Axial Magnification

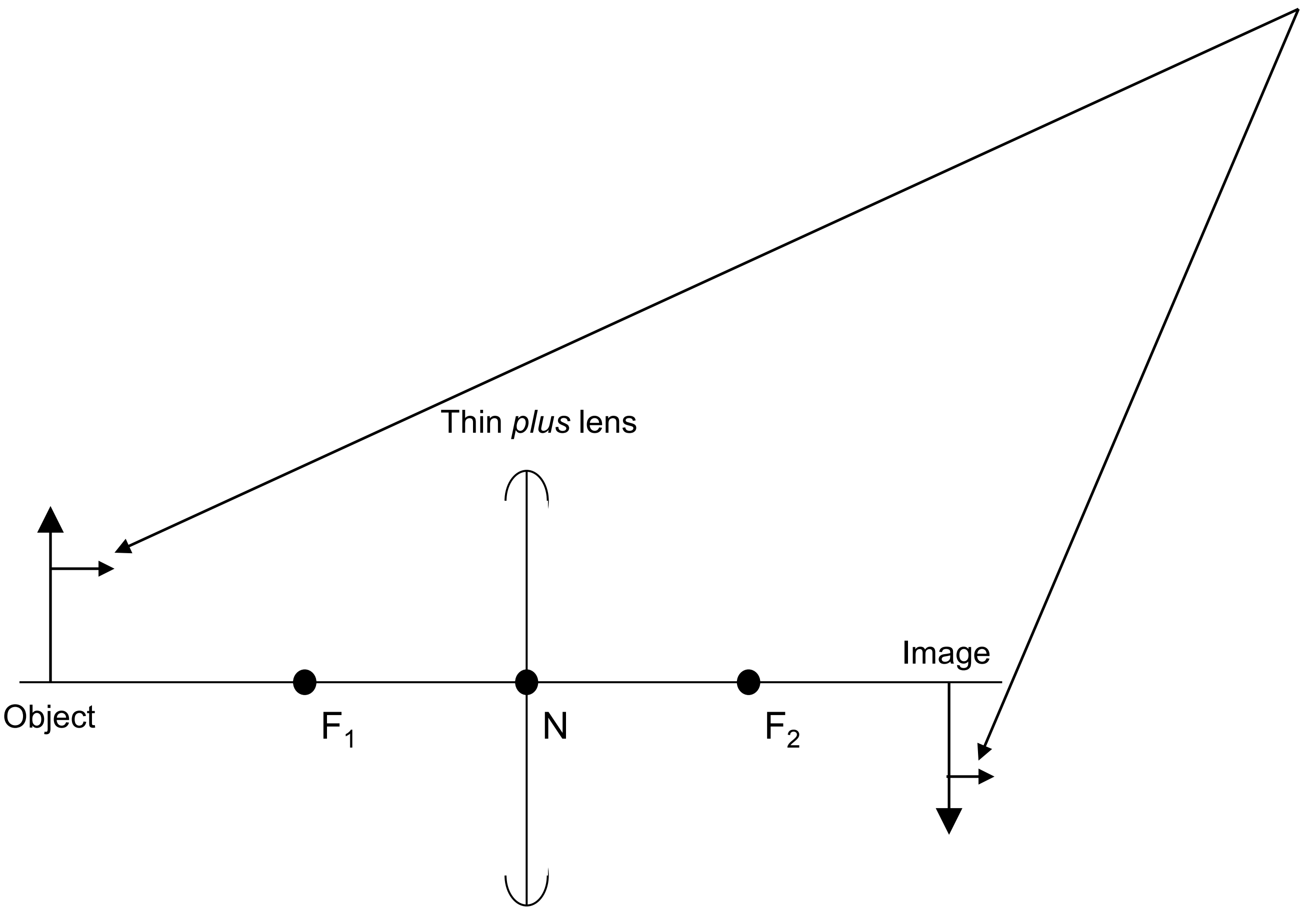
Basic Optics, Chapter 22

Axial Magnification

- We just saw that transverse mag concerns the relative heights/widths of an image and object
- But what about changes in their relative *depths*?
- This is the issue of *axial magnification*

Axial Magnification

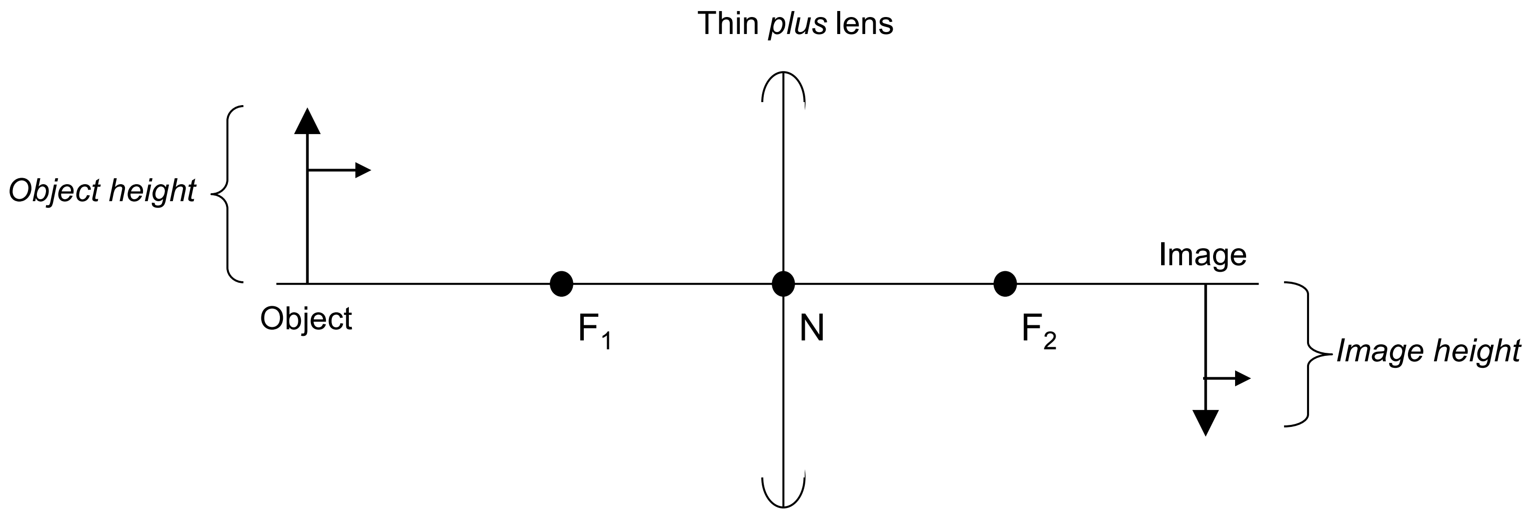
Note the addition of an **axial component** *to the object (and therefore image)*



