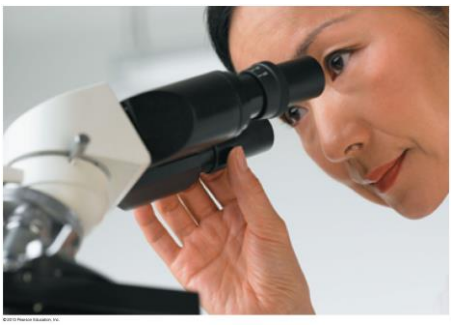
PHY132 Introduction to Physics II
Class 7 – **Outline:**

- Ch. 24
- Lenses in Combination
- The Camera
- Vision
- Magnifiers



Class 7 Preclass Quiz on MasteringPhysics

- This was due this morning at 8:00am
- 662 students submitted the quiz on time
- 98% got: Lens power is measured in units of **Diopters**. (This is actually review; I mentioned this in class last week.)
- 81% got: The magnification of a simple magnifier is

$$M = \frac{25\ \text{cm}}{f}$$

So you can increase the magnification by **decreasing** f.

- 90% got: If the near point of your eye is at 75 cm, you are **farsighted**. (Hyperopia)

Class 7 Preclass Quiz – Student Comments…

- *"Do we need to do know all the equations for these different magnifier for the test?"*
- **Harlow answer:** If it's in your reading and you can't derive it, then you should **put the equation on your aid sheet**. That's what the aid sheet is for!
- *"Why is there chromatic aberration with white light not being able to see a clear image?"*
- **Harlow answer:** If you look at the lensmaker's formula, you will see that the focal length is dependent on the index of refraction, n. For glass, n depends on frequency so in fact the focal length of a lens depends on frequency. White light is a mixture of all frequencies so the image is always a bit blurry.

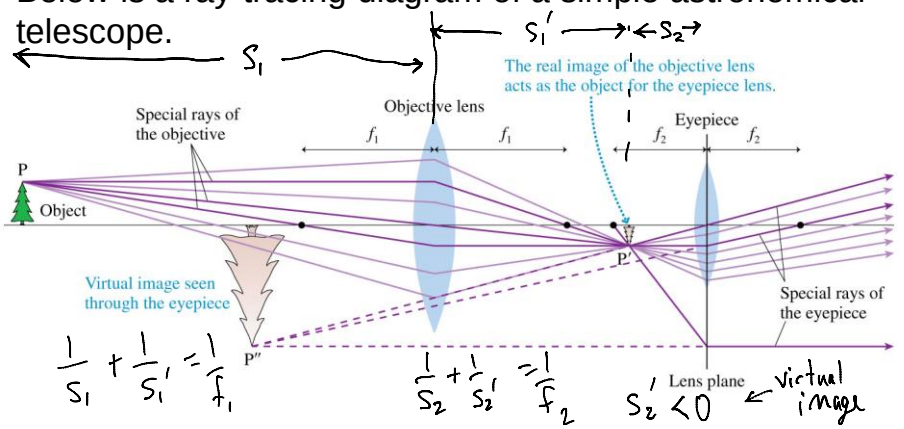
$$\frac{1}{s_{o1}} + \frac{1}{s_{i2}} = (n_l - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \simeq \frac{1}{f}$$

Class 7 Preclass Quiz – Student Comments…

- *"Understanding that I wear contacts because my eyeballs are too long was an interesting revelation.... Also that the size of the telescope, unless we find some other method, will continue to increase forever and ever so we can see further."*
- *"thank you for giving the lecture on after image when you did. The timing was perfect, because it helped me disprove an opposing argument in my philosophy paper. Thank you!"*

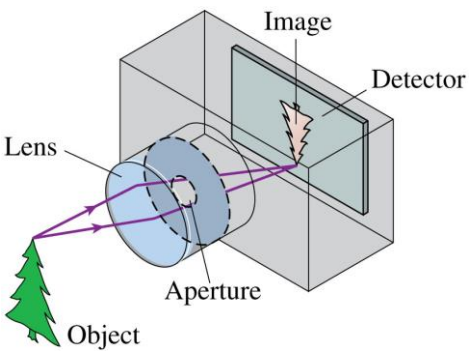
Lenses in Combination

- The analysis of multi-lens systems requires only one new rule: **The image of the first lens acts as the object for the second lens.**
- Below is a ray-tracing diagram of a simple astronomical telescope.

