SC 332 Lecture 3

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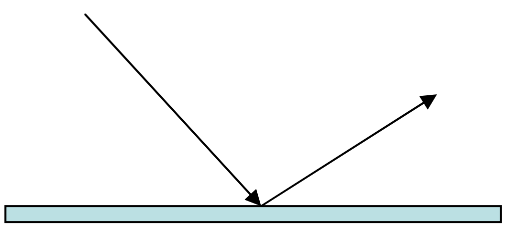
FIT Fall 2006

Today’s topics

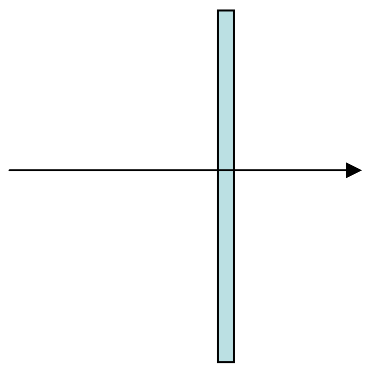
- Interaction of Light and Matter
- Exponents
- Beer’s Law
  - Filters
  - Dye Solutions

When Light Hits an Object

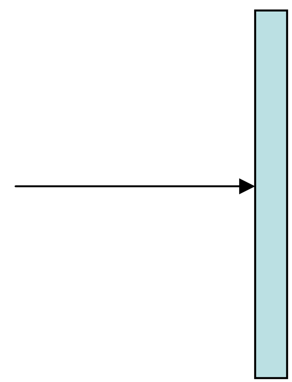
- Photons incident on an object are
  - Reflected %R
  - Transmitted %T
  - Absorbed %a



Reflection



Transmission



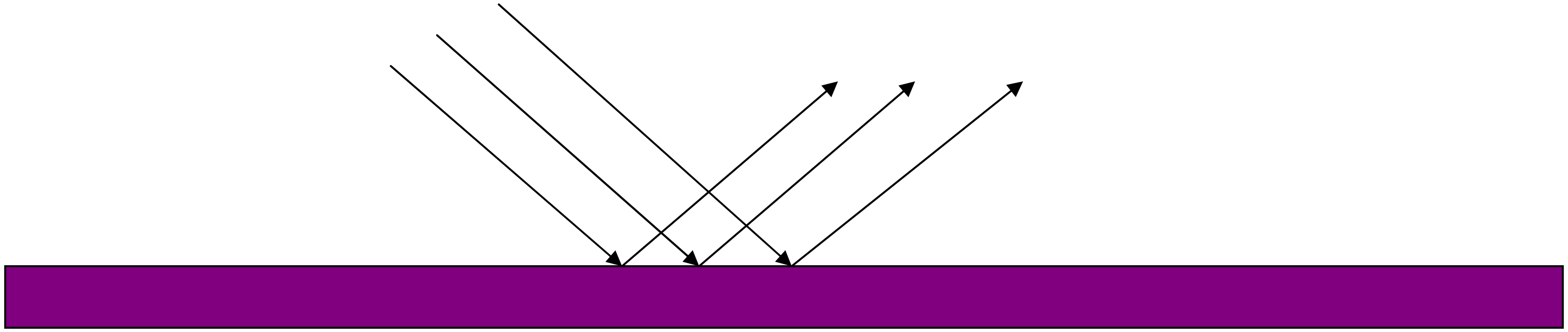
Does not pass through

Absorption

$$\%R + \%T + \%a = 100$$

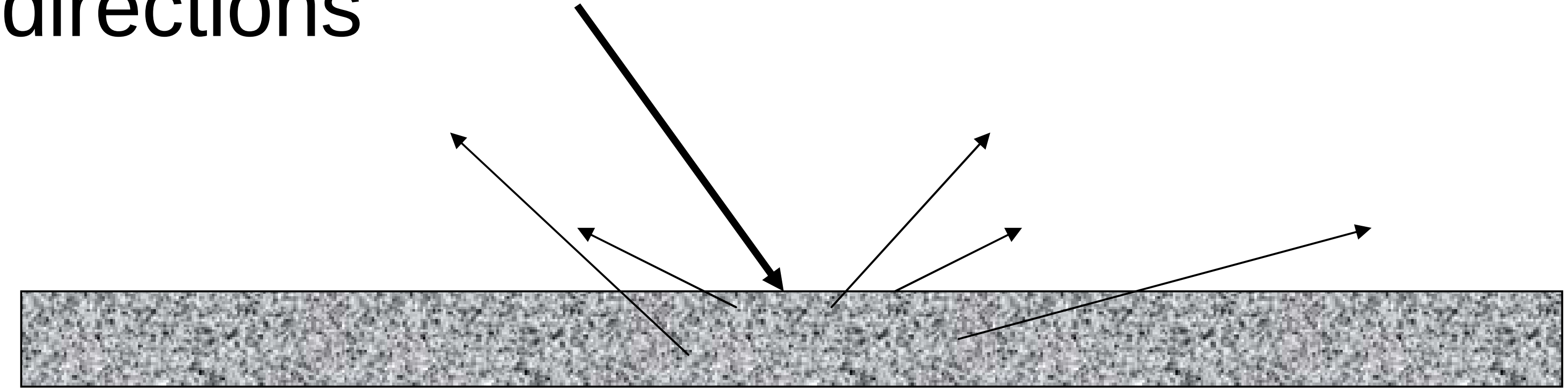
Specular Reflection

- Surface is smooth, glossy, shiny, has highlights
- Reflection can be made out clearly
- Rays stay “organized”



