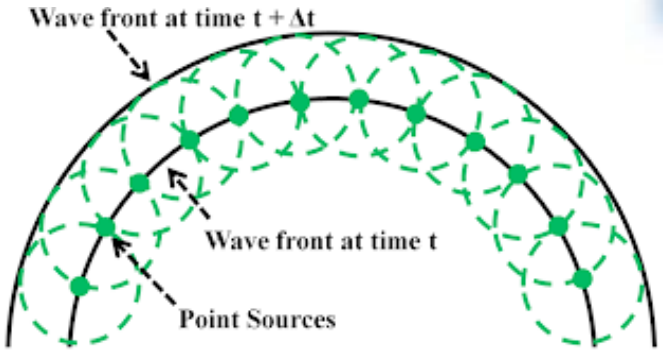
4302212 – Física IV

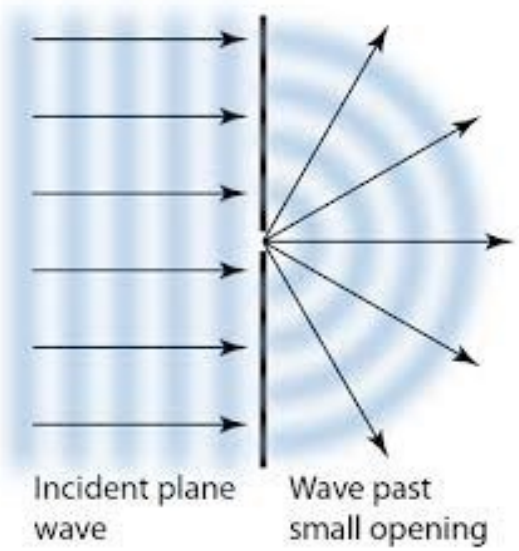
Princípio de Fermat

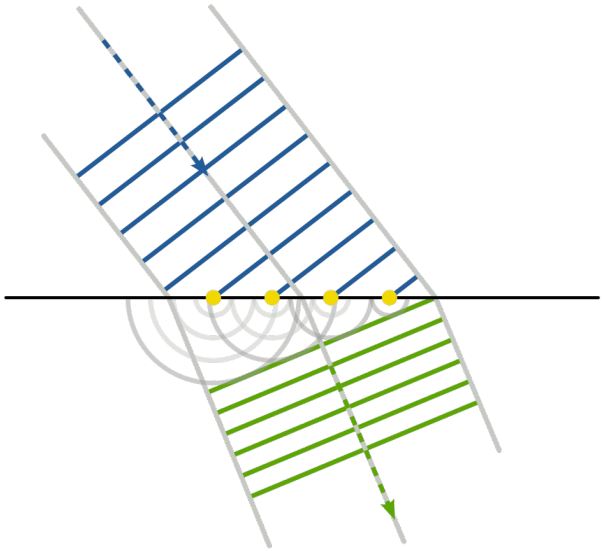
Limite de Ótica Geométrica

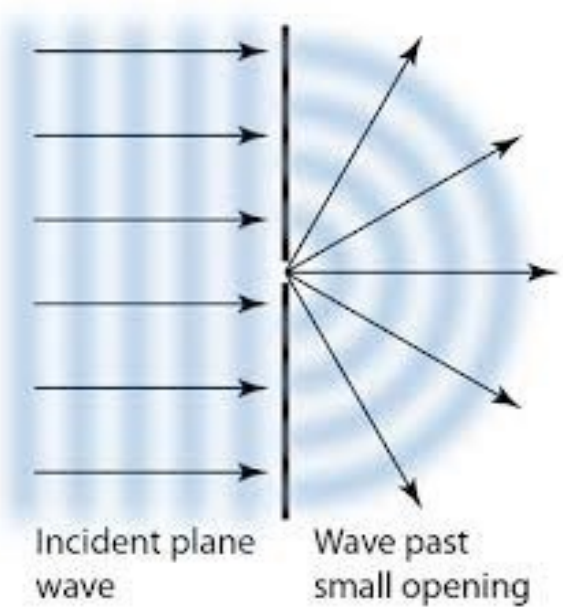
– Século XVII/XVIII: a natureza da luz é corpuscular (Newton) ou ondulatória (Huygens)?

– **Princípio de Huygens**: Cada ponto em uma frente de onda se comporta como uma fonte puntiforme, gerando ondas secundárias.









– **Raios de Luz**: retas perpendiculares às frentes de onda.

