Curvature of field

It is observed that if a single lens is free from spherical aberration-coma and astigmatism, even then the image of extended plane object obtained is not a flat one, but curved. The central portion of the image near the axis is in focus, while the outer regions of the image away from the axis are blurred (curved). This defect in image is called curvature of field or curvature. It arises because the marginal focal length (focal length due to marginal rays) is smaller than the paraxial focal length (focal length due to paraxial rays).

The ray diagram of the curvature due to convex and concave lenses are shown in Fig. 1 (a) and (b), respectively. PQ is the extended object whose image $P'Q'$ is curved.

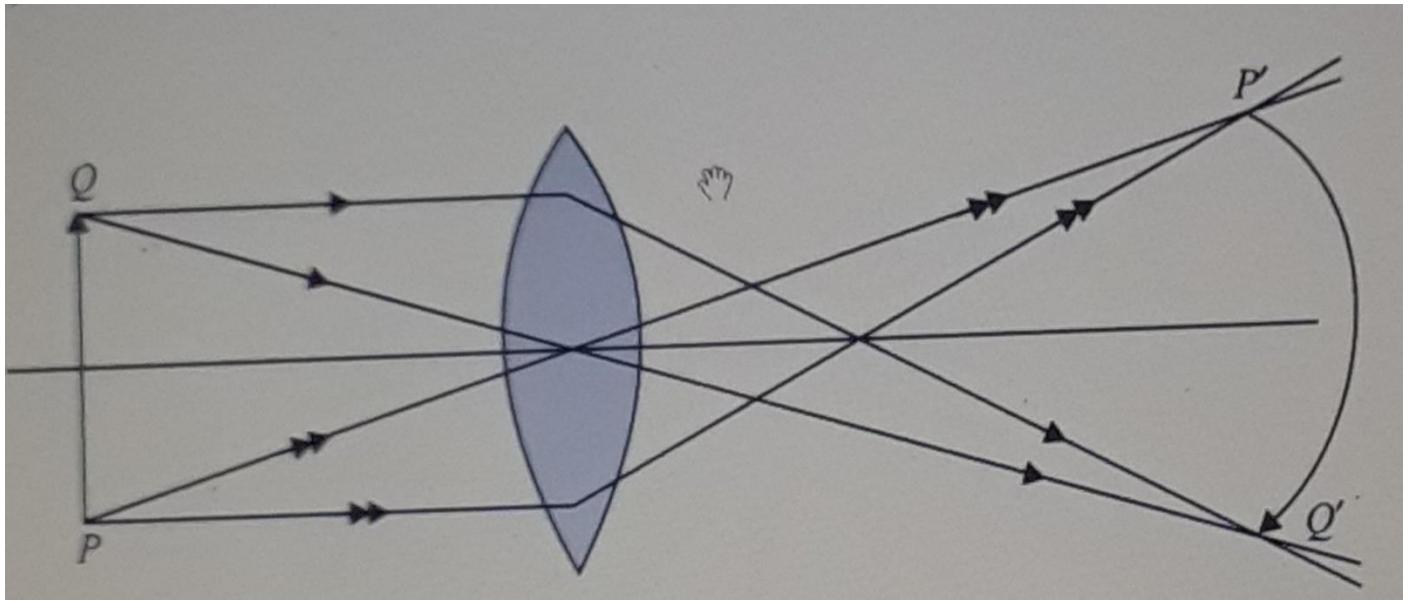


Fig. 1(a) Convex lens

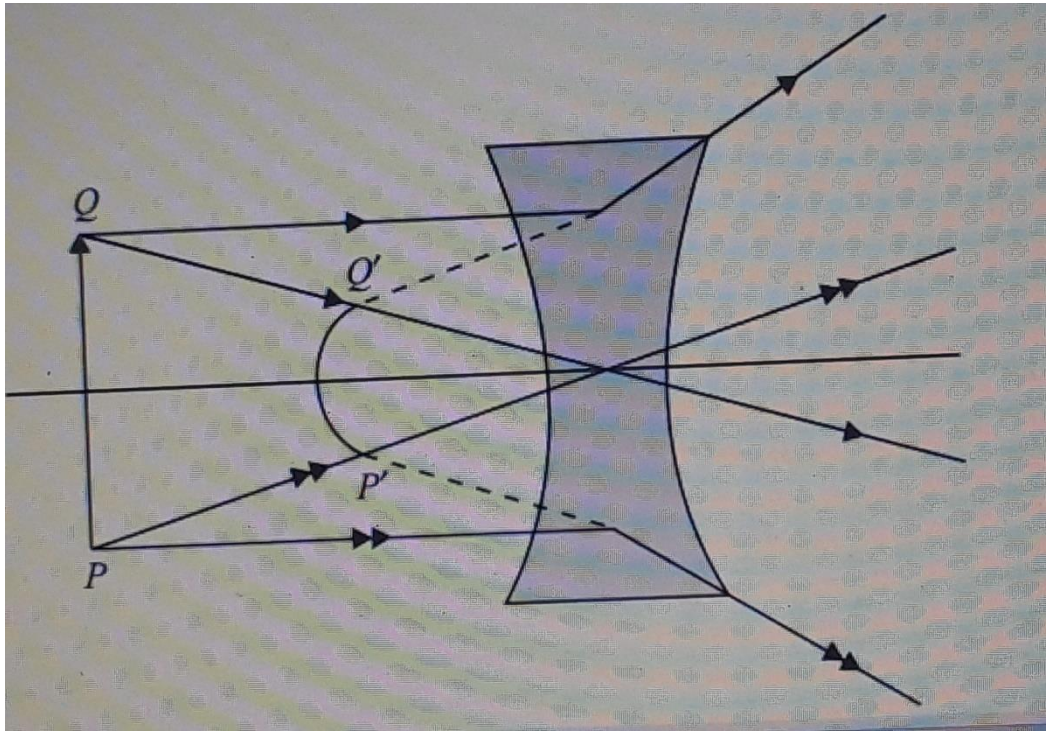
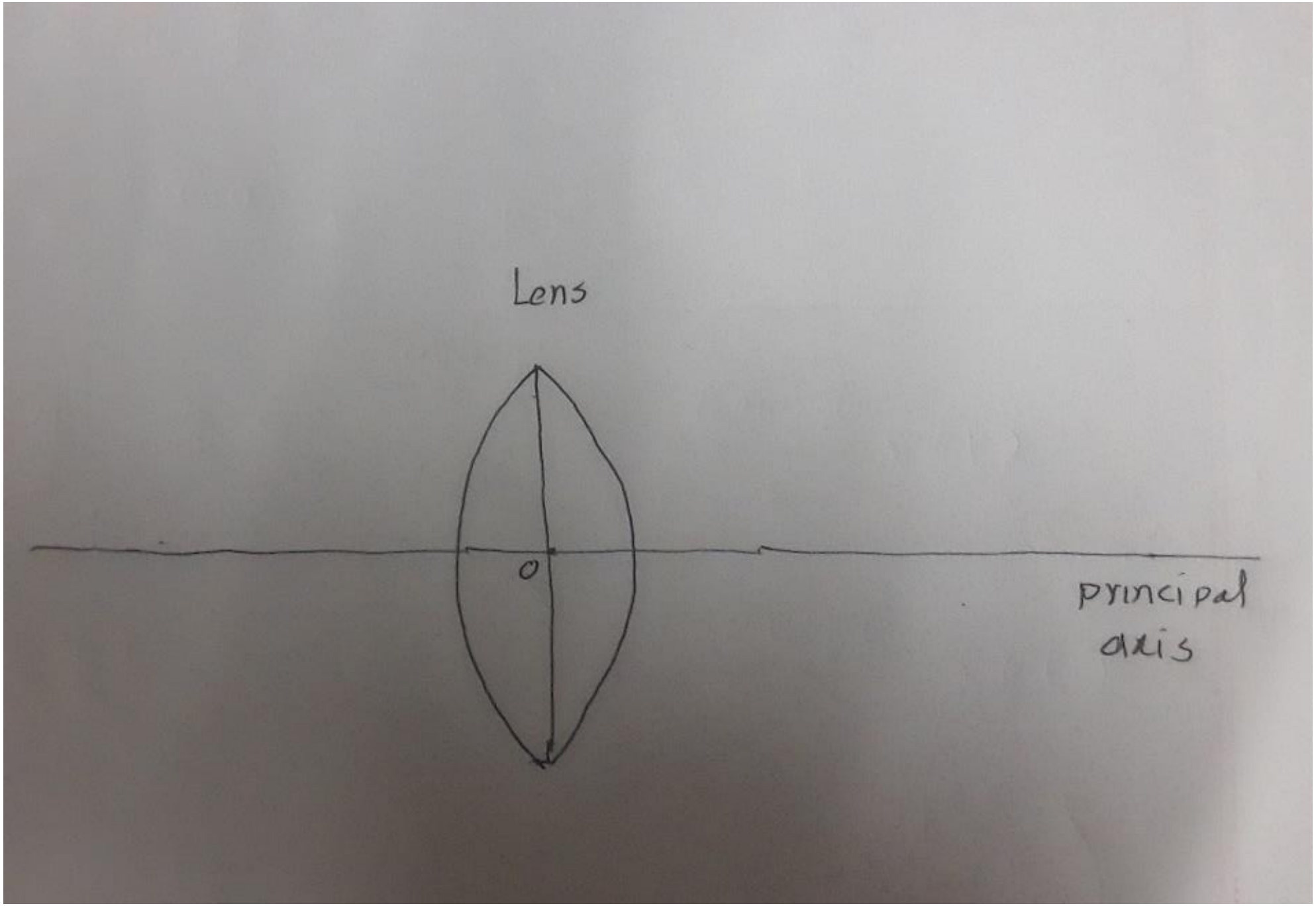
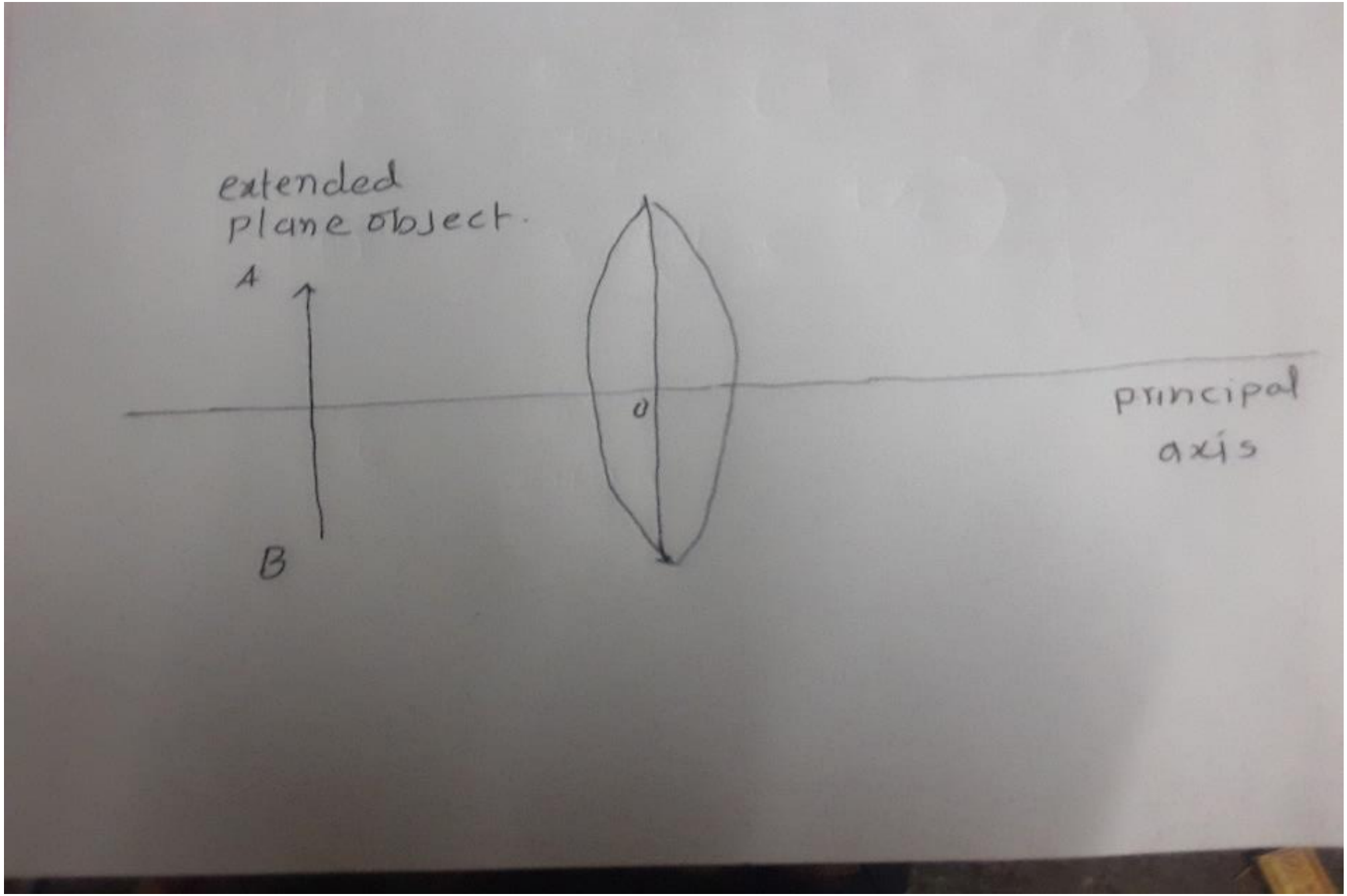
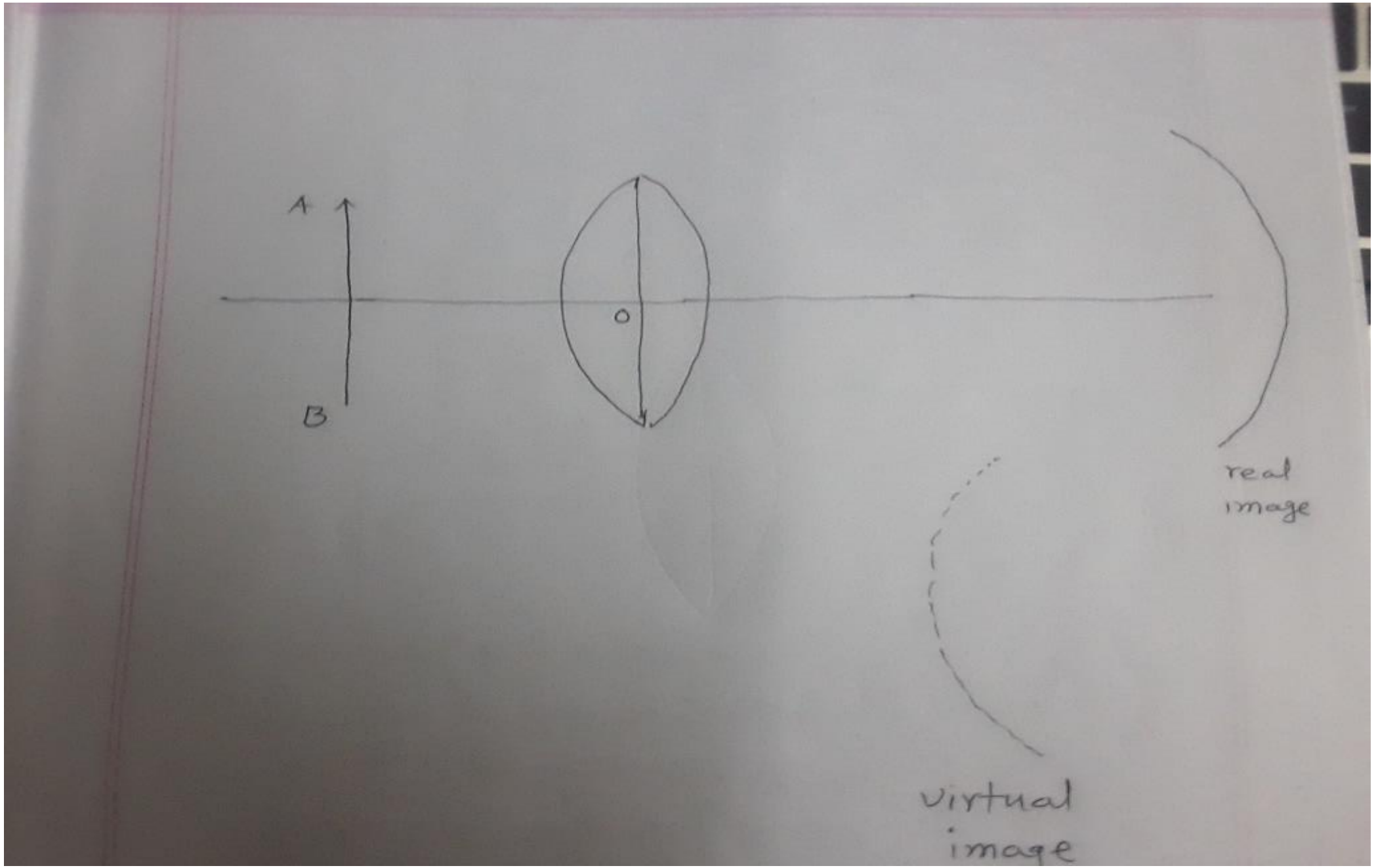
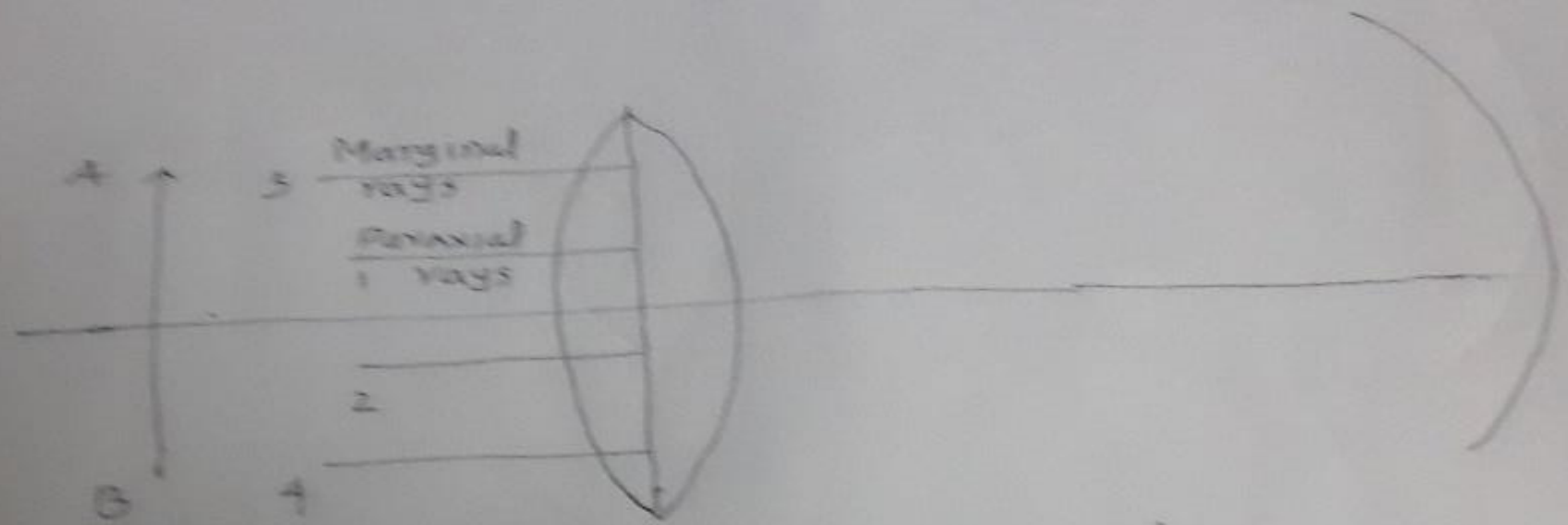


