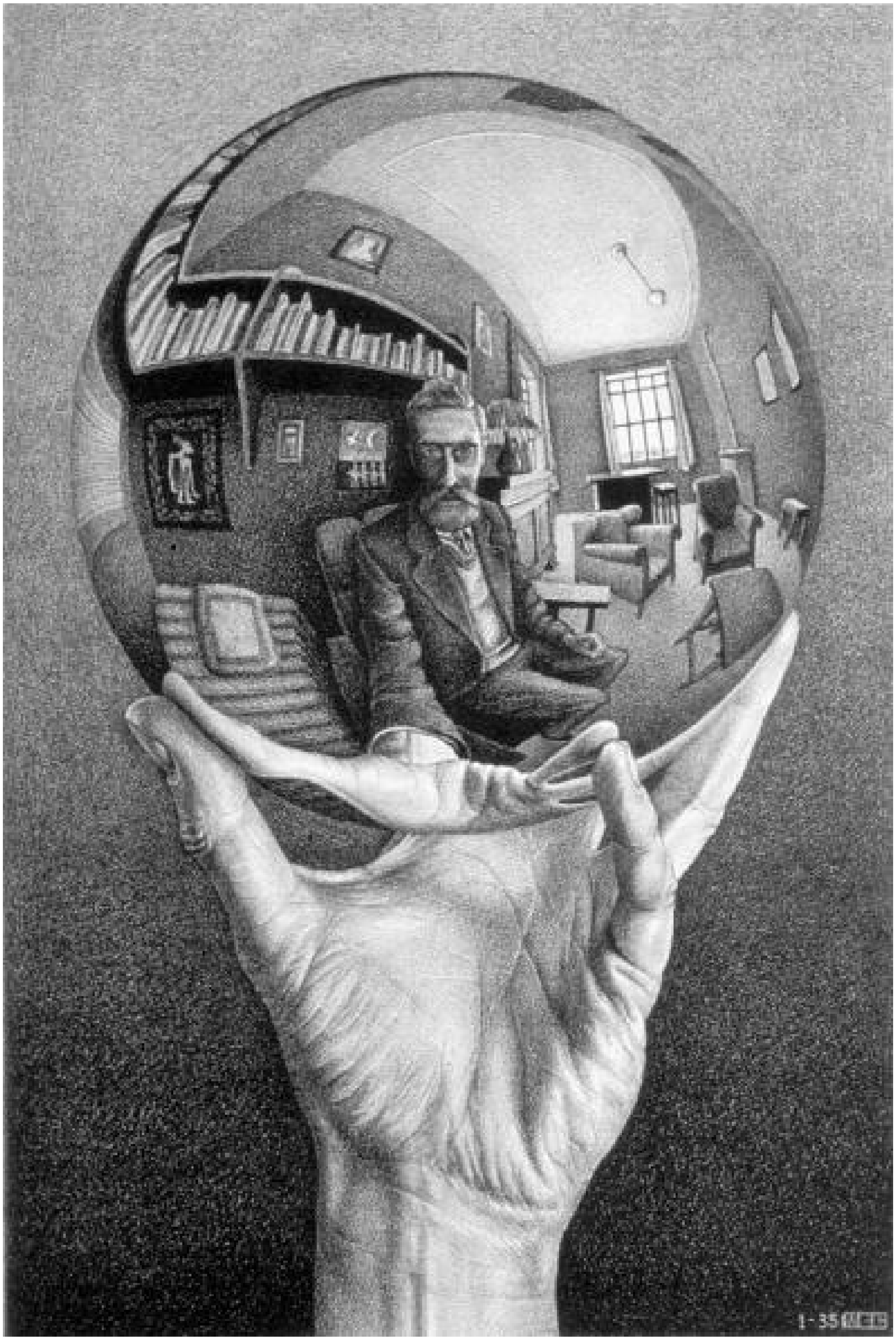
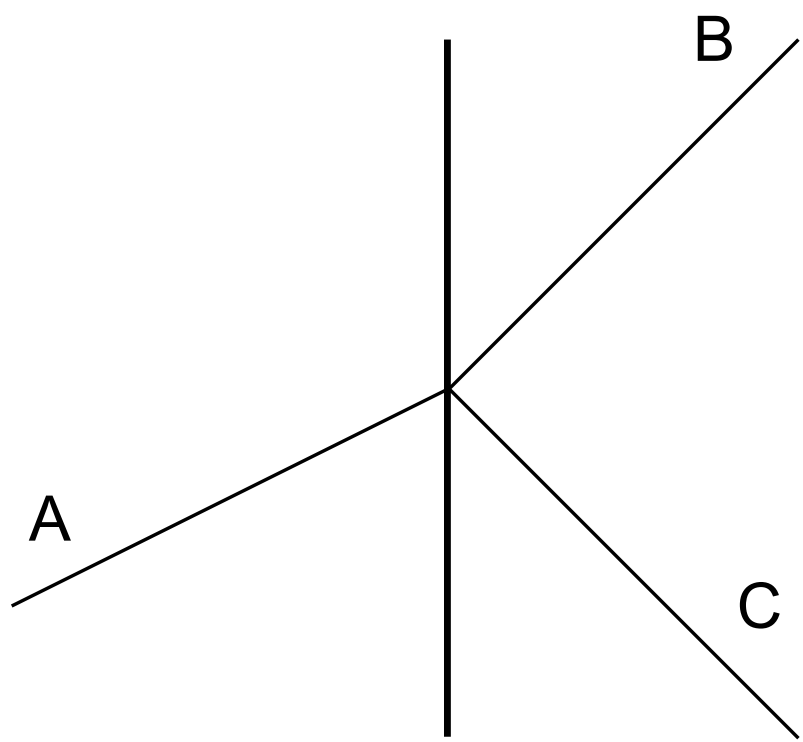
Spherical Mirrors



