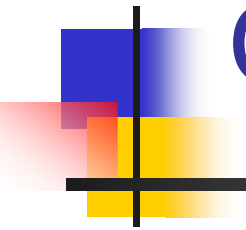


# Chapter 25

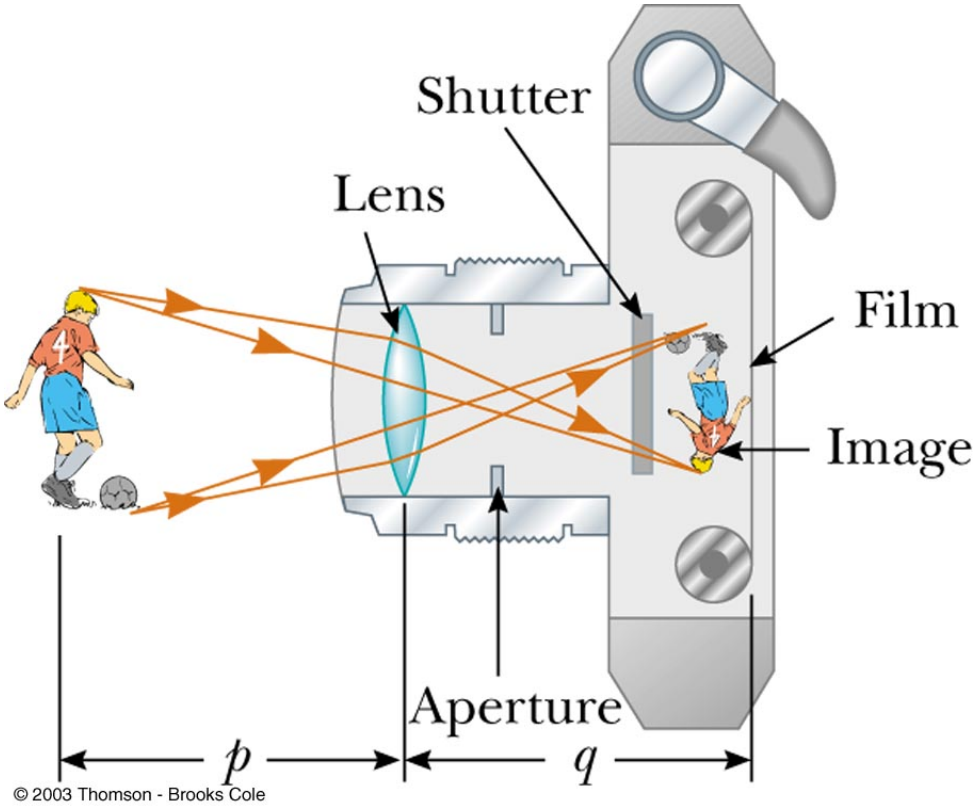
## Optical Instruments

# Optical Instruments

- Analysis involves the laws of reflection and refraction
- Analysis uses the procedures of geometric optics

# The Camera

- The single-lens photographic camera is an optical instrument
- Components
  - Light-tight box
  - Converging lens
    - Produces a real image
  - Film behind the lens
    - Receives the image

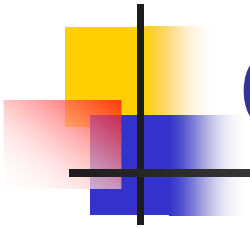


# Camera Operation

- Proper focusing leads to sharp images
  - The lens-to-film distance will depend on the object distance and on the focal length of the lens
- The shutter is a mechanical device that is opened for selected time intervals
- Most cameras have an aperture of adjustable diameter to further control the intensity of the light reaching the film

# Camera, f-numbers

- The *f*-number of a camera is the ratio of the focal length of the lens to its diameter
  - *f*-number = f/D
  - The *f*-number is often given as a description of the lens “speed”
    - A lens with a low f-number is a “fast” lens

