

# CG COMPOSITING SERIES

## Refraction Terminology

Transparency ✓

Transmission ✓

Refraction ✓

Translucency ✓

# CG COMPOSITING SERIES

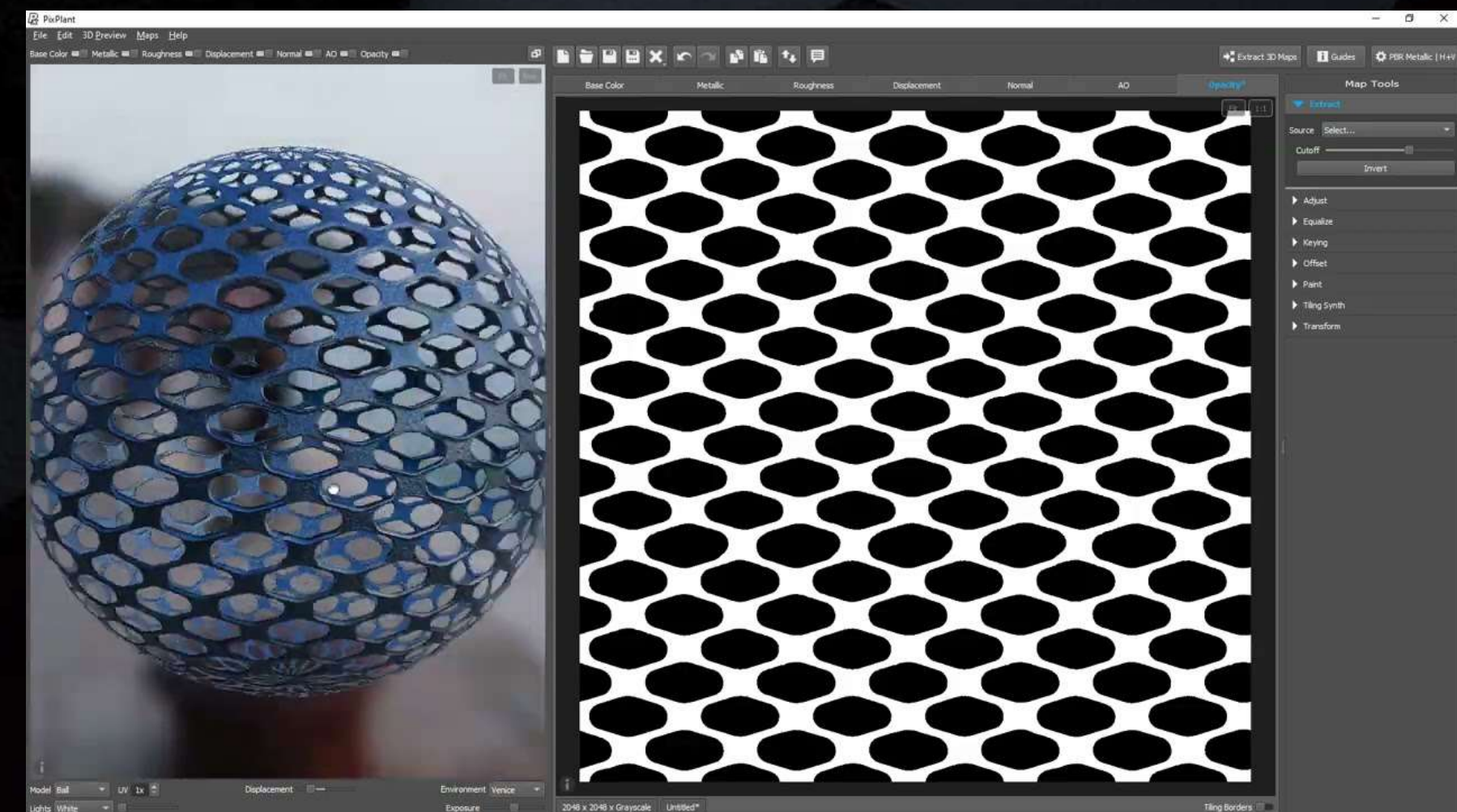
## What is Transparency?

- **Transparency** is the ability to see - through an object or surface to what's behind
- It's as if the object or material is **ignored** or nonexistent and does not have to do with Light interacting with the material.
- The light passing through is not **Distorted (Refract)**, nor does **Scatter** or change **Color** (which could be the case with **Translucency** or **Transmission**)

**Transparency** basically has only 1 setting:

**Amount** - "How much can i see through this"

- Working exactly like an alpha channel in Compositing



YouTube: Opacity Maps - PixPlant

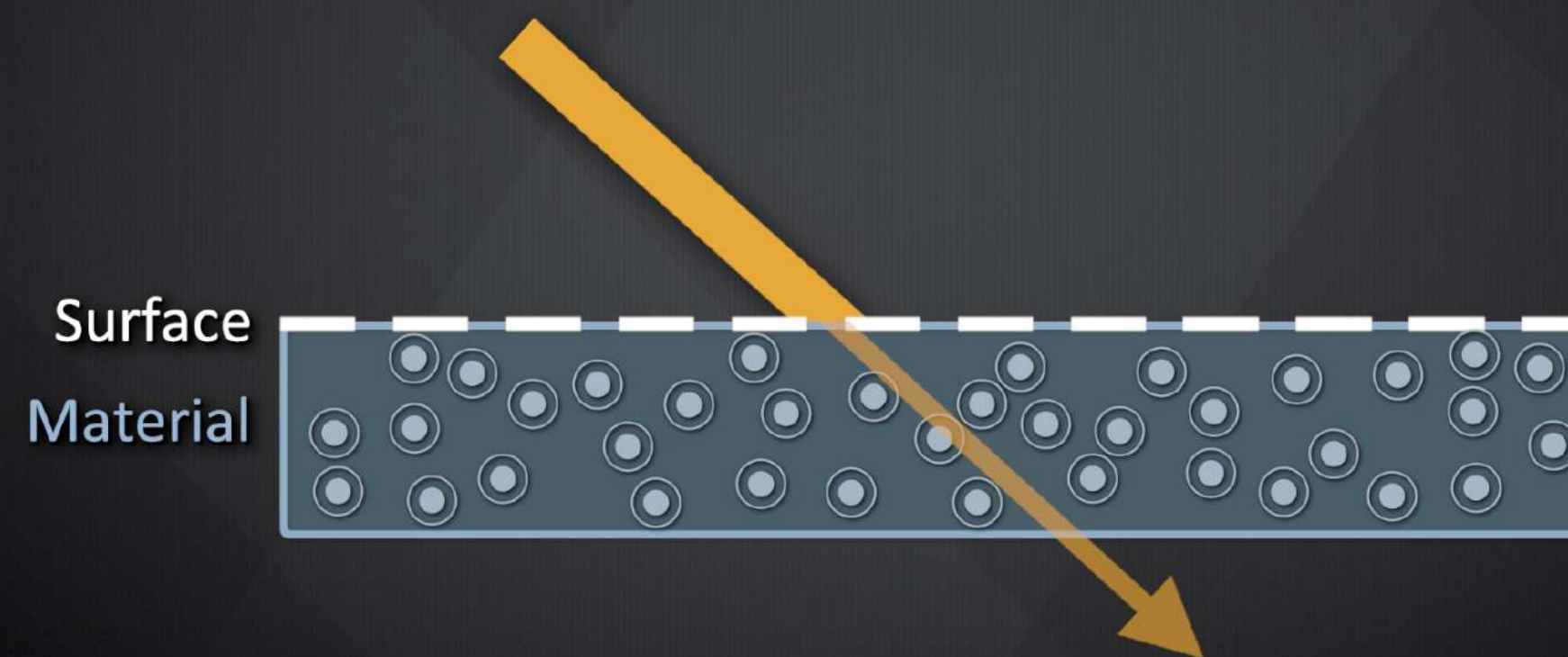
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## What is Transmission?

- Transmission is the passing of light completely through a material
- **Refractive**, **Transparent**, and **Translucent** materials all transmit light, but **Opaque** materials do not.
- If light is not transmitted, it may have been **reflected (specular)** or **absorbed**.

### Light Material Interactions

Transmission - Light Passing through a material / surface  
- Transparency

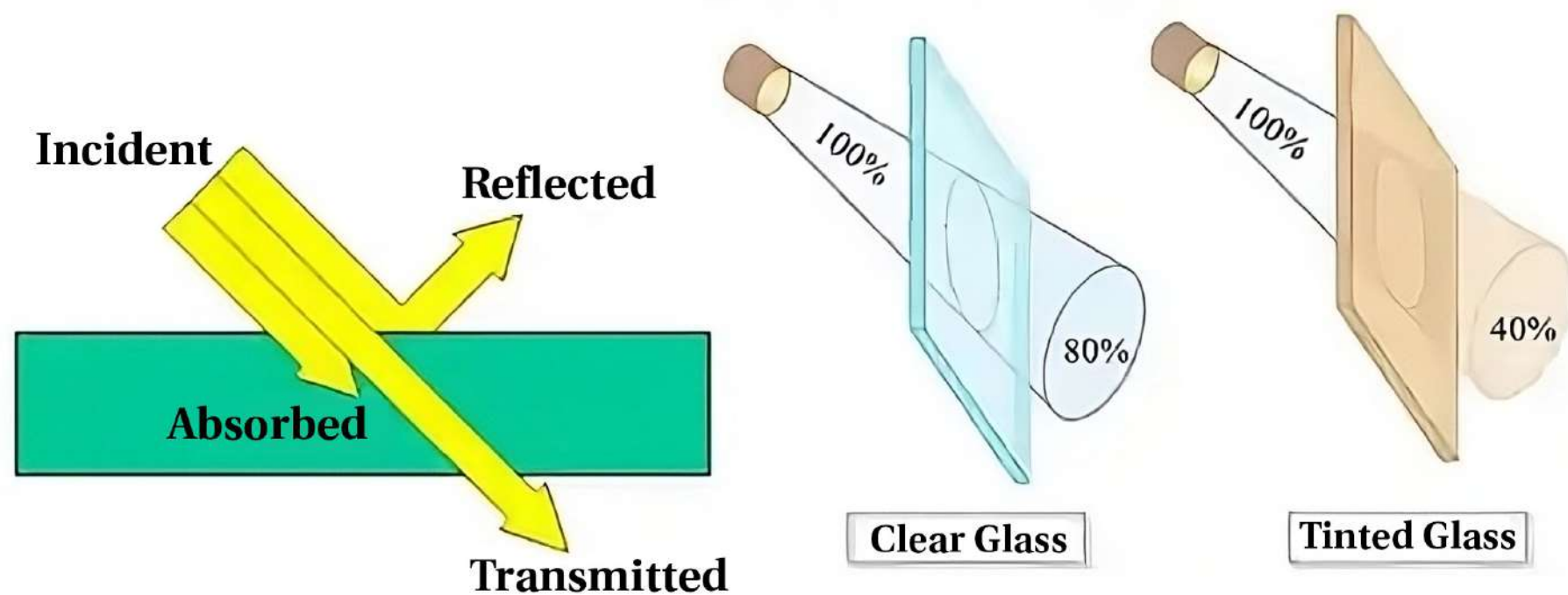


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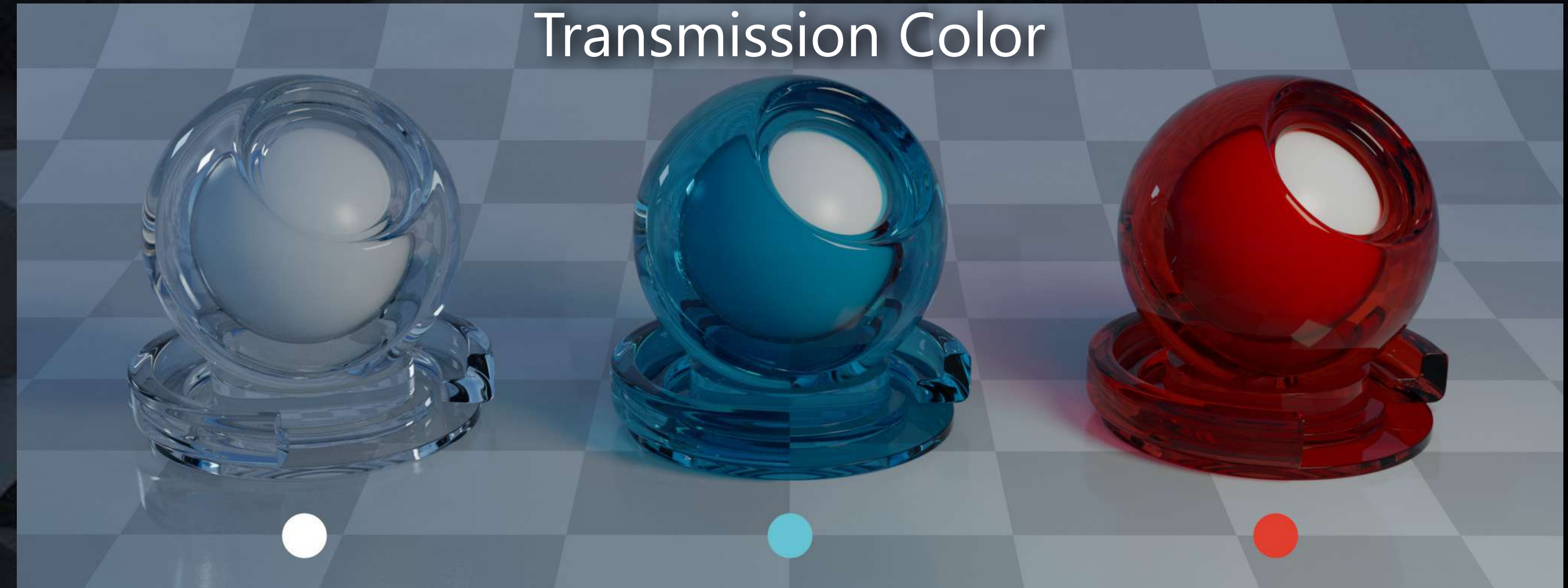
## What is Transmission?

- Transmission can sometimes cause the light to inherit a color tint as it passes through and interacts with the material. Think of colored liquids or tinted glass.

### TRANSMISSION LIGHT PASSING THROUGH AN OBJECT



### Transmission Color



3Delight Glass - Storage for referenced pages - 3DL Docs

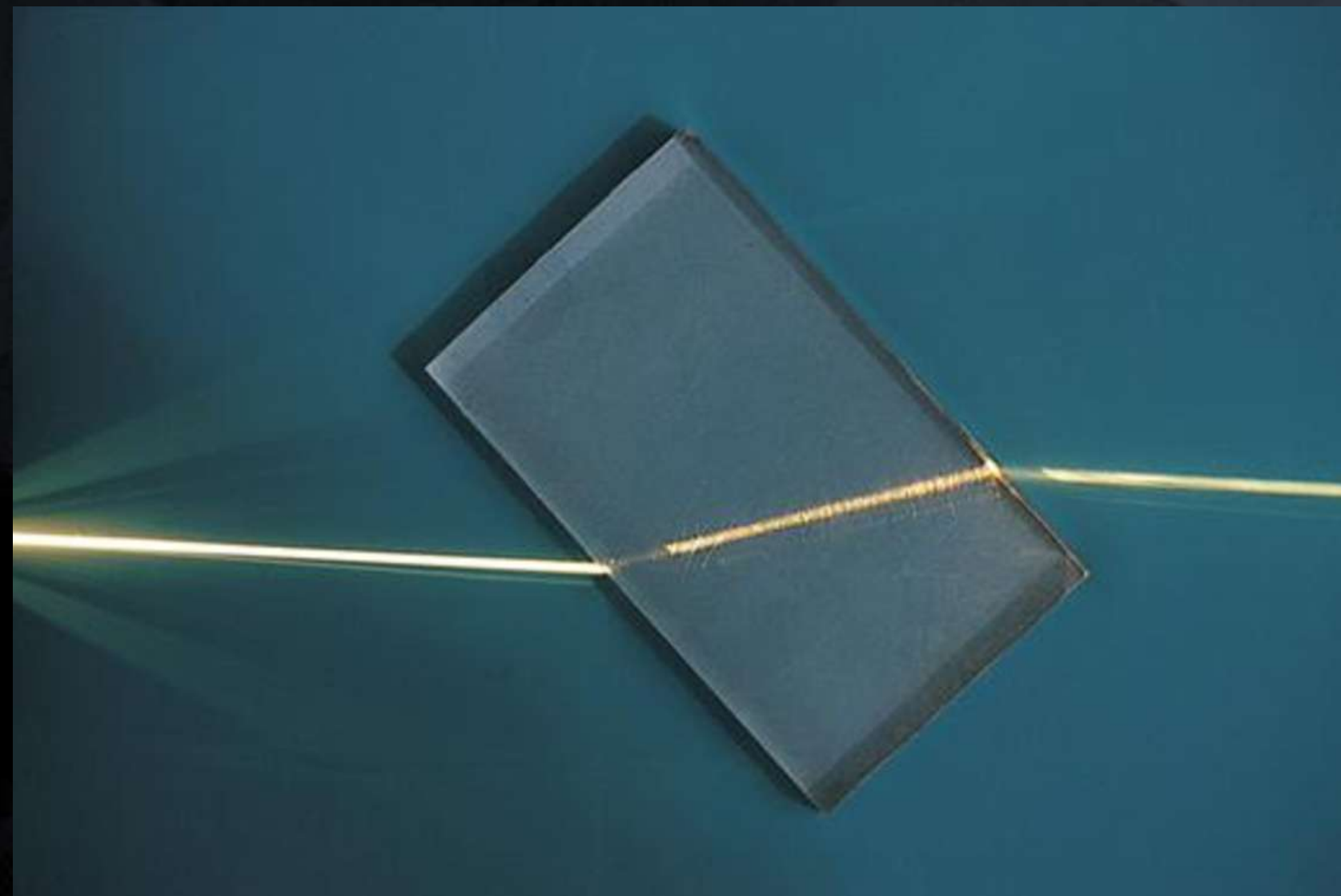
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## What is Refraction?

- **Refraction** is the change in direction and speed of a light ray as it travels through or “Transmits” through different mediums, ie. from Air to Glass or Water or Plastic

The 2 important characteristics are:

1. The Light passes through the material
2. The Light changes direction



<https://en.wikipedia.org/wiki/Refraction>

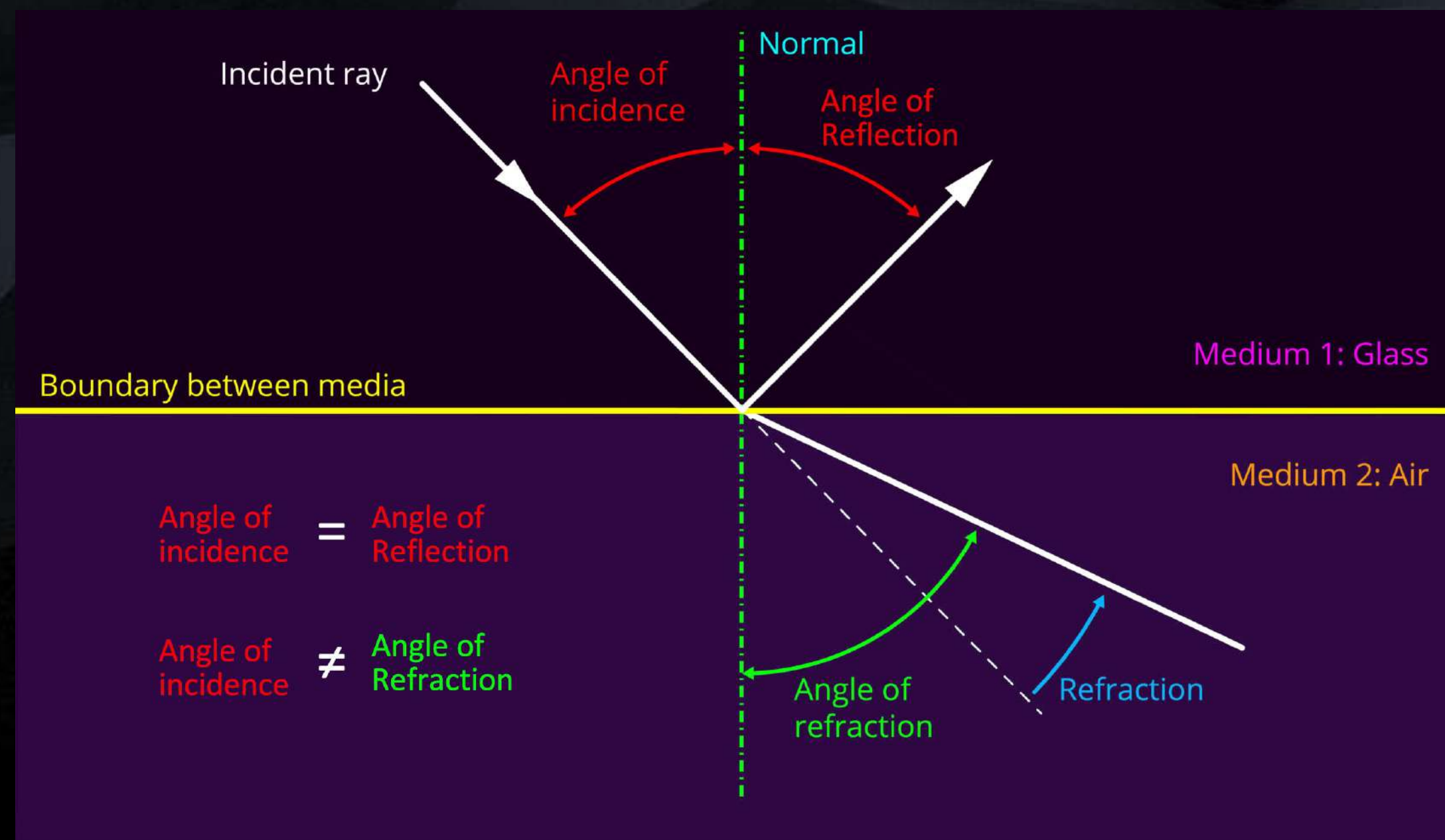
<https://en.wikipedia.org/wiki/Refraction>



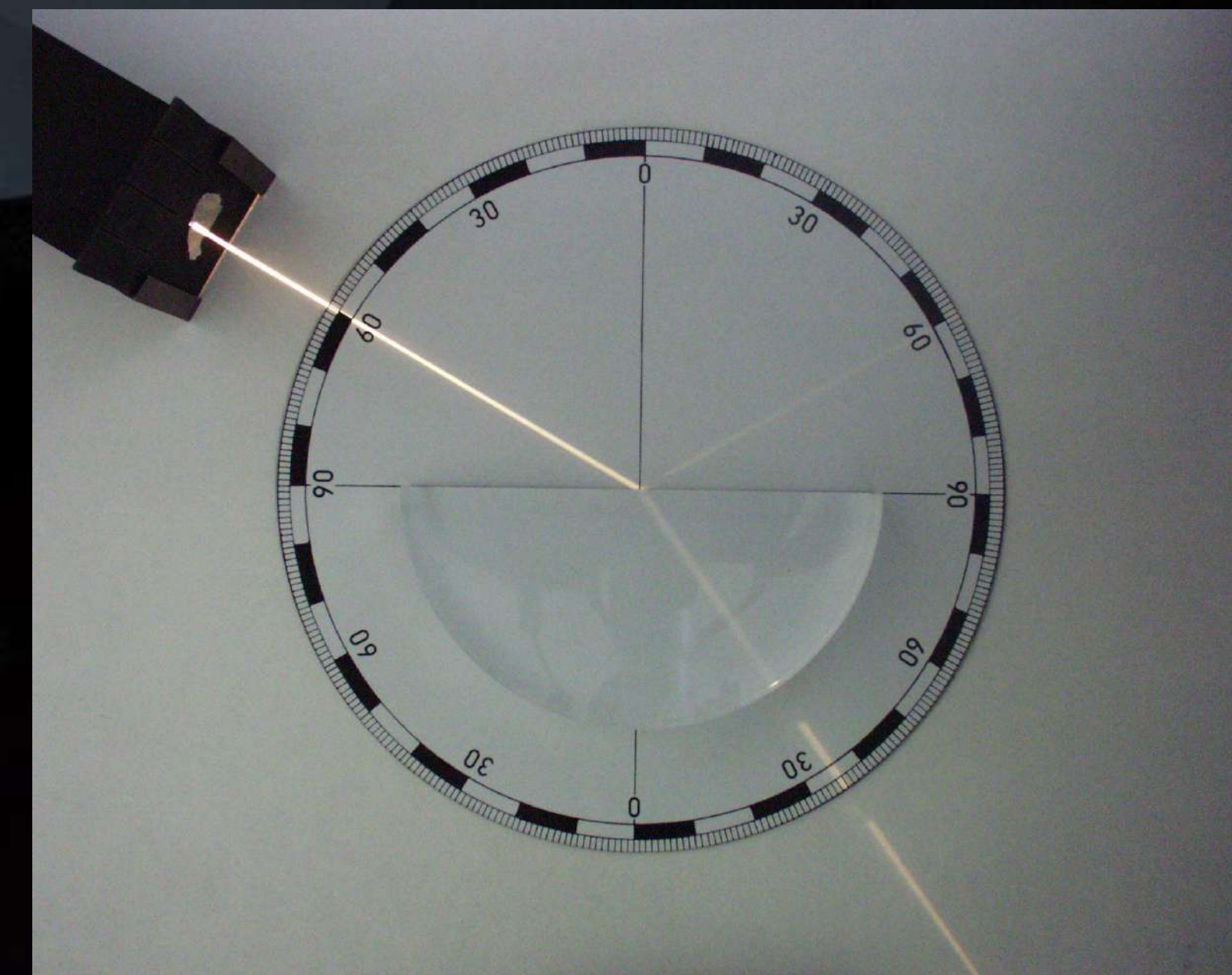
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## What is Refraction?

