Transverse Magnification

Basic Optics, Chapter 20

Transverse Magnification

- Let’s talk about transverse magnification
  - Also known as *lateral* or *linear* magnification
- Transverse mag concerns the relative height of objects and images in our ray tracings

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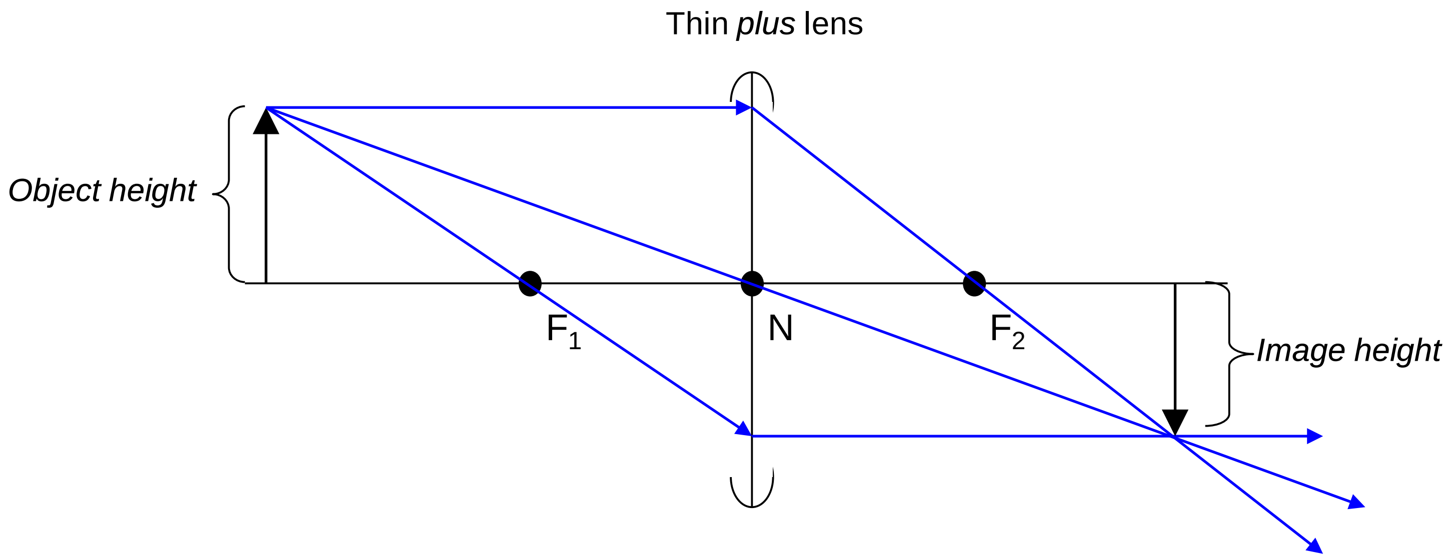
  - Also known as *lateral* or *linear* magnification
- Transverse mag concerns the relative height of objects and images in our ray tracings
- In principle, with careful tracing, one could simply measure the image and object and determine the ratio directly
  - Fortunately, there are less tedious methods

Transverse Magnification

Transverse magnification is defined as:

$$\frac{\textit{Image height}}{\textit{Object height}}$$



Transverse Magnification

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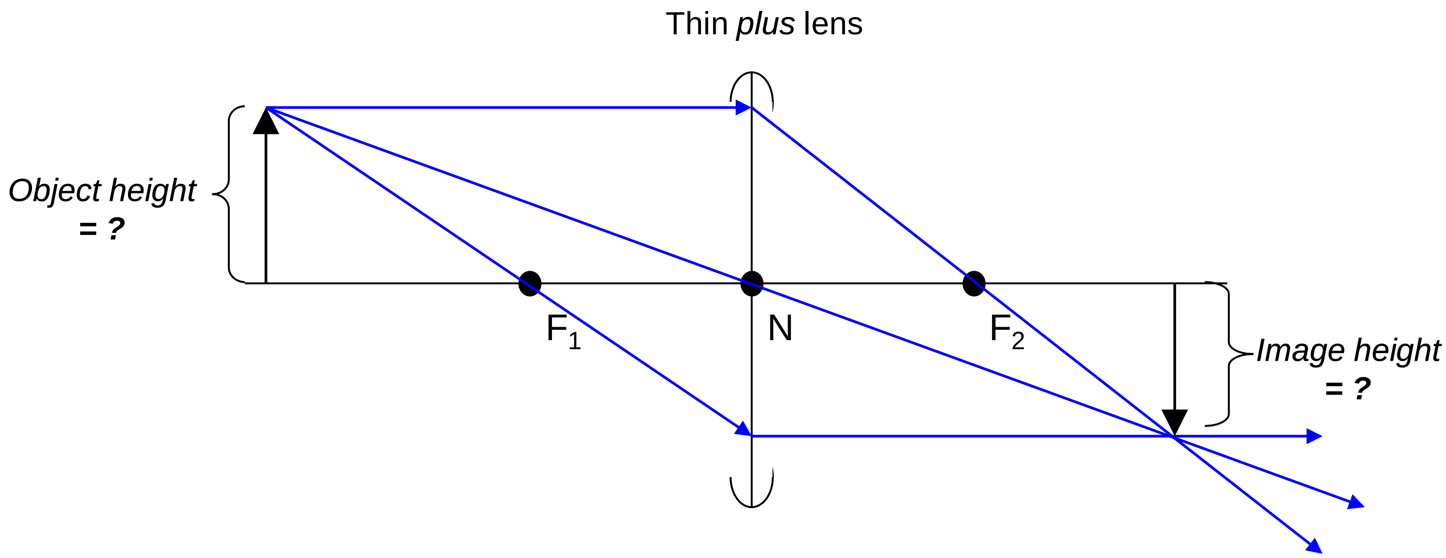
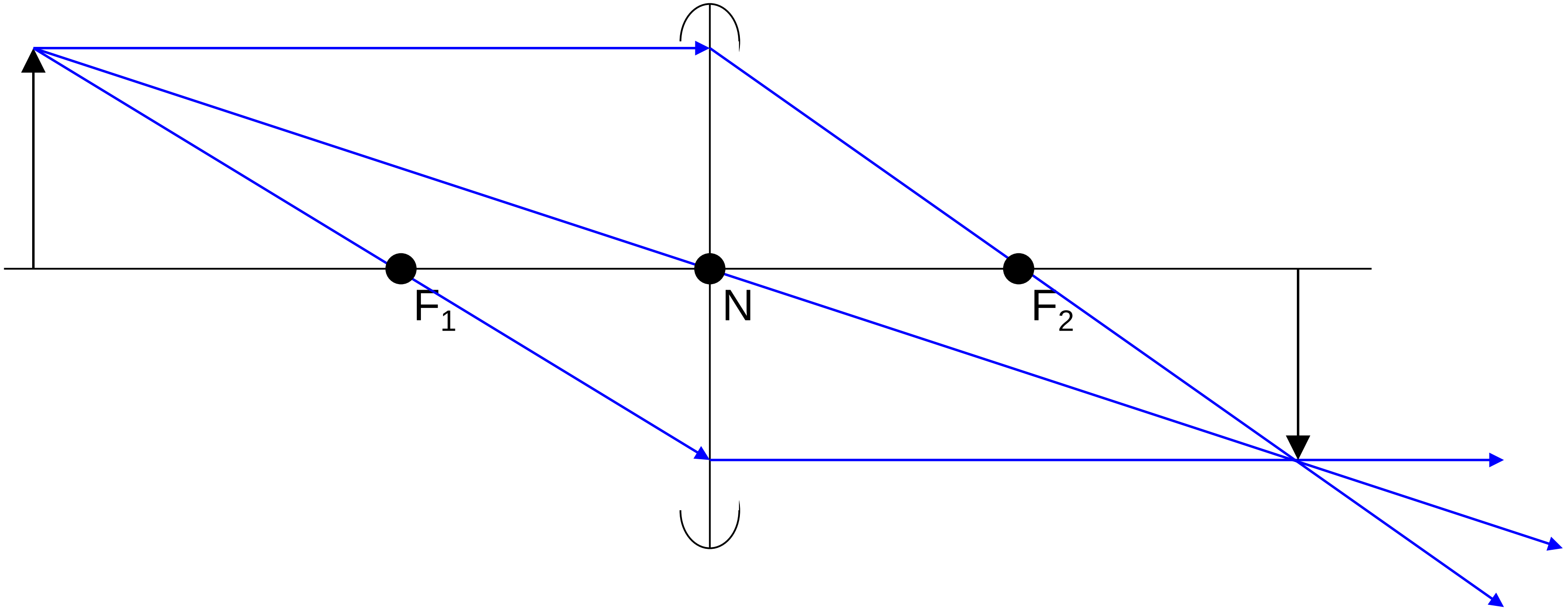
OK, but how do we determine object and image heights when all we have (usually) is info re vergence?



