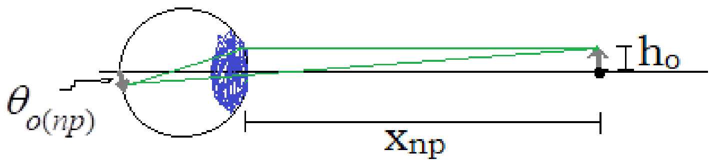
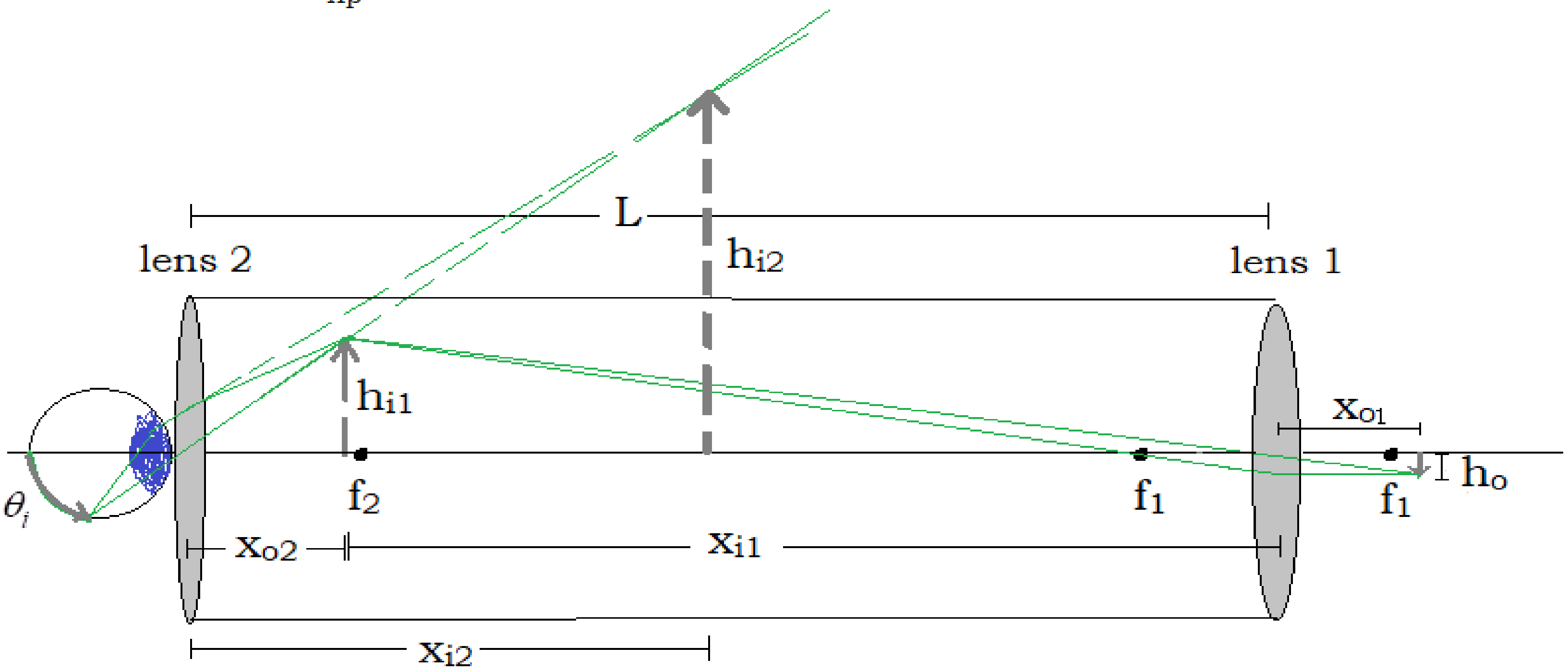
E.5 Microscopes



$$\theta_{o(np)} \approx \frac{h_o}{x_{np}}$$

angular size of object at near point as viewed by unaided eye.