- The amount of distortion, “bending”, or change in direction of a light’s path while passing through the material, depends on factor’s like:
- Thickness of the material, Angle of View, and the material’s Index of Refraction



<https://lightcolourvision.org/dictionary/definition/index-of-refraction/>



<https://en.wikipedia.org/wiki/Refraction>

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## What is Refraction?

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Photo by Jill Burrow - Pexels



drinking-straw-in-a-glass-of-water-refraction\_congerdesign\_Pixabay



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## Refraction vs Transmission?

- Transmission is only referring to Light passing through an object
- Refraction is requiring the light to have changed direction, and to pass through
- The render pass is doing both things, so some Render Engines decided to call the pass Transmission, because it's referring to light passing through the material
- Other renderers call the pass Refraction, referring to the Change of Direction, "bending" or distortion of the light



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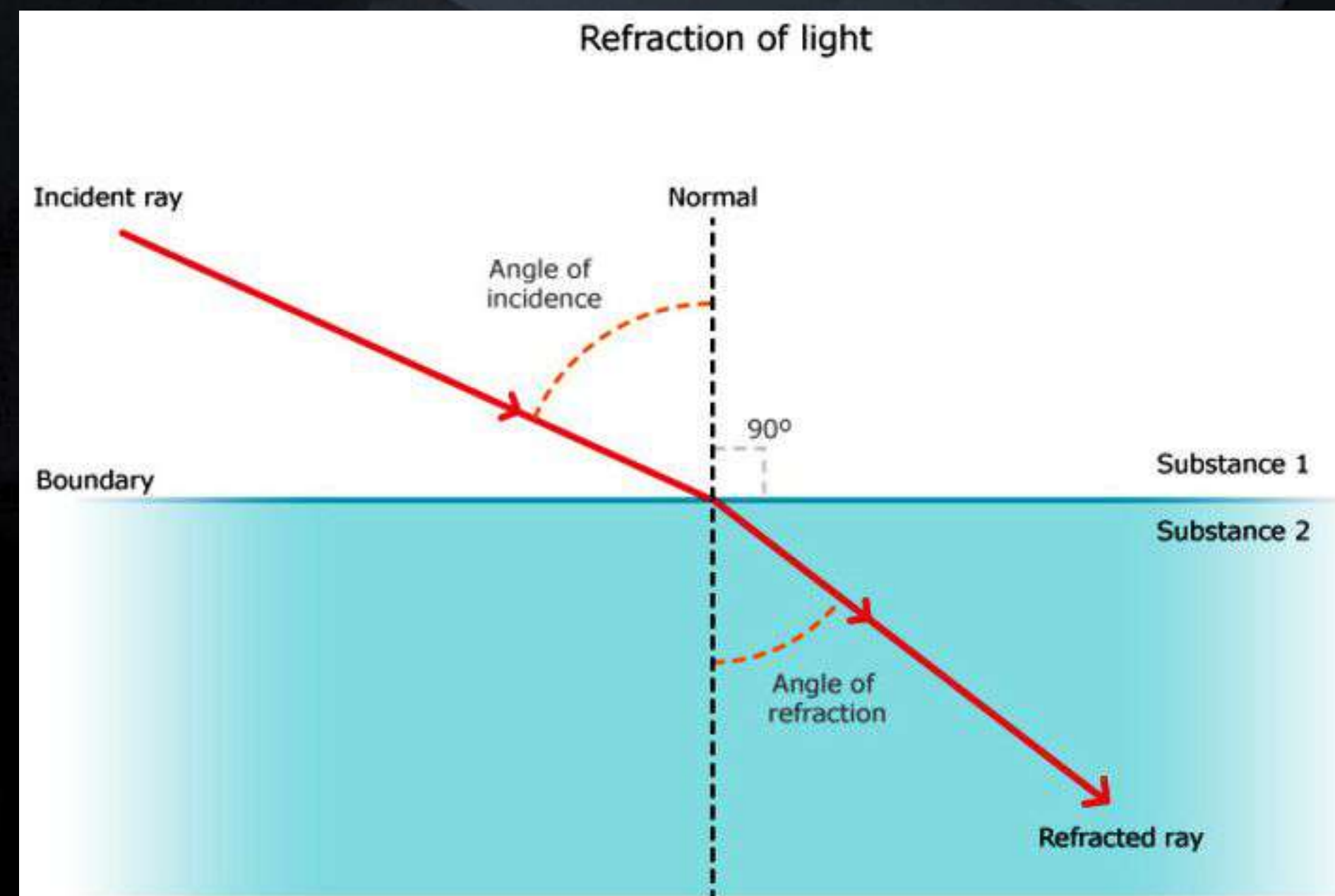
## Refraction vs Transmission?

- Both terms in this case are referring to the same phenomena, just focusing on different aspects of the light's behaviour
- Transmission might even be a more accurate label, because technically a material could have a Refraction index of 1.0, meaning no refraction/distortion is occurring, but the light is still Transmitting.
- All Refractions require Transmission
- Not all Transmissions require Refraction

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## Why is Light Redirected during Refraction?

- Light travels through different mediums at different speeds, depending on the density and make up of the medium.
- Examples of Mediums: Vacuum (space), Air, Glass, Plastic, Water, gases, etc.
- The change of light speed while passing from 1 medium into the next, causes the light to change direction when entering the 2nd medium.

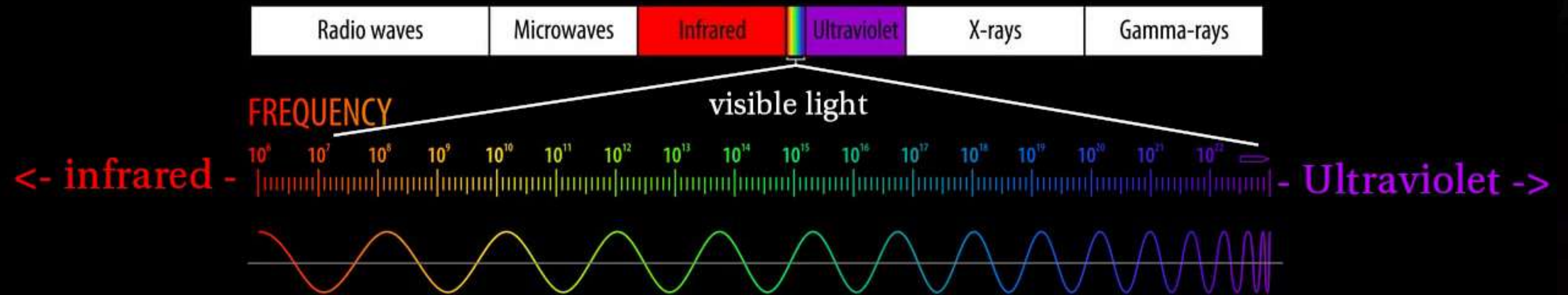


<https://stoplearn.com/refraction-of-light/>

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## Light is a Wave

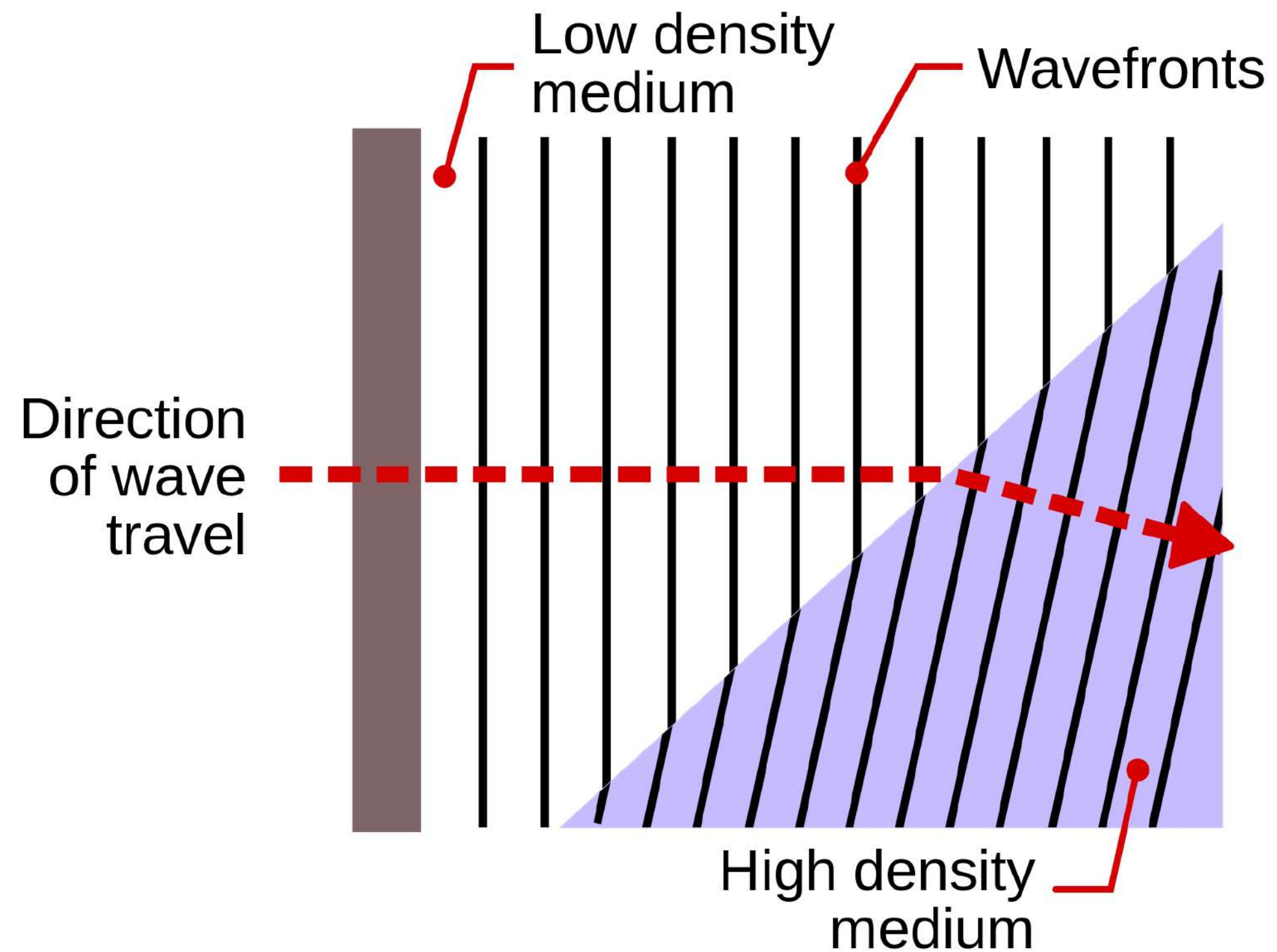
### Electromagnetic Spectrum



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## Light Wave "Turning" / "Bending"

- One side of the wave hits the new medium and slows down first, turning/bending/redirection the light wave towards a new direction.

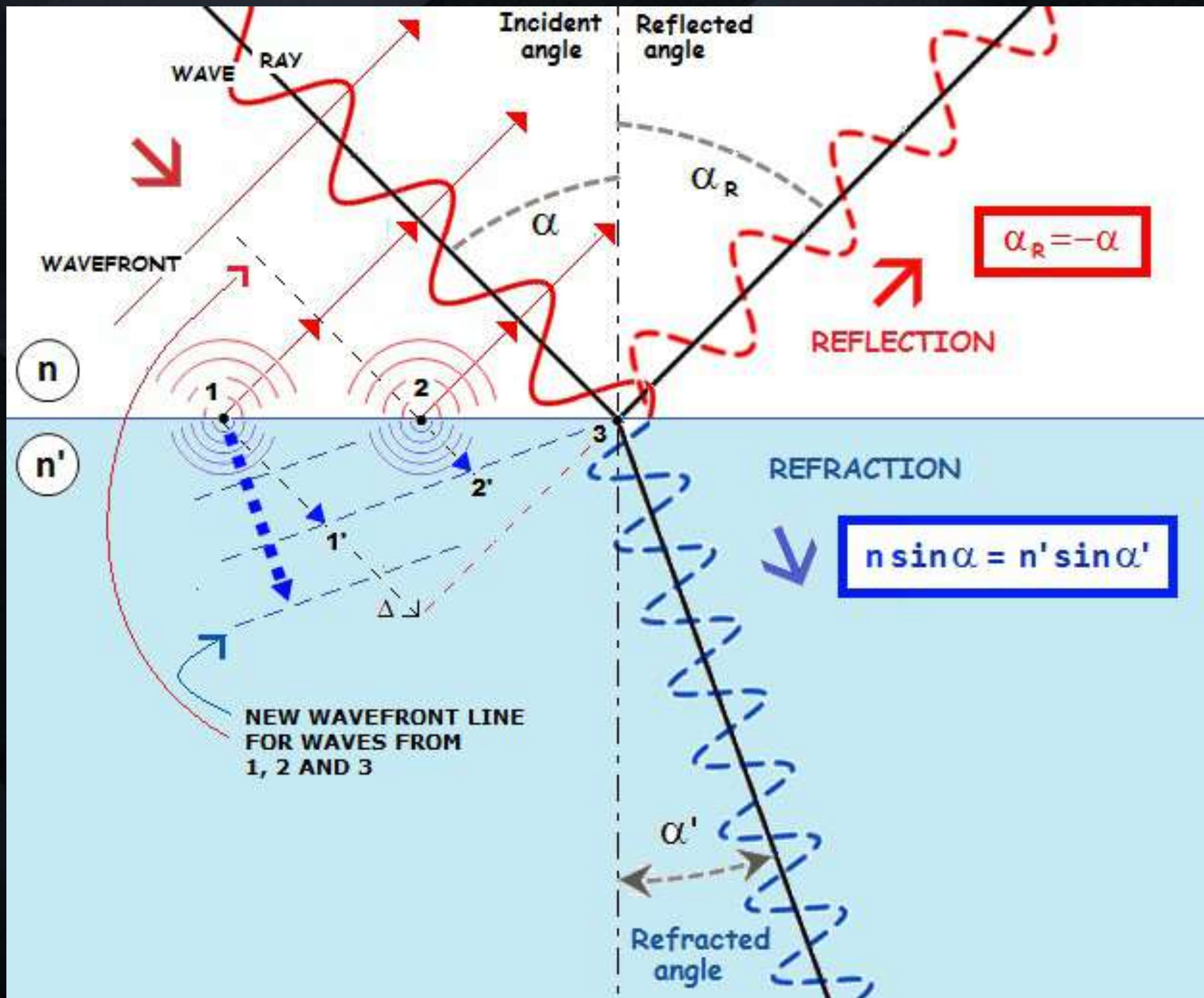


<https://en.wikipedia.org/wiki/Refraction>

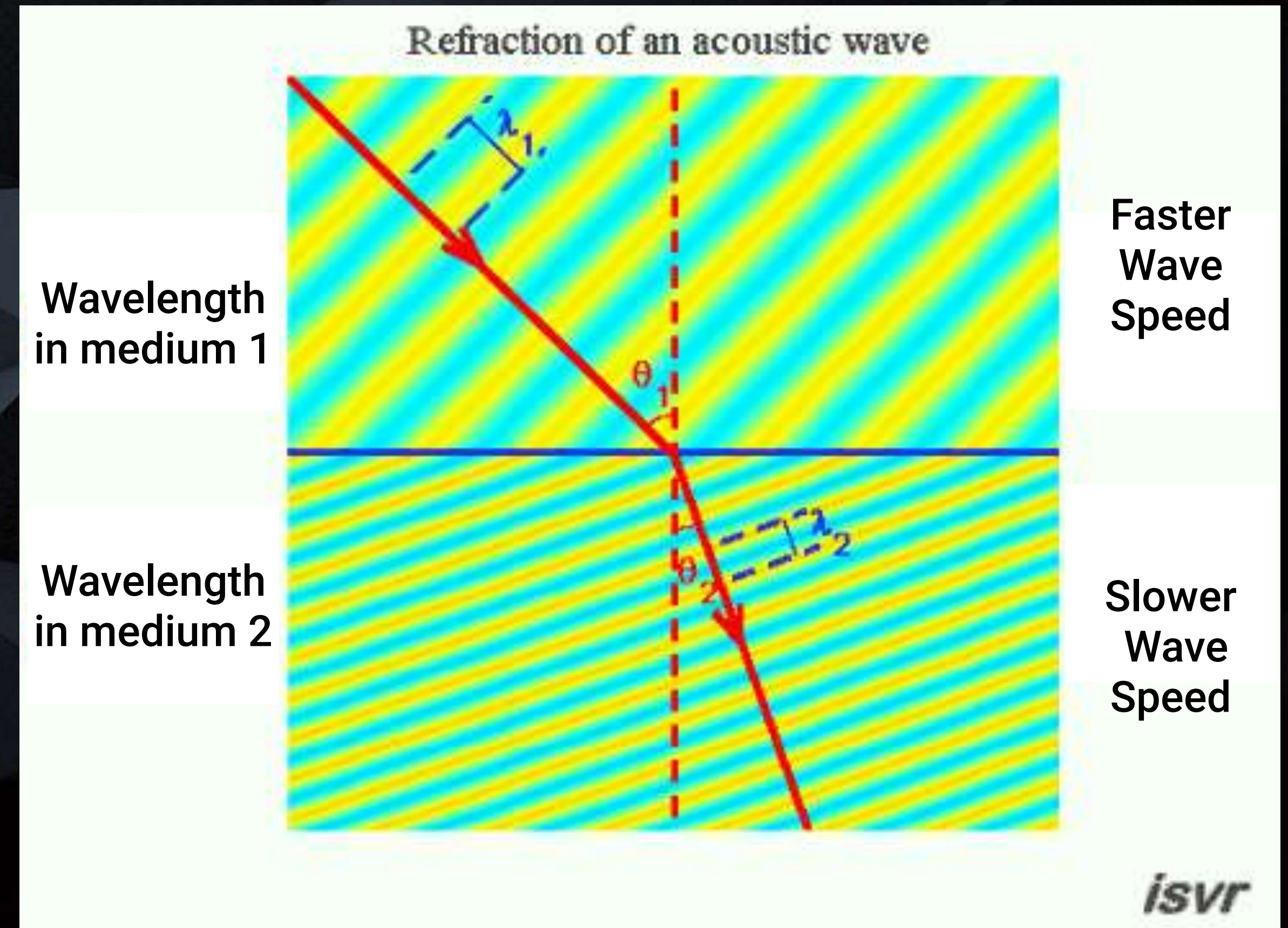
# CG COMPOSITING SERIES

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- One side of the wave hits the new medium and slows down first, turning/bending/redirection the light wave towards a new direction.