The figure below illustrates three light rays that exist together at the interface between two media.



Which of them could be incident rays?

1. A
2. B
3. C
4. A or B
5. B or C
6. C or A
7. Any of them could be incident rays

ANS: **2**—Ray B is the only possible incident ray.

Let's discuss each ray in turn.

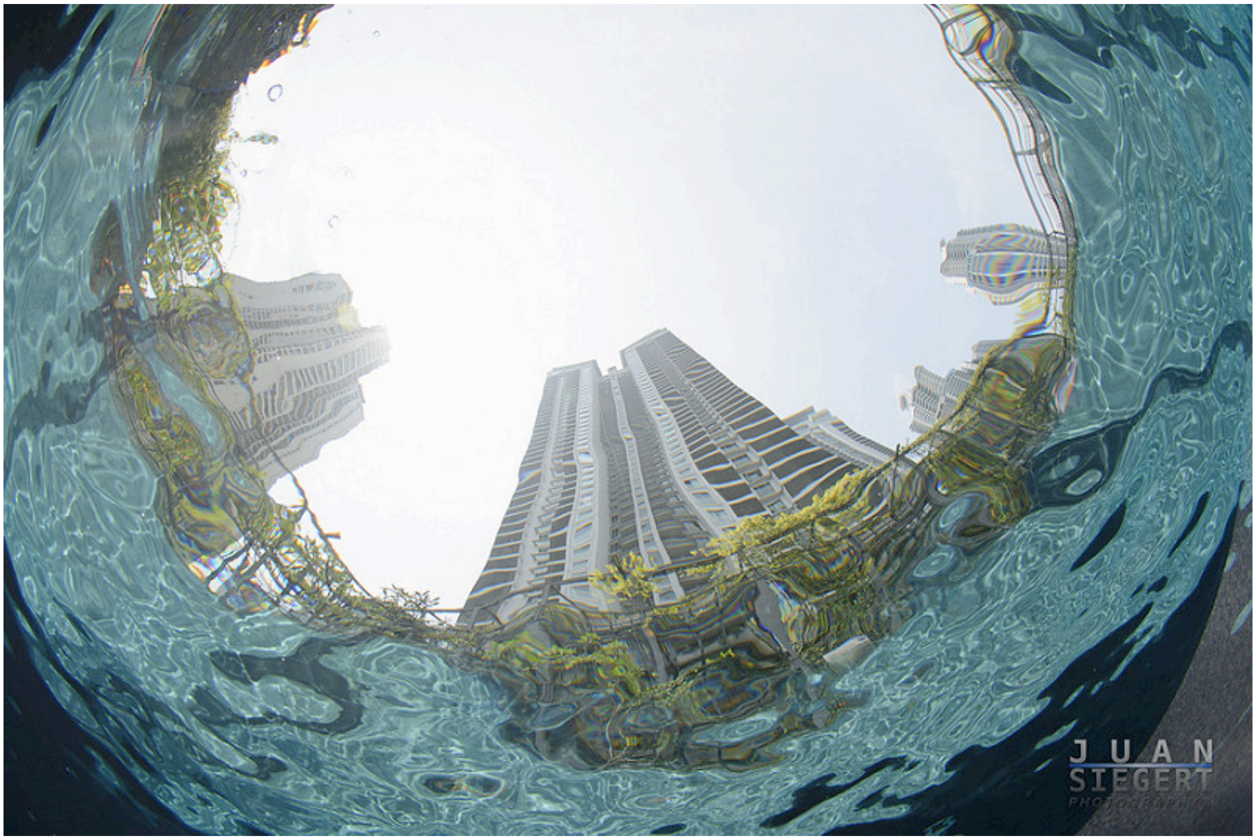
- Ray A cannot be an incident ray. If it were, there would be two transmitted rays, B and C, as the light passes through the interface.
- Ray B can be an incident ray. If it were, ray C would clearly be a reflected ray, while ray A would be a transmitted ray. Ray A is on the opposite side of the normal from the incident ray, as we would expect.
- Ray C cannot be an incident ray. If it wre, ray B would clearly be a reflected ray, while ray A would be a transmitted ray. However, ray A would be on the same side of the normal as the incident ray. Incident ray C would be "bent back" into transmitted ray A, which implies a negative transmission angle. This would require a negative index of refraction, which makes no sense.