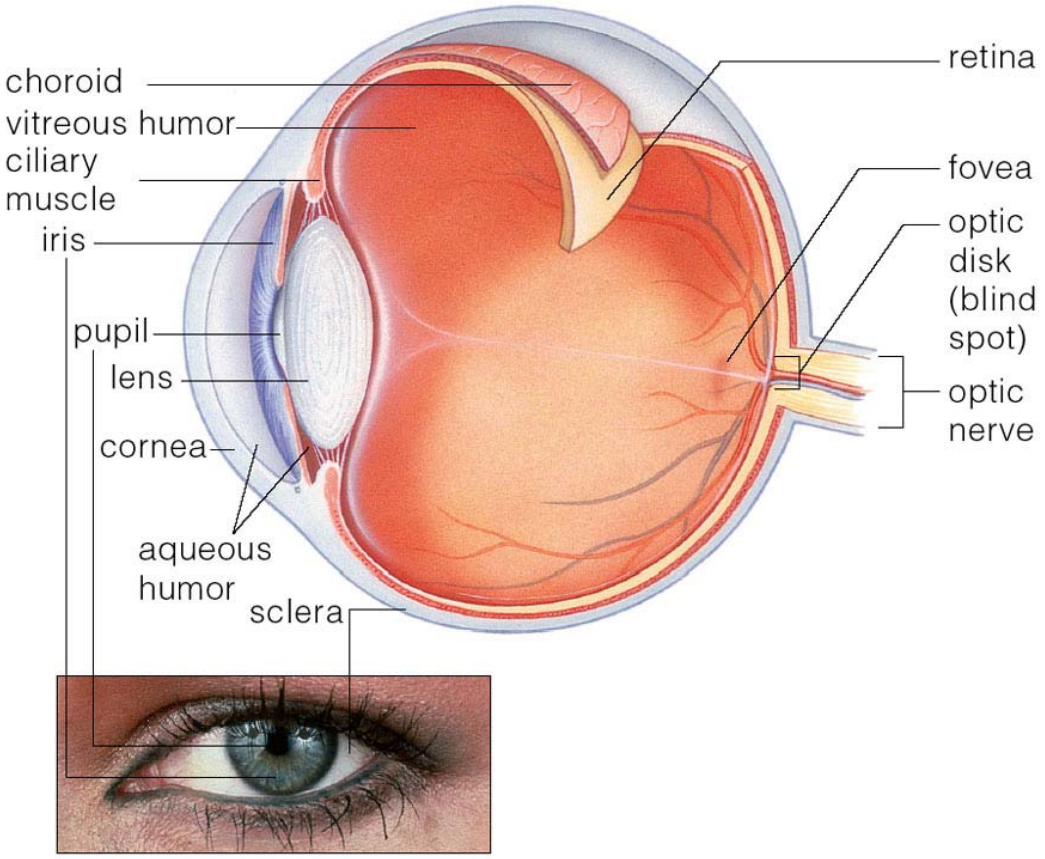


# Camera, f-numbers, cont

- Increasing the setting from one *f*-number to the next higher value decreases the area of the aperture by a factor of 2
- The lowest *f*-number setting on a camera corresponds to the aperture wide open and the maximum possible lens area in use
- Simple cameras usually have a fixed focal length and a fixed aperture size, with an *f*-number of about 11
  - Most cameras with variable *f*-numbers adjust them automatically

# The Eye

- The normal eye focuses light and produces a sharp image
- Essential parts of the eye
  - Cornea – light passes through this transparent structure
  - Aqueous Humor – clear liquid behind the cornea



# The Eye – Parts, cont

- The pupil
  - A variable aperture
  - An opening in the iris
- The crystalline lens
- Most of the refraction takes place at the outer surface of the eye
  - Where the cornea is covered with a film of tears

# The Eyes – Parts, final

- The iris is the colored portion of the eye
  - It is a muscular diaphragm that controls pupil size
  - The iris regulates the amount of light entering the eye by dilating the pupil in low light conditions and contracting the pupil in high-light conditions
  - The f-number (f/D) of the eye is from about 2.8 to 16