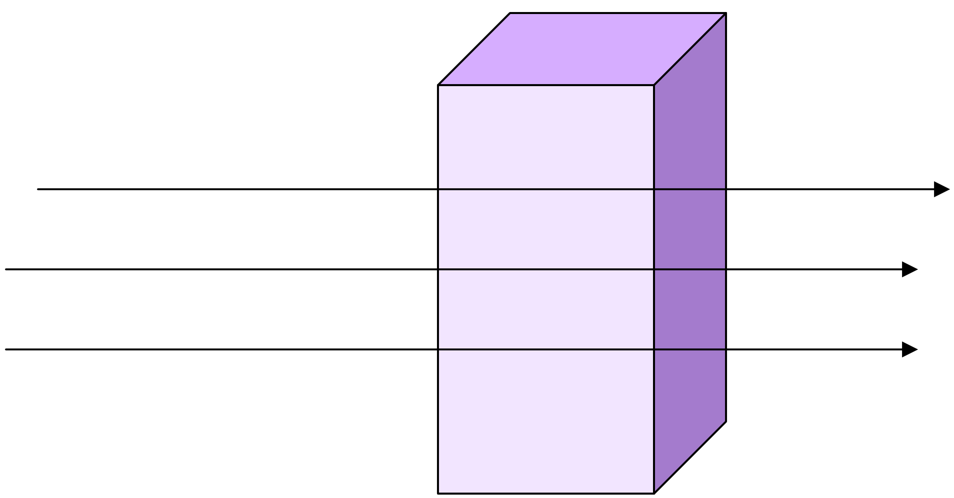
Diffuse Reflection

- Surface is rough, matte, dull, has no highlights
- Reflection can not be easily made out
- Rays are scattered in many different directions



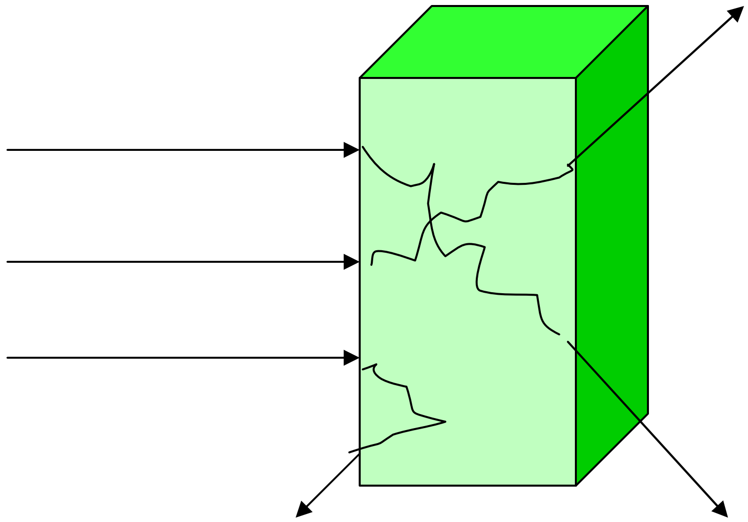
Specular Transmission

- Rays stay “organized” and pass straight through
- Can see clearly through it



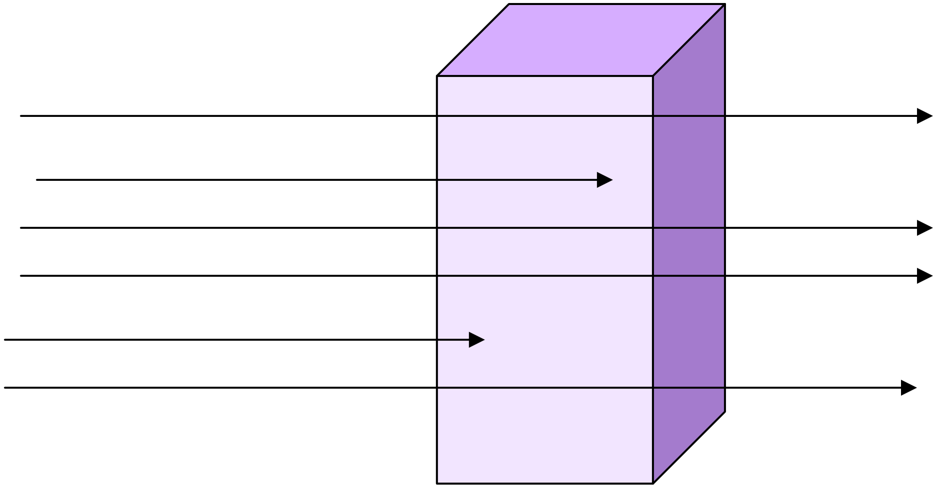
Diffuse Transmission

- Rays scattered in different directions
- Cannot see clearly through it



Transparent Object

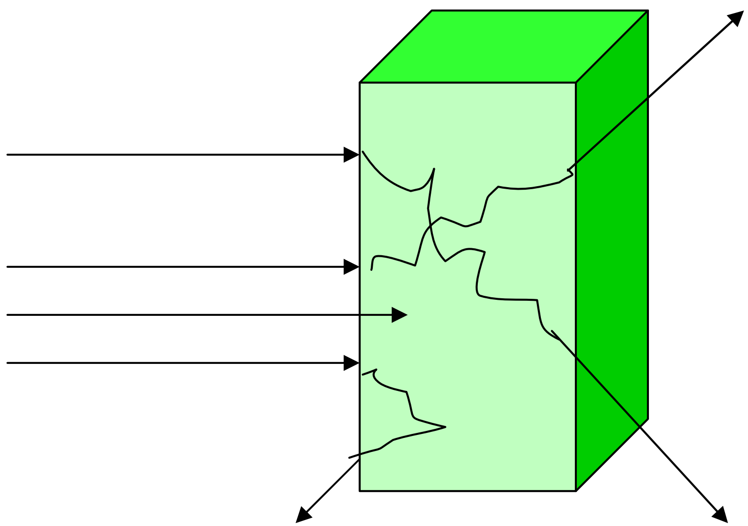
- Light is transmitted specularly or absorbed
- Absorbed light determines color
- Examples: Sunglasses, cellophane, clear window, food dye