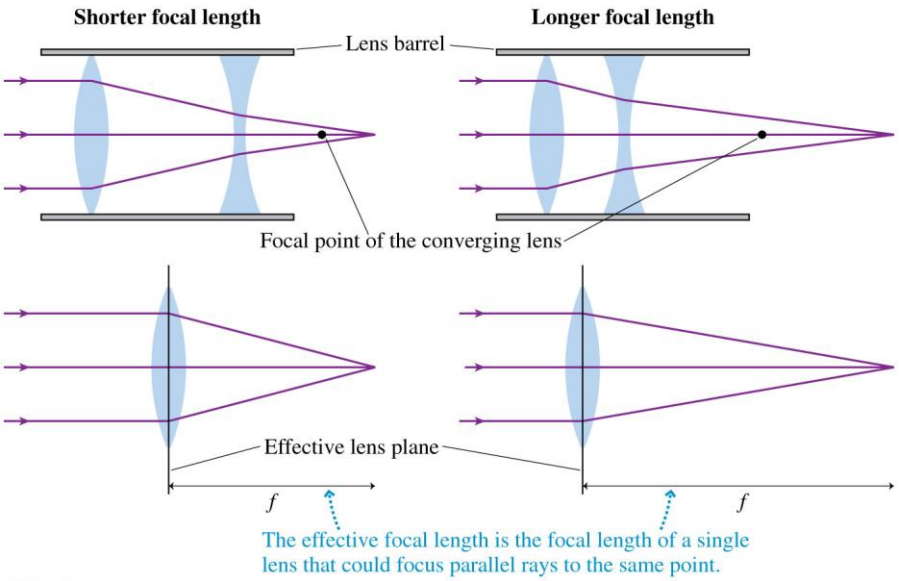


The Camera

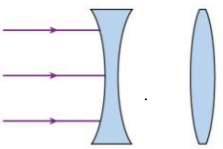
- A **camera** "takes a picture" by using a lens to form a real, inverted image on a light-sensitive detector in a light-tight box.
- We can model a combination lens as a single lens with an **effective focal length** (usually called simply "the focal length").
- A *zoom lens* changes the effective focal length by varying the spacing between the converging lens and the diverging lens.



A Simple Camera Lens Is a Combination Lens



The parallel light rays will be focused at a point _____ the second lens than would light focused by the second lens acting alone.



A. closer to
B. the same distance from
C. farther from

Zoom Lenses

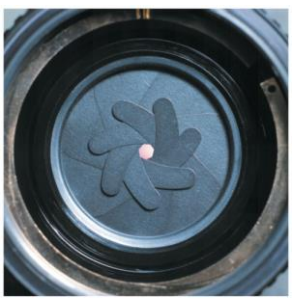
$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ $\quad s \to \infty, \frac{1}{s} \to 0$ $\quad s \approx f$

- When cameras focus on objects that are more than 10 focal lengths away (roughly $s > 20$ cm for a typical digital camera), the object is essentially "at infinity" and $s' \approx f$.
- The lateral magnification of the image is

$$m = -\frac{s'}{s} \approx -\frac{f}{s}$$

- The magnification is much less than 1, because $s >> f$, so the image on the detector is much smaller than the object itself.
- More important, **the size of the image is directly proportional to the focal length of the lens.**

Controlling the Exposure



- The amount of light passing through the lens is controlled by an adjustable **aperture,** shown in the photos.
- The aperture sets the effective diameter *D* of the lens.
- The light-gathering ability of a lens is specified by its ***f*-number**, defined as

dimensionless

$$f\text{-number} = \frac{f}{D}$$ f = focal length [m], D = diameter of aperture [m]

- The light intensity on the detector is related to the lens's *f*-number by

$$I \propto \frac{D^2}{f^2} = \frac{1}{(f\text{-number})^2}$$

"F4.0" means $\frac{f}{D} = 4.0$, "F8.0" means $\frac{f}{D} = 8.0$

If the *f*-number of a camera lens is doubled, say from F4.0 to F8.0, that means the diameter of the lens aperture is

A. Quadrupled (increased by a factor of 4).

B. Doubled (increased by a factor of 2).

C. Halved (decreased by a factor of 2).

D. Quartered (decreased by a factor of 4).

Controlling the Exposure

- Focal length and *f*-number information is stamped on a camera lens.
- This lens is labeled 5.8–23.2 mm 1:2.6–5.5.
- The first numbers are the range of focal lengths.