– **Limite da Ótica Geométrica**:

$$\lambda \ll d$$

(visível: ~400 nm a ~700nm)

– **Índice de Refração (*n*)**: propriedade do meio associada à velocidade de propagação da luz (radiação EM).

$$v = \frac{c}{n}$$

$$n(\lambda) \approx A + \frac{B}{\lambda^2}$$

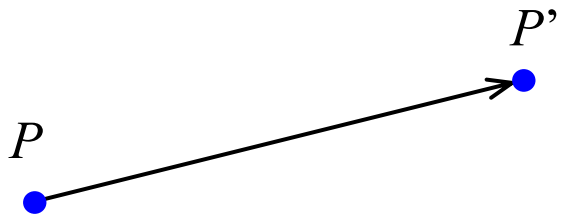
(equação de Cauchy)

Material	Index of Refraction (n)
Vacuum	1.000
Air	1.000277
Water	1.333333
Ice	1.31
Glass	About 1.5
Diamond	2.417

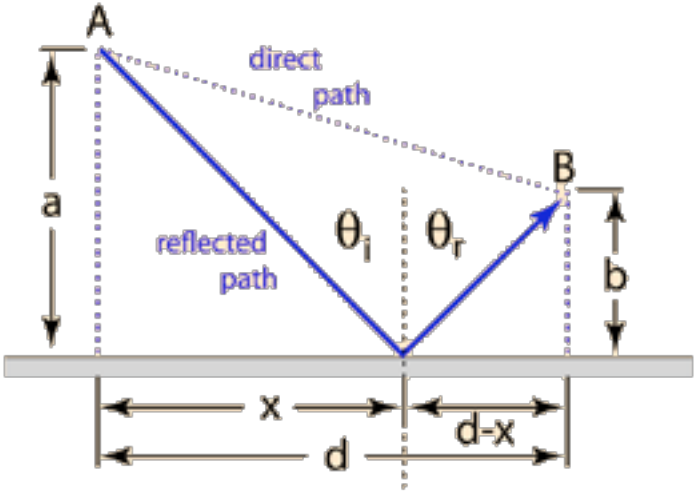
$\lambda \approx 600\,\mathrm{nm}$

Princípio de Fermat

– **Fermat (1657)**: dentre todos os caminhos entre dois pontos, a luz segue aquele percorrido no menor tempo.

