Consider a symmetric bi-convex thin lens having radius \( R \) and index of refraction \( n_L \) immersed in a medium having index of refraction \( n \). From the Lens Makers’ Formula, its focal length is

\[
f = \frac{R}{2} \frac{n}{n_L - n}
\]  

(1)

In air and water the lens’ focal lengths are, respectively, \( f_A \) and \( f_W \), where

\[
f_A = \frac{R}{2} \frac{n_A}{n_L - n_A} \quad \quad f_W = \frac{R}{2} \frac{n_W}{n_L - n_W}
\]  

(2)

Their ratio is

\[
\frac{f_W}{f_A} = \frac{n_W}{n_A} \left( \frac{n_L - n_A}{n_L - n_W} \right)
\]  

(3)

The magnifying power of this simple lens is defined as the ratio of two angles:

1. The half-angle \( \phi \) subtended at the eye by the lens’ virtual image when the object is situated at the lens’ primary focal point (the virtual image will be at infinity).
2. The half-angle \( \phi_E \) subtended at the eye (without the aid of the magnifying lens) when the object is at the eye’s minimum focusing distance “d”.

The magnifying power, \( M \), is

\[
M = \frac{\phi}{\phi_E}
\]  

(4)

We wish to compare the magnifying powers of a lens in air and underwater. In the latter case, the only complicating factor is the presence of the scuba diver’s mask.

For a small object of height “h” at the distance \( f_A \) from the lens in air (see diagram), we have (angles in radians)

\[
\phi \approx \tan \phi = \frac{h}{f_A}
\]  

(5)
Similarly, for the same object at the distance “d” in front of the unaided eye, we have

$$\phi_E \approx \tan \phi_E = \frac{h}{d}$$  \hspace{1cm} (6)$$

Thus, the magnifying power in air is

$$M_A = \frac{h/f_A}{h/d} = \frac{d}{f_A}$$  \hspace{1cm} (7)$$

For the same object and lens in water, the angle $\phi$ arises from two effects. In addition to the refraction by the lens, there is additional refraction by the water-air interface at the mask faceplate. The latter effect increases the angle. Together they produce

$$\phi = \frac{h}{f_w} \left( \frac{n_w}{n_A} \right)$$  \hspace{1cm} (8)$$

Without the magnifying lens, the largest angle at the eye is still $\phi_E = h/d$ (as in air) because the distance d now refers to the closest “apparent” position of the object. Hence,

$$M_w = \frac{h/f_w}{h/d} \left( \frac{n_w}{n_A} \right) = \frac{d}{f_w} \left( \frac{n_w}{n_A} \right)$$  \hspace{1cm} (9)$$
Thus,

\[ \frac{M_W}{M_A} = \frac{f_A}{f_W} \left( \frac{n_w}{n_A} \right) \]  

(10)

Substituting from (3) into (10), we finally get

\[ \frac{M_W}{M_A} = \frac{n_L - n_w}{n_L - n_A} \]  

(11)

For a glass magnifying lens with \( n_L = 1.5 \), and with \( n_A = 1.0 \) and \( n_w = 1.33 \), the ratio becomes

\[ \frac{M_W}{M_A} = 0.34 \]

which indicates that the lens loses 66% of its magnifying power when moved from air into water.