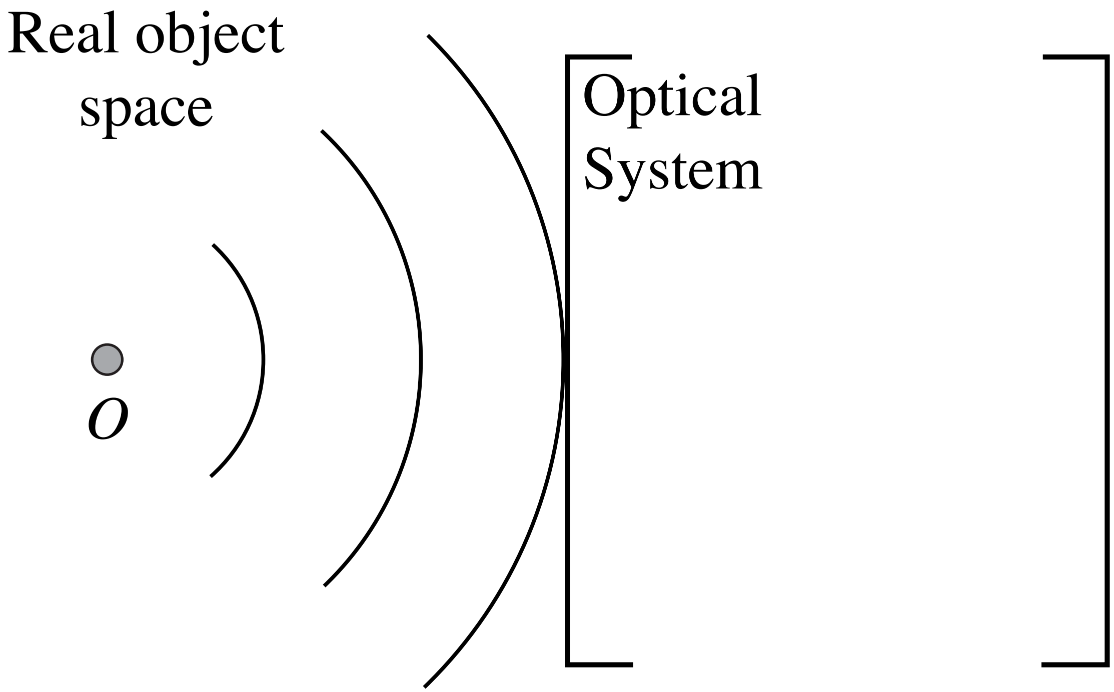
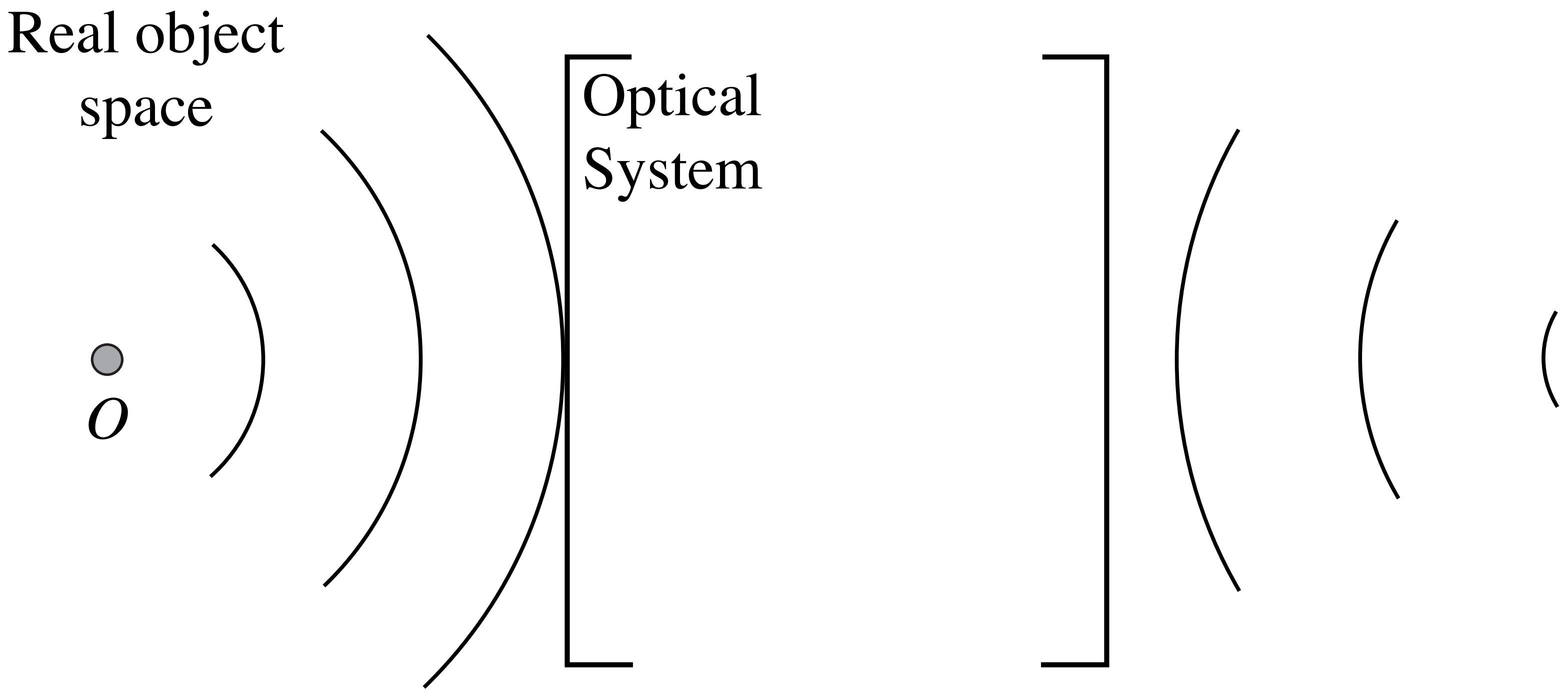
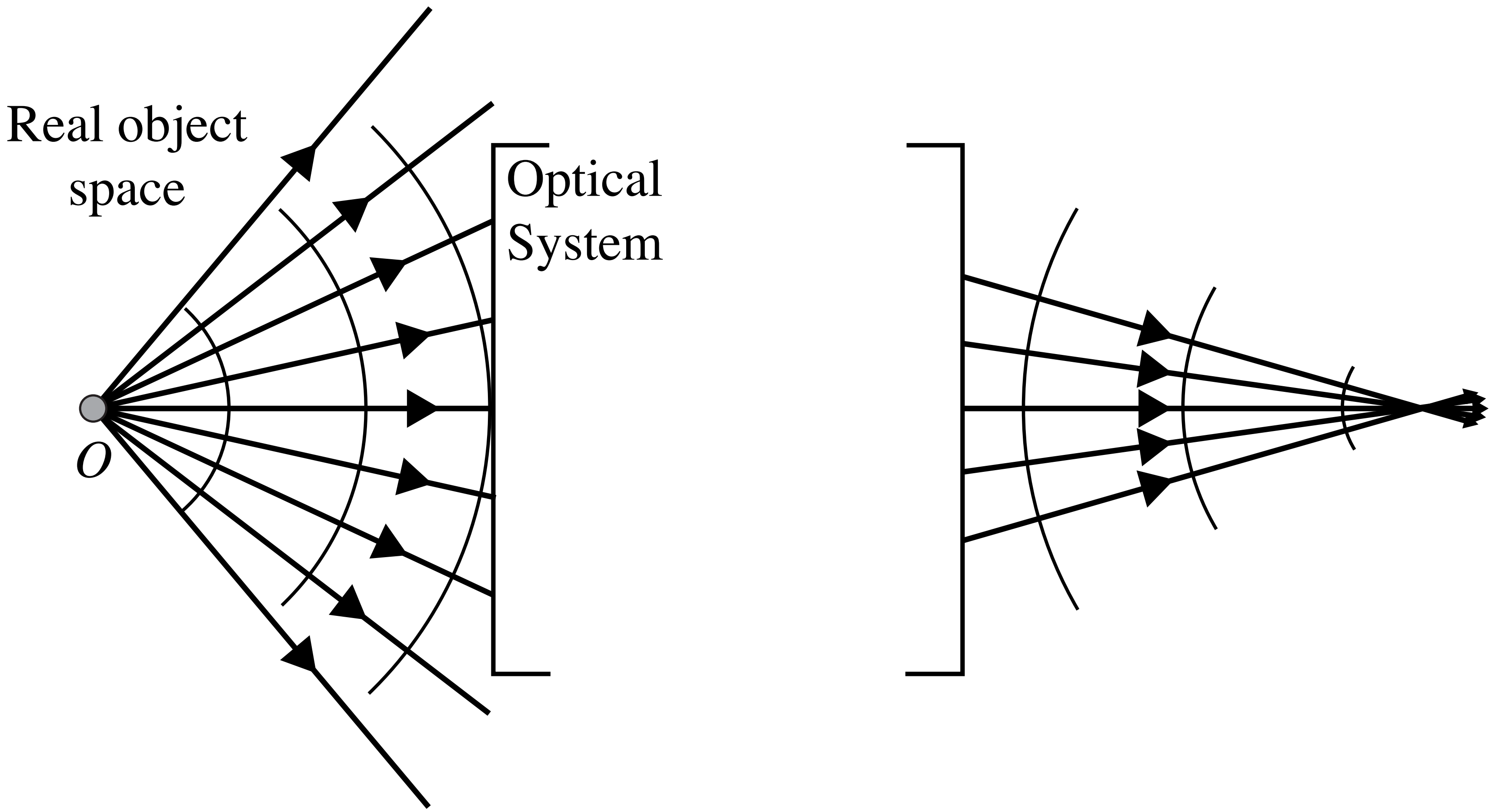
Optical
System

