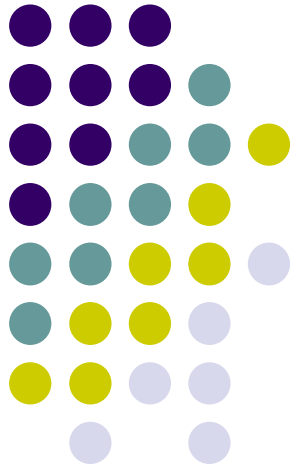
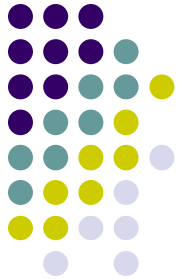
Refraction: Points and Planes

Basic Optics, Chapter 18



Points and Planes



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  - the *primary focal point*
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Points and Planes

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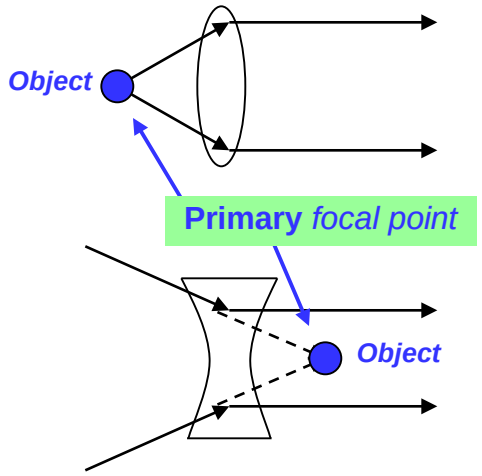

  - Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)

Points and Planes

- As we learned in Chapter 4, every lens has two focal points:
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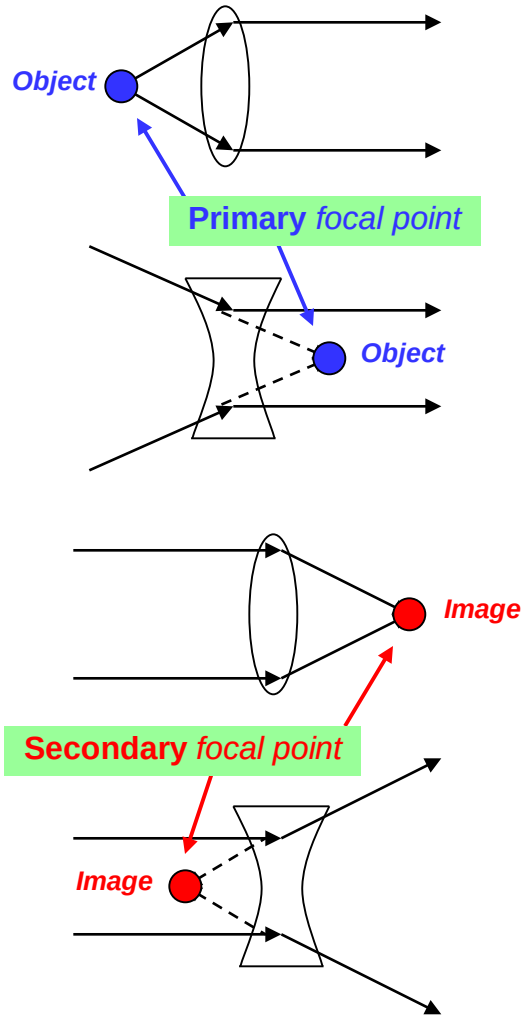
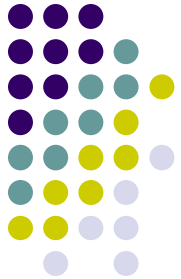
  - Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)
  - Secondary focal point: Location at which the **image** is formed when light rays with zero vergence (i.e., parallel) encounter a given lens



Points and Planes



- As we learned in Chapter 4, every lens has two focal points:
  - the *primary focal point*
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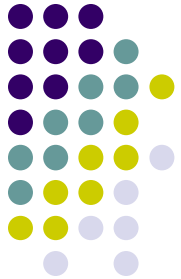
- And as we shall see shortly, these points are simply special locations on two important planes:
  - the *primary focal* ***plane***
  - the *secondary focal* ***plane***

Points and Planes



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  - the *primary focal point*
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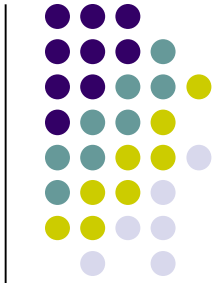
- And as we shall see shortly, these points are simply special locations on two important planes:
  - the *primary focal **plane***
  - the *secondary focal **plane***
- But first we will meet several other important members of the light-ray model family:
  - the *nodal point(s)* ← *We'll address the reason for this waffling shortly*
  - the *lens axis*

Points and Planes



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- And as we shall see shortly, these points are simply special locations on two important planes:

The primary focal points, nodal points, and two others called the *principal points* (which, you will be happy to learn, we won't get into) comprise what are known as the ***cardinal points*** for a lens system. Taken together, the cardinal points capture and describe the critical optical properties of any lens system. (And that's all I think you need to know about cardinal points *per se*.)

members of the light-ray model family:

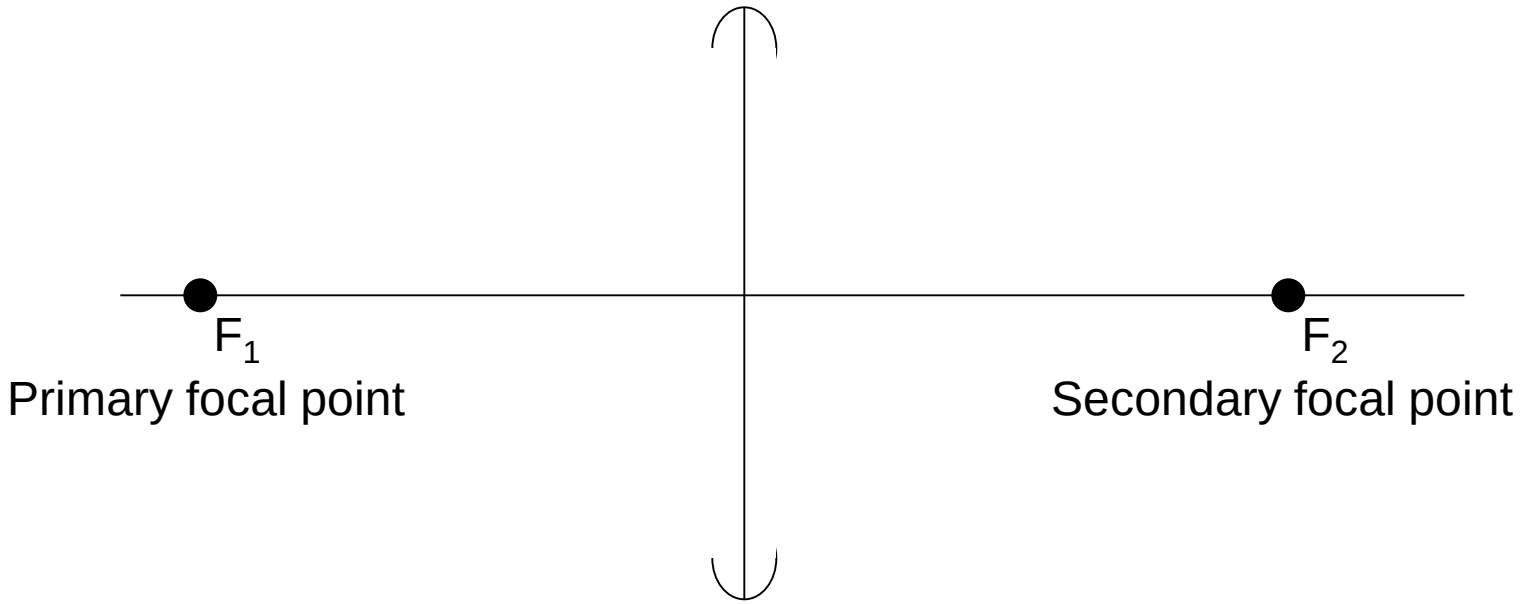
  - the ***nodal point(s)***
  - the *lens axis*

We'll address the reason for this waffling shortly

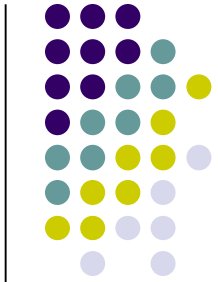
Points and Planes

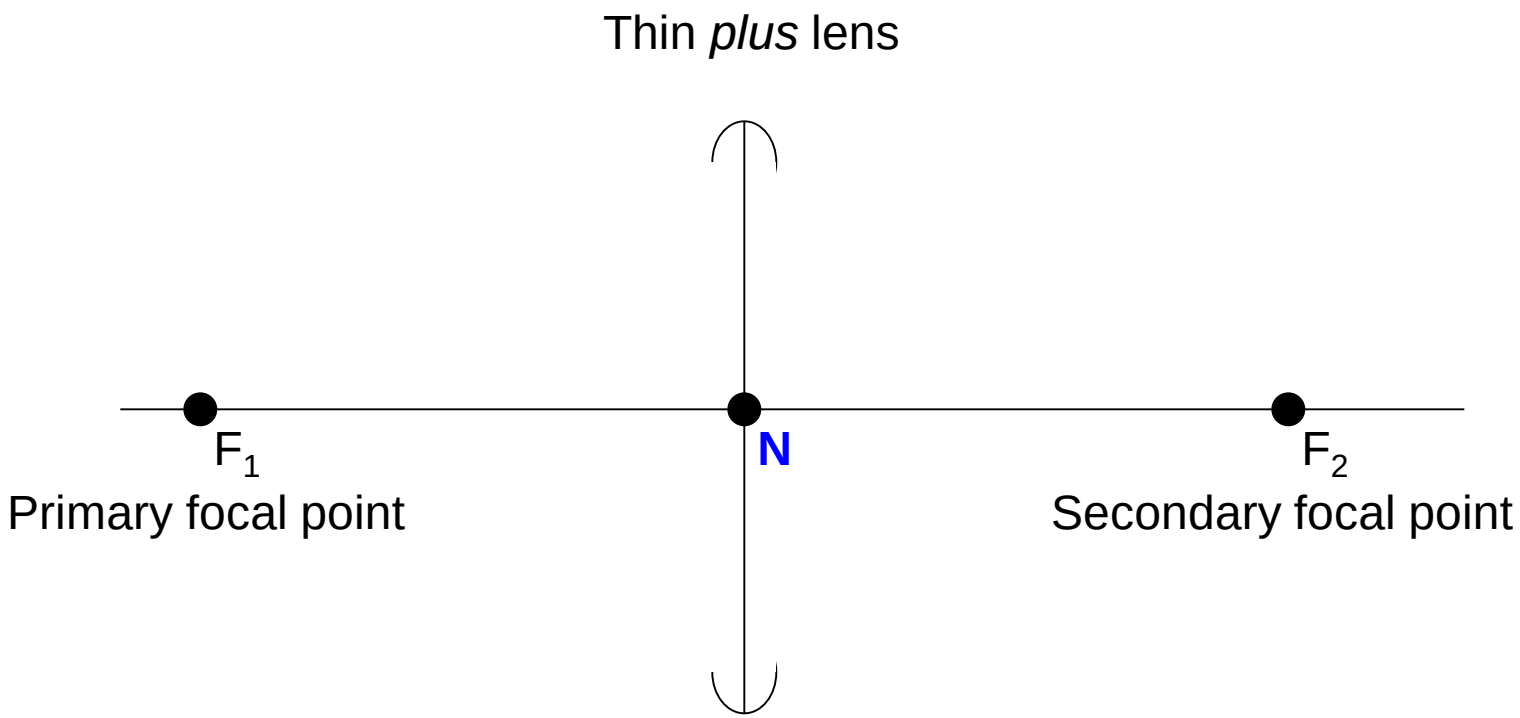
Note: The term *thin* here means ***infinitely thin***. Obviously, real lenses are not infinitely thin! A thin lens is a *theoretical construct* we employ because it simplifies the optics and thereby facilitates understanding.

