Human-machine interaction in virtual reality

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Homework: dive into VR

DUE MONDAY FEBRUARY 18th

Your task is to get familiar with VR by choosing 3 VR apps / experience… …riting about how they exploit the strengths of VR as a new media form. P… …ss each of the following:

1) What is it about the app that would not be possib… …a movie or video game on a screen?
2) What level of presence did you feel in eac…
3) What factors do you think contribute… …ng of presence? (Hint: consider discussing tracking, grap… …, user input methodology, etc.)
4) Discuss some strengths and w… …using the system. How do you think this might compare to oth… …s (Oculus Quest, HTC Vive, etc) out there?
5) What would impr… …ence?
6) Finally, discus… … impact of each app (societal, economic, psycholog…

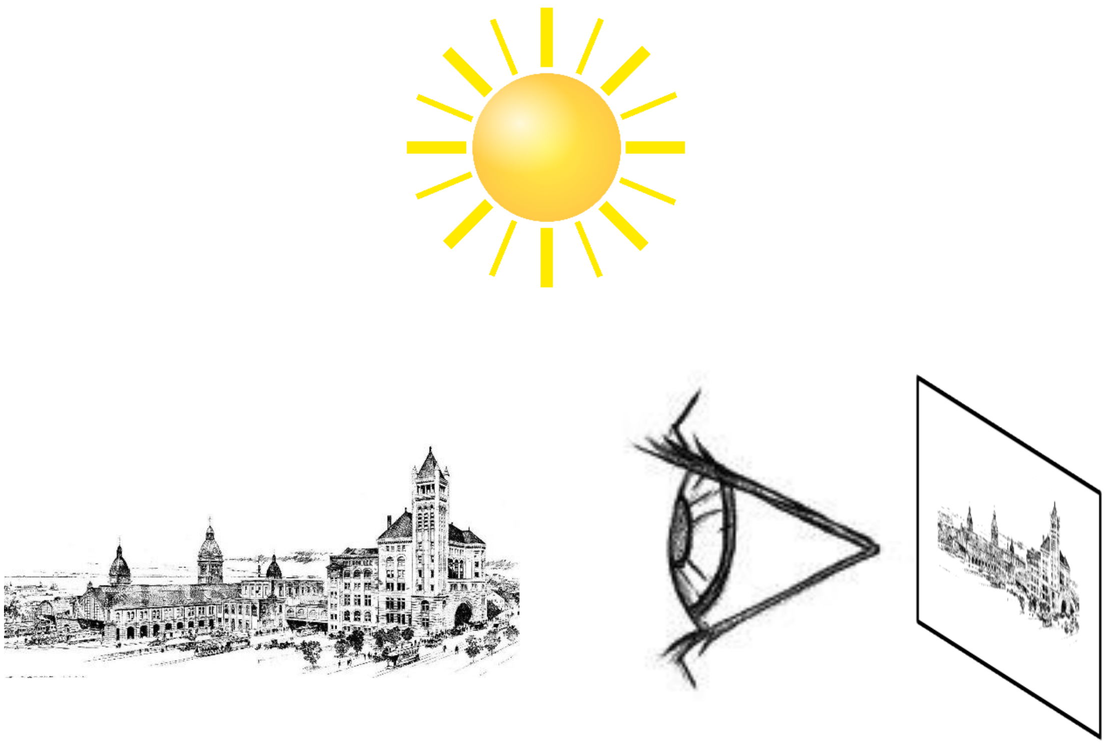
Please writ… …one paragraph for each app and feel free to compare and contrast between the… … you are reviewing. Your writeup must be uploaded as a PDF.

Access to VR

- Check out Oculus Quest 2
- One per group
  - At least 1 CS and 1 PSY/NS student per group
- Contact TA: mobara@unr.edu

- Book a time slot in AtReality in the knowledge center: https://library.unr.edu/specialty-rooms/at-reality

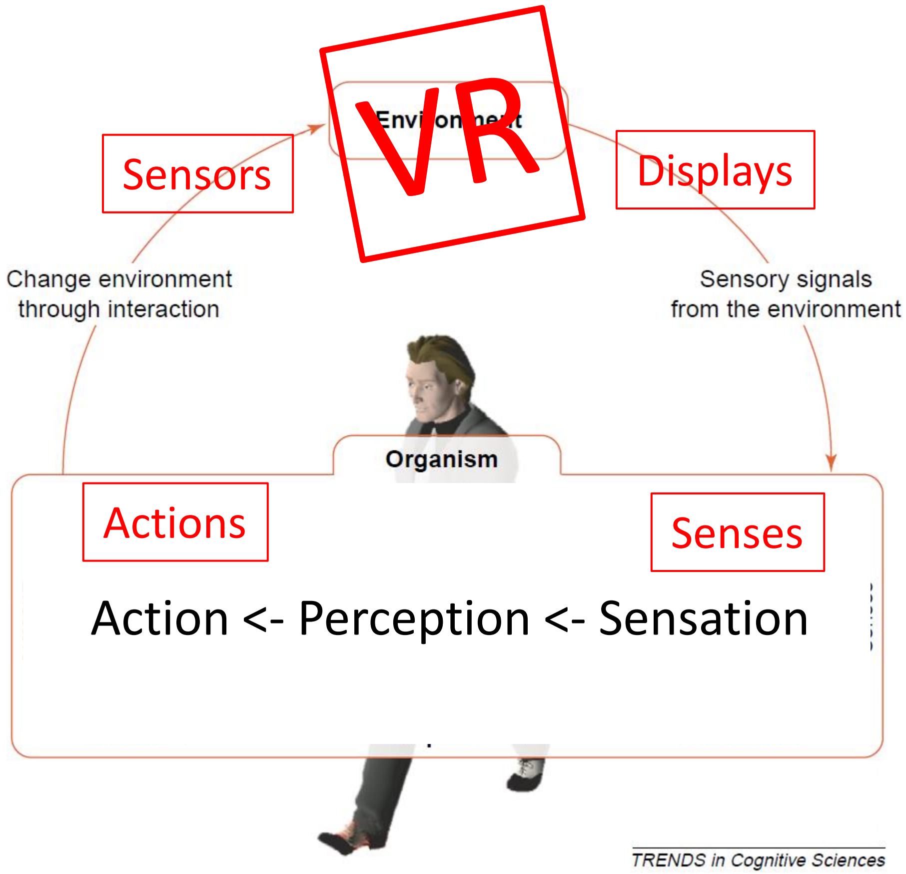
Light and optics: why do we care?