Axial Magnification

You will recall that ***transverse*** mag is defined as:

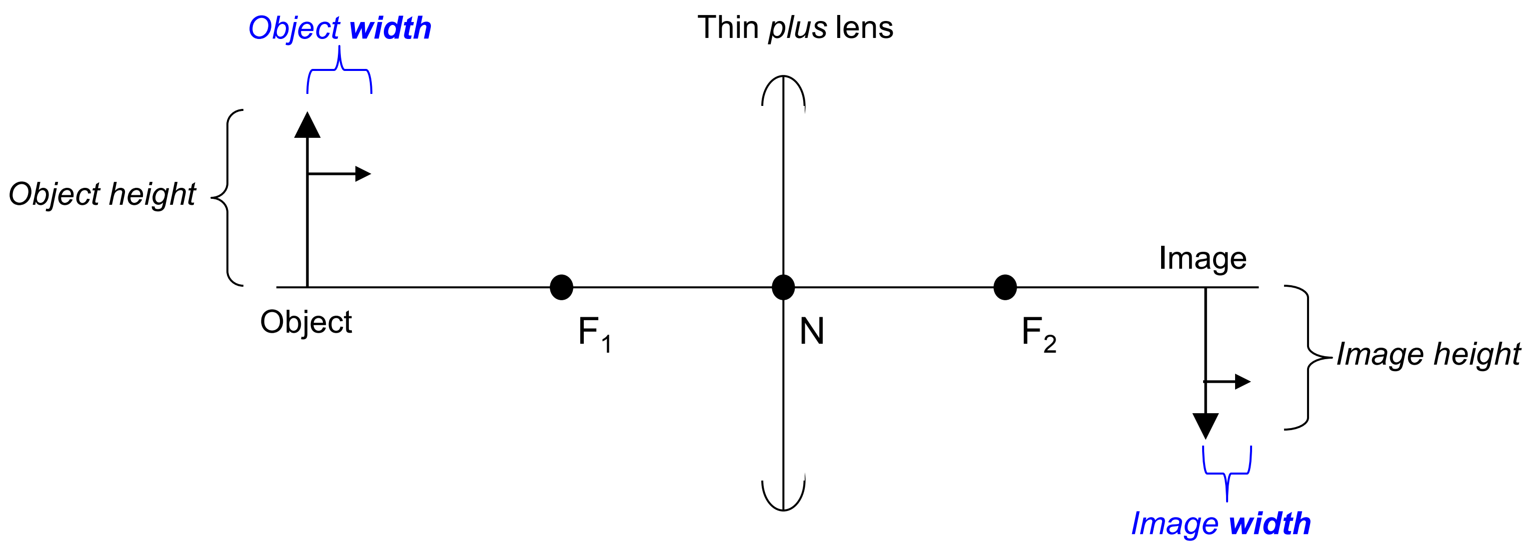
$$\frac{\textit{Image height}}{\textit{Object height}}$$



Axial Magnification

You will recall that ***transverse*** mag is defined as: $\dfrac{\textit{Image height}}{\textit{Object height}}$

Likewise, ***axial* magnification** is defined as: $\dfrac{\textit{Image width}}{\textit{Object width}}$



Axial Magnification

- Precisely determining axial mag is mathematically laborious

Axial Magnification

- Precisely determining axial mag is mathematically laborious
- Fortunately, it can be well-approximated as *the square of the transverse mag*

$$\textit{Axial mag} \approx (\textit{Transverse mag})^2$$

Axial Magnification

~~Transverse~~ Axial magnification is defined as: $\left(\frac{\text{Image height}}{\text{Object height}}\right)^2$

~~Transverse~~ Axial magnification is equal to:

(By the Vergence Law)

$\left(\frac{\text{Vergence of incoming light (U)}}{\text{Vergence of light leaving lens (V)}}\right)^2$

(By similar triangles)

$\left(\frac{\text{Image distance (v)}}{\text{Object distance (u)}}\right)^2$

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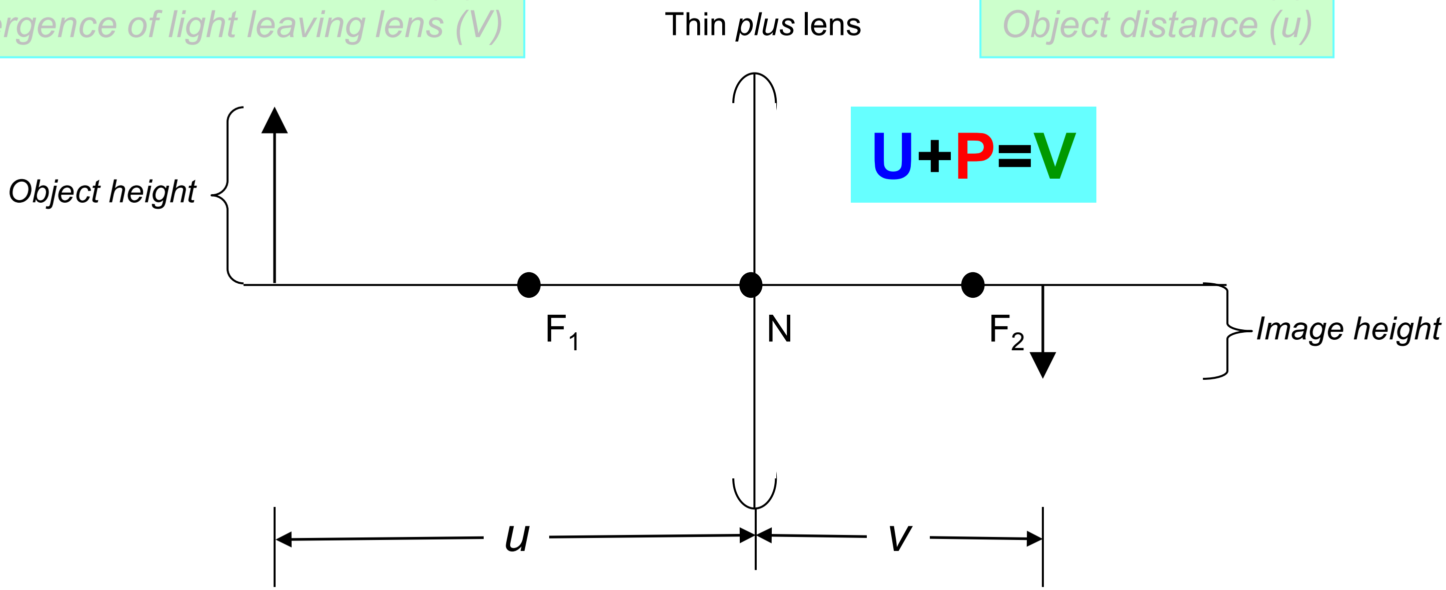