Thin *plus* lens



Points and Planes

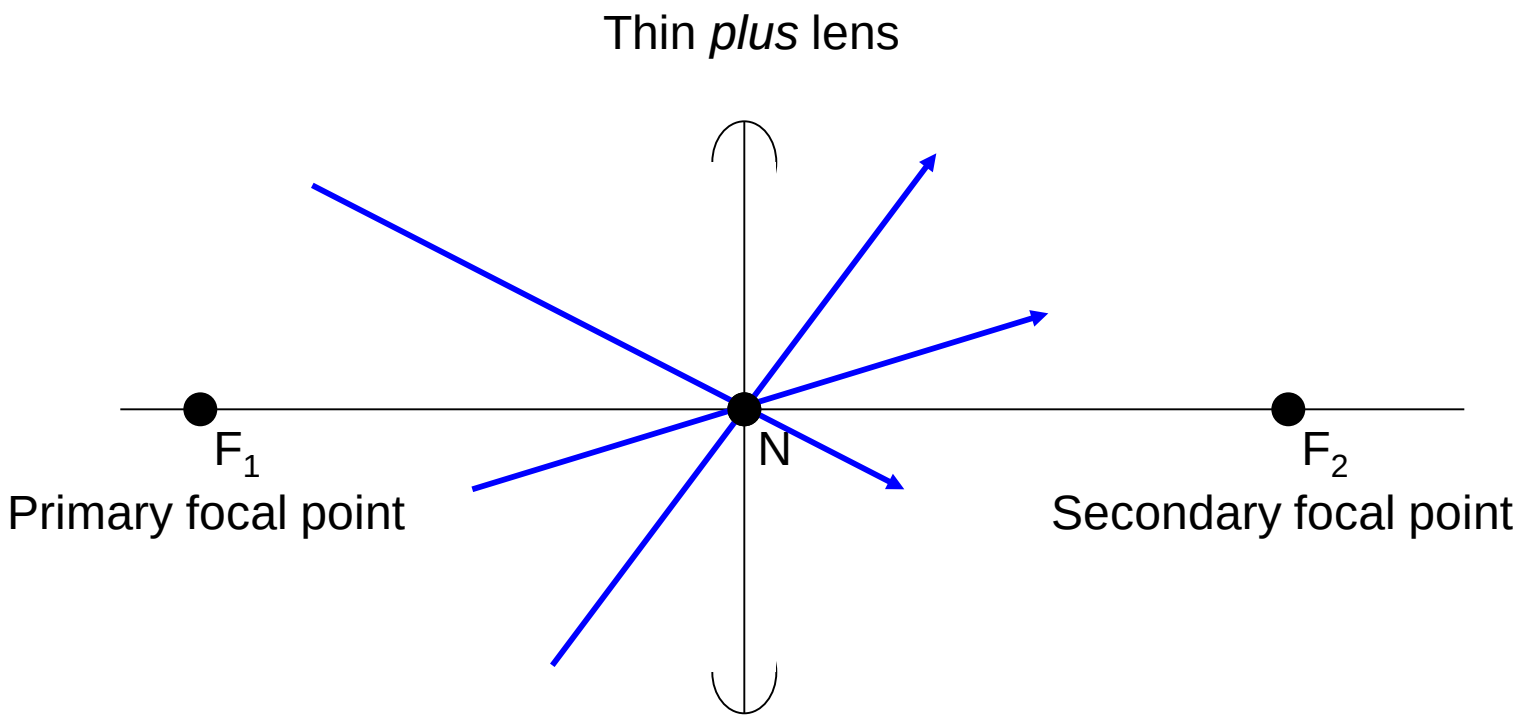




Nodal point (N): Location through which any ray, from any angle, will pass **undeviated**

Points and Planes

If a ray passes through the nodal point, it will not be refracted--that is, *it will exit the lens with the same angle at which it entered*



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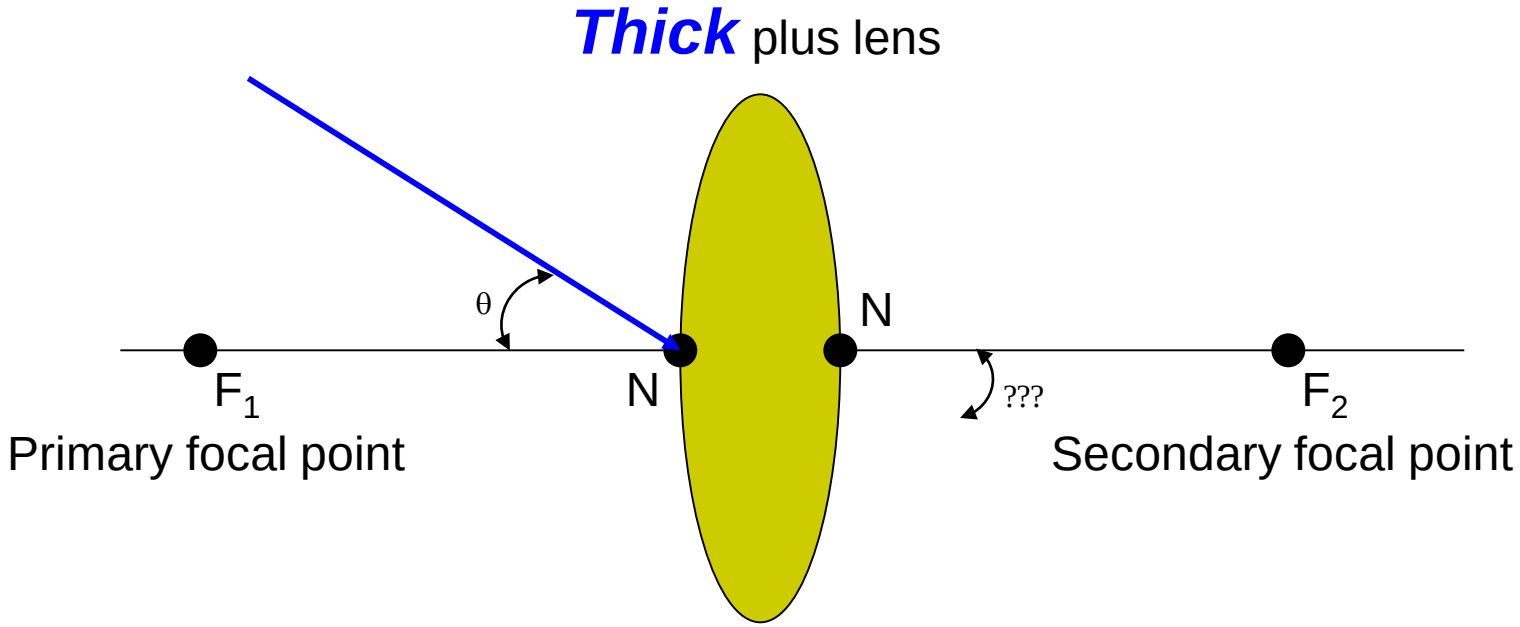
Points and Planes

As an important aside…



In a thick (i.e., real) lens, there are **two** nodal points. However…

Points and Planes

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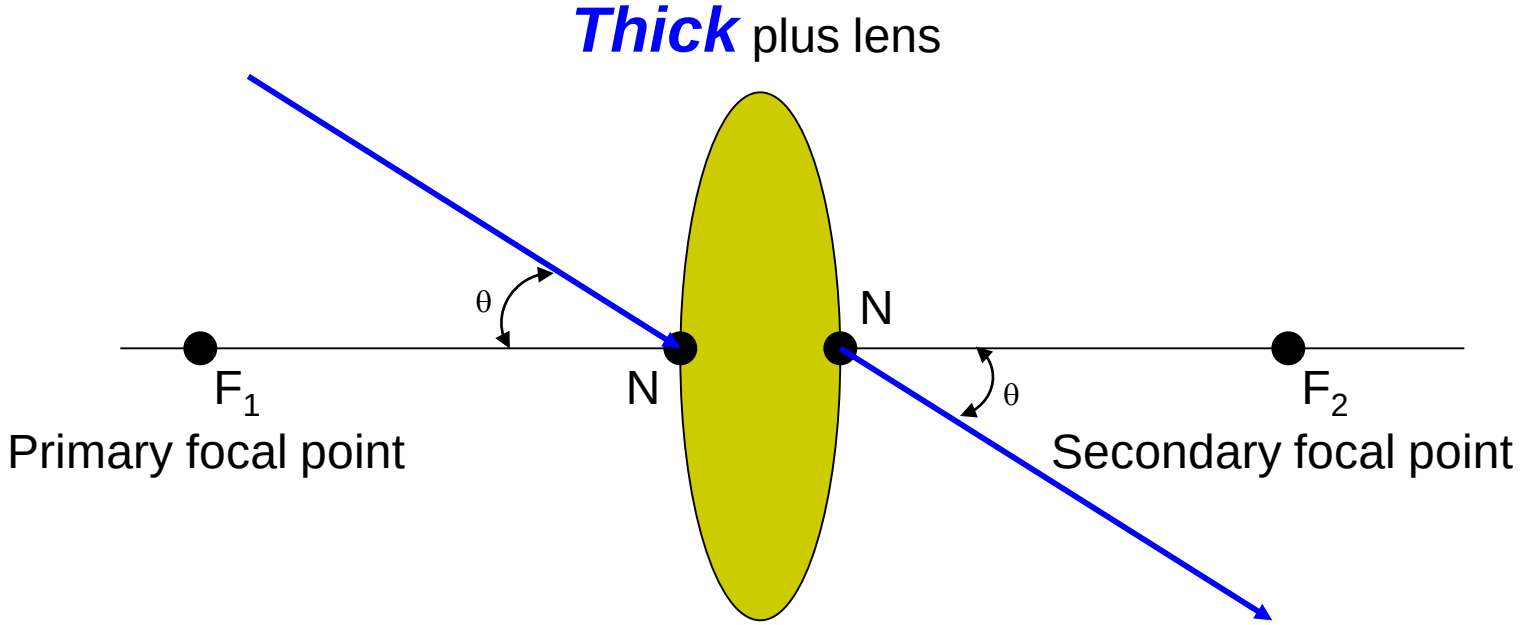
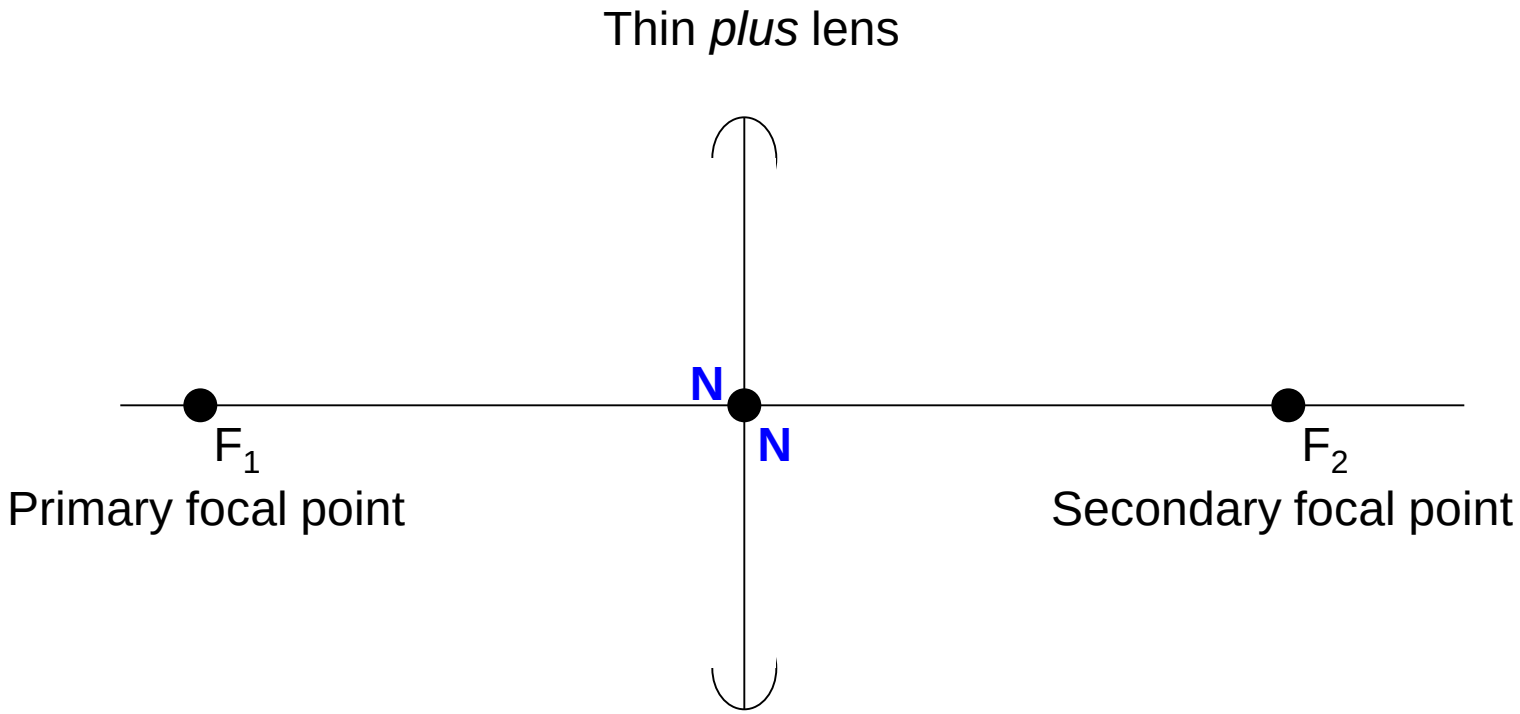