3D Real world

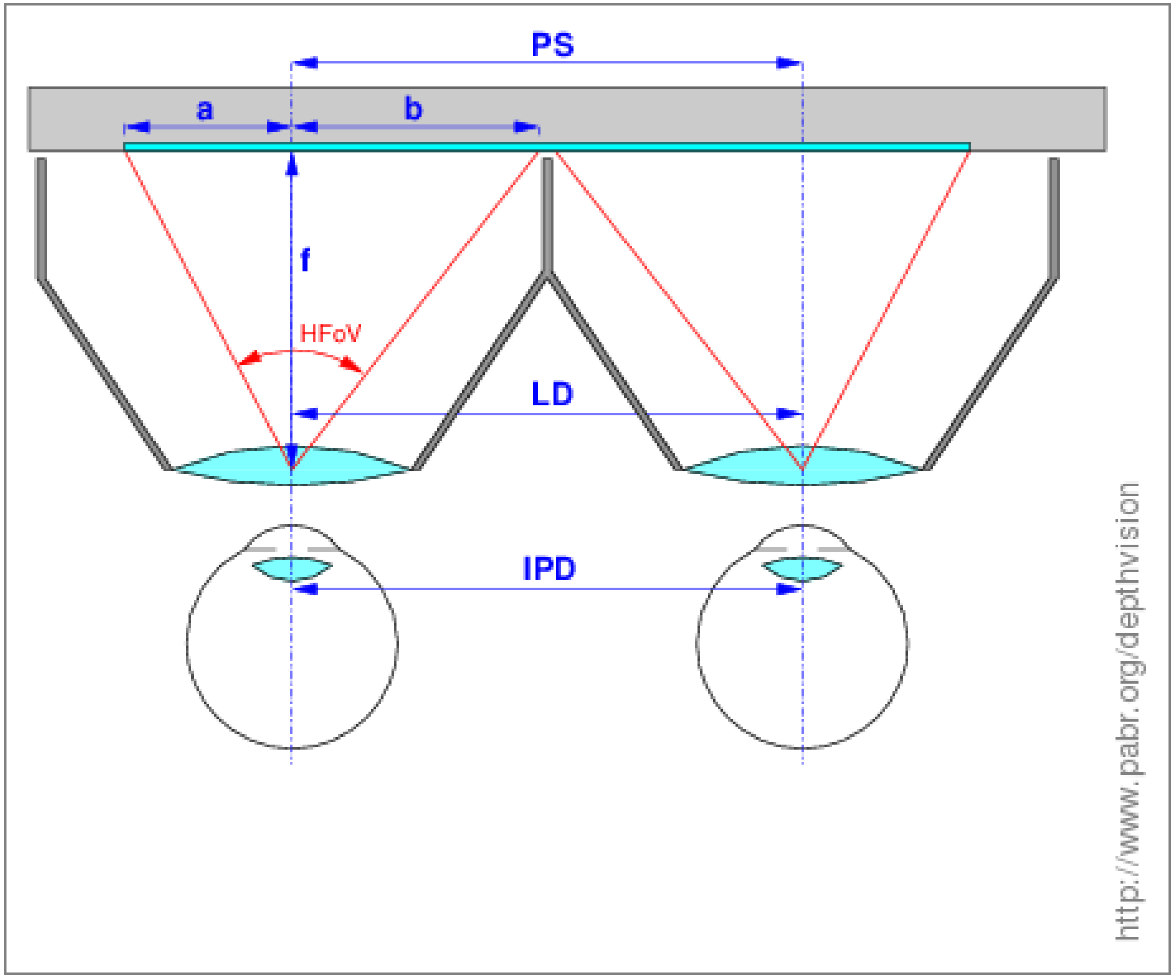
2D Image

Human-machine Interaction



Ernst & Buelthoff 2004

Light and optics: why do we care?



Screen

Lenses

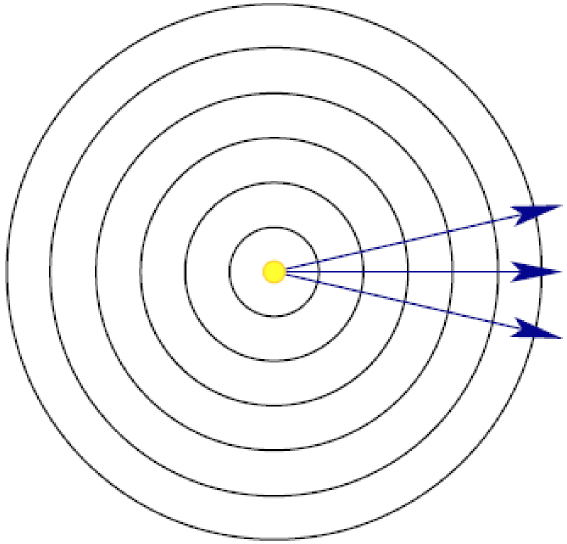
Eye

Outline

- Behavior and properties of light
- Lenses
- Aberrations
- Human eye
- Cameras

Light and Optics

- Describing light:
  - Particles – how much light received
  - Waves – wavelength - > describe color
  - Rays – describing lenses



How light interacts with surfaces?

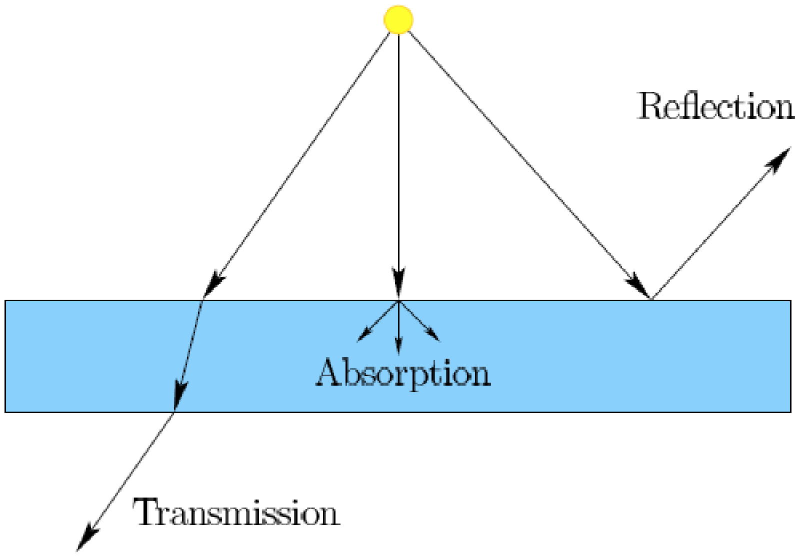


Figure 4.3: As light energy hits the boundary of a different medium, there are three possibilities: transmission, absorption, and reflection.

How light interacts with surfaces

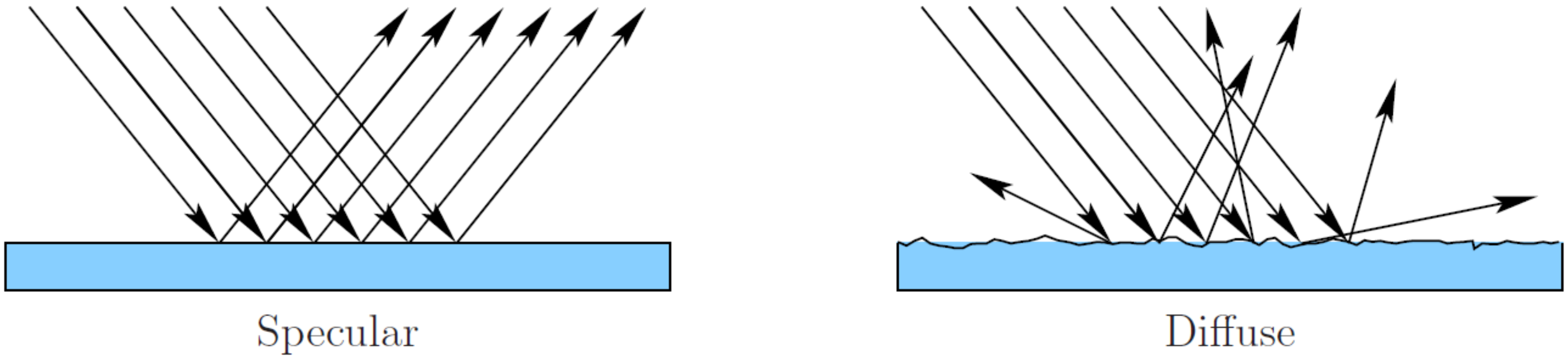


Figure 4.4: Two extreme modes of reflection are shown. Specular reflection means that all rays reflect at the same angle at which they approached. Diffuse reflection means that the rays scatter in a way that could be independent of their approach angle. Specular reflection is common for a polished surface, such as a mirror, whereas diffuse reflection corresponds to a rough surface.

Wavelength & Color

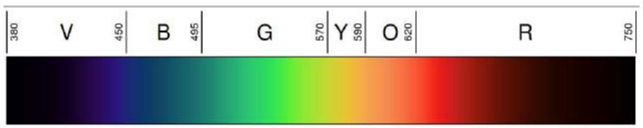
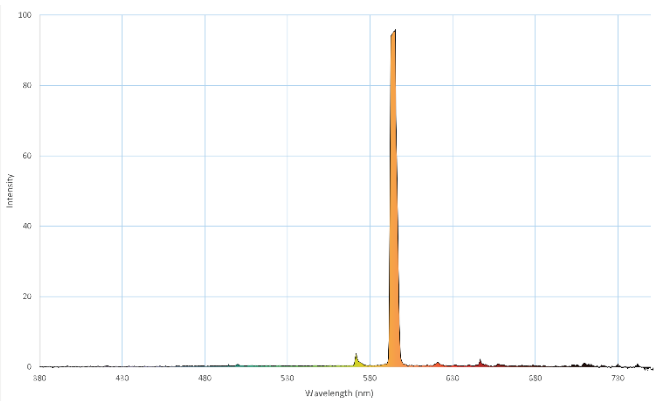


Figure 4.5: Visible light spectrum corresponds to the range of electromagnetic waves that have wavelengths between 400nm and 700nm. (Figure by David Eccles for Wikipedia.)