Fig. 1(b) Concave lens


Lens
O
principal
axis

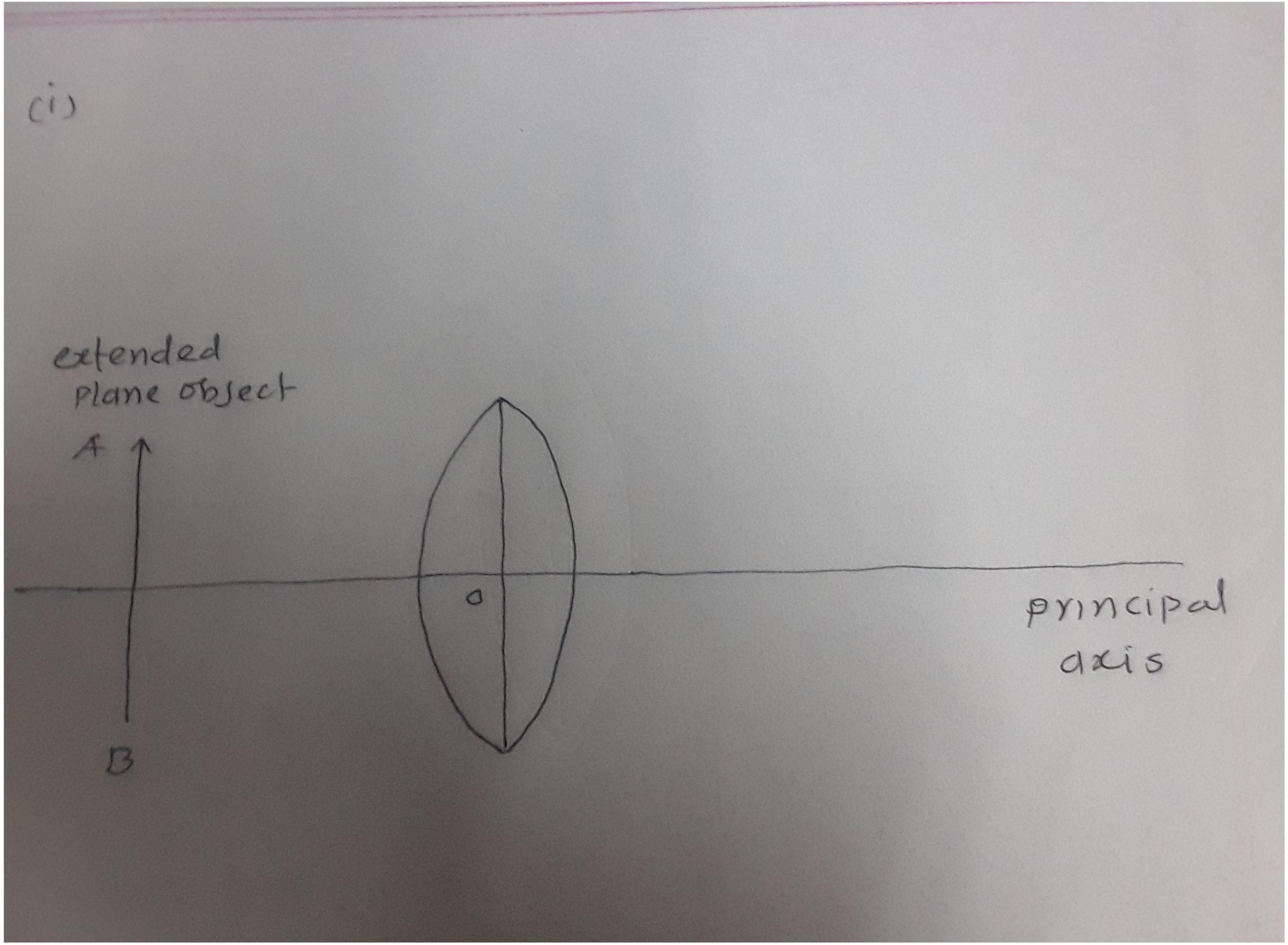

extended
plane object.
A
B
O
principal
axis

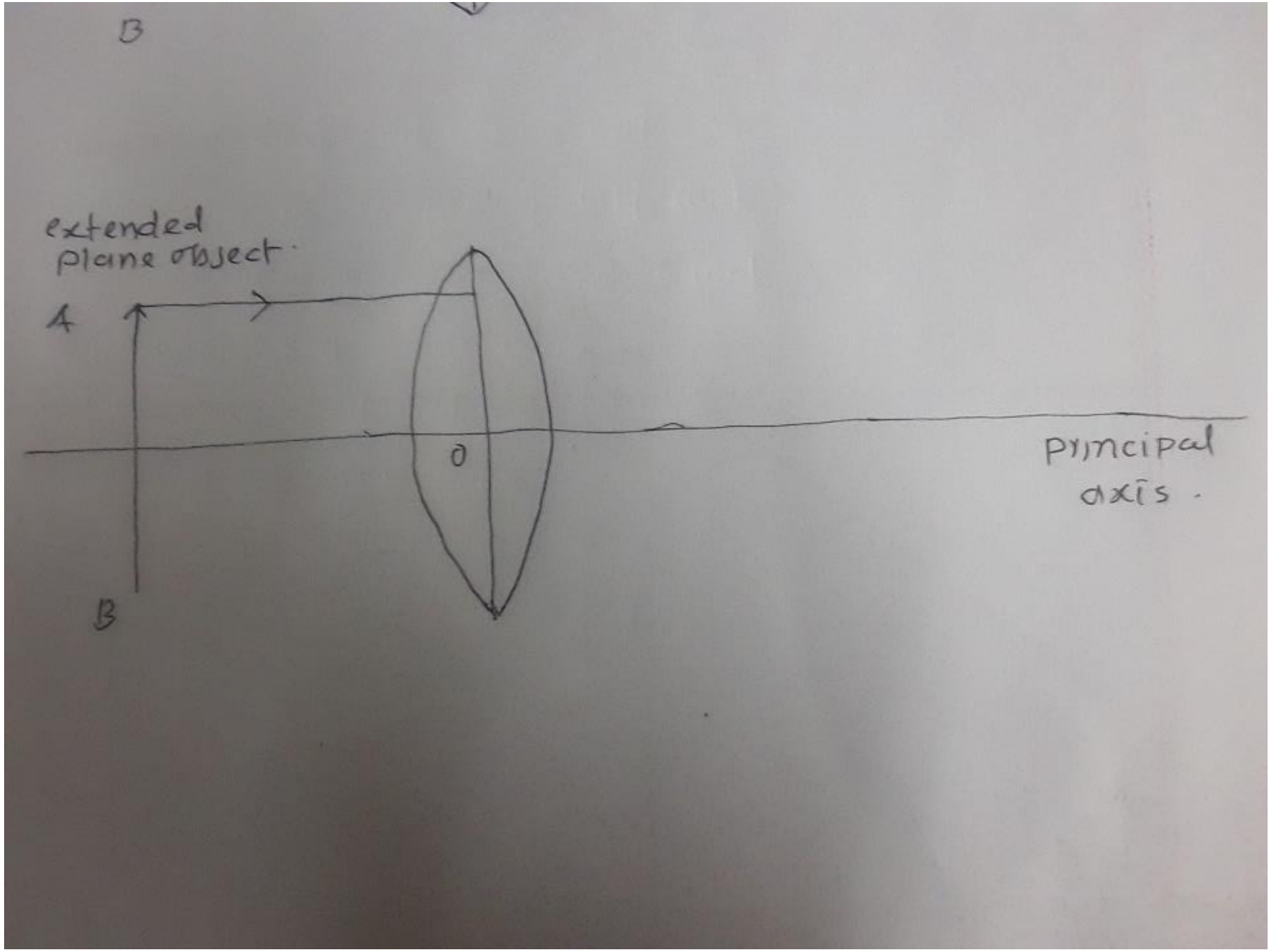

A
B
O
real image
virtual image

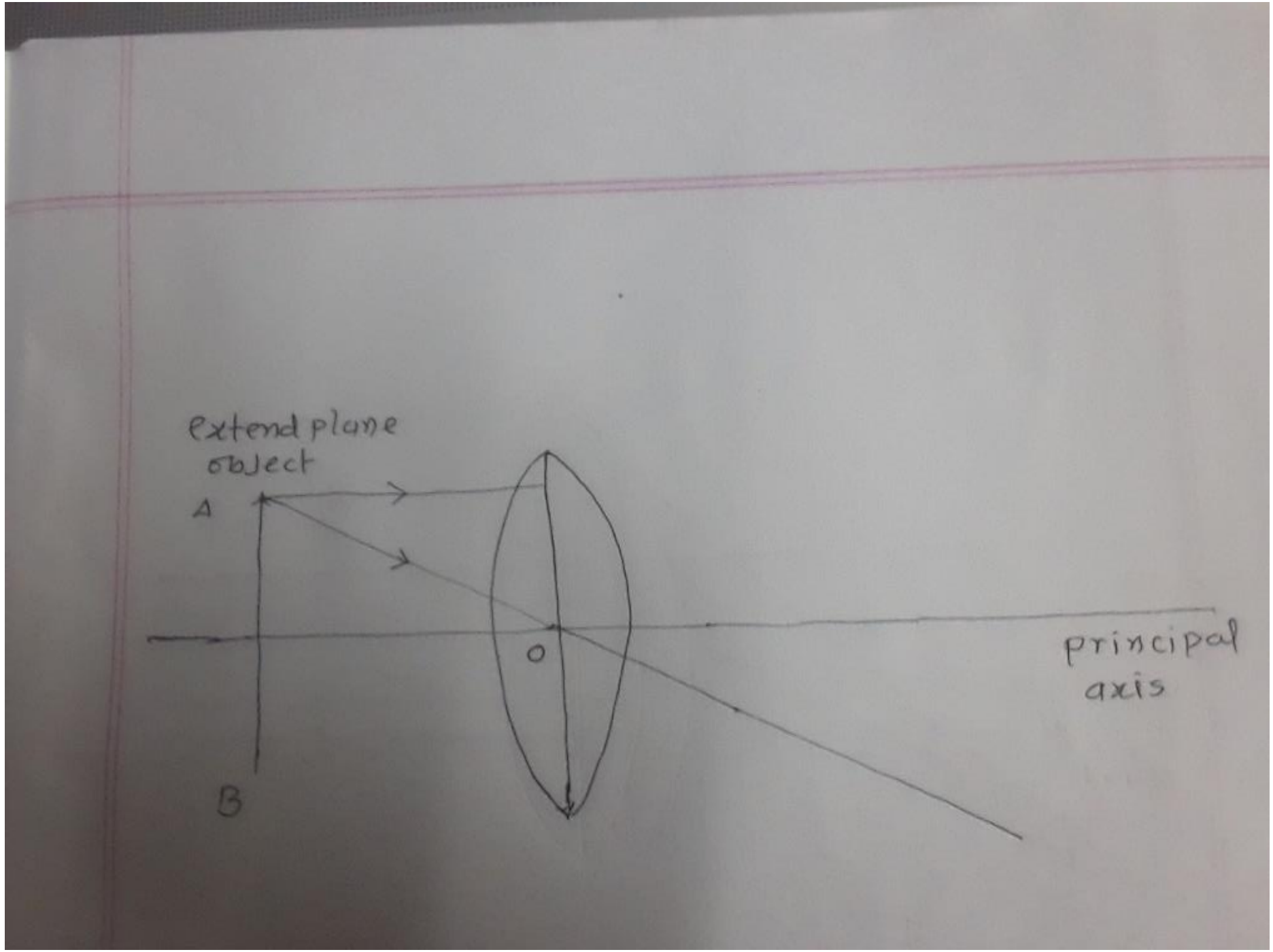


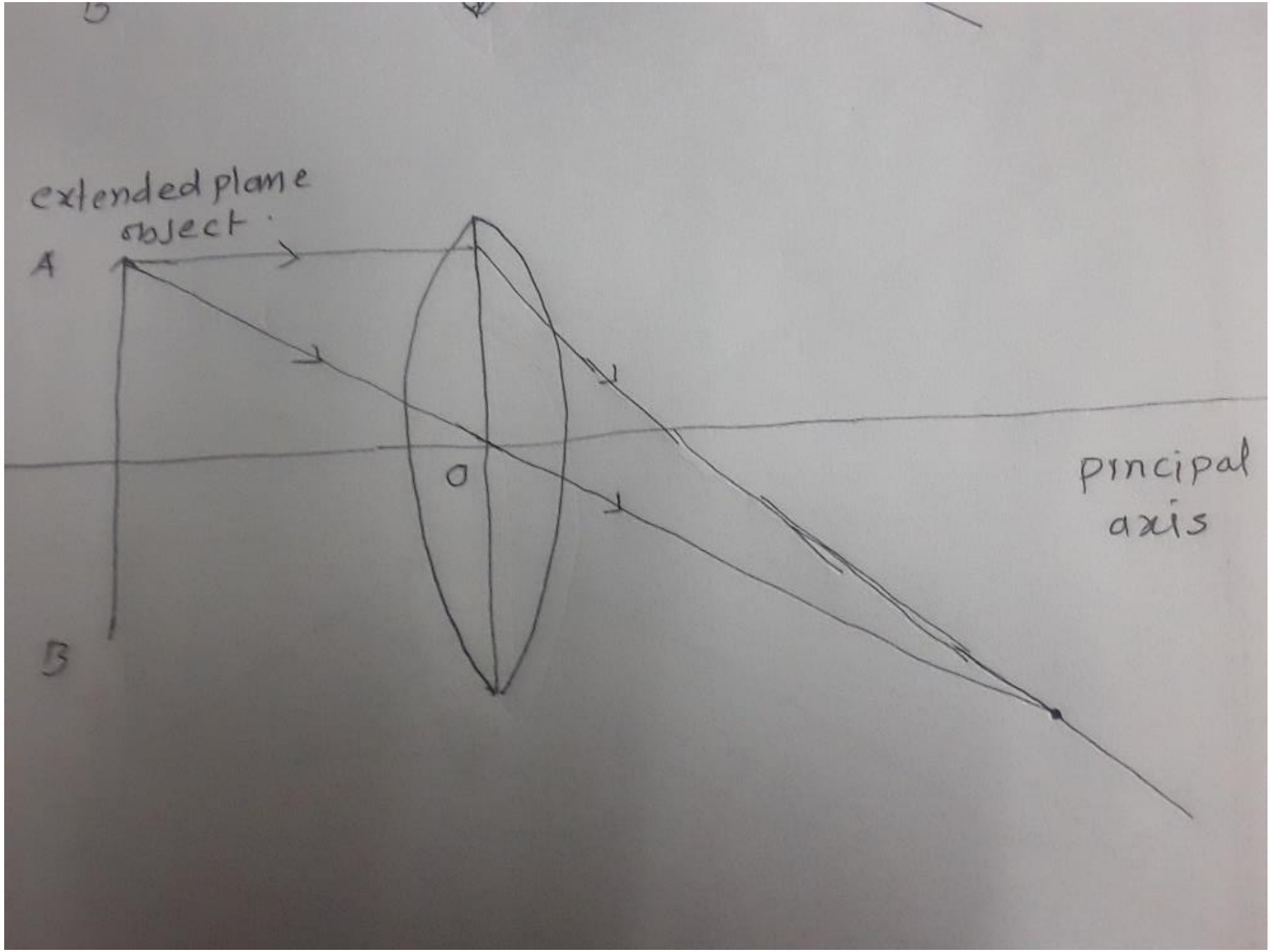
The paraxial and marginal rays form images of different parts of extended plane object at different positions.
So image will not be plane & it will be curved.

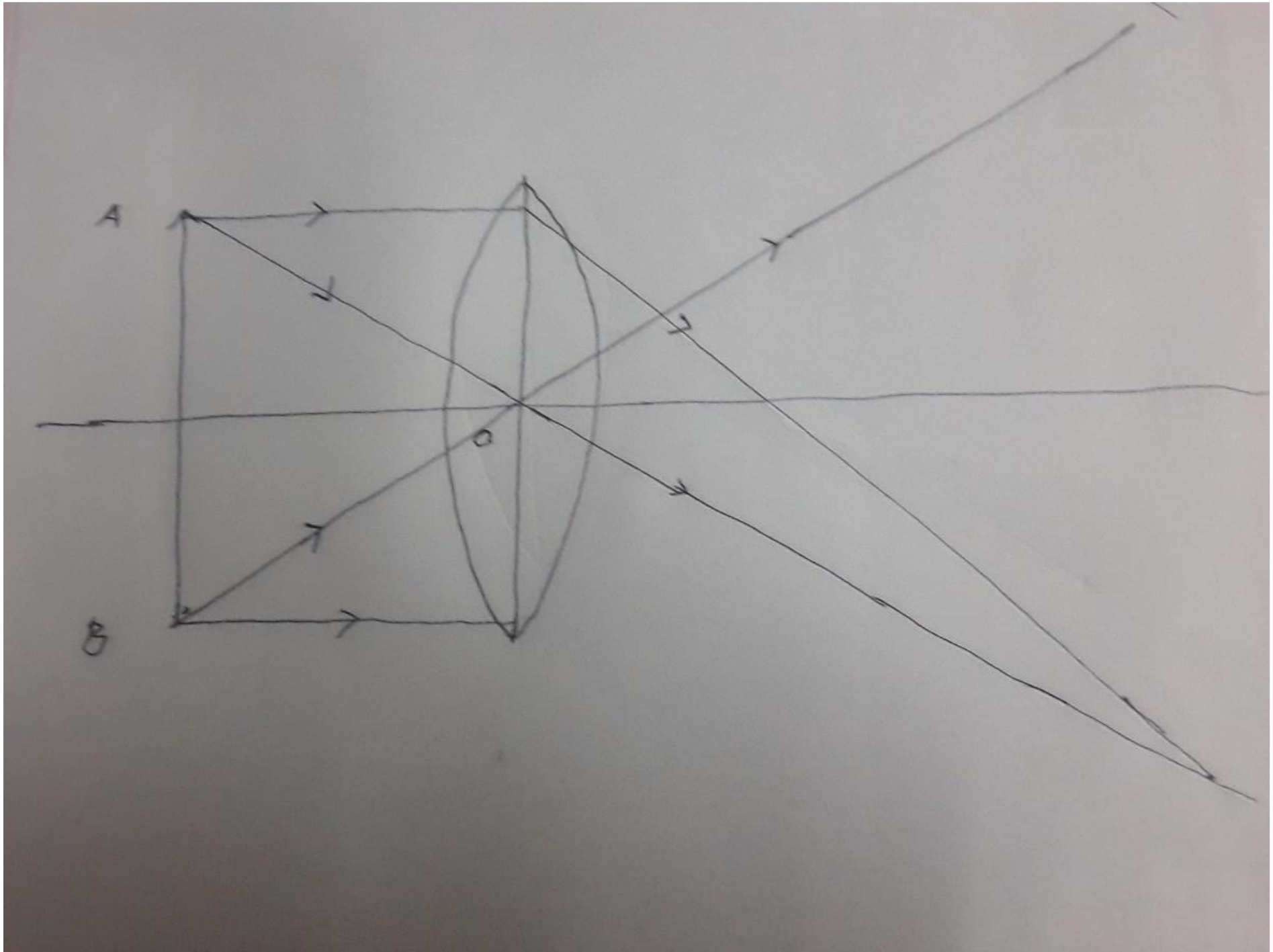
(i)

