Announcements 2/2/10

Graded PS1 at back (can also pick up outside physics office before Tuesday classes); solutions online

Please turn in PS2 and self-test separately.

Post lingering questions about optics on website forums by Weds evening; I can go over during Thurs evening problem session

Handouts: PS3, lens figures, magnification figures

Reading for Thursday: Wolfson 20.3 and 20.4

[redacted] to 2

+

Key ideas from last time

With a combination of two lenses, the image formed by the first lens serves as the object for the second lens

Normal human vision:
- the eye's lens adjusts its f to form focused images of objects that are from ~25 cm away ("near point") to very far away
- retina located at **maximum** f of eye's lens

Nearsightedness:
retina is farther away than normal, so images of distant objects form in front of retina and appear blurry
- correct with a diverging lens that creates an image closer to the eye than the object
- prescription: diverging lens must have a (virtual) focus at the farthest distance at which wearer can see clearly; images of distant objects will form there, images of nearer objects will be still closer

(Address loose ends question)

Farsightedness: eye cannot form focused images of near objects (multiple physiological reasons)
- correct with a converging lens that creates an image farther from the eye than the object

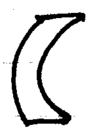
Lens power: P (diopters) = $1/f$ (f in meters)

Focal plane: plane that is normal (perpendicular) to the axis of the lens, at a distance f from the lens

Loose ends

Elizabeth asked why nearsighted person can't keep adjusting f of eye to see distant objects

(show w/applet in screen mode) (distant object screen positioned at f)
normal vision: retina @ max f
nearsighted: retina behind f_{max} – can't see distant obj but as move object in, can see it
To move image back, must increase f of lens
BUT we are already at max f of lens when viewing distant objects – can't increase further
must move object, or create closer image
(Lots of ? here)

Real lenses  or  one converging side, one diverging side

whichever side is more sharply curved dominates

J.J.

2/2/2010

Today: 0. Loose ends from last class (part of "Key Ideas")
1. Magnification with two lenses
2. "Aperturing"
3. Begin electrostatics

If you know everything about images formed:
mag with two lenses = product of individual magnif

$$M_{total} = M_{lens\,1} \, M_{lens\,2}$$

PS 3 microscope problem: tells you objective → 40x
eyepiece → 2x
⇒ overall mag is 80x

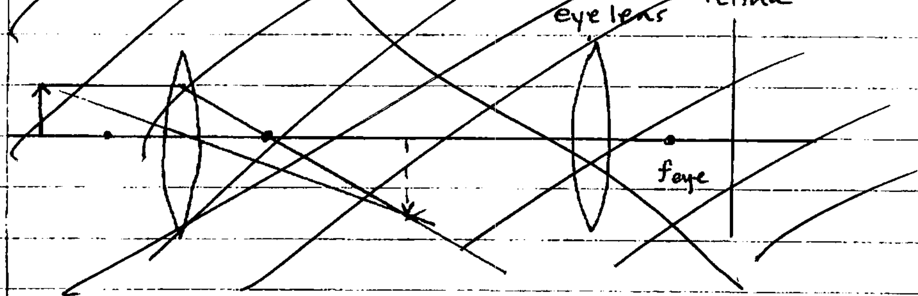
Why? $$M_{total} = \frac{h_{final\ image}}{h_o} = \frac{h_{image\ 1}}{h_o} \times \frac{h_{final\ image}}{h_{image\ 1}}$$

But sometimes this is complicated to calculate, especially with magnifying glasses — want shortcut
Wolfson formula for the angular mag of a magnifying glass is an approximation: Let's go through how it works

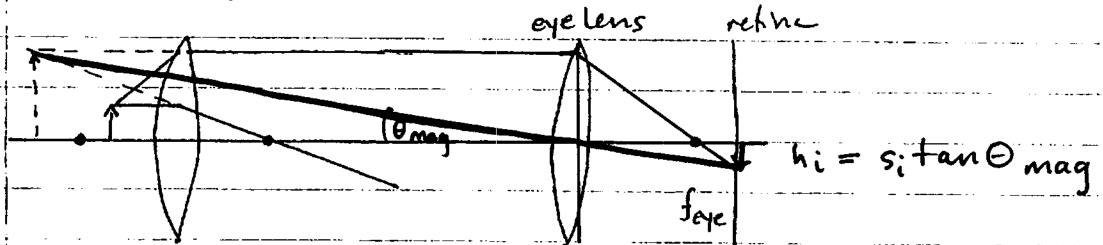
Begin with: How big is the image of something on your retina? Depends on both size of object and how close to you it is, BUT:
- Always much smaller than the object!
But that doesn't matter so much as how much of your retina it covers.
Because distance from eye's lens to retina s_{retina} is fixed, so s_i is also fixed, can describe size of image either as height h_i or as angle it fills
~~([illegible], θ_o = Wolfson's α)~~
~~(Draw on blackboard)~~
Use handout Start w/adding single lens

