Physics 9 — Friday, September 28, 2018

- Turn in HW#3. HW#4 will be due two weeks from today; I will hand out HW#4 Monday.
- I found a way to run both Odeon and CATT-Acoustic on MacOS without a virtual machine! Stay tuned.
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- Later today, we'll start talking about light (optics), which is another wave phenomenon.
- But wavelengths for visible light are so short (about 0.5 $\mu\mathrm{m}$) that wave effects like interference and diffraction can be less obvious for light than they are for sound.
- Also, for architecture, I think the wave nature of sound is probably more relevant than the wave nature of light: for example, diffraction of sound waves is important in modeling an auditorium or in modeling e.g. the barriers that block highway noise.
- In most everyday situations, light travels in straight lines (except at a boundary between air/glass, etc.), whereas low-frequency sound waves diffract around obstacles.
- So let's use a simulation to illustrate some wave effects in two and three dimensions that affect both sound and light. We'll see them again next week in the context of light.

- Start with single source, with and without reflecting wall.
- “Ripple Tank Applet” setup “wja 1” shows reflection from barrier, similar to last week’s sound waves reflecting from a wall. You can see that higher frequencies are easier to stop than lower frequencies.
- “wja 2” shows double wall.
- “wja 3” shows constructive interference of waves in circular tube.
- “wja 4” shows incoming “plane wave” going through an opening in a barrier: angular spread (in radians) $\approx \lambda/D$.
- “two sources” is like the two speakers in the room, but notice that effect is ruined when you add reflective walls
- “obstacle” shows how low-frequency sounds diffract around e.g. a column in an auditorium, or a noise wall along a highway, while high-frequency sounds show a “shadow”
- “half plane” more resembles highway noise barrier
- “ellipse” is like HW3/q7 whispering gallery

- “refraction” shows waves “bending toward the slower medium” as described by Richard Muller’s PTFP.
- “internal reflection” is like the sound channels described by Richard Muller: waves that start out in the slow medium and strike the boundary at a glancing angle can’t escape (“total internal reflection”) — that’s how fiber-optics cables work.
- “doppler effect 1,” and “doppler effect 2,” and “sonic boom”
- “temperature gradient 2” shows sound traveling more slowly in cool air (blue). Waves “bend toward the slower medium.”
- “temperature gradient 1” is like a “temperature inversion”
- “temperature gradient 4” is like the sound channel described by Muller. Compare source inside vs. outside the channel!
- “temperature gradient 3” is the opposite of a sound channel.
- “parabolic mirror 2” and “parabolic mirror 1” are fun: see waves focus as you expect rays to focus

OK, we're finally transitioning from sound to light

How far does light travel in one nanosecond (10^{-9} s)?

answer: 0.30 meters (about 1 foot)

About how far does sound travel in one millisecond (10^{-3} s)?

answer: 0.34 meters (also about 1 foot)

$\Rightarrow$ Light travels about a million times faster than sound.

By the way: "In space, nobody hears you scream." But does light require a "medium" in which to propagate?

Specular reflection from smooth surface

What happens when light reflects from a mirror? (Demo!)

- Incident ray, reflected ray, and surface normal all lie in the same plane.
- Angle (w.r.t. surface normal) of reflected light equals angle (w.r.t. surface normal) of incident light.

