Making Sense of Attenuation of Light Through a Medium

Start with the definitions:

Transmission

The **process** of light passing through a medium

Transmittance (T_λ)

The **percentage** of light transmitted for a given wavelength.

The percentage of incident light transmitted.

Absorption

The **process** of light being absorbed by a medium.

Absorptance (α_λ)

The **percentage** of light absorbed by a medium.

The percentage of incident light absorbed.

The whole story: $T_\lambda + \alpha_\lambda + r_\lambda = 1$

Transmittance + Absorptance + Reflection* = 1

*In this module we are considering reflection to be insignificant.

Therefore, the relationship we will consider is: **$T + \alpha = 1$**

Transmittance Through Multiple Filters

When light is transmitted by more than one filter, the total transmission of the system is the product of the individual filters.

$T_{total} = T_1 \times T_2 \times T_3$

Example:
What is the total transmission of light through a series of two filter with each having a Transmittance of 50%:

$T_{total} = T_1 \times T_2$

$T_{total} = (0.50)(0.50)$

T_{total} = 0.25 or 25%

What is the absorptance for this system of filters:

$\alpha = 1 - T$

$\alpha = 1 - 0.25$

α = 0.75 or 75%

Absorbance (A)

A measure of the light-blocking ability of a material.

A = -logT* *base 10 logarithm

What is the absorbance of one of the filters in the previous example:

T = 0.50

A = -log(0.50) or log(1/0.50) or log (2.0)

A = -(-0.301)

A = 0.301

Note: absorbance can be greater than 1

Absorbance Problems

Example: given the Transmittance, find the Absorbance.

What is the absorptance and absorbance of a filter with a transmittance of 25%:

Find Absorptance (α)

$\alpha = 1 - T$

$\alpha = 1 - 0.25$

α = **0.75**

Find Absorbance (A)

A = -logT

A = log(1/T)

A = log(1/0.25)

A = 0.602

Example: given Absorbance, find Transmission and Absorptance.
What is the transmission of a medium with an absorbance of 1.5:

Find Transmission (T)
$A = -\log(T)$
$10^{-A} = T$
$10^{-1.5} = T$
$10^{-1.5} = 0.176$
OR $\log(1.5) =$ **0.176**

Find Absorptance (α)
$\alpha = 1 - T$
$\alpha = 1 - 0.176$
α = 0.824

Example: given Absorptance, find Transmission.
What is the transmission of a lens that has an absorptance of 0.40:
$T = 1 - \alpha$
$T = 1 - 0.40$
T = 0.60 or 60%

Optical Density
Although Absorbance and Optical Density are used interchangeably, Optical Density considers the effect of scattering while Absorbance does not. The formula is the same for both.
The Effect of Changing the Thickness of a Material

Transmittance is multiplicative: $T_{total} = T1 \times T2 \times T3$
Transmittance is exponentially related to change in thickness
Absorbance is additive: $A_{total} = A1 + A2 + A3$
Absorbance is linearly related to change in thickness

Example: given absorptance, find transmittance if lens thickness is doubled.
Your patient has a plano sunglass lenses that are 1.0mm thick. Concerned about safety, you decide to remake the lenses with a thickness of 2.0mm. You measure the absorptance of the original lenses to be 45%. What is the transmittance of the new lenses:

Find Transmittance (T) of original lenses (1.0mm thickness)

$T = 1 - \alpha$

$T = 1 – 0.45$

$T = 0.55$

Find Transmittance (T) for new lenses (2.0mm thickness)

The transmittance increases exponentially.

$T_{2.0mm} = T^2_{1.0mm}$

$T_2 = (0.55)^2$

$T_2 = 0.30$

What is the Absorbance of the new lenses

$A = -\log(T)$

$A = \log(1/0.30)$

$A = 0.52$

Does this support the linear relationship between thickness and Absorbance

Original A

$A = -\log(T)$

$A = \log(1/0.55)$

$A = 0.26$

Yes, the absorbance at 2mm is twice that at 1mm

Selective Transmission & Absorption

Neutral Density Filters

Gray in color

Even transmission across the visible spectrum.

Colored Filters

Any color other than gray

Color is from wavelengths of light with highest transmission.

Selective transmission.

Opaque Materials

Opaque materials reflect selected wavelengths and absorb all other wavelengths.

The color of the material is the wavelengths with the highest reflectance.

A black material absorbs all the visible wavelengths equally.

Scatter
Scatter can be selective or nonselective.
Classification depends on particle size.

Mie Scatter
Scatter from a particle that is larger than the wavelength of light.
Example: clouds

Rayleigh Scatter
Scatter from a particle that is smaller than the wavelength of light.
Example: blue sky

Tyndall Scatter
Scatter from a particle that has similar size to the wavelength of light.

Translucent
A material that scatters transmitted light.