$$\%T + \%a = 100$$

Translucent Object

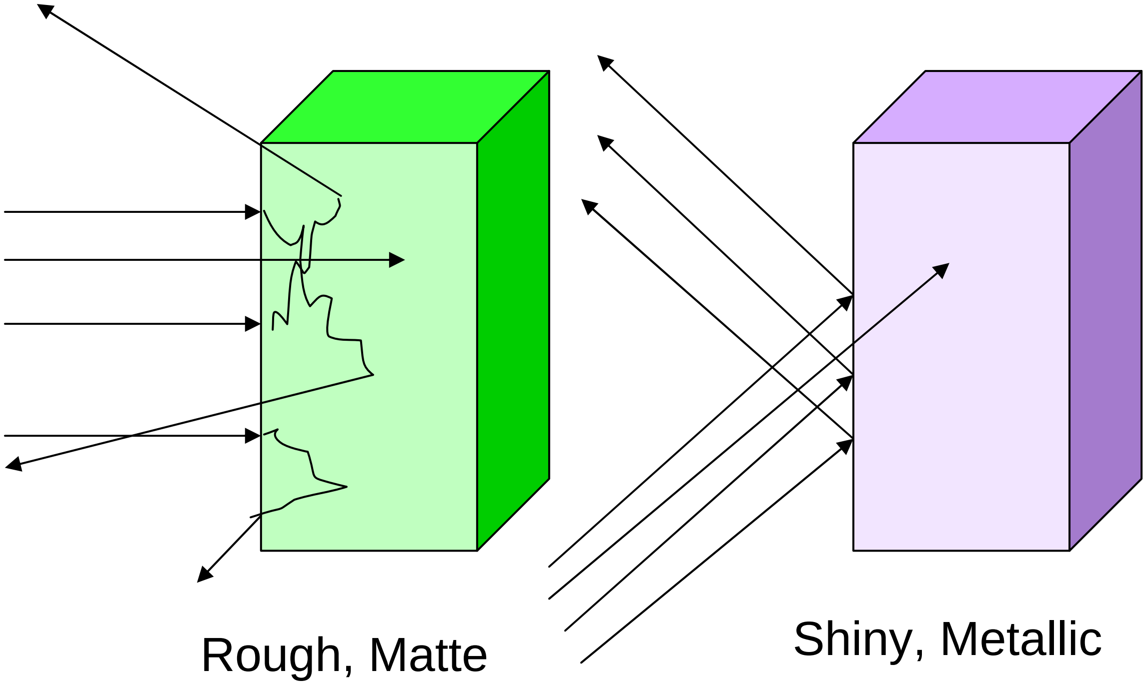
- Light is transmitted diffusely or absorbed
- Absorbed light determines color
- Examples: Frosted glass, shower glass, plastics