- They span a factor of 4, so this is a 4 × zoom lens.
- The second numbers show that the minimum *f*-number ranges from *f*/2.6 (for the $f = 5.8$ mm focal length) to *f*/5.5 (for the $f = 23.2$ mm focal length).

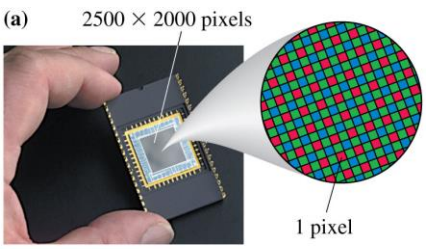
A camera gives a proper exposure when set to a shutter speed of $1/250$ s at f-number F8.0. The photographer wants to change the shutter speed to $1/1000$ s to prevent motion blur. To maintain proper exposure, she should also change the f-number to

A. F2.0.
B. F4.0.
C. F8.0.
D. F16.
E. F32.

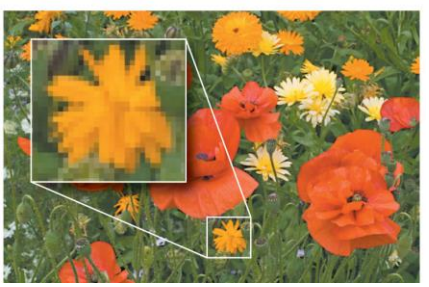
time reduced by $\frac{1}{4}$.
You want same amount of energy...
You should increase area of aperture by 4.
→ increase D by 2.
decreases f-number by 2....

The Detector

- Figure (a) shows a CCD "chip."
- To record color information, different pixels are covered by red, green, or blue filters.
- The pixels are so small that the picture looks "smooth" even after some enlargement.
- As you can see in figure (b), sufficient magnification reveals the individual pixels.

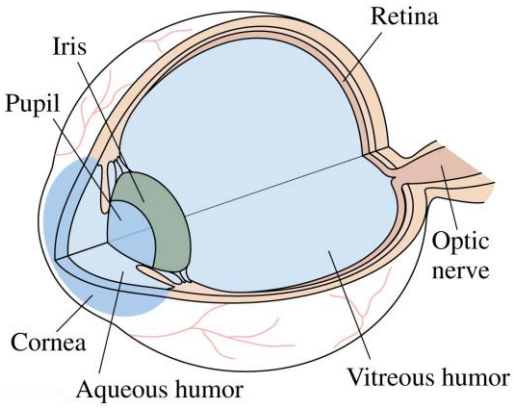


(b)



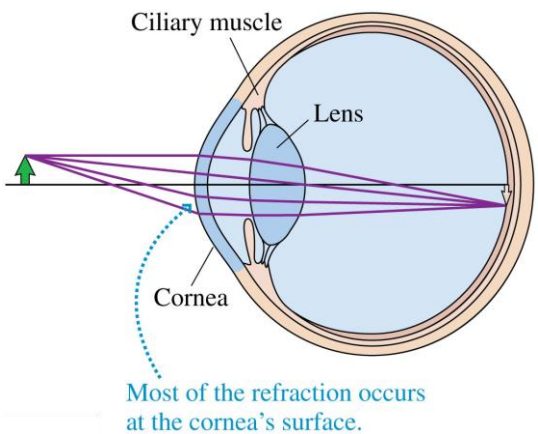
Vision

- The human eye is roughly spherical, about $2.4\ \text{cm}$ in diameter.
- The transparent **cornea** and the *lens* are the eye's refractive elements.
- The eye is filled with a clear, jellylike fluid called the *aqueous humor* and the *vitreous humor.*



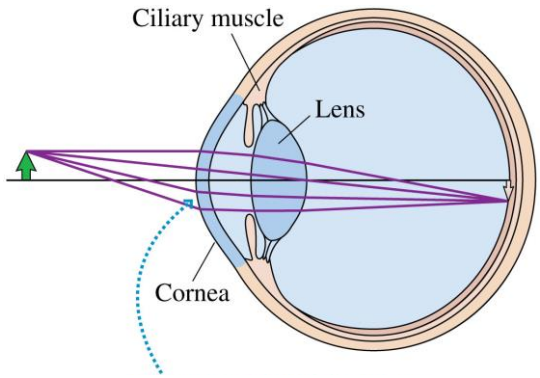
Vision

- The indices of refraction of the aqueous and vitreous humors are 1.34, only slightly different from water.
- The lens has an average index of 1.44.
- The **pupil,** a variable-diameter aperture in the **iris,** automatically opens and closes to control the light intensity.
- The f-number varies from roughly $f/3$ to $f/16$, very similar to a camera!