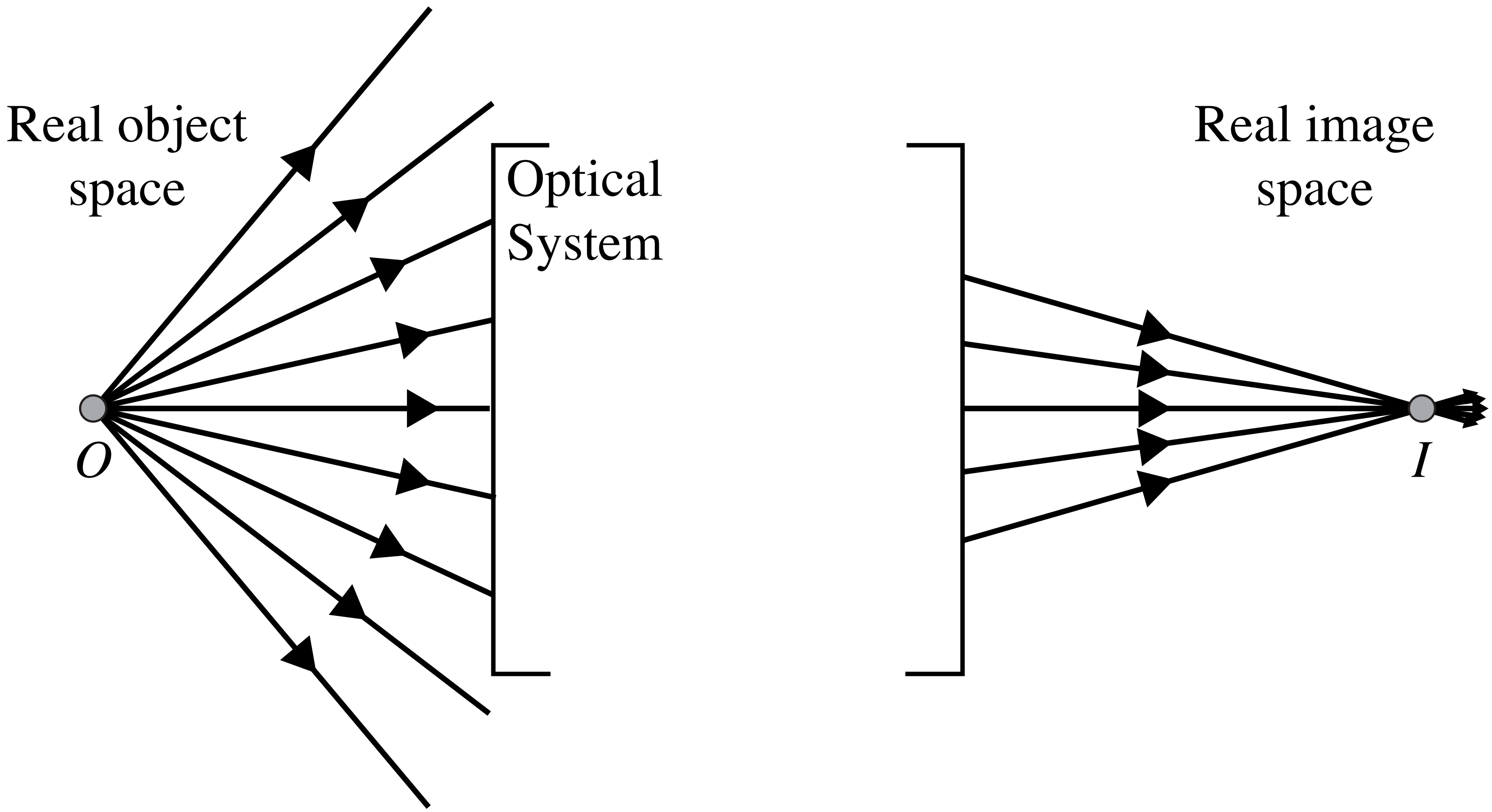
Media – **homogeneous**
– **isotropic**


Real object
space
O
Optical
System

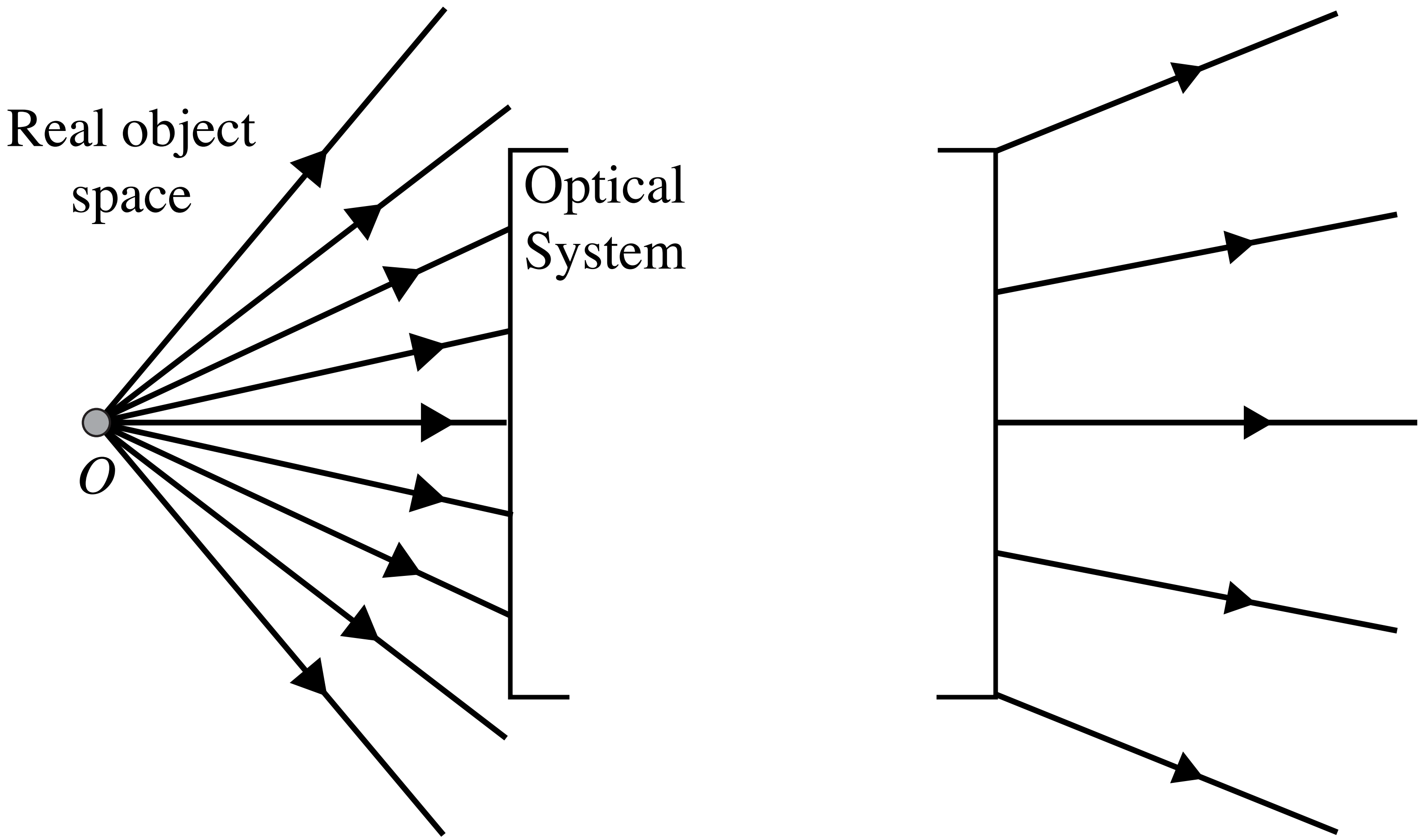

Real object
space
O
Optical
System

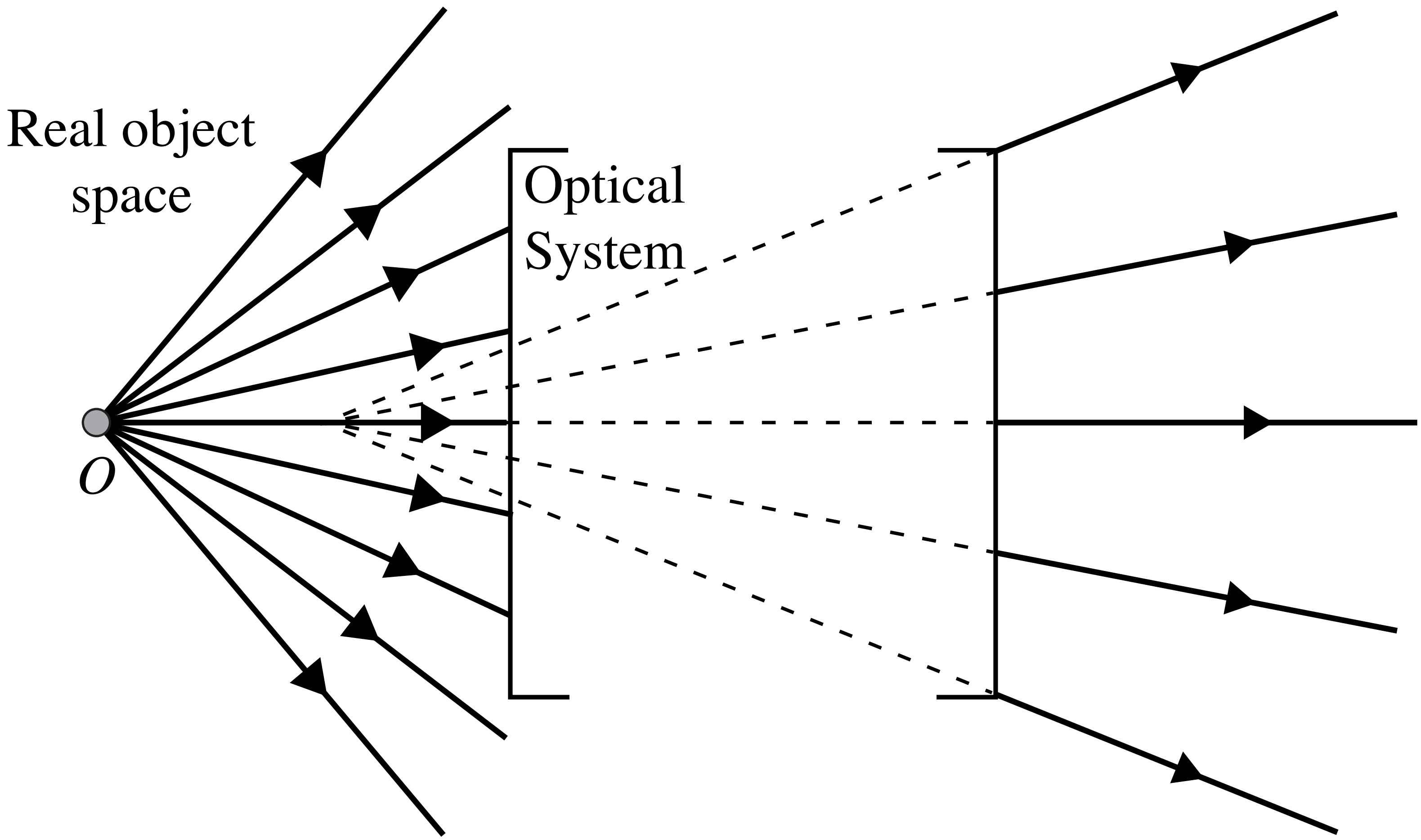


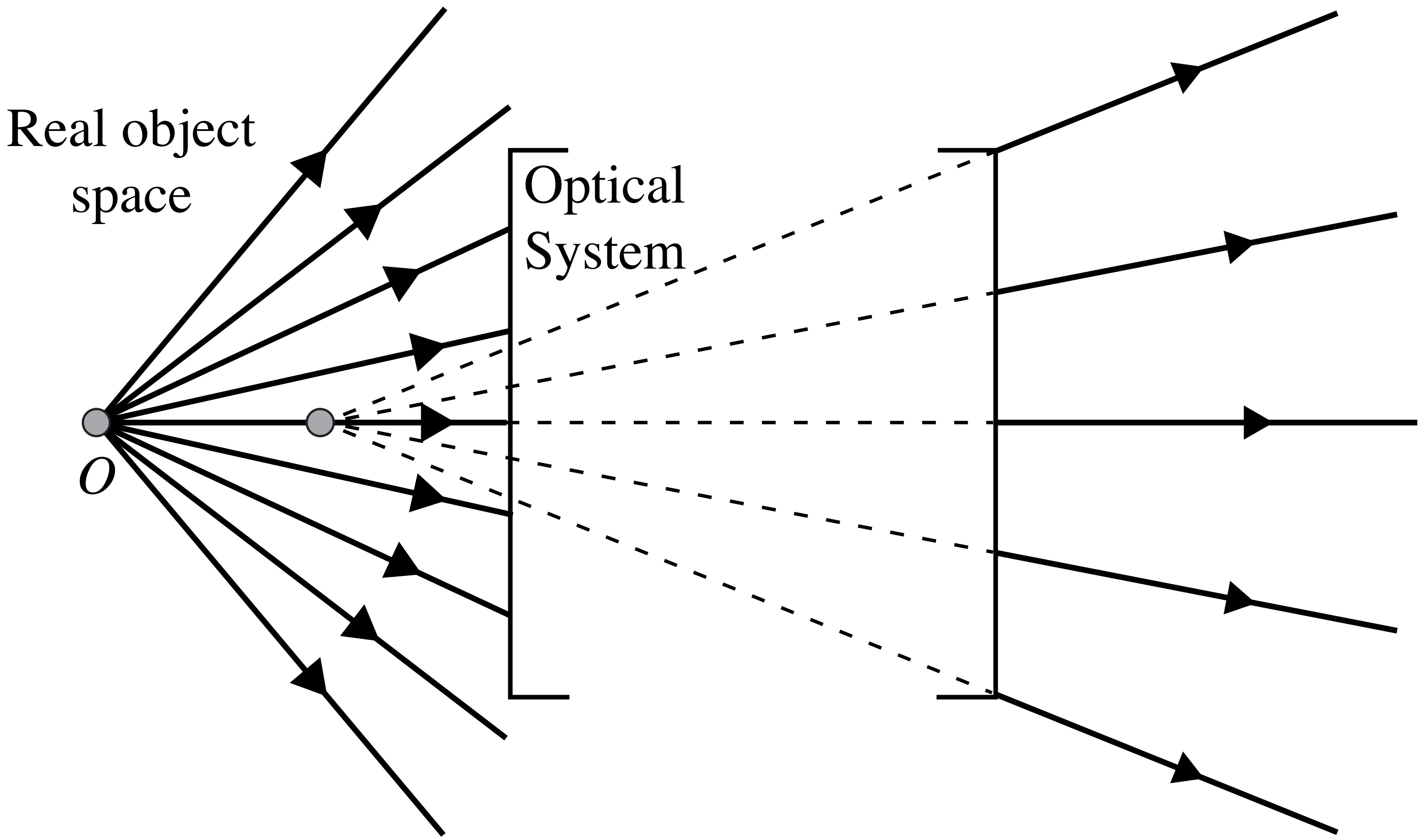
Isochronous – each ray has same transit time.
(Fermat's principle)

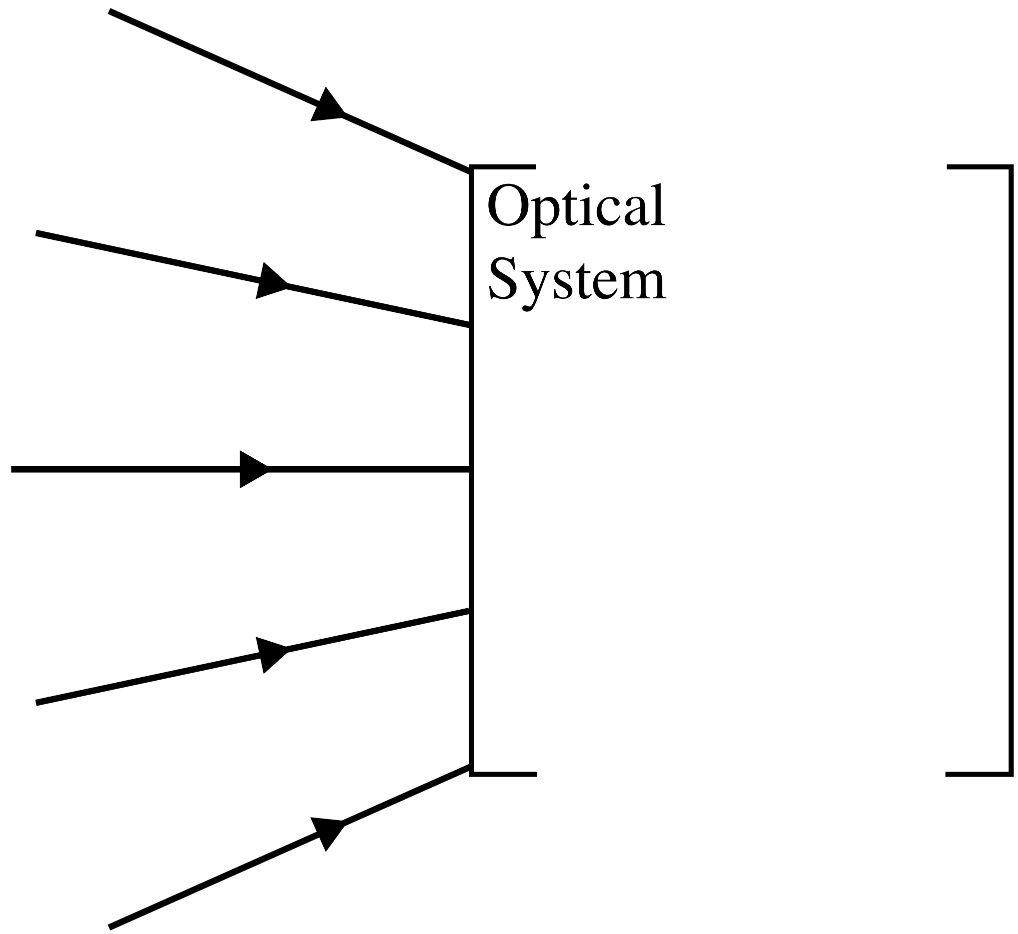


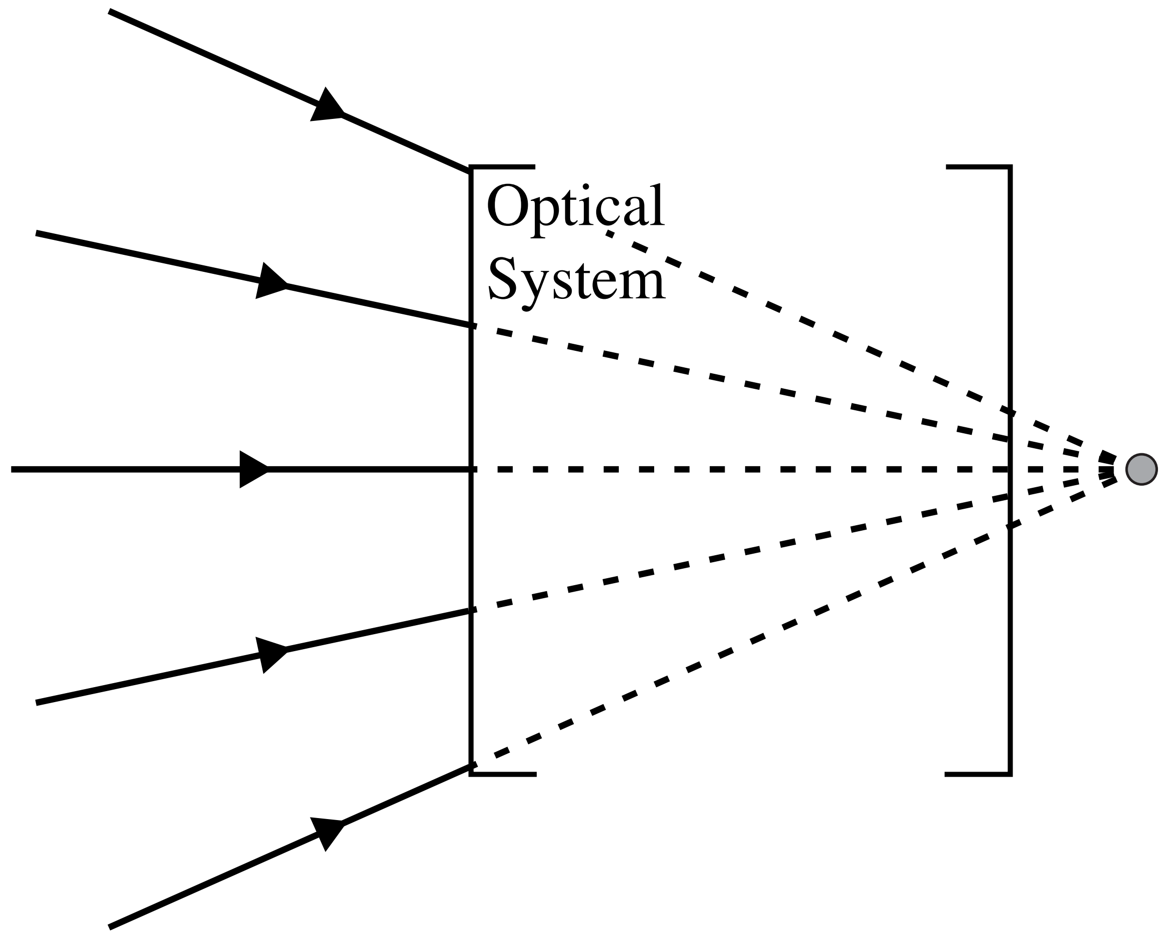
O **and** ***I*** **are conjugate points.**
(principle of reversibility)