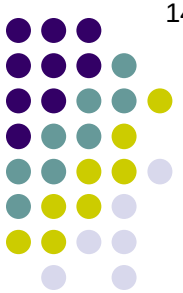
In a thick (i.e., real) lens, there are **two** nodal points. However…the same rule applies—a ray entering one nodal point will appear to 'jump' to the other and exit at the same angle (i.e., undeviated)

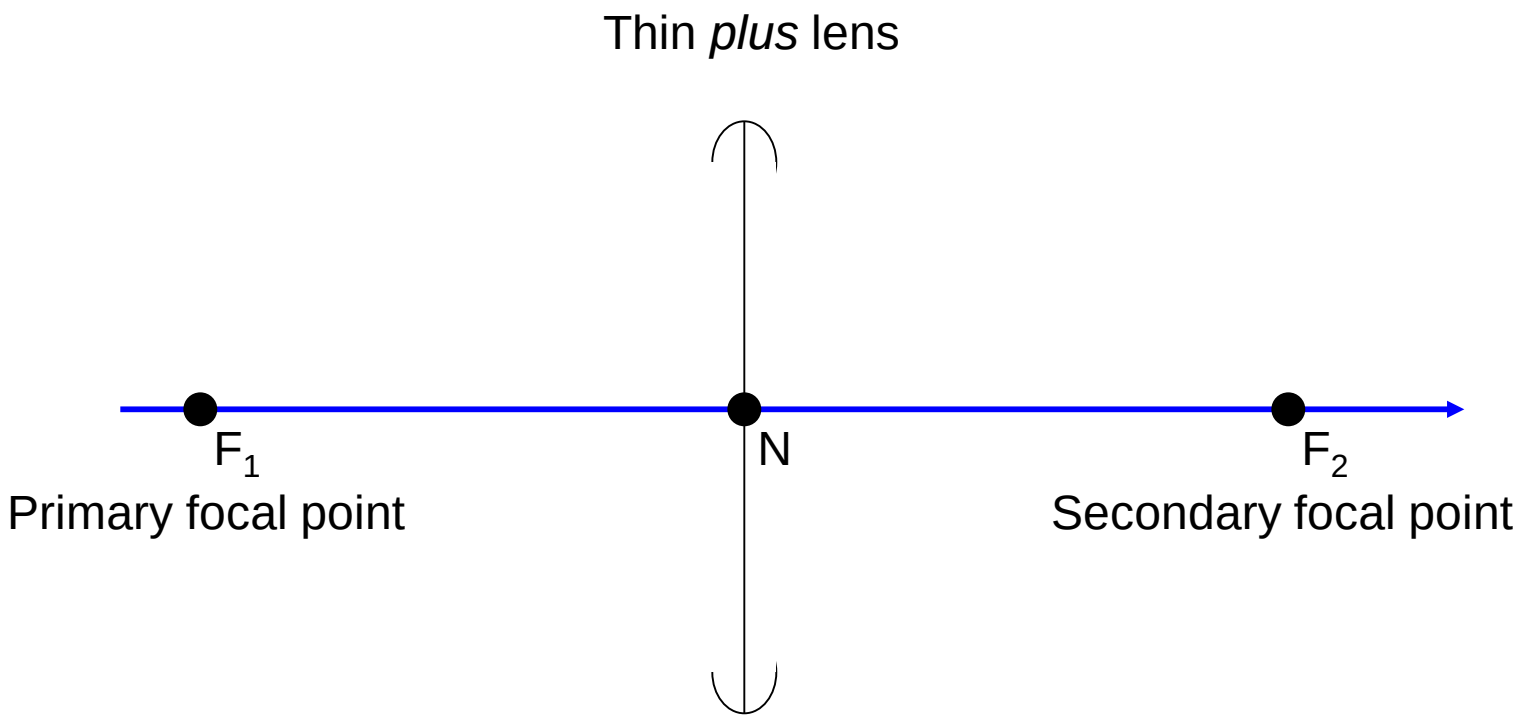
Points and Planes



(Technically speaking, a thin lens has two nodal points as well—it's just that they are both located at the same point in optical space.)

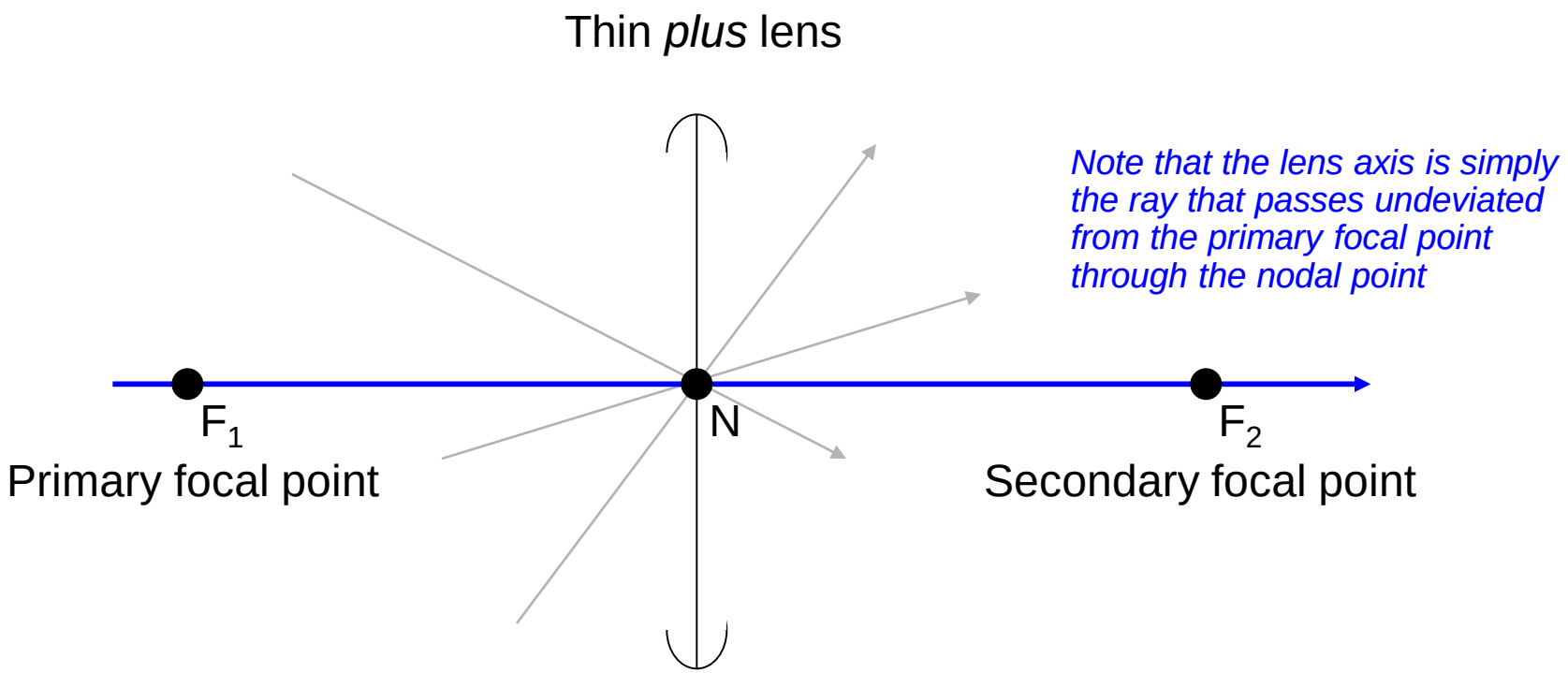
Points and Planes





Lens axis: The ray that passes through both focal points and the nodal point

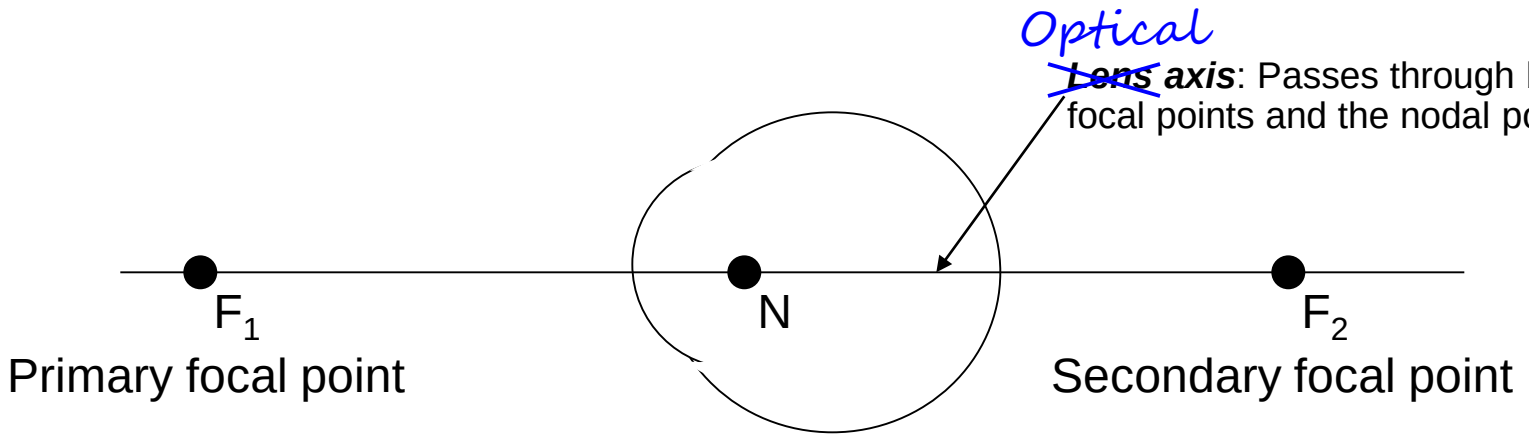
Points and Planes



Lens axis: The ray that passes through both focal points and the nodal point

Points and Planes

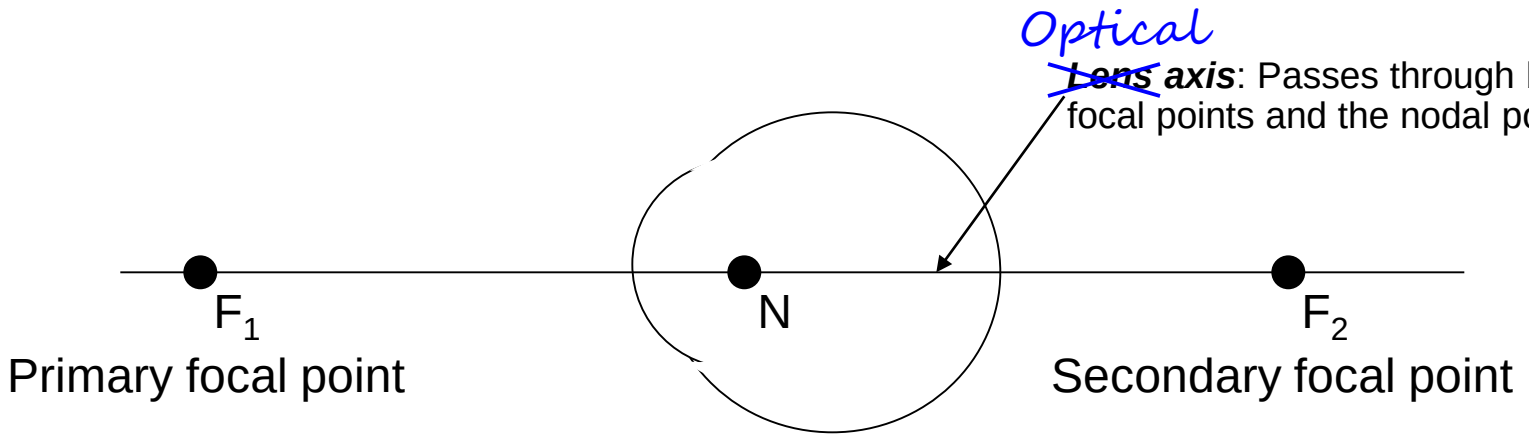
The term **optical axis** is more general, and can be applied to eyes as well as lenses. (Recall from Chapter 4 that eyes have focal points; trust me that eyes also have nodal points.)



