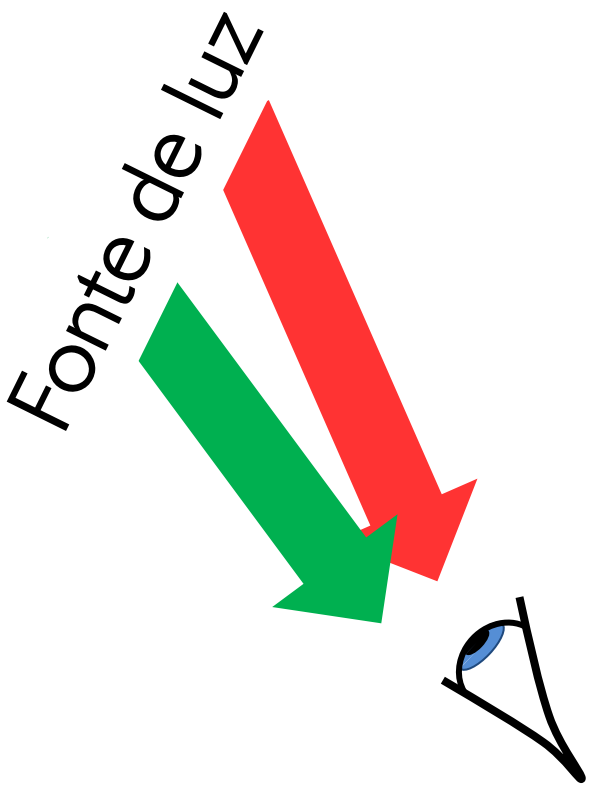
CORES

SUBTRATIVAS

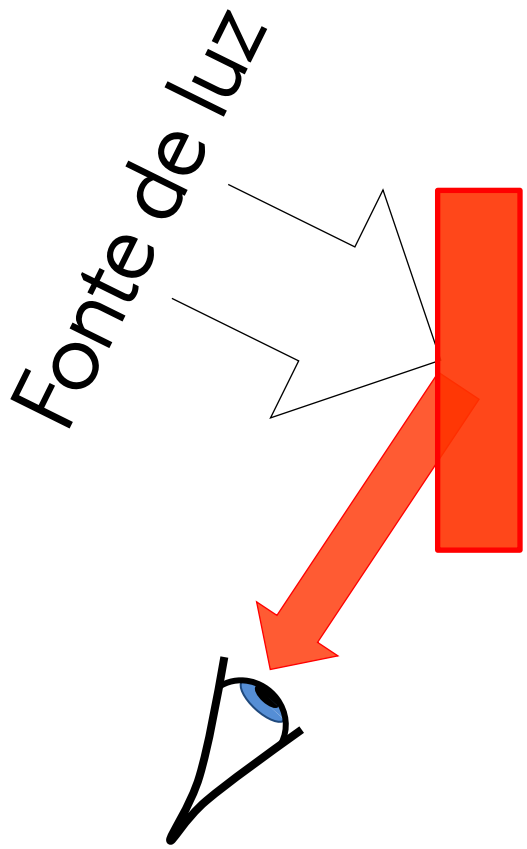
De onde vem a cor?

Uma pedra de mármore muito polida pode virar um “espelho”?

GERAÇÃO DE CORES



Aditiva



Absorção +

Reflexão +

Espalhamento +

Transmissão +

Luminescência +

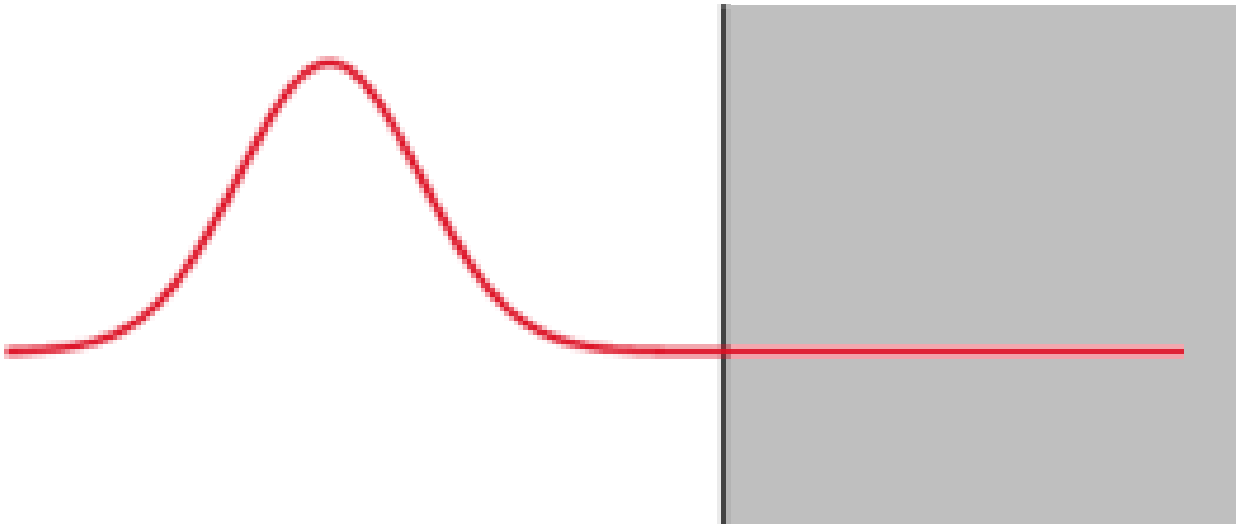
Interferência

Subtrativa

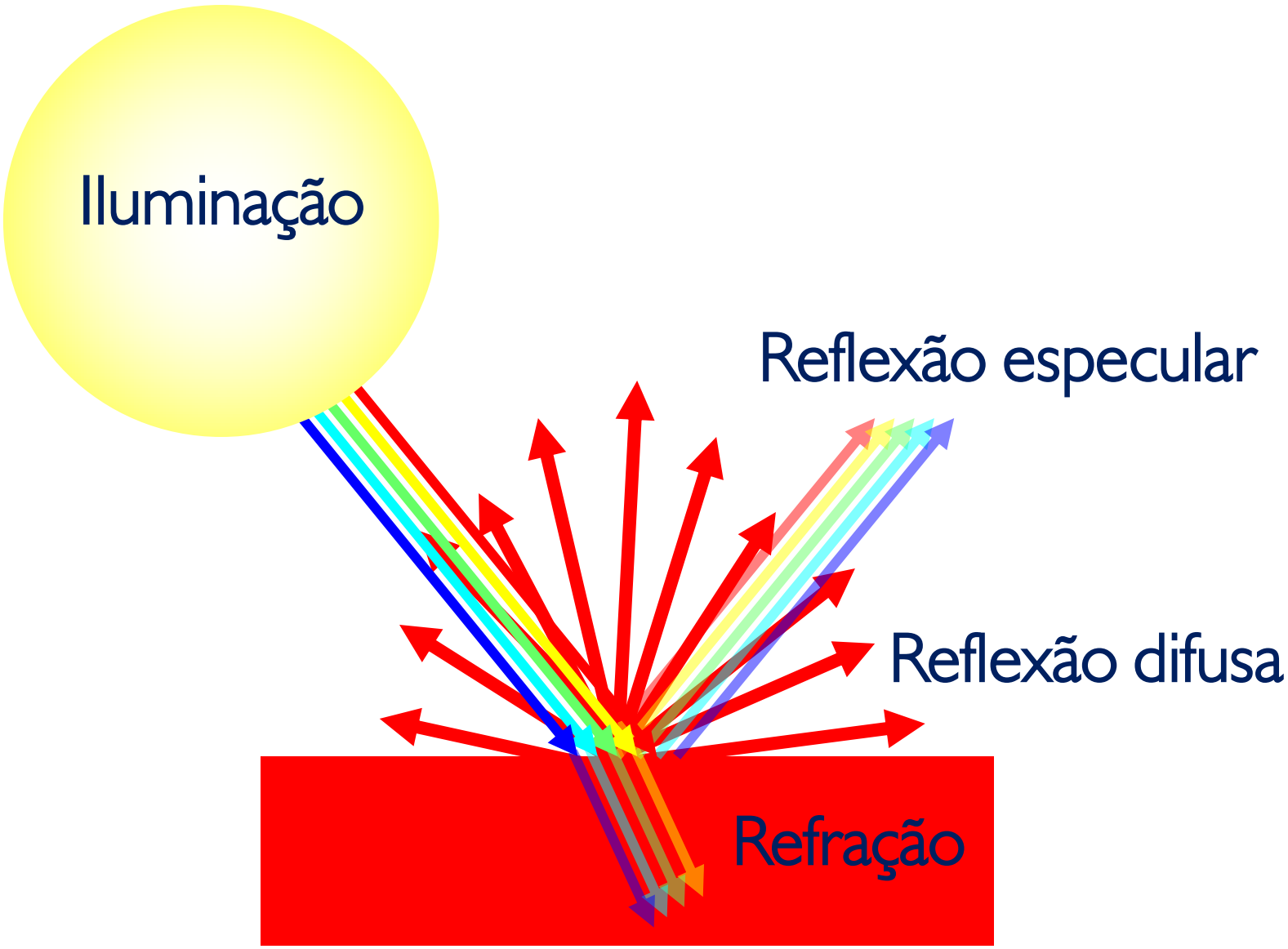
UNICAMP

REFLEXÃO

INTERFACE 2 MEIOS



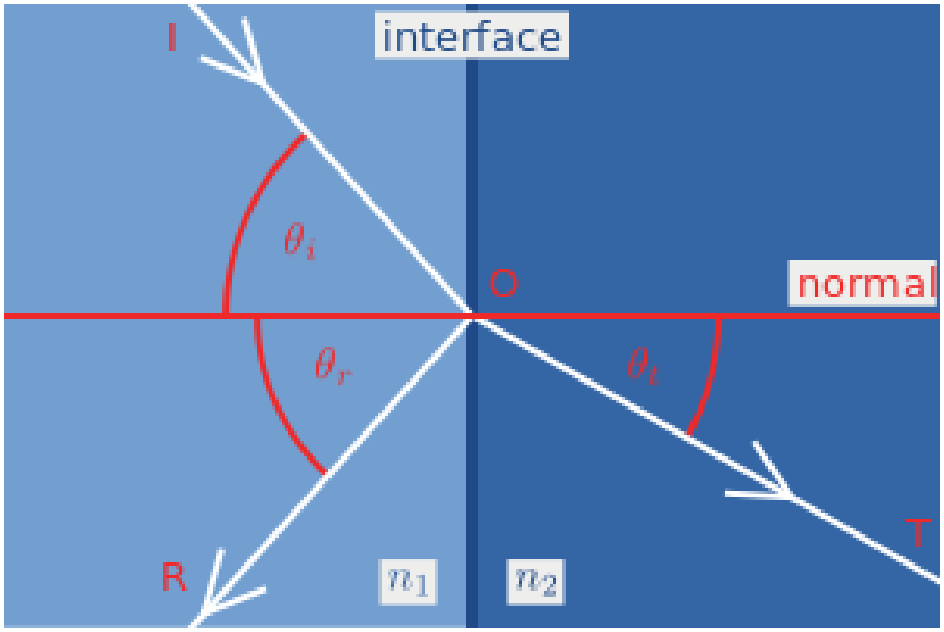
REFLEXÃO



Para onde vai....

Lei da Reflexão **especular**

$$\theta_i = \theta_r$$



Lei da Refração: Snell

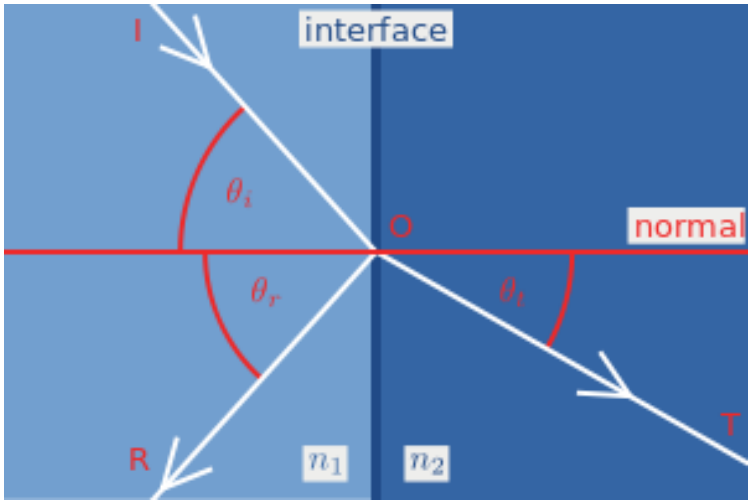
$$\frac{\sin\theta_i}{\sin\theta_t} = \frac{n_2}{n_1}$$

Quanto vai....