Images with two lenses

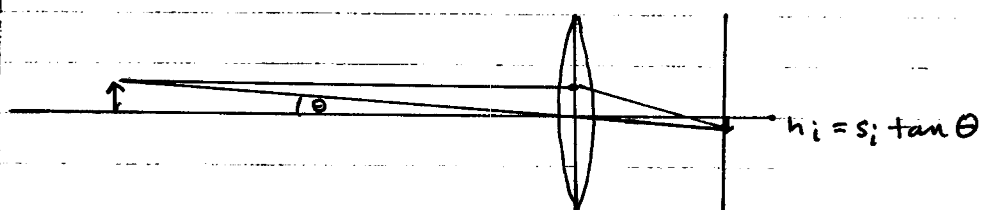
Real image from 1^{st} lens:



Virtual image from 1^{st} lens:



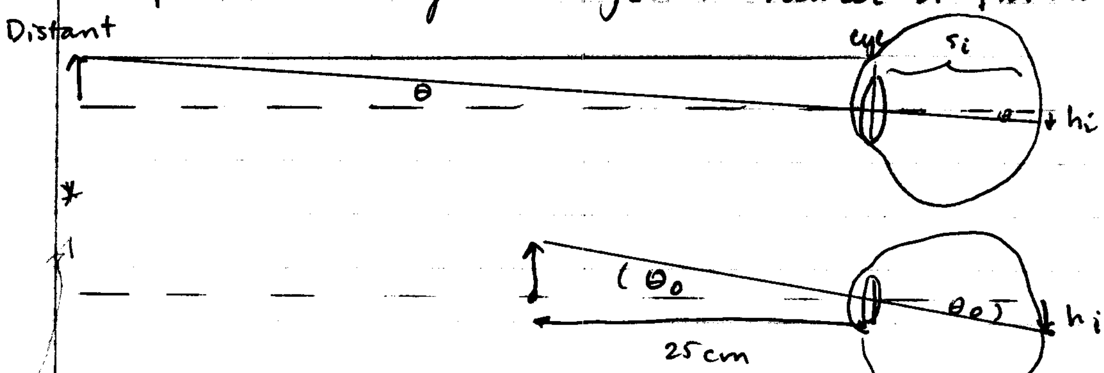
Compare to image viewing object without mag. lens:



add after virtual image

Image gets larger, but also further away
BUT $\boxed{\text{angular size}}$ increases because ray from virtual image through center of ~~the~~ eye's lens comes from higher up → $\boxed{\text{linear size also increases}}$
(lots of algebra to prove mathematically, can see it from figure)

Compare that angle as object is nearer or farther:



Angle is θ
height is
$h_i = s_i \tan\theta$

Largest $\theta_0 \to$
longest h_i

Angle gets bigger as object gets closer (show w/apple!; f also shorter)
BUT can't move object closer than 25 cm to the
normal eye - it can't focus closer (Eric's figures)
(can't shorten f more)

So greatest magnification with unaided eye
comes when place object at "near point" = closest distance
at which your eye can focus

maybe up here?

$\boxed{\text{CT}}$: longest or shortest focal length of your eye?