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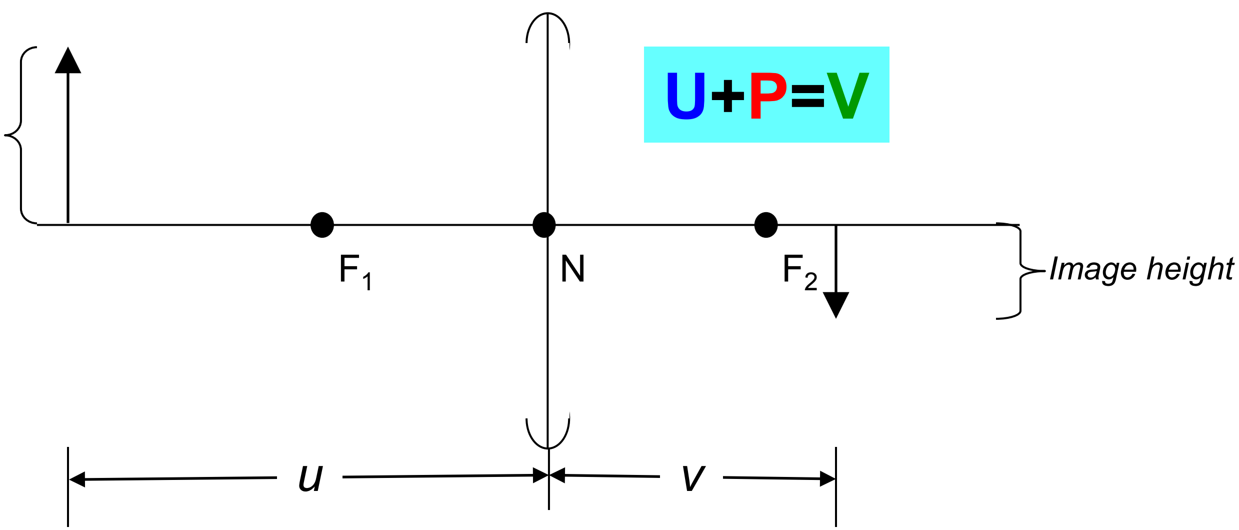
Thin *plus* lens

U+P=V



If u = -100cm, and
P = +3, then v = ?

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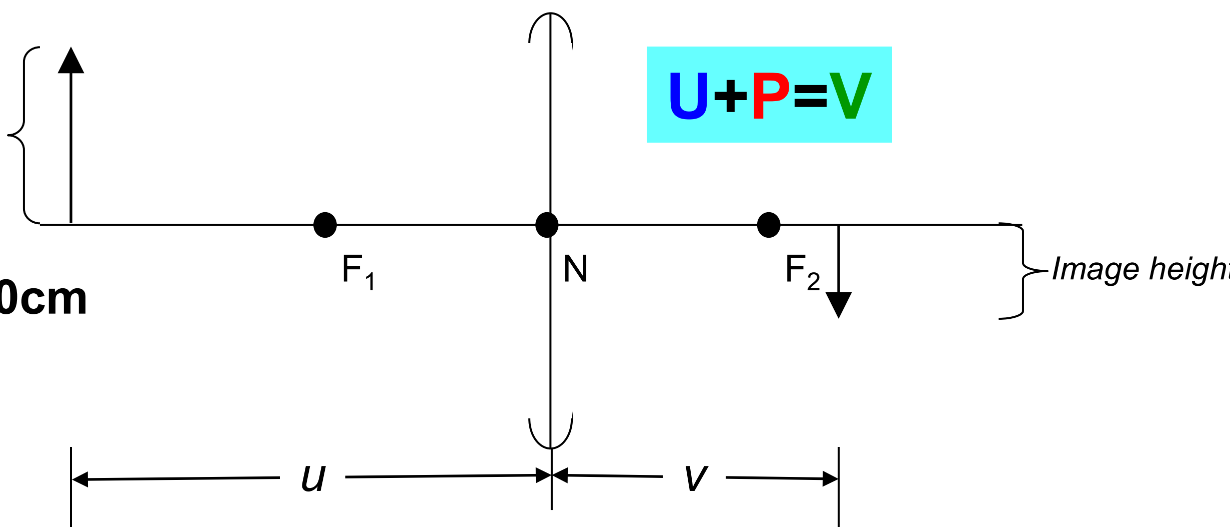

If u = -100cm, and
P = +3, then ***v* = 50cm**

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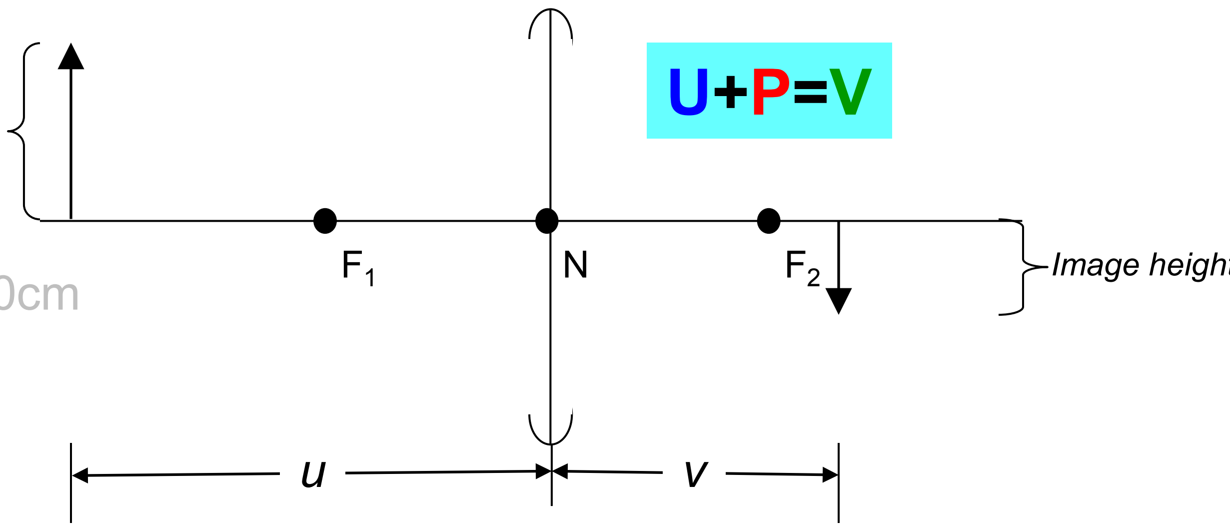

If *u* = -100cm, and **P** = +3, then *v* = 50cm

Transverse mag = *v/u* = 50/-100 = ?