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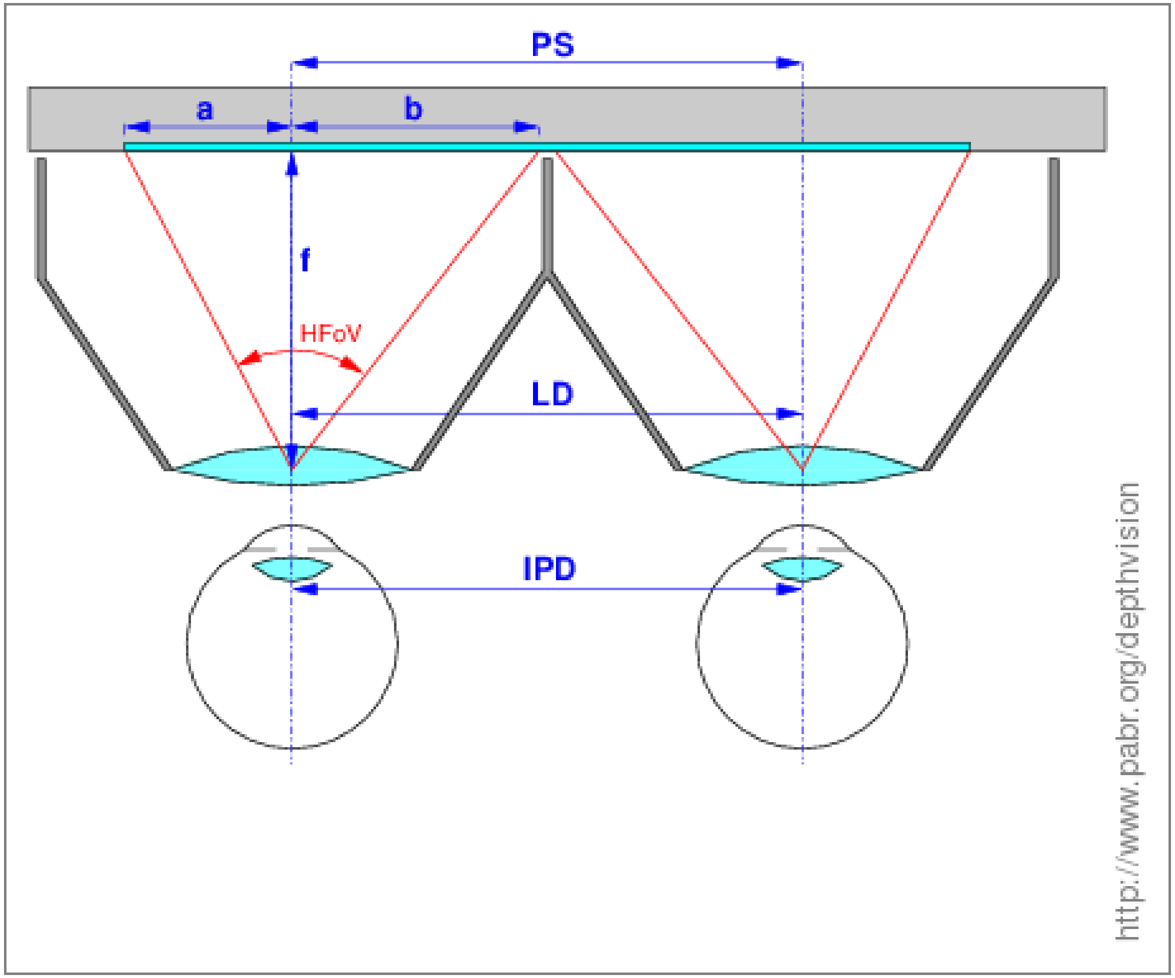
Light and optics: why do we care?



Screen

Lenses

Eye

Lenses bend light

- Refractive index

$$n = \frac{c}{s}$$

Speed of light in vacuum

Speed of light in medium

- c = 3 x 10^8 m/s^2
- Air: n = 1.000293
- Water: n = 1.33

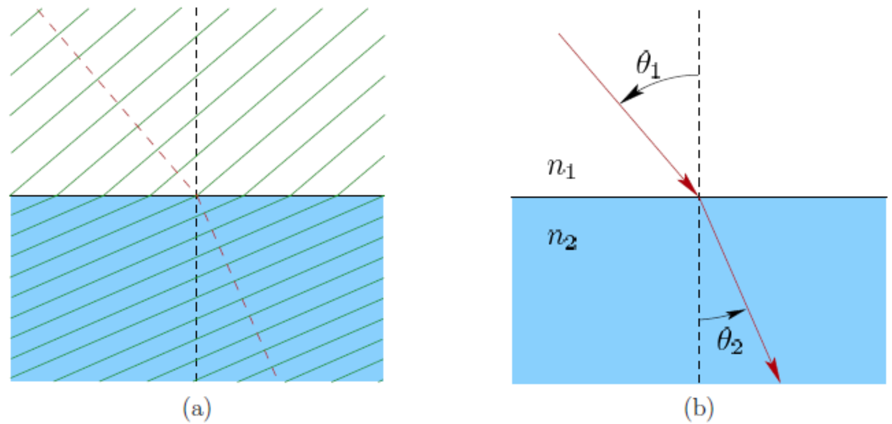


Figure 4.9: Propagating wavefronts from a medium with low refractive index (such as air) to one with a higher index (such as glass). (a) The effect of slower propagation on the wavefronts is shown as they enter the lower medium. (b) This shows the resulting bending of a light ray, which is always perpendicular to the wavefronts. Snell's Law relates the refractive indices and angles as $n_1 \sin\theta_1 = n_2 \sin\theta_2$.

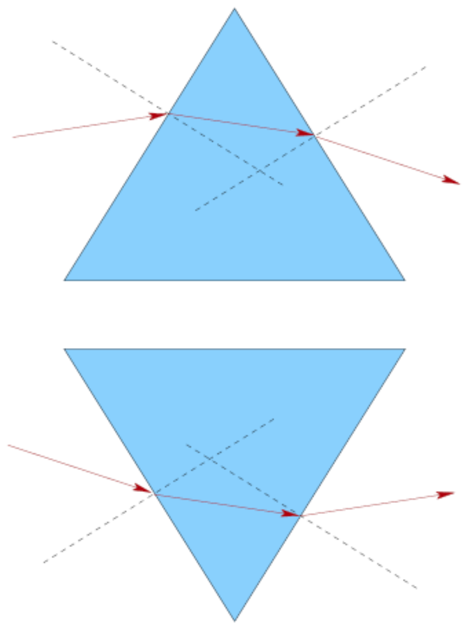
- Snell's law

$$n_1 sin\theta_1 = n_2 sin\theta_2$$

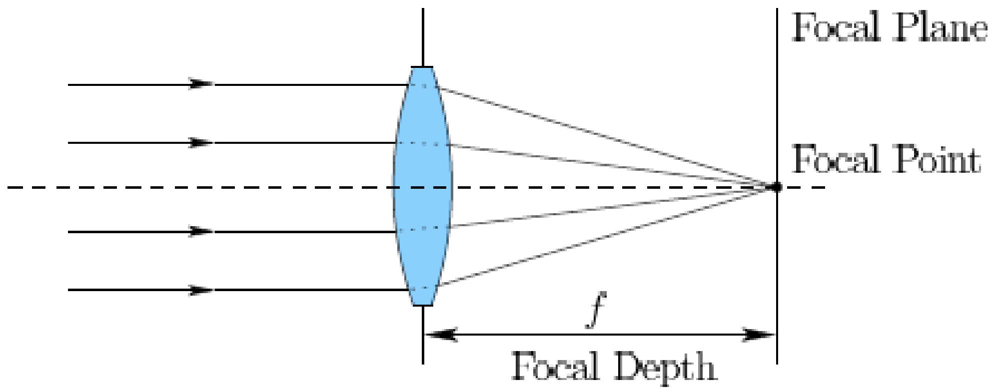
$$\theta_2 = sin^{-1}(\frac{n_1 sin\theta_1}{n_2})$$

Lenses bend light

Prism

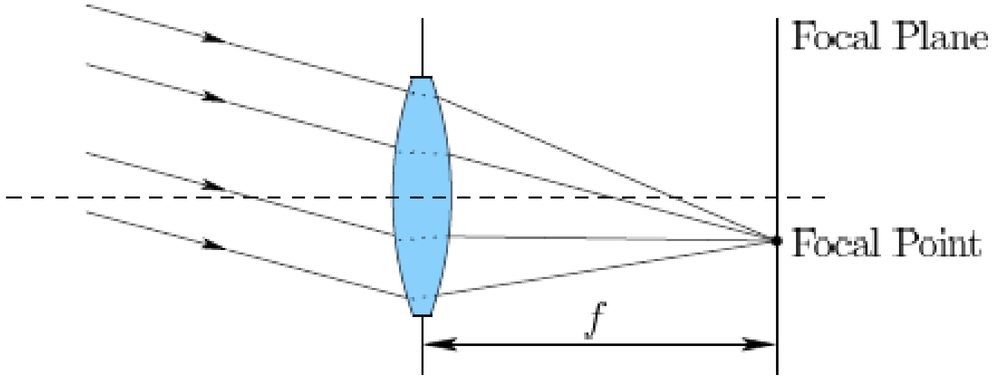


Convex Lens



Lenses bend light

- Non-perpendicular rays converge off the optical axis -> defines the focal plane



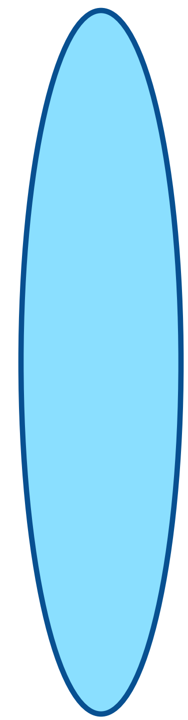
Determining Focal Length

- How do you make a lens of a given optical power?