Focusing and Accommodation

- The eye focuses by changing the focal length of the lens by using the *ciliary muscles* to change the curvature of the lens surface.
- Tensing the ciliary muscles causes **accommodation,** which decreases the lens's radius of curvature and thus decreases its focal length.

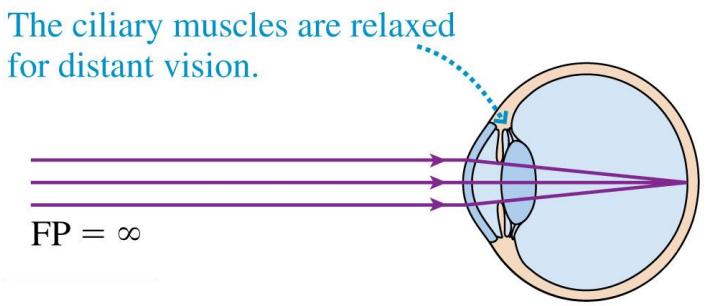


Class 7 Preclass Quiz – Student Comments…

- *"If farsightedness and nearsightedness depends on the shape of the eye, how does people that are not born farsighted or nearsighted become farsighted or nearsighted? Does their eyeball change shape? Parents always say that watching too much television will make your eyes nearsighted. How does television make you nearsighted?"*
- **Harlow answer (keep in mind, I am not an optometrist):** When you relax your eye, your lens has its lowest power and you are focusing on the most distant objects. To look at nearby objects, you must increase the focussing power by squishing the lens. Too much long term squishing can reduce the flexibility of your lens to spring back to unsquished.

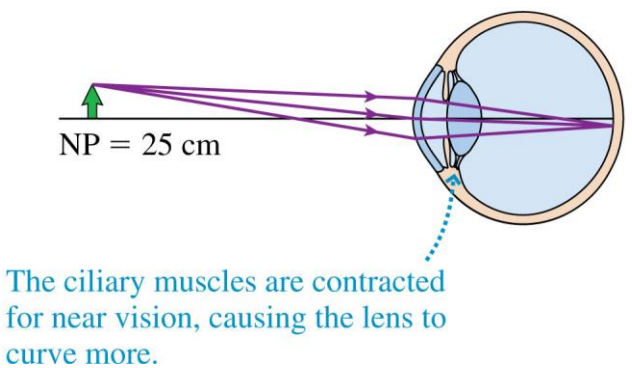
Focusing and Accommodation

- The farthest distance at which a relaxed eye can focus is called the eye's **far point** (FP).
- The far point of a normal eye is infinity; that is, the eye can focus on objects extremely far away.



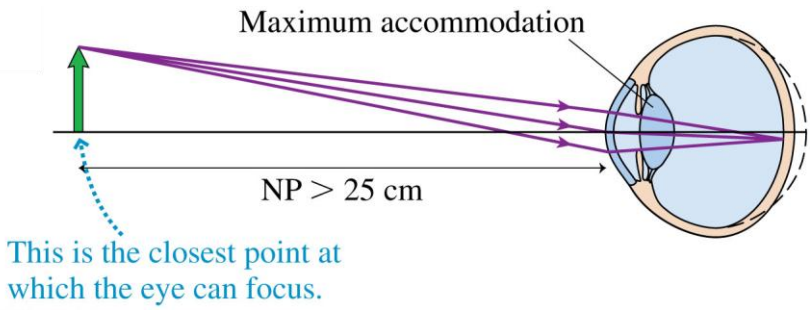
Focusing and Accommodation

- The closest distance at which an eye can focus, using maximum accommodation, is the eye's **near point** (NP).