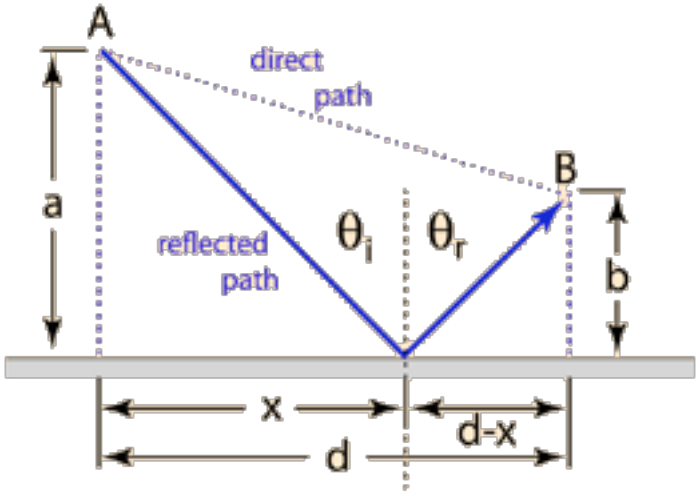


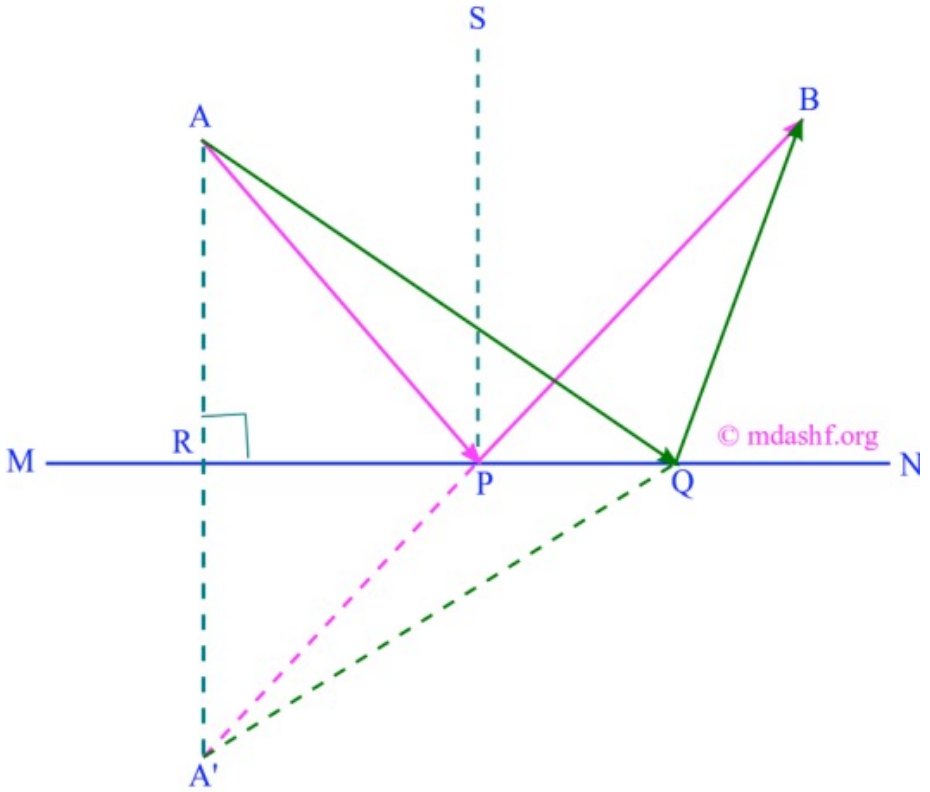
1) Em um meio homogêneo, a propagação da luz é retilínea.



2) **Lei da Reflexão:** Os raios incidente, a normal e o raio refletido estão no mesmo plano (plano de incidência). Além disso,

$$\theta_i = \theta_r$$



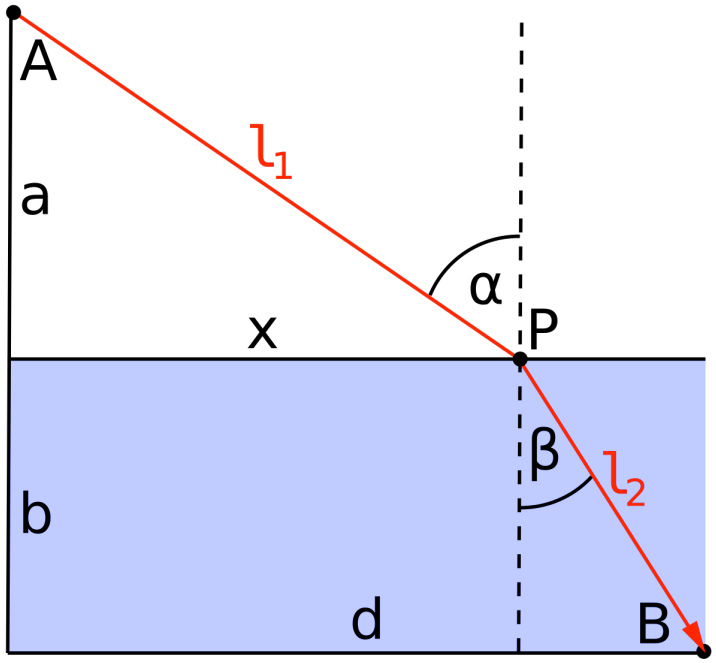


$$t = \frac{1}{v}\left\{(a^2 + x^2)^{1/2} + [b^2 + (d-x)^2]^{1/2}\right\}$$

$$t_{\min} \Longrightarrow x = \frac{d}{2}$$

$$\theta_i = \theta_r$$

$$\alpha = \theta_i \qquad \beta = \theta_r$$



3) **Refração (Lei da Snell):** Os raios incidente, a normal e o raio refletido estão no mesmo plano (plano de incidência). Além disso,