- Lensmaker's Equation:

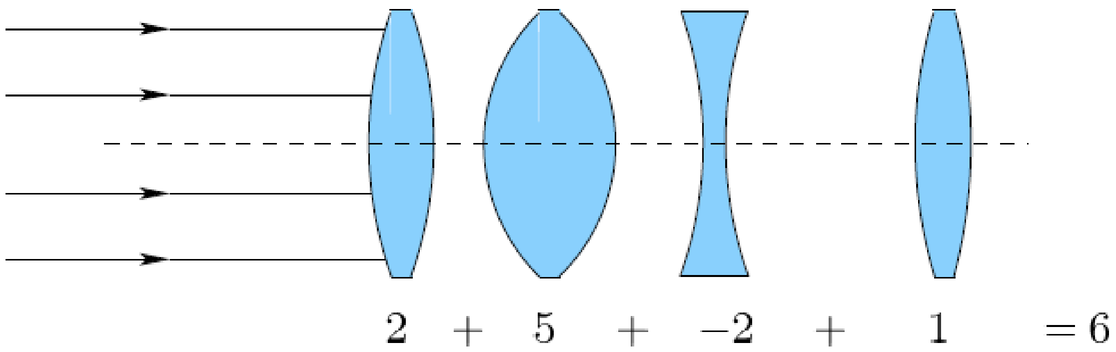
$$(n_2 - n_1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right) = \frac{1}{f}$$

Optical power



Diopters and Multiple Lenses

- Diopter (optical power): D = 1/f



- Magnification of the system – add diopters

Real Image – $s_1 > f$

- f=focal depth
- s_1=object distance
- s_2=image distance

Real image in focus

$$\frac{1}{s_1} + \frac{1}{s_2} = \frac{1}{f}$$

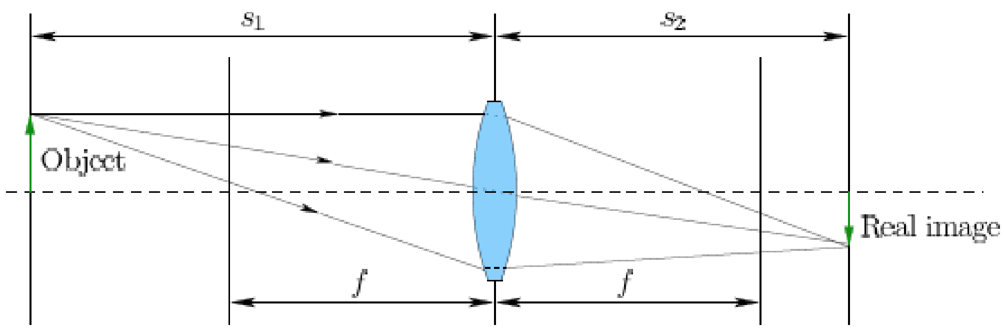


Figure 4.13: In the real world, an object is not infinitely far away. When placed at distance s_1 from the lens, a real image forms in a focal plane at distance $s_2 > f$ behind the lens, as calculated using (4.6).

Virtual Image – $s_1<f$

- f=focal depth
- s_1=object distance
- s_2=image distance

$$\frac{1}{s_1}+\frac{1}{s_2}=\frac{1}{f}$$

Magnification

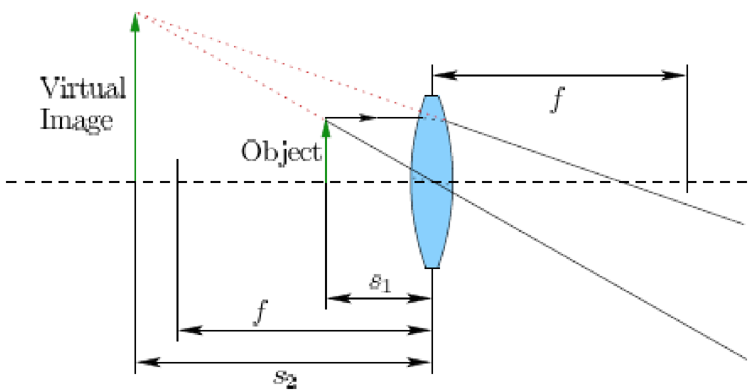
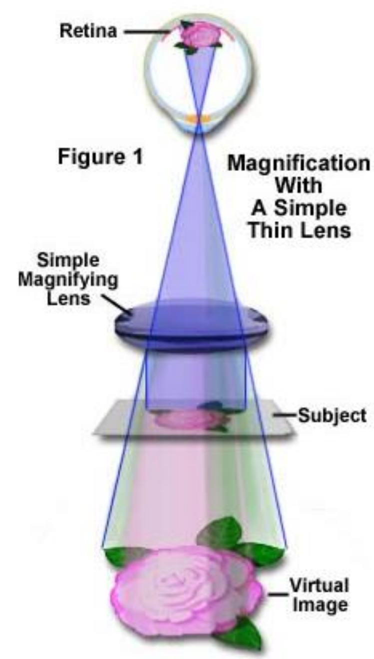


Figure 4.14: If the object is very close to the lens, then the lens cannot force its outgoing light rays to converge to a focal point. In this case, however, a virtual image appears and the lens works as . This is the way lenses are commonly used for VR headsets.



Outline

- Behavior and properties of light
- Lenses
- Aberrations
- Human eye
- Cameras

Aberrations

- Scenes viewed through lenses have artifacts
- Types of aberration:
  - Chromatic
  - Spherical
  - Optical distortion
  - Astigmatism
  - Coma
  - Flare

Chromatic Aberration

- Prism separates light

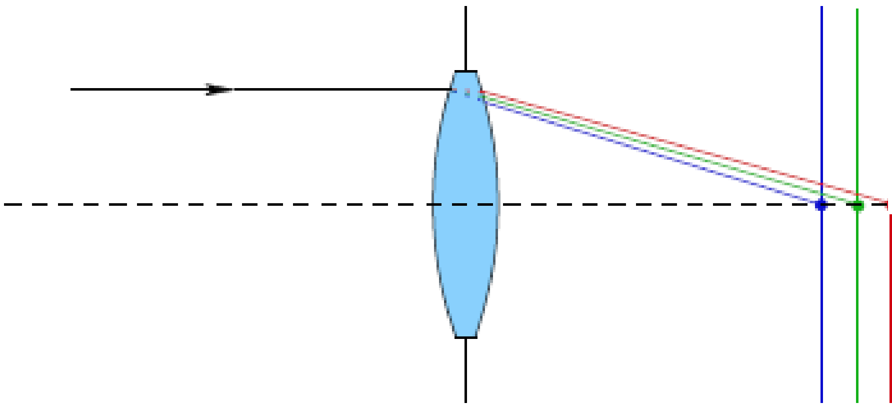


Figure 4.17: Chromatic aberration is caused by longer wavelengths traveling more quickly through the lens. The unfortunate result is a different focal plane for each wavelength or color.