<https://www.telescope-optics.net/reflection.htm>



<https://blog.soton.ac.uk/soundwaves/wave-interaction/3-refraction/>

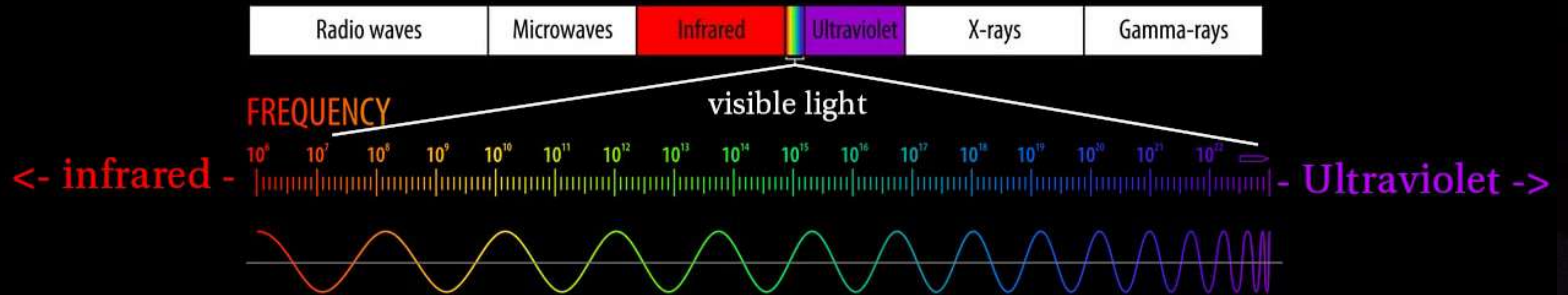
TONY LYONS | COMPOSITINGMENTOR.COM

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## Color Light Wave Frequencies

- Remember that Different Frequencies of Light Spectrum show up as different colors

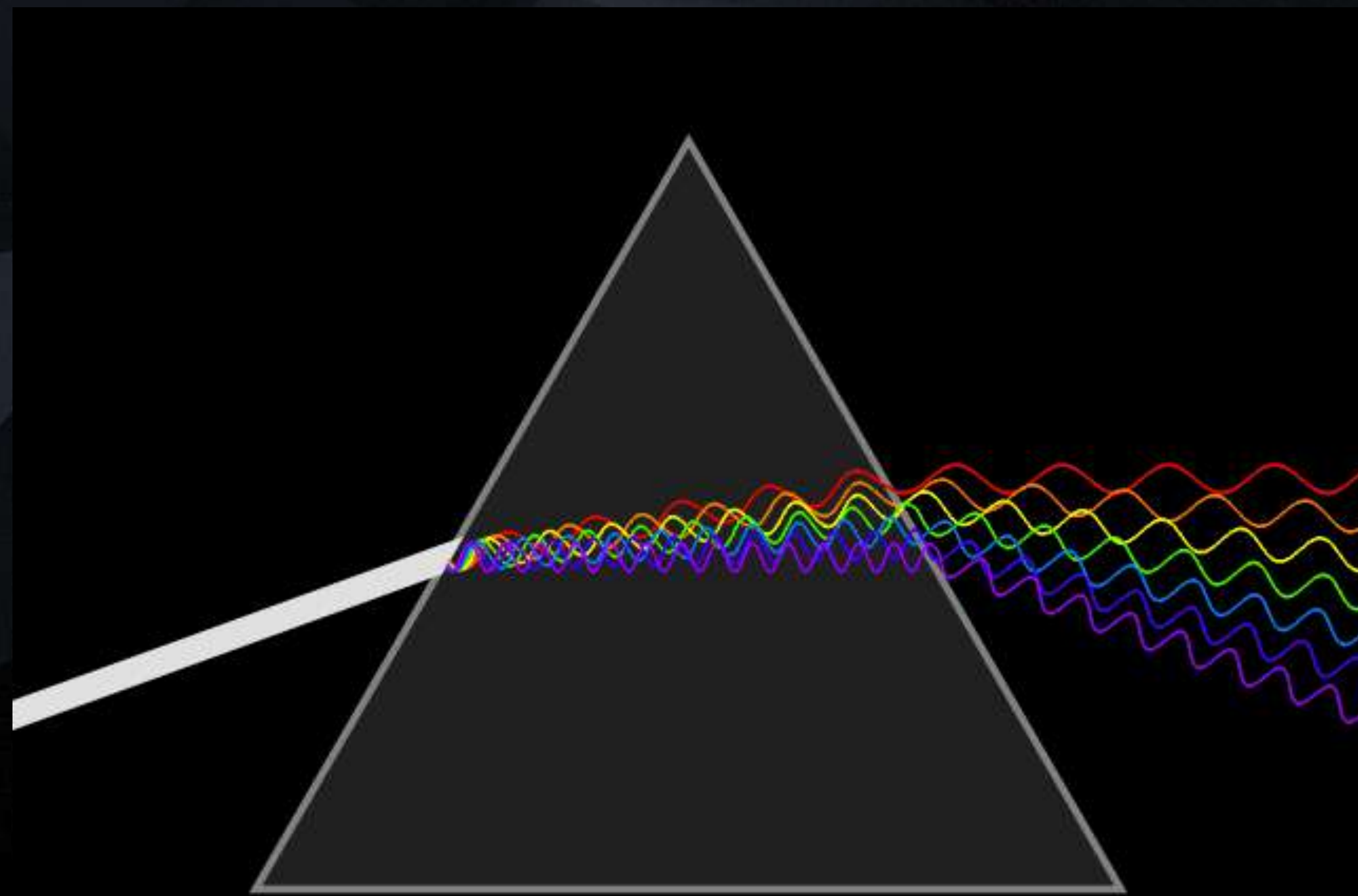
### Electromagnetic Spectrum



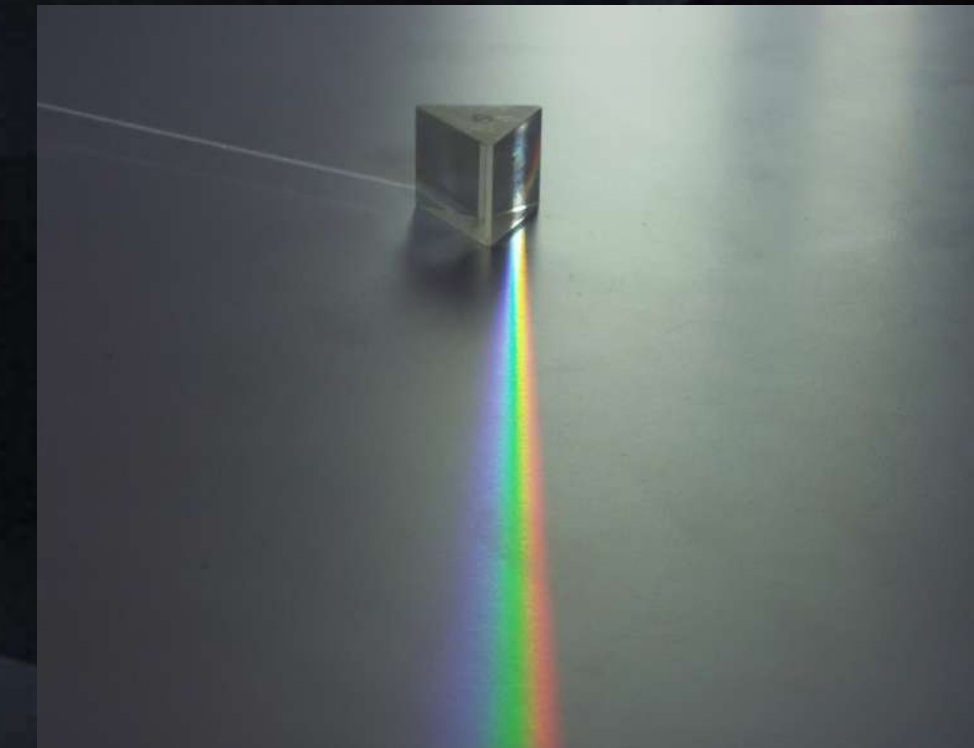
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## Color Spectrum Refraction

- Different frequencies of light refract at slightly different angles, causing the colors to separate. This is what happens with Color Prisms

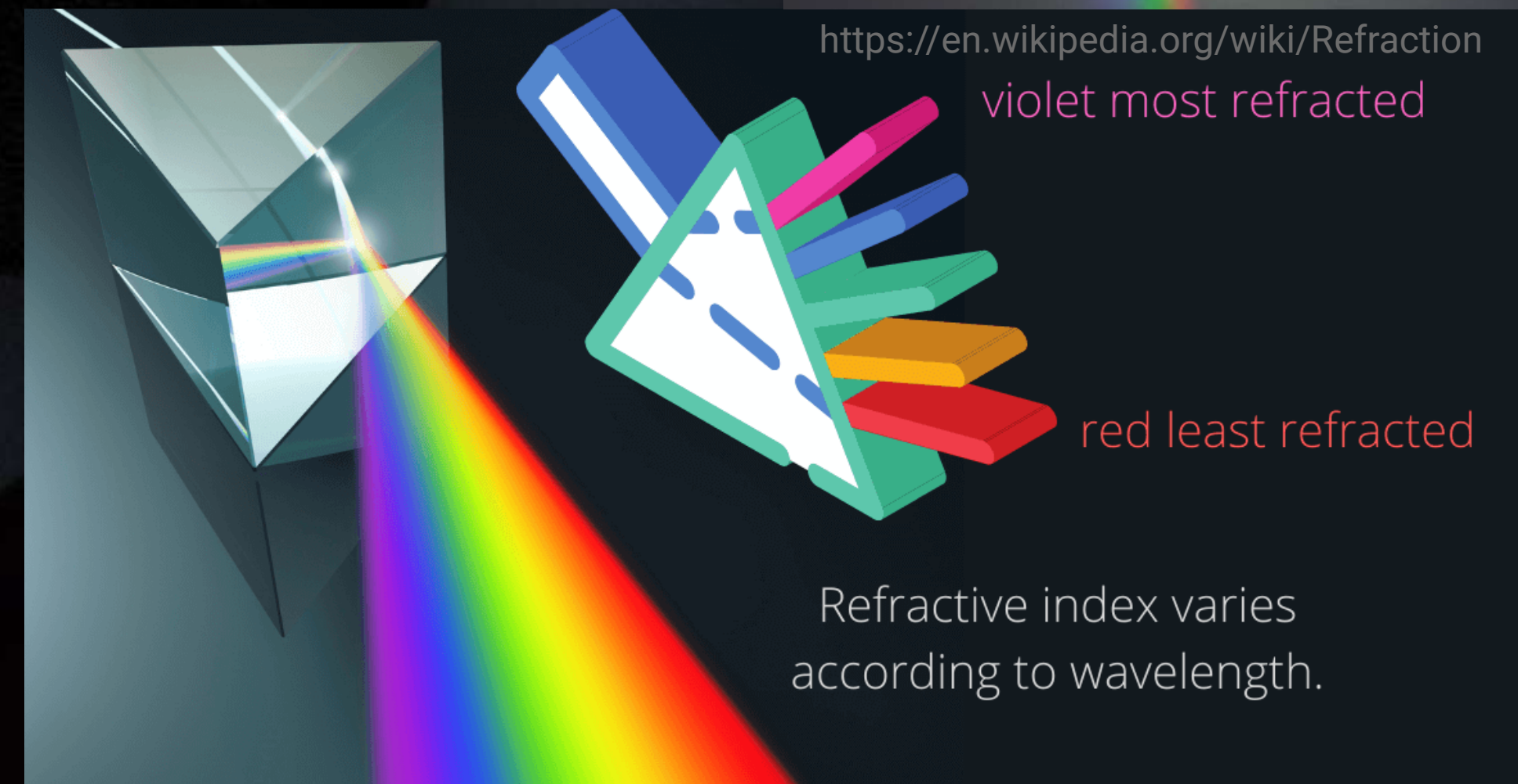


[https://en.wikipedia.org/wiki/Dispersive\\_prism](https://en.wikipedia.org/wiki/Dispersive_prism)



<https://en.wikipedia.org/wiki/Refraction>

violet most refracted



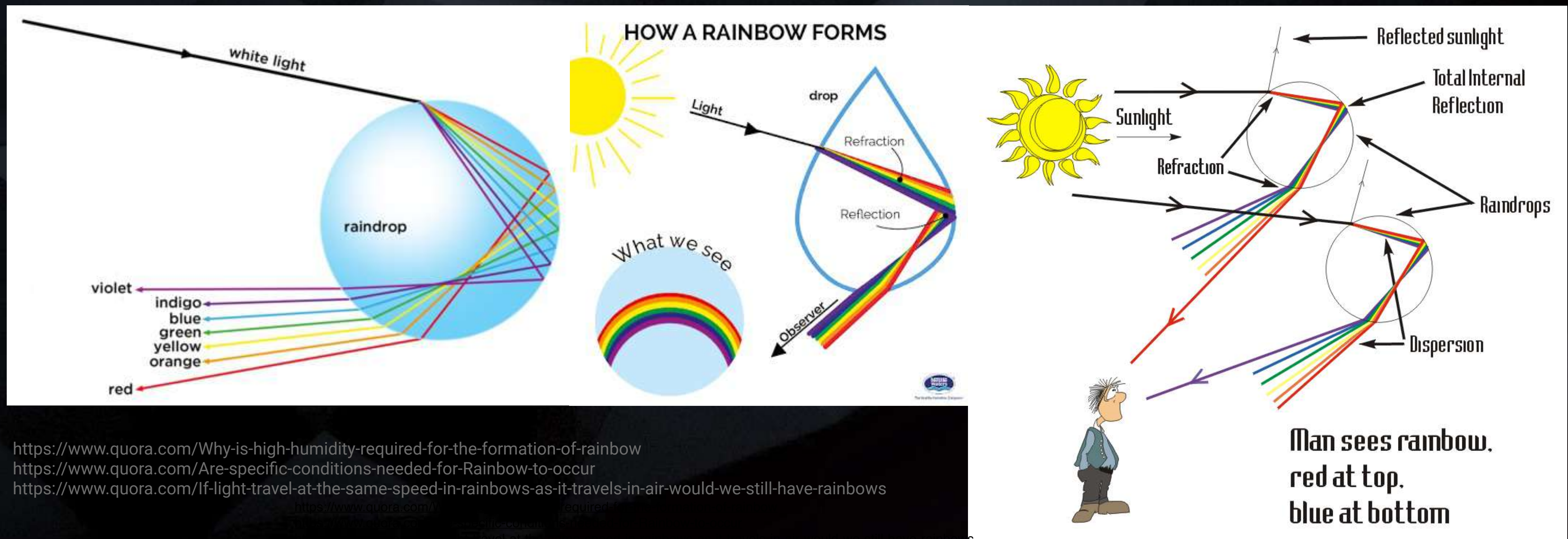
Refractive index varies according to wavelength.

<https://sciencenotes.org/refraction-definition-refractive-index-snells-law/>

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## Refraction / Reflection in Rainbows

- A Combination of this Refraction Color Separation and Reflections within water droplets is what allows us to see Rainbows



<https://www.quora.com/Why-is-high-humidity-required-for-the-formation-of-rainbow>  
<https://www.quora.com/Are-specific-conditions-needed-for-Rainbow-to-occur>  
<https://www.quora.com/If-light-travel-at-the-same-speed-in-rainbows-as-it-travels-in-air-would-we-still-have-rainbows>

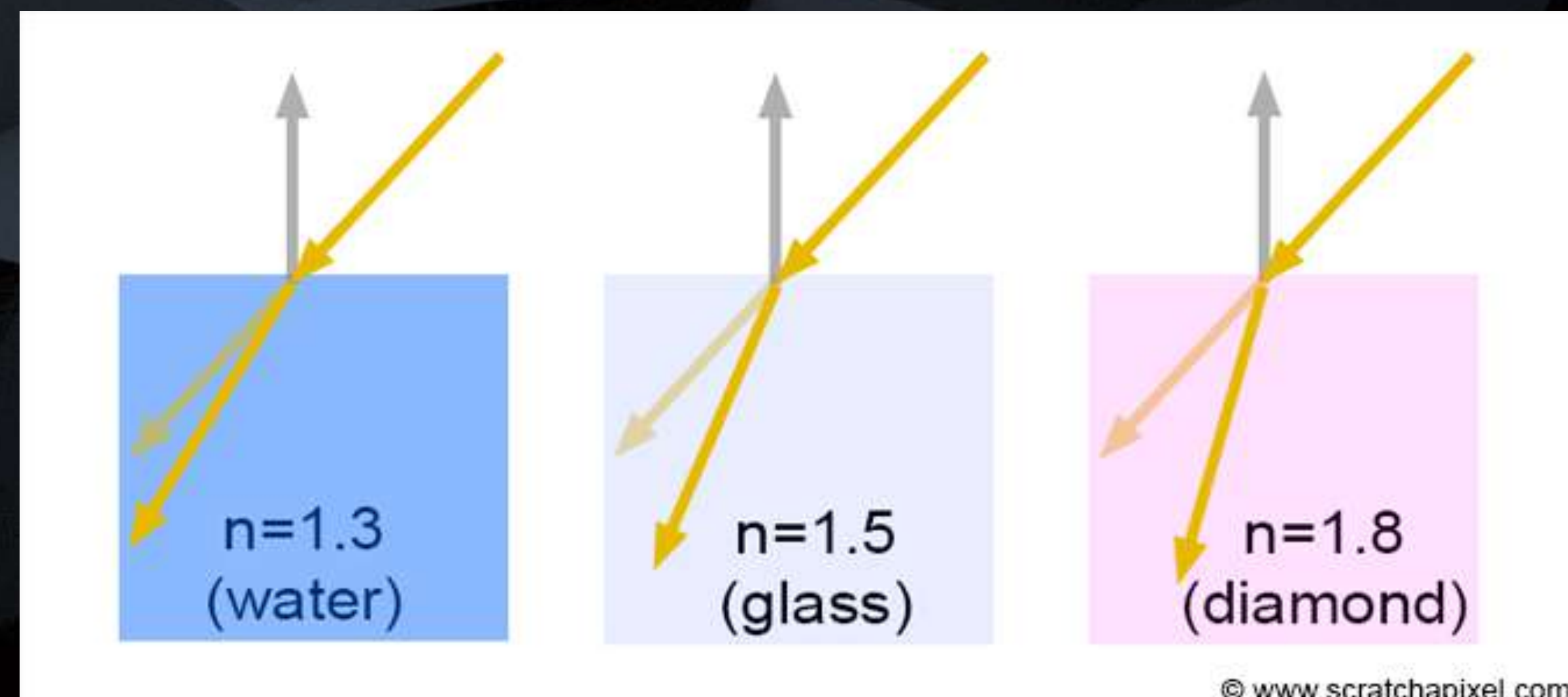


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## Index of Refraction

- Different materials have different densities and make ups and will cause light waves to move through at different speeds
- This is measured with an Index of Refraction, which measures how fast light moves through that medium, and therefore how much it refracts
- An Index of 1.0 is light's speed in a Vacuum - or no change in direction
- Higher numbers mean light travels through the medium slower and light bends more

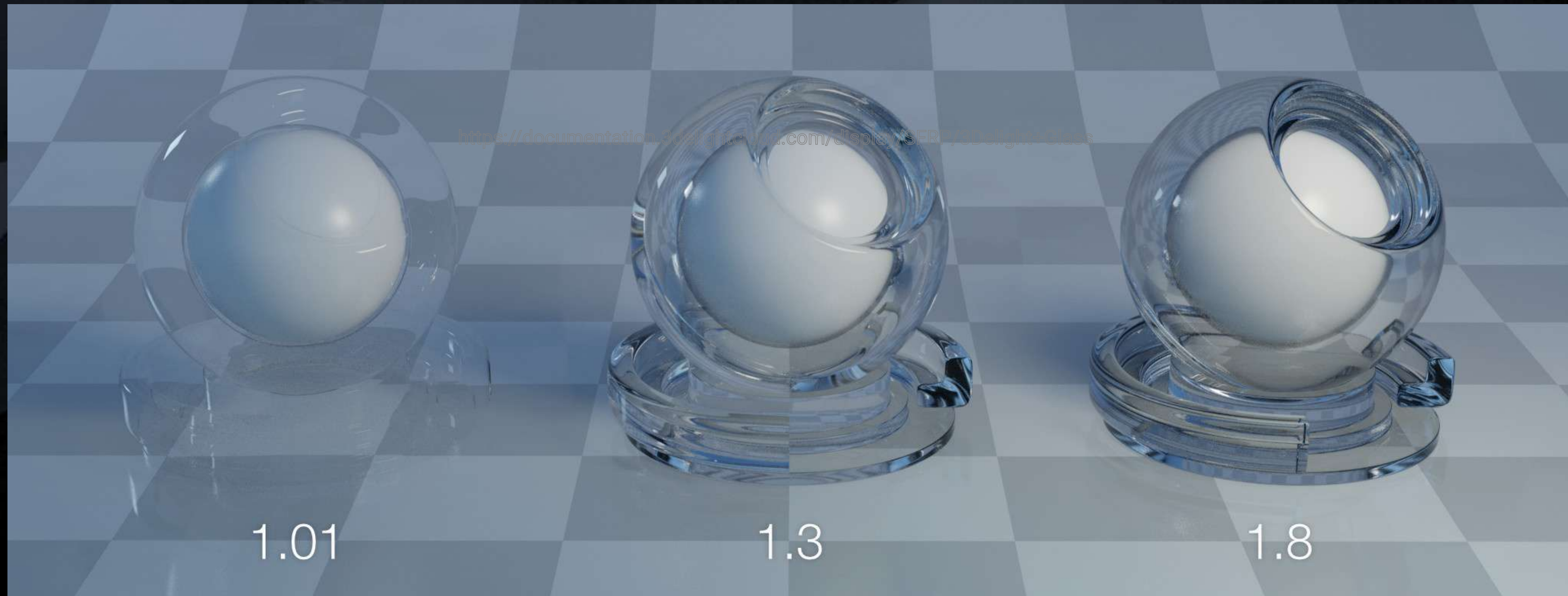
| Material      | Refractive Index |
|---------------|------------------|
| Air           | 1.0003           |
| Water         | 1.33             |
| Glycerin      | 1.47             |
| Immersion Oil | 1.515            |
| Glass         | 1.52             |
| Flint         | 1.66             |
| Zircon        | 1.92             |
| Diamond       | 2.42             |
| Lead Sulfide  | 3.91             |



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## Index of Refraction

- In CG, this Index of Refraction is an attribute setting on Materials that will make it more or less refractive