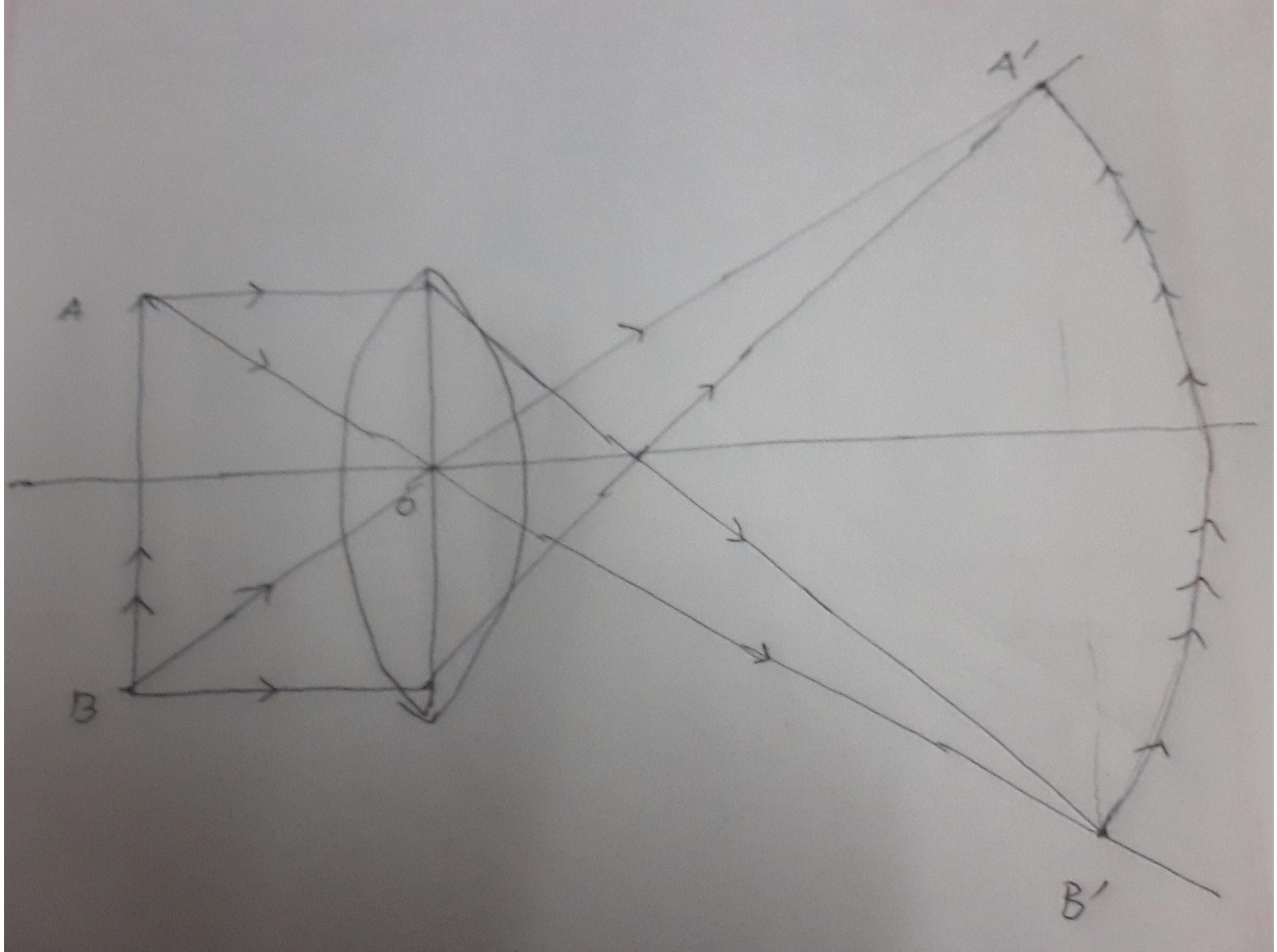



B
extended
plane object.
A
O
principal
axis.
B

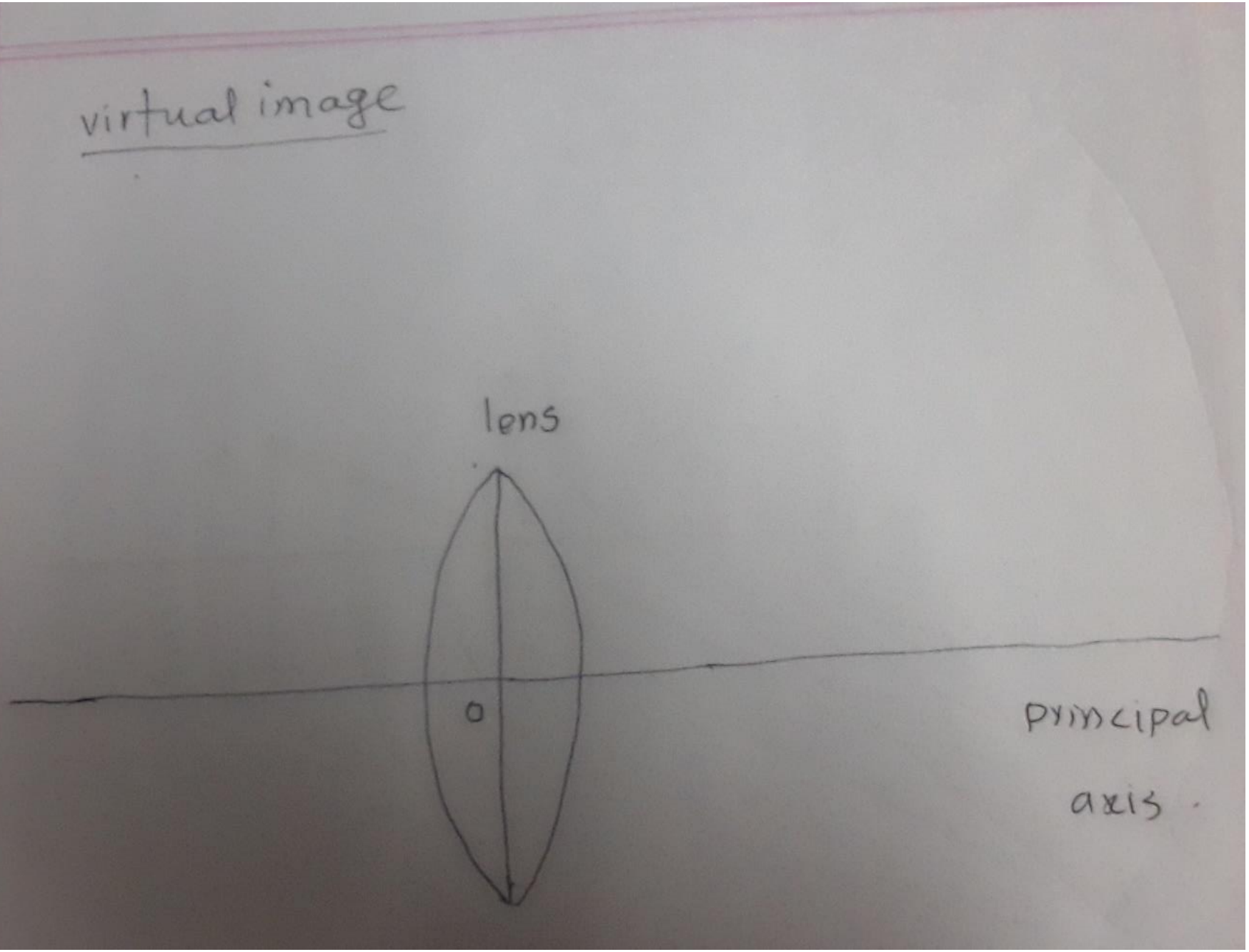

extend plane
object
A
B
O
principal
axis

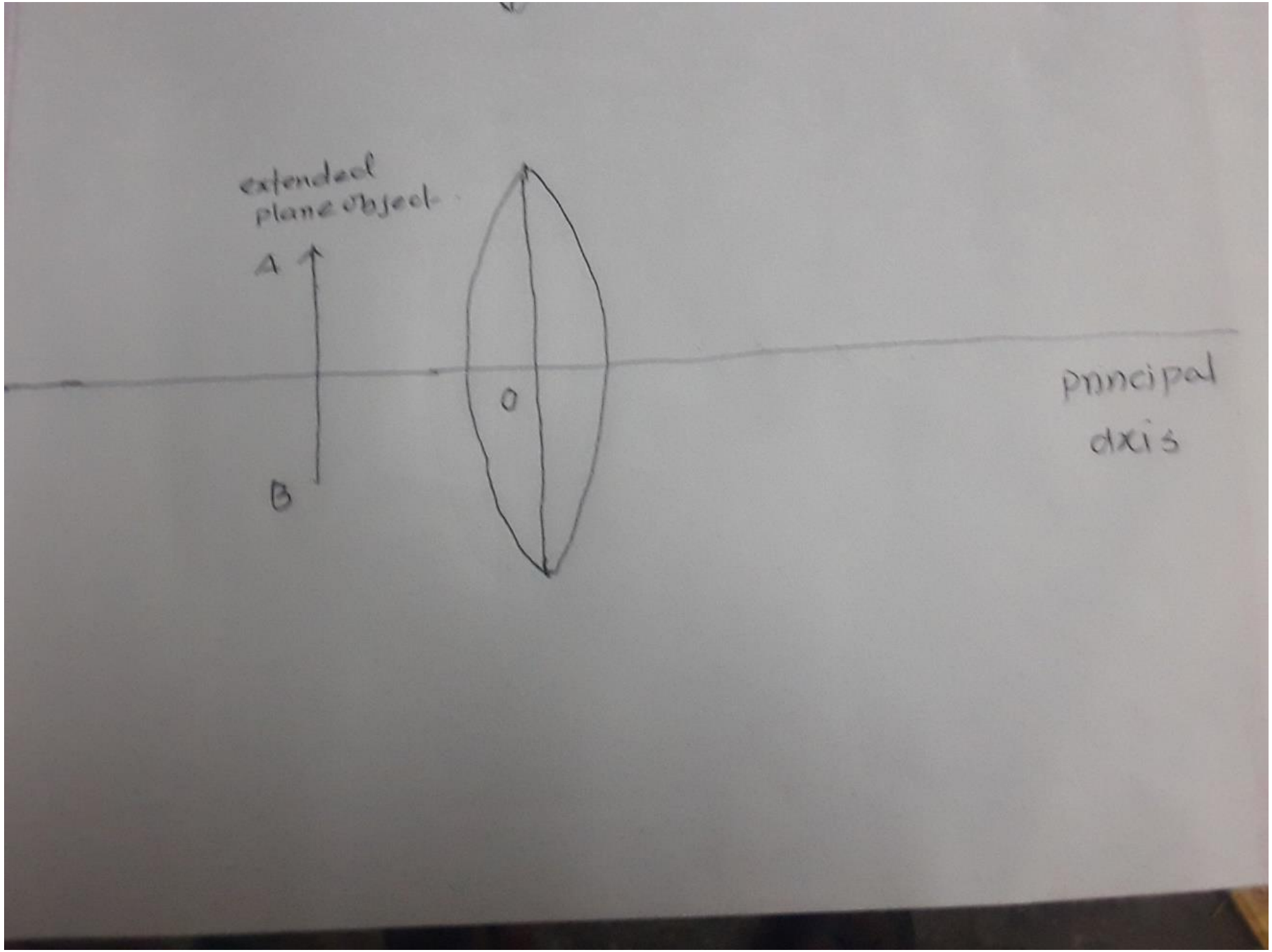