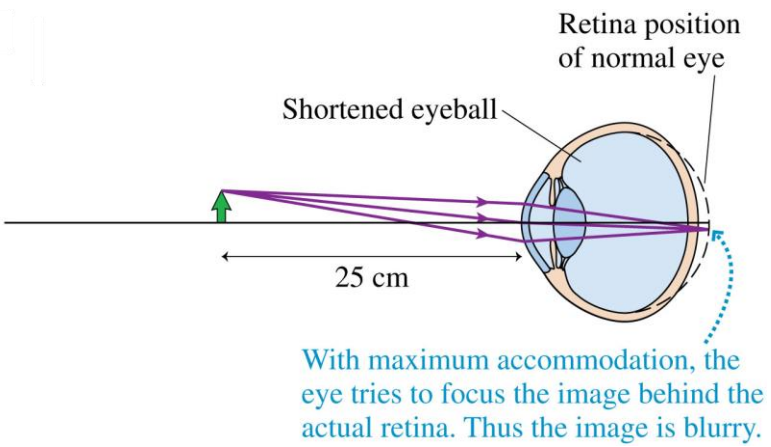
Hyperopia

A person who is *farsighted* can see faraway objects (but even then must use some accommodation rather than a relaxed eye), but his near point is larger than 25 cm, often much larger, so he cannot focus on nearby objects.



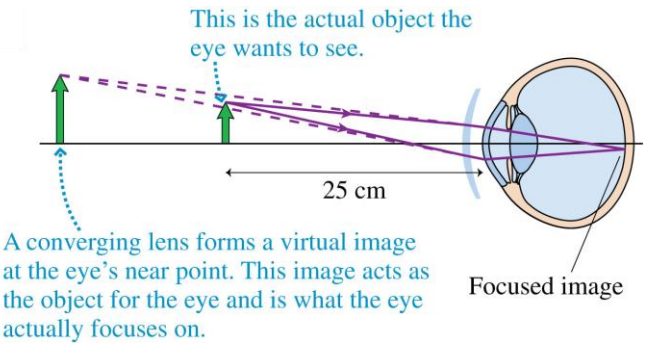
Hyperopia

The cause of farsightedness — called **hyperopia** — is an eyeball that is too short for the refractive power of the cornea and lens.



Hyperopia

- With hyperopia, the eye needs assistance to focus the rays from a near object onto the closer-than-normal retina.
- This assistance is obtained by adding refractive power with the positive (i.e., converging) lens.



Ch.24 Problem 12.

- Ramon has contact lenses with the prescription +2.0 D.
- What eye condition does Ramon have, and what is his near point without the lenses?

Positive prescription means you have hyperopia.

Object is at 25 cm away:

$s = 25\ cm.$

$\frac{1}{f} = 2\ m^{-1}$

Image is virtual, at Ramon's near point.

Use thin lens eq:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

solve for s':

$$s' = \left[\frac{1}{f} - \frac{1}{s}\right]^{-1}$$

$$= \left[2 - \frac{1}{0.25}\right]^{-1} = (2-4)^{-1}$$

$$s' = -\frac{1}{2} = -0.5\ m$$

NP is 50 cm away.

Announcement

- Test 1 is Tuesday Feb. 4th from 6:00-7:30pm.
- Room To Be Announced

- If you have a conflict with the above time, the **alternate sitting** will be from 4:30-6:00pm on Tuesday Feb. 4th
  - To register, students should submit the Alternate Sitting Registration Form, available now in the PHY132S Portal course menu.
  - The location will be emailed on Jan. 31 to the people who have registered.
  - You have until Jan. 30 at 4:00pm to do it (the form will not be available after).

Lecture Participation Reminder

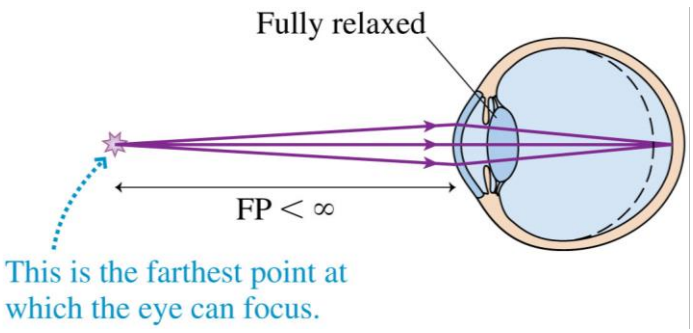
- For each lecture beginning with class 2, one participation point is awarded for clicking any answer (right or wrong) for each physics question we ask.
- At the end of the semester, only 85% of the clicker questions we ask are counted for your lecture participation mark.
- The in-class clicker mark will count for 2% of the total course mark.
- If, for example, you only answer 80% of the clicker questions this semester, you will receive (80/85)*2% = 1.88%.
- If you must miss classes and you are worried about losing marks, please provide me with documentation, medical or otherwise, and I will excuse these absences.

