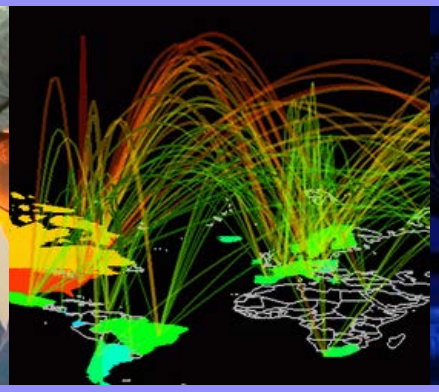
Optika

Svetska godina svetlosti 2015

UNESCO

INTERNATIONAL YEAR OF LIGHT 2015

Medicina **Komunikacije** **Ekonomija** **Okolina** **Društvo**


Svetska godina svetlosti

The resolution was adopted in Committee on 3 December 2013 with many co-sponsors, and subsequently adopted at the General Assembly by unanimous acclamation.

United Nations A/RES/68/221

General Assembly

Distr.: General
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Sixty-eighth session
Agenda item 21 (*b*)

Resolution adopted by the General Assembly on 20 December 2013

[*on the report of the Second Committee (A/68/440/Add.2)*]

68/221. International Year of Light and Light-based Technologies, 2015

Primene svetlosti u tehnici

- Prenos informacija
- Senzori
- Prenos energije

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \equiv 299792458 m/s$$

Pointingov vektor

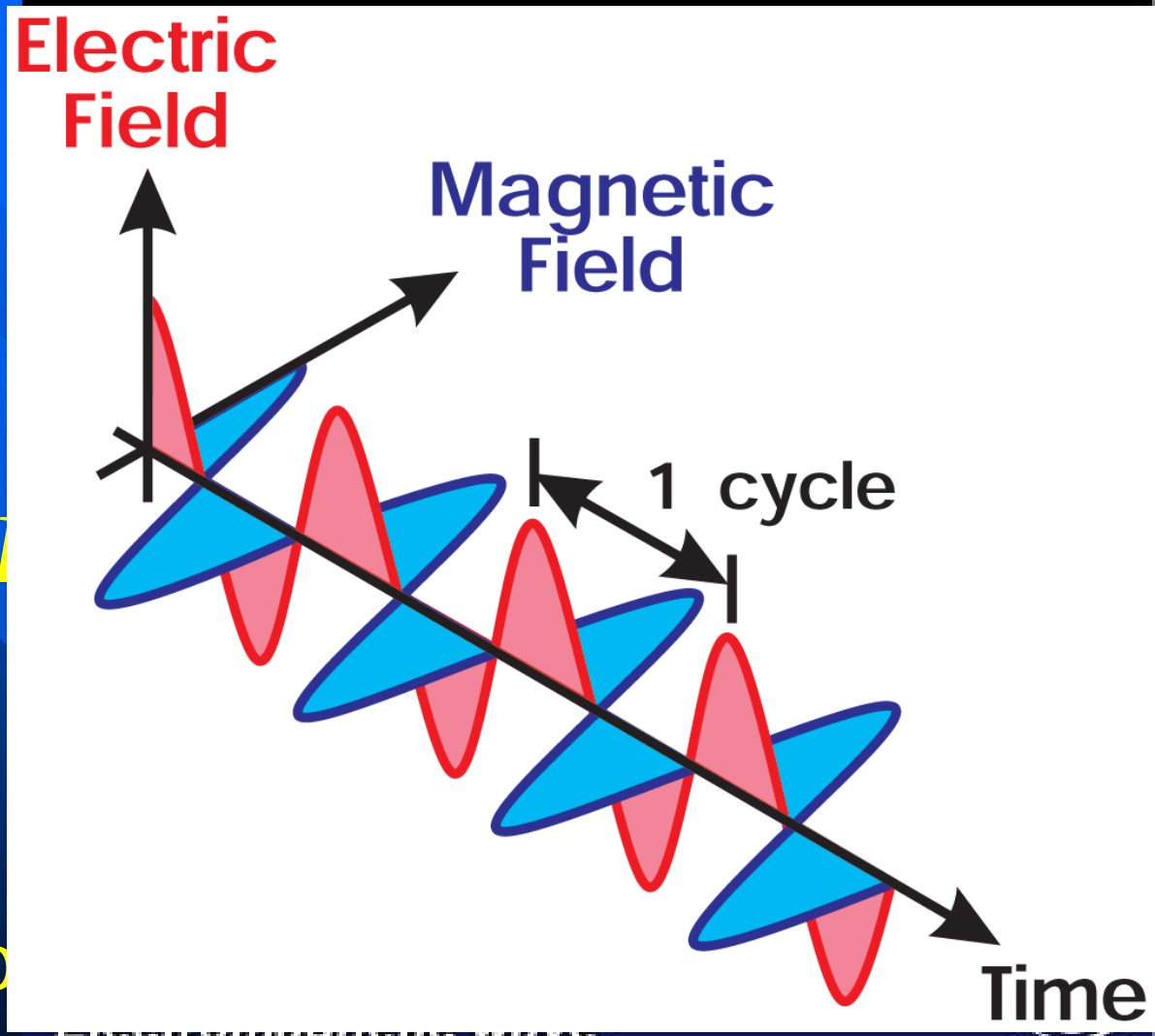
$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

Iradijansa:

$$I = \langle S \rangle_T = \frac{c\varepsilon_0}{2}$$

Fotonski fluks:

Φ



Stanja polarizacije svetlosti

- Za ravanski talas koji se prostire u smeru *z* ose važi:

$$\vec{E}_x(z,t) = \vec{e}_x E_{0x} \cos(kz - \omega t)$$

$$\vec{E}_y(z,t) = \vec{e}_y E_{0y} \cos(kz - \omega t + \varepsilon)$$

ε relativna fazna razlika između komponenata

k talasni broj duž z ose

Stanja polarizacije svetlosti

Za $\varepsilon = 2m\pi$, $m \in Z$, dobijamo linearno polarizovanu svetlost:

$$\vec{E}(z,t) = \vec{E}_x + \vec{E}_y = \left(\vec{e}_x E_{0x} + \vec{e}_y E_{0y}\right)\cos(kz - \omega t)$$

$E_{0x} = E_{0y} = E_0$ i $\varepsilon = \pi/2$ dobijamo cirkularno polarizovanu svetlost:

$$\vec{E}_x(z,t) = \vec{e}_x E_0 \cos(kz - \omega t) \qquad \vec{E}_y(z,t) = \vec{e}_y E_0 \sin(kz - \omega t)$$

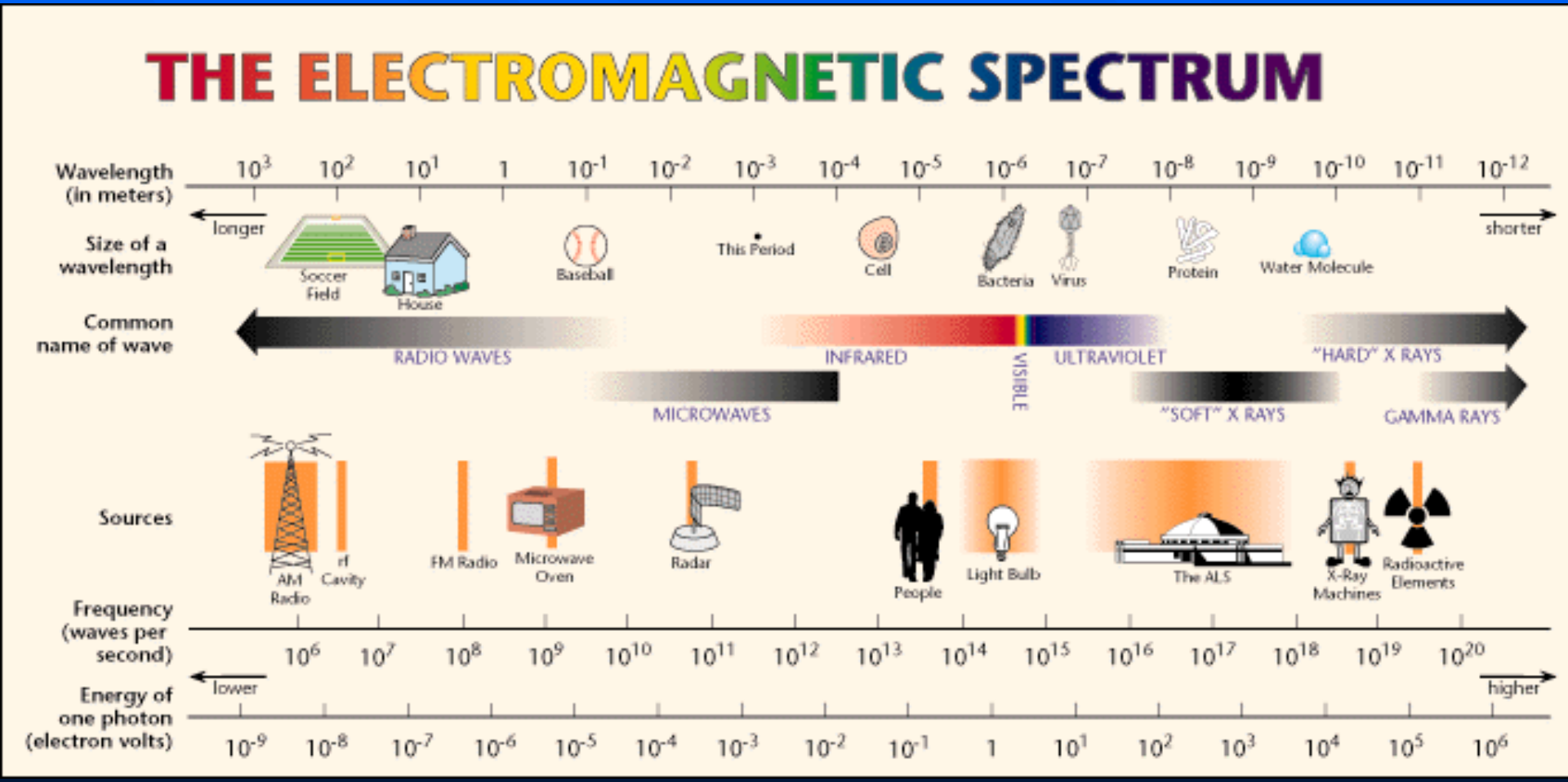
$$\vec{E}_R = E_0\left[\vec{e}_x \cos(kz - \omega t) + \vec{e}_y \sin(kz - \omega t)\right]$$

$$\vec{E}_L = E_0\left[\vec{e}_x \cos(kz - \omega t) - \vec{e}_y \sin(kz - \omega t)\right]$$