extended plane object
A
B
O
principal axis

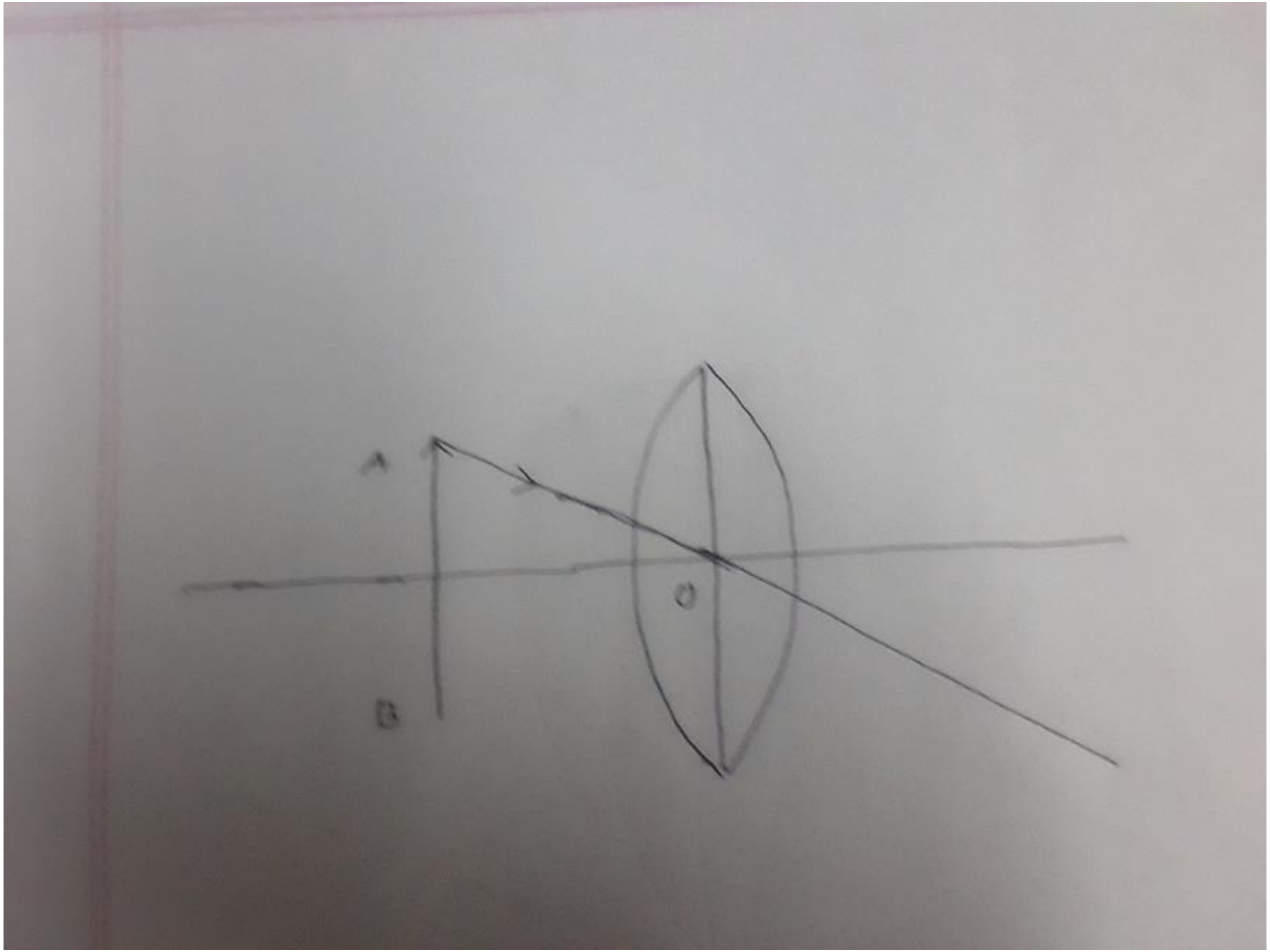

A
B
O

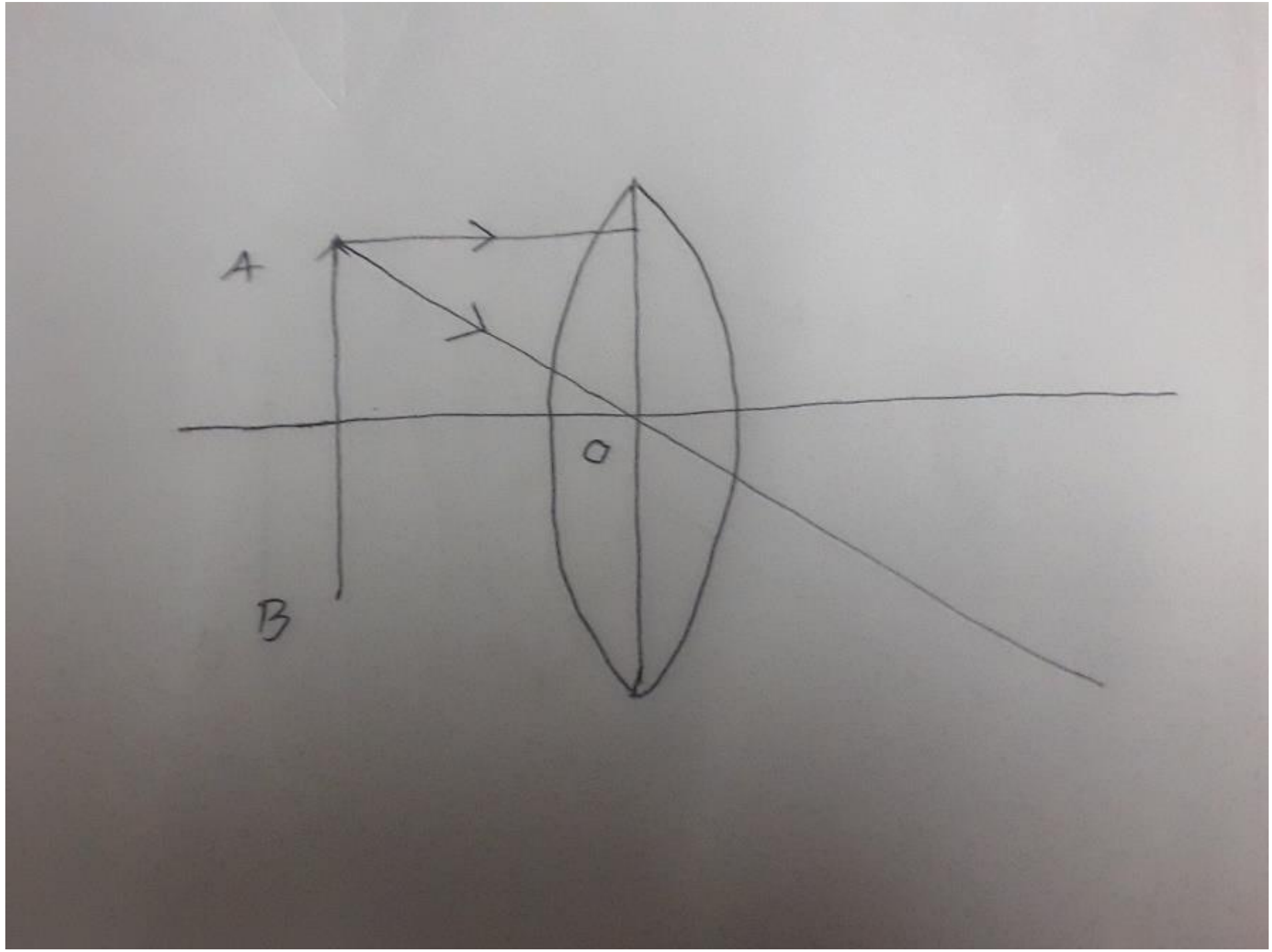

A
B
O
A′
B′

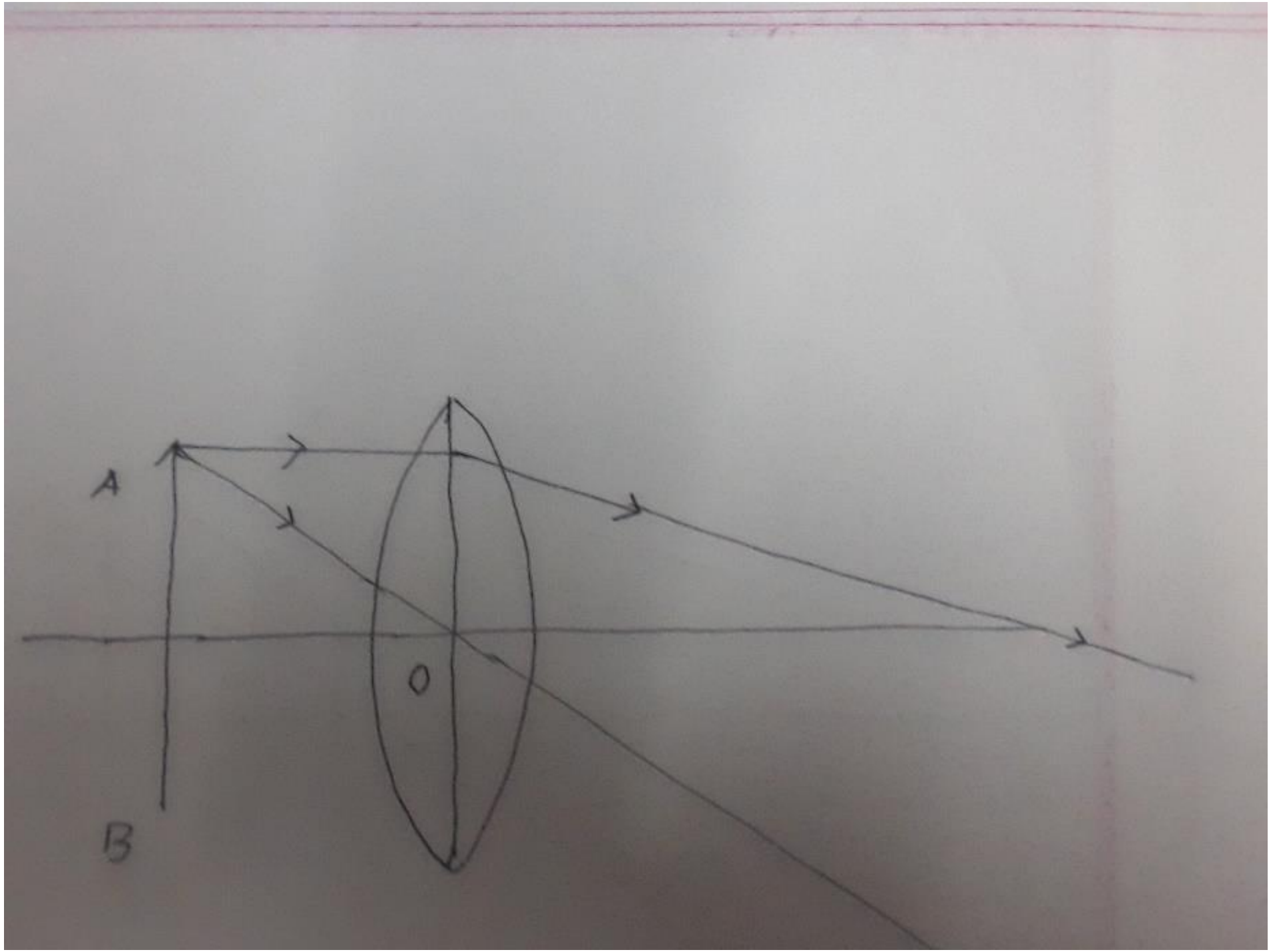