$$\theta_r = \theta_i$$

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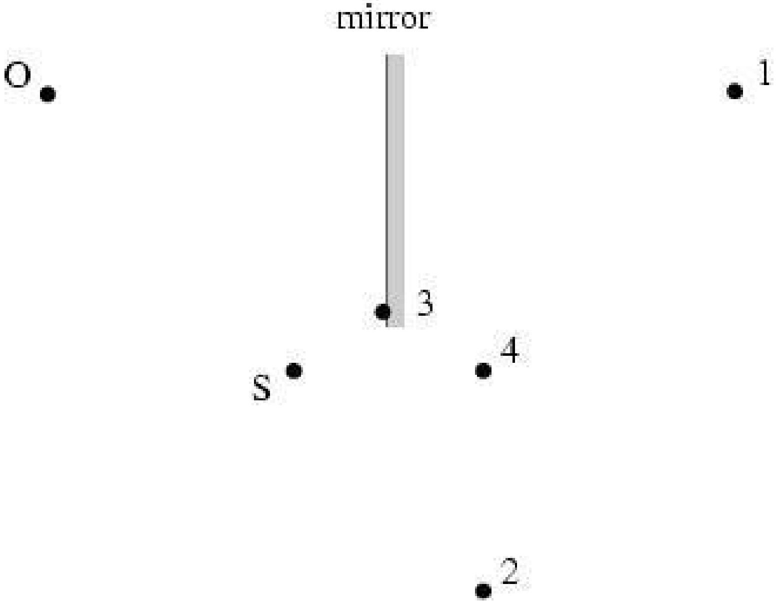
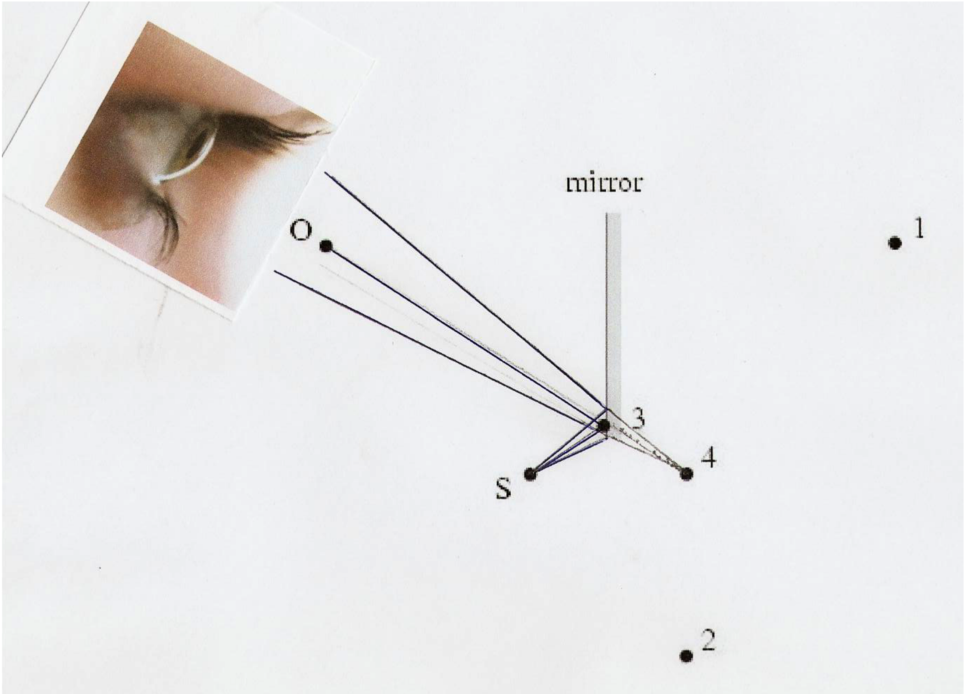
By the way: What happens if instead of a smooth surface, you have a rough surface, like a crumped piece of foil?

An observer O, facing a flat mirror, observes a light source S. Where does O perceive the mirror image of S to be located?




mirror
O
1
3
4
S
2

You are standing in front of a mirror holding a camera, and you want to take a picture of yourself. The mirror is **two meters** in front of you.

For what distance should the camera lens be focused?

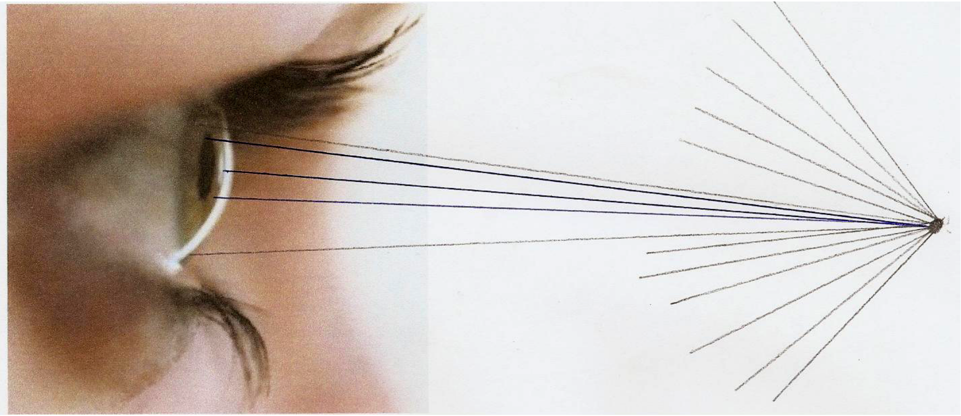
In other words, how far away from the camera's eye is the virtual image of yourself that you see in the mirror?