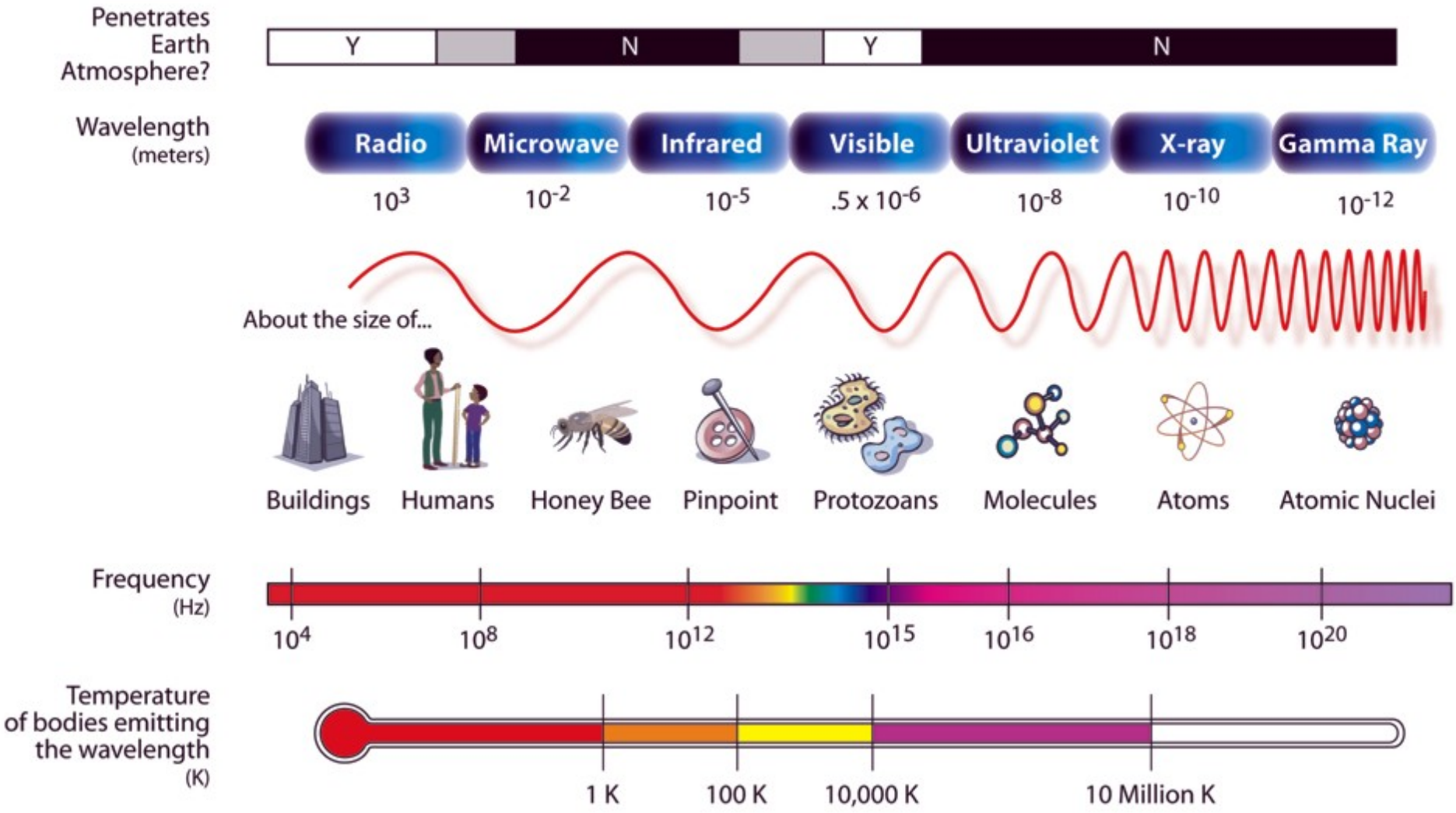
Linearno polarizovana svetlost

- Pravac vektora električnog polja je konstantan iako se intenzitet i smer menjaju u vremenu
- Može se pretstaviti kao superpozicija levo i desno cirkularno polarizovane svetlosti

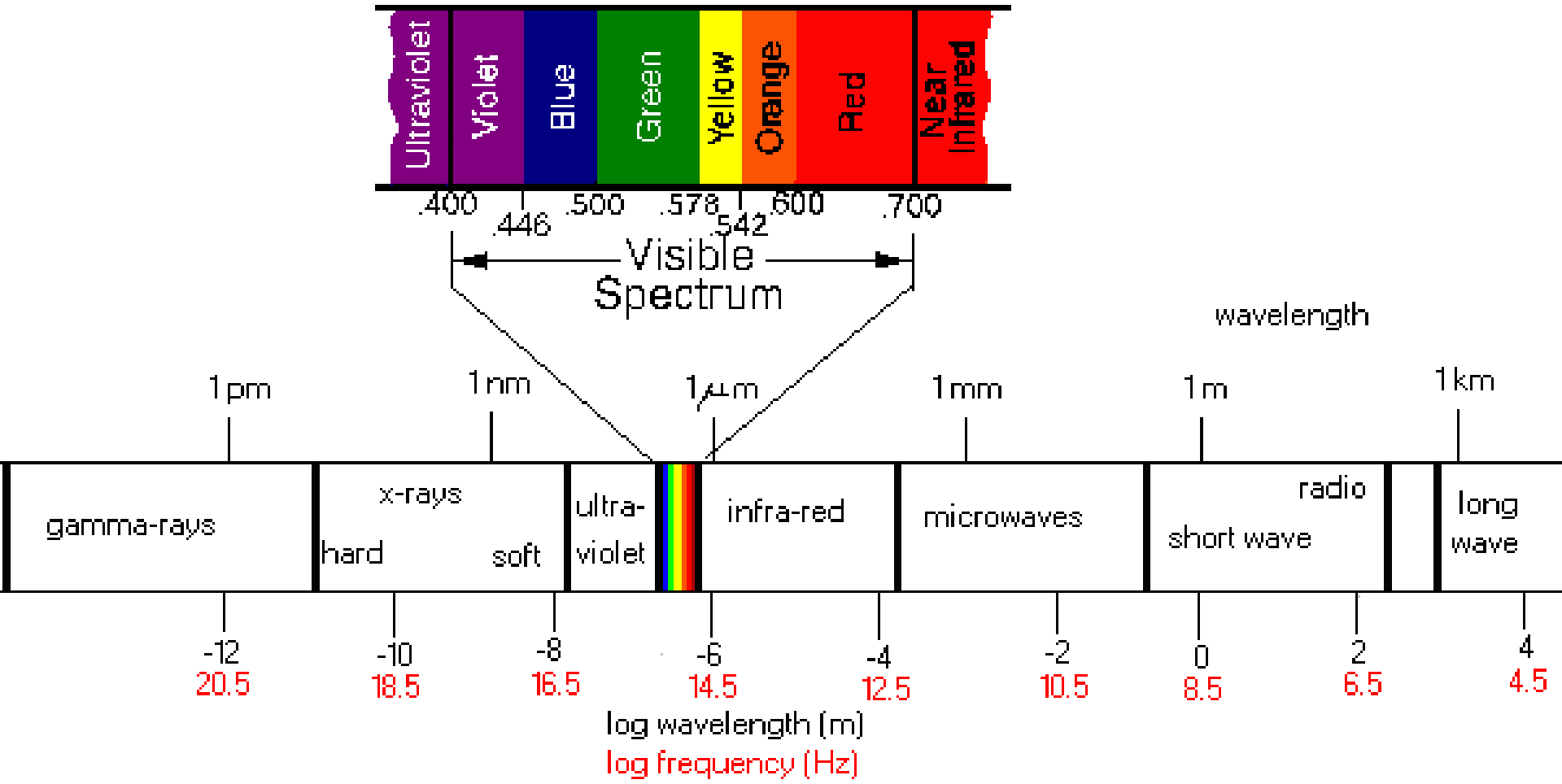
Elektromagnetni spektar



THE ELECTROMAGNETIC SPECTRUM



Vidljiva svetlost

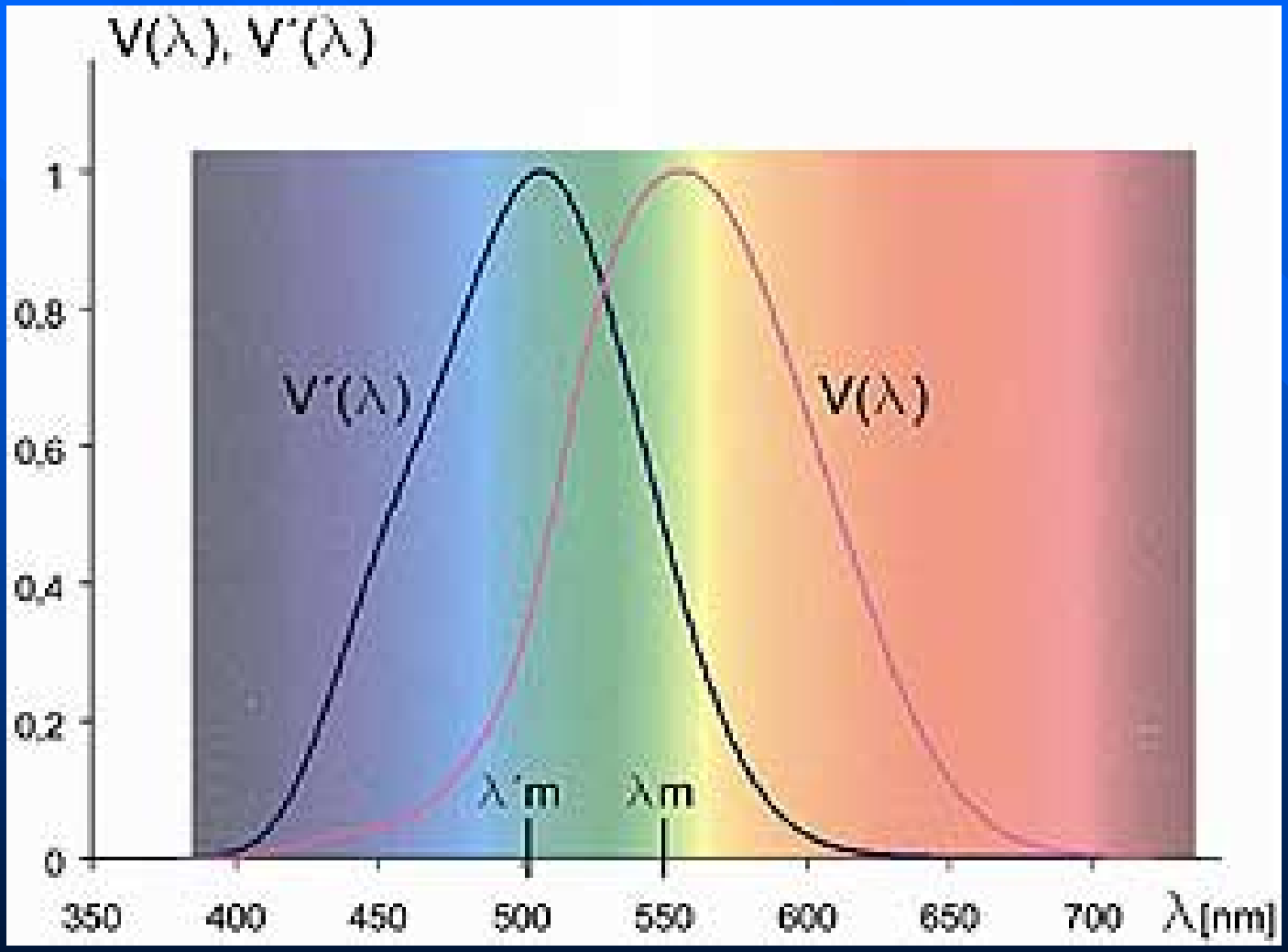


Vidljiva svetlost

Boja	λ [nm]	υ [THz]
Crvena	780-622	384-482
Oranž	622-597	482-503
Žuta	597-577	503-520
Zelena	577-492	520-610
Plava	492-455	610-659
Ljubičasta	455-390	659-769