Equações de Fresnel

$$R_s = \left|\frac{n_1\cos\theta_i - n_2\cos\theta_t}{n_1\cos\theta_i + n_2\cos\theta_t}\right|^2 = \left|\frac{n_1\cos\theta_i - n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}{n_1\cos\theta_i + n_2\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2}}\right|^2$$

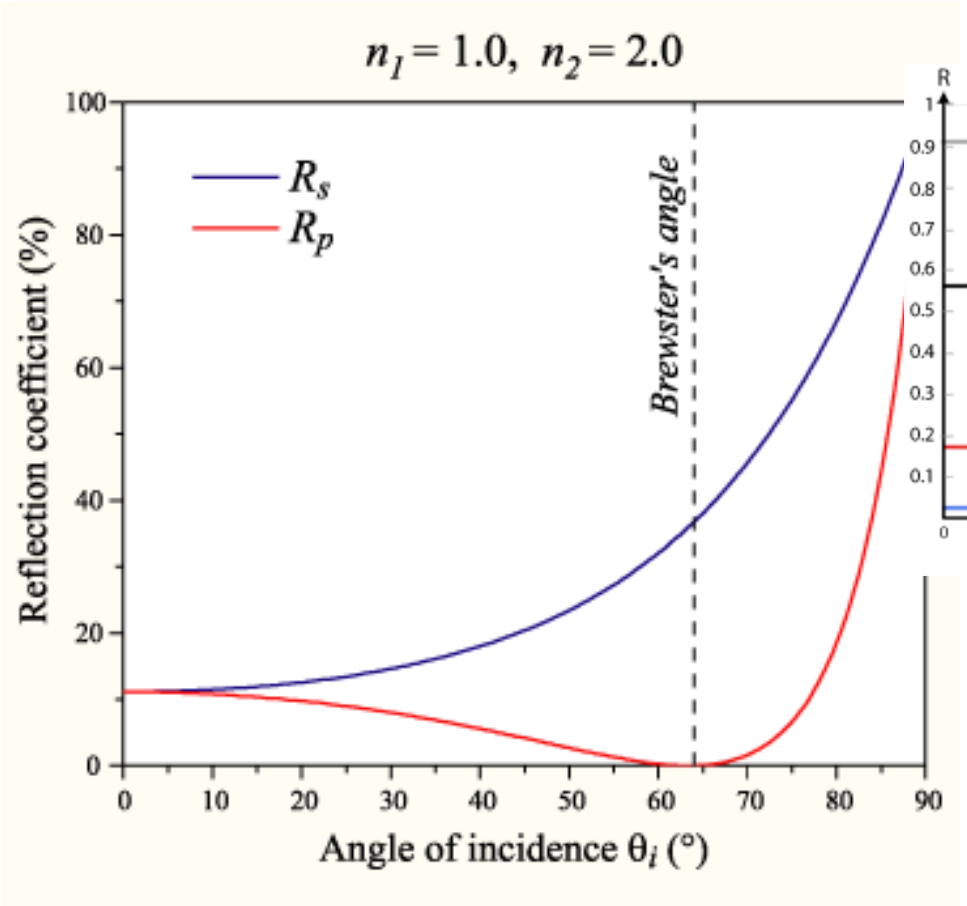
$$R_p = \left|\frac{n_1\cos\theta_t - n_2\cos\theta_i}{n_1\cos\theta_t + n_2\cos\theta_i}\right|^2 = \left|\frac{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} - n_2\cos\theta_i}{n_1\sqrt{1-\left(\frac{n_1}{n_2}\sin\theta_i\right)^2} + n_2\cos\theta_i}\right|^2$$

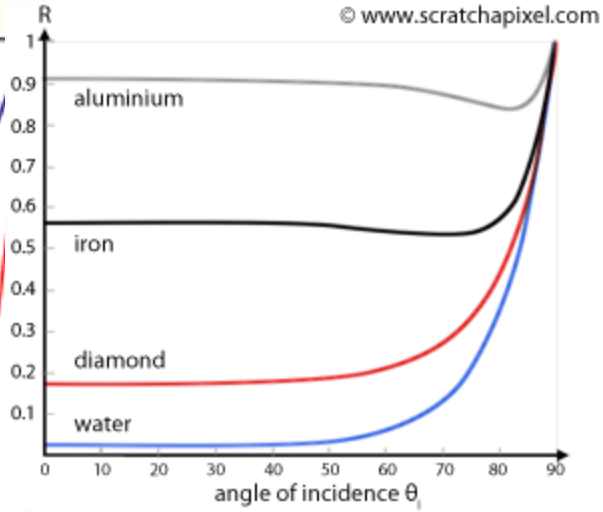


$$T_s = 1 - R_s$$

$$T_p = 1 - R_p$$

Quanto vai....


$n_1 = 1.0,\ n_2 = 2.0$
R_s
R_p
Brewster's angle
Reflection coefficient (%)
Angle of incidence θ_i (°)
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90


© www.scratchapixel.com
R
aluminium
iron
diamond
water
angle of incidence θ_i
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90

Quanto vai....