(Ignore the length of the camera.)

(A) 1 meter (B) 2 meters (C) 3 meters (D) 4 meters

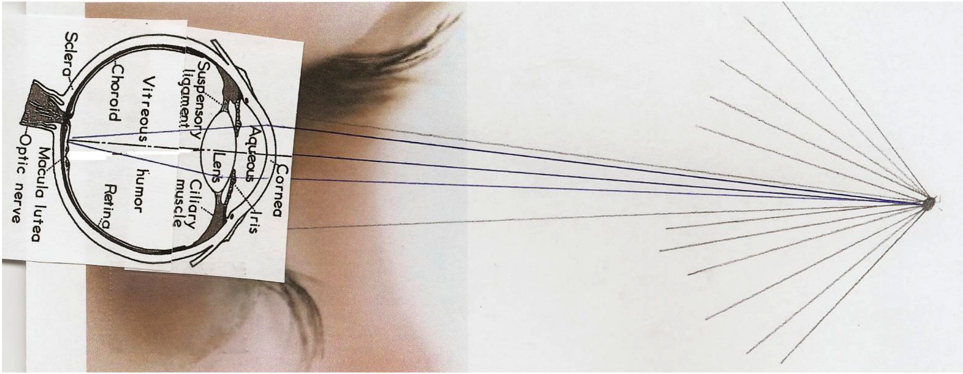
Ray tracing, finding images

If an object is right in front of us, each point on that object emits light (or more likely reflects ambient light) in all directions. Some fraction of those rays reach our eye.



Ray tracing, finding images

Your eye's cornea and lens then focus those diverging rays onto the retina, which is basically a grid of light sensors at the back of the eye. Separate points in the image plane are mapped onto separate points on the retina, like an upside-down movie projection.



Ray tracing, finding images

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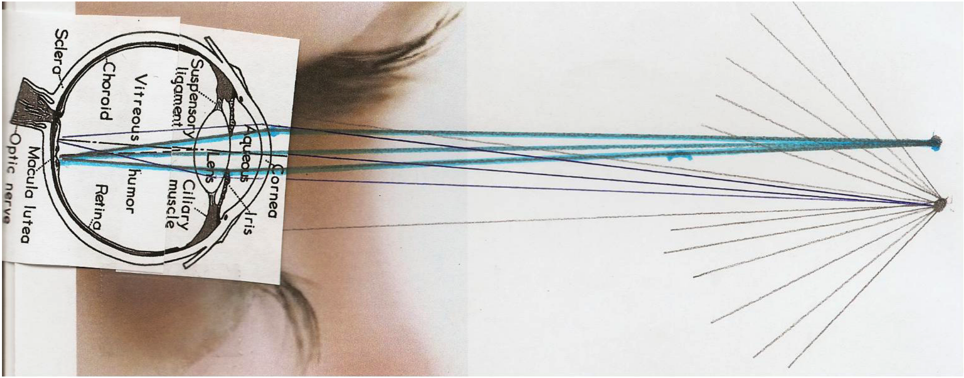
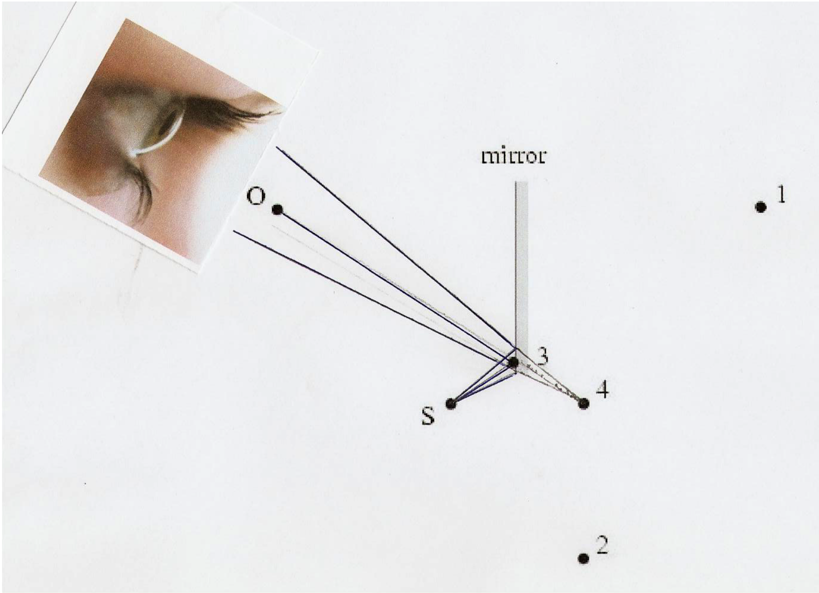