$$\lambda = c/\upsilon$$

Osetljivost ljudskog oka



Interakcija svetlosti sa materijom

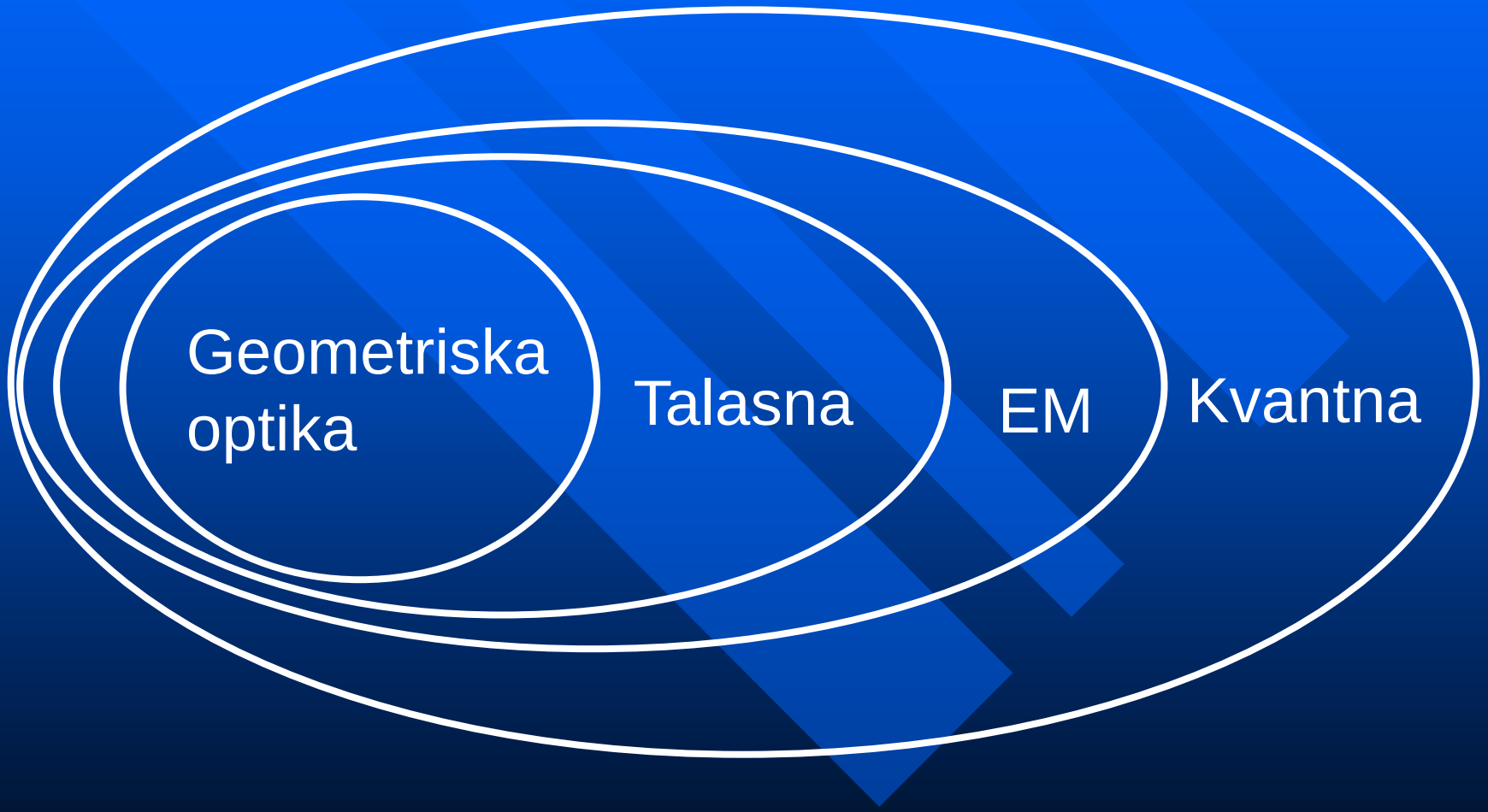
$$v = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\frac{1}{\sqrt{\mu_r\varepsilon_r}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}} \equiv \frac{c}{n}$$

Za dielektrike: $\mu_r \to 1 \Rightarrow n = \sqrt{\varepsilon_r}$

$n = n(\lambda)$ Disperziona relacija

Košijev zakon $n = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \ldots$

Pristupi razmatranja svetlosti



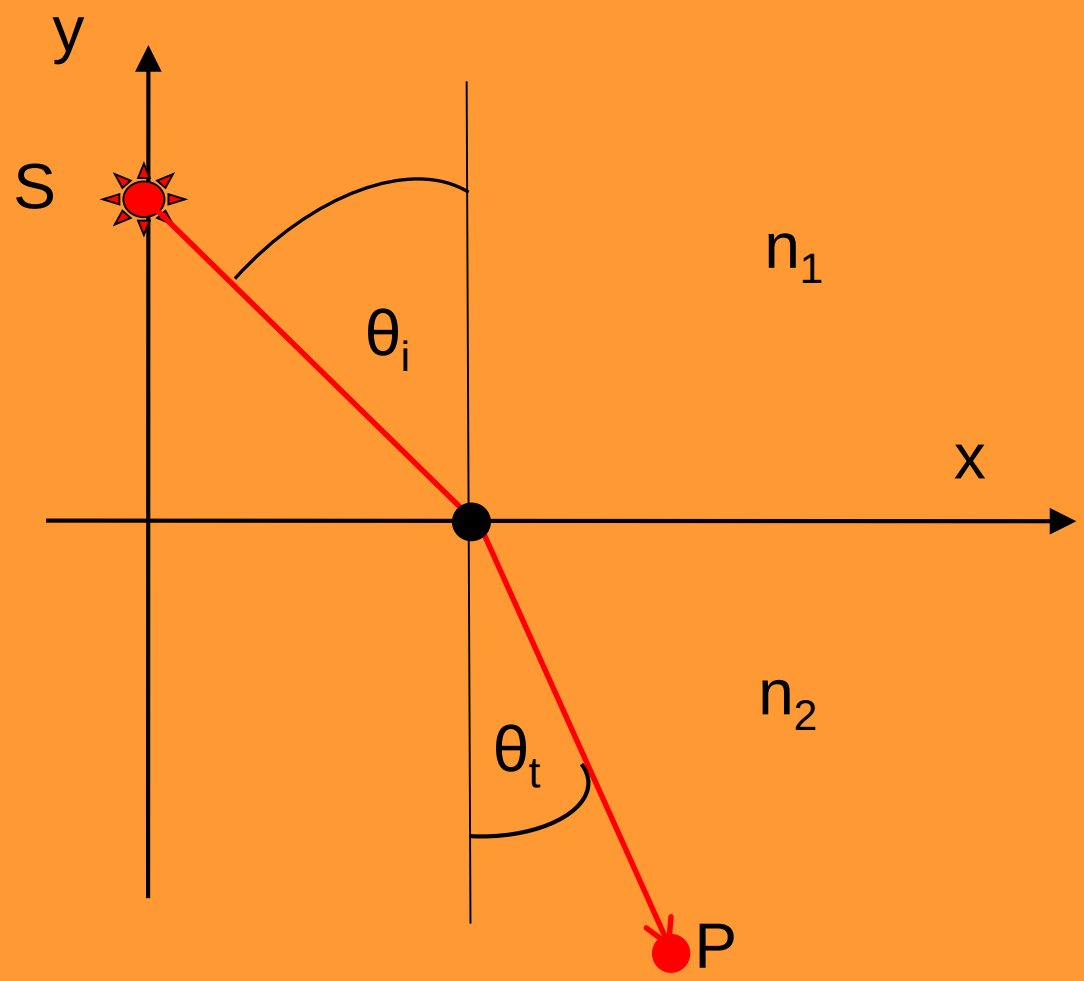
Geometriska optika

$$\lambda \to 0$$

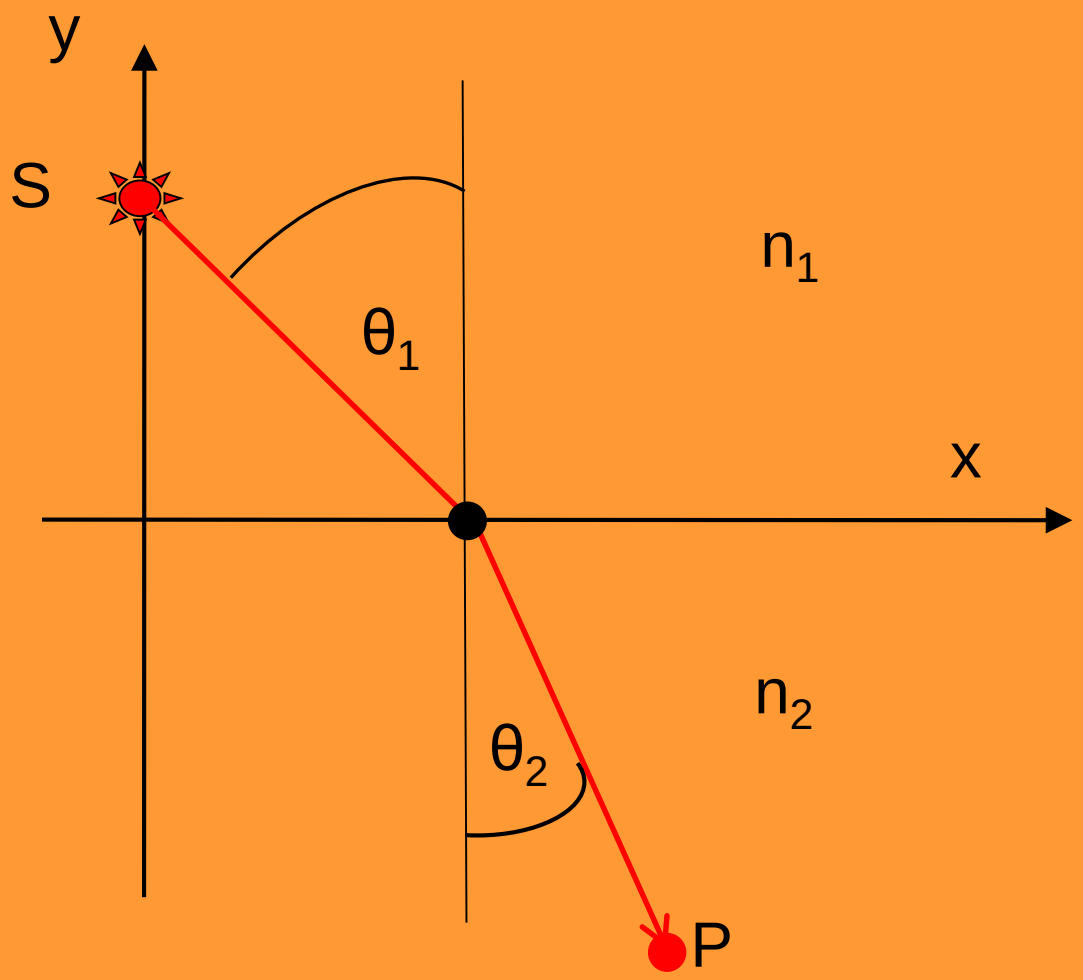
- Pravolinisko prostiranje u homogenoj sredini
- Nezavisnost svetlosnih zaraka
- Zakon odbijanja svetlosti
- Zakon prelamanja svetlosti

Zakoni geometriske optike su posledica Fermaovog principa: Svetlosni zrak će se kretati između dve tačke po putanji koja zahteva najkraće vreme.