Axial Magnification

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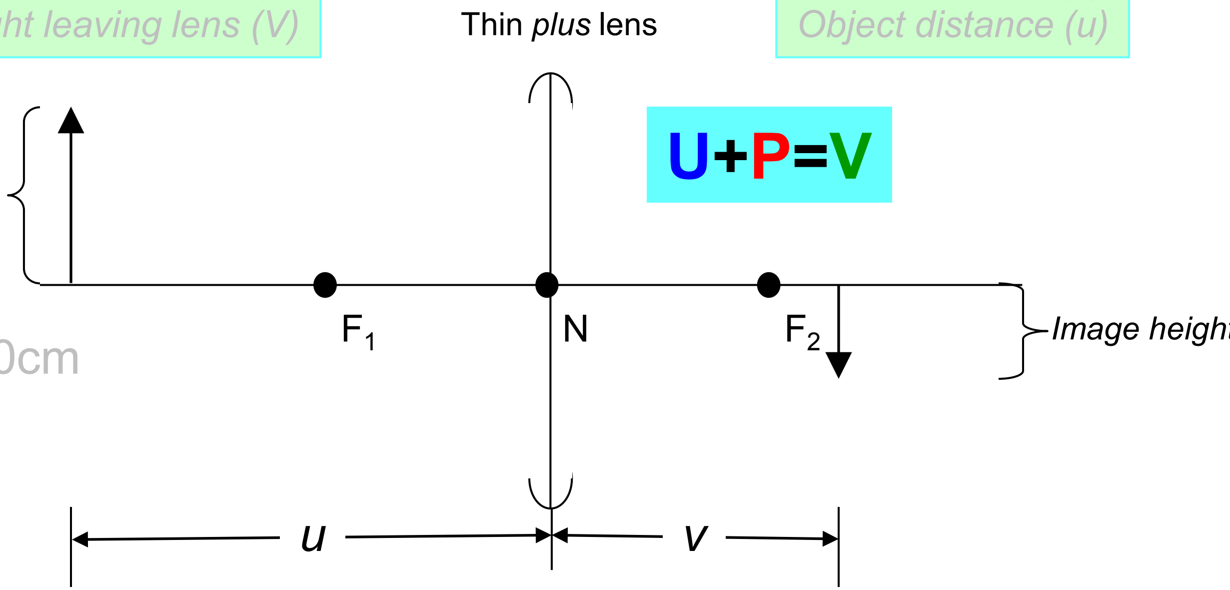

If *u* = -100cm, and **P** = +3, then *v* = 50cm

Transverse mag = *v/u* = 50/-100 = **-.5**

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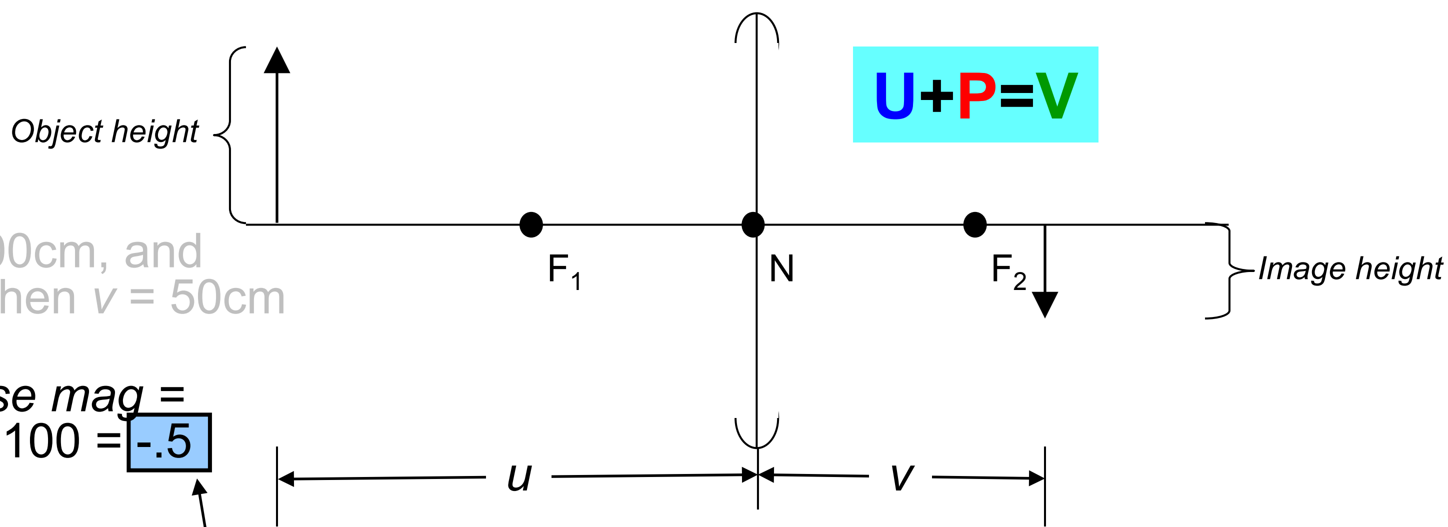
U+P=V



If *u* = -100cm, and
P = +3, then *v* = 50cm

Transverse mag =
v/*u* = 50/-100 = -.5

(The **.5** *tells us the image is ½ the size of the object; the* **minus sign** *indicates the image is* ***inverted)***