When we set up an exterior lens, mirror, etc., we want to find the point from which all of a given pixel's rays diverge. That "image" point is where the eye perceives that pixel to be located in space.
The eye+brain perceives the point from which the rays diverge.

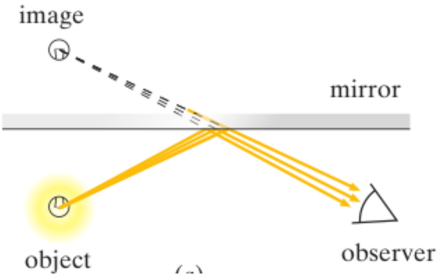
So, for a flat mirror, the rays that enter the eye for each object point appear to converge behind the mirror. The image is at the same height as the object. The image is as far behind the mirror as the object is in front of the mirror. It's a "virtual" image, because if you put a projection screen, film, etc., at the location of the image, no picture would appear on that screen, film, etc.

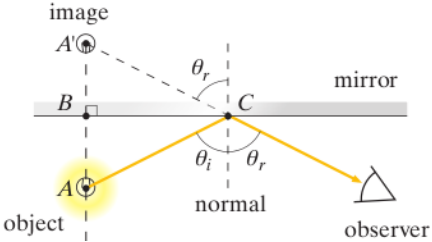
Mirror: $\theta_r = \theta_i$.



Object is at point **S**. Eye sees rays that appear to come from point **4** (where they meet), so brain perceives image located at point **4**.

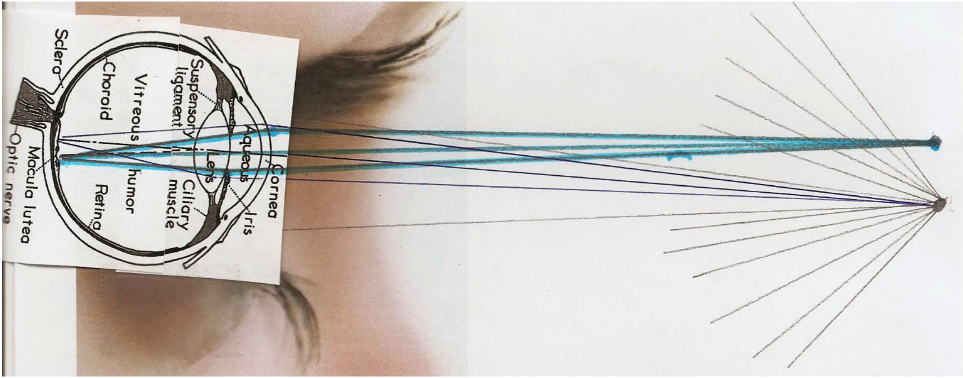
Mirror: $\theta_r = \theta_i$. Angles measured w.r.t. surface normal.





Question: is this a “real” or a “virtual” image?