Primena Fermaovog principa na prelamanje

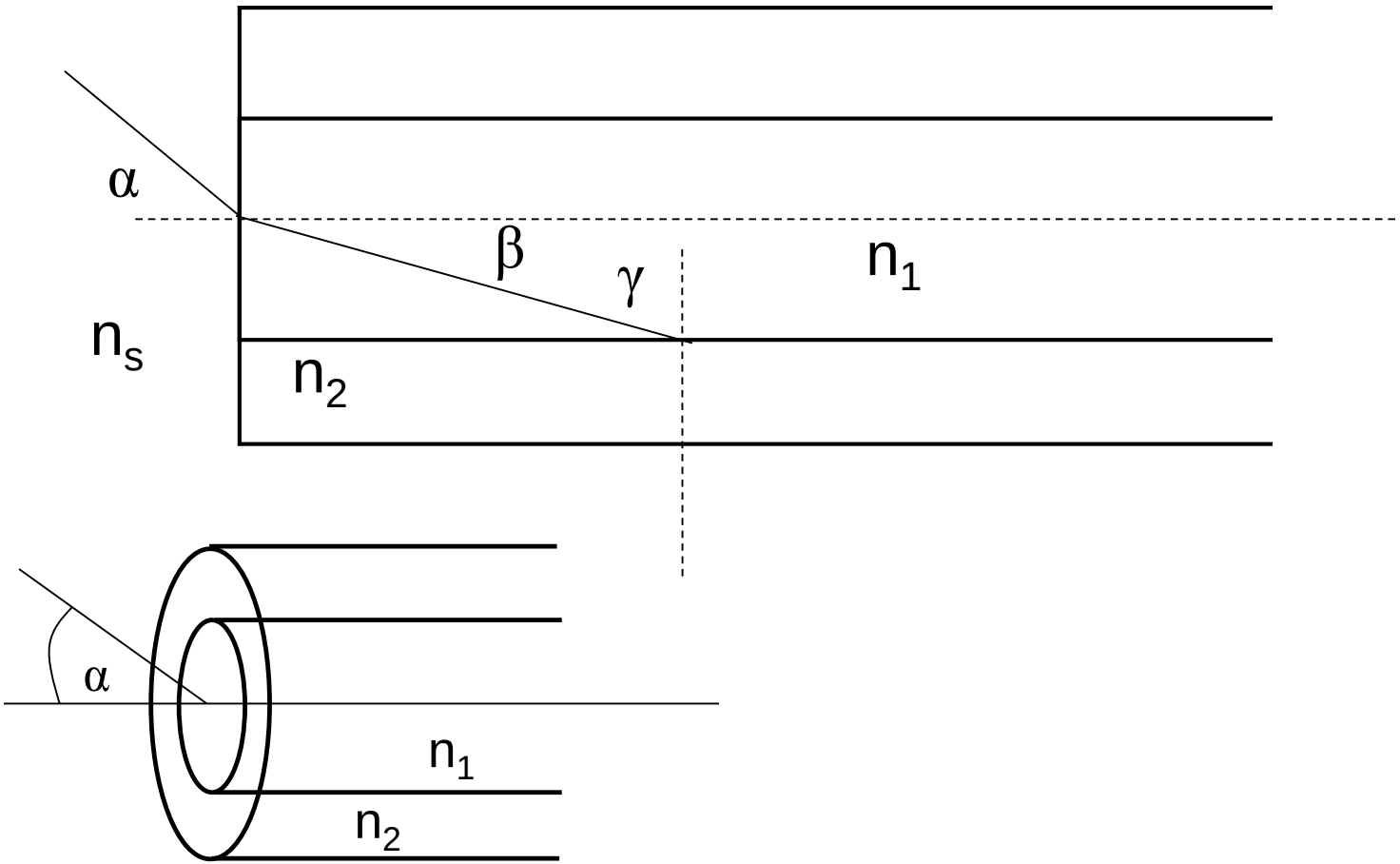


Šnelov zakon

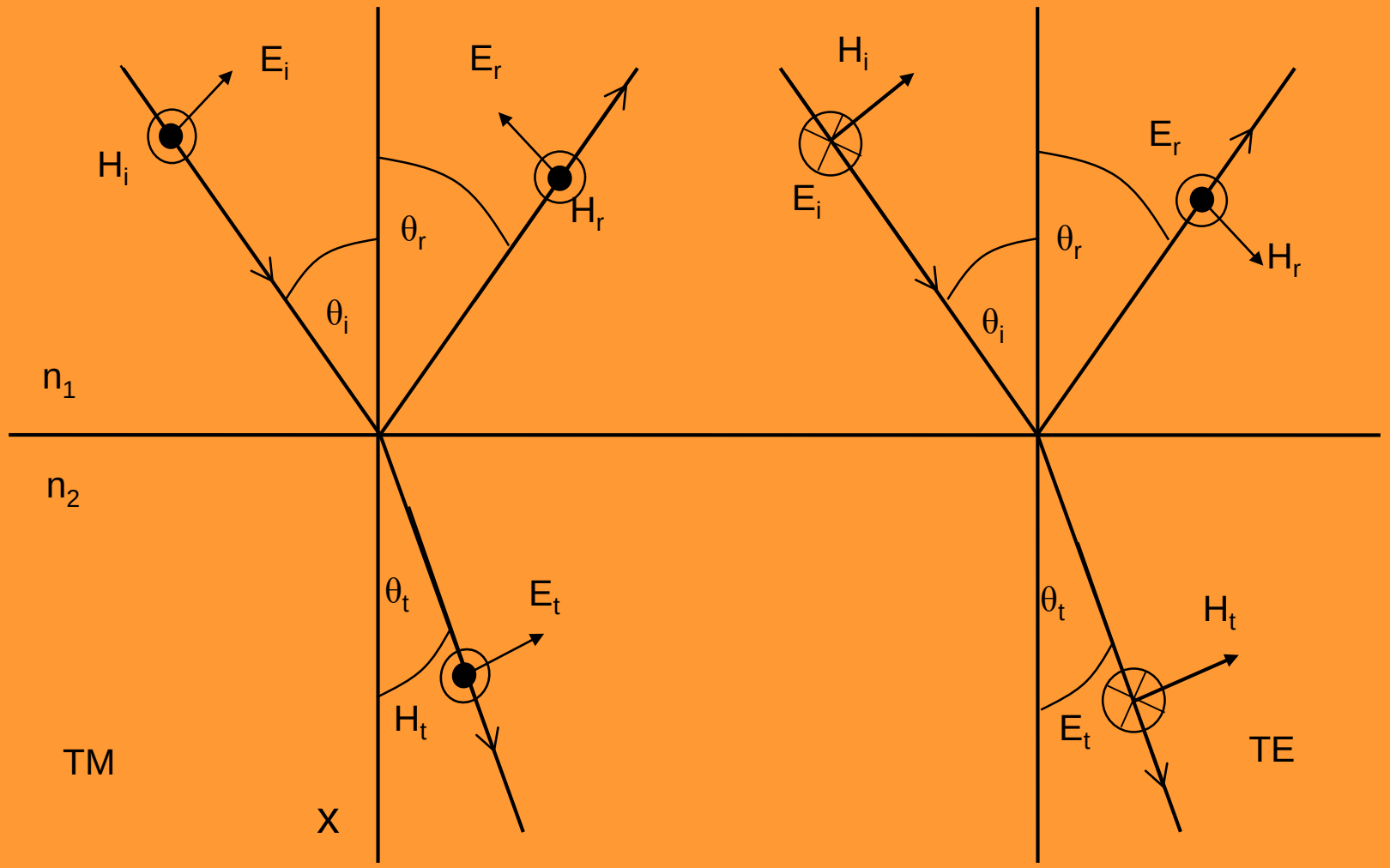


$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Totalna unutrašnja refleksija