Transverse Magnification

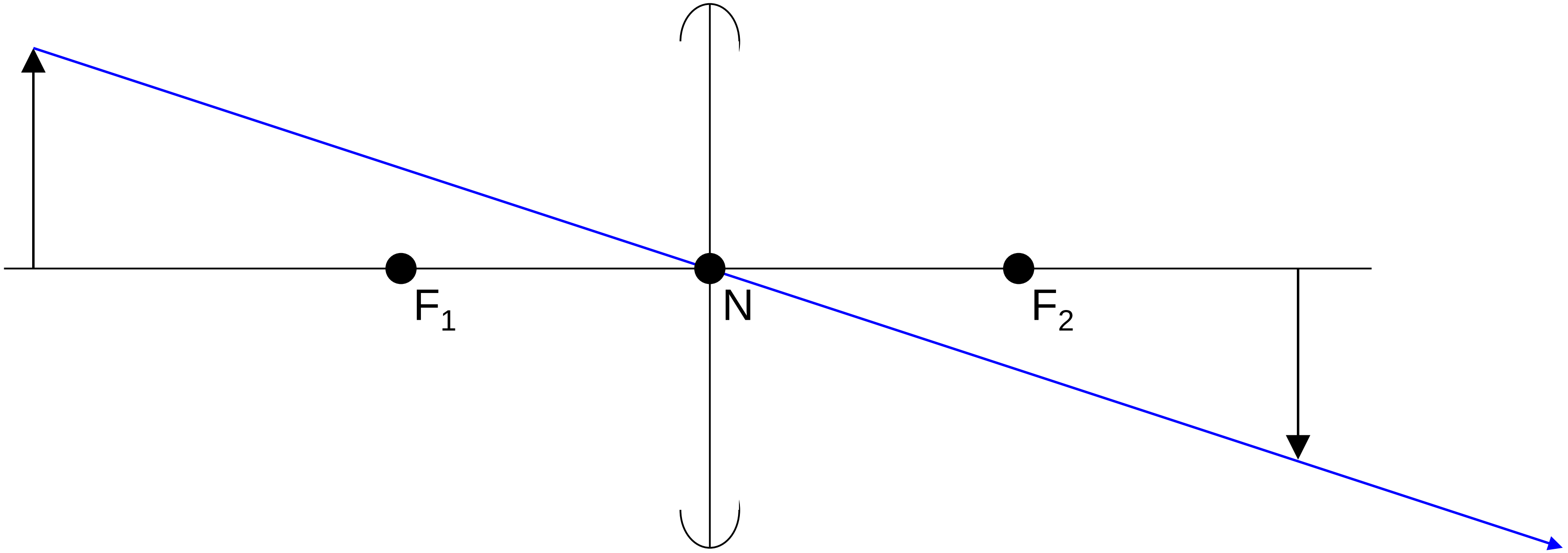
Thin *plus* lens



Here is a ray tracing from a previous chapter.

Transverse Magnification

Thin *plus* lens



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Here it is with only the nodal ray and lens axis ray drawn.

Transverse Magnification

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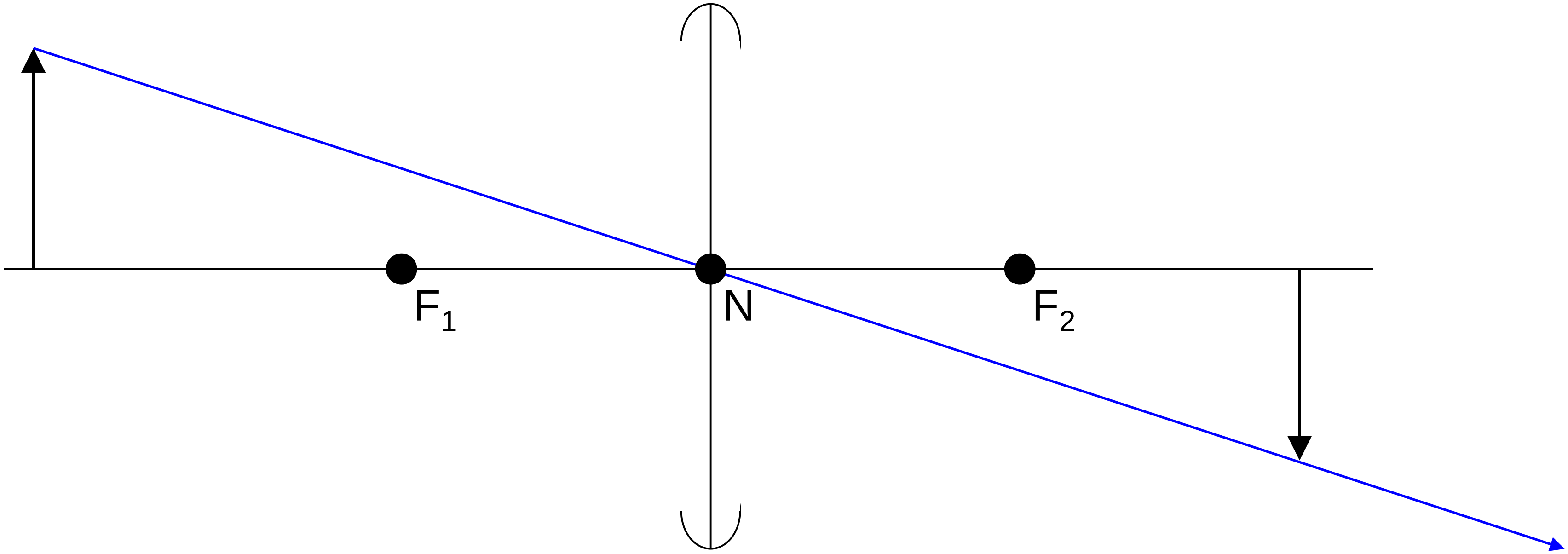
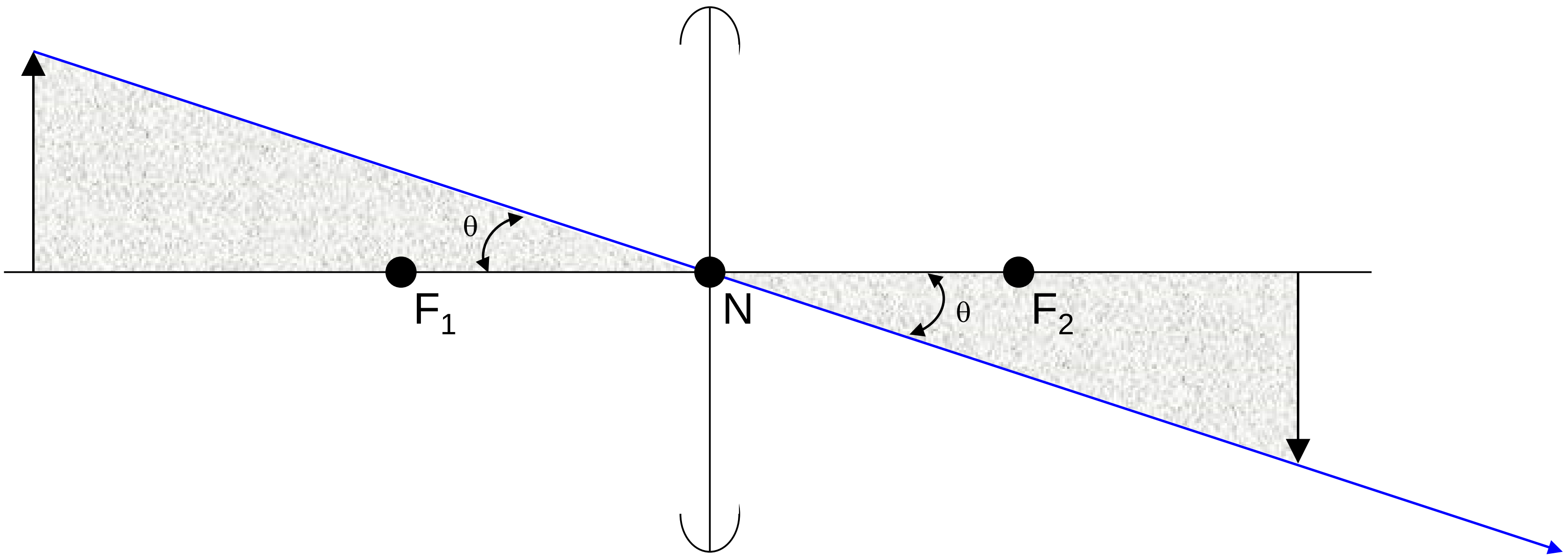


Here is a ray tracing from a previous chapter.
Here it is with only the nodal ray and lens axis ray drawn.
Think back to high-school geometry—what does the figure look like?