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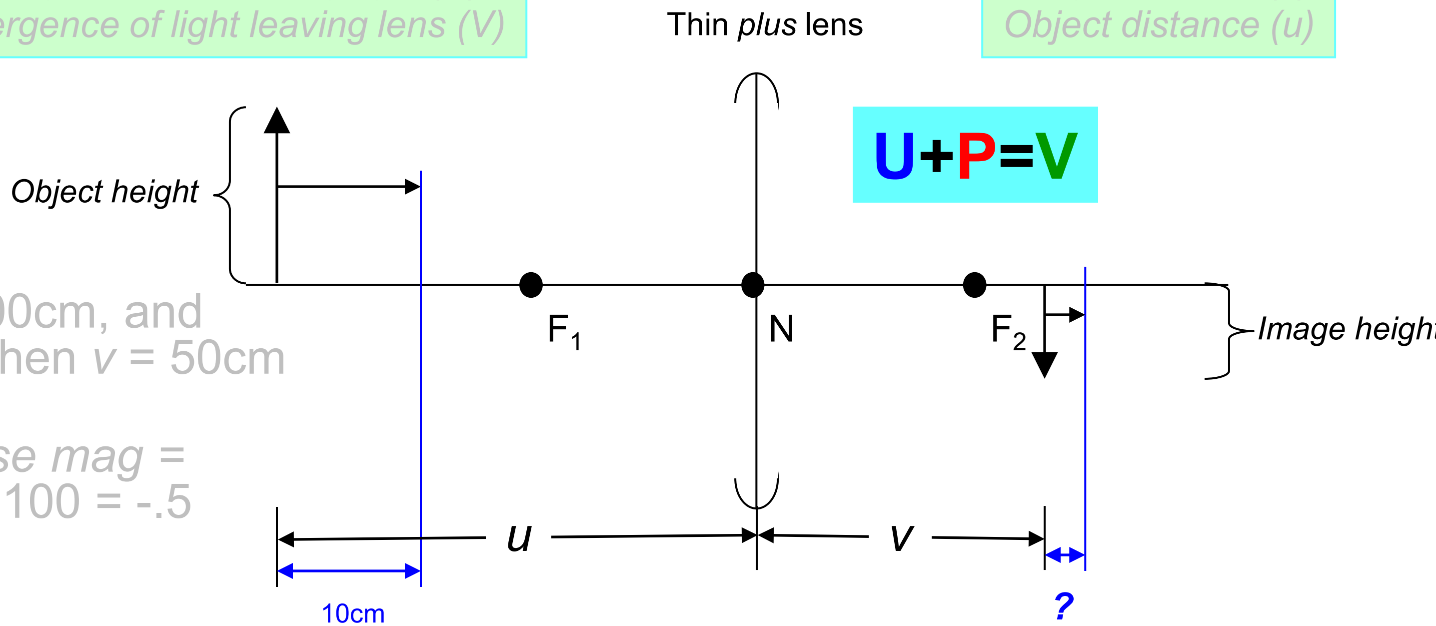

If *u* = -100cm, and **P** = +3, then *v* = 50cm

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If our arrow has a 10cm ‘nose,’ how big will the image nose be?

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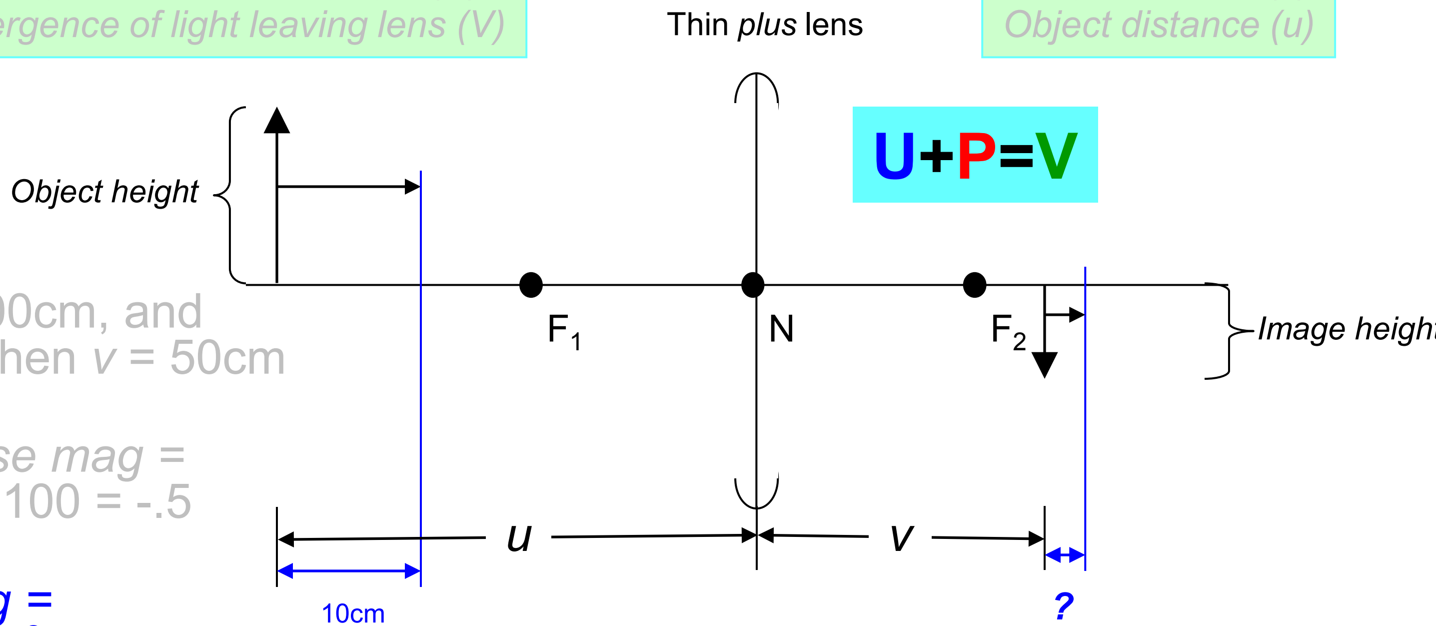

If *u* = -100cm, and **P** = +3, then *v* = 50cm

Transverse mag =
v/u = 50/-100 = -.5

Axial mag =
$(v/u)^2 = -.5^2 = .25$

If our arrow has a 10cm ‘nose,’ how big will the image nose be?

