Beer’s Law

Color filtering

Transparent materials appear colored because they absorb some of the light that passes through them

Amount of absorption depends on wavelength and distance traveled through the material

Source: http://graphics.ucsd.edu/~jwills/renders/mm_beers.html

Color filtering

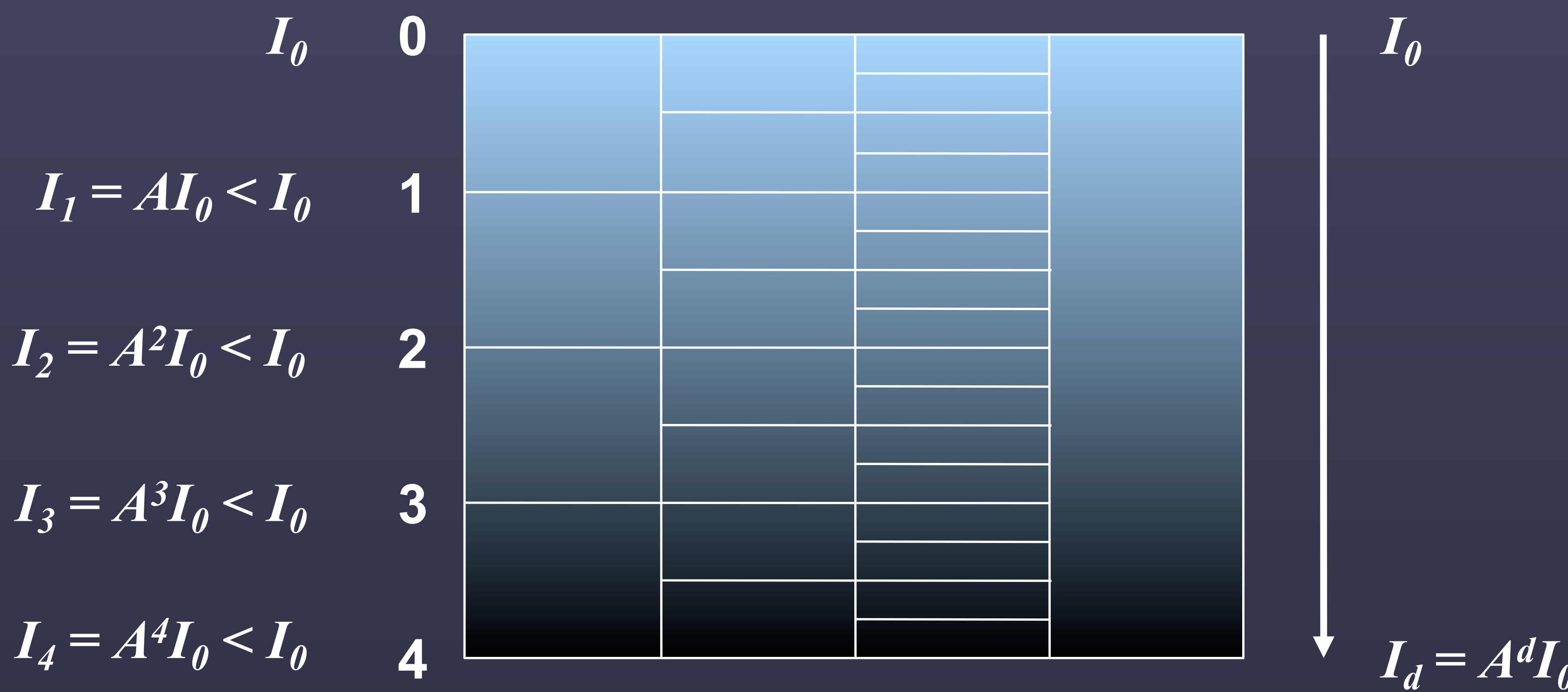
Without filtering

With filtering

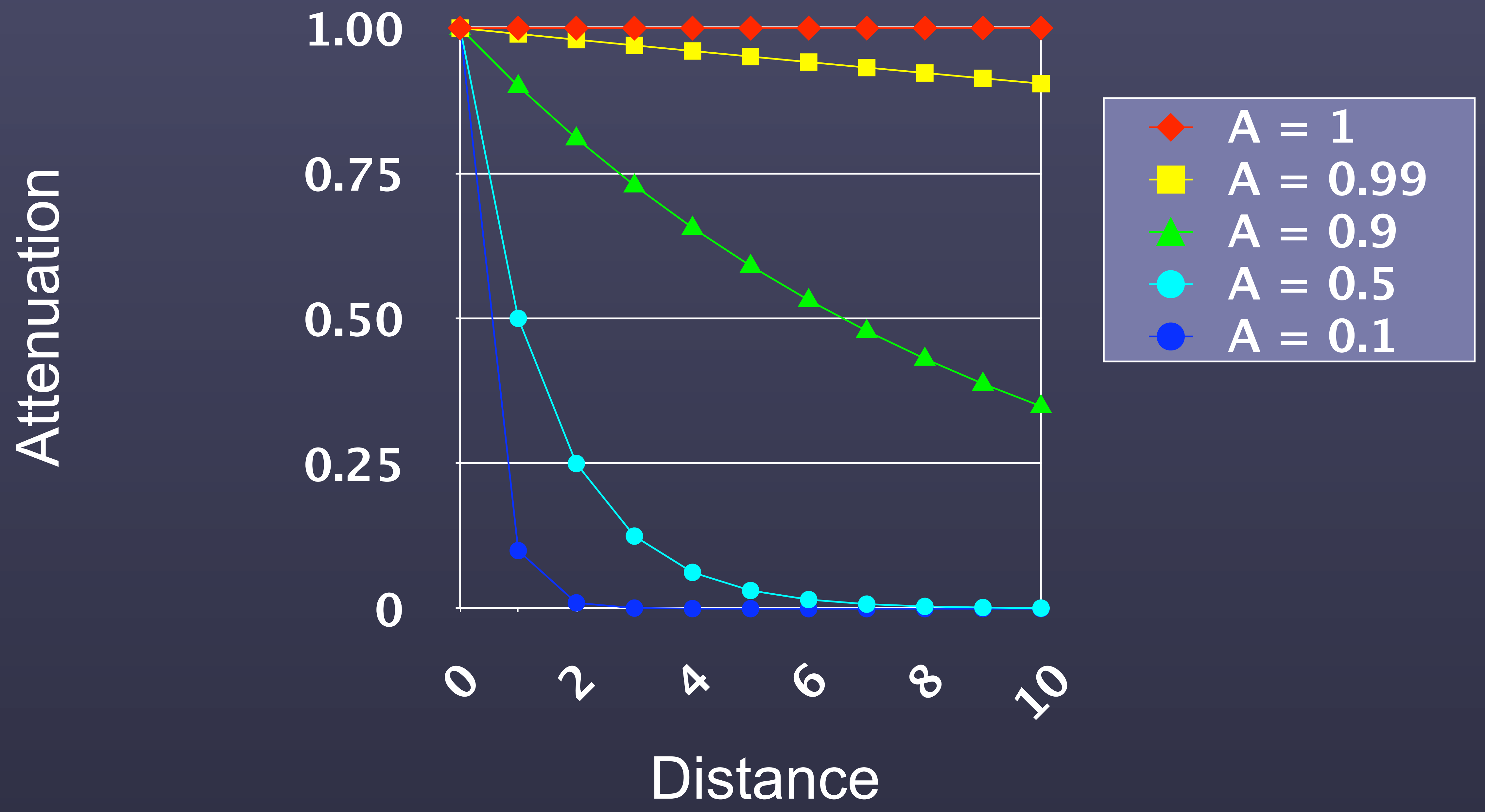
Note the differences in the color of the liquid and ice cubes between these two images

Color filtering

The *transmission coefficient* A ($0 \le A \le 1$) of a homogeneous material is the amount of absorption after one unit distance



Color filtering



Beer’s Law

Relates the amount of absorption to the distance the light has traveled through the medium

As a ray travels through a medium, it loses intensity according to:

$$dI = -CIdx \quad \Rightarrow \quad \frac{dI}{dx} = -CI$$

This equation is solved by the exponential:

$$I = k\mathrm{e}^{-Cx}$$

Beer's law

Recall the *transmission coefficient* A, which is the attenuation after one unit of distance

To solve the exponential, apply the boundary conditions:

$$I(0) = I_0$$

$$I(1) = AI_0$$

Beer's Law

The first condition implies that:

$$I(x) = I_0 e^{-Cx}$$

while the second implies:

$$AI_0 = I_0 e^{-C}$$

so:

$$-C = \ln(A)$$

Beer's Law

Finally:

$$I(x) = I_0 e^{\ln(A)x}$$