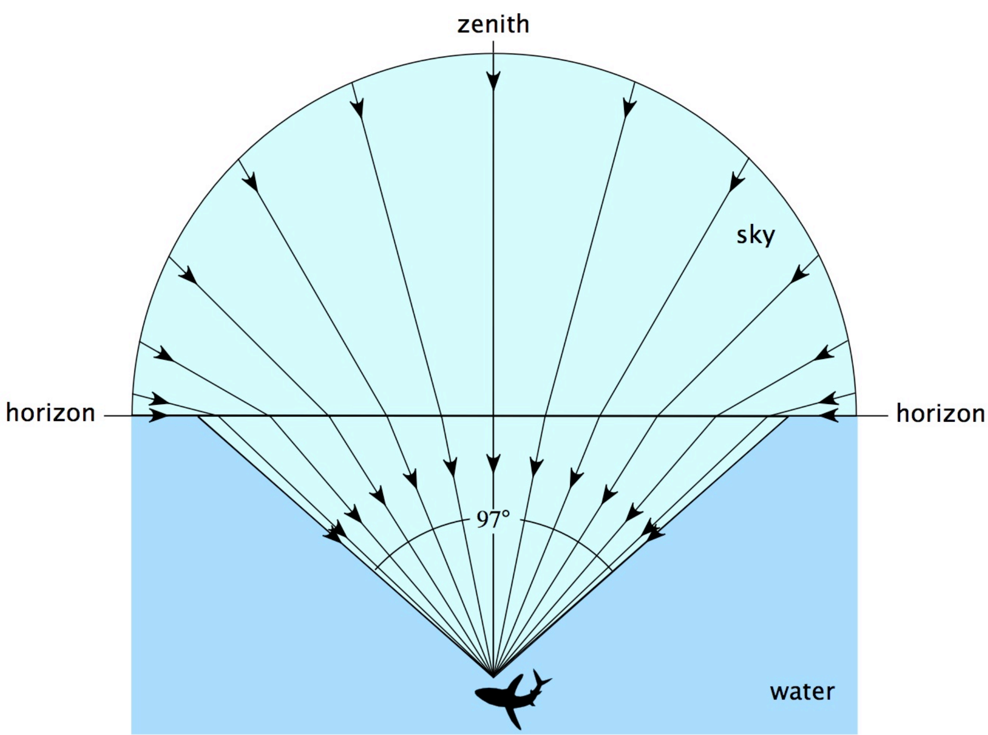
The angle from the normal increases when a light ray passes into a faster medium. If the angle of incidence is steadily increased, can the angle of refraction ever exceed 90°?

1. Yes, and it will be refracted back into the slower medium
2. No, it will remain at 90°
3. No, it will only approach 90° asymptotically
4. No, there is no refraction beyond 90°