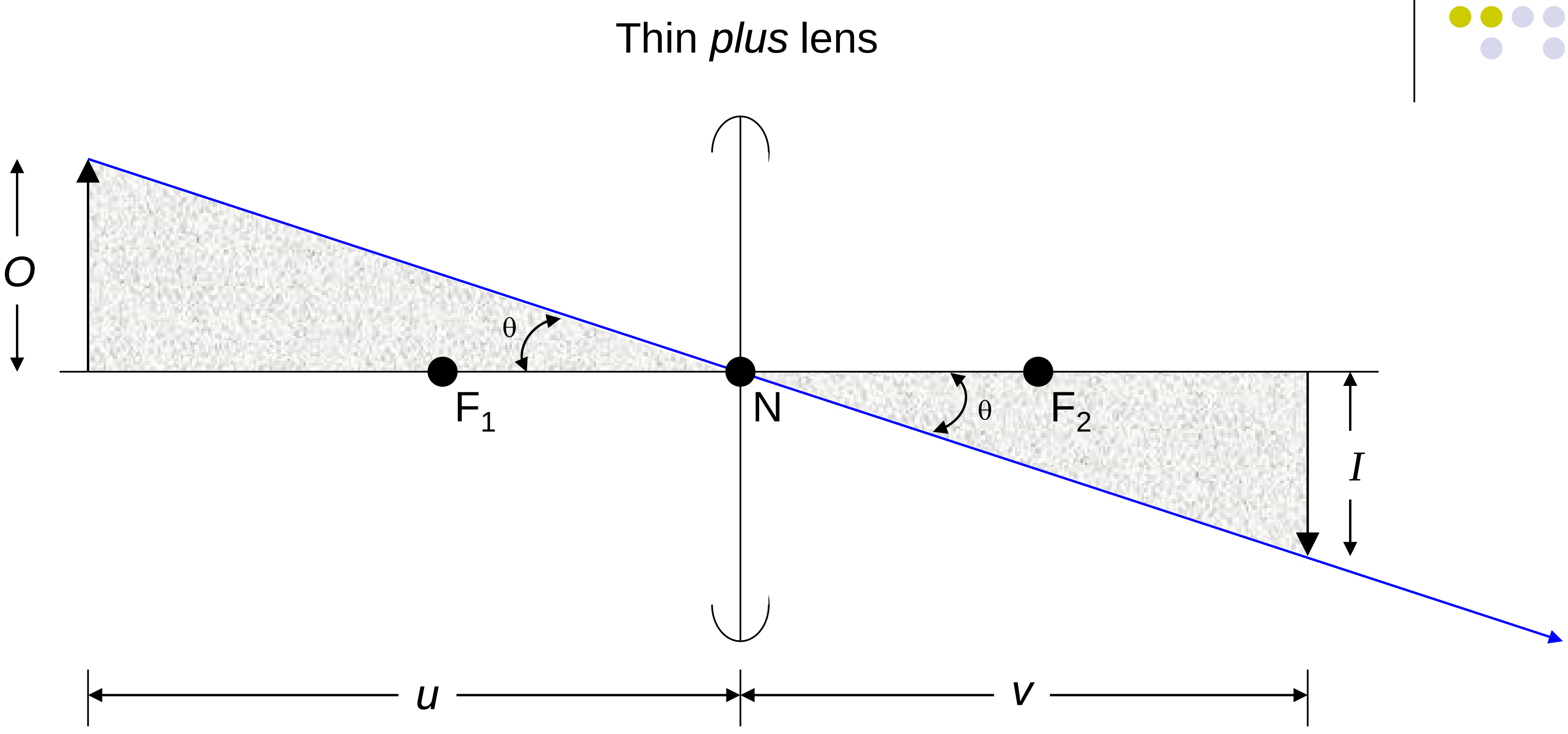
Transverse Magnification

Thin *plus* lens

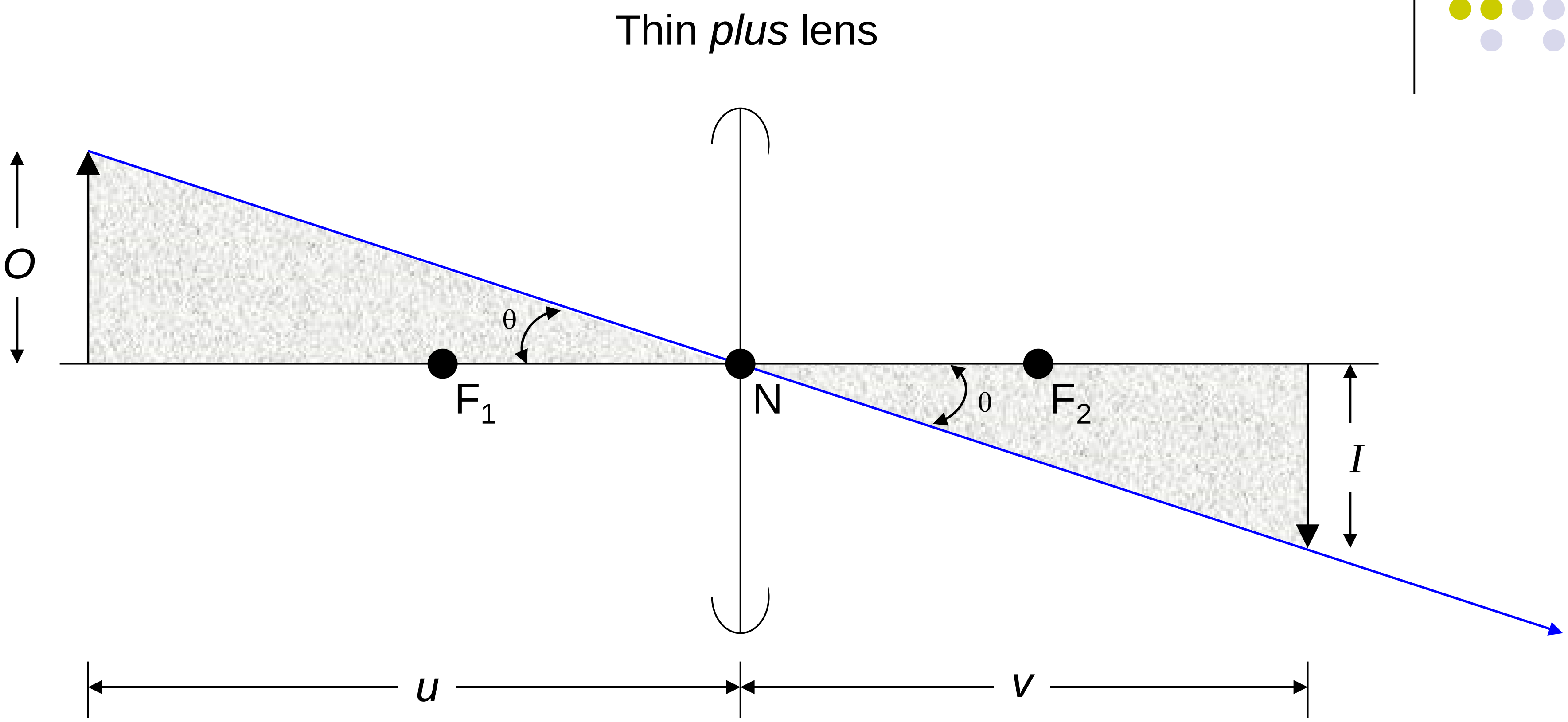


Similar triangles

Transverse Magnification

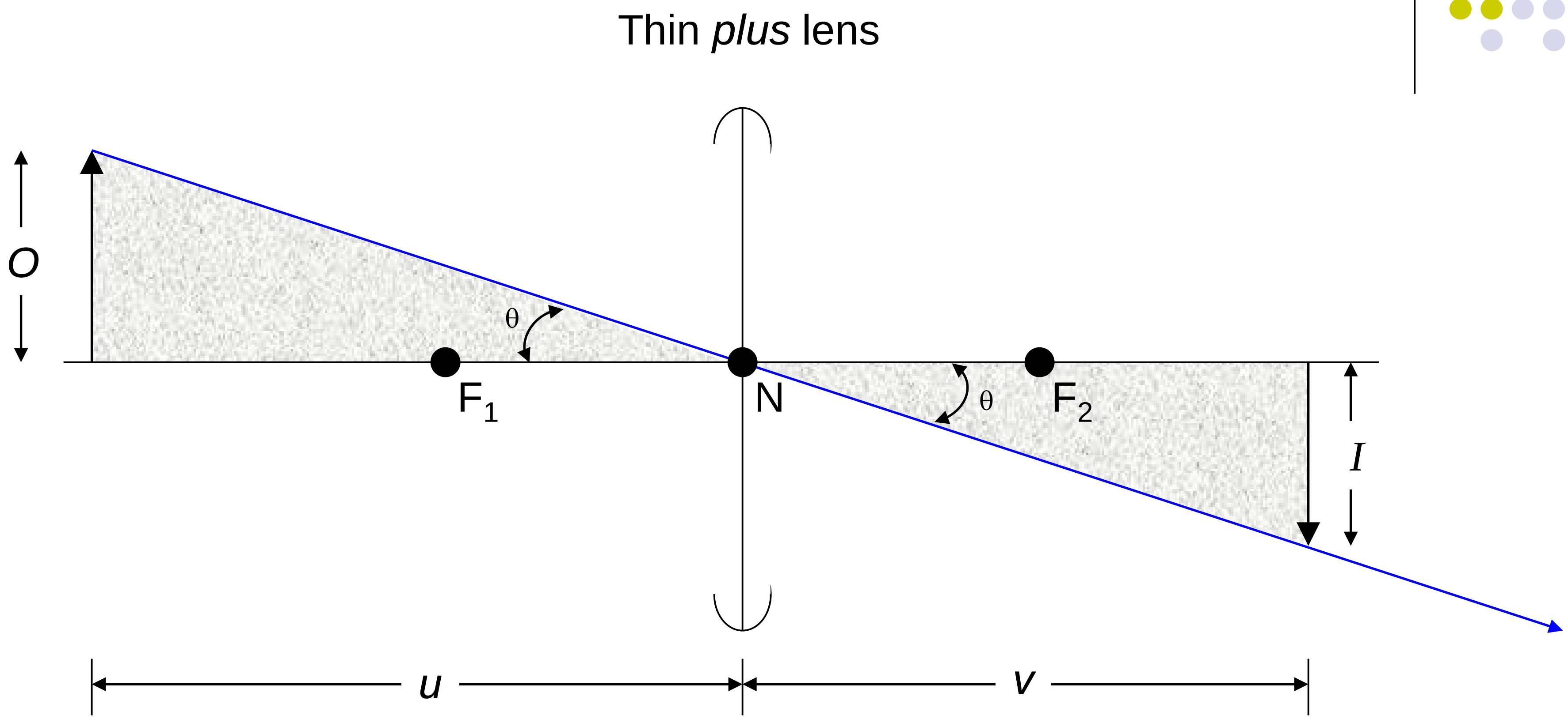


Transverse Magnification



Transverse magnification = *I*/*O* (by definition)

Transverse Magnification

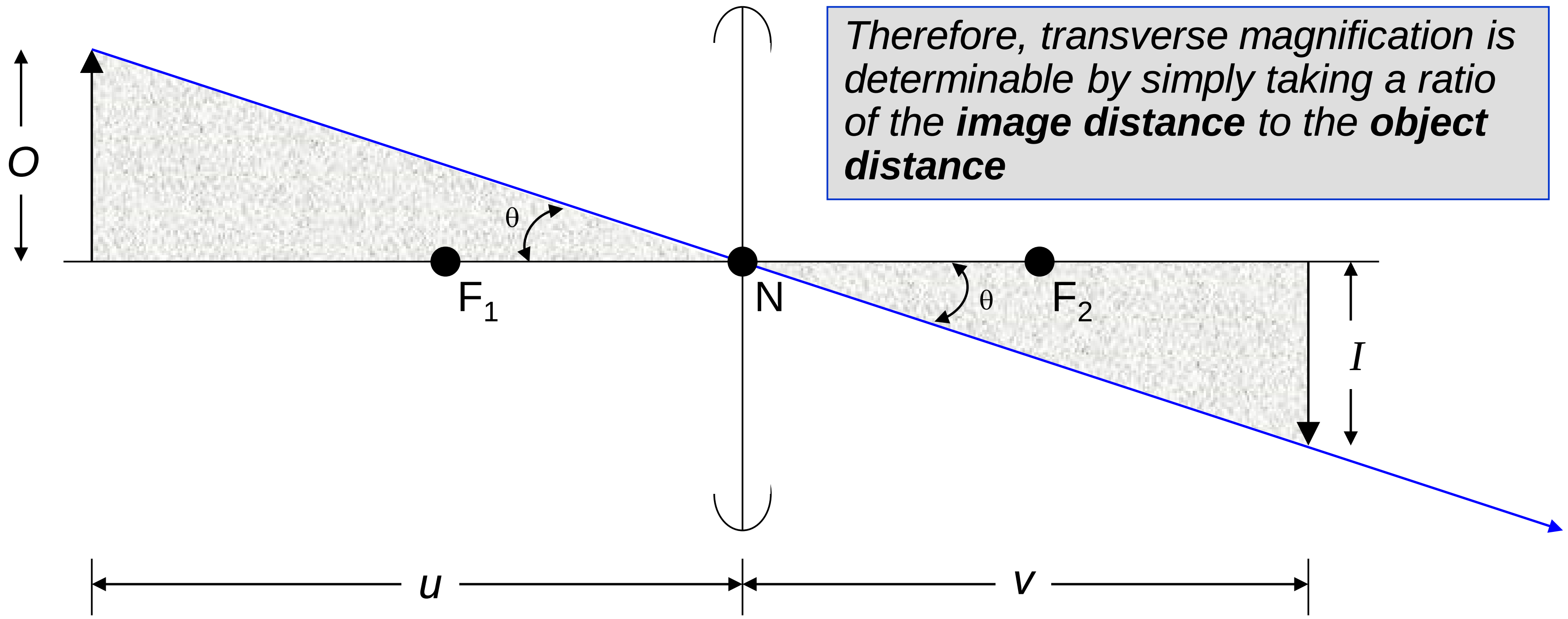