Points and Planes

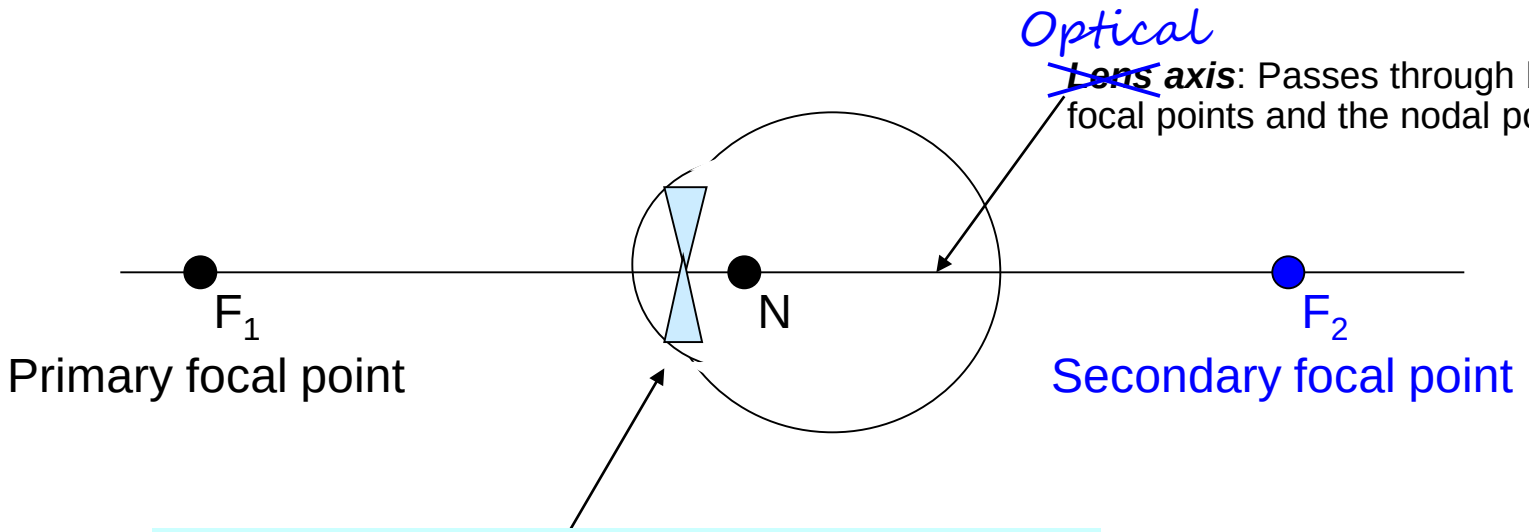
The term **optical axis** is more general, and can be applied to eyes as well as lenses. (Recall from Chapter 4 that eyes have focal points; trust me that eyes also have nodal points.)

Bonus question: As shown, is this an *emmetropic*, *hyperopic* or *myopic* eye?

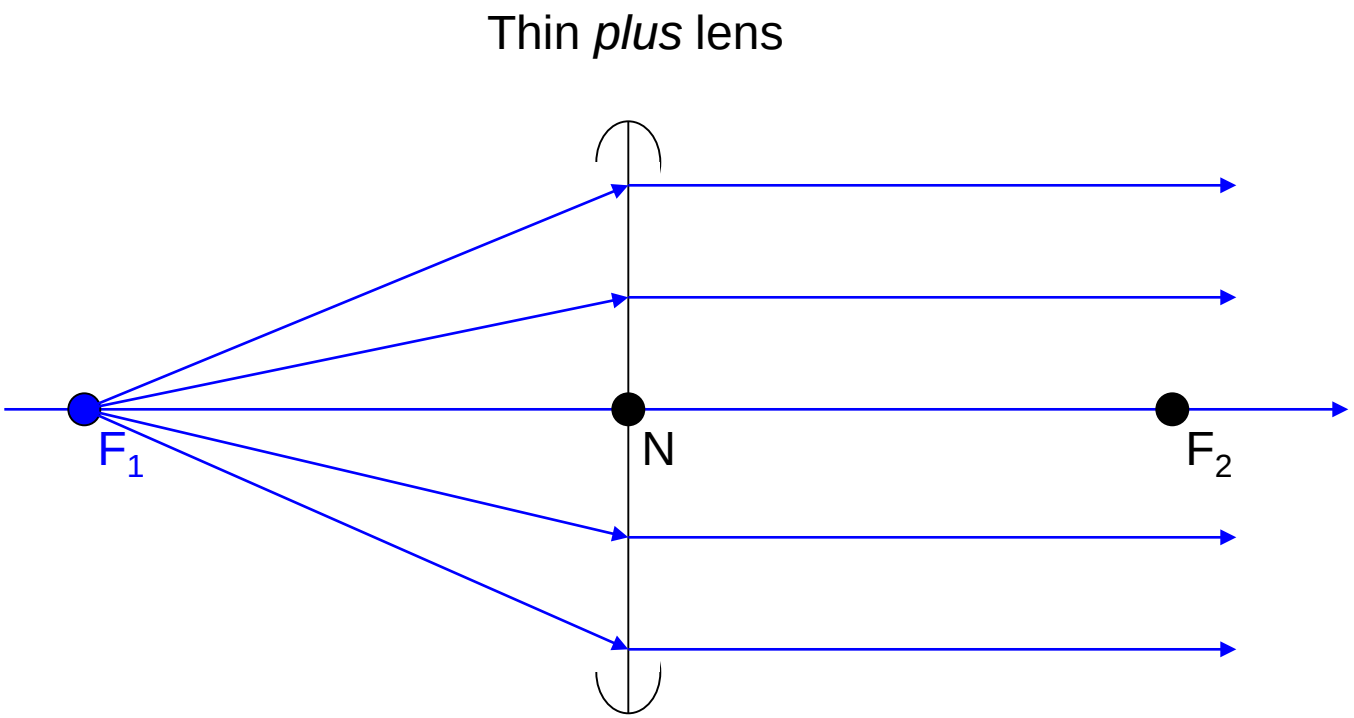


Points and Planes

The term **optical axis** is more general, and can be applied to eyes as well as lenses. (Recall from Chapter 4 that eyes have focal points; trust me that eyes also have nodal points.)
Bonus question: As shown, is this an *emmetropic*, *hyperopic* or *myopic* eye?
Hyperopic. (The tipoff: The secondary focal point is *behind* the eye.)



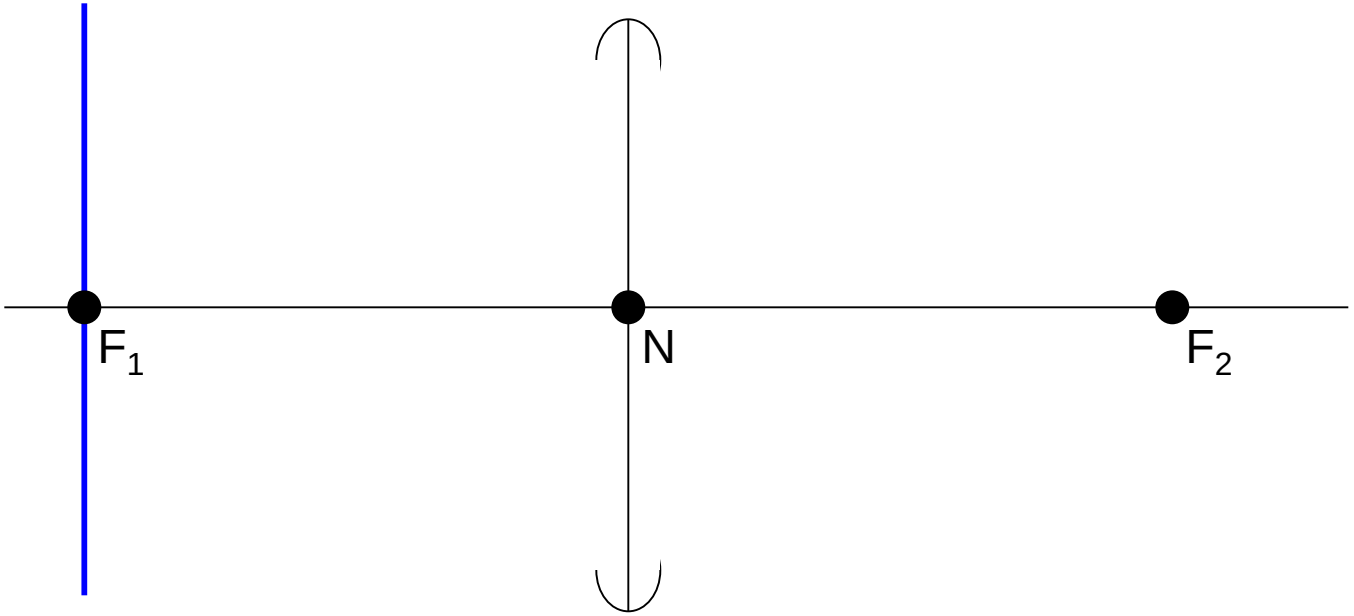
Points and Planes



Primary focal point: The location from which rays hitting a lens will leave that lens with zero vergence (i.e., parallel to lens axis). You know this from Chapter 4.

Points and Planes

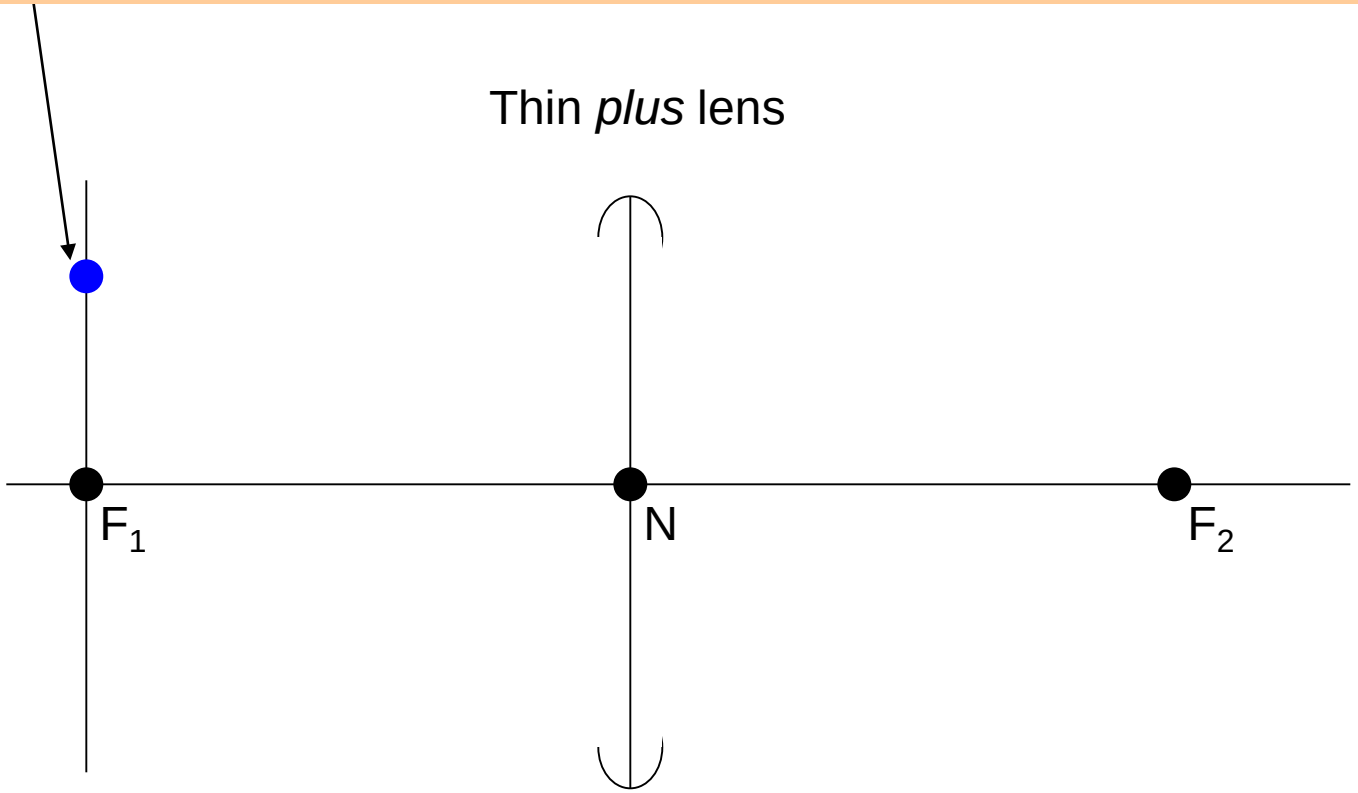
Thin *plus* lens



Primary focal ***plane***: Rays emanating from ***any*** point on this plane will exit the lens parallel to one another (but ***not*** necessarily parallel to the lens axis)

Points and Planes

Consider this point on the primary focal plane. Rays passing through the lens from here will exit the lens parallel to one another. But how can we know which direction that will be?