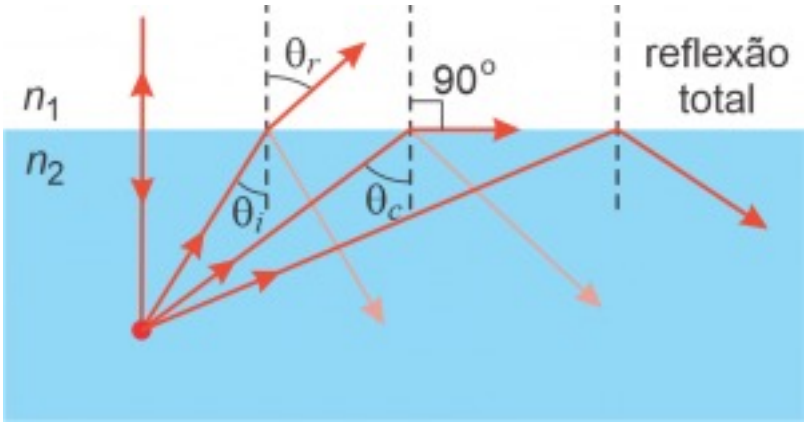
$$\frac{n_i}{n_r} = \frac{\operatorname{sen}(\theta_r)}{\operatorname{sen}(\theta_i)}$$

$$t = \frac{1}{v_i}(a^2 + x^2)^{1/2} + \frac{1}{v_r}[b^2 + (d-x)^2]^{1/2}$$

$$t_{\min} \Longrightarrow n_i \operatorname{sen}(\theta_i) = n_r \operatorname{sen}(\theta_r)$$

Reflexão Total

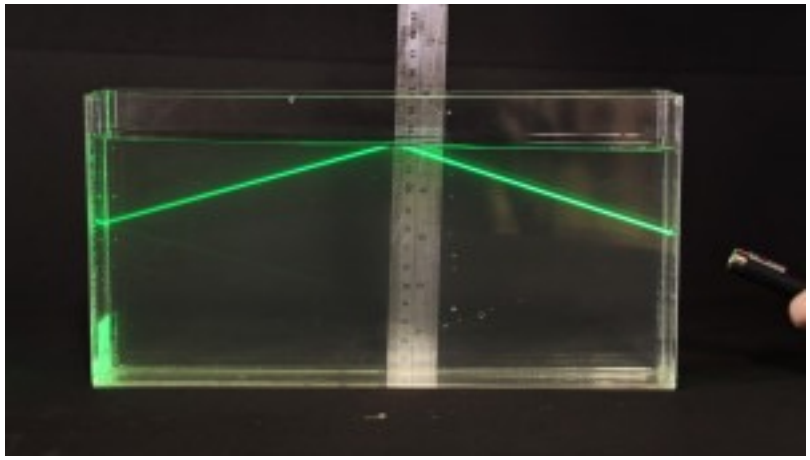
$n_2 > n_1$



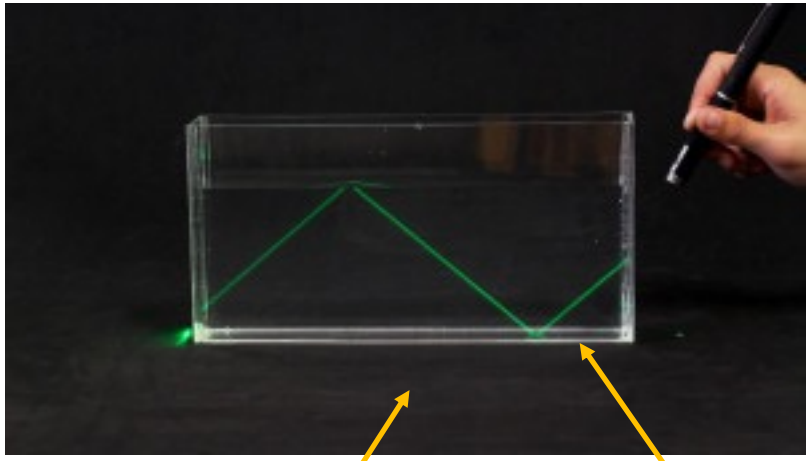
Ângulo Crítico (θ_c): $\theta_r = \pi/2$