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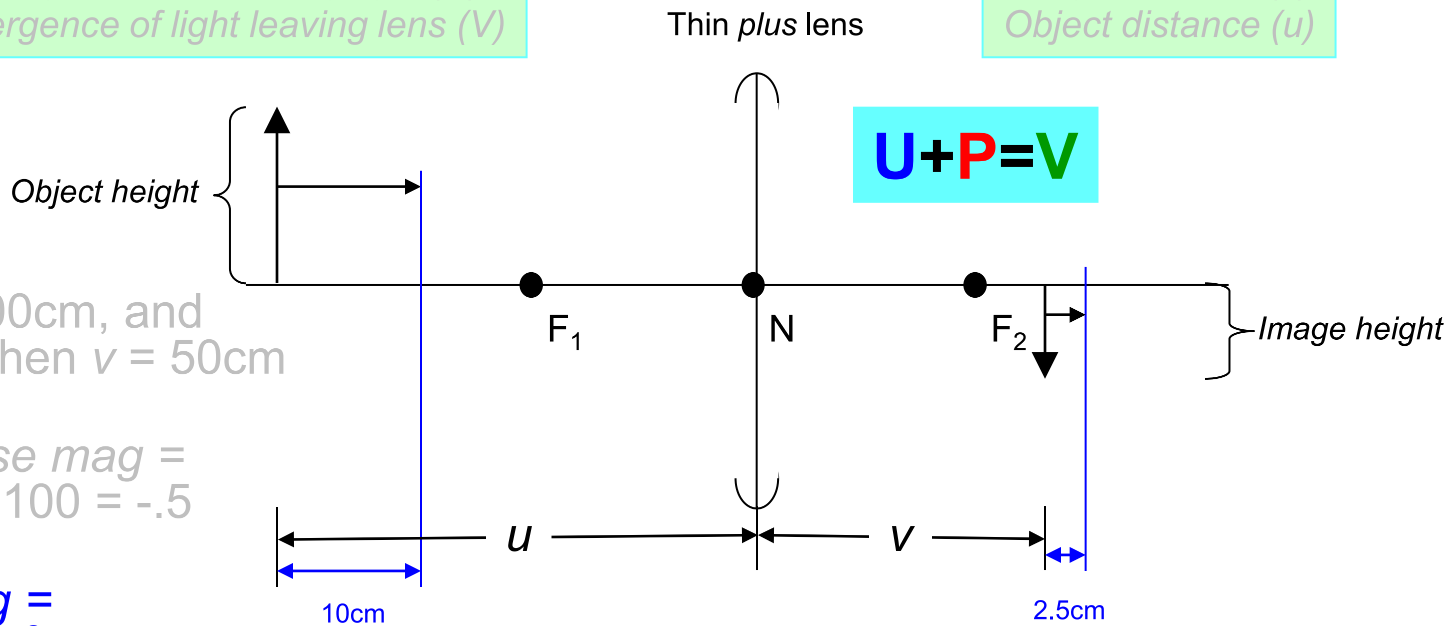

U+P=V

If *u* = -100cm, and **P** = +3, then *v* = 50cm

Transverse mag = *v/u* = 50/-100 = -.5

Axial mag = $(v/u)^2 = -.5^2 = .25$

If our arrow has a 10cm 'nose,' how big will the image nose be? **.25 x 10 cm = 2.5 cm** (approx)

Axial Magnification

- On an exam, I would look for axial magnification to be tested in the context of *binocular indirect ophthalmoscopy (BIO)*

Eg, 'A pt has an elevated choroidal mass. If the height of the mass is 3 mm, what will be the height of its image on indirect exam using a 20D condensing lens?'

Axial Magnification

- On an exam, I would look for axial magnification to be tested in the context of *binocular indirect ophthalmoscopy (BIO)*

But first, let's unpack what makes indirect ophthalmoscopy indirect by comparing/contrasting it with **direct** ***ophthalmoscopy***

Eg, 'A pt has an elevated choroidal mass. If the height of the mass is 3 mm, what will be the height of its image on indirect exam using a 20D condensing lens?'

Axial Magnification

- In direct ophthalmoscopy, the examiner looks directly at the retina
  - Just as if they held it in their palm and looked at it with a magnifying glass*
  - The scope is there mainly to provide a light source
  - The image is upright, virtual, and magnified
  - The image is 2D (ie, not stereo)

*I know—*eww*

Axial Magnification

If the direct ophthalmoscope is just a light source, what does turning the knob on the side do?

with a magnifying glass

- The scope is there mainly to provide a light source
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Axial Magnification

If the direct ophthalmoscope is just a light source, what does turning the knob on the side do?
Well, I said *mainly*, not *just*…Anyway, the knob places plus and minus lenses of different powers between the examiner's eye and that of the pt. The purpose of this is to offset any refractive error on the part of the pt or examiner. In doing so, the image will appear sharper to the examiner (hence why it's referred to as the *focusing knob*).

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What determines whether a plus vs minus intervening lens is needed?

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The type of refractive error that needs offsetting. For simplicity's sake, let's assume the examiner is plano. If the pt is a myope, she has a [ ] error lens, and therefore a [ ] lens must be dialed in to offset it. (The reverse is true if the pt is a hyperope.)

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So with a myopic pt, once the examiner has adjusted the focusing knob she is looking through a minus *lens (in the instrument) and then a* plus *lens (the error lens in the pt's eye). What optical instrument does that sound like?*

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A(n) Galilean *vs* astronomical telescope

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What does this imply about the image seen by the examiner when looking at a myope's fundus as opposed to that of an emmetrope?

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Because she's effectively using a telescope when examining a myope, the image will be magnified

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What if the pt is hyperopic?

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In this case, the examiner must dial in a ____ lens to offset the pt's ____ error lens

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What if the pt is hyperopic?

In this case, the examiner must dial in a plus lens to offset the pt's minus error lens. Thus, during the exam she (the examiner) is looking at the retina through a plus (the scope)-then-minus (the error lens) optical device, ie, a Galilean telescope, but **backwards**.

What does this imply about the image seen by the examiner when looking at a myope's fundus as opposed to that of an emmetrope?

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What if the pt is hyperopic?

In this case, the examiner must dial in a plus lens to offset the pt's minus error lens. Thus, during the exam she (the examiner) is looking at the retina through a plus (the scope)-then-minus (the error lens) optical device, ie, a Galilean telescope, but **backwards**. Because of this, when examining a hyperope the image will be minified (relative to the same image in an emmetrope).

What does this imply about the image seen by the examiner when looking at a myope's fundus as opposed to that of an emmetrope?

Because she's effectively using a telescope when examining a myope, the image will be magnified

Axial Magnification

- In direct ophthalmoscopy, the examiner looks directly at the retina
  - Just as if they held it in their palm and looked at it with a magnifying glass
  - The scope is there mainly to provide a light source
  - **The image is** upright, virtual, and **magnified**
  - *If the ophthalmoscope serves only as a light source and (if needed) focusing device, what is the source of the magnification?*

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    The pt's eye (ie, their cornea and lens)

Axial Magnification

How much magnification occurs during direct ophthalmoscopy?