Transverse magnification = *I/O* (by definition)
By similar triangles: *I/O* = *v/u*

Transverse Magnification

Thin *plus* lens

*Therefore, transverse magnification is determinable by simply taking a ratio of the **image distance** to the **object distance***



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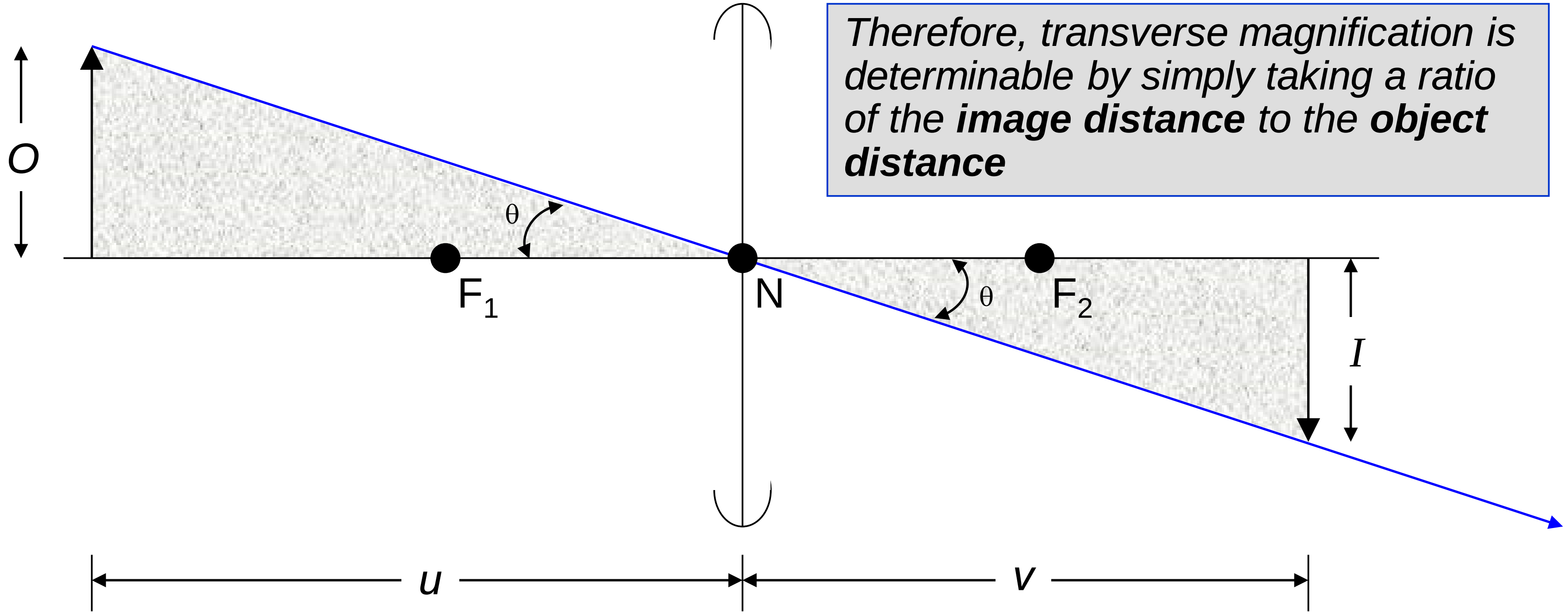
By similar triangles: $I/O = v/u$