Metais

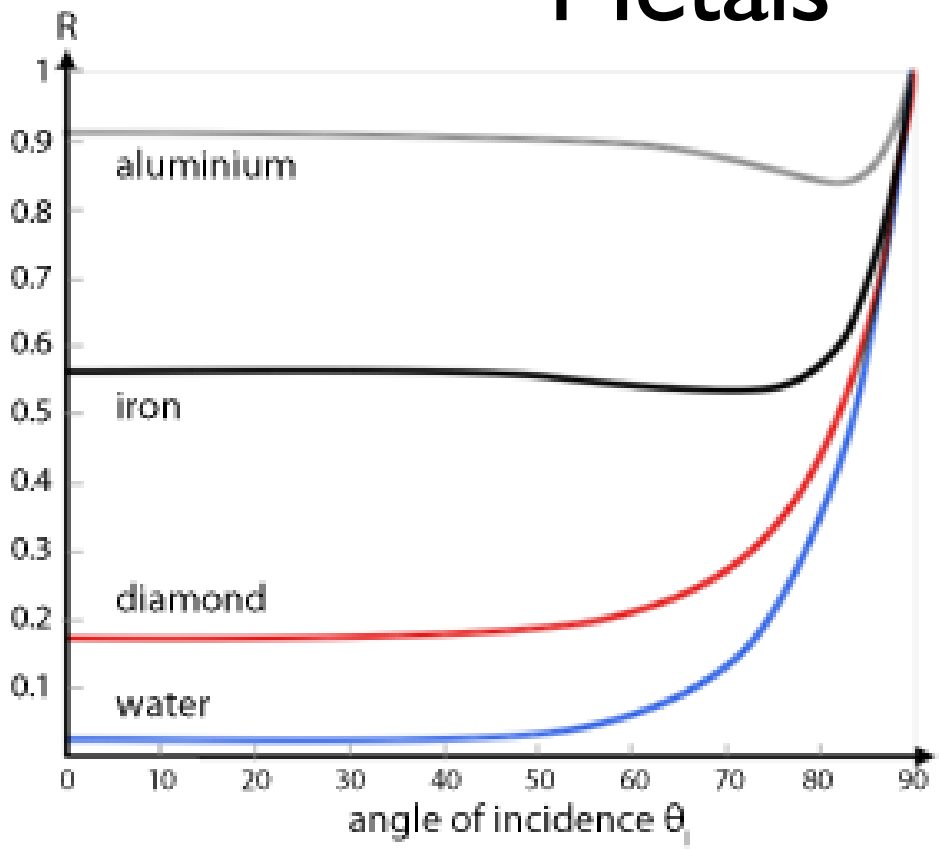
n COMPLEXO

ALTA ABSORÇÃO

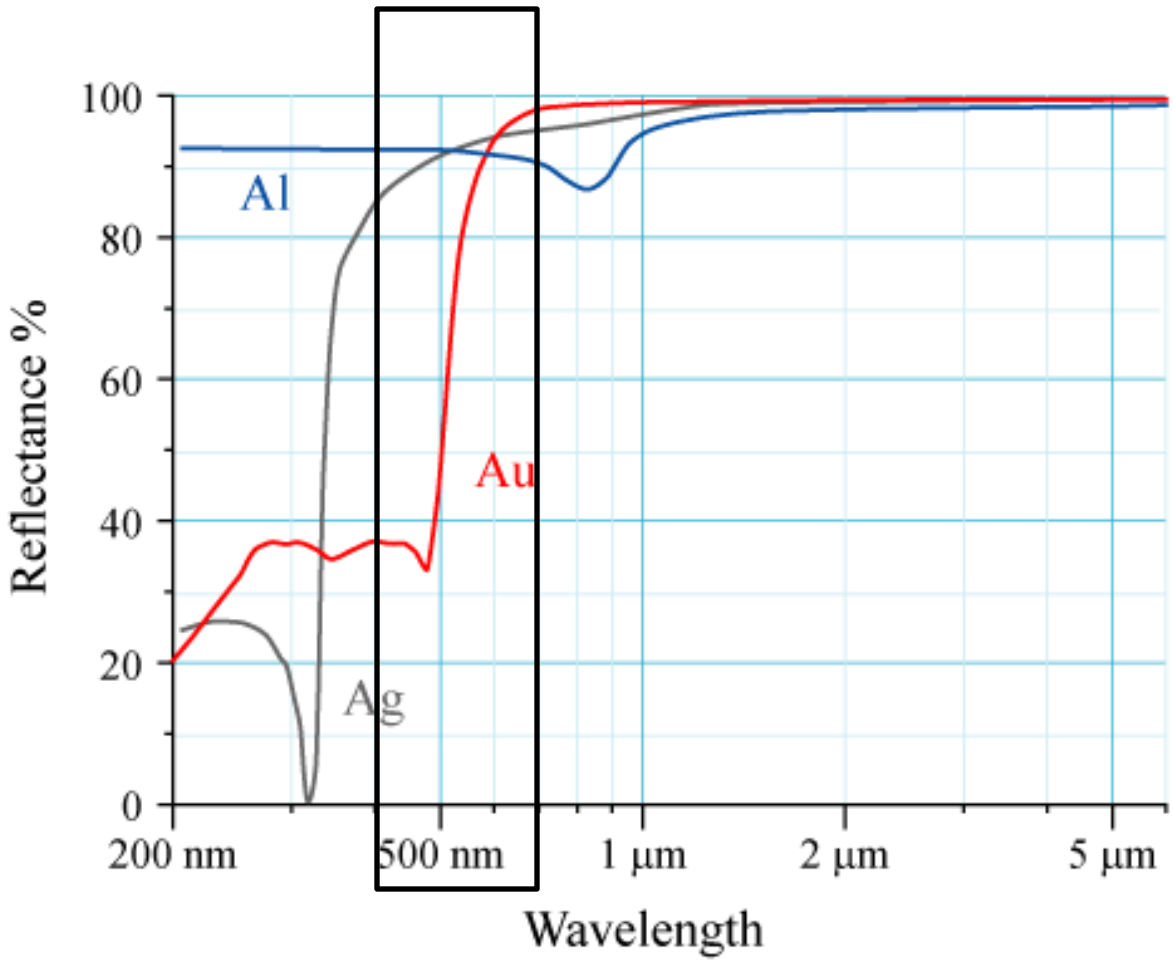
PROFUNDIDADE DE PENETRAÇÃO

SUPRESSÃO DO FEIXE REFRATADO

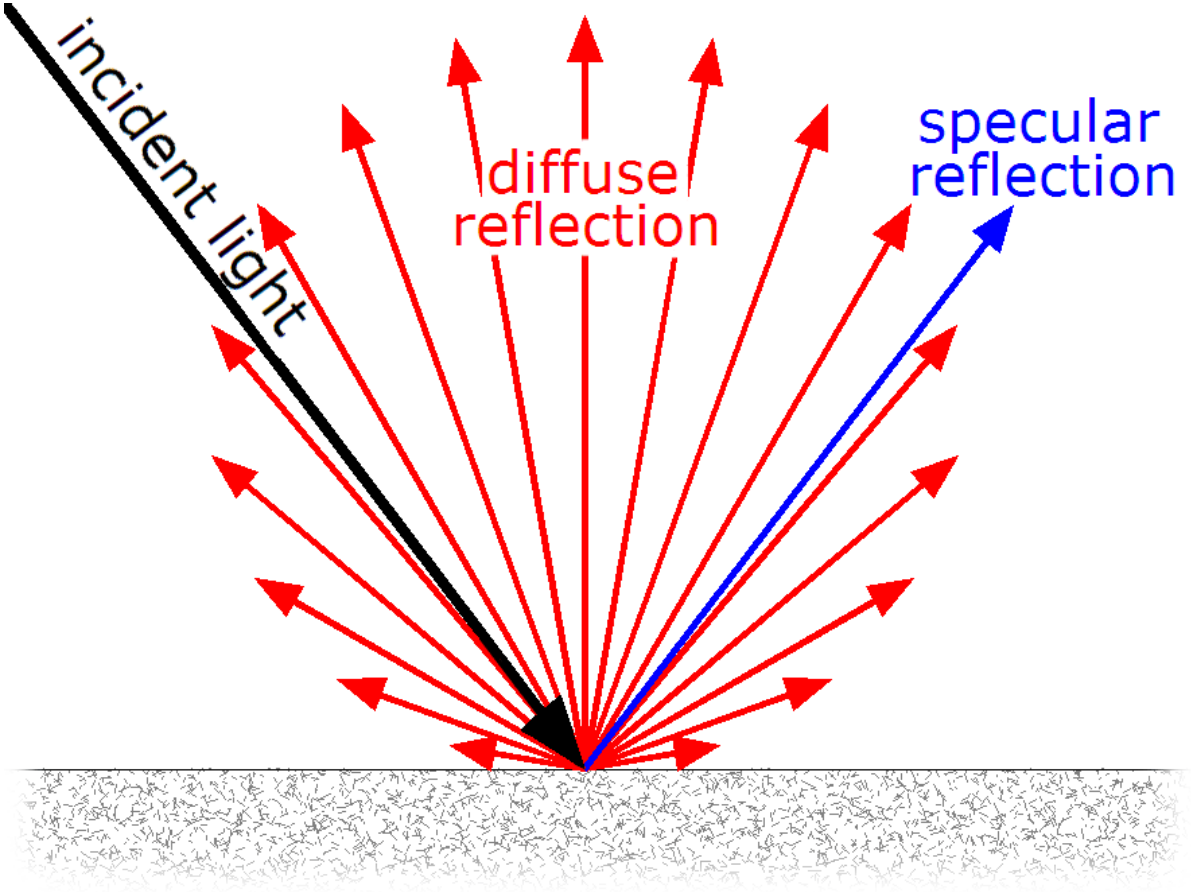
ALTA REFLETIVIDADE



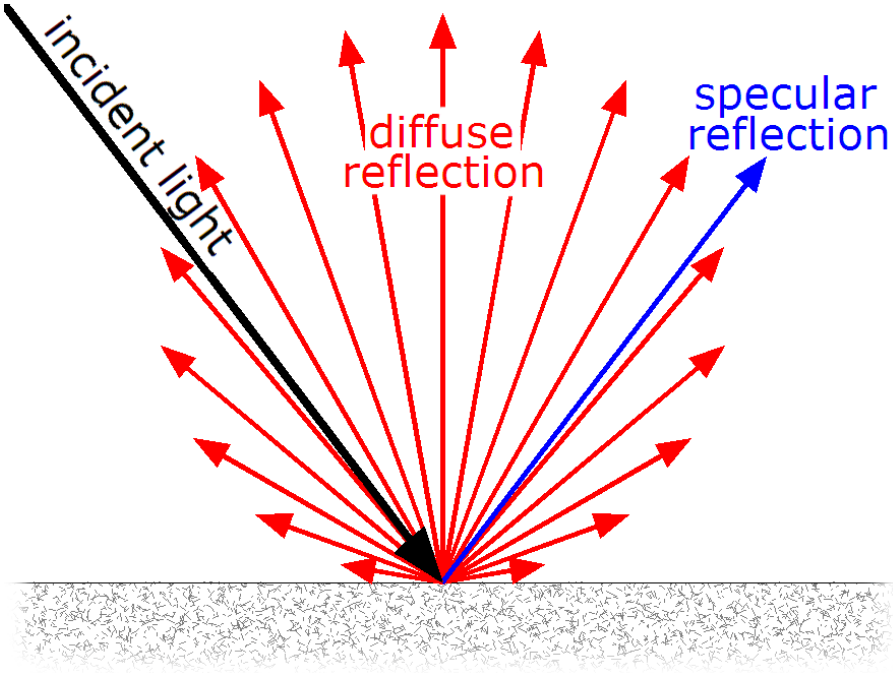
METAIS


100
80
60
40
20
0
Reflectance %
Al
Au
Ag
200 nm
500 nm
1 µm
2 µm
5 µm
Wavelength

REFLEXÃO difusa



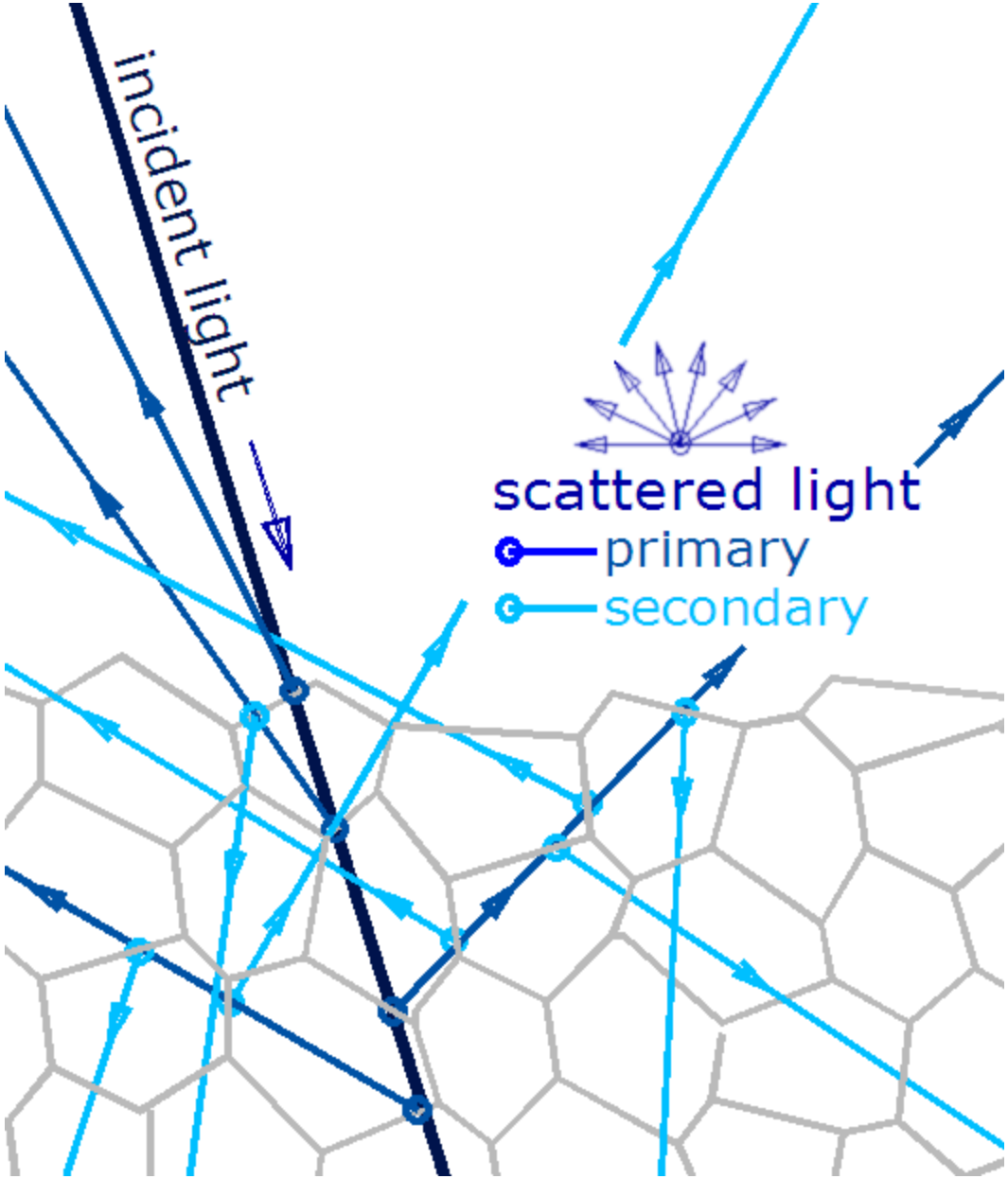
REFLEXÃO difusa



em geral, NÃO vem só da rugosidade da superfície.

em geral, vem de baixo da superfície.

Reflexão + refração + espalhamento nas partículas que formam o material.

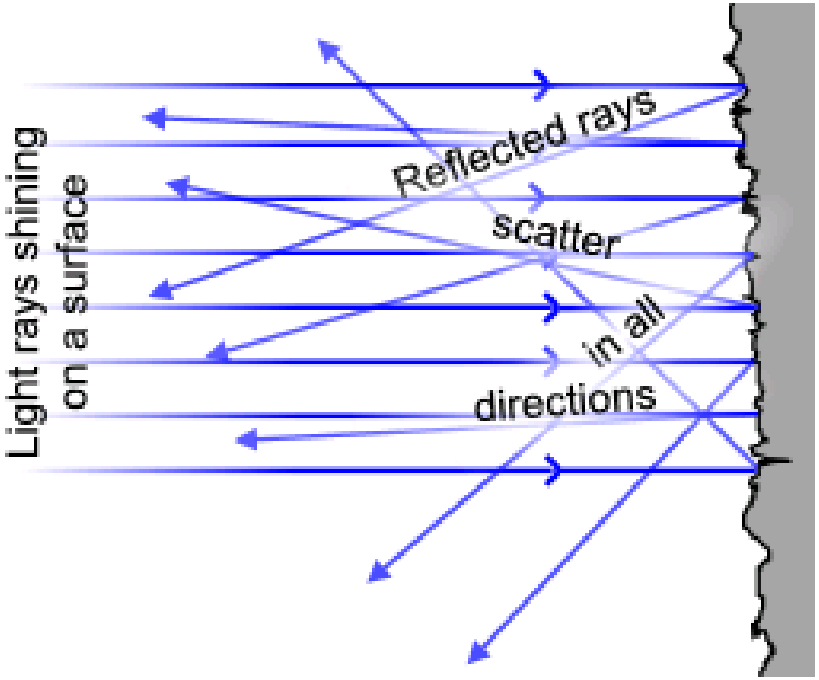


De onde vem a cor?

Reflexão especular: n (λ) dependência com λ fraca

Reflexão difusa: Absorção Dependência com λ forte

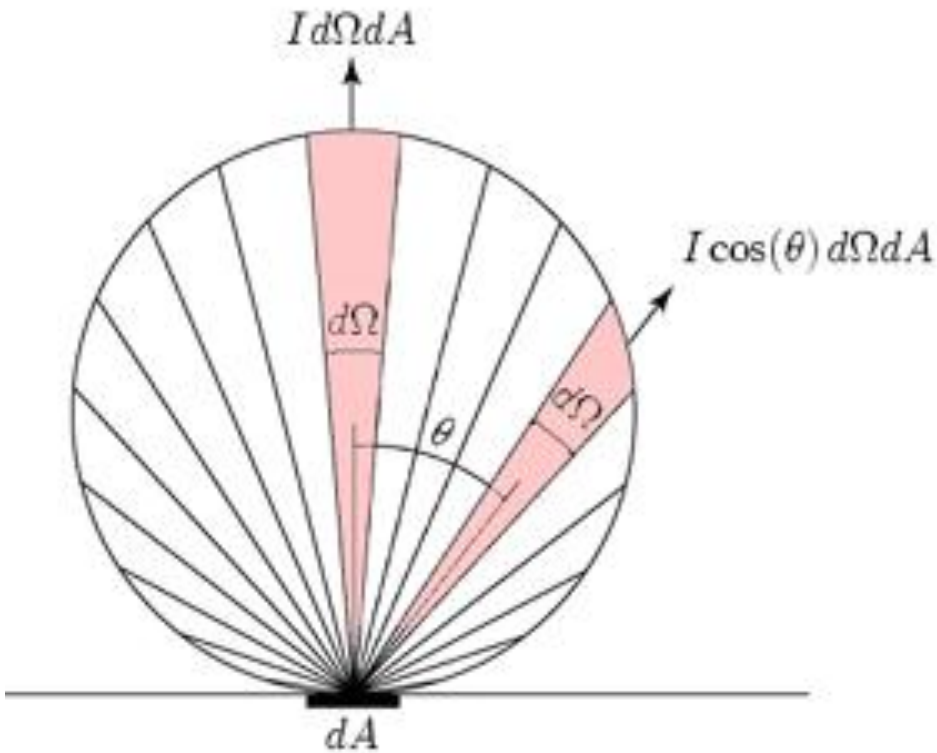
REFLEXÃO especular difusa



rugosidade da superfície também
pode gerar luz difusa,
mas seguindo equações de Fresnel.

REFLEXÃO Lambertiana

Superfície difusa ideal

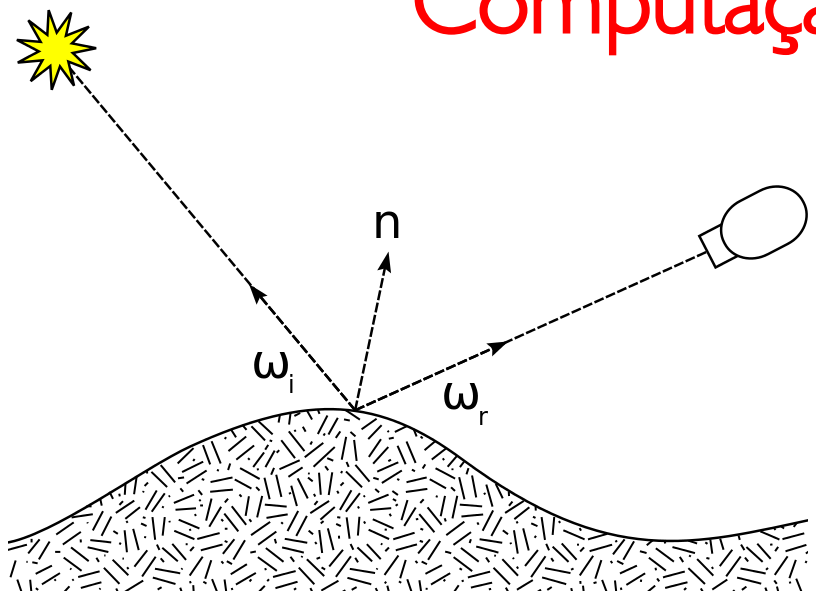


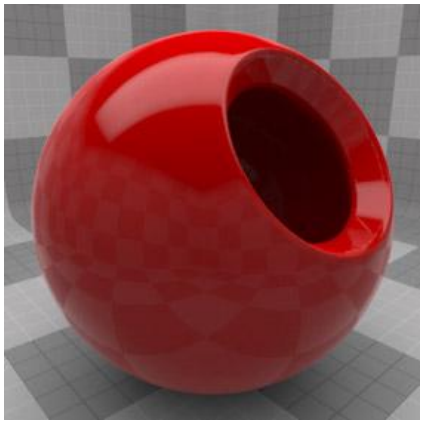
Luz difusa uniformemente em toda as direções.