Beer's law + Total internal refraction

Beer's Law attenuation

$$beers\_attenuation(double\ t)$$

$$\{$$

$$\quad \text{return Color(exp(t*A}_\text{r}\text{),exp(t*A}_\text{g}\text{),exp(t*A}_\text{b}\text{));}$$

$$\}$$

Where:

$$A_r, A_g, A_b = \ln(E_r), \ln(E_b), \ln(E_b)$$

$Note: E_{rgb}$ is scale dependent

Improved Dielectric shading (continued)

if depth of ray <maximum depth:

$$\text{costheta2}^2 = 1 + \frac{\left(\cos theta^2 - 1\right)}{\eta_{tmp}{}^2}$$

if $\text{costheta2}^2 < 0$

Total internal reflection, trace reflection ray (Just like metal material)

result += refl color*beers_attenuation(t_{refl})

else

... (next page)

Improved Dielectric shading (continued)

... (last page)

else

$\text{costheta2} = \sqrt{\text{costheta2}^2}$

cosm=min(costheta, costheta2)

$F_r = R_0 + (1 - R_0)(1 - \cos m)^5$

Trace reflection ray, just like metal material

if(entering)

  $\text{result} \mathrel{+}= \text{refl color} * F_r$

else

  $\text{result} \mathrel{+}= \text{refl color} * F_r * beer\_attenuation(t_{refl})$

$F_t = 1 - F_r$

$$\text{transp direction} = \frac{1}{\eta_{tmp}}\vec{V} + \left(\frac{\cos theta}{\eta_{tmp}} - \cos theta2\right)\vec{N}$$

Trace transparency ray

if(entering)

  $\text{result} \mathrel{+}= \text{transp color} * F_t * beer\_attenuation(t_{trans})$

else

  $\text{result} \mathrel{+}= \text{transp color} * F_t$

Beer’s law on ‘05 Program 4