Real object
space
Optical
System
O

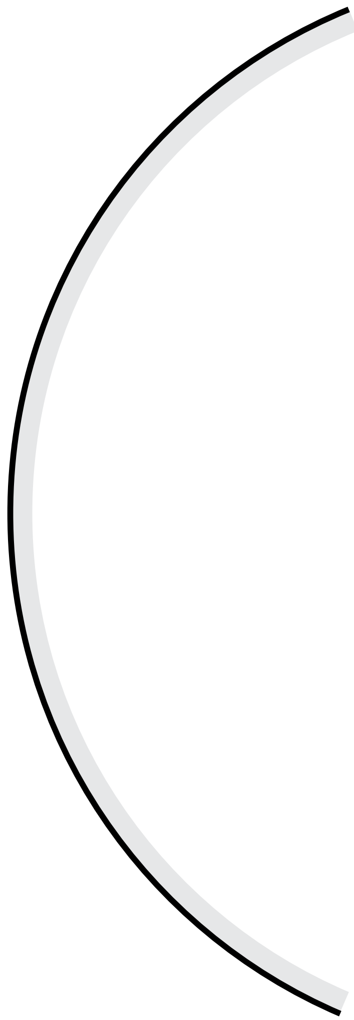

Real object space
Optical System
O


Real object
space
Optical
System
O

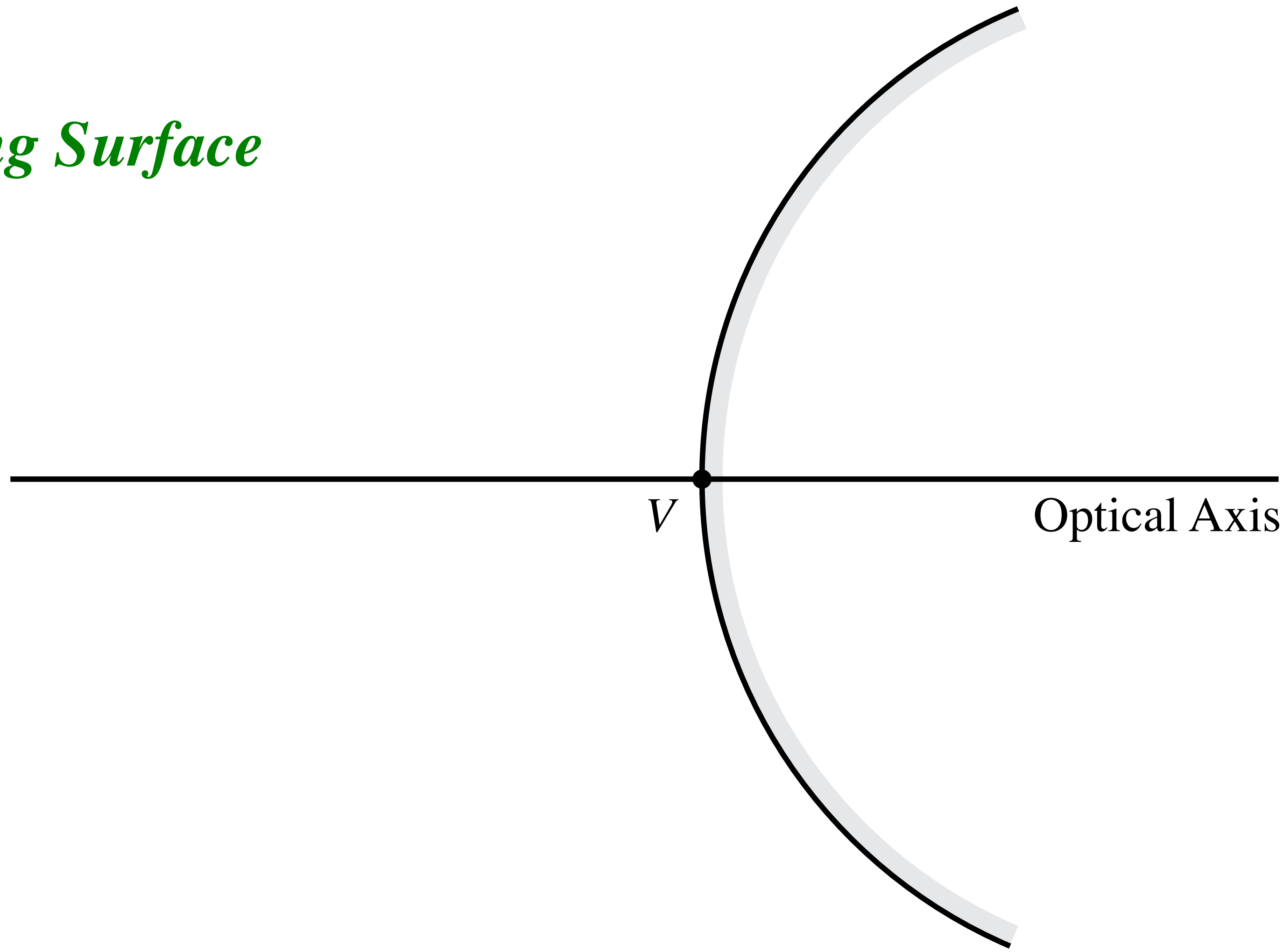

Optical
System


Optical
System

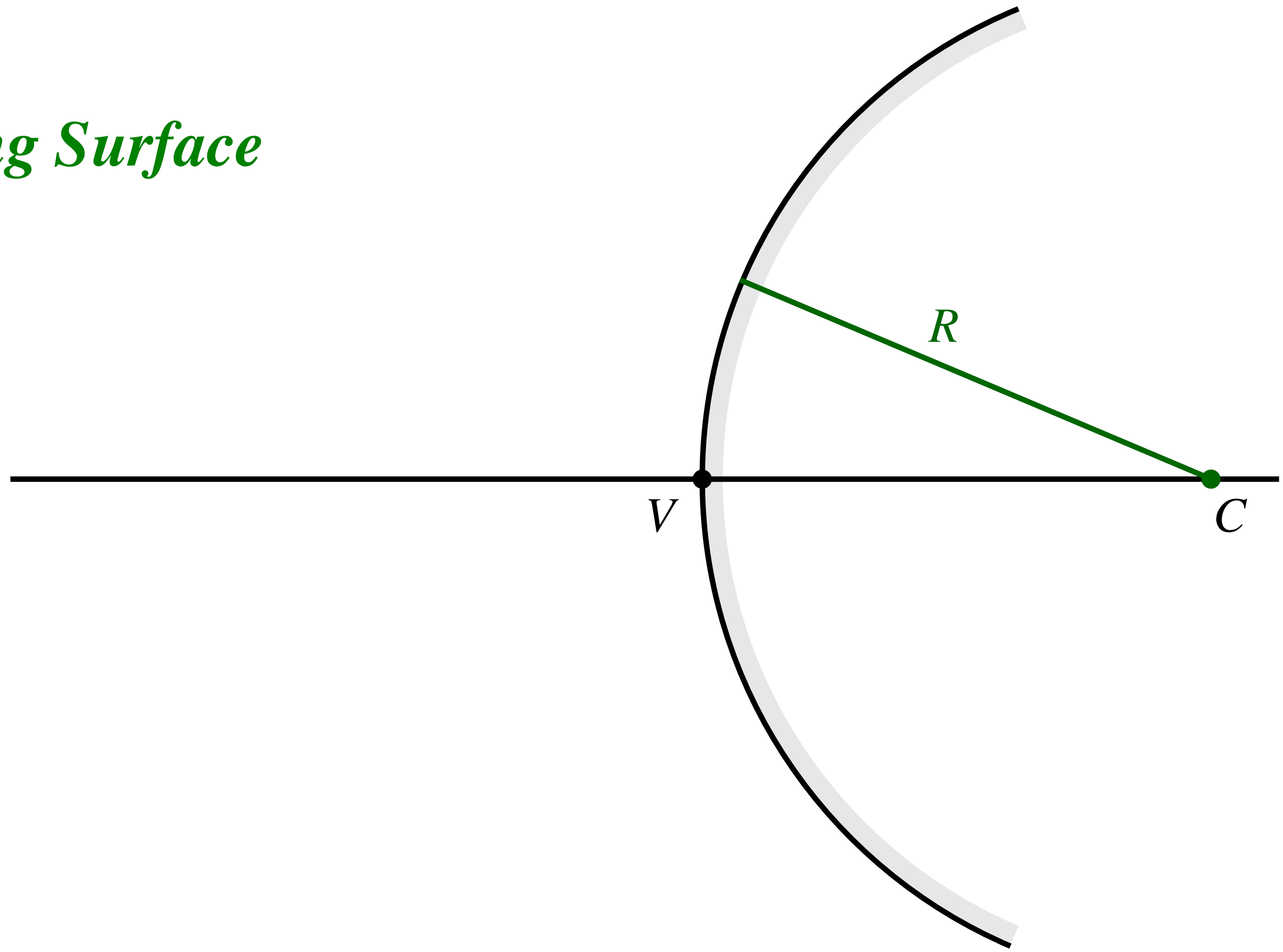
Convex Reflecting Surface



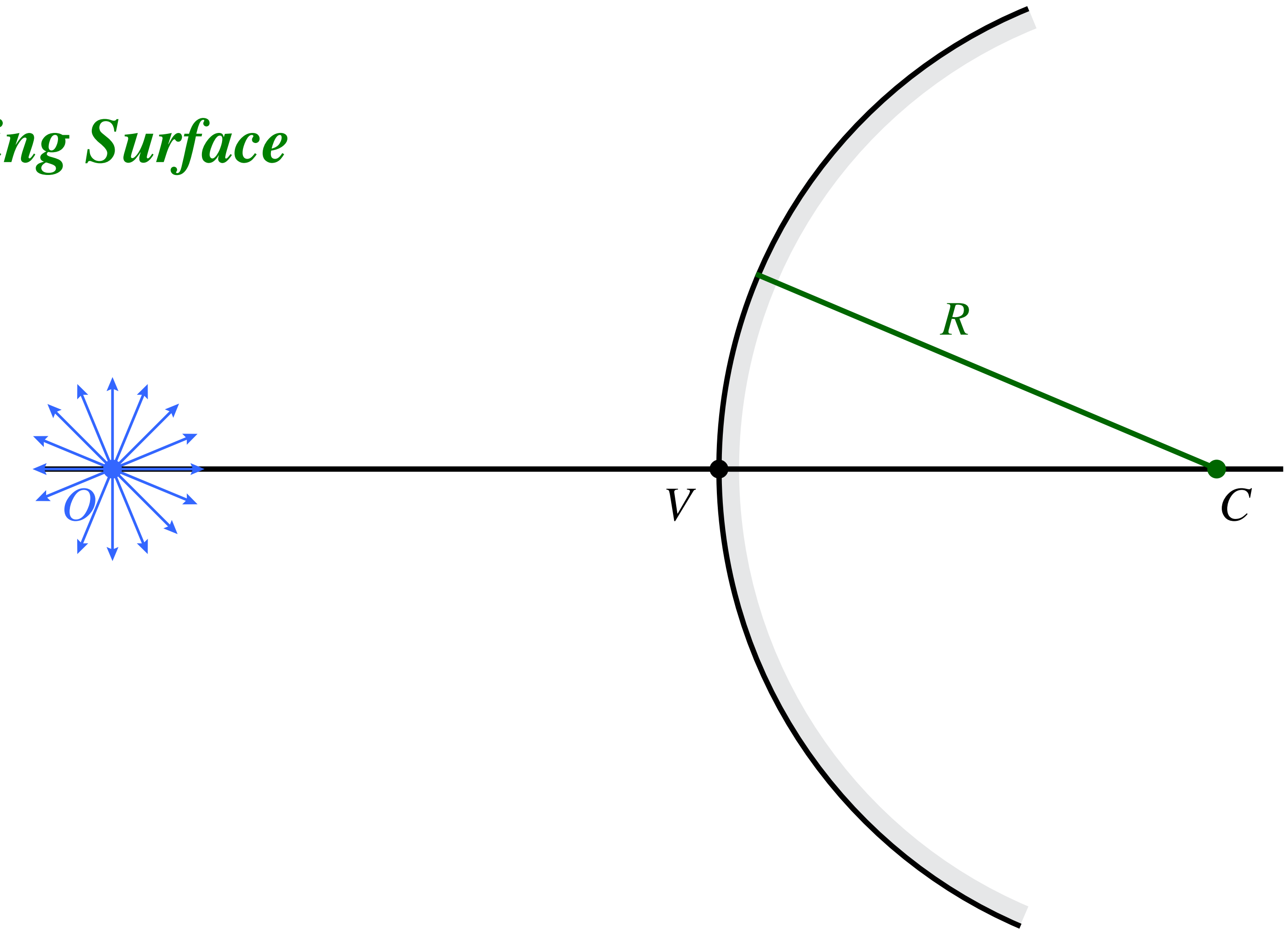
Convex Reflecting Surface



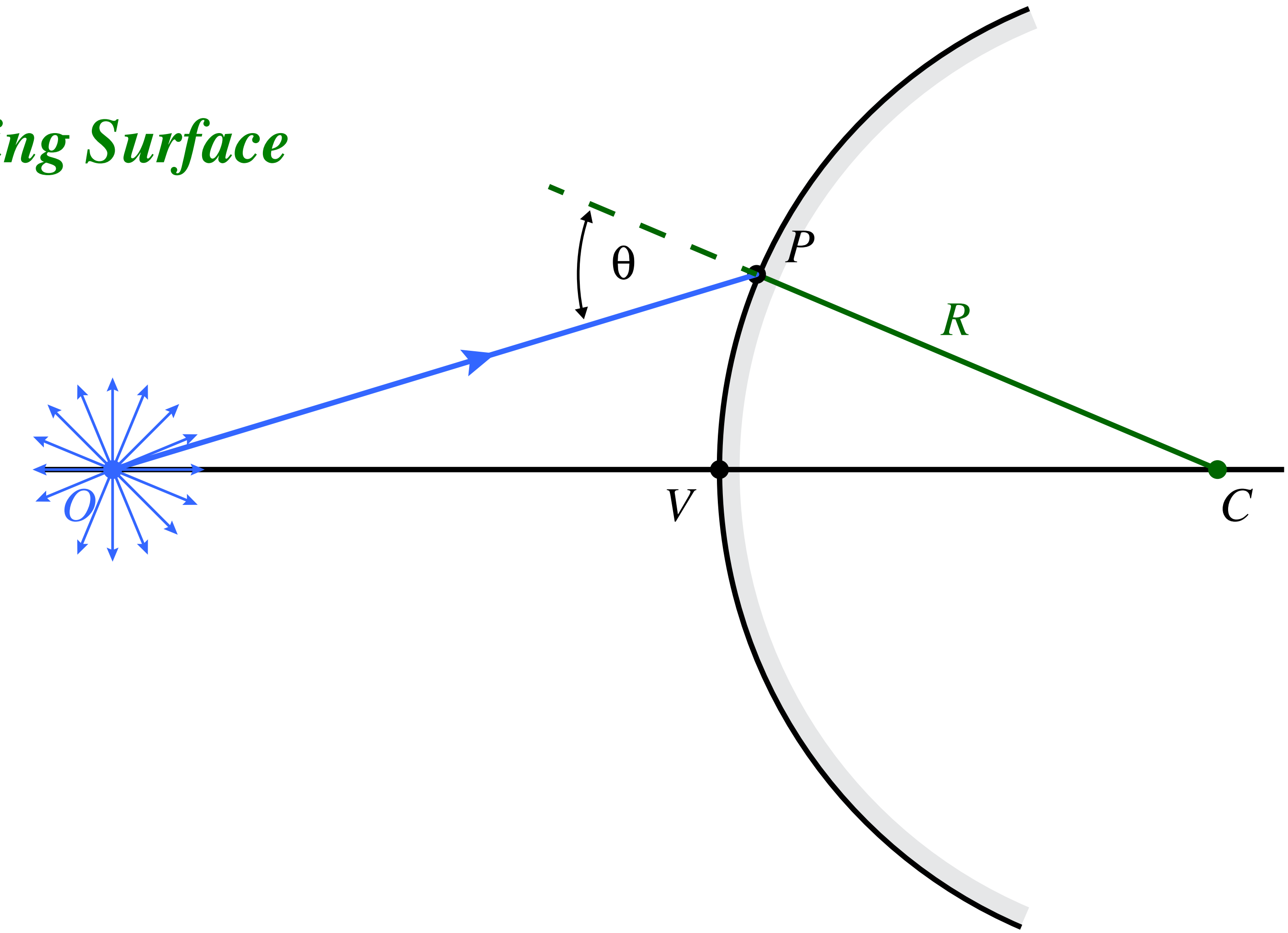
Convex Reflecting Surface



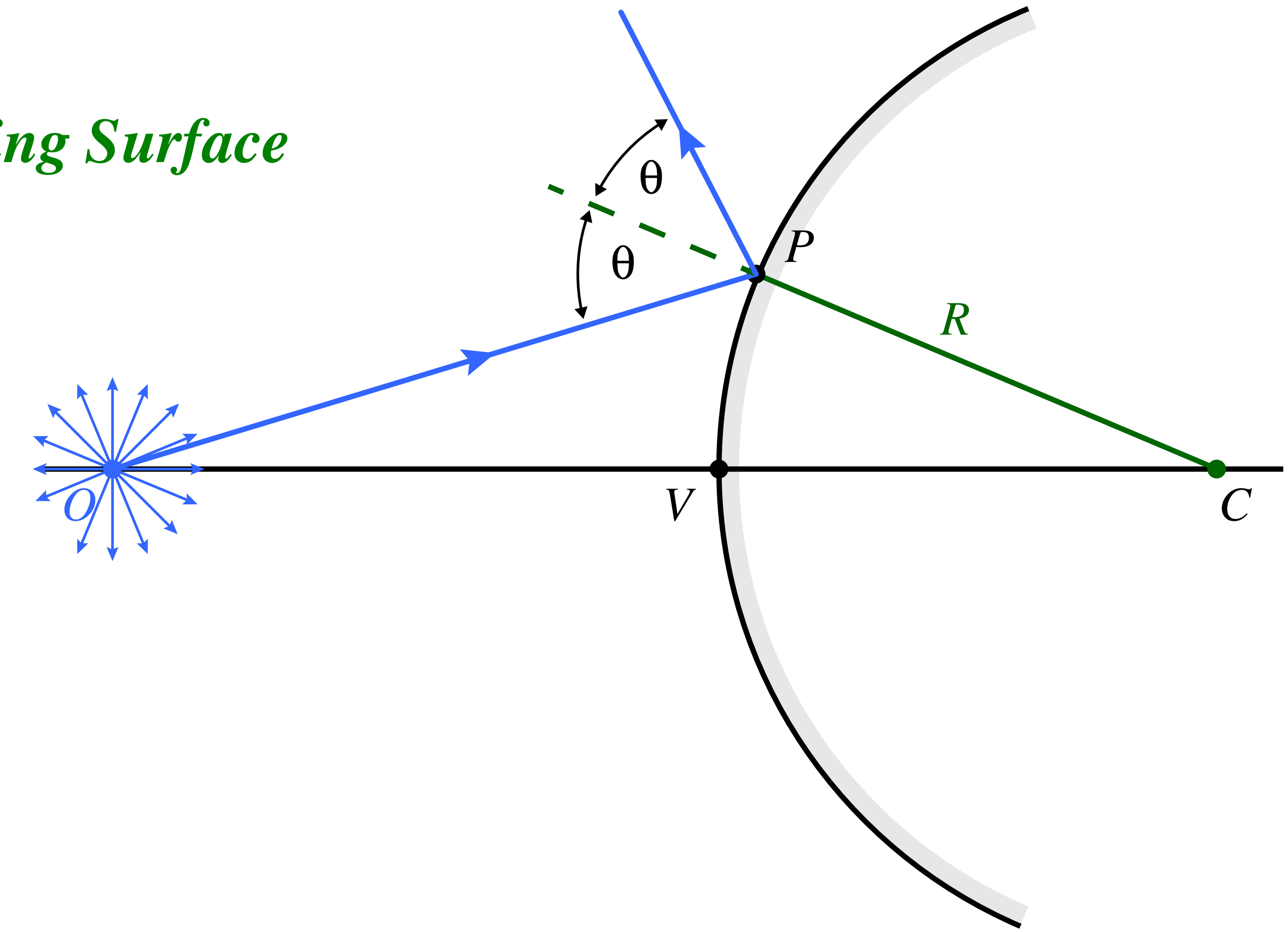
Convex Reflecting Surface



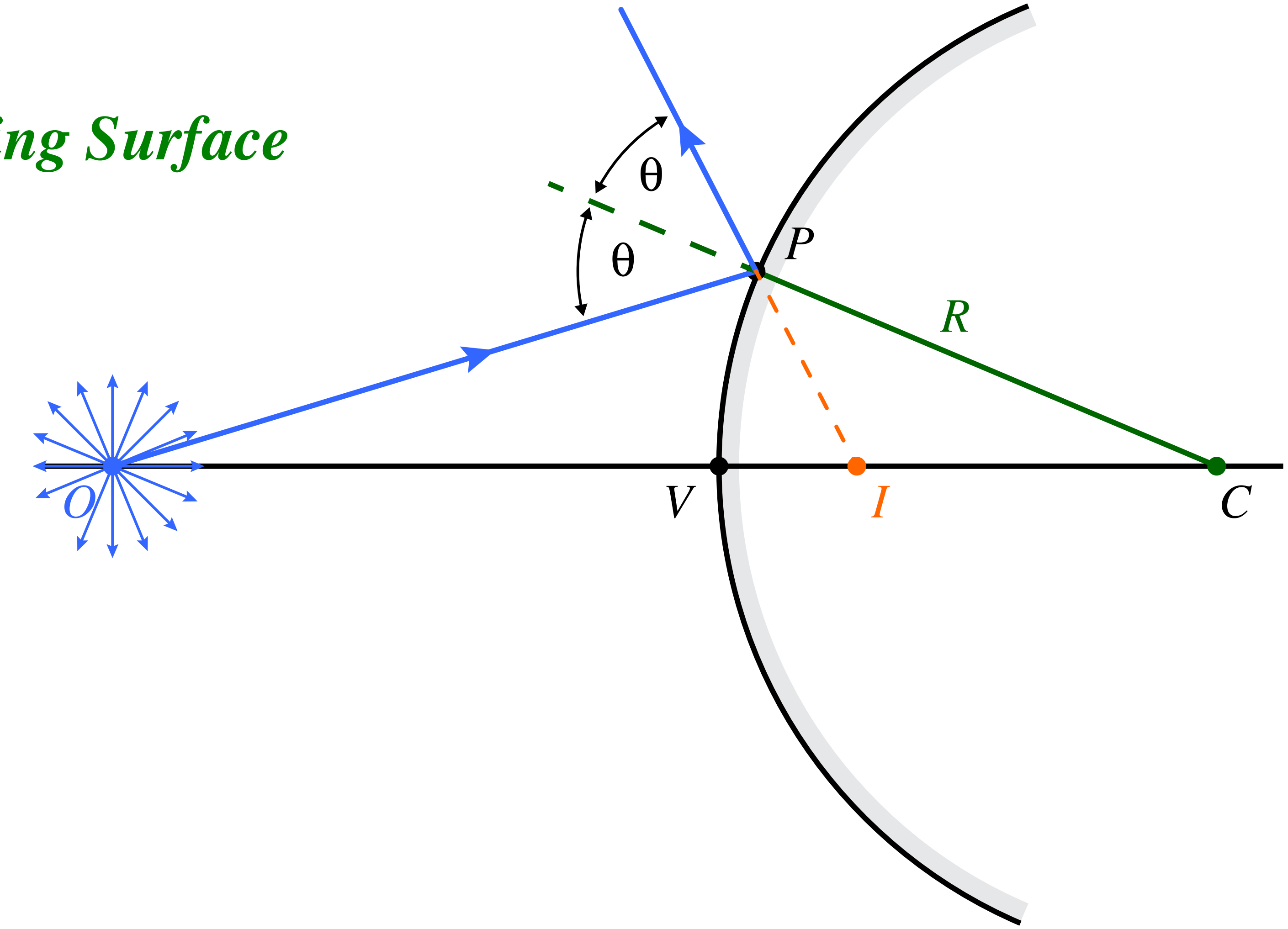
Convex Reflecting Surface



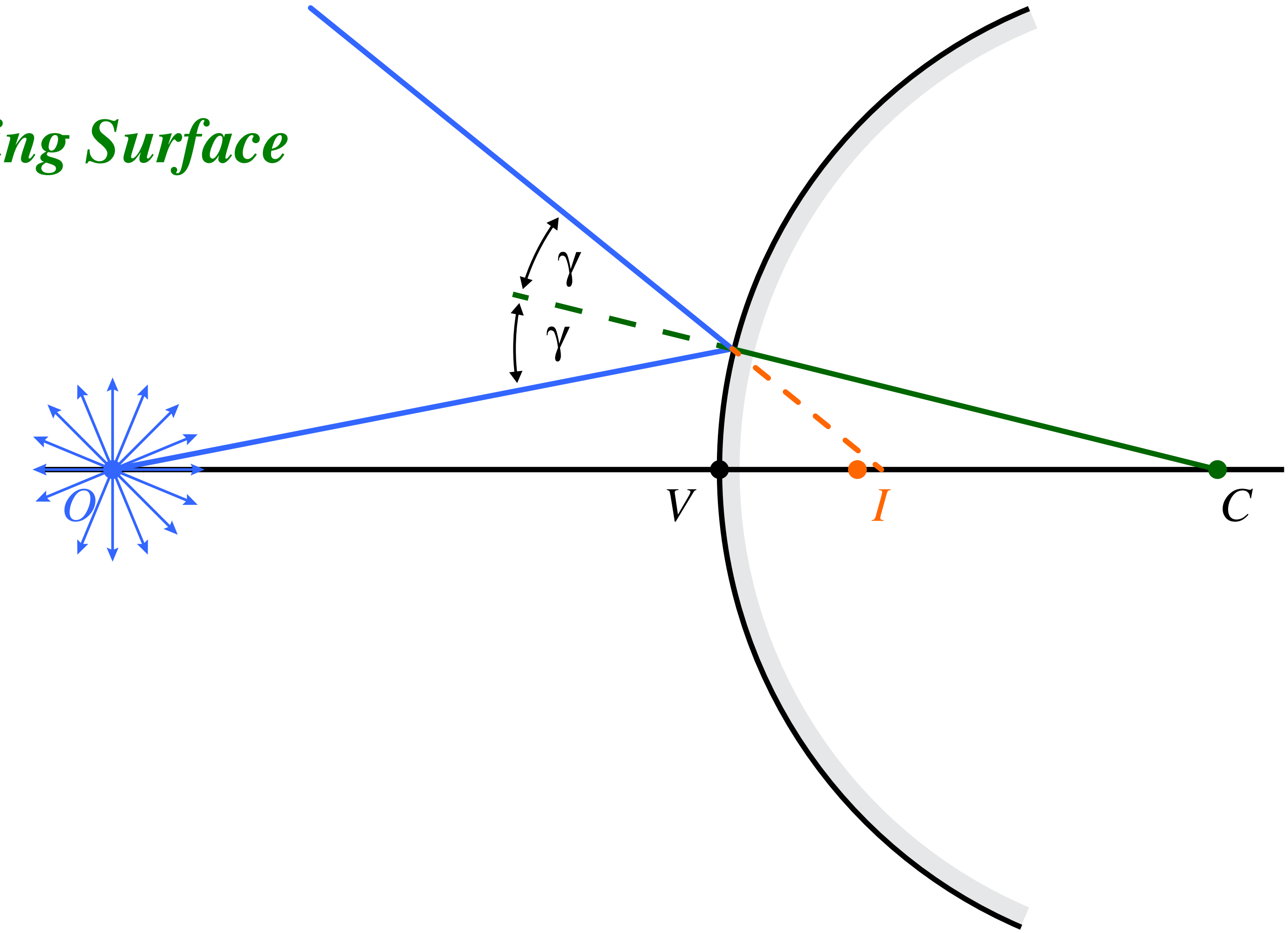
Convex Reflecting Surface



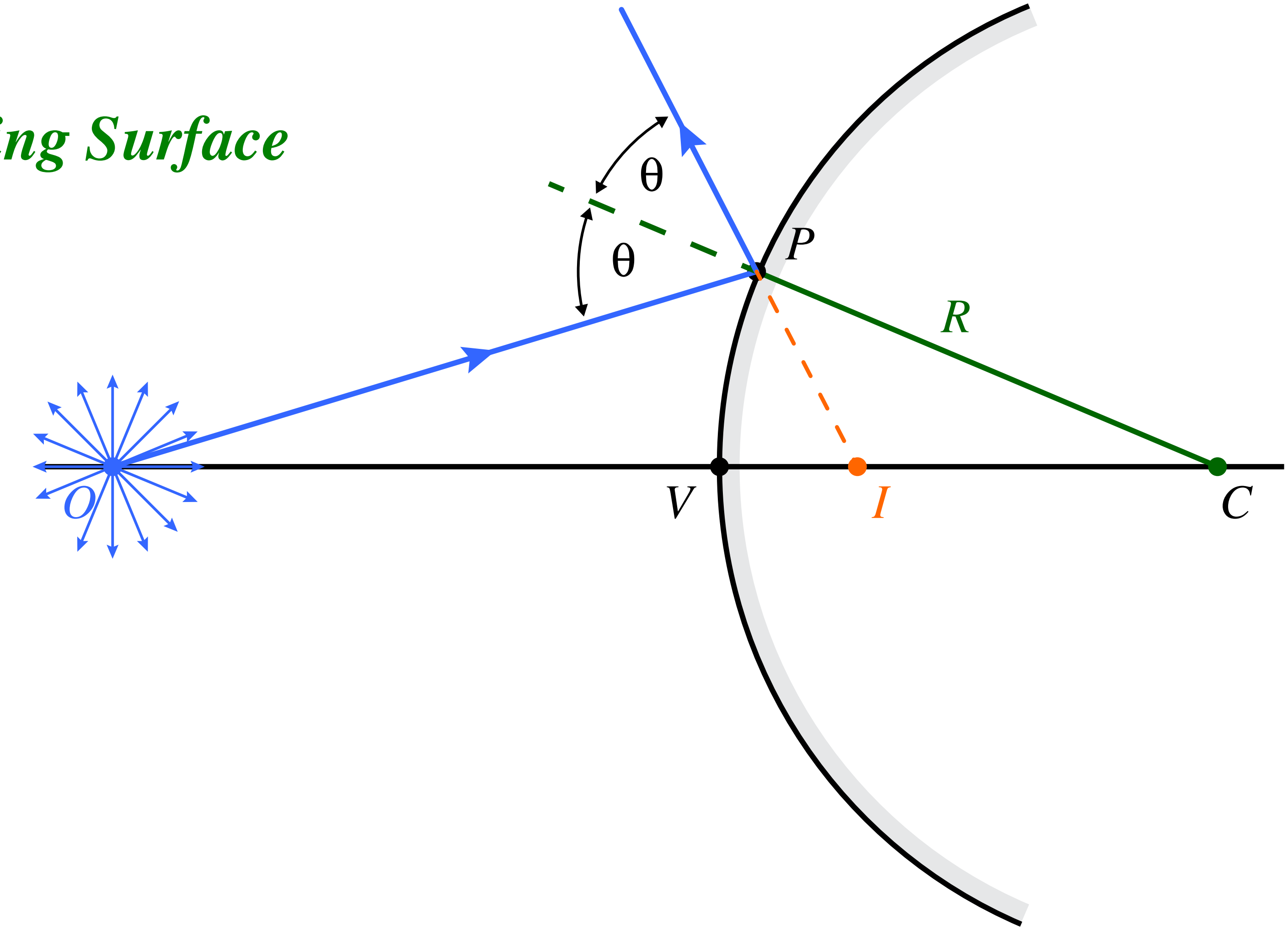
Convex Reflecting Surface



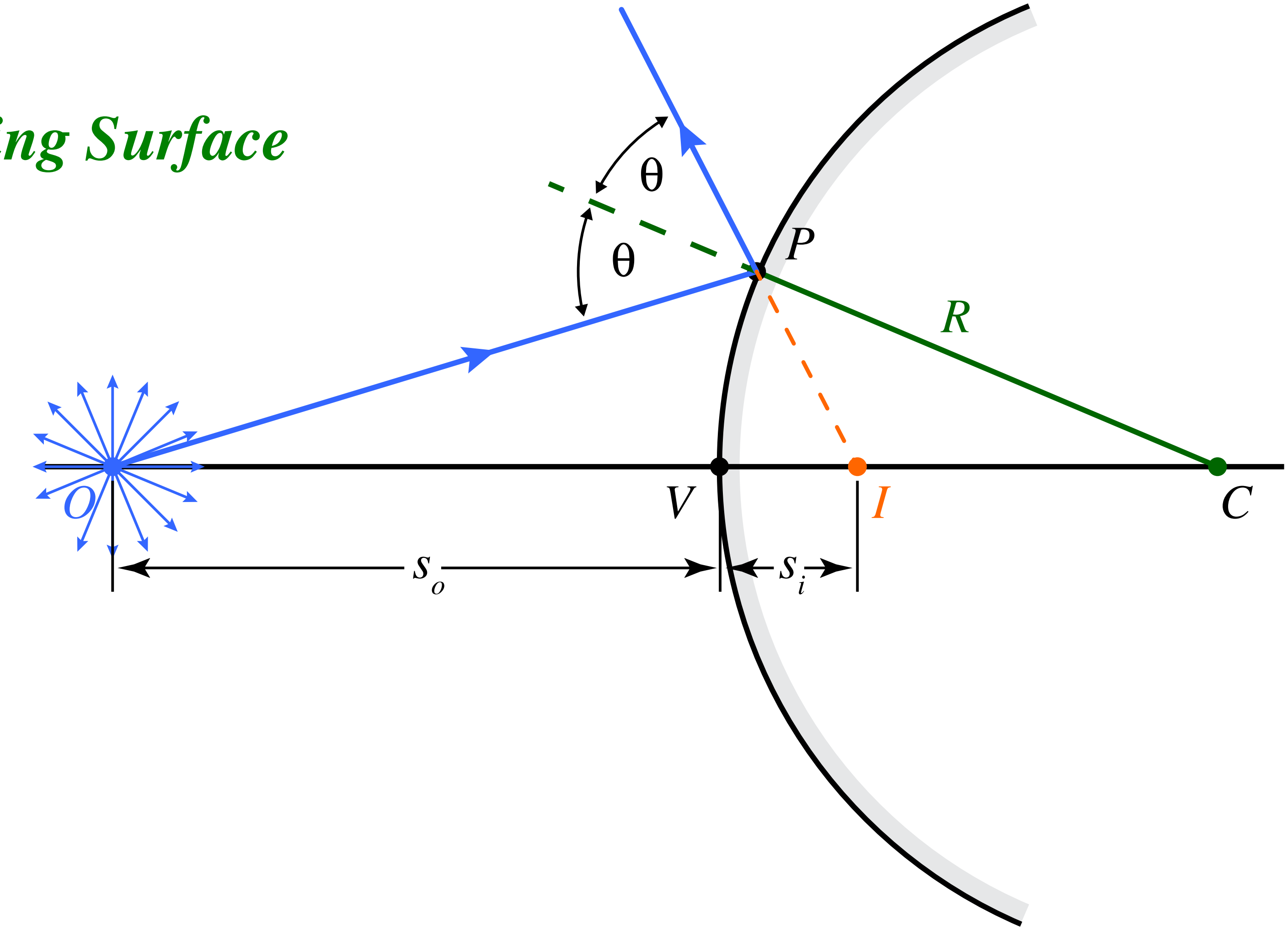
Convex Reflecting Surface