BRDF

Bidiretional Reflectance Distribution Function

Computação Gráfica



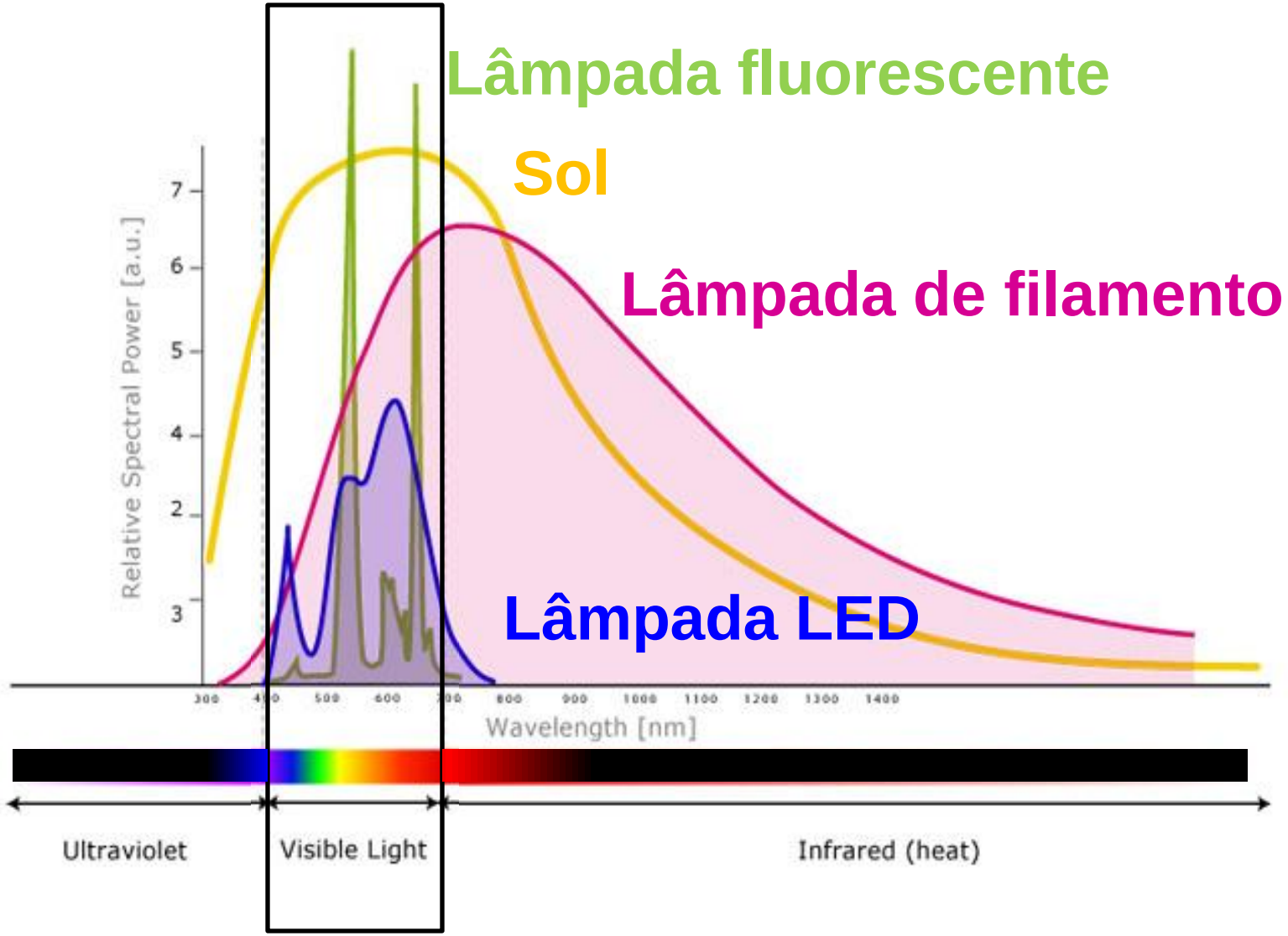


$f_r(\omega_i, \omega_r)$: Reflexão de uma superfície opaca

BSSRDF: B Sub-Surface RDF

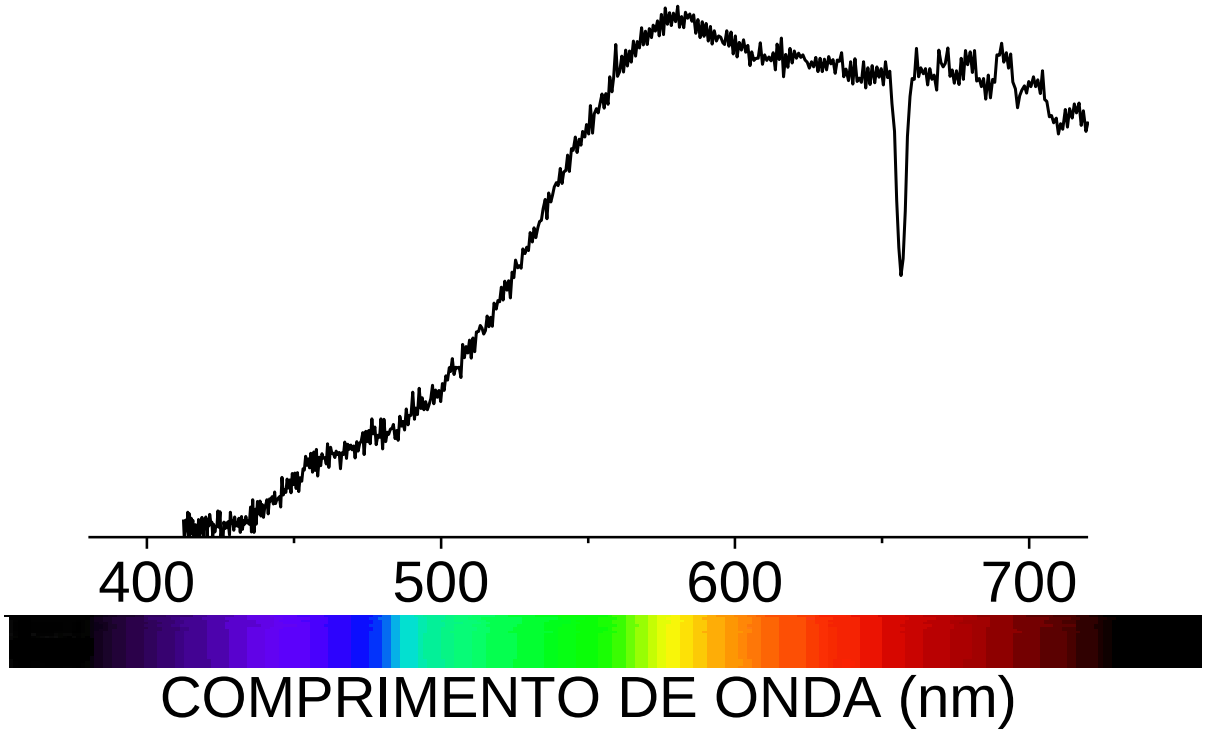
Espectral BRDF : COR

FONTES DE LUZ

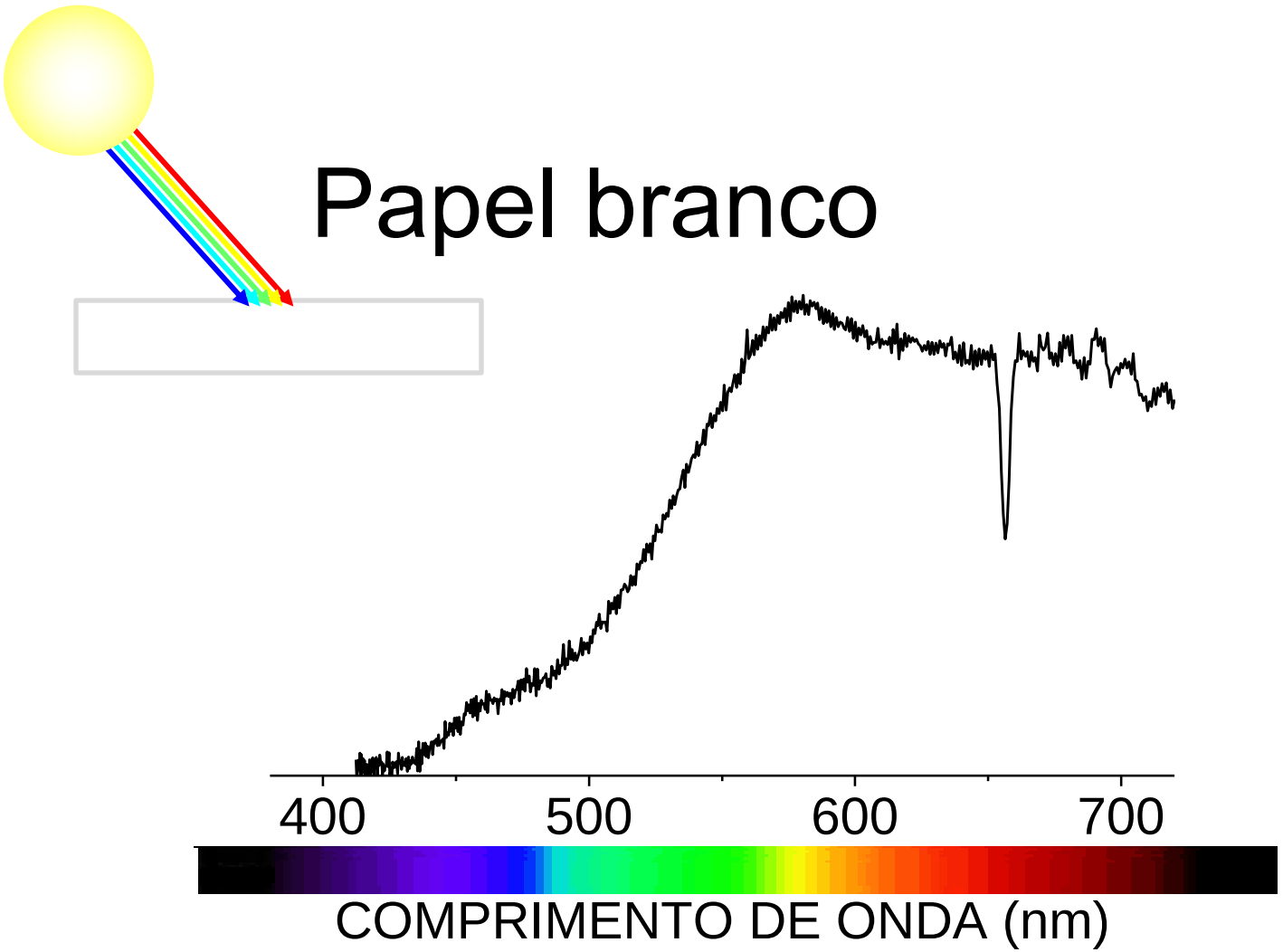


ILUMINAÇÃO

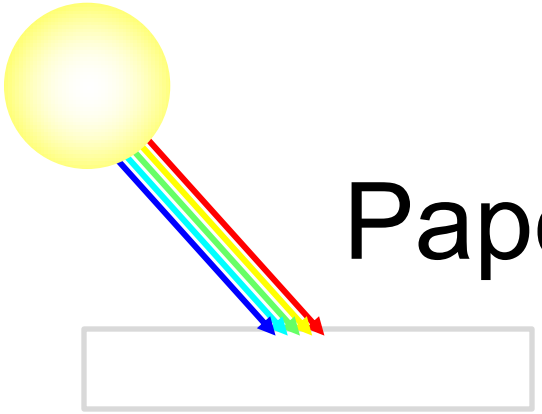
Lâmpada Halogênea



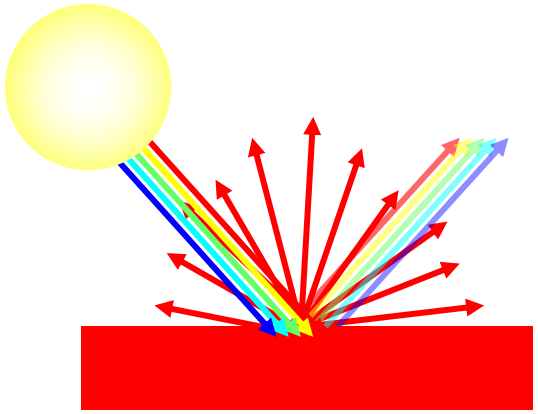
ILUMINAÇÃO



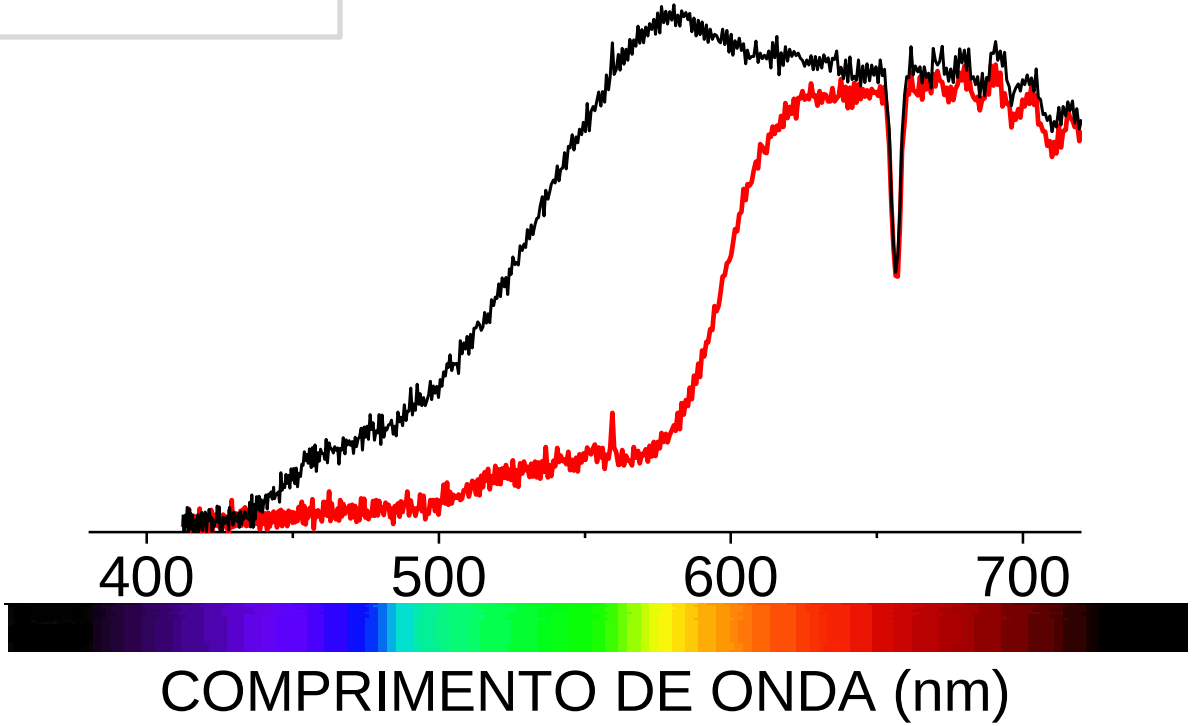
REFLEXÃO



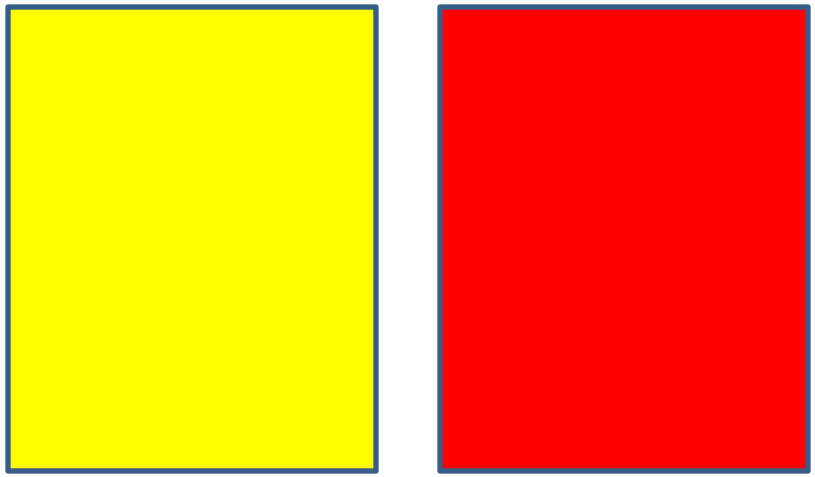
Papel branco



Papel vermelho

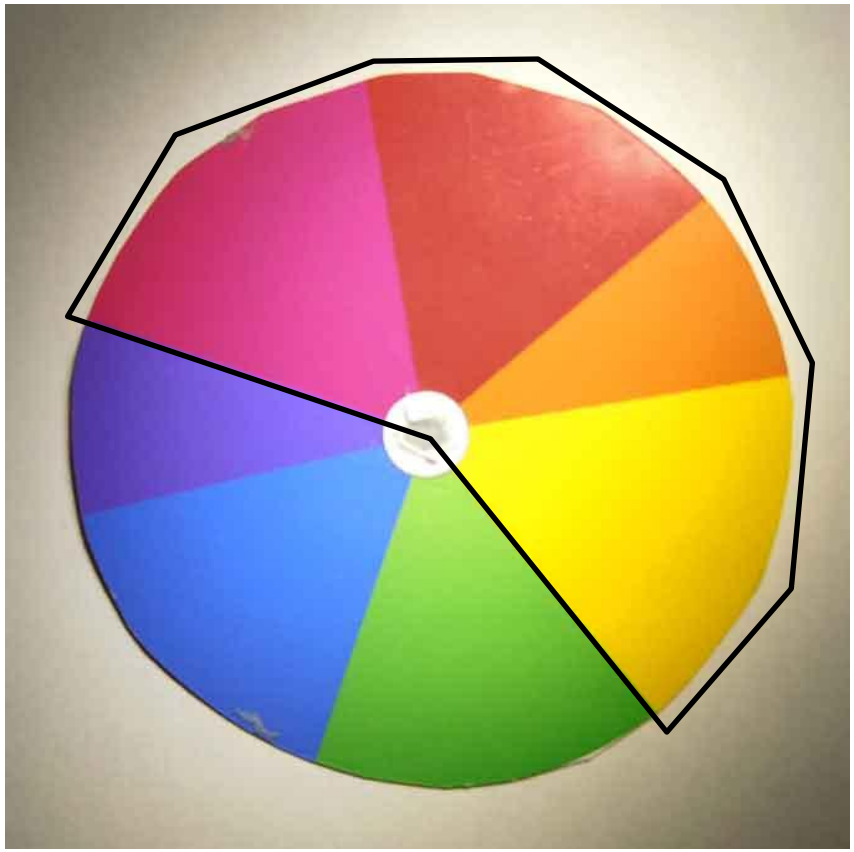


Um “papel amarelo” pode refletir tanto “vermelho” quanto um “papel vermelho”.