Lecture Participation Reminder

- You are not allowed to vote with another student's clicker, or ask another student to vote for you.
- Doing so is an academic offense called "impersonation", and will be dealt with by the Office of Student Academic Integrity (OSAI)
- If a student is caught using more than one clicker or i-clicker GO account, the minimum penalty is a 2% reduction in mark for the course.
- Additional penalties could include a further letter grade reduction in course mark, a 3-year mark on your transcript, and a 12 month suspension from U of T.

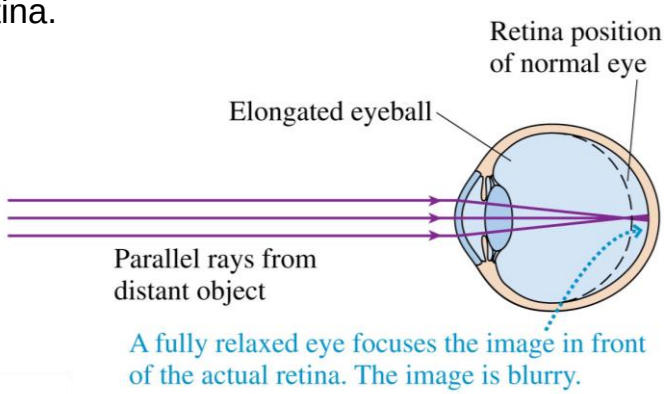
Myopia

A person who is *nearsighted* can clearly see nearby objects when the eye is relaxed (and extremely close objects by using accommodation), but no amount of relaxation allows her to see distant objects.



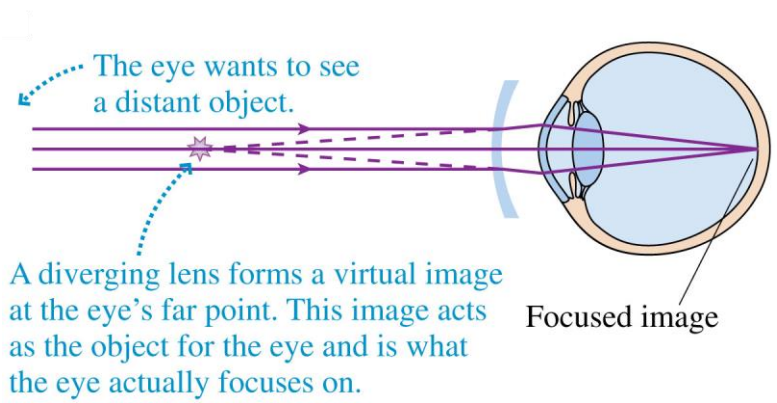
Myopia

- Nearsightedness—called **myopia**—is caused by an eyeball that is too long.
- Rays from a distant object come to a focus in front of the retina and have begun to diverge by the time they reach the retina.



Myopia

To correct myopia, we needed a diverging lens to slightly defocus the rays and move the image point back to the retina.



Crossing the street

- You are crossing the street, and you look to your left. You either see Car A or Car B. What do you think is the difference?

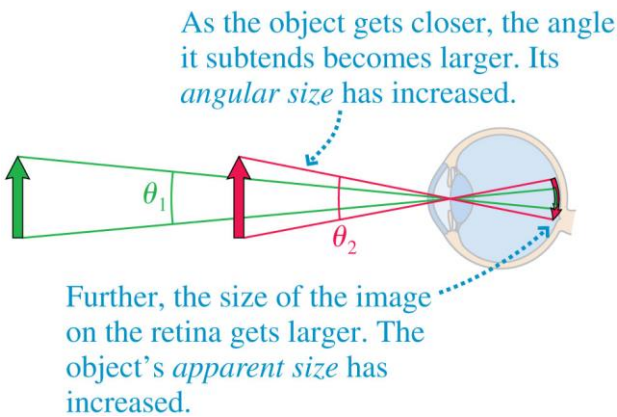
B

A

A. Car B is bigger
B. Car B is closer
C. It is impossible to tell without further information

Optical Systems That Magnify

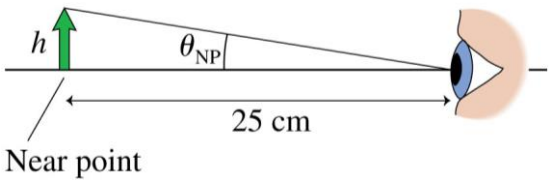
- The easiest way to magnify an object requires no extra optics at all; simply get closer!
- Closer objects look larger because they subtend a larger angle θ, called the **angular size** of the object.



