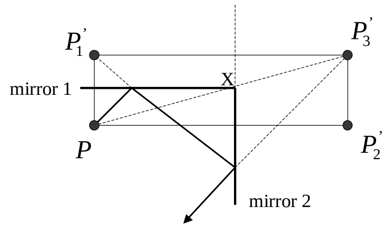
PHY2208 Lecture 2

The retroreflector
Introduction to spherical mirrors

Y&F p. 1088 & Section 33-5

An important concept

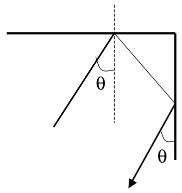
An **image** can form the **object** for a second optical element



Object P produces images P'_1 in mirror 1 and P'_2 in mirror 2. Also, Mirror 2 produces a virtual image of $P'_1 \Rightarrow P'_3$

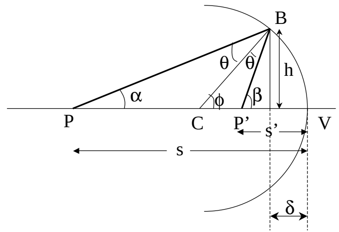
Clearly P'_3 lies on line PX for **any orientation** of this so-called 'retro-reflector' i.e. the reflected image remains static as the retro-reflector rotates (c.f. plane mirror, where image moves as mirror rotates).

Also, **any** ray entering a retro-reflector exits **parallel to itself**. This leads to a **high reflectivity** for any orientation.



Curved mirrors

These are widely employed to produce **magnified images** (e.g. in telescopes). Consider a **spherical** concave mirror, with a centre of curvature at *C*, and a radius of curvature *R*.



To locate the image P' of the 'on axis' object P we trace two rays

Ray 1 strikes mirror at V and is reflected back along the optical axis PV.

Ray 2 is reflected through angle θ at B.

The rays intersect at P', distance s' from V.

1) Express the object and image distances s and s' in terms of tan α and tan β.

2) Apply the paraxial approximation to simply these expressions

3) The law of reflection at B and standard geometry relate α to β and hence s to s'.

1)

$$\tan\alpha = \frac{h}{s-\delta} \qquad \tan\beta = \frac{h}{s'-\delta} \qquad \tan\phi = \frac{h}{R-\delta}$$

The **paraxial approximation** means restricting ourselves to only consider rays which make **small angles** with the optical axis i.e. 'paraxial rays'.

2) Hence angles α, β, and ϕ and distance δ are all sufficiently small that:

$$\alpha \approx \frac{h}{s} \qquad \beta \approx \frac{h}{s'} \qquad \phi \approx \frac{h}{R} \qquad \text{[Eqns 1]}$$

3) $\phi = \alpha + \theta$ $\beta = \theta + \phi$

so $\alpha + \beta = 2\phi$ [Eqn 2]

Subsitute Eqns 1 into Eqn 2 then cancel *h* yields:

$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R}$$

Object-image relationship for a spherical mirror

NB since this relation applies to any ray (i.e. it is independent of θ) P' is indeed an image of P.

- The image is **real**
- Only paraxial rays obey this simple relationship. Rays making large angles to PV **will not** be brought to focus at P'.
- This defect is called **spherical aberration** and is most serious for mirrors of larger diameters

Repeat the derivation for a **convex mirror** and show that the same object-image relationship applies.
[**Hint**: watch the sign convention, R and s' will be negative for the convex mirror which affects Eqns 1]