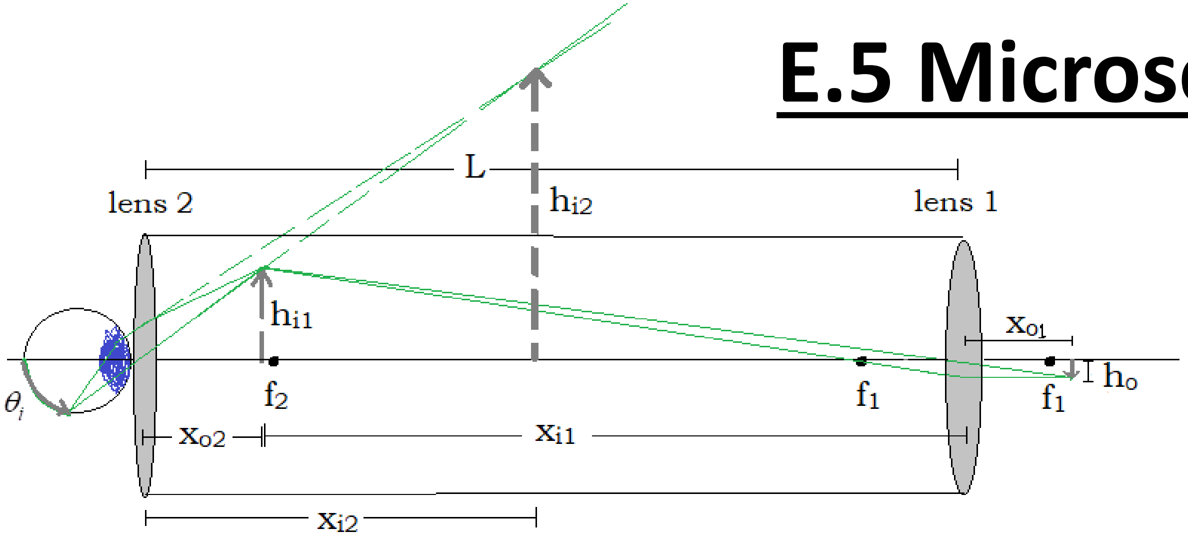
$$\theta_i \approx \frac{h_{i2}}{x_{i2}}$$

angular size of image as viewed by eye through microscope

Angular magnification of microscope:

$$m_\theta = \frac{\theta_i}{\theta_{o(np)}} \approx \frac{L x_{np}}{f_1 f_2}$$

E.5 Microscopes



Say we have the following numbers…..
What's the angular magnification exactly?
And approximately?
eye: x_{np} = 25cm,
microscope: f_1 = 1cm, f_2 = 2cm, L = 12.9cm.
object: x_{o1} = 1.1cm, h_o = 6μm.

1. First find the angular size of object at near point:

$$\theta_{o(np)} = \frac{h_o}{x_{np}} = \frac{6\mu\text{m}}{25\text{cm}} = 2.4\times10^{-5}\,\text{rad}$$

2. Next find the first image's location and height:

$$\frac{1}{x_{o1}} + \frac{1}{x_{i1}} = \frac{1}{f_1} \rightarrow \frac{1}{1.1} + \frac{1}{x_{i1}} = \frac{1}{1} \rightarrow x_{i1} = 11$$

$$h_{i1} = m_1 h_o = -\frac{x_{i1}}{x_{o1}} h_o = -\frac{11\text{cm}}{1.1\text{cm}}(-6\mu\text{m}) = 60\mu\text{m}$$

3. Then find the second image's location and height:

$$\frac{1}{x_{o2}} + \frac{1}{x_{i2}} = \frac{1}{f_2} \rightarrow \frac{1}{1.9} + \frac{1}{x_{i1}} = \frac{1}{2} \rightarrow x_{i2} = -38$$

$$h_{i2} = m_2 h_{i1} = -\frac{x_{i2}}{x_{o2}} h_{i1} = -\frac{-38\text{cm}}{1.9\text{cm}}(60\mu\text{m}) = 1200\mu\text{m}$$

4. Calculate angular size of image:

$$\theta_i = \frac{h_{i2}}{x_{i2}} = \frac{1200\mu\text{m}}{38\text{cm}} = 3.2\times10^{-3}\,\text{rad}$$