$$\text{sen}(\theta_c) = \frac{n_1}{n_2}$$

$n_{ar} = 1.00$
$n_{ag} = 1.33$
$\theta_c = 49^o$



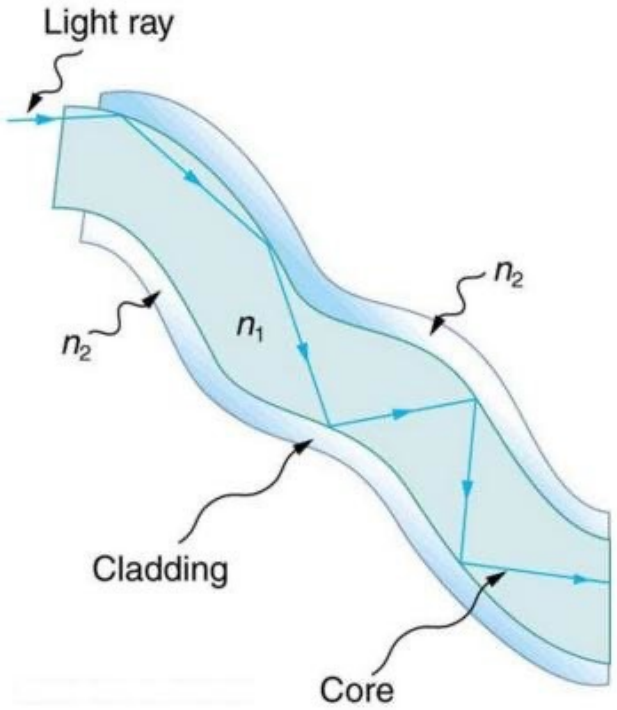
$n_{ar} = 1.00$
$n_{ac} = 1.5$
$\theta_c = 42^o$



(ar)

(acrílico)

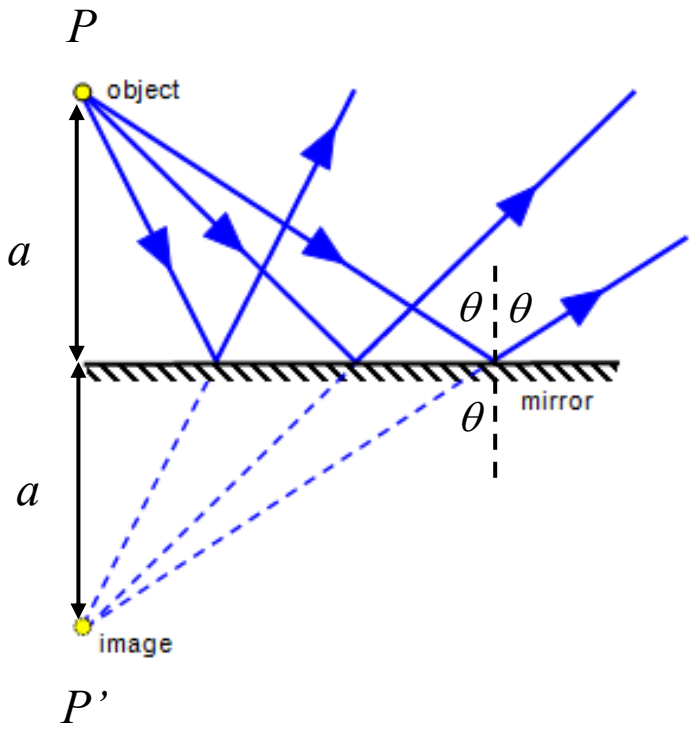
Fibra Ótica:

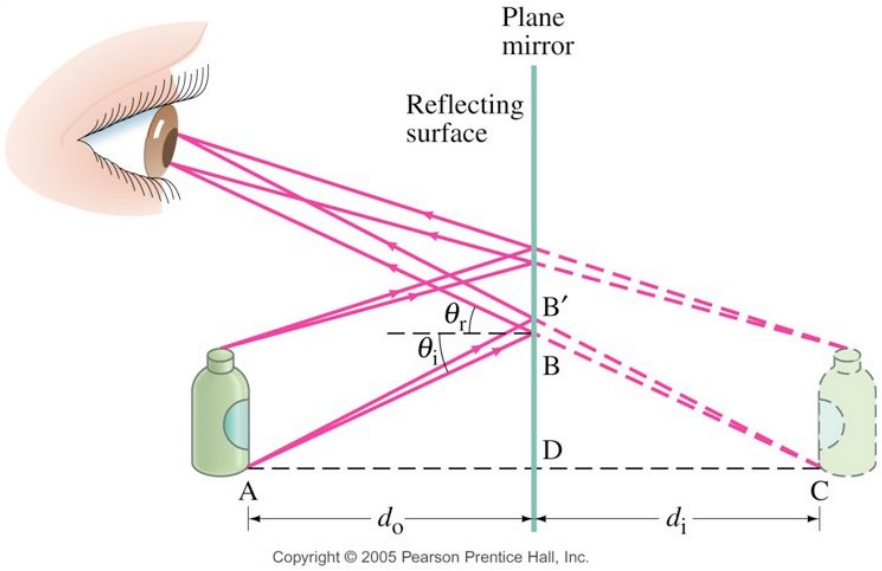


demonstração:

