



**Figure 4**

(a) To the cat on the pier, the fish looks closer to the surface than it really is. (b) To the fish, the cat seems to be farther from the surface than it actually is.

### Objects appear to be in different positions due to refraction

When looking at a fish underwater, a cat sitting on a pier perceives the fish to be closer to the water's surface than it actually is, as shown in **Figure 4(a)**. Conversely, the fish perceives the cat on the pier to be farther from the water's surface than it actually is, as shown in **Figure 4(b)**.

Because of the reversibility of refraction, both the fish and the cat see along the same path, as shown by the solid lines in both figures. However, the light ray that reaches the fish forms a smaller angle with respect to the normal than does the light ray from the cat to the water's surface. The reason is that light is bent toward the normal when it travels from a medium with a lower index of refraction (the air) to one with a higher index of refraction (the water). Extending this ray along a straight line shows the cat's image to be above the cat's actual position.

On the other hand, the light ray that reaches the cat from the water's surface forms a larger angle with respect to the normal, because the light from the fish travels from a medium with a higher index of refraction to one with a lower index of refraction. Note that the fish's image is closer to the water's surface than the fish actually is. An underwater object seen from the air above appears larger than its actual size because the image, which is the same size as the object, is closer to the observer.

### Why it Matters

## Conceptual Challenge

**1. The Invisible Man** H. G. Wells wrote a famous novel about a man who made himself invisible by changing his index of refraction. What would his index of refraction have to be to accomplish this?

**2. Visibility for the Invisible Man** Would the invisible man be able to see anything?

**3. Fishing** When trying to catch a fish, should a pelican dive into the water horizontally in front of or behind the image of the fish it sees?