$$\%R + \%T + \%a = 100$$

Opaque Object

- No light is transmitted
- Absorbed light determines color



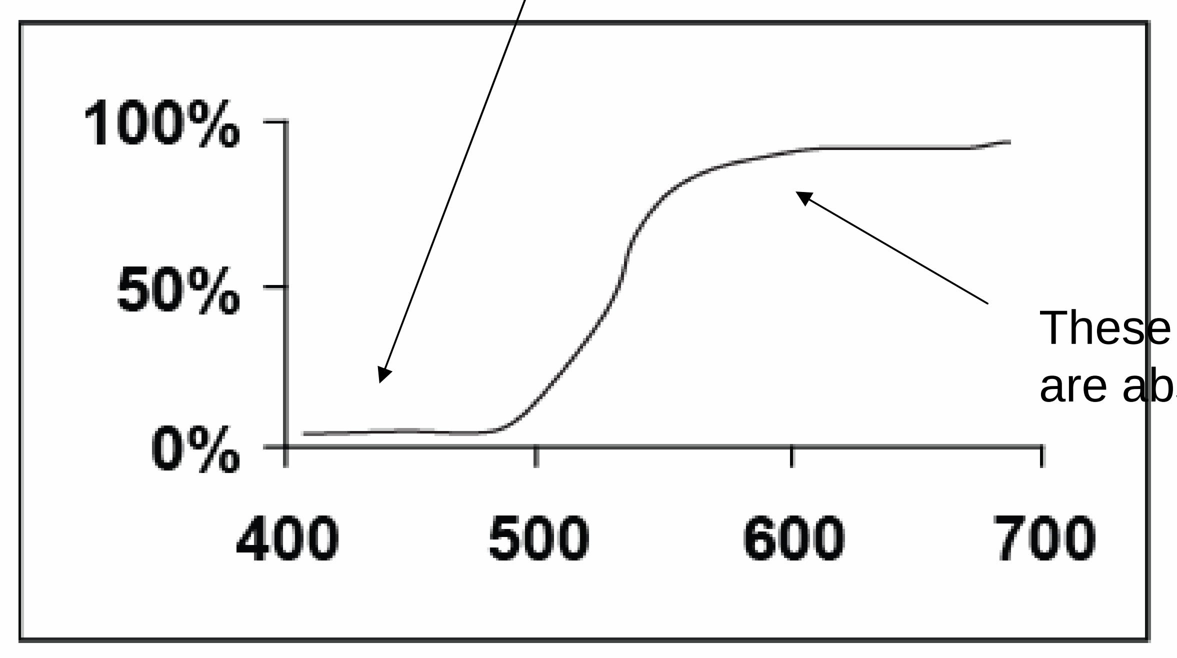
$$\%R + \%a = 100$$

Selective Absorption

- Some wavelengths are absorbed more than others

These wavelengths are absorbed more

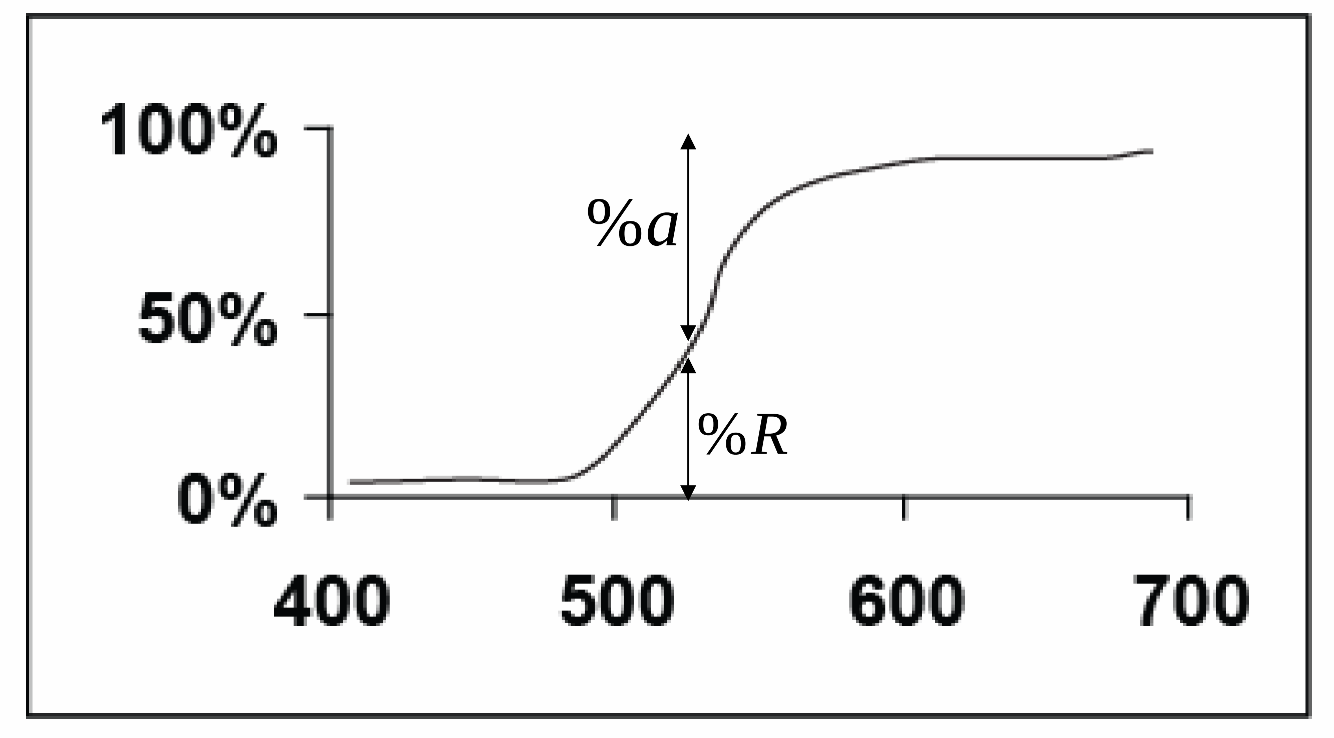
Spectral Curve



These wavelengths are absorbed less

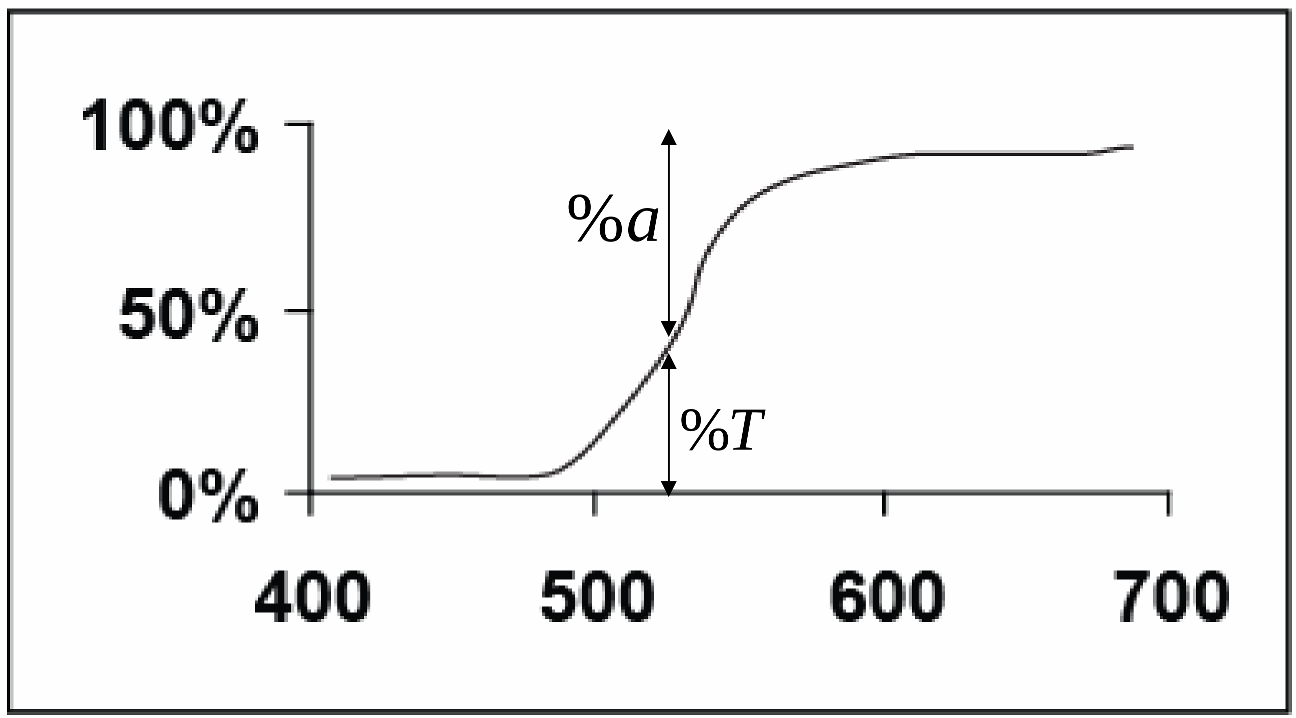
Spectral Reflectance Curve – Opaque Object