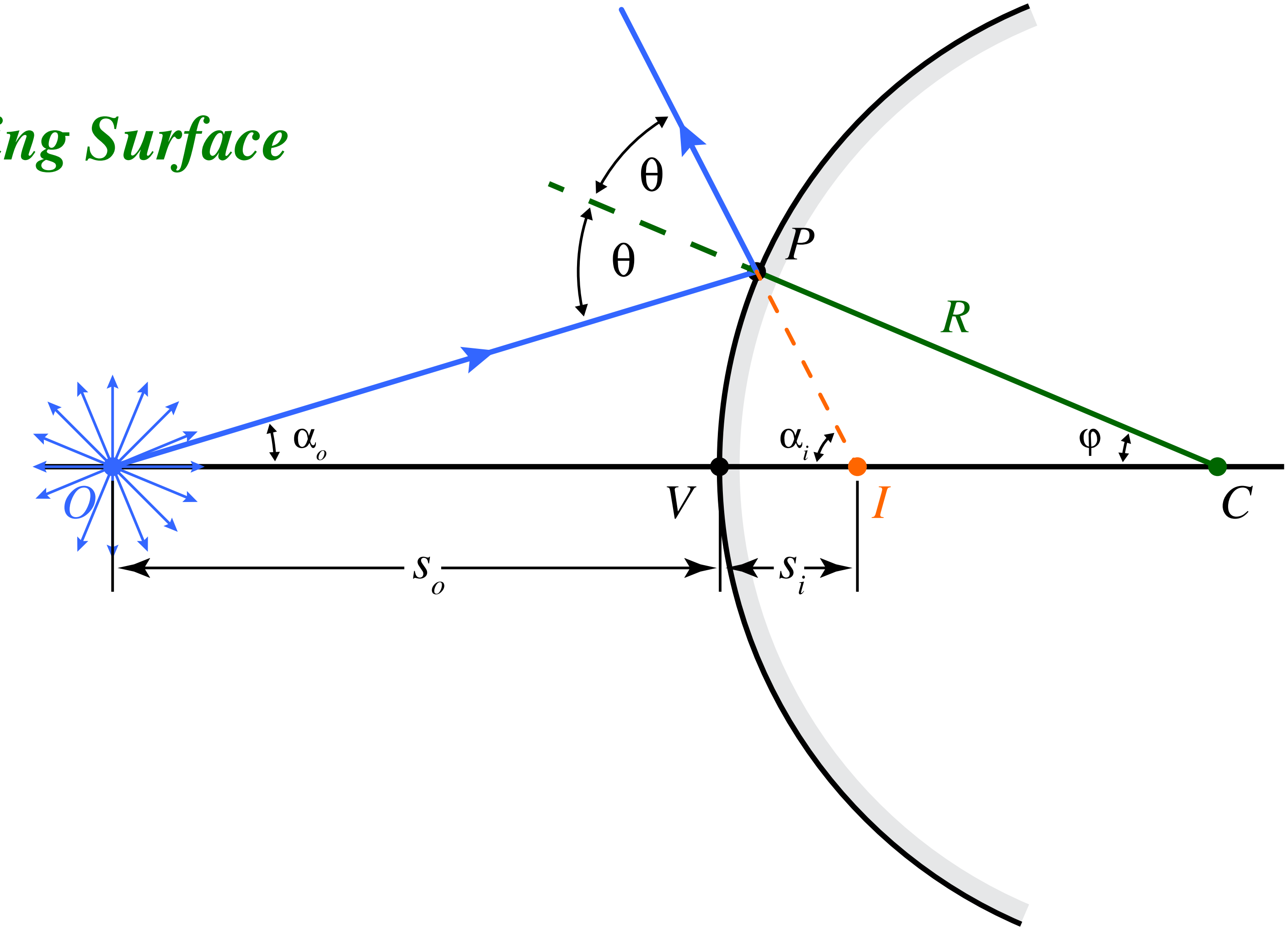
Convex Reflecting Surface



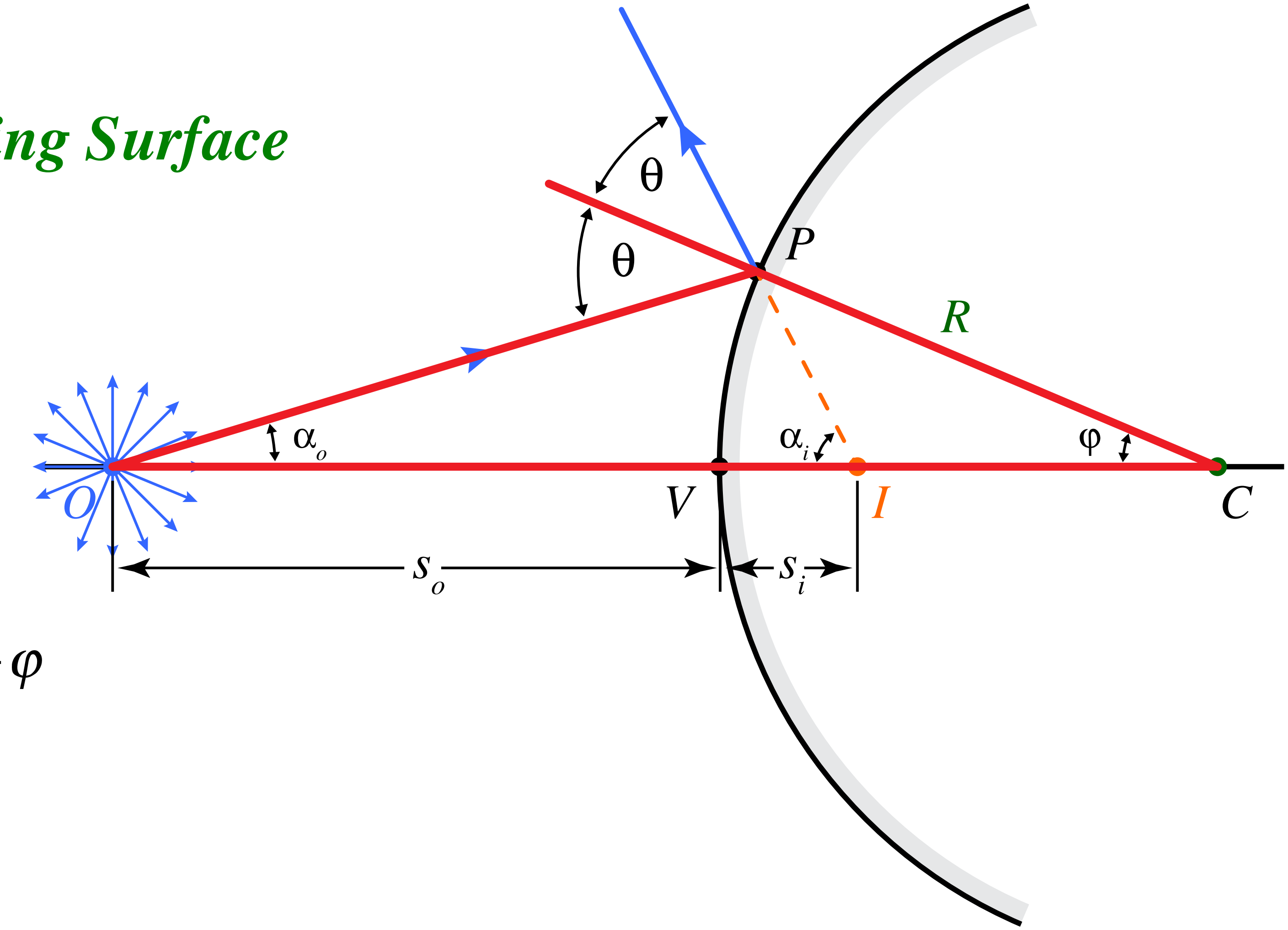
Convex Reflecting Surface



Convex Reflecting Surface

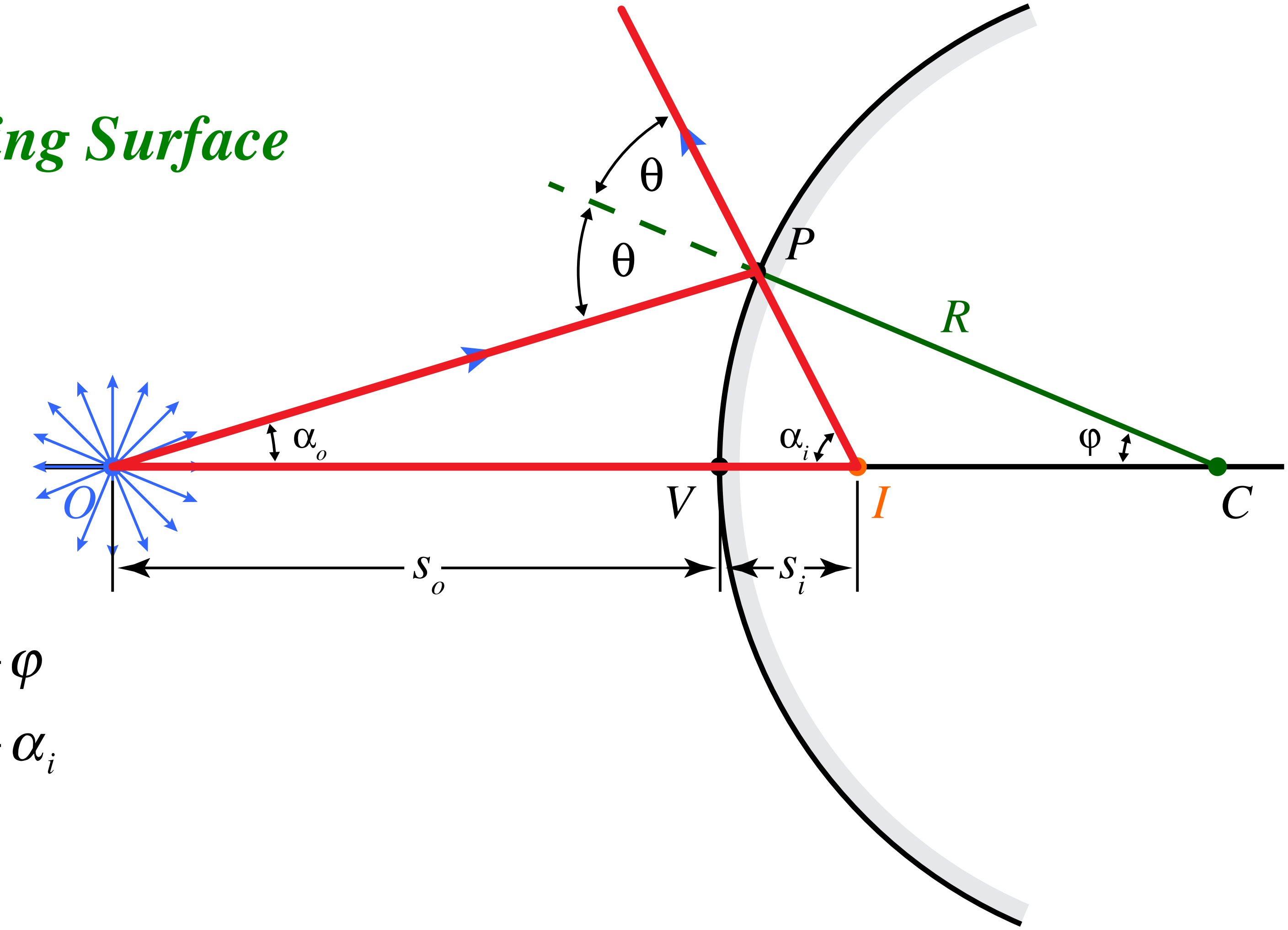


Convex Reflecting Surface



$$\theta = \alpha_o + \varphi$$

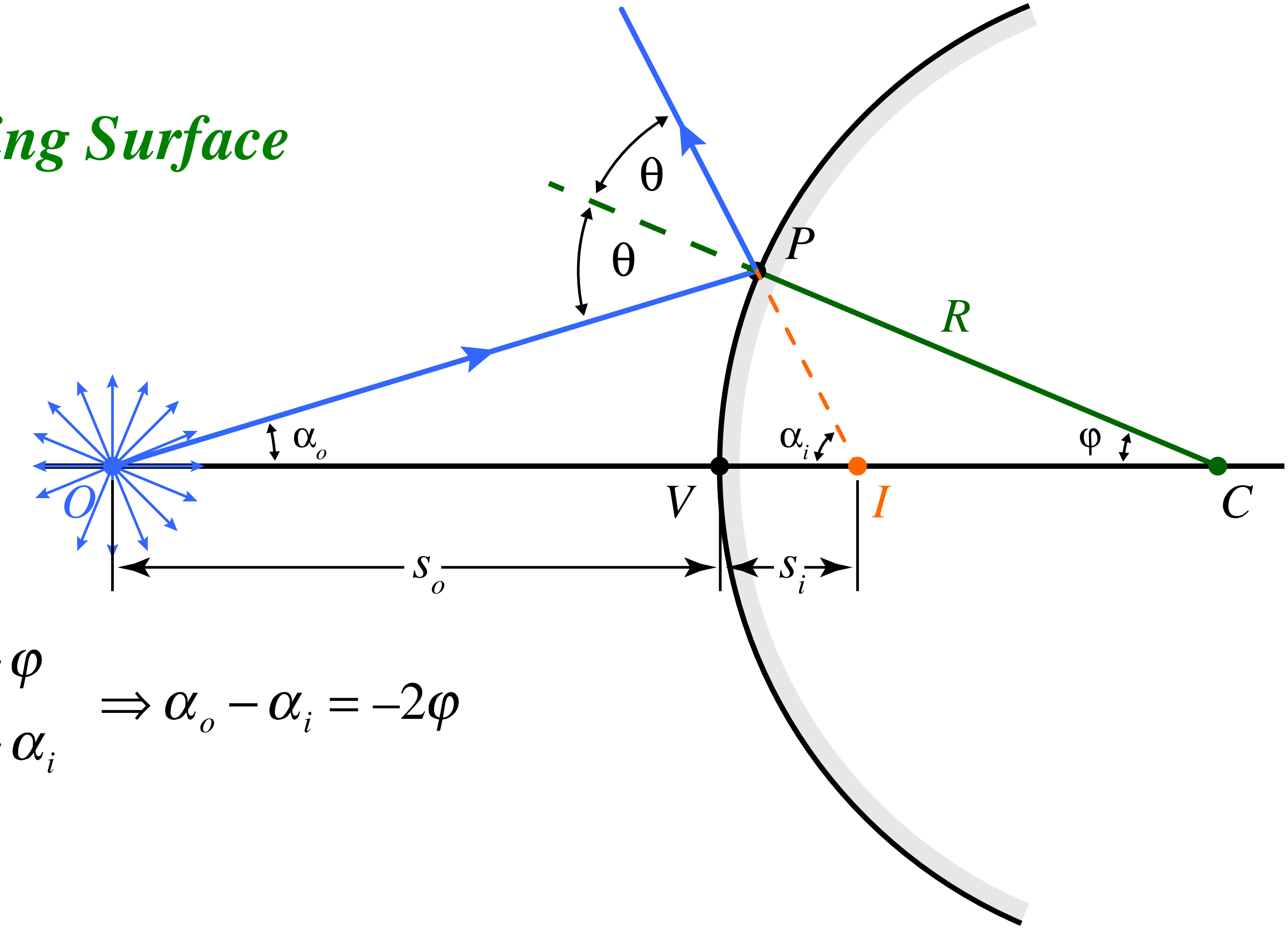
Convex Reflecting Surface



$$\theta = \alpha_o + \varphi$$

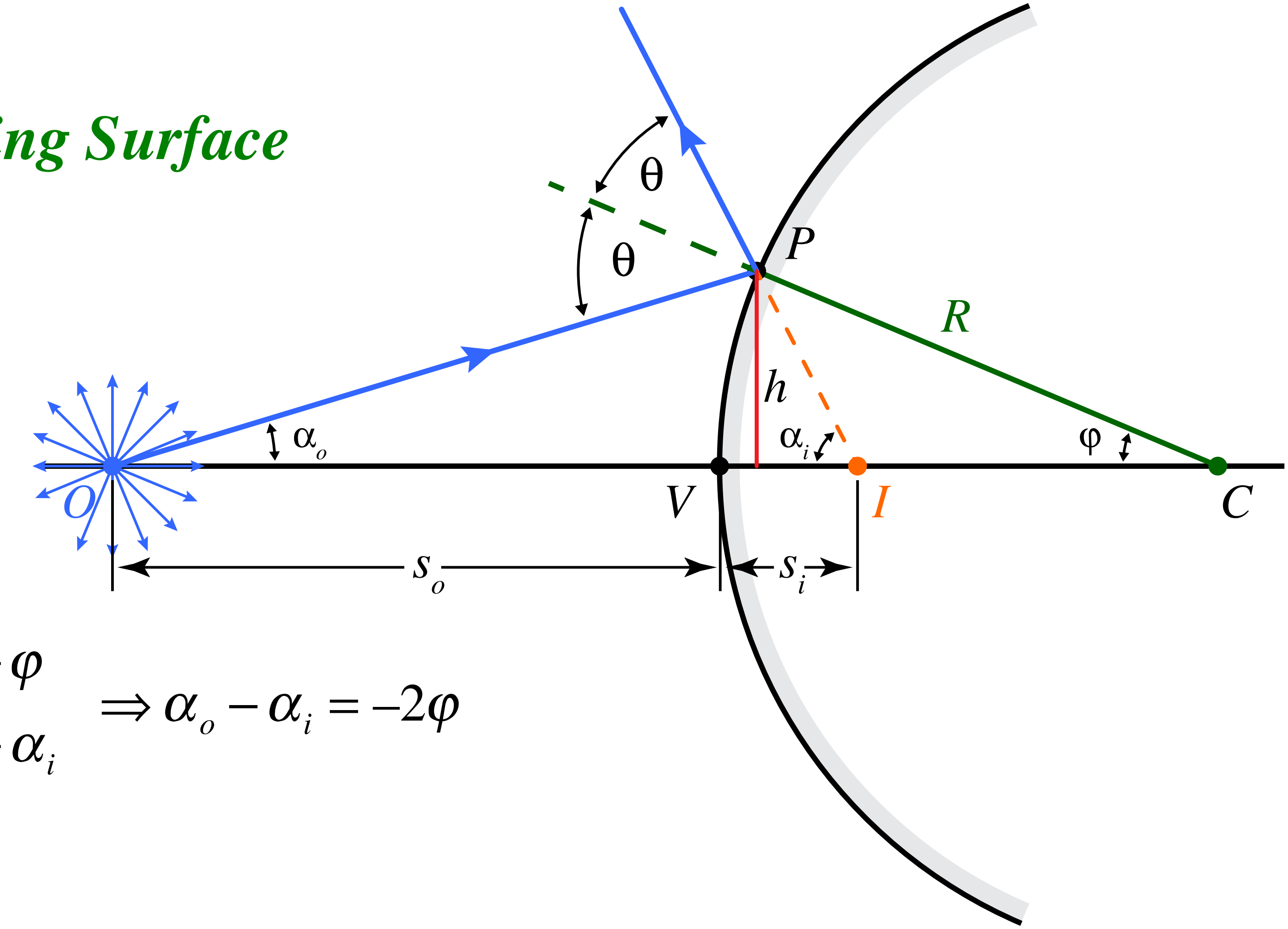
$$2\theta = \alpha_o + \alpha_i$$

Convex Reflecting Surface



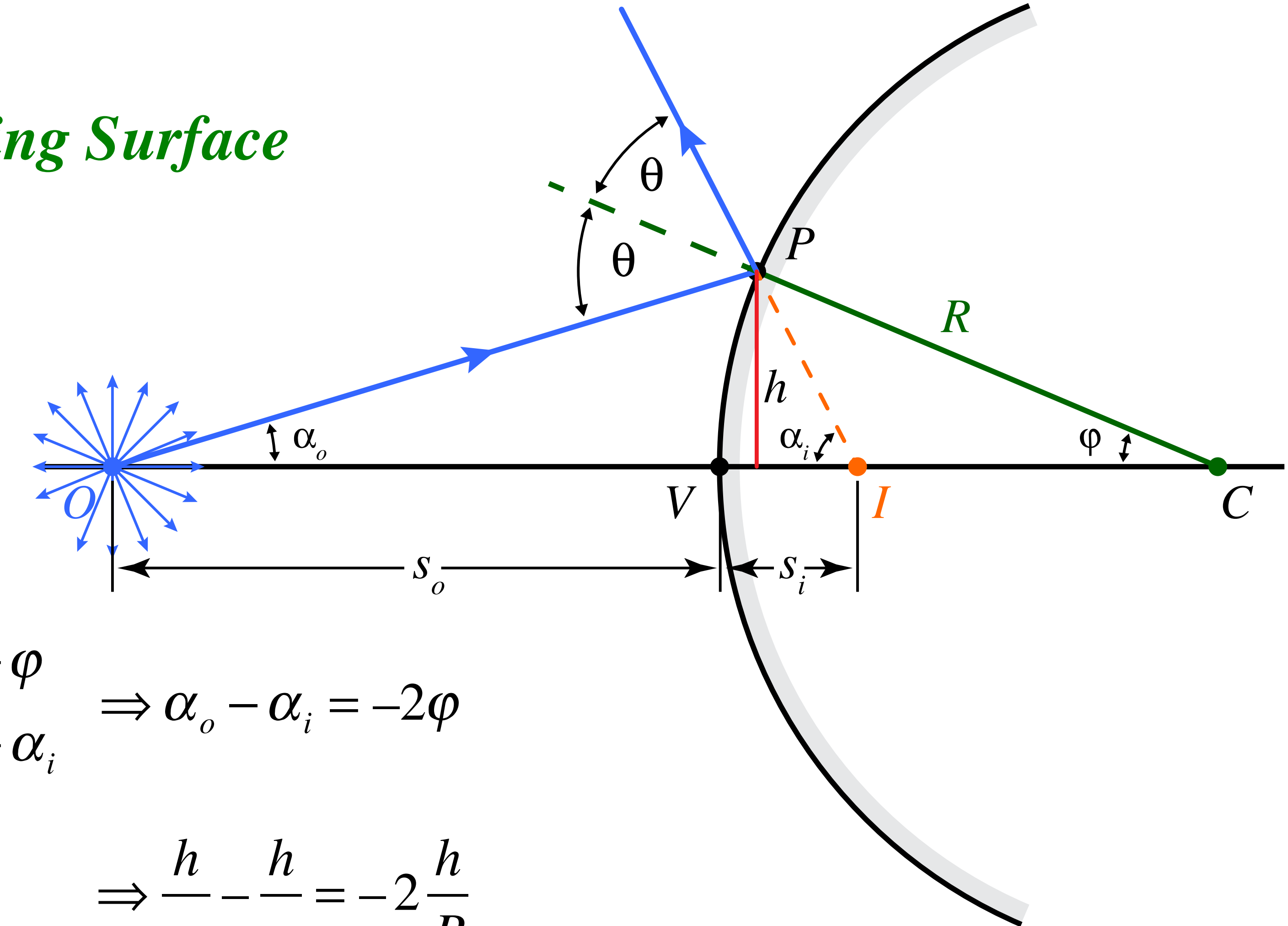
$$\theta = \alpha_o + \varphi$$
$$2\theta = \alpha_o + \alpha_i$$
$$\Rightarrow \alpha_o - \alpha_i = -2\varphi$$

Convex Reflecting Surface



$$\theta = \alpha_o + \varphi$$
$$2\theta = \alpha_o + \alpha_i$$
$$\Rightarrow \alpha_o - \alpha_i = -2\varphi$$

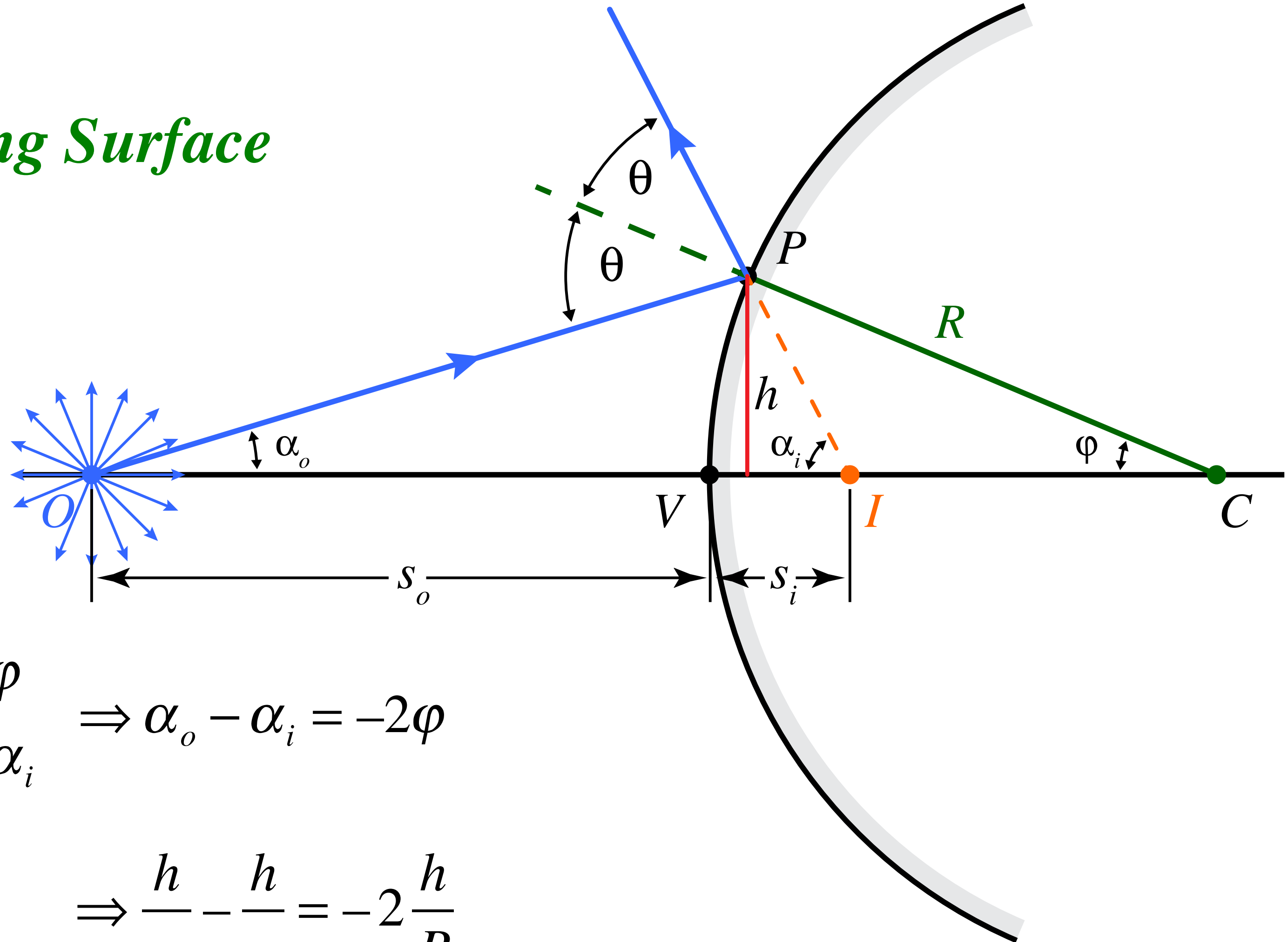
Convex Reflecting Surface



$$\theta = \alpha_o + \varphi$$
$$2\theta = \alpha_o + \alpha_i$$
$$\Rightarrow \alpha_o - \alpha_i = -2\varphi$$

$$\Rightarrow \frac{h}{s_o} - \frac{h}{s_i} = -2\frac{h}{R}$$

Convex Reflecting Surface



$$\theta = \alpha_o + \varphi$$

$$2\theta = \alpha_o + \alpha_i$$

$$\Rightarrow \alpha_o - \alpha_i = -2\varphi$$

$$\Rightarrow \frac{h}{s_o} - \frac{h}{s_i} = -2\frac{h}{R}$$

$$\Rightarrow \frac{1}{s_o} - \frac{1}{s_i} = -\frac{2}{R}$$

Convex Reflecting Surface

$$\frac{1}{s_o} - \frac{1}{s_i} = -\frac{2}{R}$$

Concave Reflecting Surface

$$\frac{1}{s_o} + \frac{1}{s_i} = +\frac{2}{R}$$

Let's standardize on one equation

$$\frac{1}{s_o} + \frac{1}{s_i} = -\frac{2}{R}$$

and adopt a sign convention (rays coming from the left)