# The Eye – Operation

- The cornea-lens system focuses light onto the back surface of the eye
  - This back surface is called the *retina*
  - The retina contains receptors called rods and cones
  - These structures send impulses via the optic nerve to the brain
    - The brain converts these impulses into our conscious view of the world

# The Eye – Operation, cont

- Rods and Cones
  - Chemically adjust their sensitivity according to the prevailing light conditions
    - The adjustment takes about 15 minutes
    - This phenomena is “getting used to the dark”
- Accommodation
  - The eye focuses on an object by varying the shape of the crystalline lens through this process
  - An important component is the *ciliary muscle* which is situated in a circle around the rim of the lens
  - Thin filaments, called *zonules*, run from this muscle to the edge of the lens

# The Eye – Focusing

- The eye can focus on a distant object
  - The ciliary muscle is relaxed
  - The zonules tighten
  - This causes the lens to flatten, increasing its focal length
  - For an object at infinity, the focal length of the eye is equal to the fixed distance between lens and retina
    - This is about 1.7 cm

# The Eye – Focusing, cont

- The eye can focus on near objects
  - The ciliary muscles tenses
  - This relaxes the zonules
  - The lens bulges a bit and the focal length decreases
  - The image is focused on the retina

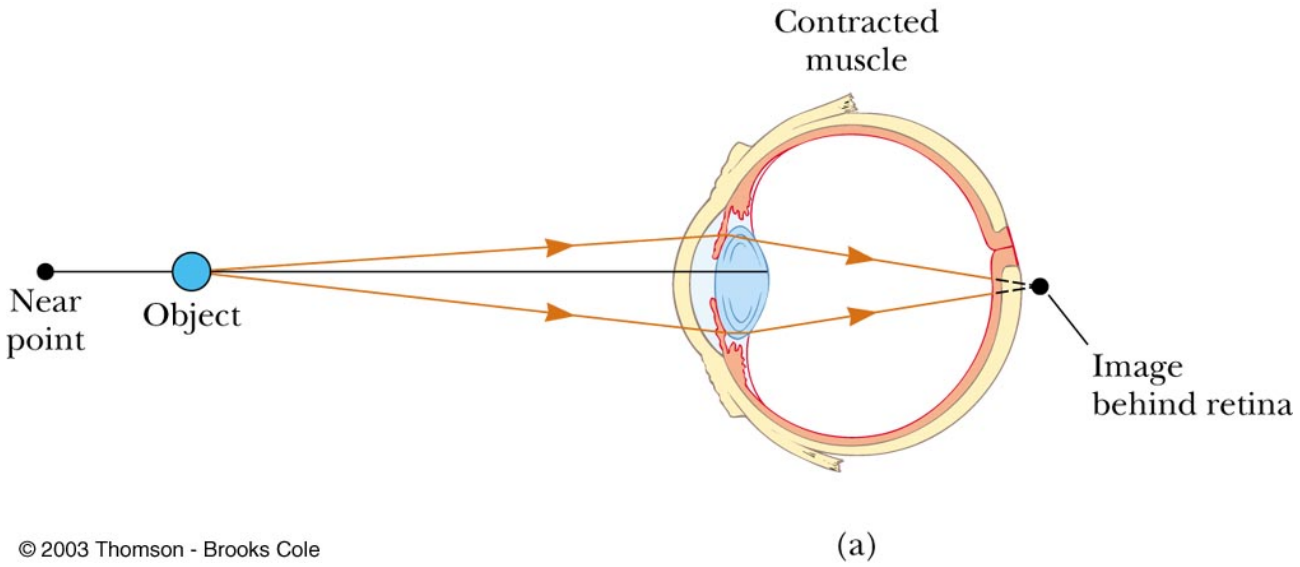
# The Eye – Near and Far Points

- The *near point* is the closest distance for which the lens can accommodate to focus light on the retina
  - normal value for a grown person is about 25 cm
  - Usually at age 10, this is about 18 cm
  - It increases with age
- The *far point* of the eye represents the largest distance for which the lens of the relaxed eye can focus light on the retina
  - Normal vision has a far point of infinity