- **The image is** upright, virtual, and **magnified**
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  The pt's eye (ie, their cornea and lens)

Axial Magnification

How much magnification occurs during direct ophthalmoscopy?
For testing purposes, the total power of a human eye is ______ (recall this value derives from the [four words]), and is considered to stem from a single lens.*

- **The image is** upright, virtual, and **magnified**
- *If the ophthalmoscope serves only as a light source and (if needed) focusing device, what is the source of the magnification?*
  The pt's eye (ie, their cornea and lens)

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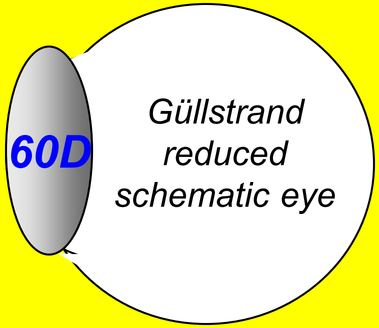
How much magnification occurs during direct ophthalmoscopy?
For testing purposes, the total power of a human eye is 60D (recall this value derives from the *Güllstrand reduced schematic eye*), and is considered to stem from a single lens.*



*That's the main 'reduction' in this model—the eye's two plus lenses are 'reduced' to one

- **The image is** upright, virtual, and **magnified**
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For testing purposes, the total power of a human eye is 60D (recall this value derives from the *Güllstrand reduced schematic eye*), and is considered to stem from a single lens.* Since the retina is being examined through a single lens during direct ophthalmoscopy, the exam is analogous to looking at something through a *simple magnifier*.

- **The image is** upright, virtual, and **magnified**
- *If the ophthalmoscope serves only as a light source and (if needed) focusing device, what is the source of the magnification?*
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$$\frac{\textbf{Lens power (D)}}{\textbf{4}}$$

the lens in this case being the pt's eye. Thus, the magnification of the retina as seen by the examiner is 60/4 = 15x.*

- **The image is** upright, virtual, and **magnified**
- *If the ophthalmoscope serves only as a light source and (if needed) focusing device, what is the source of the magnification?*
  The pt's eye (ie, their cornea and lens)

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- **The image is** upright, virtual, and **magnified**
- *If the ophthalmoscope serves only as a light source and focusing device, what is the source of the magnification?*
  The pt's eye (ie, their cornea and lens)

*In an emmetrope; as per the recent discussion, the mag will be greater than 15 if the pt is [ ] and less than 15 if the pt is a [ ]

Axial Magnification

How much magnification occurs during direct ophthalmoscopy?
For testing purposes, the total power of a human eye is 60D (recall this value derives from the *Güllstrand reduced schematic eye*), and is considered to stem from a single lens.* Since the retina is being examined through a single lens during direct ophthalmoscopy, the exam is analogous to looking at something through a *simple magnifier.* As you know (from a very recent chapter), the power of a simple magnifier is

$$\frac{\textbf{Lens power (D)}}{\textbf{4}}$$

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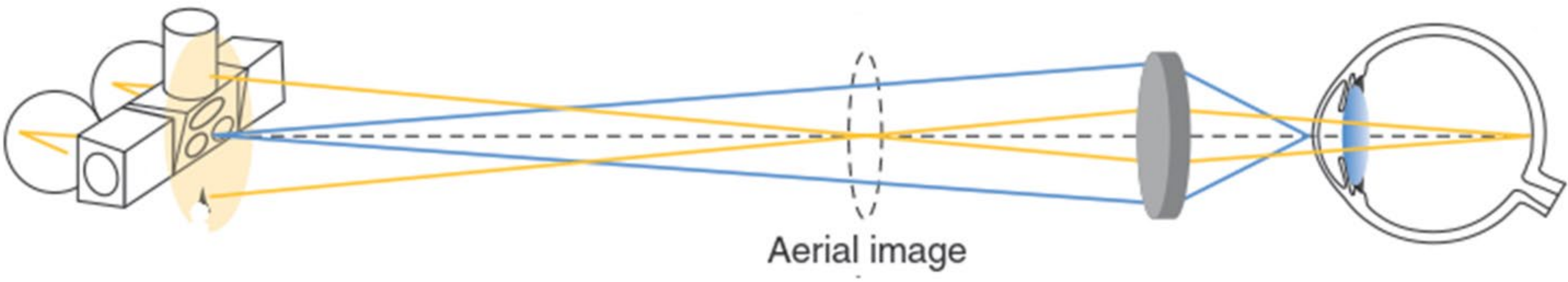
  - Put another way: You don't look at the retina directly; rather, you do so *indirectly,* by looking at an *image* of it

Axial Magnification



During BIO, the examiner looks at an *image* of the pt’s retina, not the retina itself

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- Note what this implies (correctly) about conjugacy during BIO—namely, that the *pt's retina*, the *image* of the pt's retina, and the *observer's retinas* are all conjugate with one another

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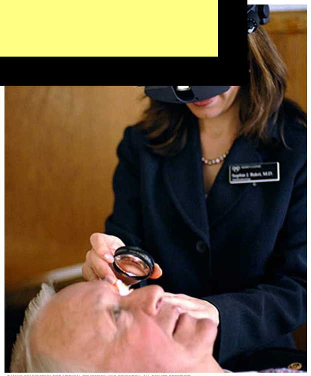

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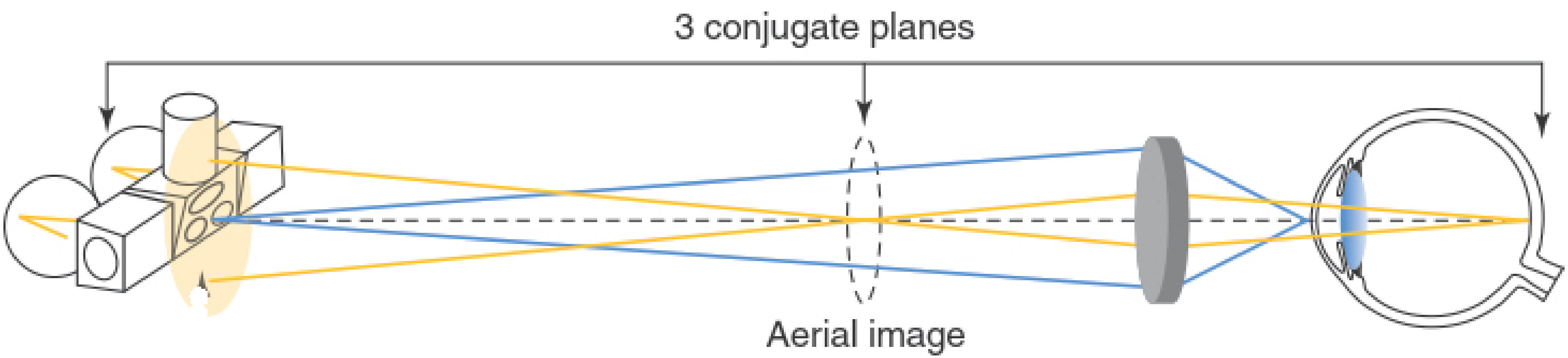