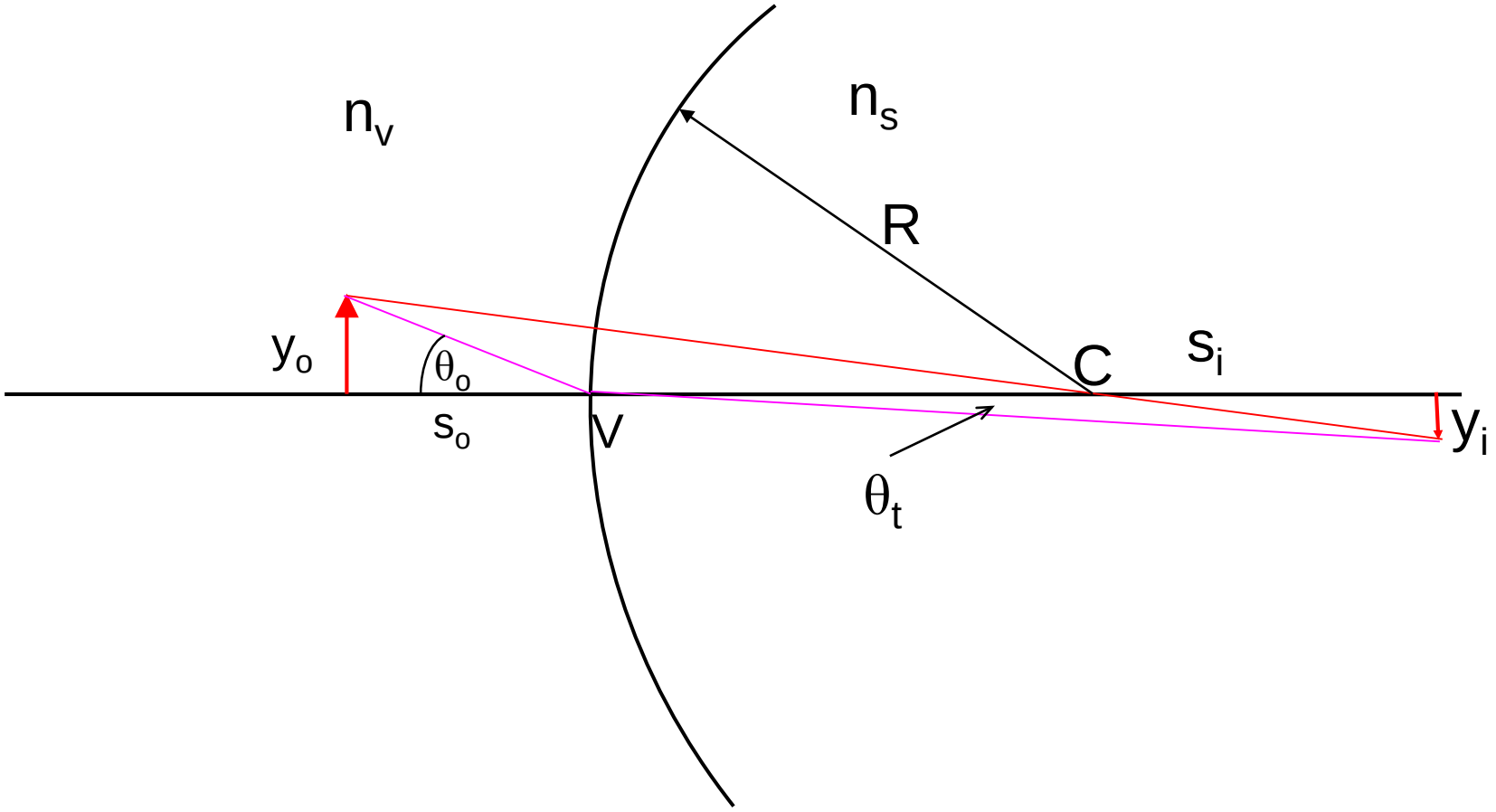
Frenelovi koeficijenti



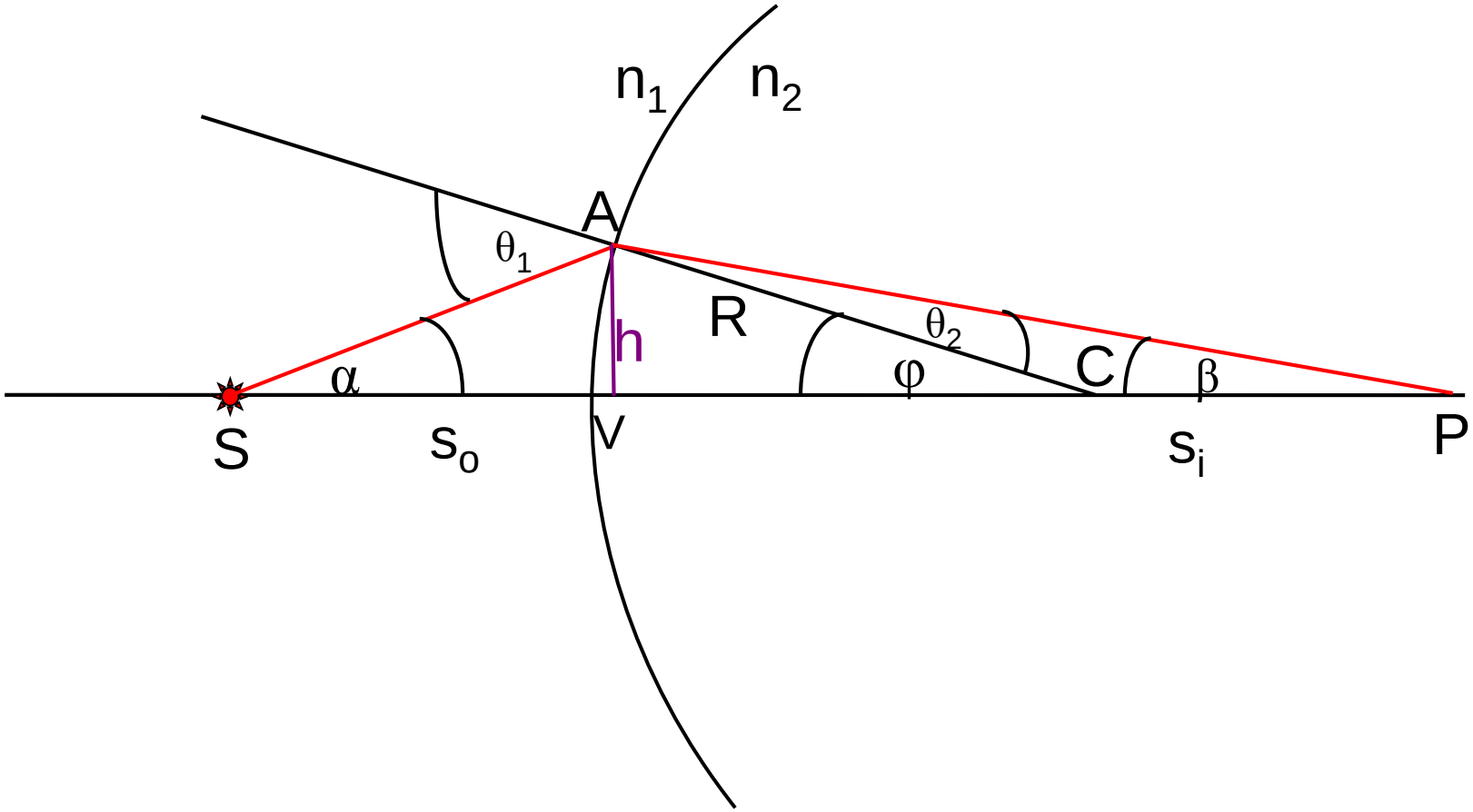
Polarizacioni (Brusterov) ugao

$$tg\theta_P = \frac{n_2}{n_1}$$

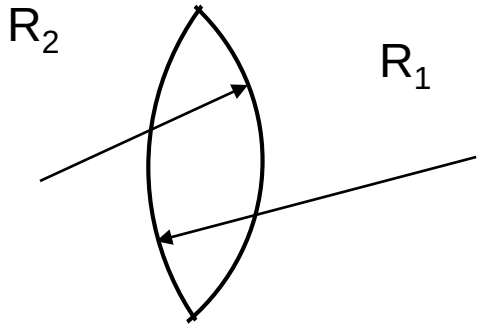
Prelamanje na sfernoj površini

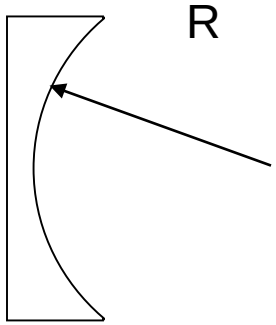


Prelamanje na sfernoj površini

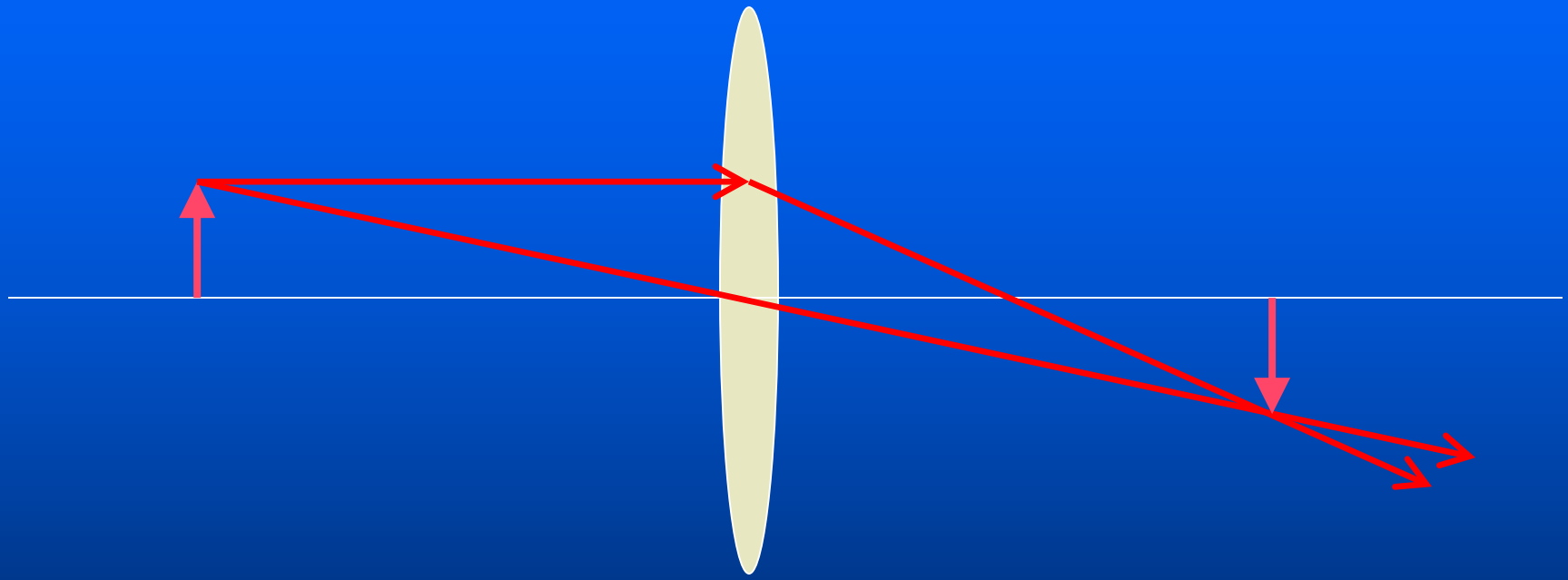


Sferna sočiva

