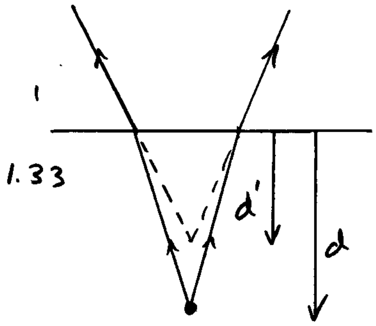
Air / Water Interface

a) Object under water; Observer in air



Use the reduced thickness

or

Use the object-image equation

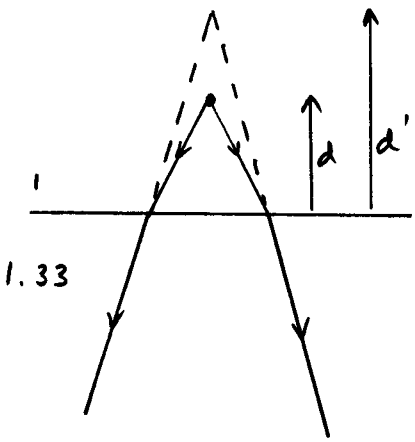
$$\frac{n'}{z'} = \frac{n}{z} + \frac{1}{\phi} \qquad \phi = 0$$

$z = d \qquad n = 1.33$

$z' = d' \qquad n' = 1$

$$\boxed{d' = z/n = d/1.33}$$

b) Observer underwater; Object in air



$$\frac{n'}{z'} = \frac{n}{z}$$

$n' = 1.33 \qquad n = 1.00$

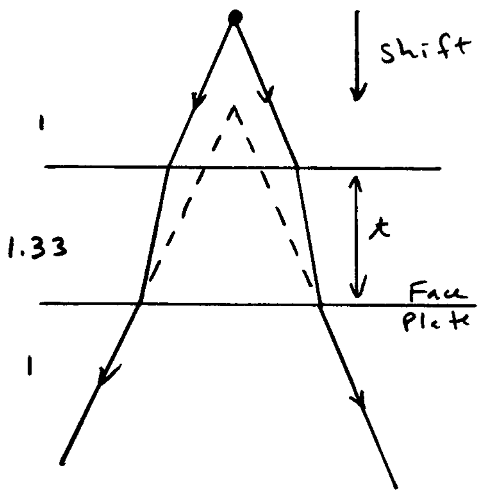
$z = d$

$$\boxed{d' = n'z = 1.33\,d}$$

c) Observer is underwater with a face mask.

This is a completely different situation. The face plate and the water surface form a plane-parallel plate. The image will shift due to this thickness

- Assume the observer is a distance t underwater.
- The face plate thickness is small compared to t



$$\text{Shift} = -\left(\frac{n-1}{n}\right) t$$

$$\text{Shift} = -\left(\frac{1.33-1}{1.33}\right) t$$

$$\boxed{\text{Shift} = -.248\ t}$$

Towards the water surface

Note: All of these are paraxial analyses.

Consider the paths of the rays leaving the object and heading towards the observer.