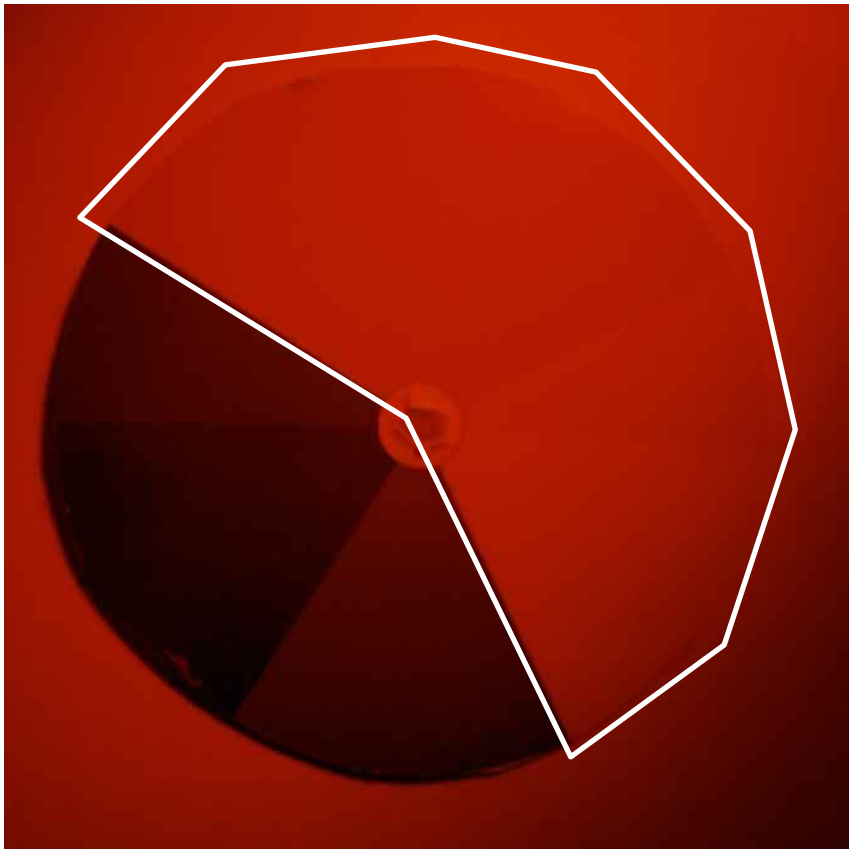


LUZ BRANCA

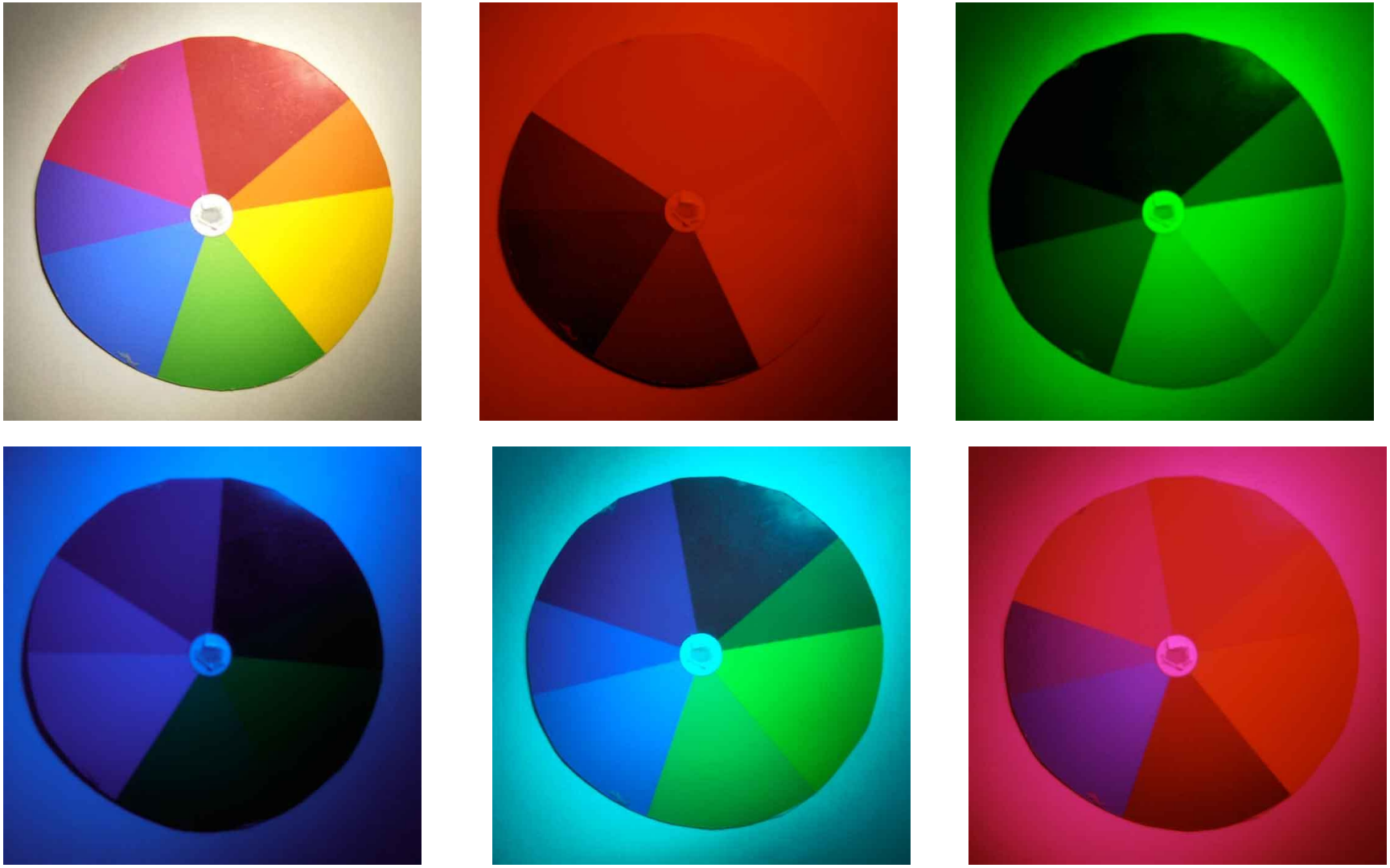
LUZ BRANCA



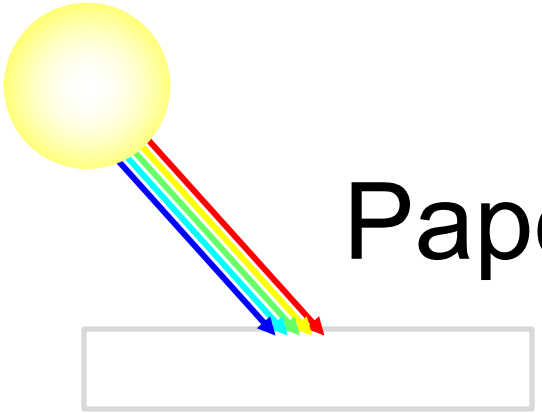
LUZ VERMELHA



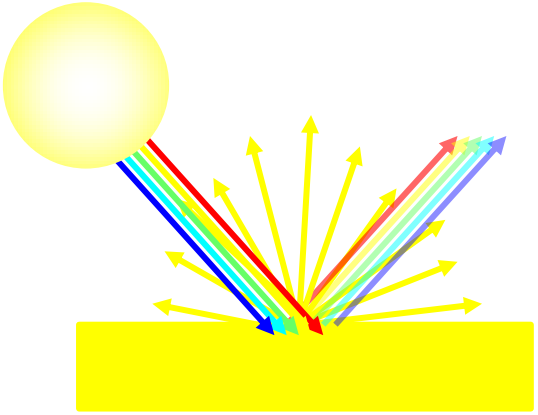
CORES SOB ILUMINAÇÃO LIMITADA



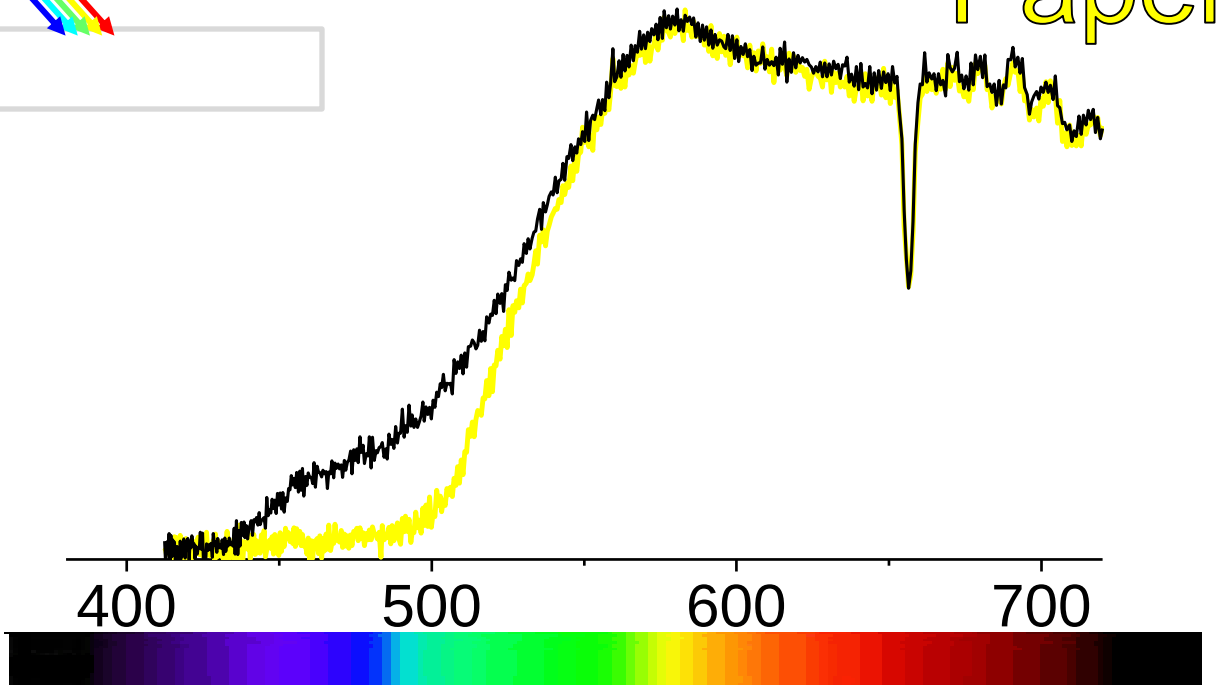
REFLEXÃO



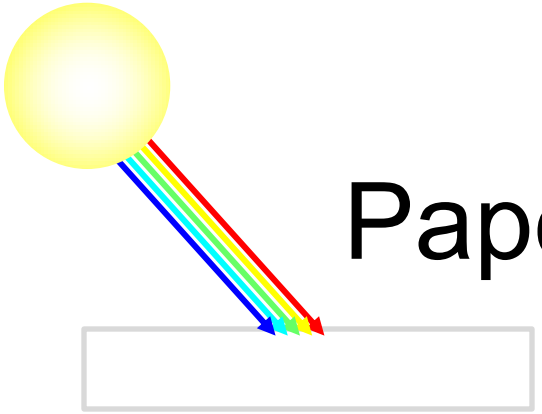
Papel branco



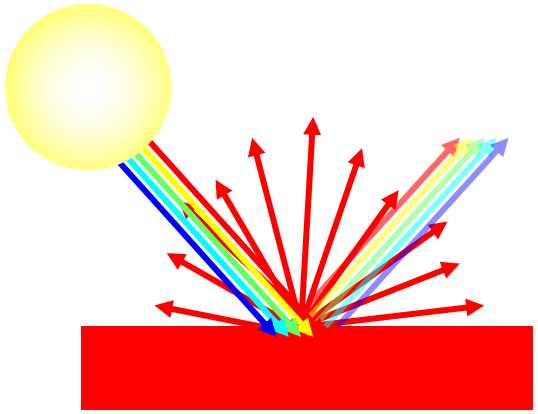
Papel amarelo



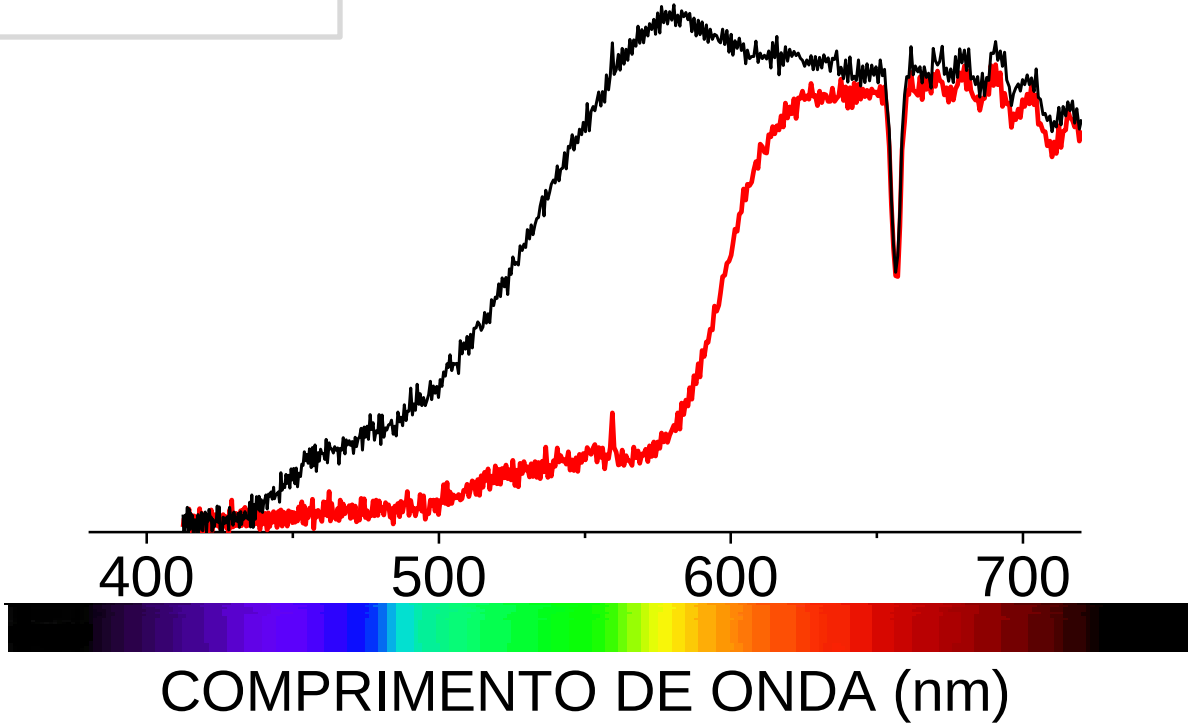
REFLEXÃO