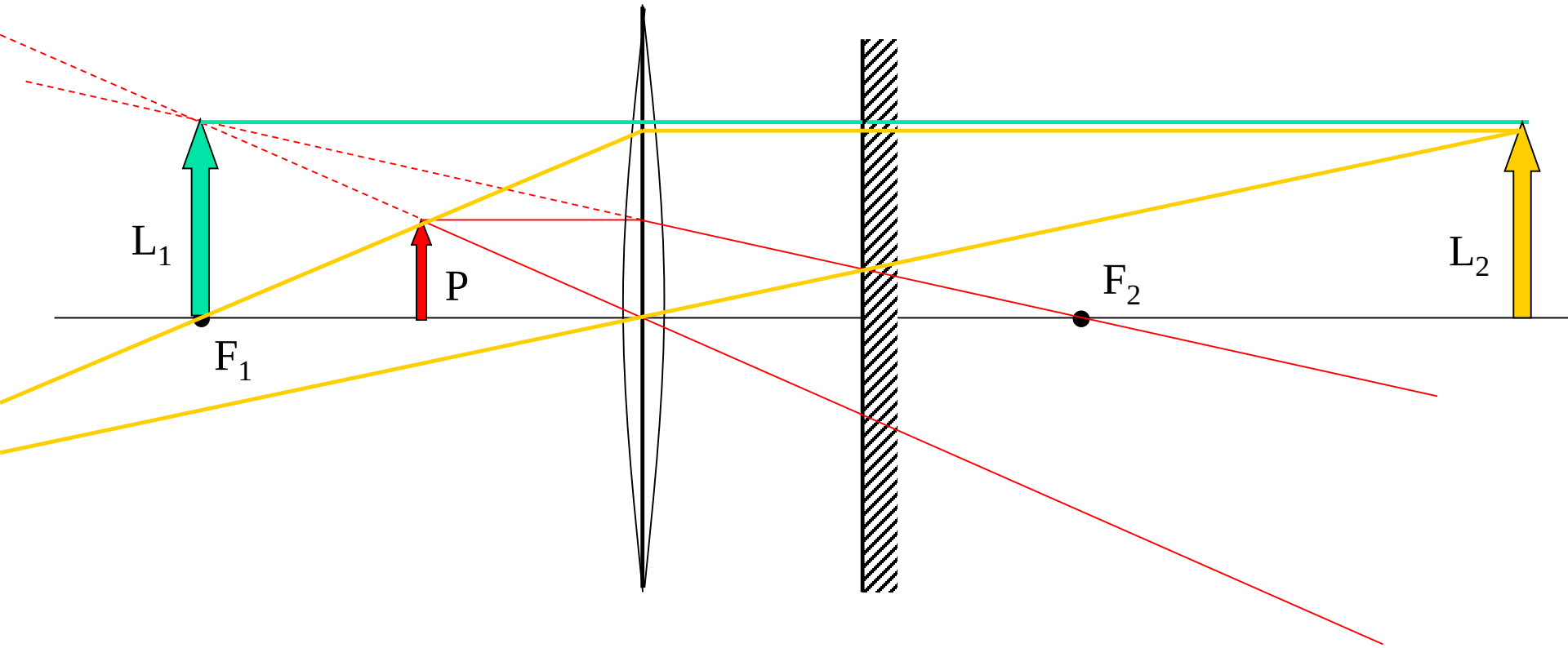




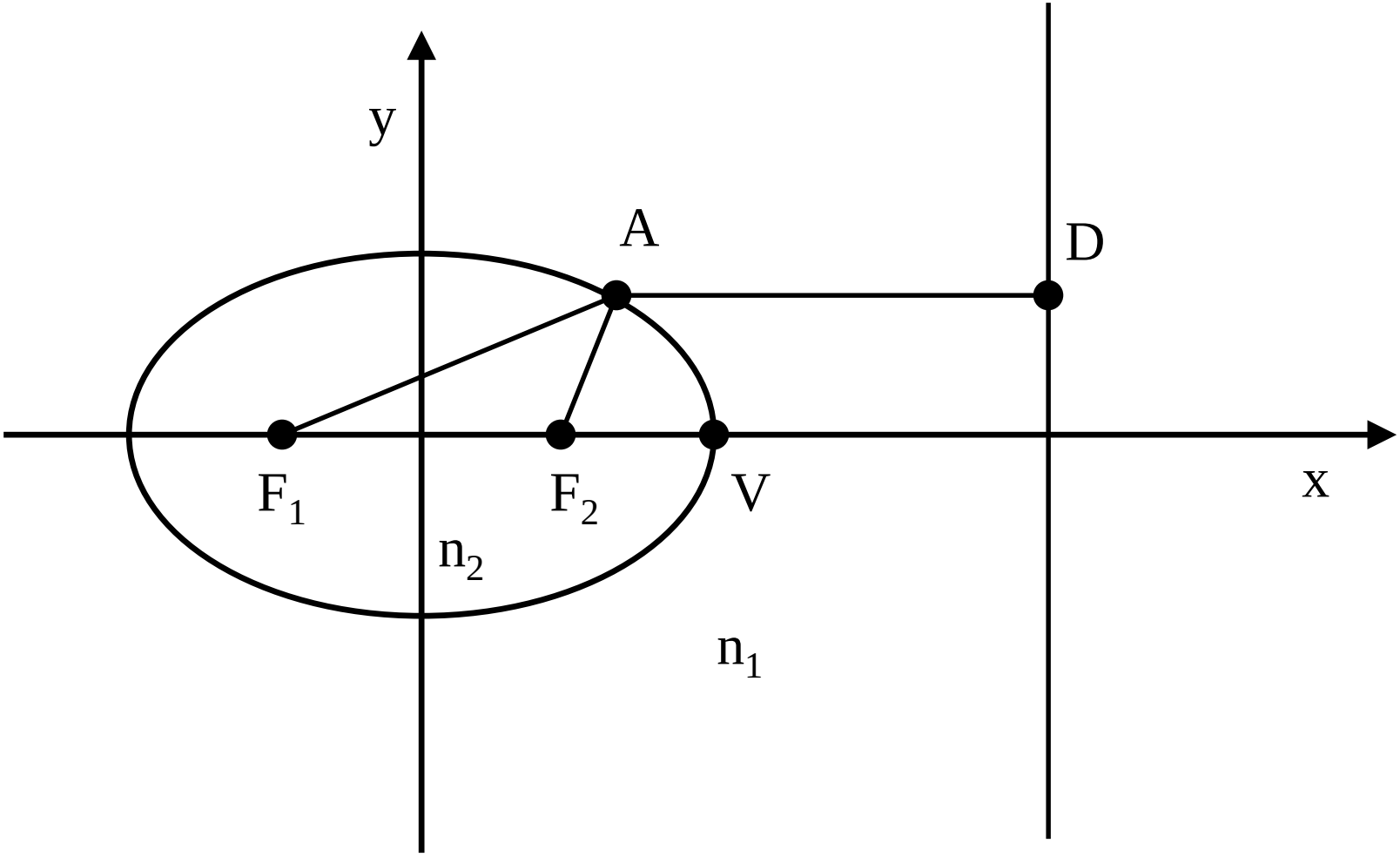
Sferna sočiva



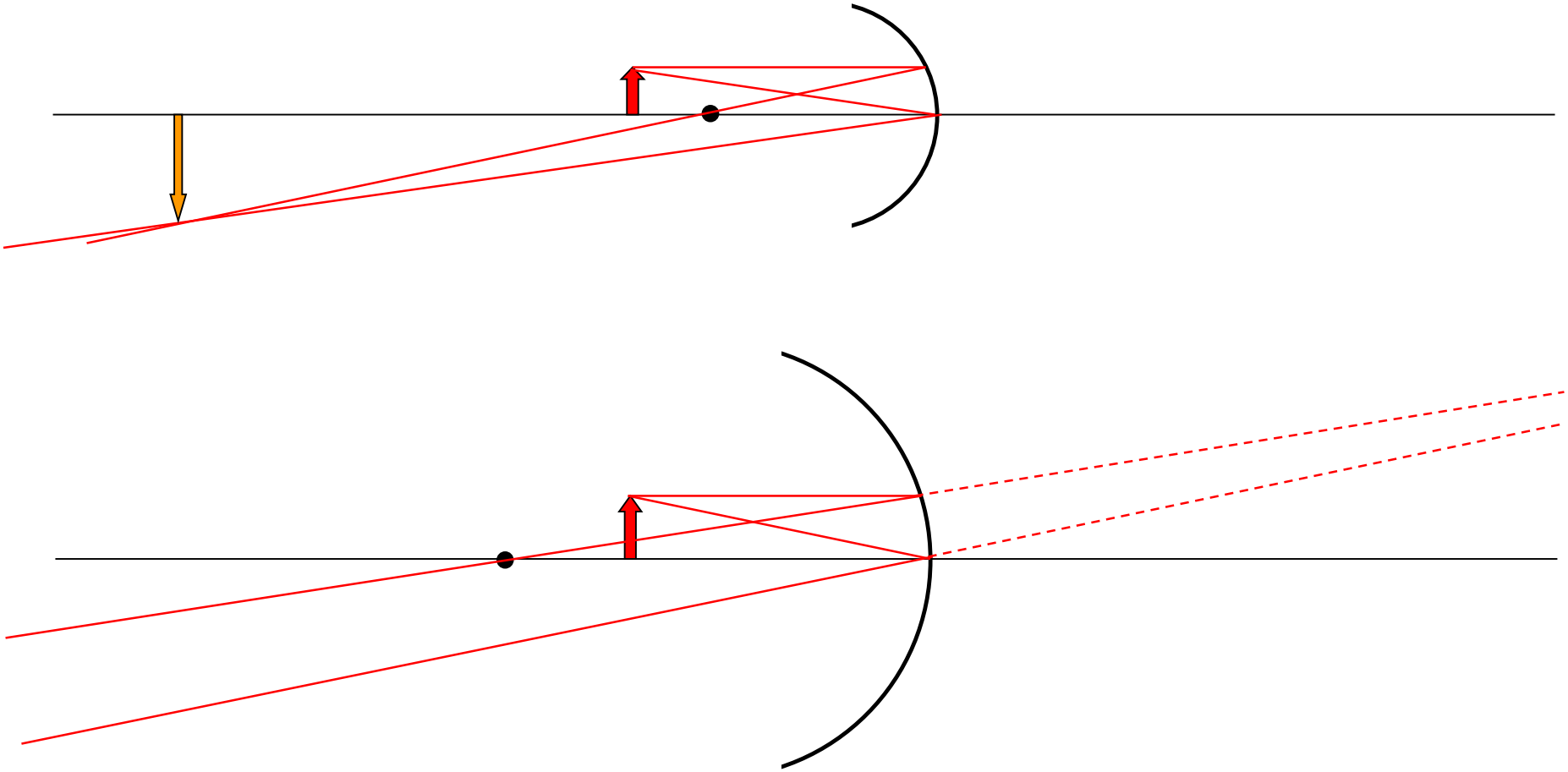
Optički sistemi



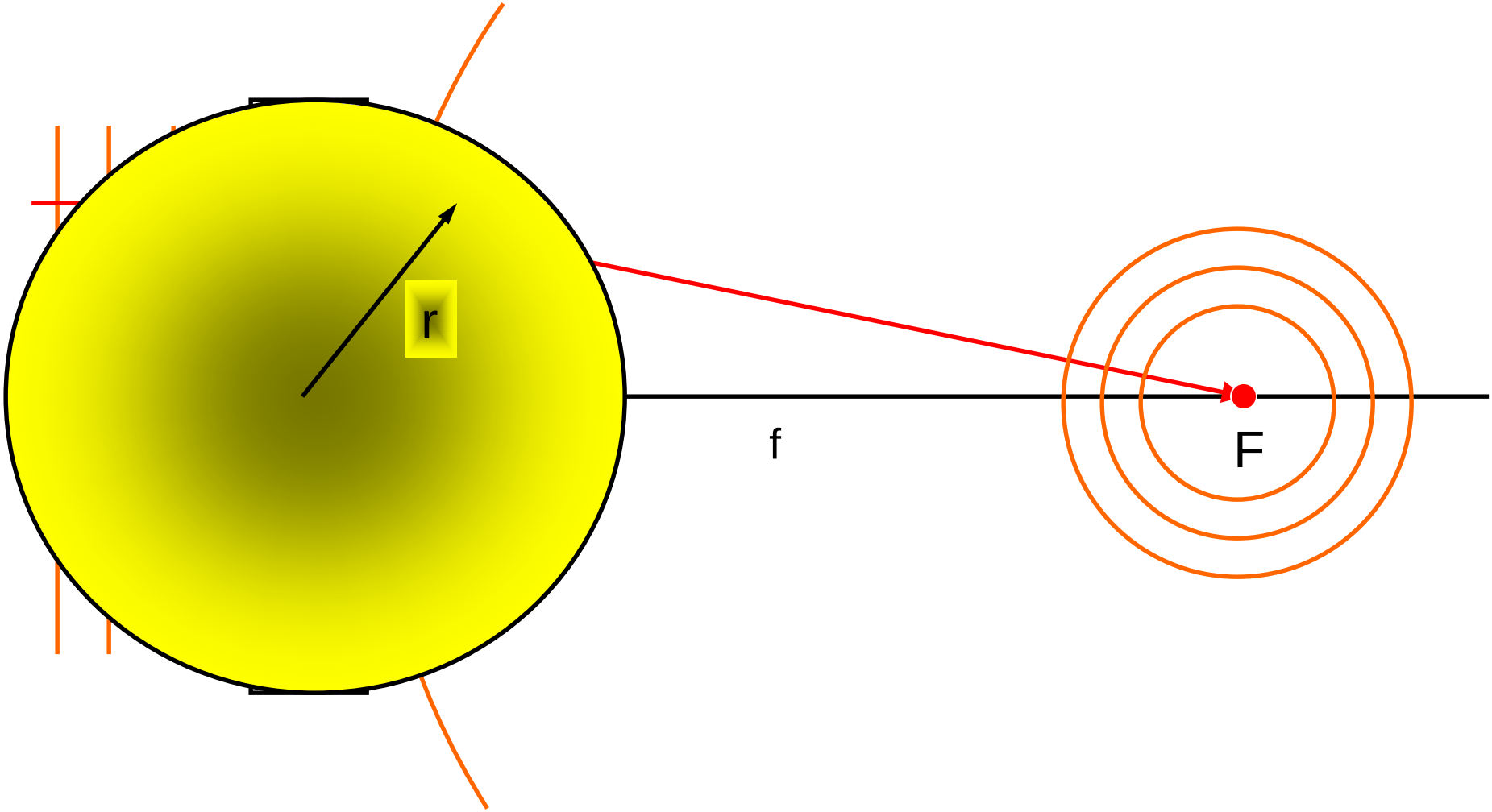
Aberacije sočiva



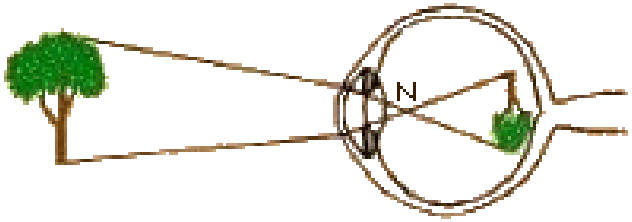
Ogledala

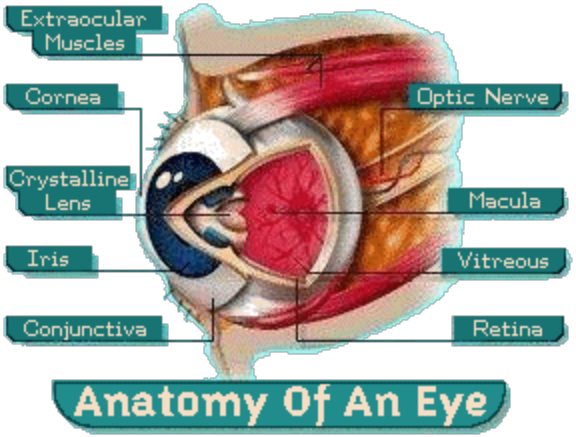


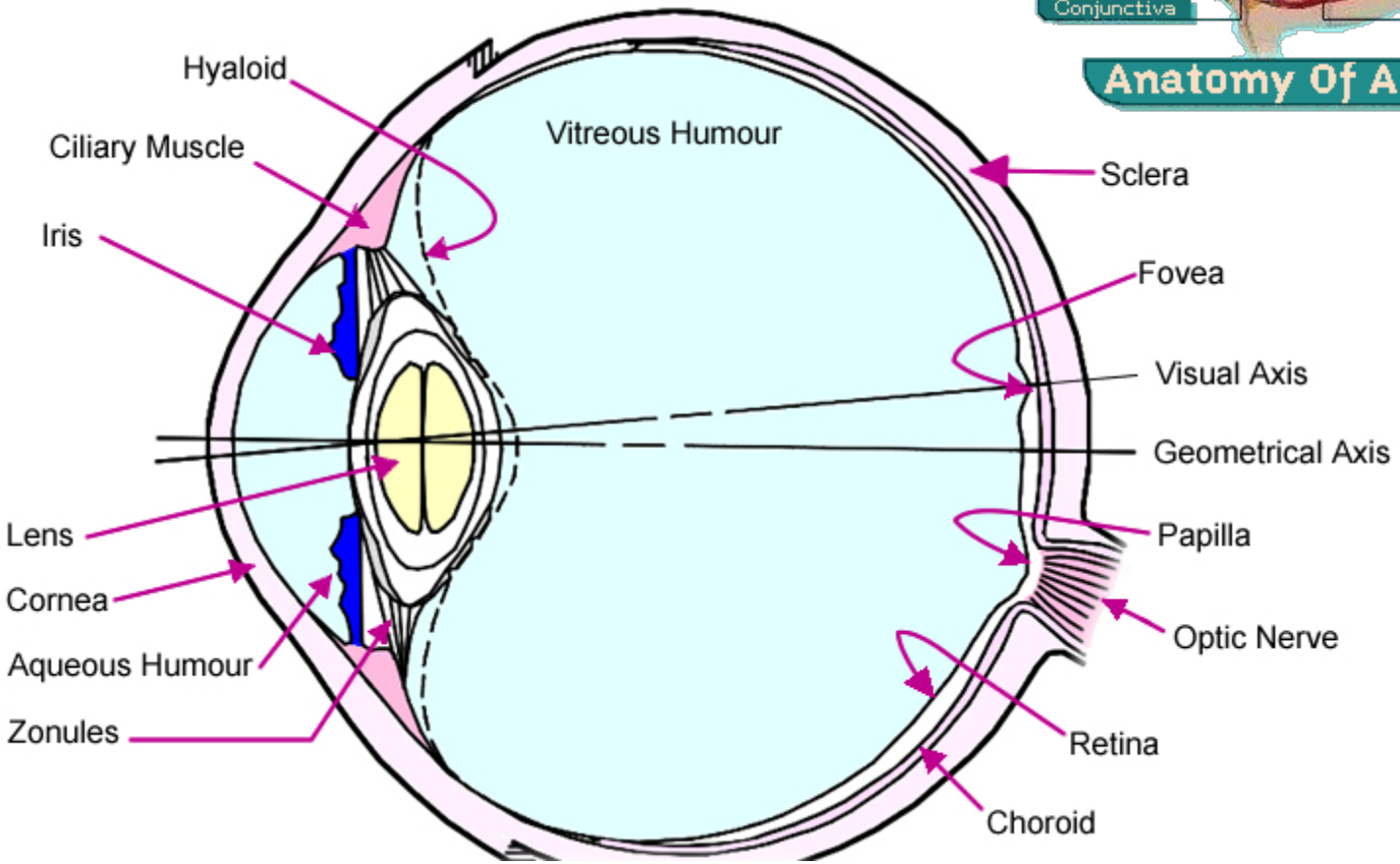
GRIN sočiva



Optički instrumenti, prizme, oko...