Transverse Magnification

Thin *plus* lens



Therefore, transverse magnification is determinable by simply taking a ratio of the ***image distance*** *to the* ***object distance***

Transverse magnification = *I/O* (by definition)
By similar triangles: *I/O* = *v/u*

But we can make it more convenient still…

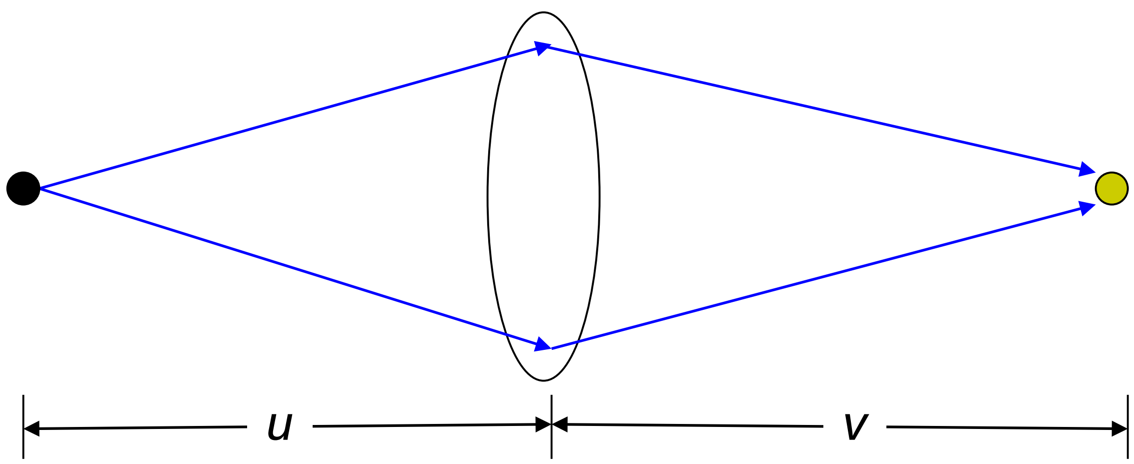
Transverse Magnification

- The Vergence Formula

Recall the ***Vergence Formula***…

Vergence of incoming light — *Vergence contributed by the lens* — *Vergence of light leaving lens*

$$U + P = V$$



***u* = 1/U**

***v* = 1/V**

Transverse Magnification

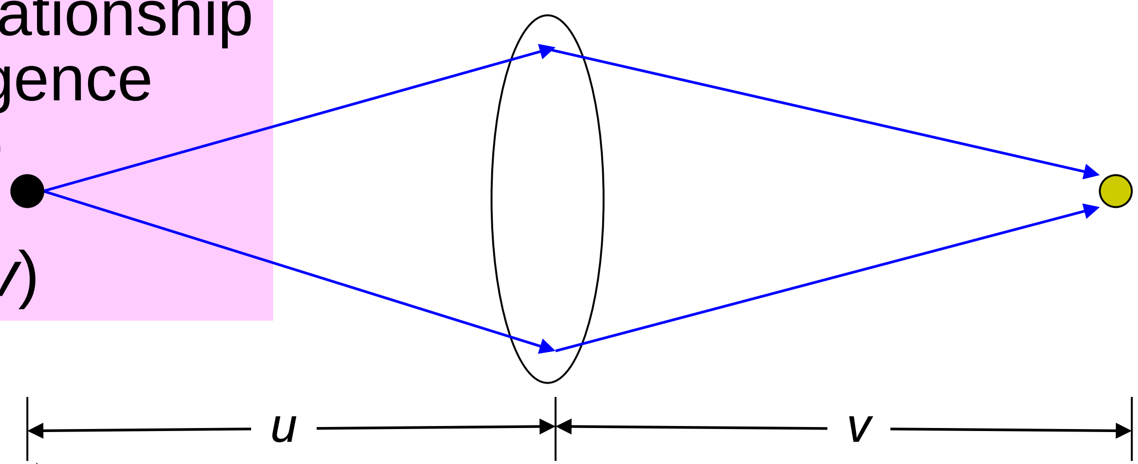
- The Vergence Formula

Recall the ***Vergence Formula***…

Vergence of incoming light | *Vergence contributed by the lens* | *Vergence of light leaving lens*

$$U + P = V$$

…and the relationship between vergence (big **U**, big **V**) and distance (little *u*, little *v*)



***u* = 1/U**

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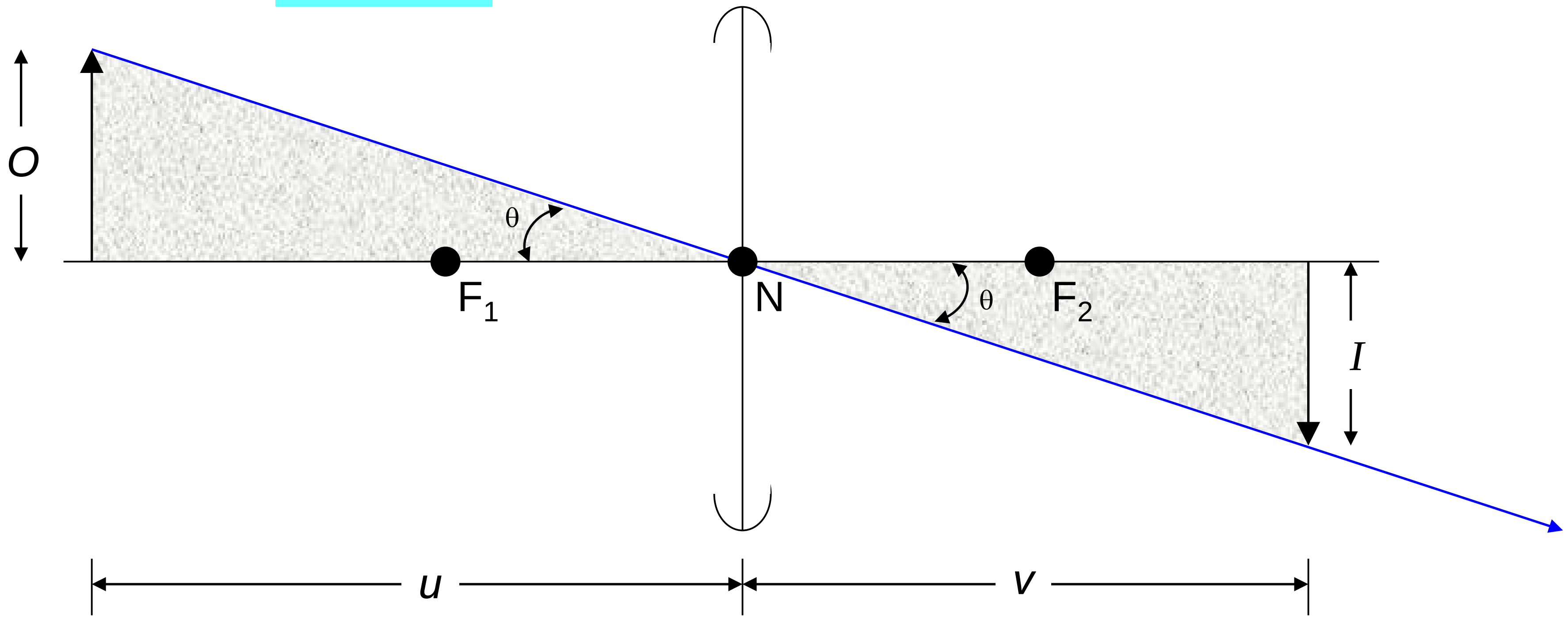
Transverse Magnification