virtual image

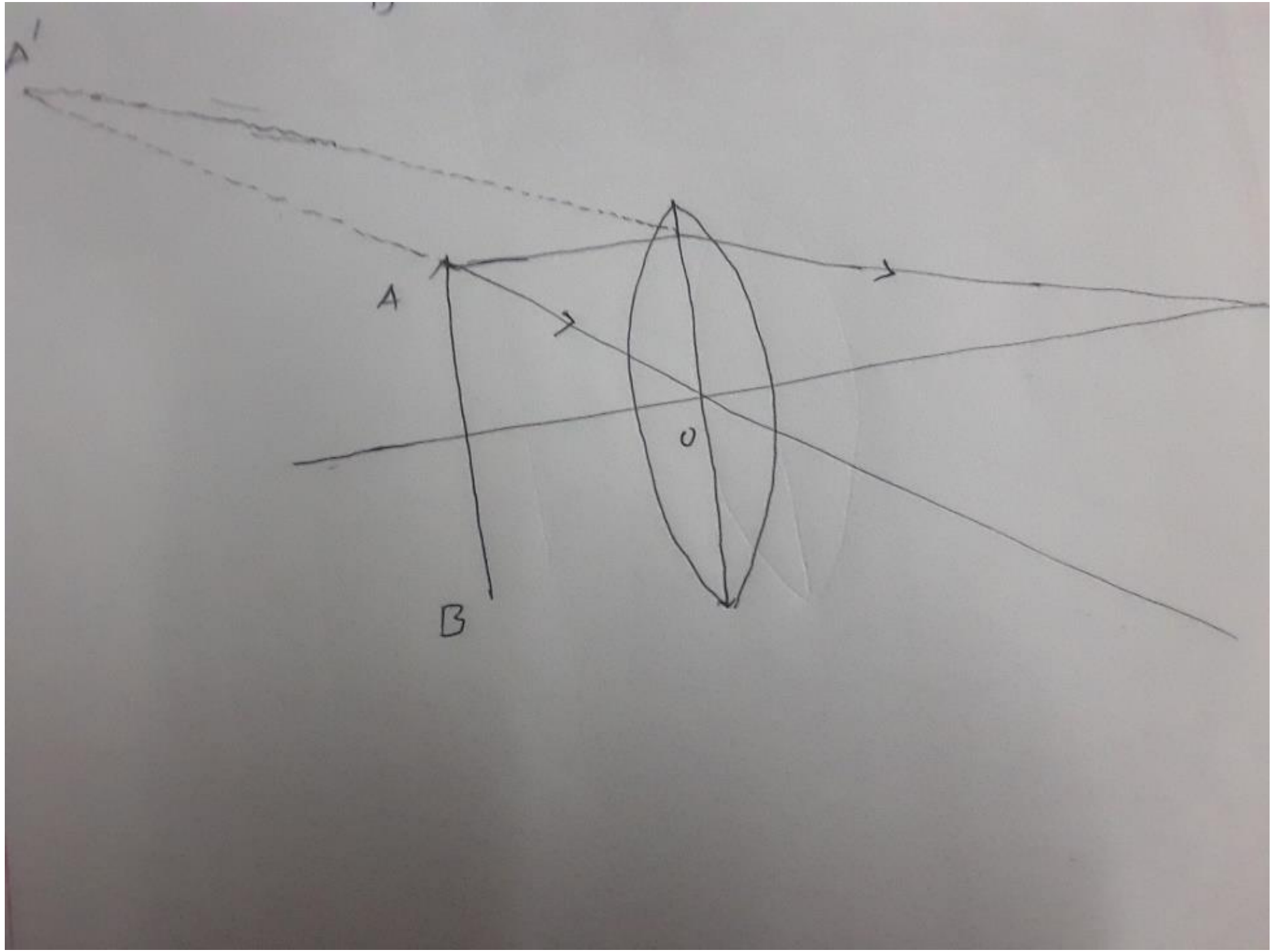


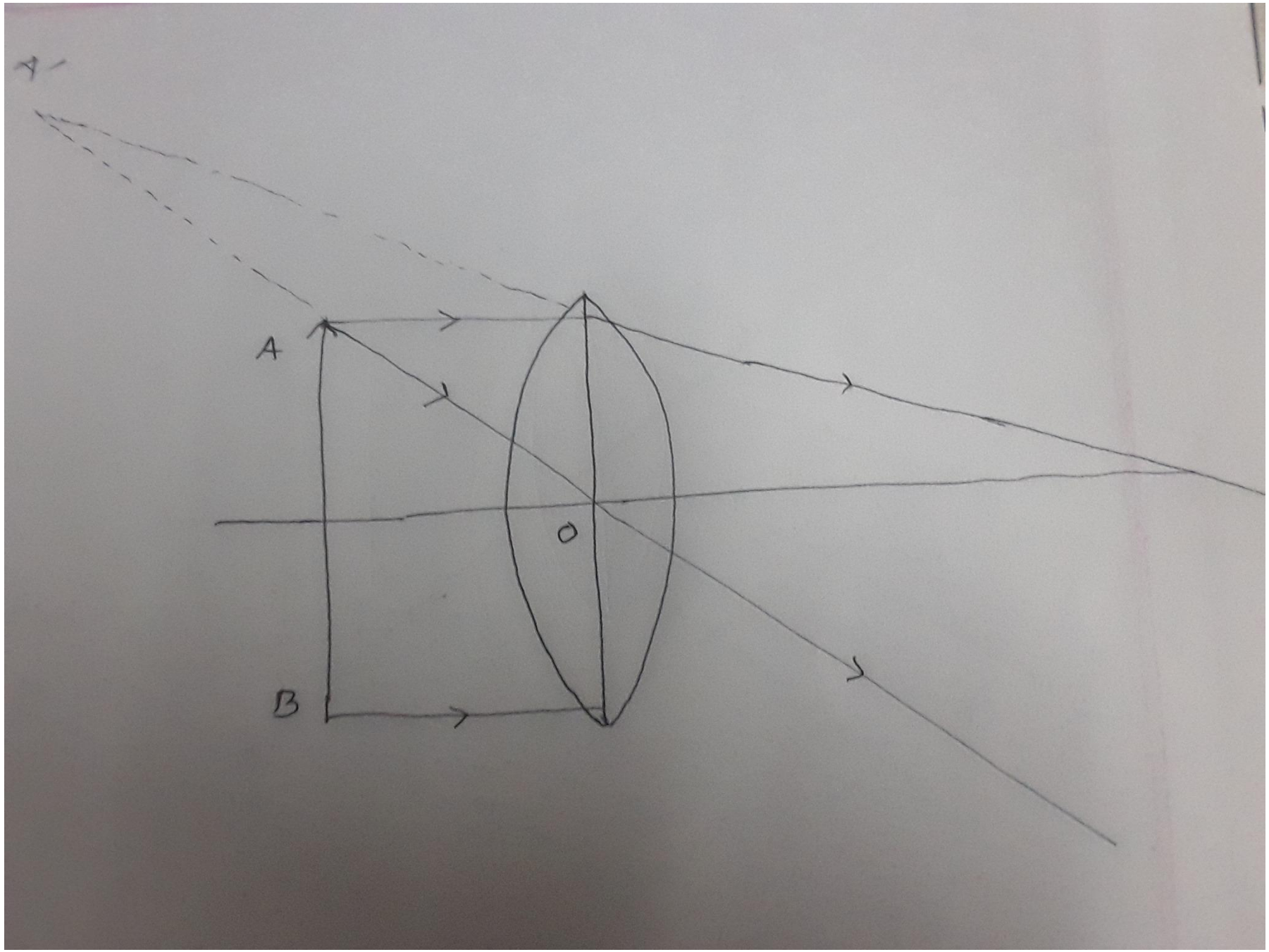

extended
plane object
A
B
O
principal
axis

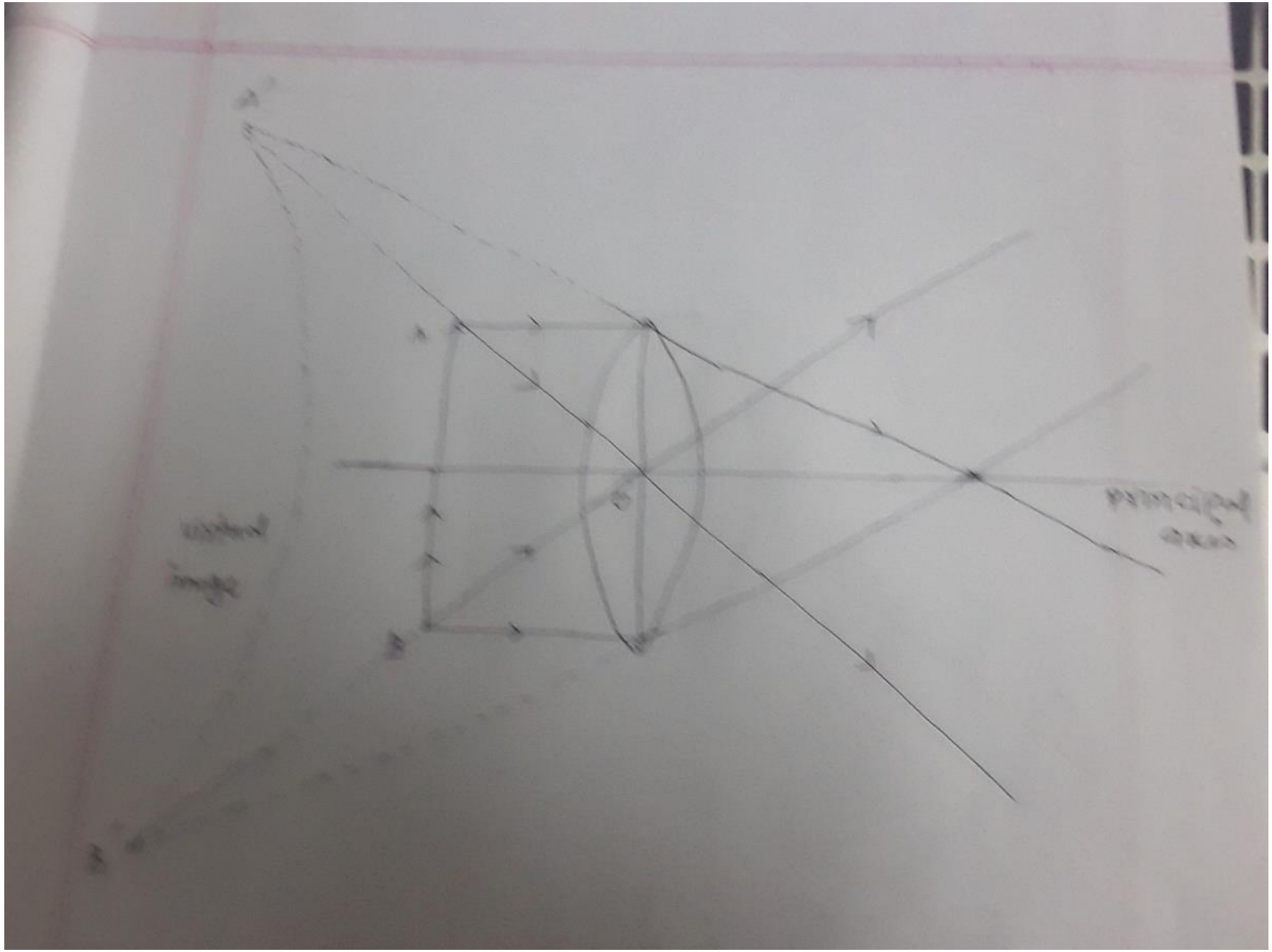

A
O
B


A
O
B


A
O