Optical Systems That Magnify

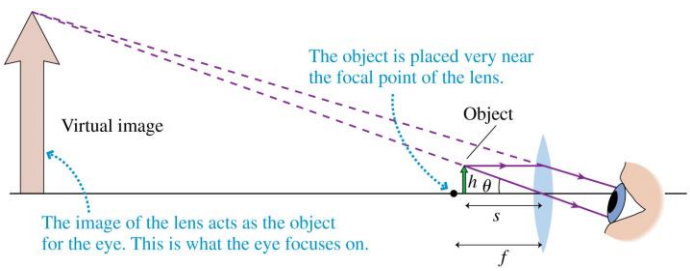
- You can't keep increasing an object's angular size because you can't focus on the object if it's closer than your near point, which is ≈ 25 cm.
- The maximum angular size viewable by your unaided eye is:

$$\theta_{\text{NP}} = \frac{h}{25 \text{ cm}}$$



The Magnifier

- Suppose we view an object of height *h* through a single converging lens.
- If the object's distance from the lens is less than the lens's focal length, we'll see an enlarged, upright image.
- Used in this way, the lens is called a **magnifier**.



The Magnifier

- When using a magnifier, your eye sees a virtual image subtending an angle $\theta = h/s$.
- If we place the image at a distance $s' \approx \infty$ the object distance is $s \approx f$, so:

$$\theta = \frac{h}{s} \approx \frac{h}{f}$$

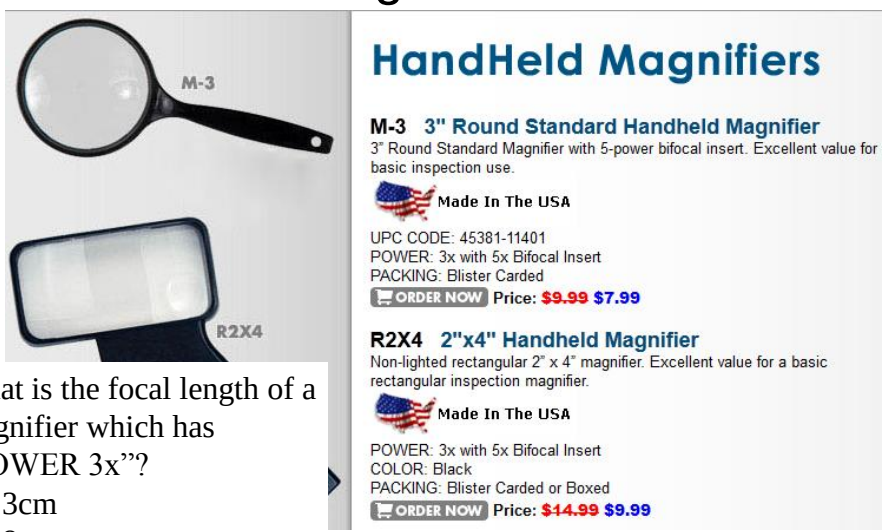
- Angular magnification is the ratio of the apparent size of the object when using a magnifying lens rather than simply holding the object at your near point:

$$M = \frac{\theta}{\theta_{\text{NP}}}$$

- Combining these equations, we find the angular magnification of a magnifying glass is:

$$M = \frac{25\text{ cm}}{f}$$

www.magnifier.com



What is the focal length of a magnifier which has "POWER 3x"?

A. 3cm
B. 8 cm
C. 16 cm
D. 25 cm

Before Class 8 on Wednesday

- Please read Knight Pgs. 720-736:
  Ch. 25, sections 25.1-25.4
- Please do the short pre-class quiz on MasteringPhysics by tomorrow night.

- Something to think about: If you rub a balloon on your head, it becomes negatively charged. Where does this charge come from? Does your hair also become negative, or does your hair become positive?