U+P=V



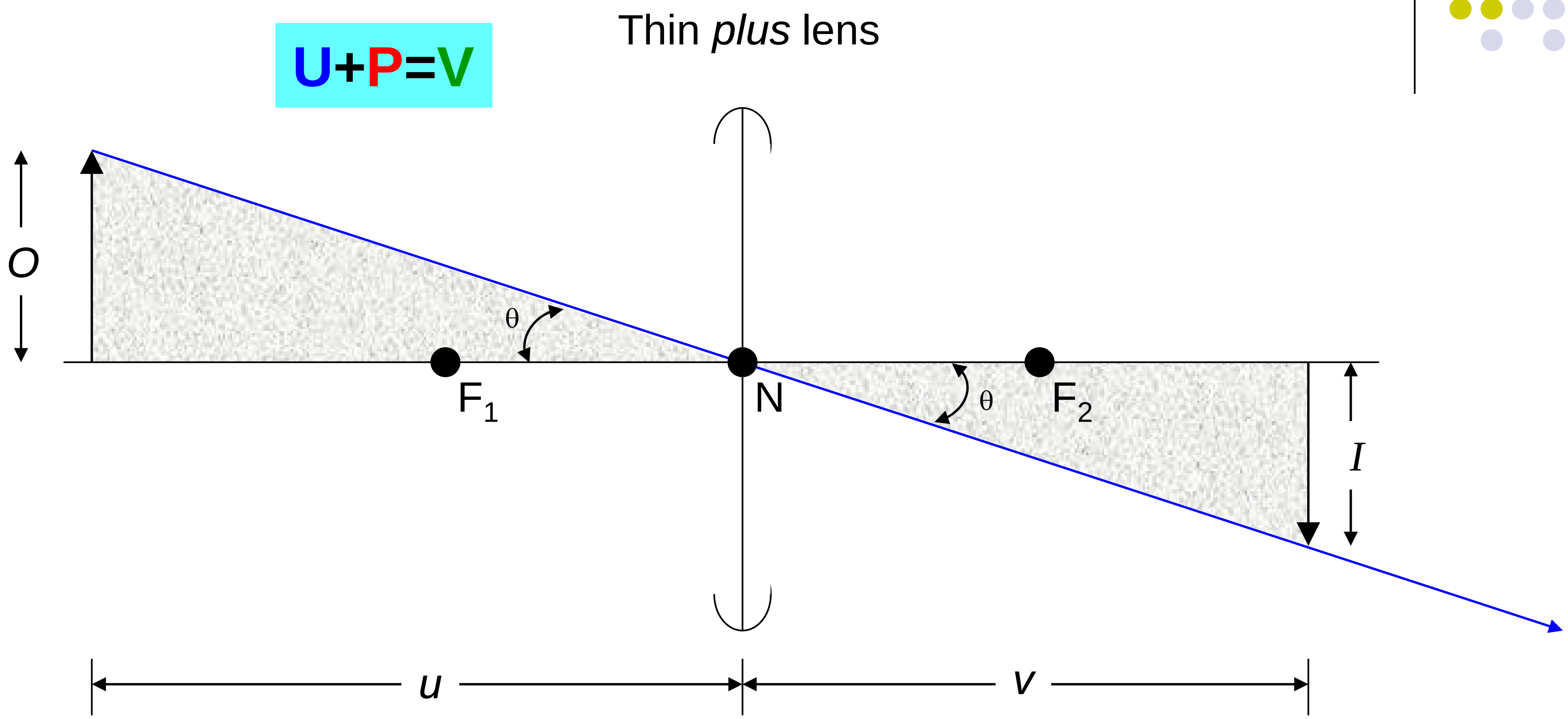
SO, **transverse magnification = *I/O*** (by definition)
AND, by similar triangles, ***I/O* = *v/u***
AND, by the Vergence Formula, ***v/u*** $= \frac{1/V}{1/U} = \frac{U}{V}$

***u* = 1/U**

***v* = 1/V**

Transverse Magnification

U+P=V



SO, **transverse magnification = *I/O*** (by definition)
AND, by similar triangles, ***I/O* = *v/u***
AND, by the Vergence Formula, ***v/u*** $= \frac{1/V}{1/U} = \frac{U}{V}$

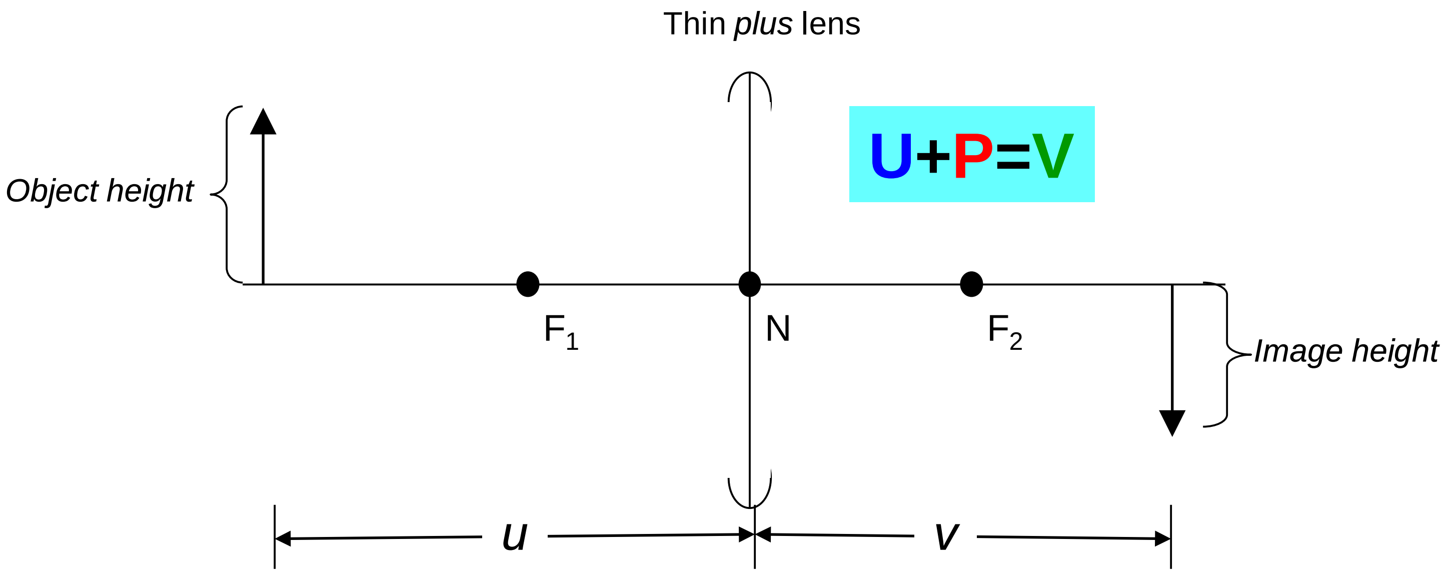
THEREFORE, **I/O = U/V**

***u* = 1/U**

***v* = 1/V**

Transverse Magnification

So, in summary:



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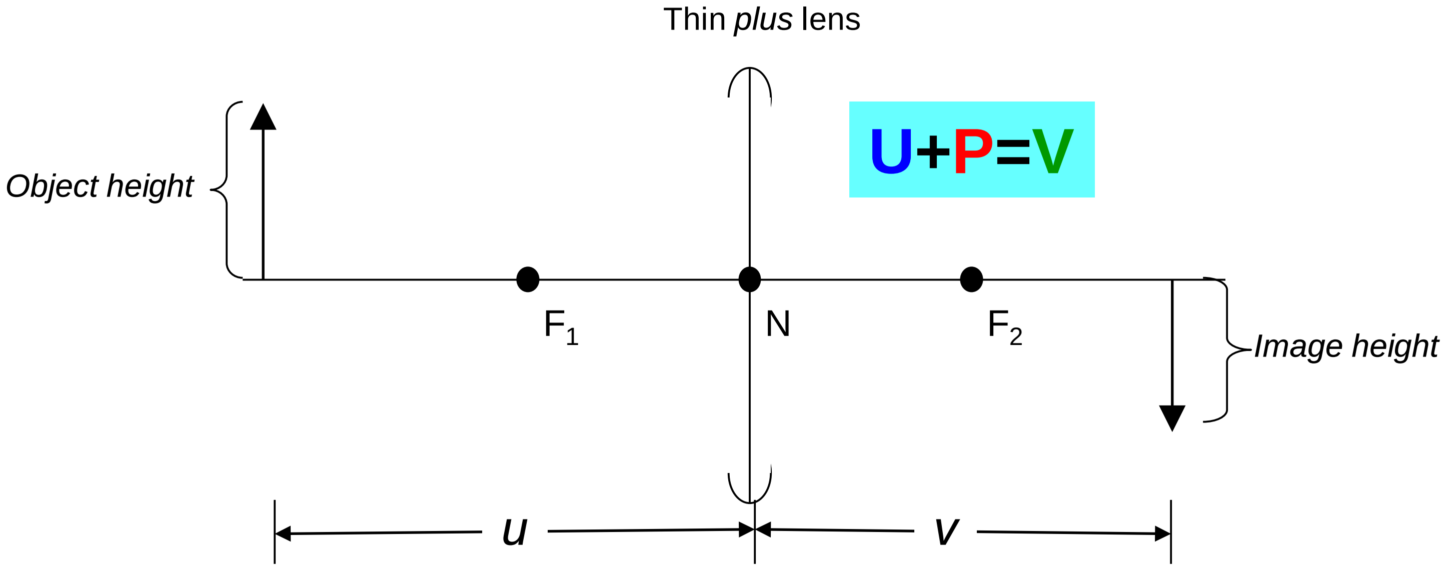
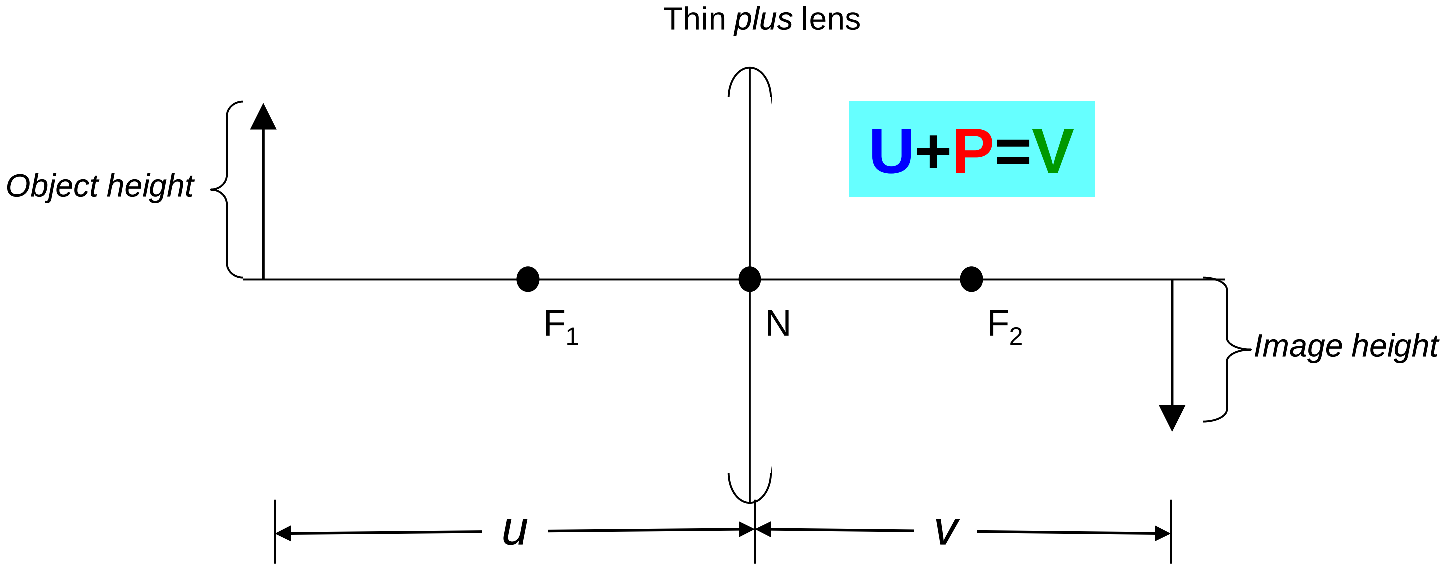
Transverse magnification is defined as: $\frac{\textit{Image height}}{\textit{Object height}}$



Transverse Magnification

Transverse magnification is defined as: *Image height* / *Object height*

Transverse magnification is equal to:



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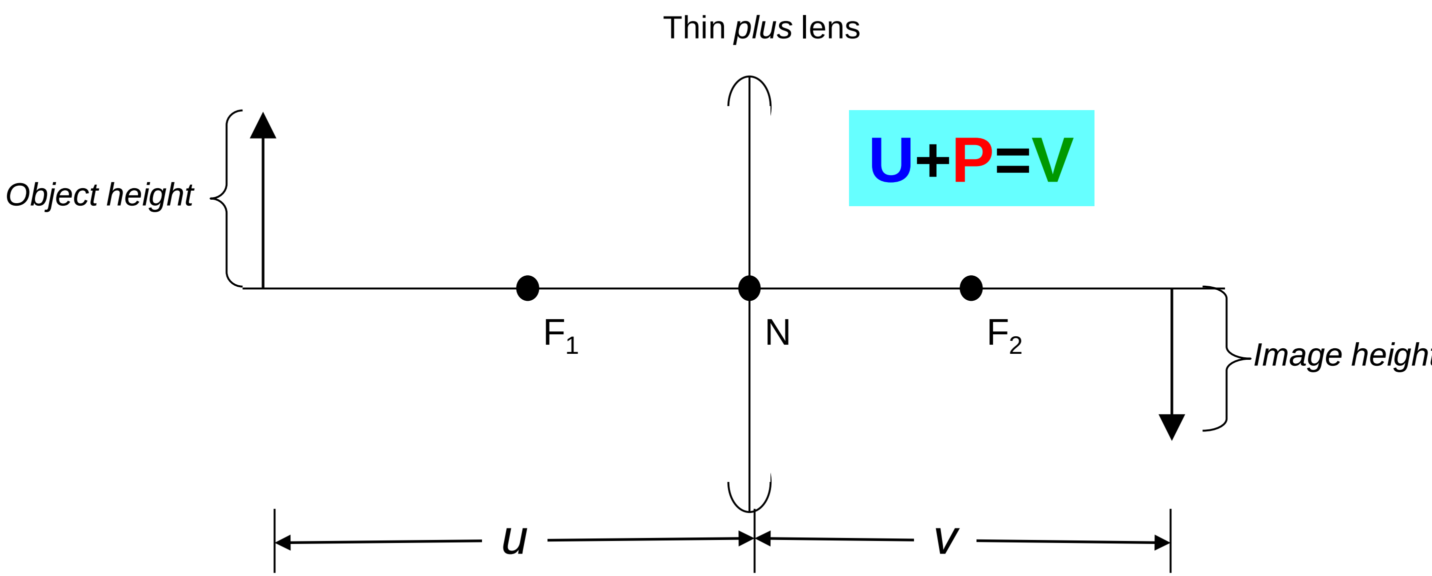
Transverse magnification is equal to:

(By similar triangles)