# Conditions of the Eye

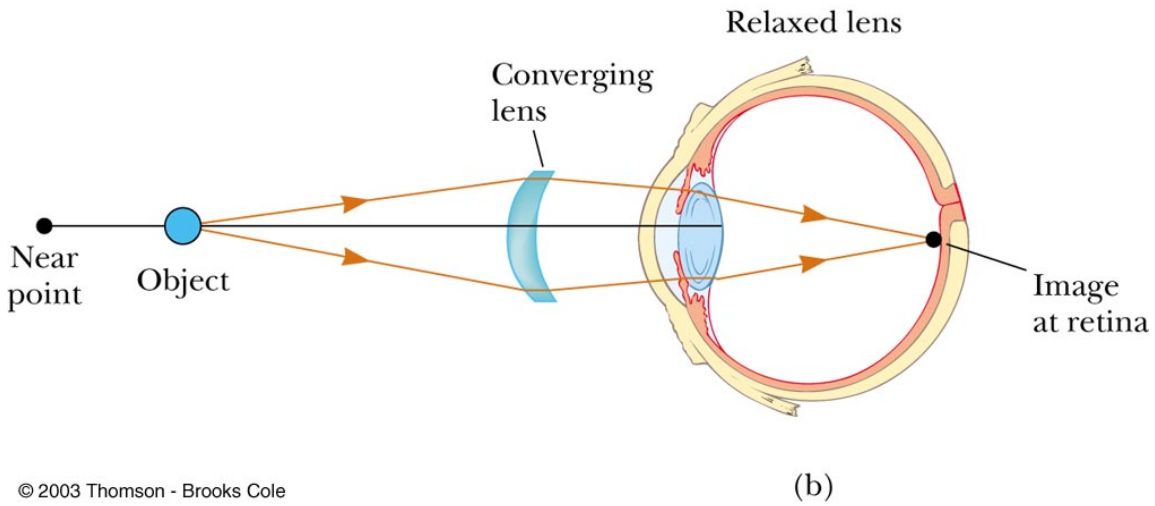
- Eyes may suffer a mismatch between the focusing power of the lens-cornea system and the length of the eye
- Eyes may be
  - Farsighted
    - Light rays reach the retina before they converge to form an image
  - Nearsighted
    - Person can focus on nearby objects but not those far away