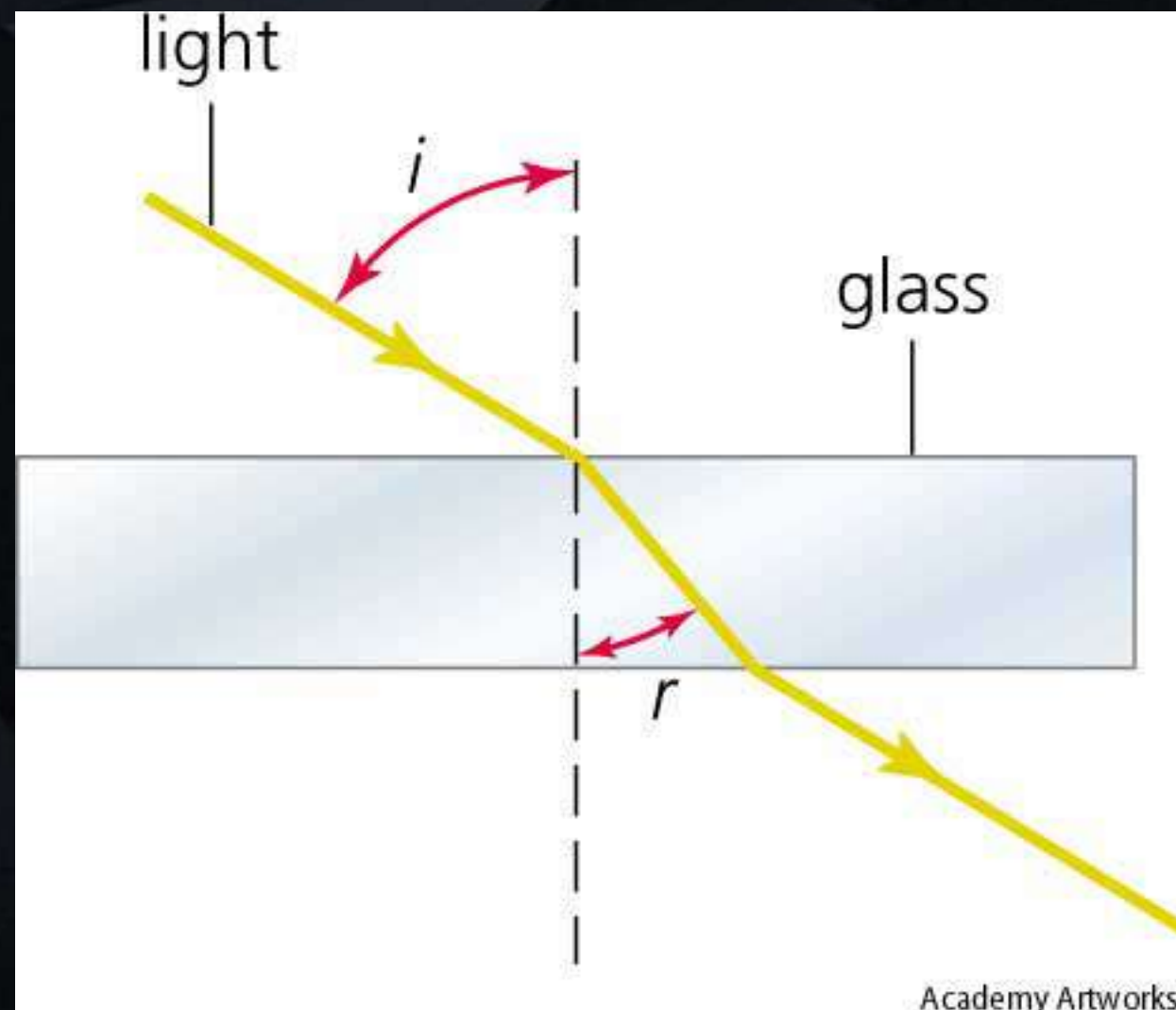


<https://documentation.3delightcloud.com/display/SFRP/3Delight+Glass>

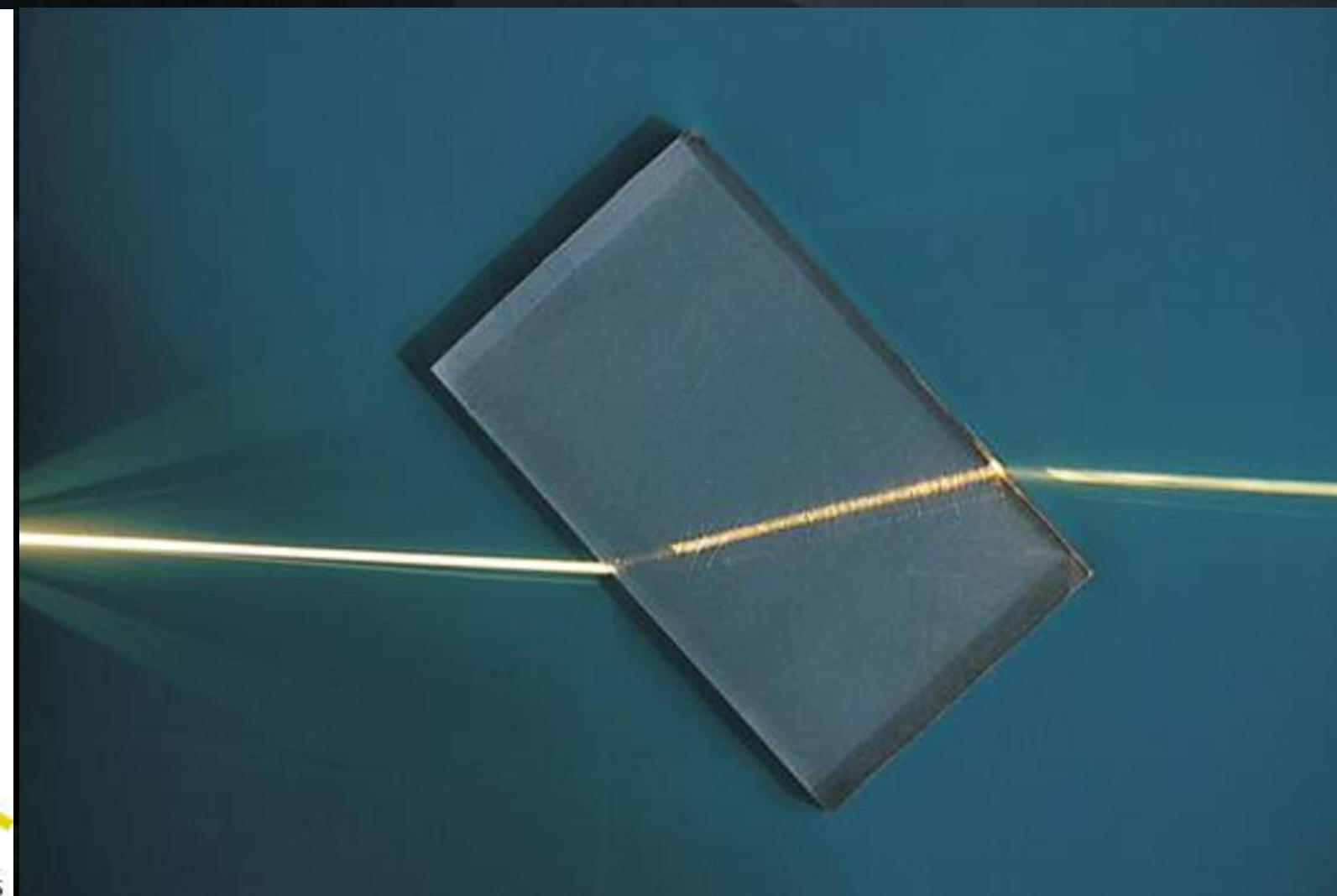
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## Refraction Re-entering Original Medium

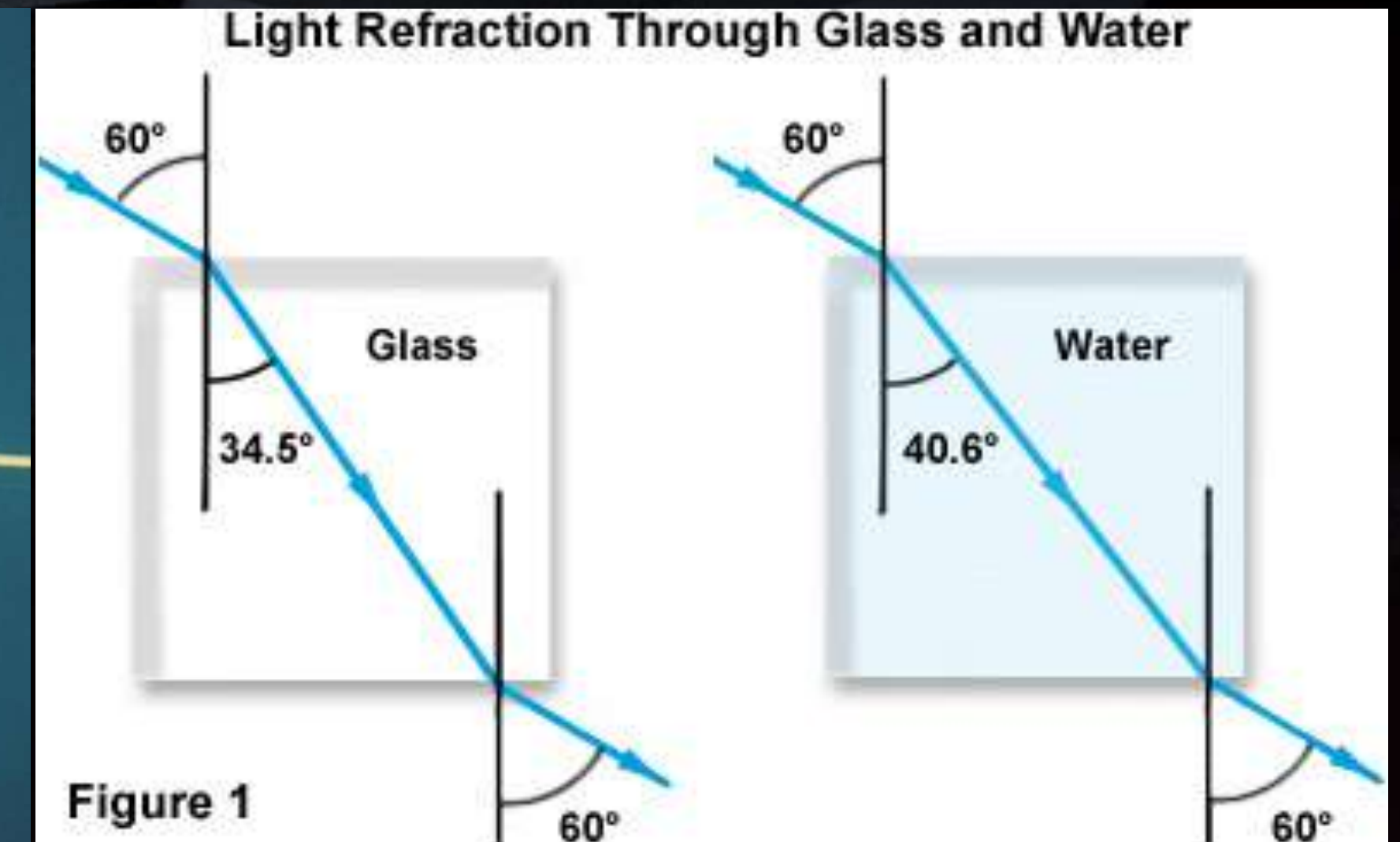
- When the Light goes from a fast medium, to slower medium, and back into the fast medium on the other side, it has another refraction turn
- This time, instead of one side of the light wavelength slowing first, one side speeds up first
- If the exit angle is the same as the entrance angle, it will reverse the lightwave back to the original direction, and is parallel to the original light direction, just offset



<https://www.quora.com/Will-the-angle-of-refraction-of-a-ray-of-light-passing-from-glass-to-air-be-equal-to-the-angle-of-incidence-greater-than-the-angle-of-incidence-smaller-than-the-angle-of-incidence-or-45-What-are-the-reasons-for-your>



<https://en.wikipedia.org/wiki/Refraction>

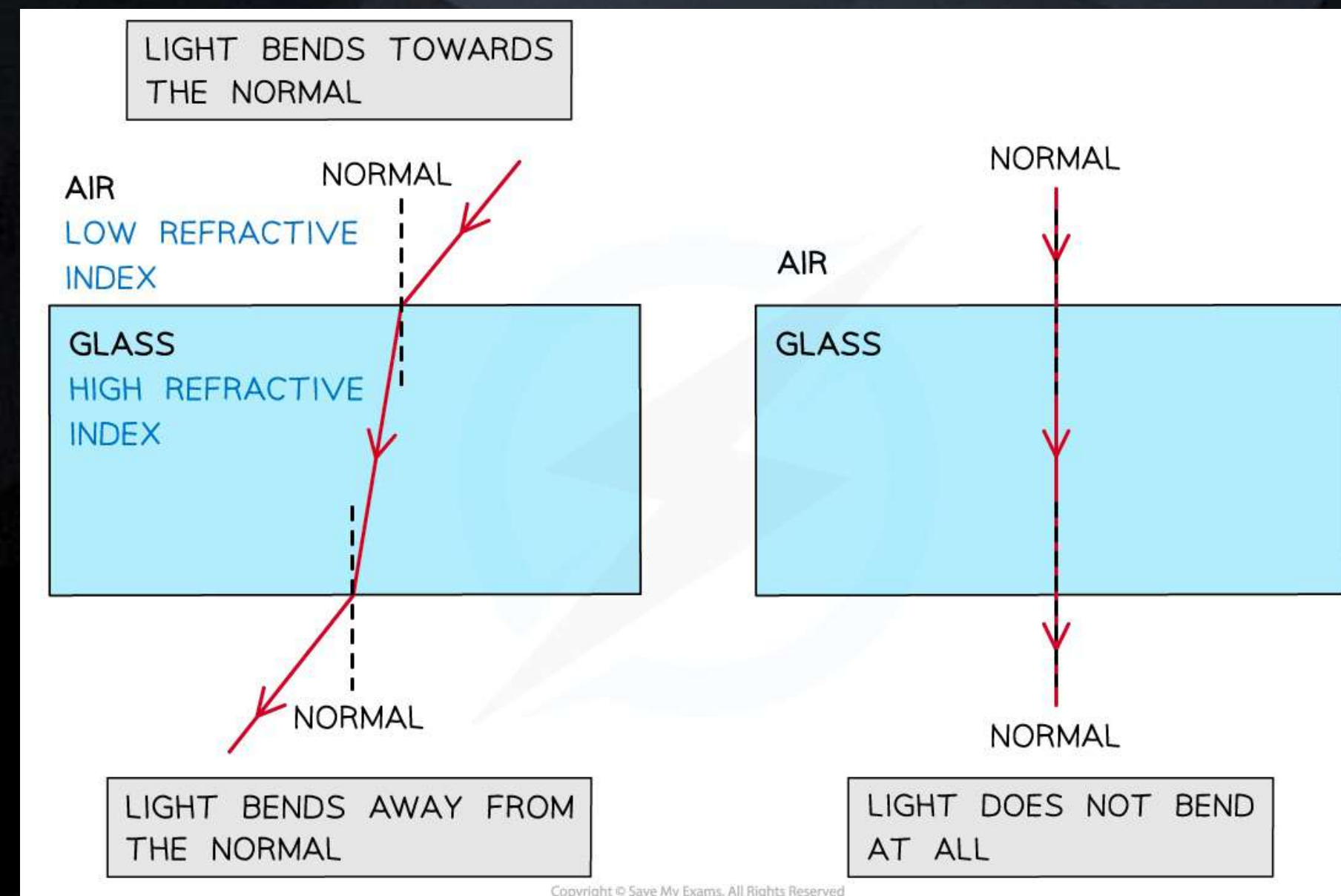


<https://micro.magnet.fsu.edu/optics/lightandcolor/refraction.html>

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## Refraction Angle

- The Angle that the light wave hits the surface also matters
- If the light hits the material exactly perpendicular to the surface normal then it will pass through and the light does not bend at all
- The more extreme the angle, the more refraction. This is why light appears most warped at the edges of curved surfaces.



<https://www.hanlin.com/archives/695184>

# CG COMPOSITING SERIES

## Refraction Angle

- The more extreme the angle, the more refraction. This is why light appears most warped at the edges of curved surfaces.



Pexels - Photo by Burak The Weekender



# CG COMPOSITING SERIES

## Refraction Angle

- This is exactly what causes lens distortion to be more extreme at the edges of frame vs the center of frame



[https://en.wikipedia.org/wiki/Fisheye\\_lens](https://en.wikipedia.org/wiki/Fisheye_lens)

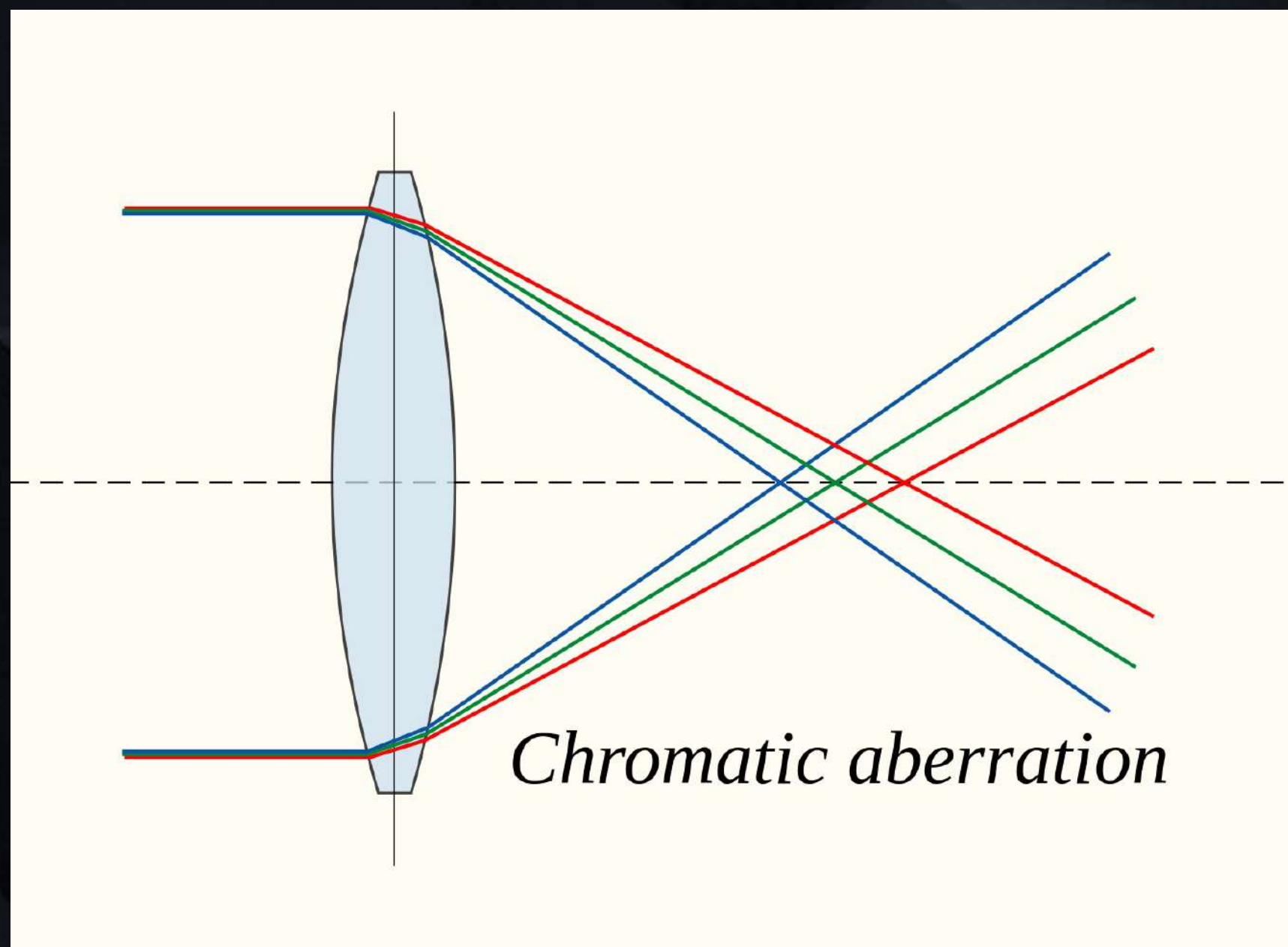


<https://help.shopmoment.com/article/181-superfish-distortion-correction>

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## Chromatic Aberration

- Combining the more extreme distortion with the Color separation is why we get Chromatic Abberation more in the edges of frame as well.



[https://en.wikipedia.org/wiki/Chromatic\\_aberration](https://en.wikipedia.org/wiki/Chromatic_aberration)

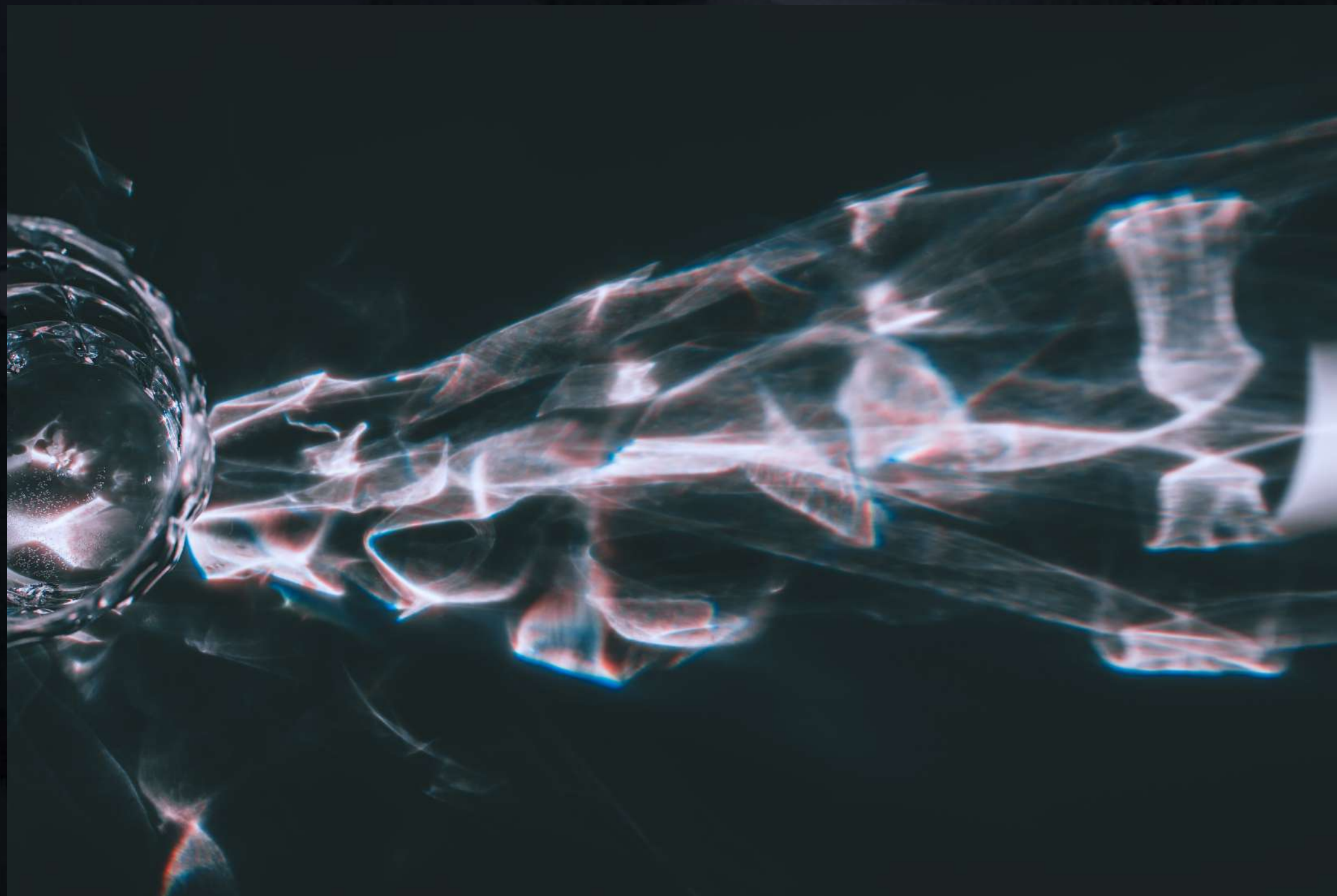


<http://www.tlc-systems.com/artzen2-0047.htm>

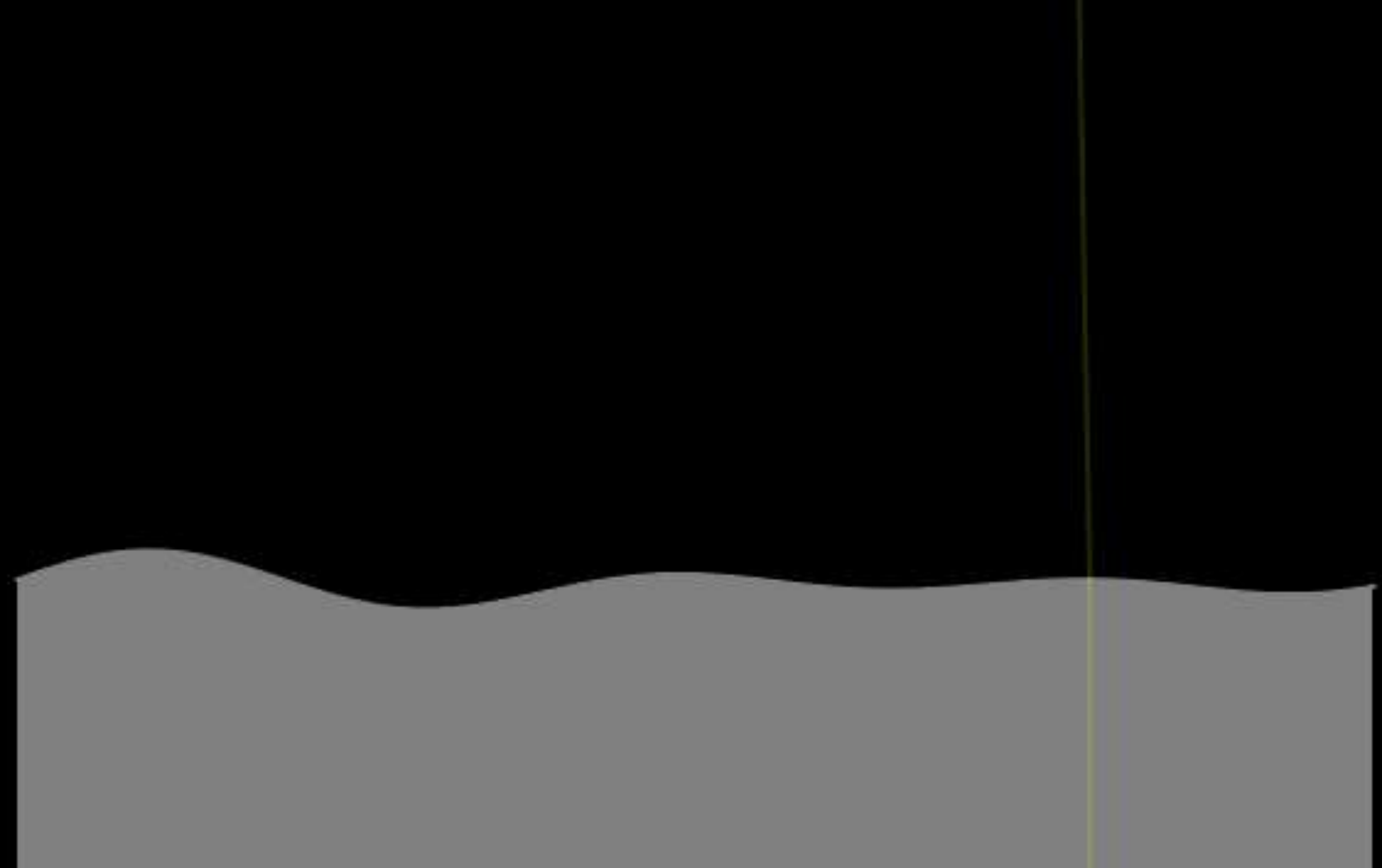
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## Caustics

- Light Refracting through complex shaped objects, changes direction, and concentrate towards certain areas more than others and create Caustics.