Spherical Aberration

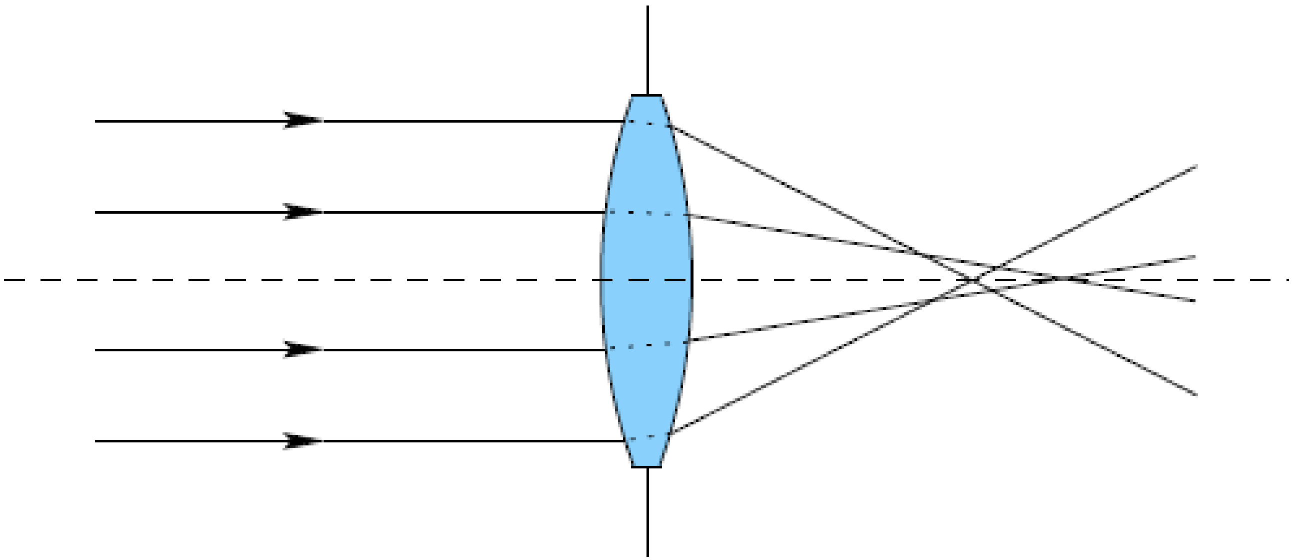
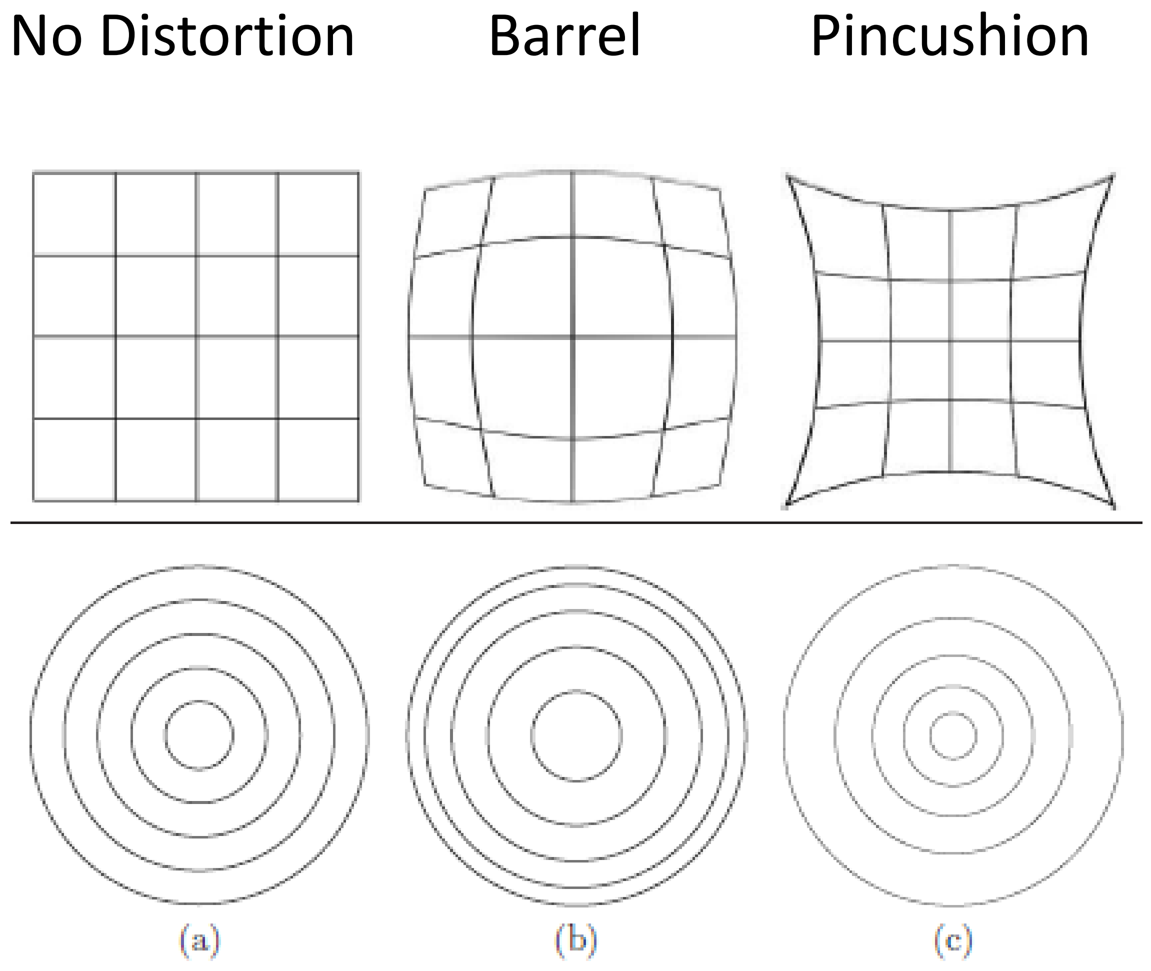


Figure 4.19: Spherical aberration causes imperfect focus because rays away from the optical axis are refracted more