# Farsightedness



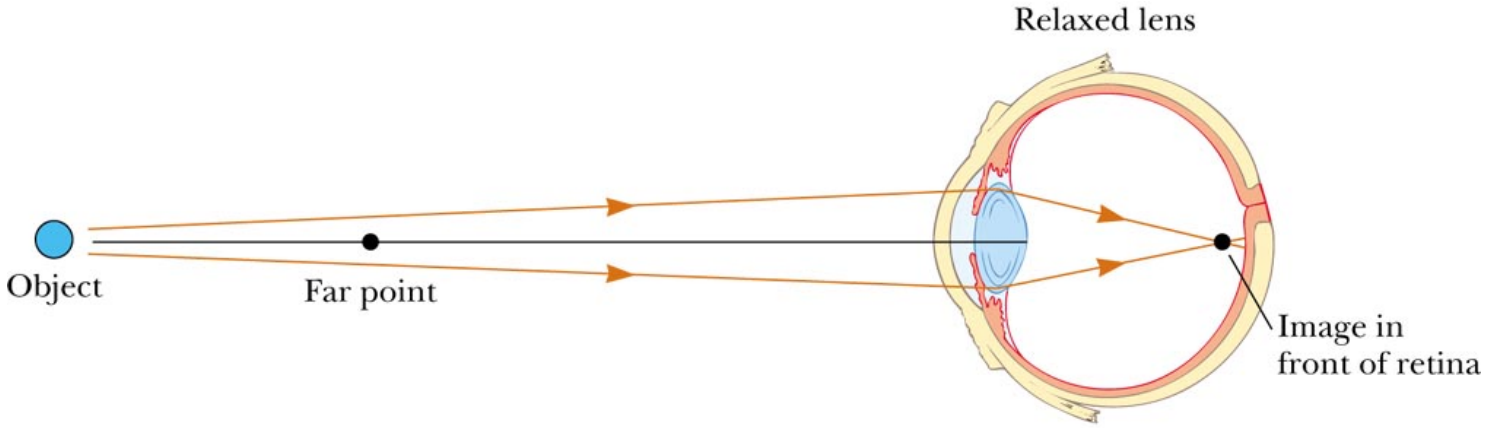

- Also called hyperopia
- The image focuses behind the retina
- Can usually see far away objects clearly, but not nearby objects

# Correcting Farsightedness




- A converging lens placed in front of the eye can correct the condition
- The lens refracts the incoming rays more toward the principle axis before entering the eye
  - This allows the rays to converge and focus on the retina

# Nearsightedness

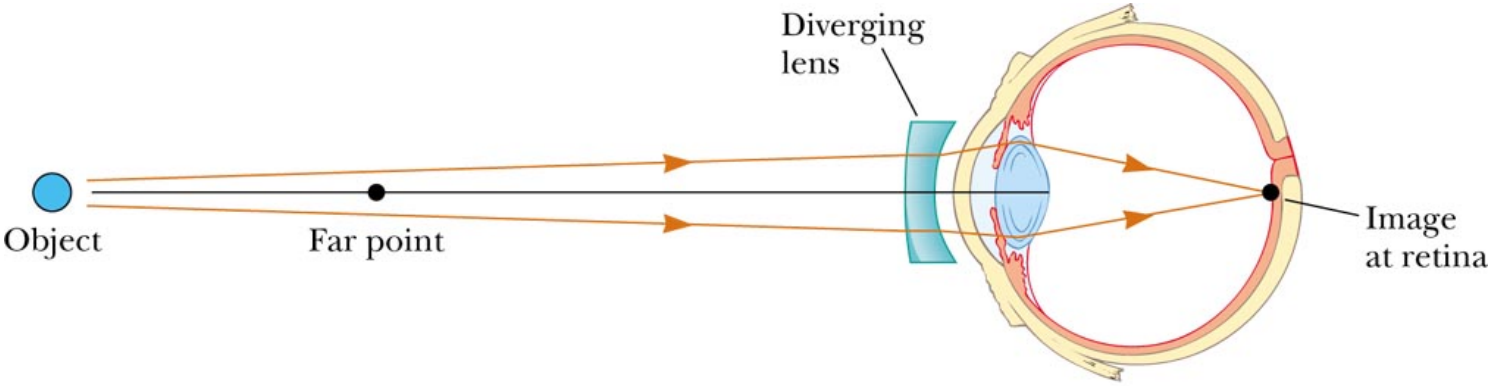





(a)

- Also called myopia
- In *axial myopia* the nearsightedness is caused by the lens being too far from the retina
- In *refractive myopia*, the lens-cornea system is too powerful for the normal length of the eye

# Correcting Nearsightedness






(b)

- A diverging lens can be used to correct the condition
- The lens refracts the rays away from the principle axis before they enter the eye
  - This allows the rays to focus on the retina

# Presbyopia and Astigmatism

- Presbyopia is due to a reduction in accommodation ability, usually due to age
  - The cornea and lens do not have sufficient focusing power to bring nearby objects into focus on the retina
  - Condition can be corrected with converging lenses
- In astigmatism, the light from a point source produces a line image on the retina
  - Produced when either the cornea or the lens or both are not perfectly symmetric