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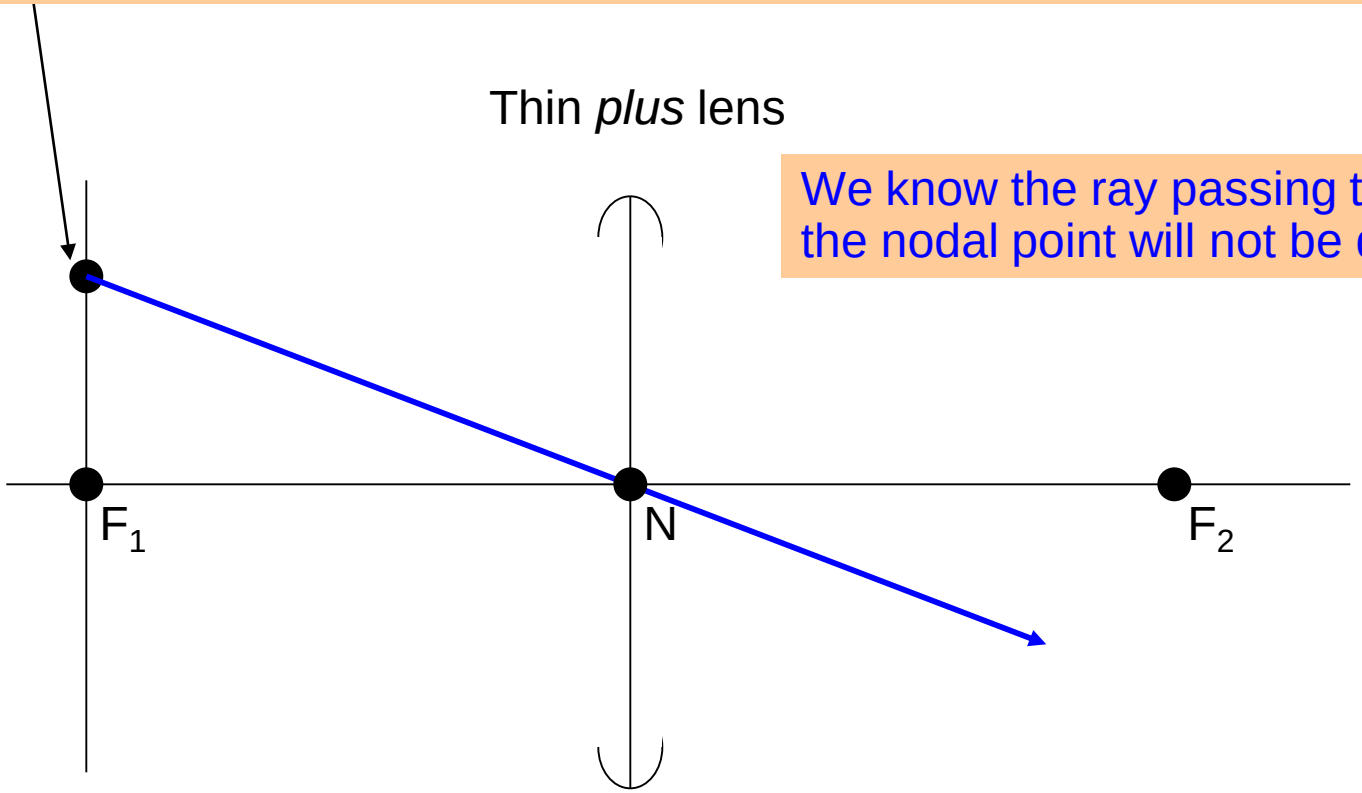

We know the ray passing through the nodal point will not be deviated…

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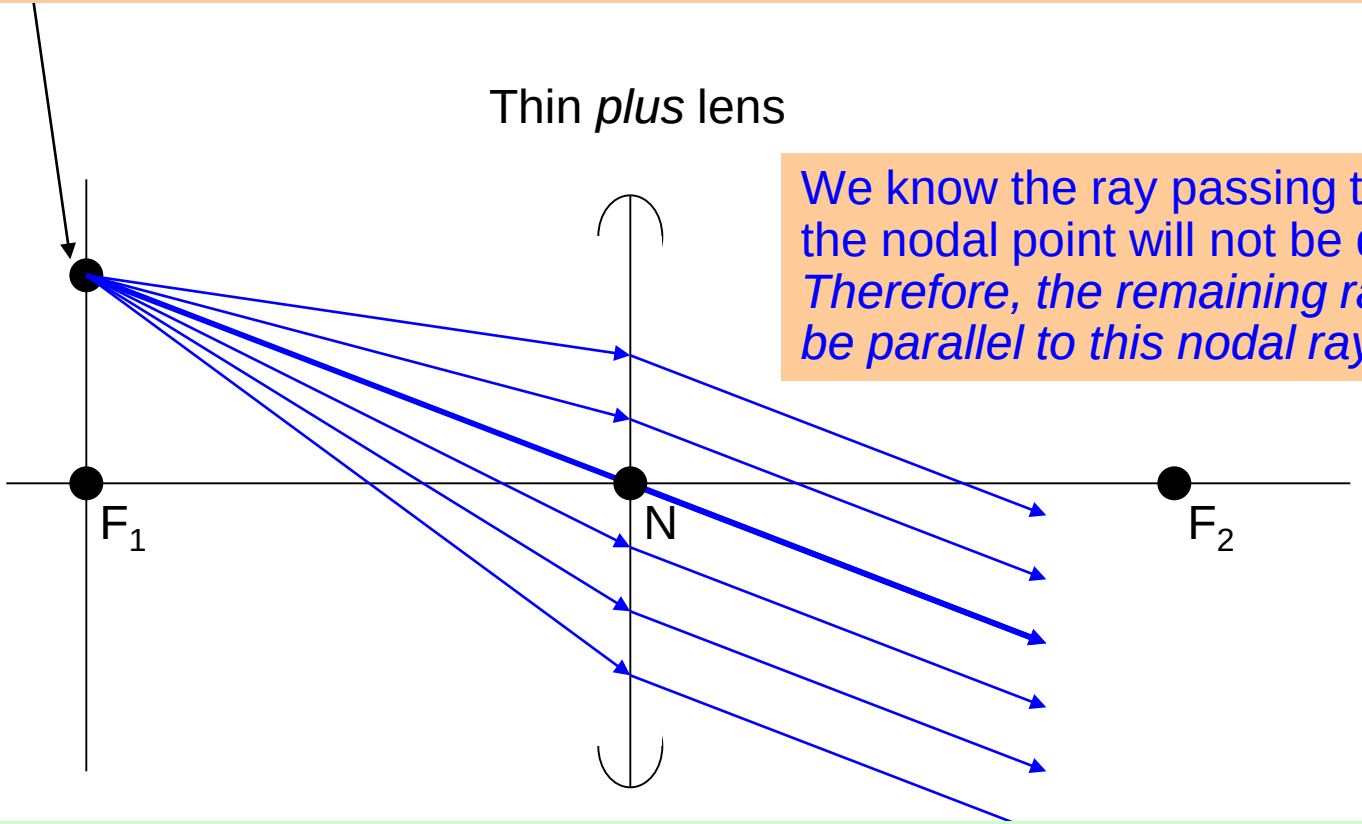
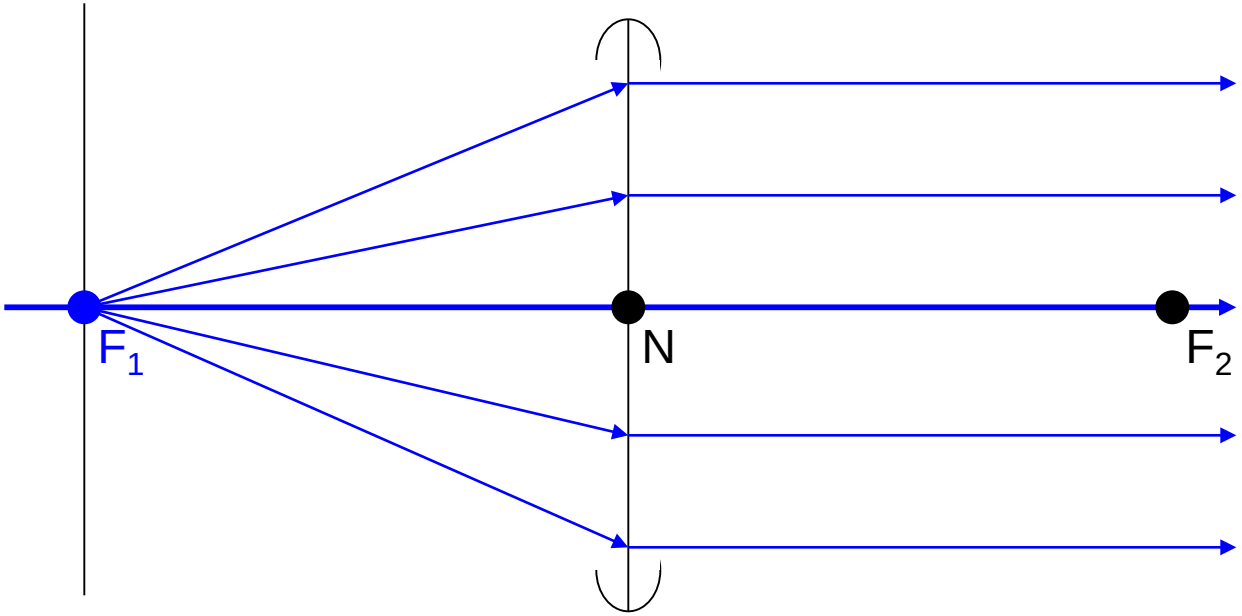


We know the ray passing through the nodal point will not be deviated… *Therefore, the remaining rays must be parallel to this nodal ray*

Primary focal ***plane***: Rays emanating from ***any*** point on this plane will exit the lens parallel to one another (but ***not*** necessarily parallel to the lens axis)