Optical Distortion

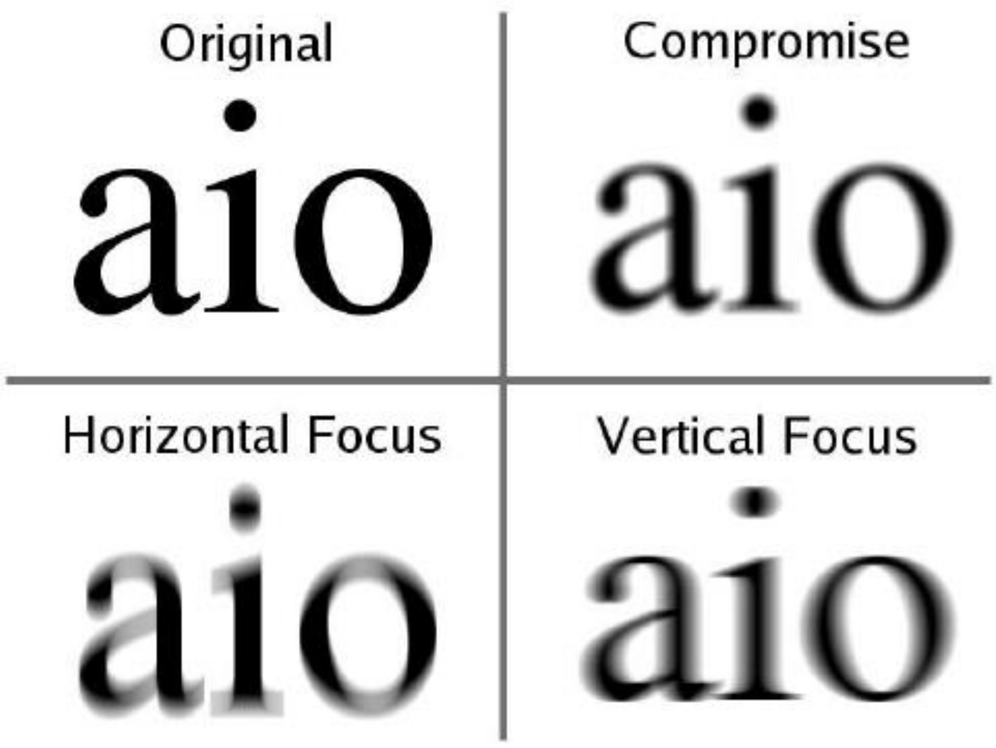


Optical Distortion

- Barrel distortion corrected in HMDs

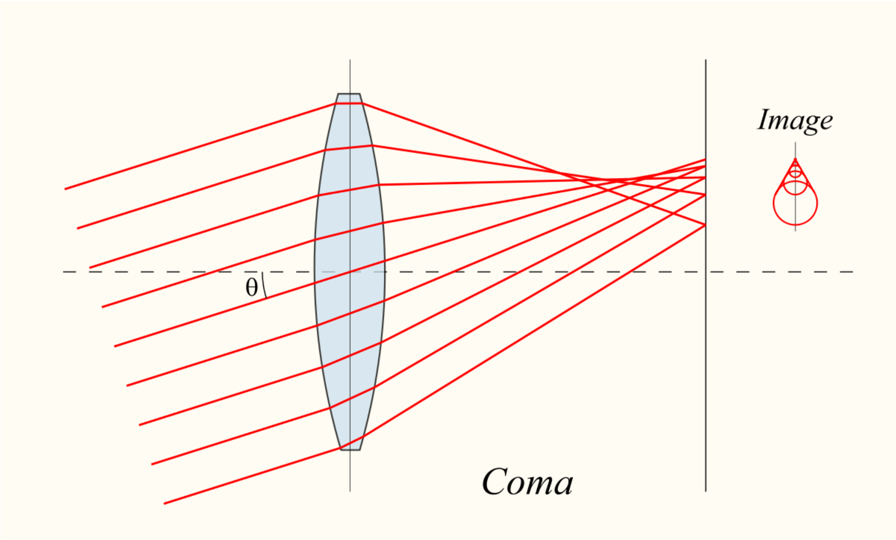
Astigmatism

- Different horizontal and vertical convergence



Coma and Flare

Coma



Light coming in at steep angle

Flare

Scattering of especially bright light

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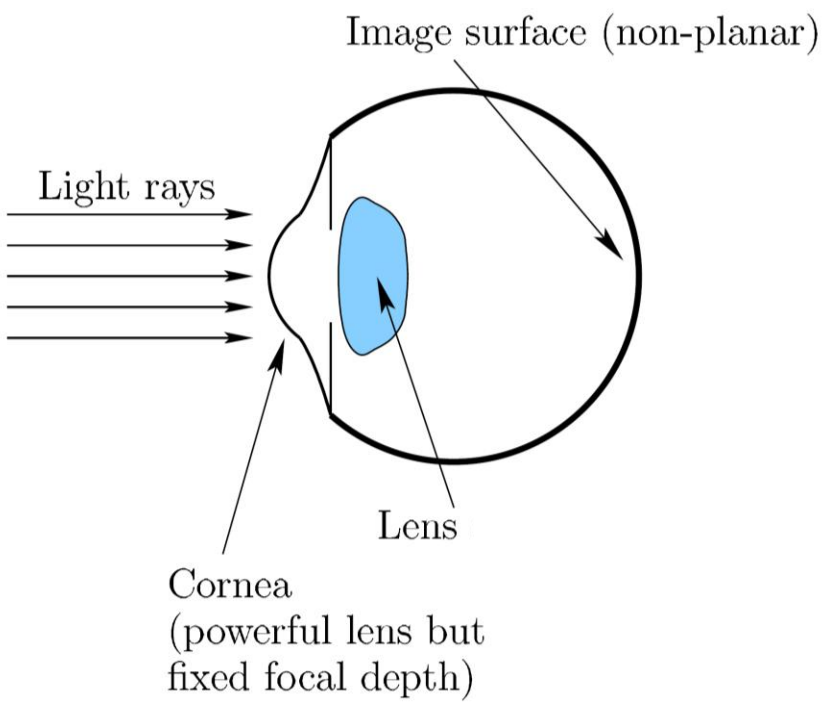
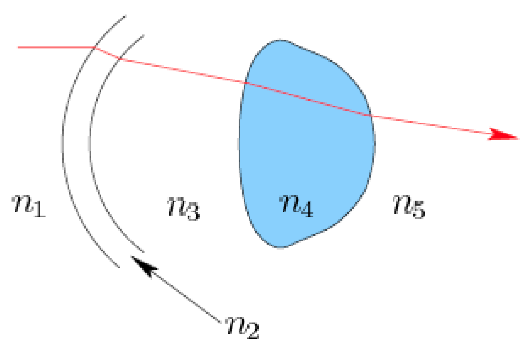
Optics of the Human Eye



How does the human eye change focus?



1. $n_1 = 1.009$ (air)
2. $n_2 = 1.376$ (cornea)
3. $n_3 = 1.336$ (aqueous fluid)
4. $n_4 = 1.413$ (lens)
5. $n_5 = 1.337$ (vitreous fluid)

Accommodation

- Changing the thickness of the lens

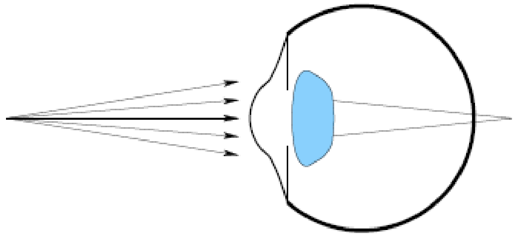


Figure 4.27: A closer object yields diverging rays, but with a relaxed lens, the image is blurry on the retina.

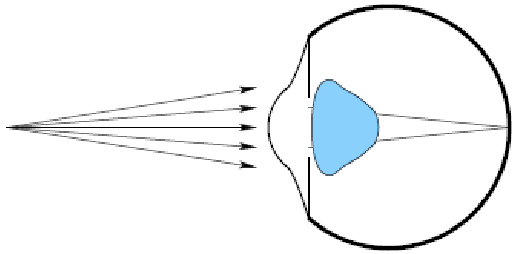


Figure 4.28: The process of accommodation: The eye muscles pull on the lens, causing it to increase the total optical power and focus the image on the retina.

Presbyopia

- Stiffness of the lens - inability to focus near

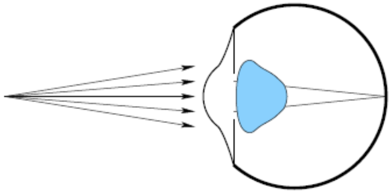


Figure 4.28: The process of accommodation: The eye muscles pull on the lens, causing it to increase the total optical power and focus the image on the retina.

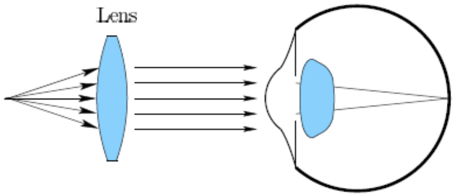
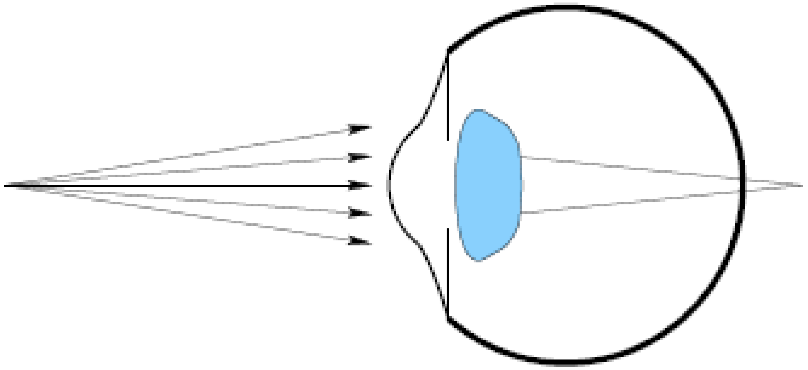


Figure 4.29: Placing a convex lens in front of the eye is another way to increase the optical power so that nearby objects can be brought into focus by the eye. This is the principle of reading glasses.

Near- or Far-sighted?