To get the image even larger, use converging lens
as mag. glass $\longrightarrow$ image moves farther away as
well as getting larger - but <u>angular size always increases</u>
$\boxed{\text{handout}}$

Calculating mag exactly involves lots of steps
Approximate:

Very large, distant image if object is just inside
focus of magnifying lens, as shown in lower
figure on handout

Angular size of <u>this</u> image is θ_i

If: (1) mag lens very close to eye
(2) image distant b/c object is near focus of mag lens

then $\tan\theta_i \approx \dfrac{h_0}{f}$

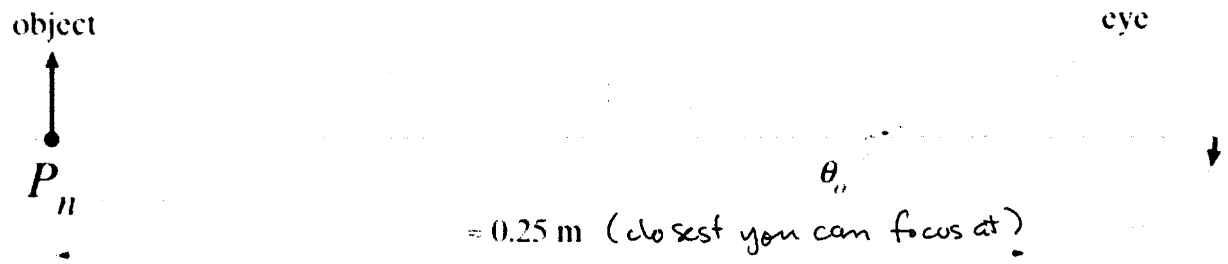
$$\Rightarrow \text{magnification is } M = \frac{\tan\theta_i}{\tan\theta_0} = \frac{h_0}{f}\cdot\frac{1}{h_0/25\,\text{cm}} = \frac{25\,\text{cm}}{f}$$

To see more fine detail, you want to make the focused image of the object on your retina larger. To do so without a magnifying glass, you:

1. move the object closer to your eye and increase *f* of your eye's lens.
2. move the object farther from your eye and increase *f* of your eye's lens.
3. move the object closer to your eye and decrease *f* of your eye's lens.
4. move the object farther from your eye and increase *f* of your eye's lens.

$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$ s_i fixed

s_o smaller $\rightarrow$ f gets smaller too



(closest you can focus at)

this gives maximum size with unaided eye

Linear size $h_i = s_i \tan\theta_o$

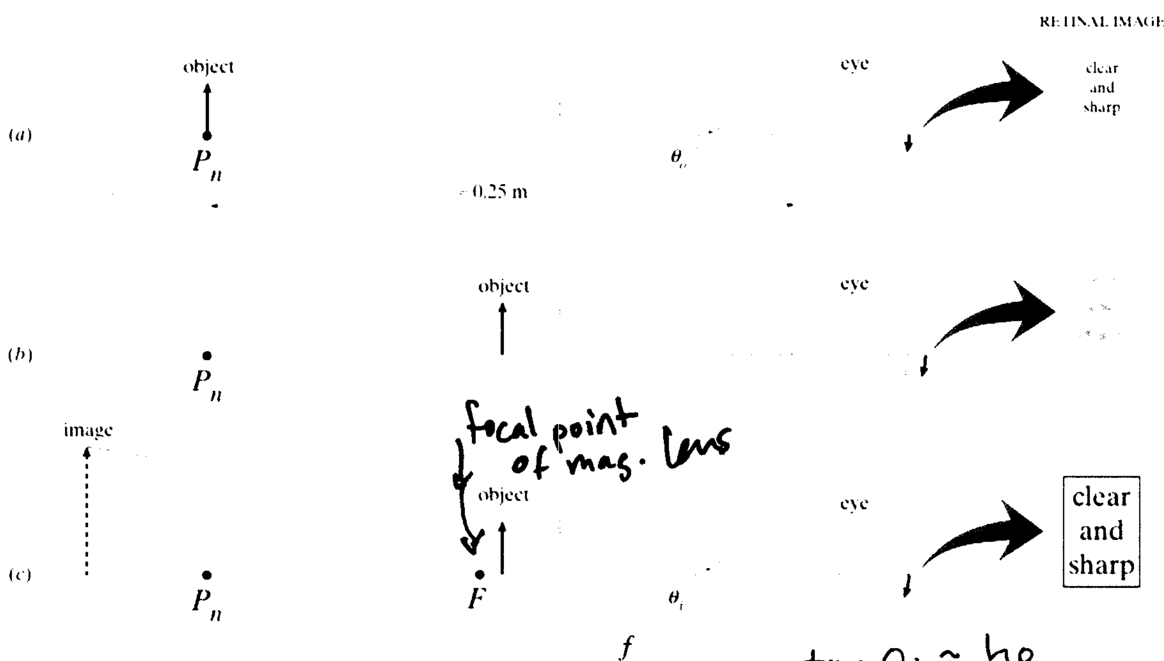
$\underline{\text{angular}}$ size is θ_o