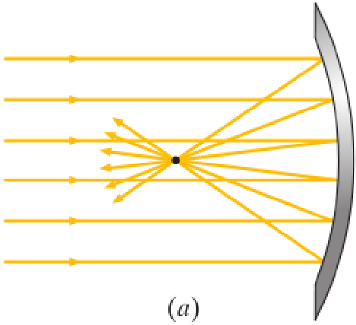
(A) real
(B) virtual

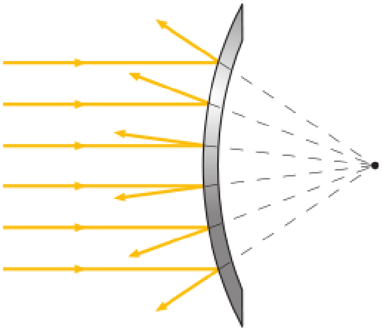


Again: the eye detects (and focuses onto the retina) rays of light that diverge from a point. That point from which the rays diverge is where the eye/brain perceives the image to be.

$$\theta_r = \theta_i$$

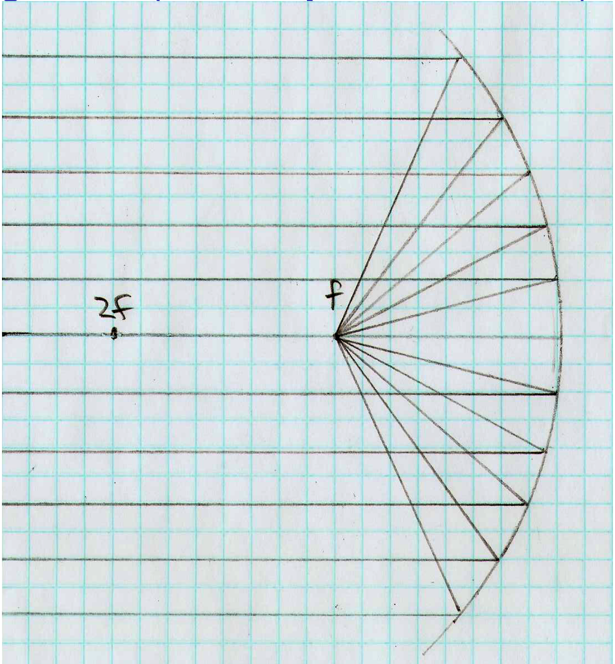
works for curved mirrors as well as flat ones. The farther away you are from the middle of the mirror, the bigger the slope, and thus the larger the change in angle. So parallel rays are focused to a point by a "concave" ("converging") mirror. The "focal length" is $f = R/2$, where R is radius of curvature.



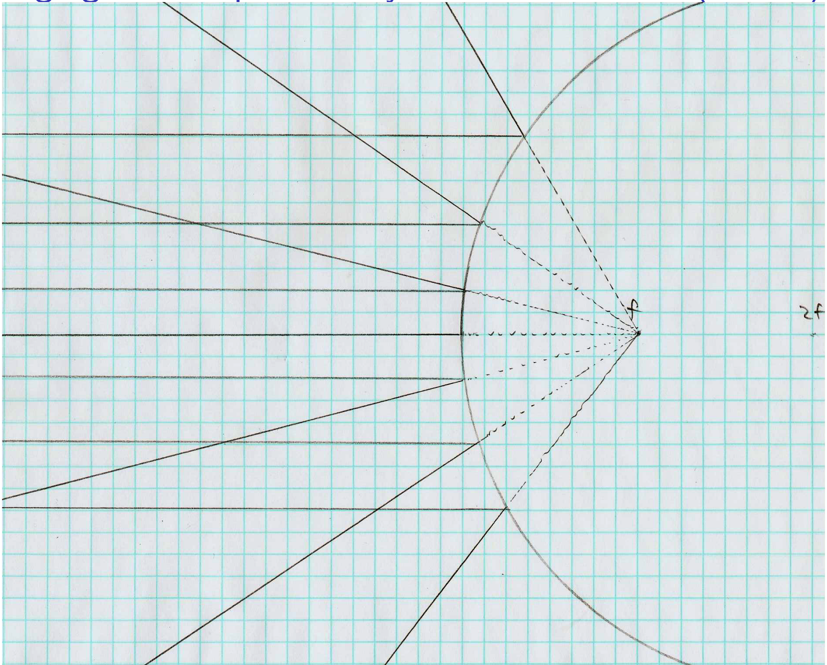


concave/converging mirror convex/diverging mirror

Converging mirror: parallel rays focus on LHS (real)



Diverging mirror: parallel rays "focus" on RHS (virtual)



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