# Diopters

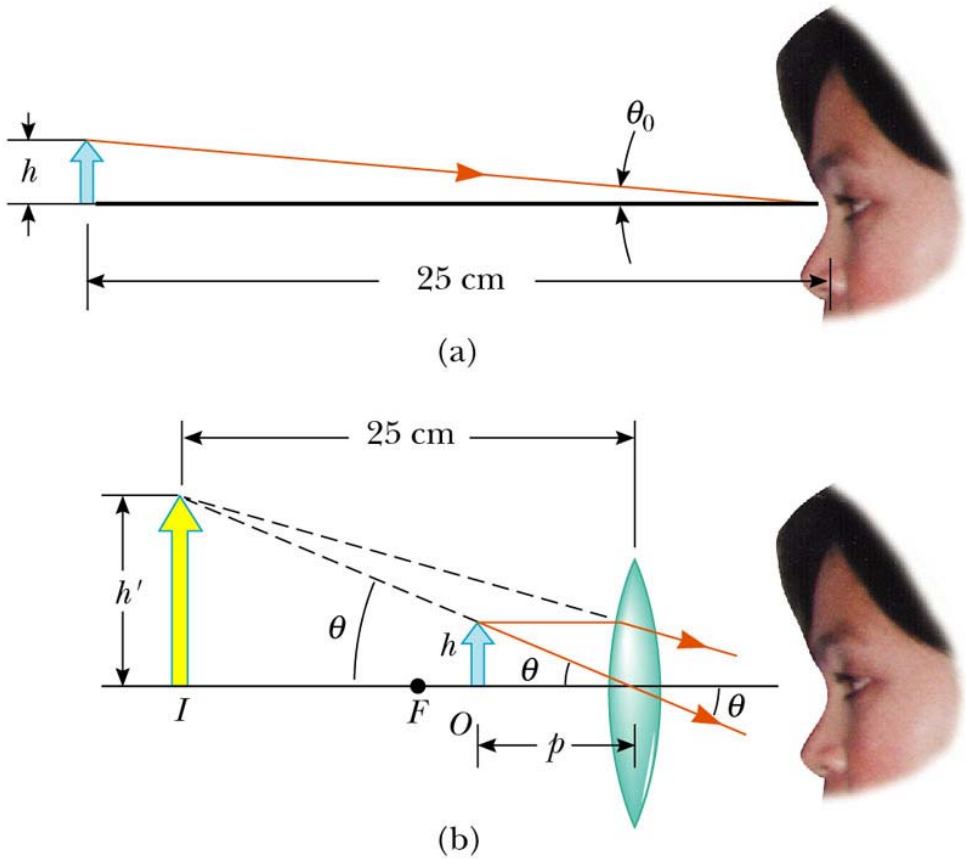
- Optometrists and ophthalmologists usually prescribe lenses measured in diopters
  - The power of a lens in diopters equals the inverse of the focal length in meters
  - $$\wp = \frac{1}{f}$$

# Simple Magnifier

- A simple magnifier consists of a single converging lens
- This device is used to increase the apparent size of an object
- The size of an image formed on the retina depends on the angle subtended by the eye

# The Size of a Magnified Image

- When an object is placed at the near point, the angle subtended is a maximum
  - The near point is about 25 cm
- When the object is placed near the focal point of a converging lens, the lens forms a virtual, upright, and enlarged image



# Angular Magnification

- Angular magnification is defined as

$$m \equiv \frac{\theta}{\theta_o} = \frac{angle\ with\ lens}{angle\ without\ lens}$$

- The angular magnification is at a maximum when the image formed by the lens is at the near point of the eye
  - q = - 25 cm
  - Calculated by $m_{max} = 1 + \frac{25\,cm}{q}$

# Magnification by a Lens

- With a single lens, it is possible to achieve angular magnification up to about 4 without serious aberrations
- With multiple lenses, magnifications of up to about 20 can be achieved
  - The multiple lenses can correct for aberrations