$$\%R + \%a = 100$$



Spectral Transmittance Curve – Transparent Object

$$\%T + \%a = 100$$



Exponents

- Use the button $\boxed{y^x}$ or $\boxed{\wedge}$ on your calculator

Example (Exponents):

$$(.40)^3 = .064$$

$$(.75)^{\frac{1}{2}} = (.75)^{.5} = .866$$

$$(.60)^{\frac{5}{3}} = (.60)^{1.33} = .507$$

Square Roots and Exponents

Example (Square roots notation):

$$\sqrt{16} = (16)^{\frac{1}{2}} = (16)^{.5} = 4$$

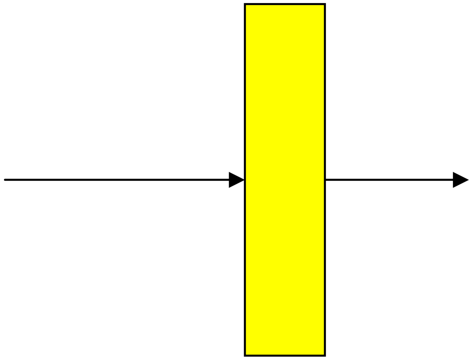
$$4^2 = 16$$

$$\sqrt{.75} = (.75)^{\frac{1}{2}} = (.75)^{.5} = .866$$

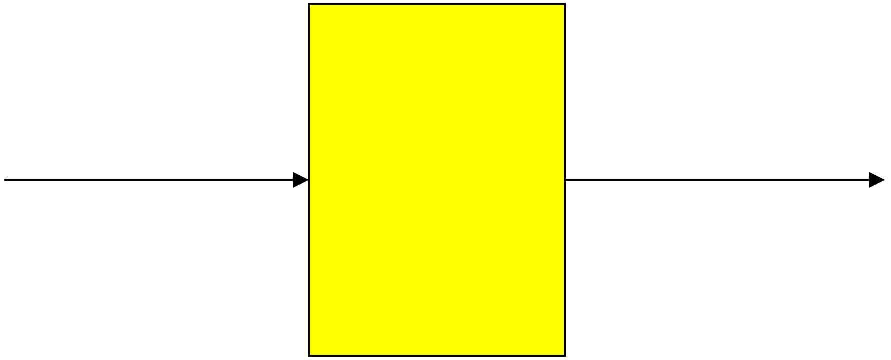
$$(.866)^2 = .75$$

Beer’s Law

- Can calculate the spectral curve of a transparent object from it’s physical properties
  - Thickness – how far the light must travel through it
  - Concentration – how dense the dye molecules are
- Applies to filters and dye solutions