Pexels - Photo by Maria Orlova



[https://en.wikipedia.org/wiki/Caustic\\_\(optics\)](https://en.wikipedia.org/wiki/Caustic_(optics))



# CG COMPOSITING SERIES

## Caustics

- Complex shapes create complex caustics, and moving surfaces, like water, create dynamic and organic moving Caustic patterns.

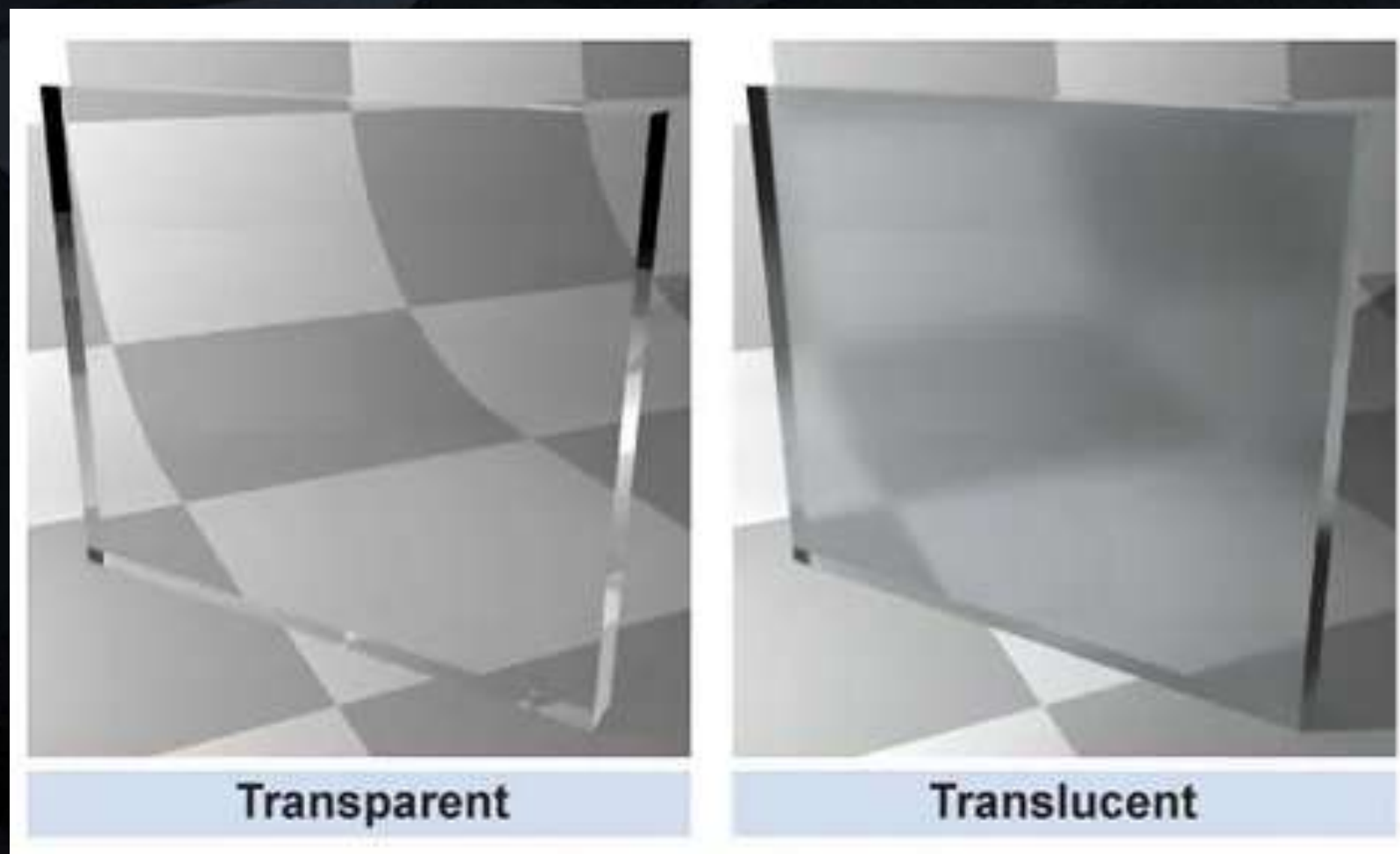


[https://en.wikipedia.org/wiki/Caustic\\_\(optics\)](https://en.wikipedia.org/wiki/Caustic_(optics))

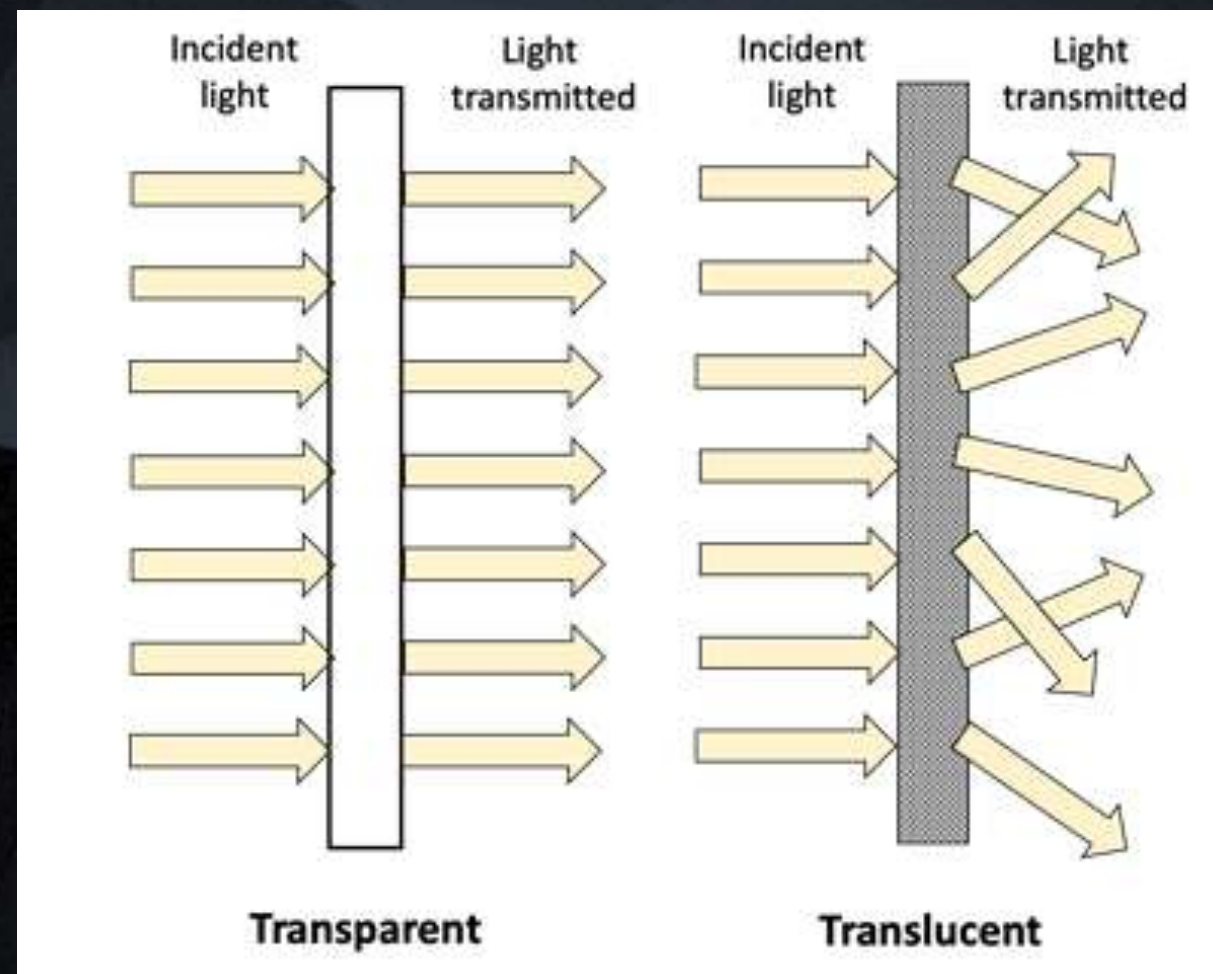
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## What is Translucency?

- Transmissive materials have a Roughness or Glossiness setting that works in the same way as it does on Specular Highlights
- Increasing the Transmission Roughness causes the light rays traveling through to scatter / “diffuse” or blur together. Think of Frosted Glass or Plastics.
- This effect of “Blurring” or Scattering the Transmitted light is called Translucency



<https://medium.com/@stevesi/on-bigco-leaks-transparency-and-disclosure-6d7812e227a0>



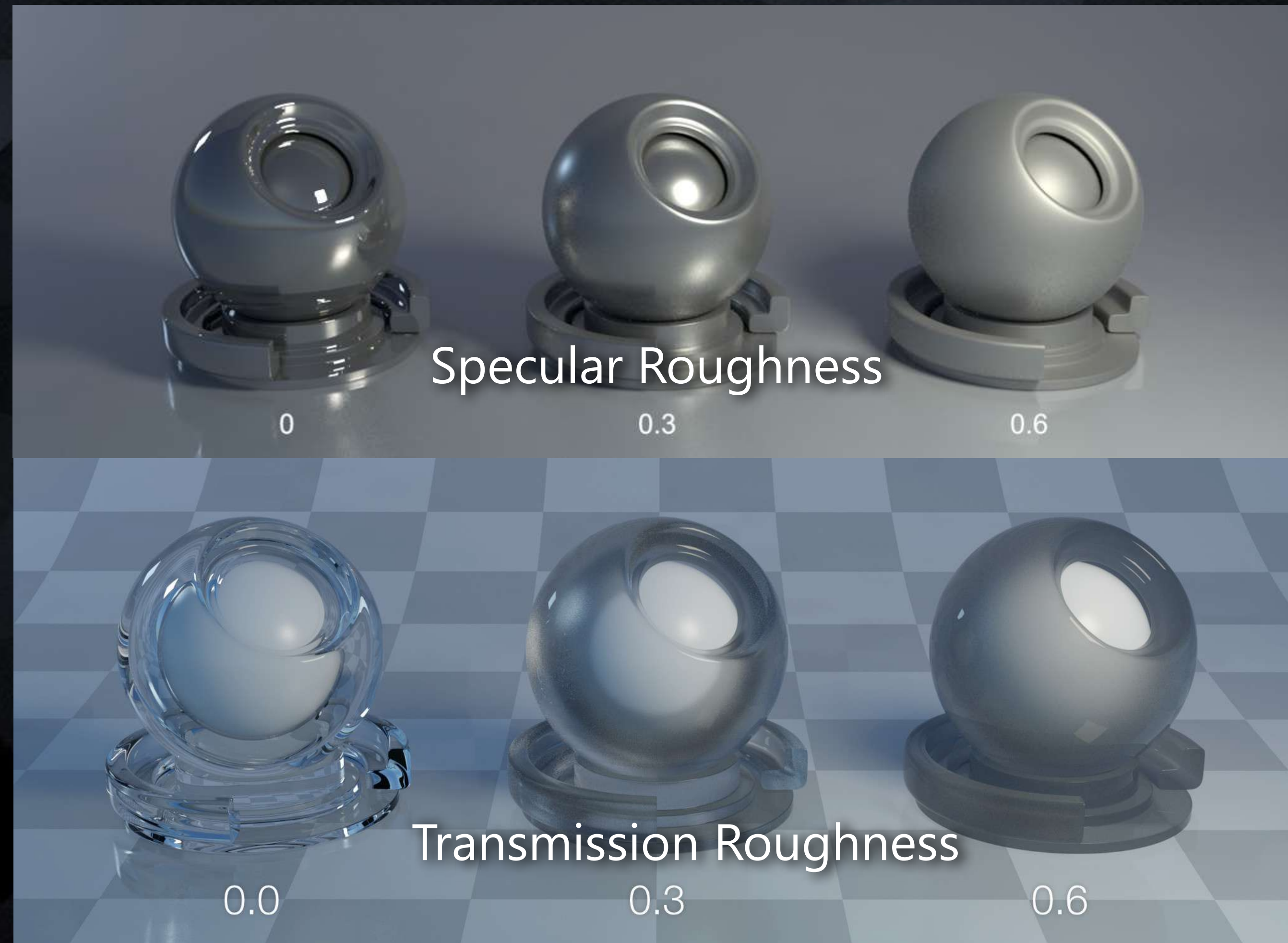
<https://www.sciencebuddies.org/teacher-resources/lesson-plans/light-transparent-translucent-opaque>



<https://slideplayer.com/slide/8349700/>  
Light and Color Presentation - by Elijah Dixon

# CG COMPOSITING SERIES

## Roughness Blurs Everything Together



# CG COMPOSITING SERIES

## Recap Overview

**Transparency** - You can see through to BG, as if the material or object is not visible or ignored

**Transmission** - Light allowed to pass through the surface / material

**Refraction** - Light changes direction as it passes through the material / surface

**Translucency** - Light passes through material and gets scattered / blurred

# CG COMPOSITING SERIES

## Virtual Images / Worlds

- When looking at fully reflective and refractive objects, we are seeing a distorted representation of our surroundings.



<https://www.scratchapixel.com/lessons/3d-basic-rendering/introduction-to-shading/reflection-refraction-fresnel.html>



<https://en.wikipedia.org/wiki/Refraction>

# CG COMPOSITING SERIES

## Concave/Convex Reflections

- When looking at curved mirrors, it is very obvious that the object we are looking at, is a **redirected** and **distorted** view of our surrounding environment



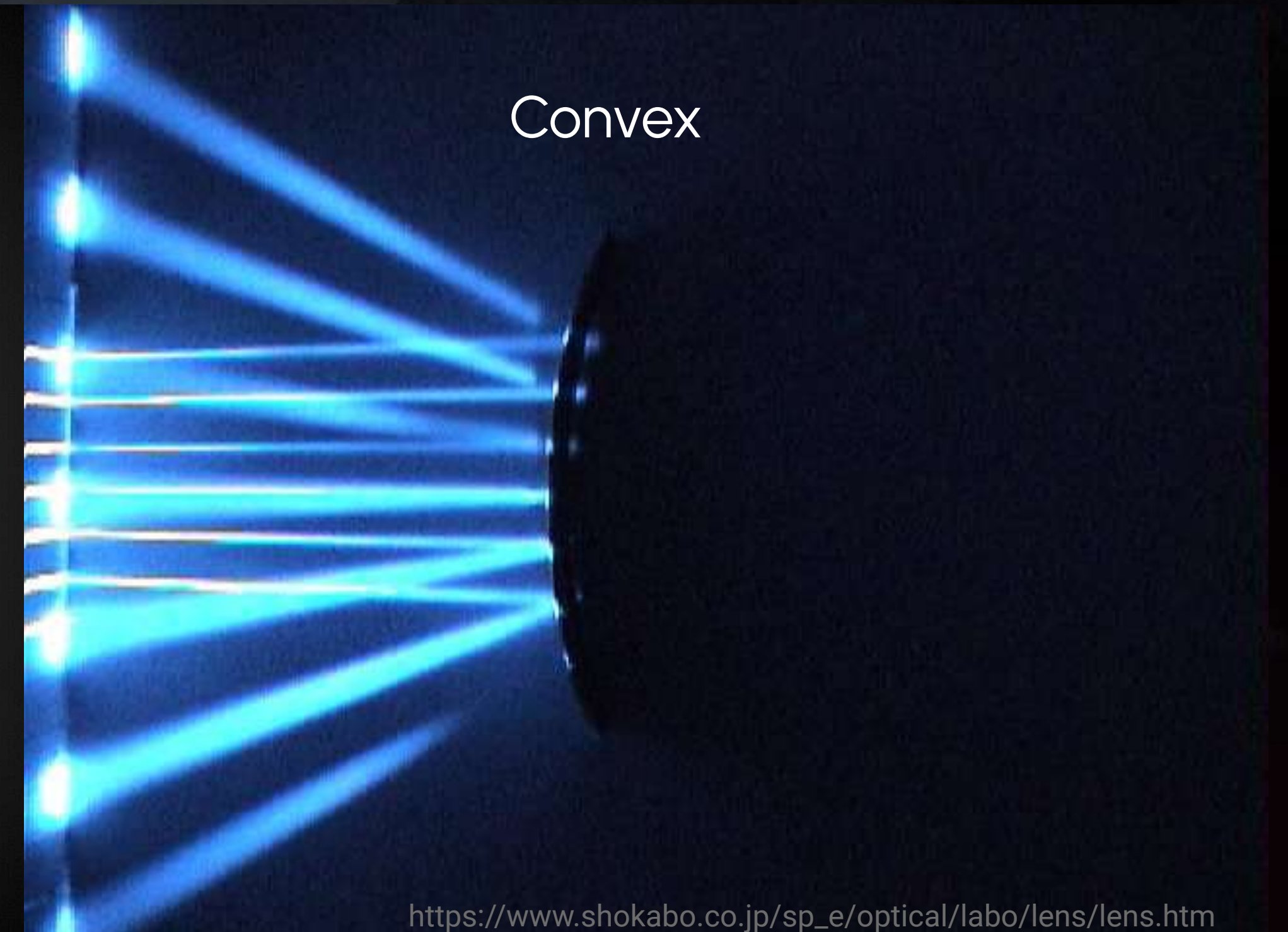
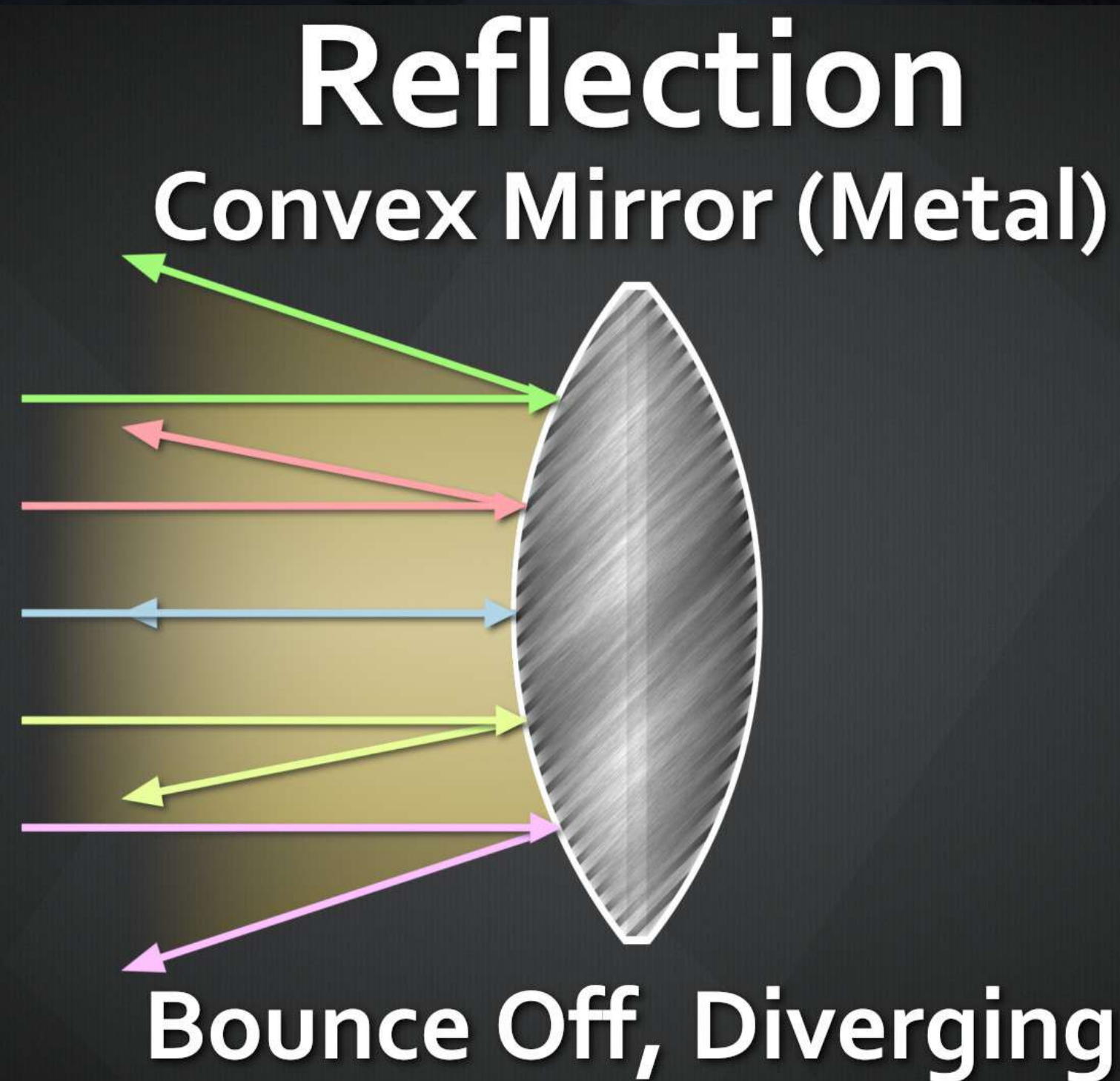
[https://www.simply.science/images/content/physics/waves\\_optics/reflection/Concept\\_map/Convexconcave\\_mirrors.html](https://www.simply.science/images/content/physics/waves_optics/reflection/Concept_map/Convexconcave_mirrors.html)