$\dfrac{\textit{Image distance (v)}}{\textit{Object distance (u)}}$



Transverse Magnification

Transverse magnification is defined as:

$$\frac{\textit{Image height}}{\textit{Object height}}$$

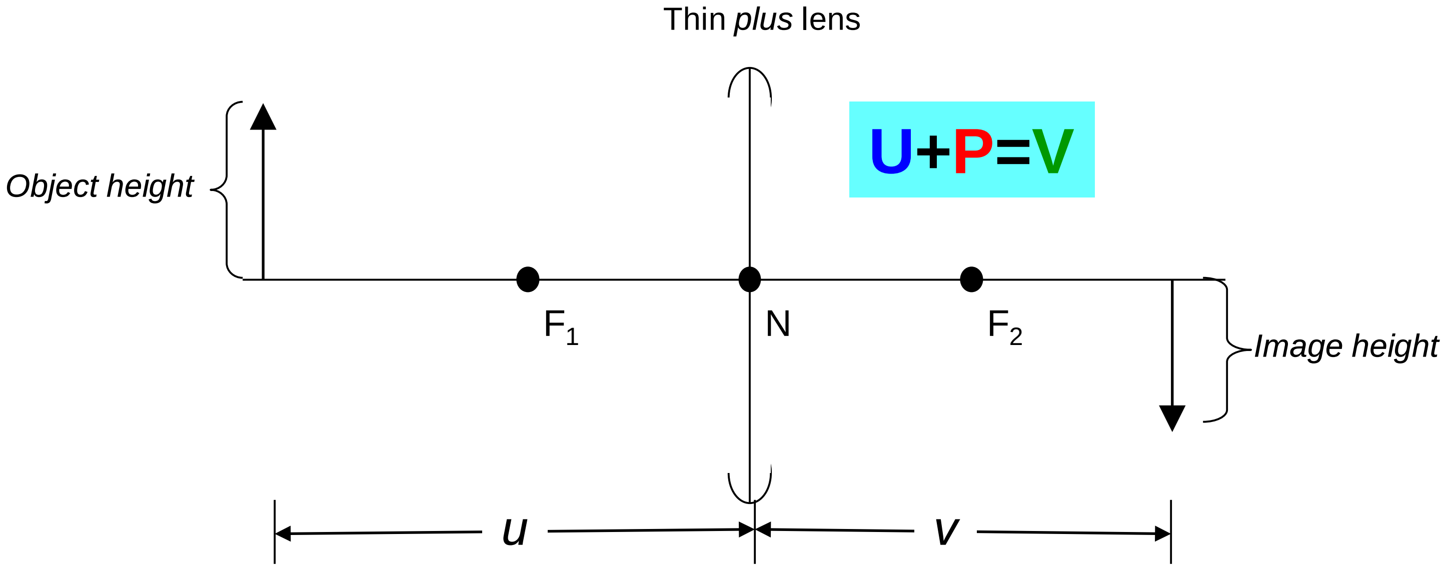
Transverse magnification is equal to:

(By the Vergence Law)

$$\frac{\textit{Vergence of incoming light } (U)}{\textit{Vergence of light leaving lens } (V)}$$

(By similar triangles)

$$\frac{\textit{Image distance } (v)}{\textit{Object distance } (u)}$$



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A few final points about transverse magnification:

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--The ***sign*** of the value indicates the relative orientations of object and image

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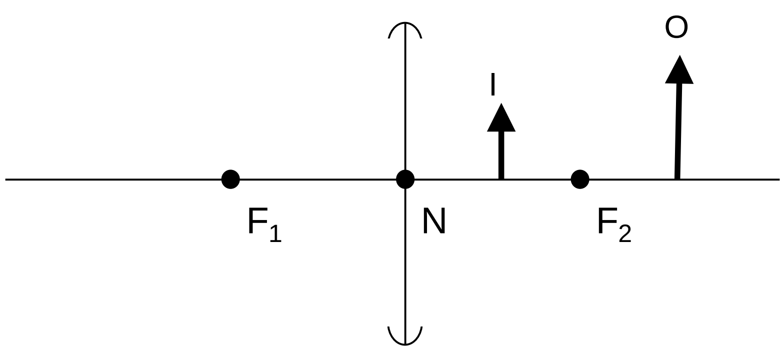
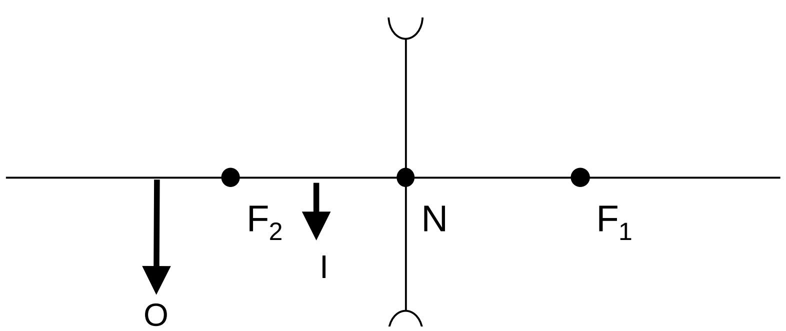
--The ***sign*** of the value indicates the relative orientations of object and image

--A ***positive*** value indicates the image has the same orientation as the object (i.e., both are either *above* or *below* the lens axis)





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A few final points about transverse magnification:

--The ***sign*** of the value indicates the relative orientations of object and image

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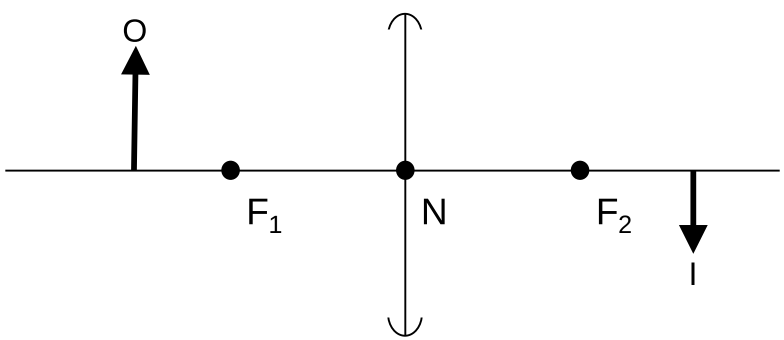
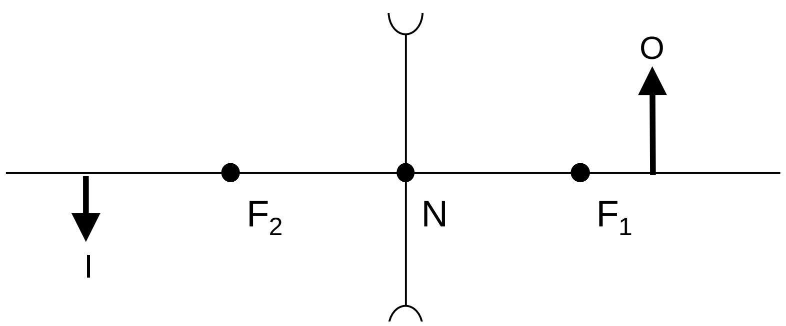
--A ***negative*** value indicates they are on **opposite** sides of the lens axis





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--The ***size*** of the value indicates the relative size of object and image

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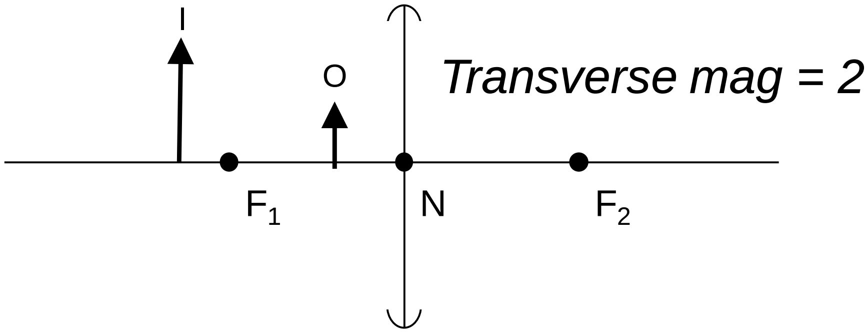
--The ***size*** of the value indicates the relative size of object and image

--Transverse mag > 1 →Image is ***larger*** than the object



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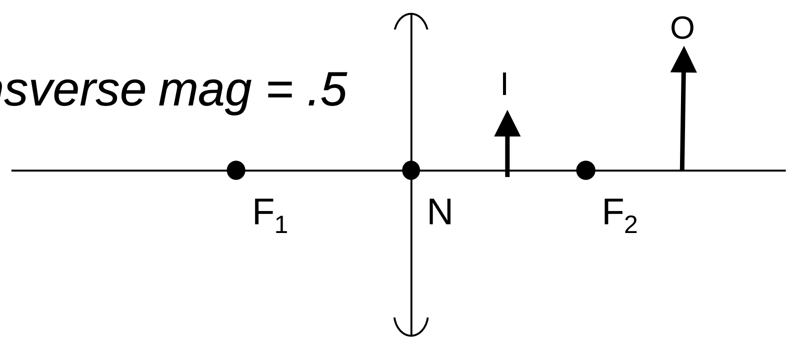
- --Transverse mag > 1 →Image is ***larger*** than the object
- --Transverse mag < 1 →Image is ***smaller*** than the object

Transverse mag = .5



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A few final points about transverse magnification:

--The ***size*** of the value indicates the relative size of object and image

- --Transverse mag > 1 →Image is ***larger*** than the object
- --Transverse mag < 1 →Image is ***smaller*** than the object
- --Transverse mag = 1 →Image and object are the ***same size***