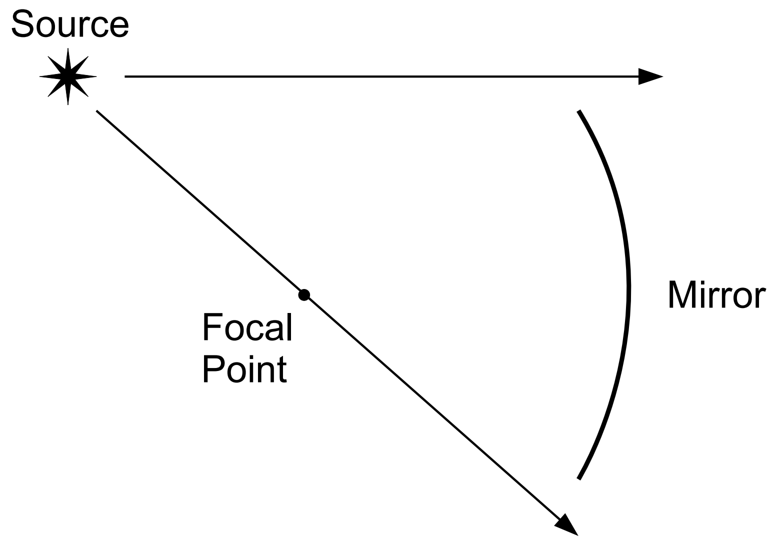
You are at the bottom of a swimming pool looking upward. What do you see?

1. Just the image of the sky spread out on the surface
2. The image of the sky within a circle above you, surrounded by a second, distorted image of the sky
3. The image of the sky reduced to a circle above you, surrounded by a distorted image of the pool floor
4. Something else


J U A N
SIEGERT


zenith
sky
horizon
horizon
97°
water

We use the intersection of any two out of the three possible principal rays to locate the image of an object. In the figure below, two principal rays are not available because the mirror is too small. In this situation



1. No image is formed
2. There is an image, but we can’t find it
3. The image is virtual because principal rays don’t reach it
4. The image is smaller than it would be in a larger mirror
5. The image is dimmer than it would be in a larger mirror
6. The image is unchanged

ANS: **5**—The image is dimmer than it would be in a larger mirror.

There is nothing special about the principal rays except that they are easy for us to draw. There are an infinite number of rays from the source that are focused to form an image. Even if the principal rays aren’t available, there are countless others, all which obey the law of reflection. If the mirror were larger, more rays would focus to form the image and make it brighter, but otherwise the image would be no different.

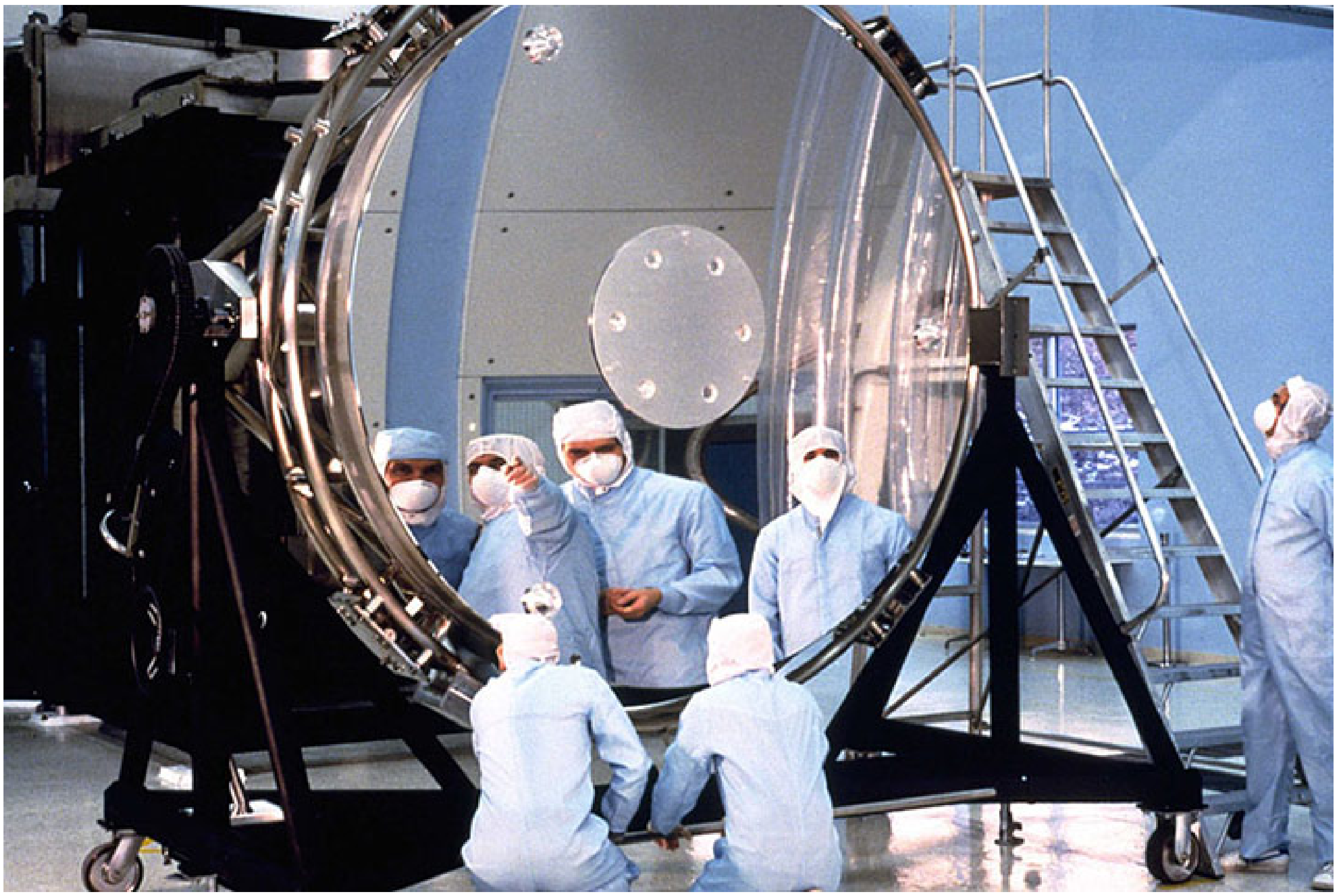
What kind of mirror is used for security in convenience stores, the kind that allows the clerk to see the entire store from the front register?