<https://wbbseolutions.guru/wbbse-solutions-for-class-10-physical-science-and-environment-chapter-5/>

# CG COMPOSITING SERIES

## Convex Reflections

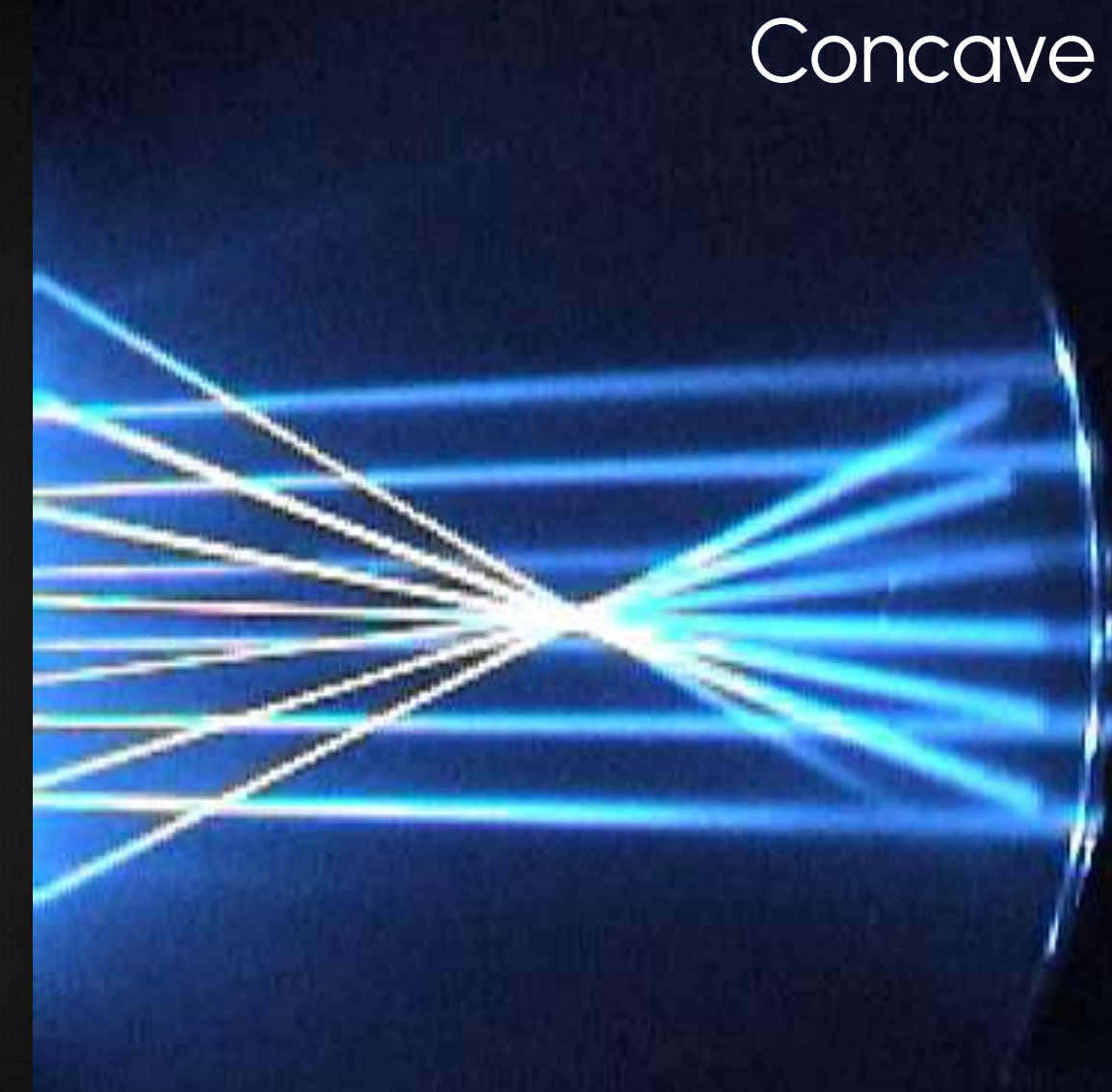
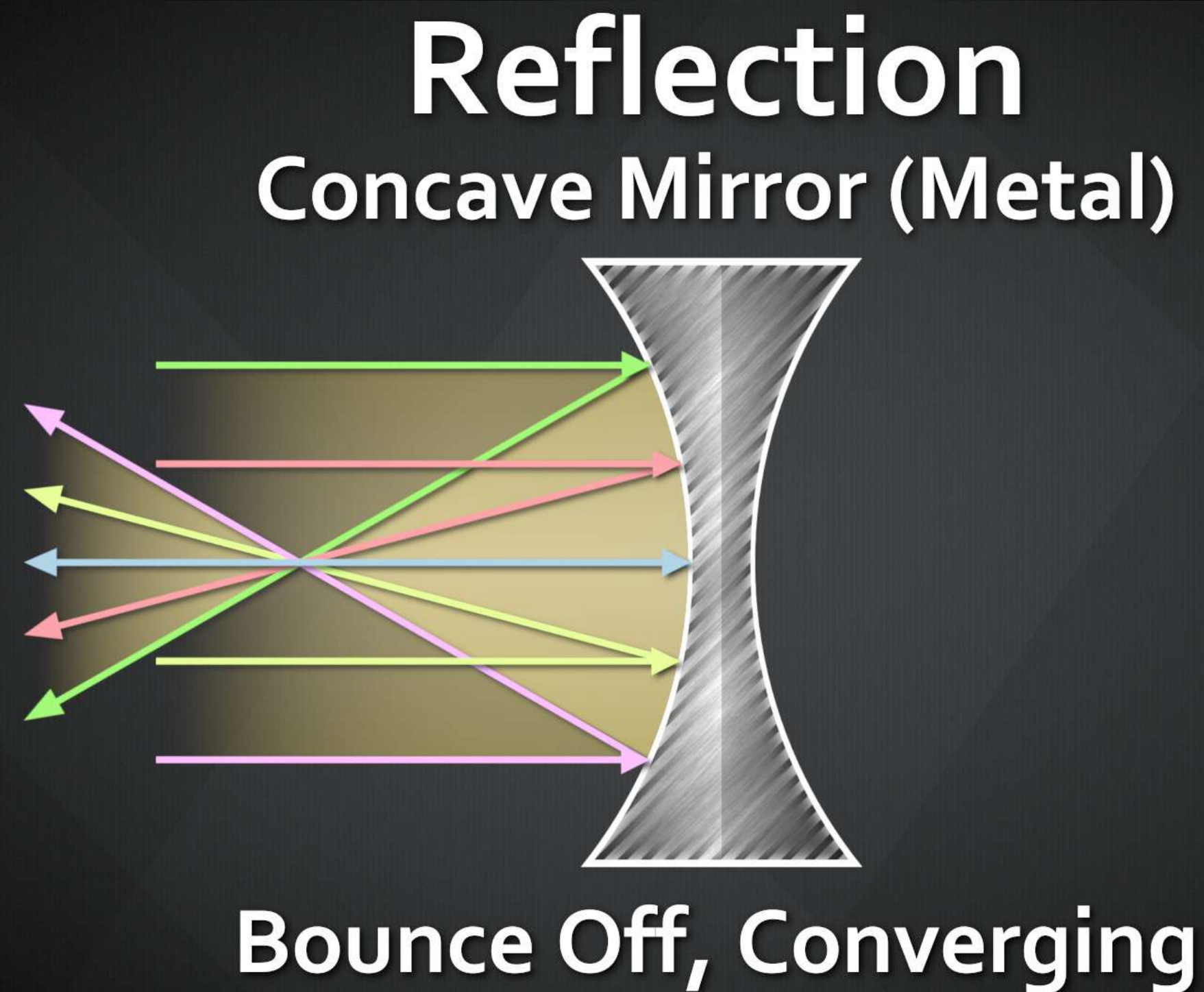
- With Reflections, light bounces off the material and, depending on the surface shape, changes direction upon reflecting
- Convex shapes cause the light to Diverge - spread apart



# CG COMPOSITING SERIES

## Concave Reflections

- With Reflections, light bounces off the material and, depending on the surface shape, changes direction upon reflecting
- Concave shapes cause the light to Converge - come together



[https://www.shokabo.co.jp/sp\\_e/optical/labo/lens/lens.htm](https://www.shokabo.co.jp/sp_e/optical/labo/lens/lens.htm)



# CG COMPOSITING SERIES

## Concave/Convex Refractions

- When looking at curved glass, or lenses, light that we are looking seeing through the glass, is a **redirected** and **distorted** view of our surrounding environment



photo by betül balcı on pexels



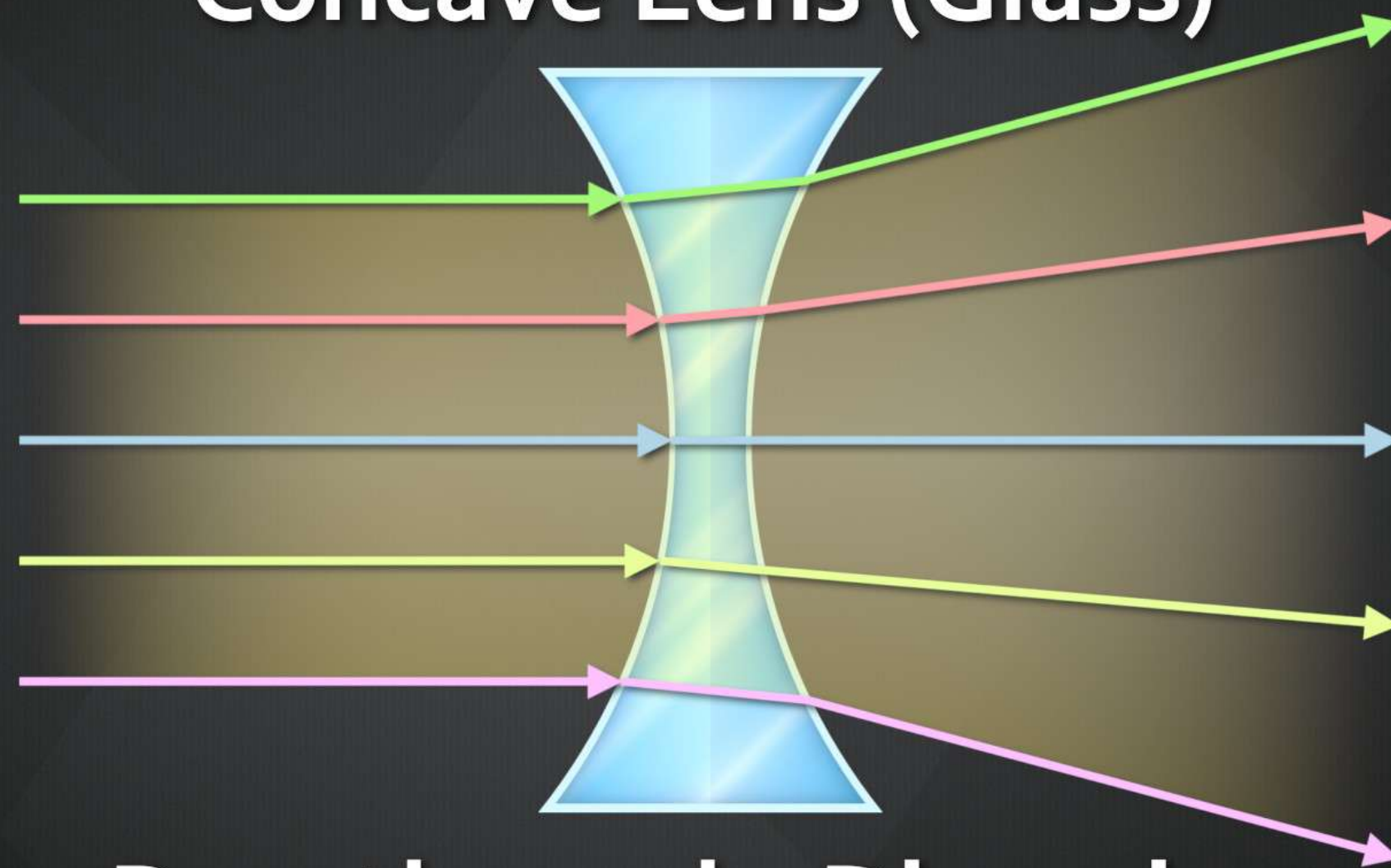
photo by shukhrat-umarov on pexels

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## Concave Refractions

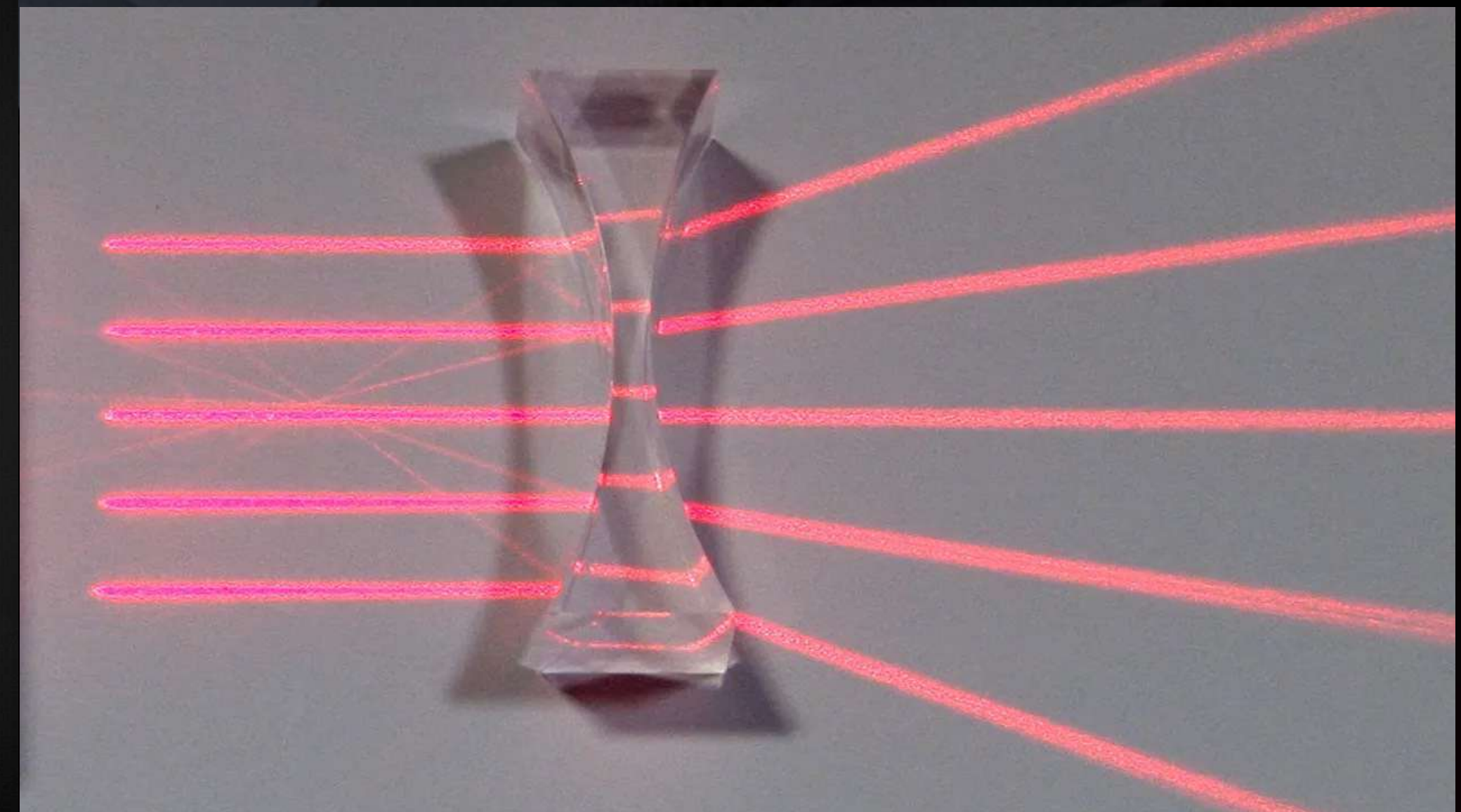
- With **Refractions**, light passing through the material and, depending on the surface shape, changes direction upon **refracting**
- **Concave** shapes cause the refracted light to **Diverge** - spread apart

### Refraction Concave Lens (Glass)



Pass through, Diverging

Concave



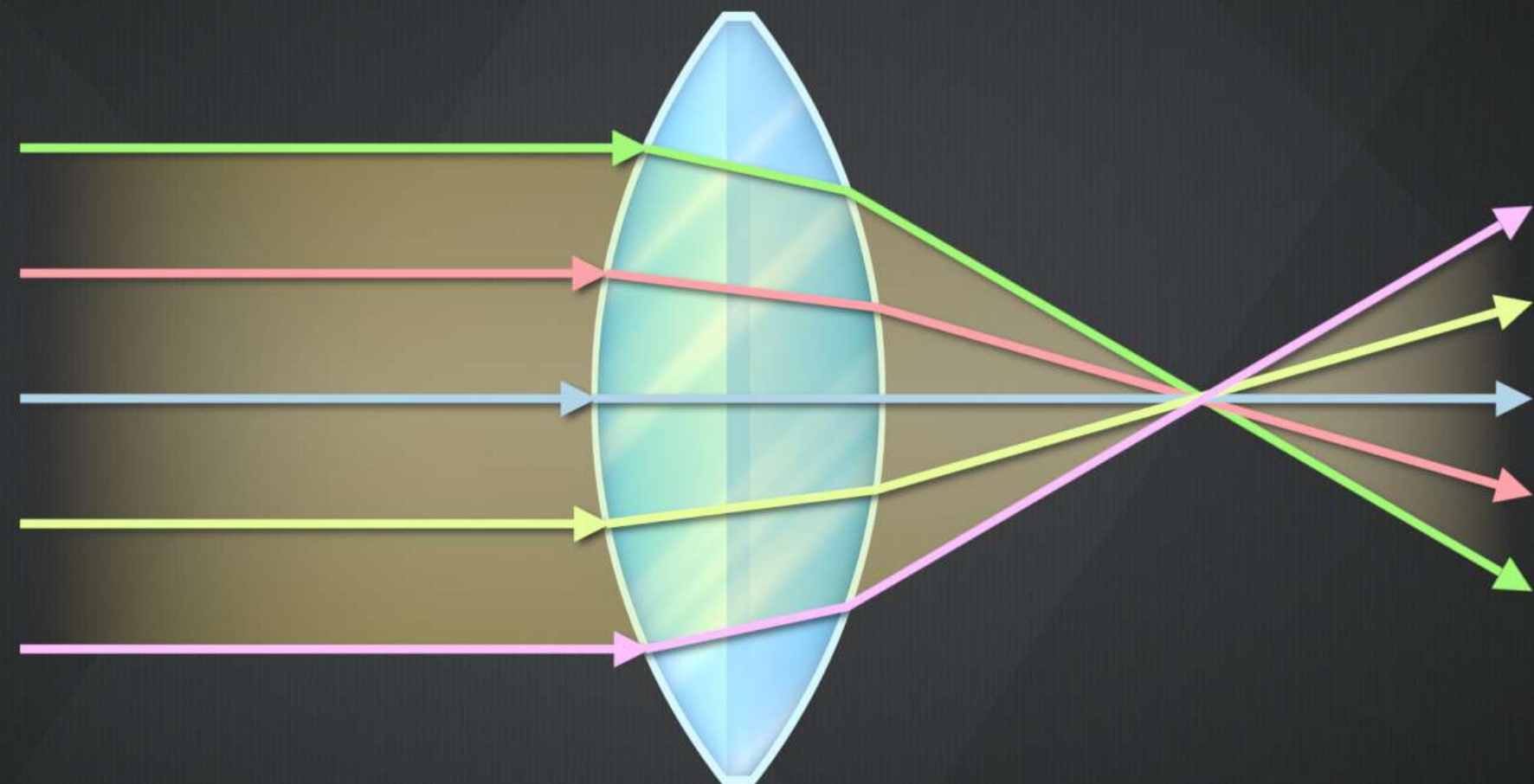
<https://www.britannica.com/technology/lens-optics>

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## Concave/Convex Refractions

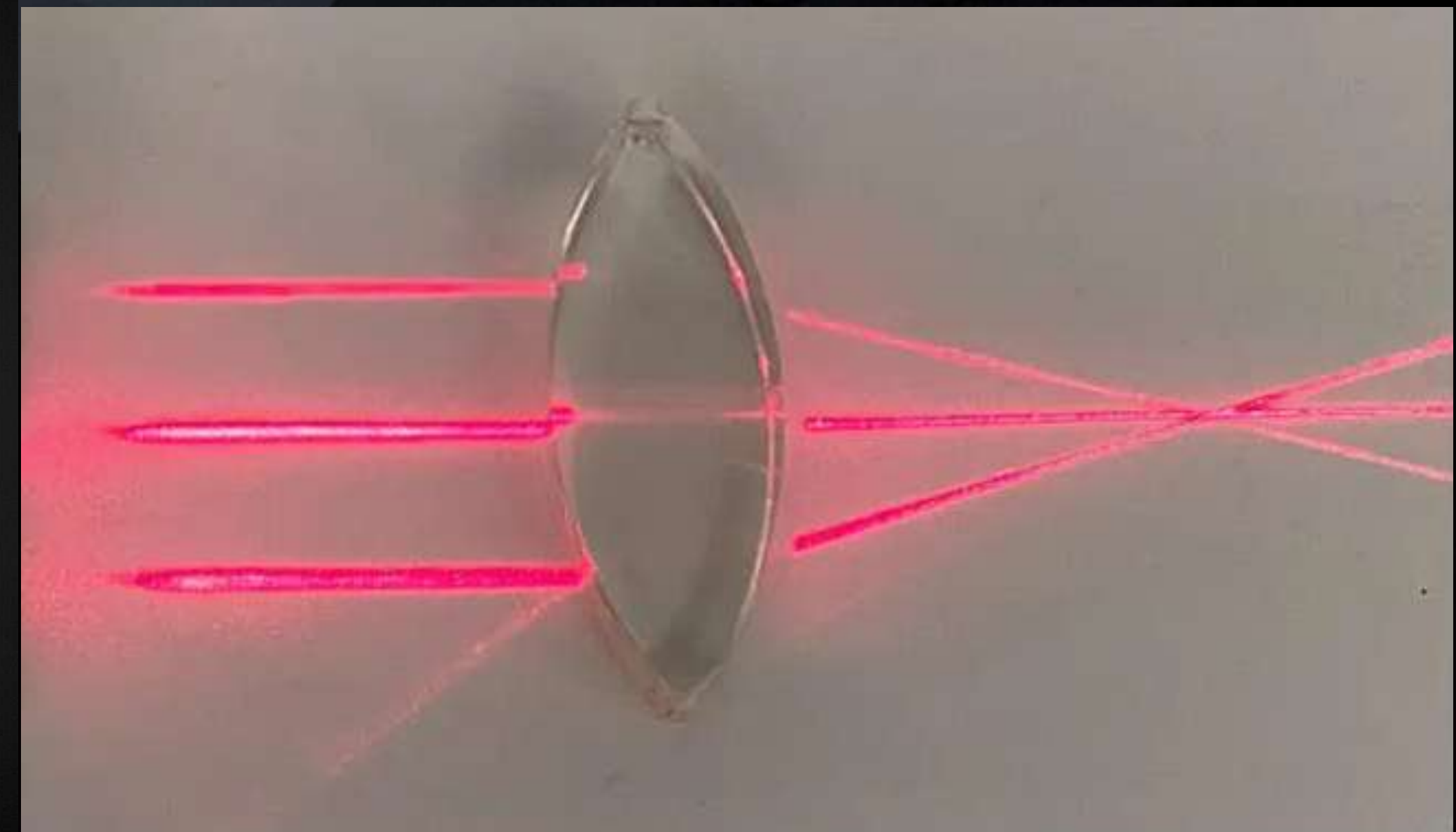
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Pass through, Converging