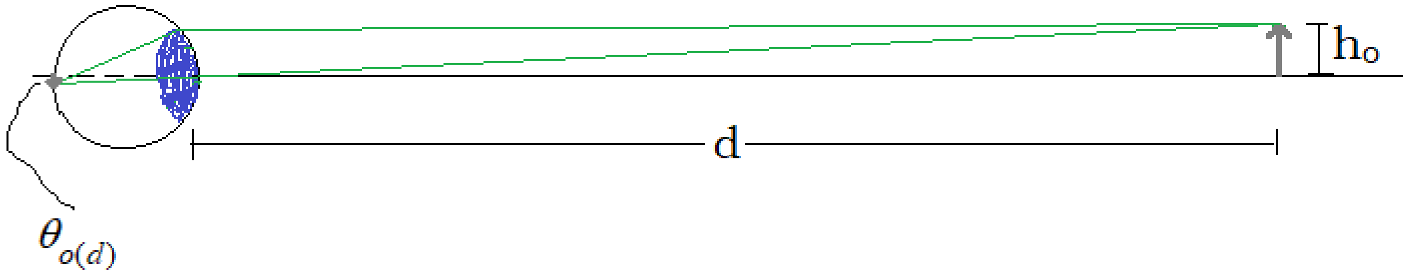
5. Calculate m_θ

$$m_\theta = \frac{\theta_i}{\theta_{o(np)}} = \frac{3.2\times10^{-3}\,\text{rad}}{2.4\times10^{-5}\,\text{rad}} = 133$$

and approximation, just to compare, is:

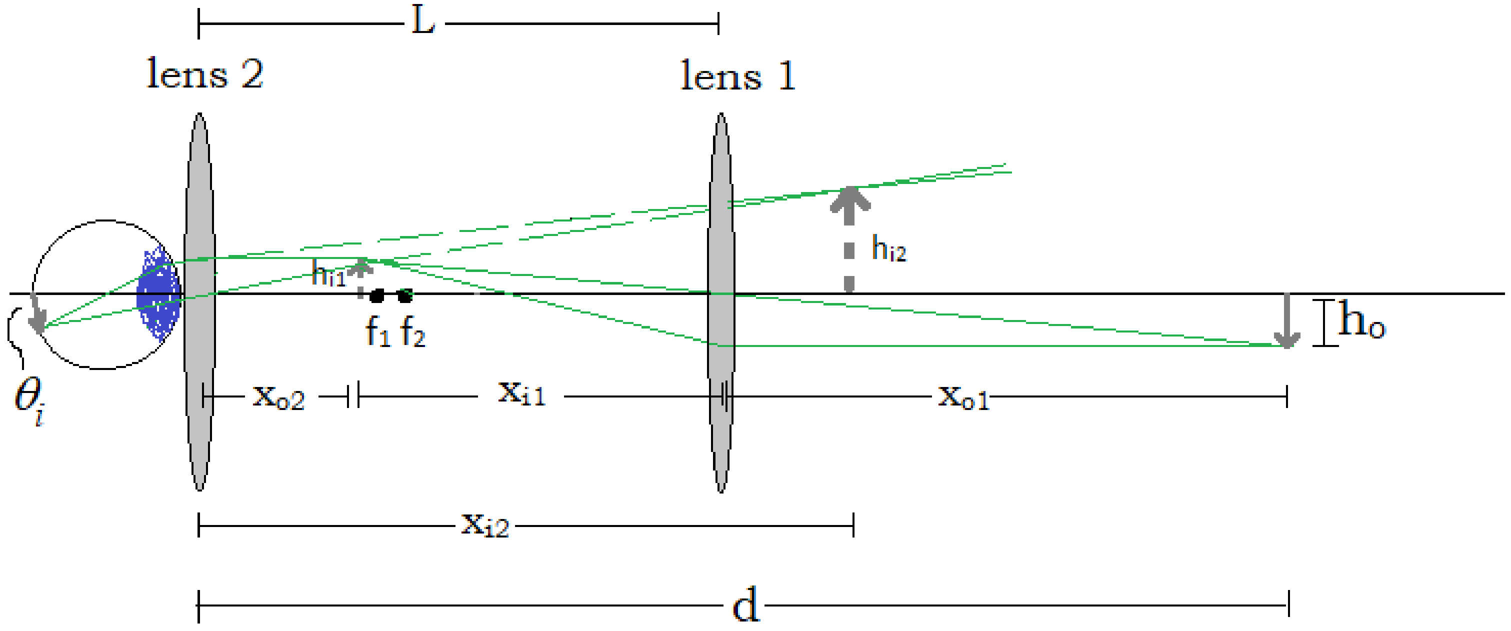
$$m_\theta \approx \frac{L x_{np}}{f_1 f_2} \approx \frac{(12.9\text{cm})(25\text{cm})}{(1\text{cm})(2\text{cm})} = 161$$

E.5 Telescopes



$$\theta_{o(d)} \approx \frac{h_o}{d}$$

angular size of object at that distance, as viewed by unaided eye.