- Lens focuses image off the retina



Lenses for VR

- Screen appears to be at infinity

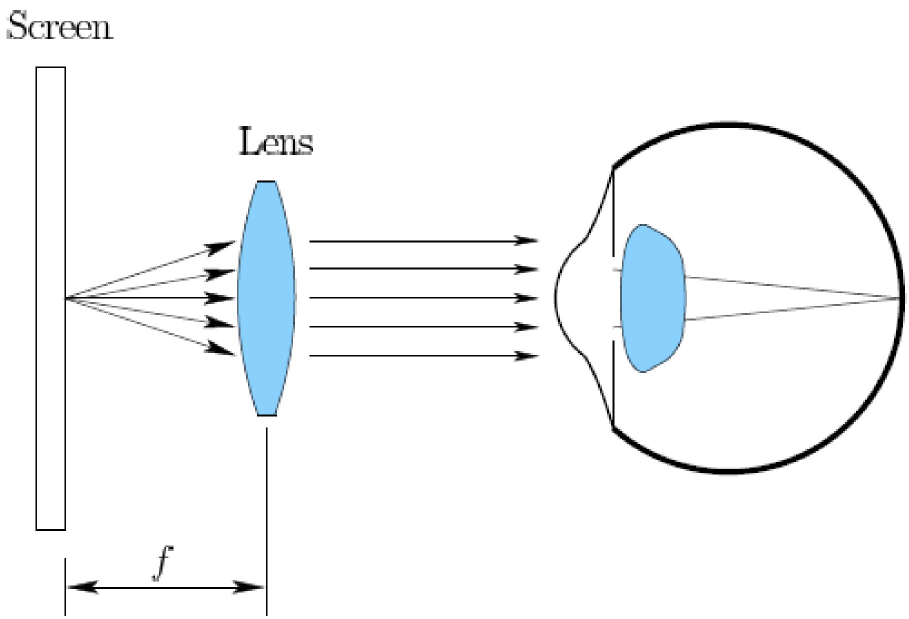
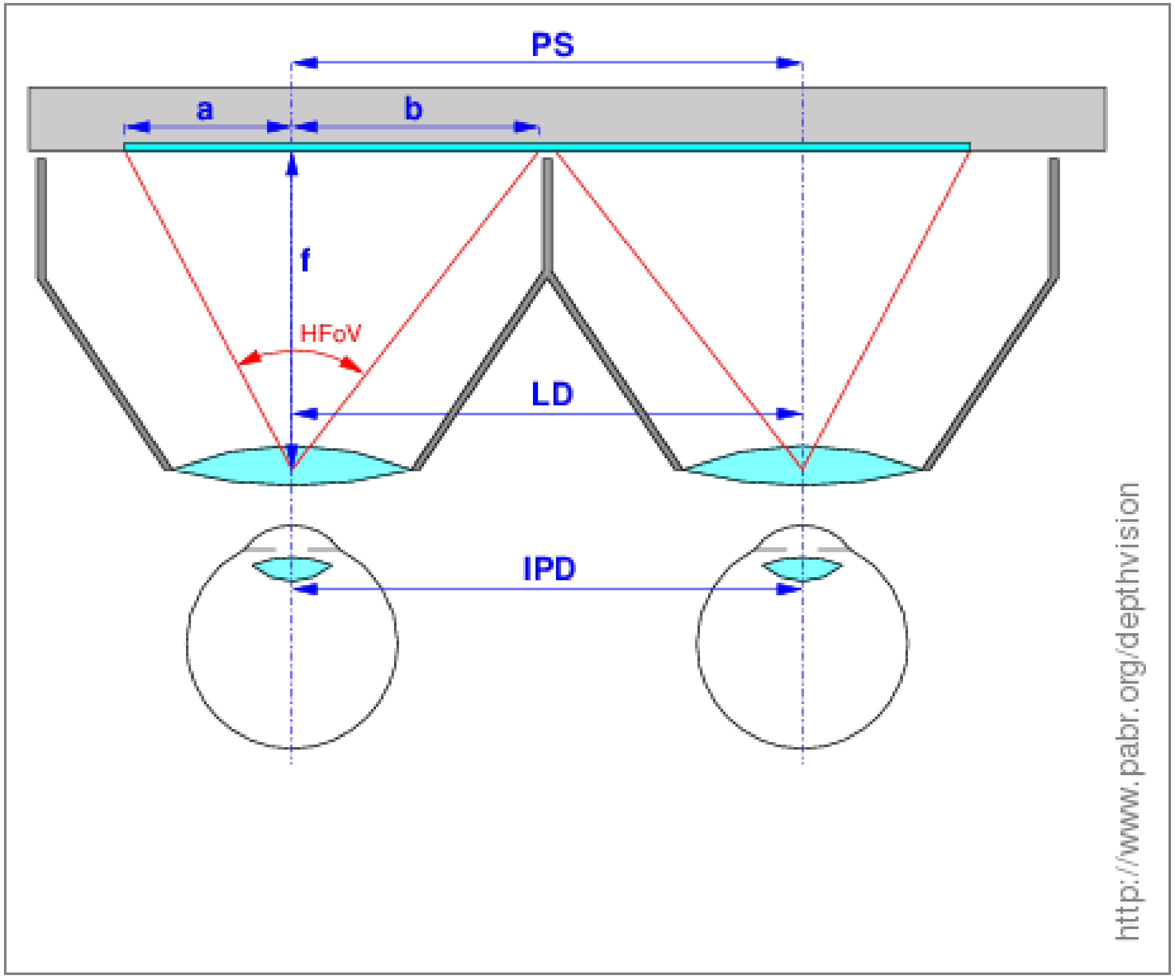


Figure 4.30: In VR headsets, the lens is placed so that the screen appears to be infinitely far away.

- What is the accommodative state of the lens?

Alignment of eyes for VR



Screen

Lenses

Eye

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Cameras – artificial eyes

- Pinhole camera (camera obscura)

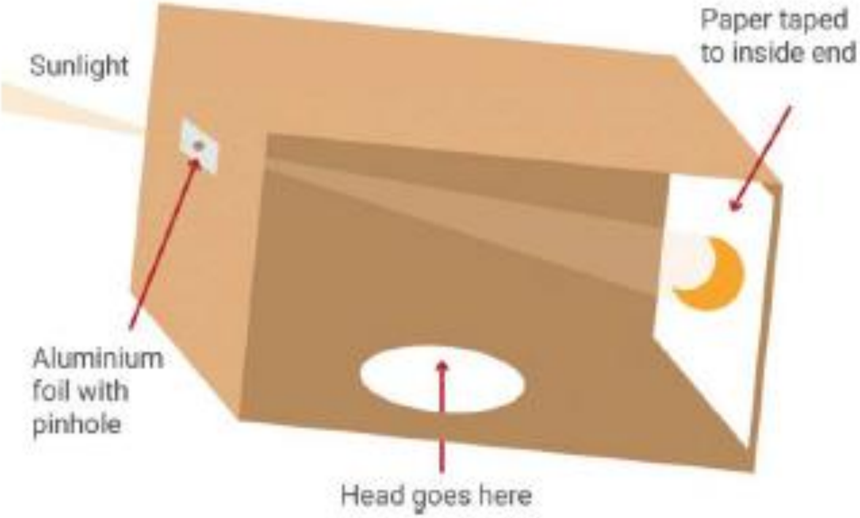


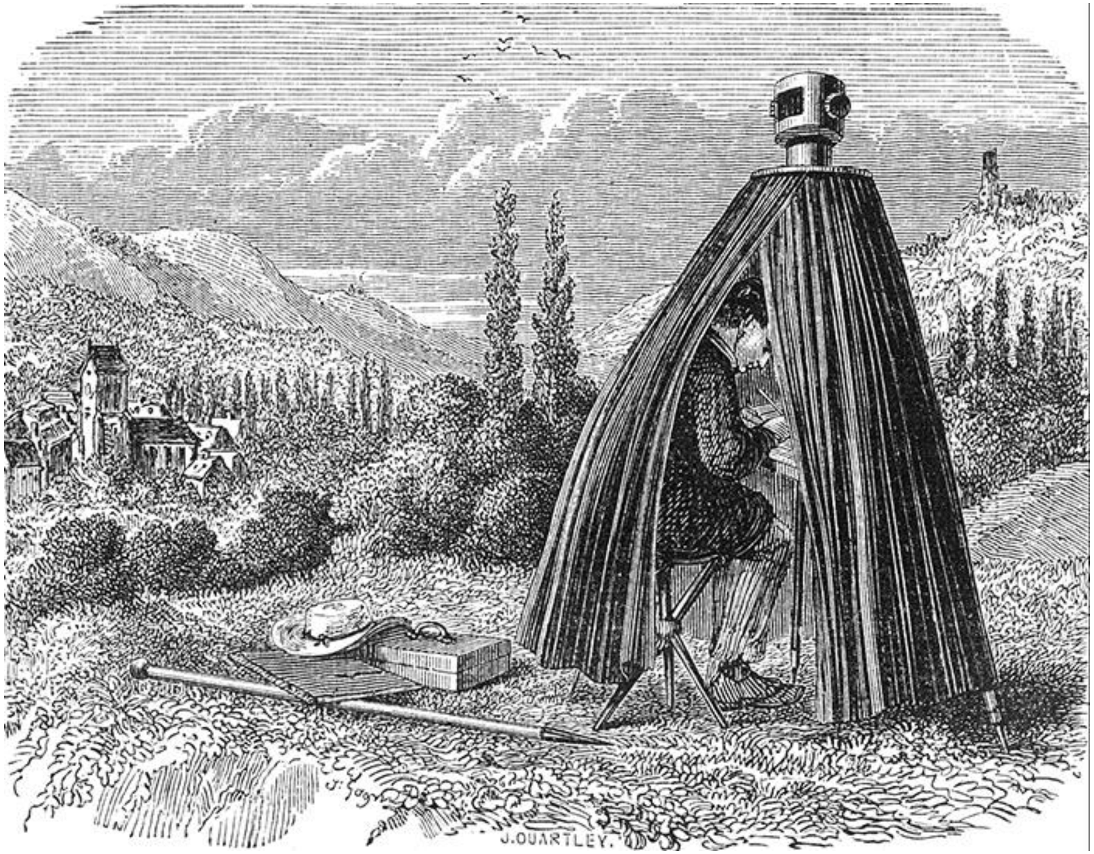
Figure 4.31: A pinhole camera that is recommended for viewing a solar eclipse. (Figure from TimeAndDate.com.)