Convex

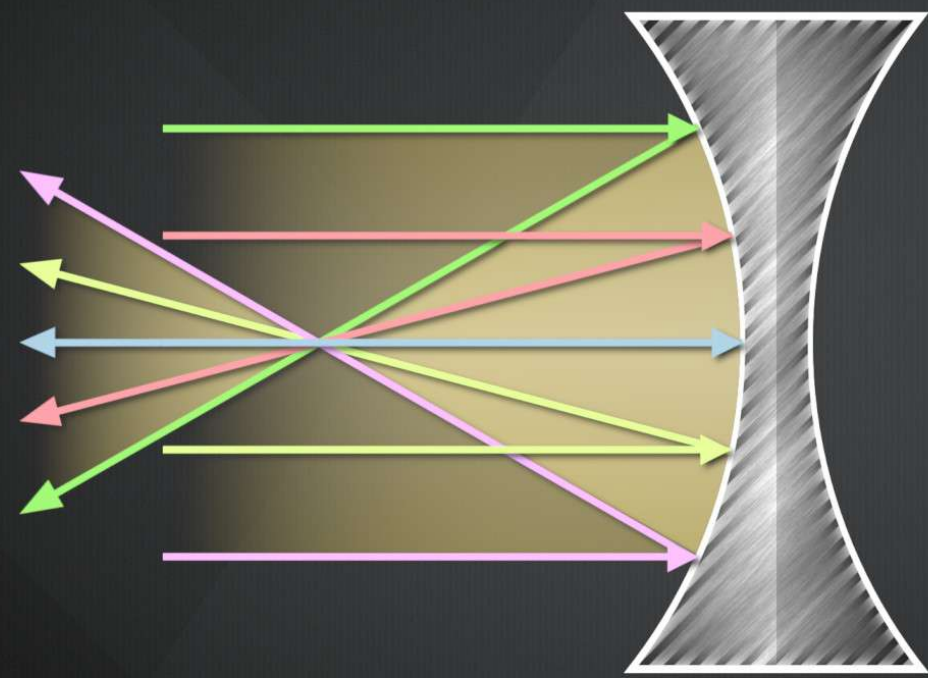


<https://www.britannica.com/technology/lens-optics>

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## Reflection

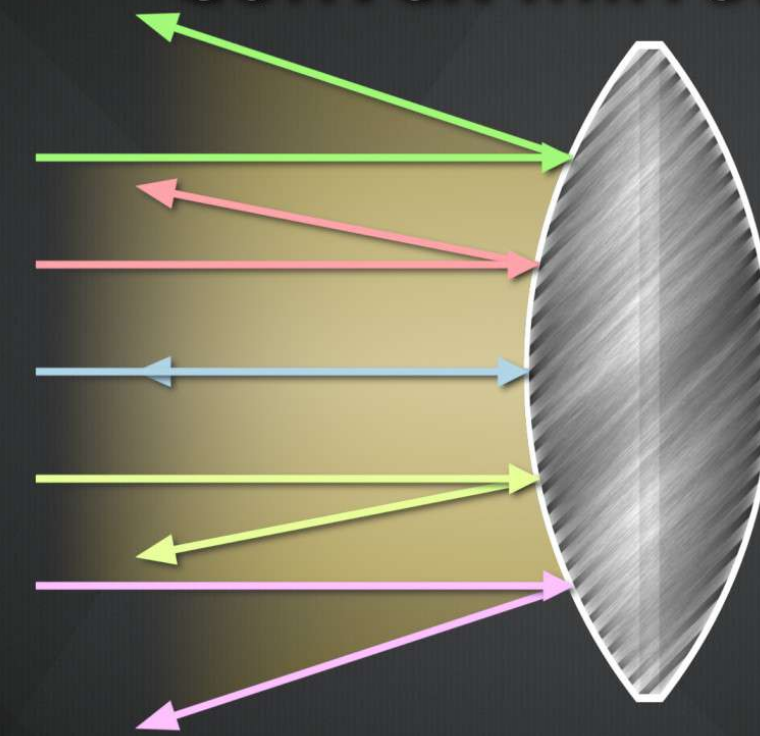
Concave Mirror (Metal)



Bounce Off, Converging

## Reflection

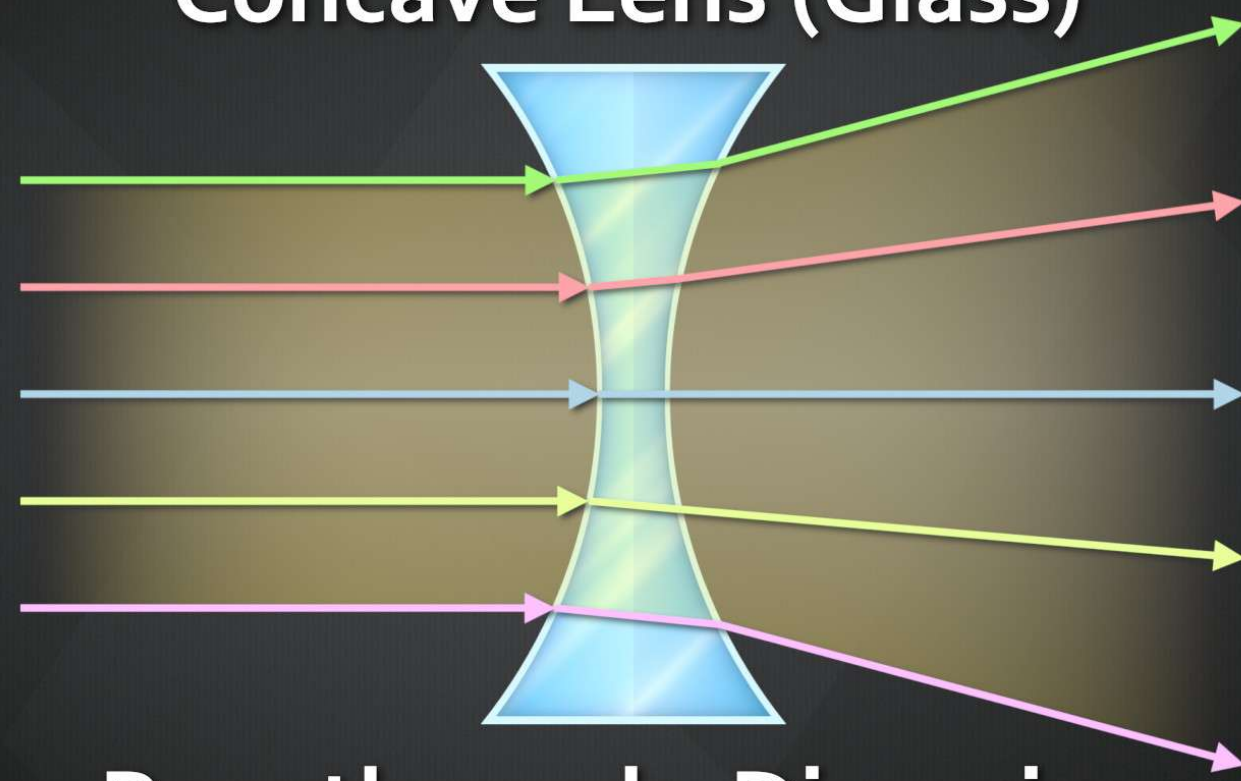
Convex Mirror (Metal)



Bounce Off, Diverging

## Refraction

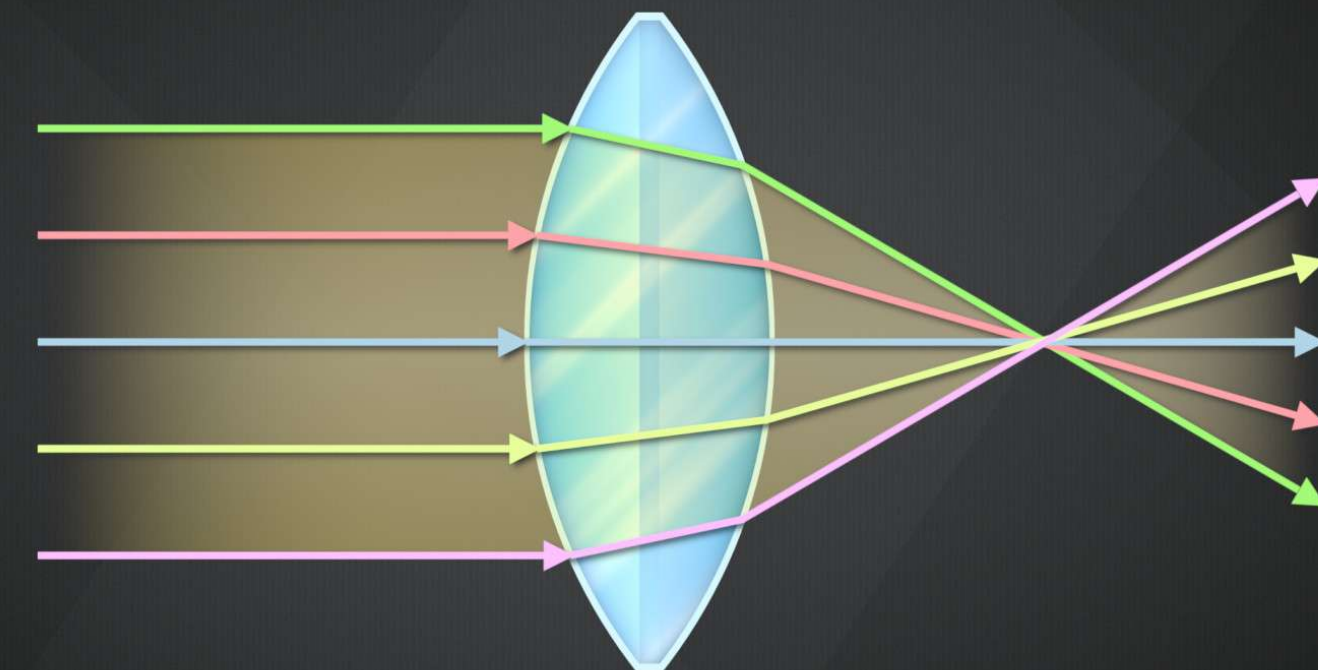
Concave Lens (Glass)



Pass through, Diverging

## Refraction

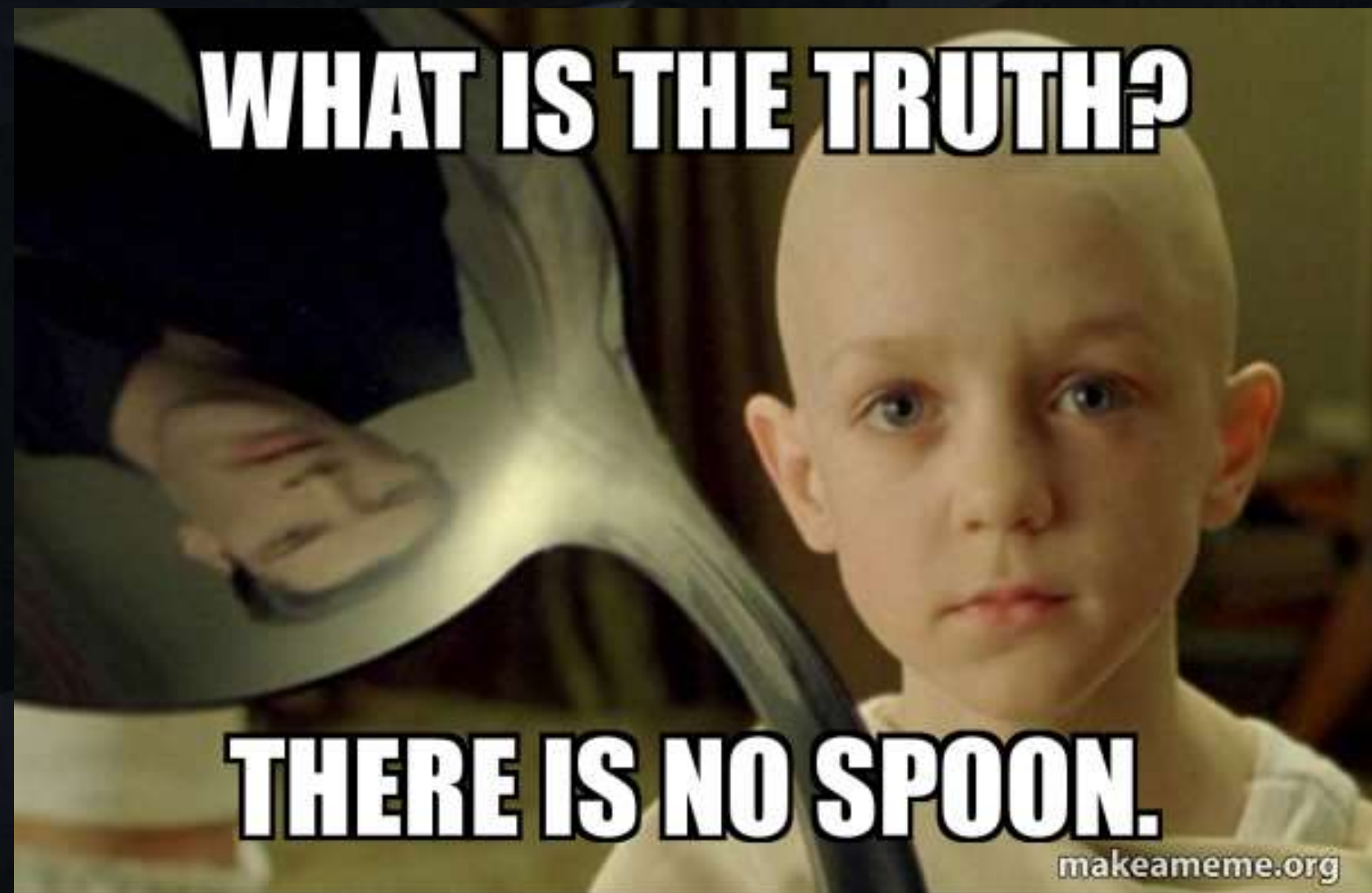
Convex Lens (Glass)



Pass through, Converging

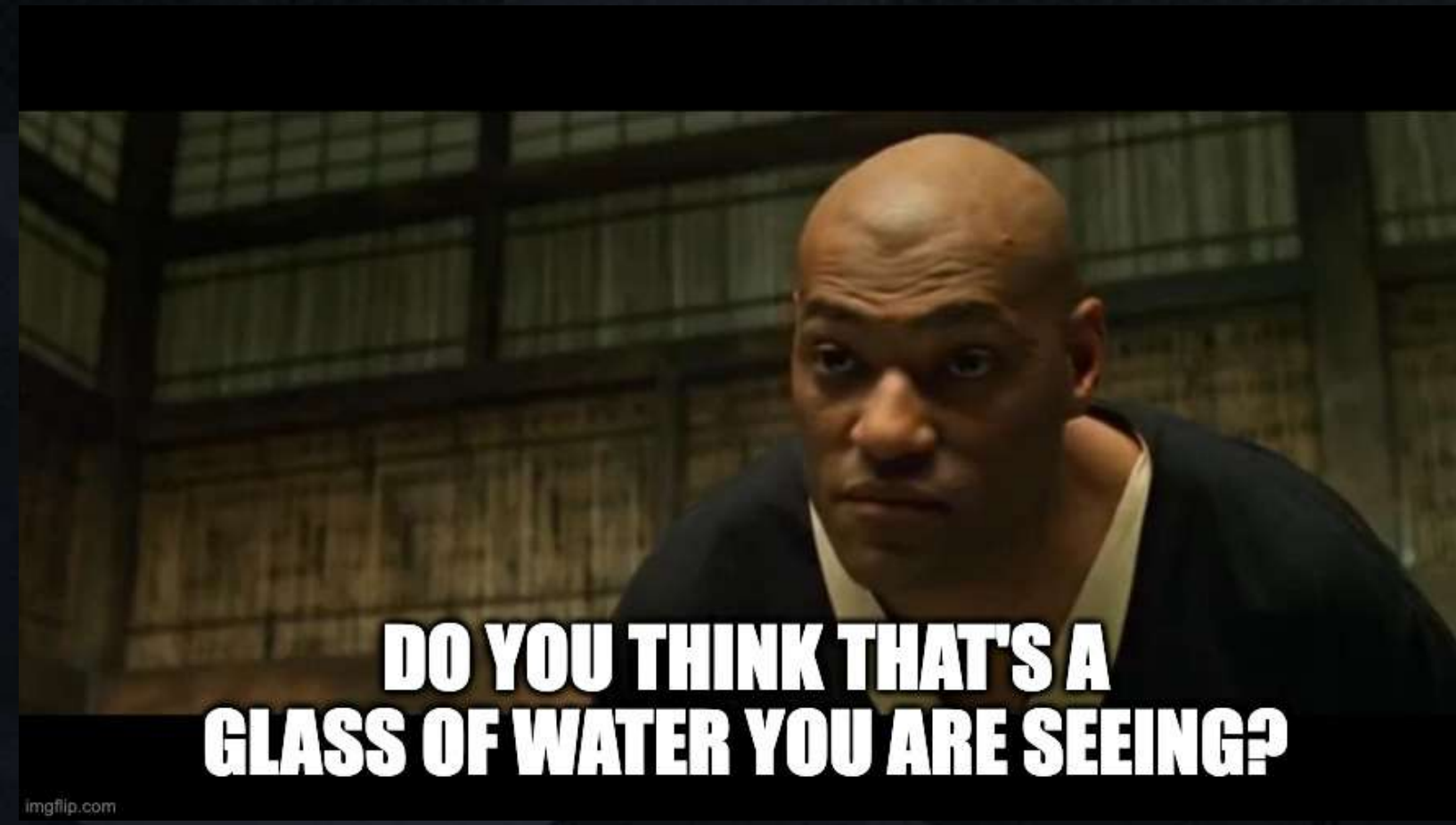
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## There is No Spoon



# CG COMPOSITING SERIES

## There is No Glass



<https://wifflegif.com/gifs/490974-pouring-water-reverses-arrow-gif>



<https://www.cleverpatch.com.au/ideas/by-product-type/paper-and-card/refraction-in-action>

# CG COMPOSITING SERIES

Diffuse - Specular - Transmission

Diffuse - All Light Interaction with Material / Object

Specular - All Surface Reflections

Transmission - All Pass through Refractions

# CG COMPOSITING SERIES

## Diffuse - Specular - Transmission

### Diffuse

Light Interacting with  
the Material

Direct - 1st bounce

Indirect - 2nd bounce  
and beyond

Albedo - Color /  
Texture map

### Specular

All Light Reflecting  
off the Surface

\*more common

Direct - 1st bounce

Indirect - 2nd bounce  
and beyond

Albedo - Filter /  
"How Much"

### Transmission

All Light Passing  
through Materials

Direct - 1st pass through

Indirect - 2nd pass  
through and beyond

Albedo - Filter /  
"How Much"



# CG COMPOSITING SERIES

## Separation of AOV Passes



Normal Material

Diffuse Pass

Specular Pass



Metallic / Reflective Material

Light Bounces off

Specular Pass



Transmissive /  
Refractive Material

Light Passes Through

Transmission / Refraction Pass

Light Bounces off

Specular Pass



# CG COMPOSITING SERIES

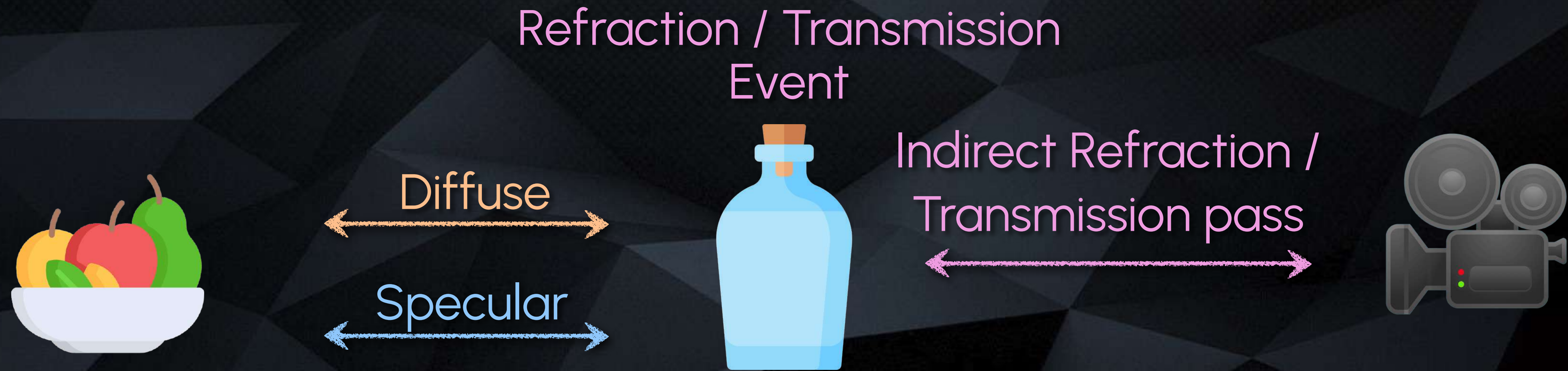
## Reflection Events



Creates a Virtual Image. What you are looking at is not really there.

