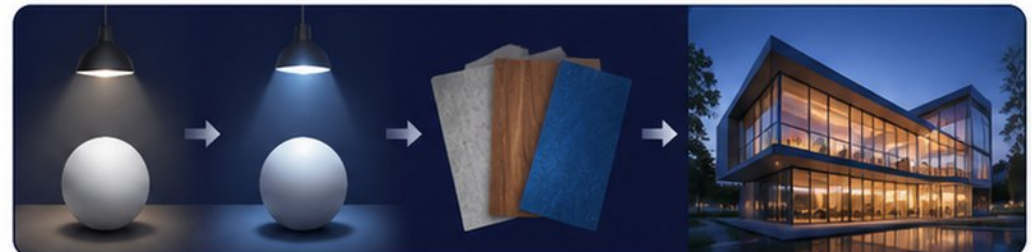
- Screens create full-color images through additive RGB pixel mixing



- Anti-reflective coatings reduce glare via thin-film interference



- Lighting and material properties shape color perception in design, art, and architecture



Summary and Key Takeaways



- Light is an electromagnetic wave; wavelength determines visible color



- Objects reflect wavelengths we see and absorb the rest



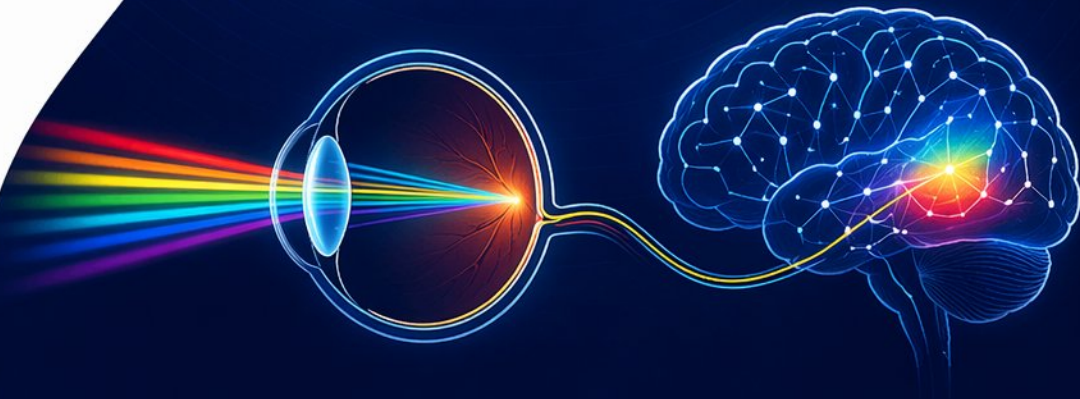
- Perception depends on light source, object, eye, and brain



- Color is a constructed perception, not a physical property



- Explore optics and color science through the suggested next steps



LIGHT SOURCE



OBJECT



REFLECTED LIGHT



EYE



BRAIN



PERCEIVED COLOR

PersonWise.

PersonWise • AI digital-human course platform



Scan the code or click anywhere to watch this course live, with voice Q&A

personwise.ai/t/b8523044/public