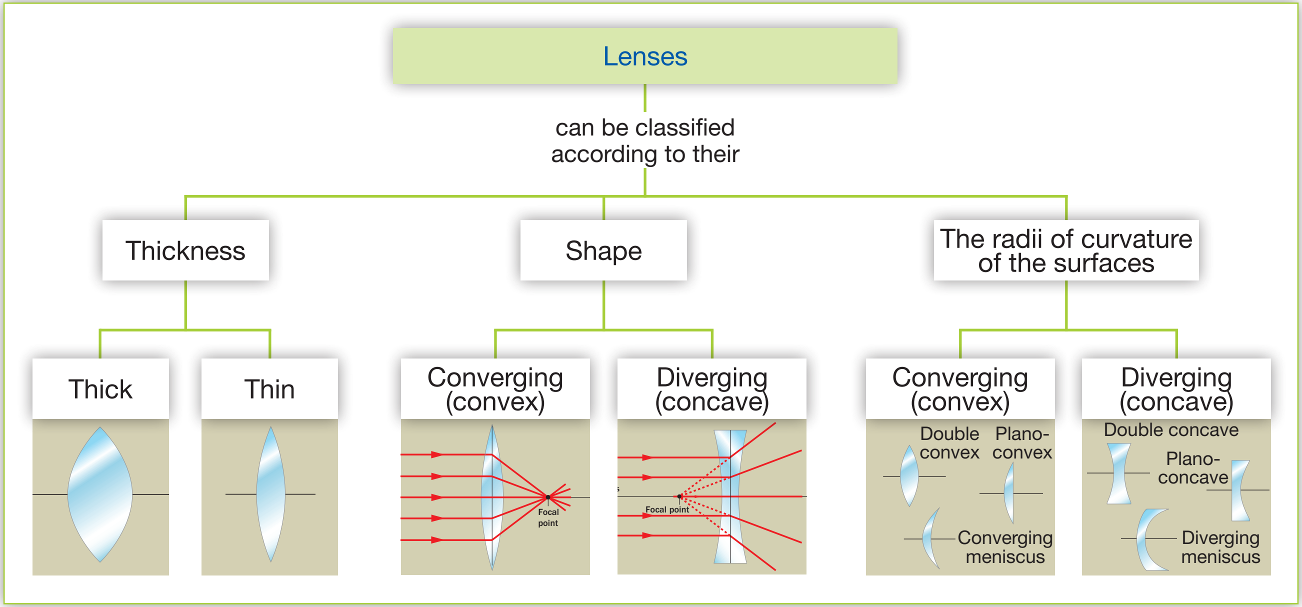
Unit 12

Lenses

As you know, a **lens** is an optical device made of a transparent material with **two surfaces**, at least one of which is curved.



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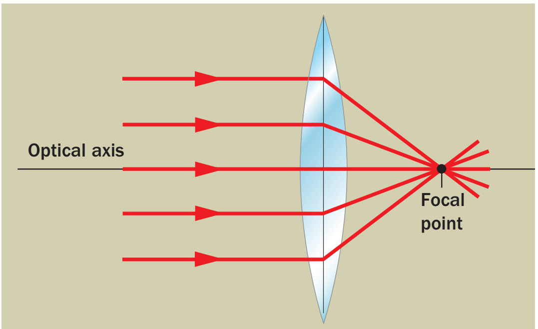
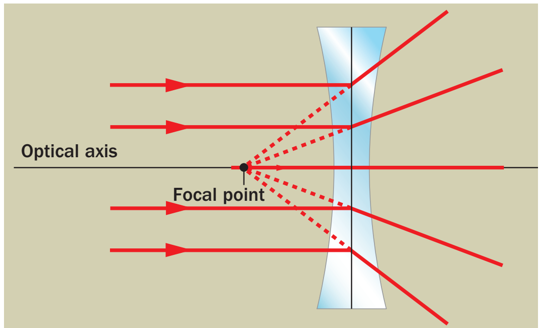
Characteristics of thin lenses

A thin lens is one whose thickness is small compared to the radii of curvature of its surfaces. We will only be studying this type of lens.

In a **converging** lens (left), rays approaching parallel to the optical axis converge at a point called the **image focal point**, or simply focal point. In a **diverging** lens (right), rays travelling parallel to the optical axis diverge after passing through the lens, but the extensions of the rays intersect at the **focal point**.





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Focal lengths

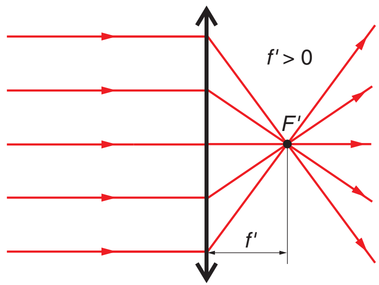
Another way to define the **image focal point,** *F*4, in a thin lens is as the point at which the image of an object at infinity would be formed.

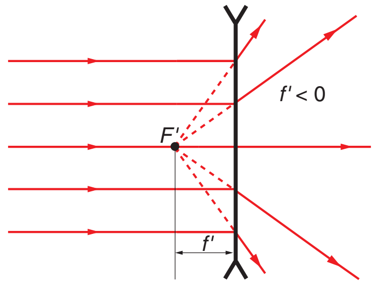
Similarly, the **object focal point**, *F*, can be defined as the point from which a lens forms an image at infinity.

We call the distances between these points and the centre of the lens the **object focal length**, *f*, and the **image focal length,** *f*4. The lengths are **equal** in absolute value but opposite in sign: *f* = –*f*4

In a converging lens, the image focal length, *f*4, is positive; however, in a divergent lens (below), the image focal length is negative.