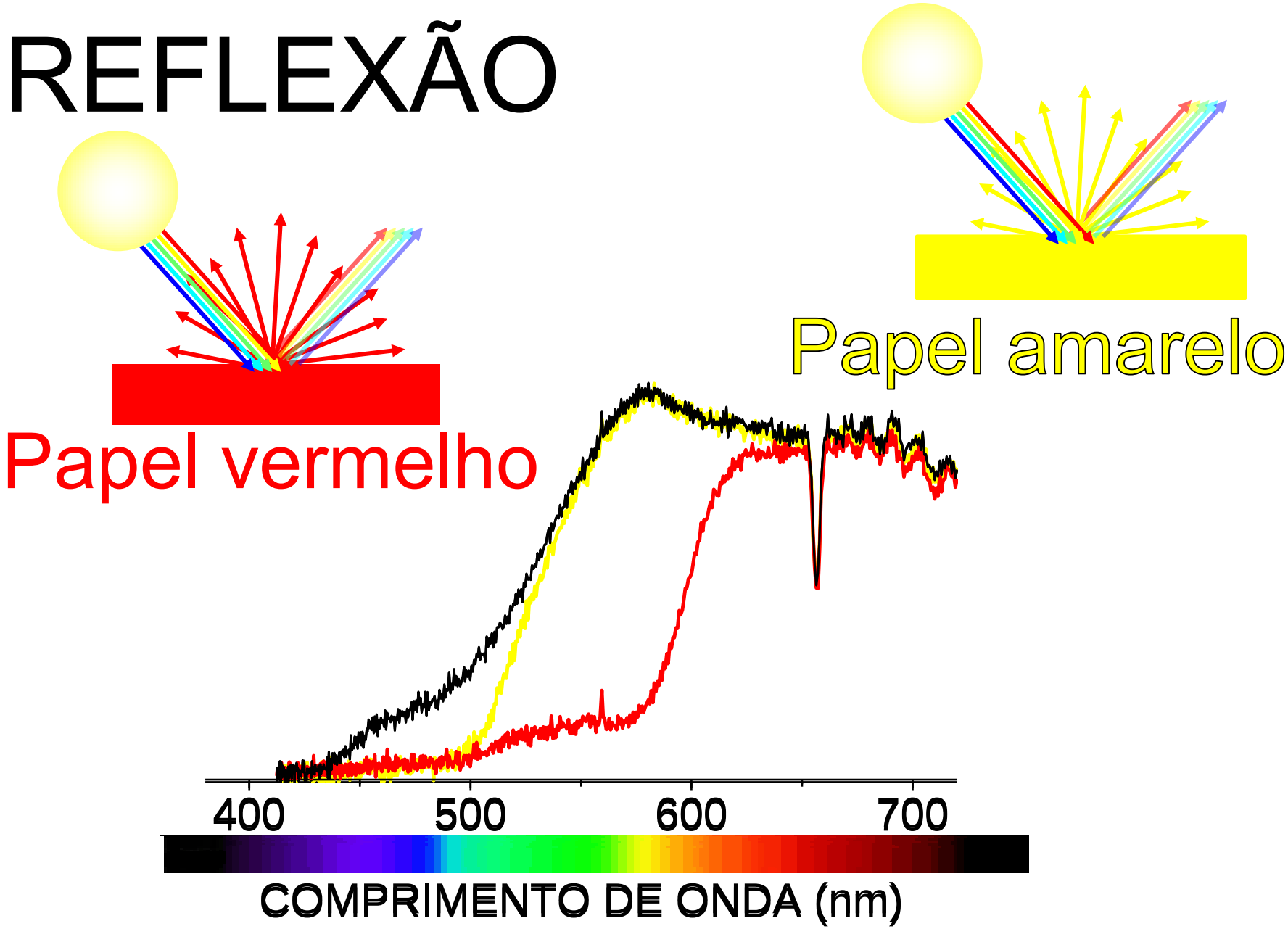
Papel branco



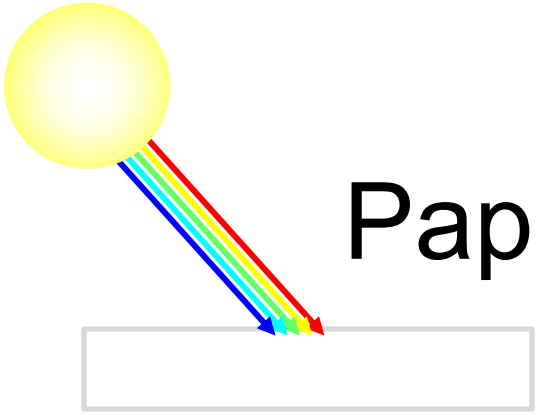
Papel vermelho



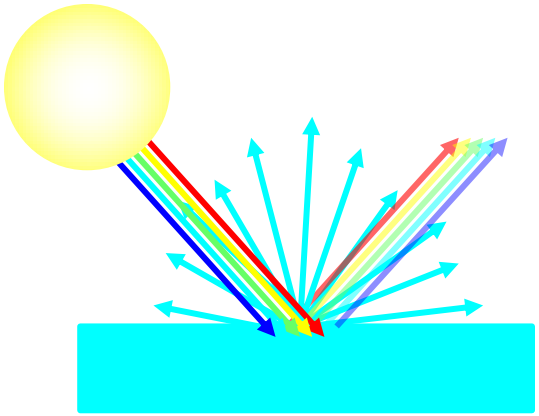
REFLEXÃO


Papel vermelho
Papel amarelo
400
500
600
700
COMPRIMENTO DE ONDA (nm)

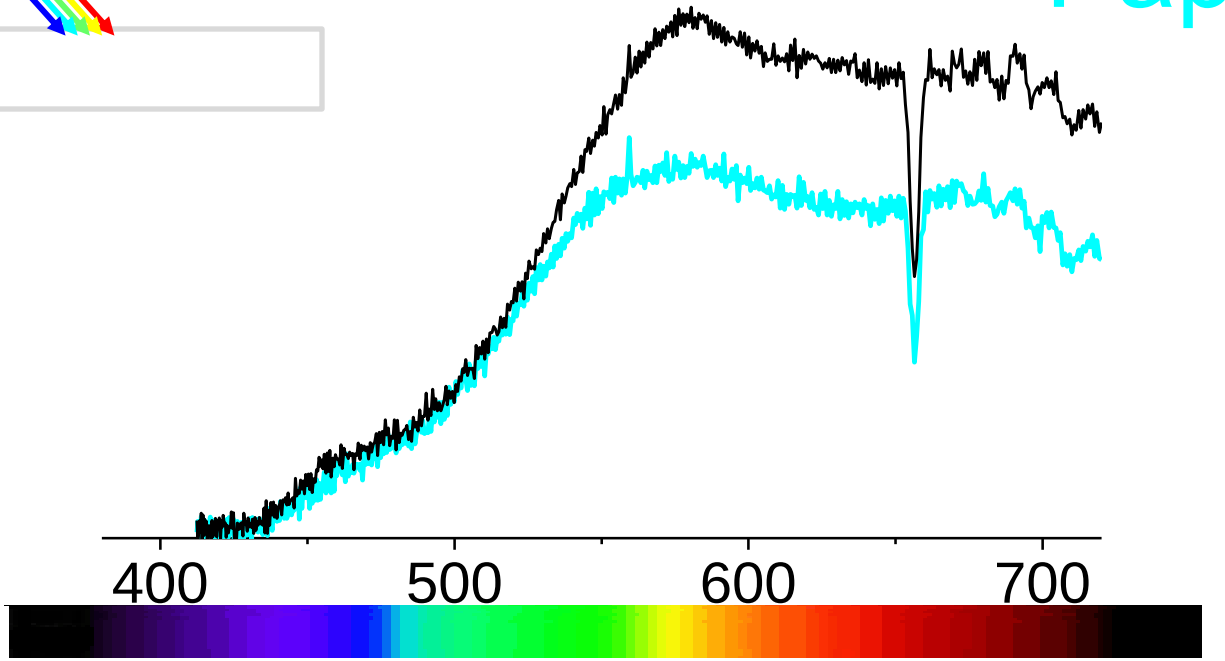
REFLEXÃO



Papel branco



Papel cyan

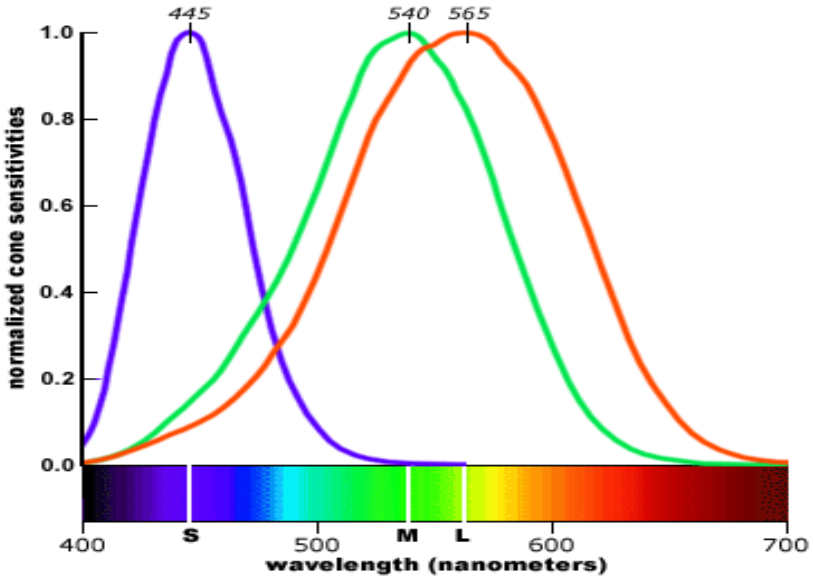


TRÍ-ESTÍMULOS

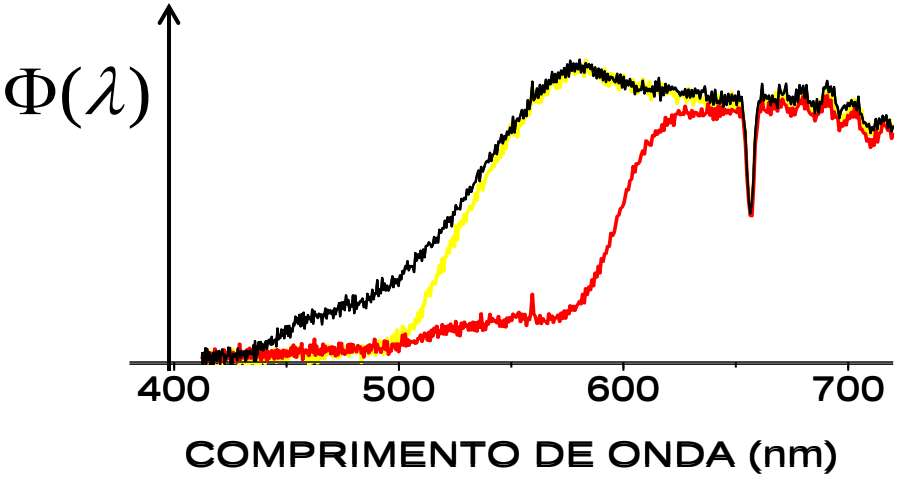
$$L_1 = \int \Phi(\lambda)\, L(\lambda)\, d\lambda$$