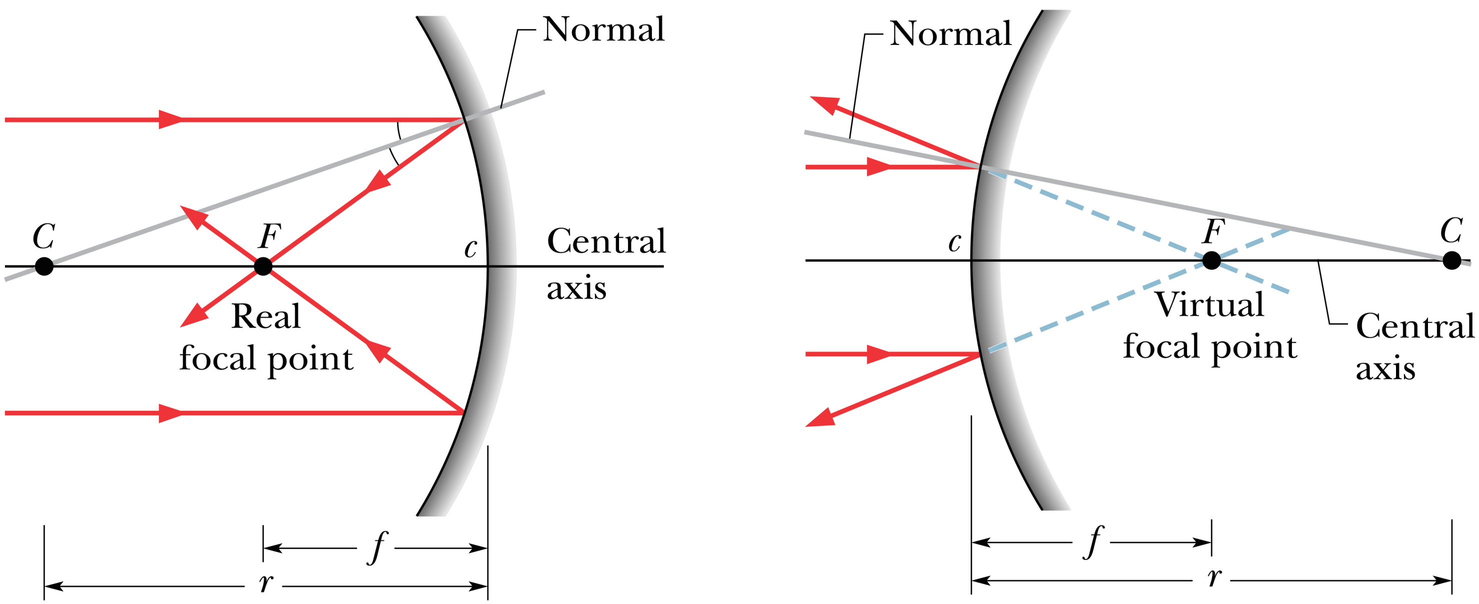
Object, s_o :
- $+$ when O is to the left of V (real object)
- $-$ when O is to the right of V (virtual object)

Image, s_i :
- $+$ when I is to the left of V (real image)
- $-$ when I is to the right of V (virtual image)

Radius, R :
- $-$ when C is to the left of V (concave surface)
- $+$ when C is to the right of V (convex surface)

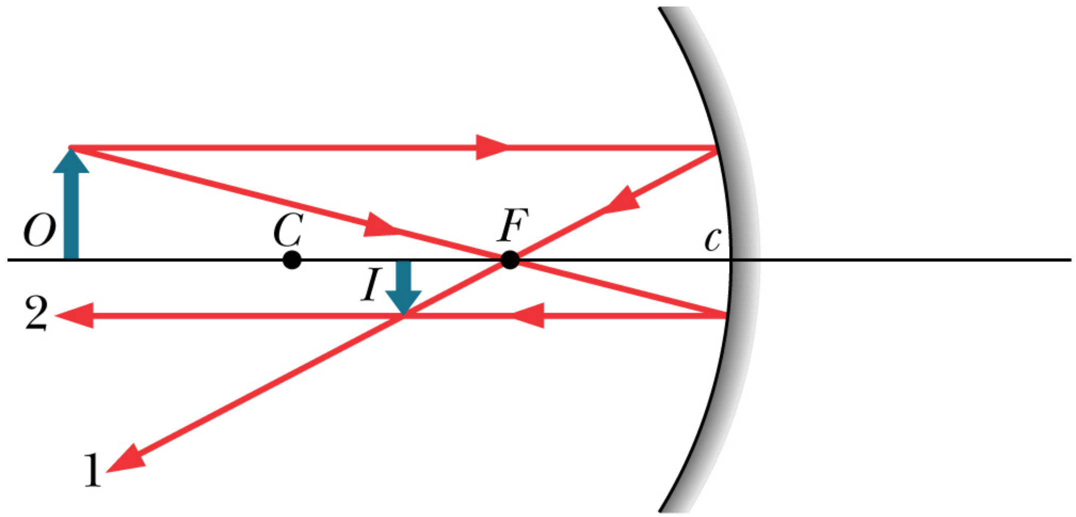
For an object at infinity

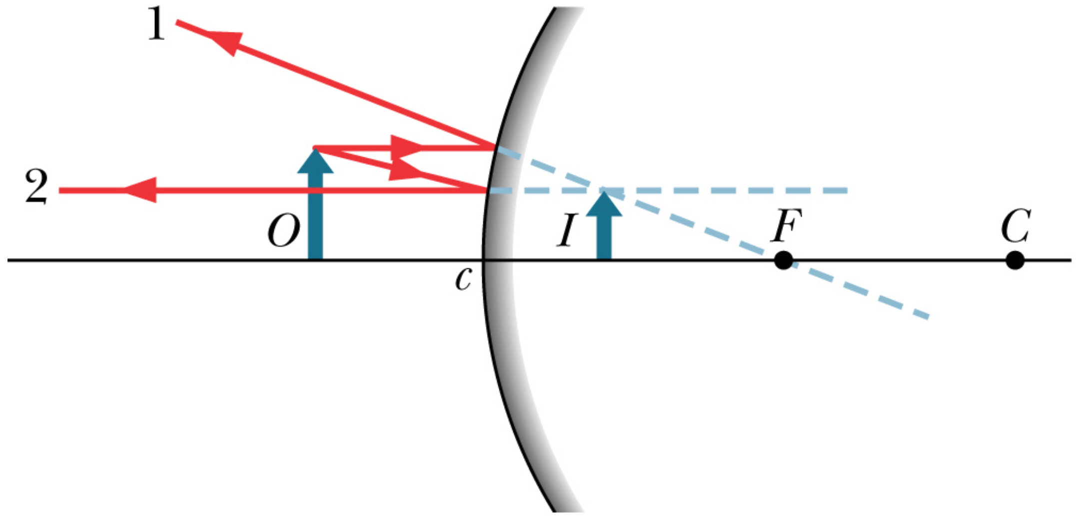
$$s_o = \infty \quad \Rightarrow \quad \frac{1}{\infty} + \frac{1}{s_i} = -\frac{2}{R} \quad \Rightarrow \quad s_i = -\frac{R}{2} = f$$