Cameras – artificial eyes

- Pinhole viewing of eclipse

Cameras – artificial eyes

- Aid for drawing and painting

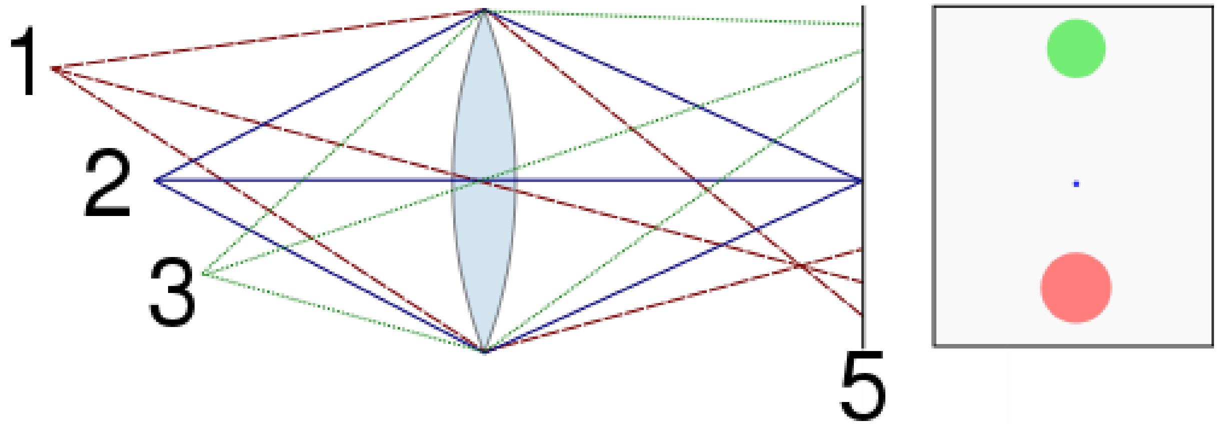


Cameras – artificial eyes

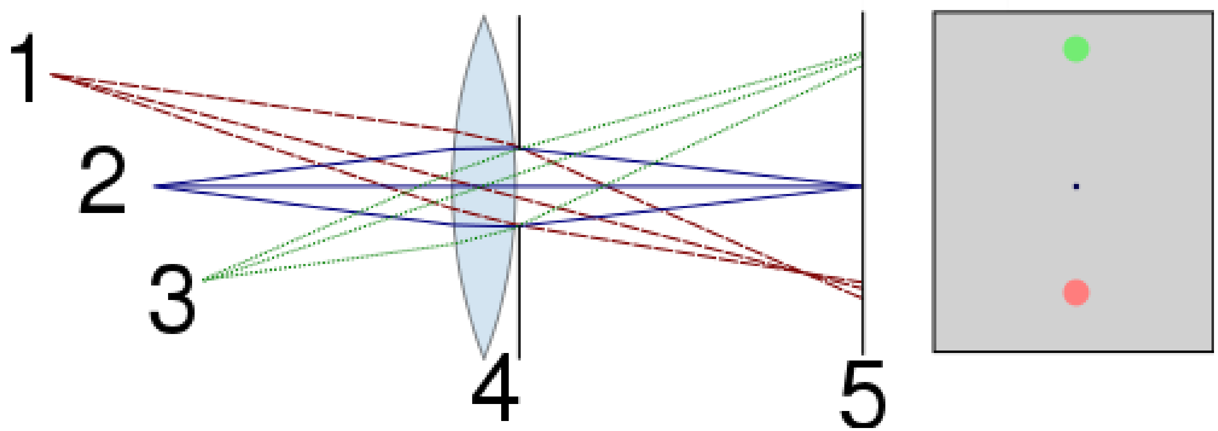
- Burning man – pinhole project

Aperture and Depth of Field

Large aperture



Small aperture



Camera Aperture and Shutter Speed

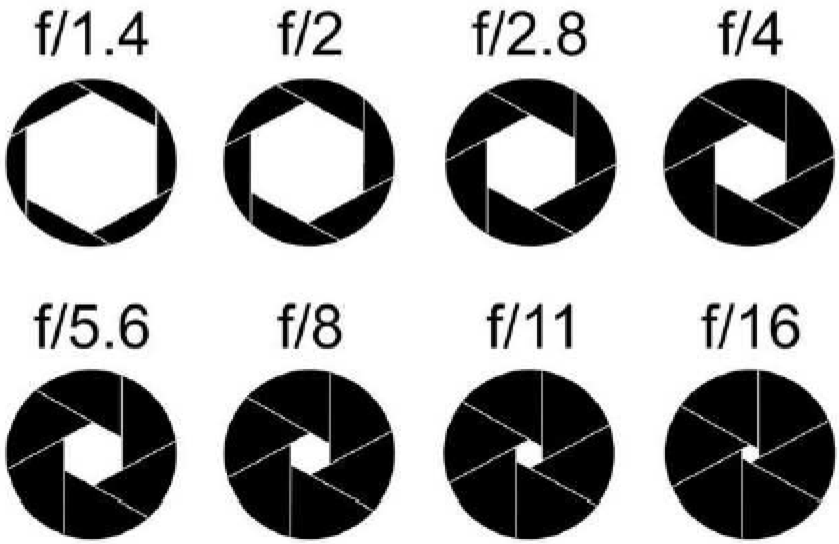
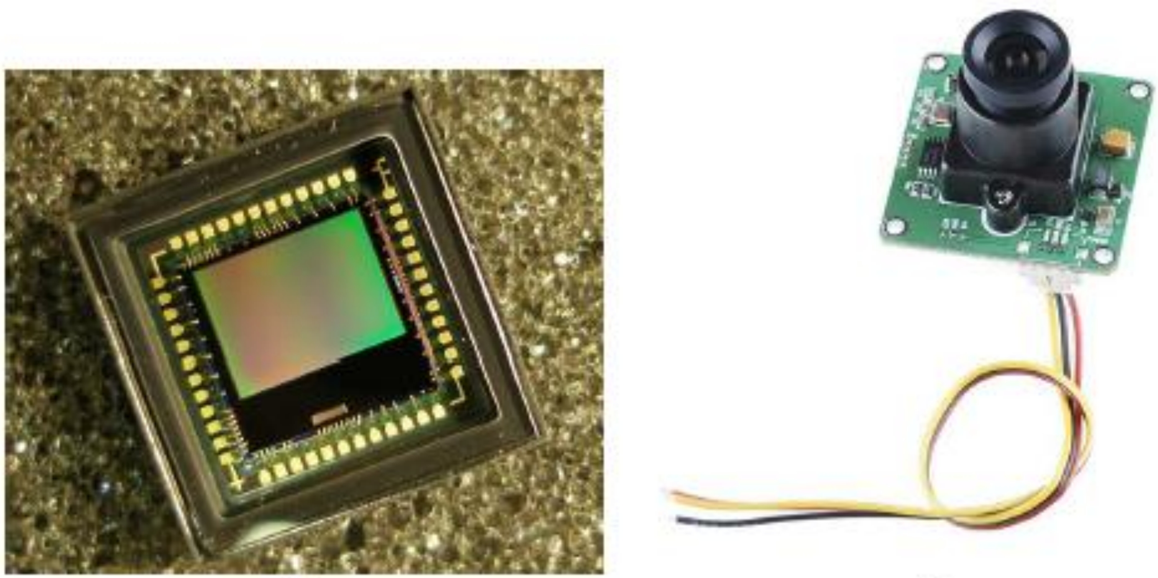


Figure 4.34: A spectrum of aperture settings, which control the amount of light that enters the lens. The values shown are called the *focal ratio* or *f-stop*.

Shutter Speed and Blur

Digital Cameras

- RGB sensors
- Rolling shutter



(a) (b)

Recap

- Behavior and properties of light
- Lenses
- Aberrations
- Human eye
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- Next week: Physiology of human vision