$$M_1 = \int \Phi(\lambda)\, M(\lambda)\, d\lambda$$

$$S_1 = \int \Phi(\lambda)\, S(\lambda)\, d\lambda$$

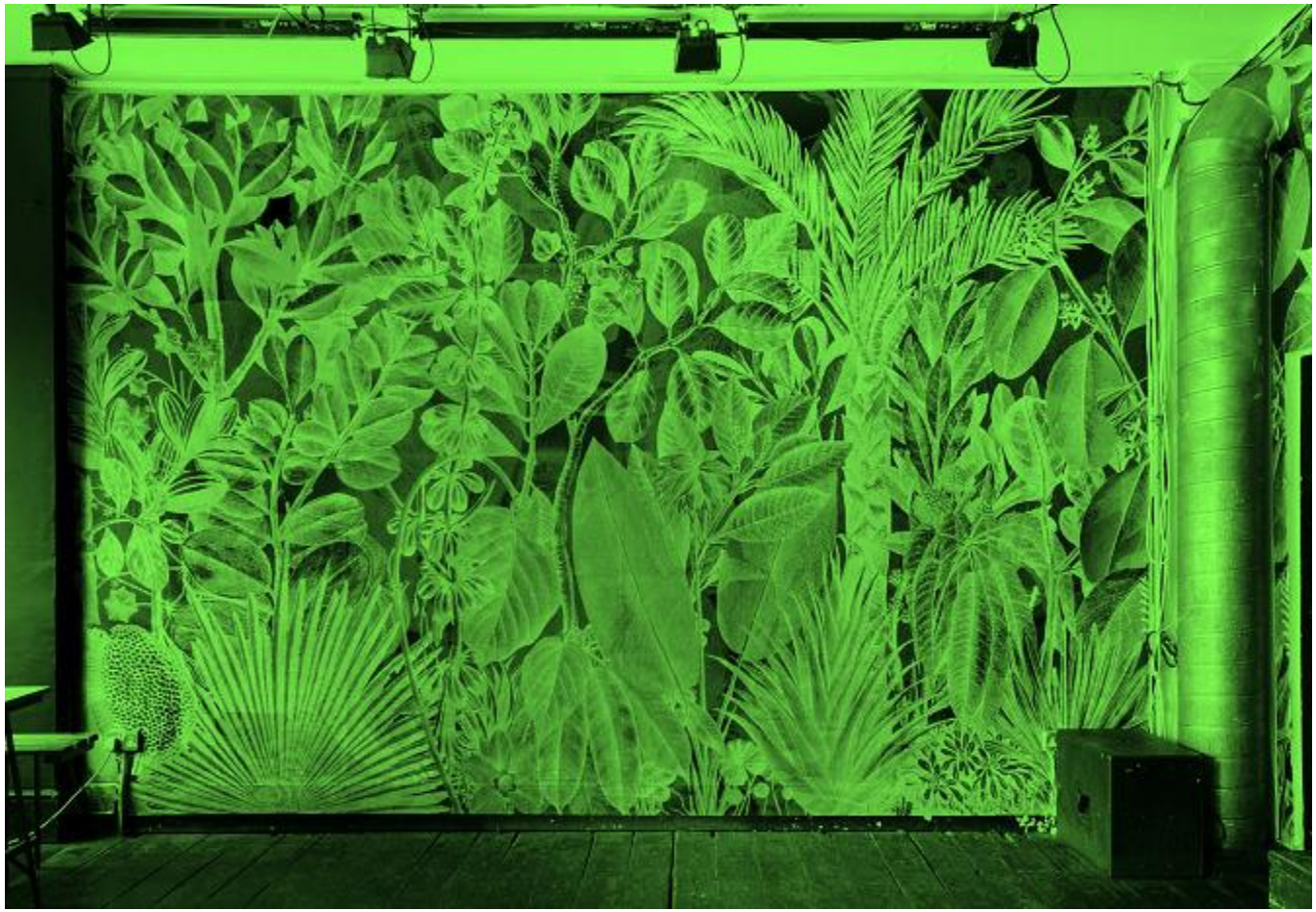


$$\Phi(\lambda) = I(\lambda).R(\lambda)$$



Reflectância: $R(\lambda)$

RGB by Carnovsky



RGB by Carnovsky

RGB by Carnovsky

RGB by Carnovsky

CORES SUBTRATIVAS

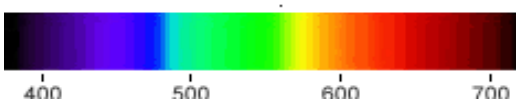
Subtrai

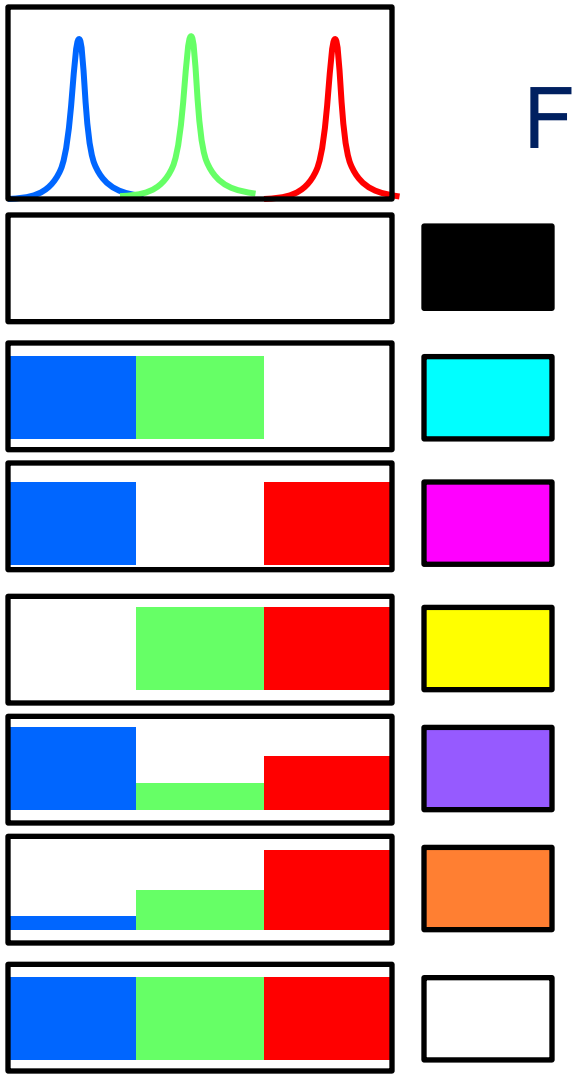
uma porcentagem

(dependente do comprimento de onda)

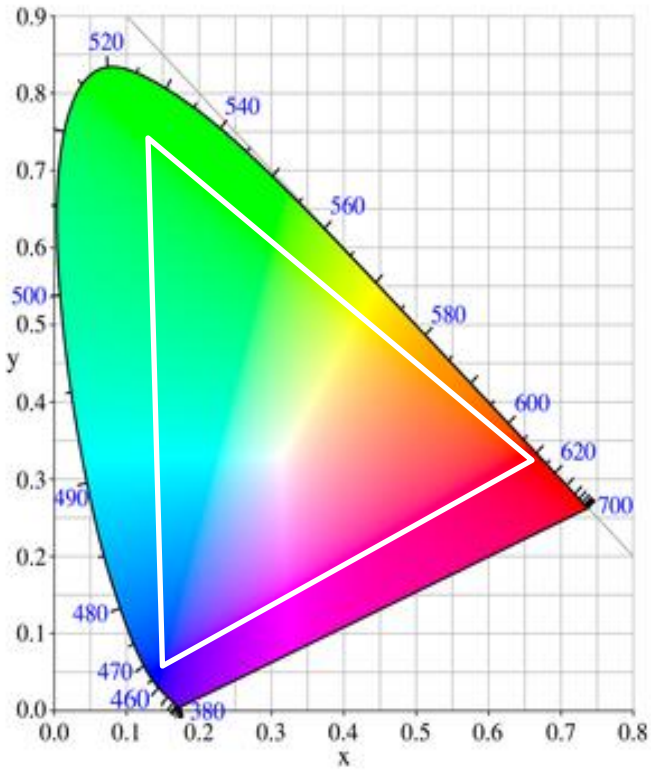
de intensidade de LUZ.