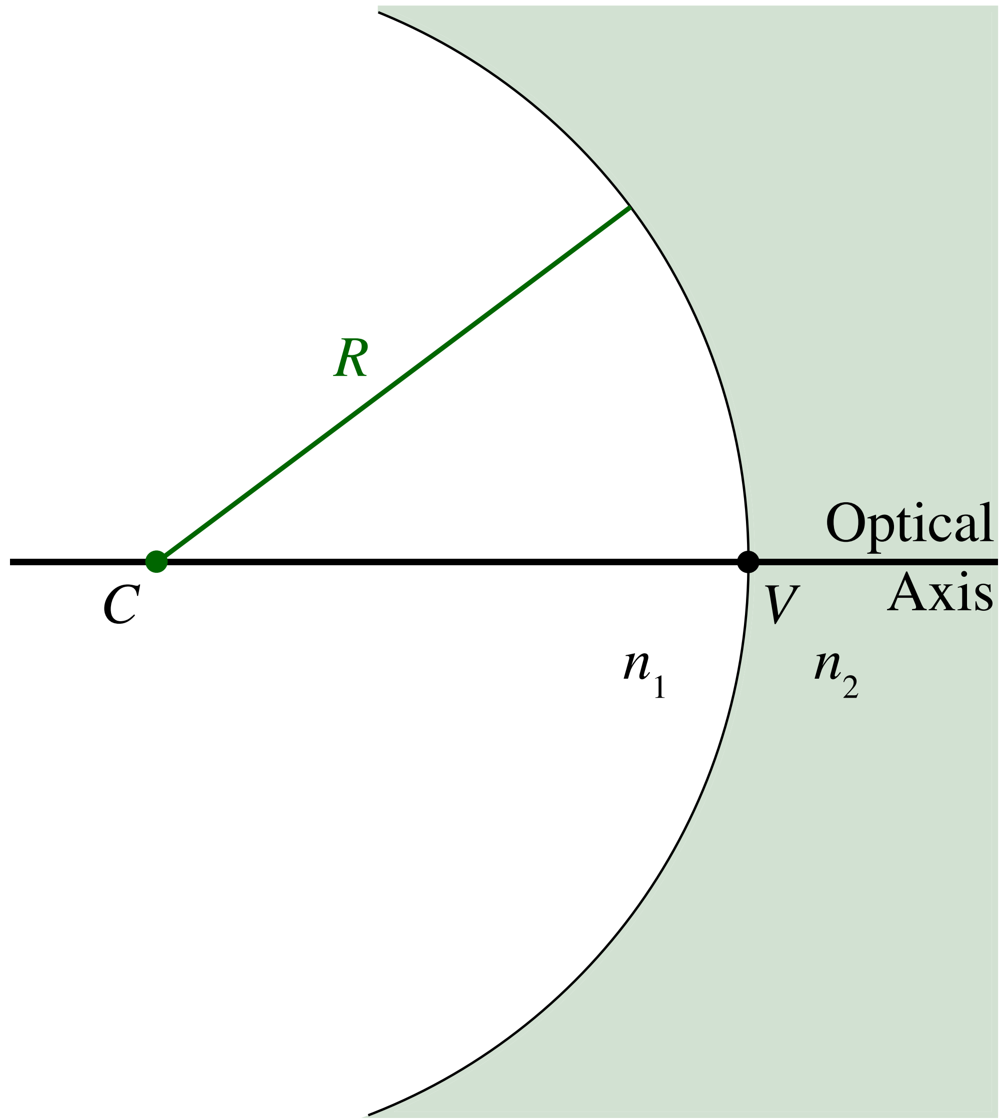
f: focal length of the mirror

Knowing f is useful for drawing ray diagrams to find the image

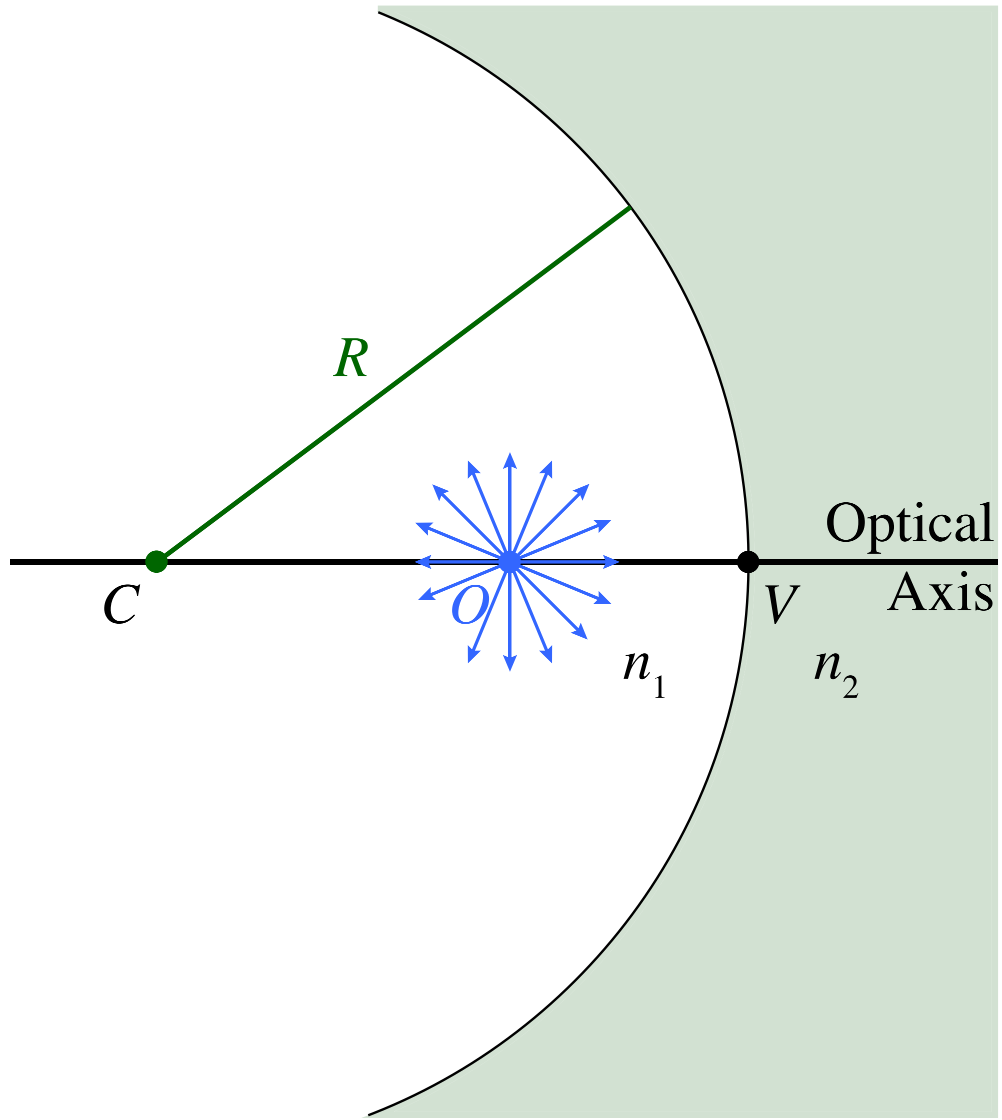




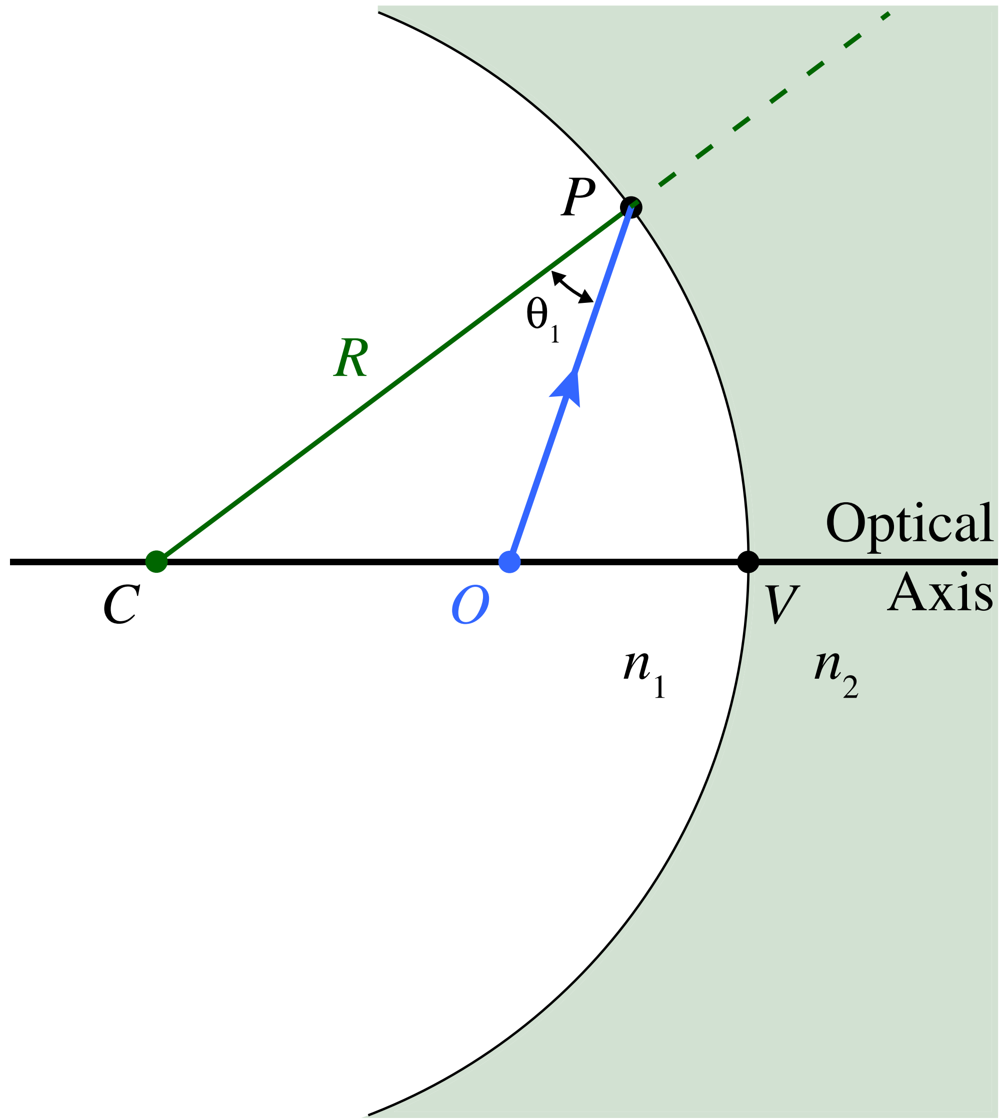
Concave Refracting Surface



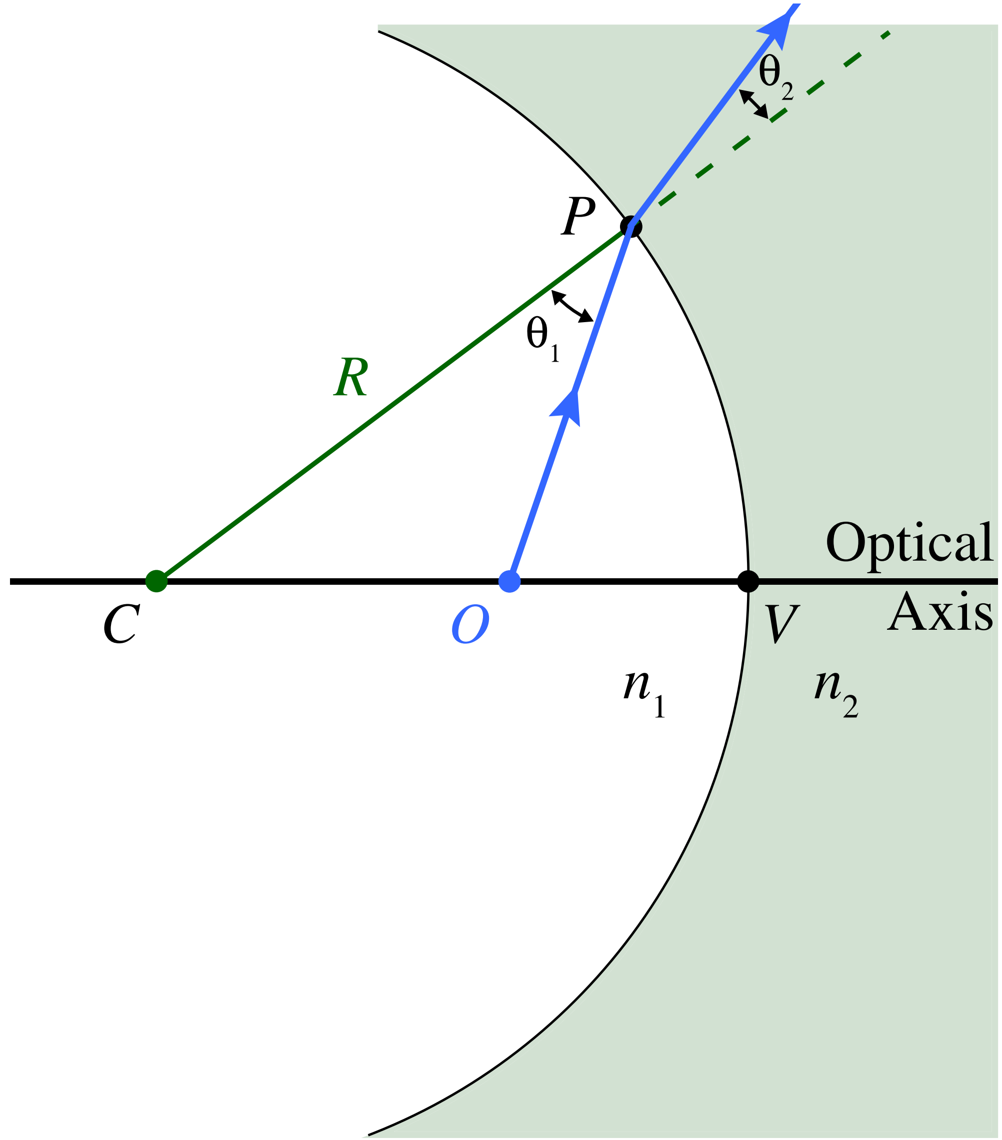
Concave Refracting Surface



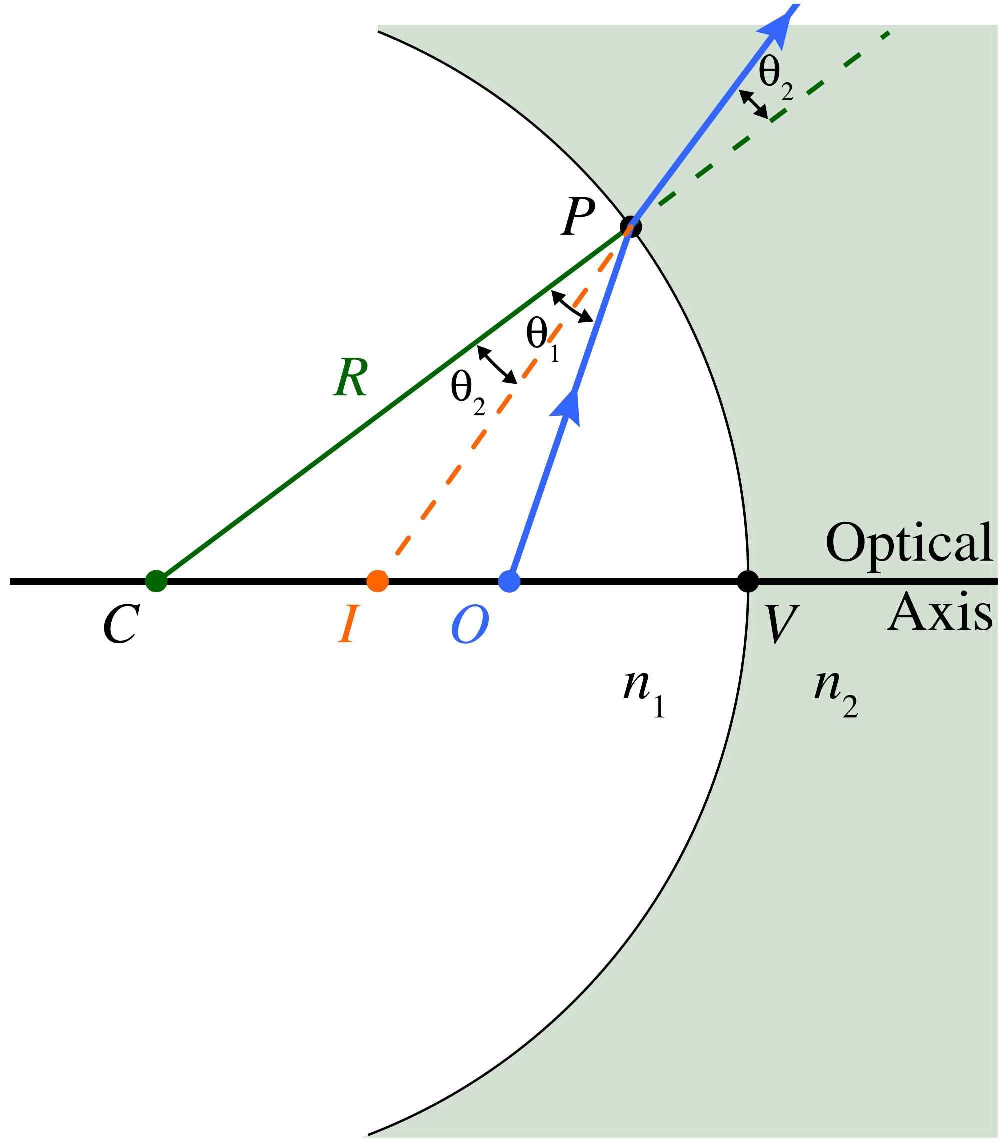
Concave Refracting Surface



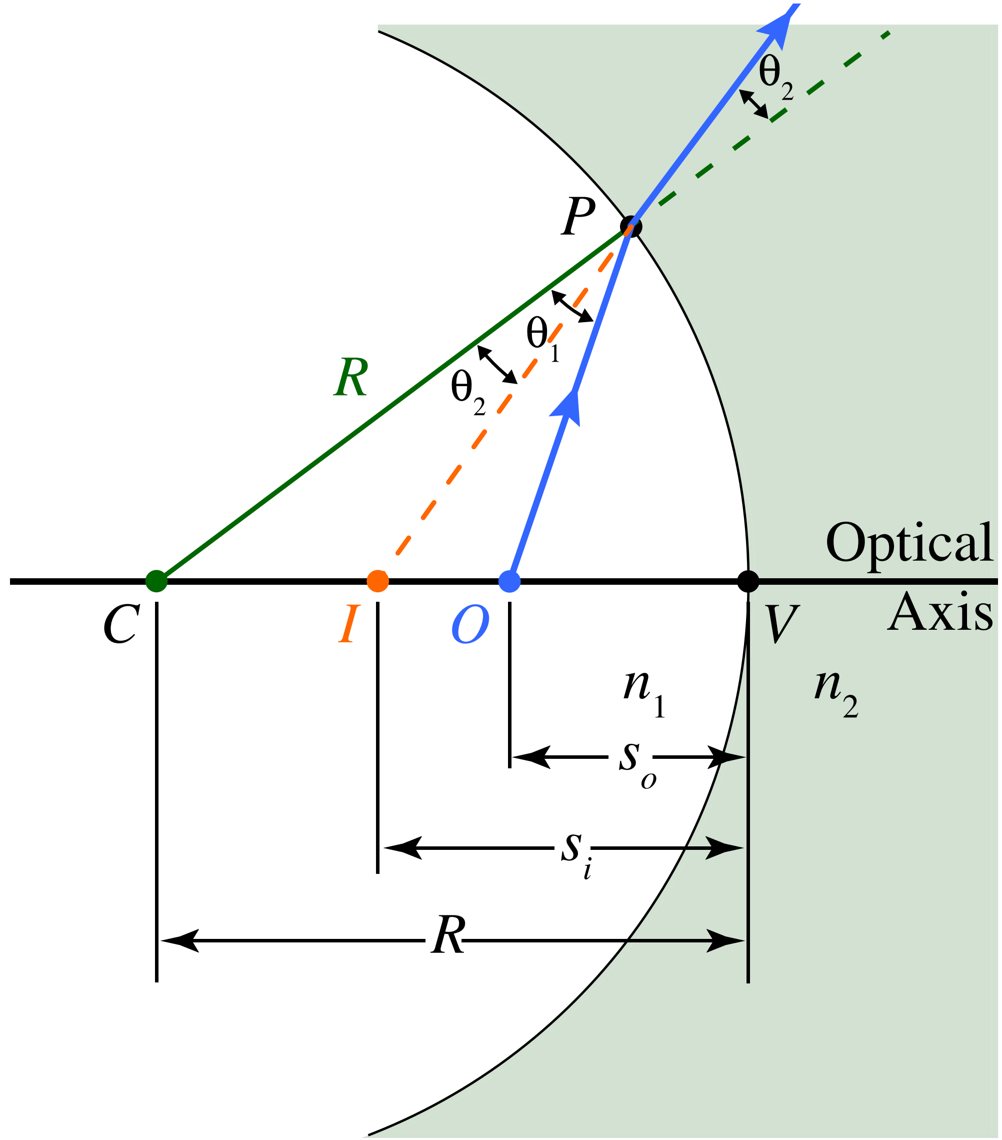
Concave Refracting Surface



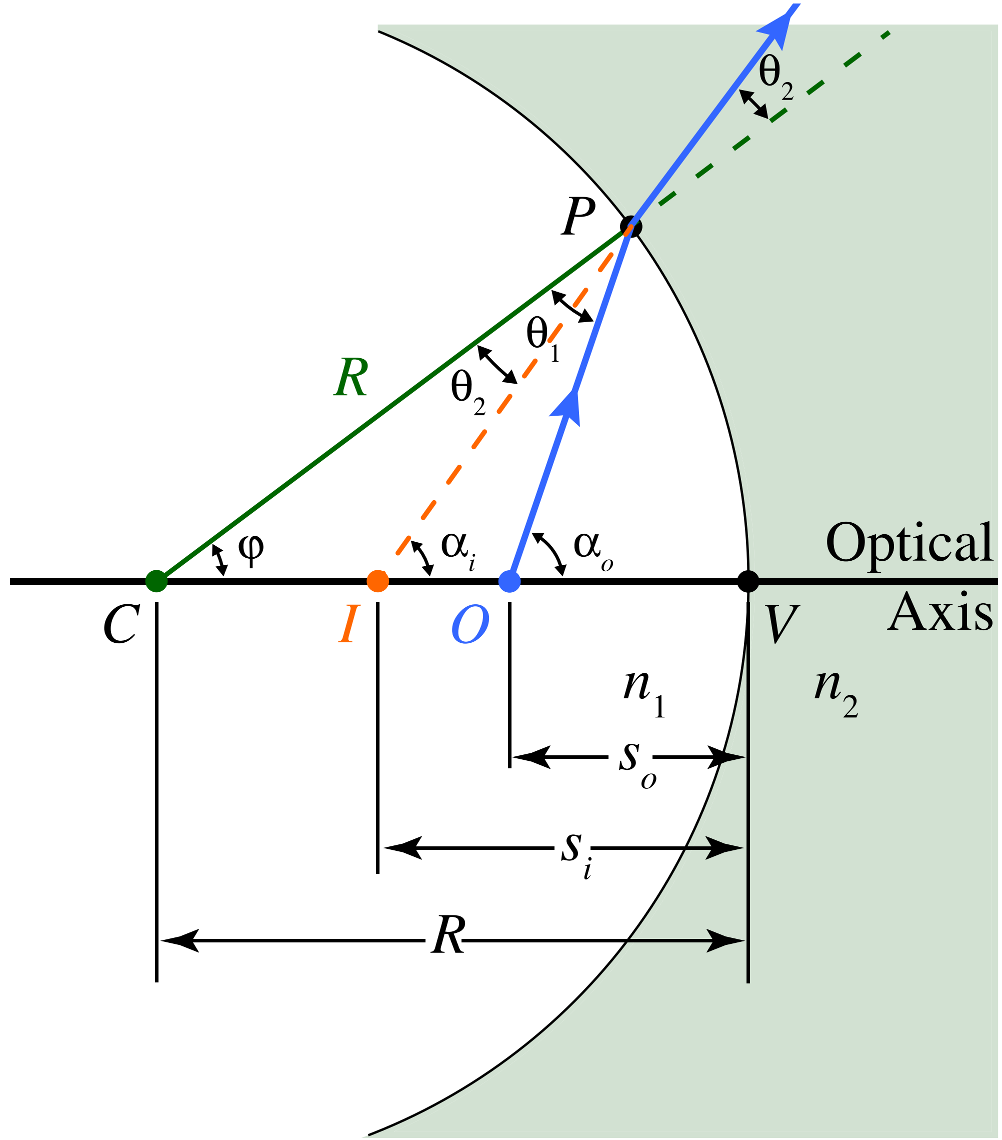
Concave Refracting Surface



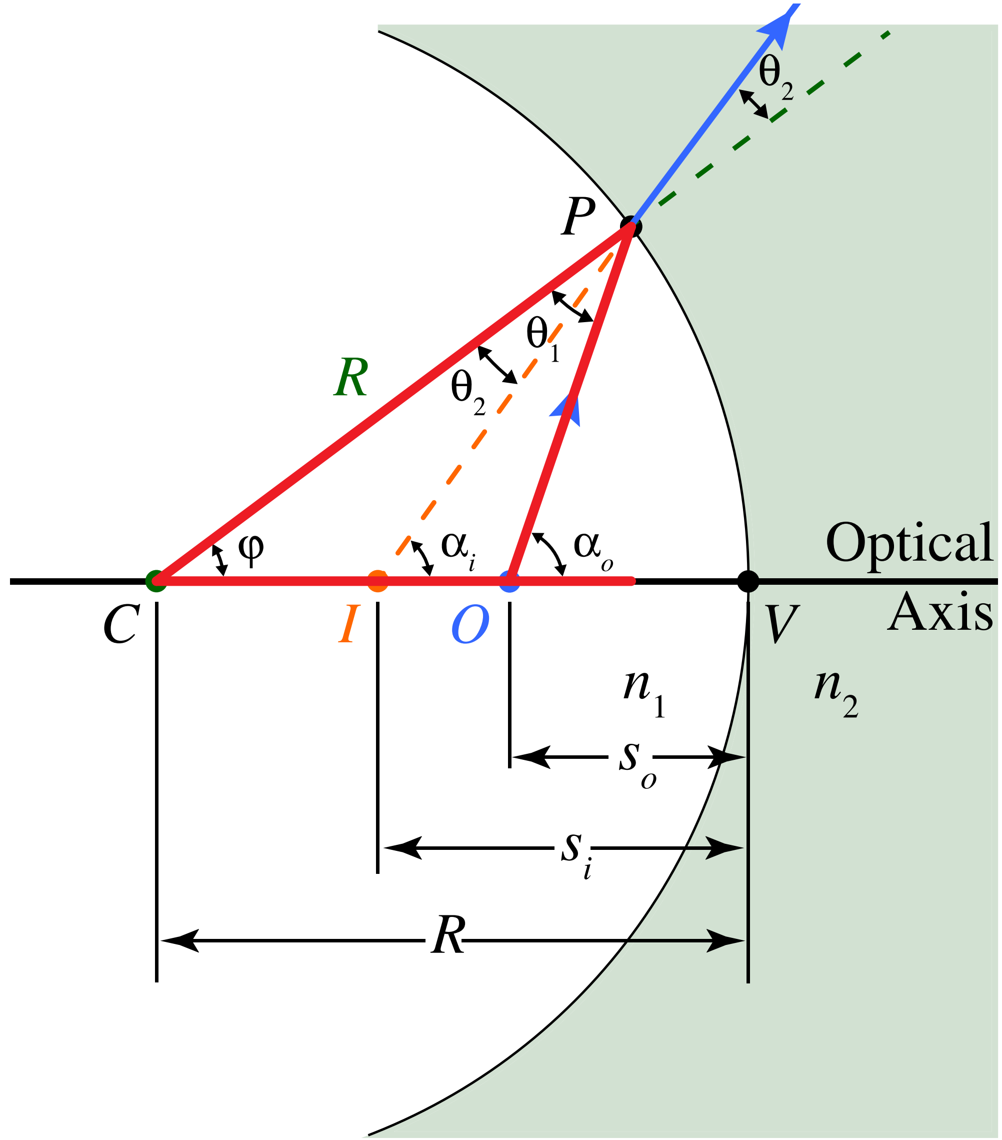
Concave Refracting Surface



Concave Refracting Surface

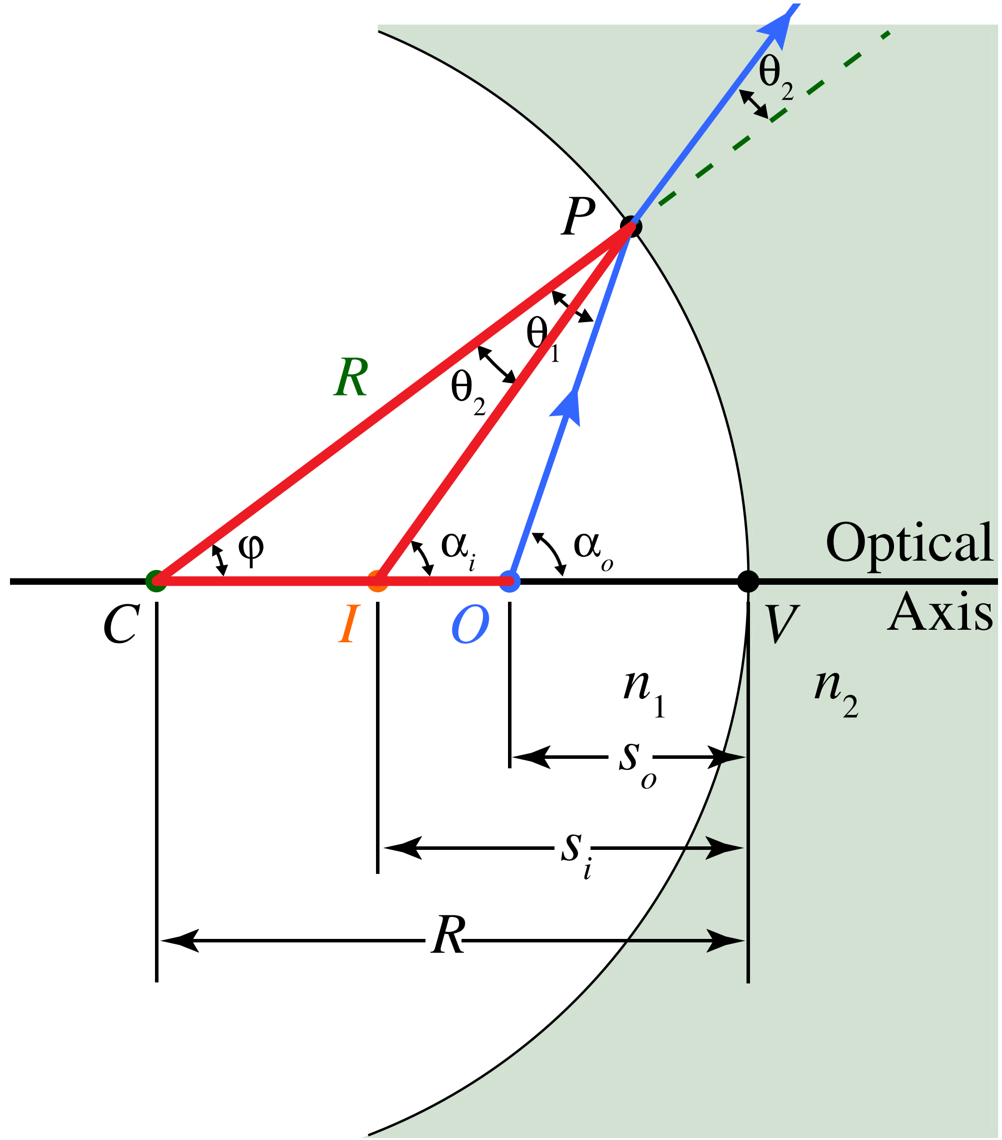


Concave Refracting Surface



$$\alpha_o = \varphi + \theta_1$$

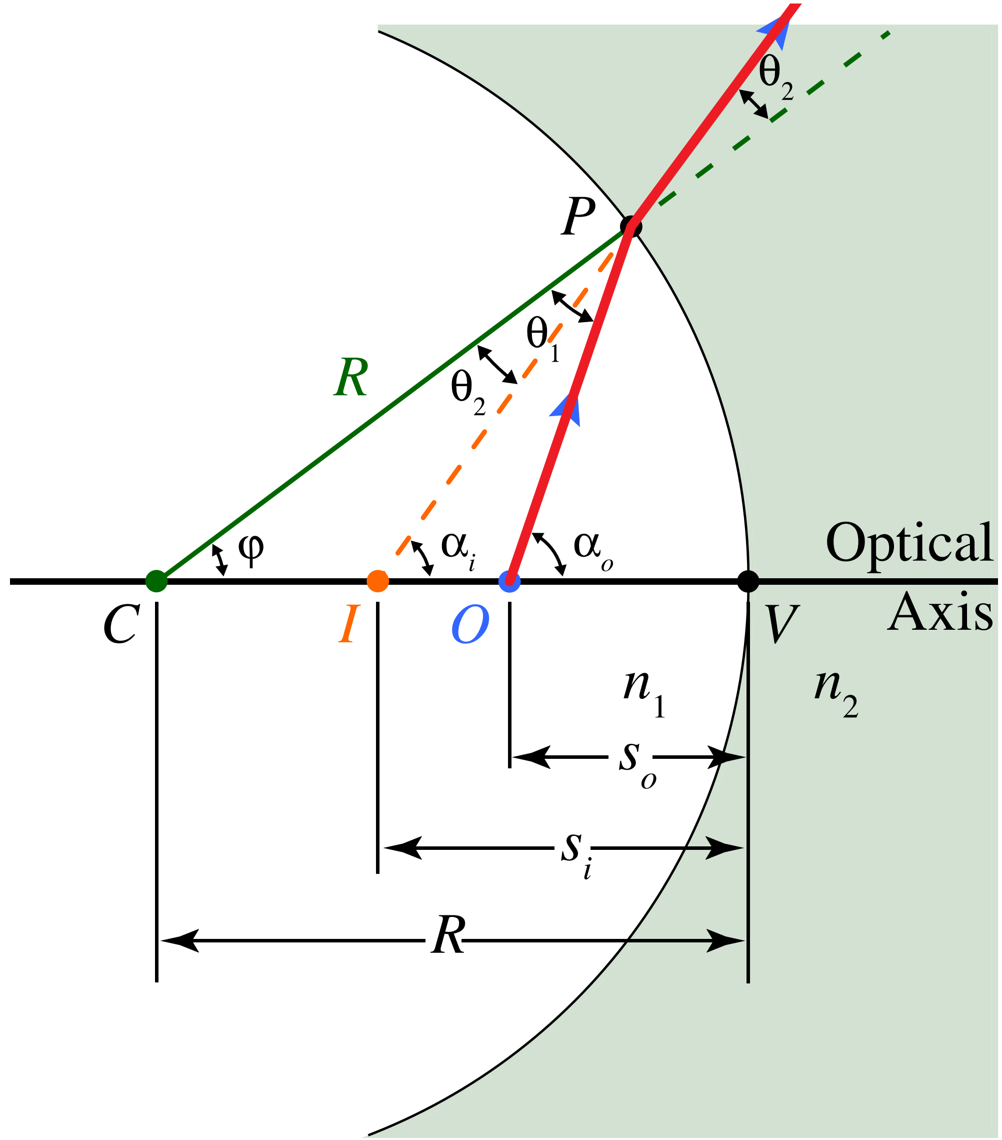
Concave Refracting Surface



$$\alpha_o = \varphi + \theta_1$$

$$\alpha_i = \varphi + \theta_2$$

Concave Refracting Surface

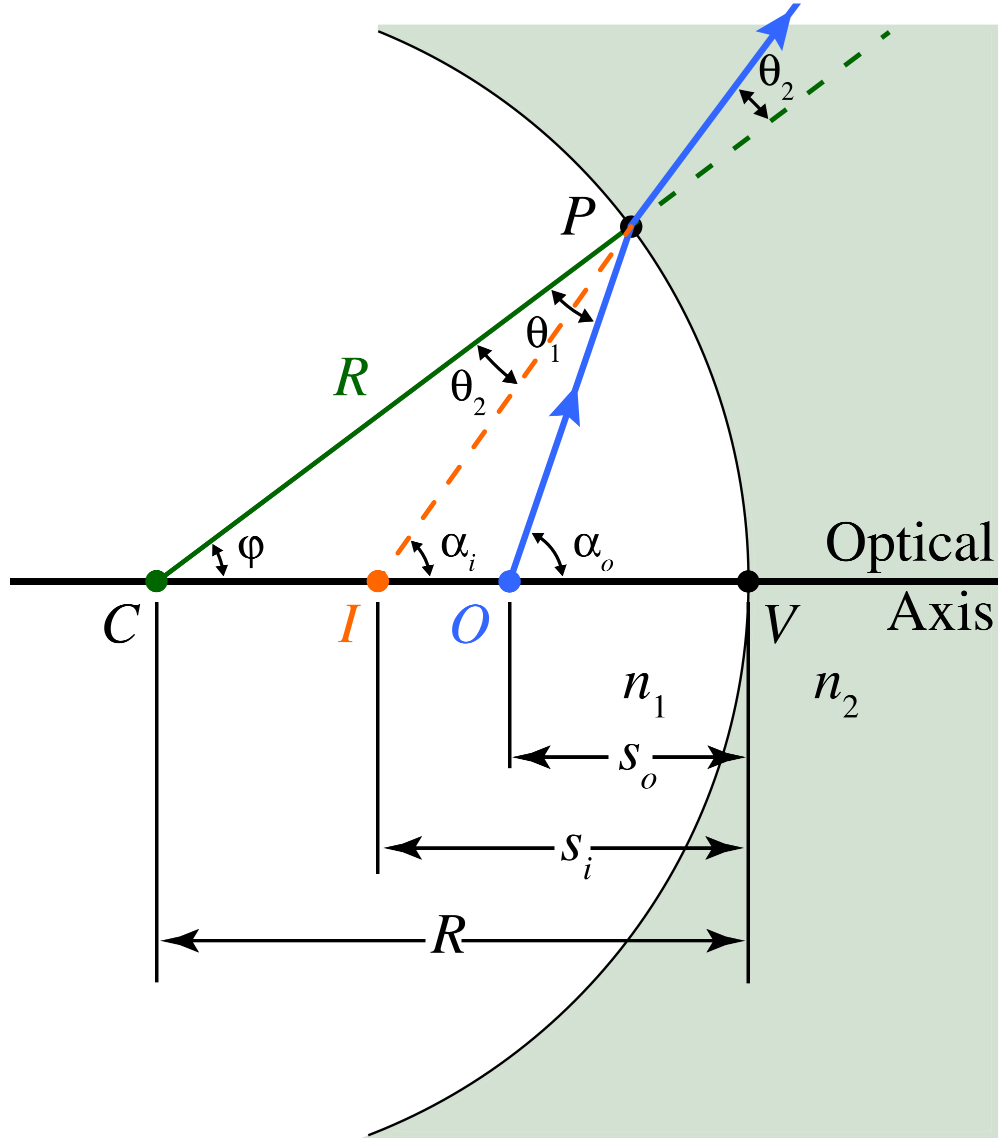


$$\alpha_o = \varphi + \theta_1$$

$$\alpha_i = \varphi + \theta_2$$

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

Concave Refracting Surface



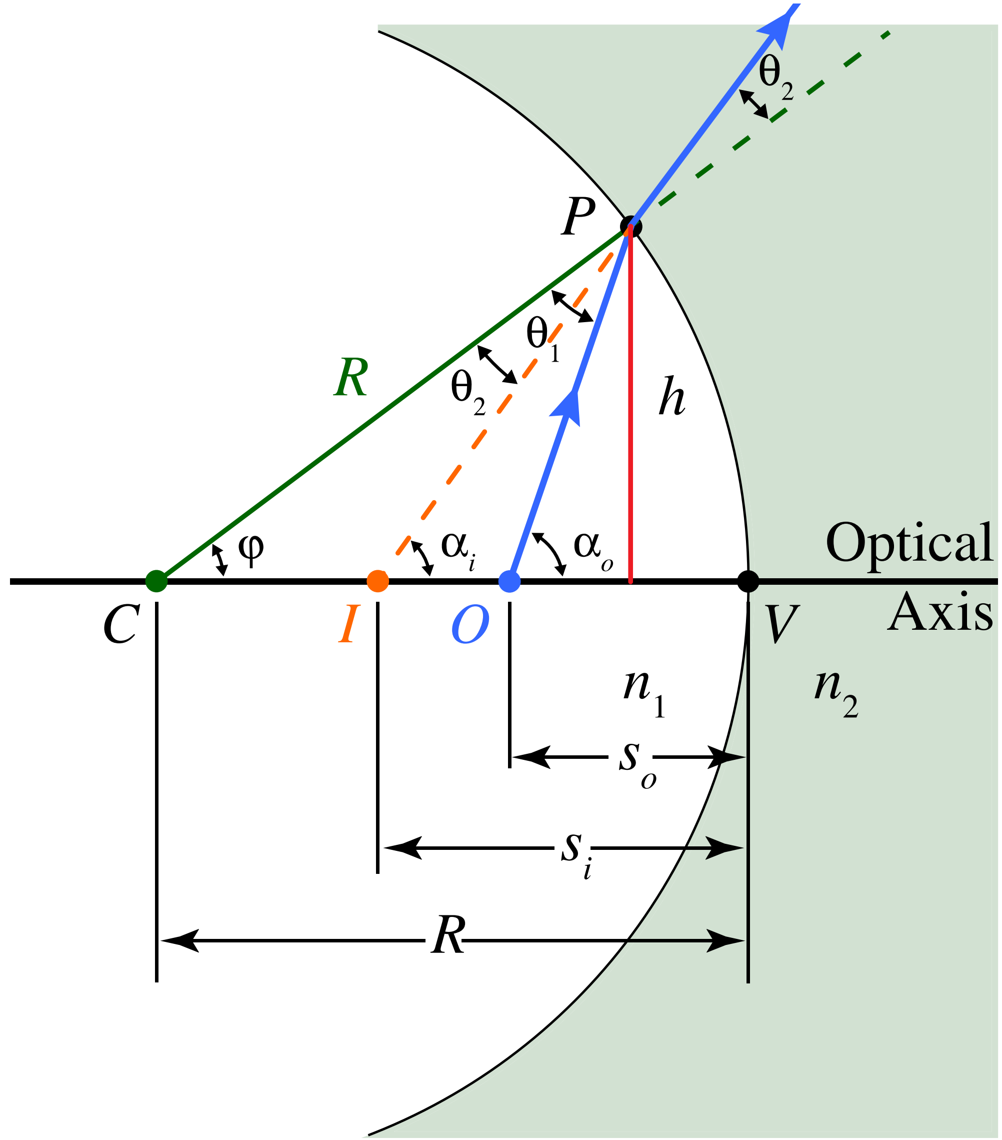
$$\alpha_o = \varphi + \theta_1$$

$$\alpha_i = \varphi + \theta_2$$

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

$$\Rightarrow n_1\left(\alpha_o - \varphi\right) = n_2\left(\alpha_i - \varphi\right)$$

Concave Refracting Surface