https://www.youtube.com/watch?v=Lic3gCS_bKo

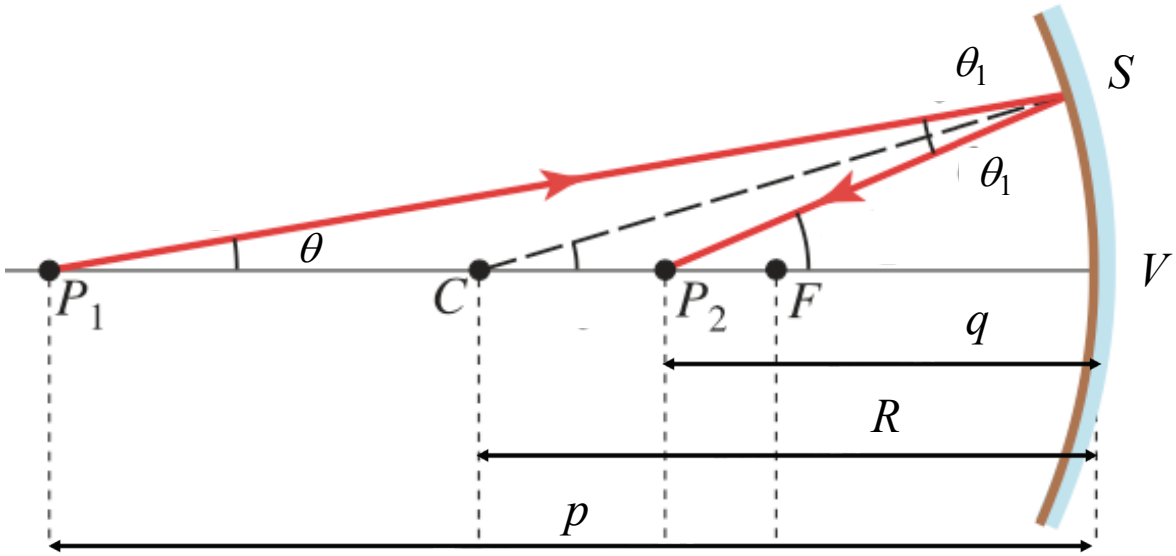
Espelho Plano





As continuações de todos os raios refletidos convergem para *P*', formando a **imagem** de *P*.

Espelho Esférico



Triângulo P_1CS:

$$\frac{(p-R)}{\text{sen}\theta_1} = \frac{R}{\text{sen}\theta}$$

Triângulo CP_2S:

$$\frac{(R-q)}{\text{sen}\theta_1} = \frac{R}{\text{sen}(\pi-\theta-2\theta_1)}$$

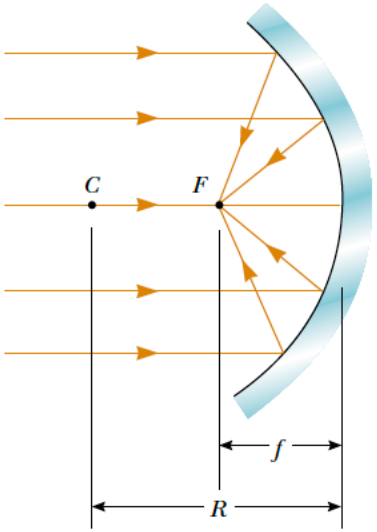
$$= \frac{R}{\text{sen}(\theta+2\theta_1)}$$

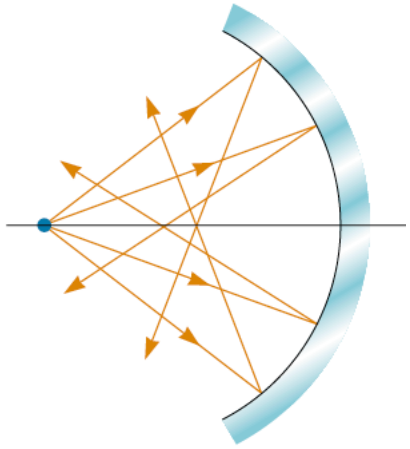
Aproximação Paraxial
(pequenos ângulos)

$$\text{sen}(\theta_1) \approx \theta_1$$

$$\text{sen}(\theta) \approx \theta$$

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$





(aberração esférica)

Ponto Focal (Foco)

$$p \longrightarrow \infty$$

$$\frac{1}{f} \equiv \frac{1}{q} = \frac{2}{R}$$

$$f = \frac{R}{2}$$