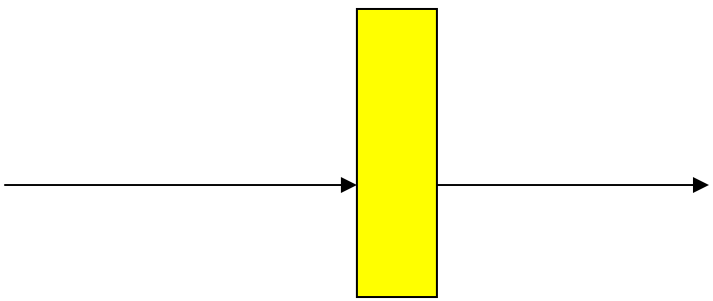
A thin filter

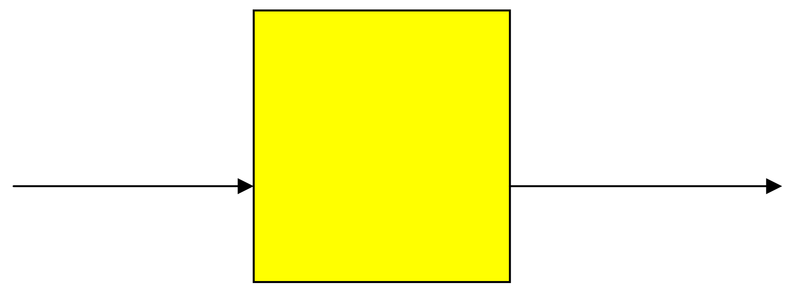


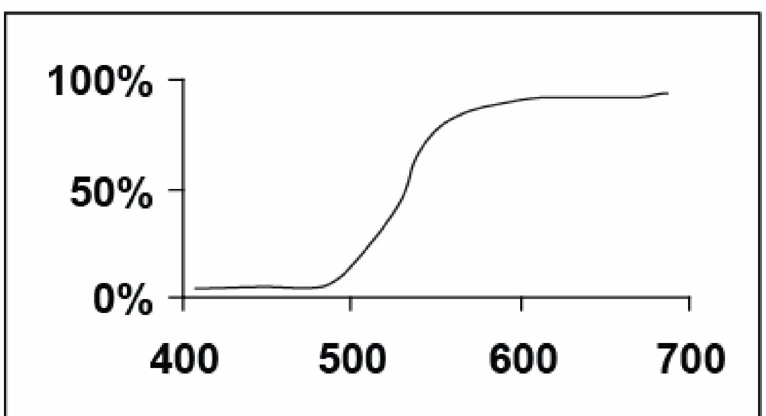
A thick filter

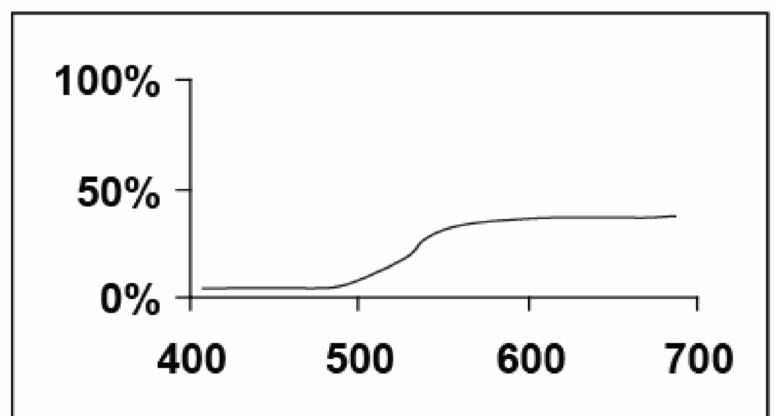
Spectral Curves from Beer's Law

- If we know the spectral curve for the thin filter, we can find the spectral curve for the thick filter







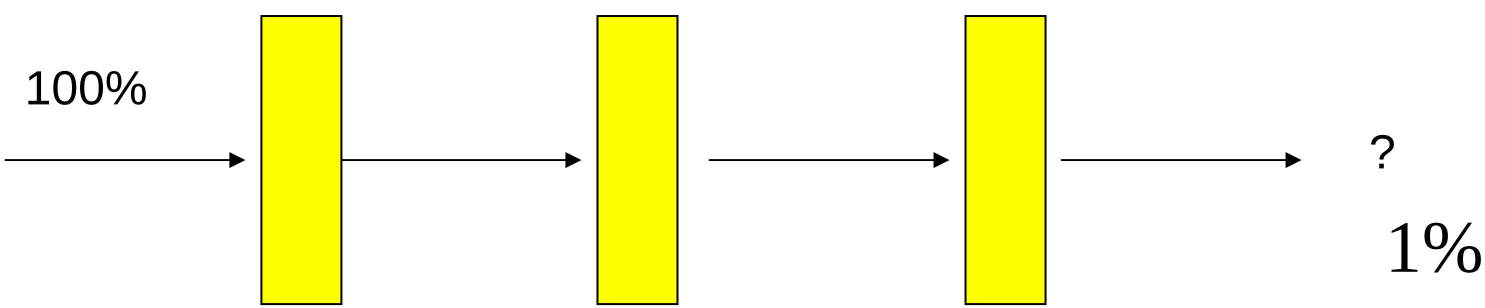


Beer’s Law for Filters

- Beer’s Law (Filters)

Example (Three filters of same thickness):

Each filter removes 33% of the light. What is the transmittance at the end?   Is it 1%?



$T_0 = .67$ $T_0 = .67$ $T_0 = .67$

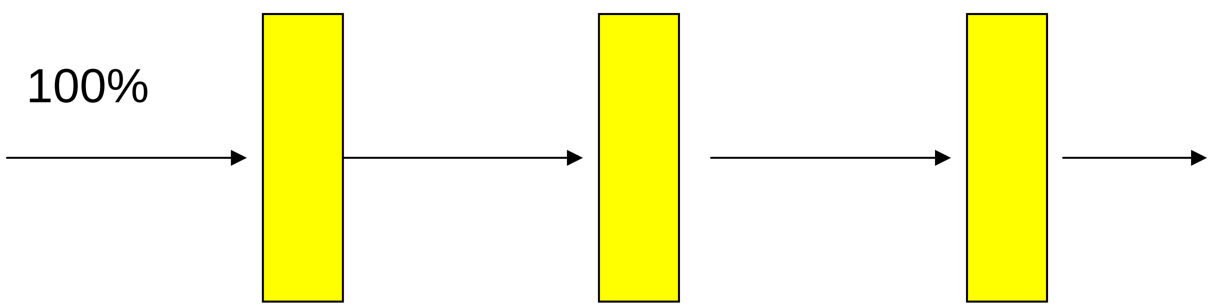
Beer's Law - Filters All Same

- Beer's Law (Filters of same thickness)

$$n = \text{number of filters}$$

$$T = (T_0)^n$$

Example(3 filters transmitting 66% each):