Three conjugate planes during BIO of the retina

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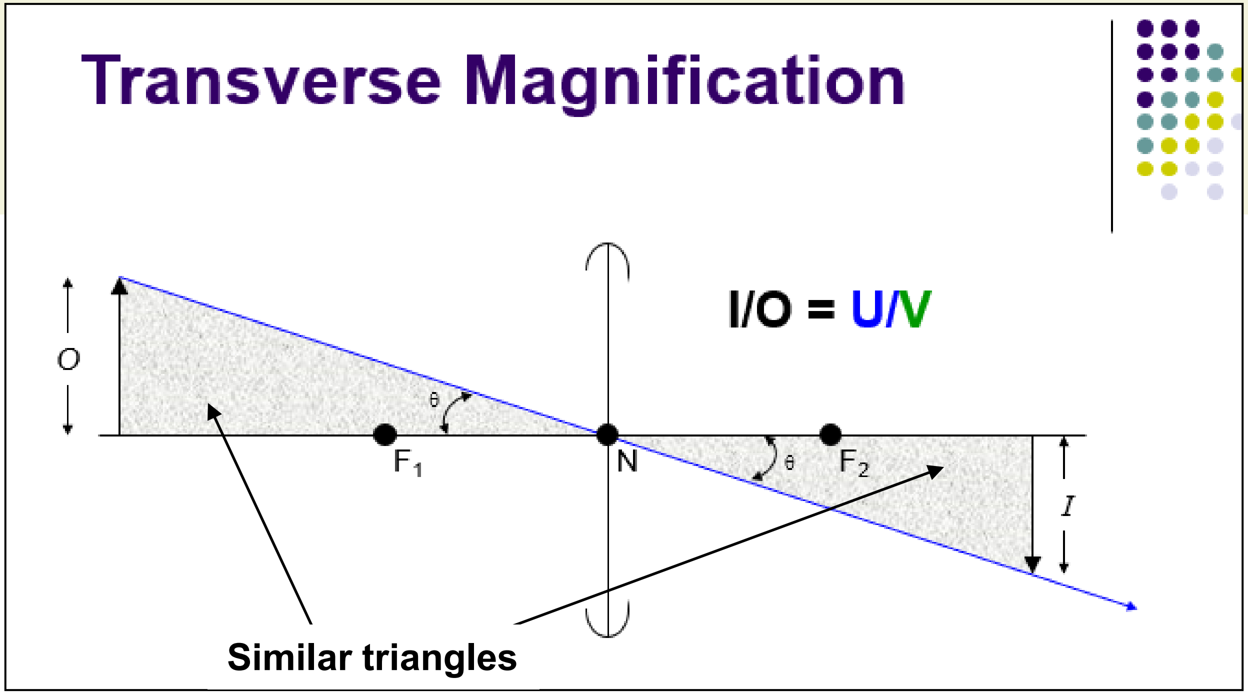

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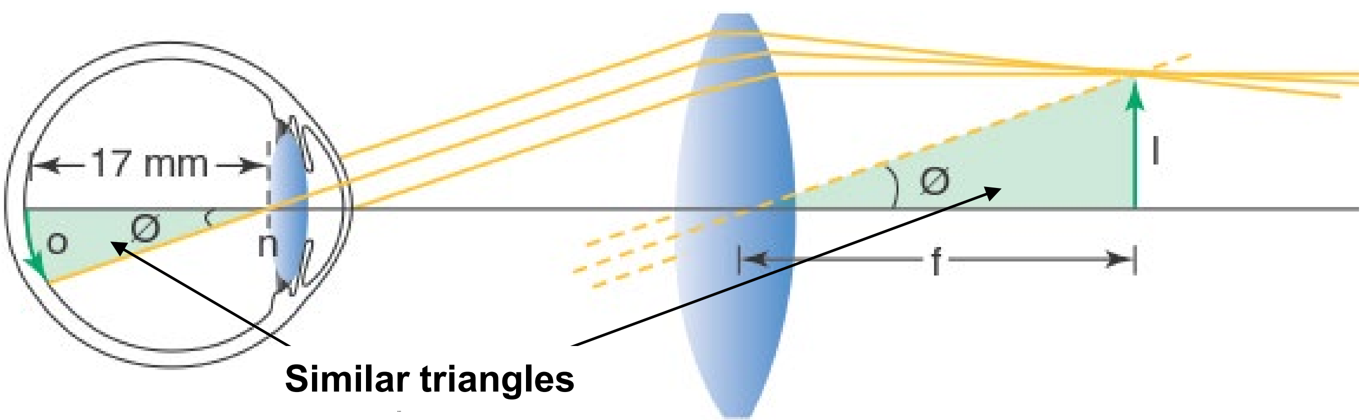

*Because Güllstrand reduced schematic eye

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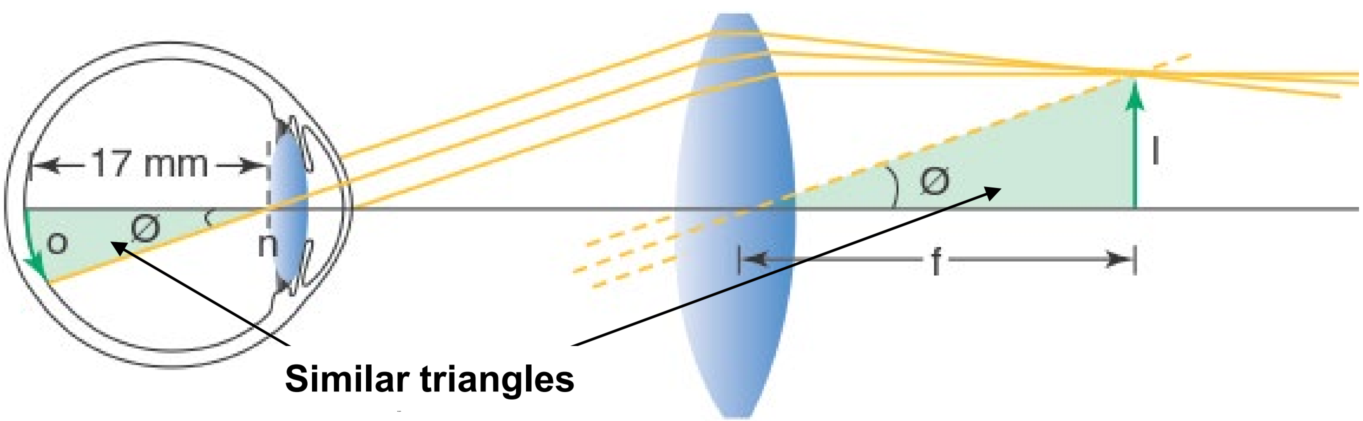

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*There's that number 60 again…Why is PD assumed to be 60 mm? Because it makes the maths easier.

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So the **transverse** mag during 20D BIO is 3x, but the **axial** mag is 2.25