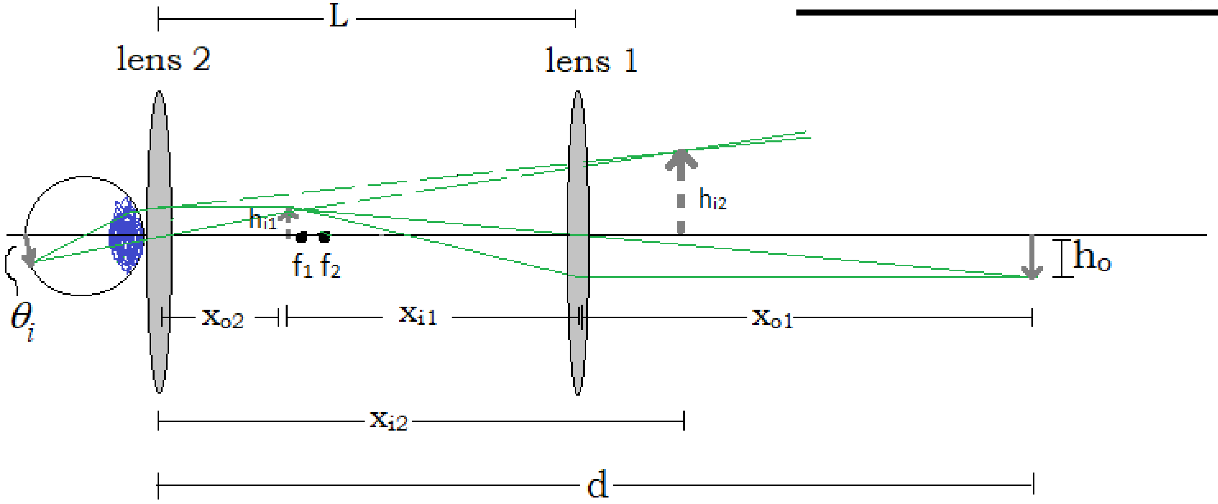


$$\theta_i \approx \frac{h_{i2}}{x_{i2}}$$

angular size of image as viewed by eye through telescope

$$m_\theta = \frac{\theta_i}{\theta_{o(d)}} \approx \frac{f_1}{f_2}$$

E.5 Telescope



Say we have the following numbers.....
What's the angular magnification exactly?
And approximately?
microscope: f_1 = 10cm, f_2 = 2cm, L = 11.9cm.
object: x_{o1} = 3200m, h_o = 2m.

1. First find the angular size of object at d:

$$\theta_{o(d)} = \frac{h_o}{d} = \frac{2\text{m}}{3200.119\text{m}} = 6.25\times10^{-4}\,\text{rad}$$

2. Next find the first image's location and height:

$$\frac{1}{x_{o1}} + \frac{1}{x_{i1}} = \frac{1}{f_1} \rightarrow \frac{1}{3200} + \frac{1}{x_{i1}} = \frac{1}{0.10} \rightarrow x_{i1} = 0.10$$

$$h_{i1} = -\frac{x_{i1}}{x_{o1}} h_o = -\frac{0.10\text{m}}{3200\text{m}}(-2\text{m}) = 6.2\times10^{-5}\,\text{m}$$

3. Then find the second image's location and height:

$$\frac{1}{x_{o2}} + \frac{1}{x_{i2}} = \frac{1}{f_2} \rightarrow \frac{1}{1.9} + \frac{1}{x_{i1}} = \frac{1}{2} \rightarrow x_{i2} = -38$$

$$h_{i2} = -\frac{x_{i2}}{x_{o2}} h_{i1} = -\frac{-38\text{cm}}{1.9\text{cm}}(6.2\times10^{-5}\,\text{m}) = 1.24\times10^{-3}\,\text{m}$$

4. Calculate angular size of image:

$$\theta_i = \frac{h_{i2}}{x_{i2}} = \frac{1.24\times10^{-3}\,\text{m}}{38\text{cm}} = 3.3\times10^{-3}\,\text{rad}$$

5. Calculate m_θ

$$m_\theta = \frac{\theta_i}{\theta_{o(d)}} = \frac{3.3\times10^{-3}\,\text{rad}}{6.25\times10^{-4}\,\text{rad}} = 5.3$$

and approximation, just to compare, is:

$$m_\theta \approx \frac{f_1}{f_2} \approx \frac{10\text{cm}}{2\text{cm}} = 5$$