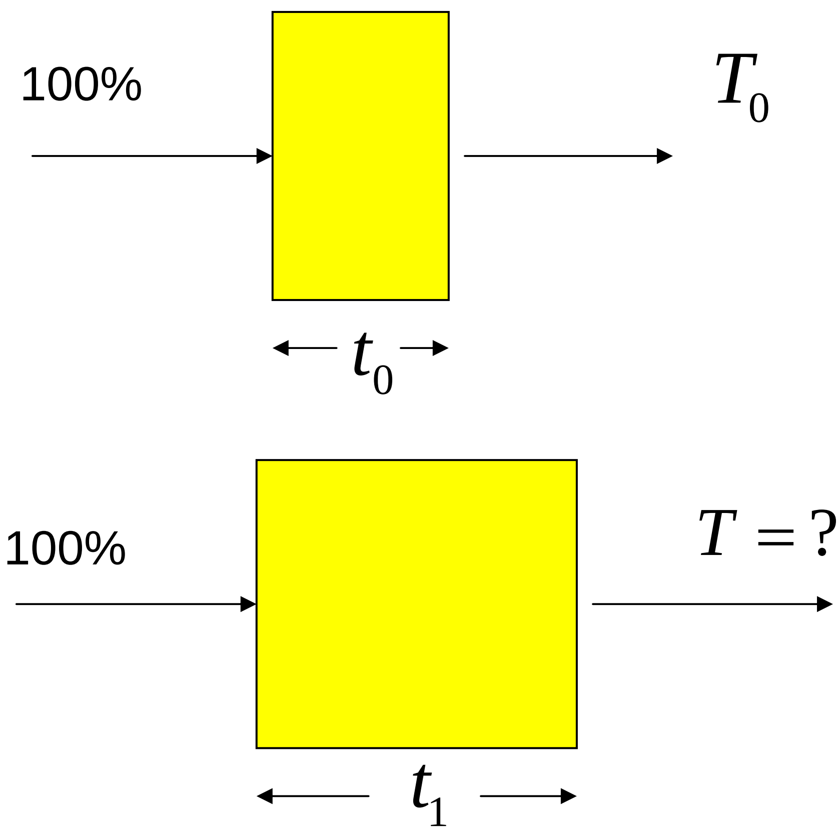
$$T = (.67)^3 = .30$$

Or 30%

$$T_0 = .67 \qquad T_0 = .67 \qquad T_0 = .67$$

Beer's Law - Filters Different

- Beer's Law (Filters with different thickness)

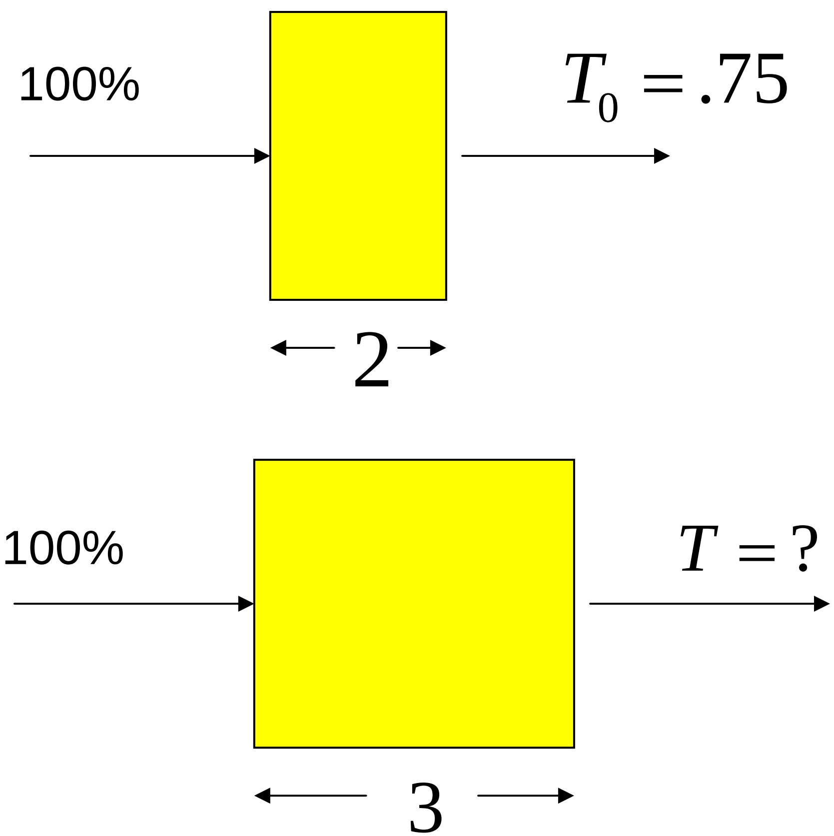


$$n = \frac{\text{new thickness}}{\text{old thickness}} = \frac{\mathrm{t}_1}{\mathrm{t}_0}$$

$$T = (T_0)^n$$

Beer's Law - Filters Different

Example (Filters of different thickness):