1. concave
2. convex
3. flat

ANS: **2**—The mirror is convex.

Convex mirrors are useful for two reasons. First, a convex mirror always gives an upright image. This is certainly useful if you want to quickly get a sense of what's going on in the mirror. Second, the convex mirror always gives a reduced image. This allows you to see more of the store than you would see in a flat mirror.

The picture below shows scientists inspecting the mirror of the Hubble Space Telescope before it was launched. What kind of mirror is this?



1. concave
2. convex
3. flat

ANS: **1**—This is a concave mirror.

The image is upright, so it could be any kind of mirror. However, you also know that the image is magnified because the images of scientists who must be located somewhere to the left of the frame are much larger than those kneeling in front of the mirror. Only a concave mirror can do this. It's is easy to prove this with your simple mirror equations.

We have $M = -s'/s > 1$, so $s' < -s$. Then

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} > \frac{1}{s} + \frac{1}{-s} = 0\,.$$

Therefore, the focal length is positive—a concave mirror!

Warmup Question

An ordinary metal spoon makes a fairly good spherical reflector, convex from one side, concave from the other. Estimate the radius of curvature and the focal length for a typical soup spoon.

ANS: I just looked at one and estimated that the focal length was around 2cm. The way I determined this is to look at the reflection of an object in the converging (“concave”) face of the spoon. When the object is outside the focal point, the image will be inverted and real. When the object is inside the focal point, the image will be upright and virtual. When the object is at the focal point, no image will be formed (“image at infinity”). Move the object back and forth relative to the spoon to determine Where the image switches from upright to inverted. The switch occurs at the focal point.

Warmup Question Given the general properties of spherical reflectors, what kind of mirrors would you expect to be used to observe shoppers in convenience stores? Why?

ANS: I would expect a *diverging* ("convex") mirror. There are two good reasons to use this. First of all, you want to make sure you always get an upright image. An inverted image of the store will be very disorienting too the observer. More importantly, you want to get a *reduced* image. You want the mirror to show you an image of a significant part (or possibly the entirety) of the store. Only a converging mirror will give you an upright, reduced image regardless of the object position.

Warmup Question

Objects in the mirror may be closer than they appear.

This warning often appears on the passenger-side mirror of a car. What leads to this impression?

1. The object is closer to the mirror than its image
2. The image is smaller than an object at the actual distance would appear
3. Both of the above
4. Neither of the above

ANS: **2**—The Image is smaller than an object at the actual distance would appear.

The warning is to remind you that the mirror is not a flat mirror. We humans are good at understanding flat mirrors. In these devices, the image is as large as the object. The distance between us and the image in a flat rear-view mirror is the same as the distance between us and the object (a car behind us). The farther the car is from us, the smaller it will appear in the mirror.

The passenger-side mirror, however, is convex. It will create a reduced image that will be smaller than the one produced by a flat mirror. Thinking in terms of flat mirrors could lead us to think that the car behind us in the passenger mirror is farther from us than it really is. In fact, the image in the mirror is actually closer than the original object, so answer #1 above is not correct. The image only appears farther away because it is so much smaller than the image in a flat mirror.