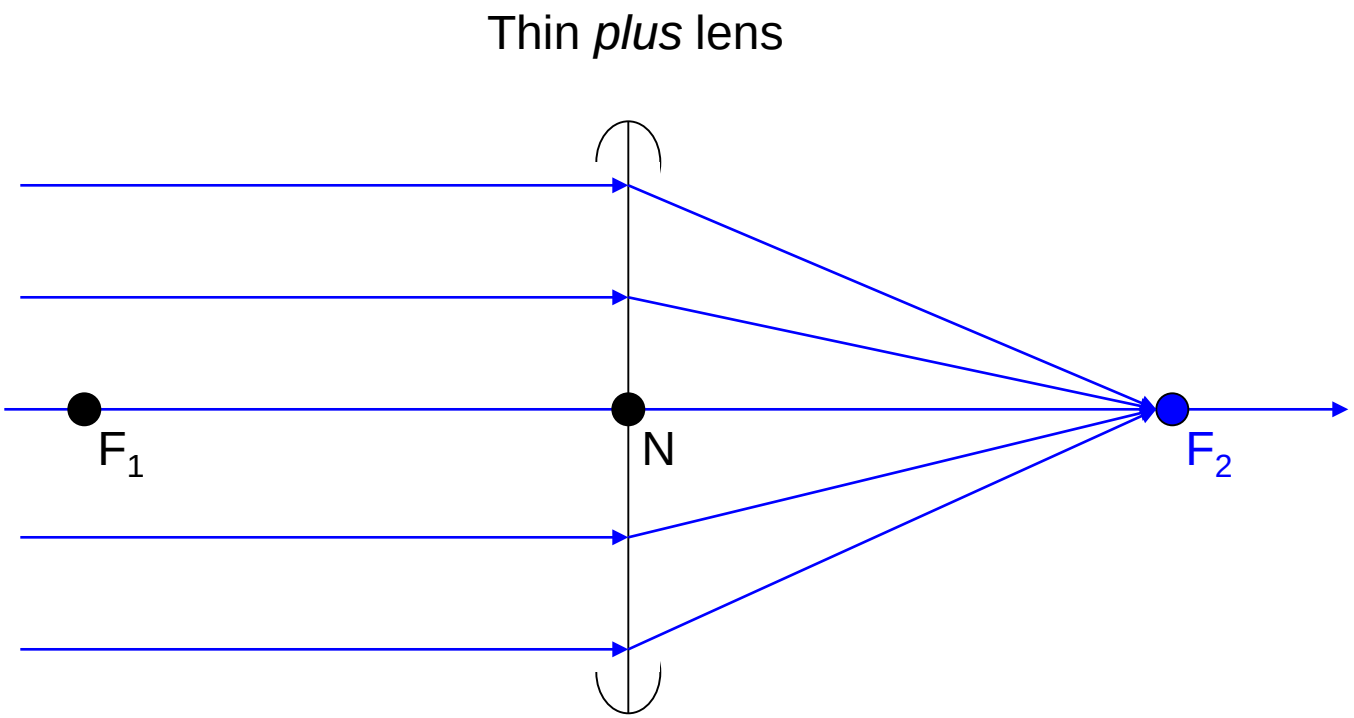
Points and Planes

Thin *plus* lens



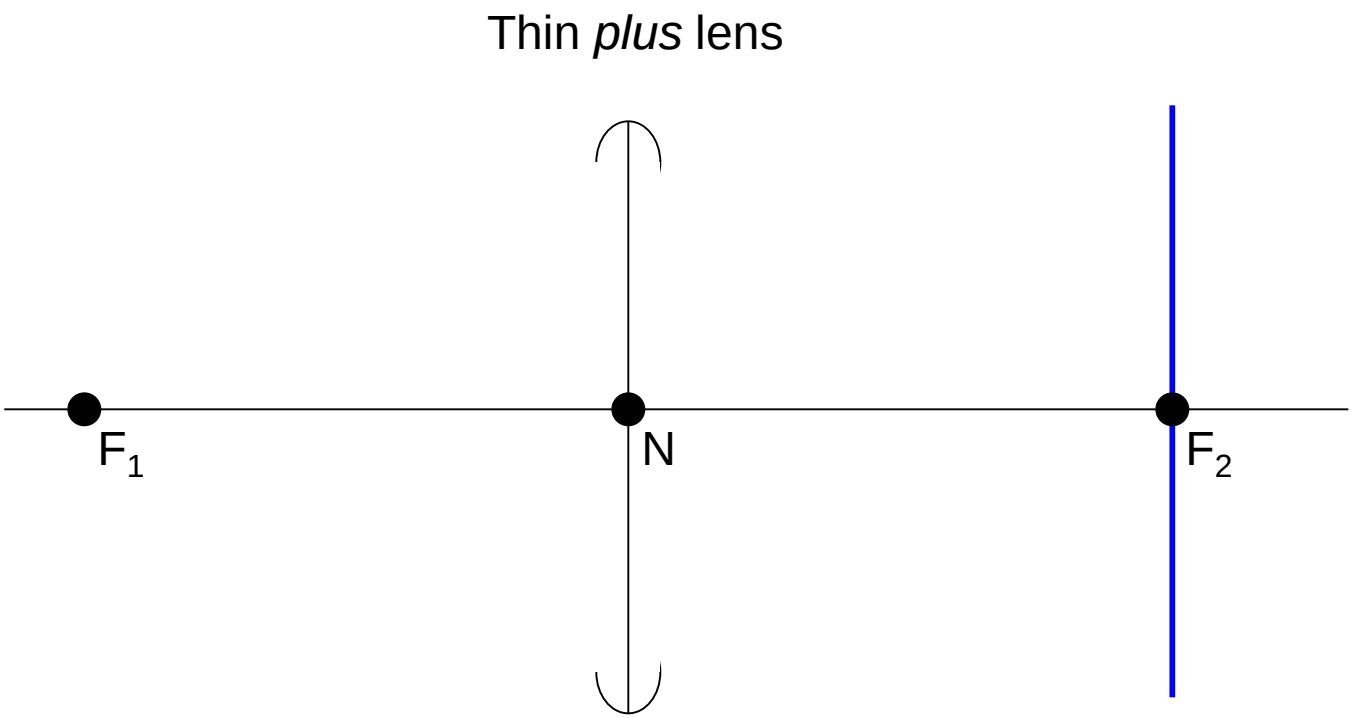
Here again is the slide depicting the primary focal point within the context of the primary focal plane. You can now see that the nodal ray of the primary focal point is the lens (optical) axis.

Points and Planes



Secondary focal point: The location where rays parallel to the axis ray (ie, traveling with zero vergence) will be focused. (Also from Chapter 4.)

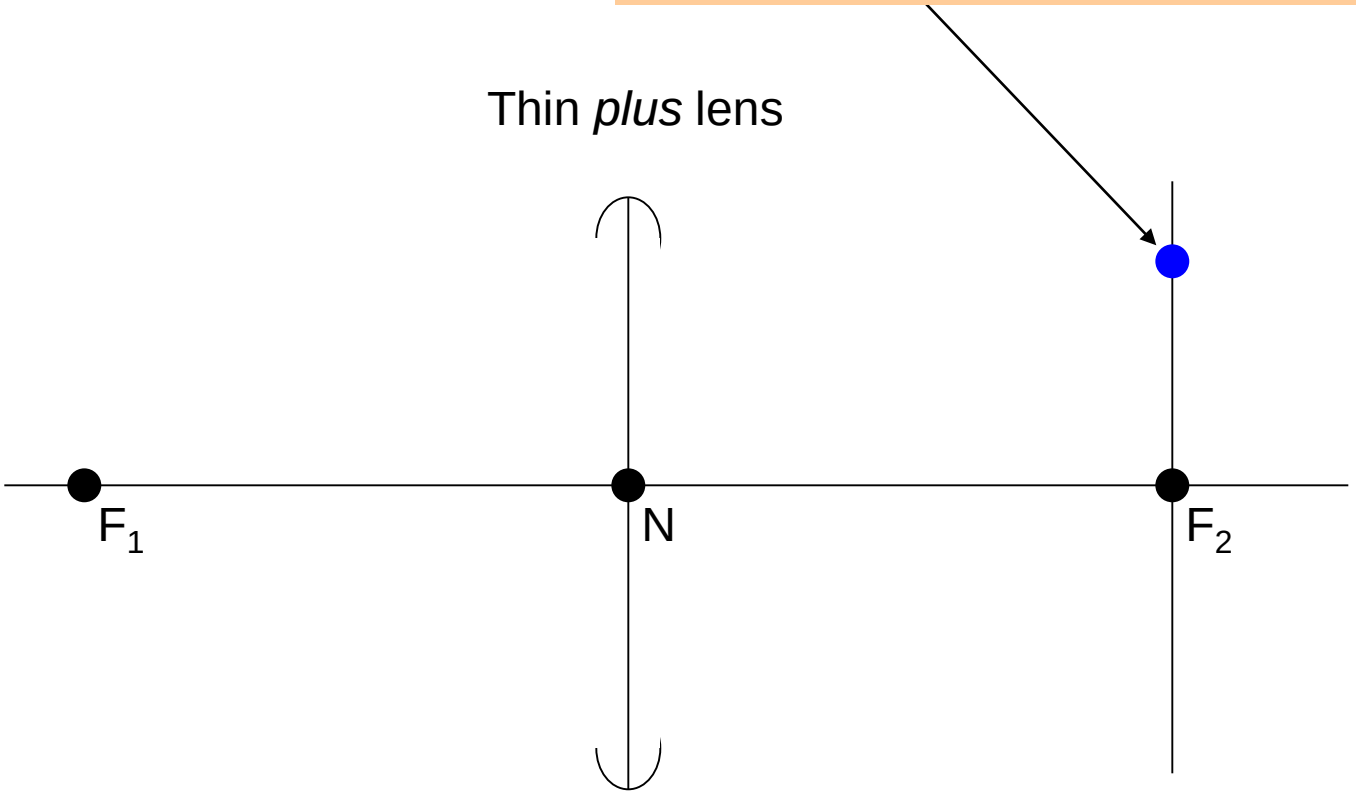
Points and Planes



Secondary focal ***plane***: The 'home location' of all images formed by parallel rays hitting the lens

Points and Planes

Consider this point on the secondary focal plane. From what direction will its formative rays arrive?



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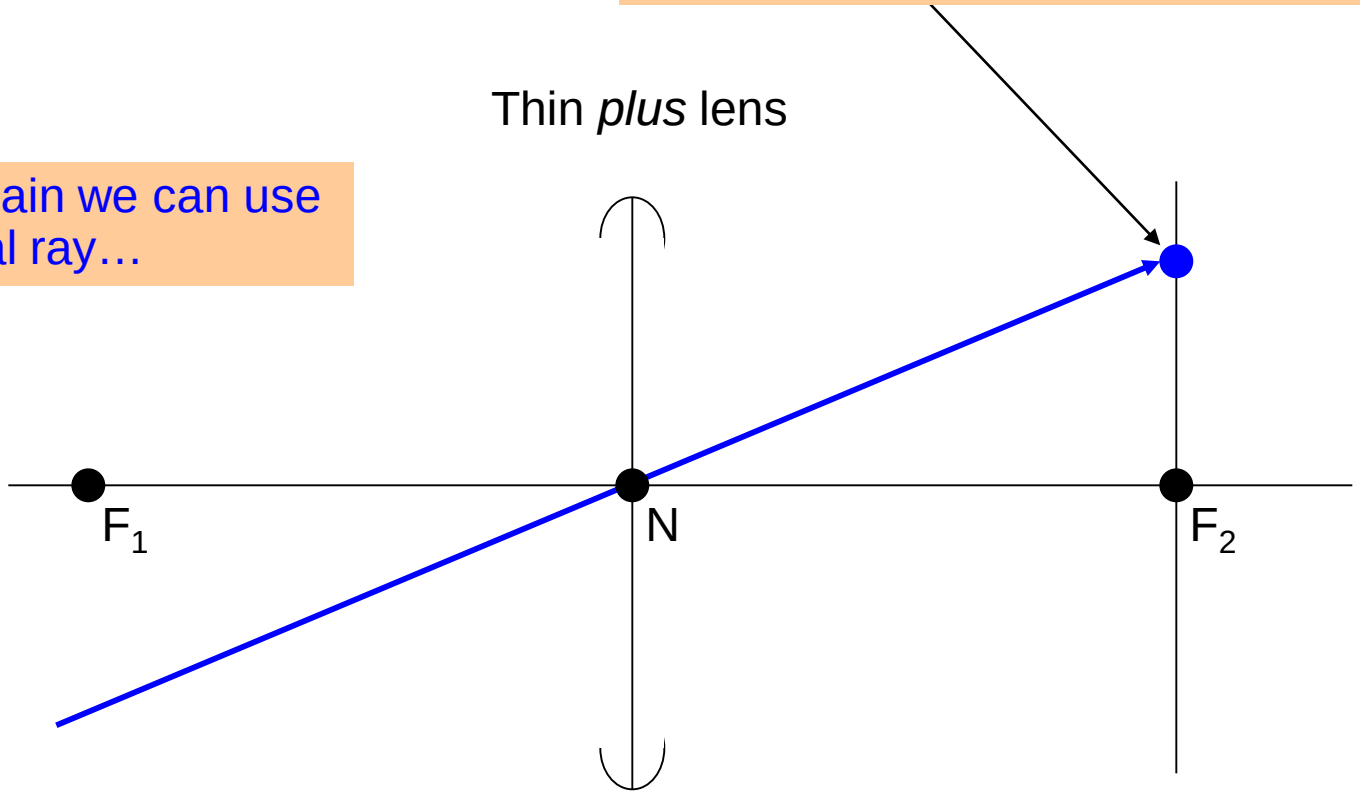
Once again we can use the nodal ray…



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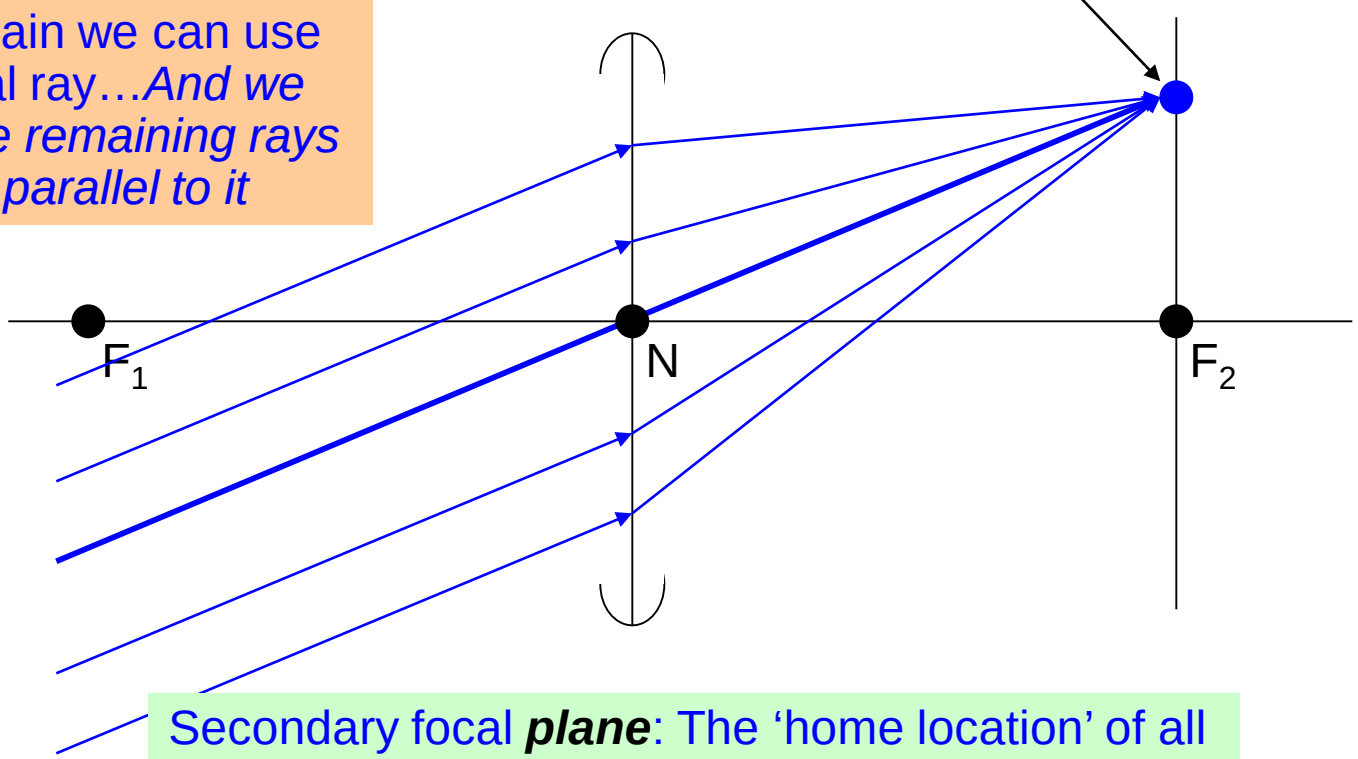
Points and Planes

Consider this point on the secondary focal plane. From what direction will its formative rays arrive?