B

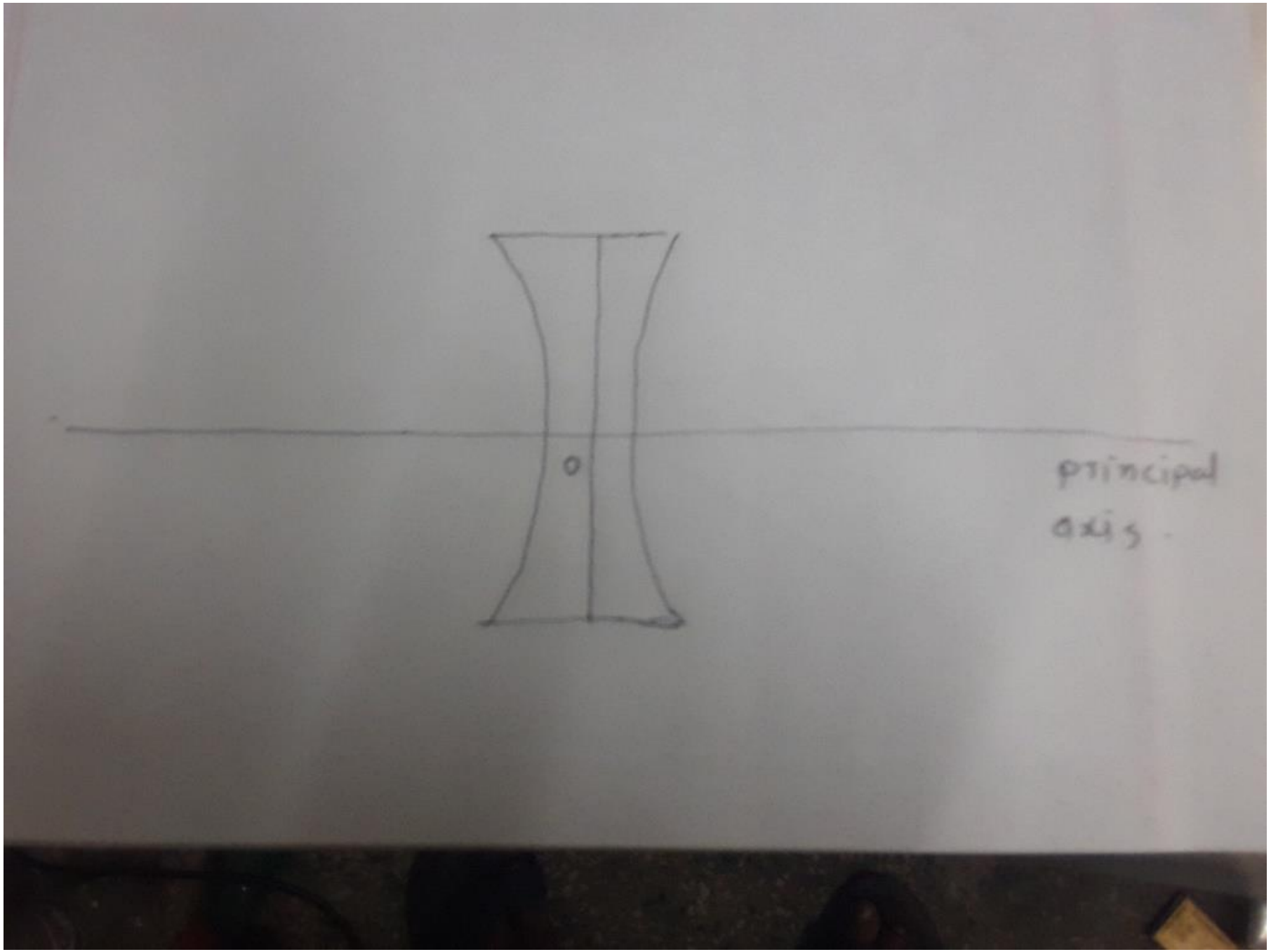

A'
A
B
O

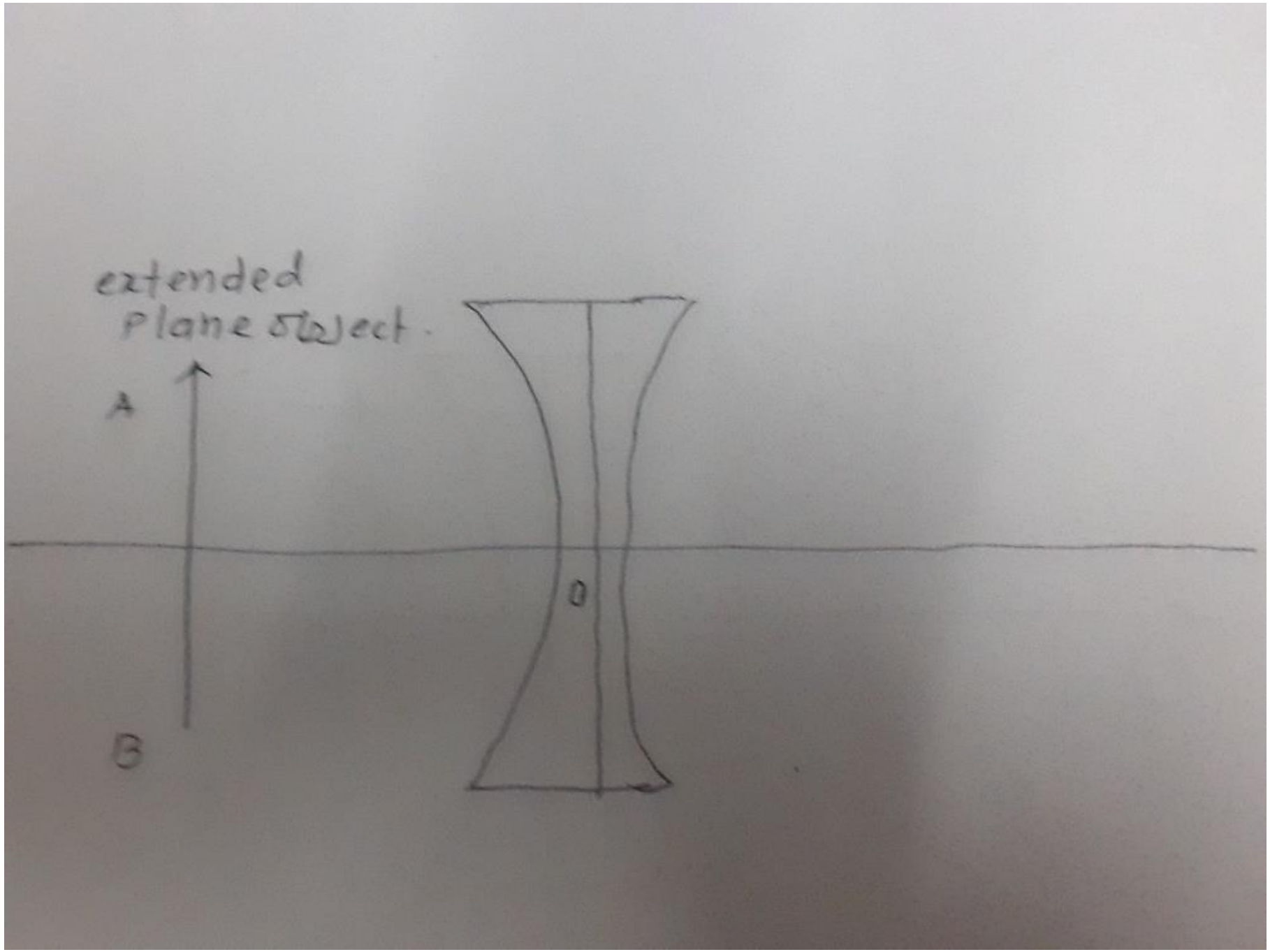

A'
A
O
B

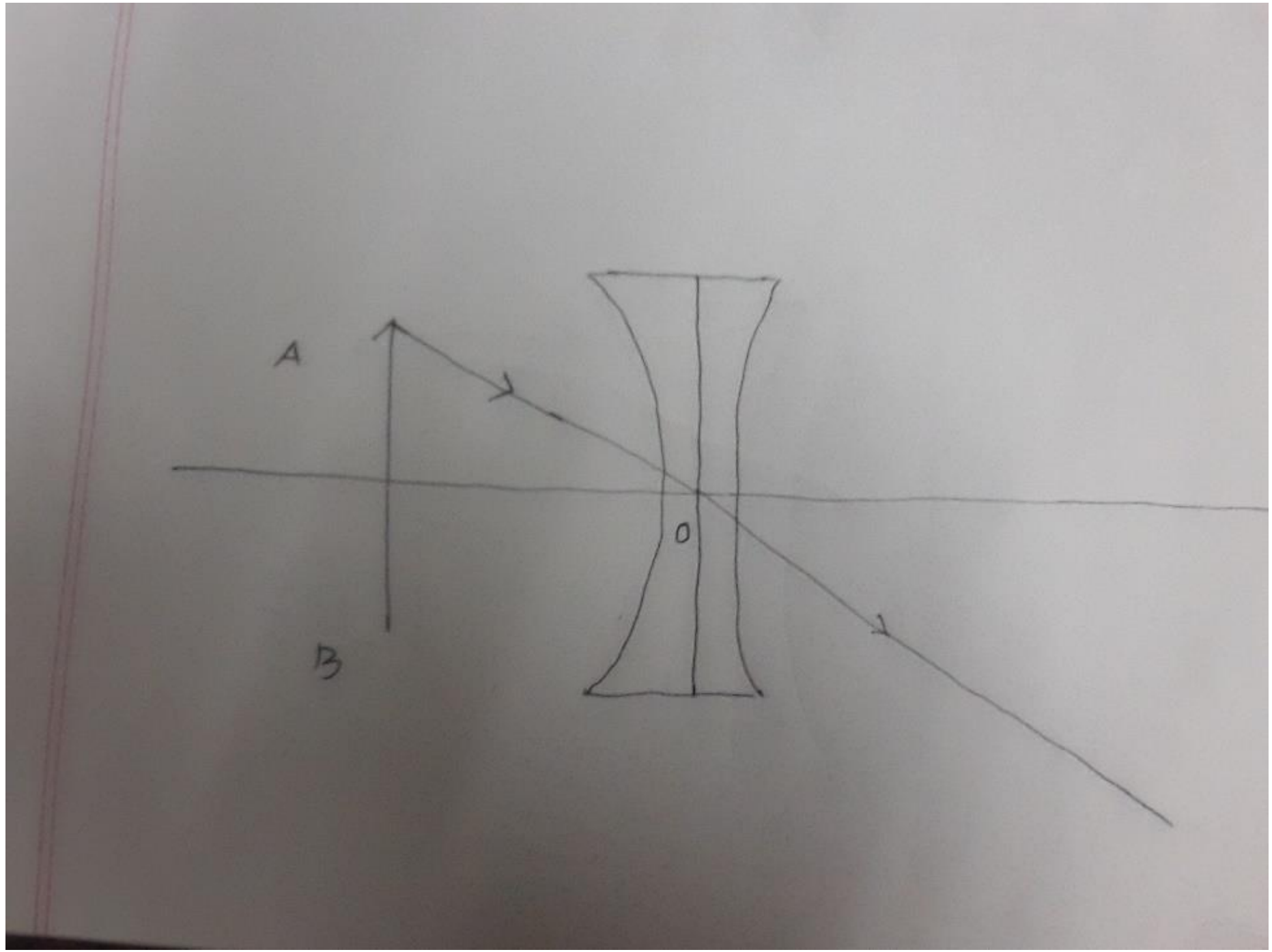


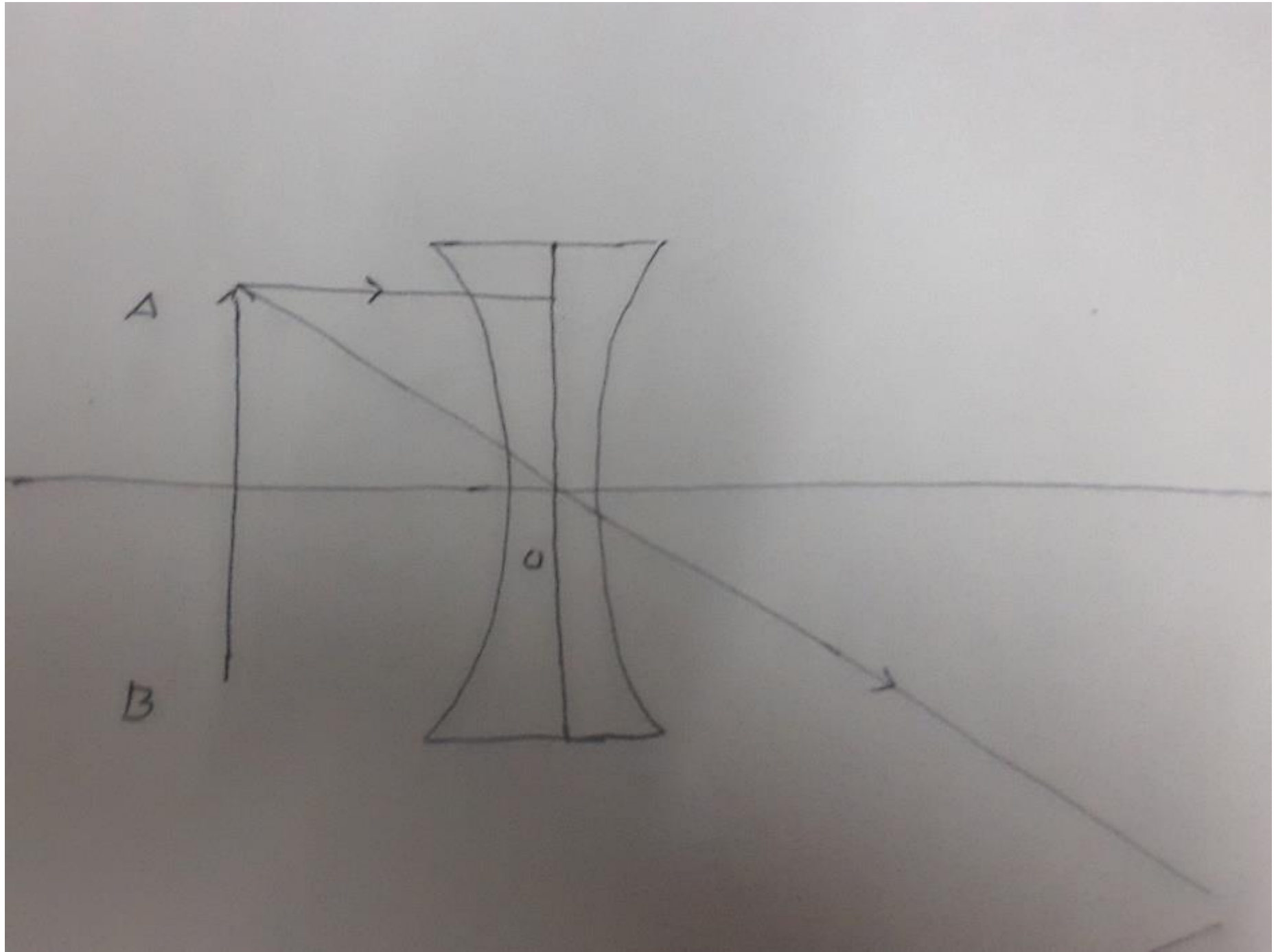
Concave lens:

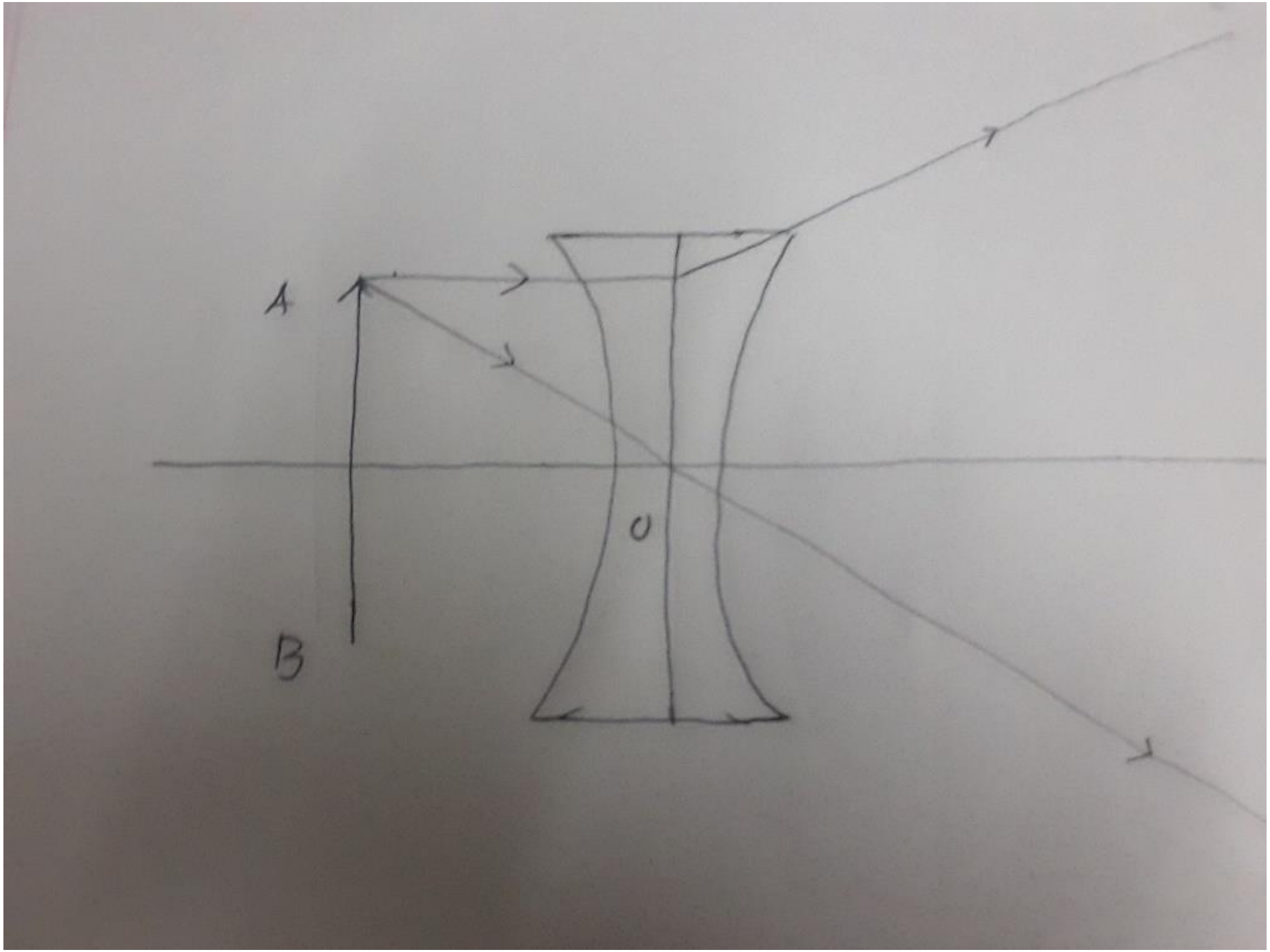
Concave lens

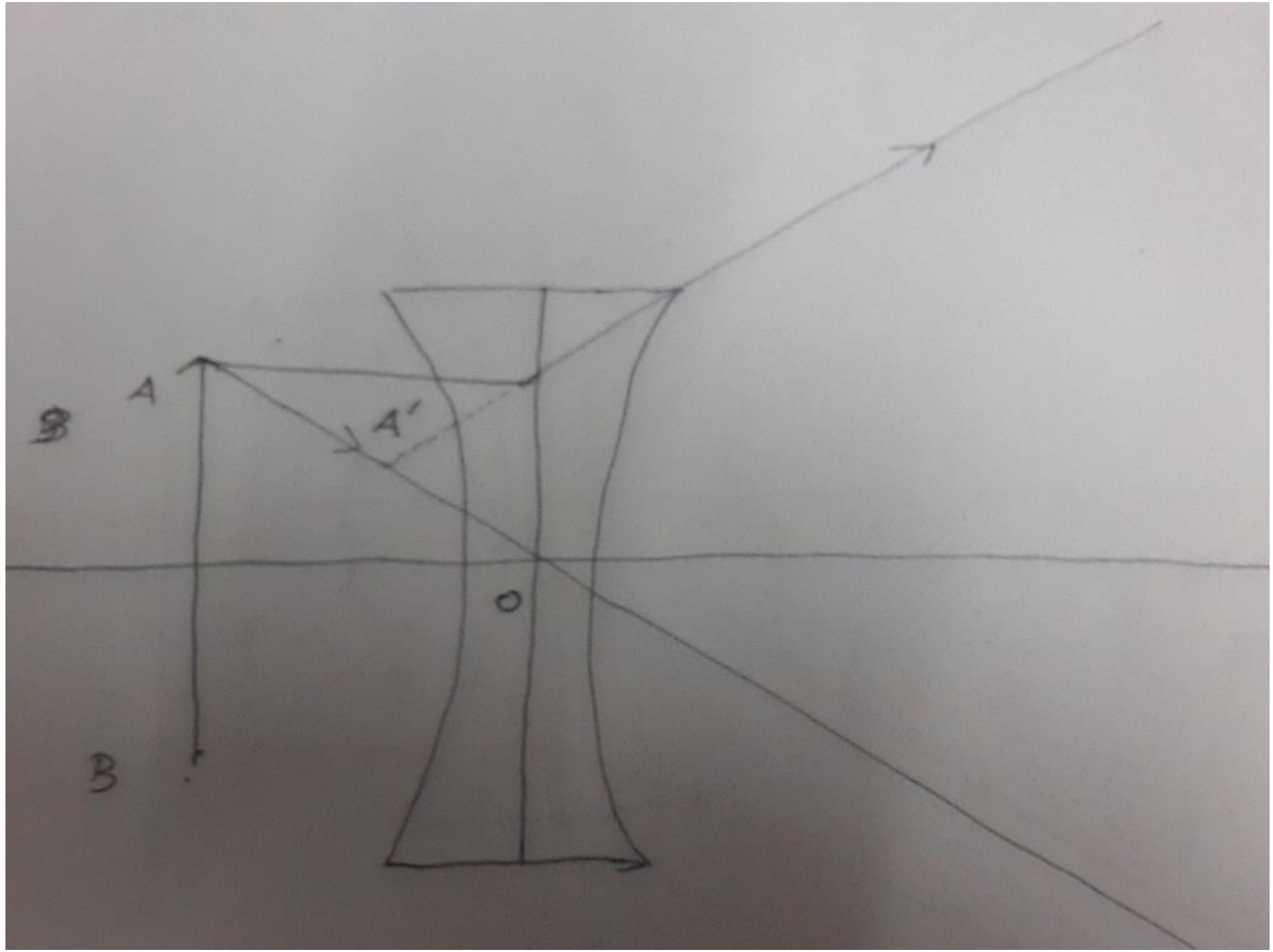

O
principal
axis

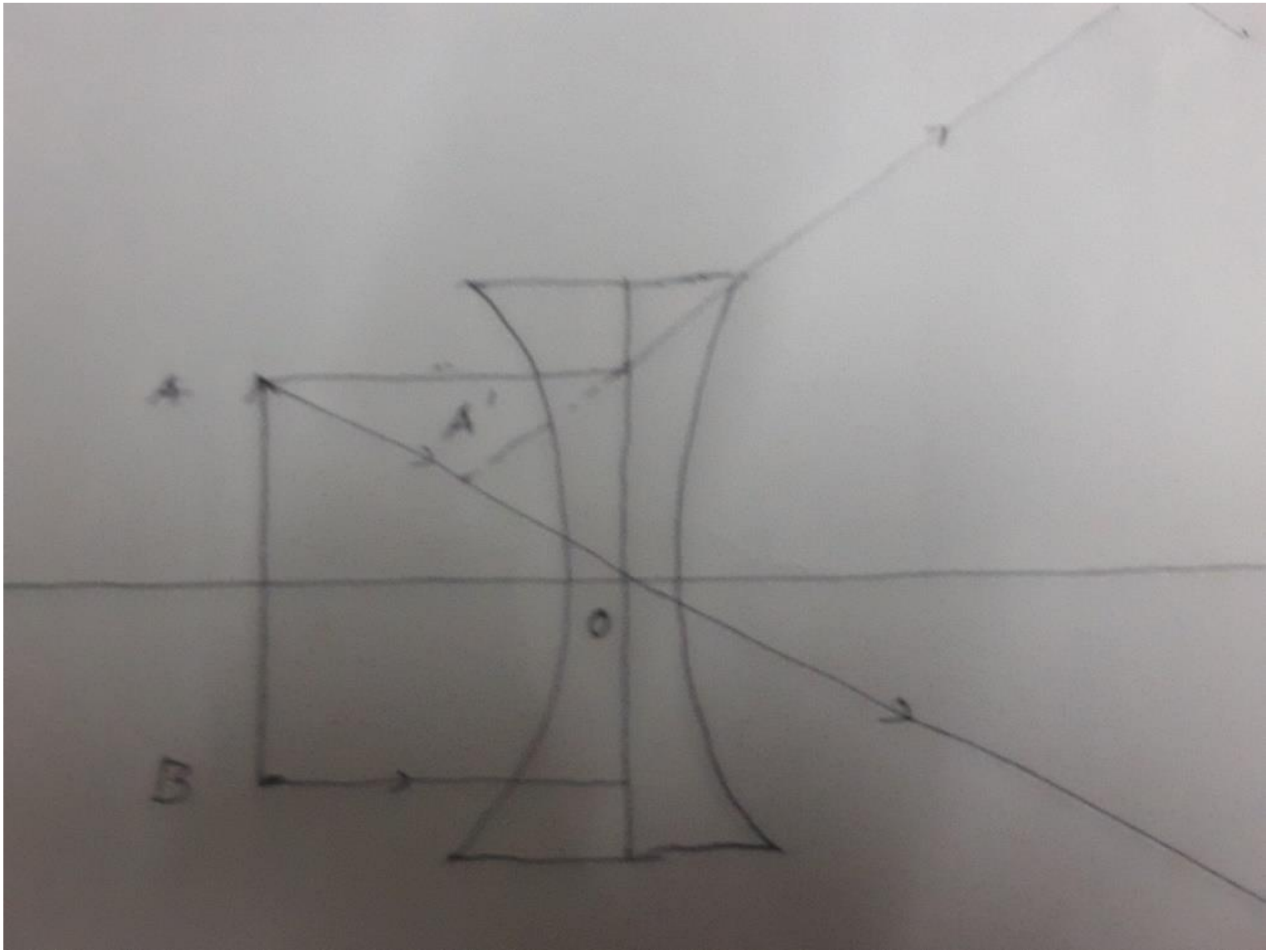

extended
Plane object.
A
B
O

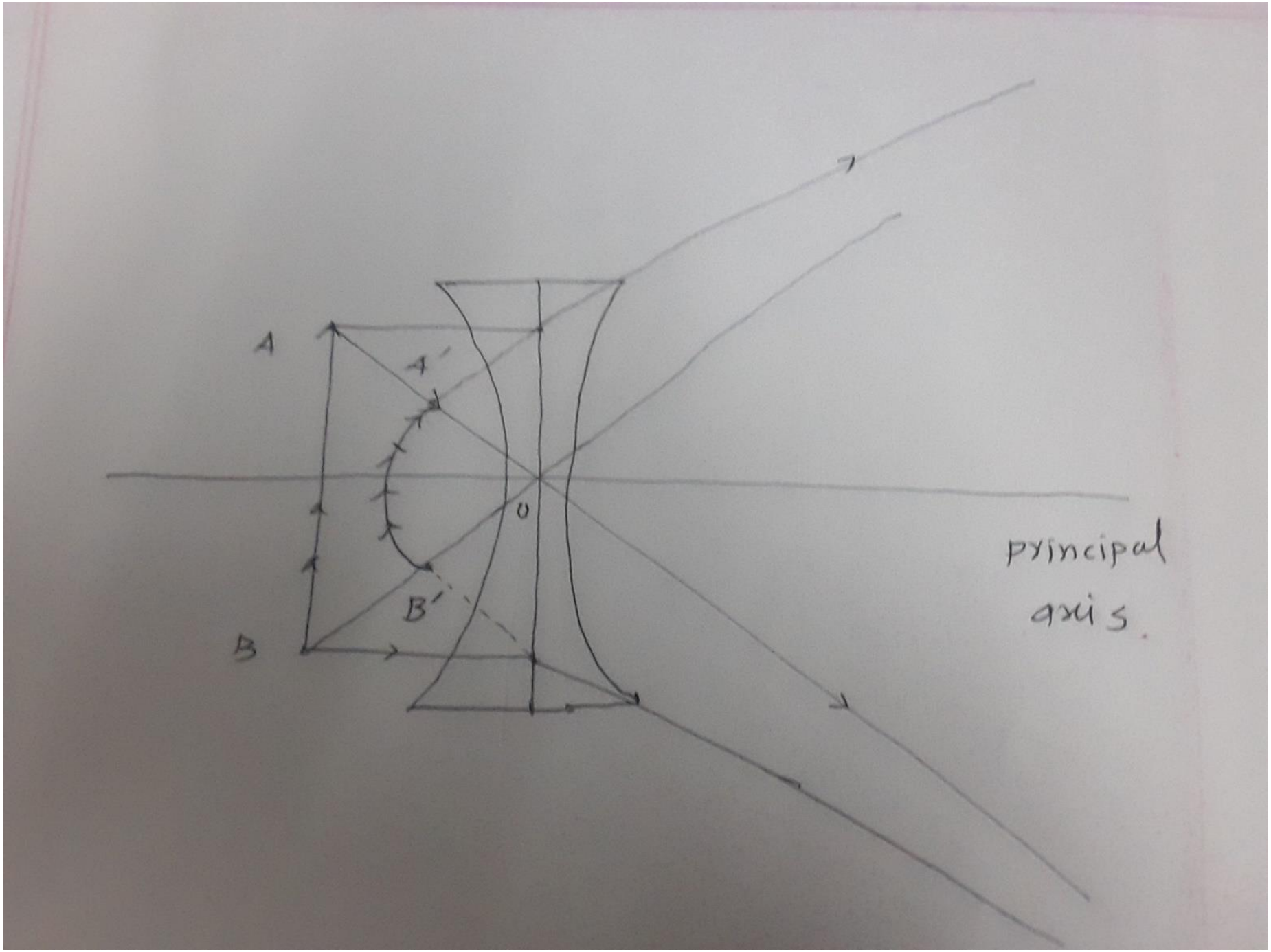

A
B
O


A
B
O


A
B
O

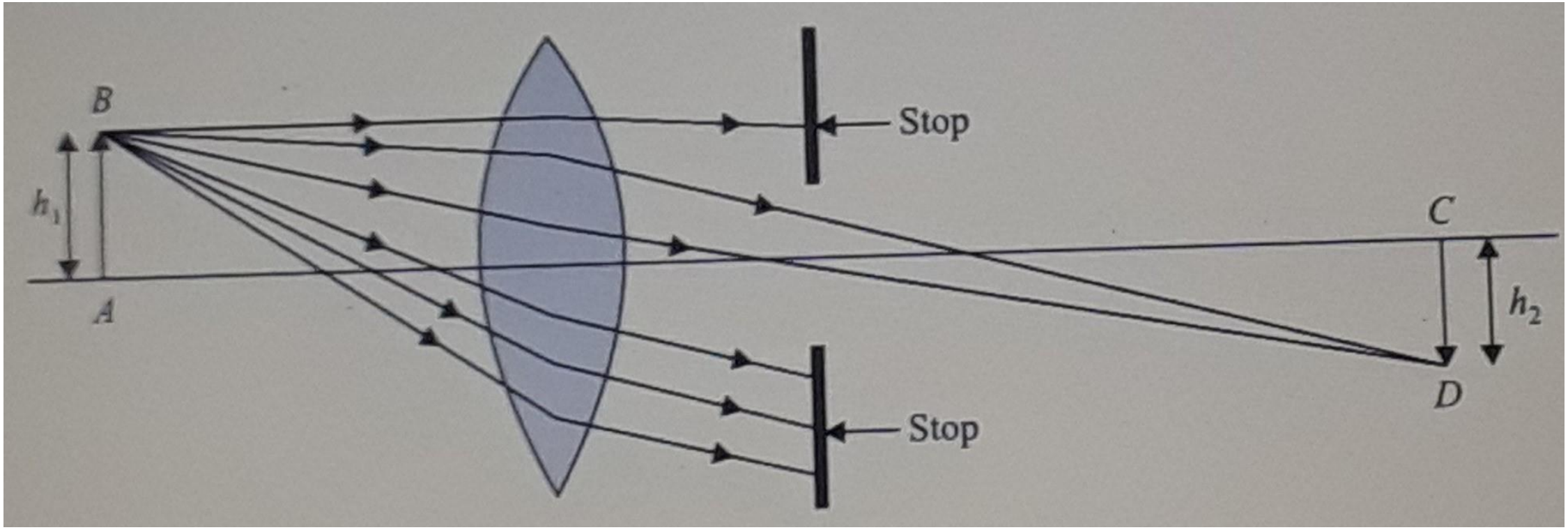

A
B
A'
O
B'


A
A'
O
B


A
A'
O
B'
B
principal
axis.

Removal of curvature

(i) Using stops: By using proper stops in front of the lens, the curvature of the field can be minimized.



(ii) **Using Petzval condition**: According to Petzval, the curvature of field will be zero for two equicurved lenses in contact or separated by a distance if they satisfied the condition $n_1 f_1 + n_2 f_2 = 0$

$$\text{or} \qquad \frac{n_1}{n_2} = -\frac{f_2}{f_1}$$

where n_1, f_1 are the refractive index and focal length of one lens and n_2, f_2, the refractive index and focal length of second lens. Since n_1, n_2 are positive, therefore, f_1 and f_2 must be of opposite sign. Thus, if the combination of a convex lens and a concave lens of different materials satisfy the above Petzval condition, the curvature of image can be minimized.