$$n = \frac{\text{new thickness}}{\text{old thickness}} = \frac{3}{2}$$

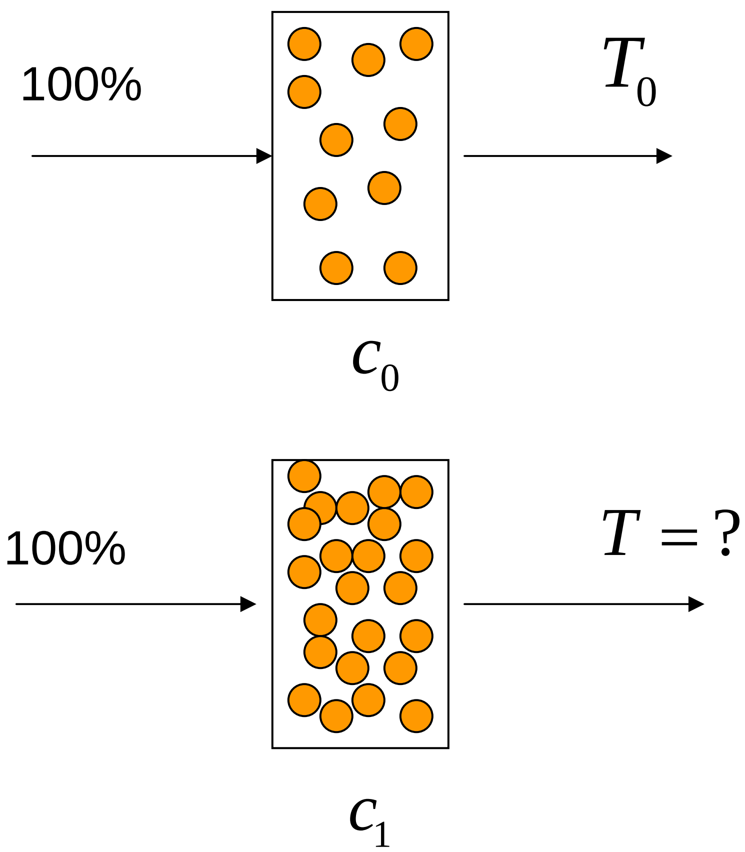
$$T = (.75)^{\frac{3}{2}}$$

$$= (.75)^{1.5}$$

$$= .65 \text{ or } 65\%$$

Beer's Law – Dye Solutions

- Beer's Law (Dye Solutions)

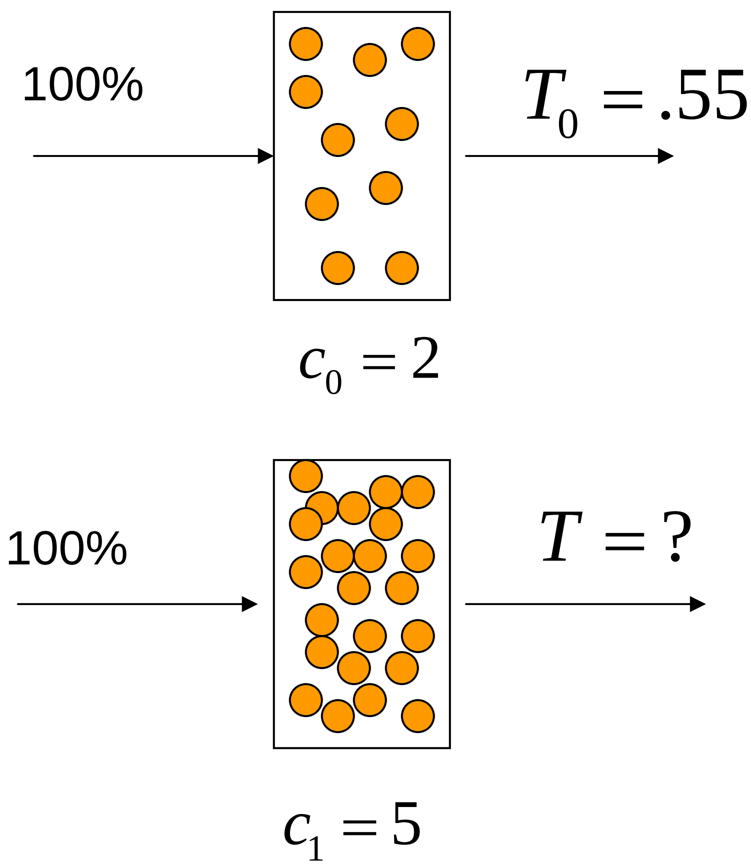


$$n = \frac{\text{new concentration}}{\text{old concentration}} = \frac{c_1}{c_0}$$

$$T = (T_0)^n$$

Beer's Law – Dye Solutions

Example (Dye Solutions):



$$n = \frac{\text{new concentration}}{\text{old concentration}} = \frac{5}{2} = 2.5$$

$$T = (T_0)^n = (.55)^{2.5} = .22$$

Why is Yellow Food Dye Red?

- Why does yellow food dye look red in the bottle?

When Concentrated

When Dilute

- Hint: Draw a yellow spectral curve and show how to use Beer’s Law to change it into a red spectral curve
- Convincing Answer worth 10 extra points on next test.

Transmittance and Absorbance

- Transmittance and absorbance are related
- Different ways of describing same thing

$$T = \text{Transmittance}$$

$$A = \text{Absorbance}$$

$$T = 10^{-A}$$

A	10^{-A}	$\%T$
0	10^{0}	$1.0 = 100\%$
1	10^{-1}	$.1 = 10\%$
2	10^{-2}	$.01 = 1\%$
3	10^{-3}	$.001 = .1\%$

Beer's Law – Absorbance Form

- Expresses absorbance in terms of concentration, thickness and dye characteristics

$c = \text{concentration}$

$t = \text{thickness}$

$\varepsilon_\lambda = \text{extinction factor}$

$\varepsilon_\lambda = \text{chance a photon}$
$\text{of wavelength } \lambda \text{ is absorbed}$
$\text{if it hits a dye molecule}$

$$A_\lambda = c \cdot t \cdot \varepsilon_\lambda$$

Beer's Law – Absorbance Form

$$T_\lambda = 10^{-A_\lambda} \qquad A_\lambda = c \cdot t \cdot \varepsilon_\lambda$$

- Note $c = 0 \rightarrow A = 0 \rightarrow T = 1.0 \text{ or } 100\%$
- Note $t = 0 \rightarrow A = 0 \rightarrow T = 1.0 \text{ or } 100\%$
- Since c and t do not depend on wavelength all selective absorption is contained in the extinction factor ε_λ
- Extinction factor is determined by dye characteristics

Beer's Law Experiment – Absorbance vs Concentration

$$A_\lambda = c \cdot t \cdot \varepsilon_\lambda$$