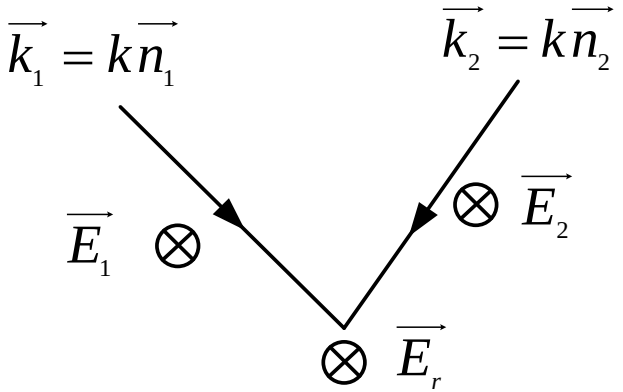






Talasna optika

Interferencija



$$E_1 = E_{10}\sin(k\vec{n}_1\vec{r} - \omega t + \varphi_1)$$

$$E_2 = E_{20}\sin(k\vec{n}_2\vec{r} - \omega t + \varphi_2)$$

$$E_r = E_1 + E_2$$

$$I \propto \overline{E_r^2}$$

$$E_r^2 = E_{10}^2\sin^2(k\vec{n}_1\vec{r} - \omega t + \varphi_1) + E_{20}^2\sin^2(k\vec{n}_2\vec{r} - \omega t + \varphi_2) +$$

$$2E_{10}E_{20}\frac{1}{2}\left[\cos\left(k(\vec{n}_1 - \vec{n}_2)\vec{r} + (\varphi_1 - \varphi_2)\right) - \cos\left(k(\vec{n}_1 - \vec{n}_2)\vec{r} - 2\omega t + (\varphi_1 + \varphi_2)\right)\right]$$

$$\frac{1}{T}\int_0^T \sin^2(\alpha - \omega t)dt = \frac{1}{2} \quad \Rightarrow \quad I_r = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$$

$$\delta = \frac{2\pi(\vec{n}_1 - \vec{n}_2)\vec{r}}{\lambda} + \Delta\varphi, \quad \Delta\varphi = \varphi_1 - \varphi_2$$

$$I_r = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta\cos\alpha$$

Antirefleksioni slojevi

Young-ov eksperiment

$$\delta = \frac{2\pi(s_2 - s_1)}{\lambda}$$

$$s_2^2 = D^2 + (y + d/2)^2$$

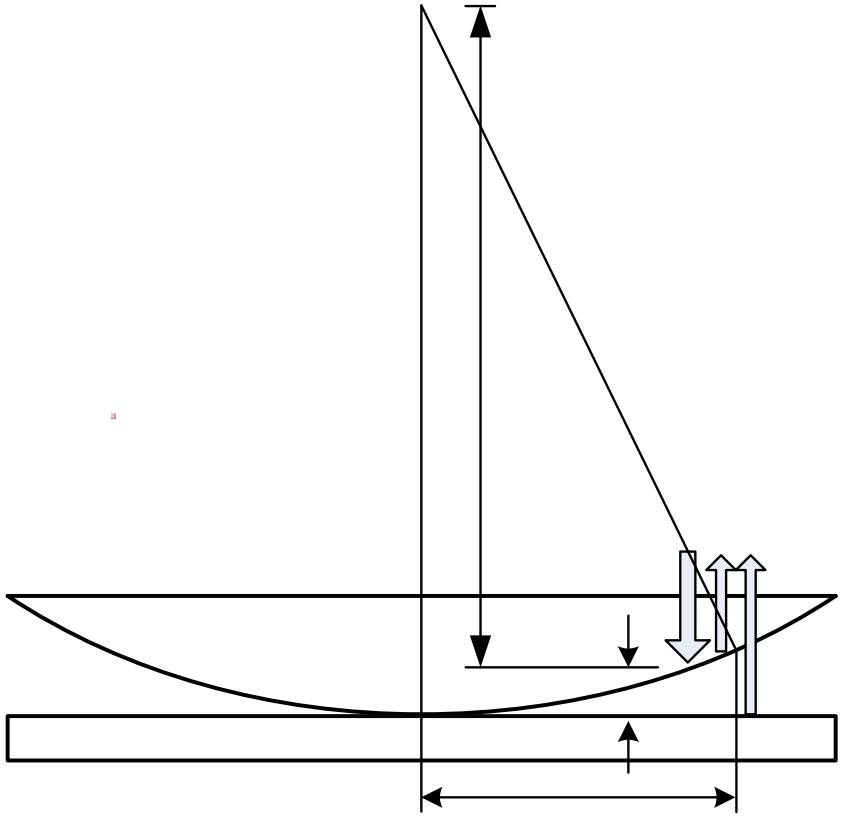
$$s_1^2 = D^2 + (y - d/2)^2$$

$$s_2^2 - s_1^2 = (s_2 - s_1)(s_2 + s_1) = 2yd$$

$$s_2 + s_1 \approx 2D \Rightarrow s_2 - s_1 = yd/D \Rightarrow \delta = \frac{2\pi yd}{\lambda D}$$

$$\text{prvi maksimum} \Rightarrow \delta = 2\pi \Rightarrow \lambda = yd/D = 500\ \text{nm}$$

Newton-ovi prstenovi



$$\varphi_1 = \pi + \frac{2\pi}{\lambda} 2d, \quad \varphi_2 = 0$$

$$R^2 = (R-d)^2 + r_m^2 \;\Rightarrow\; d \approx \frac{r_m^2}{2R}$$

$$\delta = \varphi_1 - \varphi_2 = m\pi \;\Rightarrow\; r_m^2 = (m - 1/2)R\lambda$$

$$S = (r_{m+1}^2 - r_m^2)\pi = \pi R\lambda$$

Difrakcija

- Frančesko Grimaldi (XVII vek)
- Hajgens-Frenelov princip

  Svaka tačka talasnog fronta, u datom trenutku, služi kao izvor sekundarnih talasa, koji imaju istu frekvenciju kao i primarni talas. Amplituda optičkog polja u bilo kojoj tački je superpozicija svih sekundarnih talasa, uzimajući u obzir njihove amplitude i relativne faze.
- Kirhofova teorija
- Zomerfeldovo rešenje