and $\tan\theta_o = \dfrac{h_o}{25\text{ cm}}$

Bringing object closer requires decreasing f_{eye} to keep image in focus

When object is at P_n (≈25 cm), can't decrease f_{eye} any more

→ can't increase size of image further



focal point of mag. lens

$\tan\theta_i \approx \dfrac{h_o}{f}$

Figure 37.39 (*a*) Ray diagram for the eye forming an image of an object that is placed at the near point P_n; the object subtends an angle θ_o in the field of view. Note that while one of the rays drawn is a ray through the center of the lens, the other ray is not one of the principal rays; we know that the image lies on the retina, so that determines the path taken by rays entering the lens at a small angle to the axis. (*b*) Ray diagram for the eye forming an image of the object that is between the near point and the eye. As the eye is unable to adjust enough to focus the light rays onto the retina, the image plane falls behind the retina and the observer perceives a blurred image. (*c*) Ray diagram for the eye assisted by an external lens. Rays refracted by the external lens form a virtual image beyond P_n that subtends an enlarged angle θ_i; the eye's lens then focuses these rays onto the retina, producing a clear, enlarged image.

Apertoning (how your pupil works)

Does the size and shape of the lens matter?

Think about the following question

$\boxed{\text{CT}}$ covering lens

$\boxed{\text{Answer w/demo}}$

Gets dimmer — why?

Use applet — many rays view

If block part of lens just reduces amount of light

This is why your eye's pupil can open and close to change amount of light

—··· ~12:10 up to here

A lens is used to image an object onto a screen.
If the top half of the lens is covered,

1. the top half of the image disappears.
2. the bottom half of the image disappears.
3. the entire image disappears.
4. the image becomes blurred.
5. the image becomes fainter.

Electrostatics

Two kinds of charge

early studies: rub rubber with fur, glass with silk;
See sparks in dry weather

Balloon electroscope demo

Two charged rubber rods repel
fur and rubber are attracted!

Conclusion:

macroscopic objects ordinarily made up of equal amounts of two types of charge "electrically neutral"

Can remove one type through rubbing two dissimilar materials → "oppositely" charged objects

Call types of charge ⊕ and ⊖ to convey idea of cancellation – an object with equal amounts of ⊕ and ⊖ mostly behaves as if it has zero charge

Charge is <u>conserved</u> and comes in units of e (elementary charge)

Properties of e⁻static interactions

Draw charges + vector

$\vec{r}_{12} = r_{12}\hat{r}_{12}$

$q_1 \longrightarrow q_2$

For future: Define $\hat{r}_{12}$ here

1. Force between two pointlike charged objects:

$$\vec{F}_{\text{by 1 on 2}} = \vec{F}_{12} = \frac{k q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

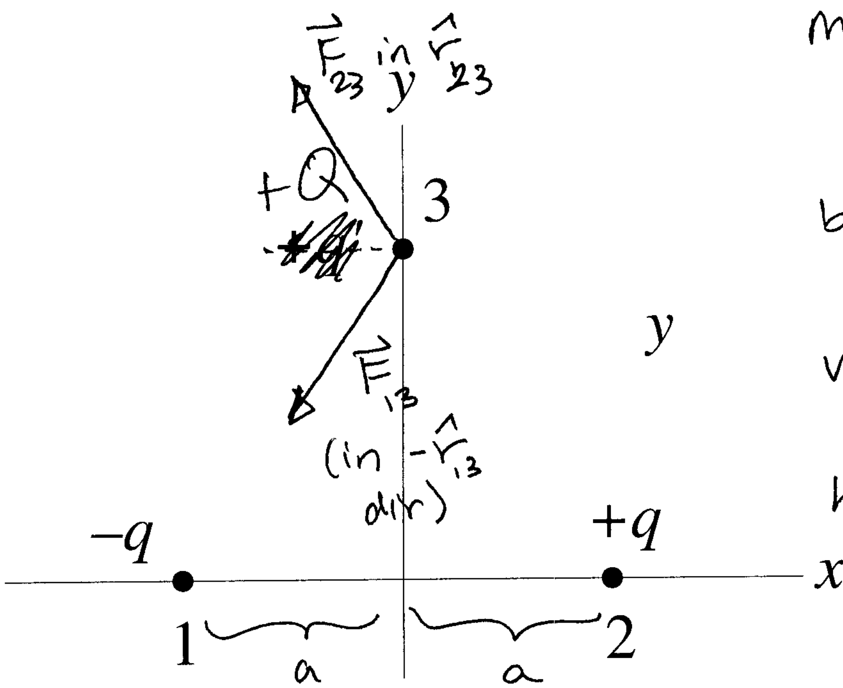
(I use r_{12} where Wolfson uses r)

