PH202-1G
Spring 2014

Worksheet March 17

Optics of the human eye

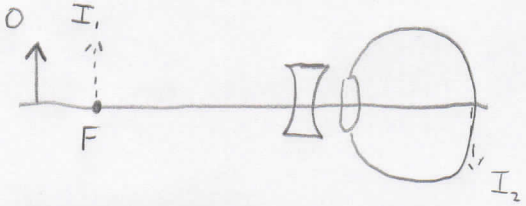
Describe how the eye creates an image? What kind of lens is involved?

The eye uses a converging lens to create a real, inverted image on the retina.

What is nearsightedness?

Nearsightedness is an inability to see distant objects because the image is formed in front of the retina.

How is nearsightedness corrected? Draw a diagram to show the optics involved.

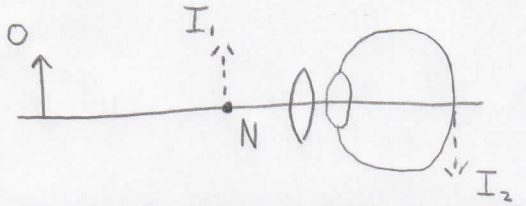


A diverging lens creates an image at the far point (I_1). The lens of the eye then creates an image on the retina (I_2).

What is farsightedness?

Farsightedness is the inability to see close objects because the image forms behind the retina.

How is farsightedness corrected? Draw a diagram to show the optics involved.



A converging lens creates an image at the near point (I_1). The lens of the eye then creates an image on the retina (I_2).

What is refractive power? What is its unit of measurement?

Refractive power $= \frac{1}{F}$. Units are diopters, equal to reciprocal meters.

Applications of compound lens systems

What is the angular size of an object? Give an approximation for the angular size at small angles.

$\theta = \arctan\left(\frac{h_o}{d_o}\right)$ For small angles, $\theta \approx \frac{h_o}{d_o}$

What is angular magnification?

$$M = \frac{\theta'}{\theta} = \frac{\text{Angular size with lens}}{\text{Angular size without lens}}$$

What is the angular magnification of a magnifying glass?

$$M = \frac{h_o/d_o}{h_o/N} = \frac{N}{d_o} = N\left(\frac{1}{f} - \frac{1}{d_i}\right)$$

At maximum magnification, $M \approx \frac{N}{f}$ where N is the viewer's near point

What is the total magnification of a compound microscope?

$$M_T = M_{eyepiece}\, m_{objective} \approx -\frac{(L - f_e)\, N}{f_o\, f_e}$$

where L is the distance between the eyepiece and the objective lens

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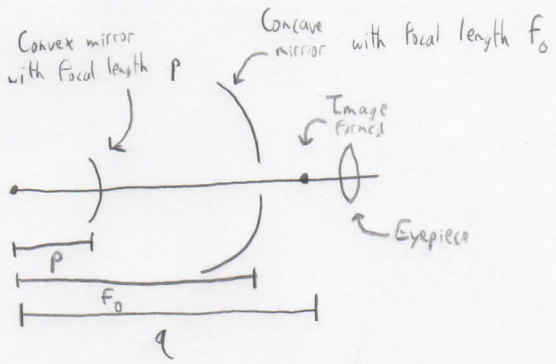
What is the angular magnification of a refracting telescope?

$$M \approx -\frac{f_o}{f_e}$$

What is the angular magnification of a reflecting telescope?

$$M \approx -\frac{f_o}{f_e}\frac{q}{p}$$

Reflecting telescope



What is spherical aberration? How can it be corrected?

Spherical aberration is blurriness caused by light farther from the center of a lens being refracted more strongly. It is corrected by blocking these distant rays.

What is chromatic aberration? How can it be corrected?

Chromatic aberration is blurriness caused by light with larger wavelengths being refracted more strongly. It is corrected by using a compound lens.

Problems

1. A farsighted man uses eyeglasses that have a refractive power of 3.26 diopters. When the glasses are 2.5 cm from his eyes, the minimum distance from his eyes at which he can read a newspaper is 24.0 cm. If the man decides to switch from his eyeglasses to contact lenses, what should the refractive power of the contact lenses be to achieve the same optical effect?

First find the near point, since that will not change.

$$N = d_i + 2.5\text{ cm} = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1} + 2.5\text{ cm} = \left(3.26\text{ m}^{-1} + \frac{1}{0.24\text{ m}}\right)^{-1} + 2.5\text{ cm} = 16.0\text{ cm}$$

Now find the refractive power necessary to form an image at the near point without the 2.5-cm separation.

$$\frac{1}{f'} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{0.240\text{ m}} + \frac{1}{0.160\text{ m}} = 10.4\text{ diopters}$$

2. A person with a near point of 18.0 cm can see the letters on an inscription with an angular size of 0.040 rad. A certain magnifying glass allows the person to see the letters with an angular size of 0.052 rad. What is the focal length of the magnifying glass?

$$f = \frac{N}{M} = \frac{N\theta}{\theta'} = \frac{18.0\text{ cm} \cdot 0.040\text{ rad}}{0.052\text{ rad}} = 13.8\text{ cm}$$