Thin *plus* lens

Once again we can use the nodal ray…*And we know the remaining rays must be parallel to it*



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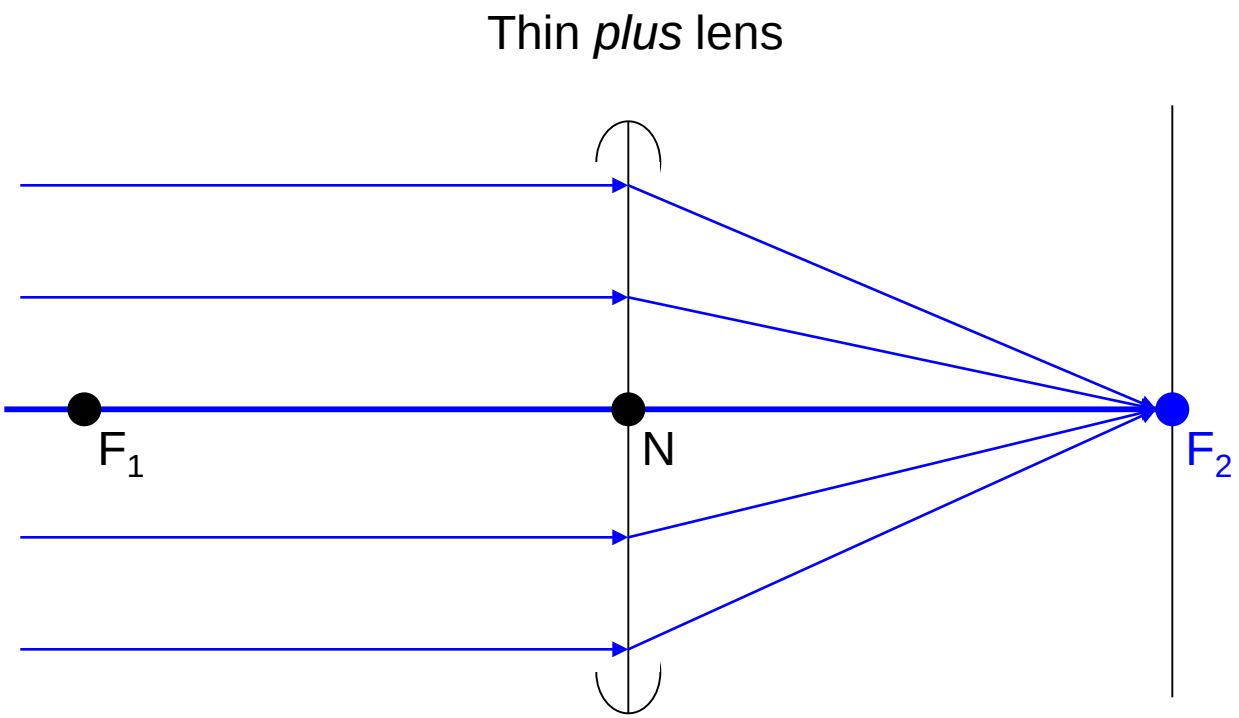
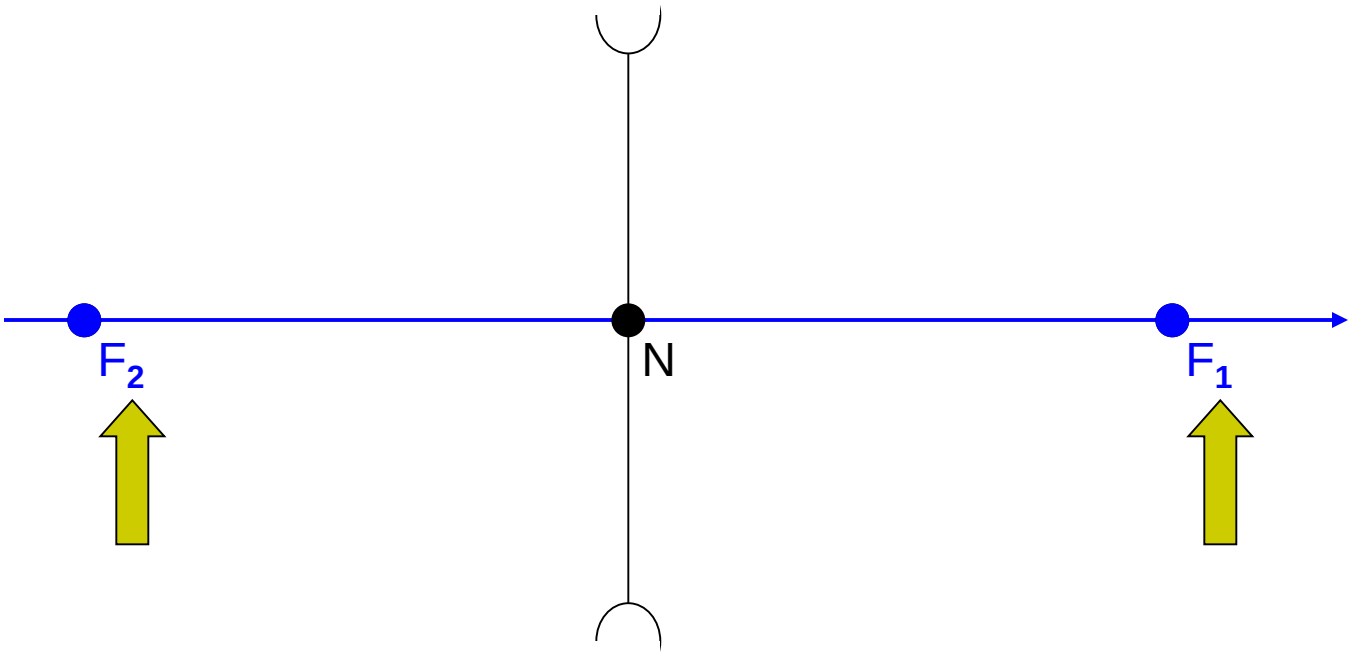


Here again is the slide depicting the secondary focal point within the context of the secondary focal plane. You can now see that the nodal ray of the secondary focal point is the lens (optical) axis.

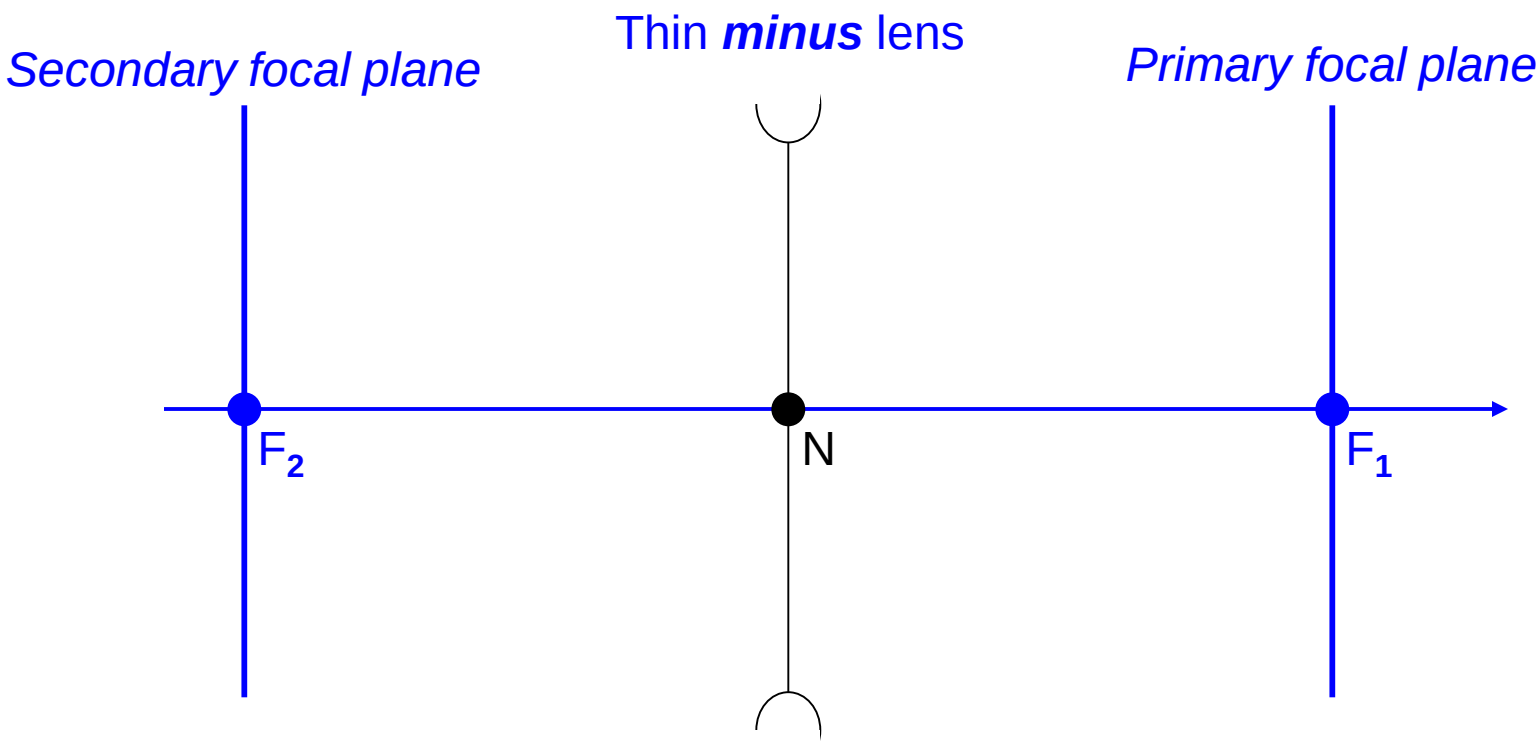
Points and Planes

Thin ***minus*** lens



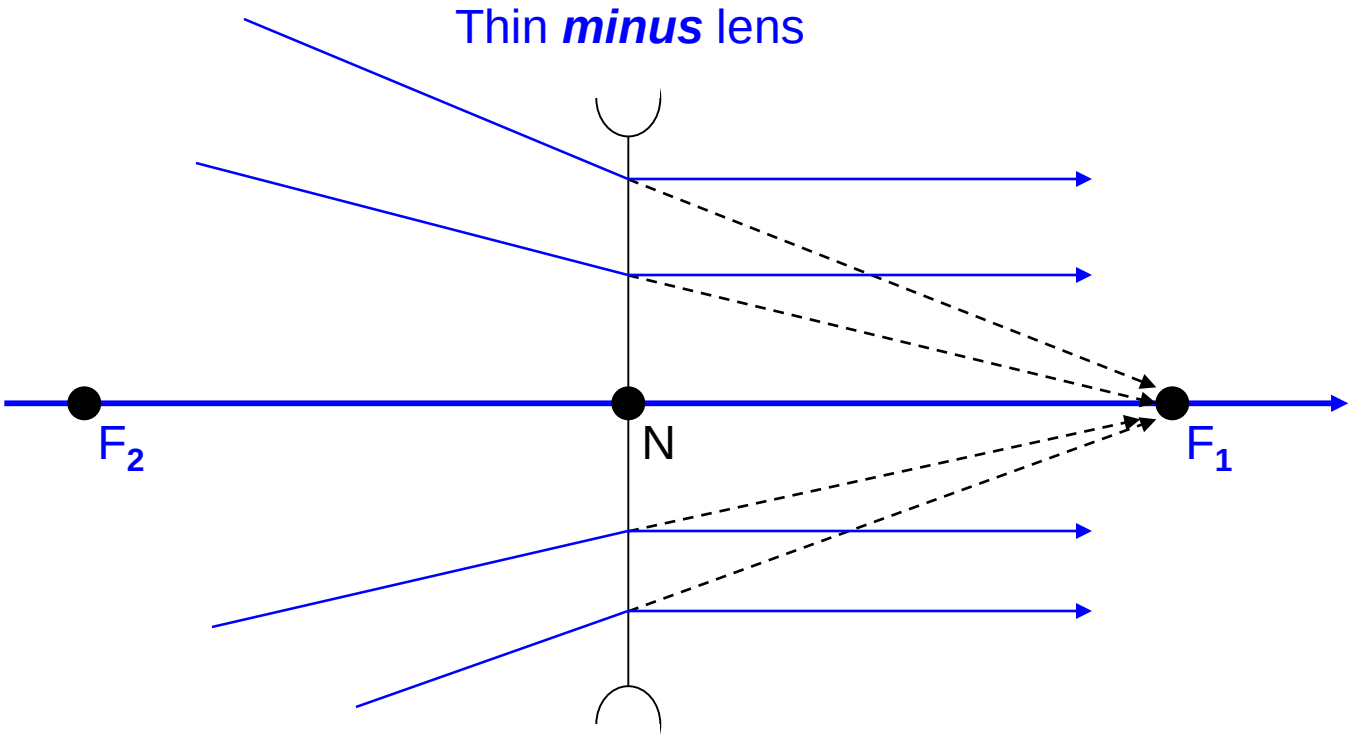
Here is a thin **minus** lens. Recall that the locations of the primary and secondary focal points are reversed as compared with a plus lens.