- force proportional to charge of each
- force decreases as distance r_{12} between increases
- force always points along line between q_1 and q_2; attractive for unlike, repulsive for like charges

($\hat{r}_{12}$ is a unit vector (vector of length 1) from q_1 to q_2)

- constant $k = 9.0 \times 10^9\ \mathrm{Nm^2/C^2}$ makes units work

In the arrangement of charge shown, charges 1 and 2 have equal magnitudes and opposite sign, and they are placed equal distances from the origin.
What is the direction of the vector sum of the forces exerted by 1 and 2 on 3?



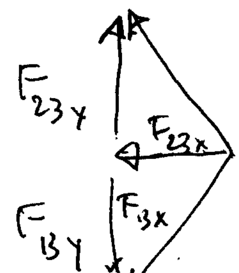
magnitudes

F_{13} and F_{23} same

b/c magnitude of chg same, distances same

vertical components cancel

horizontal add



1. The +x direction
2. The –x direction
3. The +y direction
4. The –y direction
5. Another direction
6. The vector sum of the forces on 3 is zero.

2. Electrical forces add like vectors ("principle of superposition")
- if there are many charged objects,
  net force on one object (say #3) = sum of ~~individual~~ forces on it from other individual objects

i.e. three objects: $\vec{F}_{on\,3} = \vec{F}_{13} + \vec{F}_{23}$

$\boxed{\text{Dipole CT}}$ Result: $-x$ direction

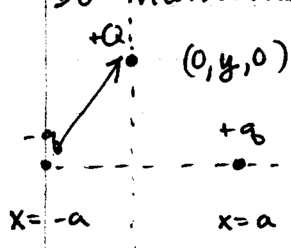
Forces are equal in magnitude b/c distances are same and magnitudes of charges same

horiz (x) components reinforce
vert (y) components cancel

$\Rightarrow$ $\overleftarrow{\quad \vec{F}_{on\,3} \quad}$ in $-x$ direction

up to here

Do mathematically:



$\vec{r}_{13} = a\hat{i} + y\hat{j}$

Magnitude $= \sqrt{a^2+y^2} = r_{13}$

~~Unit vector magnitude unit vector~~:

Unit vector $\hat{r}_{13}$: just divide $\vec{r}_{13}$ by its mag

$$\Rightarrow \hat{r}_{13} = \frac{a\hat{i} + y\hat{j}}{\sqrt{a^2+y^2}} = \frac{a}{\sqrt{a^2+y^2}}\hat{i} + \frac{y}{\sqrt{a^2+y^2}}\hat{j}$$

Add $\vec{r}_{23}$: same magnitude, only difference is x-comp is opp

$$\vec{r}_{23} = -a\hat{i} + y\hat{j} \quad \text{and} \quad \hat{r}_{13} = -\frac{a}{\sqrt{a^2+y^2}}\hat{i} + \frac{y}{\sqrt{a^2+y^2}}\hat{j}$$

Add forces: $\vec{F}_{13} = -\frac{kqQ}{r_{13}^2}\hat{r}_{13}$ and $\vec{F}_{23} = \frac{kqQ}{r_{23}^2}\hat{r}_{23}$

x-components are both in $-x$ while y-comp are opposite so just add x

$$\vec{F}_{on3} = \left(F_{13,x} + F_{23,x}\right)\hat{i} = -\frac{kqQ}{a^2+y^2}\frac{a}{\sqrt{a^2+y^2}} + \frac{kqQ}{a^2+y^2}\left(\frac{-a}{\sqrt{a^2+y^2}}\right)$$