# CG COMPOSITING SERIES

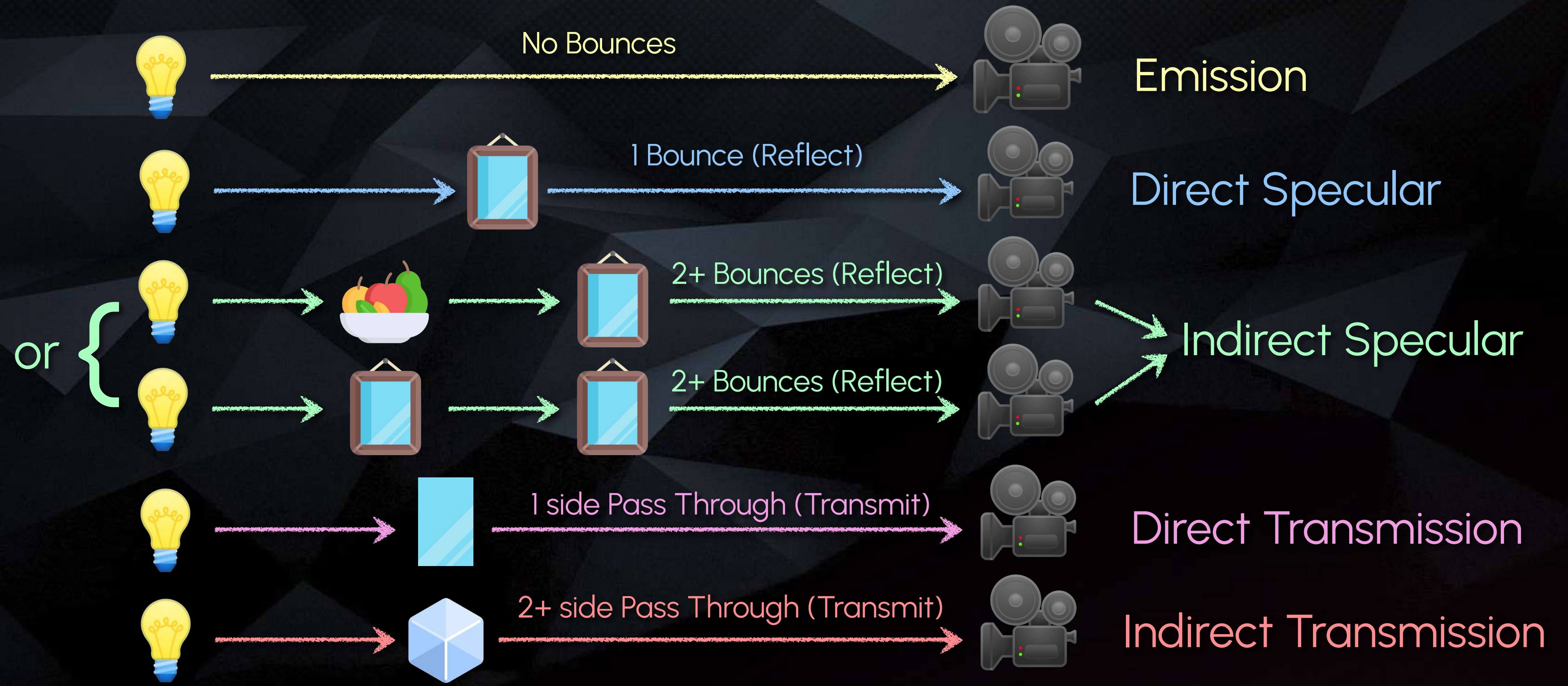
## Refraction / Transmission Events



Creates a Virtual Image. What you are looking at is not really there.

# CG COMPOSITING SERIES

Number of Light Path "Events" = Different Passes



# CG COMPOSITING SERIES

## Recap

- **Transmission** - Light passes through
- **Refraction** - Light redirects.
- The CG pass could be named either or but is often referring to the same phenomenon.
- **Specular** and **Transmission** are both similar in that they are capturing light redirecting and showing a virtual image of the distorted surroundings

- **Emission** is the light source
- **Diffuse** describes the object itself
- **Specular Events** captures light bouncing off the object's surface
- **Transmission Events** capture light passing through an object.
- These all get separated into their own categories.

# CG COMPOSITING SERIES

## Recap

- Both **Specular** and **Transmission** have:
- A **Direct** pass that show the first **reflection** or first **transmission** of light
- An **Indirect** pass showing all subsequent **bounces** or **pass throughs**
- An Albedo Filter (mask)
  
- **Transmissive** surfaces like glass are often modelled with 2 sides
- Therefore the light usually passes through 2+ sides and ends up in the **indirect** pass, and the **direct Transmission** shows up empty
- Often rendered as just an overall combined **Transmission** pass, for convenience.

# LIGHTING CONCEPTS: Planar Mirror and Virtual Image



Photo by Max Avans from Pexels:  
<https://www.pexels.com/photo/glass-pyramids-in-louvre-museum-5088287/>



Photo by Rachel Claire from Pexels:  
<https://www.pexels.com/photo/reflection-of-a-woman-in-white-dress-on-the-pool-water-5531606/>

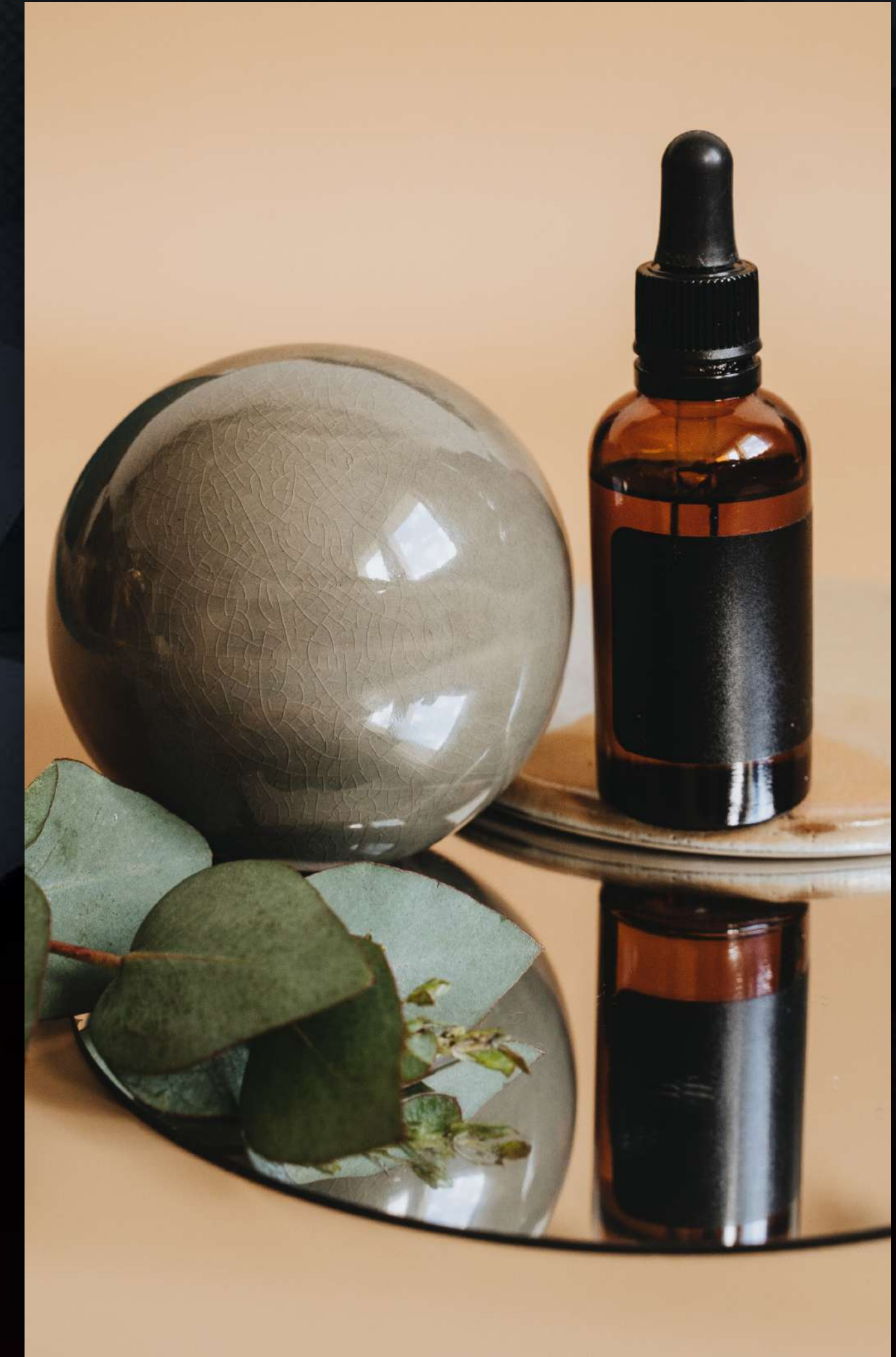
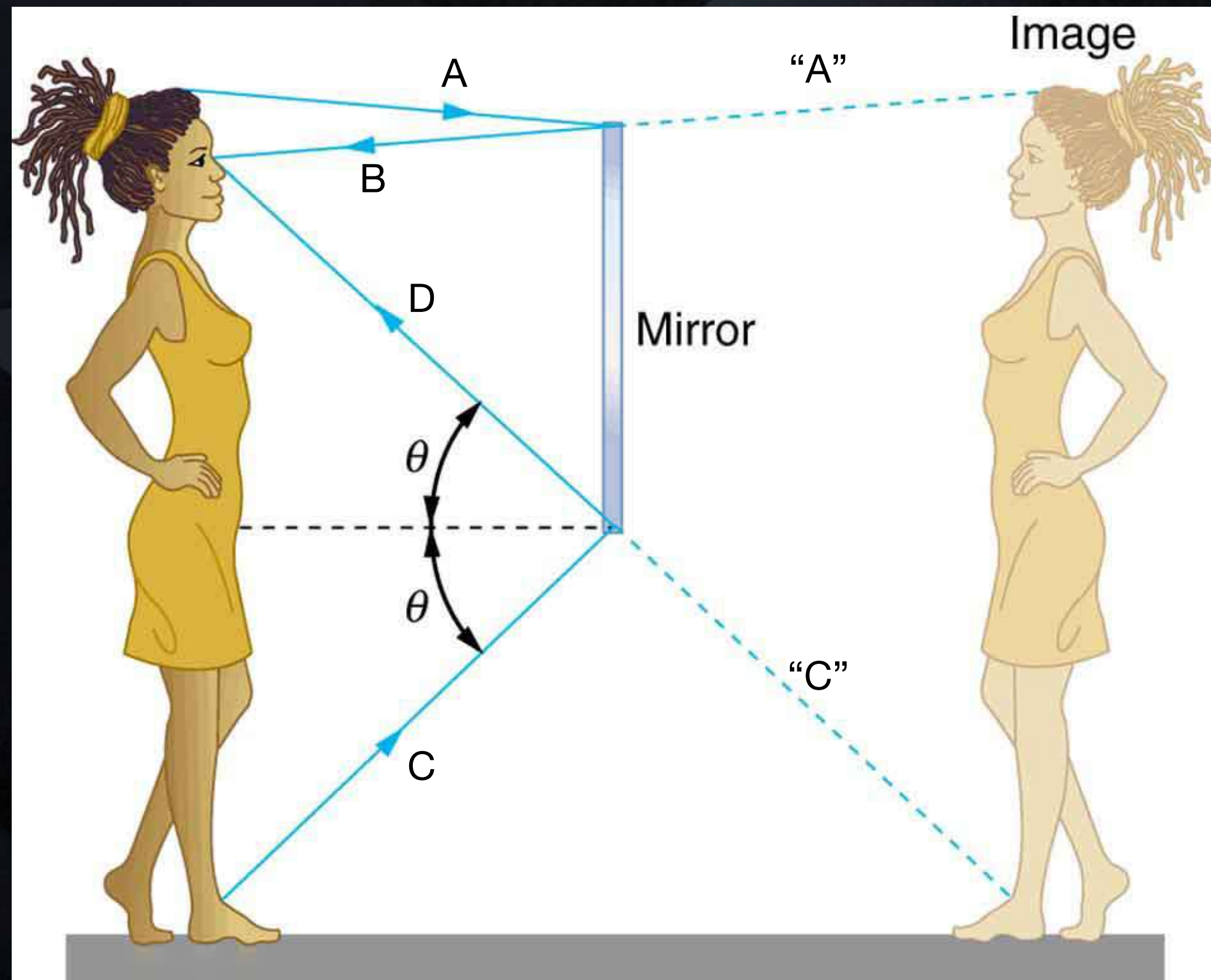


Photo by Alesia Kozik from Pexels:  
<https://www.pexels.com/photo/colored-glass-bottle-on-round-mirror-7796810/>

# LIGHTING CONCEPTS:

## Planar Mirror and Virtual Image

- An Image created by planar specular reflection that does not actually exist as a physical object is referred to as a Virtual Image.
- The Virtual Image appears to be located “behind” the mirror
- Virtual Image distance = Object to Mirror + Mirror to Observer.
- **Speculum** is the Latin word for “mirror”, which is where “**Specular**” derives from



<https://pressbooks.bccampus.ca/introductorygeneralphysics2phys1207/chapter/25-2-the-law-of-reflection/>



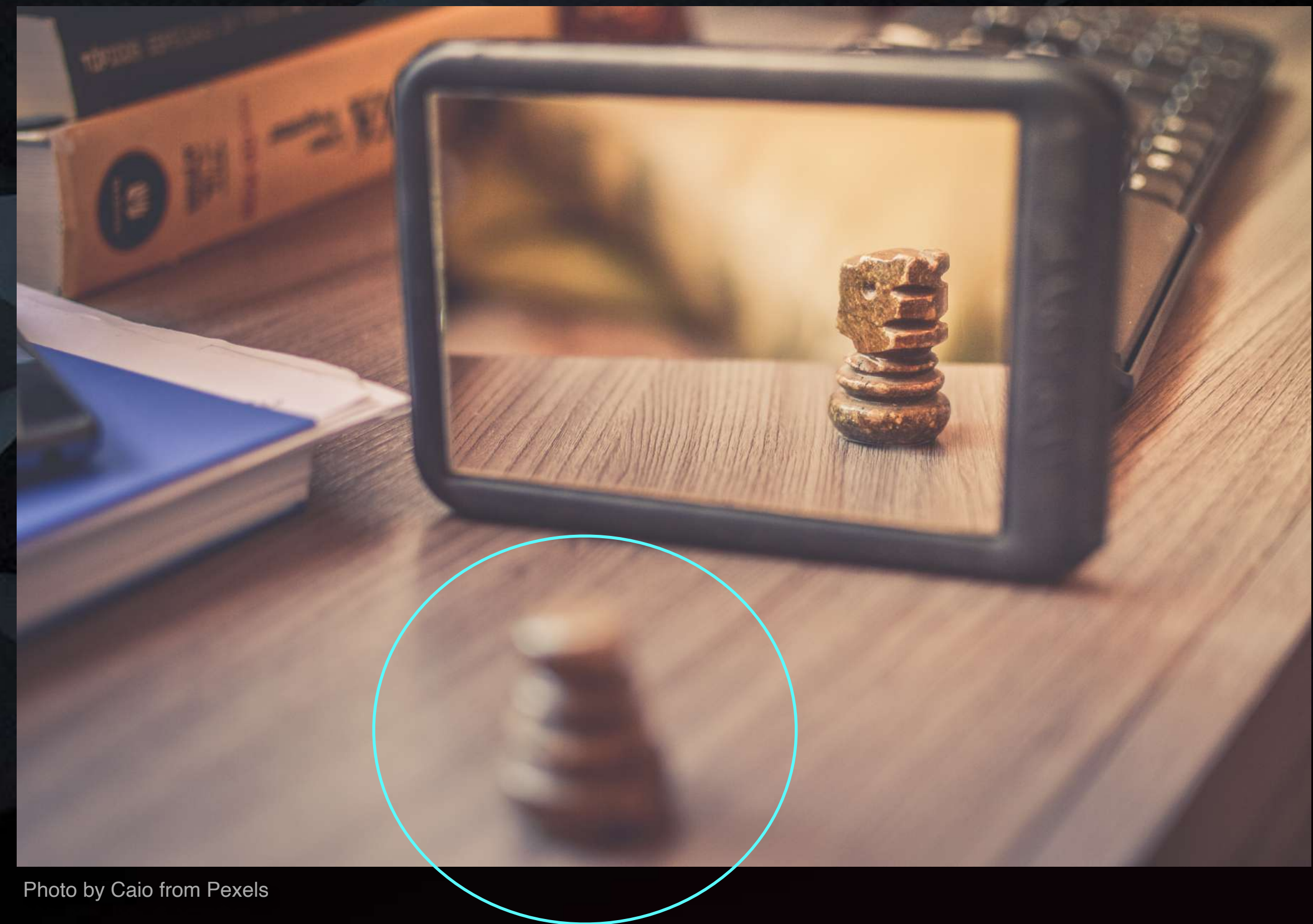
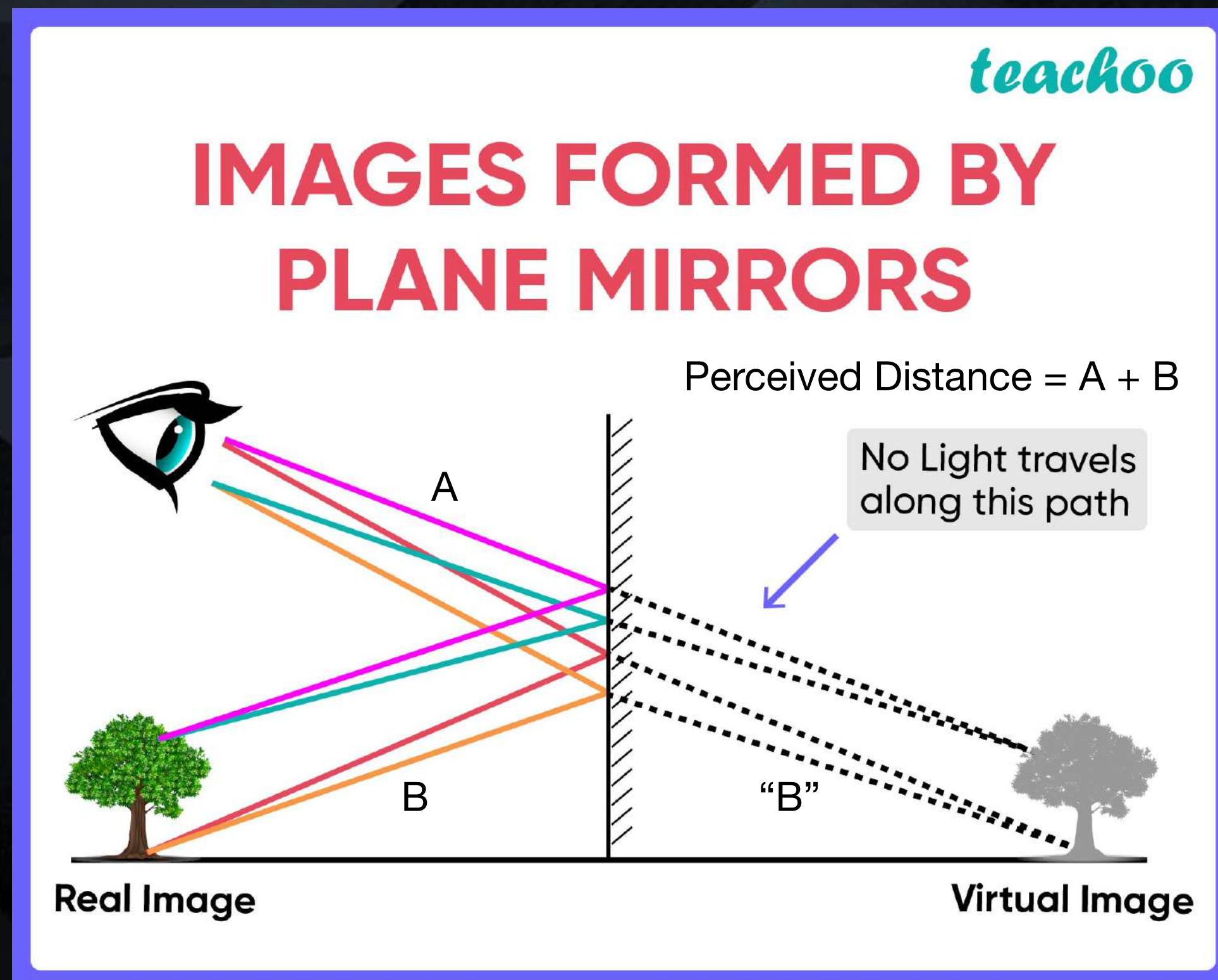
Photo by Lucas Pezeta from Pexels



# LIGHTING CONCEPTS:

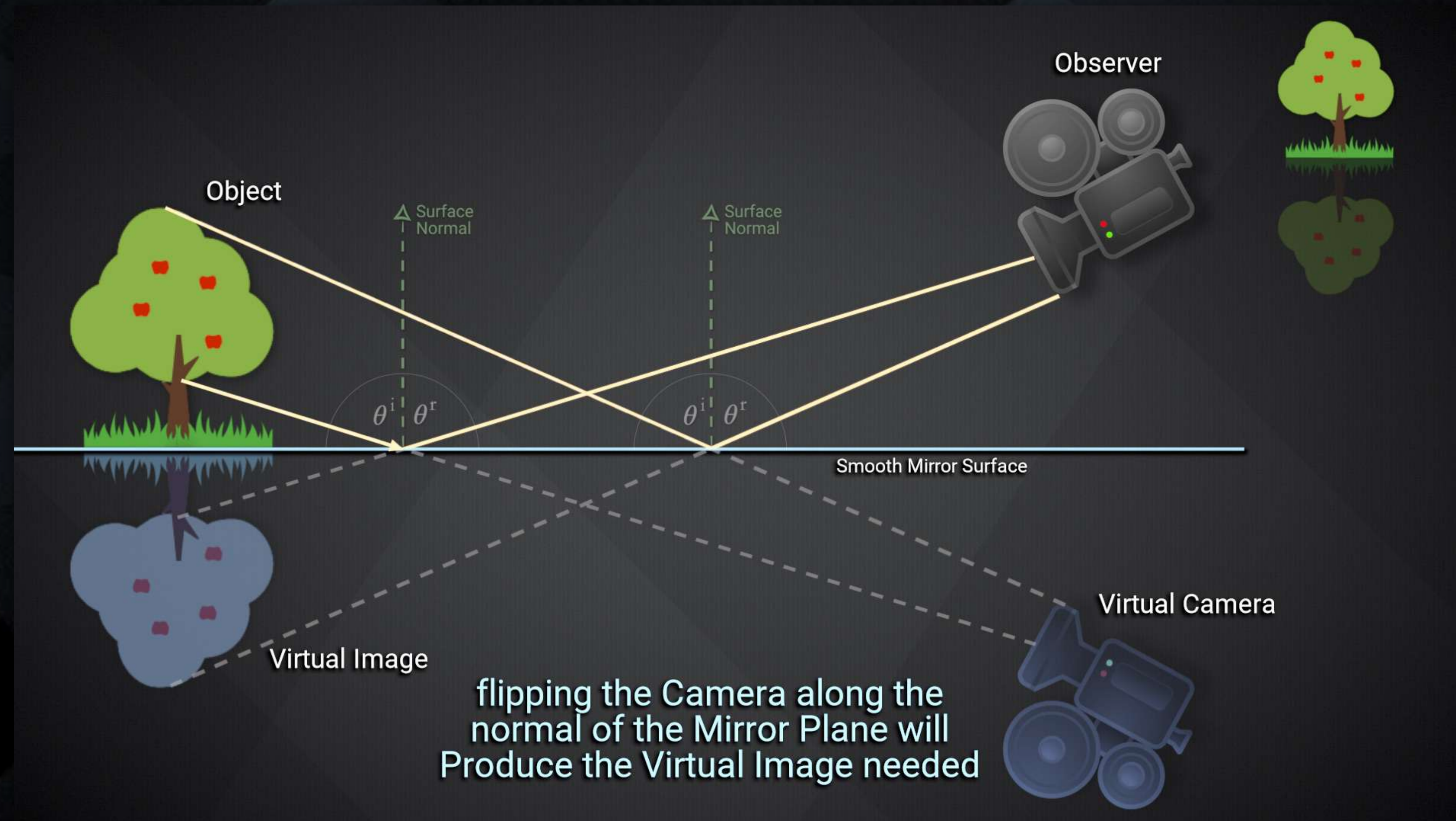
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# LIGHTING CONCEPTS: Planar Mirror and Virtual Image

- Flipping the Camera along the normal of the Mirror Plane will produce a Virtual camera for you to render the Mirrored Virtual Image from the right perspective



# CG COMPOSITING SERIES

## How Renderer Handles Events