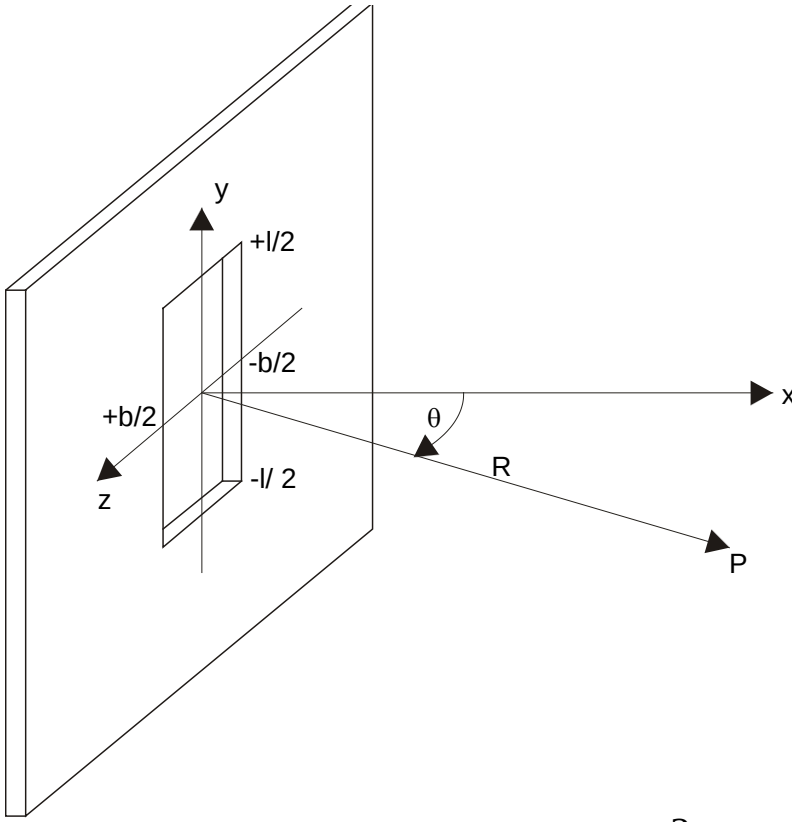
Difrakcija

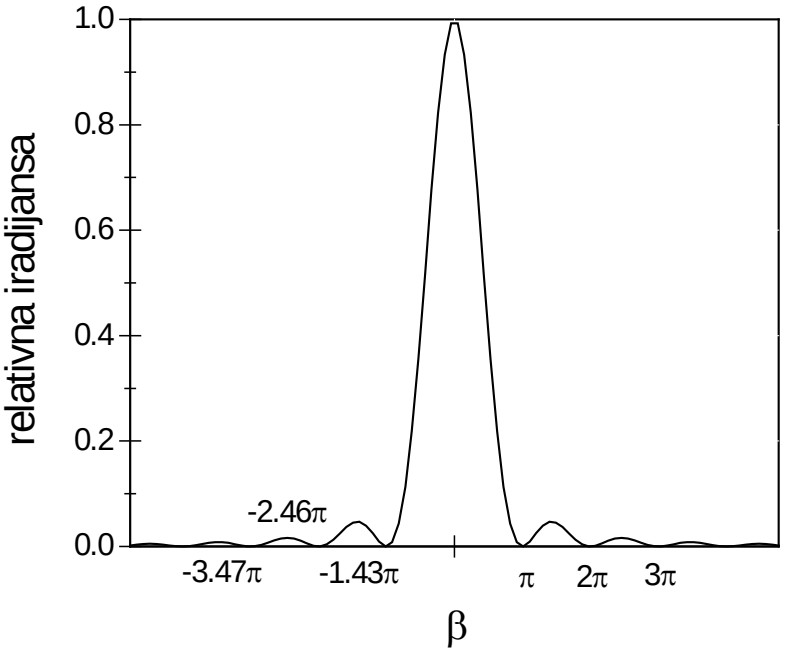
- Frenelova

- Fraunhoferova

Fraunhoferova difrakcija

Difrakcija na jednom prorezu

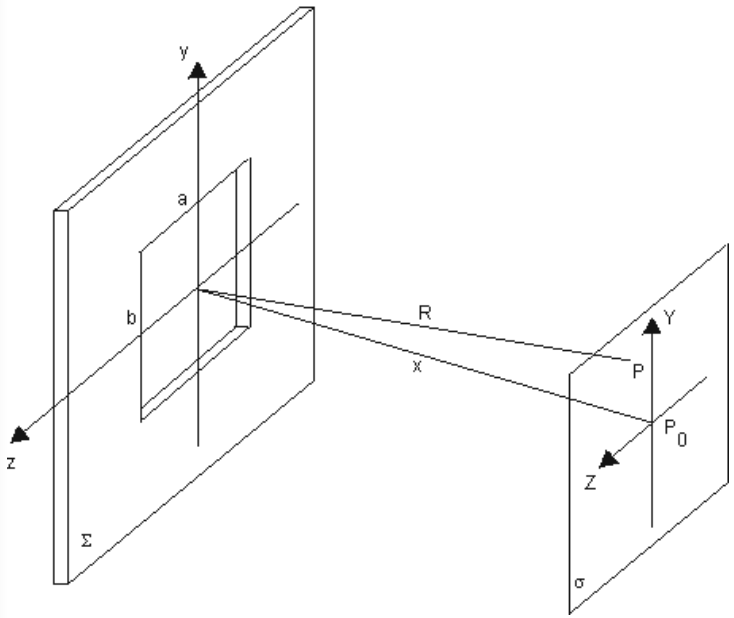


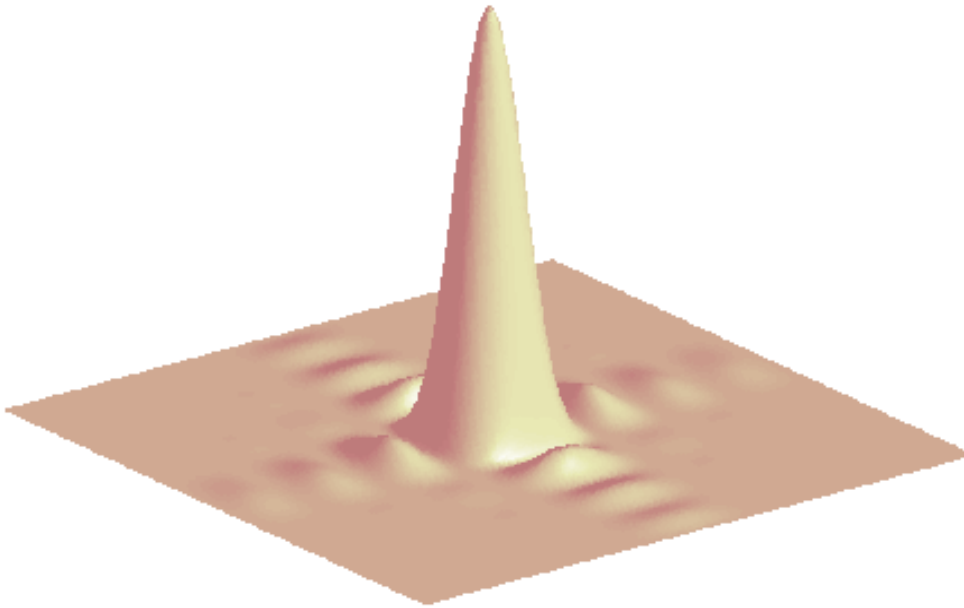


$$I(\theta) = I(0)\left(\frac{\sin\beta}{\beta}\right)^2$$

$$\beta = (kb/2)\sin\theta$$

Difrakcija na pravougaonom otvoru





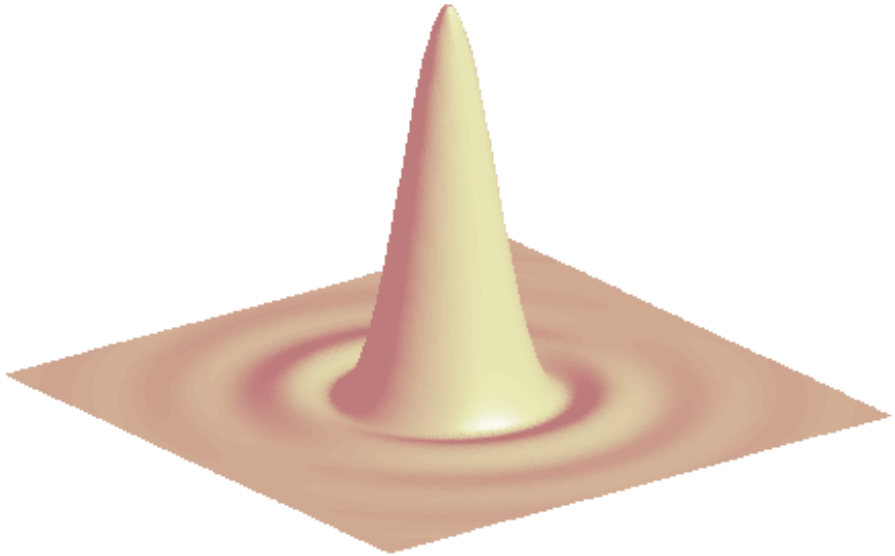
$$I(Y,Z) = I(0)\left(\frac{\sin\alpha'}{\alpha'}\right)^2\left(\frac{\sin\beta'}{\beta'}\right)^2$$

$\alpha' = kaZ/2R \quad \beta' = kbY/2R$

Difrakcija na kružnom otvoru

$$I = I(0)\left[\frac{2J_1(ka\sin\theta)}{ka\sin\theta}\right]^2$$

- Ejrijev disk

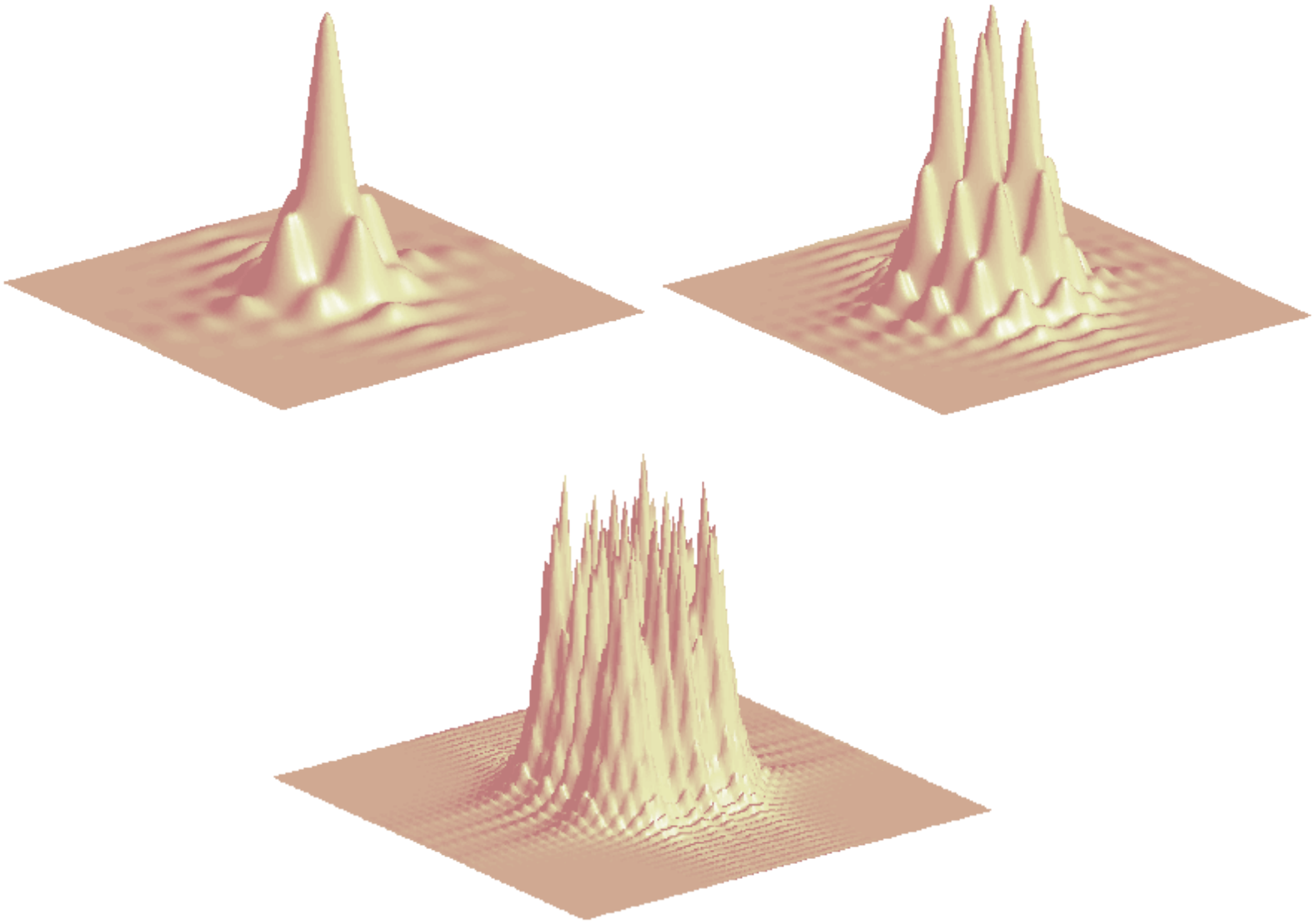


$$q_1 = 1.22\frac{R\lambda}{2a}$$

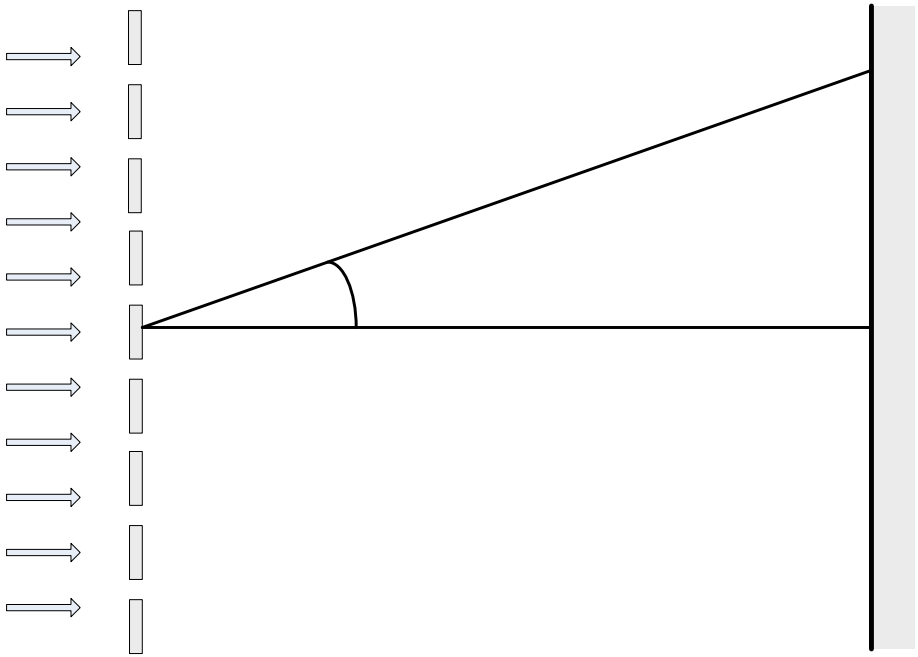
Frenelova difrakcija

- Neemitovanje sekundarnih talasa ka izvoru
- Faktor inklinacije: $K(\theta) = \frac{1}{2}(1+\cos\theta)$
- Frenelovi integrali: $C(w) = \int_0^w \cos(\pi w'^2)\,dw',$ $S(w) = \int_0^w \sin(\pi w'^2)\,dw'$
- Kornuova spirala: $B(w)=C(w)+iS(w)$ $(-\infty<w<+\infty)$

Difrakcija na kvadratnom otvoru



Difrakciona rešetka



$d \sin\theta_z = z\lambda, \quad d = 1/N = 2.5 \cdot 10^{-6}$ m

gde je z redni broj maksimuma,

a θ_z ugao skretanja

$\theta_{z_{max}} = \pi/2 \;\Rightarrow\; z_{max} = 4$

$N = 2z_{max} + 1$ (centralni maksimum)

$N = 9$