Converging lens





Diverging lens

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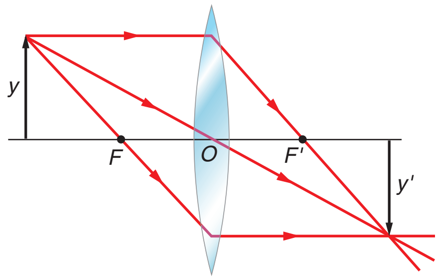
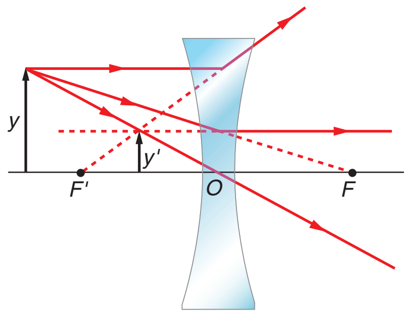
Image formation by thin lenses

We can use ray diagrams to determine the image of an object in front of a thin lens. All we need to do is draw the path of two of the three rays whose paths are known.



The three rays are:

- A ray that travels parallel to the optical axis of the lens. After refracting through the lens the ray (or its extension) passes through the image focal point.
- A ray that passes through the optical centre of the lens. In this case, the path of the ray does not change.
- A ray that passes through the object focal point (or its extension passes through it). After refracting through the lens it travels parallel to the optical axis..



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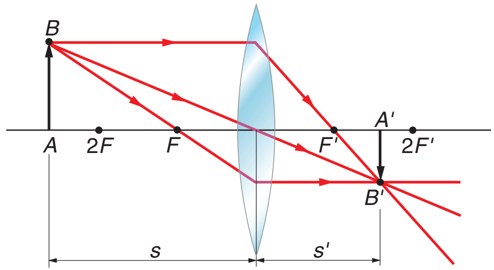
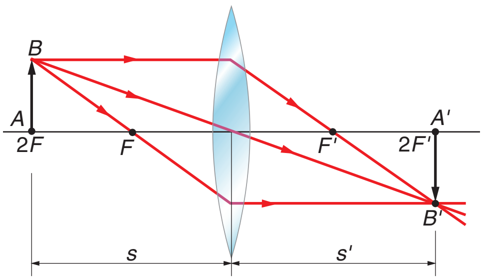
Examples of image formation by thin lenses

- If an object lies at a distance of more than 2 · *f* from a converging lens, the image is real, inverted and smaller than the object. It is located at a distance, *s*4, s’, in which (*f* 4 < *s*4 < 2 · *f* 4).





- If an object lies at a distance of 2 · *f* from a converging lens, the image is real, inverted and the same size as the object. It is formed at 2*F*4 (*s*4 = 2 · *f* 4).

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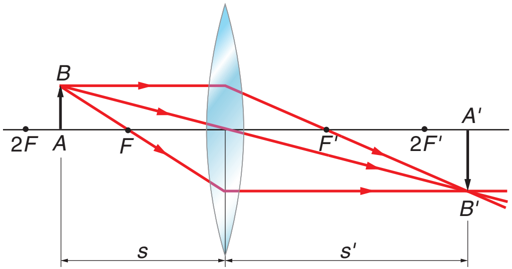
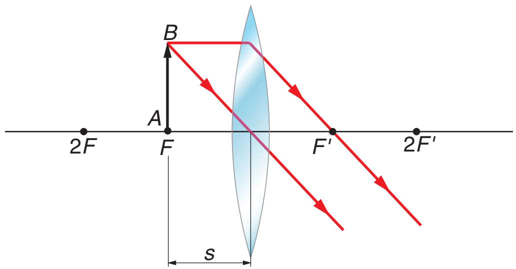
Examples of image formation by thin lenses



- If an object lies between F and $2F$, , the image is real, inverted and larger than the object. It is formed at a distance greater than $2F4$ ($s4 > 2 \cdot f4$).

- If an object lies at the focal point, F, no image is formed, because, as you can see in the ray diagram, after refracting through the lens, the rays travel parallel to one another.



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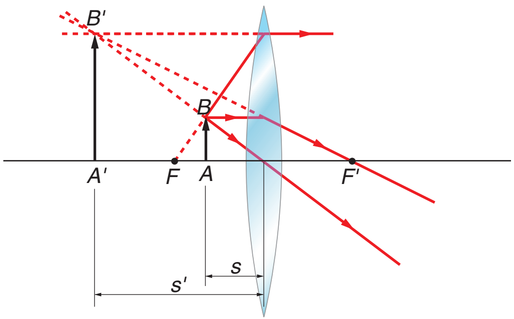
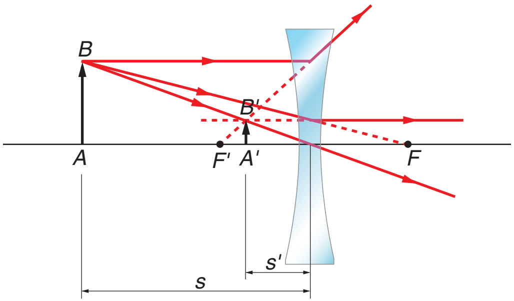
Examples of image formation by thin lenses

- The distance from the object to the converging lens is less than the focal length of the lens. The image is virtual, upright and larger than the object.

- Diverging lenses always produce images that are virtual, upright and smaller than the object, regardless of the object's location in relation to the lens.





Lenses

Activities

1 What is a real image? And a virtual image?

2 Do diverging lenses form real images, or virtual images? Why?

3 A lens produces an upright image that is larger than the object. What type of lens is it?

4 A lens produces a real, inverted image that is larger than the object. What can we deduce about the object's location in relation to the lens?

5 Name one application of diverging lenses and one application of converging lenses.