Points and Planes



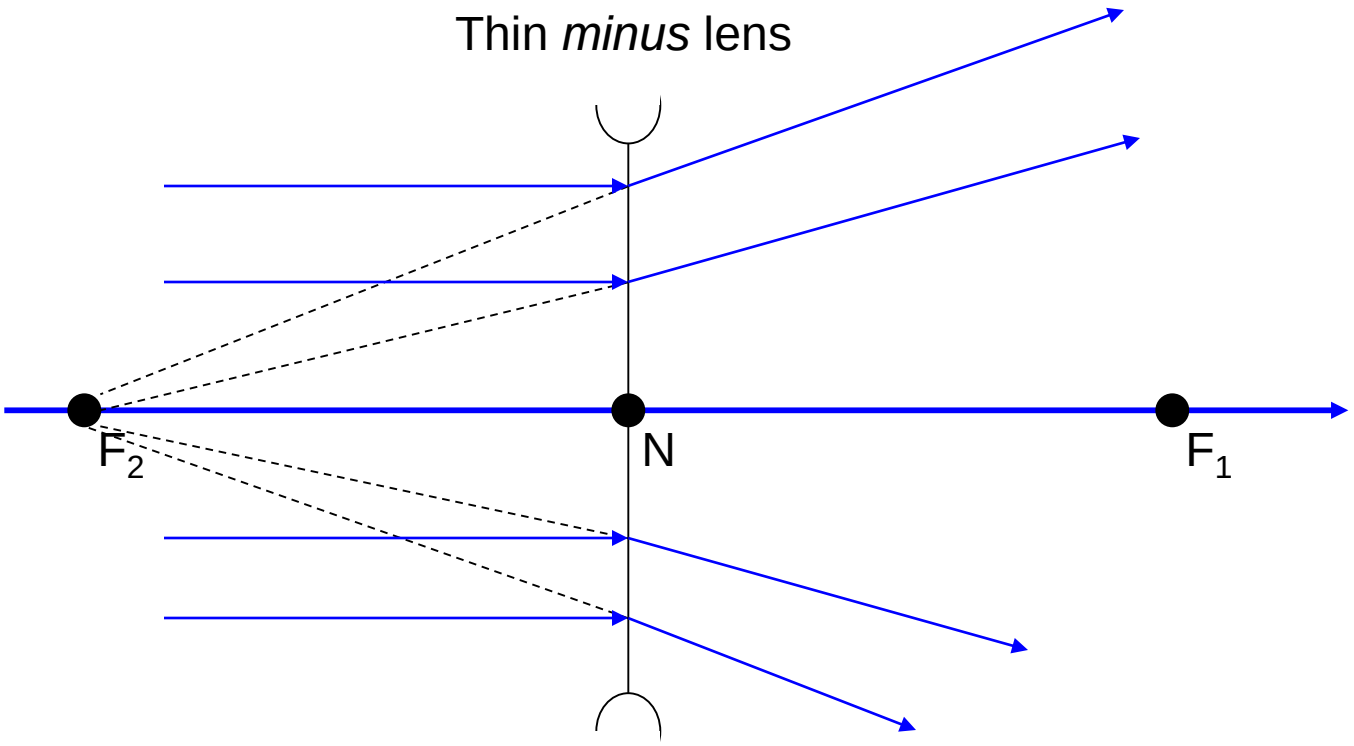
Here is a thin **minus** lens. Recall that the locations of the primary and secondary focal points are reversed as compared with a plus lens.
Naturally, the same must be true of the primary and secondary focal **planes**.

Points and Planes



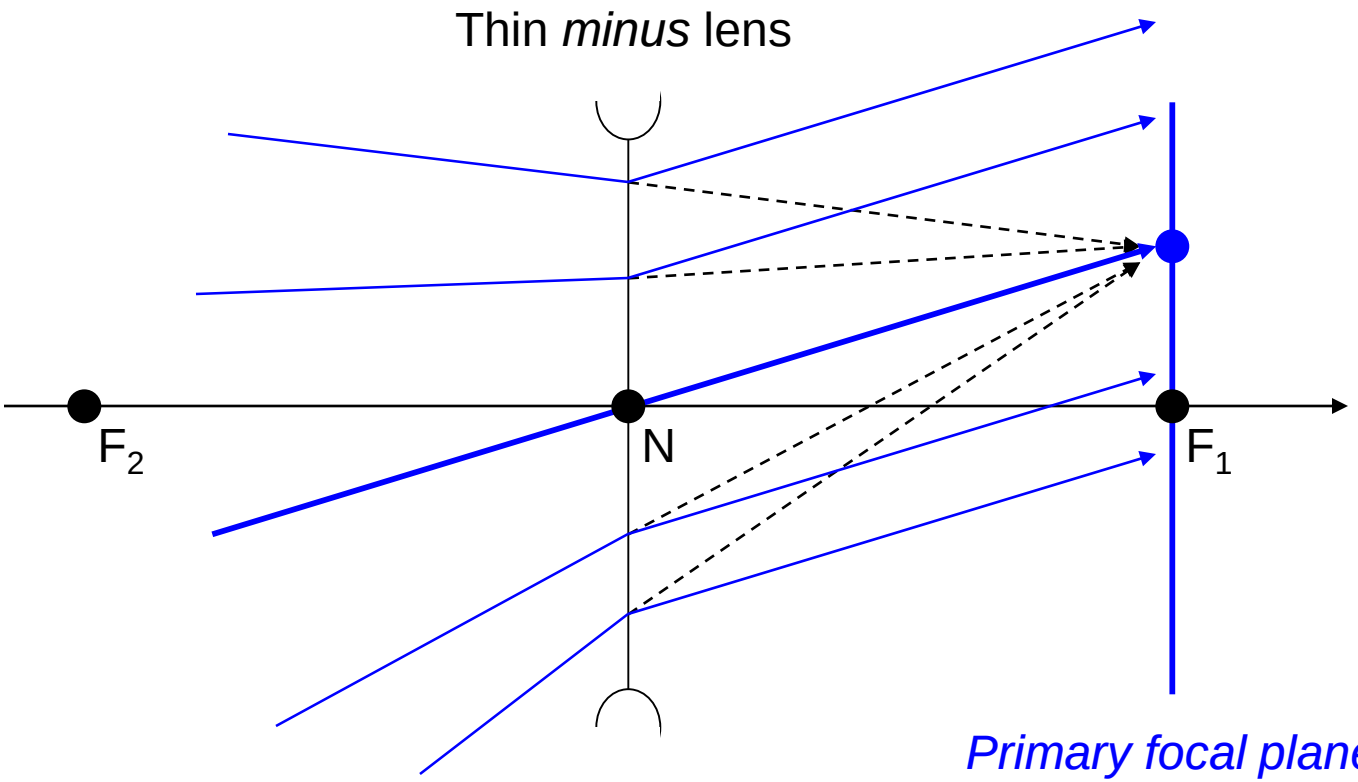
Rays associated with the *primary focal point* exit the lens parallel to the lens axis…

Points and Planes



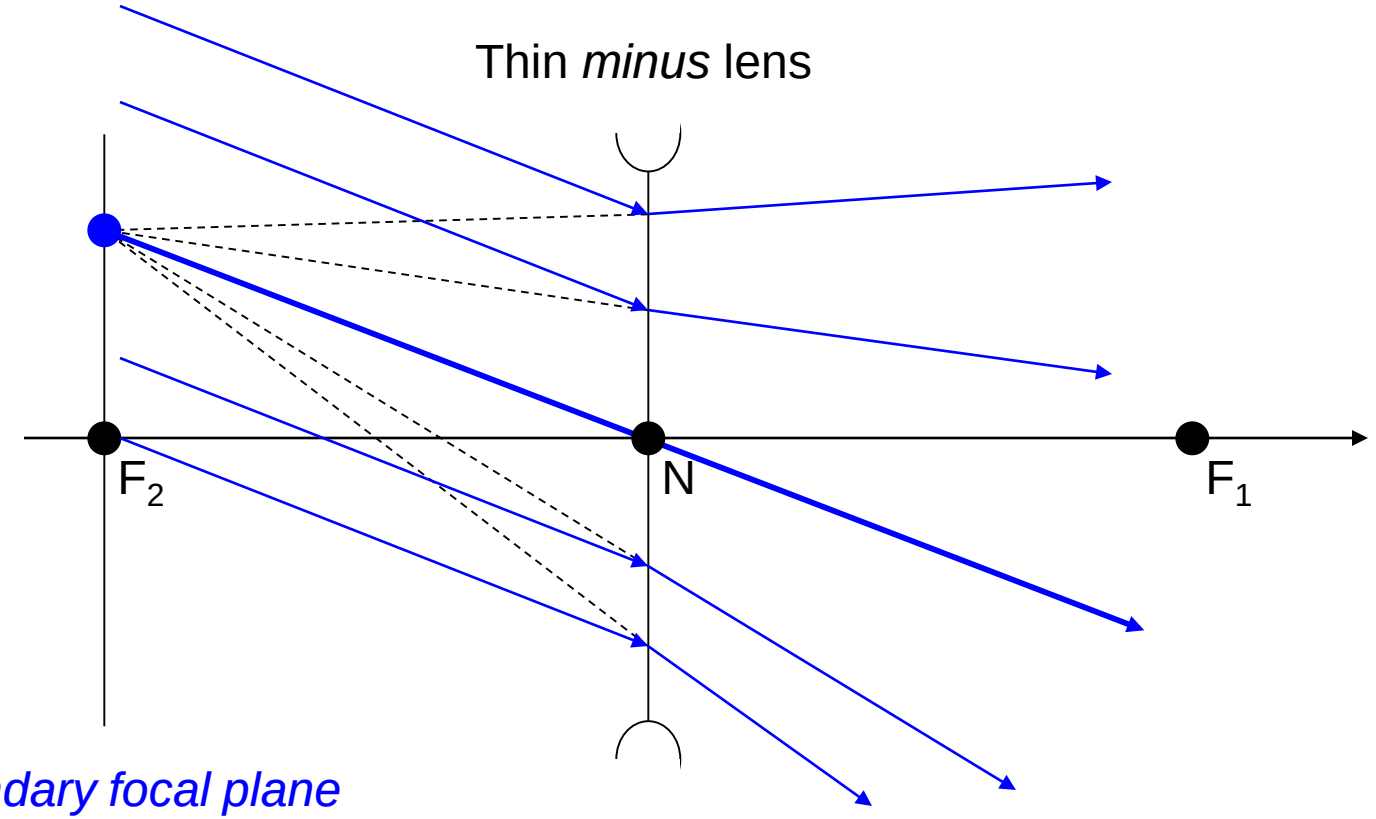
…and rays associated with the *secondary focal point* are those that enter the lens with zero vergence (i.e., parallel to the lens axis).

Points and Planes



Primary focal ***plane***: Rays associated with a point on this plane exit the lens parallel to one another (but ***not*** necessarily parallel to the lens axis)

Points and Planes



Secondary focal ***plane***: The 'home location' of all images formed by parallel rays hitting the lens