$$\alpha_o = \varphi + \theta_1$$

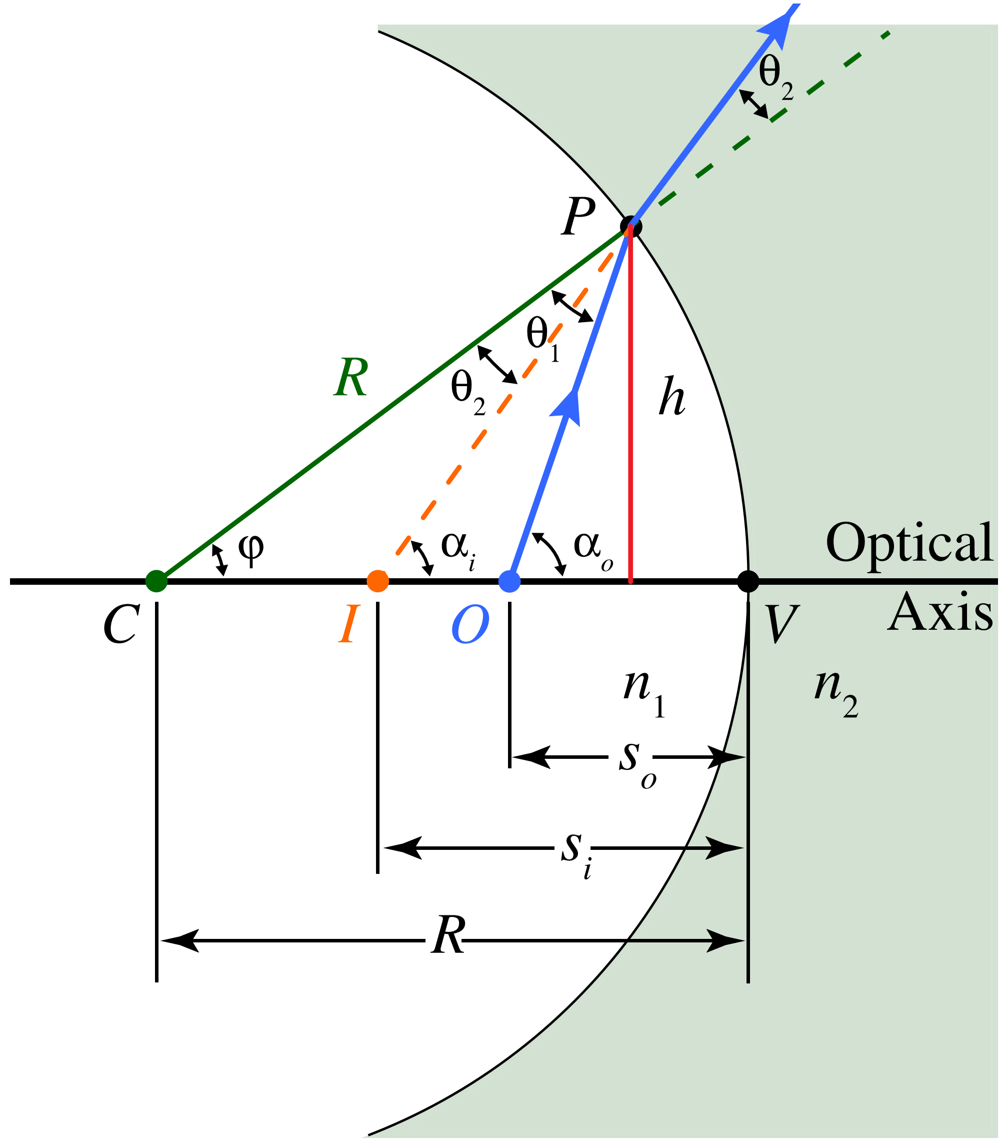
$$\alpha_i = \varphi + \theta_2$$

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

$$\Rightarrow n_1\left(\alpha_o - \varphi\right) = n_2\left(\alpha_i - \varphi\right)$$

$$\Rightarrow n_1\left(\frac{h}{s_o} - \frac{h}{R}\right) = n_2\left(\frac{h}{s_i} - \frac{h}{R}\right)$$

Concave Refracting Surface



$$\alpha_o = \varphi + \theta_1$$

$$\alpha_i = \varphi + \theta_2$$

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

$$\Rightarrow n_1\left(\alpha_o - \varphi\right) = n_2\left(\alpha_i - \varphi\right)$$

$$\Rightarrow n_1\left(\frac{h}{s_o} - \frac{h}{R}\right) = n_2\left(\frac{h}{s_i} - \frac{h}{R}\right) \quad \Rightarrow \frac{n_1}{s_o} - \frac{n_2}{s_i} = \frac{n_1 - n_2}{R}$$

Concave Refracting Surface

$$\frac{n_1}{s_o} - \frac{n_2}{s_i} = \frac{n_1 - n_2}{R}$$

Convex Refracting Surface

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = -\frac{n_1 - n_2}{R}$$

Again, let's standardize on one equation

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$

and adopt a sign convention

$$\left.\begin{array}{c}\text{real objects}\\ \text{real images}\\ \text{convex surface}\end{array}\right\} + \text{distances}$$

$$\left.\begin{array}{c}\text{virtual objects}\\ \text{virtual images}\\ \text{concave surface}\end{array}\right\} - \text{distances}$$