ADITIVAS IDEAIS

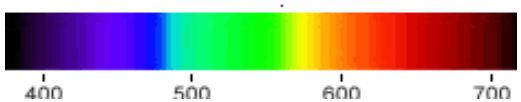




FONTES



SUBTRATIVAS IDEAIS

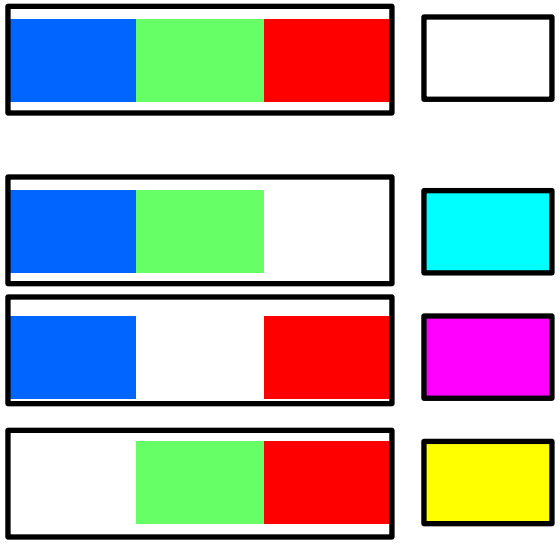


MEIO ABSORVE

VERMELHO

VERDE

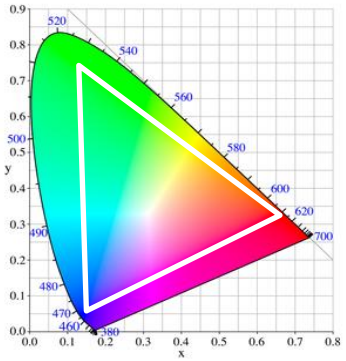
AZUL



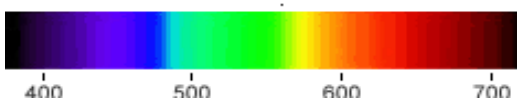
ILUMINANTE

PIGMENTOS

Branco – Vermelho = Cyan
Branco – Verde = Magenta
Branco – Azul = Amarelo



SUBTRATIVAS IDEAIS

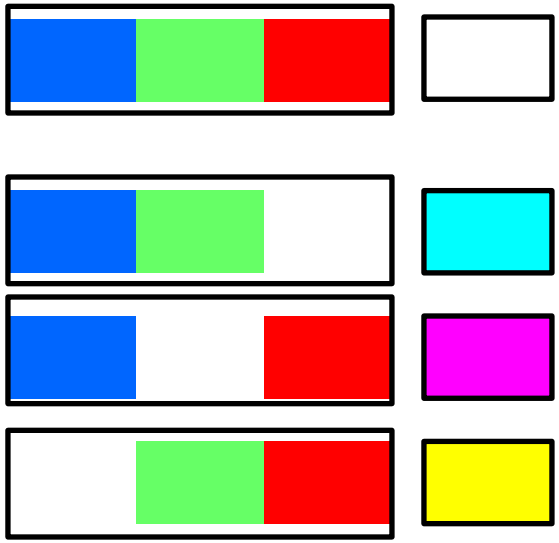


MEIO ABSORVE

VERMELHO

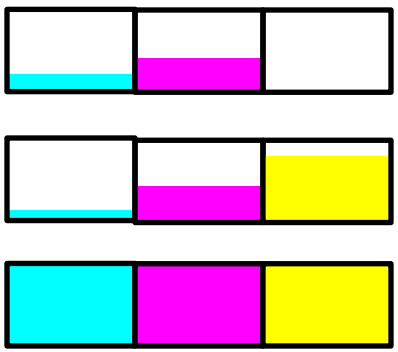
VERDE

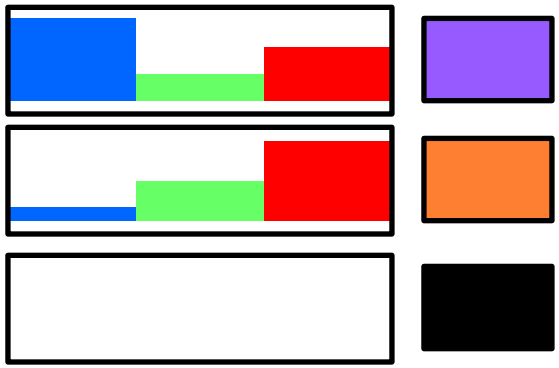
AZUL

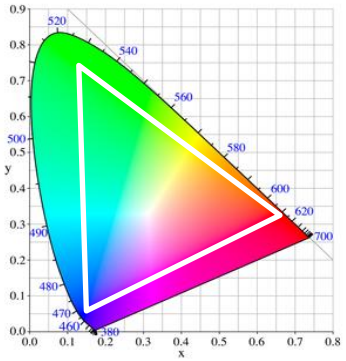


ILUMINANTE

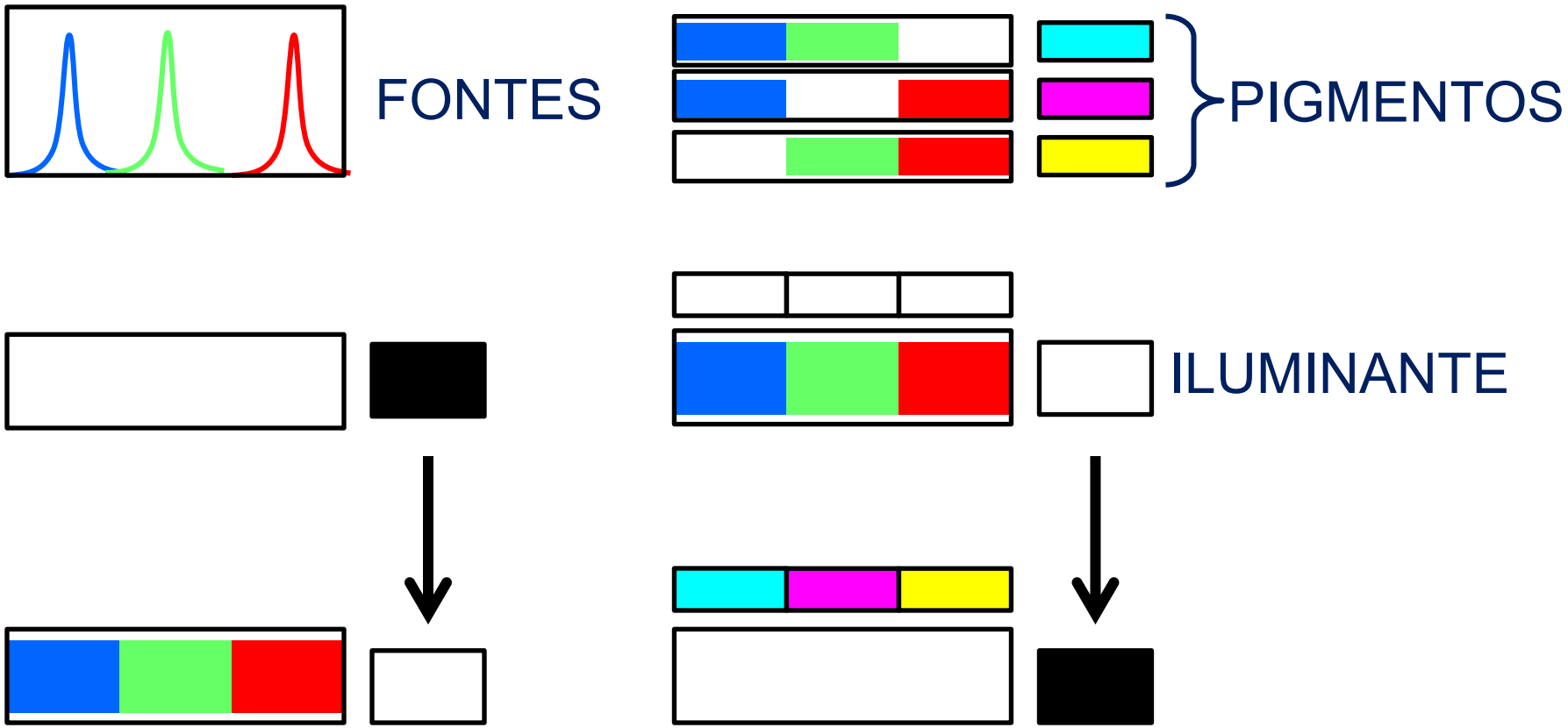
PIGMENTOS







ADITIVA vs SUBTRATIVA



CORES PRIMÁRIAS

" MAIS CONHECIDAS"

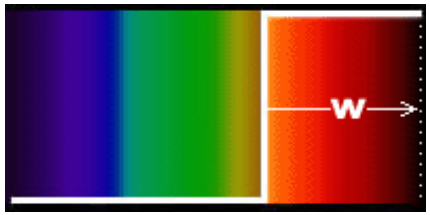
"MAIS ADEQUADAS"

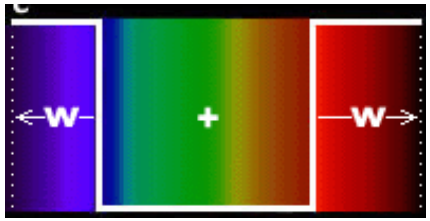
3 cores básicas subtrativas que podem gerar um espaço com cromaticidade-saturação maximizados.

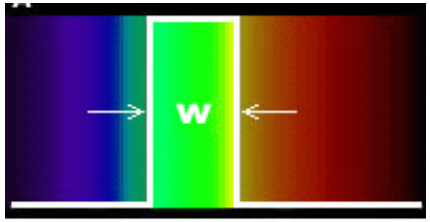
REFLECTÂNCIAS

Bandas de absorção

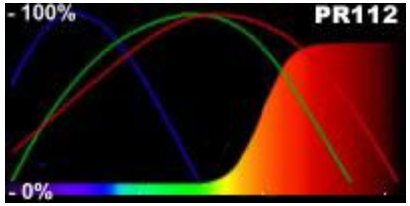
Ideais



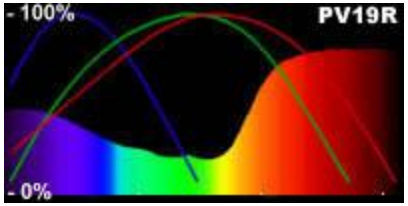




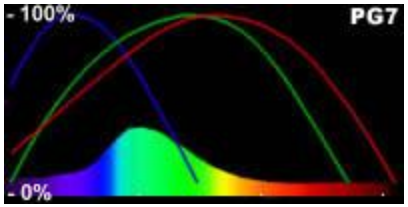
Reais



Naphthol AS-D red



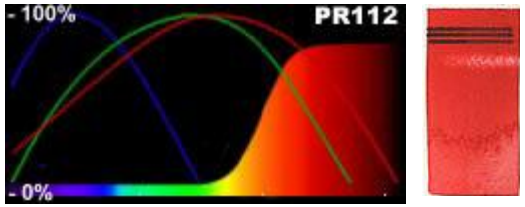
Quinacridone rose



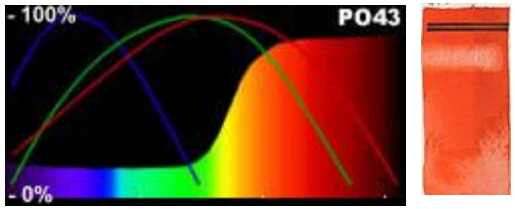
Phthalocyanine green

REFLECTÂNCIAS

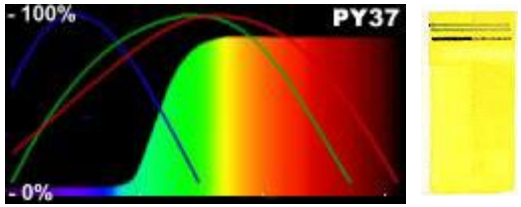
Naphthol AS-D red



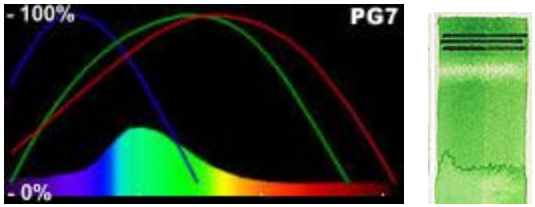
Perinone orange



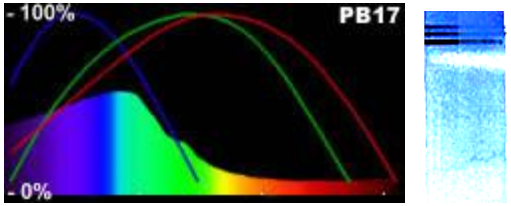
Cadmium yellow



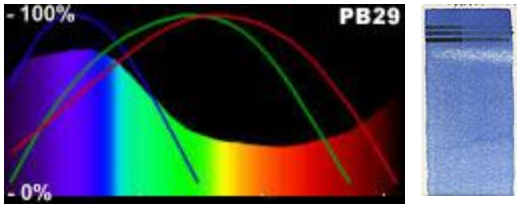
Phthalocyanine green



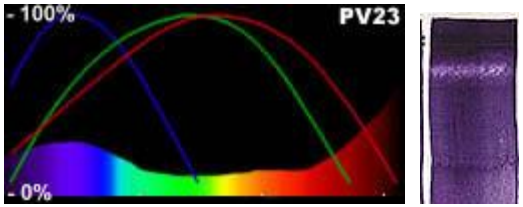
Phthalocyanine cyan



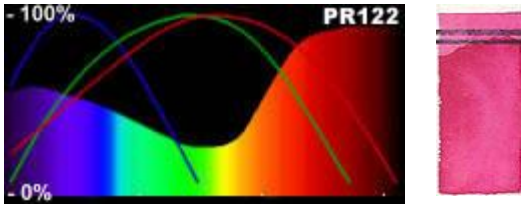
Ultramarine blue



Dioxazine violet

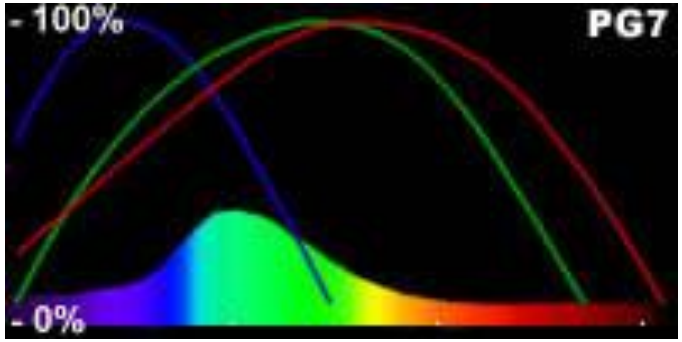


Quinacridone magenta



REFLECTÂNCIAS

Verdes tem baixa reflectância

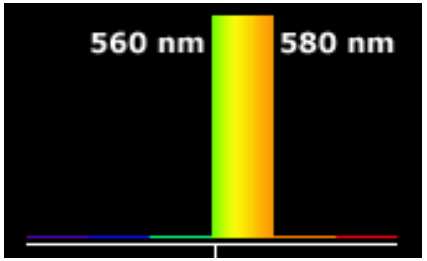


Phthalocyanine green

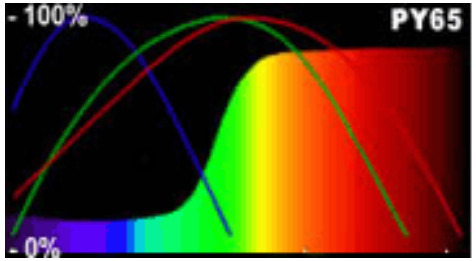
REFLECTÂNCIAS

Não existem amarelos “puros”

Ideal



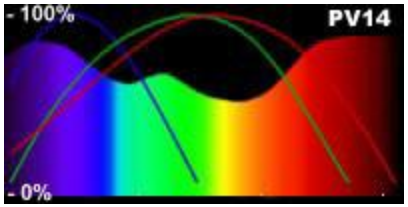
Real

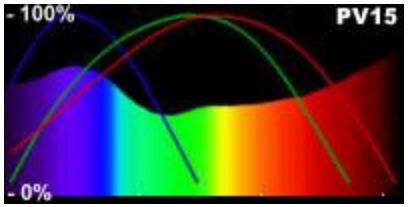


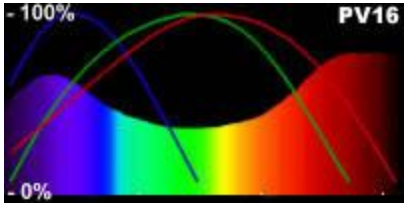
REFLECTÂNCIAS

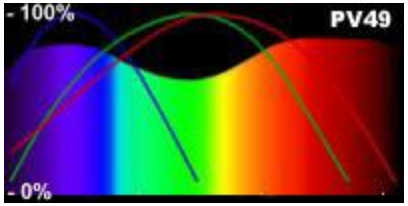
Saturação dos pigmentos

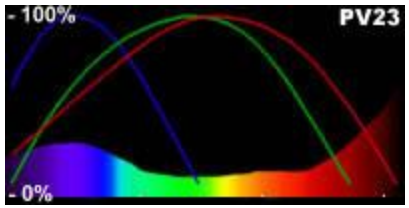
Não existem violetas “puros”



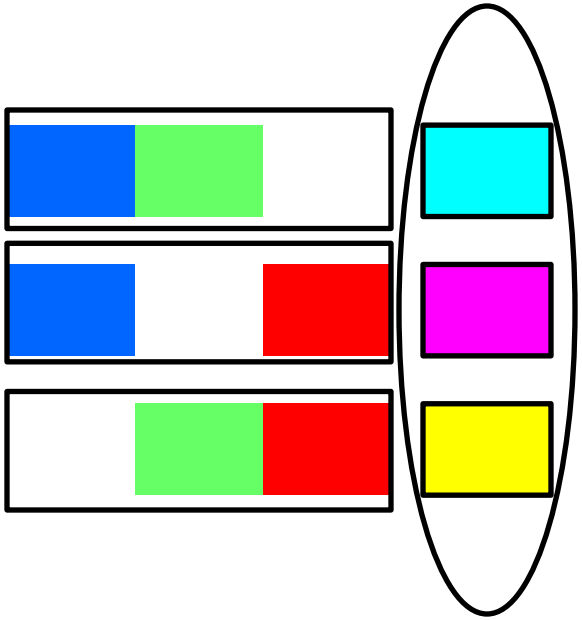


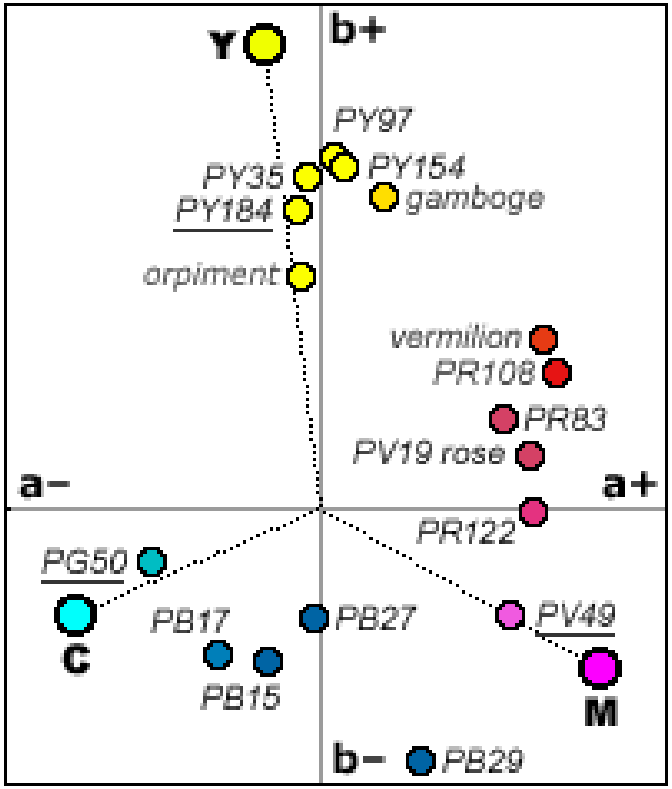






CORES PRIMÁRIAS





PY184: bismuth yellow
PG50: cobalt teal blue
PV49: cobalt violet